National Aeronautics and Space Administration

Developing a Coupled Weather-Composition OSSE System for Future Mission Formulations

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Program: FY21 R&TD Topics **Strategic Focus Area: Atmospheric composition and dynamics**

Objectives

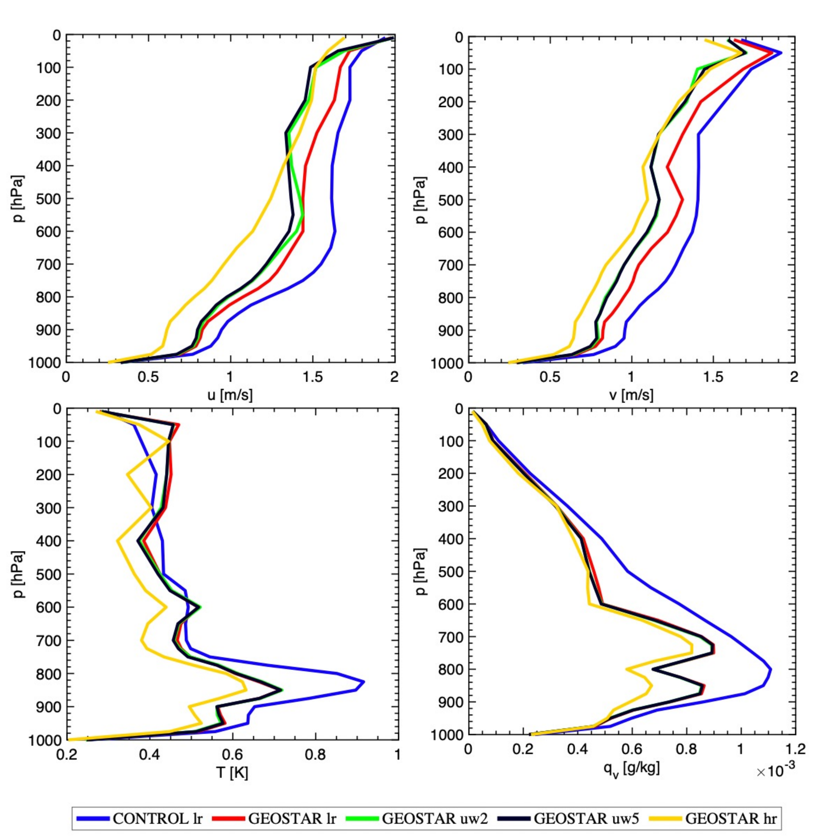
The objective of this project was to reduce uncertainties in chemical transport and carbon flux inversion estimates and accurately assess the impacts of the future weather and composition missions on CO_2 flux inversion by developing a coupled weather-composition Observing System Simulation Experiment (CWC-OSSE) System.

Background

Accurate inference of surface CO2 fluxes from atmospheric CO2 observations requires not only high-quality atmospheric CO2 measurements but also improved measurements of meteorological fields including temperature, humidity and wind profiles.

A CWC-OSSE system is needed to assess the impacts of weather and composition missions on weather, chemical and climate processes in an integrated and physically consistent manner.

