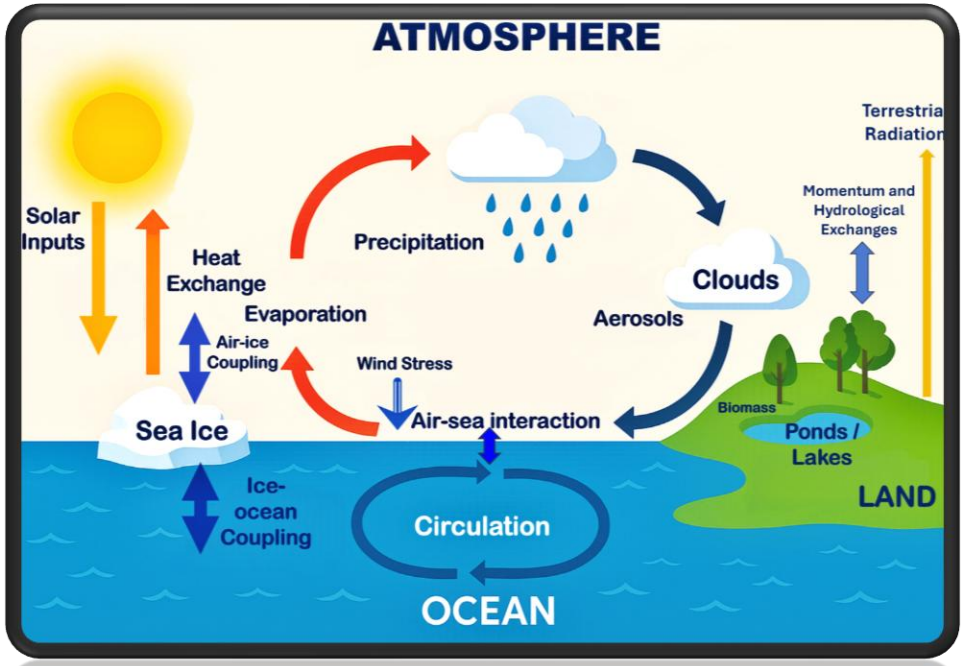


Recent Developments at NCMRWF Coupled Modelling System

Mithuna (मिथुना) -FS

Seamless Modelling System

Integrates weather and climate predictions across multiple timescales and spatial resolutions

Global Deterministic Model

12 km resolution, 70 vertical levels, 10-day forecast (daily)

Regional Models

Focusing Indian subcontinent with 4 km (72 hrs. forecast) &1.5 km (48hrs. Forecast, winter) horizontal resolution

City-Scale Modeling

330m resolution, 48-hours forecast (winter), incorporating urban complexities for Delhi

Ensemble Prediction System

12km resolution, 22 perturbed ensembles 10-day forecast daily

Coupled Model(S2S)

Integrated atmosphere, land, ocean, and sea-ice models for subseasonal to seasonal forecasts(S2S)
Frequency: weekly & monthly
Forecast Length: 4- weeks (16 ENS) & 3-months(55 ENS)

Operational Models

Experimental

Kilometre-Scale Modelling

Experimental 6km Global deterministic model, 5-day forecast, 70 vertical levels

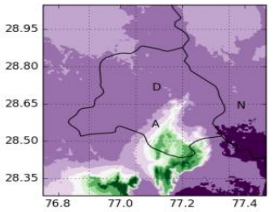
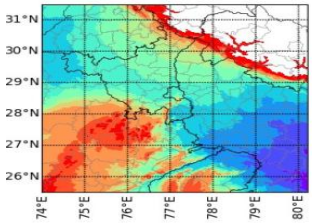
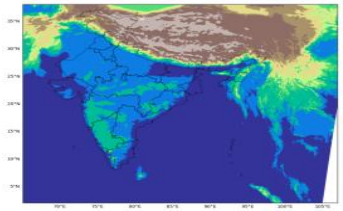
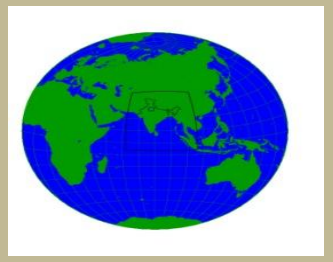
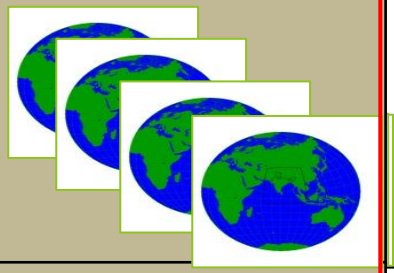
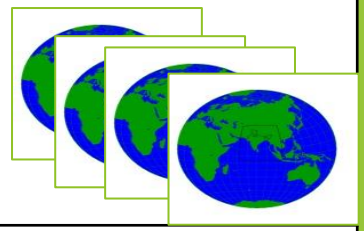
Regional Coupled NWP Model

