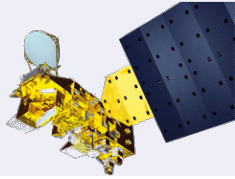

Influence of Global Vegetation on Mid-Tropospheric CO2 Early Results

AIRS Science Team Meeting
April 25, 2012

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California Institute of Technology, Jet Propulsion Laboratory
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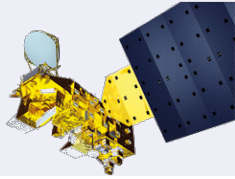
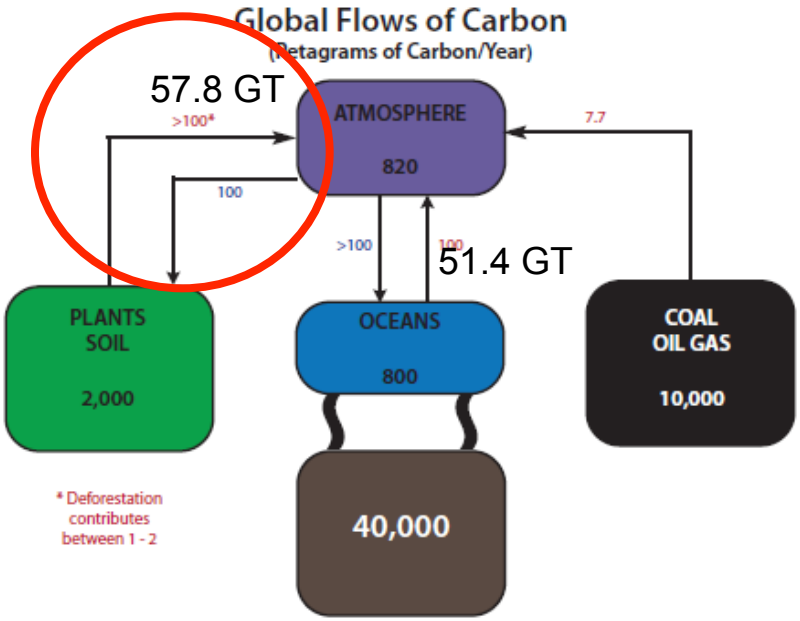
Introduction

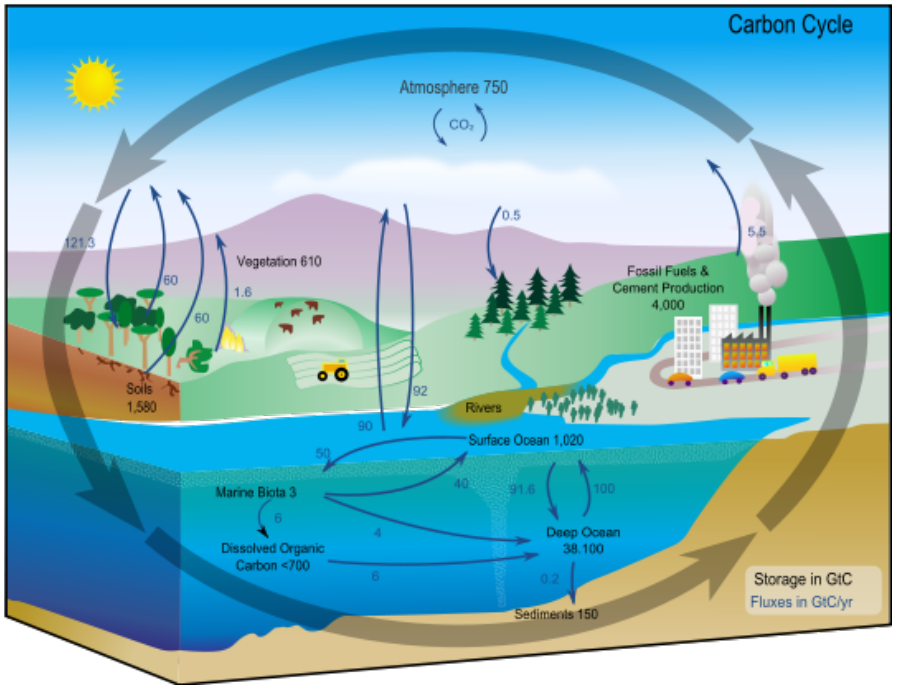


- AIRS Mid-Tropospheric CO2 shows a high degree of horizontal variability
- Ongoing efforts show AIRS data influenced by global circulation patterns including ENSO and MJO
  - Jiang, X., M. T. Chahine, E. T. Olsen, L. L. Chen, and Y. L. Yung (2010), Interannual variability of mid-tropospheric CO2 from 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 CO_2 variability driven by the Madden-Julian oscillation, *PNAS*, 107 (45), 19171-19175, doi:10.1073/pnas.1008222107.
- What is the influence of global vegetation cycle on CO2 seasonal behavior?
  - Can we correlate mid-trop CO2 seasonal variability with global vegetation for different regions?
  - For now: First look at zonal averages and Land Vegetation (ocean biomass later)
  - Goal: Sanity Check on AIRS Data Seasonal Cycle, Solicit interest by carbon cycle community
  - Outreach Opportunity: International Workshop on Greenhouse Gas Measurements (IWGGMS) 2012 at CalTech

Can Regional Carbon Transport and Storage Be Validated using Satellite Obs?

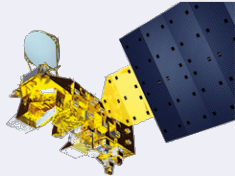
How well known are global flux estimates?





1 Pg = 10^{15} g x (10^{-3} kg/g) x (1T/907.2 kg) =1.102 GT

Agenda



- CO2 Data
  - AIRS Level 3
  - Creation of a “Climatology”
- Land Vegetation Data: GPP Gross Primary Productivity
  - MODIS Enhanced Vegetation Index
  - MODIS Land Surface Temperature
  - GPP Climatology
- Early Zonal Correlation Results
- Future Work

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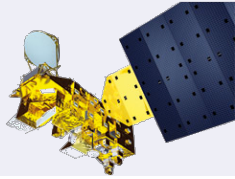
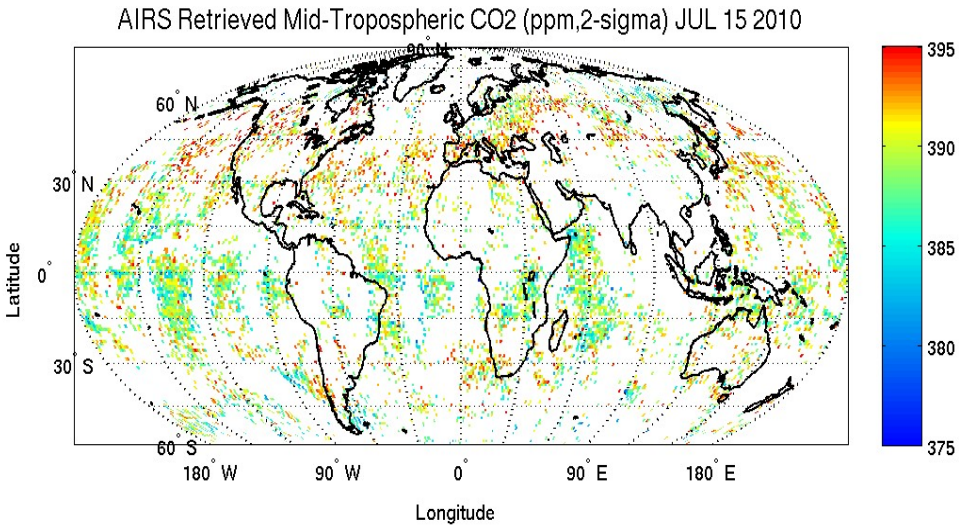
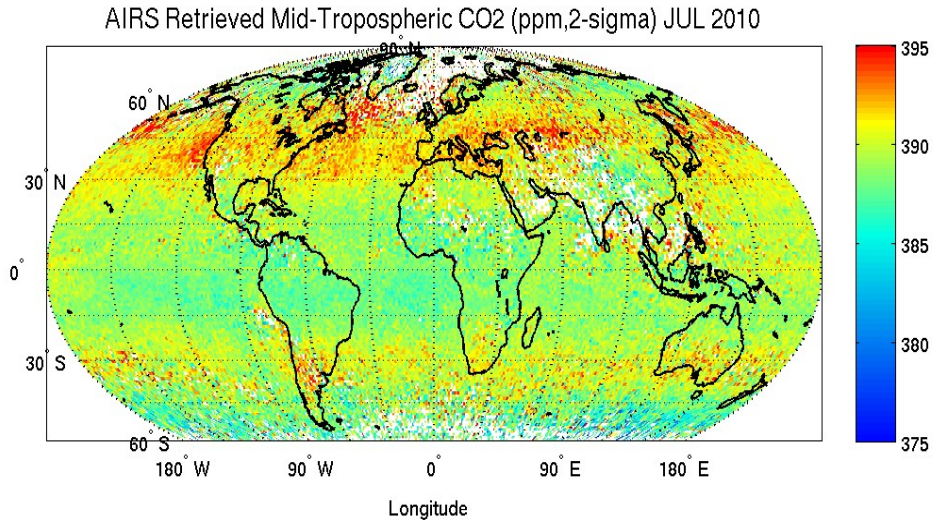
AIRS V5 Mid-Tropospheric CO2 Shows Horizontal Variability



AIRS Daily CO_2 Yield
1ºx1º Spatial Resolution



AIRS Monthly CO_2 Yield
1ºx1º Spatial Resolution



Day/Night, Pole-to-Pole, Land/Ocean/Ice, Cloudy/Clear

AIRS CO2 Data Products Released (2002 to present)
http://airs.jpl.nasa.gov/AIRS_CO2_Data

