Complex AVHRR Vegetation Phenological Trends as a Response to Warming Climates

Xiaoyang Zhang

Dan Tarpley, Jerry T. Sullivan

Research Reported in News Media
(more than 60 websites)

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NewScientist

November 10-16, 2007

In brief

Life could survive long on a super-Earth

Spring arrives later i

THE last thing a seasoned gardener would expect from global warming is for leaves to appear later in spring, but exactly that is happening across the southern US.

"It's really surprising," says Xiaoyang Zhang of Earth Resources Technology in Camp Springs, Maryland, because studies usually show plants greening earlier. "Nobody had noticed

www.newscientist.com

WIRED

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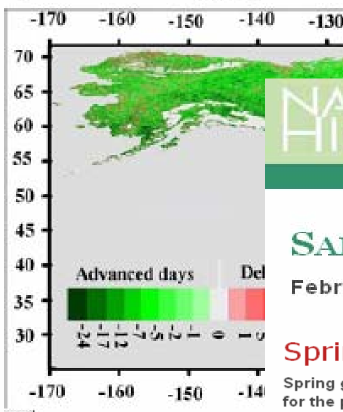
Greenup of the P White

By Carl Zimmer 11.09.07 | 12:00 AM



Spring greenup is coming earli satellite observations, climate

Image: Xiaoyang Zhang

Every spring, the Earth bloom continents turns green.

Exactly when greenup takes pl They track the rising temperat calculate when to start growin

People have been trying to fig to plant their crops; herders ne Japan, greenup records reach b

In 18th-century Europe, green noted the days on which oaks l

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Samplings—News from Nature

February 2008

The Warming Earth

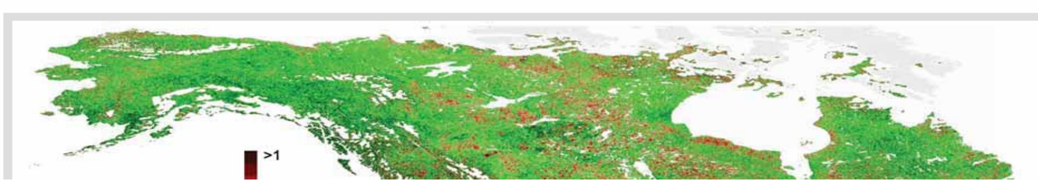
Spring Timing

Spring green-up—when plant buds burst open at winter's end—has been arriving ahead of schedule in the northern United States for the past twenty-five years, as a result of global warming. In fact, spring has been springing progressively earlier by about a day every three years, according to Xiaoyang Zhang and two colleagues at the National Oceanic and Atmospheric Administration in Camp Springs, Maryland, who examined records of lilac-bloom dates and satellite images of vegetation to reach their conclusions.

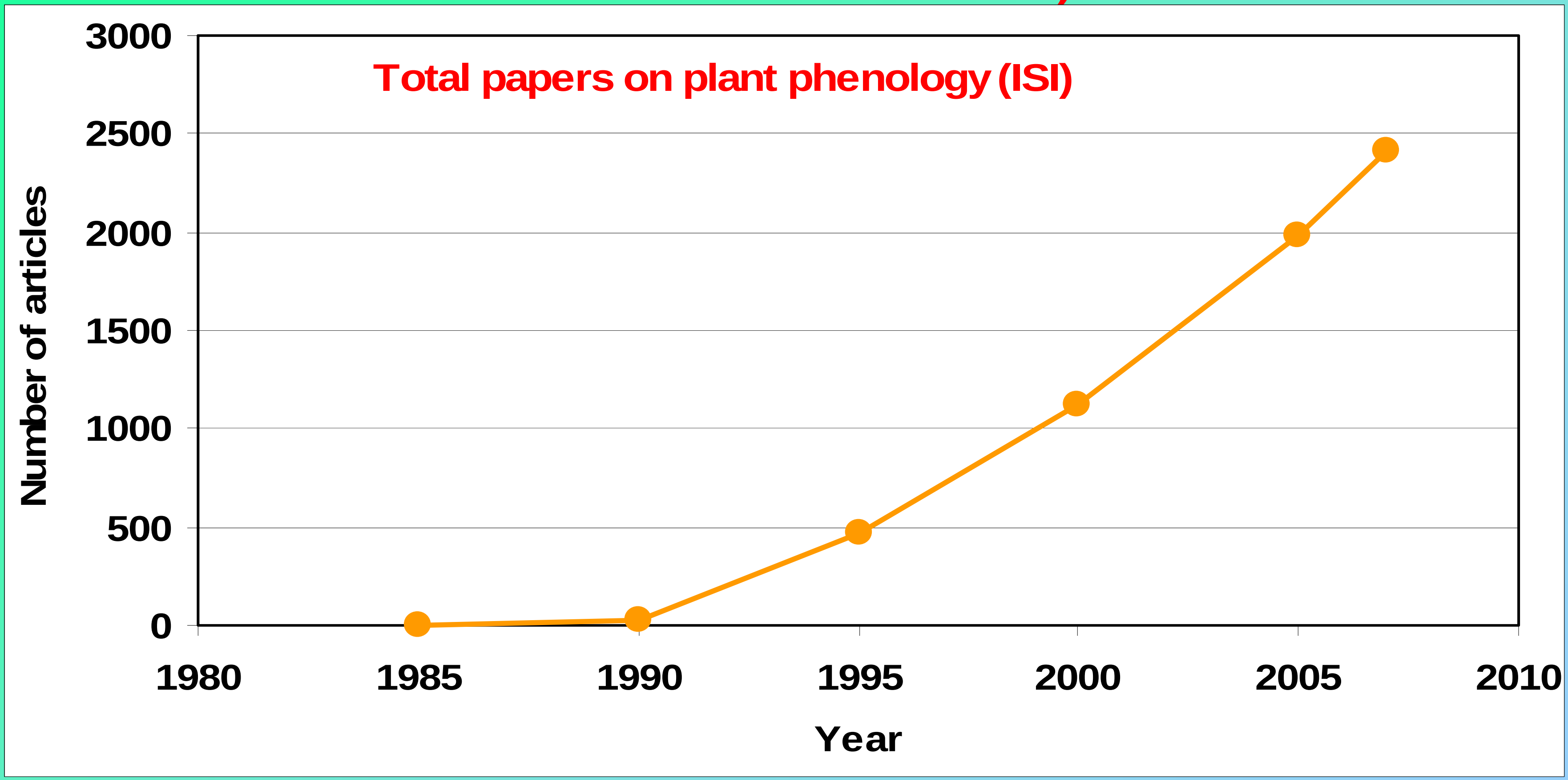
But the trend applies only to plants up north. In southern states, the reverse is true: spring green-up has been arriving later by about a day every seven years. What's going on? Aren't southern states experiencing global warming, too?

Absolutely, Zhang's team says, just a little differently. The effect stems from the fact that most plants going dormant in autumn must remain just so cold for just so long before they can fully respond to the warmth of spring. Northern winters, though truncated, are still cold enough for long enough that plants can leaf out once balmy weather returns. But down south, cool days—already few to start with—have diminished so much that plants' chill requirements aren't always met. When that happens, only additional spring warmth can wake them; hence southern states' progressively later green-up. *(Geophysical Research Letters)*

—S.R.



Importance of Plant Phenology (Journal Articles from ISI)

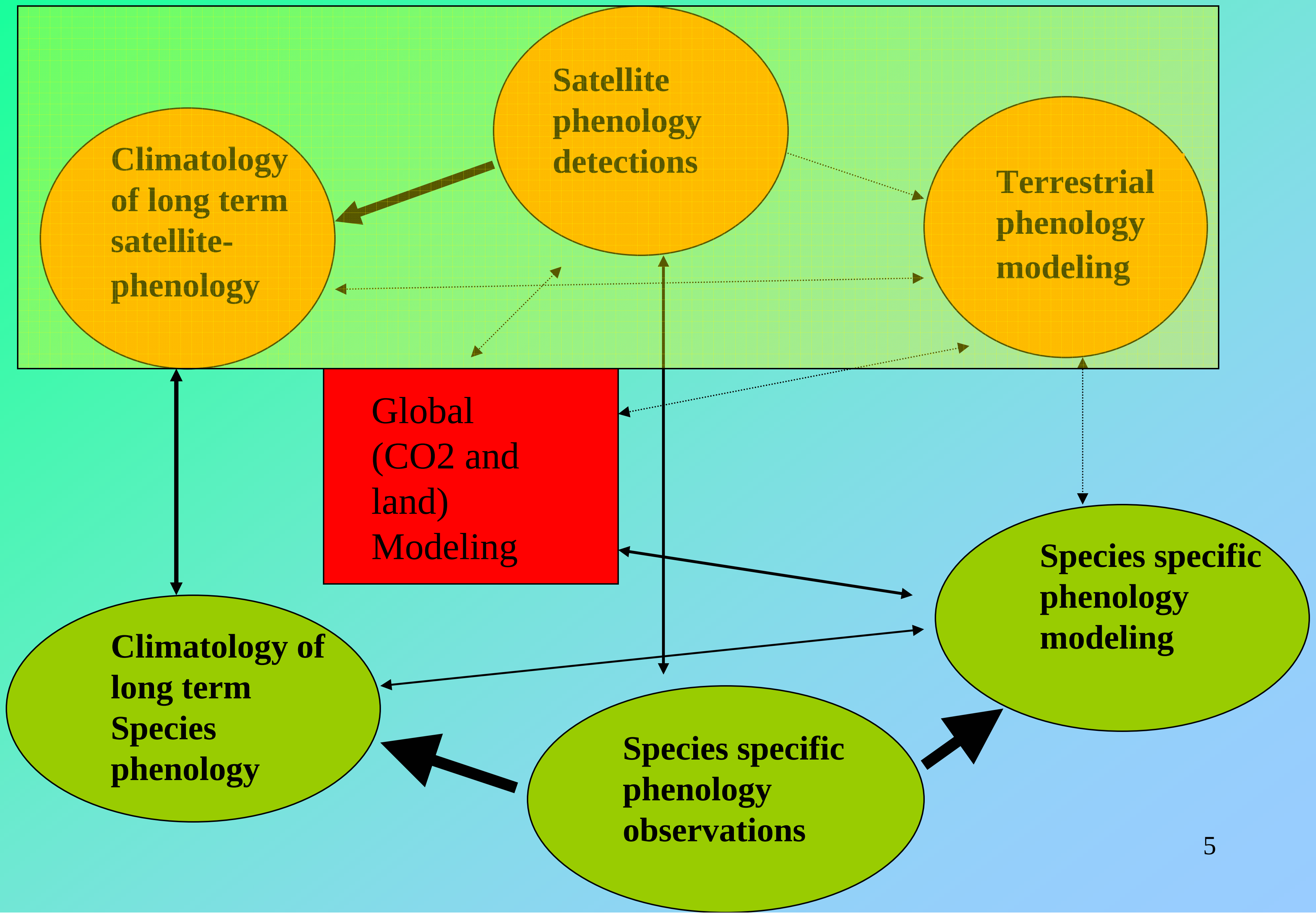


Plant (vegetation) phenology: Annual cycles of vegetation (timing of flowering, budburst, greenup onset, leaf drop, etc.) and how they respond to seasonal climate changes

Outline

1. Background
2. Phenology estimates from AVHRR data
3. Long term trends of phenological pattern
4. Mechanism of long term phenological variations in North America
5. Conclusions
6. Several research issues

Background

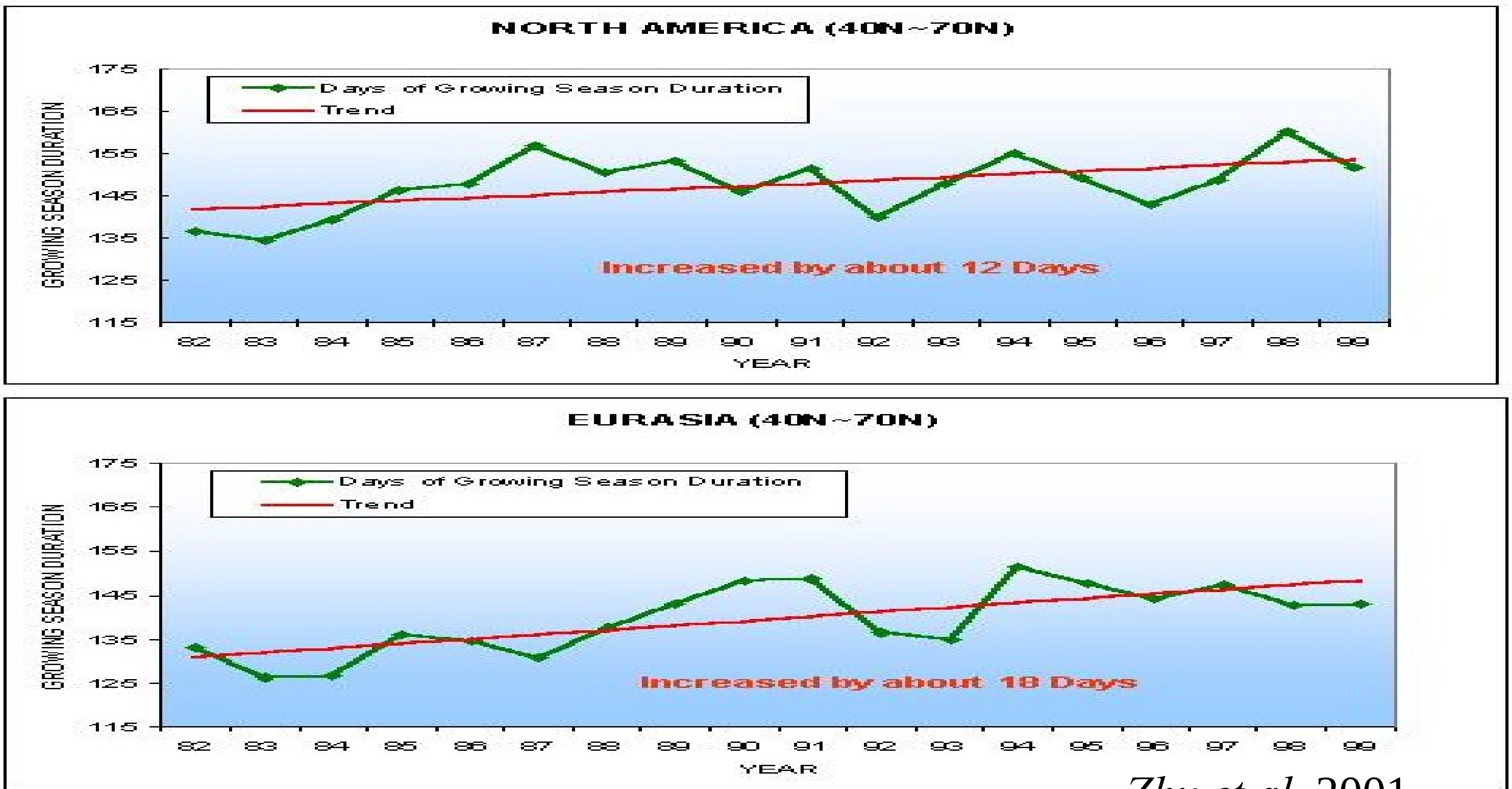


Satellite phenology detections
Climatology of long term satellite-phenology
Terrestrial phenology modeling
Global (CO2 and land) Modeling
Species specific phenology modeling
Climatology of long term Species phenology
Species specific phenology observations

