

Quantification of the relationship between AIRS Xco₂ and surface CO₂ & Surface CO₂ flux estimation with OSSE

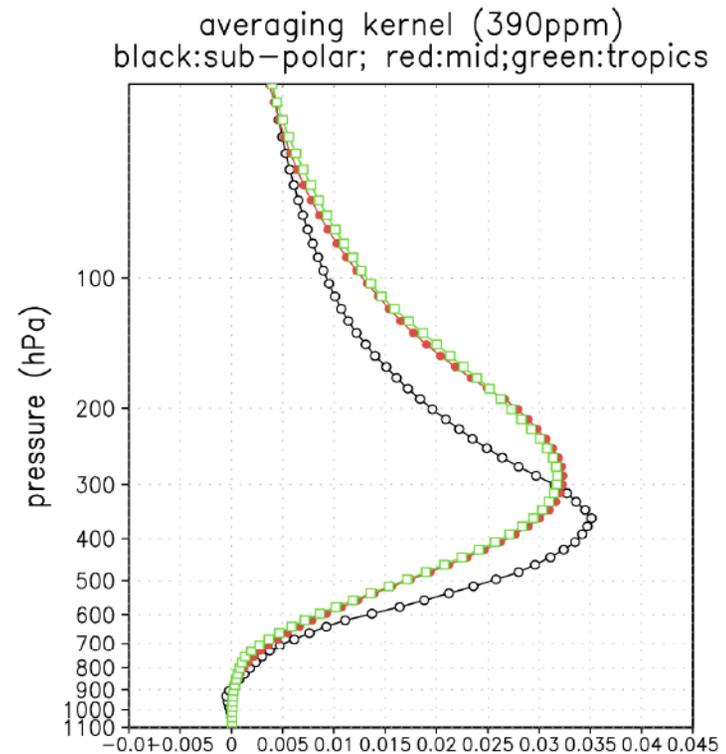
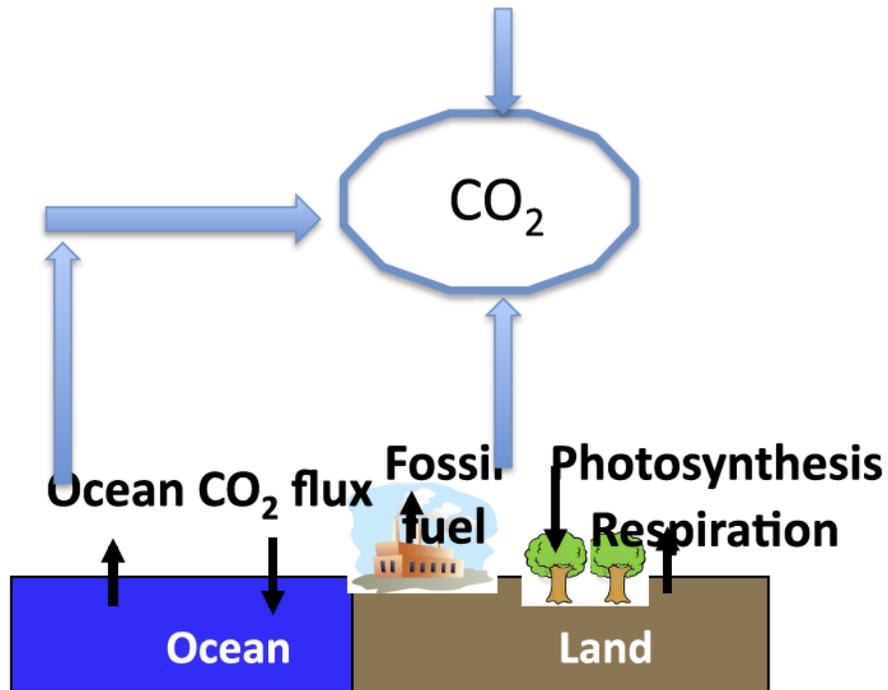
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We dedicate this work to the memory of Mous Chahine, who made it all possible. We are very grateful to Mous and Ed Olsen who generously provided us with the AIRS CO₂ retrievals, and helped us in using them. This work is funded by NASA NNH09ZDA001N-TERRAQUA , and DOE grants DEFG0207ER64337 and ER64437

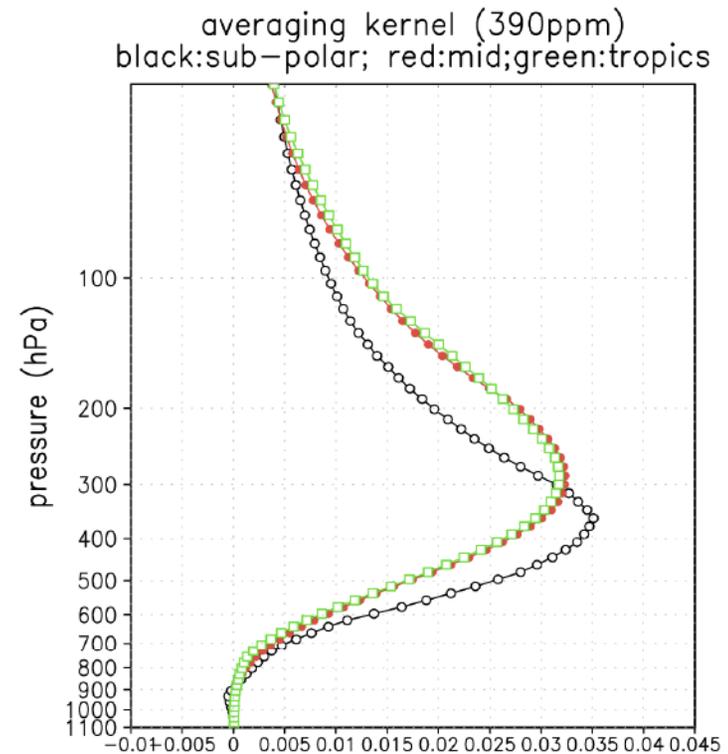
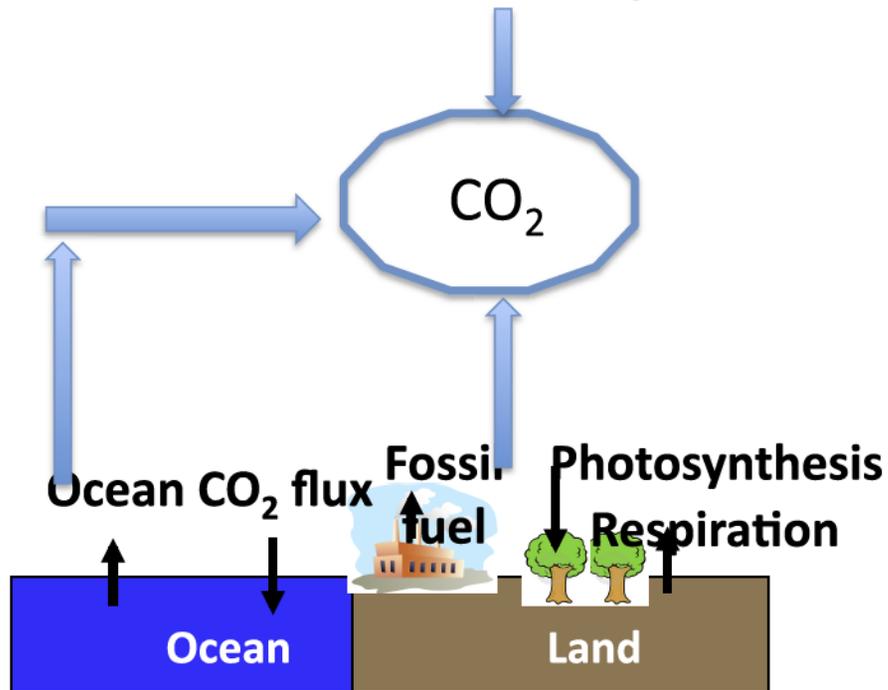
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Motivation



