A BUFR and GRIB Tailoring System for Satellite Operational Products

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Abstract

A tailoring software system that will convert the satellite operational products into Binary Universal Form for the Representation of meteorological data (BUFR) and GRIdded Binary Edition 2 (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), the Japanese next generation Himawari-8/9 Advanced Himawari Imager (AHI), and the Geostationary Operational Environmental Satellite - R Series (GOES-R) into BUFR and GRIB2 files. The current toolkit development schedule consists of five phases, each adding new tailoring capabilities. In phase 1, the NPP Cross-track Infrared Sounder (CrIS) Radiances, Advanced Technology Microwave Sounder (ATMS) Radiances and Visible/Infrared Imager Radiometer Suite (VIIRS) Radiances 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 the Advanced Clear-Sky Processor for Oceans (ACSPO) 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 reformat the GCOM-W1 AMSR2 Microwave Brightness Temperature and Sea Surface Temperature (SST) into BUFR files, Sea Ice into GRIB2 files, and convert the AHI Radiances into BUFR file. In phase 5, the GOES-R radiances, Winds and other products will be converted into BUFR files. Currently, the toolkit is running in the NPP Data Exploitation (NDE) system tailoring phase 1, 2, 3 and part of phase 4 products. The 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 2015. The GOES-R Winds BUFR table has been designed and under review. 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.
- Aug 08: Started to design the operational BUFR and GRIB Tailoring toolkit.
- Apr 09: Preliminary Design Review.
- Sep 09: Critical Design Review.
- Oct 11: SST, AOT and OMPS Nadir Profile BUFR tables were approved as pre-operational.
- 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 WINFS, Global and Regional GVF, ACSPO 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.
- Aug 14: Delivered the AMSR2 SST BUFR converting program to OSPO operational system.
- May 15: Distributed the JMA AHI radiance BUFR program as pre-operational,
- Jul 15: The CrIS Full Spectrum Resolution Radiance sample BUFR file was sent to EMC for evaluation.
- Oct 15: Sent out sample AMSR2 Sea Ice GRIB2 file.

