Title of Grant / Cooperative Agreement:	2014 GEO-CAPE MISSION PRE-FORMULATION STUDY ACTIVITY: GEO-CAPE ATMOSPHERIC OSSE DEVELOPMENT AND ANALYSIS OF JULY 20
Type of Report:	Summary of Research
Name of Principal Investigator:	Allen Lenzen
Period Covered by Report:	4/1/2014 - 9/30/2018
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NASA Grant / Cooperative Agreement Number:	NNX14AH03G

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X. Regional OSSE Working Group

The GEO-CAPE Regional and Urban Observation System Simulation Experiment (OSSE) Working Group was initiated in 2013 to assess the impacts of geostationary observations of ozone (O3), nitrogen dioxide (NO2), and formaldyhde (HCHO) within a robust OSSE framework. The main components of the Regional OSSE (nature run, observation simulator, data assimilation system) are illustrated in Figure 1 and follows the recommendations of Timmermans et al., (2015) which provided a framework for the use of OSSEs for assessing the impact of satellite trace gas retrievals on air quality forecasts, including requirements for the individual components. These requirements include the following; 1) the nature run must provide a reasonable representation of the real atmosphere, 2) the observation simulator must be able to calculate radiances from the nature run which account for the spectral resolution, signal to noise ratio, and averaging kernels of the instrument being assessed, 3) the model used within the data assimilation system should be different than the model used to generate the nature atmosphere. The first 2 years of the Regional OSSE activities were summarized in Table 3-3 of the GEO-CAPE 2009-2015 Summaritive White Paper and focused on completion of ultraviolet (UV) visible (VIS) and thermal infrared (TIR) forward modelling, generation of multi-spectral retrievals for subset of CONUS profiles, and generation of averaging kernel (AK) regression to extend training set to entire North America for the O3 OSSE studies.

During the 2015-2018 period we completed the regional O3 OSSE. The results were presented at the Second Atmopsheric Composition Observation System Simulation Experiments (OSSE) Workshop, which was hosted by the European Center for Medium Range Weather Forecasting (ECMWF) in Reading UK on 9-11 November, 2016. The GEO-CAPE Regional O3 OSSE demonstrates systematic and significant increase in lower to mid tropospheric correlations and reductions in rms errors and biases when hourly geostationary UV, UV/VIS, and UV/VIS/TIR ozone retrievals are assimilated, respectively. Results show improvements in lower tropospheric correlations and rms errors for all experiments, but the UV and UV/VIS experiments introduce higher biases. Comparisons with the nature run at US EPA surface monitoring sites shows that the overall positive impacts obtained with UV/VIS/TIR retrieval assimilation are due to reductions in nighttime biases, which highlights the importance of the TIR radiances in the multi-spectral retrievals. A manuscript describing the O3 OSSE is currently in prepartion (Pierce et al., 2018).

We have also completed the NO2 OSSE and are nearing completion of the HCHO OSSE. Since NO2 and HCHO both have significantly larger spatial variability than O3 the AK regression approach was deemed unlikely to produce robust results. The working group determined that we would need to generate synthetic radiances and full optimal estimation retrievals for each cloud free grid point of the nature run. This required JPL development of fast forward modeling approaches to generate the synthetic radiances in the NO2 and HCHO bands. JPL ported updated forward modeling code to SSEC and we generated synthetic radiances for all cloud free gridpoints at hourly intervals for the full nature run timeperiod (July 2011) utilizing the Supercomputer for Satellite Simulations and Data Assimilation Studies (S4, Baukabara et al, 2016) at the UW-Madison Space Science and Engineering Center (SSEC).

Since NO2 and HCHO are short lived species, assimilation of NO2 or HCHO column retrievals does not lead to systematic changes in the concentrations of these species. Instead, the NO2 and HCHO column retrievals must be used to constrain the emissions of these species. As part of the Regional OSSE working group activities during 2015-2018 we developed an offline

