National Aeronautics and Space Administration

DEVELOPING A COUPLED WEATHER-COMPOSITION OSSE SYSTEM FOR FUTURE MISSION FORMULATIONS

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***Left JPL in August, 2022, *Left JPL in April 2022; + Retired in July 2022**

Program: FY21 R&TD Topics Strategic Focus Area: Earth Science Data Analysis

Overall 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 coalescing existing in-house modeling and data assimilation capabilities in weather and composition. It is critically important to enhance JPL's mission formulation capabilities and competitiveness for future missions. This project leverages JPL's strength in remote sensing and atmospheric composition data assimilation, and will further substantiate JPL's science leadership within NASA and across federal agencies. The Year-1 project developed the coupled weather-composition OSSE (CWC-OSSE) modeling framework and applied it to quantify the impacts of GeoSTAR and GeoCarb missions. The Year-2 project applied the modeling framework to estimate the potential impacts of a JPL mission concept that involves a geostationary infrared imaging Fourier Transform Spectrometer (GeoIR-FTS).

Significance/Benefits to JPL and NASA:

Leveraging existing in-house capabilities and connecting the weather and chemistry DAS into a streamlined CWC OSSE, we have developed a coupled weather-composition OSSE framework that can quantitatively estimate the joint mission impacts on both atmospheric dynamics and composition. We demonstrated that assimilating GeoSTAR, GeoCARB and GeoIR-FTS measurements could significantly improve the CO_2 flux inversion. The mission impacts depend on model resolution and simulation period, and measurement coverage and uncertainty. This coupled weather-composition OSSE framework is strategically important to prepare JPL for the competition of Explorer missions, future Earth Venture missions, and potentially for the PBL incubation mission design. It is particularly useful to address the synergy between different observables for the Explore mission formulations. It will help JPL to strengthen the leadership in greenhouse gas data assimilation and lay the foundation for building an integrated Earth System OSSE framework that would include the interactions between atmosphere, land, ocean and cryosphere. The integrated Earth System OSSE framework is our ultimate goal to help conducting future mission trade studies that will enable designing integrated Earth observing systems that can provide the highest science impact with the least economic cost.

Publications

[A] 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.

[B] Meemong Lee, Kay Suselj, Longtao Wu, Junjie Liu, Ming Luo, Vijay Natraj, Nicholas Parazoo, Stanley Sander, Hui Su, Coupled Weather and Composition OSSE Framework and Impact Analysis of New Observing Systems, journal article in preparation, 2022.

Approach and Results:

The weather OSSE system employs GEOS-5 Data Assimilation System (DAS) from the GMAO to analyze the impact of weather observing system concepts on meteorology data products. The composition OSSE system employs JPL's Carbon Monitoring System (CMS) to analyze the impact of atmospheric carbon tracer observing system concepts on carbon emission estimates. The coupling between them is achieved by sharing the GMAO's Nature Run data products for generating the synthetic measurements of all observing system concepts and applying the assimilated meteorology products during the flux inversion. Figure 1 shows the components and flow chart of the CWC-OSSE framework.

We perform the CWC-OSSE for two summer months, July and August based on the availability of the synthetical observations associated with the 7km resolution nature run (G5NR). Figure 2 shows the control run produces deviations in humidity from the nature run in the tropical lower and middle troposphere, and large wind errors in the equatorial upper troposphere. After assimilating the projected GeoIR-FTS temperature and humidity measurements, the errors in humidity and zonal-wind become smaller in most of the troposphere.

In order to isolate the impacts of meteorological fields on CO_2 flux inversion, we perform four types of OSSEs, a system OSSE, a nature run (NR) OSSE, a control run (CR) OSSE, and a GeoSTAR (GS) or GeoIR-FTS OSSE (GFTS), each performing GeoCarb observation assimilation with a unique meteorological input.

The errors in the flux estimate informs the combined impact of the GeoCarb observation error and the representation error from the resolution difference between the observation simulation and the flux inversion. The regional average of the System OSSE error is assumed to be the uncertainty of the remaining three OSSE results. All of the three OSSEs with three meteorology data types employ an external emission inventory, CLIMATE terrain biosphere, as the prior CO_2 terrain biosphere flux. The flux inversion is based on the GEOS-Chem adjoint-model-based 4DVAR assimilation system. The flux estimates from an OSSE is referred to as posterior emission and its accuracy is measured with respect to the prior emission error as defined as $ER_{OSSE} = (E_{OSSE} - E_{prior})/E_{prior}$, where E_{OSSE} is the posterior emission error of a given OSSE and E_{prior} is the prior emission error. To capture the inter-regional relationship of the impact, the E_{OSSE} and E_{prior} are computed as a regional average in 12 regions over the global land masses.

Figure 3 shows that assimilating the temperature and humidity measurements from GeoIR-FTS significantly improves the CO_2 flux estimates compared to the control run and the run with GeoSTAR temperature and humidity assimilated. In Region 3, the tropical Central and South America, the improvement is about 15% over the control run and the GeoSTAR run. Owing to atmospheric transport, the positive impact extends beyond the GeoIR-FTS observing domain, especially over the Africa (Region 5 and 6).

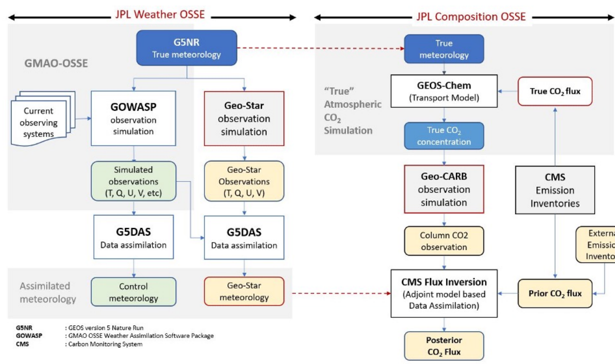

Figure 1 Components and flow chart of the Coupled Weather-Composition OSSE framework developed in this project.

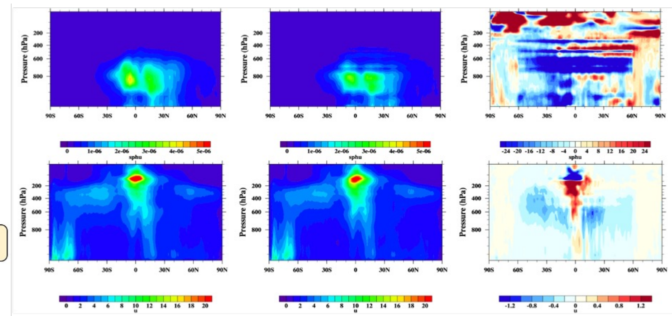

Figure 2. Squared error relative to the nature run in the zonal-mean humidity (top) and zonal wind (bottom) in the control run (left) and the GeoIR-FTS run (middle), and the difference in squared error between the GeoIR-FTS run and the control run.

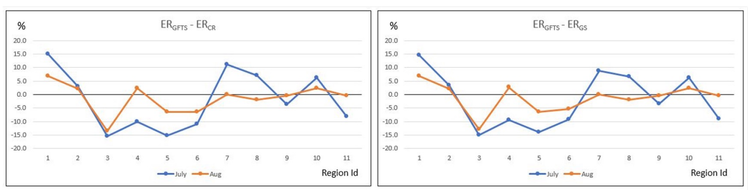

Figure 3. Errors in CO_2 flux estimates from the GeoIR-FTS run(ER_{GFTS}) compared to the errors from the control run (ER_{CR}) and the GeoSTAR run (ER_{GS}).

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