Evaluation of Transport Characteristics of GEOS5 Using Chemistry Transport Simulations of Atmospheric CO2

Nicholas C Parazoo[1], Scott Denning[1], Randy Kawa[2], Steven Pawson[2], Ian Baker[1]

[1]*Dept of Atmospheric Science, Colorado State University,* [2]*NASA Goddard Space Flight Center*

Introduction

To utilize space-borne and ground based atmospheric CO2 measurements measurements properly, the ability of numerical models to accurately simulate carbon cycle processes must be improved. We evaluate a modeling system to analyze carbon cycle processes and interpret CO2 observations, consisting of forward models of terrestrial photosynthesis and respiration, air-sea gas exchange, and atmospheric transport.

Atmospheric transport is simulated using the PCTM (see Acronyms Section) combined with GEOS5 Data Assimilation System, which has replaced GEOS4 as the operational assimilation model at GMAO with new physical parameterizations, enhanced spatial resolution (0.5° lat x 0.67° lon x 42 vertical), and more observations in the analysis. GEOS5 is also used to drive offline carbon flux calculations in the SiB terrestrial land surface model. Careful evaluation is needed to determine whether GEOS5 improves tracer transport simulation. This study evaluates forward simulations of atmospheric CO2 transport by Version 1.0 of GEOS5 in 2004 and 2007 compared to ground-based CO2 observations, including those from MCI, and simulations driven by GEOS4. We focus on synoptic variations, and evaluate the affect of increased resolution and new model physics on atmospheric variations.

Methods (Model and Observations)

PCTM: Chemistry Transport Model driven by weather reanalysis, and surface CO2 fluxes from the land (SiB3), air-sea exchange, and fossil fuel sources (see below). Kawa et al., 2004; Parazoo et al., 2008

GEOS4: 1.25° lat x 1.0° lon x 25 vert, 6-hourly, discontinued GMAO reanalysis product

GEOS5.1.0: 2003-2008, 0.5° lat x 0.67° lon x 42 vert, 6-hourly, GMAO EOS-Aura analysis

GEOS5.2.0: Oct 2008-present, 0.5° lat x 0.67° lon x 42 vert, 6-hourly, GMAO Operational

SiB: Terrestrial land surface photosynthesis-conductance model driven by offline reanalysis satellite vegetation indices (LAI/fPAR) from MODIS (hourly), soil maps, C3/C4 maps, crop map

Takahashi: Monthly air-sea exchange based on pCO2 measurements (Takahashi et al, 2002)

Fossil Fuel: Constant in time (Andres et al, 1998)

Observations:
Well-calibrated continuous surface tower measurements (North America and Europe)
Globalview-CO2 Aircraft Flask measurements (North America)
MCI Ring 2 Tower measurements (Upper Mississippi Valley)

Note: Only well-calibrated CO2 mixing ratio is used for analysis of PCTM experiments

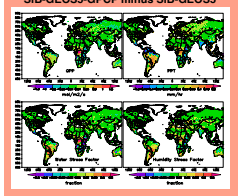
Land Surface Experiments (SiB)

4 simulations show sensitivity of SiB GPP to weather:
1) SiB driven by GEOS4 (***SiB-GEOS4***)
2) SiB driven by GEOS4, precipitation weighted by monthly mean GPCP (***SiB-GEOS4-GPCP***)
3) SiB driven by GEOS5 (***SiB-GEOS5***)
4) SiB driven by GEOS5, precipitation weighted by monthly mean GPCP (***SiB-GEOS5-GPCP***)

2004 GPP (Gt/yr)	GEOS4 (gpcp wtd)[mm/d]	GEOS4	GEOS5 (gpcp weighted)	GEOS5
Global	111.31	110.93	121.88	120.62
North America	13.76	13.88	15.32	15.41
Eurasia	17.91	17.71	19.92	19.80
Africa	26.12	27.02	28.36	27.91
South America	31.21	30.43	33.64	32.93

