



# Operational HWRF Modeling System -2021

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

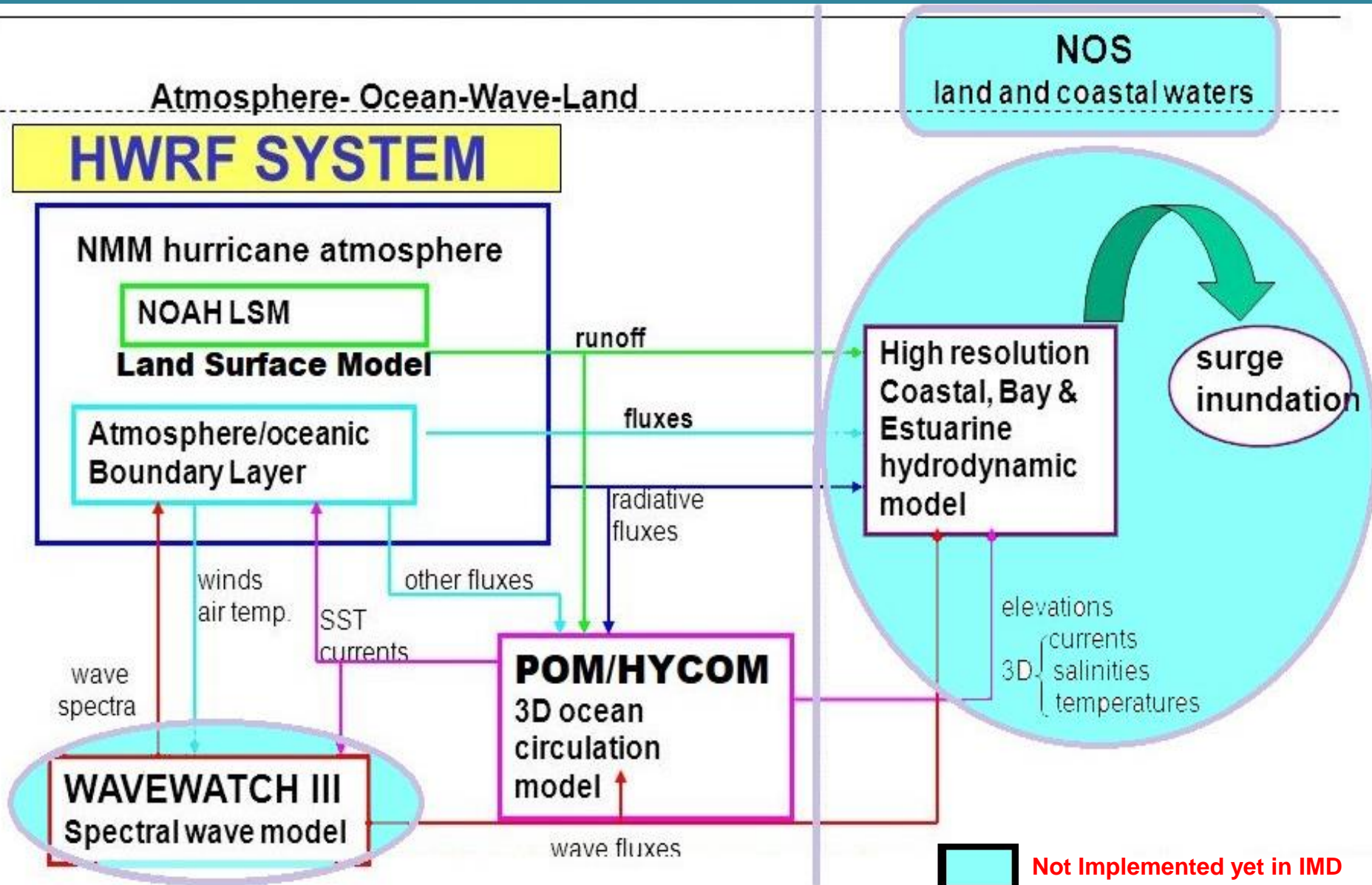
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**भारत मौसम विज्ञान विभाग**  
**INDIA METEOROLOGICAL DEPARTMENT**

