ESTIMATING THE TIMING OF KEY GROWING SEASON EVENTS IN TUKTUT NOGAIT NATIONAL PARK USING AVHRR SATELLITE IMAGERY

By

Bradley K. Sparling

A thesis submitted to the Faculty of Graduate Studies in partial fulfillment of the requirements for the degree of Master of Arts.

Department of Geography
University of Manitoba
Winnipeg, Manitoba

0-612-80033-4

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

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A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF ARTS

ABSTRACT

Through the use of remote sensing technology, researchers are able to monitor inaccessible regions common to the Canadian Arctic. Parks Canada currently receives GEOCOMP-n 10-day composite AVHRR imagery from the Manitoba Remote Sensing Centre. The federal agency is using the data to develop methods for monitoring various ecosystem variables within protected areas located throughout northern Canada. This study, located in Tuktut Nogait National Park (TNNP), Northwest Territories, uses GEOCOMP-n imagery to monitor the timing of four key growing season events during the 1999 to 2001 period. The specific objectives of the study were:

1. To determine which vegetation index is best suited for use with AVHRR data in the TNNP study area,
2. To describe the characteristics of basic components of the GEOCOMP-n data set for TNNP, and
3. To produce unbiased estimates of key timing events in the Arctic growing season using GEOCOMP-n data.

Using both quantitative and qualitative criteria, field data were analyzed to assess four vegetation indices. The normalized difference vegetation index (NDVI) was determined to be the most appropriate vegetation index for use in this study. All vegetation indices tested were found to be acceptable predictors of photosynthetic biomass and percent cover, but the NDVI proved to have a stronger ability to suppress the influence of background noise. A qualitative assessment reaffirmed these findings, by demonstrating a history of performance and ease of use in other studies.

Through an examination of GEOCOMP-n data characteristics, as they pertain to the TNNP study area, extremely high solar zenith angles were found to be causing inaccurate NDVI values during the end of October. Examination of the data also demonstrated that sensor zenith angles were relatively high before and after the growing season, when a large portion of the composites were covered by snow and cloud. In addition, acquisition dates were found to have a pooled distribution within most composites. It was determined that this pooled distribution was the result of cloud covers and the nature of the compositing procedure.

A time-series of the GEOCOMP-n NDVI data was used to estimate the timing of four key events in the Arctic growing season: the onset, end, and length of greenness, and the maximum NDVI. Spatial analysis of each metric revealed the presence of a significant southwest-to-northeast trend in the evolution of the metrics, excluding the date of maximum NDVI. Spatial analysis also established that the timing of these events was dependent upon the dominant vegetation type in the immediate area. The timing of key vegetation events corresponded closely to the mean air temperature recorded at a weather reporting station located centrally within TNNP.

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CHAPTER 1 - INTRODUCTION

1.1. INTRODUCTION

A 1988 amendment to the National Parks Act declared the maintenance of ecological integrity the highest priority in the protection of Canada's national parks (Parks Canada, 1998). Achieving this goal depends on effective monitoring of the ecological processes at work within and around these regions. Effective monitoring requires consistent, reliable and timely information. Satellite remote sensing meets these requirements, and is therefore a valuable tool to maintaining ecological integrity of protected lands.

Monitoring programs, which rely on ground-based data collection, may observe diminishing returns on collection effort. In arctic ecosystems, where research and travel costs are prohibitive, ground-based monitoring is even less suitable. Remote sensing, and particularly the Advanced Very High Resolution Radiometer (AVHRR) deployed on the National Oceanic and Atmospheric Administration (NOAA) series of polar-orbiting satellites, is widely used for the purposes of regional and global monitoring of terrestrial vegetation (e.g. Goward et al., 1994; Gutman, 1991). The AVHRR collects medium and coarse resolution imagery in five spectral bands at least once per day, and is available at a relatively low cost.

Since 1992, the Manitoba Remote Sensing Centre (MRSC) has produced 10-day AVHRR composite images for the Canada Centre for Remote Sensing (CCRS). Composites were originally processed by the Geocoding and Compositing System (GEOCOMP) (Robertson et al., 1992). In 2000, the next generation of GEOCOMP, GEOCOMP-n, was put to use operationally. Parks Canada currently uses GEOCOMP-n data for ecological monitoring in northern national parks (McCanny, 1999; Wilmshurst et al., 2001; Wilmshurst et al., 2002). Similar data have been used effectively for many years to monitor American northern national parks (Markon, 1994).

The primary drawback of multi-day composites in comparison to daily AVHRR imagery is a reduced temporal resolution. This is particularly problematic for studies attempting to identify the precise timing of events. In this sense, there is a need to develop methods that regain the information left out of the multi-day composites.

1.2. PURPOSE & OBJECTIVES

The purpose of this thesis is to develop a method to monitor the precise timing of key events in the Arctic growing season using a single vegetation index derived from GEOCOMP-n AVHRR composite satellite imagery. Basic phenological metrics such as onset and end of greenness, duration of greenness and date of maximum greenness are determined for Tuktut Nogait National Park, Northwest Territories, for the 1999, 2000 and 2001 growing seasons. The final product provides not only a method to determine such measurements, but also a measure of the current status of vegetation in Tuktut Nogait National Park against which future measurements can be compared. This corresponds closely to the objective of Parks Canada: to learn more about how AVHRR data can be used to monitor Canada's National Parks. The specific objectives of this thesis are:

1. To determine which vegetation index is best suited for use with AVHRR data in this study area.

2. To describe the characteristics of the basic components of the GEOCOMP-n data set for Tuktut Nogait National Park.
3. To produce unbiased estimates of key timing events in the Arctic growing season using GEOCOMP-n data.

1.3. SIGNIFICANCE OF THE STUDY

This study develops a method to monitor the precise timing of key events in the growing season. The final product provides not only a method to determine such measurements, but also contributes to the knowledge base on the current status of the vegetation of Tuktut Nogait National Park (TNNP). Important management decisions are based on the best information available. Increasing the quantity and quality of information park managers are able to attain, provides the opportunity to make more informed decisions.

Research shows that climate change is affecting the TNNP region (Foster, 1989). Higher temperatures and greater precipitation are expected consequences of current climatic trends (Betts et al., 2000). When these consequences are experienced on regional scales they have been shown to increase rates of vegetative population growth (Carlsson and Callaghan, 1994), change net primary productivity (Plochl and Cramer, 1995) and cause longer growing seasons (Bliss and Matveyeva, 1992; Oechel and Billings, 1992; Shaver and Kummerow, 1992). Such changes at the global scale have been shown to produce the same effects (Post and Stenseth, 1999). Monitoring the timing of key events in an arctic growing season aids in the identification and description of climate change on both a regional and global scale (Randerson et al., 1999).

Also, this research provides the opportunity to monitor migration routes. Arctic vegetation provides the only food source for many mammals permanently residing in, and/or passing through the study area. Travel routes of migratory species, such as the barren-ground caribou, may follow the green-up of the local vegetation (Van der Wal et al., 2000). Monitoring the progression of the growing season may provide the ability to remotely monitor the migration of such mammals.

1.4. THESIS OUTLINE

This thesis is divided into 5 chapters. The first chapter outlines the topic and presents the objectives of the research. The second chapter reviews the relevant scientific literature related to the research presented in this thesis. Chapter 3 explains the methodology of the research in order to achieve the research objectives. The fourth chapter presents the research results and associated discussion. The thesis wraps up in Chapter 5 with a summary of the research, conclusions and recommendations.

CHAPTER 2 – BACKGROUND

Chapter 2 discusses the relevant background information in three major sections. The first section discusses the optical remote sensing of vegetation, and includes descriptions of the science of monitoring vegetation with remote sensing, as well as the various uses of optical remote sensing data for vegetation applications. The second section provides a description of the various vegetation indices used in this study. The third section discusses the monitoring of plant phenology. Emphasis in the third section is placed on the use of remote sensing and abiotic determinants of phenology.

2.1. OPTICAL REMOTE SENSING OF TERRESTRIAL VEGETATION

Different objects interact with solar energy in different ways. Energy, at any particular wavelength, is reflected, absorbed or transmitted when it contacts an object. Energy that is not absorbed or transmitted is reflected. Optical remote sensing technologies measure the amount of energy reflected in the visible and near-infrared (NIR) portions of the electromagnetic spectrum (EMS). Reflectance characteristics of green leaves makes optical remote sensing ideal for monitoring vegetation canopies.

2.1.1. Spectral Reflectance of Green Vegetation

Green vegetation is unlike other common terrestrial surfaces, such as bare soil and water, in the way it interacts with visible and NIR energy (**Figure 2.1.**). The typical reflectance pattern of healthy, green vegetation is low in the visible portion (0.4 – 0.7 μm) and high in the NIR portion (0.7 – 1.3 μm) of the EMS. In contrast, bare soil reflects less visible and NIR light than vegetation and water absorbs almost all optical light, resulting in low reflectance throughout.

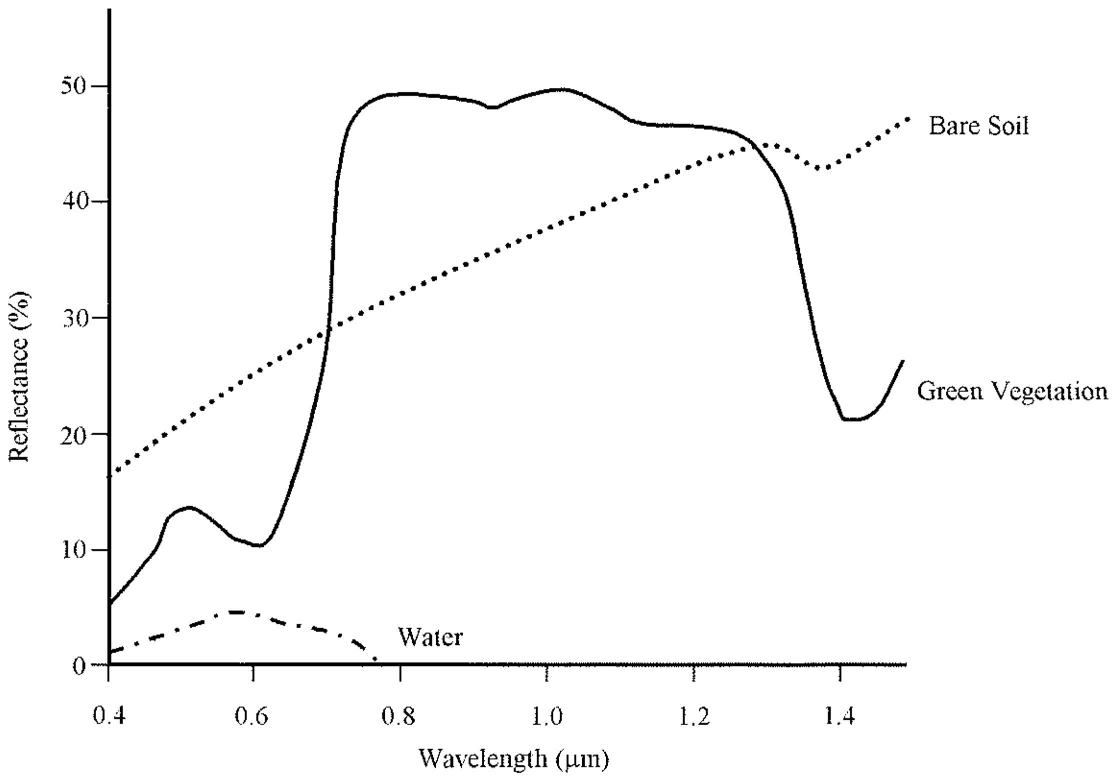

Figure 2.1. Typical spectral reflectance in the visible and NIR portions of the EMS for common terrestrial surfaces.

In the visible portion of the EMS, reflectance from green vegetation is low due to the high amount of red and blue energy absorbed by chlorophyll in the leaves (Woolley, 1971). The green appearance of healthy vegetation results from the low amount of green light absorption relative to red and blue light absorption. Within the NIR portion, healthy vegetation reflects a relatively large amount of NIR energy. High reflectance of NIR energy is the result of the cellular structure within the leaves of healthy vegetation (Woolley, 1971). The signal reaching the sensor is also influenced by surfaces other than vegetation.

2.1.2. Signal Interference

Observing terrestrial surfaces from a remote location (i.e. a satellite sensor) is an effective method for monitoring green vegetation. However, the non-vegetated background such as soil and non-photosynthetic portions of plants and atmospheric conditions also influence the signal. Such influences must be accounted for in order to accurately describe vegetation conditions from remote observations.

2.1.2.1. Non-Vegetated Background Influences

Non-vegetated background influences are derived from the soil under the vegetation canopy as well as non-photosynthetic portions of the vegetation. These influences may be separated into two categories: spectral effects and brightness effects (Elvidge and Lyon, 1985). Spectral influences result from the portion of energy that is scattered or transmitted towards the soil background, providing irradiance to an area that would otherwise be in shadow. Though part of the irradiance will be absorbed by the soil, another portion of it will be reflected back to the sensor, and may be interpreted as having come from the vegetation canopy. Such effects are generally consistent over short spans of time, but variable over space.

Brightness influences are caused by variations in soil type and soil moisture conditions. Such influences are variable over short periods of time and space, making correction difficult. For example, a rain event would cause a large change in soil brightness over a short period of time. In such cases, the change in soil moisture may appear to be a change in vegetation cover. Optical satellite data may be misinterpreted if the user is unaware of a recent rain event.

2.1.2.2. Other Background Influences

There are important background effects other than soil that influence reflectance signals. Standing water and vegetation litter are the most common influences in this group. Hope et al. (1993) reported that tussock tundra communities with standing water had similar vegetation index values to tussock tundra communities with higher biomass and no standing water. In arctic communities where poor drainage can lead to the accumulation of standing water, this effect may cause the overestimation of vegetation over large areas.

Colwell (1974) noted that non-photosynthetic plant components such as stalks, limbs and leaf litter are strong determinants of the reflectance from a vegetated surface. In the Arctic, while stocks and limbs are limited relative to mid-latitude vegetation canopies, non-photosynthetic leaves may remain on the plant or on the ground for multiple growing seasons. It has been reported however, that vegetation indices correlate better with total biomass than green biomass (Shippert et al., 1995).

2.1.2.3. Atmospheric Influences

Particles in the atmosphere also influence the signal reaching the sensor. Atmospheric particles absorb and scatter portions of visible and NIR light. The absorption of energy causes a reduction in signal strength. Scattering can either increase or decrease the signal, depending on directional characteristics. Atmospheric influences are generally wavelength dependant. That is, the smaller, visible wavelengths are affected more than the longer, NIR wavelengths Correcting for atmospheric influences is difficult, given the inconsistent effects of atmospheric particles. Without applying proper corrections, the accurate descriptions of vegetation conditions may be disrupted. (Goward et al., 1991).

2.1.3. NOAA-AVHRR

The AVHRR was first flown on the TIROS-N meteorological satellite in 1978. Originally, the AVHRR was designed with 4 channels (0.55 - 0.9 μm; 0.73 - 1.1 μm; 3.5 - 3.9 μm; and 10.5 - 11.5 μm), which were configured for meteorological-based research. TIROS-N was followed by the NOAA series of satellites.

The NOAA series of meteorological satellites operate in a near-polar, sun-synchronous orbit. The altitude of the orbit ranges from 833-870 km. The AVHRR, which is carried on the NOAA satellites, currently collects data in 6 spectral bands (0.58 – 0.68; 0.725 – 1.1 μm; 1.58 - 1.64 μm; 3.55 - 3.93 μm; 10.3 - 11.3 μm; and 11.5 – 12.5 μm) with 10-bit radiometric resolution. The AVHRR scans at angles up to 55.4 degrees off nadir, which permits view zenith angles to reach 68.9 degrees and a swath width of 2894 km. Ground resolution varies from 1.1 x 1.1 km at nadir to 2.4 x 6.9 km at scene edges.

There are three types of AVHRR data: High Resolution Picture Transmission (HRPT), Local Area Coverage (LAC), and Global Area Coverage (GAC) (Kidwell, 1998). HRPT data are full resolution data transmitted to a ground station as they are collected. LAC data are also full resolution data, but as they are collected, they are recorded on onboard tapes and subsequently transmitted to a ground station during the next overpass. GAC data are low-resolution images (4km) that provide global coverage recorded on tapes for subsequent transmission to ground stations.

Since the launch of NOAA-6 in 1979, the AVHRR has been used for meteorological and terrestrial applications. The NOAA-6 AVHRR was the first in the series to confine the Channel 1 to the upper portion of the visible spectrum. Channel 1 was narrowed from 0.55 – 0.9 μm to 0.58 – 0.68 μm in order to increase the ability of the AVHRR to monitor snow covers (Tucker, 1996). In addition, the narrowing of Channel 1 made daily satellite-based vegetation monitoring possible. Since the change to Channel 1 there has been a continuous expansion of knowledge concerning the uses of AVHRR for land applications such as forest fire monitoring, crop yield prediction, primary productivity modeling and land cover mapping.

2.1.3.1. Forest Fire Monitoring

AVHRR imagery has proven valuable for forest fire management. Leblon et al. (2001) found a strong correlation between AVHRR spectral variables and fire weather index variables for coniferous forest stands, allowing for the generation of forest fire risk maps. AVHRR data can also be used to map the locations, and areal extent, of fires (e.g. Remmel and Perera, 2001; Barbosa et al., 1999; Kasischke et al., 1993).

2.1.3.2. Crop Yield Estimation

Agricultural research also benefits from the AVHRR. Crop yields may be accurately predicted months before harvest based on information from the AVHRR. AVHRR data have been used for operational crop yield estimates in Canada (Hochheim and Barber, 1998; Bullock, 1992), the United States (Hayes and Decker, 1996), Europe

(Vossen, 1996; Quarmby et al., 1993; Benedetti and Rossini, 1993), and Africa (e.g. Maselli and Rembold, 2001; Unganai and Kogan, 1998).

2.1.3.3. Primary Productivity Modeling

AVHRR data have been used on several occasions to monitor and map terrestrial primary production. O'Brien (2001) successfully mapped terrestrial net primary productivity (NPP) using vegetation indices determined from AVHRR. Satellite-based vegetation indices were related to the fraction of photosynthetically active radiation that is absorbed by the vegetation canopy and to autotrophic respiration. Box et al. (1989) and Fung et al. (1986) used a different method to map NPP. In these studies, AVHRR data are correlated with measurements of atmospheric CO_2. Improvements in modeling NPP from AVHRR have allowed the mapping of productivity in many ecologically diverse regions.

2.1.3.4. Land Cover Mapping

Mapping the distribution of land cover types at regional and global scales is often accomplished by classifying AVHRR imagery. Using visible, NIR and infrared bands of imagery, many different regions have been mapped at coarse scales (e.g. Walker, 1999; Lathrop and Bognar, 1994; Loveland et al., 1991). Cihlar and Beaubien (1999) classified the land cover of Canada into 29 different types at a ground resolution of 1 km^2. Mapping large areas with AVHRR imagery is often aided by supplementary digital data concerning elevation and climate. Using surface temperature derived from AVHRR data may improve classification when used in combination with AVHRR spectral data to map land cover (Wen and Tateishi, 2001; Lambin and Ehrlich, 1995).

2.1.3.5. Limitations of AVHRR Data

While AVHRR imagery is a proven asset to many monitoring programs, it does have limitations. Cloud cover imposes the primary limitation. Clouds obscure approximately half of the Earth's surface every day (Tarpley et al., 1984). Clouds are visible to sensors of visible and NIR energy. Their presence prevents the acquisition of optical information from the surface beneath.

Limitations are also imposed by the sensor viewing geometry. AVHRR sensor zenith angles can exceed 68 degrees; imposing problems on pixels at scene edges. Problems include lesser geometric accuracy, increased atmospheric attenuation and lower spatial resolution. The topic of sensor zenith angles is examined closely in section 3.4.2.

2.1.3.6. Image Compositing

The most effective way around the limitations of AVHRR imagery is through image compositing (Holben, 1986). Image compositing is defined by Goward et al. (1991) as a "procedure in which geographically registered data sets collected over a sequential period of time, are compared and the maximum or minimum of a defined measurement (e.g. NDVI, sensor zenith angle) is selected to represent the conditions observed during that time period".

A composite is constructed on a pixel-by-pixel basis by comparing the value at a given location to all other values at the same location. The maximum (or minimum, depending on the criterion) value is selected and inserted into the composite at the appropriate location. Composites are generally based on maximum NDVI or minimum sensor zenith angle. The effect of maximum NDVI composites is to reduce the proportion of an image that is affected by atmospheric influences (Huete and Jackson, 1992). Maximum NDVI composites have also been shown to minimize the effects of high sensor and solar angles and directional surface reflectance differences (Holben, 1986). Minimum sensor zenith angle composites reduce the directional effects on the imagery by selecting pixels that are acquired closest to nadir. However, less directional effects are accomplished at the expense of increasing residual cloud cover and increasing the frequency of sharp edges between images from adjacent orbits (Cihlar and Huang, 1994). All composites sacrifice temporal resolution in order to produce the final image.

2.2. VEGETATION INDICES

Healthy vegetation typically displays a large difference in reflectance values between the visible and NIR wavelengths. As vegetation senesces or is stressed in some way, the reflectance signal changes. The typical response is for the difference between the visible reflectance and the NIR reflectance to shrink. Researchers are able to use this relationship to formulate vegetation indices that measure the amount, and overall abundance and health, of a vegetation cover. The indices can also measure how these properties change over space and time. Vegetation indices can be used to monitor both individual vegetation types (e.g. Vogelmann and Moss, 1993) and mixed vegetation covers (e.g. Yin and Williams, 1997). Measurements can occur over a short (e.g. Tucker, 1979) or long time period (e.g. Jano et al., 1998). It is important to note, however, that since vegetation indices require the amount of measured reflectance in the visible and NIR energy bands, values only represent a general view of the vegetation characteristics. Visible and NIR reflectances (and as a result, vegetation index values) are a function of the many different characteristics of vegetation (e.g. species composition, structural properties), non-vegetated surfaces (e.g. water, bare soil), landscape features (e.g. slope and aspect of the land), atmospheric influences and sensor characteristics.

The foundation for the formulation of vegetation indices was laid by Jordan (1969), who showed that the ratio between NIR and visible energy could provide information regarding the leaf-area index of a forest canopy. Advancement since Jordan's finding has seen the development of many different vegetation indices (see Bannari (1995) for a complete inventory and discussion of vegetation indices). Vegetation indices are often put into one of two categories: distance-based and slope-based.

2.2.1. Distance-based Vegetation Indices

Distance-based vegetation indices measure the amount and health of a vegetation canopy by determining the Euclidian distance between any vegetated pixel and the bare soil line (**Figure 2.2.**). The bare soil line represents the reflectance of all bare soil pixels for all degrees of soil brightness. It is determined by plotting bare ground pixels in visible and NIR space and determining the equation of the line that best represents the relationship. By using the distance of a vegetated pixel from the soil line, rather than strictly the two-dimensional position of the pixel, changing soil brightness conditions are accounted for. Distance-based vegetation indices assume that vegetation isolines run parallel to each other. All pixels on the same isoline have similar vegetation characteristics, but may have different brightness conditions represented by different positions on the same isoline. Distance-based vegetation indices tend to be more computationally complex than their slope-based counterparts.

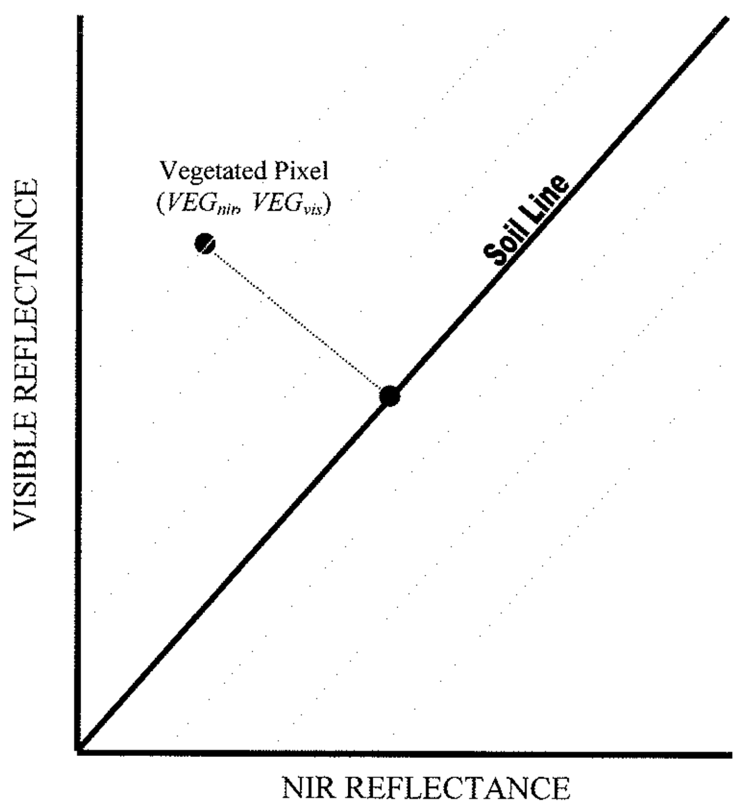

Figure 2.2. A diagram showing the theory of distance-based vegetation indices. Vegetation characteristics are assessed by measuring the Euclidean distance from the vegetated pixel to the soil line.

Richardson and Weigand (1977) developed the Perpendicular Vegetation Index (PVI) as a way to monitor vegetation development where variable soil brightness is a problem. The PVI is given by the equation:

$$PVI = \sqrt{(SOIL_{vis} - VEG_{vis})^2 + (SOIL_{nir} - VEG_{nir})^2} \tag{2.1}$$

Where: (VEG_{nir}, VEG_{vis}) is the candidate vegetation pixel, ($SOIL_{vis}$, $SOIL_{nir}$) is the point on the bare soil line nearest the candidate vegetation pixel.

High PVI values represent pixels displaced furthest from the bare soil line in a positive direction, and thus high density, healthy vegetation. Lesser vegetation density results in lower, but still positive PVI values. Water-filled pixels have negative PVI values, and fall below the bare soil line.

Results of experiments using the PVI have been mixed. Elvidge and Lyon (1985) reported that the PVI was the best among all vegetation indices tested for reducing the influence of noise from non-vegetated backgrounds. However, Baret and Guyot (1991) conclude that the PVI is dramatically affected by variations in soil optical properties, particularly for low vegetation densities. An unsuccessful attempt was made to improve the PVI for its treatment of variable soil conditions by adding a correction factor (Sanden et al., 1996).

The PVI is also computationally complex relative to most other vegetation indices. To ease this problem, Richardson and Weigand (1977) also developed the Weighted Difference Vegetation Index (WDVI). The WDVI calculation is as follows:

$$WDVI = y * NIR - VIS \tag{2.2}$$

Where: *NIR* = reflectance in the NIR Channel and *VIS* = reflectance in the visible Channel; and *y* is the slope of the bare soil line.

The effect of weighting the NIR reflectance with the slope of the soil line is that the response attributed to soil reflectance is minimized, and the response due to the vegetation is maximized. WDVI values greater than zero indicate the presence of vegetation, while values less than zero represent water. The WDVI was shown to be relatively unaffected by varying soil brightness conditions, but it is also insensitive to low amounts of vegetation (Qi et al., 1994), which causes a problem for its use in arctic environments. The WDVI and PVI are functionally equivalent vegetation indices (Perry and Lautenshlager, 1984).

2.2.2. Slope-based Vegetation Indices

Slope-based vegetation indices graphically display different vegetation conditions with isolines having different slopes and diverging from the origin (**Figure 2.3.**). The slope of isolines increase with higher amounts of vegetation. For example, a vegetated pixel has a particular VI-value (Figure 2.3. point A). If the soil brightness conditions were to change, the pixel would theoretically shift along the same isoline. As a result, slope-based vegetation indices are thought to account for such influences. Pixels with a greater amount of vegetation would fall on an isoline with a higher slope (Figure 2.3. point B). All isolines would meet at the origin.

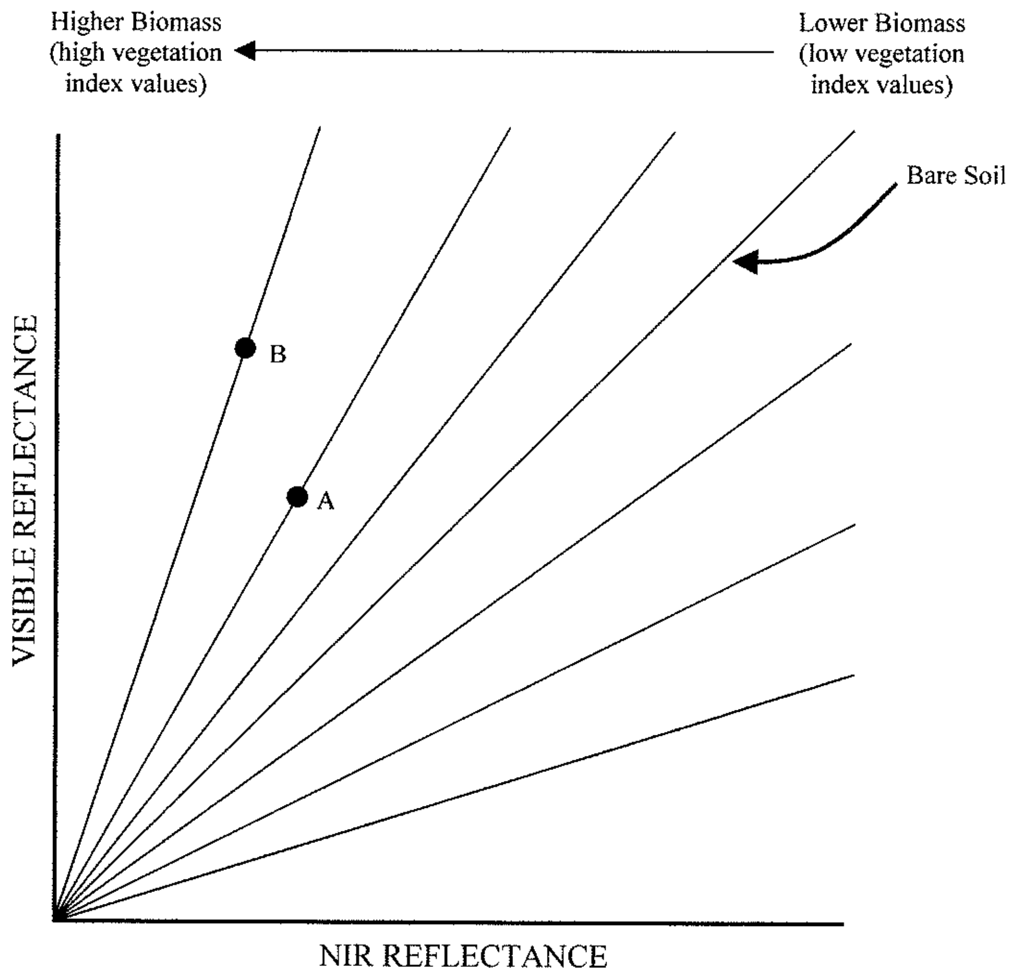

Figure 2.3. A diagram showing the theory of slope-based vegetation indices. The slope of vegetation isolines increase with greater amounts of healthy vegetation. Points falling on the same isoline have similar characteristics, but are viewed under different soil brightness conditions

Slope-based vegetation indices are determined by computing ratios of NIR and visible reflectances (or radiances). The use of a ratio of NIR to visible light was first proposed by Jordan (1969) who used it to determine leaf area index for tropical rain forest canopies. The simple ratio (SR), as it is known, is defined by the following equation:

$$SR = \frac{NIR}{VIS} \tag{2.3}$$

Where: *NIR* = reflectance in the NIR Channel and *VIS* = reflectance in the visible Channel.

The normalized difference vegetation index (NDVI) was developed to make use of the first Landsat satellite in the early 1970s (Rouse et al., 1973). The NDVI is defined by the following equation:

$$NDVI = \frac{NIR - VIS}{NIR + VIS} \tag{2.4}$$

Where: *NIR* is reflectance in the NIR Channel; and *VIS* = reflectance in the visible Channel.

The NDVI is the most commonly used vegetation index in the scientific community. NDVI values range from −1 to +1; negative values generally signify the presence of water and positive values signify vegetation. The NDVI has been shown to relate very well to actual and potential evapotranspiration rates in Canada (Cihlar et al., 1991) and biomass and leaf area index in Alaska (Shippert et al., 1995). It has also been used successfully as an input band for image classification and mapping of arctic vegetation types (Stow et al., 2000).

The normalization provided by dividing the difference by the sum is used to reduce sun angle differences and atmospheric attenuation. Atmospheric influences, however, are reported to influence NDVI values (Singh and Saull, 1988; Groten, 1993; Karnieli et al., 2001). The magnitude of the influence increases with decreasing cover proportions (Hansen, 1991). Variable soil background also influences the NDVI signal. Darker or wetter soil backgrounds tend to cause an increase in NDVI (Todd and Hoffer, 1998; Huete et al., 1985), which leads to serious problems for interpretation and characterization of vegetation covers.

2.2.3. Accounting for Soil Background

To reduce the influences of variable background effects, efforts have been aimed at modifying the NDVI equation. The soil adjusted vegetation index (SAVI) was the first ratio-based VI that attempted to account for the influences of soil background (Huete, 1988). The SAVI incorporates a constant soil adjustment factor into the equation for the NDVI to account for variable background effects:

$$SAVI = \frac{NIR - VIS}{NIR + VIS + L} \times (1 + L) \tag{2.5}$$

Where: NIR = reflectance in the NIR channel; VIS = reflectance in the visible channel; and L is the soil adjustment factor.

The soil adjustment factor is set between 0 and 1. It varies with the amount of soil that is visible to the sensor. Higher proportions of vegetation cover results in less visible soil background and a lower soil adjustment factor. A higher soil adjustment factor is required when percent vegetation cover is low and large amounts of soil are visible. Using a soil adjustment factor of 0.5, soil background noise was minimized when viewing broad-leaf cotton and narrow-leaf grass (Huete, 1988).

The characteristics of vegetation isolines were examined by Huete et al. (1985). It was determined that isolines are not parallel and meet in negative space rather than at the origin (**Figure 2.4.**). The soil adjustment factor accounts for the actual position of isoline convergence at the origin.

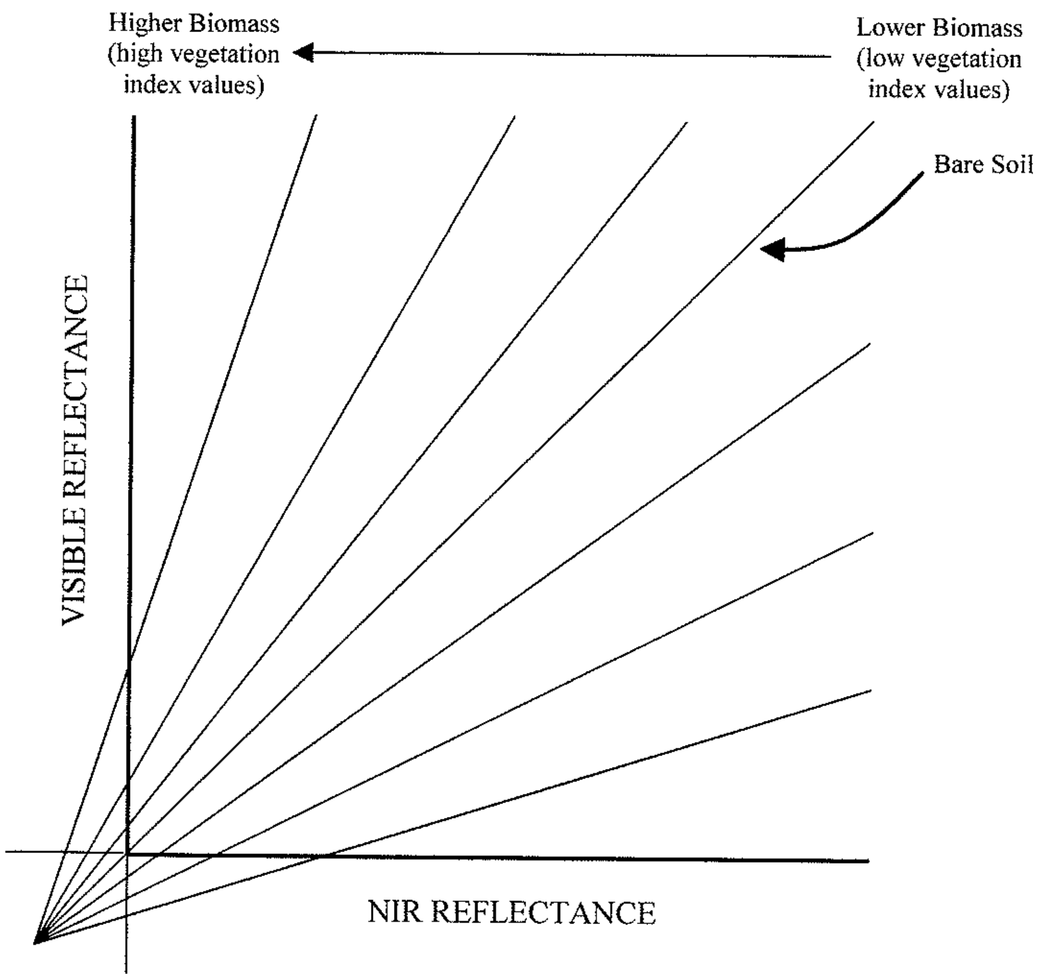

Figure 2.4. A diagram showing the theoretical vegetation isolines for soil adjusted vegetation indices (Adapted from Huete, 1988). Similar to slope-based vegetation indices, though vegetation isolines converge in negative space rather than at the origin.

Although initial results were promising, setting of the soil adjustment factor presented two major problems. First, one soil adjustment factor is used for an entire image. This is a problem when vegetation cover varies significantly across an image. Second, substantial knowledge of the study area is required before the appropriate soil adjustment factor can be determined.

The modified soil adjusted vegetation index (MSAVI) was proposed in response to the shortcomings of the SAVI (Qi et al., 1994). Two variations of the MSAVI were proposed, however both use a soil adjustment factor. The benefit of the MSAVIs is that no previous knowledge of the study area is required. Also, the soil adjustment factor is determined for the user, rather than by the user, and is variable over space. The $MSAVI_1$ is defined by the equation:

$$MSAVI_1 = \frac{NIR - VIS}{NIR + VIS + L} \times (1 + L) \tag{2.6}$$

Where: NIR = reflectance in the NIR Channel and VIS = reflectance in the visible Channel.; and L is determined by the equation:

$$L = 1\text{-}2y\text{NDVI}*\text{WDVI} \tag{2.7}$$

Where: NDVI is calculated using equation 2.4; WDVI is calculated using equation 2.2; and y is the slope of the bare soil line.

The equation for $MSAVI_1$ (2.6) is identical to the equation for the SAVI (2.5). The difference lies with the determination of the soil adjustment factor. The soil adjustment factor of the $MSAVI_1$ is based on the product of NDVI and WDVI. Although the NDVI and WDVI are sensitive to soil background, they have opposite responses (**Figure 2.5**). For identical vegetation amounts, the NDVI is higher for darker backgrounds than for lighter backgrounds, while the WDVI is lower given dark background conditions (Qi et al., 1994).

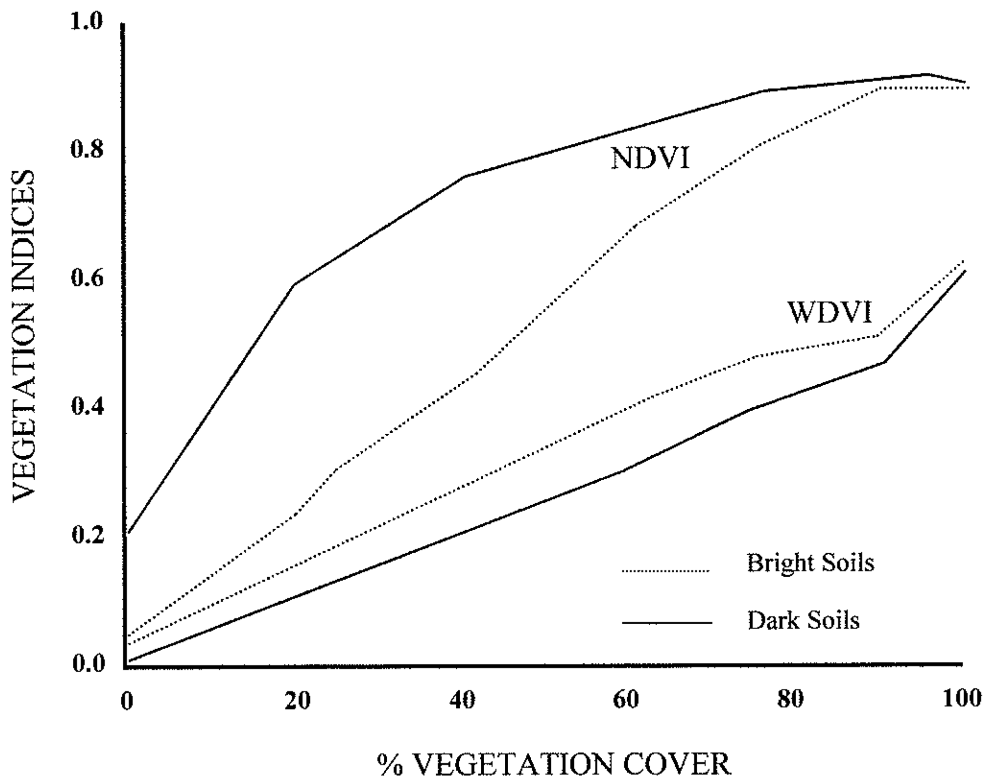

Figure 2.5. Different responses of NDVI and WDVI to soil moisture changes (From Qi et al., 1994). NDVI increased with darker soil background conditions, whereas WDVI increases with brighter soil background conditions.

The $MSAVI_2$ determines the soil adjustment factor iteratively and is determined using the following equations:

$$MSAVI2_n = \frac{NIR - VIS}{NIR + VIS + L_n} \times (1 + L_n) \qquad (2.8)$$

Where: NIR = reflectance in the NIR Channel and VIS = reflectance in the visible Channel; n is the iteration; and L is the soil adjustment factor.

In the first iteration, L is any number between 0 and 1 determined by a random number generator. A value for $MSAVI_2$ is determined and it is then used to determine L using the following equation:

$$L_n = 1 - MSAVI2_{(n-1)} \qquad (2.9)$$

With each iteration there is an improvement to both $MSAVI_2$ and L. Iterations continue until no further improvement is possible. At this point, the iterations stop and the $MSAVI_2$ is finalized. The equation for $MSAVI_2$ (2.8) is identical to those for the $MSAVI_1$ (2.6) and the SAVI (2.5) with the difference found in the determination of the soil adjustment factor.

2.3. MONITORING REGIONAL PHENOLOGY

Implications of plant phenology are important to climate change, and climate modeling studies (Schwartz, 1992). For the most part, phenological research has focused on individual plants or plant species, monitored at fine scales (e.g. Pop et al., 2000;

Wagner and Reichegger, 1997; Junttila and Robberecht, 1993). However, with the development of remote sensing technologies, phenology can be monitored on regional and global scales. In the mid-1980s, several studies laid the foundation for the use of AVHRR for monitoring the progression of vegetative seasons (Tucker et al., 1985; Justice et al., 1985, Townshend et al., 1987).

Though initial results were encouraging, two substantial limitations were identified. First, persistent clouds contaminate scenes such that they are not useful for analysis of terrestrial vegetation studies. Generating maximum-value composites reduces the cloud contamination problem, but does not eliminate it (Schwartz and Reed, 1999; Cihlar, 1996; Reed et al., 1994). Compositing also reduces the temporal resolution of satellite data (Holben, 1986). In the case of AVHRR data, temporal resolution is usually reduced from one-day to 10-, 15- or 30-days. Reduced temporal resolution may lead to the precise timing of an event being missed (Reed et al, 1994; Schwartz and Reed, 1999).

Second, limitations were imposed on analysis of satellite data by a lack of proper radiometric calibration techniques. In recent years, significant progress has been made addressing this issue (e.g. Rao and Chen, 1999; Rao and Chen, 1996, Cihlar and Teillet, 1995). As a result, sensor effects are currently a less significant problem.

The mid-1990s saw a renewal in interest of time-series AVHRR data for vegetation studies. Reed et al. (1994) were the first to develop measures of phenological events solely with satellite-based observations. The study derived several phenological metrics for the conterminous United States using bi-weekly (15-day) composites of AVHRR imagery. The key events determined were the onset and end of the growing season. The methodology for determining these metrics compared the actual NDVI time-series to a time-lagged moving average of the NDVI time-series. The point where the actual time-series deviates from the time-lagged moving average indicated a significant trend change that was interpreted as the onset of the growing season. The end of the growing season was determined in a similar manner; the difference being the time-series were analyzed in reverse chronological order.

The methodology developed by Reed et al. (1994) has been used numerous times since it was first proposed. Schwartz and Reed (1997) used the methodology in conjunction with climate station data. They found that 95 percent of satellite-derived events were within 1 bi-weekly composite period of those predicted with a surface model. Markon (2001) used the methodology to document the phenological record of Alaska between 1991 and 1997. He concluded that the methodology is more efficient, and more effective, than ground-based studies for monitoring regional phenology.

An alternative method for mapping the timing of key growing season events with AVHRR composite data was presented by Markon et al. (1995). The study determined the composite during which an NDVI threshold was crossed for the whole of Alaska. In this way, onset, end and length of the green season were determined. However, this methodology contains significant limitations. First, using a single NDVI threshold where vegetation type varies over space is inappropriate (Sparling, 2001; Chen et al., 2000; Schwartz and Reed, 1997). The NDVI value signifying the onset of the growing season is different than the value signifying the end to the growing season. Also, onset and end values vary from year-to-year (Chen et al., 2000).

All of the above-mentioned methods involving bi-weekly composites are unable to assess change between years. Using data with low temporal resolution to map timing events would be made more effective if interpolation was used to monitor the ground between the composites.

2.3.1. Abiotic Factors Affecting Phenology

Phenological processes can vary in terms of timing from one species to another. Abiotic factors also have a major influence on plant phenology. Air temperature and precipitation are the two obvious abiotic determinants of phenology. In higher latitudes, snow and snowmelt patterns also have an influence. The use of climate records alone can be used to detect phenological events such as spring onset (Schwartz, 1990).

In the Central Great Plains region, NDVI trends have a strong east-west gradient. The same gradient is evident in average precipitation for the region (Wang et al., 2001). Average temperature is also positively related to NDVI, but the correlation is weaker than it is between average precipitation and NDVI (Wang et al., 2001).

The trend of NDVI is increasing in arctic environments (Tucker et al., 2001; Myneni et al., 1997). Increased NDVI coincides with an increase in winter and spring temperatures in high latitudes (Rigor et al., 2000; Oechel et al., 2000). Others have reported that temperature appears to be more important than other abiotic factors in influencing arctic vegetation growth (Pop et al., 2000, Schultz and Halpert, 1993). High latitude regions, more than mid- and low- latitude regions, have high NDVI-temperature correlations (Shultz and Halpert, 1995).

Precipitation is less a determining factor because melting snow and sub-surface ice provide the majority of spring moisture. Additionally, a limited active soil layer results in pooling of water at the surface. Thus, moisture is available for plant growth long after a precipitation event.

2.4. CHAPTER SUMMARY

This chapter provided a general background on the theories and methodologies used in this thesis. Collecting optical data with the AVHRR provides information at moderate ground resolutions. AVHRR spectral data can be converted into several vegetation indices. Vegetation indices provide the ability to monitor terrestrial vegetation from a remote location. Examining the temporal pattern of vegetation indices for a given region allows for the identification of several phenological metrics. The ability to monitor the progression of vegetative seasons provides a greater amount of information on which to base important management decisions. The following chapter presents a detailed description of the methodologies this study employs to determine the phenological characteristics of Tuktut Nogait National Park.

CHAPTER 3 – RESEARCH METHODS

This chapter will introduce the area of study and discuss the methods used to address the objectives presented in Chapter 1. The methods section of this chapter is further separated into four sections: (1) field sampling procedures; (2) assessment and comparison of vegetation indices; (3) description of GEOCOMP-n 10-day composite AVHRR satellite imagery; and, (4) the determination of relevant phenological metrics, which also includes a presentation of the methods for data preprocessing and model validation.

3.1. STUDY AREA

The study area for this research was comprised within the physical boundaries of Tuktut Nogait National Park, Northwest Territories, Canada (**Figure 3.1.**). Tuktut Nogait National Park (TNNP) is Canada's fifth largest national park, spanning 16340km^2. The park is located in the Inuvialuit Settlement Region, and was established in 1996 to protect an area representative of the Tundra Hills Natural Region. TNNP was also established to preserve the calving grounds of the Bluenose caribou herd, and to encourage a greater understanding of the Inuvialuit cultural heritage. The hamlet of Paulatuuq is the nearest settlement, located roughly 35 km west of TNNP.

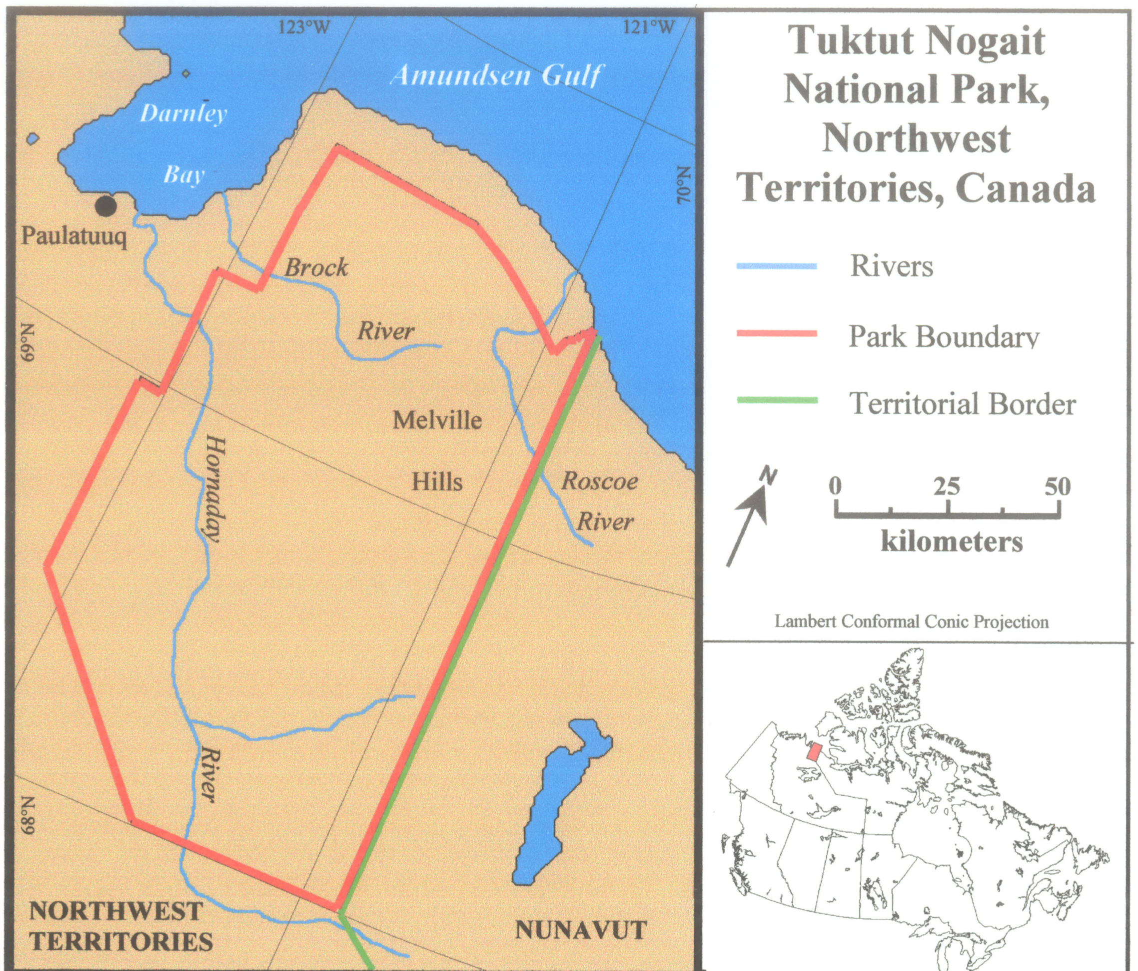

Figure 3.1. Tuktut Nogait National Park, Northwest Territories, Canada. The location of the study area.

3.1.1. Climate

In the coastal regions of TNNP, maritime air masses moving in from the west are the main climatic influence. In the southern portion of TNNP, conditions are more characteristic of a continental climate (Zoltai et al., 1992). Long, cold winters and short, cool summers are the norm. Mean daily temperatures range from –27.6°C in January to 7.4°C in July (Zoltai et al., 1992). Annual precipitation totals average 181.5 mm and the persistent snow cover exists up to 250 days per year (Phillips, 1990). The climate varies from other northern Canadian regions by the alternation of cyclonic and anticyclonic activity of air masses (Maxwell, 1981).

3.1.2. Geology

The geology of the region has been summarized by Zoltai et al. (1992), Balkwill and Yorath (1970), and Yorath et al. (1966). The following description is based on these works.

The study area is primarily contained within the Brock Upland Physiographic Division, characterized by Paleozoic and Mesozoic sediments exposed sporadically at lower elevations and Precambrian sedimentary and intrusive rocks in higher reaches.

Glacial landforms are completely absent from the highest elevations of the Melville Hills. In the central portion of TNNP, glacial deposits are present, though quantities are small and distribution is sparse. Surficial deposits also indicate that parts of the Melville Hills escaped glaciation during the Pleistocene (Zoltai et al., 1992). A high number of drumlins and oversized stream channels indicate recent glaciation in the northern, western and southern regions of TNNP.

Surface materials are generally non-calcareous loamy till, with calcareous materials present in relatively small pockets in the far north and far south portions of TNNP. Soils in the study area are mainly Turbic Cryosols, with Static Cryosols limited to areas with glaciofluvial parent material. Peat is limited to a few thin deposits, rarely exceeding 1 m, generally found in poorly drained depressions.

The climate creates conditions for permafrost to occur under all land surfaces. The thickness of the permafrost is estimated to reach several hundred meters (Zoltai et al., 1992). The thickness of the active layer varies with ground material. It is generally thickest in bedrock and dry, coarse soils, where it reaches 1 m. Well-drained loamy soils thaw to a depth between 65 and 80 cm. Poorly drained, peaty soils have the thinnest active layer at approximately 40 cm.

3.1.3. Hydrology

There are 3 major rivers within TNNP: the Hornaday, Brock and Roscoe. The Hornaday River and its tributaries drain the majority of the study area. Its headwaters are located south of TNNP. From there, the Hornaday River flows 350 km in a northwest direction where it drains into Darnley Bay. The Little Hornaday drains the southern portion of TNNP and is the largest tributary of the Hornaday River. The Brock River, which originates in the central region of TNNP, also drains into Darnley Bay. The Roscoe River drains the northeastern portion of TNNP, and is a more gentle, meandering river that empties into the Amundsen Gulf.

Small lakes and ponds are abundant in TNNP; the vast majority of which are less than 1 km^2. The Melville Hills region is unique in that small lakes are relatively uncommon – more evidence that recent glaciations did not affect this region. The largest lake fully contained within TNNP is Cache Lake at approximately 10 km^2.

3.1.4. Fauna

Relatively little is known about the abundance, distribution, and ecology of most animal species both in, and around, the study area. Zoltai et al. (1992) confirmed the study area is home to 22 mammal species, and that it is likely visited by an additional 18 species from the adjacent forest and marine ecosystems. The most notable mammal within TNNP is the Barren-ground caribou (*Rangifer tarandus groenlandicus*) of the Bluenose herd. The Hornaday, Brock and Roscoe rivers outline the border for the traditional calving grounds of the herd.

Three mammal species identified on the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) list of sensitive species make their home in TNNP (Government of Northwest Territories, 2000). These are the Grizzly Bear (*Ursus arctos*), the Polar Bear (*U. martimus*) and the Tundra Shrew (*Sorex tundraensis*).

With an admittedly small sampling effort, Zoltai et al. (1992) also confirmed the occurrence of 81 bird species, not including species expected, but not observed, in coastal areas. Of the 81 species of birds observed by Zoltai and his research partners, 14 are recognized as sensitive or at risk by COSEWIC. These include: the Northern Pintail (*Anas acuta*), Common Eider (*Somateria molissima*), King Eider (*S. spectabilis*), Oldsquaw (*Clangula hyemalis*), Surf Scoter (*Melanitta fusca*), White-winged Scoter (*M. fusca*), Golden Eagle (*Aquila chrysaetos*), Peregrine Falcon (*Falco peregrinus*), Rock Ptarmigan (*Lagopus mutus*), Lesser Yellowlegs (*Tringa flavipes*), Buff-breasted Sandpiper (*Tryngites subruficollis*), Short-eared Owl (*Asio flammeus*), American Pipit (*Anthus rubescens*) and Harris Sparrow (*Zonotrichia guerula)*.

Twenty-one fish species have been captured in or near the study area (Zoltai et al., 1992). Four species were captured during field-research including the Arctic greyling (*Thymallus arcticus*), Arctic flounders (*Liopsetta glacialis*), Lake Trout (*Salvenlinus namaycush*) and Arctic charr (*S. alpinus*). Commercial fisheries operating in the area from 1968 to 1986 depleted fish stocks, particularly those of the Arctic charr. Steps are now being taken to ensure the long-term sustainability of the stock (Department of Fisheries and Oceans, 1999).

3.1.5. Flora

Tuktut Nogait National Park is a floristically diverse area relative to similar regions. The diversity is linked to the fact that a portion of the park escaped the most recent glaciation (Zoltai et al., 1992). Four inventories of the vegetation have been taken in the region (Zoltai et al., 1992; Cody et al., 1992; Scotter and Vitt, 1992; Thompson and Scotter, 1992). The TNNP region is home to 103 species of bryophytes, 158 species of lichen and 263 taxa of vascular plants (Zoltai et al., 1992). Species distribution is determined by local elevation and exposure differences.

Five broad vegetation types were identified for the purposes of this thesis: Barren, Sparsely Vegetated, Sedge Meadow, Dwarf Shrub Tundra and Tussock Tundra (**Figure 3.2.**). Classification is based primarily on temporal growth patterns rather than species composition. As a result, the quantity of classes is limited and the species variability within each class is large.

