



Ensemble Prediction System for Tropical Cyclone prediction

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UM based modelling System of NCMRWF







Mihir HPC (Cray XC40)





2.8 PetaFLOPS6 Peta Byte Storage2320 Compute Nodes





- NWP is an Initial Value Problem.
- The more accurate the estimation of the *Initial Conditions*, the better is the quality of forecasts.
- **Data Assimilation** is the process which combines the observations of the atmospheric conditions with a short range (usually 6 hours) model forecast to produce the best estimate of the current state of atmosphere called the *Analysis*, on the regular model grid.
 - 3D-Var, 4D-Var, EnKF, ETKF, Hybrid 4D-Var, En-4DEnVar
- Best Estimated Initial Condition or Analysis has uncertainty which is represented by analysis co-variance



Uncertainty in Model Physics Parameterization



•Small scale processes are not resolved by large scale models, because they are **sub-grid**.

- •The **effect** of the sub-grid processes on the large scale can only be represented statistically.
- •The procedure of expressing the effect of sub-grid processes is called **parameterization**.
- Radiation transfer
- Surface processes
- Vertical turbulent processes
- Clouds and largescale condensation
- Cumulus convection





Growth in forecast uncertainty is flow dependent

Communicating Forecast Uncertainty helps in better decision making





Why to communicate forecast uncertainty?

- 1. Useful for both forecast provider and the user
- 2. Assists people to make more effective decisions
- 3. Communicating uncertainty helps manage user expectations
- 4. Communicating uncertainty retains user confidence
- 5. Forecast uncertainty reflects the state of the science



Ensemble Prediction System (EPS)



EPS provides a way of quantifying the uncertainty in forecasts using multiple forecasts from slightly different initial conditions.

Deterministic Forecast







- Estimates the PDF of the initial state
- Forecasts the evolution of this PDF using dynamical model
- Estimates the forecast PDF



Useful aspects of EPS



- Ensemble mean can be used as a single deterministic forecast
- It provides an indication of the reliability of the forecast. **Spread** in the forecast is a measure of disagreement between the ensemble members.
- It provides a quantitative basis for probabilistic forecasting.

Probability of an event = Fraction of the total number of ensemble members predicting the event



NCMRWF Global Ensemble Prediction System (NEPS-G)

- Horizontal resolution
- No. of grid points
- No. of vertical levels
- No. of Ensemble members
- **IC Perturbation method**
- **Surface Perturbations**
- **Physics Perturbation method**
- **Forecast length**

- : 12 km
- **:** 2048 x 1536
- : 70 (up to a height of 80 km)
- : 22
- : Ensemble Transform Kalman Filter (*ETKF*)
- : SST, Deep soil temperature and Soil Moisture Perturbations
- : Stochastic Kinetic Energy Backscattering (SKEB) and Random Parameter (RP) schemes
- **:** 10 days







Ensemble Prediction Systems of Major operational Centres

| Centers | Model | Grid/Scale & Forecast Length | |
|--------------------------|--------------------------------------|------------------------------|--|
| NCEP, USA | GEFS, 32 Members | ~25 km; 16 days | |
| ECMWF, European Union | IFS-ENS, 51Members | ~18km; 15days | |
| Met Office, UK | MOGREPS-G, 36 Members | ~20km; 7 days | |
| JMA, Japan | GEPS, 50 members | ~40 km; 18 days | |
| BoM, Australia | ACCESS-G, 36 Members | ~ 33 km; 10 days | |
| India | NEPS, 23 Members GEFS, 21 Members | ~12 km; 10 days | |
| For Severe Weather | Nested UM based Regional Ensemble | ~ 4 km; 3 days (with BCWC) | |





In ETKF, only the perturbations are updated



ETKF





Inflation factor

Ensemble size is small and No. of degrees of freedom is large

- Forecast error covariance is not fully estimated
- Analysis error covariance is underestimated

An inflation factor, I, is used to tune the spread of the ensemble

 $z_a = z_f T.I$

'I' ensures that the spread of the ensemble matches the RMSE of the ensemble mean forecast





