Mauna Loa Observatory shows sensitivity to distant climate change:

MLO is still a good proxy for global carbon levels.

Mathematics Climate Change Seminar
November 4, 2009

Mauna Loa Observatory shows sensitivity to distant climate change:

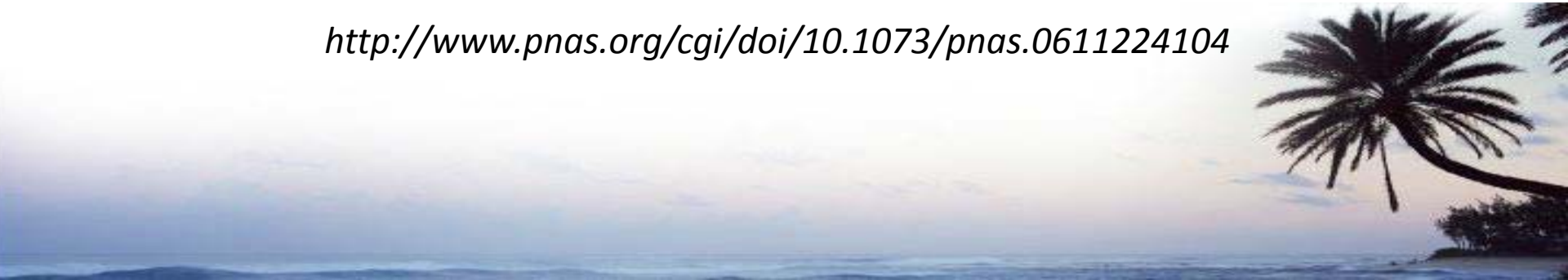
Hawaii is awesome.

Mathematics Climate Change Seminar
November 4, 2009

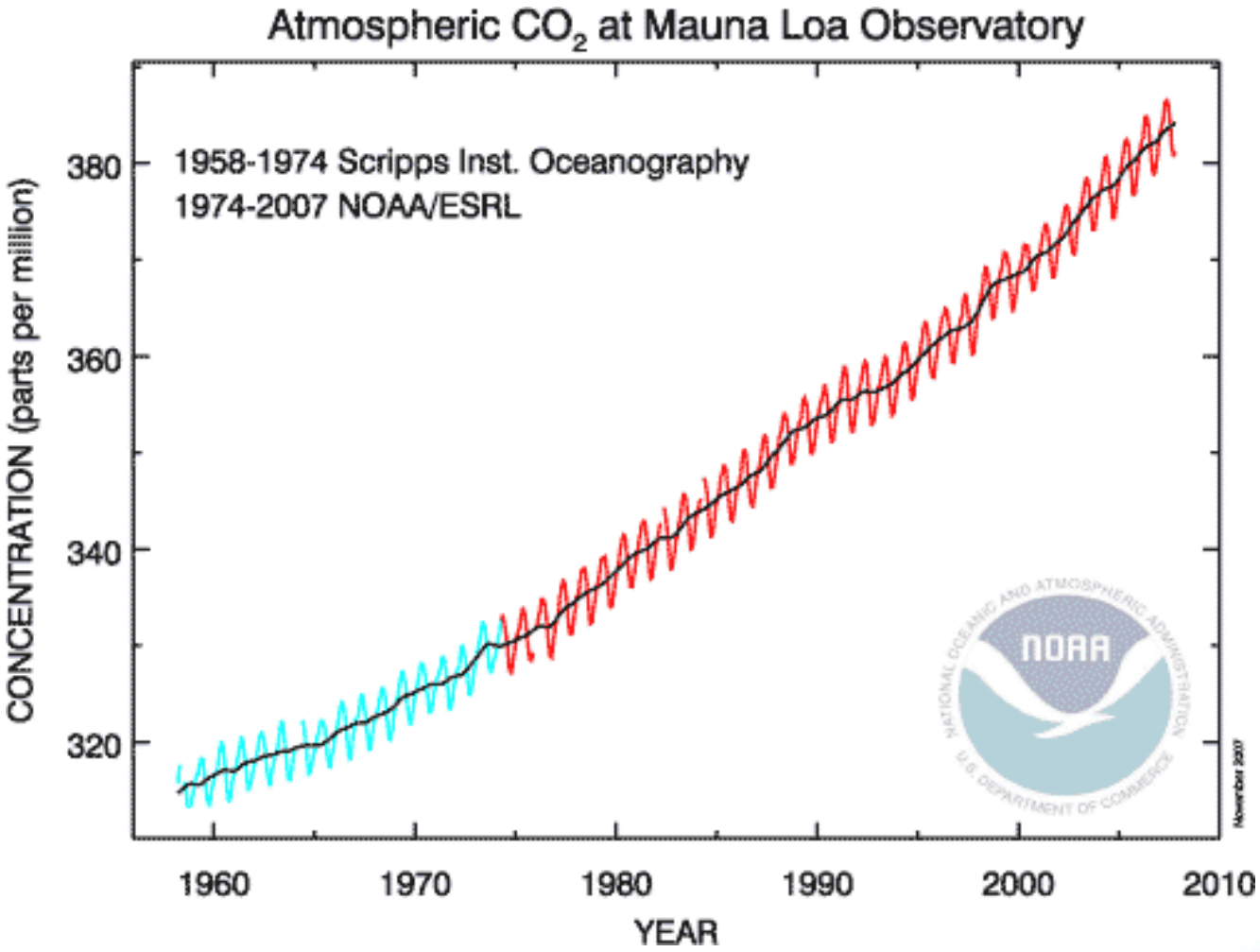
This presentation is designed to present information from the following paper:

Wolfgang Buermann, Benjamin R. Lintner, Charles D. Koven, Alon Angert, Jorge E. Pinzon, Compton J. Tucker, Inez Y. Fung. *The changing carbon cycle at Mauna Loa Observatory. PNAS vol. 104, no. 11, March 13, 2007*

http://www.pnas.org/cgi/doi/10.1073/pnas.0611224104



www.carboncyclescience.gov/news-archive.php
…and google maps



http://www.esrl.noaa.gov/news/2007/50YearCO2Record.html

Mauna Loa Observatory (MLO)