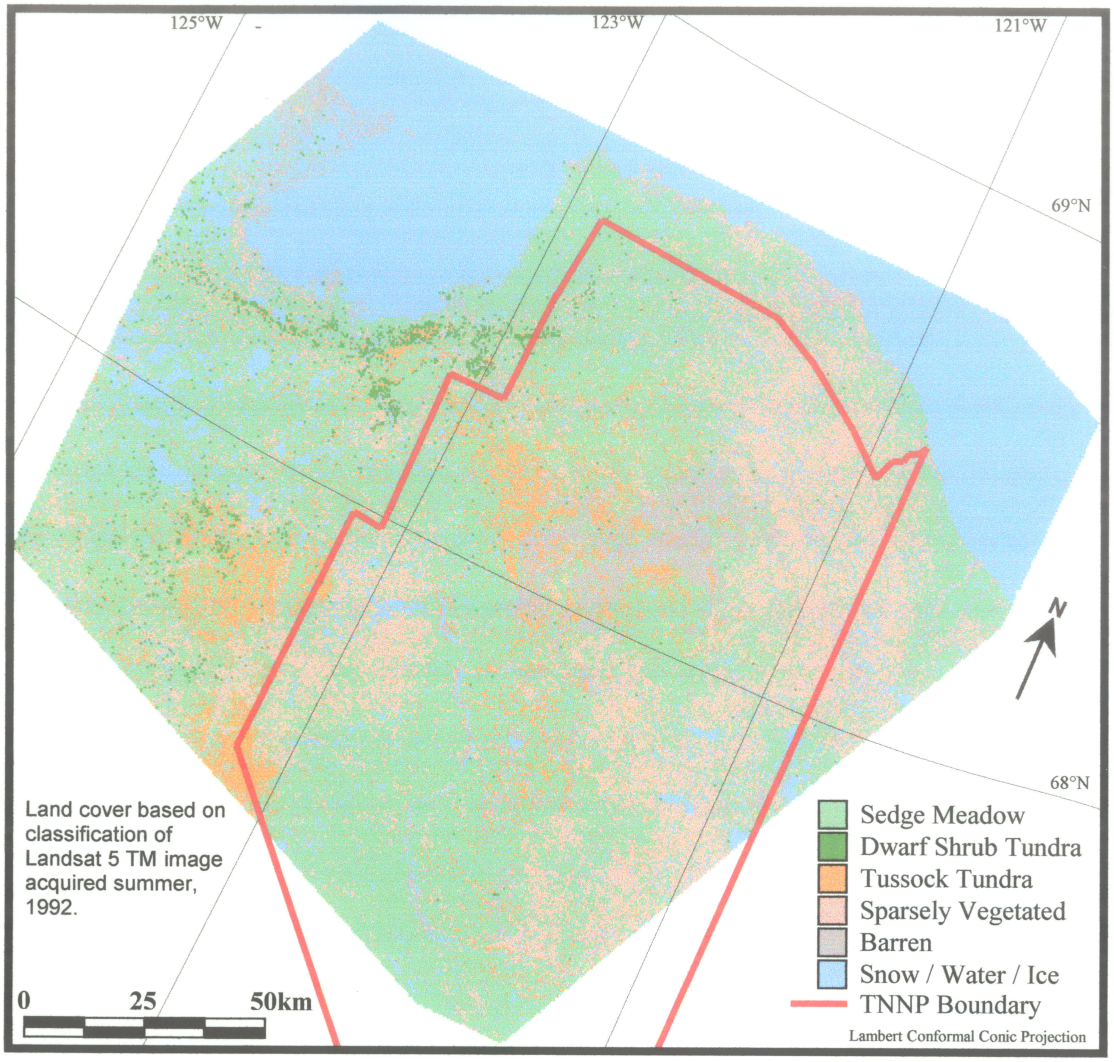

Figure 3.2. Land cover of Tuktut Nogait National Park. Modified from original classification by O'Brien (2001).

3.1.5.1. Barren

The ground cover of the Barren vegetation type is composed mainly of rock, with small amounts of lichens and dwarf shrubs (**Figure 3.3. A** and **B**). Bouldery terrain dominates and vegetation cover is less than 10 percent (**Figure 3.3. C**). The barren type corresponds to other classifications such as Rock-Lichen (Zoltai et al., 1992), Polar Semi-Desert (Bliss et al., 1973) Polar Desert (Bliss and Gold, 1999; Bliss et al., 1994).

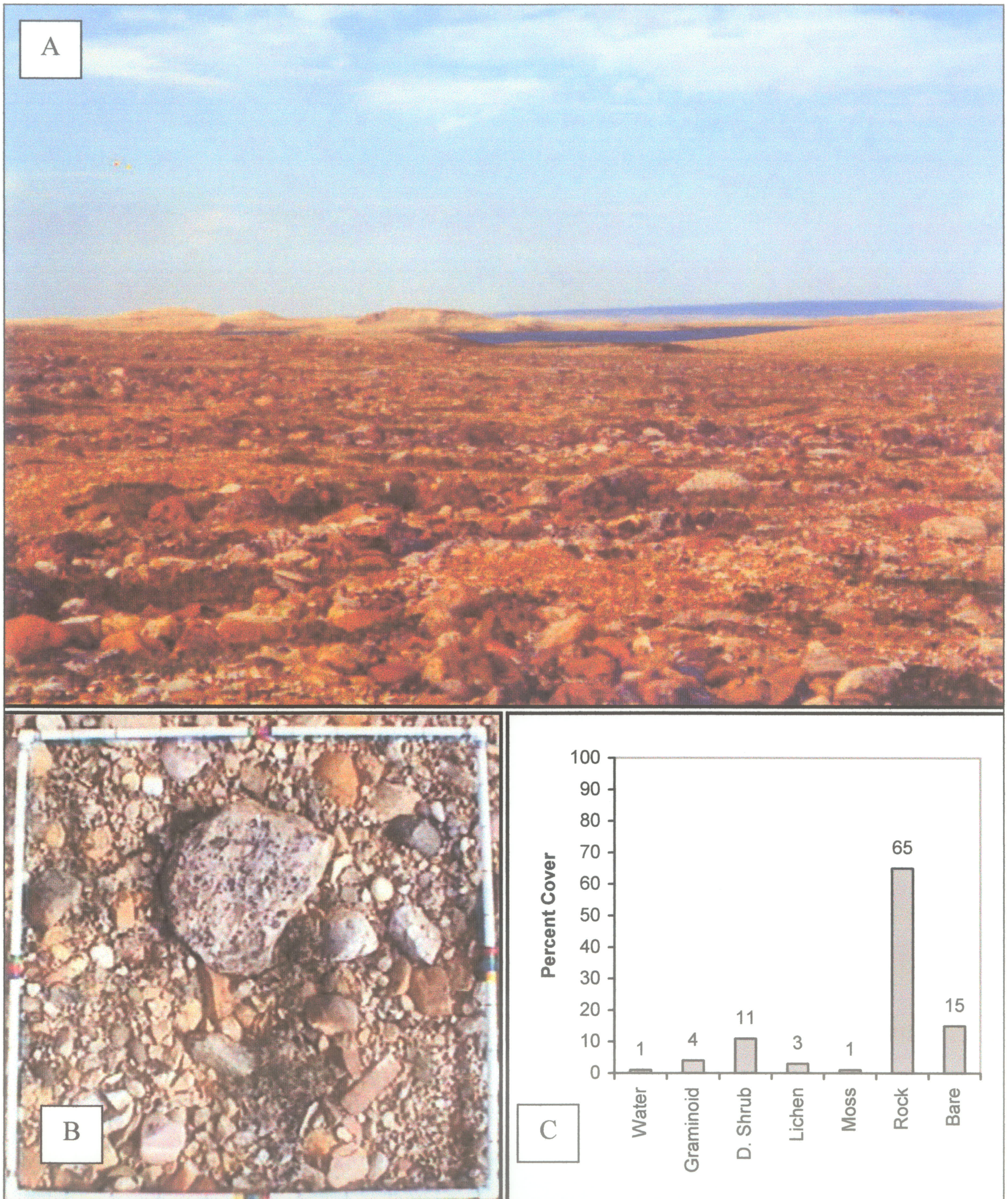

Figure 3.3. Landscape (A) and overhead (B) views and composition (C) of the Barren vegetation type.

3.1.5.2. Sparsely Vegetated

The Sparsely Vegetated class is similar to the Barren class, but is characterized by greater vegetation cover. It can be considered equivalent to the Dwarf Shrub-Herb-Sedge class (Zoltai et al., 1992), Polar Deserts (Gold and Bliss, 1995) and Dry Prostrate-Shrub Tundra (Muller et al., 1999). Vegetation cover varies from 10 to 50 percent, but rock and bare ground are the most common land cover (**Figure 3.4. A** and **B**). Dwarf shrubs are the dominant vegetation type (**Figure 3.4. C**), with *Dryas integrifolia* as the most widespread species.

3.1.5.3. Sedge Meadow

The Sedge Meadow vegetation type is the most common of the land cover classes within TNNP. Vegetation cover varies between 50 and 100 percent, and the most common vegetation type within the Sedge Meadow cover is graminoid (**Figure 3.5.**). Dominant species are *Eriophorum angustifolium* and *Carex aquatilis*. This vegetation class is often separated into two different classes, based on soil moisture conditions: Wet Sedge Meadow and Mesic Meadow. Wet Sedge Meadow is consistently identified in arctic communities (e.g. Miller et al., 1976; Shaver and Chapin, 1991; Zoltai et al., 1992), and is found in more moist regions. Mesic Sedge Meadow is also described as Herb-Nadum (Zoltai et al., 1992) and Moist Graminoid, Prostrate Shrub Tundra (Muller et al., 1999). Greater proportions of dwarf shrubs and bare ground occur in areas where mesic or dry conditions dominate.

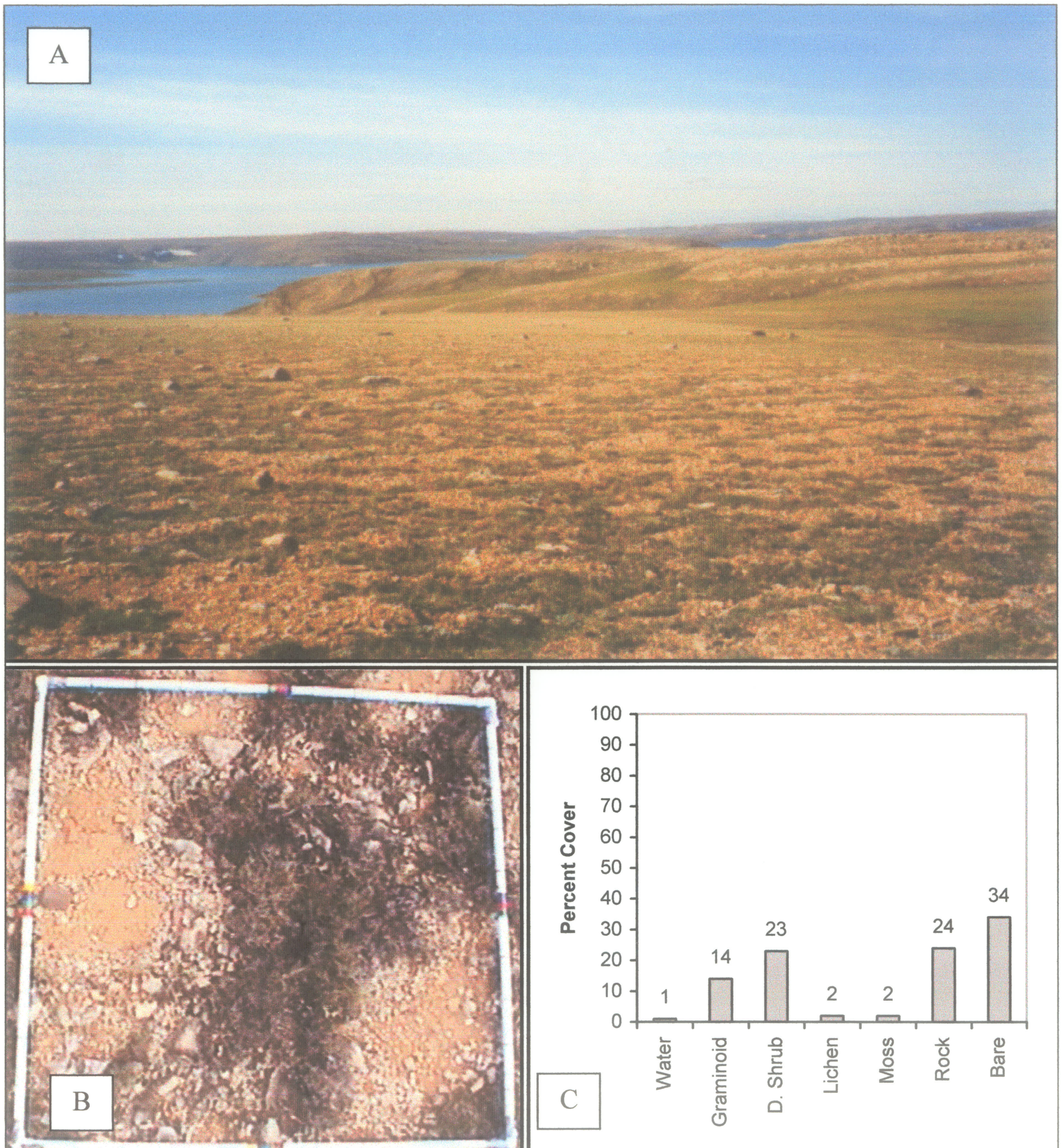

Figure 3.4. Landscape (A) and overhead (B) views as well as composition (C) of the Sparsely Vegetated vegetation type.

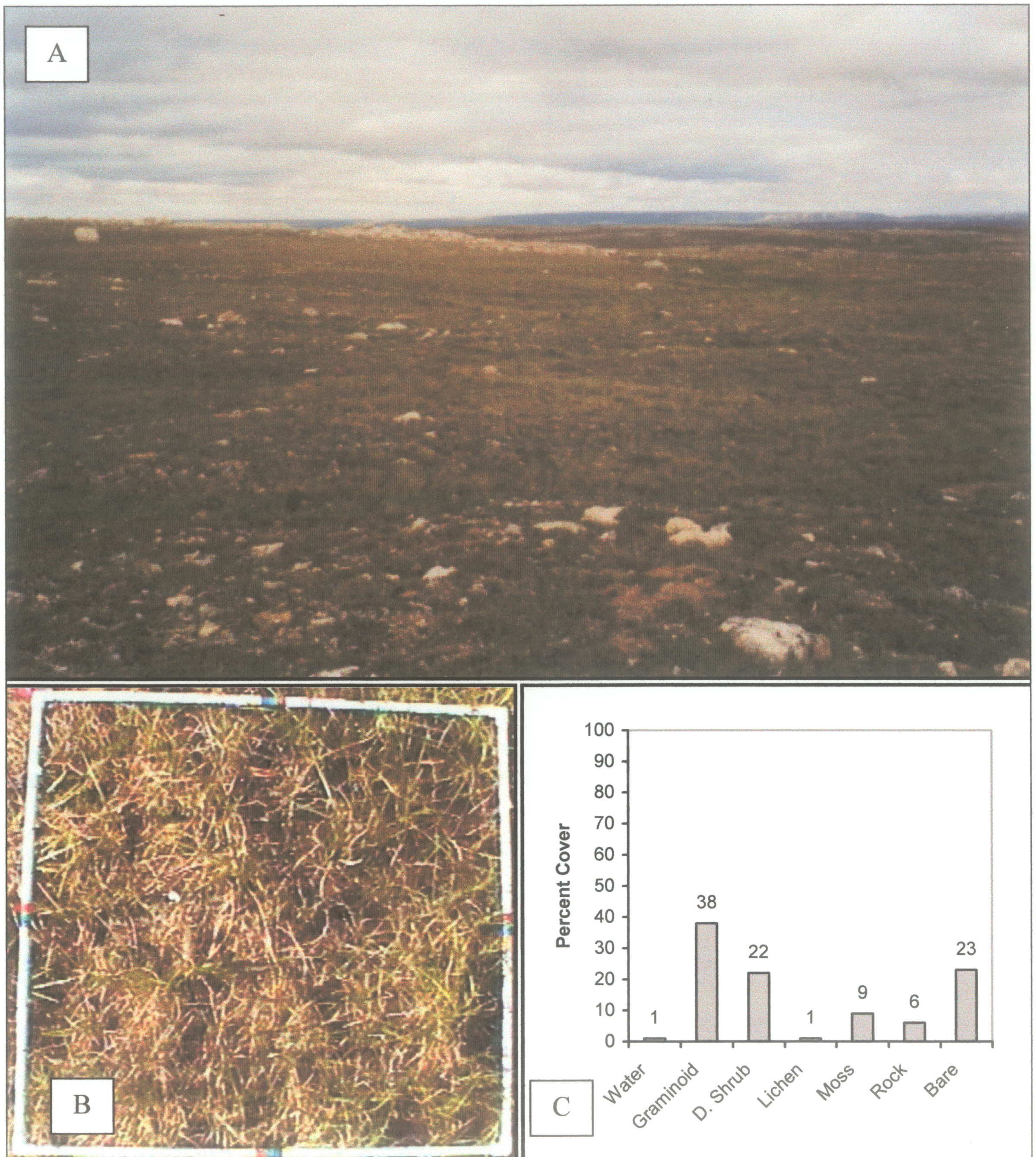

Figure 3.5. Landscape (A) and overhead (B) views as well as composition (C) of the Sedge Meadow vegetation type.

3.1.5.4. Tussock Tundra

The Tussock Tundra is the highest productivity vegetation type within TNNP (O'Brien, 2001). Local topographic variation is up to 30cm (**Figure 3.6. A**). Species dominating this vegetation type are *Eriophorum vaginatum*, *Salix arctica* and *Sphagnum spp*. Graminoid cover dominates, while smaller proportions of dwarf shrubs and mosses are found (**Figure 3.6. B**). Standing water may also be found in inter-tussock areas, but is often hidden beneath the vegetation canopy (**Figure 3.6. C**). Similar descriptions of Tussock Tundra are commonly provided (e.g. Muller et al., 1999; Grogan and Chapin, 2000; Bliss 1981).

3.1.5.5. Dwarf Shrub Tundra

The final vegetation class found in TNNP is Dwarf Shrub Tundra. This is the least common vegetation type within TNNP. It resembles the Dwarf Shrub-Herb-Sedge and High Shrub classes described by Zoltai et al. (1992) and Moist Low Shrub Tundra described by Muller et al., (1999). Common species include *Lupinus arcticus*, *Cassiope tetragona* (**Figure 3.7. A** and **B**). Dwarf shrubs are most common, along with moderate amounts of graminoid, moss and bare ground (**Figure 3.7. C**).

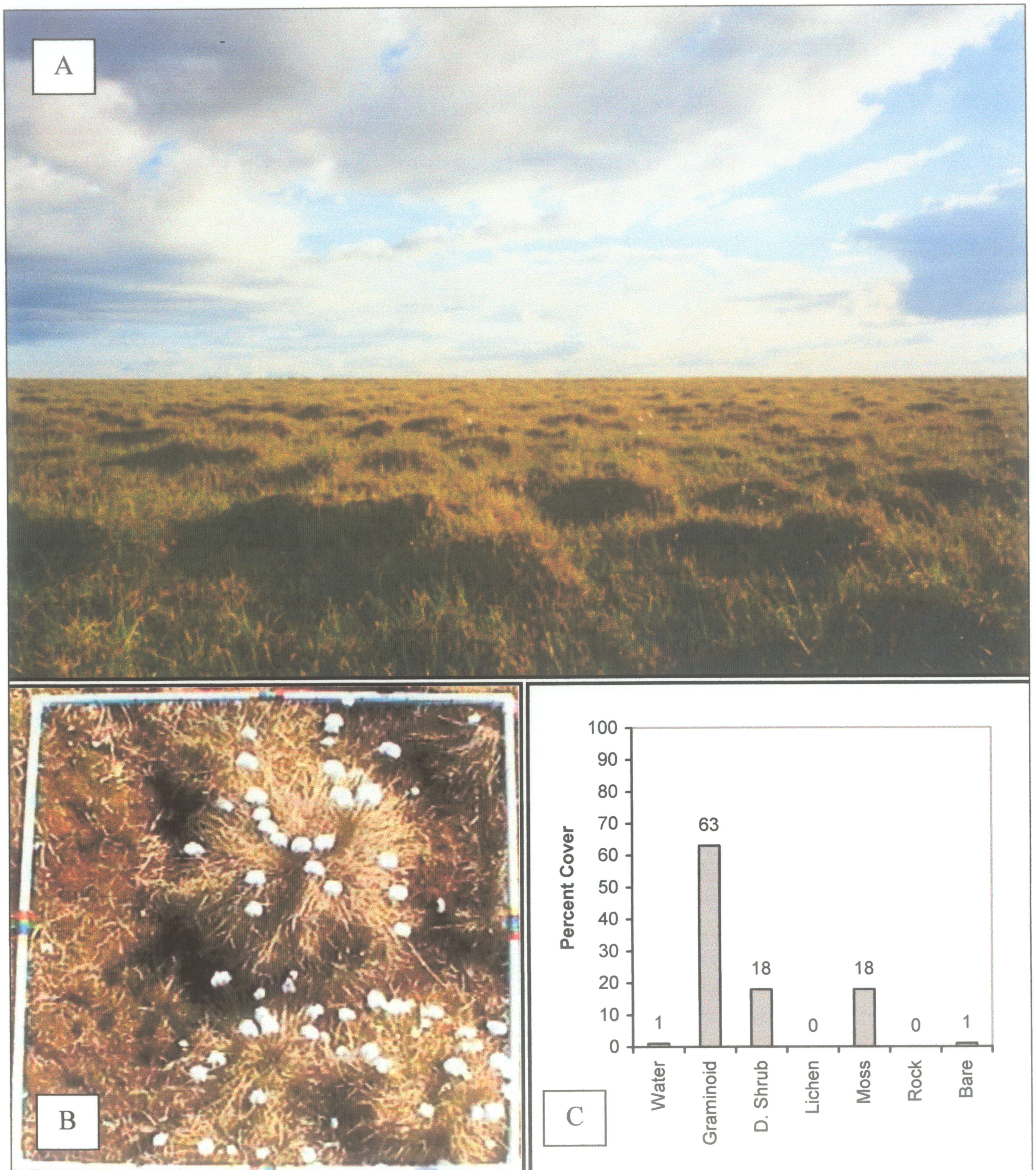

Figure 3.6. Landscape (A) and overhead (B) views as well as composition (C) of the Tussock Tundra vegetation type.

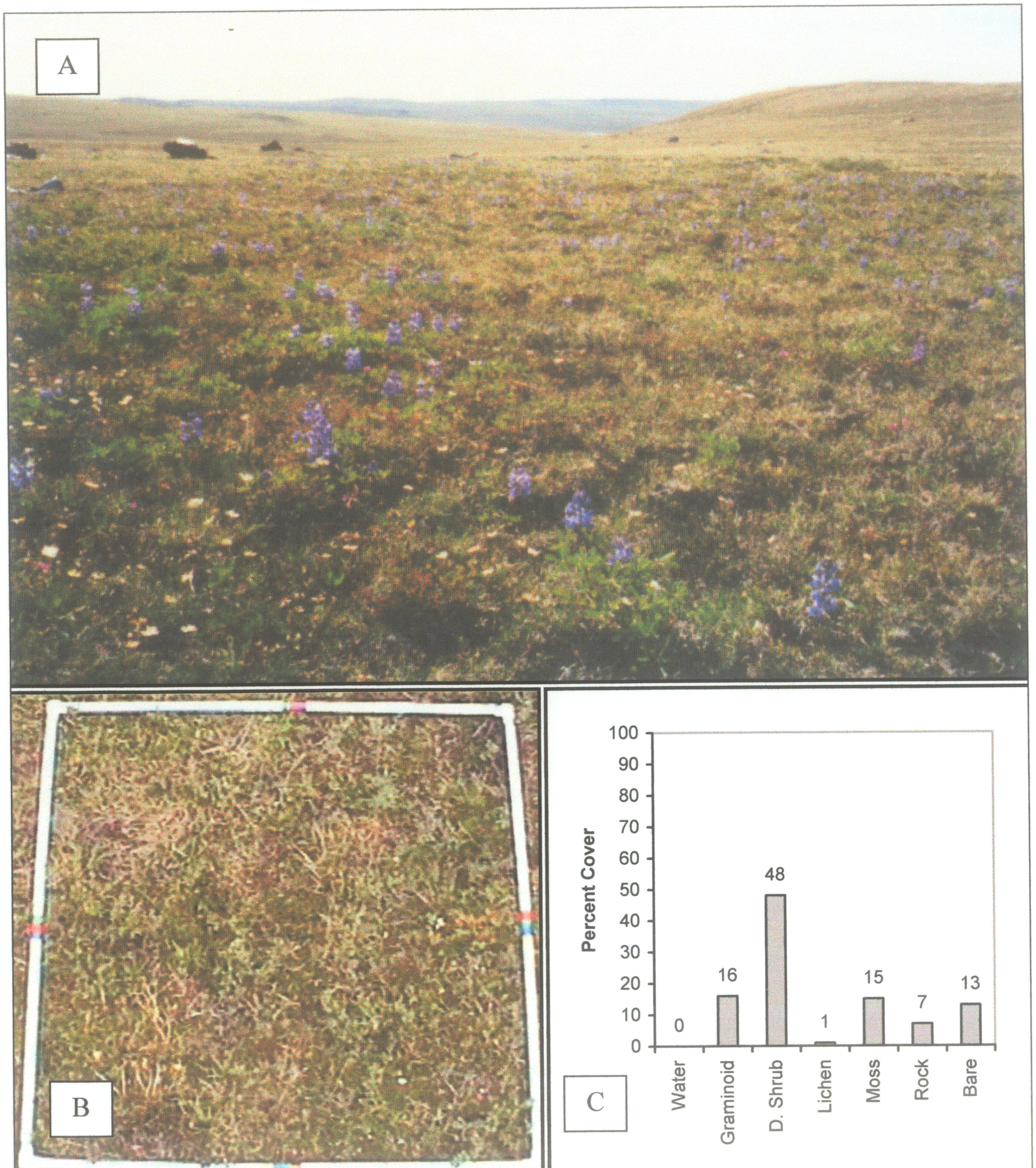

Figure 3.7. Landscape (A) and overhead (B) views as well as composition (C) of the Dwarf Shrub Tundra vegetation type.

3.2. FIELD SAMPLING

Field studies were conducted from 08-July-2000 to 10-August-2000. A total of 18 sample sites, each 1 km^2, were surveyed. The location of sample sites was limited to the western, northwestern and northeastern portions of the park. Selection of sites was generally limited to areas within walking distance (< 10 km) of the three base camps ([1] 68° 53'N, 122° 49'W; [2] 69° 16'N, 122° 58W; [3] 69° 22'N, 121° 24'W) (**Figure 3.8.**). However, four of the sample sites were accessed by helicopter. These were sites 5,11,12 and 13 (**Figure 3.8.**). Efforts were made to select sites representative of a variety of land cover types, and to survey locations with little topographic variation and minimal surface water.

3.2.1. Sampling Procedure

A systematic sampling procedure was used within each site (**Figure 3.9.**). Each site contained 9 sample plots measuring 30 m x 30 m. Within each sample plot there were 5 – 1 m x 1 m sample quadrats. The lower-left corner of each sample plot was located with a hand-held GPS unit. Sample sites were then marked using a measuring tape and compass. Data collection commenced after each sample quadrat was located and marked.

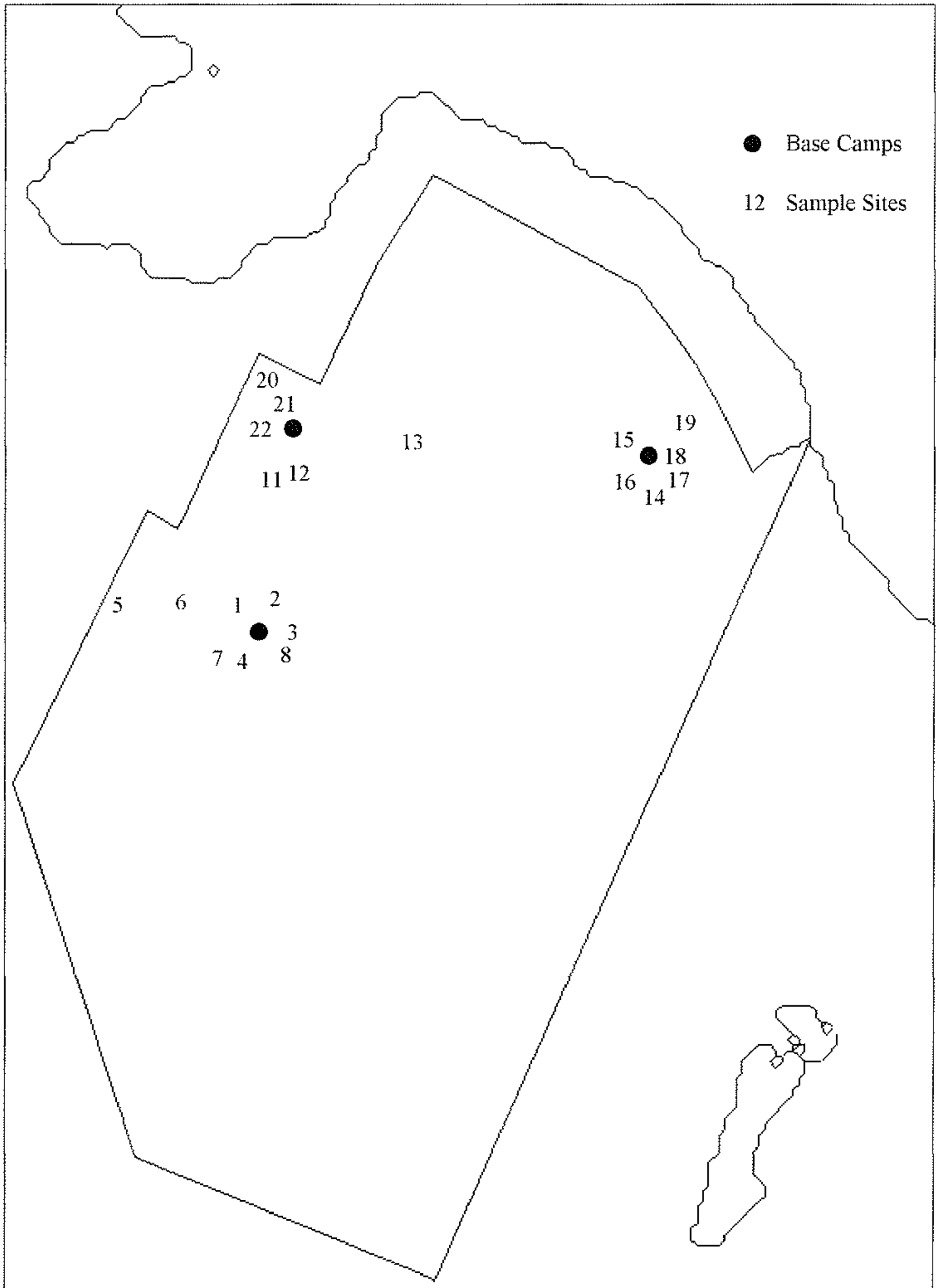

Figure 3.8. Sample site and base camp locations within TNNP. Note: Sample sites 9 and 10 do not exist.

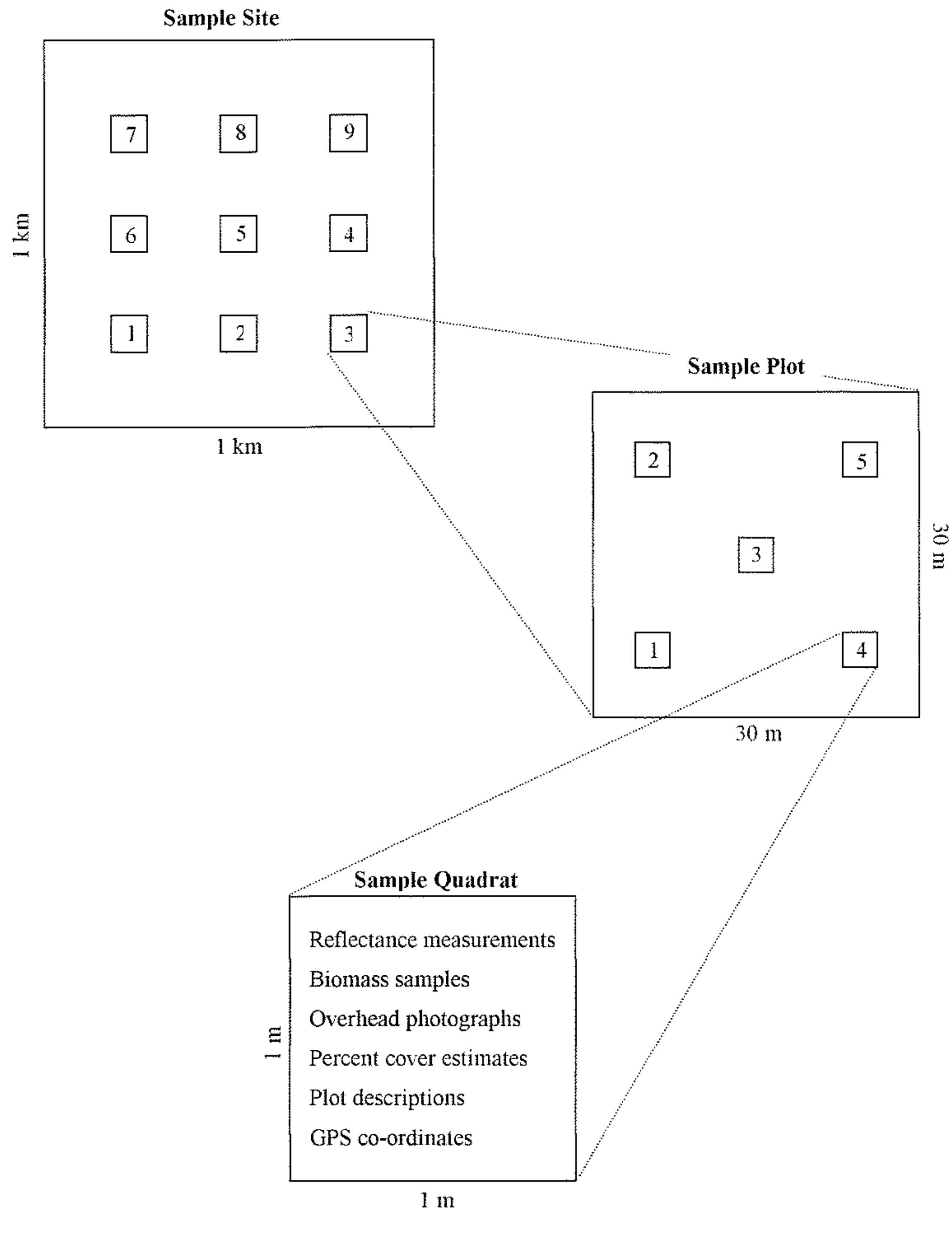

Figure 3.9. Diagram of the sampling procedure employed for data collection. Sample sites were designed to describe areas represented by AVHRR imagery; Sample plots were designed to describe areas represented by Landsat TM imagery; and all data was collected at the sample quadrat scale.

Data collection at each sample quadrat consisted of visual estimates of percent cover, slope, aspect and soil conditions, as well as overhead digital photographs and surface reflectance measurements. Overhead digital photographs were taken from an approximate height of 2 m (**Figure 3.10A.**). Surface reflectance measurements were collected using a Cropscan MSR 5 radiometer (Cropscan Inc, 2002) (**Figure 3.10B**). The radiometer measured reflectance in 5 spectral bands (450-520 nm 520-600 nm 630-690 nm 760-900 nm 1550-1750 nm). Finally, green vegetation from 2 to 3 sample quadrats within each sample site was harvested by hand (n=37). Data summaries for each sample quadrat are presented in Appendix I. Data collected in the field were used primarily to determine which vegetation index is best suited to this study.

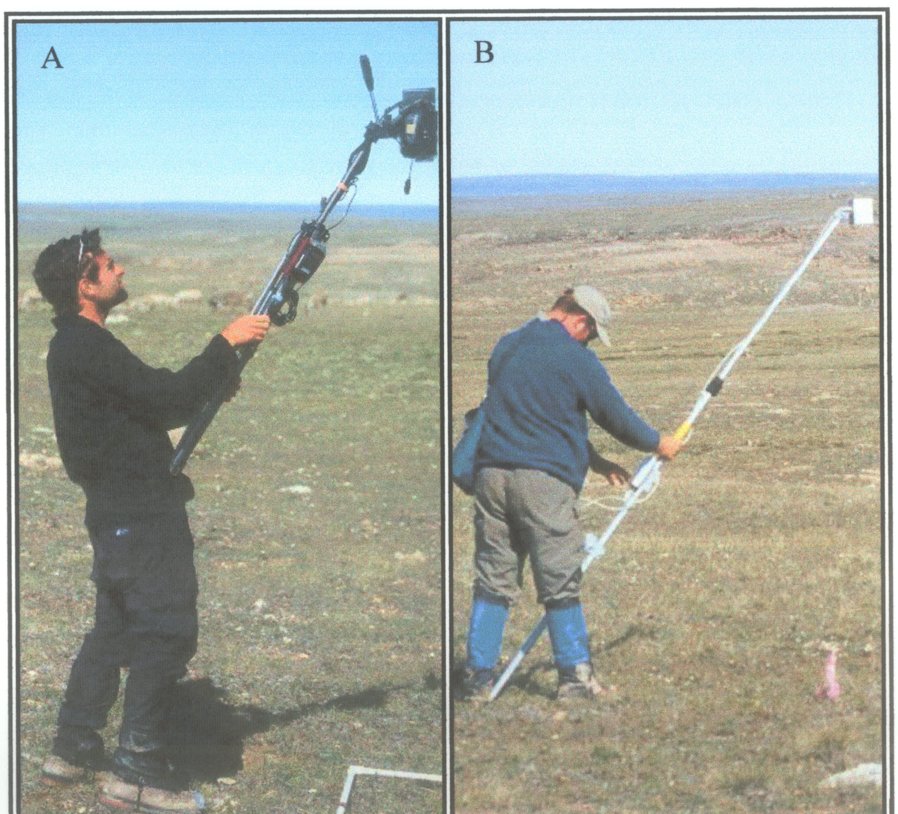

Figure 3.10. Data collection methods (A: digital overhead photographs; B: radiometric measurements). Photographs by Ryan Brook.

3.3. VEGETATION INDEX ASSESSMENT

The vast majority of vegetation indices have been developed and tested using vegetation commonly located in low- to mid-latitude regions (e.g. Rouse et al., 1973; Richardson and Weigand, 1979; Huete, 1988). The use of vegetation indices in the Arctic has been questioned (Rees et al., 1998). Reasons for skepticism include the build-up of melt water early in the growing season (Box et al., 1989) and the large spectral differences between arctic vegetation types (Rees et al., 1998). An assessment of several vegetation indices was performed to determine the single vegetation index most appropriate for TNNP. Four vegetation indices were selected for this analysis: the WDVI, NDVI, $MSAVI_1$ and $MSAVI_2$. The assessment was based on both quantitative and qualitative criteria.

3.3.1. Quantitative Assessment

Measures of spectral reflectance were collected at each sample quadrat. For each channel, the average of five consecutive measurements was recorded. Radiometer bands did not perfectly correspond to AVHRR bands (**Figure 3.11.**). To ensure the closest possible correspondence between the radiometer and the AVHRR, the mean of radiometer Channels 2 (520-600 nm) and 3 (630-690 nm) was used as the visible reflectance. NIR reflectance was taken directly from Channel 4 (760-900 nm) of the radiometer.

The WDVI, NDVI, $MSAVI_1$ and $MSAVI_2$ were calculated using equations 2.2, 2.4, 2.6 and 2.8, respectively. The vegetation indices were compared to corresponding measurements of photosynthetic biomass and estimates of percent cover. The indices were analyzed for their ability to predict these two photosynthetic variables, and the degree to which each was influenced by background noise.

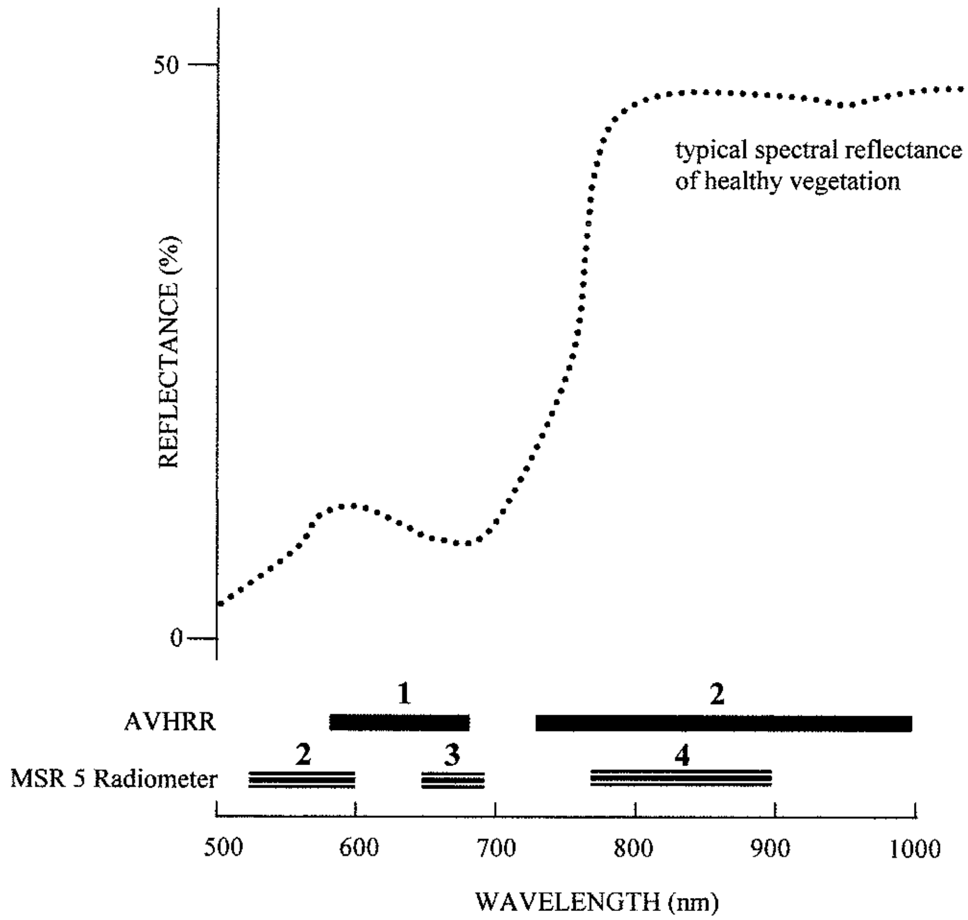

Figure 3.11. Respective bandwidths for the AVHRR and the Cropscan MSR5 Radiometer in the visible and NIR wavelengths.

3.3.1.1. Relating Vegetation Indices to Photosynthetic Variables

The first portion of the quantitative assessment established a measure of ecological significance for each vegetation index. Above ground green biomass was harvested from selected sample quadrats (n=37). Eleven of the samples were dried and massed in the field. The remaining samples were shipped to Winnipeg, and frozen until they could be processed. The frozen samples were massed, and three 10 percent sub-samples were taken. The three sub-samples were separated into green and non-green components and subsequently dried and massed. The mean of the sub-samples was multiplied by 10 to determine the dried photosynthetic biomass of the full sample. Regression analysis was used to determine the degree to which each vegetation index could predict photosynthetic biomass.

Additionally, visual estimates of percent cover were compared to each vegetation index. Regression analysis was used to determine which vegetation index was the best predictor of percent cover.

3.3.1.2. Influence of Background Noise

The influence of background noise was established by determining the vegetation signal-to-noise (SN) ratio using radiometer measurement of reflectance (Qi et al., 1994; Elvidge and Lyon, 1985). The data set was divided into groups of similar percent cover at 10 percent intervals. For each group, the mean vegetation index value was compared to the background noise using the following equation:

$$SN = \frac{\overline{VI}}{2\sigma} \tag{3.1}$$

where: $\overline{VI}$ = the mean vegetation index value and σ = standard deviation of vegetation index values.

3.3.2. Qualitative Assessment

Several considerations were made in undertaking the qualitative assessment of the four vegetation indices. The qualitative assessment considered if the particular vegetation index was produced by the GEOCOMP-n system. If the vegetation index was not produced by GEOCOMP-n, then it was essential that it could be easily generated from the AVHRR data that are available through GEOCOMP-n. The final step considered the degree to which the particular vegetation index was used and accepted as a measure of tundra vegetation.

3.4. GEOCOMP-n SATELLITE DATA CHARACTERISTICS

Since 1992, the Manitoba Remote Sensing Centre (MRSC) has produced 10-day AVHRR composite images for the Canada Centre for Remote Sensing (CCRS). The data were originally processed by the Geocoding and Compositing System (GEOCOMP) (Robertson et al., 1992). Since 2000, the next generation of the system – GEOCOMP-n – has been used by the MRSC. GEOCOMP-n registers the imagery to an equal area map projection. The default projection is Lambert Conic Conformal, though a wide variety of projections are supported. All pixels are resampled to 1 km^2. Geometric accuracy of GEOCOMP-n data has been shown to be within one pixel (Czajkowski et al., 1997; CCRS, 1999). A full description of the GEOCOMP-n system characteristics is provided by Adair et al. (2002).

Inclusion of pixels in the final GEOCOMP-n composites can be selected based on maximum NDVI or minimum sensor zenith angles. Composites used in this study are based on maximum NDVI. The result of maximum NDVI composites is generally an image with the least possible cloud or atmospheric contamination for a 10-day period. Brief descriptions of the GEOCOMP-n data used in this study are provided below.

3.4.1. Band Descriptions

The original GEOCOMP system produced the following bands of data: top-of-atmosphere (TOA) radiance in the five AVHRR channels, NDVI computed from TOA reflectance, pixel acquisition dates, solar zenith angles, sensor zenith angles and relative azimuth angles. Higher-level products such as leaf area index and surface temperature were also generated. The GEOCOMP-n system produces the data provided by the original system, as well as many other higher level products including: TOA reflectance corrected for atmospheric effects[1] or atmospheric and bi-directional effects[2]; two fraction of photosynthetically active radiation products; three absorbed photosynthetically active radiation products and photosynthetically active radiation surface albedo. Cihlar et al. (2002) provide thorough descriptions of all higher-level GEOCOMP-n products.

The current research uses only the basic products provided by the original GEOCOMP system. Actual bands of data used are described in **Table 3.1**.

Table 3.1. GEOCOMP-n bands used in this study (Adapted from Adair et al., 2002).

Band Identifier	Measurement Units	Description
B01_RATOA	$W/m^2/sr/\mu m$	Calibrated TOA radiance in Band 1*
B02_RATOA	$W/m^2/sr/\mu m$	Calibrated TOA radiance in Band 2*
NDVI_RETOA	Unitless	NDVI computed from TOA reflectance**
SATELLITE_ZENITH	Degrees	Sensor zenith angle
SUN_ZENITH	Degrees	Solar zenith angle
REL_DATE	Days	Days since 01 January 1970

* Calibration method is explained in Section 3.4.2.1.

** NDVI is scaled such that values are integers ranging from 0 to 20000 (rather than real numbers from –1 to 1).

[1] Atmospheric correction is accomplished using the Simplified Method for Atmospheric Correction (SMAC) see: Rahman and Dedieu, 1994.

[2] Atmospheric and bi-directional correction is accomplished using the bi-directional reflection reflectance distribution (BRDF) correction see: Roujean et al., 1992.

The decision to avoid using higher-level products was based on two factors. First, the basic data are available from the early 1990s, and it was important to permit the application of methods developed here to the earlier data. Second, it was important to avoid the corrected bands of GEOCOMP-n imagery based on a lack of confidence in the data. The SMAC and BRDF corrected bands contain significant errors due to the use of incorrect input coefficients (G. Fedosejevs, pers. comm. 2001). While the CCRS is working to correct these errors, time constraints did not permit the use of higher-level products in this study.

3.4.2. Sensor Zenith Angle Distribution

The sensor zenith angle refers to the angle between the satellite and a line perpendicular to the earth at a pixel's center (**Figure 3.12.**). Ideally, sensor zenith angles are less than 45°. When sensor zenith angles are greater than 45°, geometric accuracy as well as correspondence between composites and the raw imagery may be compromised (Czajkowski et al., 1997). Pixels acquired with high zenith angles are furthest from the sensor, and as a result, are influenced by more atmosphere than pixels close to nadir. They also have reduced spatial resolution compared to pixels acquired closer to nadir. Spatial resolution is approximately 1.1 x 1.1 km at nadir as opposed to 2.4 x 6.9 km at scene edges.

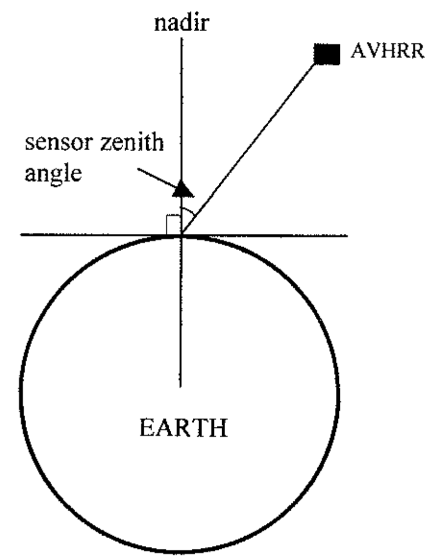

Figure 3.12. Sensor zenith angles describe the angle between the satellite and a line perpendicular to the earth at a pixel's center

Different vegetation indices show different responses to changes in sensor zenith angle. Values of NDVI are smallest with higher sensor zenith angles, and are also influenced by the direction at which the surface is being viewed. The SAVI, on the other hand, is positively related to sensor zenith angles and is independent of viewing direction (Huete et al., 1992).

Raw data values in the sensor zenith angles band range from 0 to 9000. Values were converted to degrees by dividing the raw numbers by 100. Frequencies were extracted from the sensor zenith angle data layers for each composite period. The frequencies were grouped into the following categories: less than 15°, less than 30°, less than 45°, less than 60°, and greater than or equal to 60°. Sensor zenith angles differ from solar zenith angles and have different effects on the imagery.

3.4.3. Solar Zenith Angle Distribution

Solar zenith angles describe the angle between the sun and a line perpendicular to the earth at a pixel's center (**Figure 3.13.**). Changes in solar zenith angles may result in changes in vegetation index values, particularly in the Arctic, where vegetation covers are usually incomplete. Large solar zenith angles limit the amount of direct light reaching the soil. Without background influences, reflectance from vegetation dominates resulting in higher vegetation index values (Kimes et al., 1985; Huete, 1987). These effects change with vegetation cover densities, because the amount of ground directly illuminated depends on the amount of vegetation that covers the soil (Jasinski, 1990). As a result, changes in solar zenith angles impact vegetation index values less when vegetation cover is high. This is because the amount of shaded ground is relatively stable.

Raw solar zenith angle values range from 0 to 9000. Raw values were converted to degrees by dividing the raw numbers by 100. The mean, minimum and maximum solar zenith angles were extracted for each composite.

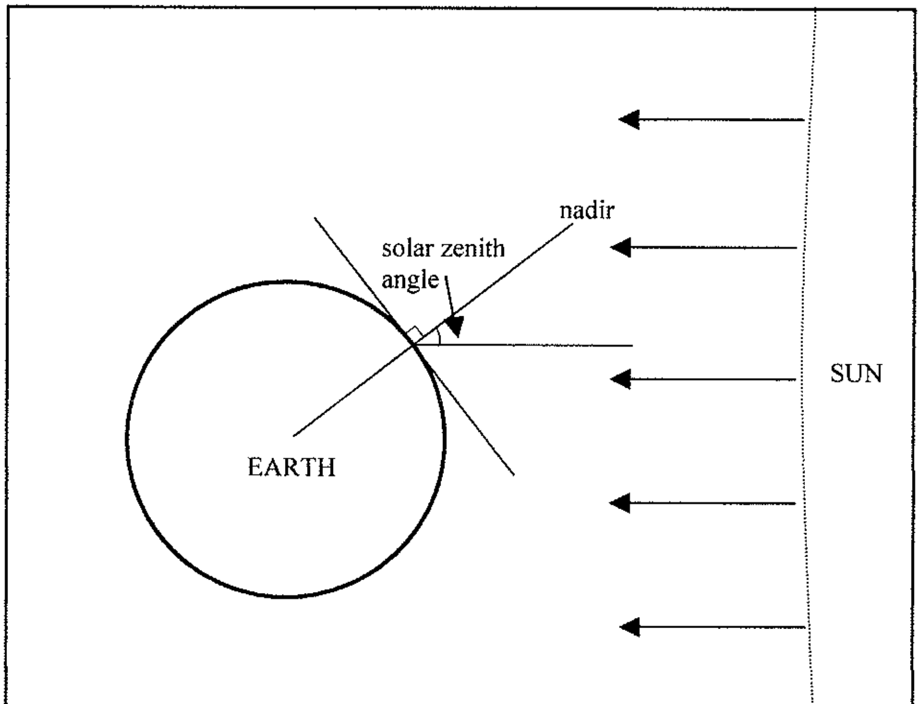

Figure 3.13. Solar zenith angles describe the angle between the sun and a line perpendicular to the earth at a pixel's center.

3.4.4. Acquisition Dates

GEOCOMP-n images for this region are processed from the beginning of April through the end of October. For each image, the relative dates band was examined. Values in the relative dates band represent the number of days since 01-January-1970 (CCRS, 1999). In this study, relative dates were converted to julian dates to permit simple comparisons between years (see Appendix II for dating conventions). Frequencies of each acquisition date were determined from the julian dates layers. Examining the distribution of pixel acquisition dates provides definitive information on the data in two ways. First, it shows temporal biases inherent in the data. Second, it demonstrates how representative each composite image is of the time period under consideration. It may also be possible to infer the general distribution of cloud cover during the composite period from acquisition dates.

It was expected that the pixel acquisition dates would be biased towards the peak of the growing season. That is, during the green-up portion of the season pixel acquisition dates will tend to be later in the 10-day window, while during the green-down portion of the season, they will tend towards earlier dates. This bias results from the compositing criterion that selects the highest NDVI during a particular time period. Given cloud-free conditions, the highest NDVI will be found closest to the peak of the growing season.

3.5. MAPPING TEMPORAL GREEN SEASON METRICS

The final objective of this thesis was to develop methods to use vegetation indices, derived from AVHRR composite data, to monitor the timing of key events related to the growing season in TNNP. Preprocessing of the satellite data must be performed to ensure high quality data are used in the analysis. Following data preprocessing, the analysis of the timing of key growing season events was undertaken and verified with supplementary data.

3.5.1. Image Algebra

Image algebra is used in many of the following sections. Image algebra creates a new image by performing mathematical operations on the cell values of an existing image (or images). Images can be transformed by another image, or by a constant (**Figure 3.14.**

A and **B**). Boolean logic can also be performed on images using similar techniques (**Figure 3.14. C**).

A)

$$\begin{bmatrix} 1 & 1 & 6 & 5 \\ 2 & 0 & 5 & 5 \\ 3 & 1 & 0 & 0 \\ 2 & 4 & 1 & 1 \end{bmatrix} + \begin{bmatrix} 5 & 4 & 3 & 4 \\ 6 & 7 & 2 & 1 \\ 6 & 5 & 5 & 5 \\ 4 & 3 & 1 & 1 \end{bmatrix} = \begin{bmatrix} 6 & 5 & 9 & 9 \\ 8 & 7 & 7 & 6 \\ 9 & 6 & 5 & 5 \\ 6 & 7 & 2 & 2 \end{bmatrix}$$

B)

$$\begin{bmatrix} 1 & 1 & 6 & 5 \\ 2 & 0 & 5 & 5 \\ 3 & 1 & 0 & 0 \\ 2 & 4 & 1 & 1 \end{bmatrix} + 2 = \begin{bmatrix} 3 & 3 & 9 & 8 \\ 4 & 2 & 7 & 7 \\ 5 & 3 & 2 & 2 \\ 4 & 6 & 3 & 3 \end{bmatrix}$$

C)

$$\begin{bmatrix} 4 & 1 & 9 & 2 \\ 2 & 2 & 6 & 4 \\ 0 & 0 & 4 & 4 \\ 9 & 4 & 3 & 1 \end{bmatrix} \times \begin{bmatrix} T & T & T & F \\ F & T & T & F \\ F & T & F & F \\ F & T & T & T \end{bmatrix} = \begin{bmatrix} 4 & 1 & 9 & 0 \\ 0 & 2 & 6 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 4 & 3 & 1 \end{bmatrix}$$

Figure 3.14. Examples of image algebra using mathematical operators (A and B) and Boolean operators (C).

3.5.2. Data Preprocessing

Performing certain preprocessing steps reduced the possibility of errors resulting from the use of satellite imagery. The preprocessing steps performed during the course of this study addressed errors caused by using data from different satellites (NOAA-14 and NOAA-16) and residual cloud and atmospheric attenuation.

3.5.2.1. Radiometric Calibration

Data from 1999 and 2000 were collected by the NOAA-14 AVHRR. Data from 2001 data were collected by the NOAA-16 AVHRR. It was imperative that the different data sets be compatible with each other. This requires that data be radiometric calibrated to account for differences in measurements resulting from the use of different sensors for data collection.

The orbits of the NOAA satellites carrying the AVHRRs were designed to cross the equator at the same time each day to ensure consistent scene illumination. However, the satellite orbits have been shown to drift over time causing changing illumination conditions (Price, 1991). This creates problems when comparing time series data over several years. Additionally, AVHRR Channels 1 and 2 have been shown to degrade in orbit (e.g. Roa and Chen, 1995; Brest and Rossow, 1992).

Radiometric calibration established a relationship between radiant energy reaching the sensor and the actual recorded values. Without on-board calibration capabilities for Channel 1 and Channel 2, the user of AVHRR data is responsible for radiometric calibration. However, using pre-launch calibration coefficients, provided by NOAA, may cause significant errors in the calculation of vegetation indices (Che and Price, 1992). GEOCOMP-n converts the raw data to TOA radiance using the Piecewise Linear (PWL) calibration technique (Teillet and Holben, 1994) as recommended by CCRS. The radiometric calibration from digital signal level to radiance units is accomplished using the following equation:

$$L_i = \frac{(D_i - O_i)}{G_i} \tag{3.2}$$

Where: L = radiance ($W/m^2/sr/\mu m$), D = digital signal level; O = calibration offset coefficient (counts); G = calibration gain coefficient (counts / ($W/m^2/sr/\mu m$)) and i refers to AVHRR Channel 1 or 2.

Radiance values, L, are then scaled to a fixed 10-bit output scale. Calibration gain and offset coefficients are determined using the following equations:

$$G_{i,d} = A_i d + B_i \tag{3.3}$$

$$O_{i,d} = C_i d + D_i \tag{3.4}$$

Where: d = the number of days since the launch of the particular satellite; $G_{i,d}$ *and* $O_{i,d}$ are gain and offset coefficients on day d; i refers to AVHRR Channel 1 or 2 and A, B, C, and D are Channel dependent coefficients derived from radiometric analysis of known ground targets (Cihlar and Teillet, 1995) (**Table 3.2.**). The GEOCOMP-n system performs radiometric calibration on the data prior to distribution to clients.

Table 3.2. Coefficients used by GEOCOMP-n to calibrate AVHRR optical data.

	Coefficient	Channel 1	Channel 2
NOAA – 14	**1999**		
	A	-1.209E-04	-3.714E-05
	B	1.587	1.883
	C	0	0
	D	41	41
NOAA – 14	**2000**		
	A	-1.249E-04	-3.837E-05
	B	1.639	1.946
	C	0	0
	D	41	41
NOAA – 16	**2001** (low radiance)	Raw counts <=495	Raw counts <=504
	A	0	0
	B	3.653	5.920
	C	0	0
	D	38.5	37.9
	2001 (high radiance)	Raw counts >495	Raw counts >504
	A	0	0
	B	1.250	2.011
	C	0	0
	D	339.7	342.8

3.5.2.2. Reducing Cloud Contamination

Maximum-value compositing intends to eliminate the presence of all cloud cover, however, significant cloud cover may remain in the final images when cloud cover persists throughout the composite period (Holben, 1986; Reed et al., 1994; Schwartz and Reed, 1999). To address this, residual cloud contamination was identified and the effects were removed from the vegetation index and relative dates values prior to undertaking the temporal analysis.

To reduce the frequency of cloud-contaminated pixels, a Channel 1 cloud masking procedure was used. Thick clouds are strong reflectors of visible energy. A threshold value of 250 (in 10-bit digital counts) was set for Channel 1 to find latent cloud contamination. The threshold was based on the examination of Channel 1 histograms of daily AVHRR imagery for days having significant cloud cover. The threshold value was set high in order to reduce the occurrence of false cloud identification. The drawback to this decision was that thin clouds would often be missed.