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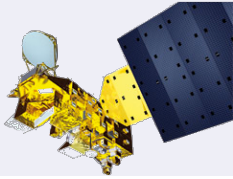
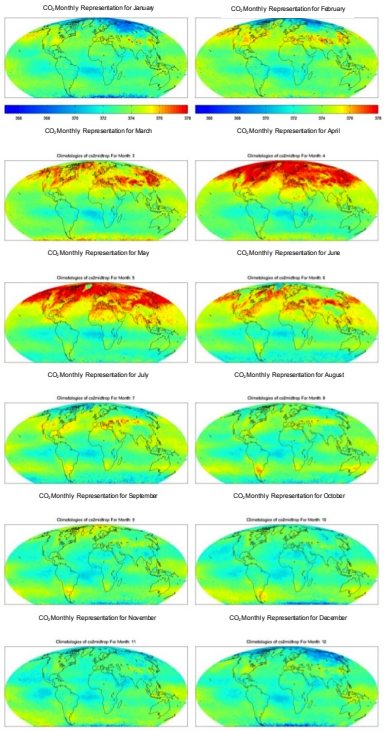
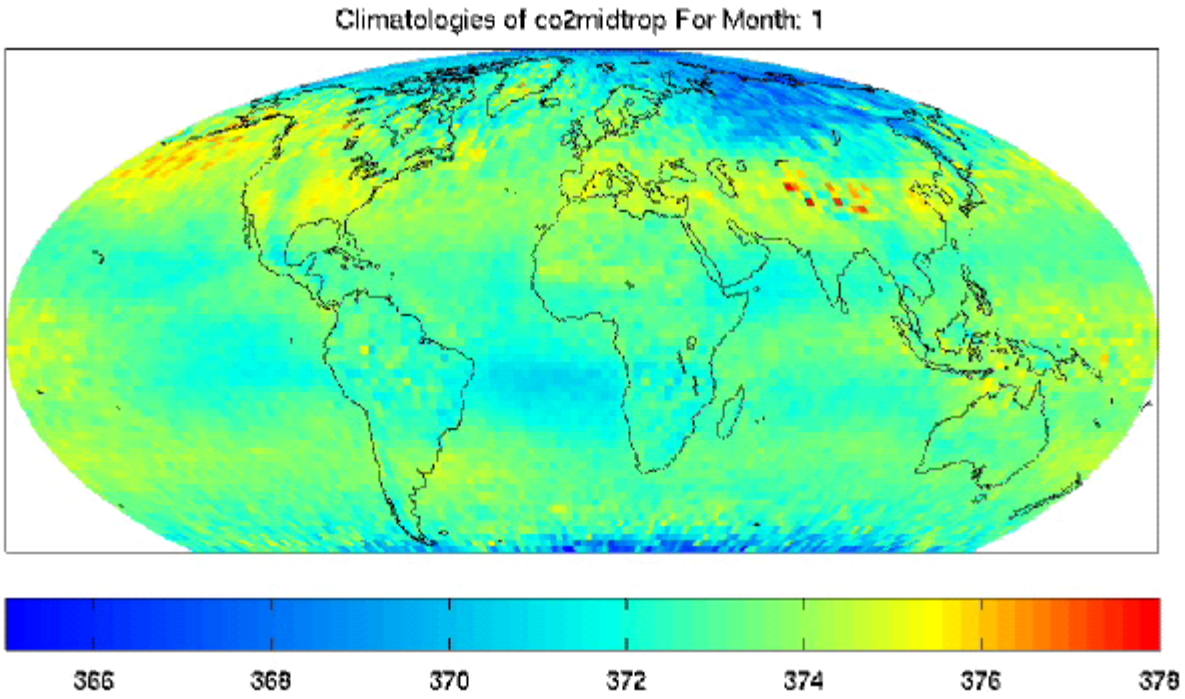
AIRS Mid-Tropospheric CO_2 Representations ("Climatologies")



Average of L3 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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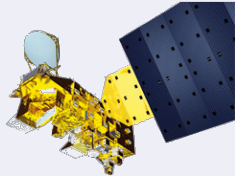
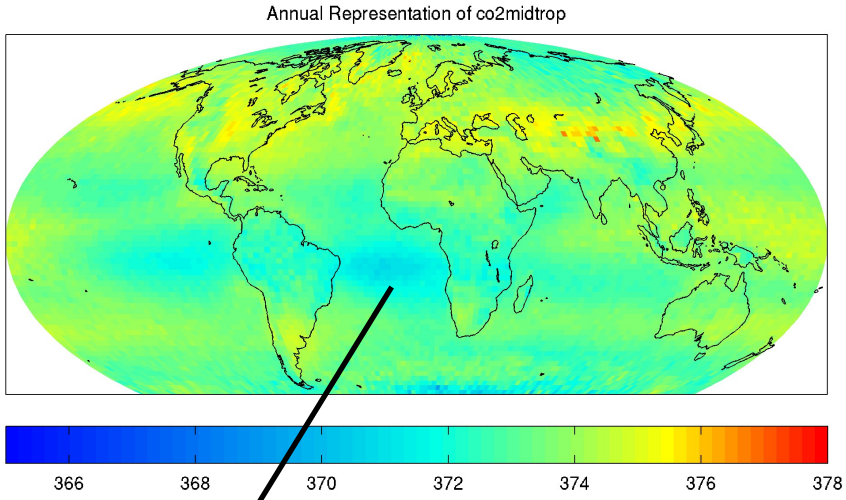
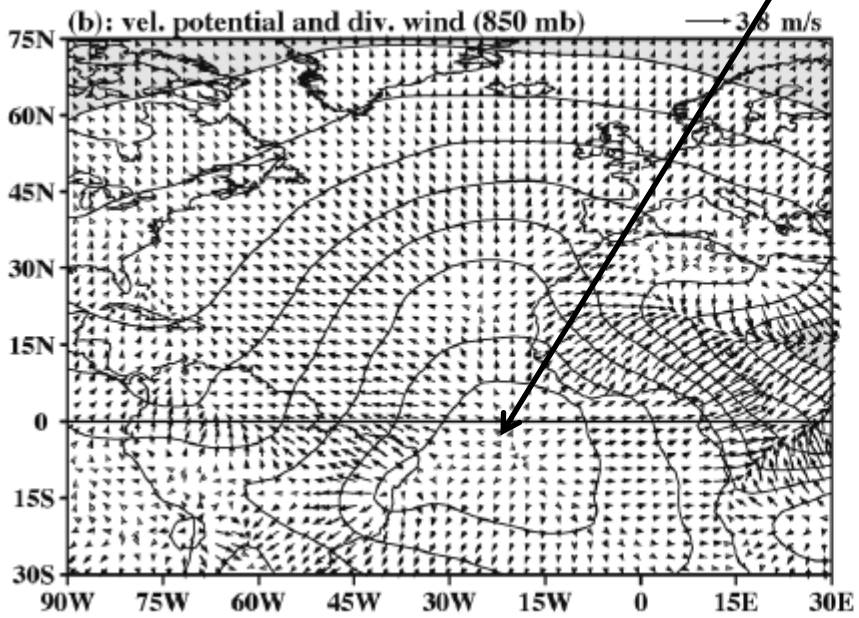
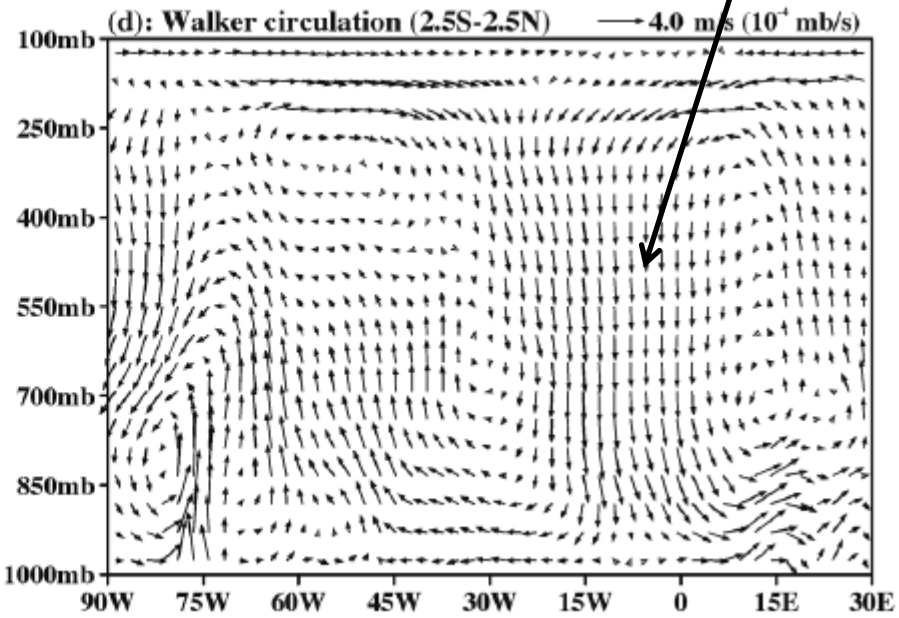
"Depleted Band of CO2 Not Due to Surface Vegetation"





