PARLIAMENT QUESTION: ADVANCED COMPUTER SIMULATION MODELS TO IMPROVE LOCALISED WEATHER FORECASTING

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Under the Mission Mausam, the Bharat Forecast System (BharatFS), an advanced computer simulation model, has already been developed, and it has been operational at a very high spatial resolution of 6 km. It also has the capability to provide predictions of rainfall events up to 10 days, covering the short and medium-range forecasts. Due to its higher resolution and improved dynamics, it generates weather forecasts at the panchayat or cluster of panchayats level. To further support the operations of high-resolution model simulations in real-time, the computing facilities (Arunika and Arka) have been substantially increased to integrate voluminous data and run meso-scale, regional, and global models.

Further, a major achievement is the introduction of the Mithuna Forecast System (Mithuna-FS). This new-generation global coupled model integrates the atmosphere, ocean, land surface, and sea ice components with state-of-the-art physics and an upgraded data assimilation framework. Currently, this forecasting system operates at 12-km resolution, marking a significant advancement in India’s medium-range localized weather forecasting capability. The Mithuna-FS suite also includes –

- A 4-km high-resolution regional model for accurate simulation of monsoon dynamics, cyclones, and mesoscale extreme events over the Indian subcontinent;
- A 330-m hyper-resolution urban model for fog, visibility, and air-quality forecasting over the Delhi region.

These models operate on the Arunika Supercomputer (8.24 PFLOPS) and assimilate dense observational inputs from radars, satellites, automatic weather stations (AWS), profilers, and ocean systems. Together, they enable high-quality, panchayat-level predictions of rainfall, thunderstorms, fog, heat stress, and pollutants. This work complements the operational Bharat Forecasting System (BharatFS).

These models under the Mission Mausam are specifically configured for India's diverse climate regimes. This includes monsoon-tuned convection schemes, improved cloud microphysics, enhanced representation of the Western Ghats and Himalayas, and specialized coastal and urban physics. The 4-km regional domain captures sub-continent heterogeneity, while the 330-m Delhi model resolves winter boundary-layer inversions and pollution episodes. Assimilation of dense radar, satellite, and surface observations provides forecasts aligned to India's agro-climatic and hazard-prone regions.

The multi-scale Mithuna-FS suite reduces biases in rainfall, temperature, and fog visibility. Coupled with intelligence and machine learning (AI/ML)-based post-processing, these models provide sharper medium-range forecasts, better nowcasting capability, and more reliable district-scale probabilities for extreme rainfall, heatwaves, fog, air quality, and thunderstorms.

The Ministry has established a dedicated virtual centre involving the India Meteorological Department, National Centre for Medium Range Weather Forecasting (NCMRWF), and other institutes to integrate AI/ML systematically into the weather forecasting chain under the Mission Mausam. This virtual centre coordinates the development of AI/ML tools for bias correction, statistical post-processing, downscaling, nowcasting, and multi-source data fusion from radars, satellites, and AWS networks.

NCMRWF also experimentally runs global operational AI models such as Pangu-Weather, FourCastNet, and GraphCast on the Arunika Supercomputer at ~25 km resolution and fine-tunes them for India. These data-driven components run alongside the dynamical NWP systems on the Ministry's HPC resources, enabling the rapid generation of tailored hyperlocal products for sectors such as agriculture, urban management, and disaster risk reduction.

AI/ML Integration enables rapid downscaling of coarse numerical weather prediction (NWP) fields to urban-ward resolutions using ML super-resolution (e.g., GANs) and CNN nowcasting from real-time observations, producing tailored products for agriculture (monsoon breaks), aviation (fog visibility), and urban management ($PM_{2.5}$ alerts). Data fusion pipelines on Arunika accelerate last-mile delivery via APIs to IMD portals and stakeholder apps, supporting decision-centric forecasts during high-impact events. A dedicated functional group has been established within the IMD under the Ministry to strengthen R&D activities in AI/ML.

NCMRWF employs global pretrained AI/ML models, including Pangu-Weather (3D Earth-Specific Transformer), GraphCast (Graph Neural Networks), and FourCastNet (Adaptive Fourier Neural Operators), running experimentally at 25 km resolution on the Arunika Supercomputer. Additional techniques encompass deep learning-based statistical post-processing, convolutional neural networks (CNNs) for radar/satellite nowcasting, and machine learning downscaling methods like super-resolution generative adversarial networks (GANs) to refine Mithuna-FS outputs from 12 km global/4 km regional to hyperlocal scales. A novel deep learning model (meteoGAN) has been developed for the Delhi-NCR region and successfully tested for rainfall downscale using ground-based and Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) rainfall analysis at 300 meters spatial resolution.

These techniques enhance accuracy by learning systematic biases in dynamical NWP outputs, yielding reduced root-mean-square errors in key variables such as rainfall accumulation (up to 20-30% improvement in medium-range skill), temperature extremes, wind speeds, fog visibility, and $PM_{2.5}$ concentrations compared to raw model baselines. GraphCast and Pangu-Weather excel in hierarchical feature extraction across atmospheric scales, providing sharper spatial localization of convective events, monsoon breaks, and urban pollutants, while CNN-based nowcasting from high-frequency observations extends skillful short-range predictions (0-6 hours) beyond traditional extrapolation limits.

AI/ML models compute forecasts 100-1000 times faster than traditional NWP cycles, enabling near-real-time updates (every 15-30 minutes) between main dynamical runs on Arunika, which supports hyperlocal products for panchayat-level warnings during rapidly evolving events like thunderstorms or Delhi winter fog episodes. Post-processing pipelines fuse multi-source data (AWS, radars, satellites) into calibrated probabilistic guidance, accelerating last-mile delivery to stakeholders in agriculture, aviation, and disaster management.

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