RESEARCH TO OPERATIONS OF SATELLITE PRODUCTS WITHIN NESDIS

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1. INTRODUCTION

The National Environmental Satellite, Data, and Information Service (NESDIS) provides timely access to atmospheric, oceanic, and land surface satellite data from a variety of polar-orbiting and geostationary satellites to satisfy end user requirements. New and enhanced products from existing satellite systems and new products from new satellite systems are generated as user requirements are identified and validated, and product development resources are secured. Data are often blended from multiple satellite sources to generate a single dataset. NESDIS product development efforts that transition to operations result in improved weather forecasts and assist in monitoring of Earth's climate and oceans.

Some recent operational products include blended total ozone, blended snow and ice cover, microwave hydrologic and land surface products, sea surface temperature, oceanic heat content, polar winds, and solar radiation products. This paper will describe those and other examples of product development efforts that have successfully transitioned from research to operations and will highlight some products that are currently in the transition process.

2. SATELLITE PRODUCTS AND SERVICES REVIEW BOARD

The Satellite Products and Services Review Board (SPSRB) is a structured process for developing satellite data products to satisfy operational user needs. The SPSRB is responsible for the oversight and guidance necessary to effectively manage the product life cycle process from product development to transition into operations, and includes product enhancements and retirement

Requirements for new or improved satellite products are identified through user requests. Scientific agencies can identify maturing satellite product development or algorithms that improve shortfalls and provide significant benefits by submitting a user request. A requirement can also be directed by NOAA (e.g., NOAA satellite program managers). An integrated product team (IPT) is established at the beginning of the product development process. IPTs consist of researchers, operations, and users and are a key component for a successful transition from research to operations.

3. PRODUCTS

To meet the NESDIS mission, data is processed from numerous satellites, as shown in Figure 1, and science data products are produced. The sources of satellite data range from domestic to international and include both geostationary and polar-orbiting. NESDIS has recently declared several research products as operational and these products are described in the following subsections.

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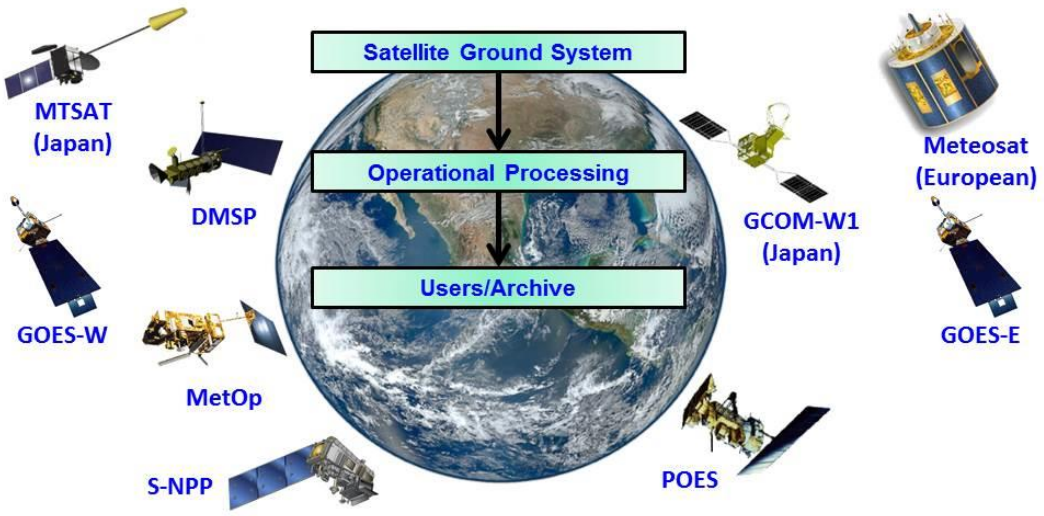

Figure 1. Satellite Processing.

3.1 Atmospheric Polar Winds

Atmospheric winds over the poles are derived by tracking cloud features in infrared channel imagery in the Suomi National Polar-orbiting Partnership (S-NPP) satellite's Visible Infrared Imaging Radiometer Suite (VIIRS) longwave infrared channel, band M15 (10.76 µm). Wind speed, direction, and height are measured throughout the troposphere, pole-ward of approximately 65 degrees latitude, in cloudy areas only. For quality control, winds are derived using three consecutive orbits. Wind vectors are assigned the time of the middle image of the orbit triplet, thereby adding 101 minutes to the latency.

