Multi-model ensemble prediction of Super Cyclone Amphan using ECMWF, GEFS and NEPS-G forecasts

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Using ECMWF's Forecasts (UEF)

1-4 June 2021

SuCS Amphan (16-21 May 2020) and its damage potential:

Peak intensity : 260 km/h (140 knots)
Lowest Central pressure: 920 mb

➢**Large-scale flooding & inundation of sea water**

128 fatalities,
60 million population affected,
Increasing death toll of pandemic

➢**Washed 1.7 million hectares of productive cropland**

➢**Uprooted 28% mangroves**

➢**Extensive structural damage of bridges causing large-scale disruption of rail, road traffic**

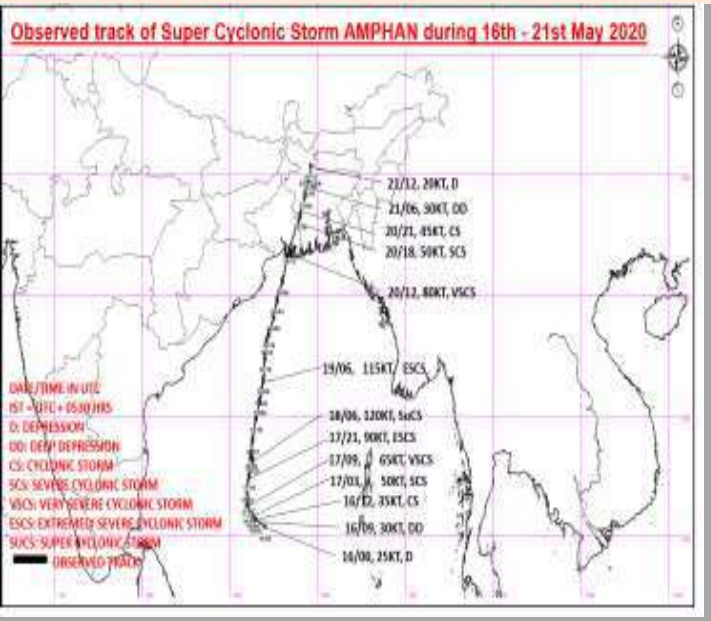
21.14° N, 88.94° E
175° @ 103 km/h

earth

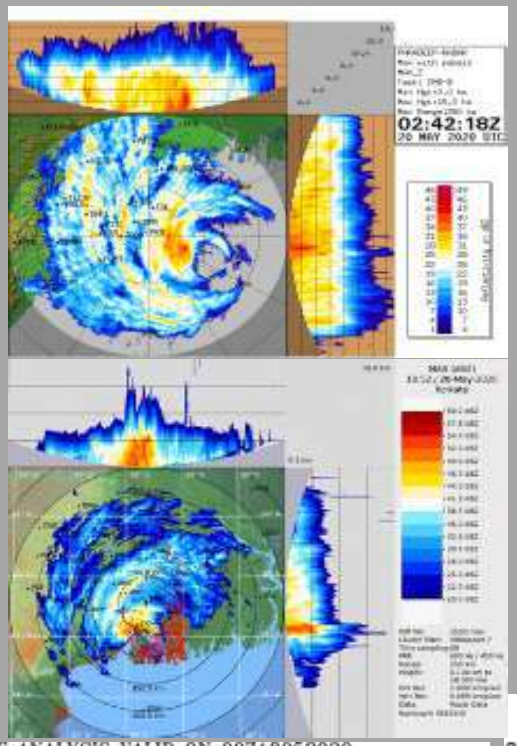
➢**Total disruption of communication and power supply.**

➢**Damaged 2.9 million homes**

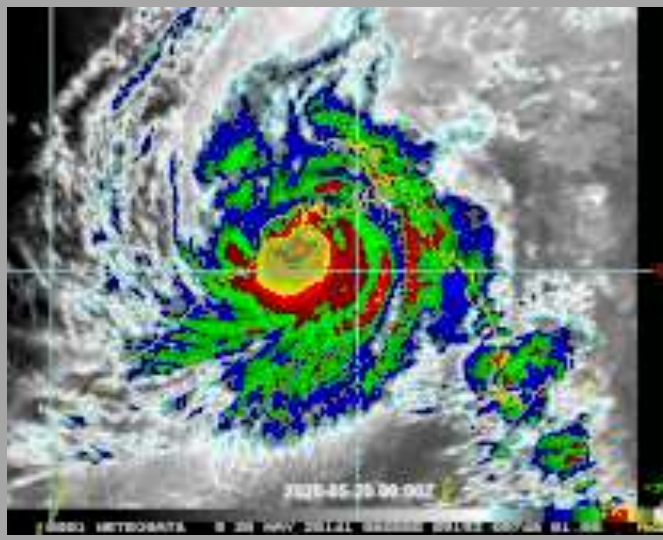
Observed imageries of genesis and intensification of SuCS Amphan



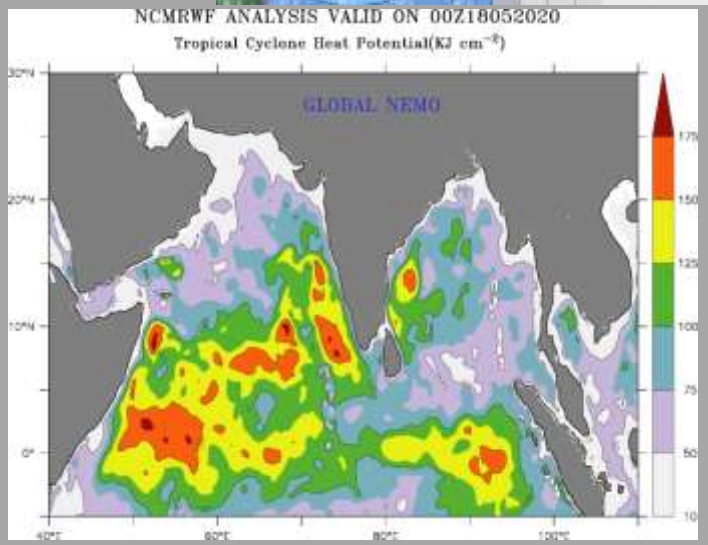
DWR image at Paradip & Kolkata



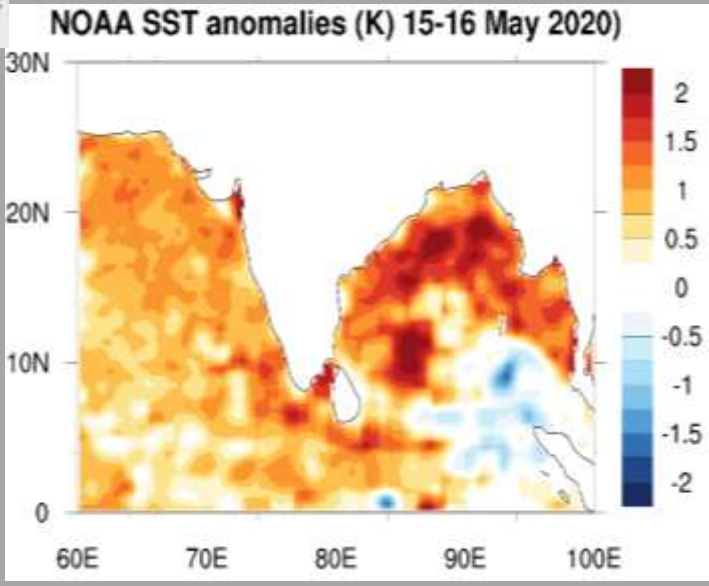
Meteosat imagery 20th May 06-13 UTC



Areas affected:
India (West Bengal, Odisha, Andaman Islands), Bangladesh, Sri Lanka, Bhutan



TCHP 15th May 2020

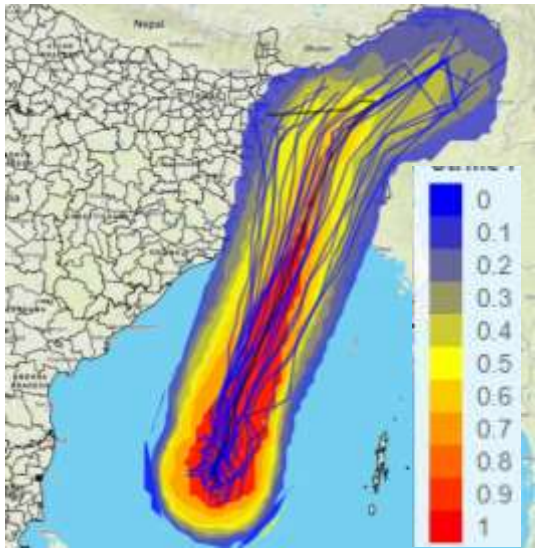


Main features of ECMWF, GEFS and NEPS-G systems

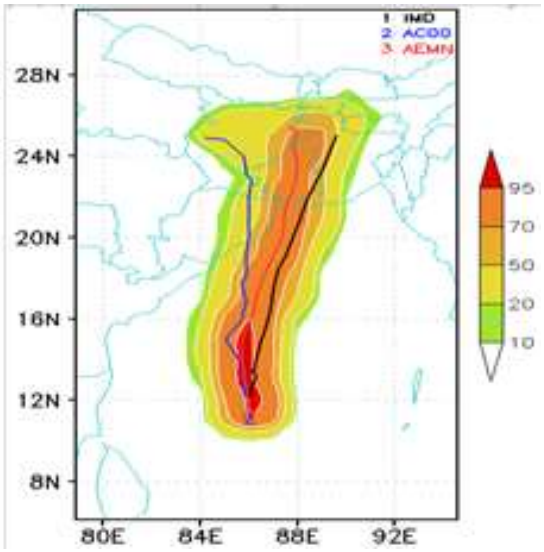
Features	NEPS-G	GEFS	ECMWF
Model version	Unified Model 10.8	GFS, V14.1.1.3	IFS, Cycle 47r2
Ensemble Size	CNTL + 11 mem (00UTC) +11 mem (12 UTC)	CNTL + 20 mem (00UTC) +20 mem (12 UTC)	CNTL + 50 mem (00UTC)
Horizontal resolution;	~12 km	~12 km	~18km
Vertical levels	70	64	137
IC perturbations method	ETKF	Ensemble Kalman Filter (ENKF) (fcst pers)+Ensemble Transform rescaling(anl perts)	Ensemble of data assimilations (EDA)+Singular Vectors
Model Physics perturbations	SKEB and Random Parameters	Stochastic total tendency perturbation (STTP)	Stochastically Perturbed Parameterization Tendencies (SPPT)