MLO is a great proxy for Global Carbon Levels

1. There is low pollution.
   MLO is far from any industrial Influences.

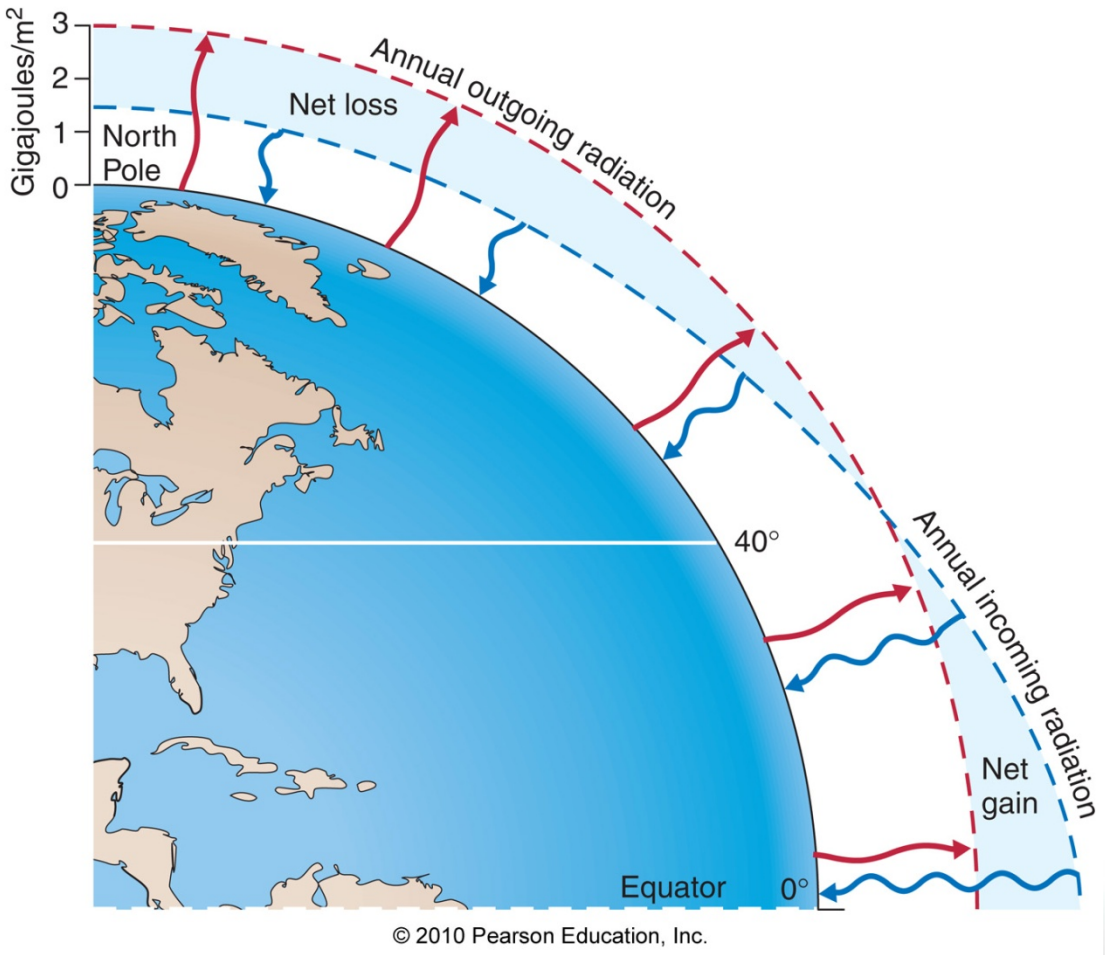
2. MLO's elevation is above the inversion layer.

3. There was a handy road to the summit built by the military.

4. Hadley Walker Cells:
   - Insolation
   - Transport
   - Earth Rotation
   - Seasonal Solar Declination

Hadley Walker Cells

Step 1: **Insolation**

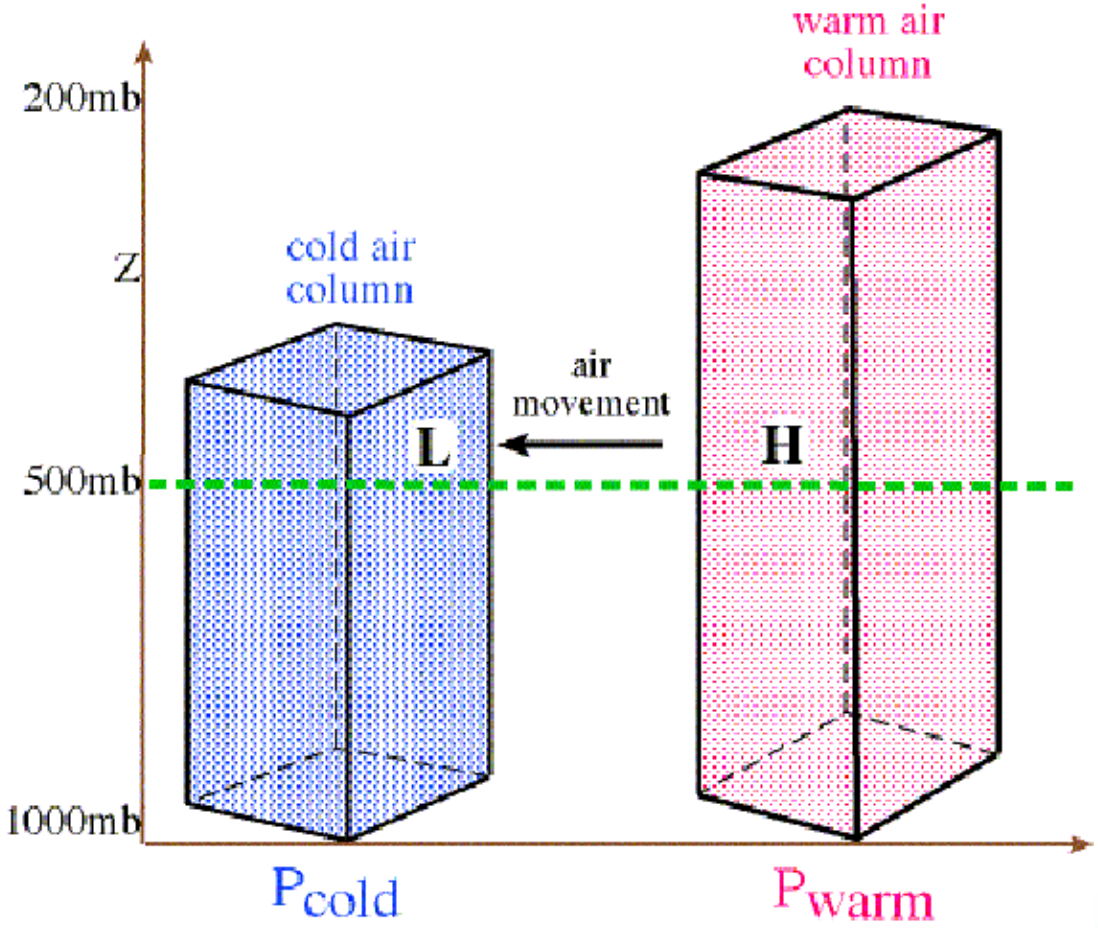


Edward Aguado, *San Diego State University* , **James E. Burt**, *University of Wisconsin – Madison*

