Operational HWRF Modeling System -2021

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

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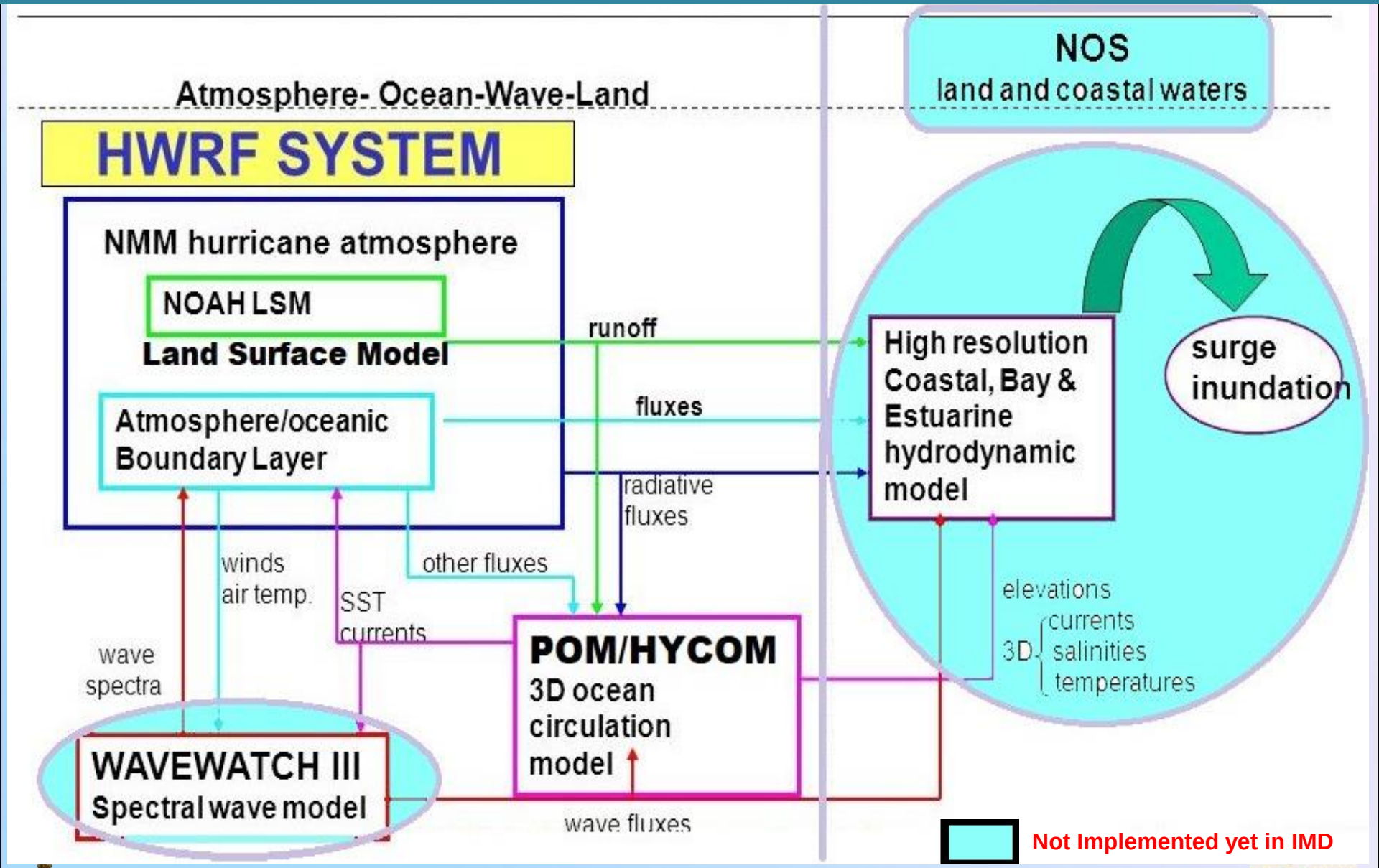
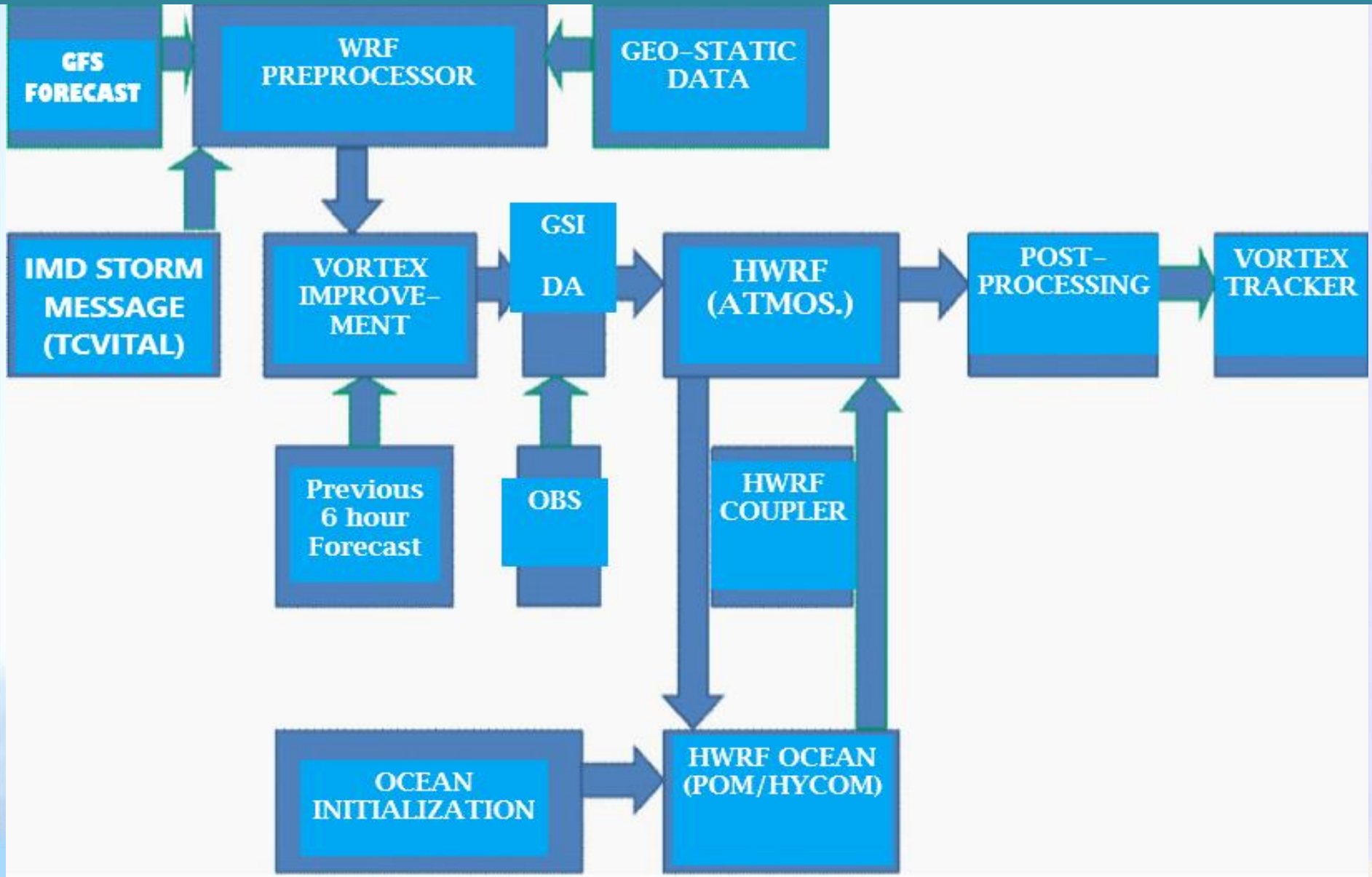
Progress in HWRF Modeling System

