Evaluating the impact of AIRS mid-troposphere CO2 on the tropical surface CO2 flux estimation

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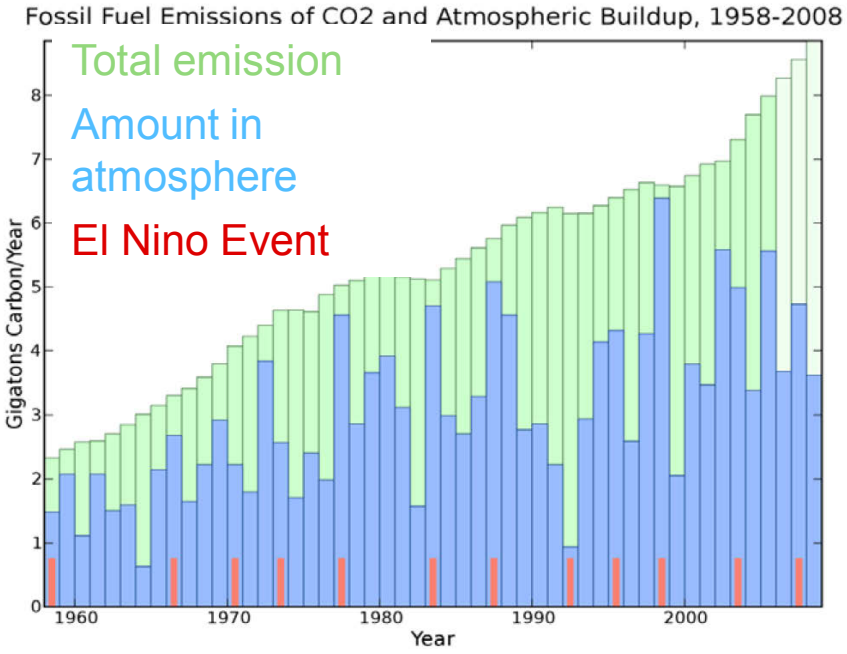
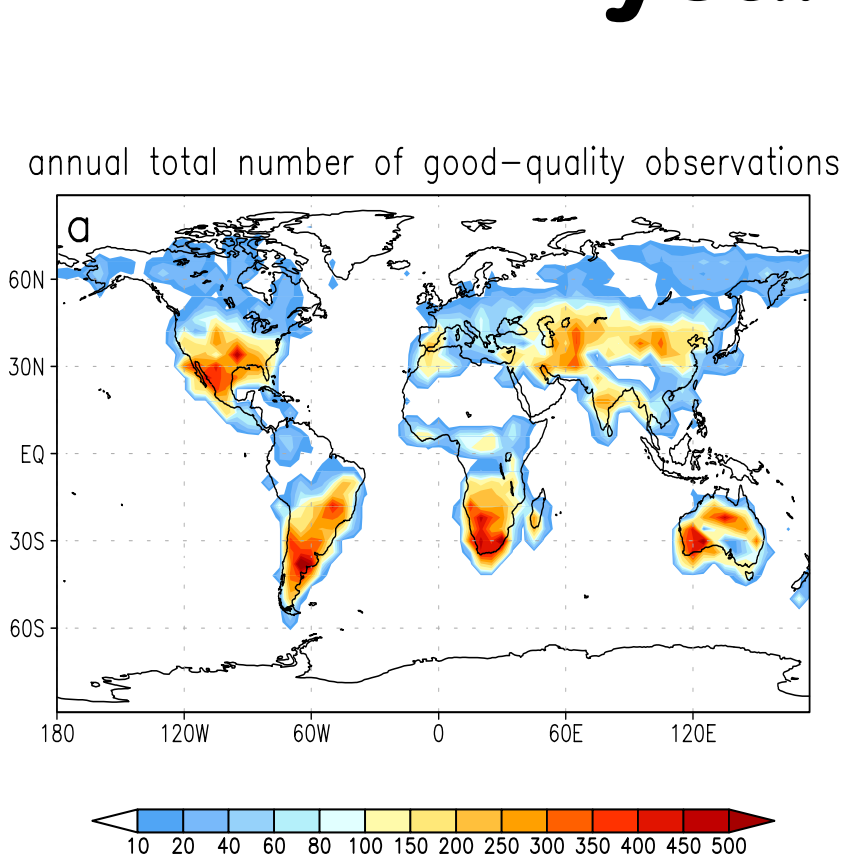
Motivation and Objectives

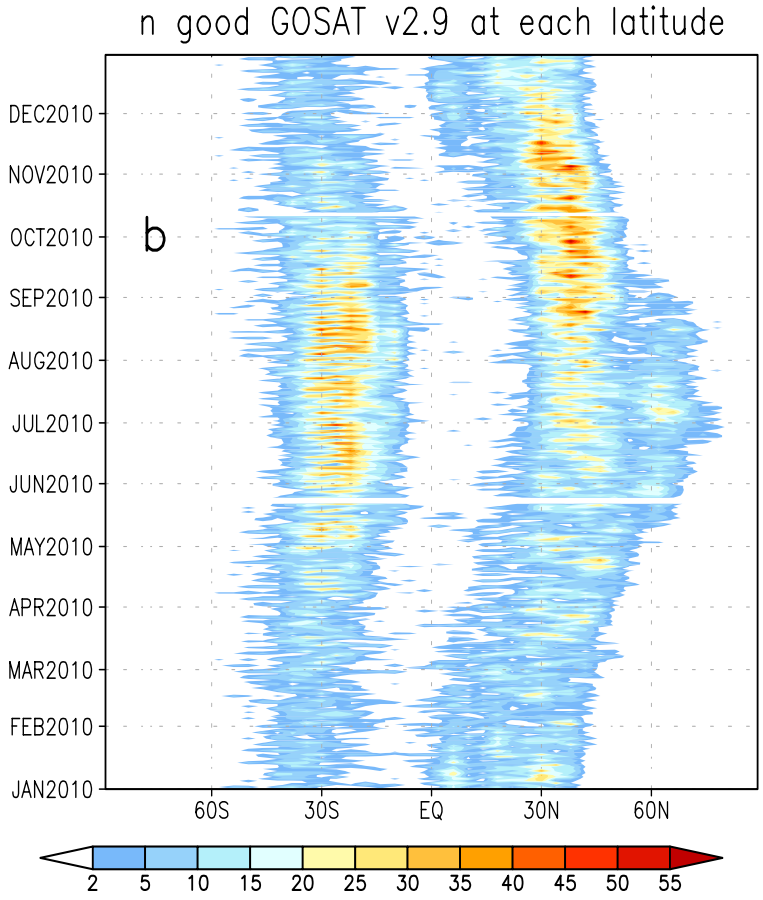
Only about half of the fossil fuel emissions remains in the atmosphere. Where the other half goes?

- **Could mid-troposphere CO2 help constrain the surface flux forcing in addition to the column CO2 (Xco2) from Greenhouse gases Observing SATellite (GOSAT)?**
  - **What is the sensitivity of AIRS mid-troposphere CO2 to surface flux forcing?**
  - **What is the impact of AIRS CO2 on surface flux estimation with OSSEs?**