Prior to being declared operational from the VIIRS instrument, polar winds products were validated against radiosonde wind observations, aircraft wind observations, and forecast model analysis winds. Polar winds are used operationally at numerical weather prediction centers.

Figure 2 shows an example of the VIIRS polar wind product.

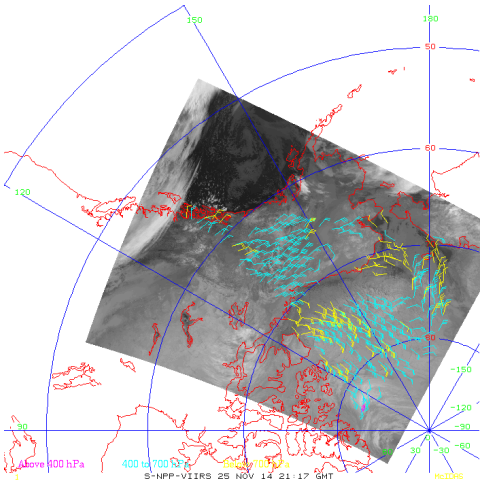

Figure 2. VIIRS Polar Winds.

3.2 Blended Snow and Ice Cover

Many satellite sources are used to generate the snow and ice products, including visible and infrared imagery, and data from scatterometers, microwave sensors, and synthetic aperture radar returns. Additional data used to generate snow and ice products include surface data, model data, information from buoys and reconnaissance flights. Snow and ice charts are prepared on a polar stereographic projection centered on the North Pole.

Blended snow and ice cover products were recently enhanced with the addition of VIIRS data. Snow and ice cover have an improved resolution of 1-km due to the availability of VIIRS. Snow depth is determined by weighted blending of interpolated snow depth from surface observations and analyst adjustments, the blended snow cover analysis, and elevation-based downscaling of snow water equivalent.

Ice thickness is a new product. To determine ice thickness approximation and range, analysts use data from a variety of sources to examine flow shapes, ice temperatures, backscatter from scatterometry data, and lead structures.

Figure 3 shows a blended 4-km snow depth product. Figure 4 shows an example of sea ice thickness.

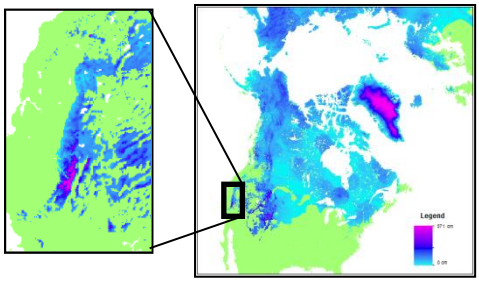

Figure 3. Blended snow depth.

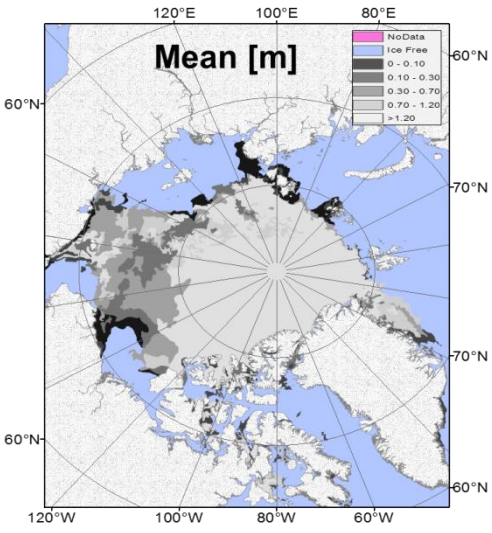

Figure 4. Sea Ice Thickness.

Snow and ice products are used for numerical weather prediction and climate monitoring.

