Influence of Global Vegetation on Mid-Tropospheric CO2 Early Results

AIRS Science Team Meeting
April 25, 2012

Thomas S. Pagano, Hai Nguyen, Ed Olsen
California Institute of Technology, Jet Propulsion Laboratory
4800 Oak Grove Drive, Pasadena, CA, USA 91109

tpagano@jpl.nasa.gov, (818) 393-3917, http://airs.jpl.nasa.gov

• 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

• 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
How well known are global flux estimates?

1 Pg = $10^{15} \text{ g} \times (10^{-3} \text{ kg/g}) \times (1 \text{T}/907.2 \text{ kg}) = 1.102 \text{ GT}$
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
AIRS V5 Mid-Tropospheric CO2 Shows Horizontal Variability

AIRS Daily CO₂ Yield
1ºx1º Spatial Resolution

AIRS Monthly CO₂ 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
AIRS Mid-Tropospheric CO$_2$ Representations ("Climatologies")

Average of L3 Monthly Data by Month over 8 years

"Depleted Band of CO2 Not Due to Surface Vegetation"

Gross Primary Productivity using MODIS Temperature and Greenness (TG)

GPP = (scaledEVI × scaledLST) × m

MODIS Night LST

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

scaledEVI = EVI - 0.1

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}_{an} \quad \text{for deciduous sites}

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

Using Average m gives < 18% error

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 1 degree 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.
perc_fill_value = 100/400 x 100 = 25%
perc_good_pixels = 70/100 x 100 = 70%

Ignore perc_fill_value (for now)
• **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 starting 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 0.05° (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](http://landval.gsfc.nasa.gov/ProductStatus.php?ProductID=MYD11)
MODIS Night Land Surface Temperature

MODIS Night LST for: 5/2003
GPP Quality Control

- Start with Monthly $1\times1^\circ$ EVI and LST Climatologies
- Use QC provided

\[ QC_1 = QC_{evi} \times QC_{lst} \times QC_m \]
\[ QC_{GPP} = QC_1 \times (GPP \geq 0) \times (LST \geq 0) \]
MODIS GPP Climatology Developed using MODIS EVI and LST
Correlate AIRS CO2 and MODIS Derived GPP to Qualitatively Assess Influence

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

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

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
Seasonal Amplitude Grows as we go Poleward in NH

Using Sine Fit

**CO₂**

**EVI**
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

[Graphs showing seasonal response for GPP and CO2 by zone]
Correlation of Seasonal Amplitude GPP and CO2 by Region: $r=0.54$

- **NH**
- **Tropics and SH**

Delta-CO2 (ppm) vs. Delta-GPP (mol-C/m²-d)
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