Greening and Seasonality: Multi-scale Approaches

Jiong Jia
Chinese Academy of Sciences
jiong@tea.ac.cn

Yonghong Hu
Hesong Wang
Howie Epstein
Skip Walker

Rovaniemi, March 8, 2010

Available Data

- NOAA/AVHRR GIMMS bi-monthly 8km 1981-2006; Recent update for 2004-2009 and correction (Gimms 3g). Almost 30-yr record.
- NOAA/AVHRR PAL monthly 5.5km 1982-1999
- NOAA/AVHRR LAC: weekly 1990-2010 Alaska, 1986-2006 Canada
- AVHRR Long-term data record: 5.5km daily 1981-2004 (stopped)
- OrbView-2/SeaWiFS: 1.1/4.5km daily/weekly 1997-2010
- Terra/MODIS NDVI/EVI 2000-2010, collection 5 (ORNL subsets)
- Envisat/MERIS: 300m, 3-day, 2002-2010, 390-1040nm
- Landsat MSS, TM, ETM+ over many locations since early 1970s with 1-5 yr interval. Lansat-5 still alive!
- Near future: NPP January 2011; NPOESS March 2014

AVHRR Data Corrections

Compared to newer sensors (e.g. MODIS, MISR), AVHRR lacks of onboard calibration;

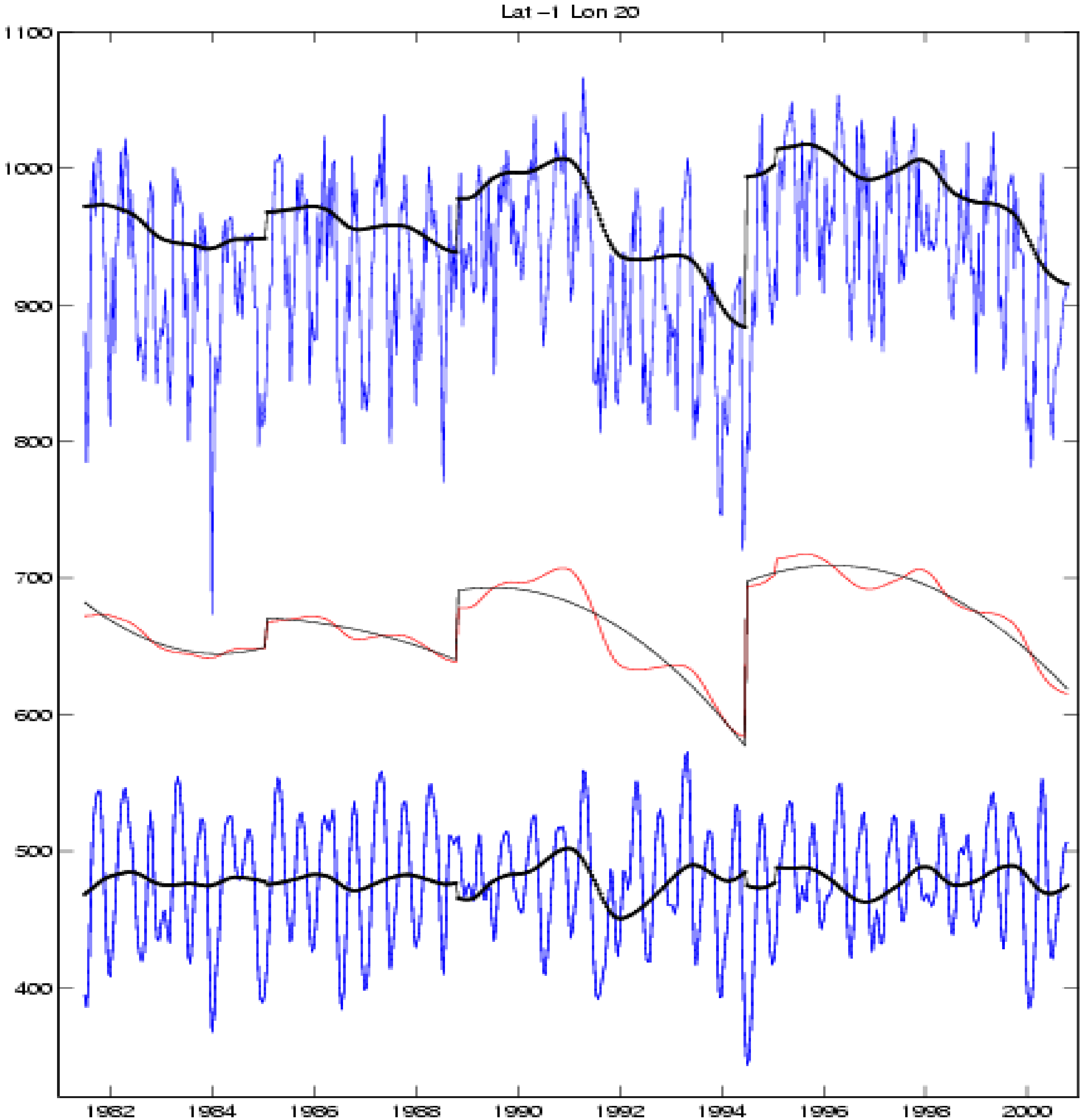
Low SNR due to cloud contamination and water vapor (Mostly corrected with MVC);

Geometric registration errors (Mostly corrected);

Volcanic aerosol effects for 1982-1984 and 1991-1994 (partly corrected);

Residual sensor degradation and viewing angle effects due to satellite drift (partly corrected);

Critical uncertainty over most recent years.



Use of EMD technique and the removal of SZA-correlated trends

Top: Before draft correction,

Middle: trend removed

Bottom: resulting series.

What we have done

Unmix the signal of vegetation and select areas with relatively homogeneous vegetation with MODIS and Landsat ETM+ for each subzone and boreal forest;

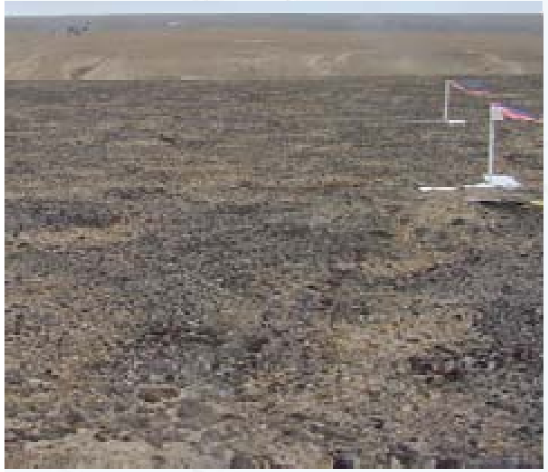
Mask pixels of water and ice/snow in analysis;

Temporal-spatial analysis of peak and time-integrated NDVI by continents and subzones;

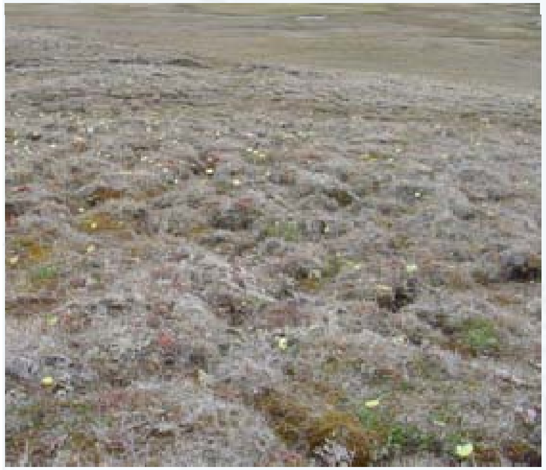
Analysis of vegetation phenology;

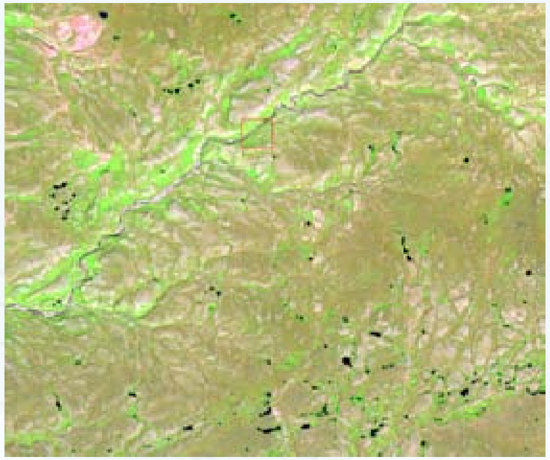
Examining the uncertainties in interpreting trends of greenness.

Vegetation shown on photos and Landsat ETM+ images

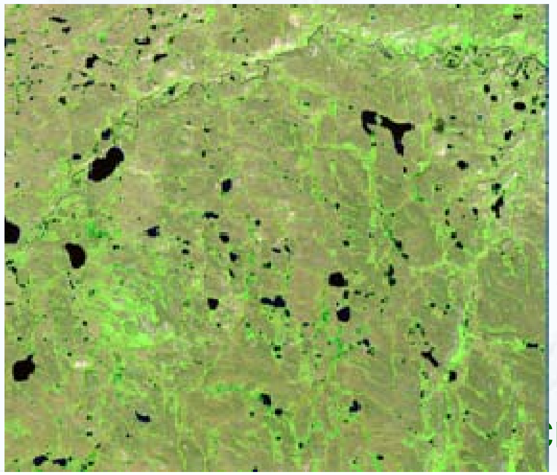


Subzone A



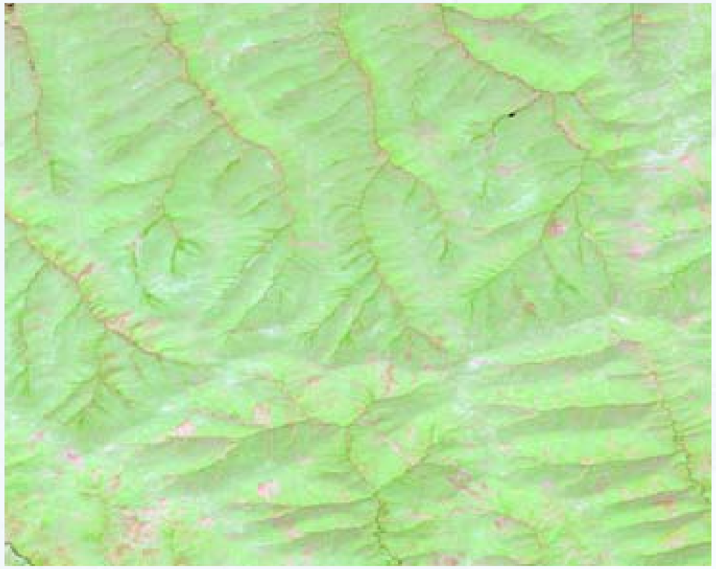


Subzone B



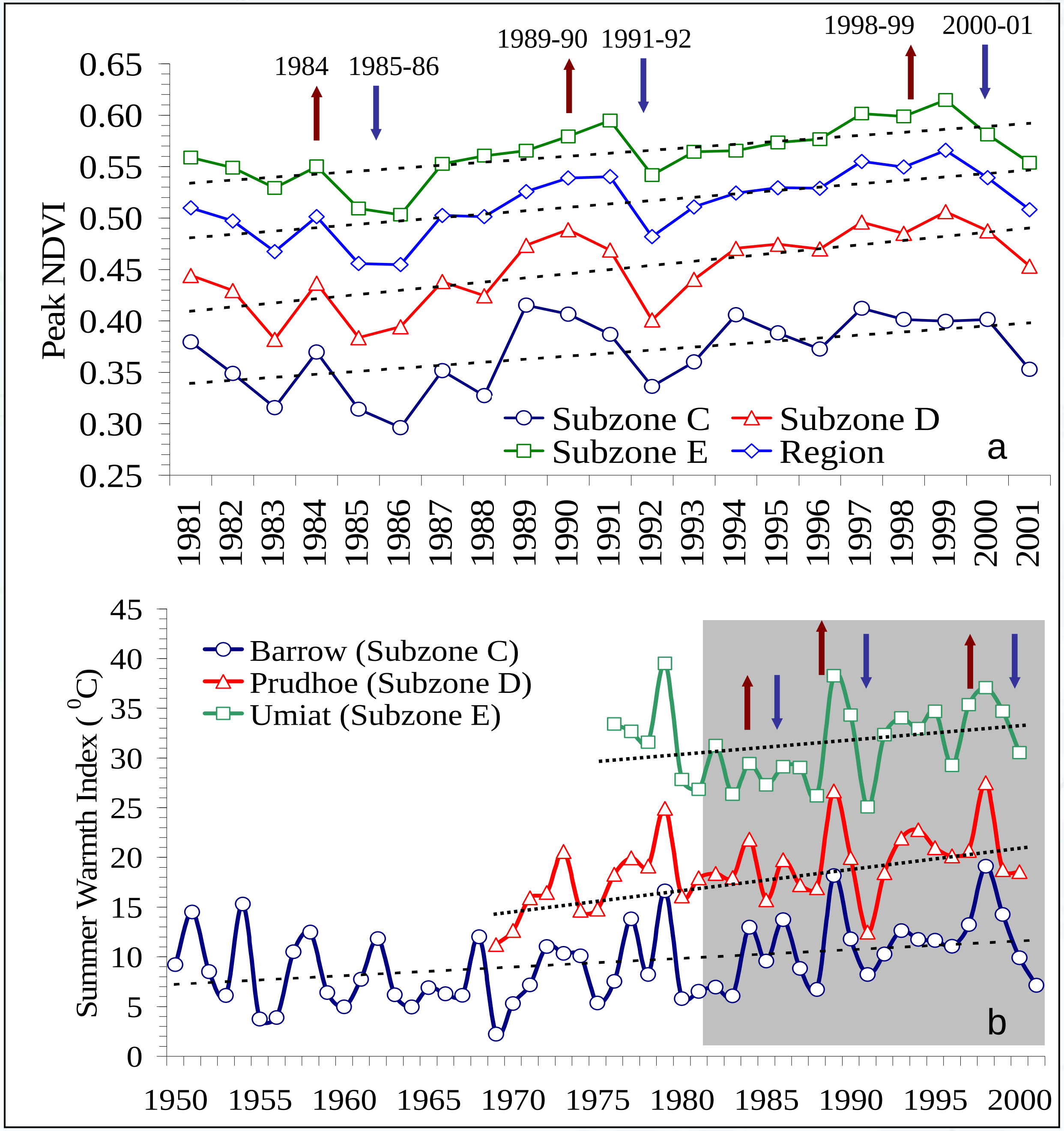
Subzone C

Vegetation shown on photos and Landsat ETM+ images



Subzone D

Subzone E



NDVI Increases with Warming, 1981-2001

- Peak greenness increased by 13-19% in two decades.

- This increase is higher than that in high-latitude N America

- With brief declines in 1985-86, 1992, and 2000-01

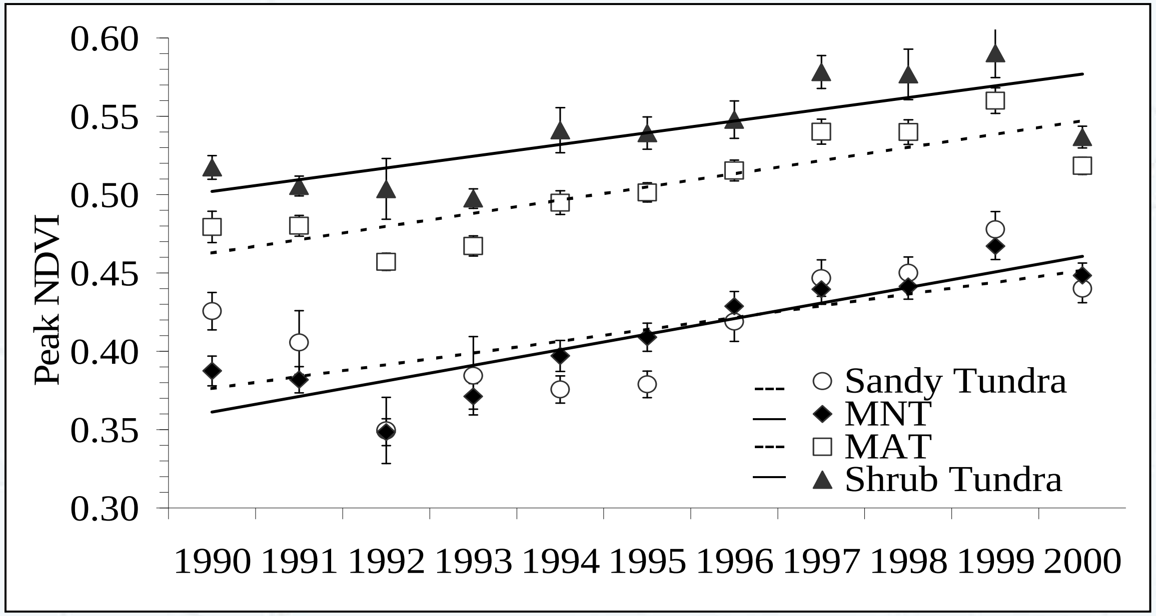
- Greatest increase in Subzone D

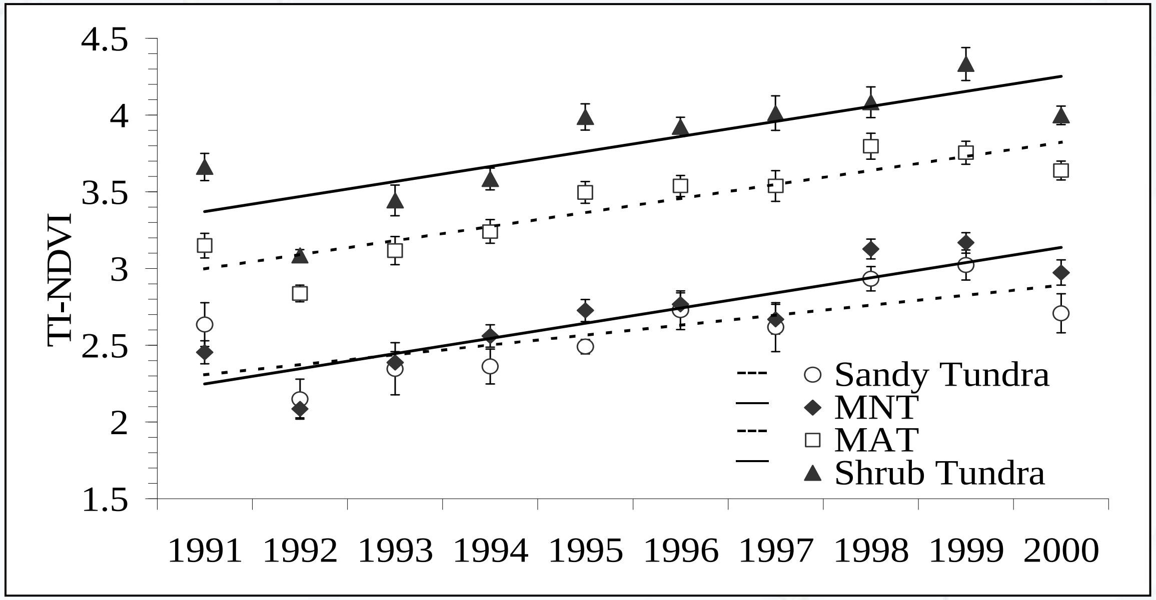
- Similar peaks and declines in SWI as arrows show

- The increase is likely responsive to SWI rise of 0.16-0.34 °C/yr.

