Analysis of AIRS CO2 sensitivity to surface CO2 flux using GEOS-Chem adjoint model

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Motivation and Objectives

Transport and surface flux forcing control the variability of mid-troposphere AIRS CO2

- What is the sensitivity of AIRS CO2 in different latitude bands to surface CO2 flux forcing?
- What is the transport time between source to AIRS CO2 in different seasons?
- What is the comparison of the sensitivity to surface flux forcing between mid-troposphere AIRS CO2 and GOSAT CO2 (column CO2)?
Adjoint sensitivity using 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 $E$.
• Transport time: the time it takes for surface CO2 flux at a region transported to locations that J is defined.

Schematic plot of adjoint sensitivity
Adjoint sensitivity of \((\text{AIRS CO2})_{45S-25S}\)

Sensitivity to instantaneous surface CO2 flux

Sensitivity to CO2 at ~600hPa
Adjoint sensitivity cases

Regions: 45S-25S (green); 20S-20N (orange); and the AIRS CO2 over the whole globe;

Date: July30, Nov30, March30

Schematic plot of adjoint sensitivity case
The sensitivity of AIRS CO2 over 45S-25S to surface CO2 flux forcing

- Nov has shortest transport time between surface CO2 flux forcing and (CO2)_{45S-25S};
- Tropical flux forcing increases (CO2)_{45S-25S} in Nov and July, decreases it in March;
- The NH flux affects (CO2)_{45S-25S} after about 17 days in July.
1. The land surface CO2 flux over 0-30S controls the change of \((CO2)_{45S-25S}\).
2. Indonesia, Amazon and Africa are dominant regions.
The sensitivity of AIRS CO2 over 25S-25N to surface CO2 flux forcing

- Surface CO2 flux forcing quickly transports to $\text{AIRS}_{\text{CO2}}_{25S-25N}$ (less than three days);
- July: ITCZ is at the north of Equator, surface flux beyond 60N affects $\text{AIRS}_{\text{CO2}}_{25S-25N}$.
The sensitivity of AIRS CO2 over the globe to surface CO2 flux forcing

- Surface CO2 flux quickly transports to the NH mid-troposphere in July
AIRS has larger sensitivity over tropics; GOSAT is more sensitive to surface flux over NH in Nov.

AIRS CO2 (good quality) on Nov 30

GOSAT CO2 (good) on Nov 30
AIRS and GOSAT sensitivities complement with each other.
GOSAT has larger sensitivity in mid-latitudes; AIRS has larger sensitivity over the tropics.

**AIRS CO2 coverage on Jul 30**

**GOSAT CO2 coverage on Jul 30**
AIRS has larger sensitivity over tropics; GOSAT has larger sensitivity over mid-latitudes
Conclusions and Discussions

Analyzed the sensitivity of AIRS CO2 at different latitude bands to surface CO2 flux forcing in different seasons, and compared to the sensitivity of GOSAT CO2 observations.

• \((\text{CO2})_{45S-25S}\) is strongly affected by tropical CO2 flux: tropical CO2 flux forcing increases \((\text{CO2})_{45S-25S}\) in Nov and July, decreases it in March;

• AIRS CO2 over tropics has larger sensitivity to surface flux forcing, and the transport time between surface and AIRS CO2 is \(~1\text{day}\);

• Atmospheric circulation affects the sensitivity: in July when ITCZ is in the north of equator, the NH surface flux forcing affects \((\text{CO2})_{45S-25S}\) after 17 days;

• AIRS and GOSAT sensitivities complement with each other: AIRS has larger sensitivity over the tropics; GOSAT is more sensitive to surface flux over the mid latitudes.
Spatial plot comparison
AIRS and GOSAT sensitivities complement with each other

AIRS CO2 coverage on Jul 30

GOSAT CO2 coverage on Jul 30