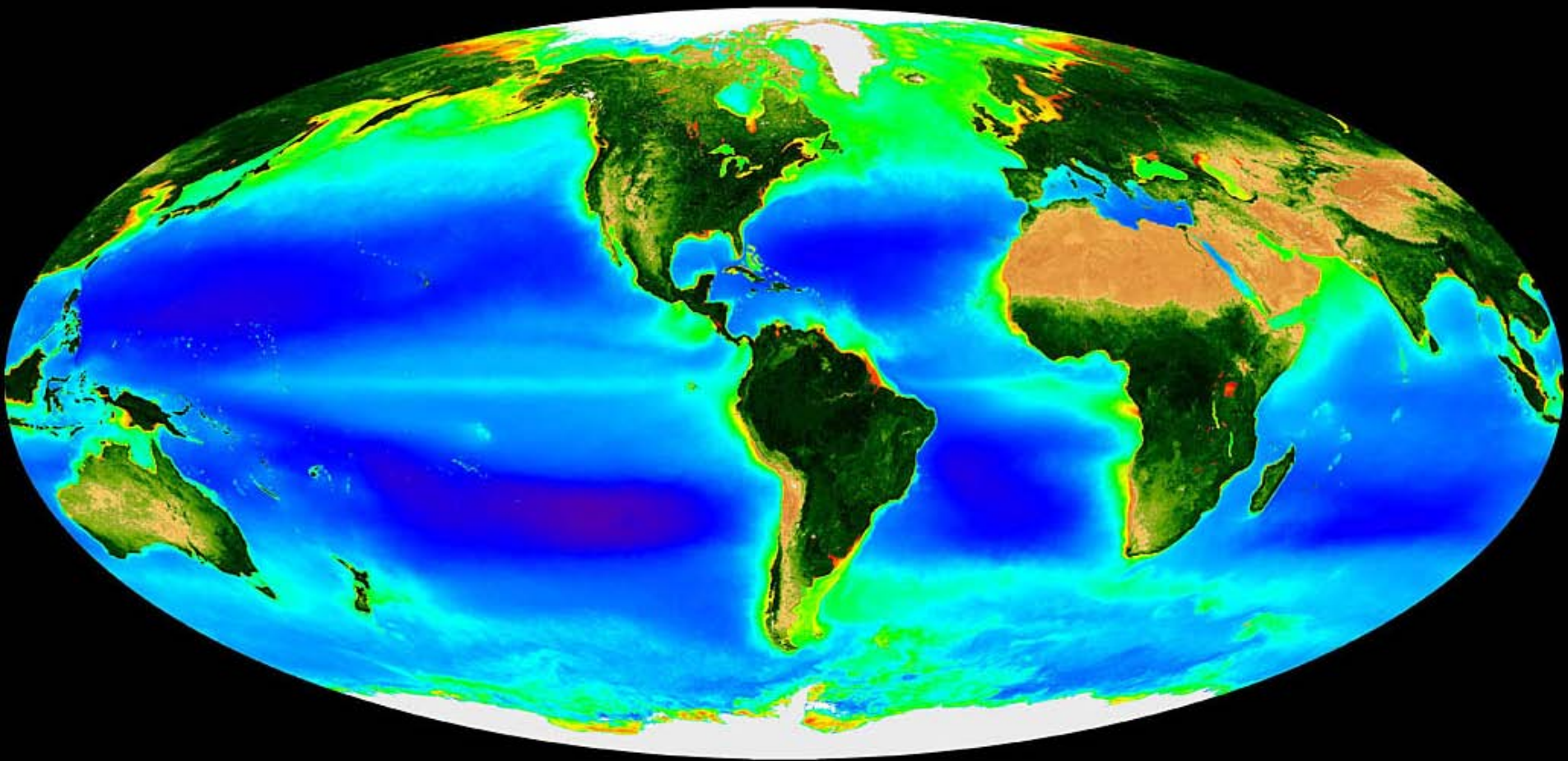


Critical Land Climate Observations



Compton Tucker
Climate Change Science Program &
NASA/GSFC

Climate/Carbon Cycle and Carbon Emission Verification--Satellites are crucial

- **Land & Ocean Photosynthesis – MODIS-VIIRS**
- **LULCC, Deforestation etc. – Landsat MODIS**
- **Land fires esp. forest fires – Landsat-MODIS**
- **Permafrost soils, peat etc. – Landsat-MODIS**
- **Direct measurement of atmospheric CO₂**
 - **Orbiting Carbon Observatory-2**
 - **Laser techniques (ASCENDS)**
- **Vegetation height and structure**

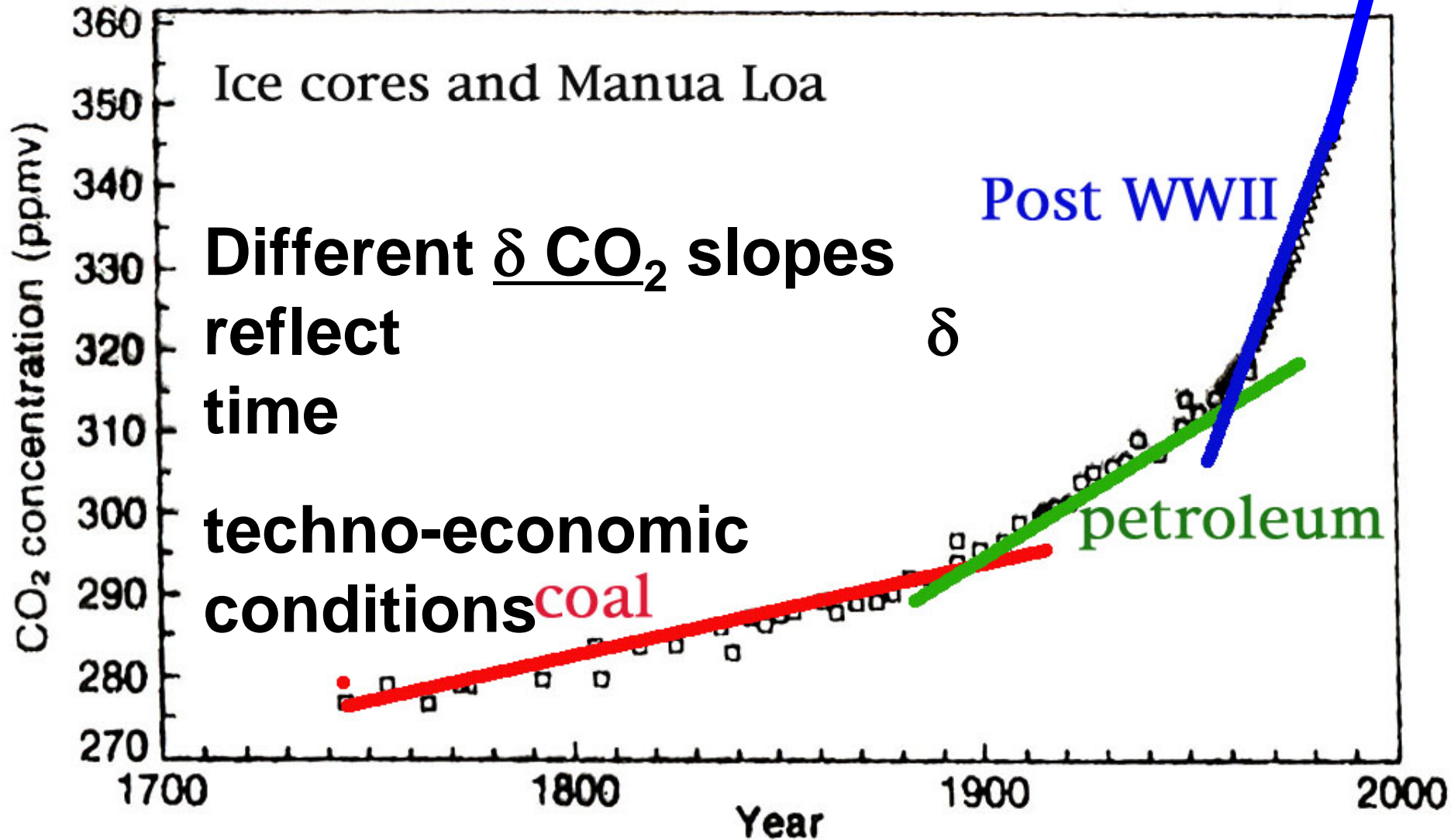
Houston, We Have a Problem...