Jia et al. *GRL*, 2003

green.tea.ac.cn





NDVI Increases for all tundra types in 90s

Peak NDVI and TI-NDVI sampling categorized by tundra types.

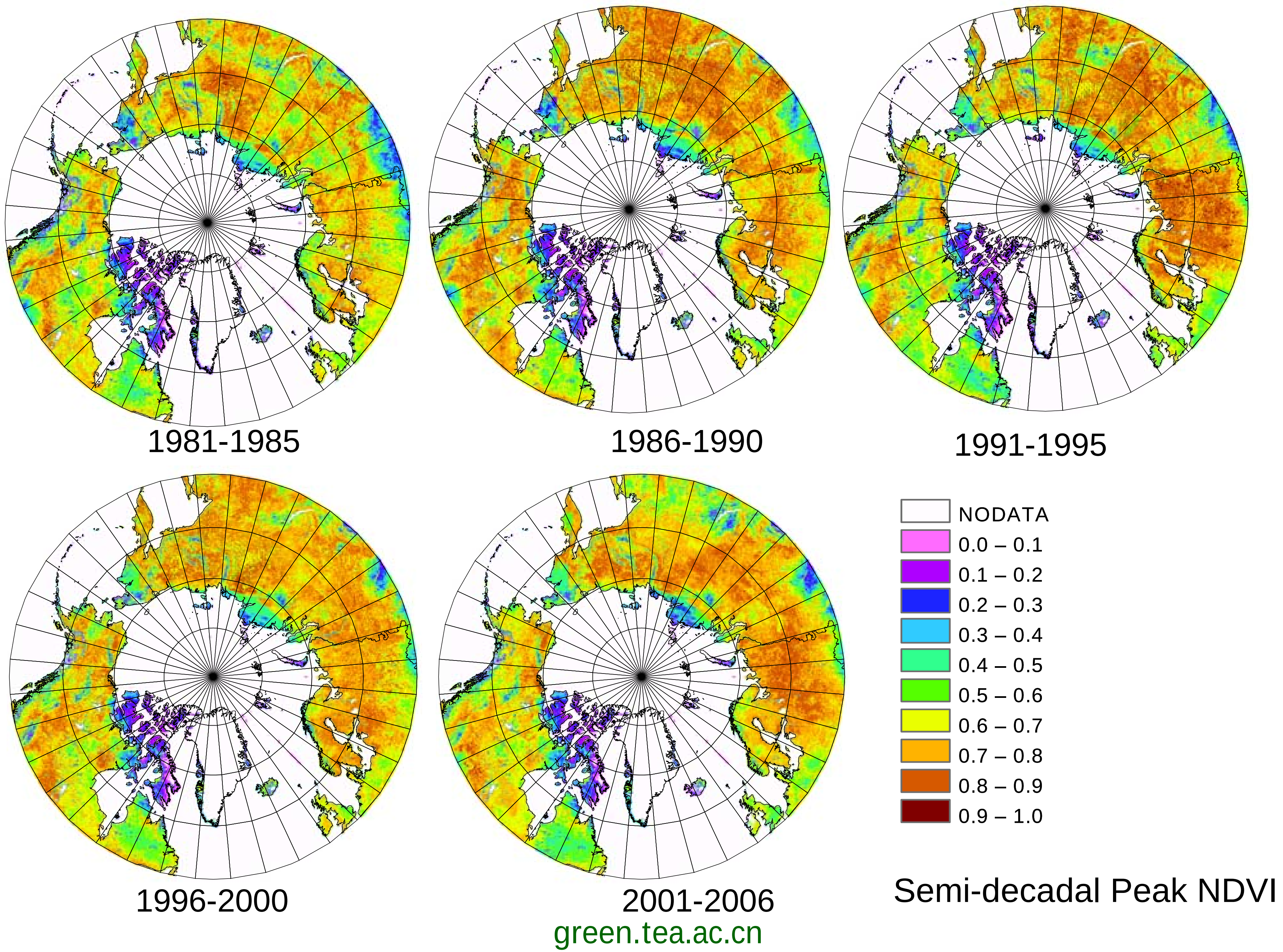
Both indices increased for all tundra types: averagely 13.6% for peak NDVI and 17.7% for TI-NDVI.

Moist nonacidic tundra has the Greatest decadal increase in NDVI

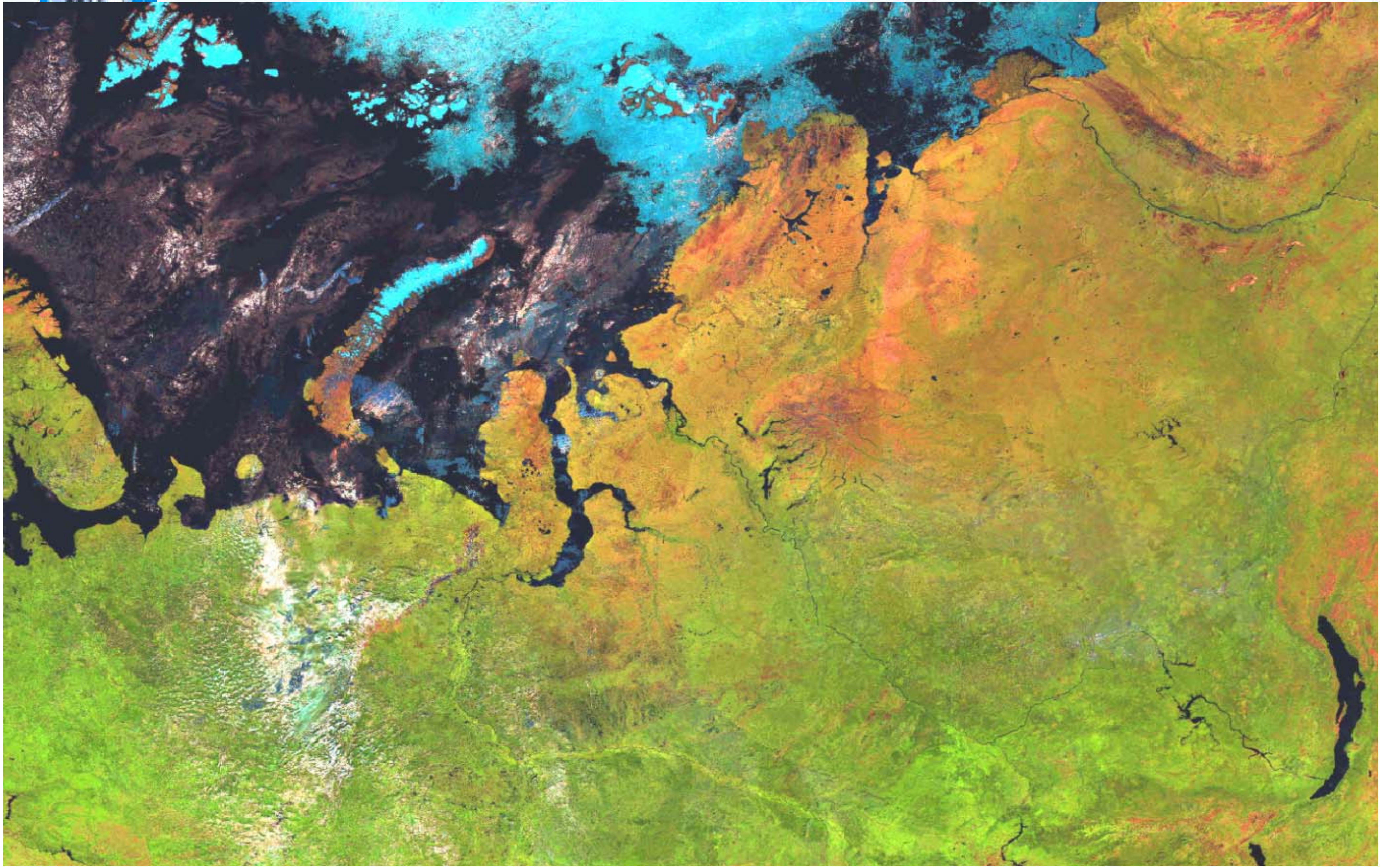
Higher TI-NDVI increased were found in southern types.

NDVI decline in 1992 after Mt Pinatubo eruption occurred for all tundra types.

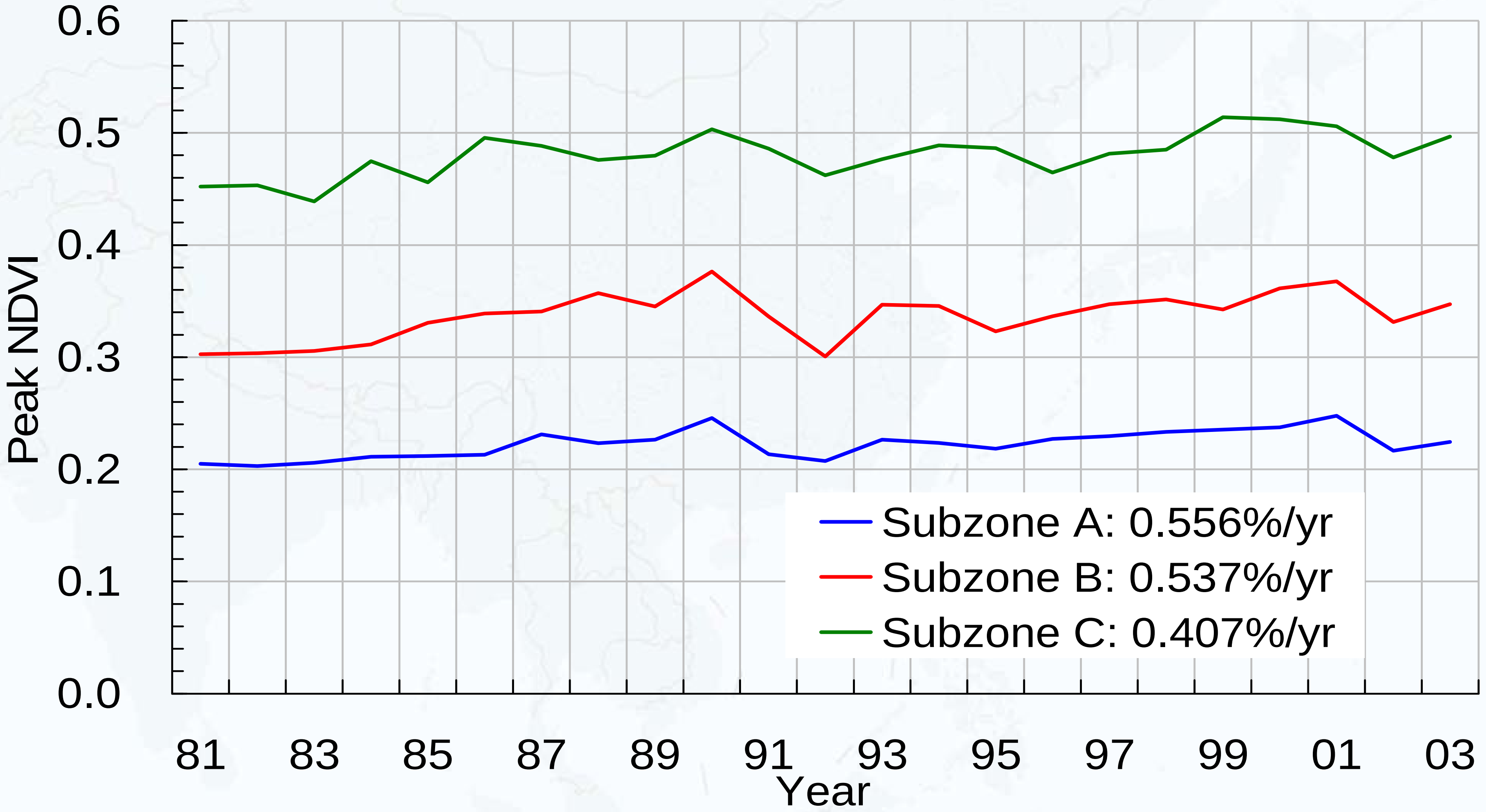
Jia et al. *GRL*, 2003


1981-1985
1986-1990
1991-1995
1996-2000
2001-2006
NODATA
0.0 – 0.1
0.1 – 0.2
0.2 – 0.3
0.3 – 0.4
0.4 – 0.5
0.5 – 0.6
0.6 – 0.7
0.7 – 0.8
0.8 – 0.9
0.9 – 1.0
Semi-decadal Peak NDVI
green.tea.ac.cn