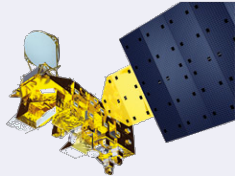
Downward Flow of Walker Circulation

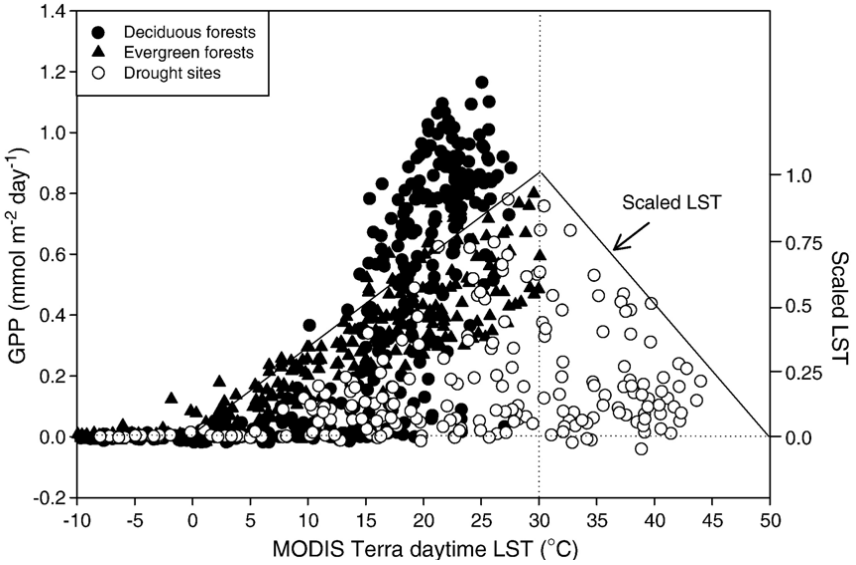


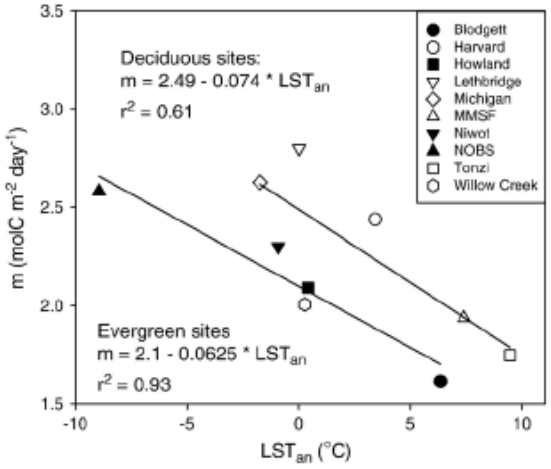


CHUNZAI WANG, Atlantic Climate Variability and Its Associated Atmospheric Circulation Cells, Journal of Climate, 2001

Gross Primary Productivity using MODIS Temperature and Greenness (TG)







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

MODIS Night LST

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

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

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

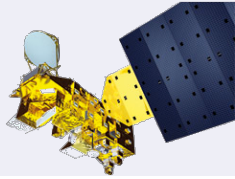
$$m = 2.49 - 0.074 \times \text{LST}_{\text{an}} \quad \text{for deciduous sites}$$

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

Using Average m gives < 18% error

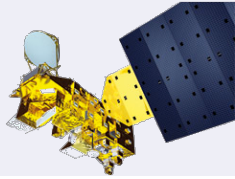
Sims, D. et al., A new model of gross primary productivity for North American ecosystems based solely on the enhanced vegetation index and land surface temperature from MODIS, Remote Sensing of Environment 112 (2008) 1633–1646

Data Sets



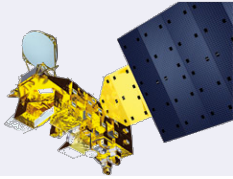
- Mirador.gsfc.nasa.gov
- MYDVI.005 MODIS/Aqua Monthly Vegetation Indices Global 1x1 degree
- MYD11CM1N.005 MODIS/Aqua Monthly mean Night-Time Land Surface Temperature at 1x1 degree
- AIRX3C2M.005 AIRS/Aqua Level 3 Monthly CO2 in the free troposphere (AIRS+AMSU)

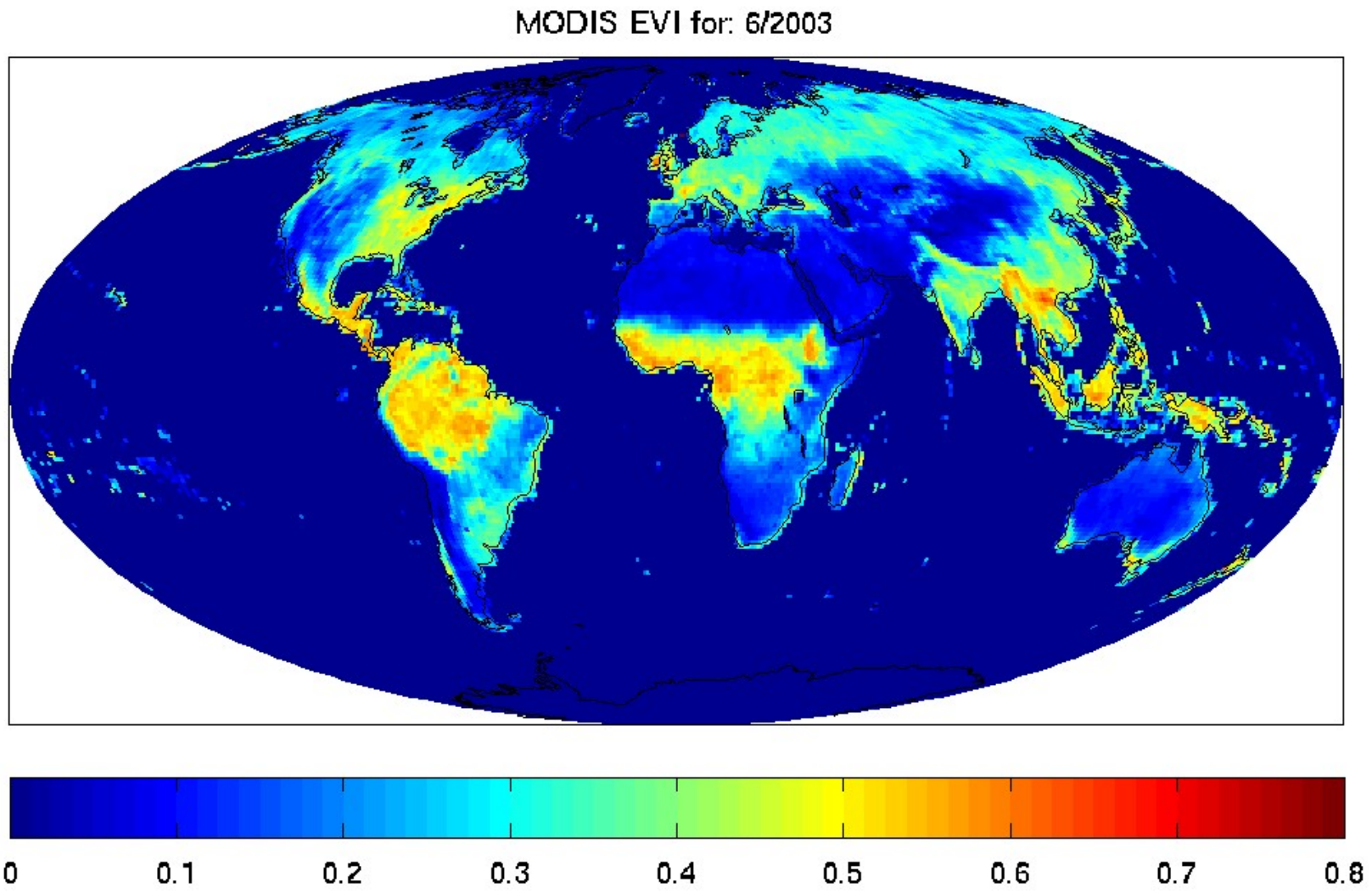
MODIS EVI needed to make GPP



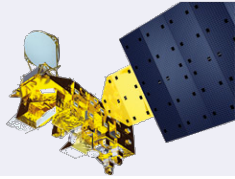
- EVI
  - Simple mean EVI (Enhanced Vegetation Index) was calculated from MOD13C2 sds2 CMG 0.05 Deg Monthly EVI only for cells within valid EVI range. Cells with Fill_Values were not included in the analysis. The dataset is produced with full global coverage. Land/water mask is accepted from the original dataset resolution 0.05 degrees. Grid cells with no land surface are assigned the "_FillValue" – 1.0.
- perc_fill_value = (Fill_Cell_Count * 100) / 400
  - where Fill_Cell_Count is the number of the 0.05 degree cells with the Fill Value within the 1 degree cell, and 400 is the total number of 0.05 degree cells within the aggregated 1 degree cell. The output values are rounded to the nearest integer. Percent Fill Values were calculated for each 1 degree cell. No "_FillValues" are assigned to this layer.
- perc_good_pixels = (Count_GOOD_pixel * 100) / Count_NonFill_Cell
  - where Count_GOOD_pixel is the number of 0.05 degree cells flagged as "GOOD" (value 0) quality within the aggregated 1degree cell, Count_NonFill_Cell is the number of 0.05 degree cells within the valid range of pixel reliability values within the aggregated 1 degree cell. The output values are rounded to the nearest integer. Percent GOOD Quality Data are calculated for each 1 degree cell. No "_FillValues" are assigned to this layer.
  - Percent GOOD Quality Data is calculated from MOD13C2 sds13 CMG 0.05 Deg Monthly pixel reliability only for cells within the valid range of values.

