Simultaneous assimilation of GOSAT and tropical AIRS CO2 to constrain tropical surface CO2 flux

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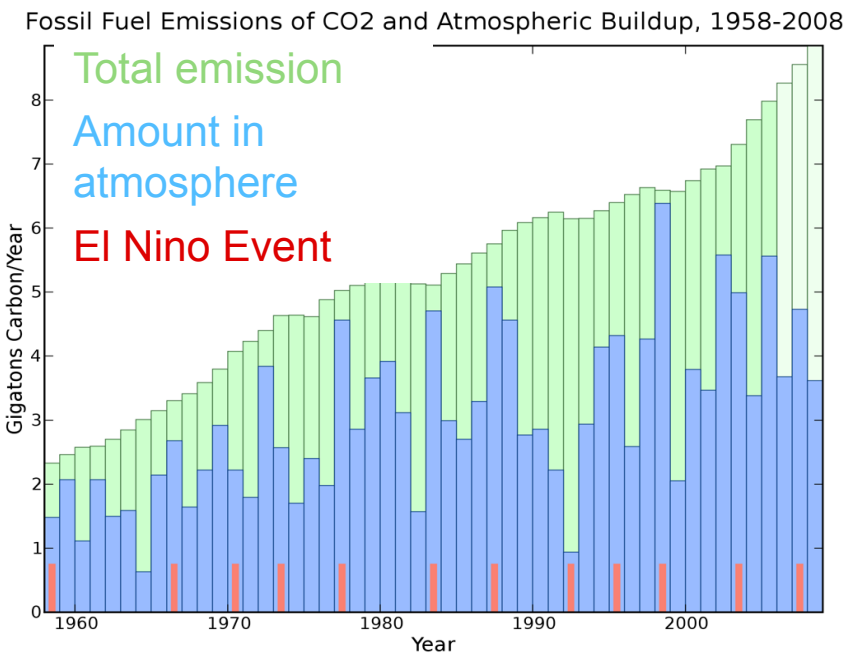
Motivation and Objectives

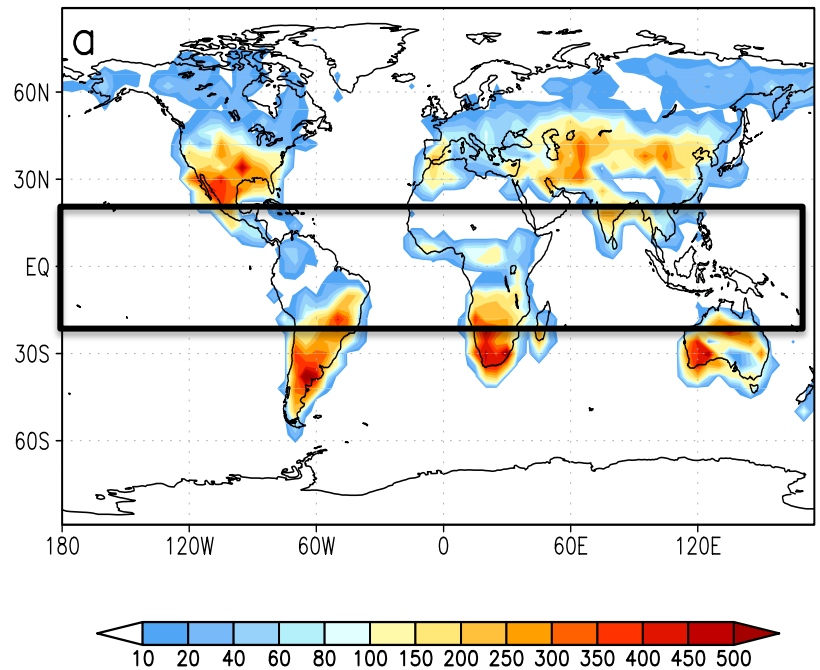
Only about half of the fossil fuel emissions remains in the atmosphere. Where the other half goes?



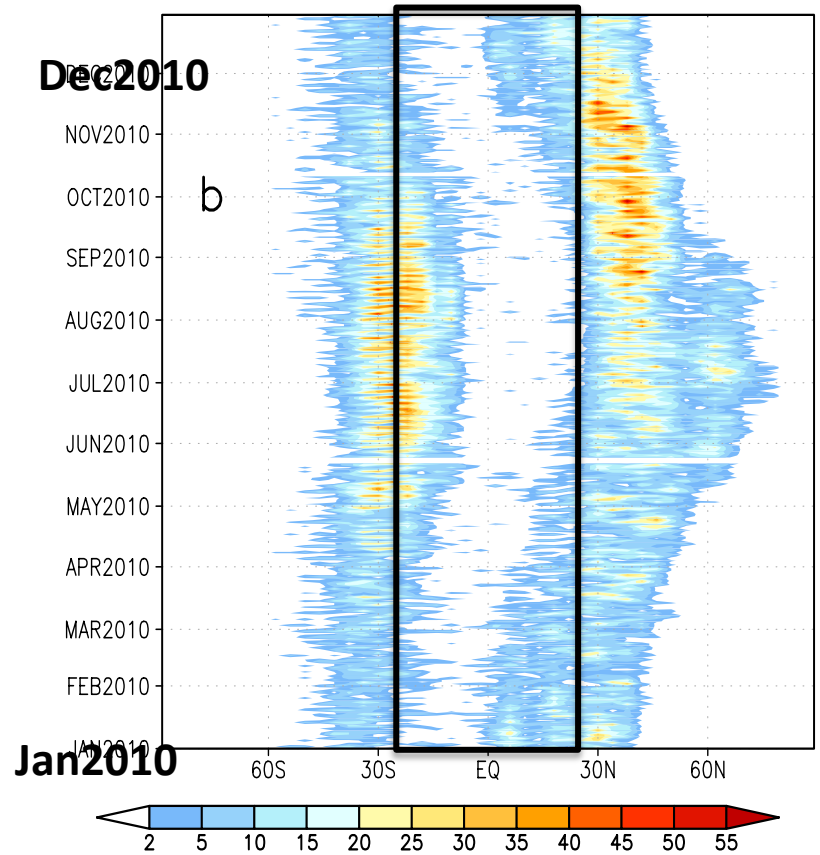
- **Could mid-troposphere CO2 help constrain the surface flux forcing in addition to the column CO2 (Xco2) from Greenhouse gases Observing SATellite (GOSAT)?**
  - **What is the impact of AIRS CO2 on tropics (25°S-25°N) surface flux estimation?**

Why we focus on the tropics ?

