

High-resolution Global Ensemble Forecast System (GEFS T1534) for the Indian summer monsoon and extreme rainfall: Verification and forecast products

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**9th NOAA Ensemble Users Workshop
23rd August 2023**

Increase of extreme rainfall events

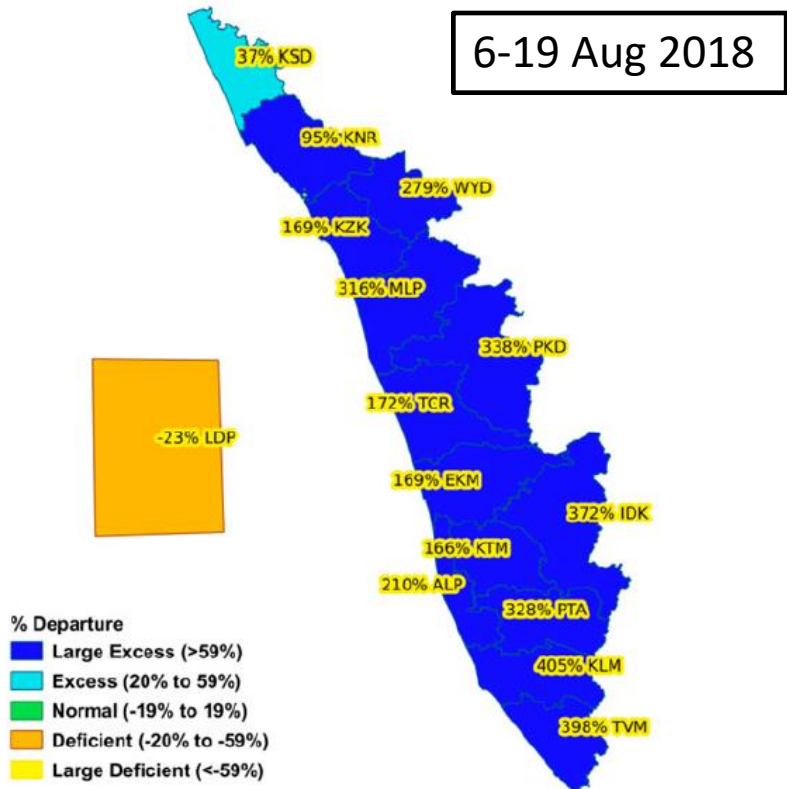


RAINFALL % DEPARTURES FROM THE LONG PERIOD AVERAGES FOR DISTRICTS IN KERALA.

Period 06.08.18 to 19.08.18
 Actual: 704 mm
 Normal: 209 mm
 Dep From Normal: 236%

- KSD - KASARAGOD
- KNR - KANNUR
- WYD - WAYANAD
- KZK - KOZHIKODE
- MLP - MALAPPURAM
- PKD - PALAKKAD
- TCR - THRISSUR
- EKM - ERNAKULAM
- IDK - IDUKKI
- KTM - KOTTAYAM
- ALP - ALAPPUZHA
- PTA - PATHANAMTHITTA
- KLM - KOLLAM
- TVM - THIRUVANANTHAPURAM
- LDP - LAKSHADWEEP

6-19 Aug 2018

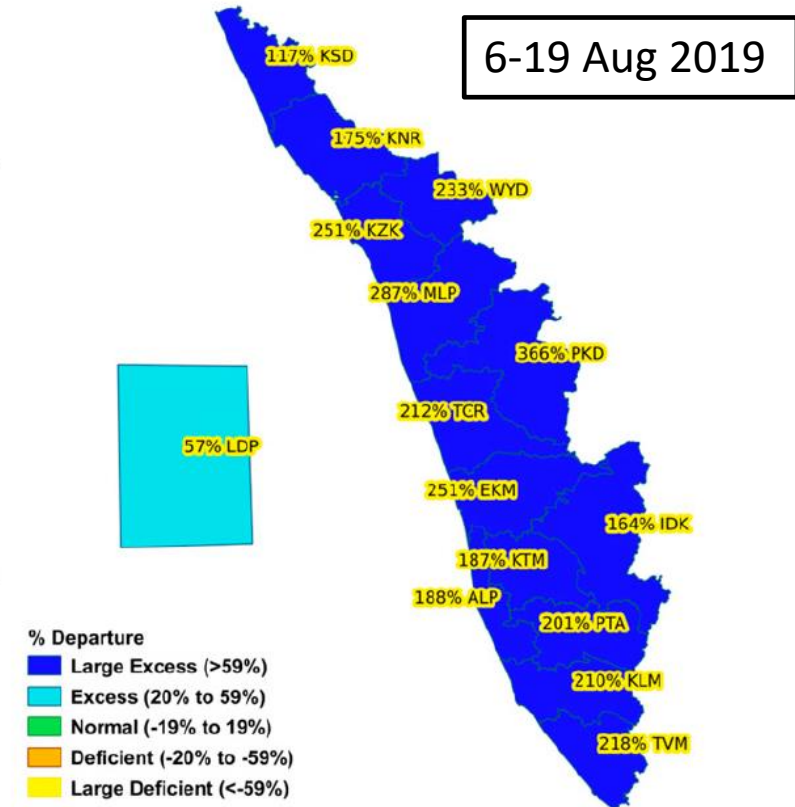


RAINFALL % DEPARTURES FROM THE LONG PERIOD AVERAGES FOR DISTRICTS IN KERALA.

Period 06.08.19 to 19.08.19
 Actual: 668 mm
 Normal: 209 mm
 Dep From Normal: 219%

- KSD - KASARAGOD
- KNR - KANNUR
- WYD - WAYANAD
- KZK - KOZHIKODE
- MLP - MALAPPURAM
- PKD - PALAKKAD
- TCR - THRISSUR
- EKM - ERNAKULAM
- IDK - IDUKKI
- KTM - KOTTAYAM
- ALP - ALAPPUZHA
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- KLM - KOLLAM
- TVM - THIRUVANANTHAPURAM
- LDP - LAKSHADWEEP

6-19 Aug 2019

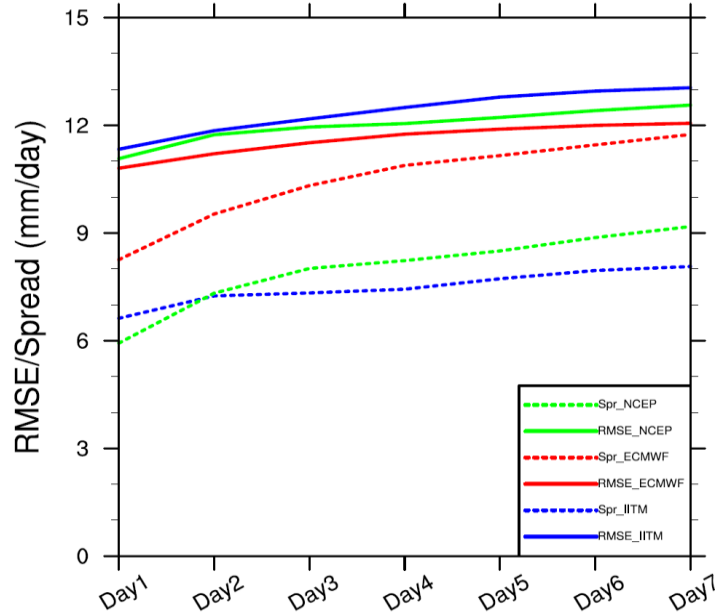


Description of operational Global Ensemble Forecast System (GEFS) T 1534

Model Description	Two-time level semi-implicit, Semi-Lagrangian linear grid
Time-steps	Dynamics 900, Physics 450, Radiation: 1Hour for SW/LW
No of Ensembles	21 (20 perturbed + 1 Control)
Perturbation Method	Ensemble Kalman Filter
Parameters	Critical Relative Humidity = 0.9,0.9,0.9 Auto Conversion(Ice to snow) =6.0e-4,3.0e-4 Auto conversion (cloud to rain) = 1.0e-4, 1.0e04 Threshold (ice/water) = 1.0e-5,1.0e-5 coeff for evaporation of large scale rain = 2.0e-5 Factors for CDMB and GWD : 2.0, 0.25
Resolution	T1534 (3072 x 11534) ~ 13Km at poles
Land Surface Model	NOAH Land Surface Model
PBL	Hybrid Eddy-diffusivity Mass-flux Scheme
GWD	Orographic and Convective Gravity Wave Drag
Deep Convection	scale- & aerosol-aware mass-flux deep conv scheme
Shallow Convection	New Mass flux based shallow convection
Microphysics	Zhao-Carr Microphysics scheme
Radiation	Optimized versions of RRTMG for Long-wave and Short-wave

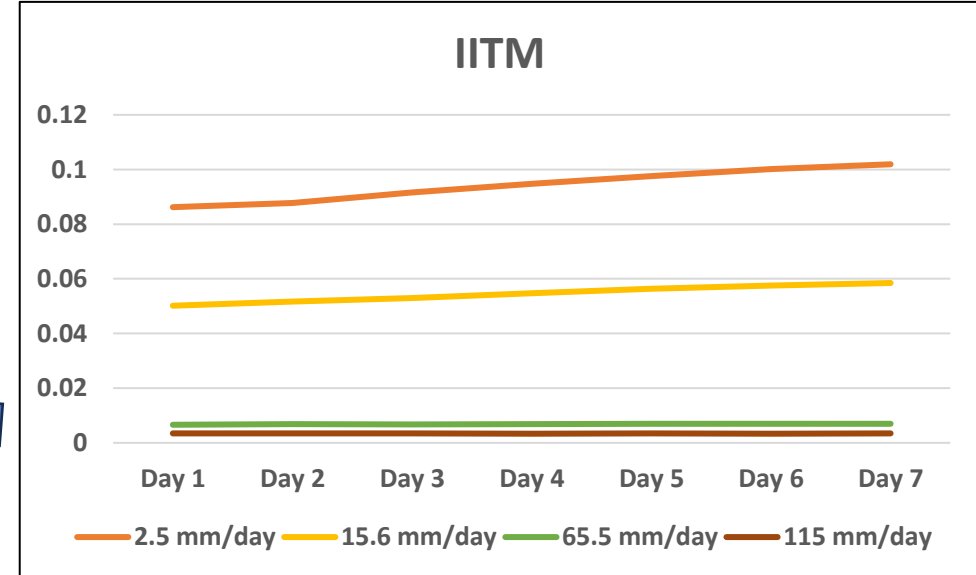
The GEFS has been operational at India Meteorological Department (IMD) since 2018 to generate 10 days forecast at a 3 hr intervals and a resolution of 0.125°x0.125°

