Current and Future Experiments to Improve Assimilation of Surface Winds from Satellites in Global Models

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Review: Scatterometer data in global model forecasts of tropical cyclones

- Atlas et al. (2001): Significant positive impact on NWP
  - For TCs, NSCAT improved ECMWF initial conditions.
- Atlas et al. (2005): Improvements for 2 mos. of forecasts in 1999.
  - Very significant impact on track and intensity of Hurricane Cindy
- Zapotocny et al. (2007): Improvements in NCEP track forecasts in 2003 (48h: 10%, 25 cases; 72h: 16%, 19 cases)
- Goerss (2009): Little change in NOGAPS for 2005-6 seasons.
- Limited data impact studies to date with regional models

- Generally focused on track, not structure or intensity
- All results are crucially dependent on data assimilation scheme.

Purpose of this study

- To investigate the operational use of QuikSCAT data in the NCEP Global Forecast System (GFS), using their new Gridpoint Statistical Interpolation (GSI) data assimilation scheme.

- **Ultimate goal: To propose recommendations on how best to utilize QuikSCAT (and future scatterometer) wind vectors in global models.**

How QuikSCAT is assimilated at NCEP

- Data Processor reads 25-km res QuikSCAT wind retrievals in BUFR
  - Quality Control
    - Probability of rain > 10% → reports skipped
    - Swath edge QC
  - Pre-processing
  - Wind retrieval
  - Ambiguity removal
  - Super-ob: average over 1 x 1^{o} boxes; output at 0.5^{o} resolution

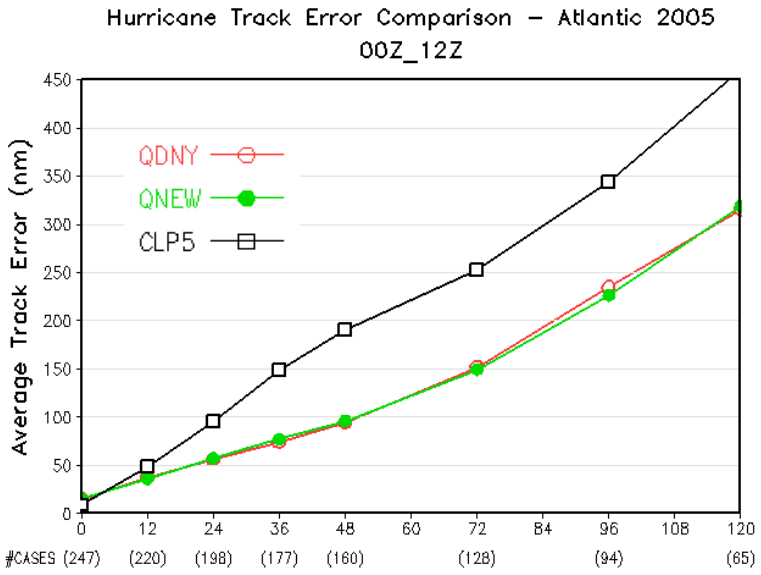
- Output in BUFR for use in data assimilation (ob error = 3.5 m/s)

- Blend these output wind vectors with other obs and NCEP ‘first guess’ in 3d-Variational Gridpoint Statistical Interpolation every 6h

1. NCEP Data Denial Experiments

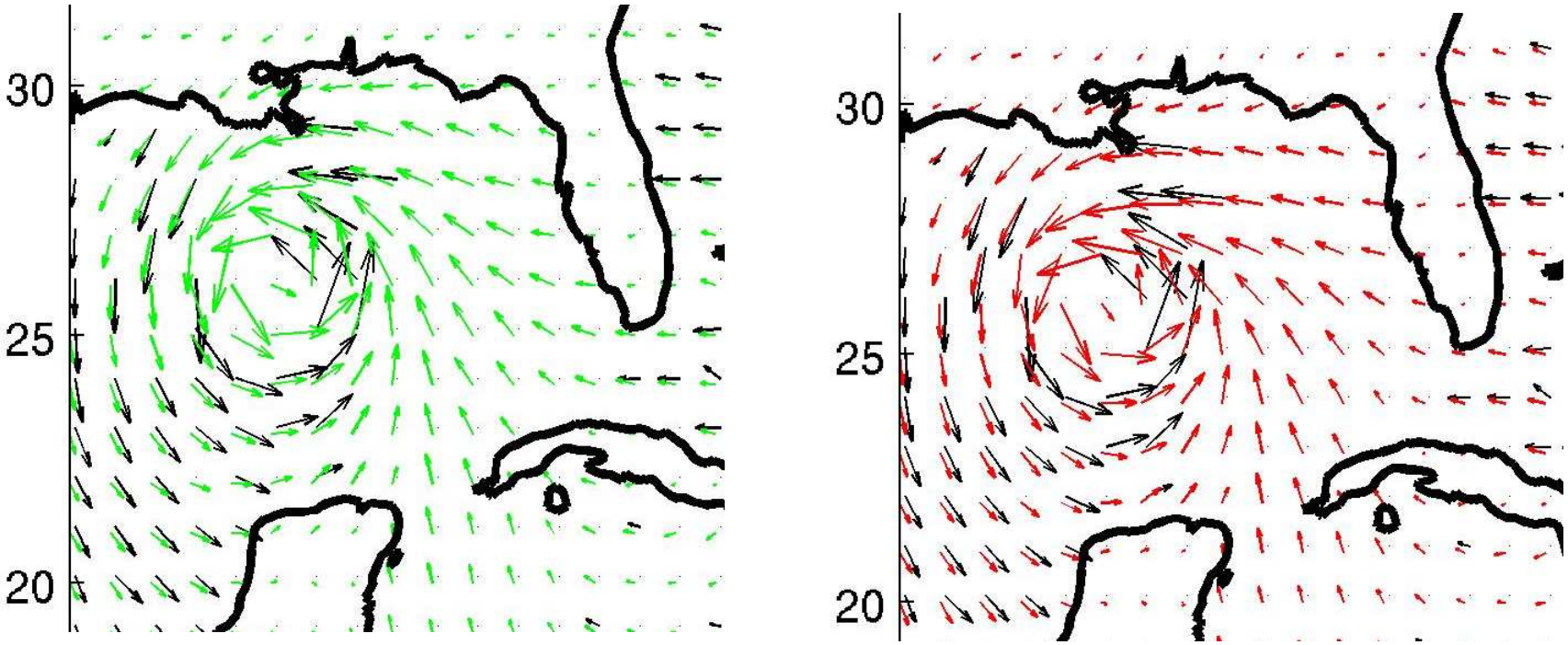
- QDNY (no QuikSCAT)
- QNEW (with newly processed QuikSCAT observations from NESDIS)
- CLP5 (Climatology and persistence)

- Nov 07 version of GFS system & GSI analysis (35km, 64 levels)
- 20050705-20051025; 20060801-20061004



Overall conclusion: Assimilating QuikSCAT data had little impact on hurricane track errors.

