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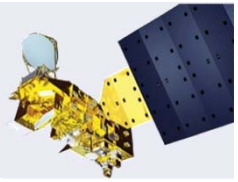

Temporal and Spatial Variability in the AIRS Version 5 Mid-tropospheric Carbon Dioxide

NASA Sounder Science Team Meeting
November 14, 2012

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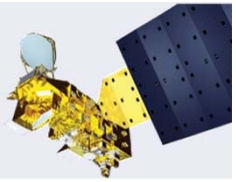
AIRS on Aqua uses Hyperspectral IR to Measure Atmospheric Greenhouse Gases

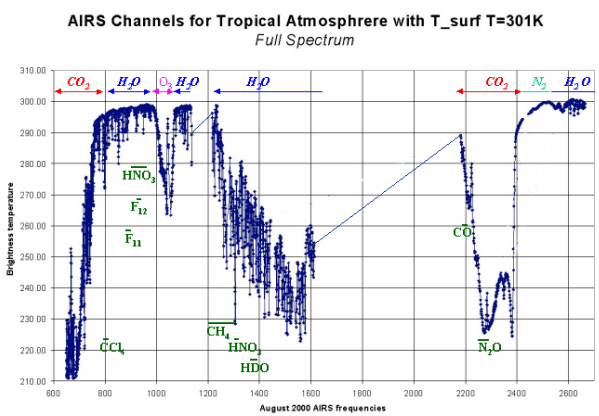


Atmospheric Infrared Sounder (AIRS)

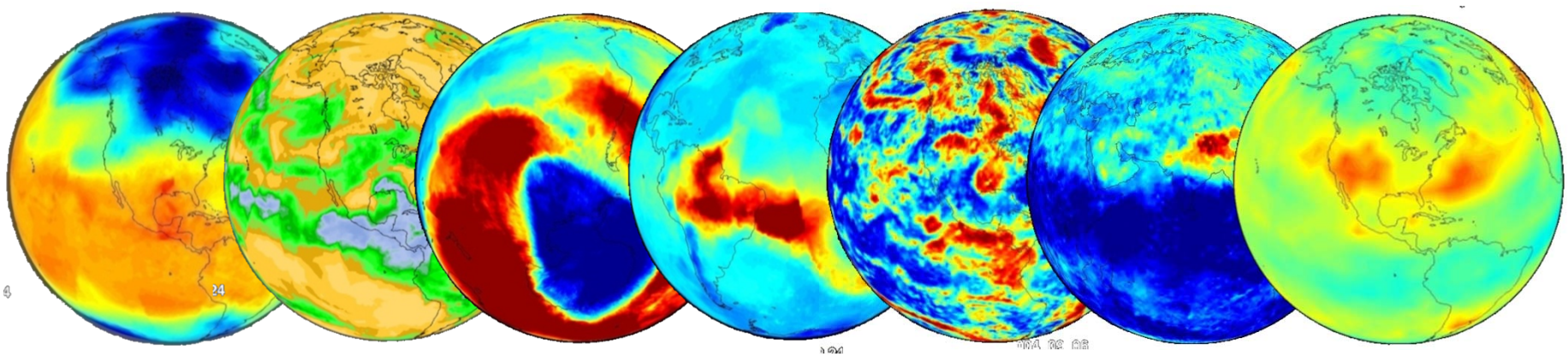
AIRS Characteristics

- Aqua Spacecraft
- Launched: May 4, 2002
- Orbit: 705 km, 1:30pm
- IFOV : 13.5 km
- Global Daily Coverage
- Spectral Range: 3.5-15.4 µm
- No. Channels: 2378
- Climate Quality Accuracy and Stability

AIRS Hyperspectral Infrared Spectrum

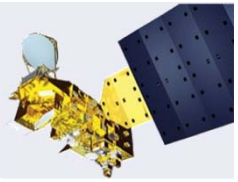


AIRS Measures Key Greenhouse Gases with Global Daily Coverage



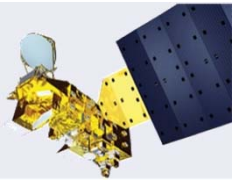
Temperature | Water Vapor | Ozone | Carbon Monoxide | Cloud Properties | Methane | Carbon Dioxide

Introduction



- AIRS Mid-Tropospheric CO2 V5 Available from 9/2002-Present
  - http://disc.sci.gsfc.nasa.gov/AIRS/data-holdings
- Ongoing efforts show AIRS data influenced by global circulation patterns including ENSO, Monsoon, and MJO
  - Wang, J., X. Jiang, M. T. Chahine, M.-C. Liang, E. T. Olsen, L. L. Chen, S. J. Licata, T. S. Pagano, and Y. L. Yung (2011), The influence of tropospheric biennial oscillation on mid-tropospheric CO2, Geophys. Res. Lett., 38, L20805, doi:10.1029/2011GL049288
  - Feng,L.; Palmer,P.I.; Yang,Y.; Yantosca,R.M.; Kawa,S.R.; Paris,J-D.; Matsueda,H.; Machida,T., Evaluating a 3-D transport model of atmospheric CO2 using ground-based, aircraft, and space-borne data, Atmospheric Chemistry and Physics, 2011, 11, 6, 2789-2803
  - Jiang, X., M. T. Chahine, E. T. Olsen, L. L. Chen, and Y. L. Yung (2010), Interannual variability of mid-tropospheric CO2 from Atmospheric Infrared Sounder, Geophys. Res. Lett., 37, L13801, doi:10.1029/2010GL042823
  - Li, K. F., B. Tian, D. E. Waliser, Y. L. Yung (2010), Tropical mid-tropospheric CO2 variability driven by the Madden-Julian oscillation, PNAS, 107 (45), 19171-19175, doi:10.1073/pnas.1008222107.
- What factors influence the observed zonal seasonal variability in AIRS Mid-Trop CO_2?
  - First Order Analysis

Data Sets Used in the Investigation



Product	Instrument	Level	Source
Mid-Trop CO2 $T_{mid\text{-}Trop}$, T_{surf}	AIRS	L3	GES/DISC
Surface CO_2	In-Situ/Flask	Txt	NOAA CMDL
EVI, T_{surf} (for GPP)	MODIS	L3	GES/DISC

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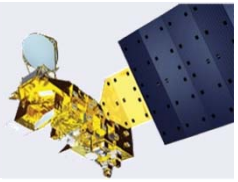
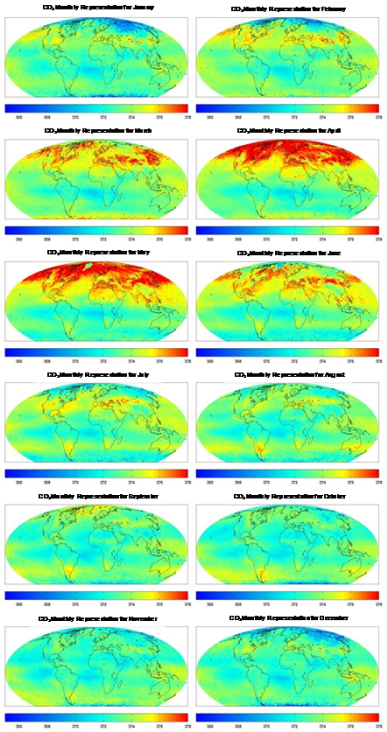
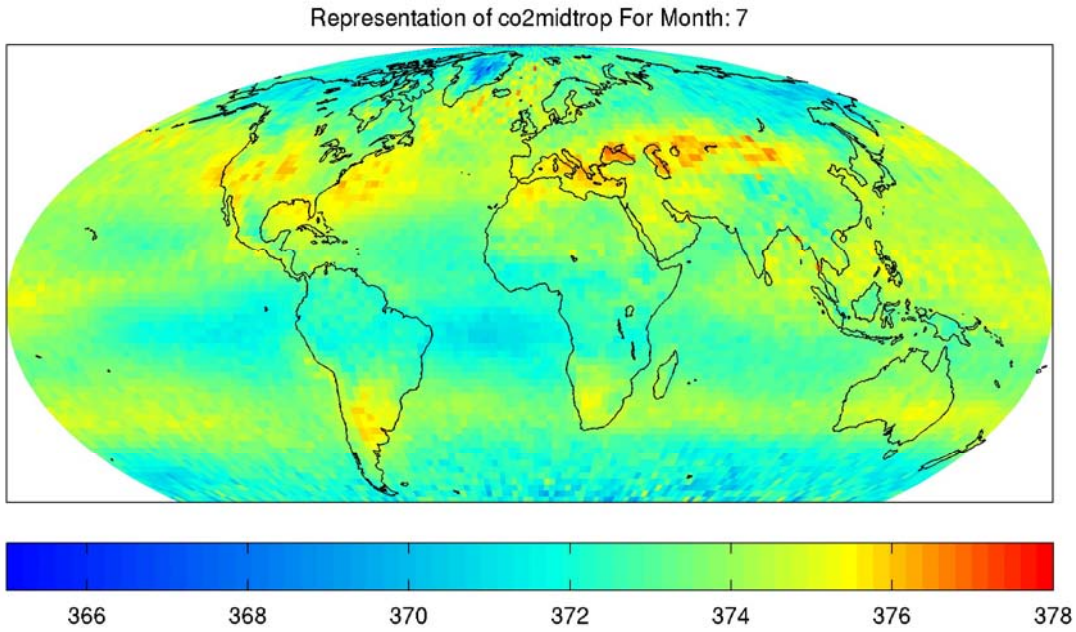
AIRS Mid-Tropospheric CO_2 Level 3 Examined from 2003-2010 Inclusive



