4D-Ens-Var System at NCMRWF

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Outline

- NCMRWF DA systems and their uniqueness
- Development of Ensemble Forecasting.
- Applications
- Retrospective Analysis and Re-Forecasting.

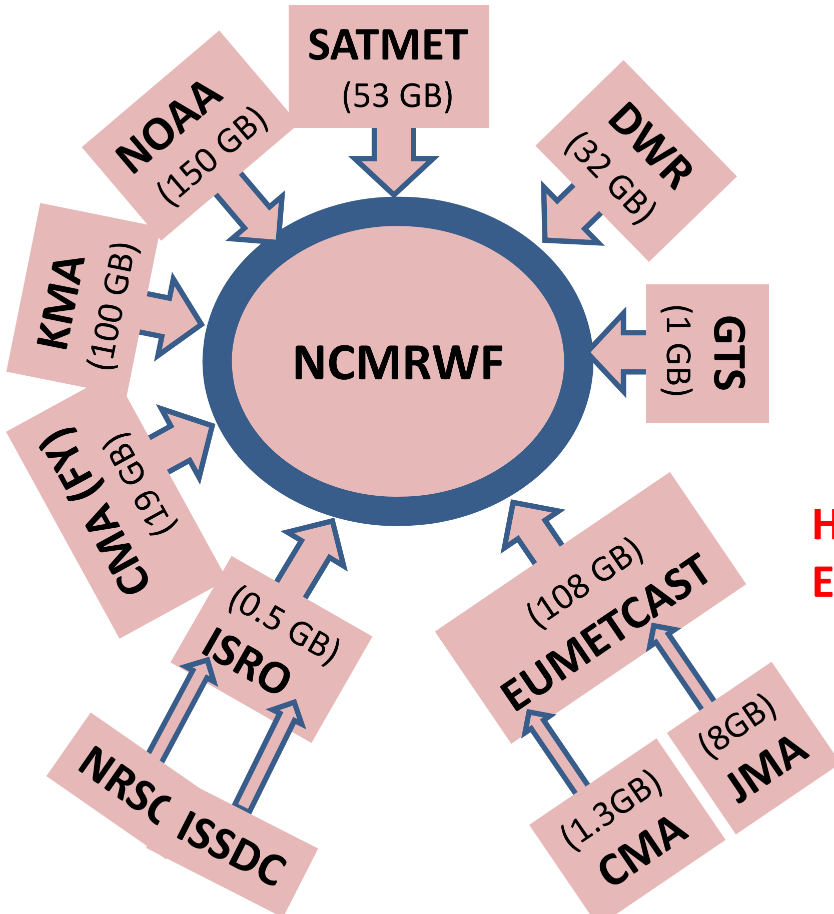
NCMRWF is maintaining the following two data assimilation system towards for achieving a reasonable weather forecasting system over Indian Monsoon region

- NGFS (GFS-14)
- Legacy system
- 1994 -2007 - SSI
- 2007-2015 GSI
- 2015 EnKF-GSI hybrid
- 4D-Ens-Var from 2018
- Initial conditions for IMD, IITM and INCOIS etc.

- NCUM (N1024L70))
- 4D-Var ; Since 2012
- UM10.8
- Seamless prediction system under monsoon mission.

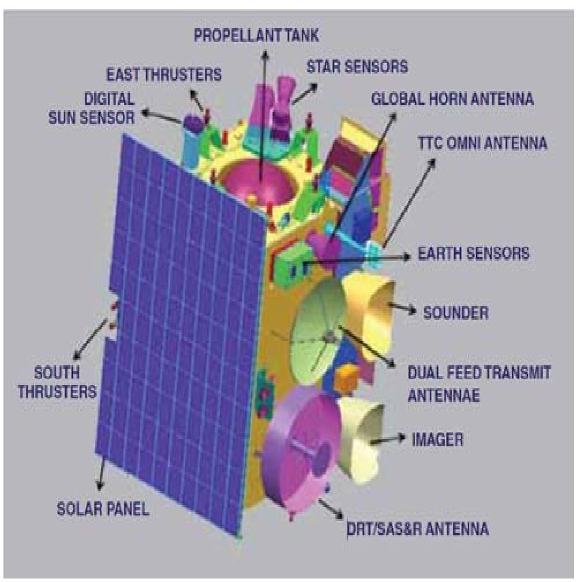
Assimilation of observations from Indian Observation Network

Meghatropiques
SAPHIR & ROSA



Oceansat
Scatterometer

High Resolution (12 km)
Ensemble members.



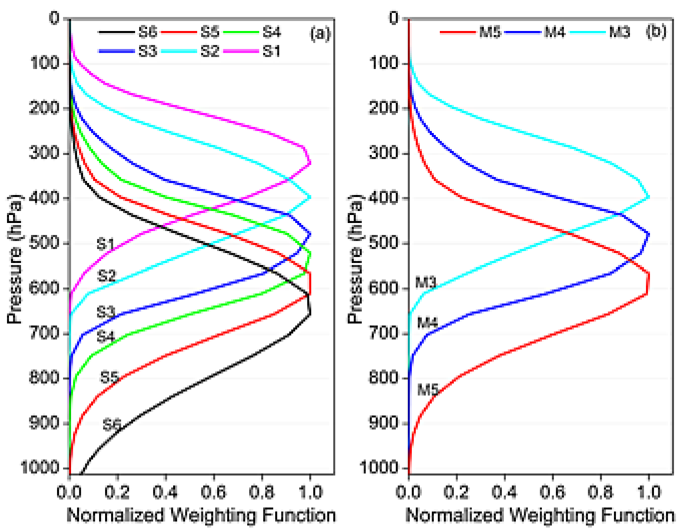
INSAT- 3D
Sounder & Imager

24 member DWR Network
44 Sonde observation stations
AWS/ARG Stations
68 Lighting Detection Stations
25 GNSS stations
Indian Buoy program (NIOT)

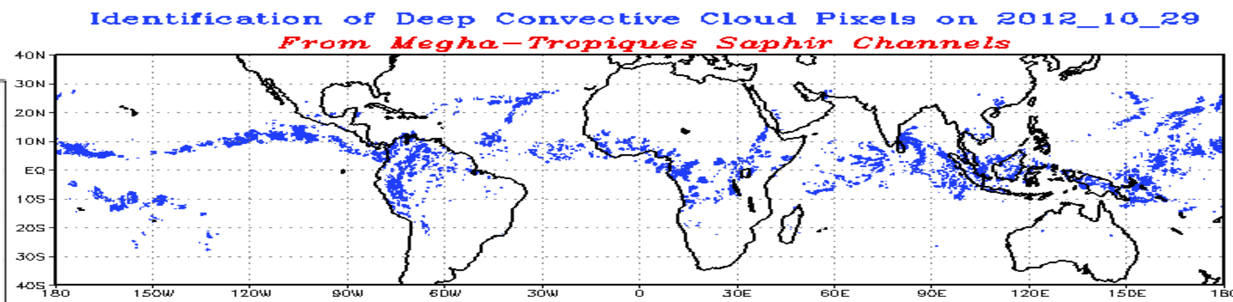
MT-Saphir Radiance Assimilation

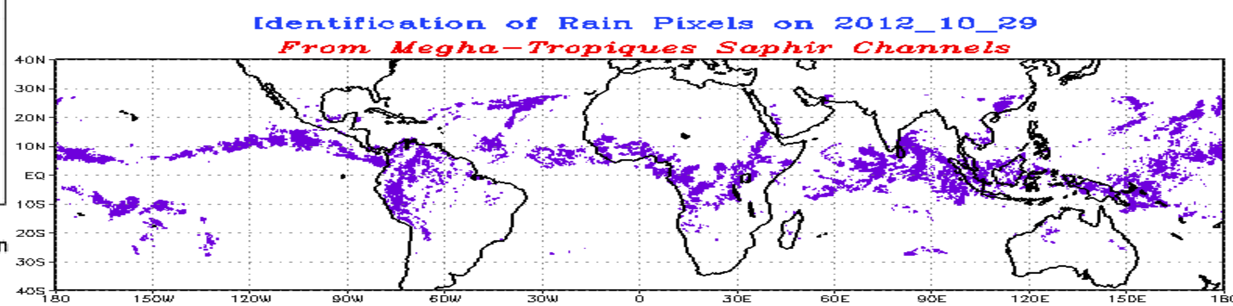
MeghaTropique SAPHIR is a humidity sounder instrument similar to NOAA/Metop- MHSWorking at 183 GHz water vapour band except in a number of channels and not having Window channels. New forward model and qc checks are developed for assimilating cloud free radiance.

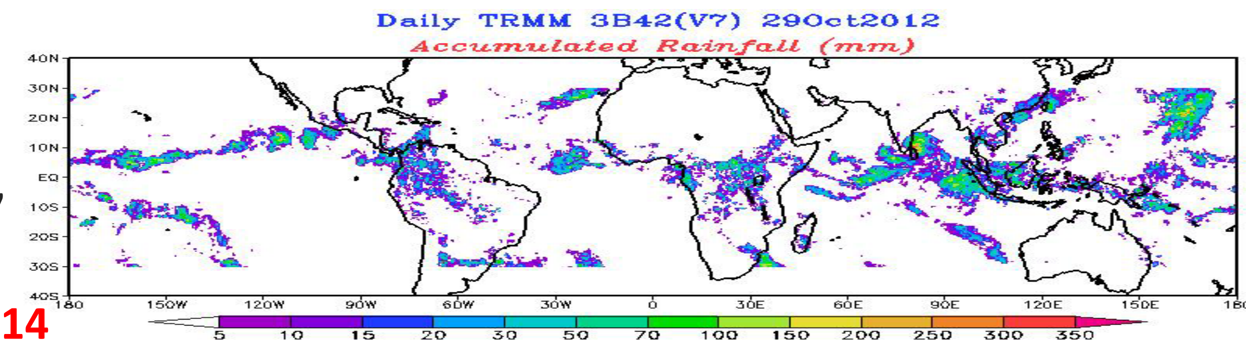
S_2-S_5 >= 0K ; S_2-S_3>=0K; S_3-S_5 >=0K . About 4% improvement in humidity forecast. (2013)



Comparison of Weighting Functions of MT-Saphir (6 ch in ~183GHZ) and MHS (3 ch in 183 ~Ghz + 2 window ch) channels.



