DA/Initialization Team Milestones and Priorities

Presented by

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Acknowledgement
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UCF: Ping Zhu

HFIP annual review meeting
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Summary of Primary Accomplishments

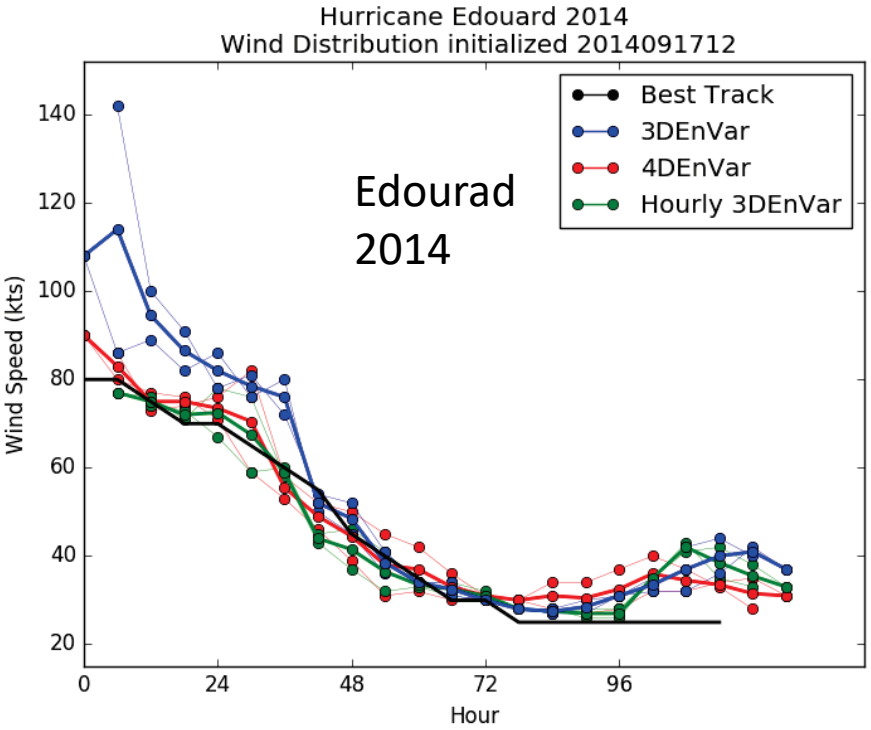
- The newly developed fully cycled, self consistent, dual resolution GSI hybrid DA system is operationally implemented for HWRF in 2017.
- Paper documenting the new hybrid DA system (which the current operational HWRF hybrid DA system is based on) is published (Lu, Wang, Tong and Tallapragada 2017, MWR, in press).
- Successful collaboration between academia and NOAA, and R2O.
- Testing/tuning of the new system (e.g. full ensemble covariance, tuned localization, stochastic physics to increase spread, etc.) in operational settings suggests 10-20% Vmax improvement.
- Further hybrid DA system development: 4DEnVar & hourly 3DEnVar w/o relocation, adaptive 4DIAU.
- In-depth diagnostics to understand why spin down during RI prediction exists when HWRF is initialized with more realistic analysis produced by the new DA system.
- Advancement of assimilation of existing or new observations.

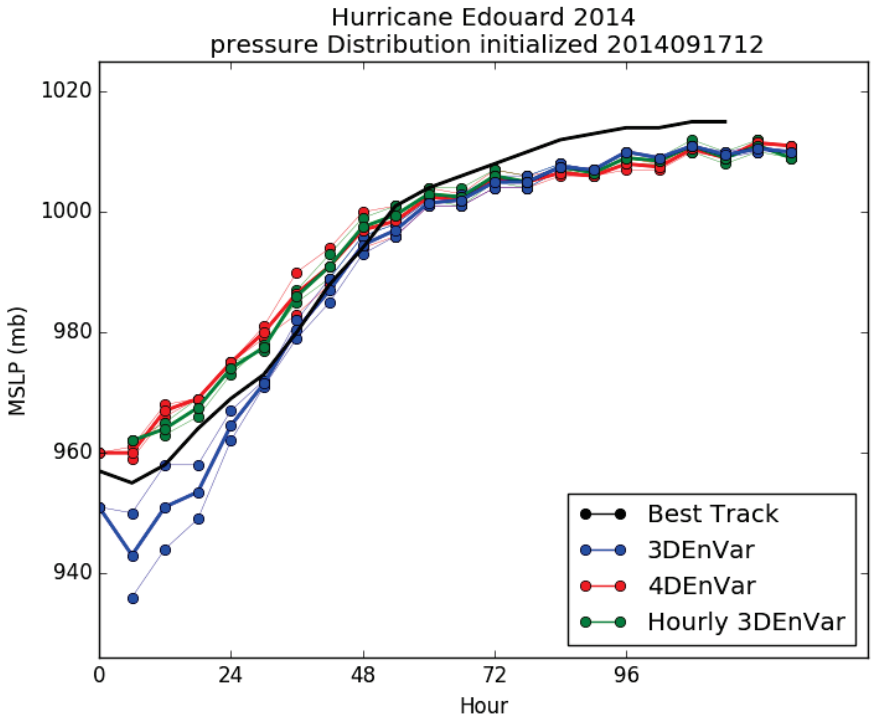
Further hybrid DA system development: 4DEnVar w/o relocation, hourly 3DEnVar w/o relocation, adaptive 4DIAU

4DEnVar, hourly 3DEnVar vs 6hourly 3DEnVar

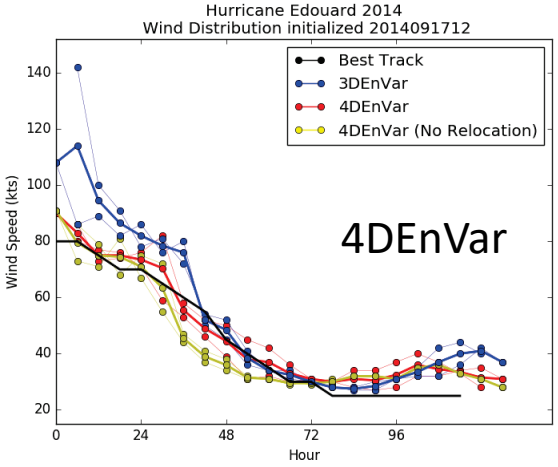
Ben Davis, Xuguang Wang, Xu Lu

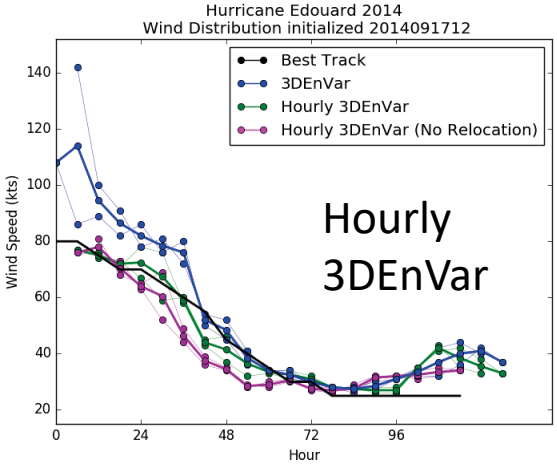
- The hybrid system for operational HWRF (which is now 6 hourly 3DEnVar) is further extended for 4DEnVar and hourly 3DEnVar.
- Relocation option is developed for both 4DEnVar and hourly 3DEnVar.
- Experiment with Edouard 2014 so far suggests both 4DEnVar and hourly 3DEnVar improve intensity forecast. Comparable performance of 4DEnVar and hourly 3DEnVar.

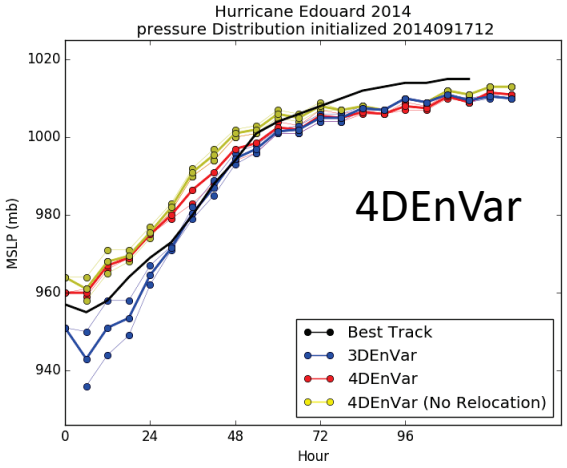


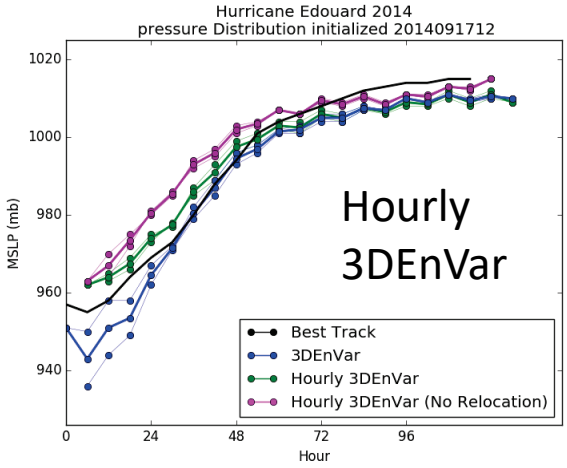


Impact of relocation



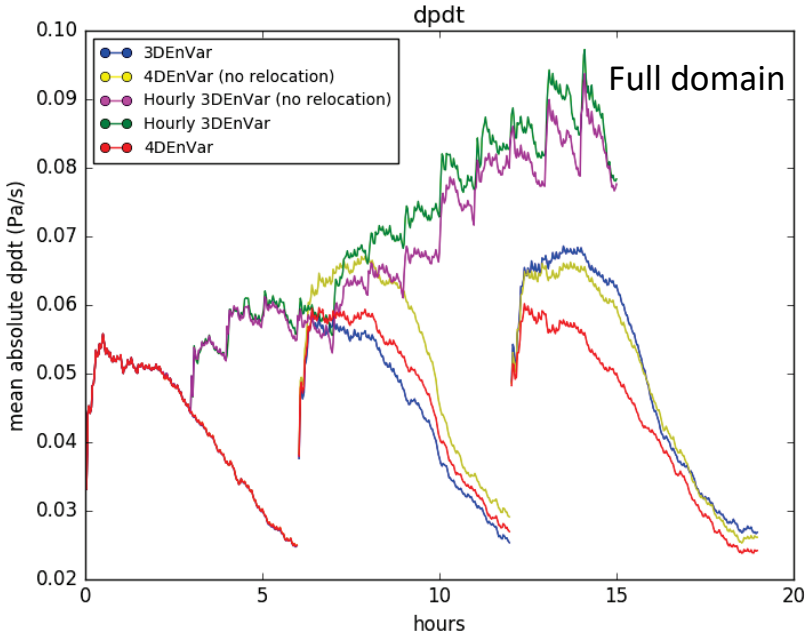


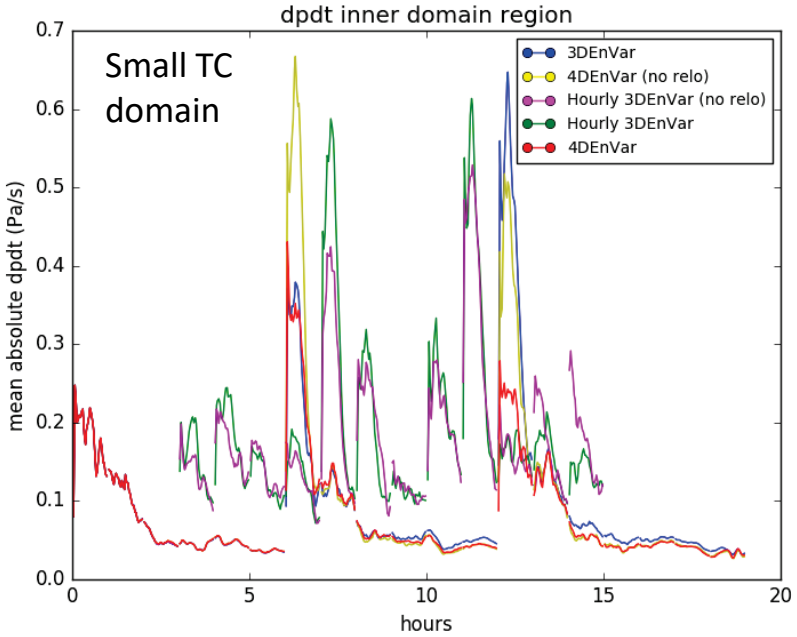




- Relocation further improves 4DEnVar and hourly 3DEnVar

Measure of 4DEnVar and hourly 3DEnVar analyses imbalance (dp/dt)

