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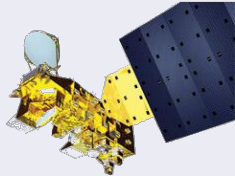

Correlations of the seasonal variability of AIRS Mid-tropospheric CO_2 with MODIS Derived Gross Primary Productivity (GPP)

International Workshop on Greenhouse Gases from Space (IWGGMS)
June 18, 2012

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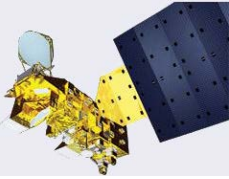
AIRS on Aqua uses Hyperspectral IR to Measure Atmospheric Greenhouse Gases

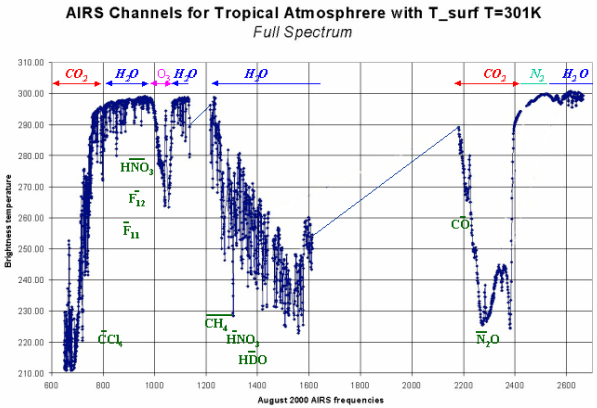


Atmospheric Infrared Sounder (AIRS)

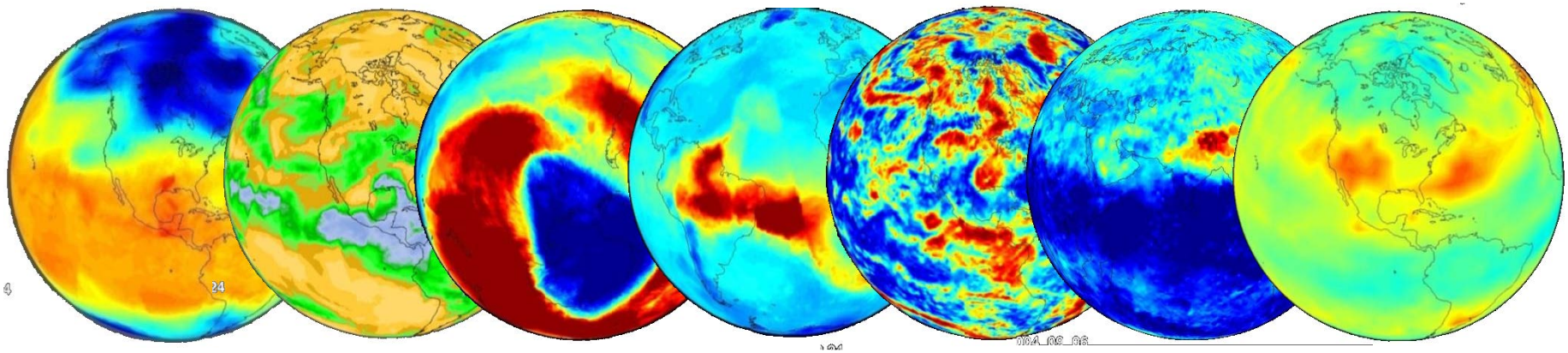
AIRS Characteristics

- 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

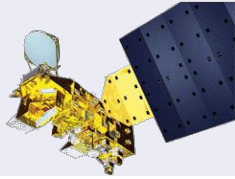


AIRS Measures Key Greenhouse Gases with Global Daily Coverage



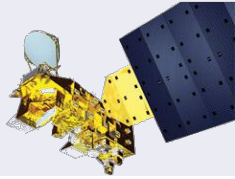
Temperature | Water Vapor | Ozone | Carbon Monoxide | Cloud Properties | Methane | Carbon Dioxide

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
EVI, T_{surf} (for GPP)	MODIS	L3	GES/DISC
Surface CO_2	In-Situ/Flask	Txt	NOAA CMDL
Surface CO_2	In-SituFlask	Txt	SCRIPPS

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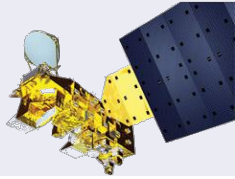
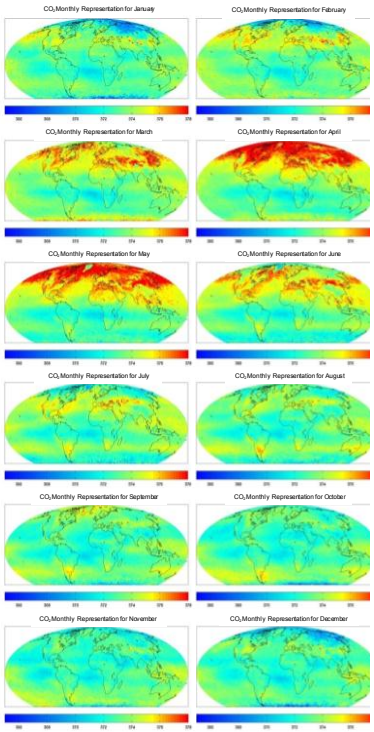
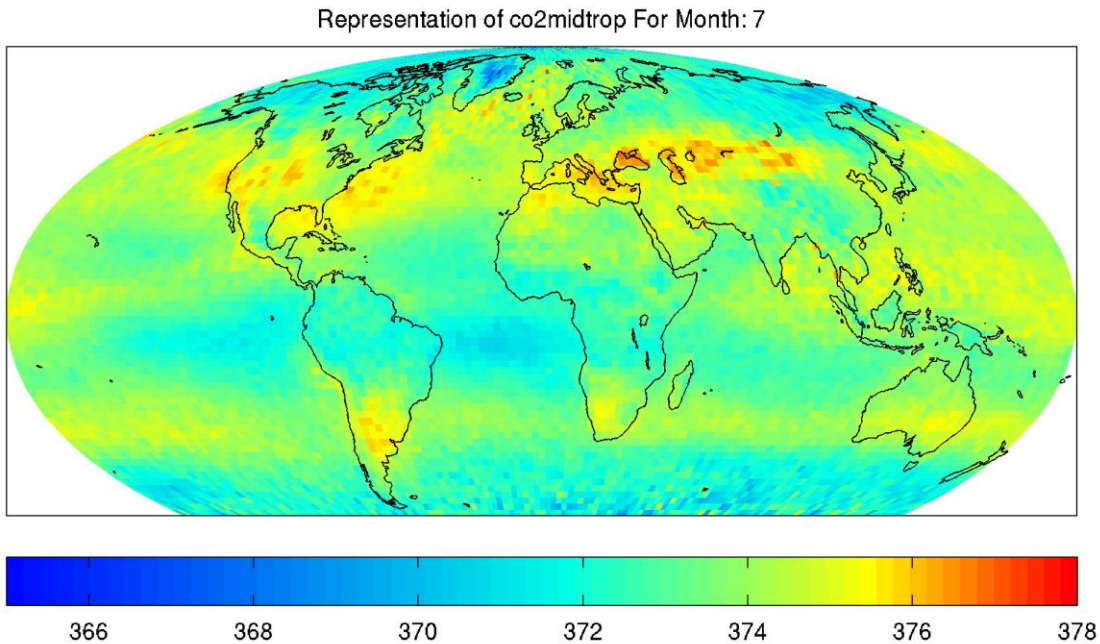
AIRS Mid-Tropospheric CO_2 Representations ("Climatologies")