Verification of rainfall forecast for JJAS 2018-2022 from IITM, NCEP and ECMWF models over the Indian land region (8°N-37.5°N, 68°E-97.5°E)

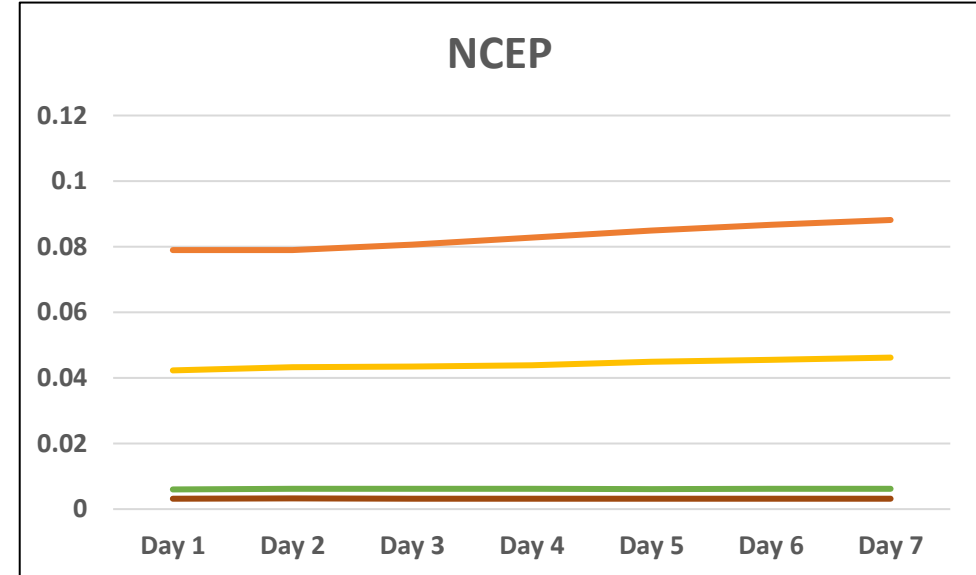
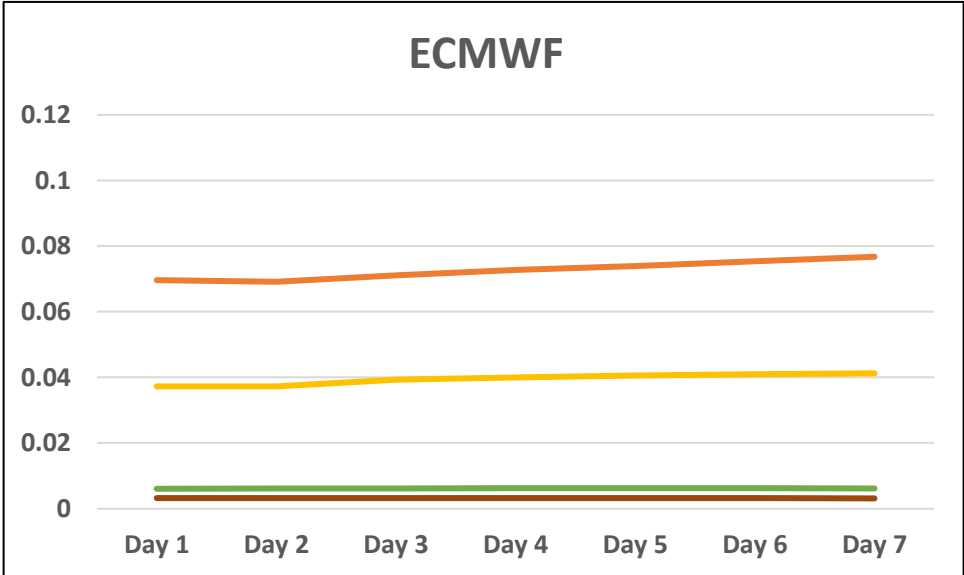


Observation:
IMD-GPM merged rainfall dataset
for the same time period and at a
resolution of 0.5° × 0.5°

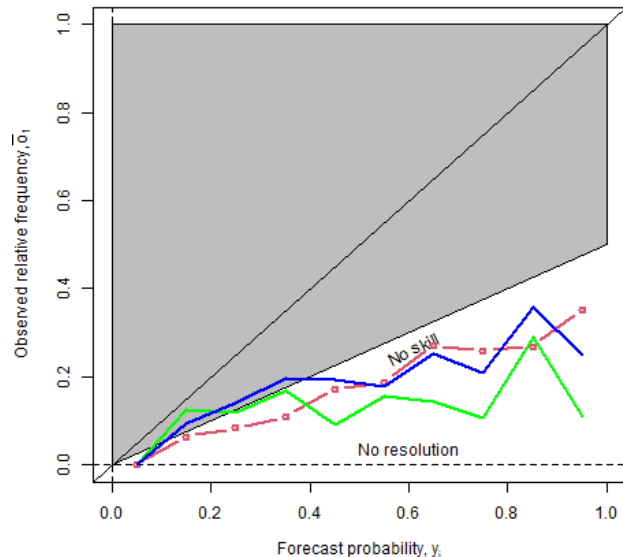
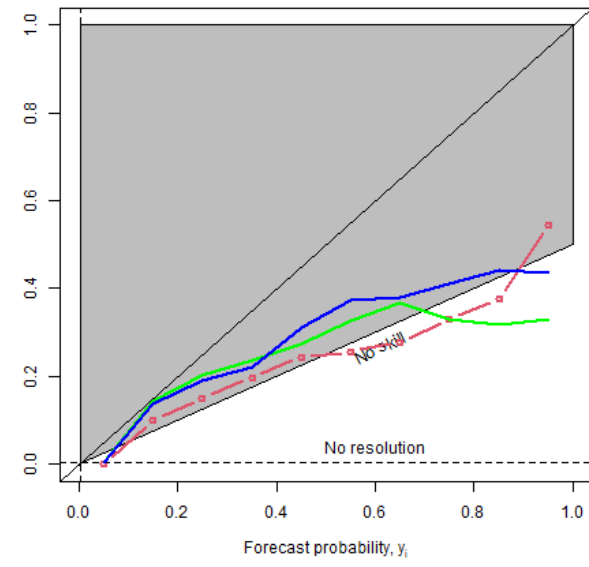
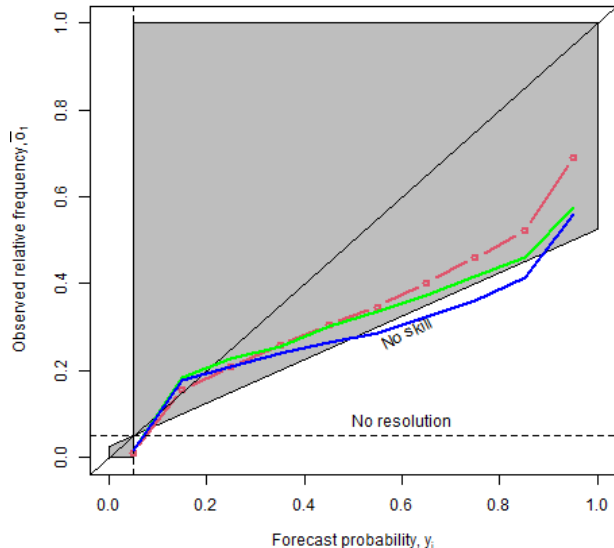
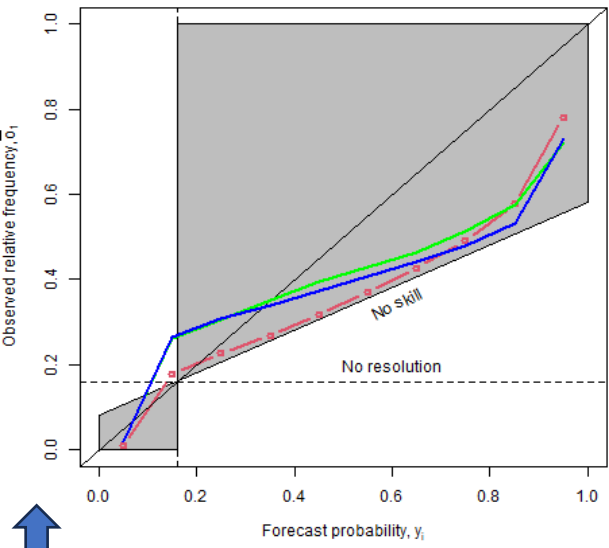
Brier Score (BS) for
rainfall forecast.
Lesser the BS, better
the skill.