Understanding Weather and Climate, 5/E Prentice Hall, 2009

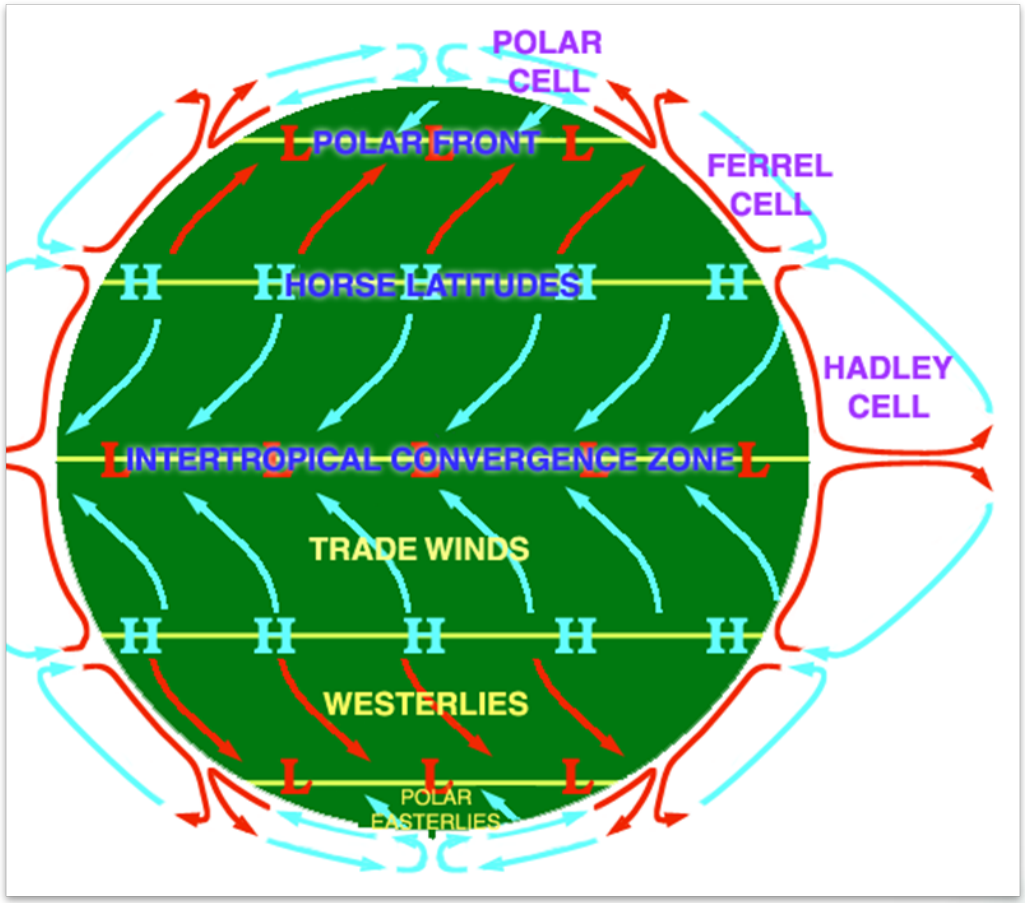
Hadley Walker Cells

Step 2: **Transport**



Hadley Walker Cells

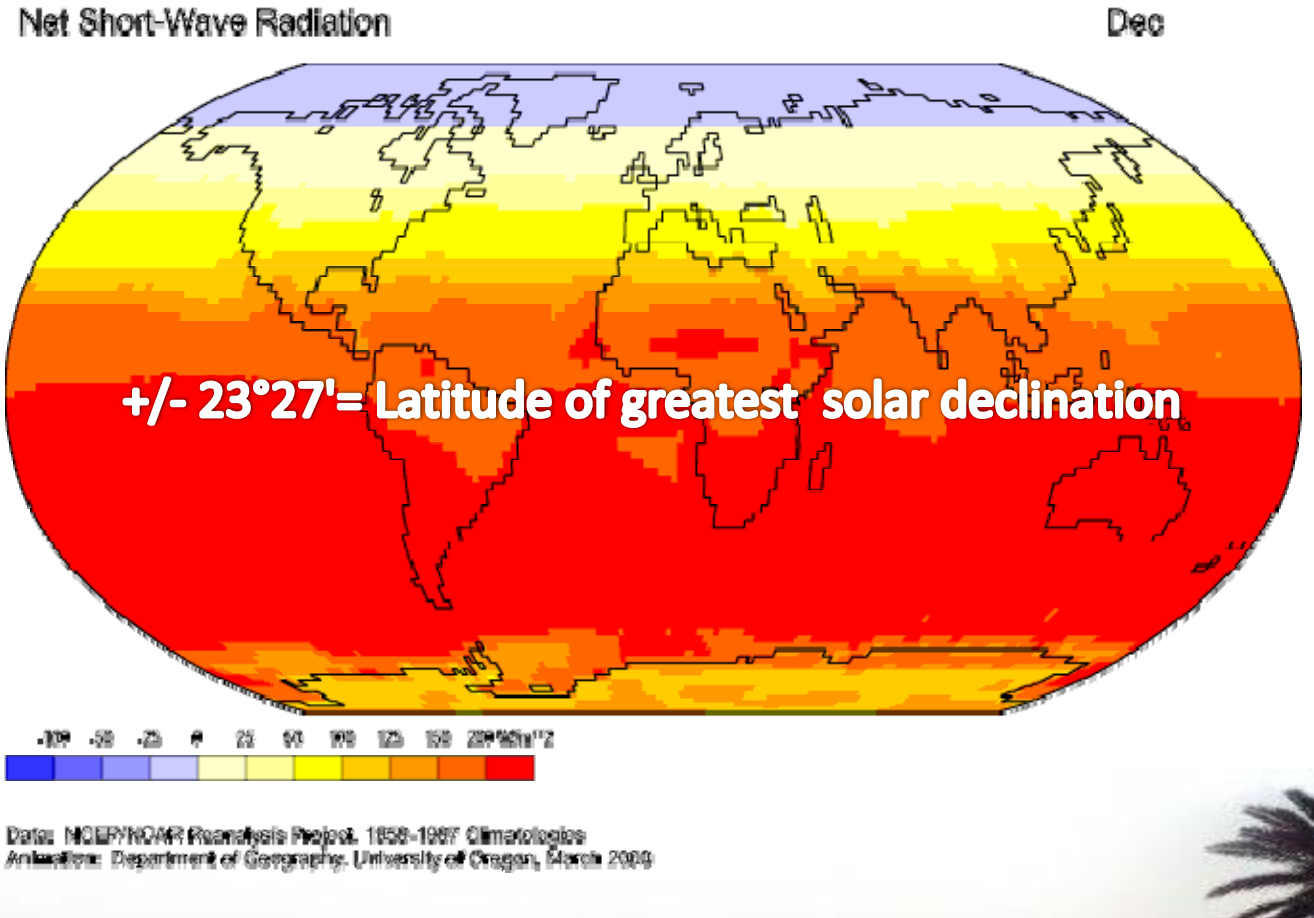
Step 3: **Earth Rotation**



http://en.wikipedia.org/wiki/File:AtmosphCirc2.png

Hadley Walker Cells

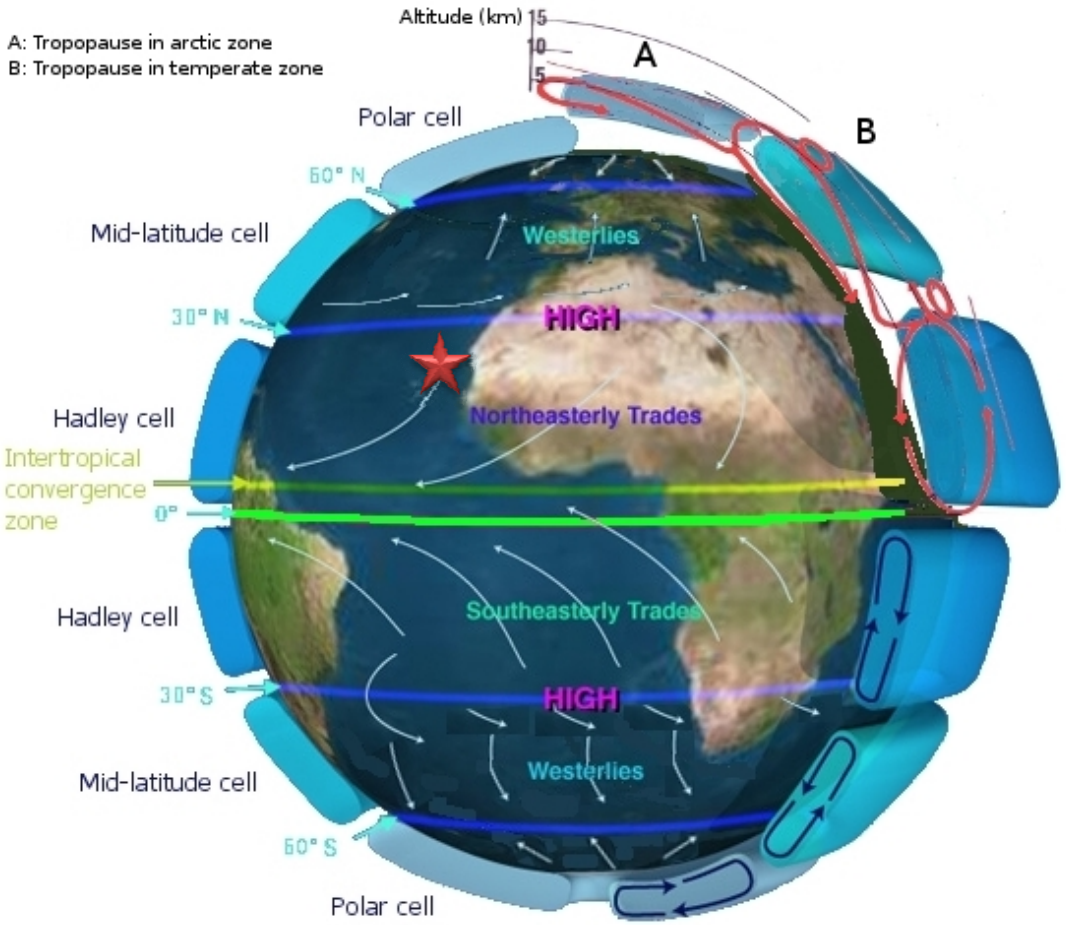
Step 4: **Solar Declination**



http://geography.uoregon.edu/envchange/clim_animations/

Hadley Walker Cells

Step 5: **Putting it all together**



- 20° 57.1'= Latitude of Hawaii