Average of Detrended AIRS Version 5, L3 CO2 Monthly Data by Month over 8 years

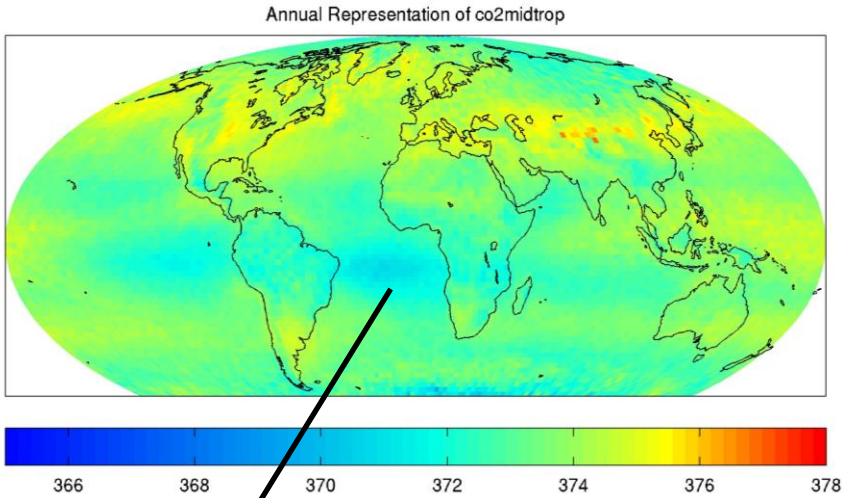




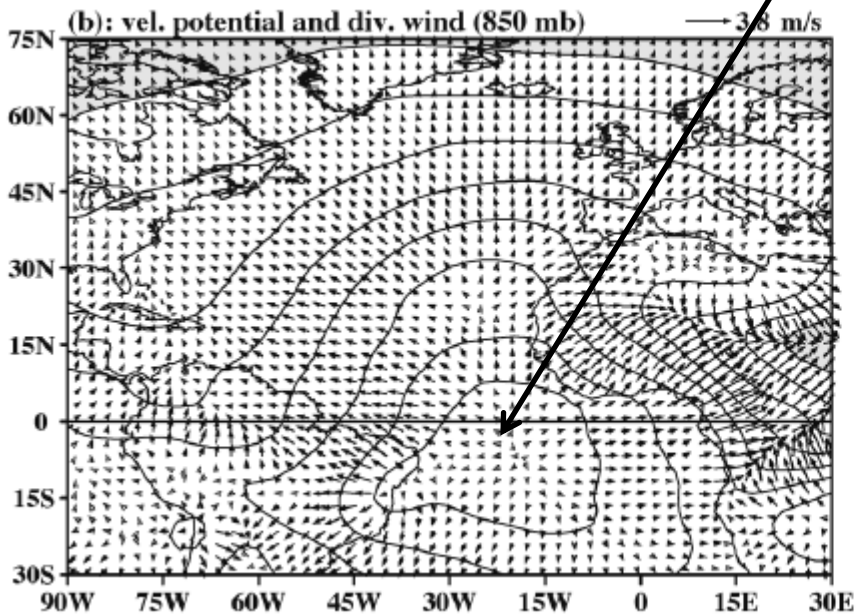
Pagano, T. S., Olsen
representations of mid-tropospheric carbon dioxide from the Atmospheric Infrared Sounder," Proc. SPIE 8158-11, San Diego, CA (2011).

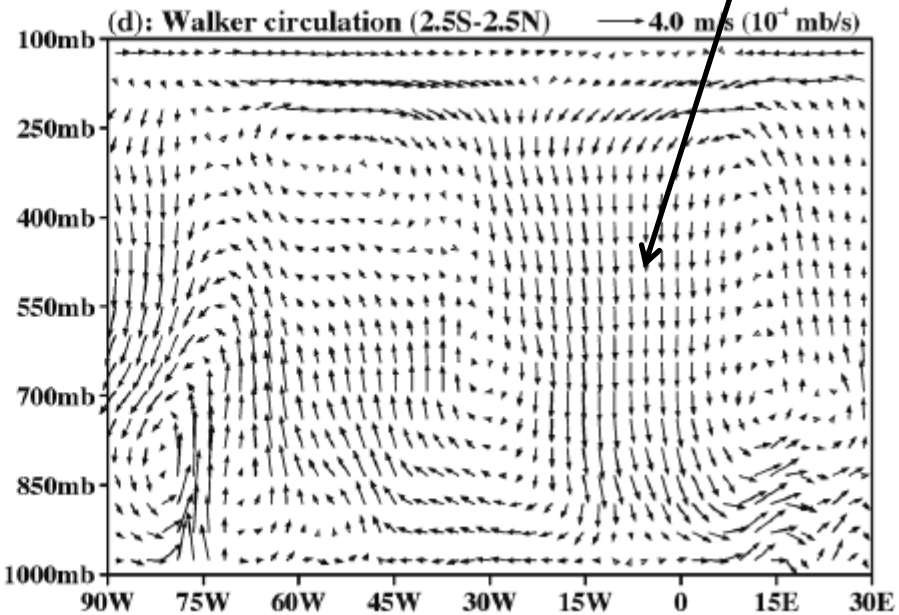
Depleted Region in of Mid-Tropospheric CO_2 in South Atlantic Related to Walker Circulation