Model uncertainty

Random Parameters (RP): The parameterization of physical processes involve a number of empirical- adjustable parameters and thresholds which are given somewhat arbitrary values. RP scheme aims to account for the uncertainty associated with these parameters

Stochastic Kinetic Energy Backscattering (SKEB): It attempts to scatter back the lost kinetic energy from the processes like convection (which are not accounted for by the model) to the larger resolved scales as horizontal wind increments at each forecast time step



NCMRWF Regional Ensemble Prediction System (NEPS-R)

- Horizontal resolution
- Vertical levels
- **Model Domain**
- No. of grid points
- **Ensemble size**
- **Initial Conditions (IC)**
- **Boundary Conditions**
- Convection
- **Physics Perturbation**
- **Forecast length**

- : 4 km
- : 80 levels up to 38.5 km
- : 62° E -106° E and 6° S 41° N
- : 1200 x 1200
- : 12 (1 control + 11 perturbed)
- : From NEPS-G
- : From NEPS-G
- : Explicit
- : Random Parameter scheme
- : 3 days

Dust is now used as prognostic variable in NEPS-R.
Soil moisture and soil temperature are obtained from the analysis dump instead of climatology





Valid for 00 UTC 20thMay 2020





Ensemble Mean Precipitation





Ensemble Mean provides valuable information if spread is small. It is not a good indicator for an extreme event if the spread is large



Ensemble Mean Precipitation

TC - Gulab

64

32

16

-0.1





72E

76E

80E

84E

88E

9ŻE

96E

68E



Ensemble Mean Rainfall (cm)



Ensemble Mean Track for SuCS "Amphan"



IC: 12UTC on 18th May 2020





Ensemble Mean Track TC "PHANI"



IC:00Z 1 May 2019



– NEPS-R – NEPS-G – Observation





Track Error

Decrease in DPE, ATE and CTE in New NEPS-G was about 38%, 48% and 15% respectively. (Dube *et al.*, 2020) . Study was carried out on 13 TCs occurred between May 2016 and December 2018





Postage stamp maps for TC Amphan







Ens mem 4



Ens mem 8



NEPS-R: Day-2 Rainfall (cm/day) FCST valid for 03Z21MAY2020 Ens mem 1 Ens mem 2 Ens mem 3



Ens mem 5



Ens mem 9







Ens mem 7

Ens mem 11









16

8



32

64



Postage stamp maps for TC Gulab



Cntl fcst



Ens mem 4



Ens mem 8





Ens mem 5



Ens mem 9





Ens mem 6

Ens mem 10

8

16

32

64



Ens mem 7



Ens mem 11





8N

80E

84E

88E

92E

96E

Probability of Exceedance

Ensemble Mean Rainfall (cm)



30

10

Observed Rainfall(cm) valid on 03Z21MAY2020 28N 24N 20N 16N 12N 8N 80E 84E 88E 92E 96E Probability of >6.55cm/day rainfall 28N 24N 20N 16N 12N



Probability of >1.56cm/day rainfall



70

50

16N

12N

8N

8ÔE

84E

88E

92E

96E



Probabilistic Precipitation forecast of NEPS-R

Ensemble Mean

Day-2 Forecast Valid for 03Z03MAY2019 Ini:20190501

Ensemble Mean Rainfall (cm) Forecast of NEPS-R NEPS-R Based Probabilistic Quantitative PrecipitationNEPS-R Based Probabilistic Quantitative Precipitation Day-02 Forecast Valid for 03Z03MAY2019 Probability of >0.25cm/day rainfall Day-02 Forecast Valid for 03Z03MAY2019 Probability of >1.56cm/day rainfall IC:20190501 IC:20190501

Day-2

IC: 20190501

NCMRWA



Observation



Observed maximum precipitation: > 32 cm

Probability > 50% for precipitation > 19.5 cm and probability > 70% for precipitation > 11.5cm over same location



EPSGRAM

Location specific probabilistic forecast

Max

Min

EPSGRAMS are generated from NEPS-G forecast for

- all major cities of India and **BIMSTEC** member countries
- 660 districts of India







