Coupled global Numerical Weather Prediction System at NCMRWF (India) for medium range weather forecast.

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National Centre for Medium Range Weather Forecasting (NCMRWF, Ministry of Earth Sciences, Government of India) is an operational numerical weather prediction centre. NCUM global and regional NWP system of NCMRWF has been adapted from Unified Model (UM) seamless prediction system of "UM Partnership". The NCUM global system, operational since 2012, has been upgraded many times by adapting the improvements in the UM system and through in-house research and development (Sumit et al., 2020). These improvements resulted in significant benefits to the NCUM forecast skill (Sushant et al., 2022). Many improvements were also made to the observation pre-processing system, observation monitoring system, postprocessing of the model forecast etc.

Improving the skill of weather forecast is a continuous process and extend the skilful forecasts to longer lead time is another challenging task. There exists demonstrated evidence that air-sea coupling plays an important role in increasing the forecast skill in the atmosphere at short to extended range (Vellinga et al. 2020). In the uncoupled operational NWP forecasts, SST and sea ice have been prescribed initially to fix the lower boundary conditions for the atmospheric model forecast. However, in the coupled system, atmosphere drives the ocean through the input of momentum, heat, and moisture fluxes whereas the ocean controls the atmosphere through its supplies of moisture and heat. So, in the coupled NWP system, interacting models helped to advance the weather forecast skill through a more physically consistent representation of air-sea interaction.

Table 1: Various Components of Coupled Global assimilation-forecast System (C-NCUM)

Model	**Data Assimilation-Atmosphere**	**Data Assimilation – Land Surface**	**Data Assimilation-Ocean & Sea Ice**
Model: Unified Model; Version 11.9 **Domain:** Global **Horizontal Resolution:** 10 km **Vertical levels:** 70 levels (model top at 80 km) **Time step:** 4 min.	**Method:** Incremental 4D-Var ***Observations assimilated:*** Observations received at NCMRWF from GTS and other sources. (NOAA/NESDIS, EUMETSAT, ISRO etc.)	**Soil Moisture analysis:** *Method:* Simplified Extended Kalman Filter ***Observations assimilated:*** ASCAT soil wetness observations, Screen Temperature and Humidity increments (pseudo observations from 3D-Var screen analysis).	**Model:** NEMO ocean model (Vn 3.6) **Resolution:** ¼° quasiisotropic resolution (ORCA025 tripolar horizontal grid) **Vertical Levels:** 75 levels in the vertical varying in thickness. **Time step:** Both the ocean and CICE model components use a 20min time step. **Assimilation method:** 3D-Var FGAT (NEMOVAR)
In coupled simulations the atmosphere and land components exchange information with the ocean and sea ice components via the OASIS3 coupler using an hourly coupling frequency			

Implementation of coupled NWP system of "UM Partnership" (Vellinga et al. 2020) at NCMRWF is a major milestone in its progress. This article presents a brief description of the new-coupled NWP system implemented at NCMRWF (C-NCUM). Experimental forecasts run of C-NCUM are being conducted at the NCMRWF Mihir HPC system. The C-NCUM differs in many ways compared to its parent UM coupled system, including very different observation preprocessing. C-NCUM uses an in-house developed atmosphere, ocean, sea ice, land observation preprocessing systems, which uses

observations received at NCMRWF through GTS and various other sources. The data pre-processing system pack the observations in desired format for its further processing, including quality control. The quality-controlled observations are used in the weakly coupled Data Assimilation (DA) system. In the coupled DA system, atmospheric assimilation is based on 4D-Var/Hybrid 4D-Var method, whereas ocean and sea ices assimilation uses 3D-Var and land data assimilation is based on Extended Kalman Filter (EKF) method. Details of the C-NCUM assimilation-forecast system are given in Table-1. There are some differences in observations usage in C-NCUM compared to its parent UM system, like the use of INSAT satellite observations, GeoOptics GPSRO data etc. List of observations assimilated in the coupled C-NCUM is given in Table-2.

Table 2. Observations used for Atmosphere, Land and Ocean assimilation in C-NCUM

<table>
<tr><th colspan="7">Conventional Observations</th></tr>
<tr><td colspan="7">Atmosphere: Surface observations over land (SYNOP), SHIP, BUOY (Moored & Drifter), Pilot balloon, Radio-sonde, Wind Profiler, DWR, VAD Winds, Aircraft observations, GroundGPS
Ocean: Temperature and salinity profile (XBT-TESAC), ARGO, BUOY (Moored & Drifter)</td></tr>
<tr><th colspan="7">Satellite Observations</th></tr>
<tr><td rowspan="3">Atmosphere</td><td colspan="2">Radiances</td><td colspan="2">Satellite AMVs</td><td rowspan="2">Scatterometer Winds</td><td rowspan="2">GPSRO</td></tr>
<tr><td>Geostationary</td><td>Polar</td><td>Geostationary</td><td>Polar</td></tr>
<tr><td>INSAT-3D (Imager & Sounder) SEVIRI (Meteosat-8/10/11), ABI (GOES-16) AHI (HIMAWARI 8/9)</td><td>AMSU-A & B (METOPB/C, NOAA-15/18/19) ATMS (SNPP & NOAA20), IASI (METOP B/C), AIRS(AQUA), CrIS (SNPP, NOAA-20) SSMIS (F17), AMSR2 (GCOMW1), GMI-GPM (Low & High),</td><td>INSAT3D/3DR, Meteosat-8/10/11/70, HIMAWARI 8 & 9, GOES-16,17,18</td><td>NOAA 15/18/19/20, METOP A/B/C MODIS (Aqua & Terra), NPP_Soumi_VIRS</td><td>ASCAT (Metop B/C)</td><td>COSMIC-2E1-E6, SPIRE, FY-3C/3D, TerraSAR-X, TenDEM, PAZ KOMPSAT-5, METOP-B/C, GeoOptics, GRACE C & D,</td></tr>
<tr><td>Ocean</td><td colspan="6">SST (GHRSST), Sea Level Anomaly (SLA): Sentinel3A/3B/Altika, Sea-Ice Concentration (SSMIS)</td></tr>
<tr><td>Land</td><td colspan="6">ASCAT soil moisture observations</td></tr>
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Experiments have been carried out with the coupled global NWP system to assess its benefits and limitations, especially over the Indian monsoon region. The results of the studies are encouraging, but more long period studies are needed for robust conclusions. Operational use of the coupled system is planned from last quarter of this year, if the study results support.

References

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