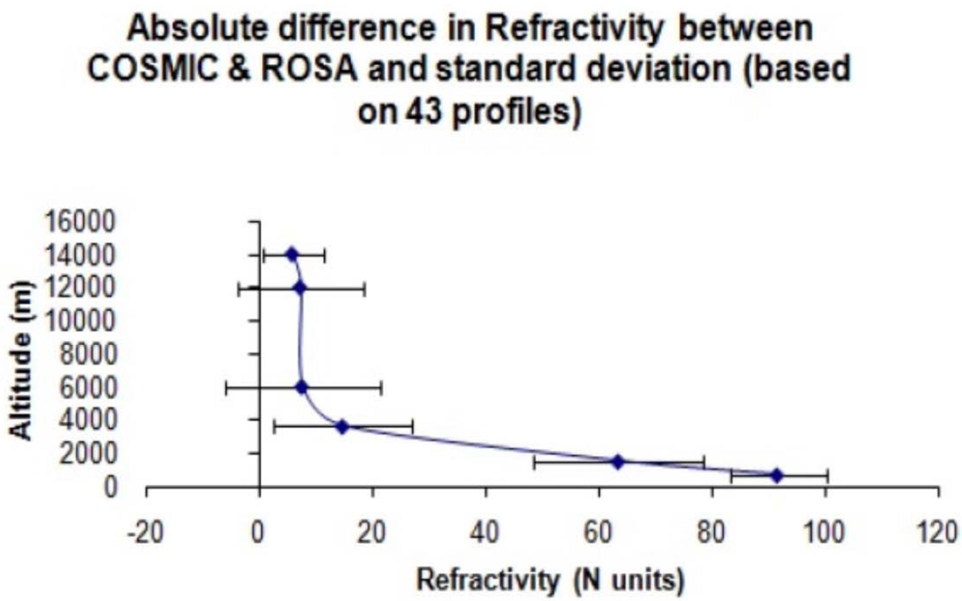


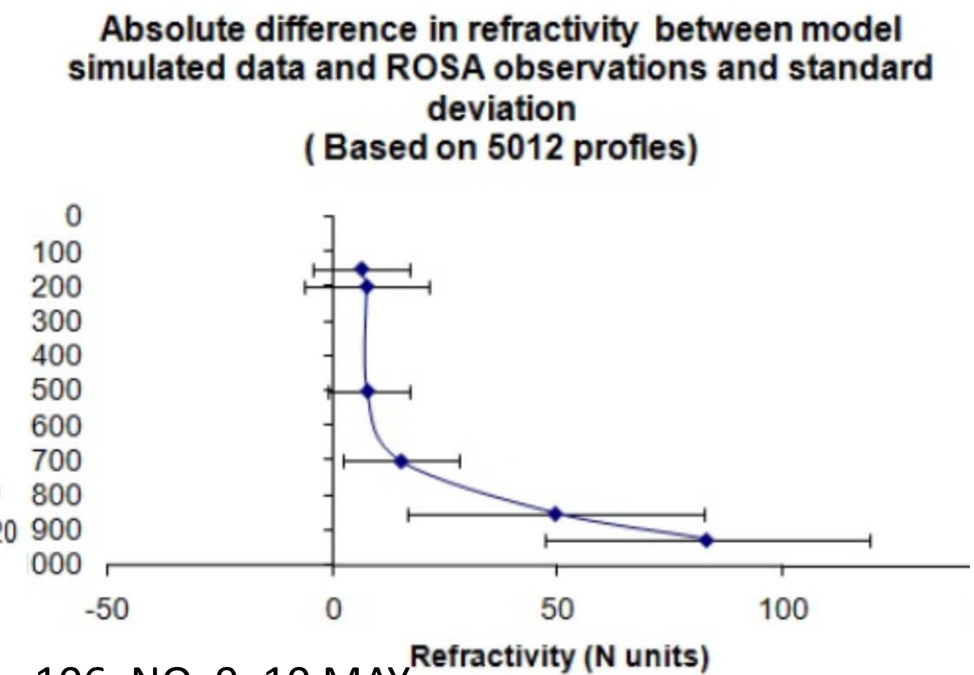


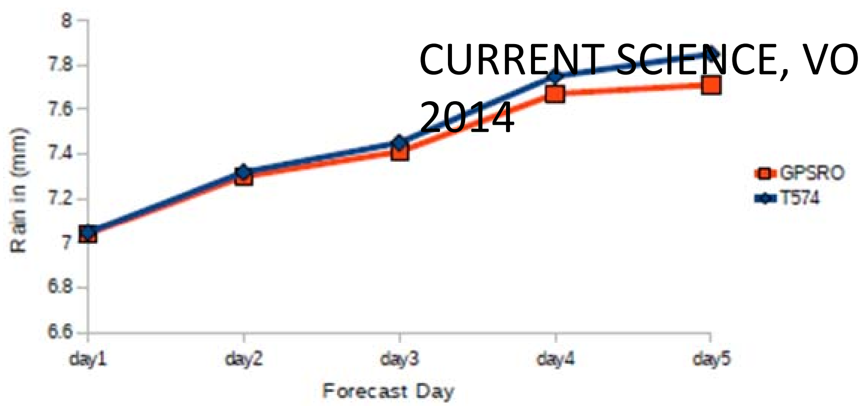
S.K. Singh and Prasad, IJRS 2017

Prasad and singh,19 ITWG,

South Korea**26 March-1 April 2014**







CURRENT SCIENCE, VOL. 106, NO. 9, 10 MAY 2014

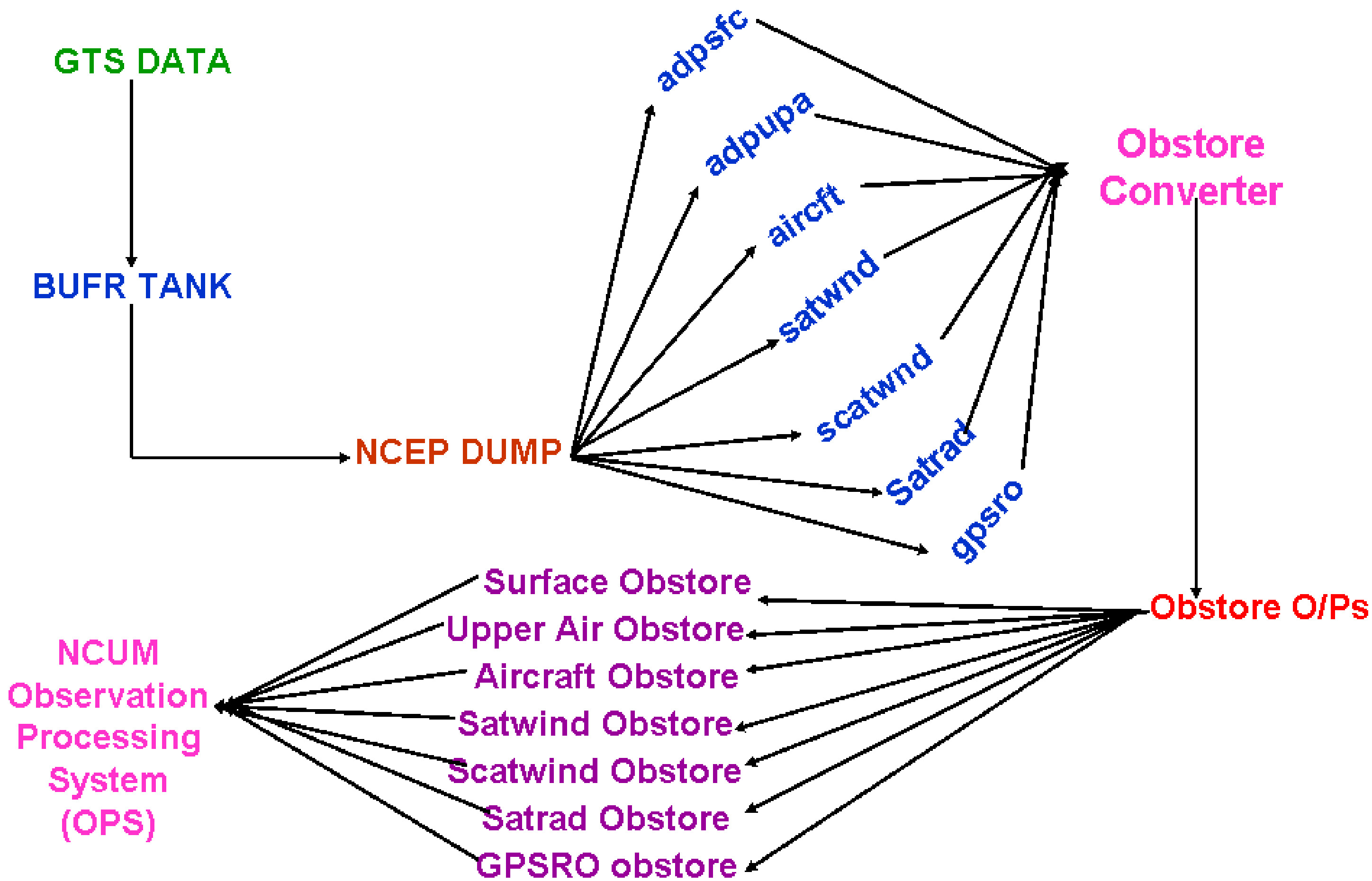
Pressure (hpa)	COSMIC and METOP	Megha-Tropiques
700-850	3.02	10.39
550-700	1.43	2.64
500-550	0.71	1.13
400-500	0.38	0.44
350-400	0.19	0.21
300-350	0.15	0.20
100-300	0.13	0.28
50-100	0.24	0.34
10-50	0.13	0.16

Mean RMSE in 24 hour FCST rain Involving OSSE ROSA

Johny & Prasad ,CURRENT SCIENCE, VOL. 106,2014
Johny & Prasad ,CURRENT SCIENCE, VOL. 114,2018

The quality of ROSA improved and made available on GTS. Similarly AMV & sounder from INSAT

Combined Data Pre-processing system for NCUM & NGFS



Not using METDB or ODB like other UM partners

Prasad 2012 & 14; Buddhi Prakash et al 2019

Development of Ensemble Approach

Work on Ensemble Techniques at NCMRWF were initiated in mid 1990's

Iyengar G. R., Zoltan Toth, **Eugenia Kalnay** and John S. Woollen, 1996: Are the bred vectors representative of analysis errors? Preprints of the 11th AMS Conference on Numerical Weather Prediction, 19-23 August 1996, Norfolk, Virginia, USA.

Iyengar, G. R, E. N. Rajagopal, S. C. Kar, and A. K. Bohra, 2004: Use of Ensemble Forecasting Techniques in Medium and Extended Range Prediction at NCMRWF. Paper presented at the Workshop on Ensemble Methods: From Weather Forecasting to Climate Change, Exeter, UK, 18-21 October, 2004.

