Probabilistic Predictions for Hydrology Applications

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EMMDA

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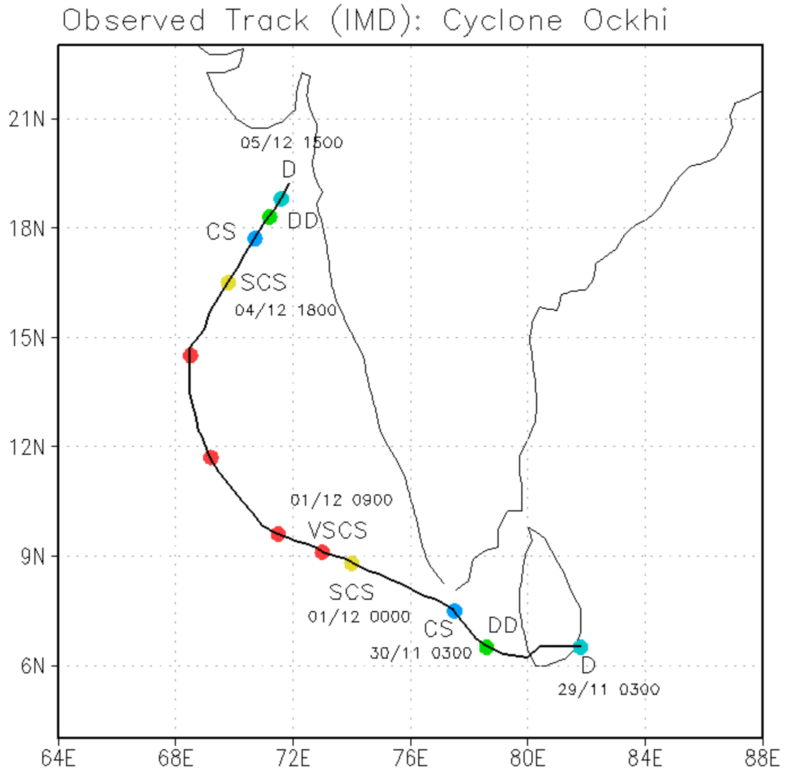
NCMRWF

Motivation



Observed Track (IMD): Cyclone Ockhi
05/12 1500
D
DD
CS
SCS
04/12 1800
01/12 0900
VSCS
SCS
01/12 0000
CS
DD
30/11 0300
D
29/11 0300
21N
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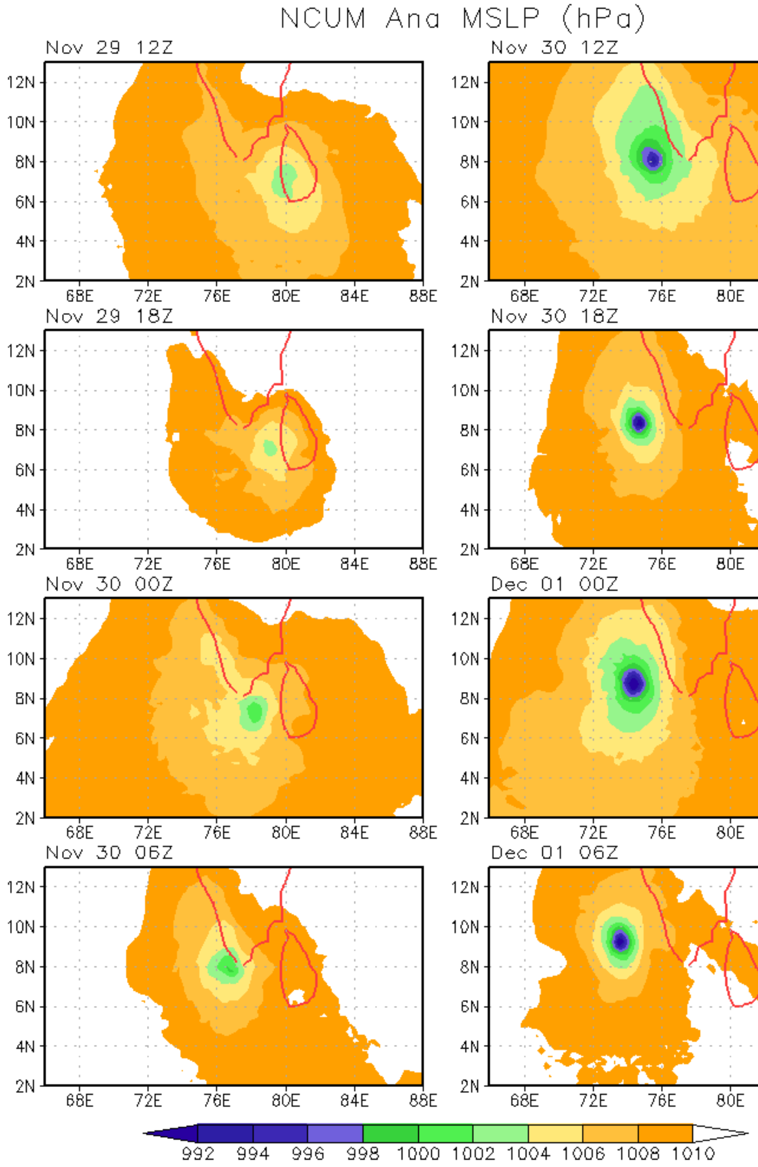
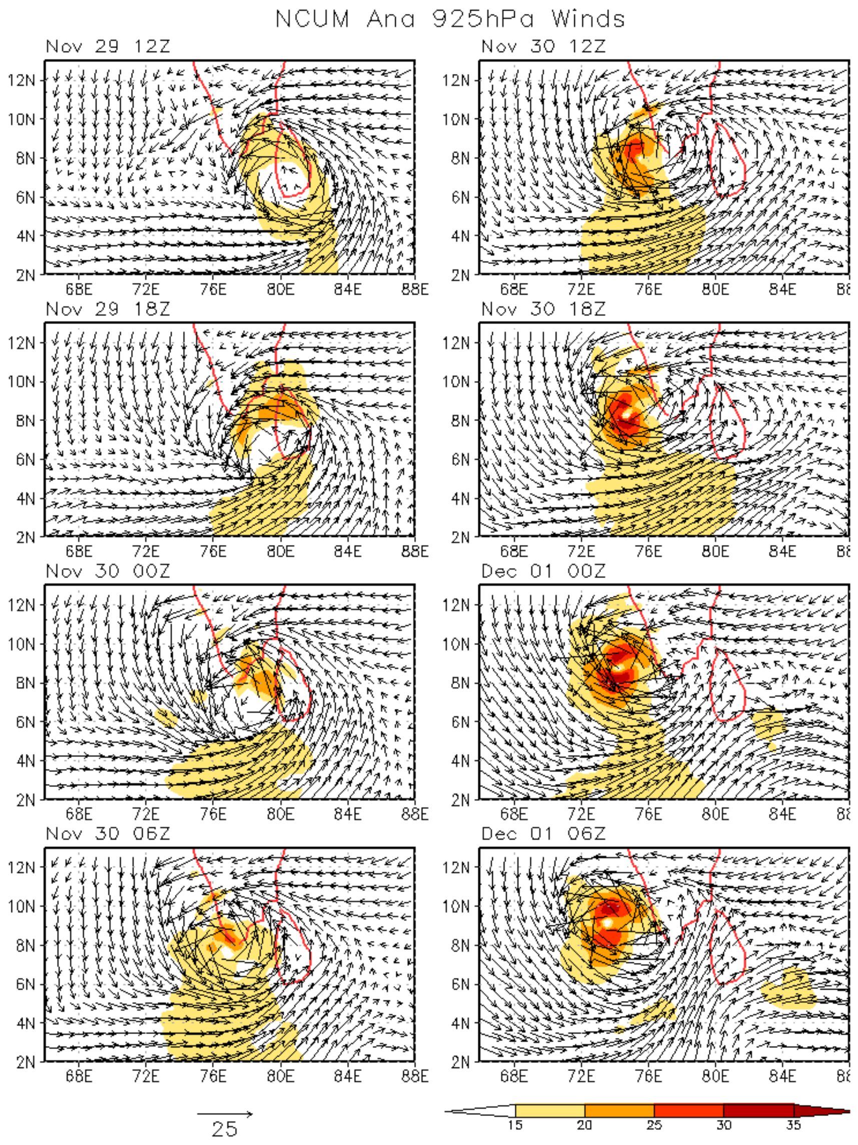
12N
9N
6N
64E
68E
72E
76E
80E
84E
88E

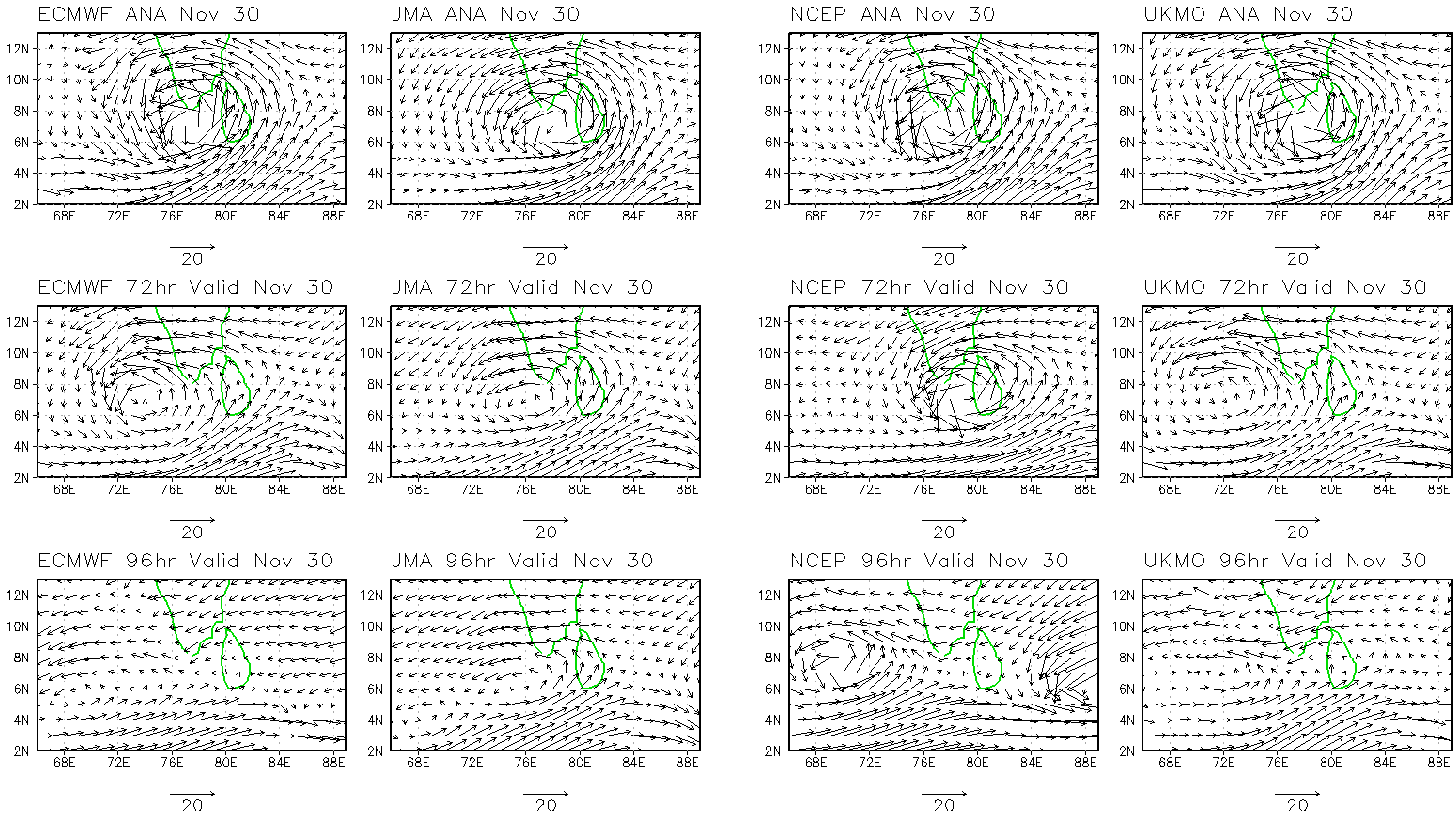


NCUM Ana MSLP (hPa)
Nov 29 12Z
Nov 30 12Z
Nov 29 18Z
Nov 30 18Z
Nov 30 00Z
Dec 01 00Z
Nov 30 06Z
Dec 01 06Z
992 994 996 998 1000 1002 1004 1006 1008 1010

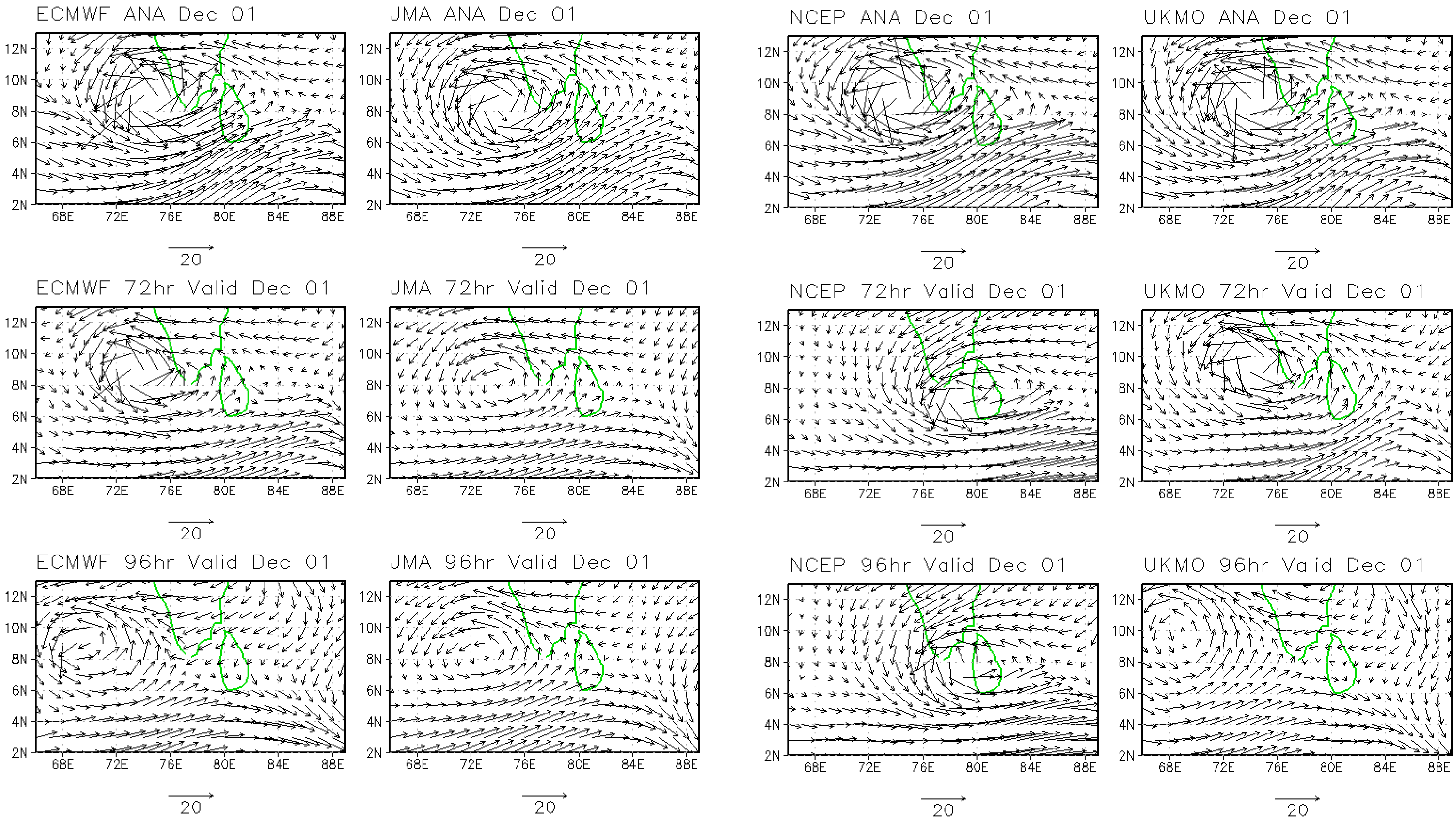


NCUM Ana 925hPa Winds
Nov 29 12Z
Nov 30 12Z
Nov 29 18Z
Nov 30 18Z
Nov 30 00Z
Dec 01 00Z
Nov 30 06Z
Dec 01 06Z
25
15 20 25 30 35

