NESDIS Product Developments from New Satellite Systems

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1. INTRODUCTION

The National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) has been and continues to be actively involved with satellite product development from new satellite systems that were recently launched in late 2011 and also those expected to launch in 2012. These satellites include the United States' Suomi National Polar-orbiting Partnership (NPP), Europe's Metop-B, the French-Indian Megha-Tropiques, the Japanese Global Change Observation Mission – Water (GCOM-W), and also the Indian satellite Oceansat-2.

NOAA's NPP Data Exploitation (NDE) is a data processing system that will provide the critical link between the NPP ground segment and the civilian operational user community. The system will receive NPP environmental, sensor, and temperature data records and will be tailoring them to satisfy user-required attributes such as alternative data formats, aerial coverages, frequencies, and projections. NDE will also apply value-added science algorithms to some NPP data records generating what are known as NOAA unique products (NUPs). Generation of such products will help satisfy additional NOAA mission requirements. NOAA is also preparing to generate products from Metop-B, which will provide continuity of polar data from the mid-morning orbit. Products from both the NPP and Metop-B satellites will include atmospheric, oceanic, and land surface products. Space weather products will also be available from Metop-B.

The Megha-Tropiques mission will study the tropical water and energy cycle enabling NOAA with the opportunity to provide its users with additional products over tropical regions. Investing resources in product generation from Megha-Tropiques sensor will help mitigate the future loss of data currently being provided from the jointly owned National Aeronautics and Space Administration (NASA) and Japan Aerospace Exploration Agency (JAXA) Tropical Rainfall Measuring Mission (TRMM) Satellite, which has already exceeded its life expectancy.

With the loss of NASA's QuikSCAT instrument, NESDIS has decided to pursue acquisition of and product generation from scatterometer data onboard the Oceansat-2 Indian satellite. Products which will be made available from this data source will include both 25- and 50-km ocean surface winds vectors.

GCOM-W1 data will be utilized by NESDIS to generate a suite of microwave products. Onboard GCOM-W1 will be the Advanced Microwave Scanning Radiometer 2 (AMSR2) instrument providing many users, including NOAA, valuable microwave data. Planned products to be generated by NESDIS include ocean surface wind speed, soil moisture, and snow depth. Users will be able to take advantage of these continuity products, as well as the improved and expanded suite of products, from all satellite platforms mentioned above. This paper will describe product development taking place at NESDIS to exploit the data from these new satellites.

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2. NPP DATA EXPLOITATION

NDE's mission is to assist NOAA and other civilian end users of polar data to realize the potential of NPP and Joint Polar Satellite System (JPSS) observations. Data processing and distribution of NDE products to the civilian operational user community will begin with the NPP satellite, which launched successfully on 28 October 2011.

A suite of environmental, sensor, temperature, and selected application-related data records (xDRs) from NPP will be provided to NOAA's NDE system and are made available by subscription to its real time operational end users. NDE will receive such xDR products in HDF5 format; however, will be reformatting them into NetCDF4 prior to distribution. Furthermore, NDE will have developed and integrated new algorithms to allow additional processing capabilities of the delivered xDRs. The resultant products will satisfy NOAA requirements and are namely known as NOAA Unique Products (NUPs). NDE's capability to generate and deliver NUPs is one of many system objectives. A list of NDE objectives are provided below:

NDE's system objectives are to:

- Provide routing of data records to end users
- Generate and disseminate tailored NPP data records to end users
- Generate and disseminate NOAA-unique products (NUPs)
- Deliver NUPs, product processing elements, and associated metadata to the NOAA Long-Term Archive
- Provide services to end users, such as NDE product training, product enhancement, and implementation support across NOAA
- Develop a sustainable system that meets end user needs
- Provide software for NPP data record format translation and other manipulations.

Products from NPP are prioritized by NESDIS based on user needs and priorities which are re-evaluated and adjusted annually. As it relates to NPP data, NOAA's highest priority is the continuation of current capabilities from existing polar-orbiting satellites. If a user request for a new sensing capability from NPP is feasible and resources are secured, NDE will also develop new products.

Products from NPP will be generated by NDE from four instruments:

- Cross-track Infrared Sounder (CrIS)
- Advanced Technology Microwave Sounder (ATMS)
- Visible/Infrared Imager/Radiometer Suite (VIIRS).
- Ozone Mapping and Profiler Suite (OMPS), including OMPS Limb Profiler

Table 1 below shows the initial product suite that NDE plans on delivering to the user community operationally in July 2012. These initial data sets will be distributed and utilized by numerical weather prediction (NWP) communities across the globe. For reference, the blue cells indicate JPSS contractor-delivered products (xDRs) and the yellow cells are NOAA-unique products.