  23°27'= Latitude of highest solar declination

Mixing between NH and SH occurs at MLO near summer solstice.

Mixing between higher and lower NH latitudes occurs at MLO during the colder seasons.

It's an excellent Location!

http://en.wikipedia.org/wiki/Atmospheric_circulation

Further Seasonal Atmosphere Effects

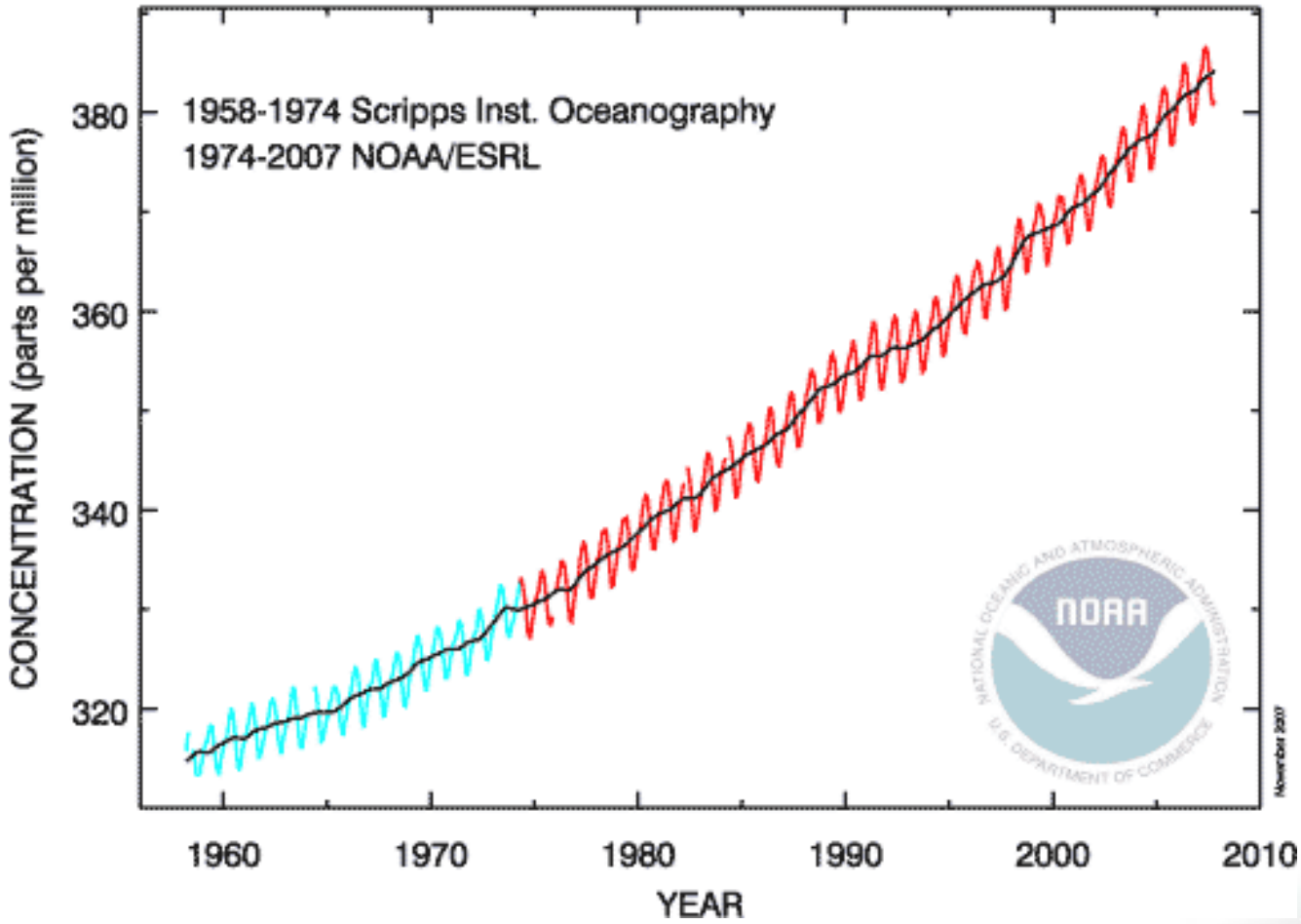
"In cold season, air masses from Eurasia dominate transport to the MLO as a result of a deepening of the Aleutian Low and intensified mid-latitude westerly flow."

