Satellite based evaluation of terrestrial carbon models

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I. Objective

Use satellite observations of CO_2 to evaluate the Simple Biosphere (SiB) and Carnegie-Ames Stanford Approach (CASA) carbon model in poorly constrained regions.

II. Why is this important?

Approximately 25% of anthropogenic CO_2 emissions are removed from the atmosphere and stored in a terrestrial carbon sink. This land sink and its mechanisms are not well understood. Improved models, backed by greater data coverage, are crucial to better understanding the carbon cycle on regional scales. This may shed light on the mechanisms of the terrestrial carbon sink and aid future mitigation and sequestration efforts.

III. Introduction & Background

i. Carbon cycle

- Gross Primary Production (GPP)
  - CO_2 uptake via photosynthesis
  - GPP ≈ 120 GtC/yr
- Respiration (R_T)
  - CO_2 emitted by plant and animal respiration
  - R_T ≈ 117 GtC/yr
- Net Ecosystem Exchange (NEE)
  - NEE = R_T – GPP ≈ -3 GtC/yr (1990-2011)
  - Implies net land sink! This sink may take up ≈¼ anthropogenic emissions

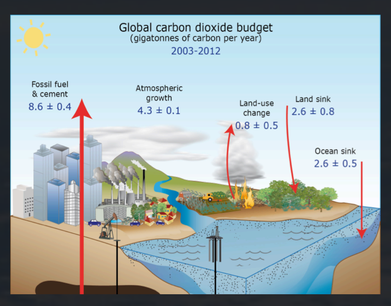


Fig. 1 Carbon Cycle (taken from GCP)

Fig. 2: Net Ecosystem Exchange plots

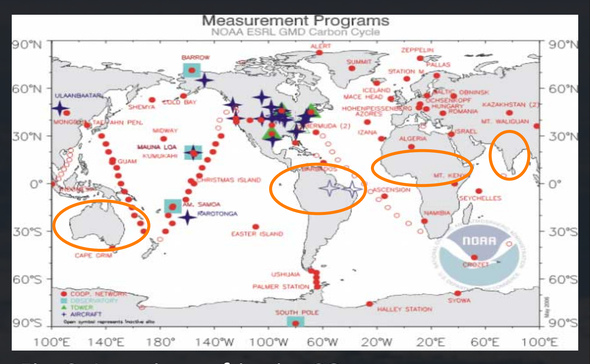


Fig. 3: Locations of *in situ* CO_2 measurements

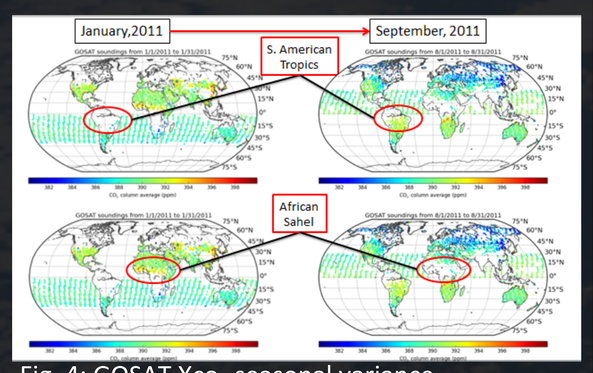


Fig. 4: GOSAT Xco_2 seasonal variance

ii. Terrestrial Carbon Models

- Vegetation models that estimate global CO_2 sources and sinks.
- Forced balance of GPP and Respiration
- SiB-3: Single vegetation type per grid cell
- CASA is similar to SiB-3
- SiB-4: Several vegetation types per grid cell

iii. Satellite observations

- Greenhouse Gas Observing satellite (GOSAT).
- One of the first made to measure CO_2 sources and sinks regionally.
- Uses Fourier Transform Spectrometer (FTS) observations of reflected sunlight to measure Xco_2 (atmospheric column averages of CO_2)

iv. Data Constraints

- *In situ* data does not constrain much of the globe (Fig. 3)
- Satellite data often varies temporally and spatially (Fig. 4)
- GOSAT cannot penetrate clouds