**We are altering
our planet's
climate**



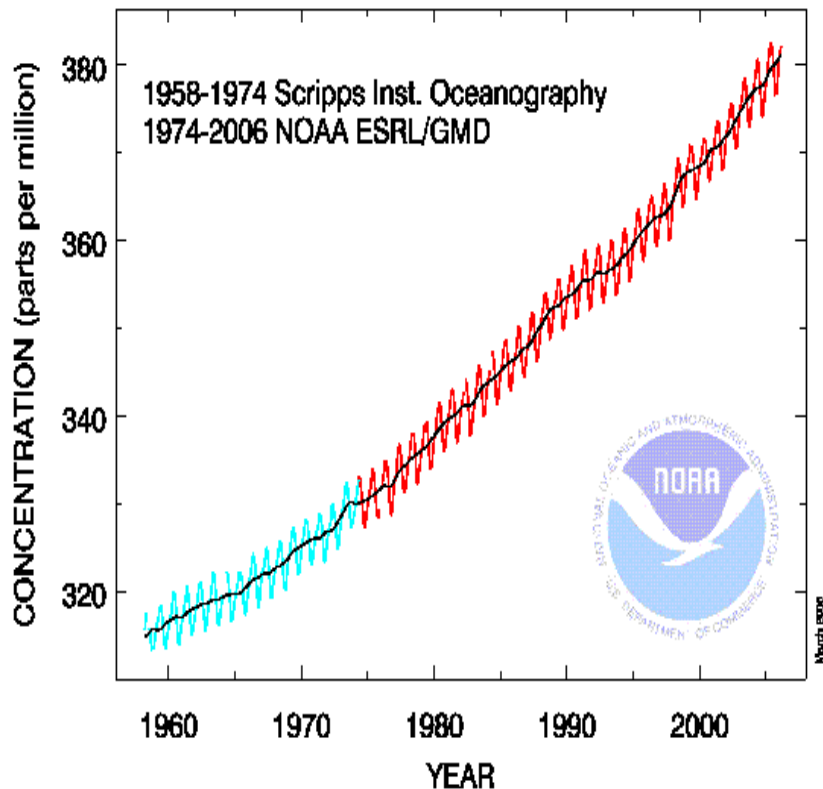
Atmospheric CO₂ since 1740

385 ppm now

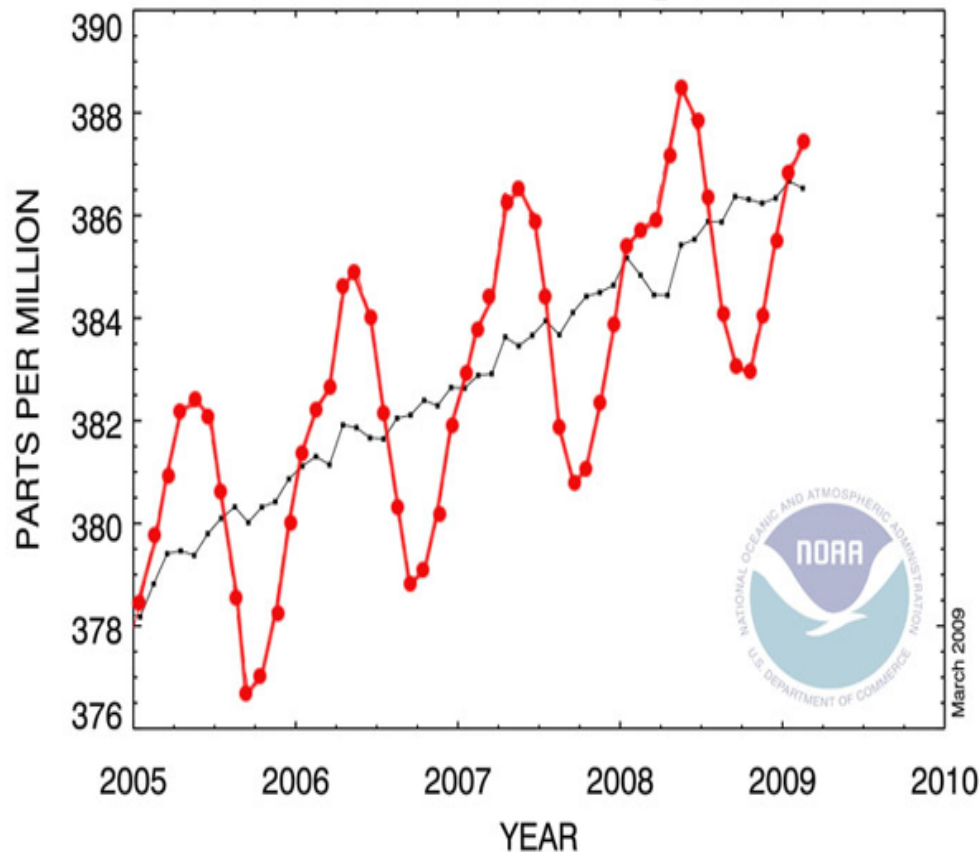


Atmospheric CO₂ measurements

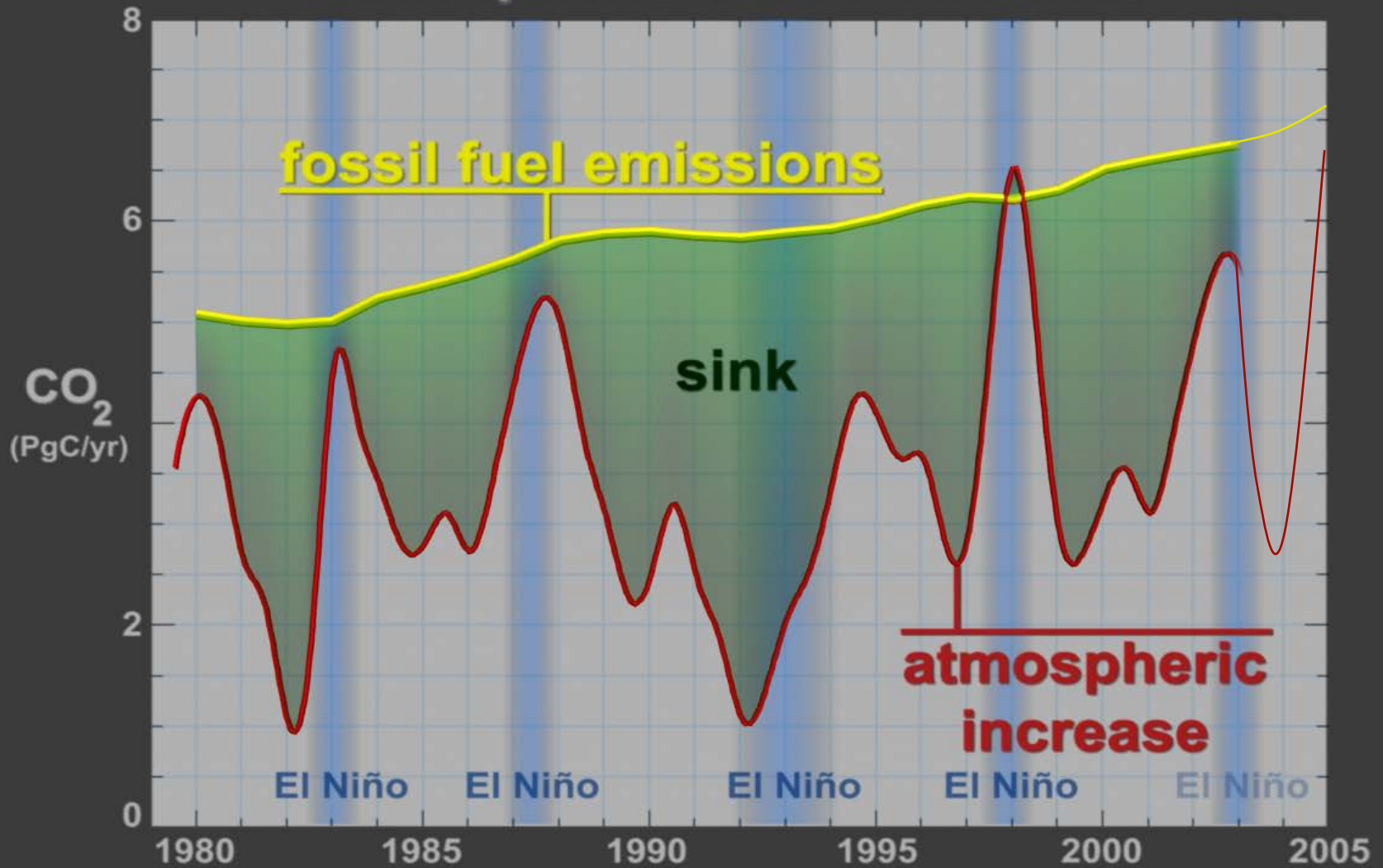
Atmospheric CO₂ at Mauna Loa Observatory