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

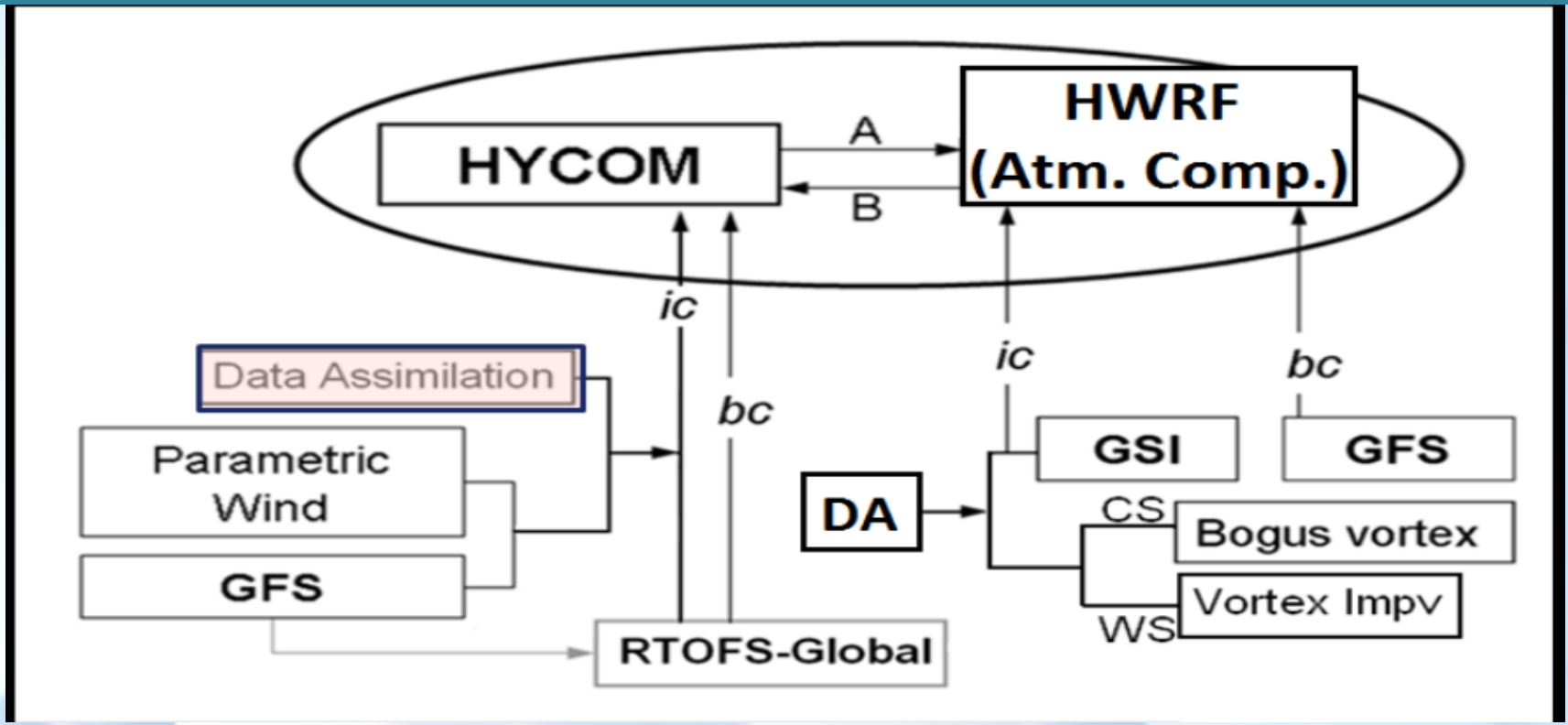


HWRF Modeling System with GSI Data Assimilation



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

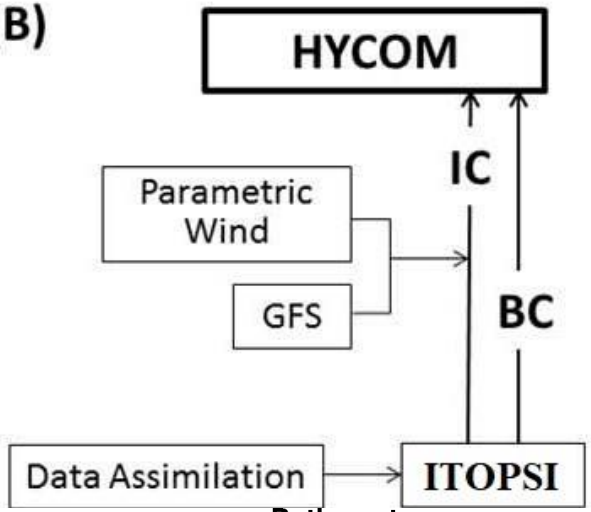
3. Heat fluxes – Sensible, latent, total and net shortwave radiation

4. Wind stress

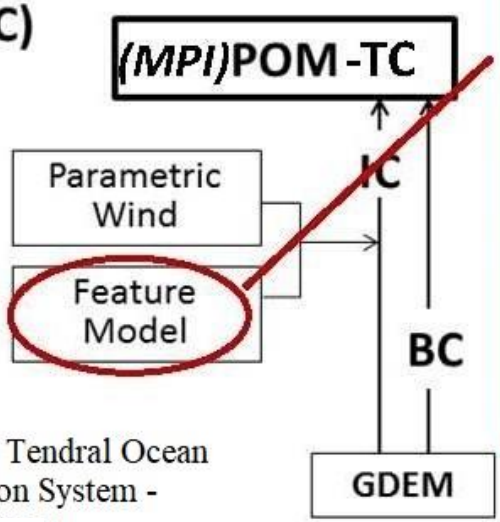
Ocean Coupling