Annual total number of good-quality GOSAT observations

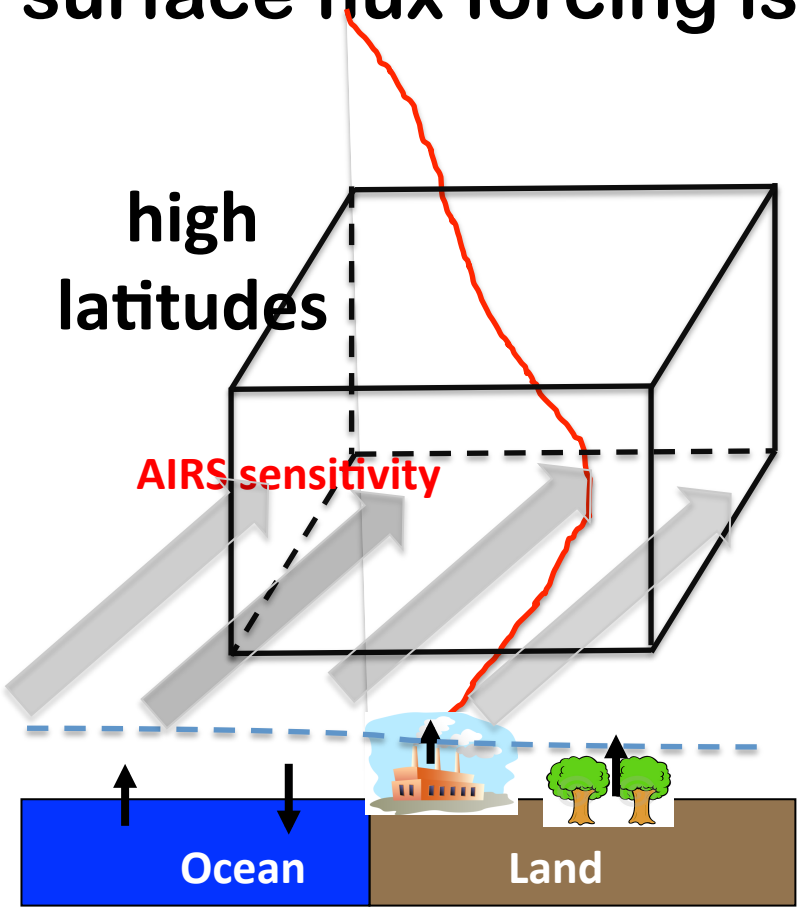


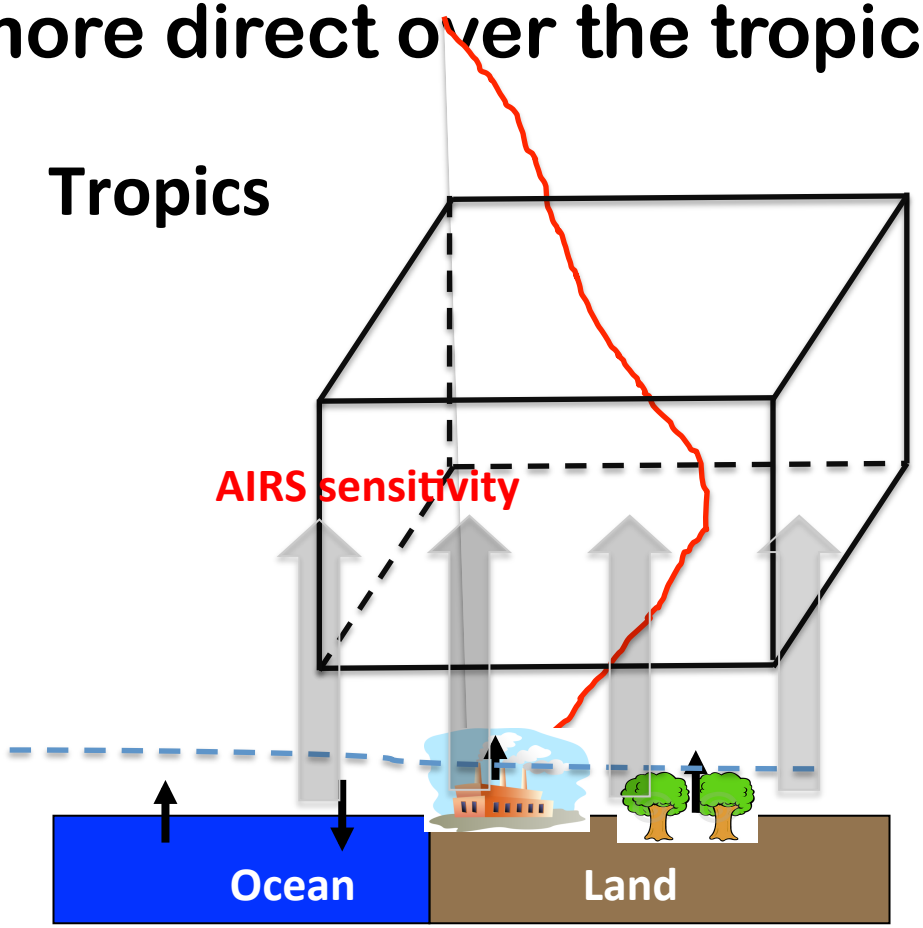
The amount of good-quality GOSAT at each latitude



- **GOSAT has sparse observation coverage over the tropics;**

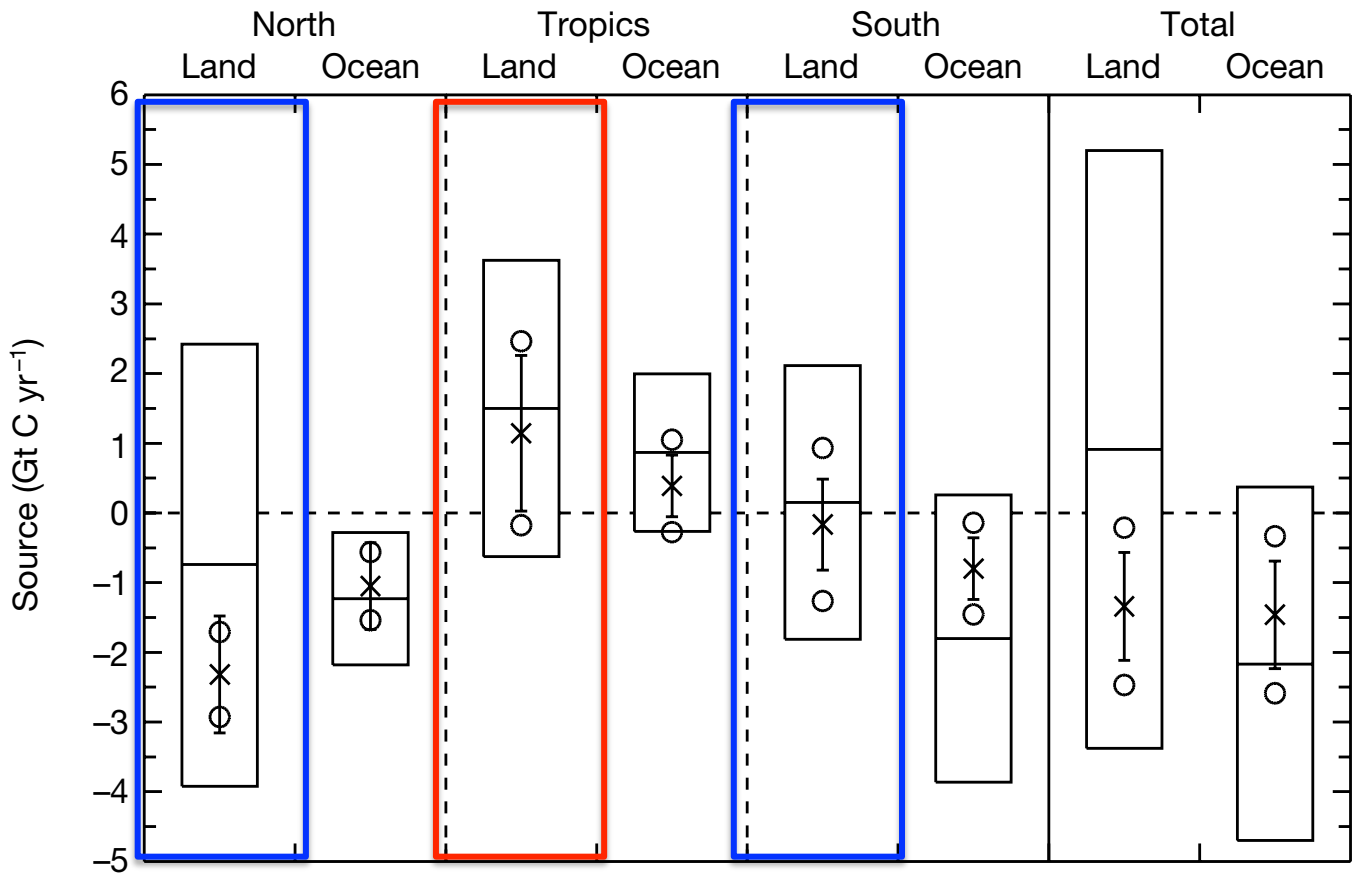
Connection between mid-troposphere CO2 and surface flux forcing is more direct over the tropics





- Advection dominates the transport in the high latitudes during large portion of the year;
- Connection between mid troposphere CO2 over the tropics is more direct than the observations over mid latitudes;

Tropical land flux forcing is most uncertain



The boxes are the prior and its uncertainty; the central horizontal bar is prior flux

Crosses: posterior flux estimate; error bars: cross model uncertainty; open circles: within-model uncertainty;