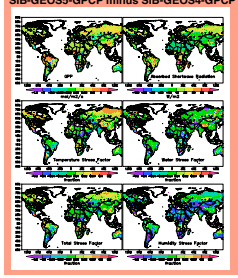
1) Total annual global GPP estimated from GEOS4 is consistent with 2000-2003 estimates from the GEOS4 driven MODIS algorithm (Zhao et al., 2005).
*2) **Total annual global GPP** is most sensitive to transition from GEOS4 to GEOS5. Precipitation (PPT) more important for regional distribution…*

SiB-GEOS5-GPCP minus SiB-GEOS5



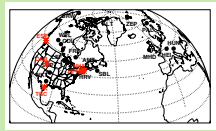
Difference in Annual Mean, SiB-GEOS5-GPCP minus SiB-GEOS5: *GPP directly linked to PPT. As increase PPT via GPCP, Water Stress Factor increases (less soil moisture stress), Humidity Stress Factor (less vapor pressure deficit), GPP increases. Largest impact is in tropics, east of the Rockies, and Europe*

SiB-GEOS5-GPCP minus SiB-GEOS4-GPCP



Difference in Annual Mean, SiB-GEOS5-GPCP minus SiB-GEOS4-GPCP: *Nearly global increase in GPP due to change in SiB driver from GEO4 to GEOS5. Each region, from tropics to midlatitudes, is effected in different ways by temperature, soil moisture, canopy humidity, and absorbed shortwave radiation*

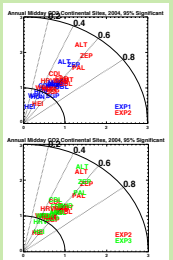
PCTM - 2004 (sensitivity)



Continuous (black) and flask (red) CO2 observations in North America and Europe. We assess the affect of synoptic weather patterns (air mass movement) and surface flux on day-to-day variability and time-mean vertical CO2 gradients due to with the following transport experiments:

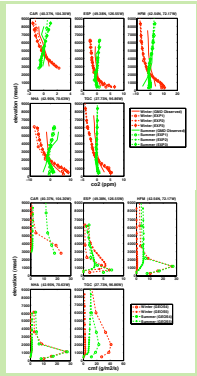
EXP1: *SiB driven by GEOS4, PCTM driven by GEOS4*
EXP2: *SiB driven by GEOS4, PCTM driven by GEOS5*
EXP3: *SiB driven by GEOS5, PCTM driven by GEOS5*

Vertical profiles assessed on the right, and synoptic variability below



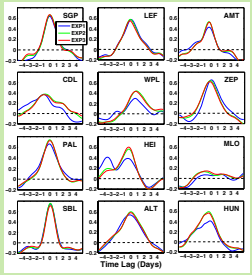
*Top Panel: Taylor plots of **EXP1** and **EXP2** vs continuous observations. GEOS5 yields better correlations to observations, yet more variability*

*Bottom Panel: Taylor plots of **EXP2** and **EXP3** vs continuous observations. Variability is less sensitive to surface flux.*



Vertical Profiles of CO2: *Not a large difference in vertical CO2 profile in Summer or Winter. Very weak sensitivity to surface flux. Most noticeable is tendency for weaker gradient in the winter in **EXP1** due to use of GEOS4 weather.*

Vertical Profiles of Moist Convective Mass Flux: *Tendency for less vertical mixing in GEOS5 in Summer and Winter, especially near the surface*



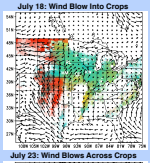
Lag Correlations of Midday CO2: *Strongest correlation occurs near zero lag suggesting good phase match in synoptic variability between model and observations. The correlation is generally stronger when GEOS5 weather (**EXP2** and **EXP3**) is used for transport.*

PCTM - 2007 (crops)

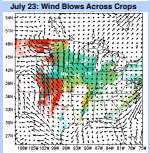
Crop Map: *Blue = Corn*
Green = Soybean
Red = Wheat