Shown here are Average of Detrended AIRS Version 5, L3 CO_2 Monthly Data by Month over 8 years





Pagano, T. S., Olsen, E. T., Chahine, M. T., Ruzmaikin, A., Nguyen, H., Jiang, X., "Monthly representations of mid-tropospheric carbon dioxide from the Atmospheric Infrared Sounder," Proc. SPIE 8158-11, San Diego, CA (2011).

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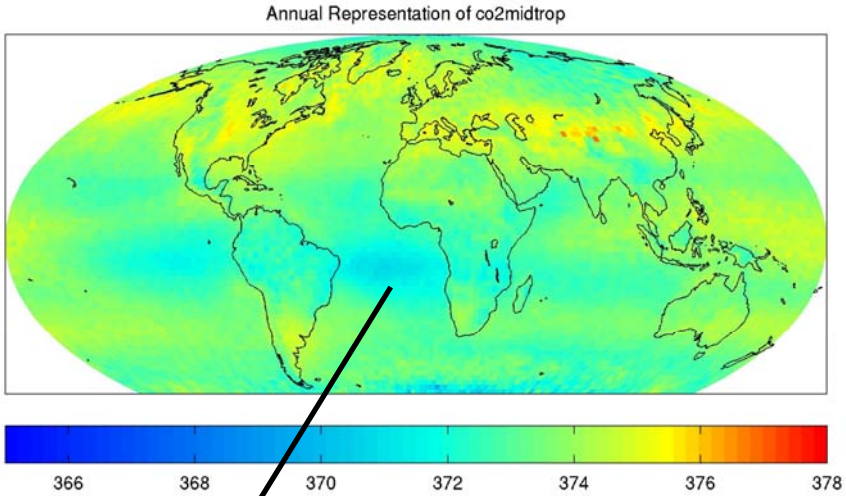
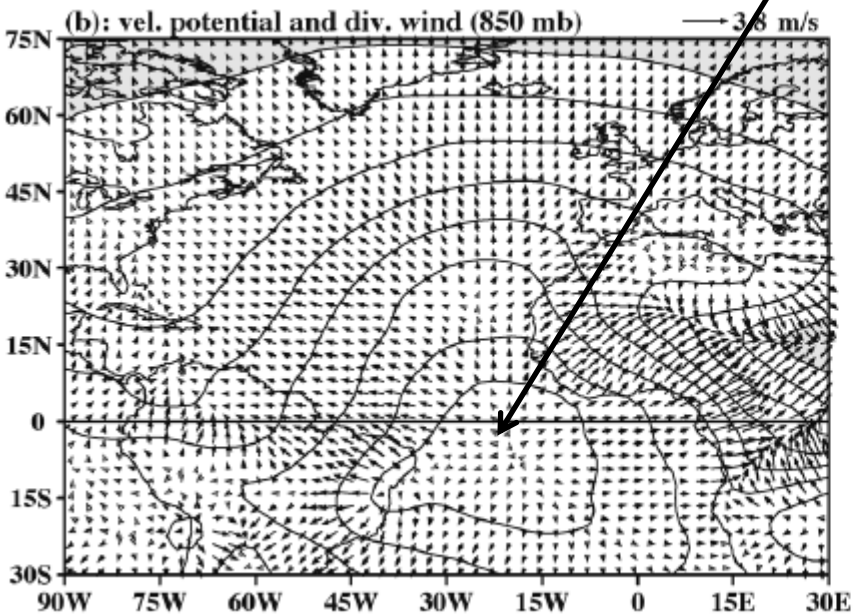
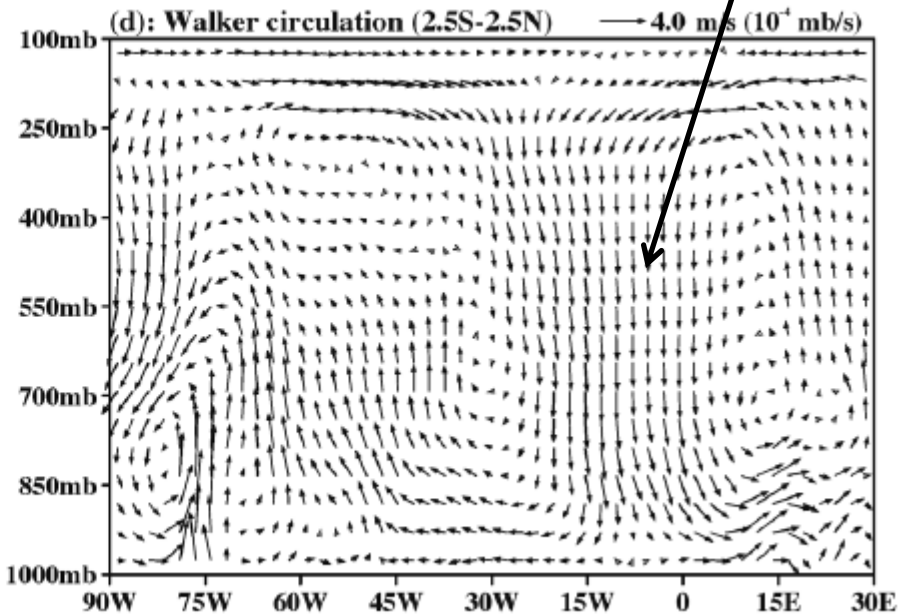
Depleted Region in of Mid-Tropospheric CO_2 in South Atlantic Related to Walker Circulation

