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TECHNICAL REPORT

Improved NCUM Observation Pre-processing System (NOPpS)

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Gibies George, Sumit Kumar and John P. George**

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**National Centre for Medium Range Weather Forecasting
Ministry of Earth Sciences, Government of India
A-50, Sector-62, NOIDA-201309, INDIA**

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10	Abstract	The existing NCUM pre-processing system is modified to process more meteorological observations reliably and efficiently. The NCUM Observation Pre-processing system (NOPpS) handles observation files in four different formats, NCEP BUFR, ECMWF BUFR, hdf and ASCII. Different procedures are followed for extracting and pre-processing the observations. The real-time meteorological observations, both conventional and satellite based, received at NCMRWF from different sources/agencies, like from GTS, IMD, ISRO, NOAA/NESDIS and EUMETCast, are processed via NOPpS to produce the “obstore” files which are the input to the Observation Processing System (OPS) of NCUM NWP system. ATOVS and AVHRR Pre-processing Package (AAPP), UK-Met office Encode/Decode and ECMWF ecCodes softwares are used in addition to in-house developed softwares to process the multi-spectral and hyper-spectral radiances from satellites before converting to obstore files. This report describes the details of the extraction and pre-processing of observations which are available in different format to use it in the Observation Processing System (OPS) of NCUM NWP system.
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Abstract

The existing NCUM pre-processing system is modified to process more meteorological observations reliably and efficiently. The NCUM Observation Pre-processing system (NOPpS) handles observation files in four different formats, NCEP BUFR, ECMWF BUFR, hdf and ASCII. Different procedures are followed for extracting and pre-processing the observations. The real-time meteorological observations, both conventional and satellite based, received at NCMRWF from different sources/agencies, like from GTS, IMD, ISRO, NOAA/NESDIS and EUMETCast, are processed via NOPpS to produce the “obstore” files which are the input to the Observation Processing System (OPS) of NCUM NWP system. ATOVS and AVHRR Pre-processing Package (AAPP), UK-Met office Encode/Decode and ECMWF ecCodes softwares are used in addition to in-house developed softwares to process the multi-spectral and hyper-spectral radiances from satellites before converting to obstore files. This report describes the details of the extraction and pre-processing of observations which are available in different format to use it in the Observation Processing System (OPS) of NCUM NWP system.

1. Introduction

NCMRWF Unified model (NCUM) global Numerical Weather Prediction system is used for medium-range weather prediction at NCMRWF since 2012 (Rajagopal et al., 2012, George et al., 2016, Sumit et al. 2018). The model and its data assimilation systems are upgraded periodically to adapt new scientific and technological advances. NCUM Observation Pre-processing system processes the conventional and satellite observations received at NCMRWF through different sources, viz., Global Telecommunication System (GTS) via India Meteorological Department (IMD), ISRO, NOAA/NESDIS, and EUMETCast. Figure 1 shows the global data reception at NCMRWF from different sources. Observation Processing System (OPS) of NCUM data assimilation system, which does the quality control of observations and pack them for assimilation, require pre-processed observations in desired formats. An Observation pre-processing system for NCUM was developed (Prasad, 2012) to extract the decoded observations from the bufr-tank (NCEP based system) and pack it in a desired format, known as “obstore” format, for the NCUM data assimilation system. Major improvements are introduced in this pre-processing system during the last few years to include more and more observation types and improve the efficiency and reliability of the pre-processing for timely availability of pre-processed observations for its further use in the NCUM data assimilation system. An advanced version of this NCUM Observation Pre-processing system (NOPpS) with capabilities to “extract and pack” is developed and made operational at NCMRWF.