MODIS EVI Gridded 1x1°Monthly

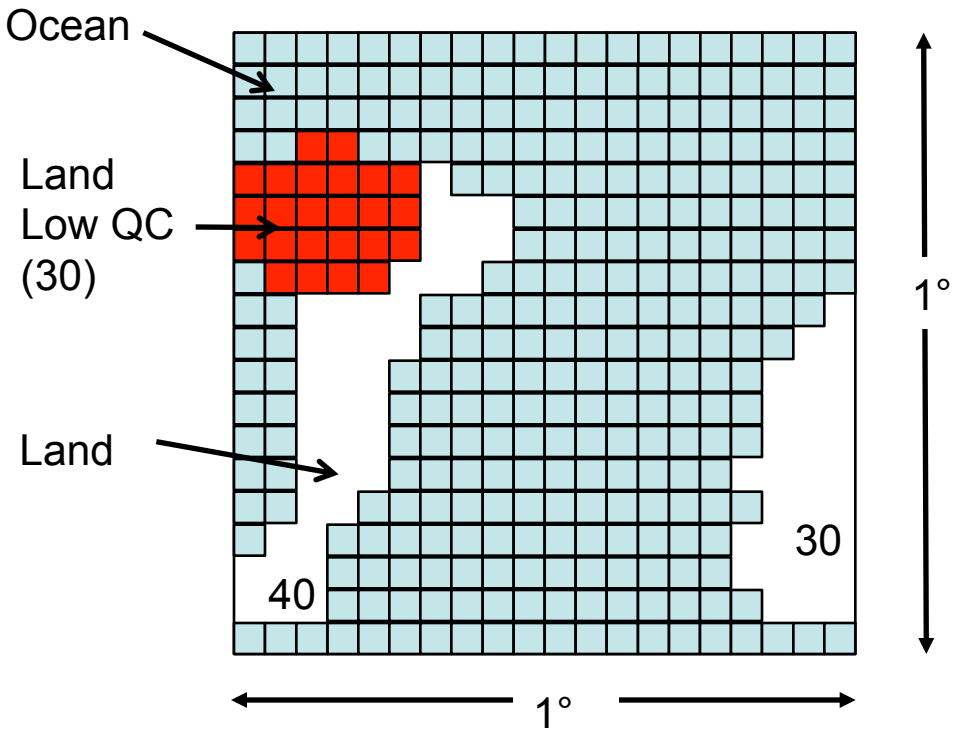




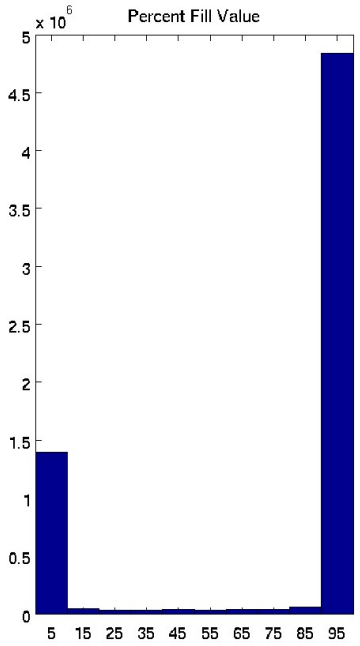
MODIS EVI QC Example

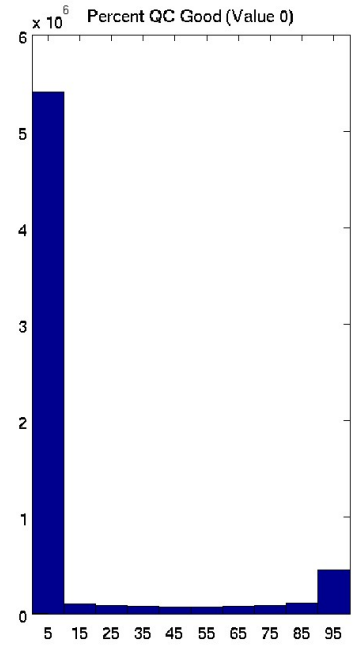


0.05 degree Climate Modeling
Grid global coverage product



Mostly >90% Fill
Mostly >0 QC



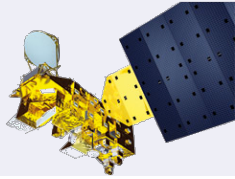


perc_fill_value = 100/400 x 100 = 25%

perc_good_pixels = 70/100 x 100 = 70%

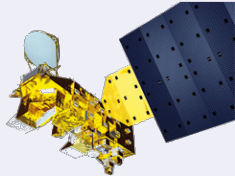
Ignore perc_fill_value
(for now)

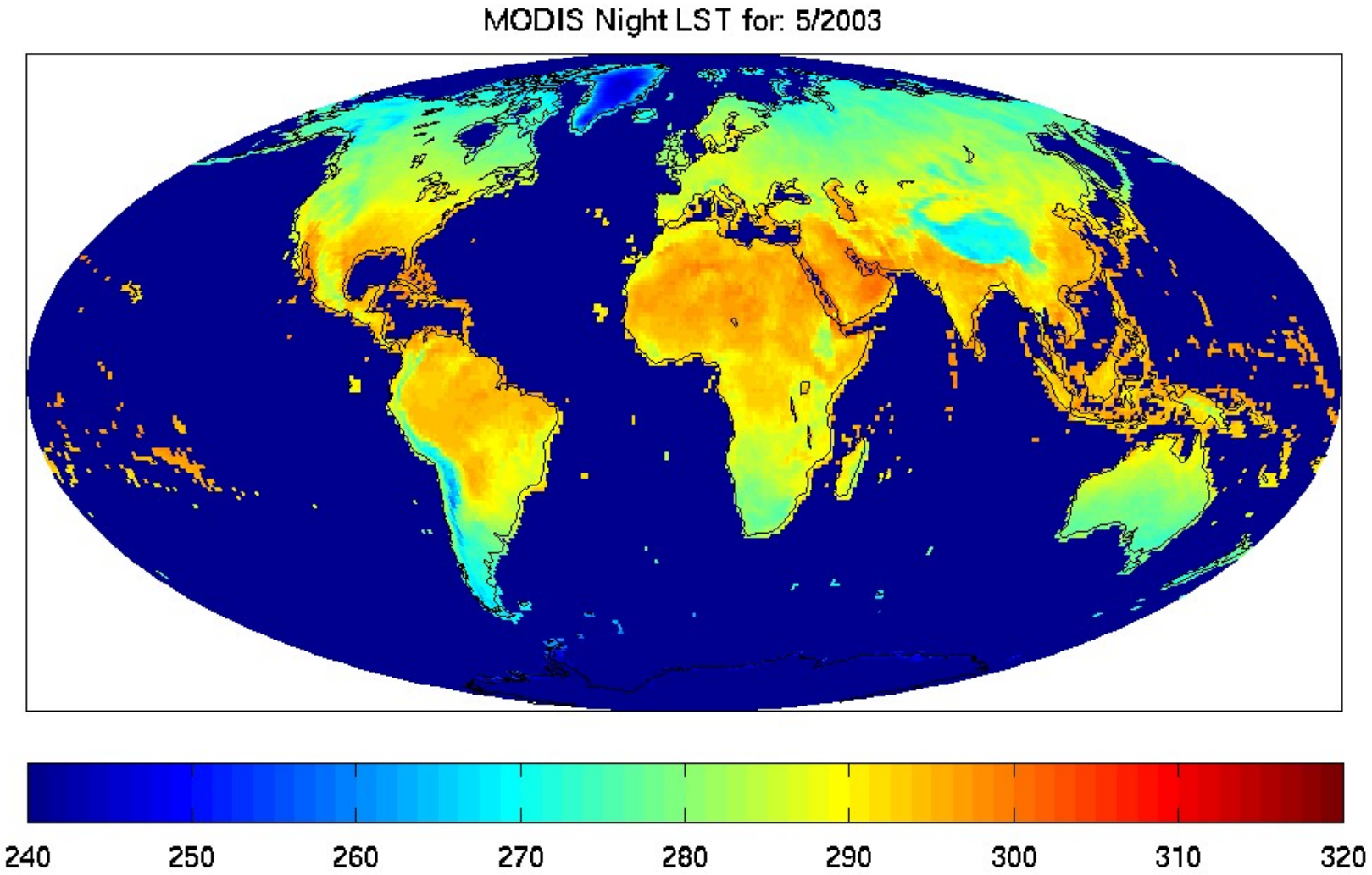
MODIS Night LST needed to make GPP



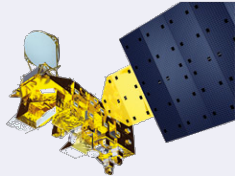
- night_lst
  - The dataset contains global monthly-mean day-time and night-time land surface temperature averaged within 1 by 1 degree grid cells. The source for the data is MODIS MOD11C3 product (MODIS Monthly mean land surface temperature at 0.05 degree spatial resolution). The dataset covers the time period strating January 2000.
  - The MODIS/Aqua V4 LST/E 8-Day L3 Global CMG product (Short name: MYD11C3) is a monthly composited average, derived from the MYD11C1 daily global product, and stored as clear-sky LST values during a month's period in a 0.05º (5600 meters) geographic CMG. MYD11C3, therefore, inherits all the structural features of its MYD11C1 parent except for the temporal configuration. Please refer to the MYD11C1 product documentation for all algorithm-related details.
  - The V4 MYD11C3 product comprises the following Science Data Set (SDS) layers for daytime and nighttime observations: LSTs, quality control assessments, observation times, view zenith angles, clear sky coverages, and emissivities for bands 20, 22, 23, 29, 31, and 32.
  - The V4 Aqua/MODIS LST/E products, including MYD11C3, are validated to Stage-1 with well-defined uncertainties over a range of representative conditions. Further details regarding MODIS land product validation for the LST/E products is available from the following URL: http://landval.gsfc.nasa.gov/ProductStatus.php?ProductID=MYD11