"In the northern hemisphere warm season, the dominant subtropical North Pacific high-pressure system located to the northeast of the MLO leads to short-range transport of air masses to the MLO that originate over or near the North American continent."

Buermann, Lintner, Koven, Angert, Pinzon, Tucker, Fung. *The Changing Carbon cycle at the Mauna Loa Observatory. PNAS March 13,2007 Vol. 104, No 11. www.pnas.org/cgi/doi/10.1073/pnas.0611224104*

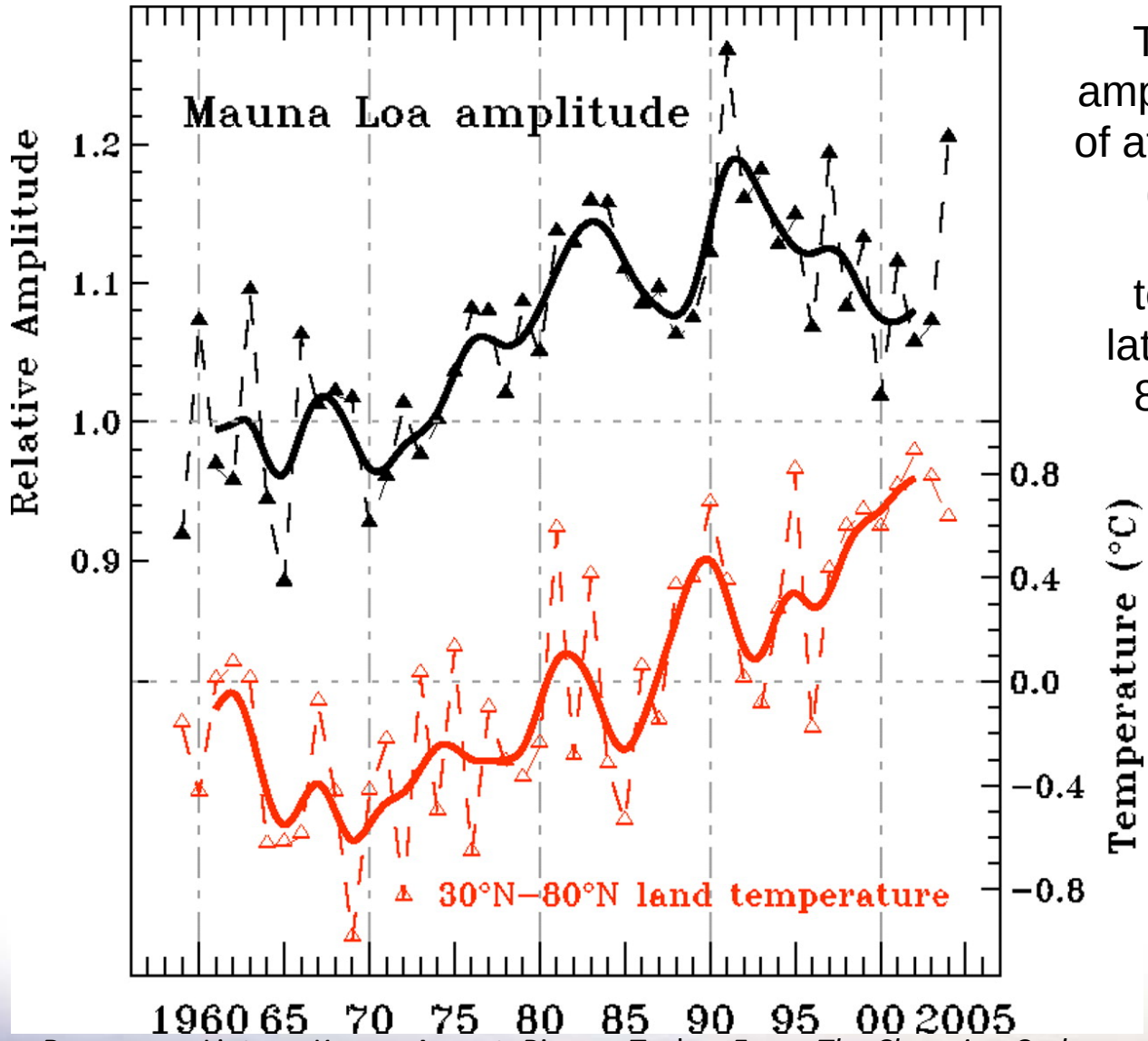
Historically at the MLO: 1950-1993

Keeling CD, Chin JFS, Whorf TP (2006) Nature 382: 146-149



http://www.esrl.noaa.gov/news/2007/50YearCO2Record.html

Recently at the MLO: 1994- 2004



Time series of the relative amplitude of the seasonal cycle of atmospheric CO2 at the MLO (black) and anomalies in observed annual land temperatures (red) for the latitudinal band from 30°N to 80°N (except Greenland).

Why does the amplitude decrease when the land temperature is continuing to increase?

Buermann, Lintner, Koven, Angert, Pinzon, Tucker, Fung. *The Changing Carbon cycle at the Mauna Loa Observatory. PNAS March 13,2007 Vol. 104, No 11. www.pnas.org/cgi/doi/10.1073/pnas.0611224104*

Methods of Buermann et al.

1. Normalized Difference Vegetation Index (NDVI)

2. Amplitude means by smoothed time series based on a five-point binomial filter.

3. “Recent integration of an atmospheric transport model”

