Operational HWRF Modeling System -2021

A Collaborating effort between MoES-NOAA
IMD, NCMRWF, INCOIS and EMC

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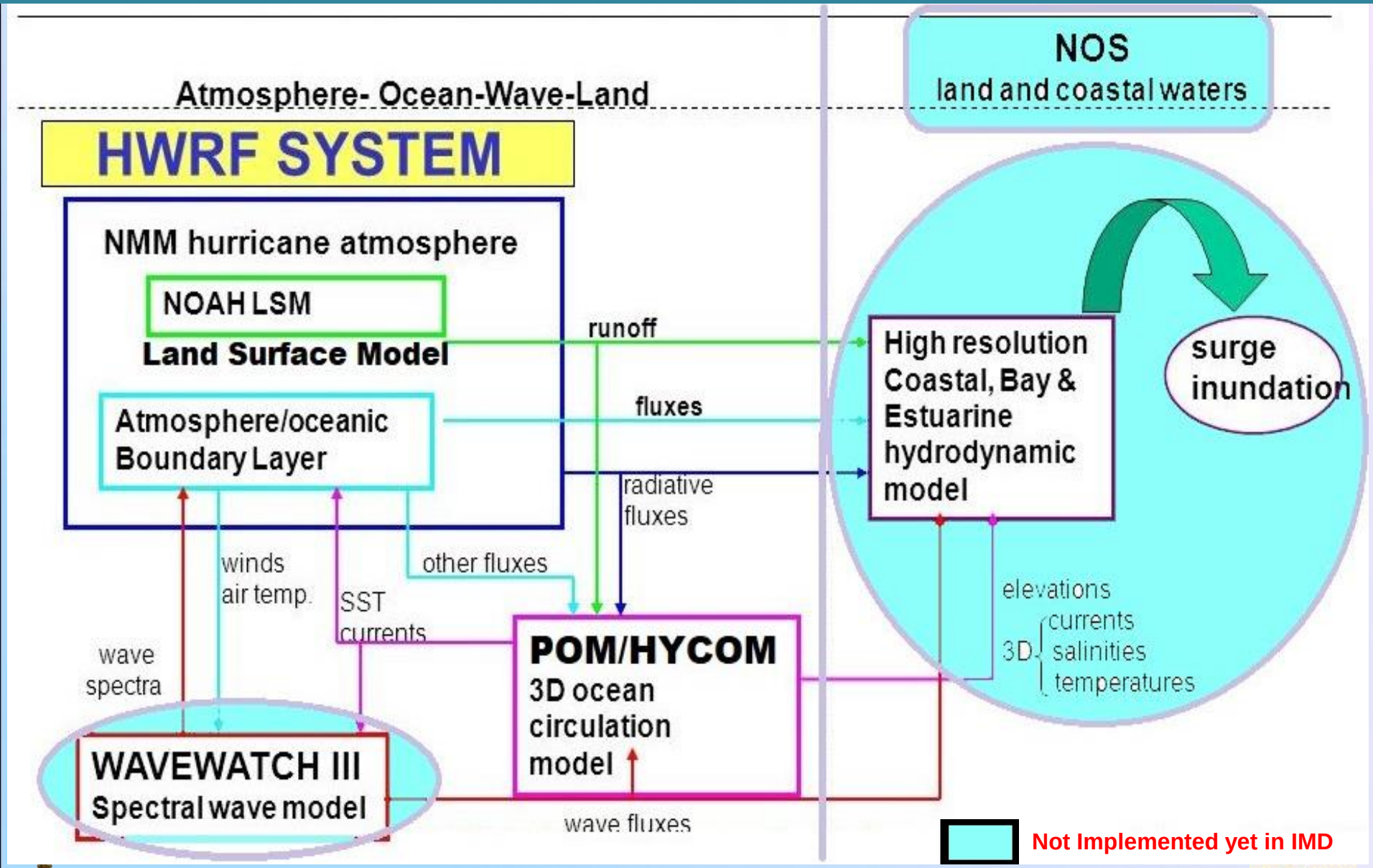
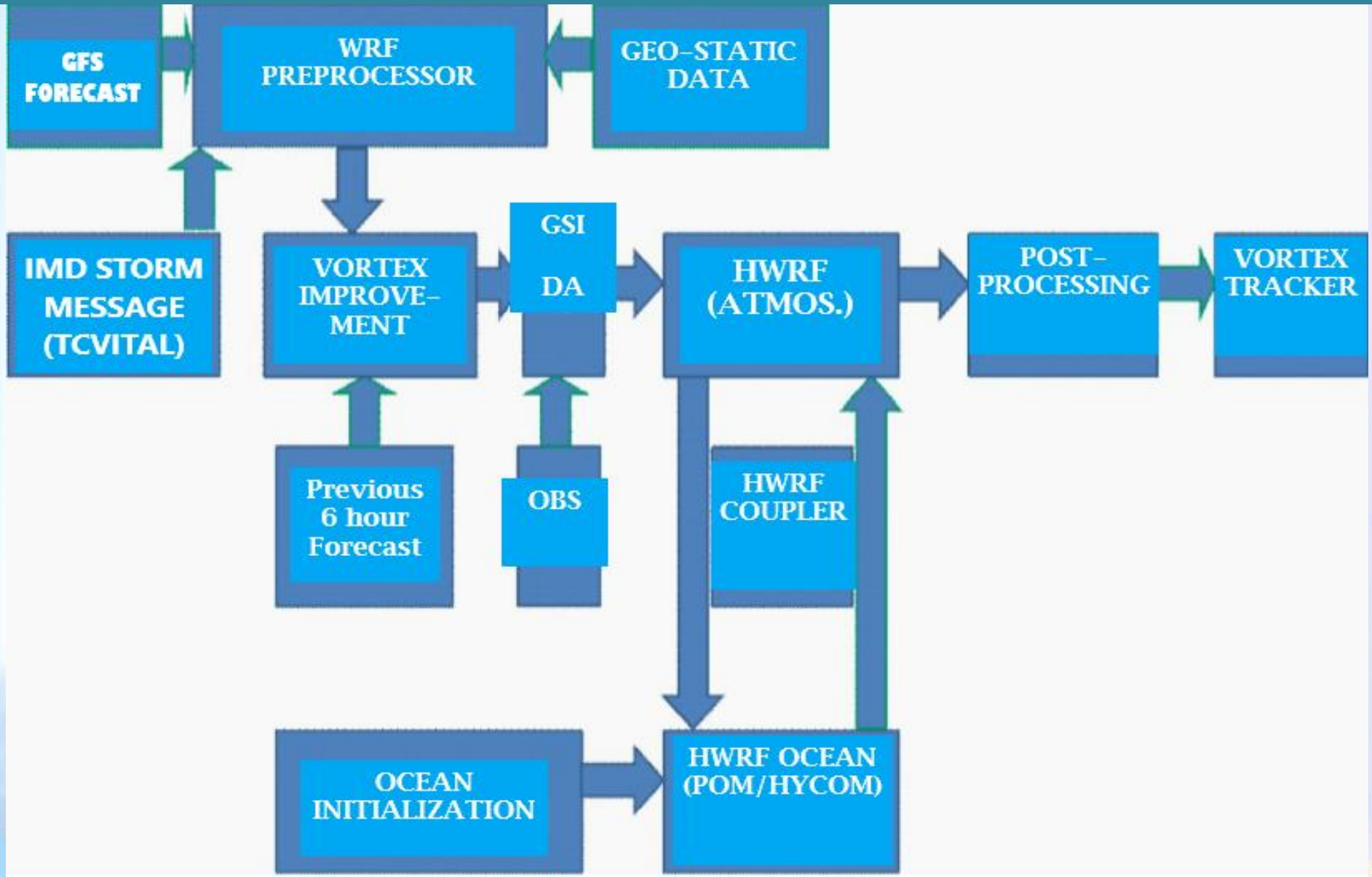
Progress in HWRF Modeling System