MODIS Night Land Surface Temperature 1x1°

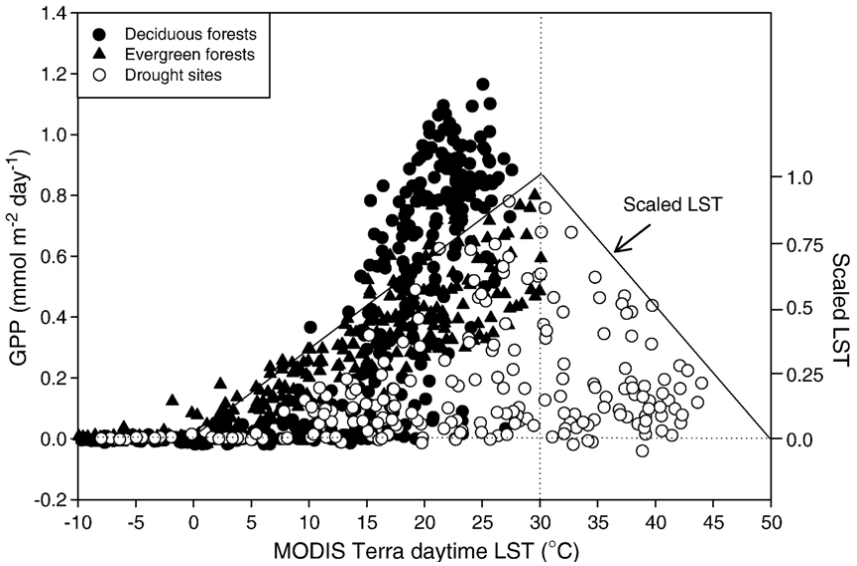


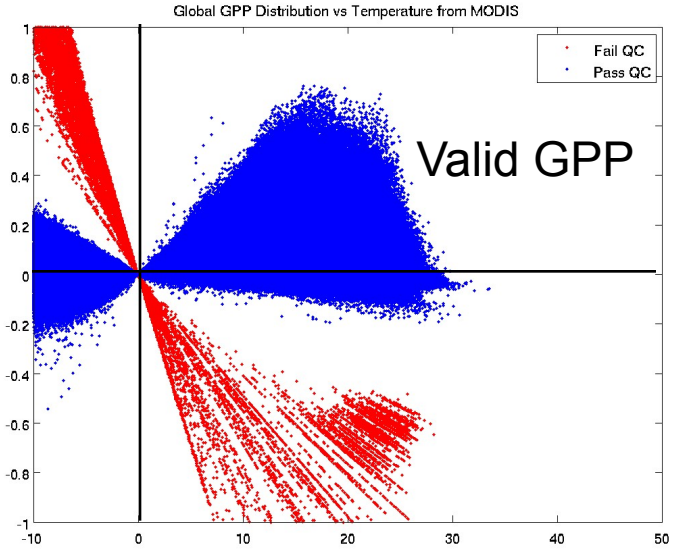


GPP Quality Control



- Start with Monthly 1x1°EVI and LST Climatologies
- Use QC provided





$$QC_1 = QC_{evi} \text{ x } QC_{lst} \text{ x } QC_m$$

$$QC_{GPP} = QC_1 \text{x } (\text{GPP} \geq 0) \text{ x } (\text{LST} \geq 0)$$

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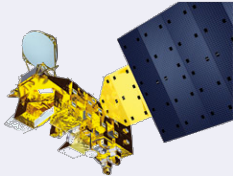
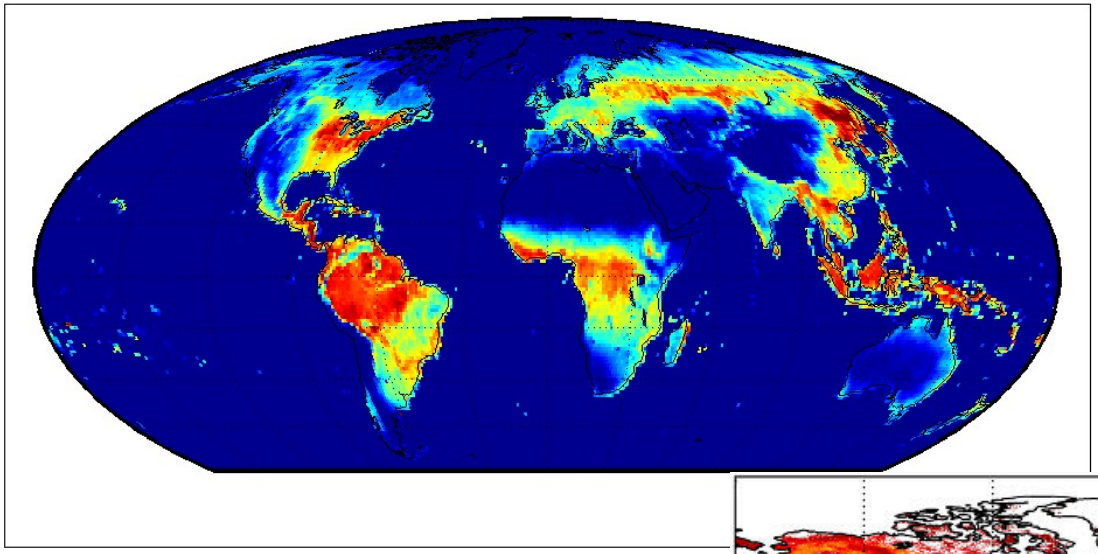
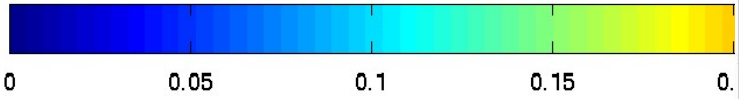
MODIS GPP Climatology Developed using MODIS EVI and LST

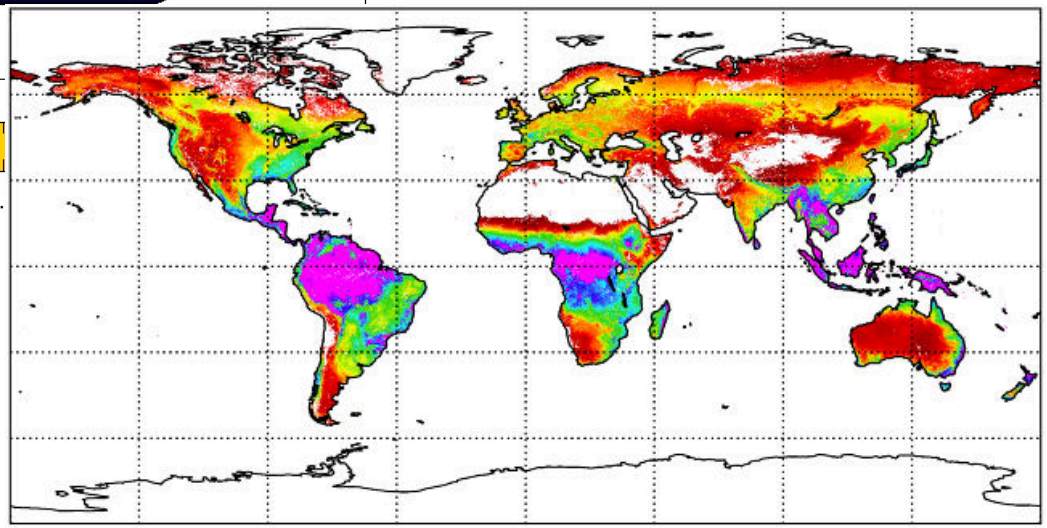


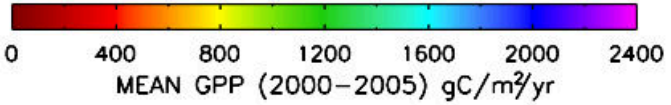
MODIS Level 3 GPP Average over 2002-2011



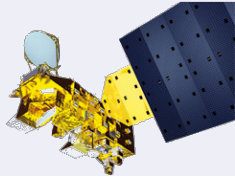


UMT GPP





Correlate AIRS CO2 and MODIS Derived GPP to Qualitatively Assess Influence



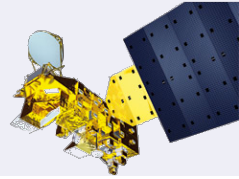
$$CO_2 = \overline{CO_2} + \frac{dCO_2}{dt}t + Ao_c\sin(\omega t + \varphi_c)$$

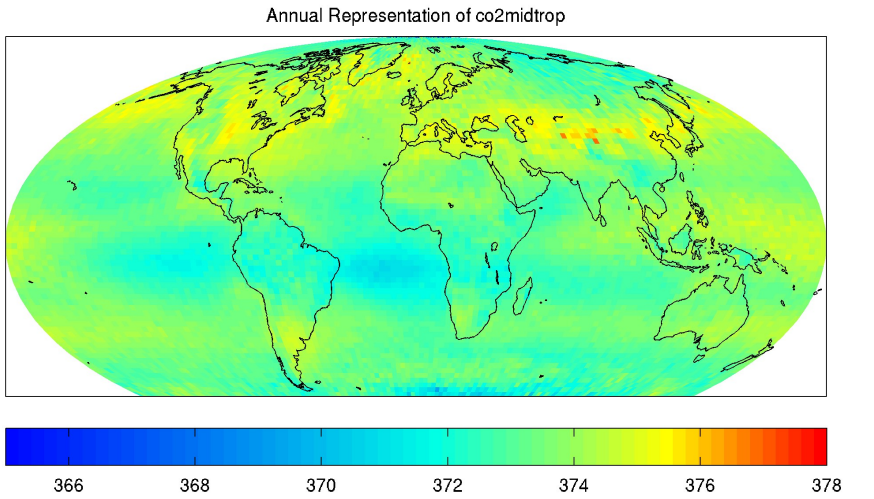
Average Trend Amplitude Phase

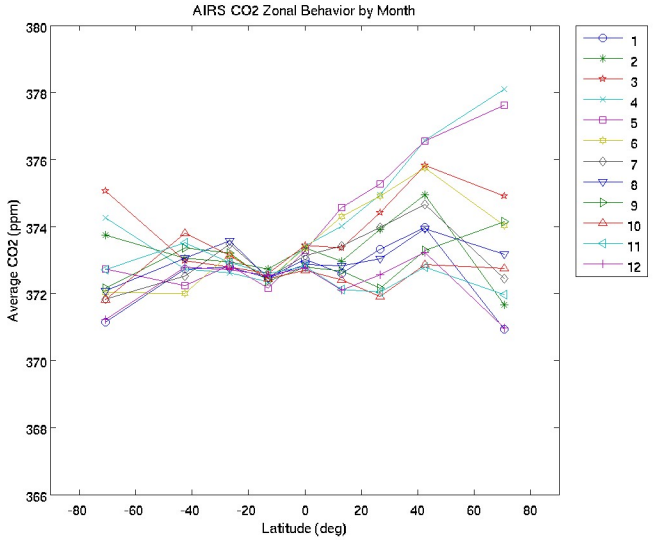
$$GPP = \overline{GPP} + \frac{dGPP}{dt}t + Ao_g\sin(\omega t + \varphi_g)$$

