# A pseudo-ensemble hybrid data assimilation system for HWRF

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# Motivations

- ***EnKF shows great potential in improving hurricane forecasts***

  *(Torn and Hakim 2009; Zhang et al. 2009, 2011; Hamill et al. 2010; Whitaker et al. 2010; Weng and Zhang 2012; …)*

  *Advantage*: ***flow-dependent background error covariance***

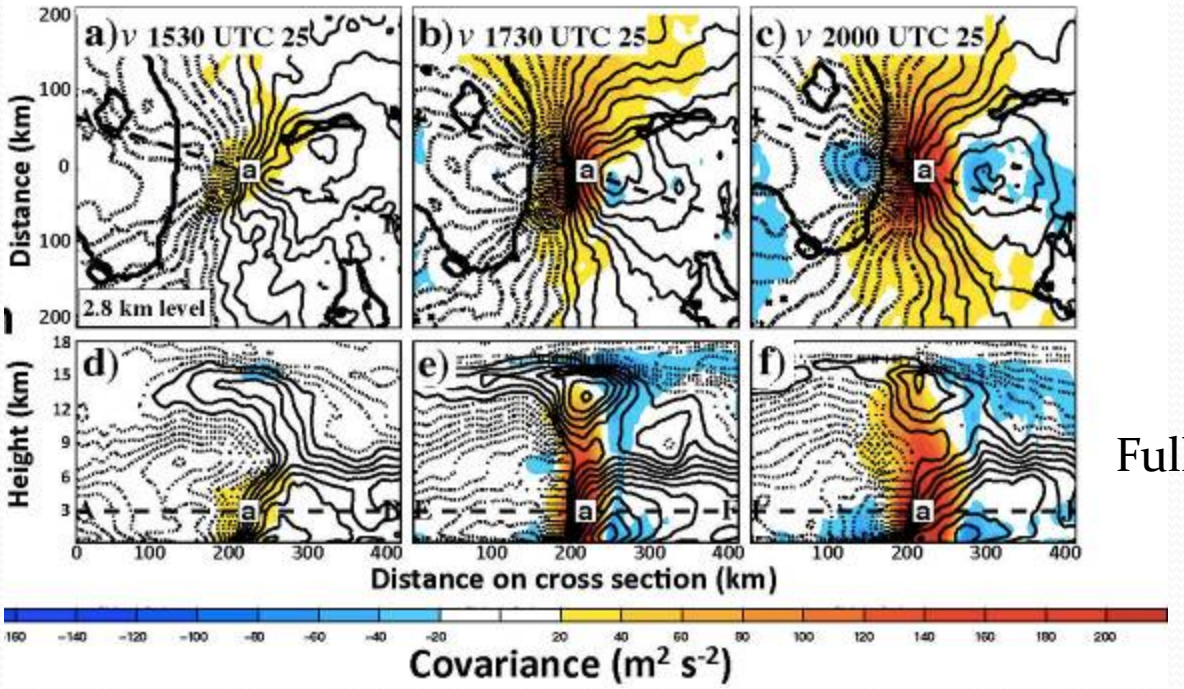
  **Disadvantage:** ***computational cost remains prohibitive*** *for running a concurrent convection-permitting ensemble required for a full EnKF in the current operational implementation.*

# Motivations (cont.)

Poterjoy and Zhang (2011 JAS) :

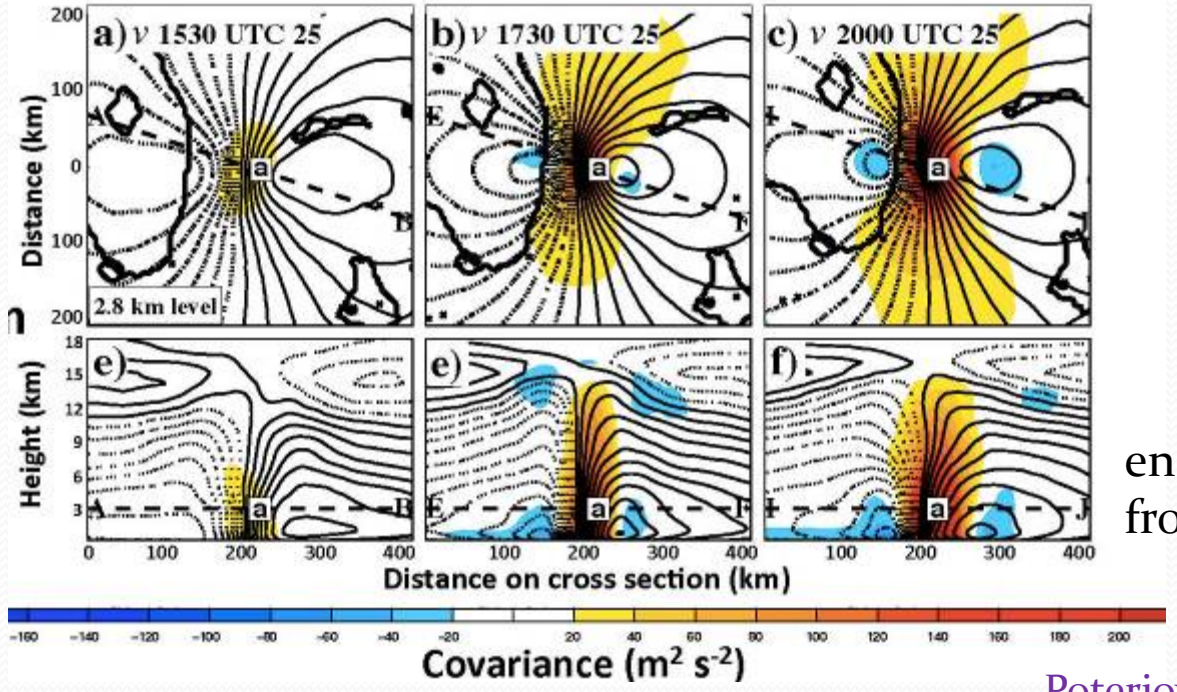
- *Wavenumber 0 storm structures have the largest influence on both ground- and storm-relative forecast uncertainty for TCs with category 1 or higher intensity*

- *The vortex-scale flow-dependent background error covariance may be approximated by nearly symmetric idealized vortex with similar intensity*