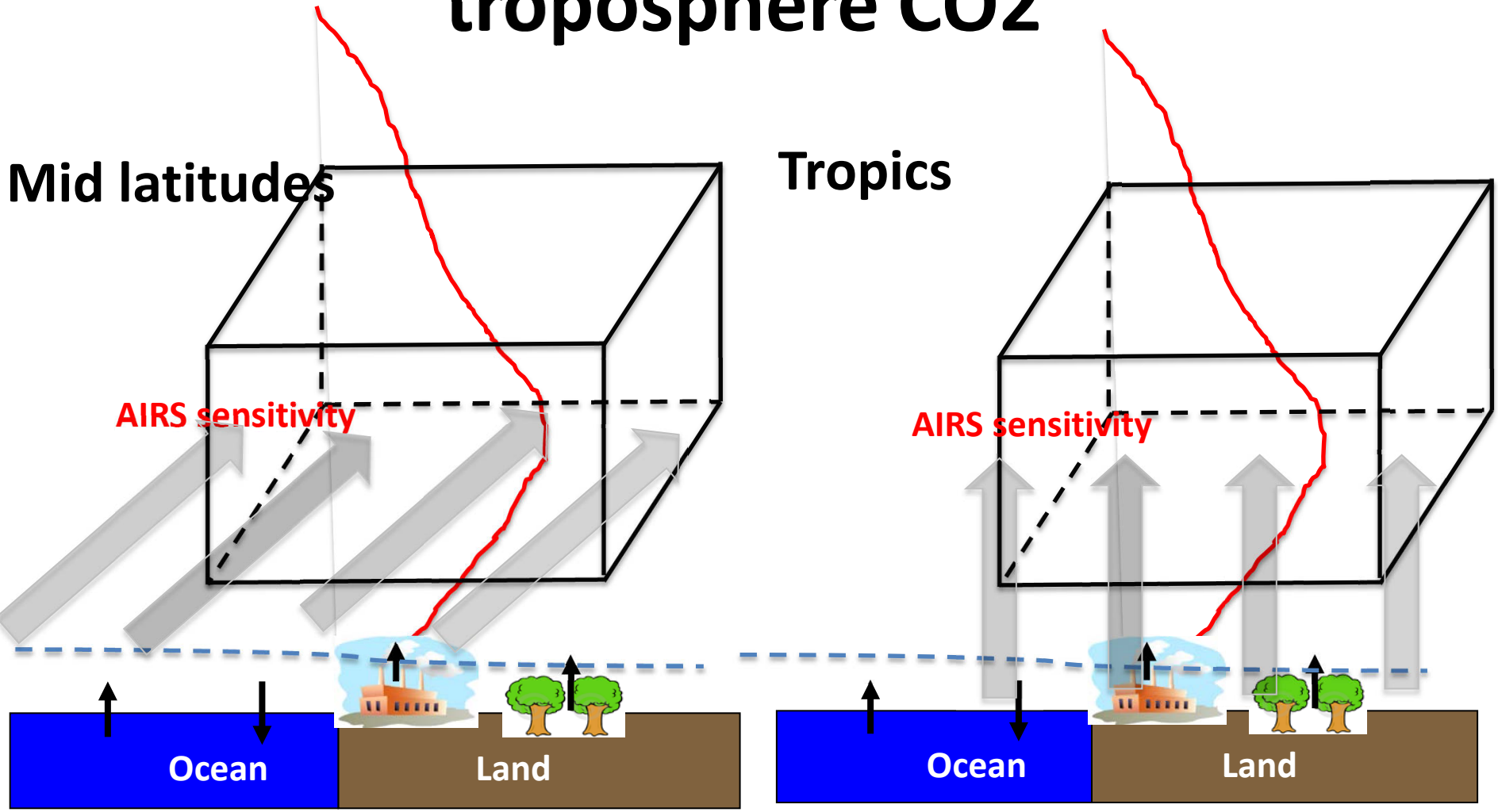
GOSAT observation coverage for year 2010





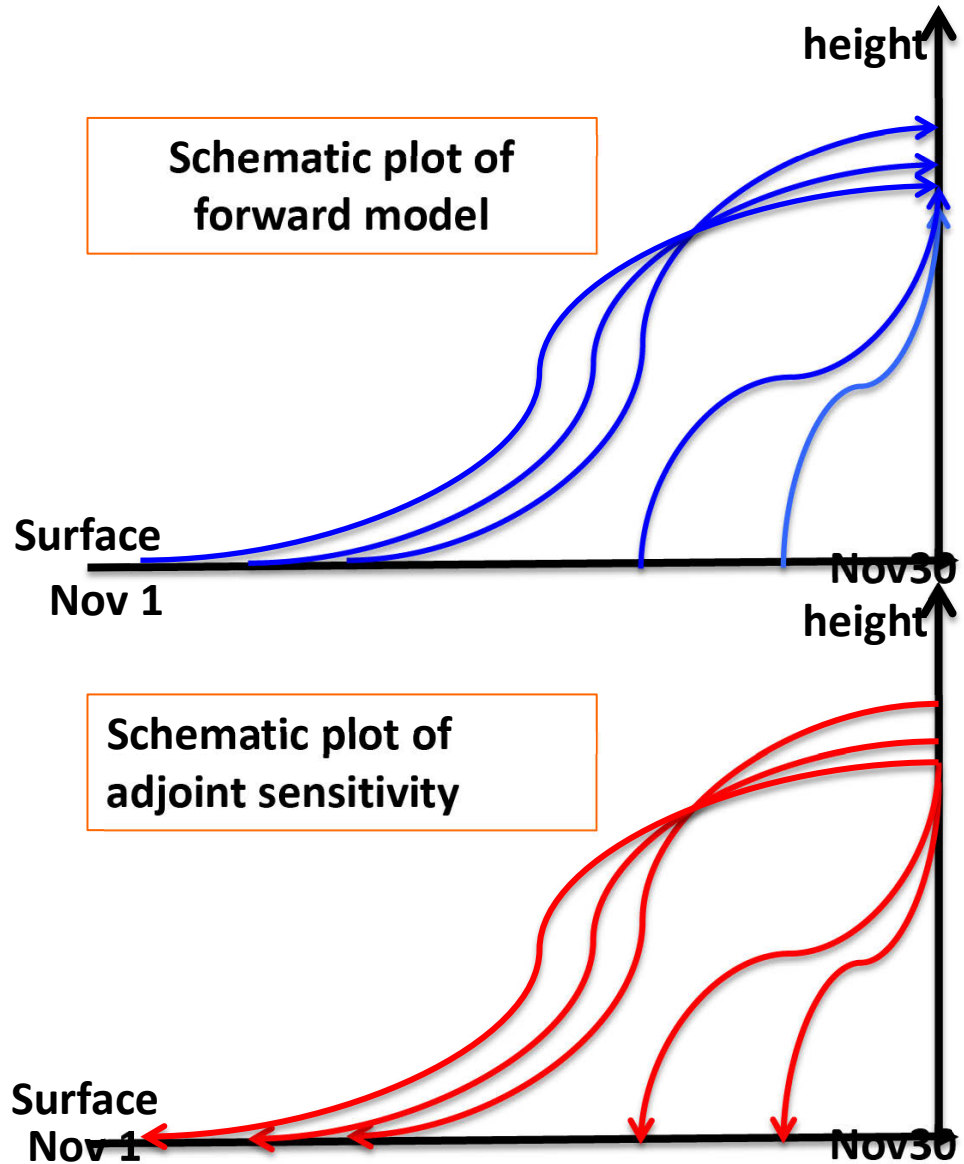
- GOSAT has sparse observation coverage over the tropics and high latitudes.
- Could AIRS CO2 over the tropics improve the tropics surface flux forcing?

Processes controlling mid-troposphere CO2



- Different dynamical processes control the variability of mid troposphere CO2 over mid latitudes and the tropics; Connection between mid troposphere CO2 over the tropics is more direct than the observations over mid latitudes;

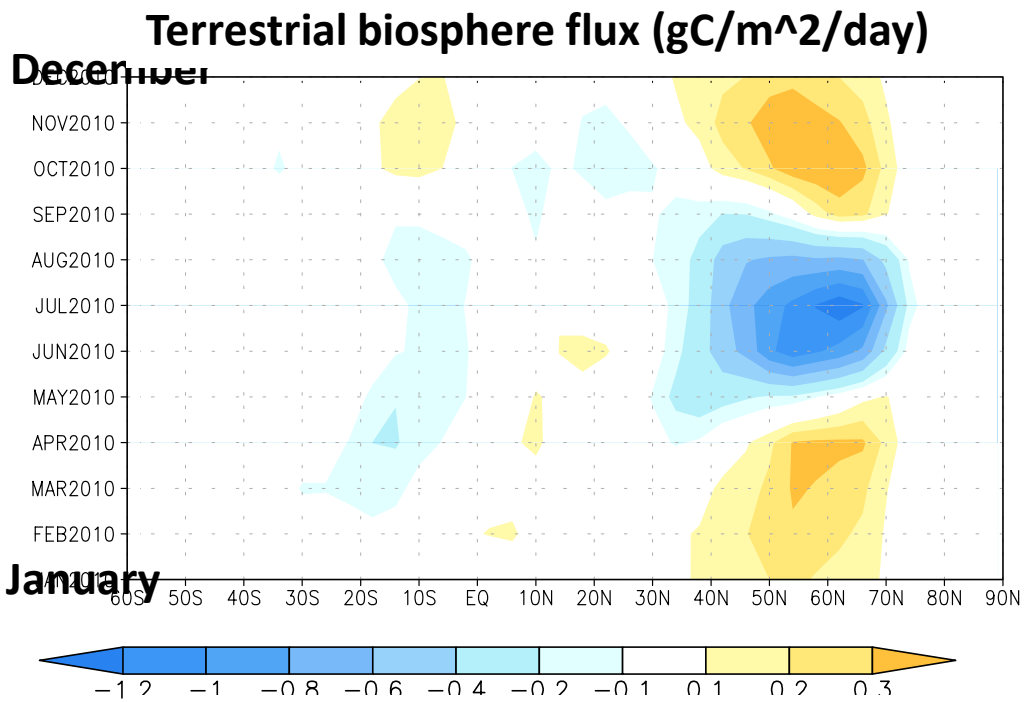
Calculation of the sensitivity of mid troposphere CO2 to surface flux forcing with GEOS-Chem adjoint model