Annual Average AIRS Mid-Trop CO_2



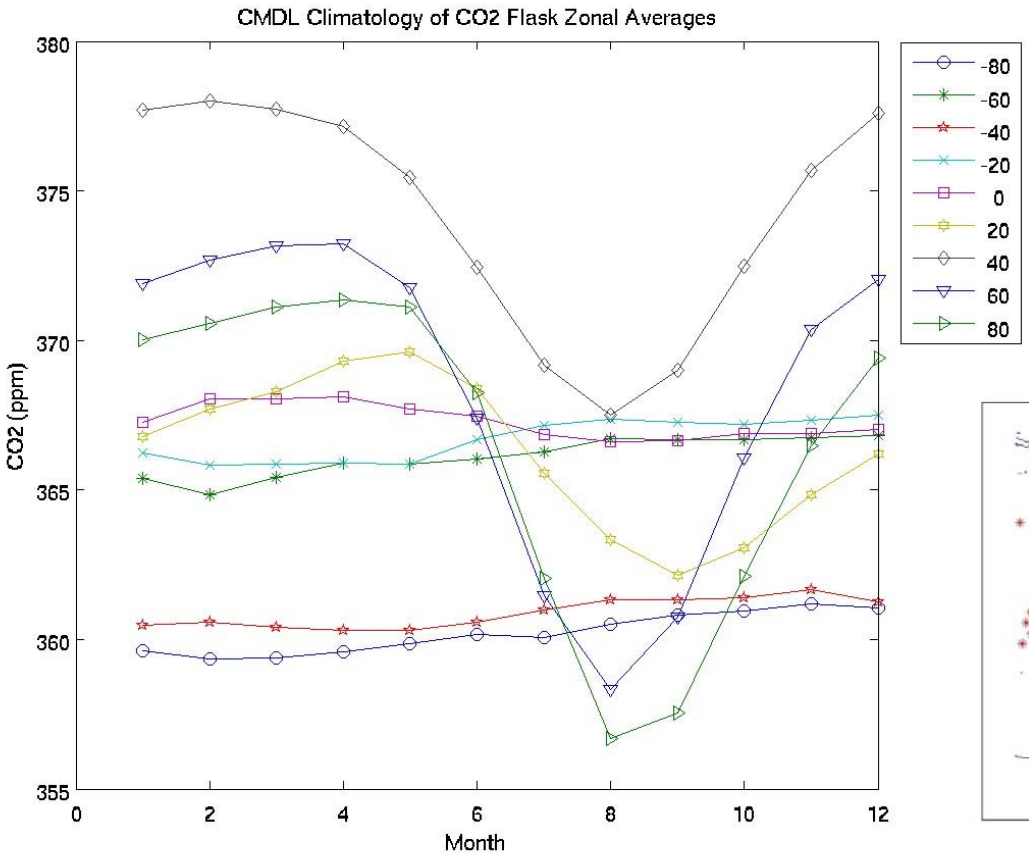
Downward Flow of Walker Circulation



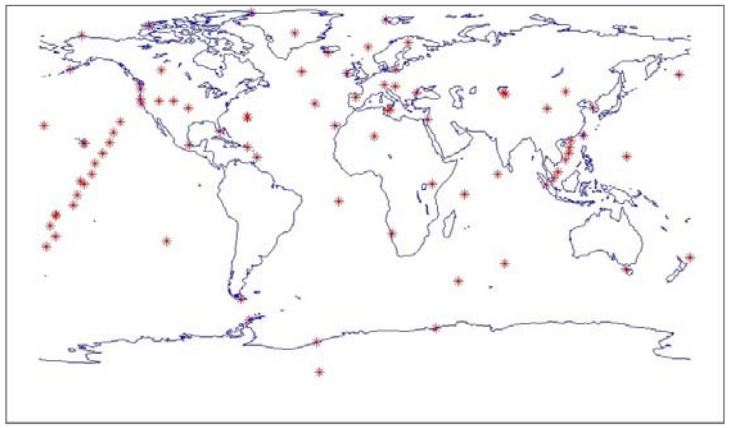


CHUNZAI WANG, Atlantic Climate Variability and Its Associated Atmospheric Circulation Cells, Journal of Climate, 2001

NOAA CMDL In-Situ / Flask Data used for Comparison

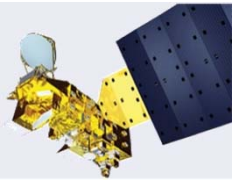


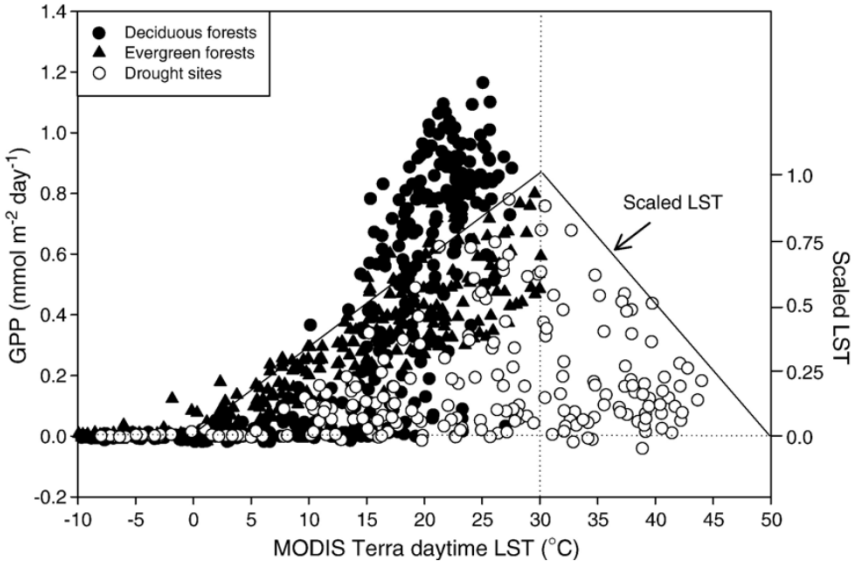
87 Surface Sites Worldwide

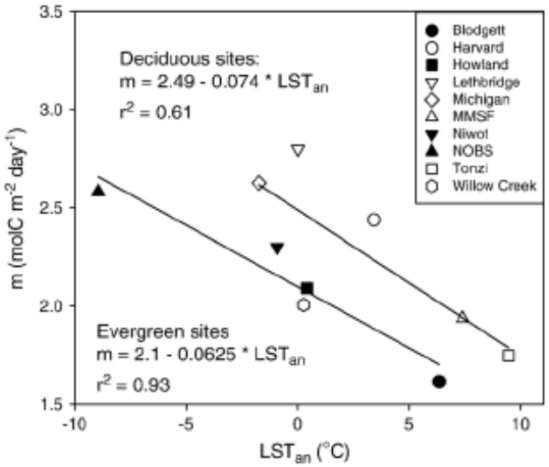


Conway, T.J., P.M. Lang, and K.A. Masarie (2011), Atmospheric Carbon Dioxide Dry Air Mole Fractions from the NOAA ESRL Carbon Cycle Cooperative Global Air Sampling Network, 1968-2010, Version: 2011-10-14, Path: ftp://ftp.cmdl.noaa.gov/ccg/co2/flask/event/.

Gross Primary Productivity using MODIS Temperature and Greenness (TG)







$$\mathrm{GPP} = (\mathrm{scaledEVI} \times \mathrm{scaledLST}) \times m$$

MODIS Night LST

$$\mathrm{scaledLST} = \min\left[\left(\frac{\mathrm{LST}}{30}\right); (2.5 - (0.05 \times LST))\right]$$

$$\mathrm{scaledEVI} = \mathrm{EVI} - 0.1$$

$$\mathrm{EVI} = G\frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{Red}}}{\rho_{\mathrm{NIR}} + C_1\rho_{\mathrm{Red}} - C_2\rho_{\mathrm{Blue}} + L}$$

$$m = 2.49 - 0.074 \times \mathrm{LST_{an}} \quad \text{for deciduous sites}$$

$$m = 2.10 - 0.0625 \times \mathrm{LST_{an}} \quad \text{for evergreen sites.}$$

Using Average m gives < 18% error

Sims, D. et al., A new model of gross primary productivity for North American ecosystems based solely on the enhanced vegetation index and land surface temperature from MODIS, Remote Sensing of Environment 112 (2008) 1633–1646

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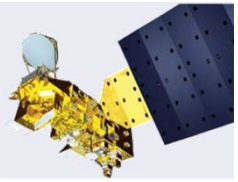
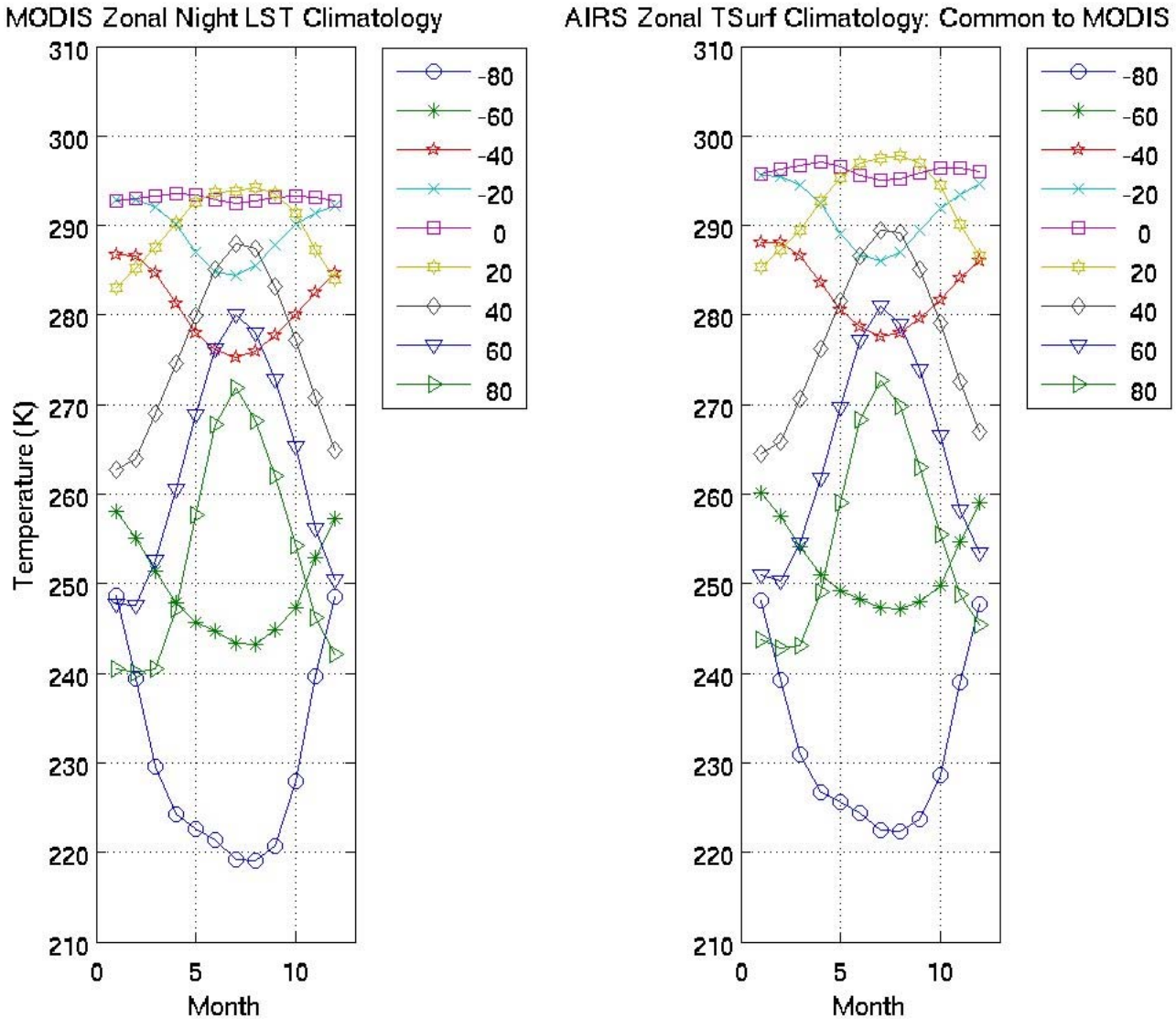
Small Differences in Night Land Surface Temperature between AIRS and MODIS L3





