Resume

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National Centre for Medium Range Weather Forecasting (NCMRWF)
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Research Interest

Atmospheric modeling, data assimilation in NWP models, upper troposphere lower stratosphere characteristics.

PROFESSIONAL PROFILE

Experience in using NWP models WRF and NGFS (NCEP GFS based) and familiar with different data assimilation techniques.

Experience in pre-processing and assimilation of Indian DWR observations in WRF model.

Experience in sensitivity experiments using different Physics options in high resolution WRF model.

OSSE experiment with Megha-Tropiques ROSA refractivity (simulated observations at locations of ROSA observations) in NGFS model. Implemented Megha-Tropiques ROSA bending angle assimilation in NGFS model.

Experience in implementing hybrid data assimilation system in NGFS model. Expertise in implementing and debugging of different components of NGFS model.

Expertise in UTLS characteristics (temperature, water vapour) over Indian region and transport between troposphere and stratosphere.

Expertise in handling of different type of observations like GPSRO, AIRS, HRPT, GPSIPW, SCATSAT ocean surface wind, satellite radiances, Doppler weather radar and familiar with different data formats like netcdf, hdf, bufr, grib.

Expertise in estimations of trace gas emissions (CH_4) from coastal water-bodies in Kerala and experience in using Gas chromatograph and analysis of gas, sediment and water samples.

Expertise in verification packages VSDB (Verification statistical data base) and MET (model evaluation tool)

Experience in satellite radiance pre-processing through AAPP (ATOVS and AVHRR Pre-processing Package) software

EDUCATIONAL QUALIFICATIONS

P h.D Completed from Sri Krishna Devaraya University, Ananthapur in 2011.

M.Tech in Ocean Technology from Physical Oceanography department, Cochin University of Science and Technology in **2003** .

MSc in Physics from Physics department, Cochin University of Science and Technology in **2000**.

Bsc in Physics from St.Thomas College, Thrissur, affiliated to University of Calicut in 1997

Career History

Job title: Project Scientist D October 2017 to Present

National Centre for Medium Range Weather Forecasting (NCMRWF), NOIDA, India

Description: I have been associated with NCEP GFS based model operational in the centre. Associated in implementing NEMSIO based V14 GFS model and associated products in the New HPC (Mihir) operational in the centre. V14 model produces forecasts in native grid and uses NSST instead of SST as Oceanic boundary forcing. I have been associated in implementation of high resolution (T-1534) ensemble forecasts. Implemented assimilation of SEVIRI, AHI, AMSR2 and INSAT 3DR radiance observations in the operational GFS model.

Job title: Project Scientist C November 2012 to September 2017

National Centre for Medium Range Weather Forecasting (NCMRWF), NOIDA, India

Description: I have been associated with NCEP GFS based model operational in the centre. Present operational model is of T1534 resolution with semi-Lagrangian dynamics and hybrid 4DEnsVar data assimilation system. I was involved in implementing and testing of the model and at different upgrade stages, OSSE with Megha-Tropiques GPSRO data in NCMRWF GFS (NGFS) -T574 model, Hybrid assimilation using ETR and EnKF Ensembles, GPSIPW assimilation, VSDB verification tool, Satellite radiance pre-processing, Impact study with Megha-Tropiques GPSRO observations in NGFS model, Impact study with SCATSAT surface winds in NGFS model, testing quality of Indian GPSIPW observations, satellite radiance pre-processing, Preparing Atmospheric flux files for Ocean models, Preparing reanalysis data using NGFS model.

Job title: Project Engineer **2012 February to 2012 October**

Centre for Development in Advanced Computing (CDAC) Pune, India

Description: Worked on data assimilation and sensitivity Studies inWRF model

Job title: Project Scientist C **2010 June to 2012 February**

National Centre for Medium Range Weather Forecasting (NCMRWF), NOIDA, India

Description: Worked on data processing and assimilation of Doppler Weather Radar data in WRF model.

Job title: Senior Research Fellow **2007 to 2010**

Radio & Atmospheric Science Division, National Physical Laboratory, New Delhi, India

Description: Worked on temperature and water vapour characteristics of tropical upper troposphere lower stratosphere region and their relation to surface meteorological changes.

Job title: Project Fellow **2003 to 2007**

Atmospheric Sciences Division, Centre for Earth Science Studies, Trivandrum.

Description: Estimation of Methane emission from coastal water bodies of Kerala.