$$\langle V_a ; V \rangle$$

Full ensemble covariance

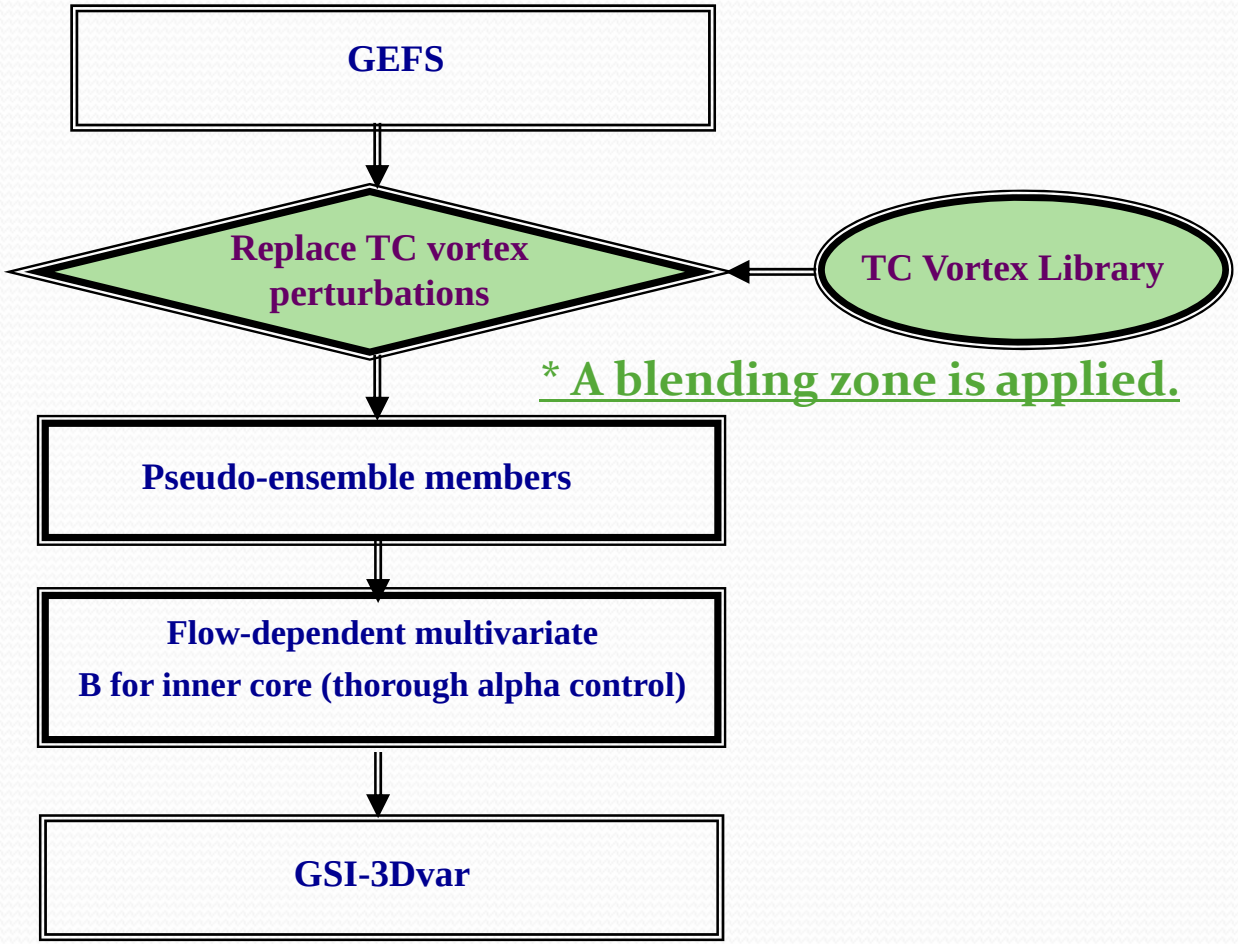



$$\langle V_a ; \overline{V} \rangle$$

ensemble covariance
from wavenumber o

Poterjoy and Zhang (2011)

# Pseudo-ensemble hybrid data assimilation system (PEDA) for TC initialization




***PEDA: Using an existing hybrid system such as GSI-EnKF hybrid, the vortex-dependent error covariance is approximated by random sampling of nearly axisymmetric idealized TC vortices from a pre-constructed library to assimilate inner-core observations.***

# To create TC vortices with sufficient spreads:

*1) varied Vmax /size/Rmax*

*2) perturb sounding profile*

*3) latitude effect*

*4) physics options*

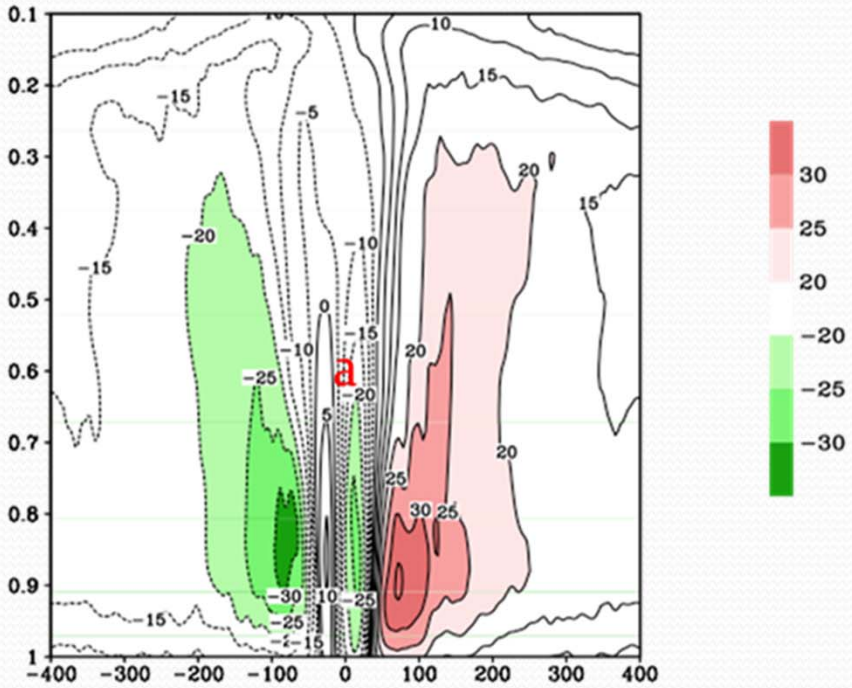
*5) SST (27.5-29C)*

- **Binned into groups with an interval of 5m/s in $\overline{V}_{max}$;**
  **V15, V20, …V60;**
- **Each group has at least 80 vortices**

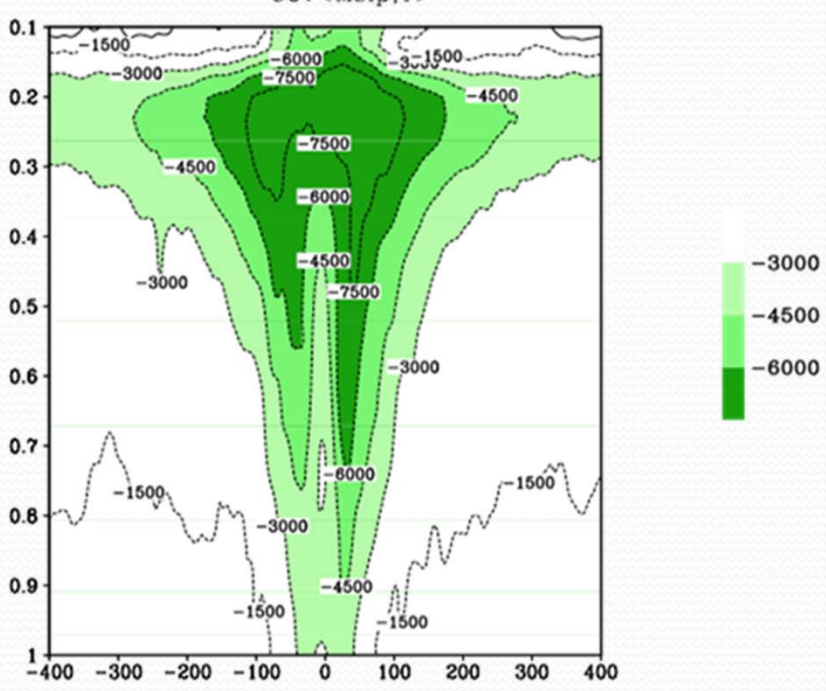
HWRF model (27, 9, 3km)