Yamal land cover

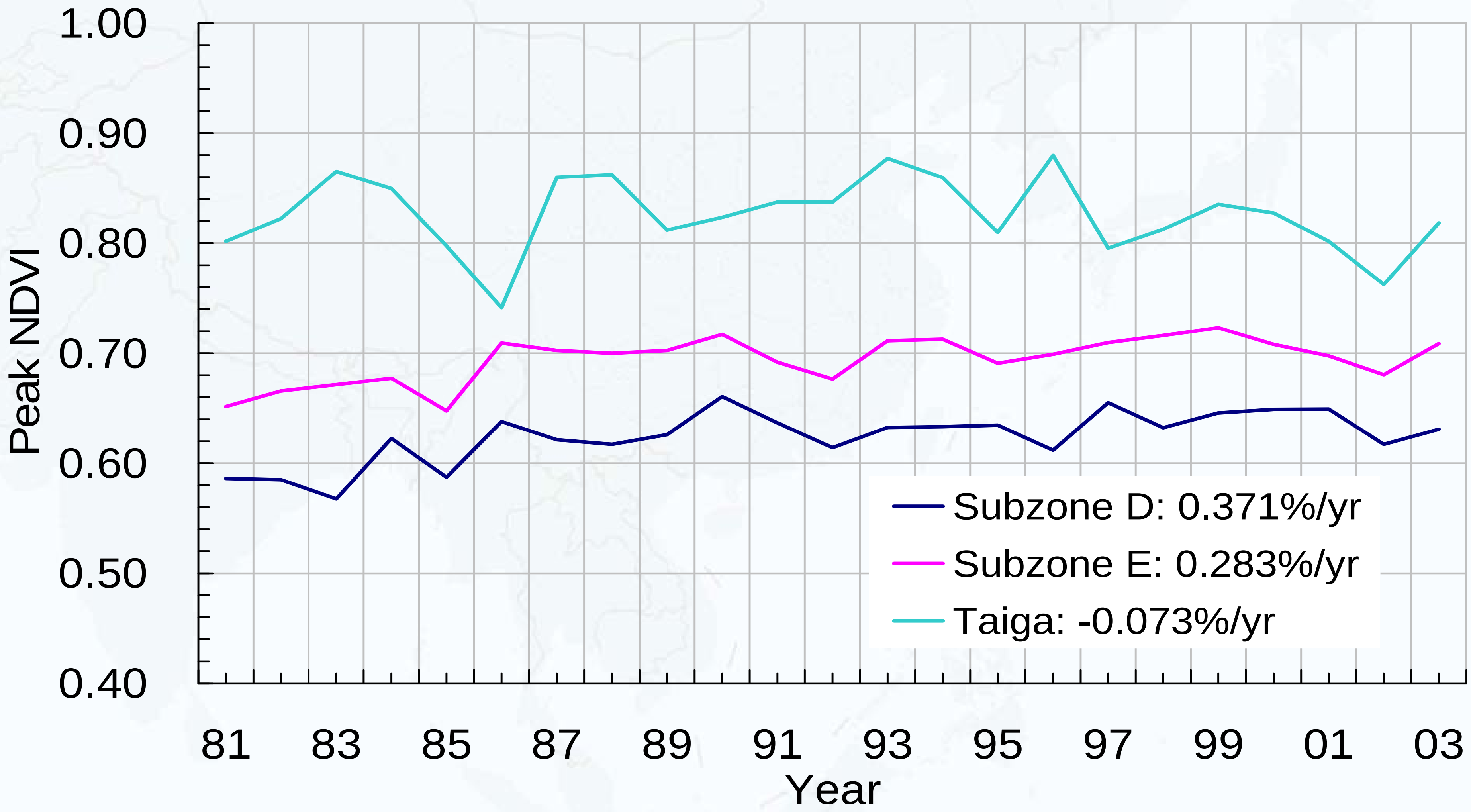


Russia High Arctic

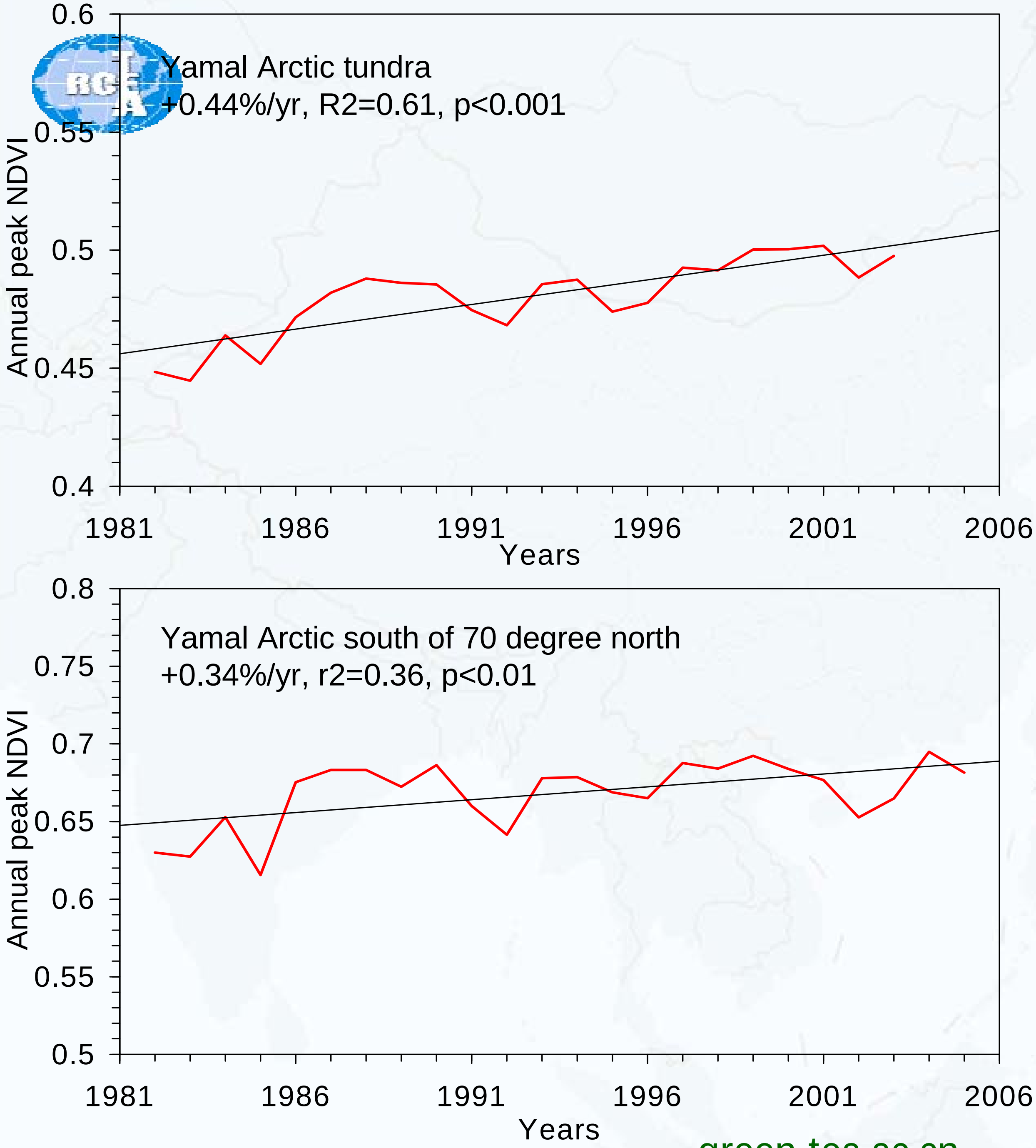


green.tea.ac.cn

Russia Low Arctic and Taiga



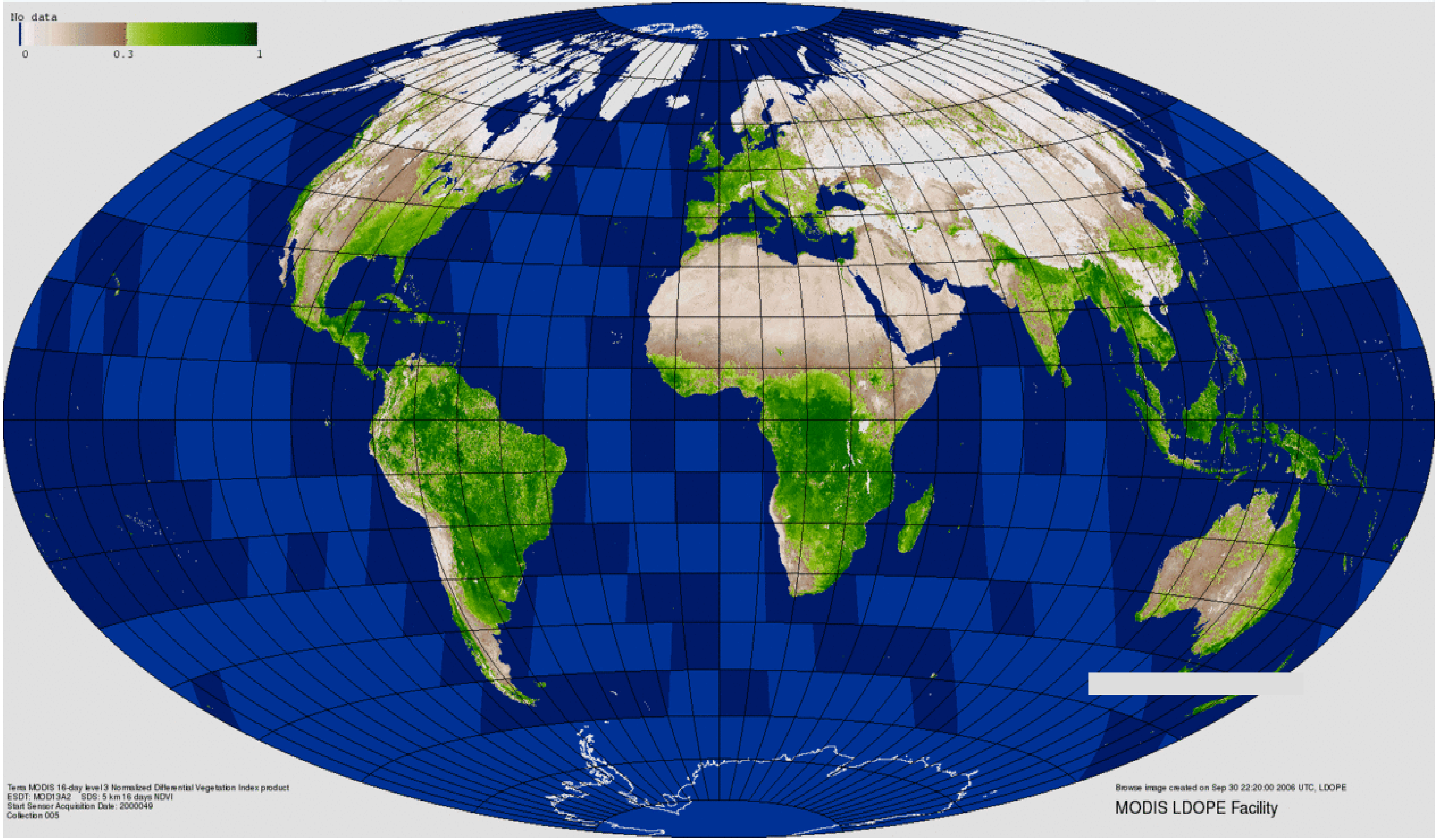
green.tea.ac.cn



Changes of annual peak vegetation greenness (NDVI) over tundra biome from 1982-2003 (top) and below 70 degree north from 1982-2006 (bottom) in Yamal Arctic, Russia as detected by NOAA AVHRR time series data.

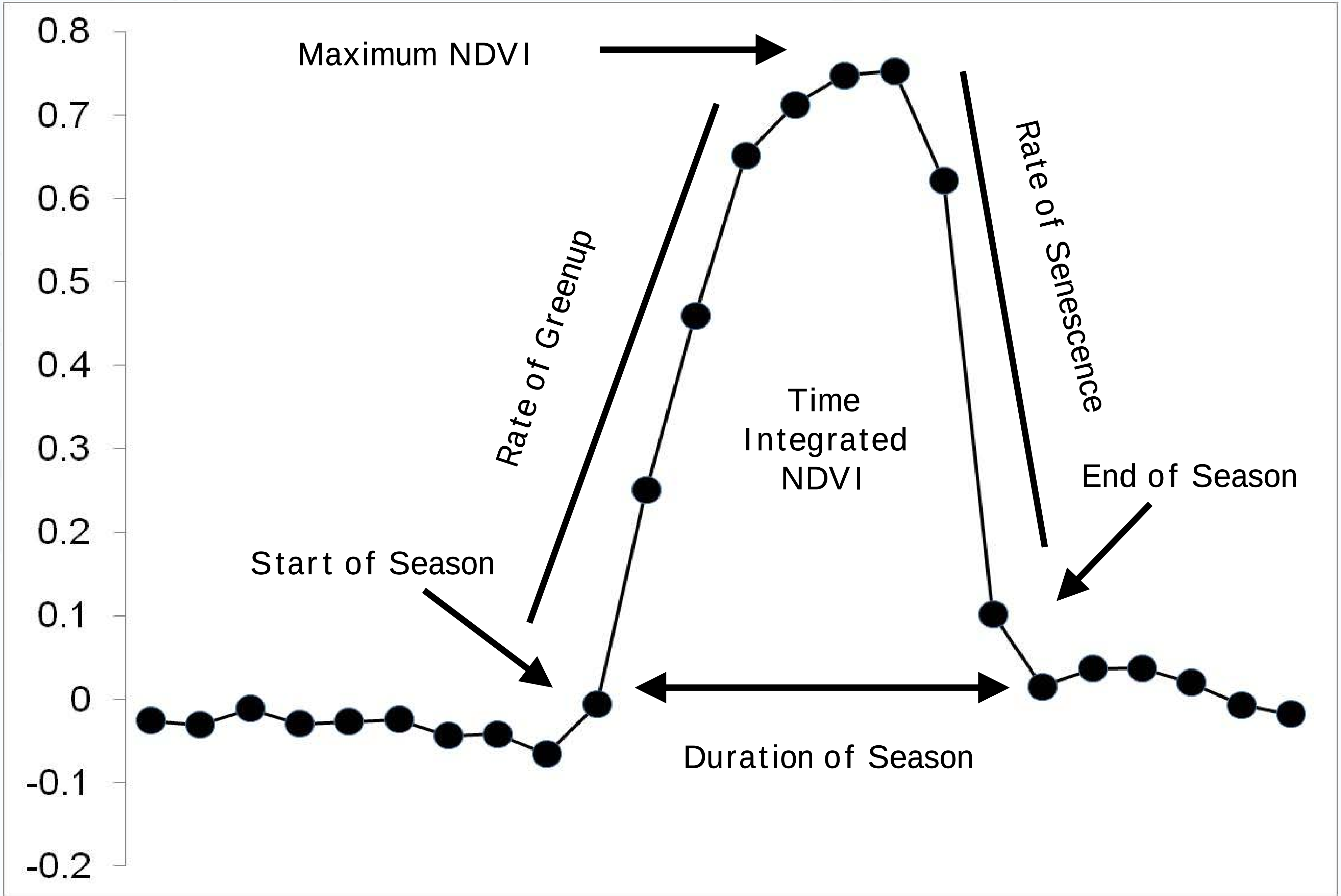
green.tea.ac.cn

Seasonal Pattern of Vegetation Greenness



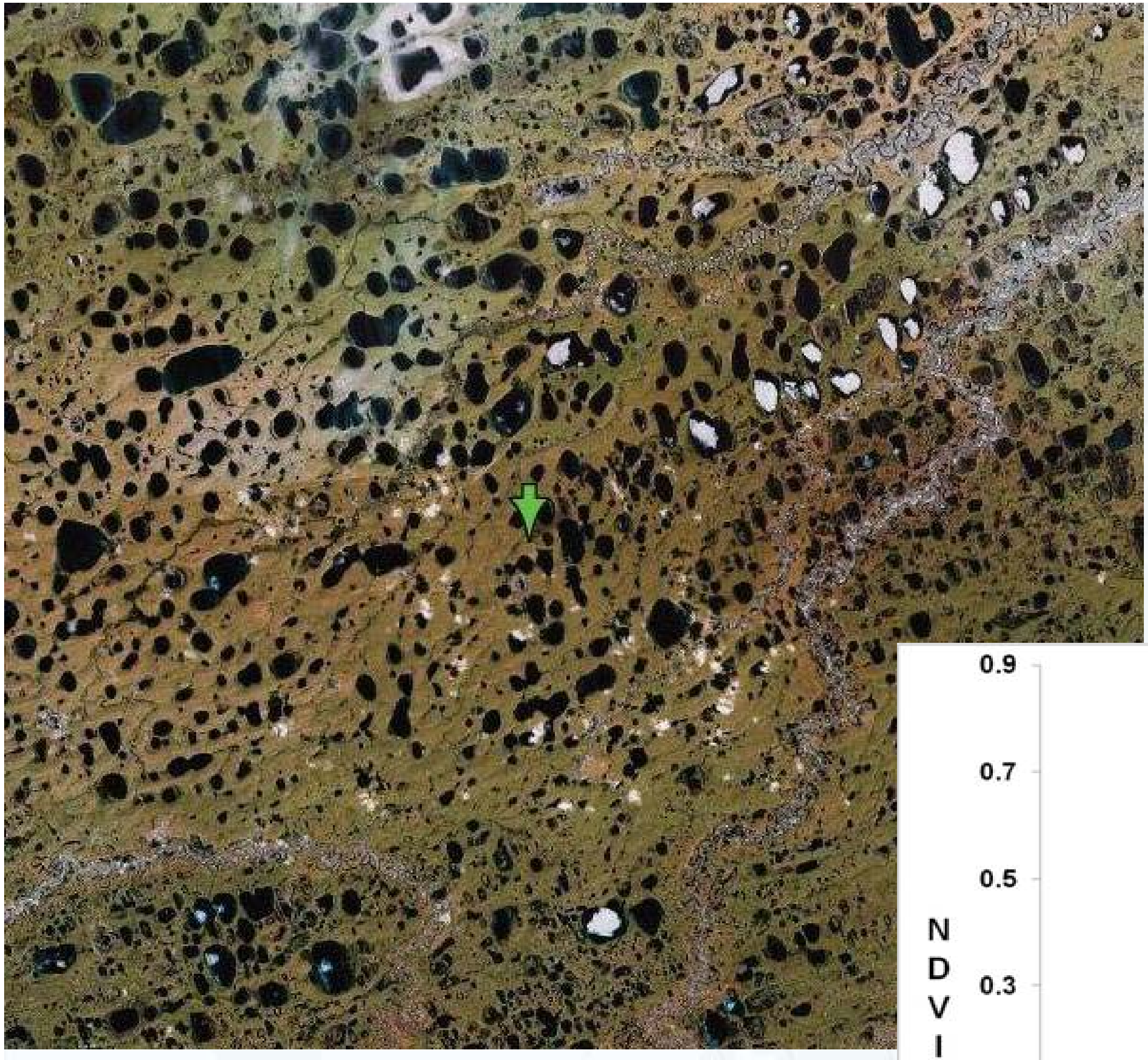
Phenological Metric → Phenological Interpretation

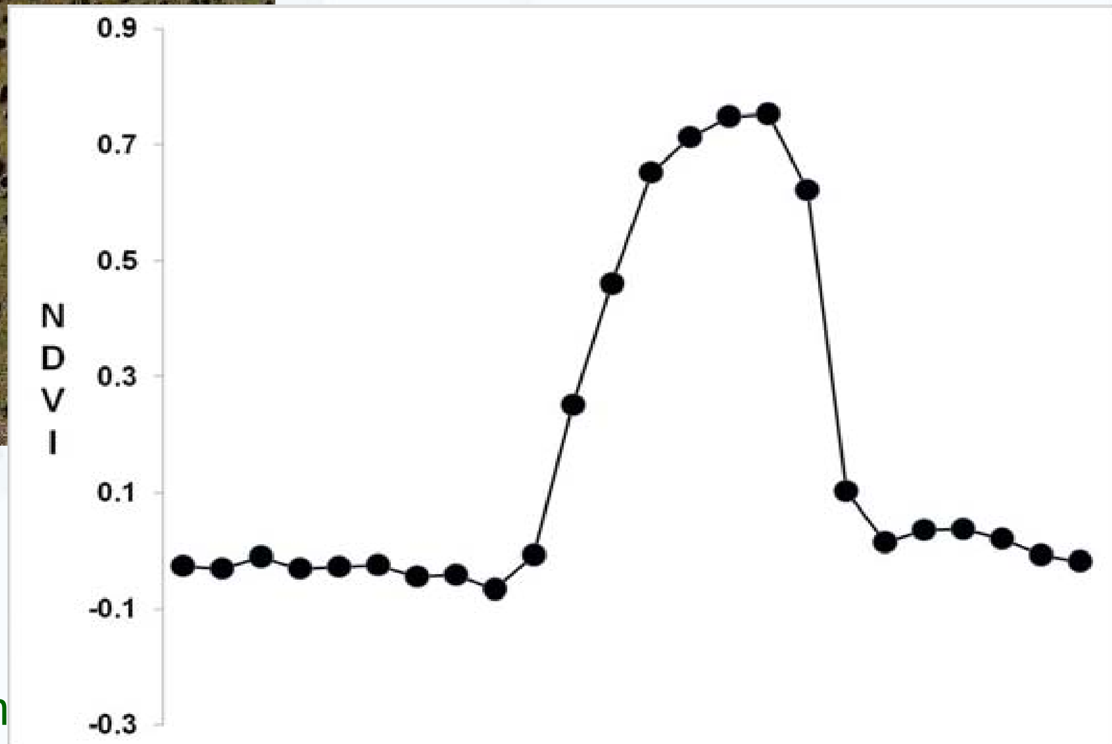
- Onset of greenness:
  beginning of measurable photosynthesis.
- Senescence of greenness:
  end of measurable photosynthesis.
- Length of the growing season:
  duration of photosynthetic activity.
- Time of Maximum NDVI:
  time of maximum photosynthesis.
- NDVI at peak:
  level of photosynthetic activity at peak season.
- Seasonal integrated NDVI:
  photosynthetic activity during the growing season.



0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
Maximum NDVI
Rate of Greenup
Rate of Senescence
Time Integrated NDVI
End of Season
Start of Season
Duration of Season

de Beurs





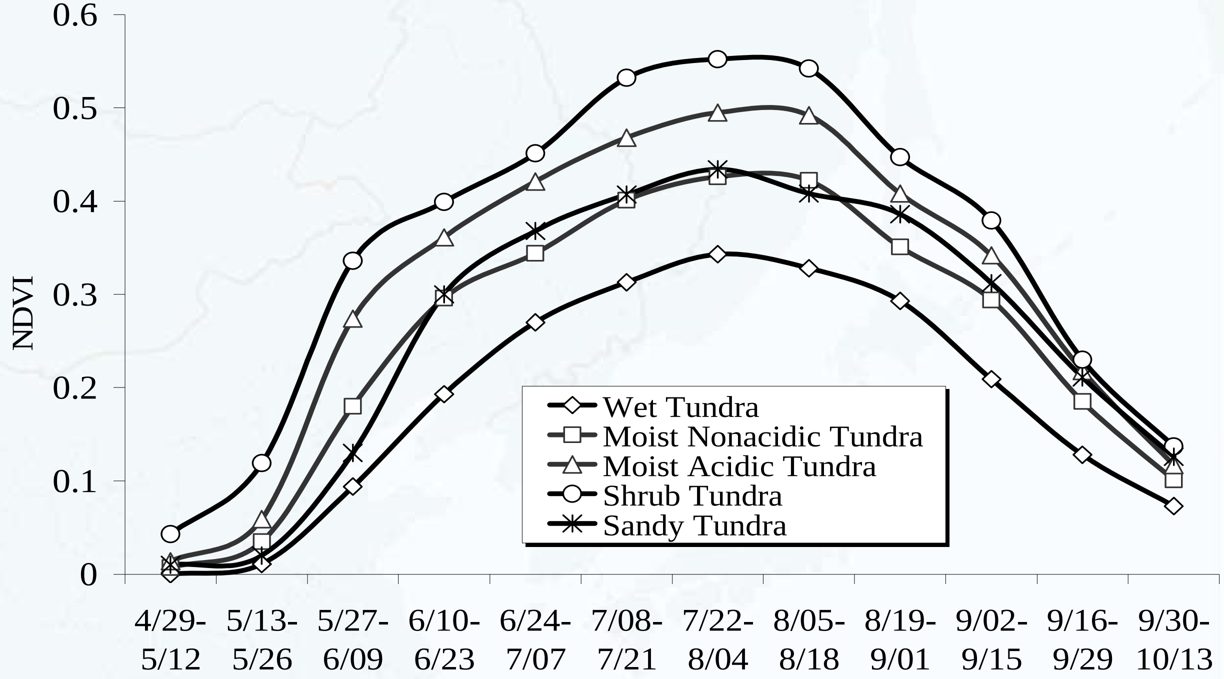
Seasonal NDVI curve over tundra
FieldSpec read