Years	Domain Configuration	Data Assimilation	Ocean Coupling
2019	**Triple nest (18x6x2 km) with enhanced domain size 4 times a day**	**GSI (hybrid-EnVar) assimilation (80 members) with 6 hourly cycle in cycling mode**	**Coupled with HYCOM model + NCEP coupler – Ocean initial state from RTOFS (regional HYCOM) of INCOIS**
2017-2018	Triple nest (18x6x2 km) 4 times a day	GSI (hybrid-EnVar) assimilation with 6 hourly cycle in cycling mode	Coupled with POM model + NCEP coupler
2012 to 2016	Starting from Double nests (27 x 9 km) twice a day To Triple nests (18x6x2 km) 4 times a day	GSI (3DVAR) assimilation without cycling (cold start mode) To GSI (3DVAR) assimilation with 6 hourly cycle in cycling mode	No ocean coupling

HWRF Coupled Modeling System

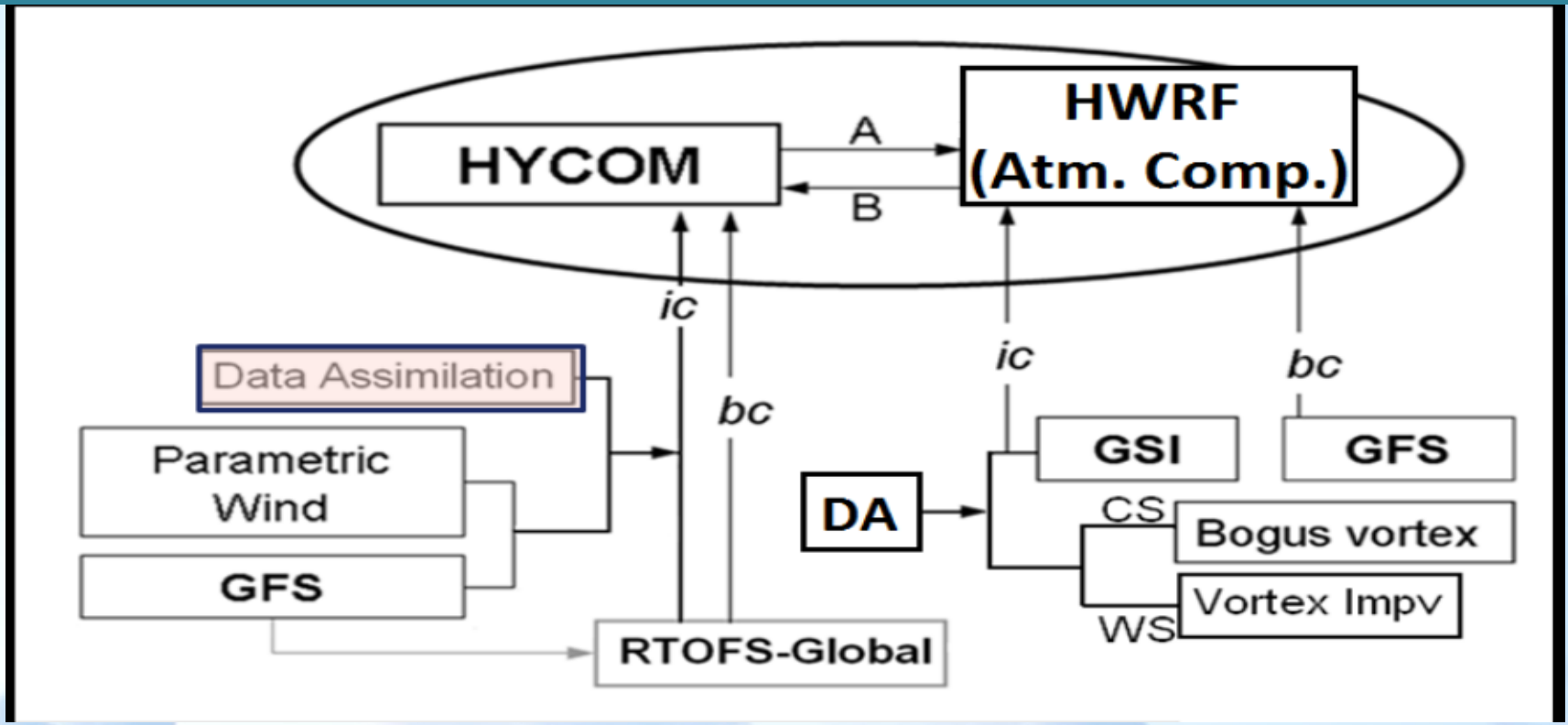


HWRF Modeling System with GSI Data Assimilation



HWRF Operational Configuration	
Domain-Parent	Center:- Storm Center Size:- 80^0 X 80^0 Grid Spacing:- 18 Km Grid Points:-288 X 576
Intermediate Nest (Moving)	Center:- Storm Center Size:- 24^0 X 24^0 Grid Spacing:-06 Km Grid Points:-265 X 532
Inner Most Nest (Moving)	Center:-Storm Center Size:- 7^0 X 7^0 Grid Spacing:- 02 Km Grid Points:- 235 X 472
Map Projection	Rotated Latitude and Longitude
Vertical Levels In Hybrid Pressure Sigma Coordinates	61
Top Boundary	10 Hpa
Cloud-Microphysics	Ferrier-Aligo Cloud Microphysics
Radiation	Rapid Radiative Transfer Model For General Circulation Models (RRTMG)
Surface Layer Physics	Modified Geophysical Fluid Dynamics Laboratory (GFDL) Surface Layer
Surface Flux Calculation	The Monin-Obukhov
Represent The Land Surface	The Noah Land Surface Model
Planetary Boundary Layer	Global Forecasting System (GFS) Eddy-Diffusivity Mass Flux
Cumulus Parametrization	Scale-Aware Arakawa-Schubert

Ocean Coupling



A: sea surface temperature (SST)

B: 1. Precipitation

2. Atmospheric pressure

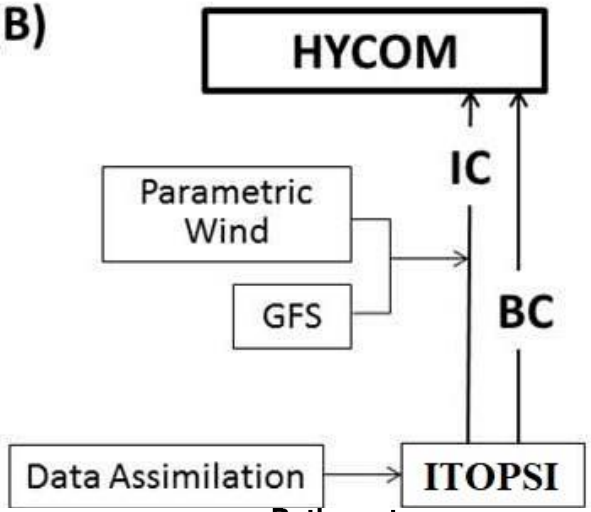
3. Heat fluxes – Sensible, latent, total and net shortwave radiation

4. Wind stress

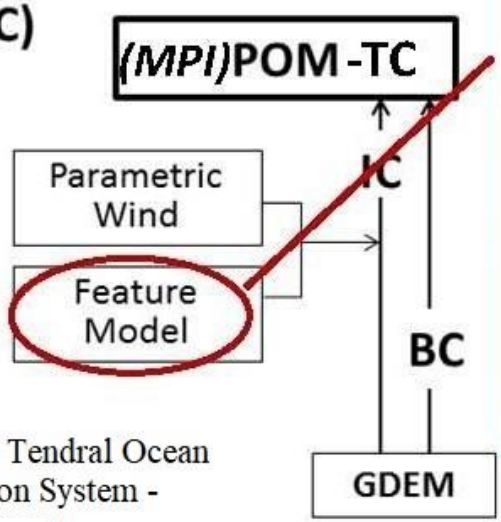
Ocean Coupling

3D ocean:

(B)



(C)



GDEM monthly climatology
Sharpen eddies & currents
Use daily NCEP SST

↓

SST held constant, 48-h geostrophic adjustment

↓

Cold wake generated by parametric winds using NHC message file

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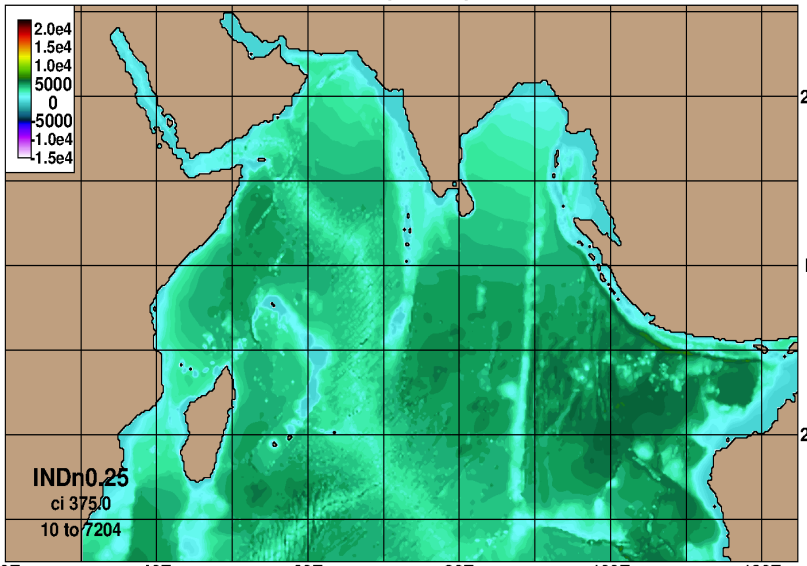
Model coupling performed

INCOIS Tendral Ocean Prediction System -

(Generalized Digital Environmental Model)

Bathymetry



POM:

a. dx/dy=9km
b. 40 levels
c. Coarse resolution of MLD
   - 10 m (top), 20 m (2nd), ...
d. **M-Y mixing**

INCOIS Tendral Ocean Prediction System over Indian Ocean (ITOPSI)

eddy-permitting

Ocean Coupling

	POM	HYCOM
Dynamics & Configurations	Hydrostatic, free-surface, primitive equations on C grid	
	1/12-degree	
	Rectangular Projection	Mercator Projection
	40 vertical sigma level	41 vertical Hybrid isopycnal-Z levels
Mixing Physics	Mellor-Yamada 2.5 closure	KPP (K-Profile Parameterization)
Initialization	Monthly GDEM3 Climatology + daily NCEP SST + Feature Model	6 hourly HYCOM analysis from INCOIS-RTOFS
Lateral Boundary	Adjusted T/S fields	6 hourly 2D and 3D INCOIS-RTOFS forecasts

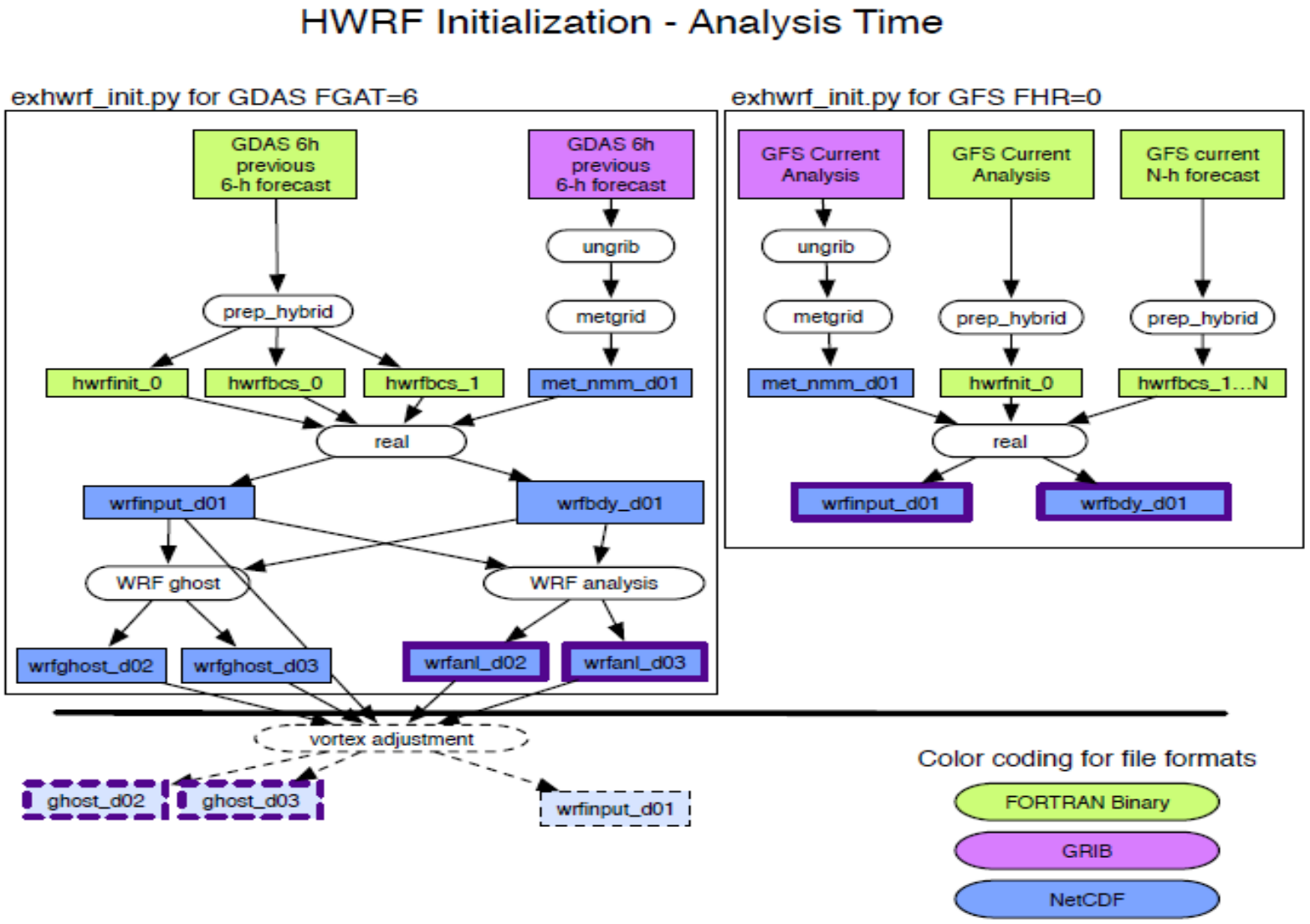
Following files are provided by INCOIS for HYCOM run:-

1. **RestartFiles** - rtofs_glo.t00z.n00.restart.b/*.a
2. **archv Files** - rtofs_glo.t00z.n00.archv.b/*.a (n-24 through <all forecast hours> every 6 hours)
3. **archs Files** - rtofs_glo.t00z.n00.archs.b/*.a (n-21 through <all orecast hours> every 6 hours)