# Dynamics and Structure of Error Covariance

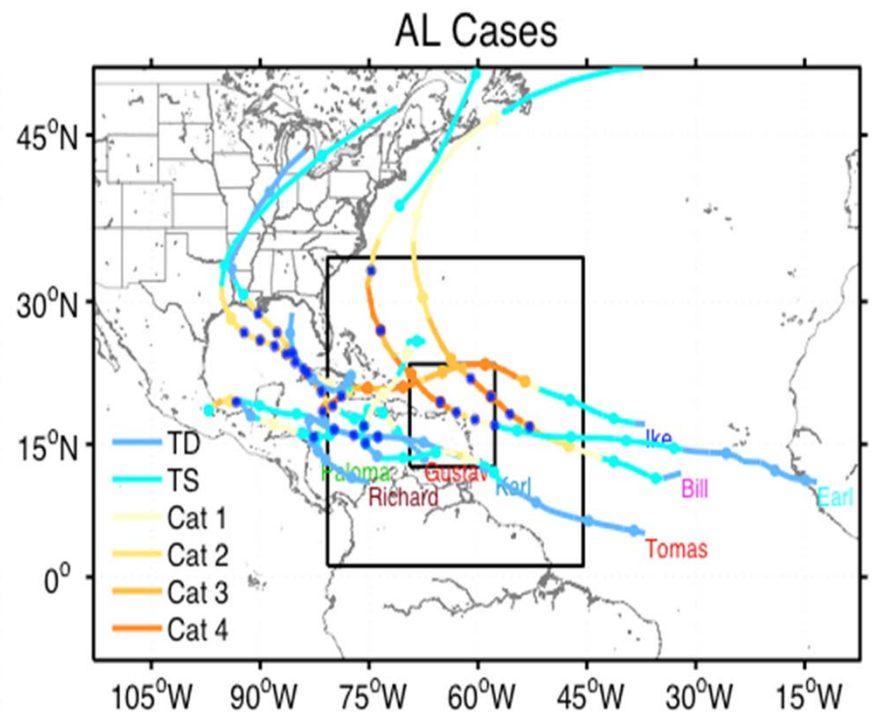
$< T_a \cdot v >$

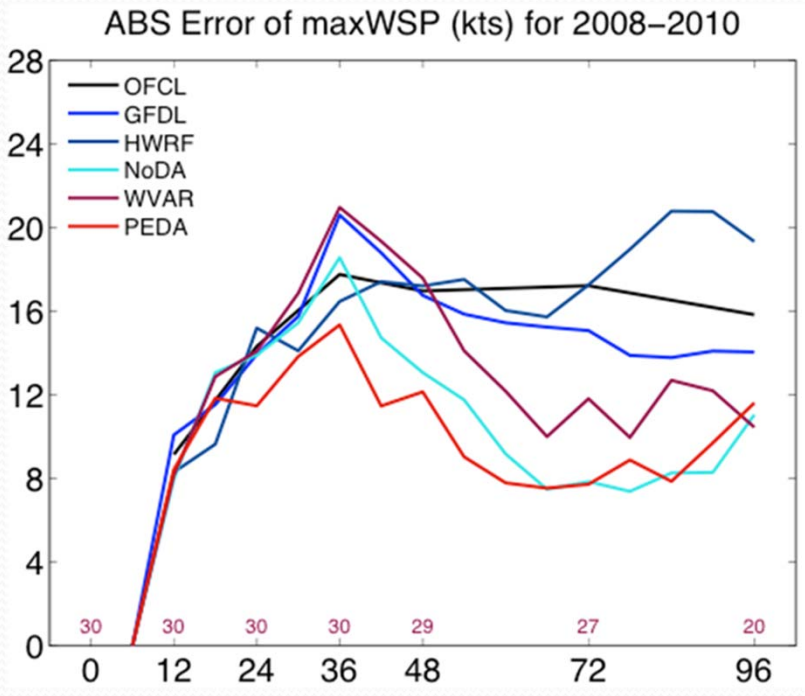



$< Mslp \cdot T >$



# PEDA Experiments with WRF-ARW




$$\text{Interpolated } WSP(t) = \text{WSP(t)} - \left(\frac{36\text{h} - \text{t}}{36\text{h}} \times Bias(6\,h)\right)$$

* Three domains with horizontal grid spacing of 40.5, 13.5, and 4.5 km;
* Retrieved airborne dual Doppler radar wind observations

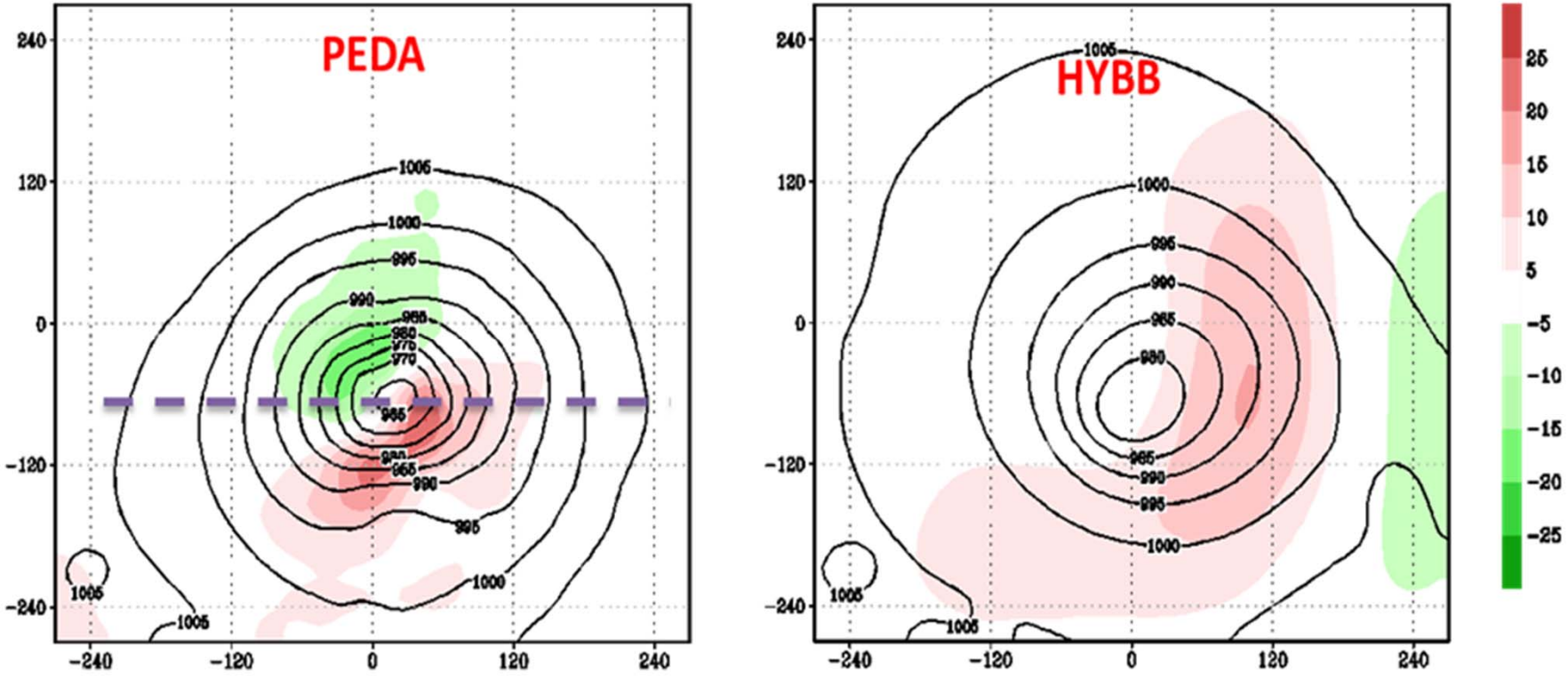
# PEDA_HWRF

## PEDA *vs.* HYBB

| EXP. | Inner area | Environment |
|---|---|---|
| PEDA | **error statistics from pre-constructed vortex library with vortex-scale covariance** | **global ensemble forecasts** |
| HYBB | **error statistics from global ensemble forecasts** without vortex-scale covariance | |