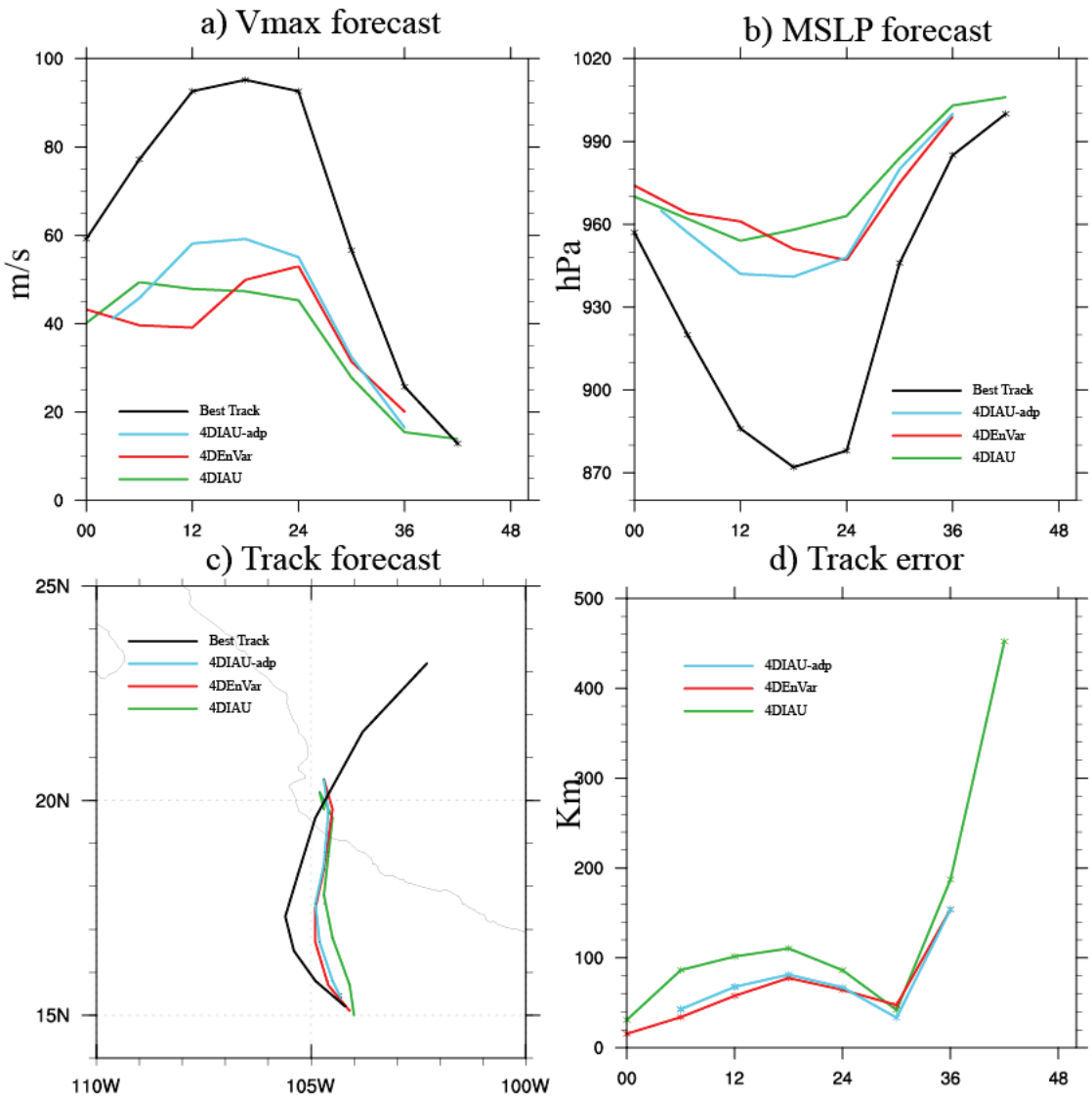




- Imbalances accumulated for Hourly 3DEnVar cycles for the full domain.
- Waves induced by imbalance propagated out of the small TC domain within 1 hour and therefore no accumulation of imbalance for hourly inner core DA.
- Additional experiments with more cases (e.g. rapidly developing) are ongoing.

Newly proposed adaptive 4DIAU method: Patricia 2015

Xu Lu, Xuguang Wang



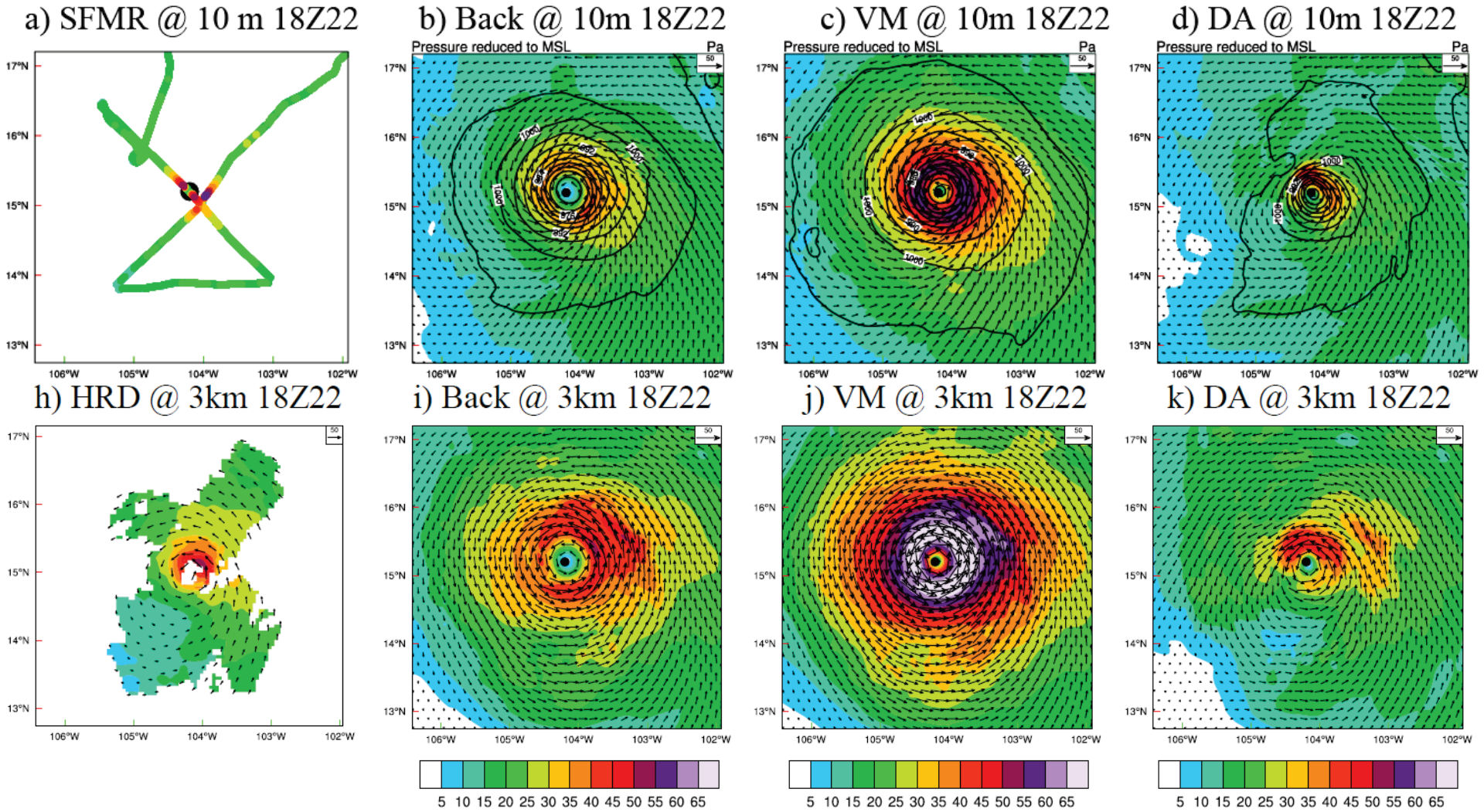
- Traditional 4DIAU alleviates the spin-down issue and improves the intensity forecast.
- However, traditional 4DIAU degrades the track forecasts due to the pre-determined increments violating the linear assumptions in the 6-hour time-window for a rapid evolving TC.

- Adaptive IAU can produce even better intensity forecast than traditional IAU.
- Unlike traditional IAU, adaptive IAU does not increase the track error.
- Additional experiments are ongoing.

Why spin-down exists when HWRF initialized with more realistic analysis produced by the new DA system?

