NOAA ROSES Semi-Annual Report

Reporting Period: September 2021 – February 2022 (3rd report)

PI: Jaime Daniels (NOAA/STAR)

Co-I(s): James Carr (Carr Astronautics), Houria Madani (Carr Astronautics), and Wayne Bresky (IMSG, Inc.)

Project Title: New Fused GEO+LEO Multi-Satellite Product: Stereo-Winds from Collocated ABI and VIIRS Datasets

Executive Summary

This project involves the development, validation, and demonstration of a new GEO-LEO stereo-winds product using an ABI-family imager instrument (aboard GOES-16/17/18, Himawari-8, and GEO-KOMPSAT 2A) as one eye and the VIIRS instrument (aboard S-NPP, NOAA-20) as the other. This new capability will be an extension of the GEO-GEO stereo winds capability developed by STAR's Winds Science Team that will further extend stereo winds coverage. Use of a stereo approach offers a direct method of cloud height assignment that relies only on the geometric parallax observed from two different vantage points. This approach does not rely on cloud microphysical properties or explicit knowledge of the atmospheric thermal structure, both of which, can challenge infrared-based cloud height retrieval approaches in certain conditions. As a result, the stereo approach produces highly accurate cloud-top heights that enable highly accurate height assignments to be determined for satellite winds. The GEO-LEO stereo winds quality will be quantitatively determined and characterized by comparing them to rawinsonde and aircraft winds observations. GEO-LEO stereo winds will be generated over select time periods and made available to NCEP and other operational Numerical Weather Prediction (NWP) centers for data assimilation experiments aimed at assessing their value to the accuracy of global and regional NWP forecasts.

Progress toward FY22 Milestones and Relevant Findings

Algorithm Development - ABI-VIIRS Stereo Winds Capability

Work this reporting period focused on establishing an end-to-end capability that enables the generation of AHI-VIIRS stereo winds using STAR's Satellite Application Processing Framework (SAPF), standardizing and documenting the stereo retrieval software to facilitate its future use as an operational enterprise capability, conducting an assessment of GEO-VIIRS stereo winds configurations, applying the stereo winds approach to GOES-17 and Himawari-8 geostationary imagery to study 15 January 2022 eruption of the Hunga Tonga-Hunga Ha'apai volcano, and performing outreach by preparing and delivering a stereo winds presentation at the 2022 Annual American Meteorological Society (AMS) meeting.

ABI-VIIRS Stereo Winds Progress

During this reporting period we have completed development work that now enables us to generate ABI-VIIRS stereo winds for the Tandem VIIRS Case using STAR's Satellite Application Processing Framework (SAPF). Recall that in the tandem VIIRS case, remapped (to ABI fixed grid) VIIRS imagery from S-NPP and NOAA-20 are used together with GOES ABI imagery to generate stereo winds. Figure 1 shows an example of composite GOES-16 ABI band 14 (shown in green), remapped S-NPP VIIRS M15 band (shown in gold), and NOAA-20 VIIRS M15 band imagery (shown in blue). The overlap area between the ABI and the tandem VIIRS imagery (depicted in violet) is where the stereo winds are retrieved. These are shown on the right-hand side of Figure 1.

