

# Testing and Evaluation of the GSI-Hybrid 3DVAR for basin scale HWRF

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# What is GSI-Hybrid 3DVAR?

## ▣ GSI-3DVAR (static BE)

$$J(x) = \frac{1}{2}(x - x_b)^T B^{-1}(x - x_b) + \frac{1}{2}[y - H(x)]^T R^{-1}[y - H(x)]$$

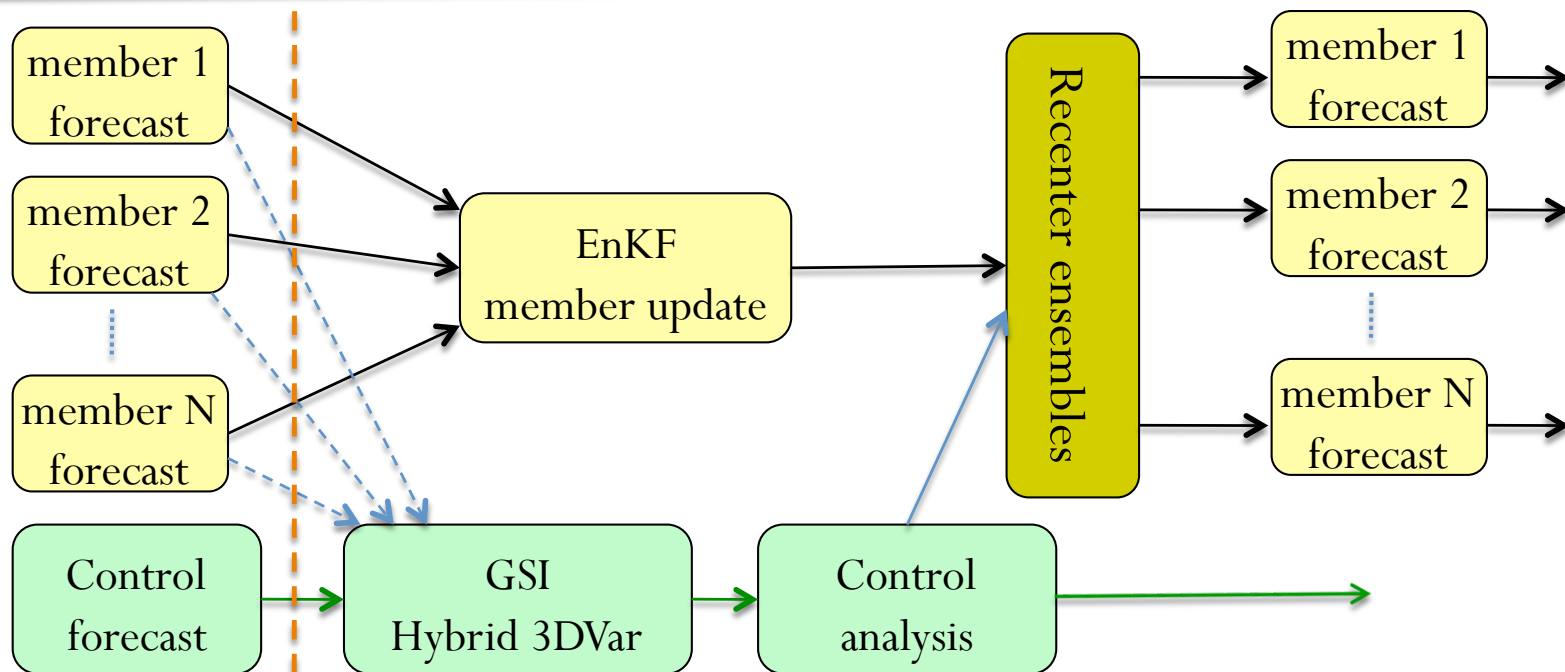
## ▣ GSI-Hybrid 3DVAR

$$J(x, \alpha) = \beta_1 J_b + \beta_2 J_e + J_o$$

$$= \beta_1 \frac{1}{2}(x - x_b)^T B^{-1}(x - x_b) + \beta_2 \frac{1}{2} \alpha^T A^{-1} \alpha + \frac{1}{2}[y - H(x + x_e)]^T R^{-1}[y - H(x + x_e)]$$

3DVAR →  $\frac{1}{2}(x - x_b)^T B^{-1}(x - x_b)$  +  $\beta_2 \frac{1}{2} \alpha^T A^{-1} \alpha$  +  $\frac{1}{2}[y - H(x + x_e)]^T R^{-1}[y - H(x + x_e)]$

ensembles →  $\alpha$  (extended control variables)



# What is GSI-Hybrid 3DVAR?

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## ▣ GSI-Hybrid 3DVAR

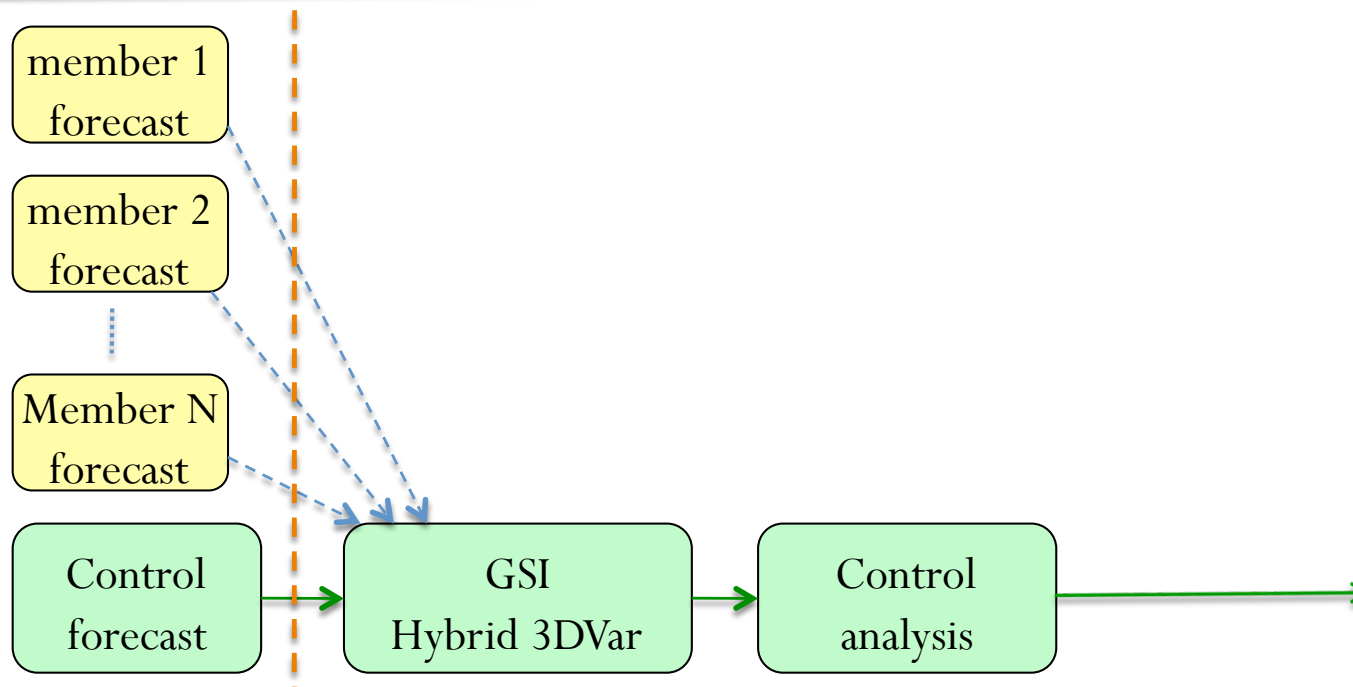
$$J(x, \alpha) = \beta_1 J_b + \beta_2 J_e + J_o$$

$$= \beta_1 \frac{1}{2}(x - x_b)^T B^{-1}(x - x_b) + \beta_2 \frac{1}{2} \alpha^T A^{-1} \alpha + \frac{1}{2}[y - H(x + x_e)]^T R^{-1}[y - H(x + x_e)]$$

3DVAR →  $\beta_1 \frac{1}{2}(x - x_b)^T B^{-1}(x - x_b)$

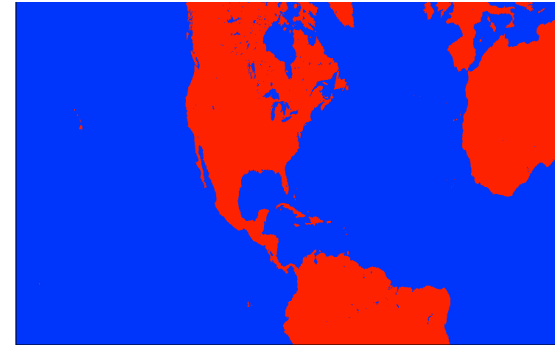
ensembles →  $\beta_2 \frac{1}{2} \alpha^T A^{-1} \alpha$

extended control variables →  $\alpha$



# Model configuration

- ❑ HWRF: basin scale branch from EMC, 61 vertical levels, model top at 2mb, horizontal grid spacing=27km, on basin scale domain
- ❑ GSI: basin scale branch from EMC
- ❑ Background: GFS



## Cross-covariance investigation

- **3DVAR**:  $\beta_1=1.0, \beta_2=0.0$

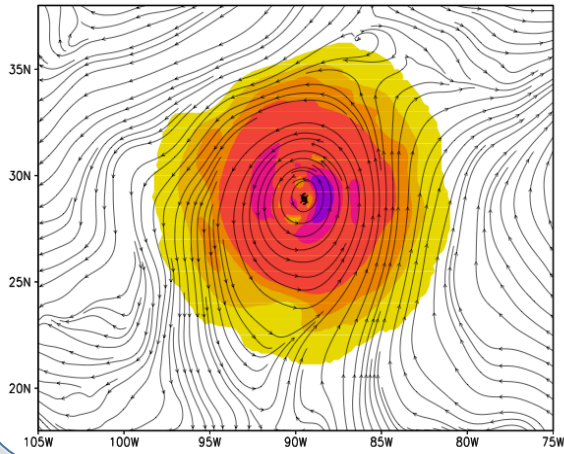
- **HYB**:  $\beta_1=0.25, \beta_2=0.75$

- **ENS**:  $\beta_1=0.0, \beta_2=1.0$

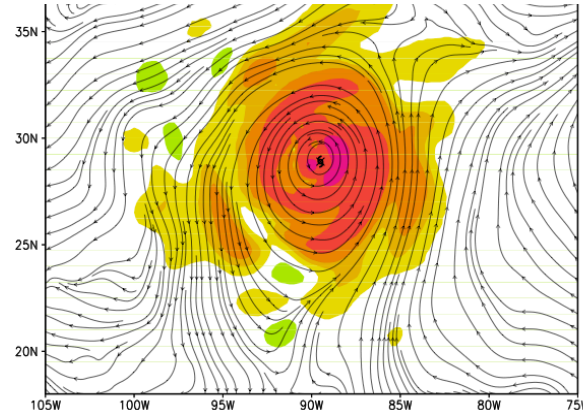
- 80 global ensembles
- The single observation is at or around storm center of Isaac (Hurricane) or Kirk (tropical storm)
- Background: 2012082900

- Obs:  $q=1\text{g/kg}$  at 700mb at 28.9N, 270.5E (Isaac center)

