Satellite-derived Winds from VIIRS: Status and Outlook

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Abstract

The properties of tropospheric winds – speed, direction, and pressure – are derived by tracking cloud features using visible/near-infrared/thermal infrared (IR) satellite imager data from both geostationary and low-earth orbiting satellites. In the high latitudes (poleward of 60 deg. latitude), winds are derived from three successive satellite passes using data from the Moderate Resolution Imaging Spectroradiometer (MODIS), the Advanced Very High Resolution Radiometer (AVHRR), and, most recently, the Visible and Infrared Imaging Radiometer Suite (VIIRS). These polar Derived Motion Winds (DMW) products are generated operationally by the National Oceanic and Atmospheric Administration /National Environmental Satellite, Data, and Information Service (NOAA/NESDIS) using an Enterprise algorithm.

Additionally, the high latitude winds are produced routinely in near real-time at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) by the CIMSS/NOAA polar winds team using the heritage winds algorithm (WINDCO). WINDCO is used at CIMSS to prototype and test new satellite-derived winds products, as the software can easily be modified and reconfigured to use additional channels or satellite combinations. For example, a new product in development at CIMSS uses the short-wave IR (SWIR) channel for tracking clouds, which employs Polar2Grid to concatenate and reproject the VIIRS granules into a polar stereographic composite image. Also, we are evaluating the use of a triplet of alternating passes from polar orbiting satellites flying in tandem (NOAA20/SNPP/NOAA20) to derive winds, as the coverage extends more equatorward (to 45 deg. latitude). We are also testing the use of image doublets from alternating satellites, which provides winds globally from VIIRS.

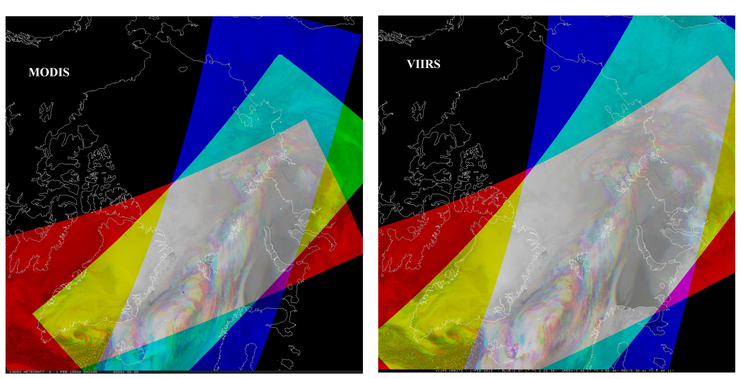
We will report on the status and evaluation of the SWIR winds, and their use in numerical models. In addition, we will provide examples and discuss the doublet and triplet tracking from alternating satellites, and the implications for the DB community

Satellite-derived Winds Algorithms

- In 1969, the NOAA National Environmental Satellite Service (NESS, now NESDIS) began routine production of a completely manual technique for producing wind vectors from viewing time loops of visible satellite images. The technique was partially computerized in the 1970s, automated in the 1990s, and was recently updated for the GOES-R series of geostationary satellites. NOAA/NESDIS maintains and operates an Enterprise algorithm.
- Concurrently, the University of Wisconsin-Madison Space Science and Engineering Center (SSEC) developed a computerized algorithm (WINDCO) in the 1970s to manually track clouds from the imagery of the first generation geostationary weather satellites. This technique was fully automated in the 1990s, and variations of this technique are still in use today. This heritage algorithm is maintained at CIMSS, with support from NOAA, for prototyping and testing new winds products.
- Similar efforts were also underway at EUMETSAT and JMA during the 1970s, with launch of their first geostationary satellites: Meteosat and GMS, respectively. There are now nearly 10 wind producing centers, worldwide.

Heritage Algorithm Applied to VIIRS Images, Facilitated by using Polar2Grid

- The heritage algorithm was first applied to polar orbiting satellite data in the early 2000s with the launch of Terra and Aqua, using images from the MODIS instrument. This was followed by the use of AVHRR from both the NOAA satellites and Metop. The McIDAS (Man computer Interactive Data Access System) is used to combine granules and reproject for use with WINDCO.
- The latest polar orbiting data is from VIIRS onboard Suomi NPP and NOAA-20. With the short duration of each VIIRS granule and the bow tie deletion, Polar2Grid is used to reproject and remove the bow tie effect.
- The figure below shows the improved coverage of VIIRS (right) over MODIS (left). The gray area is where three images overlap for wind derivation. The wider swath of VIIRS means wider coverage and more equatorward.



VIIRS has a wider swath (3000 km) than MODIS (2320 km), so the coverage will improve and extend further equatorward.

Acknowledgements

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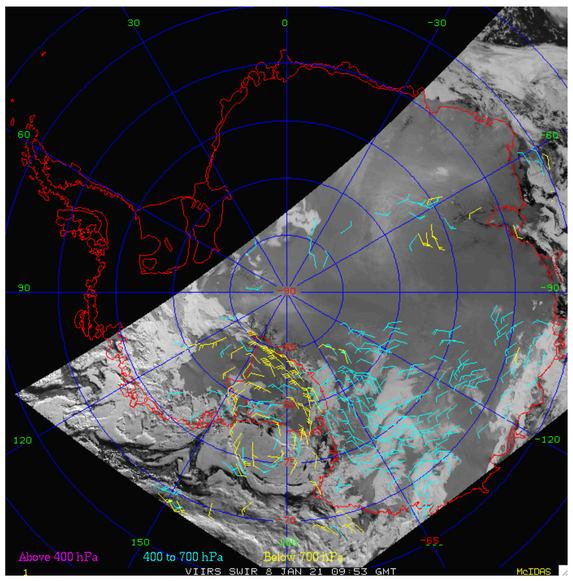
Shortwave Infrared Winds

