JPSS Tandem, Shortwave Infrared and Day-Night Band VIIRS Polar Winds

Rich Dworak[1], David Santek[1], Dave Stettner[2] and Jeff Key[2]

[1]Space Science and Engineering Center, Madison, Wisconsin
[2]NOAA/National Environmental Satellite, Data, and Information Service

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Introduction

The properties of winds from visible/near-infrared/thermal infrared satellite imagers – speed, direction, and altitude – are derived by tracking clouds in data from the Visible and Infrared Imaging Radiometer Suite (VIIRS), the Moderate Resolution Imaging Spectroradiometer (MODIS), and the Advanced Very High Resolution Radiometer (AVHRR), and by tracking water vapor with MODIS. However, polar clouds are notoriously difficult to detect and characterize with satellite imagers because of the similarities between their temperature and reflectance properties and those of the underlying snow and ice surface. Ubiquitous lower-tropospheric temperature inversions in winter and nearly isothermal temperature profiles in summer result in a very small temperature contrast between low, stratiform clouds – the most common cloud type over much of the Arctic Ocean – and the surface. In visible imagery, clouds and snow/ice are similarly bright, again resulting in very low contrast. This lack of contrast means that there are fewer good features to track, yielding fewer and/or lower quality wind vectors.

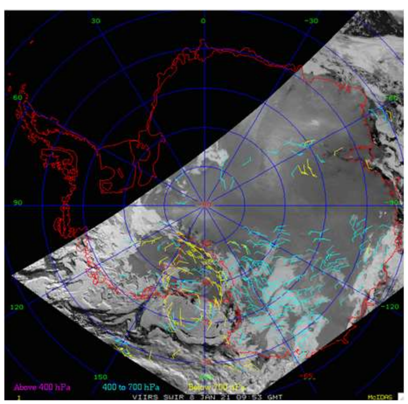
In the shortwave infrared (SWIR) portion of the spectrum the scattering properties of liquid-phase clouds and snow/ice are significantly different. Clouds are much brighter than the underlying snow or ice surface and the contrast between low clouds and the surface is large in SWIR bands around 1.6, 2.2, and 3.7 µm. This fact that has been exploited in polar cloud detection algorithms at least since the early 1990s. AVHRR, MODIS, and VIIRS all have bands at 1.6 and 3.7 µm; MODIS and VIIRS also have bands at 2.1-2.2 µm. In theory, SWIR data will provide more good features for cloud tracking and atmospheric motion vector derivation in the presence of sunlight (daytime), especially for liquid clouds over snow and ice. The VIIRS day-night band (DNB) provides another unique source of spectral information: reflected radiation at night in the presence of moonlight.

Here we report on the advantages of utilizing these new spectral bands and tandem JPSS (S-NPP/NOAA-20) IR to extend the current VIIRS polar winds products. Tests using a MODIS SWIR band have demonstrated that additional wind information can be obtained, particularly lower in the atmosphere. The DNB has not previously been employed for winds, though it is currently being successfully employed for sea ice motion.

Shortwave Infrared

For many years, SWIR winds have been routinely generated using MODIS band 7 (2.1 µm) from both Terra and Aqua satellites. These data are available here:
ftp://stratus.ssec.wisc.edu//pub/winds/rts/aqua/SWIR/
ftp://stratus.ssec.wisc.edu//pub/winds/rts/terra/SWIR/

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 below. 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.



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).