TC Amphan strike probability from NEPS-G and GEFS

NEPS strike probability
IC: 20200517 00 UTC



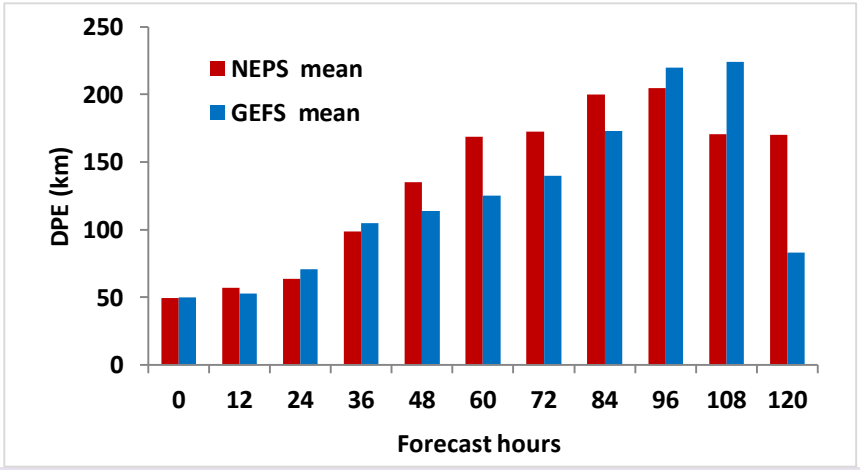
GEFS strike probability
IC: 20200517 00 UTC

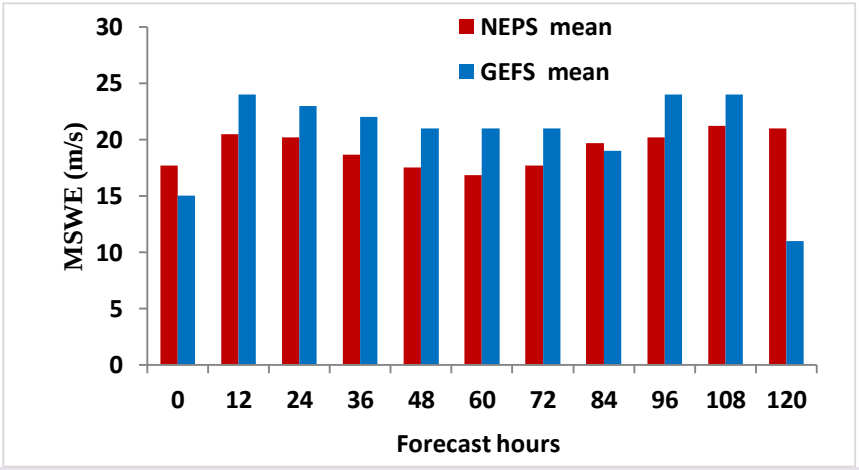


➢**GEFS CNTL and ensemble** tracks show a **westward** (far to the left of observed track) **bias** relative to IMD best-track.

➢There is **eastward bias in NEPS** (far to the right of observed track) in addition **to a fast bias** in the member tracks **resulting to large DPE**.

TC track and intensity forecasts errors (verified with IMD obs)

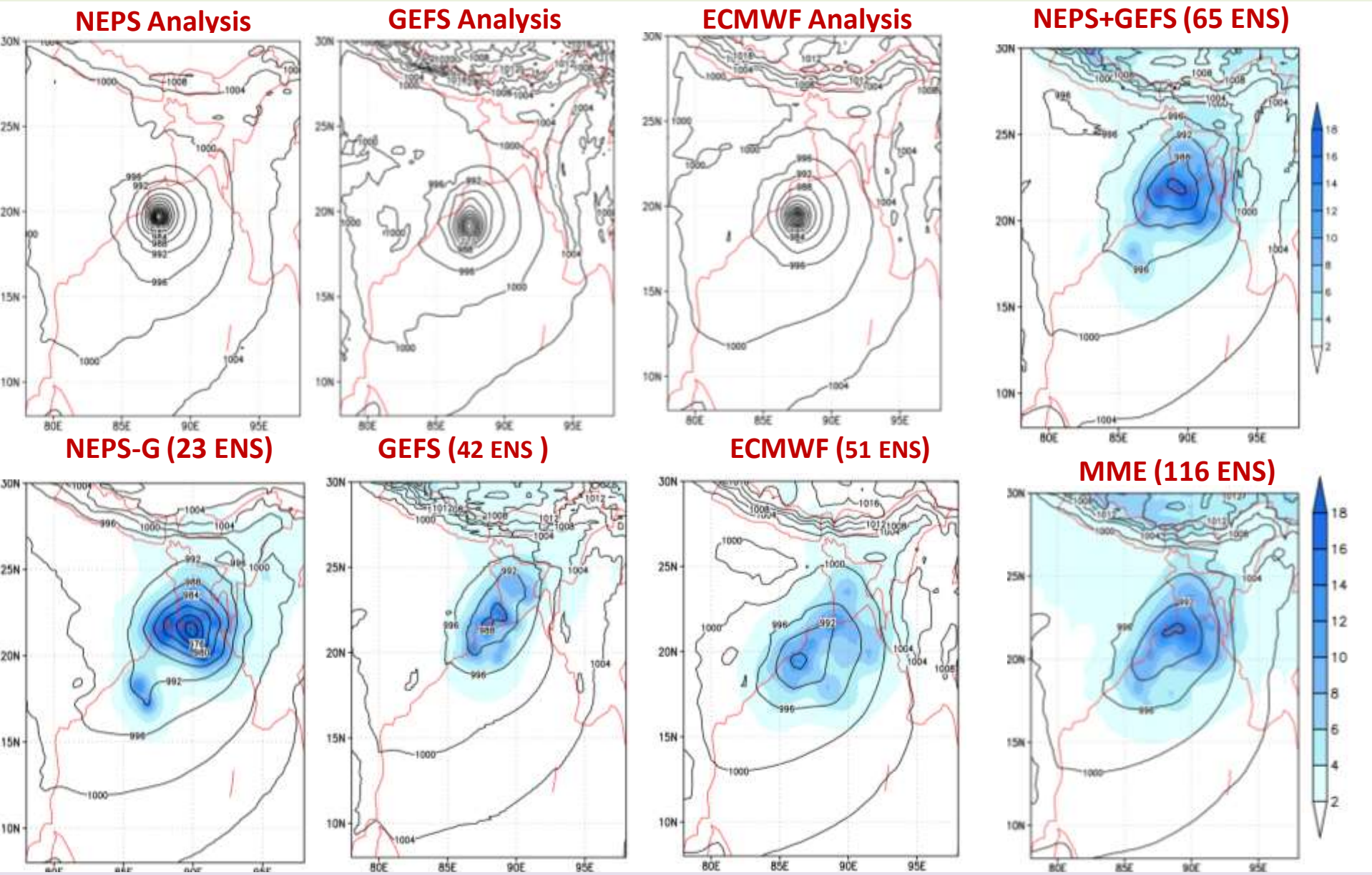




❑The **mean initial position error** of the two EPS **are comparable,** errors **increase with lead time, reduces after day-4** forecast lead time**.**

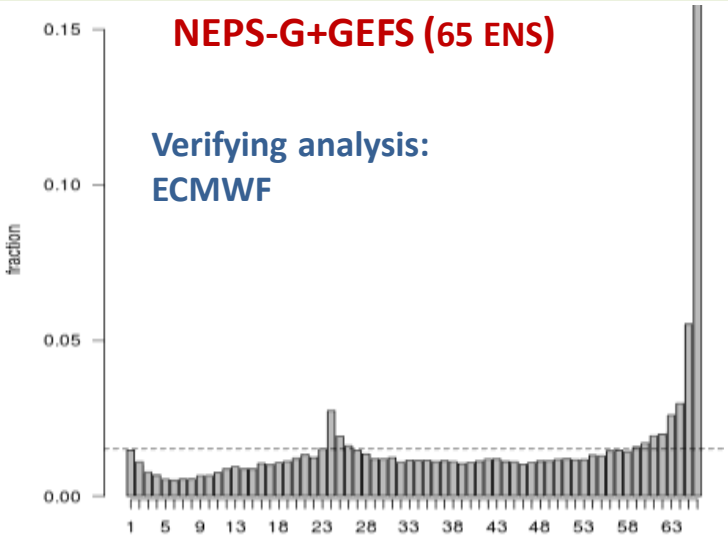
❑ While the **DPE is larger for NEPS** mostly, the **intensity errors are more in GEFS**.

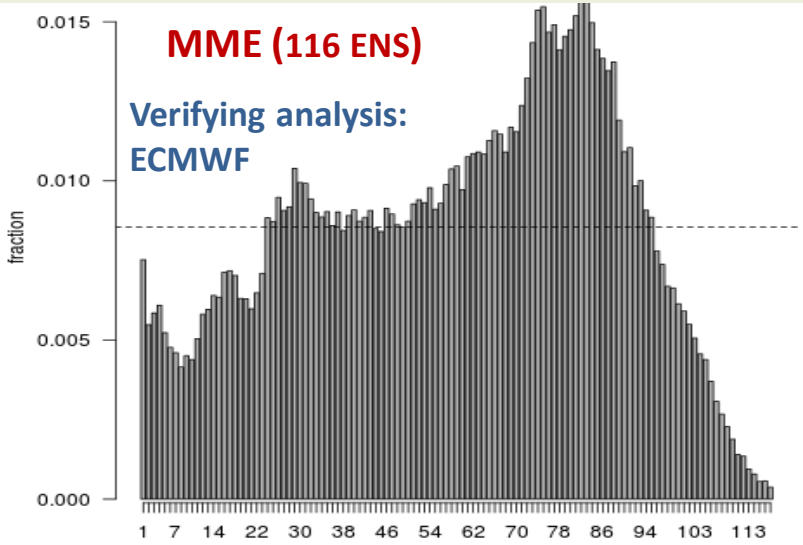
Mean (contours) and Spread (shaded): MSLP; Day 4 forecast valid for 00Z 20200520