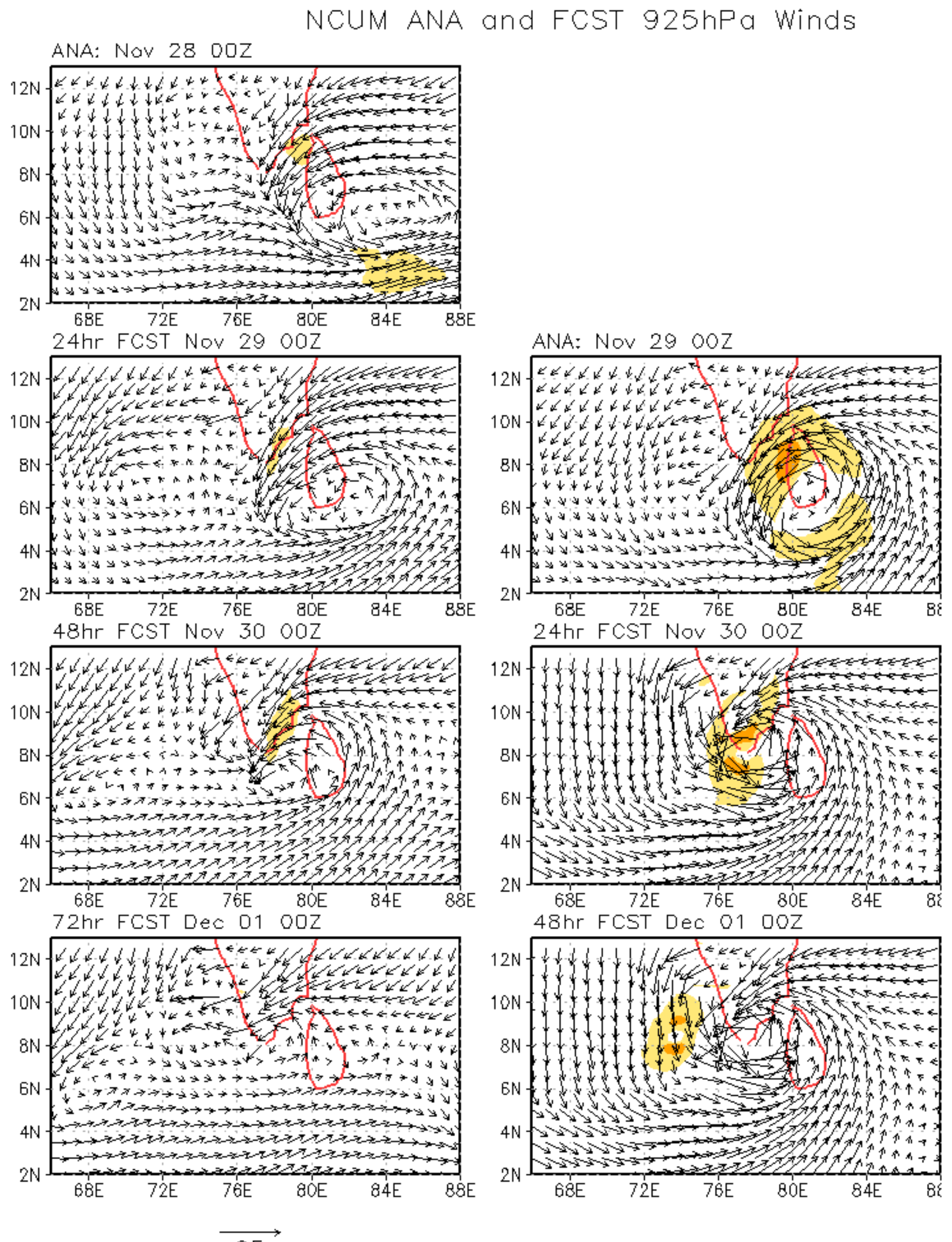
TIGGE Datasets ANA and FCST for Nov 30 2017

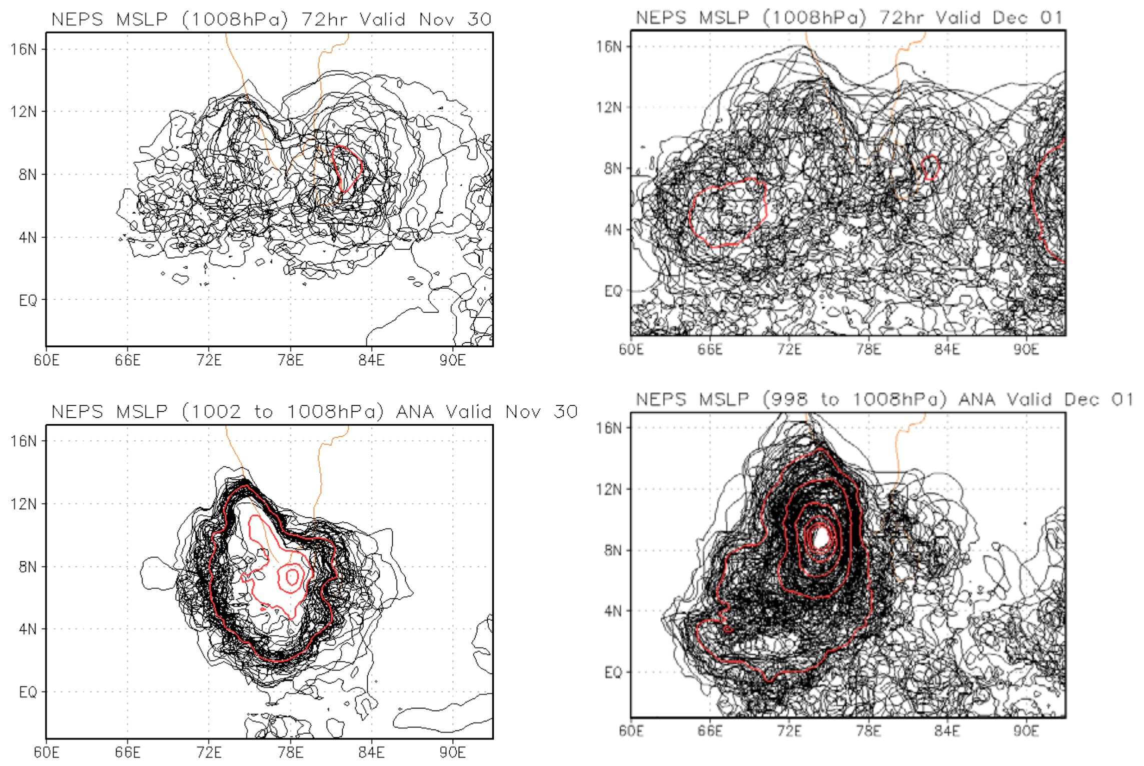


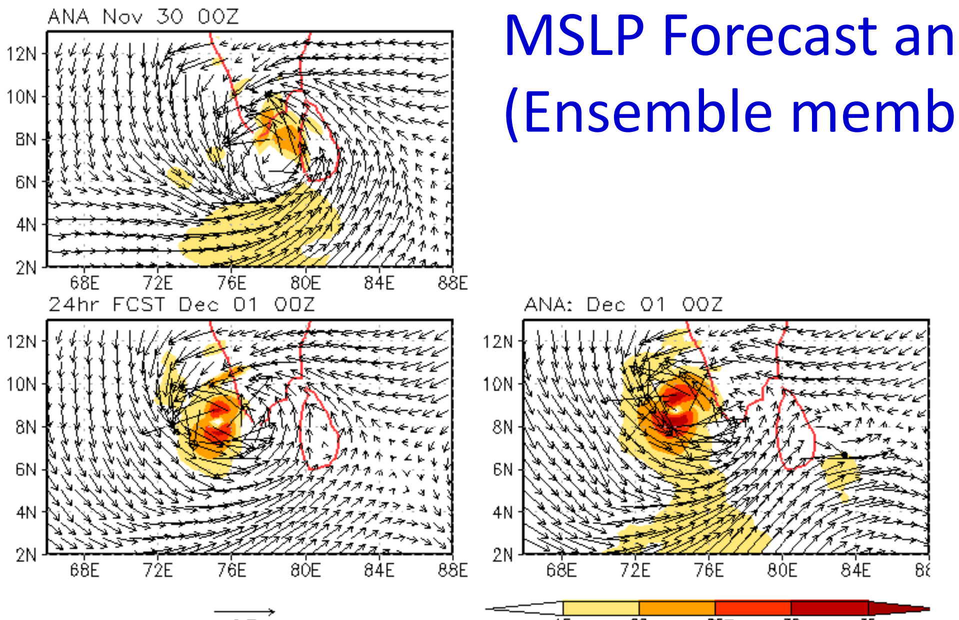
TIGGE Datasets ANA and FCST for Dec 01 2017



Analysis and Forecasts of Winds at 925hPa

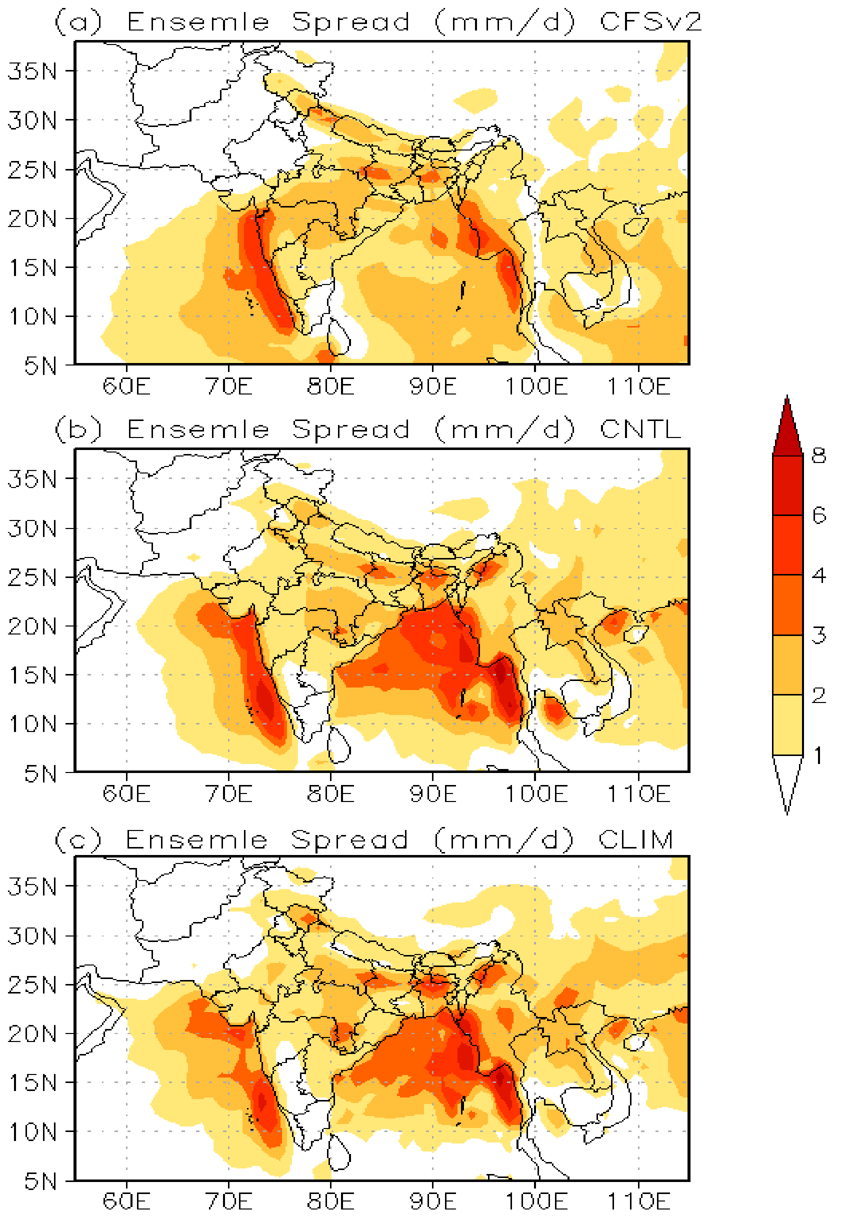


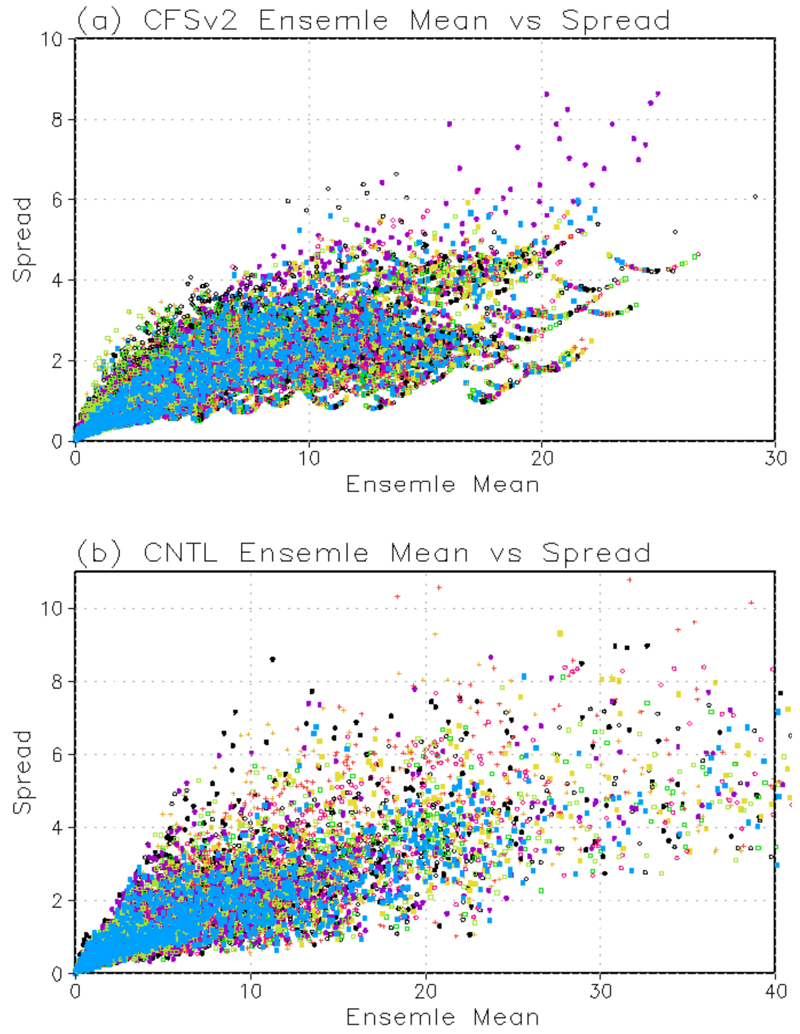


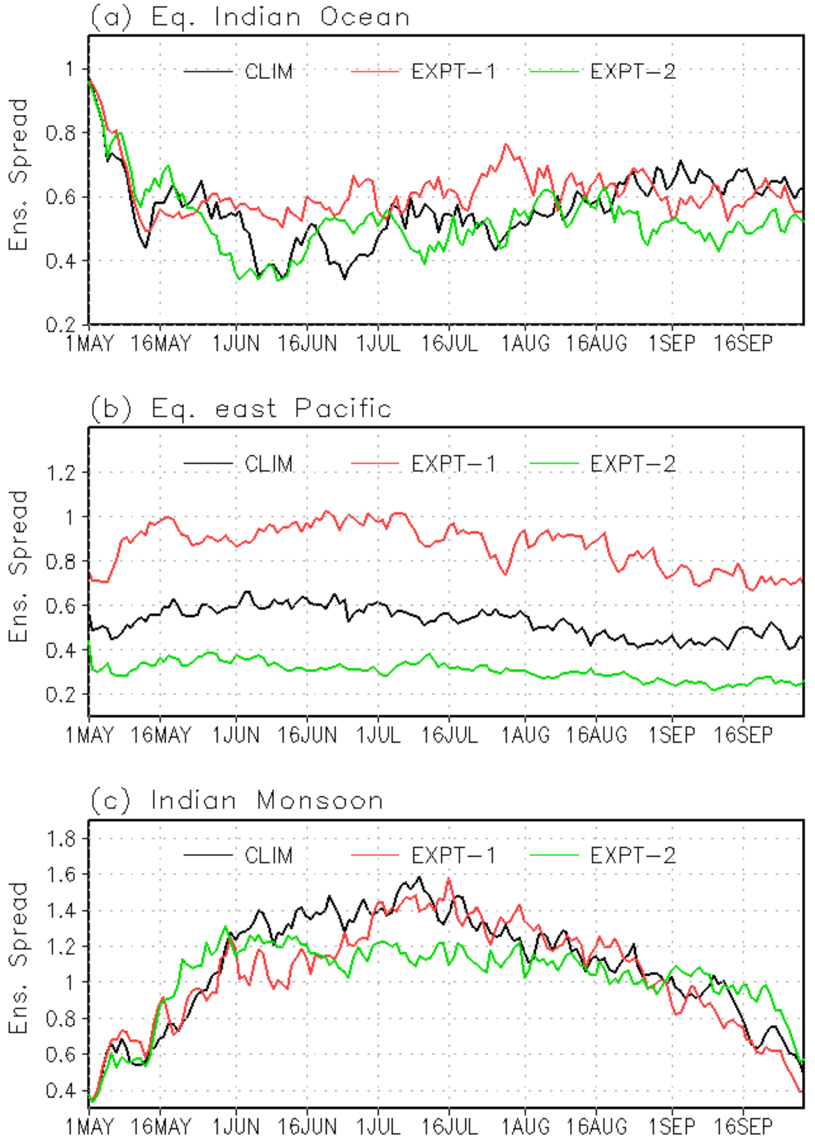


MSLP Forecast and Analysis (Ensemble members)

Uncertainties in Seasonal Simulations (CFS and GFS)