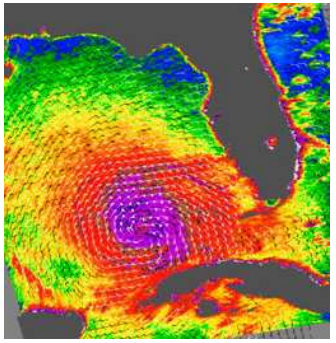
1. NCEP Data Denial Experiments



10-m analysis wind vectors resemble first guess more closely than **QuikSCAT**

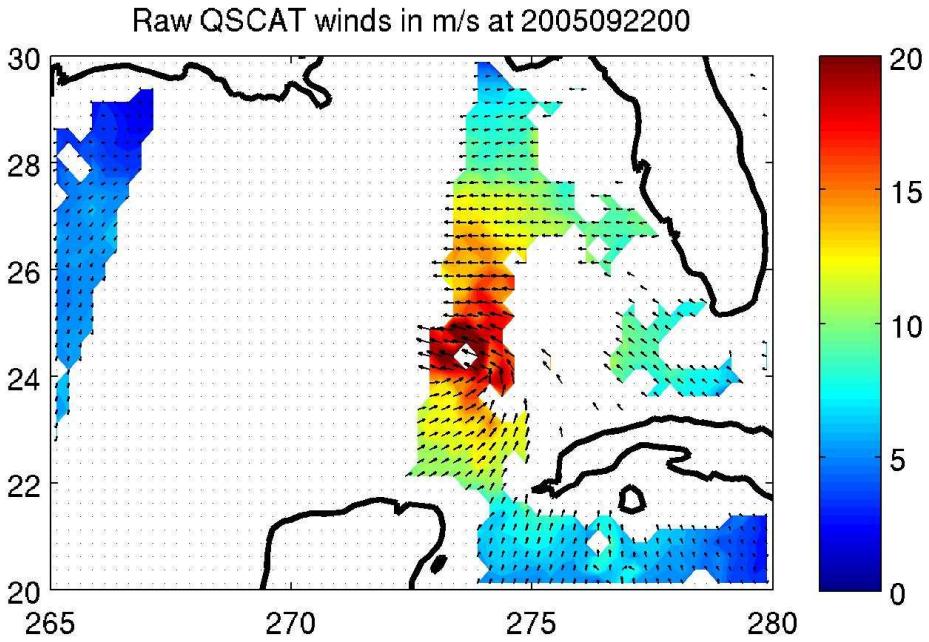
Why do QuikSCAT winds appear to be under-utilized?

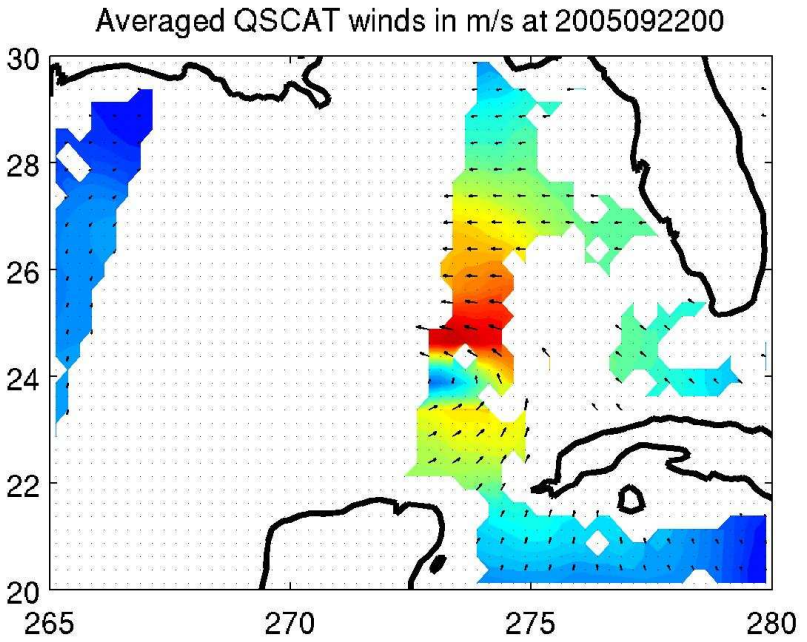
2. Super-Obs method



- Next 3 slides: Hurricane Rita in Gulf of Mexico
- Left panel: QuikSCAT winds at 0.25^{o} resolution
- Right panel: Super-obbed (averaged) QuikSCAT winds for each grid point at 0.5^{o} resolution.
- (White areas: zero obs or rain-flagged obs)

2. Super-Obs method





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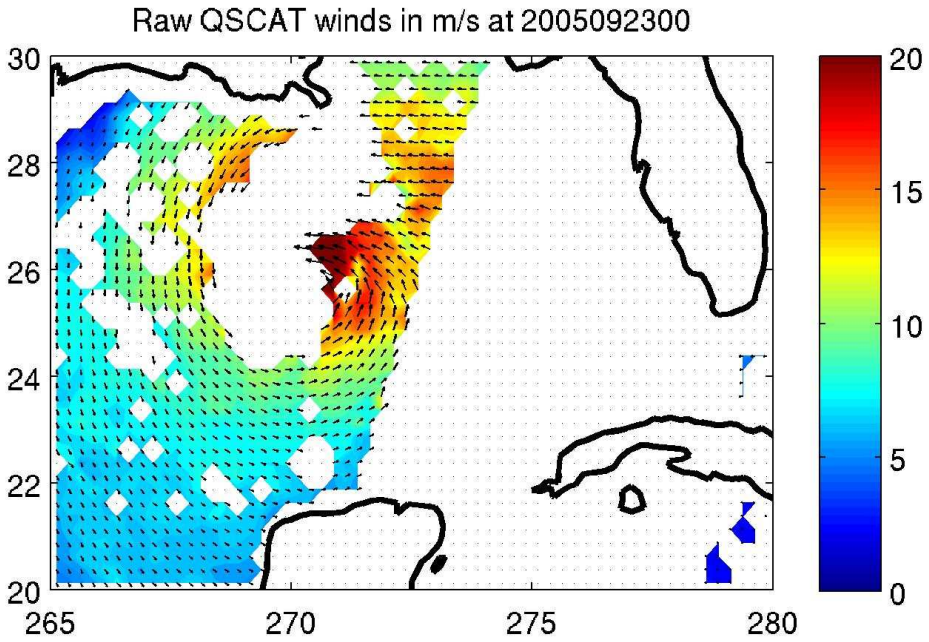