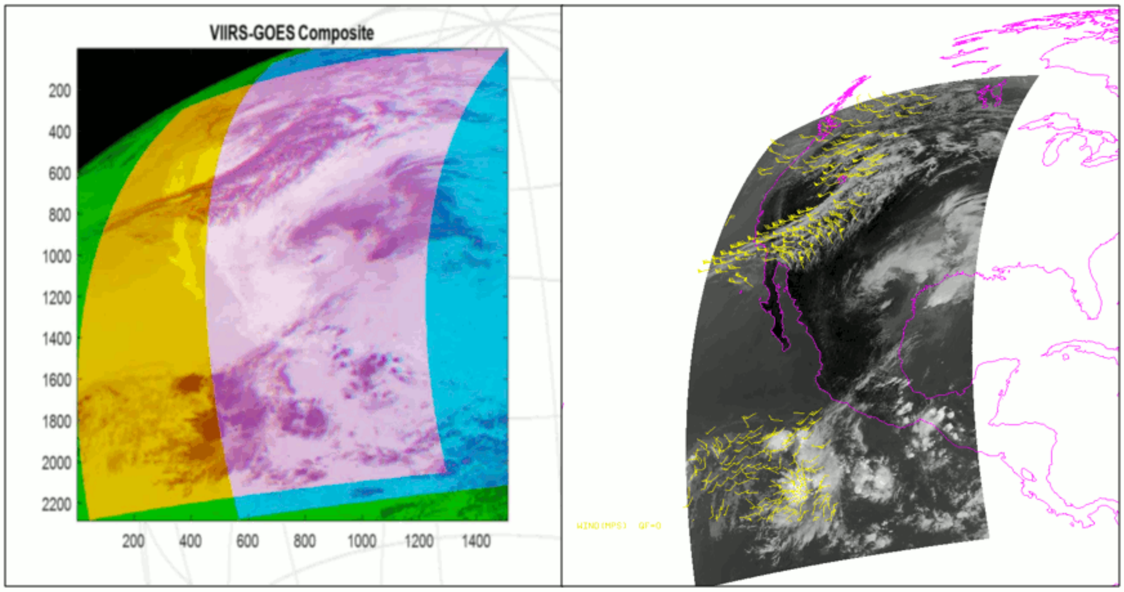

Figure 1. Left: Composite image GOES-16/ABI FD (green), SNPP/VIIRS (gold), and NOAA20/VIIRS (blue). The violet shows the overlap among these images. Right: First set of retrieved GOES16/SNPP/NOAA20 stereo winds (05-01-2021; 19:50 UTC) using stereo winds software developed to execute in STAR's SAPF

Himawari-VIIRS Stereo Winds Progress

VIIRS Image Remapping

We are utilizing the open source Polar2Grid software developed at the Cooperative Institute for Meteorological Satellite Studies (CIMSS)/University of Wisconsin to perform the required remapping of VIIRS imagery to the appropriate GEO grid. In our last semi-annual report, we reported that we successfully tested the use of Polar2Grid to remap VIIRS imagery to the GOES-R series ABI fixed grid. During this reporting period, we have successfully tested the use of Polar2Grid to remap VIIRS imagery to the Himawari AHI grid. This is illustrated in Figure 2 where stitched SNPP/VIIRS M15 band granules (16:31 – 17:01 UTC) from 14 March 2022 have been remapped to the Himawari AHI grid.

Work is in progress to apply the VIIRS time model to AHI which involves remapping the VIIRS pixel times to the AHI grid. Once complete, we will be able to attempt to generate our first set of Himawari-VIIRS stereo winds.

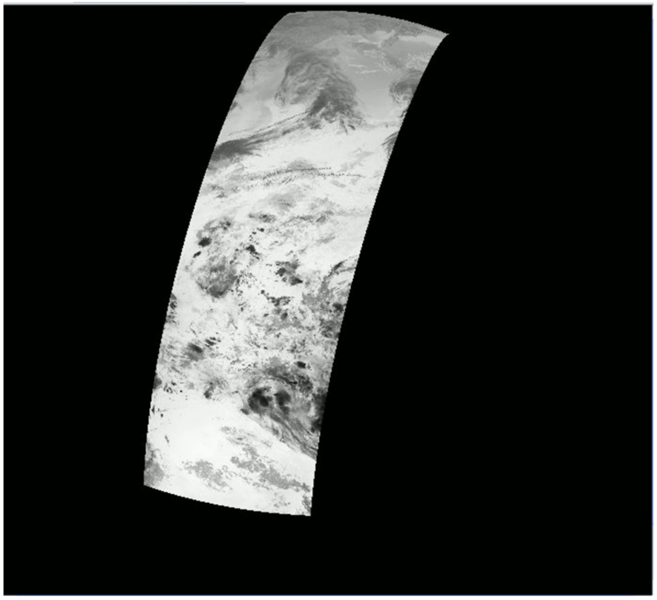

Figure 2. Stitched SNPP/VIIRS M15 band granules (16:31–17:01 UTC) from 14 March 2022 that have been remapped to the Himawari AHI grid.