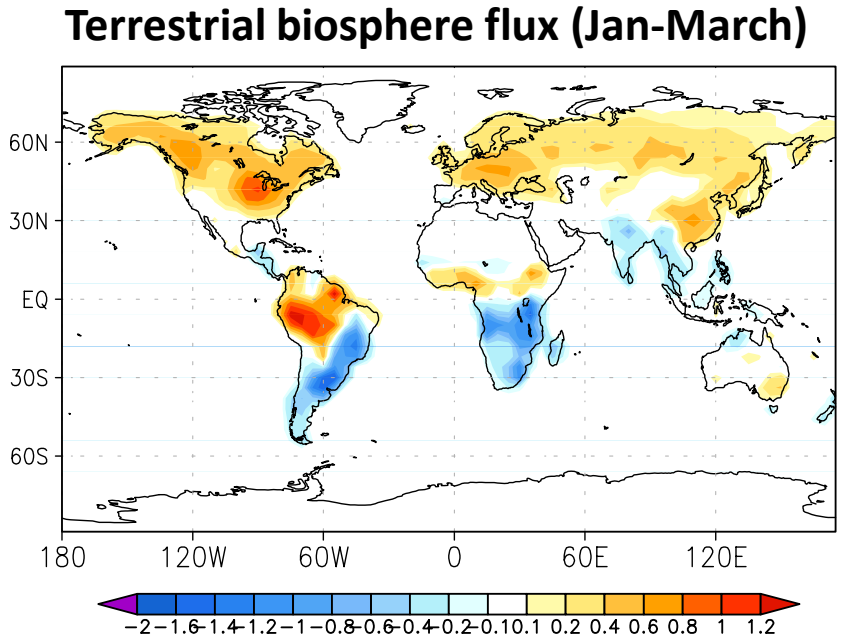


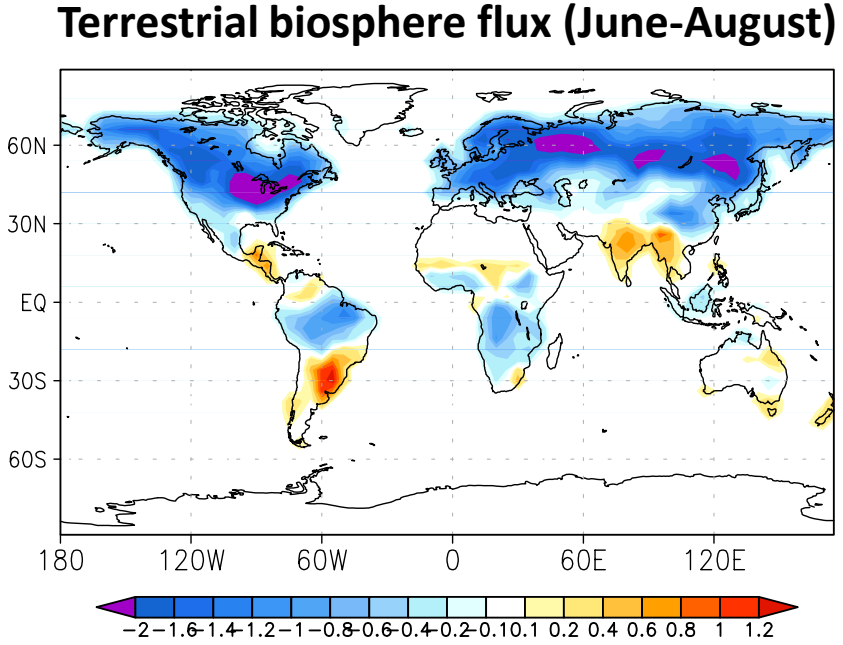
- Adjoint model: integrates model backward.
- Adjoint sensitivity: the sensitivity of a response function to model input parameters (e.g., surface forcing, initial conditions);
- Response function J: normalized AIRS CO2 concentration over a region over a particular time interval;
- $E\partial J/\partial E$: change of CO2 concentration in PPM due to surface forcing E.

Surface CO2 flux

- Strong seasonality in NH terrestrial biosphere CO2 flux





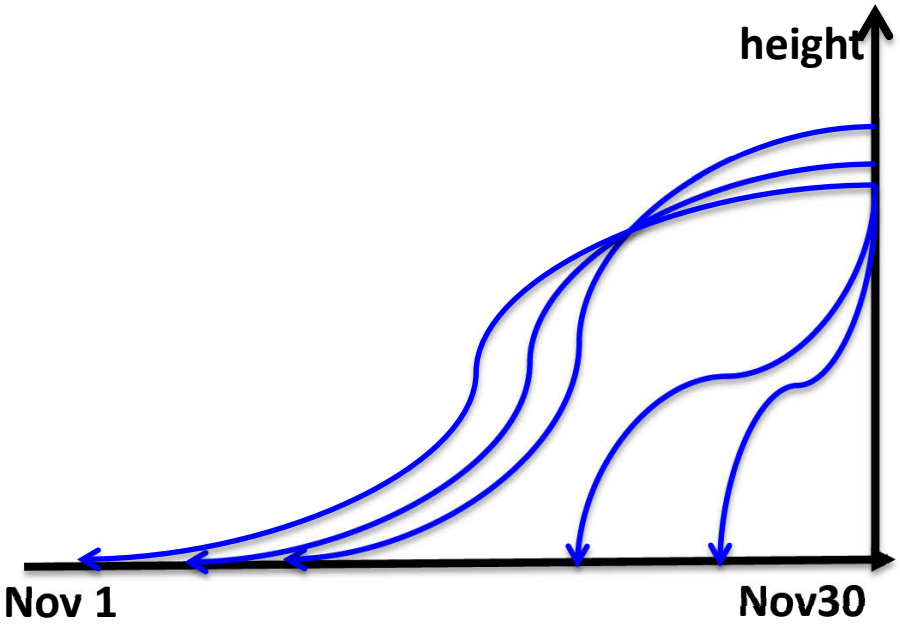


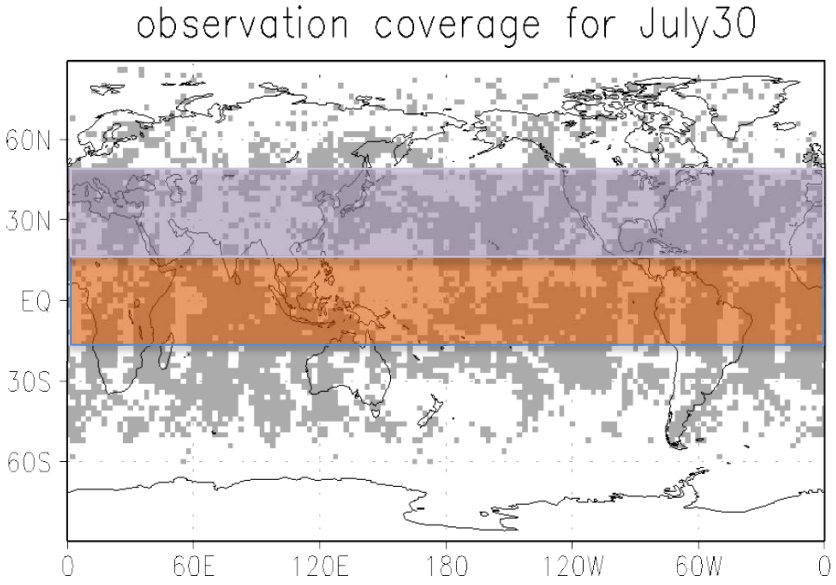
Adjoint sensitivity cases

Regions: tropics (orange); 25N-45N (light purple);