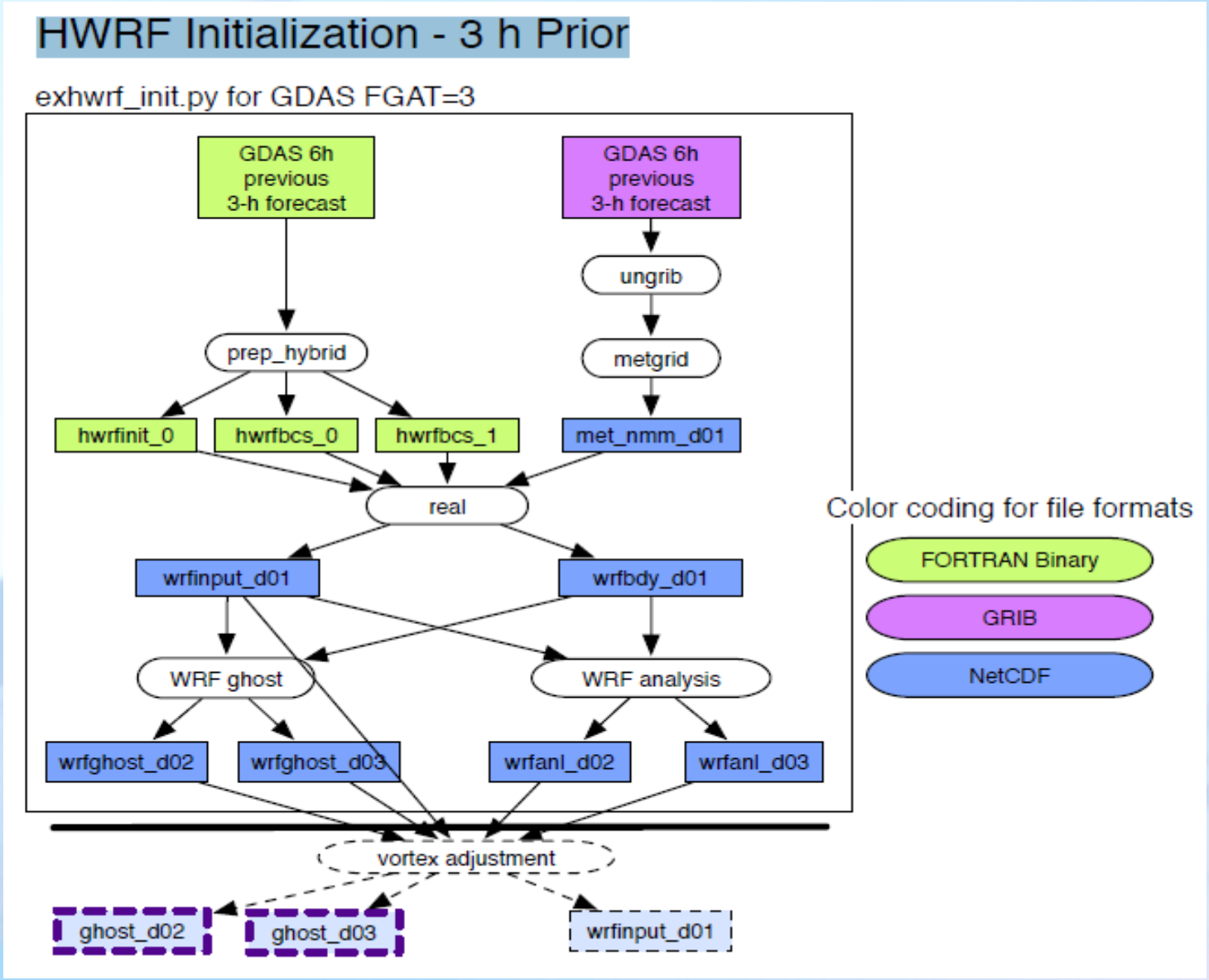
*.a Binary data files , *.b ASCII files describing *.a binary files.

INCOIS data files size in a single cycle for 4 days forecast is 11 GB.