# Progress in HWRF Modeling System

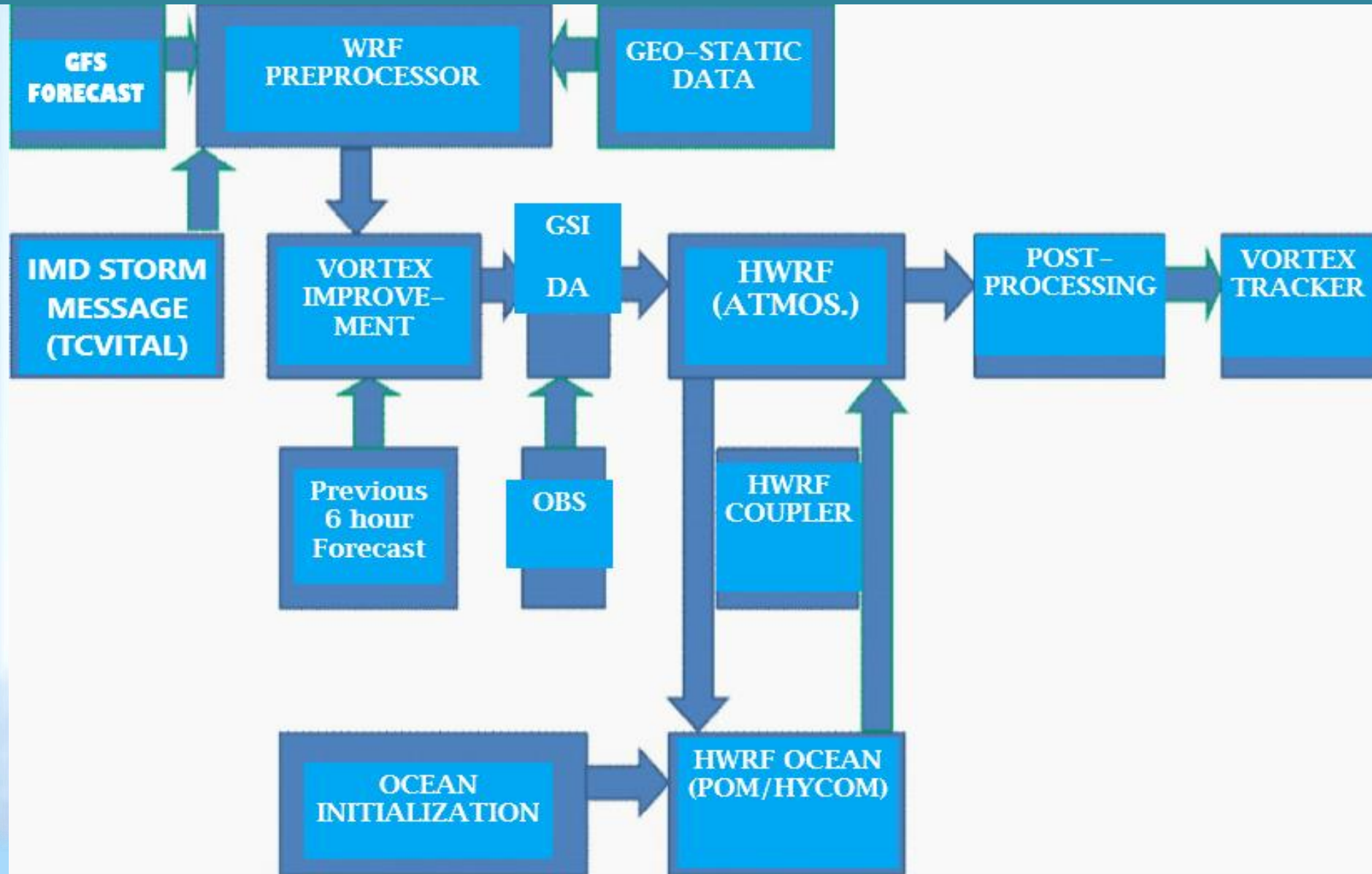
Years	Domain Configuration	Data Assimilation	Ocean Coupling
2019	Triple nest (18x6x2 km) with enhanced domain size 4 times a day	GSI (hybrid-EnVar) assimilation (80 members) with 6 hourly cycle in cycling mode	Coupled with HYCOM model + NCEP coupler – Ocean initial state from RTOFS (regional HYCOM) of 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