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

- Oct15: Deliver the operational reformatting toolkit for Global Precipitation Measurement (GPM) common calibrated brightness temperature in BUFR file.
- The future functions to convert GOES-R products and NPP updated products into BUFR/GRIB2 formatted files have been 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.
- 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 radiance, SST, AOT, Polar Winds and Nadir Profile Ozone BUFR data.
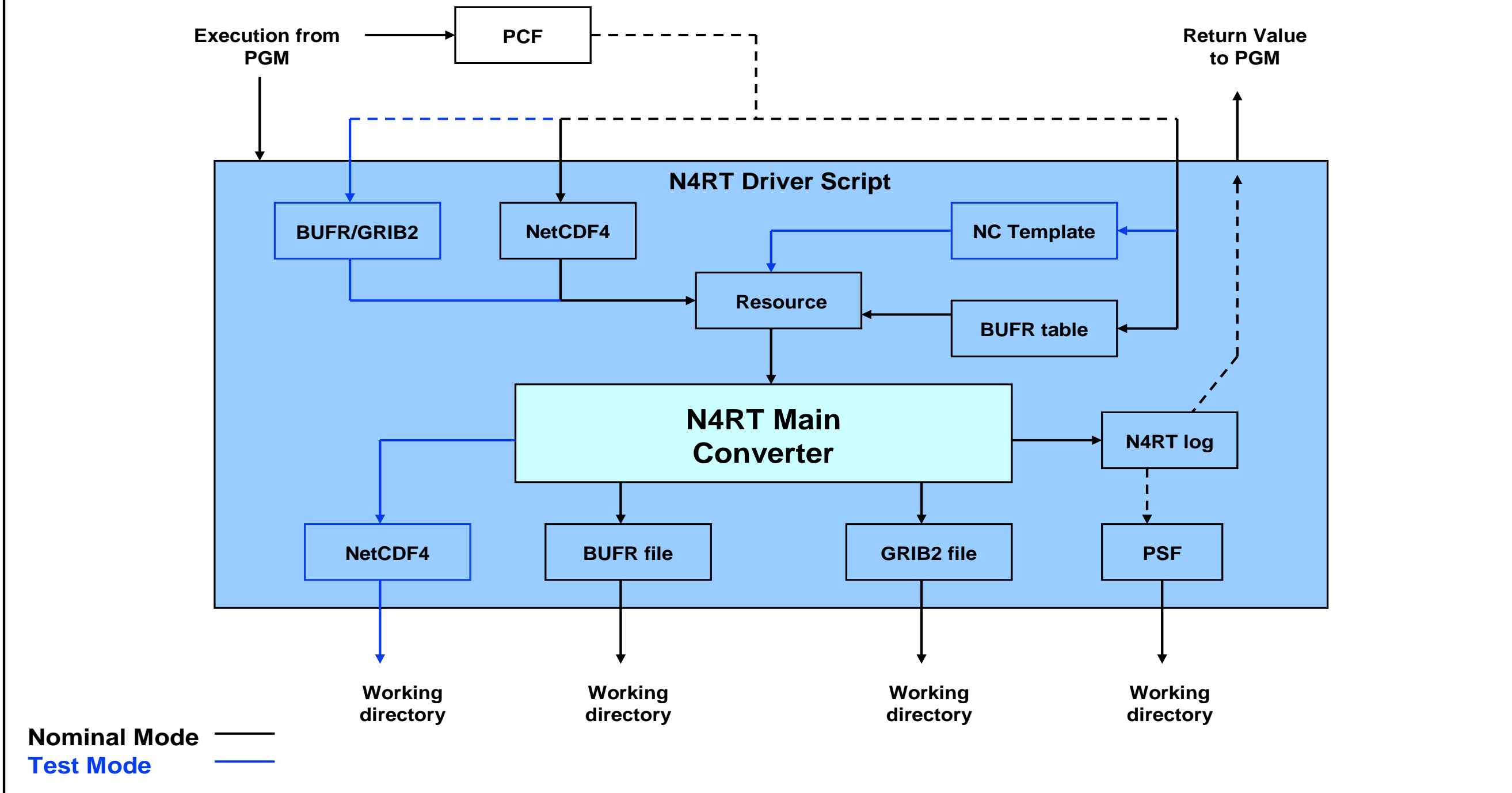 - The NetCDF4 Reformatting Toolkit code will run as a stand-alone unit within the NDE DHS.
- **Composed of 4 Components:**
  - NC2BF: Converts NetCDF4 file (input) to BUFR file (output).
  - NC2GB: Converts NetCDF4 file (input) to GRIB2 file (output).
  - BF2NC: Converts BUFR file (input) to NetCDF4 file (output).
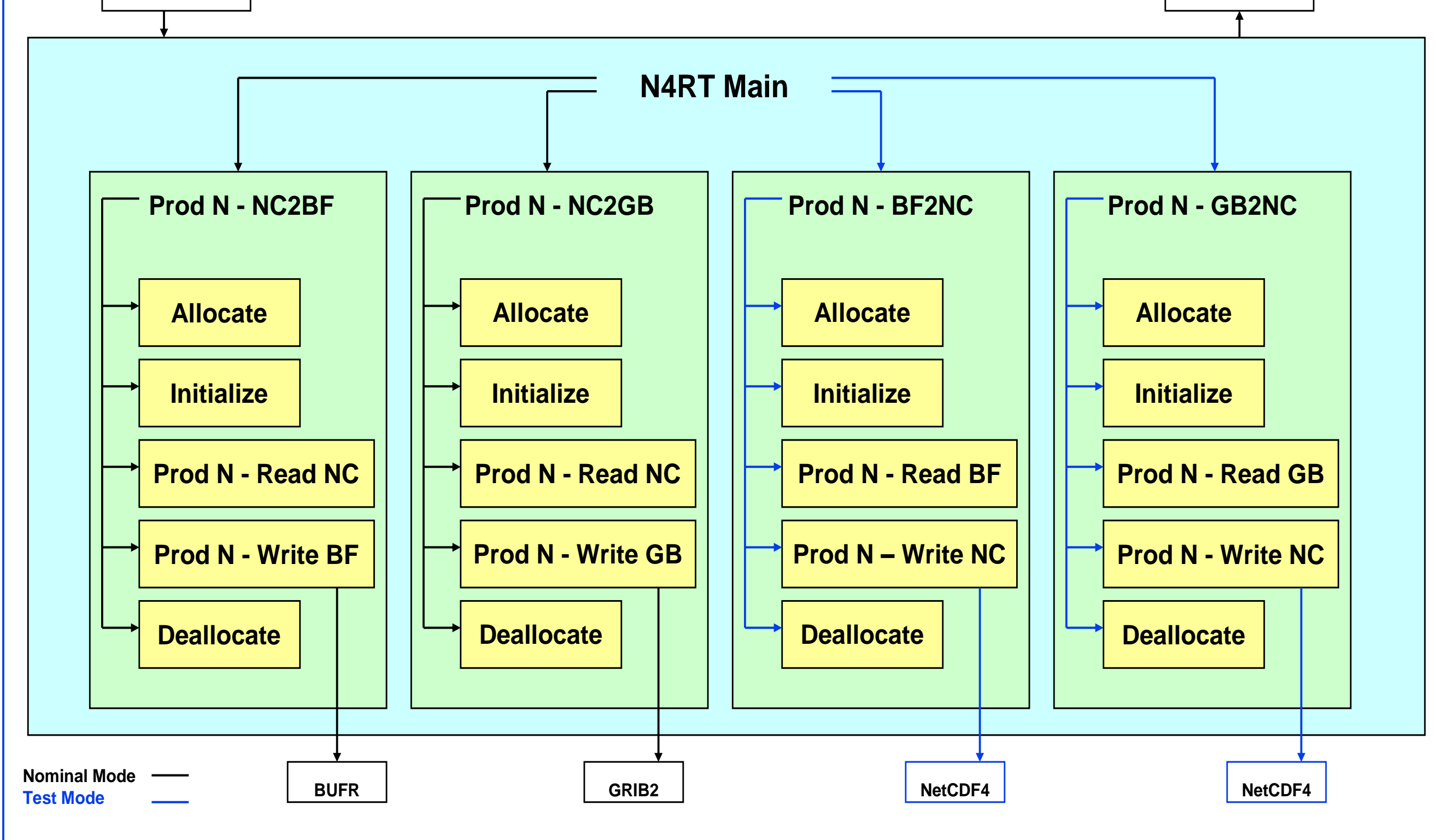 - GB2NC: Converts GRIB2 file (input) to NetCDF4 file (output).