3.3 Blended Total Ozone

A total ozone product is generated by blending infrared and ultraviolet data. Data from the S-NPP Cross-track Infrared Sounder (CrIS) has been added to the blended total ozone algorithm. The blended total ozone product combines tropospheric and lower stratospheric (4 to 23 km) ozone retrievals from the infrared instruments with mid-to-upper stratospheric (24 to 54 km) layer ozone retrievals from solar backscatter ultraviolet data.

Blended total ozone is a global product and is retrieved over the poles. The product is used to monitor the Antarctic ozone hole and the long-term global ozone trend.

Figure 5 shows a blended total ozone product generated over the Antarctic ozone hole and depicts the ozone concentration levels for the Southern Hemisphere.

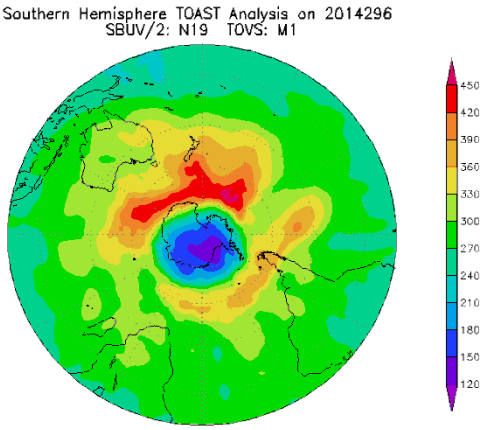

Figure 5. Blended total ozone over the Antarctic.

3.4 Blended Sea Surface Temperature

Blended sea surface temperature (SST) products are generated using data from both polar-orbiting and geostationary satellites. Polar-orbiters offer a higher spatial resolution data while geostationary satellites provide a higher temporal resolution. S-

NPP VIIRS data was recently added to enhance the blended SST product, which is generated once daily with a 5-km resolution. The incorporation of higher resolution VIIRS data provides the ability to acquire more data in areas of broken cloud for input into the analysis.

Blended SST products support ocean monitoring and are used as input to ocean models and in mesoscale oceanography, such as fronts and eddies.

Blended SST products are being enhanced with data from the Japanese Global Change Observation Mission – Water (GCOM-W1) satellite's Advanced Microwave Scanning Radiometer 2 (AMSR2) and these products will be transitioning from research to operations.

Figure 6 shows an example of the daily blended SST product.

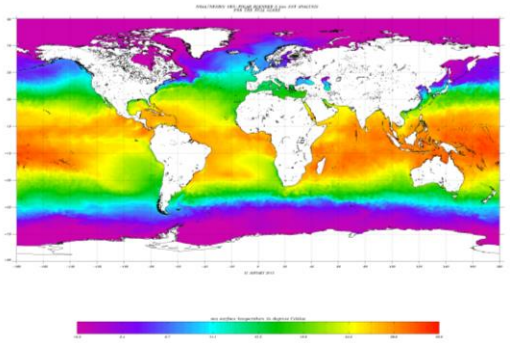

Figure 6. Blended Sea Surface Temperature.

3.5 Solar Radiation Product Suite

The solar radiation product suite provides information on clouds, surface temperature, and longwave and solar radiation at the surface and the top of the atmosphere. Enhancements to the product suite extended the coverage to the West Pacific, East Indian, and West Atlantic Oceans through the addition of data from the European Meteosat and the Japanese Multi-functional Transport Satellite (MTSAT). In addition, the resolution was increased from 14 km to 4 km.

With these enhancements, two new daily blended products are also now available: insolation and photosynthetically active radiation (PAR). Both of these products are generated at the surface using data from all geostationary satellites.

Solar radiation products are generated in support of coral reef monitoring and numerical weather prediction.

Figure 7 shows the new daily photosynthetically active radiation product at the surface. PAR is also known as the visible downward radiative flux and it is generated on a daily basis.

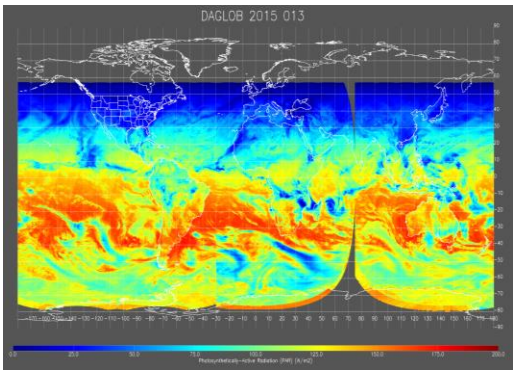

Figure 7. Daily PAR.