Product	NDE Ops Planning Date
ATMS Radiances	Jul-12
ATMS Radiances (BUFR)	Jul-12
CrIS Radiances	Jul-12
CrIS Radiances (BUFR)	Jul-12
VIIRS Radiances	Jul-12
VIIRS Radiances (BUFR)	Jul-12
VIIRS Imagery	Jul-12

Table 1. NDE's projected operational products in July 2012.

The yellow highlighted products within Table 1 are among the NUPs generated within NDE. These unique product sets have specific end users who have submitted requirements for additional formatting. Table 1 reflects radiances from the CrIS,

VIIRS, and ATMS sensors; however, to satisfy the format required for National Weather Service NWP models, NDE will reformat the data file and will make them available in BUFR format.

Also included within Table 1 is NPP VIIRS imagery which is also projected to go operational in the July 2012 time frame. NPP VIIRS data began flowing into the NDE system on 21 November 2011 allowing NDE product engineers to test and validate ingest and processing capabilities associated with the VIIRS data set. Figure 1 below is a screen capture of the first VIIRS Channel 1 visible composite occurring 21 November 2011 over the continental United States (CONUS). The image below was generated by NDE and proved successful ingest of the data from upstream sources.

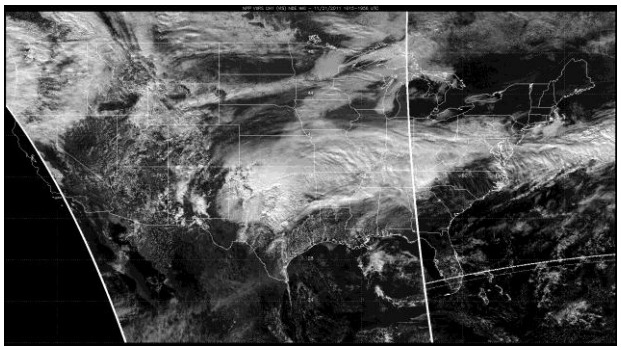

Figure 1. VIIRS Channel 1 visible image over CONUS.

NDE products expected to transition to operations between September 2012 and December 2012 are found in Table 2. Many of these are the hydrological and surface products available from NDE's Microwave Integrated Retrieval System (MIRS), which generates products over all weather conditions from microwave sensors aboard a variety of polar-orbiting satellites and will soon include products from NPP's ATMS.

Additional products include green vegetation fraction, which is used to improve surface characterization in land surface models and cloud-tracked atmospheric wind vectors over the poles, called polar winds, which are also used in NWP models to improve forecasts for the Northern and Southern Hemisphere extratropics.

Radiances from the OMPS sensor and limb profiler will also be available in this time frame. The nadir sensor measures directly below the satellite and the limb instrument measures ozone at an angle to the Earth's surface.

Product	NDE Ops Planning Date
OMPS Radiances	Sep-12
Polar Winds (VIIRS BUFR)	Oct-12
Rainfall Rate (ATMS)	Oct-12
Total Precipitable Water (ATMS)	Oct-12
Snow Cover (ATMS)	Oct-12
Land Surface Emissivity (ATMS)	Oct-12
Temperature Profiles (ATMS)	Oct-12
Moisture Profiles (ATMS)	Oct-12
Cloud Liquid Water (ATMS)	Oct-12
Sea Ice Concentration (ATMS)	Oct-12
Snow Water Equivalent (ATMS)	Oct-12
Ice Water Path (ATMS)	Oct-12
Land Surface Temperature (ATMS)	Oct-12
Rain Water Path (ATMS)	Oct-12
Green Vegetation Fraction	Dec-12
Ozone Limb Profile Radiances	Dec-12

Table 2. NDE's projected operational products in late 2012.

Table 3 shows the NDE products that are projected to become available in the early 2013 time frame. These products will include NUPs from the CrIS and ATMS instruments including cloud cleared radiances, temperature and moisture profiles, ozone retrievals, trace gas retrievals of carbon dioxide, carbon monoxide, methane, and sulfur dioxide, as well as stability products like lifted index and convective inhibition.

The early 2013 products also will include sea surface temperature (SST) products that

are used in operational forecasts models, to assess areas with coral reef heat stress, to help predict coral reef bleaching events, and to locate oceanic temperature fronts.

A variety of multi-satellite blended products is also projected to be available for operational use in this time frame. Among these includes a blended total precipitable water product, which is generated from sensors aboard multiple satellites blended together to make one product. This blended approach enables a more accurate and complete observation of the movement of moisture in the atmosphere to locate areas of heavy precipitation. . The blended SST analysis will use data from NPP and geostationary satellites.