Background

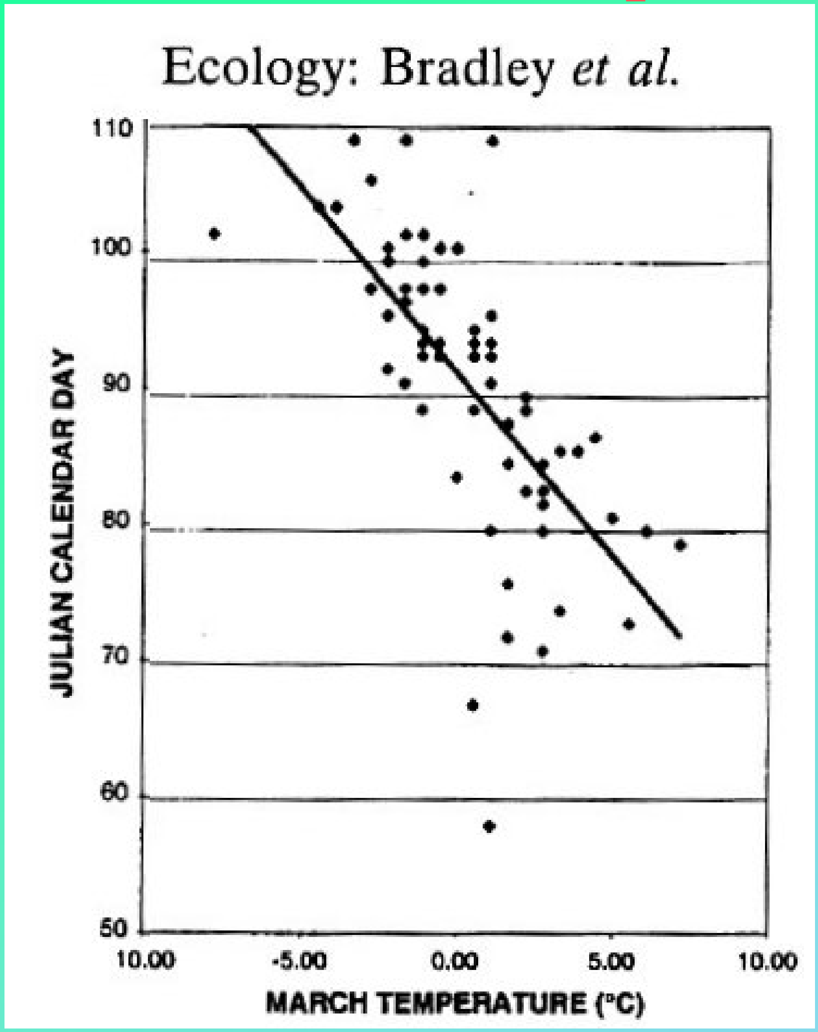
Vegetation phenology-- an effective indicator of climate changes

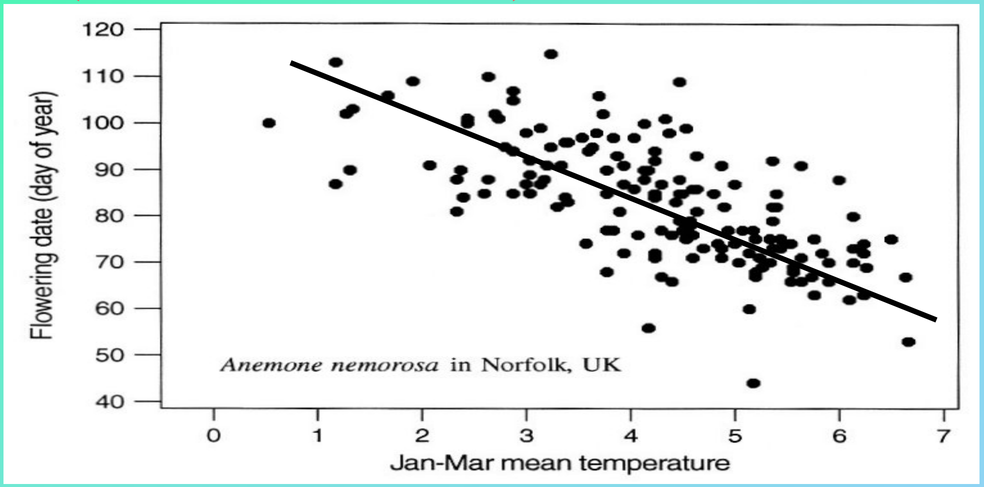
- Vegetation spring burdbud occurs early
- Vegetation growing season becomes longer

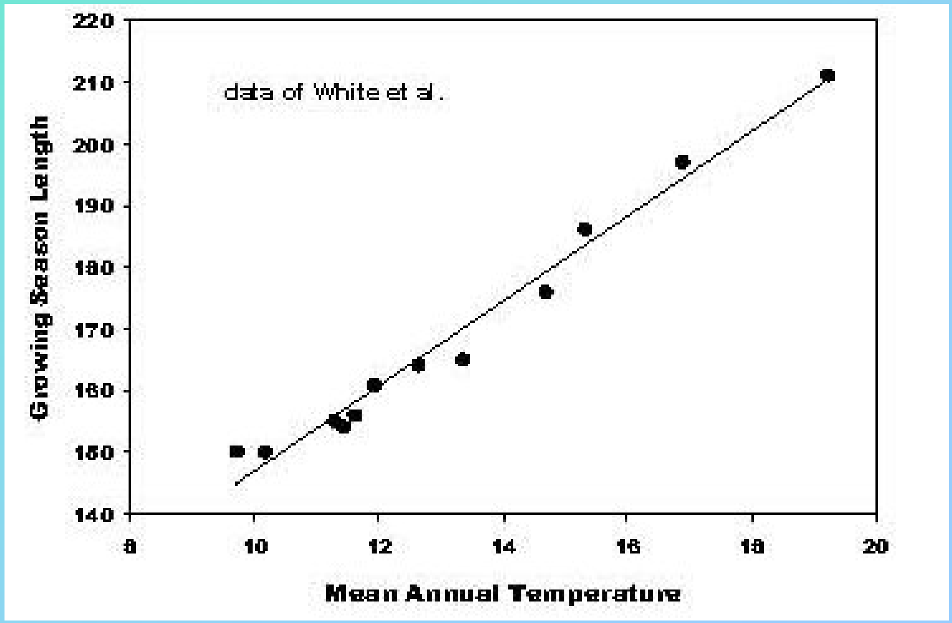


Zhu et al. 2001

Background
Earlier Phenological Trends Associated with Warming Temperature (linear models)







Basic Understanding

- Vegetation spring events are LINEARLY related to mean annual temperature or mean monthly temperature during last several decades.
- Warming climates advance spring vegetation phenological events.
- BUT…

Background

Are There Any Delayed Trends?

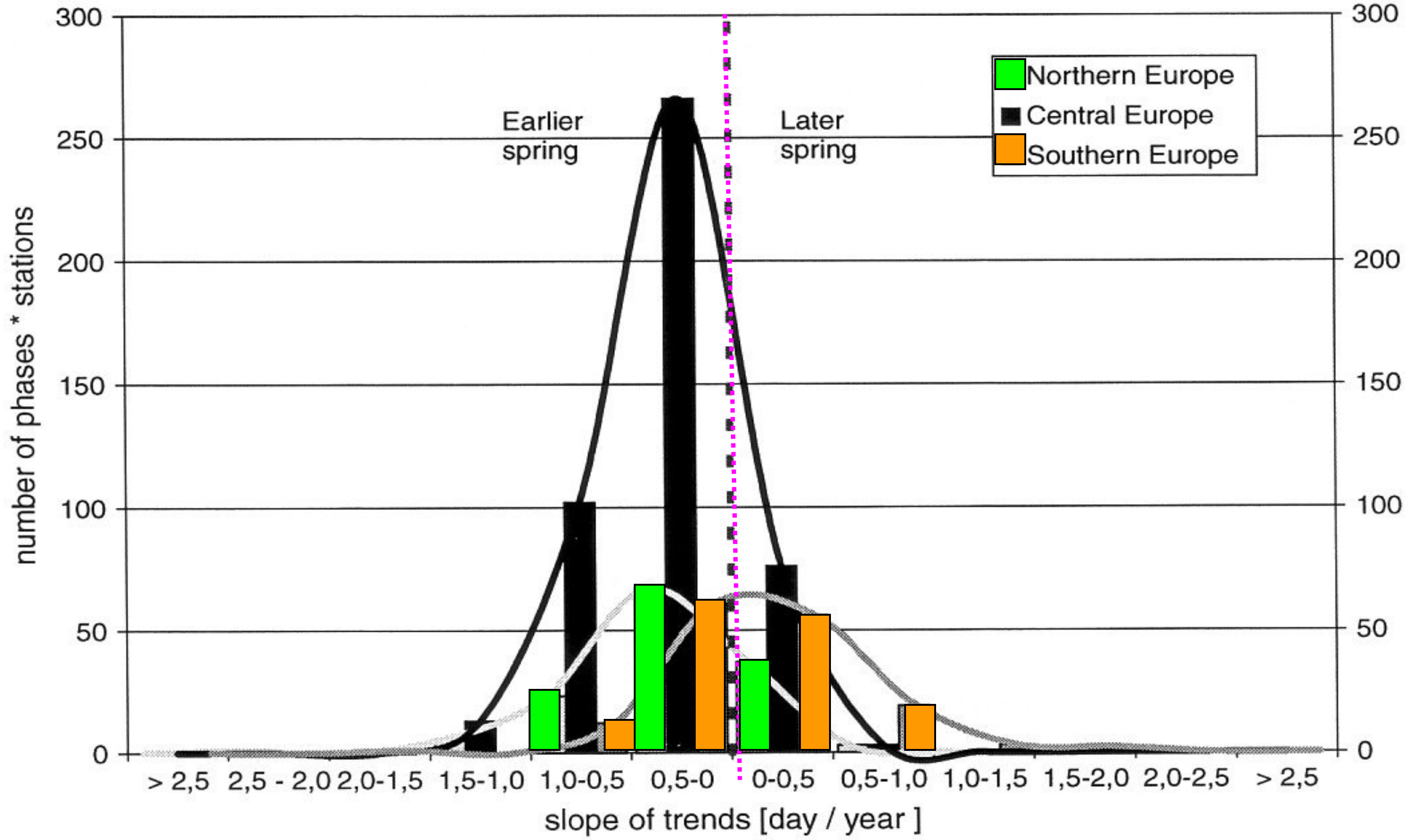
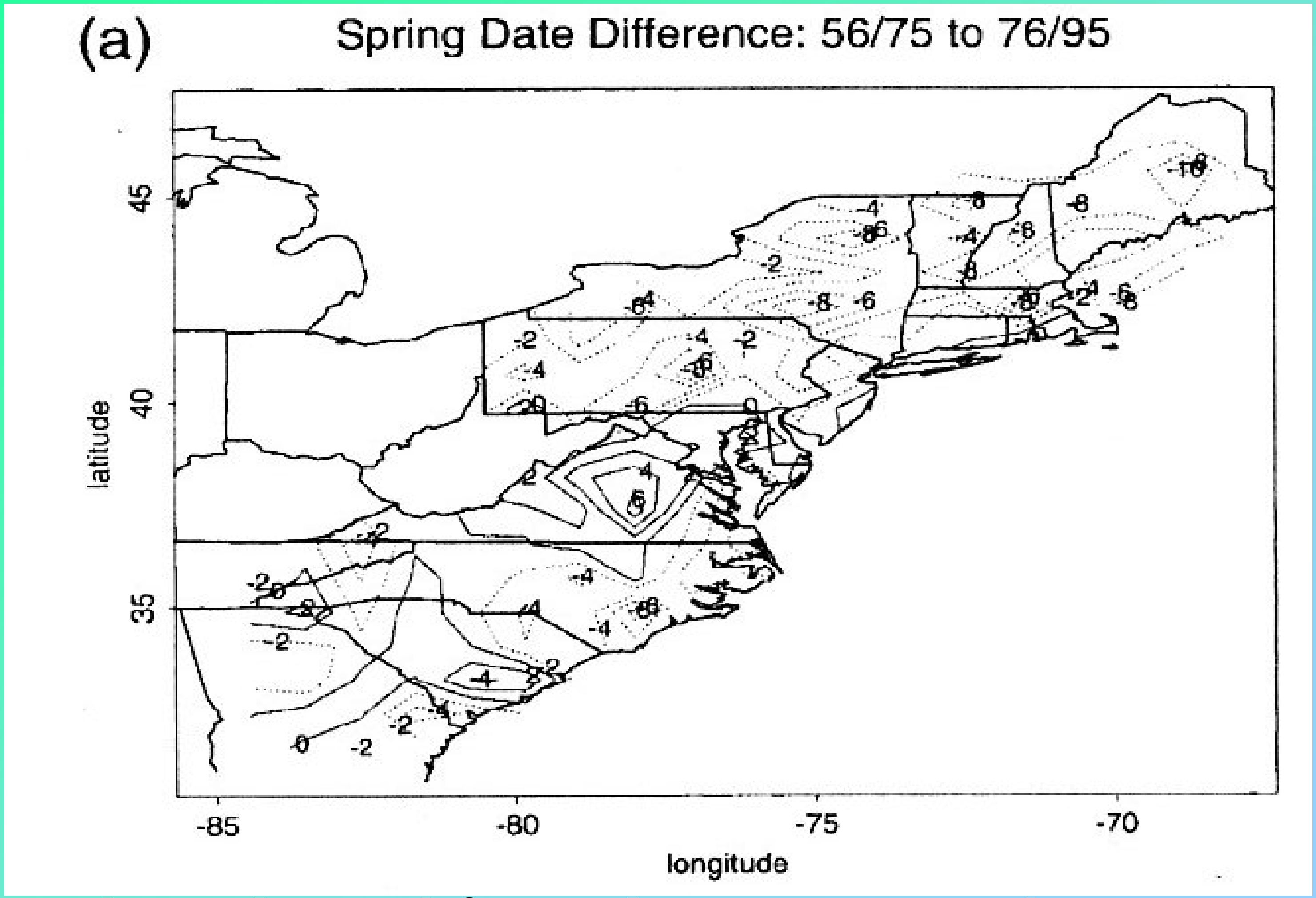


Figure 5. Frequency of slopes of linear regressions (trends in days/year) for spring phases in the International Phenological Gardens (1959–1996; only records with more than 20 years of observation included) (after Menzel and Fabian, 2001)

Background

Are There Any Delayed Trends?