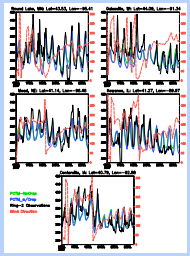
MCI Experiment: *Five towers (Ring-2) located across the Midwest. This region is strongly influenced by crops We add crops to PCTM and evaluate the difference..*

July 18: Wind Blow Into Crops

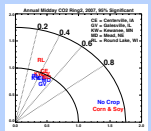


July 23: Wind Blows Across Crops





Taylor Plot of Midday Values: *Crops do not affect the correlation of midday values, but do enhance the amount of variability*



Frontal Passage Case Study: *PCTM is run with SiB with (Blue) and without (Red) a crop module that includes corn and soybean in North America. As the wind blows over the crops, we see a noticeable improvement in simulations with crops*

Conclusions

- **SiB experiments show sensitivity of Global GPP to Reanalysis Products**
- **Correlations of synoptic variability improve with GEOS5 weather**
- **Vertical CO2 profiles are only slightly sensitive to the change from GEOS4 to GEOS5**
- **The MCI field campaign helps to show that transport simulations are sensitive to crops**

Acknowledgements

This research is driven strongly by well calibrated CO2 observations. We thank Margaret Torn, Sebastien Biraud, and Marc Fischer at LBNL for SGP, William Munger and Steve Wofsy at Harvard University for HRV, Arlyn Andrews at NOAA GMD for LEF, WKT, and AMT, Douglas Worthy at MSC for CDL, FRS, ALT, and SBL, Larry Flanagan at UL for WPL, Philippe Ciais and Leonard Rivier for the work in the Carboscope Database, Johan Strom at SU for ZEP, Tuula Aalto at FMI for PAL, Ingeborg Levin at UHEI-IUP for HEI, Michel Ramonet at CEA-LSCE for MHD, Laszlo Haszpra and Zoltan Barcza for HUN, and WMO WDCGG and NOAA/ESRL-GMD for making CO2 data publicly available, and the people at Penn State University for MCI data. This research is supported by the National Aeronautics and Space Administration Contracts #NNX08AC75G, #NNG05GD15G, #NNX05GF41G, #NNX08AN66G, and #NNG06GB41G.

References

Andres, R.J., Marland, G., Fung, I., and Matthews, E.: A 1 degree x 1 degree distribution of carbon dioxide emissions from fossil fuel consumption and cement manufacture, 1950-1990, Global Biogeochem. Cy., 10, 419-429, 1996.

Kawa, S. R., D. J. Erickson III, S. Pawson, and Z. Zhu, CO2 transport simulations using meteorological data from the NASA data assimilation system, *J. Geophys. Res.*, 109, D18312, doi:10.1029/2004JD004554, 2004.

Parazoo, N. C., A. S. Denning, S. R. Kawa, K. D. Corbin, R. S. Lokupitiya, and I. T. Baker, Mechanisms for synoptic variations of atmospheric CO2 in North America, South America and Europe, *Atmos. Chem. Phys.*, 8(23), 7239-7254, 2008.

Takahashi, T., R. A. Feely, R. F. Weiss, R. H. Wanninkhof, D. W. Chipman, S. C. Sutherland, and T. T. Takahashi, Global air-sea flux of CO2: An estimate based on measurements of sea-air pCO2 and seasonal biological and temperature effects, Deep-Sea Research Part II, 49, 1601-1622, 2002.

Zhao, M., F. A. Heinsch, R. R. Nemani, S. W. Running, Improvements of the MODIS terrestrial gross and net primary production global data set, *Remote Sens. Environ.*, 95, 164-176, 2005.

Acronyms

PCTM : Parameterized Chemistry Transport Model - Chemistry Transport Model
SiB: Simple Biosphere Model - Terrestrial Land Surface Model
GPCP: Global Precipitation Climatology Project - Precipitation Reanalysis
GPP: Gross Primary Production
GEOS: Goddard Earth Observing System Weather Analysis Products
GMAO: Goddard Modeling and Assimilation Office
MCI: Mid Continent Intensive - Field Campaign in North America in Upper Miss. Valley