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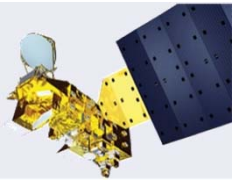
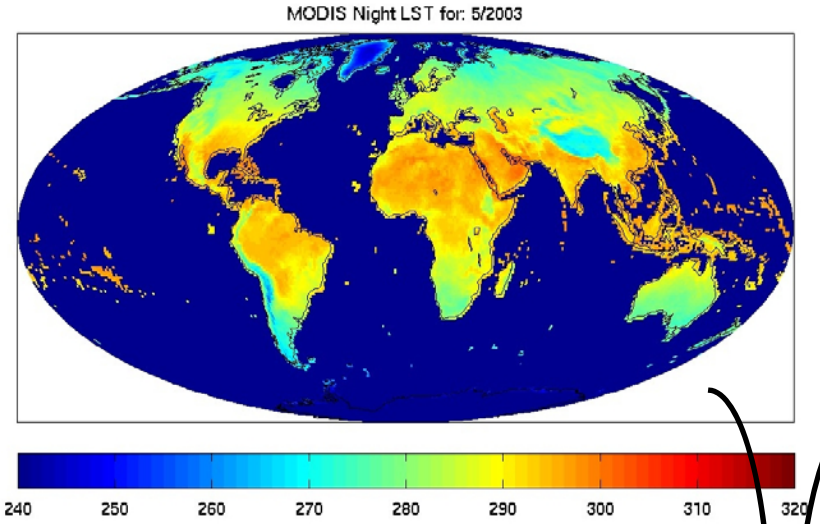
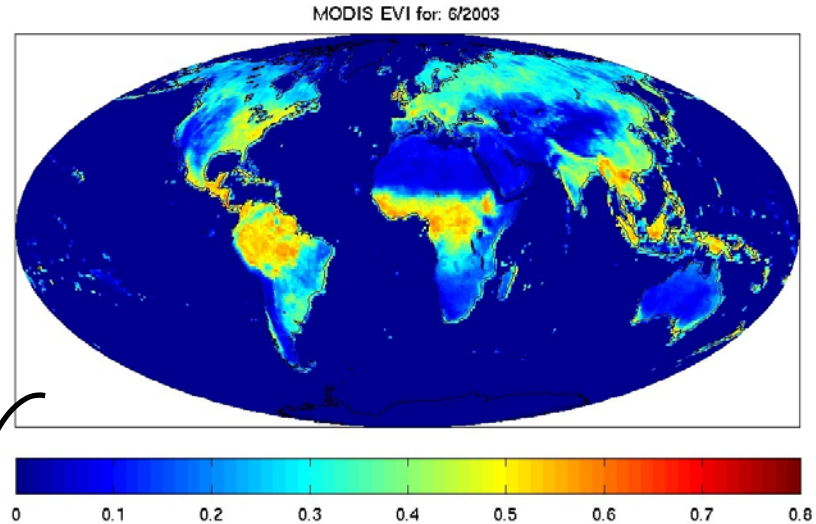
MODIS EVI and Night Land Surface Temperature used to make GPP