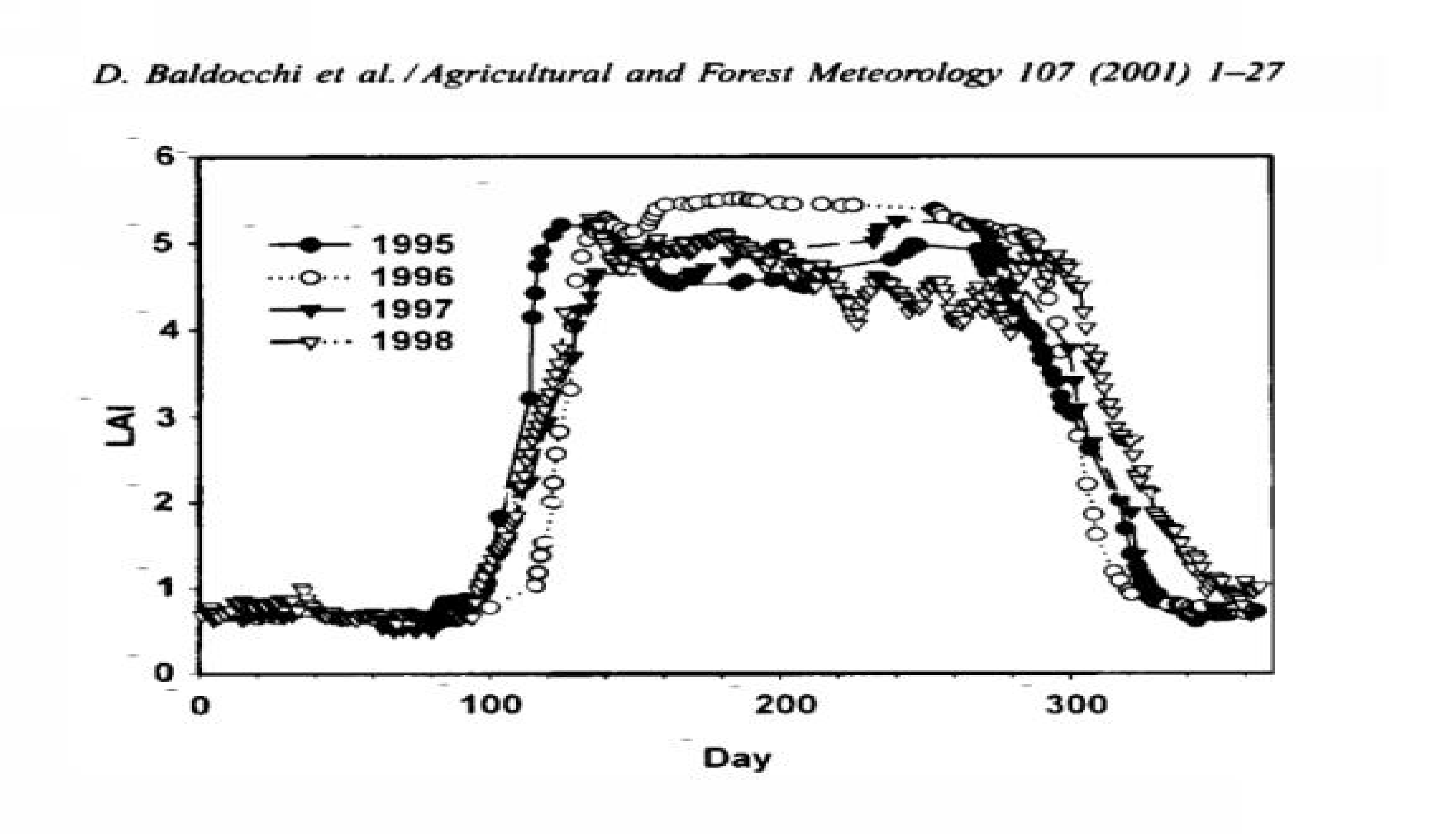
Phenology derived from climate-station data (Fitzjarrald et al. (2001), *J. Climate, 14*, 598–614)

What Is the Mechanism for the Delayed Trends?

- Likely associated with elevated CO_2 and N in field-controlled experiments (Cleland et al, 2006, PNAS)
- Likely regulated by photoperiod or by a physiological signal other than local temperature (Bradeley et al., 1999, PNAS)
- Don’t know or no explanations in most of the literature

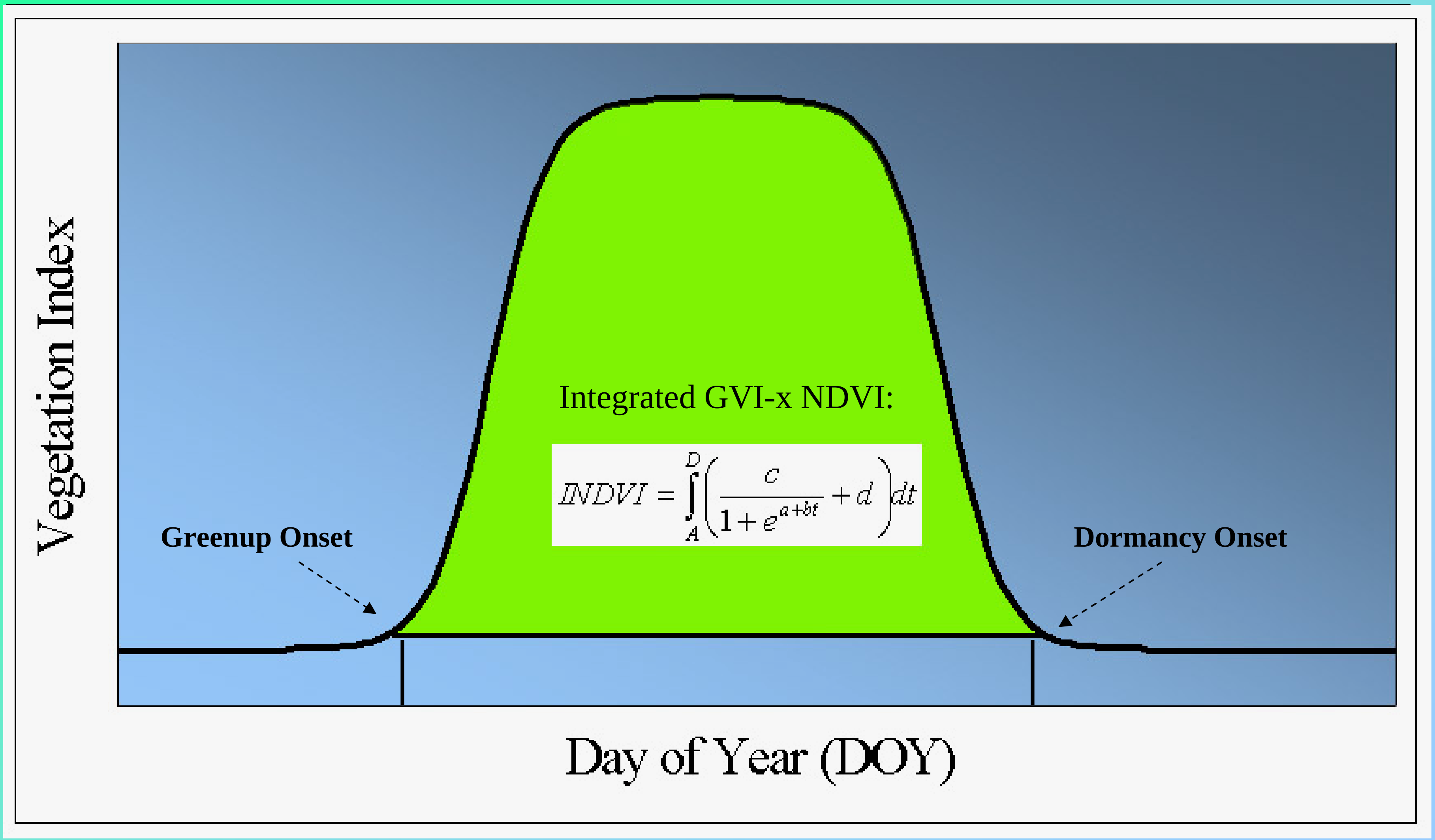
Vegetation Phenology Derived from Long Time Series of AVHRR NDVI Data (GVI-x)

Seasonal Canopy Variation in Temperate Deciduous Forests



From Baldocchi et al., 2001.

Temporal Vegetation Index from Satellite Data and Phenological Matrix



A General Logistic Model for Describing Vegetation Growth

$$Vc(t) = \frac{c}{1 + e^{a+bt}} + d$$

t is time in day of year

Vc(t) is the green vegetation index (NDVI) at time *t*

a and *b* are fitting parameters

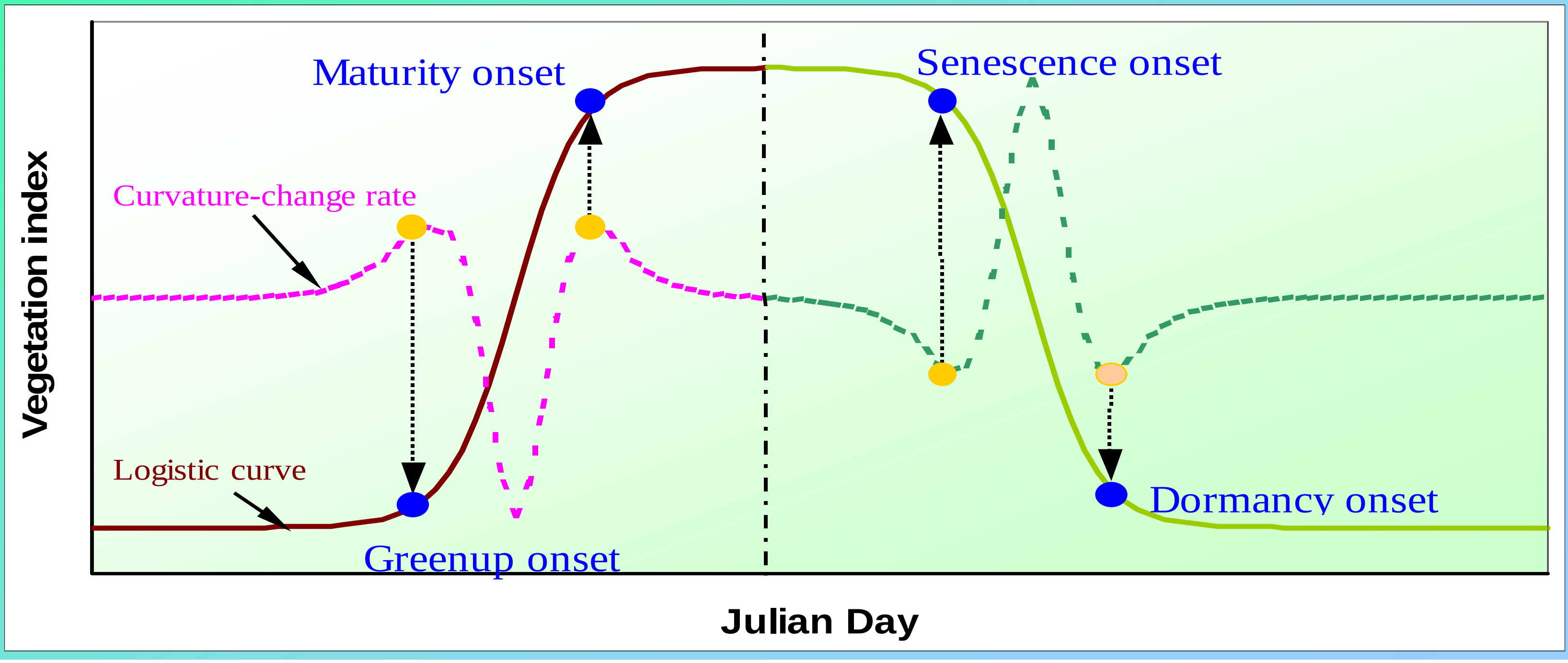
c+ *d* is the maximum Vc value

d is the initial background Vc value

Algorithm for Automatically Determining Vegetation Phenology

The rate of curvature change

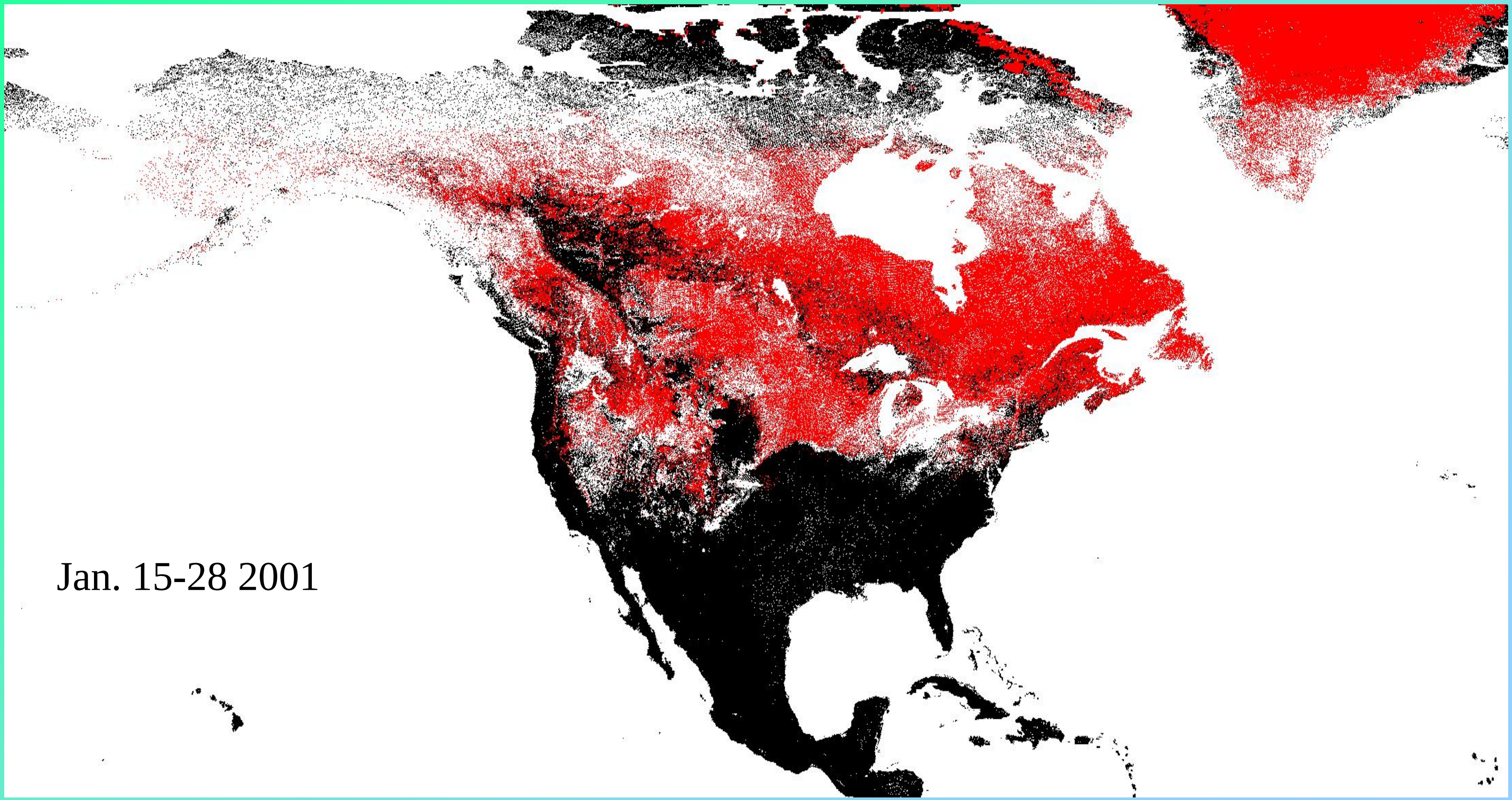
$$K' = b^3cz\left\{\frac{3z(1-z)(1+z)^3\left[2(1+z)^3+b^2c^2z\right]}{\left[(1+z)^4+(bcz)^2\right]^{\frac{5}{2}}}-\frac{z^2\left(1+2z-5z^2\right)}{\left[(1+z)^4+(bcz)^2\right]^{\frac{3}{2}}}\right\}$$