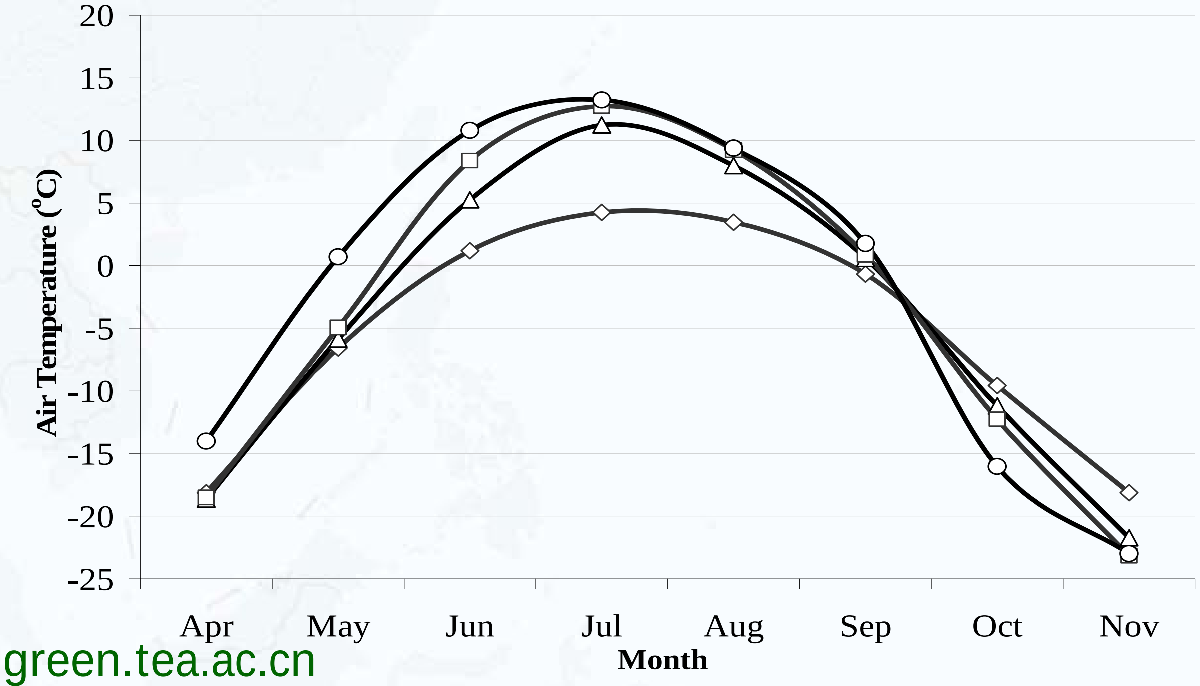
Tundra Northern Alaska

de Beurs

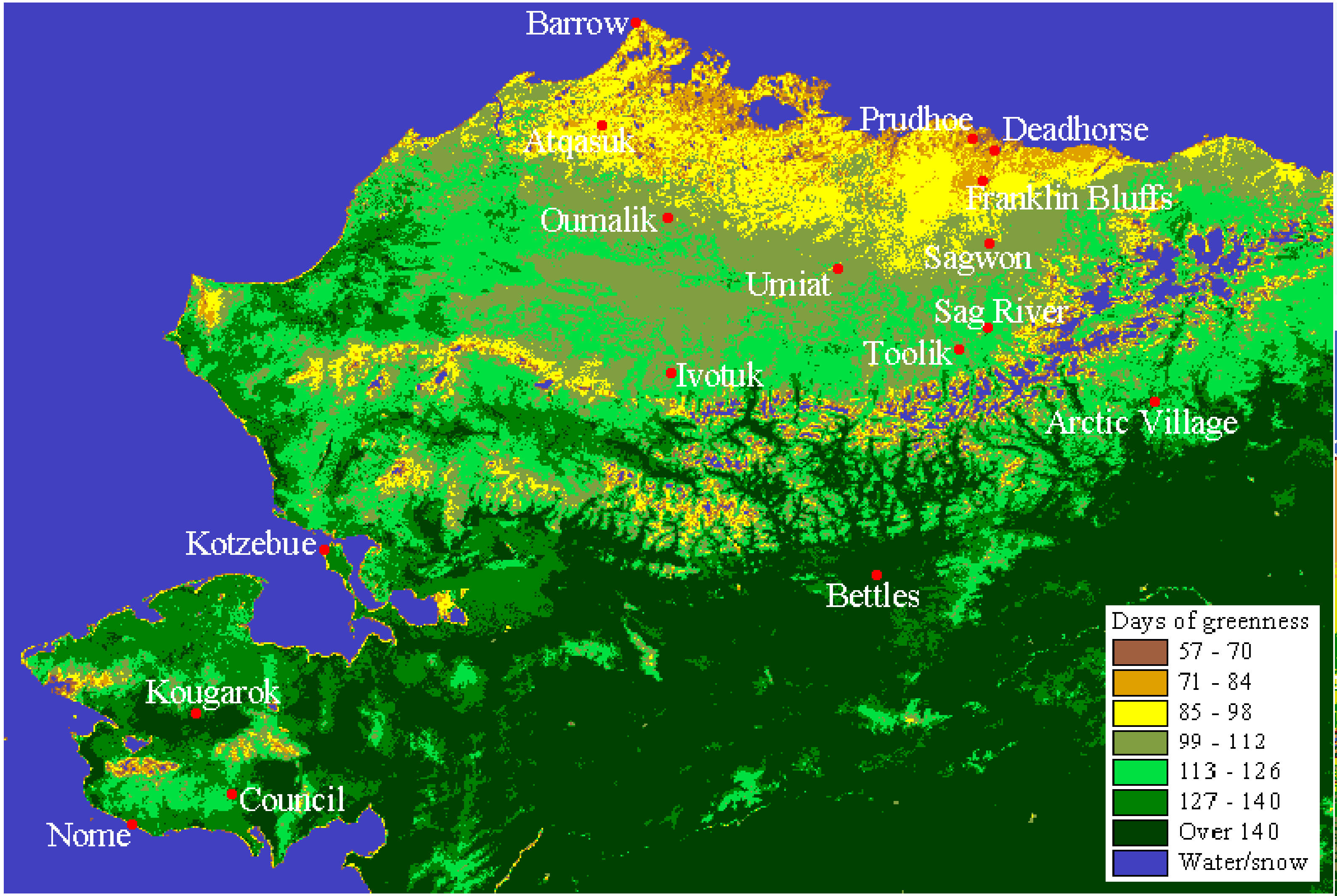
green

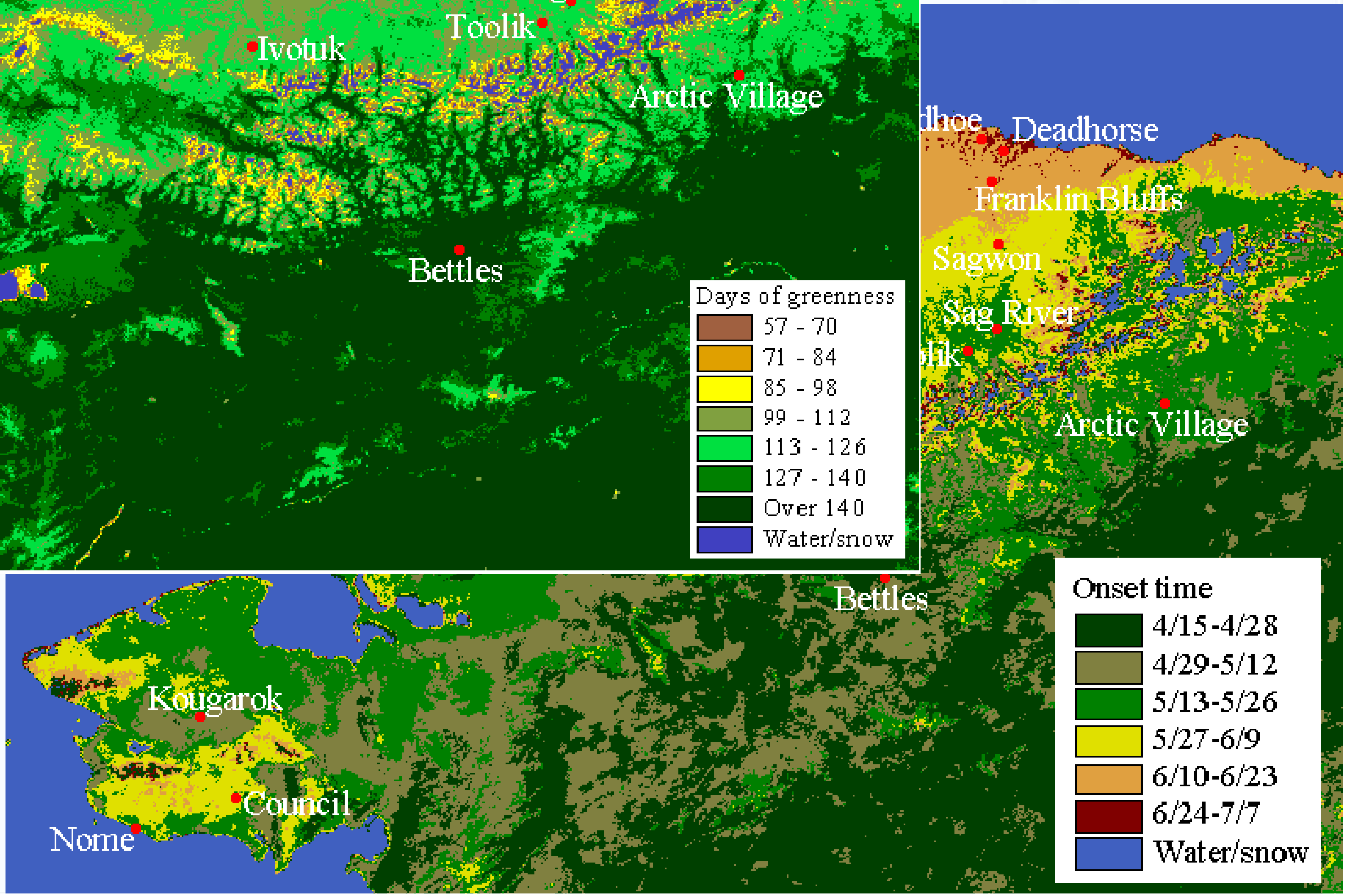
LAC AVHRR Seasonal NDVI Alaska tundra





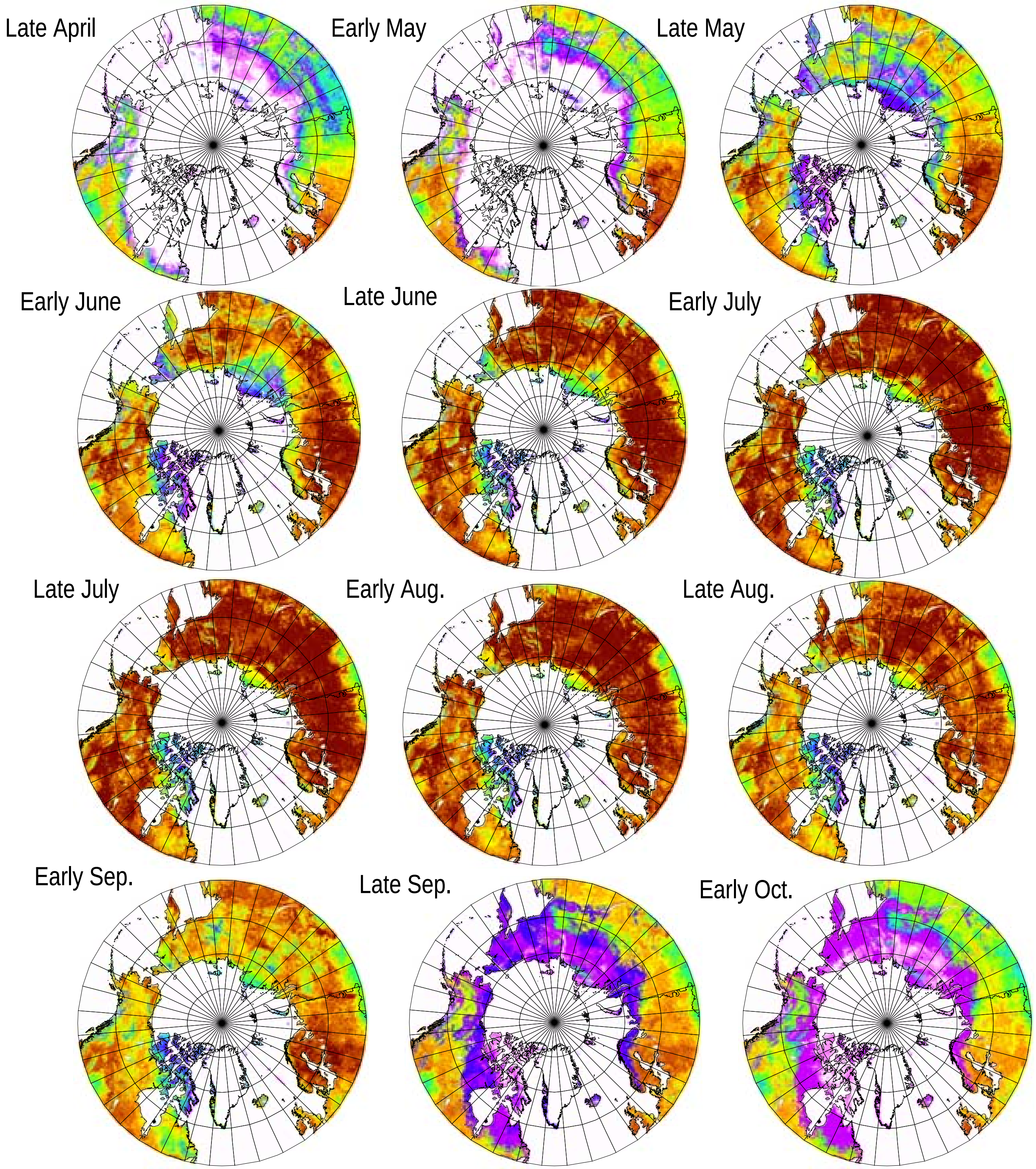
Jia et al, IJRS, 2002

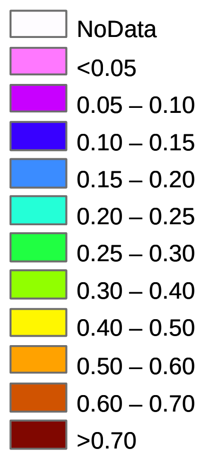




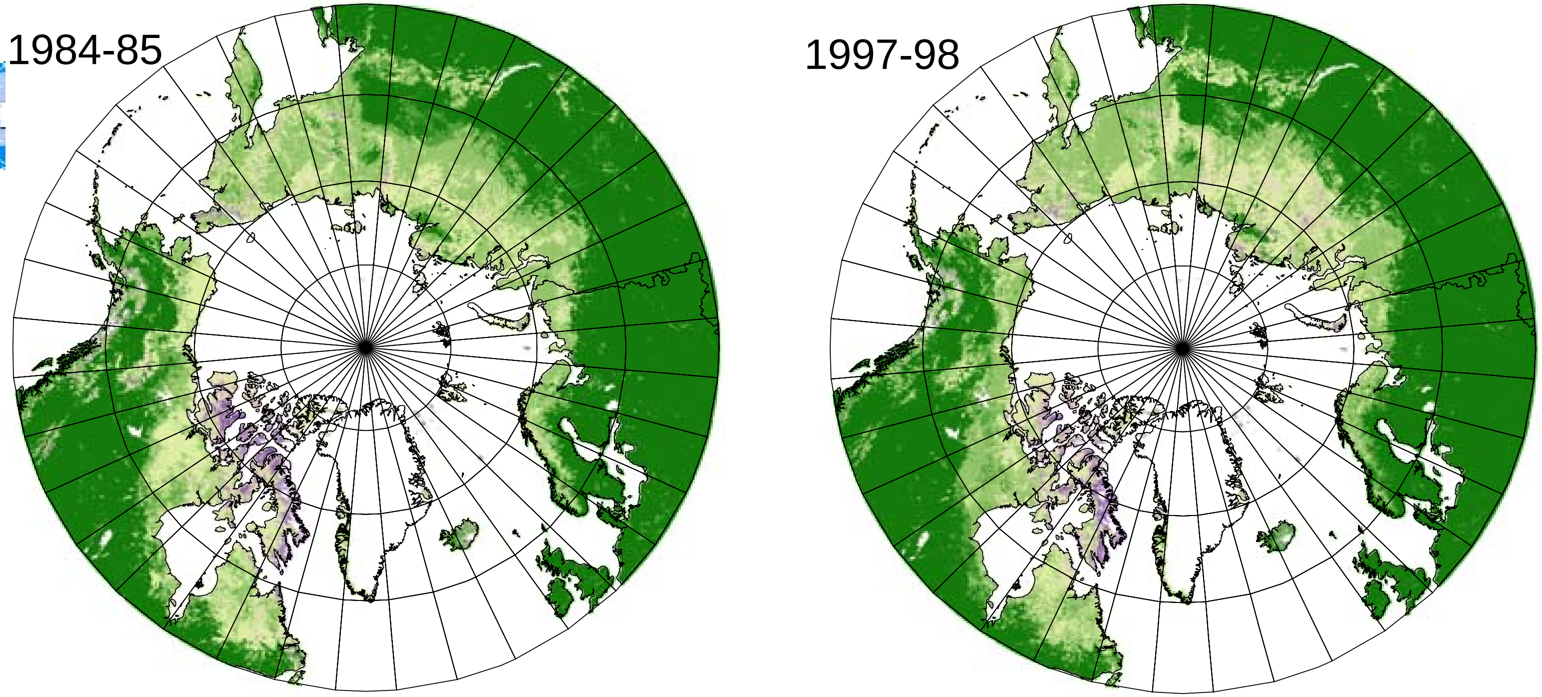
Jia et al. *IJRS* 2002

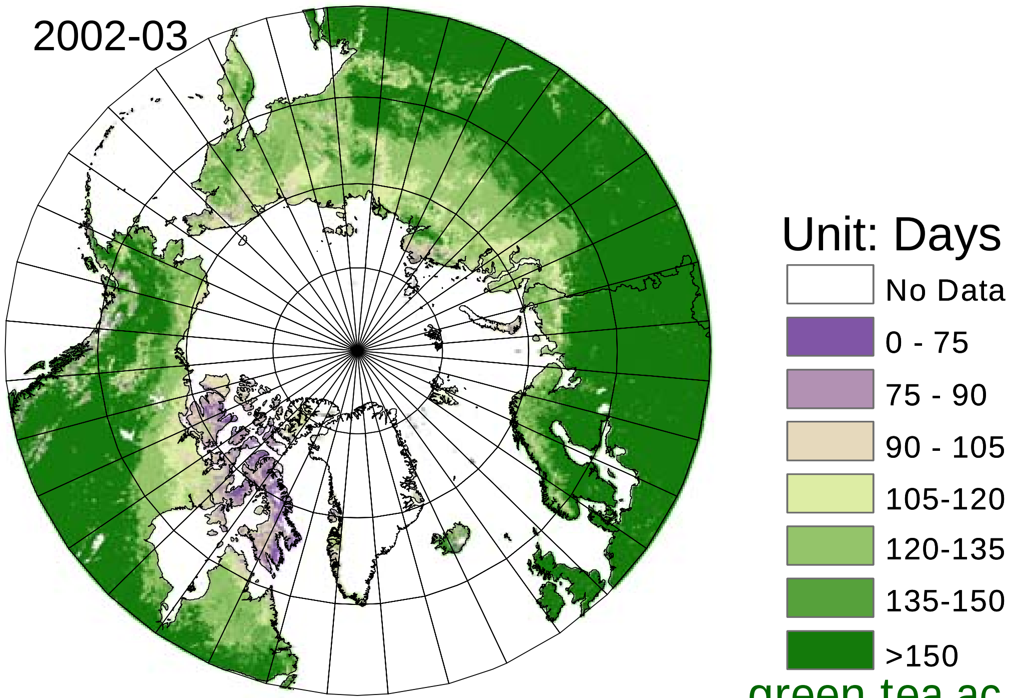
Gimms 1981-2003 Seasonal NDVI Circumpolar