IV. Methods

From fluxes to Xco_2

(1) Atmospheric transport model

Figure retrieved from NOAA

(2) Add additional sources and sinks

Figure retrieved from EPA

(3) Resampled to match GOSAT soundings

(4) Isolated the regions of interest

Isolating Regions of interest

Region 1: African Sahel

Region 2: South American Tropics

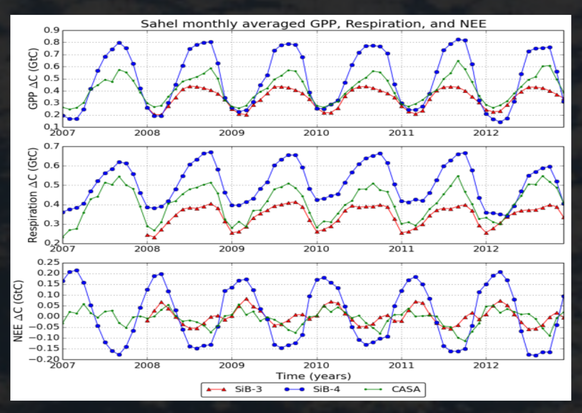
Why these regions?

- The least constrained by in situ data
- Not well understood and historically do not agree in models

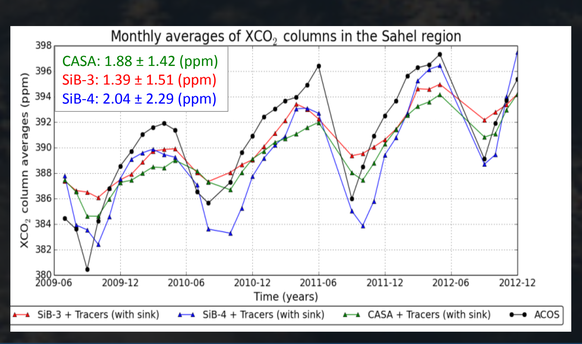
V. Results

i. African Sahel

- Sahel is a larger producer in SiB-4
- The driver of SiB-4's seasonal cycle is unclear
- CASA and SiB-3 have a much smaller seasonal cycle than SiB-4

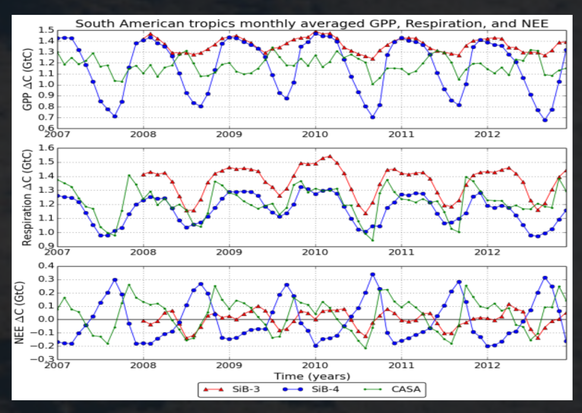


- Despite a slight negative offset, SiB-4 has a seasonal cycle amplitude much closer to GOSAT than SiB-3 and CASA.

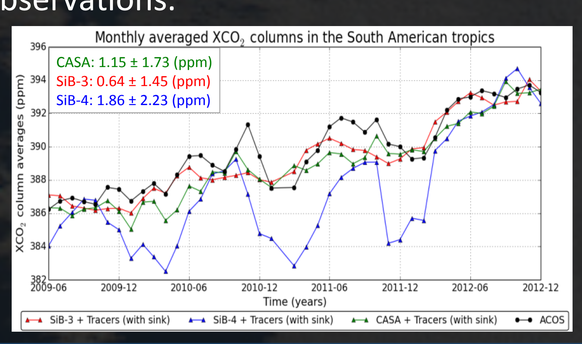


ii. South American Tropics

- SiB-3 shows nearly constant and high CO_2 uptake in all seasons
- SiB-4 has dramatically reduced uptake in dry season



- SiB-4 largely underestimates Xco_2, especially in the wet season.
- SiB-4 large seasonal cycle is not supported in observations.



VI. Conclusions

- SiB-3 and CASA underestimate seasonal cycles in tropical regions that have seasonal precipitation.
- SiB-4 most likely overestimates the seasonal cycle in the Amazon, though due to observational limitations it is unclear if this applies to the whole region or a smaller sub-region.
  - Future work to analyze sub-regions
- Satellite data is useful in analyzing carbon models, especially in regions with poor *in situ* coverage.

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