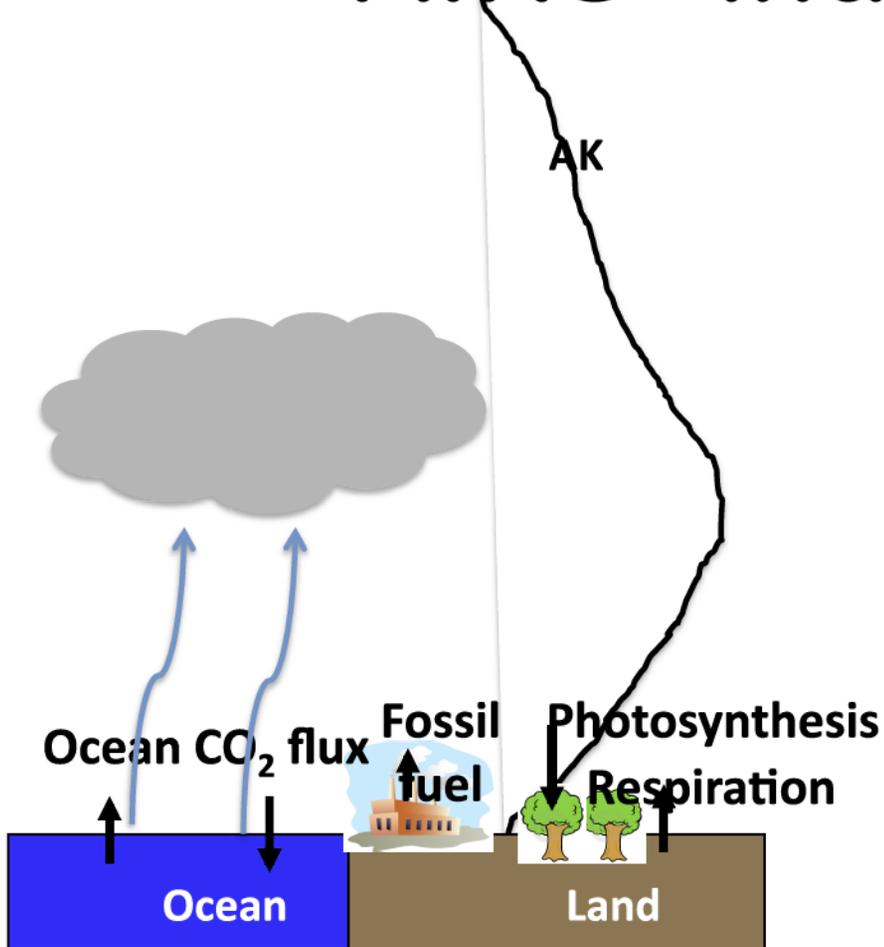
- Mid troposphere CO₂ is a mixture of the CO₂ from remote and local region;
- It involves more complicated transport process to infer surface CO₂ flux when AIRS X_{CO₂} is mainly from remote areas.

Questions



- Could we select AIRS X_{CO_2} which closely connects to local surface flux?
- Where (and when) are these AIRS X_{CO_2} observations?

“AIRS” index definition



$$I(x,y,t) = \frac{ccldfrc(x,y,t) \times \int_{P_{surface}(x,y,t)}^{0.016hPa} \eta \times AK(x,y,P,t) dp}{\int_{P_{surface}(x,y,t)}^{0.016hPa} AK(x,y,P,t) dp}$$

$$\eta = 1, P_{cloud_top} \leq P \leq P_{surface},$$

$$= 0, otherwise$$

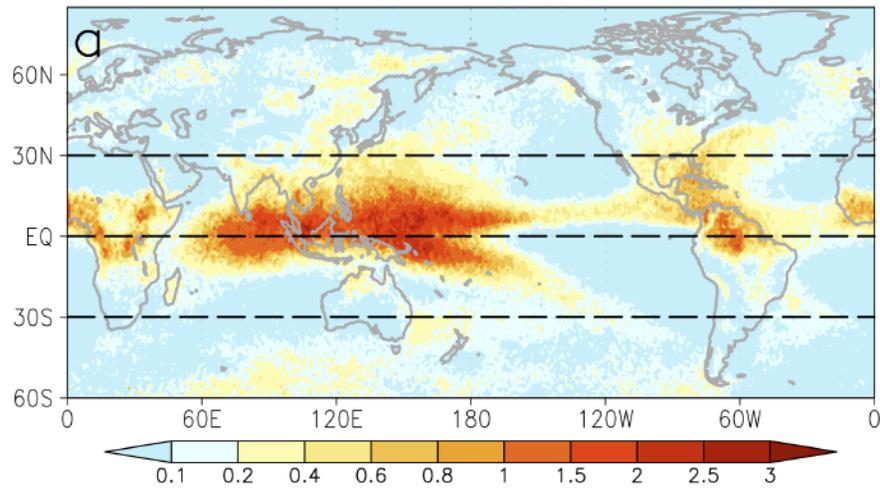
$ccldfrc(x,y,t)$: convective cloud fraction