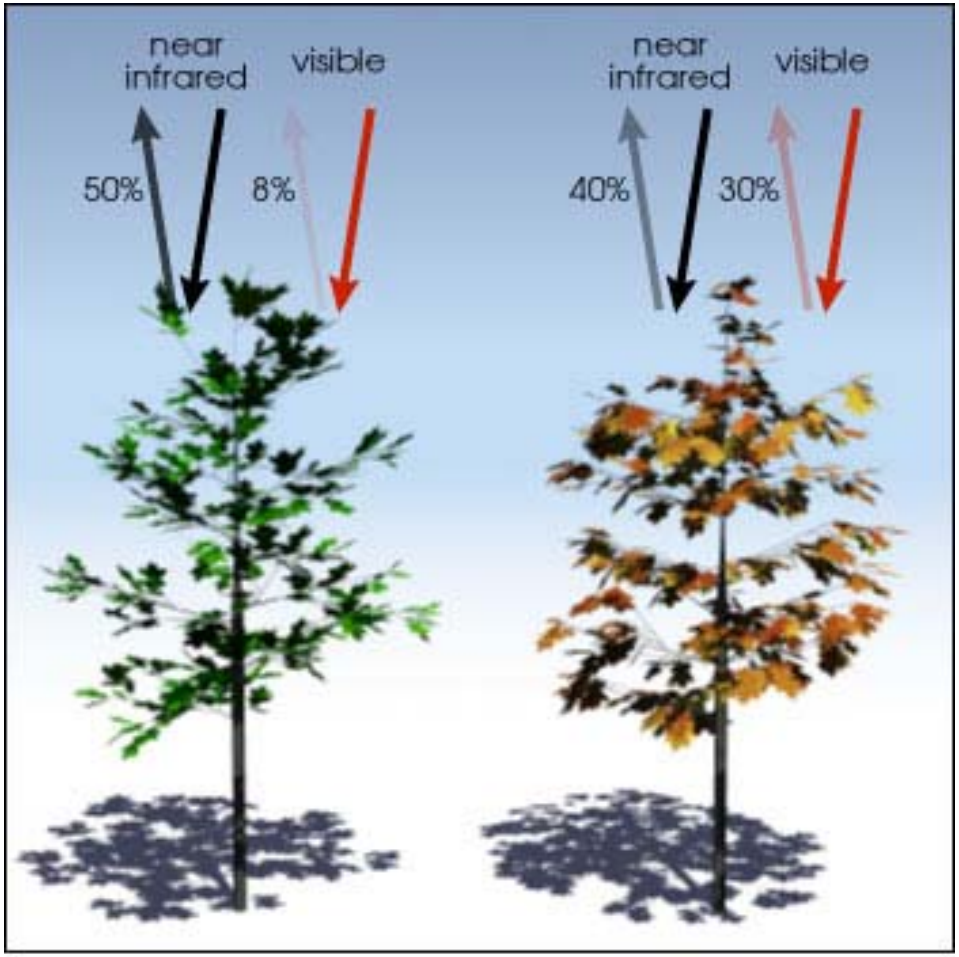
4. 6-month Standardized Precipitation Index (SPI6)
   A long-term dryness indicator that is a function of precipitation alone.

5. Palmer drought-severity index (PDSI)
   Another long-term dryness indicator that is a function of precipitation, evapotranspiration and runoff.

6. Several one tailed t-test to determine correlation.

Buermann, Lintner, Koven, Angert, Pinzon, Tucker, Fung. *The Changing Carbon cycle at the Mauna Loa Observatory. PNAS March 13,2007 Vol. 104, No 11. www.pnas.org/cgi/doi/10.1073/pnas.0611224104*

Normalized Difference Vegetation Index



$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72$$

$$\frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

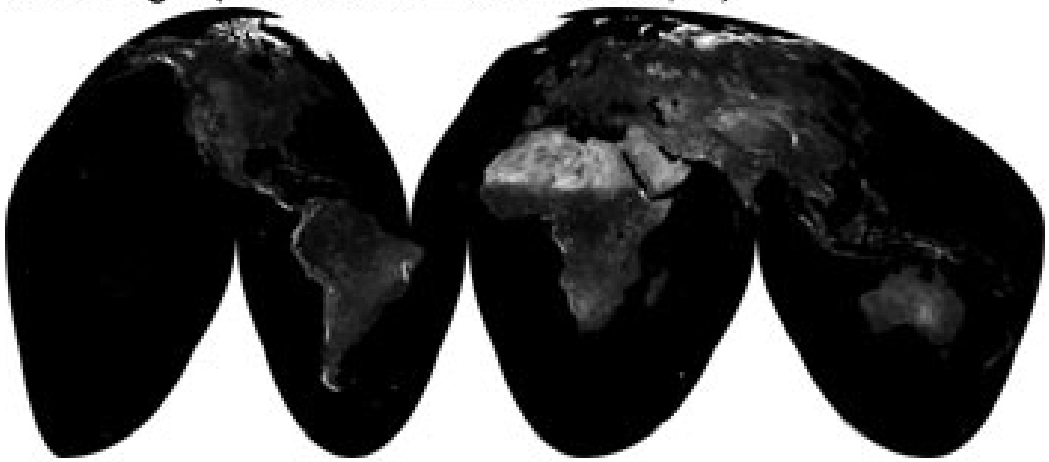
$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{RED})}{(\mathrm{NIR} + \mathrm{RED})}$$

NIR = Near infrared reflection
RED= visible red reflection

http://earthobservatory.nasa.gov/Features/MeasuringVegetation/measuring_vegetation_2.php

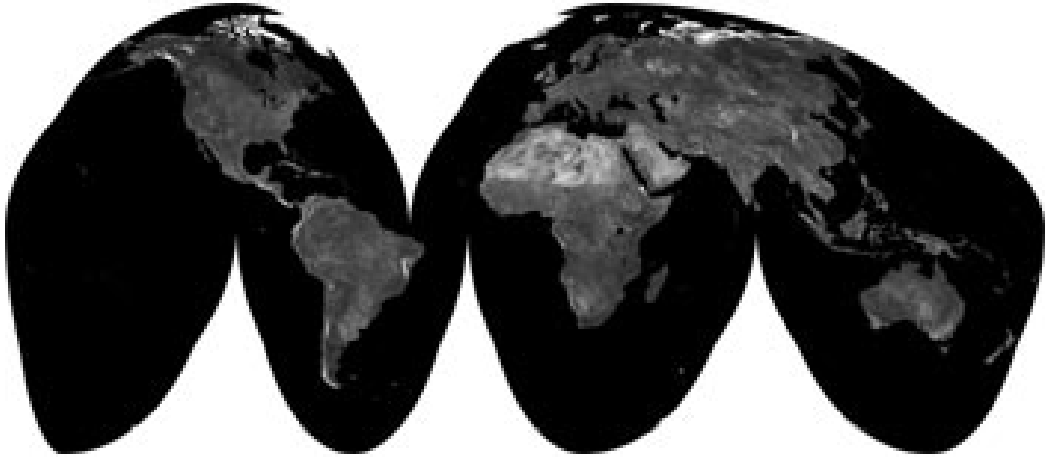
Normalized Difference Vegetation Index

Visible Light (AVHRR Channel 1, .58–.68 µm)



In visible light (top), vegetated areas are very dark, almost black, while desert regions (like the Sahara) are light.