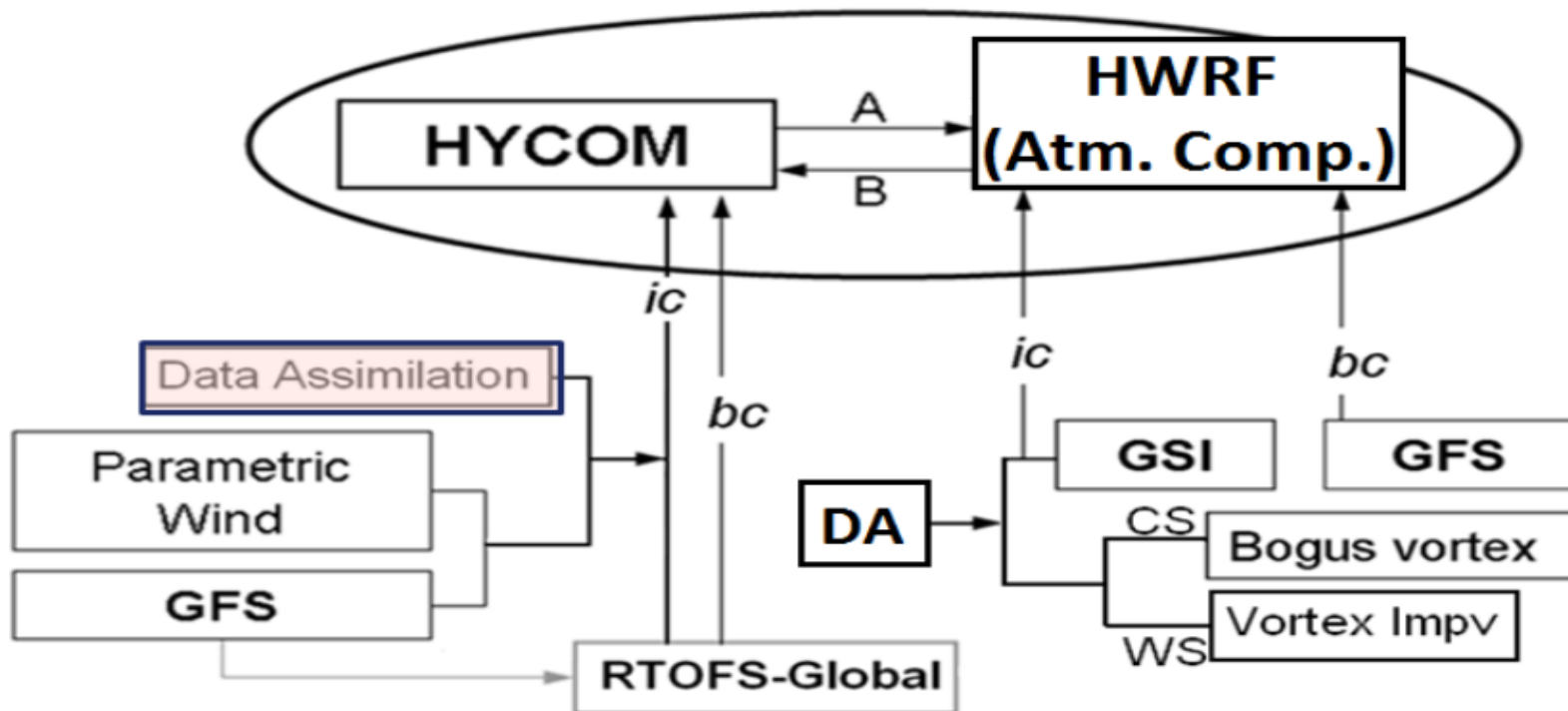


## HWRF Operational Configuration

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



# Ocean Coupling



**A:** sea surface temperature (SST)

**B:** 1. Precipitation

2. Atmospheric pressure

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