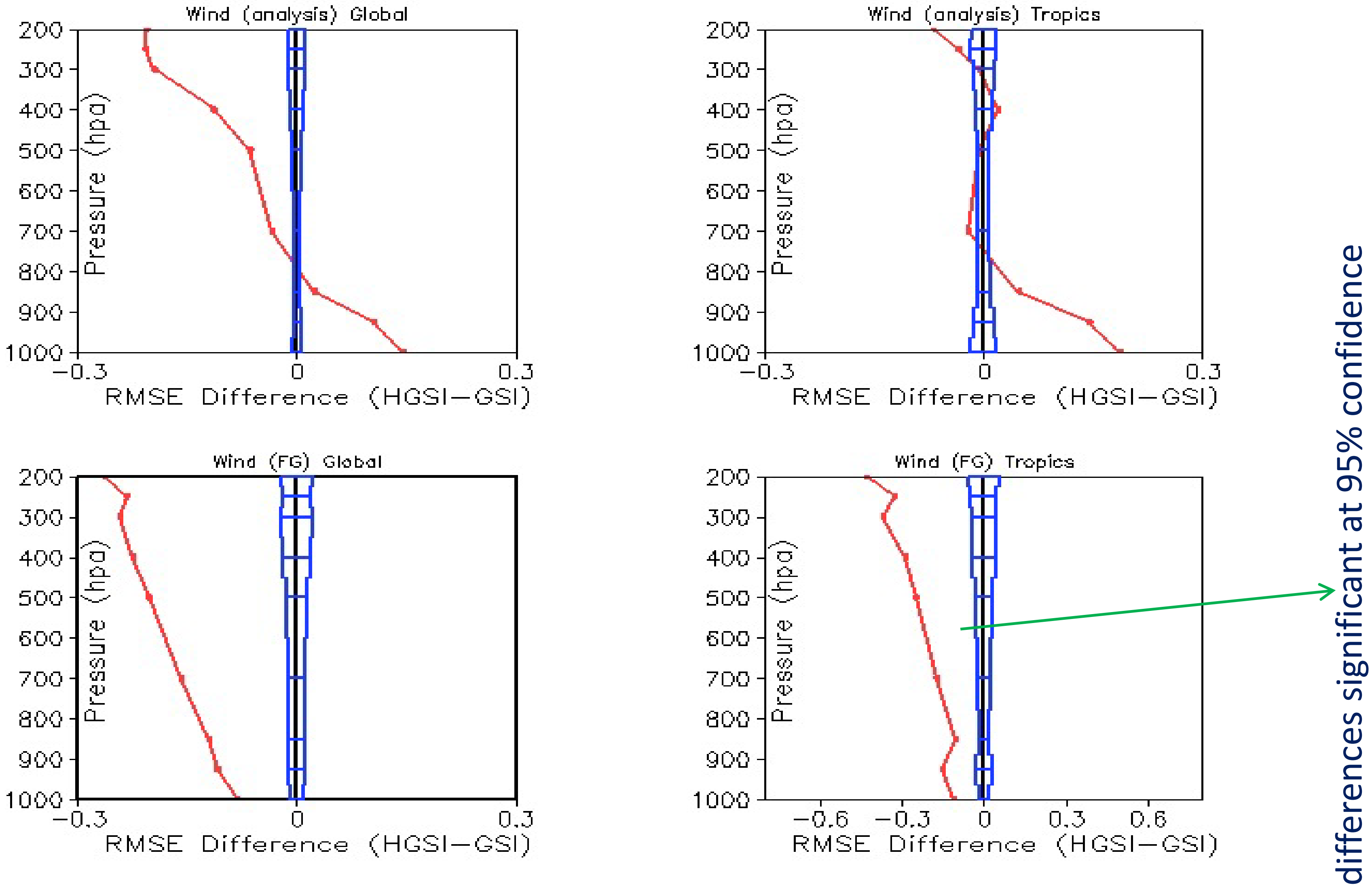
Kar S. C., G. R. Iyengar and A. K. Bohra, 2011: Ensemble spread and systematic errors in the medium-range predictions during the Indian summer monsoon. Atmósfera, 24(2), 173-191.

Operational GEFS system was implemented in the year 2012

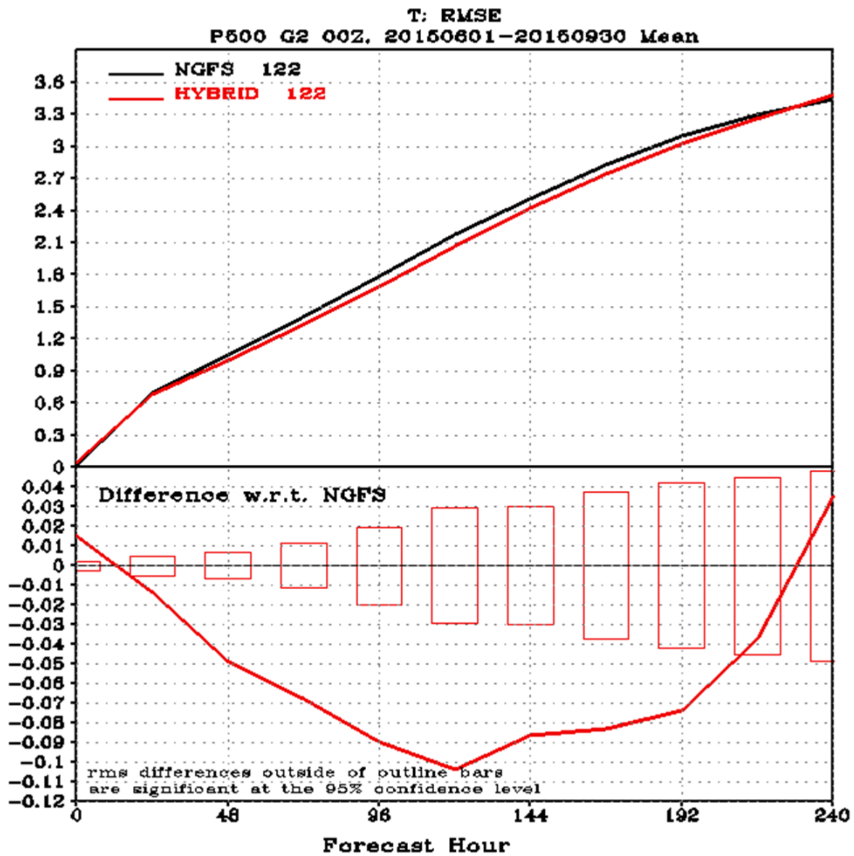
Using the ETR based 10 member ensemble GEFS system , **a one way coupled dual resolution** (deterministic T574, with T190 ensembles) Hybrid assimilation system experiments were carried out in the year 2014 (Prasad and Johny 2016). These studies clearly showed that this one-way coupled dual resolution hybrid assimilation did show moderate improvement in the model forecast skill on comparison with 3D Var during the investigation period. (**Prasad V. S. and C. J. Johny, 2016, Impact of hybrid GSI analysis using ETR ensemble, Journal of Earth System Science, 125(3), 521-538)**

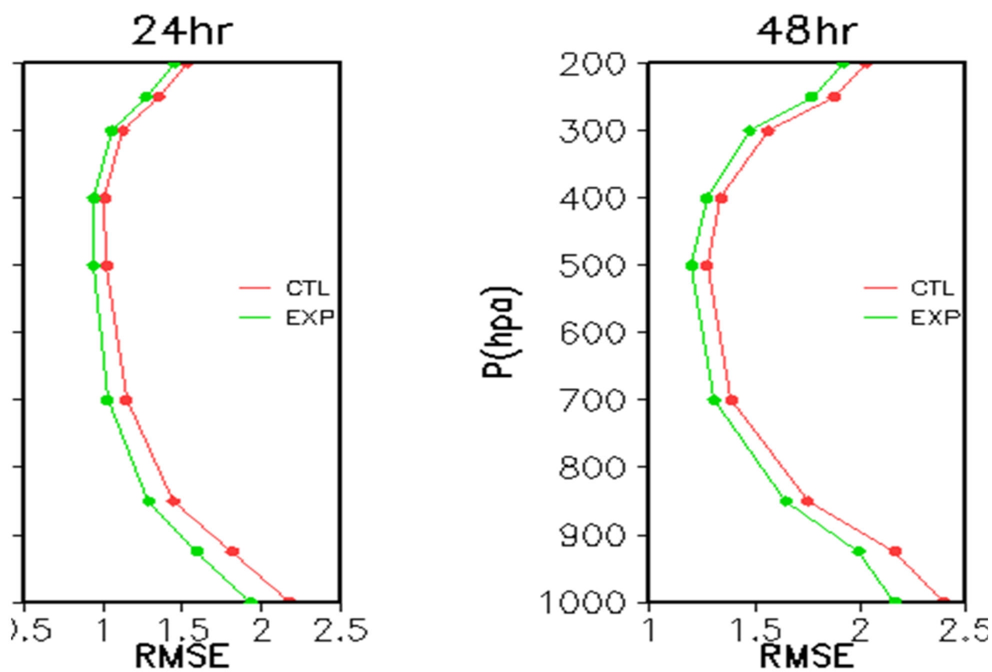
Following this study **a two-way coupling with an 80 member** Ensemble Kalman Filter of T254L64 resolution was successfully tested for the Indian summer monsoon season (June– September) for the year 2015 (Prasad et al., 2016). They found that hybrid assimilation marginally improved the quality of the forecasts of all variables over the deterministic 3D Var system, not only in terms of statistical skill scores , but also in terms of circulation features. (**Prasad & Johny J. Earth Syst. Sci., DOI 10.1007/s12040-016-0761-3, 125)**

Vertical profile of RMSE differences in wind analysis (Top) and First guess (bottom) between the experiments (hybrid-3D Var) computed against radiosonde observations in global (left) and tropics (right).