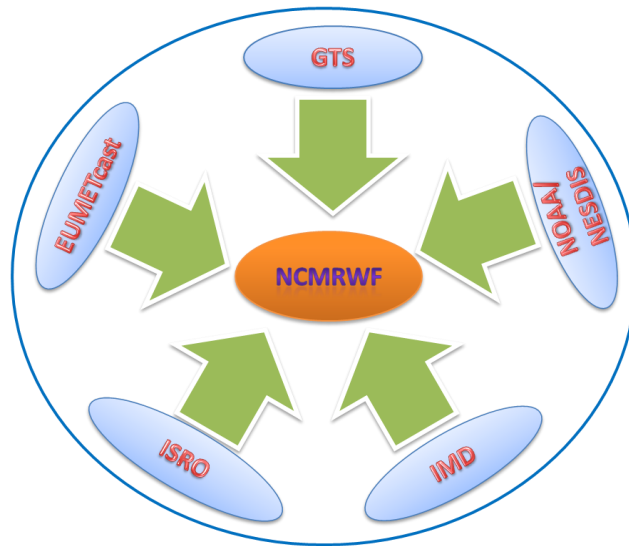


Figure 1: Data reception at NCMRWF from different sources

Observations available in the desired time-window of any particular assimilation cycles are extracted from the bufr-tank using the NCEP dump program. Some of the satellite radiances, particularly the multispectral and hyperspectral radiances from the polar satellites are processed through “ATOVS and AVHRR Pre-processing Package” (AAPP) and UKMO Encode/Decode softwares. Observation Pre-processing System for NCUM is developed to pack the observations decoded through NCEP decoders, AAPP and UKMO Encode/Decode softwares in obstore format files which are used by Observation Processing System (OPS) of NCUM. The pre-processing system is modified several times in the past to include the pre-processing of new observation types, including satellite radiances (Prasad, 2014, Prasad and Rani, 2014). In the recent years many new meteorological observations (both conventional and satellite) are added to the pre-processing system. The latest pre-processing system with advanced features, NOPpS, handles input data of different formats, viz, BUFR (NCEP, ECMWF, and UK Met Office), binary, hdf, ASCII, etc.

There are two major components of the NOPpS, developed for NCUM DA-5 system installed in May 2018 (Sumit et al., 2018), one is for pre-processing of all conventional observations, satellite winds, scatterometer ocean surface winds from satellites, geostationary radiances, GPSRO, ground GPS total zenith delay, and some of the LEO satellite radiances and the second component is exclusively for satellite radiances which are required to be processed using AAPP (hyperspectral (IASI and CrIS), multispectral (ATOVS and ATMS) and UKMO Encode/Decode Software (AIRS). This report describes the NOPpS system operational at NCMRWF since May 2018.

2. Observations processed directly in NOPpS

The observations received through GTS include the types of Surface, Sonde, Aircraft, GPSRO, and some of the geostationary satellite winds (AMVs). VAD winds from Indian Doppler Weather Radars (DWRs) are received via IMD. The observations received from ISRO include Megha-Tropiques SAPHIR radiances and Scatsat scatterometer wind (sea surface winds). INSAT-3D sounder and imager radiances in hdf are being received from IMD. Some of the geostationary (GOES) and polar satellite (NOAA series and DMSP) radiances, GOES-East and GOES-West AMVs and all polar satellite winds, suominet ground GPS total zenith delay, and

MetOp-A and B ASCAT sea surface winds are also processed by first component of NOPpS. The data received through both GTS and NOAA/NESDIS are decoded and placed in the NCEP bufr-tank of NCMRWF. Large volume of satellite observations from EUMETCast is also directly processed in the NOPpS, without the use of AAPP or UKMO Encode/Decode softwares. These observation types include SEVIRI, AMSR-2 and FY3C-MWHS satellite radiances. The ground GPS total zenith delay observations over the Europe are being received via EUMETCast.

The types and sub-types of meteorological observations processed in NOPpS other than those processed through AAPP and UKMO encode/decode softwares is shown in Figure 2. Figure 2 includes SURFACE, SONDE, AIRCRAFT, GPSRO, Ground GPS, Satellite Winds (Atmospheric Motion Vectors, AMVs), Scat Winds (sea surface winds), and some types of Satellite radiances. Each observation type includes one or more sub-type depending on the measurement techniques/platforms. For example, “Sonde” obstore file, created by NOPpS, contains observations of radiosonde, pilot balloon, wind profilers (including radar VAD winds), drop sonde etc. Conventional observation types like SURFACE and SONDE contain mostly synoptic observations; while other observations, mainly aircraft and satellite based (space/ground) are generally asynoptic in nature.

3. Processing of satellite radiances using AAPP and UKMO encode/decode software

Some of the multispectral and hyperspectral infra-red (IR) and micro-wave (MW) radiances from polar orbiting satellites are processed through AAPP and UKMO encode/decode software. The radiances processed through AAPP are the multispectral IR and microwave sounders like ATOVS (AMSU-A, AMSU-B/MHS, HIRS) onboard NOAA satellites (15, 18, 19) and MetOp-1 and 2 and ATMS onboard Suomi NPP and NOAA-20 and hyperspectral IR sounder radiances from IASI onboard MetOp-1 and 2, and CrIS onboard SNPP and NOAA-20. Observations from AIRS, the hyperspectral instrument onboard AQUA satellite is processed using UKMO Encode/Decode software.