To identify pixels with a thinner cloud cover, a supplementary line-smoothing algorithm was applied to the vegetation index time-series data. The algorithm identified pixels that were erroneously low by comparing the vegetation index value to the values in the previous and subsequent composites. Pixels with uncharacteristically low vegetation index values were determined to be cloud-contaminated.

Clouds were identified at locations where there was a significant trend change in the time-series. That is, where the time-series saw a reduction in NDVI of at least 0.05 when the time-series was previously increasing. The time-series on either side of the peak of the growing season were examined separately. The portion of the growing season after the peak was examined in reverse chronological order so the same algorithm could be used for both halves of the growing season.

3.5.2.2.1. Adjusting the Vegetation Index Time-Series

Pixels identified as contaminated were replaced by the average of vegetation index values on either side of the contaminated pixels in the time series using the following equation:

$$VI_i = \left(\frac{VI_{i+1} + VI_{i-1}}{2} \right) \tag{3.5}$$

Where: VI = the vegetation index value; and i = composite under examination.

3.5.2.2.2. Adjusting the Relative Dates Layer

Using the above method to remove cloud cover has the unwanted effect of rendering corresponding dates values incorrect. As a result, all pixels that needed adjustments made to the vegetation index values also required corresponding adjustments to the relative acquisition dates. Just as the vegetation index values were adjusted to the mean of the two surrounding values. The dates layer is changed using the following equation:

$$DATE_i = \left(\frac{DATE_{i+1} + DATE_{i-1}}{2} \right) \quad (3.6)$$

Where: $DATE$ = relative acquisition date; and i = composite under examination.

3.5.3. Determining the Timing of Key Growing Season Events

After all data issues were addressed, the primary objective of this study was attended to: to estimate the timing of key growing season events using satellite-derived vegetation index time-series data. Specific key growing season events examined were the onset, end, length and peak of the green season (**Table 3.3.**). The timing of such events and how they can be observed in remotely sensed data was the focus.

Table 3.3. The four temporal metrics observed from GEOCOMP-n data in this study.

TEMPORAL METRIC	INTERPRETATION
Onset of Green Season Date	First day of detectable photosynthesis
End of Green Season Date	Final day of detectable photosynthesis
Length of Green Season	Range between Onset Date and End Date
Date of Maximum Greenness	Day on which the greatest vegetation index is detected

3.5.3.1. Onset and End of Green Season Dates

This study employs Reed et al.'s (1994) method for detecting phenological metrics. This method has been used successfully on several occasions in many different ecosystems (Reed et al., 1994; Schwartz and Reed, 1999; Chen et al., 2000). The approach, adapted from autoregressive moving average models (Poole, 1974), compares the vegetation index time-series to a moving average of the same time-series to detect deviations from the trend. A significant trend change, indicating the onset or end of greenness, is occurring at the point where the actual time-series crosses the moving average time-series (Reed et al., 1994). To detect the onset of the green season, the first step calculates the moving average (or predicted) time-series using the following equation for each composite:

$$Y_t = (X_t + X_{t-1} + X_{t-2} + ... + X_{t-(w-1)})/w \qquad (3.7)$$

Where: t = the composite period; Y = the predicted vegetation index value; X = actual vegetation index-value for composite period t; and w = the number of vegetation indices included in the time series.

The choice of w is important as it determines the sensitivity of the test. Higher w values detect more general changes while using a lower w makes the test detect small changes that may not necessarily be indicative of changes in vegetation condition (Reed et al., 1994). Selection of w must also not be so high as to allow data from the previous growing season to affect the average (Hoff, 1983). A trial and error method was used to find the appropriate w for this study. This value was determined to be 8, but it should be noted that using any value from 6 – 10 would have produced nearly identical results.

It was also necessary to create additional data points before and after the GEOCOMP-n data collection period in order to allow the analysis of 8 vegetation index values. Building composites from existing daily AVHRR imagery was not an option because snow cover made georeferencing impossible. Instead, vegetation index values from the April 1 composite (April 11 in 1999) were used to represent the values in the four composites prior to April 1. The seven composites after October were constructed using the final vegetation index values from the last usable image for each year.

Determining the date on which the actual time-series crosses the predicted time-series first requires the determination of the composite in which the two time-series cross. Next, the calculation of the slope and intercept of the respective time-series segments under consideration is necessary (**Figure 3.15.**). The slope and intercept of each line is determined using the following equations, respectively:

$$SLOPE_{x,i} = \left(\frac{VI_{x,i} - VI_{x,i-1}}{DATE_{x,i} - DATE_{x,i-1}} \right) * G_i \tag{3.8}$$

$$INT_{x,i} = (VI_{x,i} - (SLOPE_{x,i} * DATE_{x,i})) * G_i \tag{3.9}$$

Where: x = the time series under consideration (predicted or actual); *SLOPE* = the slope of the line; i = the composite period under consideration; *VI* = the vegetation index from composite i; *DATE* = the acquisition date from composite i; G = a mask showing the location of pixels the actual time series crossed the predicted time series during composite i; and *INT* = the intercept of the line.

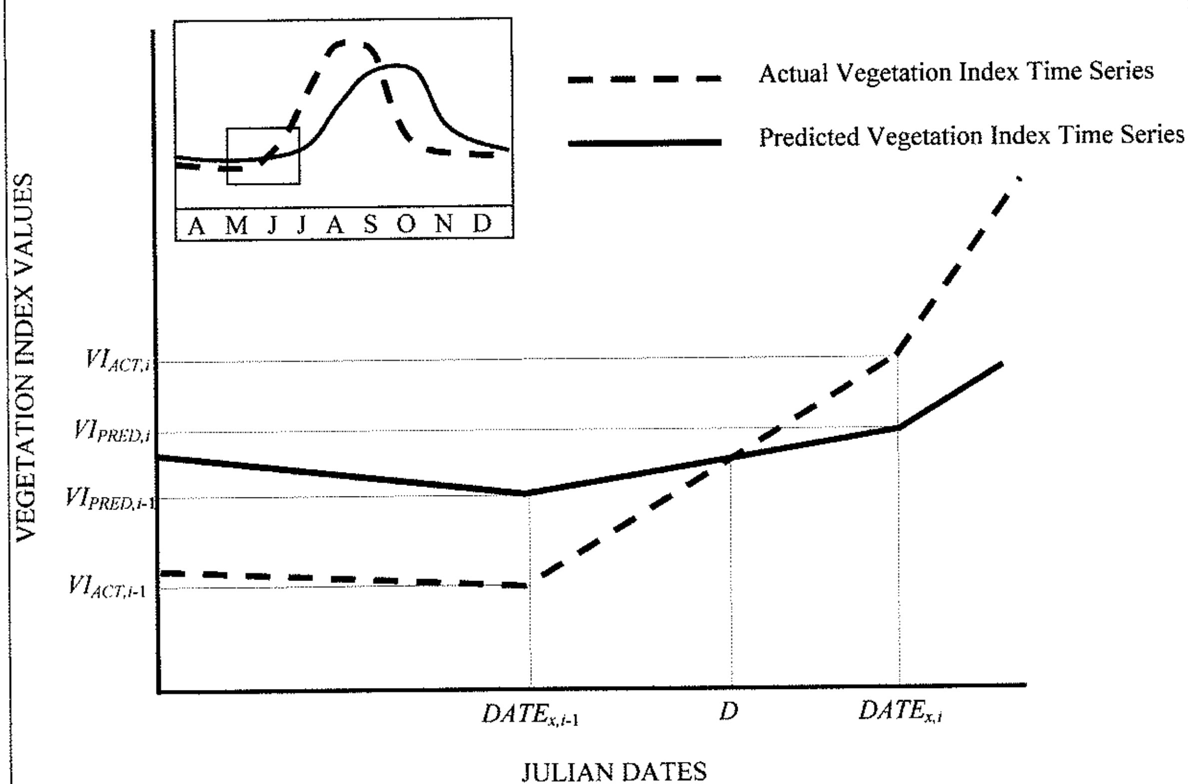

Figure 3.15. An example of the slope and intercept calculation of each time-series segment to determine the day on which a significant trend change occurred. Where: x = the time series under consideration (predicted or actual); *PRED* = the predicted time-series; *ACT* = the actual time-series; *SLOPE* = the slope of the line; i = the composite period under consideration; *VI* = the vegetation index from composite i; *DATE* = the acquisition date from composite i; D = the day on which a significant trend change occurs; and *INT* = the intercept of the line.

The next step determines precisely when the lines cross using the following equation:

$$D_i = \left(\frac{INT_{p,i} - INT_{a,i}}{SLOPE_{a,i} - SLOPE_{p,i}} \right) \tag{3.10}$$

Where D = the date on which the lines cross (onset or end); i = the composite under consideration; a denotes the actual vegetation index time-series; and p denotes the predicted vegetation index time-series.

The end of the green season is determined using the methods developed for detecting the onset of the green season; the only difference being that several variables were determined in reverse chronological order. The predicted time-series is calculated using the following equation:

$$Y_t = (X_t + X_{t+1} + X_{t+2} + \ldots + X_{t+(w-1)})/w \tag{3.11}$$

Slope and intercepts are also calculated in reverse order such that:

$$SLOPE_{x,i} = \left(\frac{VI_{x,i} - VI_{x,i-1}}{DATE_{x,i} - DATE_{x,i-1}} \right) * G_i \tag{3.12}$$

$$INT_{x,i} = (VI_{x,i} - (SLOPE_{x,i} * DATE_{x,i})) * G_i \tag{3.13}$$

The onset and end of green season maps were then used to determine the total length of the green season for each pixel.

3.5.3.2. Length of Green Season

The length of the green season metric represents the number of continuous days between the growing season onset and end. The end of green season date is subtracted from the onset of green season date to determine the total length of the green season:

$$LENGTH = END - ONSET \tag{3.14}$$

Where: *LENGTH* is an image of green season length; *END* is the map of end of green season dates; and *ONSET* is the map of green season onset dates.

3.5.3.3. Date of Maximum Greenness

Unlike determination of onset and end of the growing season there is no interpolation used in the determination of date of maximum greenness maps. The nature of the construction process of maximum-value GEOCOMP-n images dictates that the yearly maximum index should be included in one of the composites. Cloud contamination may hide the actual date of maximum greenness, but no interpolation technique can circumvent this problem.

The date of maximum greenness was determined by completing the following steps: (1) the maximum vegetation index value was determined for each pixel during the course of the growing season; (2) for each composite, a mask was made of pixels in which the maximum vegetation index value was found during that particular composite period; (3) these masks were then multiplied by the corresponding dates layers. Results of the image multiplication were maps showing the date of maximum vegetation index value for each composite. (4) The final step combined the date of maximum vegetation index for each composite into a single map. When all maps were generated, spatial and temporal trends were determined for each metric and the entire model was verified with supplementary data.

3.5.3.4. Spatial and Temporal Trends

Spatial and multi-year temporal trends were assessed for the study area. Spatial trends were assessed by looking for directional and land cover-based differences. Values for each metric were extracted at 1 km intervals along south-north, west-east and southwest-northeast transects within the map area (**Figure 3.16.**). Values were plotted over space and trends were considered significant if the slope of the line was statistically different from zero with a p-value less than 0.05. Additionally, a sample of 250 random points was extracted from each metric. Each metric was assessed for differences among land cover types with analysis of variance (ANOVA) tests. Post-hoc a pairwise multiple comparison test determined which means were significantly different (a = 0.05) than each other using the Tukey's honestly significant difference test.

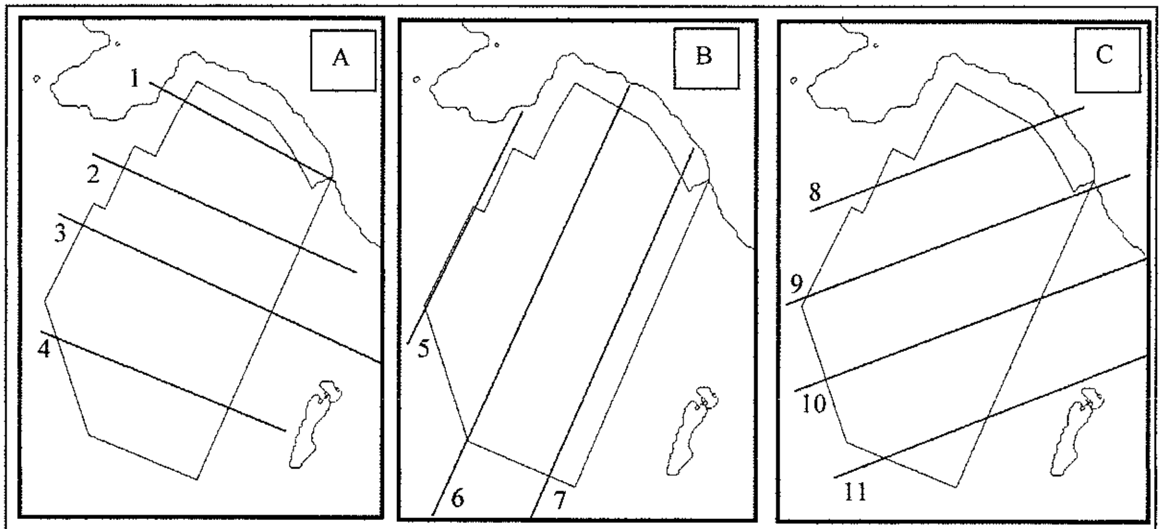

Figure 3.16. Location of transects for spatial trend analysis. (A) west-east; (B) south-north; (C) southwest-northeast.

Temporal trends were assessed by plotting the mean value of each metric over the three-year period. Given that the study is limited to three years, the statistical calculation of trends was not undertaken. Instead, trends were described without calculating statistics.

3.5.4. Model Validation

Model validation was required to verify that satellite-derived growing season metrics are representative of the actual events. The validation was performed in two steps. The first step determined if linear interpolation was indicative of the actual pattern of the vegetation index over a short period of time. The second validation step compared the satellite-derived phenological metrics to climate data within the study area.

3.5.4.1. Linear Interpolation

Linear interpolation was used throughout the research, based on the assumption that vegetation index values have a simple linear relationship with time over a 10-day period. Linear and second-order polynomial interpolations were compared to verify this assumption.

Daily AVHRR data were available for 1999 and 2000. A Channel 1 cloud-masking algorithm was applied and pixels with lengthy periods (at least 10 days) of cloud-free conditions were identified. The vegetation index response at these locations was plotted against time and the linear and polynomial regressions were calculated. Root-mean-square (RMS) deviations of the residuals were compared to identify the most appropriate relationship.

3.5.4.2. Validating Event Timing with Climate Data

Field research for this study was not undertaken at either end of the growing season. Additionally, many climate stations in the vicinity are missing too much data to construct a meteorological-based phenological classification against which the satellite-derived metrics could be compared. Instead, a single climate station within the study area was used to assess general findings. Daily mean temperatures were compared to the vegetation index time-series to assess the findings of satellite-derived onset, peak and end of the green season metrics. Air temperature has been shown to be closely associated with the timing of green season events (White et al., 1997). The availability of data limited the assessment to 1999 and 2000, the first two years of the study.

3.6. CHAPTER SUMMARY

This chapter explained the research methods employed to meet the research objectives. To effectively map the timing of key phenological events, a vegetation index suited to monitoring arctic vegetation must be identified. Four vegetation indices were tested for their ability to determine percent cover and photosynthetic biomass, and limit the influence of background noise. It was also necessary to examine the characteristics of the primary data source for this study – GEOCOMP-n AVHRR imagery. GEOCOMP-n data were examined to determine the typical satellite and sensor zenith angles and acquisition dates for each composite. Finally, the satellite data were converted to the appropriate vegetation index and analyzed. Analyses were designed to identify key phenological events within the GEOCOMP-n data set for the years 1999-2001. Phenological events of interest in this study were the date of green season onset and end, the length of the green season and the date of maximum greenness. The following chapter presents the results of the analyses and a discussion of these results.

CHAPTER 4 – RESULTS

This chapter addresses the objectives of the study outlined in Chapter 1. The objectives are addressed individually in three sections. The first section answers the question "which vegetation index is best suited for analysis of arctic vegetation using AVHRR data?". Addressing this question includes a quantitative assessment of the ability of each vegetation index to predict photosynthetic biomass and percent cover, and to limit the influence of background noise. It also entails the use of a qualitative assessment to determine other practical considerations. The second section determines the basic characteristics of GEOCOMP-n data for the study area. This is accomplished by observing the distribution of sensor zenith angles, solar zenith angles and data acquisition dates. The third section is concerned with estimating the timing of key events in the Arctic growing season using GEOCOMP-n data. Before these estimators could be developed, the data required adjustment to account for the influence of cloud cover and data errors. Once these were accounted for, estimators, or green season metrics, were developed by examining the NDVI time series for significant changes that represented changes in the growing season. The third section of this chapter also includes an examination of spatial and temporal trends in the green season metrics as well as a validation of the methodology.

4.1. VEGETATION INDEX ASSESSMENT

Four vegetation indices were examined through both a quantitative and qualitative approach. These include the WDVI, NDVI, $MSAVI_1$ and $MSAVI_2$.

4.1.1. Quantitative Assessment

Three quantitative tests were conducted. First, a regression analysis was used to determine which vegetation index is the best predictor of photosynthetic biomass. The findings of the regression analysis suggest that all vegetation indices tested show very similar relationships to photosynthetic biomass (Figure 4.1.). Specific results of the analysis show that r-square values range from of 0.705 for the two MSAVIs, to 0.619 for the NDVI. The r-square value for the WDVI was 0.695.

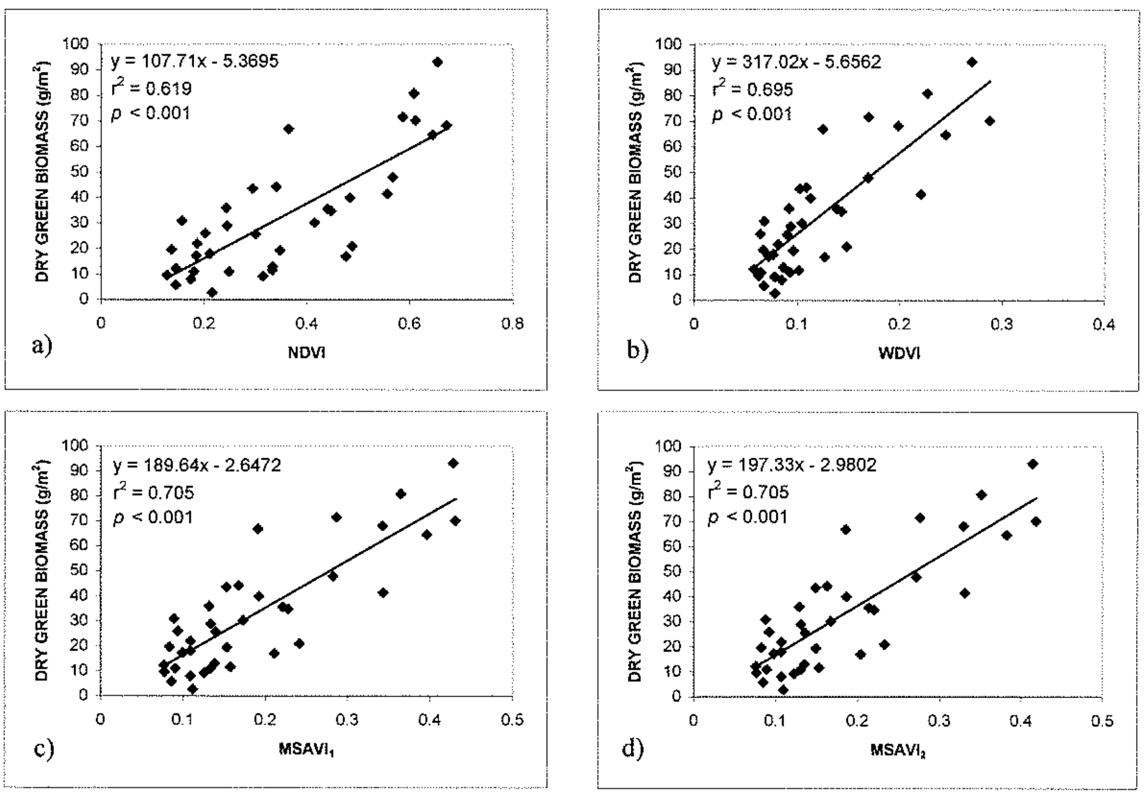

Figure 4.1. Regression between photosynthetic biomass and a) NDVI, b) WDVI, c) $MSAVI_1$, and d) $MSAVI_2$

Second, regression analysis was conducted to the ability of each vegetation index to predict values of percent vegetation cover. The findings demonstrate that the relationship between vegetation index values and percent cover estimates are similar among the indices, but differ from the results concerning photosynthetic biomass. Values of the NDVI had the highest correspondence to percent cover, as characterized by an r-square of 0.762 (**Figure 4.2.**). The $MSAVI_2$ and $MSAVI_1$ also performed well, having r-square values of 0.744 and 0.741, respectively. The WDVI was found to have the lowest r-square value among the various vegetation indices.

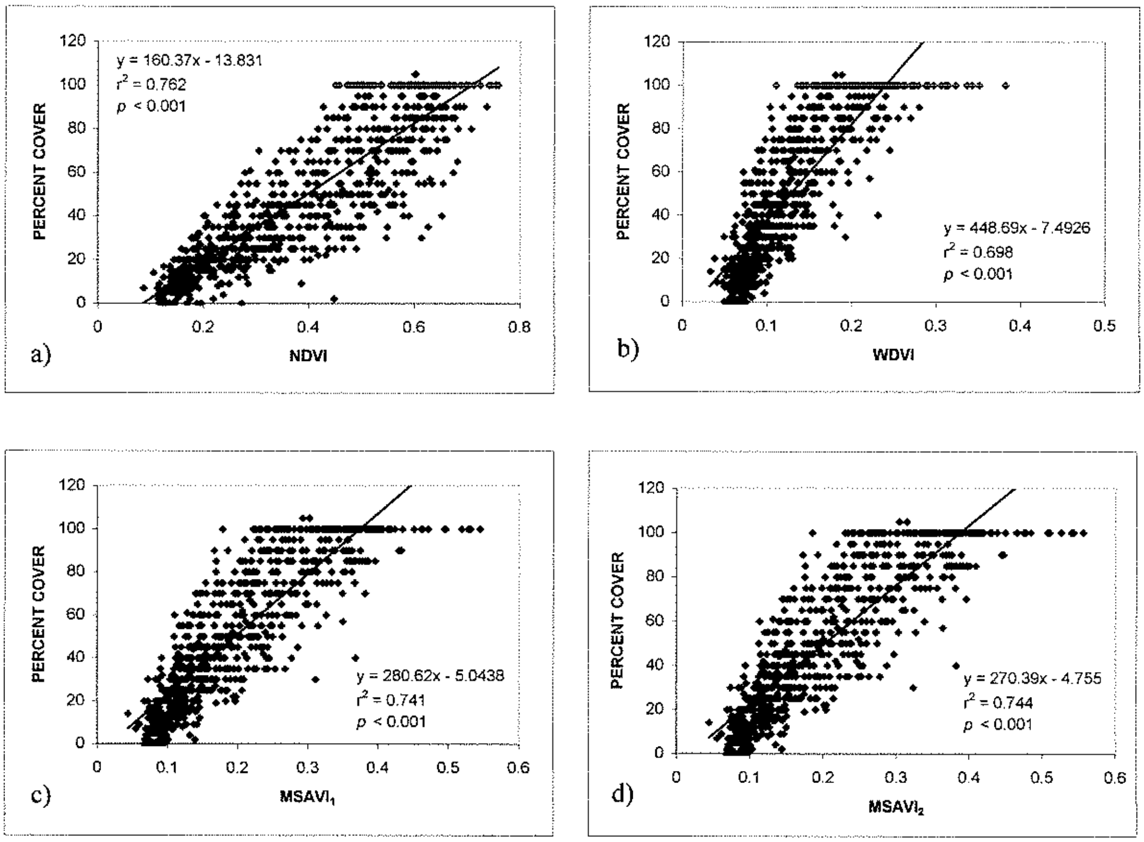

Figure 4.2. Regression between percent cover and a) NDVI, b) WDVI, c) $MSAVI_1$, and d) $MSAVI_2$

In summary, all vegetation indices were determined to predict percent cover more effectively than photosynthetic biomass. This suggests that vegetation indices describe total biomass better than they do green biomass, since percent cover estimates were based on all components of the plant, as opposed to only the green leaves as was the case with photosynthetic biomass measurements.

Third, the SN ratio was used to assess the influence of background noise on vegetation indices. The results of the analysis were similar for the WDVI, $MSAVI_1$ and $MSAVI_2$ throughout the percent cover gradient (**Figure 4.3.**). Where cover proportions were less than 50 percent, the WDVI was better able to minimize the influence of background noise than the other vegetation indices. However, SN ratios for the WDVI declined as percent cover increased. The $MSAVI_1$ and $MSAVI_2$ had relatively stable SN ratios throughout the percent cover gradient. Compared to the vegetation indices tested here, the NDVI had substantially different SN ratio values at most percent cover intervals. The SN ratios for the NDVI show a positive correlation to percent cover; a relationship not found with the other vegetation indices.

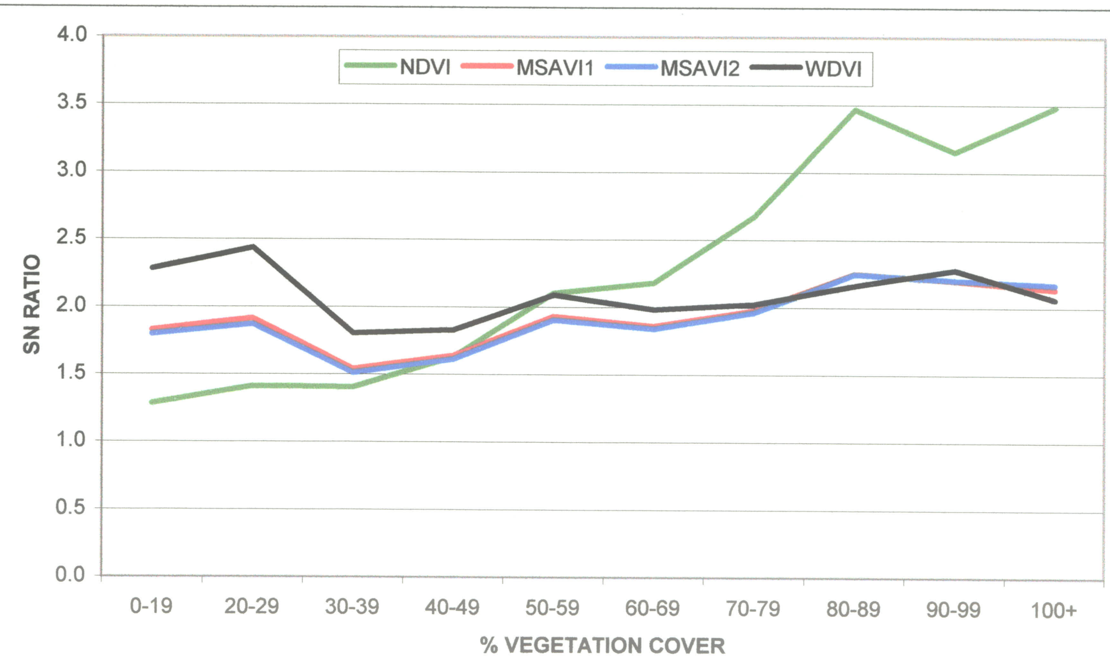

Figure 4.3. SN ratio values for four vegetation indices.

Relative to other vegetation communities, SN ratio values found in TNNP were substantially lower for all levels of percent cover. Elvidge and Lyon (1985) compared vegetation indices in an area dominated by sagebrush communities and/or juniper stands and found SN ratios for the NDVI and WDVI approached 10 and 12, respectively. Qi et al. (1994) examined cotton canopies and found SN ratio values greater than 40 for the NDVI and SAVI, and greater than 30 for the WDVI. Greater background noise and lower vegetation index values are produced in the Arctic because of the less complete vegetation canopies. Mid-latitude vegetation provides a more complete cover, reducing the amount of soil visible to the sensor. Large variations in SN ratio values result from different dominant vegetation types between studies.

4.1.2. Qualitative Assessment

The qualitative assessment provided different insights into the utility of the four vegetation indices. Two indices were eliminated from further consideration, in spite of their showing in the quantitative tests. Both the $MSAVI_1$ and WDVI require the calculation of a bare soil line. The need to recalculate the bare soil line would significantly increase the amount of time required to estimate the timing of key events in the growing season. Additionally, the AVHRR data do not provide the necessary spatial resolution to make reliable determinations of the bare soil line. This single shortcoming generated enough concern to eliminate both the $MSAVI_1$ and WDVI from further consideration. Of the two remaining indices, only the NDVI is available in the GEOCOMP-n data set. Although the $MSAVI_2$ can be produced with reflectance data from the Channel 1 and Channel 2 composites, this would dramatically add to the number of steps used in further analysis. Finally, the $MSAVI_2$ has not been tested and validated as widely as the NDVI. The NDVI is, by far, the most widely used and accepted remotely-based measurement of vegetation characteristics.

4.1.3. Vegetation Index Assessment Summary

The vegetation index assessment was designed to determine, using multiple criteria, the single index best suited for this study. Based on both the quantitative and qualitative assessments, the NDVI was selected as the most appropriate vegetation index for the purposes of this study. Though it was the weakest predictor of photosynthetic biomass, the NDVI was the strongest predictor of percent cover and had the highest overall SN ratio. The qualitative criteria eliminated the WDVI and $MSAVI_1$ due to their requirements for calculating a bare soil line. The $MSAVI_2$ is not produced by the GEOCOMP-n system nor is it widely accepted or used in the scientific literature. The NDVI is produced by GEOCOMP-n and has been the most commonly employed vegetation index since it was developed. Based on these finding, the NDVI was selected for use in this study. This selection led to the next step: determining general characteristics and biases inherent in the GEOCOMP-n data.

4.2. GEOCOMP-n DATA CHARACTERISTICS

Understanding the nature of the data is important, as it alerts the user to biases, errors, and weaknesses in the data set. For the purpose of this study three features of the data were examined: the distribution of sensor zenith angles, solar zenith angles and acquisition dates.

4.2.1. Sensor Zenith Angles

Sensor zenith angles describe the angle from which the surface is observed by the satellite sensor. Low sensor zenith angles were desired in order to maximize spatial resolution, and geometric accuracy. Low sensor zenith angles also minimize interference by atmospheric particles. Sensor zenith angles for the TNNP region are described for each year of this study.

4.2.1.1. Sensor Zenith Angle Distribution - 1999

Sensor zenith angles for 1999 are summarized in **Table 4.1**. In the early and late months of the 1999 data set, sensor zenith angles tended to be very high. Greater than 83 percent of the sensor zenith angles in the May 1 composite were at least 60 degrees off nadir. Most sensor zenith angles were less than 60 degrees during the majority of the growing season (mid-June to late September). Nearly 60 percent of viewing angles were less than 30 degrees for the eleven composites from June 10 to September 21. High zenith angles increased in frequency again towards the end of the 1999 data set. Fewer than half of all pixels in the two October composites were collected with view angles less than 60 degrees.

Table 4.1. Breakdown of sensor zenith angles for each composite in 1999 (values are percentages).

		Acquisition Angles				
Month	Composite	<15°	<30°	<45°	<60°	60°+
April	0401			NO DATA		
	0411	0.00	0.23	3.24	53.54	46.46
	0421	0.00	0.14	0.23	68.86	31.14
May	0501	0.00	0.01	0.01	16.54	83.46
	0511	0.01	0.01	1.65	92.31	7.69
	0521	0.01	0.25	0.75	52.64	47.36
June	0601	6.28	9.05	13.58	67.54	32.46
	0611	53.22	67.19	68.32	99.05	0.95
	0621	4.84	50.33	78.57	99.18	0.82
July	0701	17.38	63.35	70.36	99.71	0.29
	0711	31.60	41.44	55.75	97.76	2.24
	0721	2.41	50.78	69.51	99.78	0.22
August	0801	9.35	76.48	80.08	98.54	1.46
	0811	71.10	71.81	74.91	97.57	2.43
	0821	49.09	63.44	69.17	98.59	1.41
September	0901	9.90	42.38	95.01	98.82	1.18
	0911	41.94	90.85	99.14	99.82	0.18
	0921	0.40	38.23	69.84	86.03	13.97
October	1001	0.01	0.07	0.20	30.59	69.41
	1011	3.73	7.55	17.02	48.00	52.00
	1021			NO DATA		

4.2.1.2. Sensor Zenith Angle Distribution - 2000

Sensor zenith angles for 2000 are summarized in **Table 4.2**. Results were similar to those seen in 1999; high angles at the beginning and end of the data set with low to medium angles during the majority of the growing season. A dramatic switch from high to low sensor zenith angles was observed between the composites of June 1 and June 11. In the June 1 composite, over 94 percent of scan angles were greater than 60 degrees. In the next composite period, June 11, almost 80 percent of angle values were less than 15 degrees. A similar transition was found at the end of the growing season. During the September 21 composite sensor zenith angles were predominantly less than 60 degrees.

By the October 1 composite, nearly 71 percent of pixels were acquired at sensor zenith angles greater than 60 degrees.

Table 4.2. Breakdown of sensor zenith angles for each composite in 2000 (values are percentages).

		Acquisition Angles				
Month	Composite	<15°	<30°	<45°	<60°	60°+
April	0401	0.01	0.04	0.16	38.46	61.54
	0411	0.00	0.00	0.11	14.89	85.11
	0421	0.08	0.08	0.20	17.34	82.66
May	0501	0.29	0.43	12.44	39.18	60.82
	0511	0.00	0.00	2.50	36.34	63.66
	0521	0.01	4.75	20.16	75.02	24.98
June	0601	2.41	4.33	4.35	5.66	94.34
	0611	78.52	84.92	88.08	96.71	3.29
	0621	14.16	63.79	87.20	99.05	0.95
July	0701	59.68	67.48	72.02	98.50	1.50
	0711	11.92	21.46	40.98	85.04	14.96
	0721	22.34	25.20	62.00	90.59	9.41
August	0801	70.32	75.52	82.56	98.53	1.47
	0811	2.50	43.63	86.44	98.59	1.41
	0821	28.20	74.18	94.49	98.13	1.87
September	0901	6.13	32.72	98.96	99.58	0.42
	0911	22.73	66.51	81.01	96.50	3.50
	0921	0.89	1.93	29.10	99.70	0.30
October	1001	1.38	1.75	8.59	29.05	70.95
	1011	28.03	36.40	59.86	72.45	27.55
	1021	1.88	42.91	99.18	99.80	0.20

4.2.1.3. Sensor Zenith Angle Distribution - 2001

Sensor zenith angles for 2001 are summarized in **Table 4.3**. Results from the 2001 data set were similar to those from the previous two years. However, there was a slight variation in the early portions of the 2001 data set: angles tended to be slightly lower in 2001 than in previous years. Also, the transition, from high to low angles at the start of the growing season, and from low to high angles at the end of the growing season, occurred more gradually in 2001 than in the previous two years.

Table 4.3. Breakdown of sensor zenith angles for each composite in 2001 (values are percentages).

		Acquisition Angles				
Month	**Composite**	**<15°**	**<30°**	**<45°**	**<60°**	**60°+**
April	**0401**	0.00	0.00	0.03	100.00	0.00
	0411	0.00	0.05	0.13	86.42	13.58
	0421	0.00	0.14	9.41	100.00	0.00
May	**0501**	0.00	0.07	16.23	100.00	0.00
	0511	0.06	0.38	0.98	42.97	57.03
	0521	1.10	3.24	10.18	62.72	37.28
June	**0601**	4.56	11.21	40.34	91.68	8.32
	0611	19.01	19.01	19.01	100.00	0.00
	0621	54.21	61.73	74.46	97.90	2.10
July	**0701**	10.12	29.66	75.35	84.34	15.66
	0711	4.03	23.42	82.27	94.43	5.57
	0721	15.64	46.83	66.78	97.63	2.37
August	**0801**	9.12	30.62	61.85	97.15	2.85
	0811	13.70	48.07	58.51	100.00	0.00
	0821	0.59	45.78	94.99	99.16	0.84
September	**0901**	76.64	89.92	96.17	99.77	0.23
	0911	23.66	87.63	98.35	98.51	1.49
	0921	88.70	91.35	91.61	98.77	1.23
October	**1001**	0.01	0.13	1.76	72.10	27.90
	1011	0.00	0.00	4.54	43.20	56.80
	1021	0.48	1.61	5.71	25.74	74.26

4.2.1.4. Sensor Zenith Angle Distribution Summary

The AVHRR is unique with respect to its ability to view 55 degrees off nadir. This ability provides the user with high temporal resolution, but also provides challenges in that the spatial resolution is reduced in pixels acquired at high sensor zenith angles. Pixels viewed at nadir have a nominal ground resolution of approximately 1 km^2. Alternatively, spatial resolution at scene edges can reach 15 km^2 (2.4 km X 6.5 km).

Sensor zenith angles in this data set were typically low enough to avoid significant concern. In 1999 and 2001, sensor zenith angles were low throughout the green season. In 2000, sensor zenith angles were somewhat high in the first June composite resulting in lower than ideal spatial resolution conditions. The result was that the NDVI values for each pixel were derived from reflectances acquired over a larger ground area, resulting in less precise reflectance measurements. Imprecise reflectance measurements could cause the incorrect identification of onset, or it could hide the onset from the AVHRR, in particular pixels.

There were predictable transitions from high to low angles at the beginning of the growing season and from low to high angles at the end of the growing season. Examination of daily AVHRR imagery for these transition periods showed that the compositing process selected cloud or snow before and after the growing season. The high zenith angles for these composites suggest that NDVI values for snow and cloud increase with sensor zenith angles. Low sensor zenith angles during the growing season indicated that NDVI values for vegetation are highest given low to medium viewing angles.

4.2.2. Solar Zenith Angles

Solar zenith angles describe the angle at which the sun is located relative to the observed surface at the time of the measurement. Solar zenith angles are dependent upon day-of-year and time-of-day. They also vary as a function of latitude (given the relatively small size of the study area such variations were minimal). Solar zenith angles are summarized for each year in the data set in **Table 4.4**.

General patterns are similar in all three years of the data set. At the start of the data collection period solar zenith angles are relatively high, declining over time until the commencement of summer. At this point, solar zenith angles began to increase – a trend that continued through the end of the data collection period. The composite with the lowest mean solar zenith angle was slightly variable between years, but always occurred near the summer solstice.

Table 4.4. Solar zenith angle summary for each composite. Values represent angles in degrees.

1999

Month	April			May			June			July			August			September			October		
	0401	0411	0421	0501	0511	0521	0601	0611	0621	0701	0711	0721	0801	0811	0821	0901	0911	0921	1001	1011	1021
MIN	no data	59	54	52	49	47	45	45	45	45	46	48	50	53	56	60	64	68	72	76	no data
MAX		66	64	58	56	59	57	57	54	57	58	58	61	67	66	73	76	79	84	87	
MEAN		60	57	54	50	49	49	50	47	49	49	52	53	58	58	63	67	72	76	81	

2000

Month	April			May			June			July			August			September			October		
	0401	0411	0421	0501	0511	0521	0601	0611	0621	0701	0711	0721	0801	0811	0821	0901	0911	0921	1001	1011	1021
MIN	60	58	54	51	49	46	46	45	45	45	47	48	51	53	57	60	64	69	72	76	80
MAX	71	70	62	64	61	61	59	56	58	58	59	60	62	65	71	72	78	81	84	88	93
MEAN	64	61	56	53	51	49	47	50	50	50	49	51	56	59	63	64	71	74	75	84	92

2001

Month	April			May			June			July			August			September			October		
	0401	0411	0421	0501	0511	0521	0601	0611	0621	0701	0711	0721	0801	0811	0821	0901	0911	0921	1001	1011	1021
MIN	65	59	57	53	49	47	46	45	45	45	46	48	50	54	56	61	64	68	72	77	80
MAX	72	67	63	61	58	57	53	50	55	54	57	58	62	60	68	70	74	76	80	84	88
MEAN	70	61	62	59	54	52	49	48	46	48	49	50	53	57	57	62	65	70	77	82	86

The lowest mean solar zenith angles in both 1999 and 2001 were found in the June 21 composite. During the 2000 summer, mean solar zenith angles reached their lowest point in the June 1 composite, and subsequently increased slightly in the June 11 composite and remained steady for the following 2 composites before declining slightly in the July 11 composite. During late September or early October of each year, solar zenith angles began to exceed 80 degrees. Mean values typically reached 80 degrees one or two composites after the maximum values did.

Maximum solar zenith angles in the data set are found at the end of the data collection period in each year. Mean solar zenith angles exceeded 90 degrees during data collection in the October 21, 2000 composite image. In this situation, the sun provided no direct radiation to the surface being viewed from the satellite.

4.2.2.1. Solar Zenith Angles Summary

Mean solar zenith angles for the TNNP data set were below 65 degrees until the final few composites. As a result, the effects of solar zenith angles were minimal for the bulk of the growing season. Solar zenith angles did not dramatically affect NDVI values until the final composite periods, at which time they so large that a large jump in mean NDVI values within TNNP was observed (**Figure 4.4.**).

Results suggest that solar zenith angles greater than 80 degrees caused severe errors in the calculation of NDVI. Markon (1999) found a similar effect with a composite-AVHRR data set in Alaska. Erroneously high NDVI values would have caused an incorrect estimation of the predicted time-series used for determining the end of the green season metric. To prevent this error, solar zenith angles greater than 80 degrees were masked and replaced with the average of NDVI values from pixels that were not masked. Additionally, the October 21 composites were completely removed from the calculation of predicted time-series values.

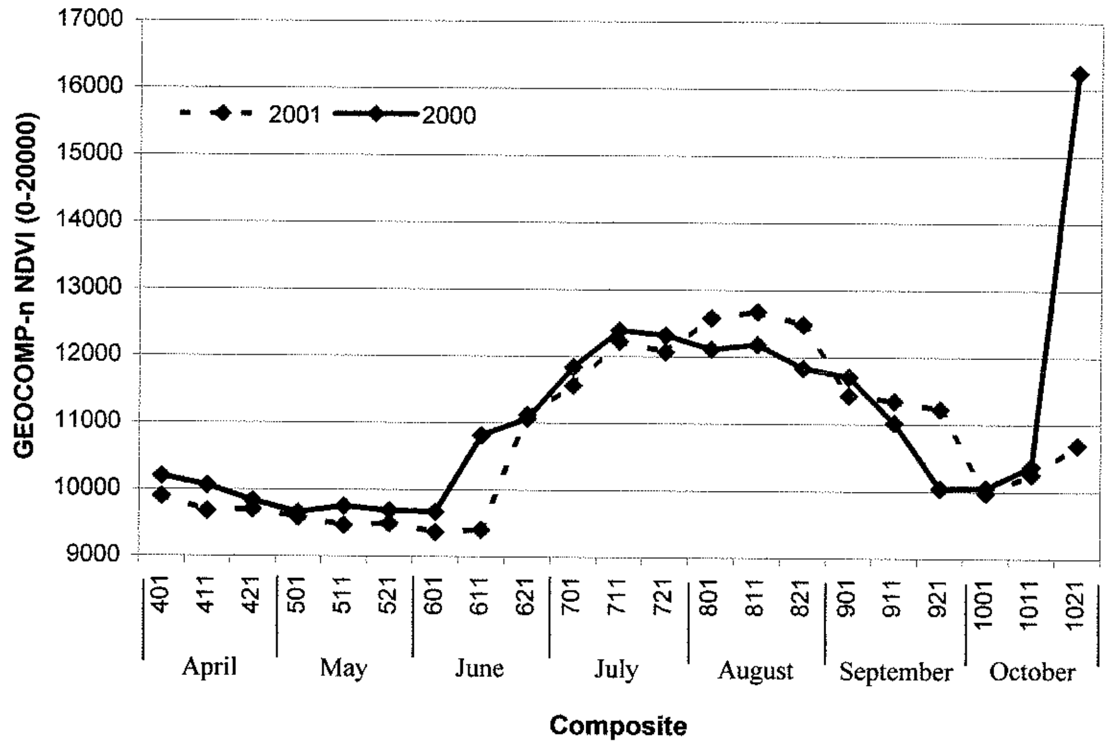

Figure 4.4. High NDVI values caused by high solar zenith angles in the final two composites. NDVI values increased more dramatically in 2000 than in 2001 because of substantially higher mean solar zenith angles.

4.2.3. Acquisition Dates

GEOCOMP-n composites were based on AVHRR imagery from 01 April to 31 October. Unspecified problems in the 1999 data set made the April 1 composite and the October 21 composite unavailable (J. Leger, pers. comm. 2000). Compositing periods are built with 10- or 11-day intervals (11 days for the third composite in months having 31 days).

Many phenologically driven studies have used multi-temporal composites without concern for the date on which each pixel was acquired (e.g. Markon et al., 1995). For the purpose of this study acquisition dates were determined to be an important consideration given that more precise measurements were required. Knowledge of the acquisition dates also provided information regarding how representative a composite was of the entire 10-day period. A 10-day composite is best represented when an equal proportion of pixels are acquired from each date within the period. Acquisition dates summaries for each year are presented below.

4.2.3.1. Acquisition Dates - 1999

The distribution of pixel acquisition dates for each 1999 composite is shown in **Figure 4.5**. Key points in the figure are as follows:

- The June 11 and July 1 composites show the distribution of acquisition dates that was expected during the green-up portion of the growing season. That is, high frequencies at the end of the composite, when NDVI is at its highest relative to other dates in the same composite.
- There is a very low frequency of pixels acquired at the end of the June 21 and the beginning of the July 1 composite, indicating the presence of a persistent cloud cover during that particular time period. The same pattern is seen when the July 11 and July 21 composites are compared.
- In the green-down portion of the season, the expected distributions are seen in the August 21 and September 11 composites. That is, high frequencies of pixels acquired early in the composite period.
- The September 1 and September 21 composites show the signs of a short-lived cloud cover at the beginning of each composite period, as seen in the lack of pixels acquired on the first day in the composites.

- In 1999 none of the composites were found to be good representations of an entire 10-day period (i.e. an equal number of pixels were not acquired from each day).

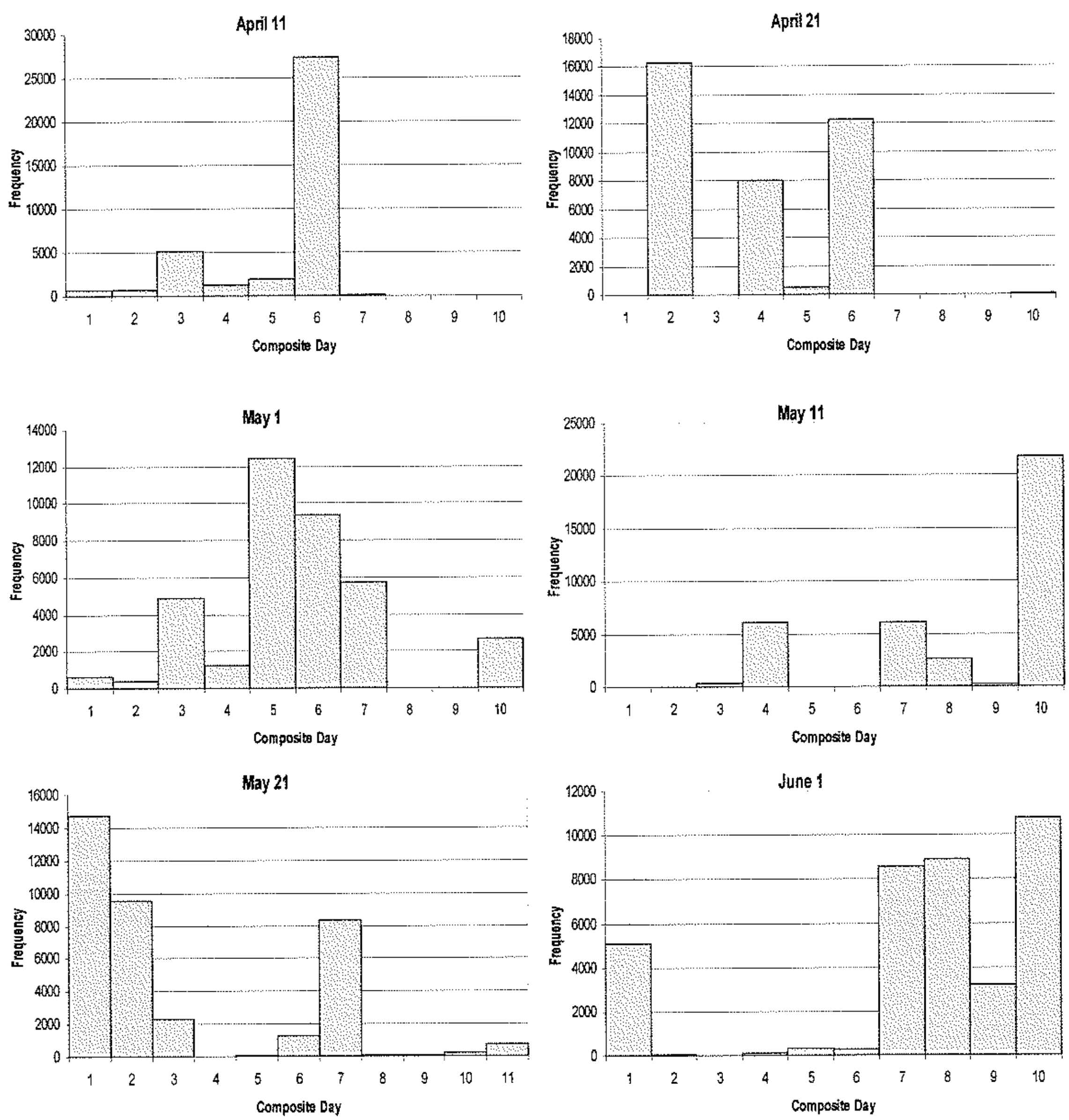

Figure 4.5. Distribution of GEOCOMP-n acquisition dates in 1999

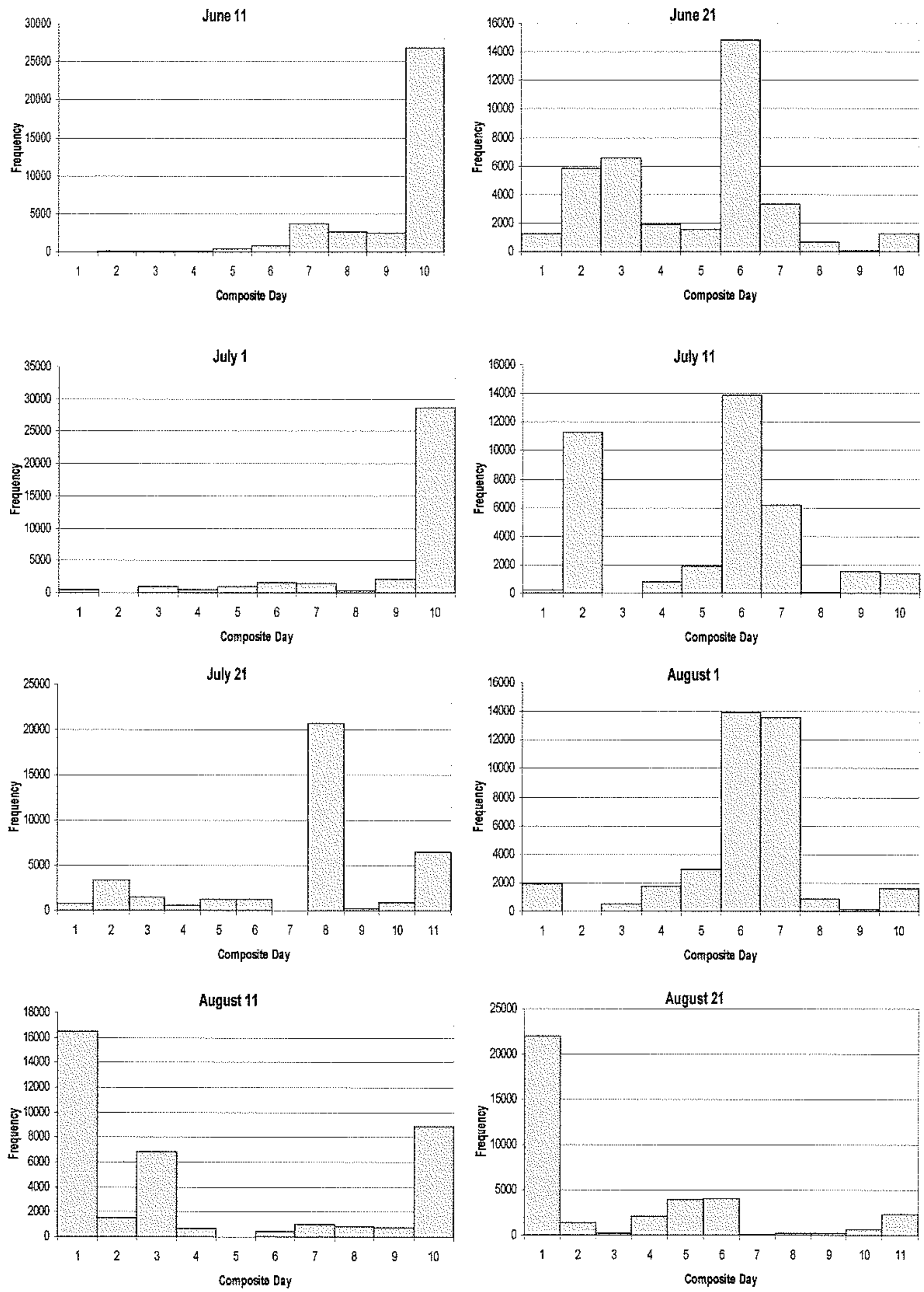

Figure 4.5. Distribution of GEOCOMP-n acquisition dates in 1999 (continued)

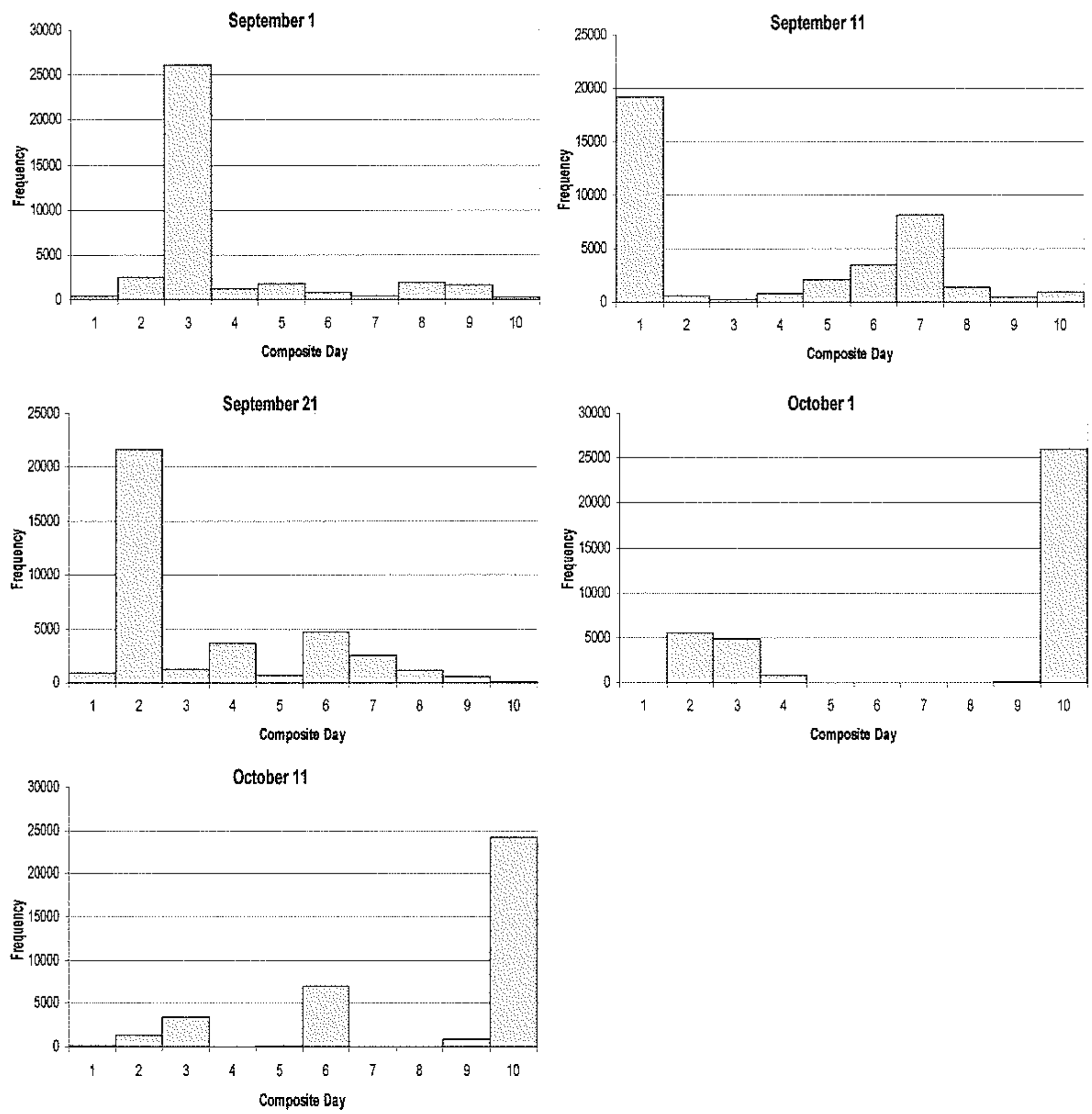

Figure 4.5. Distribution of GEOCOMP-n acquisition dates in 1999 (continued)

4.2.3.2. Acquisition Dates - 2000

Similar to 1999, a pooling of acquisition dates was found in most of the 2000 composites. There were, however, some composites in the 2000 data set that were found to be more representative of the entire 10-day period (**Figure 4.6.**). For example, the May1, May 21, and July 11 composites are somewhat representative of their respective

10-day periods. The distribution of acquisition dates for this period displayed the following:

- The June 1 composite was mostly covered with clouds; a pattern that may have persisted into the June 11 composite. An examination of daily AVHRR images verified this suggestion.
- The distribution of acquisition dates in the August 1 composite had a bimodal pattern. Since most of the park was at its peak during the August 1 composite, the bimodal pattern suggested persistent cloud cover for much of the composite with a short, cloud-free window over a few small areas in the second and third days (August 2-3). Again, by looking at daily images it was possible to verify a break in the cloud during this period.