Products	NDE Ops Planning Date
Aerosol Optical Depth (AVHRR-like)	Jan-13
Atmospheric Moisture Profile (CrIS/ATMS)	Jan-13
Atmospheric Temperature Profile (CrIS/ATMS)	Jan-13
Clear Sky Brightness Temperatures	Jan-13
Cloud Top Fraction (CrIS)	Jan-13
Cloud Top Pressure (CrIS)	Jan-13
CO2 Slicing Derived Cloud Top Pressure (CrIS) [New]	Jan-13
CrIS Cloud Cleared Radiances	Jan-13
Ocean Optimized Cloud Mask	Jan-13
Ozone (CrIS)	Jan-13
Sea Surface Temperature (SST)	Jan-13
Sea Surface Temperature (SST) (BUFR)	Jan-13
SST (AVHRR-like)	Jan-13
Stability Products (CrIS)	Jan-13
Trace Gases (Carbon Dioxide, Methane, Sulfur Dioxide)	Jan-13
Blended Rain Rate	Feb-13
Blended SST (Imagery)	Feb-13
Blended Total Precipitable Water	Feb-13
Blended Total Precipitable Water Anomaly	Feb-13
Coral Reef Bleaching Indices/Alerts	Feb-13
SST Anomalies	Feb-13
SST Degree Heating Weeks	Feb-13
SST Hot Spots	Feb-13

Table 3. NDE's projected operational products in early 2013.

In April of 2013 additional products generated from NPP instrument data sources is projected to reach operational status. Many of the products identified in Table 4, will be delivered from the JPSS Program Office with the exception of the aerosol optical thickness and ozone products, which will be made available from NDE to its users in BUFR format and used within NWP applications.

Product	NDE Ops Planning Date
Active Fires	Apr-13
Aerosol Optical Thickness	Apr-13
Aerosol Optical Thickness (BUFR)	Apr-13
Aerosol Particle Size	Apr-13
Atmospheric Moisture Profile	Apr-13
Atmospheric Pressure Profile	Apr-13
Atmospheric Temperature Profile	Apr-13
Cloud Base Height	Apr-13
Cloud Cover/Layers	Apr-13
Cloud Effective Particle Size	Apr-13
Cloud Mask	Apr-13
Cloud Optical Thickness	Apr-13
Cloud Top Height (VIIRS)	Apr-13
Cloud Top Pressure	Apr-13
Cloud Top Temperature	Apr-13
Ice Surface Temperature	Apr-13
Land Surface Temperature (VIIRS)	Apr-13
Land Surface Type	Apr-13
Nadir Profile Ozone	Apr-13
Ocean Color/Chlorophyll	Apr-13

Product	NDE Ops Planning Date
Ozone (BUFR)	Apr-13
Ozone Total Column	Apr-13
Quarterly Surface Type Gridded	Apr-13
Sea Ice Characterization (VIIRS)	Apr-13
Snow Cover	Apr-13
Surface Albedo	Apr-13
Suspended Matter	Apr-13
Vegetation Index	Apr-13

Table 4. NDE's projected operational products in April 2013.

Additional NDE products will be made available in late 2013 and beyond as requirements are validated and product development resources are identified.

3. METOP-B

Metop-A is the first European satellite in the Initial Joint Polar System agreement between NOAA and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). The Metop-B satellite will provide continuity for the mid-morning mission for atmospheric, land surface, oceanic, and space weather products.

The Metop-B instruments will include the POES equivalent sensors: Advanced Very High Resolution Radiometer (AVHRR/3), Advanced Microwave Sounding Unit (AMSU-A), Microwave Humidity Sounder (MHS), High-resolution Infrared Radiation Sounder (HIRS/3), Space Environment Monitor (SEM-2). The Metop satellites also have unique sensors which are not POES equivalent: Infrared Atmospheric Sounding Interferometer (IASI), Advanced Scatterometer (ASCAT), Global Ozone Monitoring Experiment (GOME-2).

NOAA will use the Metop-B data to generate operational products for use in NWP for forecast improvement, in support of climate research and prediction, and for weather analysis and forecasting. Products will include atmospheric temperature and moisture soundings, clouds, ocean surface and atmospheric winds, precipitation, vegetation index, ozone, snow and ice cover, radiation budget, and hazard monitoring such as fires, tropical systems, and volcanic eruptions. Space weather products that track auroral activity and energetic particles will also be generated.