Hybrid Vs Deterministic

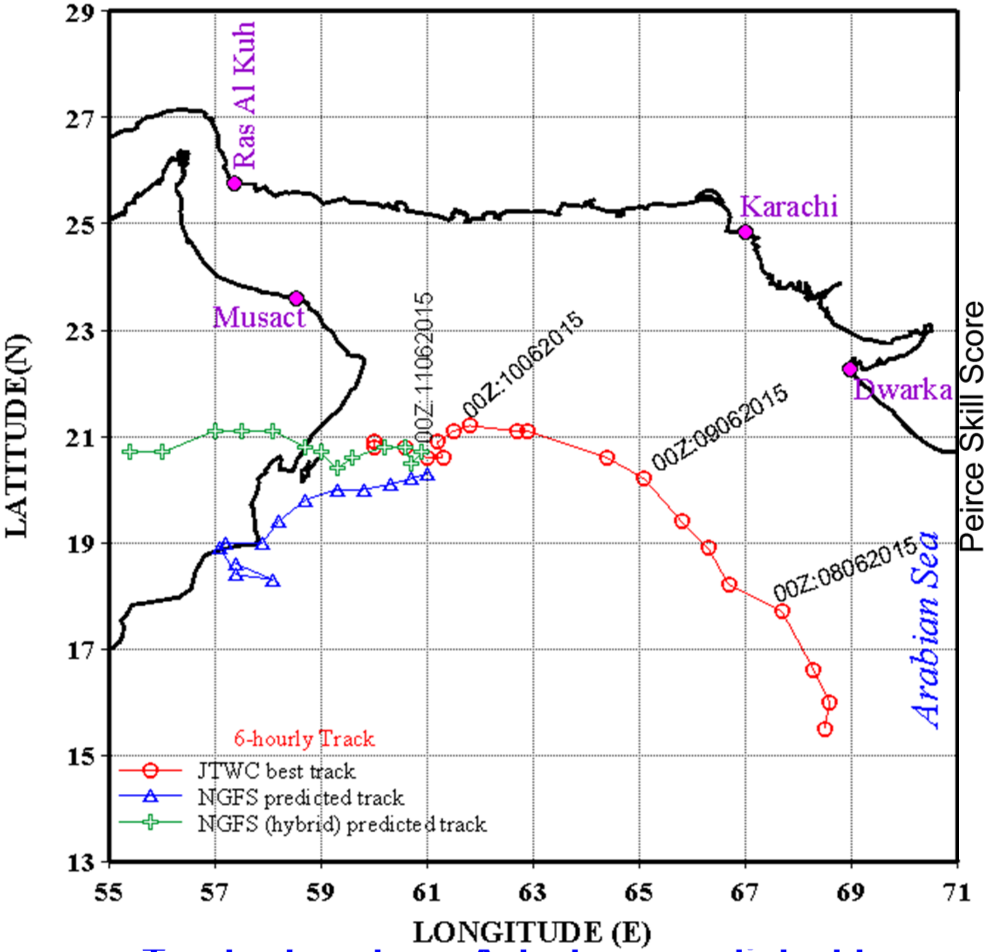




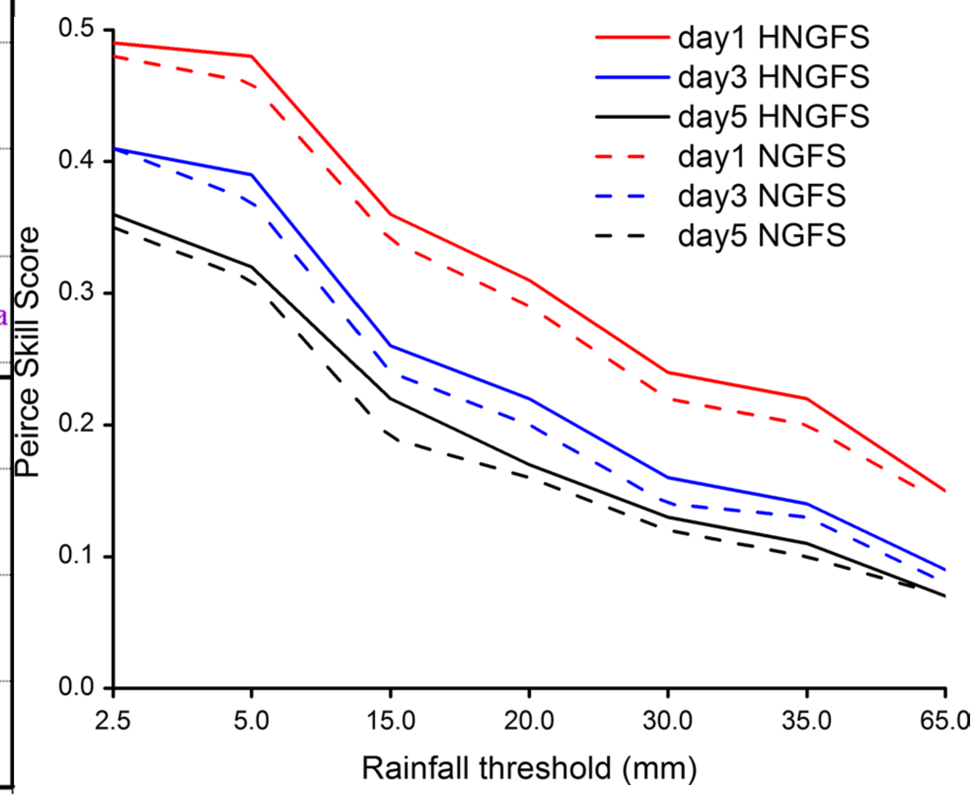
RMSE in Temperature (left) hPa with respect to analysis . Bottom panel shows RMSE difference with respect to control. (Hybrid vs 3D Var)

RMSE in 24 hr and 48 hr forecasts w.r.t. radiosonde observations
(Hybrid -> EXP, 3DVar -> CTL)

Impact of Hybrid GSI



Track of cyclone Ashobaa predicted by Hybrid EnKF (Green) and 3D Var (blue) along with JTWC best track (red)



Pierce Skill score in Hybrid and NGFS for June –Sep 2015.

S. No	HPC (with Performance)	Period	GDAF System
1	Cray – XMP (4 Mflops)	1988-1993	T80L18 with SSI
2	Cray – YMP (16 Mflops)	1993-1998	
3	Dec-Alpha (9.6 Gflops)	1999-2011	
4	Cray SV1 (28.8 Gflops)	2001-2006	
5	PARAM (500 Gflops)	2006-2011	T254L64 GSI
6	Cray – X1E (1.1 Tflops)	2006-2011	T382L64 GSI
7	IBM – Power 6 (24 Tflops)	2010 onwards	T574L64 GSI
8	IBM – Idataflux (350Tflop)	2015 onwards	T574L64 Hybrid GSI
9	Cray – XC40 (2.8 Pflops)	2018 onwards	T1534L64 4D-ENS-Var

GSI –V 14 with modifications for assimilating additional observations with an emphasis to additional observations by India

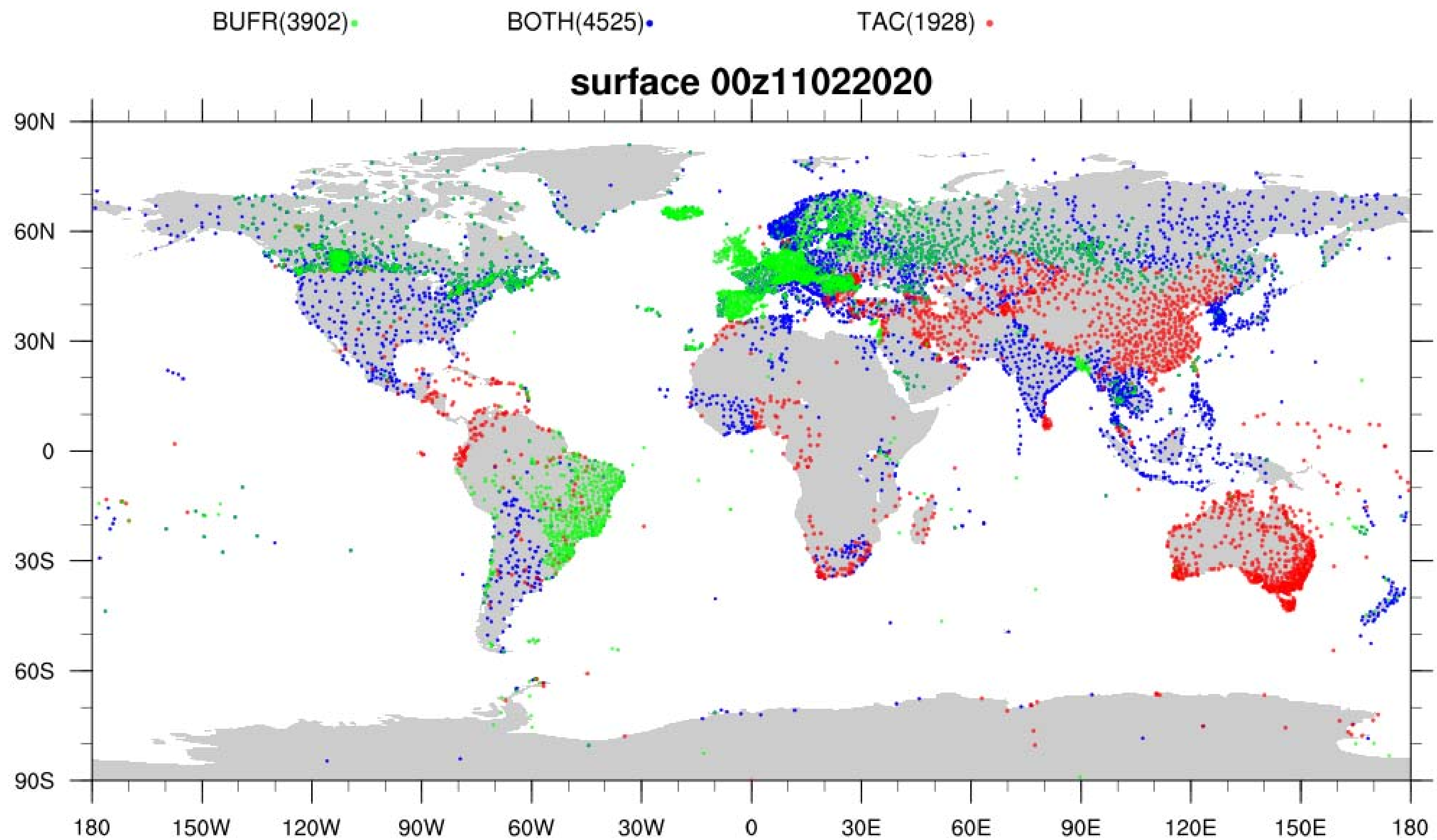
Satellite Data sets being used in Assimilation

Satellite Winds		Scatterometer winds	Satellite radiances			GPSRO
Geostationary	Polar		Geostationary	Polar		Bending Angle
			IR	IR (Hyperspectral)	MW & IR	
INSAT-3D	NOAA-18-20	ASCAT (MetOp-A,B,C)	INSAT-3D Sounder	1.IASI (MetOp-A)	AMSU-A (MetOp-A, MetOp-B, N18,N19)	COSMIC-6
Meteosat-8	AQUA	HY-2A	SEVIRI (Meteosat-8)	2.IASI (MetOp-B)	HIRS4 (MetOp-A,MetOp-B, N19)	GRAS-A
Meteosat-11	TERRA	Scatsat	SEVIRI (Meteosat-11)	3.AIRS (AQUA)	MHS (MetOp-A, N18, N19)	GRAS-B
GOES-15	MetOp-A,B,C		AHI (HIMAWARI-8)	4.CrIS (SNPP)	SAPHIR (MeghaTropique)	TerraSAR-X
HIMAWARI-8	MetOp-B		INSAT3DR	CRISFS(N-20)	ATMS (SNPP, N20)	TanDEM-X
					SSMIS (F17, F18)	ROSA (MT)
					AMSR2 (GCOM-W1)	
					GMI GPM	
					AVHRR-(MetOp-A,N18)	