RMSE (solid) and
ensemble spread
(dashed) of rainfall
forecast from IITM
(blue), NCEP (green)
and ECMWF (red)

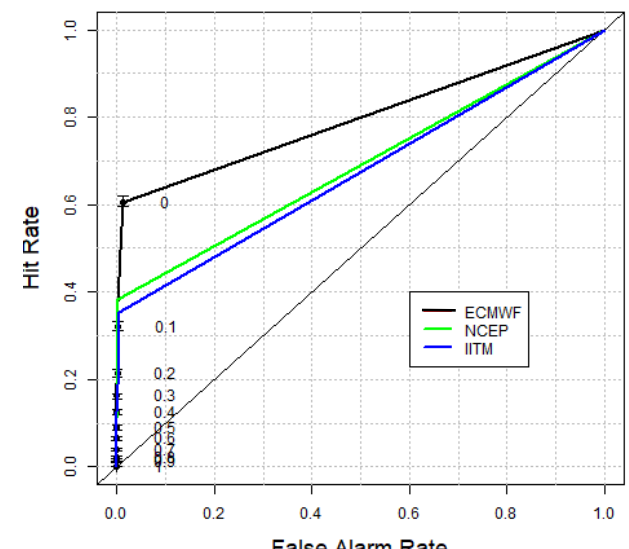
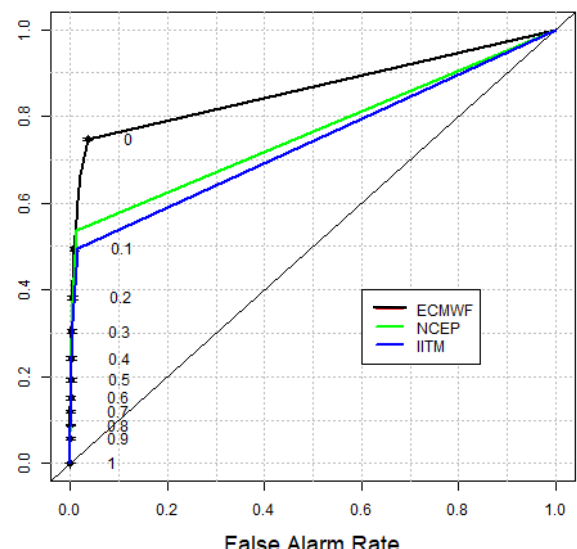
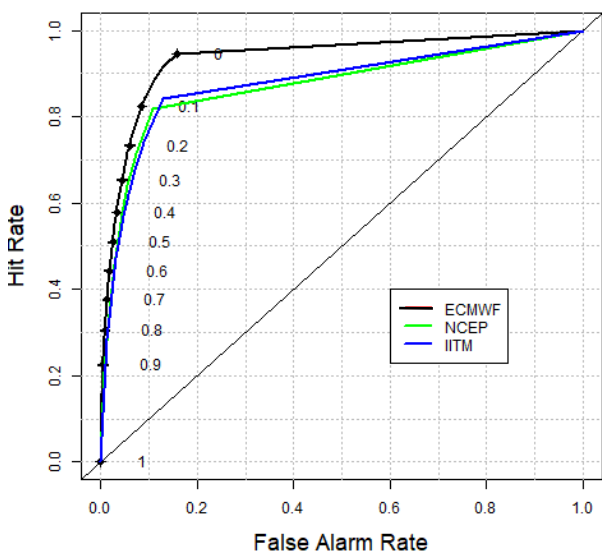
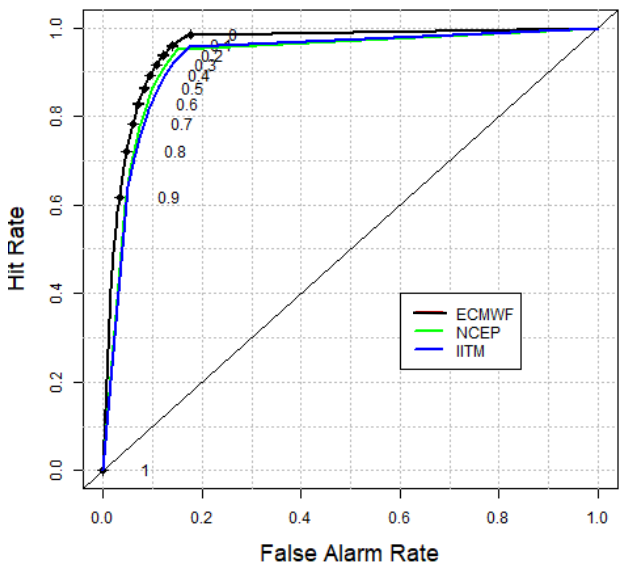


Verification (contd.)



Reliability Diagram for **day 1** rainfall forecast from IITM (blue), NCEP (green) and ECMWF (red)

ROC curve for **day 1** rainfall forecast from IITM (blue), NCEP (green) and ECMWF (black)



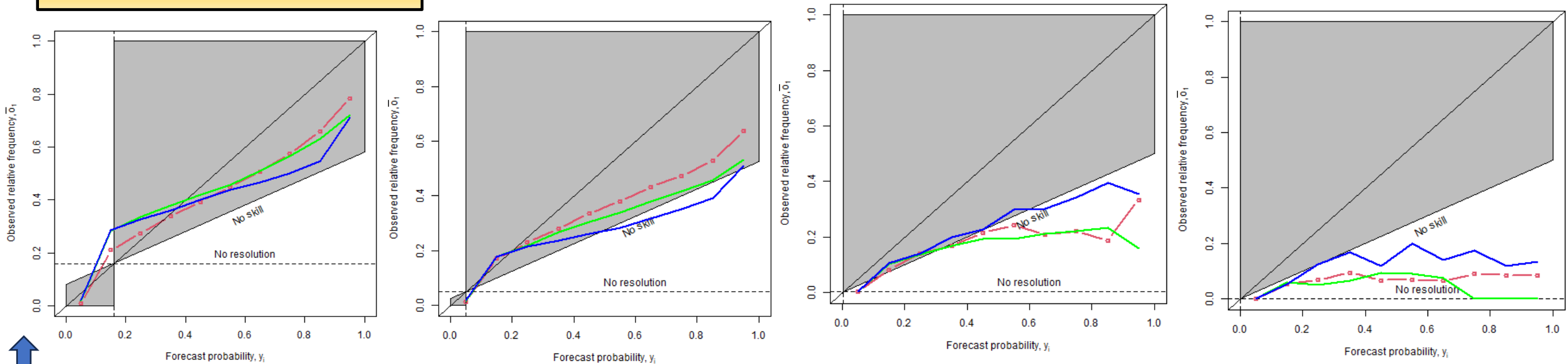
> 2.5 mm/day

> 15.6 mm/day

> 65.5 mm/day

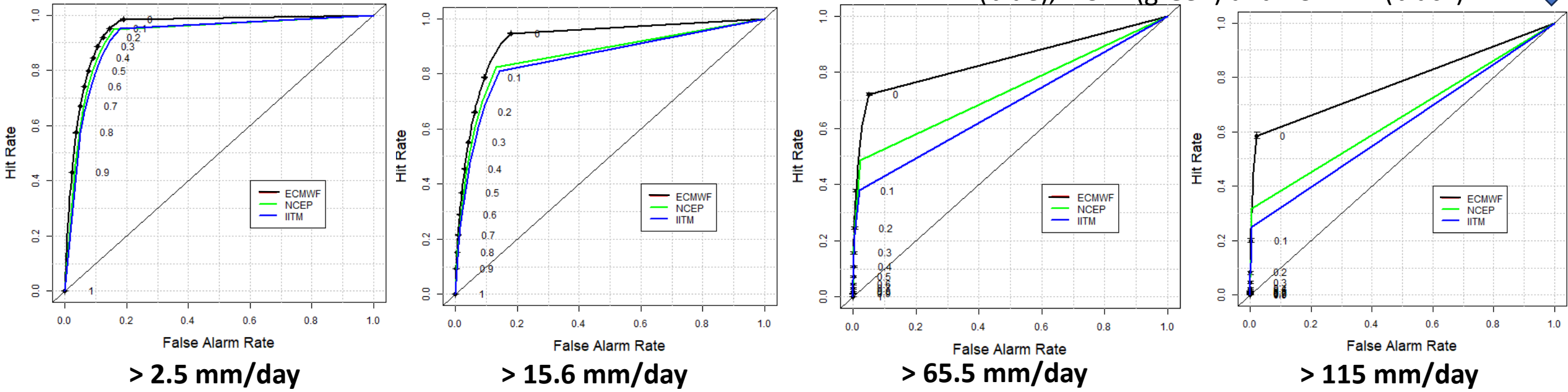
> 115 mm/day

Verification (contd.)



Reliability Diagram for day 3 rainfall forecast from IITM (blue), NCEP (green) and ECMWF (red)

ROC curve for day 3 rainfall forecast from IITM (blue), NCEP (green) and ECMWF (black)