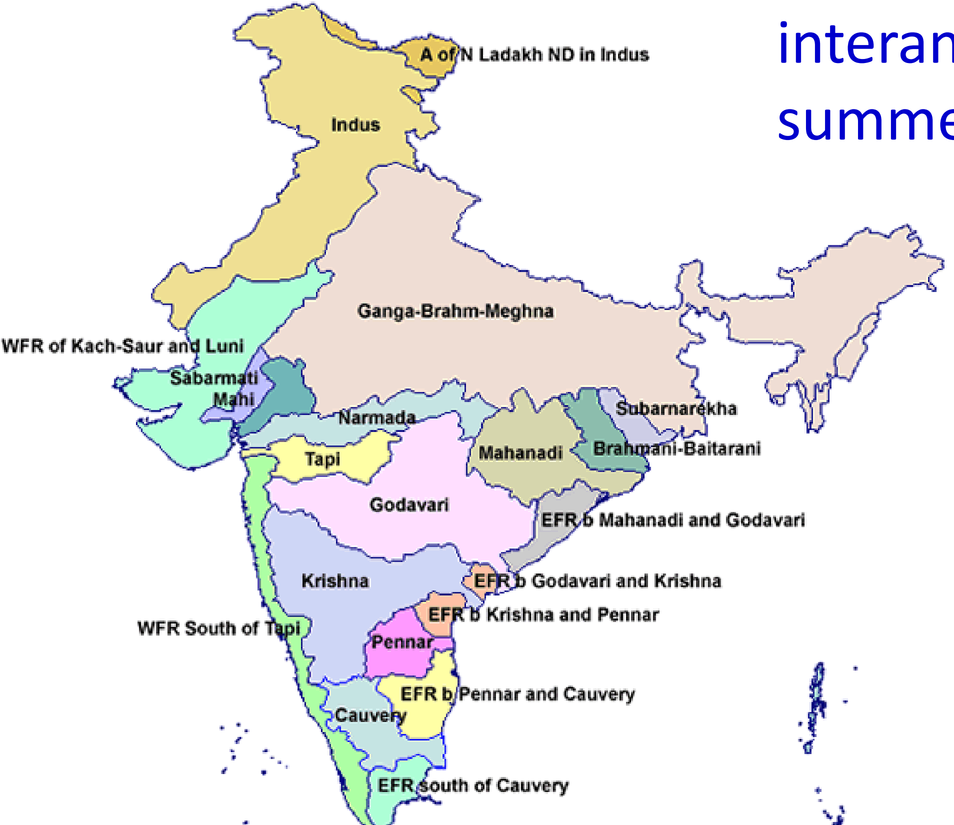




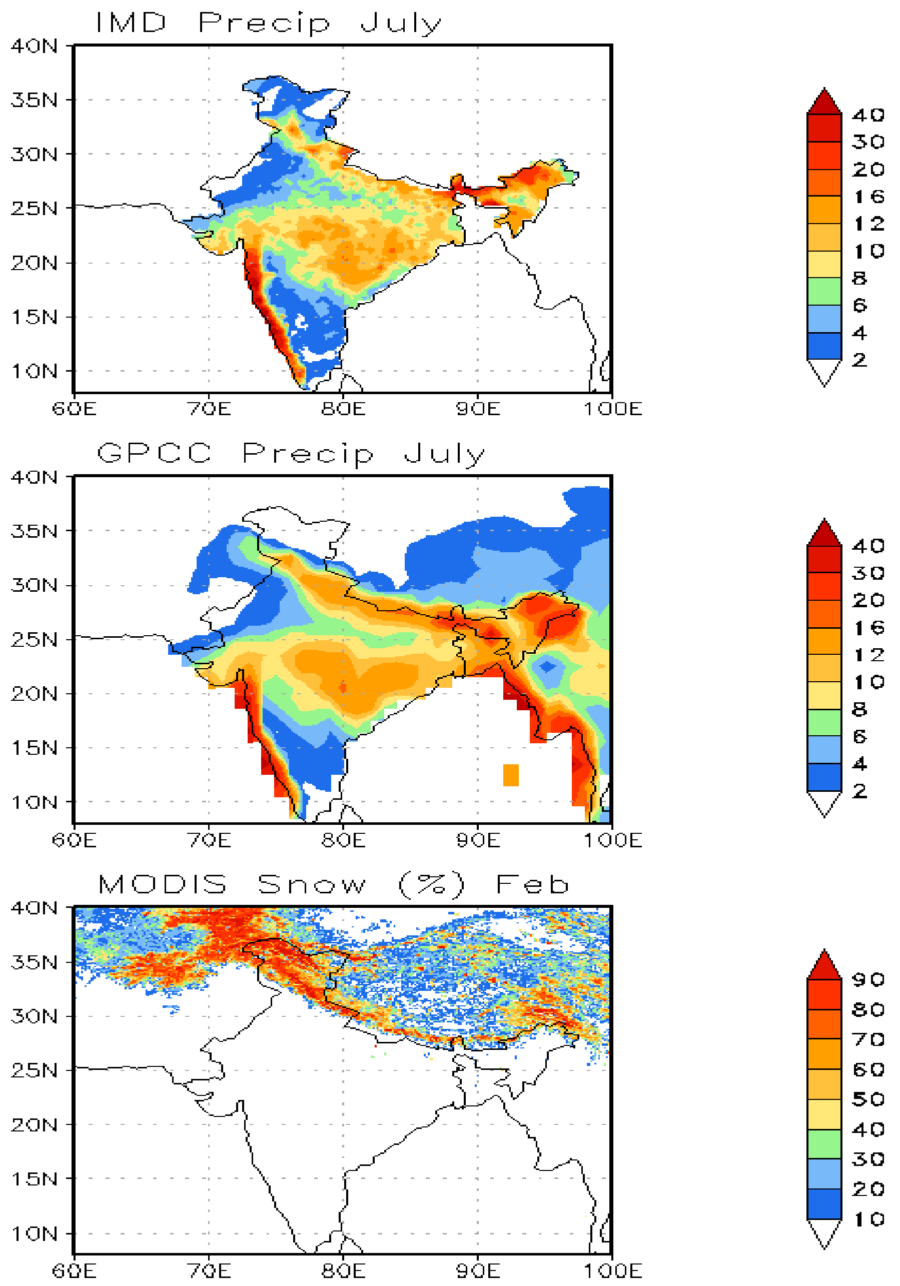


Daily Variation of Ensemble Spread

River Basins in India

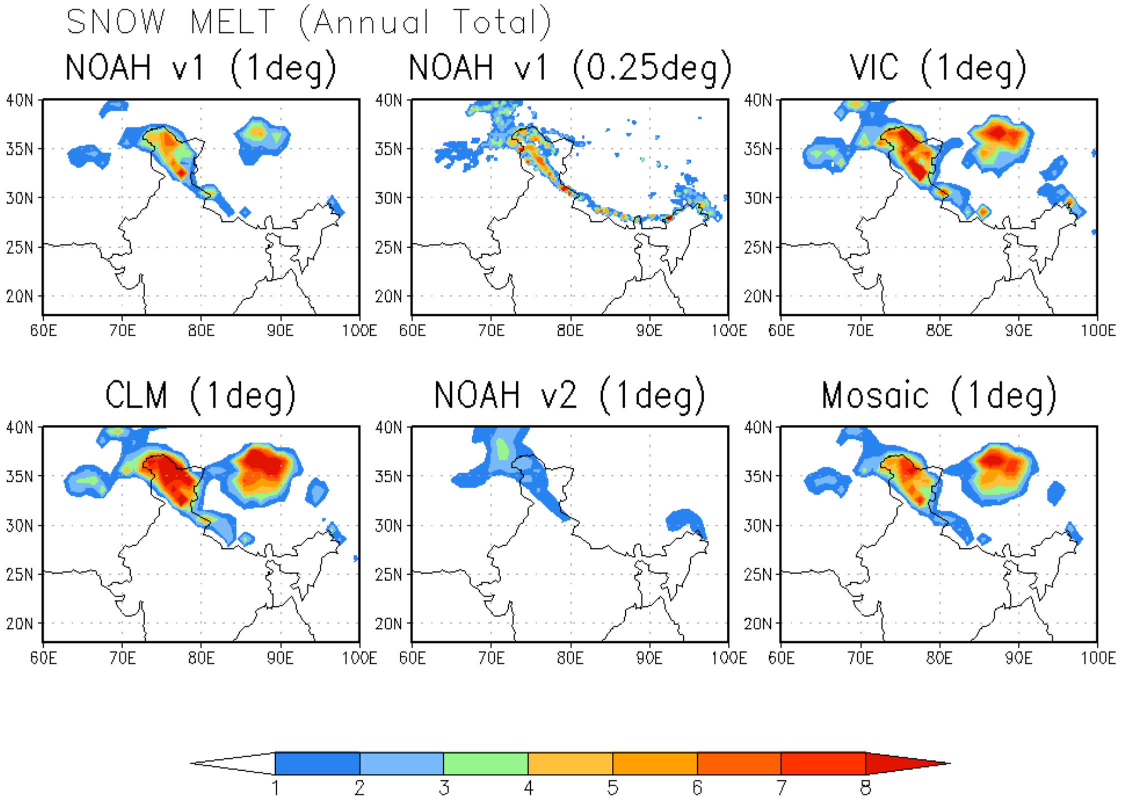


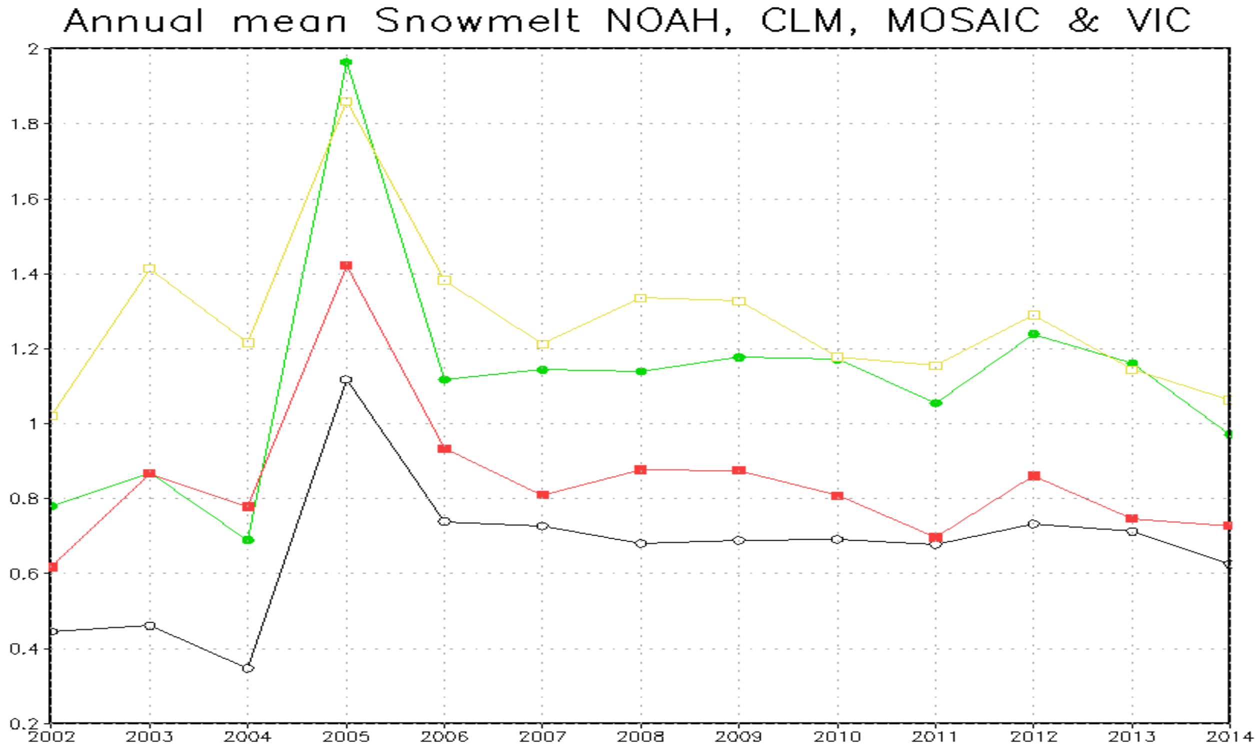
Surface hydrology exhibit significant interannual variability over this region due to interannual variations in the summer monsoon precipitation.



The western and central Himalayas including the Hindukush mountain region receive large amount of snow during winter seasons during the passage of western disturbances.

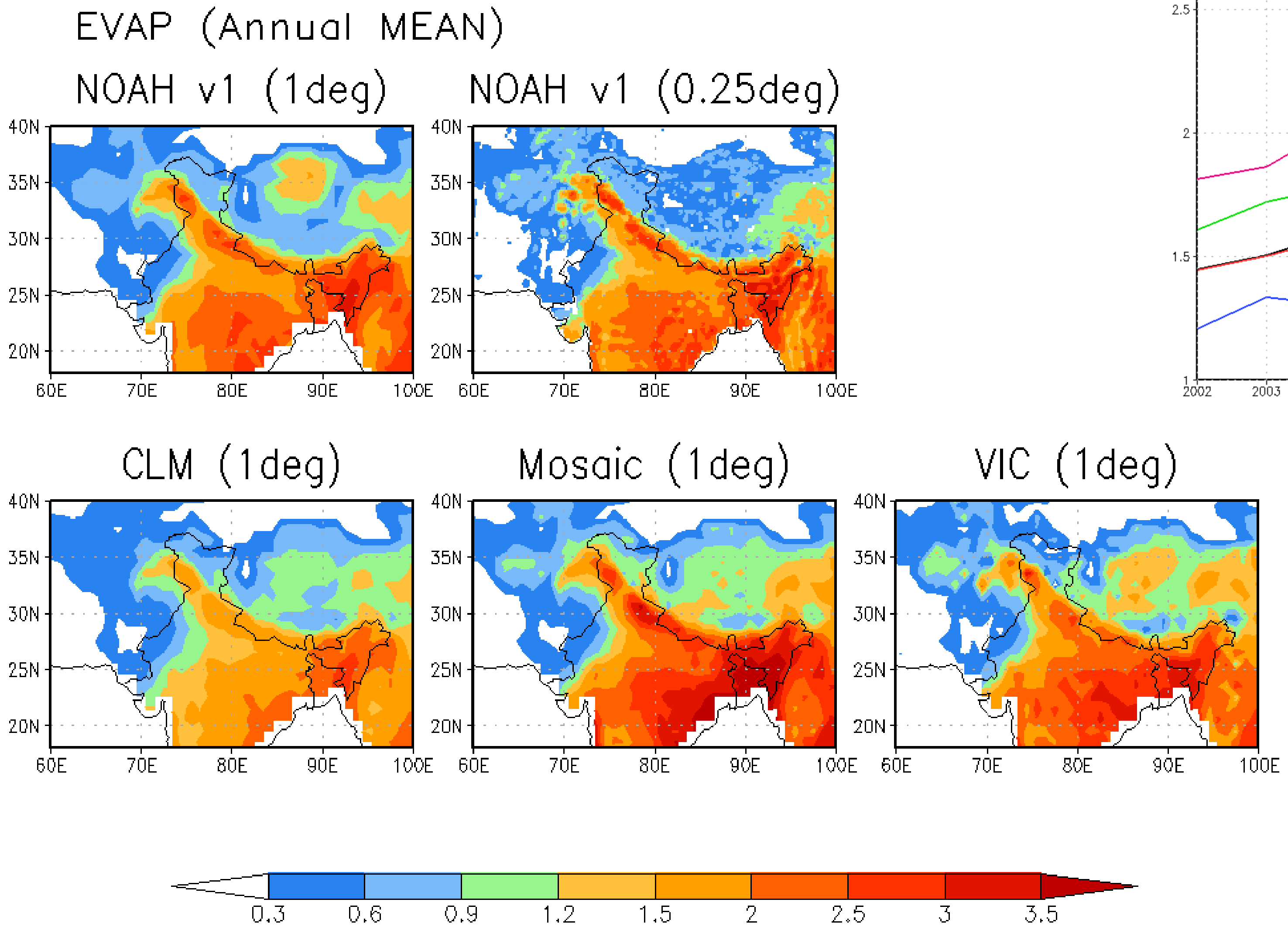
Snowmelt Modeling: GLDAS models

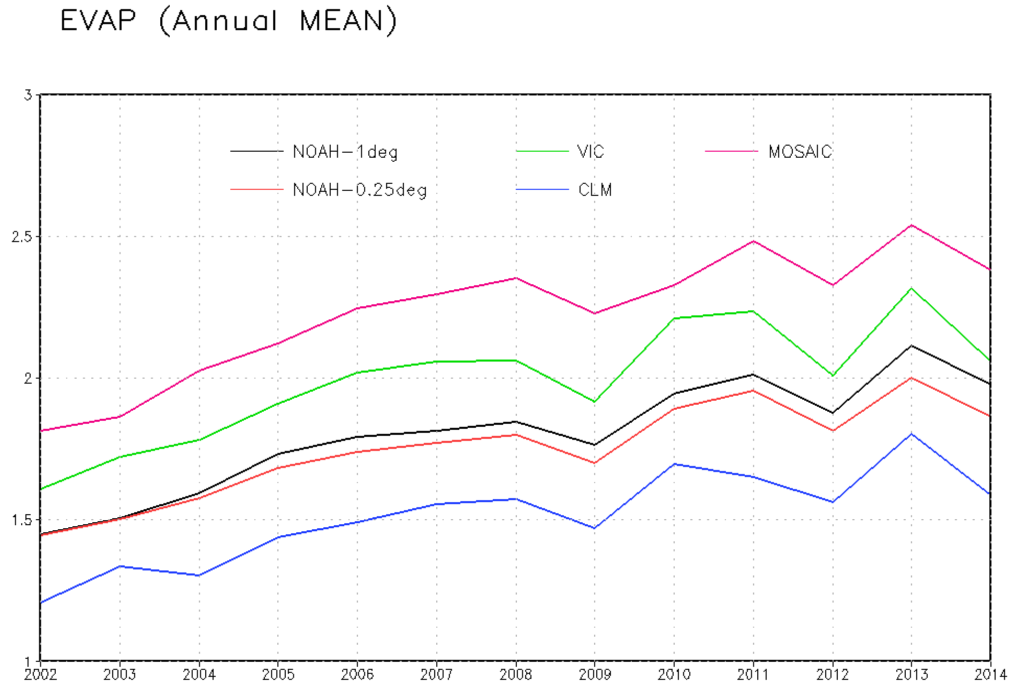




Variation in Snowmelt among Hydrology Models is quite large

Evaporation from GLDAS Models





For proper estimation Evaporation, consistent forcing to hydrology model (especially precipitation, Soil moisture etc) and proper modeling approach is required.

Extended-Range Probabilistic Predictions of Drought Occurrence

5-day accumulated rainfall forecasts (up to 20 days) have been considered.