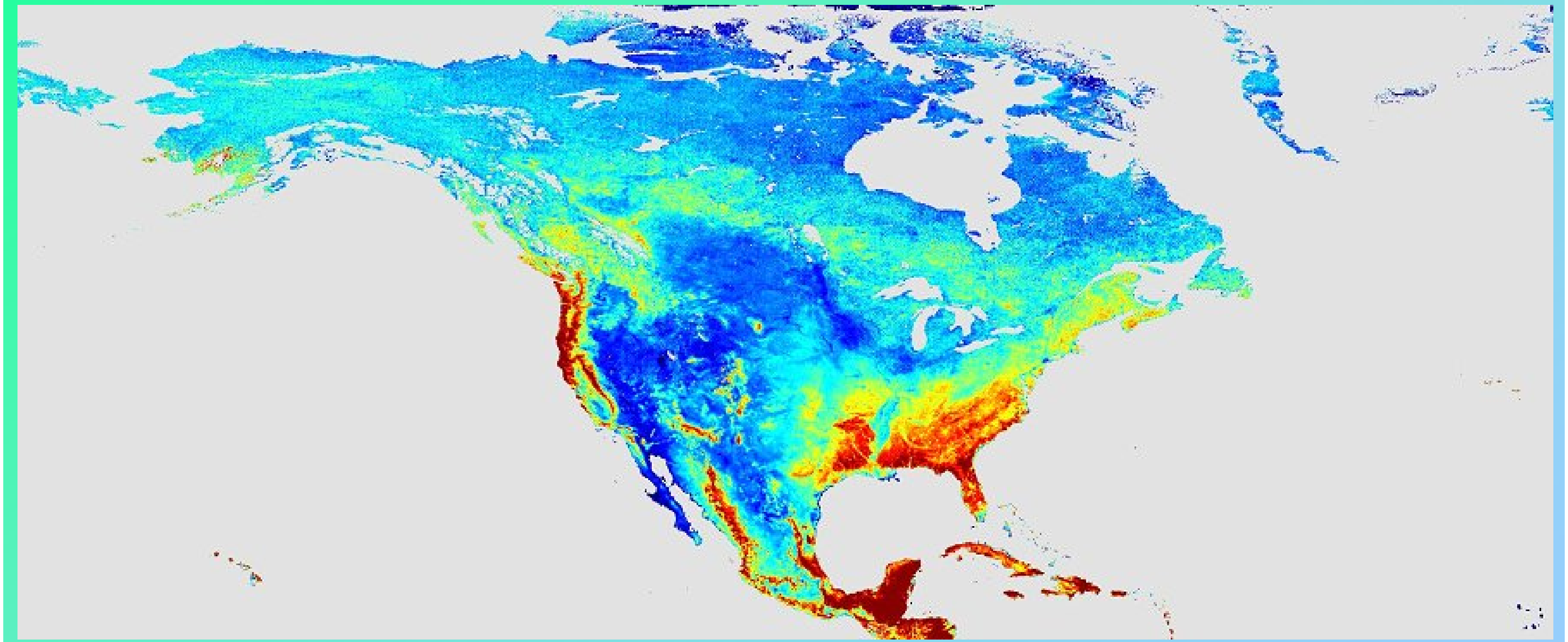
AVHRR Datasets

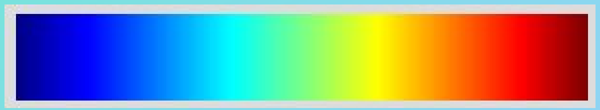
- NDVI data from weekly 4 km GVI-x NDVI from 1982-2005
- Cloud and snow flag from 4 km GVI-x QA