3D ocean:

(B)



(C)



GDEM monthly climatology
Sharpen eddies & currents
Use daily NCEP SST

↓

SST held constant, 48-h geostrophic adjustment

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Cold wake generated by parametric winds using NHC message file

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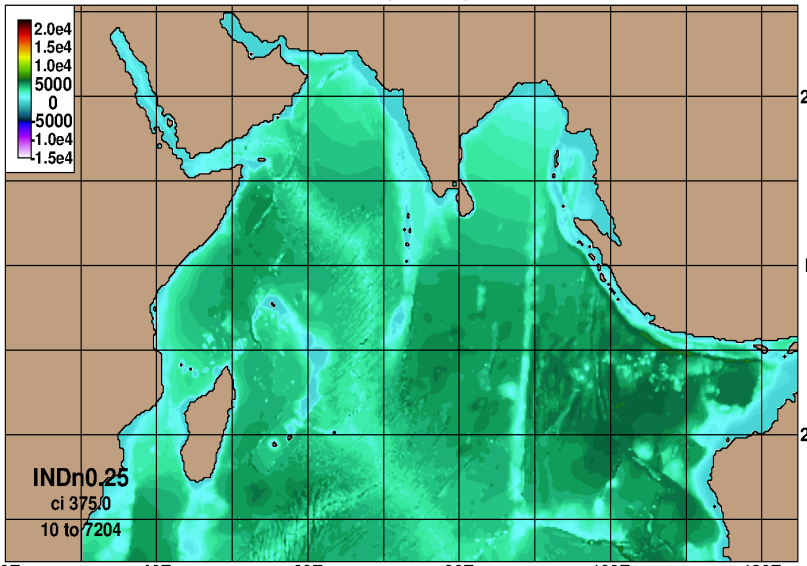
Model coupling performed