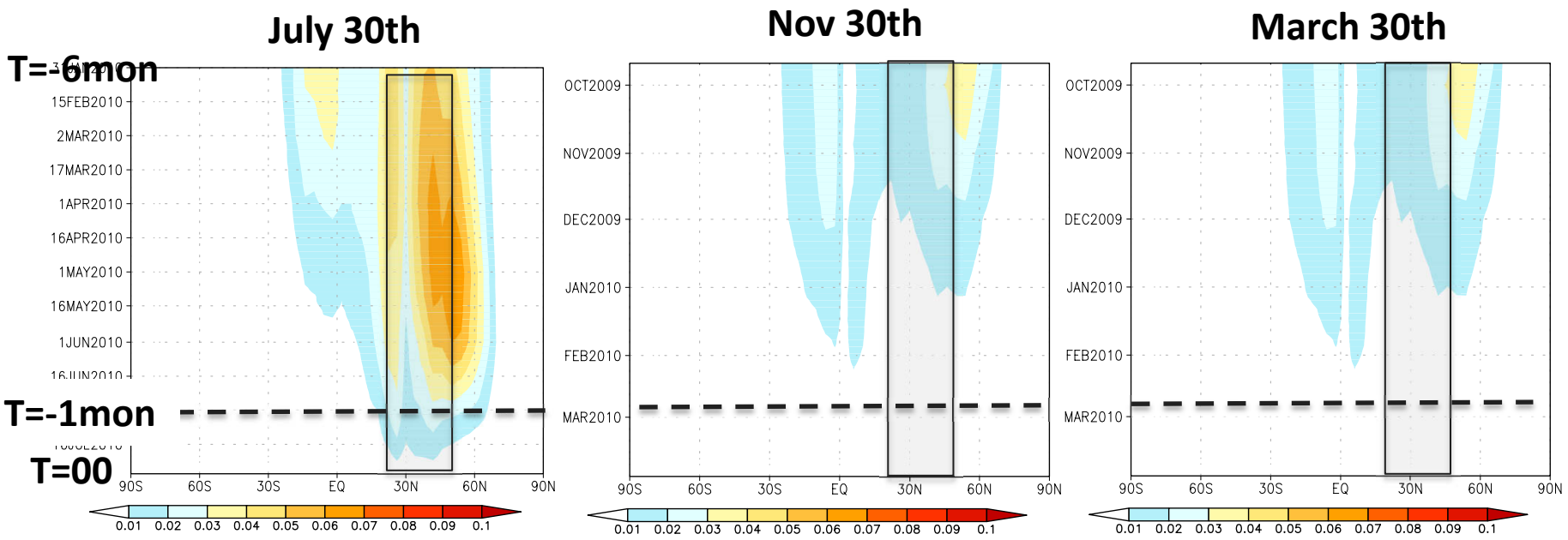
Date: July30, Nov30, March30

Schematic plot of adjoint sensitivity case



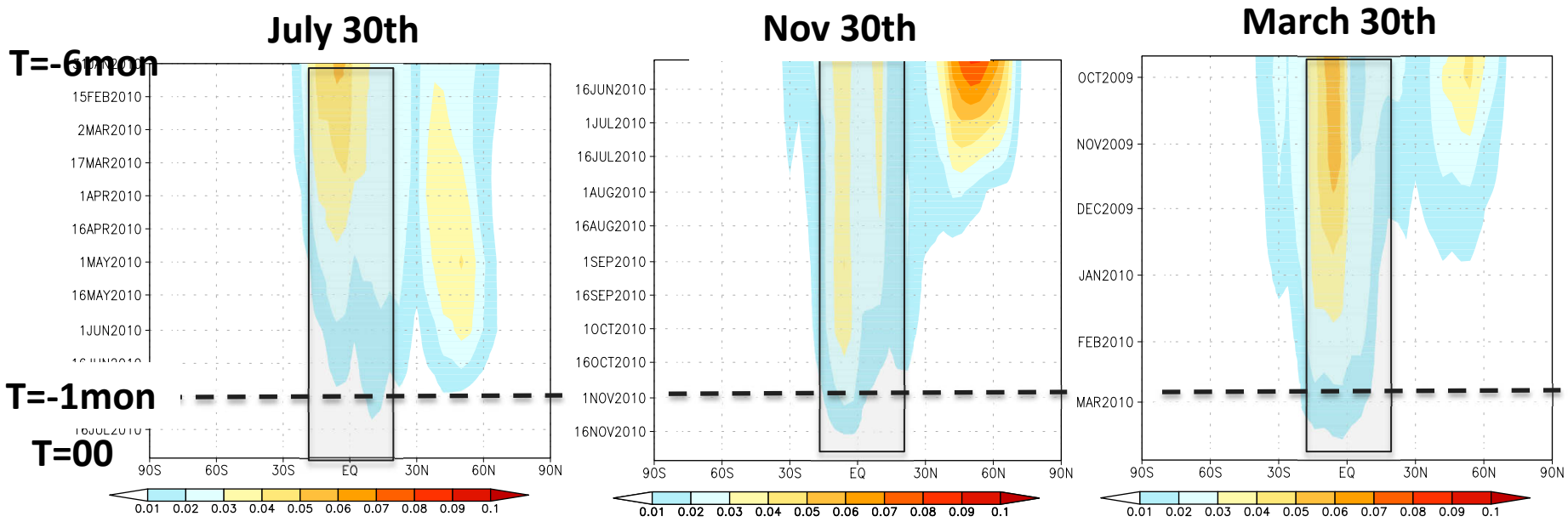


Sensitivity of AIRS CO2 over 25°N-45°N to biosphere flux forcing



- The sensitivity of AIRS CO2 to surface flux forcing is strongest during summer when GOSAT has dense observation coverage;
- Smaller sensitivity during winter and spring is due to both the weaker vertical mixing and the weaker surface flux forcing;
- Smaller sensitivity during winter and spring when when GOSAT has sparse observation coverage;