Snow Flag in GVI-x

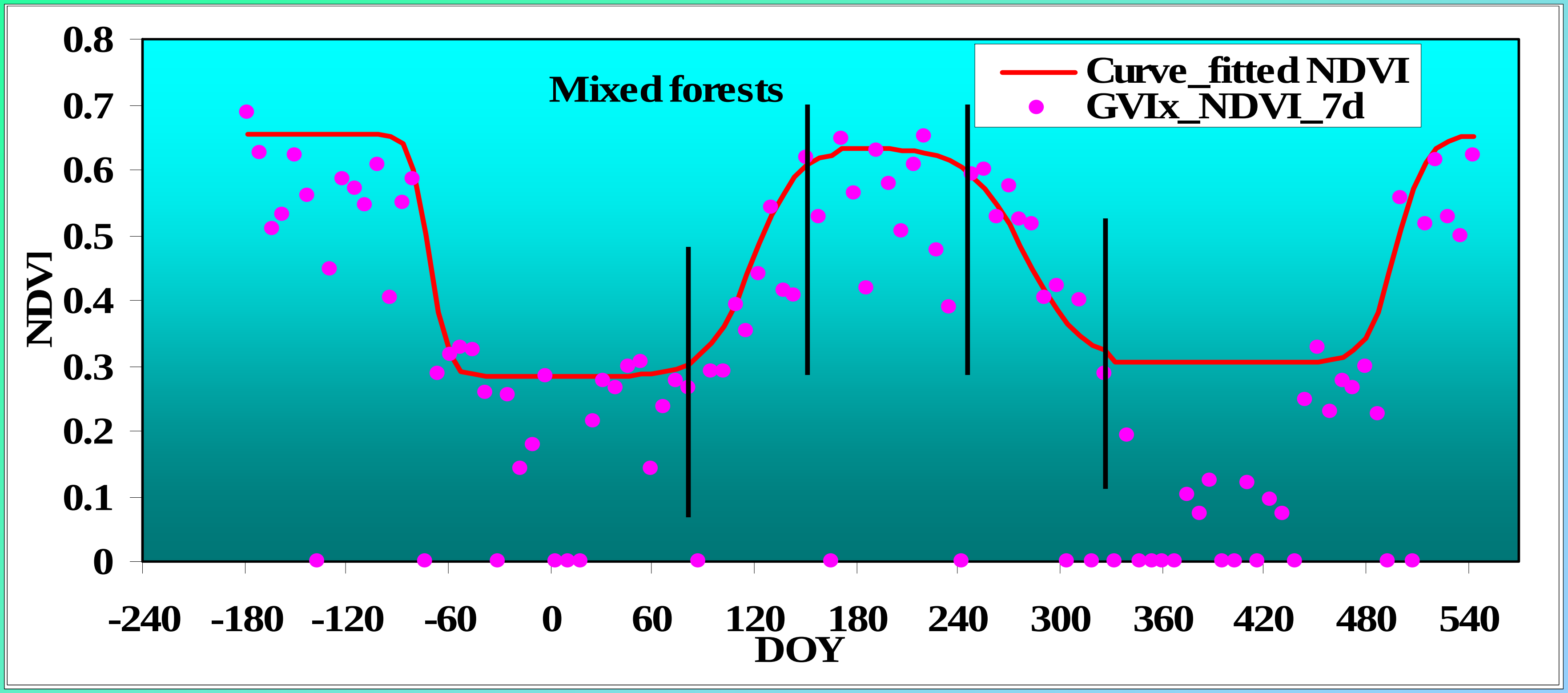


Background AVHRR NDVI

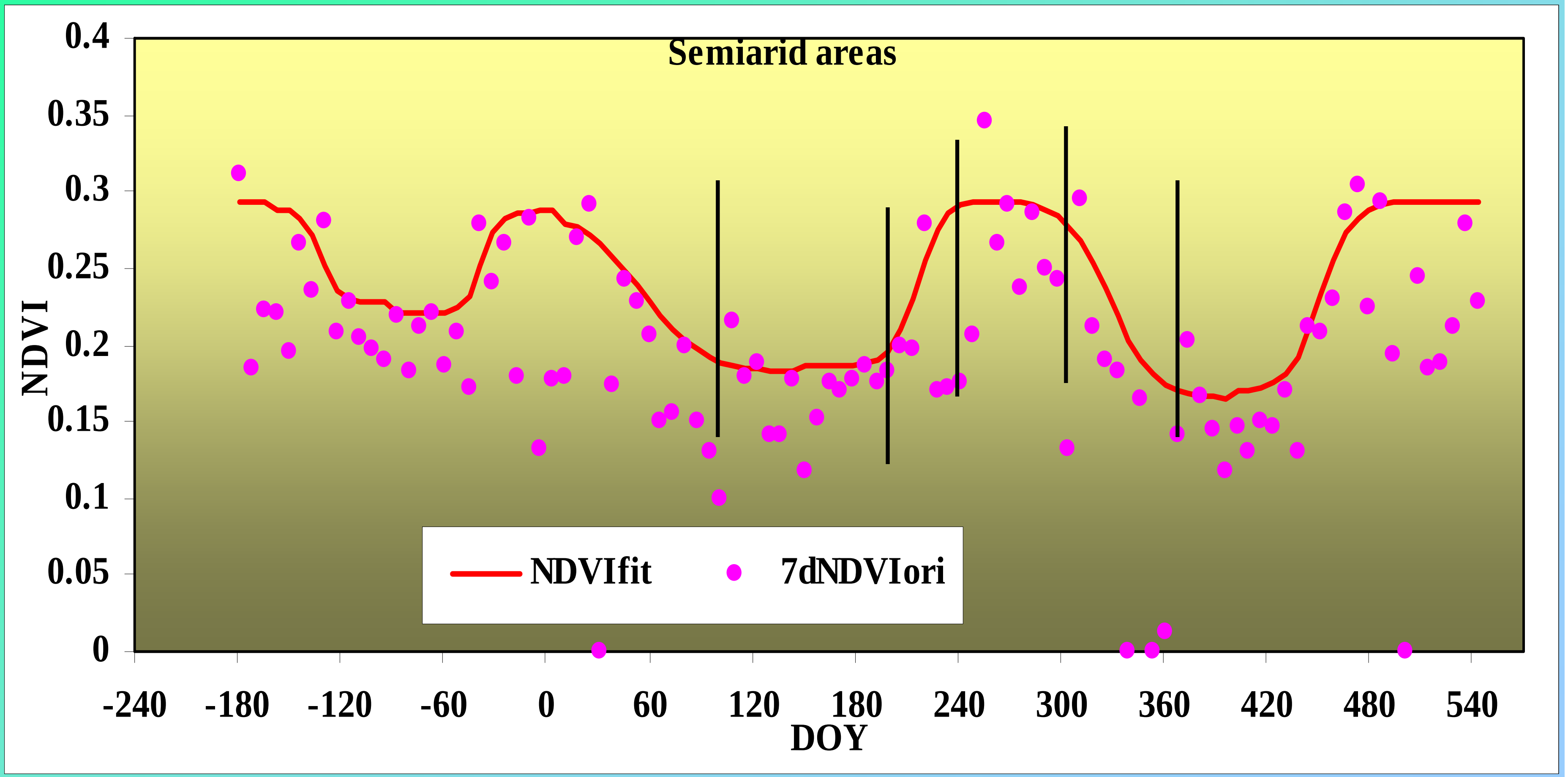




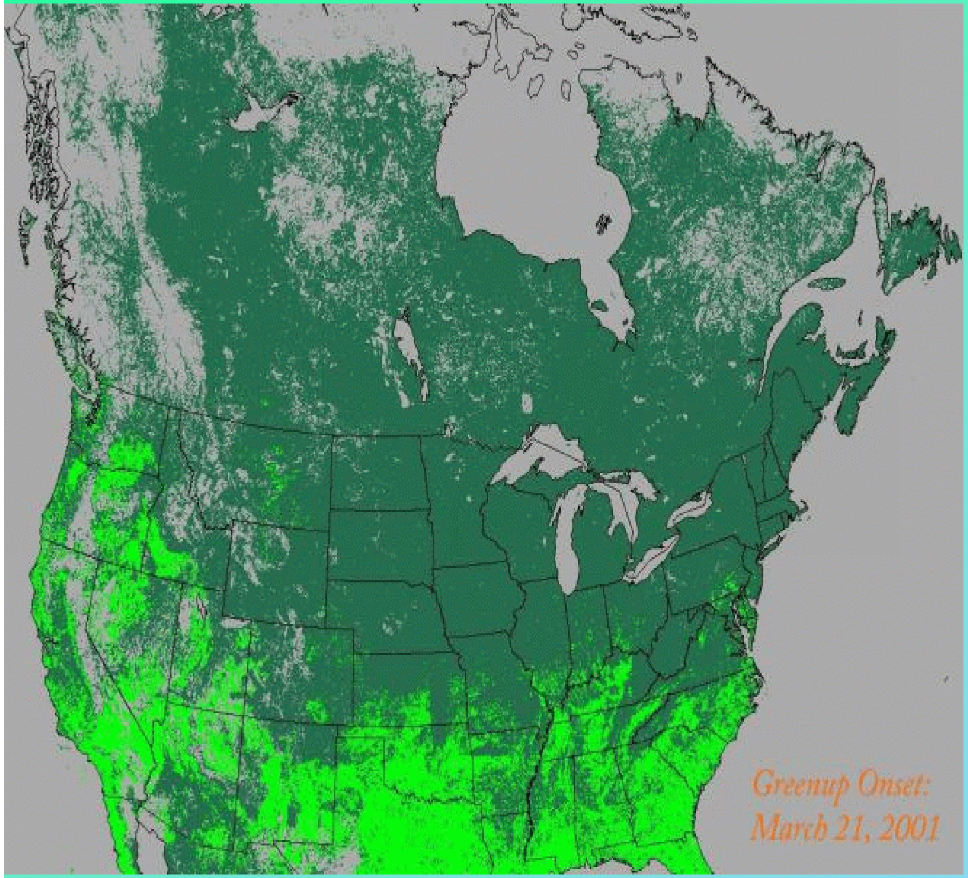
Phenology Detection in Forests

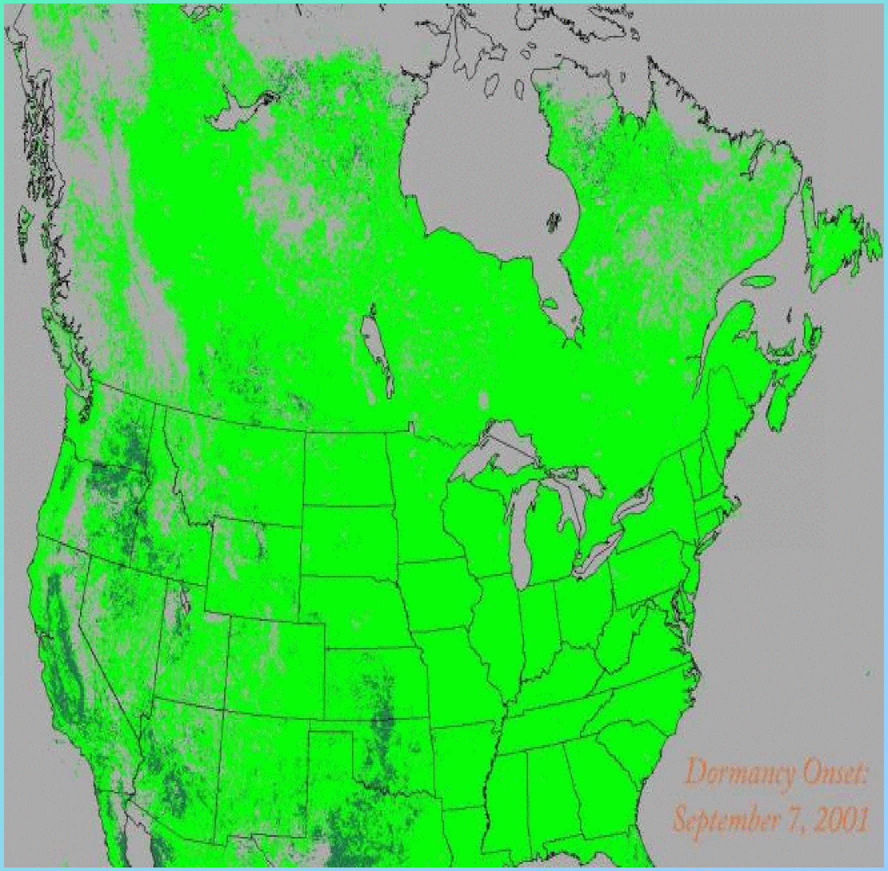


Phenology Detection in Semiarid Areas

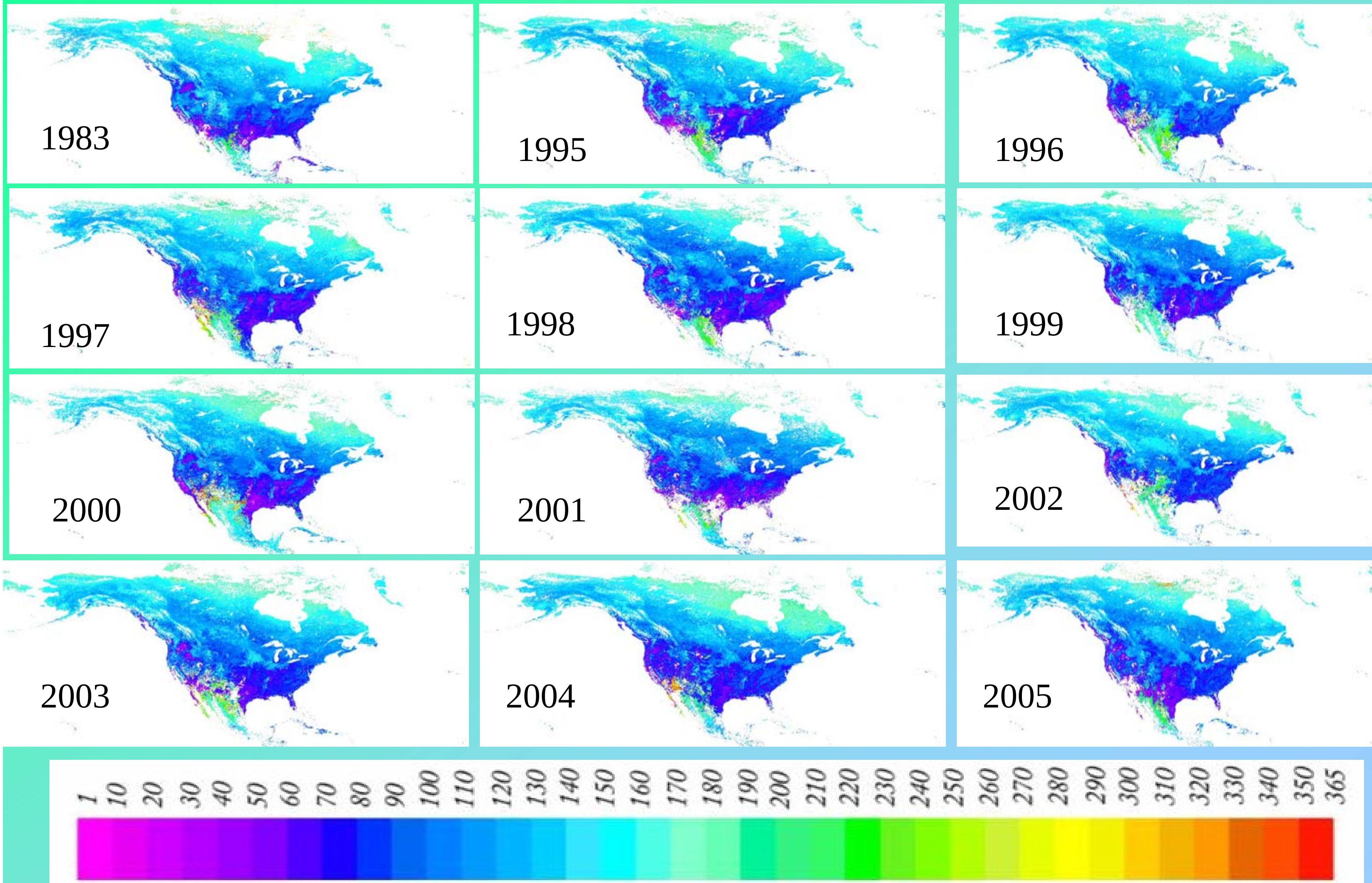


Phenology Shifts in North America (2001)

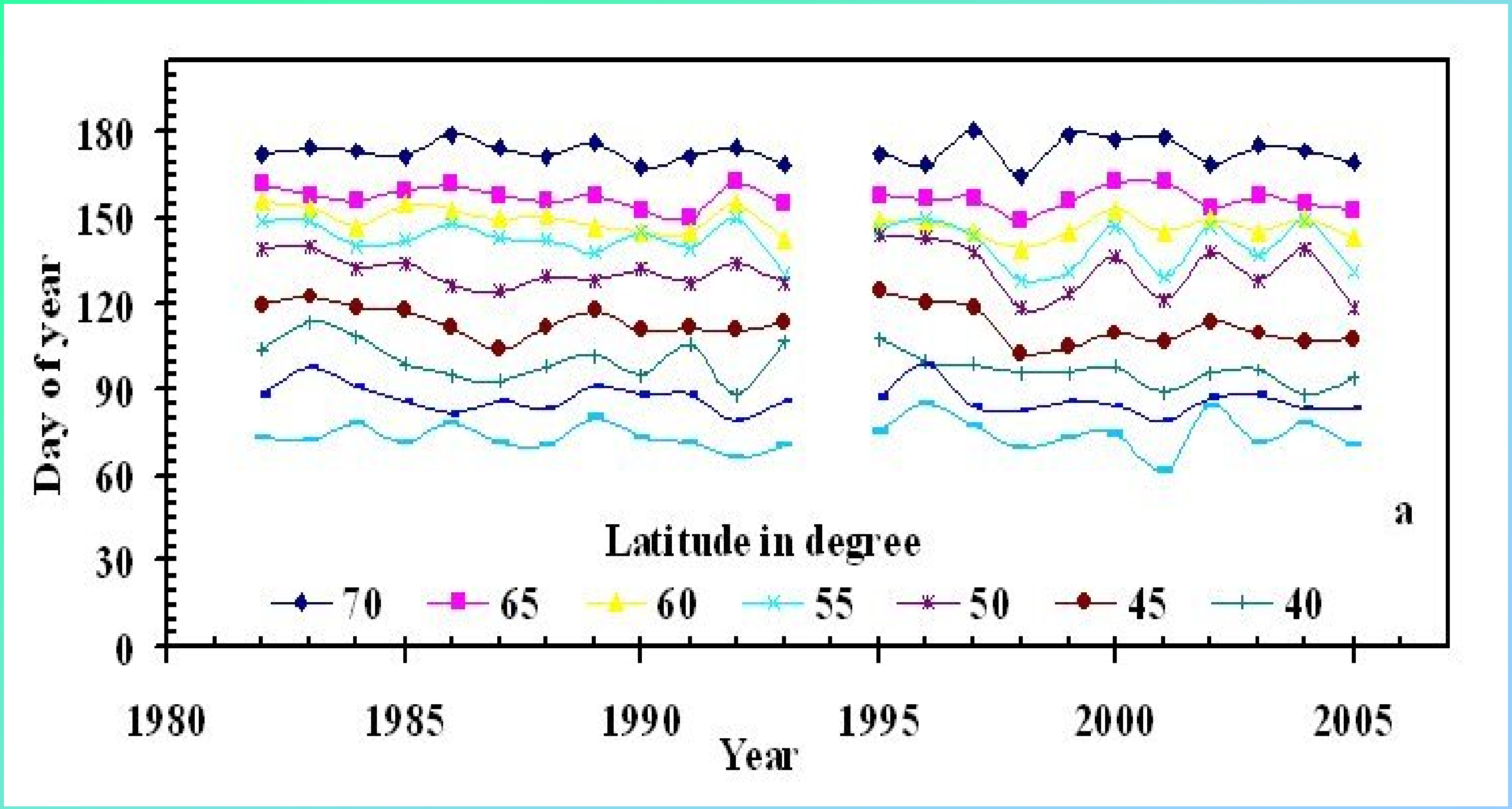




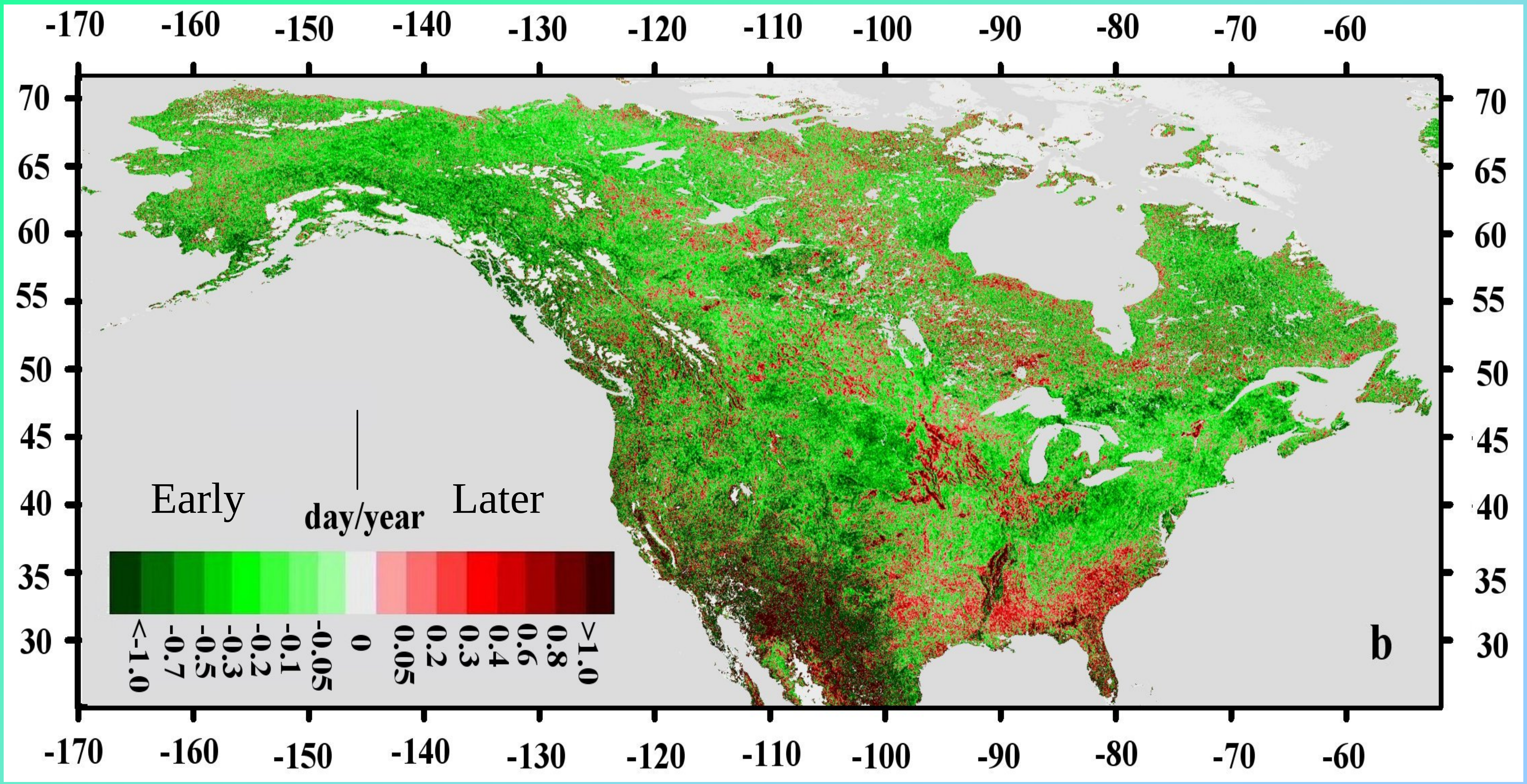
Onset of Greenup



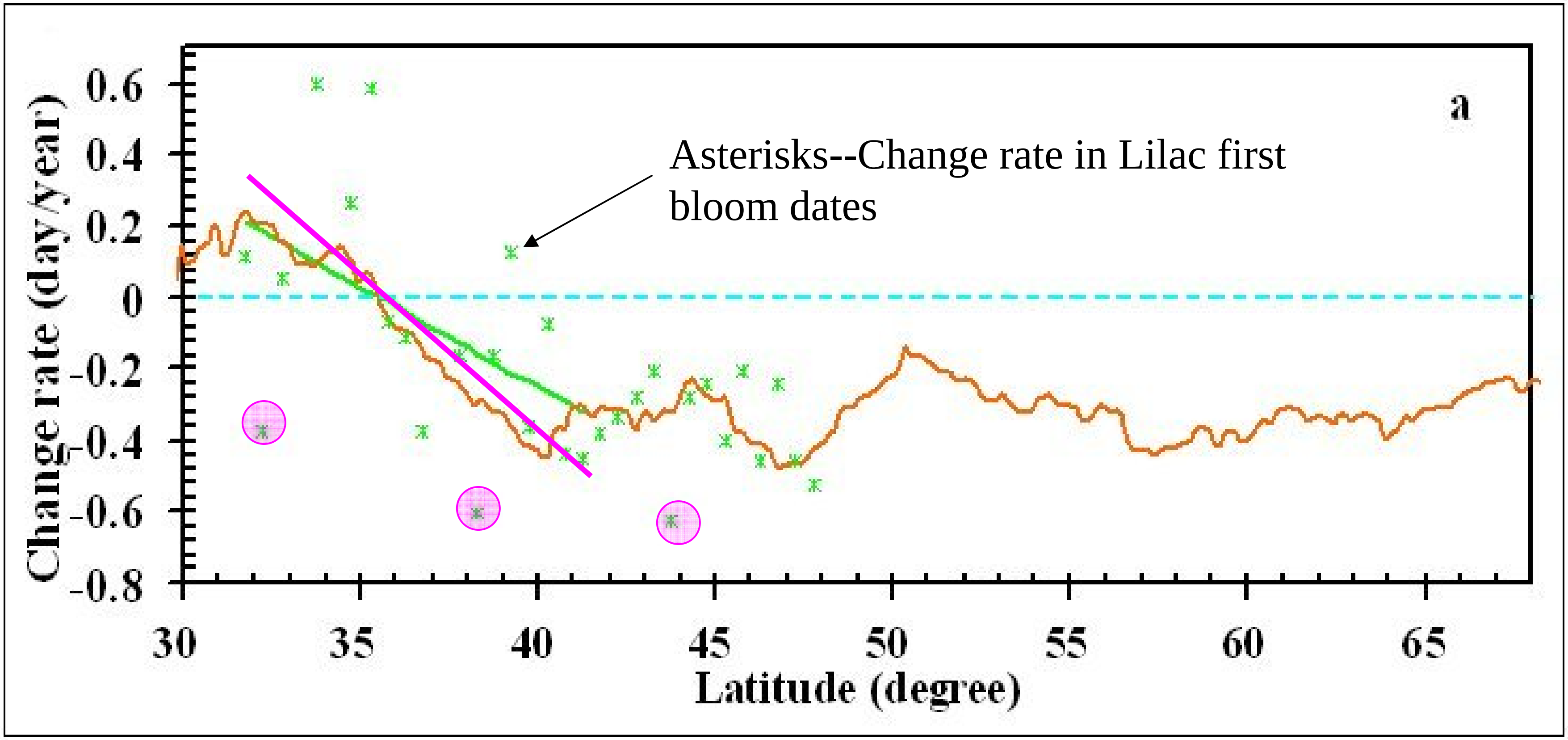
Interannual Zonal Variations in Greenup Onset