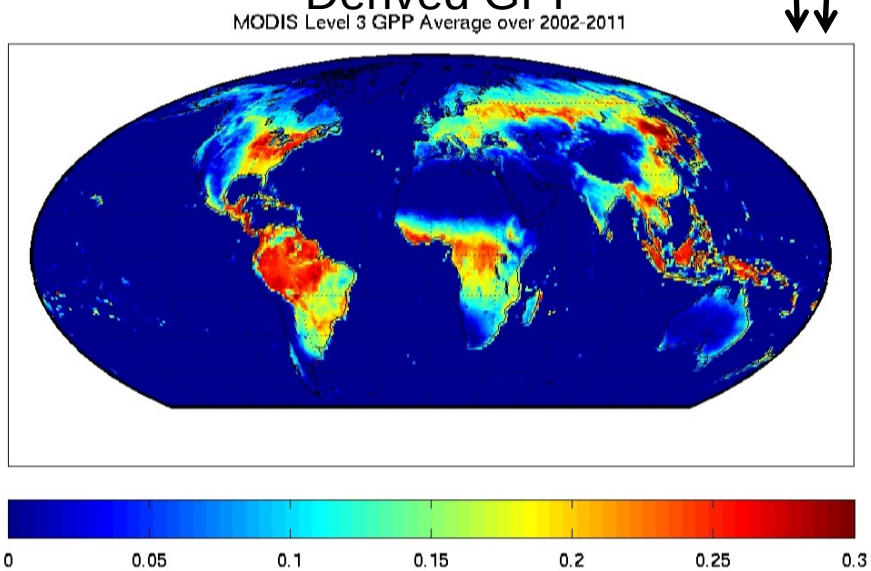
MODIS L3 LST



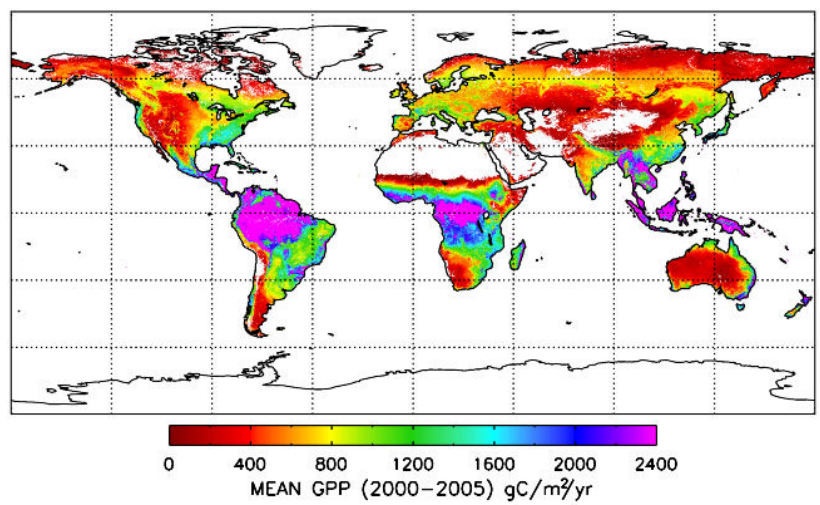
MODIS L3 EVI



Derived GPP



UMT GPP



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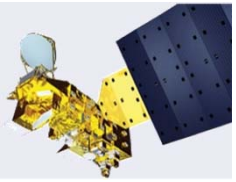
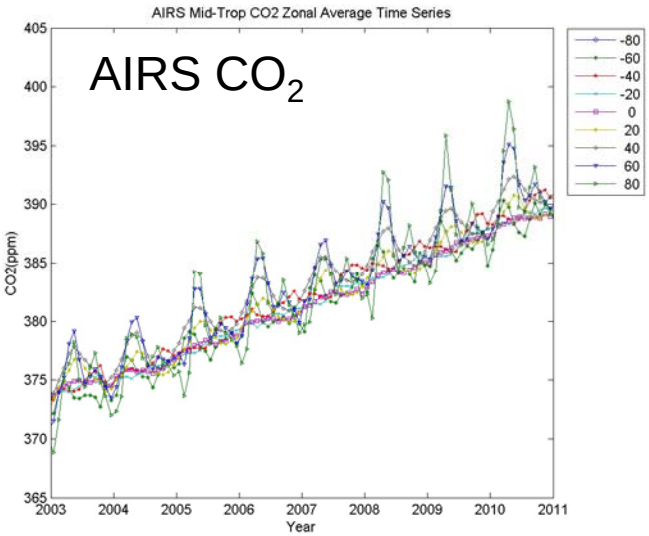
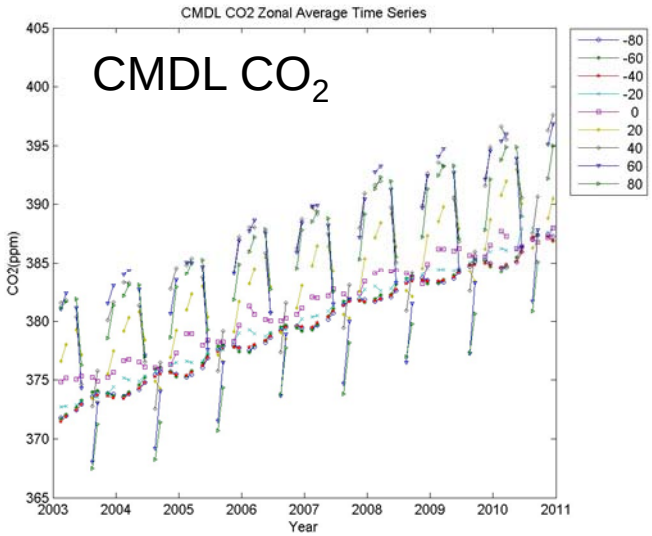
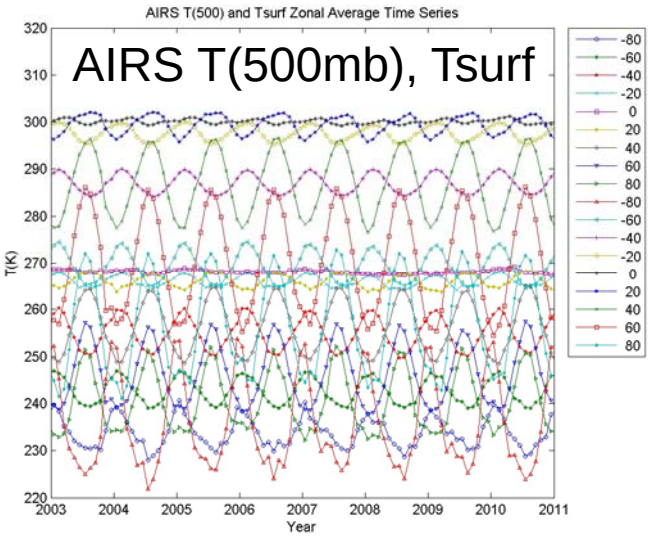
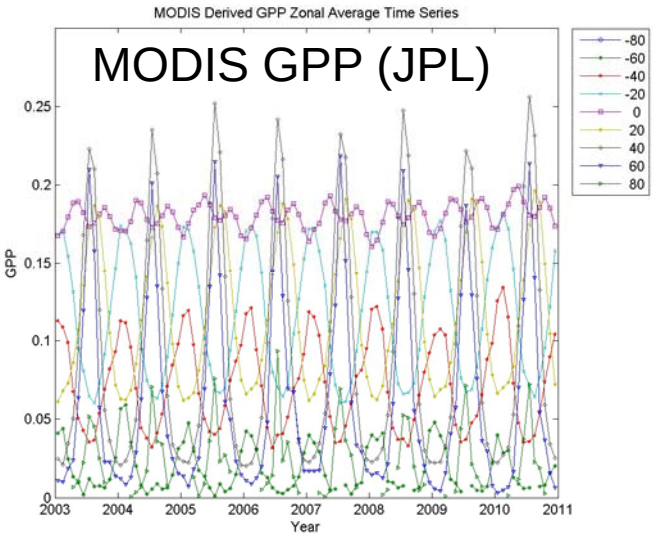
Zonal Average Time Series Used for AIRS CO_2, CMDL CO_2, AIRS T, MODIS GPP







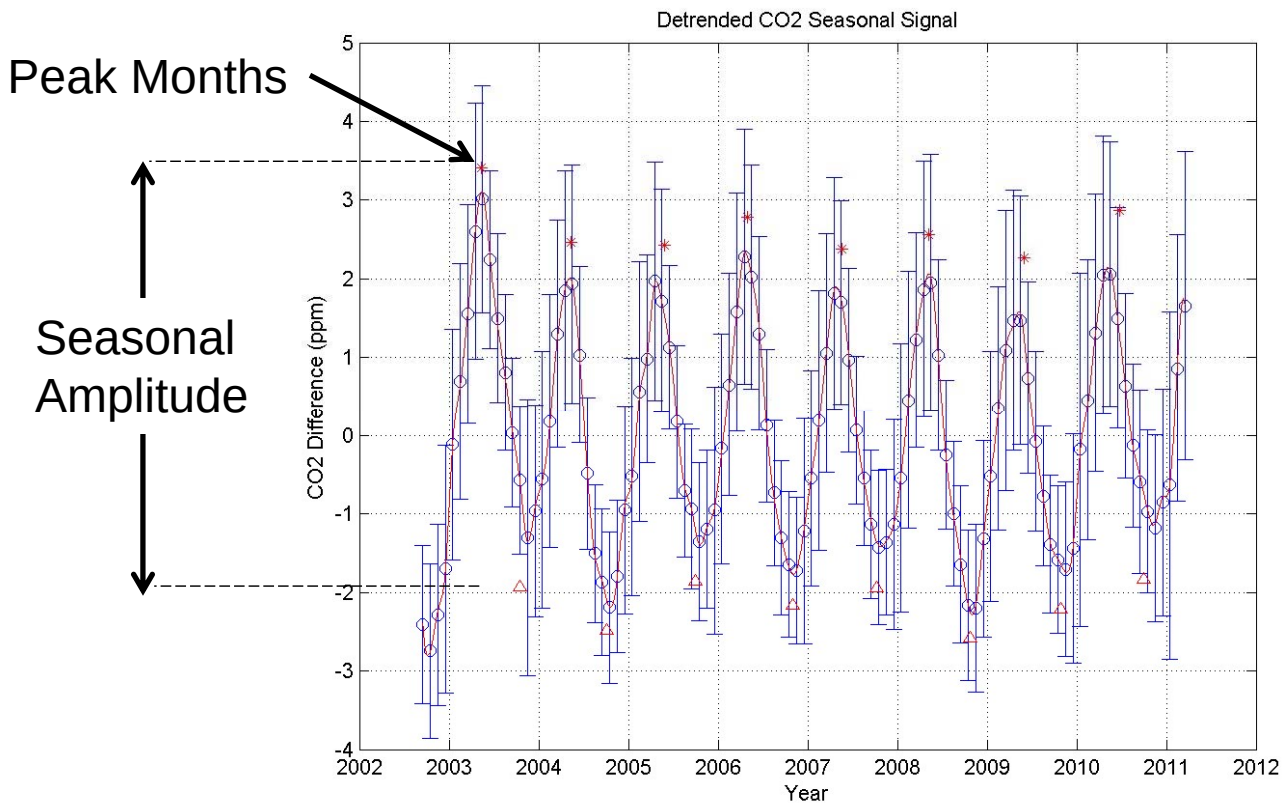




L

Example Detrend, Zonal Average and Fit for Phase and Amplitude

Zonal average from 30º-50º latitude
Standard Deviation over all measurements in the zone
Spline fit for peak, min and their positions in time
300 iterations using bootstrap method for uncertainty
Same procedure used for all data sets