Acknowledgements

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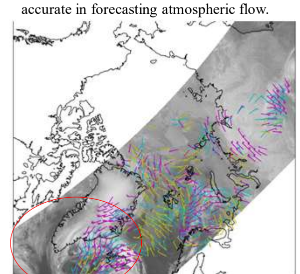
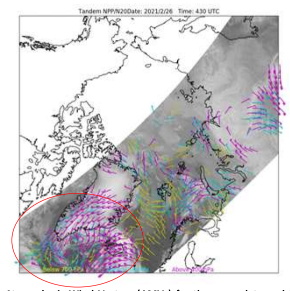
JPSS Tandem Infrared AMVs

Currently, only single satellite S-NPP and NOAA-20 VIIRS AMVs are generated for operational use. Being that the two satellites pass in synchronous orbits at 50 minutes apart, AMVs can be generated at half the time with greater coverage. A case study of Tandem AMV coverage is provided below. In this case there is a strong jet stream exit region of 40-50 knots pushing over Iceland at upper-levels (above 400 hPa) that is indicated by the magenta colored vectors. The area near Iceland exhibit ageostrophic motions and upper-level divergence. The obvious regions that emerge with enhanced AMV coverage for the JPSS Tandem product over single NOAA-20 VIIRS is over West Greenland, Labrador Sea with shortwave trough, and south of Iceland in the anti-cyclonic part of the jet exit region. The greater coverage of the JPSS Tandem AMV product is due to the greater overlap areas of preceding and succeeding S-NPP orbits with NOAA-20 and shorter time interval between sub-vectors (50.5 versus 101 minutes). This shows the ability of the experimental product to provide additional wind information that can be assimilated into global weather forecast models and downstream potential to make the weather models more accurate in forecasting atmospheric flow.



Atmospheric Wind Vectors (AMVs) for the same date and time on 2021 February 26 for 0430 UTC over the Arctic and North Atlantic from single NOAA-20 triplet of orbits.

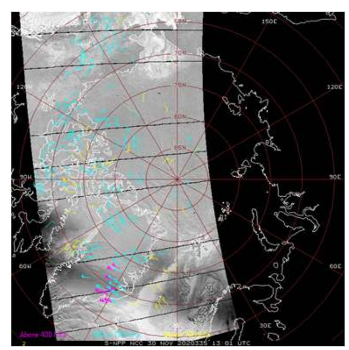


Atmospheric Wind Vectors (AMVs) for the same date and time on 2021 February 26 for 0430 UTC over the Arctic and North Atlantic from tandem S-NPP/NOAA-20/S-NPP triplet of orbits.

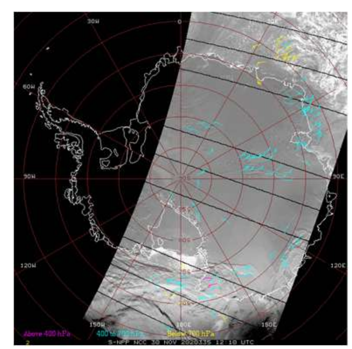
Day/Night Band

As an initial test, the heritage winds algorithm was applied to the VIIRS Day/Night Band (DNB) imagery. Since the dynamic range of the DNB radiances varies by many orders of magnitude depending on solar or lunar illumination, the Near Constant Contrast (NCC) product was chosen, which provides time-coherent pseudo-reflectance images for tracking features.

As a demonstration, winds were derived from one triplet of orbits using data from the Suomi National Polar-orbiting Partnership (NPP) satellite over each pole on 30 November 2020. Left figure depicts the derived-wind coverage over the Arctic at 1300 UTC, which is lunar illuminated in late November; winds over sunlit Antarctica at 1210 UTC are shown in the right figure. The vector heights are calculated using co-located VIIRS infrared brightness temperatures and are color-coded in the figures. Routine generation of the NCC winds is being implemented to test the algorithm in the varying lunar and solar lighting, or lack thereof, and for validation by comparing to other polar winds products.



VIIRS NCC polar winds in the Arctic from Suomi NPP on 30 November 2020 at 1300 UTC, color coded by height: Yellow (below 700 hPa), cyan (400 to 700 hPa), magenta (above 400 hPa).



VIIRS NCC polar winds in the Antarctic from Suomi NPP on 30 November 2020 at 1210 UTC, color coded by height: Yellow (below 700 hPa), cyan (400 to 700 hPa), magenta (above 400 hPa).