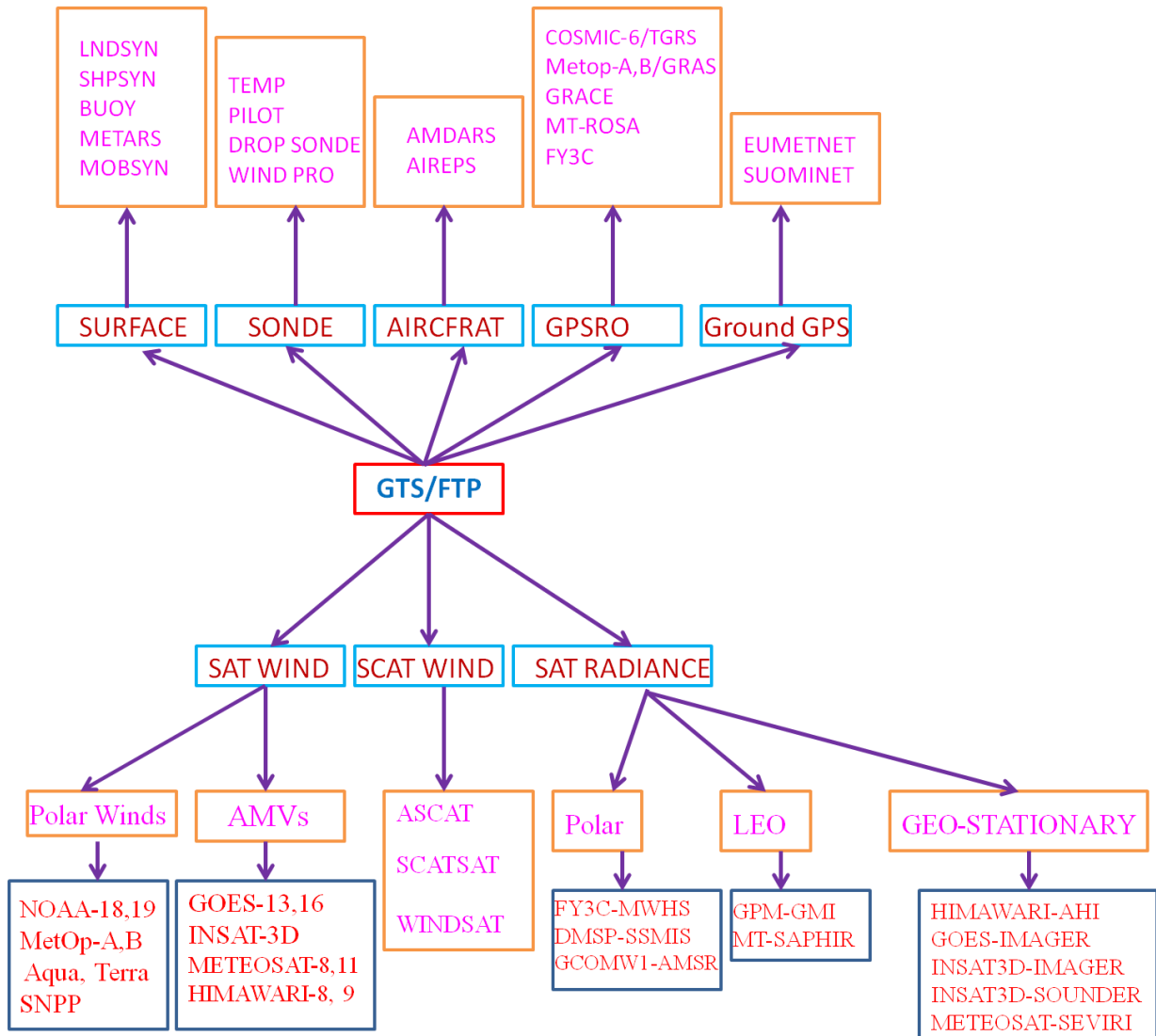


Figure 2: Meteorological observations directly processed through NOPpS.

3.1 ATOVS and AVHRR Pre-processing Package (AAPP)

AAPP package can process raw data from the instruments of NOAA polar orbiting satellites (HIRS, AVHRR, AMSU-A and AMSU-B/ MHS), METOP satellites of EUMETSAT (HIRS, AVHRR, AMSU, MHS and IASI) and Suomi NPP satellite (ATMS and CrIS). Latest versions of AAPP can also process data from the new-generation NOAA20, MetOp-C satellites, and Chinese FY-3 satellites sounder instruments. In 1992, EUMETSAT took the

initiative to processing the ATOVS data from NOAA satellites and as a result they developed the AAPP package. The AAPP is freely available from Satellite Application Facility for Numerical Weather Prediction (SAF NWP) (<https://www.nwpsaf.eu/site/software/aapp/>), which is maintained by the EUMETSAT. The first European MetOp series satellite, part of EUMETSAT Polar System (EPS), was launched in 2006. MetOp data processing capability was added in AAPP version 6. AAPP-v6 also has the capability to process the imager data from Chinese satellite FY-1D.

The Suomi National Polar-orbiting Partnership (Suomi-NPP) is the next generation US operational polar-orbiting weather satellite launched in October 2011. With the continuation of MetOp and older NOAA satellite data pre-processing, AAPP v7 (Atkinson, 2017) was designed to process data from the sounder and imager instruments on NPP satellite. A large number of improvements were made to AAPP v7 compared to its previous version. It has the ability to ingest the data from the microwave and infrared sounders on the FY-3 series of satellites, and also has the capability to create hdf5 output files.

