Seasonal and Interannual Variability of Terrestrial Ecosystem Net Carbon Exchange: Comparison of Earth System Models Simulations from CMIP5

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1. Introduction

Developing a realistic representation of global carbon cycle, including climate-carbon and concentration-carbon feedbacks, is a key objective of many earth system modeling groups contributing CMIP5 simulations for the IPCC 5th Assessment. On seasonal and interannual time scales, terrestrial net ecosystem exchange is an important driver of variability in atmospheric CO_2, and as a result, contemporary observations from flask, aircraft, and in-situ remote sensing have the potential to constrain various aspects of the terrestrial carbon cycle within these models.

2. Model and Methodology

In this study, we analyzed net biospheric production (NBP) from 12 atmosphere-ocean-land coupled models participating in CMIP5 (**Table 1**). NBP fluxes from the ESMs during 1979-2005 were run as a tracer through the GEOS-Chem 3D chemical transport model (*Bey et al.*, 2001). GEOS-Chem was forced with MERRA reanalysis meteorology and we also included separate tracers for fossil fuel emissions (*Andres et al.*, 2011), ocean carbon exchange (*Takahashi et al.*, 2009), and ship (*Corbett and Koehler*, 2003) and aircraft (*Wilkersen et al.*, 2010) emissions.

We evaluated two aspects of model performance, seasonality and interannual variability. We used NOAA GMD (*Conway et al.*, 1988) and AmeriFlux (*Gower et al.*, 1999) surface observations to evaluate model performance (see **Figure 1** for sites locations).

Table 1 Description of 12 CMIP5 historical model simulations used for this study.

Model	Institute	No. of Ensembles
Bcc-csm1-1	Beijing Climate Center, China	3
CanESM2	Canadian Centre for Climate Modelling and Analysis	5
CCSM4	National Center for Atmospheric Research, USA	1
GFDL-ESM2M	GFDL, NOAA, USA	1
HadGEM2-CC	Met Office Hadley Center, UK	1
HadGEM2-ES	Met Office Hadley Center, UK	2
INMCM4	Institute for Numerical Mathematics, Russia	1
IPSL-CM5A-LR	Institut Pierre Simon Laplace, Paris, France	2
IPSL-CM5A-MR	Institut Pierre Simon Laplace, Paris, France	1
MIROC-ESM	Japan Agency for Marine-Earth Science and Technology	1
MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology	1
NorESM1-M	Norwegian Climate Centre	3

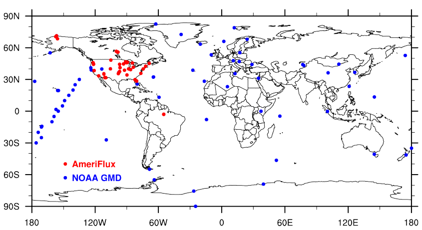

Figure 1 The distribution map for 83 NOAA GMD sites (blue solid circles) and 59 AmeriFlux sites (red solid circles) used for this study.

3. Results

We estimated the seasonal cycle and interannual variability of atmospheric CO_2 from model simulations and show these results in separate sections.

Part One: Seasonal Dynamics

In comparison with NOAA GMD CO_2 observations, the multi-model mean amplitude of the annual cycle of CO_2 was slightly larger than the observation in the northern hemisphere, with individual models varying by a factor of three (**Figure 2**). Most models had an early phase bias. Comparisons of seasonal cycles of net ecosystem exchange (NEE), gross primary production (GPP), ecosystem respiration (Reco) and surface air temperature (T_{air}) with AmeriFlux observations provide insight about the causes of this bias (**Figures 3 and 4**).

Simulated Global CO_2 vs. NOAA

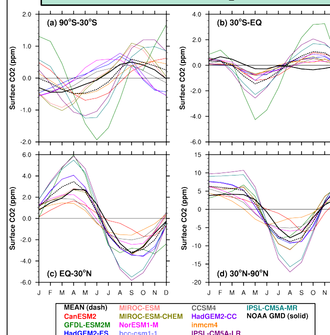

Figure 2 Mean annual cycles of GEOS-Chem simulated CO_2 sampled at NOAA GMD sites during 1979-2005.

