Lecture Topics

1. Vegetation Indices
2. Global NDVI data sets
3. Analysis of temporal NDVI trends

Why use NDVI?

- Normalize external effects of sun angle, viewing angle, and atmospheric effects
- Normalize internal effects of shadowing, soil, amount of woody material, etc
- Can be directly linked to biophysical parameters, such as leaf area index, amount of green leaf biomass, amount of photosynthetic material

Normalized Vegetation Difference Index (NDVI)

$$NDVI = \frac{R_{IR} - R_{red}}{R_{IR} + R_{red}}$$

Problems with simple VI

- In areas with low vegetation, variations in the reflectance in the red channel from differences in the soil reflectance (from variations in soil moisture and different soil types) can cause changes in the VI independent of the vegetation cover
- Low light conditions (low sun angles) will result in low NDVI

Simple Vegetation Index (VI)

VI = $\mathbf{R_{NIR}}$ ***/*** $\mathbf{R_{red}}$

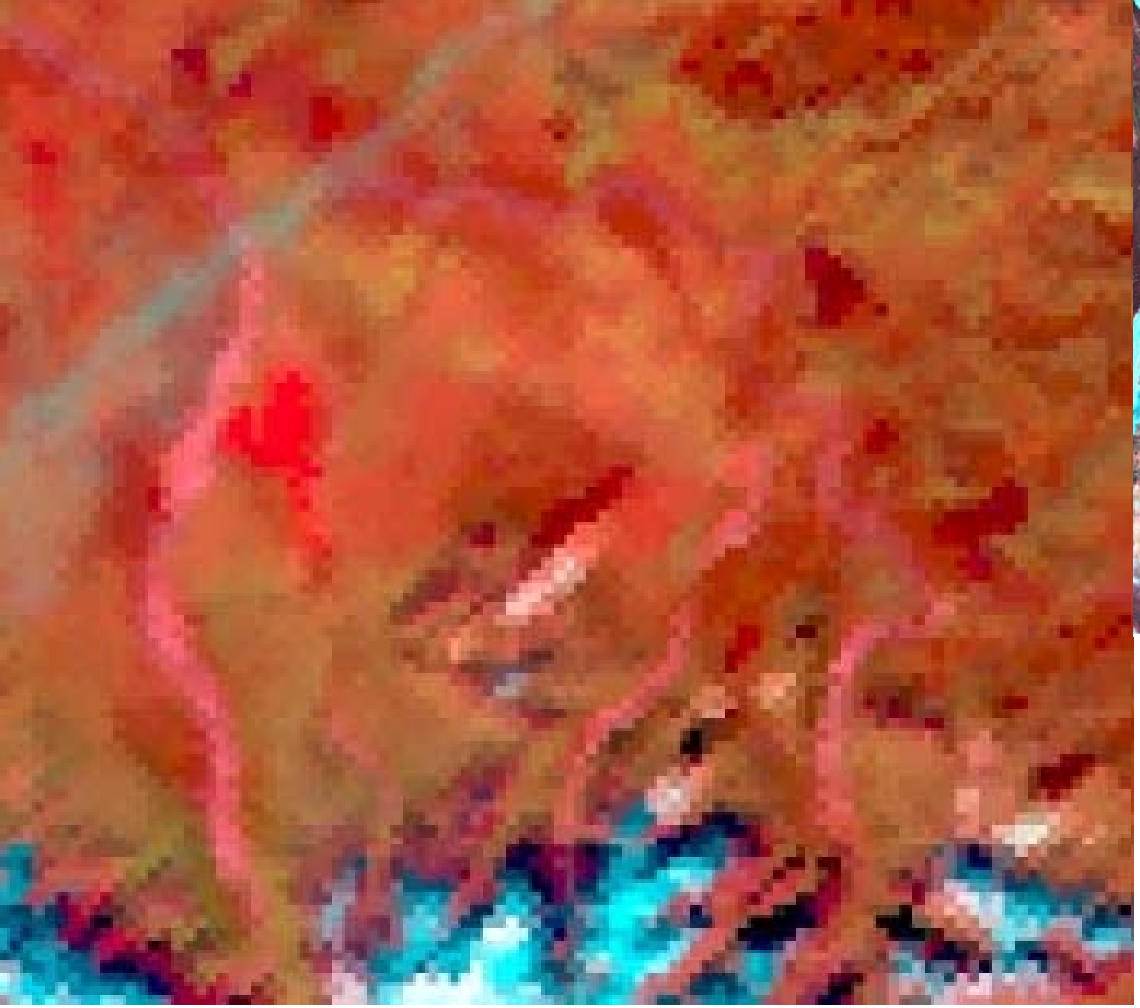
Where

$\mathbf{R_{IR}}$ is the reflectance in the red band

$\mathbf{R_{red}}$ is the reflectance in the near infrared band

Sources of variation in satellite observed NDVI

- **Differences in the overall level of vegetation cover**
  - **Broad categories of vegetation type – savannas, shrubland, coniferous vs. deciduous forests**
- **Seasonal phenology – changes in green biomass associated with seasonal growth patterns and spring green up and fall senescence**
- **Inter-annual variations in climate**
- **Disturbances that reduce green vegetation**
  - **Deforestation, fire, insect outbreaks**



AVHRR
11 Sept 1999

Landsat ETM
11 Sept 1999

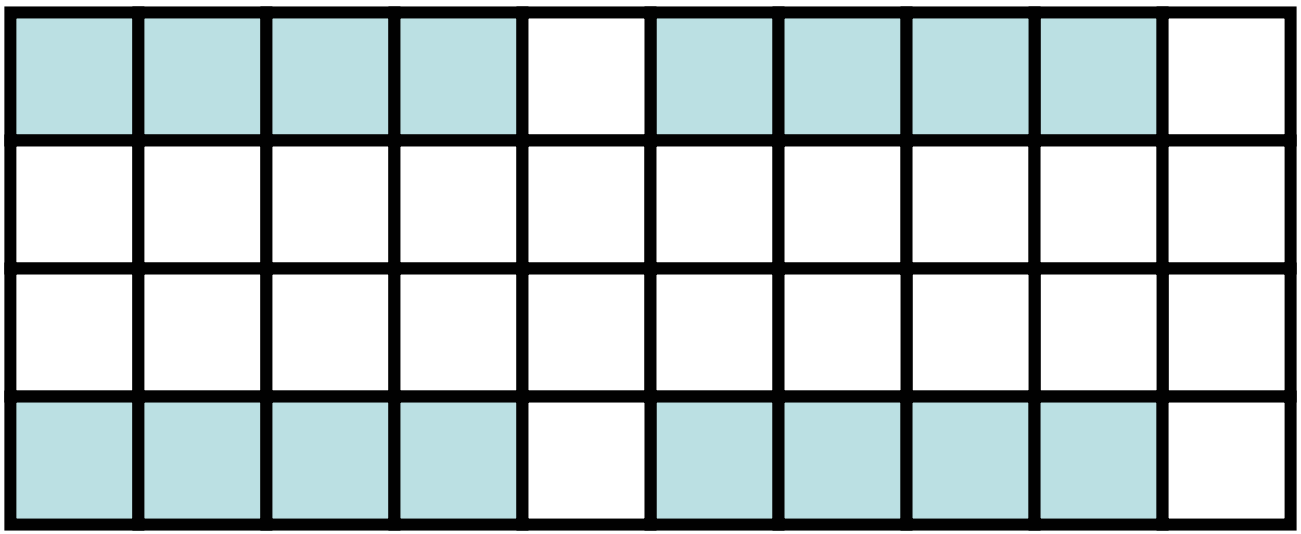
AVHRR Vegetation Indices

- The availability of the long-term satellite data set from AVHRR (since 1978) spurred much interest in developing approaches to use these data to analyze global vegetation cover
- The NDVI is an effective approach to analyzing global vegetation cover
  - Simple, yet contains meaningful information

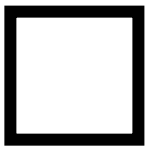
Categories of AVHRR Data

- Local Area Coverage – LAC
  - Sampled at the full resolution (1.1 km) of the AVHRR System
  - Requires downloading data at a ground receiving station
- Global Area Coverage – GAC
  - Sub-sampled data with a 4 km resolution
  - Recorded onboard the satellite

GAC Sampling Protocol



Sampled pixel



Unsampled pixel

AVHRR GAC Data

- GAC data are resampled to create an effective pixel size of 4 by 4 km

AVHRR Composite Imagery

- While AVHRR can image the earth every day, it is not possible to obtain imagery of the earth every day because of cloud cover
- Studies have shown that during over a 1 to 2 week period, most of the earth's surface is at sometime cloud free
- An NDVI composite image is one that takes the maximum NDVI over a specified period of time (1 week, 10 days, 2 weeks), and enters it into the data set
- In this way, global NDVI products are generated