approach to use satellite based trace gas retrievals to constrain area and point source emissions. The approach involves calculating the sensitivity of the trace gas column to changes in emissions following Lamsal et al. (2011) and then using this sensitivity, combined with the monthly mean trace gas analysis increment, to adjust the emissions. The results of the NO2 OSSE were presented at the Joint Committee on Earth Observation Satellites (CEOS) Atmospheric Composition Virtual Constellation (ACVC) and GEO-CAPE Meeting, which was hosted by the NOAA Center for Weather and Climate Prediction (NCWCP) in College Park, MD on May 2-4, 2018. The GEOCAPE NO2 OSSE demonstrates significant adjustments in apriori NOx emissions using hourly TEMPO like NO2 retrievals compared to daily OMI NO2 emission adjustments. However, the NO2 OSSE results show low surface ozone sensitivity to changes NOx emissions, possibly due to high urban NOx levels leading to VOC sensitive ozone production. The O3, NO2, and HCHO assimilation experiments are conducted using the NOAA gridpoint statistical interpolation (GSI, Wu et al. 2002, Kleist et al. 2009), which is a physical space-based 3-dimensional variational analysis. The observation operator for the O3, NO2, and HCHO profile retrievals was developed for GSI based on the approach used by Verma et al, (2009) for assimilation of ozone profiles from the Tropospheric Emission Spectrometer (TES). This observation operator accounts for the averaging kernel and apriori used in the retrieval.

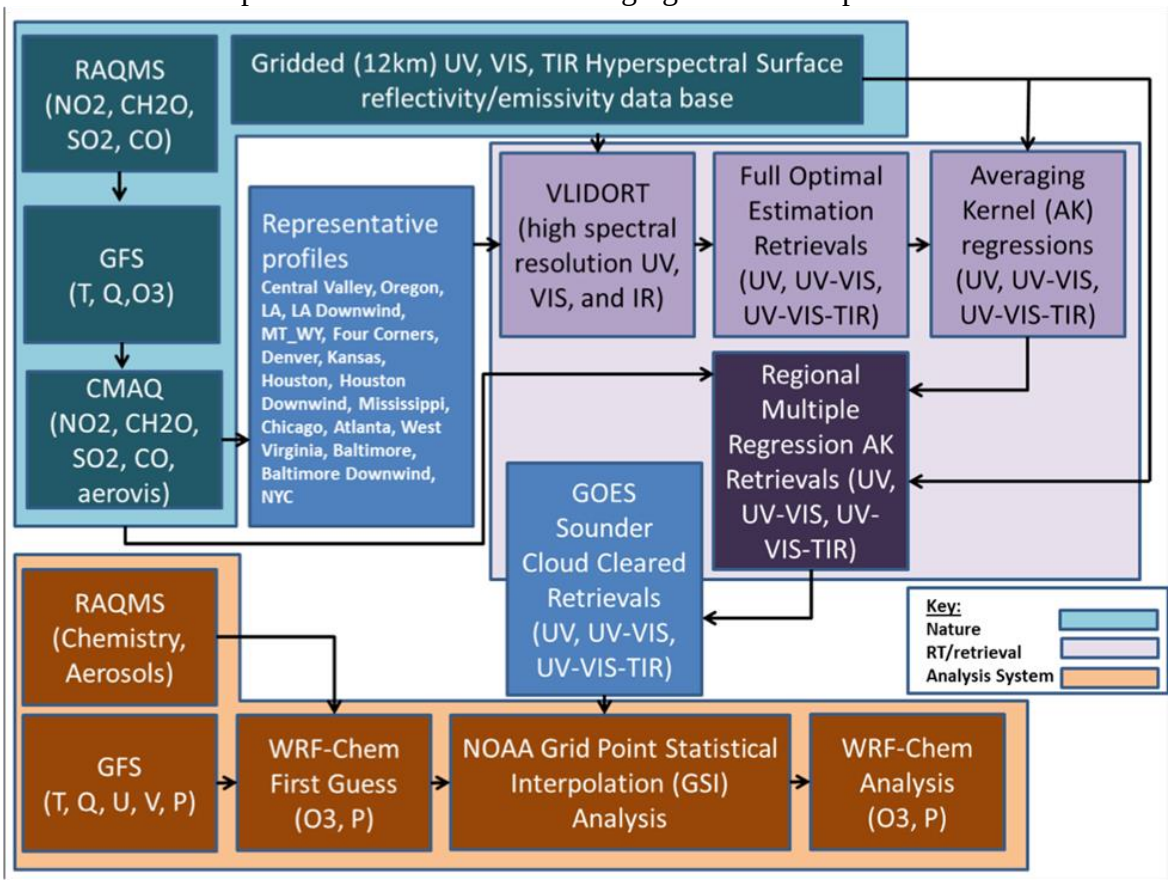

Figure 1: Components of the GEO-CAPE Regional OSSE. The nature run (teal), observation simulator (purple), and data assimilation system (brown)

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