AK: averaging kernel

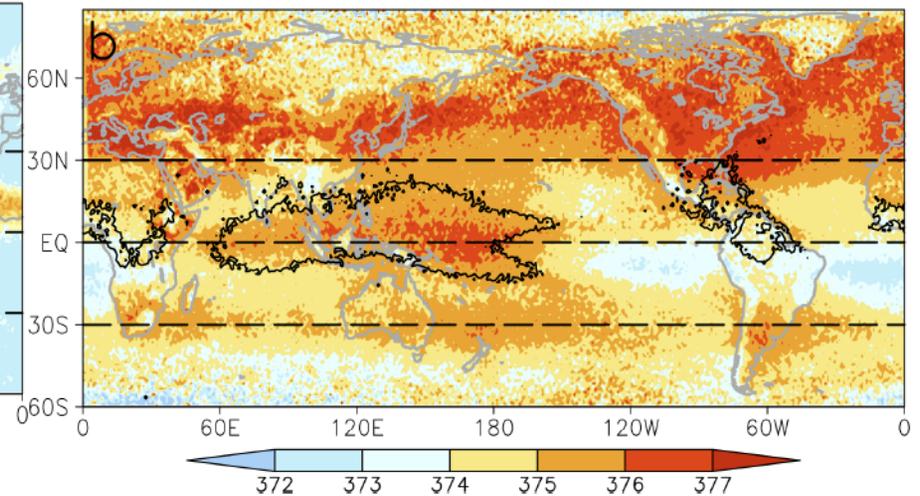
It measures the connection between AIRS X_{CO_2} and local surface CO_2 .

The regions with larger index co-locate with the regions with active convection and larger fossil fuel emission

Annual mean "AIRS" index

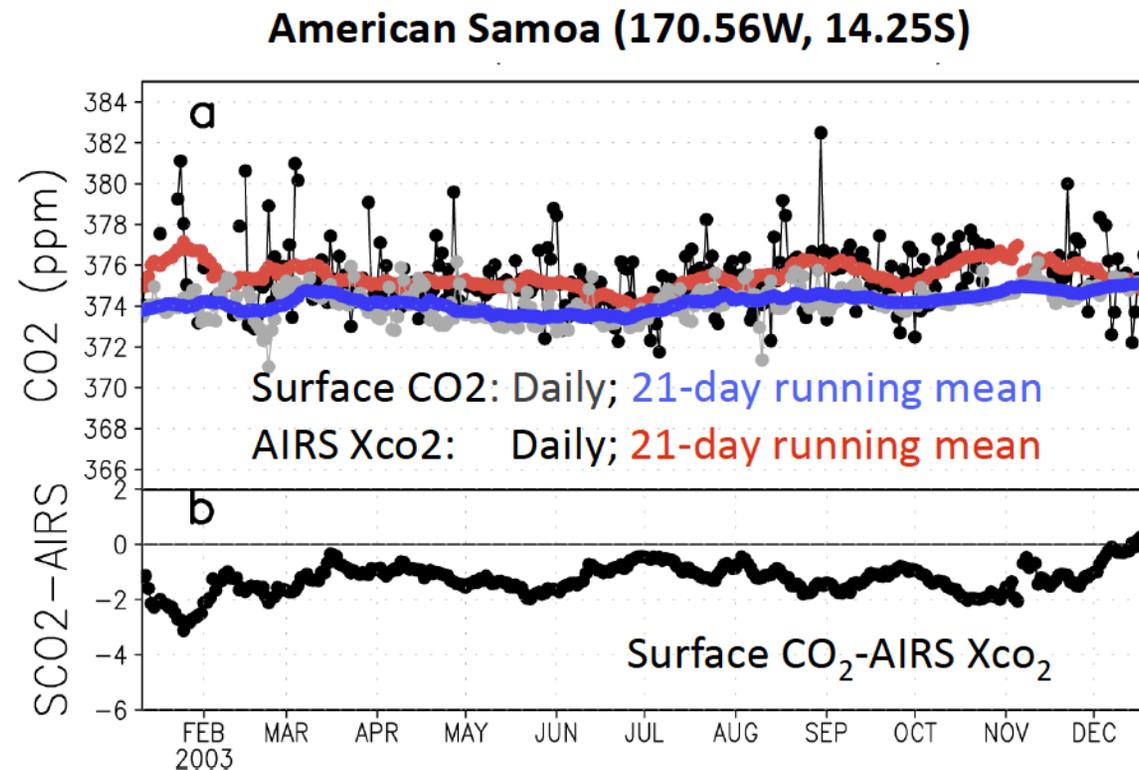


Annual mean AIRS Xco₂ and I=0.6 (contour)



AIRS Xco₂ closely connects to local surface CO₂ in the regions with larger index.

The difference between AIRS Xco₂ and surface CO₂ in convective region is small

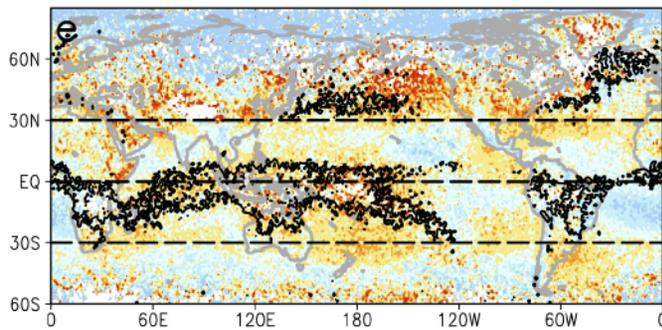


The negative difference may be due to the ocean uptake of CO₂ in the region or the transport of higher CO₂ from the upper troposphere