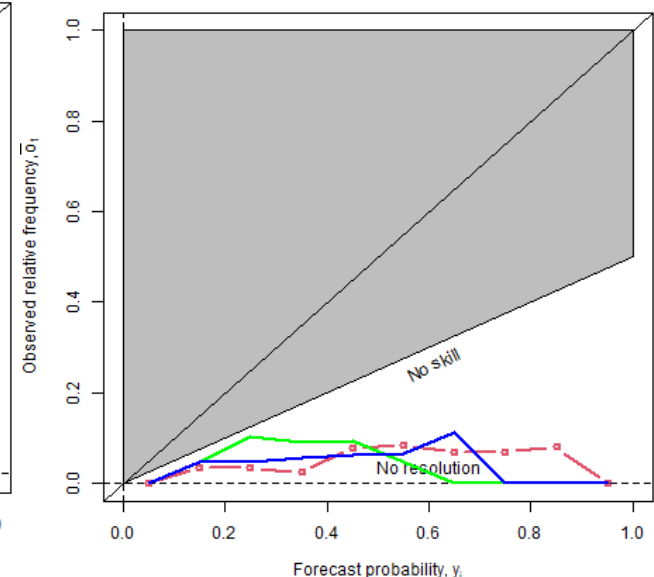
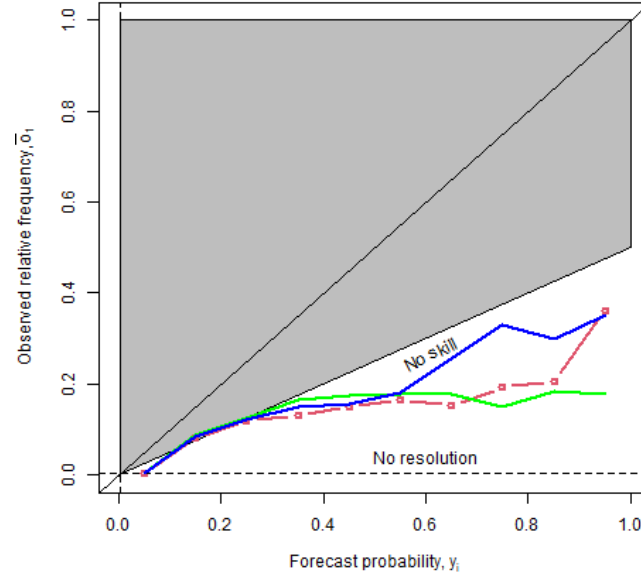
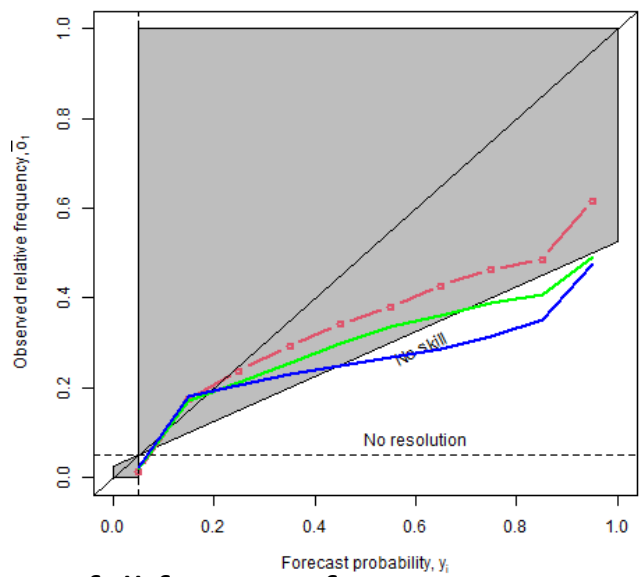
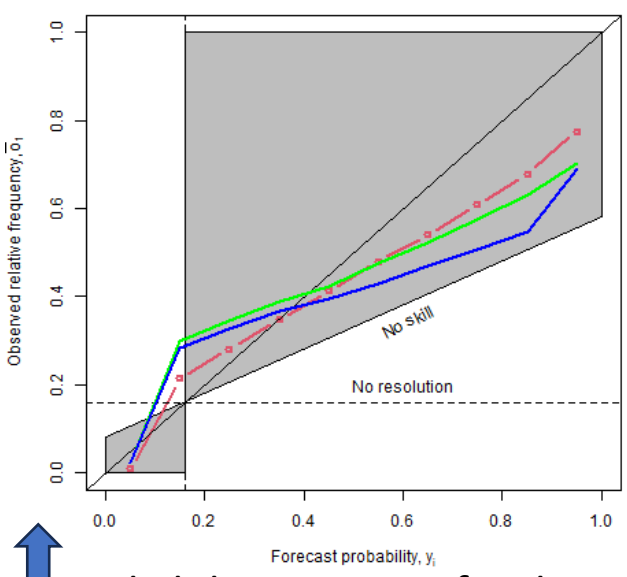
> 2.5 mm/day

> 15.6 mm/day

> 65.5 mm/day

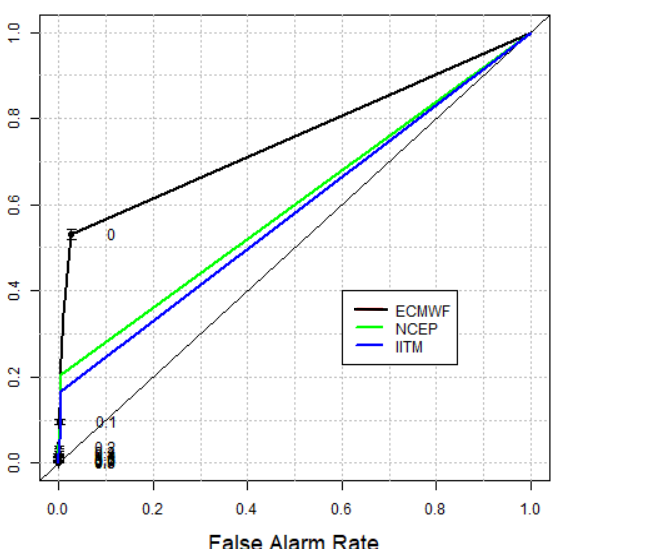
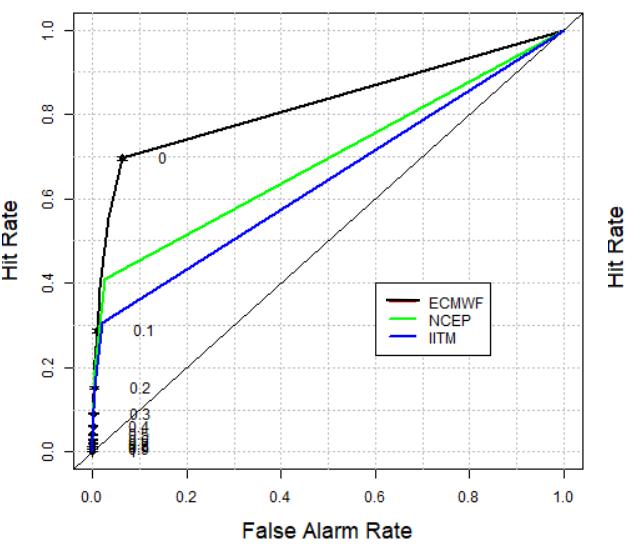
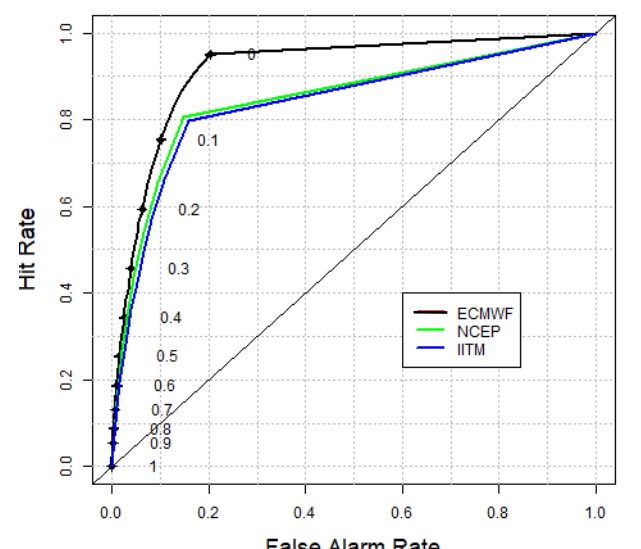
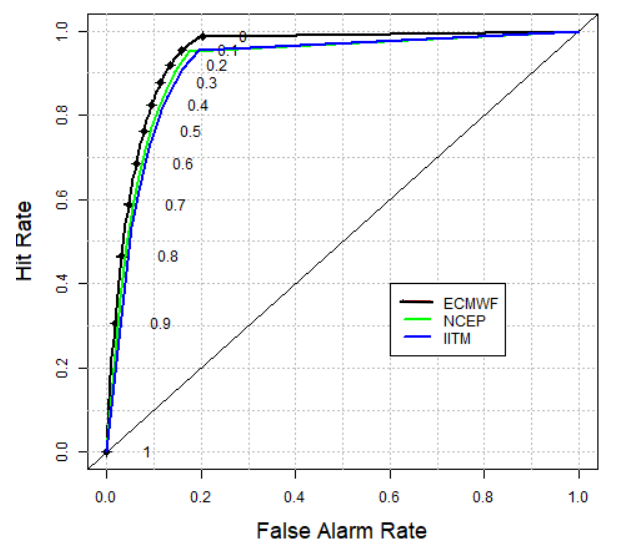
> 115 mm/day

Verification (contd.)



Reliability Diagram for day 5 rainfall forecast from IITM (blue), NCEP (green) and ECMWF (red)

ROC curve for day 5 rainfall forecast from IITM (green), NCEP (red) and ECMWF (black)



