NOAA ROSES Semi-Annual Report

Reporting Period: September 2020 – February 2021 (1st report)
PI: Elisabeth Weisz
Co-PI: Paul Menzel
Project Title: Realizing LEO Sounder Products at GEO Imager Spatial and Temporal Resolution

Executive Summary

The expected impact and knowledge gained from this LEO-GEO fusion work should suggest improved approaches for weather watch and warning operations through an improved fusion of LEO and GEO assets. One focus is to study nowcasting enhancement with ABI/CrIS spatial/temporal fusion. Algorithm adjustment (e.g., spectral bands used in k-d tree search, number of neighbors used in the sounder product averaging, refinement of the cloud mask, investigation of useful extent of temporal fusion) is a significant part of this activity. The initial focus will be on the LEO sounder product fusion into GEO imager space and time resolutions. Enhancement of low-level moisture depiction using the on-line off-line opportunities offered by the rotational water vapor lines in the infrared windows will also be part of this study. A second focus is to attempt to enhance TROPOMI detection of trace gases from natural and anthropogenic sources using ABI and AHI as imager companions in a spatial/temporal fusion. Single time spatial enhancement with VIIRS/TROPOMI will also be undertaken. Case studies will include trace gas intrusions from volcanoes, fires, and industrial activities.

Progress toward FY20 Milestones and Relevant Findings

1. Trace Gas Fusion Paper Published

A paper titled "An Approach to Enhance Trace Gas Determinations through Multi-Satellite Data Fusion" has been published in the Journal of Applied Remote Sensing (JARS) on 7 Dec 2020, and is available at http://dx.doi.org/10.1117/1.JRS.14.044519. The paper reports on combining radiances from a LEO or GEO high spatial resolution imager (e.g., VIIRS, ABI, AHI) with products from a LEO high information content sounder or trace gas monitor (e.g., CrIS, TROPOMI) to construct retrieval products (e.g., trace gas concentrations of CO, SO2, NH3) via product fusion at high spatial resolution. These products can also be provided at high temporal resolution when geostationary imager (i.e., ABI and AHI) data is used in the product fusion.

One example result from the paper compares ground measured and satellite fusion trace gas changes in time. 16-hour AHI/TROPOMI fusion time sequences of carbon monoxide (CO) emissions reveal diurnal variations in an urban/industrial pollution event. Fig. 1 shows the temporal change in CO at the urban industrial cities of Handan and Xingtai (Hebei Province). From panel (a) it can be seen that ground detections of CO emissions in Handan rises steadily during the day reaching a maximum near the middle of the day (and close to the TROPOMI time) before the concentrations decrease in the local evening hours and stay constant during the night. This signature is attributed to daily industrial activity, as well as heavy air and road traffic between the major cities in the Hebei Province. The satellite fusion estimates show a strong peak of approximately 200 DU at 11:00 CST but sustained twice as long (approx. 4 hours in the satellite fusion versus 2 hours from the ground).