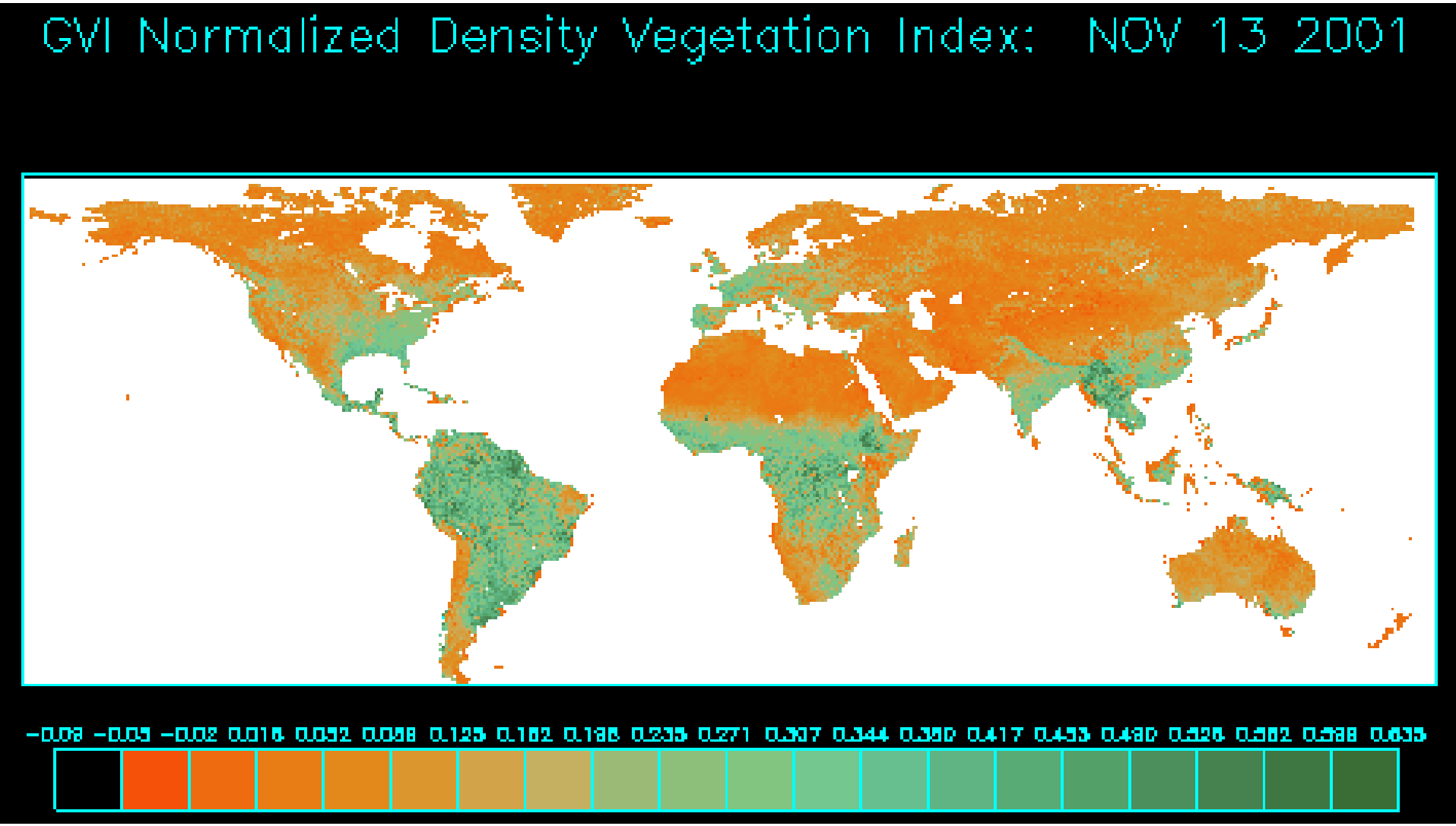
Global Vegetation Index

- An AVHRR product created by NOAA
- Re-sampled to a 16 km pixel size
- All afternoon passes of AVHRR are collected
- A simple VI index (IR – red) is created from all passes
- Pixels with the highest VI over the entire week are selected
- NDVI calculated from the values in these pixels

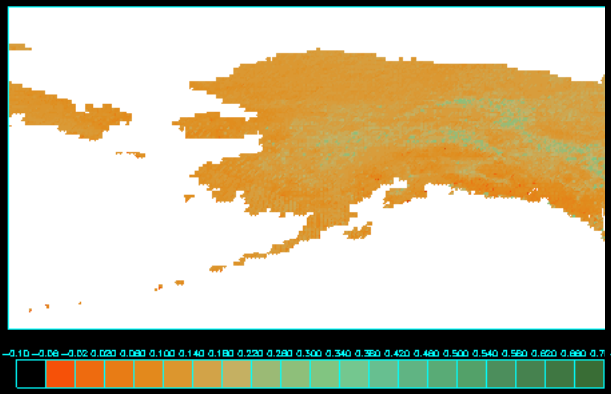
GLOBAL VEGETATION INDEX PRODUCT

- Products available from NOAA at

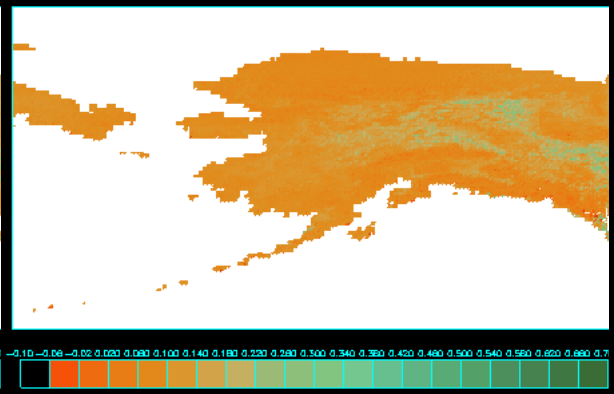
http://www.osdpd.noaa.gov/PSB/IMAGES/gvi.html


GVI Normalized Density Vegetation Index: NOV 13 2001
-0.08 -0.05 -0.02 0.016 0.052 0.088 0.125 0.162 0.198 0.235 0.271 0.307 0.344 0.380 0.417 0.453 0.489 0.526 0.562 0.598 0.635