Annual Average AIRS Mid-Trop CO_2



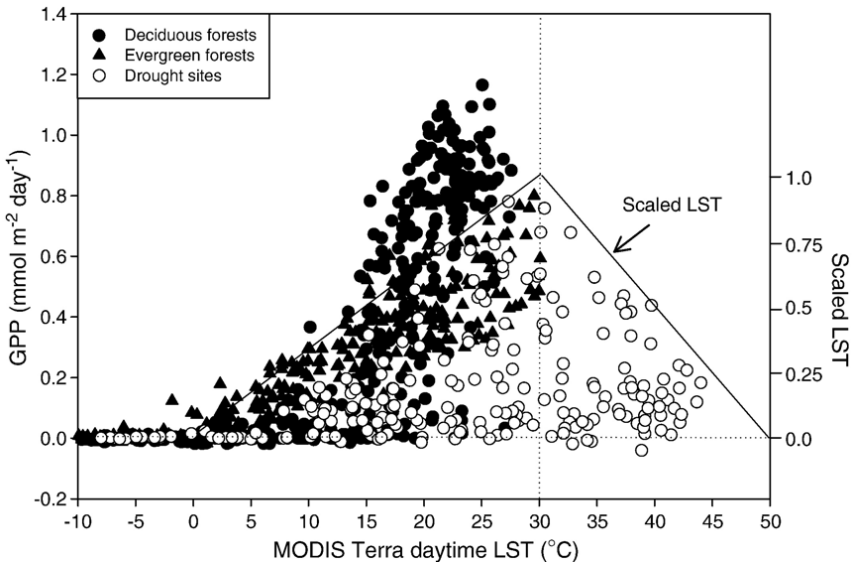
Downward Flow of Walker Circulation

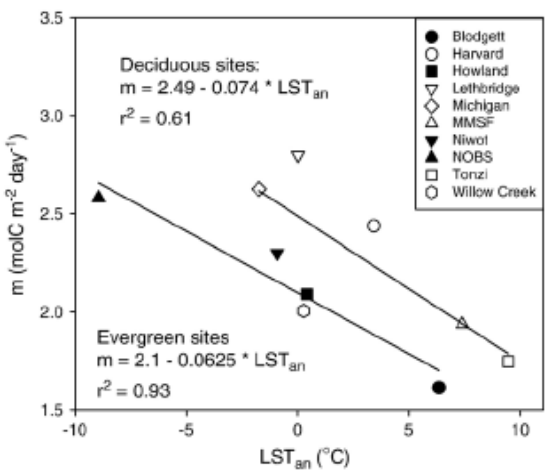




CHUNZAI WANG, Atlantic Climate Variability and Its Associated Atmospheric Circulation Cells, Journal of Climate, 2001

Gross Primary Productivity using MODIS Temperature and Greenness (TG)





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

MODIS Night LST

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

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

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

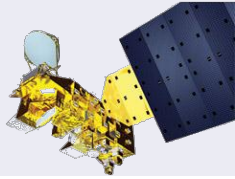
$$m = 2.49 - 0.074 \times \mathrm{LST_{an}} \quad \text{for deciduous sites}$$

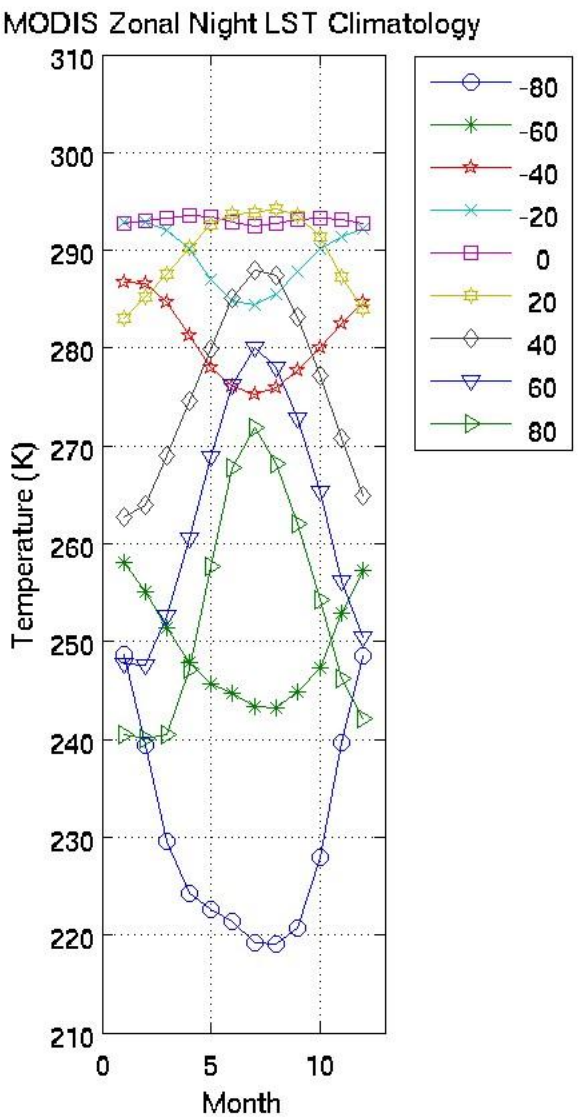
$$m = 2.10 - 0.0625 \times \mathrm{LST_{an}} \quad \text{for evergreen sites.}$$