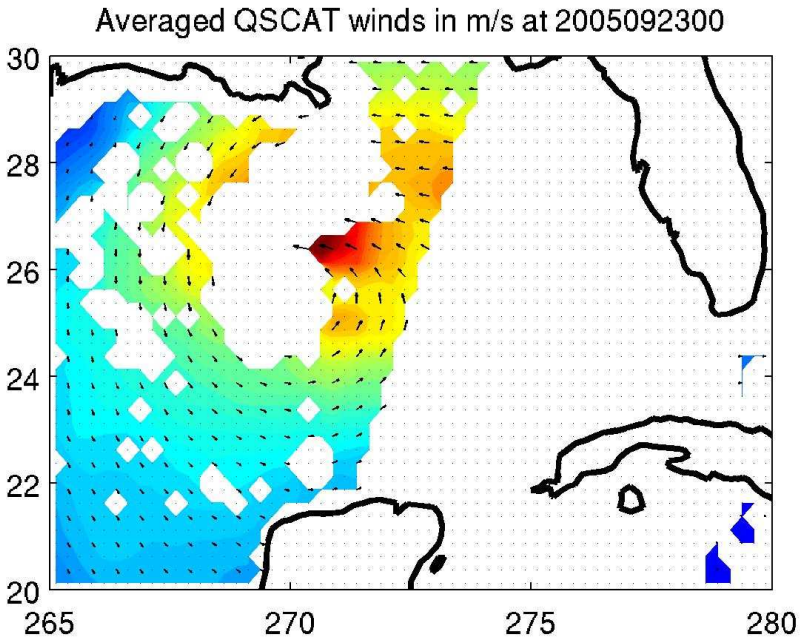

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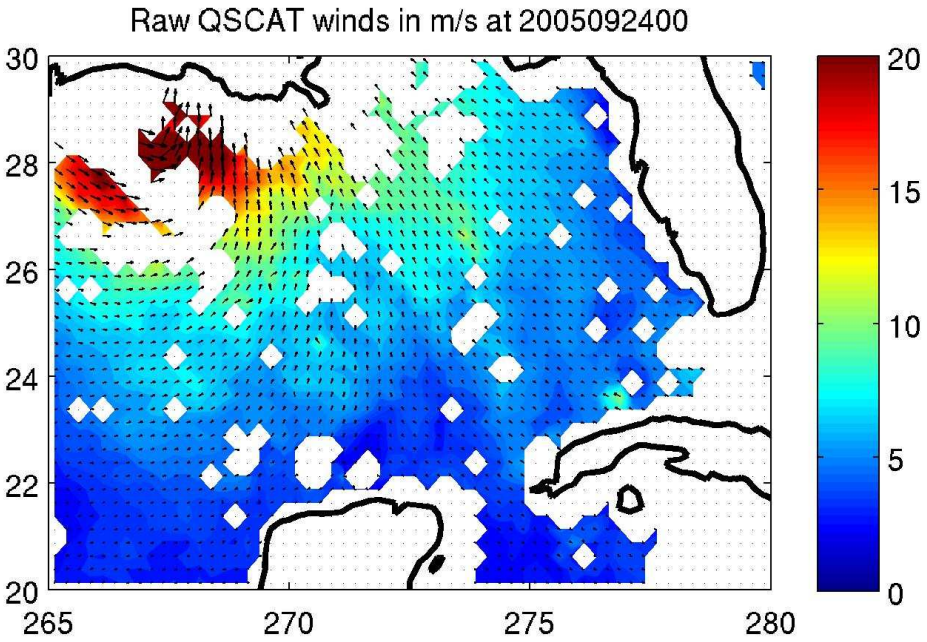
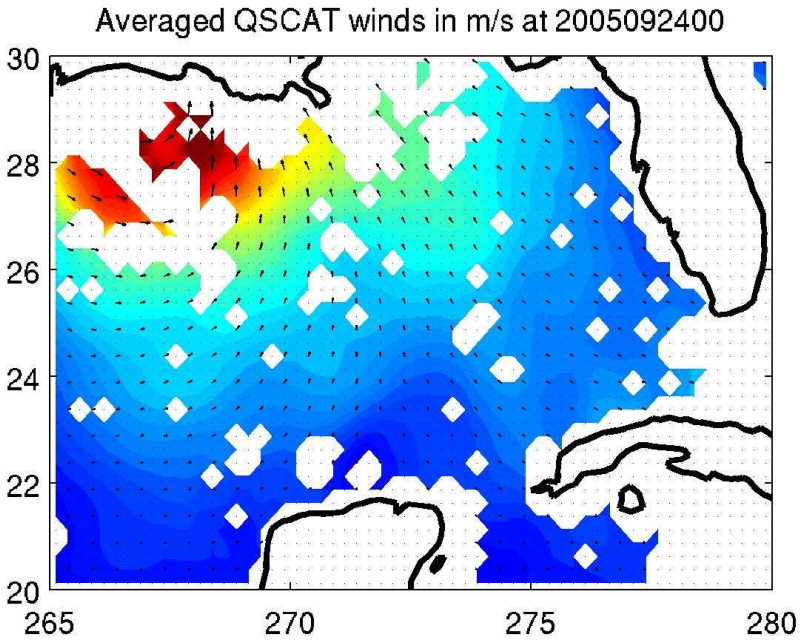




2. Super-Obs method

- Significant wind vectors (>20 m/s) are thinned due to averaging
- Suboptimal density of observations may reduce impact

Tentative Recommendation: assimilate non-averaged wind vectors at 0.25° resolution.

