NOAA ROSES Semi-Annual Report

Reporting Period: March 2021 – August 2021 (2nd report)
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Project Title: Realizing LEO Sounder Products at GEO Imager Spatial and Temporal Resolution

Executive Summary

The knowledge gained from this LEO and 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 and 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. Initially, LEO sounder products will be fused into GEO imager space and time resolutions. Subsequently, spatial-temporal fusion enhanced depiction of low-level moisture using on-line off-line rotational water vapor differences in the LEO sounder infrared windows will be attempted. A second focus is to enhance TROPOMI detection of trace gases from natural and anthropogenic sources using VIIRS, ABI, and AHI as imager companions in a spatial (and spatial-temporal with GEO) fusion.

Progress toward FY20 Milestones and Relevant Findings

1. Case Study of Ammonia (NH_3) over Imperial Valley

Using the fusion process to transfer sounder information to imager spatial resolution we explored the ammonia concentration in the Imperial Valley with VIIRS/CrIS. CrIS ammonia (NH_3) retrievals were accomplished with MUlti-SpEctral, MUlti-SpEcies, MUlti-SatEllite (MUSES) retrieval algorithm and were provided by Karen Cady-Pereira (AER) and Vivienne Payne (JPL). In addition, we compared the fusion results with FIRE-X aircraft validation data that was provided by Olga Kalashnikova, Elva Kuai, and Glynn Hulley (JPL).

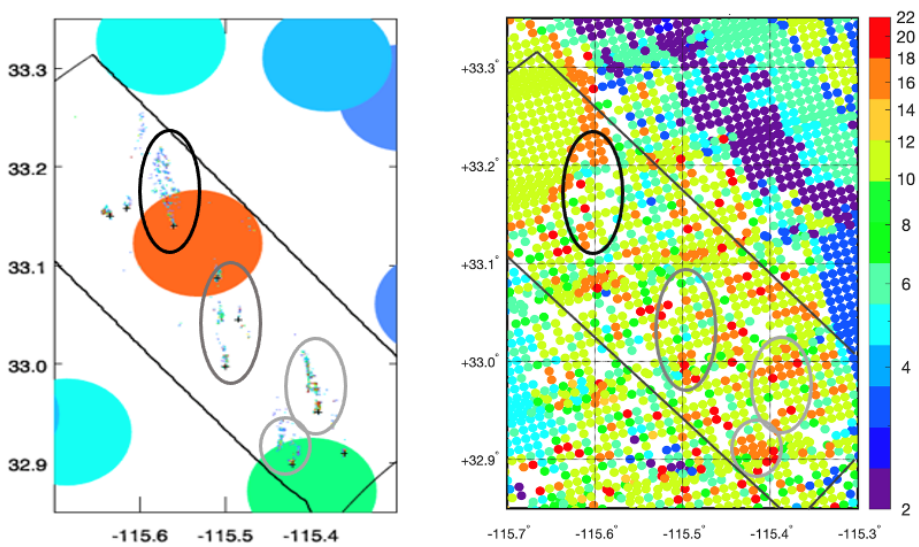

Figure 1. Ammonia (NH_3) near surface concentrations in ppb on 12 Sep 2019 associated with Imperial Valley dairy farming, fumaroles, and geothermal plants from ER2 HyTES at 34m (left) and VIIRS/CrIS-SNPP fusion at 750m (right).

Figure 1 shows near-surface concentrations of NH_3 on 12 Sep 2019 associated with Imperial Valley dairy farming, fumaroles, and geothermal plants that were measured by the ER2 HyTES (Hyperspectral Thermal Emissions Spectrometer) at 34m and SNPP CrIS at 14km along with VIIRS/CrIS fusion depictions at 750m. While correlations between the fusion and the HYTES measurements are promising, fusion indications include many unconfirmed NH_3 concentrations. More study on the impact of sensor resolution will be necessary.