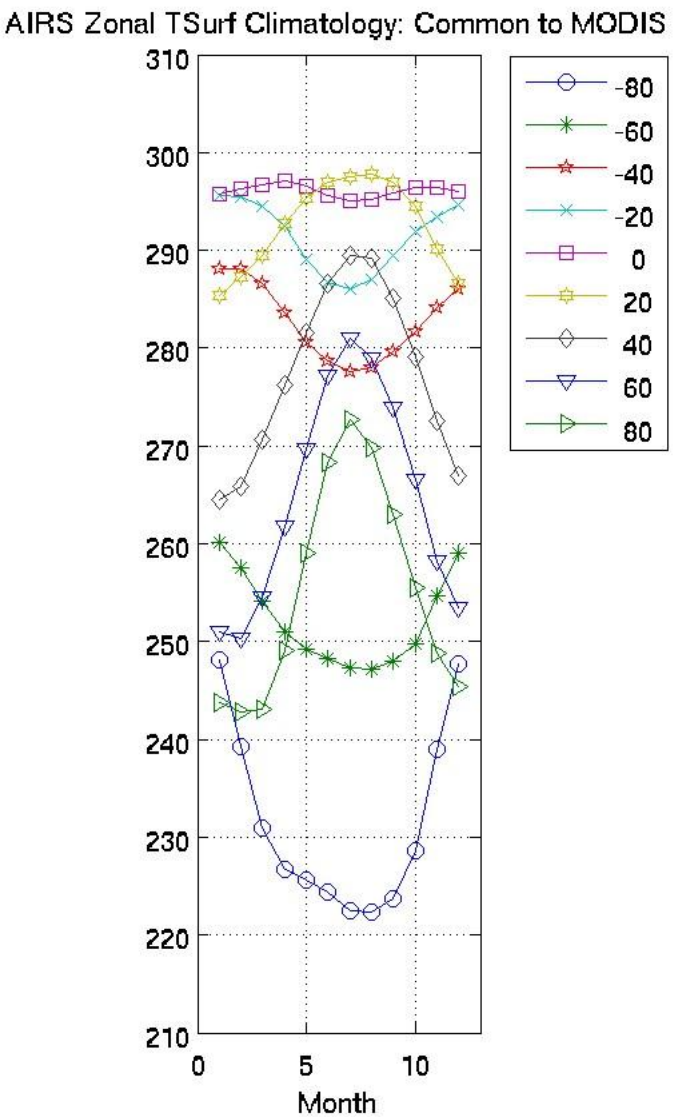
Using Average m gives < 18% error

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

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







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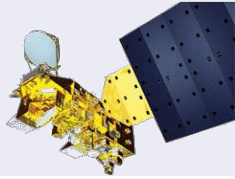
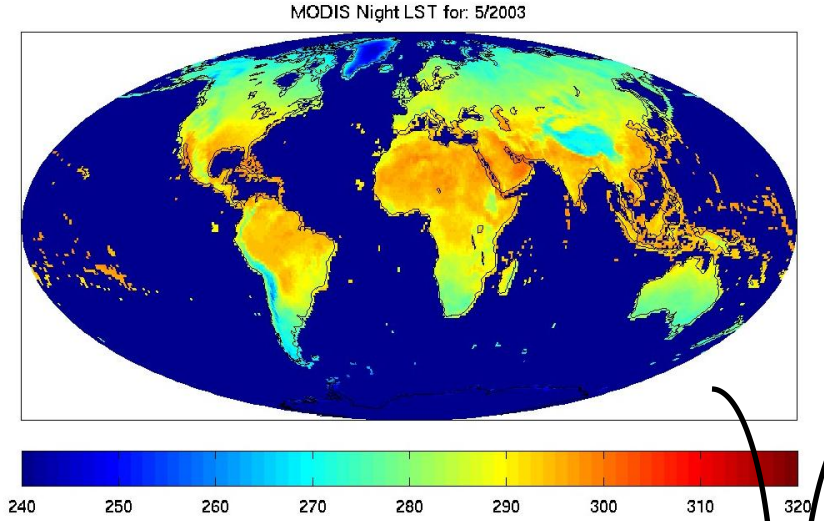
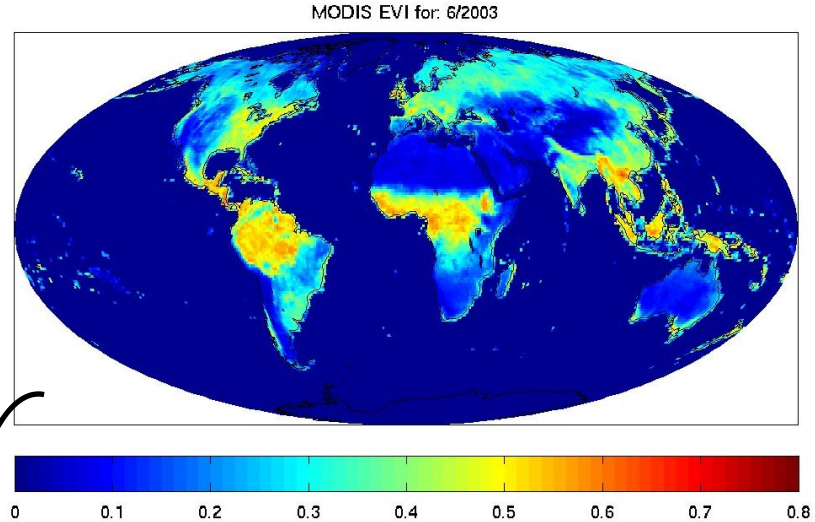
MODIS EVI and Night Land Surface Temperature used to make GPP