# *v*-wind Increments (shaded)

## Earl @2010083000

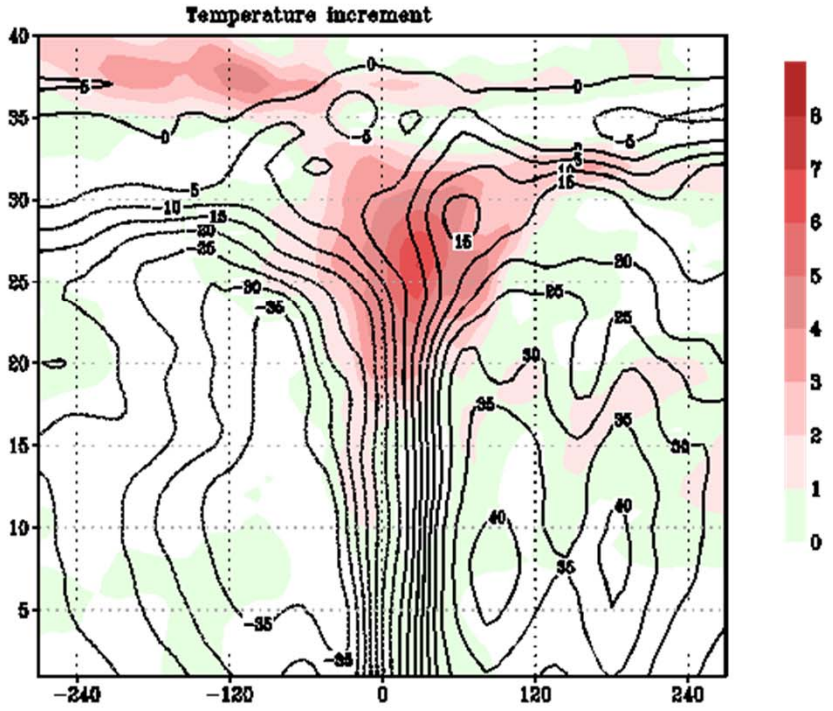



*** HWRF (27-9km)**

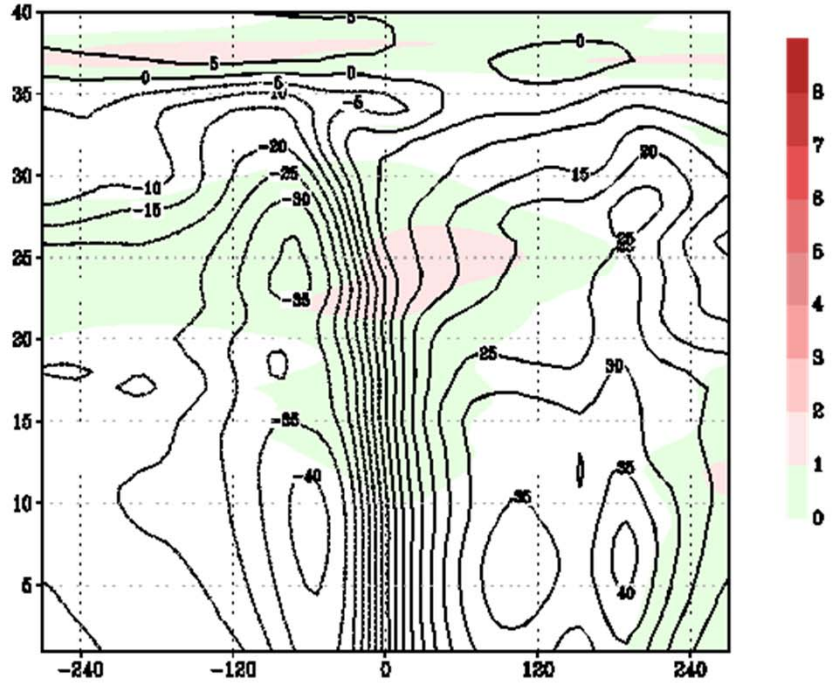
# Temperature Increments (K)