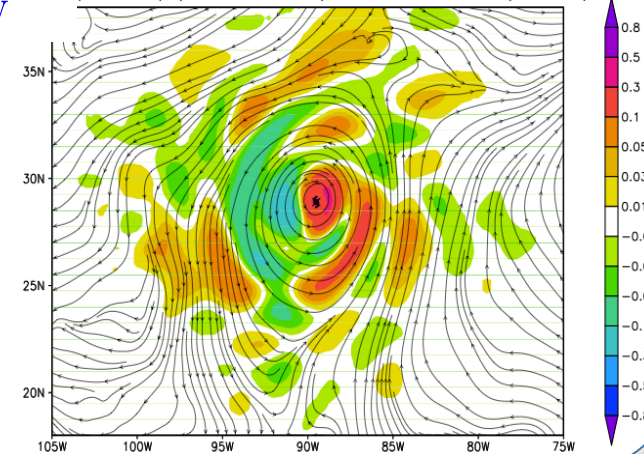
3DVAR.q -- dq (color, 700mb) and streamline (700mb)



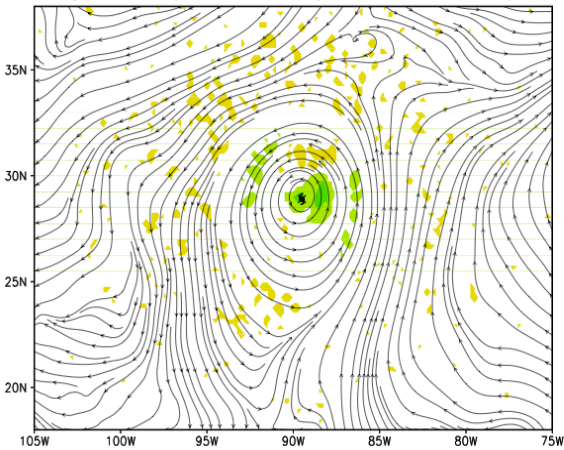
### Increment of specific humidity



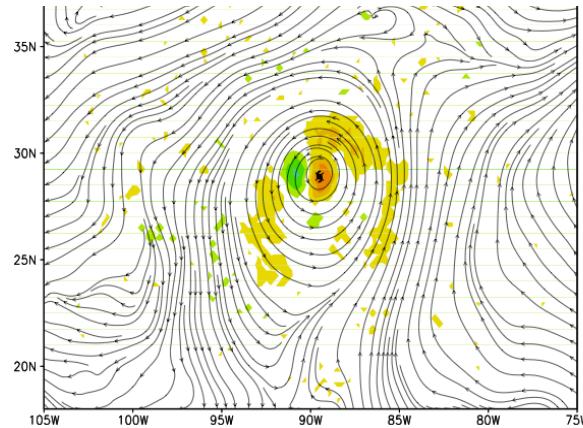
Ensemble.q -- dq (color, 700mb) and streamline (700mb)



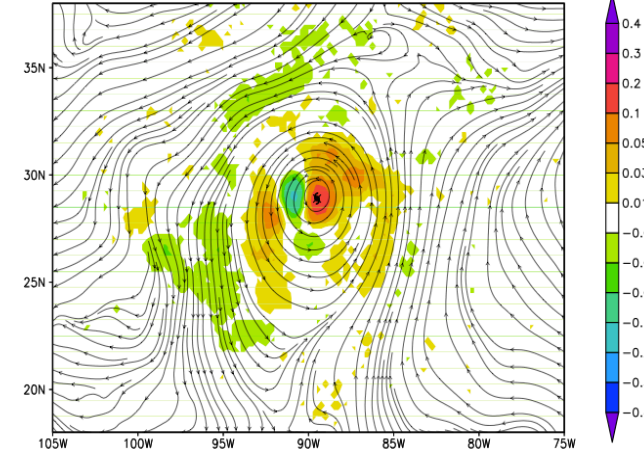
3DVAR.q -- dT (color, 700mb) and streamline (700mb)



### Increment of temperature



Ensemble.q -- dT (color, 700mb) and streamline (700mb)

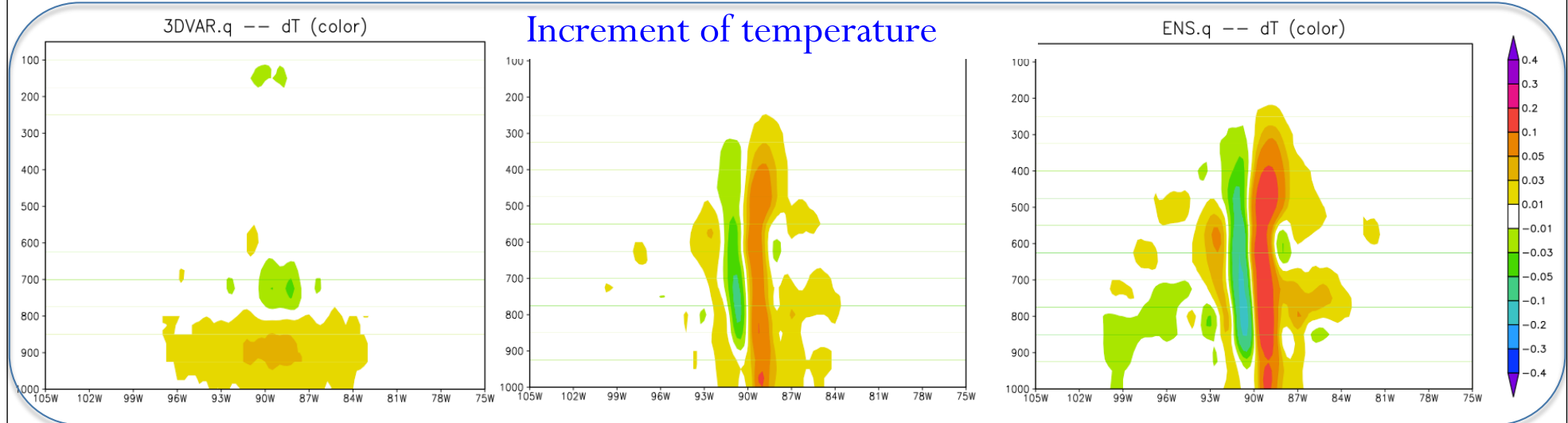
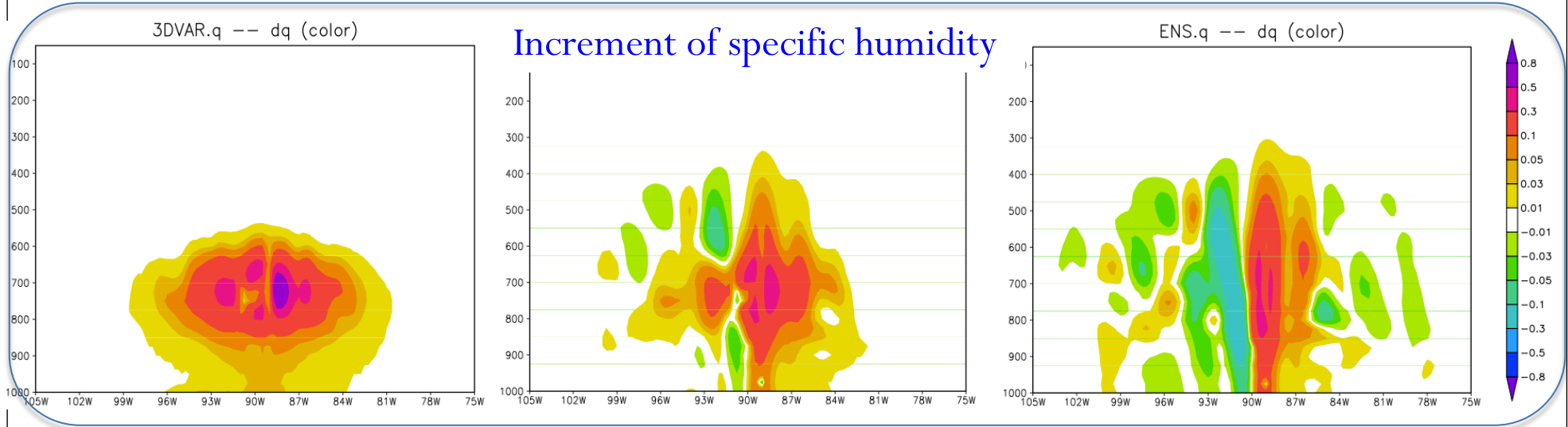


3DVAR

Hybrid

Ensemble

- Obs:  $q=1\text{g/kg}$  at 700mb at 28.9N, 270.5E (Isaac center)