Gurney et al., 2002

CO2 flux estimation with OSSE

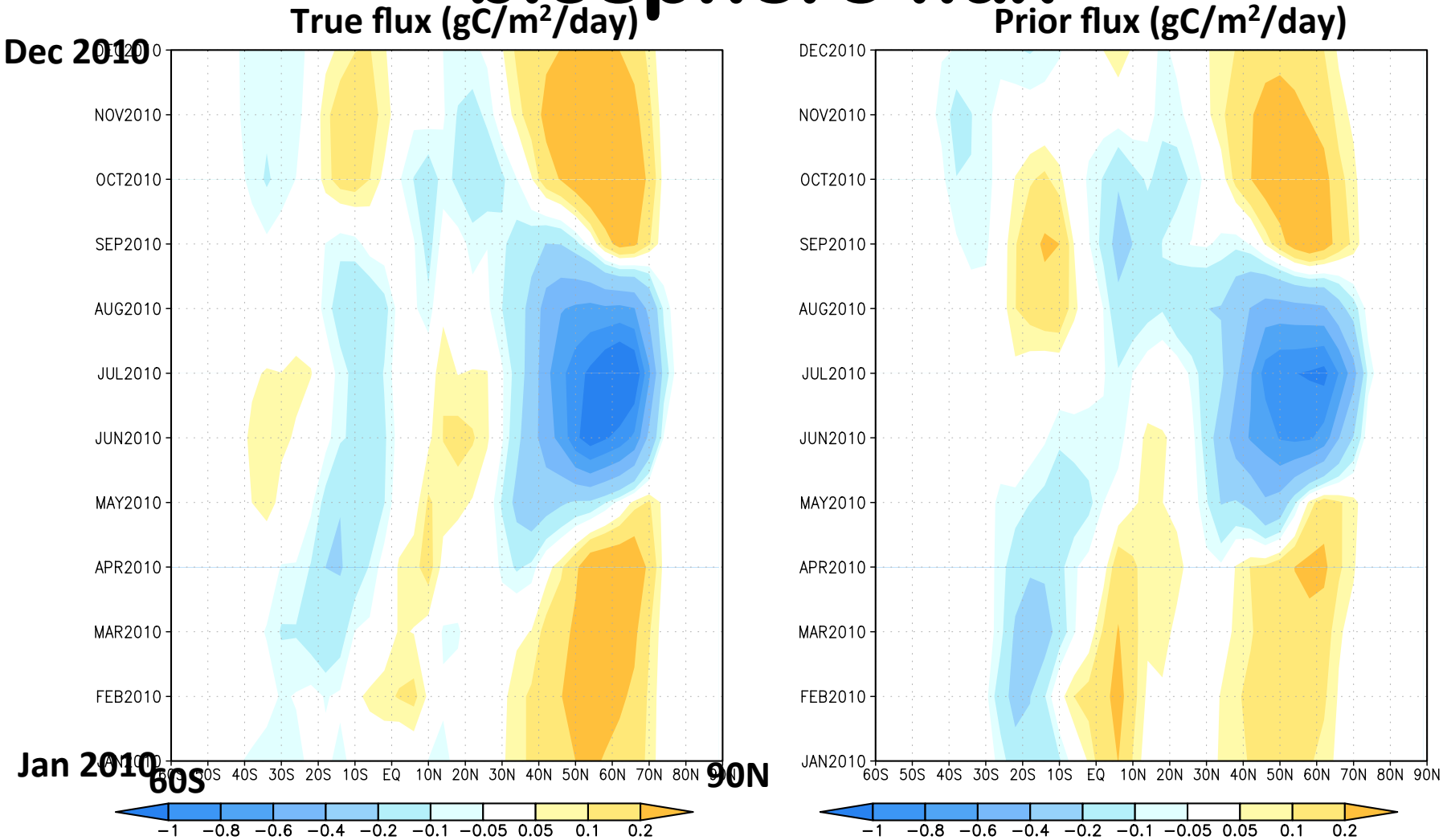
- **4D-Var flux inversion with GEOS-Chem adjoint model**

Background term Observation term

$$J = (\mathbf{s} - \mathbf{s}_o)^T \mathbf{B}^{-1} (\mathbf{s} - \mathbf{s}_o) + \sum_{t=1}^{T} [\mathbf{y}_t - (h(\mathbf{s}))_t]^T \mathbf{R}^{-1} [\mathbf{y}_t - (h(\mathbf{s}))_t]$$

- **Time period: year 2010;**
- **Control run: estimating CO2 flux with simulated GOSAT;**
- **AIRS CO2 impact runs: in addition to simulated GOSAT observations,**
  - **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).**

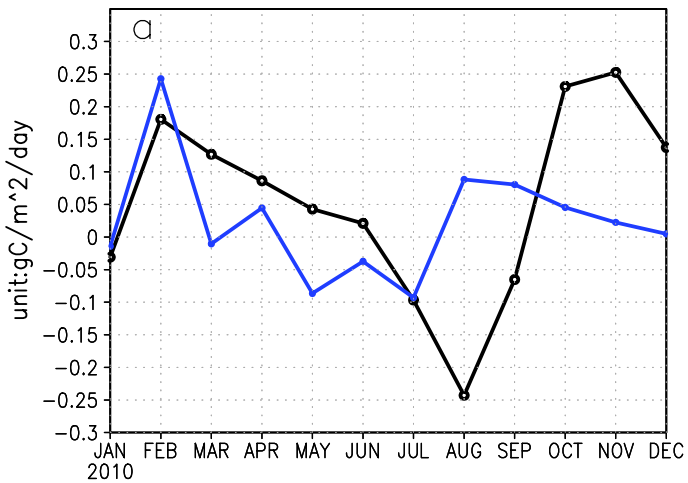
The true and prior terrestrial biosphere flux



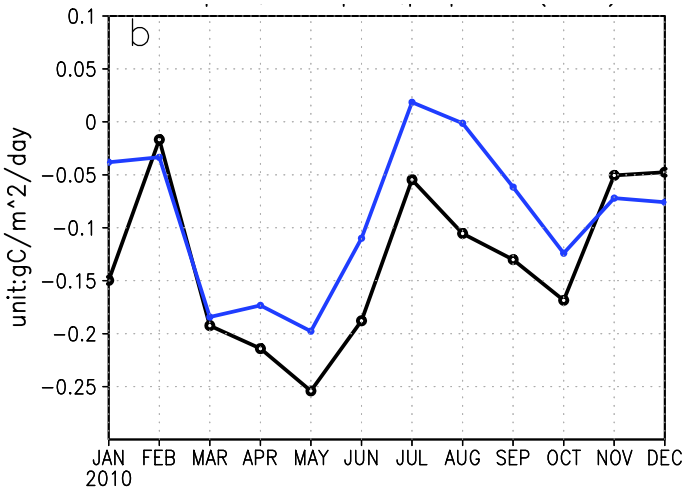
- **Both has ~5.1 GtC sink, but with different seasonal cycle and spatial distribution;**

Different seasonality between prior and true flux

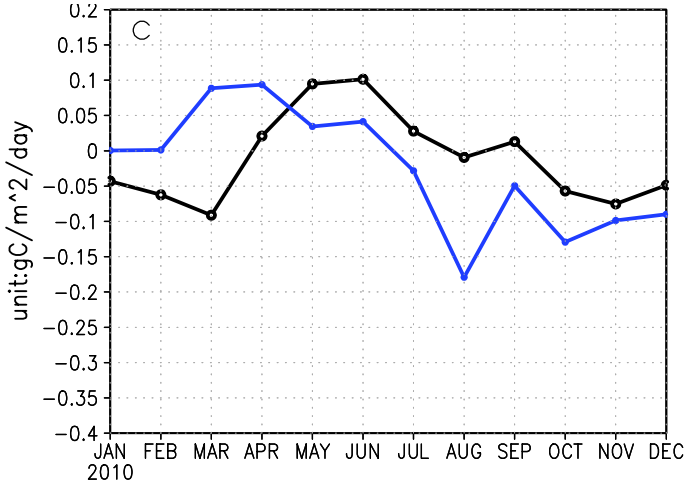
Amazon (25°S-25°N, 90°W-30°W)



Tropical Africa (25°S-25°N, 10°W-60°E)



