WRF Modeling System Overview

Ananda Kumar Das

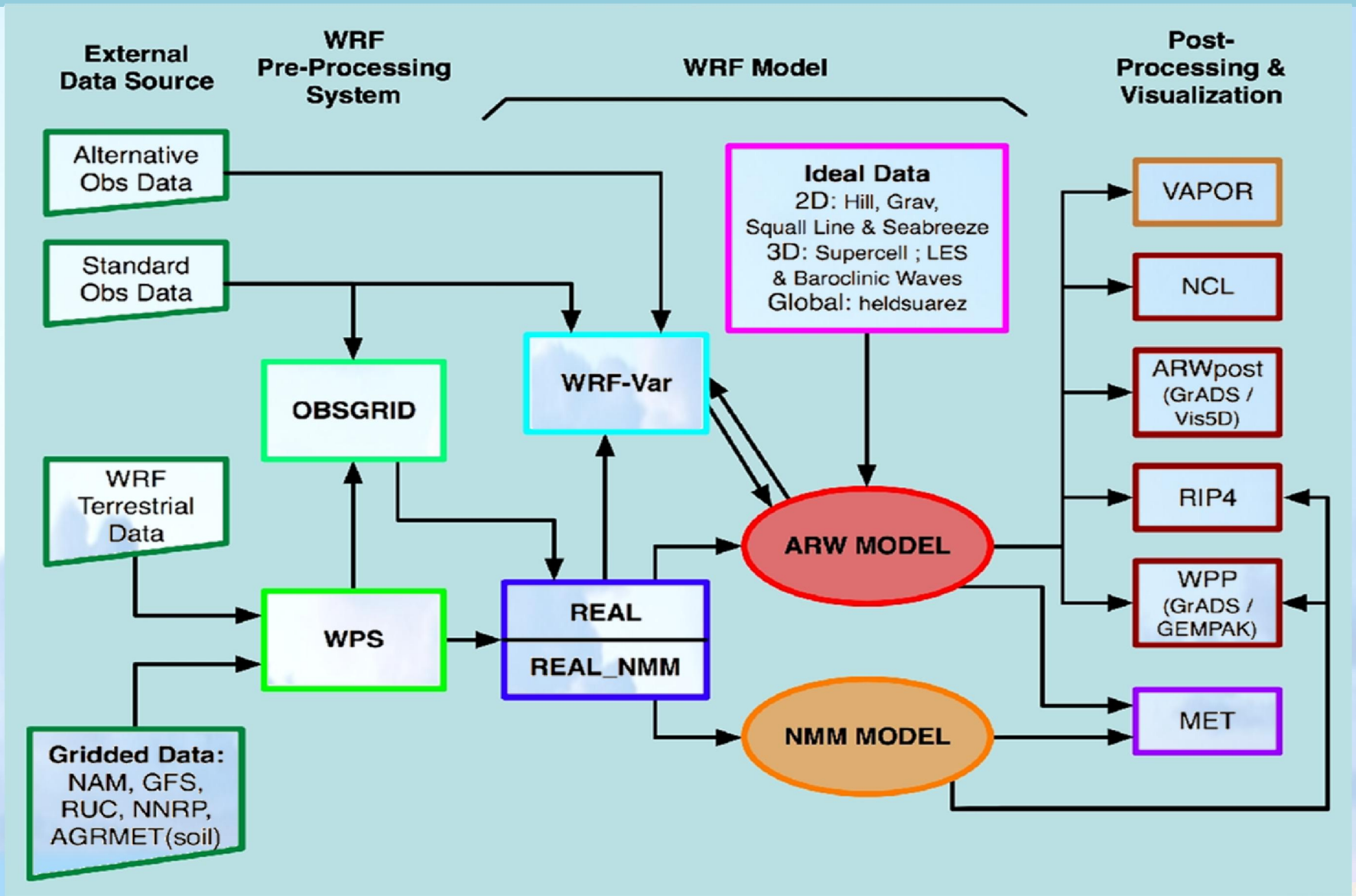
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Why WRF?