CMIP5 vs. AmeriFlux in 40-60N

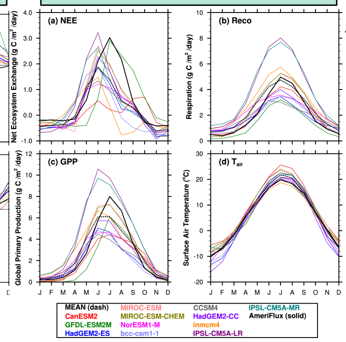

Figure 3 Mean annual cycles of CMIP5 model simulations sampled at AmeriFlux sites in the 40°-60°N latitude belt during periods over overlap with.

CMIP5 vs. AmeriFlux in 20-40N

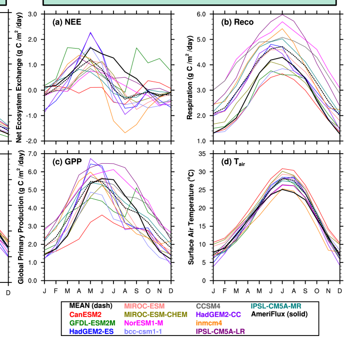

Figure 4 The same as Figure 3, but for Ameriflux stations in the 20°-40°N latitude belt.

Part Two: Interannual Variability

The magnitude of interannual variability in NBP varied by over a factor of 5 among models (**Figure 5**). Some of this variability appeared to be linked with the strength of precipitation anomalies on land, and in turn, forcing of precipitation by ocean sea surface temperatures (**Figure 6**).

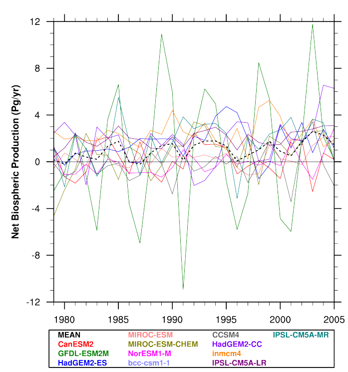

Figure 5 Yearly total global net biospheric production (Pg C/yr) from 12 CMIP5 models.

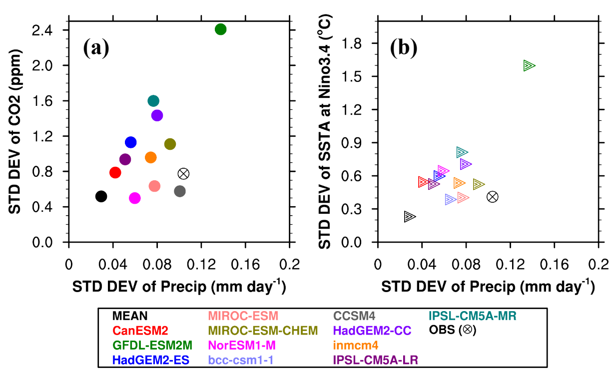

Figure 6 Scatter maps for standard deviations of global area-weighted land mean precipitation with those of CO_2 (a) and SSTA at Nino3..4 (b).

4. Conclusions

- ➢ The seasonal cycles of atmospheric CO_2 from most CMIP5 models agreed reasonably well with NOAA GMD observations (**Figure 2**). A phase bias was evident for most models, especially in the northern hemisphere, in which CO_2 drawdown occurred earlier than in the observations.
- ➢ Ameriflux observations confirmed that the onset of carbon uptake by the biosphere in the NH occurred at earlier times in the models than in the observations (**Figures 3 and 4**).
- ➢ Component fluxes from Ameriflux indicated the source of the phase bias was attributable to gross primary production and *not* ecosystem respiration.
- ➢ Some of the model-to-model differences in the magnitude of interannual variability of atmospheric CO_2 appeared to be driven by the strength of precipitation anomalies and ENSO (**Figure 6**).

Acknowledgements

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