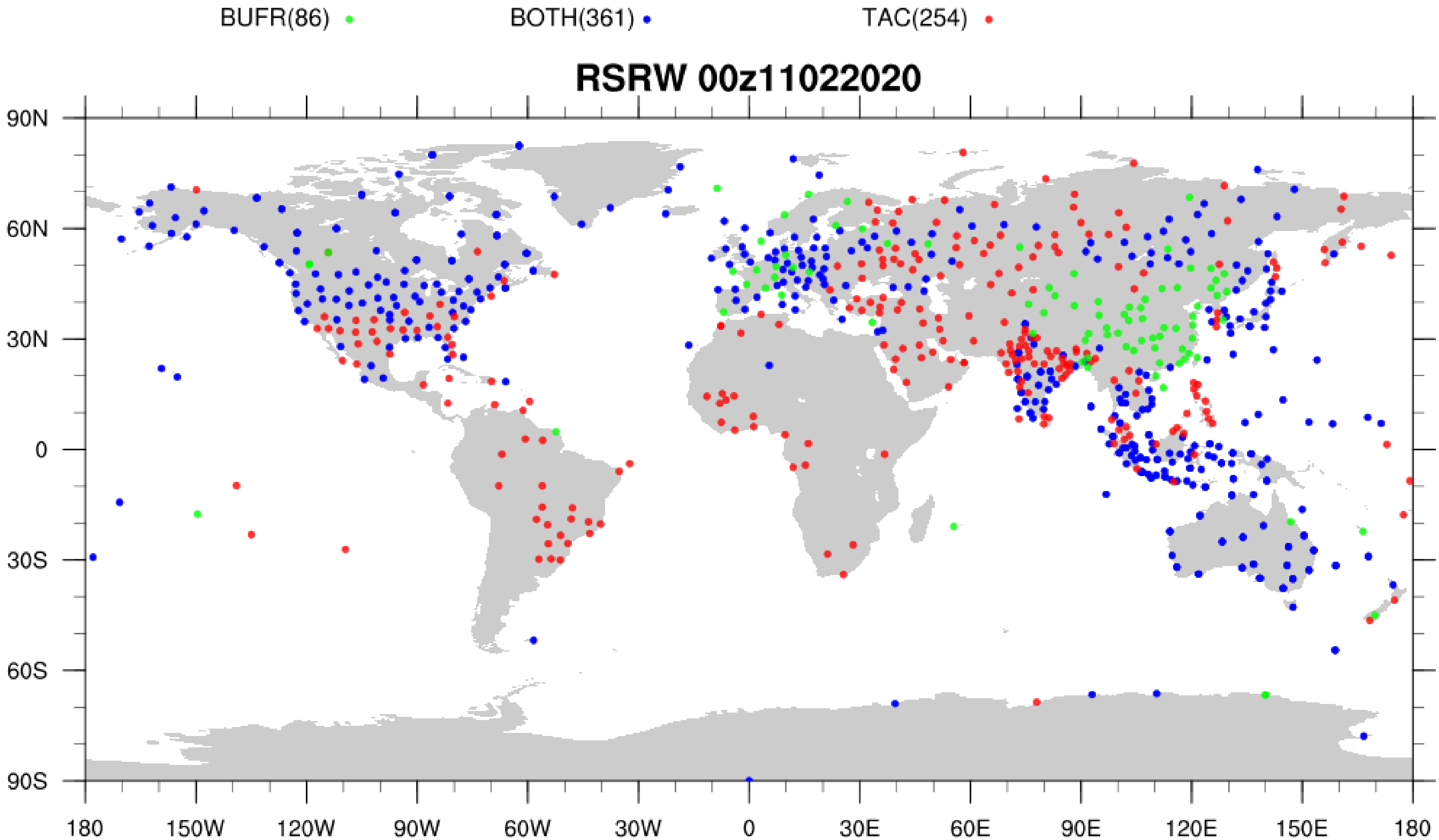
TAC-2-BUFR Migration of SYNOP & Buoy

After years of Concentration of Satellite observation focus now shifted to conventional GTS data and carried out a complete overhauling of archive and processing system. Bulletin header based file naming and archiving it on Bulletin origin date wise directory was implemented.

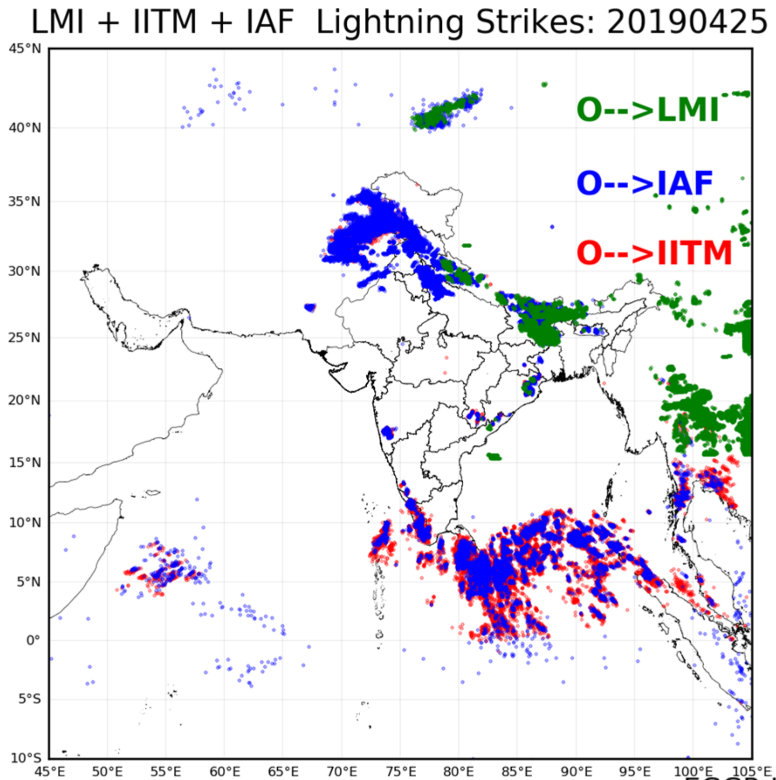
Ref: Prasad 2020, NCMRWF, Technical Report.

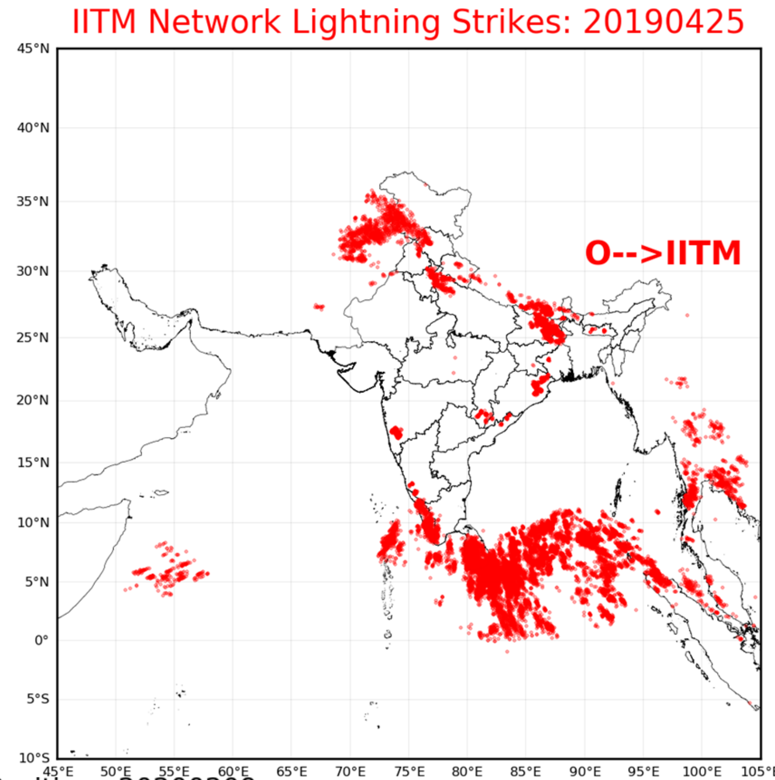


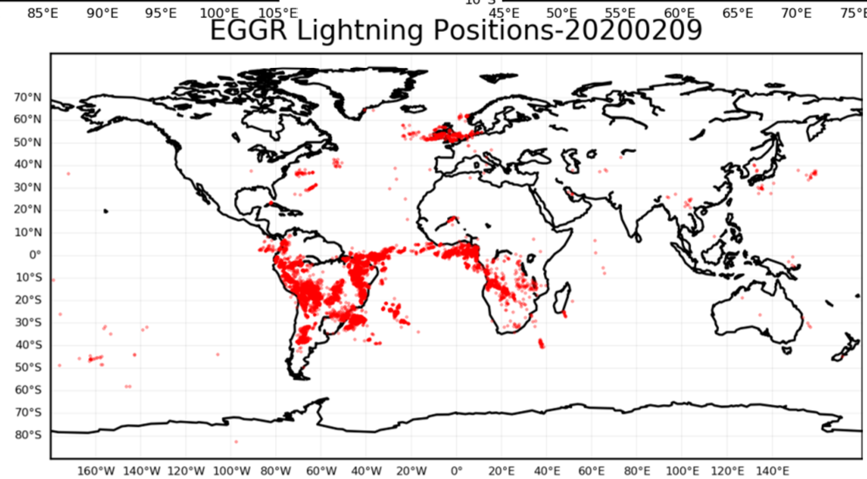
TAC-2-BUFR MIGARTION OF RS/RW
Number of Stations ~ 695