RECENT MONTHLY MEAN CO₂ AT MAUNA LOA

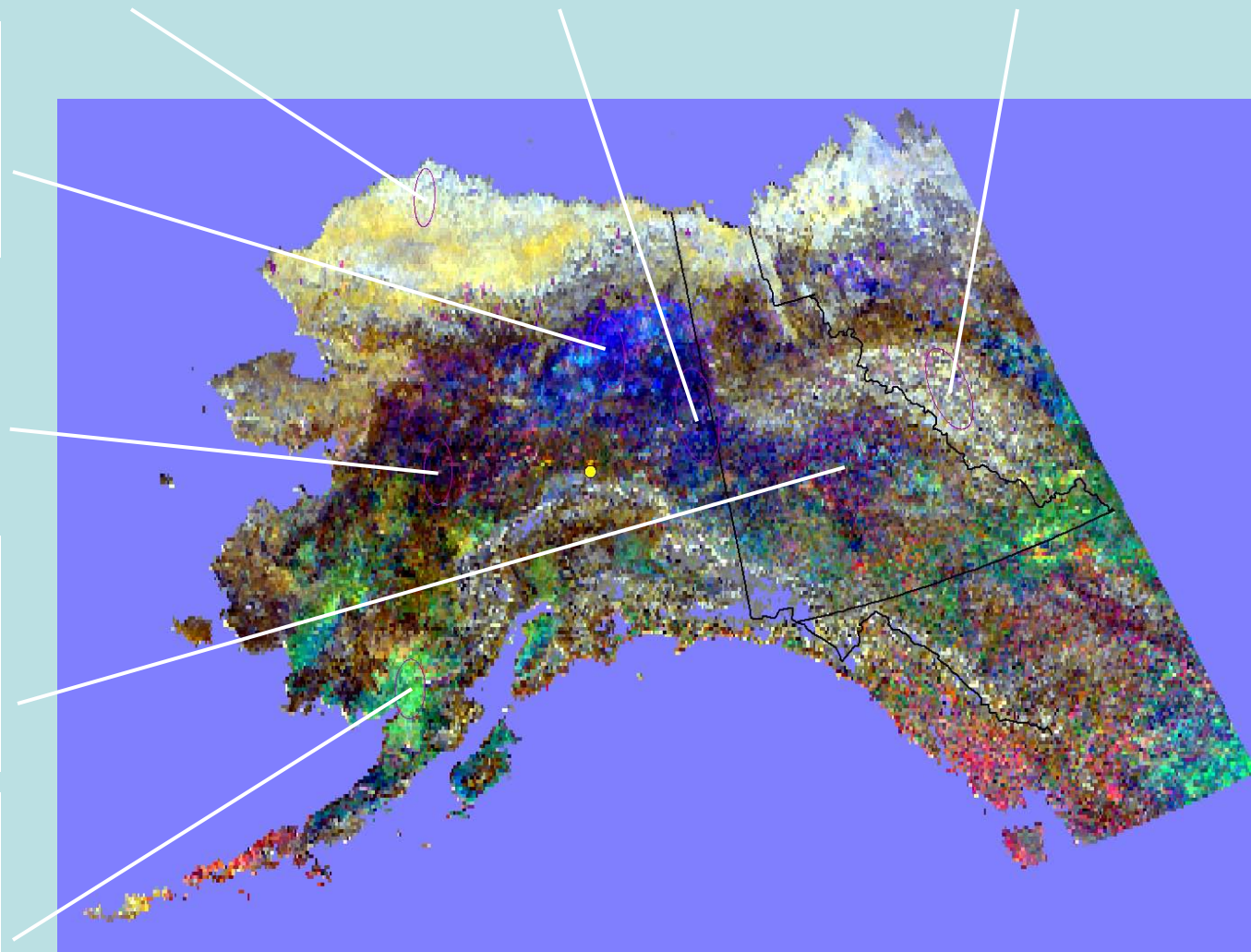
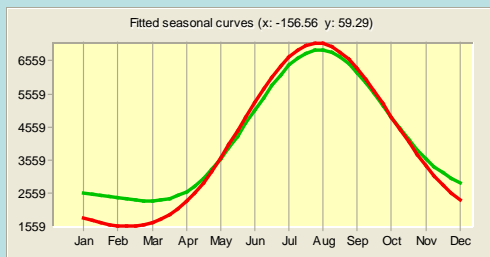
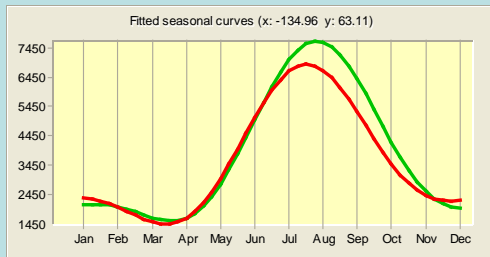
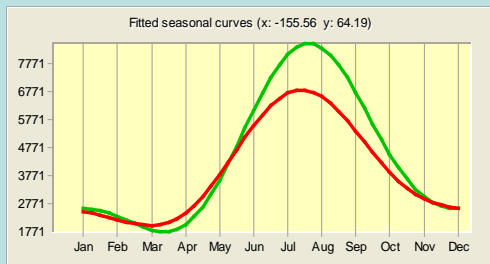
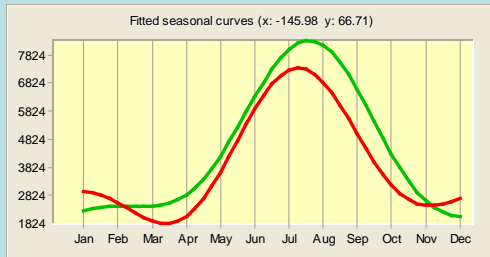
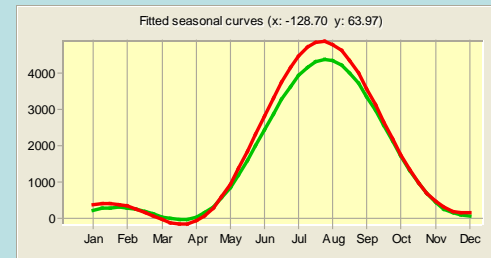
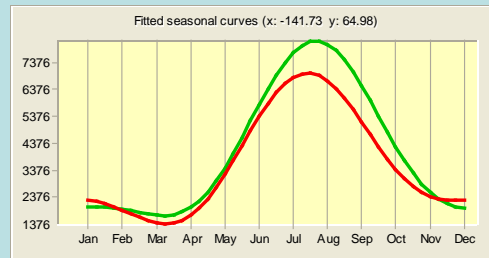
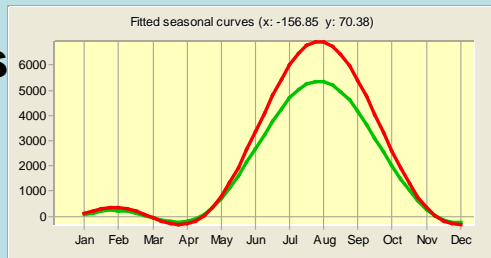


Atmospheric Carbon Dioxide

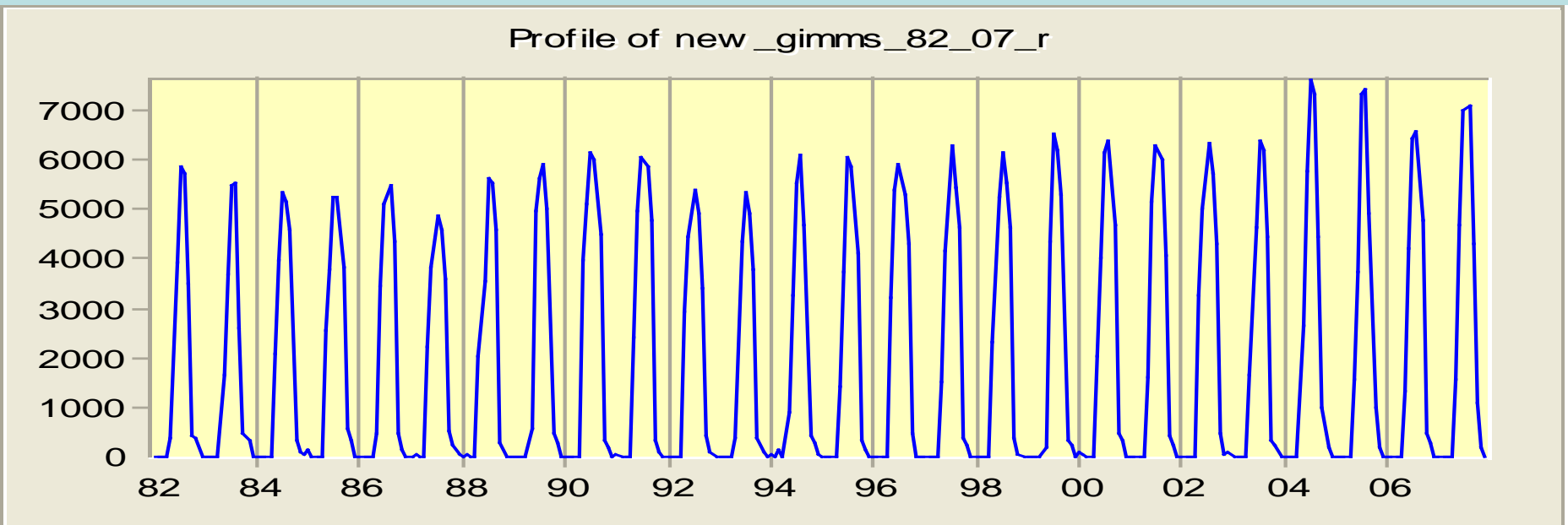
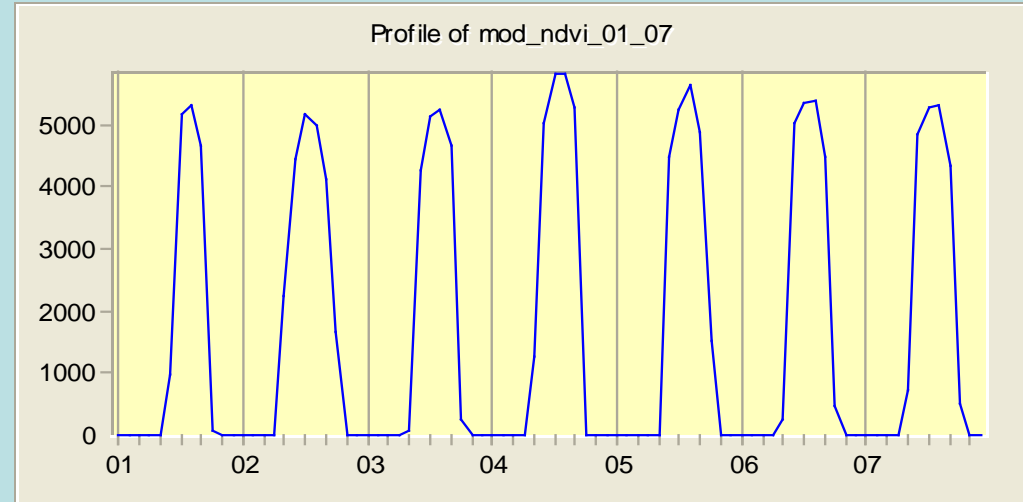
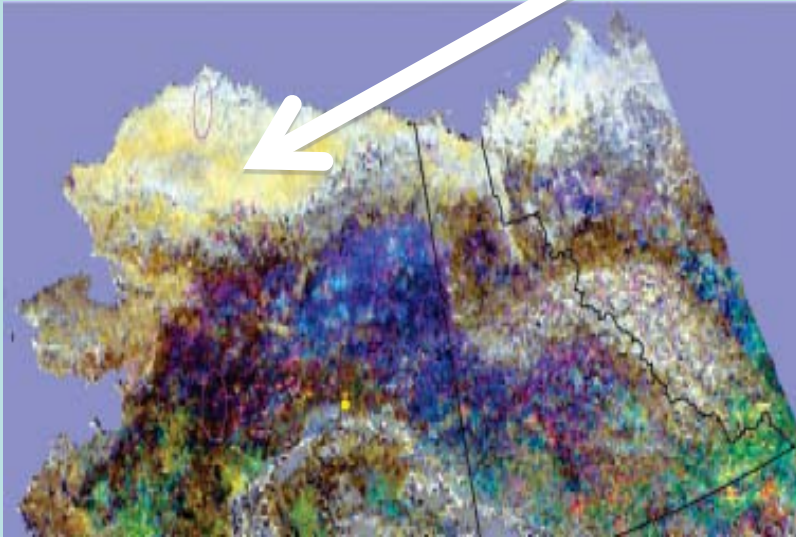