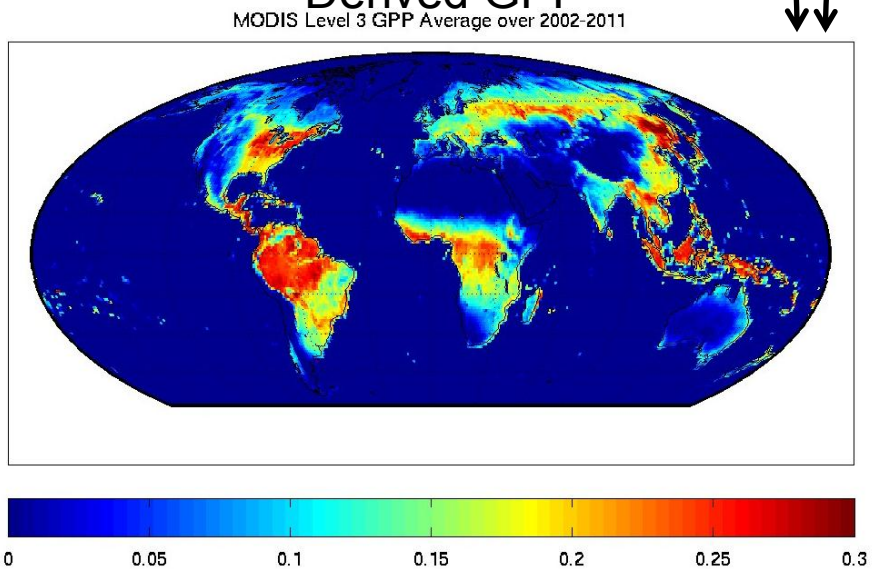
MODIS L3 LST



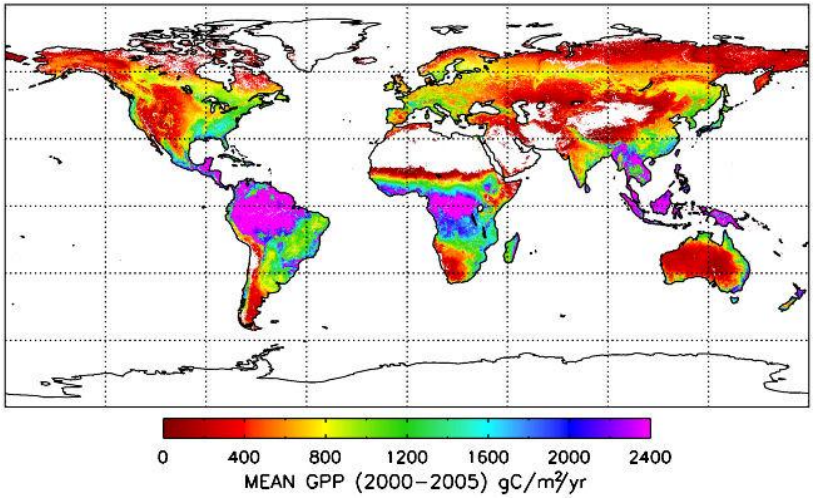
MODIS L3 EVI



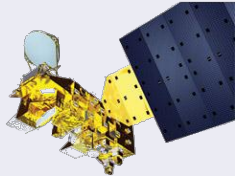
Derived GPP



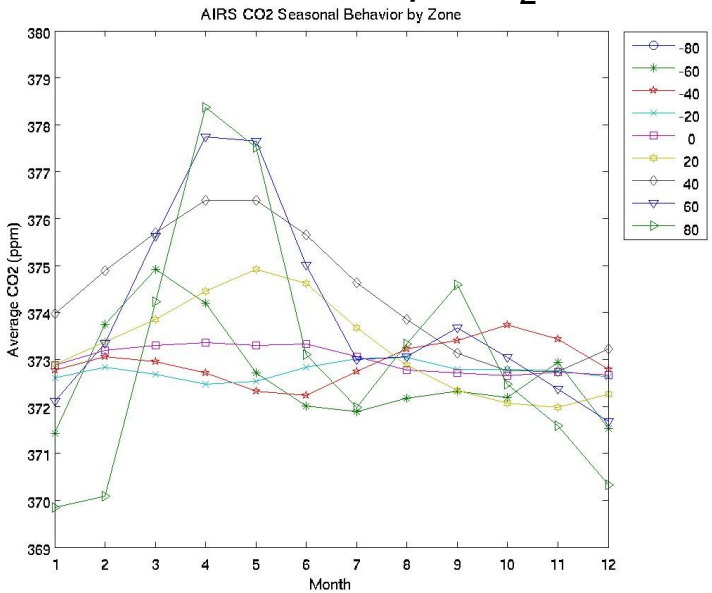
UMT GPP



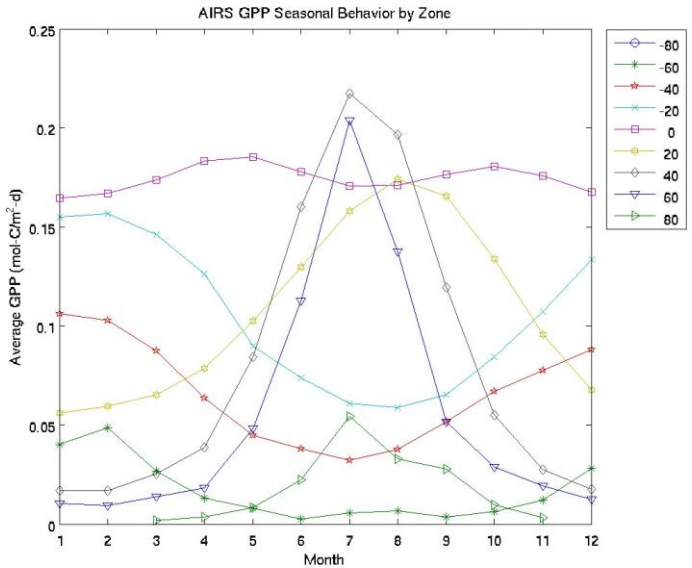
AIRS and MODIS L3 Zonal Average Time Dependence of CO_2 , GPP, T