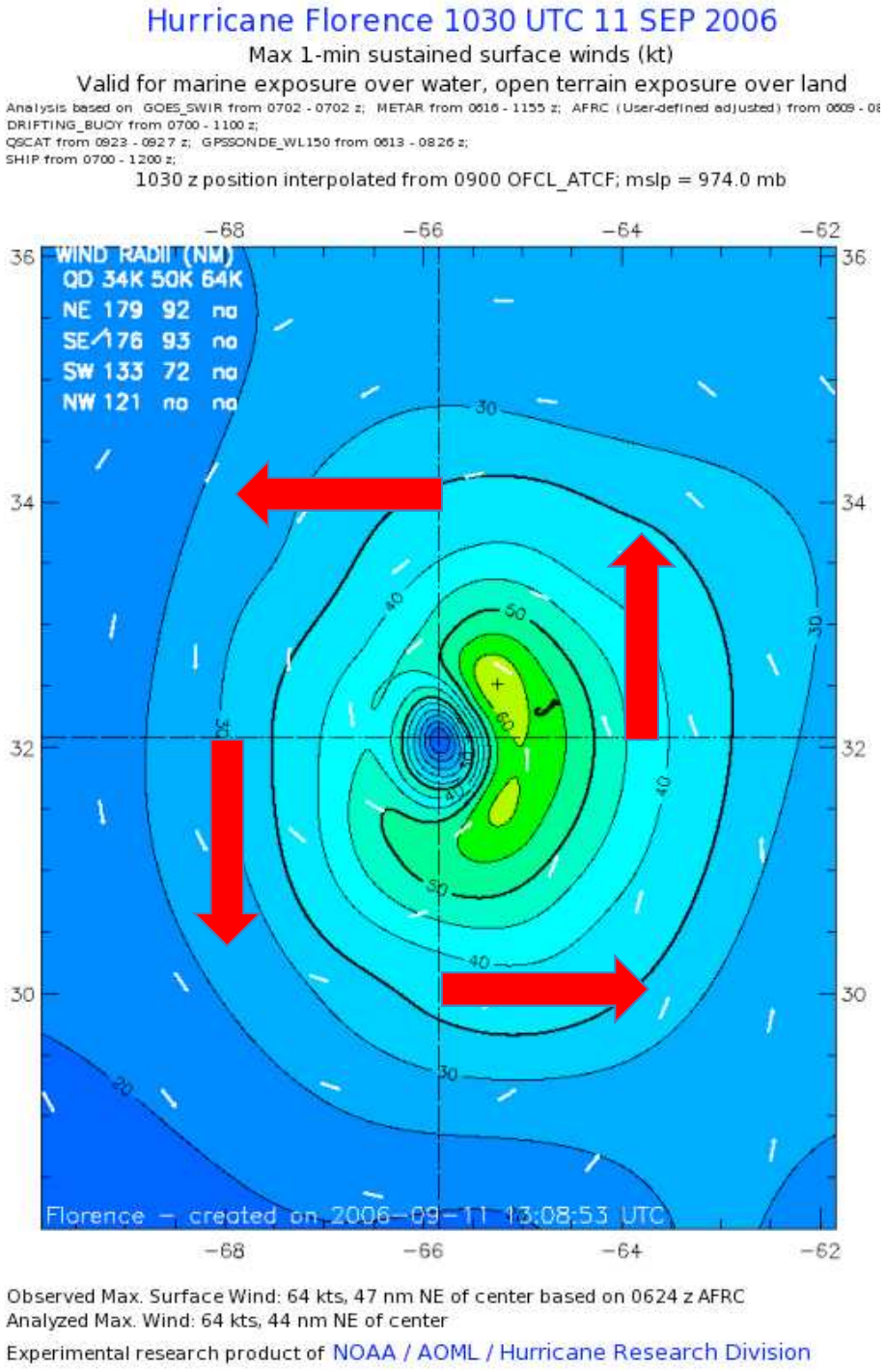
3. GSI Assimilation experiments

- One assimilation time: 2006091112
  - Hurricane Florence in western Atlantic
- Operational NCEP GSI:
  - Gridpoint-based scheme
  - Control variables Ψ and Φ
  - ~ 35 km resolution
- Current capability:
  - Assimilating all operational observations
  - Single synthetic-observation experiments