Atmosphere (4km)
Ocean (2.2km)
Frequency: Daily
Forecast Length: 10 days

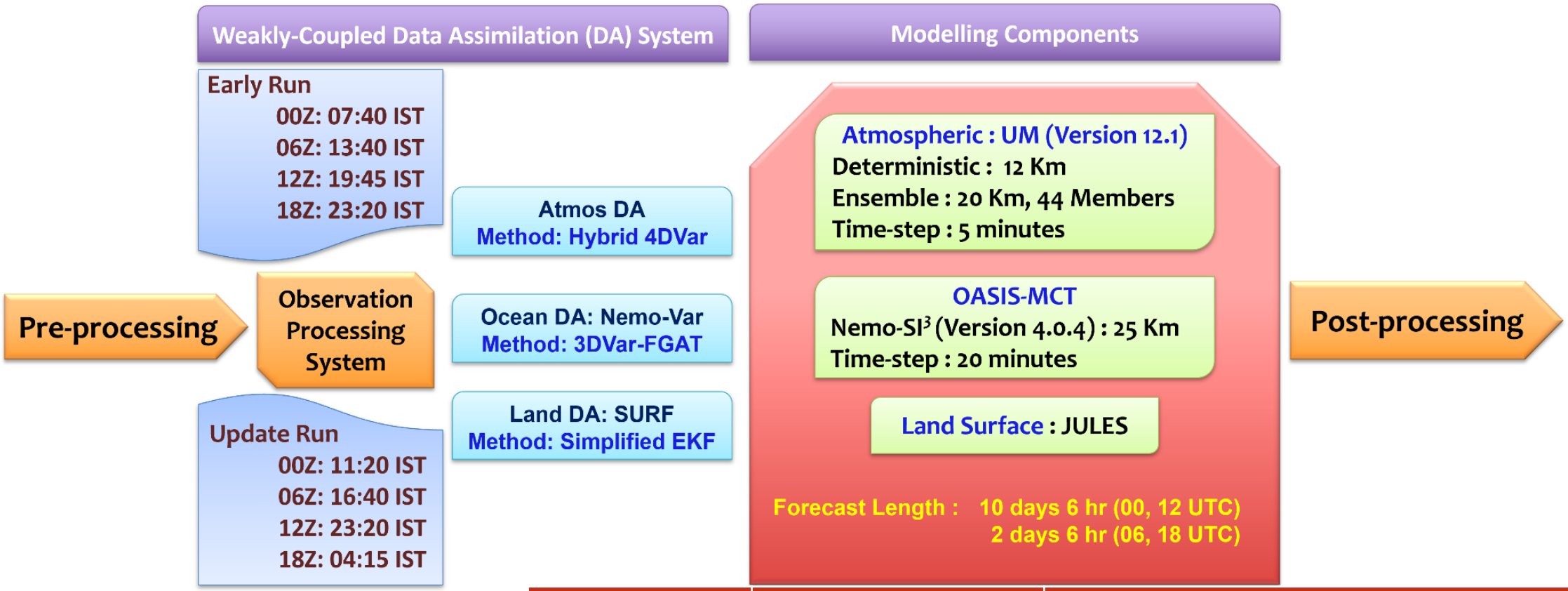
Global coupled NWP model

Atmosphere (10km)
Ocean (25km)
Frequency: Daily
Forecast Length: 5 days

Seamless prediction system of NCMRWF in Mihir HPC

	Urban Model (DM-Chem)	Meso-scale Model (1.5 km)	Regional UM (NCUM-R) (4km)	Global UM (Mithuna-GLB) (12km)	Global EPS (Mithuna-ENS) (20km)	Coupled UM (CNCUM) (60km)
Domain						
Horizontal resolution	**330m**	**1.5km**	**4.4 km**	**12 km**	**20 km**	**Atmosphere: approx. 60 km Ocean: approx. 25 km**
Fcst length (IC)	**48 hours**	**48 hours**	**75 hours (00UTC & 12UTC)**	**10 days (00,12 UTC)**	**10 days (00, 12 UTC)**	**1 month (ERP) Seasonal**
Ensemble size	-	-	-	-	**44**	**ERP:16 Seasonal: 55 (Only atmosphere)**
Initial conditions	**Downscaled IC**	**Downscaled IC**	**Atmosphere: 4D Var Land : EKF**	**Atmosphere: Hybrid 4D Var Land : EKF Ocean:3Dvar-FGAT**	**Atmosphere: Hybrid En-4D EnVar Land : EKF Ocean:3Dvar-FGAT**	**Atmosphere: Global DA Ocean: NEMOVAR**
SST Conditions	**Downscaled**	**Downscaled**	**OSTIA SST Analysis**	**Coupled SST**	**Coupled SST**	**Coupled model**

NCMRWF Operational Coupled Model Suites
Global Coupled Medium Range



Items	NCUM-G	Mithuna FS
Cluster type	Cray XC40 Intel Haswell/Broadwell 36 cores/node Cray compiler	Bull Sequana XH2000 AMD Epyc Rom 96 cores/node HPCX (NVIDIA) OpenMPI Build with Intel Compiler(X86_64)

Key objectives

- Forecast Products
  - Forecast products of BCWC member countries
  - Data requests
- R & D Collaboration
  - Co-development of forecast products/diagnostics etc
  - Forecast verification, testing and implementation etc
- Capacity Building
  - BCWC Training: Select themes and topics

Brief Summary of Activities

- Data Monitoring and Quality Control
- Data Assimilation
- Global & Regional Model Development
- Model Evaluation Diagnostics and Applications
- AI/ML Initiatives
- Forecast Products
- Reanalysis Data Products
- Post-processing & Bias Correction
- Forecast Verification

Data Monitoring and Quality Control