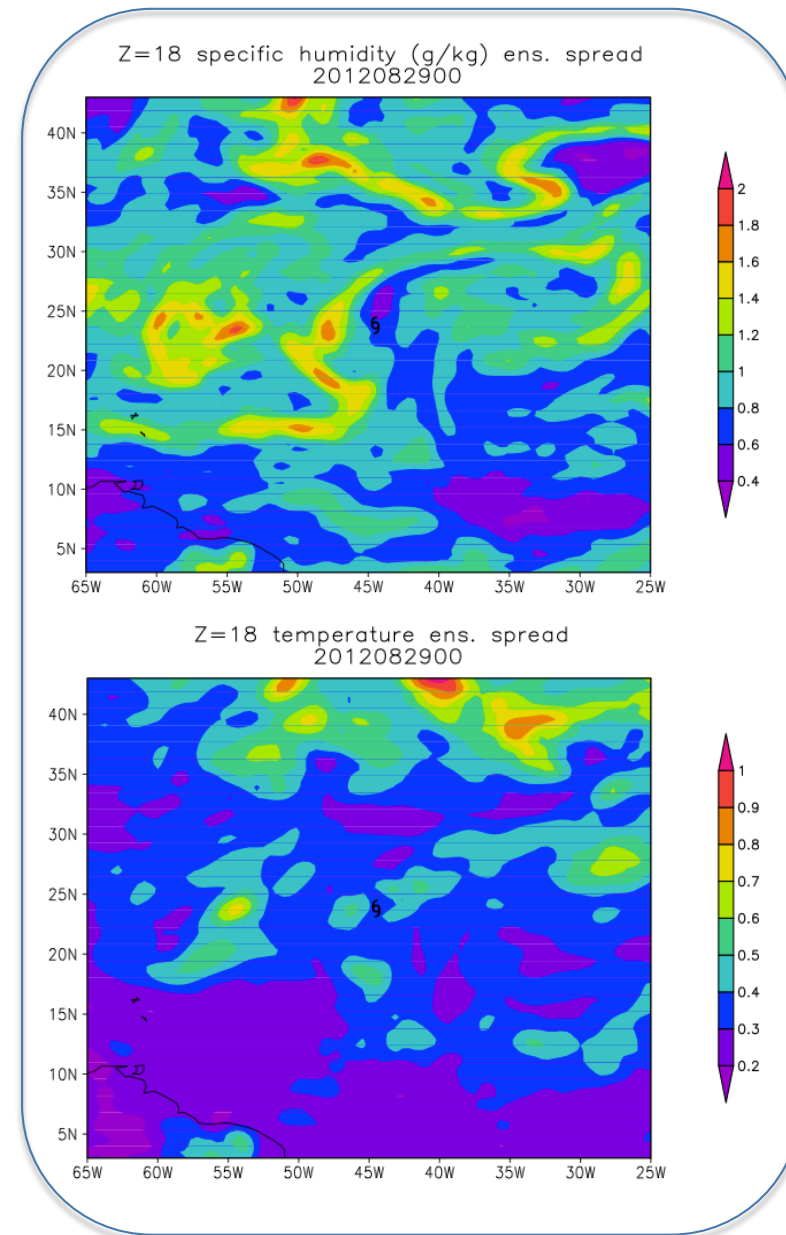
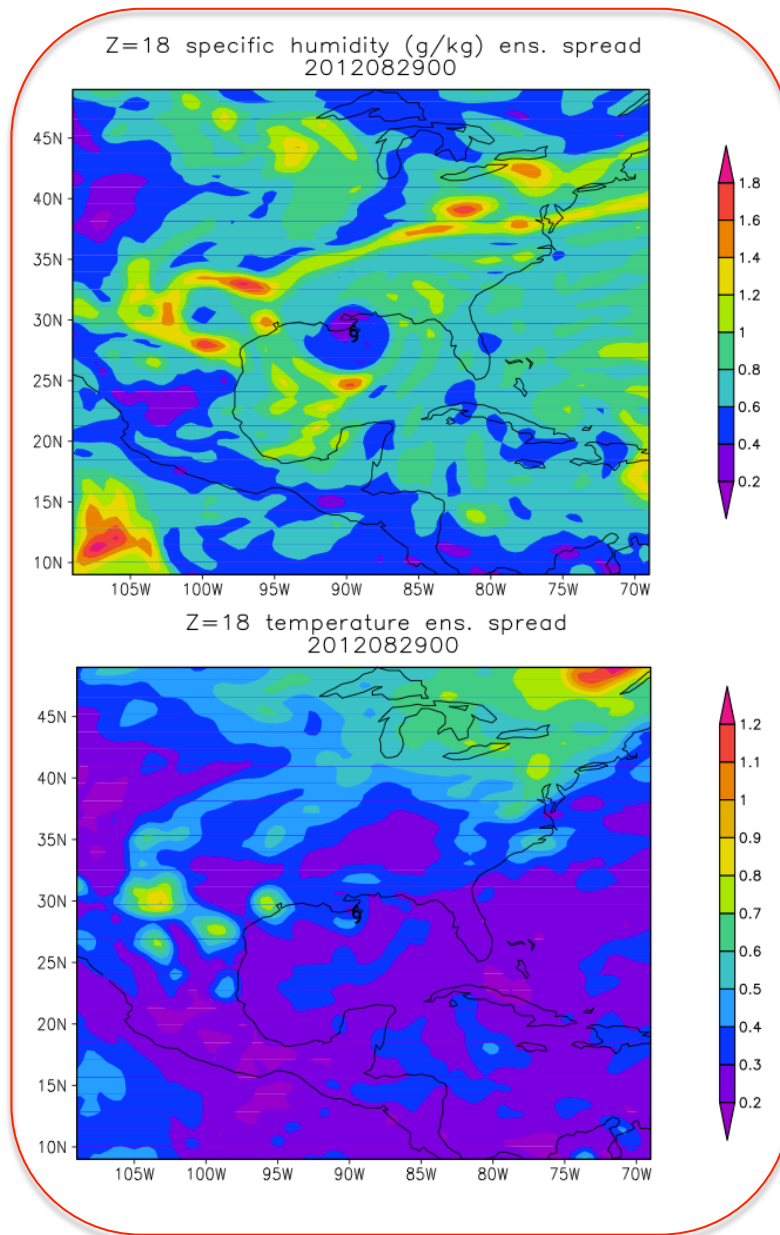
3DVAR

Hybrid

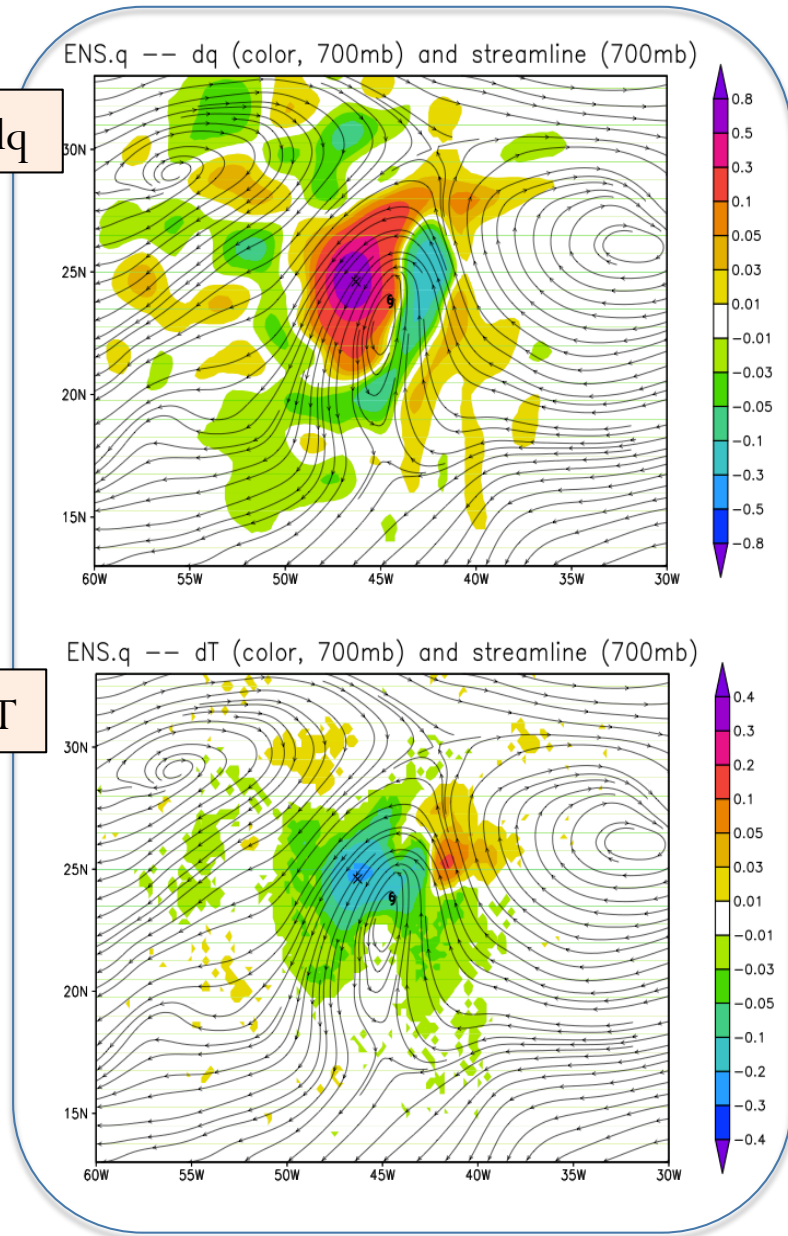
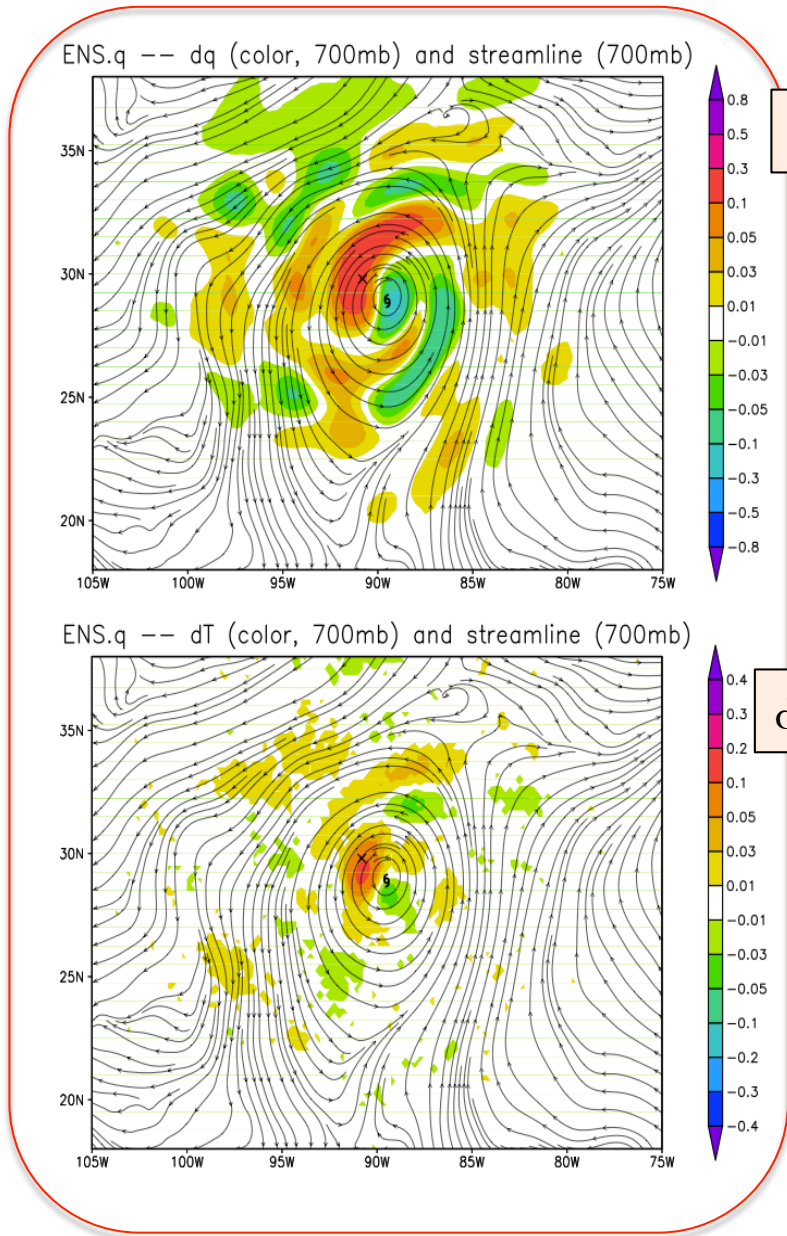
Ensemble



# Ensemble spread of q (top) and T (bottom) around Isaac (left) and Kirk (right) at 2012082900



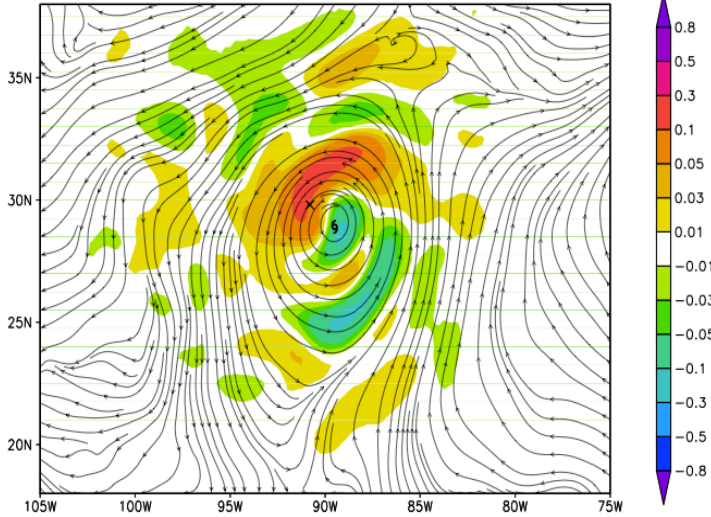
- Obs:  $q=1\text{g/kg}$  at 700mb - NW of the storm center Isaac (left) and Kirk (right)