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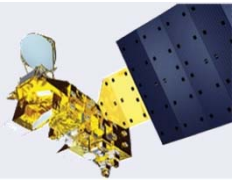
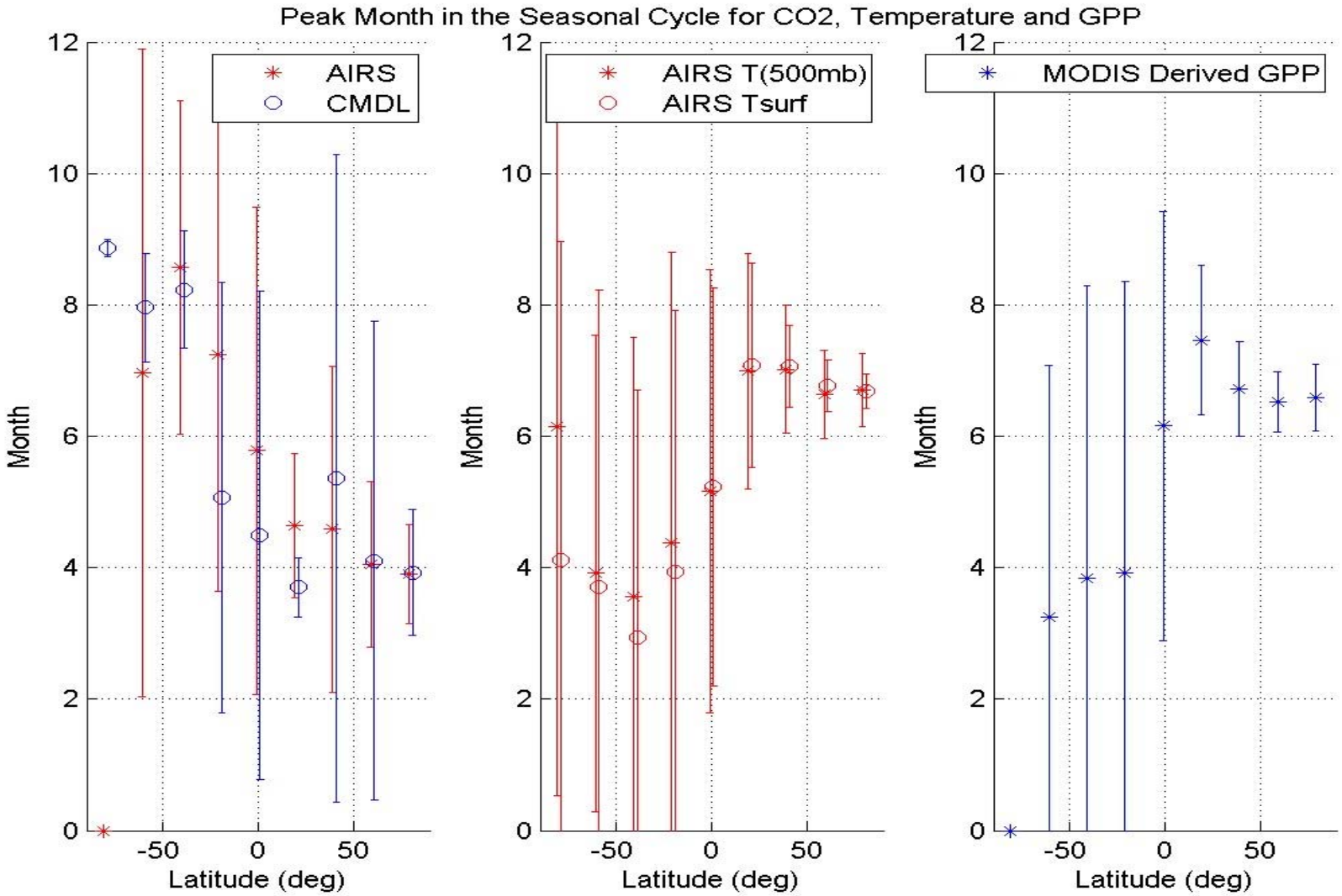
Zonal Avg. Seasonal Peak Month for CO_2, Anti-correlated with T, GPP



CO_2 | T(500mb) Tsurf | GPP



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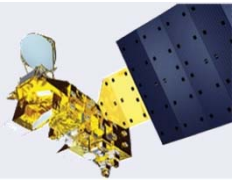
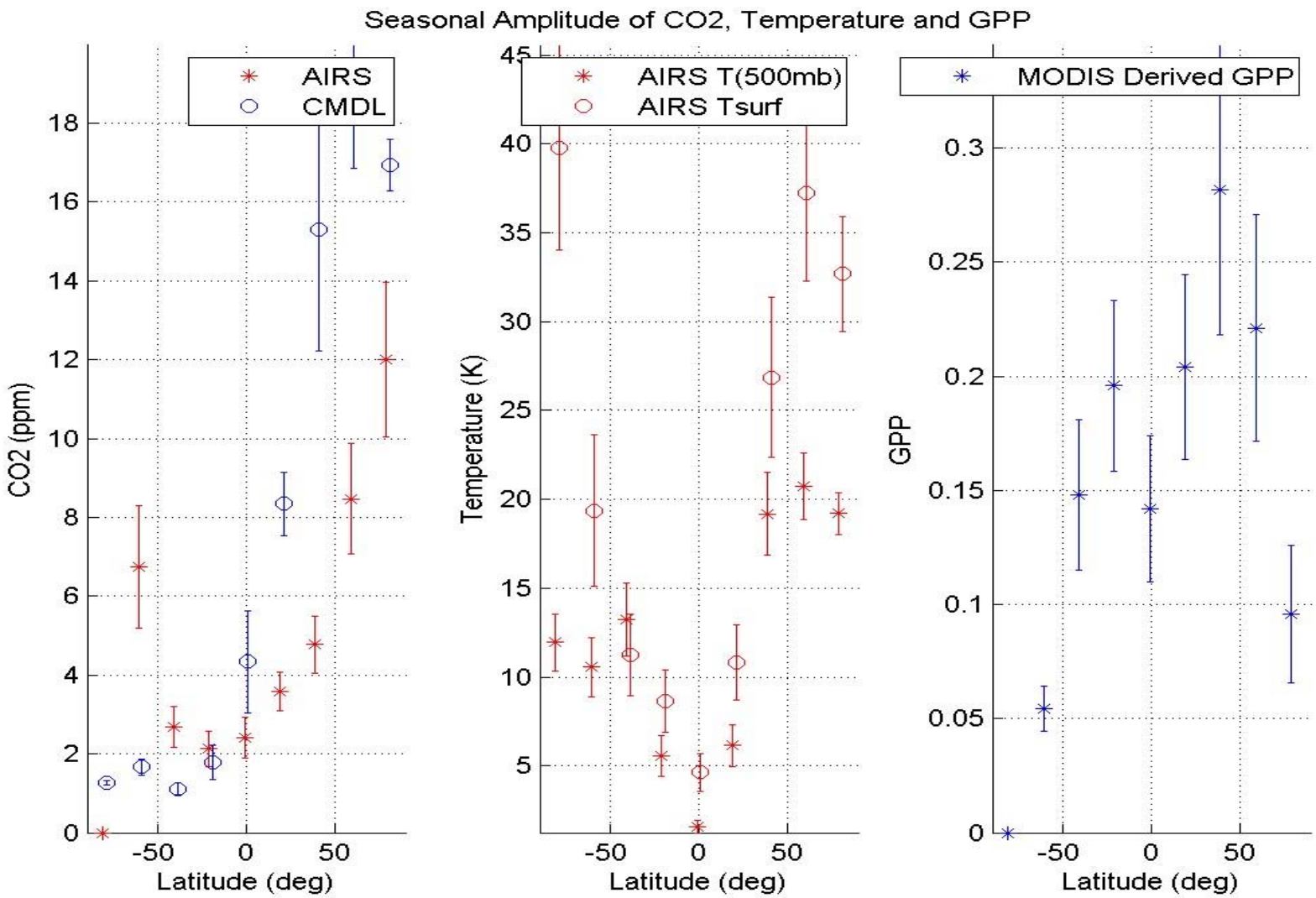
Zonal Avg. Seasonal Amplitude for CO_2, Correlated with T, ~GPP