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



Black: true flux

Blue: prior

The posterior flux assimilating GOSAT observations is closer to the true flux

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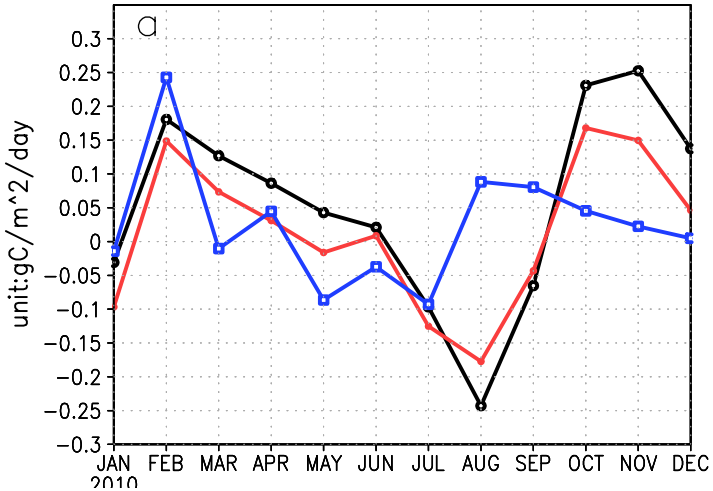

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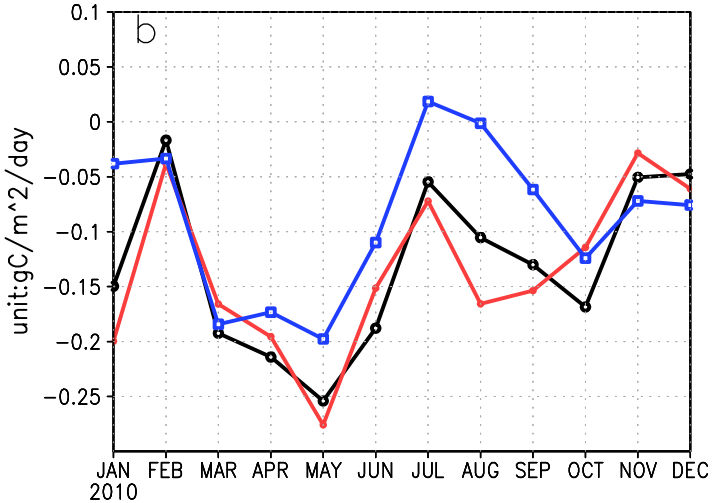

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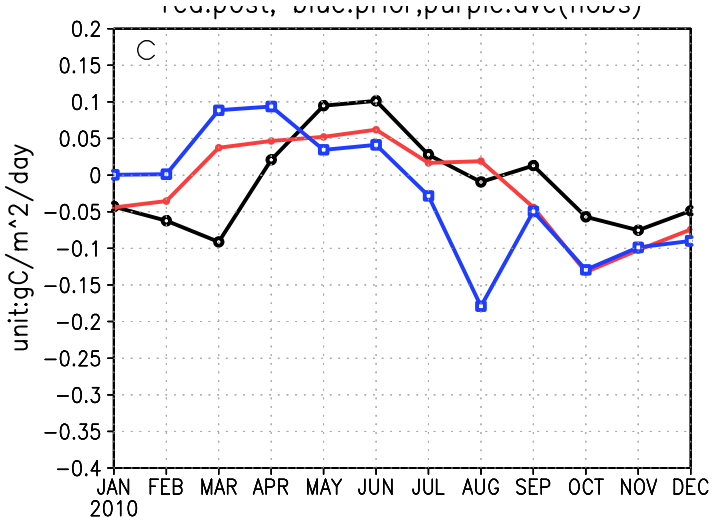

Black: true flux

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Red: posterior flux assimilating GOSAT observations

Positive impact of mid-troposphere CO2 on tropical flux estimation

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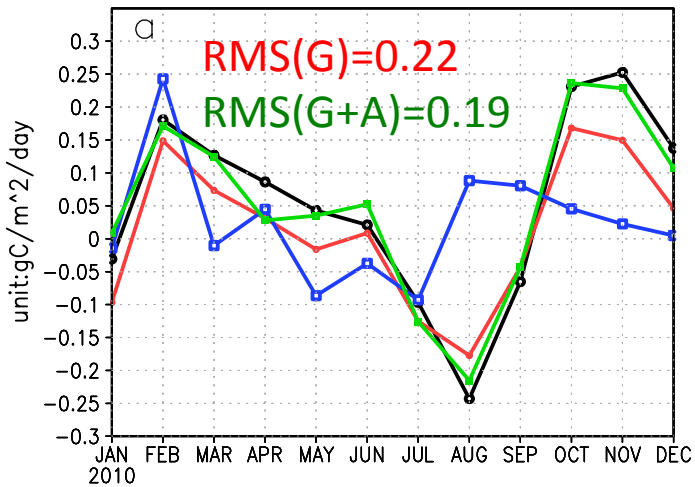

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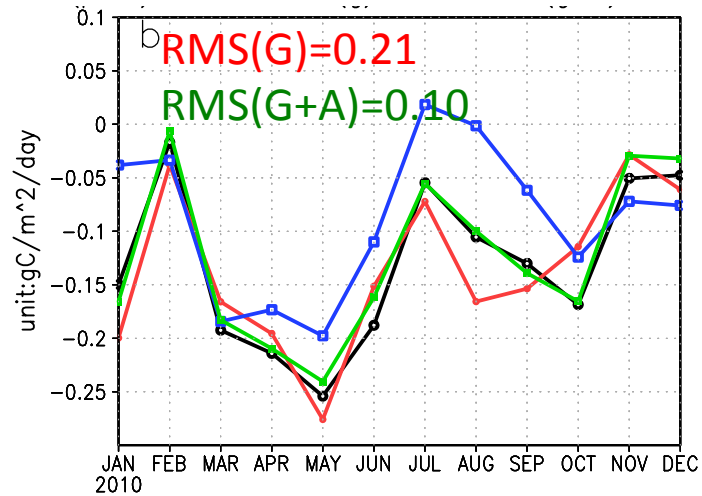

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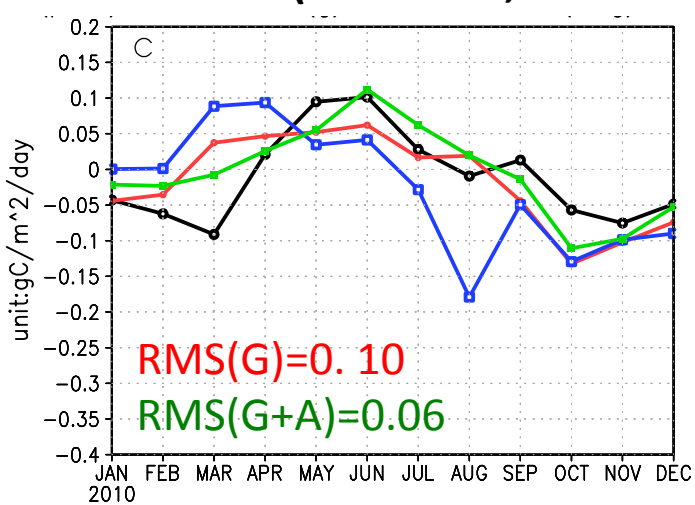

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Green: posterior flux assimilating both GOSAT and AIRS observations over tropics (exp2)

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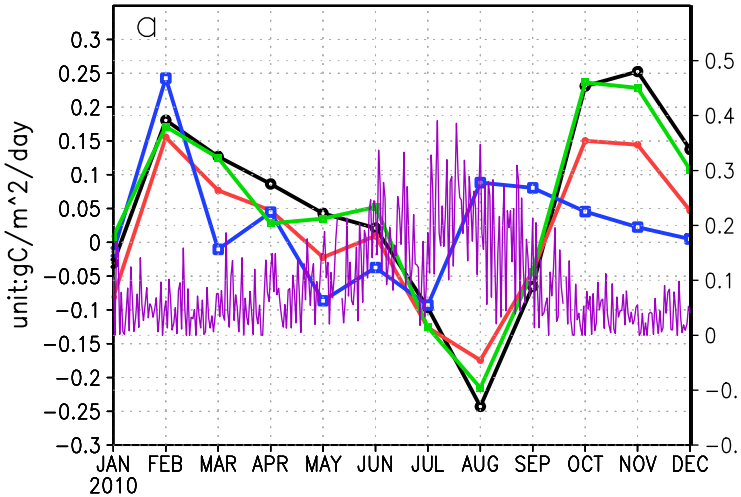