PUBLICATIONS

E J Zachariah and **C J Johny** (2006), Reduction in methane emission from Kerala estuaries**, Asian Journal of Water Environment and Pollution**, 3, No.1, 1-5.

C J Johny, D Punyaseshudu and S K Sarkar (2009) Atmospheric phenomena deduced from radiosonde and GPS Occultation measurements for various application related studies',J **. Earth Syst. Sci**., 118, 49-59.

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A R Jain, Vivek Panwar, **C J Johny**, T K Mandal, V R Rao, Rishu Gautam and S K Dhaka (2011), Occurrence of extremely low cold point tropopause temperature during summer monsoon season: ARMEX campaign and CHAMP/COSMIC satellite observations **J. of Geophys. Res**., 116, D03102. 2169-8996

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A. Sandeep, V. S. Prasad and **C. J. Johny**, 2017, Quality and Impact of Indian Doppler Weather Radar Wind Profiles: A Diagnostic Study, Pure and Applied Geophysics, 174 , 2847–2862.

C J Johny and V S Prasad, (2018) Quality and impact of GPSRO observations from Megha-Tropique satellite on NGFS model, Current Science, 114, NO. 5, 10, 1083-1088.

C J Johny, Sanjeev Kumar Singh and V S Prasad, (2019): Validation and impact of SCATSAT-1 Scatterometer winds, Pure and Applied Geophysics, DOI 10.1007/s00024-019-02096-5.

R.G. Ashrit, Manjusha Chourasia, **C J Johny** and John P George : “Improved track and intensity Predictions Using Cyclone Bogusing and Regional assimilation” (2014).Monitoring and prediction of Tropical Cyclones in the Indian Ocean and Climate Change. Springer (ISBN -978-94-007-7720-0)8, Page No. 246-254.

John P George, **C J Johny** and Raghavendra Ashrit (2011), DWR data monitoring and processing at NCMRWF, Technical report, NMRF/TR/03/2011.

PATENT

E J Zachariah and **Johny C J**, Patent for developing 'A Device and method for collecting water samples', Patent number-279781.

CONFERECES

C J Johny and V S Prasad (2016), Impact of GNSS-IPW observations on, NGFS, *Proc. SPIE* 9882, Remote Sensing and Modeling of the Atmosphere, Oceans, and Interactions VI, 988217, doi:10.1117/12.2222748.

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C J Johny and V S Prasad (2014), Hybrid data assimilation system , Prediction of Weather and Climate Systems Seamlessly (PROWES), NCMRWF, NOIDA.

C J Johny and V S Prasad (2014), Performance of NWP models used at NCMRWF during monsoon 2013 using VSDB, 6th WMO international verification methods Workshop.

COMPUTER PROFICIENCY

Operating systems : Windows, Unix, Linux

Languages : Fortran, C,C+ +

Packages : Grads, NCL, GNU PLOT, PYTHON

Working knowledge in HPC

Awards

CSIR Senior Research Fellowship 2007

CSIR Research Associate 2010

PERSONAL DETAILS

Permanent Address	:	JOHNY C J Chiramal Karath(H) P O Alapad Thrissur-680641 Kerala 0487-2272144
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Languages known	:	Malayalam, English, Hindi

REFERENCES

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Research Experiences

In my PhD thesis 'Climatology of tropical troposphere and lower stratosphere in relation to temperature water vapour over India' I have worked on temperature and water vapour characteristics in upper troposphere lower stratosphere over Indian region including adjacent oceans with an emphasis on troposphere stratosphere transport. It also investigates how surface and free troposphere influences UTLS characteristics. Radio occultation measurements COSMIC and CHAMP along with AIRS observations and radiosonde measurements are used in this study. Apart from thesis as part of work assignments in different organizations, research carried out in different disciplines of atmospheric science. In CESS I have been associated with monitoring of green house gas methane emission from coastal water bodies and familiar with instruments like gas chromatograph and associated with developing instruments suited for coastal environment. I was also involved in urban heat island studies. During my tenure in CDAC I have been associated with sensitivity studies in WRF model and receptor type air quality model CMB. In NCMRWF I am involved with data assimilation studies in NWP models. . Impact of assimilation of Doppler weather radar observations in WRF model is investigated and made it part of operational forecast system. Impact of assimilation of GPSRO observations, GPSIPW observations and hybrid assimilation system in NGFS model (adapted from NCEP GFS) forecast system is investigated and involved in radiance preprocessing for NCUM model. Done Observing system simulation experiment (OSSE) for GPSRO observations from Megha-Tropiques satellite using NGFS model. Tested quality of GPSRO observations from Megha-Tropiques satellite and done impact study using NGFS Model. Associated with implementing high resolution T1534 semi-Lagrangian GFS model and model verification package VSDB in the centre. Associated with the development of different diagnostic tools for prediction of thunderstorm activities from dynamic models. Have good experience working in coastal water bodies and participated XBT profiling program in Arabian Sea. In M.Tech project at NPOL Kochi I have worked on modeling of Acoustic propagation in ocean.