Fitted Curves

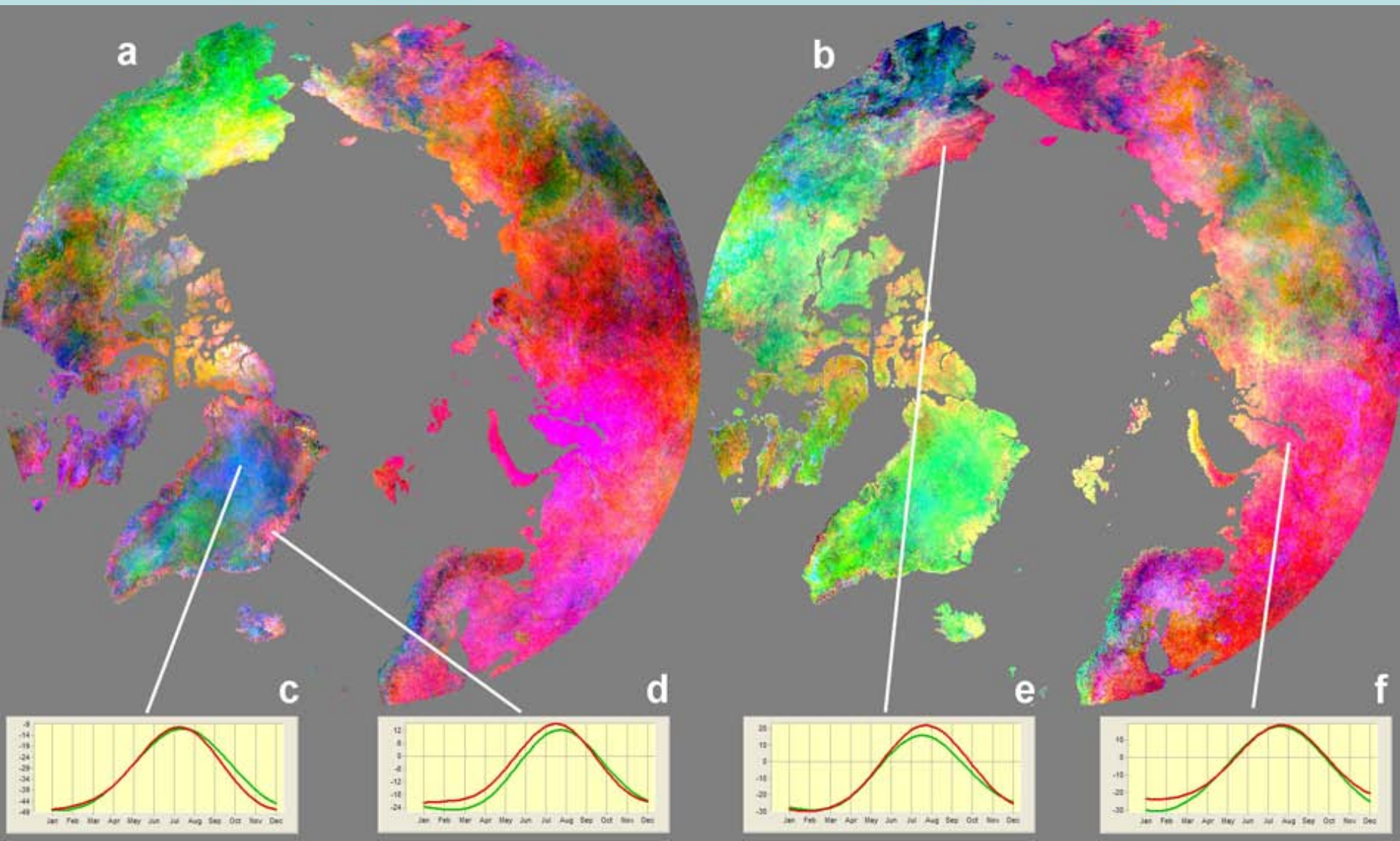
1982
2007



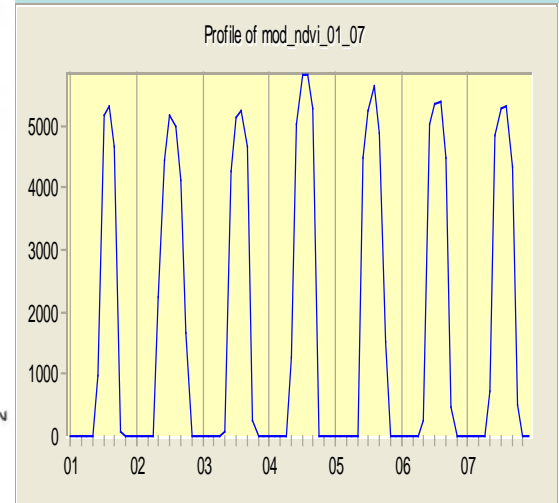
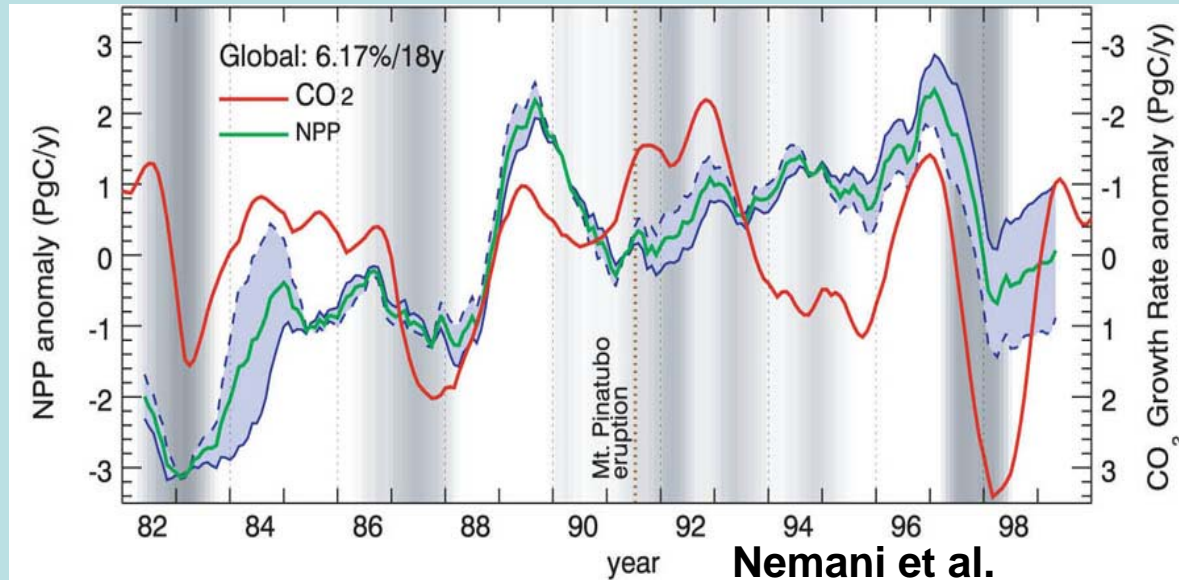
Arctic Coastal Tundra