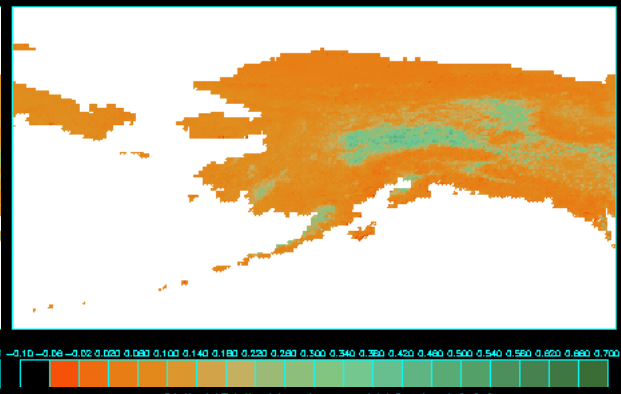
GVI NDVI Alaska: MAR 7 1999



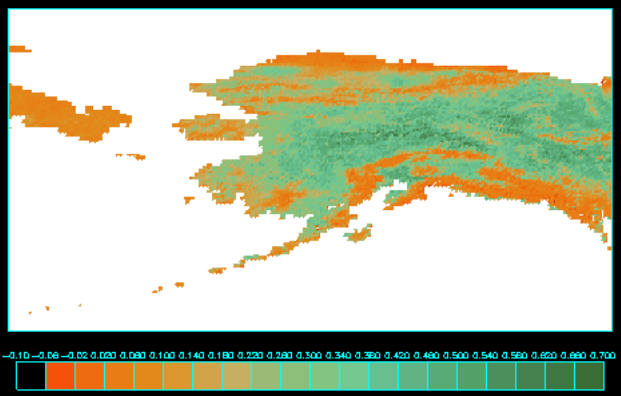
GVI NDVI Alaska: APR 4 1999



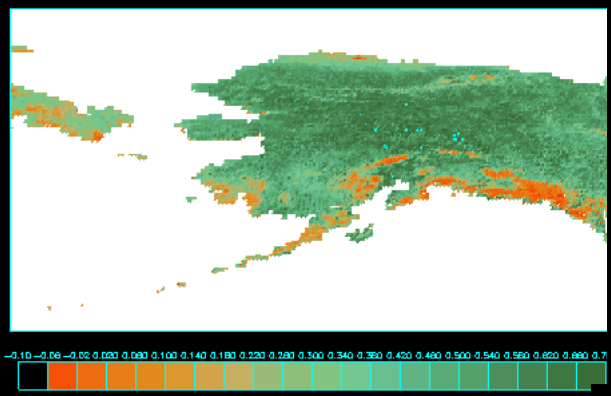
GVI NDVI Alaska: MAY 1 1999



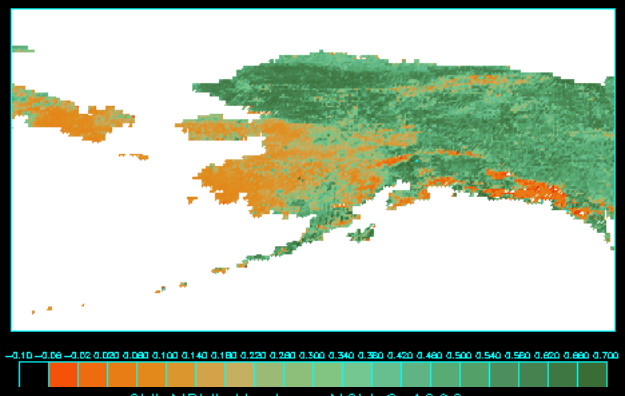
GVI NDVI Alaska: JUN 6 1999



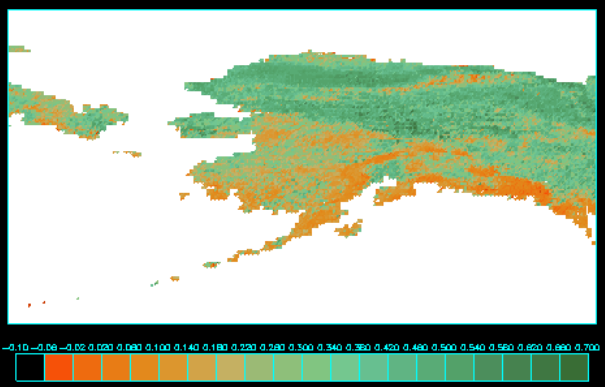
GVI NDVI Alaska: JUL 4 1999



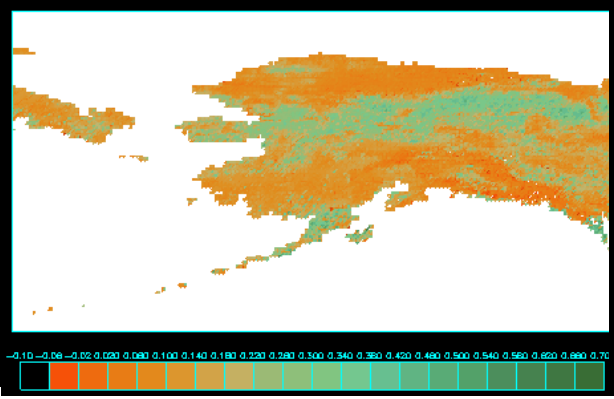
GVI NDVI Alaska: AUG 1 1999



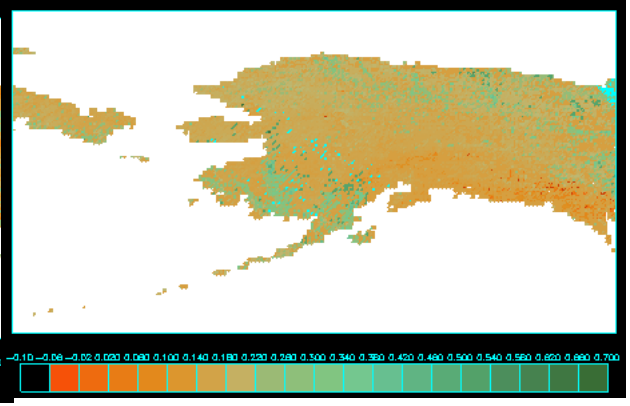
GVI NDVI Alaska: SEP 5 1999



GVI NDVI Alaska: OCT 3 1999



GVI NDVI Alaska: NOV 6 1999



Monitoring large-scale vegetation change using AVHRR data

1. Monitoring variations in the extent of the Sahara desert
2. Correlating global NDVI with atmospheric CO_2 concentrations
3. Correlating NDVI changes with surface temperatures

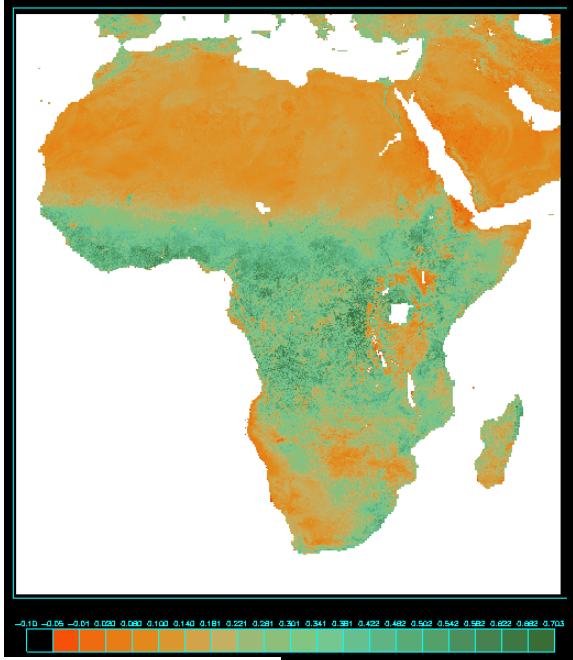
Monitoring large-scale vegetation change using AVHRR data

Monitoring variations in the areal extent of the Sahara desert

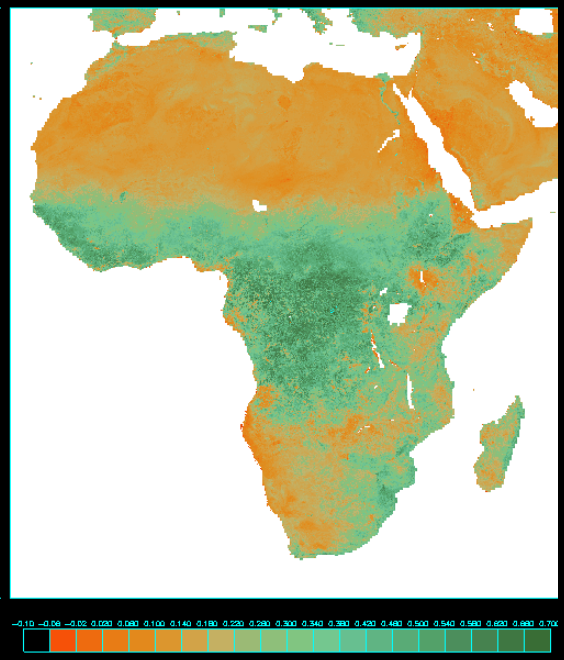
Recommended Reading

Tucker, C.J., H.E. Dregne, and W.W. Newcomb, Expansion and Contraction of the Sahara Desert from 1980 to 1990, *Science*, *253* (5017), 299-301, 1991.