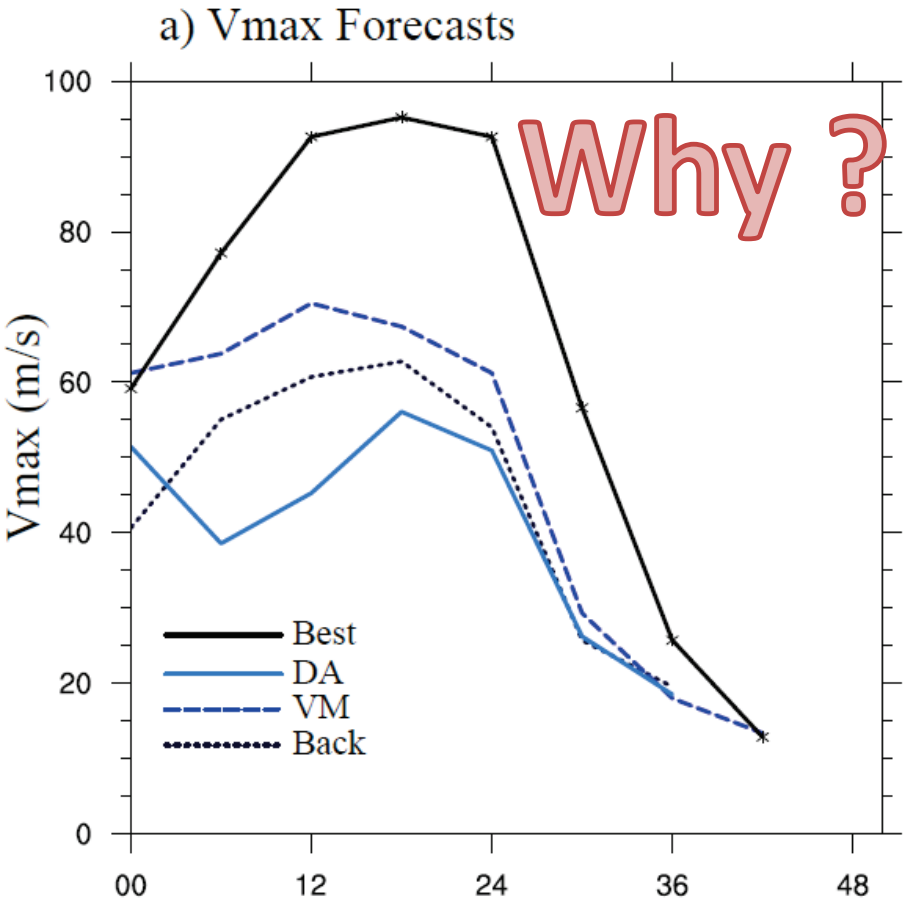
DA vs VM Analyses for Patricia 2015

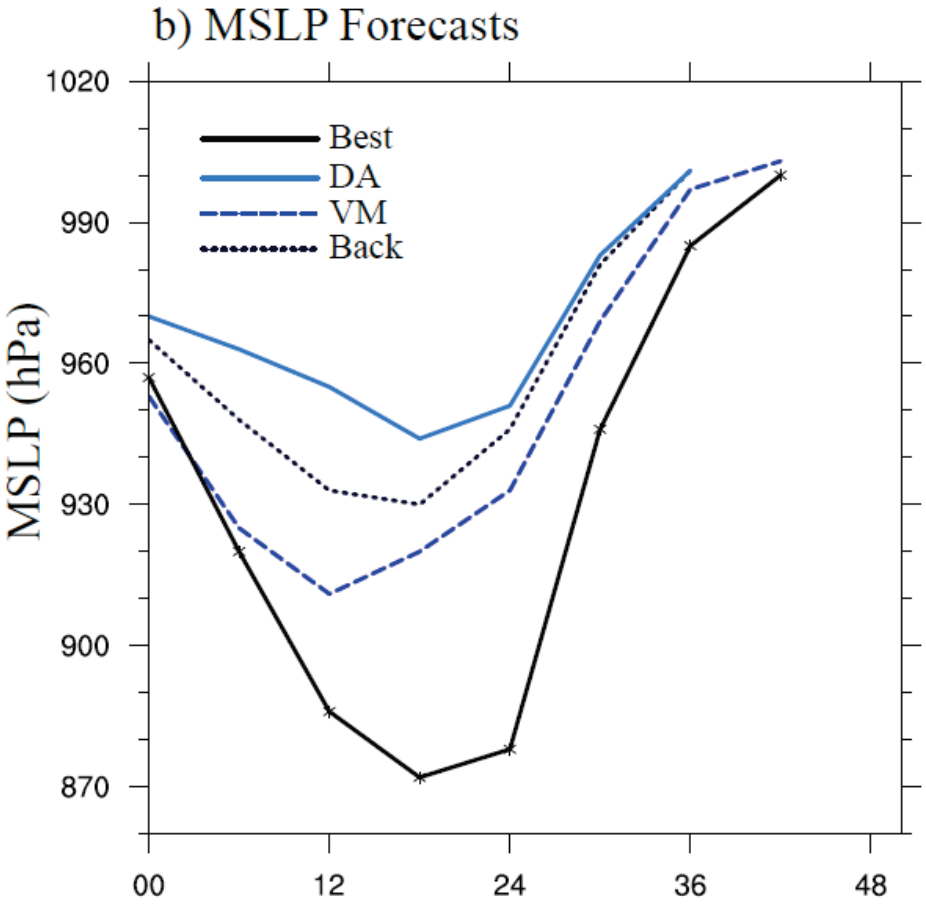
Xu Lu, Xuguang Wang



- Background storm is large and weak as compared with observations.
- VM produces spuriously strong and large size storm.
- Inner core structures are much improved upon the background through DA.

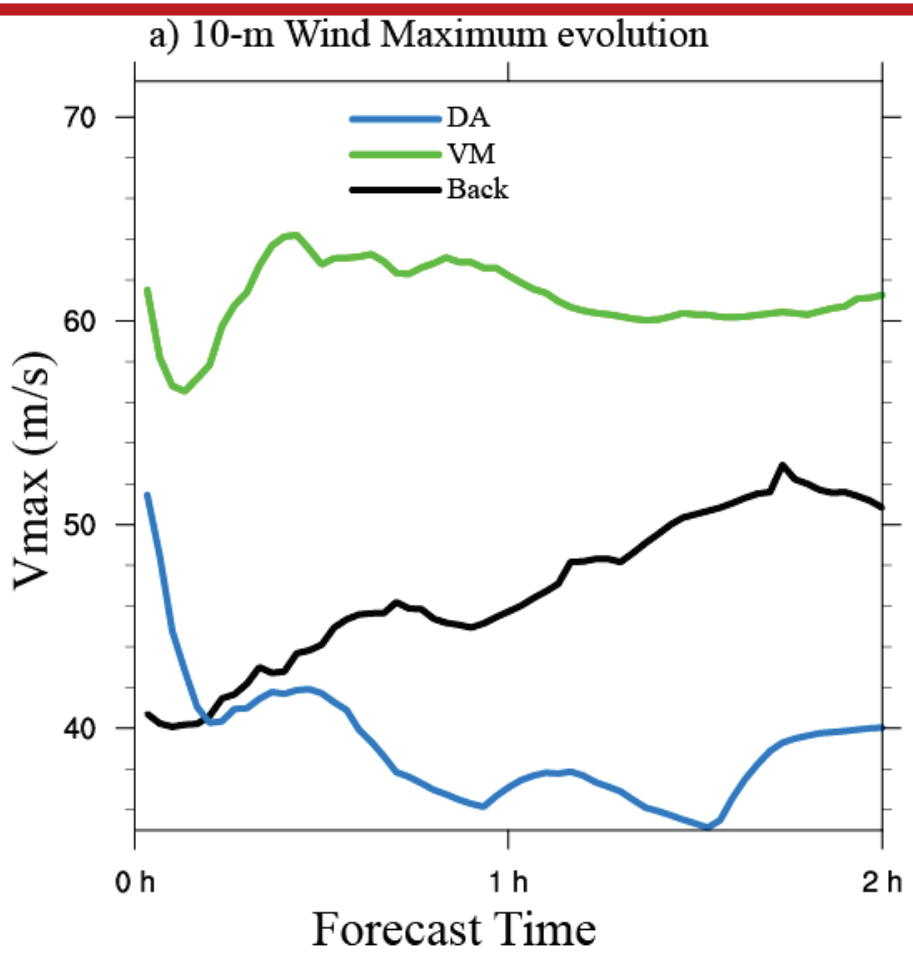
DA vs VM Intensity Forecasts

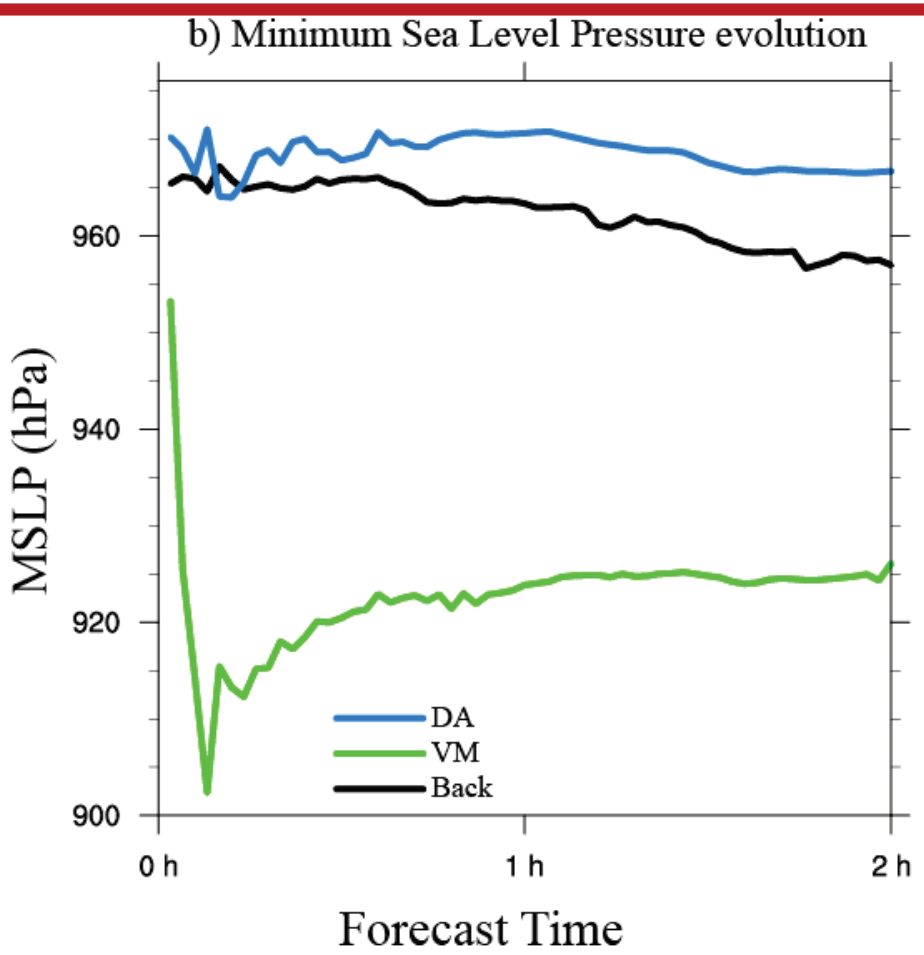




- Spin-down occurred in the experiments where inner-core structures are well captured by hybrid DA.
- Background and VM analyses do not show spin-down.

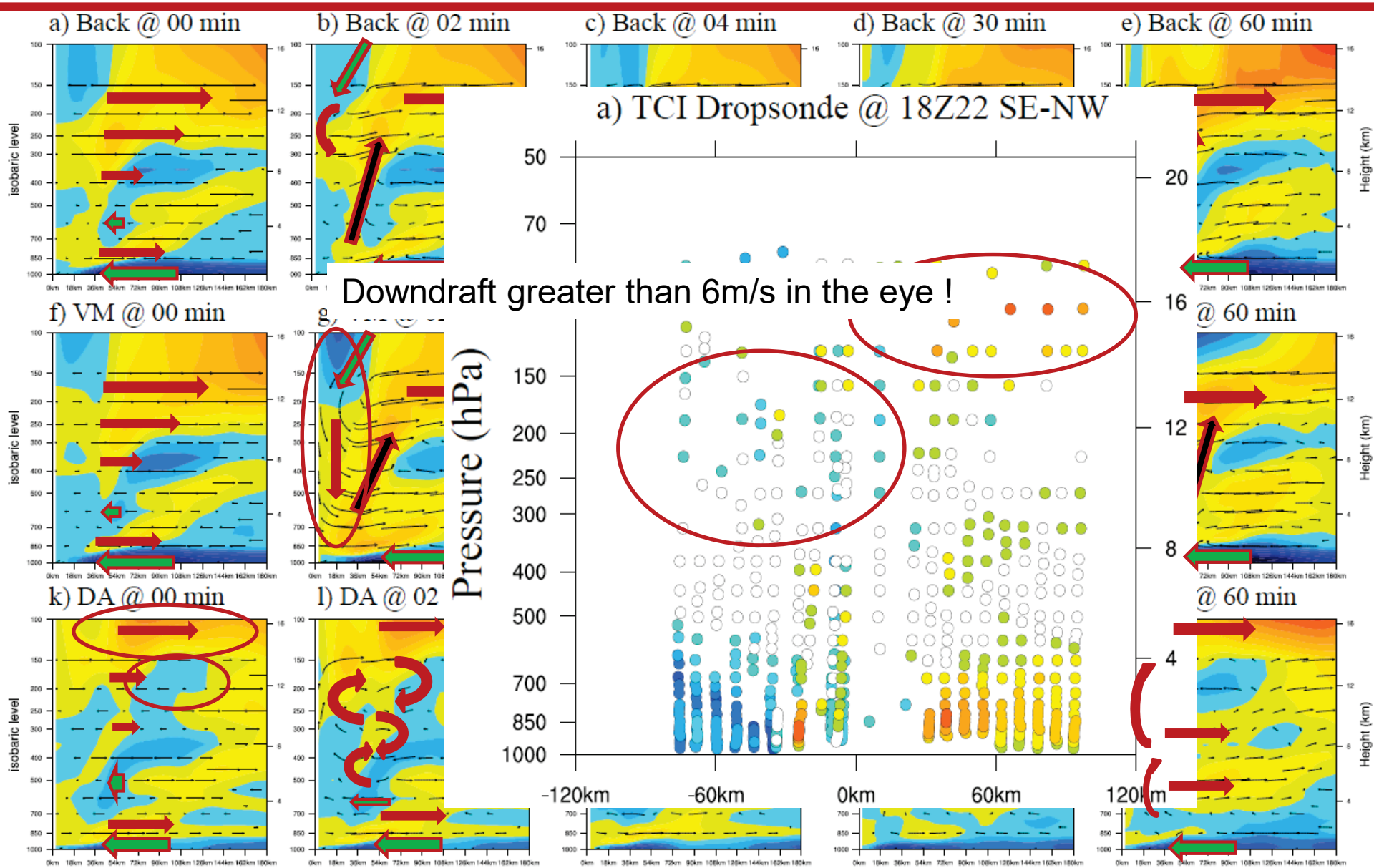
What is going on the first couple of hours?
2 min output of Vmax and MSLP