3.6 Green Vegetation Fraction

Green vegetation fraction (GVF) products provide the fraction of a pixel covered by green vegetation. GVF is generated using the VIIRS data on S-NPP. GVF is used as an input to land surface models to provide enhanced characterization of the surface. This results in improved forecasts of near-surface winds, temperature, and humidity.

GVF is a weekly product that is updated daily. It is available globally with a 4-km resolution and regionally with a 1-km resolution. GVF uses VIIRS bands I1 (0.640 µm), I2 (0.865 µm), and M3 (0.490 µm).

Figure 8 shows a comparison between the GVF from the legacy Advanced Very High Resolution Radiometer (AVHRR) aboard the Polar-orbiting Operational Environmental Satellites (POES) and the higher resolution VIIRS S-NPP data. AVHRR is shown in the top image with a 16-km resolution and VIIRS is on the bottom with a 4-km resolution.

Figure 8. GVF comparison from AVHRR (top) and VIIRS (bottom).

4. NEAR-TERM PRODUCTS

Several products have been in development and are soon to begin the process of transitioning to operations.

4.1 *Tropical Cyclone Products*

Tropical cyclone intensity products are used to estimate and forecast the radii of winds to give guidance to hurricane forecasters. Products include maximum winds, minimum sea-level pressure, and radii of 34-, 50-, and 64-knot winds. Also generated are balanced horizontal winds at 1000 to 200 millibars within 600-km of the storm center. Tropical cyclone intensity products are generated globally from S-NPP's Advanced Technology Microwave Sounder (ATMS) data and distributed in text format every six hours for the north Atlantic and northeast Pacific tropical cyclone basins.

4.2 Blended Hydrometeorological Products

Blended hydrometeorological products are used by forecasters to pinpoint the location of heavy precipitation globally and over the continental United States for use in flood guidance. Products are also used to determine the transfer of moisture from ocean to land. Products include total precipitable water (TPW), rain rate, and TPW anomalies, which shows the departure from climatology and how unusual a moisture field is.

Blended hydrometeorological products are generated from a variety of microwave data sources. Blending the individual satellite observations into one image provides forecasters with a single resource with non-gap global coverage. These blended products are being enhanced to add S-NPP ATMS data and data from GCOM-W1's AMSR2 instrument.

Figure 9 shows an example of a blended global TPW product.

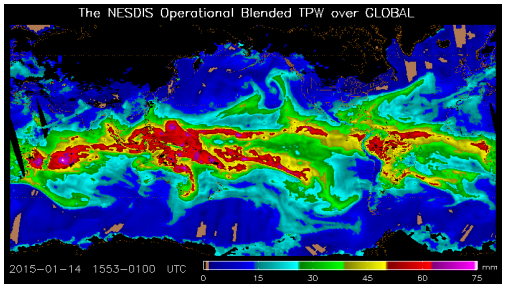

Figure 9. Blended total precipitable water.

4.3 Clouds

Cloud products for the National Weather Service include gridded products and composite or mosaic products.

Visible and infrared satellite composite imagery over the Arctic region improve operational forecasting for maritime and aviation operations. Products will be generated from a variety of polar-orbiting and geostationary satellites.

A global mosaic of geostationary satellite infrared and visible imagery is generated in support of aviation weather. Products will be used to generate a global icing analysis that will improve international flight safety.

Gridded cloud products that include cloud max, cloud phase, cloud top height, cloud liquid water path, and cloud ice water path are being enhanced for numerical weather prediction verification and assimilation. Gridded cloud products will be generated using both polar-orbiting and geostationary data.

4.4 Magnetopause Crossing Detections

Magnetopause crossing detections provide forecasters information during major geomagnetic storms that impact the space weather. Operations that might be impacted by geomagnetic storms include the electric power grid, aircraft operations, manned spaceflight, and satellite operations.