The AAPP package is being improved by continuous R&D efforts of NWP SAF and AAPP v8 has come with some major improvements. AAPP-v8 has the interfaces to ecCodes, which provide new BUFR/GRIB software library. Also AAPP v8 provide new platform to process the JPSS-1 (NOAA-20) data. At NCMRWF AAPP-v7.10 is operational and AAPP-v8.1 in being used experimentally to process ATMS and CrIS from NOAA-20.

3.2 UKMO Encode/Decode Software

The UKMO Encode/Decode software, known as the MetDB BUFR software, is portable in different linux architectures similar to other BUFR encode/decode softwares. It contains BUFR subroutines in FORTRAN, the BUFR tables, TABLE-B, TABLE-D, and CODEFIG. The CODEFIG describes the WMO defined regions or the geographical area, Satellite identifiers, satellite instruments, etc,

3.3 ECMWF BUFR Encode/Decode Software and ecCodes

AAPP Software writes the output in ECMWF BUFR format. ECMWF BUFR decoder is freely available at <https://www.ecmwf.int/en/computing/software>. BUFR is self defining, table driven and very flexible data representation system, in particular for large data volume. The

observations, which are in BUFR format needs to be decoded/ extracted with corresponding BUFR decoder, such as ECMWF BUFR Decoder (BUFRDC). At NCMRWF, for decoding the binary data (BUFR) and convert into intermediate ASCII format, the BUFRDC software has been adopted.

ecCodes is another package developed by ECMWF as a replacement to the BUFR Encode/Decode software. ecCodes has the ability to decoding and encoding messages in the following formats:WMO FM-92 GRIB edition 1 and 2, WMO FM-94 BUFR edition 3 and 4, WMO GTS abbreviated header (only for decoding). Interfaces for C, fortran-90 and Python are Provided to access to the main ecCodes functionality. ecCodes is evolved from GRIB-API (ecCodes-GRIB tools). New tools are available for the BUFR (ecCodes BUFR tools) and GTS formats (<https://www.ecmwf.int/node/1812>)

3.4 Observation processing through AAPP

3.4.1 ATOVS

The Advanced TIROS Operational Vertical Sounder (ATOVS) is a vertical sounder, which consists of the Advanced Microwave Sounding Unit-A (AMSU-A), the Advanced Microwave Sounding Unit-B (AMSU-B or MHS) and the High Resolution Infrared Radiation Sounder (HIRS). At NCMRWF, the ATOVS data are received from different sources like NOAA/NESDIS, EUMETCast and GTS. Depending on the data source, the ATOVS preprocessing is divided into four parts. Different scripts are running for: (1) AMSU-A onboard NOAA-15 from NOAA/NESDIS, (2) ATOVS from MetOp-1 and NOAA-19 RARS data received from GTS (3) ATOVS from Metop1, MetOp2 and NOAA-19 received from EUMETCast (4) ATOVS from Metop1, MetOp2, NOAA-18 and NOAA-19 received from NOAA/NESDIS. Since the same data is received from different sources, the decoded data may contain duplicate records. These duplicate records will be taken care in the Observation Processing System (OPS) of NCUM. The flow chart of ATOVS pre-processing is given in Figure 3. AAPP tools convert the level 1b radiance data into level 1c and then write into HIRS grid (level 1d). This level 1d data is converts into BUFR format through AAPP encoder. In Figure 3, Hirs.bufr represents the ATOVS data written in the HIRS grid.