- Real-time Observation Monitoring: NCMRWF tracks reception, decoding, and storage of GTS/satellite data into BUFR-tank for 6-hourly NWP cycles, with Early-Update for late-arriving observations.
- Quality Control Procedures: Applies automated QC flags (0-9 scale), OPS checks (PGE, background fields), and thinning for surface (~90k reports/cycle, 35% assimilated), radiosondes, radars, AWS.
- Specialized Networks: Real-time QC for dense rain gauges (e.g., Mumbai-MESONET); weakly coupled DA via 4D-Var/Hybrid-Var for novel observations.
- Reporting & Optimization: Generates spatio-temporal stats, availability reports; channel selection enhances radiance assimilation in models like NCUM/NGFS.

Data Assimilation

- Upgraded DA Framework in Mithuna-FS: Implemented state-of-the-art hybrid 4D-Var for the new 12 km global coupled model (atmosphere-ocean-land-sea ice), reducing biases in rainfall, temperature, fog via enhanced physics and observation integration.

- Multi-Scale Assimilation: 4 km regional NCUM-R with DWR winds/rainfall; 330m Delhi urban DA; weakly coupled ocean (NEMO-Var) and land surface for extremes like monsoons/cyclones.

- Observation Expansions: Increased Microsat-2B MHS radiances, ASCAT soil moisture; OSEs/FSO for impact verification; higher-frequency decoding (5-min cycles) for early runs.

Global & Regional Model

- NCMRWF introduced Mithuna-FS (12 km global coupled atmosphere-ocean-land-sea ice model) with upgraded DA/physics for sharper medium-range forecasts, reducing biases in rainfall/temperature/fog.
- Multi-Scale Suite Expansion: Added 4 km regional for monsoons/cyclones, 330 m hyper-local Delhi model; integrates with BharatFS for nowcasting and district-level extremes (heatwaves, rainfall).
- AI/ML Integration: Experimental runs of Pangu-Weather, GraphCast, FourCastNet (~25 km on Arunika HPC); CNNs for radar/satellite nowcasting, GANs for downscaling to urban scales.
- Advanced Developments: Enhanced NEPS ensembles, weakly coupled DA, post-processing for IBF; higher-res upgrades (10 km global, 1.5 km regional) for S2S, Third Pole, agromet applications.