> 2.5 mm/day

> 15.6 mm/day

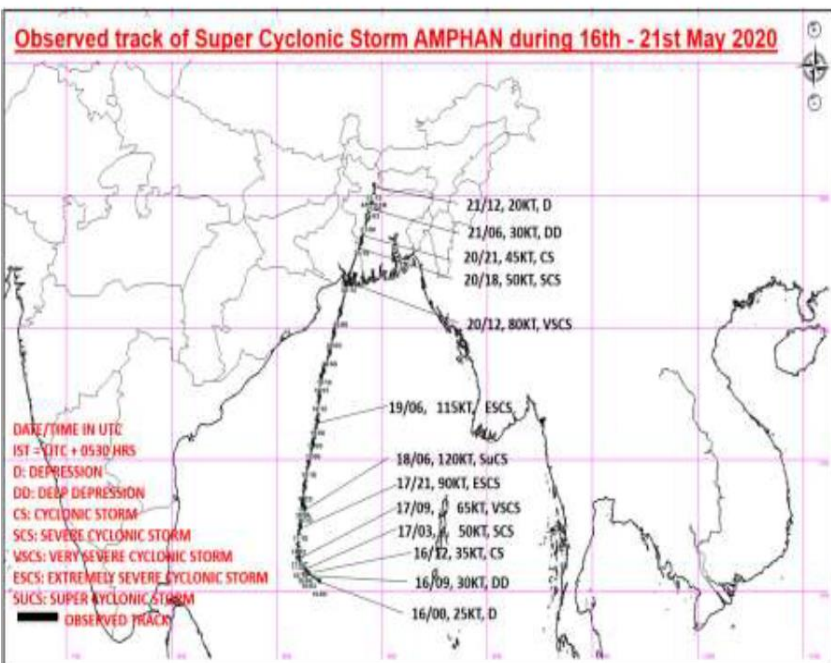
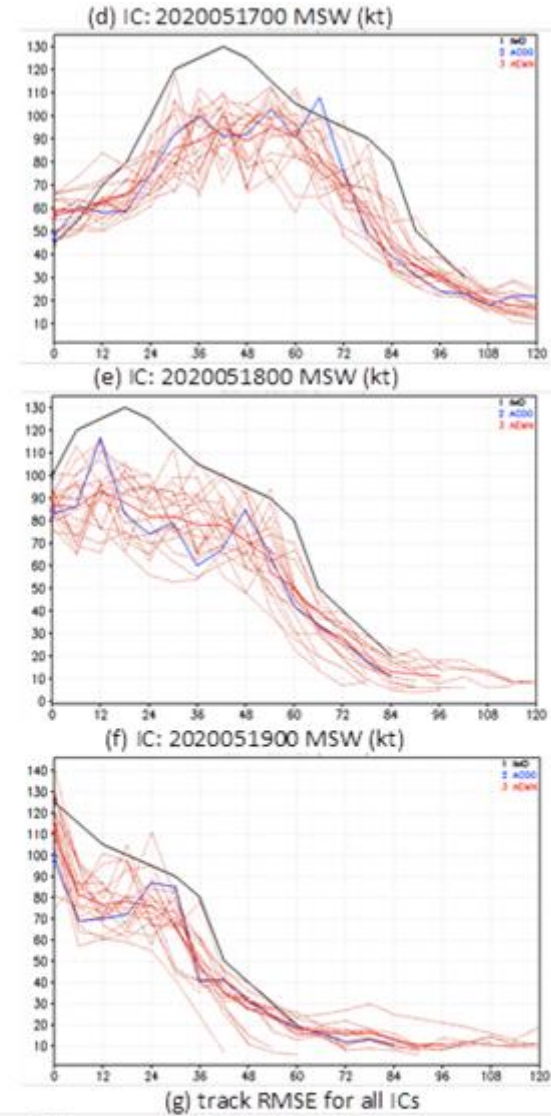
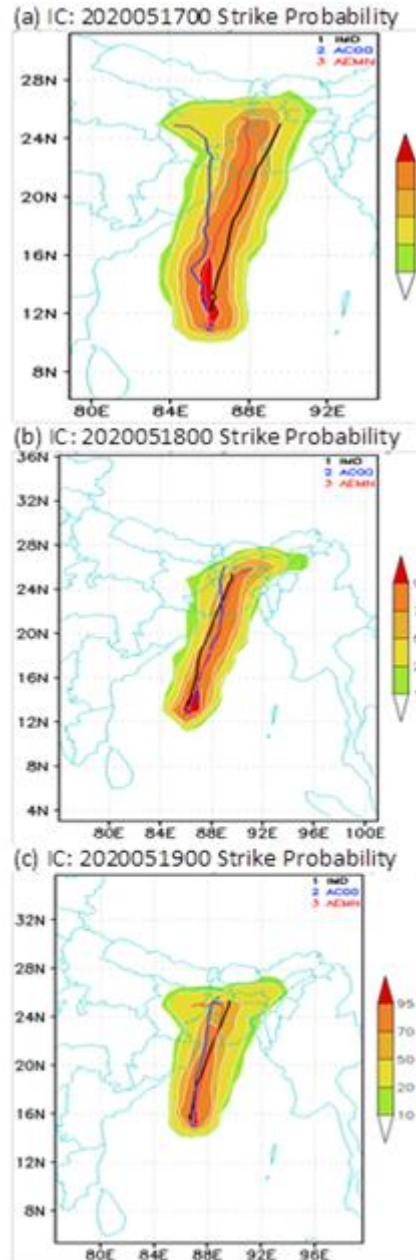
> 65.5 mm/day

> 115 mm/day

The Super Cyclonic Storm (SuCS) "AMPHAN"

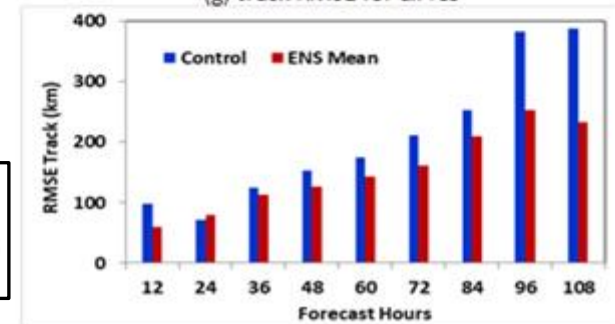
- The system intensified into Cyclonic Storm "AMPHAN" over southeast BoB in the evening (1200 UTC) of 16th May, 2020.
- It became a Super Cyclonic Storm (SuCS) around noon (0600 UTC) of 18th May, 2020 then weakened into an ESCS over westcentral BoB around noon (0600 UTC) of 19th May.
- Thereafter, it crossed West Bengal – Bangladesh coasts as a VSCS, across Sundarbans during 1000-1200 UTC of 20th May, with maximum sustained wind speed of 155 – 165 kmph gusting to 185 kmph.

Source: IMD



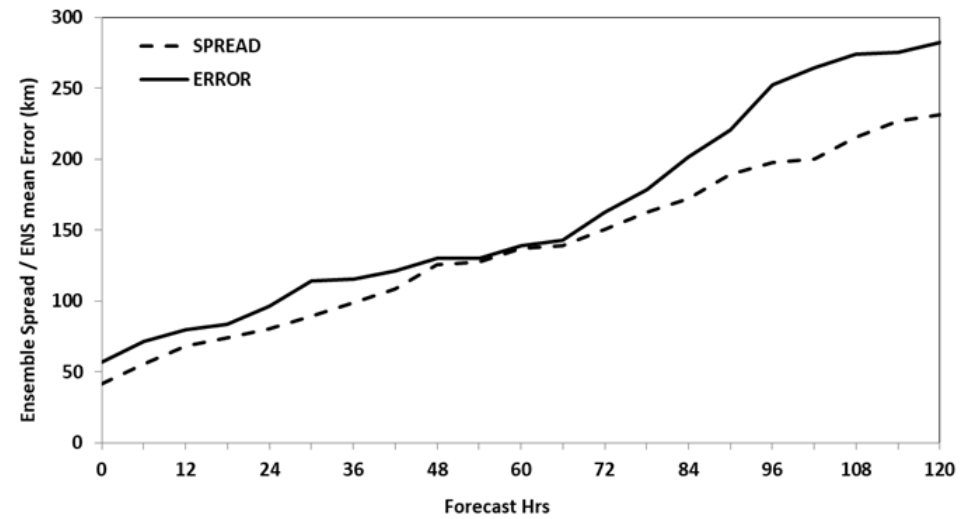
Observed Track

(a-c) Strike probability from GEFs, (d-f) Maximum sustained winds, (g) Track error