## Earl @ 2010083000

PEDA

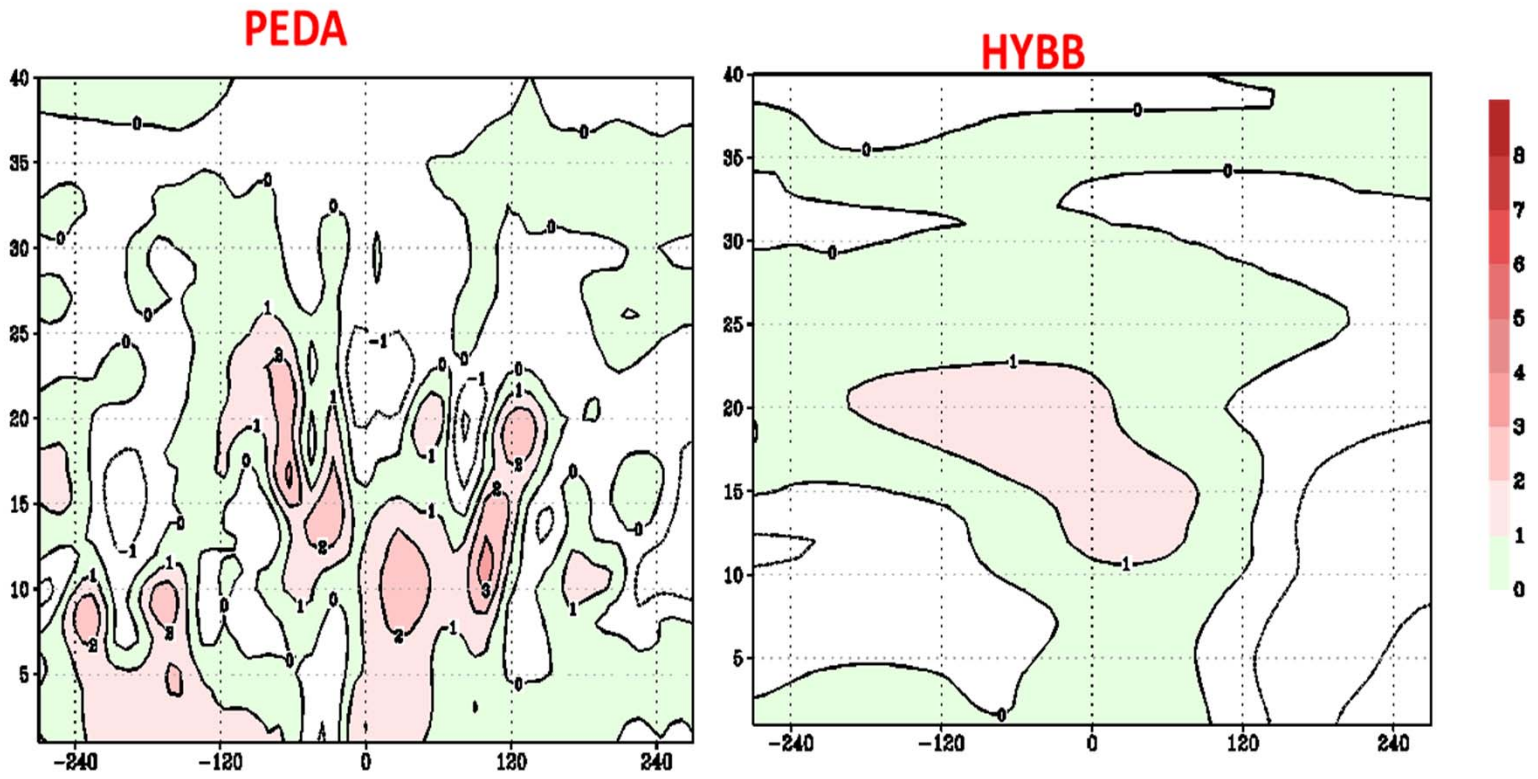


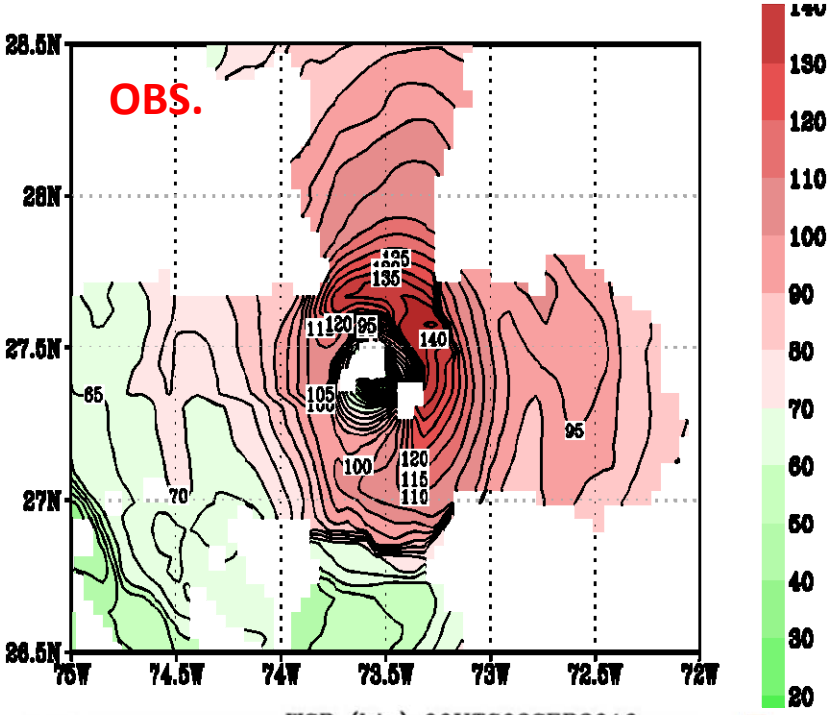

HYBB

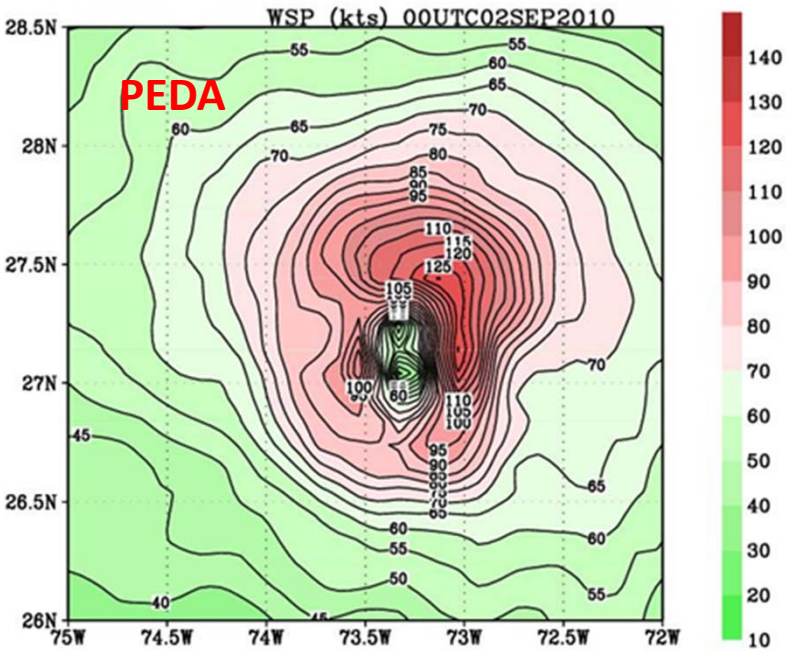


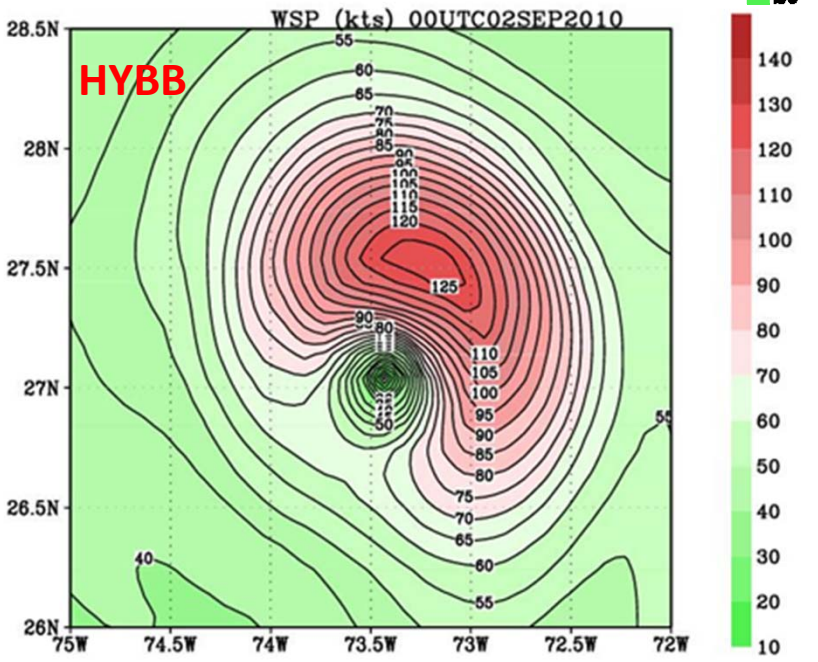

* PEDA may correct significantly warm core

# Specific humidity Increments (g/kg)





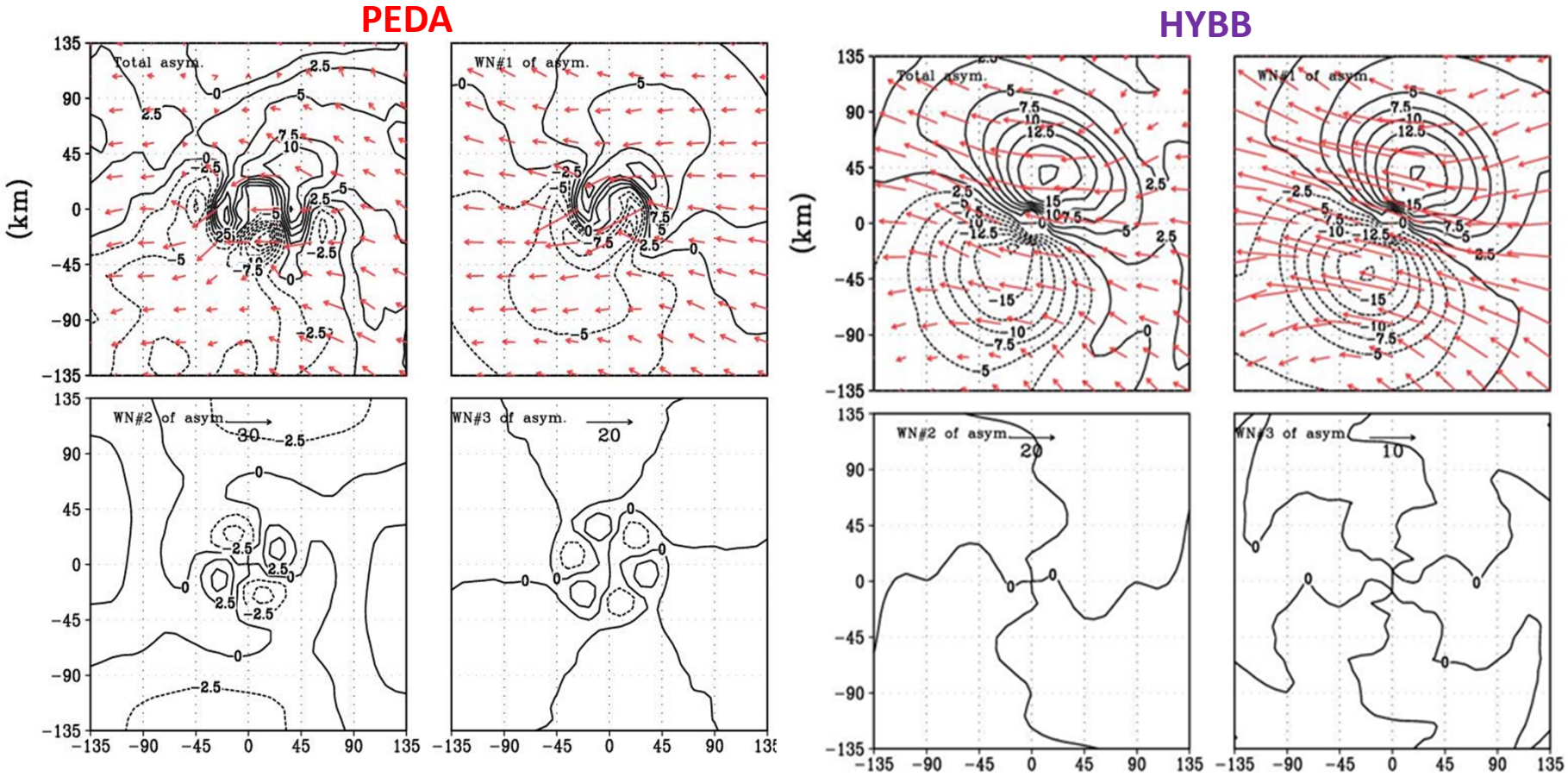




Surface wind (kts)

## Structure Comparison Inner Core

## Earl (2010090200)

# Inner area asymmetry




* PEDA likely captures fine structure in TC inner area.

# Updates: HWRF (27-9-3km)

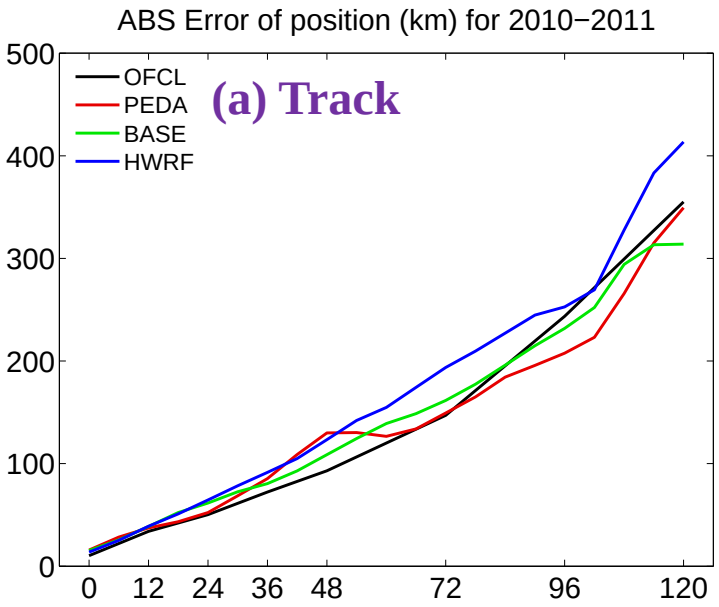
***Cases:*** *Earl (2010): 2010082912-2010090400 ( 23 cases)*
*Irene(2011): 2011082212-2011082800 (22 cases)*
*Rina(2011): 2011102406-2011102712 (15 cases)*