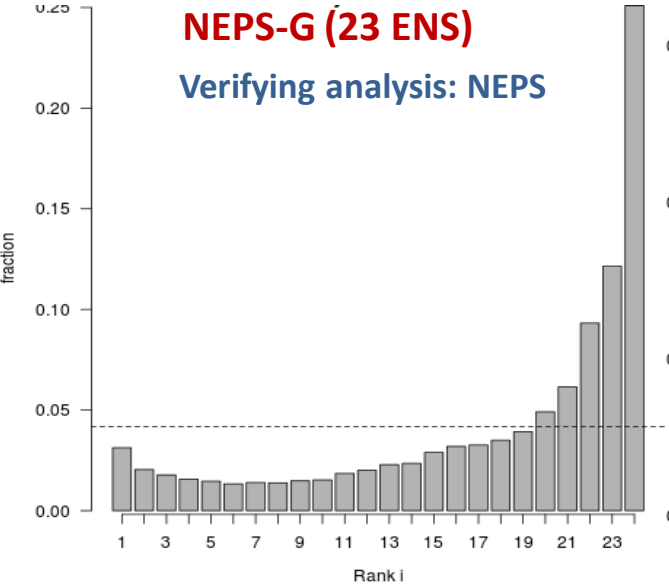


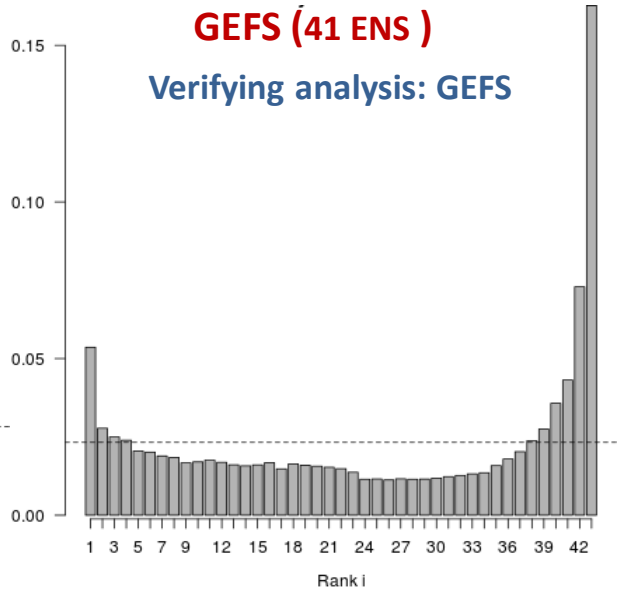
Least spread in **ECMWF EPS** contributes to **lower forecast uncertainty in the MME** as compared to that obtained in **NEPS+GEFS**. **ECMWF ensemble mean** is in **best agreement** with the **analyzed MSLP vortex** by the three models.

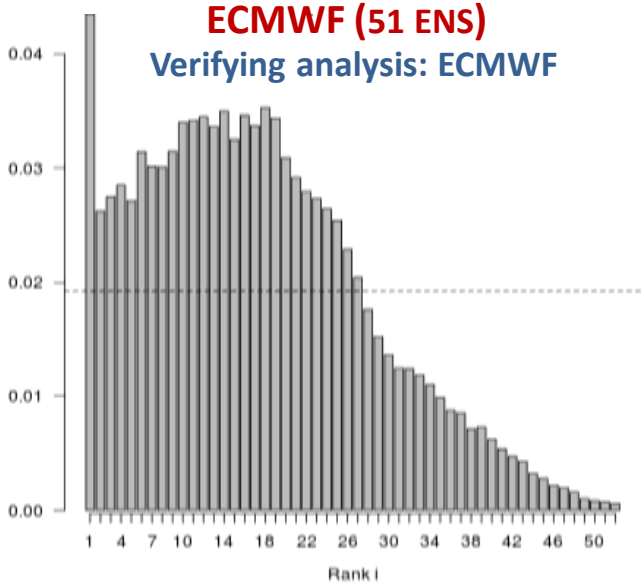
Rank histograms of the MME and respective EPS day-4 forecast of MSLP







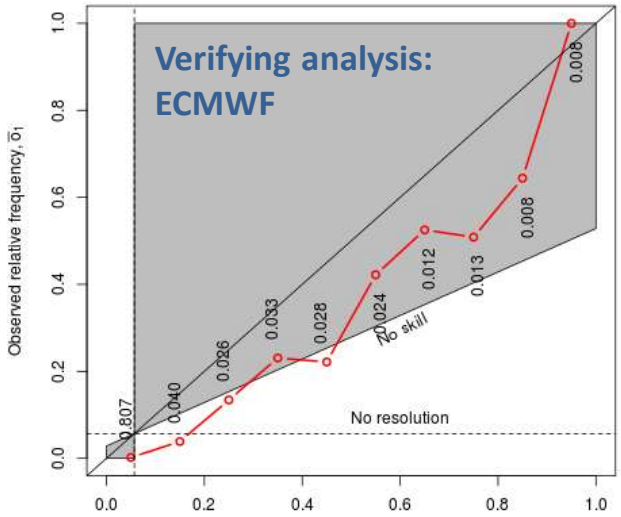




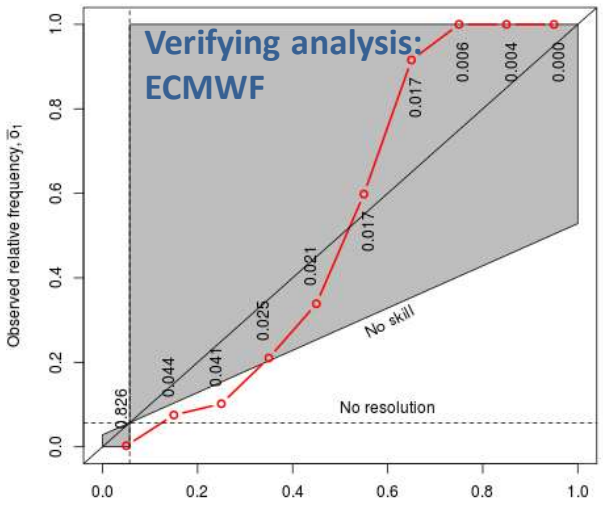
There is a tendency to predict **lower MSLP (stronger vortex) in both NEPS and GEFS** ensembles as compared to their analysis. Since the **ECMWF EPS has lesser bias**, the verifying analysis is more **uniformly distributed** in the **MME rank histograms**.

Reliability of the MME and respective EPS day-4 forecast of MSLP (<996 hPa)

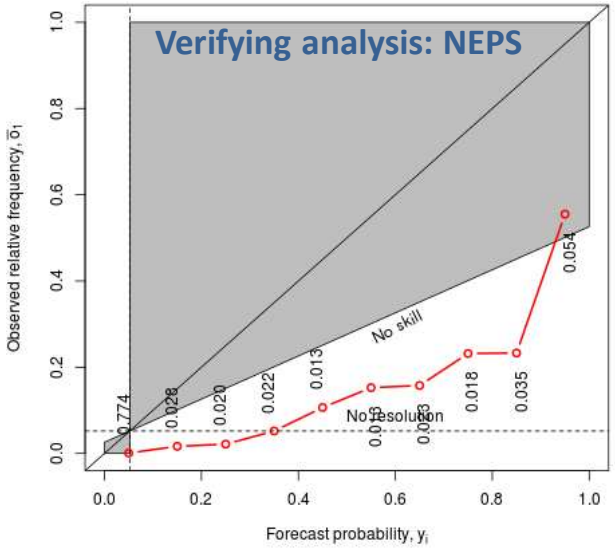
NEPS+GEFS (65 ENS)



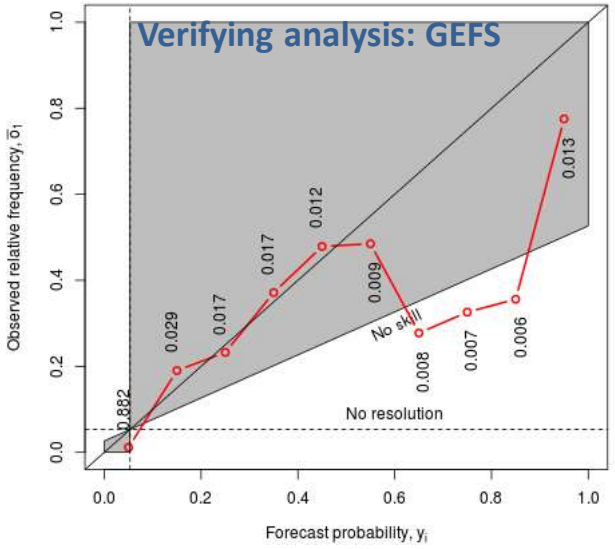
MME (116 ENS)



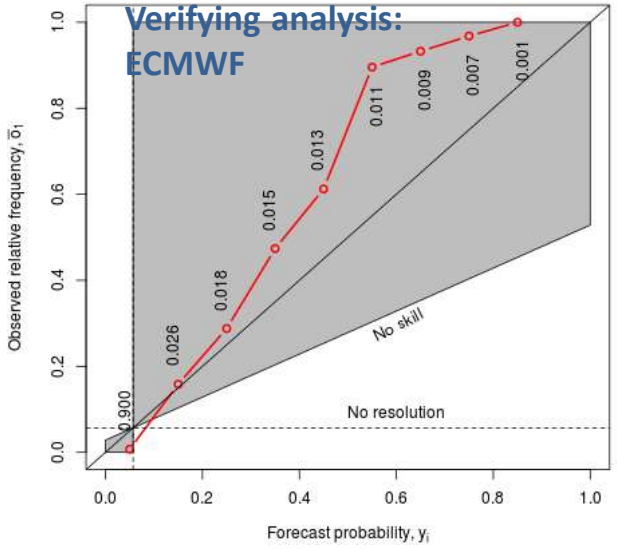
NEPS-G (23 ENS)



GEFS (41 ENS)



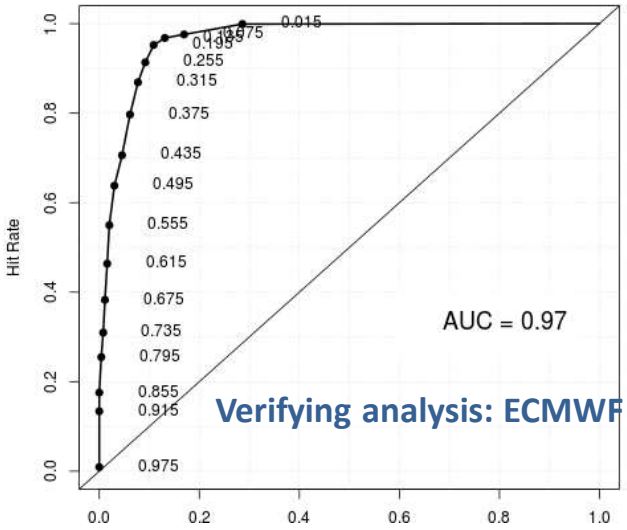
ECMWF (51 ENS)