2. Convective Case Studies

Clear sky temperature and moisture layers, along with atmospheric stability, were generated at Advanced Baseline Imager (ABI) resolution (through spatial fusion) at the time of the Cross track Infrared Sounder (CrIS) overpass. Further application of the fusion process to a time series of ABI radiances created a GEO sounder-like perspective of atmospheric changes in time (through spatial-temporal fusion). We investigated moving forward in time as well as backward in time with spatial-temporal fusion of CrIS moisture soundings with GOES-16 ABI infrared radiances using the 50-minute time difference of CrIS overpasses onboard SNPP and NOAA20. Dual-Regression retrievals (available through https://cimss.ssec.wisc.edu/cspp/) of relative humidity (RH) at 700 hPa over the western portion of the Oklahoma panhandle and surrounding US states were processed from CrIS data on SNPP and NOAA20 on 28 April 2018. These were then enhanced to ABI spatial and temporal resolution through fusion.

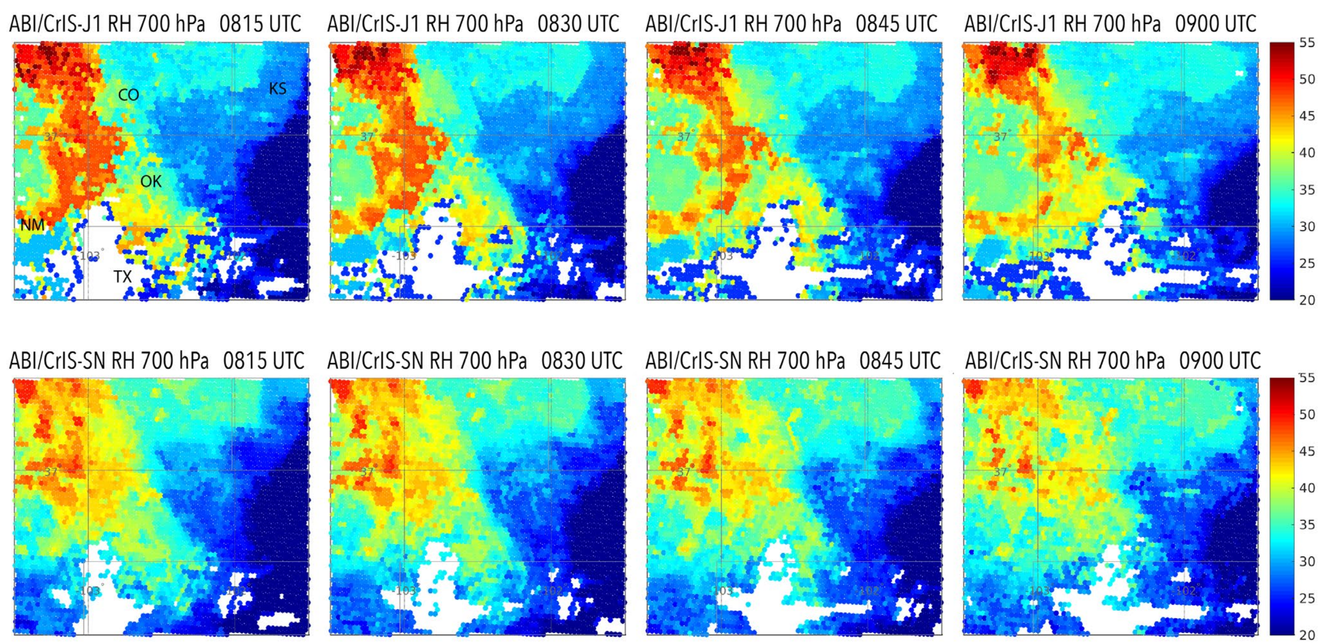

Figure 2. ABI/CrIS fusion results for DR RH [%] at 700 hPa using NOAA20 (top) and SNPP (bottom) CrIS data together with ABI measurements in 15-min intervals. Note, the NOAA20 fusion process starts at 815 UTC (and goes forward in time), whereas the SNPP fusion process starts at 900 UTC (and goes backward in time) on 28 April 2018.