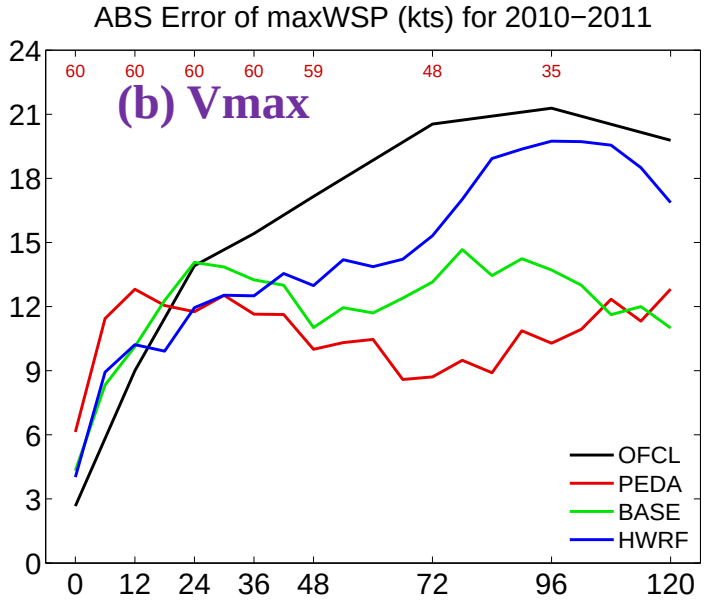
**Observation:**

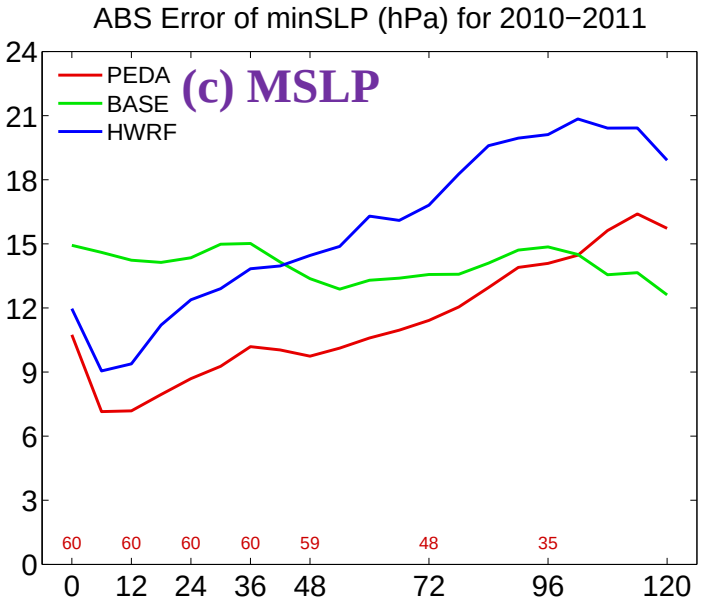
**Conventional Preburf data + tldplr radial velocity (if available)**

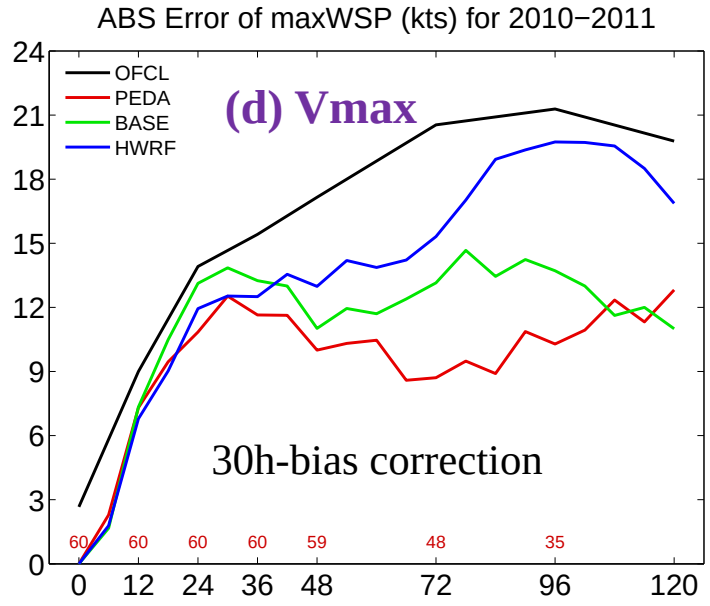
***) Change gross error check parameter for radar wind by multiply 0.9**
***) Horizontal and vertical scaling length are 300km and 25 levels**
***) BETA1_INV_REGIONAL= 0. 1**
***) remove dropsonde (u,v) but keep (t, q)**
***) remove surface pressure observations within 200km**
***) cap Vortex library ( if observed Vmax>45m/s then Vgroup=45)**