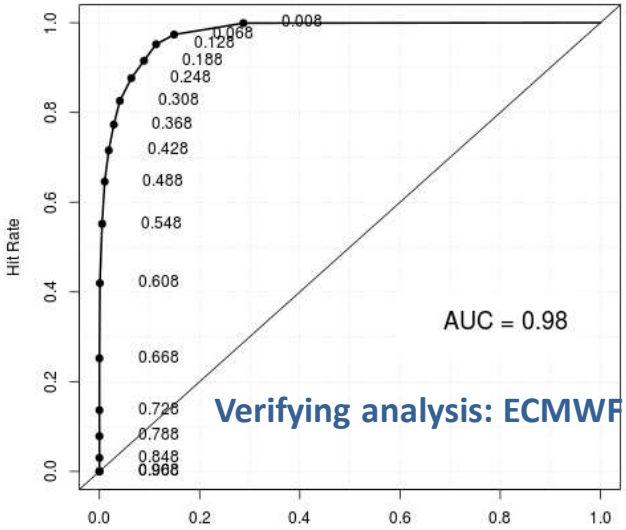
Since **reliability** of the **ECMWF EPS is better than NEPS or GEFS**, **reliability** of the **MME improves with the** incorporation of **ECMWF forecasts** .

ROC of the MME and respective EPS day-4 forecast of MSLP (<996 hPa)

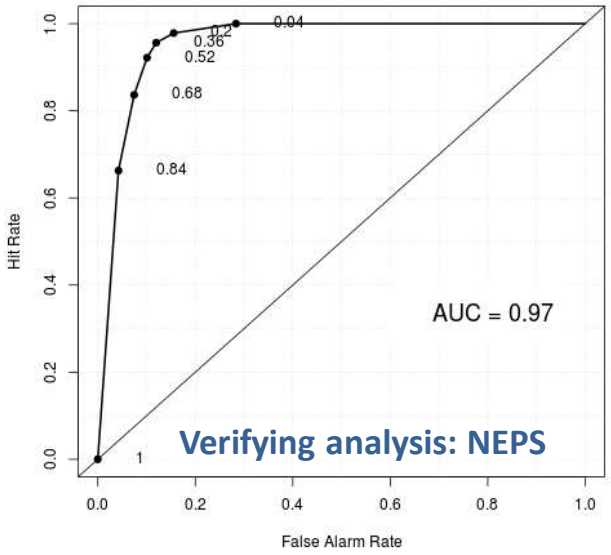
NEPS-G + GEFS (65 ENS)



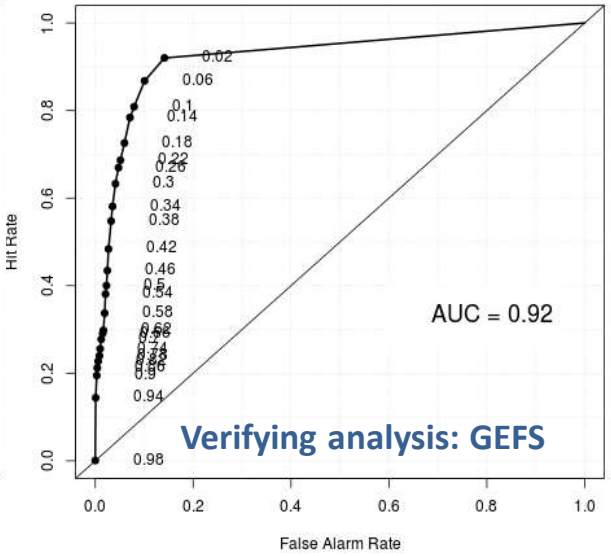
MME (116 ENS)



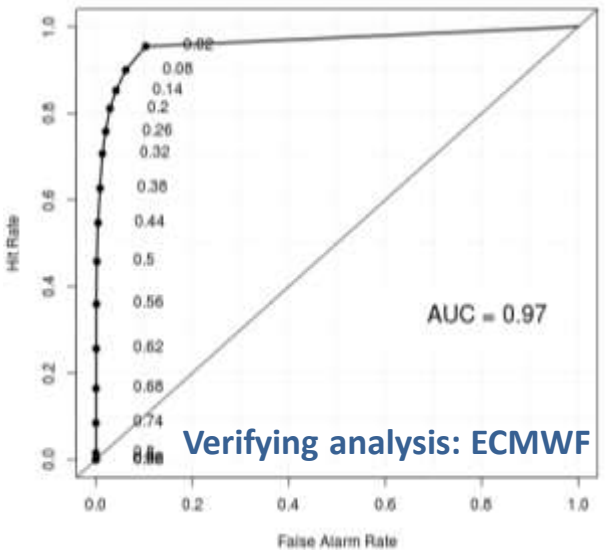
NEPS-G (23 ENS)



GEFS (41 ENS)



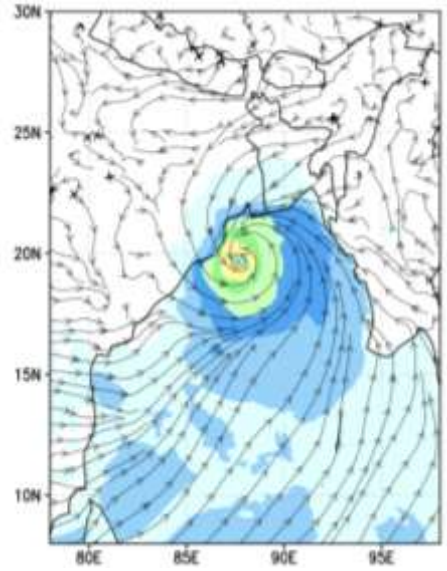
ECMWF (51 ENS)



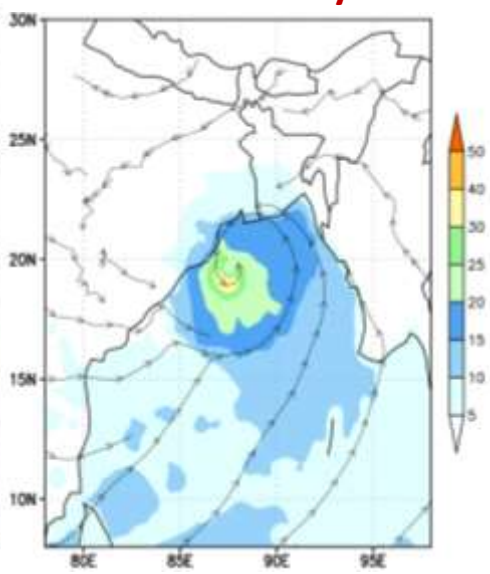
Discrimination of occurrences of event probabilities is **better in NEPS and ECMWF**. **AUC** of **MME is higher** than individual EPS **and improves with** incorporation of **ECMWF** ensembles.

Probability of 10m winds >15m/s from MME and respective EPS day-4 forecast

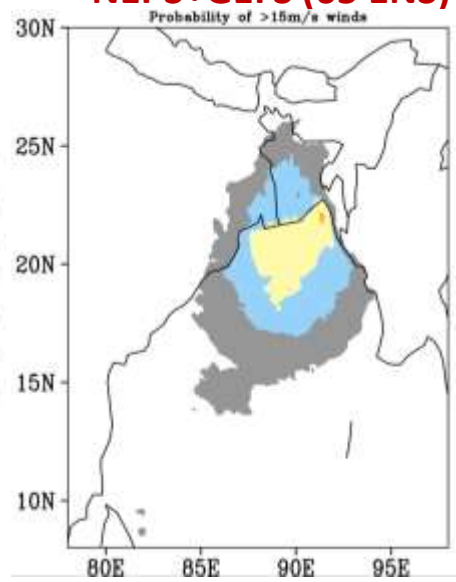
NEPS Analysis



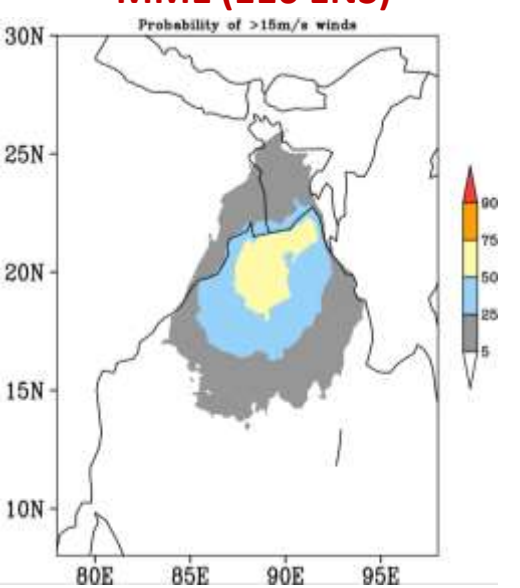
ECMWF Analysis



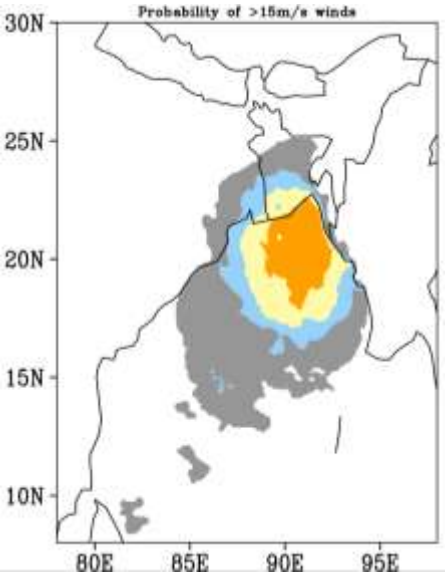
NEPS+GEFS (65 ENS)