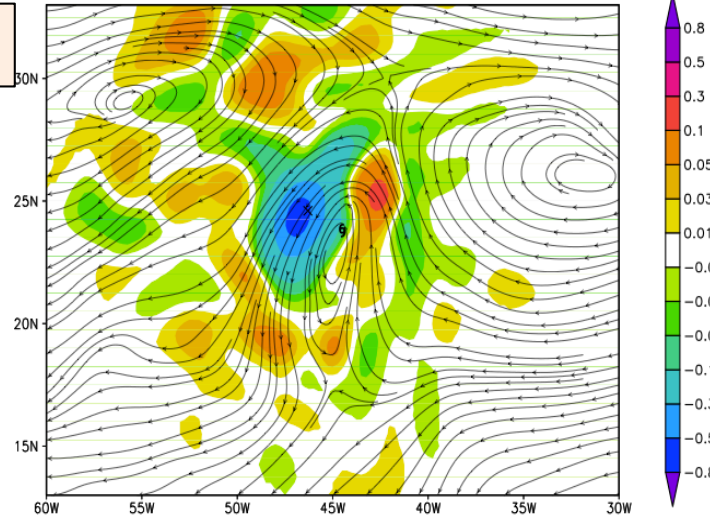
- Obs: T=1K at 700mb - NW of the storm center Isaac (left) and Kirk (right)

ENS.t -- dq (color, 700mb) and streamline (700mb)

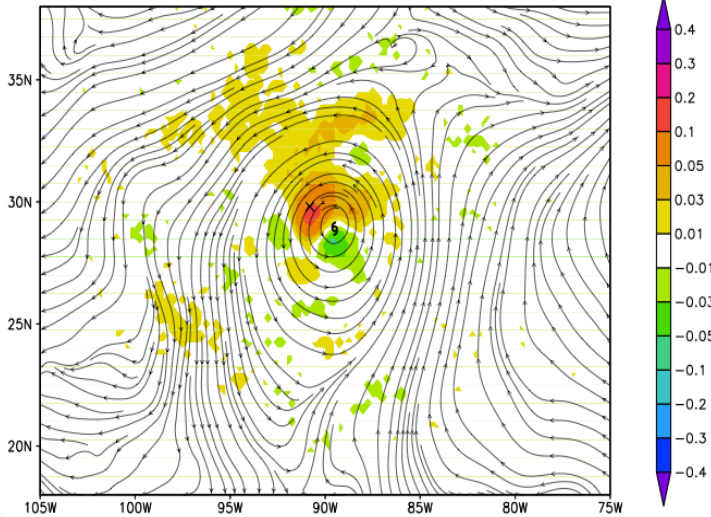


dq

ENS.t -- dq (color, 700mb) and streamline (700mb)

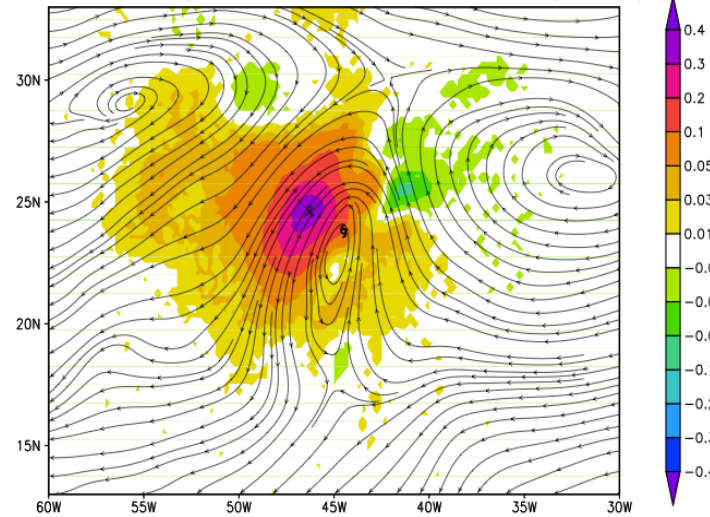


ENS.t -- dT (color, 700mb) and streamline (700mb)

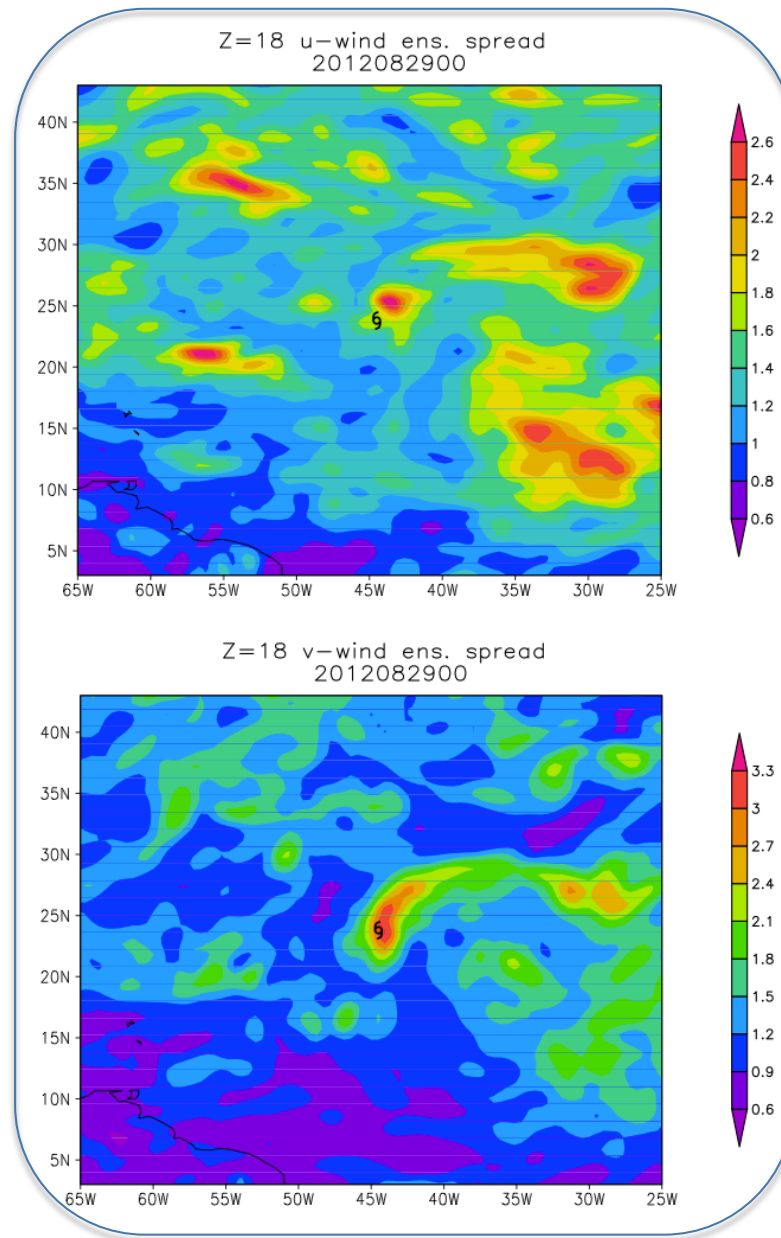
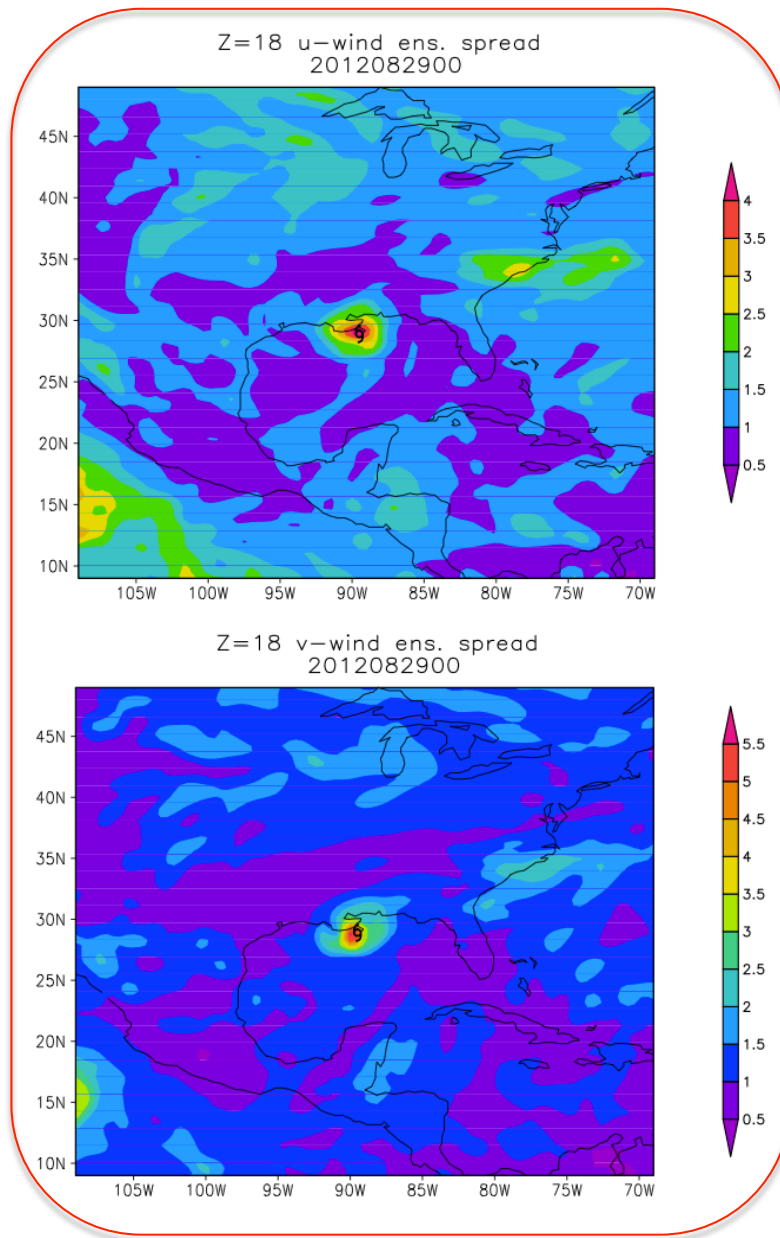


dT

ENS.t -- dT (color, 700mb) and streamline (700mb)