Continuity products from Metop-B are expected to be available operationally in 2012. Products generated from POES-equivalent sensor data are expected to become operational 90 days after launch. Products from the Metop-specific sensors will be declared operational once EUMETSAT declares their sensor data records operational.

4. MEGHA-TROPIQUES

The French-Indian Megha-Tropiques (M-T) satellite mission was launched on 12 October 2011 with the objective and intent to study the tropical water and energy cycle. NOAA will use its data to provide continuity of atmospheric data within the tropics, which has historically been provided by NASA's TRMM satellite.

The M-T satellite has several instruments onboard, including the Microwave Analysis and Detection of Rain and Atmospheric Structures (MADRAS), Sounder for Atmospheric Profiling of Humidity in the Intertropics by Radiometry (SAPHIR), and Scanner for Radiation Budget (SCARAB). Products from M-T and their expected operations dates are listed in Table 5.

Product	Date
Brightness Temperatures	Mar-13
Net Radiation Budget	Mar-13
Rain Rate	Dec-13
Cloud Liquid Water	Dec-13
Total Precipitable Water	Dec-13
Moisture Profiles	Dec-13
Ocean Surface Wind Speed	Jun-14

Table 5. Projected operational dates for Megha-Tropiques Products.

The products from M-T will be used for identifying tropical cyclone attributes (location, intensity, and wind speed), for NWP assimilation and instrument calibration, and for climate data records.

5. GCOM

The Japan Aerospace Exploration Agency (JAXA) has planned to carry out the Global Change Observation Mission (GCOM) which will consist of a two satellite series: water (GCOM-W) and climate (GCOM-C). The first satellite within the series to be launched, GCOM-W1, is scheduled for launch in early 2012. It will carry the Advanced Microwave Scanning Radiometer (AMSR2) and will focus on water circulation observation and changes.

Current plans are for products from GCOM-W1 to be routed, and in some cases processed, through NDE. Table 6 shows the GCOM-W1 products and the NESDIS operational planning dates.

Product	NESDIS Ops Planning Date
AMSR-2 SDR (GCOM)	Sep-13
Precipitable Water (GCOM)	Sep-13
Precipitation (Type/Rate) GCOM	Sep-13
Surface Type (GCOM)	Sep-13
Soil Moisture (GCOM)	Sep-13
Sea Surface Wind Speed (GCOM)	Sep-13
AMSR-2 Radiances	Sep-13
Sea Surface Temperature (GCOM)	Sep-13
Sea Ice Characterization (GCOM)	Sep-13
Snow Cover/Depth (GCOM)	Sep-13
Snow Water Equivalent (GCOM)	Sep-13
AMSR-2 Radiances (BUFR) (GCOM)	Dec-13
Blended Total Precipitable Water (GCOM)	Sep-14
Blended Soil Moisture (GCOM)	Sep-14
Blended Total Precipitable Water Anomaly (GCOM)	Sep-14
Blended Rain Rate (GCOM)	Sep-14
Tropical Rainfall Potential (GCOM)	Sep-14
Blended SST (GCOM)	Sep-14
Tropical Cyclone Intensity (GCOM)	Sep-14

Table 6. Projected operational dates for GCOM-W1 products.

6. OCEANSAT-2

Oceansat-2 was launched by the Indian Space Research Organization in September 2009. One of the sensors aboard Oceansat-2 is a wide-swath Ku-band scatterometer (OSCAT) that has the potential to restore the coverage and detection of ocean surface wind capabilities once provided by QuikSCAT. Ocean surface wind speed and direction are the products NESDIS currently plans to make available from OSCAT data. Ocean surface wind vectors are a critical input for forecasts and warnings for tropical cyclones.

Ocean surface wind vectors at 25-km and 50-km resolutions are expected to be declared operational around the March 2014 time frame.

7. SUMMARY

NOAA/NESDIS is providing satellite data from domestic and international partnerships so users can meet their requirements for improvements to weather forecasts and understanding and predicting changes in the Earth's climate and oceans. As future missions are planned and launched, NOAA will continue to generate and provide satellite products for continuity of multiple types of missions. New and enhanced products will also be generated as user requirements are identified and validated.

8. REFERENCES

JAXA GCOM-W Mission, http://www.jaxa.jp/projects/sat/gcom_w/index_e.html

Megha-Tropiques Mission, http://smsc.cnes.fr/MEGHAT/

Metop-B Mission, http://www.eumetsat.int/Home/Main/Satellites/Metop/MissionOverview/index.htm?l=en

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

Oceansat-2 Mission, http://www.isro.org/satellites/oceansat-2.aspx

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