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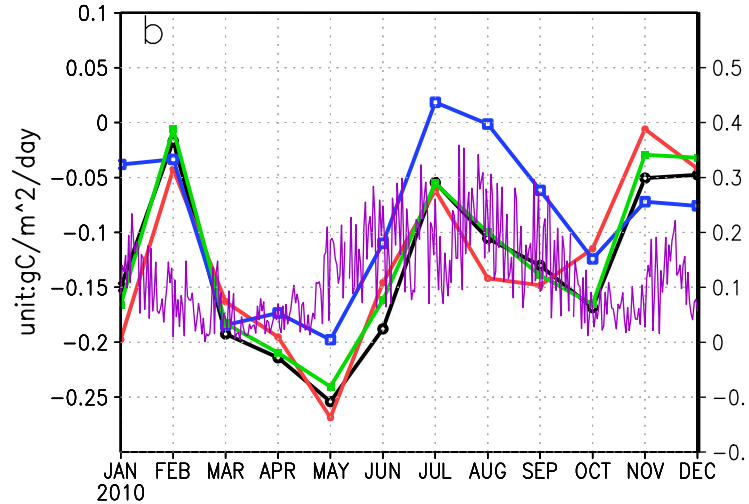

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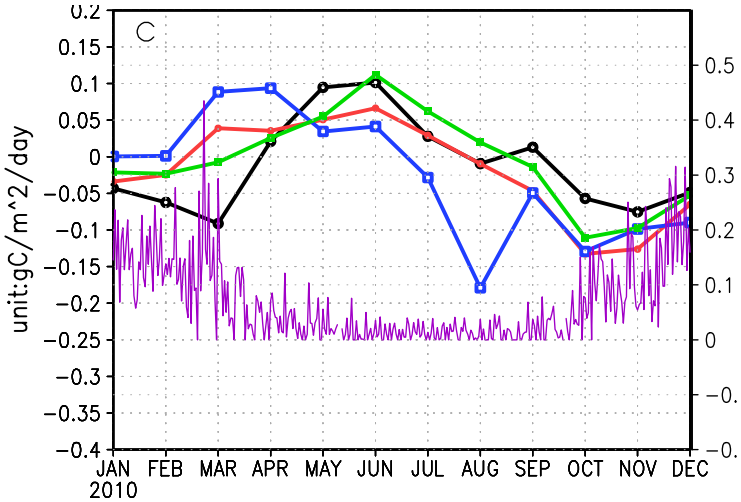


Black: true flux

Red: posterior flux assimilating GOSAT observations

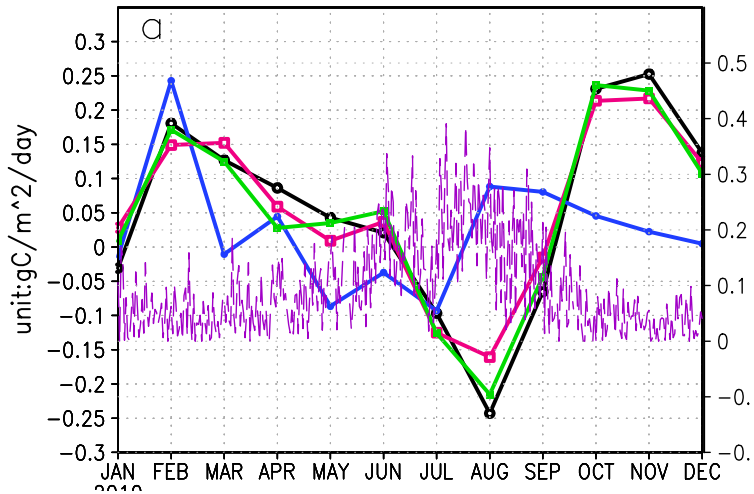
Blue: prior

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

Purple: daily area-averaged GOSAT CO2 observations at each region over land (right y-axis)

Data masking has improved the results

Amazon (25°S-25°N, 90°W-30°W)



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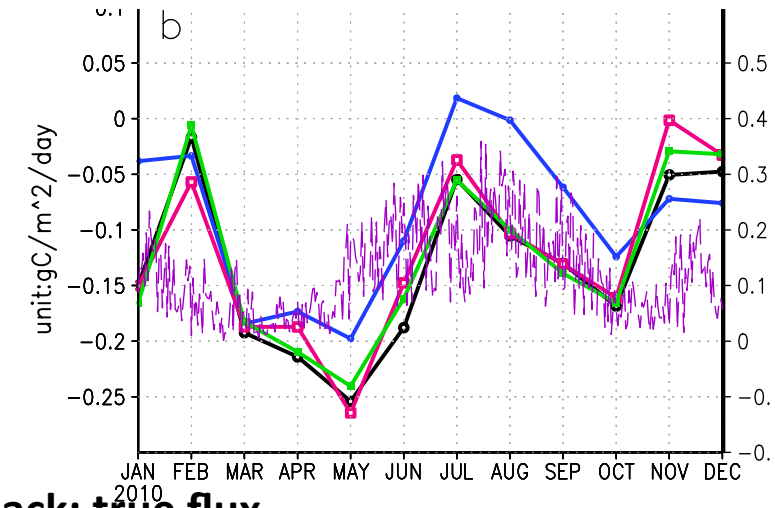

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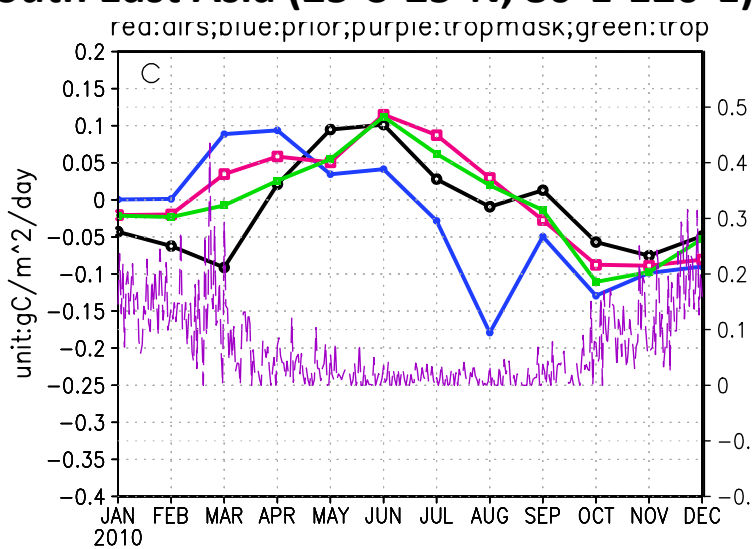


