

## NOAA's Data Exploitation of Future Polar-orbiting Operational Environmental Satellites

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expected to be validated within 9-18 months after NPP's launch.

### 1. INTRODUCTION

NOAA's National Polar-orbiting Operational Environmental Satellite System (NPOESS) Data Exploitation (NDE) project will provide operational civilian users of environmental satellite information with data from the NPOESS Preparatory Project (NPP) and the Joint Polar-orbiting Satellite System (JPSS) which was formerly known as the NPOESS program. Through NDE, heritage users will continue to receive polar-orbiting environmental satellite data to maintain their current missions, and new users can take advantage of the improved and expanded suite of products that the NPP-era and JPSS-era sensors will provide.

### 2. CURRENT NDE PRODUCT DEVELOPMENT

NDE will receive environmental, sensor, and temperature data records, application related products and intermediate products (collectively referred to as xDRs) from NPP/JPSS and tailor them to satisfy user-required attributes such as data format, coverage, frequency, and map projection. NDE will also apply value-added science algorithms to certain data records to generate NOAA-unique products (NUPs) in order to meet NOAA-unique mission requirements. NDE has worked with users such as the National Weather Service's National Centers for Environmental Prediction and others to understand requirements and has developed a prioritized list of initial products.

xDRs from NPP are shown in Table 1. These products will be tailored (repacked and reformatted) for NOAA's users. The JPSS program office controls when the xDRs are ready to be declared operational. They are

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Table 1. NPP xDRs Delivered by JPSS Contractors.

ATMS Radiances	Vegetation Index	Cloud Effective Particle Size
CrIS Radiances	Active Fires	Cloud Optical Thickness
VIIRS Radiances	Atmospheric Temperature Profile	Cloud Top Height (VIIRS)
OMPS Radiances	Atmospheric Moisture Profile	Suspended Matter
Cloud Mask	Aerosol Optical Thickness	Land Surface Temperature (VIIRS)
Sea Surface Temperature (SST)	Land Surface Type	Cloud Base Height
Nadir Profile Ozone	Surface Albedo	Ice Surface Temperature
Ozone Total Column	Cloud Cover/Layers	Sea Ice Characterization (VIIRS)
Snow Cover and Depth	Aerosol Particle Size	Atmospheric Pressure Profile
Imagery	Cloud Top Temperature	Quarterly Surface Type Gridded
Ocean Color/Chlorophyll	Cloud Top Pressure	

Table 2 shows the NOAA unique products developed by NDE. NOAA-unique products provide for mission continuity from the legacy Polar-orbiting Operational Environmental Satellite (POES), Earth Observing System (EOS), and Defense Meteorological Satellite Program (DMSP) capabilities. These products are currently in development and will be ready to

transition from research to operations 9-18 months after NPP's launch. The initial focus of NOAA-unique products will be atmospheric sounding products, microwave surface and precipitation products, and derived sea surface temperature products such as anomalies and coral reef bleaching indices and alerts. Subsequent NUPs will include polar winds, vegetation health, ocean color, and atmospheric chemistry data records.

Table 2. NOAA unique products (NUPs) Developed by NDE.

CrIS Thinned Radiances	Cloud Liquid Water (ATMS)	Blended SST
CrIS Cloud Cleared Radiances	Sea Ice Concentration (ATMS)	SST Anomalies
Ozone (CrIS)	Snow Water Equivalent (ATMS)	SST Degree Heating Weeks
Trace Gases	Ice Water Path (ATMS)	SST Hot Spots
Cloud Top Fraction (CrIS)	Land Surface Temperature (ATMS)	Coral Reef Bleaching Indices/Alerts
Cloud Top Pressure (CrIS)	Temperature Profiles (ATMS)	SST (AVHRR-like)
Stability Products (CrIS)	Moisture Profiles (ATMS)	Aerosol Optical Depth (AVHRR-like)
CO2 Slicing Derived Cloud Top Pressure (CrIS)	Rain Water Path (ATMS)	Clear Sky Brightness Temperatures
Total Precipitable Water (ATMS)	Blended Total Precipitable Water	Ocean Optimized Cloud Mask
Snow Cover (ATMS)	Blended Total Precipitable Water Anomaly	Green Vegetation Fraction
Rainfall Rate (ATMS)	Blended Rain Rate	Polar Winds (VIIRS)
Land Surface Emissivity (ATMS)		

Key NOAA users will have early access to the xDRs and NOAA unique products for evaluation.

Additional NOAA unique product development efforts will begin the research to operations transition starting in early 2012. These are shown in Table 3.

Table 3. Additional NOAA unique products beginning development in 2012.

