DESCRIPTION OF REGIONAL NCUM MODELS (NCUM-R) AT NCMRWF

Various high resolution domains for Indian region are configured with the Unified Model (UM) seamless prediction system (adapted from "UM Partnership") for various applications collectively referred to as NCUM-R. Table 1 shows the history of NCUM-R starting with Singapur version (SINGV2) in 2016. UK Met Office Regional Atmosphere version was implemented, starting with the first version of RAL1 in 2018 followed by RAL2 in October 2020. The current version is NCUM-R:V5 which is based on UK Met Office science version "Regional Atmosphere and Land version 3" (RAL3), operationalised from 1 October, 2022. A pictorial representation of various regional models used at NCMRWF operationally is given in Figure-1. NCUM-R is implemented at three resolutions with 4km (All India), 1.5km (Delhi and neighbourhood) and 330m (Delhi city). NCUM-R has a rotated latitude-longitude horizontal grid with Arakawa-C staggering and a terrain-following hybrid vertical coordinate with Charney-Philips staggering. Only 4km domain is operationally run for the whole year, while the other two resolutions are run during winter for fog and visibility forecasts every year. The 4km domain covers (62^{o}E-106 ^{o}E; 6 ^{o}S 41 ^{o}N) with 1200x1200 grid points horizontally and 90 hybrid levels in the vertical with a top at 40km. The timestep is 2minutes for 4km grid size while the timesteps for 1.5km and 330m domain are 60 seconds and 12 seconds respectively. Three days forecasts are generated routinely for All India domain based on 00 UTC and 12 UTC initial conditions while the Delhi Model with Chemistry-Aerosol-cloud feedbacks (referred to as DM-Chem) is run only for winter fog and visibility prediction every year. "4D-Var" data assimilation system is used for the preparation of high resolution initial conditions for NCUM-R. The regional data assimilation system uses Indian Doppler Weather Radar observations in addition to satellite and conventional observations. NCUM-R updates its lateral boundary conditions every hour from operational global model forecasts (NCUM-G).

The model includes a comprehensive set of parameterization schemes, however the convection is explicit and the sub-grid scale deep convection parametrization is switched off. The model employs NASA Shuttle Radar Topographic Mission (SRTM) 90m digital elevation map orography. The upgradation to RAL3 involved much improved cloud-aerosol interactive microphysics scheme (CASIM) and Bi-modal cloud generation scheme (BM). The Delhi fog Model (DM-Chem) at 330m resolution includes additional features like chemistry-aerosol-cloud feedbacks (UKCA) and urban canopy parameterisation schemes (MORUSES). The real-time biomass emissions are initiated daily using Global Fire Assimilation System (GFAS) dataset. DM-Chem currently uses local aerosol emission inventories (EDGAR and IITM-SAFAR) and diurnally varying anthropogenic heat fluxes to account for the aerosol-cloud effect on the fog and visibility forecasts. The Delhi morphology data derived by Indian Institute of Remote Sensing (IIRS) is used to generate the empirical relationships between the urban morphological parameters and urban land-use fractions to estimate the impact of urbanisation on the near-surface parameters.

Table 1: The chronology of operational NCUM-R model versions at NCMRWF.

NCUM Versions	Nesting suite Science version	Implementation year	Domain
NCUM-R:V1	SINGV2	2016	AI
NCUM-R:V2	SINGV3	2017	AI
NCUM-R:V3	RAL1	2018	AI + BIMSTEC
NCUM-R:V4	RAL2	2020	AI + BIMSTEC
NCUM-R:V5	RAL3	2022	AI+BIMSTEC

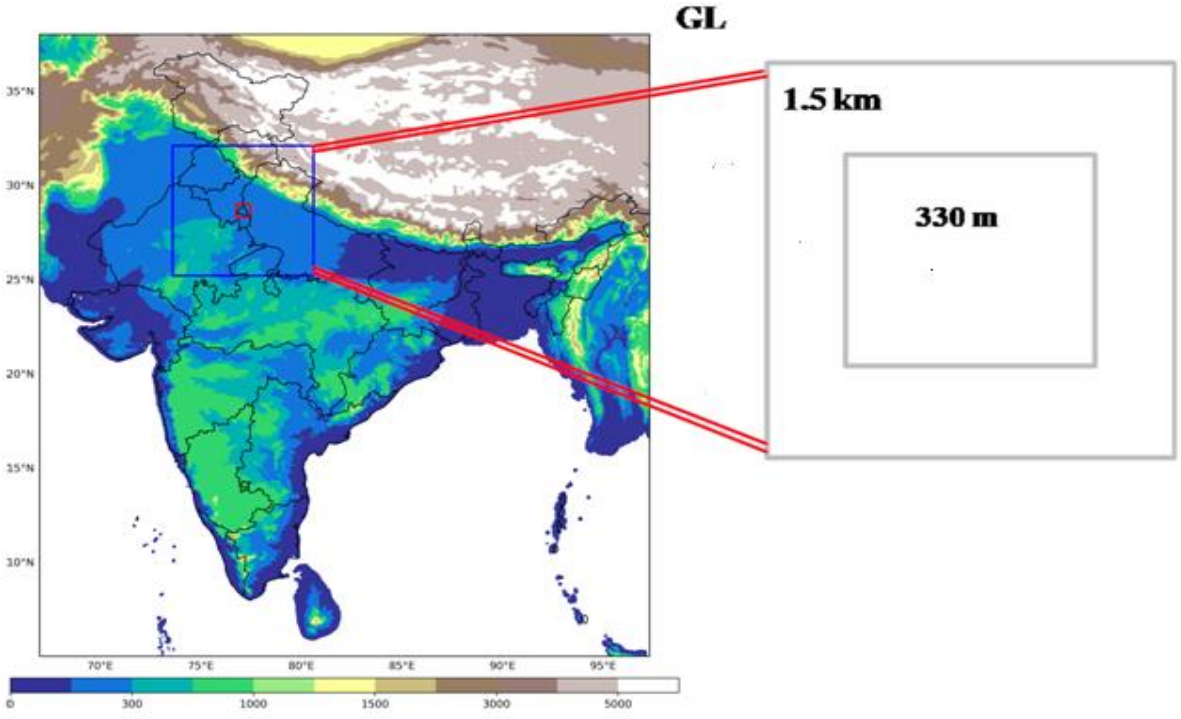

Fig. 1 The domain and orography of 4km NCUM-R and the sub-nesting domains structure of the Delhi Model (DM-Chem) at 1.5km and 330m resolutions.