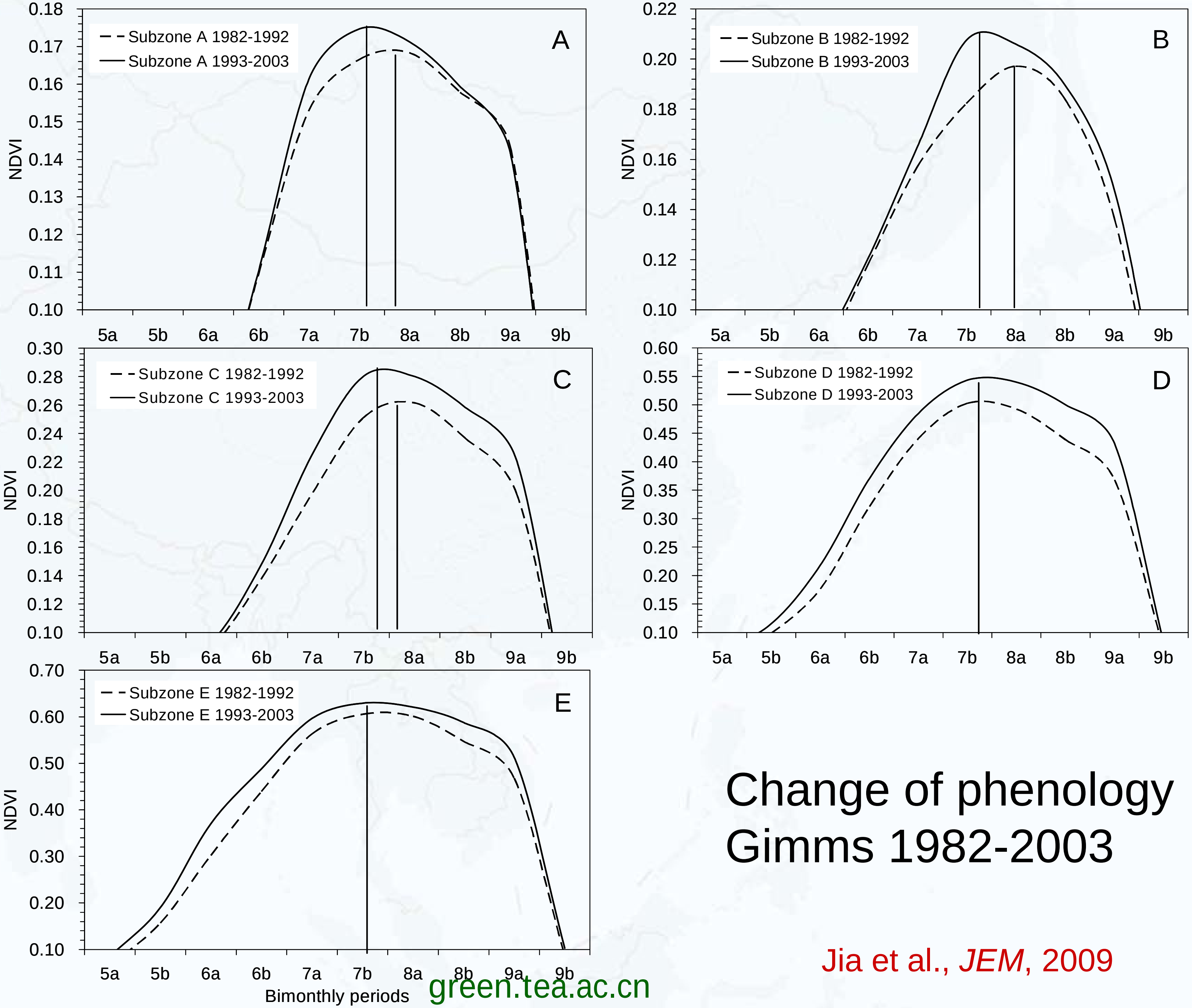


Gimms Length of growing season





green.tea.ac.cn

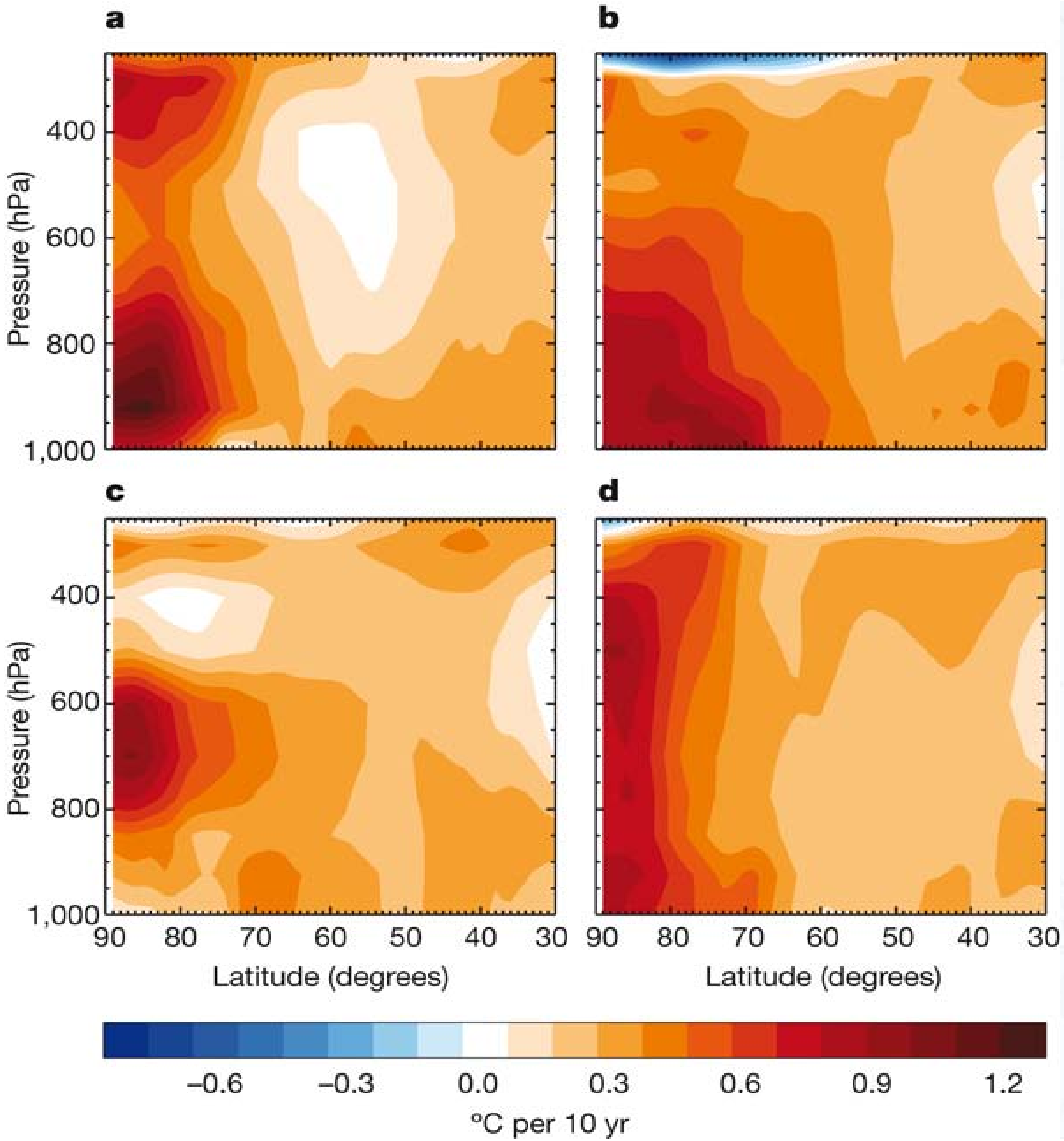


Change of phenology
Gimms 1982-2003

Jia et al., *JEM*, 2009

What's Behind the Greening

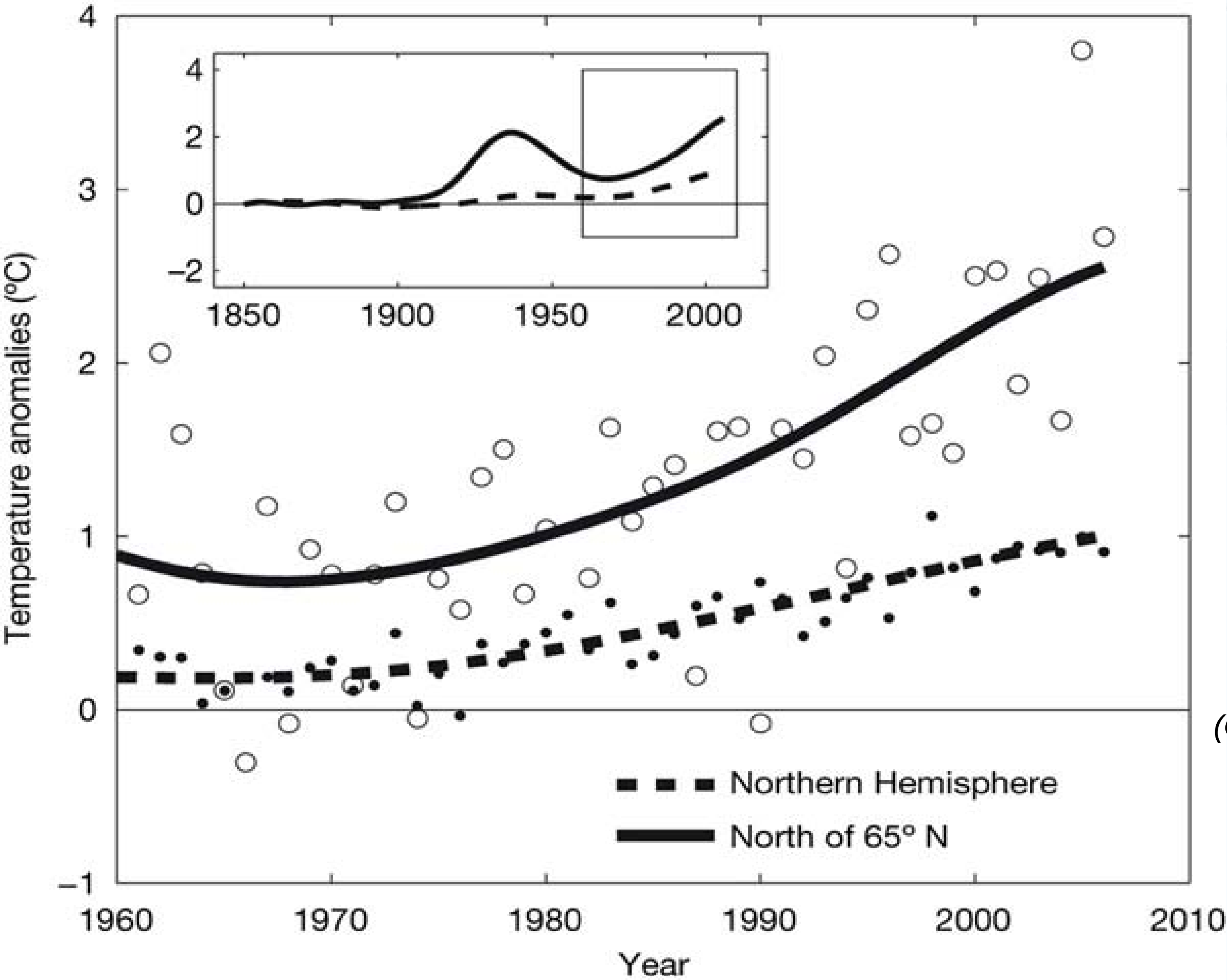
- General trend of global and regional warming;
- Stronger warming signals in the north;
- Increase in NPP and biomass;
- Different responses of PFTs to climate change;
- Fire disturbances and hydrological changes



Trends of air temperature

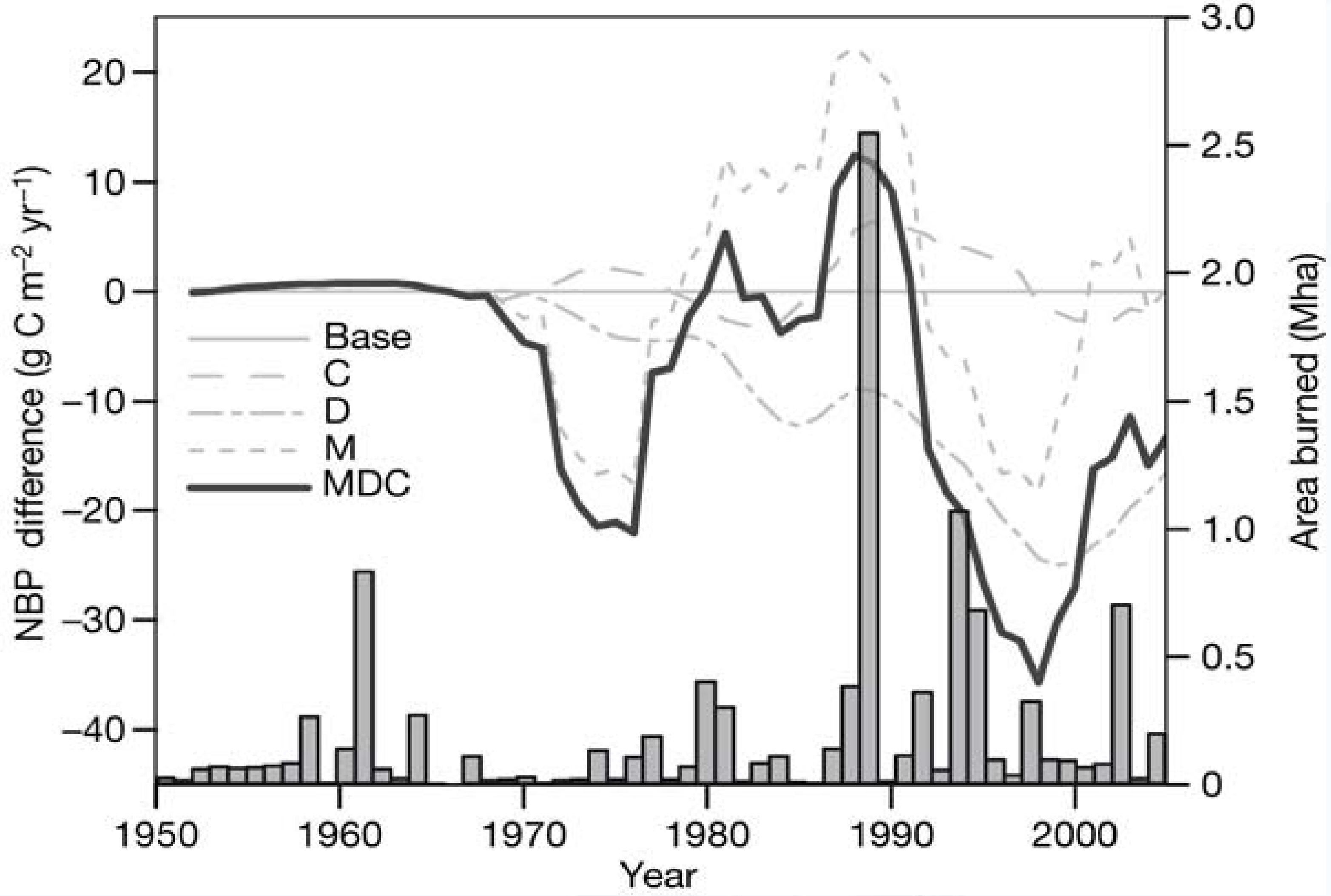
(Graversen et al, 2008, Nature)

Temperature anomalies



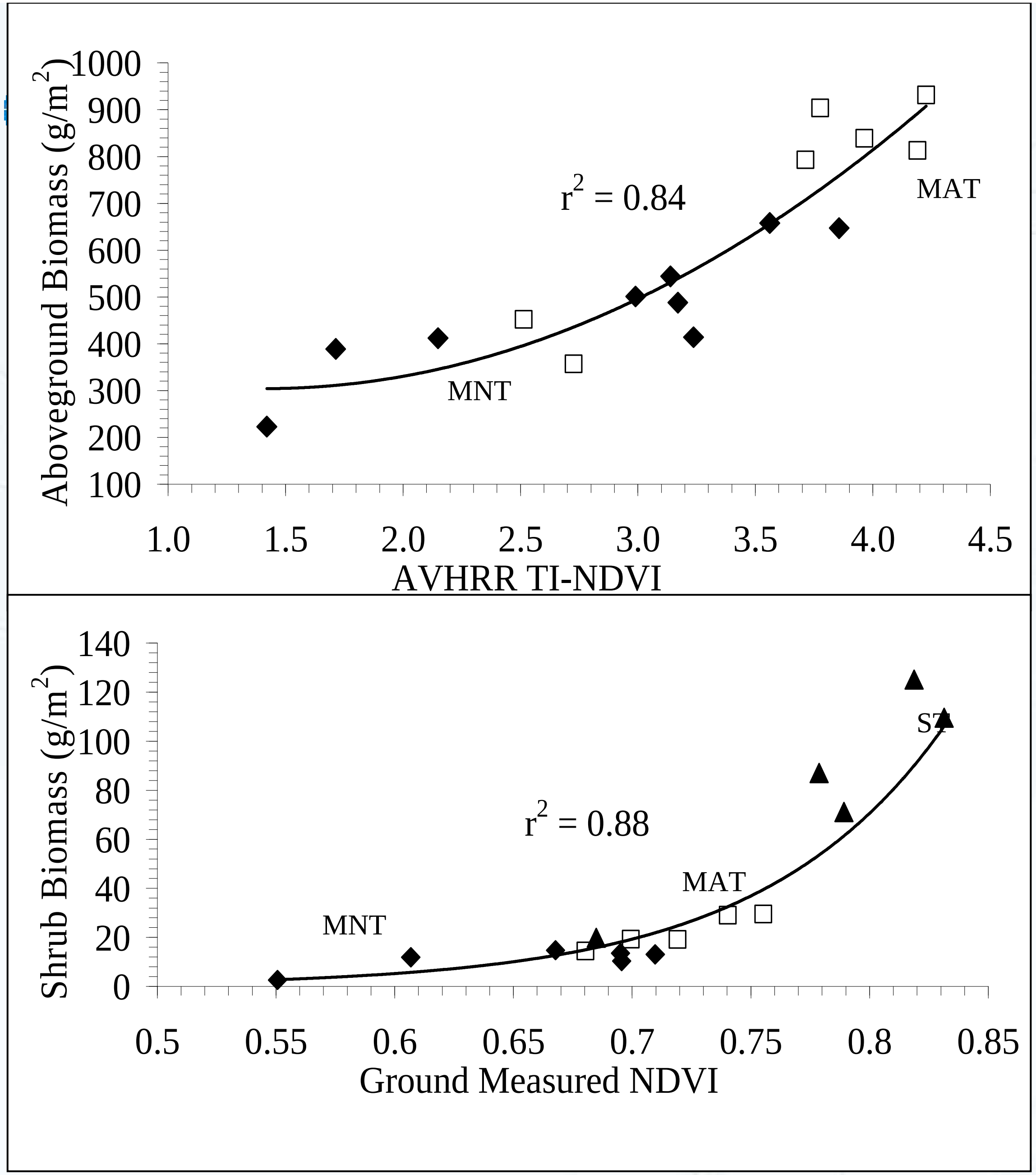
(Graversen et al, 2008, Nature)

Fire and NPP anomalies



green.tea.ac.cn

(Bond-Lamberty, 2007, Nature)



NDVI vs. Biomass

- NDVI and aboveground plant biomass are positively correlated on both regional and local scales.

- NDVI explains 84-88% of the variance in plant biomass.