Black: true flux

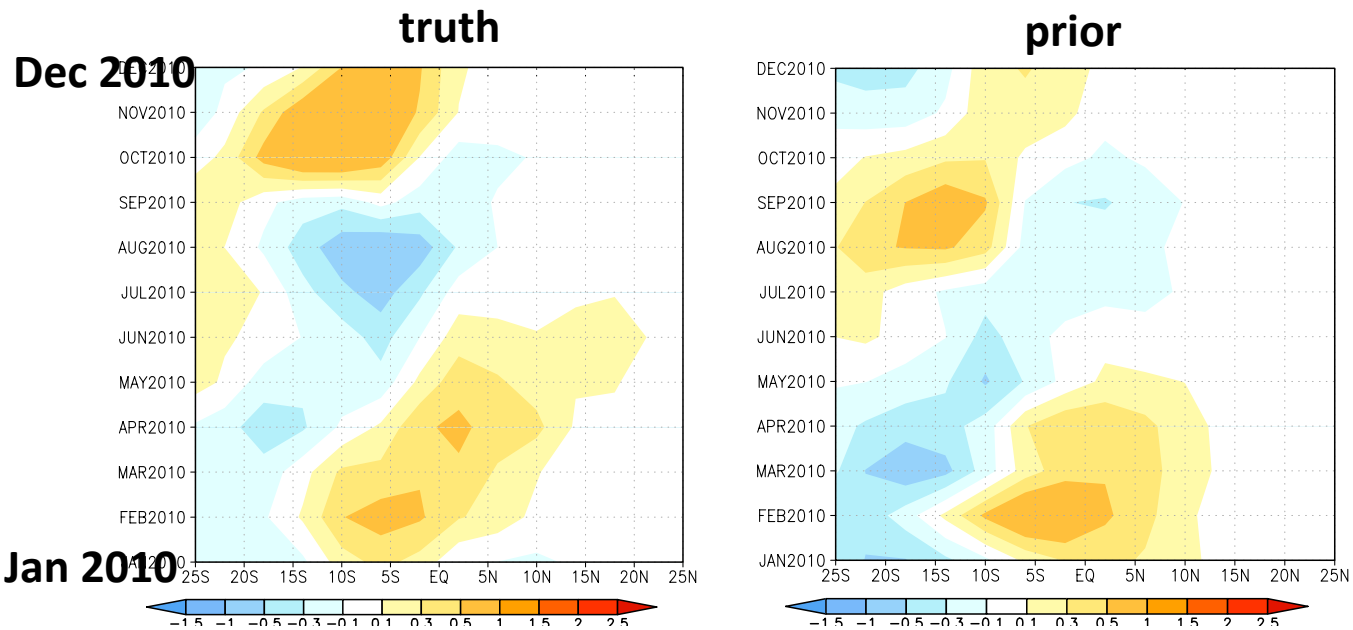
Blue: prior flux

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

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

Purple: area-averaged GOSAT CO2 observations at each region over land (right y-axis)

Zonal mean flux over Amazon (gC/m^2/day)



- **Different seasonality between prior and the true flux;**

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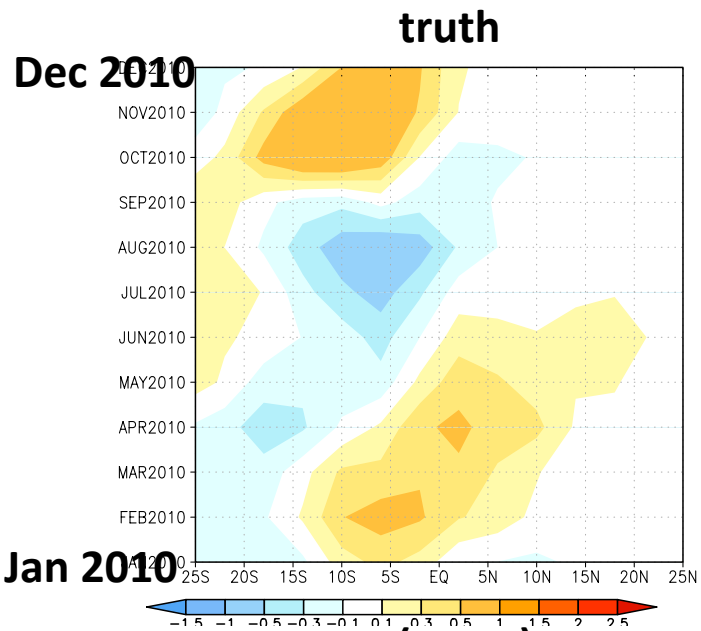

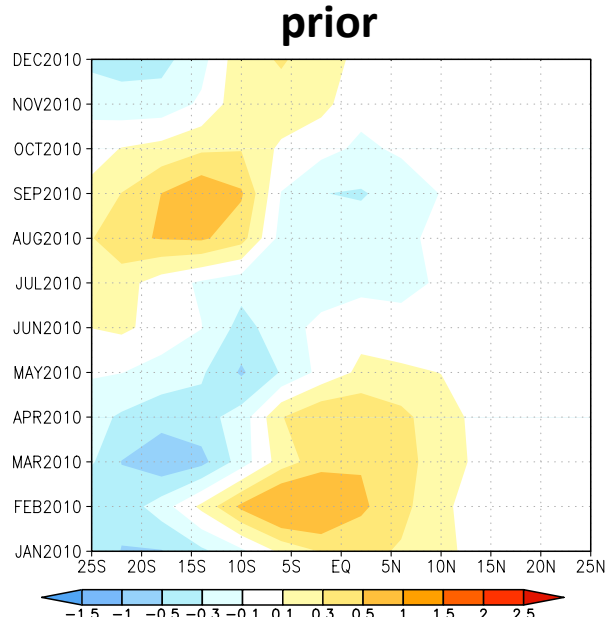

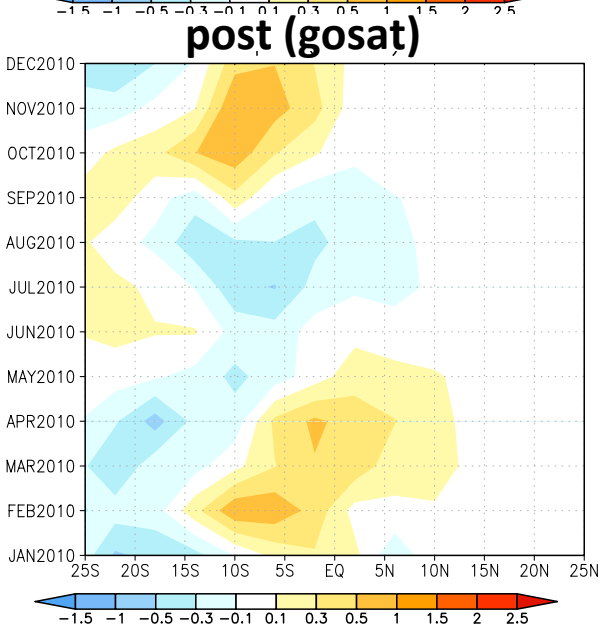

- **Different seasonality between prior and the true flux;**
- **Assimilating GOSAT observations has recovered the seasonality of true flux;**