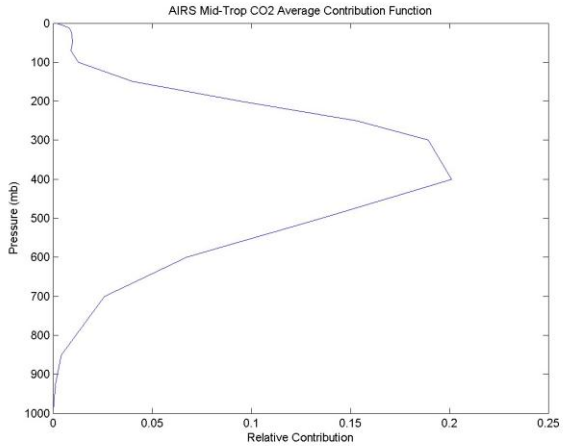
AIRS Mid-Trop CO_2



MODIS Derived GPP

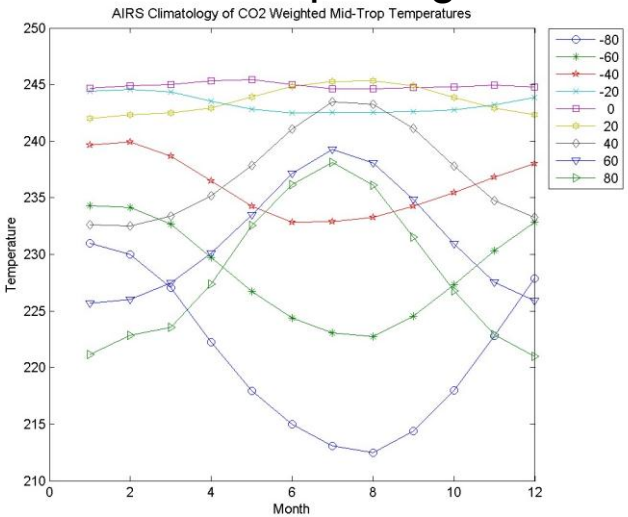


AIRS Mid-Trop CO_2 Contribution Function

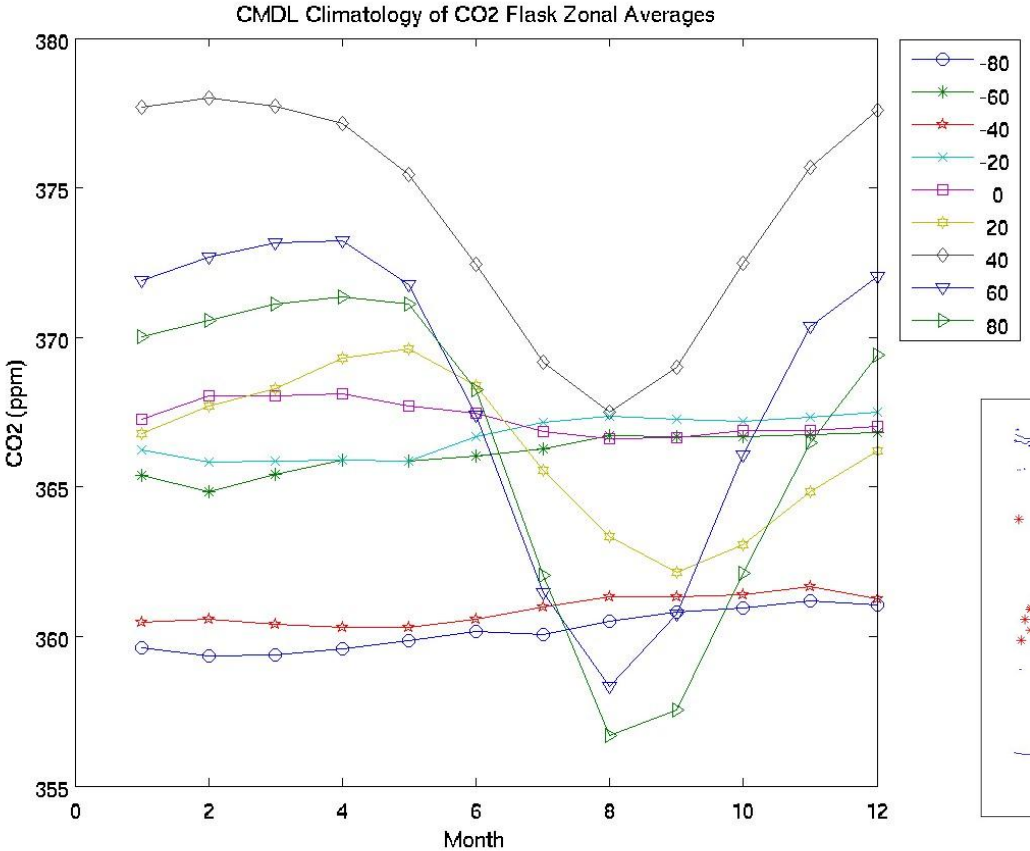


Convolved with AIRS T Profile

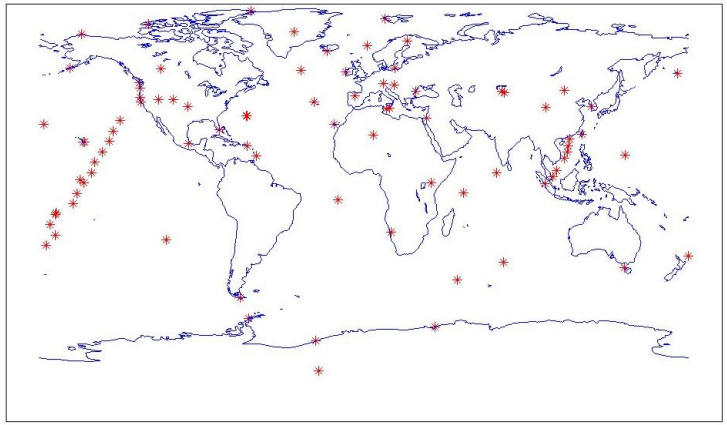
AIRS Mid-Trop Weighted T



NOAA CMDL In-Situ / Flask Data used for Comparison

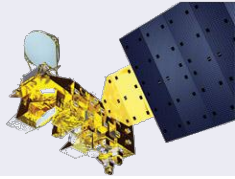


87 Surface Sites Worldwide

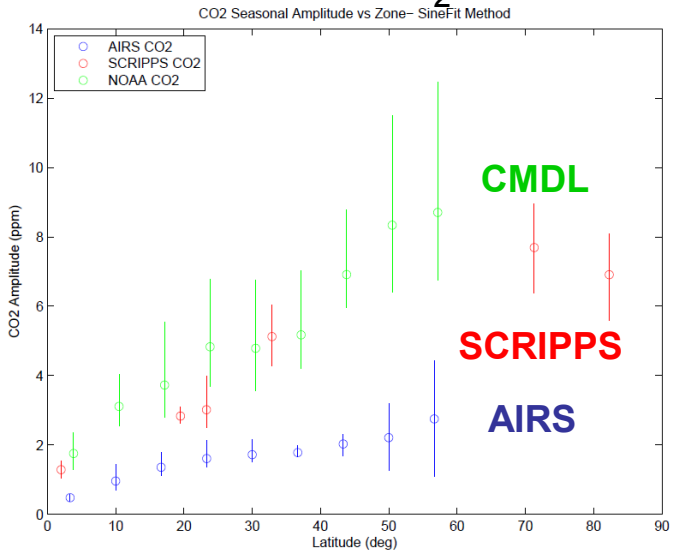


Conway, T.J., P.M. Lang, and K.A. Masarie (2011), Atmospheric Carbon Dioxide Dry Air Mole Fractions from the NOAA ESRL Carbon Cycle Cooperative Global Air Sampling Network, 1968-2010, Version: 2011-10-14, Path: ftp://ftp.cmdl.noaa.gov/ccg/co2/flask/event/.