Pure Appl. Geophys.

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Pure and Applied Geophysics

Validation and Impact of SCATSAT-1 Scatterometer Winds

C. J. Johny,[1] Sanjeev Kumar Singh,[1] and V. S. Prasad[1]

Abstract—Scatterometer winds are useful in weather forecasting and cyclone monitoring related activities. The Indian Space Research Organization has launched SCATSAT-1, which is a follow-up mission of the Oceansat-2 scatterometer in September 2016. It operates in the Ku-band frequency and provides wind vector data over oceanic region from sun synchronous polar orbit. SCATSAT-1 wind vector data are validated against buoy observations, other scatterometer observations and numerical weather prediction (NWP) analysis. It is found that SCATSAT observations are of good quality in comparison with other similar types of measurements. Impact of assimilation of these observations in NWP forecasts is investigated using the National Centre for Medium Range Weather Forecasting Global Forecast System (NGFS). The NGFS model employs a three-dimensional variational-ensemble Kalman filter (3D Var-EnKF) hybrid assimilation system with a deterministic model of T-1534 resolution and 80 member ensembles of T-574 resolution. Impact of assimilation of SCATSAT-1 observations in prediction of the Kyant, Nada and Varadha cyclones formed in the Bay of Bengal region and impact on operational forecasts are discussed. Assimilation of SCATSAT observations produced marginal improvement in general NWP forecast statistics and improvement is observed in cyclone track forecasts if observations are available near the cyclone position at analysis time.

Key words: SCATSAT, assimilation, cyclone, scatterometer, NWP.

1. Introduction

Ocean surface wind observations are useful for various applications in meteorology and oceanography. Information from ocean surface winds can improve initial conditions of the NWP model and play major role in the presence of cyclones. Conventional observations such as buoy and ship can provide highly accurate observations over an ocean, but is limited over a small region. Moore and Pierson (1967) introduced the idea of a space-based scatterometer for measuring surface winds over an ocean. The scatterometer computes surface wind speed and wind direction by measuring radar backscattered radiation from the sea surface at different directions and with the help of empirical geophysical functions. The details of different scatterometer missions and their quality assessments are discussed in Indira Rani et al. (2014). Satellite-based scatterometry started with a Ku-band, Seasat-A Scatterometer System (SASS) developed by the National Aeronautics and Space Administration (NASA) in 1978. The European Space Agency (ESA) launched two scatterometers in European remote sensing (ERS) satellites ERS-1 and ERS-2 in the years 1991 and 1992, respectively. These scatterometers operating in the C-band together provided data for a period of two decades. In comparison with C-band scatterometers, Ku-band scatterometers can provide greater ice/water contrast, but are affected by attenuation due to rain. NASA and the Japanese National Space Development Agency (NASDA) jointly launched the NASA Scatterometer (NSCAT) aboard the Advanced Earth Observing System (ADEOS)-1 satellite in 1996. It was a Ku-band scatterometer, and the mission provided continuous data for 10 months until the premature failure of the spacecraft. NASA's SeaWinds operating in the Ku-band aboard QuikSCAT, was a quick backup mission to fill the data gap from the loss of NSCAT and provided continuous data until 2009. The SeaWinds Scatterometer aboard the ADEOS-2 satellite, a joint mission of NASA and NASDA, operated in the Ku-band from 2002 to 2003. The European Organization for Exploitation of Meteorological Satellites (EUMETSAT) has operated the C-band Advanced Scatterometer (ASCAT) in the satellites Metop-A and Metop-B since 2006 and 2012, respectively. ISRO's Ku-band Oceansat-2 Scatterometer (OSCAT)

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Quality and impact of GPSRO observations from Megha-Tropique satellite on NGFS model