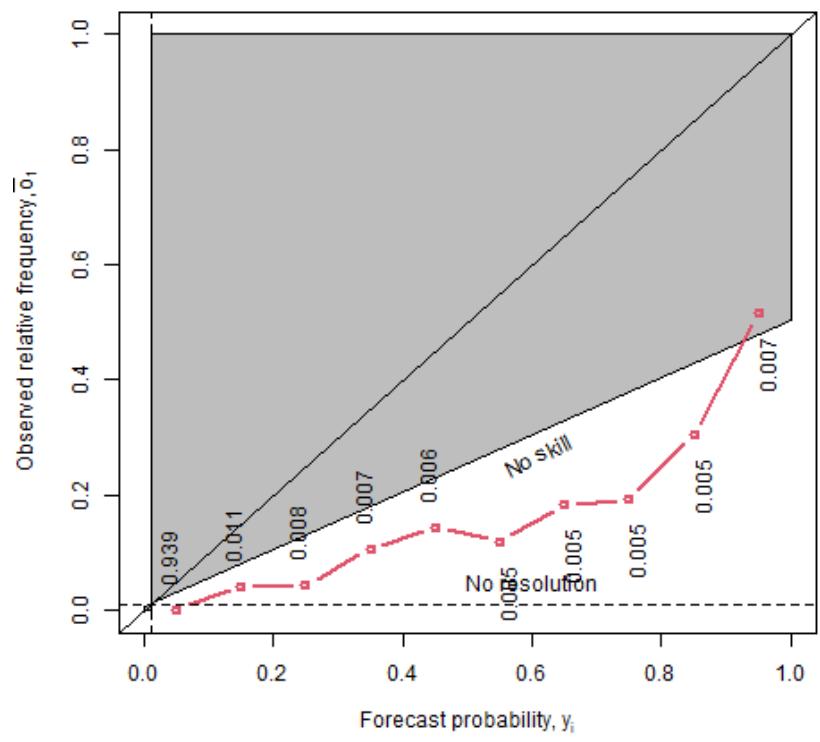


Model Skill for the Strike Probability of Tropical Cyclones

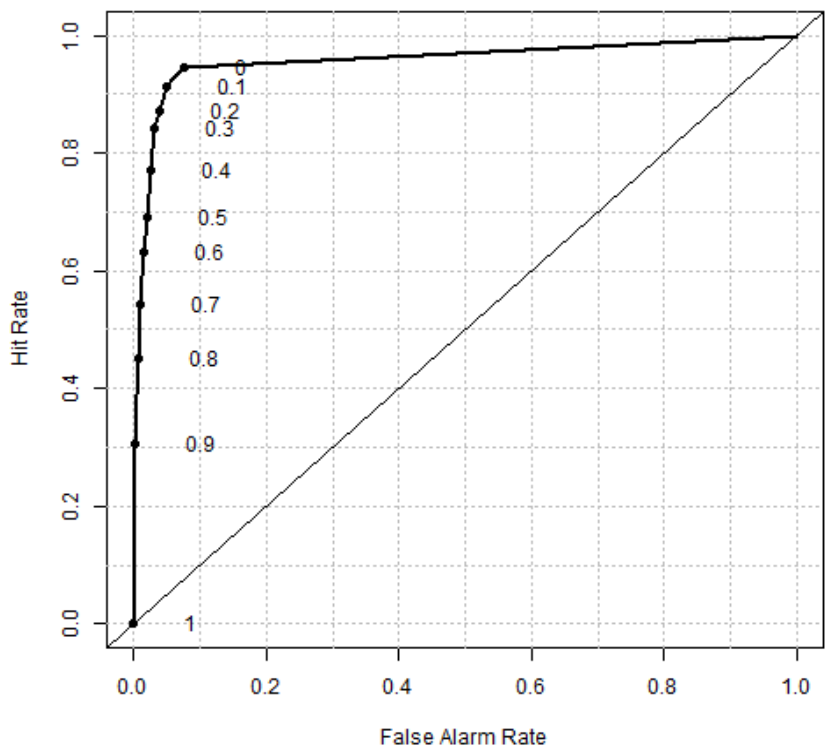
We evaluate the skill of the model in predicting TCs during 2018, 2019 and two cases in 2020 with a total of 13 cases are considered to compute various skill scores. *(Deshpande et al 2021)*



Ensemble Spread and ENS Mean Error



Reliability Diagram

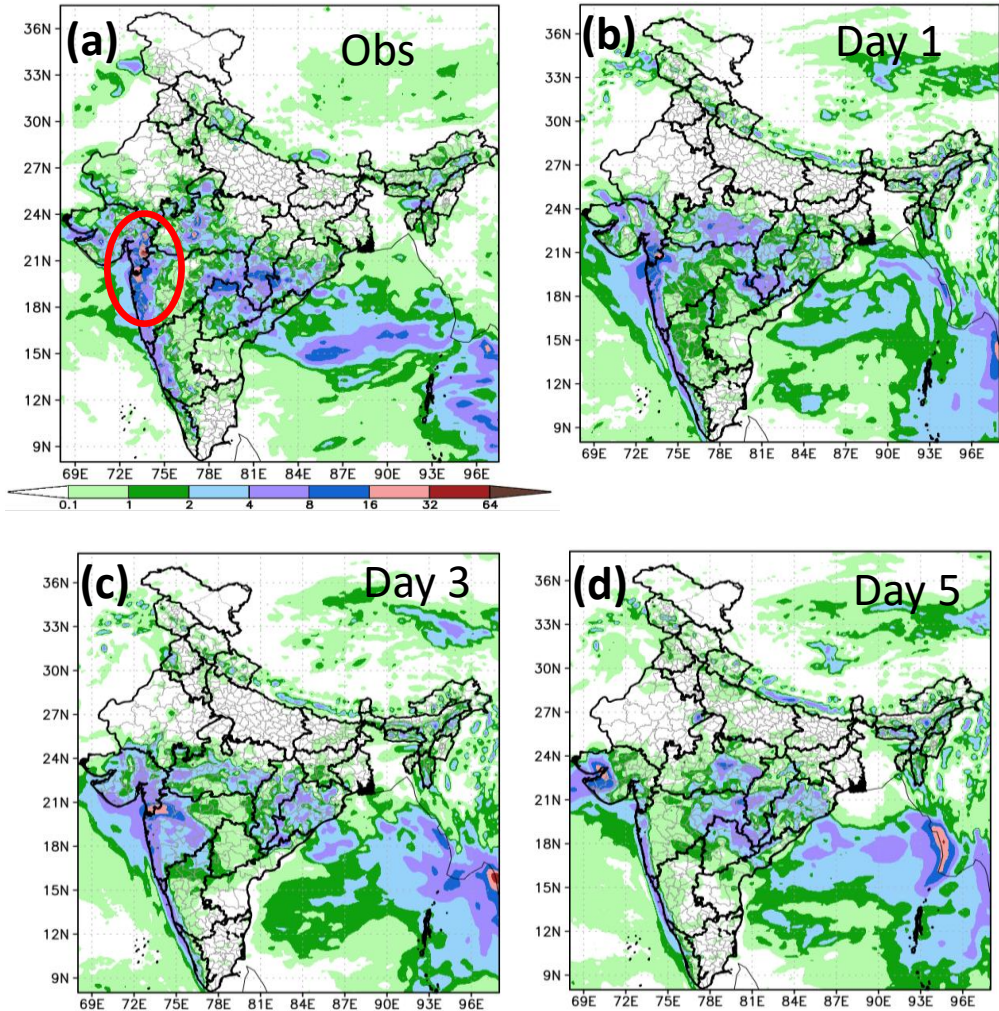


Relative Operating Characteristic (ROC) curve

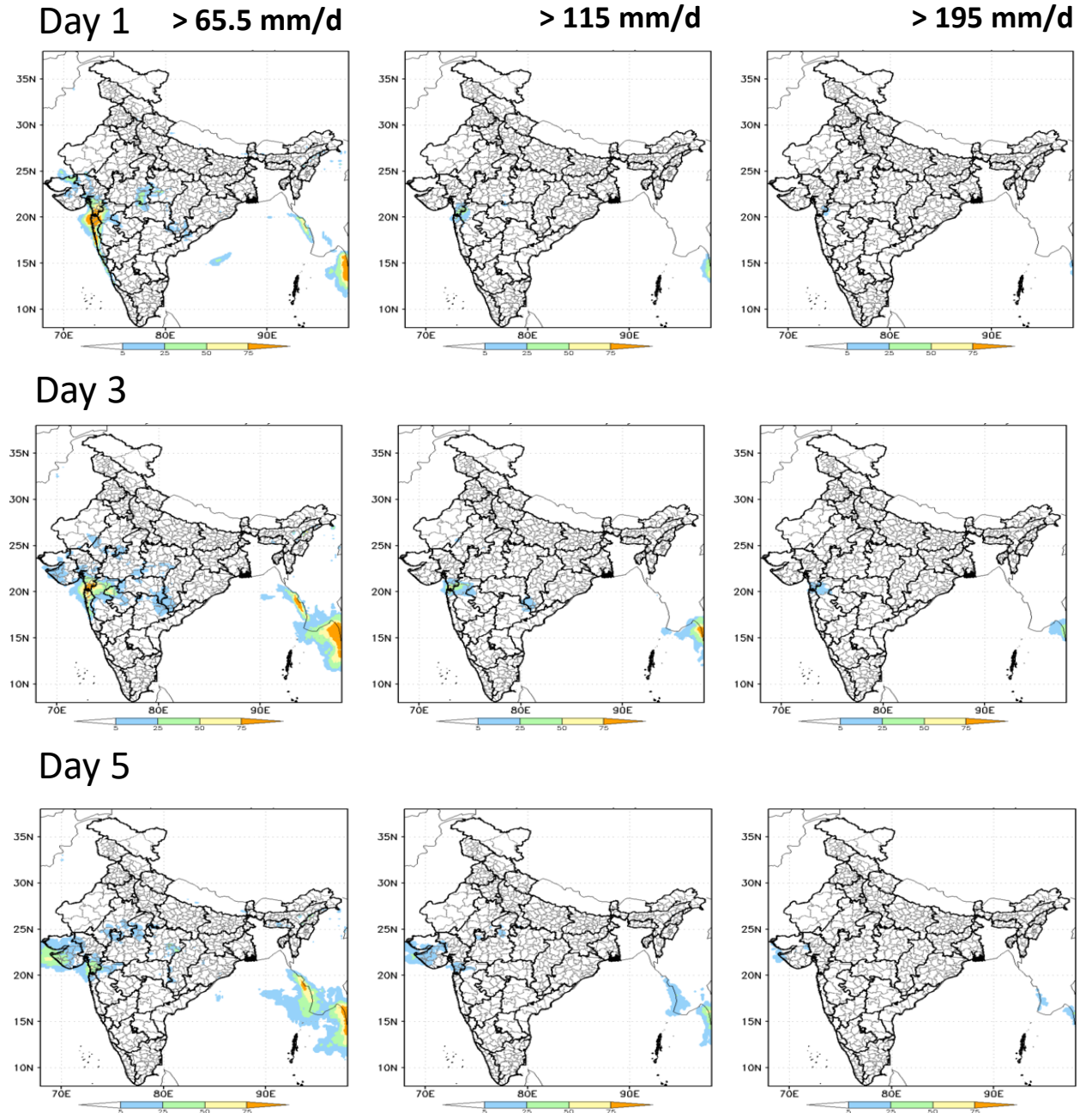
Brier Score=0.02
AROC=0.96

GEFS forecast products

A extremely heavy rainfall event over the western coast of India on 12th July 2022 from (a) IMD GPM (b-d) day 1, 3 and 5 forecast from GFS T1534