NEPS-G member tracks and strike probability forecasts for TC "PHANI"







NEPS-G 12km: Forecast tropical storm strike probability for FANI from 00UTC 01/05/2019





NEPS-R Tracks and Strike Probability forecasts for TC "PHANI"





NEPS-R_4km_FANI: Forecast tropical storm strike probability for FANI from 00UTC 01/05/2019





Storm Following Meteogram

TC "PHANI"



NEPS-G

IC: 00Z 20190429

NEPS-R

NEPS-G_12km_REGfani ensemble: Tropical Cyclone storm-following meteogram FANI (8.3N 87.4E) from 00UTC 29 April 2019 NEPS-R_4km_500 ensemble: Tropical Cyclone storm-following meteogram FANI (8.3N 87.4E) from 00UTC 29 April 2019



Rapid Intensification of "Fani" in NEPS-R

National Centre for Medium Range Weather Forecasting



NEPS-R Day-3 forecast of MSLP (hPa) valid for 00UTC 03May2019





7 members lie west of Puri







IC – 00 UTC, 16. 05. 2020



NEPS-R_4km: Forecast tropical storm strike probability for 91B from 00UTC 16/05/2020



NEPS-G_12km_4reg: Forecast tropical storm strike probability for 91B from 00UTC 16/05/2020

20N

10N



NEPS-R_4km ensemble: Tropical Cyclone storm-following meteogram 91B (10.8N 86.3E) from 00UTC 16 May 2020



NEPS-G_12km_4reg ensemble: Tropical Cyclone storm-following meteogram 91B (10.8N 86.3E) from 00UTC 16 May 2020

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NEPS-G_12km_4reg: Forecast tropical storm tracks for 91B from 00UTC 16/05/2020

•••







IC – 00 UTC, 26.09. 2021

20

Prot



NEPS-R_4km: Forecast tropical storm tracks for GULAB from 00UTC 26/09/2021



30N 20N 10N 70E 70E 50 Ensemble mean 20C 50 Ensemble mean 20C 20% 50 Ensemble mean 20C 20%

NEPS-R 4km: Forecast tropical storm strike probability

for GULAB from 00UTC 26/09/2021

NEPS-R_4km ensemble: Tropical Cyclone storm-following meteogram GULAB (18.3N 87.4E) from 00UTC 26 September 2021



NEPS-G_12km_4reg: Forecast tropical storm tracks for GULAB from 00UTC 26/09/2021



NEPS-G_12km_4reg: Forecast tropical storm strike probability for GULAB from 00UTC 26/09/2021



NEPS-G_12km_4reg ensemble: Tropical Cyclone storm-following meteogram GULAB (18.3N 87.4E) from 00UTC 26 September 2021











IC - 00 UTC, 03. 12. 2021



NEPS-R_4km_500: Forecast tropical storm strike probability for 05B from 00UTC 03/12/2021



NEPS-R_4km_500 ensemble: Tropical Cyclone storm-following meteogram 05B (14.0N 86.1E) from 00UTC 03 December 2021



NEPS-G_12km_22mem: Forecast tropical storm tracks for 05B from 00UTC 03/12/2021



NEPS-G_12km_22mem: Forecast tropical storm strike probability for 05B from 00UTC 03/12/2021



NEPS-G_12km_22mem ensemble: Tropical Cyclone storm-following meteogram 05B (14.0N 86.1E) from 00UTC 03 December 2021





Recent DD between 20th March -23rd March 2022





NEPS-R_4km: Forecast tropical storm strike probability





9 31.47 KT

OBSERVED TRACK

NEPS-G_12km_22mem: Forecast tropical storm tracks for 91B from 00UTC 21/03/2022



NEPS-G_12km_22mem: Forecast tropical storm strike probability for 91B from 00UTC 21/03/2022



NEPS-G_12km_22mem ensemble: Tropical Cyclone storm-following meteogram 91B (12.1N 94.9E) from 00UTC 21 March 2022 Number of ensemble members tracked