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Megha-Tropique satellite mission launched in 2011 was aimed at providing more observations in the tropical region. In the initial phase of the mission, it was found that the quality of global positioning system radio occultation (GPSRO) observations was not satisfactory. The Indian Space Research Organisation (ISRO) took remedial measures in this regard by modifying the data processing algorithm and releasing the new version of data. In 2012, an observing system simulation experiment (OSSE) was done at National Centre for Medium Range Weather Forecasting (NCMRWF) using simulated data at Megha-Tropiques ROSA observation location with Global Forecast System (GFS) based model. As an extension of the previous study, the quality of new version of GPSRO bending angle observations and impact of assimilation of these observations in NCMRWF GFS (NGFS) model were studied. It was found that with the use of a new data processing algorithm, quality of bending angle observations improved and comparable with other GPSRO missions in the pressure range between 500 hpa and 200 hpa. Impact study shows that the new observations improved forecasts in the middle and upper levels in the tropics.

Keywords: Assimilation, bending angle, GPSRO, Megha-Tropiques, NGFS.

THE global positioning system radio occultation (GPSRO) is a limb sounding technique in which the signal emitted by GPS is tracked by a receiver on a low earth orbit satellite. Occultation event occurs when LEO satellite rises or sets behind the earth. GPSRO observations provide atmospheric information on temperature and humidity at good vertical resolution and in all weather conditions. There are numerous studies which envisaged the quality and applications of these observations in various weather and climate studies[1–8]. A major impact of GPSRO observations was seen in upper-tropospheric and stratospheric temperatures[9]. At present GPSRO observations are available from different platforms like COSMIC, METOP/GRAS, GRACE, SAC-D, C/NOFS and TerraSAR-X. As the COSMIC-1 mission is ageing, it provides fewer observations than its peak performance period.

GPSRO observations are routinely assimilated in all major operational numerical weather prediction (NWP) centres. European Centre for Medium Range Weather Forecasting (ECMWF) employs 2D operators for GPSRO observations while all other centres use 1D operators for GPSRO observations. Assimilation of radio occultation (RO) observations in NWP models produced positive impacts on global and regional scale predictions[10–14]. Unlike other satellite observations, GPSRO observations do not require bias correction and can be used for anchoring bias correction applied to satellite radiances[15]. GPSRO and conventional observations have the largest impact per observation basis in global NWP and GPSRO has the largest mean impact on global NWP analysis[16]. With the present set of GPSRO observations there is no saturation impact and error reduces with more number of observations. In NCEP, operational assimilation of GPSRO observations in GFS model started in 2007 with refractivity data from COSMIC[17]. In 2012 operational GPSRO assimilation algorithm was modified with the use of bending angle operator and new quality control procedures. Impact studies showed that both the changes improved forecast over existing model configuration. In NGFS model, assimilation of GPSRO observations started in 2010 with refractivity observations and upgraded to bending angle observations in 2014.

Megha-Tropiques, an Indo-French mission launched in 2011, is intended to provide frequent observations over tropical regions due to its low satellite orbit inclination. Inter-comparison studies done in the initial phase of the mission showed that GPSRO observations derived from Megha-Tropique satellite were not of adequate quality to be used in NWP models[18]. The study also showed improvement in forecast on using model simulated refractivity observations at positions of Megha-Tropiques observations. Corrective measures were taken in the new data processing algorithm by ISRO to make a new product. In this study we investigate the characteristics of the new derived product of GPSRO observations from Megha-Tropiques satellite. As a continuation of the previous observing system simulation experiment[18], assimilation impact was studied using real observations obtained using new data processing algorithm. Quality of these observations was studied using bending angle, as it is of much less refined product than refractivity. Refractivity computation from bending angle requires certain climatology details and under super refraction conditions, refractive computations show negative bias[19]. Again the bending angle measurement errors are vertically less correlated than errors in refractivity profile as Abel transform is not involved[20]. Impact of assimilation of these observations in NWP model was studied using NGFS model during May 2015.