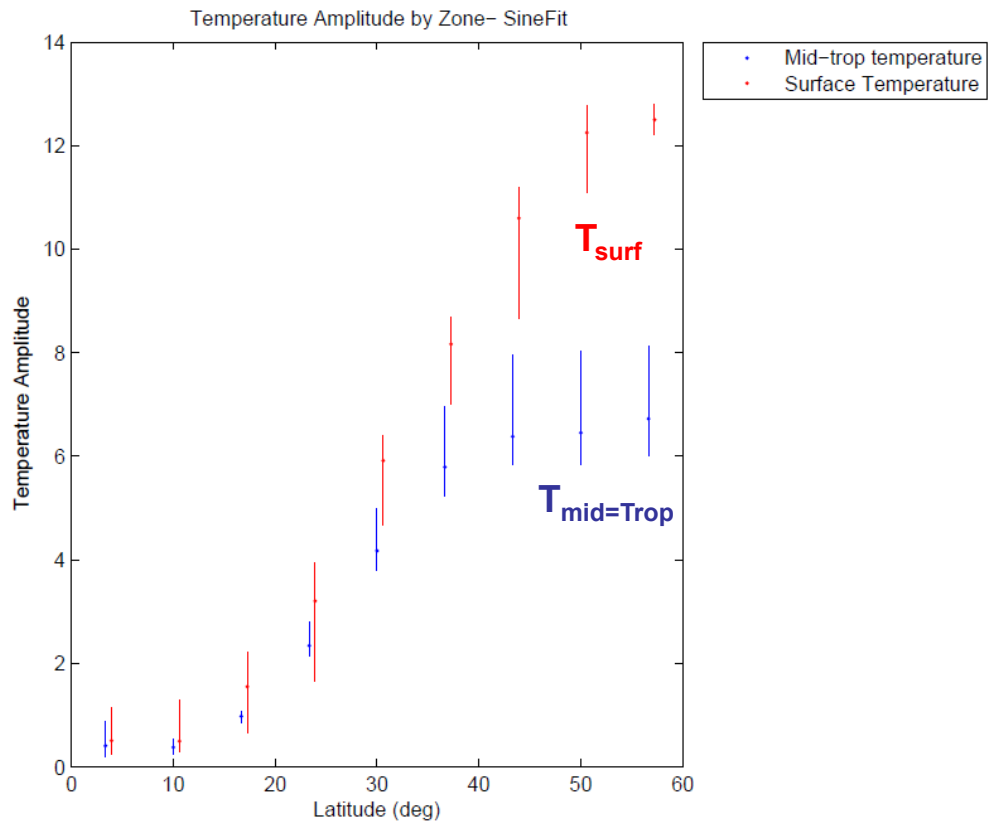
NH Seasonal Amplitude of All Products Increase Poleward