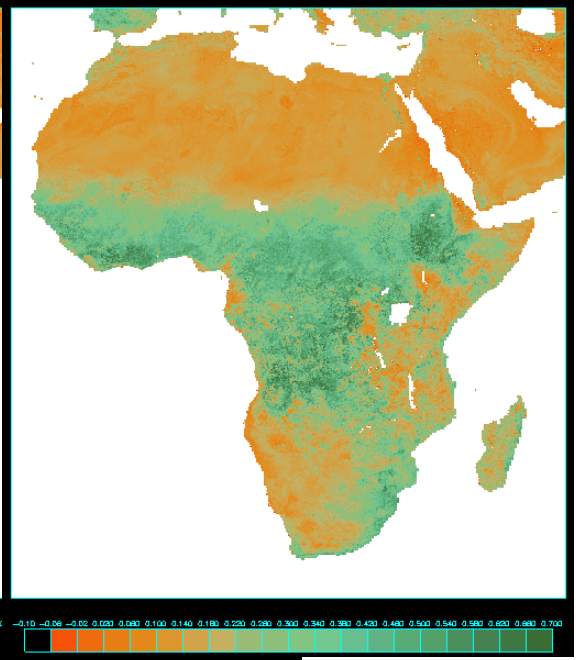
GVI NDVI Africa: NOV 16 1997



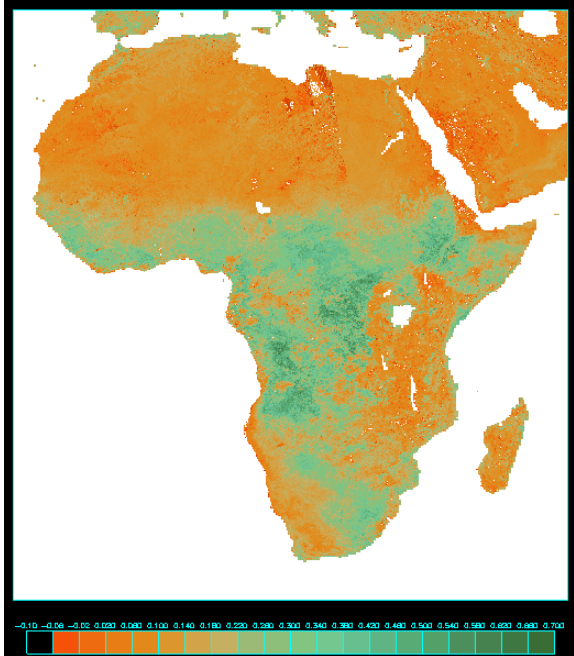
GVI NDVI Africa: NOV 15 1998



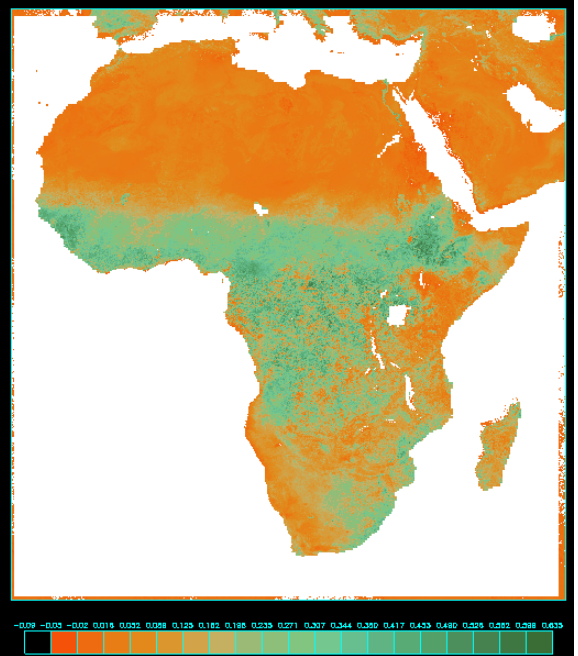
GVI NDVI Africa: NOV 14 1999

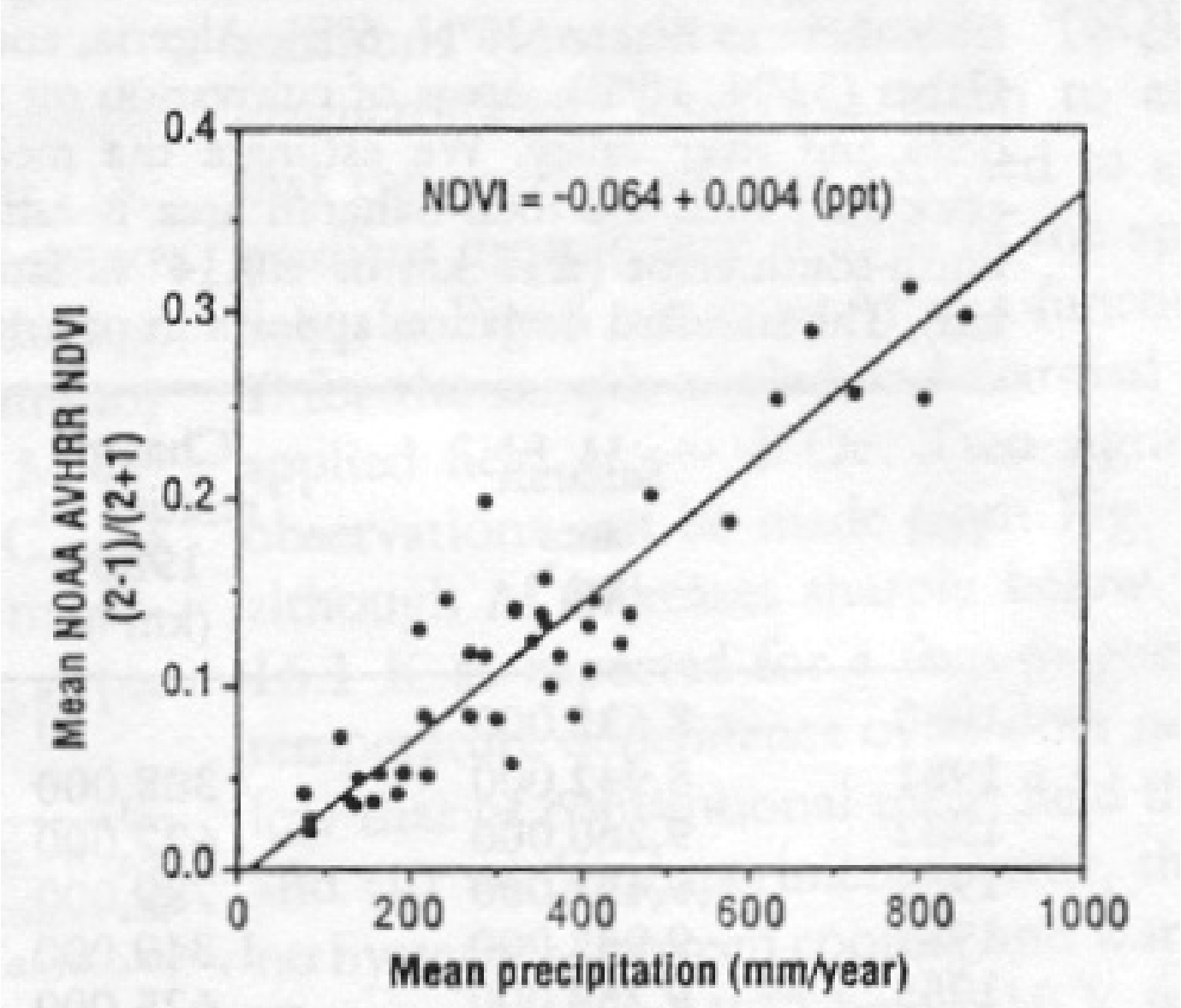


GVI NDVI Africa: NOV 6 2000



GVI NDVI Africa: NOV 6 2001





From Tucker, C.J., et al., 1991.

Results from Tucker et al. Desert Study

- AVHRR signature over Sahara desert is low and non-varying – deserts don’t change
- At southern edge of Sahara, considerable change in average AVHRR
- Average levels of AVHRR correlate closely with annual precipitation
- Inference is that precipitation in this region drives vegetation cover, which is detected through variations in NDVI
- Conclusion is that you should be able to track inter-annual variations in vegetation cover at the edge of the desert using NDVI

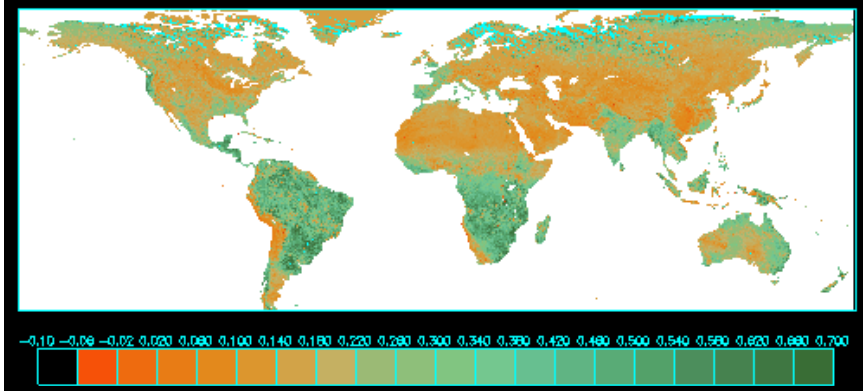
Monitoring large-scale vegetation change using AVHRR data

Correlating global NDVI with atmospheric CO_2 concentrations

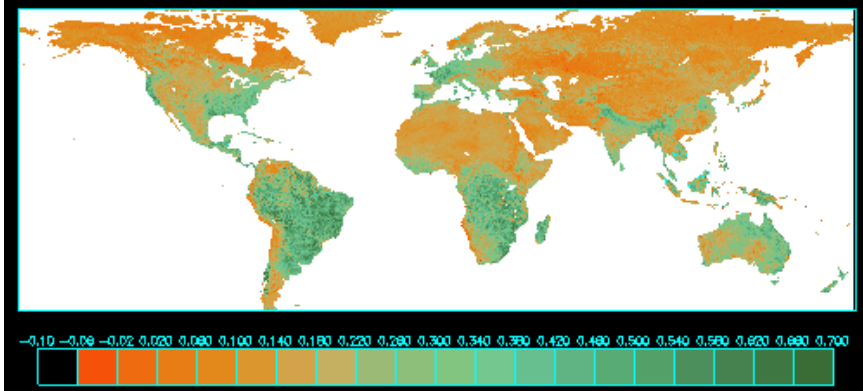
Recommended reading

Tucker, C.J., I.Y. Fung, C.D. Keeling, and R.H. Gammon, Relationship between Atmospheric CO2 Variations and a Satellite-Derived Vegetation Index, *Nature*, *319* (6050), 195-199, 1986.

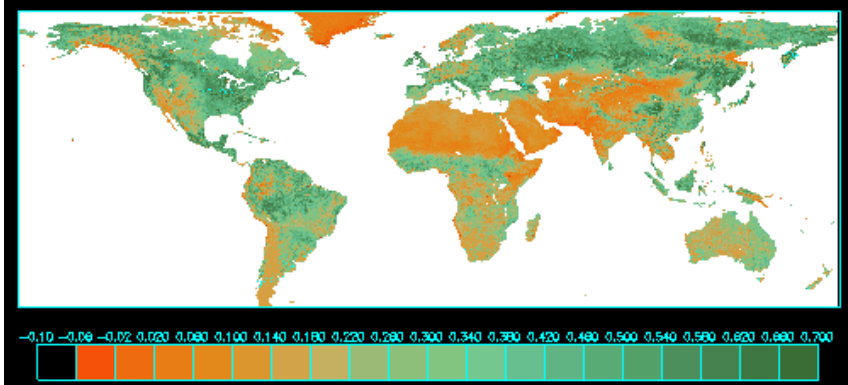
GVI Normalized Density Vegetation Index: JAN 31 2000



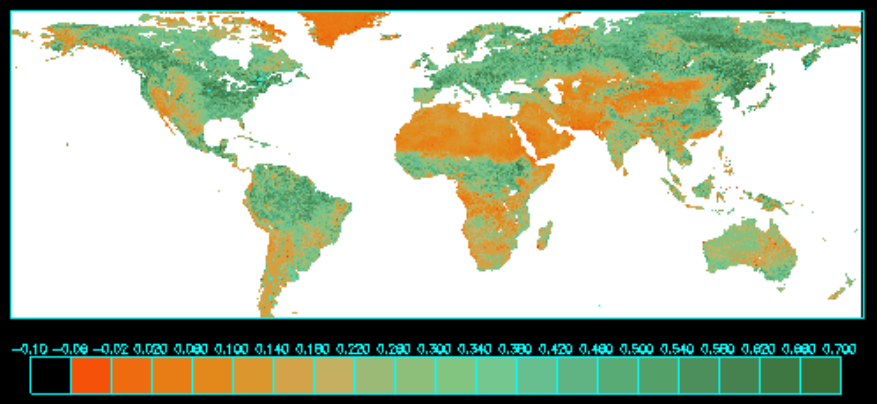
GVI Normalized Density Vegetation Index: MAR 27 2000



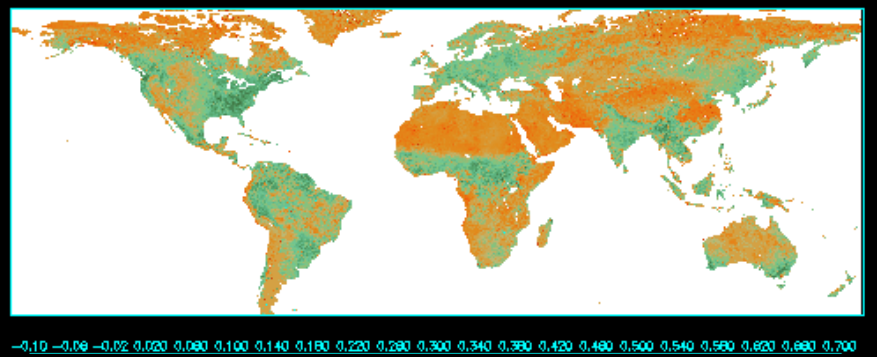
GVI Normalized Density Vegetation Index: JUL 17 2000