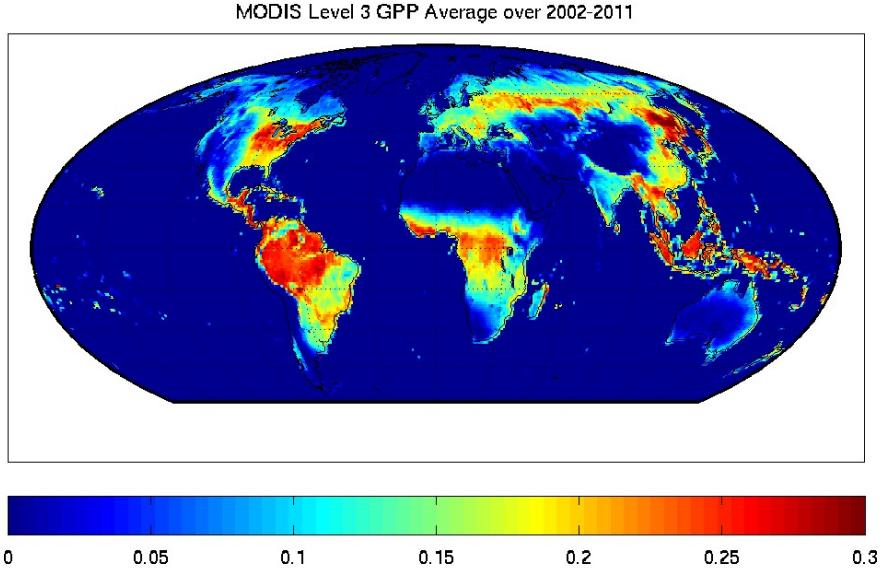
We will compare average global and regional averages, seasonal amplitude and phase
Trend contains high uncertainties that have not yet been quantified (save for later)

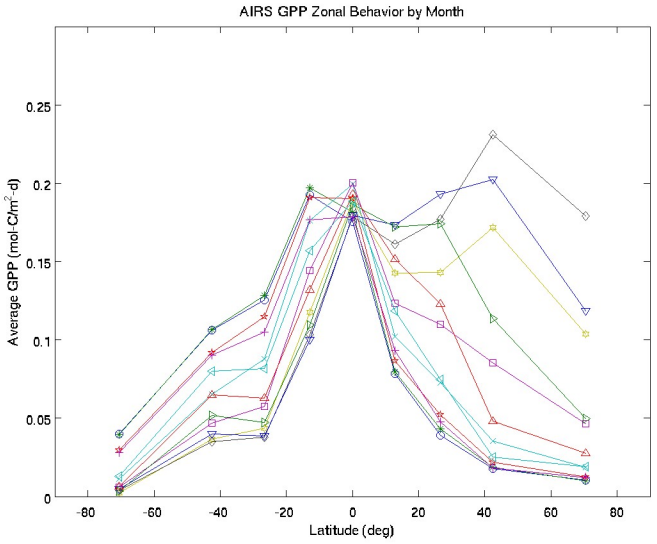
First look at Averages



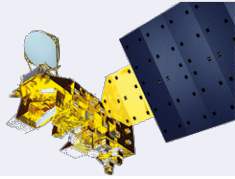






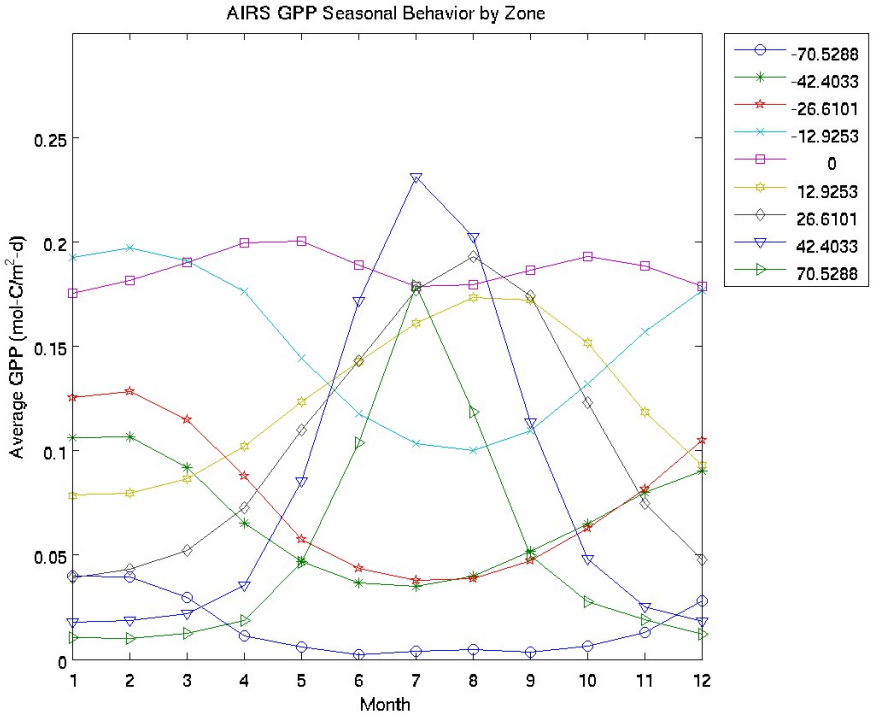


Seasonal Response Shows Key Differences

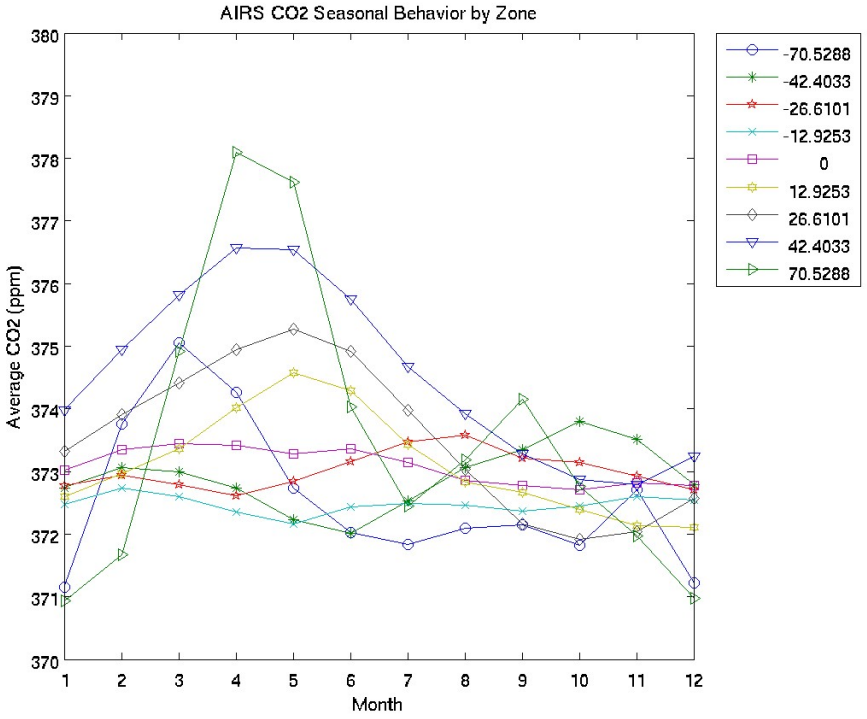


- Based on “Climatology” of 2003-2010
- Peak of GPP Response about 3mo after CO2
- Polar response of CO2 irregular