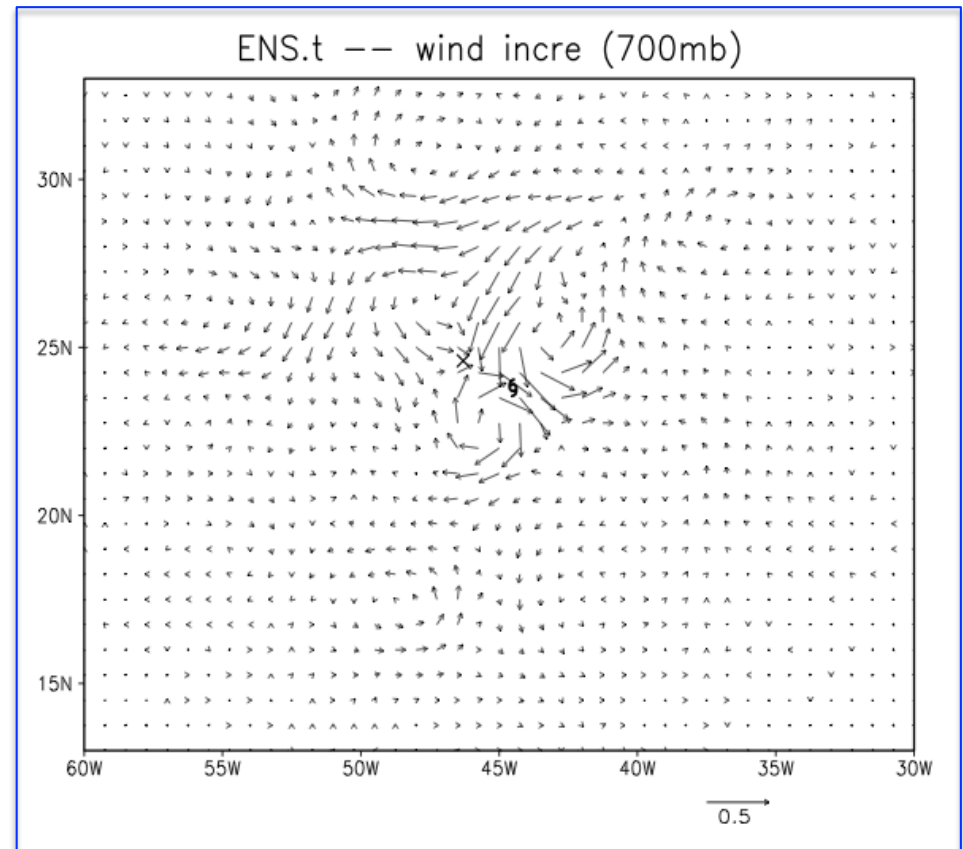
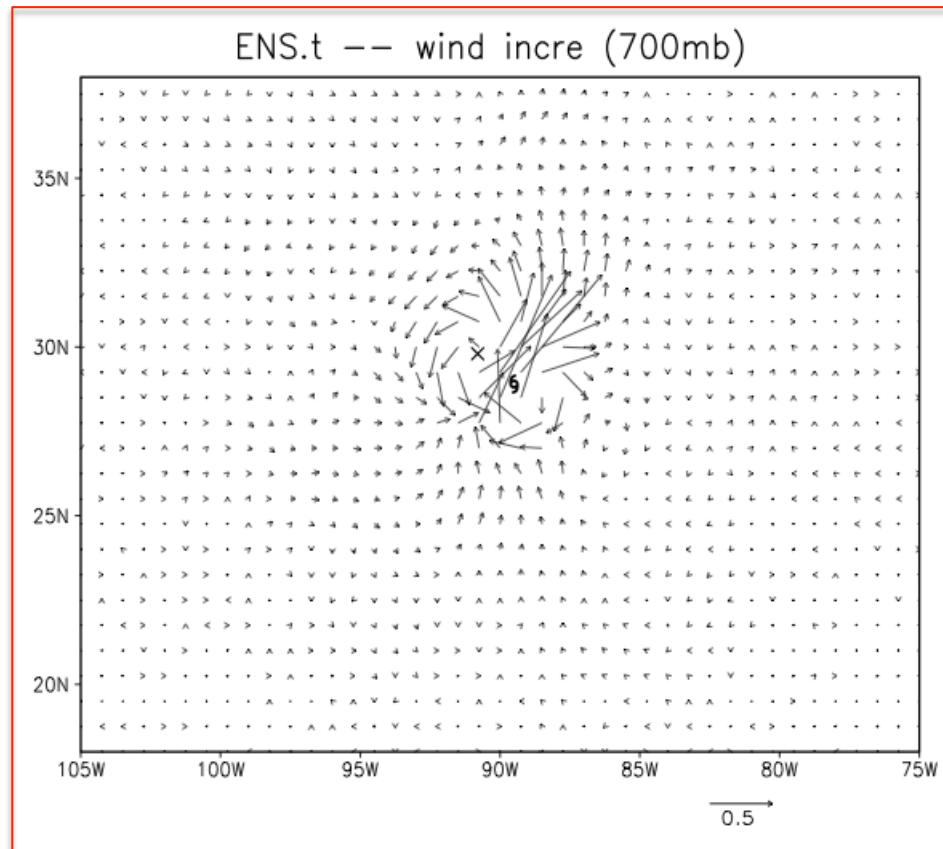


# Ensemble spread of u (top) and v (bottom) around Isaac (left) and Kirk (right) at 2012082900



- Obs: T=1K at 700mb - NW of the storm center **Isaac** (left) and **Kirk** (right)

## Wind increment at 700mb

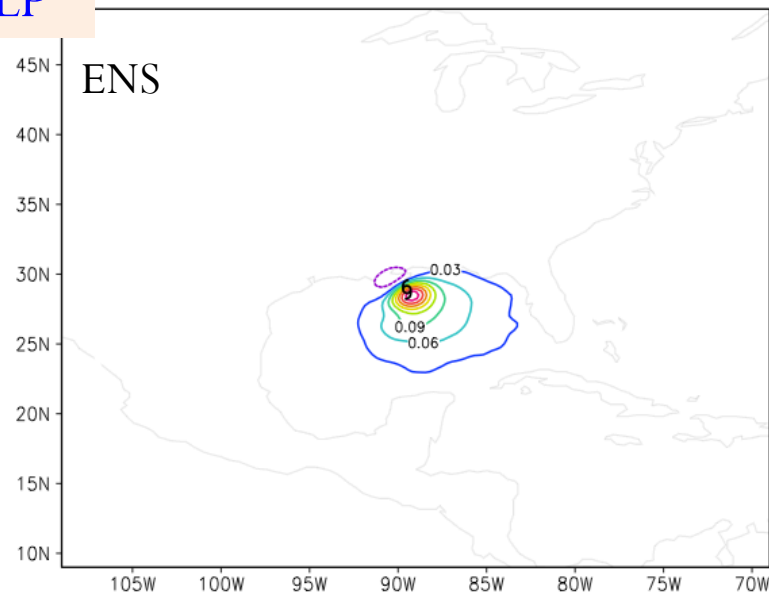
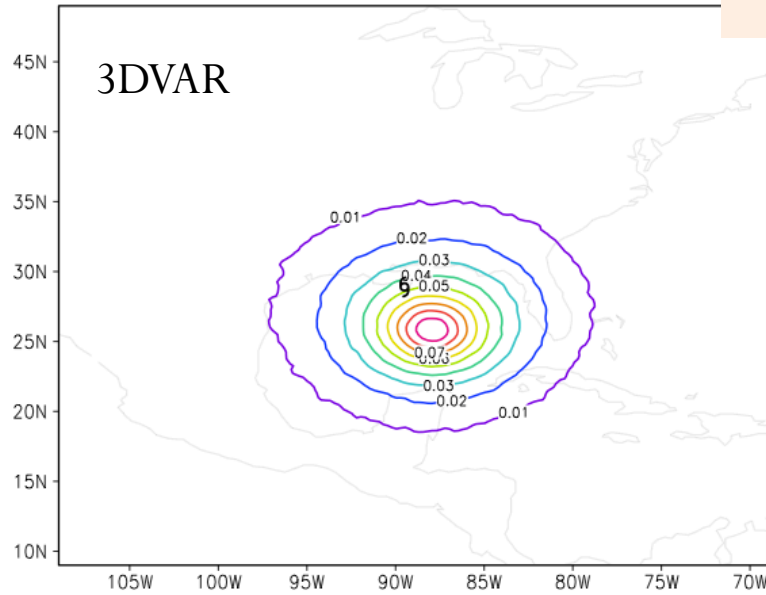


- Obs: one GPS profile at around 271.46E-272.64E, 25.2N-26.4N

MSLP (hPa) – GPS.3dvar  
2012082900, ANL–GES

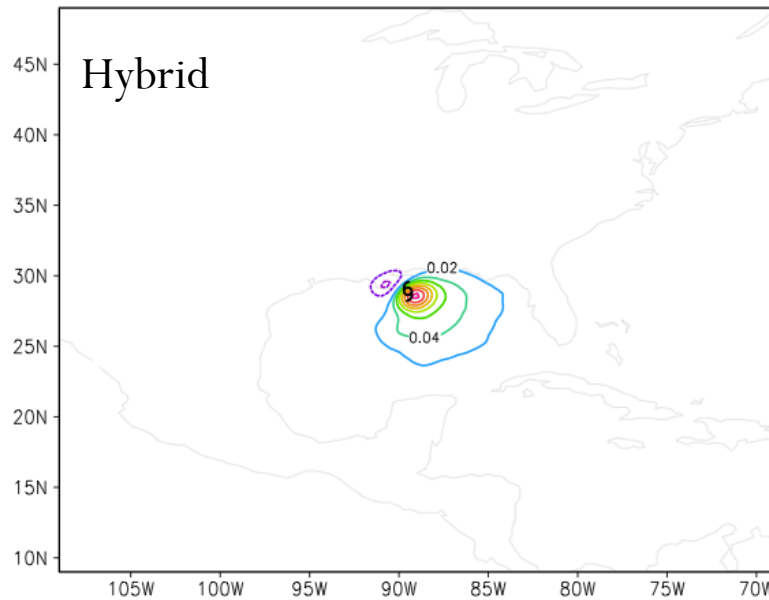
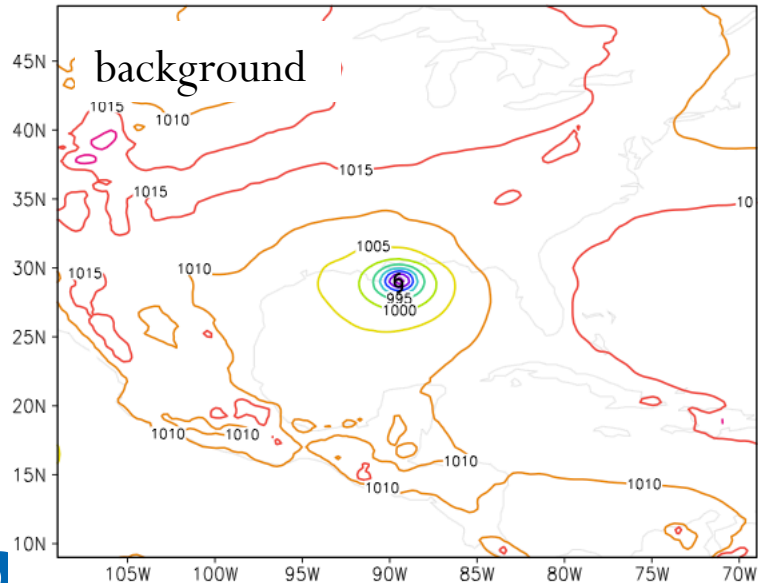
MSLP