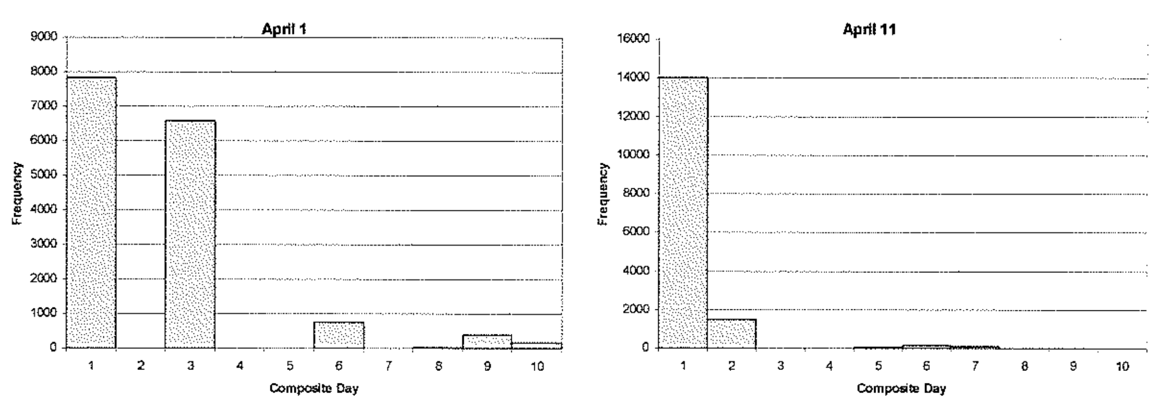

Figure 4.6. Distribution of GEOCOMP-n acquisition dates in 2000

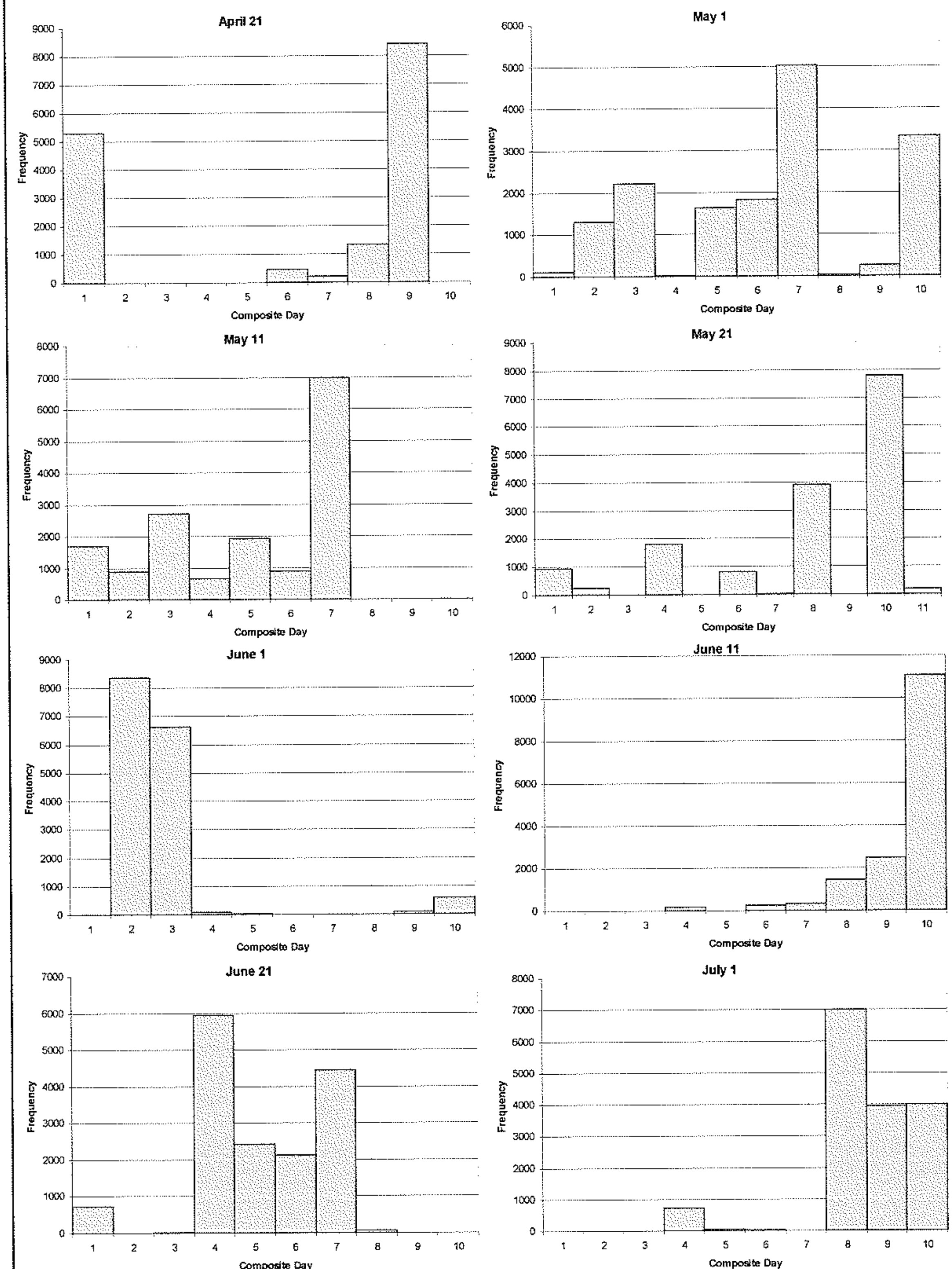

Figure 4.6. Distribution of GEOCOMP-n acquisition dates in 2000 (continued)

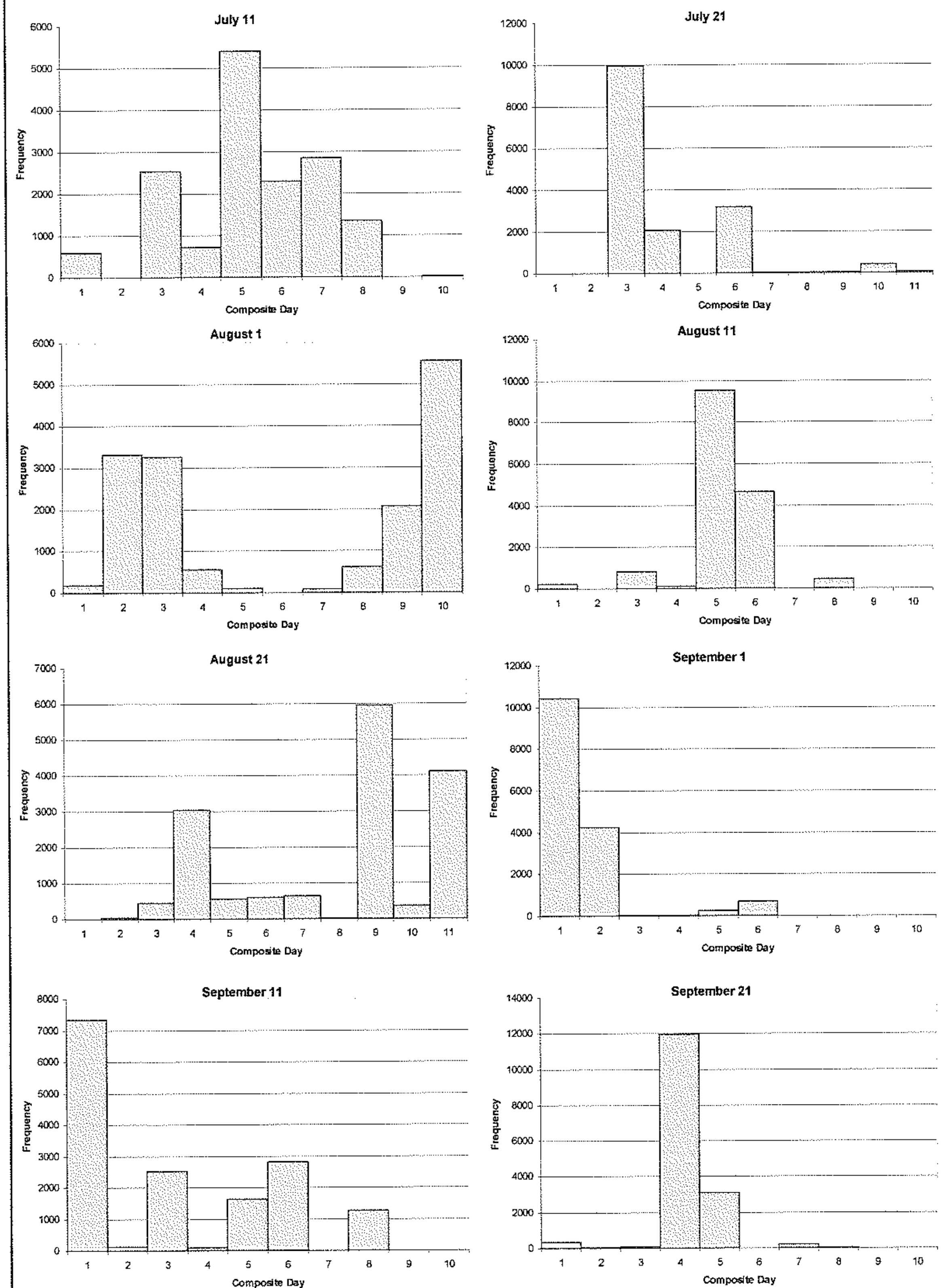

Figure 4.6. Distribution of GEOCOMP-n acquisition dates in 2000 (continued)

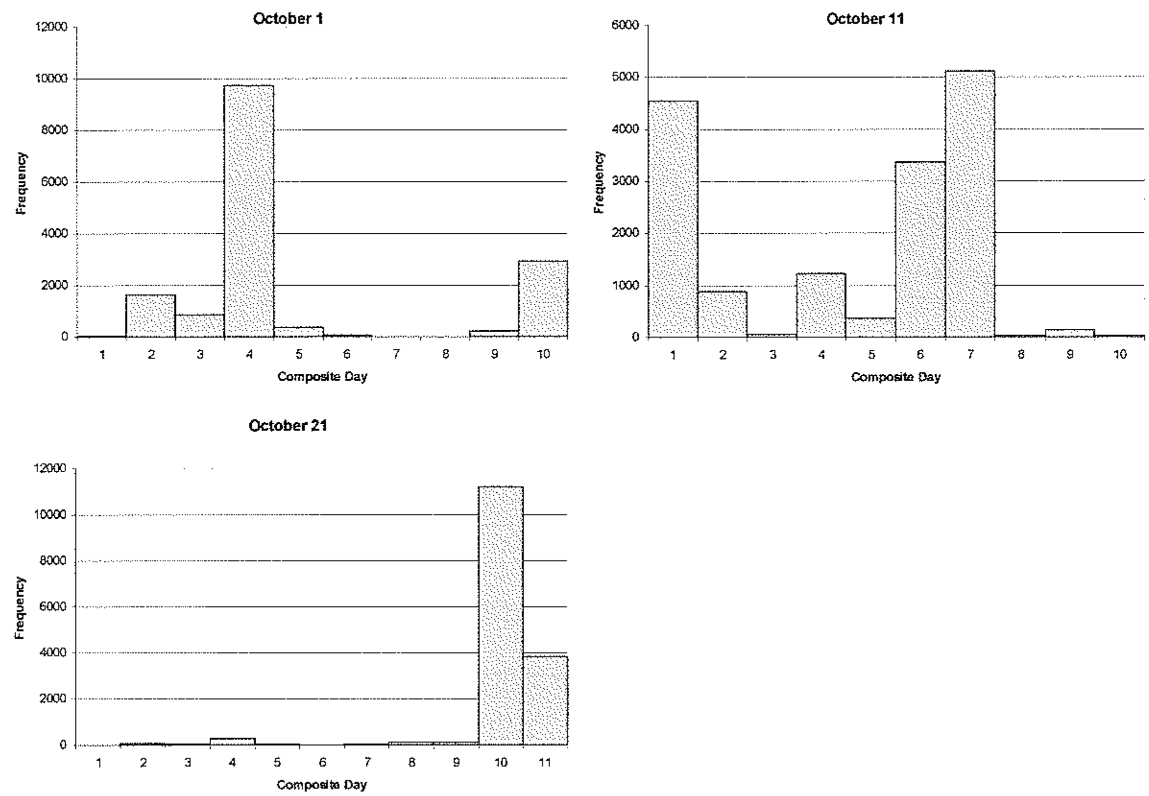

Figure 4.6. Distribution of GEOCOMP-n acquisition dates in 2000 (continued)

4.2.3.3. Acquisition Dates - 2001

Similar to the previous two years, poorly distributed acquisition dates dominate the 2001 composites (**Figure 4.7.**). Notable characteristics of acquisition dates in the 2001 GEOCOMP-n data set include the following:

- There was evidence of extensive cloud cover through much of the summer.
- The May 21-June 11, July 1, August 11 and September 1 composites all show the influence of clouds in the distribution of acquisition dates.

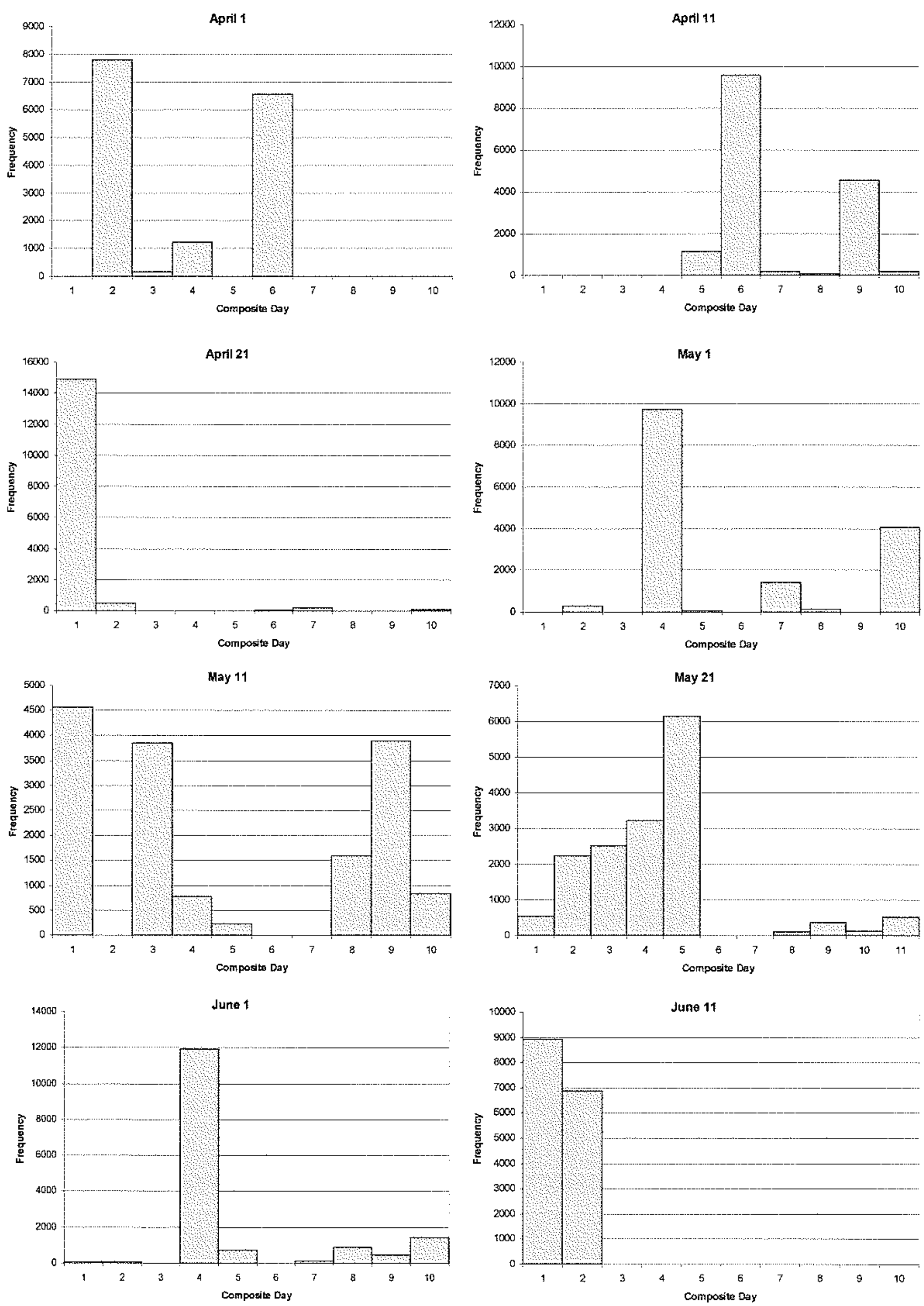

Figure 4.7. Distribution of GEOCOMP-n acquisition dates in 2001

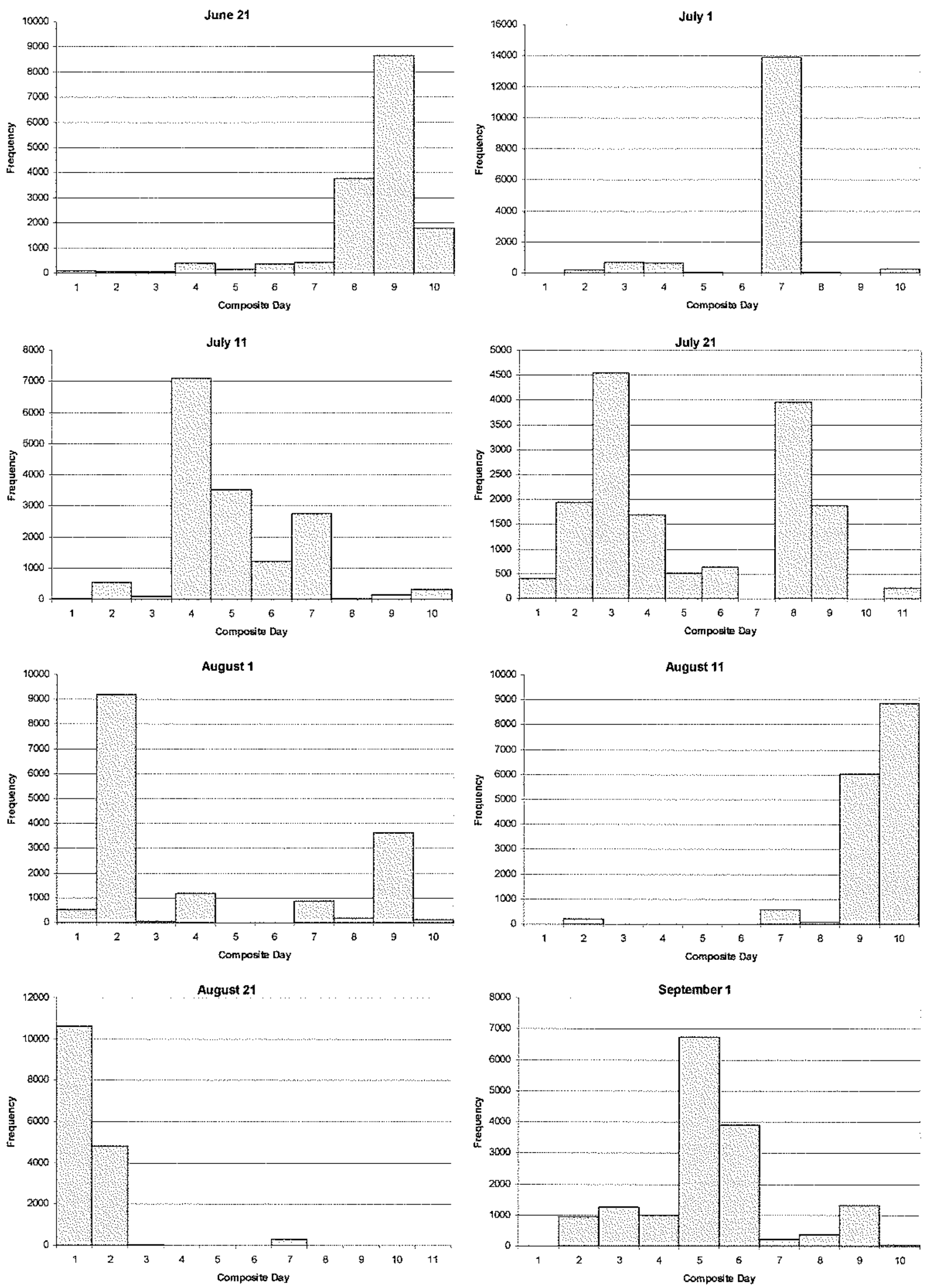

Figure 4.7. Distribution of GEOCOMP-n acquisition dates in 2001 (continued)

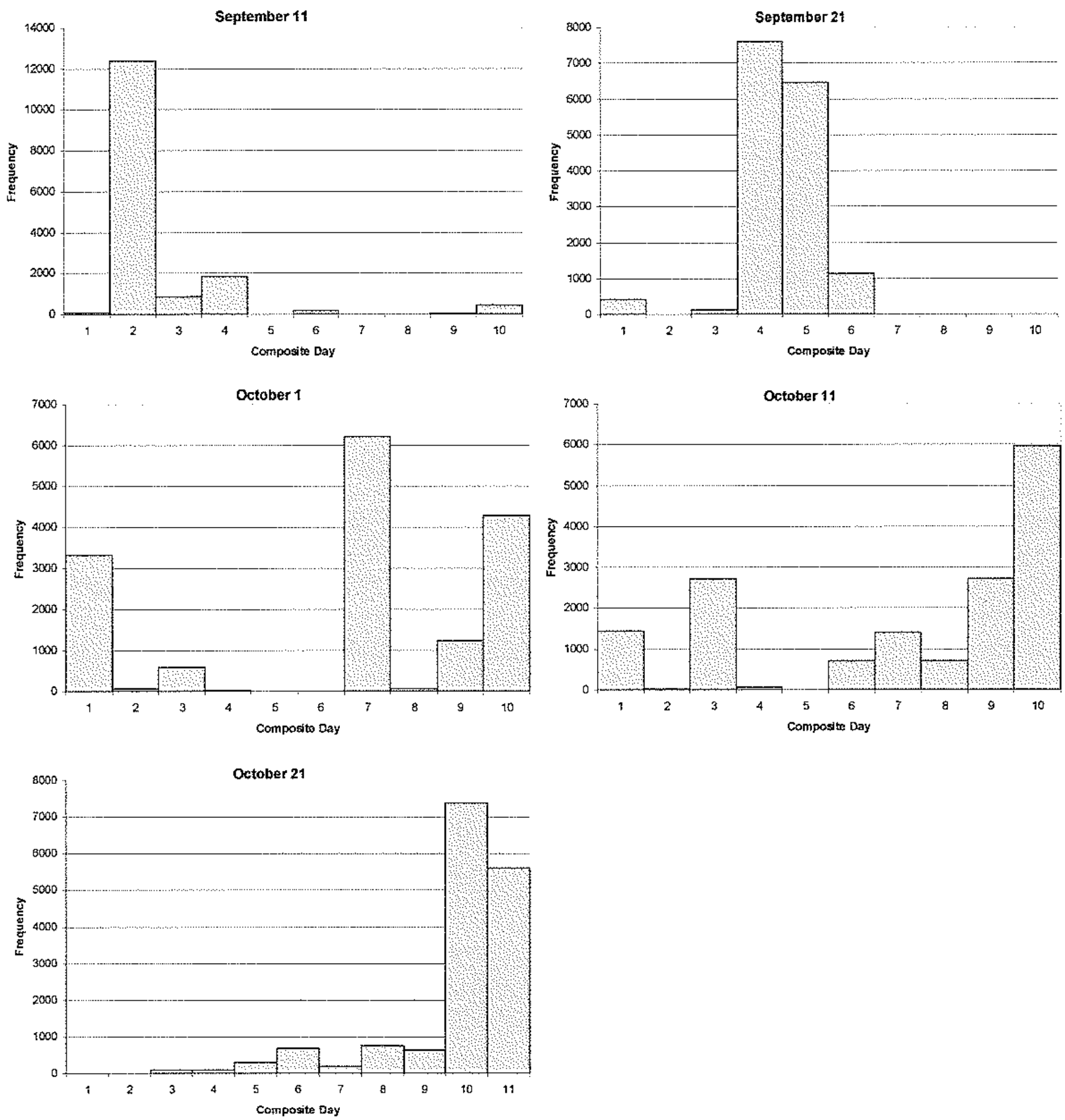

Figure 4.7. Distribution of GEOCOMP-n acquisition dates in 2001 (continued)

4.2.3.4. Acquisition Dates Summary

Actual acquisition dates were often pooled within the composites. The pooling of acquisition dates occurred for two reasons. First, a persistent cloud cover during the first (last) week of a composite period causes the acquisition dates to be pooled in the later (earlier) dates. Second, during the green-up portion of the growing season, higher NDVI values occurred during later dates; the opposite was true for the green-down portion. Composites truly representative of the entire composite period were not found during this three-year study. However, the pooled distribution of acquisition dates suggests that cloud-contaminated pixels were excluded from the final composites. That is, the final composites contained high-quality, cloud-free data wherever it was possible.

4.3. MAPPING TEMPORAL GREEN SEASON METRICS

Removing flaws in the data prior to analysis was necessary to ascertain the most reliable information from the AVHRR satellite data. Following preprocessing of the data set, the dates of onset and end of greenness, the length of green season, and the date of maximum NDVI were determined for each year (1999-2001) in TNNP. Each of these green season metrics was then examined for spatial and temporal trends, and the methodology was evaluated.

4.3.1. Data Preprocessing – Removal of Cloud Contamination

The primary reason for using maximum-NDVI composites was to minimize the effects of clouds in the imagery. However, when clouds contaminated a pixel for an entire compositing period – 10- or 11- days in this case – the effect of clouds remained in the composite image. Two cloud masking procedures were employed to locate pixels that remained contaminated: a Channel 1 threshold-based procedure; and by locating certain trend changes in the NDVI time series. Cloud-filled pixels were removed from the data set and replaced with interpolated values for the NDVI and relative dates bands of GEOCOMP-n data.

4.3.1.1. Cloud Identification

Initially, all composites were searched for residual clouds. A challenge in this process, however, was that the Channel 1 cloud masking procedure could not distinguish between cloud cover and snow or ice, and therefore was incorrectly masking too many pixels. This was particularly problematic given that the study area is covered in snow and ice through May and the early part of June (Phillips, 1990). The same problem was experienced in the September and October composites. For that reason, cloud masking was limited to the composites between May 11 and August 21, and the Channel 1 cloud masking procedure was not used until the June 10 composite each year.

While cloud masking identified residual cloud in every composite, the overall proportion of clouds remaining after compositing was low. With the exception of one composite per year, residual cloud proportions were well below 10 percent (see **Table 4.5.**). While little cloud was identified using two different detection methods, the thresholds selected were designed such that some residual cloud may have gone undetected. All attempts were made to keep the false identification of clouds to a minimum. The decision to use insensitive cloud detecting thresholds was often evident in the temporal analysis (See section 4.3.2.).

Month	COMPOSITE	1999	2000	2001
May	0511	<1 %	1 %	<1 %
	0521	5 %	1 %	1 %
June	0601	<1 %	4 %	<1 %
	0611	<1 %	3 %	11 %
	0621	<1 %	14 %	<1 %
July	0701	1 %	1 %	3 %
	0711	7 %	<1 %	<1 %
	0721	<1 %	2 %	<1 %
August	0801	15 %	6 %	<1 %
	0811	1 %	5 %	<1 %
	0821	<1 %	5 %	<1 %

Table 4.5. Percentage of cloud-contaminated pixels after compositing.

Cloud contamination was consistent across the three years. There was at least a small portion of cloud-contaminated pixels in all composites examined. The highest amount of residual cloud contamination was 15 percent found in the August 1, 1999 composite. Respective maximum residual cloud covers were 14 and 11 percent for 2000 and 2001. The pixels identified as cloud contaminated required corrections to the NDVI and relative dates values.

4.3.1.2. Adjusting Vegetation Index Values

To correct for cloud contaminated NDVI values the incorrect values were replaced by the mean of the NDVI values from the previous and subsequent composites. Adjustments to NDVI values in all three years are generally small **(Table 4.6.)**. The minimum NDVI adjustment was 0.05 for all but the May 11 composites in 1999 and 2000. In the May 11, 1999 composite, only 2 pixels were identified as cloud-contaminated. Both had exceedingly low original NDVI values and the adjustment was consequently high. Minimum adjustments in the remaining composites were equal because the second cloud identification algorithm required a minimum decline in NDVI of 0.05 to be recognized as cloud-contaminated. Mean adjustments were relatively consistent throughout the three years. Composites with relatively high mean adjustments resulted from very few cloud contaminated pixels or several large adjustments required because of data errors rather than clouds. The exception was the June 11, 2001 composite, which had a high mean adjustment as well as a large number of cloud-contaminated pixels. Standard deviations are generally low. Again, abnormally high standard deviations exist where very few pixels required adjustments and where several very large adjustments were required to repair data errors. The adjustments performed on the vegetation index values needed to be reflected in the dates layer.

Table 4.6. NDVI adjustments as a part of cloud contamination correction.

1999

Month	May		June			July			August		
Composite	0511	0521	0601	0611	0621	0701	0711	0721	0801	0811	0821
MIN	1.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
MAX	1.02	1.02	0.13	1.51	0.17	0.12	0.19	0.49	0.15	0.41	0.5
MEAN	1.02	0.07	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.06	0.08
ST DEV	0.003	0.09	0.01	0.13	0.01	0.01	0.02	0.02	0.02	0.01	0.08

2000

Month	May		June			July			August		
Composite	0511	0521	0601	0611	0621	0701	0711	0721	0801	0811	0821
MIN	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
MAX	0.20	0.16	0.26	0.11	0.17	0.22	0.57	0.52	1.11	0.51	0.77
MEAN	0.12	0.07	0.08	0.06	0.07	0.07	0.16	0.08	0.08	0.08	0.06
ST DEV	0.04	0.02	0.02	0.01	0.01	0.03	0.13	0.03	0.10	0.03	0.02

2001

Month	May		June			July			August		
Composite	0511	0521	0601	0611	0621	0701	0711	0721	0801	0811	0821
MIN	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
MAX	0.11	0.15	0.09	0.60	0.15	0.57	0.70	0.08	0.27	0.66	0.70
MEAN	0.07	0.07	0.06	0.14	0.08	0.12	0.06	0.07	0.09	0.08	0.07
ST DEV	0.03	0.02	0.01	0.12	0.03	0.11	0.02	0.01	0.03	0.09	0.03

4.3.1.3. Adjusting Relative Dates Values

Since values from both the NDVI band and the relative dates band were used to determine the precise timing of events, it was necessary to adjust the relative dates values that correspond with the adjustments made to the NDVI values. A summary of adjustments to relative dates values is provided in **Table 4.7.** All adjustments are less than 10 days, indicating that cloud was never found to contaminate the same pixel for two straight composite periods. In all but the June 11, 2001 composite, there were negative and positive adjustments made to relative dates values. When all composites are considered, the average adjustment was less than 1 day. Despite the average, there were many large adjustments made to relative dates values. Without such adjustments, the maps of timing events would have been less accurate.

Table 4.7. Relative date adjustment as part of cloud contamination correction.

1999

Month	**May**		**June**			**July**			**August**		
	0511	**0521**	**0601**	**0611**	**0621**	**0701**	**0711**	**0721**	**0801**	**0811**	**0821**
MIN	-1	-4	-5	-8	-3	-8	-6	-8	-8	-8	-5
MAX	3	9	5	8	9	4	8	8	7	8	9
MEAN	1.00	5.72	-0.66	-2.77	5.52	-4.41	2.75	-1.62	0.37	1.11	0.95

2000

Month	**May**		**June**			**July**			**August**		
	0511	**0521**	**0601**	**0611**	**0621**	**0701**	**0711**	**0721**	**0801**	**0811**	**0821**
MIN	-4	-4	-6	-7	-6	-5	-7	-6	-7	-7	-9
MAX	3	7	8	8	8	6	5	9	6	9	5
MEAN	1.11	0.98	5.29	-1.3	3.65	0.88	0.65	-1.98	-1.22	1.66	-5.12

2001

Month	**May**		**June**			**July**			**August**		
	0511	**0521**	**0601**	**0611**	**0621**	**0701**	**0711**	**0721**	**0801**	**0811**	**0821**
MIN	-3	-5	-8	1	-8	-6	-5	-5	-3	-9	-5
MAX	6	8	2	9	3	8	5	9	7	3	9
MEAN	-0.2	0.3	-5.0	5.7	-1.8	1.3	0.5	1.5	3.5	-2.5	4.5

4.3.2. Determining the Timing of Key Growing Season Events

The ability to map the precise timing of key growing season events is a requirement for future research of the effects of a changing climate on arctic ecosystems. The timing of four growing season events were mapped for three years in TNNP: the onset, end, and length of greenness, as well as the maximum NDVI. Each map increases the understanding of current conditions within TNNP.

4.3.2.1. Green Season Onset

Onset of the green season describes when the vegetation has enough density to be detected from satellite sensors notwithstanding background influences from soil, vegetation litter from previous years, standing water and snow. The date of green season onset in the study area for 1999 occurs on julian day 144 (May 24) (**Figure 4.8.**). The general pattern of green-up began in the west, and gradually moved east. Within TNNP, green season onset occurred over a period of 46 days (from May 24 through July 8) (**Figure 4.9.**). Initial signs of greenness occurred along the Darnley Bay coast, the western portion of the map area and along the Hornaday River valley. There was also early onset detected along a band near the northern border of TNNP – a pattern not detected in the next two years. This pattern was attributed, through examination of the daily AVHRR imagery, to the presence of cloud in the northern TNNP region. The cloud cover had a higher NDVI than the ground surface at this time. As a result, the cloud-filled pixel was included in the composite and subsequently caused a large enough jump in the time series to be detected as new growth. There are three distinct areas that begin green-up relatively late. A crescent-shaped area in the northern portion of TNNP abuts the band of very early onset. Late onset is also visible in the Melville Hills region in center of TNNP, and east of TNNP between the park boundary and the eastern limits of the map area.

Similar to 1999, the 2000 green season onset began on julian day 144 (May 23). Initial greening occurred on the southern coast of Darnley Bay and in the southwest corner of the map area (**Figure 4.10.**). There were a few patches of onset in the center of the map area, which appear to have been caused by cloud rather than actual vegetation growth. Detected onset within these patches is unexpectedly early compared to surrounding onset dates. There was relatively little new growth until day 159 (June 8) when the frequency of new growth jumps, and continues to increase until day 164 (June 13) when new growth is at its peak **(Figure 4.11.)** By this time, the Hornaday River valley, the western portion of the map area as well as a large portion of land east of TNNP have experienced green season onset. The onset period wraps up along the coast, within a large crescent-shaped area in the northern portion of TNNP and in the higher elevations of the Melville Hills region. Cloud cover that went undetected by two cloud-screening methods influenced the determination of green season onset, resulting in the patchy appearance to the 2000 green season onset map.

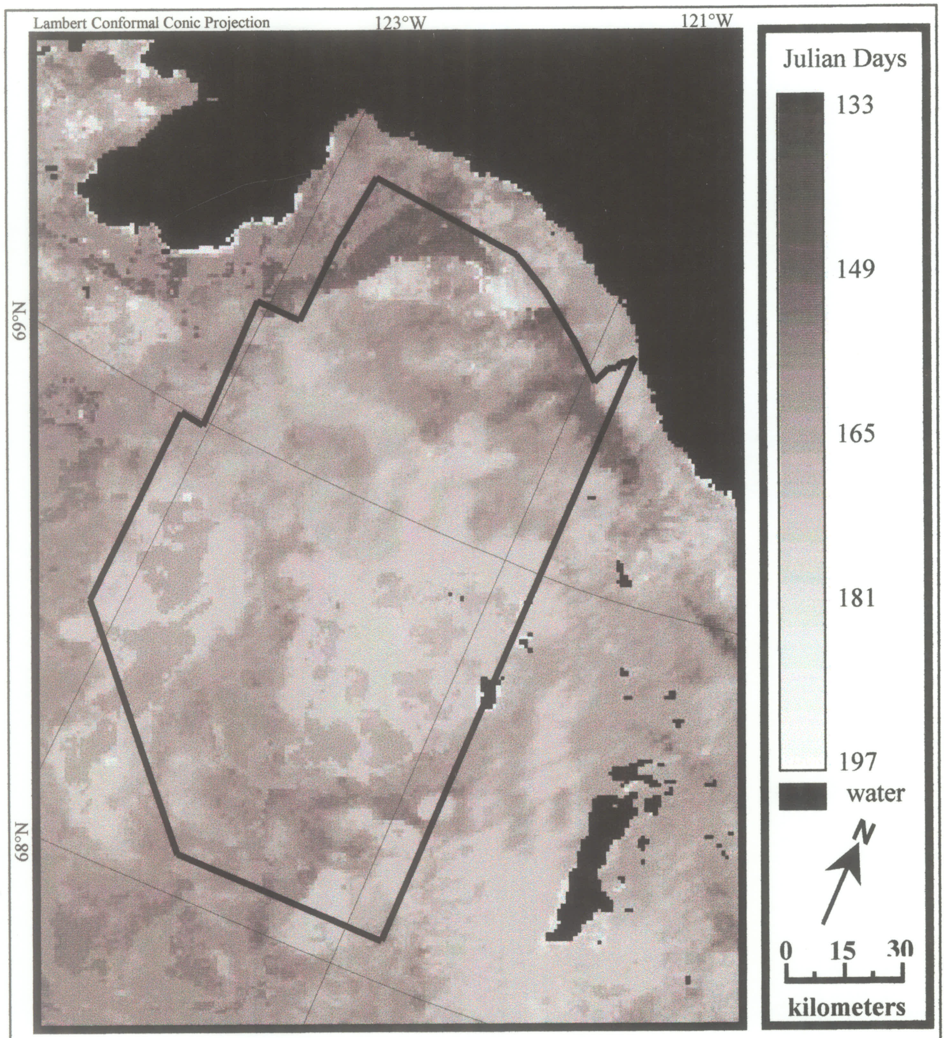

Figure 4.8. Onset of the Green Season - 1999

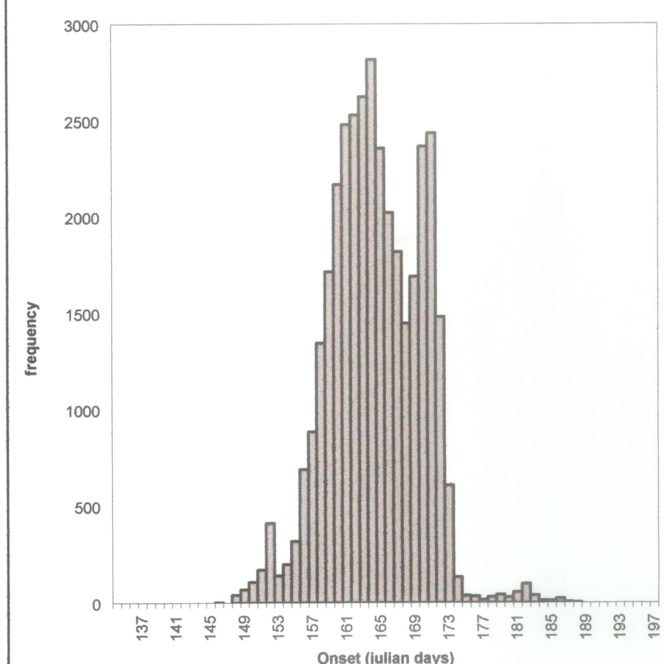

Figure 4.9. Distribution of green season onset dates in 1999

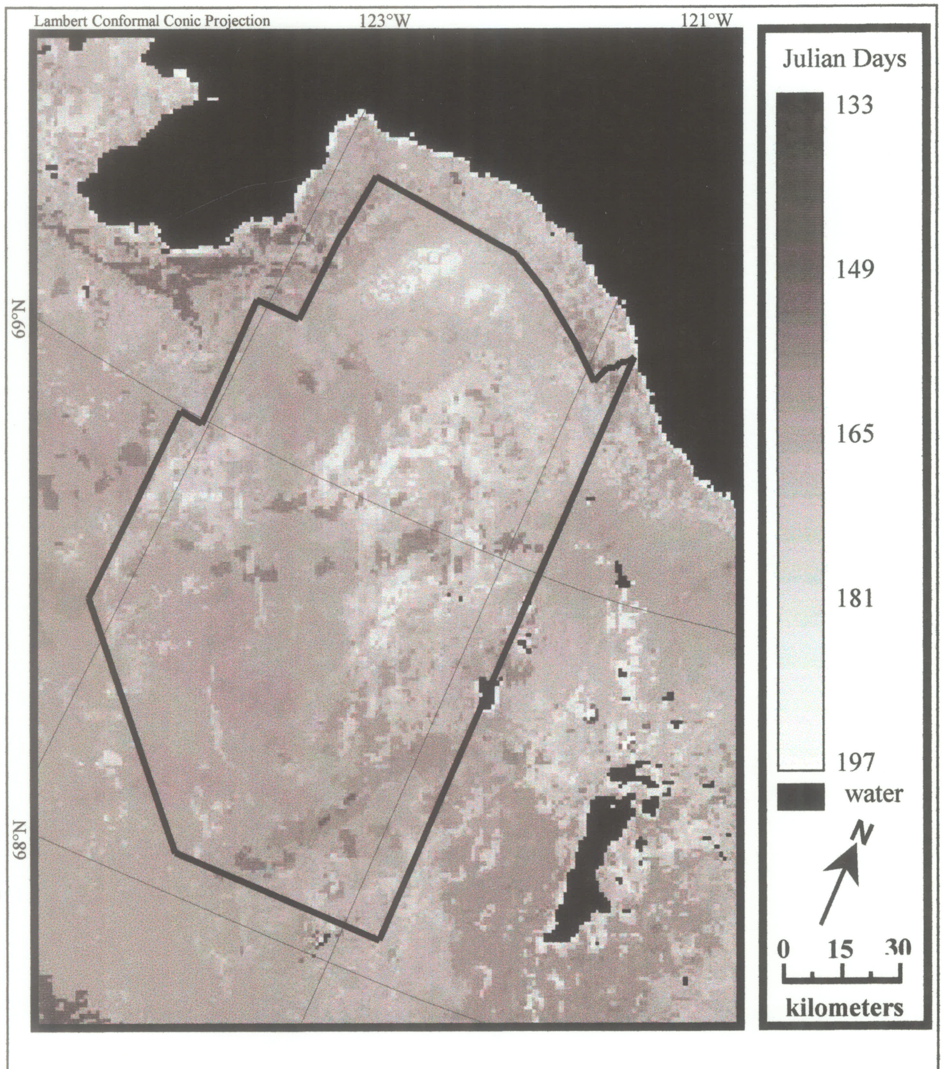

Figure 4.10. Onset of the Green Season - 2000

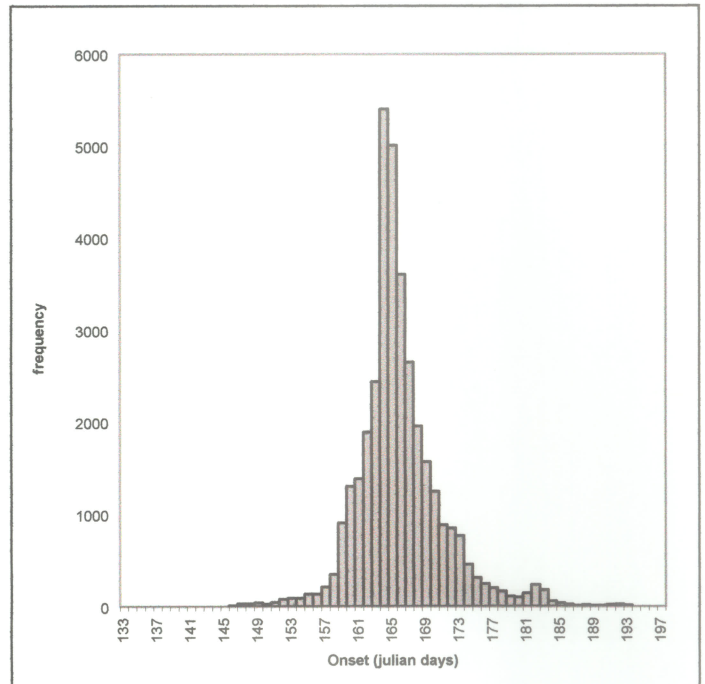

Figure 4.11. Distribution of green season onset dates in 2000

The onset period in 2001 began 11 days earlier than in the two previous years, commencing on day 133 (May 13) (**Figure 4.12.**). Despite the earlier initiation of vegetation growth, the peak of the onset occurred a week later than in 1999 and 2000, on day 171 (June 20) – the results of a relatively slow acceleration of onset and a negatively skewed histogram of onset dates (**Figure 4.13.**). The 2001 onset occurs in three steps. The first step occurs from day 133 to day 156 (May 13 to June 5). This first step is concentrated in the Darnley Bay coastal region. The second step lasts from day 157 to day 163 (June 6 to June 12). This portion of the onset extends the growth along the Darnley Bay coast north to the Amundsen Gulf, as well onset occurs along the west and Hornaday valley regions. The final step in the histogram occurs from day 164 to day 190 (June 13 to July 9). This final portion lasted nearly one month, occurring first in the south before moving on to the east. The same crescent-shaped area found during the 1999 onset period is visible in the 2001 onset map.

Analysis of daily AVHRR imagery pointed out a small number of cases in which clouds were causing false detection of green season onset. The NDVI of the cloud was high enough to be interpreted as green season onset. The method for detecting the onset of the green season was overly sensitive in a few other cases as well. However, a change to the methodology to make it less sensitive was not warranted, as it would have created a situation where onset could go undetected.

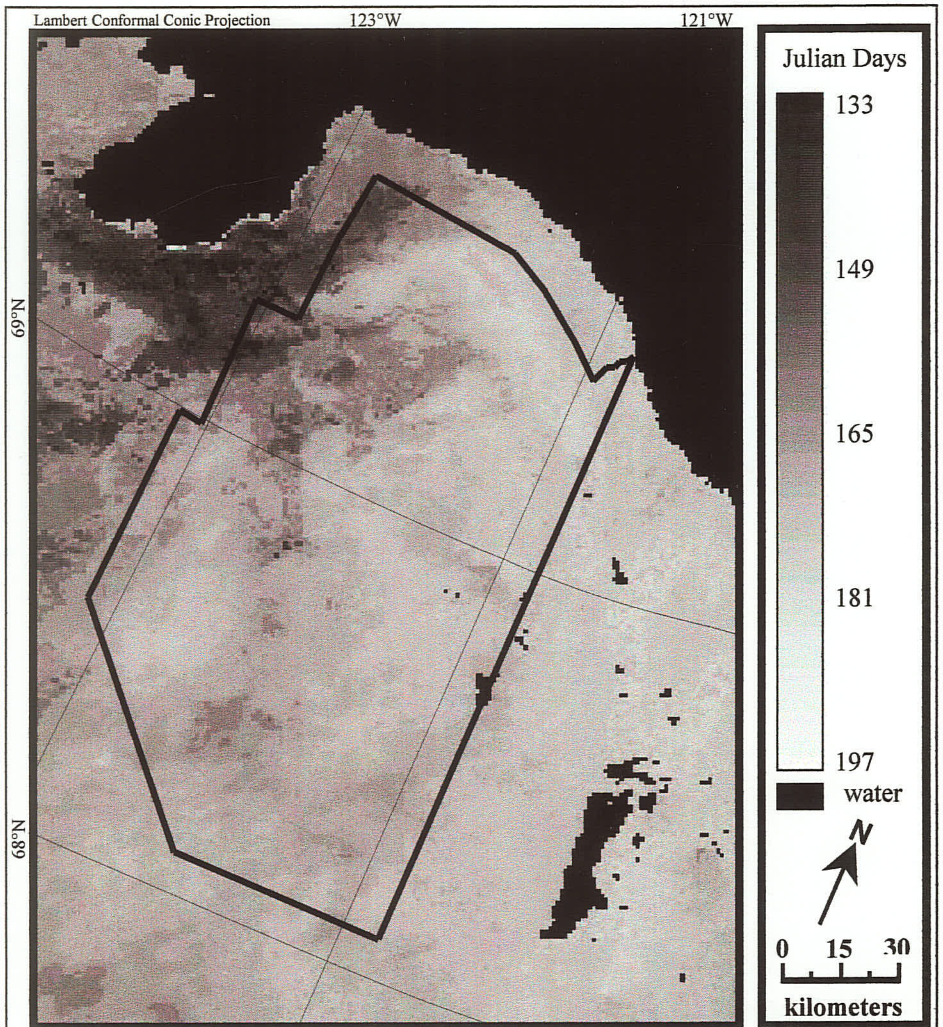

Figure 4.12. Onset of the Green Season - 2001

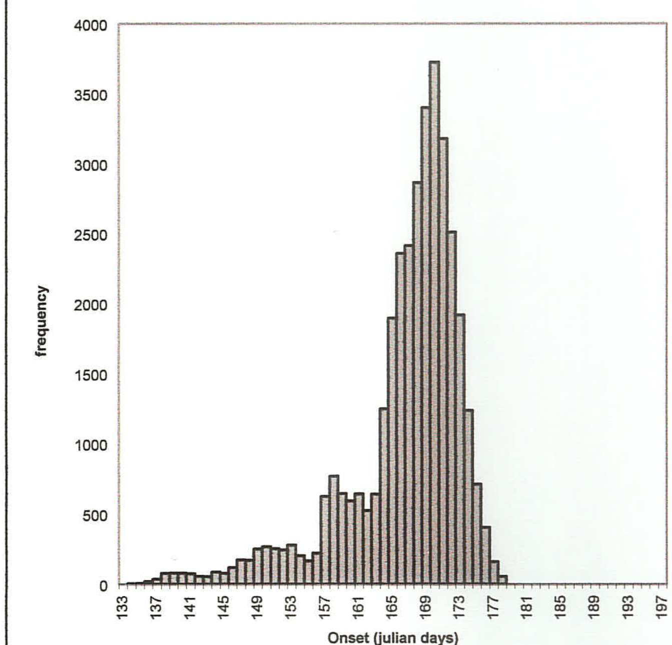

Figure 4.13. Distribution of green season onset dates in 2001

4.3.2.2. End of the Green Season

The end of the green season represents the point at which the AVHRR no longer senses the presence of vegetation. The pattern to the end of the green season of 1999 was erratic (**Figure 4.14.**). Generally, the end of greenness began in the east and progressed west, though early end patches existed adjacent to late ending patches throughout the map area. The lack of pattern in the 1999 end of green season map was the result of residual cloud contamination.

The histogram of end dates also displays the irregular green-down in 1999 (**Figure 4.15.**). The first sign of the end of the growing season occurs on julian day 255 (September 12). The frequency of pixels where photosynthesis has ceased remains very low for roughly two weeks, until approximately day 272 (September 29) when the frequency begins to rapidly increase to a peak on day 276 (October 3). From the peak to the final day of green down, frequencies jump from high to low. The final three days of the green down actually see a relatively high frequency of pixels in which the green season ends.

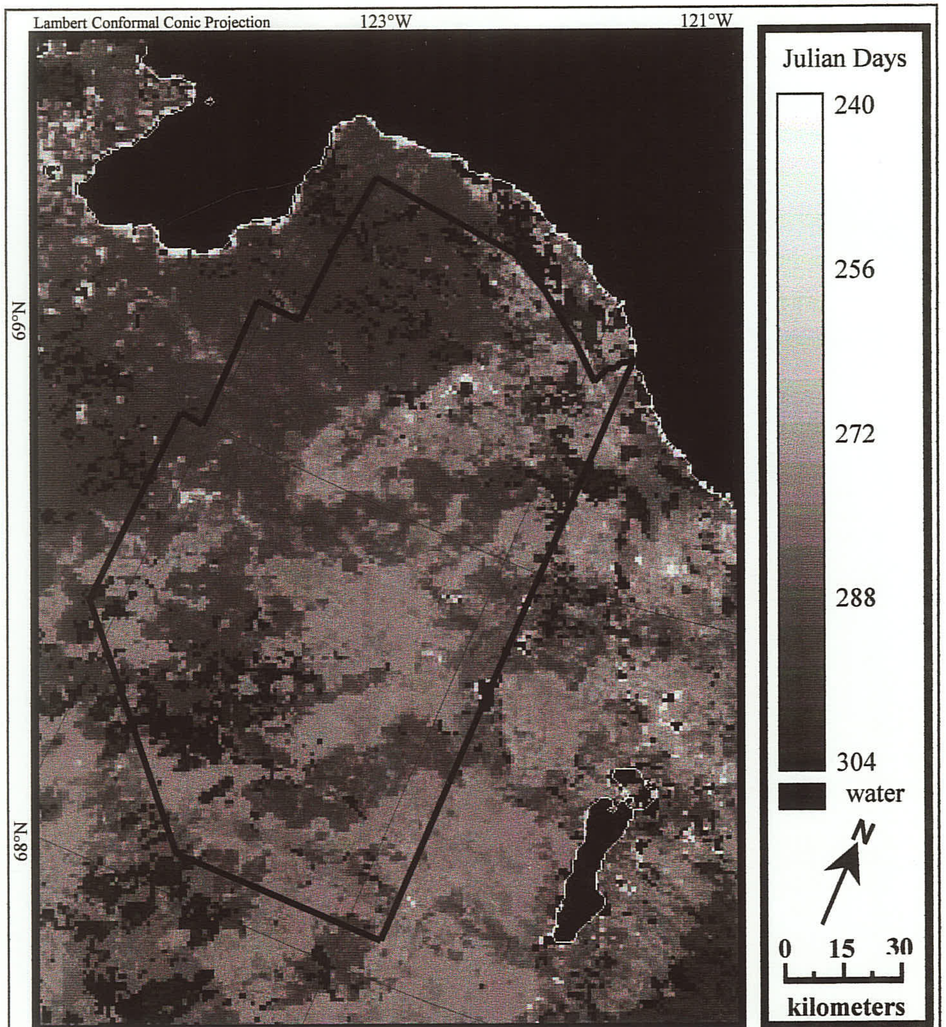

Figure 4.14. End of the Green Season - 1999

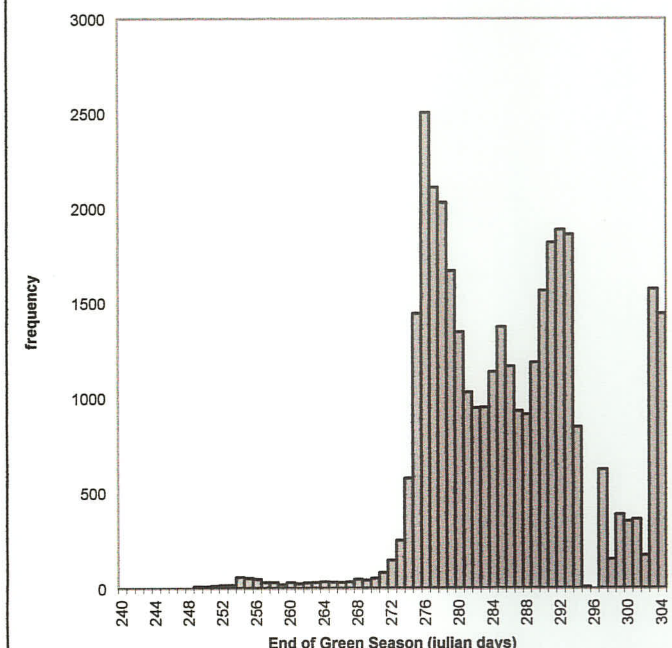

Figure 4.15. Distribution of green season end dates in 1999

In contrast to 1999, the green down in 2000 had an obvious northeast-to-southwest directional component to it (**Figure 4.16.**). Green down began in the northeast portion of TNNP as well as east of the park on day julian 249 (September 5). Green down spread in a southwest direction through the map area and concluded south and southwest of TNNP. The bulk of the green season had ended before julian day 294 (October 20), however, the green season in less than half of one percent of all pixels did not conclude until between julian days 301 and 304 (October 27 and 30).

The histogram of green season end dates also shows the pattern of green down (**Figure 4.17.**). The first peak in the histogram falls between julian days 249 and 270 (September 5 and 26). This peak is representative of the initial green down in the northeast portion of TNNP. The second peak falls between julian day 271 and 280 (September 27 and October 6). Most of the green down occurred within this 10-day window. The end of the green season occurred over all but the northeast corner of TNNP during this period. The final peak occurs after julian day 281 (October 7). This final peak is representative of the end of greenness south and southeast of TNNP.

The green down in 2001 shows a pattern that is similar to that in 2000, though less distinct (**Figure 4.18.**). The end of the green season in 2001 also began in the northeast corner of TNNP and ended in the southwest. However, the pattern is more irregular than that found in 2000.

The histogram of 2001 green season end dates is negatively skewed (**Figure 4.19.**). The green-down has a long, slow build up until day 267 (September 24). The peak of the green down occurred on day 271 (September 28), and was followed by a quick decline.