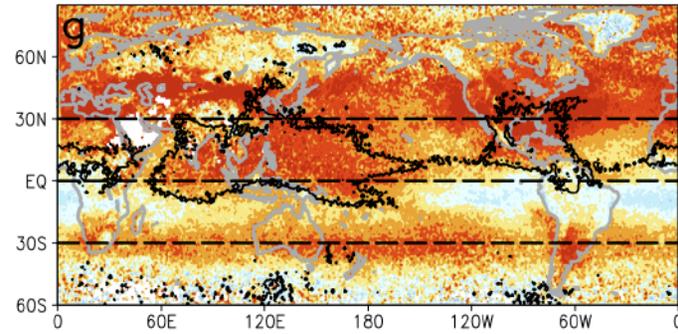
The regions where surface Xco₂ closely connects to local surface move with the movement of convective activity

Average AIRS Xco₂ (shaded, unit: ppm); *index=0.6* (contour)

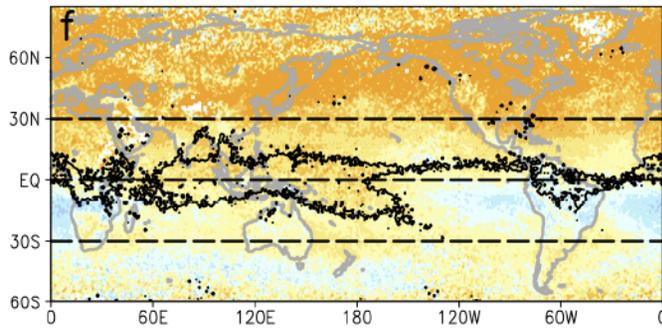
Jan&Feb



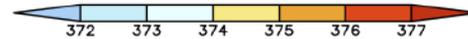
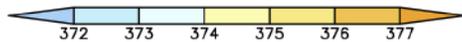
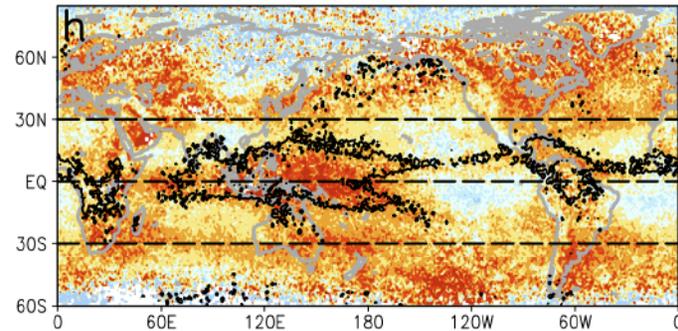
JJA