MODIS Surface Temperature

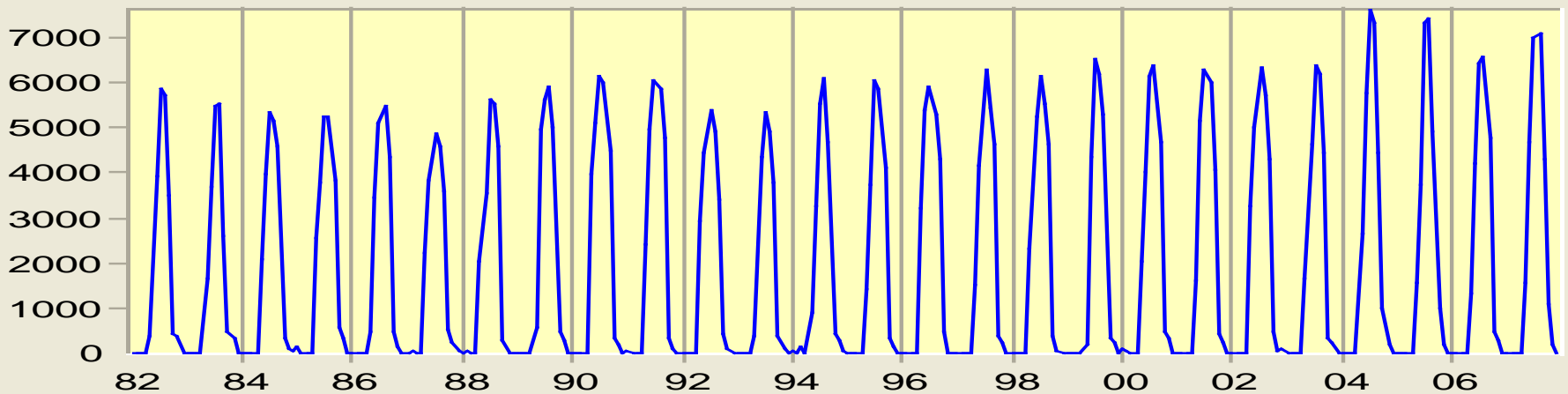


Land NPP—FPAR –NDVI driven

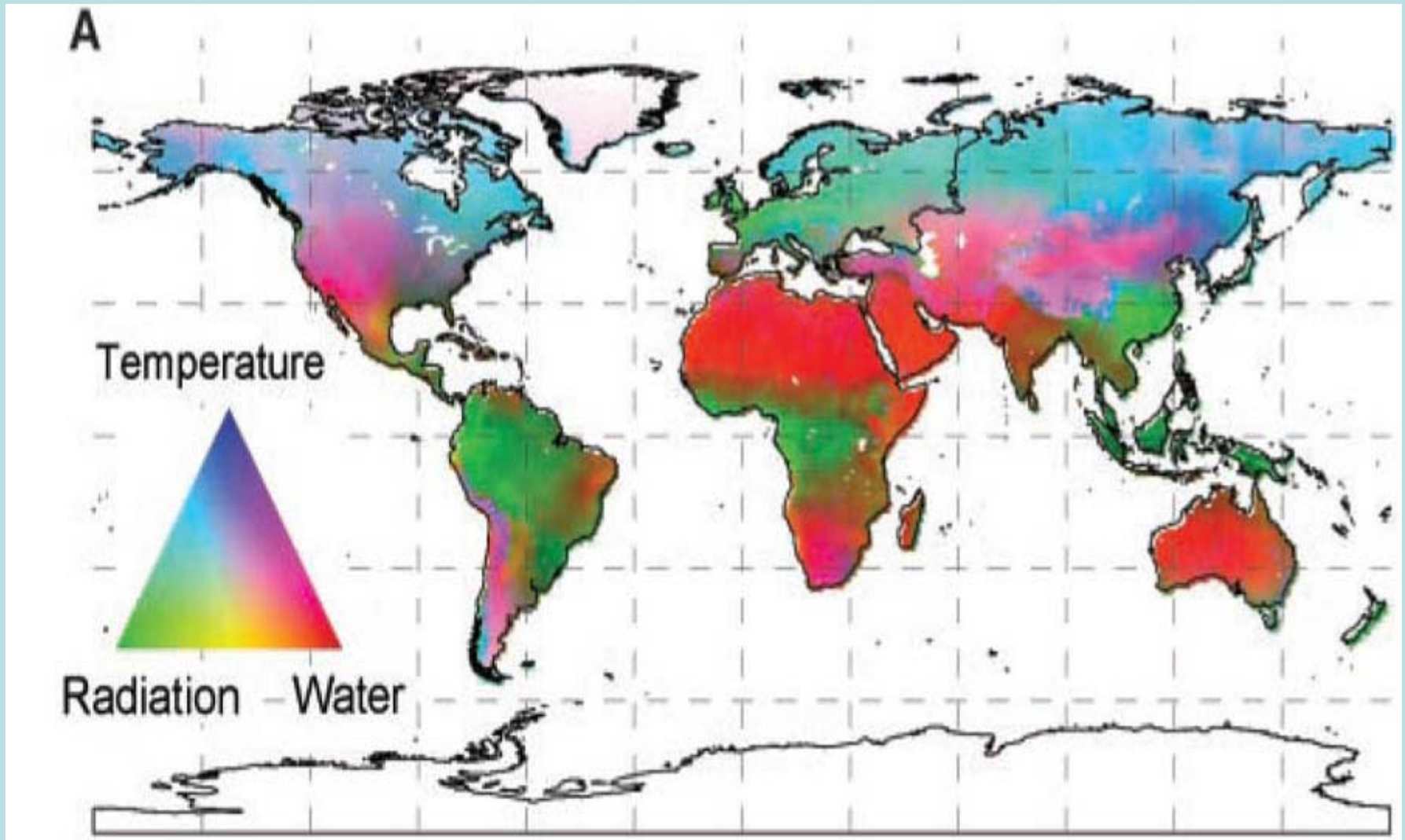


2003

Profile of new_gimms_82_07_r



Land NPP Limitations



Nemani et al. 2003

Landsat – A key climate sensor

Absolutely crucial land climate sensors:

- **Landsat 1972 – now**
- **AVHRR-MODIS-VIIRS 1981 -- now**
- **Lidar & InSAR for the 3rd Dimension
(DESDnyl)**

Why?

Land use, land cover change/climate

Carbon cycle land/climate

Cryosphere, etc.

Landsat – A key climate sensor

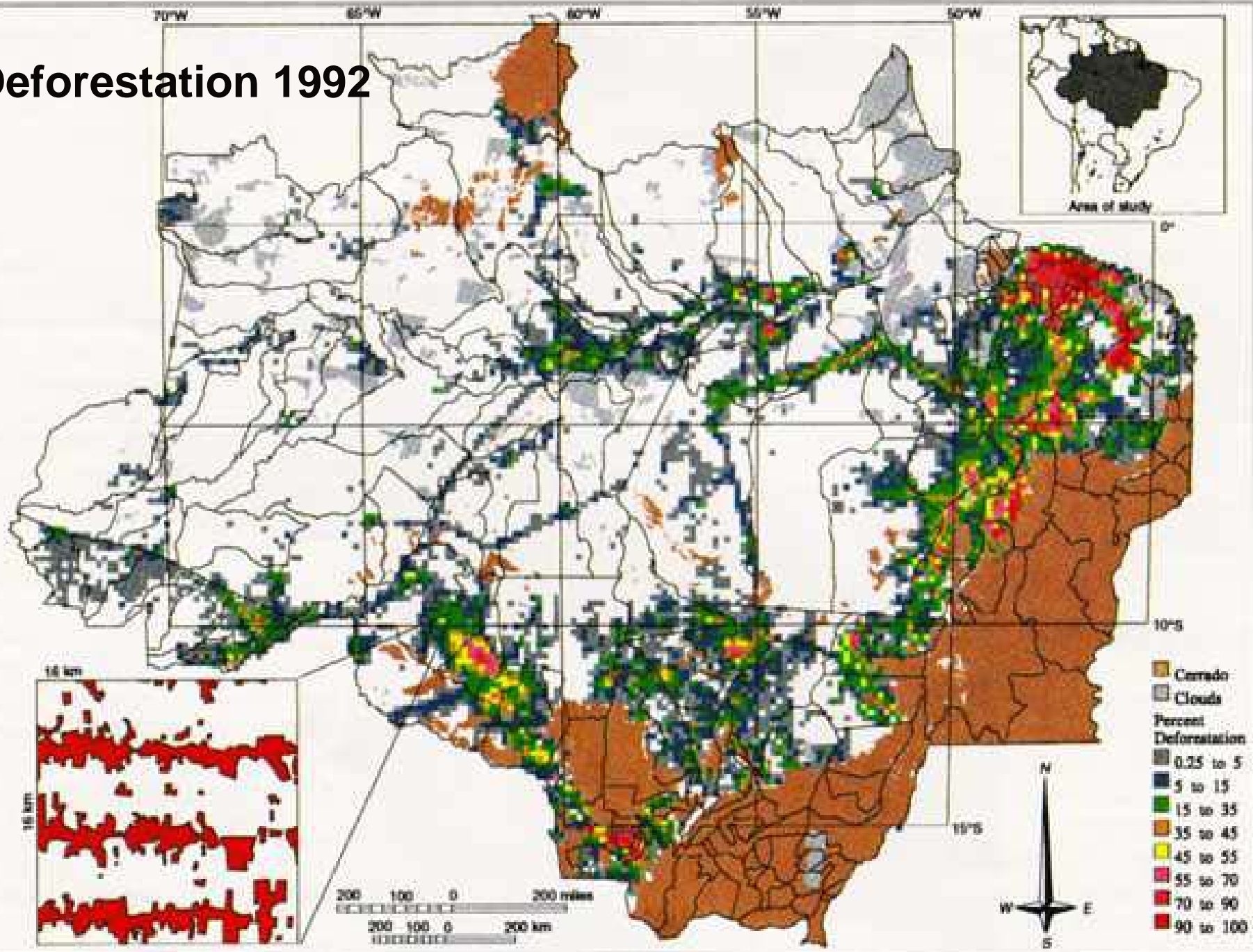
Why?

- 1. 30 m spatial resolution close-to-perfect match to surface variability (Townshend and Justice 1988)**
- 2. Spectral bands are well situated**
- 3. Repeat cycle OK**
- 4. Excellent data system**

**The Landsat
thematic
mapper and
enhanced
thematic
mapper are
ideally suited
for mapping
land use and
land cover
change**



Deforestation 1992

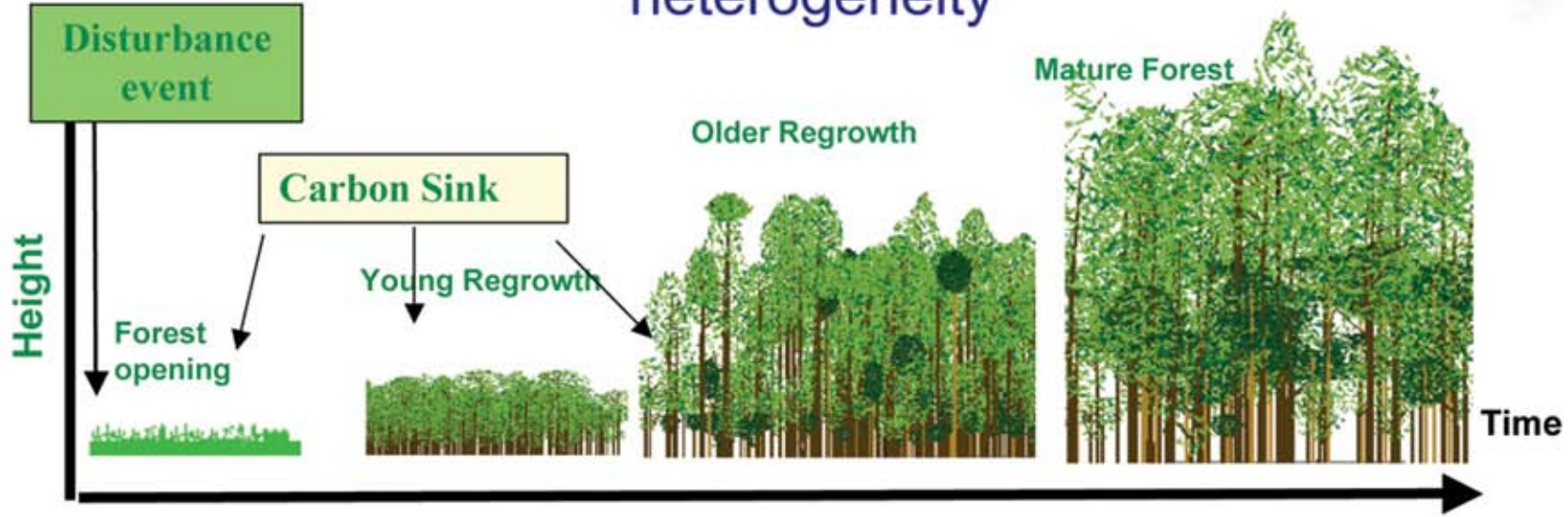


How to enhance Landsat

- Landsat exploits the spatial & spectral domains
 - 30 m spatial resolution excellent
 - Excellent spectral band selection
- Exploit the time domain (e.g. AVHRR, MODIS, Seawifs, etc.) but at 30 m spatial resolution with TM/ETM spectral bands
- Wider field of view, 4-5 day repeat cycle
- Build multiple instruments (e.g. Landsat-5's TM) = Continuity!!