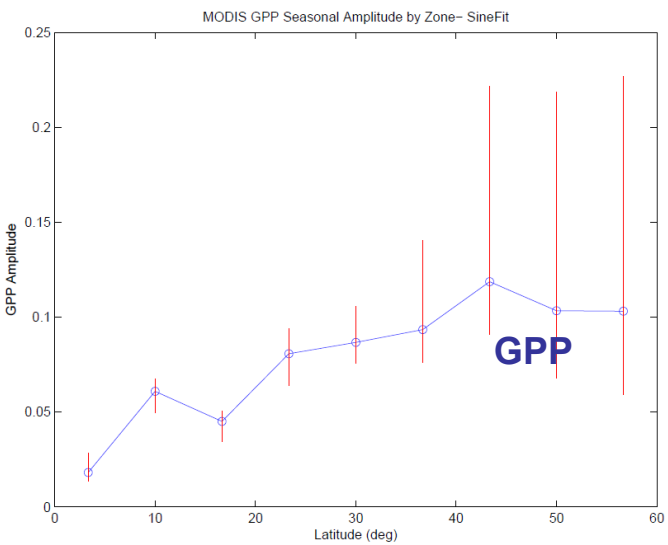
Zonal CO_2



Zonal Temperature

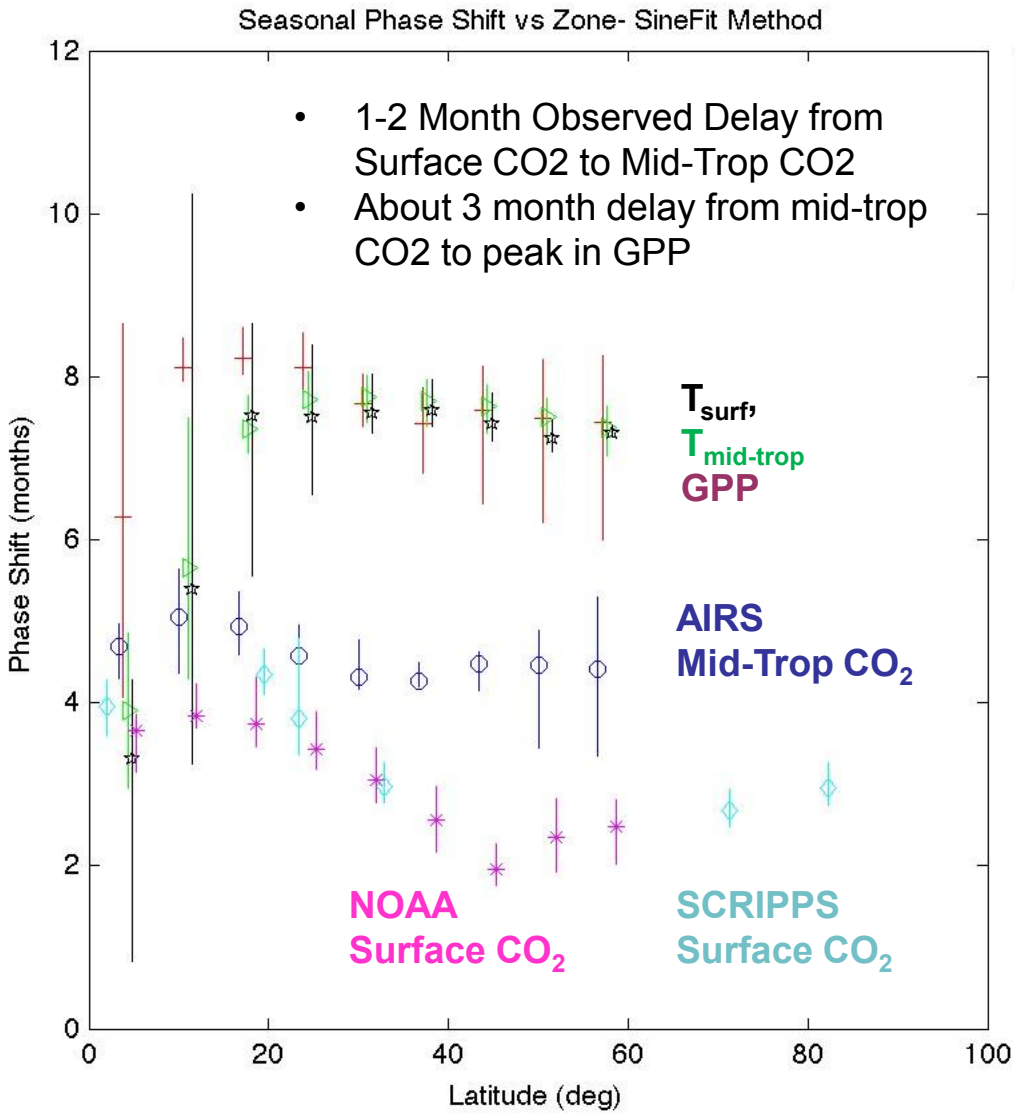


Zonal GPP

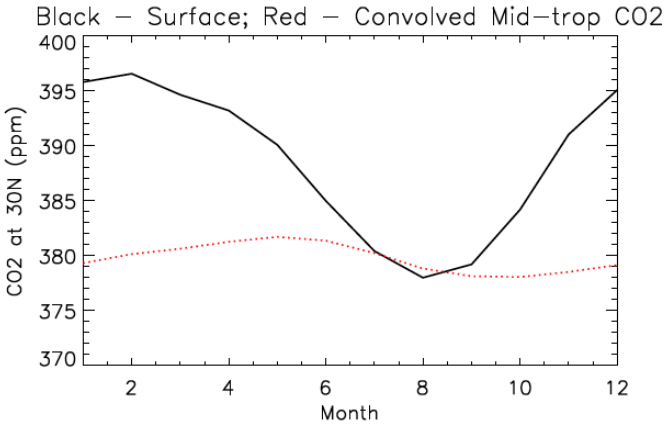


Corr(AIRS CO_2 , GPP) = 0.87

AIRS CO2 Phase Lag about 3 month's Relative to GPP, Tsurf and T(~300mb)



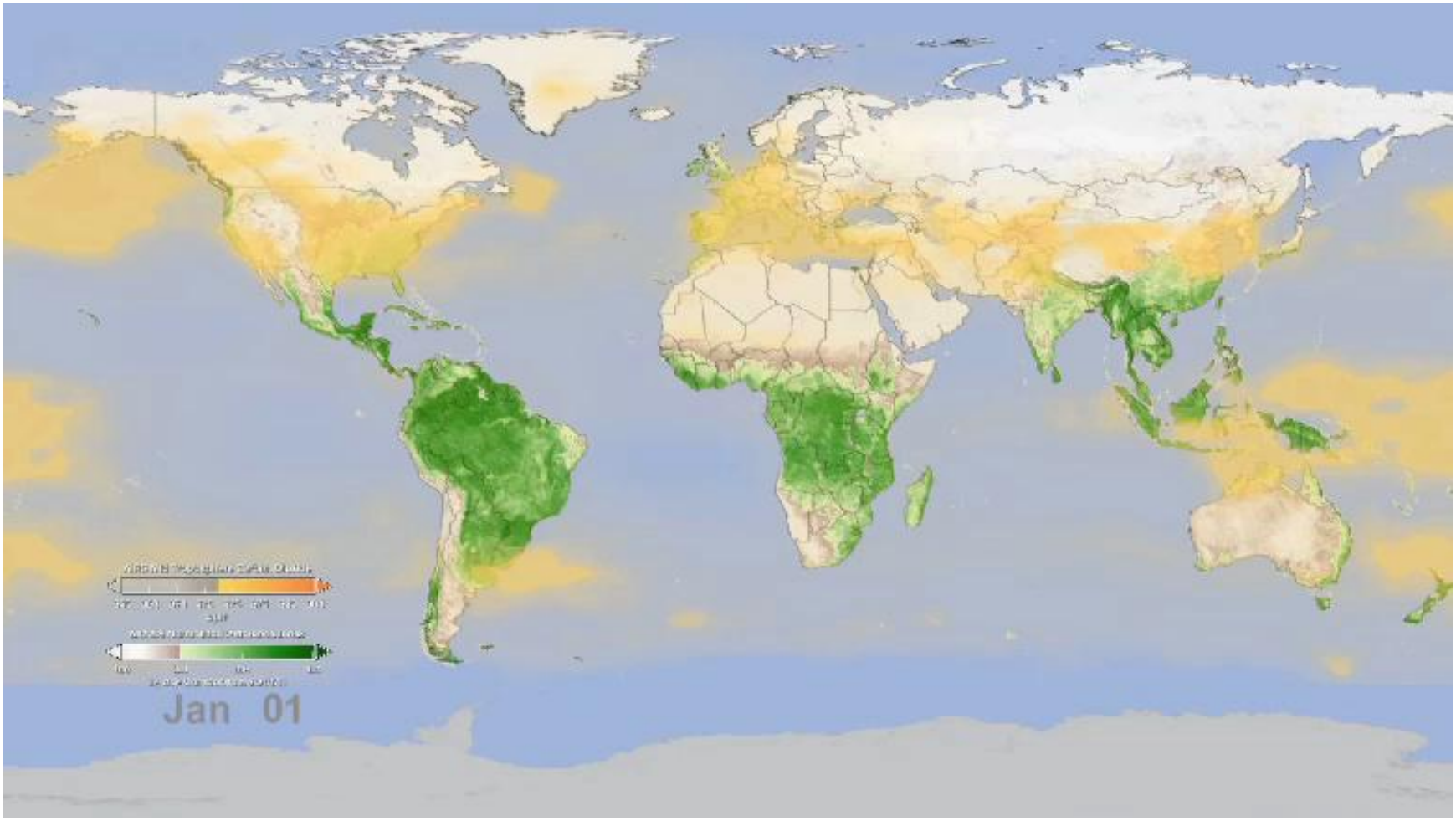
- 1-2 Month Observed Delay from Surface CO2 to Mid-Trop CO2
- About 3 month delay from mid-trop CO2 to peak in GPP



- *MOZART Model Shows Phase Lag of about 2 month's from Surface to Mid-Trop*

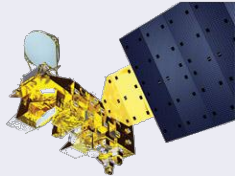
AIRS Mid-Trop CO_2 Drawdown Follows Regional Vegetation Cycle

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



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

Summary and Future Work



- Summary
  - Distinctive seasonal cycle seen in the mid-tropospheric CO_2 from AIRS
    - Amplitude of CO_2 Seasonal Cycle increases poleward in AIRS and Surface Measurements.
    - Amplitude of CO_2 diminished in mid-trop compared to surface.
    - Phase lag between surface and mid-trop CO2 of ~2 months
    - Phase predicted by model with same sign and magnitude.
    - Phase not driven by mid-tropospheric temperatures.
    - GPP phase follows surface temperature.
  - AIRS mid-trop CO_2 seasonal cycle follows expectations
- Future work
  - Repeat Results with Version 6 to increase yield and accuracy
  - Examine influence of clouds and water vapor
  - Add Ocean GPP
  - Examine Regional Correlations