Assimilation of RO refractivity observation with a regional Hybrid-Gain Data Assimilation algorithm

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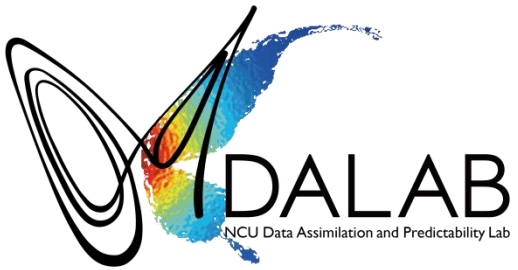


Outline

- Introduction
- WRF-KHYB system
- OSSE setup
- Performance of WRF-KHYB
- Impact on RO observation
- Conclusion

Introduction

- Traditional Hybrid Data Assimilation systems are derived from VAR perspective. The main purpose is to introduce the flow-dependent information into VAR system through the background error covariance combination.

- Hybrid-Gain DA algorithm proposed by Penny (2014) is derived from EnKF viewpoint. The Gain matrix combination considers not only the B but also the total error variance.

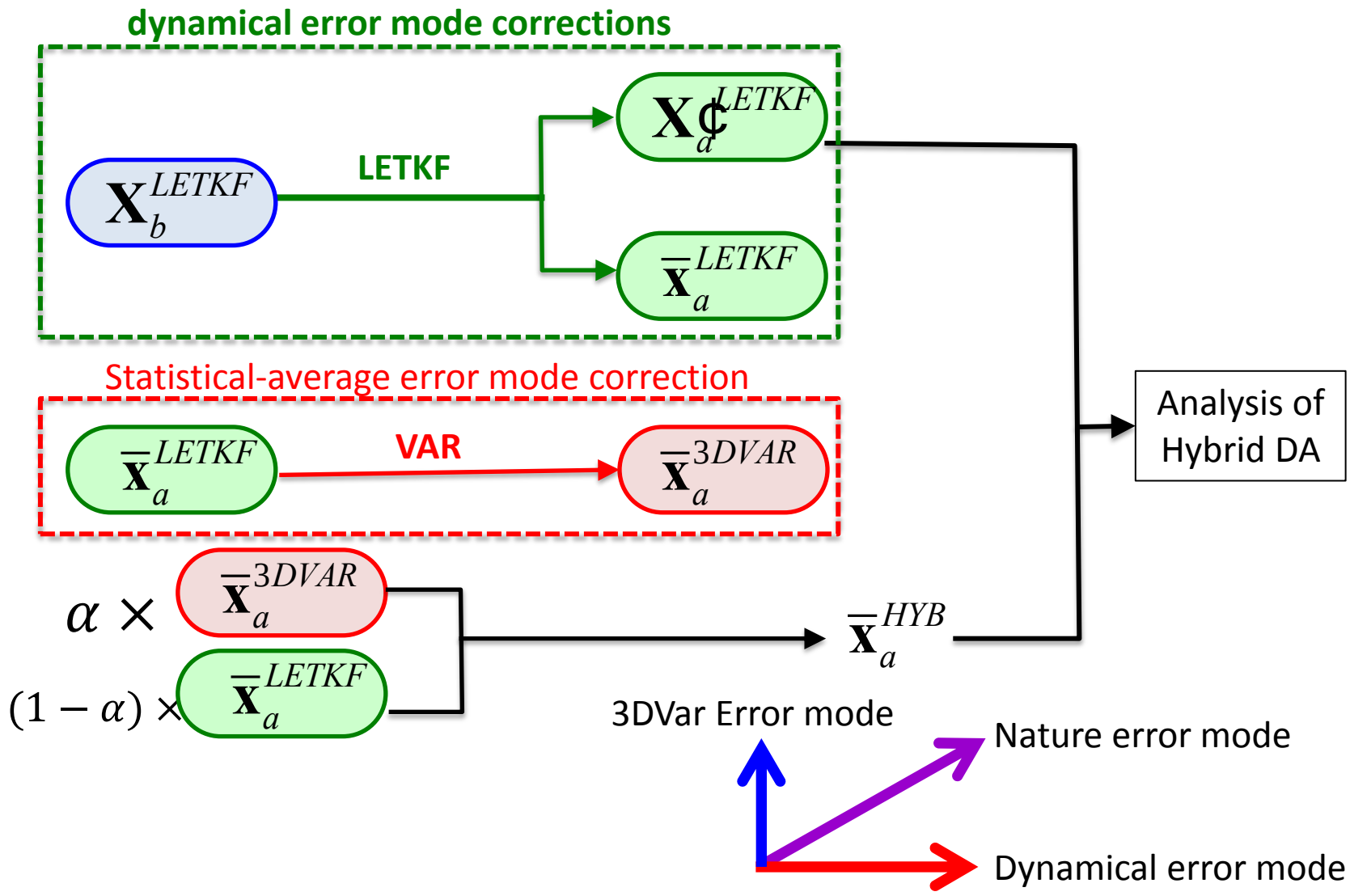
- Bonivata et al. (2015) uses ECMWF operational DA system examine the ability of HG-DA **in global model**. Results indicate that HG-DA is comparable to ECMWF's operational model without tuning.