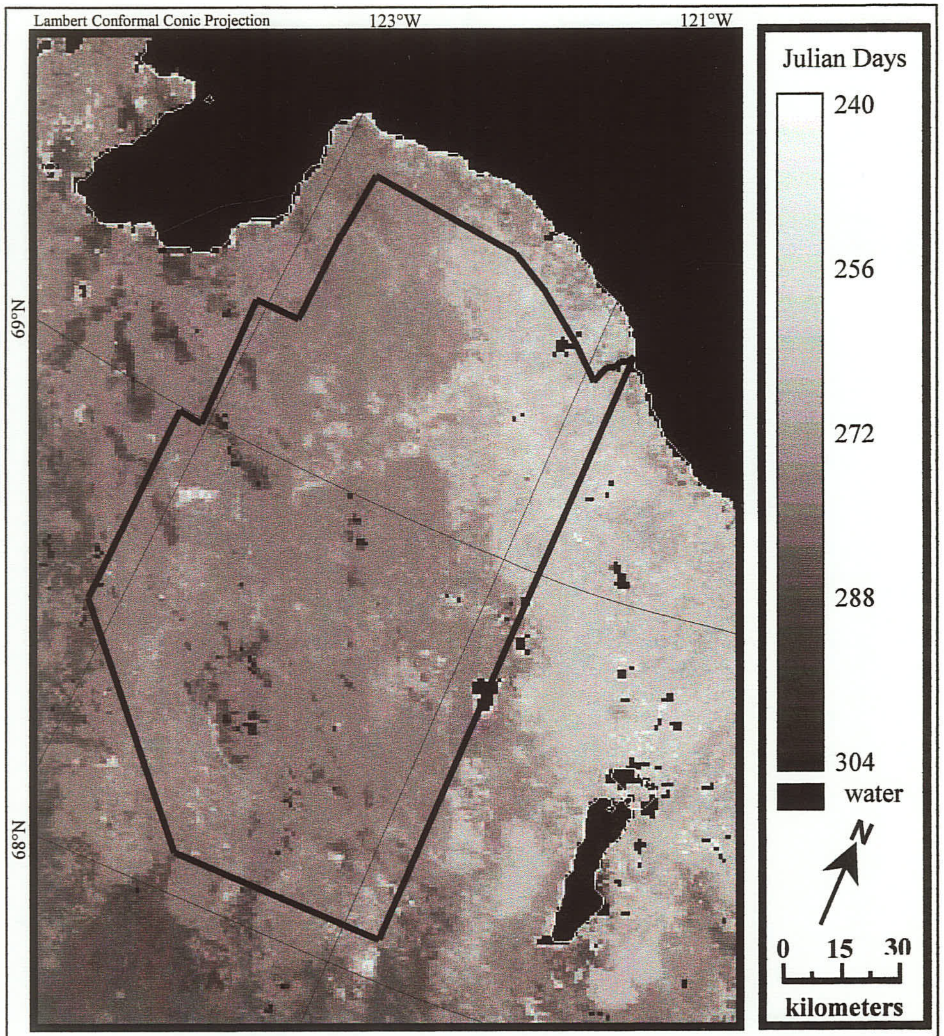

Figure 4.16. End of the Green Season - 2000

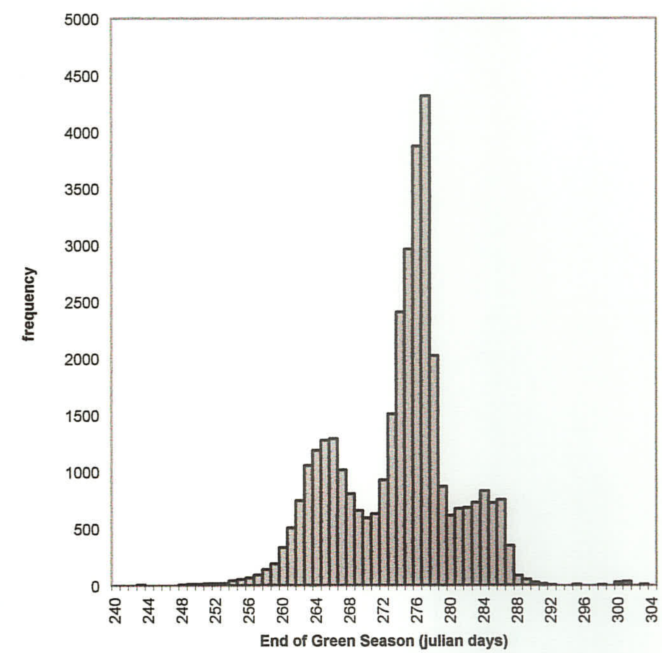

Figure 4.17. Distribution of green season end dates in 2000

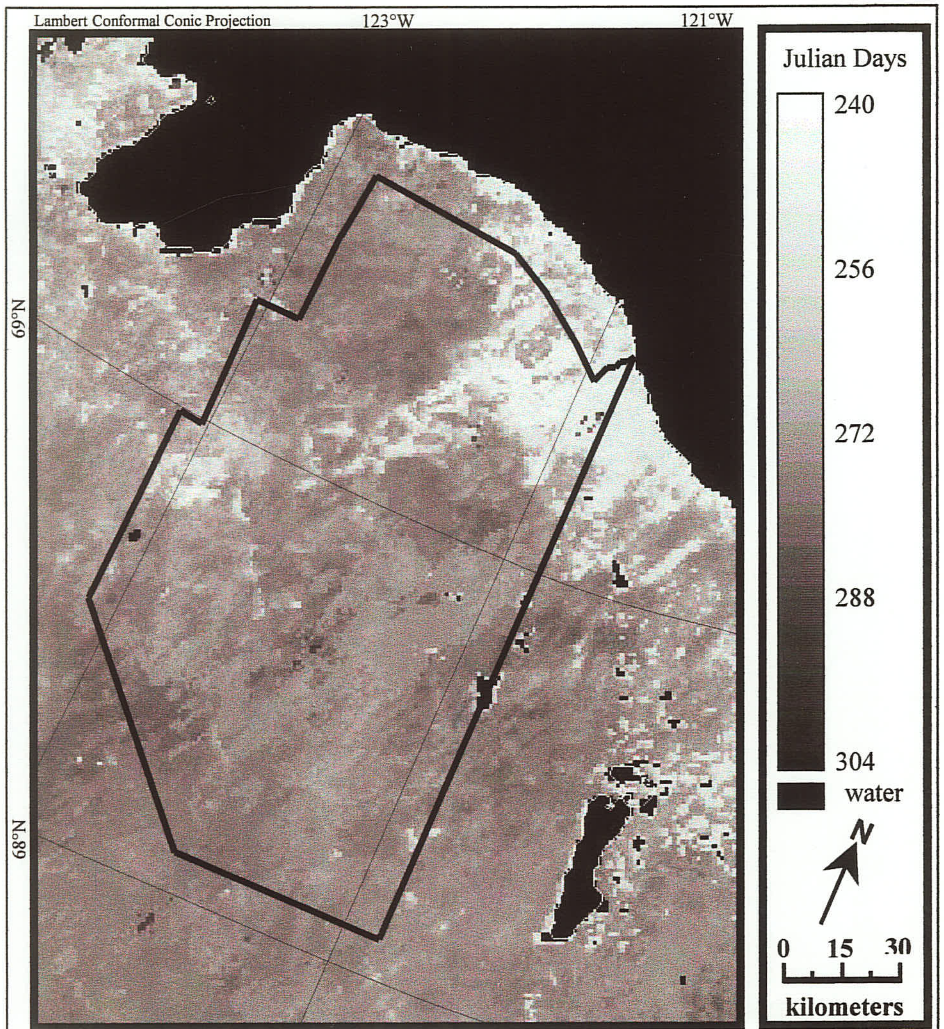

Figure 4.18. End of the Green Season - 2001

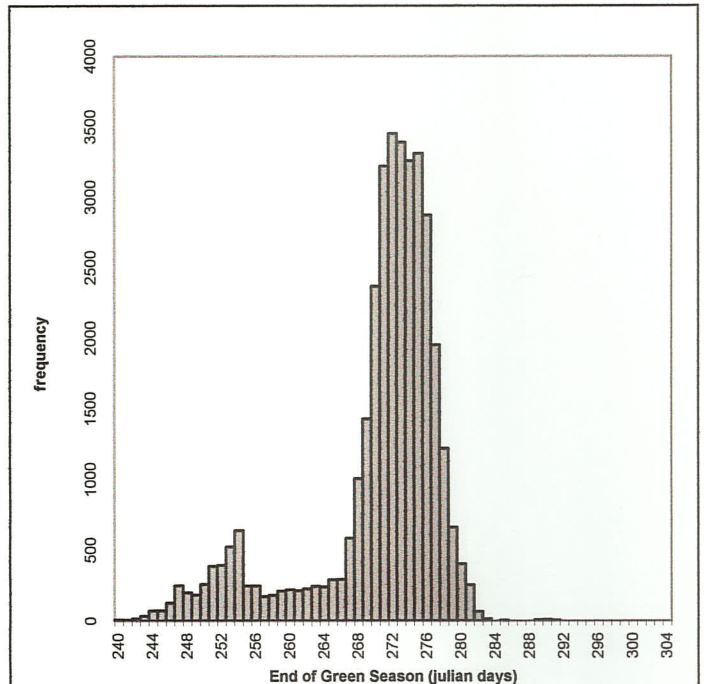

Figure 4.19. Distribution of green season end dates in 2001

4.3.2.3. Length of the Green Season

The length of the green season was determined with the maps of onset and end of the green season presented above, and was influenced by each equally. The 1999 season lasted from 60 to a maximum of 156 days (**Figure 4.20.**), though all pixels with length values less than 90 were found at the edge of water bodies and all values exceeding 150 were found in the area where the onset was misidentified as the result of clouds. The shortest green season was found in the barren regions of the Melville Hills, the eastern region of the map area and along the ridges to the east and west of the Hornaday River valley. The areas of relatively long green seasons were found along the Darnley Bay coast, as well as south and west of TNNP. The patchy appearance to the length values was the result of the same appearance in the end of green season map. The general trend, however, appears to show longer growing seasons in the west than in the east.

Examination of the histogram of green season length shows very few pixels at the short end of the green season (**Figure 4.21.**). The vast majority of pixels display growing seasons between 100 and 150 days. The histogram is also relatively flat and short compared to the 2000 and 2001 growing seasons (see below), suggesting the green season length in 1999 was uncharacteristically widely spread.

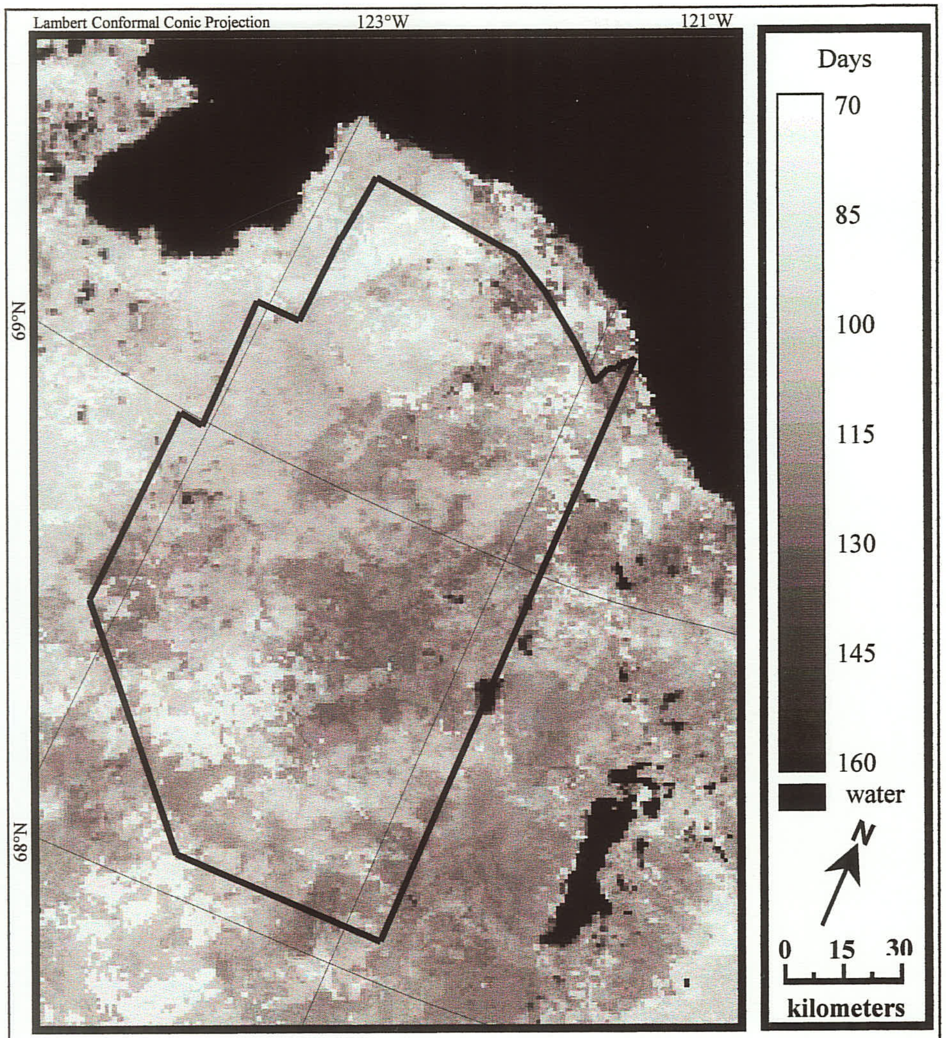

Figure 4.20. Length of the Green Season - 1999

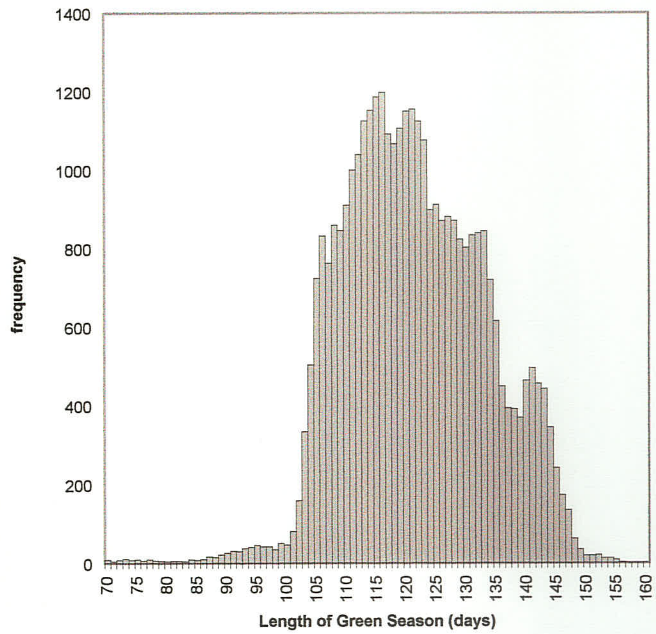

Figure 4.21. Distribution of green season lengths in 1999

The green season lasted between 58 and 148 days in 2000 (**Figure 4.22.**). All values less than 78 (and some above) were found to be the effects of mixed pixels located at the edge of water bodies. There is a general pattern showing a lengthening of the green season from northeast to southwest. The shortest green season is found in the barren areas of the Melville Hills, in the northeast portion of TNNP as well as to the east of the park boundary near the Amundsen Gulf coast. The green season lasts between 105 and 120 days in the majority of pixels. Long green seasons were found in the dwarf shrub dominated areas along the Darnley Bay coast and south and west of TNNP.

The 2000 histogram of green season length values shows a more gradual increase in frequencies to the unambiguous peak at 112 days and a more dramatic drop off over the next 18 days (**Figure 4.23.**). A very limited number of pixels had green seasons exceeding 130 days. The length of the green season had similar characteristics in 2001.

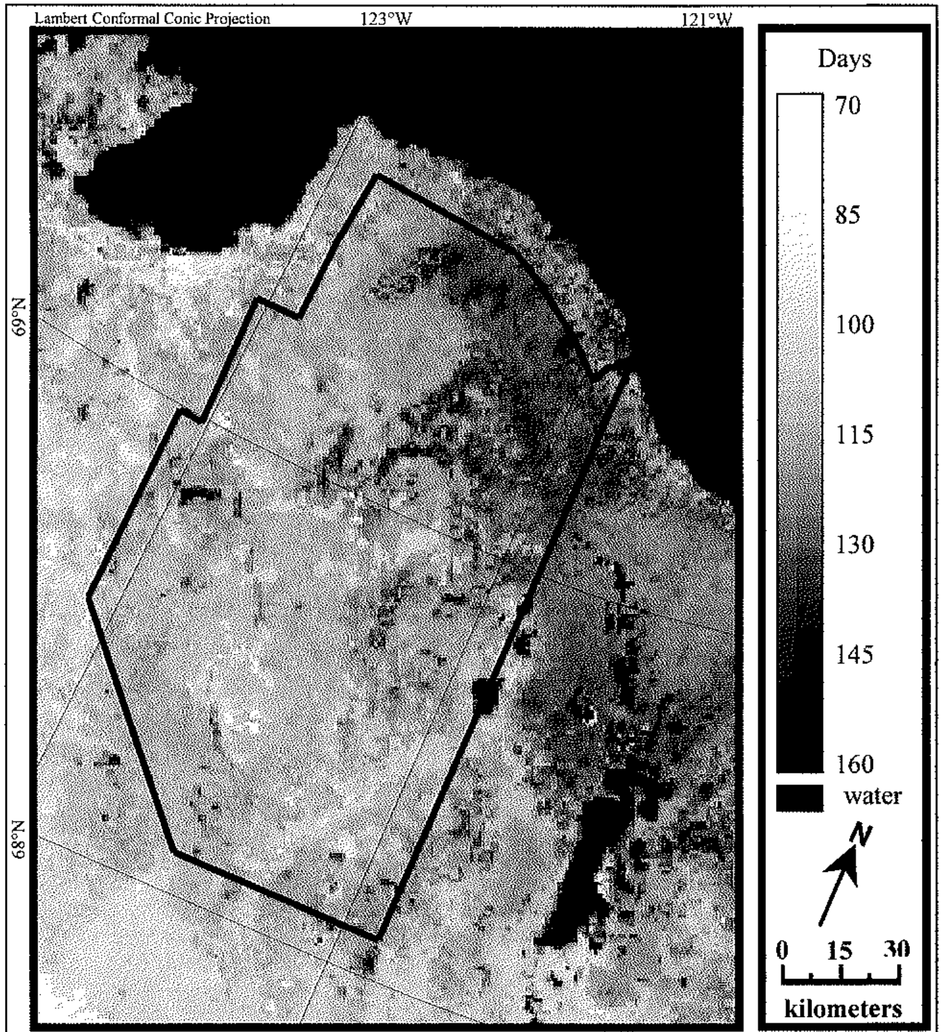

Figure 4.22. Length of the Green Season - 2000

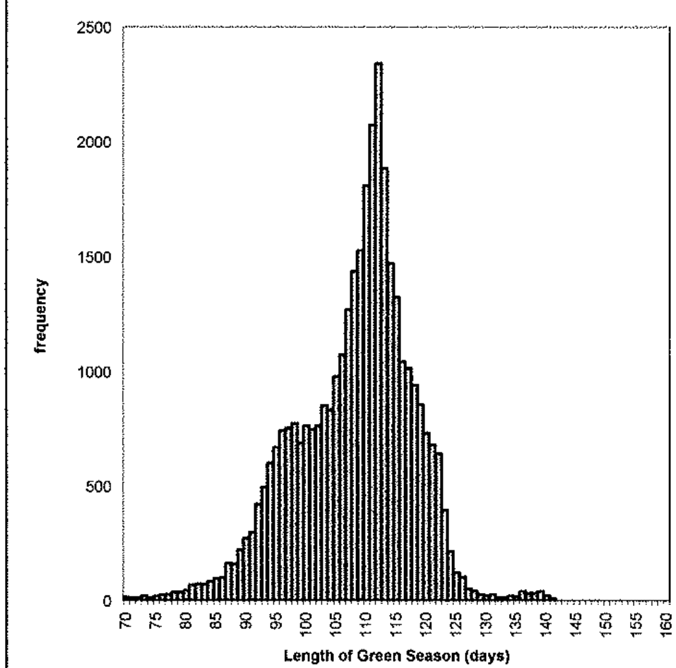

Figure 4.23. Distribution of green season lengths in 2000

The green season lasted at least 61 days and up to 145 days in 2001 **(Figure 4.24.)**. All pixels with green seasons less than 72 days were identified as being mixed pixels near water bodies. A short growing season is found in the Melville Hills and in the northeast corner of TNNP, though the total area is smaller than it was in 2000. Most of the map area has length values between 95 and 120 days. Areas with longer green seasons were found along the Darnley Bay coast and west of the TNNP boundary.

The histogram of green season length shows a small peak at 82 days **(Figure 4.25.)**. This first peak represents the particularly short green season in the northeast portion of TNNP. The more distinct peak of the histogram occurs at 105 days after which the histogram declines until it ends at 145 days.

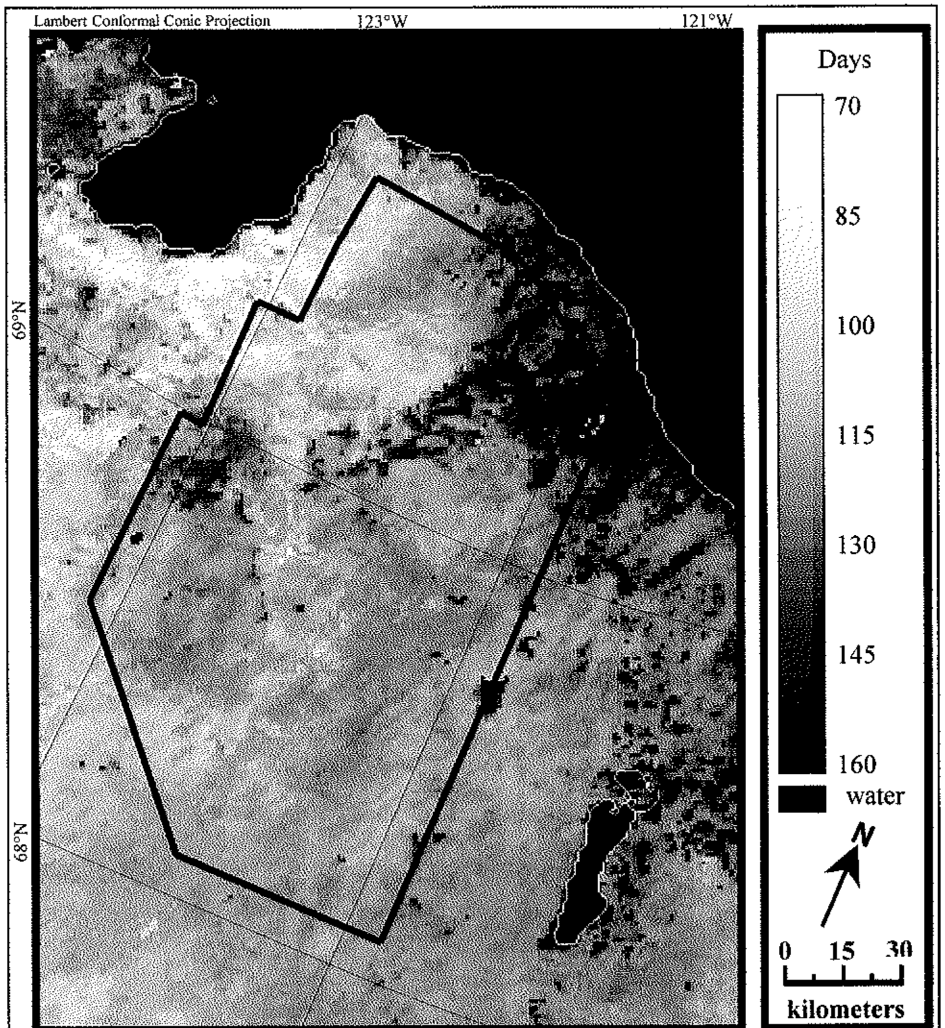

Figure 4.24. Length of the Green Season - 2001

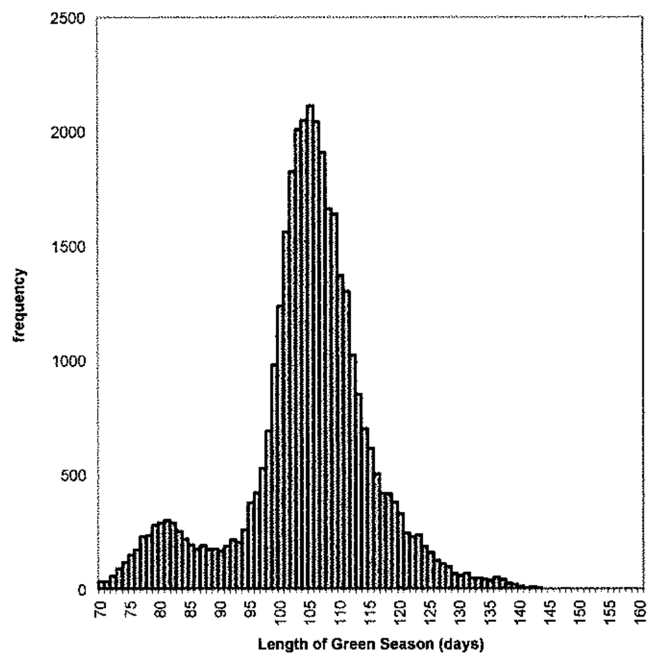

Figure 4.25. Distribution of green season lengths in 2001

4.3.2.4. Peak of the Green Season

The day on which the NDVI peaked varied dramatically between years. In 1999, greater than 60 percent of pixels reached their peak NDVI values during a two-day period in the August 1 composite **(Figure 4.26. and Figure 4.27.)**. Though no strong spatial patterns emerge, the southern region appears to have earlier dates of maximum NDVI than do northern regions.

Dates of maximum NDVI in 2000 were more spread out than in 1999 **(Figure 4.28. and Figure 4.29.)**. The histogram in **Figure 4.29.** has several peaks, representative of the acquisition dates within each composite. The progression of maximum NDVI appears to begin in the south and end in the middle, with intermediate dates found in the north, along the Amundsen Gulf.

The majority of maximum NDVI dates in 2001 were spread out in a manner similar to the 2000 green season **(Figure 4.30. and Figure 4.31.)**. Most maximum NDVI values occurred during the August 1 or August 11 composite. No strong pattern was evident in the Date of Maximum NDVI map.

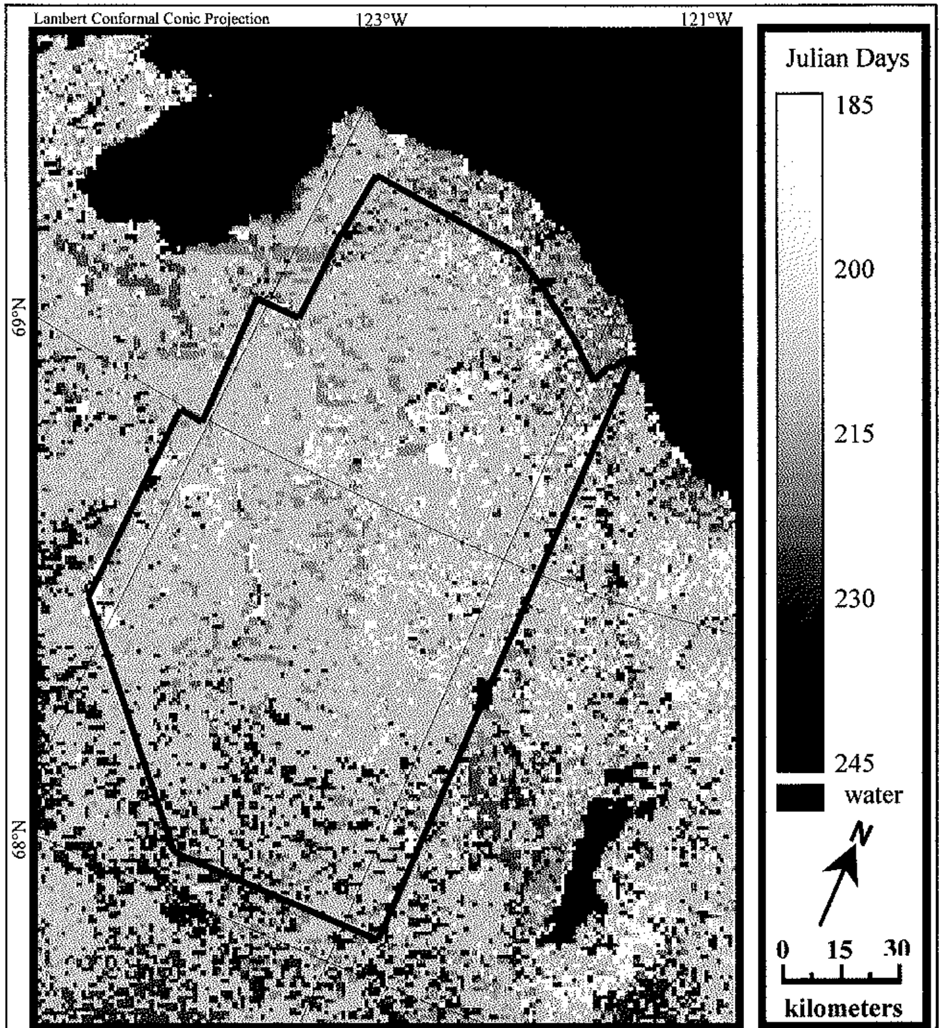

Figure 4.26. Date of Maximum NDVI in 1999

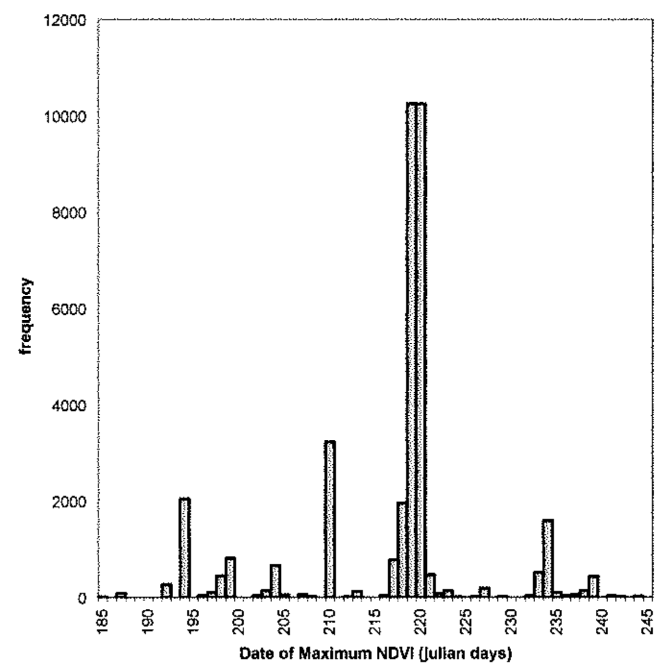

Figure 4.27. Distribution of dates of maximum NDVI in 1999

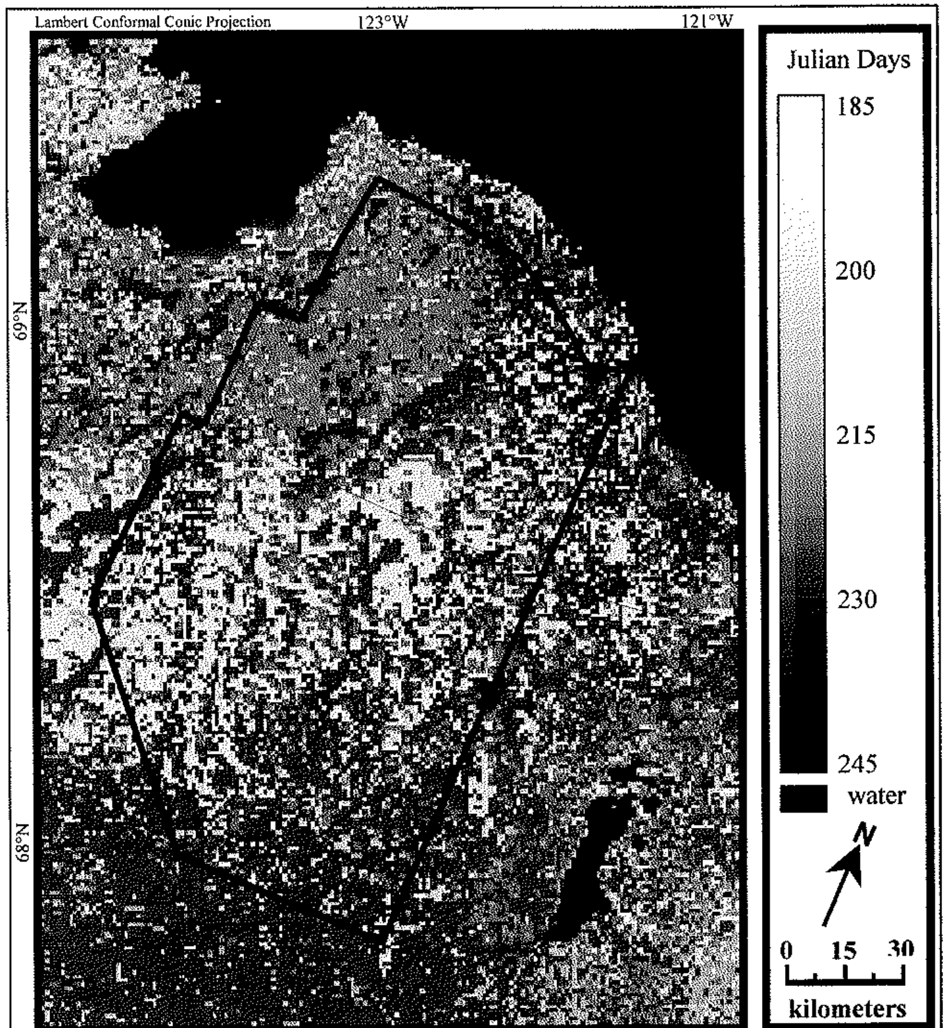

Figure 4.28. Date of Maximum NDVI in 2000

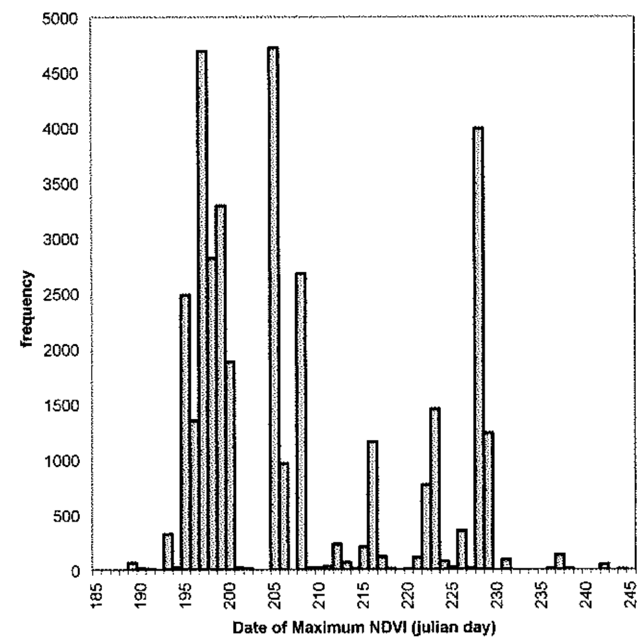

Figure 4.29. Distribution of dates of maximum NDVI in 2000

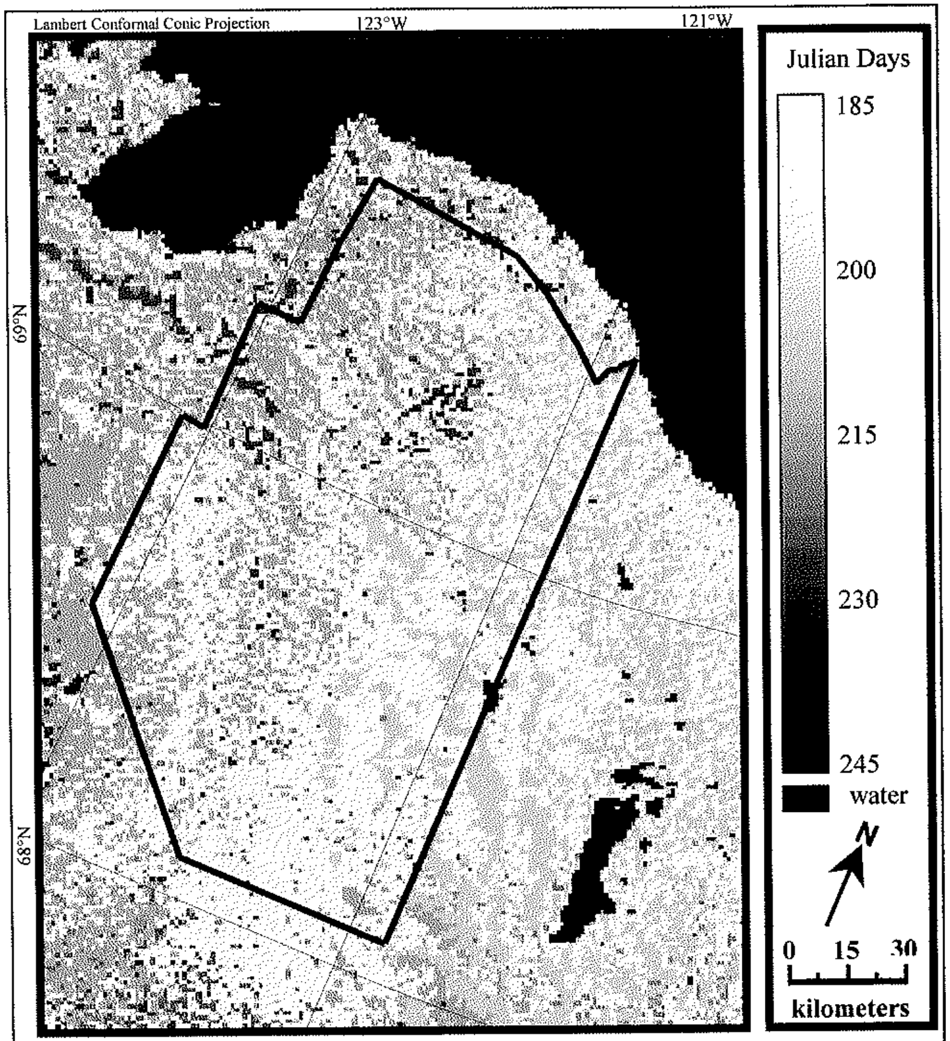

Figure 4.30. Date of Maximum NDVI in 2001

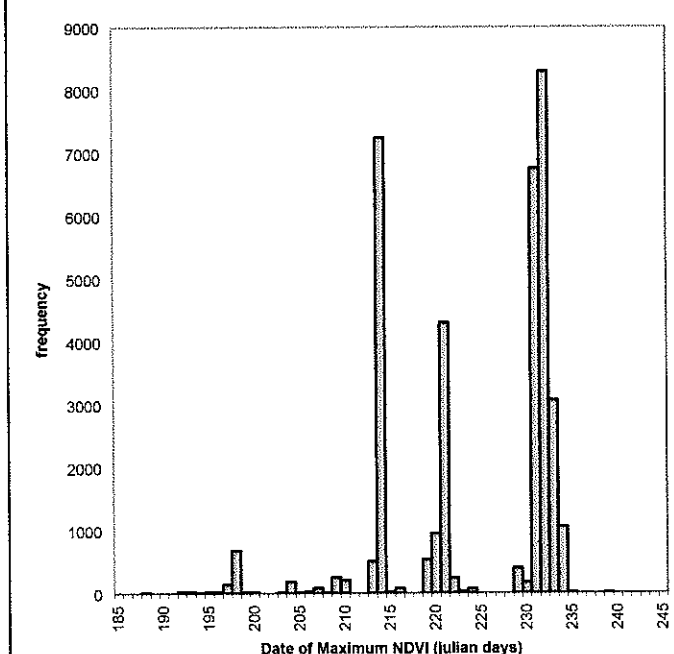

Figure 4.31. Distribution of dates of maximum NDVI in 2001

4.3.2.5. Three-Year Averages

Data from the three growing seasons were combined to produce average maps for each green season metric in the TNNP region (**Figures 4.32. – 4.35.**). Averaging the maps reduced the noise found in the yearly maps and allowed patterns to emerge much more strongly. The areas with the longest green seasons were generally located in the western portion of the map area dominated by higher productivity vegetation communities. The short green seasons were found in the east in areas dominated by low productivity vegetation communities. Histograms of average values maps show a more normal distribution than did the yearly maps (**Figures 4.36. – 4.39.**). Determining the average green season length reduced the influence of seasonal climatic variations that was evident in the yearly histograms.

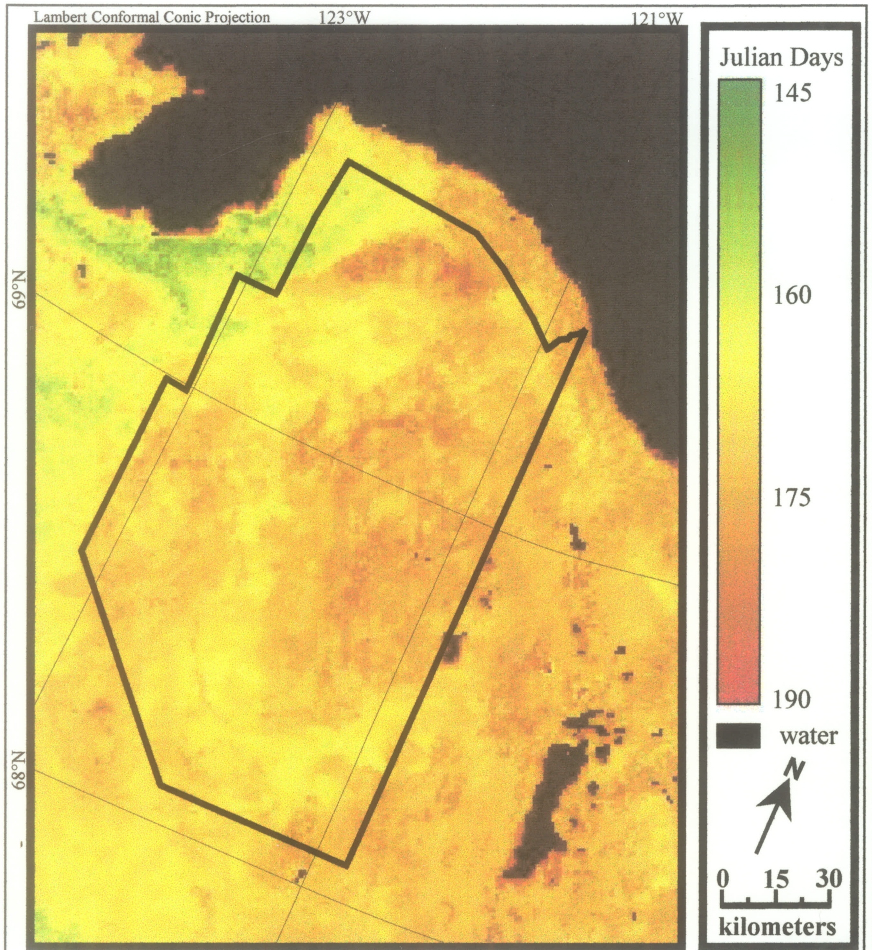

Figure 4.32. Onset of the Green Season. Average onset of green season dates for years 1999-2001

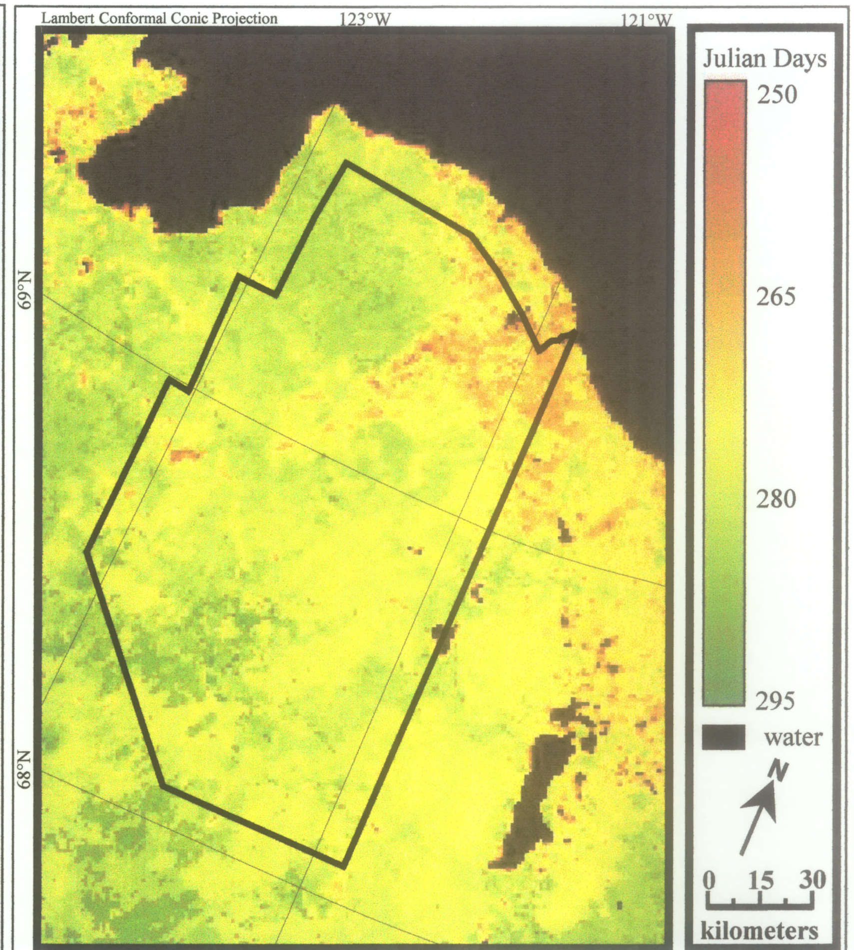

Figure 4.33. End of the Green Season. Average end of green season dates for years 1999 - 2001

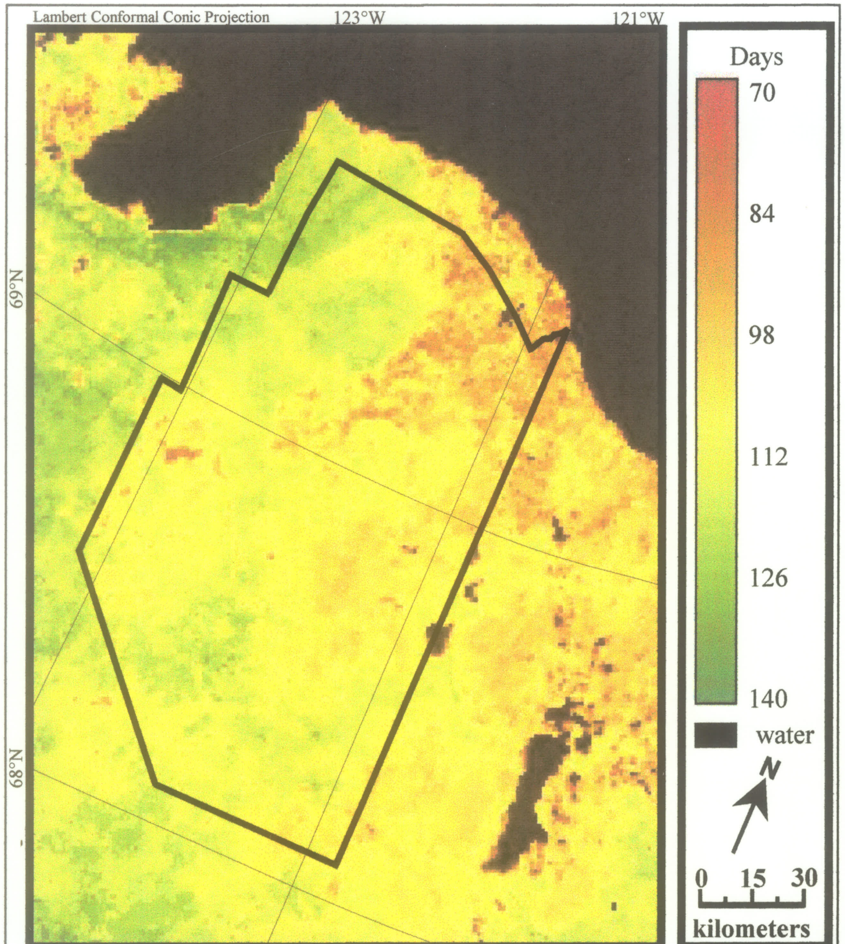

Figure 4.34. Length of the Green Season. Average green season length for years 1999 - 2001

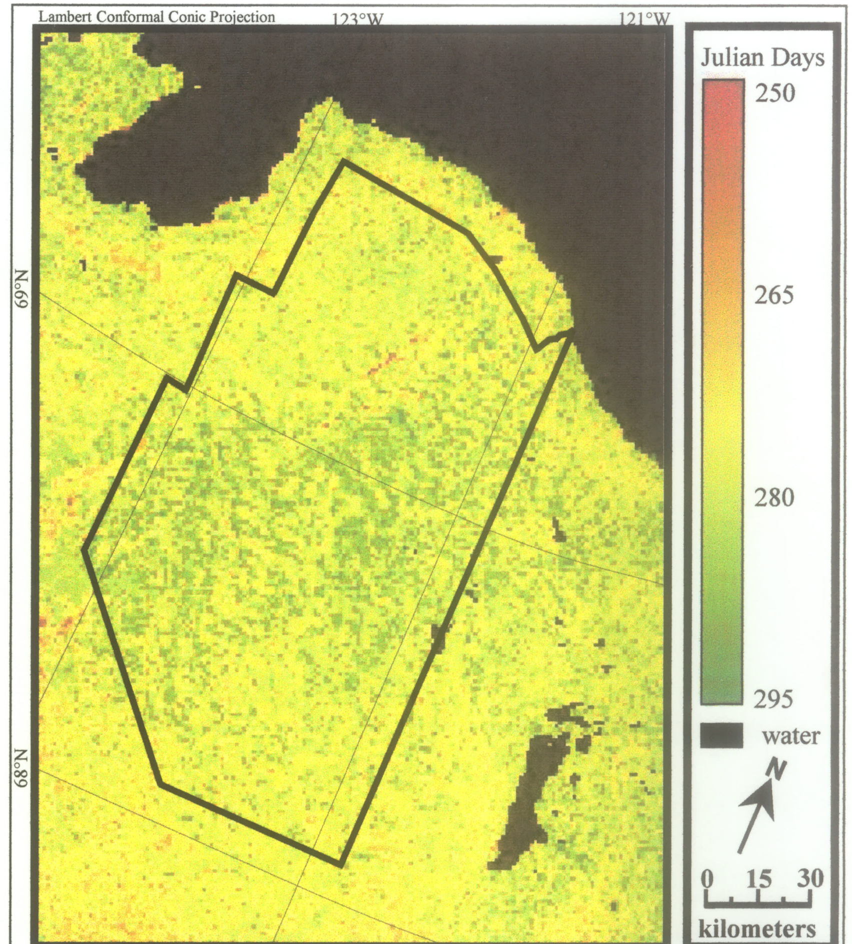

Figure 4.35. Date of Maximum NDVI. Average date of maximum NDVI for years 1999 - 2001

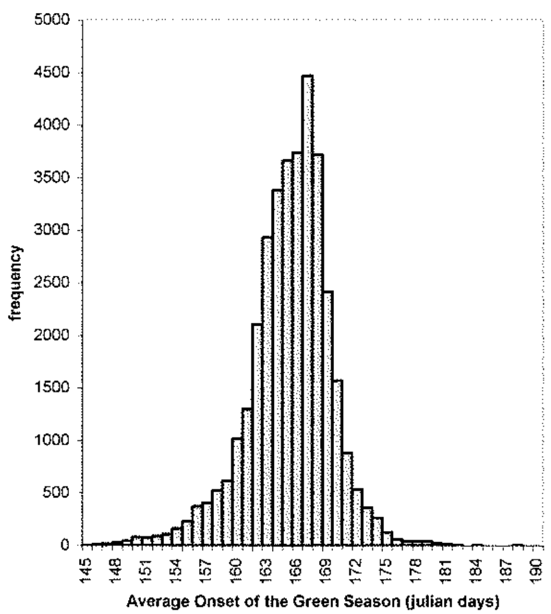

Figure 4.36. Distribution of average onset of green season dates.

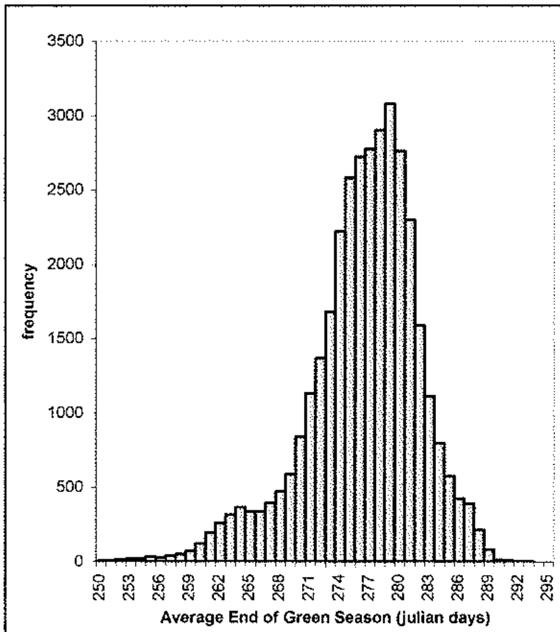

Figure 4.37. Distribution of average end of green season dates.

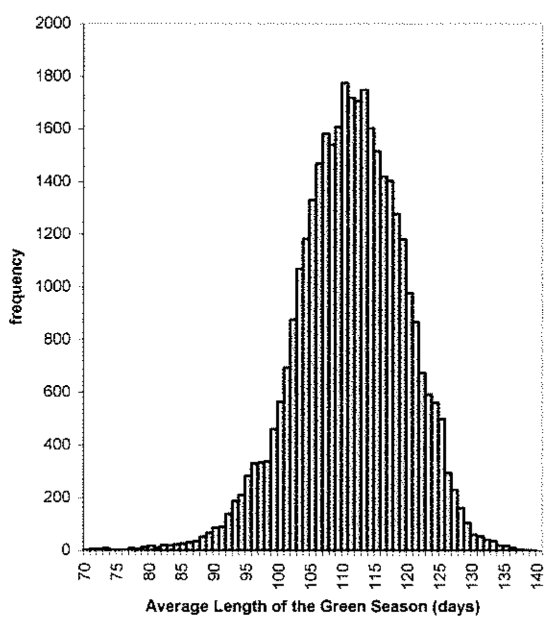

Figure 4.38. Distribution of average green season lengths.

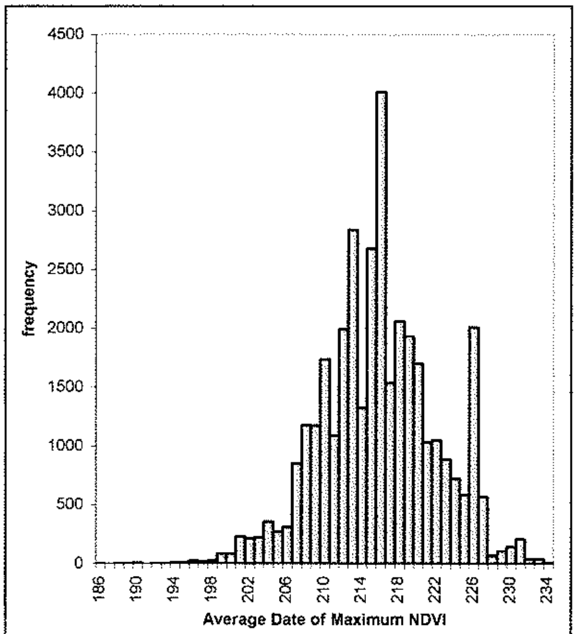

Figure 4.39. Distribution of average dates of maximum NDVI.

4.3.2.6. Spatial and Temporal Trends

Green season metrics were assessed for spatial and multi-year temporal trends in the TNNP region. The first method for examining spatial trends looked at values for each average green season metric along eleven transects running in three directions: west to east (transects 1 through 4), south to north (transects 5 through 7) and southwest to northeast (transects 6 through 11).

West-to-east trends in the green season metrics (**Table 4.8.**) can be summarized as follows:

- Date of onset increased in an easterly direction, indicating that onset was first experienced in the west and progressed east.
- Ending dates decreased in an easterly direction, indicating that the end of greenness was experienced first in the east and progressed west.
- Green season lengths also decreased in an easterly direction, indicating that and green seasons were longer in the west than they were in the east.
- There was no significant west-to-east trend in the date of peak NDVI.

Table 4.8. West to east trends for each green season metric.

TRANSECT	ONSET DATE	ENDING DATE	LENGTH	PEAK DATE
1	$y = 0.13x + 161$* $R^2=0.26$	$y = -0.28x + 286$* $R^2=0.30$	$y = -0.35x + 123$* $R^2=0.55$	$y = 0.05x + 214$ $R^2=0.04$
2	$y = 0.10x + 156$* $R^2=0.70$	$y = -0.06x + 280$* $R^2=0.27$	$y = -0.15x + 124$* $R^2=0.60$	$y = 0.05x + 210$ $R^2=0.10$
3	$y = 0.05x + 162$* $R^2=0.41$	$y = -0.07x + 282$* $R^2=0.49$	$y = -0.12x + 120$* $R^2=0.58$	$y = -0.01x + 218$ $R^2<0.01$
4	$y = 0.03x + 163$* $R^2=0.16$	$y = -0.11x + 286$* $R^2=0.60$	$y = -0.03x + 123$* $R^2=0.54$	$y = -0.02x + 215$ $R^2=0.01$

* slope is significantly different than 0 ($p < 0.001$)

South-to-north trends in the green season metrics (**Table 4.9.**) can be summarized as follows:

- Onset dates increased in a south-to-north direction only along transect 5. Onset dates along transects 6 and 7 did not trend in a south-to-north direction.
- Along two of the three transects (transects 6 and 7), the length of the green season was shorter in the north than in the south.
- Two transects (transects 5 and 7) showed significant, but opposite, south-to-north trends to the end of the green season. The trend was positive along transect 5 because the north end of this transect ends in the area along the Darnley Bay coast that typically has longer green seasons than the rest of the map area.
- There was no significant south-to-north trend found in the date of peak NDVI.

Table 4.9. South to north trends for each green season metric.

TRANSECT	ONSET DATE	ENDING DATE	LENGTH	PEAK DATE
5	$y = 0.06x + 159$* $R^2=0.33$	$y = 0.06x + 275$* $R^2=0.06$	$y = -0.02x + 118$ $R^2=0.01$	$y = -0.01x + 216$ $R^2<0.01$
6	$y = -0.01x + 165$ $R^2=0.02$	$y = 0.02x + 277$ $R^2=0.07$	$y = 0.02x + 112$* $R^2=0.06$	$y = -0.01x + 217$ $R^2=0.01$
7	$y = -0.01x + 167$ $R^2<0.01$	$y = -0.05x + 270$* $R^2=0.29$	$y = 0.05x + 102$* $R^2=0.26$	$y = -0.02x + 219$ $R^2=0.02$

* slope is significantly different than 0 ($p < 0.001$)

Southwest-to-northeast trends in the green season metrics (**Table 4.10.**) can be summarized as follows:

- Onset of the green season occurred first in the southwest of the map area and progresses in a northeast direction.
- The end of the green season progressed in the opposite direction, beginning in the northeast and ending in the southwest.
- The green season had a trend of decreasing length in a northeasterly direction.
- A significant trend in dates of peak NDVI was found along one southeast-to-northeast transect (transect 11), indicating that along this transect, the date of maximum NDVI declined in a northeasterly direction.

Table 4.10. Southwest to northeast trends for each green season metric.

TRANSECT	ONSET DATE	ENDING DATE	LENGTH	PEAK DATE
8	$y = 0.11x + 171$* R^2=0.62	$y = -0.08x + 274$* R^2=0.38	$y = -0.19x + 103$* R^2=0.67	$y = -0.03x + 217$ R^2=0.03
9	$y = 0.03x + 170$* R^2=0.14	$y = -0.16x + 262$* R^2=0.27	$y = -0.16x + 96$* R^2=0.51	$y = 0.05x + 214$ R^2=0.06
10	$y = 0.03x + 170$* R^2=0.36	$y = -0.06x + 271$* R^2=0.32	$y = -0.09x + 101$* R^2=0.47	$y = -0.02x + 218$ R^2=0.02
11	$y = 0.04x + 170$* R^2=0.36	$y = -0.11x + 268$* R^2=0.23	$y = -0.13x + 99$* R^2=0.53	$y = -0.05x + 218$* R^2=0.15

* slope is significantly different than 0 ($p < 0.001$)

The spatial nature of green season metrics was also assessed by examining how each metric varied by dominant vegetation type. The land cover map was examined to locate AVHRR pixels dominated by a single vegetation type (greater than 90 percent of the pixel belonged to the same cover type). Values for each metric were extracted at the sites of these pure pixels, and one-way analysis of variance (ANOVA) was used to test between cover type differences.

The typical values for each metric within each vegetation cover class are shown in **Figure 4.40.** Values showed differences between vegetation types for onset of green season dates (ANOVA, $F = 60.43$, $n = 420$, $p < 0.001$), end of green season dates (ANOVA, $F = 115.86$, $n = 420$, $p < 0.001$), length of green season (ANOVA, $F = 125.05$, $n = 420$, $p < 0.001$), but not date of peak NDVI (ANOVA, $F = 2.07$, $n = 420$, $p = 0.08$).

ANOVA post-hoc tests showed that most, but not all, green season metrics were unique for each cover type. **Table 4.11.** identifies which cover types had significantly different mean metric values. All bivariate comparisons result in significant differences for the onset and length metrics. With respect to the end of green season, values for Dwarf Shrub Tundra-dominated regions do not differ from those in Mesic Meadow or Tussock Tundra regions. However, there is a significant difference between end of green season dates between Mesic Meadow and Tussock Tundra regions. There were no significant vegetation-dependent differences in the date of maximum NDVI metric.

A notable pattern emerged in the green season metrics whereby the higher productivity vegetation types typically had longer growing season (earlier onset dates and later ending dates). An exception to this pattern was found in the dwarf shrub tundra type, which actually had the longest growing seasons. Dwarf shrub vegetation has the advantage of the woody component that is already established when the growing season begins in the spring. All other vegetation types must grow from nothing each spring, causing a longer time period between which growth actually begins and the satellite sensor can detect the growth.