Figure 2 shows a comparison of 15-minute progressions of ABI/CrIS-NOAA20 moving from 815 UTC (i.e., closest to the NOAA20 overpass time) to 900 UTC (top panel of Fig. 2) and ABI/CrIS-SNPP moving from 900 UTC (closest to the SNPP overpass time) to 815 UTC (bottom panel of Fig. 2) for Dual-Regression retrieval determinations of relative humidity (RH) at 700 hPa over the western portion of the Oklahoma panhandle and surrounding US states. Of note is the transition zone from 40% to 30% RH; the spatial temporal fusion forward sequence from 815 UTC ABI/CrIS-NOAA20 reshapes into the 900 UTC ABI/CrIS-SNPP spatial fusion while in reverse the spatial-temporal fusion sequence from 900 UTC ABI/CrIS-SNPP reshapes into the 815 UTC ABI/CrIS-NOAA20 spatial fusion. While the very moist values of NOAA20 CrIS are missing from the SNPP CrIS sounding, the gradient regions change in the representative fashion going forward as well as backward in time. Although values beyond the initial range cannot be created, gradients within the range of values still reshape in a realistic way.

Figure 3 shows the actual RH changes that occurred between the 15-minute intervals. Several features seemed to have evolved correctly over time. For example, the oval in the lower left panel (i.e., SNPP temporal fusion changes at 830 UTC) contains RH changes, which are similar to changes found in the upper left panel (i.e., NOAA20 RH fusion changes inferred by fusion at the NOAA20 overpass time). Vice versa the oval in the upper right panel (i.e., NOAA20 temporal fusion changes at 900 UTC) contains RH changes which are similar to changes found in the lower right panel (i.e., SNPP RH changes inferred by fusion at the SNPP overpass time). This means that these RH properties were correctly created through the temporal fusion process. This demonstrates promising potential of the spatial-temporal fusion approach for a variety of applications. How far in time GEO/LEO fusion can reliably be continued depends on the synoptic situation, but good results have been demonstrated in several case studies for over two hours.