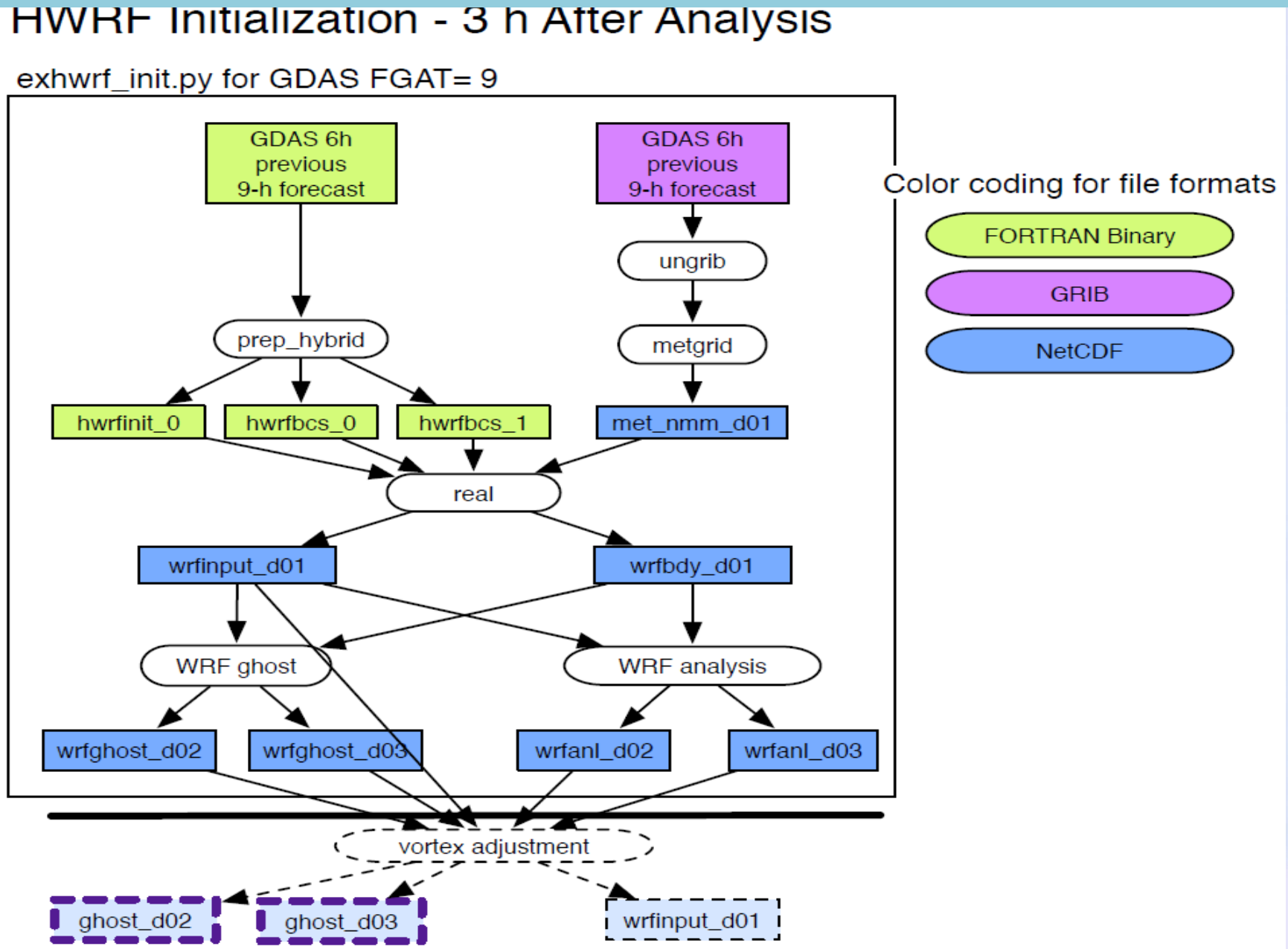
HWRF Initialization



HWRF Initialization with FGAT



HWRF Initialization with FGAT

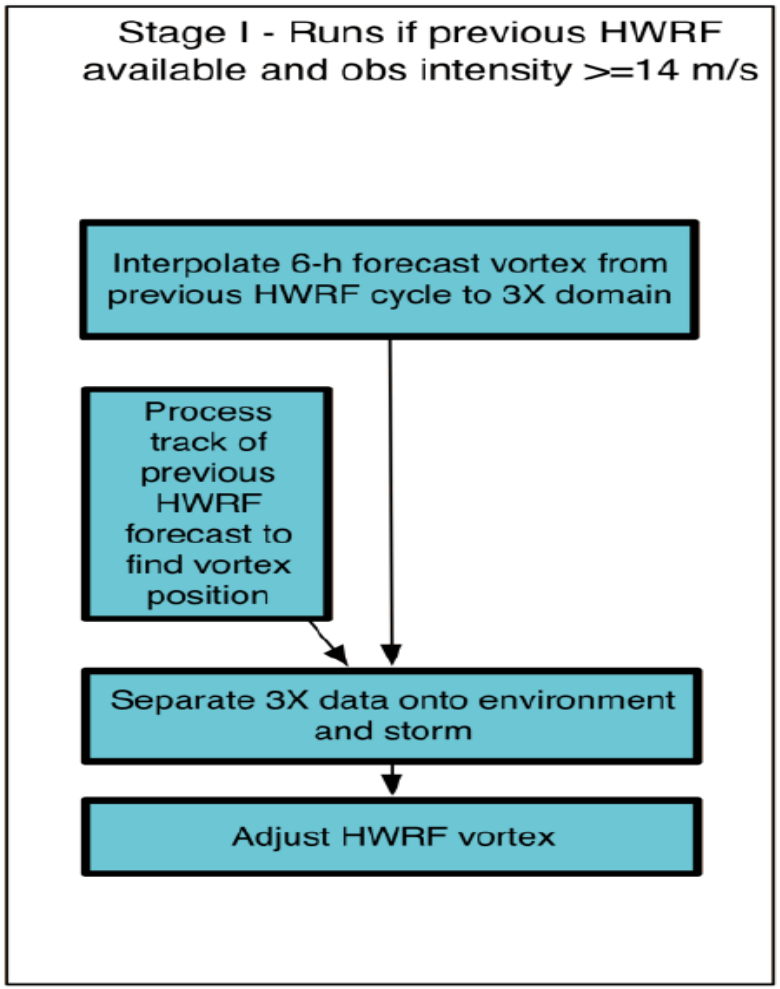


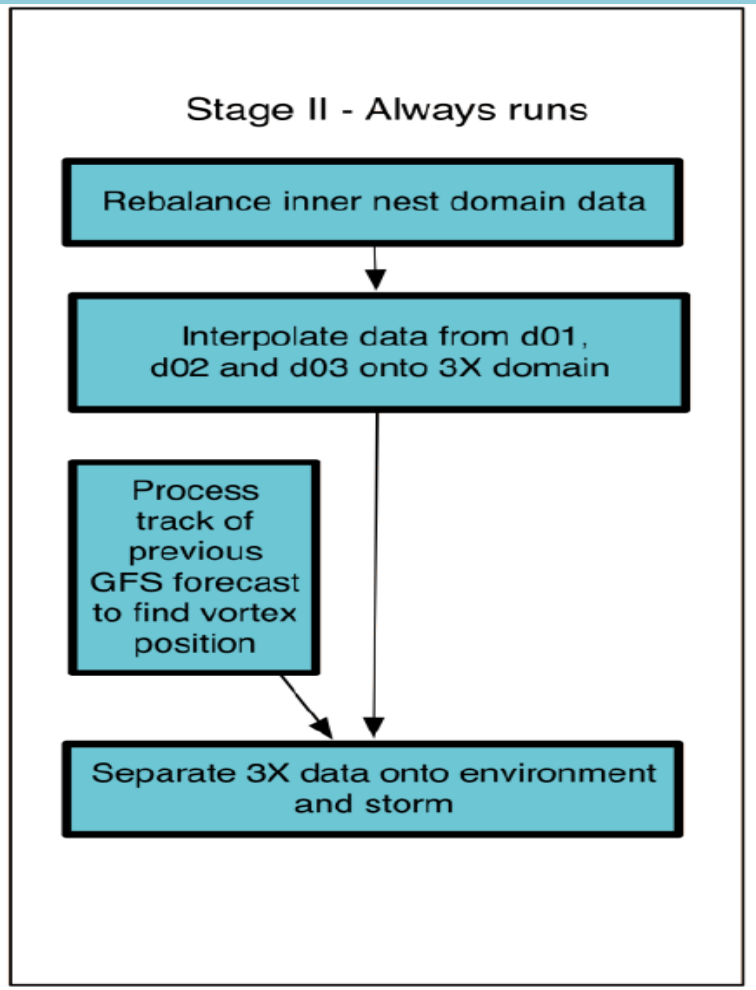
Correction of vortex in previous 6-h HWRF or GDAS forecast

The vortex correction adjusts the location, size, and structure based on the TCVitals:

- storm location (data used: storm center position);
- storm size (data used: radius of maximum surface wind speed. 34-kt wind radii, and radius of the outmost closed isobar); and
- storm intensity (data used: maximum surface wind speed and, secondarily, the minimum sea level pressure).

HWRF-Vortex Initialization (stages I and II)