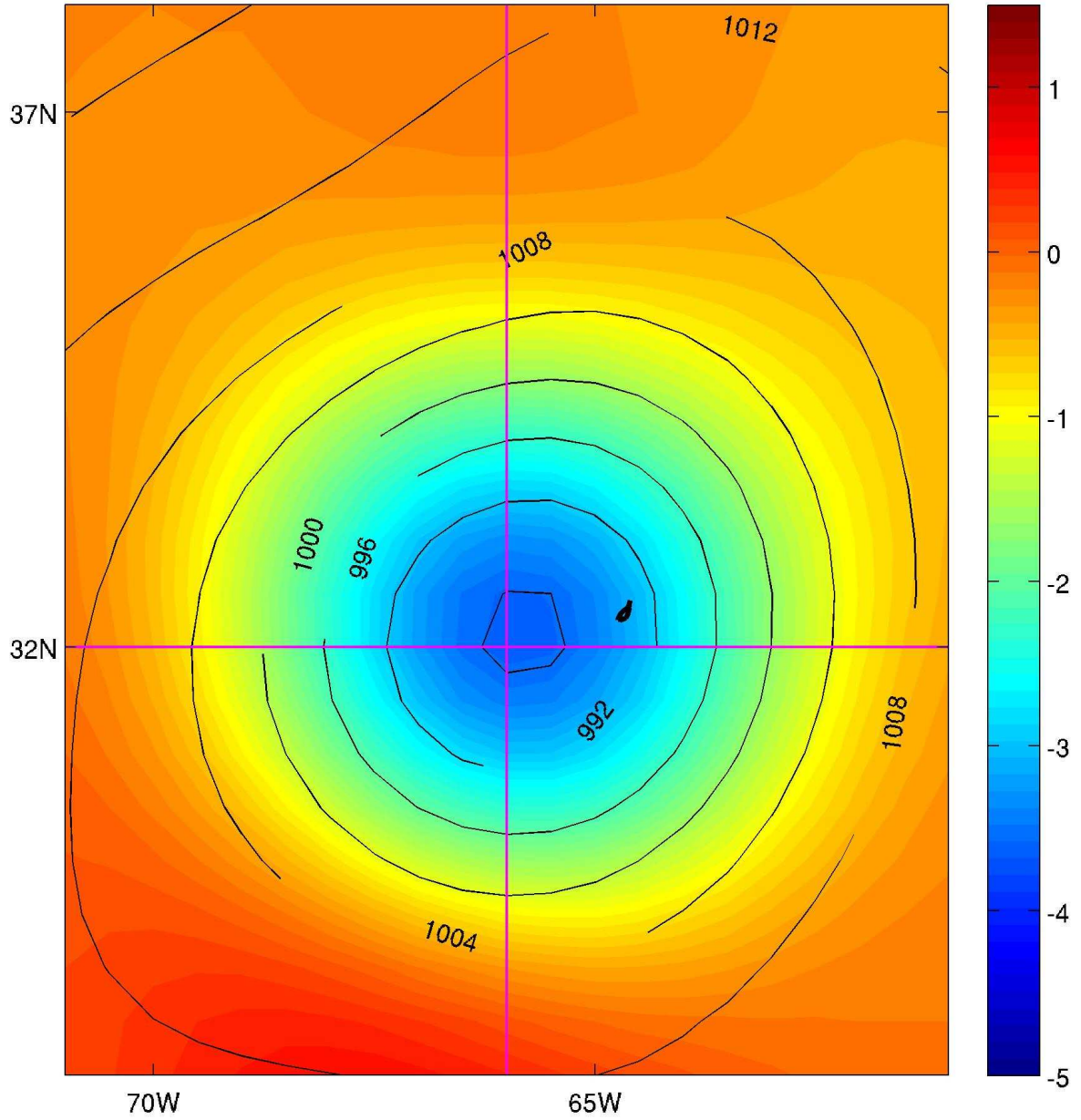
Synthetic obs of (near) surface u, v

Innovation 10 m/s
Ob error 0.1 m/s

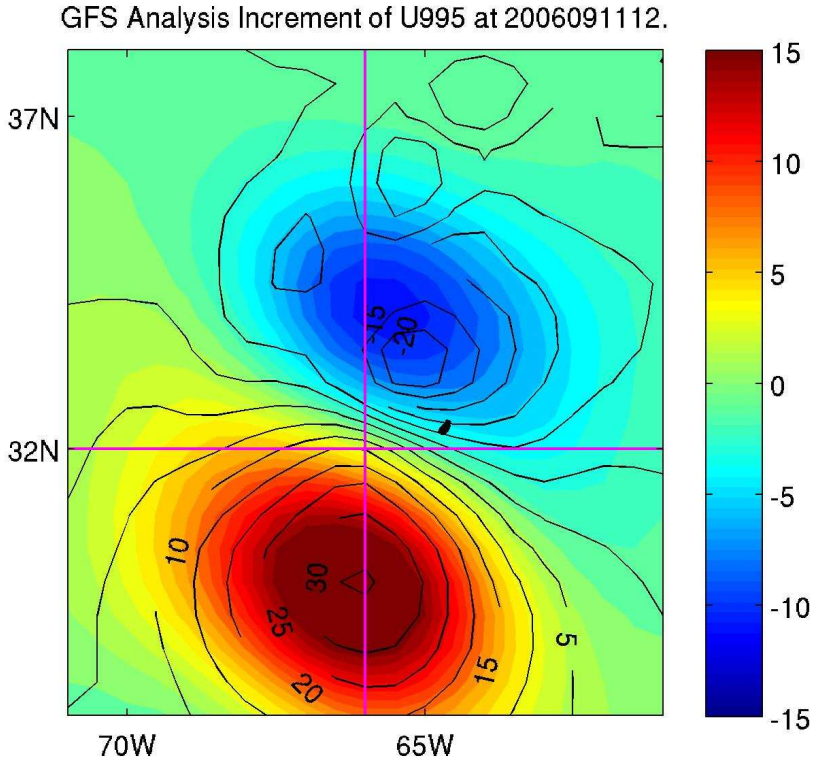
4 (u,v) obs 200 km from center

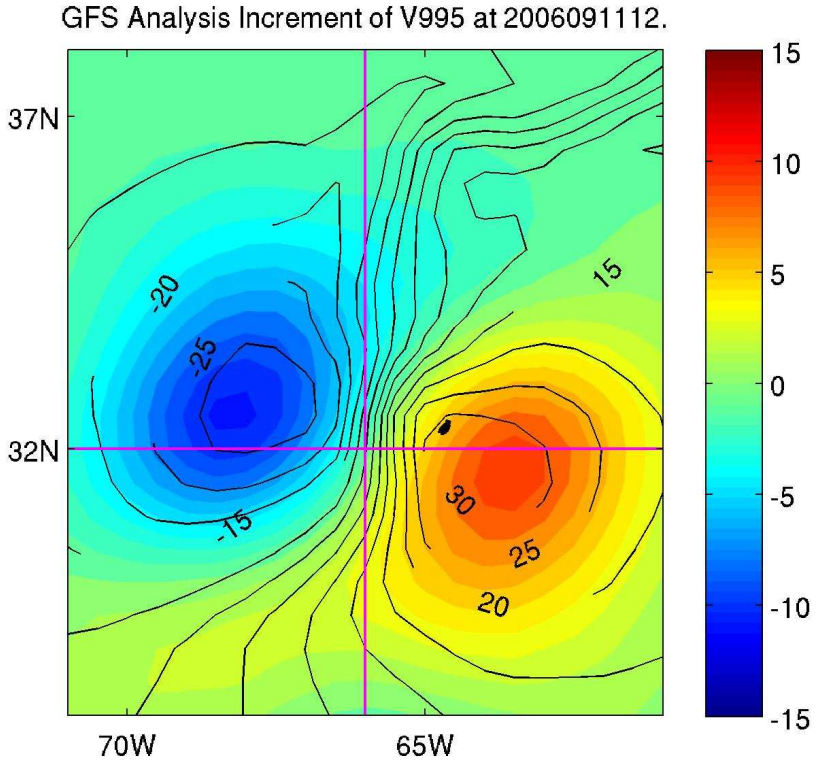


Analysis increment (analysis – f.guess) in MSLP

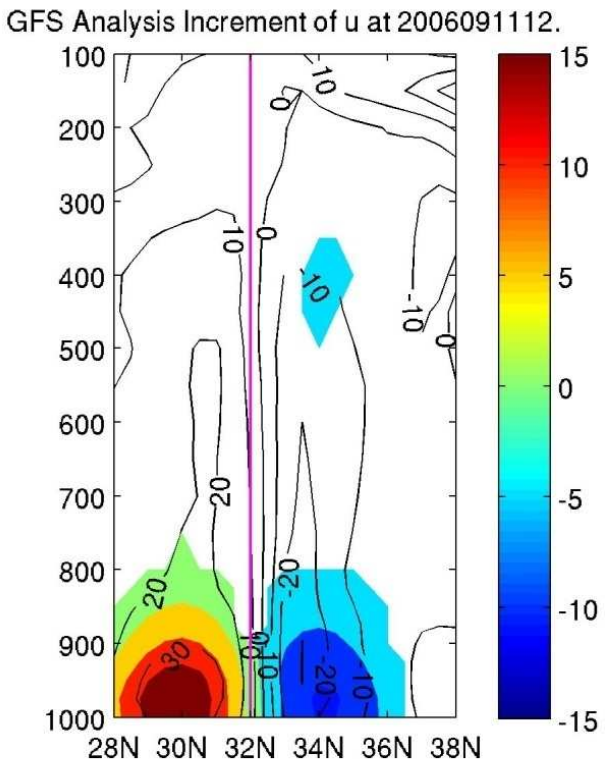


Analysis increment in (u,v) at σ=0.995 (m/s)