Goals

1. To understand the ability of Hybrid-Gain algorithm in the regional model.

2. To evaluate the benefits of RO refractivity data in WRF-KHYB system.

Hybrid-Gain DA algorithm



Advantages of HG-DA

1. Combining the gain matrix, which consider the effect of total error covariance, instead of B only.

$$K = \frac{B}{B + R}$$

2. Reducing the model bias via VAR's climatological information.

3. Reducing the sampling error and the underestimation of background error covariance due to localization.

4. Capturing the error growth direction more complete through the two-step update.

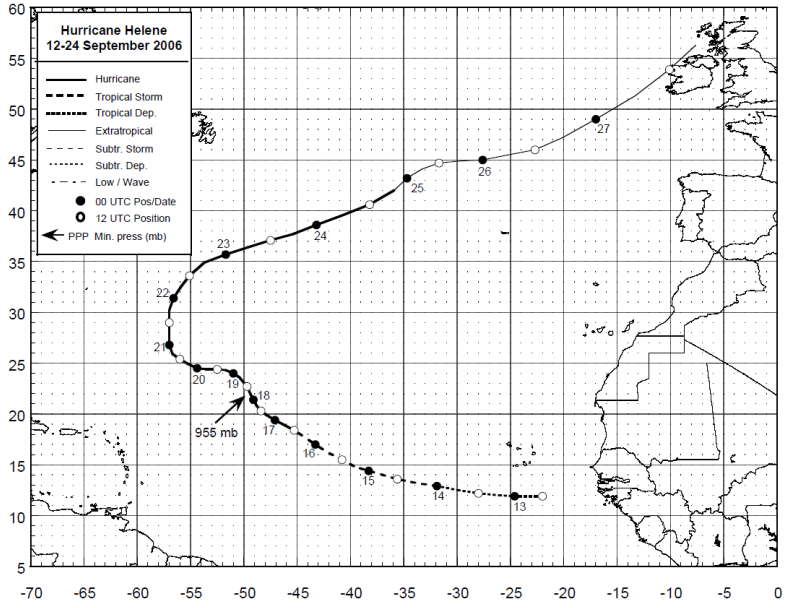
5. It allows **independent, parallel development** of its component systems.