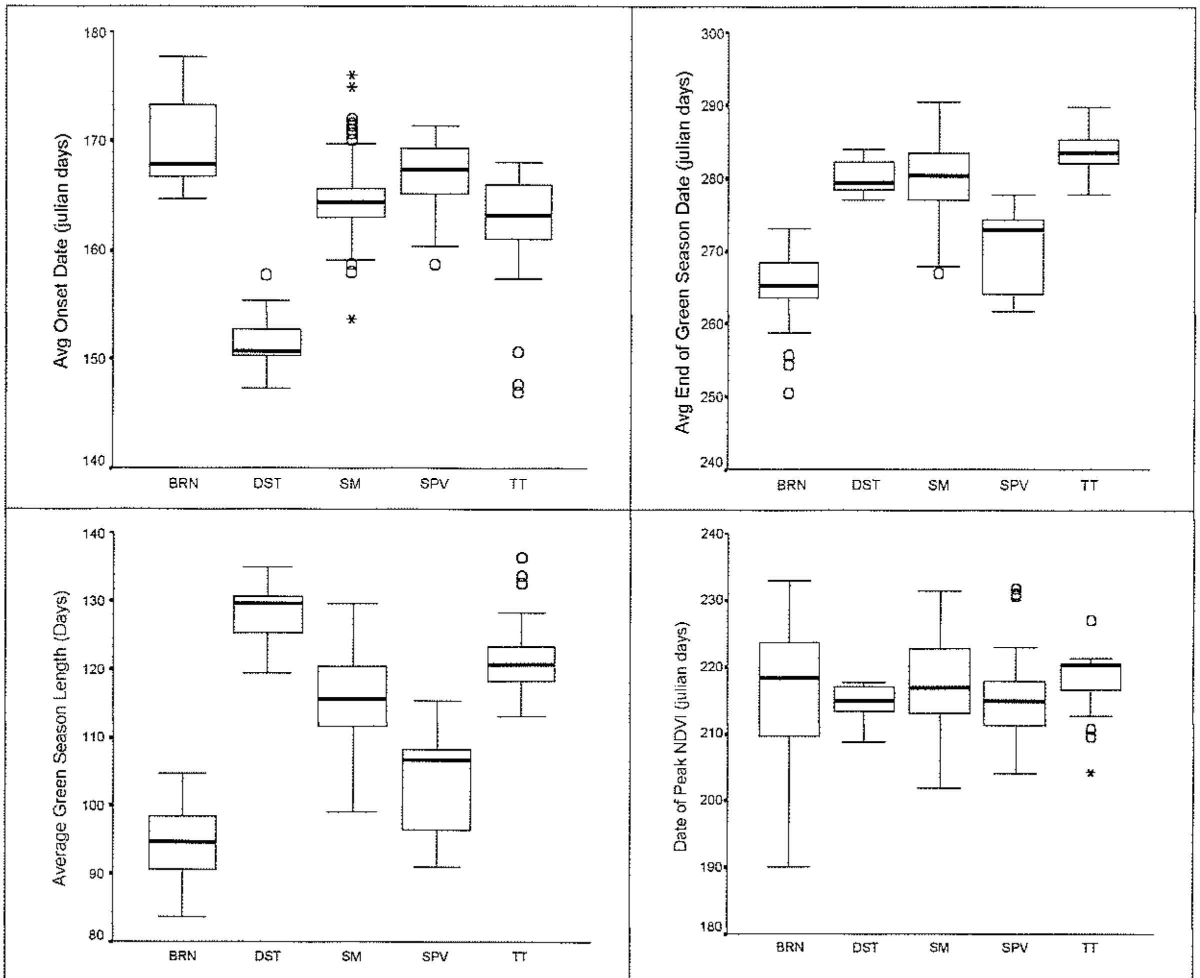

Figure 4.40. Boxplots showing the different green season metric values among vegetation classes (BRN = Barren; DST = Dwarf Shrub Tundra; SM = Sedge Meadow; SPV = Sparsely Vegetated; TT = Tussock Tundra.

Table 4.11. Significant bivariate differences for each green season metric

	ONSET					END					LENGTH					MAX NDVI				
	BRN	DST	MM	SPV	TT	BRN	DST	MM	SPV	TT	BRN	DST	MM	SPV	TT	BRN	DST	MM	SPV	TT
BRN	-	*	*	*	*	-	*	*	*	*	-	*	*	*	*	-				
DST		-	*	*	*		-		*			-	*	*	*		-			
MM			-	*	*			-	*	*			-	*	*			-		
SPV				-	*				-	*				-	*				-	
TT					-					-					-					-

* mean metric values are significantly different at the 0.05 level

The methodology employed in this study measured relative changes in the NDVI time-series. Vegetation needed to be dense enough to be detected above all background influences. A high productivity location was able to reach the required density before a low productivity location, notwithstanding the fact that actual growing seasons may have begun at the same time. This type of bias is undesirable, but unavoidable. It is also minimized with the method presented here relative to a threshold-based method of detecting key events that is currently used by Parks Canada (Wilmshurst et al., 2001; Wilmshurst et al., 2002). While spatial biases exist, the methods employed in this study do not limit the ability to monitor change over time, as the spatial distribution of vegetation types is not likely to dramatically change at the scale of AVHRR pixels from year-to-year.

Given that green season metrics were only calculated for three different years, temporal trends were not assessed quantitatively. The green season experienced a slight increase in onset dates (**Figure 4.41.A**), and a large increase in ending dates (**Figure 4.41.B**). Later onsets and earlier ends to the green seasons combined to cause shorter green seasons from year-to-year (**Figure 4.41.C**). The date of maximum NDVI has no consistent pattern between 1999 and 2001 (**Figure 4.41.D**). If data from previous years are available, it could be added to this data set, permitting a more effective assessment of temporal trends in the green season of TNNP.

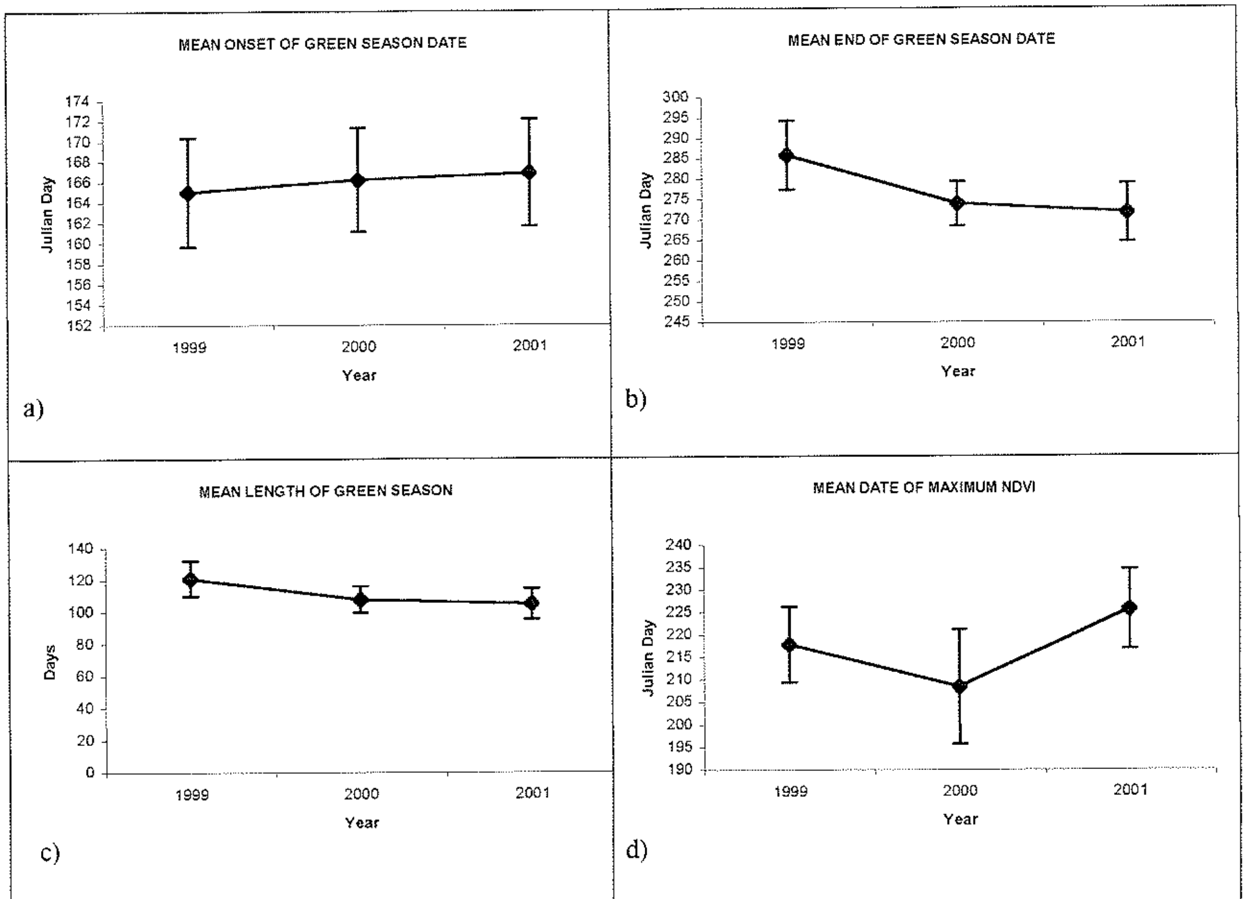

Figure 4.41. Three-year averages values of each metric calculated from all land-based points within TNNP. a) onset of the green season, b) end of the green season, c) length of the green season, and d) maximum NDVI.

4.3.3. Summary of Mapping Temporal Green Season Metrics

Using NDVI from GEOCOMP-n satellite data, it was possible to observe the timing of four key green season events in the TNNP region. The onset of the green season generally occurred in the early or middle portion of June. Green seasons lasted three and a half to four months and ended in the later stages of September or early October. The date of maximum NDVI was the most variable metric throughout the three years and was also the only metric to consistently show no spatial trends. Temporal trends appear to show declining growing seasons, which conflicts with some studies (e.g. Tucker et al., 2001) and agrees with others (Wilmshurst et al., 2002).

4.3.4. Validation

Validation of this study centers on two issues. First, the method used to interpolate values is assessed by comparing it with an alternative method. Second, climate data are used to determine if there were large errors in the methodology.

4.3.4.1. Interpolation

This study makes the assumption that the relationship between NDVI and time is linear. This assumption is used to interpolate NDVI values hidden by clouds and to make subsequent adjustments to the relative dates values. This assumption is also used to determine when segments of the predicted and actual time series cross. In order to test the validity of this assumption, the RMS errors for a time series of NDVI values were determined with linear and quadratic equations.

Overall, errors under the assumption of linearity were only slightly lower (approximately 1 percent) than for a quadratic assumption (**Figure 4.42.**). The difference between the two interpolation methods is not statistically significant ($p = 0.152$). Using a polynomial relationship would not noticeably improve interpolated NDVI values. Quadratic interpolation would provide no benefit and linear interpolation allows simpler calculations and is better suited given the temporal resolution of GEOCOMP-n imagery. As a result, employing linear interpolation was determined to be the most appropriate for this research.

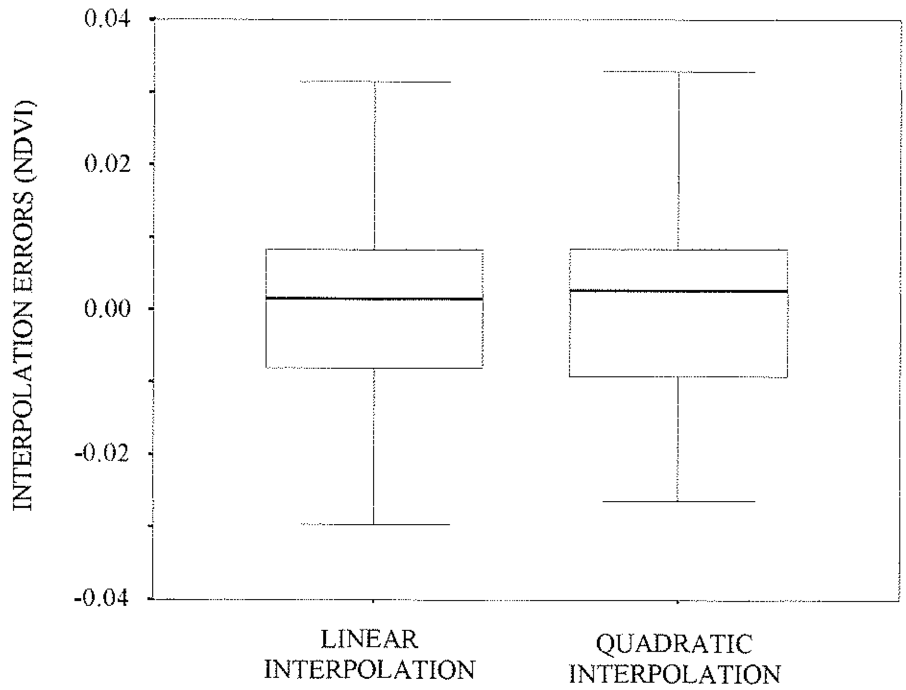

Figure 4.42. Boxplots comparing linear interpolation to quadratic interpolation.

4.3.4.2. Comparing Derived Metrics With Weather Data

While there are eleven climate reporting stations within 200 km of TNNP, only one, the Tuktut Nogait station, was able to provide data for verification of the satellite-based observations for the 1999 and 2000 growing seasons. The data provided by this station were limited to averages of hourly or daily temperatures, with missing observations from 12 June 1999 to 13 July 1999 and 24 September 1999 to 05 October 1999. The Tuktut Nogait climate station is centrally located in TNNP at 69° 15'N, 122° 22W. The ability of an incomplete data set from a single climate station to verify green season metrics over the 44000 km^2 map area is limited. It can, however, provide a general view of the agreement between daily temperature and green season metrics.

The average of all daily mean air temperatures for each composite period is presented in **Figure 4.43.** Daily mean temperatures in 1999 reached 0°C, slightly before they did in 2000. This pattern was reflected in the onset of green season dates for each year. Average onset in TNNP occurred on julian day 165 (June 14) in 1999 and julian day 166.2 (June 15) in 2000. The remaining metrics showed the same correspondence with air temperature. The average date of green season end in TNNP occurs on julian day 285.9 (October 13) in 1999 and julian day 273.9 (October 1) in 2000. Air temperatures drop below 0°C at the climate station approximately 12 days later in 1999 than they did in 2000. With respect to the length of green seasons, mean daily air temperatures remained above 0°C for approximately 11.5 composites (eight 10-day and three 11-day composites) during 1999 summer; nearly identical to the 120.8 days the average green season lasted in TNNP. The 2000 green season lasted an average of 107.7 days, while average daily temperatures remained above 0°C for slightly more than 9.5 composites – approximately 100 days. Average dates of maximum NDVI were approximately 06-August and 27-September in 1999 and 2000, respectively. Daily mean temperatures reached their maximum during the August 1 composite in 1999 and September 21 in 2000, corresponding with the date of maximum NDVI metric. Overall, daily mean temperatures corresponded to the satellite-derived green season metrics very well, though greater spatial and temporal coverage by weather stations would have provided a more thorough evaluation of the green season metrics.

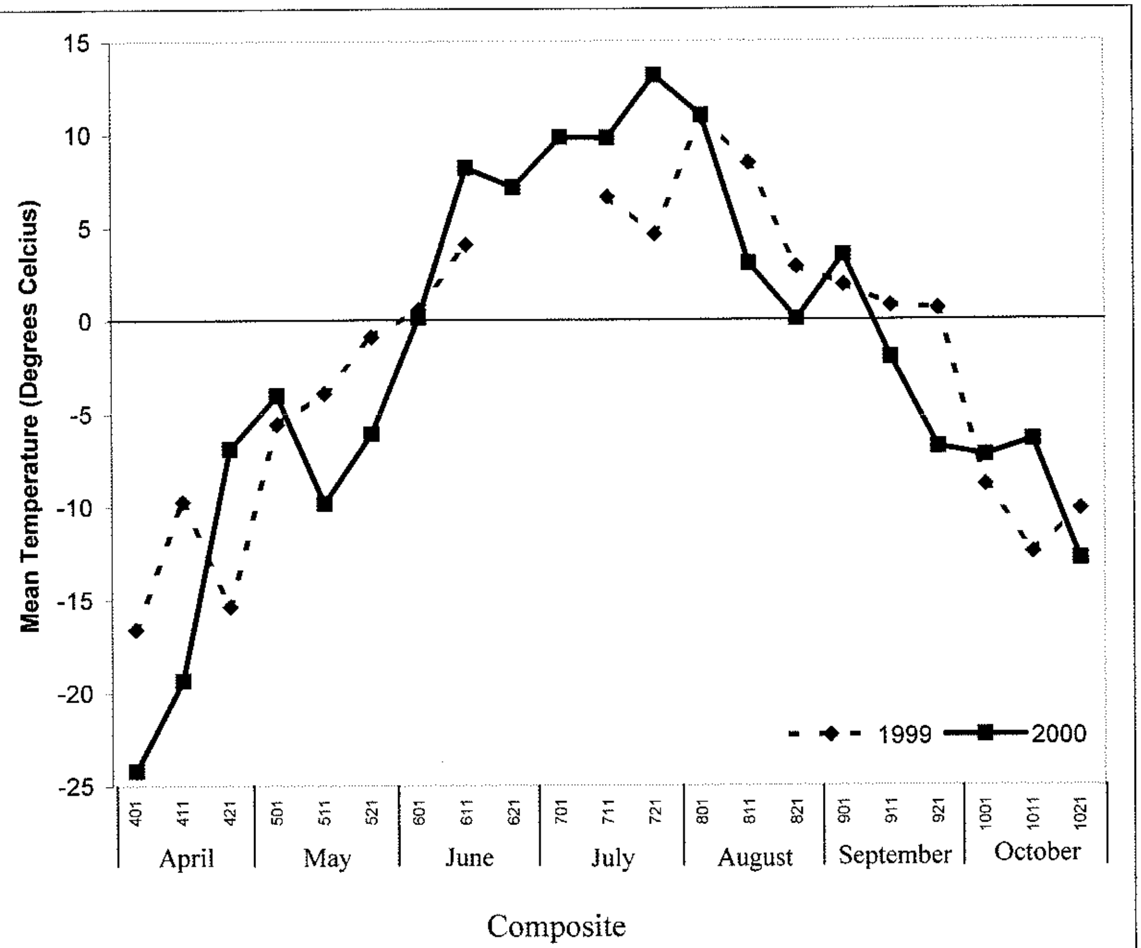

Figure 4.43. Average daily temperature for each composite in 1999 and 2000.

4.4. CHAPTER SUMMARY

The ability to precisely map several key growing season events using NDVI time-series data from 10-day AVHRR composites is an important tool that can be used to monitor Canada's national parks in a cost effective and timely manner. The NDVI was determined to be the vegetation index best-suited to this study. It was determined to be at least as effective as other vegetation indices for predicting green biomass and percent cover and for reducing the influence of variable soil backgrounds. It was also the only index provided in the GEOCOMP-n data set. The GEOCOMP-n data set was influenced only slightly by high sensor zenith angles, particularly during the main portion of the growing season. Solar zenith angles above 80 degrees caused a significant increase in NDVI values and were subsequently masked from further analyses. As well, acquisition dates were found to often show pooled distributions caused by the compositing process and/or clouds, which limited the number of composites that effectively represented a particular 10-day period. Finally, four temporal green season metrics were determined for TNNP using the NDVI time-series from the GEOCOMP-n data set. Strong south-to-north and southwest-to-northeast trends were found in the onset, end and length of green season metrics. The satellite-derived metrics were found to be accurate, based on a comparison of each metric to daily temperature data from a weather station located inside TNNP. The methods for calculating key green season metrics are suitable for use in all of Canada's national parks. The greatest benefit to this type of information will come when and if these methods are employed over a longer time period. While the metrics may not represent the absolute changes they were designed for, they undoubtedly represent relative changes. So long as a consistent methodology is used to derive green season metrics, multi-year comparisons will be valid. This research provides managers of parks and other protected areas with an added piece of information on which to base important decisions.

CHAPTER 5 – SUMMARY & CONCLUSIONS

The primary purpose of this study was to use vegetation index data from GEOCOMP-n AVHRR 10-day composites to monitor the precise timing of key growing season events in Tuktut Nogait National Park. The following sections revisit the original objectives of the study outlined in Chapter 1, and provide key conclusions on the same.

5.1. ADDRESSING STUDY OBJECTIVES

5.1.1. Objective 1: To determine which vegetation index is best suited for use with AVHRR data in this study area.

Based on several criteria, the NDVI was determined to be the vegetation index best suited for the study. The vegetation index selected needed to be a robust measure of vegetation characteristics, minimize the impact of soil noise and satisfy several qualitative requirements related to ease of use. Results of the quantitative analysis were as follows:

- All vegetation indices tested showed similar relationships to percent cover, but the NDVI had the highest r-square value.
- The NDVI proved to reduce the influence of background noise most effectively.
- All vegetation indices tested showed similar relationships to photosynthetic biomass, but the NDVI had the lowest r-square value.

It was determined that a strong performance in predicting percent cover, and ability to reduce the influence of background noise, outweighed the weaker performance in predicting photosynthetic biomass.

Results of the qualitative analysis supported the quantitative findings. Results were as follows:

- The NDVI required the least complicated calculations, and was delivered as an image band by the GEOCOMP-n system.
- Out of all vegetation indices examined, the NDVI is the most accepted and widely used.

Based on all finding outlined above, the NDVI was determined to be most appropriate vegetation index for use with AVHRR in the TNNP study area.

5.1.2. Objective 2: To describe the characteristics of the basic components of the GEOCOMP-n data set for Tuktut Nogait National Park.

The second objective of this study required an analysis, and description, of three specific GEOCOMP-n system components: sensor zenith angles, solar zenith angles and acquisition dates. Examination of these characteristics revealed the following:

- Sensor zenith angles were highest when pixels were snow-filled. Typically, both before and after the green season, sensor zenith angles were found to be relatively high. Relatively low angles were found during the growing season.
- Solar zenith angles were rose and fell along seasonal timelines. Angles were found to be extremely high during the end of October, resulting in

excessively high NDVI values. Sufficient evidence was found to support the masking of pixels acquired with solar zenith angles greater than 80 degrees.

- Acquisition dates were generally pooled within each composite. The pooling of acquisition dates is an inherent effect of the compositing process, and is caused by two factors: the selection of pixels closest to the peak of the growing season, and the presence of cloud cover which obscures the surface from the sensor.

It was important to be aware of the characteristics of the GEOCOMP-n data prior to tracking the pattern of the green season. Aside from the high sensor zenith angles found at the end of October, no data characteristics presented significant problems for the analysis.

5.1.3. Objective 3: To produce unbiased estimates of key timing events in the Arctic growing season using GEOCOMP-n data.

Estimating the timing of key growing season events is another step in the work of Parks Canada to improve and expand the program of ecosystem monitoring with the use of GEOCOMP-n satellite data. GEOCOMP-n data proved to be an effective tool for estimating the timing of four significant green season events. Linear interpolation was used to regain the information lost during compositing, thereby allowing for precise estimates. Key findings regarding the timing of key events in TNNP include:

- Onset of the green season generally began in the southwest, gradually moving towards the northeast. Average onset dates in TNNP increase from julian day 165 (June 14) in 1999 to julian day 167 (June 16) in 2001.
- End of the green season generally began in the northeast and progressed towards the southwest. Average end of the green season dates decrease from julian day 286 (October 13) in 1999 to julian day 272 (September 29) in 2001.
- The green season was longest along the southern Darnley Bay coast, and shortest in the northeast portion of TNNP and in the Melville Hills region. Average green season lengths in TNNP declined from 121 days in 1999 to 105 days in 2001.
- The date of maximum NDVI generally showed no significant directional patterns. The average date of maximum NDVI in TNNP ranged from a minimum of julian day 208 (July 27) in 2000 to a maximum of julian day 225 (August 13) in 2001.
- Onset, end and length of the green season metrics all showed significant differences between dominant vegetation types.
- Green season metrics corresponded closely to daily temperature data in 1999 and 2000. No climate data were available for 2001.

Based on the above, it was determined that GEOCOMP-n provides useful information to monitoring the temporal patterns of the green season. As such, it is a useful tool for use in ecological monitoring.

5.2. RECOMMENDATIONS

Based on the lessons of the research process, as well as the overall findings of the study, the following recommendations are put forth as a means to improve ecological monitoring in the TNNP area, and elsewhere in northern Canada:

1. Make use of the higher-level data available from the GEOCOMP-n system. Faulty input coefficients have been corrected by the CCRS. Employing the BRDF-corrected NDVI would decrease the magnitude of atmospheric and directional effects on the imagery. The correct coefficients will be applicable to all AVHRR data for the TNNP region and should be used to improve the quality of archived data.
2. Investment in improvements to weather reporting stations within TNNP, and all national parks. Of the 12 weather stations located in or near TNNP, only one had gathered sufficient data to be useful for this study. One possibility would be for Parks Canada to consider taking over responsibility for maintaining weather stations within national parks.
3. Expand the scope of the research. There is an abundance of daily and composite AVHRR data that can be processed and analyzed using the methodologies presented here. These methodologies should be applied to data that have been archived for TNNP and other national parks within Canada. Continued research and monitoring, which focuses on both temporal and spatial characteristics of flora and fauna and the surfaces upon which they live, is the only way to measure

the impact of policies and programs put in place at the governmental level to maintain ecological integrity in protected areas.

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APPENDIX I – SAMPLE QUADRAT DATA: TUKTUT NOGAIT NATIONAL PARK, SUMMER, 2000

		Site Descriptions			Cover Proporations										Radiometer Measurements					Vegetation Indices				
PLOT ID (site, plot, sample)	DATE	SLOPE	ASPECT	VEG TYPE	% VEG	% UNVEG	% HERB	% DWARF SHRUB	% LICHEN	% MOSS	% ROCK	% BARE	% H2O	% SNOW	BAND 1	BAND 2	BAND 3	BAND 4	BAND 5	NDVI	WDVI	$MSAVI_1$	$MSAVI_2$	Dry Green Biomass
111	7/12/00	5	S	SPV	85	15	60	20	0	5	5	10	0	0	5.4	7.77	9.4	22.5	34.9	0.41	0.14	0.20	0.21	34.8
112	7/12/00	10	SE	ROCK	0	100	0	0	0	0	100	0	0	0	5.49	6.77	7.8	11.6	31	0.20	0.04	0.06	0.07	-
113	7/12/00	5	SE	SPV	42	58	5	30	2	5	25	33	0	0	5.22	6.86	7.72	18.3	34.4	0.41	0.11	0.17	0.18	-
114	7/12/00	5	S	SPV	40	50	5	10	5	20	5	45	0	0	5.15	7.32	8.73	20.4	31.8	0.40	0.12	0.19	0.19	-
115	7/12/00	10	SE	SPV	40	60	15	20	5	0	20	40	0	0	4.67	6.44	7.36	16.7	29.3	0.39	0.10	0.15	0.16	-
121	7/12/00	10	SE	SPV	20	80	10	10	0	0	40	40	0	0	5.72	7.72	8.47	15.5	28.3	0.29	0.07	0.12	0.12	9.25
122	7/12/00	20	SE	SPV	15	85	5	10	0	0	65	20	0	0	11	15	17.1	24.6	40	0.18	0.08	0.11	0.11	-
123	7/12/00	20	SE	SPV	20	80	5	15	0	0	40	40	0	0	7.87	10.7	12.9	19.9	32	0.21	0.08	0.11	0.11	-
124	7/12/00	20	SE	SPV	25	75	10	15	0	0	30	45	0	0	6.69	8.91	10.1	17.7	31	0.27	0.08	0.12	0.12	-
125	7/12/00	20	SE	SPV	25	75	10	15	0	0	25	50	0	0	7.72	11	13.1	19.9	32.5	0.20	0.07	0.10	0.10	-
131	7/12/00	15	SE	SPV	45	55	20	25	0	0	30	25	0	0	9.02	12.5	13.7	21.8	36.6	0.23	0.09	0.12	0.12	11
132	7/12/00	20	SE	SPV	80	20	30	30	0	20	5	15	0	0	4.13	6.28	6.29	21.8	29.8	0.55	0.16	0.26	0.26	-
133	7/12/00	10	SE	ROCK	10	90	5	5	0	0	90	0	0	0	16.7	21.5	24	30.9	53.2	0.13	0.08	0.09	0.09	-
134	7/12/00	20	SE	SPV	35	75	15	20	0	0	40	35	0	0	8.33	11	12.5	19.8	32.5	0.23	0.08	0.11	0.11	-
135	7/12/00	20	SE	SPV	20	80	5	15	0	0	40	40	0	0	9.36	12.3	14.9	21.2	34.6	0.18	0.07	0.09	0.10	-
141	7/12/00	0	-	SPV	60	40	30	25	0	5	5	35	0	0	4.65	6.67	7.66	16.3	21	0.36	0.09	0.14	0.15	-
142	7/12/00	0	-	SPV	55	45	35	20	0	0	0	45	0	0	3.6	4.9	5.6	12.3	7.48	0.37	0.07	0.11	0.12	-
143	7/12/00	5	NW	SPV	45	55	15	30	0	0	0	55	0	0	5.71	7.34	8.88	16.6	25.4	0.30	0.08	0.12	0.13	-
144	7/12/00	5	NW	SPV	20	80	5	10	5	0	60	20	0	0	11.6	15	17.4	24.1	37.9	0.16	0.07	0.10	0.10	-
145	7/12/00	5	NW	SPV	40	50	15	20	5	0	5	45	0	0	5.93	8.07	9.51	16.8	25.6	0.28	0.08	0.12	0.12	-
151	7/12/00	5	SE	SPV	30	70	10	15	5	0	20	50	0	0	8.27	10.9	12.9	19.4	30	0.20	0.07	0.10	0.10	-
152	7/12/00	5	SE	SPV	17	83	10	5	2	0	30	53	0	0	7.91	10.4	12.3	19.1	29.4	0.22	0.07	0.10	0.11	-
153	7/12/00	0	-	SPV	25	75	15	5	5	0	25	50	0	0	6.96	9.04	10.5	17.6	28.3	0.25	0.08	0.11	0.11	-
154	7/12/00	0	-	SPV	17	80	5	10	2	0	40	40	0	0	7.7	9.97	12	19.1	28.7	0.23	0.08	0.11	0.11	-
155	7/12/00	0	-	SPV	30	75	10	15	5	0	25	50	0	0	7.26	9.25	10.9	17.6	27.9	0.24	0.07	0.11	0.11	-
161	7/12/00	10	SE	SPV	55	45	15	35	5	0	15	30	0	0	4.85	6.8	7.39	15	21	0.34	0.08	0.13	0.13	-
162	7/12/00	15	SE	SPV	50	50	10	25	15	0	30	20	0	0	6.98	9.34	10.8	18	27.9	0.25	0.08	0.11	0.12	-
163	7/12/00	5	SW	SPV	40	60	15	15	10	0	15	45	0	0	5.86	7.62	9.13	16.5	23.8	0.29	0.08	0.12	0.12	-

164	7/12/00	5	SW	SPV	75	25	15	50	10	0	10	15	0	0	5.33	7.2	8.1	18.6	24.9	0.39	0.11	0.17	0.18	-
165	7/12/00	5	SW	SPV	30	70	10	10	10	0	30	40	0	0	6.74	8.72	9.84	16.9	26.7	0.26	0.07	0.11	0.11	-
171	7/12/00	5	N	SPV	55	45	35	15	0	5	0	45	0	0	6.37	9.51	11.7	19.1	22.2	0.24	0.08	0.11	0.12	-
172	7/12/00	5	NW	SPV	35	65	5	30	0	0	0	65	0	0	5.81	8.08	9.8	16.8	22.3	0.26	0.07	0.11	0.11	-
173	7/12/00	5	NW	SPV	40	60	20	20	0	0	10	50	0	0	4.67	6.36	7.13	15.8	19.2	0.38	0.09	0.14	0.15	-
174	7/12/00	5	NW	SPV	80	20	35	30	15	0	0	20	0	0	3.4	5.21	5.57	18.5	18.5	0.54	0.13	0.22	0.23	-
175	7/12/00	5	N	SPV	70	30	40	30	0	0	15	15	0	0	5.49	6.99	8.14	16.7	24.6	0.34	0.09	0.14	0.14	-
181	7/12/00	20	NE	SPV	70	30	20	40	10	0	10	20	0	0	5.4	7.05	7.82	16	24.3	0.34	0.09	0.13	0.14	-
182	7/12/00	5	NE	SPV	75	25	30	45	0	0	0	25	0	0	3.78	5.47	5.97	16.2	18.3	0.46	0.10	0.17	0.18	-
183	7/12/00	5	N	SPV	100	0	20	55	10	15	0	0	0	0	4.56	6.06	6.97	17.3	24.3	0.42	0.11	0.17	0.18	-
184	7/12/00	5	NW	SPV	75	25	30	40	5	0	10	15	0	0	5.26	7.03	7.9	16.9	24.3	0.36	0.09	0.15	0.15	-
185	7/12/00	0	-	SPV	55	45	25	30	0	0	15	30	0	0	4.52	6.13	6.98	15.2	22.1	0.37	0.09	0.14	0.14	-
191	7/12/00	5	NE	SPV	62	38	35	25	2	0	0	38	0	0	5.61	7.29	8.44	16.2	23.5	0.31	0.08	0.13	0.13	-
192	7/12/00	5	SE	SPV	22	78	5	15	2	0	40	38	0	0	9.03	11.9	13.8	20.5	31.2	0.20	0.07	0.10	0.10	-
193	7/12/00	5	SE	SPV	25	75	5	15	5	0	25	50	0	0	5.98	7.65	8.72	15.5	25.3	0.28	0.07	0.11	0.11	-
194	7/12/00	5	NE	SPV	70	30	25	40	5	0	0	30	0	0	5.03	6.6	7.22	17.7	23.5	0.42	0.11	0.17	0.18	-
195	7/12/00	5	SE	SPV	45	55	15	25	5	0	30	25	0	0	6.51	8.28	9.46	17	25	0.28	0.08	0.12	0.12	24.25
211		15	NE	SPV	52	48	15	30	5	2	25	23	0	0										-
212		15	NE	SPV	42	58	15	25	2	0	5	53	0	0										-
213		15	NE	SPV	45	55	5	40	0	0	20	35	0	0										-
214		15	NE	SPV	30	70	15	15	0	0	25	45	0	0										-
215		15	NE	SPV	42	58	10	30	2	0	15	43	0	0										-
221	7/13/00	10	NE	SPV	55	45	10	35	5	5	10	35	0	0	5.21	6.73	7.54	17.3	22.9	0.39	0.10	0.16	0.16	30.3
222	7/13/00	5	N	SPV	27	73	5	20	2	0	10	63	0	0	5.8	7.4	8.51	16.1	23.8	0.31	0.08	0.12	0.13	-
223	7/13/00	5	N	SPV	70	30	20	50	0	0	0	30	0	0	4.48	6.04	6.7	19.1	24.5	0.48	0.13	0.21	0.21	-
224	7/13/00	0	-	SPV	50	50	20	20	0	10	15	35	0	0	3.69	5.33	5.98	15.8	16.5	0.45	0.10	0.17	0.17	-
225	7/13/00	5	N	SPV	80	20	40	40	0	0	0	20	0	0	4.55	6.49	6.83	22	24.8	0.53	0.15	0.25	0.26	-
231	7/13/00	5	N	SPV	20	80	5	15	0	0	10	70	0	0	6.59	9.08	10.9	18.6	25.5	0.26	0.08	0.12	0.12	25.75
232	7/13/00	5	NE	SPV	25	90	10	15	0	0	20	70	0	0	7.39	9.52	10.8	18.6	27	0.27	0.08	0.12	0.13	-
233	7/13/00	5	NE	SPV	35	65	15	20	0	0	15	50	0	0	5.95	7.83	9.09	17	24.9	0.30	0.08	0.13	0.13	-
234	7/13/00	5	NE	SPV	37	63	15	20	2	0	20	43	0	0	6.92	9.05	10.5	18	26.1	0.26	0.08	0.12	0.12	-
235	7/13/00	5	NE	SPV	35	65	15	20	0	0	45	20	0	0	7.68	9.96	11.2	19.1	29.4	0.26	0.08	0.12	0.13	-
241	7/13/00	5	NE	SPV	15	85	5	10	0	0	85	0	0	0	8.75	12	14.3	20.4	37.5	0.18	0.07	0.09	0.09	2.75
242	7/13/00	5	NE	SPV	36	65	10	25	1	0	15	50	0	0	4.9	6.49	7.42	15.6	24	0.36	0.09	0.14	0.14	-
243	7/13/00	5	NE	SPV	25	75	5	20	0	0	25	50	0	0	6.07	7.99	9.2	16.1	26.3	0.27	0.07	0.11	0.11	-
244	7/13/00	5	NE	SPV	61	39	20	40	1	0	10	29	0	0	4.5	5.83	6.61	15	21.8	0.39	0.09	0.14	0.15	-

245	7/13/00	5	NE	SPV	40	60	15	25	0	0	60	0	0	0	9.46	13.3	15	24.4	42.1	0.24	0.10	0.14	0.14	-
251	7/13/00	5	N	SPV	100	10	10	10	80	0	0	10	0	0	3.77	5.25	5.64	19.1	22.3	0.54	0.14	0.23	0.23	-
252	7/13/00	5	NE	SPV	75	25	5	70	0	0	0	25	0	0	3.7	5.23	5.44	17.9	21.4	0.53	0.13	0.21	0.22	-
253	7/13/00	5	NE	SPV	85	15	10	75	0	0	5	10	0	0	3.75	5.34	5.54	20.6	23.6	0.58	0.15	0.25	0.26	-
254	7/13/00	5	N	SPV	57	25	2	55	0	0	10	15	0	0	3.4	5.08	4.92	22.3	23.1	0.64	0.18	0.29	0.31	-
255	7/13/00	6	NE	SPV	80	20	15	65	0	0	15	5	0	0	3.86	5.47	5.91	18.2	24	0.51	0.13	0.21	0.21	-
261	7/13/00	5	NE	SPV	60	30	10	50	0	0	10	20	0	0	4.33	6.03	6.58	19.9	25	0.50	0.14	0.22	0.23	-
262	7/13/00	5	NE	SPV	35	65	20	15	0	0	25	40	0	0	4.3	5.87	6.65	16.7	22.8	0.43	0.10	0.17	0.17	-
263	7/13/00	0	0	SPV	45	55	30	15	0	0	0	55	0	0	2.93	4.11	4.59	12.6	11.2	0.47	0.08	0.14	0.14	-
264	7/13/00	0	0	SPV	45	55	35	10	0	0	5	50	0	0	3.32	4.88	5.49	16.4	15.3	0.50	0.11	0.19	0.19	-
265	7/13/00	0	0	SPV	40	60	25	15	0	0	0	0	60	0	2.26	3.58	3.54	13.4	6.53	0.58	0.10	0.18	0.18	-
271	7/13/00	5	N	SPV	45	55	15	30	0	0	5	50	0	0	5.87	8.36	9.98	19.6	25.9	0.33	0.10	0.15	0.16	-
272	7/13/00	5	N	SPV	45	55	20	25	0	0	0	55	0	0	4.41	6.28	7.12	17.5	24.2	0.42	0.11	0.17	0.18	-
273	7/13/00	5	N	SPV	30	70	10	20	0	0	0	70	0	0	6.85	9.56	11.3	19.7	26.3	0.27	0.09	0.13	0.13	-
274	7/13/00	5	NE	SPV	45	55	15	30	0	0	0	55	0	0	4.98	6.89	7.83	17	23.3	0.37	0.10	0.15	0.15	-
275	7/13/00	5	NW	SPV	60	40	20	40	0	0	10	30	0	0	4.95	6.99	7.93	17.8	23.2	0.38	0.10	0.16	0.17	-
281	7/13/00	0	0	SM	70	30	60	10	0	0	0	30	0	0	3.48	5.45	5.60	23.47	14.27	0.61	0.18	0.30	0.31	-
282	7/13/00	0	0	SM	80	20	80	0	0	0	0	20	0	0	3.01	4.80	5.25	18.13	11.66	0.55	0.13	0.22	0.23	-
283	7/13/00	0	0	SM	10	90	10	0	0	0	5	85	0	0	4.29	6.08	6.87	14.65	8.70	0.36	0.08	0.13	0.13	-
284	7/13/00	0	0	SPV	50	50	30	20	0	0	0	50	0	0	4.36	5.98	6.72	17.39	18.78	0.44	0.11	0.18	0.18	-
285	7/13/00	0	0	SM	5	95	5	0	0	0	0	95	0	0	3.45	4.80	5.02	12.93	6.63	0.44	0.08	0.14	0.14	-
291	7/13/00	5	NE	SPV	55	55	30	15	0	10	15	40	0	0	4.33	6.41	6.97	21.83	21.92	0.52	0.15	0.24	0.25	-
292	7/13/00	5	NE	SPV	35	65	20	15	0	0	15	50	0	0	5.32	7.36	8.21	20.30	27.03	0.42	0.12	0.19	0.20	-
293	7/13/00	5	NE	SPV	25	75	20	5	0	0	5	70	0	0	3.88	5.24	6.10	14.55	9.49	0.41	0.09	0.14	0.15	-
294	7/13/00	5	N	SPV	35	65	20	0	0	15	65	0	0	0	8.43	11.52	13.92	21.74	45.99	0.22	0.08	0.12	0.12	-
295	7/13/00	5	NW	SPV	25	75	20	5	0	0	20	55	0	0	4.07	5.47	6.27	15.53	18.04	0.42	0.10	0.16	0.16	-
311	7/14/00	5	W	SM	65	35	65	0	0	0	20	15	0	0	4.25	6.3	7.29	19.2	17.3	0.45	0.12	0.19	0.20	17
312	7/14/00	5	W	SM	80	20	80	0	0	0	0	20	0	0	4.2	5.97	7	19.3	17.2	0.47	0.13	0.20	0.21	-
313	7/14/00	5	W	SM	85	15	80	5	0	0	0	15	0	0	3.51	5.35	5.75	21	15.7	0.57	0.16	0.25	0.26	-
314	7/14/00	5	W	SM	100	0	80	15	0	5	0	0	0	0	4.46	6.97	7.64	24.2	25	0.52	0.17	0.26	0.27	-
315	7/14/00	5	W	SM	100	0	85	15	0	0	0	0	0	0	4.34	6.76	7.98	23.1	22.8	0.49	0.15	0.24	0.25	-
321	7/14/00	0	-	SM	80	20	75	5	0	0	0	0	20	0	3.58	5.4	6.48	19.5	17.5	0.50	0.13	0.22	0.22	-
322	7/14/00	0	-	SM	90	10	80	10	0	0	0	0	10	0	5.34	7.74	9.79	23.9	28.1	0.42	0.15	0.22	0.23	-
323	7/14/00	0	-	SM	45	55	25	15	0	5	0	0	55	0	3.67	5.6	6.79	19.4	18.6	0.48	0.13	0.21	0.22	-
324	7/14/00	0	-	SM	70	30	65	5	0	0	0	0	30	0	3.46	5.53	6.68	21.6	19.3	0.53	0.15	0.24	0.25	-
325	7/14/00	0	-	SM	50	50	45	5	0	0	0	0	50	0	3.11	4.95	5.72	18.1	15.1	0.52	0.13	0.21	0.22	-

331	7/14/00	0	-	SM	70	30	55	15	0	0	0	30	0	0	4.78	6.65	8.48	19.9	24.4	0.40	0.12	0.18	0.19	-
332	7/14/00	0	-	SM	60	40	45	15	0	0	0	40	0	0	4.44	6.48	8.07	22.8	24.3	0.48	0.15	0.23	0.24	-
333	7/14/00	0	-	SM	75	25	75	0	0	0	0	0	25	0	3.5	5.69	6.65	24	19.6	0.57	0.18	0.28	0.29	-
334	7/14/00	0	-	SM	85	15	85	0	0	0	0	15	0	0	4.63	6.57	8.61	20.4	23.9	0.41	0.12	0.19	0.19	-
335	7/14/00	0	-	SM	55	45	55	0	0	0	0	0	45	0	2.29	3.94	3.98	19.1	11.6	0.65	0.15	0.26	0.27	-
341	7/14/00	2	SE	SM	100	0	85	15	0	0	0	0	0	0	4.44	6.73	8.88	22.8	25.1	0.44	0.14	0.22	0.23	-
342	7/14/00	2	SE	SM	100	0	85	15	0	0	0	0	0	0	5.04	7.35	9.51	22.7	28.1	0.41	0.14	0.21	0.21	-
343	7/14/00	2	SE	SM	100	0	70	30	0	0	0	0	0	0	4.53	7.04	8.82	25.1	26.8	0.48	0.17	0.25	0.26	-
344	7/14/00	0	-	SM	100	10	55	45	0	0	0	10	0	0	3.92	6.05	7.33	22.3	24	0.51	0.15	0.24	0.25	-
345	7/14/00	0	-	SM	90	10	75	15	0	0	0	10	0	0	4.26	6.17	7.86	21.6	23.1	0.47	0.14	0.22	0.23	-
351	7/14/00	0	-	SM	100	0	100	0	0	0	0	0	0	0	3.92	6.31	7.61	23.2	24.1	0.51	0.16	0.25	0.26	-
352	7/14/00	0	-	SM	90	10	90	0	0	0	0	10	0	0	4.27	6.37	8.01	23.2	24.3	0.49	0.16	0.24	0.25	-
353	7/14/00	0	-	SM	70	30	70	0	0	0	0	25	5	0	4.48	6.73	8.21	21.1	22.3	0.44	0.13	0.21	0.21	-
354	7/14/00	0	-	SM	100	0	100	0	0	0	0	0	0	0	4.15	6.5	7.74	21.4	24	0.47	0.14	0.22	0.23	-
355	7/14/00	0	-	SM	85	15	85	0	0	0	0	0	15	0	3.37	5.23	5.95	24.3	20.6	0.61	0.19	0.30	0.31	-
361	7/14/00	SE	2	SM	70	30	60	10	0	0	0	10	20	0	6.09	8.27	8.46	24.1	18.9	0.48	0.16	0.25	0.26	-
362	7/14/00	E	2	SM	80	20	70	10	0	0	0	5	15	0	5.16	7.23	8.53	20	25.1	0.40	0.12	0.18	0.19	-
363	7/14/00	0	-	SM	50	50	50	0	0	0	0	45	5	0	3.99	5.44	6.33	16.9	15.8	0.46	0.11	0.18	0.18	40
364	7/14/00	0	-	SM	100	0	90	5	0	5	0	0	0	0	4.1	6.31	7.84	25.7	25.8	0.53	0.18	0.28	0.29	-
365	7/14/00	0	-	SM	70	30	70	0	0	0	0	25	5	0	3.22	4.89	5.49	16.7	13.6	0.51	0.11	0.19	0.20	-
371	7/14/00	0	-	SM	100	0	95	5	0	0	0	0	0	0	4.39	6.85	8.53	24.1	25.2	0.48	0.16	0.24	0.25	-
372	7/14/00	0	-	SM	100	0	80	20	0	0	0	0	0	0	5.84	7.9	10.4	25.8	31.4	0.43	0.16	0.23	0.24	-
373	7/14/00	0	-	SM	100	0	80	20	0	0	0	0	0	0	4.94	7.72	9.61	26.8	28.8	0.47	0.18	0.26	0.27	-
374	7/14/00	0	-	SM	75	25	75	0	0	0	0	25	0	0	4.61	6.99	8.85	21	25.1	0.41	0.13	0.19	0.20	-
375	7/14/00	0	-	SM	85	15	85	0	0	0	0	15	0	0	5.04	7.46	9.76	22.5	26.7	0.39	0.13	0.20	0.20	-
381	7/14/00	0	-	SM	95	5	95	0	0	0	0	0	5	0	4.7	7.07	9.09	23.9	25.4	0.45	0.15	0.23	0.24	-
382	7/14/00	0	-	SM	100	0	95	5	0	0	0	0	0	0	4.41	6.6	8.4	24.2	25.3	0.48	0.16	0.25	0.26	-
383	7/14/00	0	-	SM	55	45	55	0	0	0	0	0	45	0	3.35	5.14	6.26	20.6	16	0.53	0.15	0.24	0.25	-
384	7/14/00	0	-	SM	100	0	90	10	0	0	0	0	0	0	4.69	7.05	8.87	24	26.4	0.46	0.16	0.24	0.24	-
385	7/14/00	0	-	SM	100	0	85	15	0	0	0	0	0	0	3.97	6.3	7.42	25.8	22.2	0.55	0.19	0.29	0.30	-
391	7/14/00	0	-	SM	75	5	70	5	0	0	0	5	0	0	5.2	7.53	8.94	22.5	25.2	0.43	0.14	0.21	0.22	-
392	7/14/00	0	-	SM	35	65	30	5	0	0	0	0	65	0	2.55	4.26	4.48	19.1	10	0.62	0.15	0.25	0.26	-
393	7/14/00	0	-	SM	95	5	80	15	0	0	0	5	0	0	3.59	5.82	6.09	25.4	20	0.61	0.20	0.31	0.33	-
394	7/14/00	0	-	SM	100	0	70	20	0	10	0	0	0	0	4.08	6.4	7.03	27.1	22.5	0.59	0.20	0.32	0.33	-
395	7/14/00	0	-	SM	85	15	85	0	0	0	0	15	0	0	4.72	6.82	7.98	20.4	23	0.44	0.13	0.20	0.21	-
411	7/15/00	5	NW	SPV	47	53	20	25	2	0	15	38	0	0	5.91	7.76	8.74	16.5	24.7	0.31	0.08	0.13	0.13	13

412	7/15/00	5	NW	SPV	70	30	5	60	5	0	30	0	0	0	5.96	7.59	8.47	16.6	22.9	0.32	0.09	0.13	0.14	-
413	7/15/00	5	NW	SPV	75	25	10	60	5	0	10	15	0	0	4.68	6.49	6.95	19	21.3	0.46	0.12	0.20	0.20	-
414	7/15/00	5	NW	SPV	95	5	15	80	0	0	0	5	0	0	4.16	5.73	6.18	18.5	21.7	0.50	0.13	0.21	0.21	-
415	7/15/00	5	NW	SPV	40	60	5	35	0	0	5	55	0	0	6.48	8.63	9.81	18.2	25	0.30	0.09	0.13	0.14	-
421	7/15/00	5	NW	SPV	55	45	5	50	0	0	15	30	0	0	5.82	7.66	8.84	15.4	21.6	0.27	0.07	0.11	0.11	-
422	7/15/00	5	NE	SPV	45	55	5	40	0	0	20	35	0	0	6.65	8.9	10.4	16.6	22.8	0.23	0.07	0.10	0.10	-
423	7/15/00	5	N	SPV	42	58	5	35	2	0	20	38	0	0	7.27	9.36	10.6	17	24.4	0.23	0.07	0.10	0.10	-
424	7/15/00	5	NE	SPV	46	54	15	30	1	0	0	54	0	0	4.71	6.06	6.73	15.8	20.6	0.40	0.09	0.15	0.16	-
425	7/15/00	5	NE	SPV	55	45	5	50	0	0	10	35	0	0	6.37	8.22	9.33	16.3	22	0.27	0.07	0.11	0.12	-
431	7/15/00	5	NE	SPV	85	15	10	75	0	0	0	15	0	0	4.69	6.23	6.96	16.8	20	0.41	0.10	0.16	0.17	-
432	7/15/00	5	NE	SPV	45	55	5	39	1	0	0	55	0	0	5.85	7.63	8.51	17.1	20.2	0.34	0.09	0.14	0.14	-
433	7/15/00	5	N	SPV	40	60	10	30	0	0	0	60	0	0	5.4	7.03	7.78	15.6	18.5	0.33	0.08	0.13	0.13	-
434	7/15/00	5	NE	SPV	45	55	15	30	0	0	0	55	0	0	5.71	7.71	8.62	17.8	21	0.35	0.10	0.15	0.15	-
435	7/15/00	5	NE	SPV	90	10	20	70	0	0	0	10	0	0	4.94	6.45	6.96	16.7	21	0.41	0.10	0.16	0.17	-
441	7/15/00	5	NE	SM	90	10	20	70	0	0	0	10	0	0	5.11	6.94	8.38	19.1	26.3	0.39	0.11	0.17	0.18	-
442	7/15/00	5	NE	SM	90	10	70	20	0	0	0	10	0	0	4.55	6.58	7.88	20.8	24.6	0.45	0.13	0.21	0.21	-
443	7/15/00	0	-	H2O	20	80	10	10	0	0	0	0	80	0	1.85	3.02	3.88	7.14	4.61	0.30	0.03	0.06	0.06	-
444	7/15/00	5	N	SM	95	5	75	20	0	0	0	5	0	0	4.37	6.34	6.97	20.8	20.7	0.50	0.14	0.23	0.23	-
445	7/15/00	5	W	SM	45	55	45	0	0	0	5	50	0	0	6.04	8.72	10	22.2	22.6	0.38	0.13	0.19	0.20	-
451	7/15/00	5	NE	SPV	65	35	15	50	0	0	10	25	0	0	5.20	6.95	7.72	18.10	23.35	0.40	0.11	0.17	0.17	-
452	7/15/00	5	NE	SPV	15	85	5	10	0	0	20	65	0	0	6.21	8.30	9.46	17.63	23.49	0.30	0.09	0.13	0.13	-
453	7/15/00	5	NE	SPV	45	60	15	30	0	0	45	15	0	0	8.28	10.99	12.68	23.23	33.72	0.29	0.11	0.16	0.16	-
454	7/15/00	5	NE	SPV	40	60	10	30	0	0	45	15	0	0	8.47	10.72	12.29	21.11	32.16	0.26	0.09	0.13	0.14	-
455	7/15/00	5	NE	SPV	30	70	5	25	0	0	20	50	0	0	6.93	9.09	10.32	18.67	27.25	0.29	0.09	0.13	0.13	-
461	7/15/00	5	N	SPV	30	70	10	20	0	0	20	50	0	0	6.38	8.07	8.82	17.64	28.99	0.33	0.09	0.14	0.15	-
462	7/15/00	5	NW	SPV	20	80	5	15	0	0	20	60	0	0	7.47	9.66	11.04	18.45	26.76	0.25	0.08	0.12	0.12	-
463	7/15/00	5	NW	SPV	35	65	5	30	0	0	5	60	0	0	5.58	7.22	8.29	16.59	22.69	0.33	0.09	0.14	0.14	-
464	7/15/00	5	NW	SPV	25	75	5	20	0	0	25	50	0	0	7.59	10.43	12.25	21.07	30.64	0.26	0.09	0.13	0.14	-
465	7/15/00	5	NW	SPV	35	55	10	25	0	0	20	35	0	0	8.94	12.26	14.12	23.20	33.46	0.24	0.10	0.13	0.14	-
471	7/15/00	0	-	SM	85	15	75	10	0	0	0	15	0	0	4.54	6.67	7.77	20.17	23.47	0.44	0.13	0.20	0.21	-
472	7/15/00	0	-	SM	100	0	100	0	0	0	0	0	0	0	5.40	7.99	9.54	26.44	31.79	0.47	0.17	0.26	0.27	-
473	7/15/00	0	-	SM	100	0	90	10	0	0	0	0	0	0	5.09	7.76	8.92	26.86	29.82	0.50	0.18	0.28	0.29	-
474	7/15/00	0	-	SM	52	50	48	2	0	2	0	50	0	0	3.75	5.64	6.32	18.07	15.84	0.48	0.12	0.20	0.20	-
475	7/15/00	0	-	SM	100	0	100	0	0	0	0	0	0	0	4.66	6.97	8.32	21.42	25.55	0.44	0.13	0.21	0.22	-
481	7/15/00	3	NW	SM	90	10	80	10	0	0	0	10	0	0	5.35	7.74	8.93	23.99	28.53	0.46	0.15	0.24	0.24	-
482	7/15/00	3	NW	SM	100	0	85	15	0	0	0	0	0	0	4.47	6.61	7.50	21.41	23.56	0.48	0.14	0.22	0.23	-

483	7/15/00	3	NW	SM	80	20	75	0	0	5	0	0	20	0	3.66	6.03	6.18	24.41	20.14	0.60	0.19	0.30	0.31	-
484	7/15/00	3	NW	SM	100	0	100	0	0	0	0	0	0	0	4.86	7.39	8.36	23.24	23.94	0.47	0.15	0.24	0.24	-
485	7/15/00	3	NW	SM	60	40	60	0	0	0	0	30	10	0	3.95	5.99	6.48	19.95	18.70	0.51	0.14	0.22	0.23	-
491	7/15/00	5	NW	SPV	45	55	15	30	0	0	0	55	0	0	6.17	8.28	9.72	20.16	23.39	0.35	0.11	0.16	0.17	-
492	7/15/00	5	NW	SPV	25	75	10	15	0	0	0	75	0	0	7.11	9.52	10.99	20.35	26.27	0.30	0.10	0.14	0.15	-
493	7/15/00	3	NW	SPV	30	70	10	20	0	0	0	70	0	0	7.39	10.47	12.45	22.68	29.25	0.29	0.11	0.15	0.16	-
494	7/15/00	3	NW	SPV	60	40	20	40	0	0	0	40	0	0	5.65	7.96	9.30	21.08	23.86	0.39	0.12	0.19	0.19	-
495	7/15/00	5	NW	SPV	75	25	10	65	0	0	0	25	0	0	6.21	8.81	10.50	22.81	26.03	0.37	0.13	0.19	0.20	-
511	7/16/00	1	NE	TT	100	0	60	10	0	30	0	0	0	0	5.37	8.2	9.09	30.3	23.7	0.54	0.22	0.32	0.33	41.5
512	7/16/00	1	NE	TT	100	0	70	5	0	25	0	0	0	0	4.64	7.61	8.37	31.3	22.4	0.58	0.23	0.35	0.36	-
513	7/16/00	1	NE	TT	100	0	70	20	0	10	0	0	0	0	5.47	8.83	9.67	34.3	27.9	0.56	0.25	0.36	0.38	-
514	7/16/00	1	NE	TT	100	0	50	30	0	20	0	0	0	0	3.92	6.86	7.45	30.9	22	0.61	0.24	0.37	0.38	-
515	7/16/00	1	NE	TT	100	0	75	15	0	10	0	0	0	0	4.51	7.25	8.01	29.5	21.8	0.57	0.22	0.33	0.35	-
521	7/16/00	5	E	TT	90	10	35	10	0	45	0	10	0	0	4.49	6.75	7.15	25.1	20.3	0.56	0.18	0.29	0.30	-
522	7/16/00	5	E	TT	80	20	70	5	0	5	0	20	0	0	4.83	7.7	9.07	31.5	31.2	0.55	0.23	0.34	0.35	-
523	7/16/00	5	E	TT	100	0	60	10	0	30	0	0	0	0	4.25	7.3	7.53	30.4	21.8	0.60	0.23	0.36	0.37	-
524	7/16/00	5	E	TT	100	0	45	5	0	50	0	0	0	0	4.66	7.08	7.65	27.2	19.2	0.56	0.20	0.31	0.32	-
525	7/16/00	5	E	TT	100	0	35	15	0	50	0	0	0	0	5.21	8.05	8.03	31.5	20.8	0.59	0.24	0.36	0.37	-
531	7/16/00	10	E	TT	100	0	70	15	0	15	0	0	0	0	4.38	7	7.65	28.3	21.6	0.57	0.21	0.32	0.33	-
532	7/16/00	10	E	TT	100	0	80	10	0	10	0	0	0	0	4.15	6.99	7.36	30.7	21.8	0.61	0.24	0.36	0.38	-
533	7/16/00	10	E	TT	100	0	50	15	0	35	0	0	0	0	3.99	6.67	7.18	28.5	21.2	0.60	0.22	0.34	0.35	-
534	7/16/00	10	E	TT	100	0	70	10	0	20	0	0	0	0	4.22	6.7	7.33	27.1	20.3	0.57	0.20	0.31	0.33	-
535	7/16/00	10	E	TT	100	0	60	15	0	25	0	0	0	0	4.02	6.79	7.54	29.6	21.9	0.59	0.22	0.34	0.36	-
541	7/16/00	10	E	TT	100	0	40	15	0	45	0	0	0	0	6.55	9.59	9.62	34.2	21.8	0.56	0.25	0.36	0.38	-
542	7/16/00	10	E	TT	100	0	25	70	0	5	0	0	0	0	3.16	4.97	4.85	22.9	15.9	0.65	0.18	0.30	0.32	-
543	7/16/00	10	E	TT	100	0	75	15	0	10	0	0	0	0	8.36	11.1	11.3	32.1	24.2	0.48	0.21	0.30	0.31	-
544	7/16/00	10	E	TT	100	0	80	5	0	15	0	0	0	0	7.29	10.4	10.8	35.2	24.6	0.53	0.25	0.35	0.37	-
545	7/16/00	10	E	TT	100	0	65	20	0	15	0	0	0	0	5.41	7.83	7.93	28.1	19.3	0.56	0.20	0.31	0.33	-
551	7/16/00	10	NE	TT	100	0	75	10	0	15	0	0	0	0	5.13	8.58	9.49	37.41	27.67	0.60	0.28	0.41	0.42	70.3
552	7/16/00	10	NE	TT	100	0	75	10	0	15	0	0	0	0	4.63	7.70	8.44	32.36	25.72	0.59	0.24	0.36	0.38	-
553	7/16/00	10	NE	TT	100	0	60	20	0	20	0	0	0	0	4.76	8.17	9.03	35.64	26.16	0.60	0.27	0.40	0.41	-
554	7/16/00	10	NE	TT	100	0	65	20	0	15	0	0	0	0	4.04	6.65	7.06	32.05	22.57	0.64	0.25	0.39	0.40	-
555	7/16/00	10	NE	TT	100	0	80	10	0	10	0	0	0	0	5.09	8.56	9.27	34.50	26.03	0.58	0.26	0.38	0.39	-
561	7/16/00	5	E	TT	85	15	55	15	0	15	0	15	0	0	5.04	8.57	9.13	35.44	27.41	0.59	0.27	0.39	0.40	-
562	7/16/00	5	E	TT	100	0	60	10	0	30	0	0	0	0	4.37	7.17	7.53	30.47	23.01	0.60	0.23	0.36	0.37	-
563	7/16/00	5	E	TT	95	5	80	5	0	10	0	5	0	0	5.02	8.12	9.13	32.21	27.09	0.56	0.24	0.35	0.36	-

