



# A BUFR and GRIB Tailoring System for New Satellite Operational Products



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## Abstract

A tailoring software system that will convert the new satellite operational products into Binary Universal Form for the Representation of meteorological data (BUFR) and GRIB2 formatted files is under development at NOAA/NESDIS/STAR. This Reformatting Toolkit will convert the products of the NPOESS Preparatory Project (NPP)/Joint Polar Satellite System (JPSS), the Global Change Observation Mission 1st - Water (GCOM-W1) Advanced Microwave Scanning Radiometer 2 (AMSR2) and the Japanese next generation Himawari-8/9 Advanced Himawari Imager (AHI) into BUFR and GRIB2 files. The current toolkit development schedule consists of four phases, each adding new tailoring capabilities. In phase 1, the NPP Cross-track Infrared Sounder (CrIS) Radiances, Advanced Technology Microwave Sounder (ATMS) Radiances Visible/Infrared Imager Radiometer Suite (VIIRS) Radiances and IDPS VIIRS Sea Surface Temperature (SST) will be converted into BUFR files. In phase 2, this software system will reformat the NPP VIIRS Aerosol Optical Thickness (AOT), Ozone Mapping and Profiler Suite (OMPS) Nadir Profile (NP) and OMPS Total Column (TC) data into BUFR files. In phase 3, the NPP VIIRS Polar Winds and ACSP0 Sea Surface Temperature (SST) will be converted into BUFR files, and the Global and Regional Green Vegetation Fraction (GVF) will be converted into GRIB2 files. In phase 4, this software will convert the GCOM-W1 AMSR2 Microwave Brightness Temperature, Total Precipitable Water (TPW), Cloud Liquid Water (CLW), Sea Surface Temperature (SST), Sea Surface Winds (SSW) into BUFR files and Soil Moisture (SM) into GRIB2 file, and convert NPP Ozone Limb Profile into BUFR file. Currently, the toolkit is running in the NPP Data Exploitation (NDE) system tailoring phase 1, 2 and 3 products. NDE is distributing these tailored products to the NOAA Environmental Modeling Center (EMC) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) in near real-time. The phase 4 tailoring capabilities are currently in development with a scheduled delivery in 2014. The AHI radiance BUFR table has been designed and its sample BUFR files will be available in June 2014. The current goal is to extend the toolkit to tailor GOES-R products. The details of this toolkit design and its products will be discussed.

## Development History of BUFR and GRIB Reformatting Toolkit at NOAA/NESDIS

- July 08: IPT Branch Lead was informed to begin product development.
- July 08: Worked with NDE to verify product requirements.
- Apr 09: Preliminary Design Review.
- Sep 09: Critical Design Review.
- July 11: Subset of 399 CrIS channels was selected and included into BUFR file.
- Oct 11: Test Readiness Review for CrIS, ATMS and VIIRS SDR Products.
- May 12: Delivered the BUFR/GRIB2 Toolkit phase 1 products (NPP CrIS, ATMS, VIIRS M-Band and I-Band radiances) to NDE operation system.
- Feb 13: Delivered the BUFR/GRIB2 Toolkit phase 2 products (VIIRS AOT, IDPS SST, OMPS NP and TC) to NDE for operation.
- Sep 13: Delivered the BUFR/GRIB2 Toolkit phase 3 products (VIIRS Polar Winds, Global and Regional GVF, ACSP0 SST) to NDE operational system.
- Nov 13: Delivered the GRIB2 formatting program for Interactive Multisensor Snow and Ice Mapping System (IMS) Snow and Ice products.
- Jan 14: Delivered the GCOM-W1 AMSR2 Microwave Brightness Temperature BUFR converting program to OSPO operational system.
- Mar 14: Distributed sample BUFR files for new GOES Atmospheric Motion Vectors (AMV) algorithm products.
- May 14: drafted the AHI radiance BUFR table.

## Future Development for the BUFR/GRIB2 Reformatting Toolkit at NOAA/NESDIS

- June 14: Distribute the sample AHI BUFR files for review.
- Dec 14: Deliver the operational reformatting toolkit for OMPS Ozone Limb Profile BUFR product, and GCOM-W1 AMSR2 BUFR/GRIB2 products.
- The future functions to convert GOES-R products into BUFR/GRIB2 formatted files are being discussed and planned.