Sensitivity of AIRS CO2 over tropics to surface flux forcing

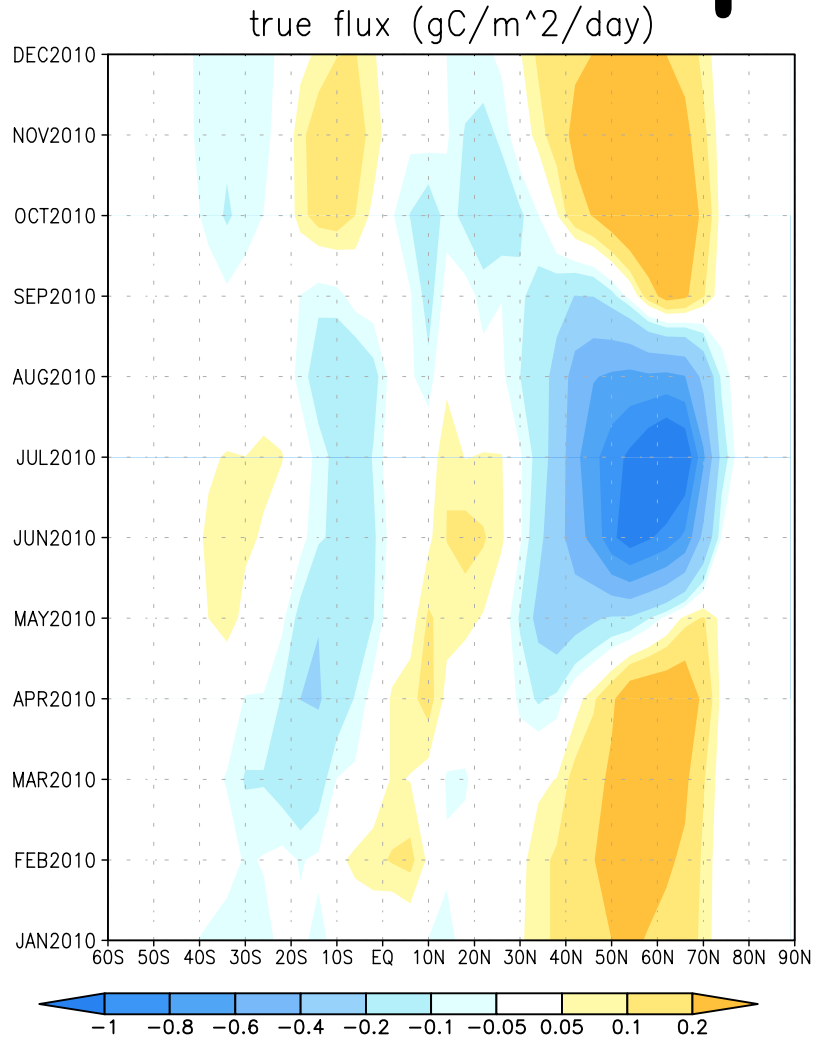


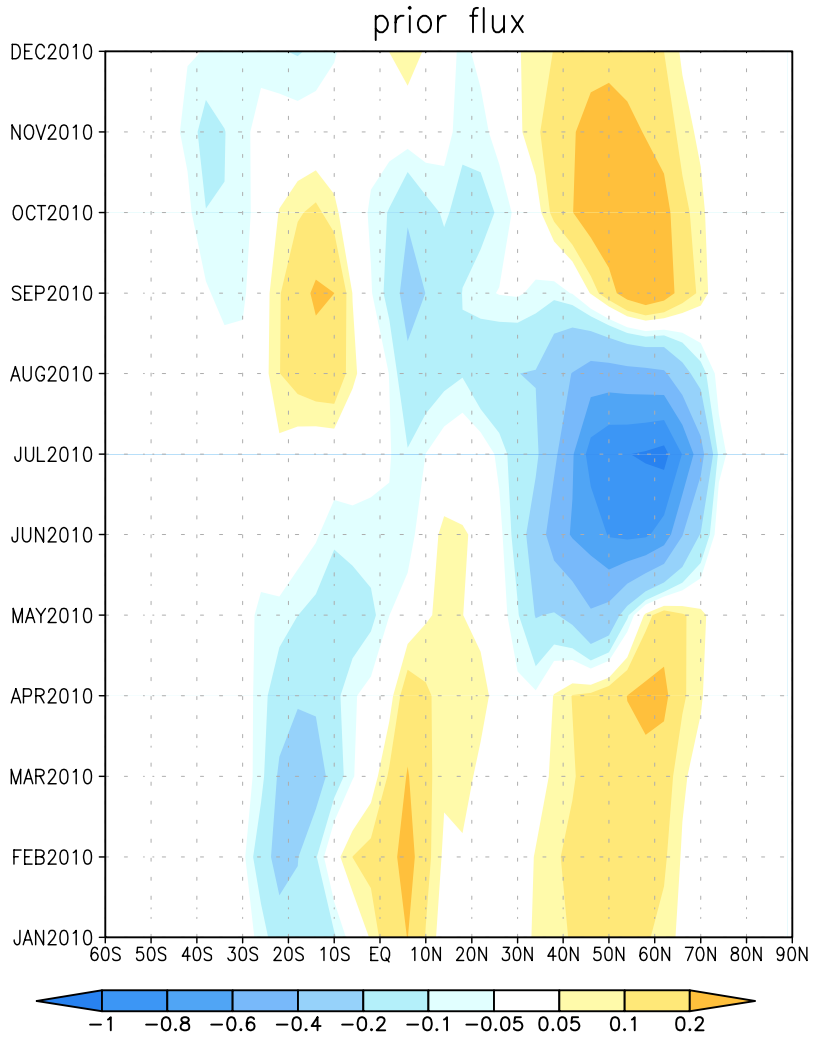
- **AIRS CO2 over the tropics has strong sensitivity to surface flux forcing over the whole year;**

CO2 flux estimation with OSSE

- **4D-Var flux inversion with GEOS-Chem adjoint model**
- **Control run: CO2 flux estimation with GOSAT observations**
- **AIRS impact runs:**
  - **Assimilate AIRS observations over the tropics (exp1);**
  - **Assimilate AIRS observations over the tropics where the number of annual GOSAT observations are less than 10 (exp2).**

The prior and true terrestrial biosphere flux

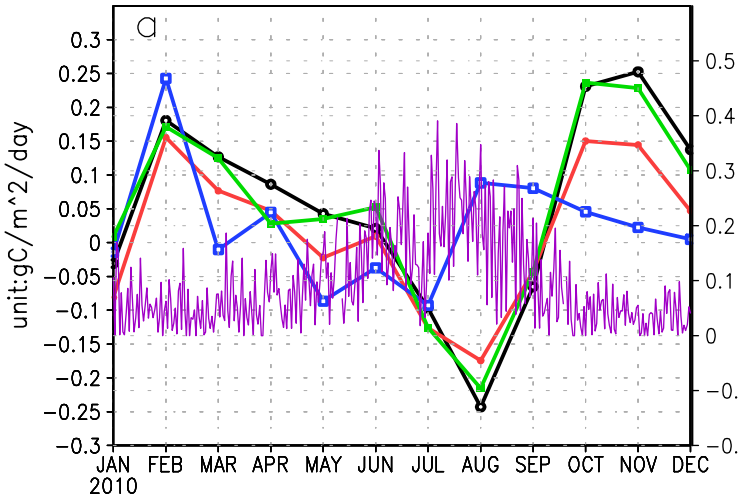




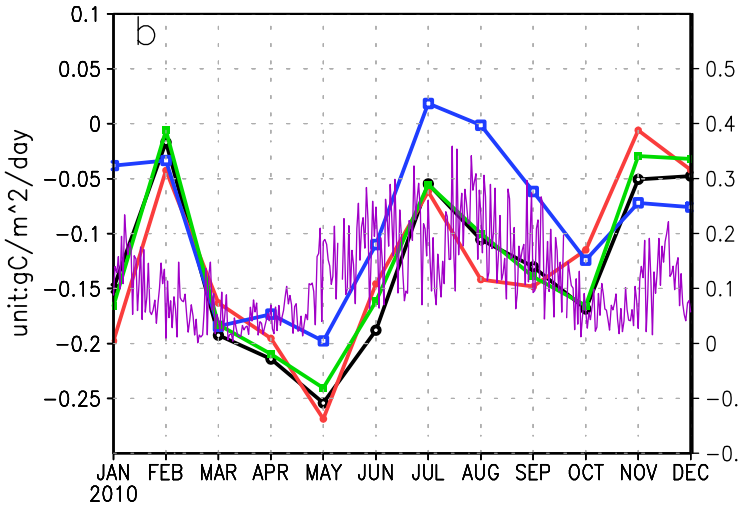
- **Both has ~5.1 GtC sink, but with different seasonal cycle and spatial distribution;**

Positive impact of mid-troposphere CO2 on tropical flux estimation

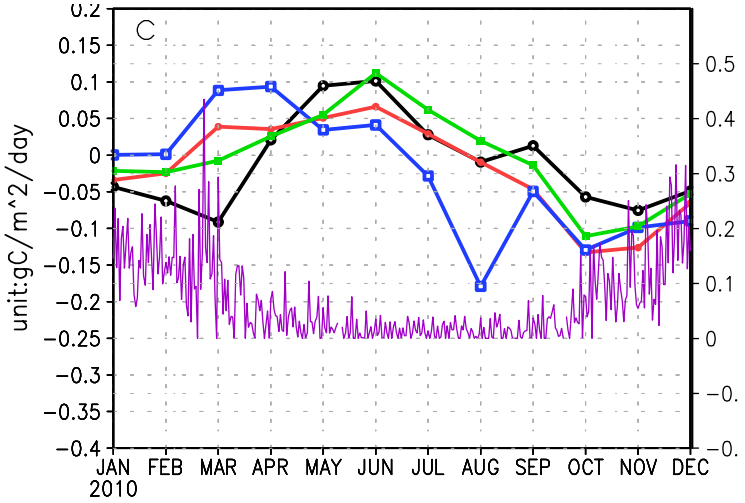
Amazon (25°S-25°N, 90°W-30°W)