Assessment of GEO-VIIRS Stereo Winds Configurations

We examined the rationale for using a GEO-*Tandem VIIRS* stereo winds configuration versus a GEO-*Single VIIRS* stereo winds configuration and evaluated the pros and cons of each. Understanding the trade-offs of these configurations is important for defining requirements for future operational production of GEO-LEO at NOAA/NESDIS.

Geographic Coverage

The tandem VIIRS configuration results in the loss of approximately one-third of VIIRS wind coverage relative to the coverage associated with the single VIIRS configuration. This can be seen in Figure 1. To increase the geographic coverage of the GEO-VIIRS winds beyond that offered by the tandem VIIRS configuration, we can use a single VIIRS configuration to generate GEO-VIIRS stereo winds in the non-overlapped areas.

Stereo Winds Quality

The stereo winds retrieval algorithm provides the means to estimate the uncertainty of the retrieved model parameters via a 5x5 covariance matrix. This covariance matrix represents the uncertainty statistics associated with the retrieved parameters (two velocity and three position vector components) assuming that the tracking errors are Gaussian and independent. The retrieval height uncertainties (not shown) associated with ABI/VIIRS stereo have a much larger range of values than the uncertainties associated with the retrieved velocity states. This behavior is explained by the ABI being capable of determining the velocity states independently of VIIRS, while height estimation relies on VIIRS and ABI collectively. The uncertainty in height estimation depends on a varying binocular angle between the ABI and VIIRS views as discussed further below

The uncertainty of the retrieved stereo heights is sensitive to the VIIRS scan angle. In addition, there is an unfavorable VIIRS viewing geometry that exists relative to that of ABI, when both their lines of sight are nearly parallel, that results in large stereo height uncertainties. In this situation, when the VIIRS line of sight is parallel or nearly parallel to the line of sight of ABI, the ability to retrieve heights is lost. To illustrate this, we present scatter plots of stereo wind heights retrieved with tandem (J1 and SNPP) VIIRS versus SNPP VIIRS only (Figure 3a) and from SNPP-only versus J1-only (Figure 3b). Note the much large scatter in the retrieved heights associated with the J1-only configuration (Figures 3b and Figures 3c). This large scatter is associated with some rather large J1-only height retrieval uncertainties that are illustrated in blue points in Figure 3d. These large uncertainties are due to the unfavorable geometric situation described above for the J1-only configuration for this day and time. The good news is, we can prescribe a height uncertainty threshold to use in a quality control check to flag retrievals that fall in this unfavorable geometry situation. For this case we prescribe an uncertainty threshold of 5e3 (unscaled from covariance, arbitrary units) which corresponds to a height error of approximately 1km (after proper scaling). After doing this and revising the Figure 3 scatter plots, we get the scatter plots shown in Figure 4. Now with only high-quality retrievals included, much better agreement between retrieved heights from each of the three VIIRS configurations is obtained. We note that an unfavorable geometric situation could also occur for the SNPP-only configuration. On the contrary, this unfavorable geometry situation will never occur with the VIIRS tandem configuration as all three satellite lines of sight will never be parallel. This is a strength of the tandem VIIRS configuration.