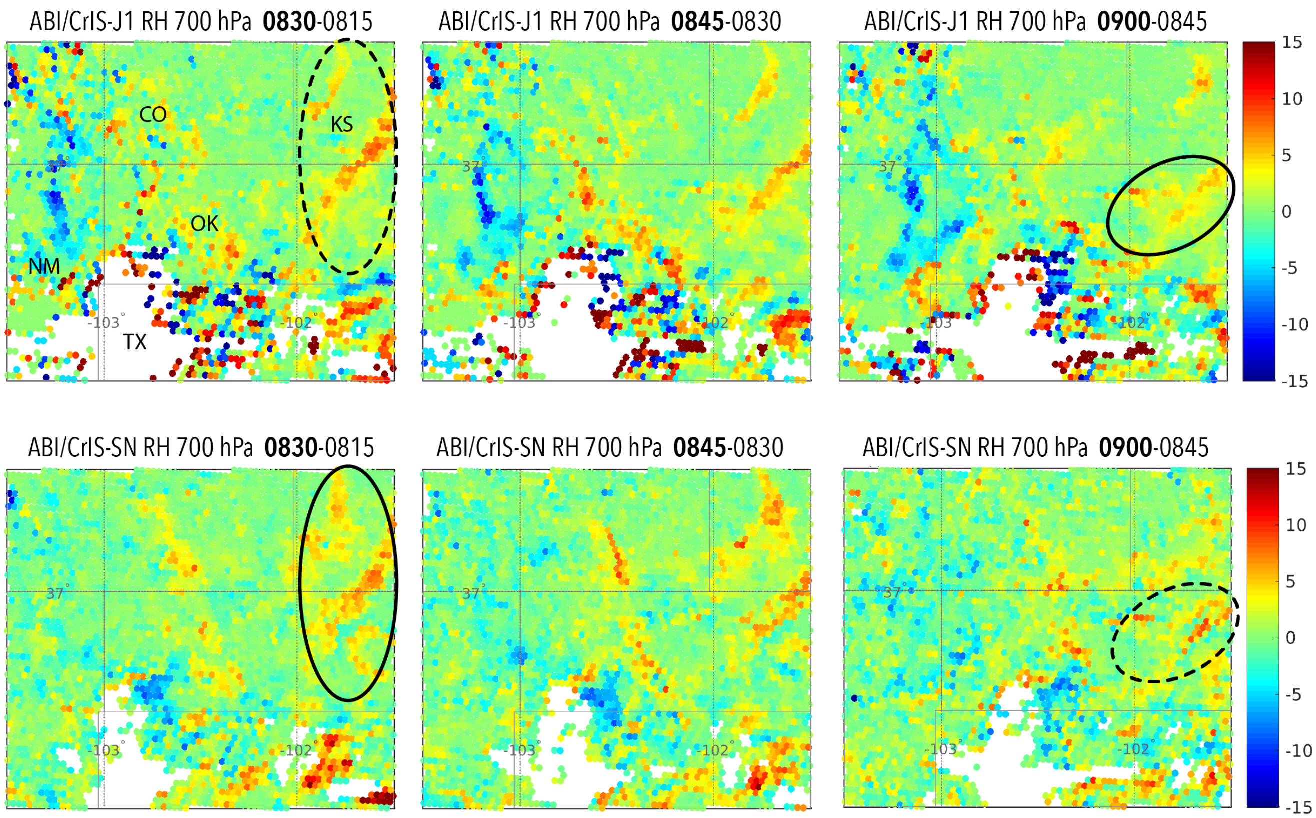

Figure 3. Change in ABI/CrIS fusion RH (at 700 hPa) in [%] between the current time step (bold in the sub-panel titles) and the previous time step is shown. Some of the NOAA20 (top) moisture changes reshape correctly into the SNPP results (bottom) and vice versa; examples are marked by ovals (dashed and solid lines refer to initial and created features, respectively). Note, the NOAA20 fusion process starts at 815 UTC (and goes forward in time), whereas the SNPP fusion process starts at 900 UTC (and goes backward in time) on 28 April 2018.

We conclude that spatial-temporal product fusion results forward in time from the SNPP CrIS overpass do not entirely match spatial-temporal fusion results when going backward in time from the NOAA20 CrIS overpass; however, gradient changes in time forward compare very well with those in time backward (and vice versa) in this case study. More case studies are planned.

3. Methane (CH_4) Release in the Frozen Tundra

Methane changes occurring over Victoria Island (Canada) during the transition from winter to summer and back again to winter are being studied using TROPOMI level 2 CH_4 determinations in clear skies. NOAA NOHRSC (National Operational Hydrologic Remote Sensing Center) snow & ice charts are being used to corroborate the change in methane emissions, found through VIIRS/TROPOMI fusion, as the snow cover evaporates and the frozen waters melt for various locations on the island. Figure 4 shows an example comparison for 1 April, 21 July, and 21 August 2021. As the snow and ice melts the presence of methane in the surrounding area becomes more pronounced. A full transition back to winter is being collected when clear skies permit.