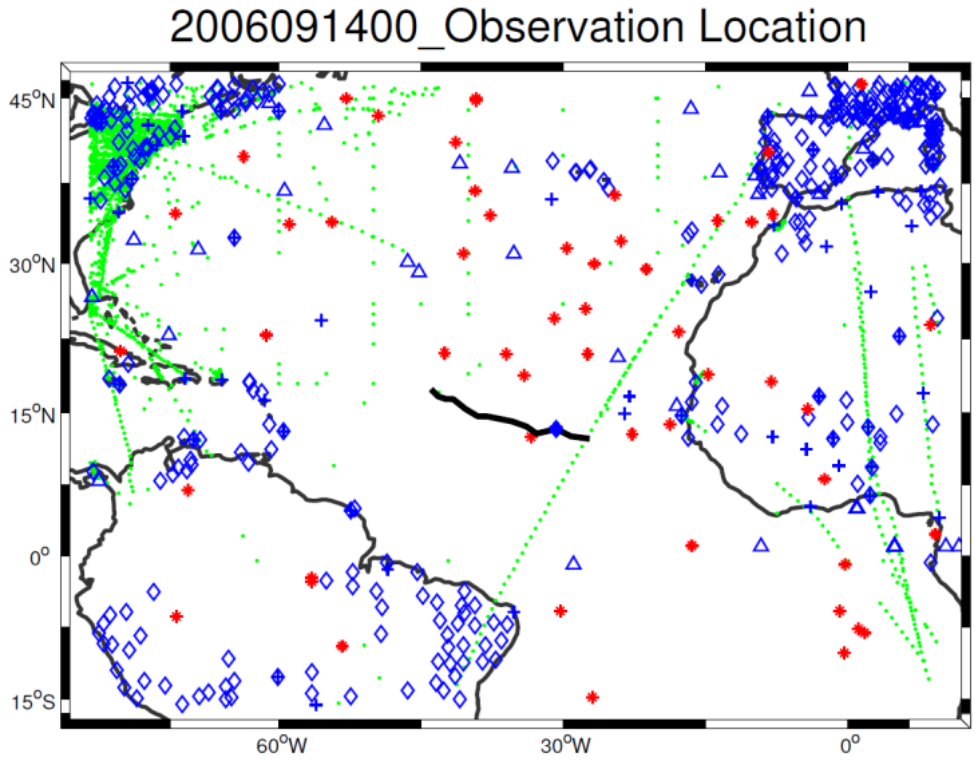
OSSE Setup

- Model: WRF V3.2.1 with 27km horizontal resolution and 31 vertical levels.
- Observation: GTS observation (Sounding, Synop, Ship, Airep) and GPS RO refractivity

• AIREP ┼ SOUND
◇ SYNOP △ SHIP
∗ GPS RO Refractivity

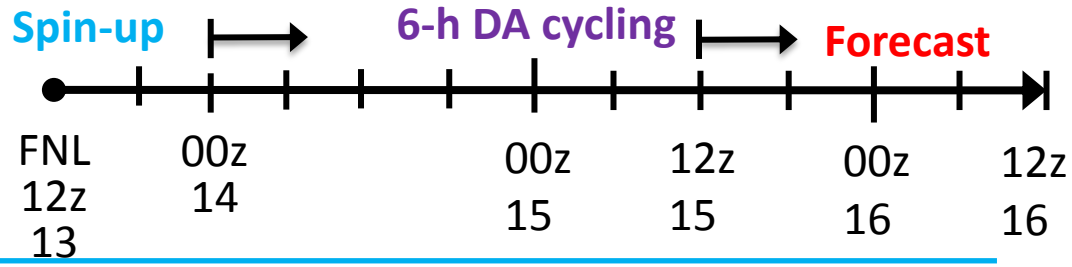
Hurricane Helene (Sep. 2006)





OSSE Setup – DA systems

- WRF-LETKF
  - 36 members
  - 8% multiplicative inflation.
- WRF-VAR
  - Use cv5 background error covariance (NMC method with 1 month forecast).
  - Use ensemble mean as background field.
  - Use VAR QC process for all DA systems
- WRF-KHYB
  - Combination weight is 0.5