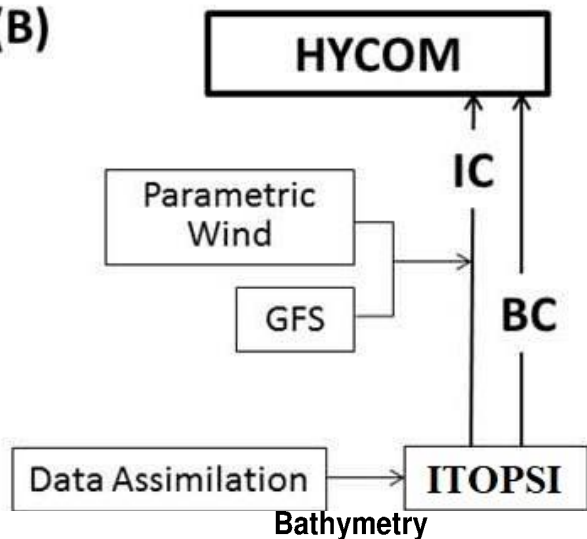
4. Wind stress



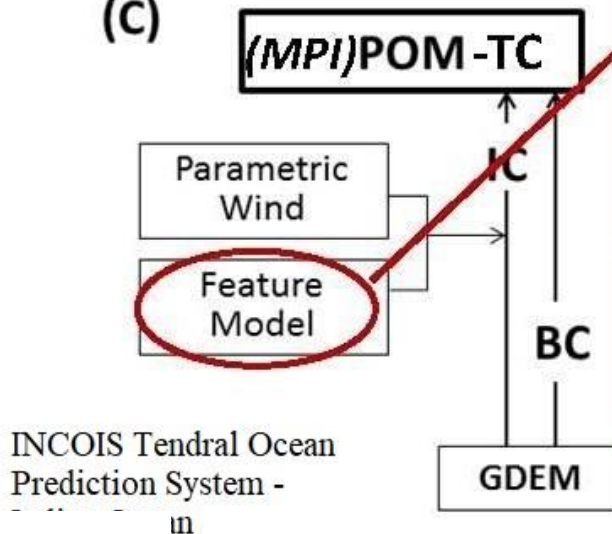
# Ocean Coupling

## 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  
↓  
Model coupling performed

(Generalized Digital  
Environmental Model)

