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# Estimates of CO<sub>2</sub> surface fluxes using an atmospheric inversion method

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- CO2 Fluxes Ensemble Assimilation System(CFEAS)
- CO2 variations
- Flux region definitions
- Results

# ENKF(Ensemble Kalman Filter) Analysis

$$X_t^a = X_t^b + K(Y_t - HX_t^b)$$

$$K = P_t^b H^T (HP_t^b H^T + R)^{-1}$$

X: Unknown regional fluxes

Y: monthly CO2 variations of surface observations ( $Y=AY_0+Y(\Delta x)$ ,  $Y-A_0Y$ )

H :GEOS-Chem trace simulations

P: a prior uncertainty matrix

R: observation error matrix

Lag window  $\longrightarrow$  initial concentrations  $\longrightarrow$  CO2 variations

$$x_i = \bar{x} + x_i'$$

(i=1... N)

$$P = X' X'^T \quad X' = \frac{1}{\sqrt{N-1}}(x_1', x_2', \dots, x_N') = \begin{pmatrix} x_{11}' & \dots & x_{1N}' \\ \dots & x_{mm}' & \dots \\ x_{M1}' & \dots & x_{MN}' \end{pmatrix}$$

$$Y(x)-H(x) \rightarrow Y(\Delta x)-C(\Delta x)$$

$$\sim(\text{obs-mod} \rightarrow \Delta \text{ obs} - \Delta \text{ mod})$$

- $Y_2 = AY_0 + Y(\Delta x)$

$Y_0$ : initial concentration at  $T_0$

$Y_2$ : concentration at  $T_0 + \Delta t$

$A$  is decided by GEOS-Chem

- $Y_2 - Y_0 = (A-1)Y_0 + Y(\Delta x)$

- $Y(\Delta x) = Y_2 - Y_0 - (A-1)Y_0$

- $Y(\Delta x) - C(\Delta x)$

$$= Y_2 - Y_0 - (A-1)Y_0 - [(C_2 - C_0) - (A-1)C_0]$$

$$= \underline{Y_2 - Y_0} - \underline{[(C_2 - C_0) - (A-1)C_0 + (A-1)Y_0]}$$

$$Y(\Delta x)$$

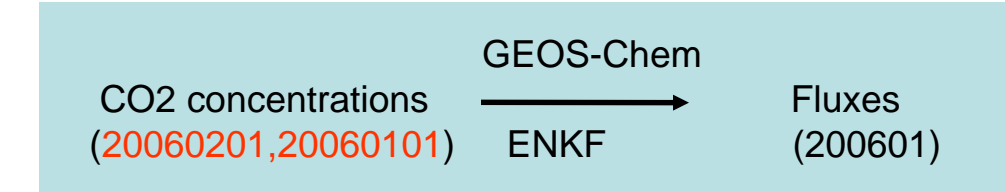


monthly CO2 variations

$$C(\Delta x)$$

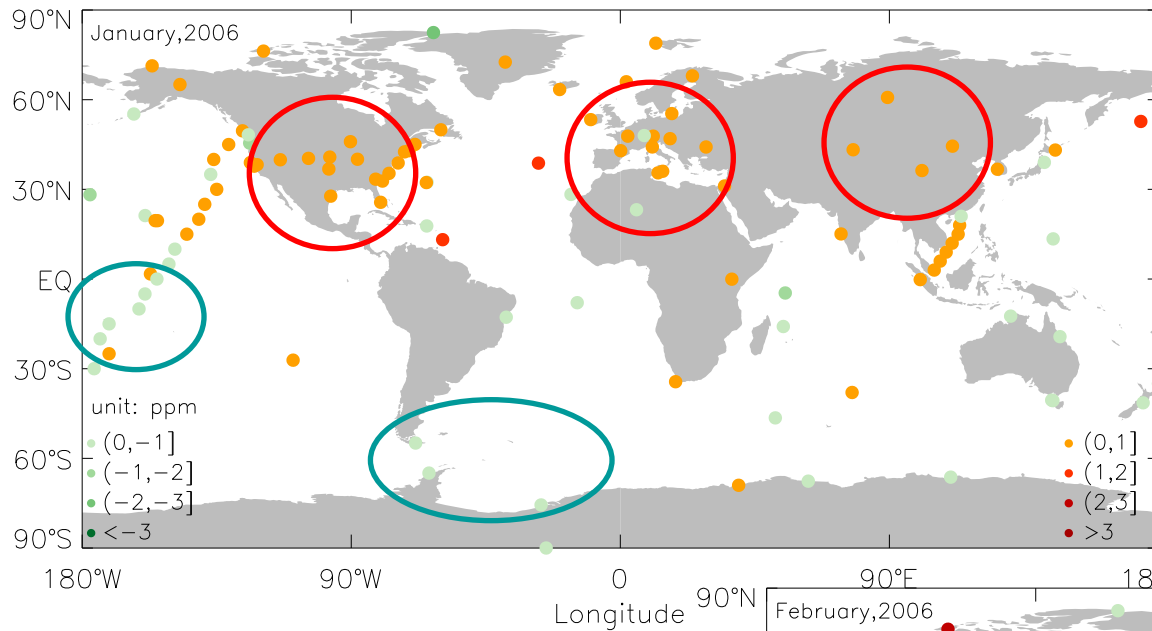


monthly fluxes



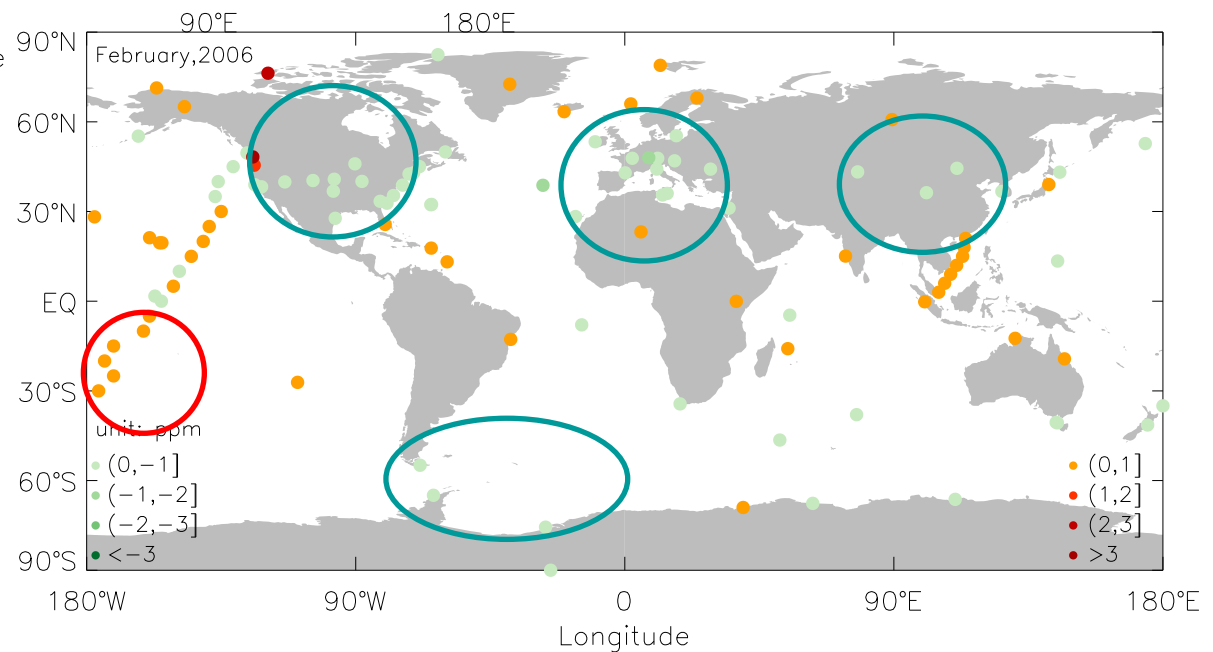
- Observations:CO2 variations
- No lag windows.
- One monthly fluxes will be updated based on the CO2 variations in one month
- Fluxes during the initial time and the end time (daily, hourly, weekly....)