MSLP (hPa) – GPS.ens  
2012082900, ANL–GES



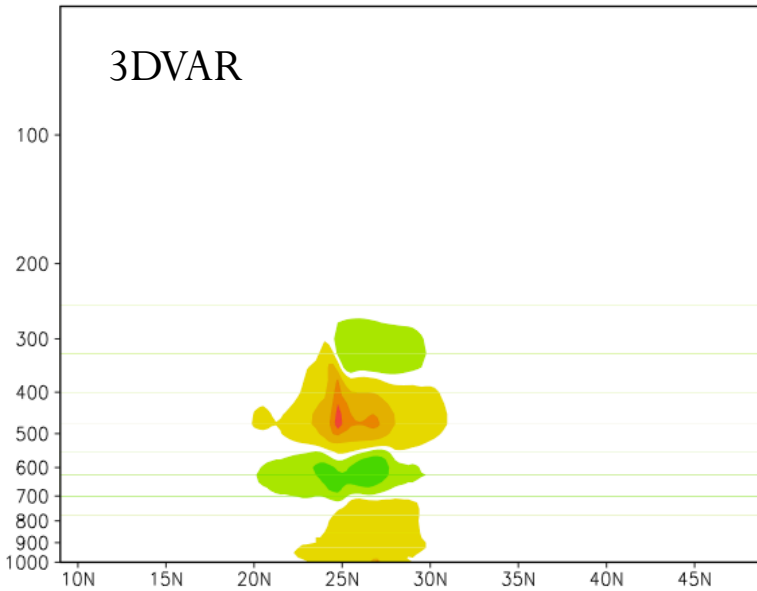
MSLP (hPa)  
2012082900, GES

MSLP (hPa) – GPS.hyb  
2012082900, ANL–GES

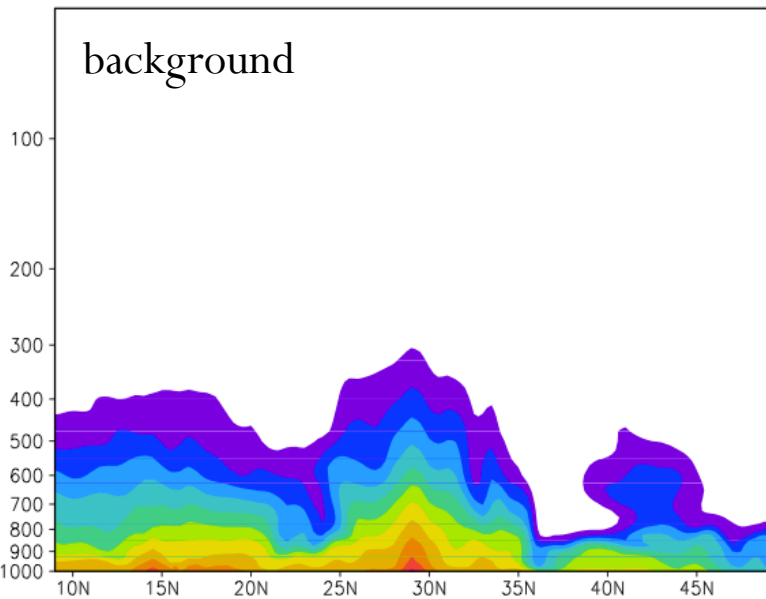


- Obs: one GPS profile at around 271.46E-272.64E, 25.2N-26.4N

SPFH (g/kg) LON=270.5 – GPS.3dvar  
2012082900, ANL-GES

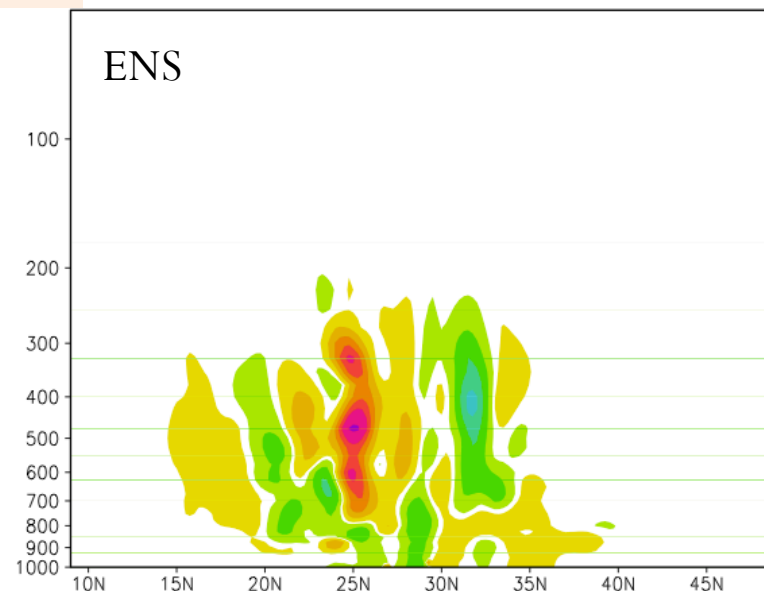


SPFH (g/kg) LON=270.5  
2012082900, GES

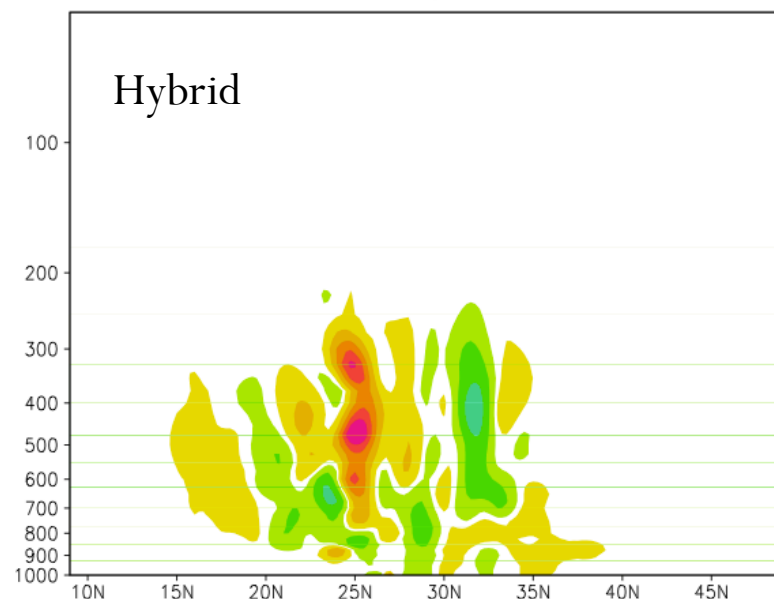


SPFH

SPFH (g/kg) LON=270.5 – GPS.ens  
2012082900, ANL-GES



SPFH (g/kg) LON=270.5 – GPS.hyb  
2012082900, ANL-GES

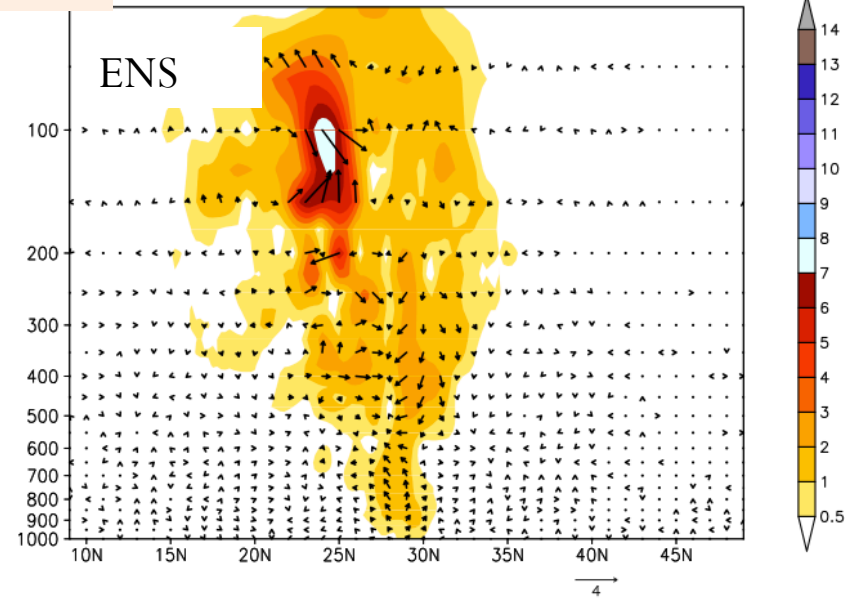
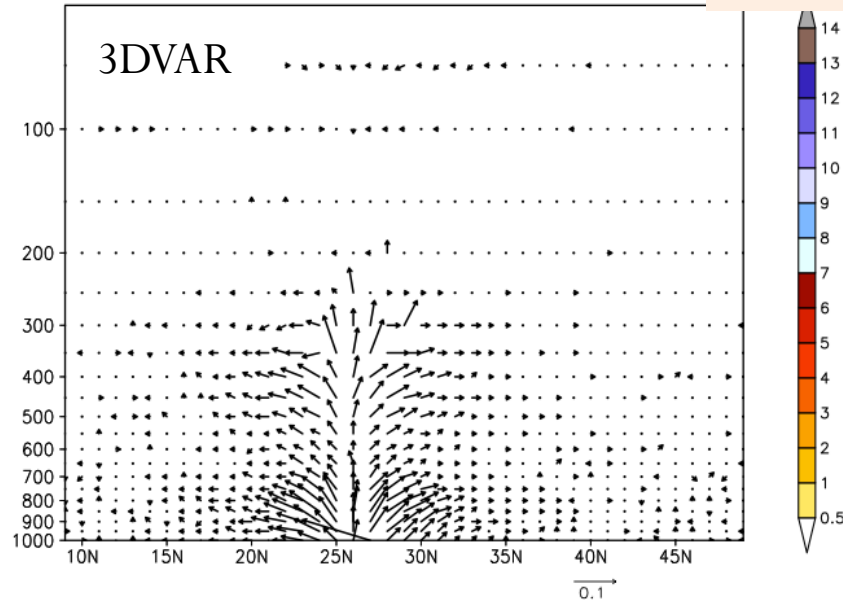


- Obs: one GPS profile at around 271.46E-272.64E, 25.2N-26.4N

uv vector and Isotach(kts) LON=270.5 – GPS.3  
2012082900, ANL-GES

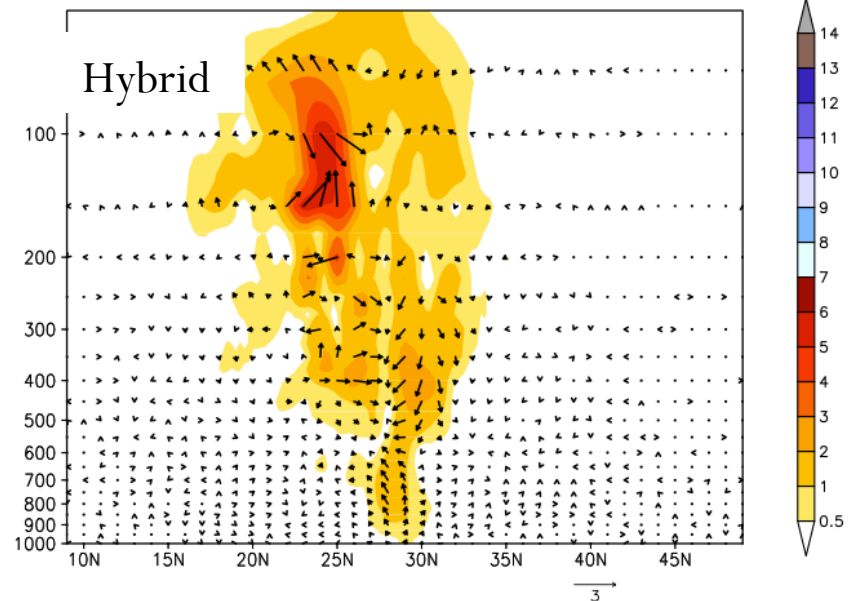
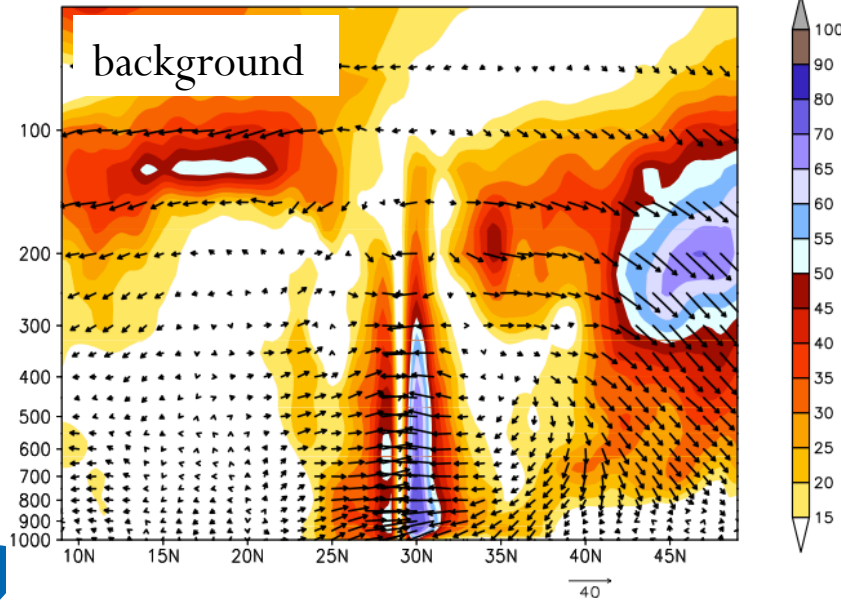
UV vector