## System Information

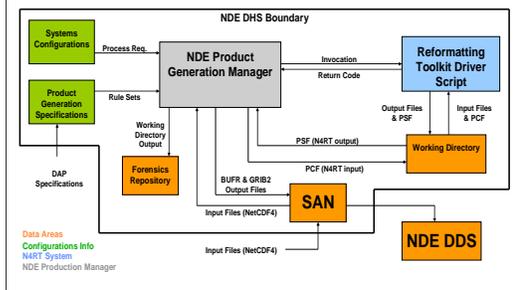
- BUFR and GRIB Tailoring System development is conducted on the NESDIS/STAR Linux machine. It is Intel(R) Xeon(R) CPU X5460 with Red Hat Enterprise Linux 5.9. GNU compiler (gfortran and gcc) and Intel compiler (ifort, icc) are on it.
- The BUFR and GRIB Tailoring System testing and integration are conducted on the NDE SADI integration platform. It is IBM P561 (AIX 5.3) with 50 TB disk space, 16 CPUs, 2 GB/CPU. IBM XL 7.0 C/C++ and IBM XL 11.1 Fortran 77/90 are on it.
- All data handling and algorithms are written in C++ and Fortran 90.
- NCEP BUFRLIB 10.2.3, NCEP GRIB2 library 1.4.0, NetCDF4.1.3 and HDF5 1.8.9, the latest versions, are used in this system.

## System Design

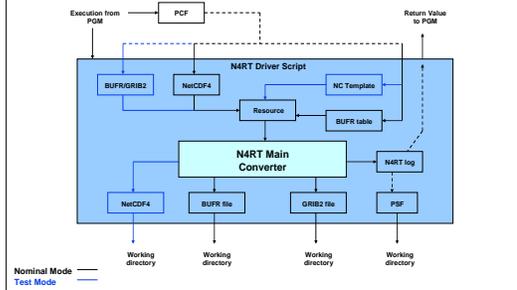
### External interfaces:

- NDE is the location for all NOAA-unique data production within OSPO.
  - NDE DHS will schedule, manage, and monitor all NUCAPS processing operationally.
  - NDE handles all product distribution and access for input CrIS, ATMS, VIIRS radiances, SST, AOT, Polar Winds and Nadir Profile Ozone BUFR data.
  - The NetCDF4 Reformatting Toolkit code will run as a stand-alone unit within the NDE DHS.
- Composed of 4 Components:**
- NC2BF: Converts NetCDF4 file (input) to BUFR file (output).
  - NC2GB: Converts NetCDF4 file (input) to GRIB2 file (output).
  - BF2NC: Converts BUFR file (input) to NetCDF4 file (output).
  - GB2NC: Converts GRIB2 file (input) to NetCDF4 file (output).

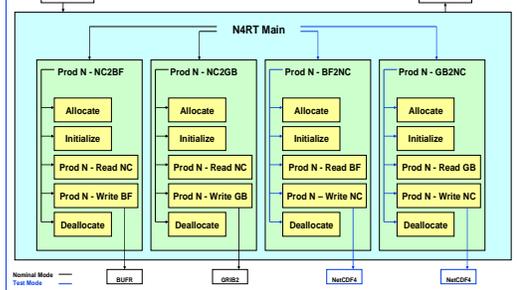
### NetCDF4 Reformatting Toolkit External Interfaces



### NetCDF4 Reformatting Toolkit System Level Data Flow



### NetCDF4 Reformatting Toolkit UNIT Level Data Flow



### ATMS Radiance BUFR Table Entries

Satellite ID	Scan line number	Solar Zenith
ID of Originating Center	FOV Number	Solar Azimuth
Satellite Instrument	Granule level quality flags	Channel Number
Year	Scan-Level Quality Flags	Channel Central Frequencies
Month	Geolocation Quality	Antenna polarization
Day	Latitude	Antenna Temperature
Hour	Longitude	Brightness Temperature
Minute	Satellite Height	Noise-equivalent delta temperature while viewing cold target
Second	Satellite Zenith Angle	Noise-equivalent delta temperature while viewing warm target
Orbit number	Satellite Azimuth	Channel-Level Quality Flags