Observed relative frequency, 01

Verification of forecast







NEPS-G forecast Verification for CS 'JAWAD' over BoB (02-05 Dec 2021)



Attribute Diagram

ROC Curve













NCMRWF Model Verification for Deep Depression over the BoB (03 – 06 Mar 2022)



RELIABILITY plot for STRIKE PROBABILITY of DD in BoB



Forecast probability, yi



IC – 00 UTC, 04. 03. 2022





NEPS-G_12km_22mem: Forecast tropical storm strike probability for 90B from 00UTC 04/03/2022



NEPS-G_12km_22mem ensemble: Tropical Cyclone storm-following meteogram 90B (10.0N 82.7E) from 00UTC 04 March 2022







NEPS-G products in TIGGE Portal

| | | × | 0 | Û | Ū |
|---|--|---|-------|-----|----|
| SquirrelMail 1.4.22-3.el6 | NCMRWF HPC- System Graphs | News - TIGGE - ECMWF Confluence Wiki | | | |
| ECMWF Spaces ~ | | Search Q | ? | Log | in |
| TIGGE Page | Home | | | | |
| SPACE SHORTCUTS S2S TIGGE TIGGE-LAM Creat (207 207 207 207 | y Richard Mladek, last modified about an hour ago | | | | |
| Image: UERRA Image: TREE PAGE: TREE • News • Description > Support | 07-2018 NCMRWF forecast system change late of NCMRWF forecast system. A new version of NCMRWF model was introduced. The first archived updated model runs are from the 1st of July. main changes are: reduced number of the ensemble size from 45 to 12 two model runs 00 and 12 UTC at very high resolution (0.12x0.18 degree) k here for more details. | | | | |
| Resources Site map 20 20 Ne | -2018 Usage statistics page with TIGGE data usage statistics was added. -2017 New model (NCMRWF, India) added to TIGGE archive model outputs (NCMRWF, India) were added to TIGGE archive. The first starting date a | available thanks to the back-archiving is the 1st of August | 2017. | | |

11-07-2017 ECMWF forecast system change

Update of ECMWF forecast system. A new version of ECMWF model (IFS cycle 43r3) was introduced. Click here for more details.





THANKS



NEPS-G and its upgradation



| | 33km NEPS | 12km NEPS |
|---|--|---|
| Grid Points | 800 x 600 | 2048 x1536E |
| Ensemble Size | 44 perturbed + 1 cntl | 22 perturbed +1 cntl |
| Initial condition perturbations | Perturbations in θ , π , q, u, & v by ETKF method | Perturbations in θ , π , q, u, & v by ETKF method and perturbations in SST , SMC & Deep Soil Temp |
| Model Physics Perturbations | Stochastic Kinetic Energy Backscattering and Random Parameter Schemes | Stochastic Kinetic Energy Backscattering and Random Parameter Schemes |
| Observations Assimilated in NEPS | AIRS, ATOVS, Aircraft, GOESClear, GPSRO, IASI, Satwind, Scatwind Sonde, Surface | AIRS, ATOVS, Aircraft, GPSRO, GOESClear, IASI, Satwind, Scatwind Sonde, Surface, SEVIRIClear, SSMIS |
| Long Forecast Start time | 44 members at 00 UTC | 11members and Cntl at 00 UTC and 11 members at 12UTC of previous day |

FANI 2019

NEPS-R_4km_FANI: Forecast tropical storm tracks for FANI from 00UTC 29/04/2019





NEPS-G_12km_FANI4reg: Forecast tropical storm strike probability for FANI from 00UTC 29/04/2019



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NEPS-G_12km_FANI4reg: Forecast tropical storm tracks for FANI from 00UTC 29/04/2019



10N



NEPS-G 22-member tracks and strike probability forecasts for TC "PHANI"



NEPS-G_12km_FANI_22mem: Forecast tropical storm tracks for FANI from 00UTC 29/04/2019



NEPS-G_12km_FANI_22mem: Forecast tropical storm strike probability for FANI from 00UTC 29/04/2019



Shaheen (30-09 to 04-10-2021)

Attribute Diagram