- Spin-down happened in VM for the first 5-10min. Additionally, a dramatic MSLP drop is found in VM. This huge jump in the MSLP can be attributed to the super-gradient VM analyses. However, VM recovered quickly within the first 20~30 min.
- The Vmax forecast in DA dropped almost 15 ms^{-1} within the first hour, is not recovered to the initial Vmax and is struggling to intensify afterwards.

Secondary circulation for the first hour



Net radial force of the analysis

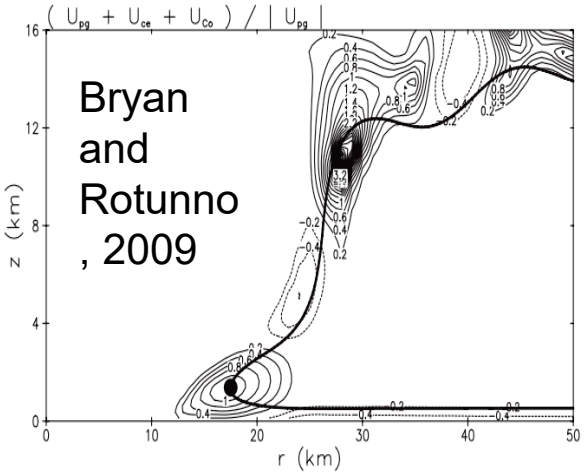
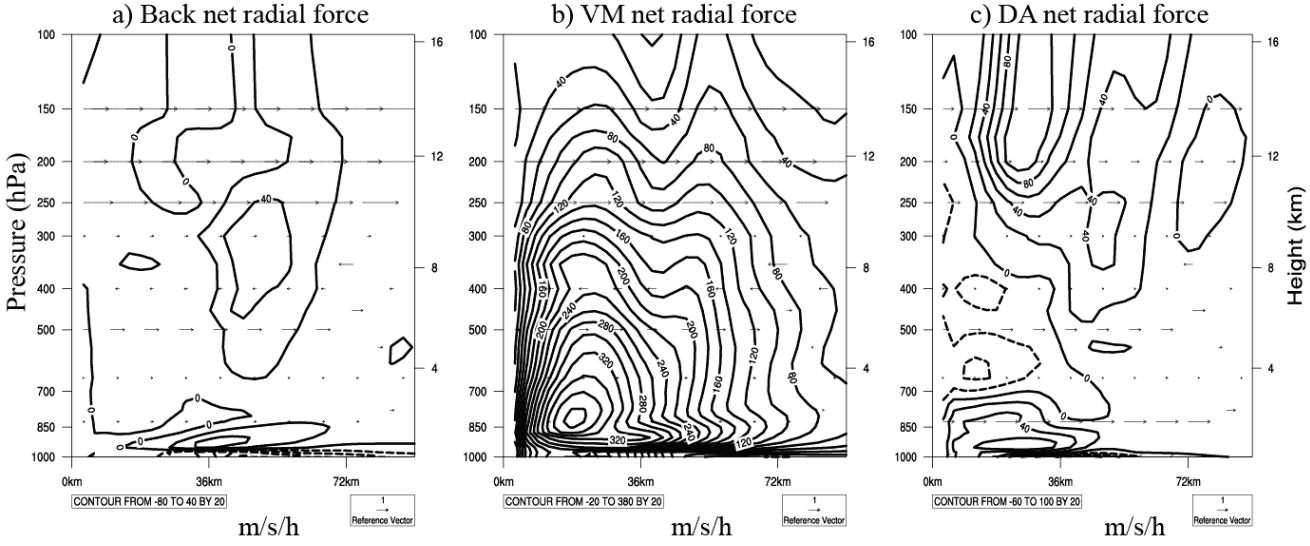


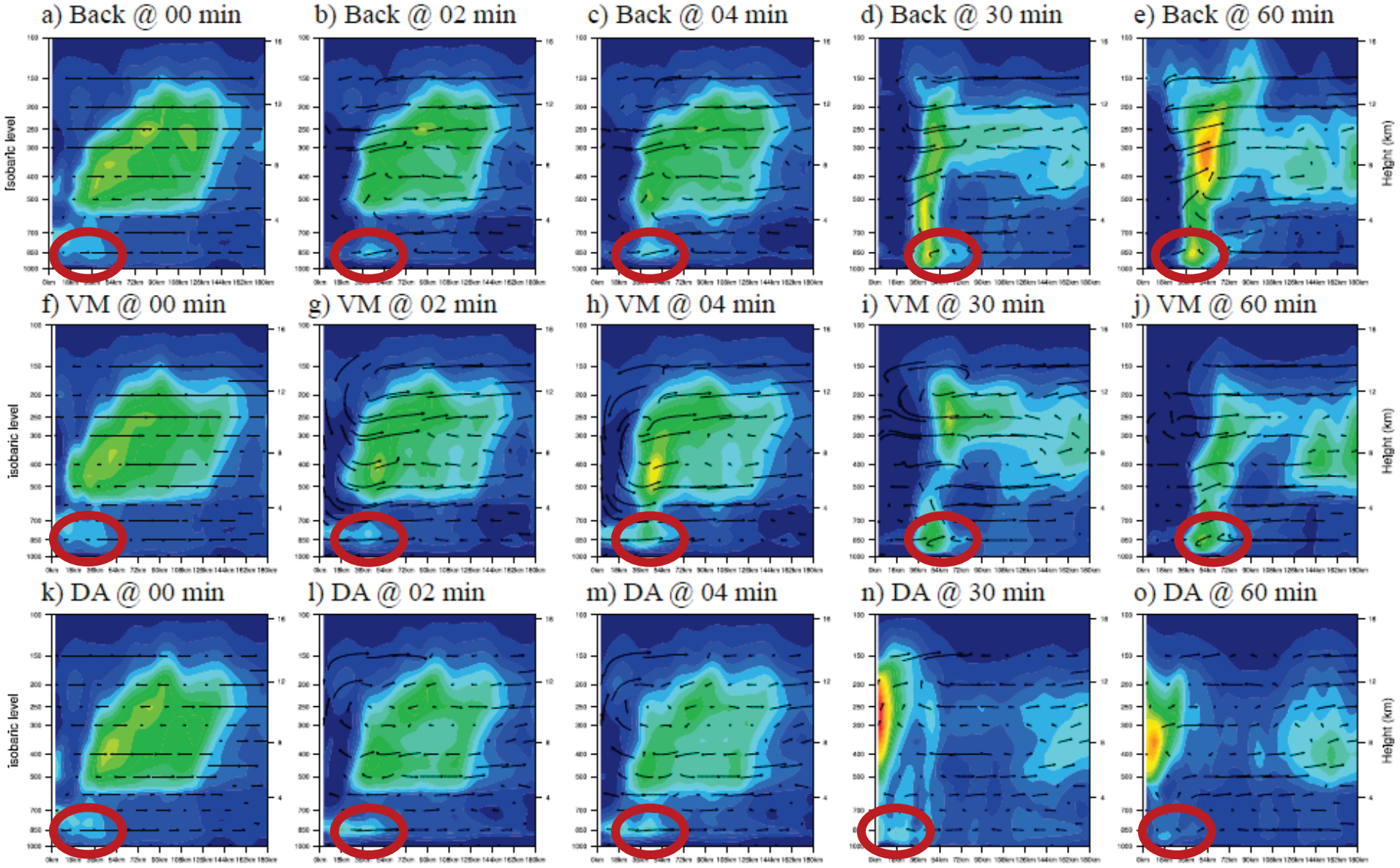
FIG. 8. Analysis of gradient-wind balance in the control simulation. Contoured is the sum $U_{pg} + U_{ce} + U_{Co}$ normalized by the magnitude of U_{pg}, with a contour interval of 0.2. The zero contour is excluded. The trajectory that passes through v_{max} is illustrated by the thick line, and the dot denotes the location of v_{max}.



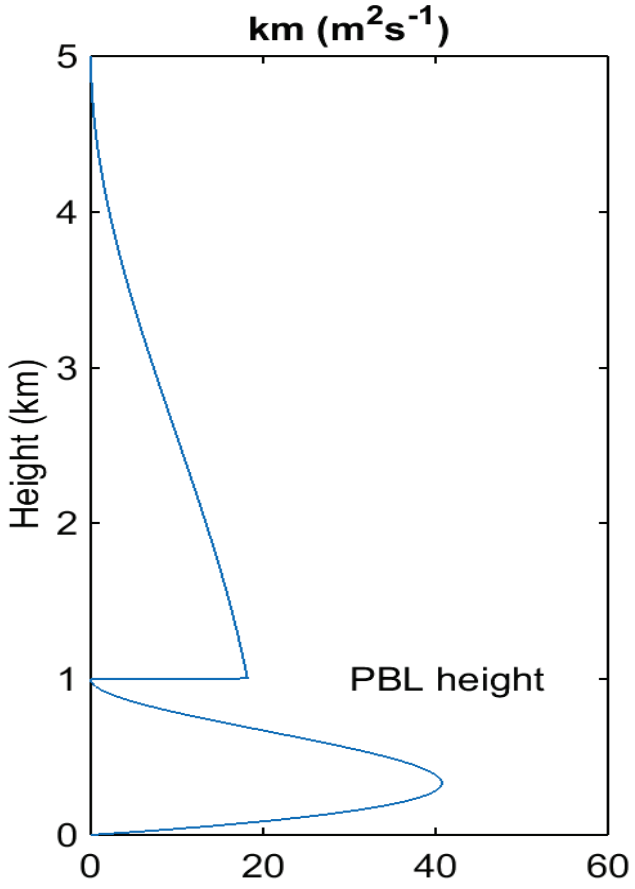
- The middle-level sub-gradient is very likely a direct response to the boundary layer super-gradient (Stern and Nolan, 2011). The oscillation roots in the PBL.
- Unbalanced flow effects have a nonnegligible effect on intensity in some cases and stronger radial diffusion damps the unbalanced flow effects (Bryan and Rotunno, 2009).

Model physics problem 1: horizontal diffusion too strong? Reduce horizontal diffusion weighting factor "coac" defined in Zhang and Marks 2015?