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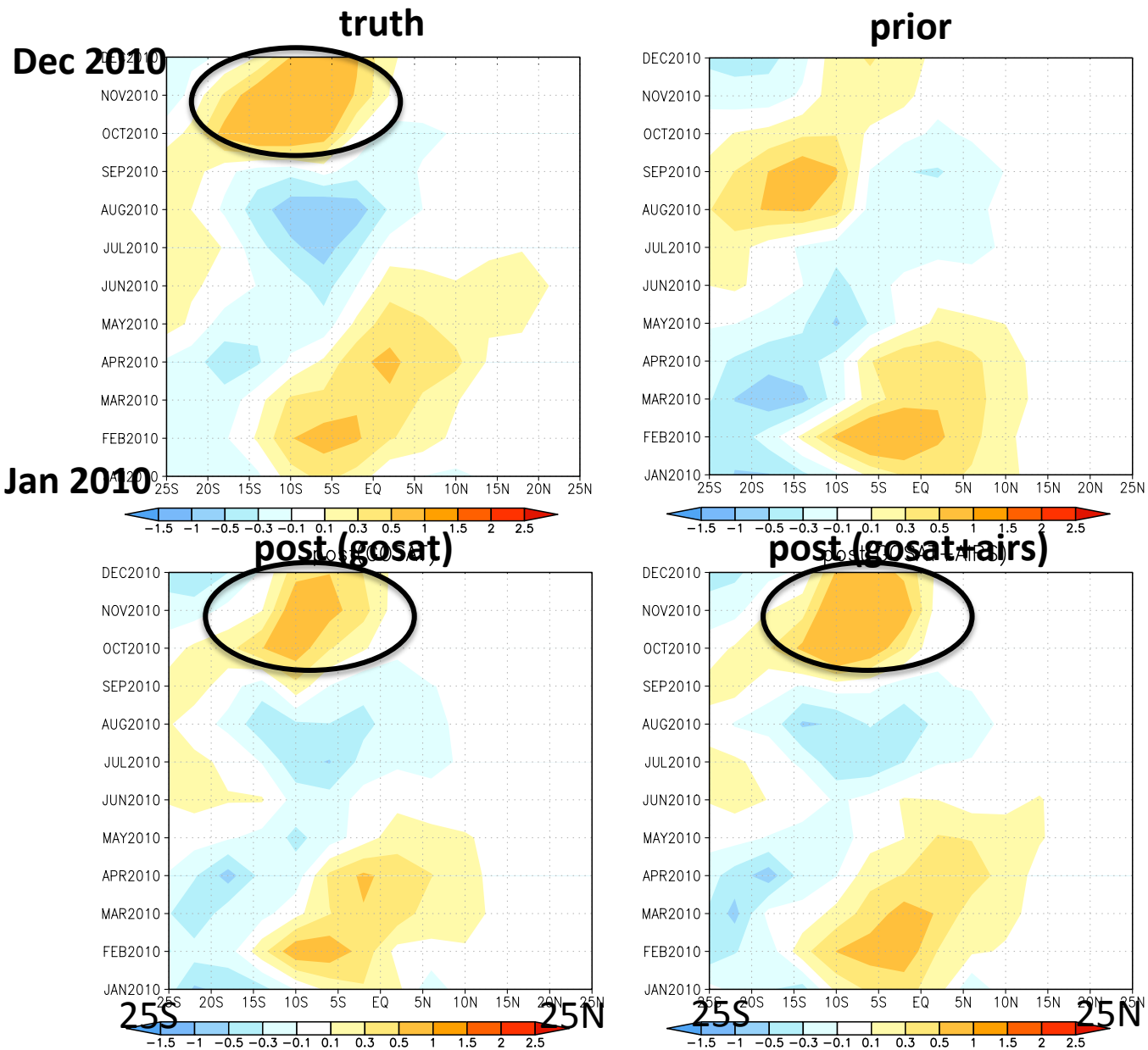
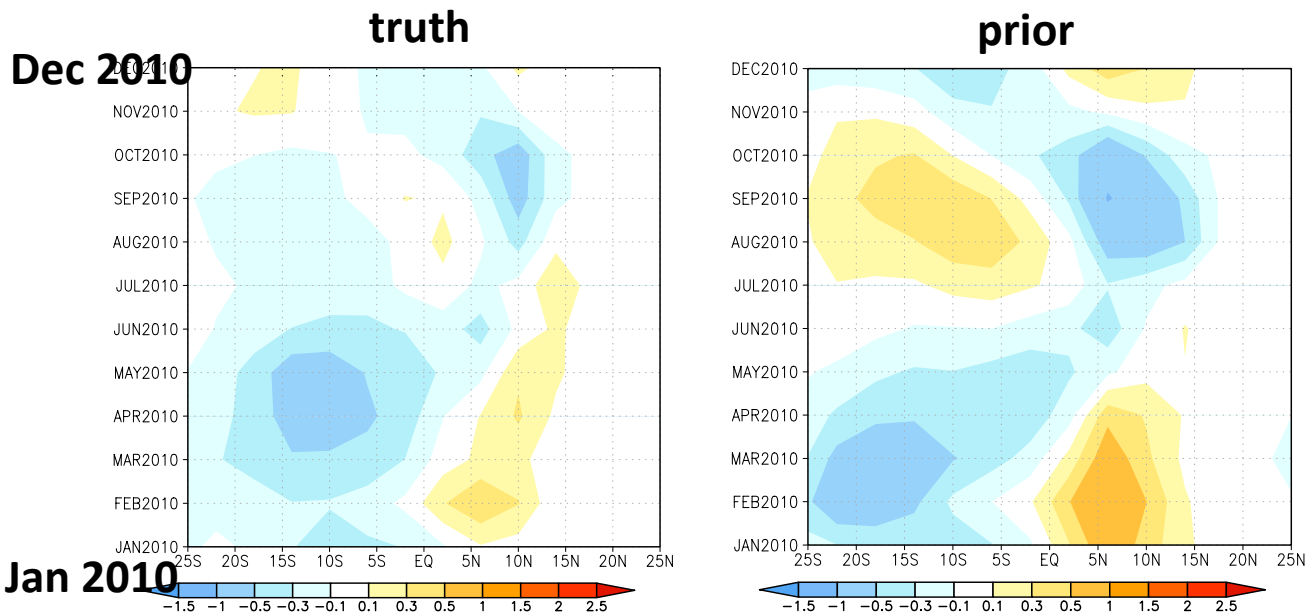


- Different seasonality between prior and the true flux;
- Assimilating GOSAT observations has recovered the seasonality of true flux;
- Assimilating AIRS over the tropics further improved the flux;

Zonal mean Flux estimation over the tropical Africa



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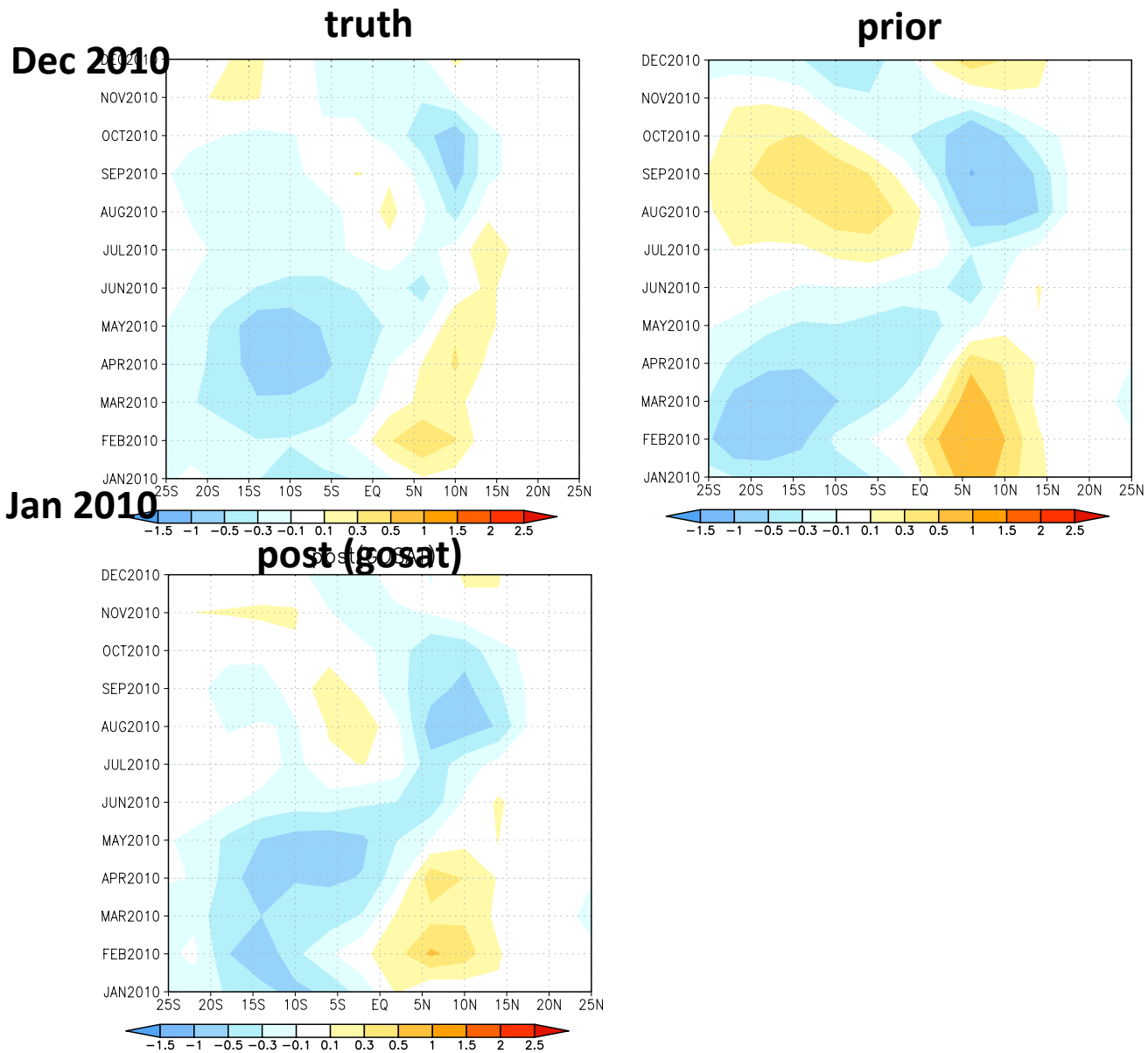