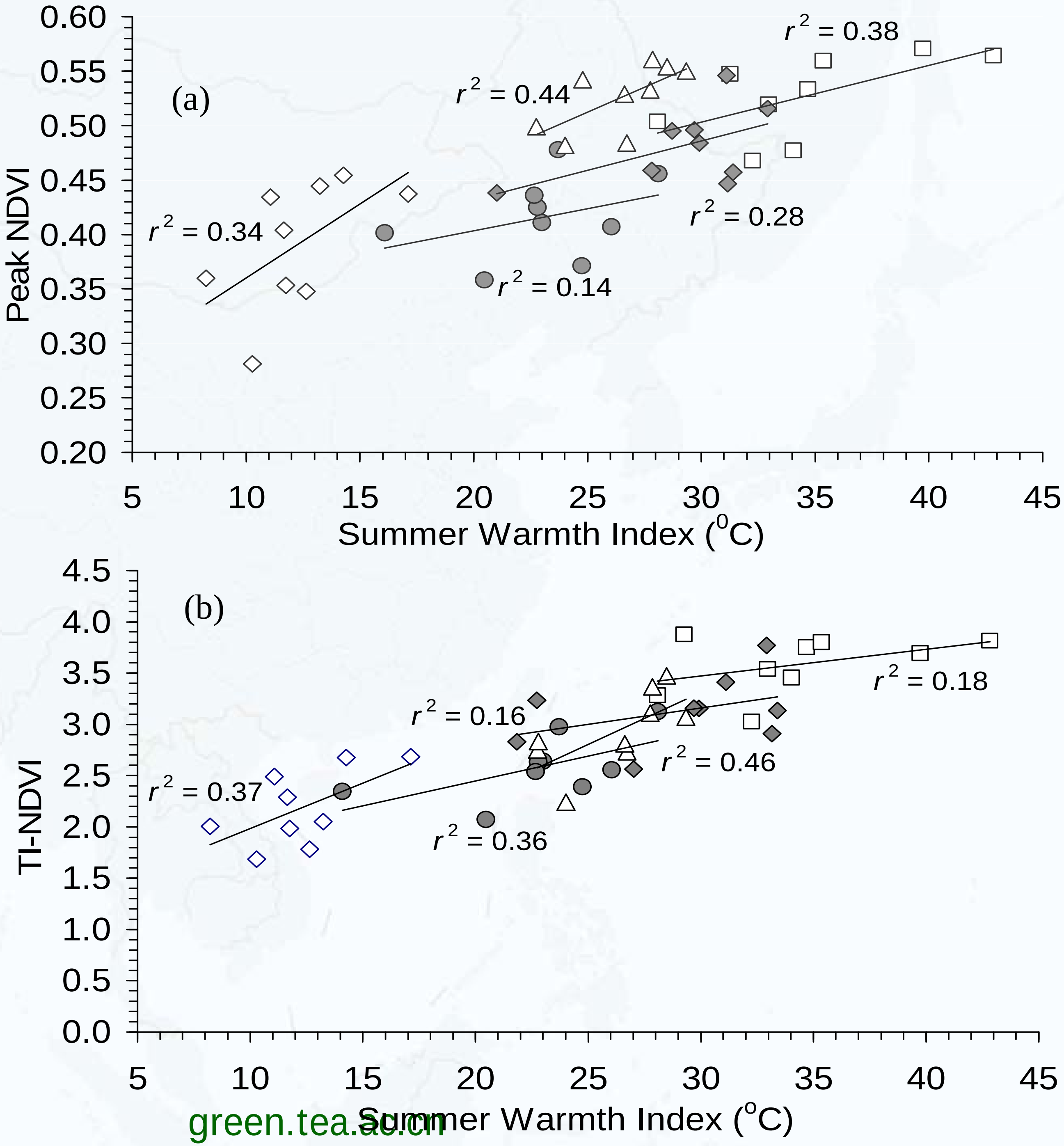
-NDVI increase corresponds to a ~20% (40-180 g/m^2) increase in plant biomass.

- Slight increase in biomass in MNT can greatly contribute to a higher NDVI

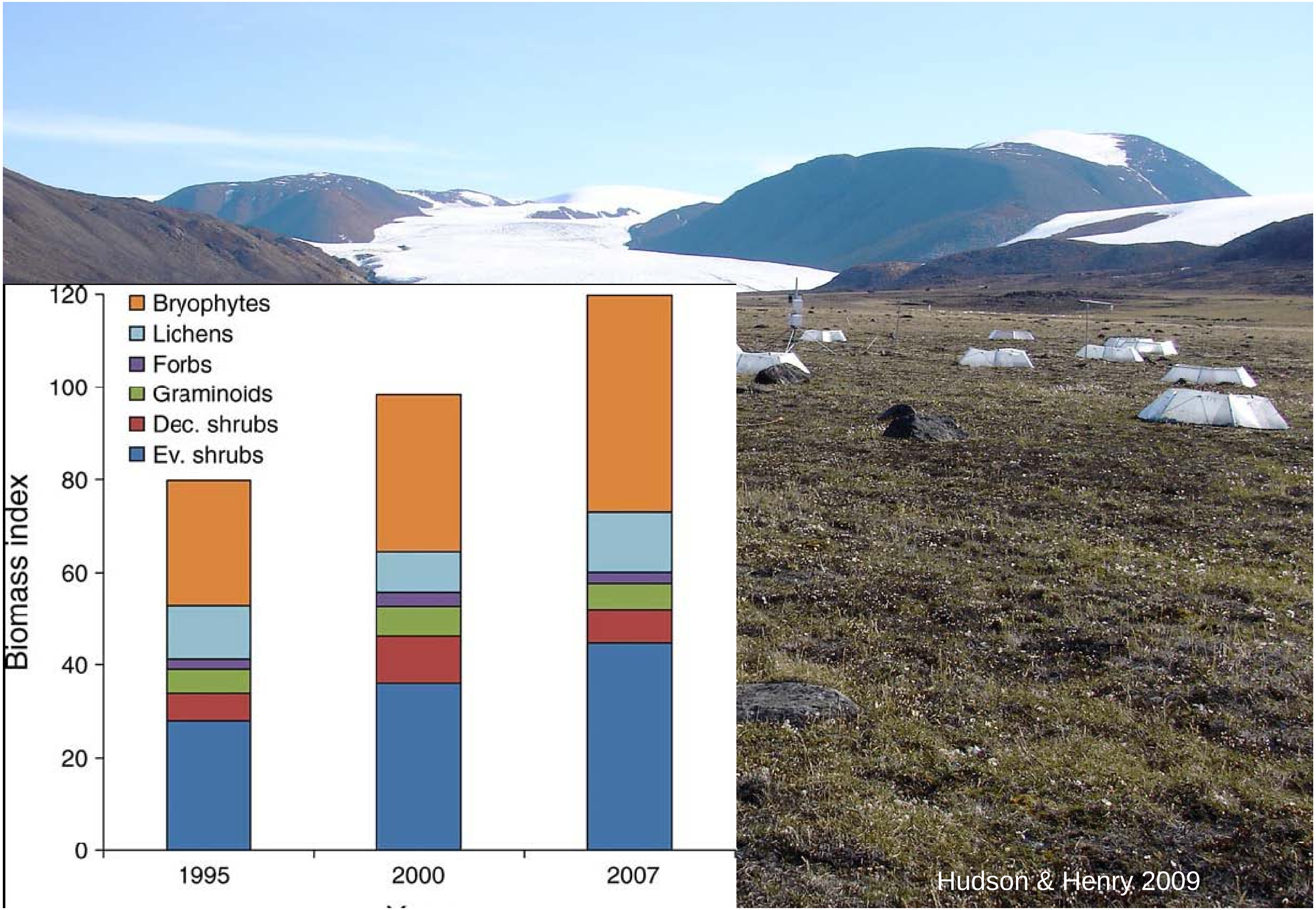
- Saturation of effect of biomass to NDVI is observed in shrub tundra.

Jia et al. *GCB*, 2006

NDVI vs. SWI North Slope



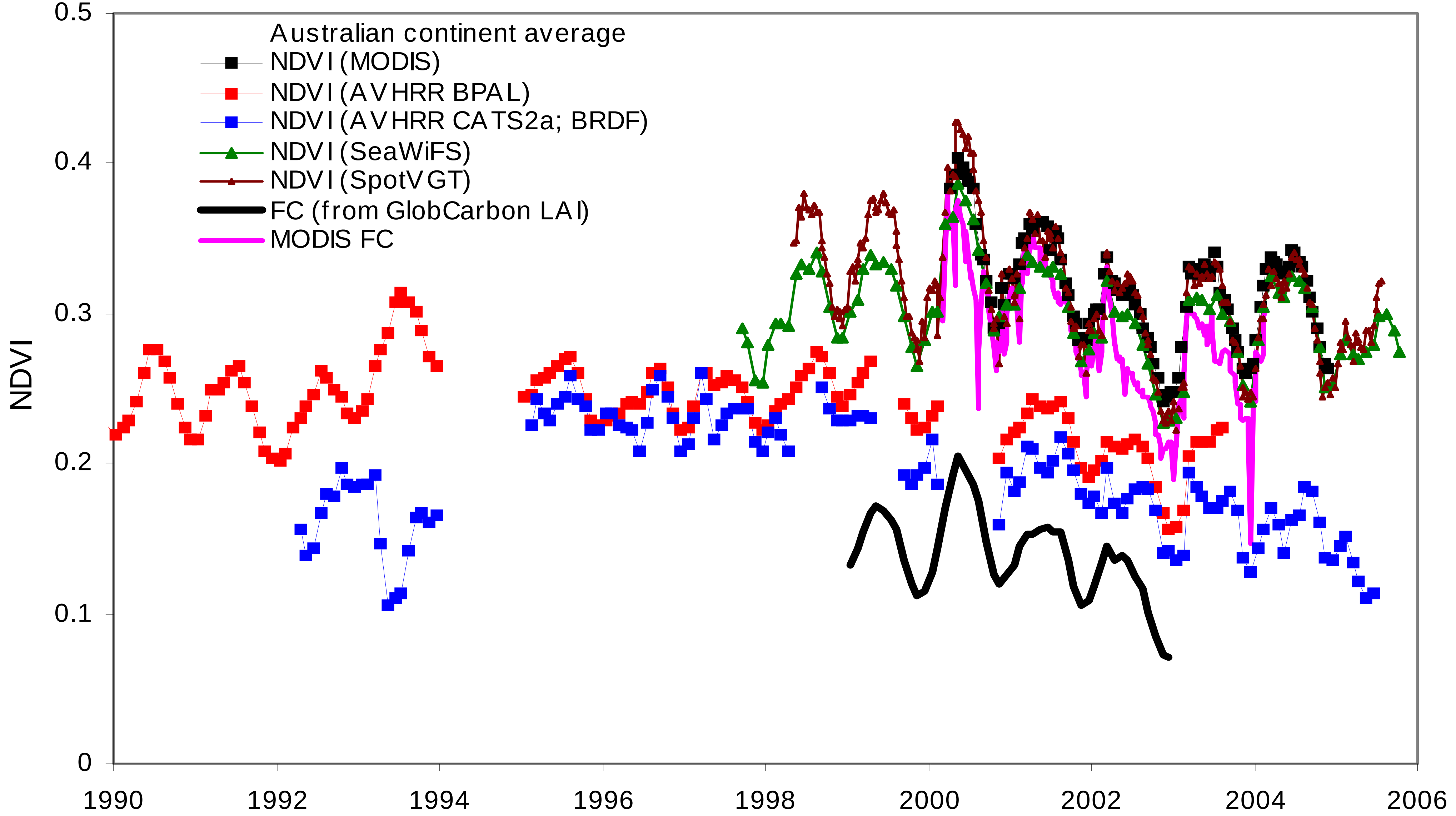
Jia et al. *GCB*, 2006


Bryophytes
Lichens
Forbs
Graminoids
Dec. shrubs
Ev. shrubs
Biomass index
0
20
40
60
80
100
120
1995
2000
2007
Hudson & Henry 2009

Uncertainties

- Major uncertainties came from data calibrations and spatial heterogeneity (mixed signals);
- Draft of AVHRR sensors and differences in spectra and algorisms between AVHRR and MODIS;
- Confused from pixels contain mixture of land cover types respond to warming in different ways;
- Time periods considered in analysis;
- Geographic extents in analysis.

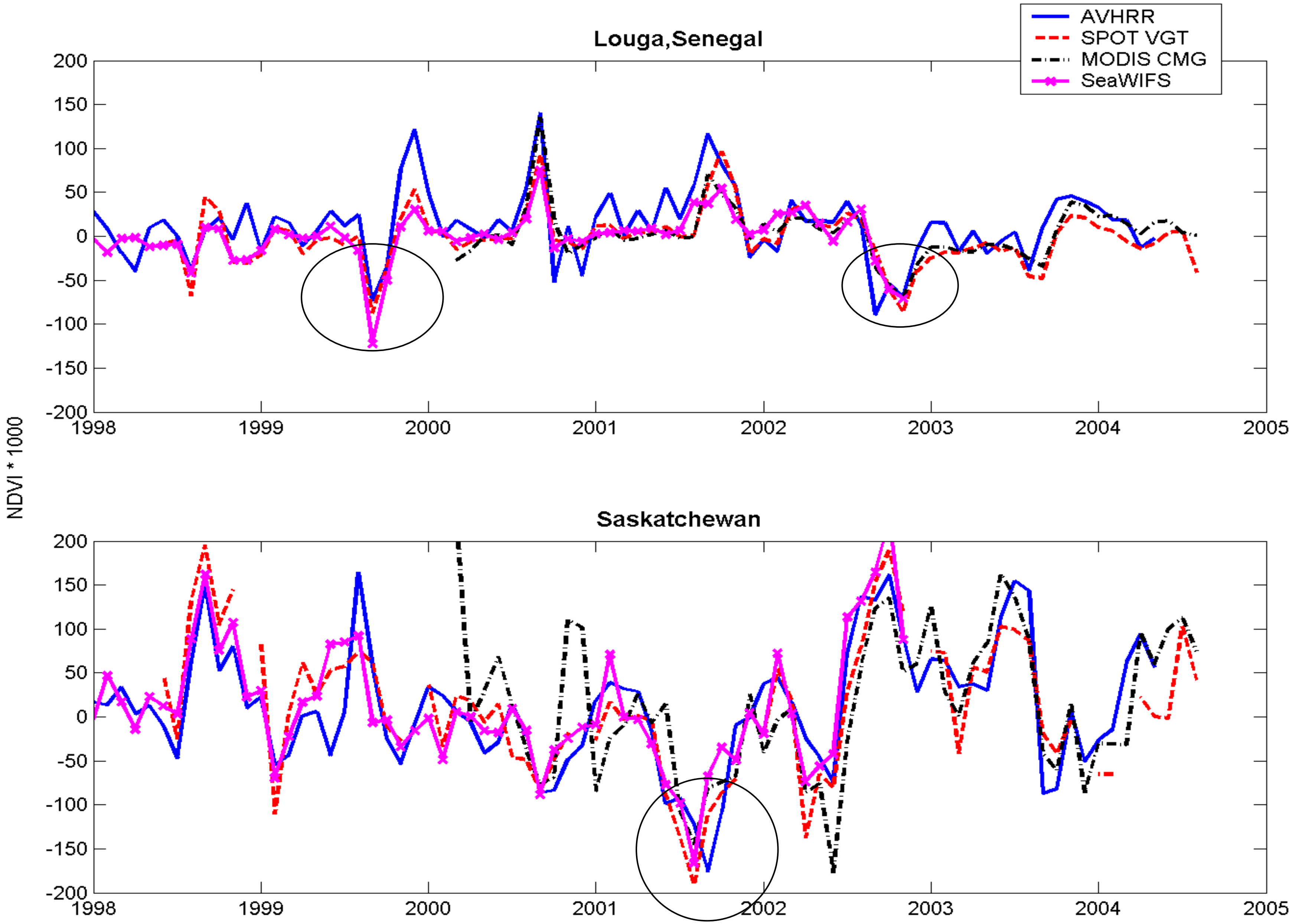
Multi-sensor Greenness trends: Australia case