# CO2 variations(Globalview-CO2)

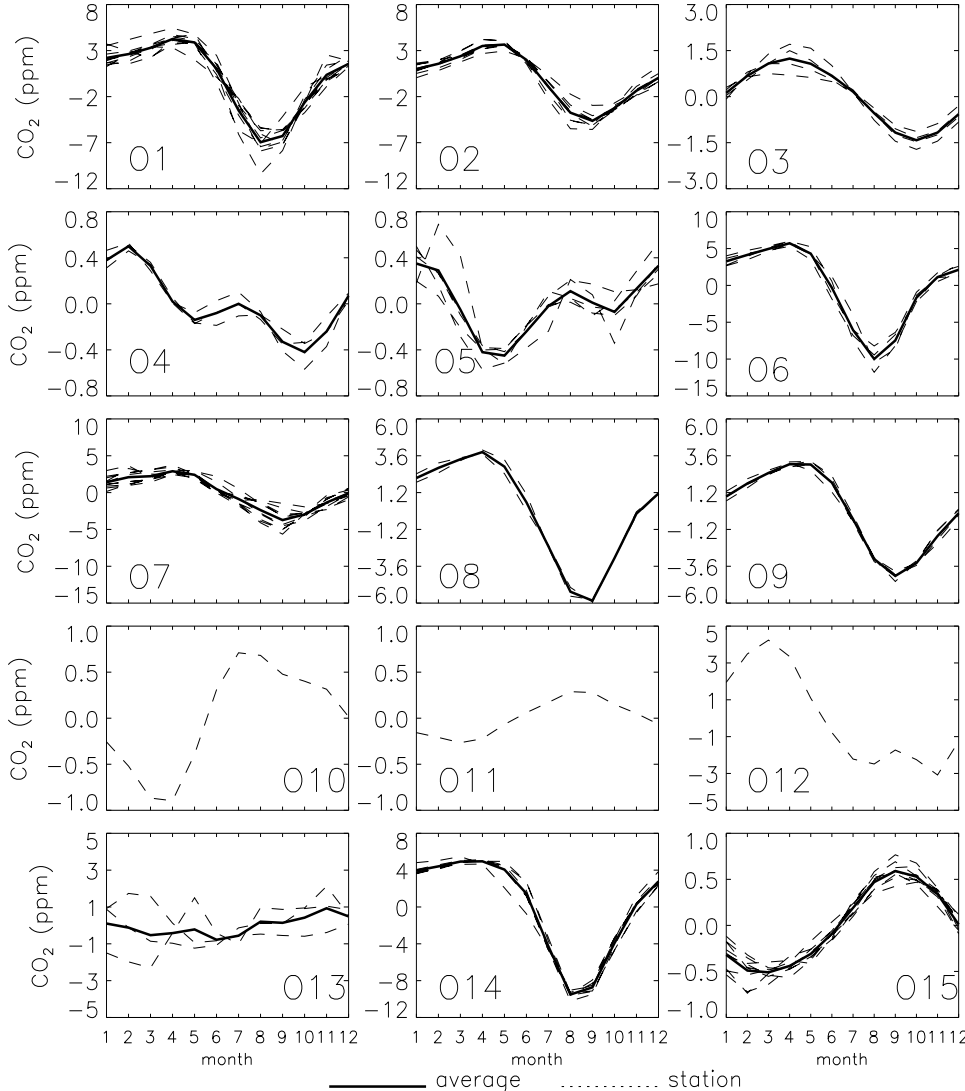


Green: negative,  
CO2 decreases  
possible sinks

Red: positive,  
CO2 increases  
possible sources

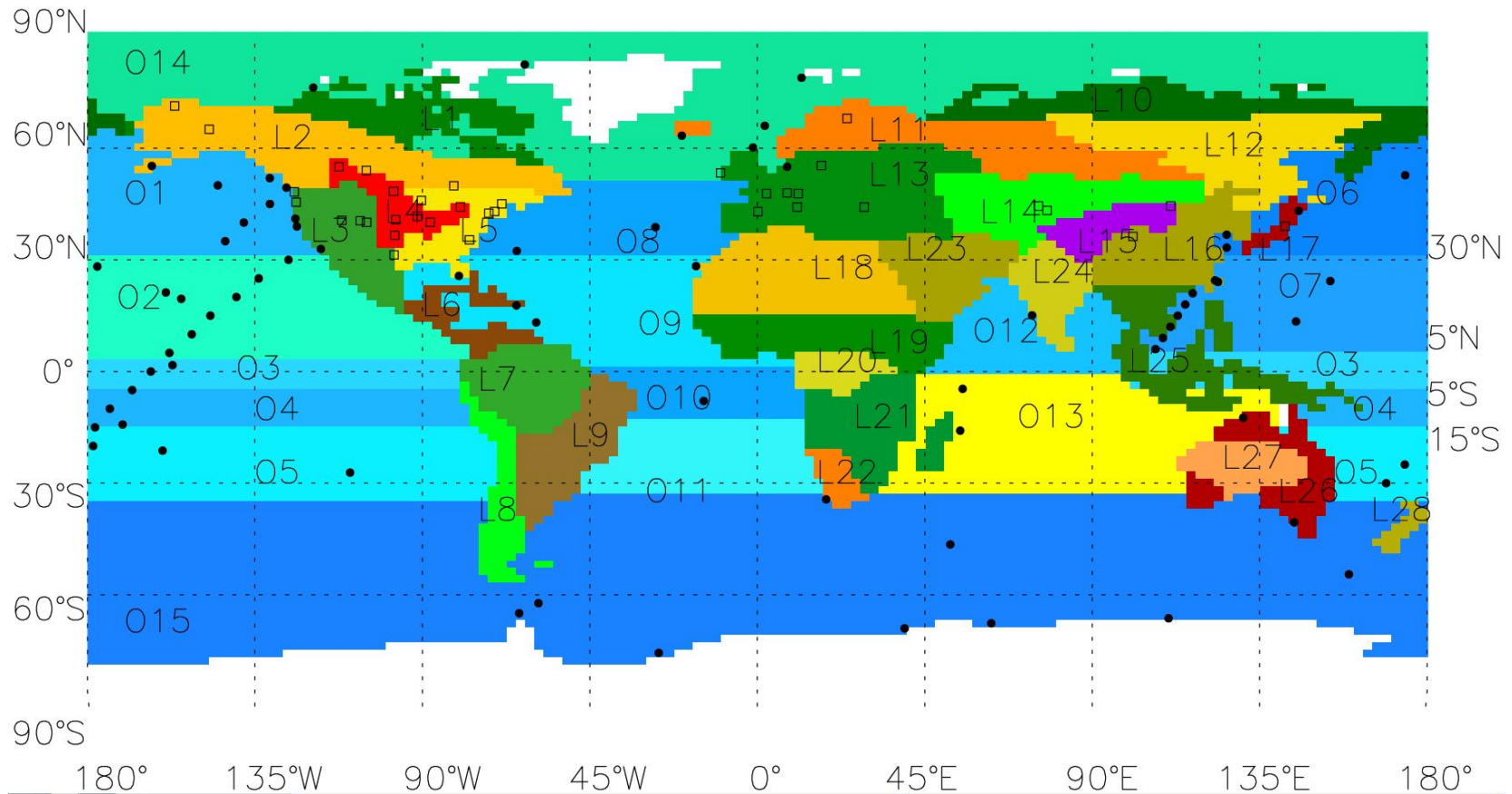


# Regional fluxes~ Regional CO2 concentrations



- 01: North East Pacific
- 02: North East Pacific Temperate
- 03: Pacific Tropics
- 04: South Pacific Tropics
- 05: South Pacific Temperate
- 06: North West Pacific
- 07: North West Pacific Temperate
- 08: North Atlantic
- 09: North Atlantic Temperate
- 010: Atlantic Tropics
- 011: South Atlantic Temperate
- 012: Indian Tropical
- 013: South Indian Temperate
- 014: Northern Ocean
- 015: Southern Ocean

# Surface Flux Inversions



15 ocean regions(seasonal cycles)+28 land regions (Nassar et al.2011)

Pseudo data experiments: N~100

“true” fluxes: monthly net land fluxes (nep from CASA); Prior fluxes: nep from CASA \*80%

“true” fluxes: Monthly net ocean fluxes(Takahashi,2009) ;Prior fluxes: Yearly net ocean fluxes(Takahashi,2002)

Observations: Pseudo data (20060201 20060101)