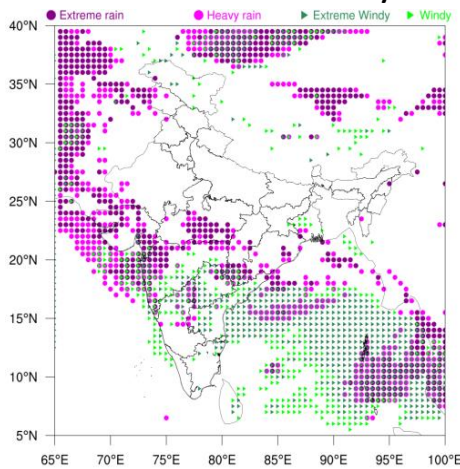


GEFS T1534 forecast valid for 12 July 2022

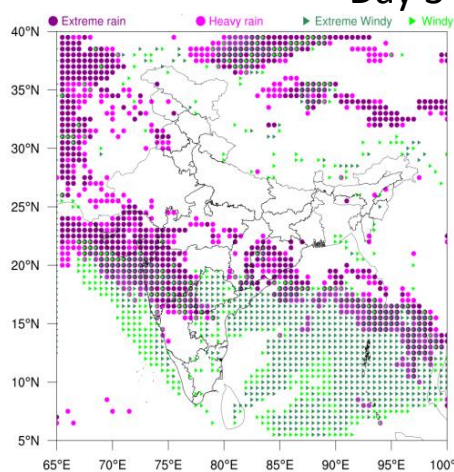


Percentile based forecast

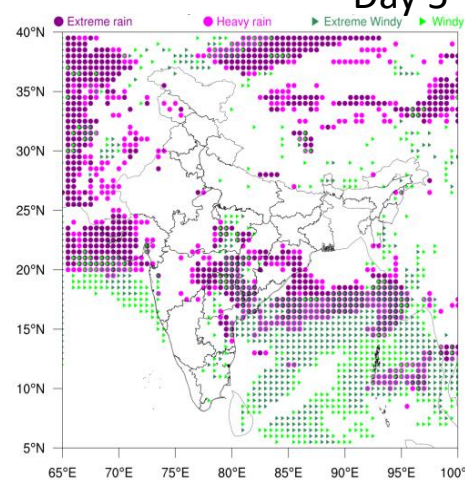
Day 1



Day 3

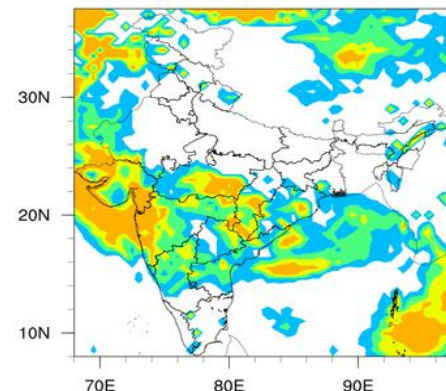


Day 5

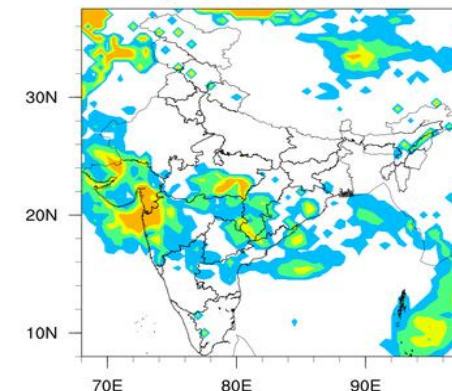


Percentile forecast from GFS T1534 for the Day 1, 3 and 5 forecast valid for 12 July 2022. GFS hindcast data from 1999-2018 JJAS is used to calculate the climatology. Forecast exceeding the 90th and 95th percentile of the climatology is indicated.

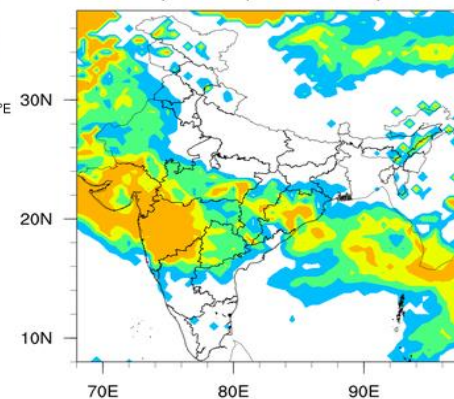
Probability > 90th percentile Day 1 FCST



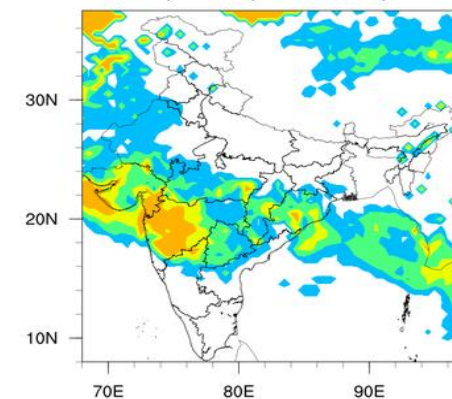
Probability > 95th percentile Day 1 FCST



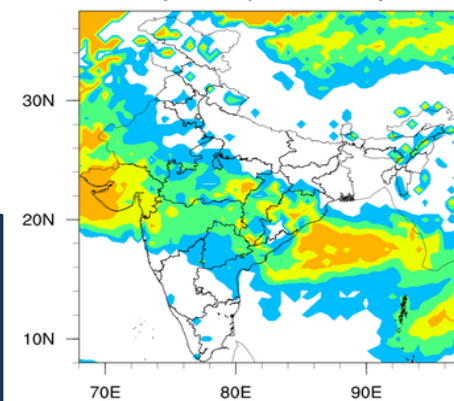
Probability > 90th percentile Day 3 FCST



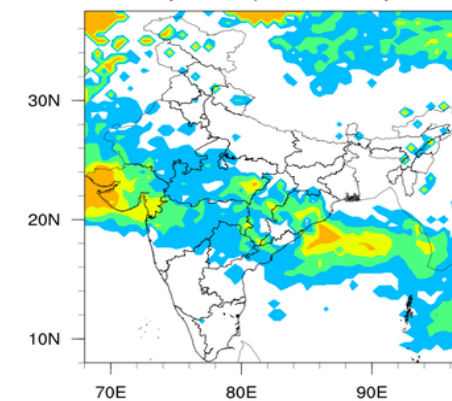
Probability > 95th percentile Day 3 FCST



Probability > 90th percentile Day 5 FCST



Probability > 95th percentile Day 5 FCST

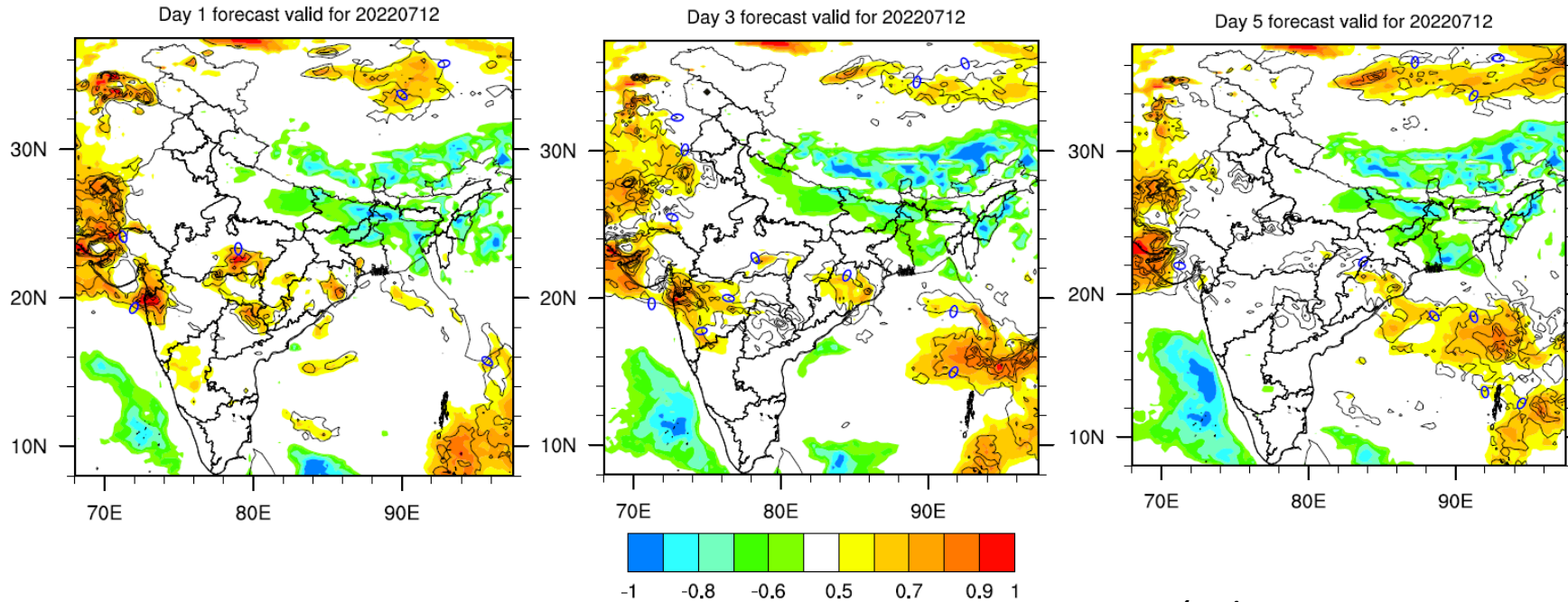
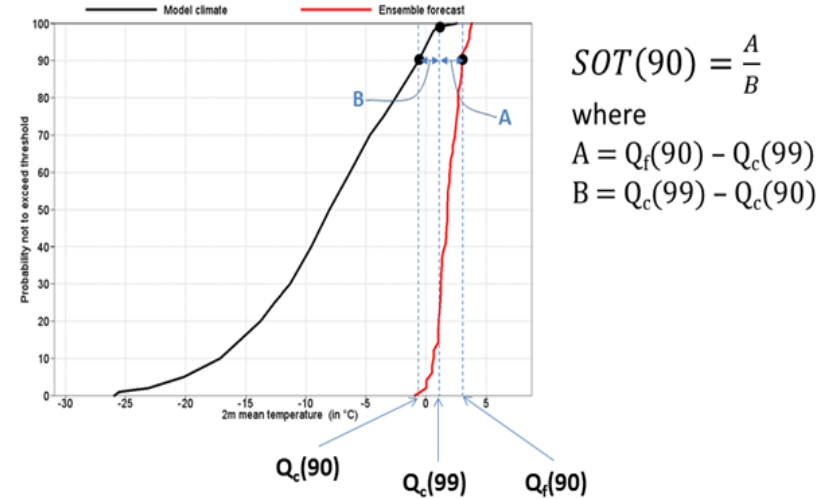


