Estimation of Surface Fluxes with an Advanced Data Assimilation Methodology
Carbon, Heat, and Moisture

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❑ Introduction

We have developed an advanced analysis system to estimate surface fluxes through assimilating data observed in the atmosphere, as a "top-down approach". Surface fluxes are estimated by a state vector augmentation (e.g. Baek et al. 2005, Annan et al. 2005) within the Local Ensemble Transform Kalman Filter algorithm (Hunt et al., 2007). We have done two independent experiments: one is to estimate surface CO_2 fluxes (EXP1), and the other is to estimate sensible and latent heat fluxes at the surface (EXP2). Those fluxes are considered as time-varying parameters defined at every model grid of the surface.

❑ Methods [Observing System Simulation Experiments, OSSEs]

- Intermediate-complexity AGCM
  - EXP1: SPEEDY-C (Kang, 2009)
  - EXP2: SPEEDY (Molteni, 2003)

	EXP1	EXP2
Estimated fluxes	**Surface CO_2 fluxes (CF)**	**Sensible & latent heat fluxes (SHF & LHF)**
True fluxes [Nature run]	Fossil fuel emission[1] Terrestrial fluxes[2] Oceanic fluxes[3]	Fluxes of the original SPEEDY

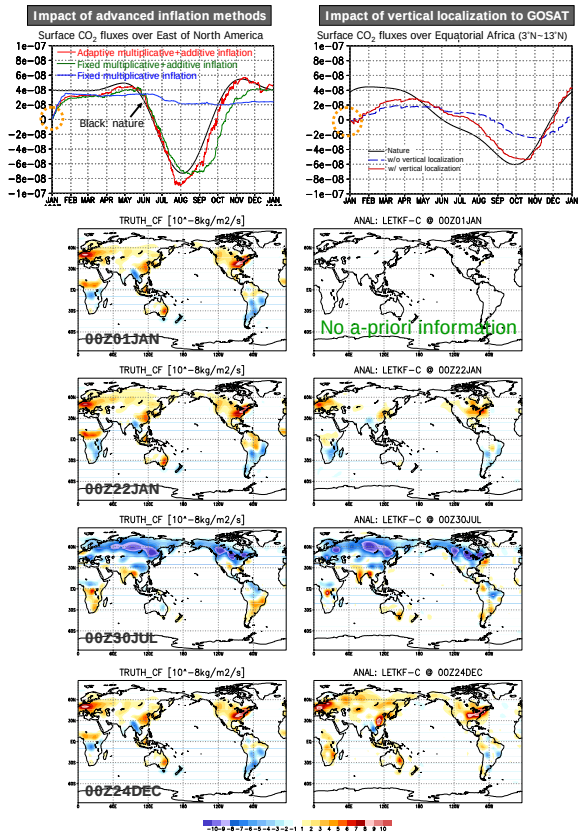
([1] Andres et al., 1996, [2] Randerson et al. 1997, [3] Takahashi et al., 2002)

- **Persistence forecast** of surface fluxes
  - Fluxes are updated only by the analysis step
- **Parameter estimation:** state vector (**X**) augmentation
  - EXP1: **X**=(**U, V, T, q, Ps, C**, **CF**)
  - EXP2: **X**=(**U, V, T, q, Ps**, **SHF**, **LHF**)
  - Fluxes are neither measured nor predicted
- Random initial conditions
  - ➔ ***No prior information***
- **Advanced inflation methods**
  - Adaptive multiplicative inflation (Miyoshi, 2011) and additive inflation
- System for estimating **Surface CO_2 fluxes**
  - "**Localization of variables**" for carbon flux estimation (Kang et al. 2011)
  - **Vertical localization** of column mixing CO_2 data (GOSAT or OCO-2) for constraining near-surface CO_2

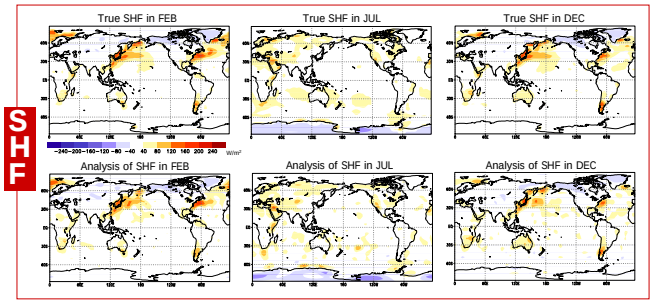
❑ Experiments

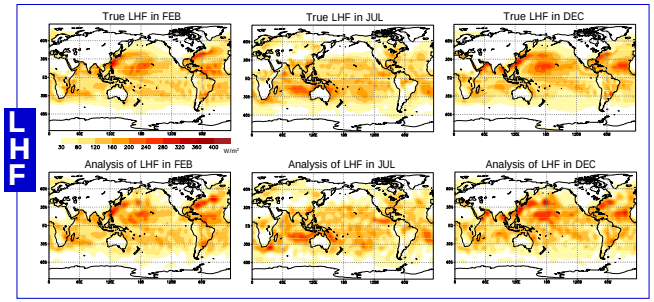
- **Estimation of surface CO_2 fluxes**
  - Conventional data for weather variables: rawinsondes
  - Near-surface in-situ and flask CO_2 data: 18 hourly and 107 weekly observations
  - GOSAT column mixing CO_2 data
  - AIRS CO_2 retrievals sensitive to CO_2 in the mid-troposphere
- **Estimation of sensible and latent heat fluxes**
  - Conventional data: rawinsondes
  - Temperature and humidity profile data from AIRS retrievals

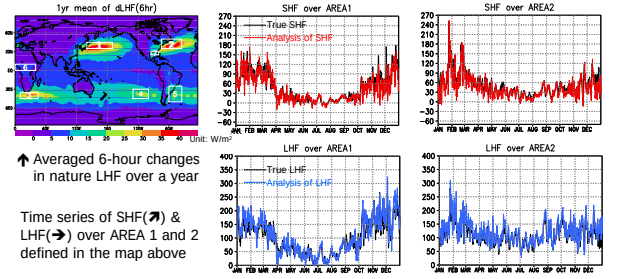
❑ Results: Surface CO_2 fluxes



❑ Results: Sensible & Latent heat fluxes







↑ Averaged 6-hour changes in nature LHF over a year

Time series of SHF(↗) & LHF(➔) over AREA 1 and 2 defined in the map above

Recall that LHF & SHF are updated only by the data assimilation here!

❑ Summary

We succeeded in estimating time-evolving surface fluxes of carbon, heat and moisture through the state vector augmentation within the Local Ensemble Transform Kalman Filter algorithm. It is essential to have a good background error covariance among the fluxes and other prognostic variables of the state vector in the flux inversion problem.