INCOIS Tentral Ocean  
Prediction System -

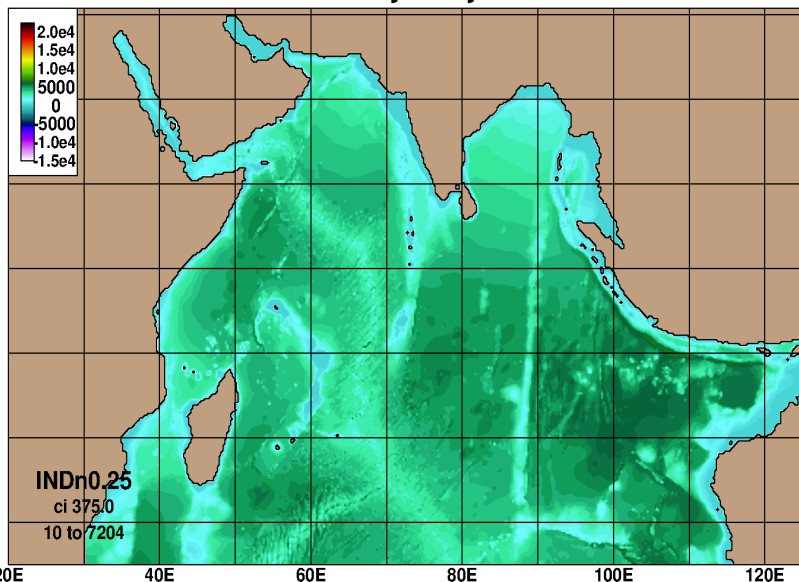
in

## POM:

- $dx/dy=9\text{km}$
- 40 levels
- Coarse resolution of MLD  
- 10 m (top), 20 m (2<sup>nd</sup>), ...
- M-Y mixing

INCOIS Tentral 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)

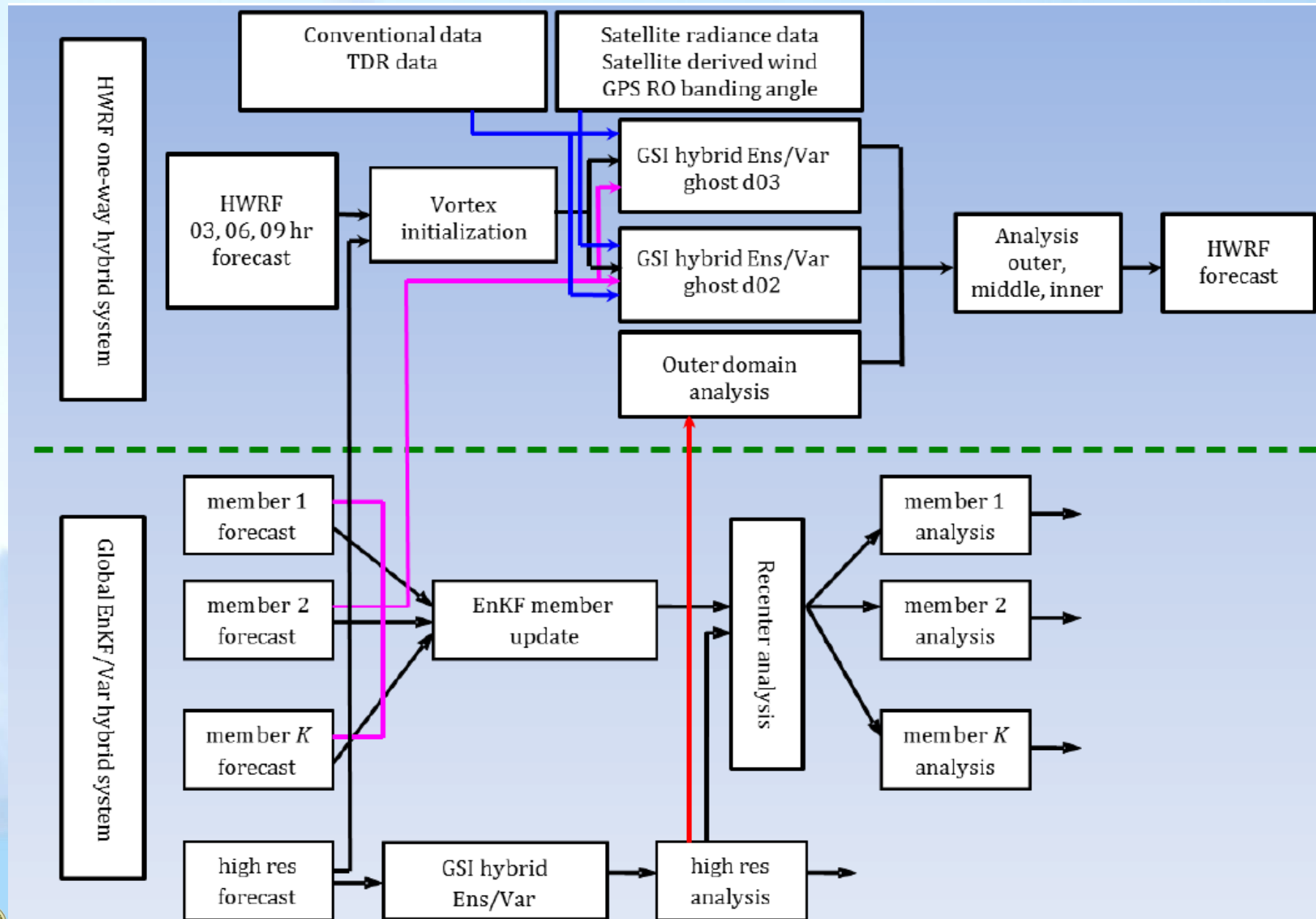
\*.a Binary data files , \*.b ASCII files describing \*.a binary files.