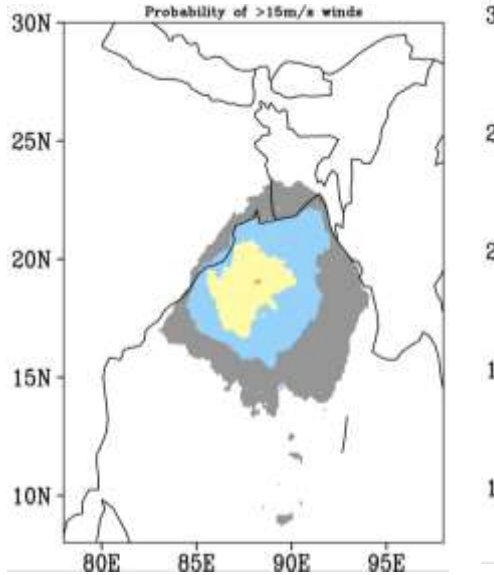
MME (116 ENS)



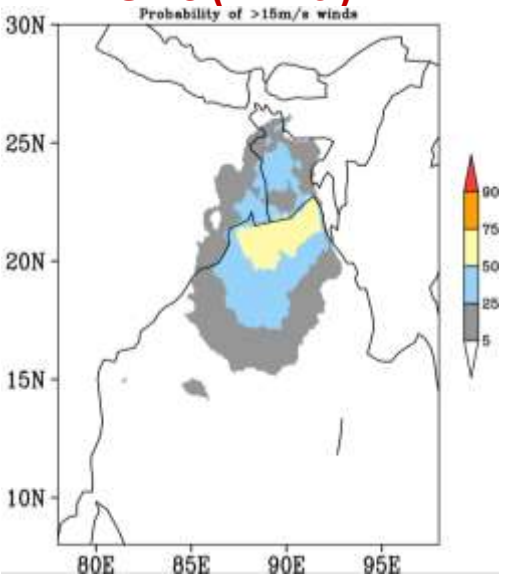
NEPS-G (23 ENS)



ECMWF (51 ENS)



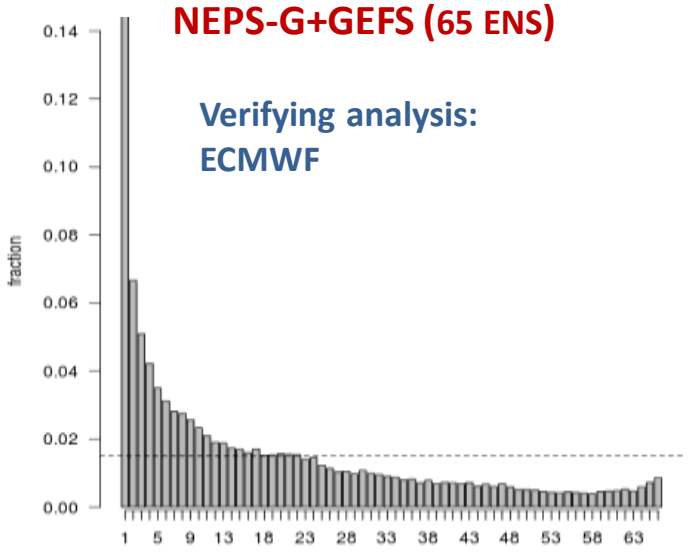
GEFS (42 ENS)

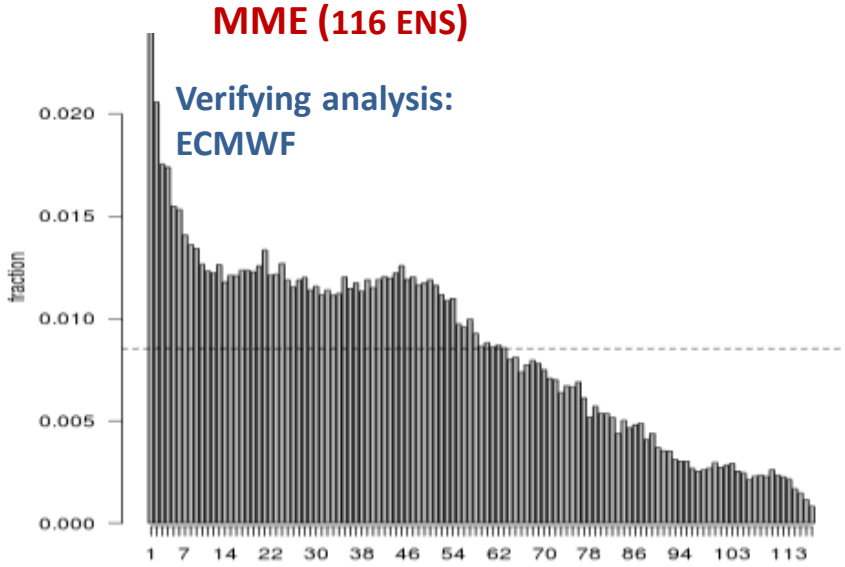


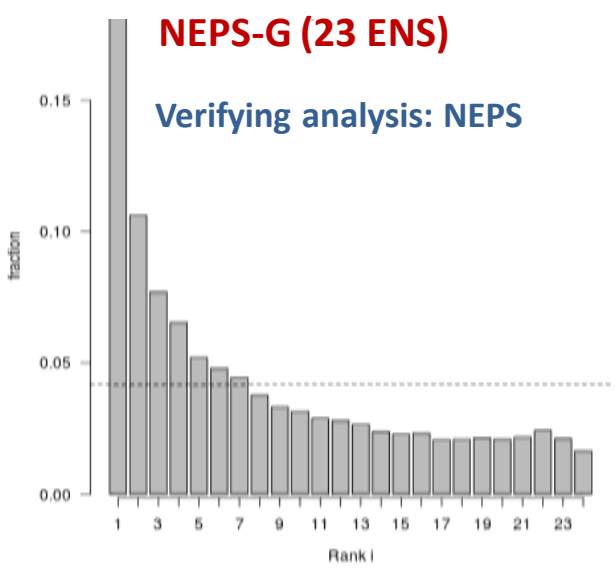
The **distribution of max probability** in **NEPS and GEFS** is **skewed north-east ward**.

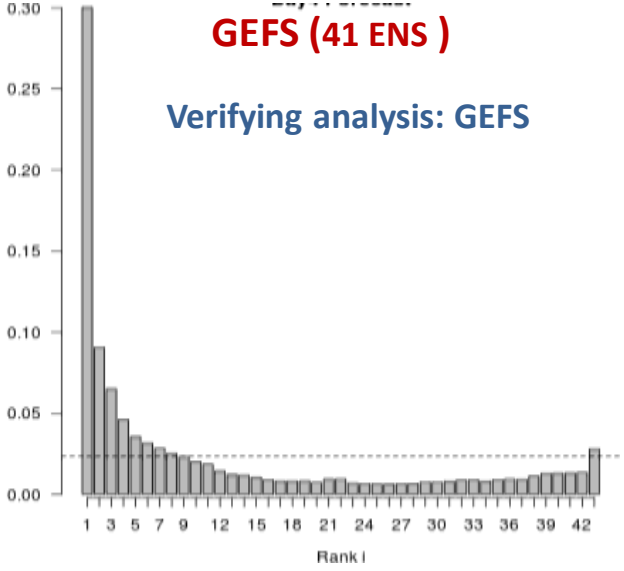
ECMWF ensemble probability distribution is in **better agreement** with the **analyzed wind vortex**, thereby slightly improving the **MME probability** distribution

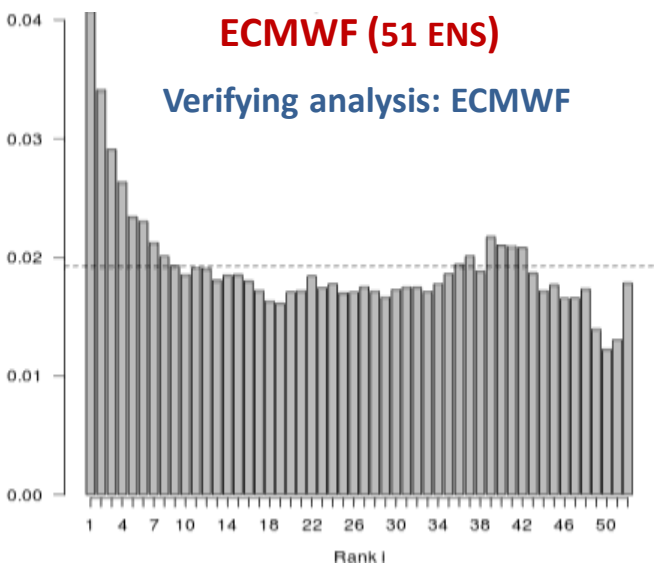
Rank histograms of the MME and respective EPS day-4 forecast of 10m wind speed







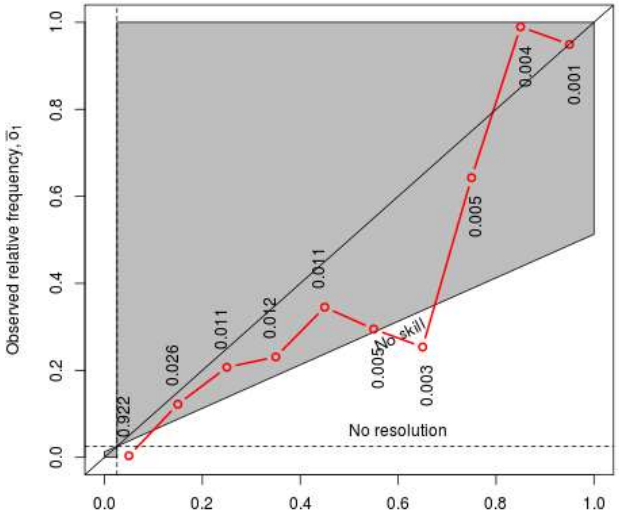




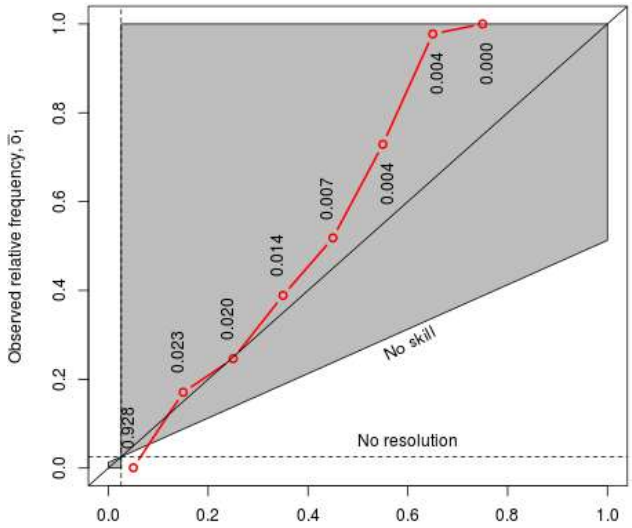
There is a tendency to predict **stronger winds (stronger vortex)** in all the ensembles as compared to their analysis. Since the **ECMWF EPS has relatively lesser bias**, the verifying analysis is somewhat more **uniformly distributed** in the **MME rank histograms**.