Interannual Trend in Greenup Onset

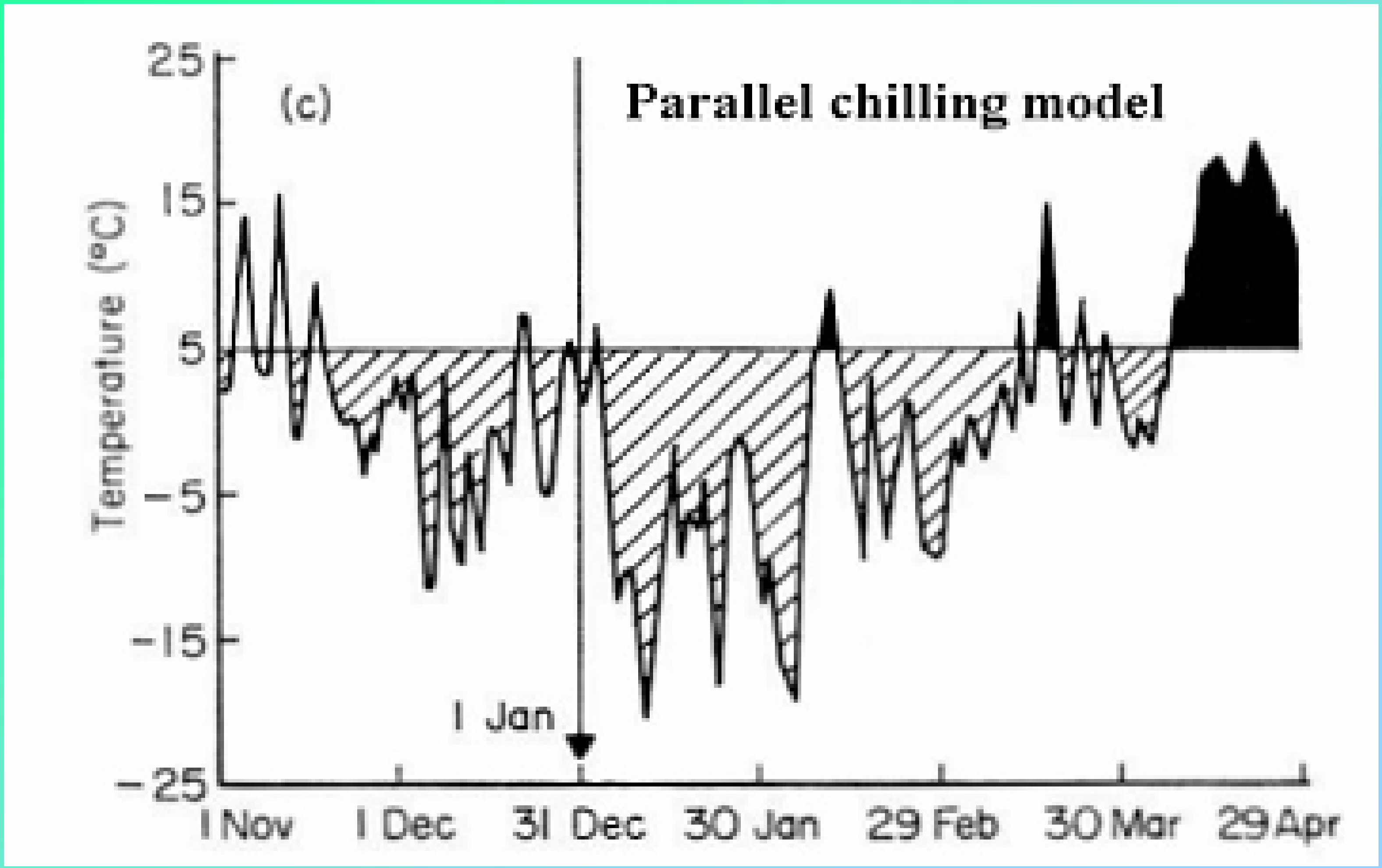


Phenological Transition Zone in Natural Vegetation Greenup Onset



What Is the Mechanism of Delayed Phenological Trends?

Species-specific Phenology Modeling



Cannell and Simth, 1983

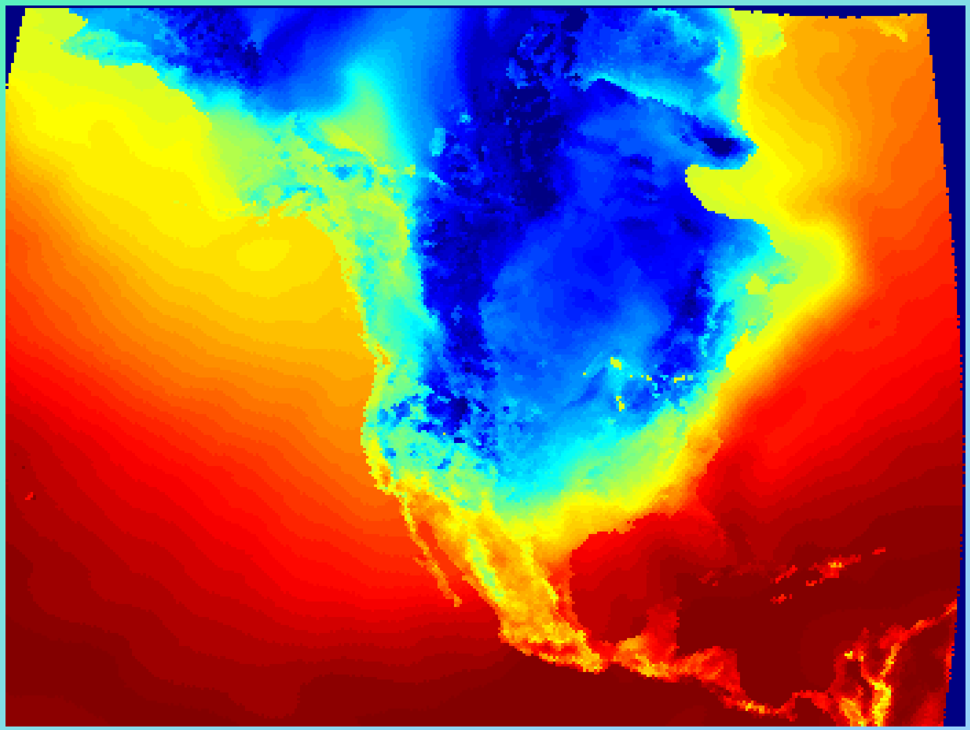
Thermal Time-chilling Model (Parallel chilling model) for Greenup Onset in Terrestrial Ecosystems

$$TTR = \alpha + \beta e^{\gamma Cd}$$

TTR is the thermal time requirement
Cd is the number of chill days
α, β and γ are coefficients

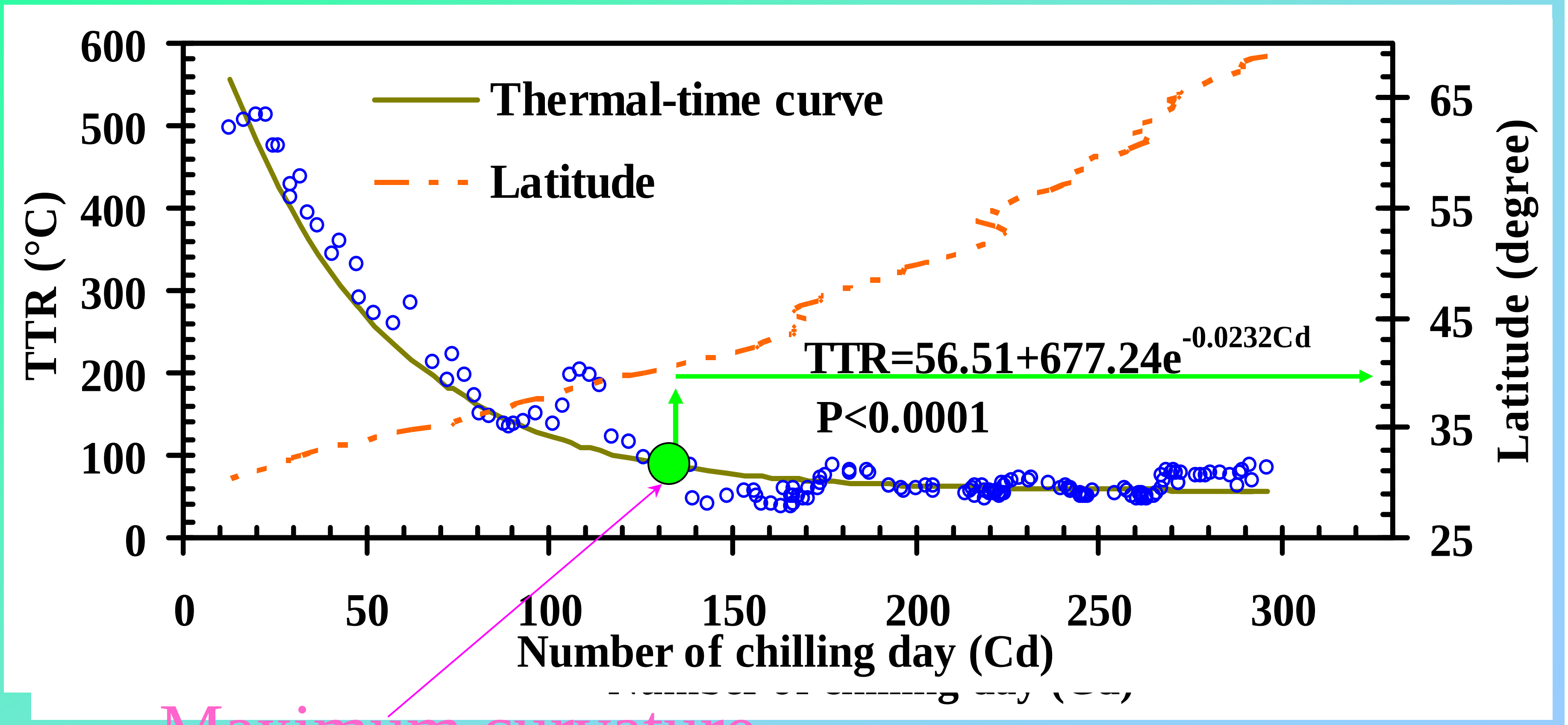
Temperature data

3-hourly LST data at a spatial resolution of 32 km between 1981 and 2005 from the NCEP North America Regional Reanalysis (Mesinger et al., 2006)