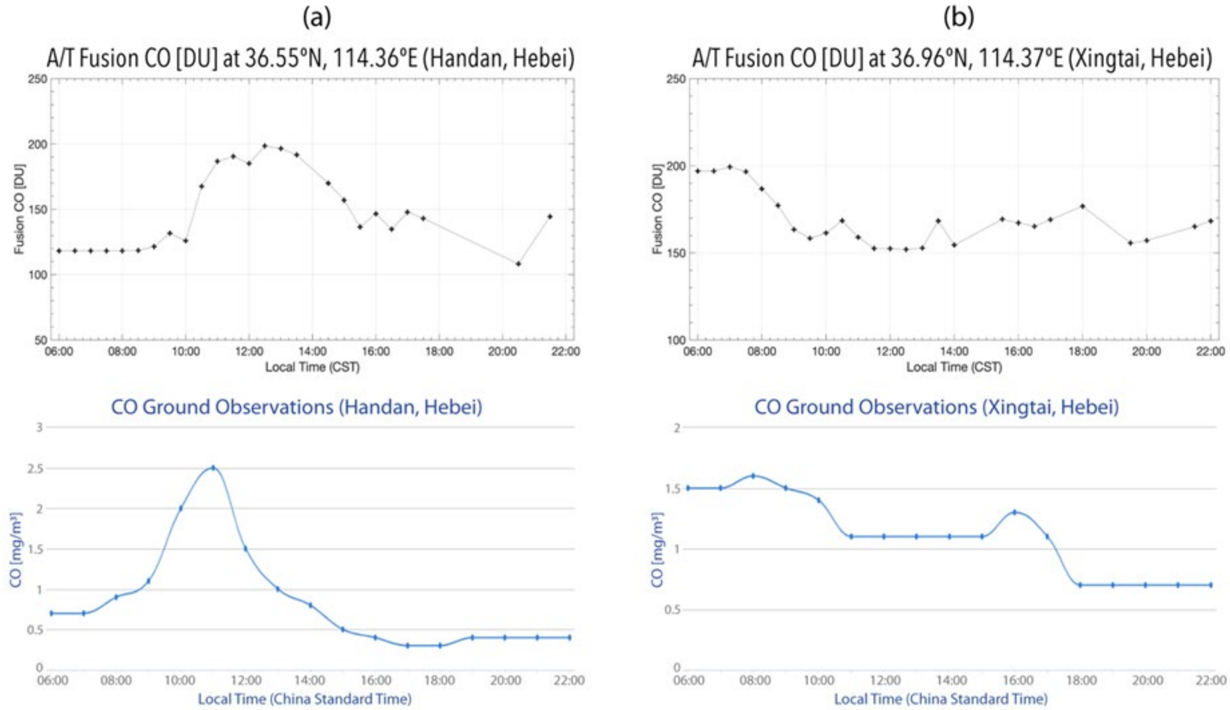

Figure 1. AHI/TROPOMI CO fusion time series (top) and AQOMAP ground observations (bottom) for the cities of Handan (a) and Xingtai (b). The time period shown is 06:00 until 22:00 CST (China Standard Time) on 23 March 2020, which is 2200 UTC on 22 March 2020 until 1400 UTC on 23 March 2020.

CO emissions from Xingtai (Fig. 1b) indicate a gradual morning drop from both the ground and satellite fusion instruments. The small afternoon rise evident in the ground data is detected by satellite fusion as well, although it is more gradual and occurs roughly two hours later. It is noted that differences are expected since ground measurements are made at the source of the emission whereas satellite determinations are time interpolated area averages of the total column of the trace gas emission, which often lingers well after the emission stops. Nonetheless, one can conclude that these observations are marking the hourly changes in CO concentration for these two cities on 23 March 2020 with similar results.

Focusing on the region surrounding Baicheng in the northern Jilin Province, dominated by agriculture and forestry industries, panel (a) of Fig. 2 shows TROPOMI CO vertical total column amounts. High CO emissions at locations “1” and “2” (about 70 km east of Baicheng) are produced by fires (likely caused by human-induced biomass burning), which is confirmed by high VIIRS M13 (4.05 μm) brightness temperatures visible as darkest spots (and highlighted in red) in panel (b). The fires are also evident in panels (c) and (d) of AHI band 7 brightness temperatures, with the hottest fires found near location 2; temperatures of the surrounding surface area decrease in time while the temperatures of the hot spots remain high. Panels (e) and (f) of AHI band 2 radiances clearly show dark areas of smoke plumes growing and blowing south during the 3 hours. The smoke plume in panel (f) and the CO plume in panel (h) extend roughly the same distance south but the stronger concentration of CO remains closer to the fire.

Additional trace gas fusion results discussed in the paper relate to volcanic sulfur dioxide (SO2) emissions from the 2018 Popocatépetl and 2019 Krakatoa eruptions and ammonia (NH3) dissemination from California fires. Overall, these studies suggest the possibility of inferring information from trace gas level 2 products at imager high spatial and temporal resolution.