The quality of Megha-Tropique GPSRO bending angle observations was studied by comparing observations with bending angle simulated from NGFS model background. Secondly, the impact of these observations on model forecasts was studied by assimilating observations in the

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Impact of hybrid GSI analysis using ETR ensembles

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Performance of a hybrid assimilation system combining 3D Var based NGFS (NCMRWF Global Forecast System) with ETR (Ensemble Transform with Rescaling) based Global Ensemble Forecast (GEFS) of resolution T-190L28 is investigated. The experiment is conducted for a period of one week in June 2013 and forecast skills over different spatial domains are compared with respect to mean analysis state. Rainfall forecast is verified over Indian region against combined observations of IMD and NCMRWF. Hybrid assimilation produced marginal improvements in overall forecast skill in comparison with 3D Var. Hybrid experiment made significant improvement in wind forecasts in all the regions on verification against mean analysis. The verification of forecasts with radiosonde observations also show improvement in wind forecasts with the hybrid assimilation. On verification against observations, hybrid experiment shows more improvement in temperature and wind forecasts at upper levels. Both hybrid and operational 3D Var failed in prediction of extreme rainfall event over Uttarakhand on 17 June, 2013.

1. Introduction

Numerical weather prediction (NWP) forecasts depend on initial conditions which are created by combining a short-term forecast from previous cycle (known as background state) with observations. Data assimilation (DA) is employed to compute an optimal correction to the background state, referred to as the analysis increment, using the observations and estimates of the uncertainty associated with the background state and the observations. The uncertainty is typically characterized by covariance matrices for the error in the background state and the observations. These covariance matrices determine the level of influence each observation has on the analysis and how this influence is distributed both spatially and among the different types of analysis variables (Buehner 2010). This method is optimal only if both the observation and background error covariance matrices are correctly specified in the analysis. Accurate specification of these covariance matrices is very important for the quality of the assimilation system. In a variational scheme, the background error is typically computed using NMC (National Meteorological Center) method (Parrish and Derber 1992) and static background error covariance, used here, does not reflect the flow-dependent error statistics. This background error covariance is time-independent and therefore does not include errors of the day. Variational scheme assumes that the background forecast-error covariances are static and nearly homogeneous and isotropic (Parrish and Derber 1992; Courtier *et al.* 1998). In reality, the background-error covariances may vary substantially depending on the flow of the day (Wang *et al.* 2007a). In order to address this issue, there were attempts to include some amount of spatial inhomogeneity and anisotropy in standard covariance models used in 3D Var (Wu *et al.* 2002; Purser *et al.* 2003). Ensemble based data assimilation in various forms of ensemble Kalman filter (EnKF) is an

Keywords. Hybrid; assimilation; GSI; ensemble.

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Impact of 3D Var GSI-ENKF hybrid data assimilation system

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The hybrid two-way coupled 3DEnsVar assimilation system was tested with the NCMRWF global data assimilation forecasting system. At present, this system consists of T574L64 deterministic model and the grid-point statistical interpolation analysis scheme. In this experiment, the analysis system is modified with a two-way coupling with an 80 member Ensemble Kalman Filter of T254L64 resolution and runs are carried out in parallel to the operational system for the Indian summer monsoon season (June–September) for the year 2015 to study its impact. Both the assimilation systems are based on NCEP GFS system. It is found that hybrid assimilation marginally improved the quality of the forecasts of all variables over the deterministic 3D Var system, in terms of statistical skill scores and also in terms of circulation features. The impact of the hybrid system in prediction of extreme rainfall and cyclone track is discussed.

1. Introduction

Numerical weather prediction models depend on the background state provided by the short-range forecast from the previous cycle. There is some amount of uncertainty in the background state and the assimilation system takes account of this uncertainty in a covariance matrix and is referred as background error. Accurate knowledge of these error statistics is extremely important for the success of the assimilation process. The assimilation system applies optimal corrections to the background state by using observations and taking account of the information on uncertainty in observations, as well as in the background state represented in respective error covariance matrices. The influence of each observation on analysis and its distribution among different model variables is determined by these error covariance matrices (Buehner 2010). Accurate specification of these uncertainties is important for the success of assimilation system. The NMC (National Meteorological Center) method used in variational schemes in estimating uncertainty in the background state is static and does not show flow-dependent error characteristics (Parrish and Derber 1992). This static background error covariance used in these methods does not represent errors associated with the flow of the day, and background forecast error covariance are assumed to be static, isotropic and nearly homogeneous (Parrish and Derber 1992; Courtier *et al.* 1998). But in reality, background-error covariance depend on flow-of-day and may vary considerably from the static background error covariance (Wang *et al.* 2007). Anisotropy and spatial inhomogeneity are introduced in background error covariance used in 3D Var models by recursive filters (Wu *et al.* 2002; Purser *et al.* 2003). Ensemble data analysis schemes based on different forms of ensemble Kalman filters (EnKF) provided an alternative to variational methods. In these methods, the flow-dependent errors, which are ignored in variational

Keywords. Assimilation; GSI; ensemble; EnKF.