### Main Entries in VIIRS Polar Winds BUFR Table

Satellite ID	Satellite derived wind computation method	Wind speed
Latitude	Pressure	Expected wind error
Longitude	Temperature	Wind quality flags
Channel wavelength	Surface type	Forecast wind direction
Satellite Zenith Angle	Wind direction	Forecast wind speed

### CrIS Radiance BUFR Table Entries

Satellite ID	Solar Zenith	Radiance Type Flags
ID of Originating Center	Solar Azimuth	Scan-Level Quality Flags
Satellite Instrument	Ascending/Descending	Type of Band
Year	Scan Line Number	Starting Wavenumber (per band)
Month	Field of Regard	Ending Wavenumber (per band)
Day	Field of View	Start Channel (per band)
Hour	Orbit Number	End Channel (per band)
Minute	Height of Land Surface	Calibration Quality Flags
Second	Satellite Height	Field of View Quality Flags
Latitude	Land Fraction	Geolocation Quality
Longitude	Land/Sea Qualifier	NUCAPS Quality
Satellite Zenith Angle	Cloud Cover	Channel Number
Satellite Azimuth	Height of Cloud Top	Channel Radiance

### VIIRS Radiance BUFR Table Entries

Satellite ID	Second	Satellite Zenith
ID of Originating Center	Orbit number	Solar Azimuth
ID of originating sub-center	Scan line number	Solar Azimuth
Satellite Instrument	Field of view number	Cloud Mask
Satellite classification	Type of Band	Surface Type
Year	Geolocation Quality	Channel Number
Month	Latitude	Channel Wavelength
Day	Longitude	Radiance Quality
Hour	Satellite Height	Channel Radiance
Minute	Satellite Zenith Angle	Channel Reflectance

### OMPS Total Column BUFR Table Entries

Satellite ID	Latitude	Aerosol contamination index
ID of Originating Center	Longitude	Sulfur dioxide index
Satellite Instrument	Satellite Zenith Angle	Snow cover
Year	Satellite Azimuth	Quality of pixel level retrieval
Month	Solar Zenith	Ozone total column quality flag
Day	Solar Azimuth	Column amount O3
Hour	Satellite Height	Ozone below cloud
Minute	Geolocation Quality	Lat/lon at each corner
Second	Cloud fraction	

### VIIRS AOT BUFR Table Entries

Satellite ID	Second	Geolocation Quality
ID of Originating Center	Latitude	Retrieval Quality
Satellite Instrument	Longitude	Surface Type
Year	Satellite Zenith Angle	Aerosol Type (land)
Month	Satellite Azimuth	AOT Quality Flag
Day	Solar Zenith	Aerosol Angstrom Wavelength Exponent
Hour	Solar Azimuth	Channel Wavelength
Minute	Satellite Height	Optical Depth

### Variables in Global/Regional GVF GRIB2 file

Latitudes of first/last grid point	Latitude direction increment
Longitude of first/last grid point	Longitude direction increment
Number of points along a parallel	Number of points along a meridian
Map projection	4km/1km GVF values

### Himawari-8/9 AHI Radiance BUFR Table Entries

Satellite ID	Field of view number	Channel Wavelength
ID of Originating Center	Latitude	Channel Radiance
Satellite Instrument	Longitude	Brightness Temperature
Scan line number	Radiance Data Quality	Albedo

### Product Quality Assurance

- All code development platforms are nearly identical to the production target platforms.
- Only the official releases of the NCEP BUFRLIB, GRIB2, HDF5 and NetCDF4 libraries will be used in the software.
- The generated BUFR and GRIB2 files will be directed back into the Reformatting Toolkit to generate new NetCDF4 files, and compare to the source input files before distributing.
- All the BUFR files will maintain consistency with the heritage products.
- The contents of the original HDF5/NetCDF4 will be kept as exact as possible; the negative radiances will be stored in BUFR files.
- The BUFR and GRIB2 products, tables, and additional resources will be released early to allow for WMO approval and customer validation of products.