Reliability of the MME and respective EPS day-4 forecast of 10m U exceeding 18 m/s

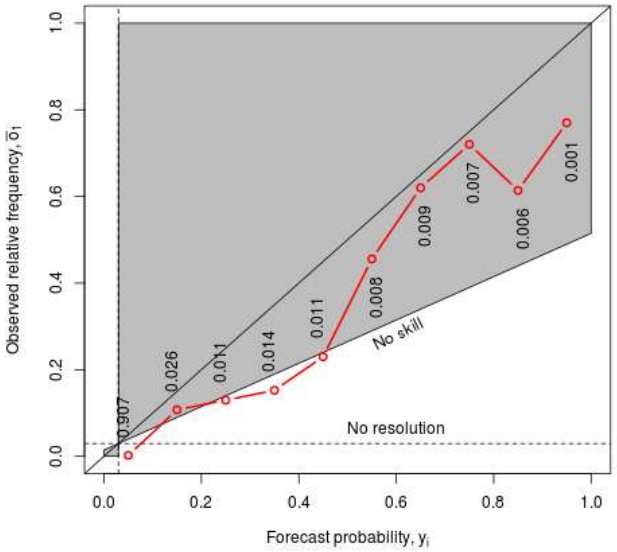
NEPS+GEFS (65 ENS)



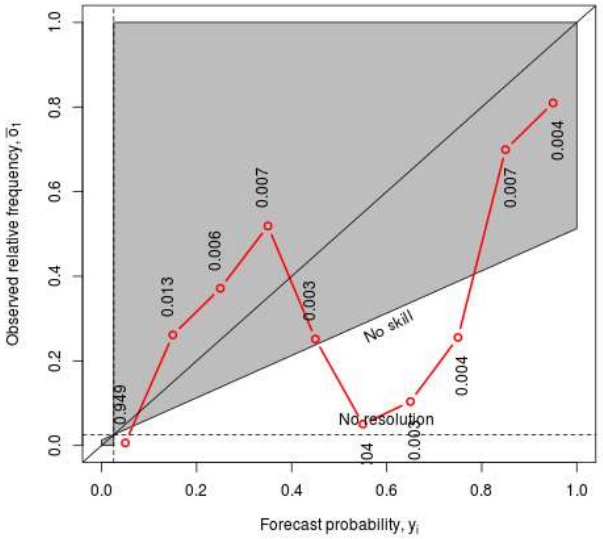
MME (116 ENS)



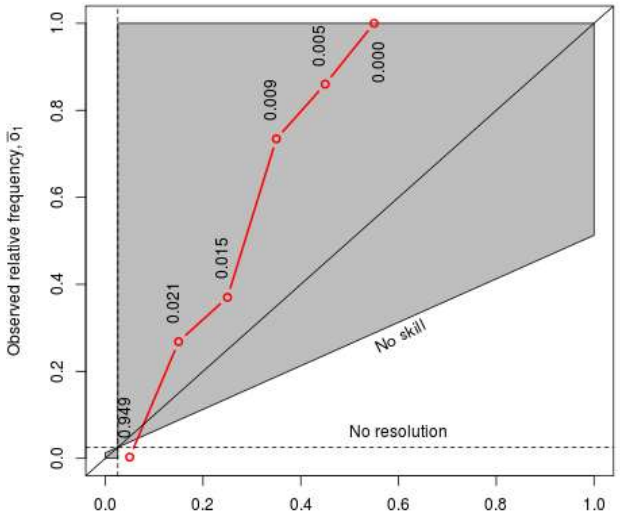
NEPS-G (23 ENS)



GEFS (41 ENS)



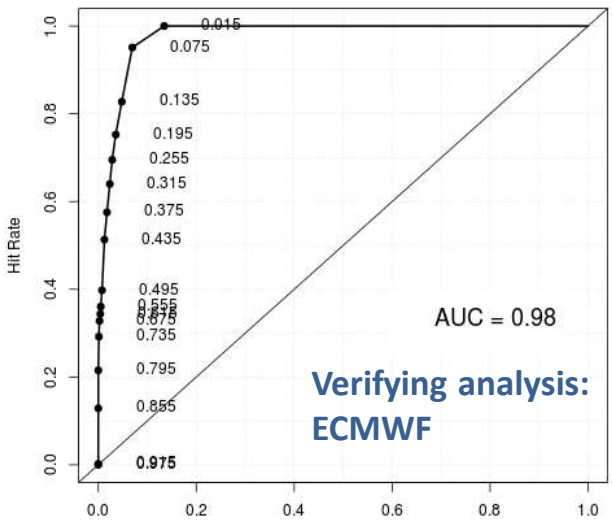
ECMWF (51 ENS)



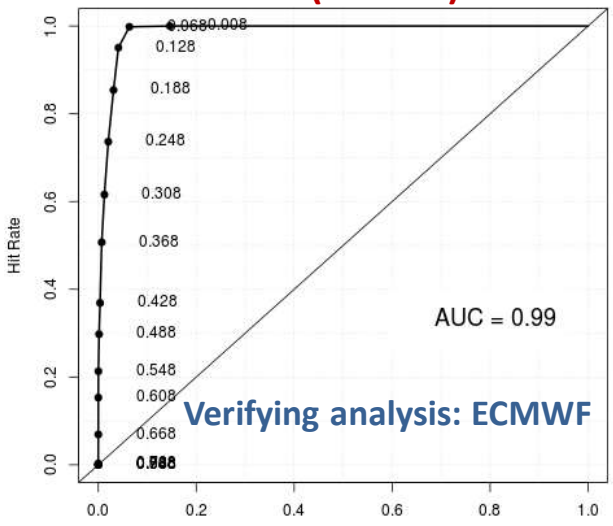
Since **reliability** of the **ECMWF EPS is better than NEPS or GEFS**, **reliability** of the **MME improves with the** incorporation of **ECMWF forecasts** .

ROC of the MME and respective EPS day-4 forecast of 10m U exceeding 18 m/s

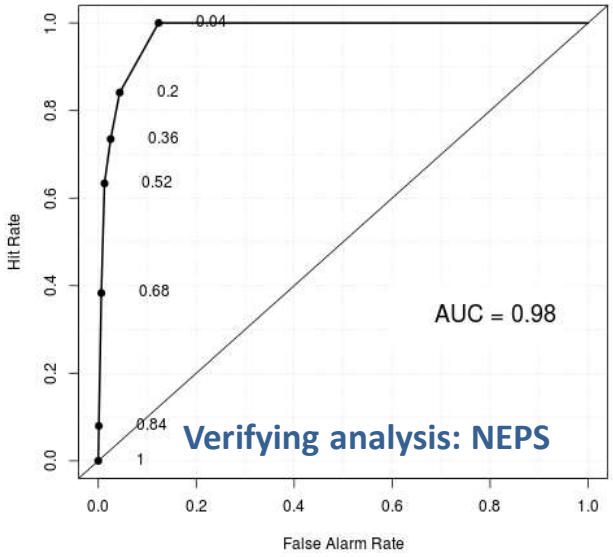
NEPS-G+GEFS (65 ENS)



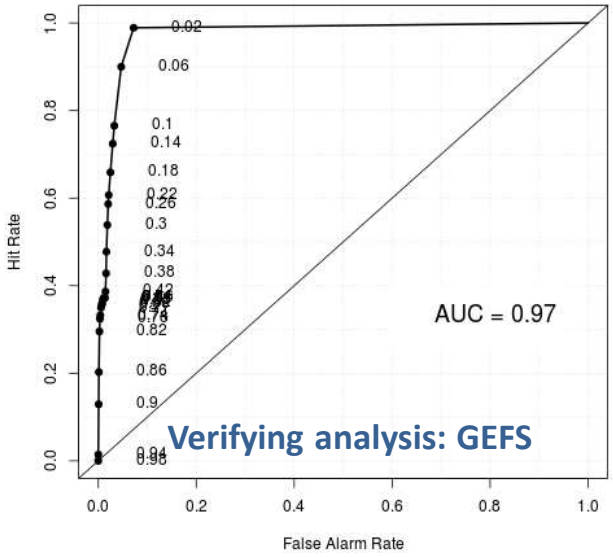
MME (116 ENS)



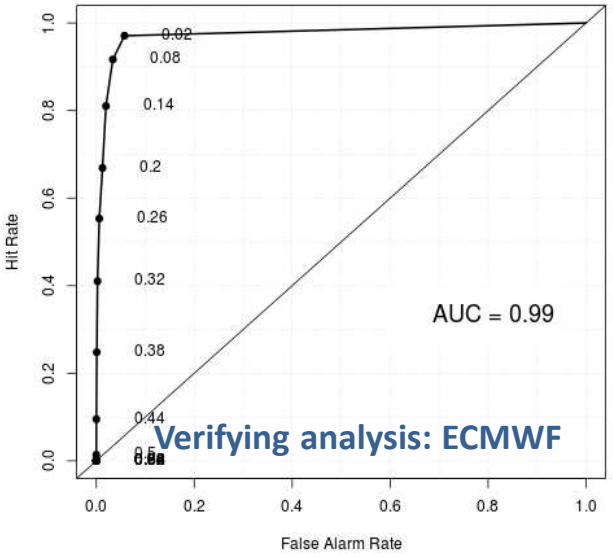
NEPS-G (23 ENS)



GEFS (41 ENS)



ECMWF (51 ENS)

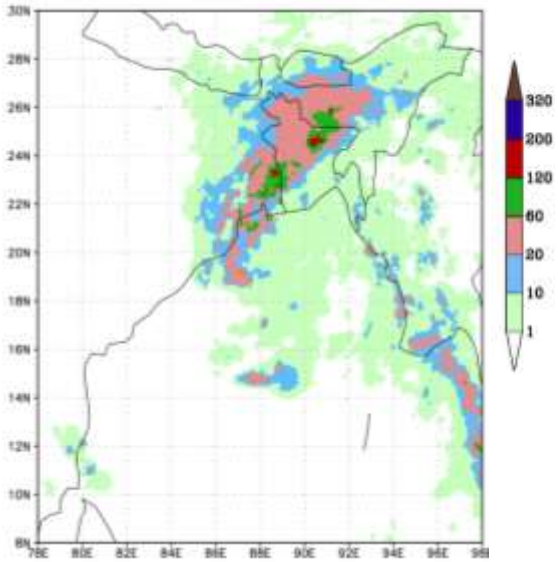


Discrimination of occurrences of event probabilities is **better in NEPS and ECMWF**. **AUC** of **MME is higher** than individual EPS and improves further with addition of ECMWF ensembles.