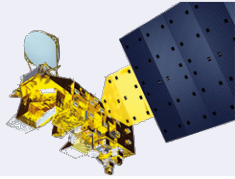
GPP



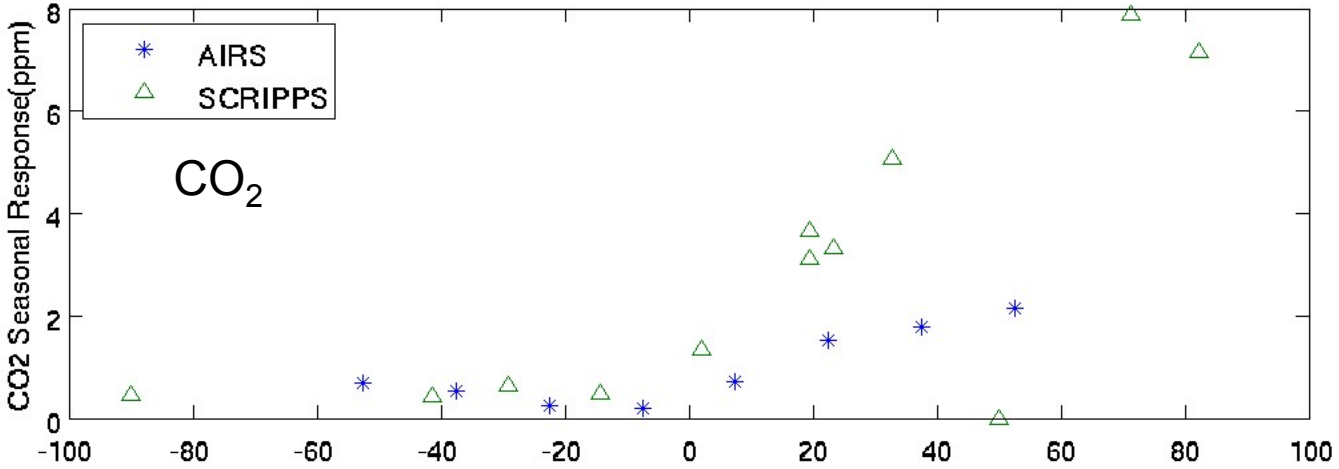
CO2

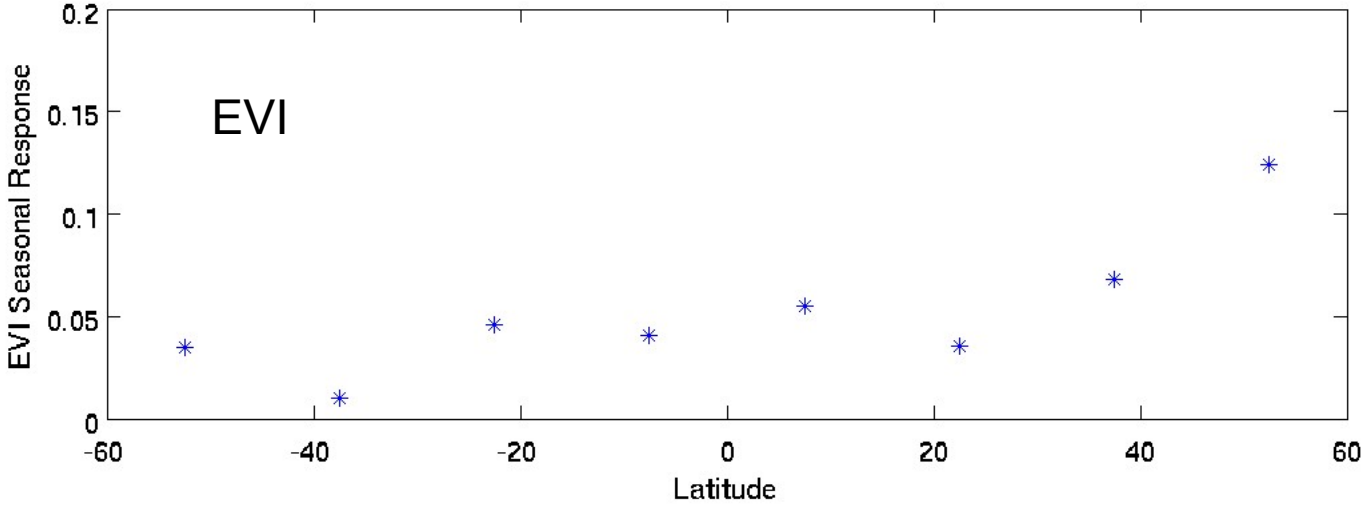


Seasonal Amplitude Grows as we go Poleward in NH

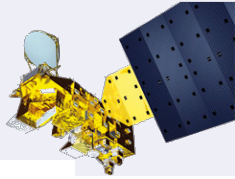


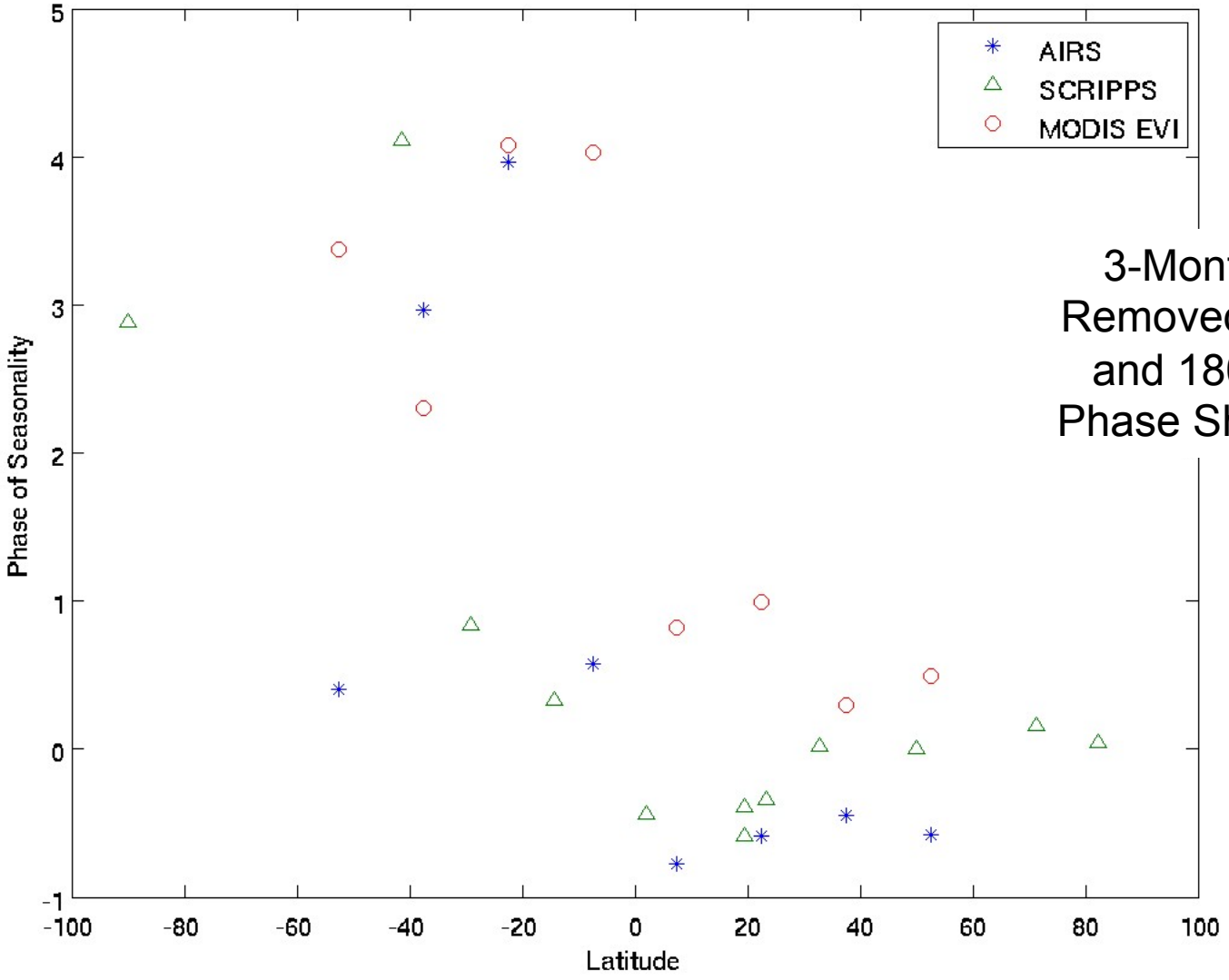
Using Sine Fit





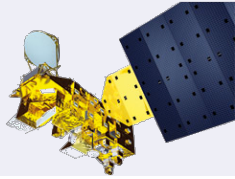
Early Phase Analysis shows Correlation between CO2 and EVI + Zonal Dependence





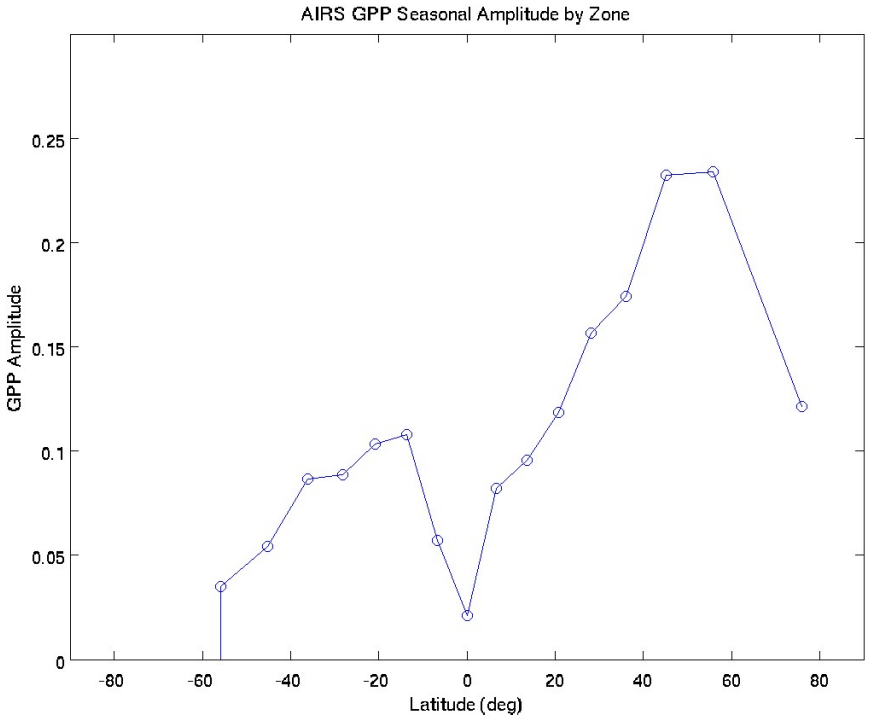
3-Month Delay Removed from EVI and 180 degree Phase Shift applied