The probability of exceeding the 90th and 95th percentile rainfall is shown from GEFS T1534 for the Day 1, 3 and 5 forecast valid for 12 July 2022

Extreme Forecast Index (EFI) and Shift of Tails (SOT)

The Extreme Forecast Index (EFI, shaded) and Shift of Tails (SOT, contours) of rainfall for Day 1, 3, and 5 forecast valid for 12 July 2022. The EFI shows the likelihood of unusual $\pm(0.5-0.8)$ weather and very unusual (more than ± 0.8) weather to occur. The SOT gives an indication of how extreme the event is with respect to the 99th quantile of the model climatology. These products are obtained from the GEFS forecast and its climatology (2013-2021 JJAS).

$$EFI = \frac{2}{\pi} \int_0^1 \frac{p - F(p)}{\sqrt{p(1-p)}} dp ; \quad SOT = \frac{Q_f(90) - Q_c(99)}{Q_c(99) - Q_c(90)}$$



(Lalurette 2003, Zsoter 2006, Dutra 2013)

Summary

- GEFS has been operational at IMD since 2018.
- For the rainfall forecast verification, the models show a very less (< 0.12) Brier Score for all thresholds and lead time.
- The reliability diagram and ROC curve indicate that the models show good reliability and discrimination for increasing threshold and lead time. At high thresholds and longer lead times the models fall below the no skill line.
- The IITM model shows good skill in forecasting the strike probabilities of tropical cyclones.
- With the increase in extreme rainfall events, forecast products catering to such events are essential. Percentile based forecast and the EFI show the efficiency of IITM model. More such products are required for the effective dissemination of forecasts.

Website: https://srf.tropmet.res.in/srf/hires_gefs/index.php

Acknowledgements:

Director, IITM

Short range prediction group, IITM

Pratyush & Mihir supercomputer facility

TIGGE data archive for NCEP and ECMWF data

IMD-GPM merged rainfall data

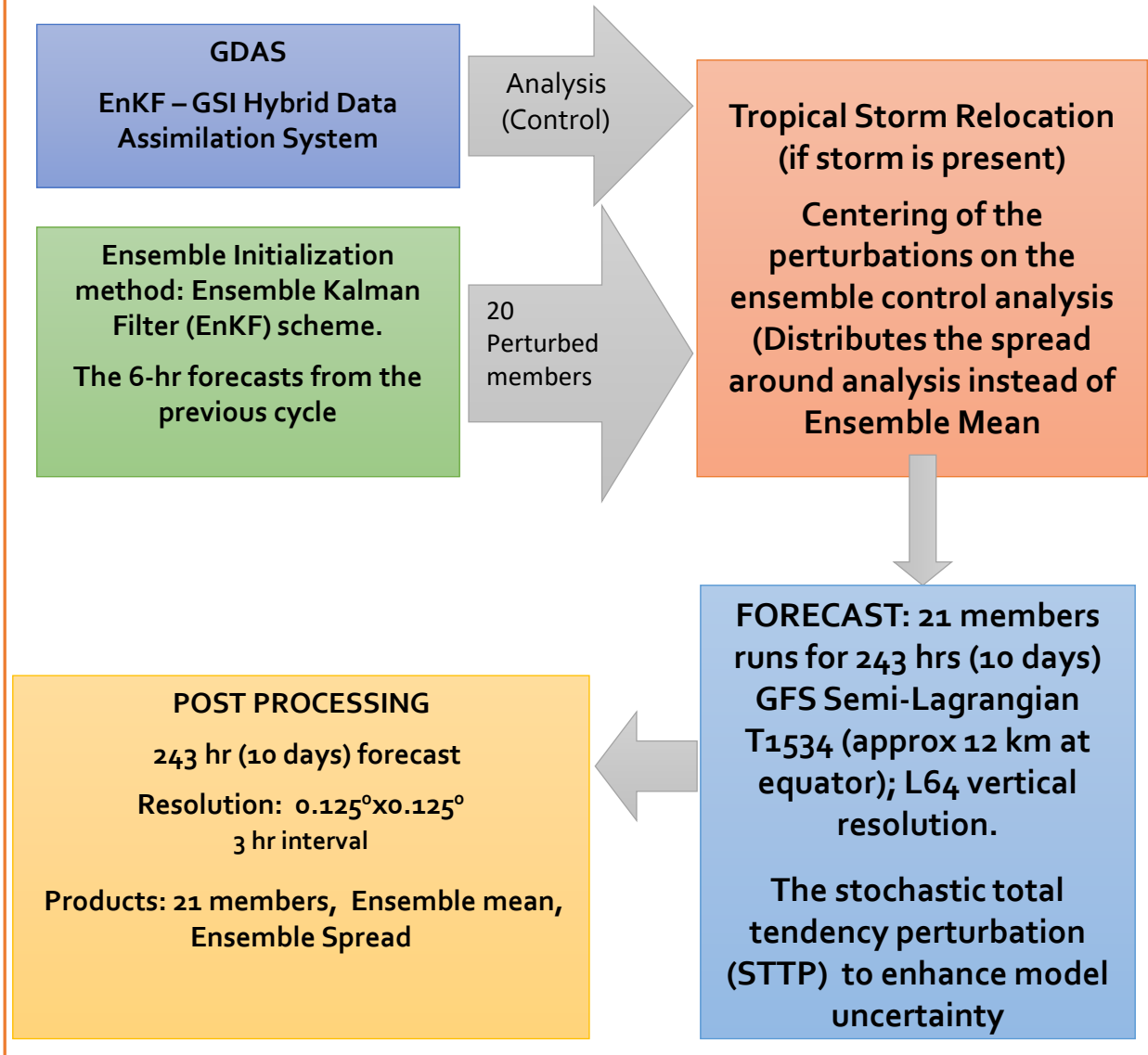
(<https://imdpune.gov.in/lrfindex.php>)

Thank you!

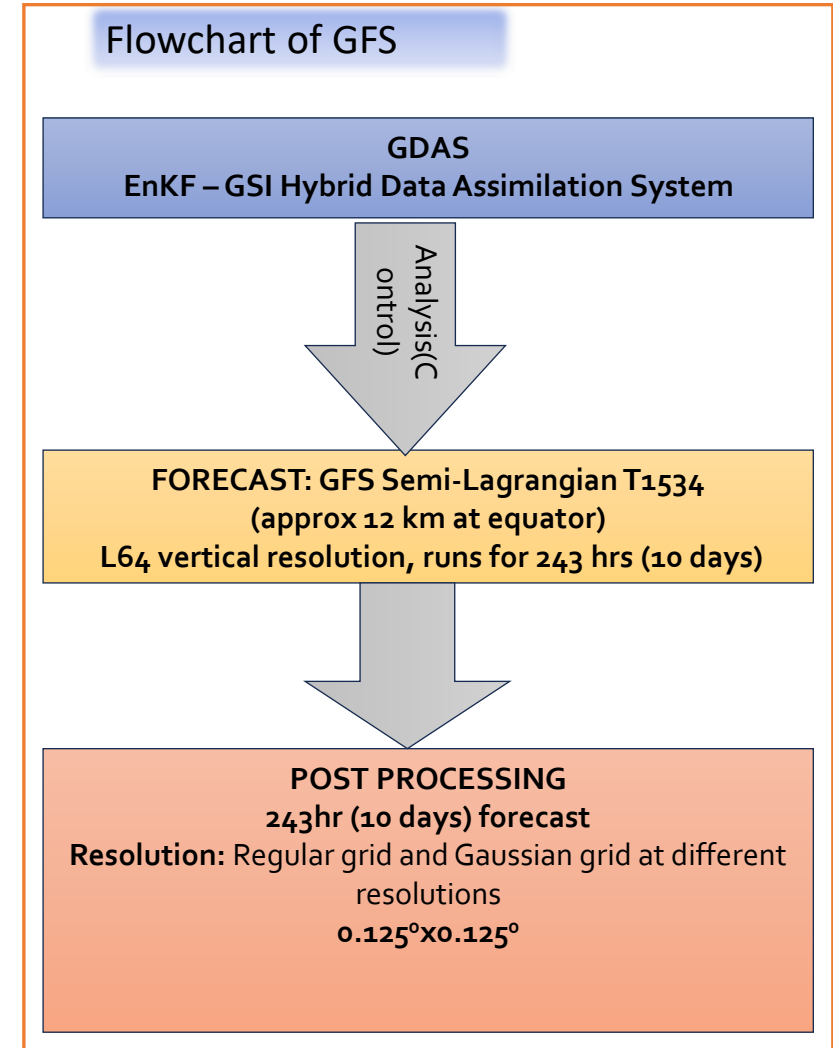
The Global (Ensemble) Forecast Model

extras

Flowchart of GEFS



Flowchart of GFS



The Global (Ensemble) Forecast Model Physics

Physics	Description
Convection	Revised Simplified Arakawa-Schubert (RSAS) and mass flux based SAS shallow convection scheme
Microphysics	Zhao-Carr-Moorthi microphysics formulation for grid-scale condensation and precipitation
Gravity Wave Drag	Orographic gravity wave drag, mountain-drag and stationary convective gravity wave drag
PBL	Hybrid Eddy Diffusion Mass flux turbulence/vertical diffusion scheme
Radiation	Solar radiation and IR based on RRTM (originally from AER, modified at EMC) with Monte Carlo Independent Column Approximation (McICA). Cloud fraction for radiation computed diagnostically from prognostic cloud condensate

The GEFS has been operational at India Meteorological Department (IMD) since 2018