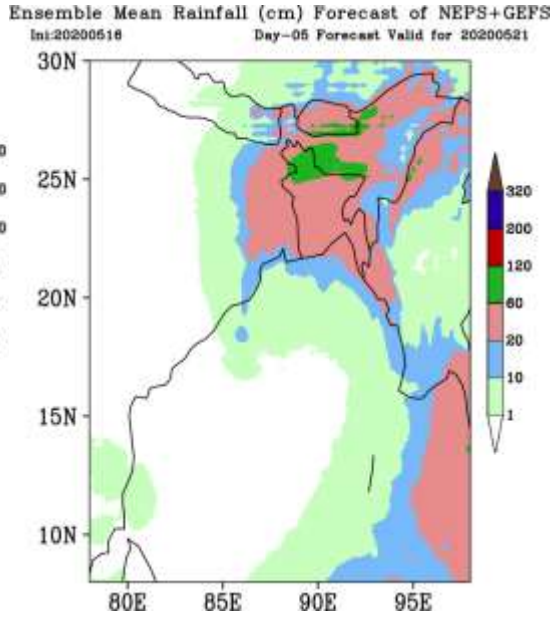
Observed and Ensemble Mean 24-hr accumulated Precipitation day-5 forecast

GPM IMERG

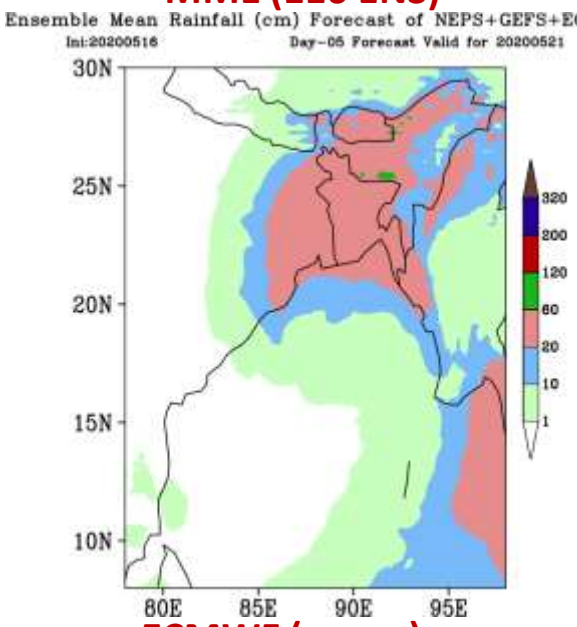
Rainfall for 21st May 2020



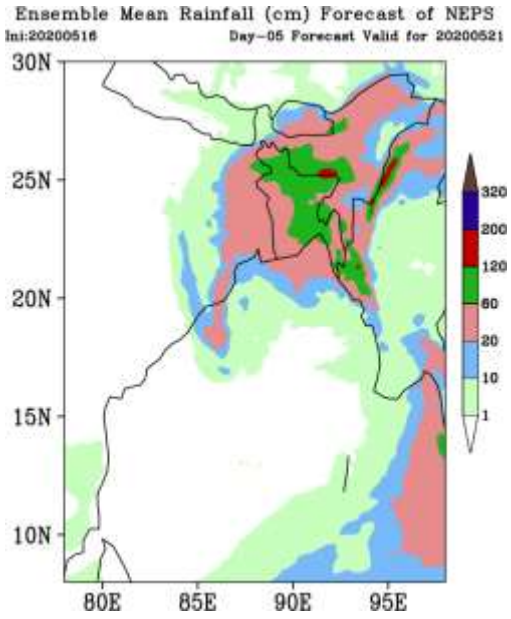
NEPS-G +GEFS (65 members)



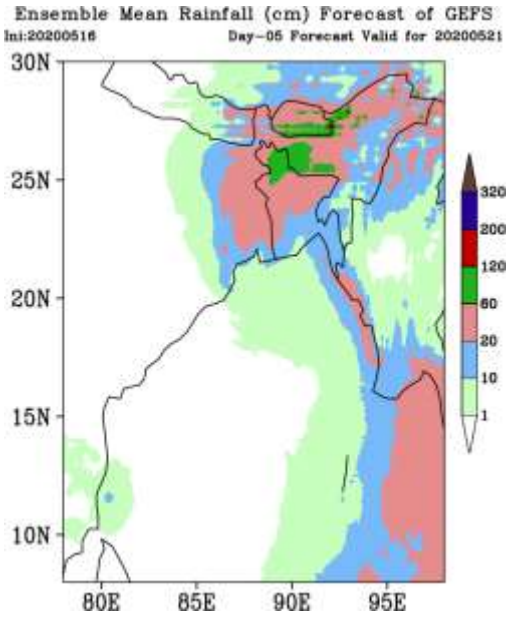
MME (116 ENS)



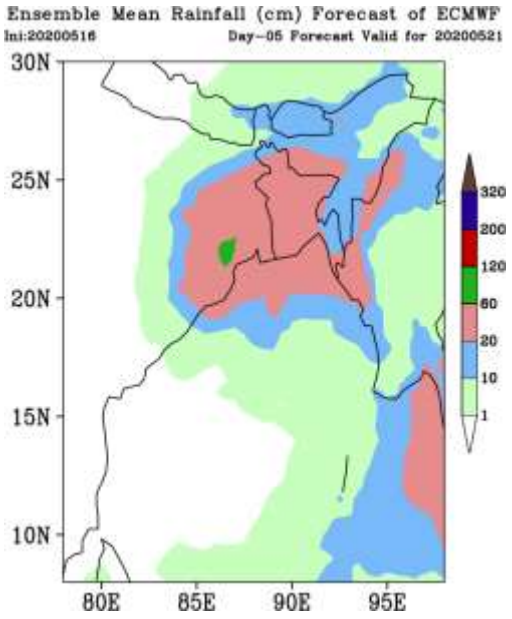
NEPS-G (23 members)



GEFS (42 members)



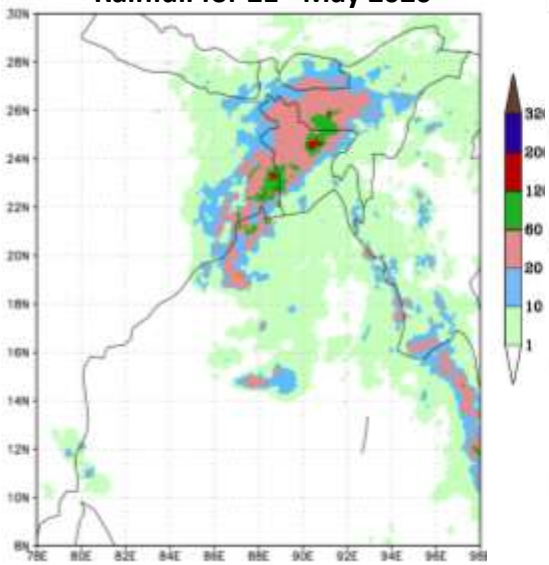
ECMWF (51 ENS)



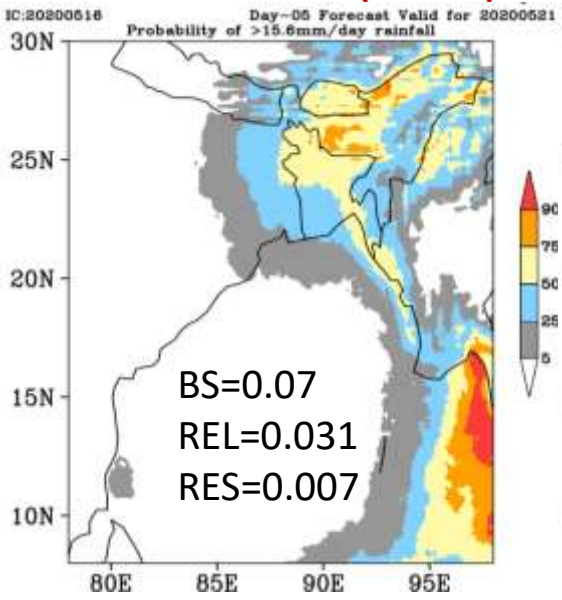
Probability of precipitation > 15.6 mm/day; Day-5 forecast

GPM IMERG

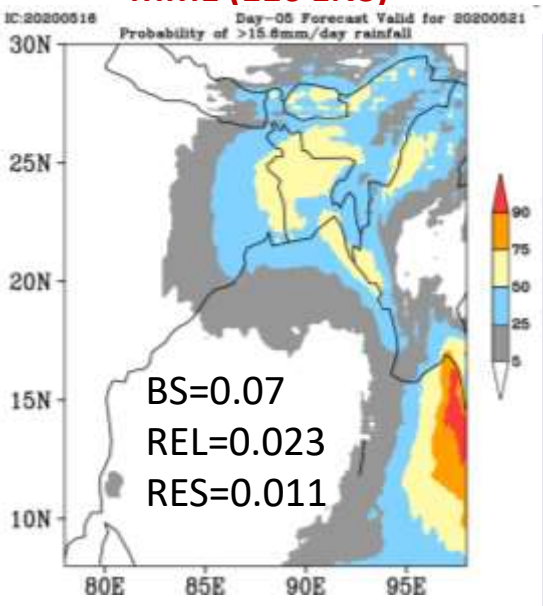
Rainfall for 21st May 2020



NEPS-G +GEFS (65 ENS)