Results



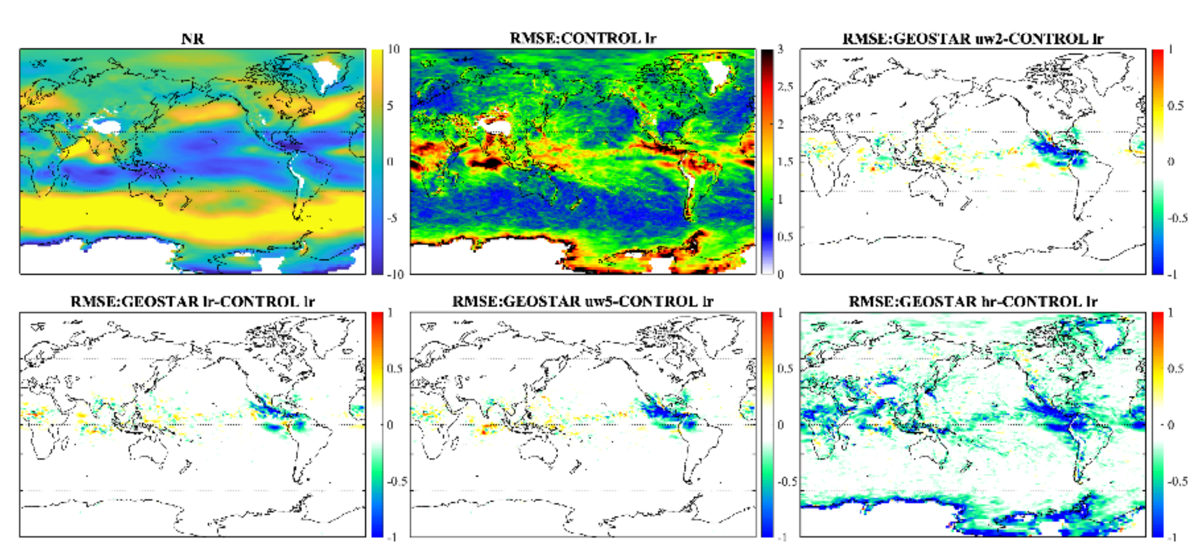


Figure 2. Two-month averaged zonal wind from nature run (NR; top left panel), RMSE of zonal wind for CONTROLlr simulation (middle upper panel) and the differences between the RMSE from four simulations and CONTROLlr simulation (upper right and lower panels) at the height of 750hPa. All RMSEs are computed with respect to the NR.

Figure 1. Vertical profiles of RMSE of zonal and meridional wind speeds (u and v), temperature (T) and water vapor (qv) from the five simulations. The RMSE is computed with respect to the reference NR simulation. Colored lines for RMSEs represent different simulations, as indicated by the legend.

Significance

- The CWC-OSSE is strategically important to prepare JPL for the competition of future Explorer missions and other Earth Venture missions, as well as for the PBL incubation mission study, particularly useful to address the synergy between different Explore Target Observables, e.g., between Atmospheric Winds and Greenhouse Gases.
- It is a natural springboard to build an integrated Earth System OSSE framework that would include the interactions between atmosphere, land, ocean and cryosphere to enable designing integrated cost-effective Earth observing systems.

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Publications

Meemong Lee, Kay Suselj, Longtao Wu, Junjie Liu, Hui Su, An OSSE framework for Coupling Meteorology and Atmospheric Composition Observing Systems, abstract submitted to the 102nd American Meteorological Society Annual Meeting, Houston, TX, January, 2022.

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Approach

- Coalesce existing in-house modeling and data assimilation capabilities in weather and composition.
- Develop interface between GEOS Data Assimilation System and CMS-Flux Inversion Framework.
- GEOS 7km Nature Run (NR) and synthetical observations for the program of record (POR) from July-August 2006.
- GEOS5 data assimilation system produced 5 meteorological fields to drive CMS-Flux Inversion Framework.
- Four CWC-OSSE system errors in terms of derived posterior CO_2 emission uncertainty were assessed (observation error due to imperfect observations, representation error due to model resolution, meteorology error, and prior emission error.