MAM

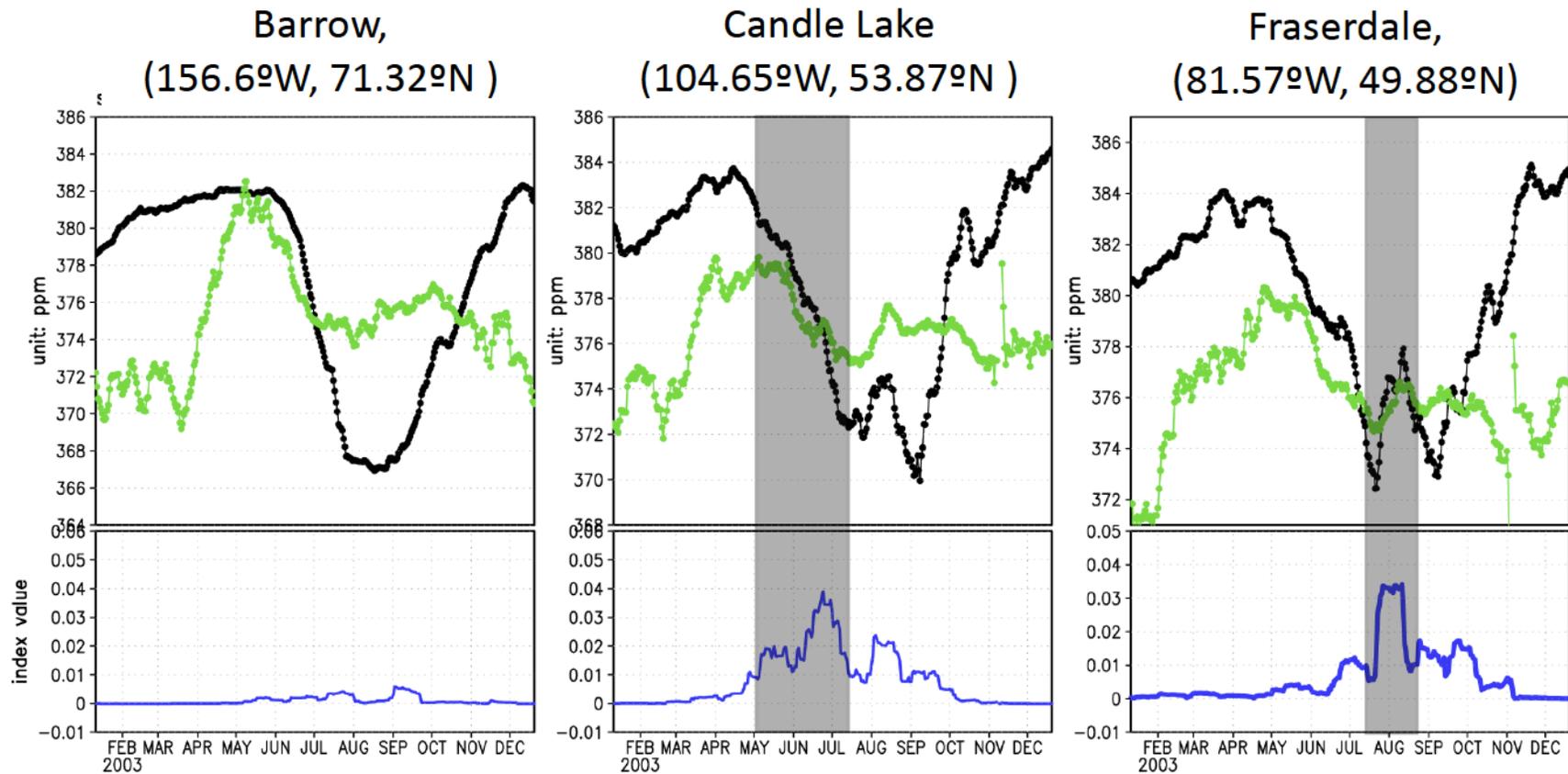


OND



Strong vertical mixing (larger index) makes (AIRS X_{CO₂}-surface CO₂) small

21-day running mean: surface CO₂; AIRS X_{CO₂}; mixing index

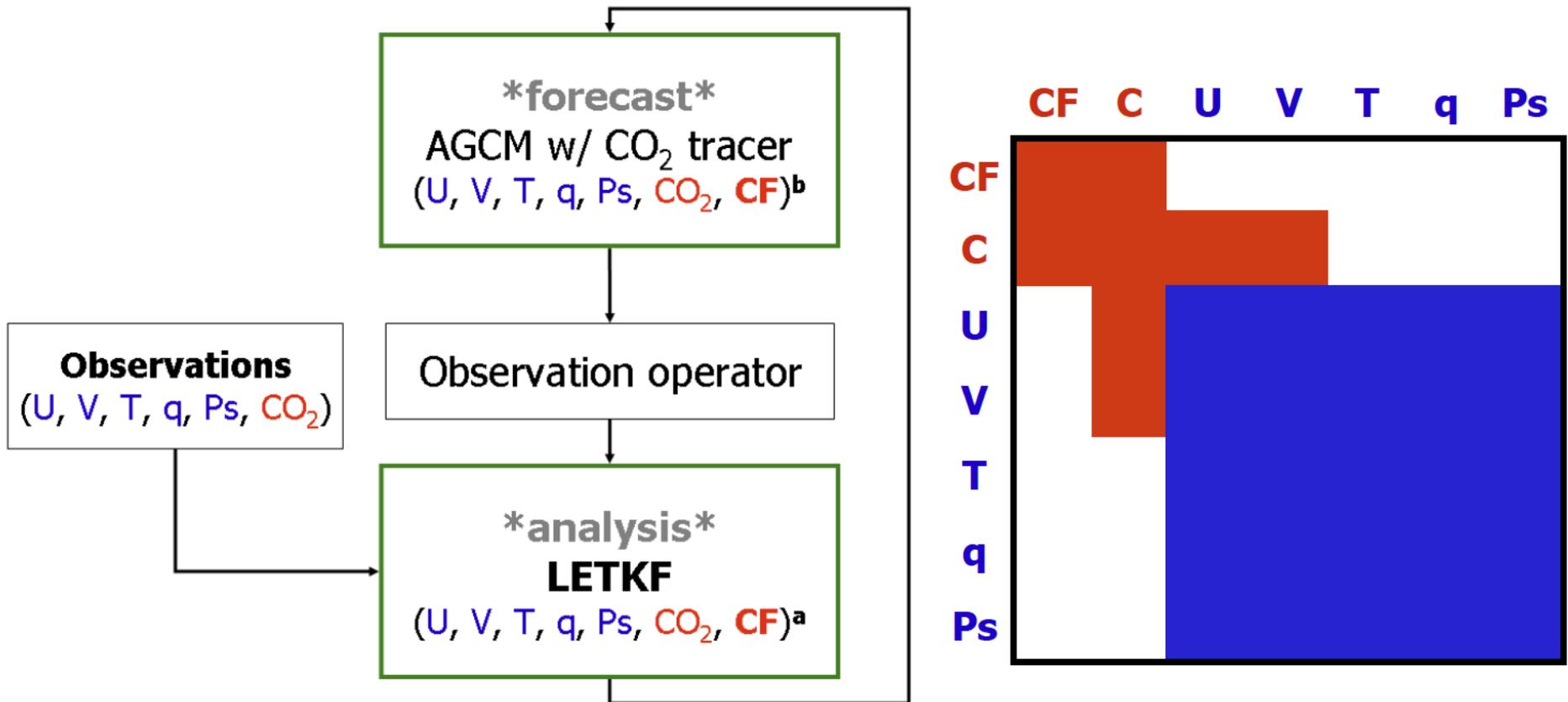


Discussions

- “AIRS” index accounts for convective activity and the vertical sensitivity of AIRS X_{CO_2} .
 - The difference between AIRS X_{CO_2} local surface CO_2 is small where the “AIRS” index is big.
 - The “AIRS” index could select the AIRS X_{CO_2} observations closely connected to local source.
- => Use the “AIRS” index to select the AIRS X_{CO_2} observations in the inversion studies to avoid the transport error from longer transport.