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

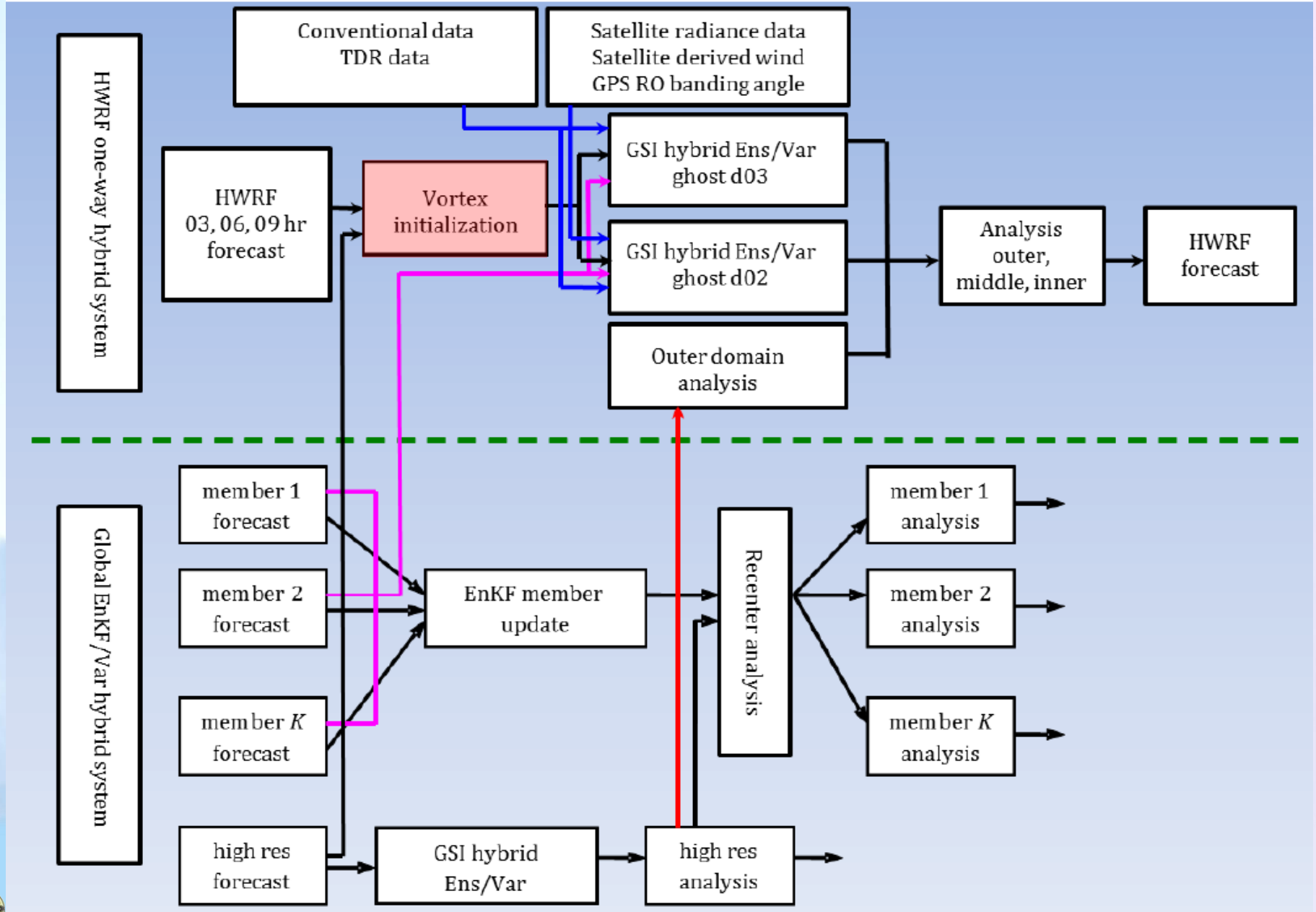
Following files are provided by INCOIS for HYCOM run:-