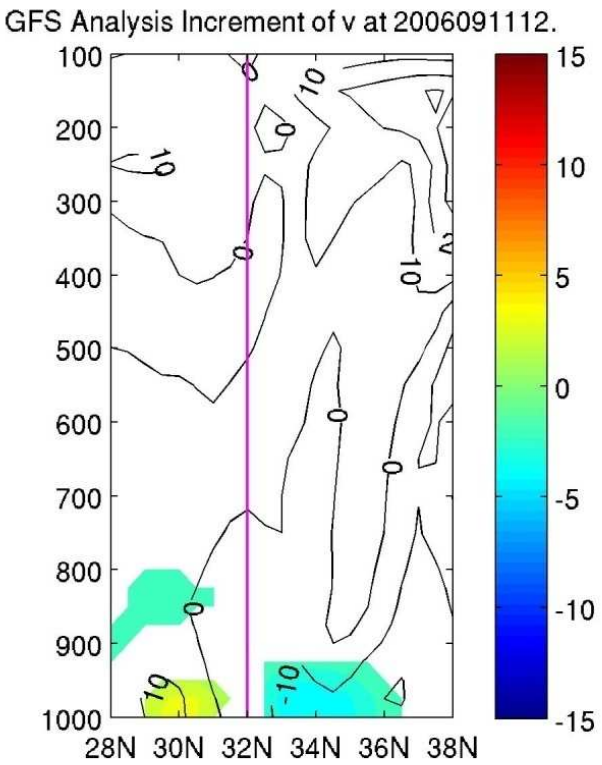




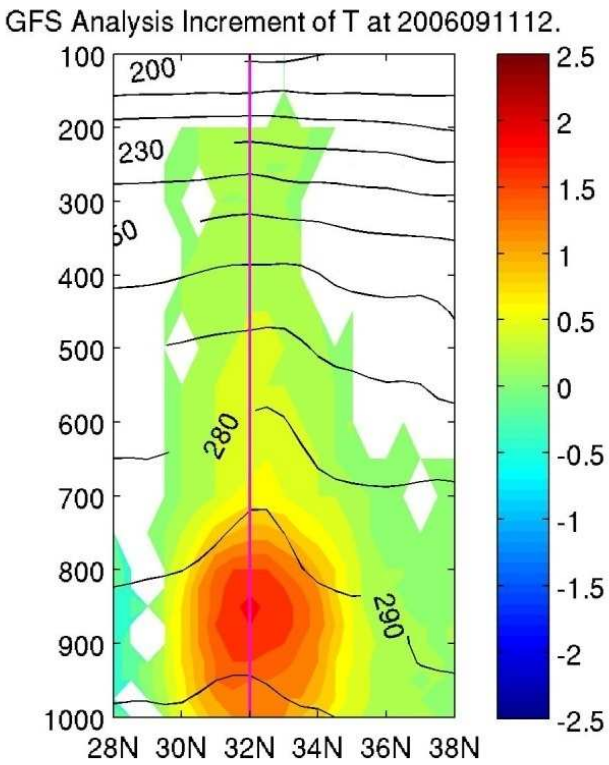
Vertical X-section of analysis increment (N-S)



u



v



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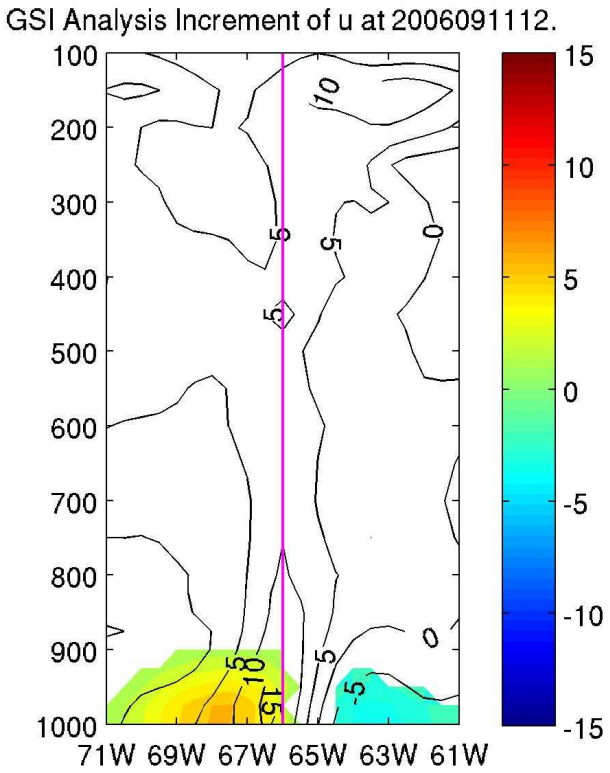
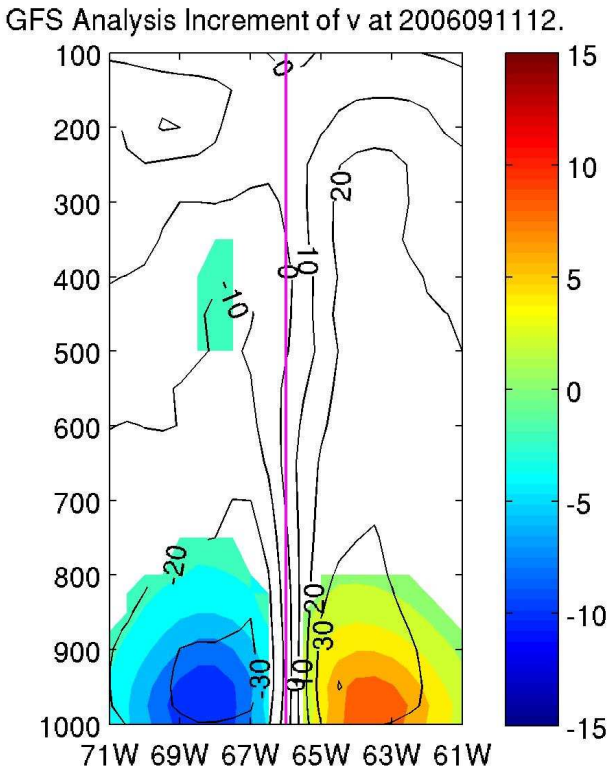
Vertical X-section of analysis increment (E-W)