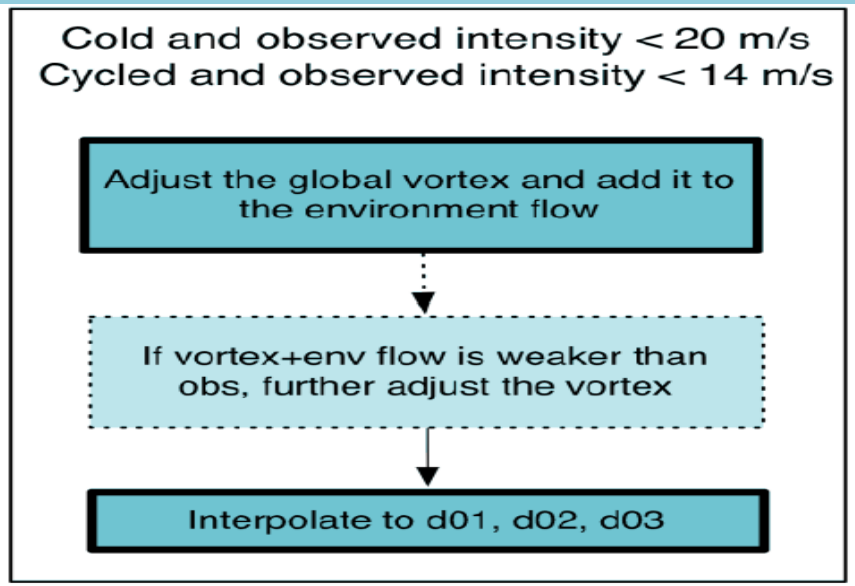


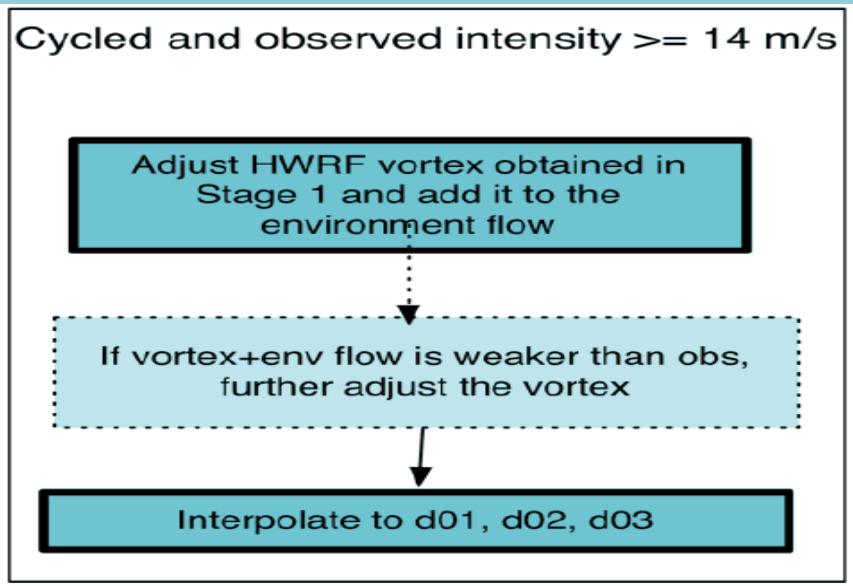


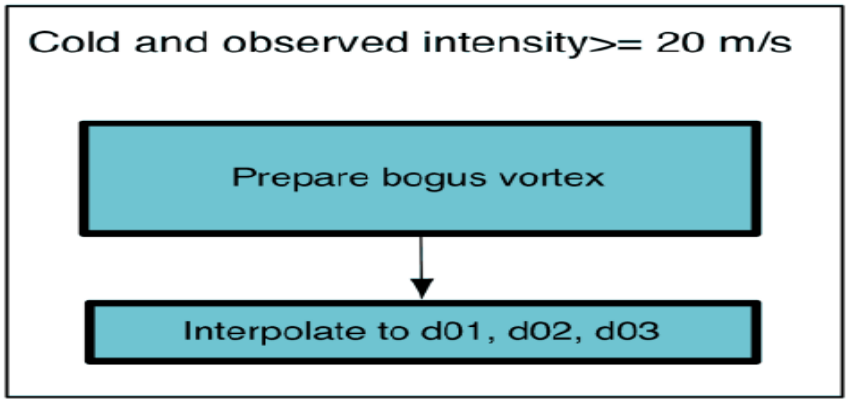
Stage I is used to split the previous HWRF forecast onto storm and environment so that the vortex can be adjusted and relocated. This is not done when the storm is very weak as it is best to use the GFS vortex in that case.

Stage II is used to split the global forecast to get the environment.

HWRF-Vortex Initialization(stage III)