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-GSI Data Assimilation



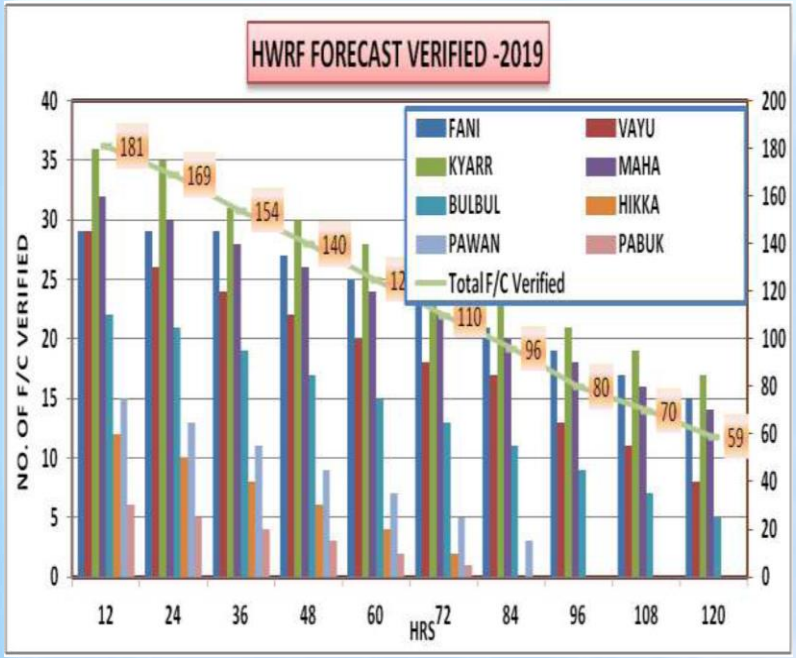
Forecast verification of Cyclones: 2019

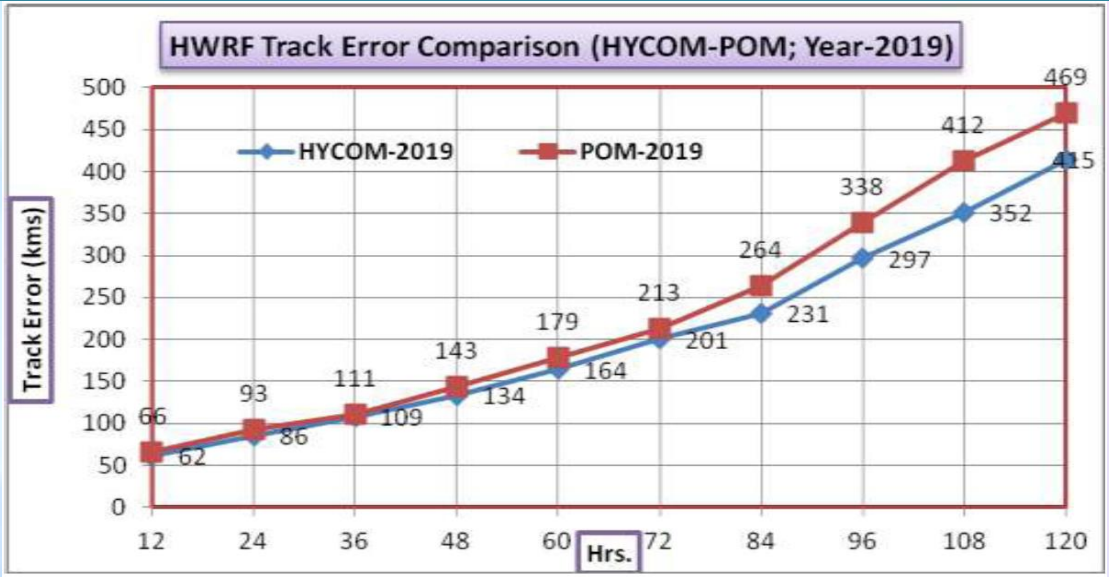
Pre-Monsoon Season – 2019 :