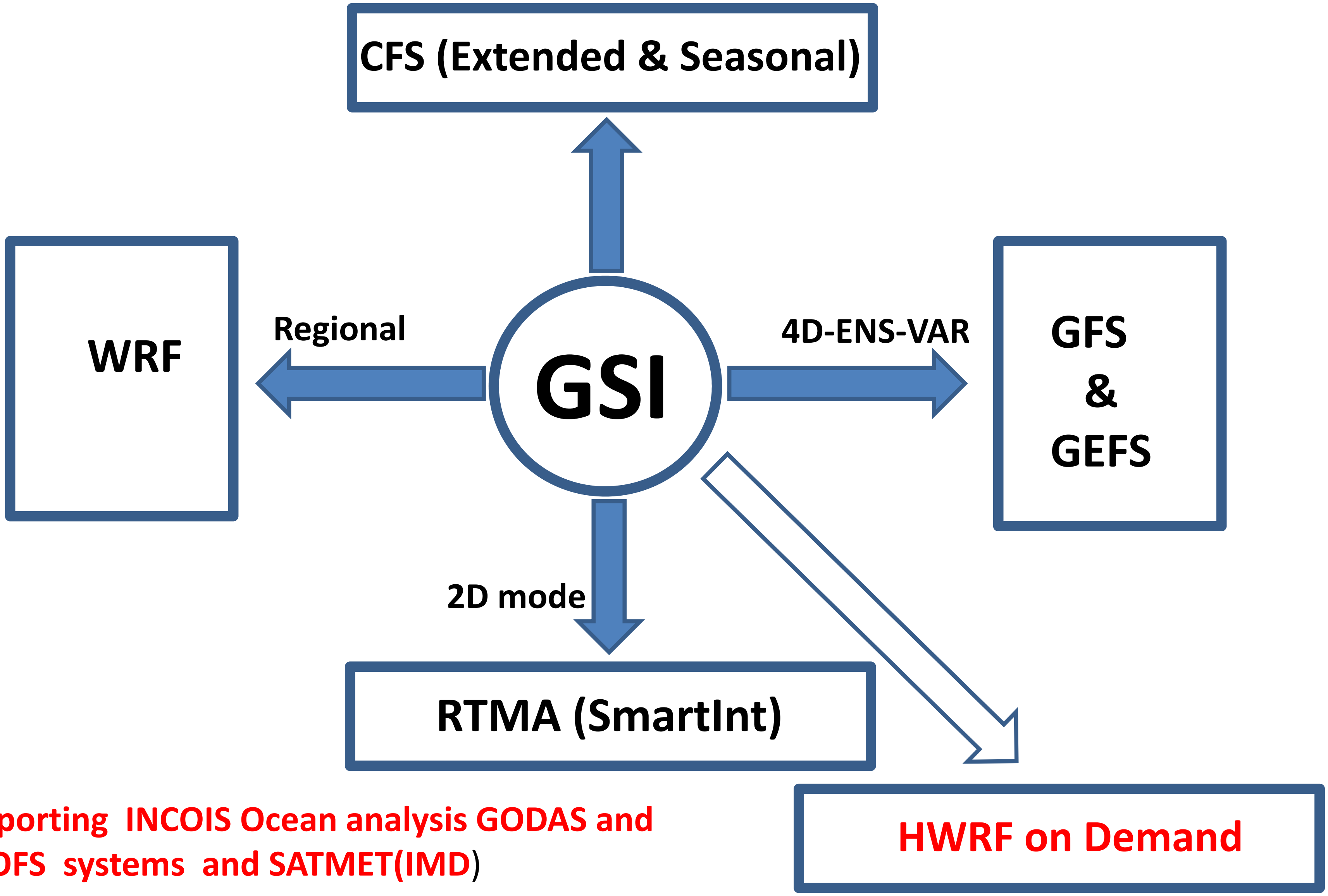
Assimilation of LIGHTNING OBSERVATIONS







GFS based Data Assimilation (DA) system for MoES Applications

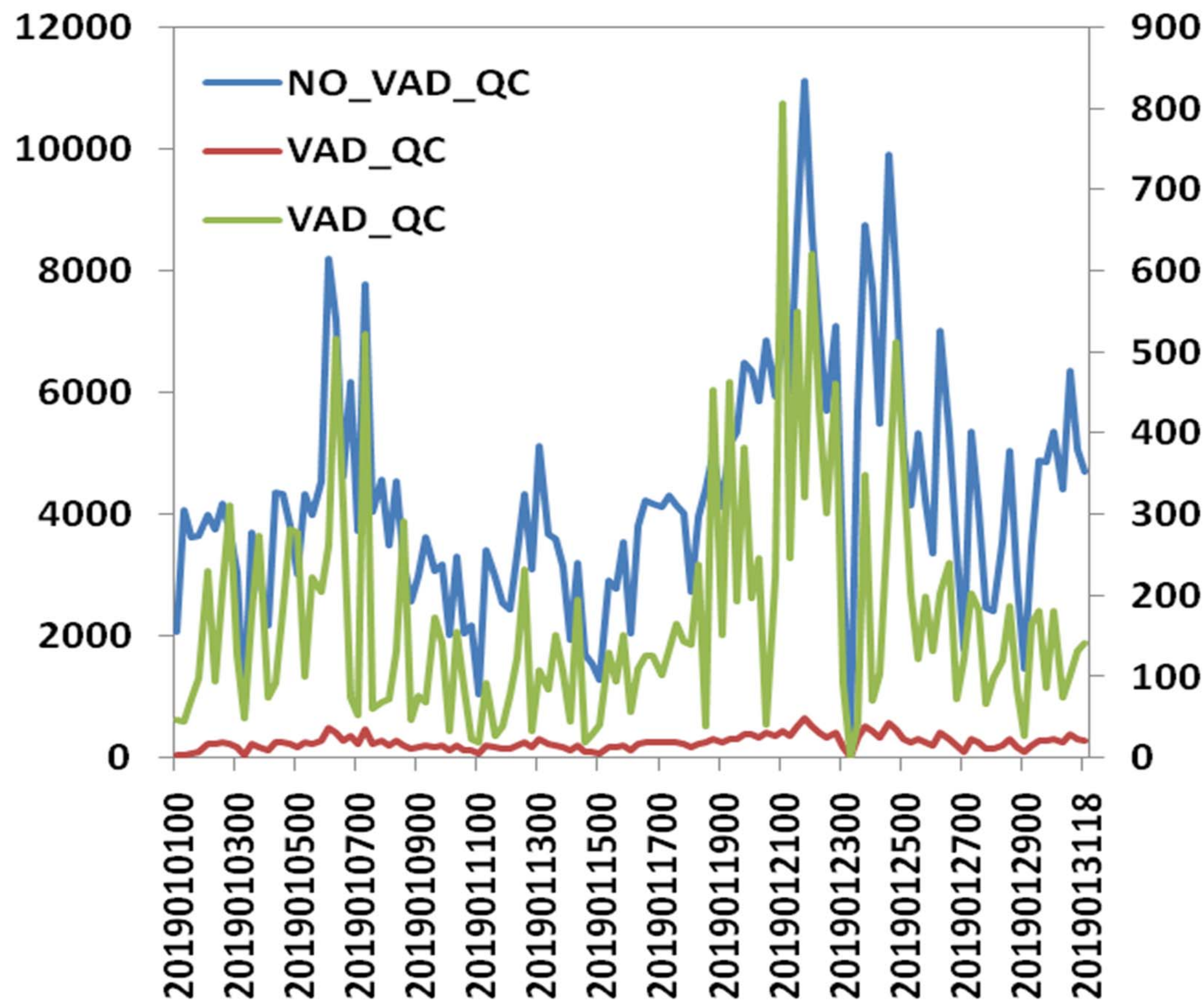


Supporting INCOIS Ocean analysis GODAS and
HOOFS systems and SATMET(IMD)

Regional GSI for WRF

- Regional GSI for 3 km WRF implemented and tested.
- Radar Radial wind assimilation scheme is modified to assimilate more winds.
- INSAT AMV, 3D-sounder radiances, Scatsat included.
- Development work is underway for inclusion of AHI.
- Modification regarding Gate distances of IMD radar network suggested.

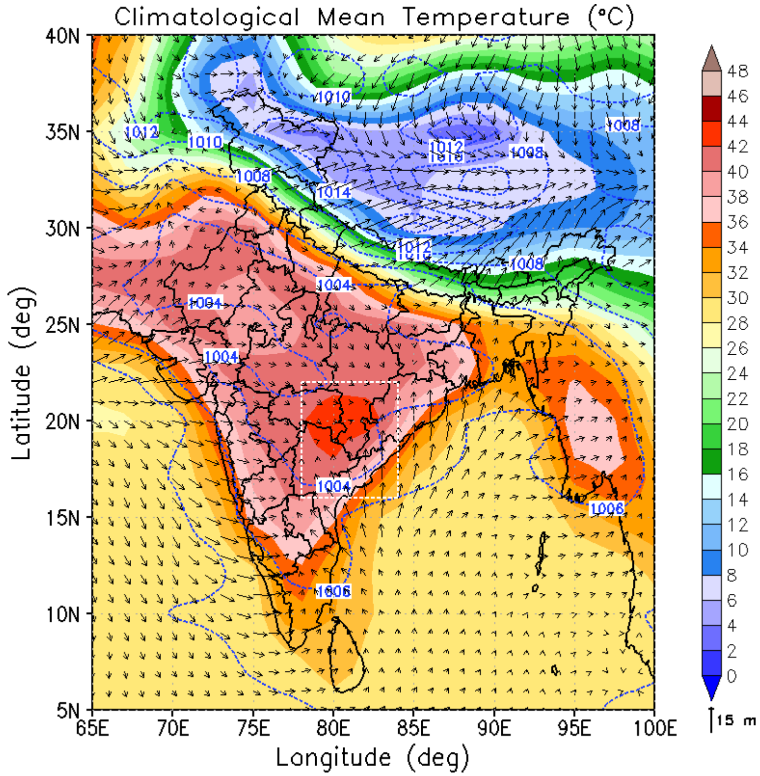
Total No. of Obs. Assimilated with different approach



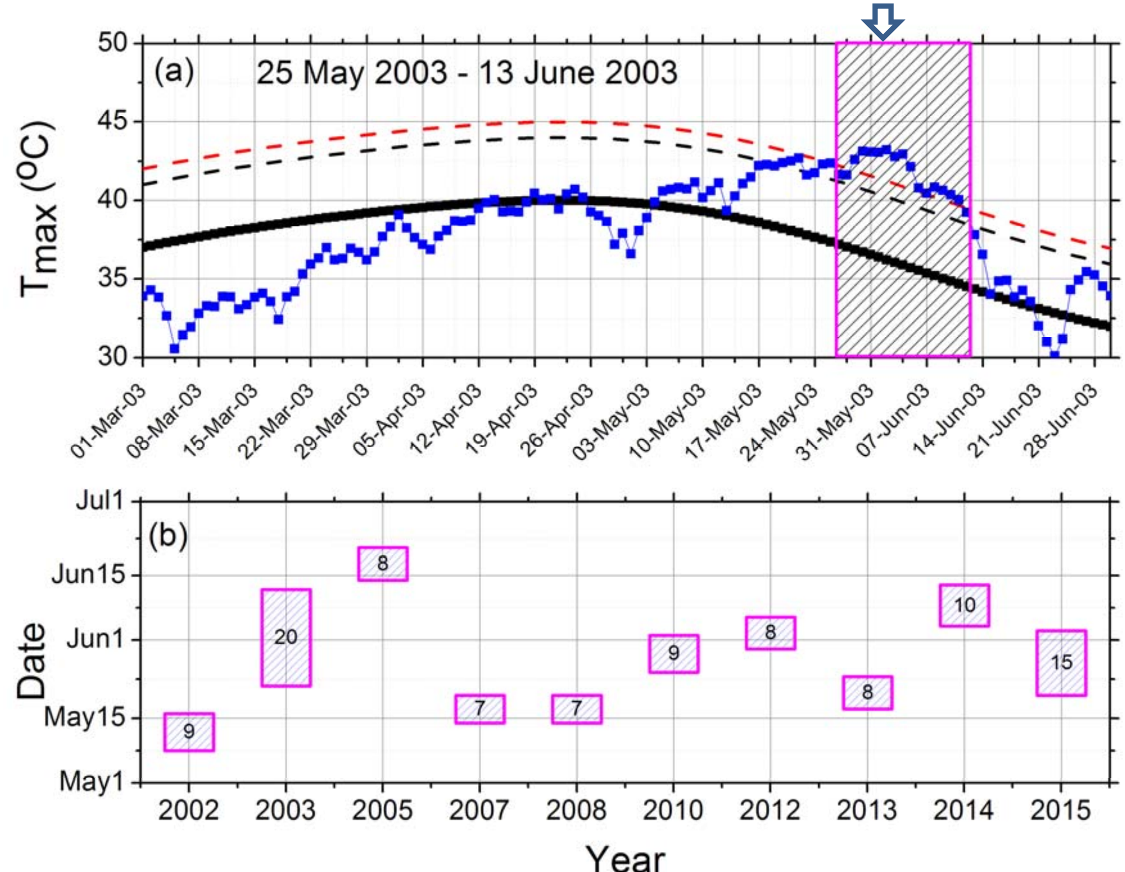
- A retrospective reanalysis for the period from 1999 to 2018 is carried out using 2011 version of NCMRWF GFS (Prasad et al 2011).
- A ten member ensemble ICs for the above retrospective period for 00z and 18z cycles are created by adding samples of 48-24 hour forecasts differences of the same GFS model with a specified amplitude and of zero mean ensemble. The initial dates for the forecasts, i.e perturbation dates are generated by taking considering the analysis date.