**OSSEs surface flux estimation with simulated
GOSAT and AIRS Xco2 and surface CO₂
network**

Experimental design

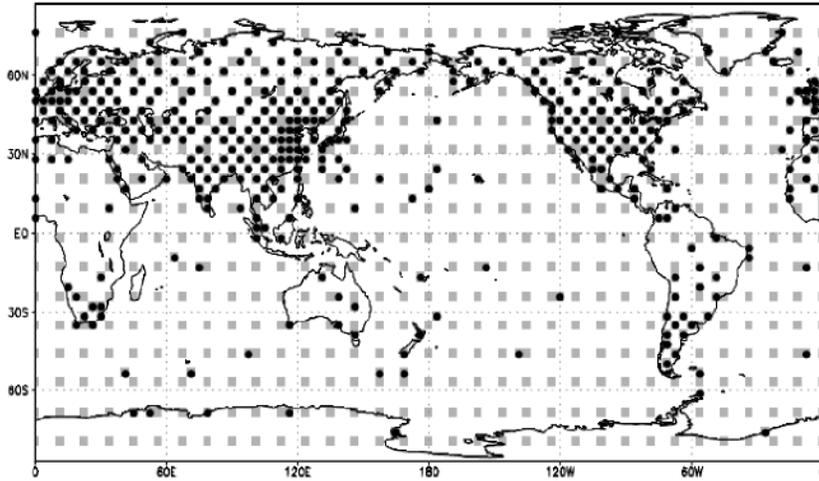


CF: CO₂ flux

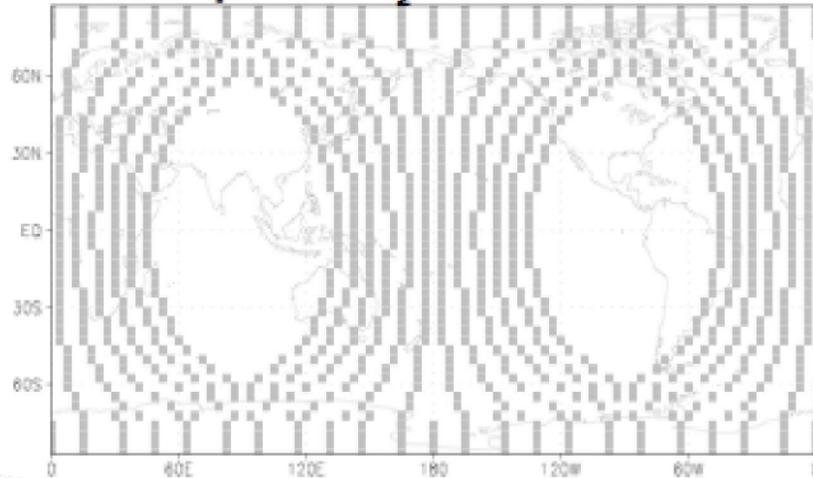
- CO₂ is updated by winds;
- Dynamical variables are updated separately from CO₂;
- No CF observations; CO₂ is used to update CO₂ and CF.

Observation Coverage

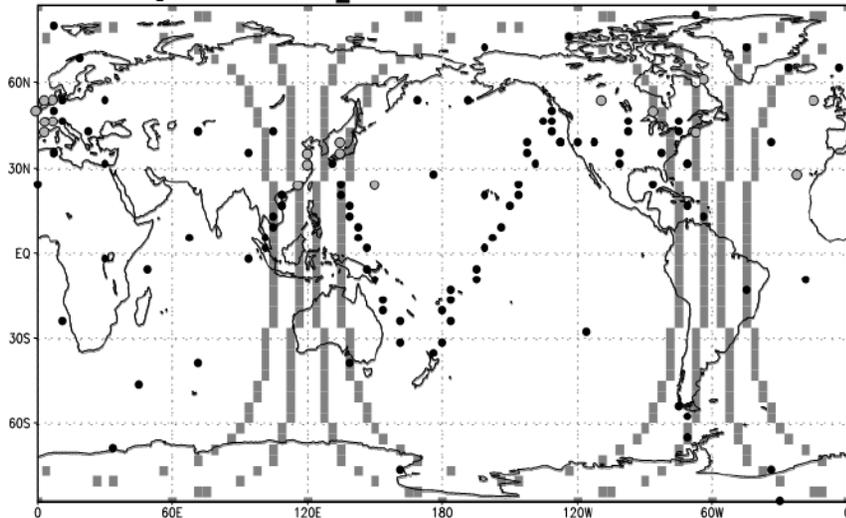
Observations for Meteorological variables



Atmospheric CO₂ observations: AIRS



Atmospheric CO₂ observations: SFC+GOSAT



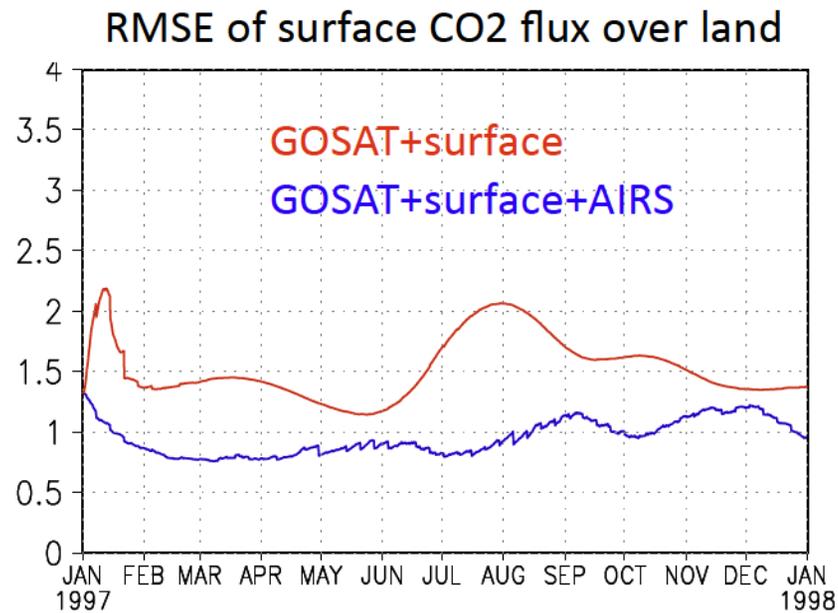
- U, V, T, q at every 12 hours
- Ps at every 6 hours

- Weekly record of CO₂ mixing ratio near the surface
- Every 6 hour record of CO₂ mixing ratio near the surface
- GOSAT column CO₂ mixing ratio for six hour

Experiments

- Exp1: GOSAT+surface+AIRS
- EXP2: GOSAT+surface

AIRS Xco₂ improves the accuracy of surface flux estimation

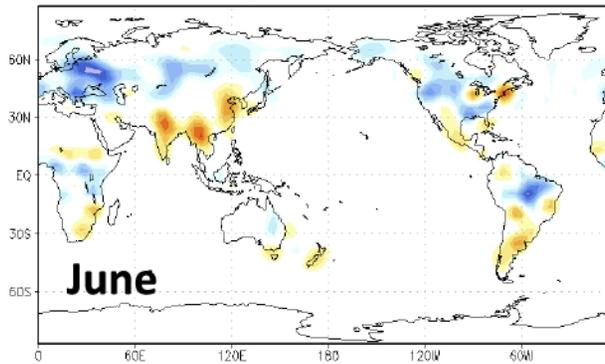


Over land

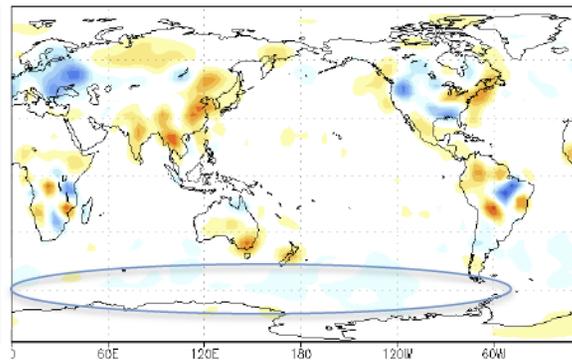
GOSAT+surface recovers most of the surface flux pattern