Ozone Limb Profile Radiances
Ozone Profile (OMPS LP)
Aerosol Optical Depth (OMPS LP)
Normalized Water Leaving Radiances
Near Coast Ocean Color (SWIR)
Harmful Algal Bloom Anomaly
Emiliania huxleyi Bloom
Chlorophyll-a (5 tailored regions)

## 2.1 CrIS/ATMS

Three of the instruments on NPP are the Cross-track Infrared Sounder (CrIS), the Advanced Technology Microwave Sounder (ATMS), and the Visible/Infrared Imager/Radiometer Suite (VIIRS). Together these instruments are used to generate a variety of temperature, moisture, ozone, and trace gas products. NDE will generate hyperspectral products from CrIS data collocated with the ATMS field of regard. The VIIRS will be used for cloud clearing.

CrIS/ATMS products will include principal components (which will compress 1305 channel radiances into approximately 85 independent values), cloud cleared radiances, ozone retrievals, and atmospheric measurements of carbon dioxide, carbon monoxide, methane, and sulfur dioxide. Additional products from CrIS/ATMS will include cloud products such as cloud top pressure and cloud top fraction; stability products such as convective available potential energy, lifted index, and convective inhibition; and surface emissivity.

NDE will distribute CrIS/ATMS products in NetCDF4 and some product in BUFR format for NWS. They will be assimilated into Numerical

Weather Prediction (NWP) models and used in climate applications.

## 2.2 MIRS

The Microwave Integrated Retrieval System (MIRS) provides data products from microwave instruments in all weather and all surface conditions. The MIRS application is adaptable to all microwave sensors to ensure physical consistency and minimal bias for the multitude of microwave sensors. The data generated from the MIRS system is used to improve NWP models, estimations of rainfall, and continuity of climate monitoring for El Niño, water cycle changes, and long-term climate change. NDE will generate MIRS products from the ATMS.

MIRS products from ATMS will include temperature profiles, moisture profiles, land surface temperature, land surface emissivity, snow water equivalent, snow cover, sea ice concentration, cloud liquid water, total precipitable water, ice water path, instantaneous rain water path, and rain rate. NDE will distribute MIRS products in NetCDF4 and some data in BUFR format and in pre-defined coverage areas and timeframes, including orbital, area of interest, daily, and monthly. These global products will continue to enhance NOAA's weather forecasting and climate monitoring capabilities.

## 2.3 Sea Surface Temperature

NDE will generate a suite of sea surface temperature (SST) products from NPP's VIIRS instrument. These products will be used as an input to environmental models and in climate and ecosystem applications.

SST derived products include SST anomalies, hot spots, and heating degree weeks, as well as global and regional SST analyses, global analyses of aerosol optical thickness (AOT), monthly means of SST and AOT, and coral reef bleaching indices and alerts. NPP SST products will also be blended with data from GOES, POES, Metop and other foreign geostationary satellites. NDE will make the SST products available in NetCDF4 format.

## 2.4 Polar Winds

The assimilation of polar tropospheric wind data in NWP models has been shown to improve model forecasts for the Northern and Southern Hemispheres. Model impact studies at major NWP centers have demonstrated that forecasts for the extratropics are improved when the MODIS polar winds are assimilated (Key, 2003). A similar impact from the VIIRS product is expected.

Wind products include wind speed, direction, and height at high latitudes. NDE will generate infrared cloud drift polar wind products from VIIRS. NDE will generate polar winds for the Arctic and Antarctic from 65 degrees latitude poleward. NDE will make these products available in BUFR format for NWP centers. There are also plans to generate them in NetCDF4 format.

## 2.5 Green Vegetation Fraction

Green vegetation fraction (GVF) is used as an input to land surface models to provide a better characterization of the surface. NDE will generate GVF products from VIIRS data.

NESDIS will evaluate the vegetation environmental data records, compare VIIRS composites to the AVHRR baseline for consistency, implement algorithm enhancements, and tailor the products for use by NWP models and continuity requirements. NDE will generate GVF products globally on a weekly basis and make them available in NetCDF4 and GRIB2 formats. They will also be available on the Internet in PNG format for several different regions.

## 2.6 Blended TPW

Blending the numerous total precipitable water (TPW) products available from multiple satellites into one product provides a forecaster with a more complete observation of the movement of moisture in the atmosphere and gives the ability to track moisture plumes. This is not possible using individual sensors due to the orbital gaps. The blended TPW product also provides forecasters with continuity on the changing levels of moisture from the ocean areas and helps analysts pinpoint the location of heavy

precipitation over the continental United States for use in flood guidance and forecasting. TPW anomaly products show the departure from climatology and help to quickly identify areas where there is a strong flooding potential or the potential for fire hazards.

NDE will enhance the blended TPW and TPW anomaly products using NPP's ATMS. These products also include data from POES AMSU/MHS, DMSP SSM/I and SSMIS, the GOES Sounder, and GPS-Meteorology. These products will be generated globally and will also be sectorized into AWIPS regions.