Near Infrared (AVHRR Channel 2, .725–1.1 µm)



At near-infrared wavelengths, the vegetation is brighter and deserts are about the same.

http://earthobservatory.nasa.gov/Features/MeasuringVegetation/measuring_vegetation_2.php

Finding Correlation between the indexes and MLO observations

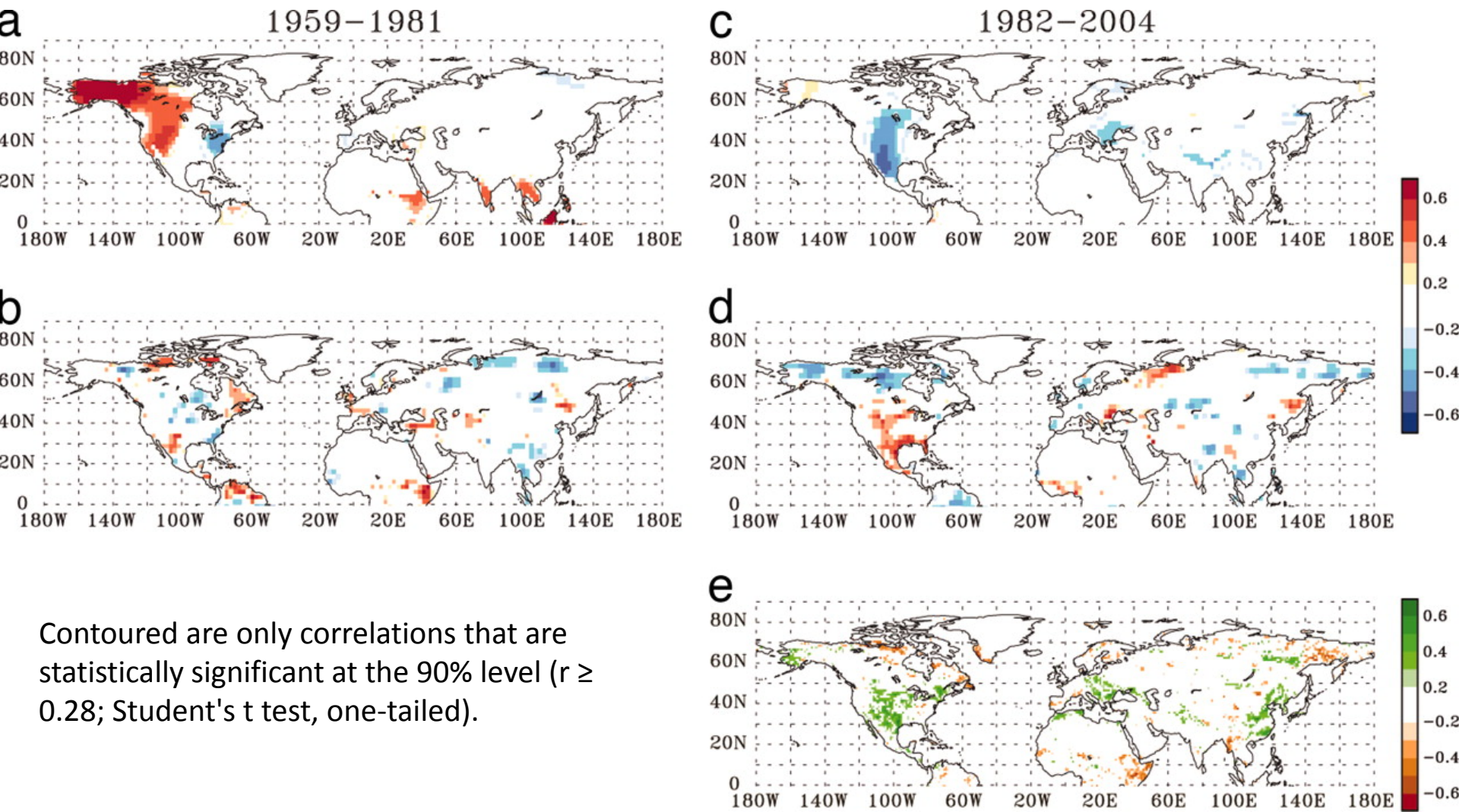
There were severe droughts from 1998-2003 which reduced carbon sequestration. This will be important to the amplitude decrease.

There may be some delay in correlation. This delay may change based on global weather patterns, so Buermann et al. use moving window correlations.

We begin by comparing land surface temperature, SPI6 (standarized precipitation index) and NDVI (normalized difference vegetation index).

Correlations of the MLO amplitude time series with mean growing-season climate

a & c: Land surface temperature b & d: SPI6 e: NDVI



Contoured are only correlations that are statistically significant at the 90% level ($r \geq 0.28$; Student's t test, one-tailed).

UPCOMING: an awesome (and large) graph

What you should know:

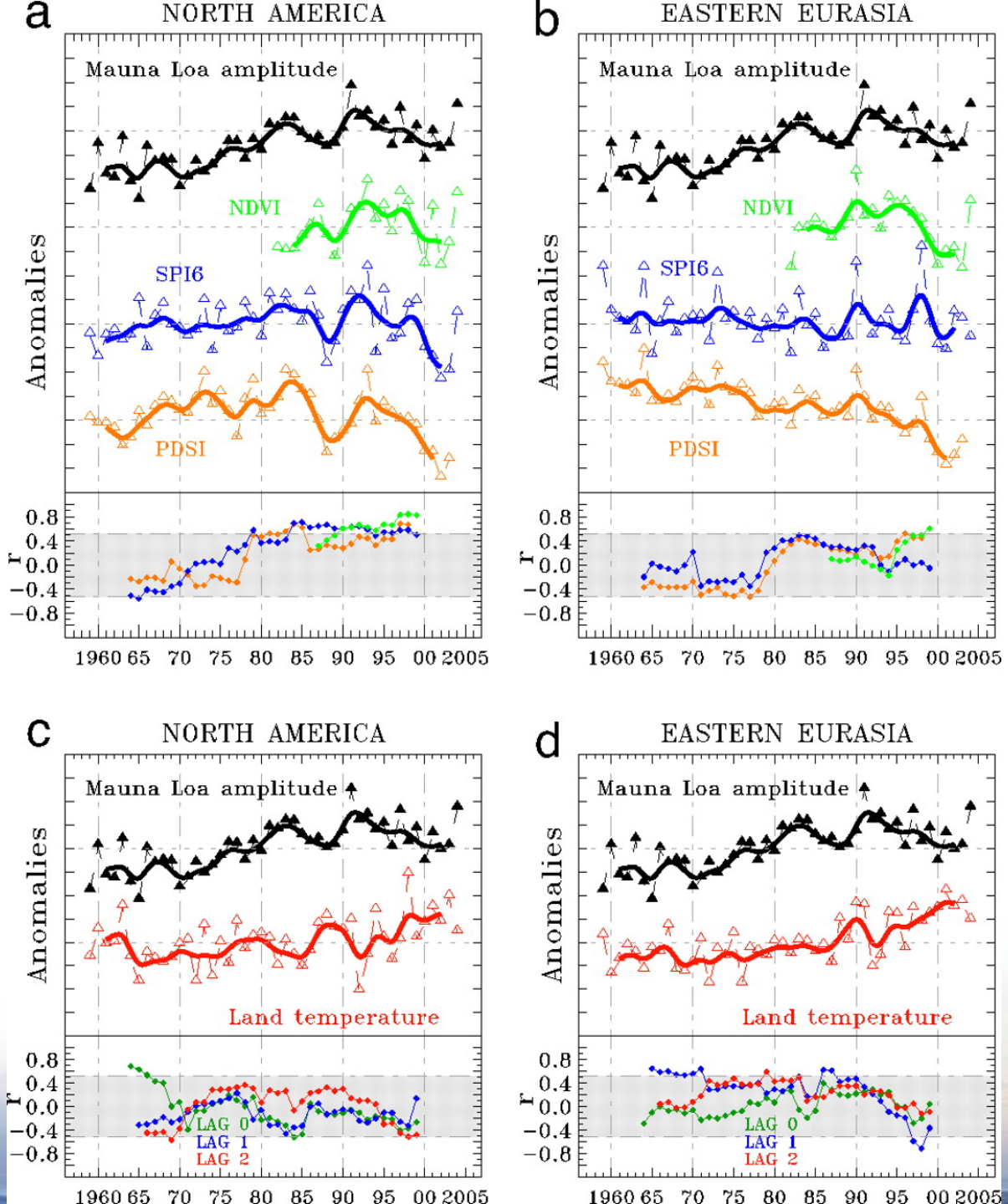
1. Bottom sections are moving-window correlations between indices and MLO observations.