Truth

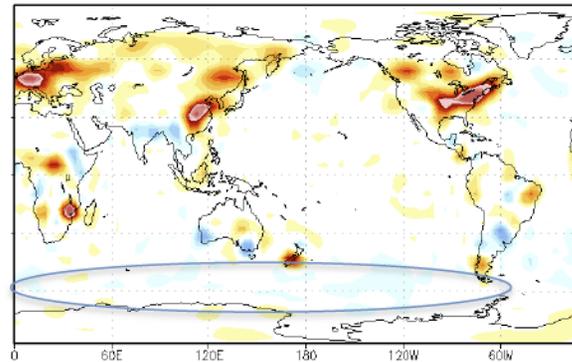
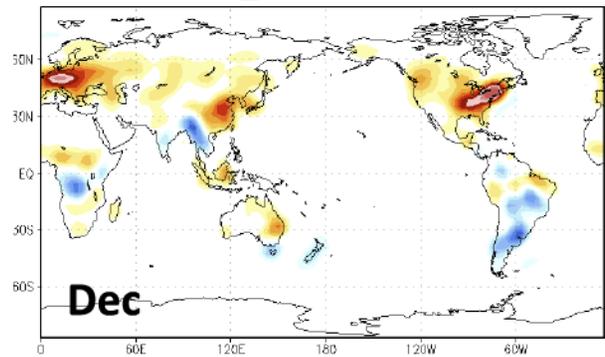
True_CF @ JUN1997



GOSAT+surface



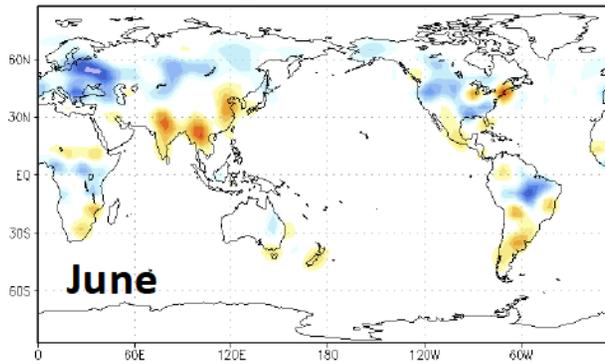
True_CF @ DEC1997



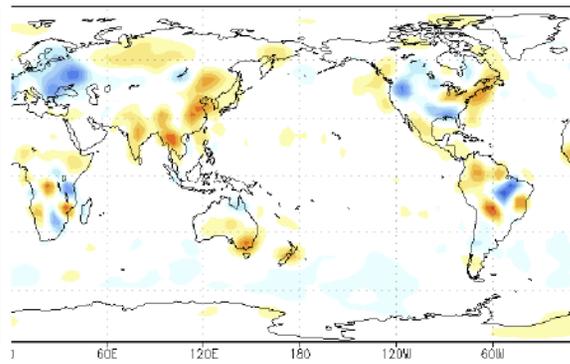
AIRS Xco2 further improves surface flux pattern

Truth

True_CF @ JUN1997

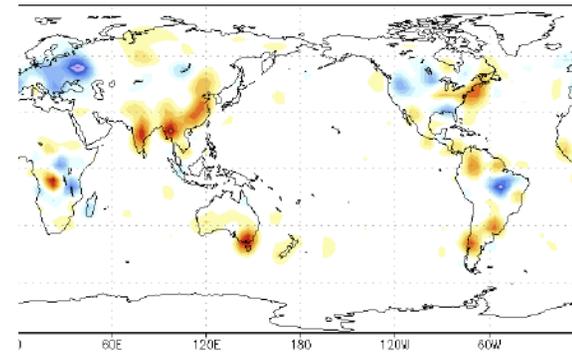


GOSAT+surface

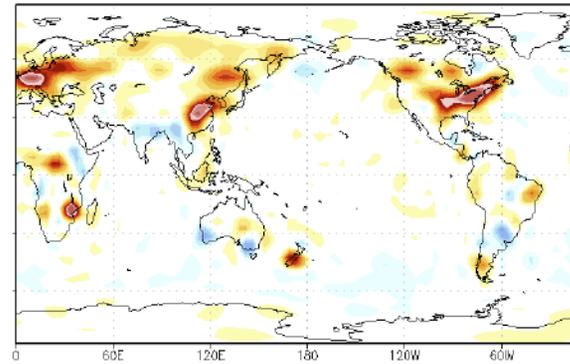
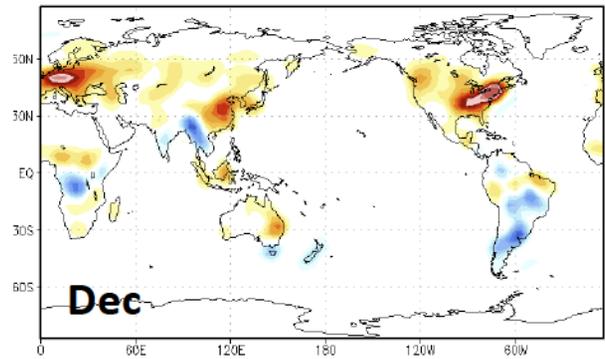