Ecosystem changes can be seen in vertical height & density distributions of vegetation & in spatial heterogeneity

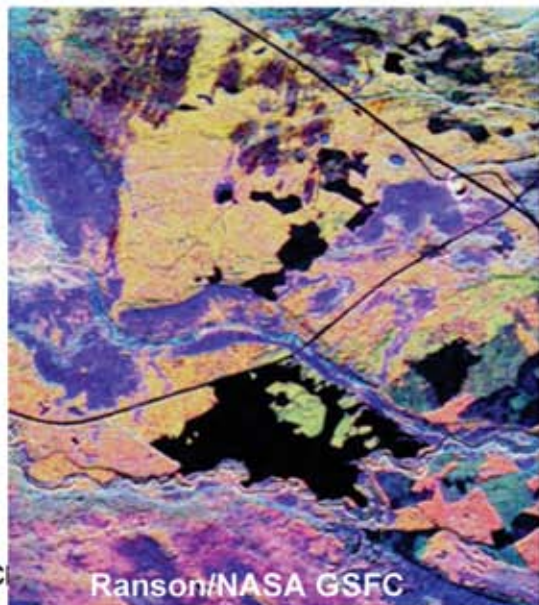


(figure from J. Drake)

More Biomass →



Disturbances from fire, logging, insects, disease, storms



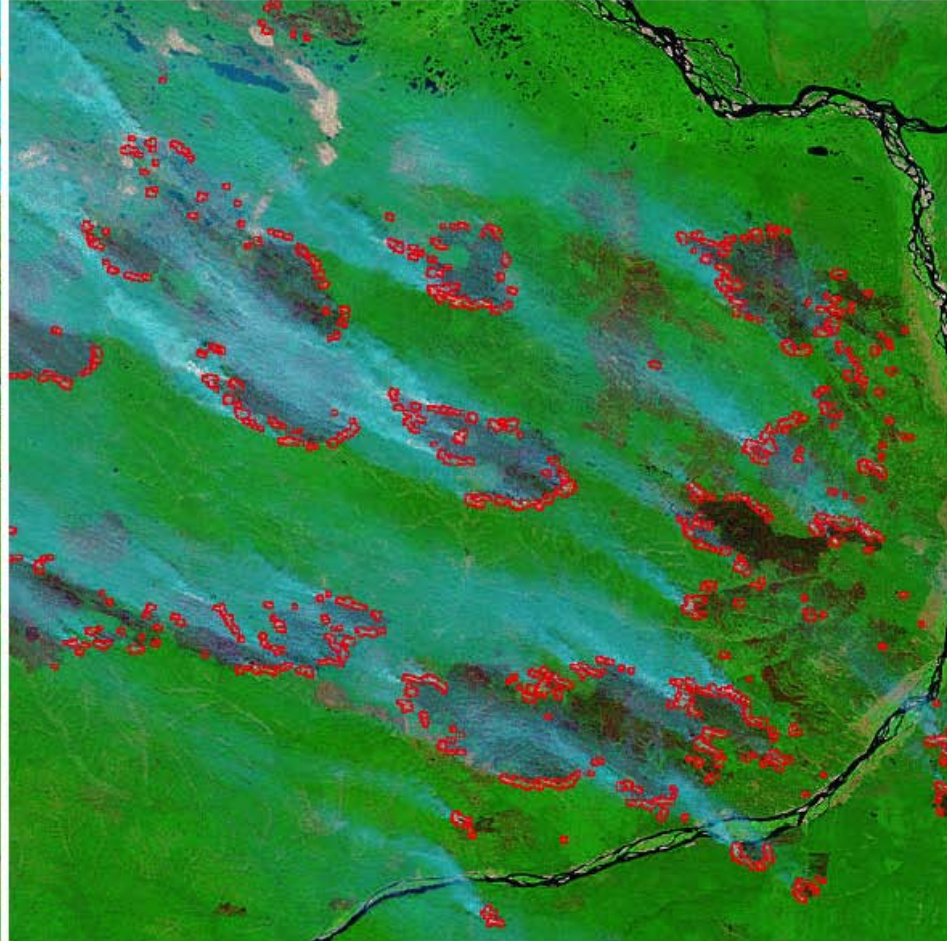
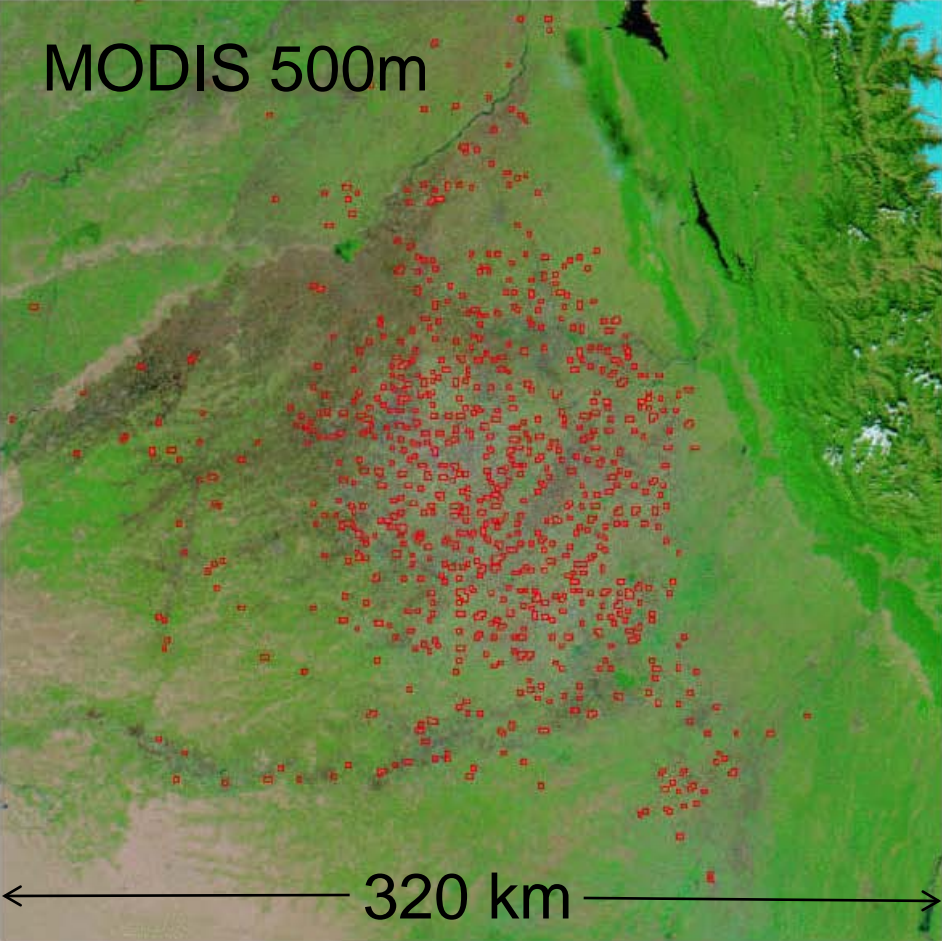
Forests tend to be patchy due to natural and human disturbances.

Radar image from Canada shows evidence of fires (dark areas at top) and logging (e.g., black features in center)

Disturbances are major forces that determine transition of forest stands, landscapes, and regions to & from carbon sinks to sources .