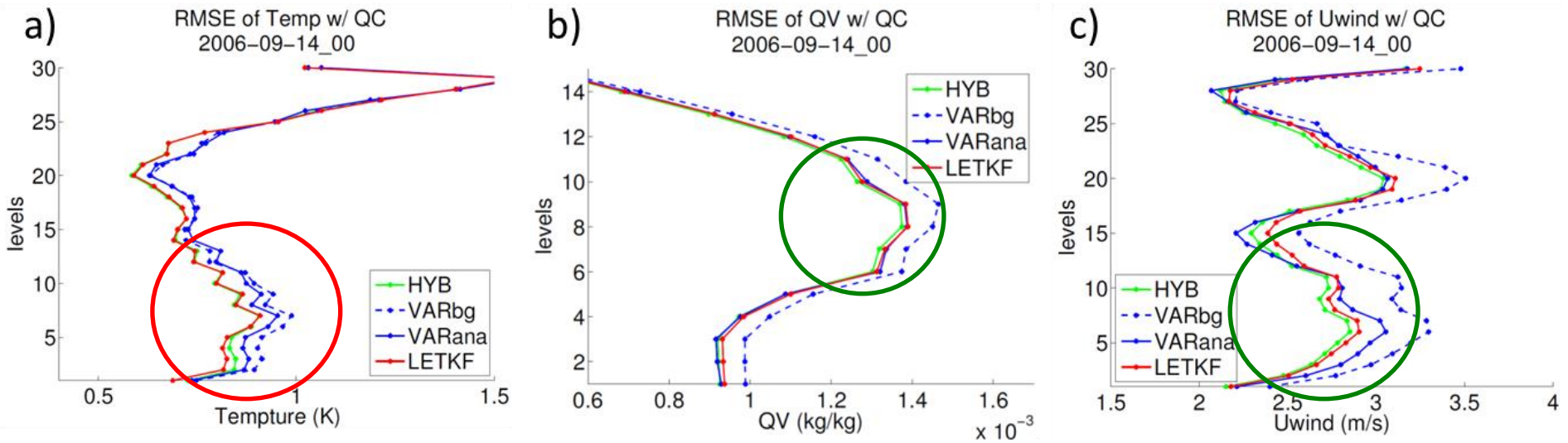


Results

1. To understand the ability of Hybrid-Gain algorithm in the regional model.

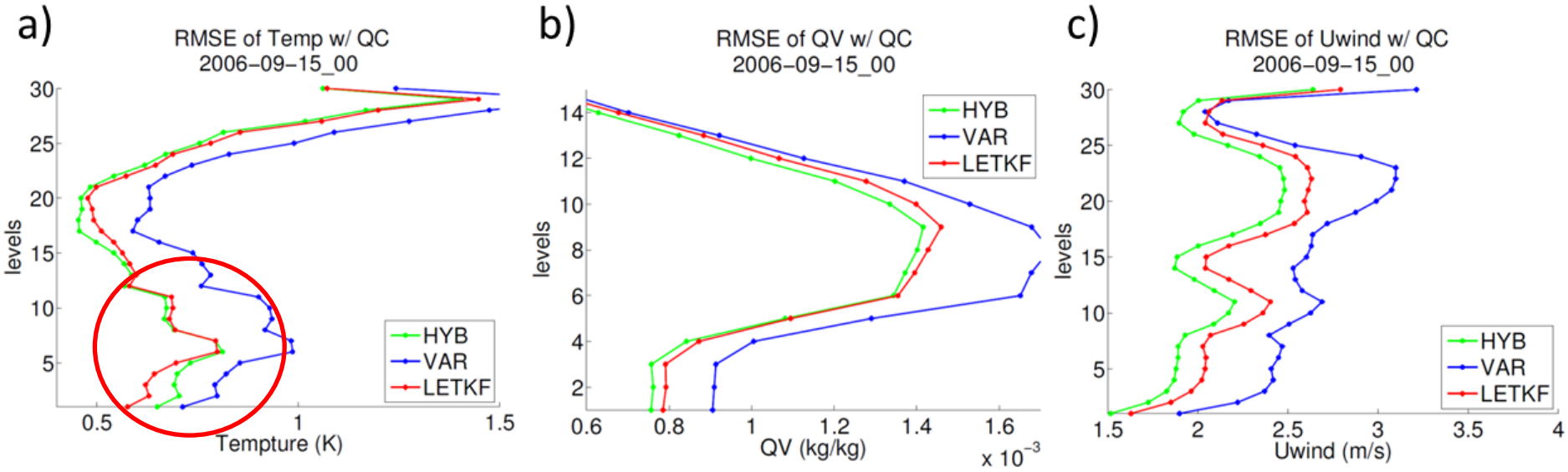
2. To evaluate the benefits of RO refractivity data in WRF-KHYB system.

