Data Assimilation and Carbon Cycle Working Groups

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What is Data Assimilation?

A framework for combining uncertain observations and a “forward” model with uncertain parameters and initial/boundary conditions to produce an “analysis” model that is statistically consistent with both.

Motivation:

1) Quantitatively attribute differences between predictions and observations to “known” unknowns.
2) Observations provides limited spatial and temporal coverage => data assimilation as interpolation
3) Produce more reliable forecasts of the state of the atmosphere using models
4) Combine data from difference sources, with different uncertainties, to obtain a consistent and optimal model.
Composition Data Assimilation with GEOS-Chem

4-Dimensional Variation Data Assimilation (4D-Var)
• Full chemistry state and source estimation
• CO₂, CH₄, N₂O source (flux) estimation

3D-Var
• Full chemistry state estimation

Kalman Filter
• Full chemistry state estimation
• CO₂ state estimation

Ensemble Kalman Filter (EnKF)
• CO₂, CH₄ flux estimation

Local Ensemble Transform Kalman Filter (LETKF)
• CO₂, CH₄ flux estimation
• Full chemistry state and source estimation
Examples of Recent Applications

Inverse modeling of OMI NO$_2$ observations


Inverse modeling of in situ surface and aircraft observations of N$_2$O

Examples of Recent Applications

Multi-constituent chemical data assimilation and the implementation of an ensemble Kalman filter (EnKF) for chemical data assimilation in GEOS-Chem

Estimated surface CO and NO$_x$ emissions in July 2010

Assimilation of TES O$_3$ in GEOS-Chem-EnKF in July 2005

Zhang et al., Quantifying emissions of CO and NO$_x$ using observations from MOPITT, OMI, TES, and OSIRIS, (in preparation).

Miyazaki et al., Development of a tropospheric chemistry data assimilation system: GEOS-Chem-EnKF, (see Poster A.26 this afternoon).
Recent Carbon Cycle Applications

Inverse modeling of regional CO₂ and CH₄ fluxes


New high-resolution CH4 emission inventory

WetCHARTs v1.0: wetland CH$_4$ emissions and uncertainty dataset

9 terrestrial carbon cycle models (MsTMIP & CARDAMOM) × 3 CH$_4$:CO$_2$ temperature parameterizations × 4 wetland extent parameterizations = Monthly 0.5° emission and uncertainty

9×3×4×3 global scale factors = 324 ensemble members

GCHP successfully applied to simulate CO$_2$

in 2015. C180 (~0.5°) simulation on Pleiades:
Run on 72 cores across 3 nodes (IFORT 15, SGI MPI)
1 simulation month in ~4 hours

Driven by 0.5° MERRA-2 meteorological data*

2015 CO$_2$ fluxes from NASA CMS-Flux (uncorrected)
Development Priorities for Adjoint/Assimilation and Carbon Cycle WGs

• The insatiable demands of Time and Space:
  • Spatial resolution of operational atmospheric assimilation models are pushing to 10-15km.
  • Climate and carbon studies are pushing to decadal scales.
• How to adapt to GCHP?
• Adjoint/forward model divide: How to keep up?
• Advances in data assimilation methodologies:
  • Multi-constituent chemistry and carbon species
  • Weak constraint 4D-var
  • Model reduction strategies
  • Hybrid schemes
• Preparation for the fire-hose of data: TEMPO, GeoCARB and TROPOMI
• Carbon Cycle as Earth System Science
  • Carbon-chemistry
    • Time-evolving chemical source
    • Biogenics and carbon
  • Carbon-climate: future winds?
  • Carbon coupling: oceans and terrestrial models
WG network

Adjoint/Assimilation WG

Carbon WG

Transport WG

High Performance WG