As a result of this analysis, we make the following recommendations regarding the VIIRS configurations to use:

- Use of the tandem VIIRS configuration is preferred
- Extend the tandem coverage with the single VIIRS configuration when the covariance shows height retrievals to be of high quality

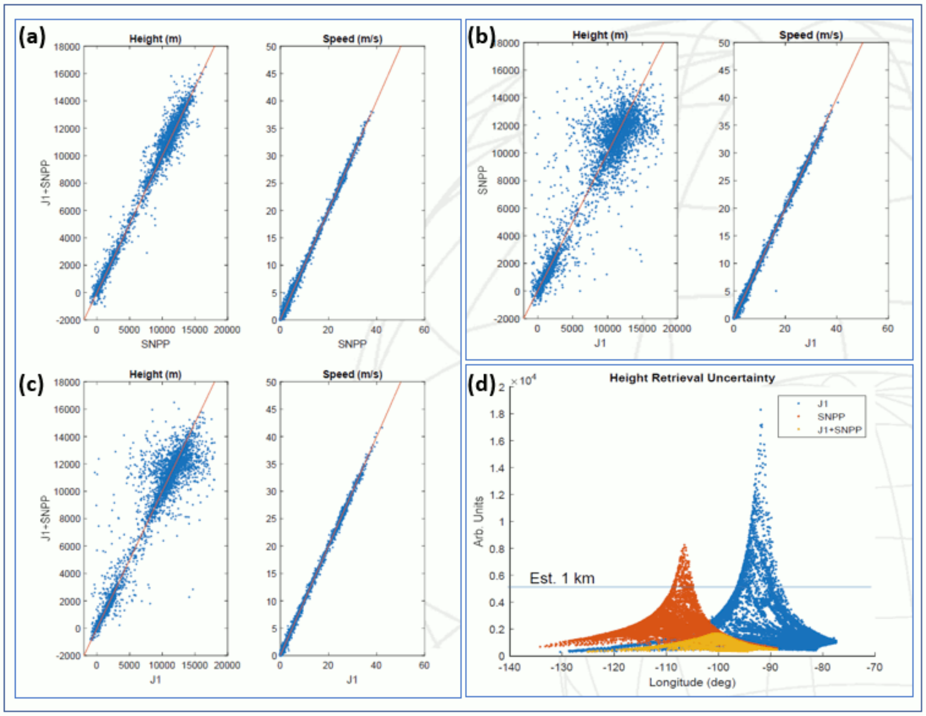

Figure 3. Scatter plots of ABI/VIIRS retrieved stereo AMV heights and speeds derived from (a) tandem use of J1 and SNPP VIIRS versus SNPP alone; (b) single use of SNPP versus J1, and (c) tandem versus single use J1. Retrieved height uncertainties for these various VIIRS configurations are shown in (d).