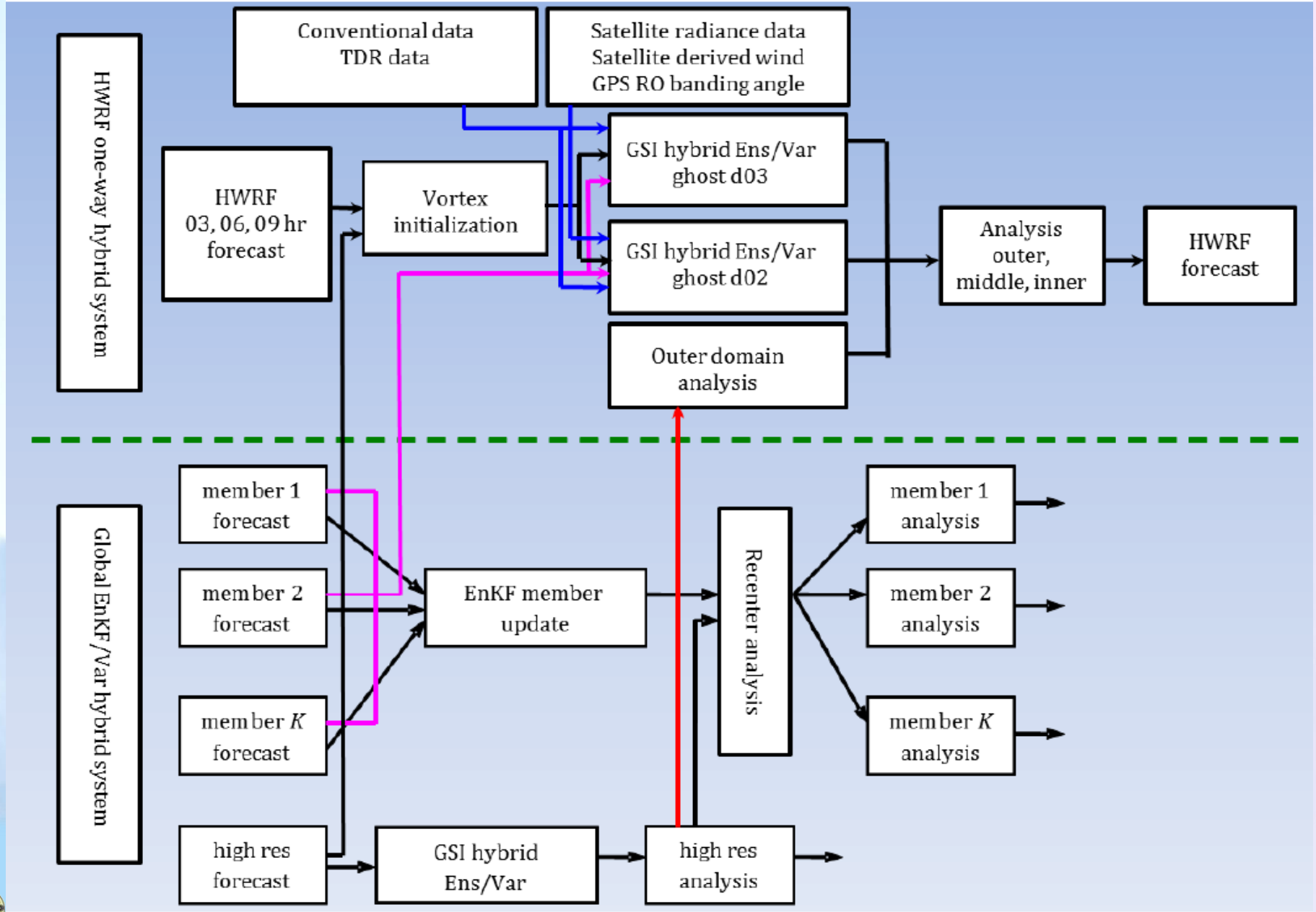




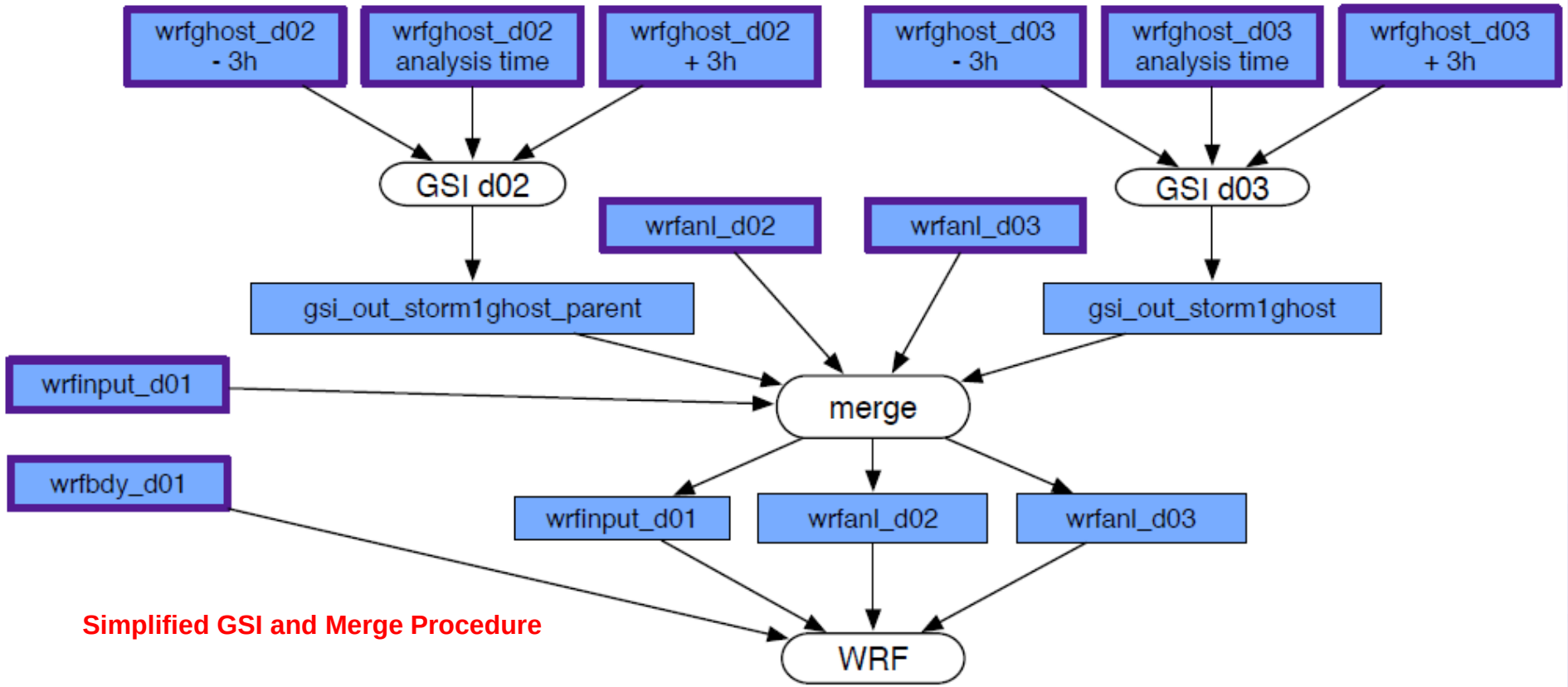
Stage III

- For cold starts, bogus strong storms but use global vortex for weak ones.
- For cycled starts, use HWRF vortex for strong storms but cycle global vortex for weak ones.

HWRF-GSI Data Assimilation



HWRF-GSI Data Assimilation



Simplified GSI and Merge Procedure

Conventional observations (contained in prepbufr file) assimilated in ghost d02 and ghost d03 domains include:

□ radiosondes; □ dropwindsondes; □ aircraft reports (AIREP, RECCO , MDCRS-ACARS, TAMDAR , AMDAR); □ surface ship and buoy observations; □ surface observations over land; □ pibal winds; □ wind profilers; □ radar-derived Velocity Azimuth Display (VAD) wind; □ WindSat scatterometer winds; and □ integrated precipitable water derived from the Global Positioning System.

Satellite observations assimilated in ghost d02 domain include:

□ Radiances from IR instruments: HIRS, AIRS, IASI, GOES Sounders □ Radiances from MW instruments: AMSU-A, MHS, ATMS □ Satellite derived wind: IR/VIS cloud drift winds, water vapor winds

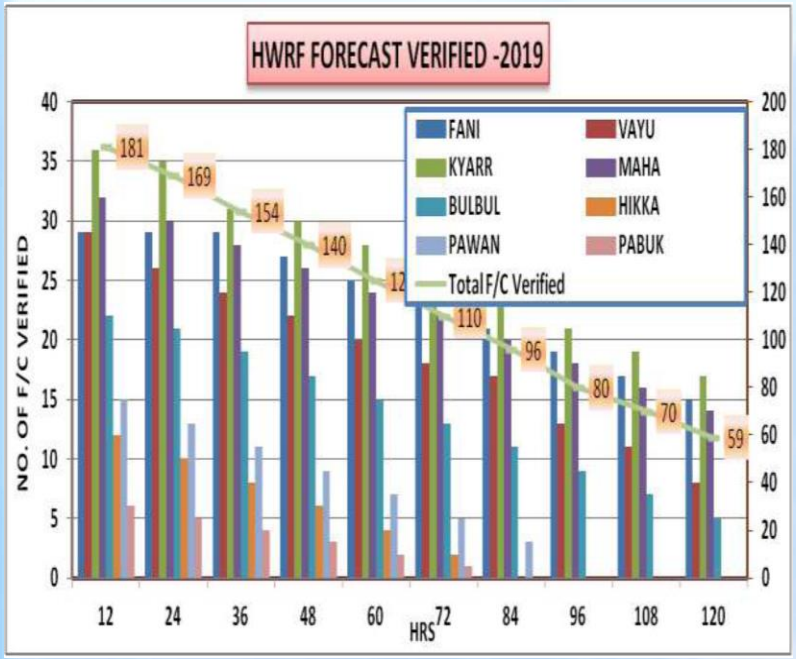
Forecast verification of Cyclones: 2019

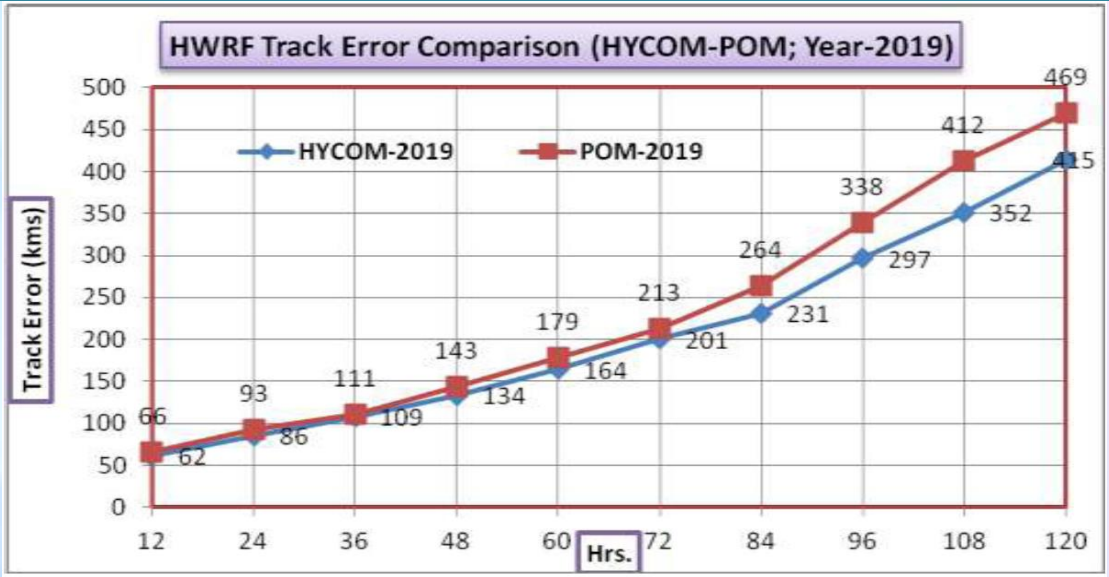
Pre-Monsoon Season – 2019 :

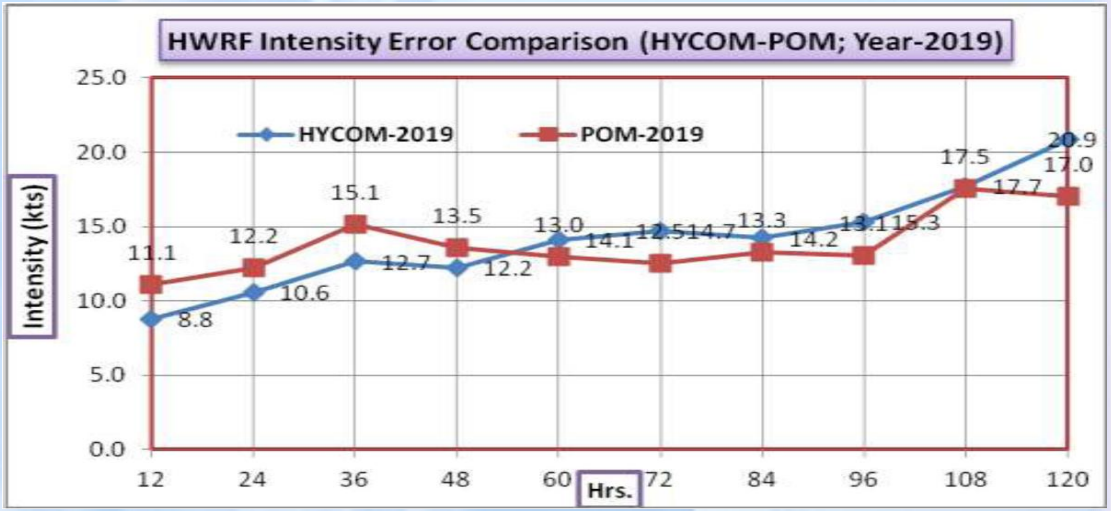
1. CS-PABUK
2. ESCS-FANI
3. VSCS-VAYU

Post-Monsoon Season : - 2019 :