Zonal Averages of Seasonal Response for GPP and CO2

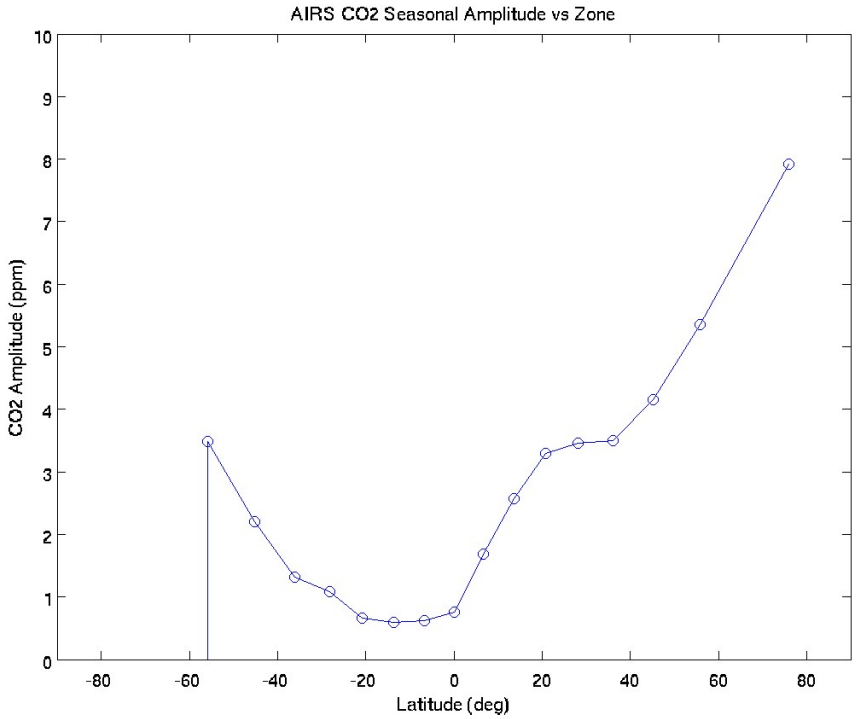


Using Max-Min Fit

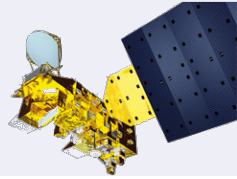
GPP

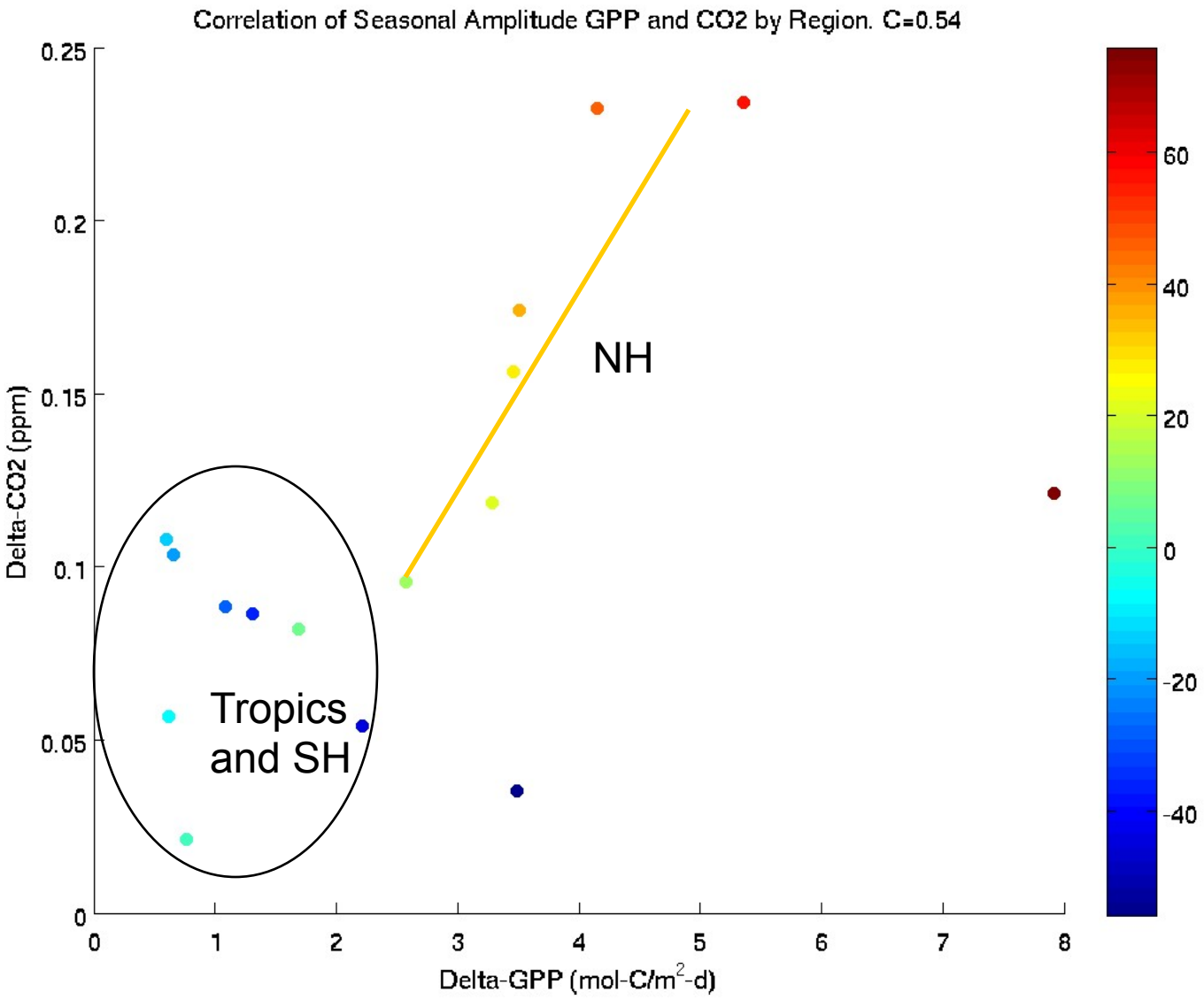


CO2

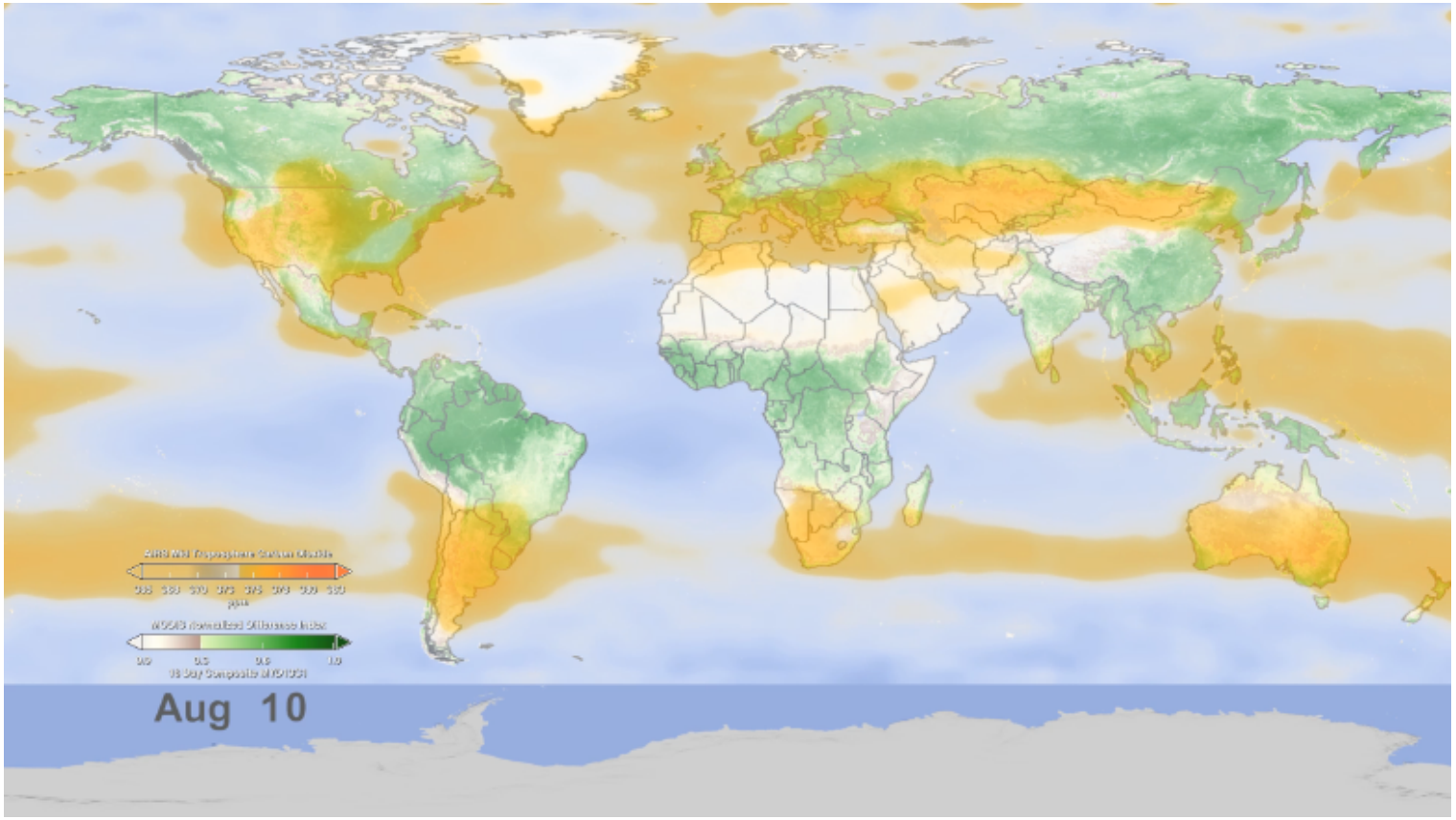


CO2 and GPP Seasonal Amplitudes Correlated by Zone

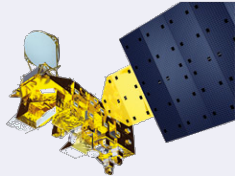




CO2 and EVI Animation (L. Perkins GSFC/SVS)



Summary, Conclusion, and Future Work



- AIRS Mid-Trop CO2 has horizontal and seasonal variability that is not well understood at this time
- AIRS Mid-Trop CO2 Climatology and MODIS GPP Climatology Developed
- Preliminary results show correlation in amplitude of seasonal variability of GPP
  - AIRS CO_2 influenced by seasonal cycle of vegetation
  - Photosynthesis (GPP) influenced by abundance of CO_2
- Future work
  - Extract Principal Component Amplitudes for Improved Correlation Analysis
  - Error Estimates including Spatial Covariance Matrix
  - Add Ocean GPP
  - Examine Regional Correlation
  - Discuss with Carbon Cycle Scientists: IWGGMS 2012