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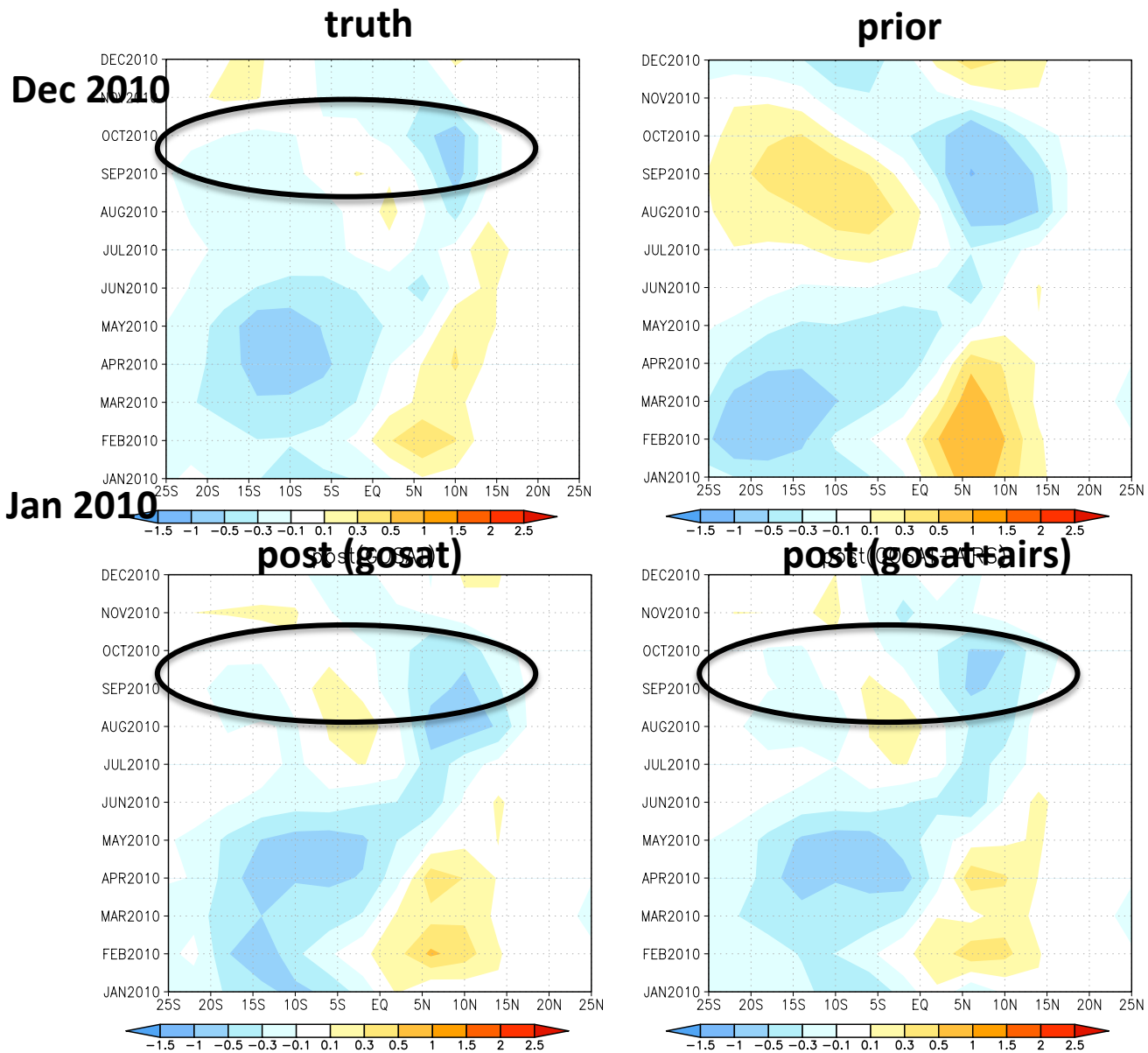

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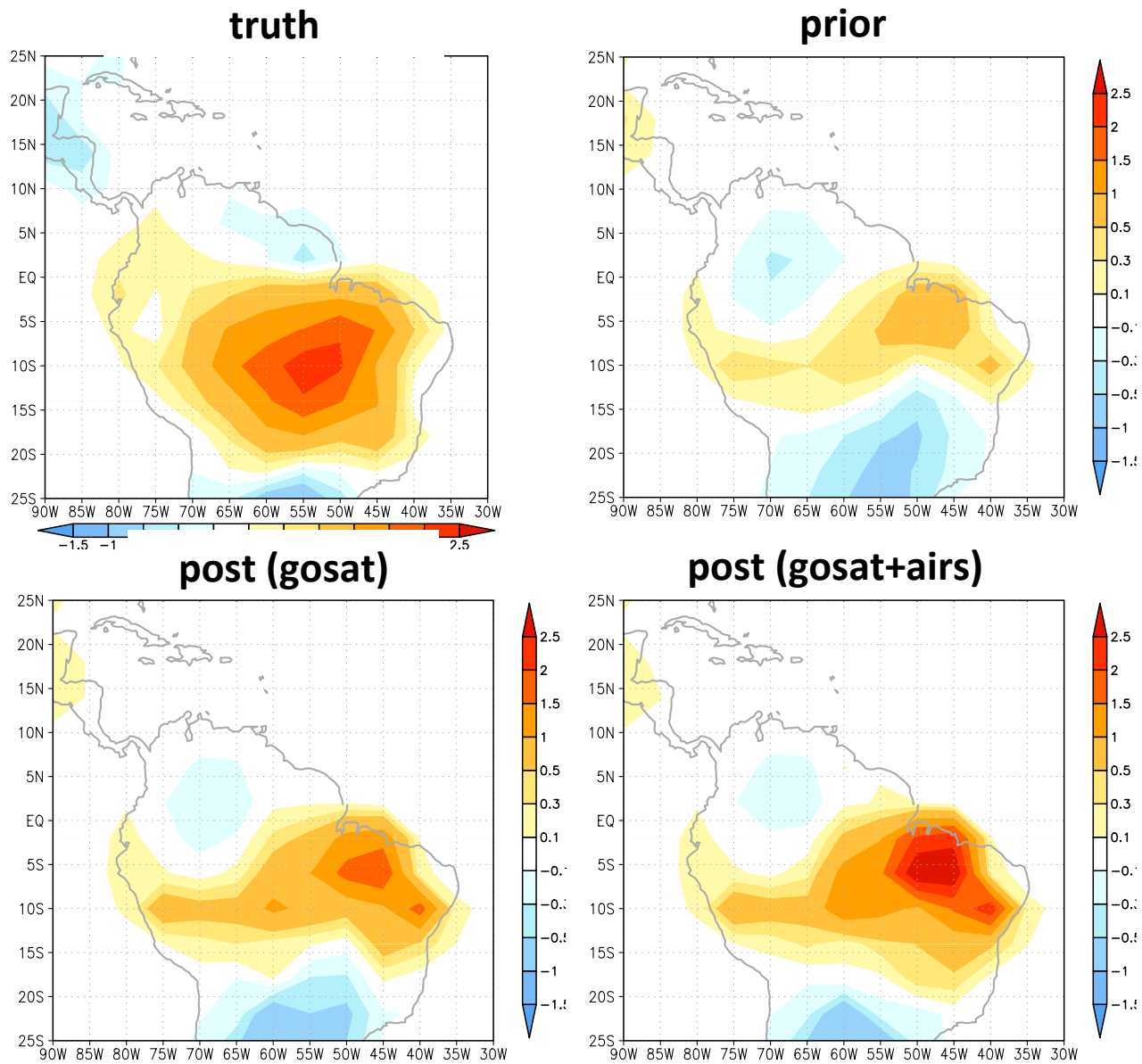
Flux estimation over Amazon region averaged between Oct and Dec



Conclusions and Discussions

We assimilated simulated AIRS CO2 observations over the tropics in conjunction with GOSAT Xco2 to examine the impact of tropical AIRS CO2 on tropical surface CO2 flux estimation with OSSEs.

- **Sparse GOSAT CO2 observation coverage over the tropics, strong sensitivity of mid-troposphere CO2 to surface flux forcing over the tropics and the large uncertainty of tropical terrestrial biosphere flux estimation make it more appealing to use mid troposphere CO2 to constrain tropical surface CO2 flux ;**
- **Assimilating AIRS CO2 over the tropics in addition to the GOSAT observations has improved the tropical surface CO2 flux forcing;**
- **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 observations in surface flux estimation.**

=> Future, we will assimilate both OCO-2 and AIRS CO2 to constrain tropical surface CO2 flux.

Flux over Africa averaged over Aug-Oct