Total condensation for the first hour
Model physics problem 2: Lack of mixing



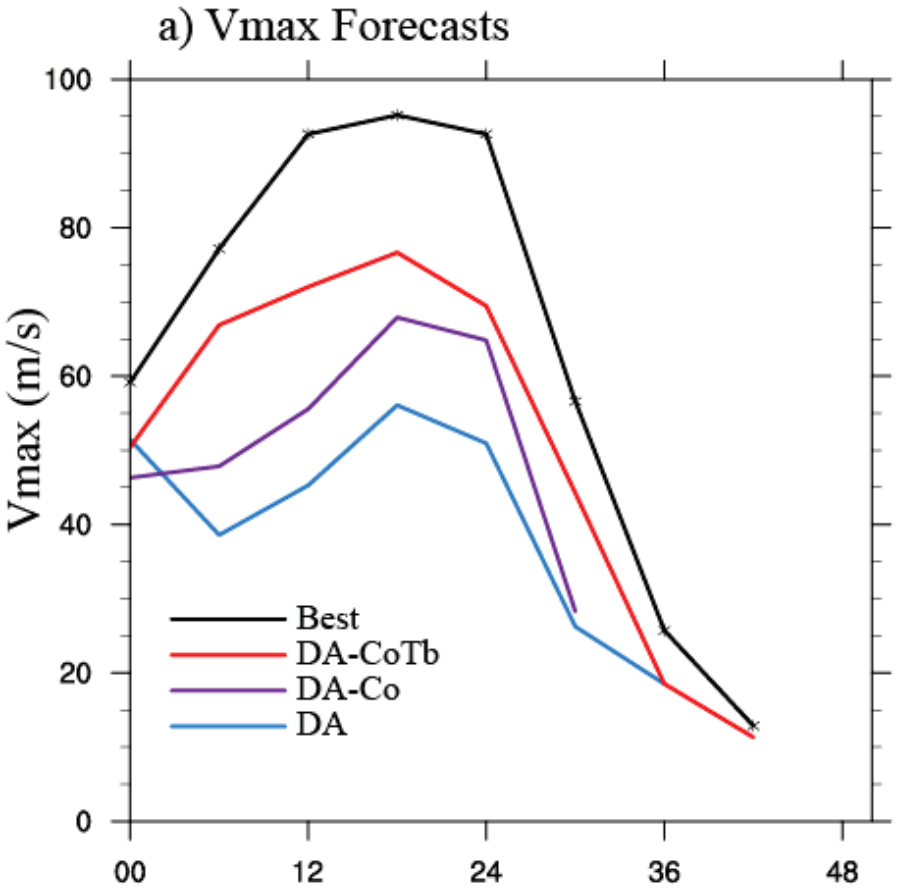
Turbulent Layer mixing

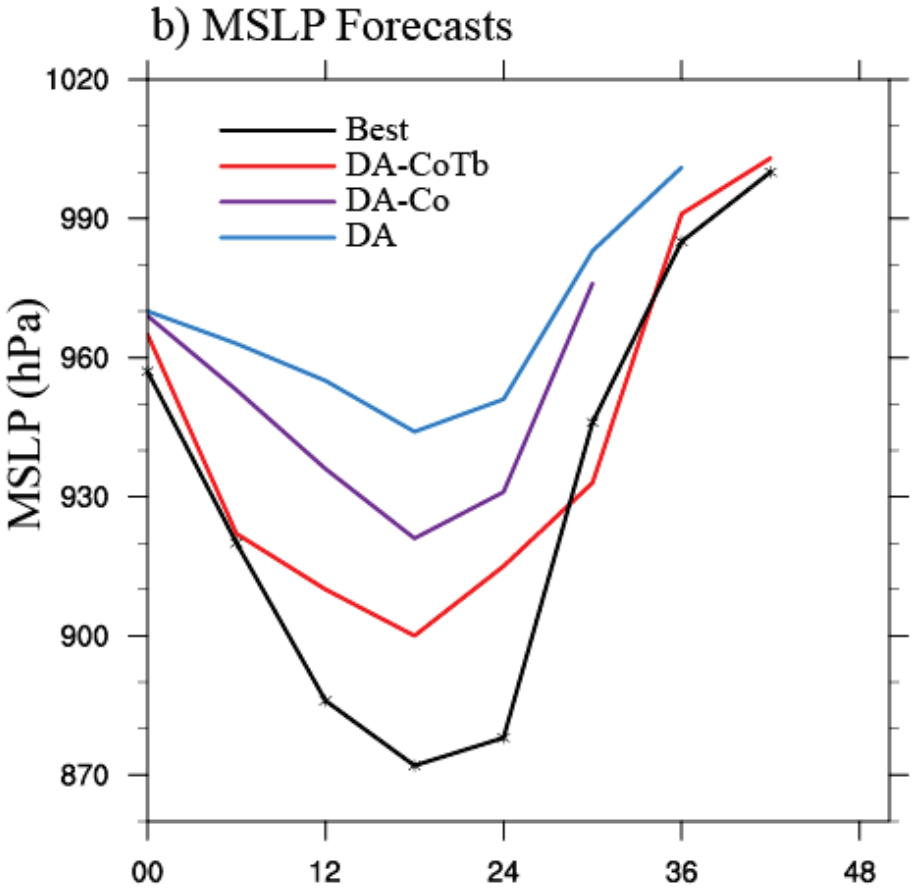


- In the original HWRF PBL scheme, the discontinuity of turbulent mixing at the boundary layer top tends to constrain the communication of moisture and heat below and above the boundary layer top.
- Turbulent layer mixing (Zhu et al. 2016) allows more moisture and heat to be transported to the free atmosphere.

Zhu et al. 2014; Zhu et al. 2016

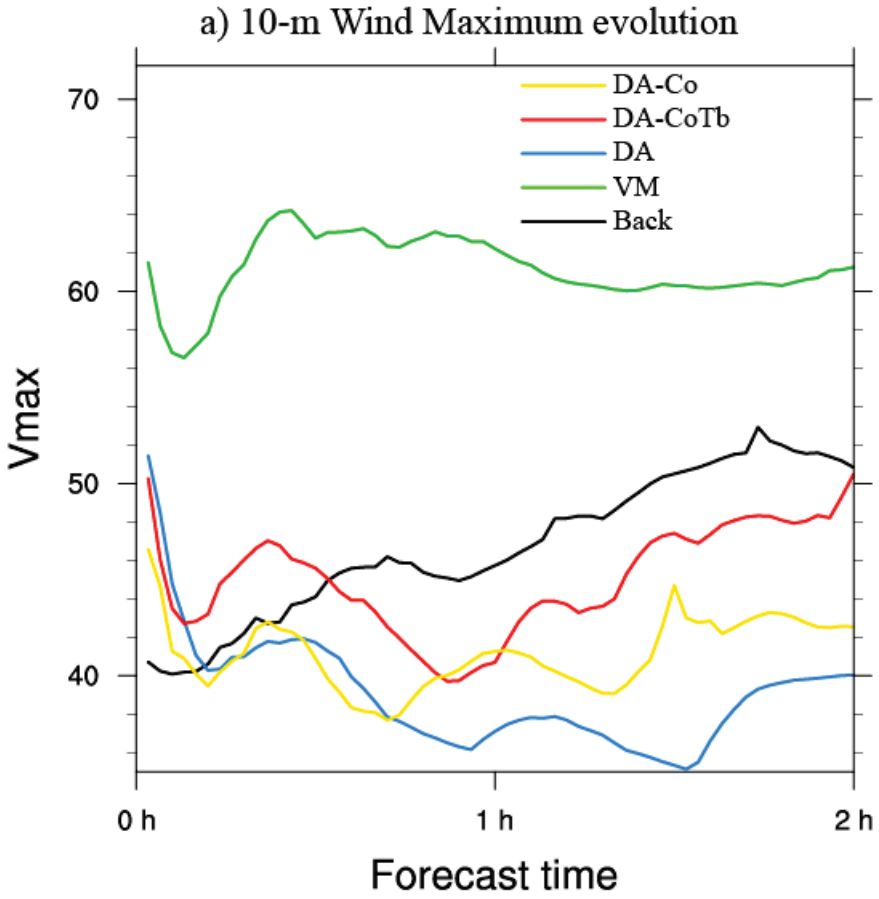
More realistic analysis produced by the advanced DA needs to accompanied by more realistic physics

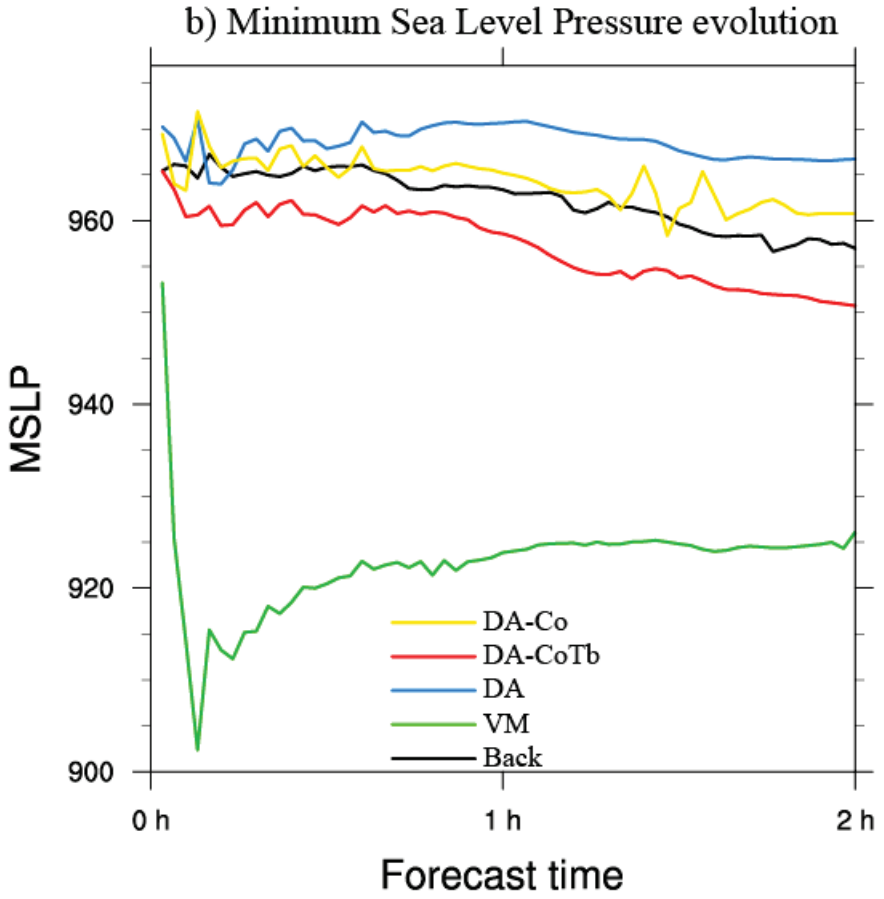




- Reducing the horizontal diffusion (COAC) in DA-Co shows improved MSLP forecast and apparent alleviation in the Vmax spin-down.
- Further using a modified turbulent mixing scheme shows significant improvement in both Vmax, MSLP and track forecasts.