4. VSCS-HIKKA
5. SUPER-CS-KYARR
6. ESCS-MAHA
7. VSCS-BULBUL
8. CS-PAWAN







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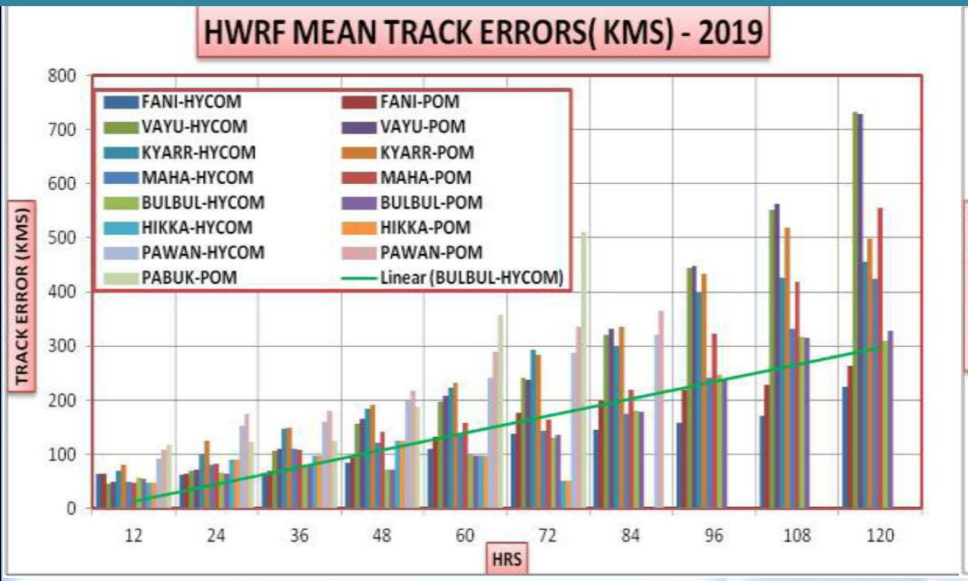
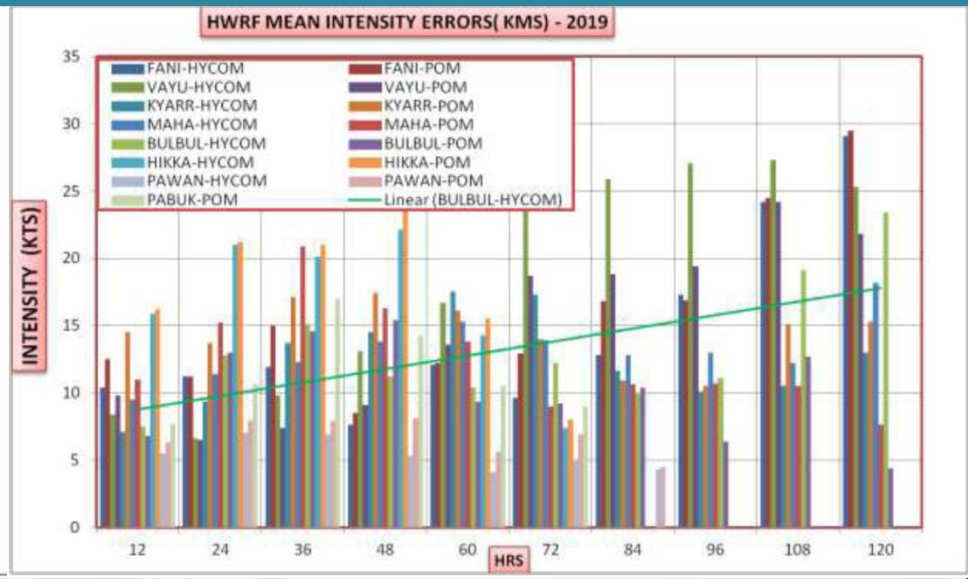
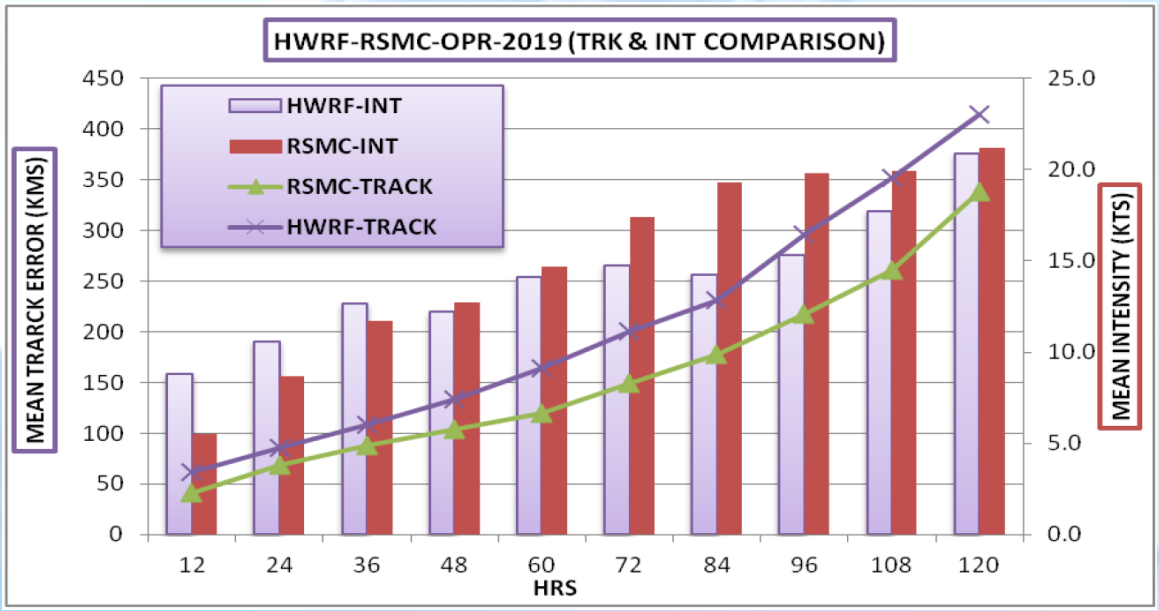
Forecast verification of Cyclones: 2019







A Few Points for Operational HWRF-HYCOM Modeling System

Atmospheric Model:

- **Initialization for weaker storm (without any TCVITAL information)**
- **Improvement in rainfall prediction (rainfall over land region)**
- ***Improvement in intensity prediction (reduction of overestimation)***
- ***Physics to represent land-air-sea interactions at high-resolution***

Atmospheric Data Assimilation:

- **Start of cycling well ahead of the system to become cyclone**
- **Emphasis on non-conventional observations (i.e. radar radial wind, reflectivity and satellite radiances)**
- ***Instead of global rather use of regional ensemble perturbations for EnVar***

Ocean Coupling:

- **Use of IMD-GFS for regional ITOPSI of HYCOM model at INCOIS**
- **HYCOM coupling with HWRF well ahead of the system to become cyclone**
- ***Effective coupling with shorter time interval preferably at every cycle***

THANK YOU