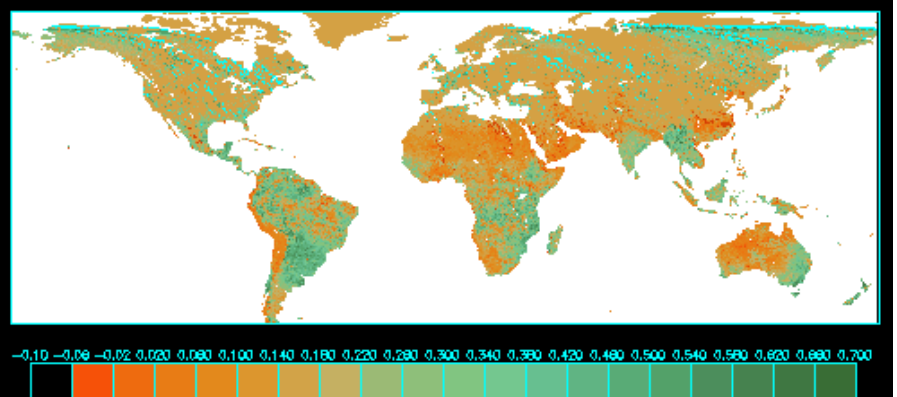
GVI Normalized Density Vegetation Index: AUG 7 2000

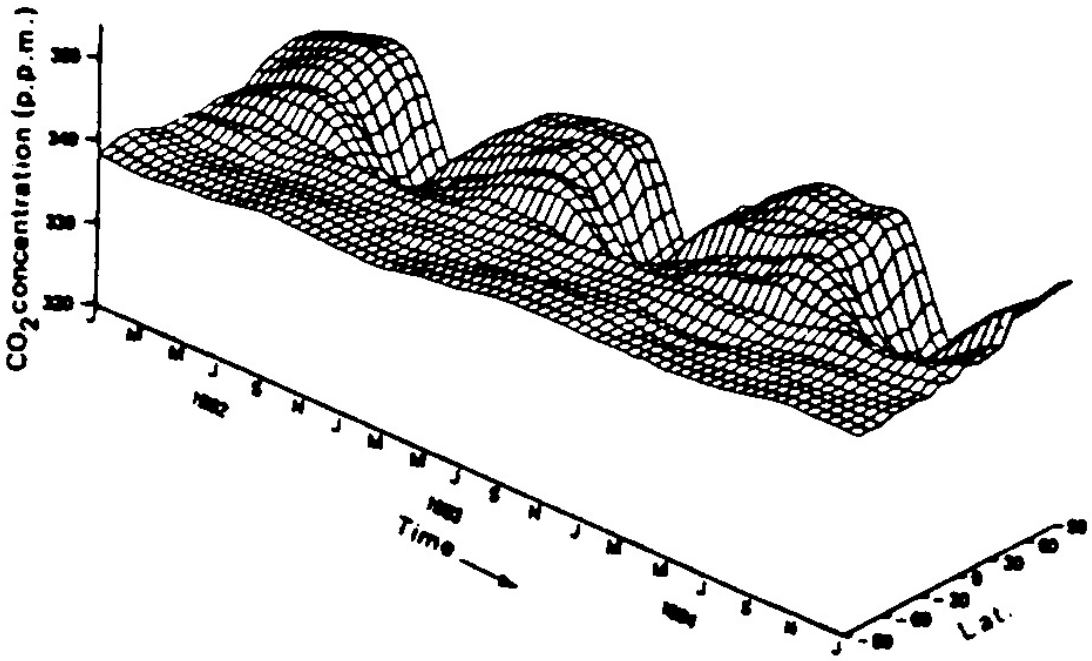


GVI Normalized Density Vegetation Index: OCT 2 2000

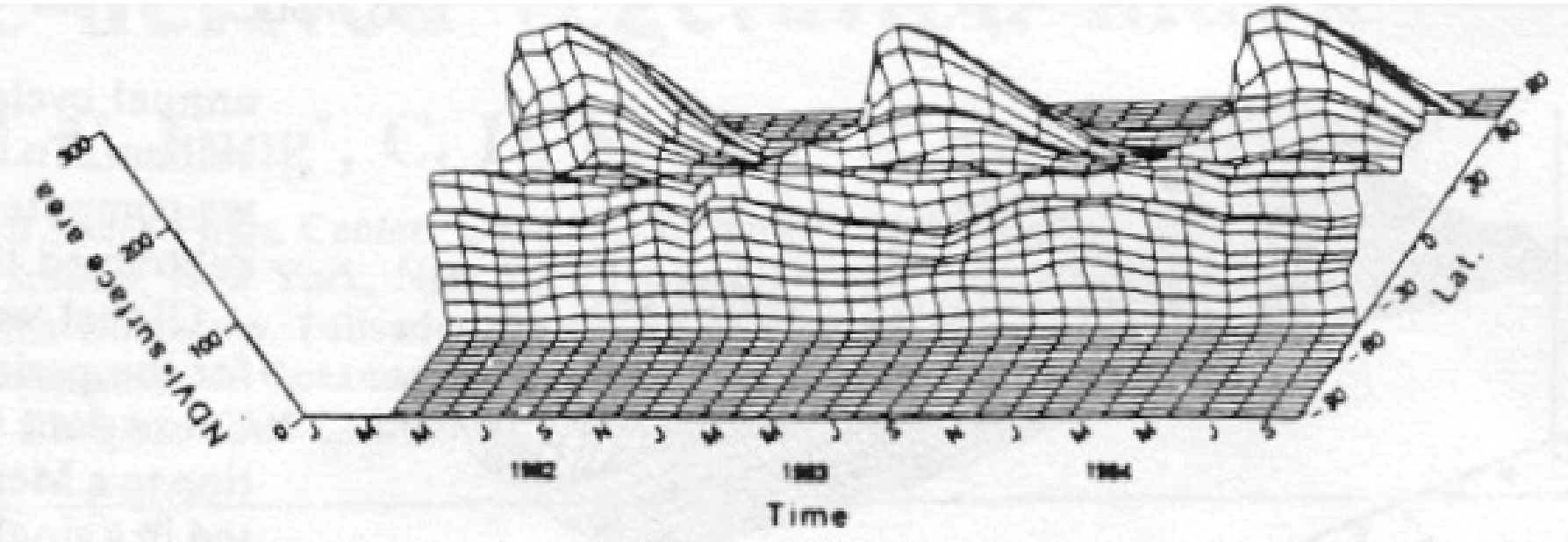


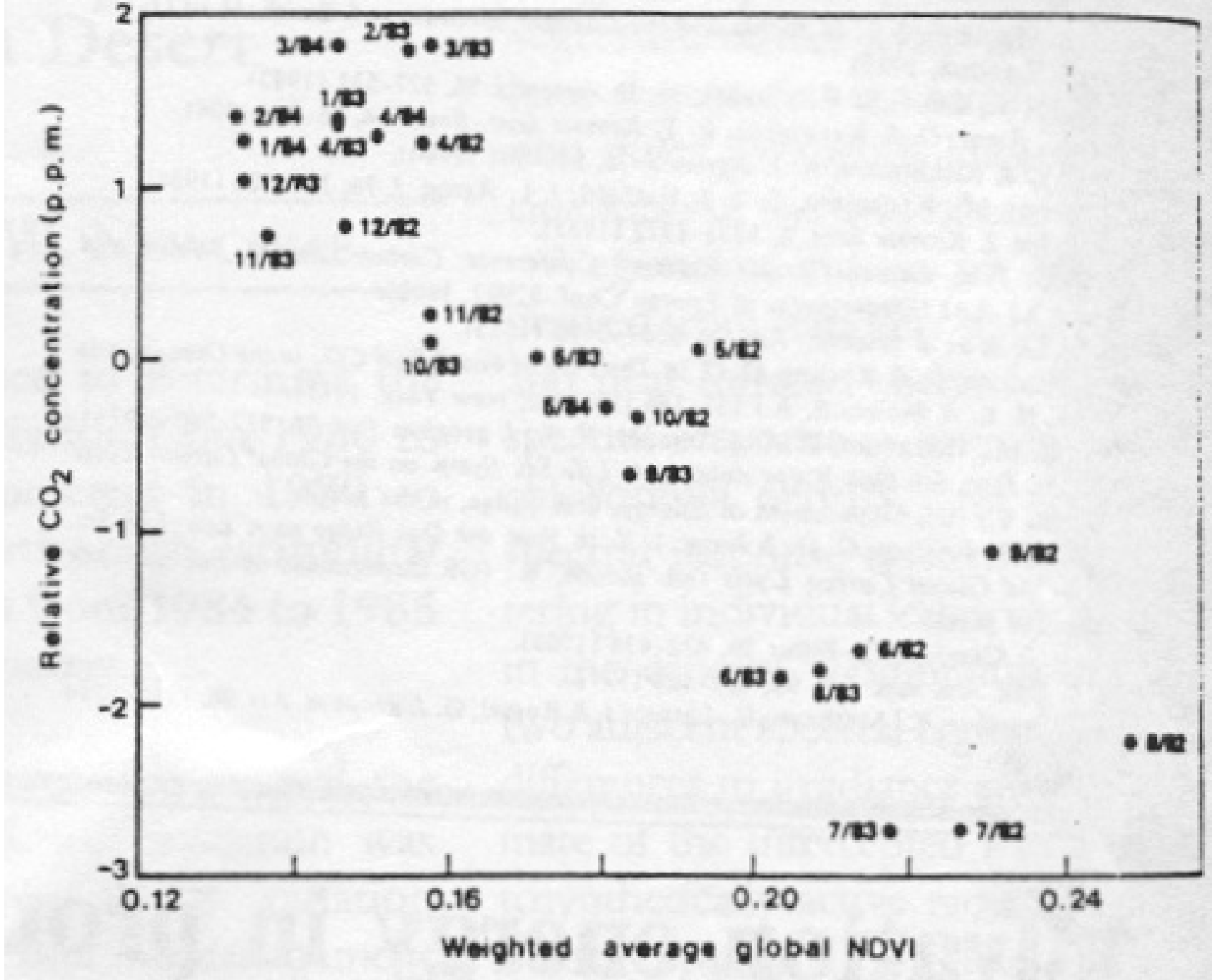
GVI Normalized Density Vegetation Index: DEC 11 2000





From Tucker et al., 1986.