1st Analysis Cycle



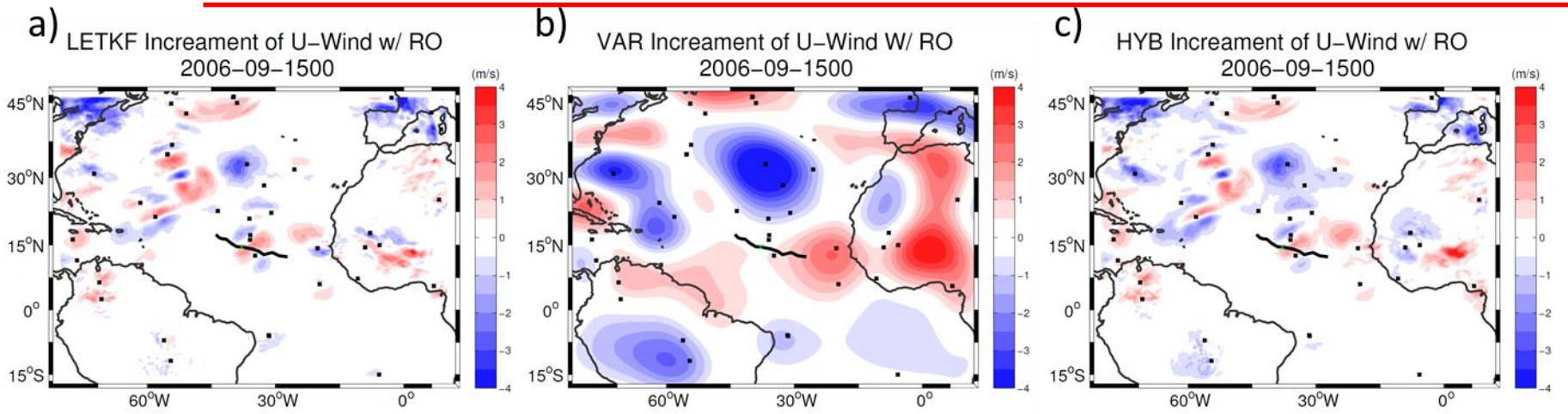
- All DA systems are able to reduce background error.
- LETKF is effective for improving the low-level temperature.
- The benefit from KHYB is more evident in U, QV and mid-level Temperature.

5th Analysis Cycle



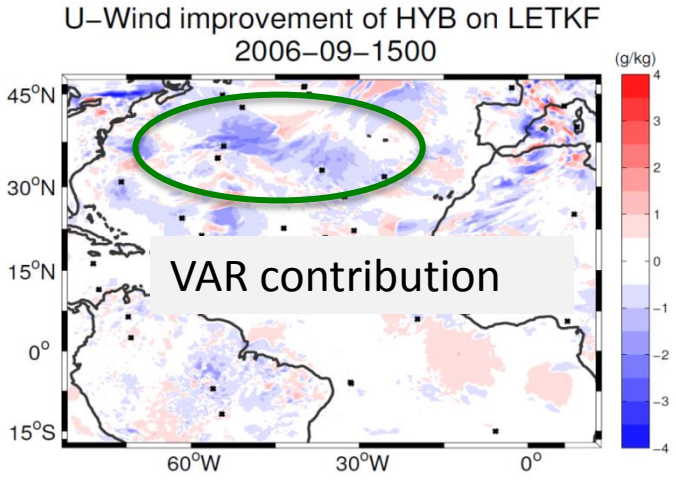
- The benefit of KHYB has been enhanced with more DA cycles.
- Except low-level temperature, KHYB improves all levels of T QV and U fields.
- Compared with EPS (No DA), KHYB has a 25-35% improvement in U field.

U-wind increment @ 5th cycle



- Increment of VAR is wider than LETKF, providing larger scale information.

- KHYB improve U-wind field and provide feedback to T and QV.