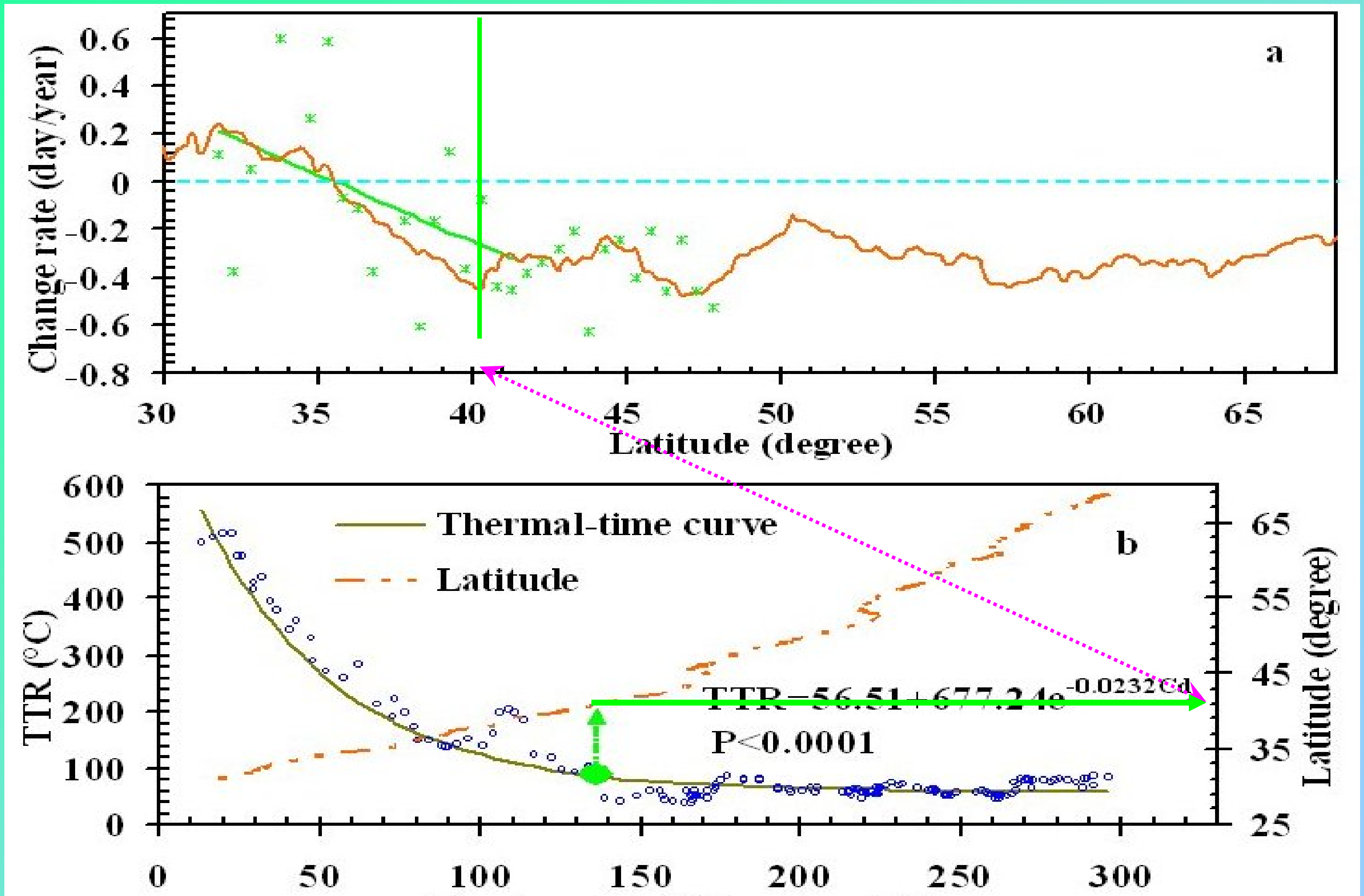
Feb. 5, 1982, 0300UTC

Terrestrial Phenolgical Model for Greenup Onset in North America



Maximum curvature change rate

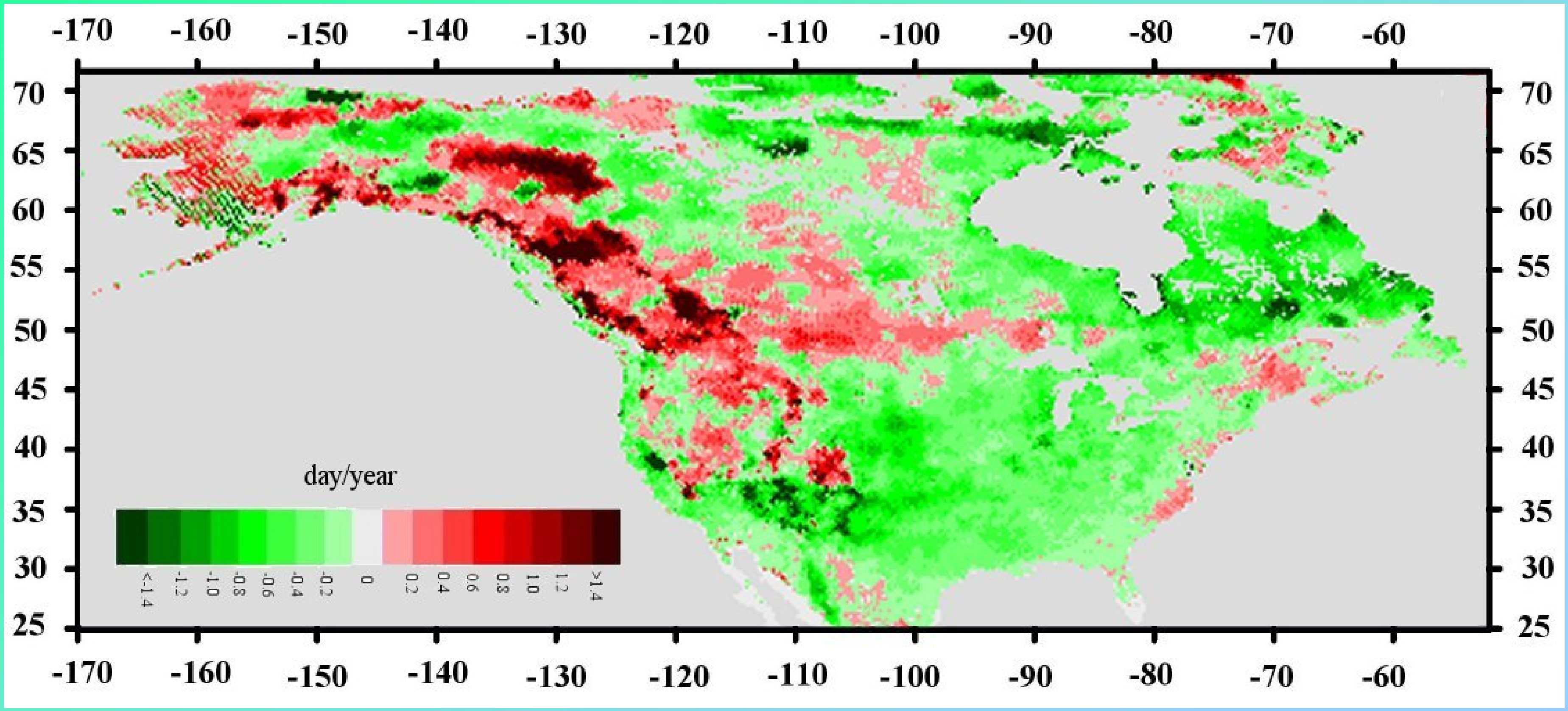
Northern Starting Point of Phenological Transition Zone from both AVHRR Data and Modeling



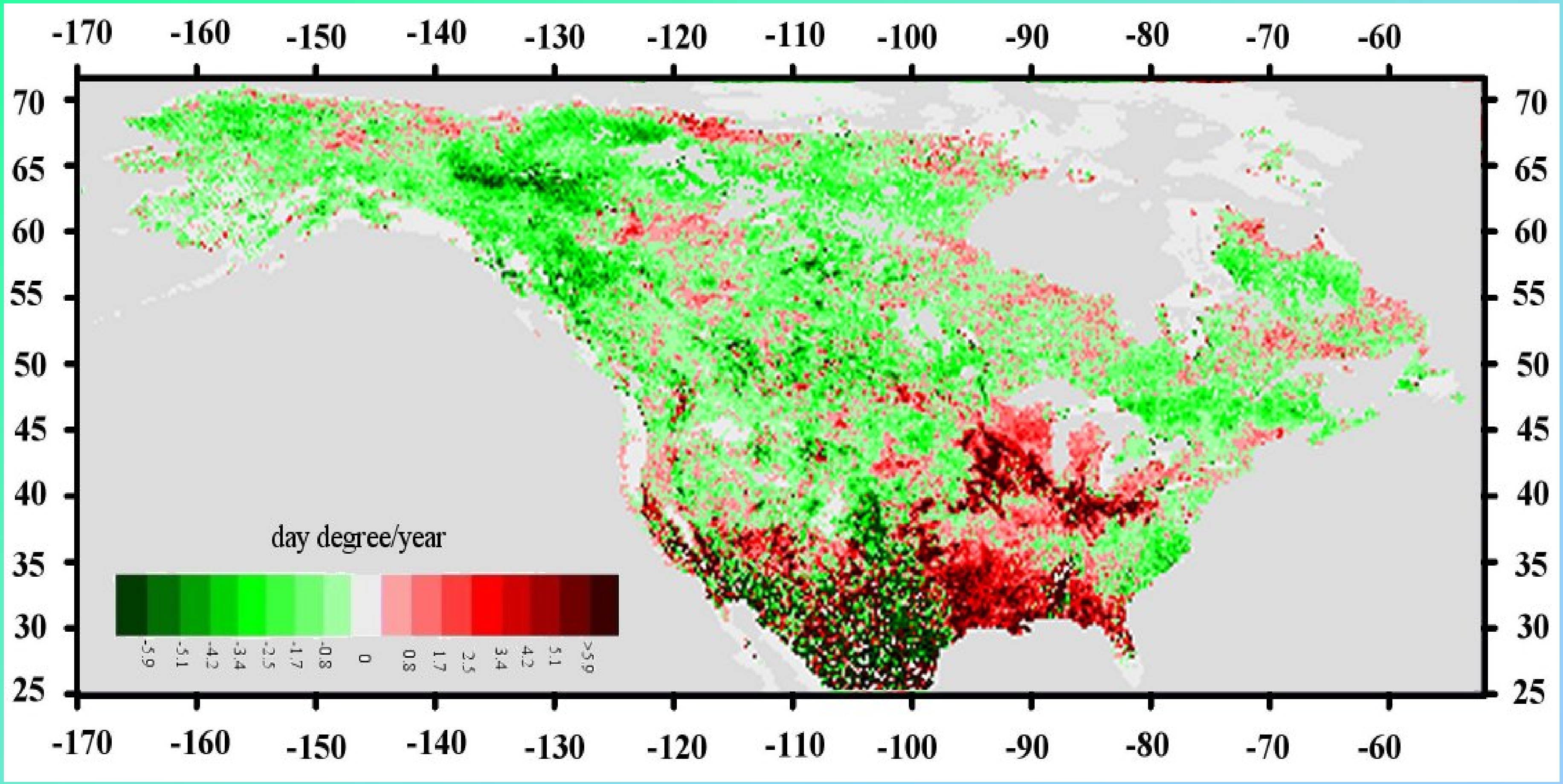
Number of chilling day (Cd)

Has winter chilling time decreased and spring temperature increased during last two decades?

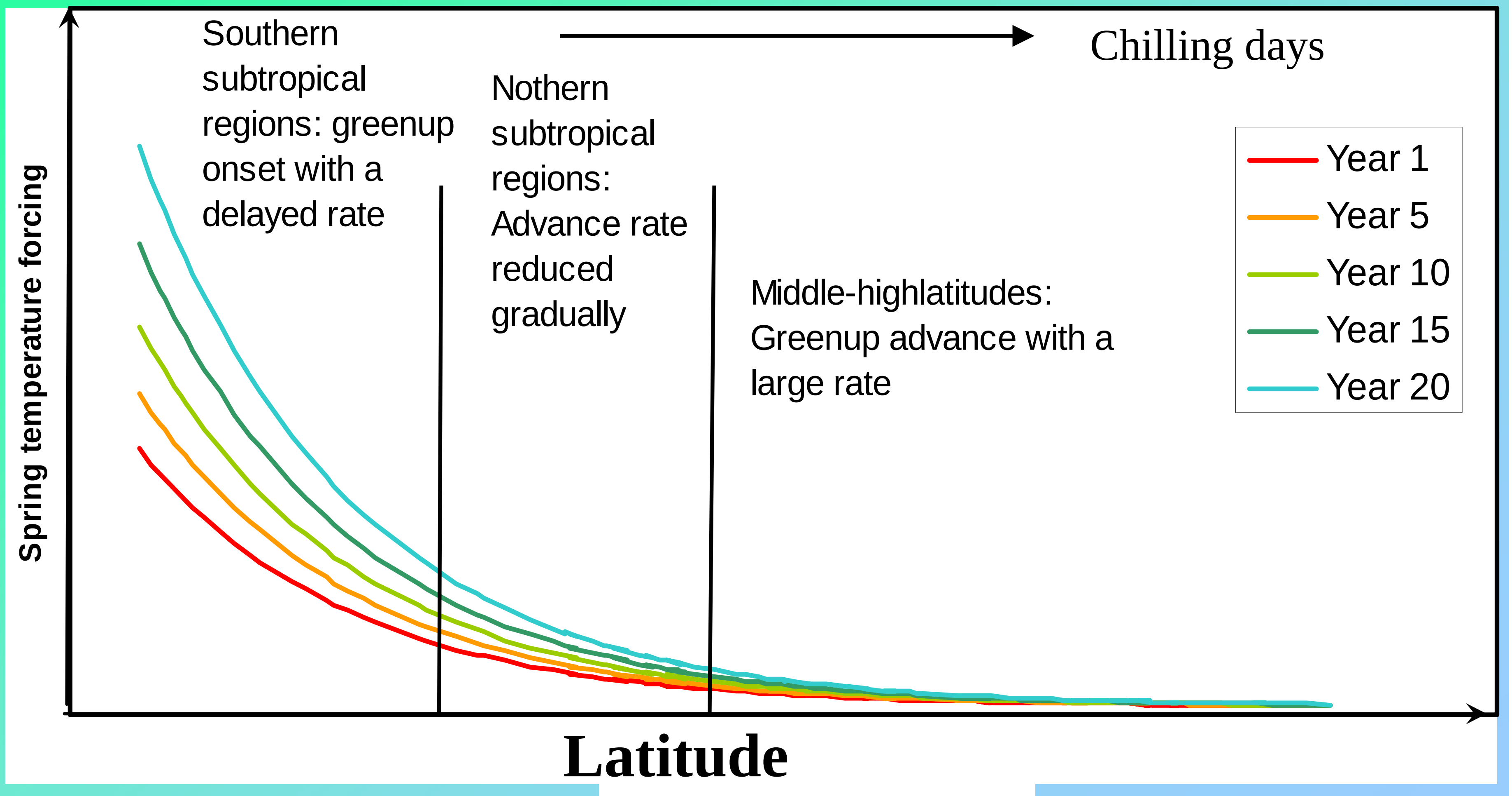
Interannual trends in Winter Chilling Days from 1982 to 2005



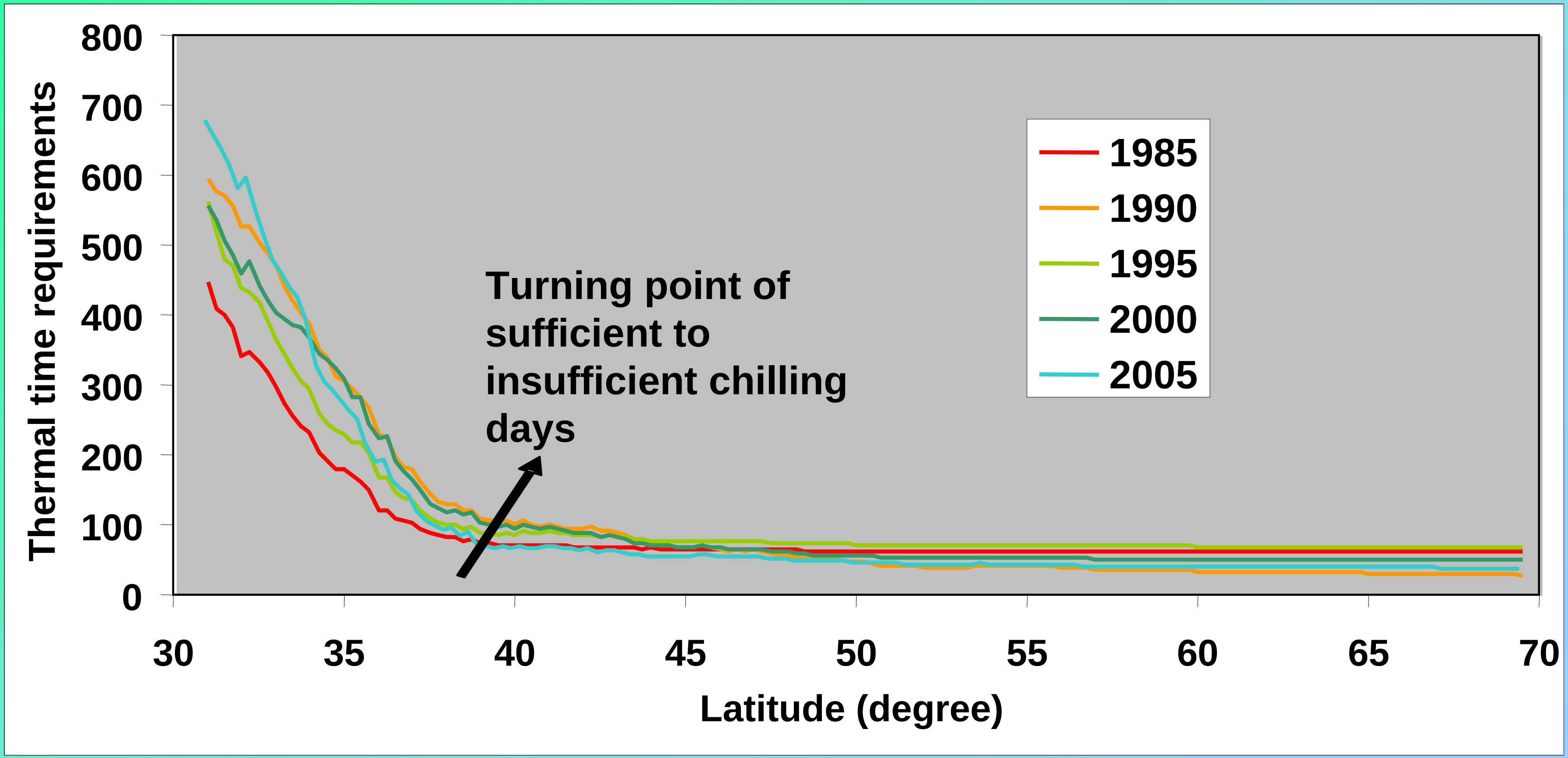
Interannual trend in Spring Temperature Requirements for Greenup Onsets from 1982 to 2005