Ensemble spread (uncertainties in forecast) examined for each model

IITM ERPS at 1degree
11 members T382GFS
11 members T382 CFS
11 members T126 GFS
11 members T126 CFS

Probabilistic extended range forecasts were prepared considering all 44 members

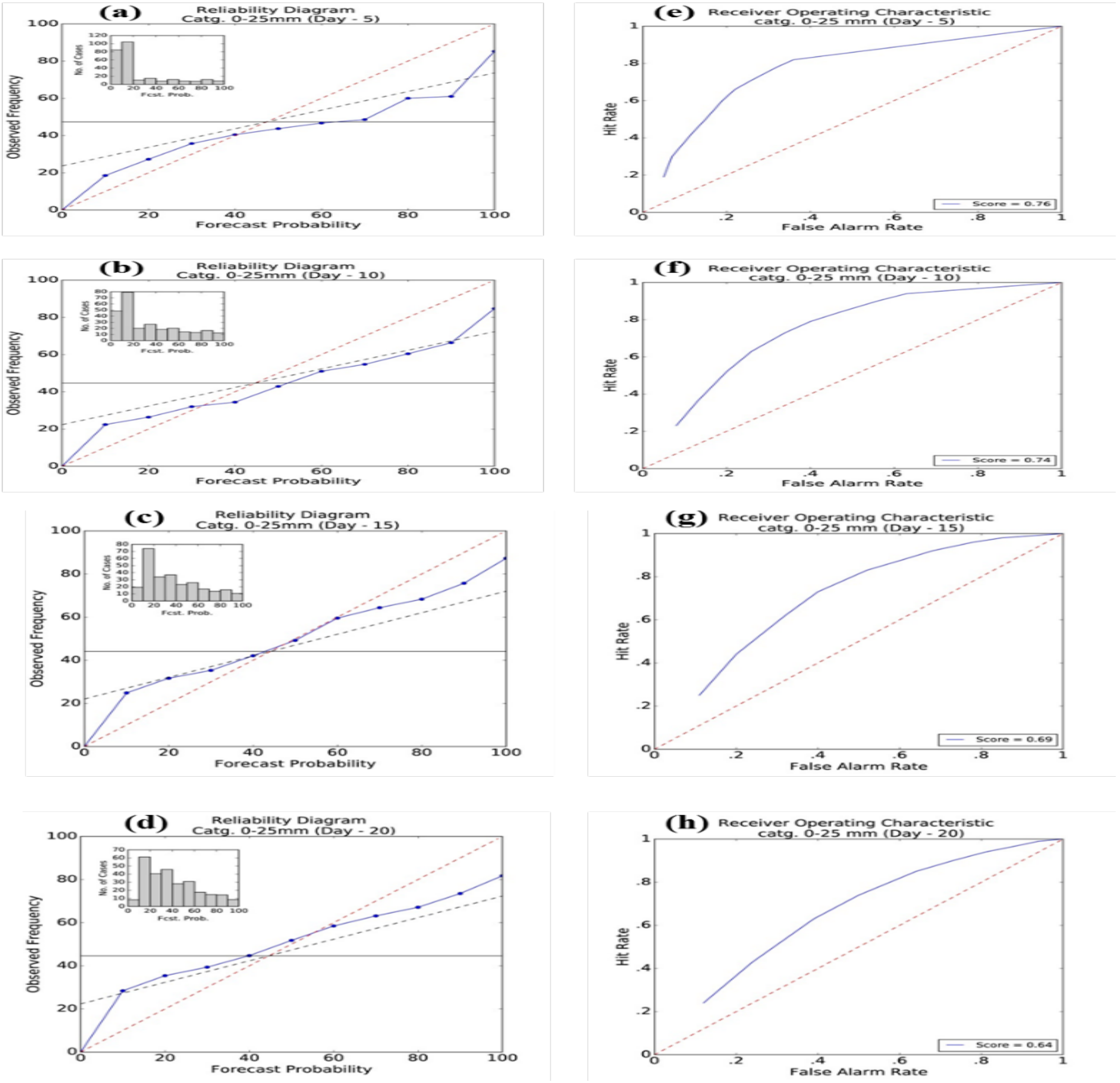
Probability that rainfall amount in next 5-days will be within 0-25mm (or probability that rainfall amount will not exceed 25mm in 5days in 5-day interval) was considered.

The model has reasonable Brier Score, RPS score, Reliability and ROC score

Extended-Range Prediction of Drought Occurrence

Probability that rainfall will not exceed 25mm in 5 days

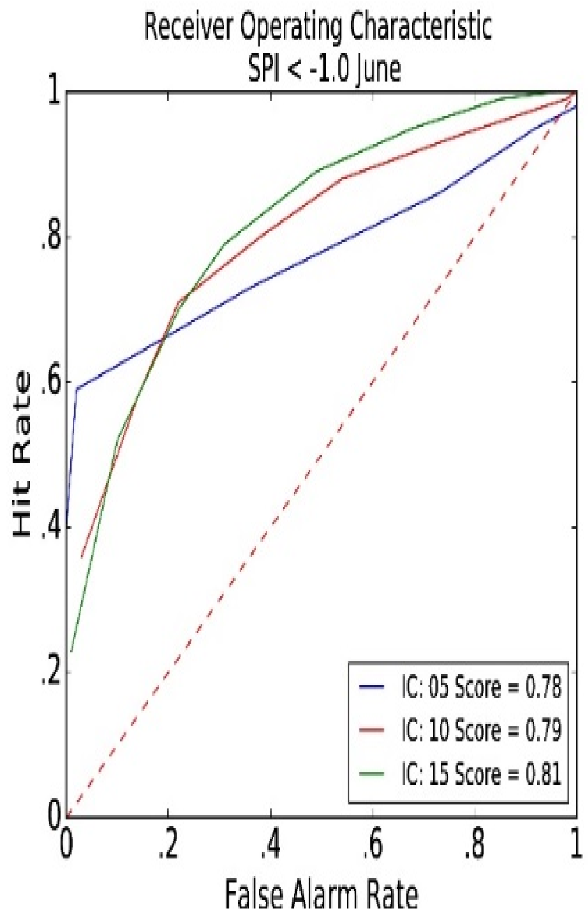
Reliability Diagram



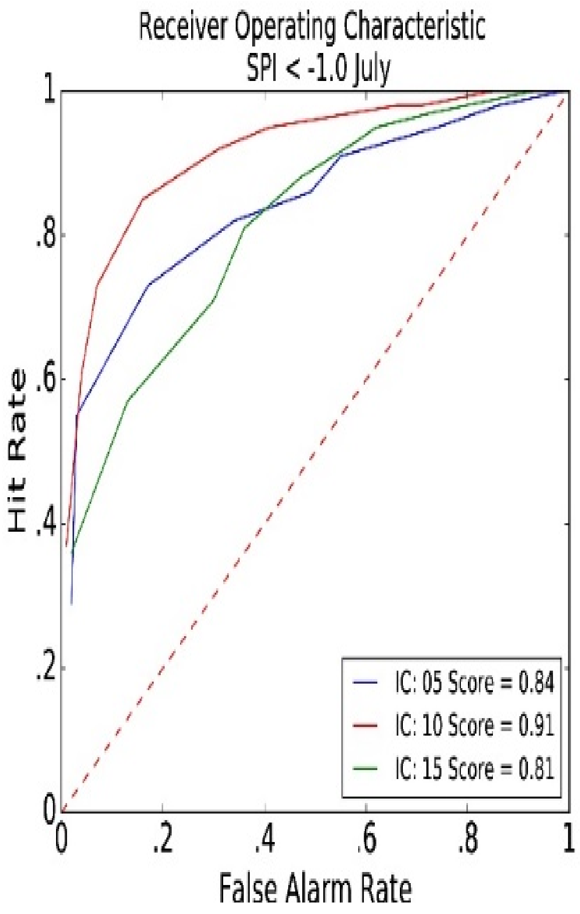
ROC Curves

Probabilistic Prediction of Drought Index (SPI) over Central India (monthly scale)

(d)



(e)



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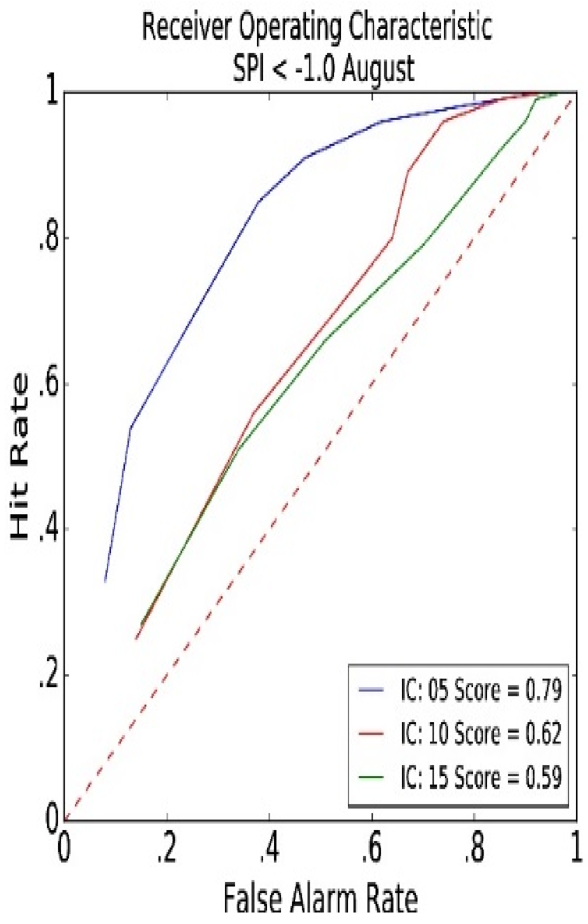
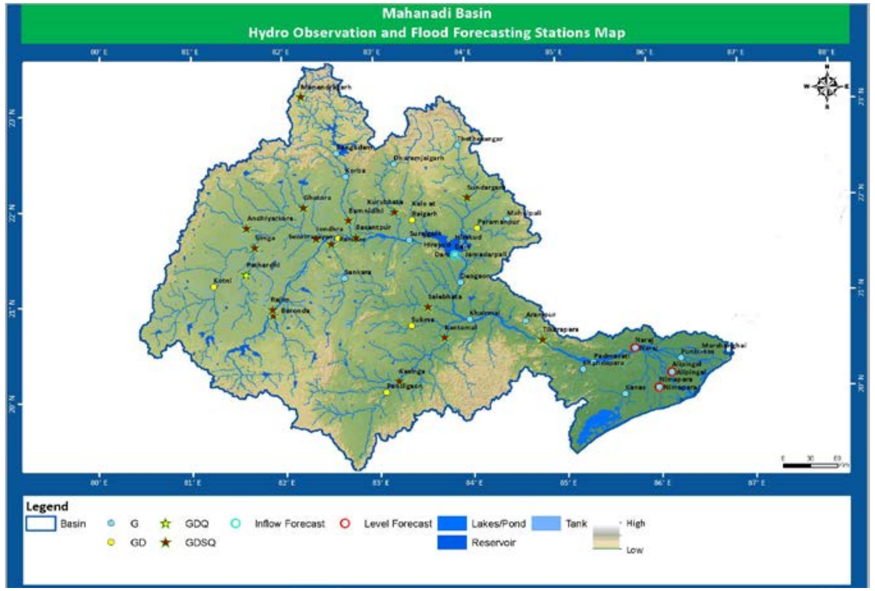
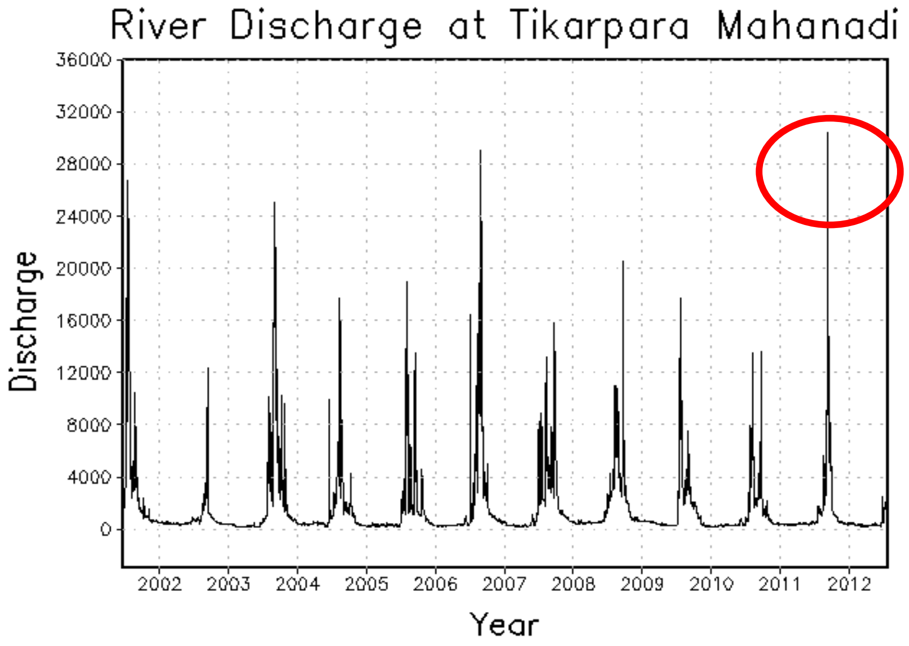
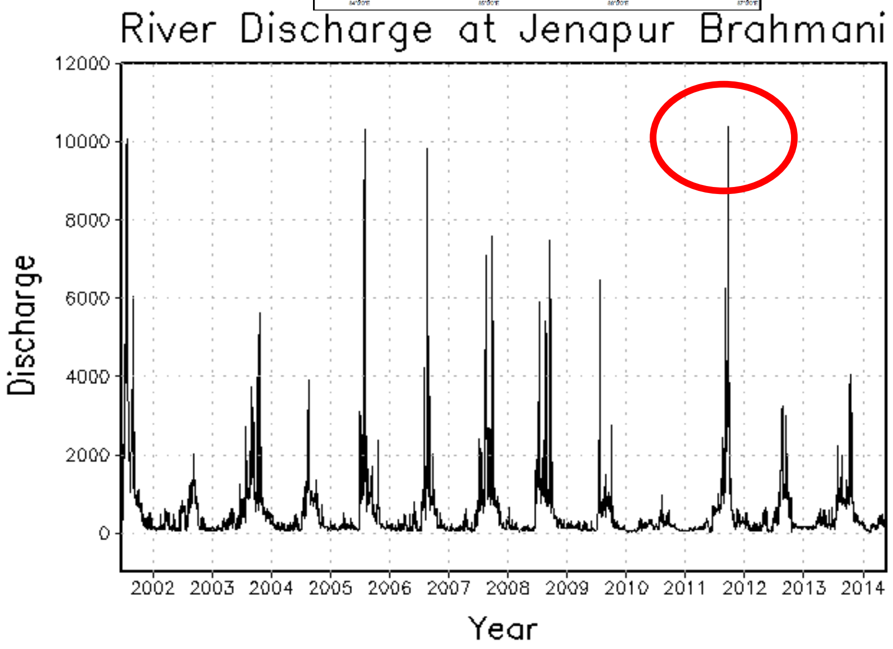


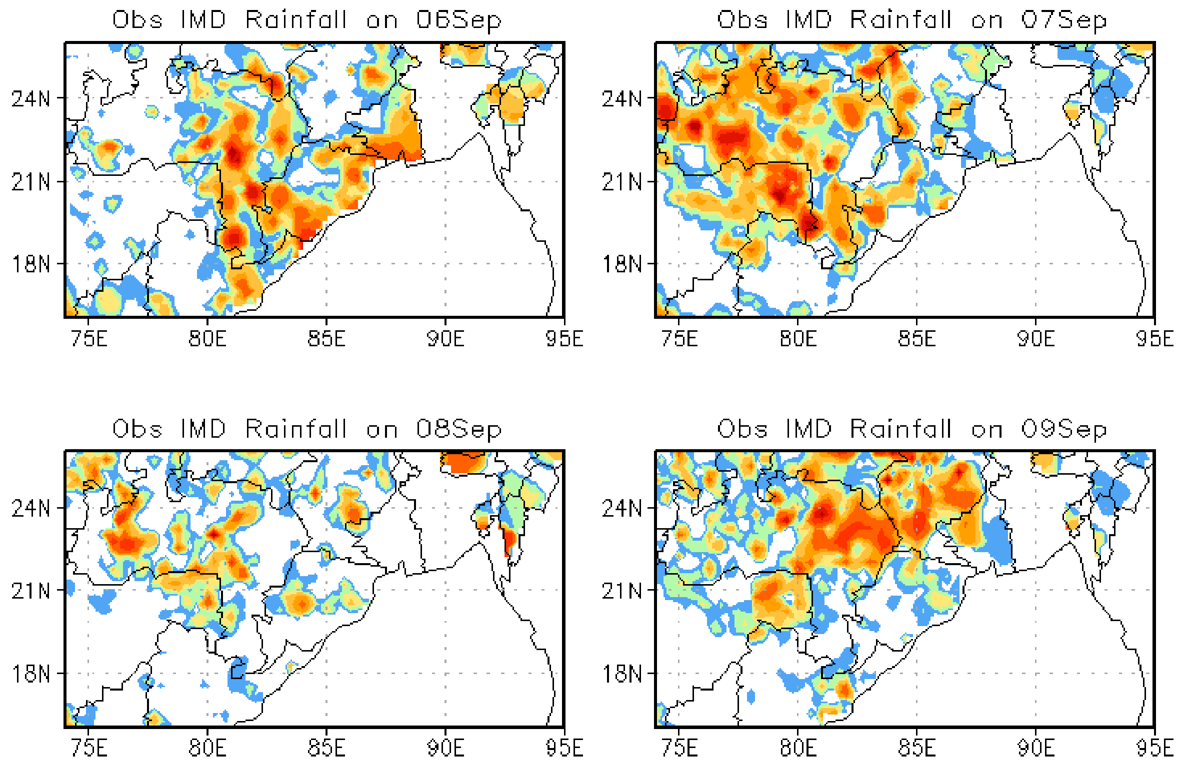
River Discharge in Mahanadi and Brahmani Rivers from 2001