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





# HWRF-GSI Data Assimilation



# Forecast verification of Cyclones: 2019

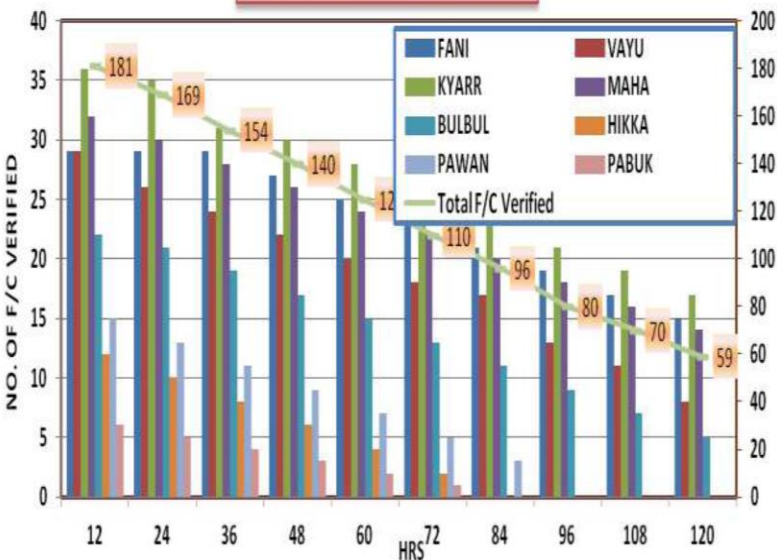
Pre-Monsoon Season – 2019 :

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

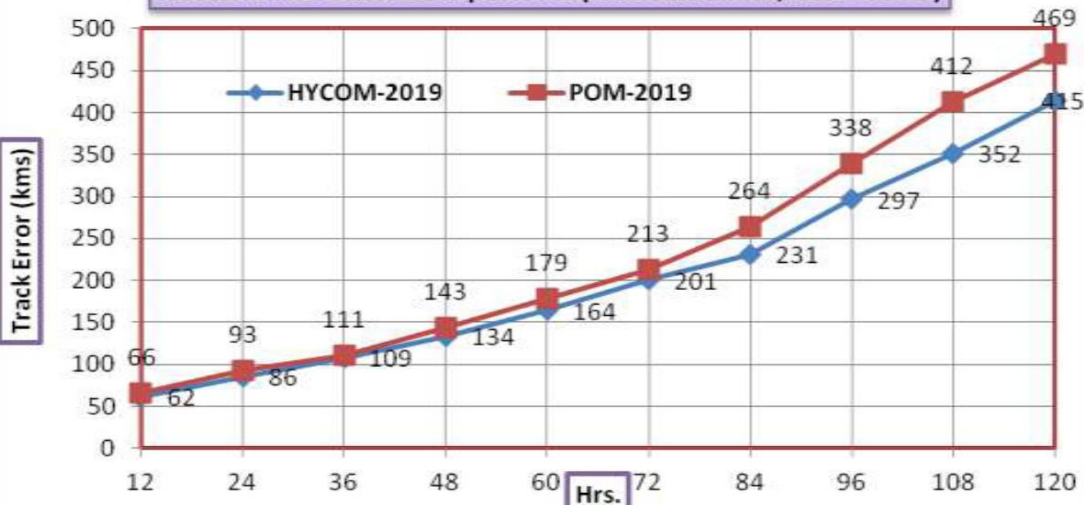
Post-Monsoon Season :- 2019 :