CO_2 | T(500mb) Tsurf | GPP



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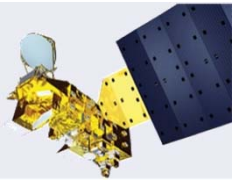
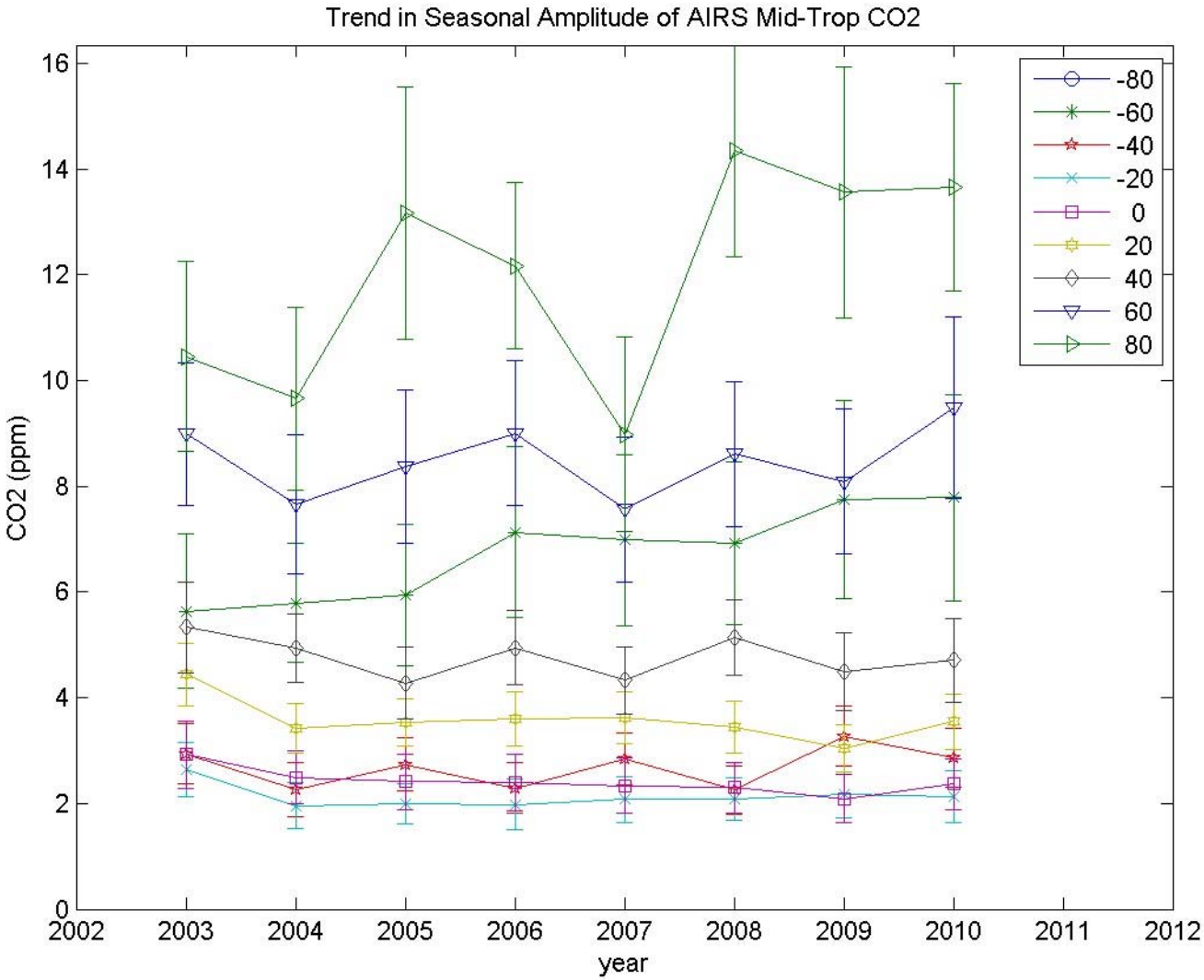
Trends in CO_2 Seasonal Amplitude Not Yet Statistically Significant?





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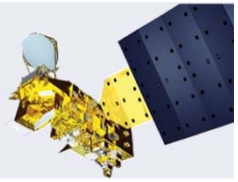
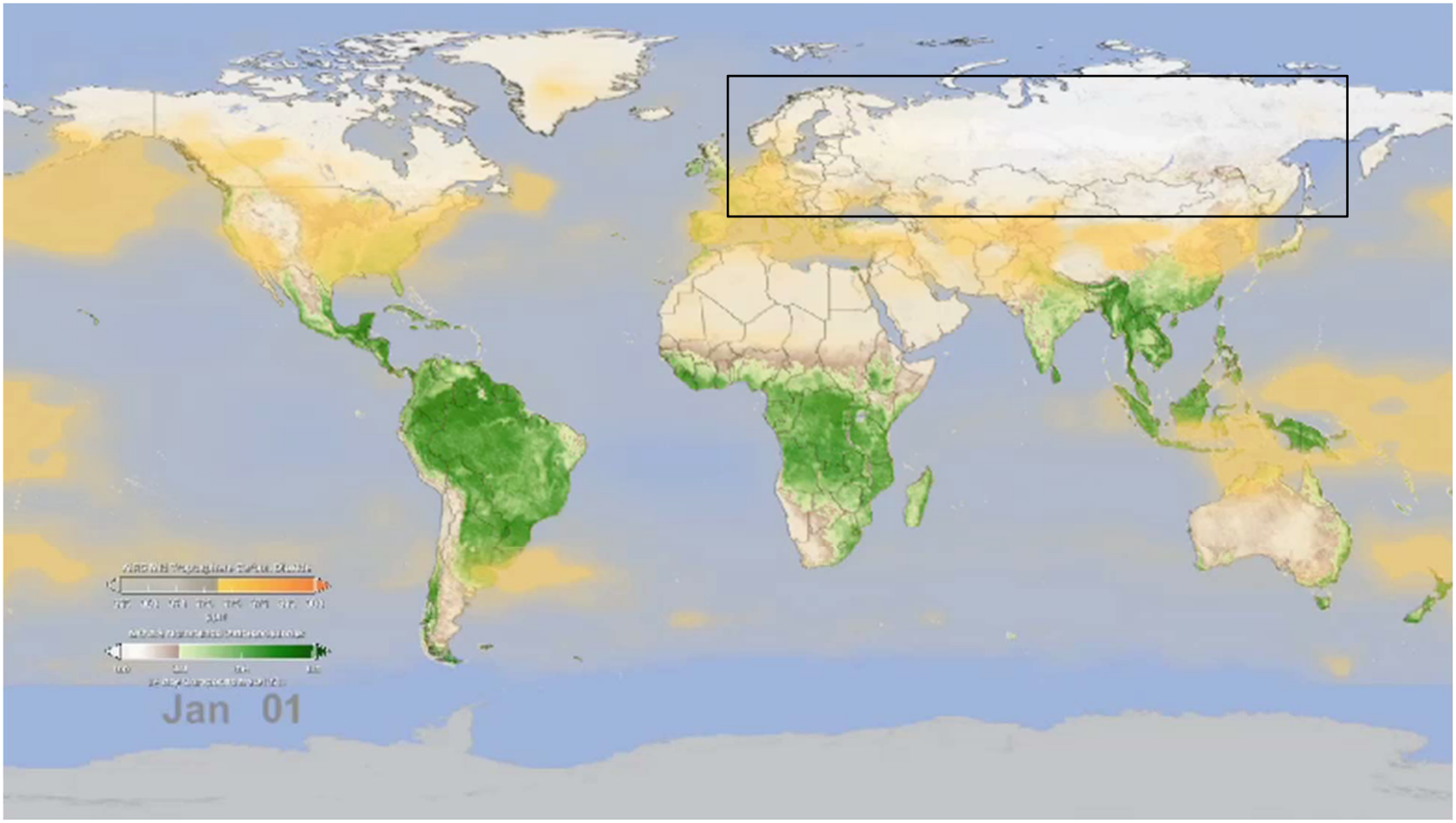
AIRS Mid-Trop CO_2 Drawdown Follows Regional Vegetation Cycle

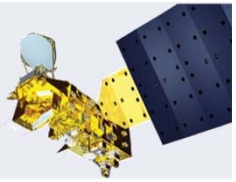




Lori Perkins (NASA/GSFC Science Visualization Studio)
T. Pagano, E. Olsen, S. Ray (JPL)