NetCDF4 Reformatting Toolkit External Interfaces
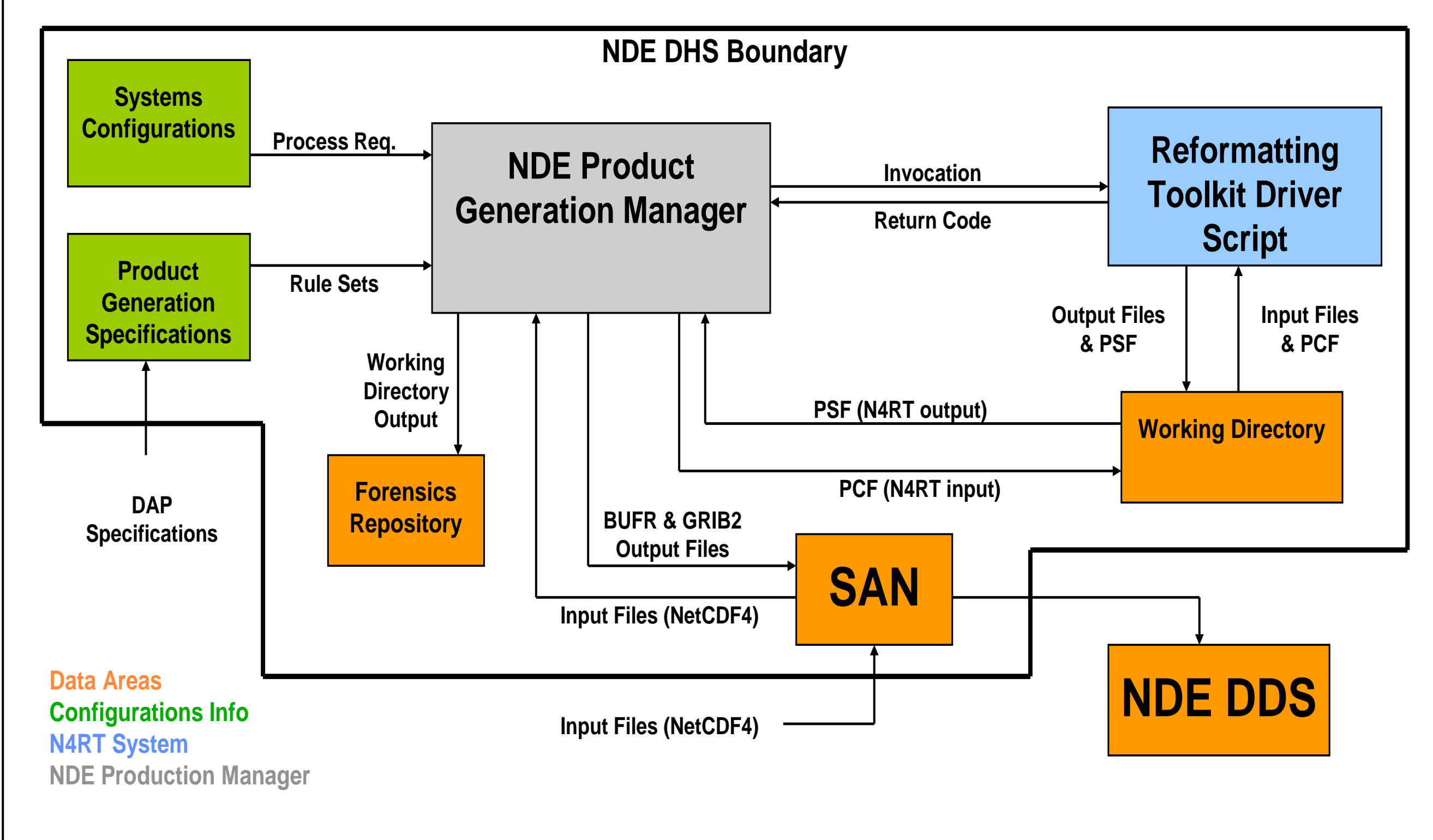
NetCDF4 Reformatting Toolkit System Level Data Flow