Africa (25°S-25°N, 10°W-60°E)



South East Asia (25°S-25°N, 80°E-120°E)



Black: true flux

Red: posterior flux assimilating GOSAT observations

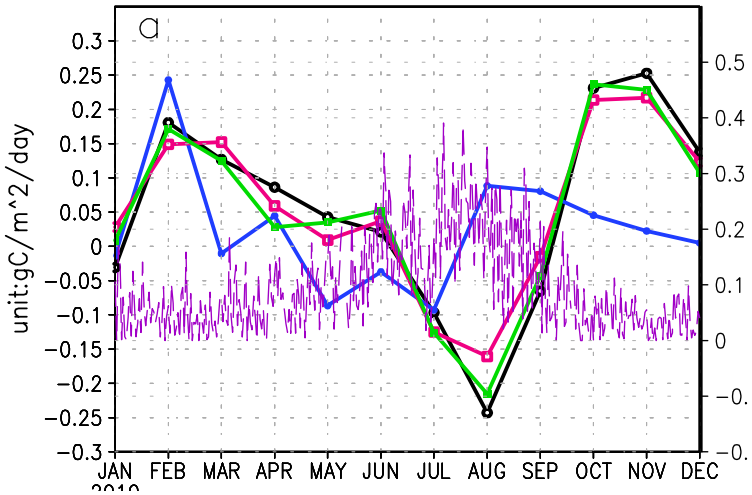
Blue: prior

Green: posterior flux assimilating both GOSAT and AIRS observations (exp2)

Purple: area-averaged GOSAT CO2 observations at each region over land

Data masking has improved the results

Amazon (25°S-25°N, 90°W-30°W)



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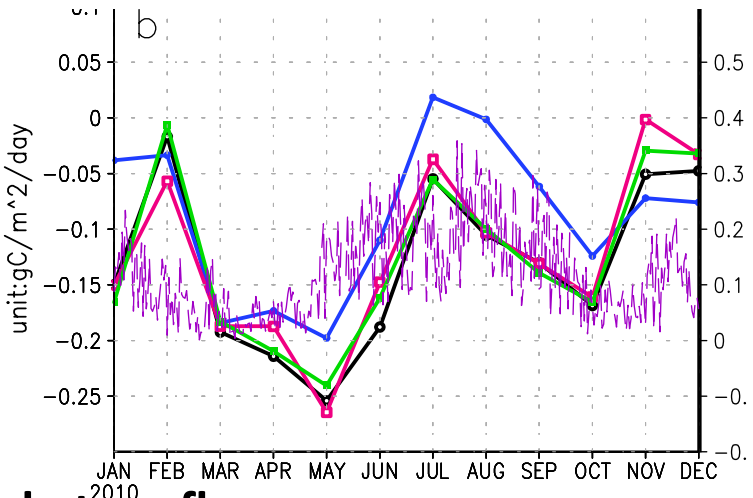

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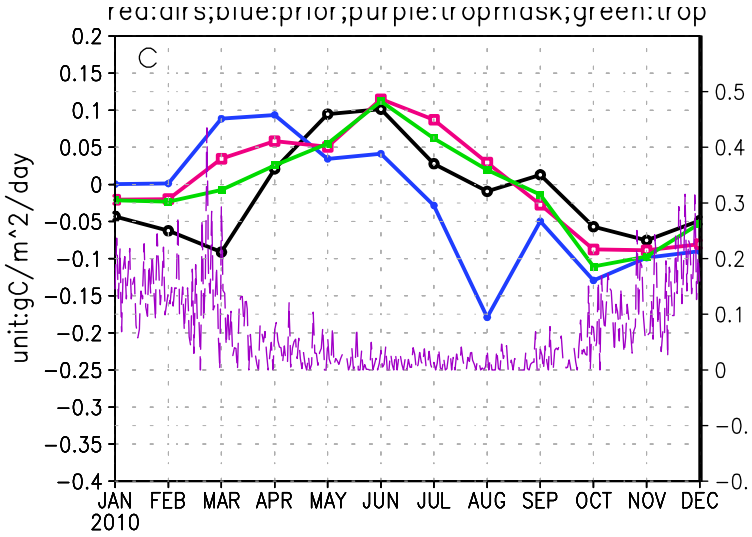


Black: true flux

Red: posterior flux assimilating GOSAT observations

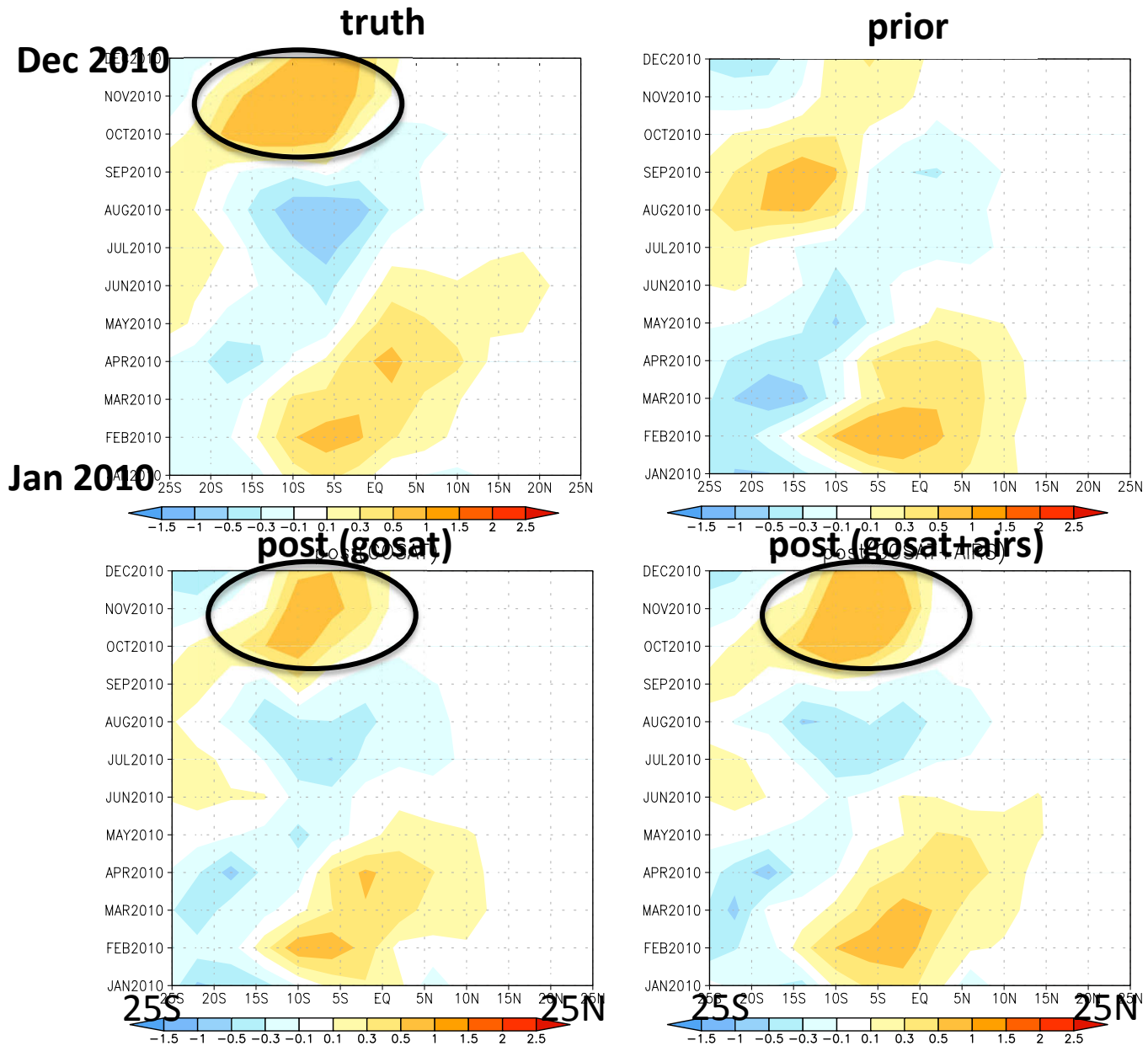
Blue: prior flux

Pink: posterior flux assimilating both GOSAT and AIRS (exp1)

Green: posterior flux assimilating both GOSAT and AIRS (exp2)