Satellite Observations of Burned Area

MODIS 500m



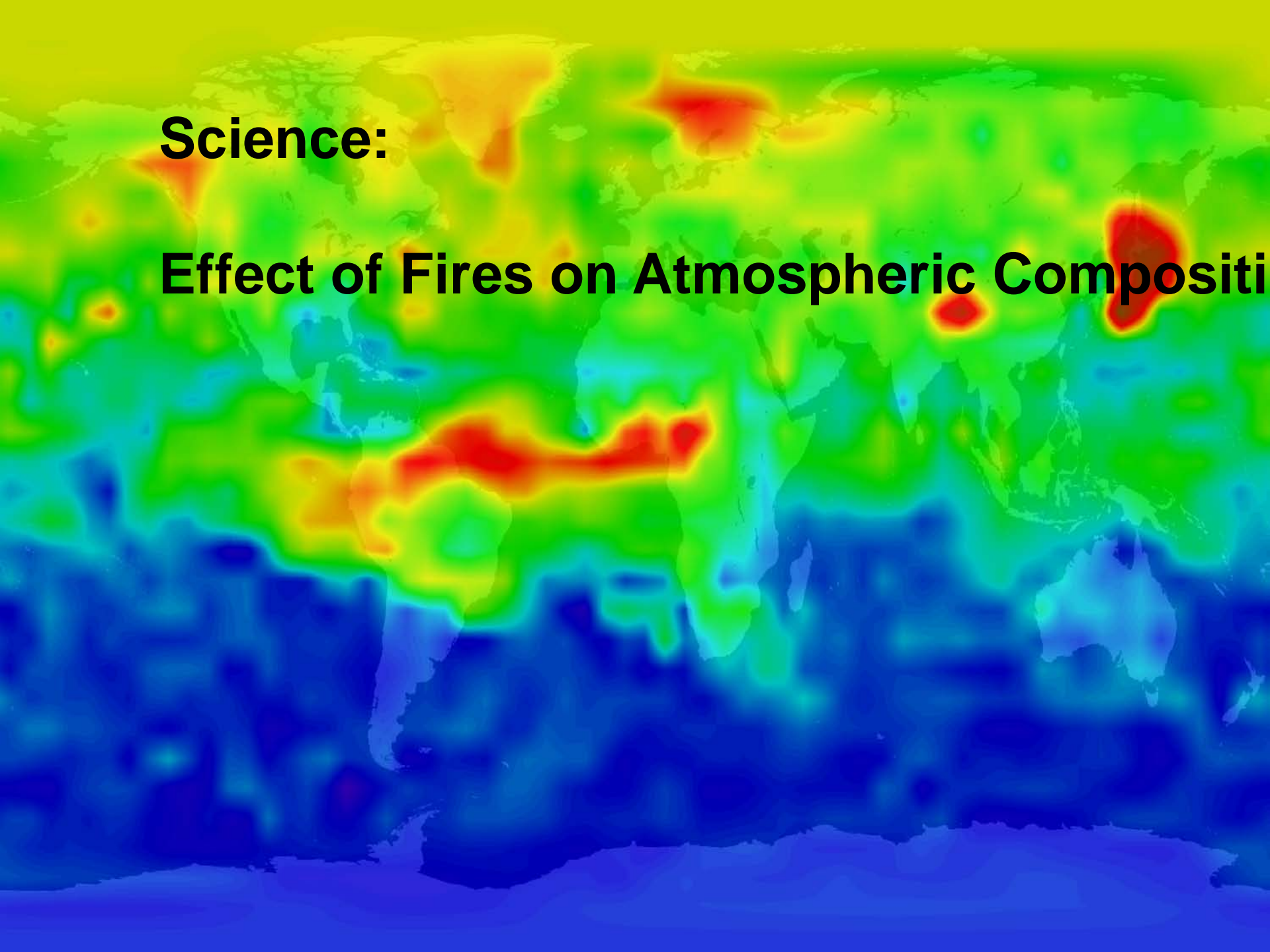
N. India -Subtropical
Pasture, Agriculture, woodlands

Siberia -Boreal
Evergreen and Deciduous forest, wetland

Relationship between burned area and fire counts can vary regionally

Science:

Effect of Fires on Atmospheric Compositi





ASCENDS Mission - Laser Sounder Approach

Goddard
Space
Flight
Center

3 simultaneous laser measurements

1. CO₂ lower tropospheric column

One line near 1572 nm

2. O₂ total column

Measured between 2 lines near 765 nm

3. Altimetry & atmospheric backscatter profile:

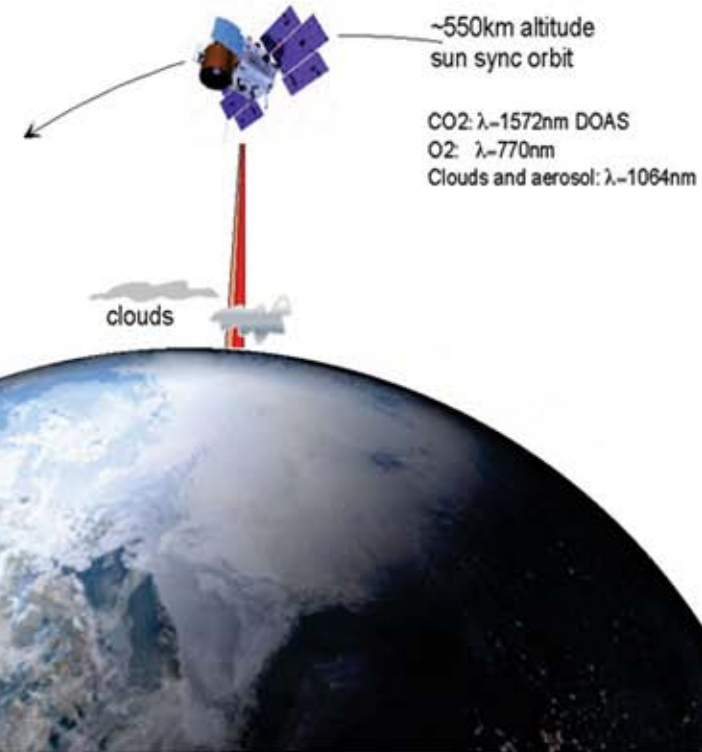
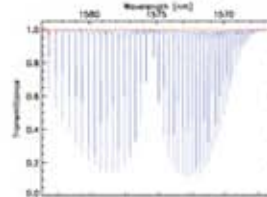
Surface height and atmospheric scattering profile at ~ 1064 nm

Measurements use:

- Pulsed EDFA lasers
- KHZ pulse rates
- 6 laser wavelengths/ gas line
- Time gated Photon counting receiver

Measures:

- CO₂ tropospheric column
- O₂ tropospheric column
- Cloud backscattering profile



Pulsed (time gated) signals :

- Isolates full column signal from surface
- Reduces noise from detector & solar background

Goal:

- ~ Monthly "grid", 1 deg spatial resolution, ~1 ppmV

Trace Gas Measurements using Lidar

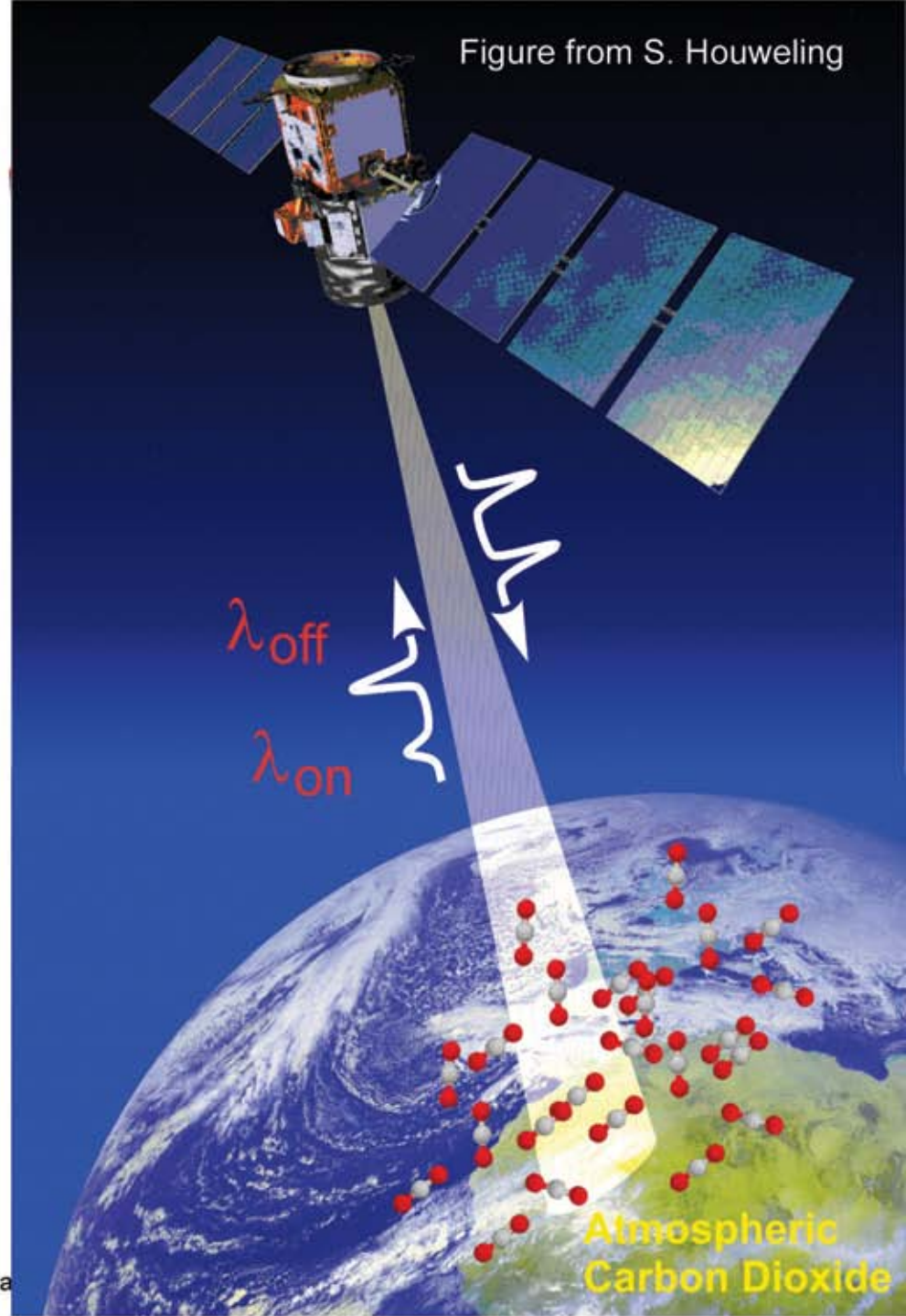
Laser Sounder:
Integrated Path Differential
Absorption Measurement