green.tea.ac.cn

Briggs 2009

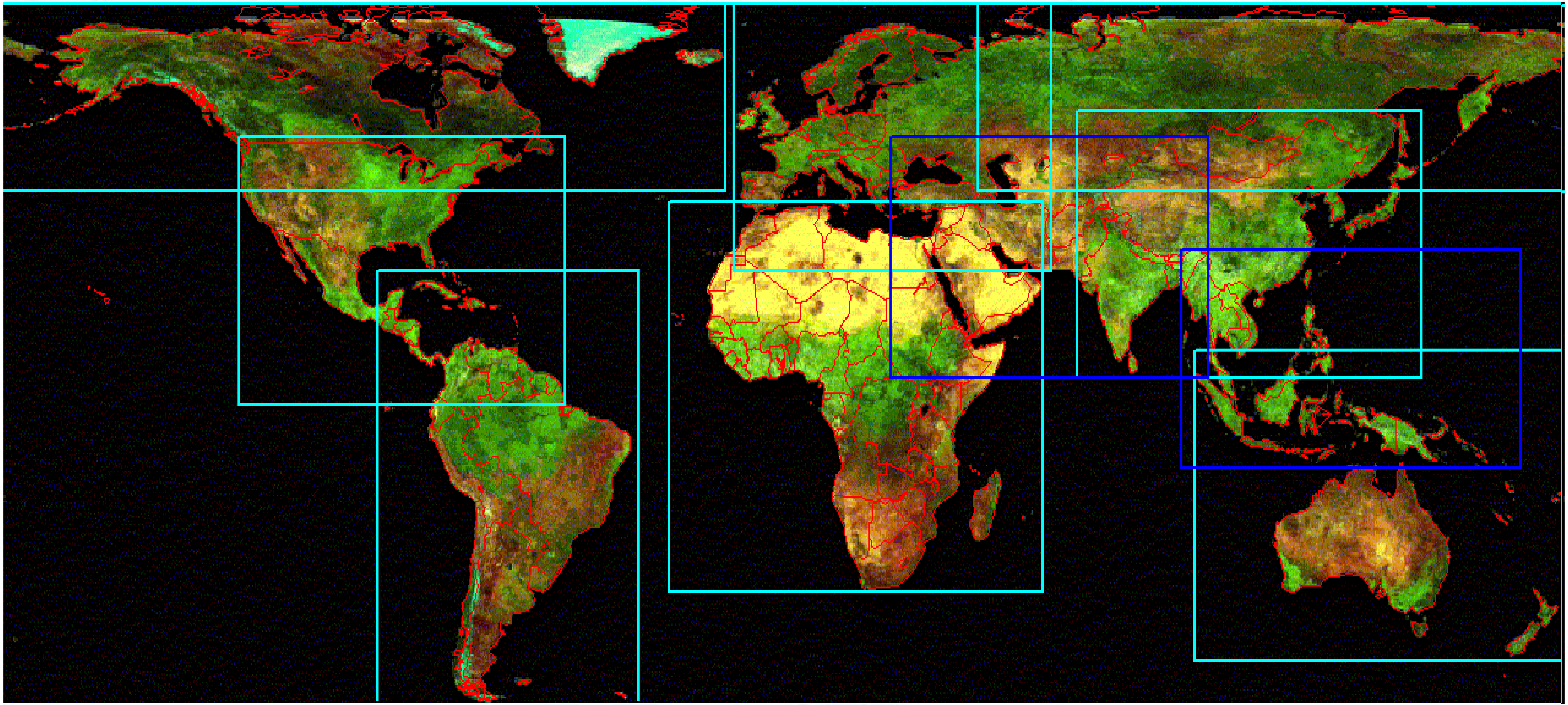
Anomaly Time Series: Drought Detection



SPOT Vegetation Coverage

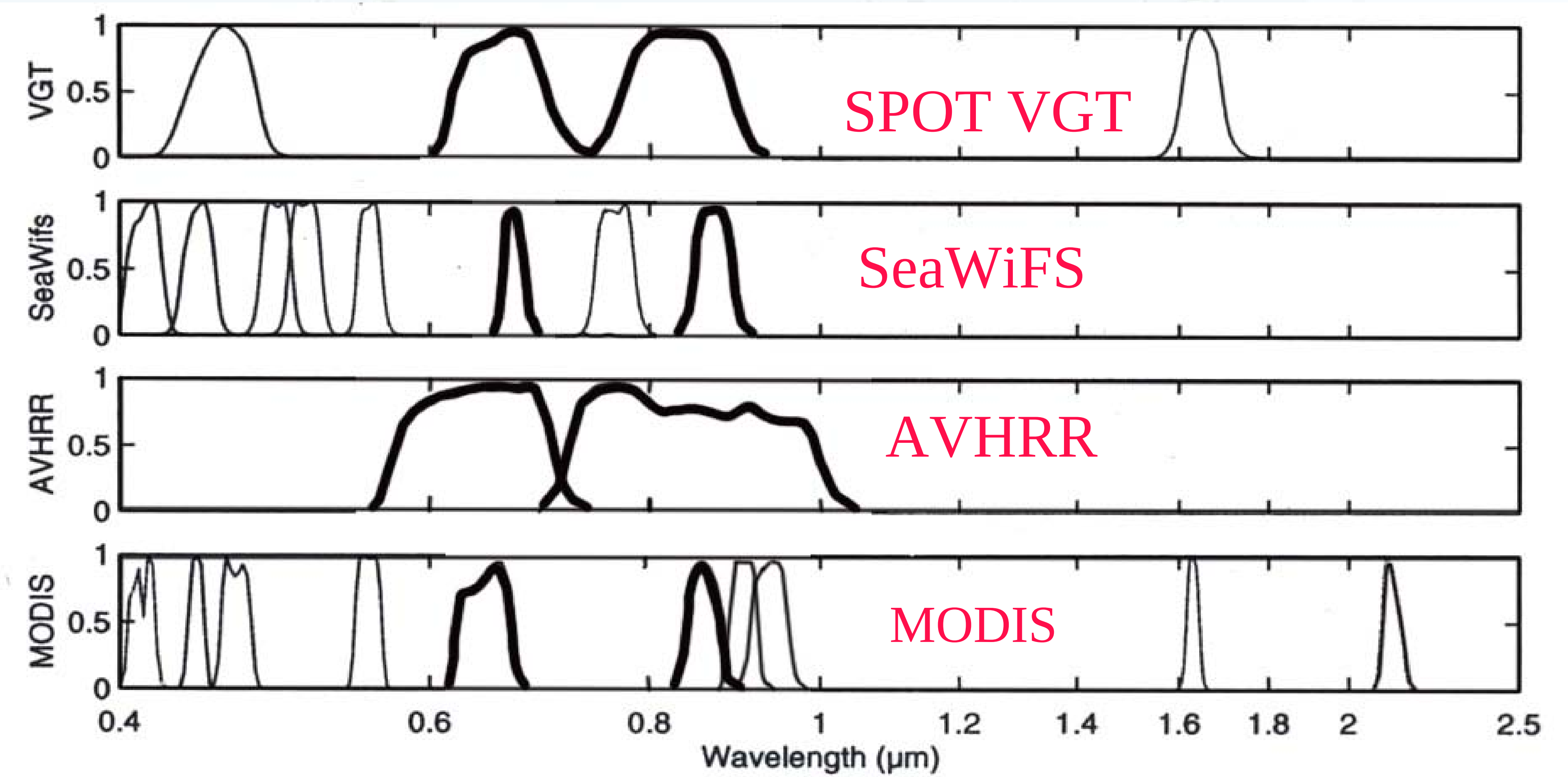
1km, daily/10-day

1998.04-2010.03, Up to 75 degree north



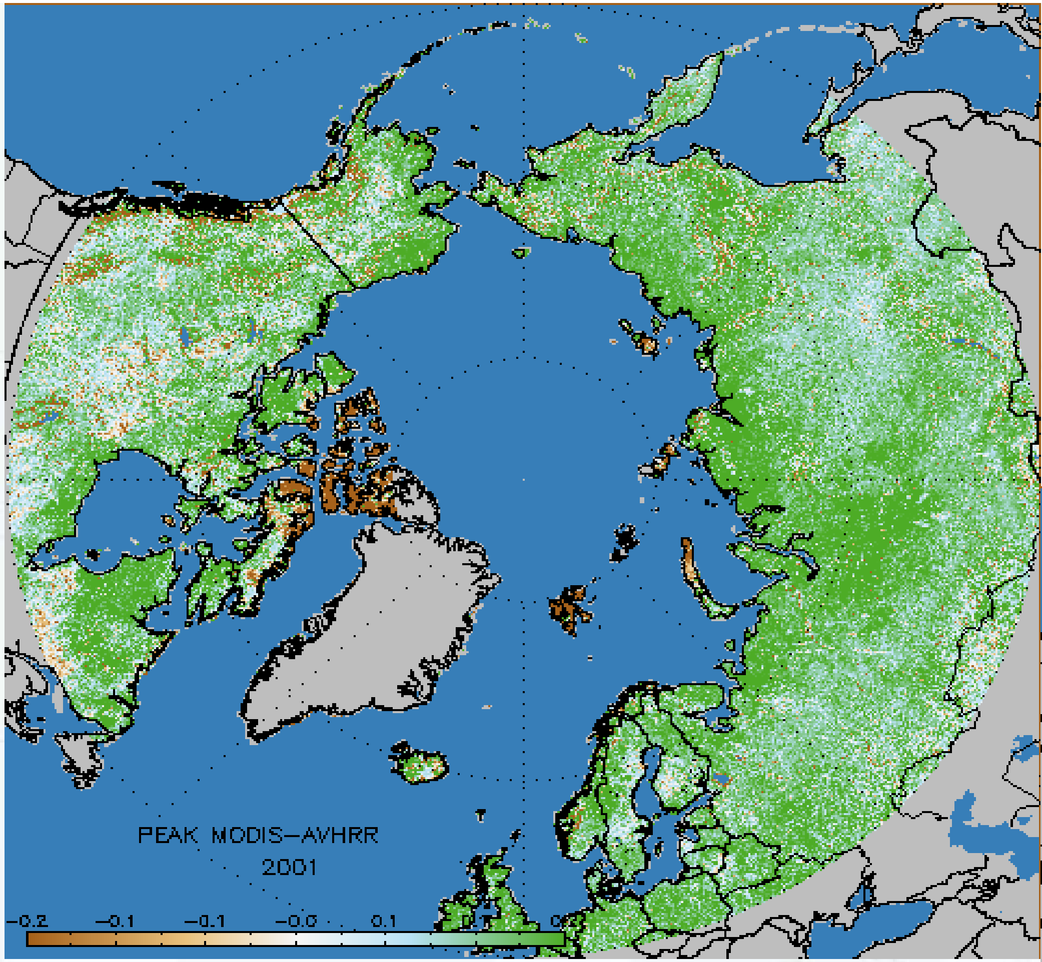
green.tea.ac.cn

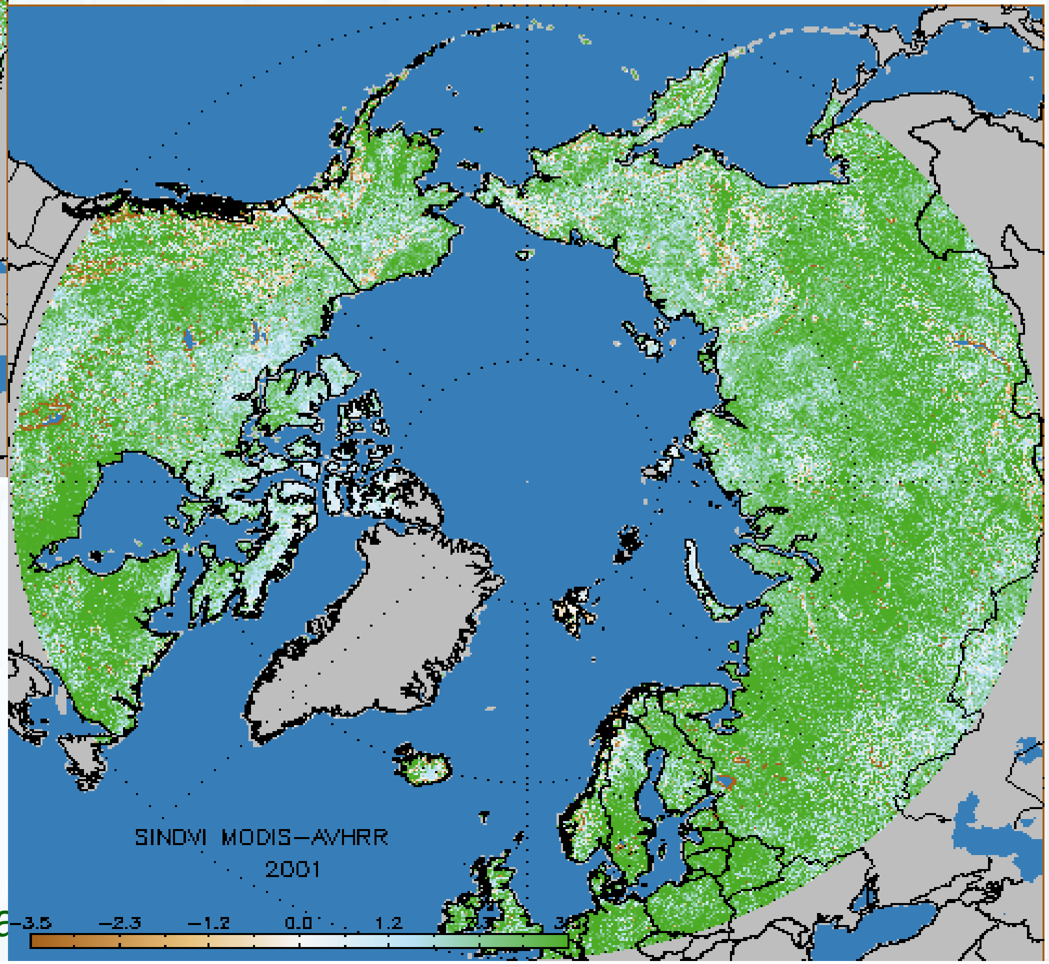
VIS/NIR/SWIR Band Comparison



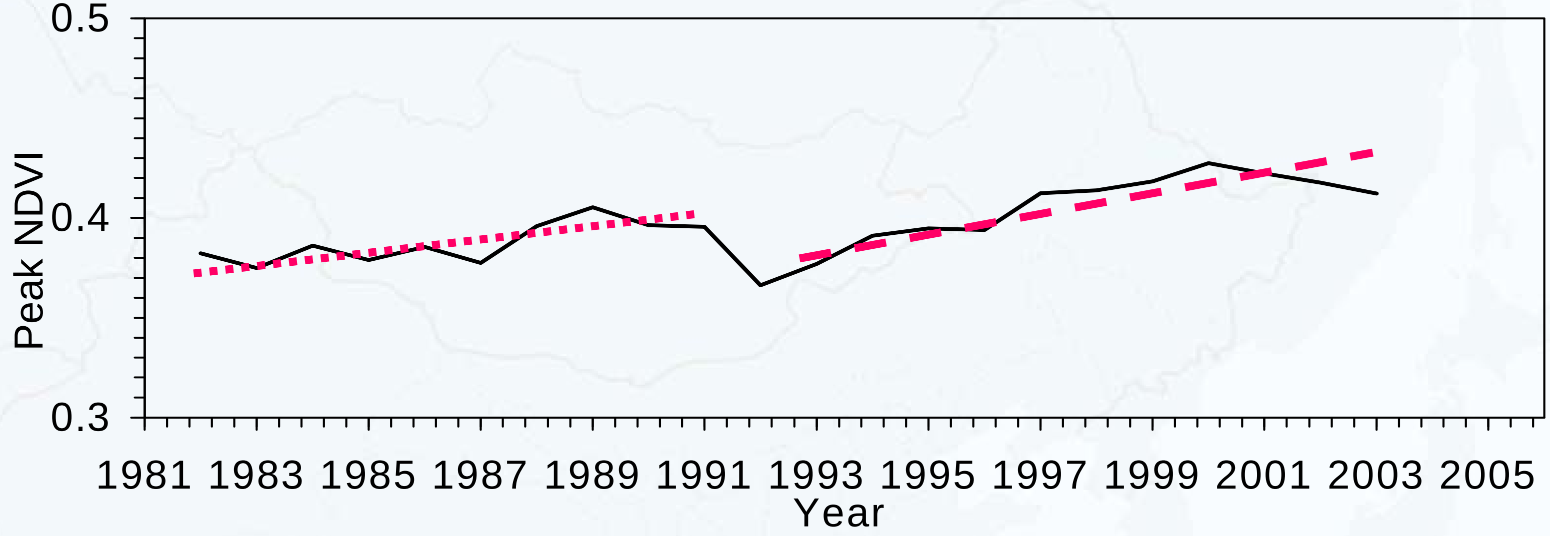
Differences in spectral range will necessitate increased processing in AVHRR and SPOT due to water vapor sensitivity.