- An attempt to create a national mesoscale prediction system to be used by both operational and research communities.
- A new, state-of-the-art model that has good conservation characteristics (e.g., conservation of mass) and good numerics (so not too much numerical diffusion)
- A model that could parallelize well on many processors and easy to modify.
- Plug-compatible physics to foster improvements in model physics.
- Designed for grid spacings of 1-10 kmeta

WRF
Two Dynamical Cores
(ARW & NMM)

WRF Modeling system Flowchart



ARW Dynamics

Key features:

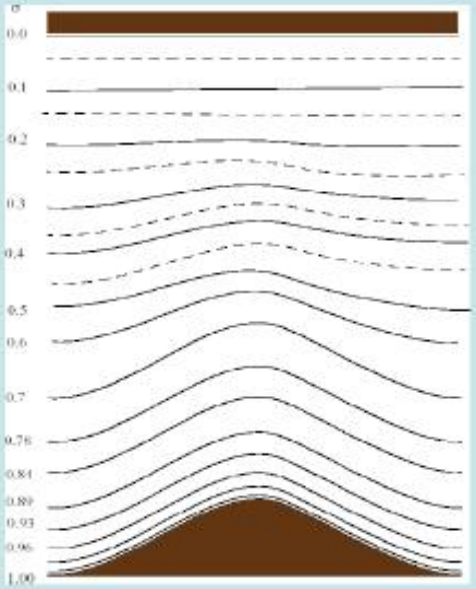
- Fully compressible, non-hydrostatic (with hydrostatic option)
- Mass-based terrain following coordinate, η

$$\eta = \frac{(\pi - \pi_t)}{\mu}, \qquad \mu = \pi_s - \pi_t$$

where π is hydrostatic pressure,
μ is column mass

- Arakawa C-grid staggering

v
u T u
v



$$J_s = \mu / \rho g$$

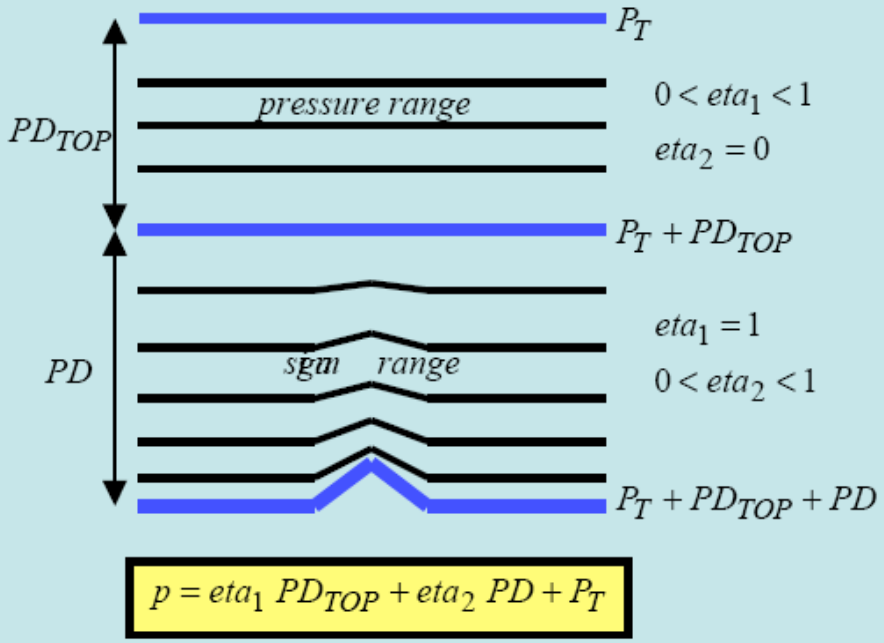
NMM Dynamics

Key features:

- Fully compressible, non-hydrostatic or hydrostatic
- Mass-based sigma-pressure hybrid terrain following coordinate similar to ARW but with constant pressure surfaces above 400 hPa
- Arakawa E-grid staggering