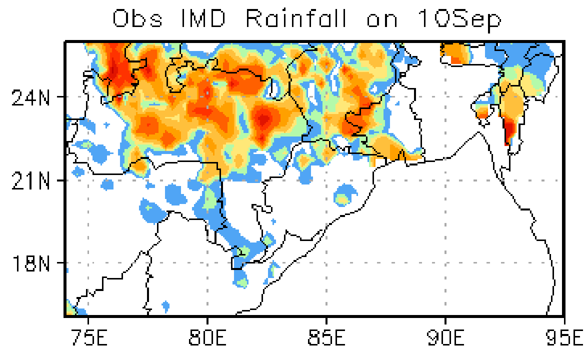




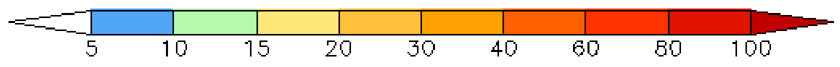


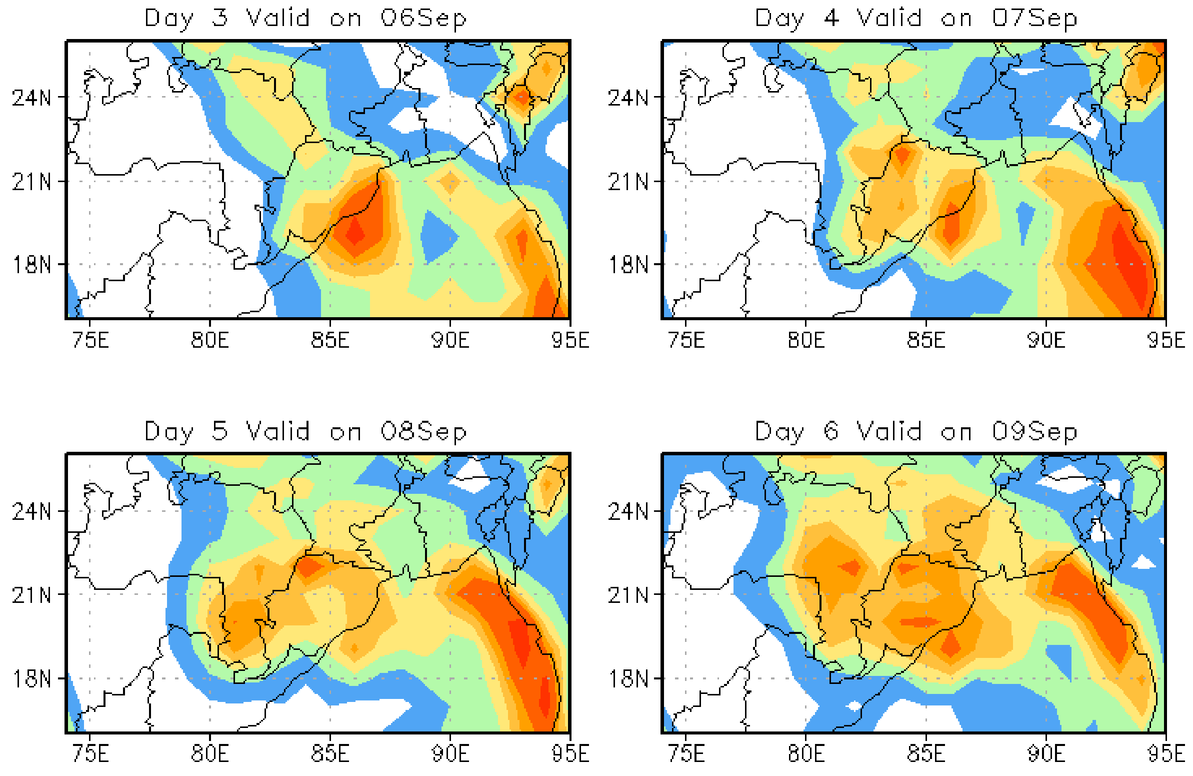
ENS MEAN Rainfall FCST based on IC 03 SEPT 2011

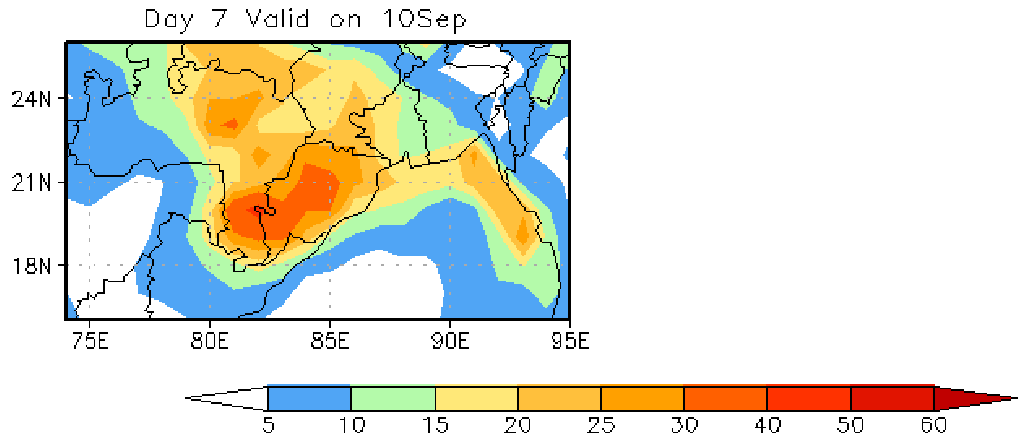


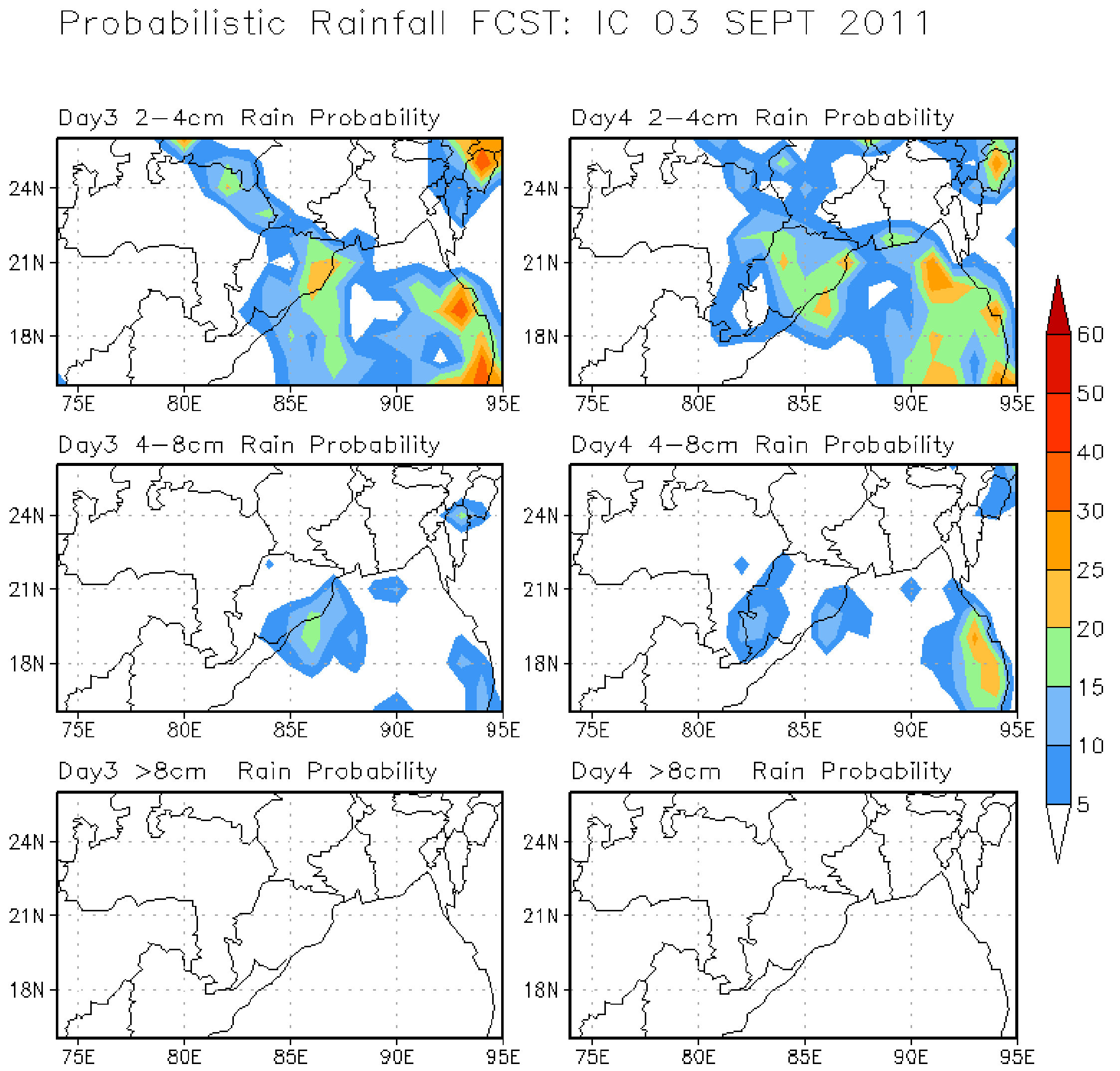


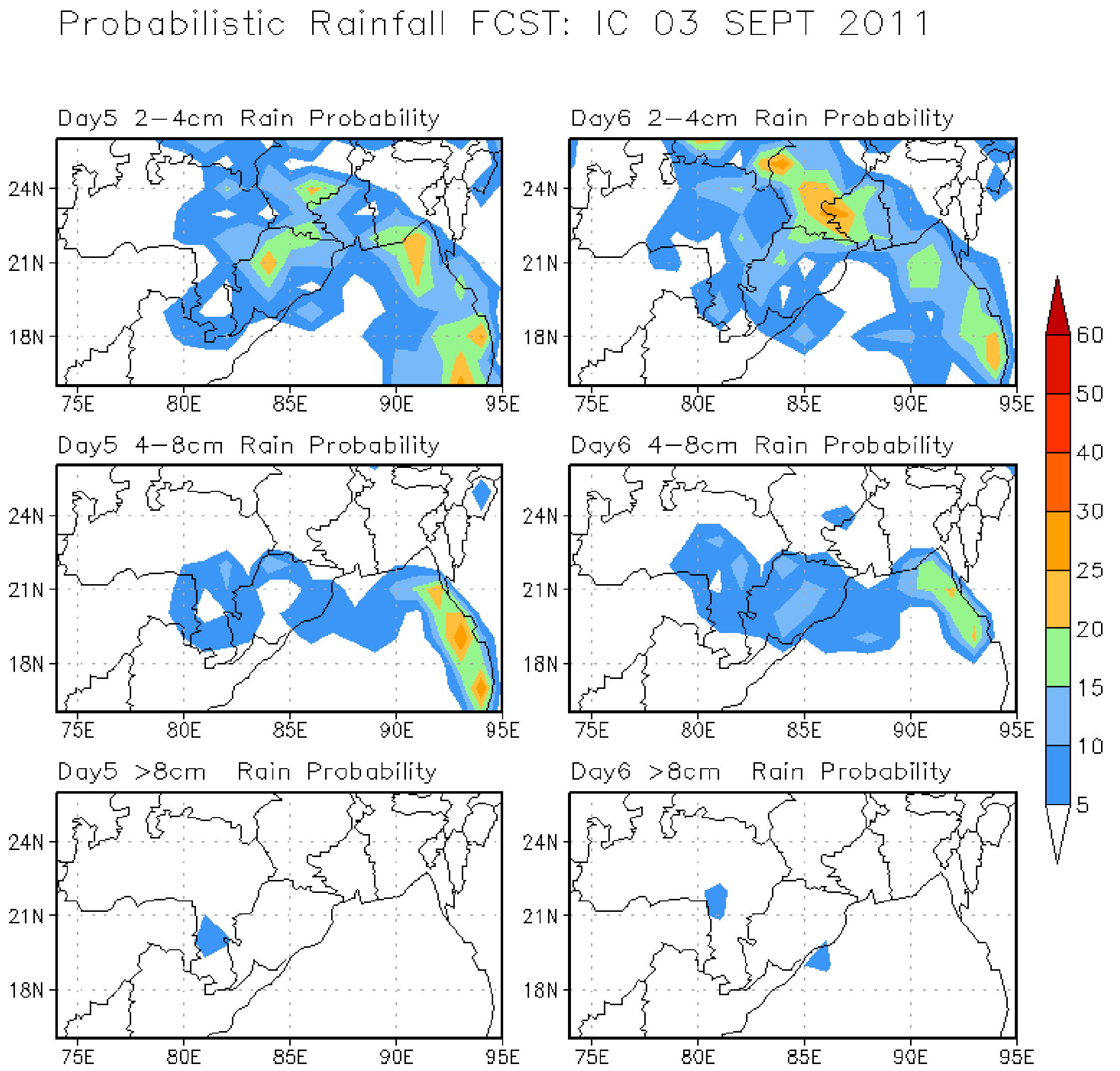
IMD 0.25degree Obs Rain From 06Sep to 10Sep 2011







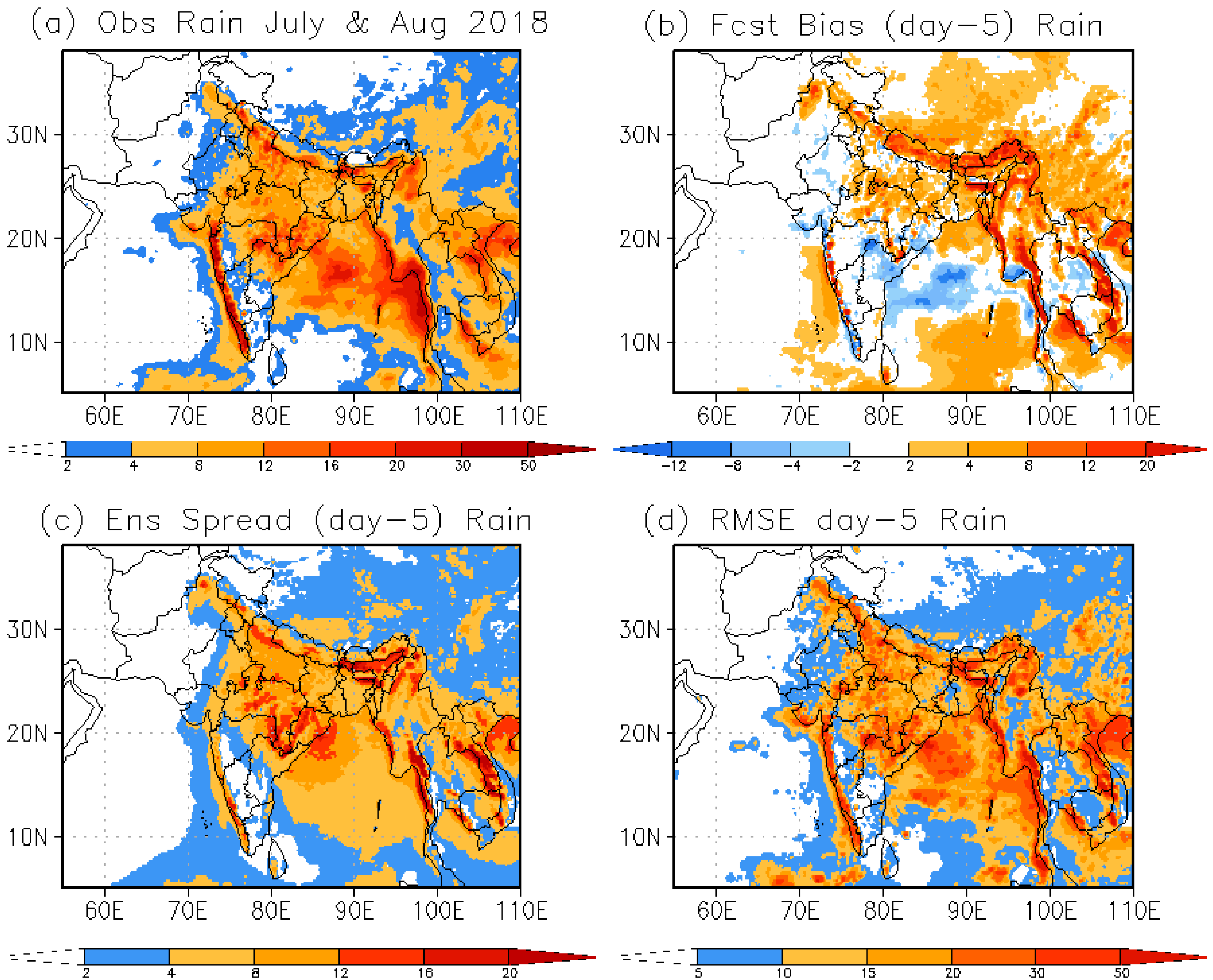




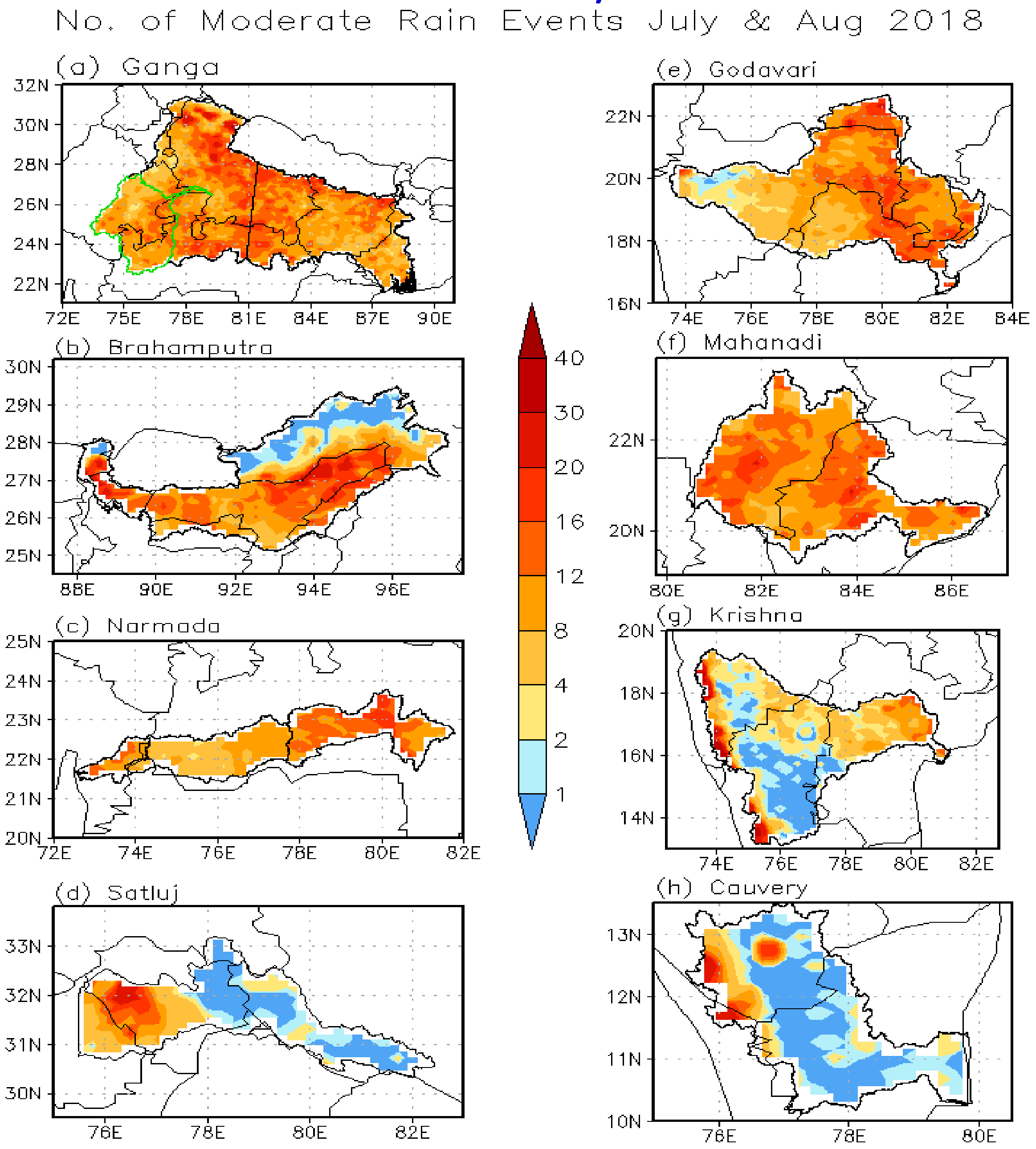
Mainly due to model limitation of capturing actual magnitude, spatial and temporal distribution of rainfall As different scales are involved, does a rainfall forecast at a model grid point tell if it has potential to cause flood?