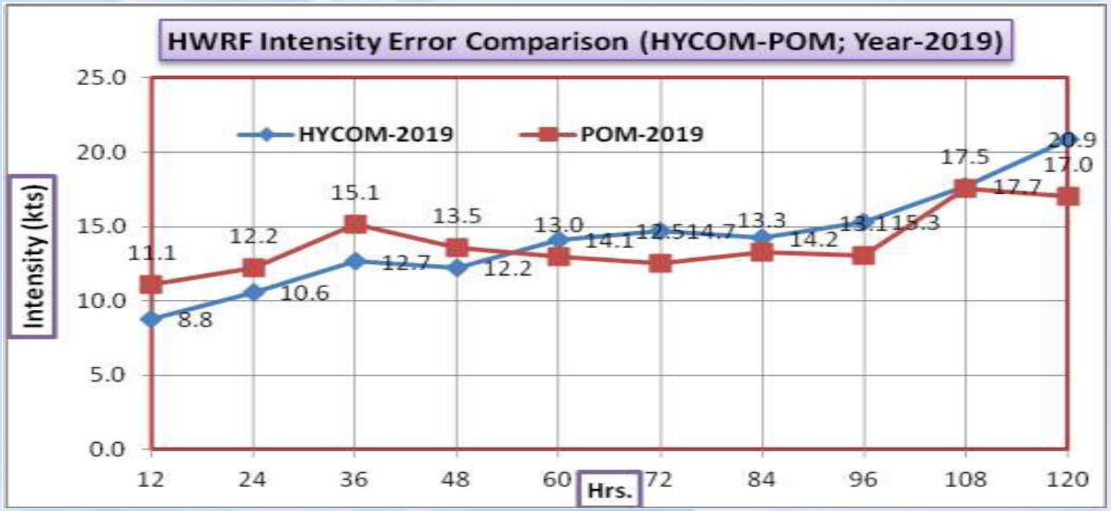
1. CS-PABUK
2. ESCS-FANI
3. VSCS-VAYU

Post-Monsoon Season : - 2019 :

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







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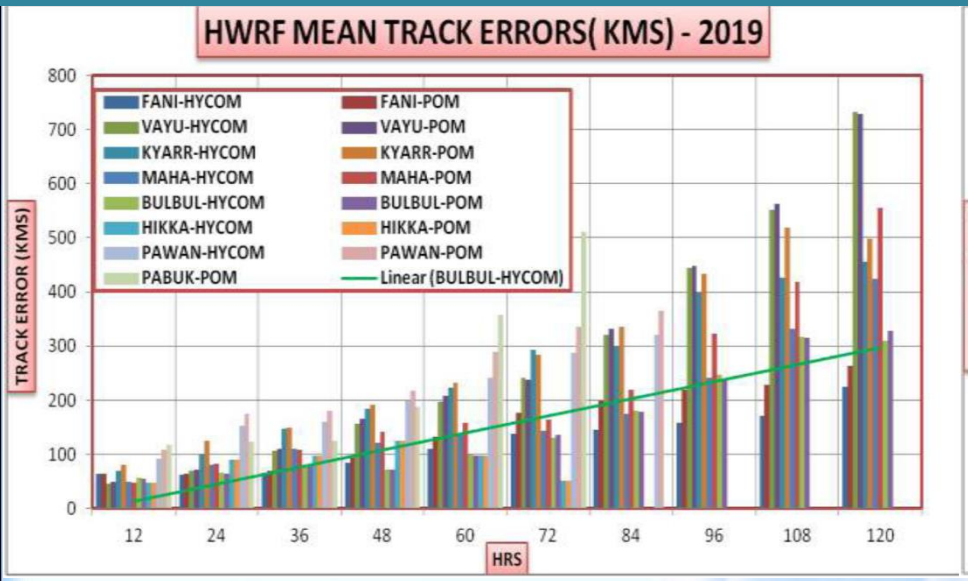