u



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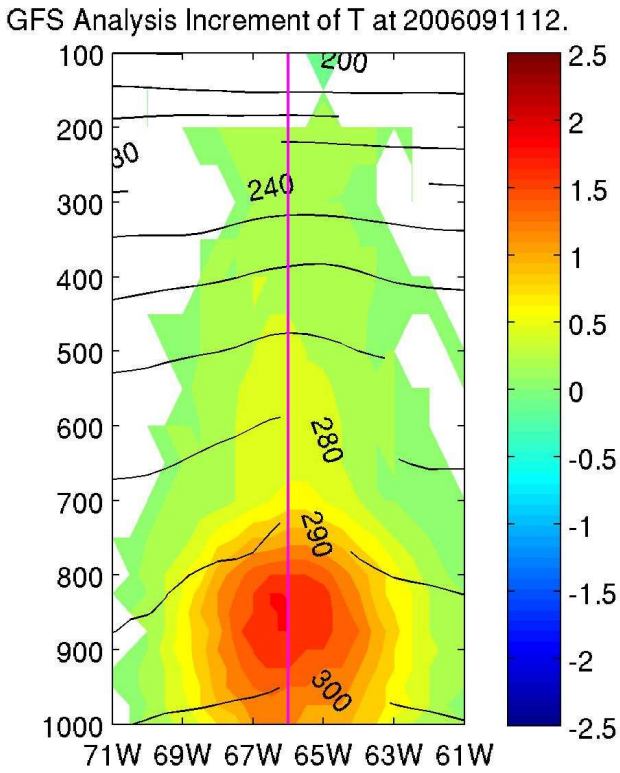

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3. GSI Assimilation experiments

A. All operational observations

- Raobs, radar, TAMDAR, scatterometer, HIRS, AIRS, GOES Sounder, AMSU-A/B, AMSR-E, SSM/I, TMI, Sat Winds etc

B. Operational observations **+ 4 wind vectors at 990 mb**

- ~200 km from Florence's center
- 10 m/s stronger than first guess, error 0.1 m/s

C. One surface pressure observation

- in Florence's center
- 10mb stronger than first guess, error 0.1 mb

First guess identical in each case (2006091106+06h)

Summary of GSI assimilation results

	OPR	OPR + 4 (u,v)	Assim sfc P only
MSLP deepening	0.3 mb	3 mb	10 mb
Surface wind increment	3 m/s	15 m/s	6 m/s
Mid-tropospheric wind increment	8 m/s	9 m/s	2 m/s
Lower-tropospheric warming	1.2 C	2 C	2 C

Assimilating surface wind observations can yield a significant impact in lower troposphere

- Do such high-wind observations nearly always fail QC?
- Are observation errors too large?
- Potential for modifying mid-troposphere (above 850mb)?