2. Y-axis tick marks denote one standard deviation each.

3. Triangles are annual values.

4. Solid lines are based on a five-point binomial filter.

Buermann, Lintner, Koven, Angert, Pinzon, Tucker, Fung. *The Changing Carbon cycle at the Mauna Loa Observatory. PNAS March 13,2007 Vol. 104, No 11. www.pnas.org/cgi/doi/10.1073/pnas.0611224104*


a
NORTH AMERICA
Mauna Loa amplitude
NDVI
SPI6
PDSI
Anomalies
r
0.8
0.4
0.0
−0.4
−0.8
1960 65 70 75 80 85 90 95 00 2005
b
EASTERN EURASIA
Mauna Loa amplitude
NDVI
SPI6
PDSI
Anomalies
r
0.8
0.4
0.0
−0.4
−0.8
1960 65 70 75 80 85 90 95 00 2005
c
NORTH AMERICA
Mauna Loa amplitude
Land temperature
Anomalies
r
0.8
0.4
0.0
−0.4
−0.8
LAG 0
LAG 1
LAG 2
1960 65 70 75 80 85 90 95 00 2005
d
EASTERN EURASIA
Mauna Loa amplitude
Land temperature
Anomalies
r
0.8
0.4
0.0
−0.4
−0.8
LAG 0
LAG 1
LAG 2
1960 65 70 75 80 85 90 95 00 2005

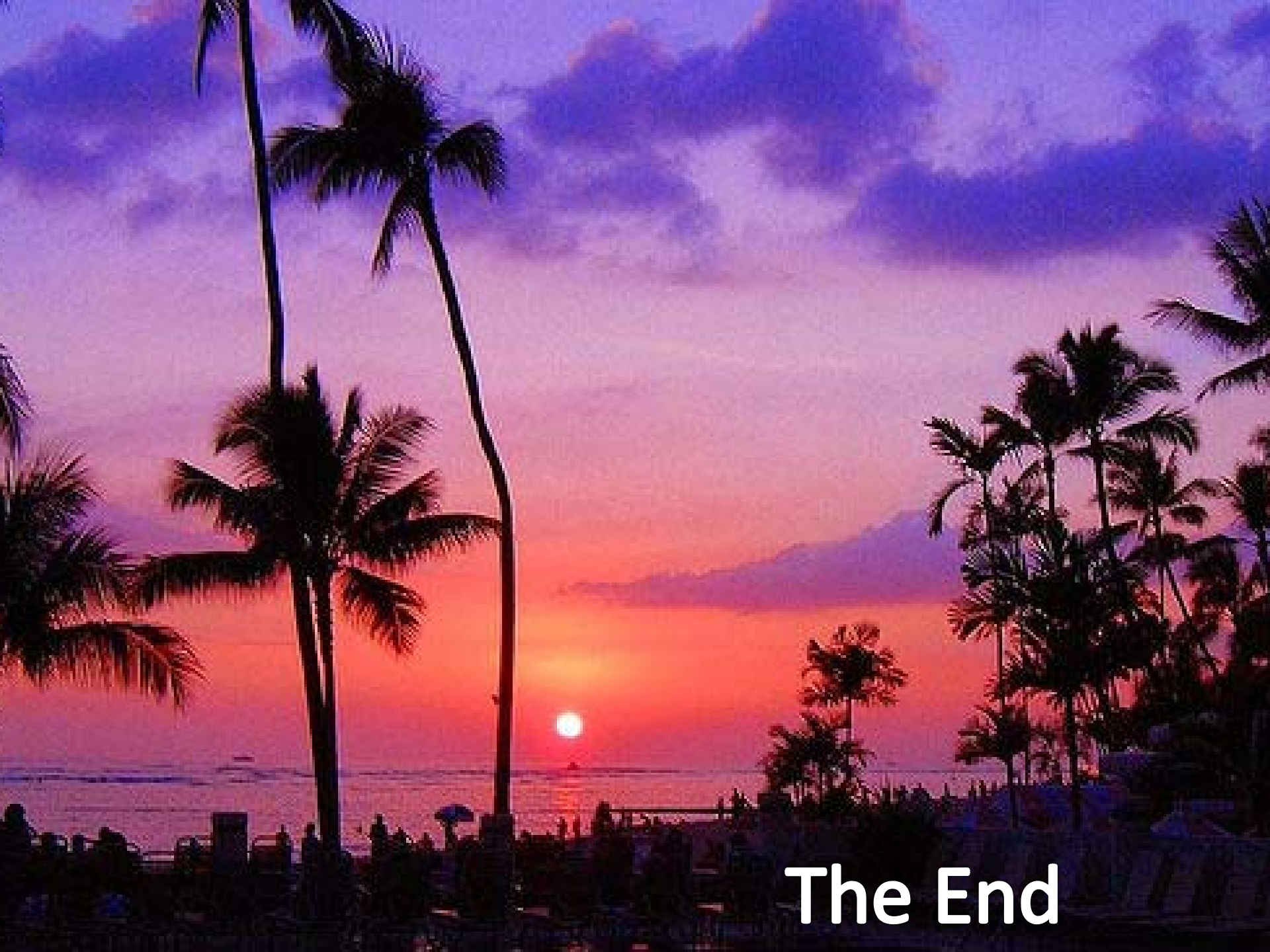
Conclusions

"Temperature variations by themselves do not dominate variations in respiration rates that influence the MLO amplitude."

"MLO CO_2 seasonal amplitude has recorded a changing North American carbon sink that is dominated by shifts in the North American hydrologic regime rather than by temperature trends."

"Work suggests that time-series measurements of atmospheric CO_2 at remote sites can continue to play an important role in documenting changes in land-carbon flux, including those related to widespread drought, which future projections show may continue to worsen as a result of global warming."

Buermann, Lintner, Koven, Angert, Pinzon, Tucker, Fung. *The Changing Carbon cycle at the Mauna Loa Observatory. PNAS March 13,2007 Vol. 104, No 11. www.pnas.org/cgi/doi/10.1073/pnas.0611224104*


The End