T **V** T
V T **V**
T **V** T

where **V** is u and v

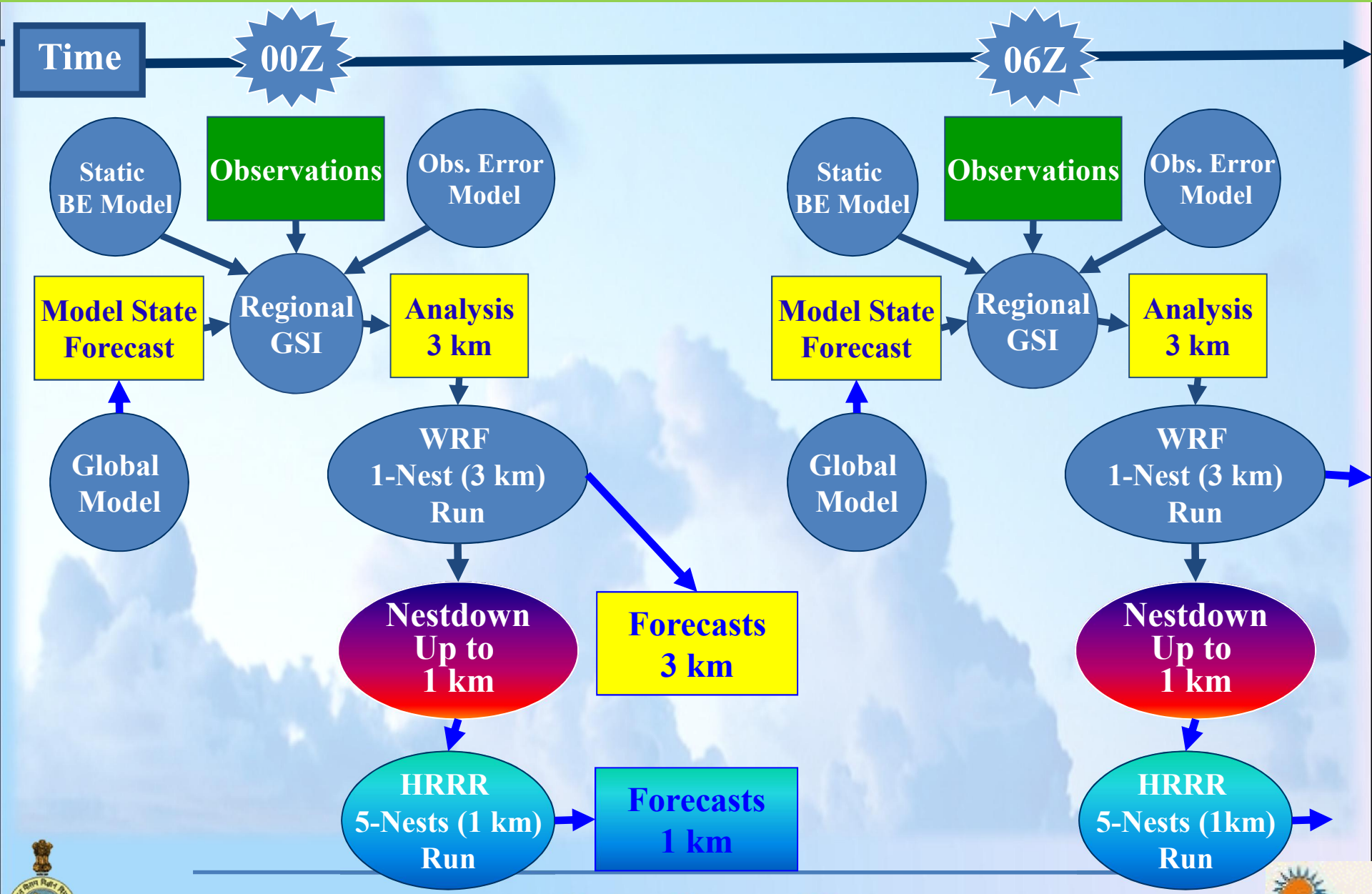


Key features

ARW	NMM
•3rd-order Runge-Kutta time integration	•Adams-Bashforth and Crank-Nicholson time integration schemes
•High-order advection scheme	•High-order advection scheme
•Scalar-conserving (positive definite option)	•Scalar and energy conserving
•Complete Coriolis, curvature and mapping terms	•Coriolis, curvature and mapping terms
•Two-way and one-way nesting	•One-way and two-way nesting
•Choices of lateral boundary conditions suitable for real-data and idealized simulations	•Lateral boundary conditions suitable for real-data and nesting
•Full physics options to represent atmospheric radiation, surface and boundary layer, and cloud and precipitation processes	•Full physics options to represent atmospheric radiation, surface and boundary layer, and cloud and precipitation processes
•Grid-nudging and obs-nudging (FDDA)	•Not yet developed
•New Digital Filter Initialization option	•Not yet developed

Operational Setup

Operational WRF Forecast: Cold-Start Assimilation



Why Nestdown ?

- **Tripple nested WRF configuration is best choice with 2-way nesting**
  - It is compute intensive / time consuming
  - No scope to improve child domain IC/BC using additional observation
  - Possible for a few child domain (may be for 2-3 child)
  - Not suited for Operational environment (may be tried in R&D)
- **Generation of IC/BC using Nestdown from Course resolution Model Output**
  - Less computing power required and task can be distributed in several computing systems
  - After nestdown, IC can be improved through data assimilation
  - Using nestdown ICs/BCs can be generated for many domains
  - ICs/BCs can be distributed amongst centers to facilitate fast and efficient operational mesoscale modeling

Model Configuration at 3 km		
Domain	1851x1951	N-S and E-W 5.0° S to 40 °N and 50° E to 102°E