The NCMRWF Ensemble prediction System based on UM

NEPS 23 members 2018



15.6-64.4 mm/d



Ganga

Brahmaputra

Narmada

Satluj

Godavari

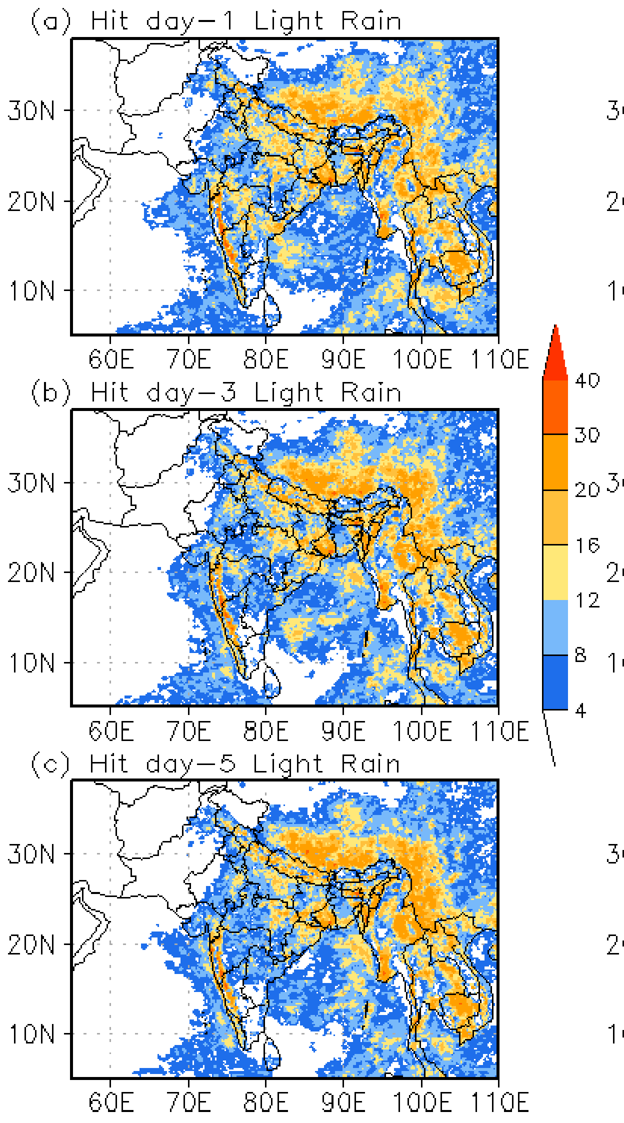
Mahanadi

Krishna

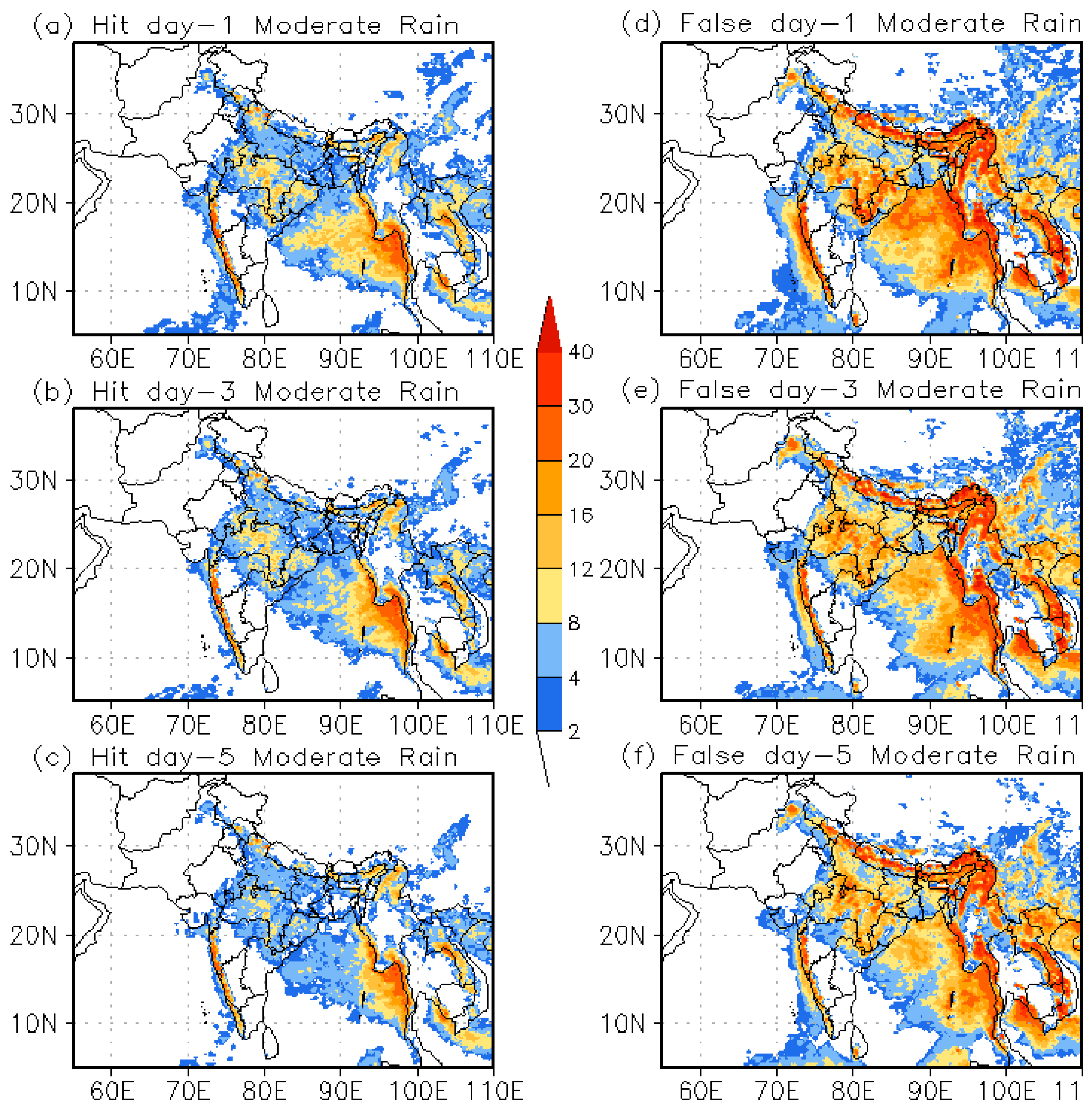
Cauvery

Hit and False Alarm Rates

2.5-15.5mm/d



15.6-64.5mm/d



The forecasts of water level of reservoirs help the user agencies to decide mitigating measures such as shifting people and property to safer locations.

The dam authorities use the inflow forecasting for optimum operation of reservoirs for safe passage of flood downstream.

This also helps them to ensure adequate storage in the reservoirs for meeting demand during non-monsoon period.

Reservoir level and storage from the first week of May to end of September 2018 have been considered.

As actual height and storage capacities of these reservoirs are different, these data have been scaled so that the water level andn storage amount are zero on May 1st 2018.

The Tehri Dam on the Bhagirathi River in Uttarakhand

Ramganga dam on the Ramganga River in Uttarakhand

Rihand dam on the Rihand River

Bansagar dam is on Sone River in Madhya Pradesh

Gandhi Sagar dam on Chambal River

Bhakra dam on the Sutlej River forms the Gobind Sagar reservoir

The Pong dam is on the Beas River in Himachal Pradesh.

Ranjit Sagar dam (Thein Dam) on the Ravi River

Indira Sagar dam on the Narmada River

Nagarjuna Sagar dam on Krishna River

Tungabhadra dam is in Karnataka on the Tungabhadra River

Krishna Raja Sagara in Karnataka is in Cauvery basin

Hirakud dam on the Mahanadi River in Odisha

Jayakwadi: is located on Godavari River in Maharashtra.
Sriramsagar across Godavari River in Telangana

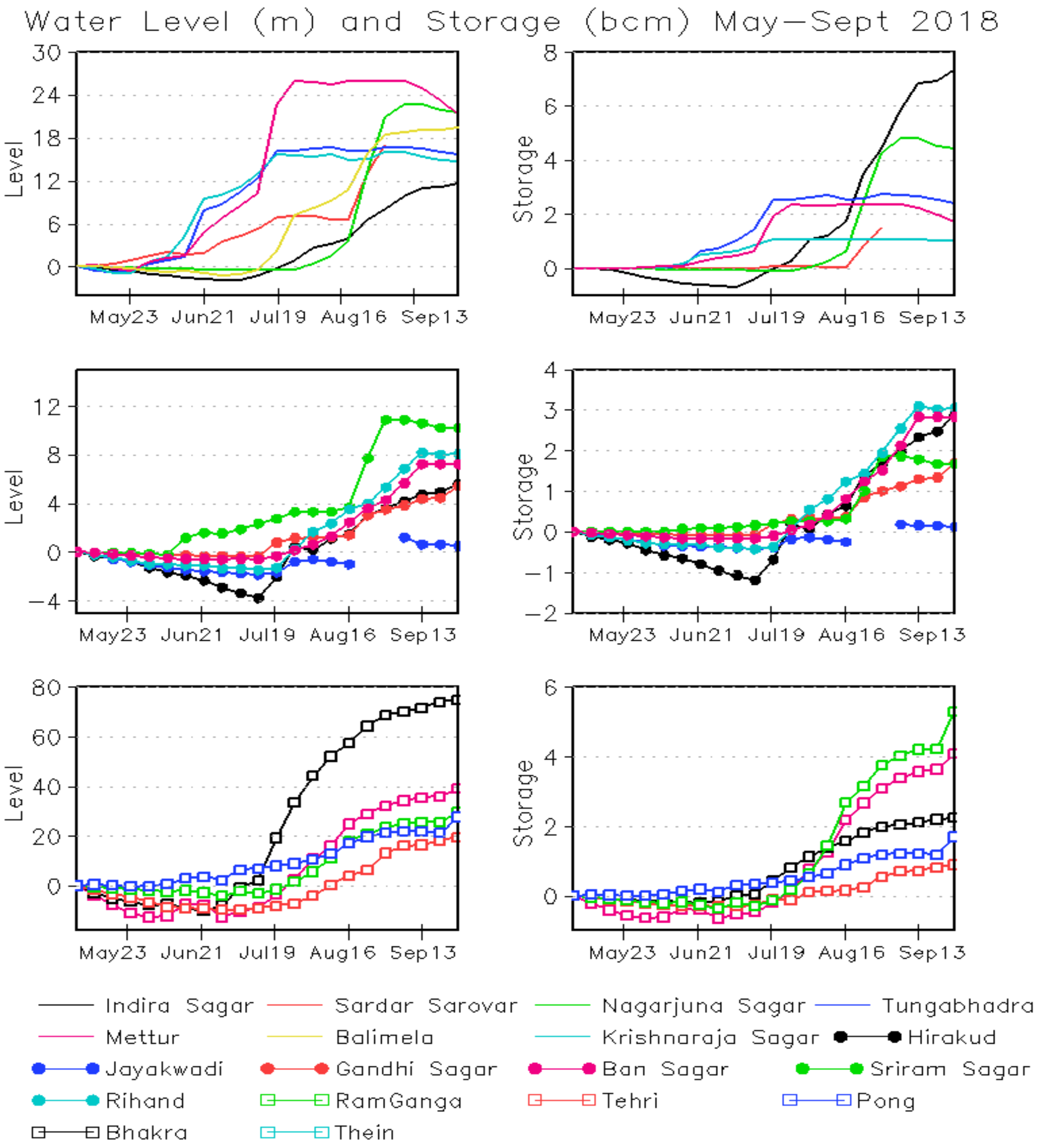
Bhakra Dam

Hirakud Dam

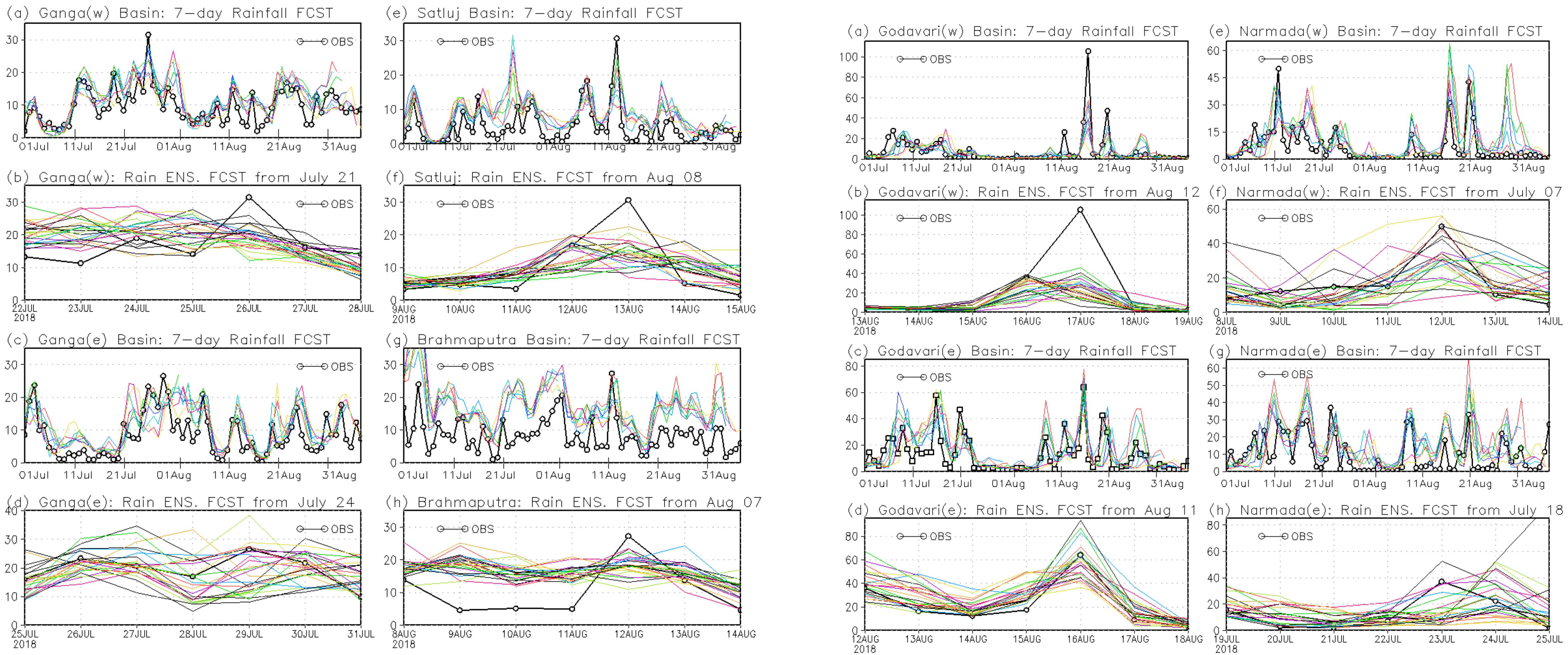
Water level and Storage amount in various reservoirs/dams in India in 2018.

Unavailability of water release data is an important constraint on hydrology/streamflow modeling in real-time

Changes of water level (m) and storage (bcm) in the reservoirs from first week of May 2018



Ensemble mean Forecasts (7day) and Ensemble Members Forecasts for River basins



It is seen that the model has reasonable skill in predicting basin-averaged rainfall in its forecasts from day-1 to day-7. However, some of the major peaks in rainfall activity could not be forecasted well Therefore, there is a need to check the usefulness of these forecasts to predict the rise in water level or water amount in the reservoirs with confidence.