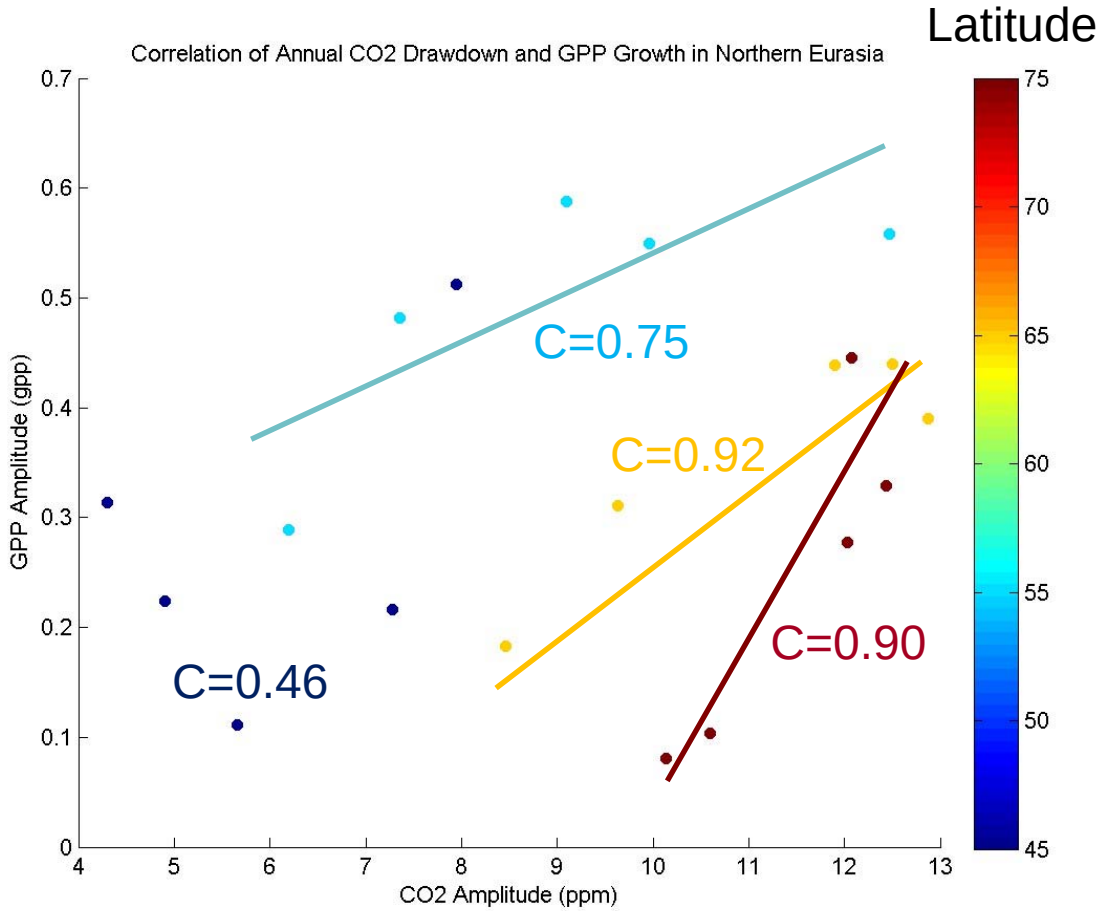
AIRS Mid-Trop CO_2 "Monthly Representation" + FRK
MODIS EVI Monthly L3

GPP and CO2 Seasonal Amplitudes Correlated by Region

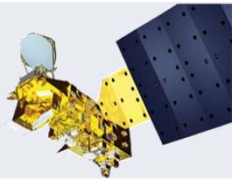


<u>Region</u>
Northern Eurasia
40º-60º Latitude
0º-150º Longitude

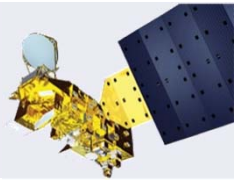
<u>Bin Size</u>
10º Lat x 30º Lon



Summary and Future Work



- Summary
  - Distinctive seasonal cycle seen in the mid-tropospheric CO_2 from AIRS
    - Amplitude of CO_2 diminished in mid-trop compared to surface.
    - Amplitude of CO_2 Seasonal Cycle increases poleward in AIRS and Surface Measurements.
    - CO_2 Phase lag Anti-Correlated with T, GPP
    - Phase lag between surface and mid-trop CO2 less certain than prior work
    - Phase not driven by mid-tropospheric temperatures.
    - GPP phase follows surface temperature.
  - Trends not statistically significant yet (wait another 10 years?)
    - Except Arctic Region
  - AIRS Mid-Trop CO_2 Regional Signal Correlated with Surface GPP
- AIRS mid-trop CO_2 seasonal cycle follows expectations
- Future Work
  - Repeat Analysis when V6 CO_2 fully processed
  - Support Development of AIRS CO_2 Climatology



Backup

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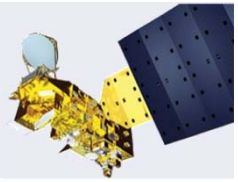
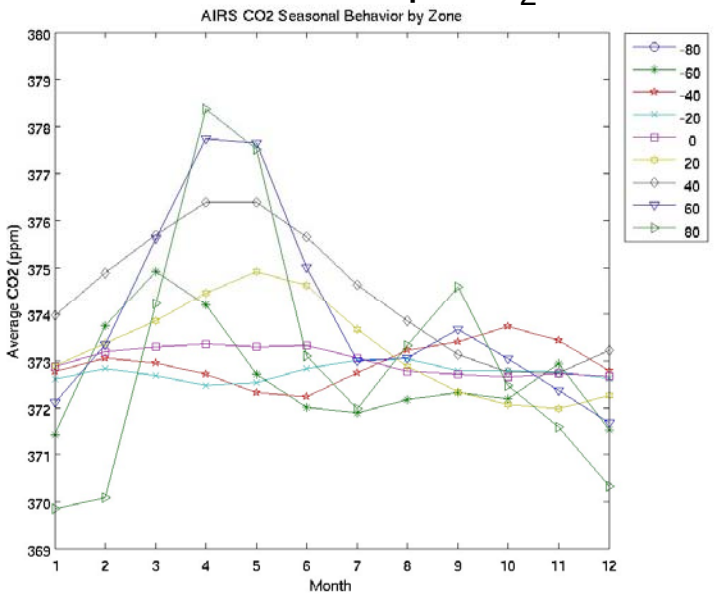
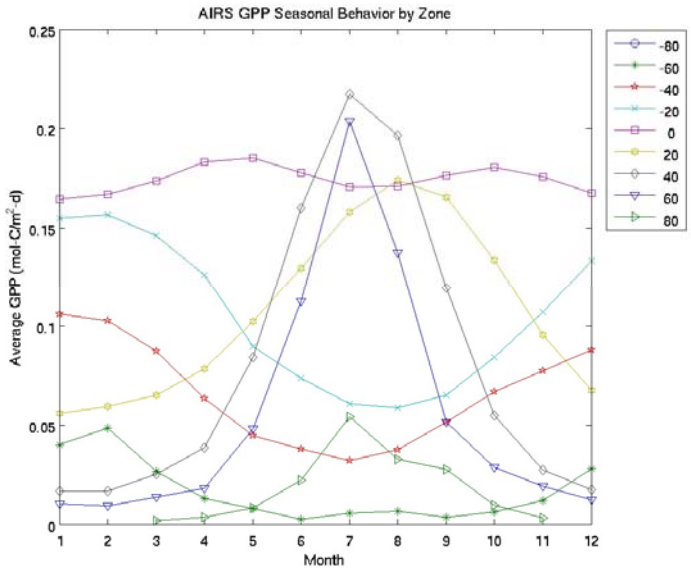
AIRS and MODIS L3 Zonal Average Time Dependence of CO_2 , GPP, T



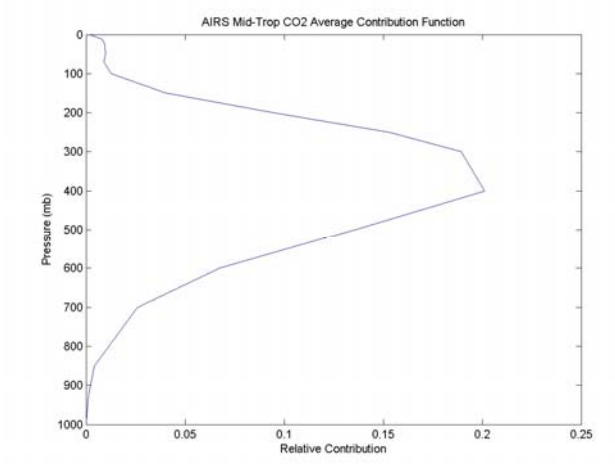
AIRS Mid-Trop CO_2

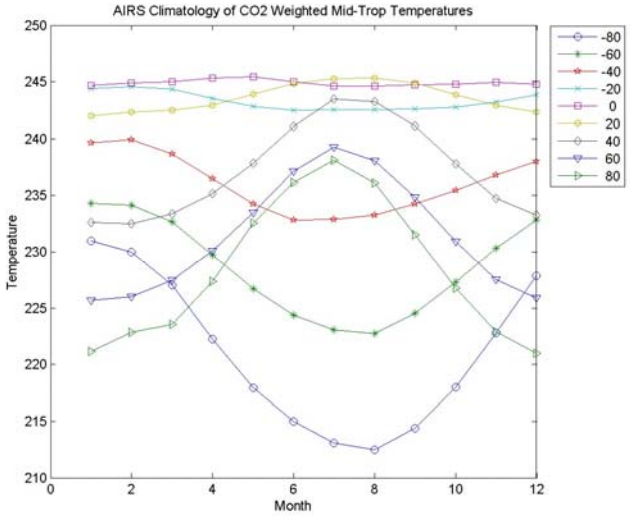


MODIS Derived GPP



AIRS Mid-Trop CO_2 Contribution Function



Convolved with AIRS T Profile

AIRS Mid-Trop Weighted T