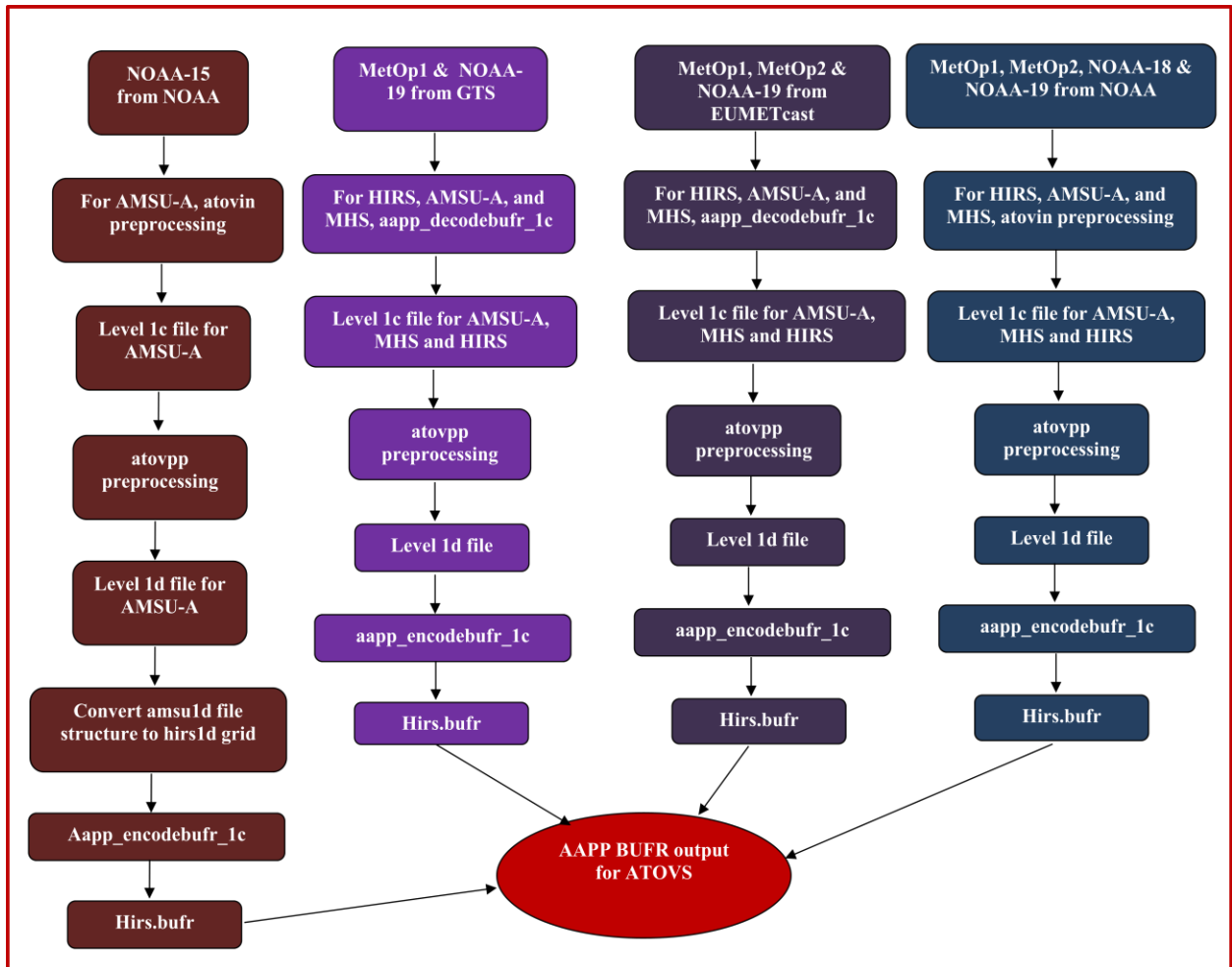


Figure 3: Flow chart of AAPP processing for ATOVS data

3.4.2 IASI

Infrared Atmospheric Sounding Interferometer (IASI) is a Fourier Transfer Spectrometer based on the Michelson Interferometer. IASI has more than 8000 channels, onboard in MetOp A & B satellites and have 12 km horizontal resolution with 2,200 km wide swath. With 14 orbits in the sun-synchronous mid-morning orbit, global observations are available over a location twice daily. NCUM uses level 1b IASI data received through EUMETCast. AAPP tools convert these level 1b data in to level 1c. Level 1c IASI principle component (PC) are used to generate the reconstructed radiances for around 500 IASI channels. These PC scores and other level 1c data are processed through ATOVPP and converted into level 1d format. AAPP encoder converts this 1d data in BUFR format. Figure 4 shows the flow chart of IASI pre-processing.