vector and Isotach(kts) LON=270.5 – GPS.ens  
2012082900, ANL-GES



uv vector and Isotach(kts) LON=270.5  
2012082900, GES

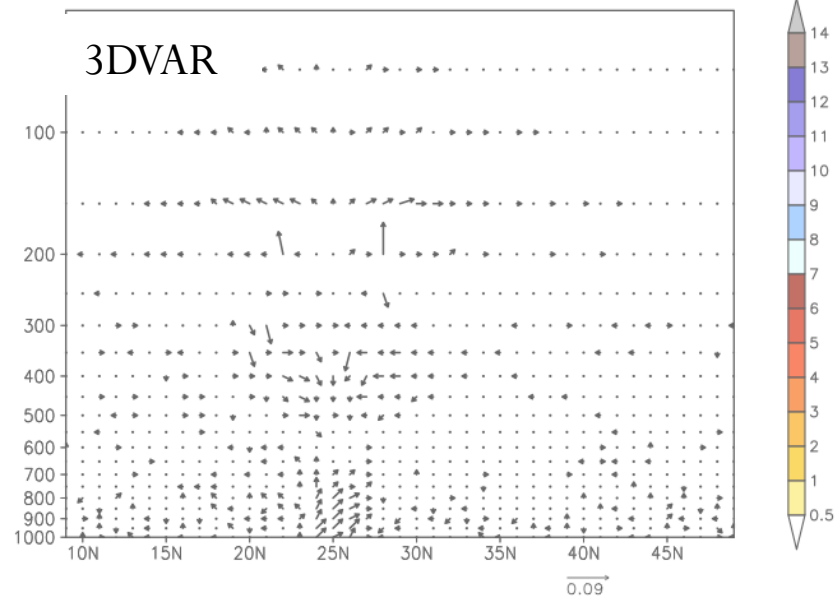
uv vector and Isotach(kts) LON=270.5 – GPS.hyb  
2012082900, ANL-GES



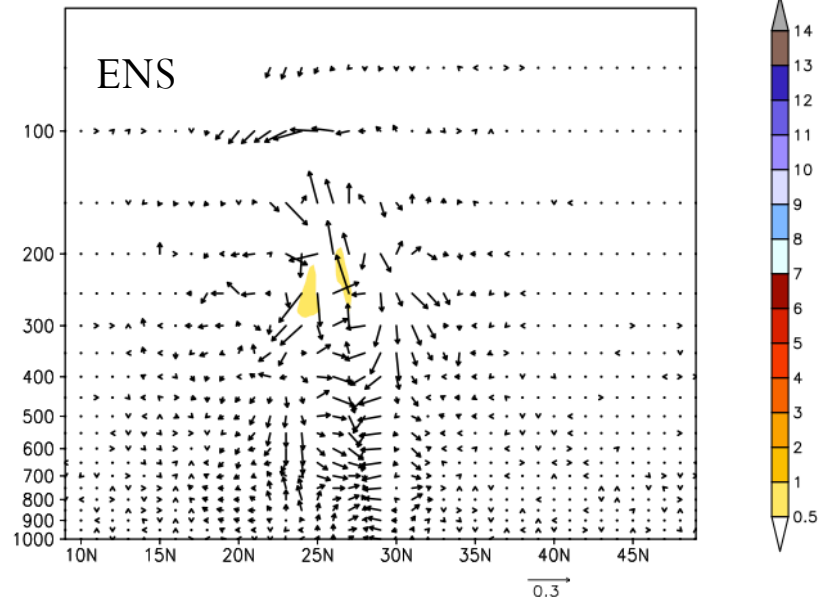
- Obs: one AMSUA radiance profile at 272E, 25.12N

UV vector

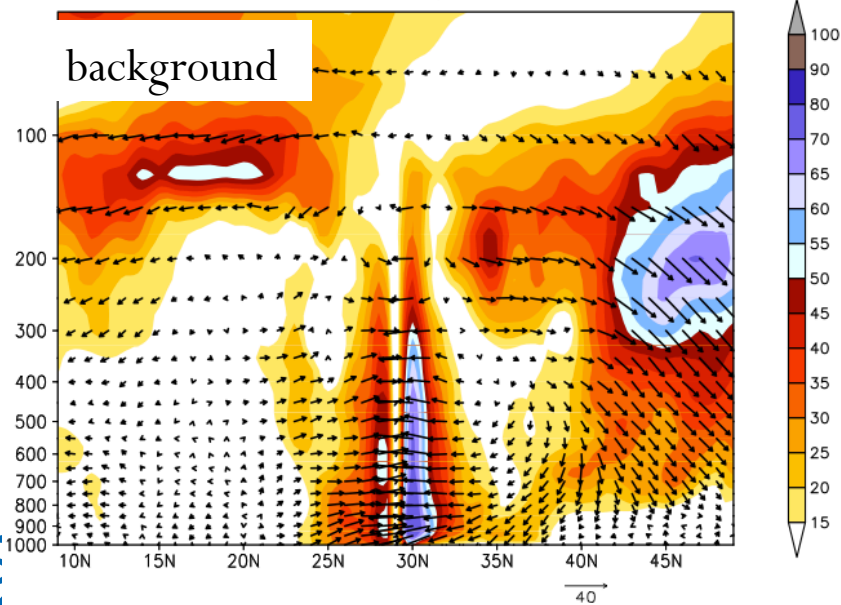
uv vector and Isotach(kts) LON=270.5 - AMSUA.3dvar.s  
2012082900, ANL-GES



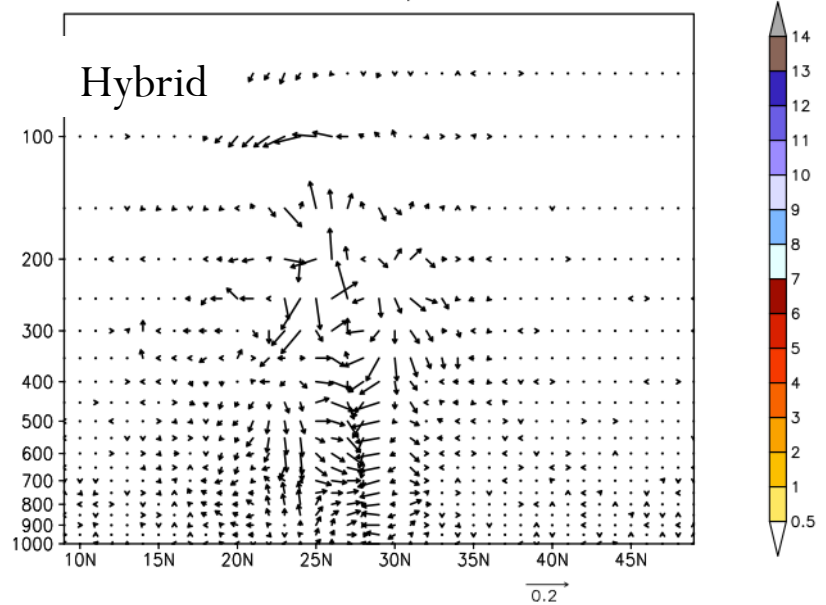
and Isotach(kts) LON=270.5 - AMSUA.ens.single  
2012082900, ANL-GES



uv vector and Isotach(kts) LON=270.5  
2012082900, GES



uv vector and Isotach(kts) LON=270.5 - AMSUA.hyb.single  
2012082900, ANL-GES



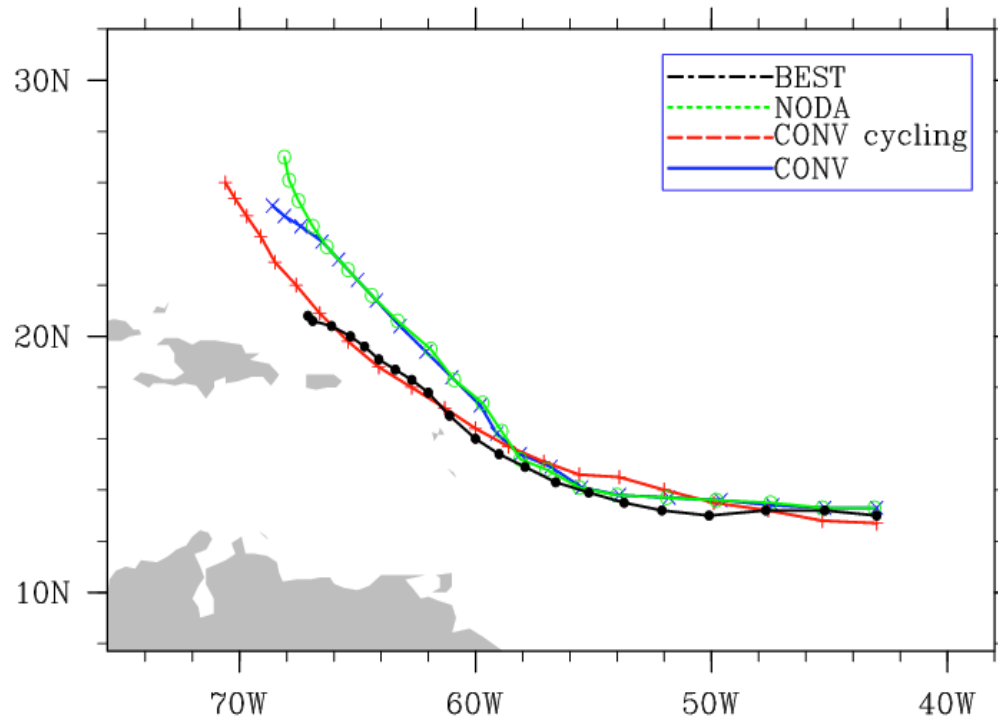
## Configuration test: GSI Partial Cycling

- ✓ CONV: conventional data, 1-time DA, no cycling
- ✓ CONV cycling: conventional data, 1-d DA cycling (6-hrly)
- ✓ GPS+CONV: conventional data + GPS RO, 1-time DA, no cycling
- ✓ GPS+CONV cycling: conventional data + GPS RO, 1-d DA cycling
- ✓ NODA: cold start at analysis time, no regional DA