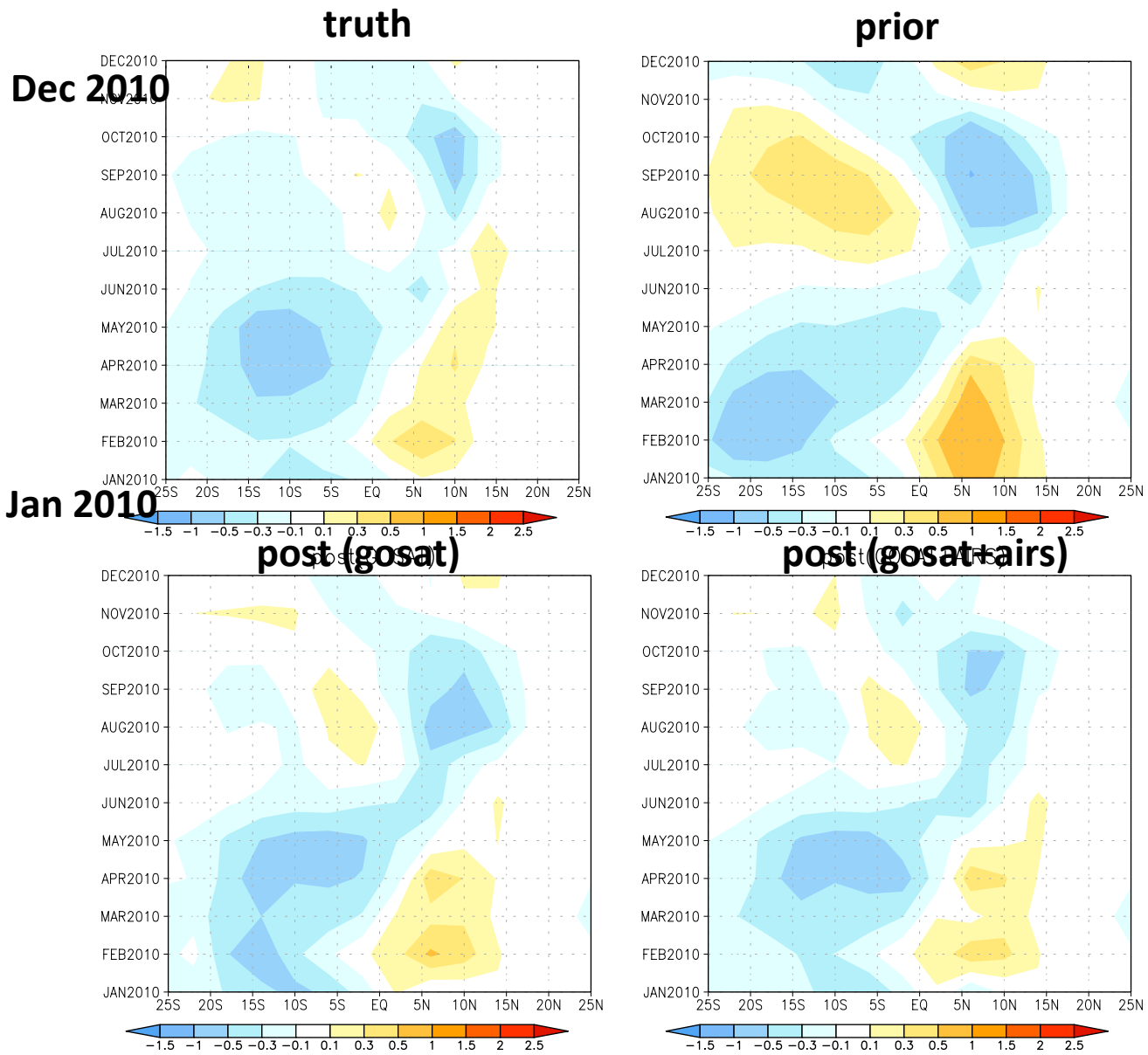
Purple: area-averaged GOSAT CO2 observations at each region over land

Zonal mean flux over Amazon (gC/m²/day)



- Different seasonality between prior and the true flux;
- Assimilating GOSAT observations has recovered the seasonality of true flux;
- Assimilating AIRS over the tropics further improved the flux;

Zonal mean Flux estimation over tropical Africa



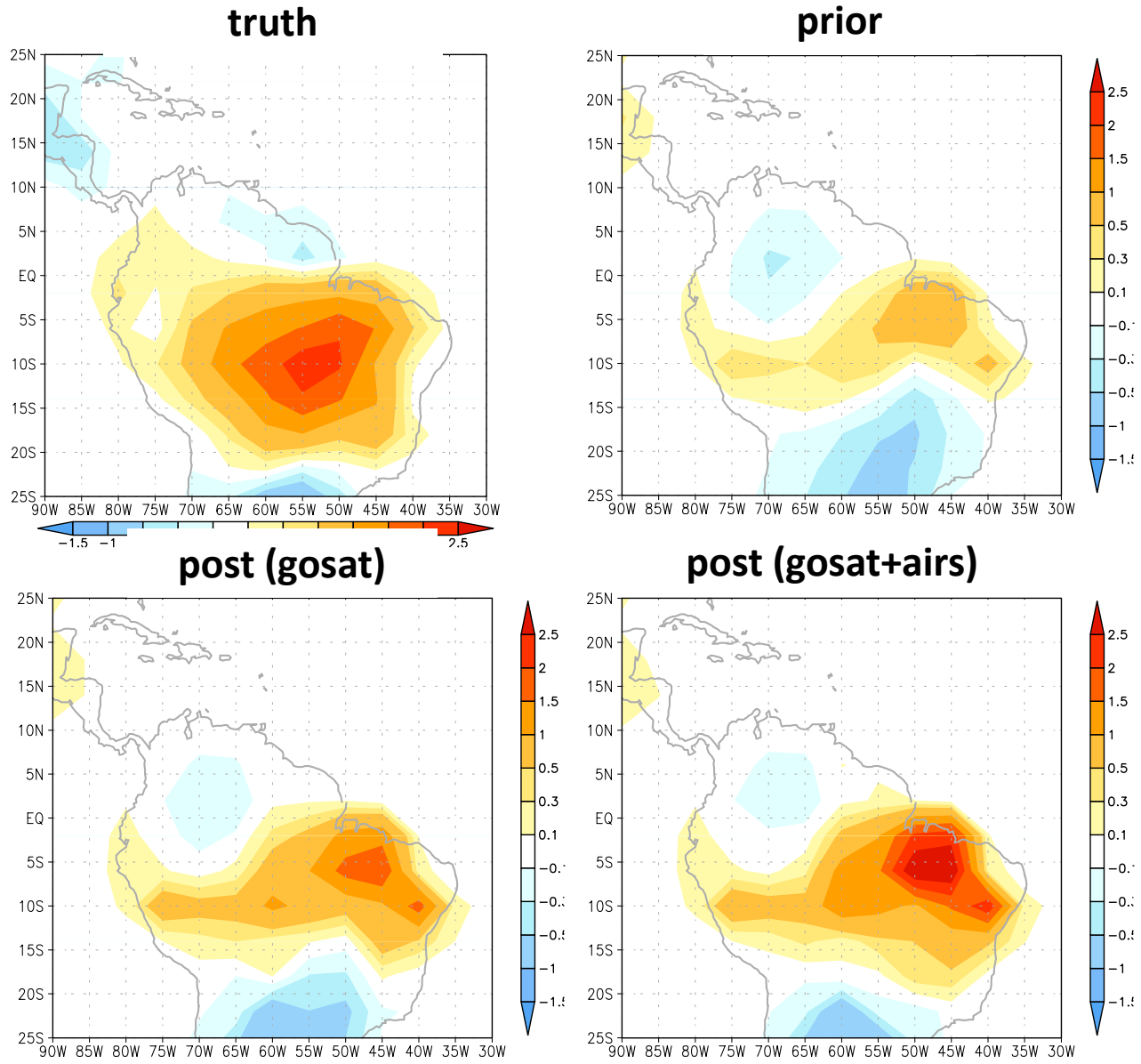
- Different seasonality between prior and the true flux;
- Assimilating GOSAT observations has recovered the seasonality of true flux;
- Assimilating AIRS over the tropics further improved the flux;