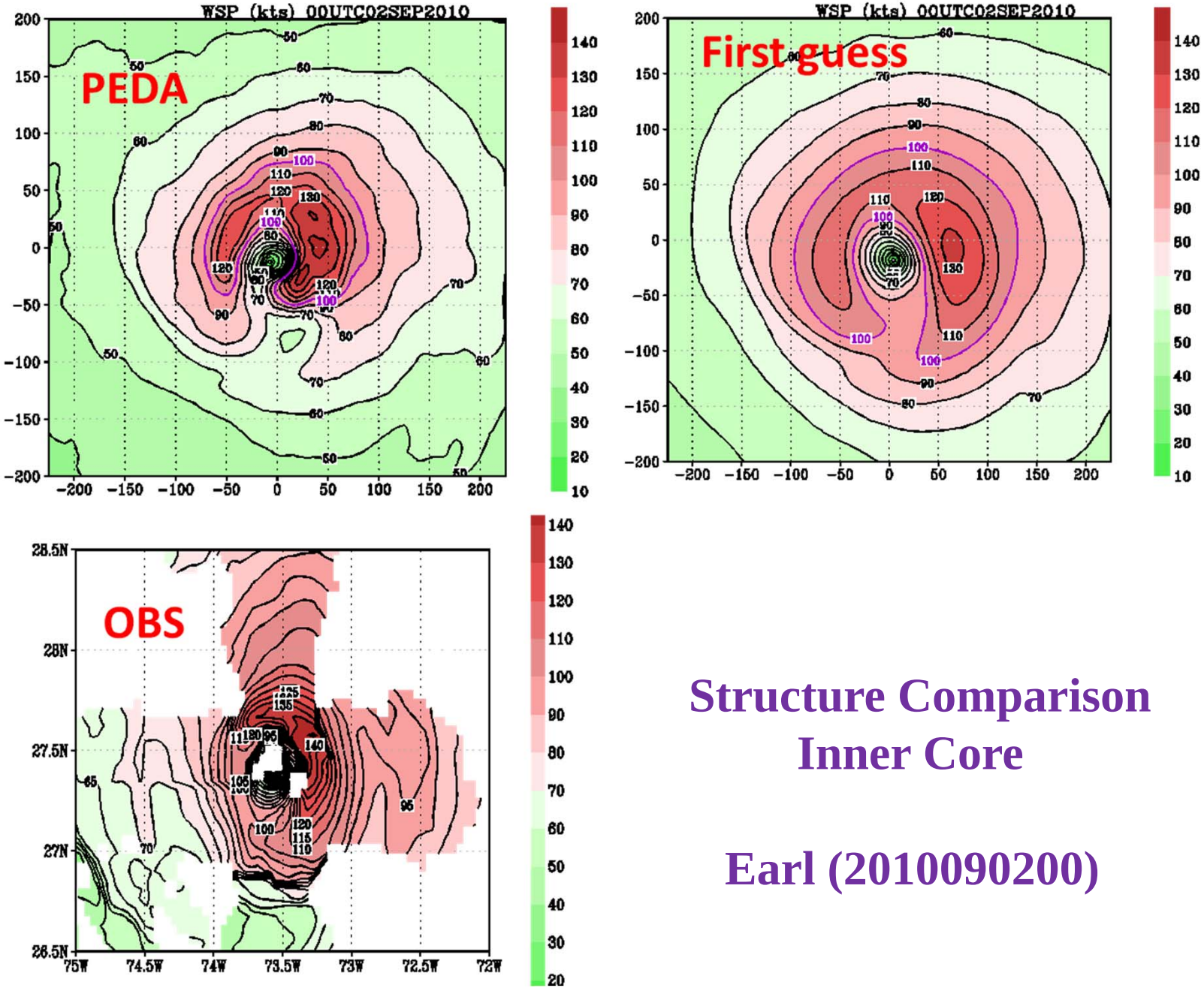
# Performance of PEDA



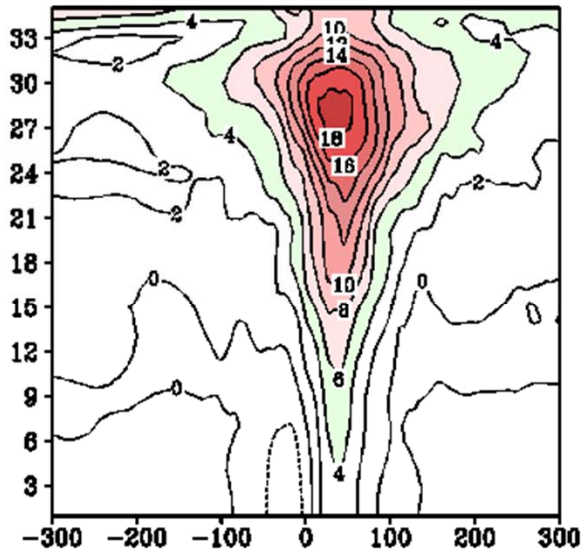



## Structure Comparison
## Inner Core

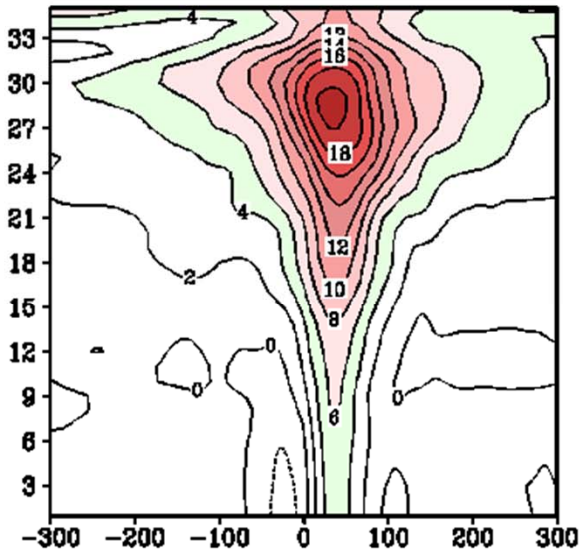
## Earl (2010090200)

# Warm core (K)

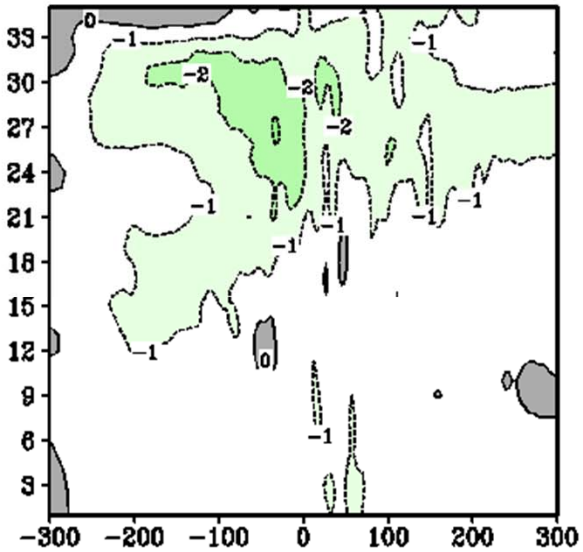
**PEDA**



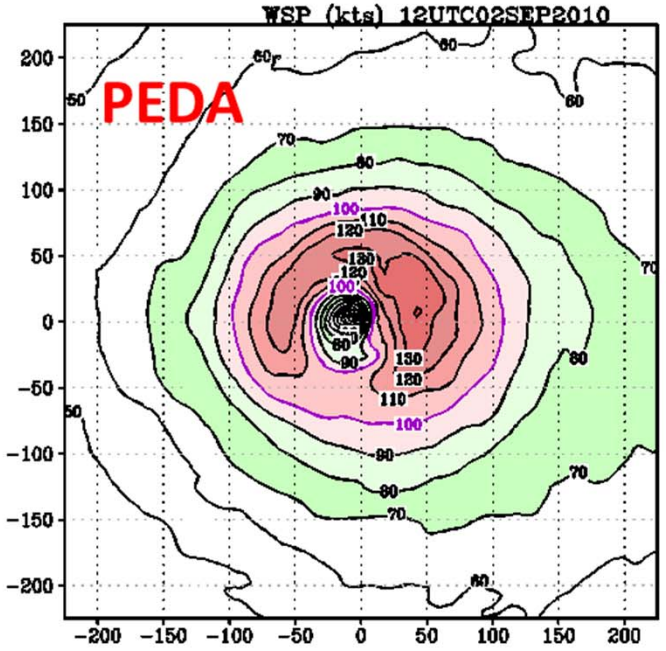

**FirstGuess**

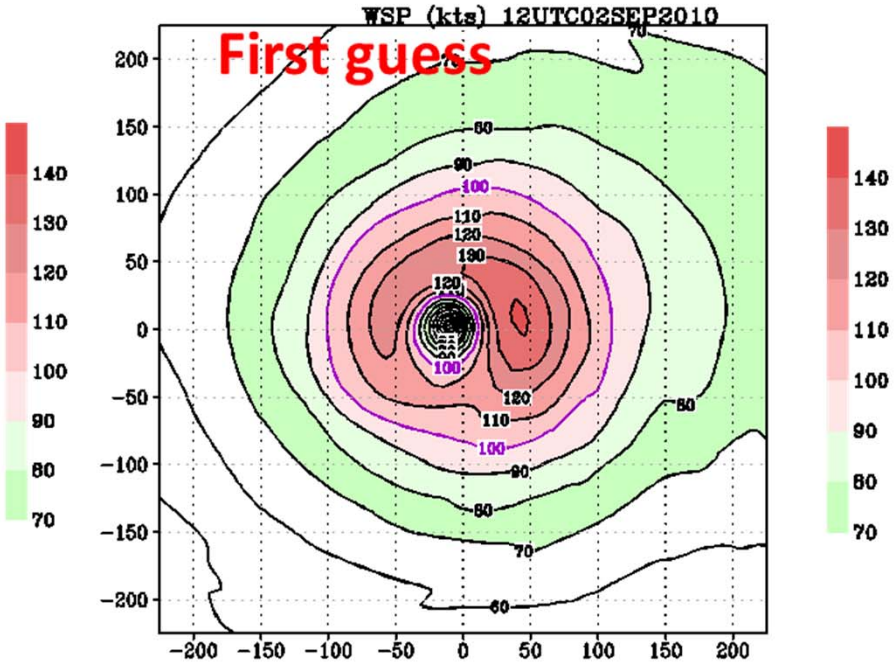


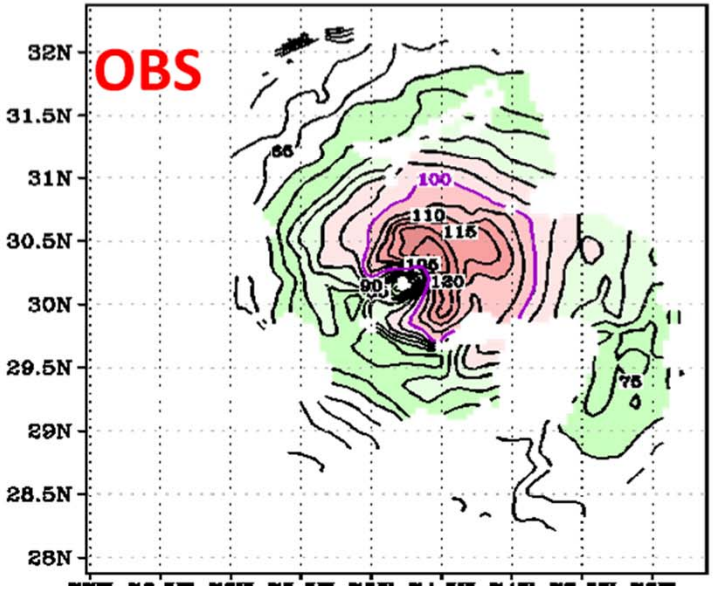

**Difference**

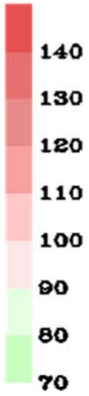



For strong storm, MSLP in the first guess is much lower than obs. <=> overestimate warm core.