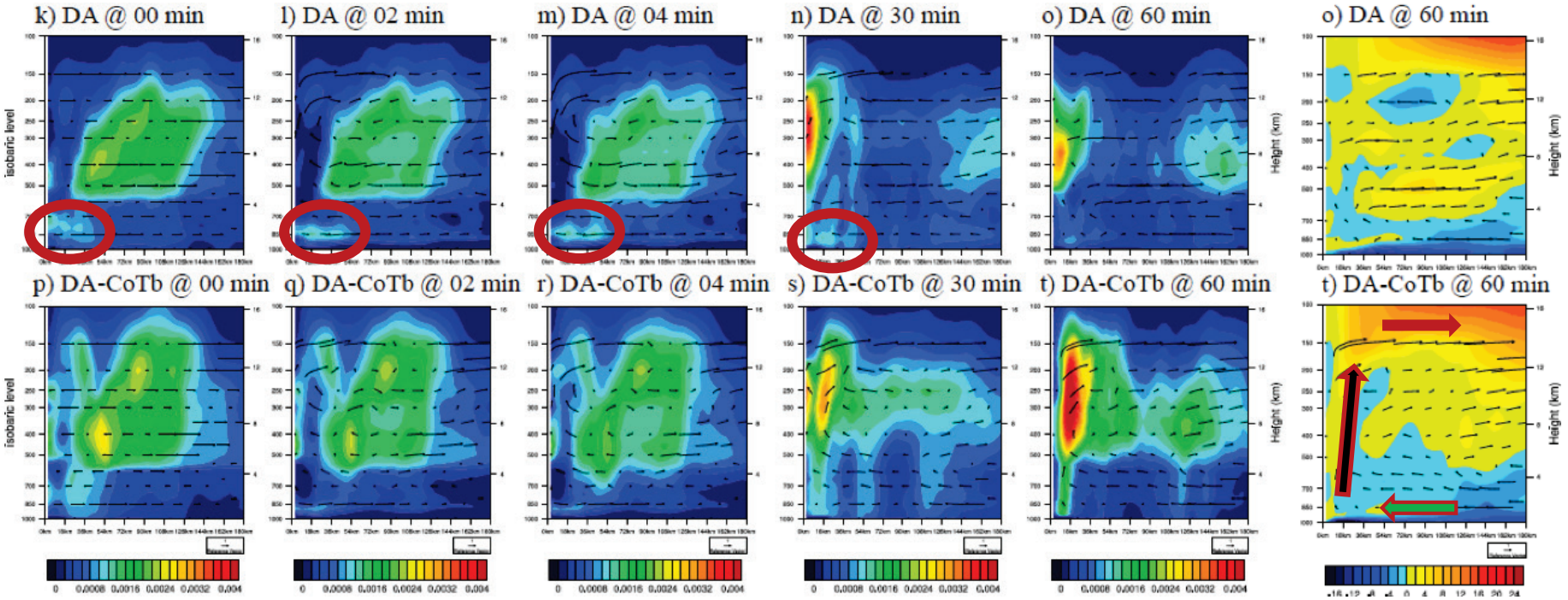
What is going on the first couple of hours?
2 min output of Vmax and MSLP



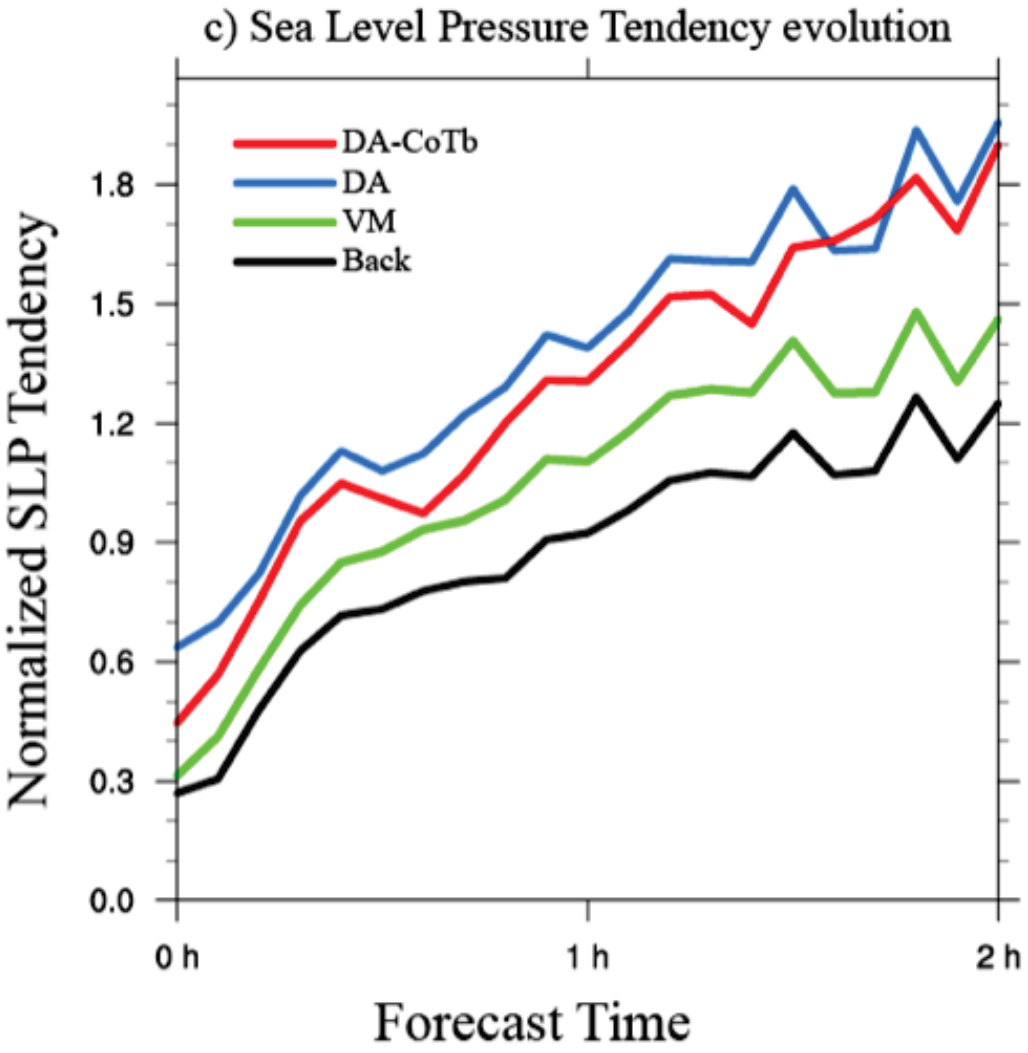


- Spin-down in DA-Co is alleviated during the first hour.
- Spin-down in DA-CoTb is further alleviated during the fist hour and rapid intensification occurs after that.

Secondary circulation/eyewall spin up more quickly with improved physics

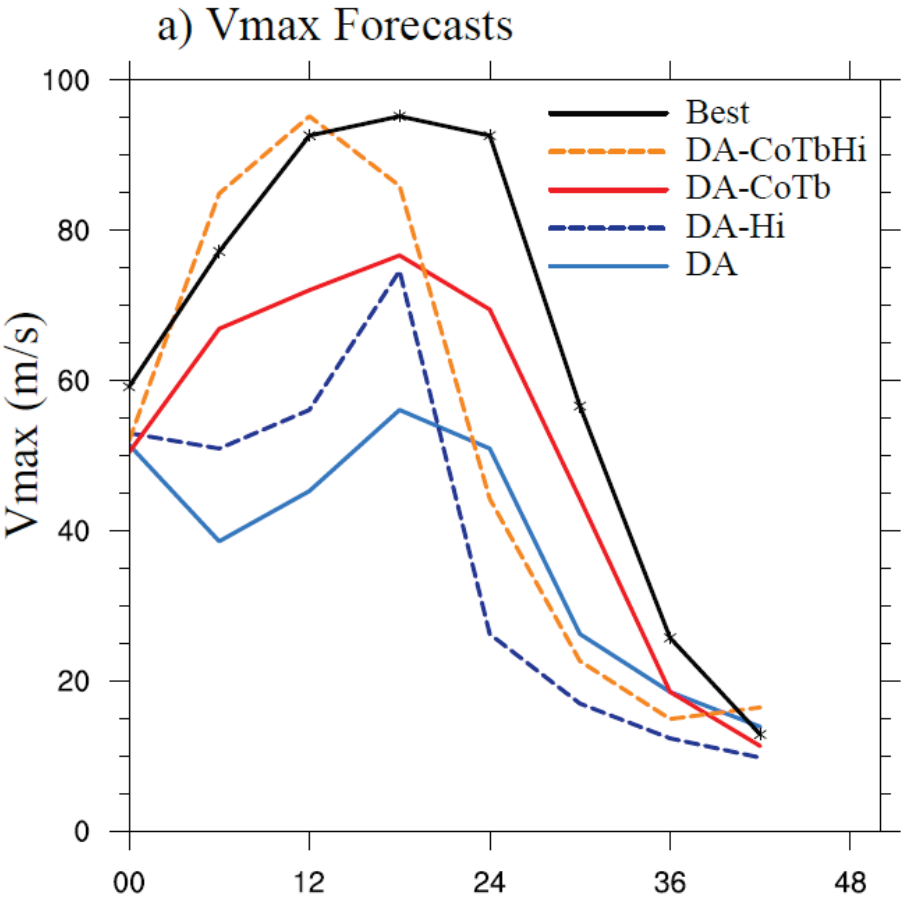


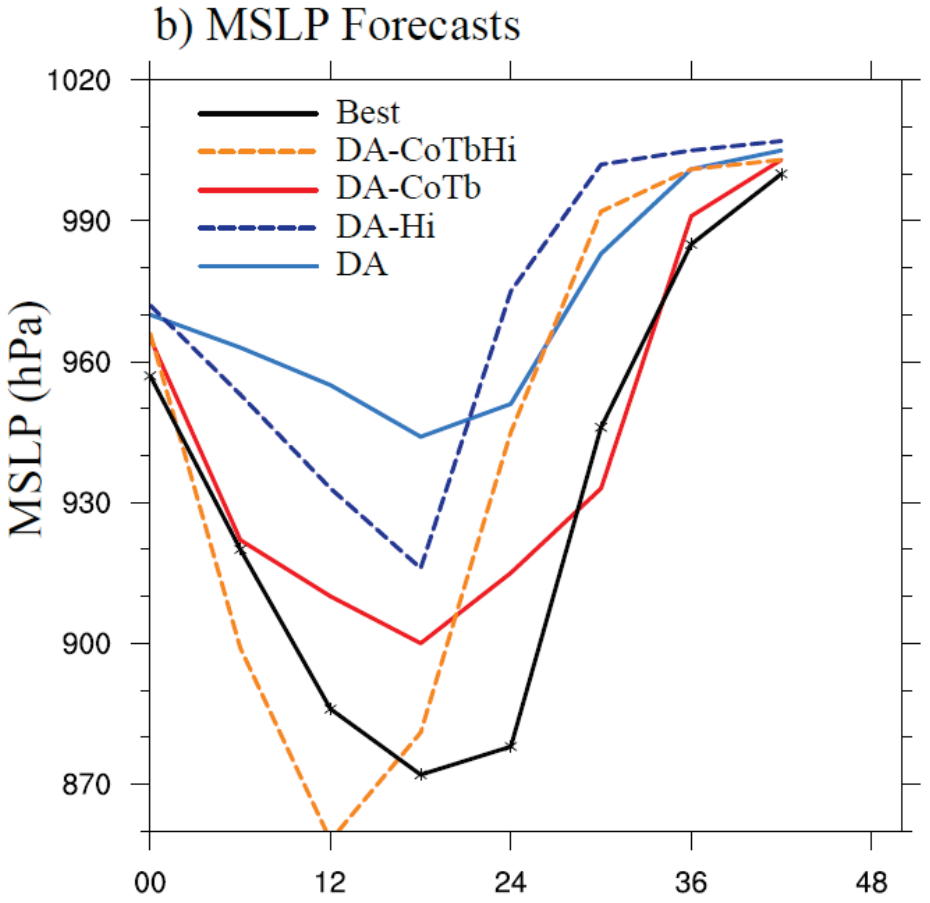
Analysis and model “imbalance” measured by dp/dt