Model Evaluation Diagnostics and Applications

- **Systematic Error Analysis**: Monthly/seasonal verification of operational models against IMD gridded data for rainfall (IMD-NCMRWF merged 0.25° analysis), temperature (Tmax/Tmin), track/intensity biases in cyclones.
- **Spatial & Categorical Metrics**: Computes ME, RMSE, spatial patterns, POD, FAR, CSI for rainfall categories; ensemble verification via NEPS spread/error ratios, TIGGE contributions.
- **Wind/Solar Forecast Products**: High-res NCUM/NCUM-R outputs (15-min regional, 1-hr global) provide wind speeds (10m/50m), GHI/DNI solar fluxes, temperature/cloud cover up to 10 days for grid integration and farm management.
- **Post-Processing**: Statistical bias correction, AI/ANN models applied to raw NWP for improved power output predictions; shared with NIWE, private firms (e.g., ReConnect, Leap Green).

AI/ML Initiatives

- **Global AI Model Integration**: Operational trials of Pangu-Weather, GraphCast, FourCastNet, and GenCast on Arunika HPC, initialized with Mithuna-FS outputs for rapid medium-range forecasts and probabilistic extremes like heavy rain/heatwaves.

- **Bias Correction & TC Intensity**: ML techniques (XGB for central pressure, RF for max winds) improve NEPS ensemble predictions for cyclones over North Indian Ocean, reducing MAE by 30-63% with better probabilistic reliability.

- **Nowcasting & Downscaling**: CNNs for radar/satellite nowcasting; GANs for hyperlocal downscaling to block-level; ANN post-processing for wind/solar power and monsoon sub-seasonal predictions.

Forecast Products

- Deterministic Forecasts
- Probabilistic/Ensemble Products
- Specialized Applications

Forecast Products

- Deterministic Forecasts

- **NCUM Global (12 km)**: 10-day medium-range forecasts (4x daily cycles at 00/06/12/18 UTC) for rainfall, wind, temperature, pressure, MSLP, geopotential heights.
- **NCUM-R Regional (4 km)**: 72-120 hr high-res predictions for monsoons, cyclones, fog over India/BIMSTEC; includes meteograms for 80+ cities.
- All severe weather monitoring and guidance : Heavy rains, Tropical Cyclones, Heat/Cold Waves, Thunderstorm/Lightening

Forecast Products

- Probabilistic/Ensemble Products

- **NEPS Global Ensemble (12 km, 22-44 members)**: 10-day probabilistic forecasts with spread maps, week-1/2/4 anomalies, cyclone tracks/intensities.
- **S2S ERPS (16-55 members)**: Weekly/multi-week up to 4 months; monsoon onset, rainfall anomalies, ocean state (TCHP, Madden-Julian Oscillation).
- All severe weather monitoring and guidance : Heavy rains, Tropical Cyclones, Heat/Cold Waves, Thunderstorm/Lightening