Uses natural surface as reflector

Gas column density from Ratio , on-
and off-line echo upulse energies

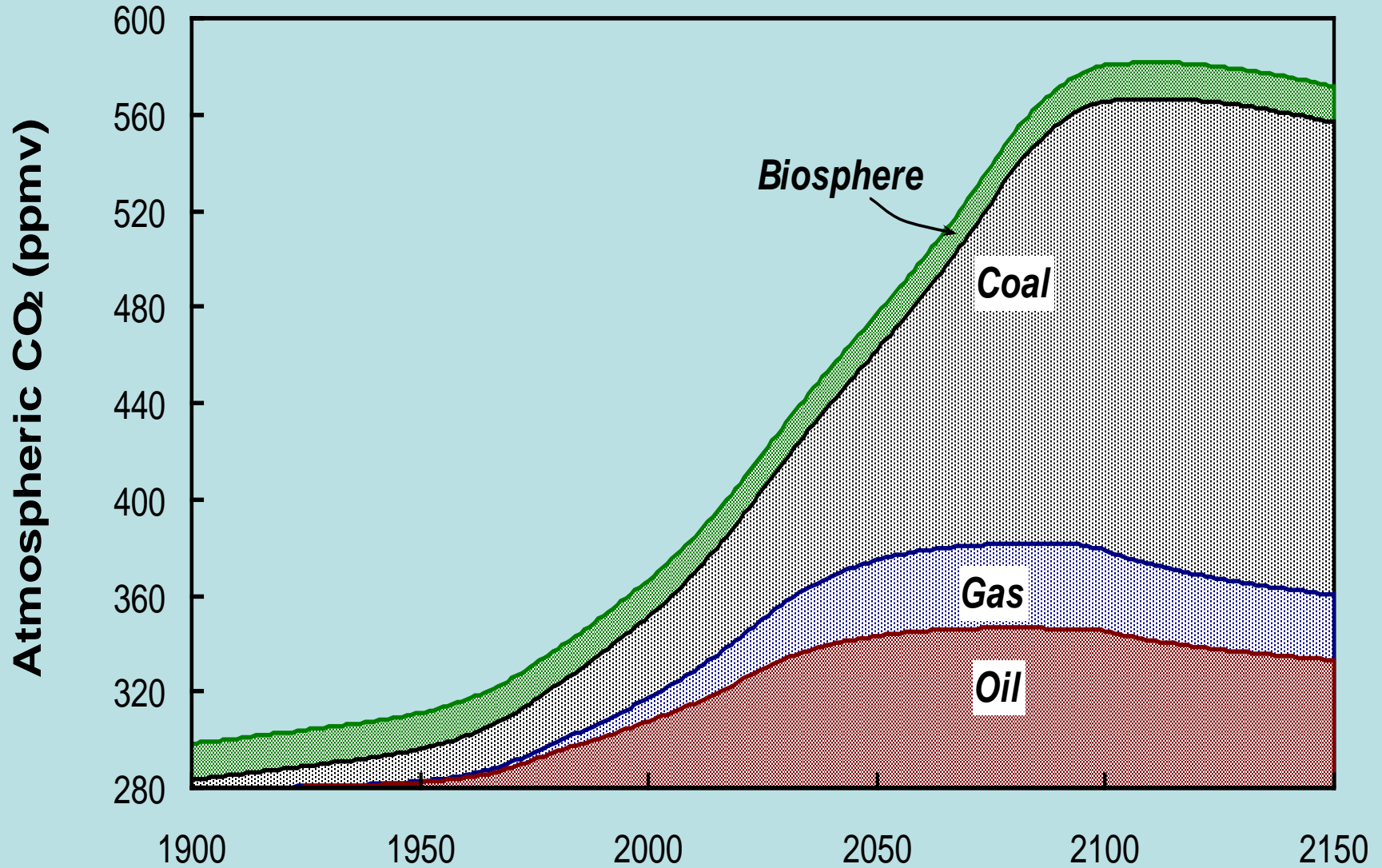
$$\int_{Surf}^{Sat.} N(r) \cdot dr = \frac{1}{2 \cdot \Delta\sigma} \cdot \ln \left[\frac{E_{off}(R)}{E_{on}(R)} \right]$$

Need 2 or more wavelengths to probe
(λ_{on}) and reference (λ_{off})



Business-as-Usual

(2% annual growth until 50% depletion, then 2% annual decline)



Western Coal



Western Coal



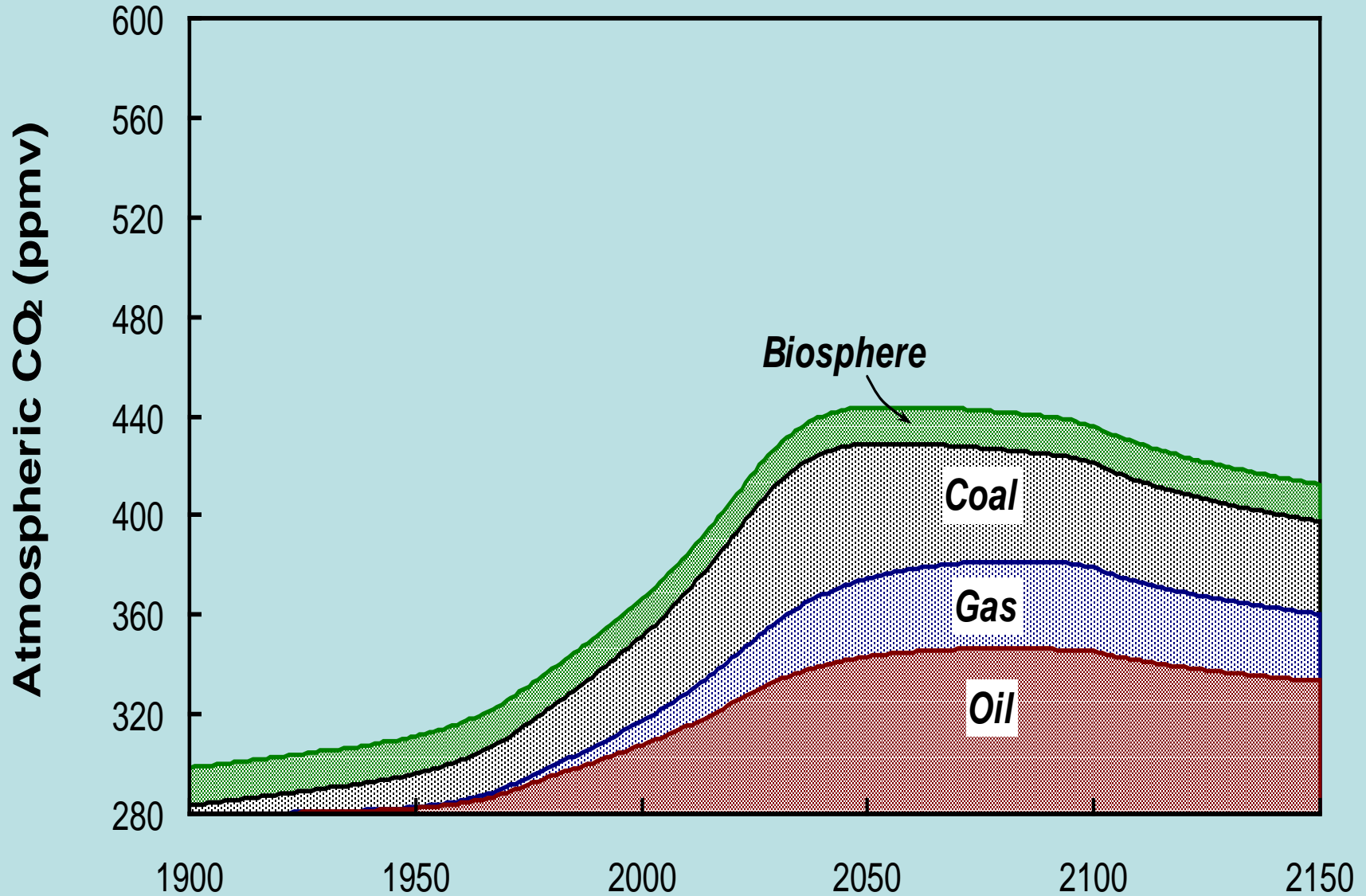
Photo by Aaron
Hockney



“Ladies and Gentlemen, it’s time we gave some serious thought to the effects of global warming”

Alternative Case: Coal Phaseout

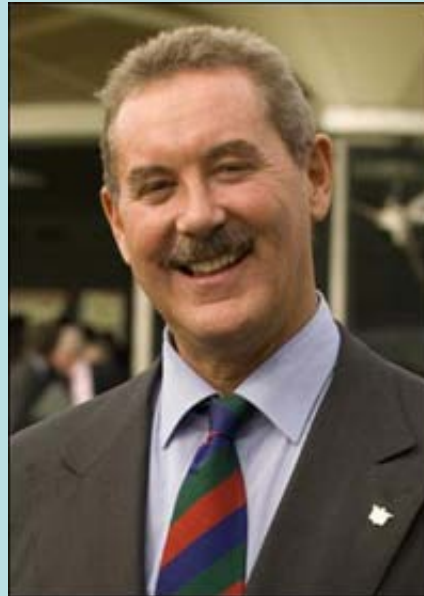
(+2%/yr to 2012; +1%/yr to 2022; linear shutdown between 2025-2050)



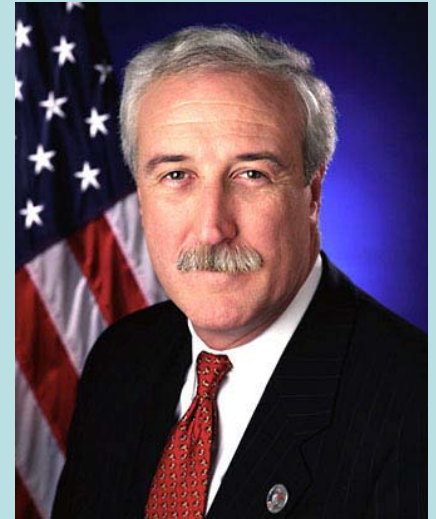
Famous Thieves of the George H.W. Bush years



**Bernie Madoff's Ponzi Scheme—
stole 60 B \$ from investors under
the noses of the SEC**



**Allen
Stanford—
stole 8 B \$
from his
investors**



**Sean O'Keefe, NASA
Administrator under
George H. W. Bush,
diverted 1 B \$ from NASA
Earth and Space Science
between 2001 and 2005.**