- Using the modified physics, “imbalance” is reduced

Impact of model resolution on peak Intensity



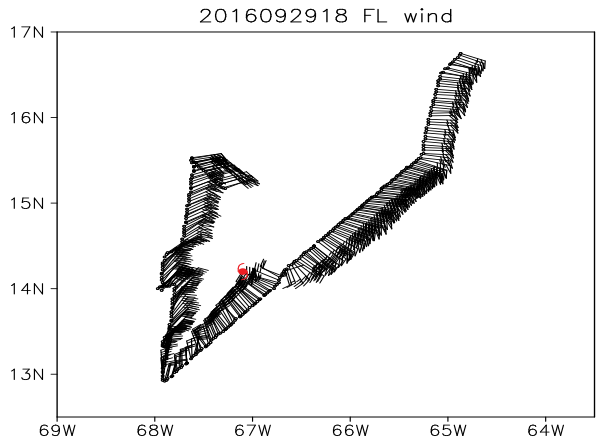


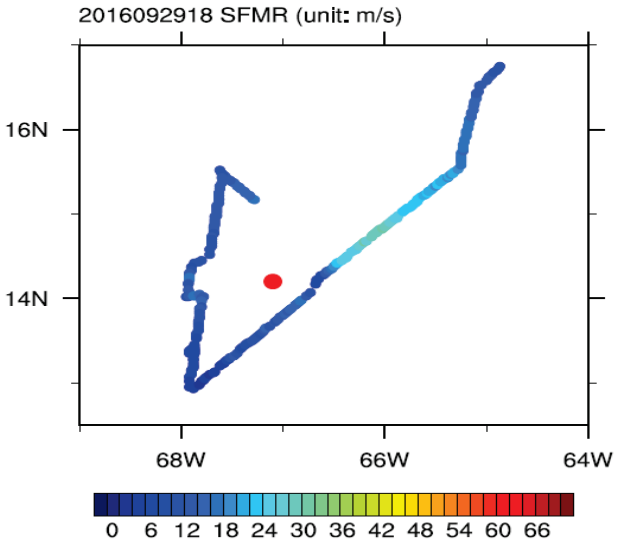
- Increasing model resolution (1km) significantly increases the peak intensity. The Peak time is shifted due to early land fall.
- Increasing model resolution can only help alleviate the spin-down slightly. Improving model physics appears more important in alleviating the spin-down in this case.

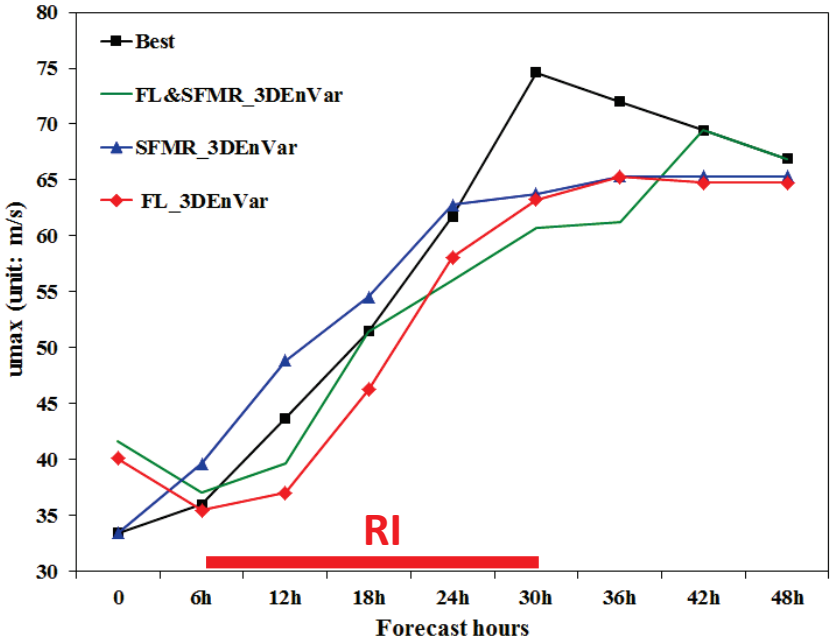
Improvement of assimilation of observations

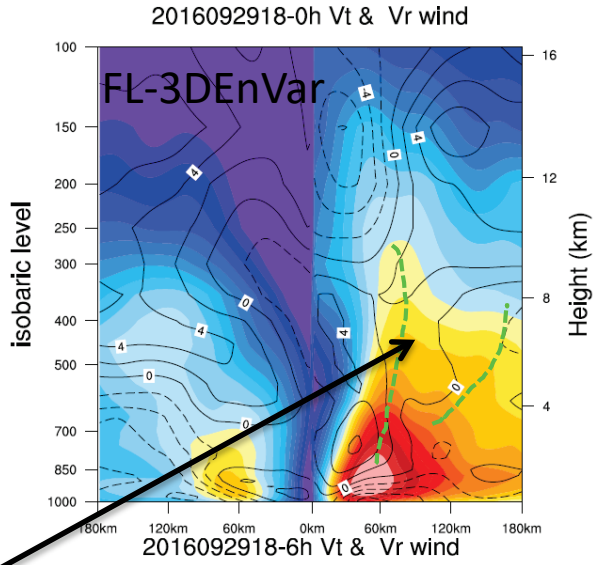
Improved use of HDOB data: Matthew 2016

Xinyan Lyu and Xuguang Wang

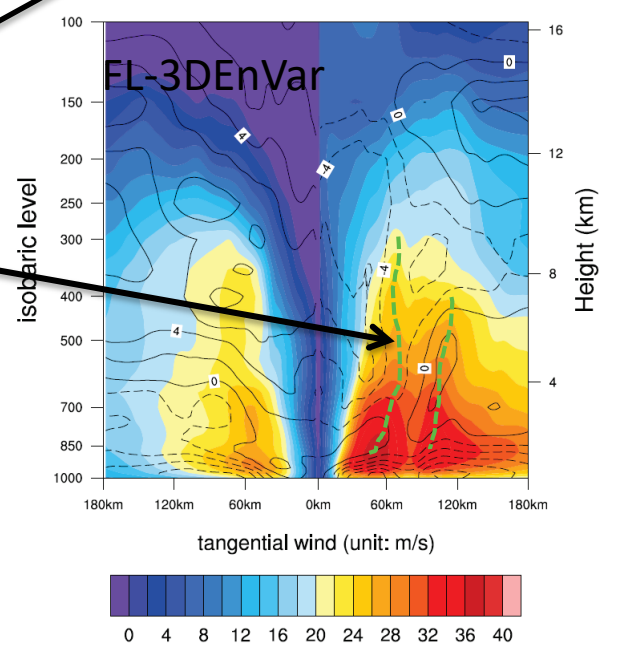




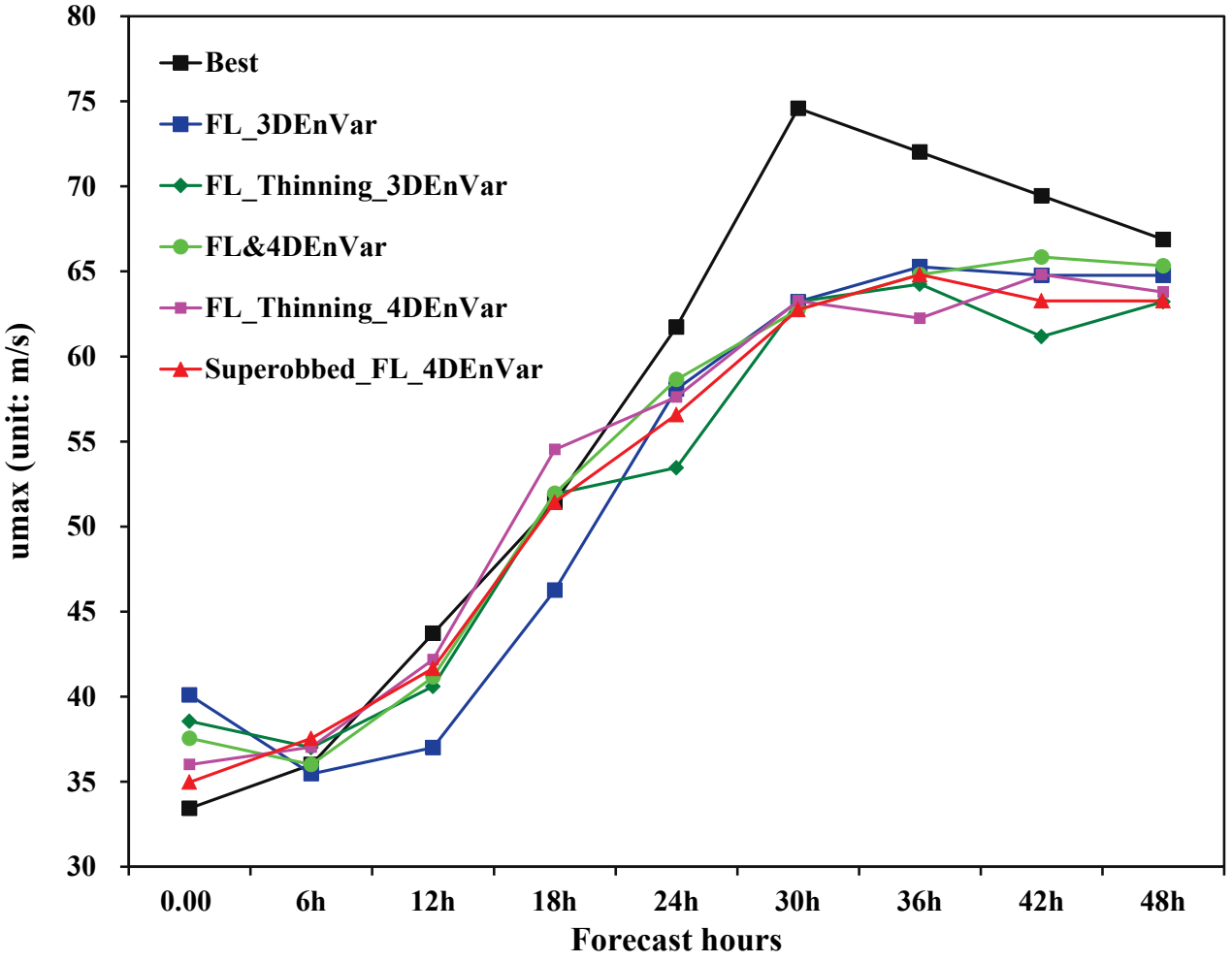


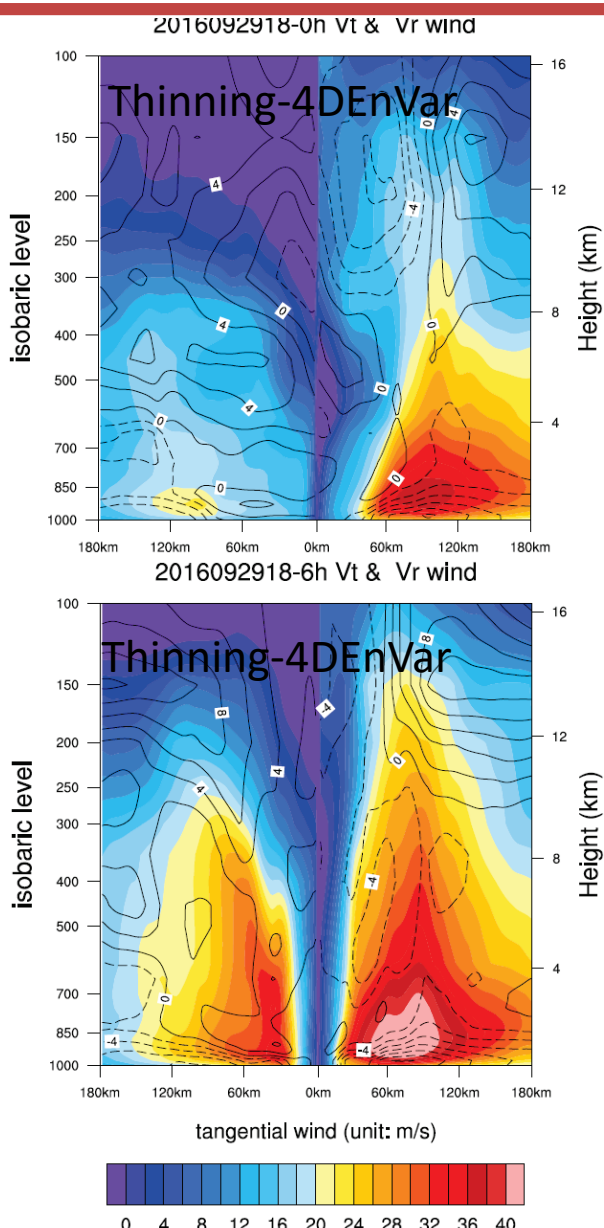


Spurious double eyewall



The proper pre-processing of HDOB data and 4DEnVar can alleviate the spin-down, improve the analysis and intensity forecast