564	7/16/00	5	E	TT	100	0	60	15	0	25	0	0	0	0	5.03	7.81	8.58	32.30	25.18	0.58	0.24	0.36	0.37	-
565	7/16/00	5	E	TT	100	0	40	25	0	35	0	0	0	0	4.04	6.45	7.33	27.08	24.34	0.57	0.20	0.31	0.32	-
571	7/16/00	5	E	DS	100	0	30	60	0	10	0	0	0	0	3.33	5.62	5.18	32.30	20.86	0.72	0.27	0.44	0.46	-
572	7/16/00	5	E	DS	100	0	45	35	0	20	0	0	0	0	3.78	6.30	6.53	25.40	19.29	0.59	0.19	0.31	0.32	-
573	7/16/00	15	E	DS	100	0	20	35	0	45	0	0	0	0	1.87	3.15	2.51	16.27	9.95	0.73	0.14	0.25	0.26	-
574	7/16/00	10	E	DS	100	0	25	15	0	60	0	0	0	0	2.87	5.30	4.72	24.49	17.03	0.68	0.20	0.33	0.35	-
575	7/16/00	10	E	DS	100	0	30	25	0	45	0	0	0	0	3.72	6.02	5.64	31.76	19.79	0.70	0.26	0.42	0.44	-
581	7/16/00	10	NE	TT	100	0	75	20	0	5	0	0	0	0	2.73	4.42	4.20	18.32	13.92	0.63	0.14	0.24	0.25	-
582	7/16/00	10	NE	TT	100	0	50	20	0	30	0	0	0	0	4.66	7.26	7.66	30.28	23.90	0.60	0.23	0.35	0.36	-
583	7/16/00	10	NE	TT	100	0	75	10	0	15	0	0	0	0	3.88	5.91	6.24	26.51	18.98	0.62	0.21	0.33	0.34	-
584	7/16/00	10	NE	TT	100	0	60	35	0	5	0	0	0	0	2.85	4.27	4.13	19.29	14.31	0.65	0.15	0.26	0.27	-
585	7/16/00	10	NE	TT	100	0	60	5	0	35	0	0	0	0	5.30	8.18	8.50	34.93	24.93	0.61	0.27	0.40	0.41	-
591	7/16/00	5	NE	TT	100	0	90	5	0	5	0	0	0	0	7.30	11.00	10.86	38.34	27.73	0.56	0.28	0.39	0.40	-
592	7/16/00	5	NE	TT	100	0	80	20	0	0	0	0	0	0	6.60	10.05	9.97	36.79	28.29	0.57	0.27	0.39	0.40	-
593	7/16/00	5	NE	TT	100	0	55	30	0	15	0	0	0	0	6.73	10.25	10.37	48.08	30.61	0.65	0.38	0.52	0.52	-
594	7/16/00	5	NE	TT	100	0	75	25	0	0	0	0	0	0	4.70	7.36	7.20	33.29	22.50	0.64	0.26	0.40	0.42	-
595		5	NE	TT	80	20	60	20	0	0	0	20	0	0										-
611	7/17/00	5	NE	SM	45	55	30	15	0	0	10	45	0	0	5.96	8.4	9.55	18.5	23.5	0.32	0.09	0.14	0.15	-
612	7/17/00	5	NE	SM	55	45	40	15	0	0	15	30	0	0	4.7	6.43	7.36	18.6	23.9	0.43	0.12	0.18	0.19	-
613	7/17/00	5	NE	SM	55	45	40	15	0	0	15	30	0	0	4.05	5.73	6.55	18.3	22	0.47	0.12	0.20	0.20	-
614	7/17/00	5	NE	SM	40	60	30	10	0	0	15	45	0	0	5.9	7.71	8.99	17.4	24.2	0.32	0.09	0.14	0.14	-
615	7/17/00	5	NE	SM	45	55	15	30	0	0	10	45	0	0	6.13	7.98	9.16	19	27.6	0.35	0.10	0.16	0.16	-
621	7/17/00	5	NE	SM	90	10	80	10	0	0	0	10	0	0	4.64	7.09	8.11	22.1	21.3	0.46	0.14	0.22	0.23	21
622	7/17/00	5	NE	SM	95	5	75	20	0	0	0	5	0	0	4.57	6.66	7.82	21.4	22.9	0.46	0.14	0.22	0.23	-
623	7/17/00	5	NE	SM	50	50	45	5	0	0	0	50	0	0	6.05	8.75	10.4	19.2	22.8	0.30	0.09	0.14	0.14	-
624	7/17/00	5	NE	SM	50	50	35	15	0	0	0	50	0	0	4.3	6.57	7.46	22	20.3	0.49	0.15	0.23	0.24	-
625	7/17/00	5	NE	SM	55	55	30	25	0	0	0	55	0	0	6.26	8.56	10.2	18.6	24.4	0.29	0.09	0.13	0.14	-
631	7/17/00	10	NE	SM	55	45	30	25	0	0	20	25	0	0	6.33	8.15	9.15	17.9	25.3	0.32	0.09	0.14	0.14	19.45
632	7/17/00	15	NE	SM	50	5	45	5	0	0	0	5	0	0	4.11	6.31	6.5	19.9	20.6	0.51	0.14	0.22	0.23	-
633	7/17/00	10	NE	SM	70	20	60	0	0	10	0	20	0	0	4.53	6.75	7.19	22.1	22.5	0.51	0.15	0.24	0.25	-
634	7/17/00	10	NE	SM	40	60	25	15	0	0	15	45	0	0	6.2	8.22	9.04	18.3	24.7	0.34	0.10	0.15	0.15	-
635	7/17/00	10	NE	SM	60	40	55	5	0	0	0	40	0	0	3.71	5.6	6.01	18.1	20.1	0.50	0.12	0.20	0.21	-
641	7/17/00	10	NE	SM	60	40	60	0	0	0	0	10	30	0	3.07	5.3	5.27	19.7	9.63	0.58	0.15	0.24	0.25	-
642	7/17/00	5	NE	SM	90	5	85	5	0	0	0	5	0	0	4.47	6.83	8.64	22.6	25.1	0.45	0.14	0.22	0.23	-
643	7/17/00	5	NE	SM	100	0	95	0	0	5	0	0	0	0	4.36	7.01	8.45	24.7	24.5	0.49	0.17	0.26	0.26	-
644	7/17/00	5	NE	SM	85	15	80	0	0	5	0	15	0	0	3.2	5.2	5.51	19.1	12.5	0.55	0.14	0.23	0.24	-

645	7/17/00	5	NE	SM	100	0	95	0	0	5	0	0	0	0	4.87	7.47	9.67	24.1	28.6	0.43	0.15	0.22	0.23	-
651	7/17/00	10	NE	SM	75	25	75	0	0	0	0	25	0	0	4.53	6.59	7.52	19.8	24.4	0.45	0.13	0.20	0.21	-
652	7/17/00	10	NE	SM	70	30	70	0	0	0	0	30	0	0	4.93	7.14	8.53	16.8	22.3	0.33	0.09	0.13	0.14	-
653	7/17/00	10	NE	SM	70	30	70	0	0	0	0	30	0	0	4.05	5.99	7.04	16.9	22	0.41	0.10	0.16	0.17	-
654	7/17/00	10	NE	SM	80	20	75	0	0	5	0	20	0	0	4.65	6.62	7.62	17.4	22.8	0.39	0.10	0.16	0.16	-
655		10	NE	SM	30	70	30	0	0	0	0	70	0	0										-
661		10	NE	SM	70	50	60	10	0	0	25	25	0	0										-
662	7/17/00	10	NE	SM	75	36	40	25	0	10	31	5	0	0	4.91	6.86	7.83	17.7	25.8	0.39	0.10	0.16	0.17	-
663	7/17/00	10	NE	SM	80	40	25	40	0	15	20	20	0	0	4.75	6.94	7.78	20.7	27	0.45	0.13	0.21	0.22	-
664	7/17/00	10	NE	SM	60	40	20	25	0	15	5	35	0	0	4.37	6.41	7.4	19.6	25.2	0.45	0.13	0.20	0.21	-
665	7/17/00	10	NE	SM	65	35	35	25	0	5	5	30	0	0	4.93	6.86	8.27	19.3	27.1	0.40	0.11	0.18	0.18	-
671	7/17/00	15	NE	SPV	35	65	20	15	0	0	35	30	0	0	6.28	8.42	9.6	16.3	21.1	0.26	0.07	0.11	0.11	-
672	7/17/00	15	NE	SPV	40	60	40	0	0	0	0	0	60	0	2.82	4.82	5.17	19.5	10.6	0.58	0.15	0.24	0.25	-
673	7/17/00	15	NE	SPV	35	65	20	15	0	0	30	35	0	0	6.47	8.29	9.12	17.2	25.8	0.31	0.08	0.13	0.13	-
674	7/17/00	15	NE	SPV	45	55	30	15	0	0	40	15	0	0	5.23	7.29	8.16	16	19.9	0.32	0.08	0.13	0.13	-
675	7/17/00	15	NE	SPV	30	70	30	0	0	0	0	15	55	0	3.41	4.67	5.17	16.9	11.7	0.53	0.12	0.20	0.21	-
681	7/17/00	15	NE	SM	90	10	85	5	0	0	0	10	0	0	4.72	6.73	7.85	22.2	26.4	0.48	0.15	0.23	0.24	-
682	7/17/00	15	NE	SPV	45	55	15	30	0	0	10	45	0	0	6.74	9.34	10.8	21.7	26.6	0.33	0.11	0.17	0.17	-
683	7/17/00	15	NE	SPV	85	15	40	45	0	0	5	10	0	0	3.74	5.72	5.94	25.2	23	0.62	0.20	0.31	0.33	-
684	7/17/00	10	NE	SPV	75	25	30	45	0	0	10	15	0	0	4.06	5.6	6.12	17.2	21.6	0.48	0.11	0.19	0.19	-
685	7/17/00	10	NE	SPV	65	35	10	55	0	0	25	10	0	0	6.47	8.24	9.12	17.5	27.9	0.32	0.09	0.13	0.14	-
691		4	SW	SM	55	4	30	25	0	0	0	4	0	0										-
692		5	SW	SM	45	55	30	15	0	0	5	50	0	0										-
693		5	SE	SM	70	30	70	0	0	0	0	30	0	0										-
694		5	SE	SM	95	5	95	0	0	0	0	5	0	0										-
695		5	SE	SM	75	25	60	15	0	0	0	25	0	0										-
711	7/19/00	5	NE	SPV	15	85	5	10	0	0	15	70	0	0	11.1	16.5	19.8	25.9	34.2	0.13	0.07	0.08	0.08	8
712	7/19/00	5	NE	SPV	30	80	10	20	0	0	45	35	0	0	8.47	11.5	13.4	22.2	33.6	0.25	0.09	0.13	0.14	-
713	7/19/00	5	NE	SPV	20	75	5	15	0	0	20	55	0	0	11.9	17.2	20.6	27.3	37.5	0.14	0.08	0.09	0.09	-
714	7/19/00	5	NE	SPV	40	60	10	30	0	0	25	35	0	0	11.1	15.5	18.1	25.4	35.8	0.17	0.08	0.10	0.10	-
715	7/19/00	5	E	SPV	15	85	5	10	0	0	10	75	0	0	10	15.2	18.2	25.2	32.9	0.16	0.08	0.10	0.10	-
721	7/19/00	5	E	SPV	35	65	15	20	0	0	25	40	0	0	6.76	9.09	10.4	19.5	29.7	0.30	0.10	0.14	0.15	11.7
722	7/19/00	5	E	SPV	35	65	15	20	0	0	15	50	0	0	8.81	12	13.8	21.7	31.5	0.22	0.09	0.12	0.12	-
723	7/19/00	5	NE	SPV	20	80	5	15	0	0	15	65	0	0	11	14.8	17.7	24.2	36	0.16	0.07	0.09	0.09	-
724	7/19/00	5	NE	SPV	35	65	20	15	0	0	20	45	0	0	6.94	9.03	10.5	18.4	28.5	0.27	0.08	0.12	0.13	-
725	7/19/00	5	NE	SPV	35	65	15	20	0	0	15	50	0	0	9.8	13.3	15.5	23	32.5	0.19	0.08	0.11	0.11	-

731	7/19/00	10	NW	SPV	25	75	5	20	0	0	10	65	0	0	6.88	9.1	11	18.4	27	0.25	0.08	0.12	0.12	-
732	7/19/00	10	NW	SPV	60	40	15	45	0	0	10	30	0	0	6.35	8.16	9.49	17.9	24.7	0.31	0.09	0.13	0.14	-
733	7/19/00	5	NW	SPV	20	80	5	15	0	0	25	55	0	0	10.2	13.4	15.6	22.9	34.5	0.19	0.08	0.11	0.11	-
734	7/19/00	5	NW	SPV	30	70	10	15	5	0	15	55	0	0	7.43	9.75	11.5	18.7	28.6	0.24	0.08	0.11	0.11	-
735	7/19/00	10	NW	SPV	15	85	5	10	0	0	45	40	0	0	9.73	12.7	15	21.7	32.5	0.18	0.07	0.10	0.10	-
741	7/19/00	0	-	SPV	25	75	20	5	0	0	5	70	0	0	3.77	5.5	6.47	16.5	12.9	0.44	0.10	0.17	0.17	-
742	7/19/00	0	-	SPV	90	10	40	5	0	45	5	5	0	0	4.07	6.05	6.75	24.4	15.9	0.57	0.18	0.29	0.30	-
743	7/19/00	0	-	SPV	5	95	5	0	0	0	10	85	0	0	7.46	10.6	12.4	18	20.6	0.18	0.06	0.09	0.09	-
744	7/19/00	0	-	SPV	20	80	15	5	0	0	0	80	0	0	4.25	5.97	6.96	14.8	21.7	0.36	0.08	0.13	0.14	-
745	7/19/00	0	-	SPV	20	80	5	15	0	0	0	80	0	0	9.47	13.5	16.2	23.1	28.4	0.18	0.08	0.10	0.10	-
751	7/19/00	5	NE	SPV	45	55	20	25	0	0	30	25	0	0	8.43	11.3	13.3	21	29.8	0.23	0.08	0.12	0.12	-
752	7/19/00	5	NE	SPV	42	58	15	25	2	0	35	23	0	0	6.86	8.96	10	19.2	28.2	0.31	0.10	0.14	0.15	-
753	7/19/00	5	NE	SPV	55	45	25	25	5	0	40	5	0	0	7.88	10.4	11.9	19.5	29	0.24	0.08	0.12	0.12	-
754	7/19/00	5	NE	SPV	25	75	5	20	0	0	10	65	0	0	10.4	14.3	17.3	24.5	34.6	0.17	0.08	0.10	0.10	-
755	7/19/00	5	NE	SPV	37	63	5	30	2	0	40	23	0	0	8.93	12.1	14.2	21.7	31.2	0.21	0.08	0.11	0.11	-
761	7/19/00	5	NE	SPV	22	78	5	15	2	0	25	53	0	0	7.2	9.36	10.9	17.9	26.6	0.24	0.07	0.11	0.11	-
762	7/19/00	5	NE	SPV	25	75	10	15	0	0	35	40	0	0	6.29	8.29	9.57	16.8	25.8	0.27	0.08	0.12	0.12	-
763	7/19/00	5	NE	SPV	35	75	15	20	0	0	20	55	0	0	6.23	8.43	10	17.3	26.7	0.27	0.08	0.12	0.12	-
764	7/19/00	5	NE	SPV	30	60	10	20	0	0	10	50	0	0	7.85	10.9	12.9	20.2	29.6	0.22	0.08	0.11	0.11	-
765	7/19/00	5	NE	SPV	45	85	15	30	0	0	10	75	-	0	5.6	7.35	8.36	16	25	0.31	0.08	0.12	0.13	-
771	7/19/00	5	NE	SPV	65	35	35	30	0	0	15	20	0	0	5.58	7.25	8.03	17.8	25.8	0.38	0.10	0.16	0.16	-
772	7/19/00	5	NE	SPV	50	50	10	40	0	0	15	35	0	0	6.08	7.93	8.8	17.5	26.3	0.33	0.09	0.14	0.14	-
773	7/19/00	5	NE	SPV	20	80	10	10	0	0	15	65	0	0	9.79	13.1	15.4	22	33.6	0.18	0.07	0.10	0.10	-
774	7/19/00	5	NE	SPV	45	55	5	40	0	0	10	45	0	0	6.11	7.97	8.93	17.2	27.8	0.32	0.09	0.13	0.14	-
775	7/19/00	5	NE	SPV	25	75	5	20	0	0	20	55	0	0	8.65	11.8	13.8	20.2	30.5	0.19	0.07	0.10	0.10	-
781	7/19/00	5	E	SPV	12	87	2	10	0	0	70	17	0	0	15.4	20.9	24.4	30	44.1	0.10	0.07	0.07	0.07	-
782	7/19/00	5	NE	SPV	20	80	5	15	0	0	60	20	0	0	13.8	18.1	20.8	27.1	41.7	0.13	0.07	0.08	0.09	-
783	7/19/00	5	E	SPV	22	77	5	15	2	0	65	12	0	0	13.2	17.9	21.2	27.7	41.4	0.13	0.07	0.09	0.09	-
784	7/19/00	5	E	SPV	15	85	5	10	0	0	65	20	0	0	11.9	16.1	18.9	26.2	39.7	0.16	0.08	0.10	0.10	-
785	7/19/00	5	E	SPV	7	93	2	5	0	0	60	33	0	0	13.1	17.7	20.6	26.9	40.8	0.13	0.07	0.09	0.09	-
791	7/19/00	5	NE	SPV	50	50	20	30	0	0	15	35	0	0	6.34	8.57	9.47	20.7	28.5	0.37	0.12	0.18	0.18	-
792	7/19/00	5	N	SPV	50	50	15	35	0	0	15	35	0	0	4.68	6.63	7.29	18.5	25.7	0.43	0.12	0.18	0.19	-
793	7/19/00	5	N	SPV	30	70	5	25	0	0	30	40	0	0	8.55	11.7	13.7	22.2	30.8	0.24	0.09	0.13	0.13	-
794	7/19/00	5	N	SPV	20	80	5	15	0	0	30	50	0	0	10.6	14.9	17.3	24.5	36.5	0.17	0.08	0.10	0.10	-
795	7/19/00	5	N	SPV	30	70	5	25	0	0	65	5	0	0	8.02	10.2	11.7	21.1	34.1	0.29	0.10	0.14	0.15	-
811	7/20/00	5	NW	SM	85	15	85	0	0	0	0	10	5	0	3.11	5.6	7.07	23	21.5	0.53	0.16	0.26	0.27	48

812	7/20/00	0	-	SM	65	35	60	5	0	0	0	0	35	0	3.14	3.4	3.52	18.3	17.5	0.68	0.15	0.26	0.27	-
813	7/20/00	5	NW	SM	90	10	90	0	0	0	0	5	5	0	3.58	5.41	6.04	24.9	26.9	0.61	0.19	0.31	0.32	-
814	7/20/00	5	NW	SM	75	25	55	20	0	0	0	25	0	0	2.62	5.19	5.78	25.3	24.5	0.63	0.20	0.32	0.33	-
815	7/20/00	5	NW	SM	55	45	50	5	0	0	0	0	45	0	2.74	4.09	5.33	20.1	15.4	0.58	0.15	0.25	0.26	-
821	7/20/00	20	W	DS	70	30	20	50	0	0	0	30	0	0	3.5	5.86	5.9	22.6	33.6	0.59	0.17	0.28	0.29	71.7
822	7/20/00	20	W	DS	45	55	5	25	5	10	55	0	0	0	4.03	6.21	6.45	23.9	38.2	0.57	0.18	0.28	0.29	-
823	7/20/00	20	W	DS	90	10	15	70	0	5	0	10	0	0	3.2	5.3	3.91	30.5	30.6	0.77	0.27	0.45	0.46	-
824	7/20/00	20	W	DS	55	45	30	15	5	5	30	15	0	0	3.89	5.83	6.59	25.6	35.2	0.59	0.19	0.31	0.32	-
825	7/20/00	25	W	DS	60	40	20	30	0	10	0	40	0	0	3.04	4.81	4.53	24	44.4	0.68	0.20	0.33	0.34	-
1111	7/24/00	25	W	DS	85	15	10	70	0	5	0	15	0	0	3.39	4.90	4.70	24.41	21.59	0.68	0.20	0.33	0.34	68.3
1112	7/24/00	20	W	DS	75	25	10	55	0	10	20	5	0	0	4.09	6.02	5.52	28.39	25.91	0.67	0.23	0.37	0.39	-
1113	7/24/00	10	W	DS	35	65	5	30	0	0	20	45	0	0	6.03	8.89	10.16	27.09	27.02	0.45	0.17	0.26	0.27	-
1114	7/24/00	10	W	DS	80	20	15	65	0	0	10	10	0	0	4.38	6.80	6.96	28.98	24.72	0.61	0.22	0.35	0.36	-
1115	7/24/00	10	W	DS	45	55	10	35	0	0	5	50	0	0	3.75	5.32	5.56	19.52	19.90	0.56	0.14	0.23	0.24	-
1121	7/24/00	5	W	SM	85	15	30	35	0	20	10	5	0	0	3.66	5.58	5.66	24.40	23.56	0.62	0.19	0.31	0.32	-
1122	7/24/00	5	SW	SM	85	15	60	15	0	10	0	15	0	0	4.52	6.98	7.05	29.55	27.14	0.61	0.23	0.35	0.37	-
1123	7/24/00	5	SW	SM	35	65	15	15	0	5	0	65	0	0	5.26	7.11	7.39	22.05	23.05	0.50	0.15	0.24	0.25	-
1124	7/24/00	5	SW	SM	60	40	20	40	0	0	0	40	0	0	4.27	6.05	6.16	23.39	24.87	0.58	0.18	0.28	0.29	-
1125	7/24/00	5	W	SM	35	55	15	20	0	0	5	50	0	0	4.93	6.84	7.26	20.99	22.11	0.49	0.14	0.22	0.23	-
1131	7/24/00	5	SW	SM	95	5	55	40	0	0	5	0	0	0	3.77	6.05	5.71	27	24.2	0.65	0.22	0.35	0.36	-
1132	7/24/00	5	W	SM	30	70	15	15	0	0	5	65	0	0	5.13	7.04	6.94	19.8	20.9	0.48	0.13	0.21	0.22	-
1133	7/24/00	5	W	SM	80	20	30	45	0	5	10	10	0	0	3.57	5.46	5.42	22.9	20.6	0.62	0.18	0.29	0.30	-
1134	7/24/00	5	W	SM	25	75	10	15	0	0	5	70	0	0	4.82	6.91	7.62	17.2	19.7	0.39	0.10	0.16	0.16	-
1135	7/24/00	5	W	SM	45	55	15	30	0	0	55	0	0	0	5.11	6.96	7.57	19.1	23.7	0.43	0.12	0.19	0.19	-
1141	7/24/00	5	SW	SM	30	70	10	20	0	0	20	50	0	0	5.93	8.2	8.79	19	22.8	0.37	0.11	0.16	0.17	-
1142	7/24/00	5	SW	SM	75	25	20	45	0	10	10	15	0	0	3.87	5.55	5.98	19.1	20.4	0.52	0.13	0.22	0.23	-
1143	7/24/00	5	SW	SM	80	20	35	40	0	5	5	15	0	0	4.38	6.28	6.7	20	22.1	0.50	0.14	0.22	0.23	-
1144	7/24/00	5	SW	SM	60	40	15	45	0	0	5	35	0	0	3.8	5.55	5.73	21.8	21.5	0.58	0.16	0.27	0.28	-
1145	7/24/00	5	SW	SM	45	55	15	30	0	0	20	35	0	0	4.17	5.94	6.37	19.8	20.8	0.51	0.14	0.22	0.23	-
1151	7/24/00	5	W	SM	40	60	10	30	0	0	20	40	0	0	5.83	8.43	9.51	20.4	23.2	0.36	0.11	0.17	0.18	-
1152	7/24/00	5	SW	SM	75	25	30	40	0	5	10	15	0	0	4.03	5.94	6.04	22.1	21.3	0.57	0.16	0.27	0.28	-
1153	7/24/00	5	SW	SM	25	85	5	20	0	0	15	70	0	0	4.32	6.1	6.79	18.9	21.5	0.47	0.12	0.20	0.21	-
1154	7/24/00	5	SW	SM	35	65	10	25	0	0	10	55	0	0	3.82	5.7	6.19	20.5	21.5	0.54	0.15	0.24	0.25	-
1155	7/24/00	5	SW	SM	70	40	25	40	0	5	25	15	0	0	4.29	6.18	6.41	21.8	23	0.55	0.16	0.25	0.26	-
1161	7/24/00	5	NW	SM	30	70	10	20	0	0	0	70	0	0	4.64	6.53	7.12	18.8	20.9	0.45	0.12	0.19	0.20	-
1162	7/24/00	5	NW	SM	45	55	15	30	0	0	10	45	0	0	3.9	5.78	5.97	20.5	20.5	0.55	0.15	0.24	0.25	-

1163	7/24/00	5	NW	SM	50	50	30	20	0	0	5	45	0	0	3.93	5.79	5.74	21.7	21.1	0.58	0.16	0.26	0.27	-
1164	7/24/00	5	NW	SM	75	25	40	20	0	15	0	25	0	0	2.94	4.91	4.77	23.5	23.1	0.66	0.19	0.32	0.33	-
1165	7/24/00	5	NW	SM	50	50	15	35	0	0	15	35	0	0	4.23	5.87	5.97	19.7	20.9	0.53	0.14	0.23	0.24	-
1171	7/24/00	5	W	SM	90	10	30	55	0	5	5	5	0	0	3.72	5.87	5.62	25.5	23.5	0.64	0.20	0.33	0.34	-
1172	7/24/00	5	W	SM	35	65	15	20	0	0	10	55	0	0	4.84	6.63	7.1	18.7	22.5	0.45	0.12	0.19	0.20	-
1173	7/24/00	5	W	SM	50	50	20	15	0	15	5	45	0	0	4.8	6.68	6.97	20.8	23.3	0.50	0.14	0.22	0.23	-
1174	7/24/00	5	W	SM	60	40	20	25	0	15	30	10	0	0	4.03	6.15	6.05	22.8	23.2	0.58	0.17	0.28	0.29	-
1175	7/24/00	5	W	SM	70	30	20	50	0	0	10	20	0	0	3.81	5.43	5.4	20	21.1	0.57	0.15	0.25	0.25	-
1181	7/24/00	5	W	SM	90	10	40	45	0	5	5	5	0	0	4.06	6.05	6.22	22.1	23.6	0.56	0.16	0.26	0.27	-
1182	7/24/00	5	W	SM	75	25	65	10	0	0	15	10	0	0	4.82	6.71	7.02	20.4	23.5	0.49	0.14	0.22	0.23	-
1183	7/24/00	5	W	SM	60	40	30	30	0	0	10	30	0	0	4.77	6.6	7.19	19.5	22	0.46	0.13	0.20	0.21	-
1184	7/24/00	5	W	SM	50	50	20	30	0	0	50	0	0	0	4.75	6.24	6.68	17.5	24	0.45	0.11	0.18	0.19	-
1185	7/24/00	5	W	SM	90	10	60	30	0	0	0	10	0	0	3.6	5.69	5.33	25.8	23.5	0.66	0.21	0.34	0.35	-
1191	7/24/00	20	W	DS	100	0	10	55	0	35	0	0	0	0	3.37	5.69	5.44	31.3	25.5	0.70	0.26	0.42	0.43	-
1192	7/24/00	20	SW	DS	100	0	20	80	0	0	0	0	0	0	3.23	5.71	5.15	34.3	24.1	0.74	0.29	0.47	0.49	-
1193	7/24/00	20	W	DS	70	40	0	25	0	45	0	40	0	0	3.01	4.84	5.52	22	23.7	0.60	0.17	0.27	0.28	-
1194	7/24/00	20	SW	DS	85	15	5	80	0	0	0	15	0	0	4.16	6.94	7.35	31	24.9	0.62	0.24	0.37	0.38	-
1195	7/24/00	20	SW	DS	100	0	0	100	0	0	0	0	0	0	2.45	4.33	3.59	29	20.2	0.78	0.26	0.44	0.45	-
1211	7/24/00	0	-	SM	30	70	20	10	0	0	35	35	0	0	6.53	9.34	10.8	20.5	24.4	0.31	0.10	0.15	0.15	44.3
1212	7/24/00	0	-	SM	45	55	10	25	0	10	10	45	0	0	4.2	6.22	6.89	20.7	23.9	0.50	0.14	0.23	0.23	-
1213	7/24/00	0	-	SM	85	15	40	25	0	20	0	15	0	0	4.12	6.26	6.42	24.7	25.5	0.59	0.19	0.30	0.31	-
1214	7/24/00	0	-	SM	30	70	5	20	5	0	10	60	0	0	5.05	7.15	8.03	17.1	21.5	0.36	0.09	0.15	0.15	-
1215	7/24/00	5	SE	SM	95	5	45	45	0	5	0	5	0	0	3.22	4.98	4.85	22.1	18	0.64	0.17	0.29	0.30	-
1221	7/24/00	5	SE	TT	100	0	70	10	0	20	0	0	0	0	4.17	6.91	7.51	29.6	30	0.59	0.22	0.34	0.36	81
1222	7/24/00	5	SE	SM	100	0	70	10	0	20	0	0	0	0	3.45	5.81	6.36	27.1	28.1	0.62	0.21	0.34	0.35	-
1223	7/24/00	5	SE	SM	85	15	35	20	0	30	0	15	0	0	4.4	6.56	7.23	22.1	25	0.51	0.15	0.24	0.25	-
1224	7/24/00	5	SE	SM	100	0	70	10	0	20	0	0	0	0	3.79	5.95	6.87	27.2	28.4	0.60	0.21	0.32	0.34	-
1225	7/24/00	5	SE	SM	85	15	60	15	0	10	0	15	0	0	3.95	6.57	7.06	29.5	28.4	0.61	0.23	0.35	0.37	-
1231	7/24/00	2	NE	SM	100	0	40	30	0	30	0	0	0	0	3.62	5.95	6.07	28.9	26.7	0.65	0.23	0.37	0.38	-
1232	7/24/00	2	NE	SM	90	10	60	15	0	15	0	10	0	0	4.22	6.85	7.45	28.6	29	0.59	0.21	0.33	0.34	-
1233	7/24/00	2	NE	SM	100	0	50	30	0	20	0	0	0	0	3.34	5.47	5.43	28.3	23.7	0.68	0.23	0.37	0.39	-
1234	7/24/00	2	NE	SM	95	5	45	30	0	20	0	5	0	0	4.07	6.02	6.42	26.3	25.8	0.61	0.20	0.32	0.33	-
1235	7/24/00	2	NE	SM	85	15	40	35	0	10	0	15	0	0	3.9	5.97	6.3	24.2	25.3	0.59	0.18	0.29	0.30	-
1241	7/24/00	2	NE	SM	80	20	30	40	0	10	0	20	0	0	4.35	6.68	7.17	26	27.2	0.57	0.19	0.30	0.31	-
1242	7/24/00	2	NE	SM	70	30	30	30	0	10	0	30	0	0	4.04	6.15	6.75	22.6	25.3	0.54	0.16	0.26	0.27	-
1243	7/24/00	2	NE	SM	75	25	40	25	0	10	0	25	0	0	4.83	7.07	8	25.1	28.8	0.52	0.17	0.27	0.28	-

1244	7/24/00	2	NE	SM	95	5	50	25	0	20	0	5	0	0	3.86	6.14	6.67	26.9	28	0.60	0.21	0.32	0.34	-
1245	7/24/00	2	NE	SM	100	0	50	30	0	20	0	0	0	0	4.25	6.58	7.2	27.7	28.8	0.59	0.21	0.32	0.34	-
1251	7/24/00	2	NE	SM	90	10	60	20	0	10	0	10	0	0	3.74	6.06	5.97	26.6	25.8	0.63	0.21	0.34	0.35	-
1252	7/24/00	2	NE	SM	35	65	20	15	0	0	0	65	0	0	4.83	7.53	8.08	21.8	23.6	0.46	0.14	0.22	0.23	-
1253	7/24/00	2	NE	SM	85	15	25	45	0	15	0	15	0	0	4.14	6.26	6.44	22.9	24.7	0.56	0.17	0.27	0.28	-
1254	7/24/00	5	NE	SM	85	15	20	45	5	15	0	15	0	0	3.61	5.43	5.37	22.1	22.1	0.61	0.17	0.28	0.29	-
1255	7/24/00	5	NE	SM	95	5	65	25	0	5	0	5	0	0	3.67	6.26	6.25	28.5	25.8	0.64	0.23	0.36	0.37	-
1261	7/24/00	5	NE	SM	90	10	40	20	0	30	0	10	0	0	3.41	5.56	6.1	23.9	27	0.59	0.18	0.29	0.30	-
1262	7/24/00	5	NE	SM	85	15	30	20	0	35	5	10	0	0	3.82	6.21	6.84	25.9	28.6	0.58	0.19	0.31	0.32	-
1263	7/24/00	5	NE	SM	90	10	20	30	0	40	0	10	0	0	4.69	7.23	8.72	25.3	31.7	0.49	0.17	0.26	0.27	-
1264	7/24/00	5	NE	SM	95	5	70	15	0	10	0	5	0	0	4.38	6.69	7.4	23.7	27.9	0.52	0.17	0.26	0.27	-
1265	7/24/00	2	NE	SM	100	0	45	15	0	40	0	0	0	0	5.13	7.95	9.05	31.2	33.6	0.55	0.23	0.33	0.35	-
1271	7/24/00	5	NE	SM	100	0	45	30	0	25	0	0	0	0	3.56	5.76	6	29.1	27.4	0.66	0.23	0.37	0.39	-
1272	7/24/00	5	NE	SM	30	70	5	25	0	0	10	60	0	0	3.7	5.82	6.09	25	25.5	0.61	0.19	0.31	0.32	-
1273	7/24/00	5	NE	SM	30	70	5	25	0	0	10	60	0	0	5.19	7.73	8.83	21.1	24.7	0.41	0.13	0.19	0.20	-
1274		5	NE	SM	95	5	20	50	5	20	0	5	0	0										-
1275		5	NE	SM	60	40	20	25	5	10	0	40	0	0										-
1281	7/24/00	5	NE	TT	100	0	60	20	0	20	0	0	0	0	5.1-7	8.42	8.98	35.33	31.61	0.59	0.27	0.39	0.40	-
1282	7/24/00	5	NE	TT	100	0	65	20	0	15	0	0	0	0	4.70	7.96	8.30	35.01	30.53	0.62	0.27	0.40	0.42	-
1283	7/24/00	5	NE	TT	100	0	40	20	0	40	0	0	0	0	4.54	7.69	7.71	38.42	30.04	0.67	0.31	0.46	0.47	-
1284	7/24/00	5	NE	TT	100	0	80	15	0	5	0	0	0	0	4.96	7.91	8.45	31.96	30.05	0.58	0.24	0.36	0.37	-
1285	7/24/00	5	NE	TT	100	0	50	35	0	15	0	0	0	0	4.33	6.98	6.81	29.16	26.55	0.62	0.23	0.35	0.37	-
1291	7/24/00	5	NE	SM	70	30	35	30	0	5	5	25	0	0	3.94	6.80	6.51	30.82	27.32	0.65	0.25	0.39	0.40	64.7
1292	7/24/00	5	NE	SM	85	15	35	25	0	25	0	15	0	0	4.07	6.89	6.37	30.44	28.70	0.65	0.24	0.38	0.40	-
1293	7/24/00	5	NE	SM	85	15	30	25	0	30	0	15	0	0	4.56	7.65	8.08	32.97	30.60	0.61	0.25	0.38	0.39	-
1294	7/24/00	5	NE	SM	100	0	55	25	0	20	0	0	0	0	4.20	7.03	7.66	31.41	30.04	0.61	0.24	0.37	0.38	-
1295	7/24/00	5	NE	SM	100	0	35	25	0	40	0	0	0	0	3.59	6.13	6.39	29.79	31.40	0.65	0.24	0.37	0.39	-
1311	7/26/00	2	NE	SPV	20	80	10	10	0	0	30	50	0	0	6.7	8.32	9.34	17.7	24.8	0.31	0.09	0.13	0.14	-
1312	7/26/00	5	NW	SPV	25	75	10	15	0	0	25	50	0	0	6.01	7.69	8.82	16.2	22.3	0.30	0.08	0.12	0.12	-
1313	7/26/00	5	NE	SPV	70	30	20	50	0	0	15	15	0	0	5.29	7.12	8.17	17.9	23.3	0.37	0.10	0.16	0.16	-
1314	7/26/00	5	NE	SPV	70	40	35	35	0	0	30	10	0	0	4.34	5.93	6.44	17.9	21.9	0.47	0.12	0.19	0.20	-
1315	7/26/00	5	NE	SPV	40	60	5	35	0	0	20	40	0	0	6.24	8.14	9.52	16.7	22.4	0.27	0.08	0.12	0.12	-
1321	7/26/00	5	N	SPV	60	40	25	30	5	0	30	10	0	0	4.92	6.63	7.18	17.3	21.4	0.41	0.10	0.17	0.17	-
1322	7/26/00	5	NE	SPV	50	50	20	20	10	0	30	20	0	0	4.55	6.28	6.72	18.6	23.3	0.47	0.12	0.20	0.20	-
1323	7/26/00	5	NE	SPV	65	35	15	45	5	0	20	15	0	0	4.75	6.6	7.32	18.5	22.3	0.43	0.12	0.18	0.19	-
1324	7/26/00	5	N	SPV	35	65	15	20	0	0	20	45	0	0	5.31	6.86	7.54	16.7	22.4	0.38	0.10	0.15	0.16	-

1325	7/26/00	5	NE	SPV	75	25	35	40	0	0	20	5	0	0	4.69	6.64	6.96	21.4	23.8	0.51	0.15	0.24	0.24	-
1331	7/26/00	5	NW	SPV	55	45	20	30	0	5	45	0	0	0	4.8	6.47	7.01	18.5	22.4	0.45	0.12	0.19	0.19	-
1332	7/26/00	5	NW	SPV	25	75	5	15	5	0	10	65	0	0	6.74	8.72	10	17.9	23.2	0.28	0.08	0.13	0.13	-
1333	7/26/00	5	NW	SPV	60	40	20	35	0	5	20	20	0	0	4.25	5.93	6.07	21.5	23	0.56	0.16	0.26	0.27	-
1334	7/26/00	5	NW	SPV	45	55	15	20	5	5	55	0	0	0	7.8	9.84	10.7	20.4	29.7	0.31	0.10	0.15	0.15	-
1335	7/26/00	5	NW	SPV	50	50	15	30	5	0	20	30	0	0	4.67	6.19	6.61	17.4	22.9	0.45	0.11	0.18	0.19	-
1341	7/26/00	50	NW	SPV	70	30	25	40	5	0	25	5	0	0	4.71	6.42	6.89	19.9	22.7	0.49	0.13	0.21	0.22	-
1342	7/26/00	5	NW	SPV	55	45	25	30	0	0	5	40	0	0	4.09	5.73	5.88	20.2	21.3	0.55	0.15	0.24	0.25	-
1343	7/26/00	5	NW	SPV	60	40	30	20	0	10	20	20	0	0	3.6	5.28	5.4	21.4	20.7	0.60	0.16	0.27	0.28	-
1344	7/26/00	5	NW	SPV	15	85	5	10	0	0	30	55	0	0	5.53	7.48	8.62	15.8	21.6	0.30	0.08	0.12	0.12	-
1345	7/26/00	5	NW	SPV	25	75	5	20	0	0	40	35	0	0	5.91	7.83	8.93	18.1	23.7	0.34	0.10	0.15	0.15	-
1351	7/26/00	5	NW	SPV	50	50	20	25	5	0	20	30	0	0	5.51	7.35	8.11	18.7	24.3	0.39	0.11	0.17	0.18	-
1352	7/26/00	10	NW	SPV	85	15	30	50	5	0	0	15	0	0	4.84	6.57	7.07	19.2	23.4	0.46	0.12	0.20	0.21	-
1353	7/26/00	5	W	SPV	60	40	20	40	0	0	15	25	0	0	4.41	6.23	6.37	20.4	23.8	0.52	0.14	0.23	0.24	-
1354	7/26/00	5	W	SPV	45	55	10	25	10	0	25	30	0	0	6.36	8.17	8.83	19.6	24.8	0.38	0.11	0.17	0.18	-
1355	7/26/00	5	NW	SPV	65	35	30	35	0	0	20	15	0	0	4.33	6.53	7.18	20.5	22.3	0.48	0.14	0.22	0.22	-
1361	7/26/00	2	NW	SPV	35	65	10	25	0	0	15	50	0	0	4.63	6.3	7.03	17.8	21.5	0.43	0.11	0.18	0.18	-
1362	7/26/00	2	NW	SPV	25	75	10	15	0	0	20	55	0	0	5.26	7.32	8.17	18.7	22.7	0.39	0.11	0.17	0.18	-
1363	7/26/00	2	NW	SPV	60	40	25	30	0	5	15	25	0	0	4.14	5.7	6.12	18.4	23.4	0.50	0.13	0.20	0.21	-
1364	7/26/00	2	NW	SPV	65	35	25	40	0	0	0	35	0	0	3.77	5.42	6.01	18	21	0.50	0.12	0.20	0.21	-
1365	7/26/00	2	NW	SPV	40	60	15	25	0	0	15	45	0	0	4.95	6.7	7.61	16.9	21.7	0.38	0.10	0.15	0.16	-
1371	7/26/00	2	N	SPV	75	25	40	15	5	15	0	25	0	0	3.9	6.05	6.51	24	23.6	0.57	0.18	0.28	0.30	-
1372	7/26/00	0	-	SPV	105	5	75	20	0	10	0	5	0	0	3.58	5.9	6.35	24.7	18.1	0.59	0.19	0.30	0.31	-
1373	7/26/00	0	-	SPV	75	25	55	15	0	5	0	25	0	0	3.01	4.3	4.41	16	13.7	0.57	0.12	0.20	0.21	-
1374	7/26/00	2	N	SPV	75	25	45	30	0	0	0	25	0	0	3.89	6.05	6.23	20	21.7	0.53	0.14	0.23	0.24	-
1375	7/26/00	0	-	SPV	50	50	20	30	0	0	0	50	0	0	3.36	4.84	5.09	17.8	16.5	0.55	0.13	0.22	0.22	-
1381	7/26/00	5	NE	SPV	70	30	45	15	0	10	0	30	0	0	3.34	5.17	5.65	19.6	14.2	0.55	0.14	0.23	0.24	-
1382	7/26/00	5	NE	SPV	60	40	40	20	0	0	0	40	0	0	5.22	7.96	9.37	21.6	23	0.39	0.13	0.19	0.20	-
1383	7/26/00	5	NE	SPV	90	10	65	10	0	15	0	10	0	0	4.6	6.98	7.75	22.5	23.7	0.49	0.15	0.24	0.24	-
1384	7/26/00	5	NE	SPV	105	0	35	5	0	65	0	0	0	0	3.36	5.33	6.34	23.6	29.6	0.58	0.18	0.28	0.29	-
1385	7/26/00	5	NE	SPV	30	70	10	20	0	0	30	40	0	0	6.66	9.08	10.8	18.1	24.7	0.25	0.08	0.11	0.12	-
1391	7/26/00	20	W	SPV	25	75	10	15	0	0	25	50	0	0	7.09	9.72	11.7	19.1	25.9	0.24	0.08	0.11	0.12	-
1392	7/26/00	20	W	SPV	35	65	10	20	5	0	20	45	0	0	6.62	8.69	9.83	20	26.9	0.34	0.11	0.16	0.16	-
1393	7/26/00	20	W	SPV	55	45	15	30	10	0	20	25	0	0	6.97	8.68	9.77	20.3	26.5	0.35	0.11	0.17	0.17	-
1394	7/26/00	20	W	SPV	35	65	15	20	0	0	40	25	0	0	7.41	10.1	12.1	19.5	27.4	0.23	0.08	0.11	0.12	-
1395	7/26/00	20	W	SPV	25	75	5	15	5	0	40	35	0	0	6.77	9.05	10.8	19.1	26	0.28	0.09	0.13	0.13	-

1411	7/27/00	10	NE	BRN	9	91	2	5	2	0	60	31	0	0	12.6	16.2	19	23.6	30.5	0.11	0.05	0.06	0.07	5.7
1412	7/27/00	10	NE	SPV	45	55	15	25	5	0	40	15	0	0	8.27	10.9	12.7	21.2	27.6	0.25	0.09	0.13	0.13	-
1413	7/27/00	10	NE	BRN	17	83	2	10	5	0	83	0	0	0	13.2	16.7	19.5	23.9	34.9	0.10	0.05	0.06	0.06	-
1414	7/27/00	10	NE	BRN	32	68	2	20	10	0	63	5	0	0	12.3	15.6	17.9	24.2	33.9	0.15	0.07	0.09	0.09	-
1415	7/27/00	10	NE	BRN	22	78	2	10	5	5	73	5	0	0	9.83	12.6	15.1	20.2	30.4	0.15	0.06	0.08	0.08	-
1421	7/27/00	10	N	BRN	9	91	2	5	2	0	76	15	0	0	9.74	12.3	14.5	19.3	27.5	0.14	0.05	0.07	0.07	11
1422	7/27/00	10	NE	BRN	22	78	5	15	2	0	63	15	0	0	8.82	11	12.4	20.5	28.2	0.25	0.09	0.12	0.13	-
1423	7/27/00	10	NE	BRN	25	75	5	15	5	0	75	0	0	0	9.98	12.7	14.6	21.5	29.6	0.19	0.08	0.10	0.10	-
1424	7/27/00	10	NE	BRN	12	88	2	5	5	0	88	0	0	0	11.8	14.3	16.5	20.9	30.3	0.12	0.05	0.06	0.06	-
1425	7/27/00	10	NE	BRN	7	93	2	5	0	0	63	30	0	0	11.3	14.1	16.4	22	28.6	0.14	0.06	0.08	0.08	-
1431	7/27/00	10	NW	BRN	5	95	0	5	0	0	75	20	0	0	13.2	16.9	20	23.3	30.9	0.07	0.04	0.05	0.05	-
1432	7/27/00	10	N	BRN	7	93	2	5	0	0	93	0	0	0	12.5	15.7	18.2	22.1	30.5	0.10	0.05	0.06	0.06	-
1433	7/27/00	10	NW	BRN	30	70	5	15	10	0	70	0	0	0	9.3	11.5	13.4	19.9	29	0.20	0.07	0.10	0.10	-
1434	7/27/00	5	N	BRN	17	83	2	5	10	0	83	0	0	0	9.86	11.9	13.7	17.8	26.1	0.13	0.05	0.06	0.06	-
1435	7/27/00	10	NW	BRN	25	75	5	15	5	0	75	0	0	0	11.4	14.1	16.5	22.3	30.4	0.15	0.07	0.08	0.09	-
1441	7/27/00	10	NE	BRN	25	75	5	20	0	0	65	10	0	0	9.5	12.2	14.1	21.4	29.8	0.21	0.08	0.11	0.11	-
1442	7/27/00	10	E	BRN	19	81	2	15	2	0	76	5	0	0	13	16.5	19.1	25.4	36	0.14	0.07	0.09	0.09	-
1443	7/27/00	10	NE	BRN	30	70	5	25	0	0	70	0	0	0	9.51	12	13.9	20.9	30.6	0.20	0.08	0.10	0.11	-
1444	7/27/00	5	NE	BRN	17	83	2	10	5	0	83	0	0	0	10.1	12.5	14.7	19	31.6	0.13	0.05	0.07	0.07	-
1445	7/27/00	10	NE	BRN	5	95	0	5	0	0	80	15	0	0	13.4	17.2	19.9	23.8	31.7	0.09	0.05	0.05	0.05	-
1451	7/27/00	10	NE	BRN	8	92	1	5	2	0	82	10	0	0	13.4	16.9	20	24.3	34.9	0.10	0.05	0.06	0.06	19.7
1452	7/27/00	10	E	BRN	5	95	0	5	0	0	90	5	0	0	11.3	14.2	16.5	21.9	32.3	0.14	0.06	0.08	0.08	-
1453	7/27/00	10	E	BRN	7	93	0	5	2	0	83	10	0	0	13	16.6	19.6	24.3	33.8	0.11	0.06	0.07	0.07	-
1454	7/27/00	5	E	BRN	9	91	2	5	2	0	91	0	0	0	12.6	15.6	17.9	22.7	33.3	0.12	0.06	0.07	0.07	-
1455	7/27/00	5	NE	BRN	2	98	0	2	0	0	93	5	0	0	13.4	17	19.8	24.2	35.7	0.10	0.05	0.06	0.06	-
1461	7/27/00	0	-	BRN	9	91	2	5	2	0	86	5	0	0	13.6	16.8	19.3	24.4	33.9	0.12	0.06	0.07	0.07	-
1462	7/27/00	5	N	BRN	17	83	5	10	2	0	83	0	0	0	11.6	14.3	16.4	21.4	31.4	0.13	0.06	0.07	0.07	-
1463	7/27/00	5	NE	BRN	10	90	0	10	0	0	90	0	0	0	14	17.7	20.5	25.8	35.8	0.12	0.06	0.07	0.07	-
1464	7/27/00	0	-	BRN	7	93	2	5	0	0	83	10	0	0	14	18.4	21.9	25.3	33.3	0.07	0.04	0.05	0.05	-
1465	7/27/00	5	NE	BRN	12	88	5	5	2	0	78	10	0	0	12.9	16.1	18.7	24.1	32.9	0.13	0.06	0.08	0.08	-
1471	7/27/00	0	-	BRN	20	80	5	15	0	0	70	10	0	0	11.7	15.1	17.1	22.1	30	0.13	0.06	0.07	0.07	-
1472	7/27/00	5	SE	BRN	7	93	2	5	0	0	63	30	0	0	12.6	16.1	18.8	23.7	31.5	0.12	0.06	0.07	0.07	-
1473	7/27/00	5	SE	BRN	7	93	2	5	0	0	83	10	0	0	13.9	17.5	20.2	25.1	34	0.11	0.06	0.07	0.07	-
1474	7/27/00	5	SE	BRN	5	95	0	5	0	0	90	5	0	0	13.6	17.6	20.5	24.5	33.2	0.09	0.05	0.06	0.06	-
1475	7/27/00	10	SE	BRN	12	88	2	5	5	0	88	0	0	0	12	15.6	18.6	23.7	35.5	0.12	0.06	0.07	0.07	-
1481	7/27/00	10	E	BRN	15	85	5	10	0	0	85	0	0	0	11.3	14.4	16.8	21.5	30.3	0.12	0.06	0.07	0.07	-

1482	7/27/00	5	E	BRN	7	93	2	5	0	0	93	0	0	0	12.1	15.6	18.2	23.2	34.3	0.12	0.06	0.07	0.07	-
1483	7/27/00	20	SE	BRN	20	80	5	10	5	0	70	10	0	0	12.9	16	19.5	24.2	35.9	0.11	0.06	0.07	0.07	-
1484	7/27/00	20	SE	BRN	27	73	2	20	5	0	68	5	0	0	12.8	16.6	18.8	24.4	33.6	0.13	0.06	0.08	0.08	-
1485	7/27/00	20	SE	BRN	9	91	2	5	2	0	91	0	0	0	16.7	19.9	22	25	46.8	0.06	0.04	0.04	0.04	-
1491	7/27/00	10	SE	BRN	12	90	2	10	0	0	85	5	0	0	12.6	16.3	18.6	23.2	33.5	0.11	0.05	0.07	0.07	-
1492	7/27/00	10	SE	BRN	35	65	10	25	0	0	40	25	0	0	9.21	11	12.9	20.1	31.4	0.22	0.08	0.11	0.11	-
1493	7/27/00	10	SE	BRN	32	68	2	20	10	0	68	0	0	0	8.94	11.2	12.7	19.1	35.1	0.20	0.07	0.10	0.10	-
1494	7/27/00	10	SE	BRN	12	88	10	0	2	0	88	0	0	0	13.30	16.76	19.41	23.25	36.03	0.09	0.05	0.05	0.05	-
1495	7/27/00	10	SE	BRN	30	70	5	15	10	0	65	5	0	0	10.18	12.72	14.31	20.72	29.07	0.18	0.07	0.10	0.10	-
1511	7/28/00	20	NE	BRN	45	55	10	25	10	0	30	25	0	0	8.84	11.1	12.2	21.4	26.9	0.27	0.10	0.14	0.14	43.67
1512	7/28/00	20	NE	BRN	37	63	2	20	10	5	63	0	0	0	8.45	10.4	11.9	16.8	27.8	0.17	0.06	0.08	0.08	-
1513	7/28/00	20	NE	BRN	22	78	2	15	5	0	68	10	0	0	11.3	14.3	16.2	24.9	30.1	0.21	0.09	0.12	0.13	-
1514	7/28/00	10	NE	BRN	14	86	2	10	2	0	50	36	0	0	11.5	15.3	18	23.3	31.3	0.13	0.06	0.08	0.08	-
1515	7/28/00	20	NE	BRN	12	88	2	5	5	0	60	28	0	0	12.1	15.5	17.9	22.6	32.4	0.12	0.06	0.07	0.07	-
1521	7/28/00	15	E	BRN	14	86	2	10	2	0	66	20	0	0	12.7	16.4	19.3	24.2	32.6	0.11	0.06	0.07	0.07	-
1522	7/28/00	20	E	BRN	4	96	0	2	2	0	96	0	0	0	12.5	15.9	18.6	22.6	35.9	0.10	0.05	0.06	0.06	-
1523	7/28/00	15	E	BRN	9	91	2	5	2	0	61	30	0	0	11.5	14.6	16.7	23.2	30.3	0.16	0.07	0.09	0.09	-
1524	7/28/00	20	E	BRN	17	83	2	10	5	0	40	43	0	0	13.1	17	20	23.8	30.7	0.09	0.05	0.05	0.05	-
1525	7/28/00	20	E	BRN	12	91	2	5	5	0	91	0	0	0	12.4	16.3	19	24	34.9	0.12	0.06	0.07	0.07	-
1531	7/28/00	20	SE	BRN	20	80	5	10	5	0	60	20	0	0	10.5	13.1	15.1	22.5	32.7	0.20	0.08	0.11	0.11	-
1532	7/28/00	25	SW	BRN	17	83	5	10	2	0	78	5	0	0	13.3	16.1	18.4	22.8	33.3	0.11	0.05	0.06	0.06	-
1533	7/28/00	25	S	BRN	9	91	2	5	2	0	86	5	0	0	15.1	19.3	22.8	28	39	0.10	0.06	0.07	0.07	-
1534	7/28/00	20	S	BRN	45	55	10	25	10	0	55	0	0	0	10.1	12.8	14.8	21.8	32.3	0.19	0.08	0.10	0.11	-
1535	7/28/00	25	SE	BRN	9	91	2	5	2	0	86	5	0	0	13.8	17.6	20.5	26.2	36.6	0.12	0.07	0.08	0.08	-
1541	7/28/00	10	NE	BRN	22	78	2	15	5	0	68	10	0	0	9.93	12.6	14.6	20.4	27.7	0.17	0.07	0.09	0.09	-
1542	7/28/00	5	E	BRN	15	85	5	10	0	0	20	65	0	0	8.93	12	14.2	20.5	25.5	0.18	0.07	0.09	0.10	-
1543	7/28/00	10	NE	BRN	27	73	2	15	10	0	63	10	0	0	10.5	13	15.1	20.3	28.3	0.15	0.06	0.08	0.08	-
1544	7/28/00	5	E	BRN	0	100	0	0	0	0	100	0	0	0	8.27	9.64	11	13.2	27.5	0.09	0.03	0.04	0.04	-
1545	7/28/00	5	E	BRN	7	93	2	5	0	0	40	53	0	0	12.6	15.9	18.8	23.4	30	0.11	0.05	0.07	0.07	-
1551	7/28/00	10	NE	BRN	25	75	5	15	5	0	55	20	0	0	10.3	13.4	15.6	21.1	28.7	0.15	0.06	0.08	0.08	17.3
1552	7/28/00	15	E	BRN	20	80	5	10	5	0	40	40	0	0	12.3	15.9	18.5	23.6	29.6	0.12	0.06	0.07	0.07	-
1553	7/28/00	15	NE	BRN	17	83	2	10	5	0	83	0	0	0	9.72	12.1	14.3	18	27.7	0.11	0.04	0.06	0.06	-
1554	7/28/00	10	NE	BRN	4	90	2	2	0	0	50	40	0	0	11.3	15	17.7	21.9	27.6	0.10	0.05	0.06	0.06	-
1555	7/28/00	10	NE	BRN	12	88	2	5	5	0	88	0	0	0	11.5	14.7	17.1	21.7	31.4	0.12	0.05	0.07	0.07	-
1561	7/28/00	10	NE	BRN	7	93	2	5	0	0	43	50	0	0	12.1	15.1	17.4	22.3	29.6	0.12	0.06	0.07	0.07	-
1562	7/28/00	10	NE	BRN	17	84	5	10	2	0	64	20	0	0	12	15.5	18.1	22.9	29.6	0.12	0.06	0.07	0.07	-