(kts)

## Structure Comparison

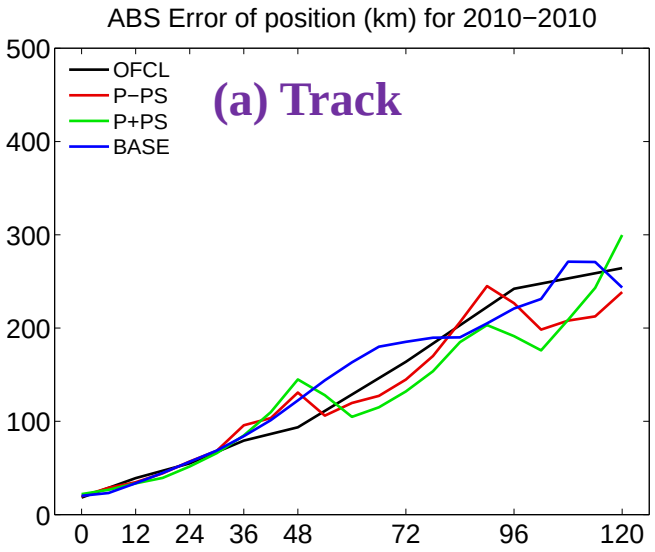
## Outer Size
## Earl (2010090212)

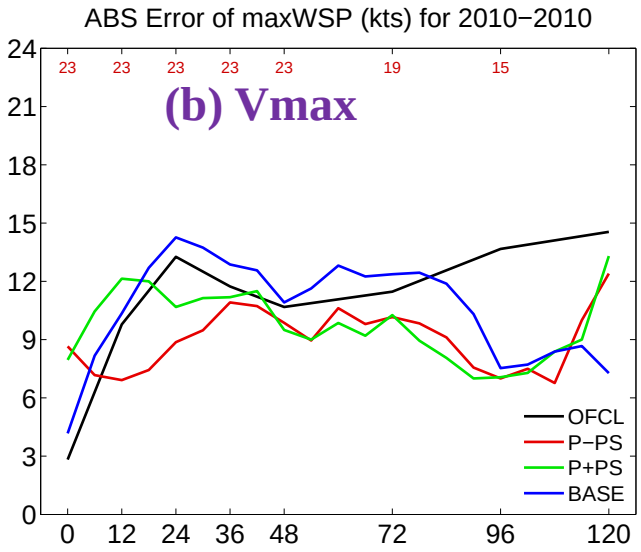
# Impacts of Surface Pressure Observation

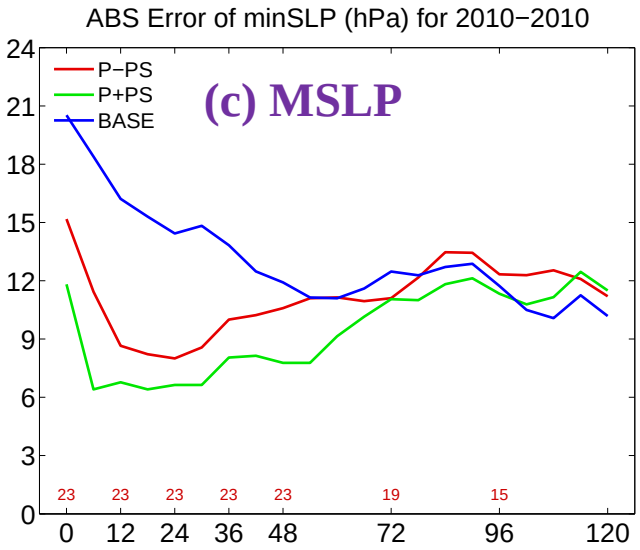
**P-PS** **no Ps obs.**

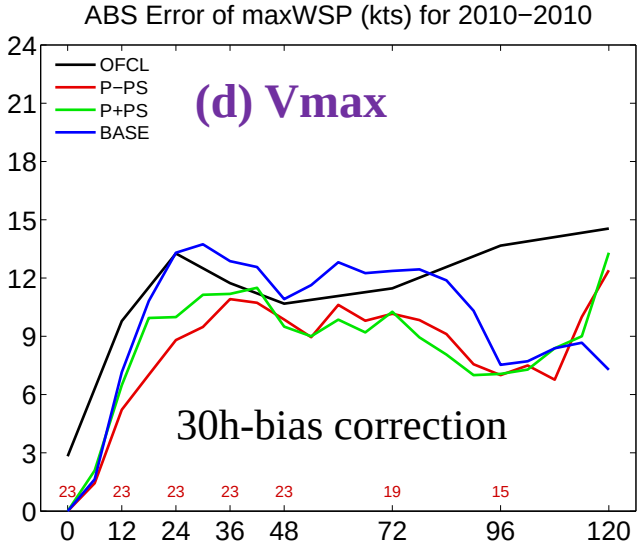
**P+PS** **with Ps obs.**

**Earl (2010)**

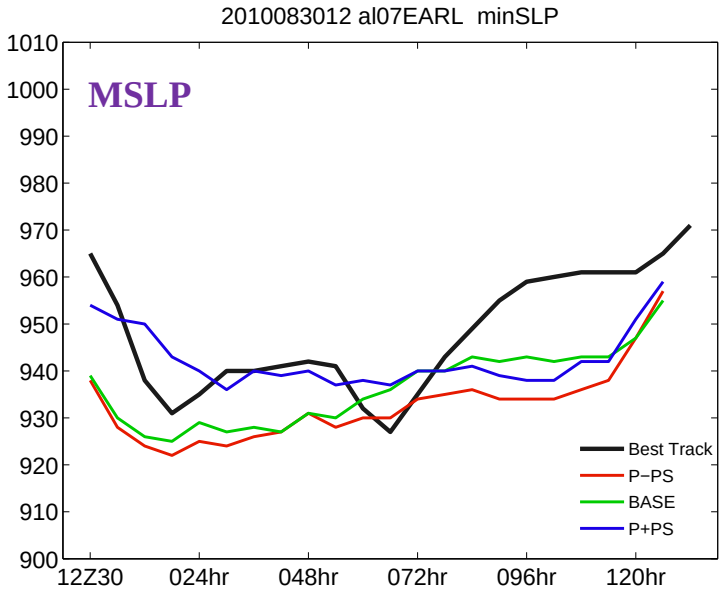


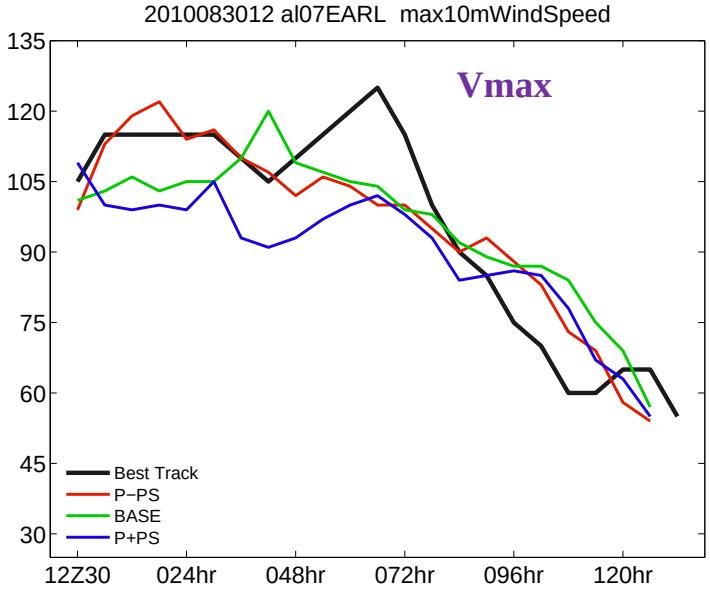



# Example


2010083012 al07EARL minSLP
MSLP
1010
1000
990
980
970
960
950
940
930
920
910
900
12Z30
024hr
048hr
072hr
096hr
120hr
Best Track
P−PS
BASE
P+PS


2010083012 al07EARL max10mWindSpeed
Vmax
135
120
105
90
75
60
45
30
12Z30
024hr
048hr
072hr
096hr
120hr
Best Track
P−PS
BASE
P+PS

# Summary

With the inclusion of flow-dependent background error covariance from the pseudo ensembles, the PEDA has a positive impact in improving the structure of the initial hurricane vortices, and thus helps hurricane forecasts.

## Ongoing works:

1) **More cases tests ( all 2011 AL storms)**
2) **Tune parameters**
3) **Vortex size variation**
4) **Vortex library**