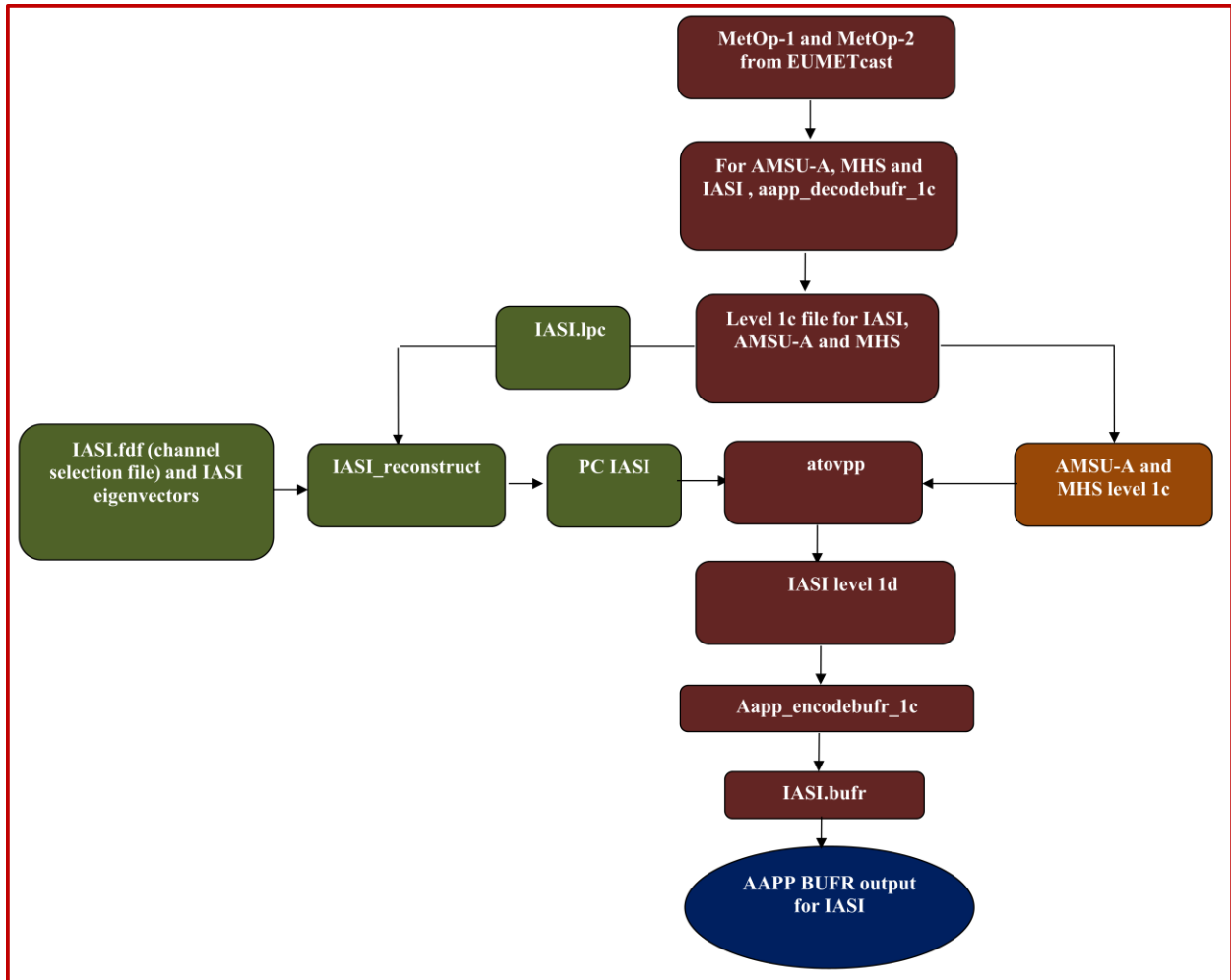


Figure 4: Flow chart of AAPP processing for IASI

3.4.3 ATMS and CrIS

The Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) are the two important instruments onboard Suomi NPP and NOAA-20 satellites. ATMS, a cross-track scanner provides sounding observations from 22 channels. ATMS combines all the channels of AMSU-A (AMSU-A1 and AMSU-A2) and AMSU-B sensors into a single package. ATMS microwave sounder measurements are from 23 GHz to 183 GHz frequency range. CrIS, is a Fourier transform spectrometer with 1305 spectral channels over 3 wavelength ranges: LWIR (9.14 - 15.38um); MWIR (5.71 - 8.26um); and SWIR (3.92 - 4.64 um).

Both ATMS and CrIS data come as granules of 32 seconds, and such five granules form a super granule. For the creation of CrIS 1d BUFR, AAPP requires mapping of ATMS to the CrIS grid as well as same granules from both ATMS and CrIS. But most of the times there may be a

mismatch in the start time of the ATMS and CrIS granules. A running check of offset has been performed to make the granules of both ATMS and CrIS same. AAPP generates ATMS level 1d BUFR files using ATMS super granules level 1c file.