Relative CO_2 concentration (p.p.m.)
2
1
0
-1
-2
-3
0.12
0.16
0.20
0.24
Weighted average global NDVI
3/84
2/83
3/83
1/83
2/84
4/84
1/84
4/83
4/82
12/83
12/82
11/83
11/82
10/83
5/83
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8/82
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6/83
6/83
8/82
7/83
7/82

Results of Tucker et al. Global CO2 Study

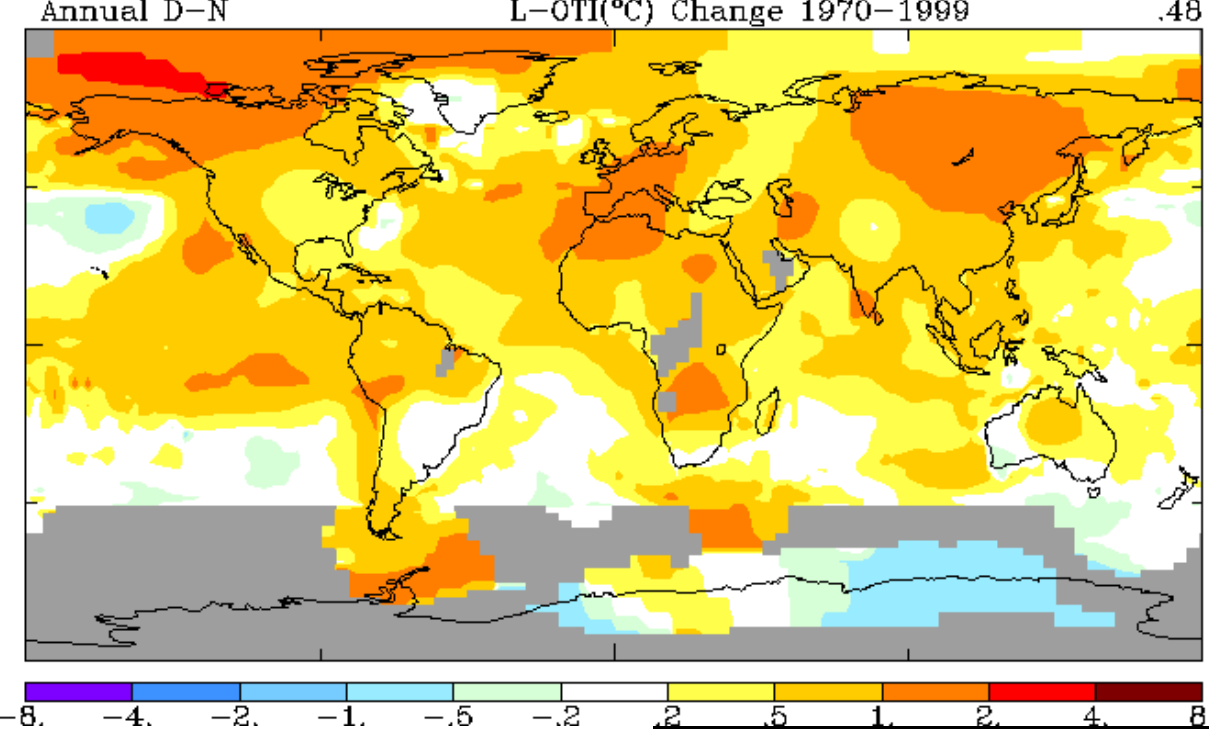
- Annual variations in plant growth result in inter-annual variations in atmospheric CO2 – decreases in summer and increases in winter
- Annual variations in plant growth also result in annual variations in NDVI on a global basis
- Global CO2 and NDVI levels are highly correlated
- Implications – Variations in NDVI have the potential to develop better under-standing of variations in atmospheric CO2

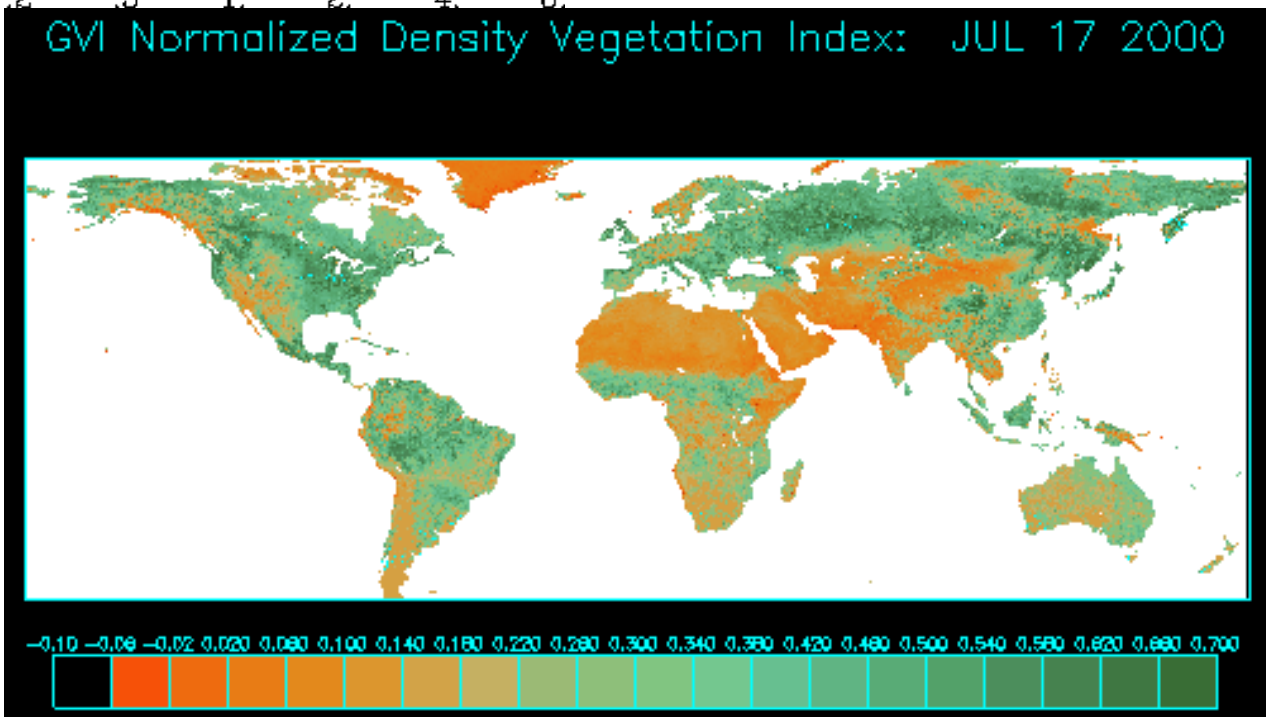
Monitoring large-scale vegetation change using AVHRR data

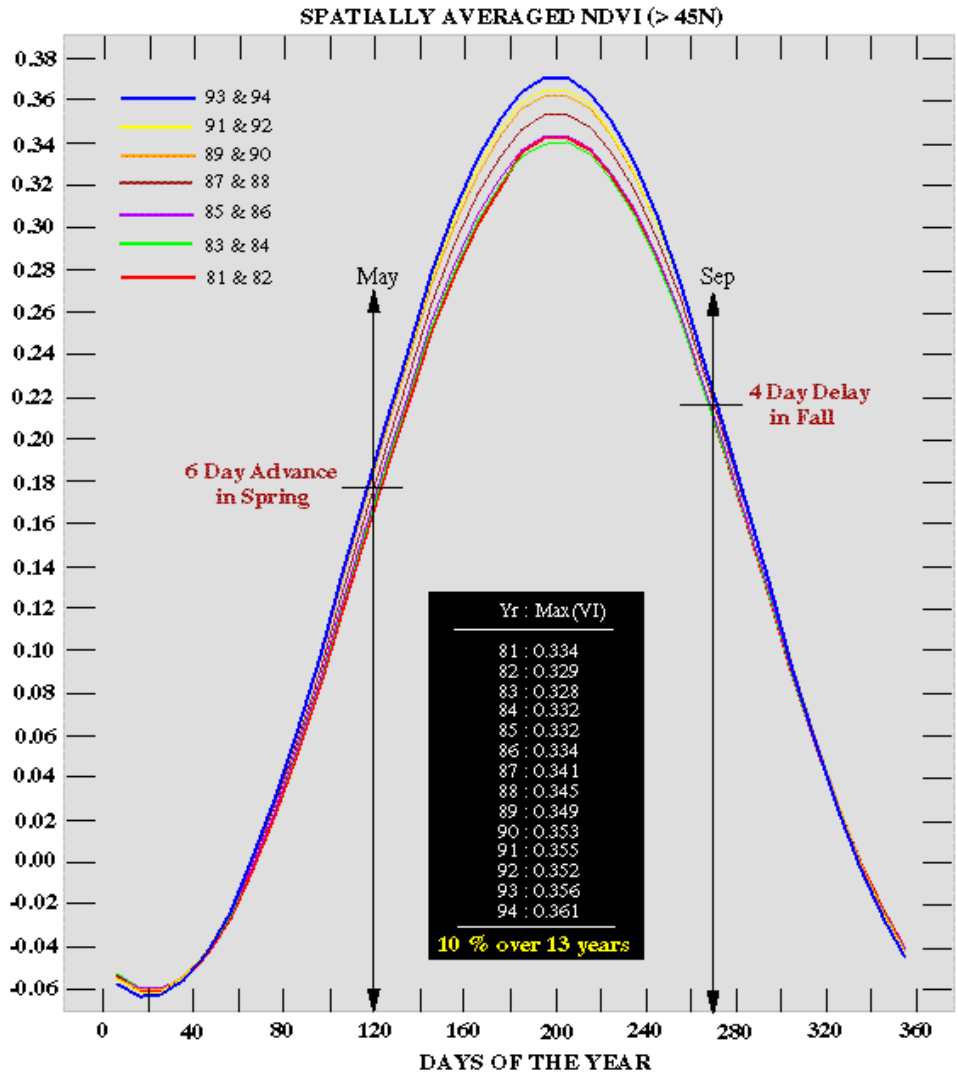
Correlating NDVI changes with surface temperatures

Recommended reading

Myneni, R.B., C.D. Keeling, C.J. Tucker, G. Asrar, and R.R. Nemani, Increased plant growth in the northern high latitudes from 1981 to 1991, *Nature*, *386*, 698-702, 1997.