NetCDF4 Reformatting Toolkit UNIT Level Data Flow

ATMS Radiance BUFR Table Entries

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

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

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

AMSR2 Radiance BUFR Table Entries

Satellite ID	Second	Azimuth Angle
ID of Originating Center	Orbit Number	Channel quality flags
ID of Originating Sub-Center	Scan Line Number	Measurement type
Satellite Instrument	Field of view number	Channel Central Frequencies
Year	Latitude (high accuracy)	Land Fraction
Month	Longitude (high accuracy)	Radiance Data Quality Flags
Day	Solar Azimuth	Antenna Polarization
Hour	Solar Elevation	Brightness Temperature
Minute	Incidence Angle	

AMSR2 SST BUFR Table Entries

Satellite ID	Hour	Longitude (high accuracy)
ID of Originating Center	Minute	Scan Angle
Satellite Instrument	Second	Incidence Angle
Year	Scan Line Number	Azimuth Angle
Month	Field of View Number	Data Quality Flags
Day	Latitude (high accuracy)	Sea Surface Temperature

AHI Radiance BUFR Table Entries

Satellite ID	Minute	Solar Zenith Angle
ID of Originating Center	Second	Solar Azimuth
ID of Originating Sub-Center	Scan Line Number	Quality Flags
Satellite Instrument	Column Number	Channel Number
Year	Latitude (high accuracy)	Satellite Channel Wavelength
Month	Longitude (high accuracy)	Brightness Temperature
Day	Satellite Zenith Angle	Albedo
Hour	Satellite Azimuth	Channel Radiance

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

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.