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

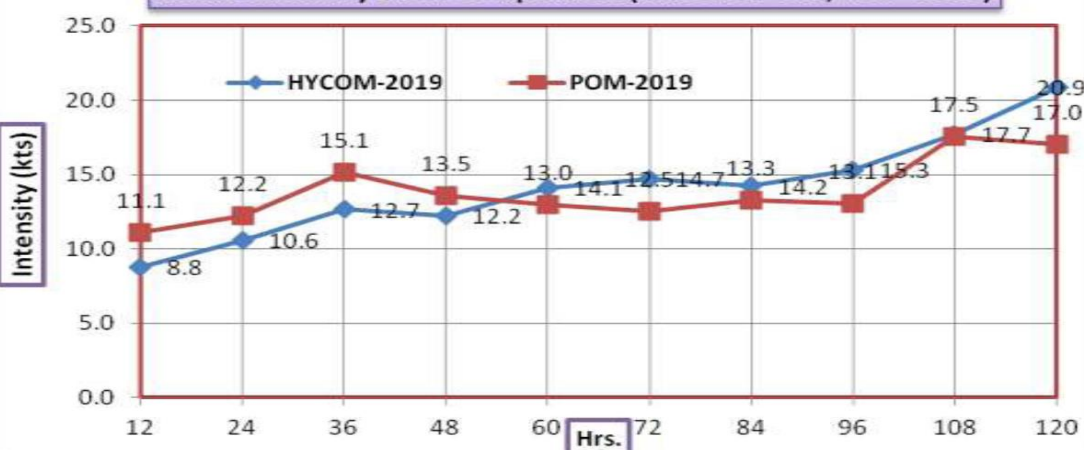
**HWRF FORECAST VERIFIED -2019**



**HWRF Track Error Comparison (HYCOM-POM; Year-2019)**

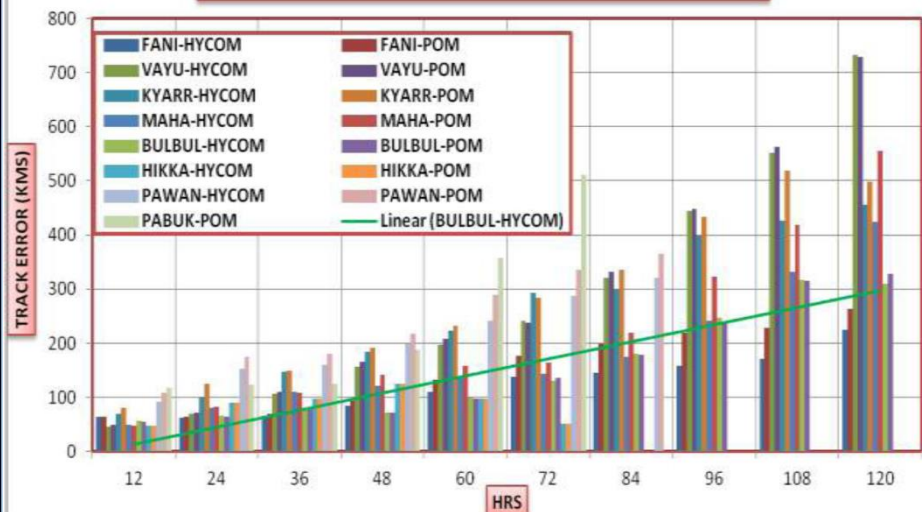


**HWRF Intensity Error Comparison (HYCOM-POM; Year-2019)**

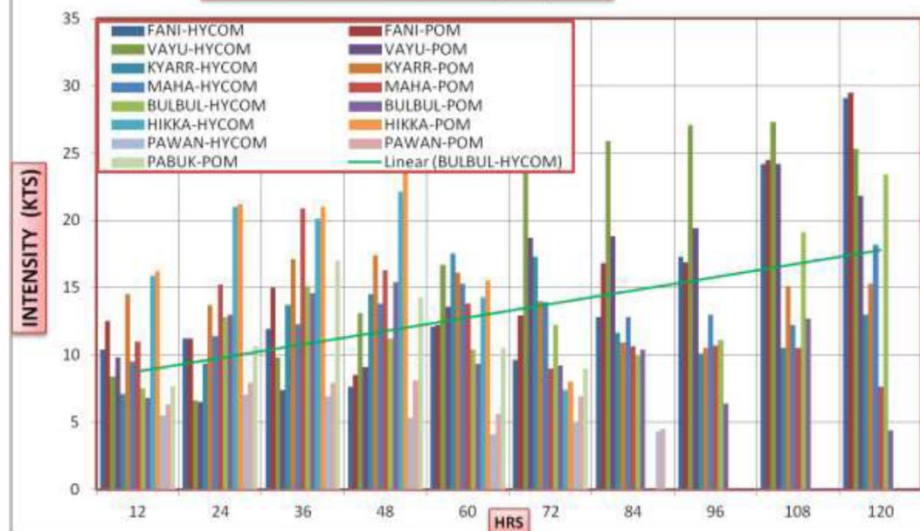