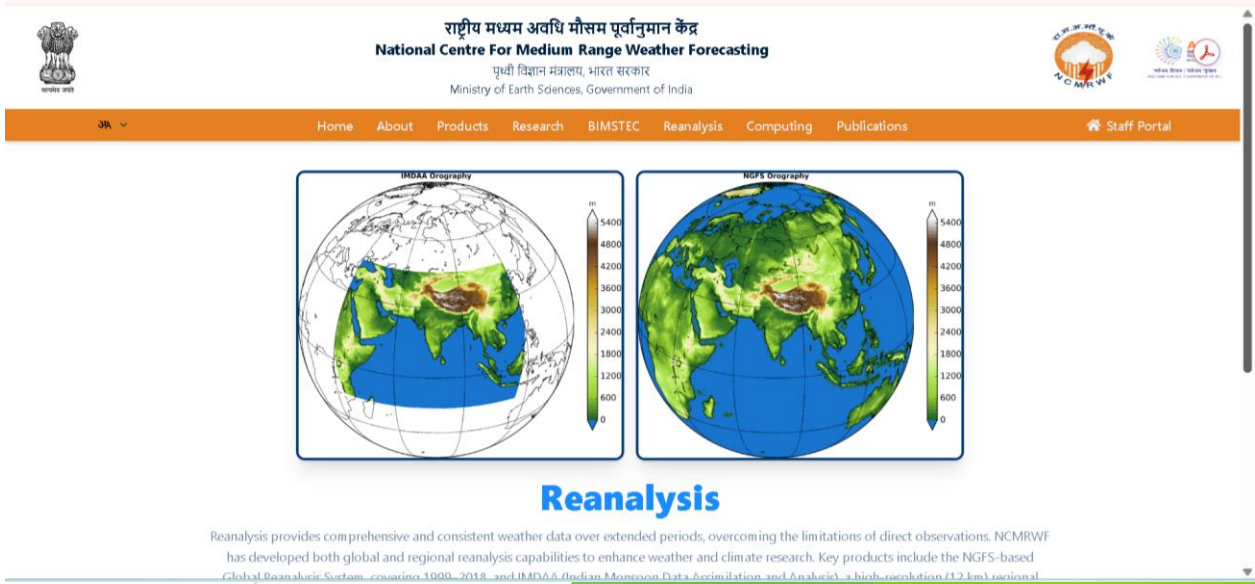
Forecast Products

- Specialized Applications
- **Agromet/IBF**: Heatwave/drought alerts, lightning/graupel forecasts; renewable energy (GHI/DNI, 10/50m winds).
- **City-Scale & AI**: Delhi 330m fog/air quality model; Pangu-Weather/GraphCast trials for rapid nowcasting/post-processing.

Reanalysis Data Products

- **IMDAA (Indian Monsoon Data Assimilation and Analysis)**: 12 km regional reanalysis (1979-2018) at hourly/3-hourly resolution; includes surface/upper-air variables, rainfall, winds, temperature—ideal for monsoon research; extended with near-real-time NCUM-like products post-2020.
- **NGFS Reanalysis**: 25 km global dataset (1999-2018) at 6-hourly intervals; atmospheric fields from operational NWP systems for broader South Asian context.

- https://nwp.ncmrwf.gov.in/reanalysis
- ~2250 registered users access ~hourly products for verification, model diagnostics, and impact studies; supports Monsoon Mission, BIMSTEC, and IBF applications.



Post-Processing & Bias Correction

- **Quantile Mapping (QM)**: Empirical (EQM), parametric (PQM), and gamma-Pareto (GPQM) methods correct precipitation distributions using IMDAA reanalysis as reference, reducing wet/dry biases for iFLOWS-Mumbai flood forecasting.
- **Decaying Average Bias Correction (BCDA)**: Kalman filter-type adaptive method for Tmax/Tmin in NEPS ensembles; combines with variance inflation for spread adjustment, boosting MAM heatwave skill.

Post-Processing & Bias Correction

- **Machine Learning Post-Processing**: ANN/NN, XGBoost/RF for cyclone intensity (30-63% MAE reduction); CNNs for nowcasting; GANs/super-resolution for hyperlocal downscaling from 12/4 km grids.
- **Applications**: Ensemble dressing for probabilistic outputs; renewable energy (wind/solar GHI/DNI); IBF/agromet advisories with verified skill gains over raw model runs.

Forecast Verification

- Core Verification Practices
- **Continuous/Deterministic Metrics**: Computes ME, RMSE, spatial correlations for rainfall (vs. IMD-NCMRWF 0.25° merged analysis), Tmax/Tmin (IMD 0.5° gridded), MSLP, winds using monthly reports and model analyses. **(Submitting scores to WMO**)
- **Categorical & Extremes**: POD, FAR, CSI, ETS for rainfall thresholds (light/heavy/very heavy); track/intensity biases for cyclones via ensemble spreads.
- **Tropical Cyclones**: Verification of track, intensity and landfall position **(Submiting scores to WGNE**)

Forecast Verification

- Advanced Diagnostics
- **Ensemble Evaluation**: Reliability diagrams, Brier/ROC scores, spread-error ratios for NEPS probabilistic forecasts; S2S anomaly verification against TIGGE/IMDAA reanalysis.
- **Contiguous Rain Areas (CRA)**: Object-based method quantifies displacement, volume, and pattern errors in NEPS ensemble rainfall forecasts over India, applied to three monsoon seasons for mesoscale evaluation.
- **Fraction Skill Score (FSS)**: Neighborhood approach relaxes grid-point matching, assessing spatial scales where forecasts skillfully match observations for heavy rain thresholds.
- **Method for Object-Based Diagnostic Evaluation (MODE)**: Identifies forecast/observation objects to compare attributes like location, area, intensity, and orientation, used for lightning and convective features.
- **Wavelet & Scale-Separation**: Decomposes fields into scales for multi-resolution diagnostics; integrated tool evaluates 50 km NCUM against gridded/raingauge data.

Thankyou