Identification of heat wave episodes

Study region (16º–22º N; 76º–82º E)



Heat wave



Total no.of heat waves 10 (100 hot days)

- The average duration of heat waves is 10-days, with longest (shortest) episode lasting for 20 (7) days in the year 2003 (2007, 2008, and 2013).
- An average duration of severe heat wave is 3.5–days longer than that of a normal heat wave.
- The onset of heat wave can be seen at the earliest (latest) on 09 May (15 June) in 2002 (2005) year.

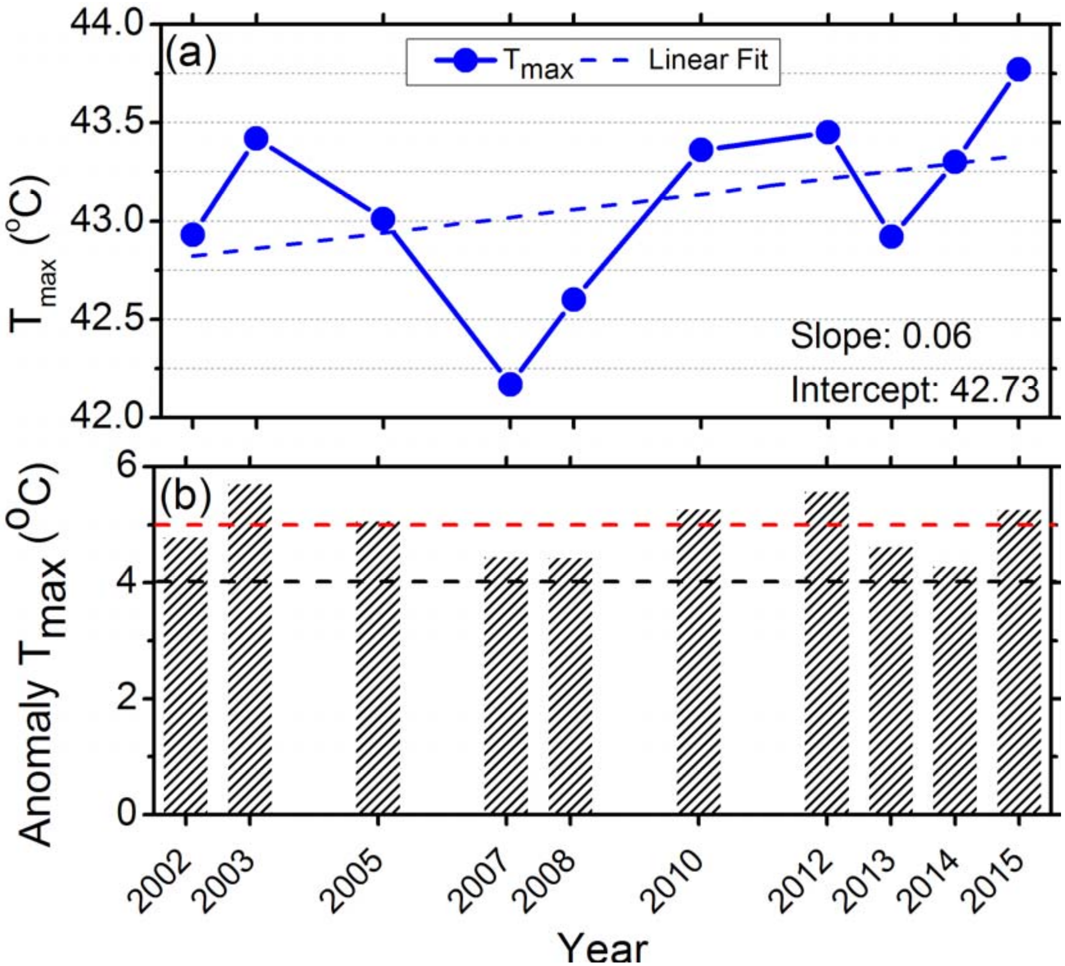
Intra-annual variability of heat wave episodes over east coast of India

- The *dashed* black (red) line in Figure 8b represent the area-averaged climatological T_{max} plus 4 (5) ^oC.

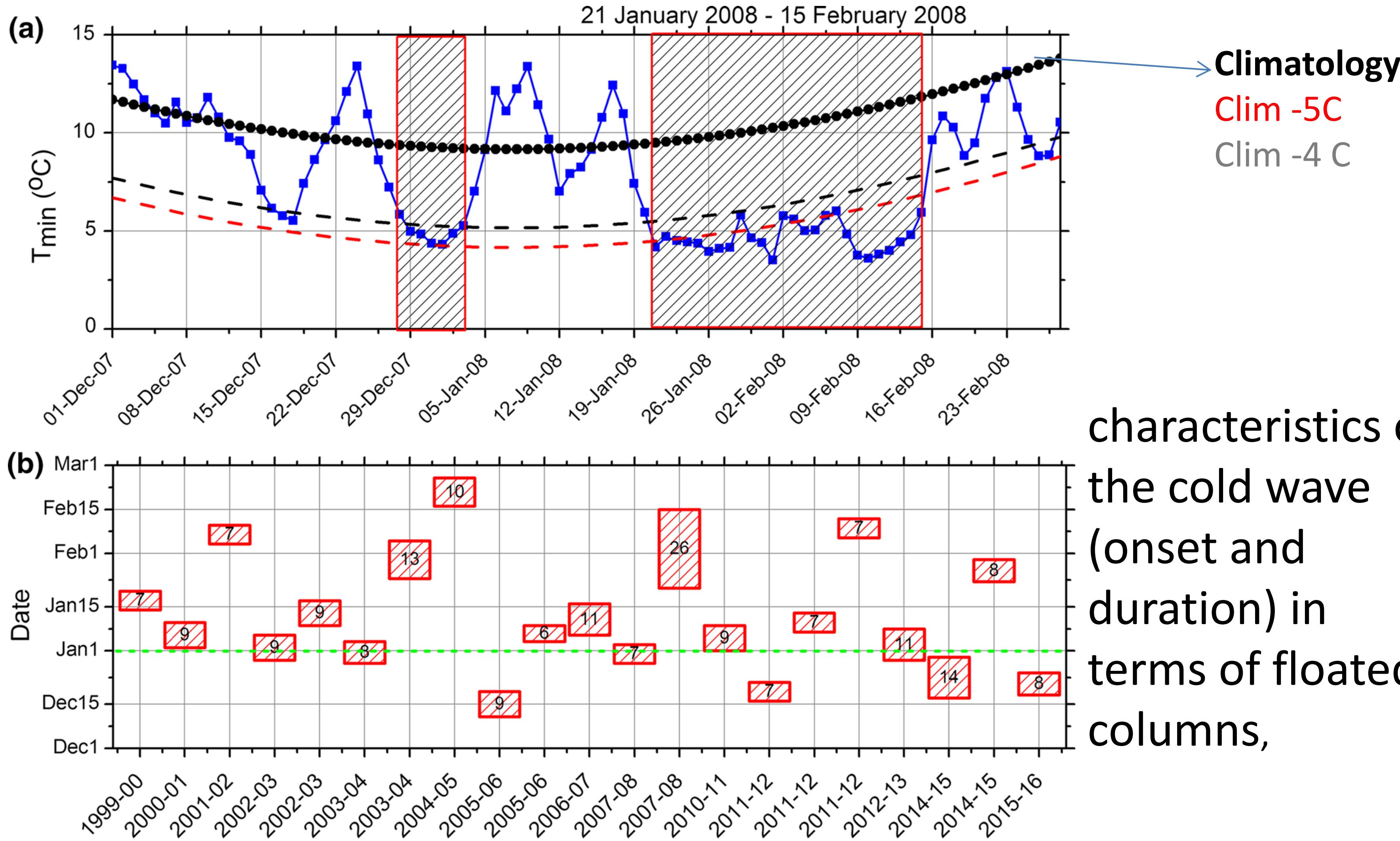
- A total of 10 heat wave episodes were obtained from 2000−2015. Out of these four (six) severe (normal) heat waves are obtained.

- Intensity of heat waves averaged over east coast of India has shown an increase of 0.06 ^oC per heat wave and maximum intensity is seen in the year 2015.

- It exhibits the presence of intra-annual variability over the study region.

