Carbon Cycle Data Assimilation within LETKF

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LETKF for carbon cycle

- **Simultaneous** assimilation of meteorological and CO$_2$ variables within LETKF
  - Assimilating meteorological variables ($U, V, T, q, Ps$) & **atmospheric CO$_2$ concentration** (ground based in-situ data, satellite)

- State vector augmentation for estimating **surface CO$_2$ fluxes**

- **Variable localization**
  - zeroes out the background error covariance among prognostic variables that are not physically related, thus reducing sampling errors

- Adaptive inflation (Miyoshi, 2010) + additive inflation for C & CF
Observing System Simulation Experiments

- Realistic observation coverage
  - Meteorological variables: conventional data
  - Atmospheric CO$_2$: ground-based in-situ data (18 continuous & 107 weekly records in the globe), GOSAT (column, orbit returning in 3 days)

- Imperfect model for CF forecast
  - Nature run: CF is varying in time
  - Forecast model: it is a persistence forecast of CF which is only updated by the analysis

- Current issues
  - Analysis of CF does not follow a reasonable changes in time after a good convergence even starting from a random initial condition (no a-priori)
Preliminary Results-1

- Updating column CO$_2$ in the analysis

After three months of the data assimilation, the Time series of CF for one year is shown.

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How to assimilate CO₂ column data

- **Vertical localization of column data**
  - **CTRL**: Using the averaging kernel
    \[ y^b = h(x^b) = A^T (Hx^b) = \sum_{i=1}^{k} a_i (Hx_i^b) \]
    \[ \Delta y_i^{o'} = a_i \times (y^o - h(\bar{x}^b)) \]
  - **EXP**: Using the column CO₂ data for updating the atmospheric CO₂ in the lowest layer only
    \[ \Delta y_i^{o'} = a_i \times (y^o - h(\bar{x}^b)) \Rightarrow a_1 = 1.0, a_2^i = 0.0 \]
Preliminary Results-2

- Updating atmospheric CO₂ on the lowest layer

After one year of the data assimilation
Summary

- **Vertical localization of column CO₂ data**
  - Updating a full column of atmospheric CO₂
    ✓ Analysis of CF converges to a reasonable pattern, but it does not vary in time after the convergence
  - Updating the lowest layer’s CO₂ only: preliminary results
    ✓ CF analysis does not get stuck in time, but the spatial pattern of CF signals is TOO noisy
    ✓ We still need to further tune some parameters
      - Initial value for the adaptive inflation
      - Amplitude of additive inflation for C & CF
  - Updating the lowest two or three layers’ CO₂ can be examined
The END

Thank You
Observations for meteorological variables

Conventional data for \( (U, V, t, q) \)
- at the surface & the upper layers
  - at every 00Z & 12Z

Conventional data for \( P_s \)
- at the surface
  - at every six hours
Observations for atmospheric CO$_2$

- GOSAT (CO2 column data)
- Continuous in-situ data on the surface
- Weekly data from flasks on the surface
Initial conditions: no *a-priori* information