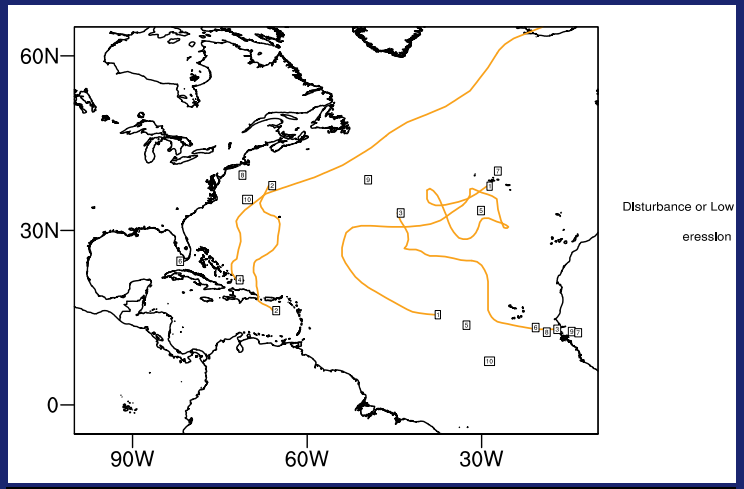


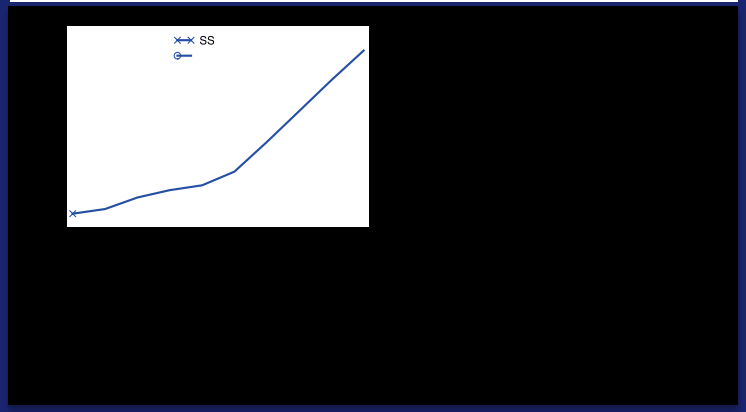


Aksoy

Recent Results from Ongoing HRD Projects

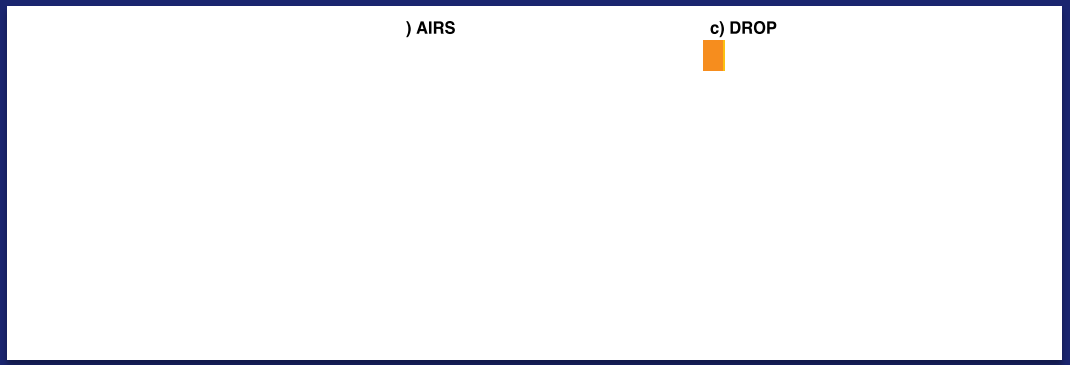
1. UAS/SHOUT Global Hawk Dropsonde Impact

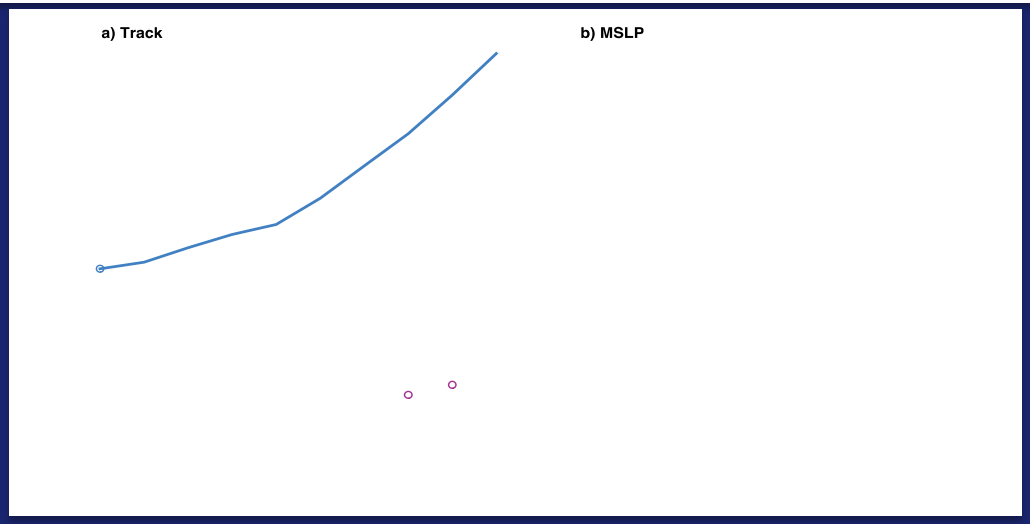




- 40 cases included
- Largest positive impact (track & MSLP) in non-steady-state cases
- Christophersen et al. (2017a, MWR)

2. UAS/SHOUT Combined Satellite & Global Hawk Impact

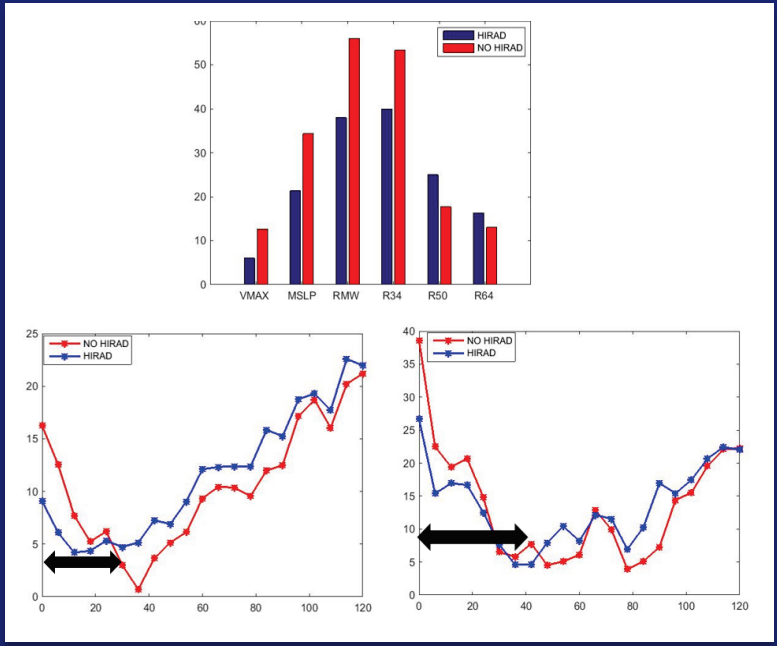




- Combined positive impact more than additive for MSLP
- Indicates complementary spatial sampling qualities
- Suggests UAS sampling should account for satellite tracks
- Christophersen et al. (2017b, JTECH, submitted)

Recent Results from Ongoing HRD Projects

3. Global Hawk HIRAD Sfc Wind Speed Retrievals



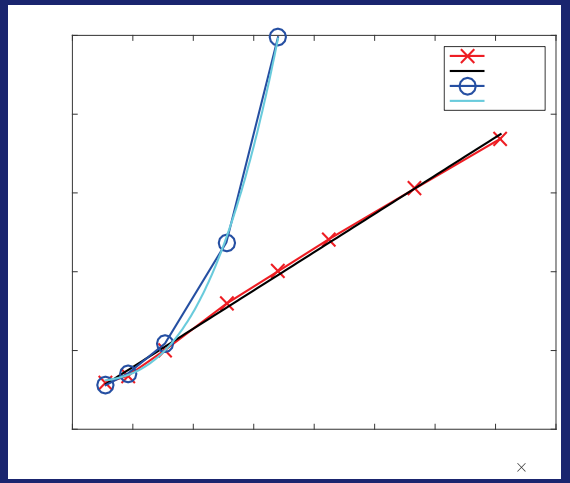
- HIRAD improves initial structure metrics in final mean analyses
- These improvements lead to forecast improvements in intensity & MSLP
- Optimization of DA parameters was necessary to balance impact from HIRAD sfc wind speed retrievals vs 3-d observations
- Sellwood et al. (2017, in preparation)

4. New Observing Platform Capabilities for Vortex-Scale DA

Aircraft-based in-situ	Flight level, drops, ACARS, Coyote UAS
Aircraft-based remote	SFMR, **HIRAD**, HAMSR, S-HIS, **DWL**
Radar radial velocity	TDR, **WSR-88D**
Satellite	ASCAT, GPSRO, AIRS, **MIRS**, AMVs, **CCVs**
Surface-based in-situ	**Buoys/drifters**

- Will become a publicly available comprehensive vortex-scale dataset
- Aksoy et al. (2017, in preparation)

5. New Parallel EnKF Approach



- Solves for all obs at once
- Based on eigenpairs of obs covariance matrix
- New method based on the theory of matrix functions uses the basis of the Krylov subspace to achieve linear scaling with obs number N

- Steward et al. (2017a, JTECH)
- Steward et al. (2017b, MWR, submitted)

Future priorities

- Continue tuning and systematic testing of the hybrid DA system in operational settings in preparation for H218 implementation

- Test the new developments of HWRF hybrid DA system with additional experiments
  - 4DEnVar vs frequent 3DEnVar (e.g. hourly)
  - Adaptive 4DIAU

- Continue improving the assimilation of inner core in-situ and remote sensing observations (HDOB, dropsondes, satellite cloudy radiances such as GOES-R, etc.)

- Working with physics group to use the new DA system to identify issues in physics parameterizations and understand interactions of DA and model physics

- Working with ensemble group to integrate ensemble prediction and ensemble DA efforts

- Extend and test the hybrid DA system for FV3 when the model is ready (or basin scale HWRF in near term)

- Investigate DA issues associated with non-Gaussianity/nonlinearity, multiscales, etc.