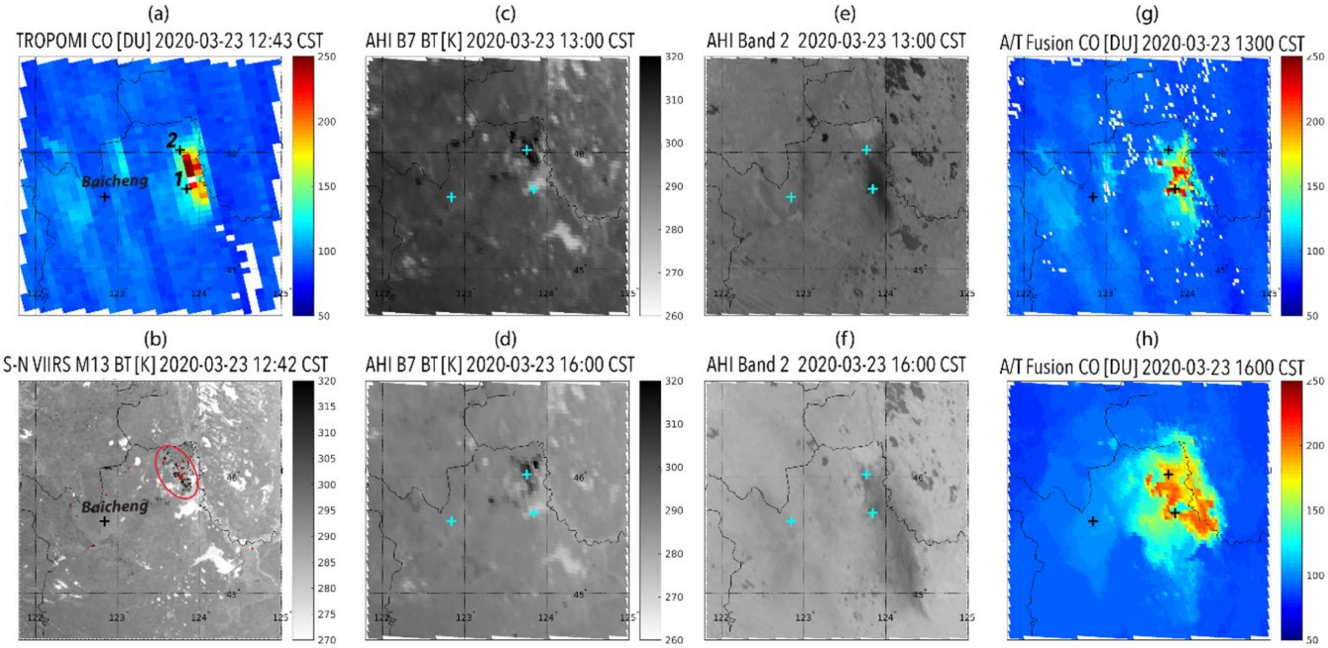

Figure 2. (a) TROPOMI CO [DU] near Baicheng (northwest Jilin Province) on 23 March 2020 at 12:43 China Standard Time (CST) or 0443 UTC; (b) S-NPP VIIRS 4 µm band brightness temperature (BT) for the same time and region as TROPOMI, with temperatures above 340 K marked in red; (c) and (d) AHI band 7 (3.85 µm) BT at 13 & 16 CST; (e) and (f) AHI band 2 (0.51 µm) radiances at 13 & 16 CST; (g) and (h) AHI/TROPOMI CO fusion results at 13 and 16 CST.

2. Masters Student publishes paper

A paper titled “Low earth orbit sounder retrieval products at geostationary earth orbit spatial and temporal scales” by James Anheuser, E. Weisz and W. P. Menzel was published in the Journal of Applied Remote Sensing (Volume 14, Issue 4) in October 2020. Mr. Anheuser, a University of Wisconsin-Madison Atmospheric and Oceanic Sciences (AOS) graduate student, combined geo-stationary ABI radiances with co-located retrievals derived from the CrIS to achieve soundings at 2 km spatial and 30-minute temporal resolution. The paper reports on his Masters work toward the validation of these ABI/CRIS spatial temporal fusion temperature and moisture profiles through comparison with co-located radiosonde data. The article is available at http://dx.doi.org/10.1117/1.JRS.14.048502.

3. Oregon Fire Study

The Oregon wildfires from 9-11 September 2020 have been studied with imager (VIIRS, ABI) / sounder (CrIS, TROPOMI) product fusion applied to CO. The ABI/TROPOMI time evolution of the CO associated with this fire is depicted in Fig. 3; the CO transport to the northwest is captured in the sequence. Time steps of 10, 20, 30 minutes were compared and little difference was found. VIIRS/TROPOMI fusion of CO from fires shows more detail, especially over land but orographic effects are also apparent (not shown).

4. Conference Attendance

Elisabeth Weisz gave an oral presentation at the 2020 AGU Virtual Fall meeting (1-17 December 2020) titled “Enhancing Trace Gas Determinations through Multi-Satellite Data Fusion” (paper number A017-03), which summarizes the GEO/LEO fusion approach and highlights key results of our GEO imager and TROPOMI trace gas fusion research.