1563	7/28/00	10	NE	SPV	35	65	20	10	0	5	50	15	0	0	8.13	10.9	12.5	19.3	24.4	0.21	0.07	0.10	0.11	-
1564	7/28/00	10	NE	SPV	2	98	2	0	0	0	10	88	0	0	7.51	10.5	12.7	17.3	20.6	0.15	0.05	0.07	0.07	-
1565	7/28/00	5	NE	BRN	10	90	0	0	10	0	90	0	0	0	11.7	14.2	16.5	19.4	34	0.08	0.04	0.04	0.04	-
1571	7/28/00	10	NE	SPV	20	80	10	10	0	0	20	60	0	0	8.1	11.4	13.2	21.5	26.5	0.24	0.09	0.12	0.13	-
1572	7/28/00	10	NE	BRN	35	65	15	10	10	0	65	0	0	0	9.47	12	14	20.3	30.6	0.18	0.07	0.09	0.10	-
1573	7/28/00	10	NE	SPV	30	70	10	15	5	0	50	20	0	0	8.28	10.6	12	19.5	27.2	0.24	0.08	0.12	0.12	-
1574	7/28/00	10	NE	SPV	35	65	5	20	10	0	65	0	0	0	12.2	15.2	17.1	23.7	33.3	0.16	0.07	0.09	0.10	-
1575	7/28/00	10	NE	BRN	10	90	0	10	0	0	90	0	0	0	7.45	8.89	10	13.2	25.4	0.14	0.04	0.05	0.05	-
1581	7/28/00	5	NE	BRN	17	83	2	10	5	0	68	15	0	0	11.3	14.3	16.1	22.3	30	0.16	0.07	0.09	0.09	-
1582	7/28/00	5	NE	BRN	2	98	0	2	0	0	58	40	0	0	12.3	15.4	18.3	21.5	31.8	0.08	0.04	0.05	0.05	-
1583	7/28/00	5	NE	BRN	7	93	2	5	0	0	33	60	0	0	13.4	17.4	20.4	25	30.9	0.10	0.05	0.06	0.06	-
1584	7/28/00	5	NE	BRN	20	80	5	10	5	0	75	5	0	0	11.5	14	16	22.1	31.6	0.16	0.07	0.09	0.09	-
1585	7/28/00	5	NE	BRN	17	83	5	10	2	0	73	10	0	0	12.8	16.1	18.4	24.6	32.1	0.14	0.07	0.09	0.09	-
1591	7/28/00	5	NE	BRN	40	60	10	25	5	0	30	30	0	0	8.29	10.1	11.2	17.8	28.1	0.23	0.07	0.10	0.11	-
1592	7/28/00	5	NE	BRN	40	60	10	20	10	0	60	0	0	0	10.1	12.1	12.8	20.4	33.4	0.23	0.08	0.11	0.12	-
1593	7/28/00	5	NE	BRN	27	73	5	20	2	0	48	25	0	0	9.77	12.3	14	20.1	29.1	0.18	0.07	0.09	0.09	-
1594	7/28/00	5	NE	BRN	30	70	5	25	0	0	40	30	0	0	7.58	9.61	10.9	18.4	25.9	0.26	0.08	0.12	0.12	-
1595	7/28/00	5	NE	BRN	35	65	10	25	0	0	45	20	0	0	8.27	10.1	11.4	19.2	27.1	0.26	0.08	0.12	0.12	-
1611	7/29/00	15	SW	BRN	17	85	5	10	2	0	40	45	0	0	12	15.1	17.3	23.6	32.1	0.16	0.07	0.09	0.09	22
1612	7/29/00	10	SW	BRN	15	85	0	5	10	0	85	0	0	0	10.2	11.3	12.3	14.6	30	0.08	0.03	0.04	0.04	-
1613	7/29/00	15	W	BRN	20	80	5	10	5	0	75	5	0	0	11.9	14	15.7	21.2	34	0.15	0.06	0.08	0.08	-
1614	7/29/00	10	W	BRN	12	88	0	10	2	0	63	25	0	0	14.5	18.3	21.2	27.2	34.8	0.12	0.07	0.08	0.08	-
1615	7/29/00	5	W	BRN	17	83	2	10	5	0	83	0	0	0	7.96	9.13	10.1	14.2	25.8	0.17	0.05	0.07	0.07	-
1621	7/29/00	5	SW	BRN	15	85	5	10	0	0	65	20	0	0	10.4	12.3	14	20.2	30.9	0.18	0.07	0.09	0.10	18
1622	7/29/00	10	SW	BRN	17	83	5	10	2	0	78	5	0	0	12.5	15.2	17.3	24.2	35	0.17	0.08	0.10	0.10	-
1623	7/29/00	10	W	BRN	7	93	2	5	0	0	88	5	0	0	13	16.4	18.9	24.1	32	0.12	0.06	0.07	0.07	-
1624	7/29/00	10	SW	BRN	15	85	5	5	5	0	80	5	0	0	12.7	15.6	17.7	23.2	34.7	0.13	0.06	0.08	0.08	-
1625	7/29/00	10	SW	BRN	20	80	5	15	0	0	80	0	0	0	10.3	12.9	15.1	21.7	30.5	0.18	0.07	0.10	0.10	-
1631	7/29/00	25	SW	BRN	6	94	2	2	2	0	74	20	0	0	13.1	16.1	18.5	23.4	33.7	0.12	0.06	0.07	0.07	-
1632	7/29/00	25	NW	BRN	7	93	2	5	0	0	53	40	0	0	11.1	14.3	16.9	20.7	28.9	0.10	0.05	0.06	0.06	-
1633	7/29/00	15	SW	BRN	12	88	2	10	0	0	48	40	0	0	14.4	18.6	22.3	27.5	36.8	0.10	0.06	0.07	0.07	
1634	7/29/00	10	S	BRN	7	93	2	5	0	0	45	48	0	0	15.1	19.4	22.8	27.4	33.3	0.09	0.06	0.06	0.06	-
1635	7/29/00	5	NW	BRN	2	98	1	1	0	0	98	0	0	0	14.1	17.7	21	26	34.8	0.11	0.06	0.07	0.07	-
1641	7/29/00	25	SE	SPV	20	80	10	10	0	0	75	5	0	0	9.5	12.1	13.8	22	31.2	0.23	0.09	0.12	0.13	-
1642	7/29/00	10	E	SPV	40	60	10	20	10	0	60	0	0	0	12.1	14.7	16.7	23.7	34.3	0.17	0.08	0.10	0.10	-
1643	7/29/00	10	E	SPV	35	65	10	15	10	0	60	5	0	0	11.8	14.2	16.3	22.5	33.7	0.16	0.07	0.09	0.09	-

1644	7/29/00	5	E	SPV	15	85	5	10	0	0	25	60	0	0	12.8	16.2	18.6	24.6	30.9	0.14	0.07	0.08	0.09	-
1645	7/29/00	5	E	BRN	12	88	5	5	2	0	78	10	0	0	13	16.2	18.7	24.4	36.3	0.13	0.07	0.08	0.08	-
1651	7/29/00	5	SW	BRN	25	75	10	15	0	0	70	5	0	0	10.4	12.6	14.3	22.2	29	0.22	0.09	0.12	0.12	29
1652	7/29/00	5	SW	BRN	22	78	5	15	2	0	78	0	0	0	11.2	13.4	15.1	21.9	32.7	0.18	0.07	0.10	0.10	-
1653	7/29/00	0	-	BRN	25	75	20	5	0	0	70	0	5	0	4.69	5.87	6.69	13.7	28.8	0.34	0.07	0.12	0.12	-
1654	7/29/00	0	-	BRN	25	75	5	20	0	0	70	5	0	0	6.88	8.94	10.2	16.7	28.7	0.24	0.07	0.10	0.11	-
1655	7/29/00	0	-	BRN	25	75	15	10	0	0	75	0	0	0	7.68	9.35	10.5	16.7	29.3	0.23	0.07	0.10	0.10	-
1661	7/29/00	10	SW	BRN	12	88	2	5	5	0	73	15	0	0	11.6	14.5	16.6	22.5	31.8	0.15	0.07	0.09	0.09	-
1662	7/29/00	10	SW	BRN	20	80	5	10	5	0	75	5	0	0	10.8	13.1	15.1	20.8	32.3	0.16	0.06	0.08	0.09	-
1663	7/29/00	10	SW	BRN	5	95	0	5	0	0	10	85	0	0	15.2	19.6	23.7	27.5	36.7	0.07	0.05	0.05	0.05	-
1664	7/29/00	10	SW	BRN	10	90	0	10	0	0	70	20	0	0	11.3	14.2	16.5	21.9	34	0.14	0.06	0.08	0.08	-
1665	7/29/00	5	NW	BRN	17	83	2	10	5	0	40	43	0	0	12.7	15.5	17.6	22.9	33.1	0.13	0.06	0.07	0.08	-
1671	7/29/00	20	SE	SPV	90	10	25	50	0	15	0	10	0	0	5.24	7.43	7.8	23	27.5	0.49	0.16	0.24	0.25	-
1672	7/29/00	20	SE	SPV	30	70	5	25	0	0	15	55	0	0	7.37	9.25	10.4	19.7	28.9	0.31	0.10	0.15	0.15	-
1673	7/29/00	15	SE	SPV	50	50	10	35	0	5	20	30	0	0	6.16	8.11	8.99	20.3	27	0.39	0.12	0.18	0.19	-
1674	7/29/00	15	S	SPV	95	5	75	20	0	0	0	5	0	0	5.62	7.93	8.36	24.9	29.2	0.50	0.17	0.26	0.27	-
1675	7/29/00	15	SE	SPV	70	30	25	35	0	10	5	25	0	0	4.89	6.39	6.88	21.8	24.9	0.52	0.15	0.24	0.25	-
1681	7/29/00	20	SW	BRN	5	95	0	5	0	0	70	25	0	0	15	19.7	23.5	27.3	37.4	0.08	0.05	0.05	0.05	-
1682	7/29/00	10	SW	BRN	12	88	2	5	5	0	70	18	0	0	13.3	16.3	18.9	24.1	35.4	0.12	0.06	0.07	0.07	-
1683	7/29/00	10	S	BRN	25	75	5	15	5	0	60	15	0	0	12.2	15.5	17.9	23.4	32.7	0.13	0.06	0.08	0.08	-
1684	7/29/00	5	S	BRN	12	88	2	10	0	0	88	0	0	0	11.3	15.1	18.1	23.7	36.4	0.13	0.06	0.08	0.08	-
1685	7/29/00	5	SW	BRN	7	94	2	5	0	0	40	54	0	0	11.9	16	19.1	23.3	32.2	0.10	0.05	0.06	0.06	-
1691	7/29/00	10	SE	BRN	17	83	5	10	2	0	83	0	0	0	10.1	12.6	14.2	20.5	31.8	0.18	0.07	0.09	0.09	-
1692	7/29/00	10	SE	BRN	12	88	2	10	0	0	58	30	0	0	11.8	14.7	16.7	22.9	28.5	0.16	0.07	0.09	0.09	-
1693	7/29/00	10	SE	BRN	20	80	5	15	0	0	60	20	0	0	8.18	10.4	11.9	19.2	28.7	0.23	0.08	0.11	0.11	-
1694	7/29/00	10	SE	BRN	7	93	2	5	0	0	93	0	0	0	9.57	12.2	14.4	18.4	30.6	0.12	0.05	0.06	0.06	-
1695	7/29/00	10	SE	BRN	20	80	5	5	10	0	80	0	0	0	8.38	10.5	12.3	16.6	28.6	0.15	0.05	0.07	0.07	-
1711	7/30/00	20	SW	BRN	9	91	2	5	2	0	91	0	0	0	14.1	17	19.7	23.8	35.7	0.09	0.05	0.06	0.06	9.6
1712	7/30/00	30	W	SPV	65	35	15	40	10	0	35	0	0	0	7.75	9.45	10.3	18	26.9	0.27	0.08	0.12	0.12	-
1713	7/30/00	20	SW	BRN	9	91	2	5	2	0	91	0	0	0	14.2	17.3	20.1	25.2	34.3	0.11	0.06	0.07	0.07	-
1714	7/30/00	25	W	BRN	7	93	2	5	0	0	83	10	0	0	13.6	16.9	19.7	24.6	32.7	0.11	0.06	0.07	0.07	-
1715	7/30/00	20	NW	BRN	17	83	2	10	5	0	73	10	0	0	13.2	16.2	18.6	23.2	31	0.11	0.05	0.06	0.07	-
1721	7/30/00	35	NW	BRN	14	86	2	10	2	0	76	10	0	0	11.4	13.8	16.2	20.1	26.9	0.11	0.05	0.06	0.06	12.3
1722	7/30/00	20	N	SPV	55	45	10	40	5	0	45	0	0	0	7.99	9.48	10.3	16.8	25.2	0.24	0.07	0.10	0.11	-
1723	7/30/00	35	N	BRN	15	85	5	5	5	0	75	10	0	0	9.85	12.1	13.6	18.1	23.2	0.14	0.05	0.07	0.07	-
1724	7/30/00	40	N	BRN	30	70	10	15	5	0	70	0	0	0	7.6	9.25	10.1	14.2	19.6	0.17	0.05	0.07	0.07	-

1725	7/30/00	35	N	SPV	35	65	15	20	0	0	50	15	0	0	7.18	8.4	9.2	14.5	20.4	0.22	0.06	0.09	0.09	-
1731	7/30/00	20	NE	BRN	15	85	5	10	0	0	55	30	0	0	8.03	10.3	11.9	17.4	21.3	0.19	0.06	0.09	0.09	-
1732	7/30/00	20	NE	BRN	20	80	5	15	0	0	30	50	0	0	8.05	10.8	12.8	17.4	21.5	0.15	0.05	0.07	0.07	-
1733	7/30/00	20	N	BRN	25	75	10	15	0	0	40	30	5	0	7.61	9.87	11.5	17.5	20.5	0.21	0.07	0.09	0.10	-
1734	7/30/00	20	NW	SPV	65	35	20	45	0	0	20	15	0	0	6.53	8.43	9.42	17.5	21.3	0.30	0.09	0.13	0.13	-
1735	7/30/00	20	NE	BRN	40	60	15	15	0	10	30	25	5	0	4.9	6.36	7.31	13.6	15.3	0.30	0.07	0.11	0.11	-
1741	7/30/00	20	W	BRN	7	93	2	5	0	0	83	10	0	0	14.3	17.4	20.3	24.2	34.3	0.09	0.05	0.05	0.05	-
1742	7/30/00	20	NW	BRN	9	91	2	2	5	0	91	0	0	0	12	14.5	16.4	20.2	31.9	0.10	0.05	0.05	0.06	-
1743	7/30/00	20	NW	BRN	4	96	2	2	0	0	76	20	0	0	15.1	19	22.2	26.5	35.6	0.09	0.05	0.06	0.06	-
1744	7/30/00	15	NW	BRN	9	91	5	2	2	0	91	0	0	0	13.2	16	18.5	24.7	32.7	0.14	0.07	0.09	0.09	-
1745	7/30/00	20	NE	BRN	12	88	5	5	2	0	88	0	0	0	13.1	16	18.3	22.7	30.9	0.11	0.05	0.06	0.06	-
1751	7/30/00	25	N	SPV	42	58	2	35	5	0	58	0	0	0	9.24	11	12.2	17.5	24.3	0.18	0.06	0.08	0.08	26
1752	7/30/00	40	N	BRN	20	80	5	10	5	0	80	0	0	0	8.98	10.7	11.8	15.8	23.2	0.15	0.05	0.06	0.06	-
1753	7/30/00	40	W	BRN	17	83	2	5	10	0	78	5	0	0	12	14.4	16.5	20.4	33	0.11	0.05	0.06	0.06	-
1754	7/30/00	35	W	BRN	9	91	2	5	2	0	91	0	0	0	14	17.4	20.4	24.9	35.9	0.10	0.05	0.06	0.06	-
1755	7/30/00	25	NW	BRN	30	70	5	20	5	0	70	0	0	0	12	14.5	16.4	22.6	32.3	0.16	0.07	0.09	0.09	-
1761	7/30/00	5	NW	BRN	7	93	2	5	0	0	93	0	0	0	10.6	13.2	15.6	19.5	29.7	0.11	0.05	0.06	0.06	-
1762	7/30/00	5	NW	SM	40	60	25	15	0	0	60	0	0	0	8.7	12.1	13.7	21.8	26.9	0.23	0.09	0.12	0.12	-
1763	7/30/00	5	NE	BRN	10	90	5	5	0	0	40	20	30	0	8.08	10.7	12.6	16.9	22.4	0.15	0.05	0.07	0.07	-
1764	7/30/00	5	NW	SPV	55	45	25	30	0	0	45	0	0	0	6.83	8.72	9.86	18.5	23.2	0.30	0.09	0.14	0.14	-
1765	7/30/00	5	NW	BRN	25	75	5	20	0	0	60	15	0	0	7.92	10.2	11.9	19.1	25.1	0.23	0.08	0.11	0.11	-
1771	7/30/00	60	NW	SPV	65	35	15	40	10	0	20	15	0	0	7.13	8.43	9	15.5	23.4	0.26	0.07	0.11	0.11	-
1772	7/30/00	45	N	SPV	50	50	15	35	0	0	30	20	0	0	5.48	6.79	7.47	14.9	20.8	0.33	0.08	0.12	0.13	-
1773	7/30/00	60	NW	SPV	30	70	15	15	0	0	40	30	0	0	9.59	11.7	13	17.7	24.5	0.15	0.05	0.07	0.07	-
1774	7/30/00	65	N	SPV	30	70	5	25	0	0	55	15	0	0	9.76	12.1	14.2	18.8	26.6	0.14	0.05	0.07	0.07	-
1775	7/30/00	60	NW	SPV	12	88	2	10	0	0	48	40	0	0	11.3	13.9	16	21.2	30	0.14	0.06	0.08	0.08	-
1781	7/30/00	5	NW	SM	50	50	40	10	0	0	15	35	0	0	5.83	7.88	8.41	21	20.3	0.43	0.13	0.20	0.21	-
1782	7/30/00	5	NW	SM	65	35	50	15	0	0	5	30	0	0	4.9	6.48	6.9	16.9	16.5	0.42	0.10	0.17	0.17	-
1783	7/30/00	5	NW	SM	50	50	35	15	0	0	0	10	40	0	3.34	4.76	5.02	14.9	10.4	0.50	0.10	0.17	0.18	-
1784	7/30/00	5	NW	SM	20	80	15	5	0	0	0	75	5	0	6.86	9.87	11.1	21.5	19.7	0.32	0.11	0.16	0.16	-
1785	7/30/00	5	SW	SM	50	50	15	35	0	0	0	50	0	0	5.05	6.55	6.9	16.9	20.3	0.42	0.10	0.17	0.17	-
1791	7/30/00	5	SW	BRN	20	80	5	10	5	0	60	20	0	0	10.3	13.5	16.3	22	32.8	0.15	0.06	0.08	0.08	-
1792	7/30/00	5	S	BRN	25	75	5	20	0	0	65	10	0	0	10.9	13.8	15.7	22.8	29.8	0.18	0.08	0.10	0.10	-
1793	7/30/00	5	SE	BRN	40	60	5	35	0	0	30	30	0	0	10.9	14.3	16.4	23.4	29.5	0.18	0.08	0.10	0.10	-
1794	7/30/00	0	-	BRN	0	100	0	0	0	0	40	0	60	0	4.6	5.75	6.89	9.31	13.3	0.15	0.03	0.04	0.04	-
1795	7/30/00	5	SW	BRN	25	80	5	15	5	0	80	0	0	0	10.7	13.3	15.5	22.3	31.4	0.18	0.07	0.10	0.10	-

1811	7/31/00	30	E	SPV	75	25	30	45	0	0	15	10	0	0	5.7	7.53	7.88	20.9	25.1	0.45	0.13	0.21	0.22	-
1812	7/31/00	30	E	SPV	60	40	15	10	0	35	15	25	0	0	5.35	7.03	7.89	16.7	27.7	0.36	0.09	0.14	0.15	-
1813	7/31/00	35	E	SPV	30	70	15	15	0	0	30	40	0	0	8.39	10.7	11.5	21.8	28.5	0.31	0.11	0.16	0.16	-
1814	7/31/00	35	E	SPV	45	55	20	25	0	0	20	35	0	0	9	11.6	12.8	23.8	31.7	0.30	0.12	0.16	0.17	-
1815	7/31/00	35	E	SPV	20	80	0	20	0	0	50	30	0	0	10.6	13.7	15.9	22.7	29.3	0.18	0.08	0.10	0.10	-
1821	7/31/00	35	E	SPV	55	45	10	45	0	0	20	25	0	0	5.31	7.07	7.31	19.6	26	0.46	0.13	0.20	0.21	-
1822	7/31/00	35	E	SPV	45	55	10	35	0	0	15	40	0	0	6.52	8.46	9.32	18.8	26.5	0.34	0.10	0.15	0.16	-
1823	7/31/00	35	E	SPV	40	60	5	35	0	0	30	30	0	0	7.37	9.57	10.8	19.7	30.4	0.29	0.09	0.14	0.14	-
1824	7/31/00	35	E	SPV	20	80	5	15	0	0	35	45	0	0	8.38	10.5	11.7	19.8	29	0.26	0.09	0.12	0.13	-
1825	7/31/00	40	E	BRN	12	98	2	10	0	0	60	38	0	0	11.1	15.3	18.1	22.7	30.9	0.11	0.05	0.07	0.07	-
1831	7/31/00	45	NE	SPV	17	83	2	15	0	0	25	58	0	0	4.29	5.65	6.5	10.7	13.7	0.25	0.05	0.07	0.07	-
1832	7/31/00	40	NE	BRN	2	98	2	0	0	0	35	63	0	0	7.43	8.94	10.5	14.3	21	0.15	0.04	0.06	0.06	-
1833	7/31/00	45	NE	BRN	5	95	5	0	0	0	15	80	0	0	4.85	6.22	7.3	11.8	16	0.24	0.05	0.08	0.08	-
1834	7/31/00	45	NE	BRN	10	90	10	0	0	0	20	70	0	0	5.89	7.63	8.94	13.8	19.2	0.21	0.05	0.08	0.08	-
1835	7/31/00	40	NE	BRN	2	98	2	0	0	0	35	63	0	0	8.56	11	13.2	17.1	23.6	0.13	0.04	0.06	0.06	-
1841	7/31/00	15	NE	SM	85	15	50	25	0	10	15	0	0	0	3	5.22	4.49	21.1	13.8	0.65	0.17	0.28	0.29	-
1842	7/31/00	10	NE	SM	100	0	70	10	0	20	0	0	0	0	3.39	5.52	5.17	22.8	17.4	0.63	0.18	0.30	0.31	-
1843	7/31/00	10	NE	SM	75	25	70	5	0	0	10	15	0	0	3.62	5.92	5.57	21.1	16.9	0.58	0.16	0.26	0.27	-
1844	7/31/00	10	NE	SM	80	20	65	15	0	0	0	20	0	0	2.43	4.5	3.48	23.4	10	0.74	0.20	0.35	0.36	-
1845	7/31/00	10	NE	SM	80	20	75	5	0	0	0	20	0	0	4.18	6.34	6.36	21.5	20.4	0.54	0.15	0.25	0.26	-
1851	7/31/00	10	E	SM	80	20	40	15	0	25	0	20	0	0	3.21	5.41	5.15	22.8	19	0.63	0.18	0.30	0.31	-
1852	7/31/00	10	E	SM	90	10	75	5	0	10	0	10	0	0	3.33	5.36	5.3	20.5	18	0.59	0.15	0.26	0.27	-
1853	7/31/00	10	E	SM	95	5	80	10	0	5	0	5	0	0	3.94	6.41	6.23	23.5	21	0.58	0.18	0.28	0.29	-
1854	7/31/00	10	E	SM	95	5	80	15	0	0	0	5	0	0	3.23	5.32	4.9	21.3	16.1	0.63	0.17	0.28	0.29	-
1855	7/31/00	10	E	SM	70	30	60	5	0	5	0	30	0	0	3.27	5.44	5.41	19.6	17.5	0.57	0.14	0.24	0.25	-
1861	7/31/00	35	E	SNOW	0	100	0	0	0	0	0	0	0	100	18.5	21.4	23.9	24.6	4.19	0.01	0.02	0.01	0.01	-
1862	7/31/00	35	E	SNOW	0	100	0	0	0	0	0	0	0	100	13.8	16.6	19.3	21.3	5.17	0.05	0.03	0.03	0.03	-
1863	7/31/00	35	E	SNOW	0	100	0	0	0	0	0	0	0	100	33.1	35.5	37.5	35.7	1.9	-0.02	0.00	-0.02	-0.02	-
1864	7/31/00	35	E	SNOW	0	100	0	0	0	0	0	0	0	100	30.4	32.2	33.1	30.6	1.5	-0.04	-0.01	-0.03	-0.03	-
1865	7/31/00	35	E	SNOW	0	100	0	0	0	0	0	0	0	100	28.2	29.9	31.2	29.7	1.71	-0.02	0.00	-0.02	-0.02	-
1871	7/31/00	35	E	SNOW	0	100	0	0	0	0	0	0	0	100	16.3	17.8	19.4	20.5	3.38	0.03	0.02	0.02	0.02	-
1872	7/31/00	35	E	SNOW	0	100	0	0	0	0	0	0	0	100	14.7	16.3	18.1	19.3	3.58	0.03	0.02	0.02	0.02	-
1873	7/31/00	35	E	SNOW	0	100	0	0	0	0	0	0	0	100	12.5	15.1	16.5	13.2	0.89	-0.11	-0.02	-0.05	-0.05	-
1874	7/31/00	35	E	SNOW	0	100	0	0	0	0	0	0	0	100	16	18.5	20.9	22.4	4.46	0.03	0.02	0.02	0.02	-
1875	7/31/00	35	E	SNOW	0	100	0	0	0	0	0	0	0	100	16.3	18.3	20	20.8	3.92	0.02	0.02	0.01	0.01	-
1881	7/31/00	10	E	SM	80	20	70	0	0	10	0	0	20	0	3.16	5.56	5.23	24.2	14.6	0.64	0.19	0.32	0.33	-

1882	7/31/00	10	E	SM	75	25	60	15	0	0	5	20	0	0	3.72	5.76	6.17	22	14.8	0.56	0.16	0.26	0.27	-
1883	7/31/00	10	E	SM	70	30	65	5	0	0	0	30	0	0	3.04	5.09	5.12	22.1	14.8	0.62	0.17	0.28	0.30	-
1884	7/31/00	5	E	SM	80	20	55	15	0	10	0	20	0	0	3.17	5.05	4.81	23.6	17.4	0.66	0.19	0.32	0.33	-
1885	7/31/00	5	E	SM	45	55	45	0	0	0	15	40	0	0	3.11	4.93	5.21	18	13.1	0.55	0.13	0.22	0.22	-
1891	7/31/00	30	NE	SPV	40	60	10	20	10	0	15	45	0	0	5.65	7	7.51	14	18.5	0.30	0.07	0.11	0.11	-
1892	7/31/00	30	NE	SPV	40	60	15	25	0	0	20	40	0	0	4.31	5.59	6.02	15	13.9	0.43	0.09	0.15	0.16	-
1893	7/31/00	30	NE	SPV	40	60	15	10	15	0	15	45	0	0	7.03	8.43	8.93	16.3	21	0.29	0.08	0.12	0.12	-
1894	7/31/00	30	E	BRN	0	100	0	0	0	0	95	5	0	0	13.5	17.6	20.5	22.6	29.2	0.05	0.03	0.03	0.03	-
1895	7/31/00	30	NE	BRN	15	85	5	10	0	0	65	20	0	0	11.7	15	17.3	21.3	28.2	0.10	0.05	0.06	0.06	-
1911	8/01/00	5	S	BRN	14	86	2	10	2	0	86	0	0	0	12.6	15.2	17.3	22.3	33.7	0.13	0.06	0.07	0.07	31
1912	8/01/00	5	S	BRN	7	93	2	5	0	0	78	15	0	0	13.6	16.7	19.3	23.8	32.5	0.10	0.05	0.06	0.06	-
1913	8/01/00	5	S	BRN	14	86	2	10	2	0	76	10	0	0	12.2	15	17.4	21.8	31.8	0.11	0.05	0.06	0.06	-
1914	8/01/00	5	S	BRN	12	88	2	10	0	0	83	5	0	0	13.7	17	19.7	24.8	34.5	0.12	0.06	0.07	0.07	-
1915	8/01/00	5	S	BRN	45	55	20	15	10	0	55	0	0	0	9.91	12.2	13.4	22	28	0.24	0.09	0.13	0.13	-
1921	8/01/00	5	W	BRN	7	93	2	5	0	0	73	20	0	0	13.9	17.4	20.4	25.4	33	0.11	0.06	0.07	0.07	-
1922	8/01/00	5	NW	BRN	10	90	5	5	0	0	70	20	0	0	11.3	14.2	16.3	21.8	28.3	0.14	0.06	0.08	0.08	-
1923	8/01/00	5	NW	BRN	15	90	5	5	5	0	55	35	0	0	11.3	14	15.9	22	29	0.16	0.07	0.09	0.09	-
1924	8/01/00	5	NW	BRN	25	75	5	15	5	0	65	10	0	0	11	13.5	15.3	21.3	28.2	0.16	0.07	0.09	0.09	-
1925	8/01/00	5	N	BRN	45	55	10	35	0	0	40	15	0	0	8.19	9.89	11.1	17.8	25.8	0.23	0.07	0.11	0.11	-
1931	8/01/00	5	SE	SPV	70	30	15	40	10	5	30	0	0	0	8.59	10.9	12.4	21.9	28.2	0.28	0.10	0.14	0.15	-
1932	8/01/00	5	SE	SPV	27	73	15	10	0	2	53	20	0	0	11.3	14.2	16.4	22.4	29.9	0.16	0.07	0.09	0.09	-
1933	8/01/00	5	SE	SPV	67	33	30	30	2	5	20	13	0	0	7.48	9.6	10.4	21.9	27.8	0.36	0.12	0.18	0.18	-
1934	8/01/00	5	SE	SPV	55	45	30	15	5	5	40	5	0	0	6.99	8.93	9.72	18.8	26.3	0.32	0.09	0.14	0.15	-
1935	8/01/00	5	SE	SPV	60	40	10	35	10	5	35	5	0	0	8.18	10.2	11.2	21	28.1	0.30	0.10	0.15	0.15	-
1941	8/01/00	5	SE	SPV	27	73	5	15	2	5	63	10	0	0	9.22	11.6	13.8	19.2	30.9	0.16	0.06	0.08	0.08	-
1942	8/01/00	5	SE	SPV	30	70	10	10	10	0	55	15	0	0	10.7	13.2	15	21.8	28.2	0.18	0.07	0.10	0.10	-
1943	8/01/00	5	SE	SPV	35	65	10	25	0	0	60	5	0	0	8.25	9.93	11.2	17.5	25.3	0.22	0.07	0.10	0.10	-
1944	8/01/00	5	SE	SPV	30	70	10	15	0	5	65	5	0	0	8.64	11	13.1	17.9	26.4	0.15	0.05	0.07	0.07	-
1945	8/01/00	5	SE	SPV	15	85	5	5	0	5	70	0	15	0	7.53	9.68	11.7	15.4	24.8	0.14	0.04	0.06	0.06	-
1951	8/01/00	5	SW	SPV	32	68	2	30	0	0	10	58	0	0	6.55	8.32	9.2	18.2	25.4	0.33	0.09	0.14	0.15	-
1952	8/01/00	5	SW	SM	85	15	35	35	0	15	0	15	0	0	4.25	6.42	6.41	24.5	25.4	0.58	0.18	0.29	0.30	-
1953	8/01/00	5	SW	SM	70	30	25	30	0	15	20	10	0	0	3.96	5.62	5.95	18.7	17.4	0.52	0.13	0.21	0.22	-
1954	8/01/00	5	SW	SM	60	40	20	20	0	20	25	15	0	0	3.83	5.48	6.28	18.5	24	0.49	0.13	0.20	0.21	-
1955	8/01/00	5	SW	SM	100	0	75	10	0	15	0	0	0	0	4.45	7.05	7.08	33.8	26.6	0.65	0.27	0.41	0.43	93.3
1961	8/01/00	5	SW	SPV	20	80	5	15	0	0	80	0	0	0	7.51	9.36	10.9	17.1	27.7	0.22	0.07	0.10	0.10	-
1962	8/01/00	5	S	SPV	25	75	5	20	0	0	70	5	0	0	10.3	12.7	14.6	22	34.9	0.20	0.08	0.11	0.11	-

1963	8/01/00	5	S	SPV	35	65	10	20	0	5	60	5	0	0	7.14	8.82	9.65	17.8	30.9	0.30	0.09	0.13	0.13	-
1964	8/01/00	5	SW	SPV	20	80	5	15	0	0	70	10	0	0	8.46	10.2	11.4	17.5	31.2	0.21	0.07	0.09	0.10	-
1965	8/01/00	5	SW	SPV	30	70	10	10	0	10	50	20	0	0	5.79	7.36	8.01	15.8	30.2	0.33	0.08	0.13	0.13	-
1971	8/01/00	5	SE	SPV	25	75	5	20	0	0	65	10	0	0	11.2	13.9	16	22.7	30	0.18	0.08	0.10	0.10	-
1972	8/01/00	5	SE	SPV	7	93	5	2	0	0	63	30	0	0	13.4	17.8	21.2	24.6	32.7	0.07	0.04	0.05	0.05	-
1973	8/01/00	5	SE	SPV	12	88	2	10	0	0	83	5	0	0	12.8	15.8	18.3	24	35.4	0.13	0.07	0.08	0.08	-
1974	8/01/00	5	SE	SPV	7	93	2	5	0	0	78	15	0	0	12	15	17.6	23.2	34	0.14	0.06	0.08	0.08	-
1975	8/01/00	5	SE	SPV	30	70	5	20	5	0	50	20	0	0	12	15.2	17.3	24.1	32.3	0.16	0.08	0.10	0.10	-
1981	8/01/00	5	SW	SPV	35	65	10	15	0	10	55	10	0	0	8.21	10.2	11.2	18.1	30	0.24	0.07	0.11	0.11	-
1982	8/01/00	5	SW	SPV	20	80	10	10	0	0	80	0	0	0	10.6	13.3	15.1	21.7	33	0.18	0.07	0.10	0.10	-
1983	8/01/00	5	SW	SPV	24	76	10	10	2	2	60	16	0	0	12.5	15.2	17.2	23.1	31.1	0.15	0.07	0.08	0.09	-
1984	8/01/00	5	SW	SPV	7	93	2	5	0	0	48	45	0	0	12.5	15.9	18.8	23.8	32.1	0.12	0.06	0.07	0.07	-
1985	8/01/00	5	SW	SPV	23	78	5	10	3	5	68	10	0	0	13.3	16.5	18.8	23.6	35.3	0.11	0.06	0.07	0.07	-
1991	8/01/00	0	-	SM	100	0	70	10	0	20	0	0	0	0	5.49	8.08	7.79	27.9	22.1	0.56	0.20	0.31	0.33	-
1992	8/01/00	5	SW	SPV	20	80	10	10	0	0	50	30	0	0	9.39	11.8	13.2	20.7	28.3	0.22	0.08	0.11	0.12	-
1993	8/01/00	5	SW	SM	80	20	50	10	0	20	20	0	0	0	5.95	8.56	8.64	28.1	26.2	0.53	0.20	0.30	0.31	-
1994	8/01/00	0	-	SM	80	20	65	5	0	10	0	20	0	0	4.46	6.18	6.53	22	18.2	0.54	0.16	0.25	0.26	-
1995	8/01/00	5	SW	SPV	30	70	10	15	0	5	45	25	0	0	8.26	10.6	11.4	22	27.6	0.32	0.11	0.16	0.17	-
2011	8/04/00	5	5	SPV	70	30	15	40	0	15	25	5	0	0	5.32	8.45	8.68	22.06	39.22	0.44	0.14	0.21	0.22	35.7
2012	8/04/00	5	5	SPV	15	85	5	10	0	0	30	55	0	0	9.90	14.01	14.17	22.08	50.92	0.22	0.09	0.12	0.12	-
2013	8/04/00	5	5	SPV	7	93	2	5	0	0	20	73	0	0	10.31	12.38	16.31	23.35	41.92	0.18	0.08	0.10	0.10	-
2014	8/04/00	5	5	SPV	10	90	5	5	0	0	30	60	0	0	9.21	13.13	14.71	22.17	46.60	0.20	0.08	0.11	0.11	-
2015	8/04/00	5	5	SPV	12	88	2	10	0	0	20	68	0	0	8.81	10.52	12.81	21.00	39.31	0.24	0.09	0.12	0.13	-
2021	8/04/00	5	5	SM	90	10	30	40	0	20	0	10	0	0	5.42	7.53	7.28	24.86	26.96	0.55	0.18	0.28	0.29	-
2022	8/04/00	5	5	SPV	25	75	10	15	0	0	5	70	0	0	5.52	7.59	8.11	19.89	27.78	0.42	0.12	0.19	0.20	-
2023	8/04/00	5	5	SM	50	50	20	25	0	5	15	35	0	0	4.65	7.45	8.59	23.77	33.64	0.47	0.16	0.24	0.25	-
2024	8/04/00	5	5	SM	100	0	55	20	0	25	0	0	0	0	3.09	5.90	5.11	29.62	25.00	0.71	0.25	0.40	0.42	-
2025	8/04/00	5	5	SM	60	40	20	25	5	10	0	40	0	0	3.74	6.04	6.74	28.24	33.86	0.61	0.22	0.34	0.36	-
2031	8/04/00	10	SE	SPV	42	58	10	25	5	2	20	38	0	0	6.53	8.63	8.70	21.23	33.30	0.42	0.13	0.20	0.21	-
2032	8/04/00	10	SE	SPV	37	63	5	30	2	0	10	53	0	0	7.18	9.92	10.47	20.37	32.37	0.32	0.10	0.15	0.16	-
2033	8/04/00	10	SE	SPV	45	55	10	30	5	0	20	35	0	0	7.23	9.58	11.18	21.42	36.56	0.31	0.11	0.16	0.16	-
2034	8/04/00	20	SE	SPV	35	65	5	25	0	5	10	55	0	0	8.04	11.16	12.90	20.44	32.48	0.23	0.08	0.11	0.12	-
2035	8/04/00	10	SE	SPV	25	75	5	20	0	0	5	70	0	0	9.15	13.27	14.95	21.95	35.81	0.19	0.08	0.10	0.10	-
2041	8/04/00	5	S	SPV	35	65	10	20	3	2	10	55	0	0	5.12	7.4	8.36	17.2	28.3	0.35	0.09	0.14	0.15	-
2042	8/04/00	10	NE	SPV	50	50	10	40	0	0	20	30	0	0	5.5	7.26	7.8	19	31.5	0.42	0.12	0.18	0.19	-
2043	8/04/00	5	SE	SPV	50	50	15	30	2	3	35	15	0	0	5.06	7.76	8.03	19.5	30.3	0.42	0.12	0.18	0.19	-

2044	8/04/00	5	NE	SPV	37	63	5	25	5	2	25	38	0	0	7.48	9.6	11.1	20.2	35.2	0.29	0.10	0.14	0.14	-
2045	8/04/00	5	NE	SPV	57	43	20	20	2	15	10	33	0	0	5.72	8.58	8.74	23.6	36.9	0.46	0.15	0.23	0.24	-
2051	8/04/00	10	S	SPV	30	60	5	20	2	3	30	30	0	0	8.52	11.9	14.2	23	35.6	0.24	0.10	0.13	0.13	-
2052	8/04/00	10	S	SPV	22	78	2	15	3	2	15	63	0	0	7.91	11.3	12.6	21.5	32.9	0.26	0.10	0.14	0.14	-
2053	8/04/00	10	S	SPV	12	88	2	10	0	0	25	63	0	0	9.59	13.2	15	22.7	35.4	0.20	0.08	0.11	0.12	-
2054	8/04/00	10	S	SPV	45	55	20	25	0	0	25	30	0	0	6.99	9.87	11.1	20.4	33.5	0.29	0.10	0.14	0.15	-
2055	8/04/00	10	S	SPV	30	70	5	20	0	5	20	50	0	0	7.67	10.3	11.4	21	32.9	0.30	0.10	0.15	0.15	-
2061	8/04/00	10	SE	SPV	20	80	5	10	5	0	30	50	0	0	8.35	11.3	12.5	20.3	36.2	0.24	0.08	0.12	0.12	-
2062	8/04/00	5	SE	SPV	12	88	5	5	2	0	15	73	0	0	7.54	11	13.2	19.6	32.5	0.20	0.07	0.10	0.10	-
2063	8/04/00	5	E	SPV	50	50	15	25	5	5	40	10	0	0	7.99	10.1	11.4	20	33.6	0.27	0.09	0.13	0.14	-
2064	8/04/00	5	SE	SPV	30	70	10	15	0	5	45	25	0	0	7.68	9.92	11.8	18.5	32.1	0.22	0.07	0.10	0.11	-
2065	8/04/00	5	E	SPV	32	68	5	25	0	2	15	53	0	0	7.31	9.52	10.9	20.7	31.9	0.31	0.10	0.15	0.16	-
2071	8/04/00	10	NE	SM	80	20	60	20	0	0	0	20	0	0	3.96	7.21	7.5	29.2	29.3	0.59	0.22	0.34	0.35	-
2072	8/04/00	10	NE	SM	90	10	50	20	0	20	0	10	0	0	3.87	6.24	6.54	26.3	26.6	0.60	0.20	0.32	0.33	-
2073	8/04/00	10	NE	SM	44	76	10	30	2	2	10	66	0	0	5.19	7.42	7.64	22.6	26.3	0.49	0.15	0.24	0.25	-
2074	8/04/00	10	NE	SM	50	50	10	40	0	0	10	40	0	0	4.92	7.2	7.53	19.1	25.9	0.43	0.12	0.19	0.19	-
2075	8/04/00	10	NE	SM	45	55	15	15	0	15	5	50	0	0	4.19	6.21	6.46	20.7	25.9	0.52	0.15	0.23	0.24	-
2081	8/04/00	10	NE	SPV	15	85	5	10	0	0	20	65	0	0	6.9	9.81	11.9	18.8	29.7	0.22	0.07	0.11	0.11	-
2082	8/04/00	10	NE	SPV	30	60	10	15	2	3	40	20	0	0	5.82	7.67	8.46	19.4	28.9	0.39	0.11	0.18	0.18	-
2083	8/04/00	10	NE	SPV	35	65	10	25	0	0	25	40	0	0	6.15	8.79	9.46	20.8	30.8	0.37	0.12	0.18	0.18	-
2084	8/04/00	10	NE	SPV	40	60	15	25	0	0	20	40	0	0	5.49	7.85	8.97	20.3	31.9	0.39	0.12	0.18	0.18	-
2085	8/04/00	10	NE	SPV	22	78	5	15	2	0	40	38	0	0	7.92	10.8	11.9	20.5	35.9	0.27	0.09	0.13	0.14	-
2091	8/04/00	10	SE	SPV	35	65	5	30	0	0	30	35	0	0	6.54	9.88	11.8	23.3	34.3	0.33	0.12	0.17	0.18	-
2092	8/04/00	10	SE	SPV	20	80	5	15	0	0	30	50	0	0	8.87	13.4	16	22.1	39.2	0.16	0.07	0.09	0.09	-
2093	8/04/00	10	SE	SPV	30	70	10	20	0	0	20	50	0	0	6.34	9.07	10.5	20	32.7	0.31	0.10	0.15	0.15	-
2094	8/04/00	10	SE	SPV	20	80	5	15	0	0	15	65	0	0	7.98	11.3	13	21.8	33.1	0.25	0.09	0.13	0.14	-
2095	8/04/00	10	SE	SPV	25	75	5	20	0	0	10	65	0	0	5.63	8.46	8.84	21.1	33.1	0.41	0.13	0.19	0.20	-
2111	8/04/00	0	-	SPV	35	65	10	20	0	5	5	60	0	0	6.46	9.64	11.3	22.5	31.6	0.33	0.12	0.17	0.18	67
2112	8/04/00	0	-	SM	80	15	45	20	0	15	0	15	0	0	4.22	6.65	7.17	24.4	28.3	0.55	0.18	0.28	0.29	-
2113	8/04/00	0	-	SM	55	45	20	25	0	10	5	40	0	0	4.41	6.29	6.7	21.7	28.6	0.53	0.15	0.25	0.25	-
2114	8/04/00	0	-	SM	25	75	5	20	0	0	10	65	0	0	6.56	10.1	12	20.4	30.7	0.26	0.09	0.13	0.13	-
2115	8/04/00	0	-	SM	60	40	15	25	5	15	10	30	0	0	4.52	6.58	7.13	20.1	27	0.48	0.13	0.21	0.22	-
2121	8/04/00	10	S	SM	95	5	40	50	0	5	0	5	0	0	4.37	7.03	6.84	28.6	27.6	0.61	0.22	0.35	0.36	-
2122	8/04/00	10	S	SM	100	0	35	55	0	10	0	0	0	0	4.85	7.48	7.52	29.1	29.3	0.59	0.22	0.34	0.35	-
2123	8/04/00	10	S	SM	100	0	35	45	0	20	0	0	0	0	3.99	7.16	7.07	30.4	29.8	0.62	0.24	0.37	0.38	-
2124	8/04/00	10	S	SM	80	20	30	45	0	5	0	20	0	0	4.32	6.8	6.79	26.8	31.2	0.60	0.20	0.32	0.33	-

2125	8/04/00	10	5	SM	25	75	5	20	0	0	10	65	0	0	7.11	10.2	11.4	22.8	32.4	0.33	0.12	0.17	0.18	-
2131	8/04/00	5	SE	SPV	17	83	2	15	0	0	20	63	0	0	8.41	12	14	21.8	31.4	0.22	0.08	0.12	0.12	-
2132	8/04/00	5	SE	SPV	4	96	2	2	0	0	40	56	0	0	10.4	14.8	17.6	22.8	35.9	0.13	0.06	0.07	0.07	-
2133	8/04/00	5	SE	SPV	15	85	5	10	0	0	20	65	0	0	7.76	11.4	13.4	22.1	32.3	0.25	0.09	0.13	0.13	-
2134	8/04/00	5	SE	SPV	15	85	2	10	3	0	30	55	0	0	8.88	12.8	15.1	21.5	31.4	0.18	0.07	0.09	0.10	-
2135	8/04/00	5	E	SPV	30	70	5	25	0	0	10	60	0	0	5.9	8.49	9.62	20.8	25.9	0.37	0.12	0.17	0.18	-
2141	8/04/00	5	S	SM	70	30	40	25	0	5	5	25	0	0	4.82	8.11	8.58	28.6	29.9	0.54	0.20	0.31	0.32	-
2142	8/04/00	5	S	SM	70	30	15	45	5	5	0	30	0	0	4.04	6.4	6	24.4	26.6	0.61	0.19	0.30	0.31	-
2143	8/04/00	5	S	SM	85	15	40	45	0	0	5	10	0	0	4.59	7.52	7.23	31	28.1	0.62	0.24	0.37	0.39	-
2144	8/04/00	5	S	SM	75	25	20	45	5	5	5	20	0	0	4.23	6.75	6.26	27.3	24.8	0.63	0.21	0.34	0.35	-
2145	8/04/00	5	S	SM	25	75	5	15	5	0	10	65	0	0	6.04	8.77	9.83	21.9	28.6	0.38	0.13	0.19	0.19	-
2151	8/04/00	5	SE	SPV	15	85	5	10	0	0	10	75	0	0	8.63	12.3	14.5	22	30.1	0.20	0.08	0.11	0.11	36
2152	8/04/00	5	SE	SPV	45	55	5	35	0	5	5	50	0	0	6.95	9.76	10.6	21.3	27.4	0.34	0.11	0.17	0.17	-
2153	8/04/00	5	SE	SPV	20	80	5	15	0	0	10	70	0	0	9.82	14	16.3	23	30.7	0.17	0.07	0.10	0.10	-
2154	8/04/00	5	SE	SPV	37	63	5	30	0	2	5	58	-	0	5.35	7.51	7.79	22.8	25	0.49	0.15	0.24	0.25	-
2155	8/04/00	5	SE	SPV	30	70	5	25	0	0	15	55	0	0	7.41	10.2	11.7	20.6	26.6	0.27	0.09	0.14	0.14	-
2161	8/04/00	5	NE	SPV	65	35	5	60	0	0	5	30	0	0	5.27	7.58	8.08	25.4	25.5	0.52	0.18	0.27	0.28	-
2162	8/04/00	5	NE	SPV	40	60	15	20	0	5	20	40	0	0	10.1	14.3	16.6	24.1	31.6	0.18	0.08	0.11	0.11	-
2163	8/04/00	5	NE	SPV	30	70	10	20	0	0	20	50	0	0	10.3	14.7	17.3	24.9	33.8	0.18	0.08	0.11	0.11	-
2164	8/04/00	5	NE	SPV	17	83	2	15	0	0	20	63	0	0	9.51	13	15.4	21.9	31	0.17	0.07	0.09	0.10	-
2165	8/04/00	5	NE	SPV	42	58	2	40	0	0	10	48	0	0	6.04	9.12	10.3	23.5	26.8	0.39	0.14	0.20	0.21	-
2171	8/04/00	10	NE	SM	75	25	20	45	0	10	0	25	0	0	3.45	6.08	5.85	27.5	25.3	0.65	0.22	0.35	0.37	-
2172	8/04/00	10	NE	SM	100	0	40	40	0	20	0	0	0	0	2.87	5.21	4.67	24.6	20.4	0.68	0.20	0.34	0.35	-
2173	8/04/00	10	NE	SM	85	15	25	25	0	35	0	15	0	0	3.63	6.34	6.51	29	27.5	0.63	0.23	0.36	0.37	-
2174	8/04/00	10	NE	SM	85	15	30	40	0	15	0	15	0	0	3.26	5.42	5.1	23.6	21.4	0.64	0.19	0.31	0.32	-
2175	8/04/00	10	NE	SM	85	15	30	25	0	30	0	15	0	0	3.47	6.02	5.71	28.2	24.6	0.66	0.23	0.37	0.38	-
2181	8/04/00	5	NE	SPV	30	70	5	25	0	0	5	65	0	0	6.24	9.41	10.6	22	28.4	0.35	0.12	0.18	0.18	-
2182	8/04/00	5	NE	SPV	70	30	30	40	0	0	5	25	0	0	4.12	6.46	6.69	21.6	25.4	0.53	0.15	0.24	0.25	-
2183	8/04/00	5	NE	SPV	70	30	10	55	5	0	5	25	0	0	5.79	8.5	9.08	21	26.7	0.40	0.12	0.19	0.19	-
2184	8/04/00	5	NE	SPV	75	25	30	40	0	5	0	25	0	0	5.17	7.74	8.21	23.5	26.9	0.48	0.16	0.24	0.25	-
2185	8/04/00	5	NE	SPV	45	55	5	35	0	5	5	50	0	0	5.12	7.56	8.07	20.9	25.4	0.44	0.13	0.21	0.21	-
2191	8/04/00	5	E	SPV	40	60	10	30	0	0	5	55	0	0	4.96	7.31	7.65	18.9	29.6	0.42	0.12	0.18	0.19	-
2192	8/04/00	5	E	SPV	50	50	10	40	0	0	10	40	0	0	6.34	8.69	9.54	20.1	35	0.36	0.11	0.17	0.17	-
2193	8/04/00	5	E	SPV	20	30	0	20	0	0	10	20	0	0	8.68	12.4	14.7	21.8	37.8	0.19	0.08	0.10	0.11	-
2194	8/04/00	5	E	SPV	60	40	15	40	0	5	10	30	0	0	5.15	6.97	7.63	21.8	31.3	0.48	0.15	0.23	0.24	-
2195	8/04/00	5	E	SPV	52	50	15	35	2	0	10	40	0	0	4.79	7.04	7.39	20.5	28.8	0.47	0.13	0.21	0.22	-

2211	8/08/00	5	NW	TT	100	0	40	40	0	20	0	0	0	0	3.43	5.56	5.72	25.3	17.1	0.63	0.20	0.32	0.33	-
2212	8/08/00	5	NW	TT	100	0	65	25	0	10	0	0	0	0	3.14	6.22	6.04	34.8	18	0.70	0.29	0.45	0.47	-
2213	8/08/00	5	NW	TT	90	10	30	30	0	30	0	5	5	0	2.77	4.86	4.57	26.1	14.8	0.70	0.22	0.36	0.38	-
2214	8/08/00	5	NW	TT	100	0	20	40	0	40	0	0	0	0	3.84	6.05	6	30	20.3	0.67	0.24	0.39	0.40	-
2215	8/08/00	5	NW	TT	100	0	65	25	0	10	0	0	0	0	3.87	6.31	6.6	31	20.4	0.65	0.25	0.39	0.40	-
2221	8/08/00	10	NW	SM	75	25	20	45	5	5	0	25	0	0	2.97	5.01	4.82	21.7	17.1	0.64	0.17	0.29	0.30	-
2222	8/08/00	10	NW	SM	90	10	10	40	0	40	5	5	0	0	4	6.66	7.15	29.9	23.2	0.61	0.23	0.36	0.37	-
2223	8/08/00	10	NW	SM	90	10	25	35	0	30	0	10	0	0	2.54	4.75	4.8	25.7	14	0.69	0.21	0.35	0.36	-
2224	8/08/00	10	NW	SM	90	0	20	40	0	30	0	0	0	0	3.32	5.3	5.8	27.2	18.3	0.65	0.22	0.35	0.36	-
2225	8/08/00	10	NW	SM	70	30	30	30	0	10	20	10	0	0	3.79	6.03	6.32	24.6	21.1	0.59	0.19	0.30	0.31	-
2231	8/08/00	15	SW	SPV	50	50	15	25	10	0	35	15	0	0	6.13	7.79	8.51	19.1	24.5	0.38	0.11	0.17	0.18	-
2232	8/08/00	15	SW	SPV	60	40	15	25	15	5	25	15	0	0	5.99	7.64	8.33	19.4	25.3	0.40	0.11	0.18	0.18	-
2233	8/08/00	15	SW	SPV	50	50	15	25	10	0	30	20	0	0	6.92	8.82	9.42	20.2	26.6	0.36	0.11	0.17	0.18	-
2234	8/08/00	15	SW	SPV	40	60	20	15	5	0	30	30	0	0	6.55	8.06	8.8	19.8	25.4	0.39	0.11	0.18	0.18	-
2235	8/08/00	15	SW	SPV	48	63	10	25	10	3	35	28	0	0	8.2	10.4	11.6	23.5	28.3	0.34	0.12	0.18	0.19	-
2241	8/08/00	15	W	SPV	75	25	20	45	5	5	5	20	0	0	3.87	5.57	5.68	21.1	20.2	0.58	0.16	0.26	0.27	-
2242	8/08/00	10	NW	SPV	60	40	25	30	5	0	10	30	0	0	3.88	6.42	6.17	19.7	21.7	0.52	0.14	0.22	0.23	-
2243	8/08/00	5	NW	SPV	35	65	10	20	0	5	0	65	0	0	4.41	5.02	6.51	16.6	21.9	0.44	0.10	0.17	0.17	-
2244	8/08/00	5	NW	SPV	45	55	20	20	0	5	0	55	0	0	4.26	5.98	6.78	16.3	20.8	0.41	0.10	0.16	0.16	-
2245	8/08/00	10	NW	SPV	50	50	20	25	5	0	5	45	0	0	4.46	6.44	7.11	17.4	22.2	0.42	0.11	0.17	0.18	-
2251	8/08/00	5	NW	TT	100	0	85	10	0	5	0	0	0	0	3.7	6.77	6.11	36.7	22.5	0.71	0.31	0.48	0.49	-
2252	8/08/00	0	-	TT	100	0	70	10	0	20	0	0	0	0	2.83	6.19	4.66	38.8	22.1	0.79	0.34	0.55	0.56	-
2253	8/08/00	0	-	TT	95	5	60	25	0	10	0	5	0	0	3.53	7.01	6.13	34.2	21.2	0.70	0.28	0.44	0.46	-
2254	8/08/00	0	-	TT	100	0	65	20	0	15	0	0	0	0	3.94	6.85	7.26	32.2	22	0.63	0.25	0.39	0.40	-
2255	8/08/00	0	-	TT	100	0	50	25	0	25	0	0	0	0	3.47	6.69	6.19	38.4	21.9	0.72	0.33	0.50	0.51	-
2261	8/08/00	5	W	TT	100	0	70	30	0	0	0	0	0	0	3.07	5.93	4.89	36.6	19.1	0.76	0.32	0.51	0.53	-
2262	8/08/00	5	W	TT	100	0	70	20	0	10	0	0	0	0	4.44	7.36	7.92	31.2	24.9	0.60	0.24	0.36	0.37	-
2263	8/08/00	5	W	TT	100	0	80	20	0	0	0	0	0	0	3.47	6.25	5	40.5	22.5	0.78	0.36	0.56	0.57	-
2264	8/08/00	5	W	TT	100	0	60	15	0	25	0	0	0	0	3.74	7.28	6.88	36.5	24	0.68	0.30	0.46	0.47	-
2265	8/08/00	5	W	TT	100	0	90	10	0	0	0	0	0	0	3.14	6.07	5.46	39.8	20.8	0.76	0.35	0.54	0.55	-
2271	8/08/00	5	SW	SM	100	0	65	20	0	15	0	0	0	0	4.31	6.86	7.79	28.9	26	0.58	0.22	0.33	0.34	-
2272	8/08/00	5	SW	SM	90	10	70	15	0	5	0	10	0	0	4	6.49	6.35	30.4	23.3	0.65	0.24	0.38	0.40	-
2273	8/08/00	5	SW	SM	100	0	40	30	0	30	0	0	0	0	2.98	4.74	4.95	24.3	16.3	0.66	0.20	0.32	0.34	-
2274	8/08/00	10	SW	SM	85	15	20	35	0	30	10	5	0	0	3.37	5.64	5.88	28.3	23.1	0.66	0.23	0.36	0.38	-
2275	8/08/00	10	SW	SM	95	5	20	40	0	35	5	0	0	0	3.88	6.32	6.16	29.7	24.7	0.66	0.24	0.38	0.39	-
2281	8/08/00	15	SE	SPV	85	15	15	70	0	0	10	5	0	0	3.38	5.31	4.82	26.9	22.2	0.70	0.22	0.37	0.38	-

2282	8/08/00	15	SE	SPV	20	80	5	15	0	0	10	70	0	0	5.68	7.86	9.25	16.8	21.2	0.29	0.08	0.12	0.12	-
2283	8/08/00	15	SE	SPV	40	60	10	25	5	0	15	45	0	0	4.96	6.84	7.28	20.2	24.2	0.47	0.13	0.21	0.22	-
2284	8/08/00	15	SE	SPV	60	40	15	40	2	3	25	15	0	0	4.55	6.44	6.37	21.4	26.7	0.54	0.15	0.25	0.26	-
2285	8/08/00	10	SE	SPV	50	50	15	30	5	0	5	45	0	0	4.77	7.09	7.06	21.5	24.3	0.51	0.15	0.24	0.24	-
2291	8/08/00	15	NE	SM	45	55	25	20	0	0	40	15	0	0	5.99	8.90	9.55	27.31	28.26	0.48	0.18	0.27	0.28	-
2292	8/08/00	10	NE	SM	45	55	15	30	0	0	20	35	0	0	4.09	6.27	5.86	28.93	24.22	0.66	0.23	0.37	0.39	-
2293	8/08/00	10	NE	SM	90	10	20	65	0	5	5	5	0	0	3.61	6.02	5.37	29.55	23.58	0.69	0.24	0.40	0.41	-
2294	8/08/00	5	NE	SM	85	35	50	25	0	10	0	35	0	0	3.76	5.76	5.89	24.88	21.05	0.62	0.19	0.31	0.32	-
2295	8/08/00	10	E	SM	100	0	70	20	0	10	0	0	0	0	3.55	5.89	5.48	29.56	18.42	0.69	0.24	0.39	0.41	-

APPENDIX II – DATING CONVENTIONS

COMPOSITE ID	DATES	JULIAN DATES*	
		1999, 2001	2000
0401	April 1 – April 10	91 – 100	92 – 101
0411	April 11 – April 20	101 – 110	102 – 111
0421	April 21 – April 30	111 – 120	112 – 121
0501	May 1 – May 10	121 – 130	122 – 131
0511	May 11 – May 20	131 – 140	132 – 141
0521	May 21 – May 31	141 – 151	142 – 152
0601	June 1 – June 10	152 – 161	153 – 162
0611	June 11 – June 20	162 – 171	163 – 172
0621	June 21 – June 30	172 – 181	173 – 182
0701	July 1 – July 10	182 – 191	183 – 192
0711	July 11 – July 20	192 – 201	193 – 202
0721	July 21 – July 31	202 – 212	203 – 213
0801	August 1 – August 10	213 – 222	214 – 223
0811	August 11 – August 20	223 – 232	224 – 233
0821	August 21 – August 31	233 – 243	234 – 244
0901	September 1 – September 10	244 – 253	245 – 254
0911	September 11 – September 20	254 – 263	255 – 264
0921	September 21 – September 30	264 – 273	265 – 274
1001	October 1 – October 10	274 – 283	275 – 284
1011	October 11 – October 20	284 – 293	285 – 294
1021	October 21 – October 31	294 – 304	295 – 305

* Julian days in 2000 differ from those in 1999 and 2001 because 2000 was a leap year.