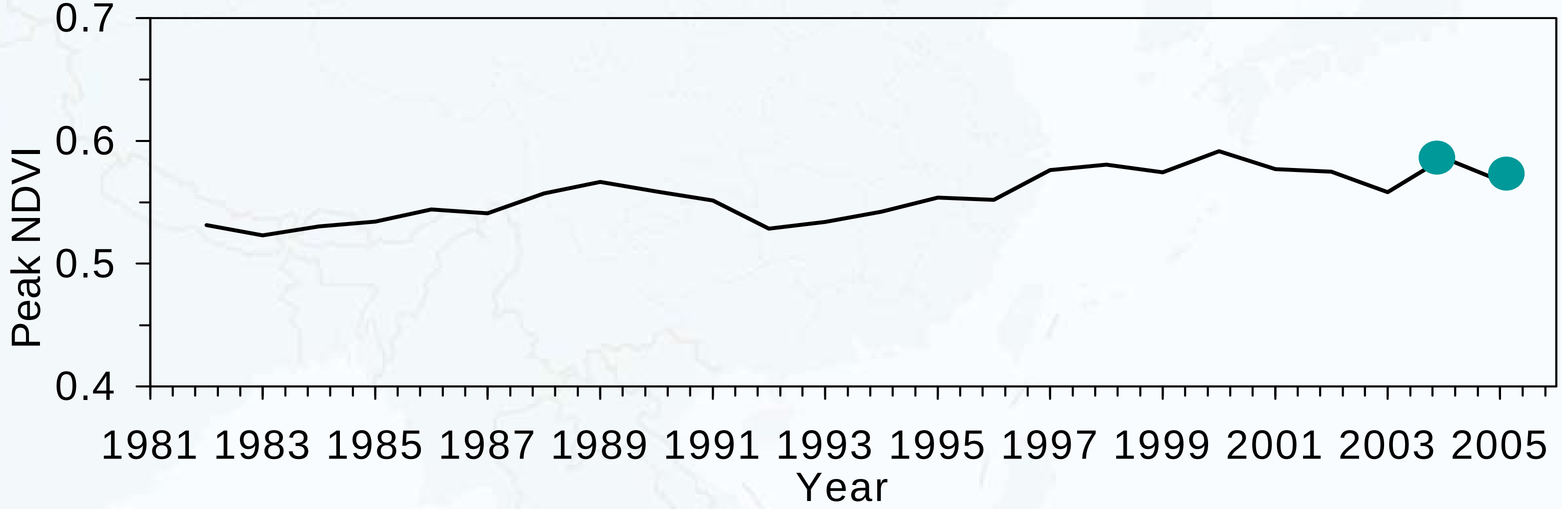
MODIS vs. AVHRR NDVI



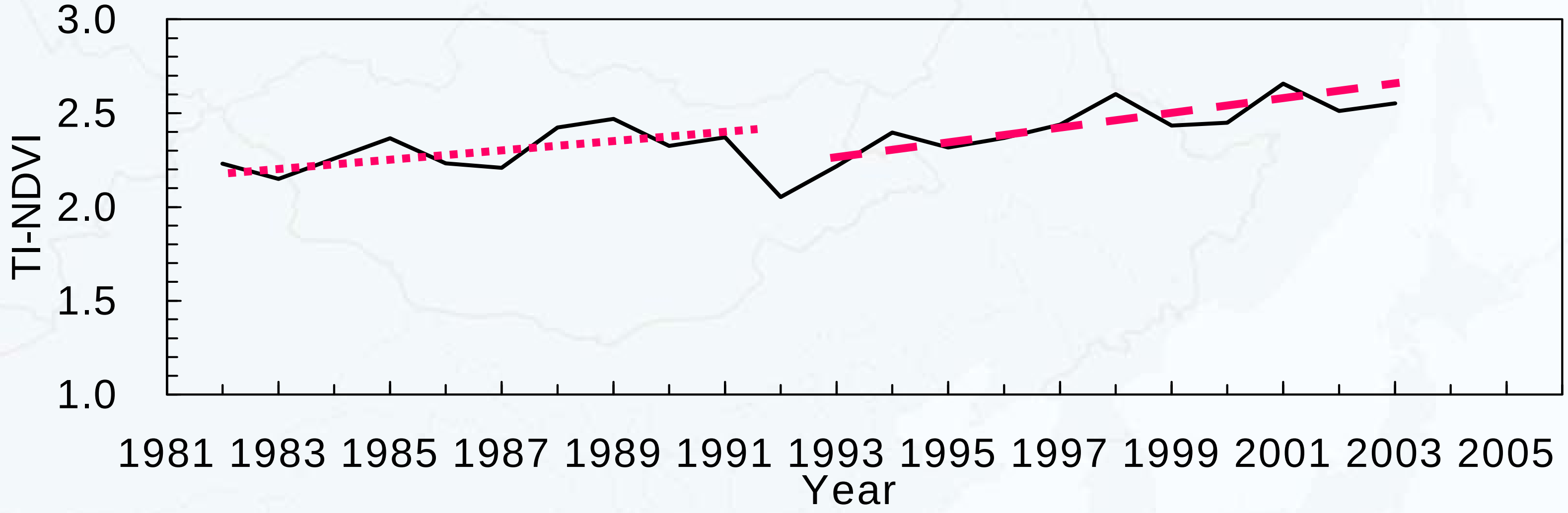


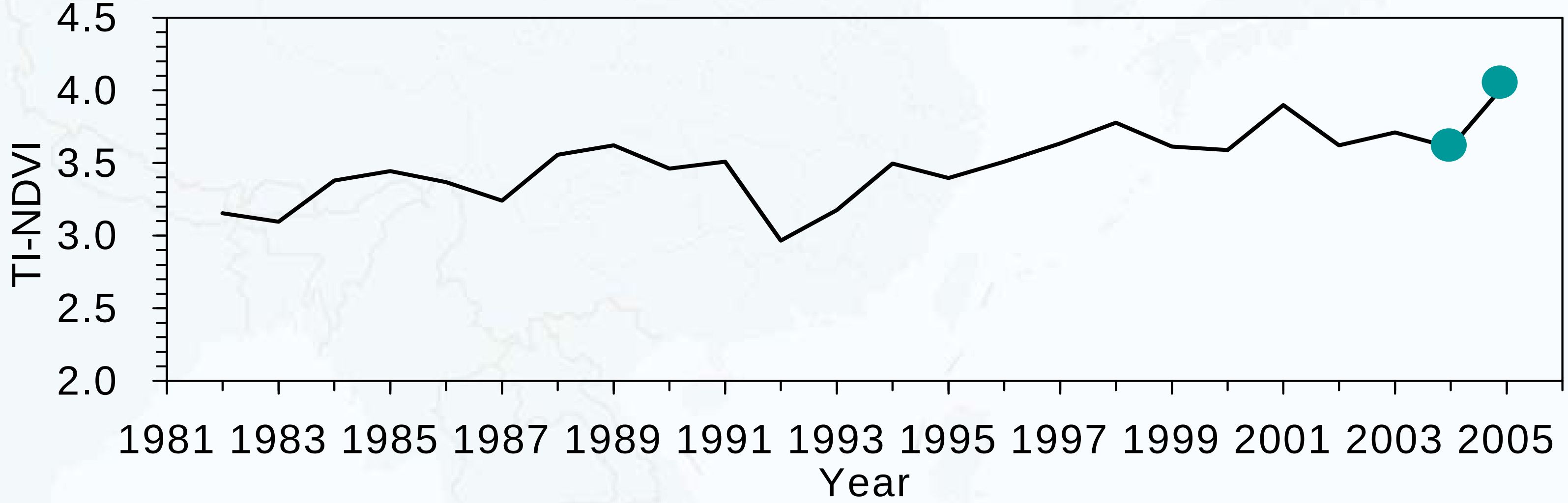
green.tea



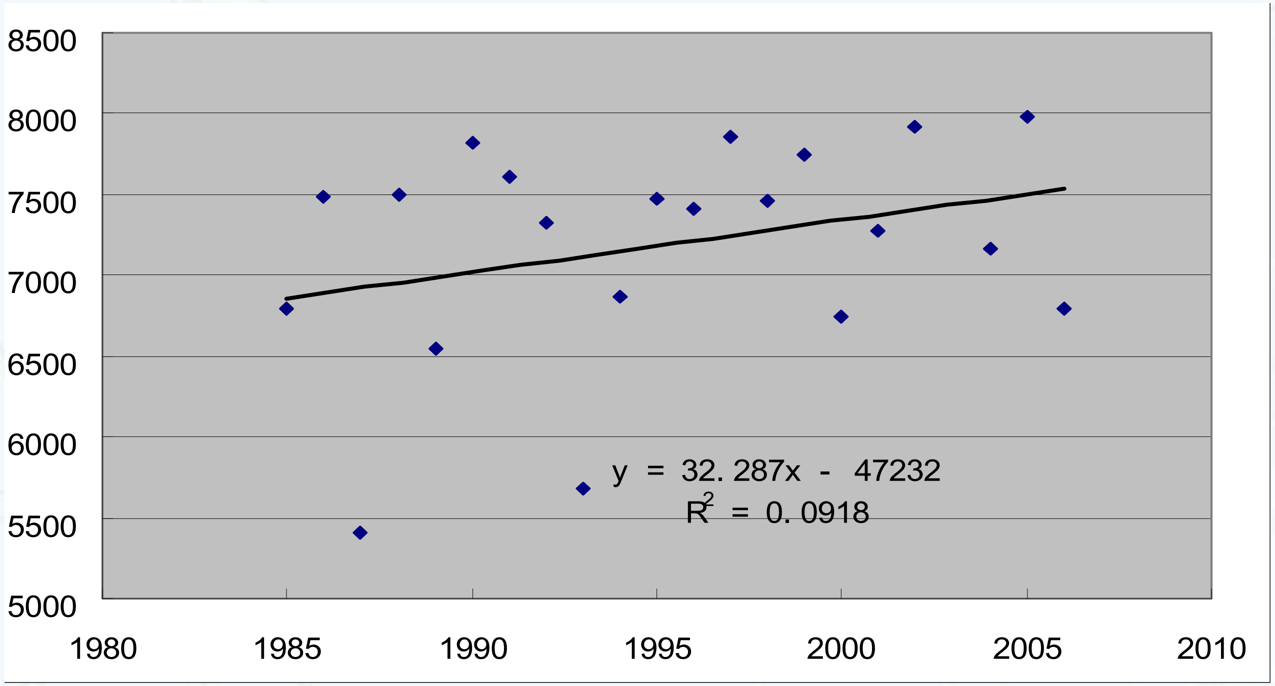


How trend of greening is affected by the length and period of time series



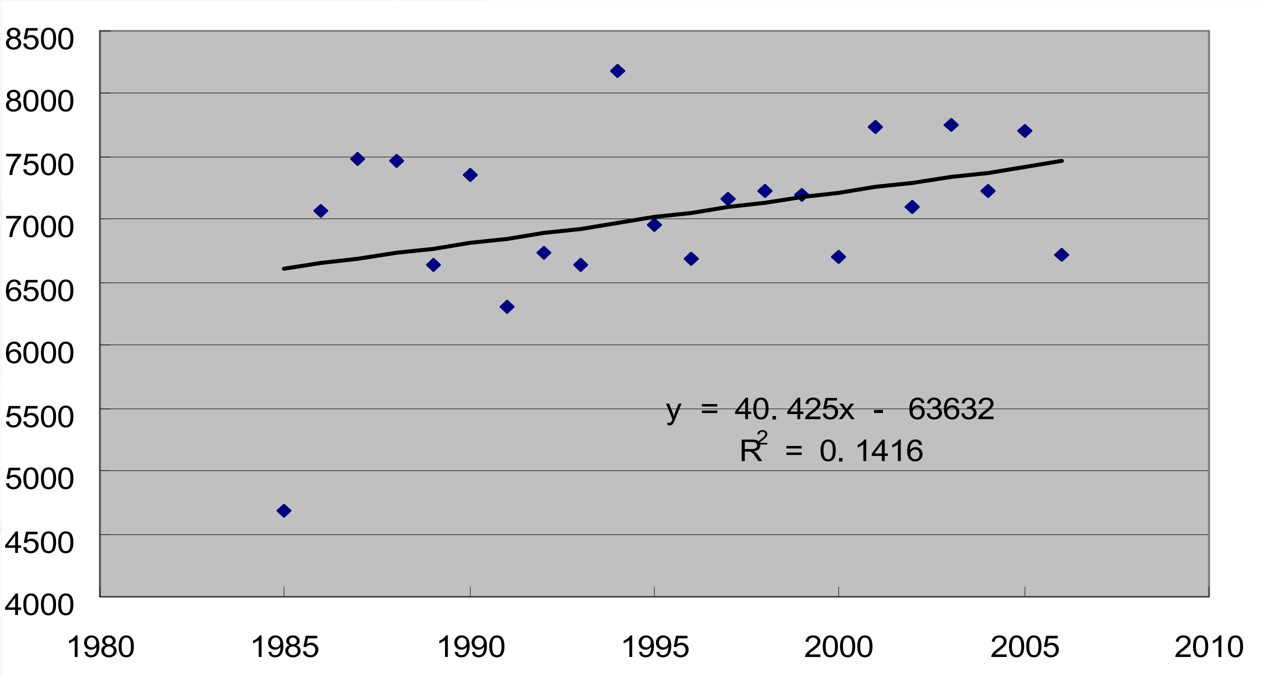


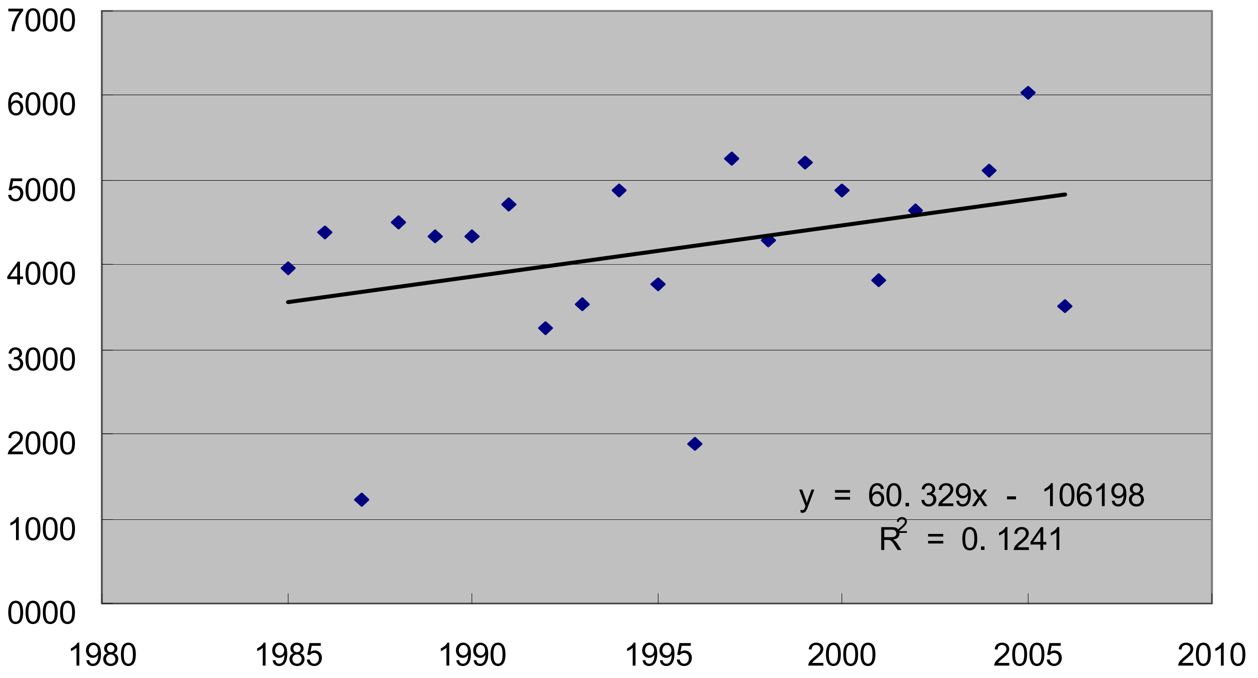
…In case of time-integrated NDVI



LAC Peak NDVI
NA boreal

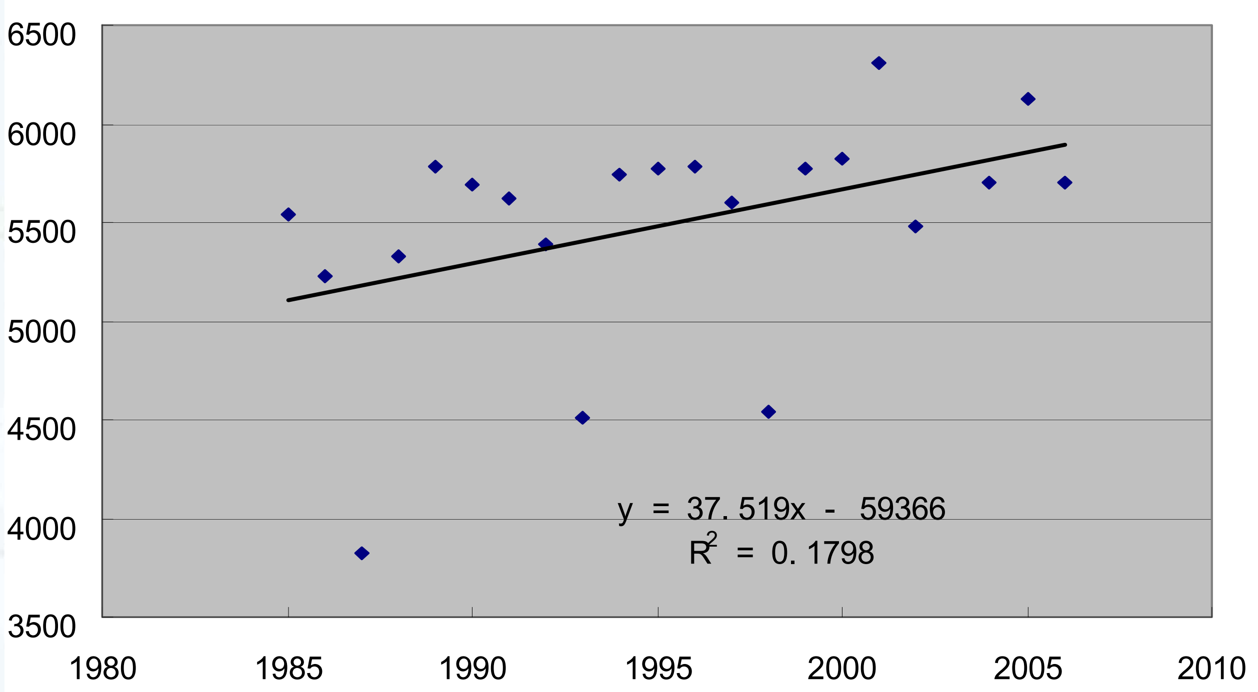
LAC summer NDVI
NA boreal





LAC Peak NDVI
NA Subzone D

LAC Peak NDVI
NA Subzone E



Related publications

Jia, G.J., H.E. Epstein and D.A. Walker, 2009, Vegetation greening in the Canadian Arctic related to decadal warming, Journal of Environmental Monitoring 11: 2231-2238;

Epstein, H.E., D.A. Walker, M.K. Raynolds, **G.J. Jia**, A.M. Kelley, 2008, Phytomass patterns across the full temperature gradient of the arctic tundra, Journal of Geophysical Research 113, G03S02, doi:10.1029/2007JG000555.

van Bogaert, R., D. Walker, **G.J. Jia**, O. Grau, M. Hallinger, M. De Dapper, C. Jonasson, T.V. Callaghan, 2008, Recent Changes in Vegetation, NOAA State of Arctic Report. (http://www.arctic.noaa.gov/reportcard/essay_vanbogaert.html)

Jia, G.J., H.E. Epstein and D.A. Walker, 2006, Spatial heterogeneity of tundra vegetation response to recent temperature changes, Global Change Biology 12: 42-55;

Jia, G. J., H. E. Epstein and D. A. Walker, 2003, Greening of Arctic Alaska, 1981-2001. Geophysical Research Letters 30 (20): 2067, doi: 10.1029/2003GL018268;

Jia, G. J., H. E. Epstein and D. A. Walker, 2004. Controls over intra-seasonal dynamics of AVHRR-NDVI for the Arctic tundra in northern Alaska. International Journal of Remote Sensing 25(9): 1547-1564;

Jia, G. J., H. E. Epstein and D. A. Walker, 2002. Spatial characteristics of AVHRR-NDVI along latitudinal transects in northern Alaska. Journal of Vegetation Science 13: 315-326.

Summary

Strong **trends of greening** over Arctic tundra since 1981 were detected by Gimms, PAL, and LAC AVHRR, with **varies magnitudes** across bioclimate gradient;

Most recent (i.e. 2004~) changes are **critical** for long-term trends, but agreements among sensors and datasets are low and **uncertain**;

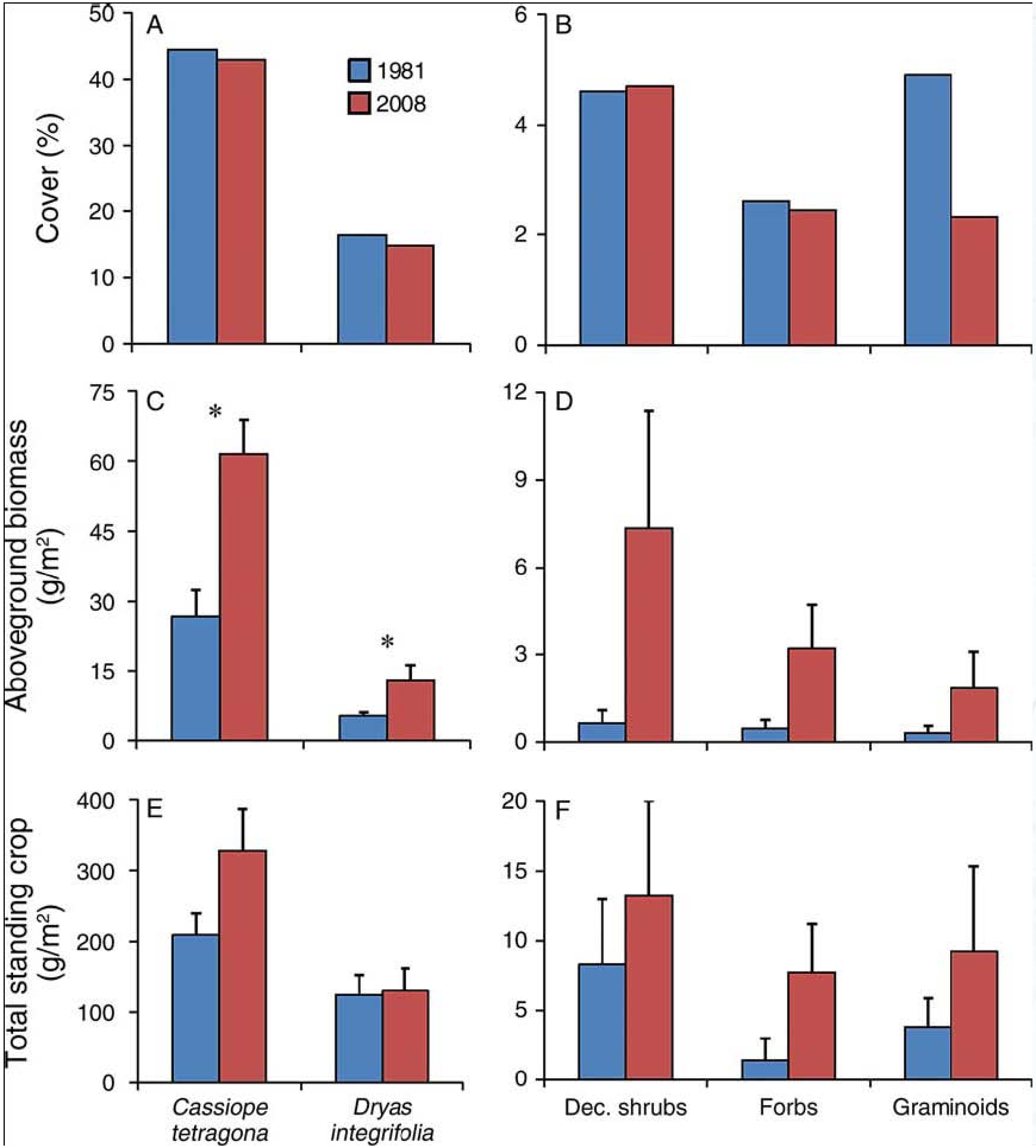
Peak greenness occurred earlier in the High Arctic, and tundra plants have experienced longer growing seasons and greater peaks in greenness as AVHRR shows. **Need finer temporal resolution**;

AVHRR Gimms is the longest and most important satellite time series for long-term greenness study. It's data quality is the key for success;

Improved satellite sensors with higher spatial and temporal resolution could be used to detect finer resolution phenomena and to validate coarse resolution patterns.

Thanks!

…Questions?



A
B
C
D
E
F
1981
2008
Cover (%)
Aboveground biomass (g/m²)
Total standing crop (g/m²)
50
40
30
20
10
0
6
4
2
75
60
45
30
15
12
9
3
400
300
200
100
20
5
*
*
Cassiope tetragona
Dryas integrifolia
Dec. shrubs
Forbs
Graminoids