Estimates of mean regional fluxes :200601

Prior error : tropical land regions:200%,other land regions:150%

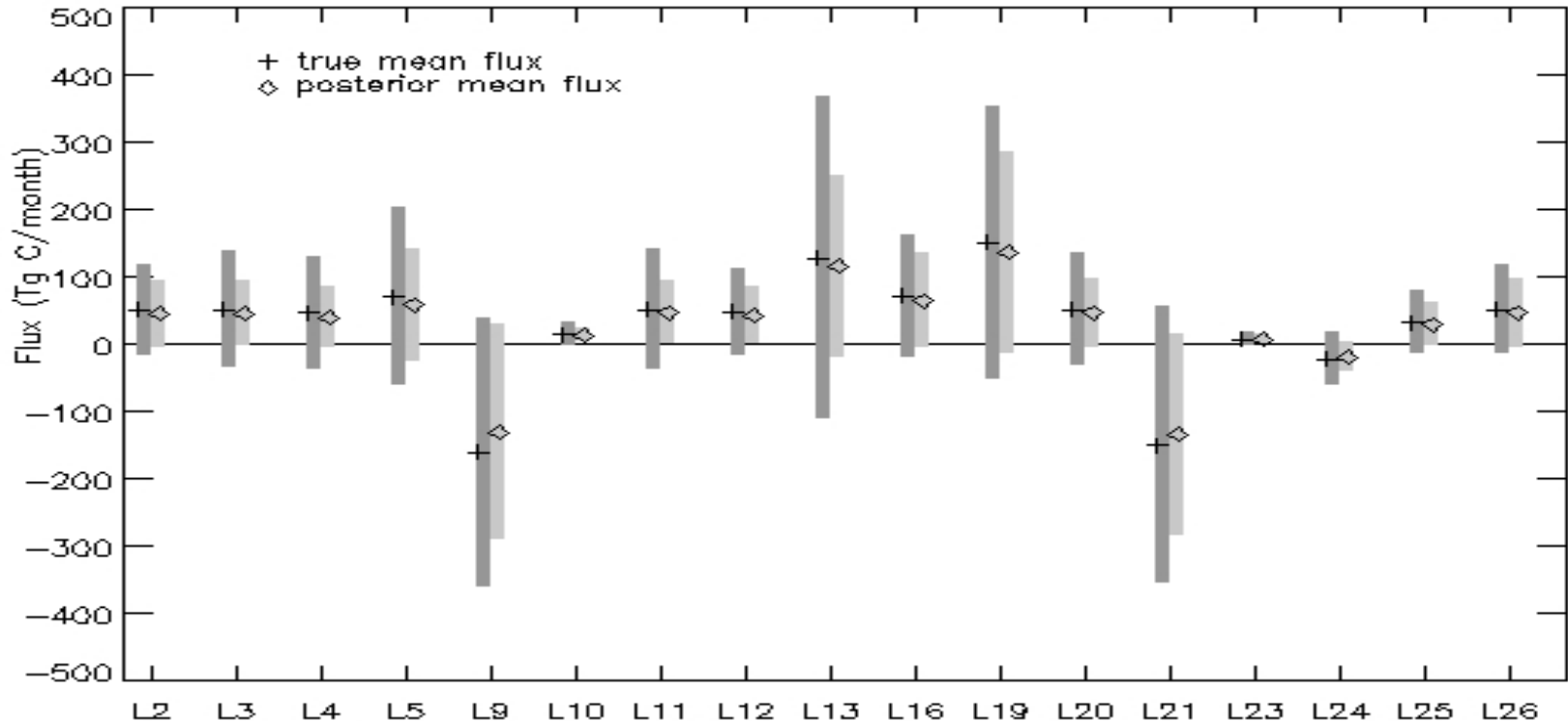
tropical ocean regions:120%,other ocean regions:100%



# Prior fluxes

- Net Land-atmosphere fluxes  
(fossil+nep+biomass burning+biofuel  
burning+residual annual terrestrial  
exchange)  
sinks=net fluxes(inversion results)  
- sources(different scenarios)
- Net ocean-atmosphere fluxes

# Pseudodata Experiment



Left error bar: Root Mean Square  
Error of the true fluxes  
Right error bar: Root Mean  
Square Error of the post fluxes

North American : L2, L3, L4, L5  
South American: L9  
Europe and Asia: L10, L11, L12, L13, L16, L23, L24  
Africa: L19, L20, L21  
Tropical Asia : L25  
Australia: L26

# Ongoing work

- More observation(GOSAT,...) in CFEAS
- Assimilate CO<sub>2</sub> surface fluxes and initial concentrations in CFEAS

**Thanks for your  
attention !**