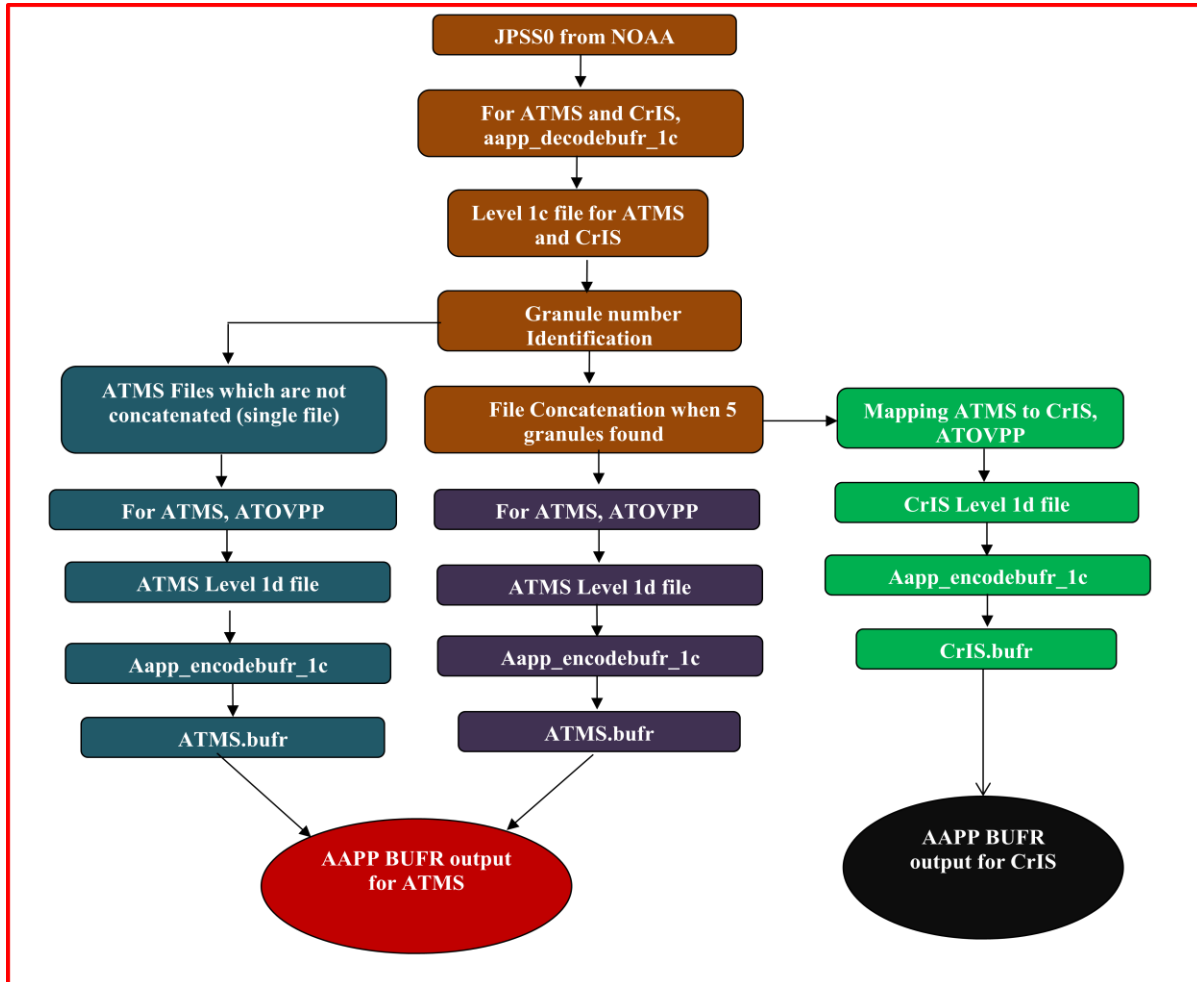


Figure 5: Flow chart of AAPP processing for ATMS-CrIS

3.5 Observation Processing through UKMO Encode/Decode Software: AIRS

Atmospheric Infra-Red Sounder (AIRS) aboard NASA's AQUA Earth Observing System satellite is the high spectral resolution infrared sounder with thousands of narrow bands. The AIRS data routinely distributed to Numerical Weather Prediction (NWP) centers in near real-time, generally within 3 hours from observation.

At NCMRWF, AIRS U3 type data (level 1b) is received through NOAA/NESDIS. These data are processed through UKMO Encode/Decode software. The BUFR encoding executable from UKMO Encode/Decode software converts these data into UK Met office BUFR format.

4. Procedures to Prepare “OBSTORES”

Figure 6 shows the preparation of “obstore” files from different sources and data in different format in NOPpS.