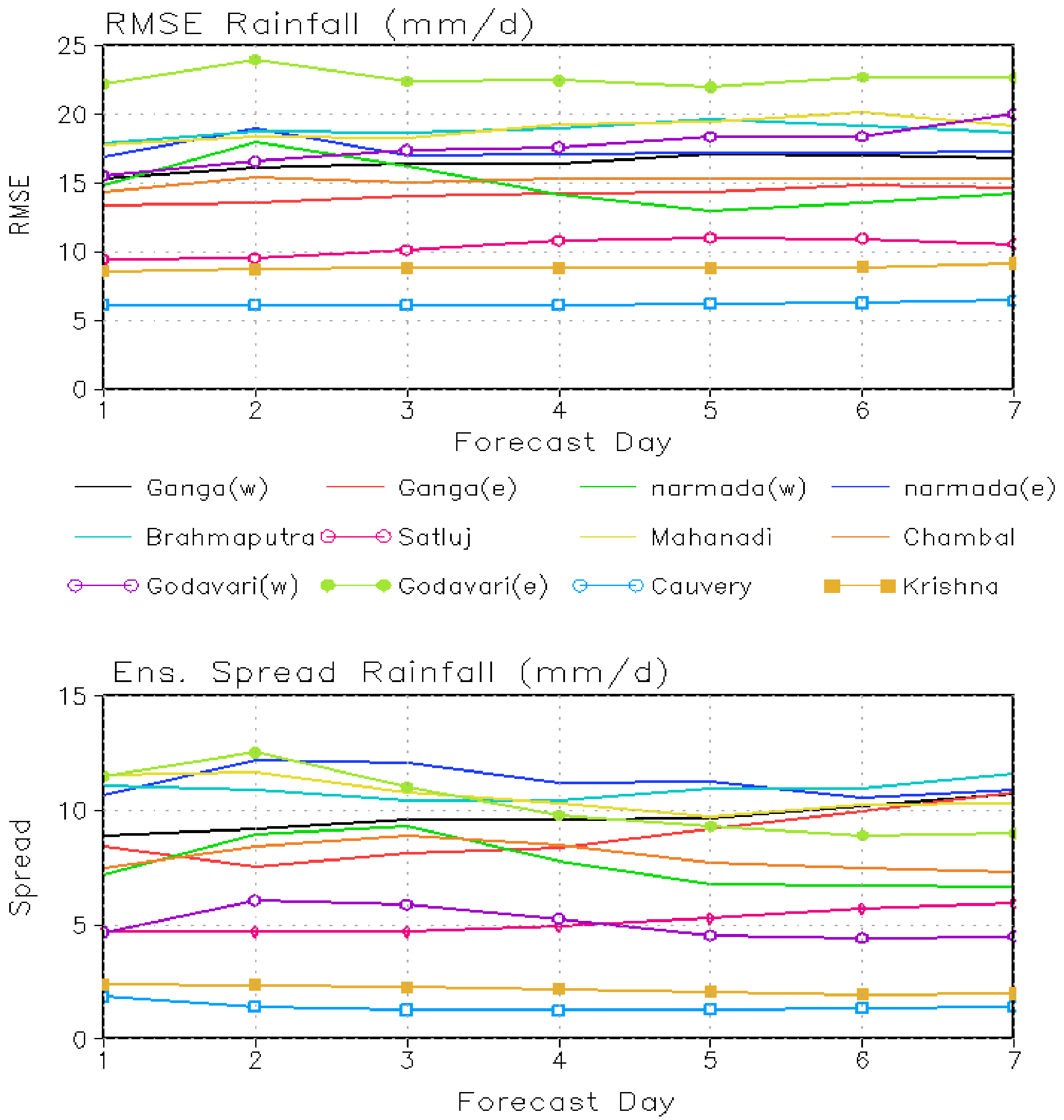
A probabilistic forecast is reliable if the observed frequency of the event for a given forecast probability is equal to the forecast probability.

Moreover, for a probabilistic system to be reliable, forecasts from ensemble members should be statistically identical to the observations.

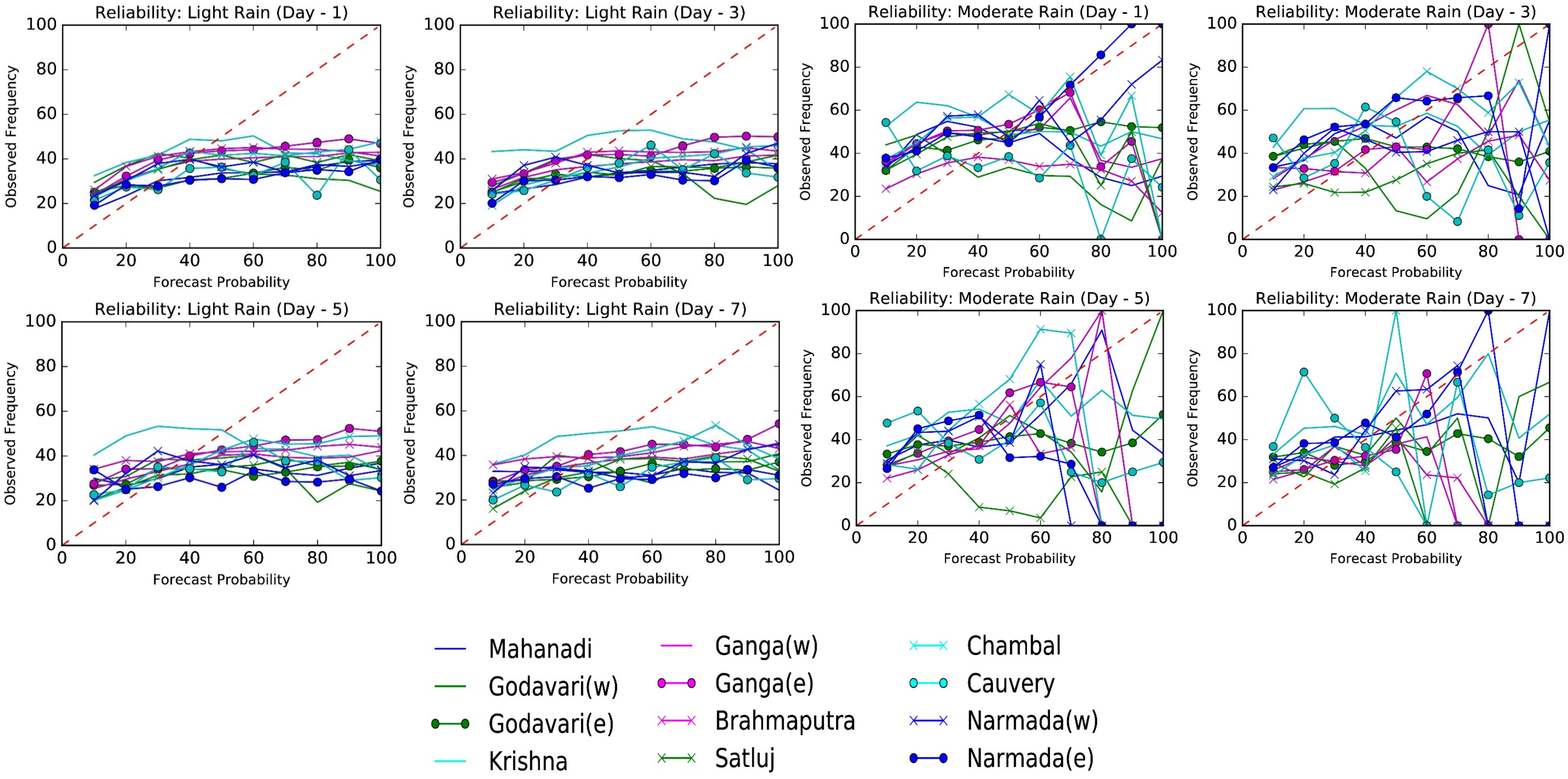
Therefore, it should be possible to draw the observation as well as an ensemble member from the same underlying distributions.

These conditions imply that the observation should lie in between ensemble spread of an ensemble system and the observation should behave like an ensemble member of the model (Doblas-Reyes et al. 2005; Weigel et al. 2008).

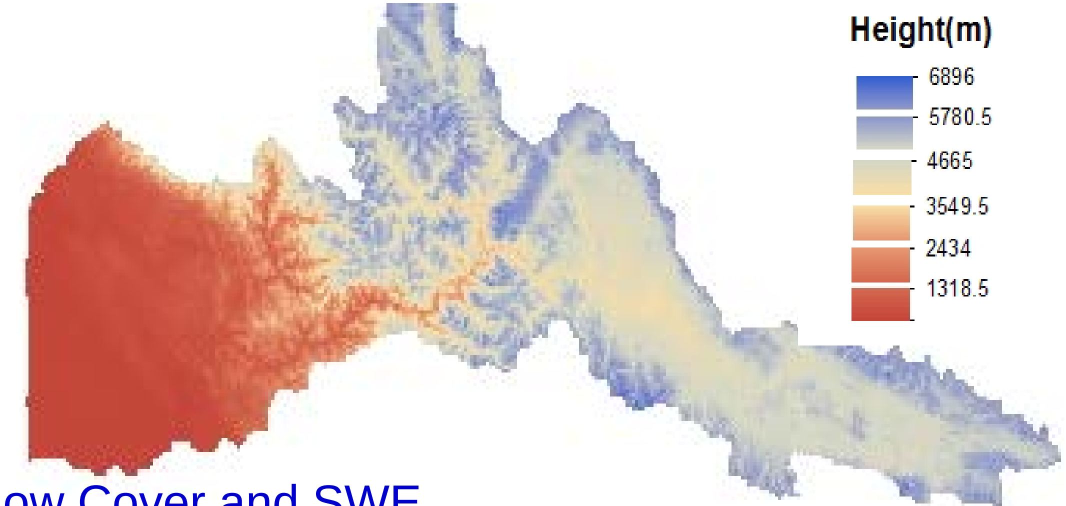
In order that the ensemble spread is representative of the uncertainty in the ensemble mean, the root mean square error (RMSE) of ensemble mean should be same as the averaged ensemble spread (weigel, 2008).

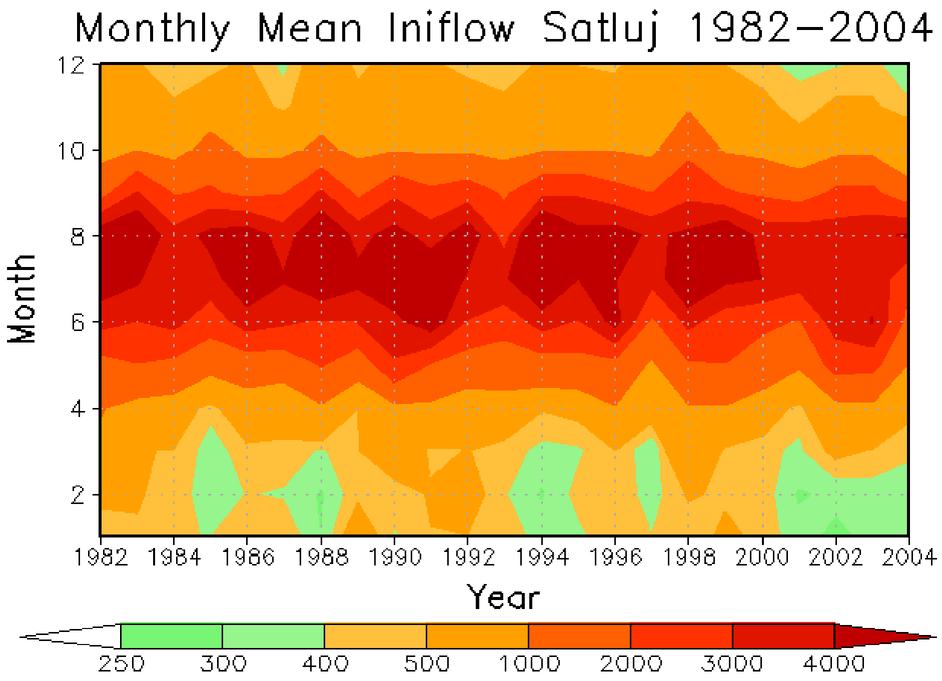


Reliability Diagrams for River Basins

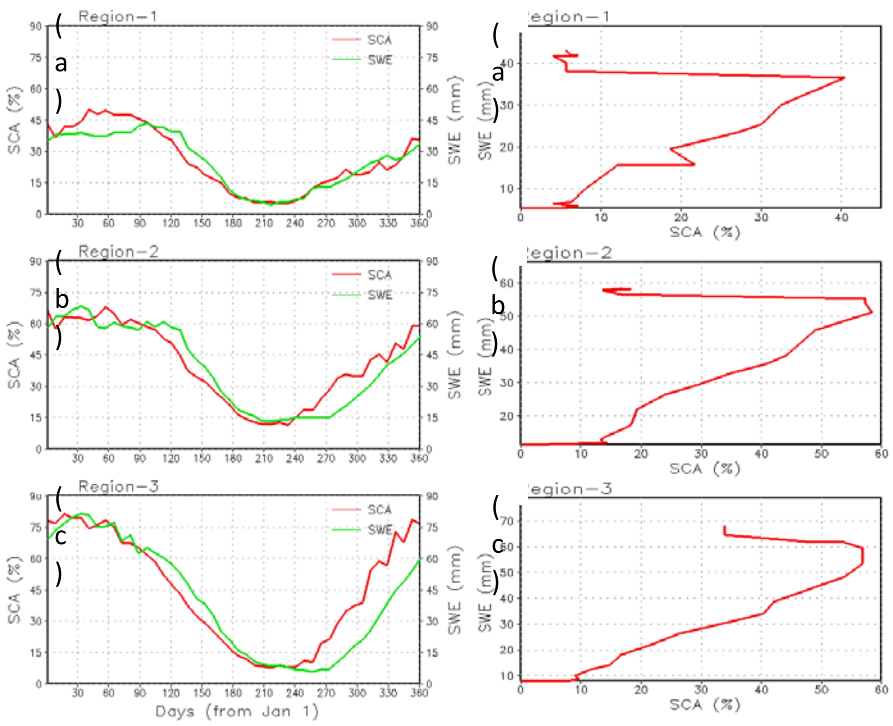


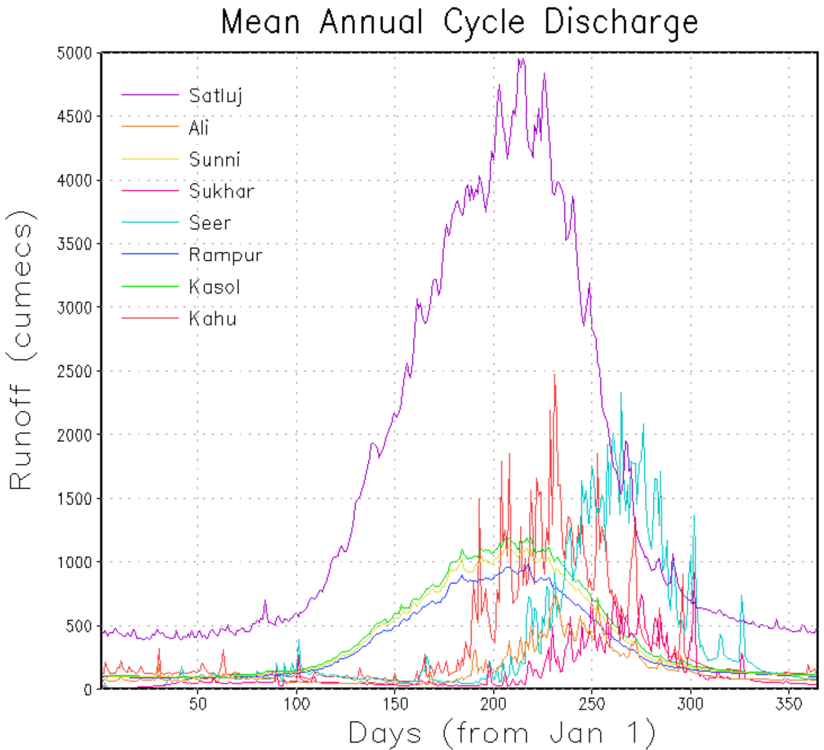
DEM for Satluj River Basin





Relation between Snow Cover and SWE





Snowmelt and rainfall Runoff in Satluj River basin has been studied extensively

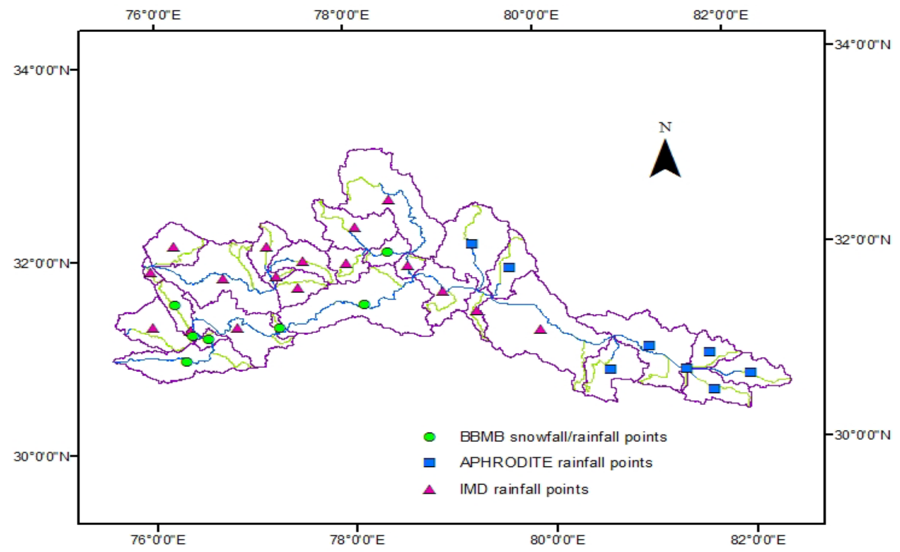
SWAT Model has been configured for Satluj Basin.

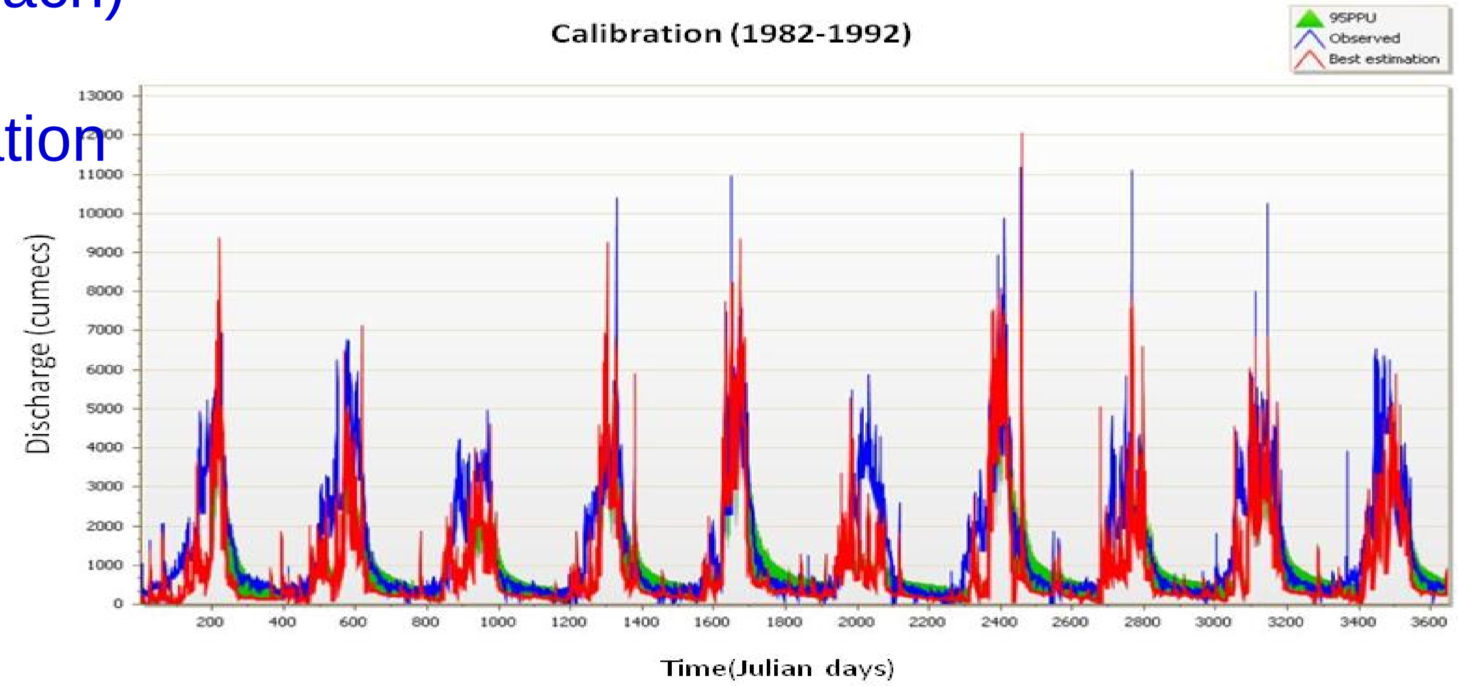
Number of Sub Basins considered: 32

Model has been calibrated and validated using observed streamflow data from 1982-2003 (10 years each)

Used forcing: observed precipitation and Temperature.