Changes in Thermal Time-chilling Curves with Warming Temperature

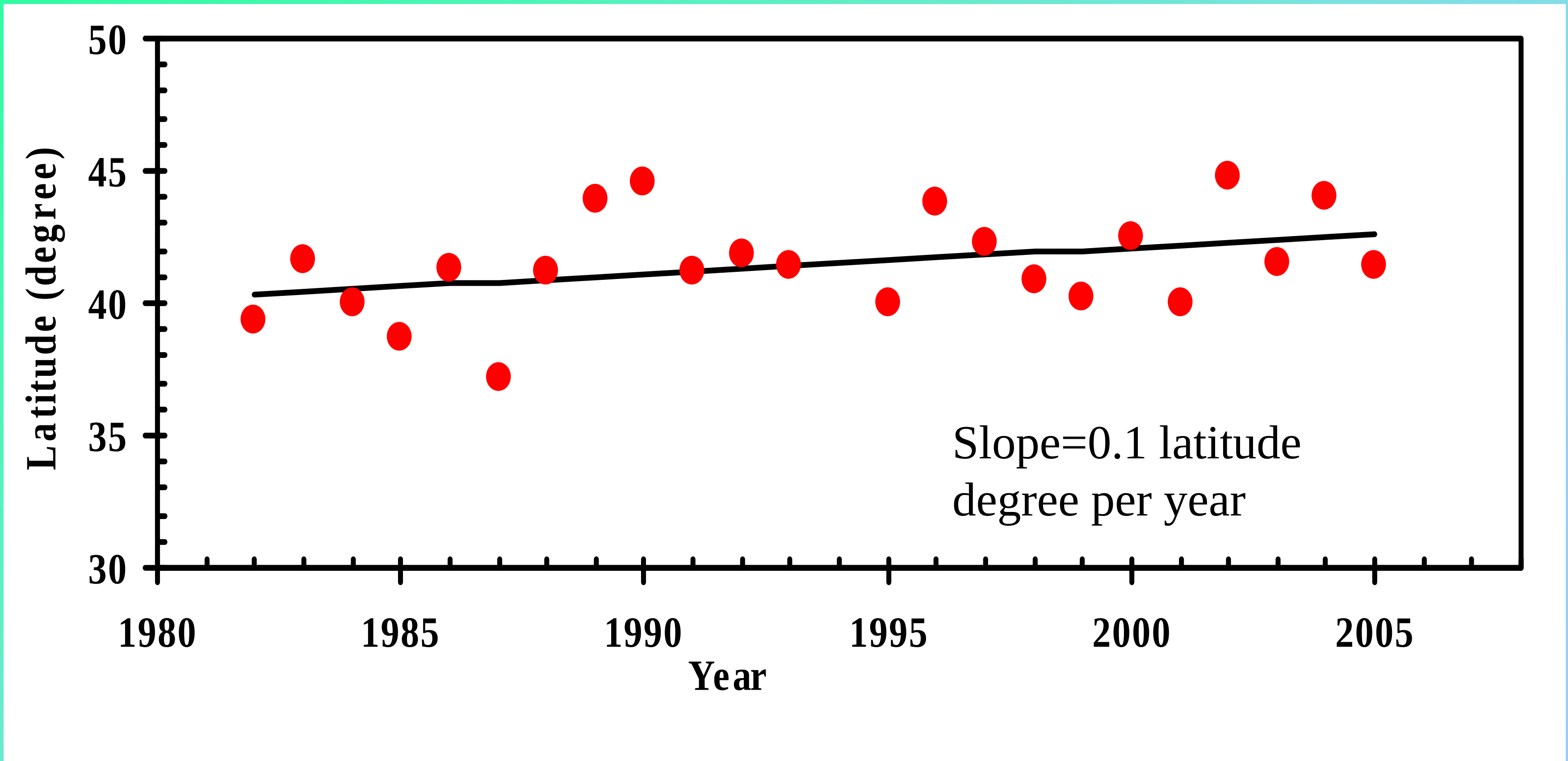


Interannual Changes in the Curves of Thermal Time Requirement



Interannual trends in the turning points of thermal-chill curves

(representing northern starting point of the transition zone)



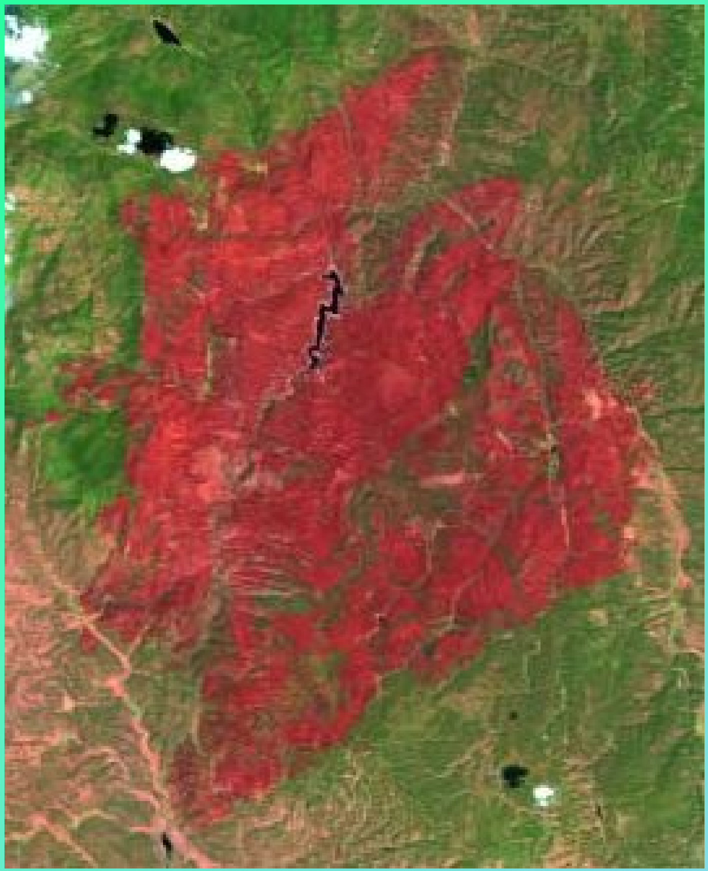
Conclusions

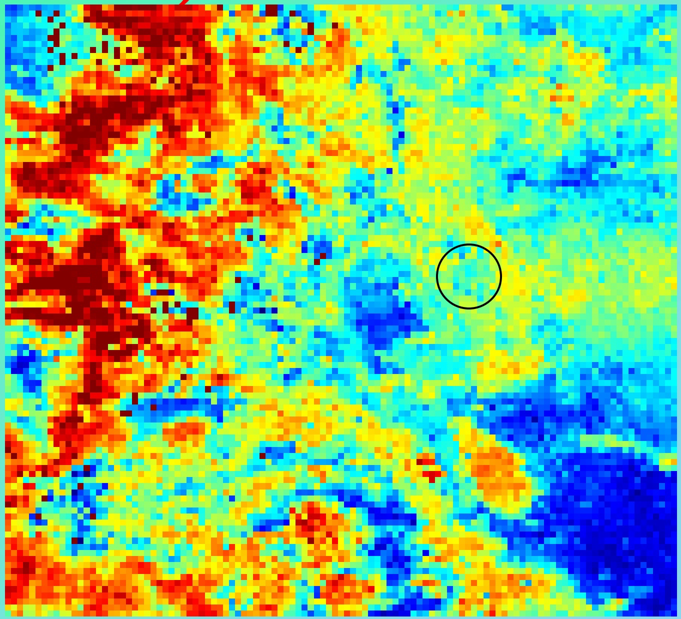
- **Warming temperature advances greenup onset in mid-high latitudes but delays greenup in low middle latitudes across North America.**
- **The phenological transition zone has shifted northwards with a rate of 0.1 latitude degree per year.**
- **The greenup onset will continuously advance with climate warming in high latitudes because plant buds are always fully chilled.**
- **The advance of greenup onset will slow down around 40°N and the timing of greenup onset between 35°N and 40°N may gradually change from advancing to slowing trends.**

Research issues

- **Are the delayed trends in southern regions affected by long term variation in precipitation?**
- **In what types of ecosystems are the delayed trends more significant?**
- **What is the global climatology of vegetation phenology?**
- **What's the long term data records in the onsets of greenup, maturity, senescence, dormancy, growing season greenness (1km)?**
- **How to monitor vegetation phenology (such as crop germination, pollination, and related disease outbreaks) in real time using new satellite data, such as GOES-R and VIIRS?**
- **Is it possible to generate long-term fire burn scars using AVHRR vegetation phenology properties and to characterize recovering vegetation phenology.**

Burn Scar from AVHRR Time Series
(Hayman Fire)





2001
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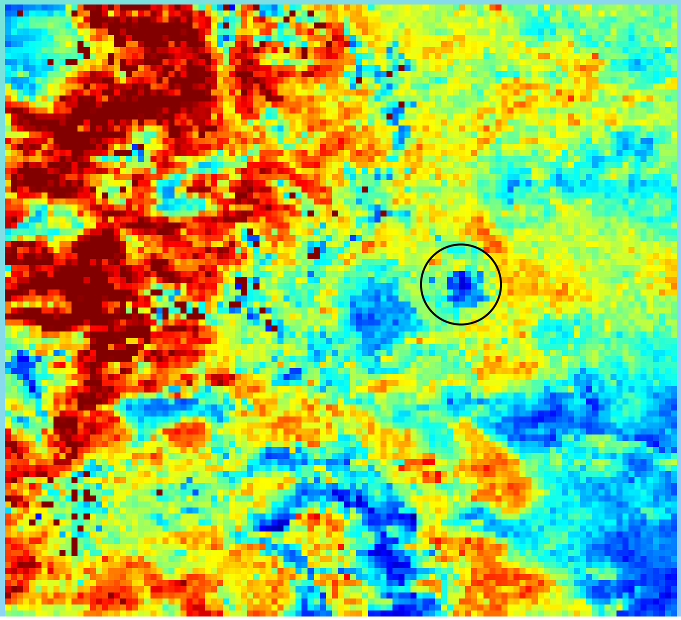

2003
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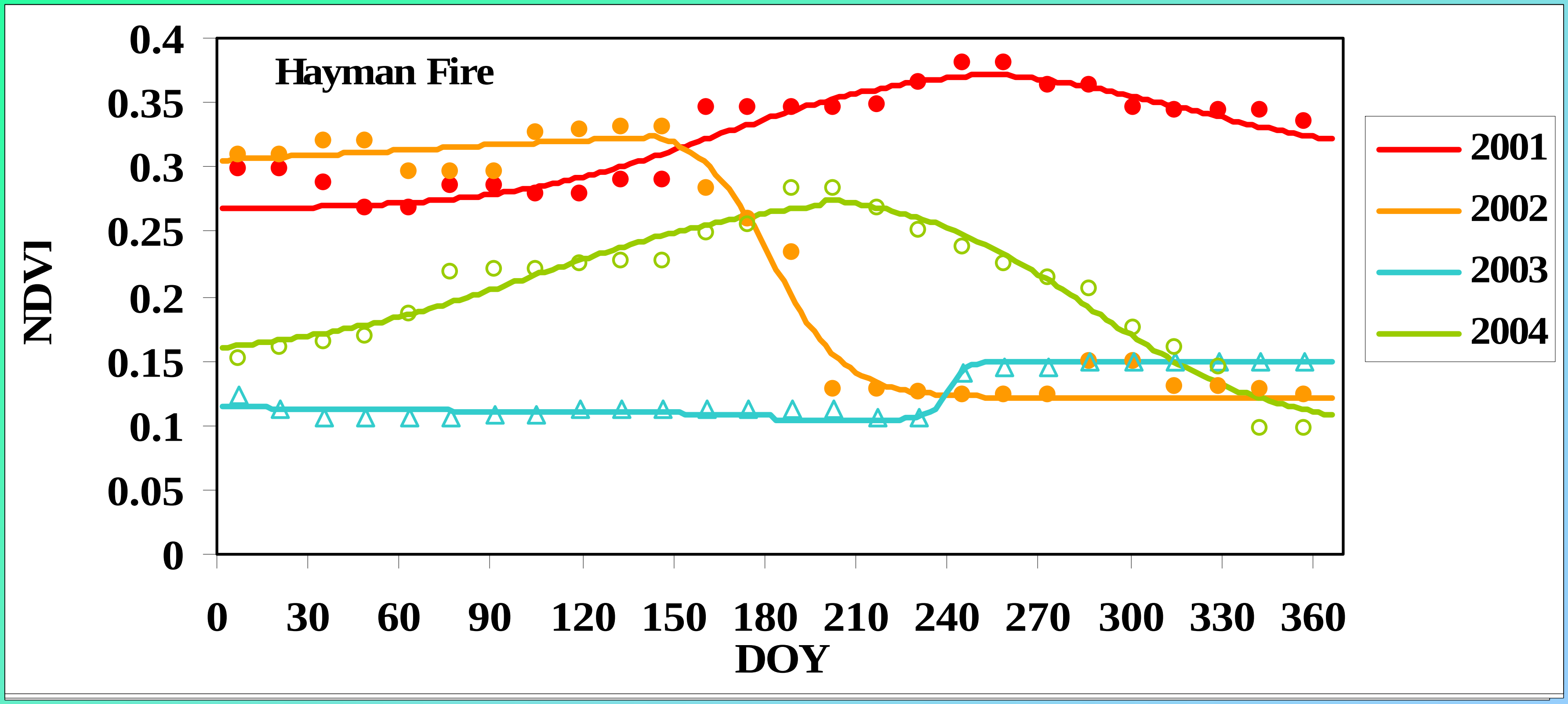
Interannual Variations in NDVI Time Series in Hayman Fire

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