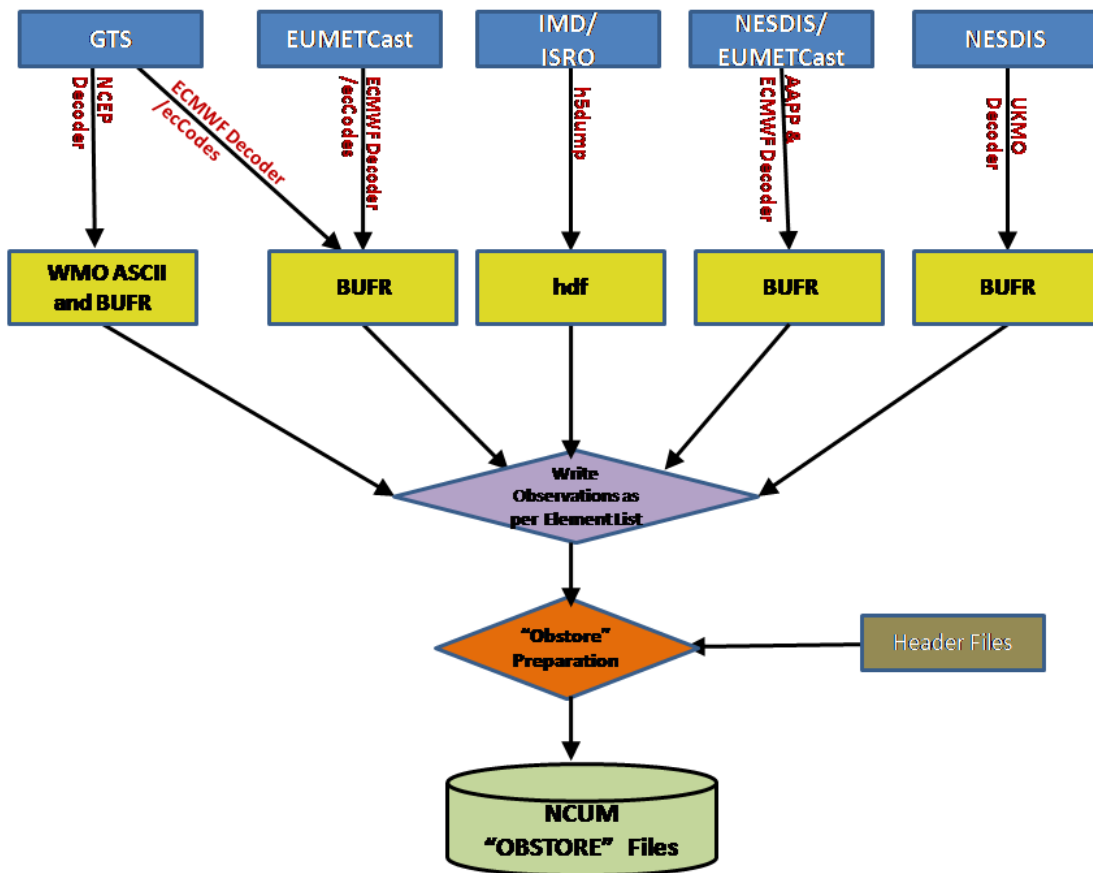


Figure 6: Preparation of “obstore” format files through NOPpS.

According to the source and format of observations, respective decoders such as NCEP, ECMWF, h5dump, etc., are used to decode the data. AAPP and UKMO encode/decode softwares are used to prepare level-1c observations in ECMWF and UKMO BUFR format. These decoded observations are then arranged according to the “Element List” of different observation types. Header files of each observation types are also prepared according to the

respective element list. FORTRAN and C programs are used to prepare the final “Obstore” files, which are the inputs to the OPS of NCUM.

The state-of-the-art Indian meteorological satellite, INSAT-3D, radiances, both sounder and imager, are being received from IMD in hdf format files. The satellite data is extracted using “h5dump” tool of “hdf” library. Intermediate “ascii” files generated are used for further processing, in which observations are packed in the “obstore” format as per the element list for both INSAT-3D sounder and INSAT-3D Imager.

5. Conclusions

In-house developed NOPpS, implemented operationally at NCMRWF, processes different conventional and satellite observations received through different sources/agencies like GTS, IMD, ISRO, NOAA/NESDIS, and EUMETCast. AAPP and UKMO encode/decode softwares are also used as part of the NOPpS to process multispectral and hyperspectral satellite radiances. NOPpS handles different input data format likes BUFR (WMO/ECMWF/NCEP/UKMO), hdf, and ASCII and write the observations “obstore” file for its use in OPS.

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References

Atkinson N., 2017: AAPP User Guide. NWPSAF-MO-UD-036.

John P George, S. Indira Rani, A. Jayakumar, Saji Mohandas, Swapan Mallick, A. Lodh, R. Rakhi, M. N. R. Sreevathsa and E. N. Rajagopal, 2016: NCUM Data Assimilation System. NMRF/TR/01/2016

OPS document, UK Met Office: OTDP6- Model Observation Types <https://code.metoffice.gov.uk/trac/ops/browser/main/trunk/doc/technical/OTDP6/OTDP6.html>.

Prasad V. S., 2012: Conversion of NCEP Decoded data to UK MET office Obstore format. NCMR/OB/1/2012

Prasad V. S., 2014: Satellite Data Processing for NCMRWF Unified Model (NCUM). NMRF/RR/2/2014

Prasad. V. S. and S. Indira Rani, 2014: Data Pre-Processing for NCMRWF Unified Model (NCUM): Version 2. NMRF/RR/1/2014

Rajagopal, E. N., G.R. Iyengar, John P. George, Munmun Das Gupta, Saji Mohandas, Renu Siddharth, Anjari Gupta, Manjusha Chourasia, V.S. Prasad, Aditi, Kuldeep Sharma and Amit Ashish, 2012: Implementation of Unified Model based Analysis-Forecast System at NCMRWF. NMRF/TR/2/2012

Sumit Kumar, A. Jayakumar, M. T. Bushair, Buddhi Prakash J., Gibies George, Abhishek Lodh, S. Indira Rani, Saji Mohandas, John P. George and E. N. Rajagopal, 2018: Implementation of New High Resolution NCUM Analysis-Forecast System in Mihir HPCS. NMRF/TR/01/2018.