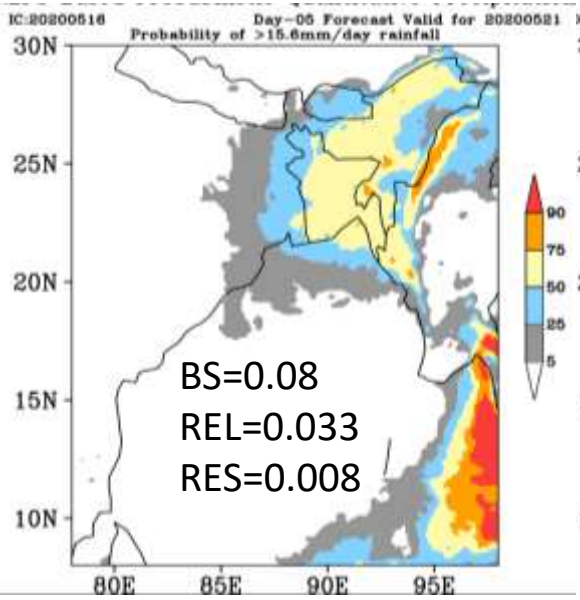
MME (116 ENS)



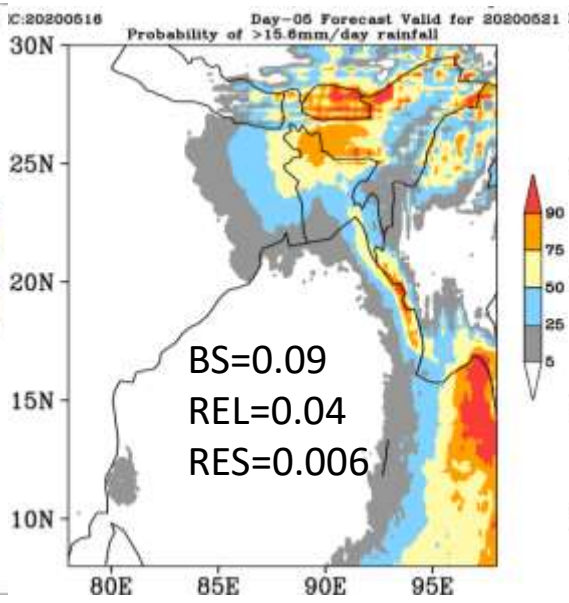
NEPS+GEFS has better scores than individual EPS.

The scores improve further in MME.

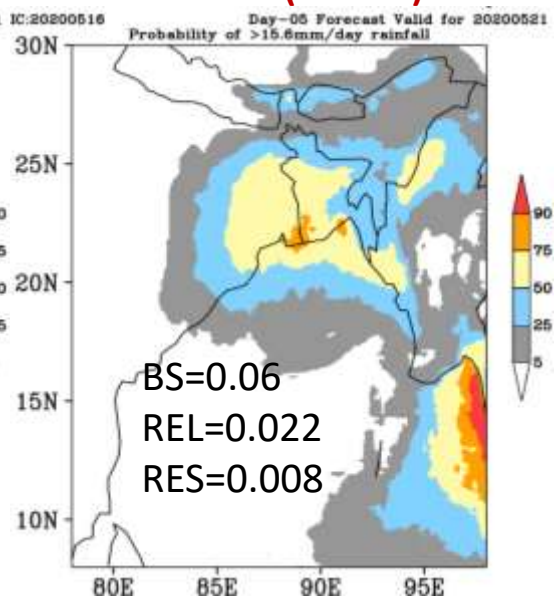
NEPS-G (23 ENS)



GEFS (42 ENS)



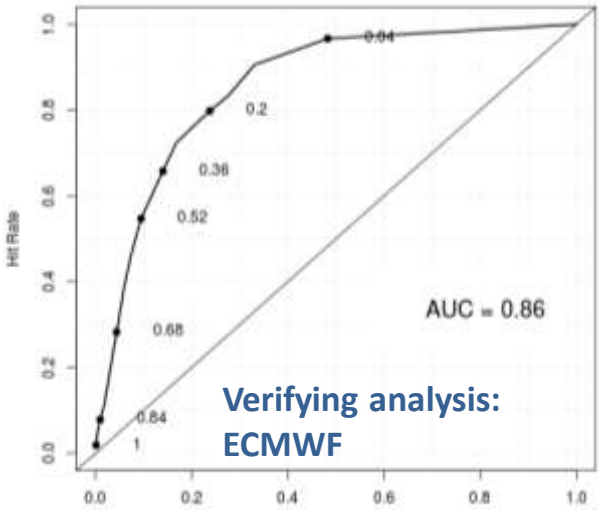
ECMWF (51 ENS)



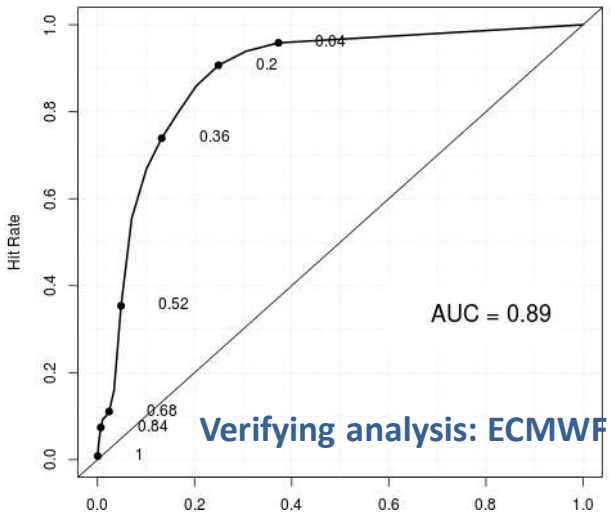
ECMWF EPS has lowest BS and reliability value (higher accuracy & reliability) than NEPS and GEFS.

ROC of the MME and respective EPS day-4 forecast of precipitation >15.6 mm

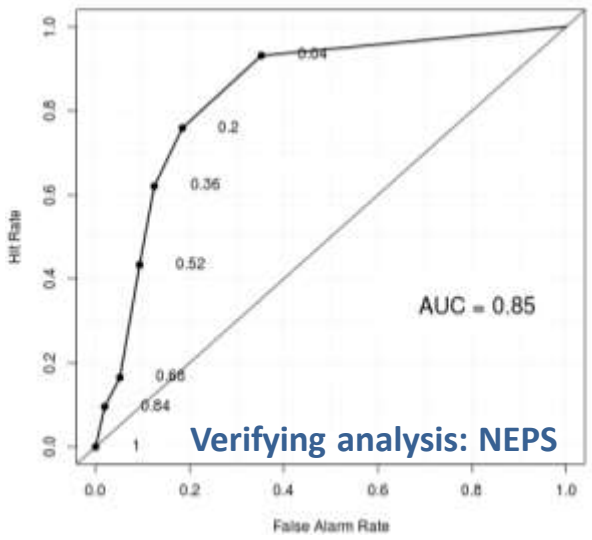
NEPS-G+GEFS (65 ENS)



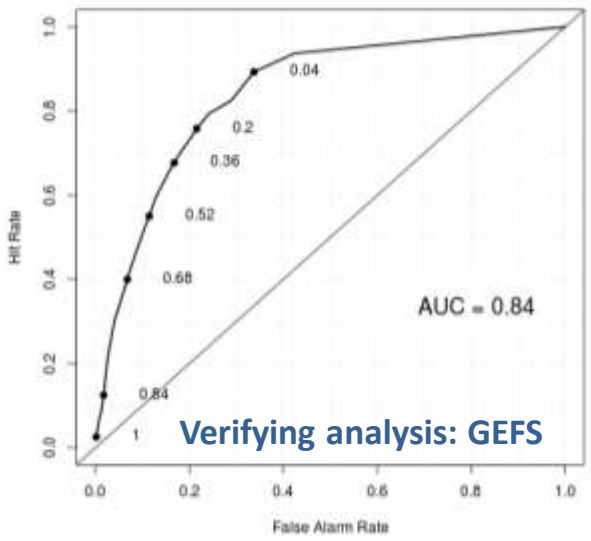
MME (116 ENS)



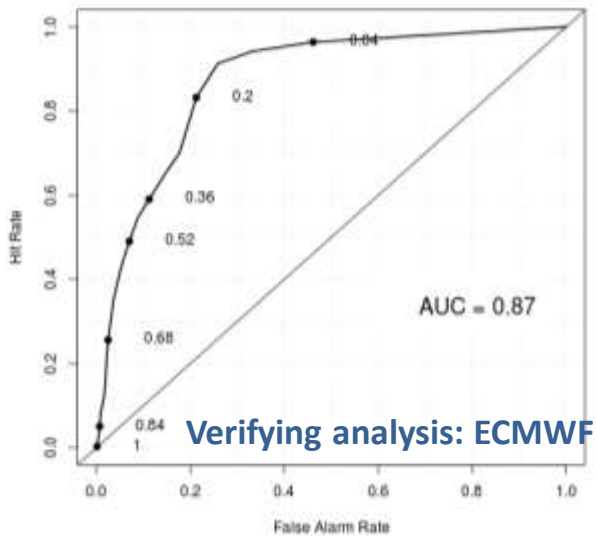
NEPS-G (23 ENS)



GEFS (41 ENS)



ECMWF (51 ENS)



Discrimination of occurrences of event probabilities is **better in ECMWF and NEPS**. **AUC** of **NEPS+GEFS is higher** than individual EPS and **improves further in MME** with addition of ECMWF ensembles.

Summary

1. The system in the NEPS forecasts lied to the right of the observed track and moved faster than the observation, whereas there was a westward bias in GEFS resulting to DPE between 49-220 km for both the EPS. Errors in ensemble mean surface winds are slightly larger in GEFS.

2. Forecast uncertainty is estimated to be lower in ECMWF EPS which contributes to reducing forecast uncertainty in the MME as compared to that obtained in NEPS+GEFS.

3. There is a bias in both NEPS and GEFS to predict lower MSLP and stronger surface winds. Since this bias is considerably lesser in ECMWF EPS, the verifying analysis is more uniformly distributed in the MME rank histograms.

4. The reliability and ROC skill (AUC) of the MME (for predicting the threshold probabilities of 10m winds and MSLP of CS stage) improves with incorporation of ECMWF ensemble forecasts.

5. Moderate to heavy rainfall was observed in GPM IMERG over east India between 20-21st May. The heavy rainfall is under estimated in all the three ensembles mean. The moderate rainfall could be predicted with 50-75% probability by the three EPS. The ROC skill (AUC), BS, REL and RES scores better for NEPS+GEFS relative to the individual EPS, improving further with addition of ECMWF ensembles in MME.

Thanks!

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