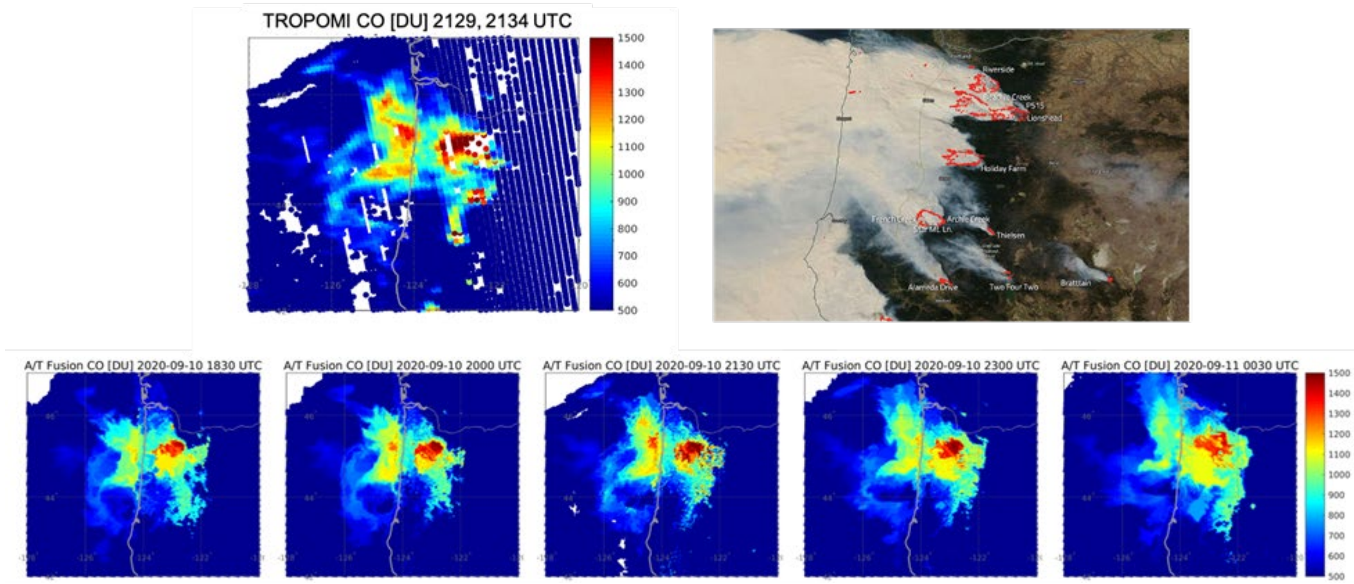

Figure 3. TROPOMI CO [DU] on 10 September 2020 at ~2130 UTC (top left) and Aqua-MODIS image from https://www.nasa.gov/image-feature/goddard/2020/nasas-aqua-satellite-captures-devastating-wildfires-in-oregon (top right). ABI/TROPOMI CO fusion results at 1830, 2000, 2130, 2300, & 0030 UTC are shown in the bottom panel.

Plans for Next Reporting Period

- Study CO for the Sheridan Fire (August 2019) using ABI/CrIS spatial and temporal fusion, as well as VIIRS/TROPOMI and VIIRS/CrIS fusion. Validation will be accomplished by comparison with SHIS (Scanning High-Resolution Interferometer Sounder) and NAST-I (NPOESS Airborne Sounding Testbed - Interferometer) retrievals from the 2019 FIREX-AQ (Fire Influence on Regional to Global Environments and Air Quality) campaign. This task was started with NOAA JPSS PGRR funding and we will continue with the NOAA ROSES funds as we add the temporal component (from ABI measurements) to the fusion approach.
- Investigate CH4 (methane) and NH3 (ammonia) emissions related to animal agriculture pollution in the Imperial Valley (Sept 2019) and Happy, Texas (September 2020) regions via VIIRS/CrIS and VIIRS/TROPOMI fusion, and validate with observations from, e.g., HyTES (Hyperspectral Thermal Emission Spectrometer).
- Validation of ABI/CrIS temporal fusion water vapor profiles from S-NPP CrIS overpass to the NOAA-20 overpass 50 minutes later. The moisture changes in the fusion results, that occurred between the 10 (or 15)-minute ABI measurements, will also be studied and analysed.