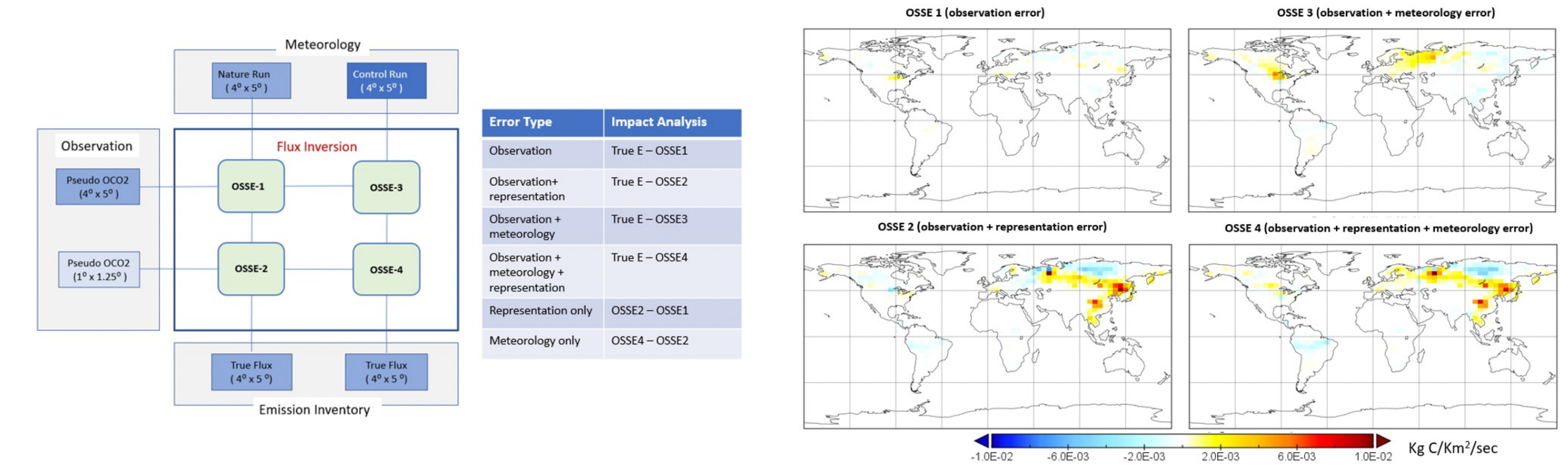

Figure 3. OSSEs for analyzing flux inversion impact of the observation error, representation error, and meteorology error.

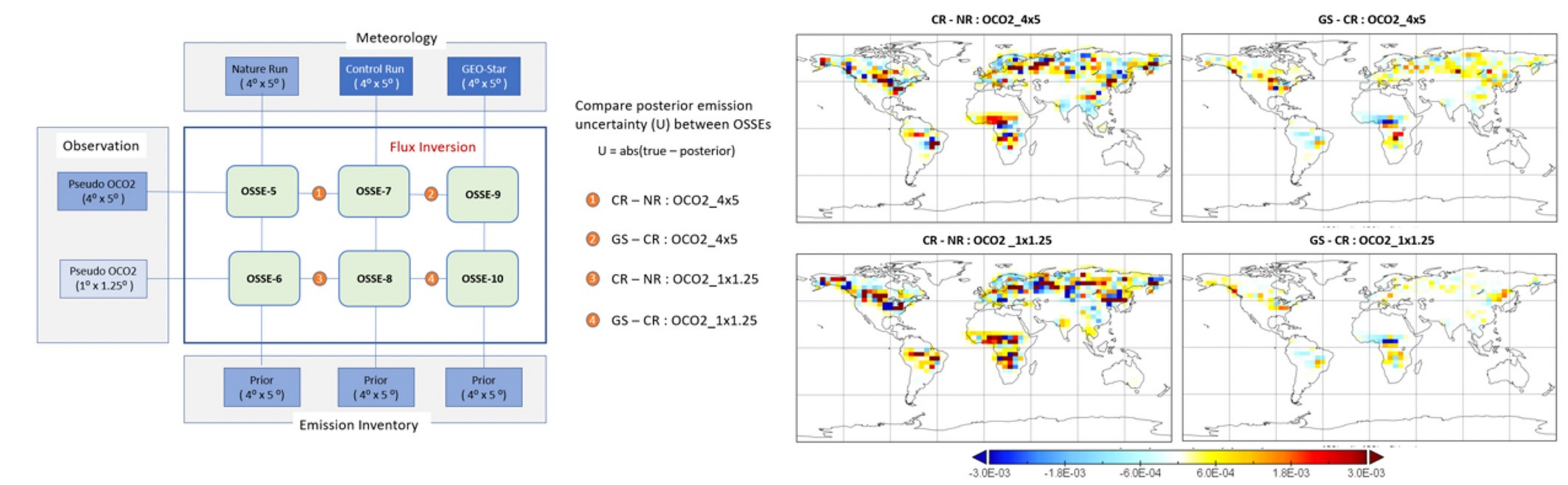

Figure 4. Meteorology OSSE set up and comparison of the posterior emission uncertainty.