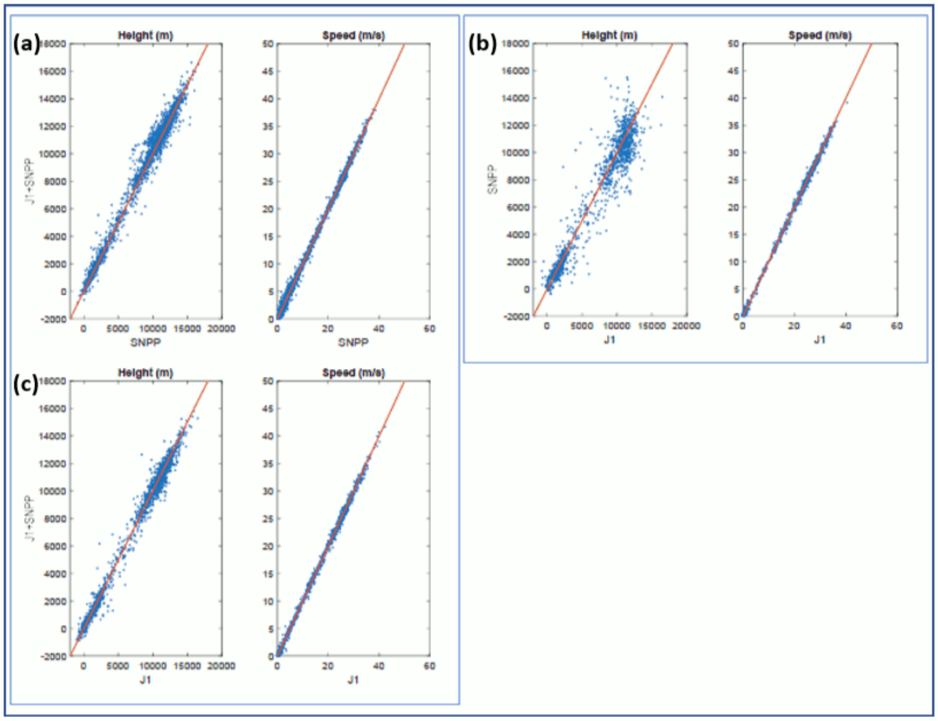

Figure 4. Scatter plots of ABI/VIIRS retrieved stereo AMV heights and speeds after quality control derived from (a) tandem use of J1 and SNPP VIIRS; (b) single use of SNPP, and (c) single use J1.

Tonga Volcanic Eruption Case Study

We applied the stereo winds approach to GOES-17 ABI and Himawari-8 AHI imagery to study the 15 January 2022 eruption of the Hunga Tonga-Hunga Ha'apai volcano, which is relevant to this study because of the ultimate goal of converging GEO-GEO and GEO-LEO stereo winds into an enterprise capability. The apparent shift in the ash plume as observed from the different vantage points of GOES-17 and Himawari-8 contains information about the plume height and the apparent movement of the plume. Determining the height of volcanic plumes has an important implication for their dispersion and transport in the atmosphere as well as their lifetime impacts on Earth's climate.

Using a triplet of GOES-17 mesoscale images (07:15, 07:16, and 07:17 UTC) and a Himawari-8 FD image (07:10 UTC), the retrieved stereo winds successfully captured the height and motion of the ash plume resulting from the eruption. Figure 5 shows the GOES-17 band-14 brightness temperatures in the vicinity of the Tonga volcano at 07:17 UTC on 15 January, 2022 which is about 3 hours after the initial eruption. A large ash plume (light blue) is clearly visible and extends well into the stratosphere as indicated by retrieved stereo heights (Figure 6a) that exceed 30.5 km (> 100,000 ft). Also visible below the ash plume is a layer of cloud and ash at ~16km (noted by light green color) indicating that it is located at/near the tropopause. Figures 6b and 6c show the retrieved u-components (positive indicating westward motion; negative indicating eastward motion) and v-components (positive indicating northward motion; negative indicating southward motion) motion and clearly show the expansion (indicated by white arrows) of the ash plume.

It is worth noting that during the course of this work on this case study, we uncovered and resolved an issue with the AHI time model. It is critically important that the instrument time model produces accurate times since the retrieval of accurate stereo cloud heights depends on these times.