Map Projection	Mercator	True at equator
Geophysical data resolution	5 minutes	SourceUSGS
Vertical levels in eta co-ordinate	45 levels	Normalized pressure
Top boundary	50 hPa	
Physics	-	-
Cloud Microphysics	Option 16	WRF Double-Moment 6-class scheme
Radiation – Long-wave	Option 4	RRTMG scheme
Radiation – Short-wave	Option 4	RRTMG shortwave
Radiation schemes frequency	Every 15 minutes	-
Surface Layer Physics	Option 2	Eta similarity
Surface Physics	Option 2	Noah Land Surface Model
Planetary Boundary Layer	Option 2	Mellor-Yamada-Janjic scheme
PBL scheme frequency	Every time step	-
Cumulus parameterization	Option 5	Grell 3D Ensemble cumulus scheme
Cu Parameterization frequency	Every 5 minutes	-

Graphics and Verification Tools

- ARW and NMM
  - UNIFIED Post-Processor (UPP)
    - Conversion to GriB (for GrADS and GEMPAK)
    - Conversion program for GrADS and Vis5D
  - MET (Model Evaluation Toolkit)
- ARW
  - NCAR Graphics Command Language (NCL)

WRF for Different Applications

- Hydro-Meteorological application
  - WRF-Hydro
- Air Quality Forecast
  - WRF-Chem
- Renewable Energy
- Forest Fire
  - WRF Fire
- Aviation

-Lightning, gust & Turbulence

- Surface Transport

Class of Products

- NWP charts for website for analysis and 3 days forecasts (27 km and 9 km)
- 27 km is processed and uploaded to Synergie server through Transmet
- Meteograms for airports from 9 km domain
- Aviation products for low-flying aircrafts from 9 km domain
- Rainfall data files are generated for a few specific domains (Bihar, NESAC, Mhanadi)
- Location specific hourly meteograms and hourly time series data for 30 locations in Delhi-NCR
- Antarctica forecasts for 2 days from polar-WRF into website
- Meteograms for two Indian stations in Antarctica
- Time-to-time additional products for different field experiments (STORM, FDP-Cyclone and Fog)

IMD Internal Website: https://nwp.imd.gov.in

NWP SOP on IMD main website

Thank You