# Forecast verification of Cyclones: 2019

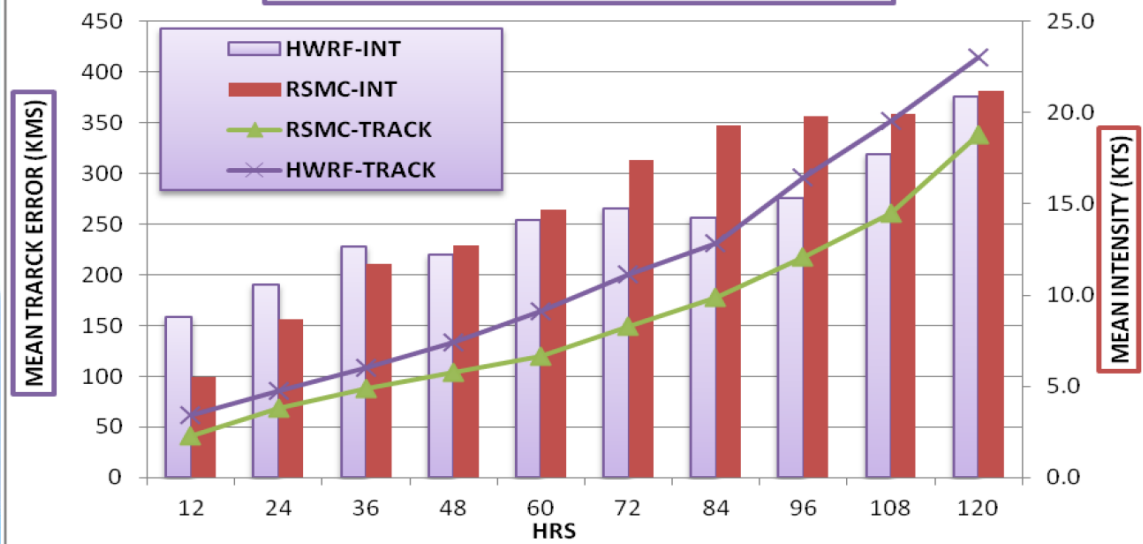
**HWRF MEAN TRACK ERRORS( KMS) - 2019**



**HWRF MEAN INTENSITY ERRORS( KMS) - 2019**



**HWRF-RSMC-OPR-2019 (TRK & INT COMPARISON)**



# 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



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