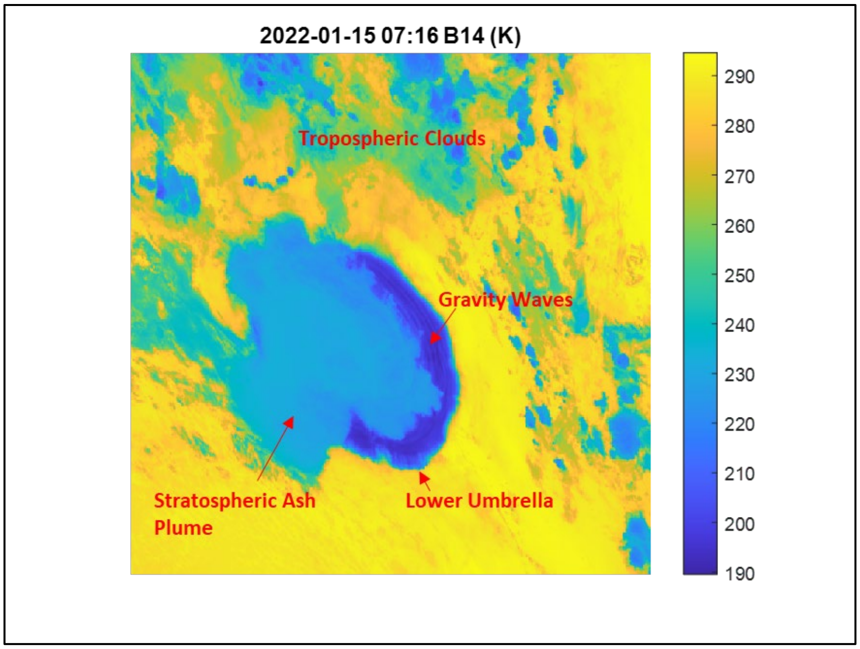

Figure 5. GOES-17 band-14 (11.2um) brightness temperatures in the vicinity of the Tonga volcano at 07:17 UTC 15 January, 2022.

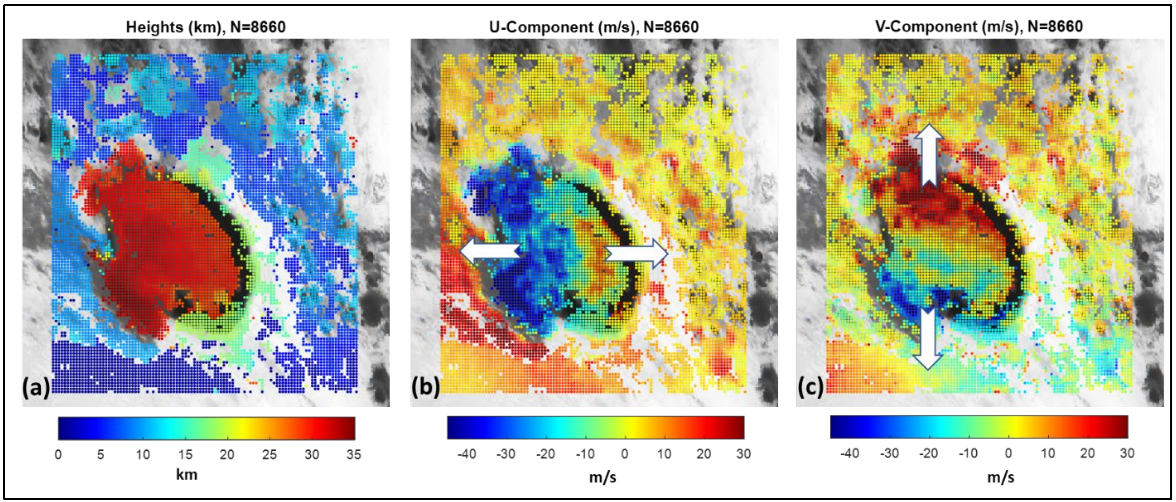

Figure 6. Retrieved stereo height (a), motion vector u-component (b) and v-component (c) of ash plume and tropospheric clouds near the Tonga volcano at 07:17 UTC on 15 January, 2022

Outreach

At the 2022 Annual AMS meeting, Jaime Daniels (NESDIS/STAR) gave an oral presentation at the 18th Annual Symposium on Operational Environmental Satellite Systems entitled, “Status of GEO-GEO and GEO-LEO Stereo Winds Development at NOAA”. Co-authors on this talk were: Jim Carr (Carr Astronautics), Dong Wu (NASA), Wayne Bresky (IMSG), Houria Madani (Carr Astronautics), and Mariel Friberg (USRA).

Plans for Next Reporting Period

- Complete development and testing of AHI-VIIRS stereo winds software in STAR’s Satellite Application Processing Framework environment
- Complete documentation and standardization of the stereo retrieval software.
- Develop script to automate the selection of VIIRS granules from STAR’s Central Data Repository (SCDR) to use in stereo winds processing.
- Perform additional case studies involving ABI-VIIRS and AHI-VIIRS stereo winds
- Generate ABI-VIIRS and AHI-VIIRS stereo winds over a longer period of time and validate quality of retrieved stereo winds against spatially and temporally collocated NESDIS operational GOES winds and rawinsonde winds.