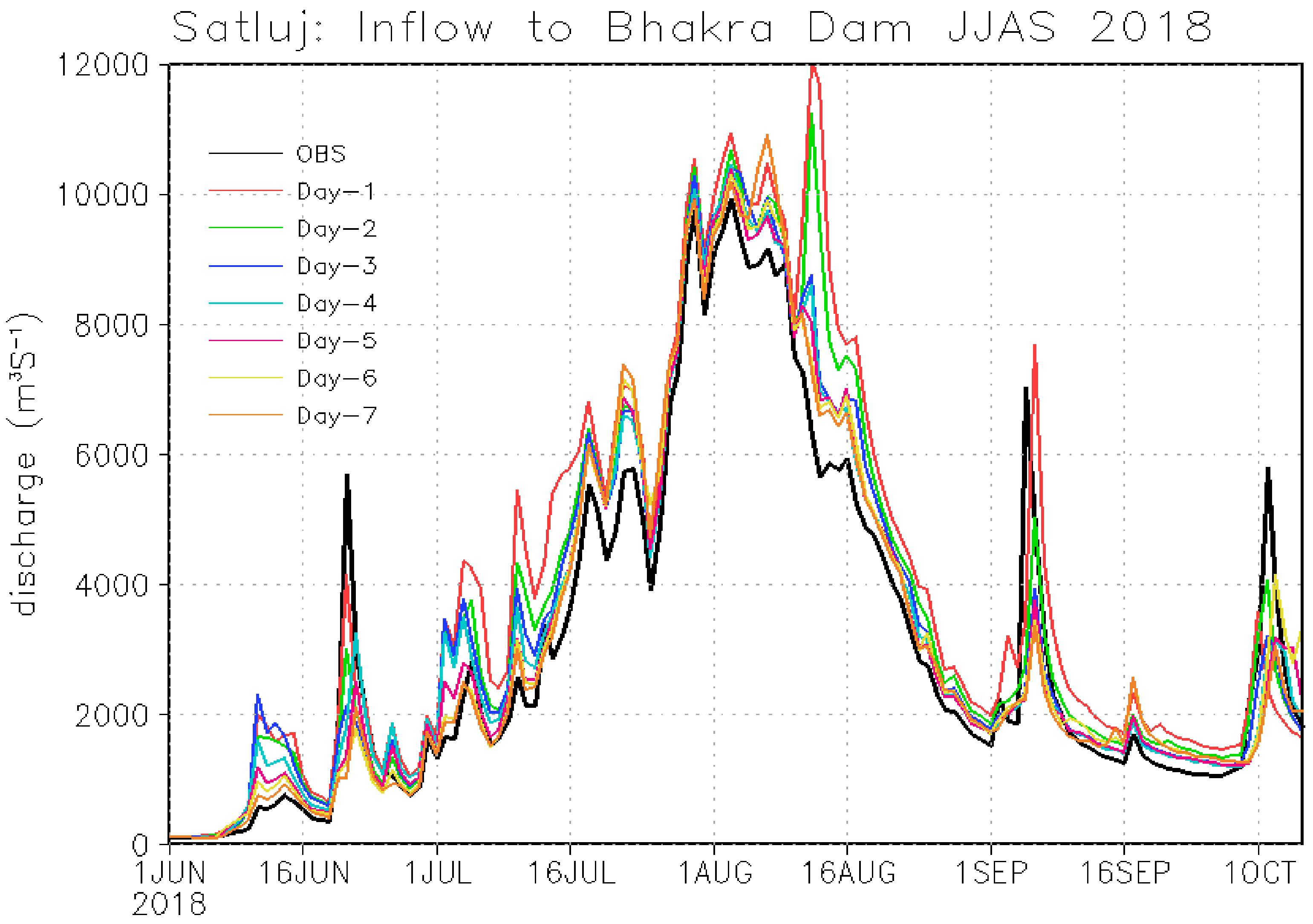
Model has reasonable skill in simulating inflow to Bhakra dam.



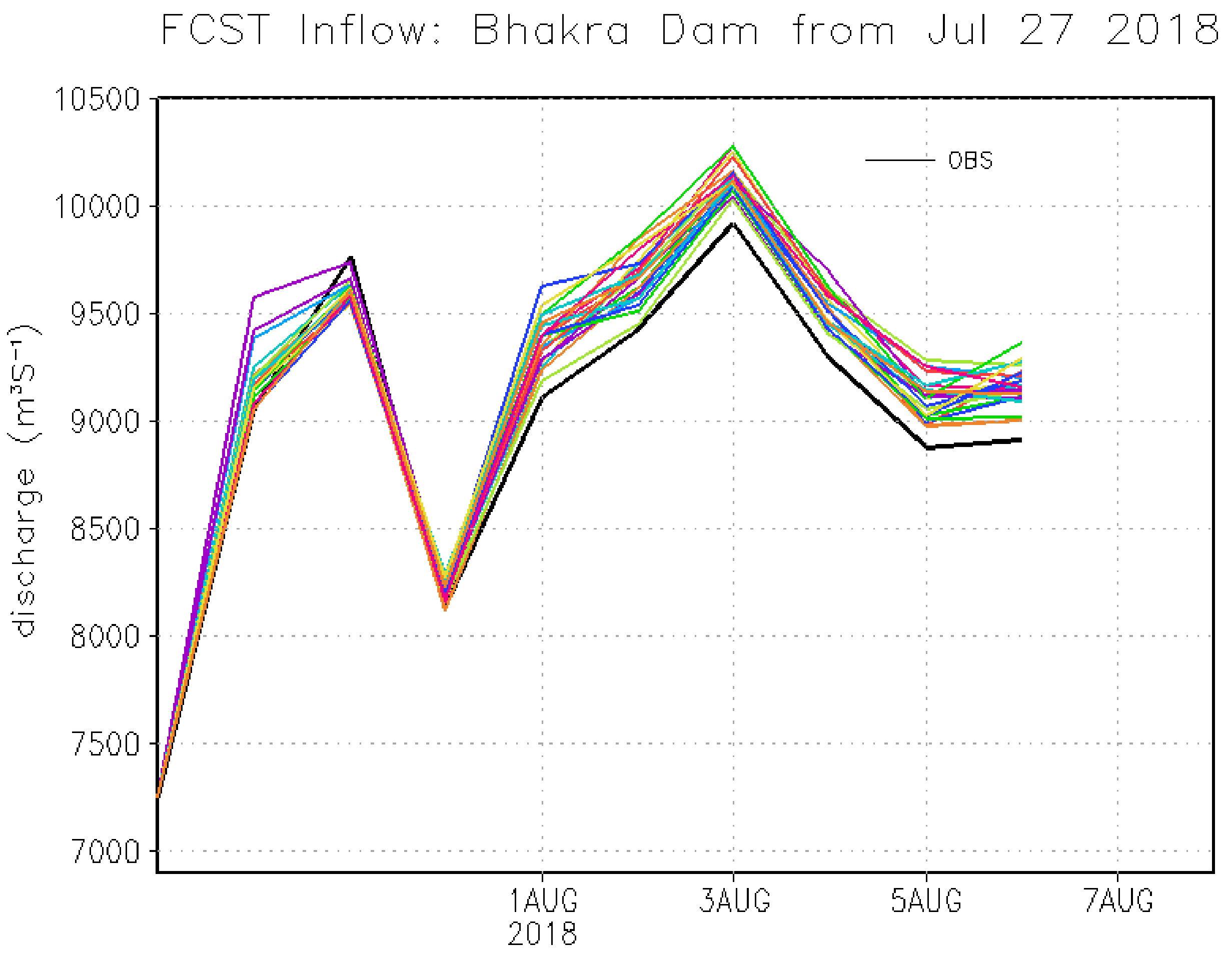


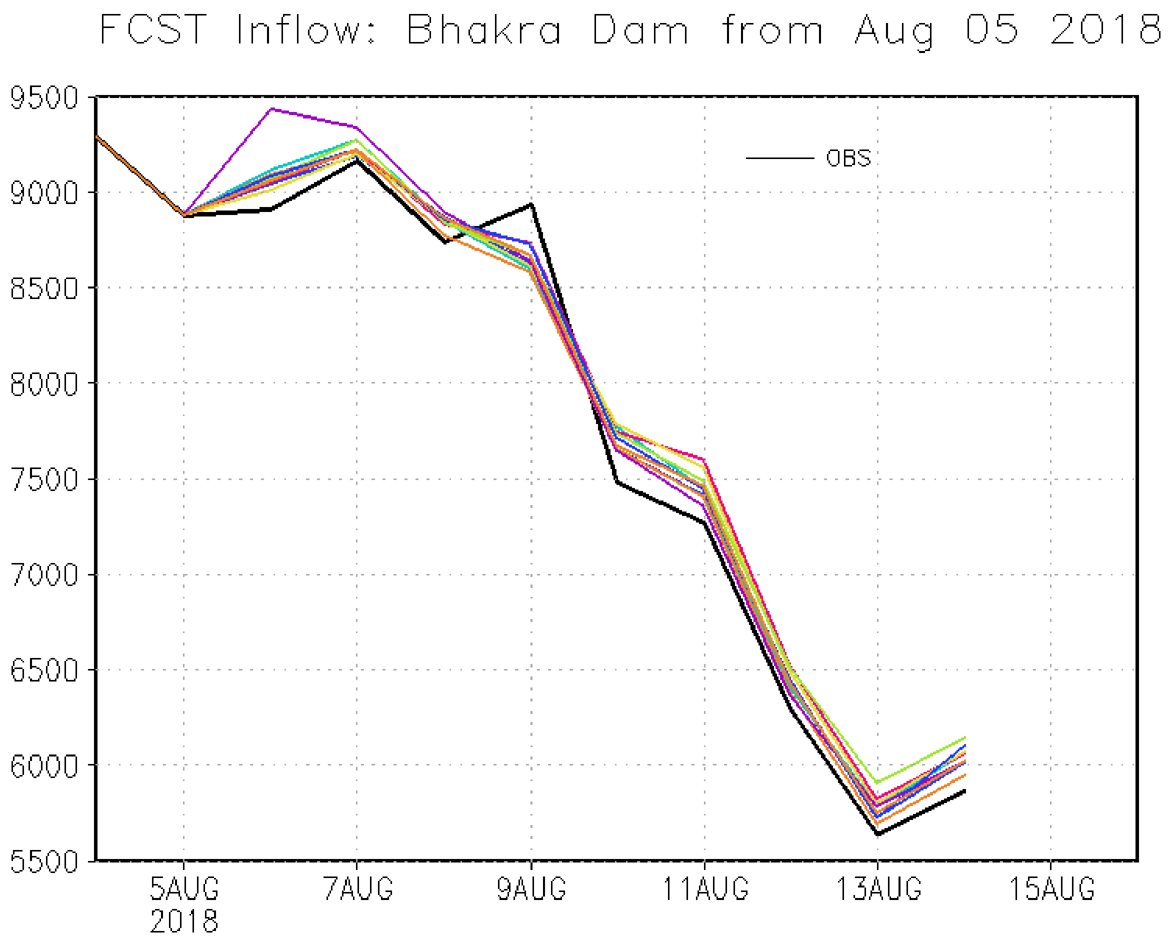
The SWAT model has been used to simulate inflow to Bhakra Dam in Satluj River using NEPS Ensemble mean forecasts for JJAS 2018 (Day-1 to Day-7).

As actual observation of inflow is not available, it is estimated using observed rainfall forcing in SWAT model



Ensemble Streamflow Prediction
Inflow prediction to Bhakra Dam (each ensemble members)
Forecasts from Jul 28 and Aug 05 2018





Bias Correction: Quantile Mapping (Quantile-Quantile Transformation)

If P_o and P_m denote observed and modeled precipitation respectively

QM attempts to find a transformation $P_o = h(P_m)$
such that its new distribution equals the distribution of the observed variable P_o.

QM is an application of the probability integral transform.

if the distribution of the variable of interest is known, the transformation h is defined as

$$P_o = F_o^{-1}(F_m(P_m))$$

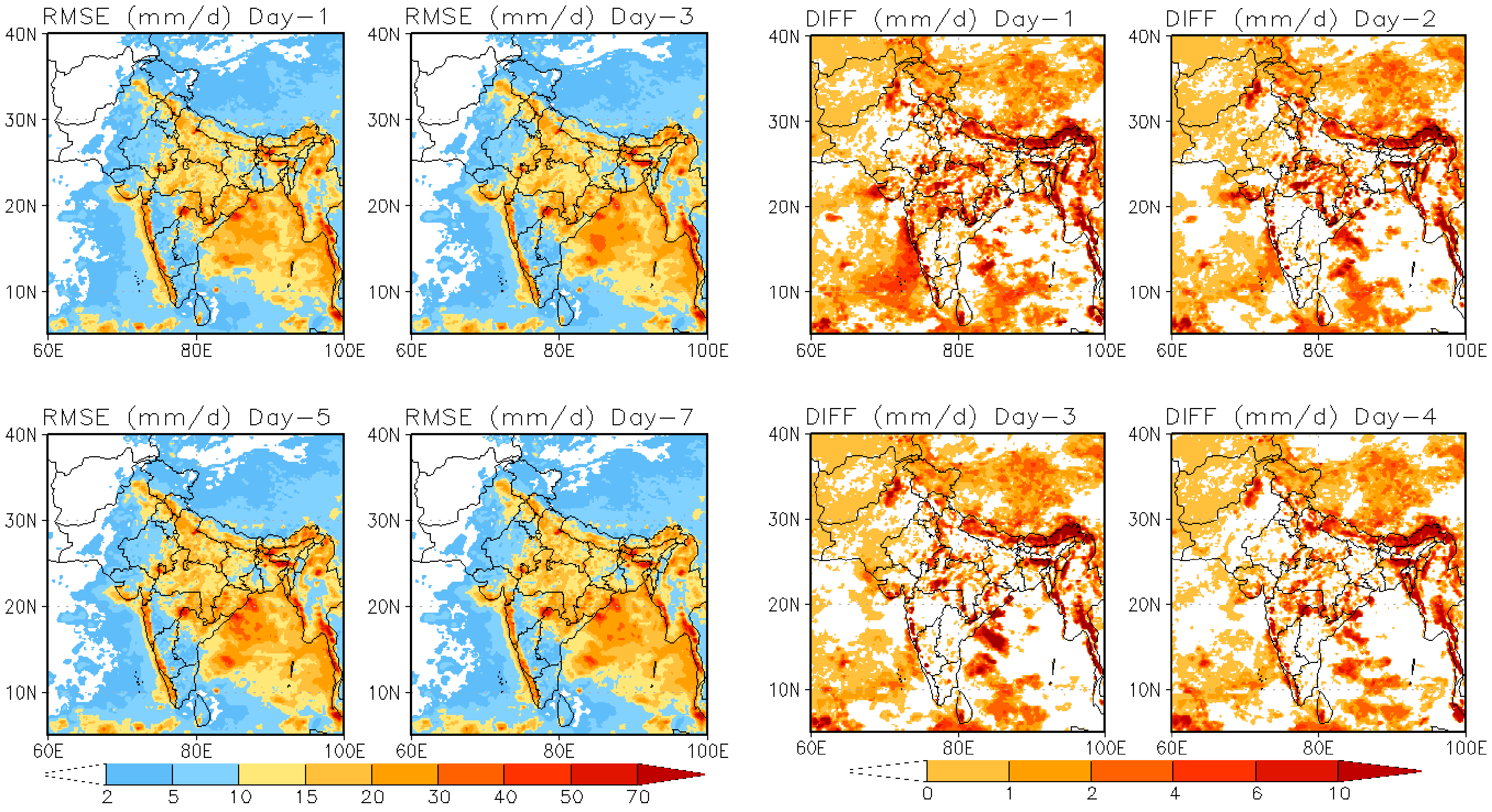
Where F_m is the CDF of P_m and F_o^{-1} is the inverse CDF (or quantile function) corresponding to P_o

Quantile Mapping Bias Correction method has been applied to NEPS rainfall forecasts.

Predictions & Observation for previous 30 days are used to compute the QM

RMSE

QM



RMSE Diff:

NEPS-QM

Summary

Probabilistic forecasts from NEPS at river basin scale have been examined.

The NEPS Precipitation products are useful for hydrological applications (ensemble streamflow)

For some of the river basins, especially Satluj basin, enhanced and reduced inflow to reservoirs can be predicted using NEPS precipitation forecasts

The bias in NEPS products can be corrected using Quantile Mapping method

Observed streamflow data are essential for calibrating and validating streamflow to reservoirs

Further studies are in progress

Thank You