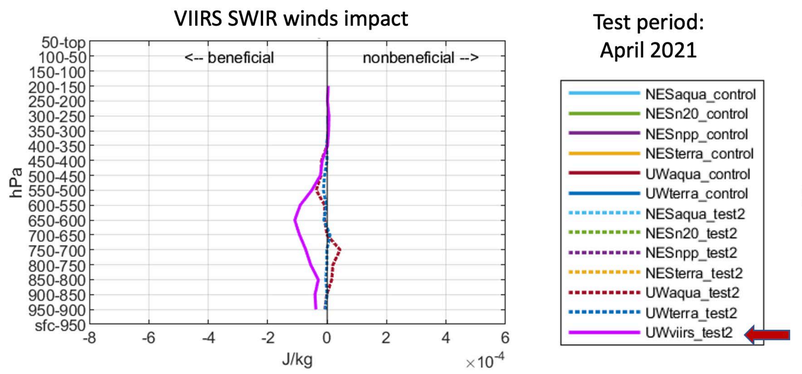
For many years, SWIR winds have been routinely generated using MODIS band 7 (2.1 µm) from both Terra and Aqua satellites.

Beginning in early 2021, VIIRS SWIR winds are now routinely generated at CIMSS using the M11 (2.2 µm) band. An example is shown in the figure (right). Using a SWIR band provides greater contrast between liquid clouds and the underlying snow/ice surface, which are both bright in the visible and may have similar temperatures in the infrared.

The U.S. Naval Research Laboratory (NRL, Monterey, CA) recently demonstrated the positive impact of the SWIR winds. NRL's test results for April 2021 show that SWIR product is beneficial to numerical weather forecasts, shown in the figure below.



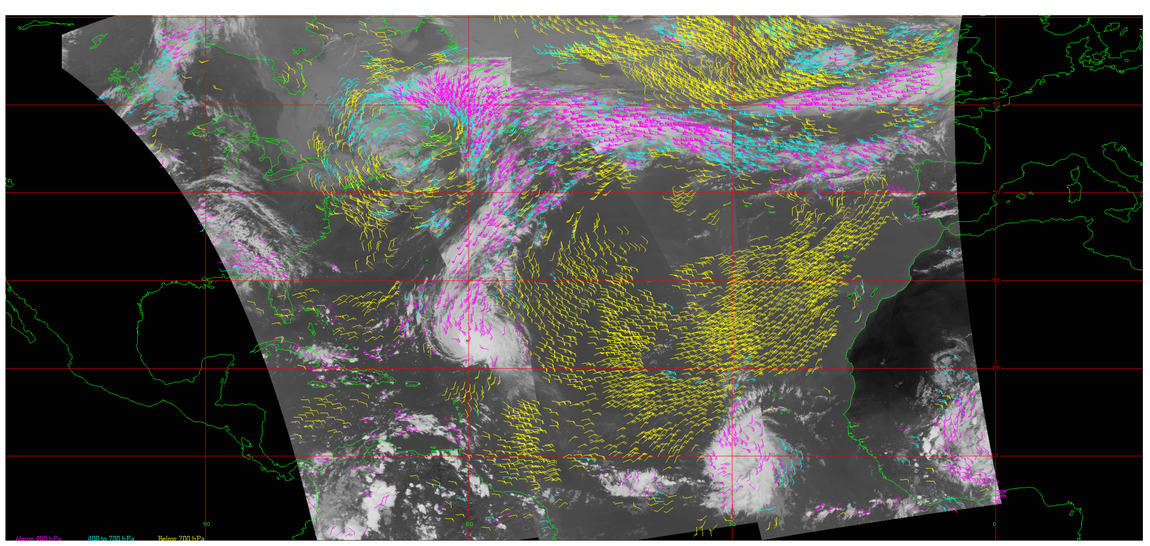
VIIRS SWIR 2.25 µm polar winds in the Antarctic from Suomi NPP on 08 January 2021 at 0953 UTC, color coded by height: Yellow (below 700 hPa), cyan (400 to 700 hPa), magenta (above 400 hPa).



Impact of the VIIRS SWIR in an April 2021 test case at NRL. The magenta "UWviirs_test2" line shows the beneficial impact of the new VIIRS winds

Tandem Infrared Winds: Triplet vs Doublet Feature Tracking

- The Tandem IR winds concept uses alternating polar orbiting satellites (e.g., S-NPP and NOAA-20). When using a triplet (S-NPP => NOAA-20 => S-NPP), the winds coverage extends from the polar regions to high mid-latitudes.
- An experimental product is being developed that uses a pair (or, doublet) of images (e.g., S-NPP => NOAA-20; NOAA-20 => S-NPP). This extends the winds coverage to all latitudes. The figure below shows the coverage from several orbits of S-NPP and NOAA-20, which will result in daily global coverage. Again, Polar2Grid is used for reprojection to a latitude/longitude grid in non-polar regions; polar stereographic projection poleward of 60º latitude. These images are exported to McIDAS for additional reformatting for use in WINDCO.
- This product has only been generated using the full, global VIIRS dataset. However, the algorithm could be adapted to use Direct Broadcast passes, to provide satellite-derived winds at DB sites.



An example of VIIRS IR winds coverage using several orbits of alternating passes from S-NPP and NOAA-20, color coded by height: Yellow (below 700 hPa), cyan (400 to 700 hPa), magenta (above 400 hPa).