Annual D-N
L-OTI(°C) Change 1970-1999
.48
-8.
-4.
-2.
-1.
-.5
-.2
.2
.5
1.
2.
4.
8.

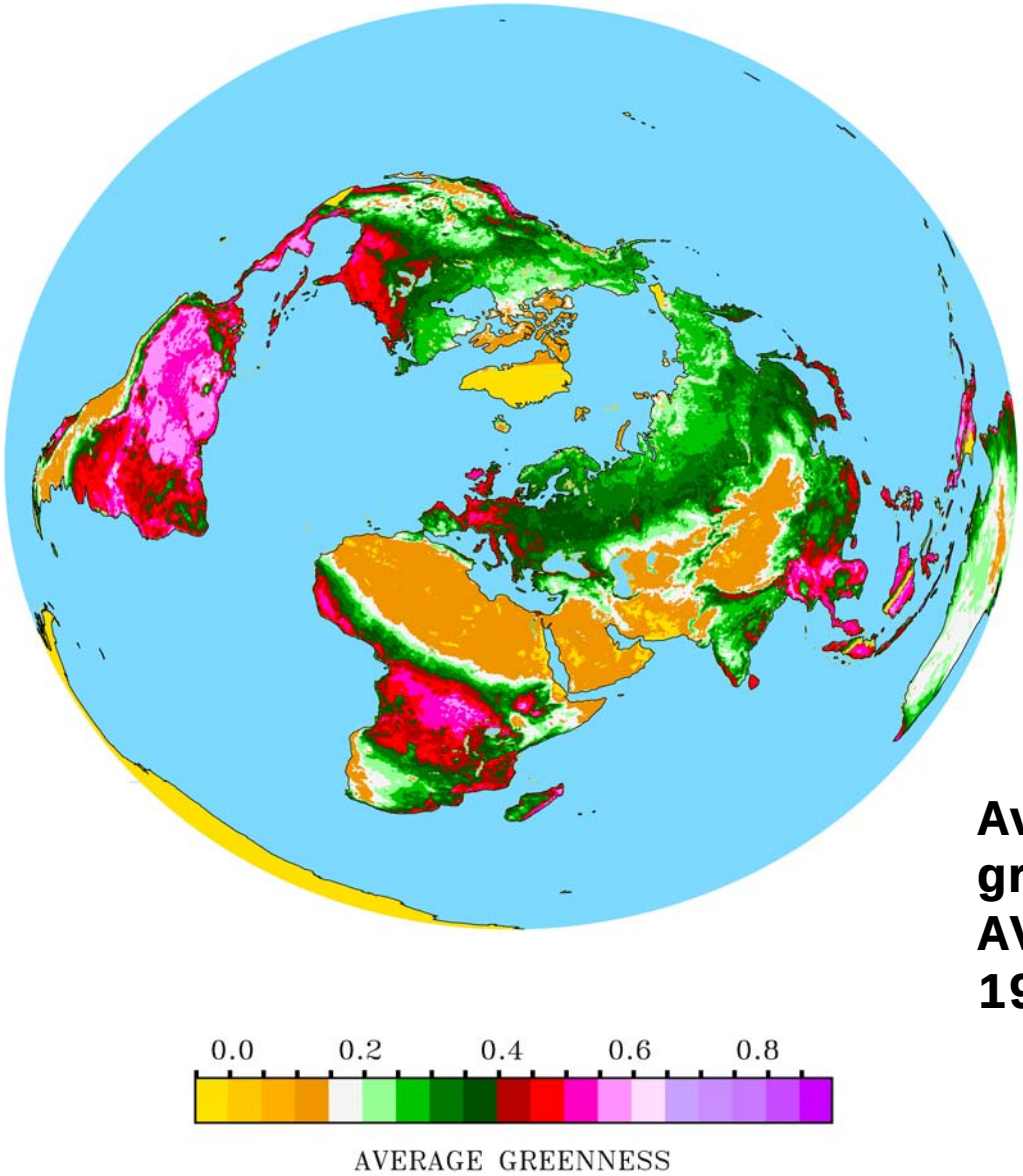

GVI Normalized Density Vegetation Index: JUL 17 2000
-0.10 -0.06 -0.02 0.020 0.060 0.100 0.140 0.180 0.220 0.260 0.300 0.340 0.380 0.420 0.460 0.500 0.540 0.580 0.620 0.660 0.700



From Myneni et al. 1997.

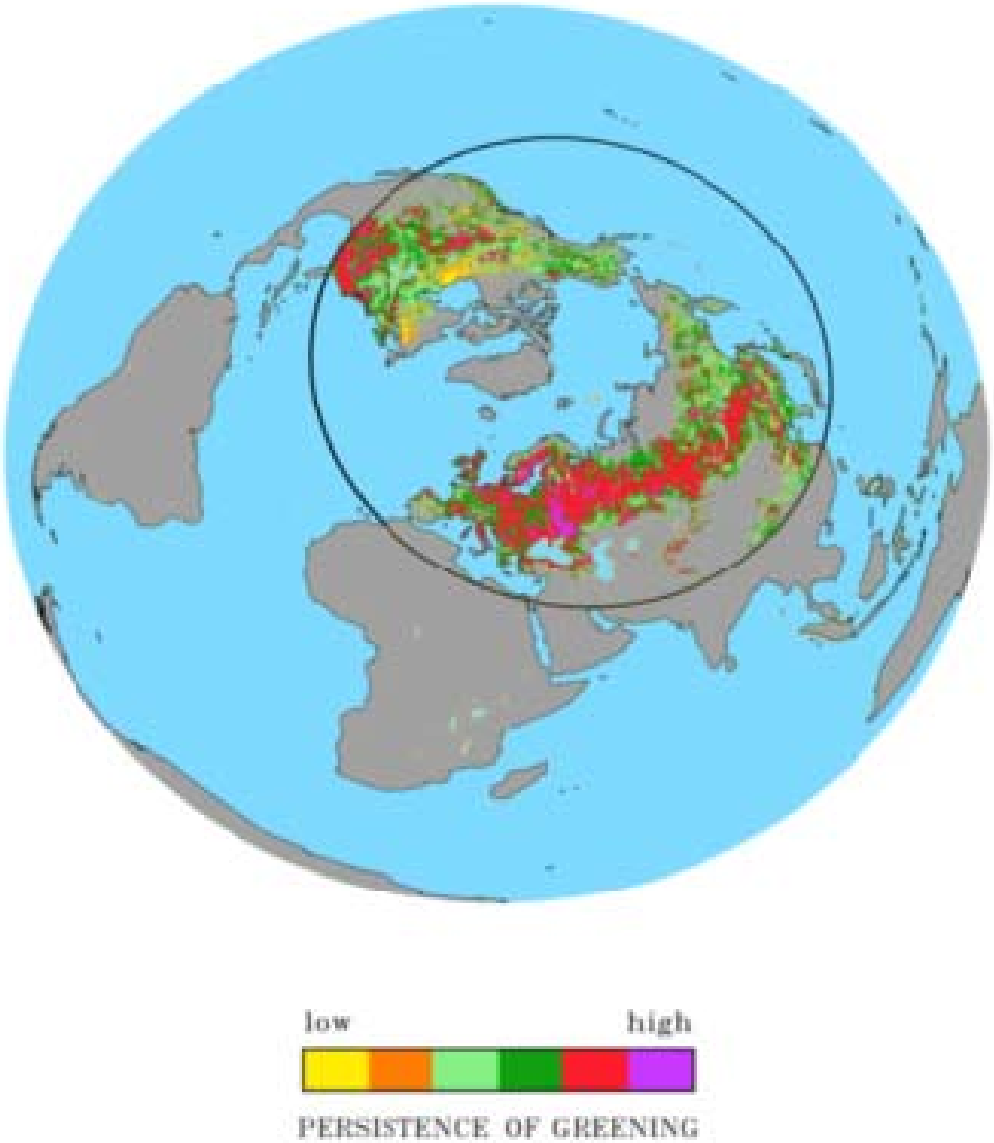
Results of Myneni et al. paper

- Average Maximum seasonal NDVI in high northern latitudes has increased during the 1980s
- Seasonal growing season length has increased, based on NDVI
- Both of these observations are consistent with increased warming in this region



Zhou, L., Tucker, C.J., Kaufmann, R.K., Slayback, D., Shabanov, N.V. and Myneni, R.B. 2001. Variations in northern vegetation activity inferred from satellite data of vegetation index during 1981 to 1999, J. Geophys. Res., 106(D17): 20069-20083.