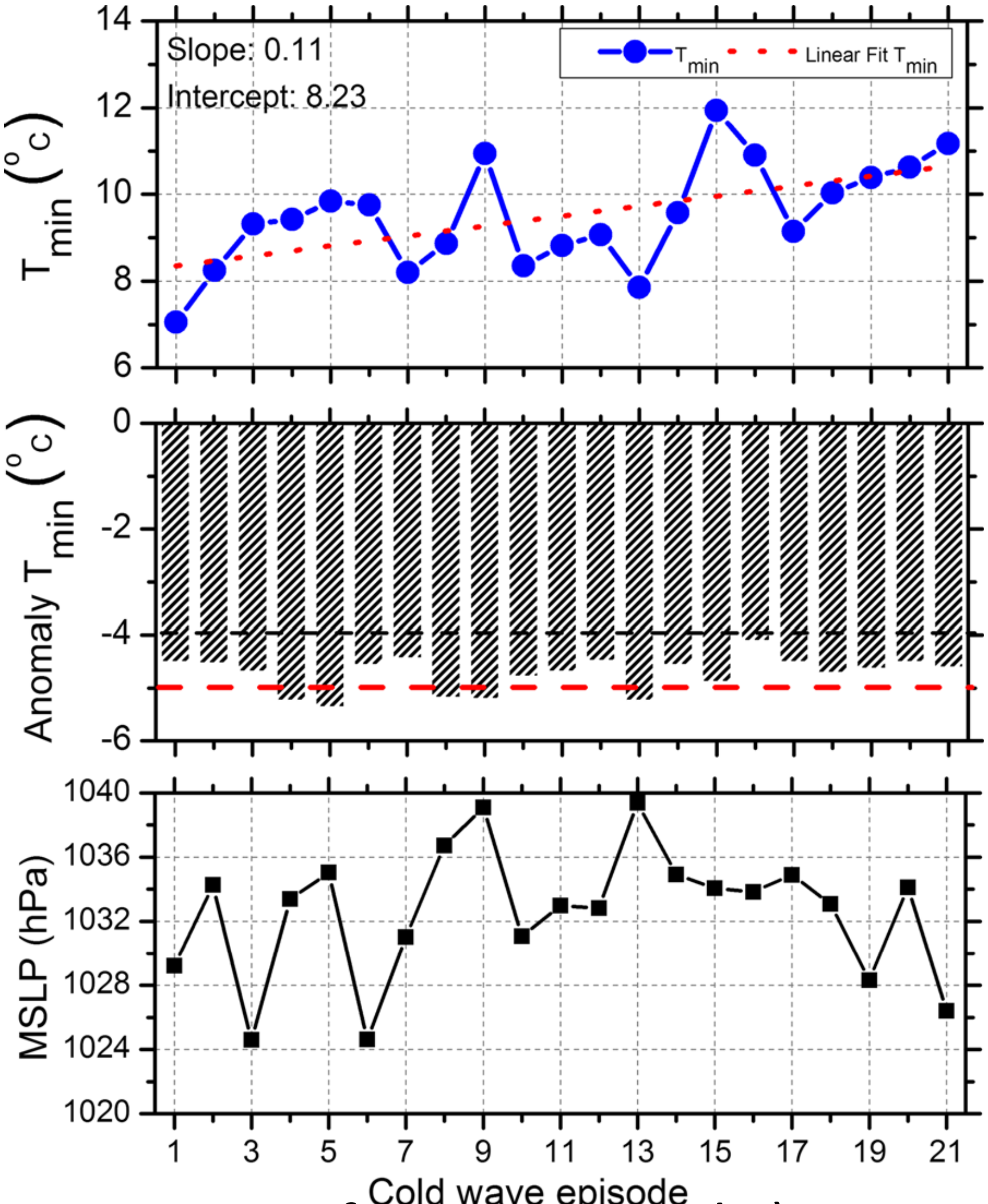


Variability of Cold Wave Episodes Over NW India in NGFS Reanalysis (21–31N, and 71–81E).



characteristics of the cold wave (onset and duration) in terms of floated columns,

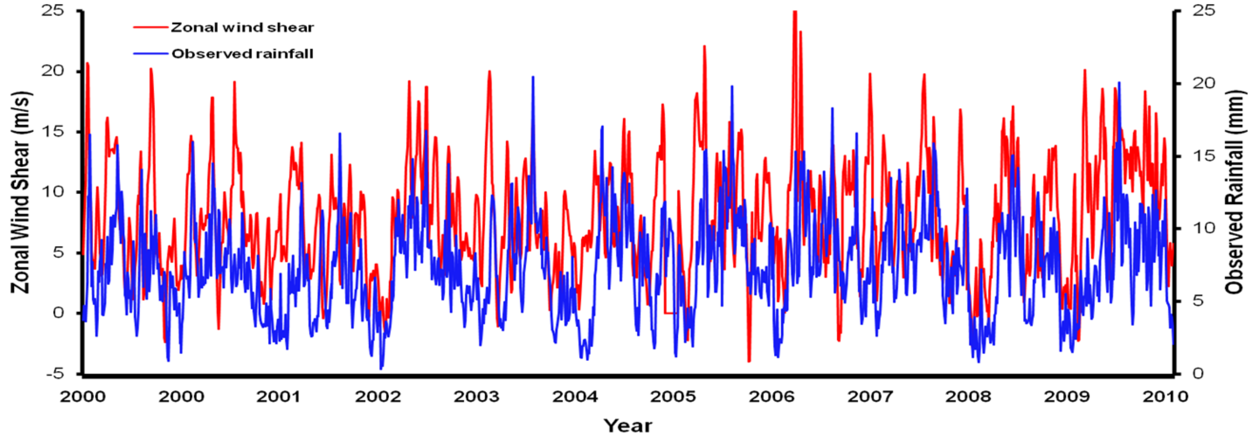
Time series of daily areal (the northwest India) minimum temperature (solid blue squares) for the 2008 cold wave climatalogical temp black solid, ,



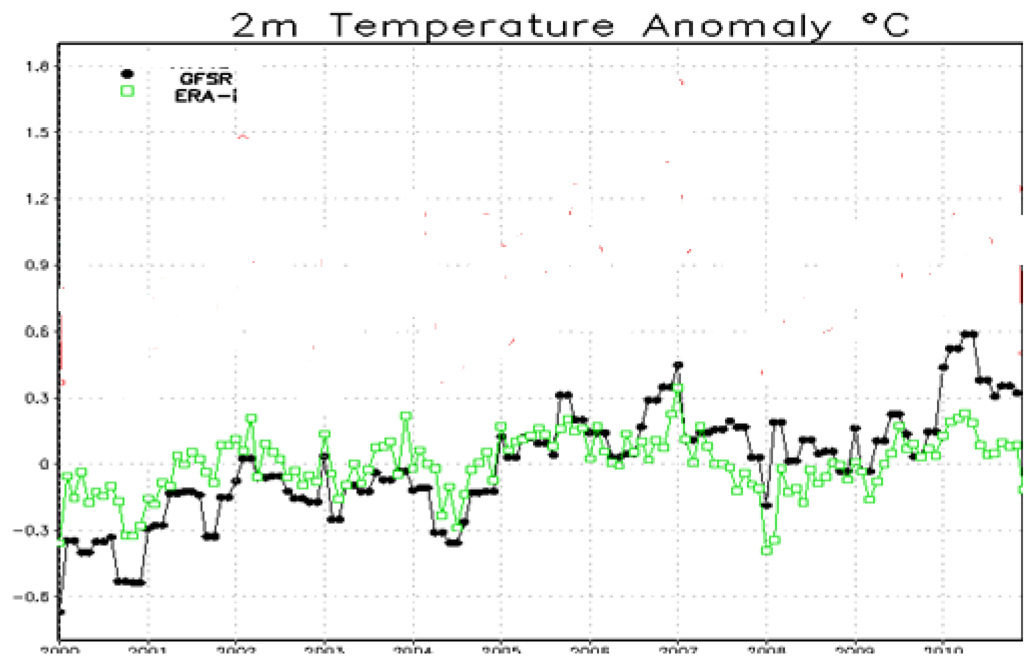
Time series of area-averaged a)Tmin b) Tmin anomaly c) MSLP

A total of 21 cold wave episodes (202 cold nights) were identified, of which 5 severe cold wave episodes (63) were registered. The 10 (6) episodes occurred during La Nina (El Nino).

The cold waves exhibit a significant intra-annual variability over northwest India. Intensity of cold wave has shown an increase of 0.11 C per cold episode.

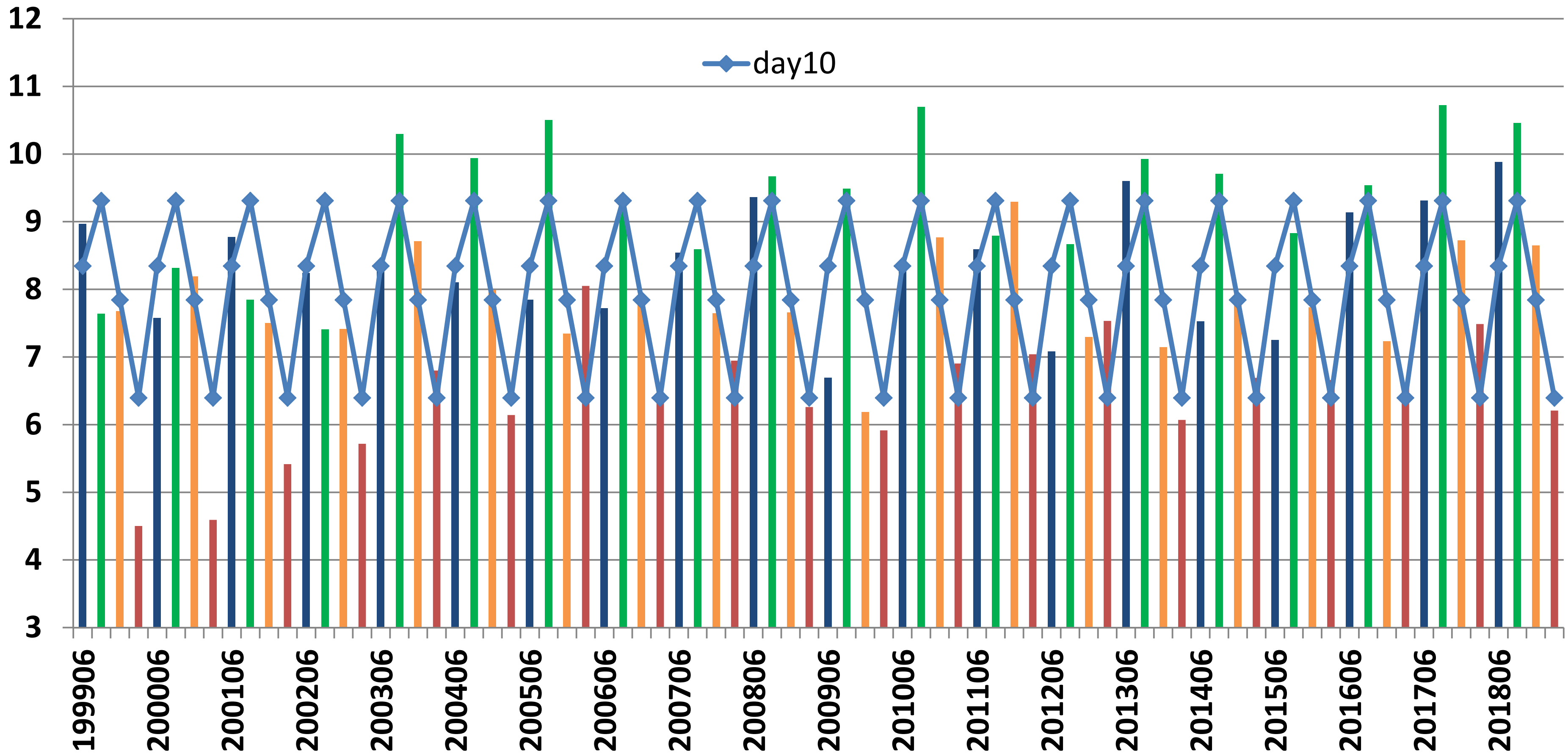


showing trends in analysed daily rainfall over Indian land mass and Wang index for Indian Summer monsoon season computed from re-analysis (2000-2011) data sets.



showing Trend of 2m surface temperature during reanalysis period

GFS Day-10 Re-forecast for JJAS Monthly Mean Rainfall for the 1999-2018 Period
Averaged over (8-38N;68-98E)



Conclusions

- 4D-Ens-Var is operational at NCMRWF from July 2018.
- It is also being used in WRF as 3DVar
- For long term model climatology a twenty year reanalysis and re-forecasting for the period 1999-2018 was carried out.
- Many applications based on these forecasts products are operational in MoES Institutes.