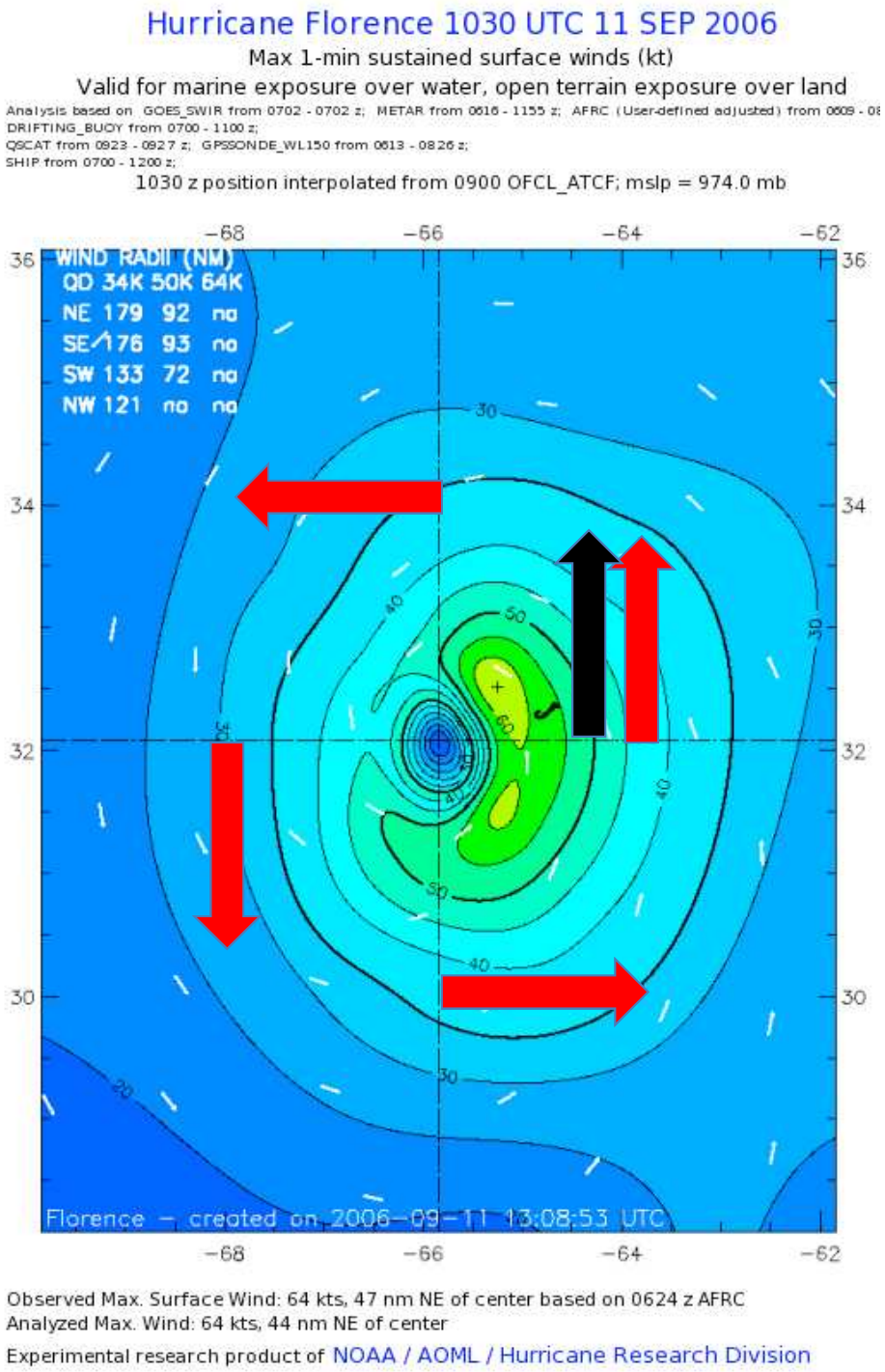
4. GSI vs EnKF

Innovation 10 m/s
Ob error 0.1 m/s

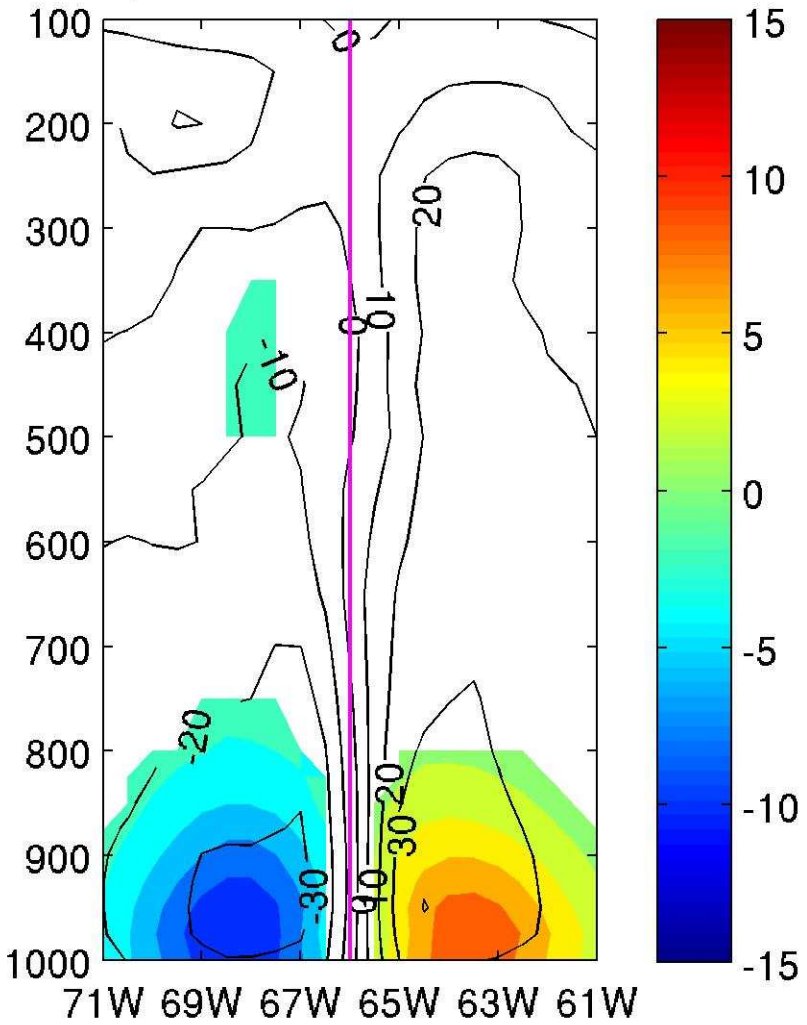
4 (u,v) obs 200 km from center in GSI

1 v ob 150km east of center in WRF/EnKF.

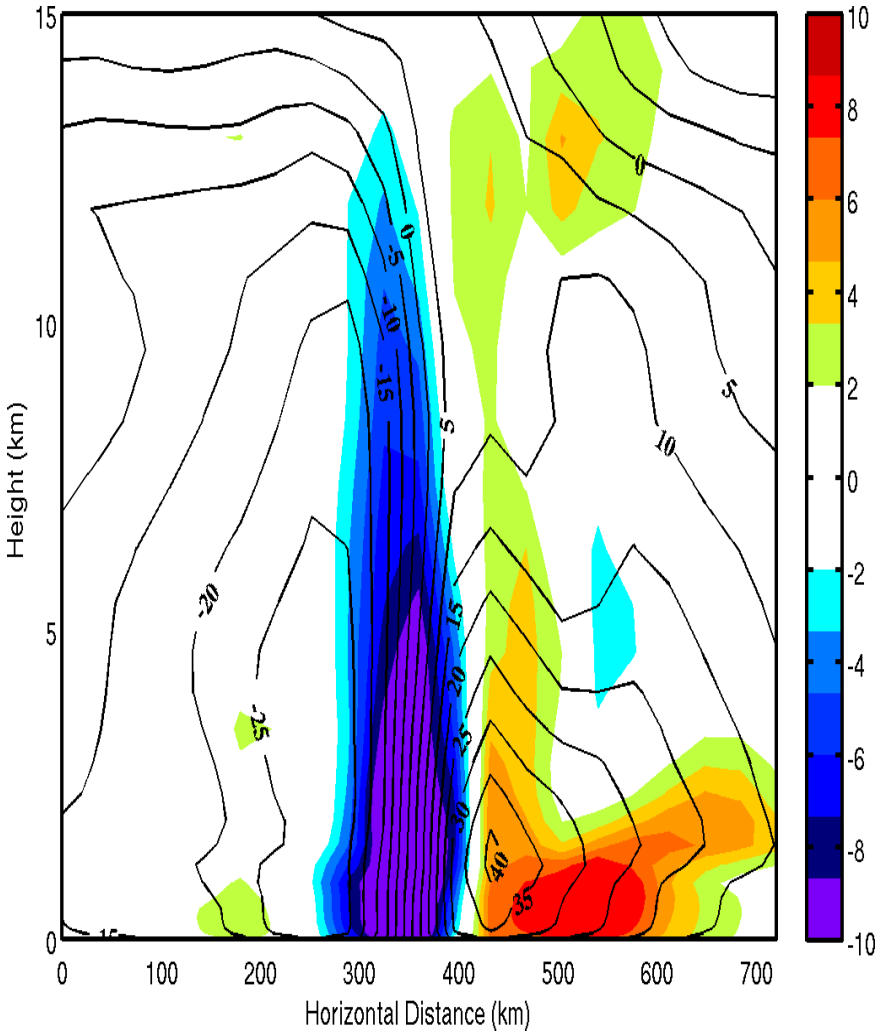
CAVEAT: Different Storms!



GSI Analysis Increment of v (m/s)



WRF/EnKF Analysis Increment of v (m/s)



Courtesy Ryan Torn

4. GSI vs EnKF

- GSI
  - Geostrophic correction (need >1 obs, used 4 here)
  - Local horizontal correction
  - Significant increment only through boundary layer
  - Virtually no change when NCEP's anisotropic error covariance was used
- EnKF
  - Gradient wind correction
  - Stronger winds associated with shifting the storm further east and increasing intensity of winds
  - Troposphere-deep increment

Future Work

- Real and synthetic surface wind observations
- Series of numerical experiments:
  - Modified GSI background error covariance (horiz. + vert.)
  - Assimilate high-density QuikSCAT vectors, no averaging
  - Relax observation error; rain contamination check
- Run GFS forecast model for multiple cases
- Investigate modification to cyclone and environment

- **Assimilate satellite surface winds using EnKF**

  Collaborators: Whitaker (GFS) and Torn (WRF)