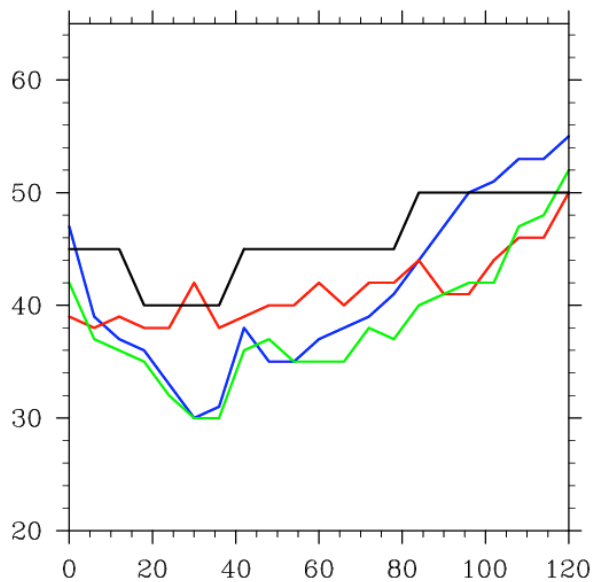




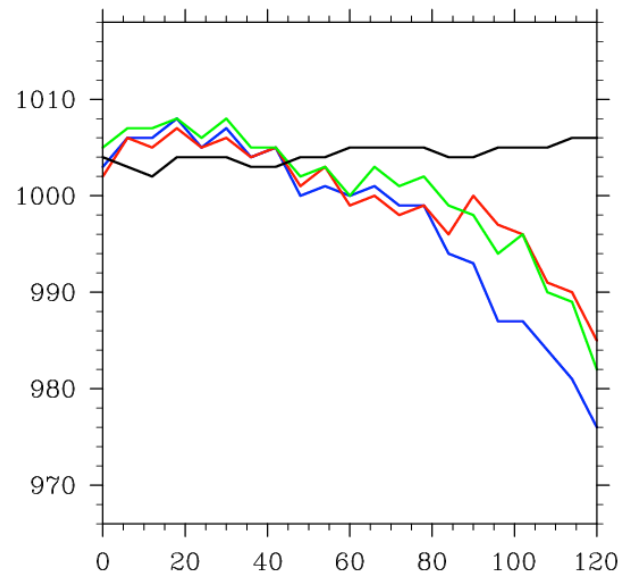
# Maria 2011090718



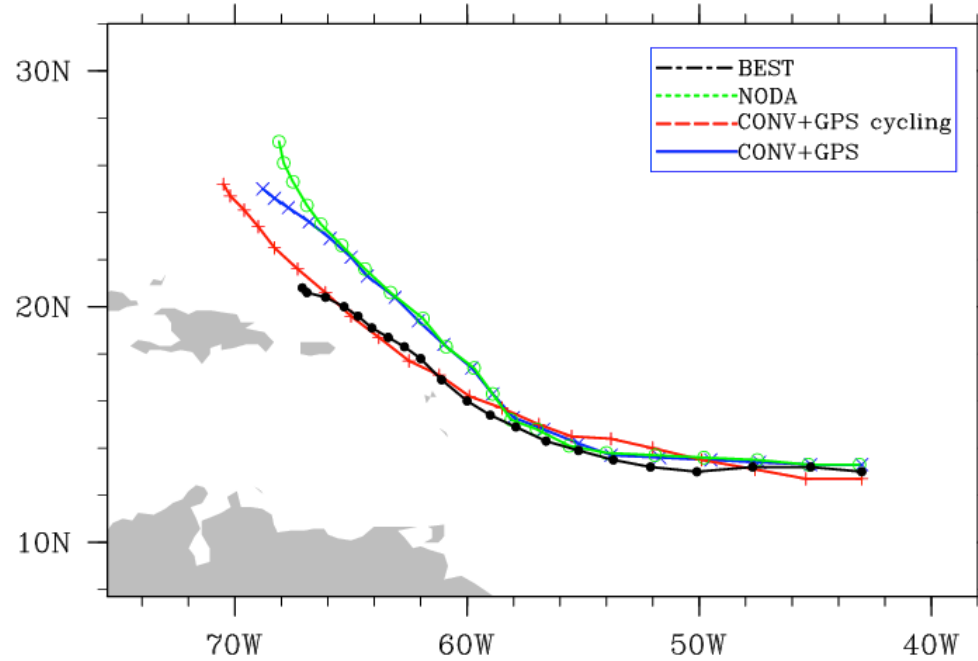
Vmax - Maria 2011090718



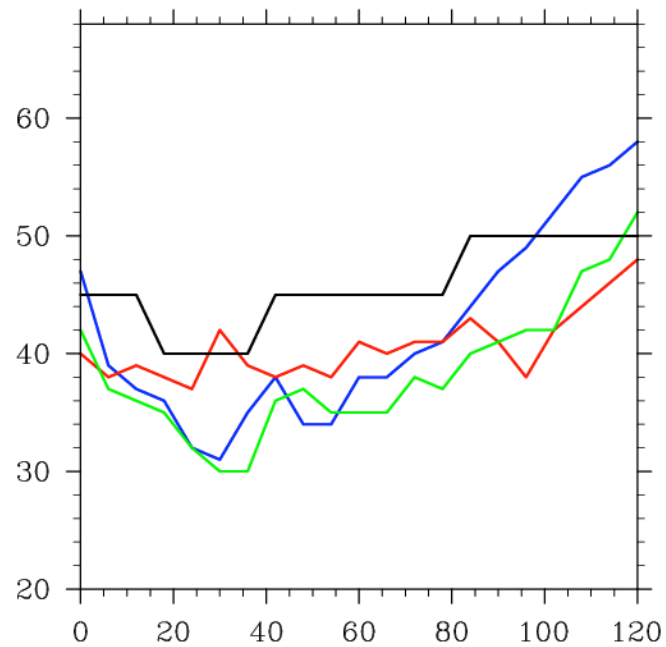
Pmin - Maria 2011090718



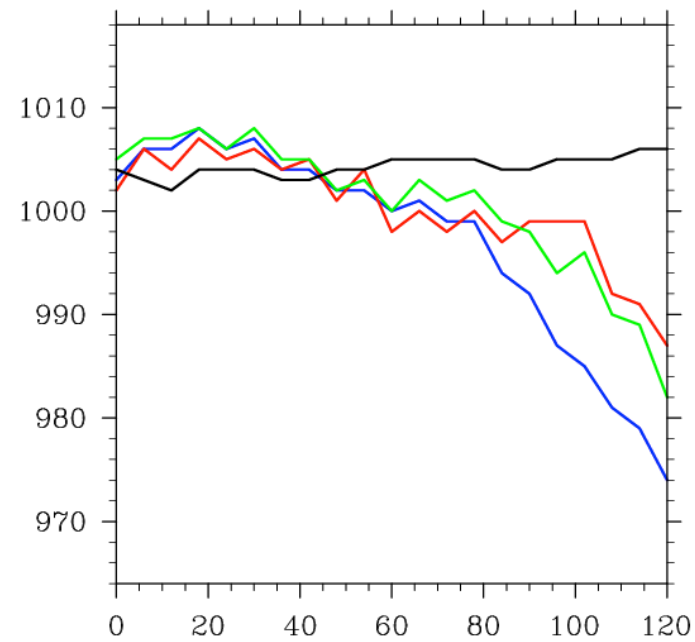
# Maria 2011090718



Vmax - Maria 2011090718



Pmin - Maria 2011090718

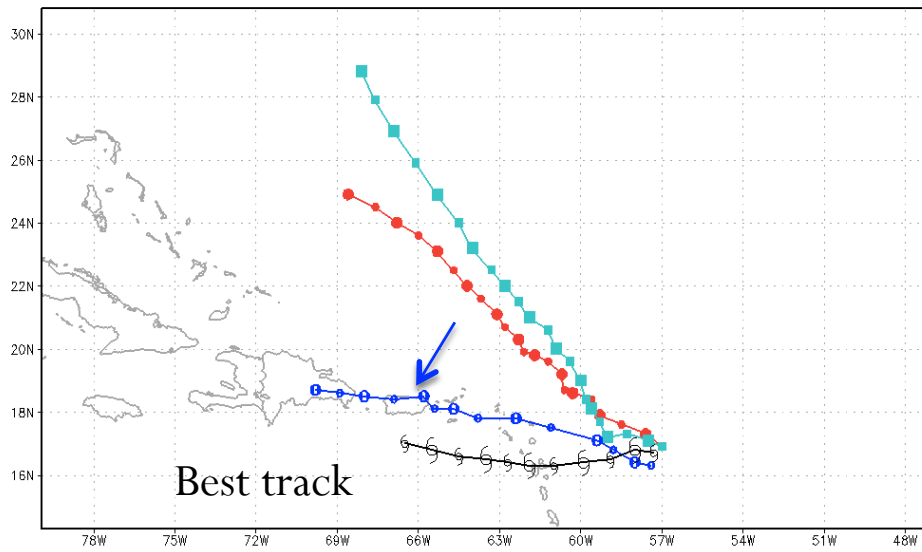


# GFS vs Partial Cycling

## Track Forecast

### 18 hr Cycling

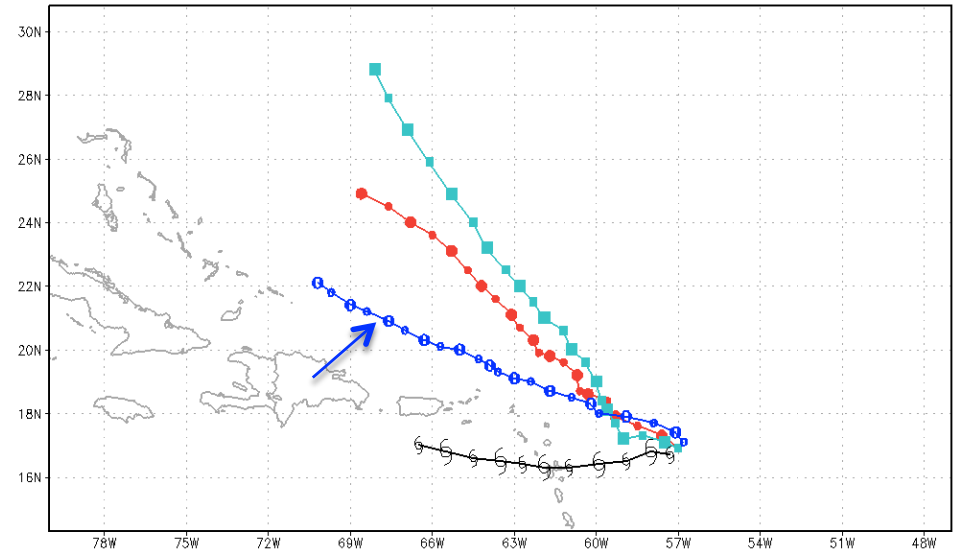
Operational HWRP (red line with circles)  
HCOM Community HWRP (blue line with circles)  
HR20 EMC R2-final (green line with squares)  
Best Track (black line with circles)



Developmental Testbed Center

### No GSI (GFS cold start)

Operational HWRP (red line with circles)  
HCOM Community HWRP (blue line with circles)  
HR20 EMC R2-final (green line with squares)  
Best Track (black line with circles)



(This run is Erika (2009) on HWRP 2011 operational domain )



# Summary and Future work:

- ✓ Single observation tests are done for investigating the cross co-variances around tropical cyclone and show reasonable flow dependent responses compared to isotropic response from the 3DVAR using static BE.
  - More tests and in-depth diagnostics: cloud variables?
  - Best combination of the static BE and the ensembles?
- ✓ Case studies show benefit in track and intensity forecast by cycling GSI data assimilation
  - More cases and extended runs - ongoing
  - Partial cycling with HWRF ensembles