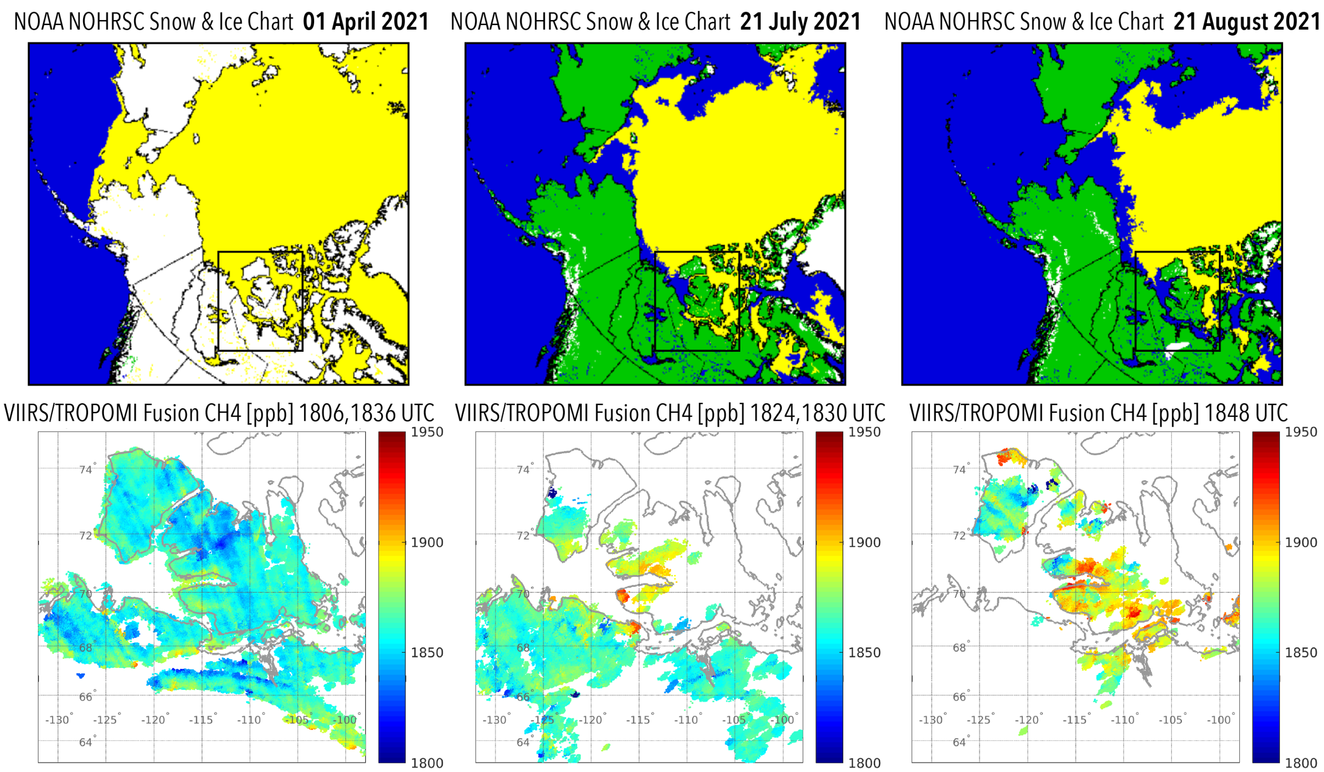

Figure 4. Top: NOAA NOHRSC snow & ice charts (adapted from https://www.nohrsc.noaa.gov/nh_snowcover/), where yellow and white refer to ice and snow, respectively, for 1 April 2021, 21 Jul 2021 and 21 Aug 2021. The area of interest - Victoria Island and surrounding regions - is marked by black frames. Bottom: SNPP-VIIRS/TROPOMI fusion methane results for the same days as the NOHRSC maps. The times in the subtitle of the bottom row figures refer to the VIIRS granule measurement start times.

4. Conference Attendance

Elisabeth Weisz gave a (virtual) poster presentation at the 2021 EUMETSAT Meteorological Satellite Conference (20-24 September 2021) titled "Improving Spatial and Temporal Resolution of LEO Sounder Retrievals through Multi-Sensor Satellite Data Fusion." It summarizes the GEO/LEO fusion approach and highlights results from a case study of ABI/CrIS mapping moisture gradients forward and backward in time on 28 April 2018 during a frontal passage in the Midwest.

Plans for Next Reporting Period

- Investigate fusion enhancement of convective destabilization and subsequent tornadic activity in the US Midwest on 5 May 2021.
- Compare results from ABI/CrIS product fusion of stability indices versus product fusion of temperature and moisture profiles followed by stability retrievals at 2 km resolution.
- Analyze information gained from LEO/GEO fusion.

- Continue year-long study of methane release from Victoria Island Canada from winter to summer to winter again.
- Case studies of trace gas intrusions from volcanoes, fires, and industrial activities are also planned.