Magnetopause locations will be generated using data from the Geostationary Operational Environmental Satellite (GOES). Solar wind density and velocity, as well as magnetic field measurements, are derived using data from NASA's Advanced Composition Explorer (ACE) satellite.

4.5 Outgoing Longwave Radiation

Outgoing longwave radiation (OLR) provides information on the diurnal signal for model verification and monitoring and is also useful for climate monitoring. OLR is generated from numerous satellites. An OLR product generated from the CrIS instrument on S-NPP will transition to operations to provide a better temporal coverage.

4.6 Ozone Limb Profiles

High vertical-resolution ozone profiles are generated from the Ozone Mapping and Profile Suite – Limb Profiler (OMPS-LP) aboard the S-NPP satellite. The OMPS-LP has three viewing angles of the atmosphere: one behind the satellite, and two angles 250-km behind and to the side of the satellite.

Ozone profiles are used as inputs to numerical weather prediction models, and for determining the ultraviolet (UV) index and climate trends.

4.7 Global Biomass Burning Emissions

Biomass burning emissions products include fire emissions and fire radiative power products from geostationary and polar-orbiting data, and burned area using geostationary data only. These products will be used for improved global aerosol predictions and for inputs into fire weather model guidance.

4.8 Oceanic Heat Content

Oceanic heat content (OHC) is a measure of the integrated vertical temperature from the ocean surface to the 26° C depth. OHC is used to monitor temperature variations that impact the health of coral reefs and provides information about the threat of coral reef bleaching events at deeper reef sites. It is also used to improve hurricane intensity forecasts and in climate studies.

OHC products are generated for the North Atlantic and North Pacific Basins using data from the Jason-2 and French-Indian SARAL satellites. It is being expanded to include the South Pacific and also Cryosat-2 satellite data.

4.9 Vegetation Health

Vegetation health products are used for drought monitoring, in global climate impact assessments, and to determine global crop production, fire risk, disaster mitigation, and food security.

Products include the vegetation health index (VHI), which characterizes total health conditions in response to weather impacts, the vegetation condition index (VCI), which characterizes moisture, and temperature condition index (TCI), which characterizes temperature. Vegetation health products will

be generated from S-NPP VIIRS data, initially with a 4-km resolution.

4.10 Evapotranspiration and drought

Satellite derived evapotranspiration and drought products will be used as inputs into land surface models and for agricultural management and forecasts. The algorithm is based on excess heating on vegetation cover caused by soil moisture deficits. Monitoring maps for North America will be generated using GOES data.

4.11 Blended Global Soil Moisture

Soil moisture information is assimilated into forecast models and is used to help forecast flash floods and the status of agricultural crops and is also used for military mobility.

Global soil moisture products are generated by retrieving data from the WindSat instrument on the Coriolis satellite and blending it with retrievals from other available instruments, including the Advanced Scatterometer (ASCAT) instrument on the MetOp satellite as well as data from the Soil Moisture and Ocean Salinity (SMOS) mission. In the short term, the algorithm is being upgraded to included data from GCOM-W1's AMSR2 instrument.

4.12 *Ensemble Tropical Rainfall Potential*

The Ensemble Tropical Rainfall Potential (eTRaP) product provides an estimate of rain rates from land-falling tropical cyclones. The eTRaP products blend a variety of polar-orbiting and geostationary satellite data. The algorithm is being upgraded to include data from the ATMS instrument.

5. SUMMARY

NESDIS has successfully transitioned new and enhanced capabilities from research to operations and is in the process of developing additional satellite products from multiple sources of satellite data. These products satisfy operational user requirements, resulting in improved weather forecasts and assisting in the monitoring of Earth's climate and oceans.

Additional products will continue to be developed for transition to operations as user requirements are identified and validated and product development resources are secured.

6. REFERENCES

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K. Berberich, T. Schott, and S.L. Bunin: "NOAA'S Transition to Operations of NDE S-NPP Products", *Fourth Conference on Transition of Research to Operations* in Atlanta, Georgia, February 2014

NESDIS Office of Satellite and Product Operations, http://www.ospo.noaa.gov/

Suomi National Polar-orbiting Partnership, http://jointmission.gsfc.nasa.gov/