### 2.7 OMPS Limb Profiler

NDE will generate high-vertical resolution ozone profiles from the Ozone Mapping and Profiler Suite (OMPS) Limb Profiler onboard the NPP satellite. These products will be used to benefit the NCEP forecast accuracy and to improve upon the ultraviolet index prediction and climate trends.

OMPS-LP products will include limb scattered radiances, high vertical resolution ozone profiles at 150km and 1km, and stratospheric aerosol optical depth at 150 km and 1 km, all generated in NetCDF4 format.

### 2.8. Ocean Color

Ocean color products are used to monitor marine and freshwater ecosystems, manage coastal resources, detect the presence of harmful algal blooms, and determine trends related to regional to global climate variability and change. NDE will generate ocean color products from VIIRS data.

Ocean color products will include normalized water leaving radiances, chlorophyll-a, chlorophyll frontal product, harmful algal bloom anomaly product, *Emiliania huxleyi* bloom maps, and near coastal ocean color. Many of these ocean color products are used in ecosystem-based fishery management. NDE will make these products available daily in CoastWatch HDF, NetCDF4, and GeoTiff formats.

### 2.9. NetCDF Reformating Tool

In the past, each individual product application software system was responsible for providing products in specific formats. This led to software redundancy, difficulties in maintenance and increased costs over the long run. To avoid these issues, a project has been started to provide consistency of formats for all NPP and JPSS products. The project leverages current data translators to design, develop, and create NetCDF4 to BUFR data and NetCDF4 to GRIB2 data. This will allow for an improvement in the maintenance, flexibility, and efficiency of the BUFR and GRIB2 reformatting. The reformatter toolkit will be integrated into the NDE system and will be made available to NOAA's Long Term Archive by NDE.

Table 4 shows the NPP products that will initially be reformatted into BUFR and GRIB2 formats.

Table 4. Planned BUFR and GRIB products.

Product	BUFR	GRIB2
ATMS Radiances	X	
CrIS Radiances	X	
Nadir Profile Ozone and OMPS Radiances	X	
VIIRS Radiances	X	
Snow Cover		X
Vegetation Index		X
Aerosol Optical Thickness	X	
Sea Surface Temperature	X	
Polar Winds	X	
Green Vegetation Fraction		X
OMPS-Limb Profiles	X	

## 3. FUTURE NDE PRODUCT DEVELOPMENT

New product development efforts will start as new user requirements are submitted and validated. Future products will include Earth radiation budget and tropical cyclone products.

### 3.1 Earth Radiation Budget

Radiation budget products will be generated from NPP's Clouds and the Earth's Radiant Energy System (CERES) instrument. These products will include net solar radiation, outgoing

longwave radiation, downward longwave radiation, and downward shortwave radiation, all at the top of the atmosphere. The radiation budget products from NPP will be used to study the Earth's climate.

### 3.2 Tropical Cyclone Intensity

Tropical cyclone intensity and structure products are used to determine whether a cyclone is tropical, subtropical, or extratropical, to estimate and forecast the radii of winds, and diagnose the structure, including intensity, size, and warm and cold core structures. These products will be useful to tropical cyclone forecasting centers and marine forecasters. NDE will generate these tropical cyclone products from the ATMS instrument on NPP.

Tropical cyclone products from the microwave instrument will include maximum winds, minimum sea level pressure, and radii of 34-, 50-, and 64-knot winds. These will be available as text-based products.

## 4. NDE DATA DISTRIBUTION

NDE users will subscribe to NPP and JPSS xDRs and NUPs through a web-based interface. The NDE database will contain the definitions of all products, algorithms, product generation rules, files, user profiles, subscriptions, interfaces, and resources. The NDE system will make products available based upon the rules in each user's subscription. The subscription database will contain a list of xDRs and NUPs, along with their pre-defined tailoring options. Optional parameters that may be selected will include limiting the distribution of a product by spatial coverage area and data quality threshold, the type of compression of the delivered file, delivery mechanism, and notification options.

During post-launch testing, NDE will ensure that the NOAA user community, including NWS, NOS, and NMFS, has access to the highest-priority products so that they can evaluate them and prepare to use them in operations.

## 5. SUMMARY

The NDE Project will begin providing tailored products from NPP to NOAA's user community

after the launch and checkout of the satellite. xDRs and NOAA-unique products from NPP are expected to become operational 9-18 months following NPP's launch. NOAA will use NPP to validate new instruments and to upgrade science processing algorithms prior to the launch of the first JPSS satellite. For NOAA, NPP is a critical satellite that will provide for mission continuity between the current POES NOAA-19 mission and the future JPSS mission. NESDIS has started product development projects to prepare for NPP data and is developing capabilities to process and disseminate those products. The primary focus of NDE will be to ensure that legacy capabilities are maintained and exploited using NPP data. As new user requirements are defined and validated, NDE will develop and implement additional products from NPP and JPSS.

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