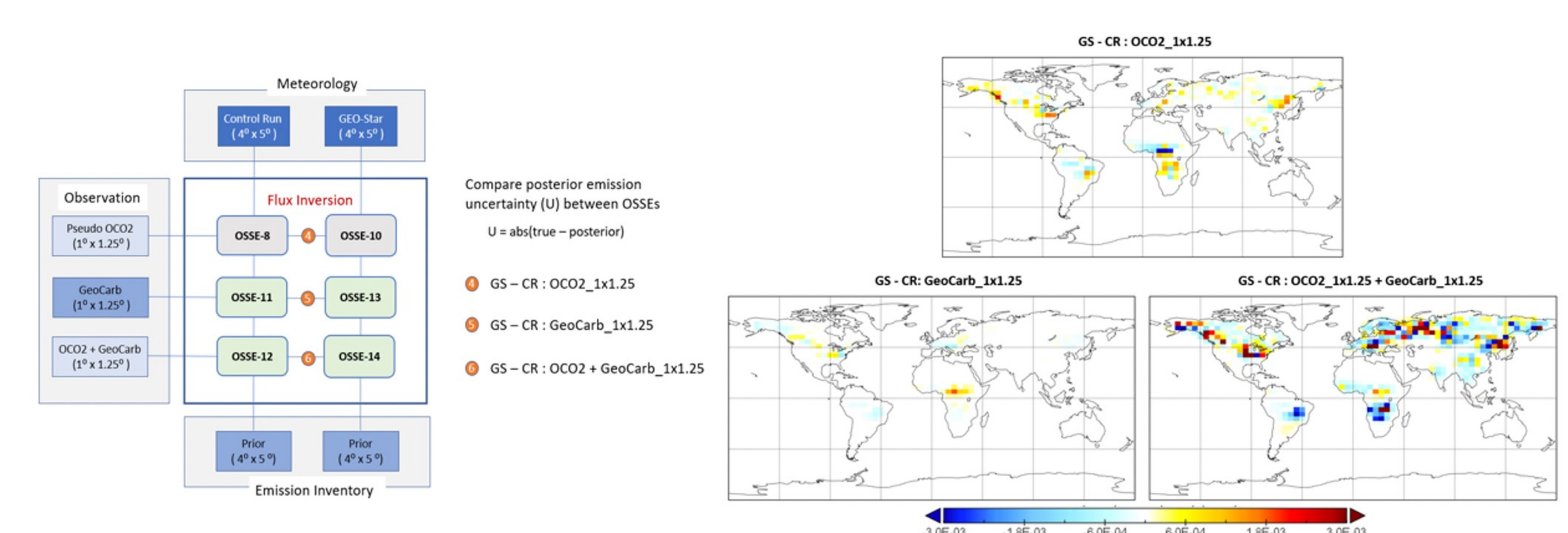

Figure 5. Meteorology combined with composition mission OSSE setup and comparison of the posterior emission uncertainty.

Summary

- Assimilation of GeoSTAR-observed temperature and moisture substantially reduces errors in both thermodynamic and dynamic fields throughout most of the troposphere.
- The flux-inversion error resulting from the observation error is negligible.
- The meteorology error introduces up to 10% posterior emission uncertainty.
- The representation error is the most significant and introduces up to 30 % posterior emission uncertainty.
- The GeoSTAR meteorology field decreases the posterior CO_2 emission uncertainty in South America and northern Africa. Such positive impacts are greater when both OCO2 and GeoCARB observations are included.
- Assimilating observations of higher spatial resolution produces greater reduction in the posterior emission uncertainty.

Clearance Number:
RPC/JPL Task Number: R21107