Conclusions and Discussions

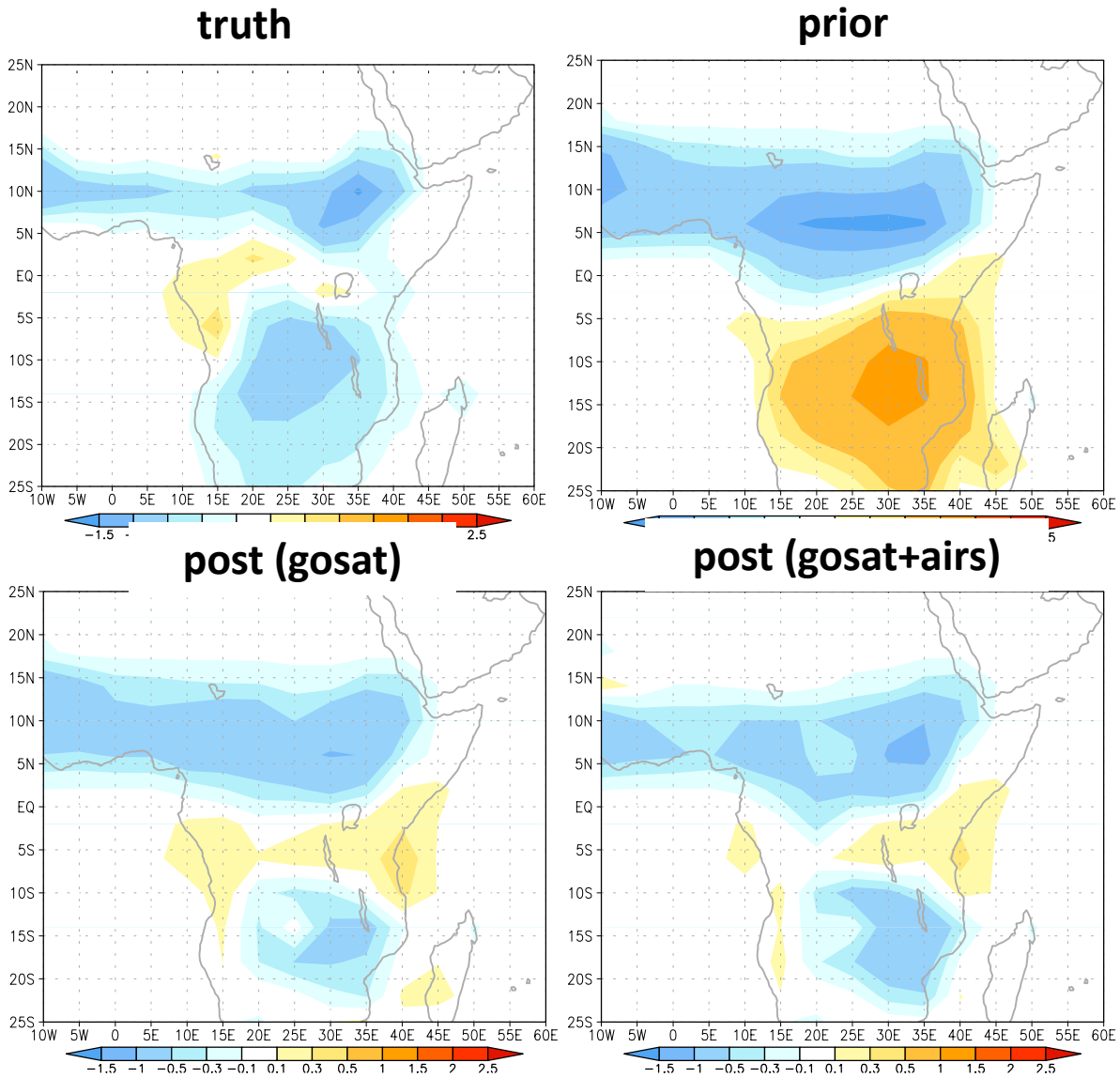
We tested the impact of AIRS CO2 over the tropics where GOSAT has sparse observation coverage on surface CO2 flux estimation with OSSEs.

- **AIRS CO2 has strong sensitivity to surface CO2 flux forcing during the whole year;**
- **Assimilating AIRS CO2 over the tropics in addition to the GOSAT observations has improved the surface CO2 flux forcing over the tropics, where the current understanding of carbon cycle is most uncertain;**
- **Assimilating AIRS only over the locations where the GOSAT has sparse coverage further improves the results;**
- **Surface CO2 flux estimation is sensitive to observation biases. It needs strict validation of the data before using the real in surface flux estimation.**

Flux estimation over Amazon region averaged between Oct and Dec

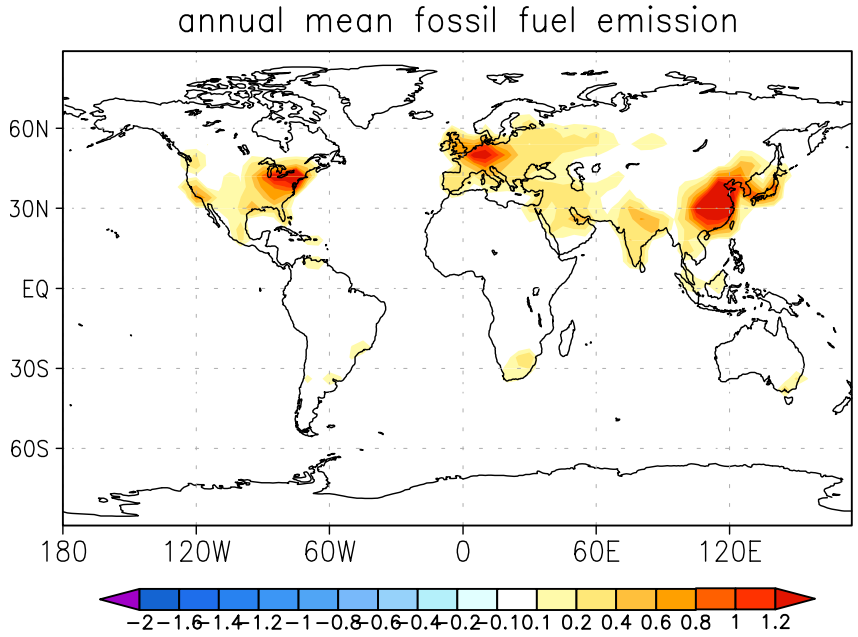


Flux over Africa averaged over Aug-Oct

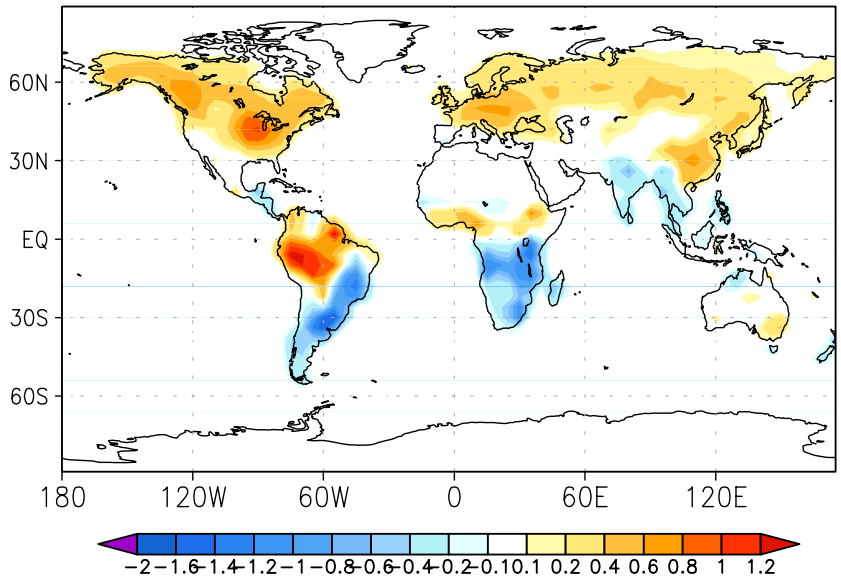


Surface CO2 flux

- Concentrated fossil fuel emissions upon biosphere flux;



Terrestrial biosphere flux (Jan-March)



Terrestrial biosphere flux (June-August)