GOSAT+surface+AIRS

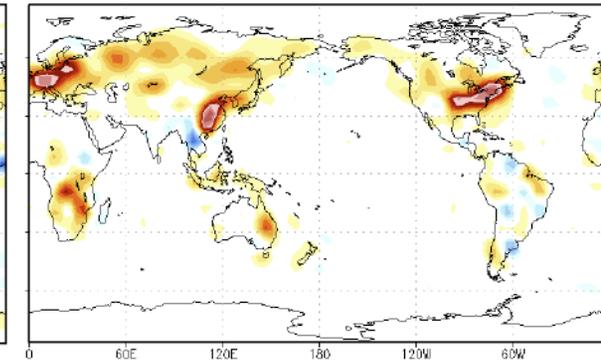
Analysis @ JUN1997



True_CF @ DEC1997



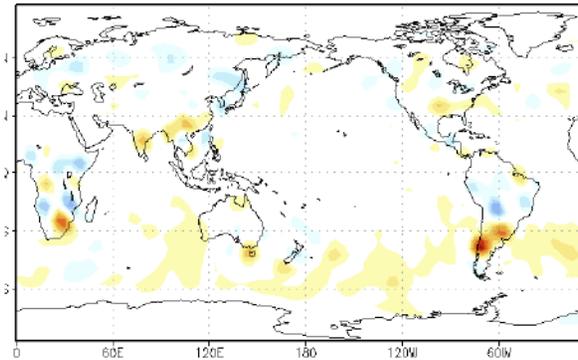
Analysis @ DEC1997



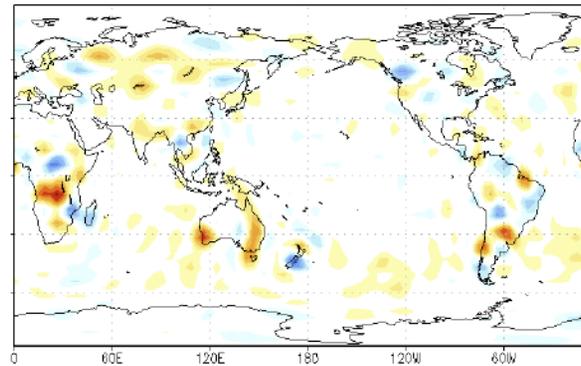
AIRS Xco₂ have strong impact over the SH ocean and tropical land area

All obs-(GOSAT+surface)

Difference of CF [10^{-9} kg/m²/s]



Difference of CF [10^{-9} kg/m²/s]



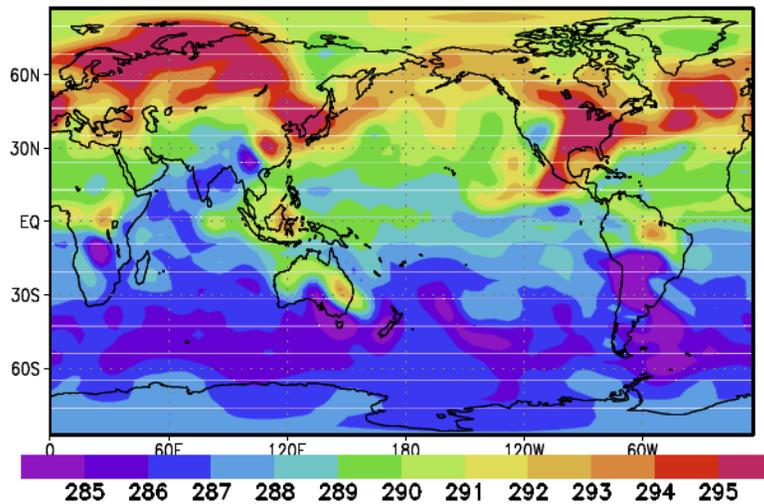
Conclusions and next step

- The LETKF data assimilation system is able to recover surface fluxes of carbon and their time evolution **better when simulated AIRS Xco2 is added** to simulated GOSAT/OCO and surface observations.
- The improvements are especially significant in the tropics and the SH.
- These results do not depend on the use of a priori information of the surface fluxes.
- Several improvements on the methodology of the LETKF were necessary in order to reach these results. They include, for example, the explicit assumption that the short-time changes in total column CO₂ measurements by GOSAT are due to changes in the surface fluxes.

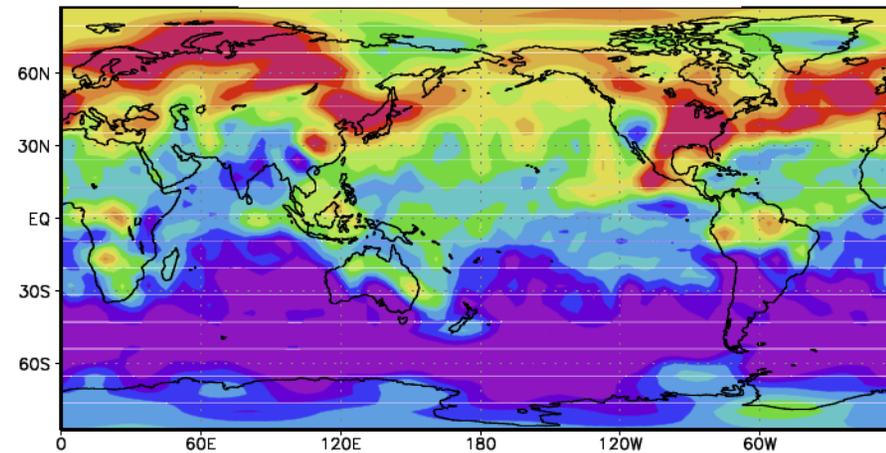
⇒ Estimate surface CO₂ flux with real observations.

AIRS Xco₂ improves the analysis of atmospheric CO₂, especially over the SH

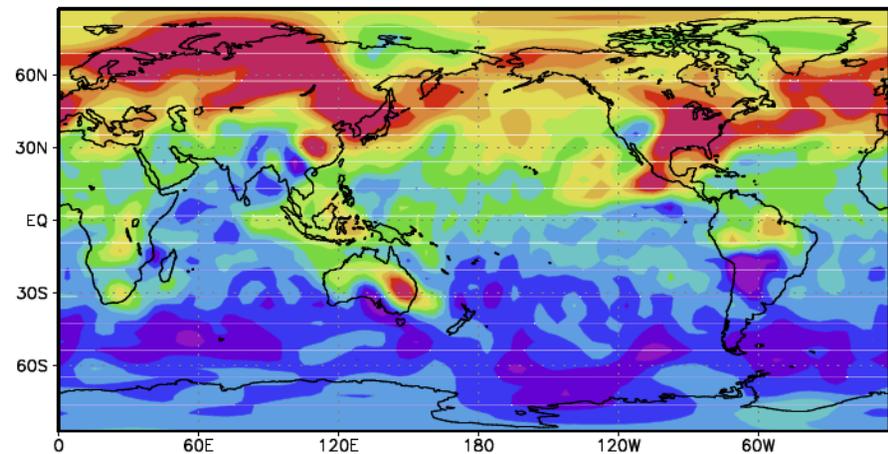
Truth



GOSAT+surface



GOSAT+surface+AIRS



- After one year of analysis