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Global retrospective analysis using NGFS for the period 2000–2011

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The National Centre for Medium Range Weather Forecasting (NCMRWF) conducted its first global data retrospective analysis (reanalysis) for the period 1 January 2000–31 March 2011 using its GFS based system (NGFS). This reanalysis is called NGFS-R and the main objectives of this effort are to address issues for studying decadal variability of the Indian summer monsoon, high-resolution global analysis fields to study the Indian monsoon and to provide short-term mean fields for its seasonal/long-term forecasts by ensemble methods. NGFS-R has been conducted with the T574L64 version of the Global Data Assimilation and Forecasting System of NCMRWF that is operational as of May 2015, and using CFS-reanalysis data dump. With this effort, a high-resolution global data analysis at 6 h intervals is made available for about 16 years (2000–2015) for various uses and applications.

Keywords: Global data assimilation and forecasting, monsoon season, numerical weather prediction models, retrospective analysis.

THE objective of data assimilation methods is to provide an estimate of the state of the atmosphere at any particular time by combining information from *in situ* and remote sensing observations with an a priori estimate of that state obtained from a short-term forecast generated using numerical weather prediction (NWP) models. The quality of these analyses depends on data assimilation methods and NWP models used to generate the a priori 'first guess' analysis estimates[1]. Operational runs of Global Data Assimilation and Forecasting (GDAF) system at National Centre for Medium Range Weather Forecasting (NCMRWF), have been started since 1994 and this system has been upgraded from time to time for incorporating the latest advances in model physics, analysis schemes and skills to assimilate new types of datasets into the model[2]. These changes were made with an aim to increase the forecast skill of the GDAF system. The latest significant change in the system is the enhancement of the model resolution to T574L64 and other relevant changes that are reported in detail by Prasad *et al.*[3]. This upgraded system produces model forecasts at about 23 km horizontal resolution and the skill of the useful forecast increased by about 24 h. The analysis and forecasts generated by this system are in turn used in mesoscale models, coupled atmospheric models and with ocean state forecast models in India. Using these improved GDAF outputs also improved the user model systems[4]; however, some of the systems require long-term GDAF outputs. The GDAF analysis is crucial for generating accurate real-time forecasts, but it has limited utility in studying trends over longer period and in climate change research due to artificial variability associated with the above-mentioned frequent changes. Modern reanalyses have been proposed as a remedy for this problem, with an emphasis on regenerating the synoptic analyses over several decades using a fixed data assimilation system and NWP model[1,5–7]. By adopting the same strategy, NGFS-R reanalysis has been initiated for the period 1 January 2000–31 March 2011. NGFS-R took about nine months to be completed (in January 2016) and was run using the new High Power Computing (HPC) system (Bhaskara 350 terraflop IBM idataplex system).

Before the 2010 period, the main source of global meteorological observations at NCMRWF was Regional Telecommunication Hub (RTH), India Meteorological Department (IMD), New Delhi, which in turn receives data through the Global Telecommunication System (GTS) of World Meteorological Organisation (WMO). The volume of these data is comparatively less than the contemporary operational NWP centres and it mainly consists of conventional data. The satellite and other remote sensing data were almost absent, except for few datasets like atmospheric motion vector (AMV) winds from geostationary satellites and scatterometer winds, etc. Thus, for maximizing data usage in reanalysis data dumps in CFS-analysis system are used. In these data dumps global conventional dataset and wind observations from geostationary satellites (AMV) and scatterometers are available in the PREPBUFR format (Figure 1). They are compared with current operational conventional observations (Figure 2). It clearly shows that the distribution of observations that are ingested is similar to most of the observations. The number of ship observations increased and additional ship routes have also been added over the years. The number of land synoptic observations over Amercian and European continents is more in CFS-observational data, as India is not receiving METAR-type of observations in real time. Further, it can be clearly seen that CFS-observational dataset contains a good number of observations over the Indian region as well. Figure 3 shows increase in conventional observations over the reanalysis period. This increase is mainly due to increase in satellite-based wind products such as AMV winds, scatterometer ocean surface wind, and rain observations like SSM/I and TRMM precipitation rates. Even though these are satellite-based datasets, they are retrieved geophysical products and are considered as conventional observations only and packed in PREPBUFR format. The satellite direct radiance datasets are packed in separate files in NCEP-BUFR format. Figures 4 shows

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