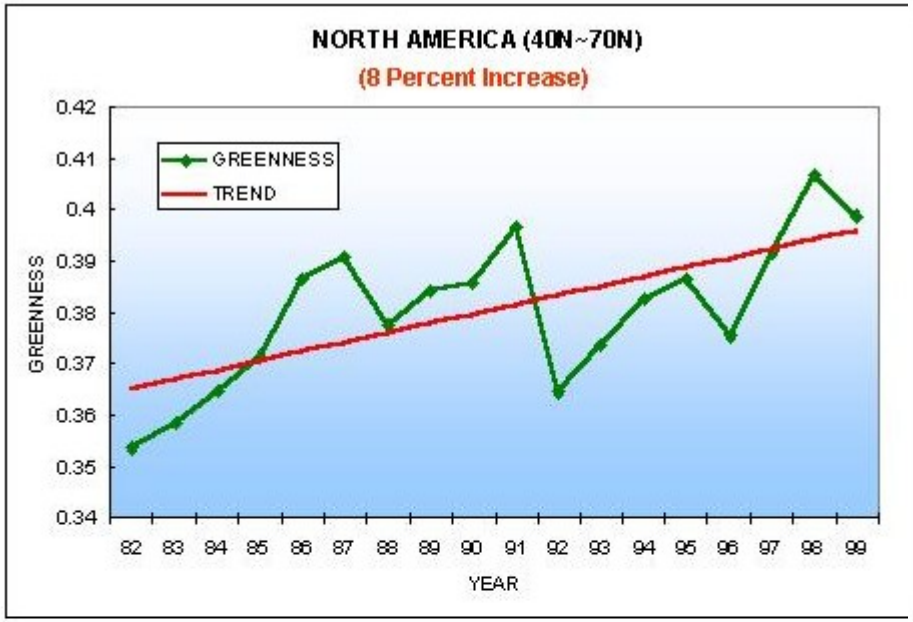
Average vegetation greenness derived from AVHRR NDVI from 1981-1999

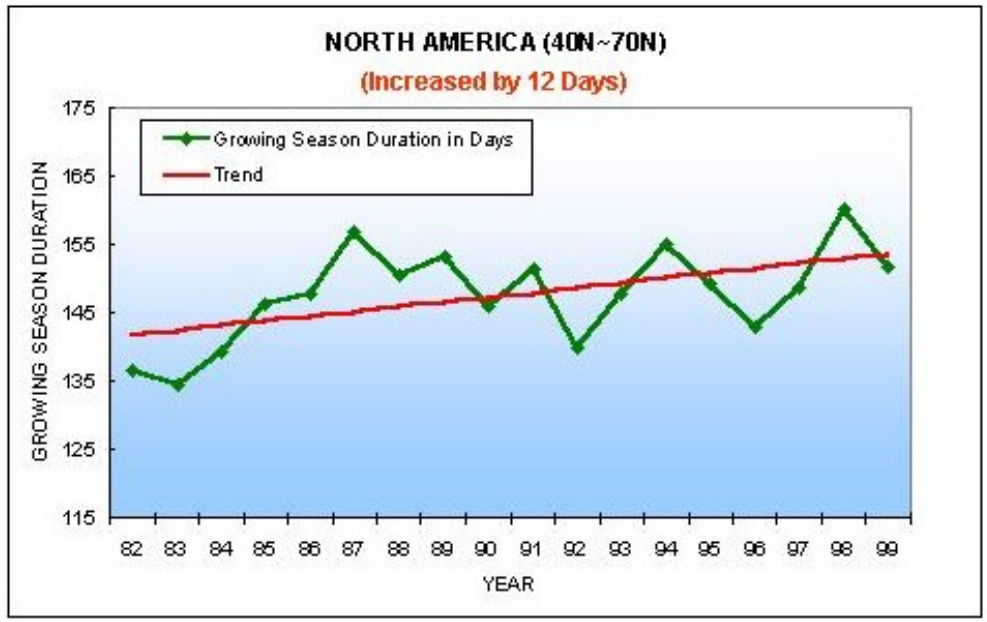


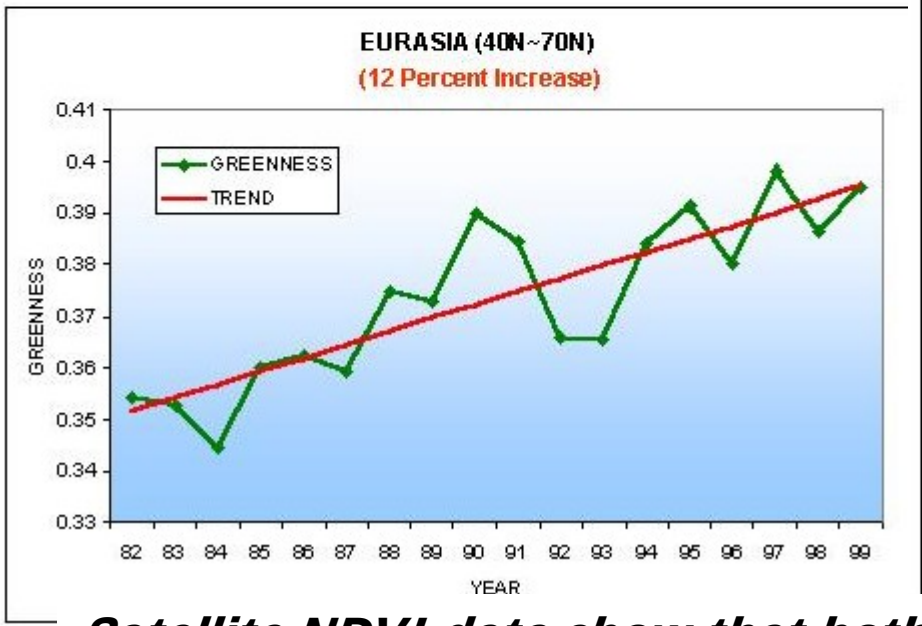
Or increases in greenness

Plot of change in greenness between 1981 and 1999

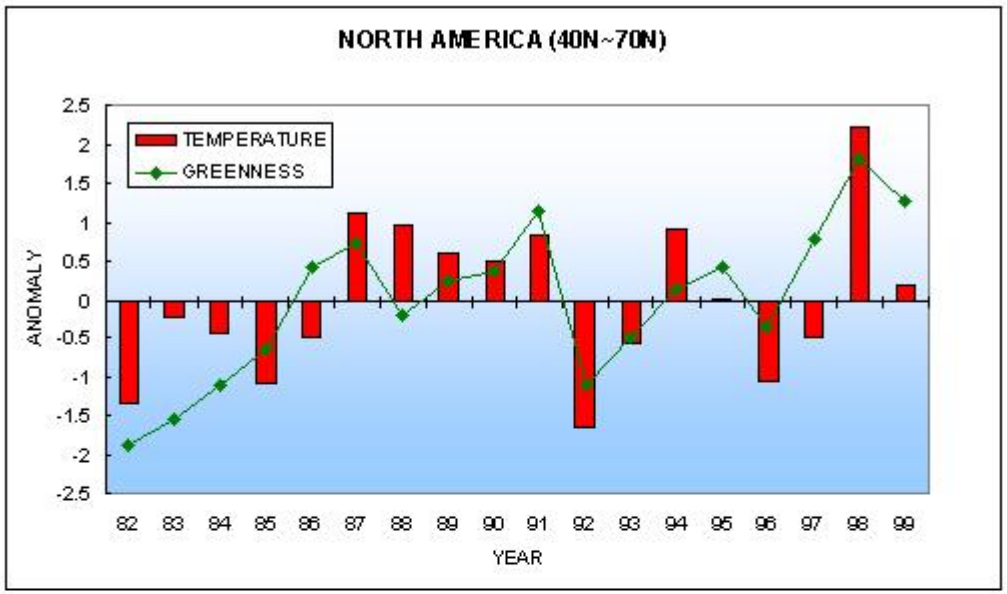
Satellite data show that most persistent increases in greenness occur in high northern latitudes

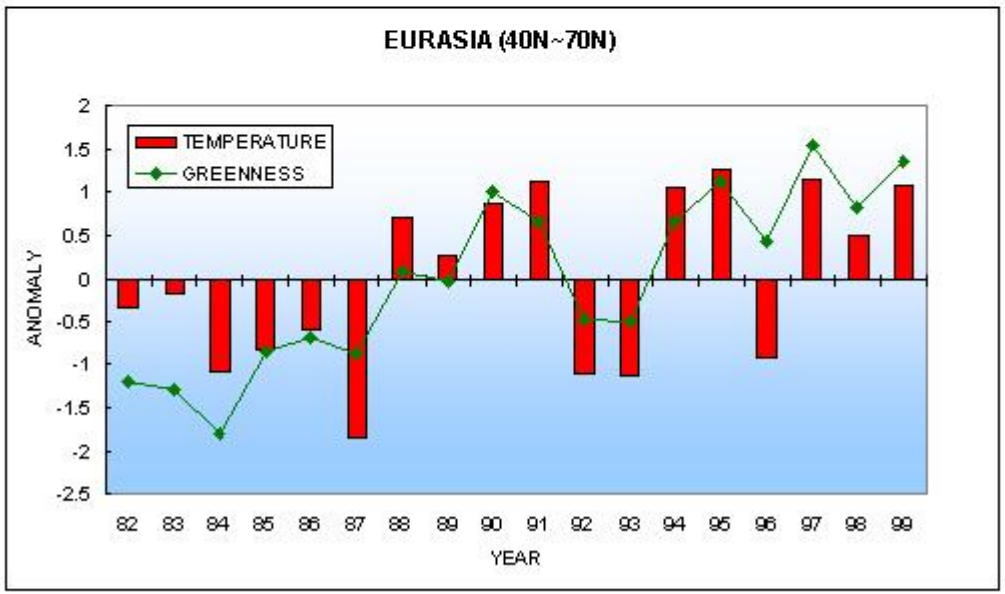






Satellite NDVI data show that both average greenness and growing season length have increased, with greater increases occurring in Eurasia





Satellite data show that inter-annual variations in NDVI greenness are correlated with inter-annual variations in temperature

Results of Zhou et al.

- While there has been an overall increase in NDVI in high Northern Latitude region over past 20 years, their has been considerable inter-annual variations
- Inter-annual variations in NDVI appear to be correlated with variations in average air temperature
- Conclusion – Differences in NDVI are related to differences in seasonal net primary production

Summary- Vegetation Indices and Global Applications

1. Fundamentals of Vegetation Indices: capturing NIR/red difference
2. Problems with simple VI
3. Factors affecting NDVI variation
4. Global NDVI datasets
5. Applications

- Monitoring variations in the extent of the Sahara desert
- Correlating global NDVI with atmospheric CO_2 concentrations
- Correlating NDVI changes with surface temperatures