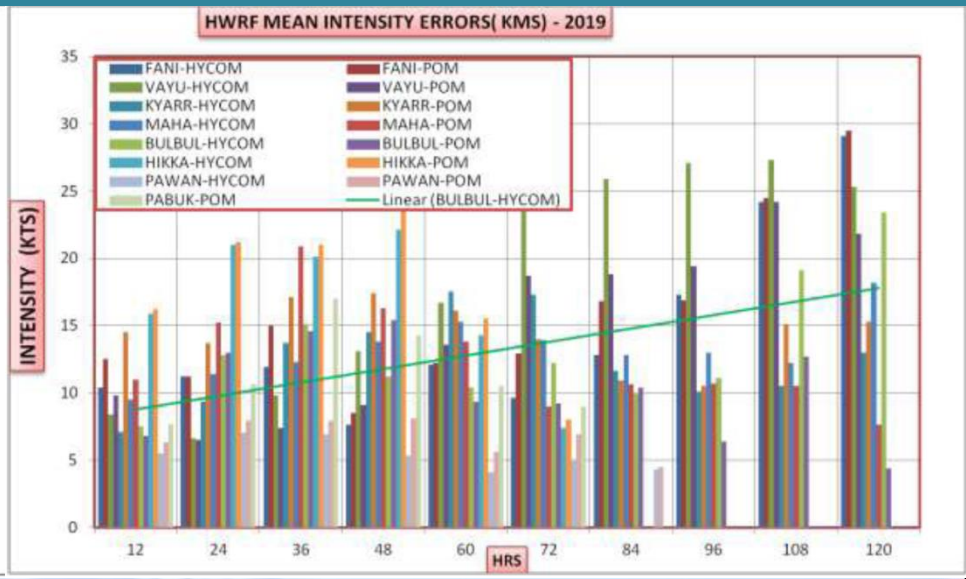

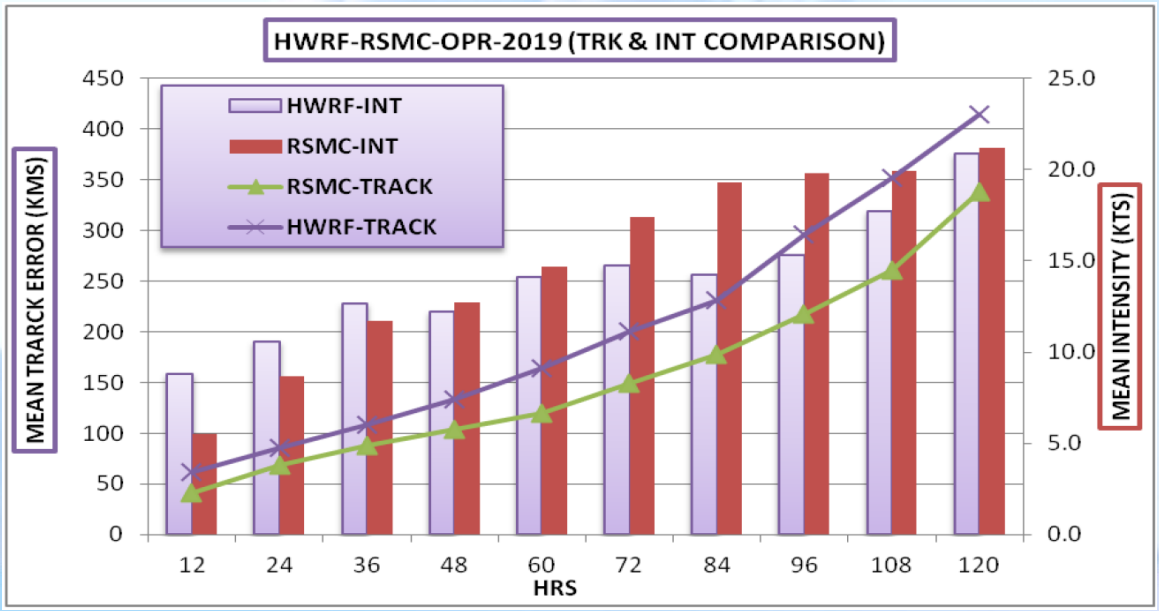

A Few Points for Operational HWRF-HYCOM Modeling System

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