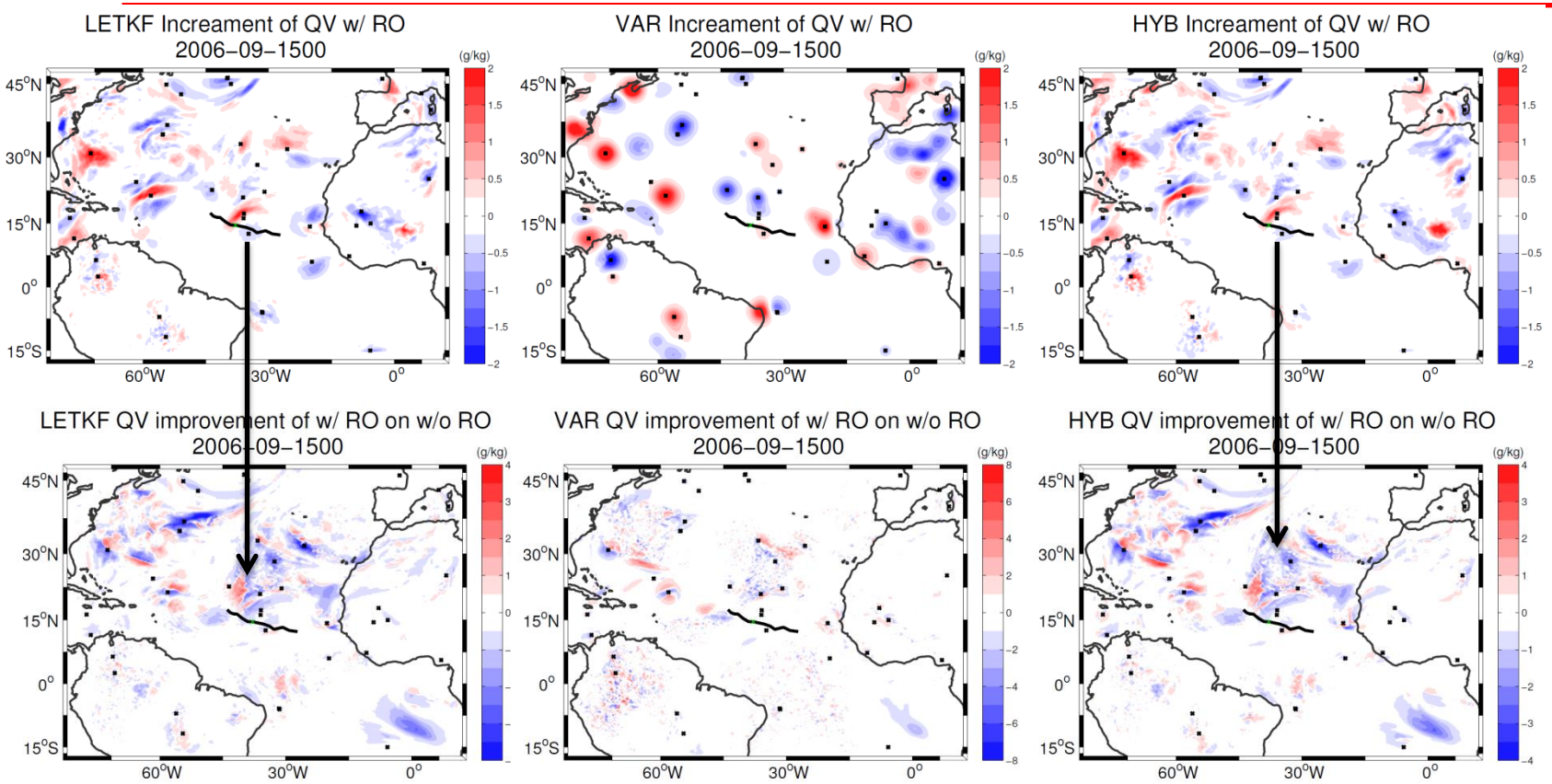
$RMSE_{KHYB} - RMSE_{LETKF}$

Goals

1. To understand the ability of Hybrid-Gain algorithm in regional model.

2. To evaluate the benefits of RO refractivity data in WRF-KHYB system.
   - W/ RO observation
   - W/o RO observation

Impact from RO observation

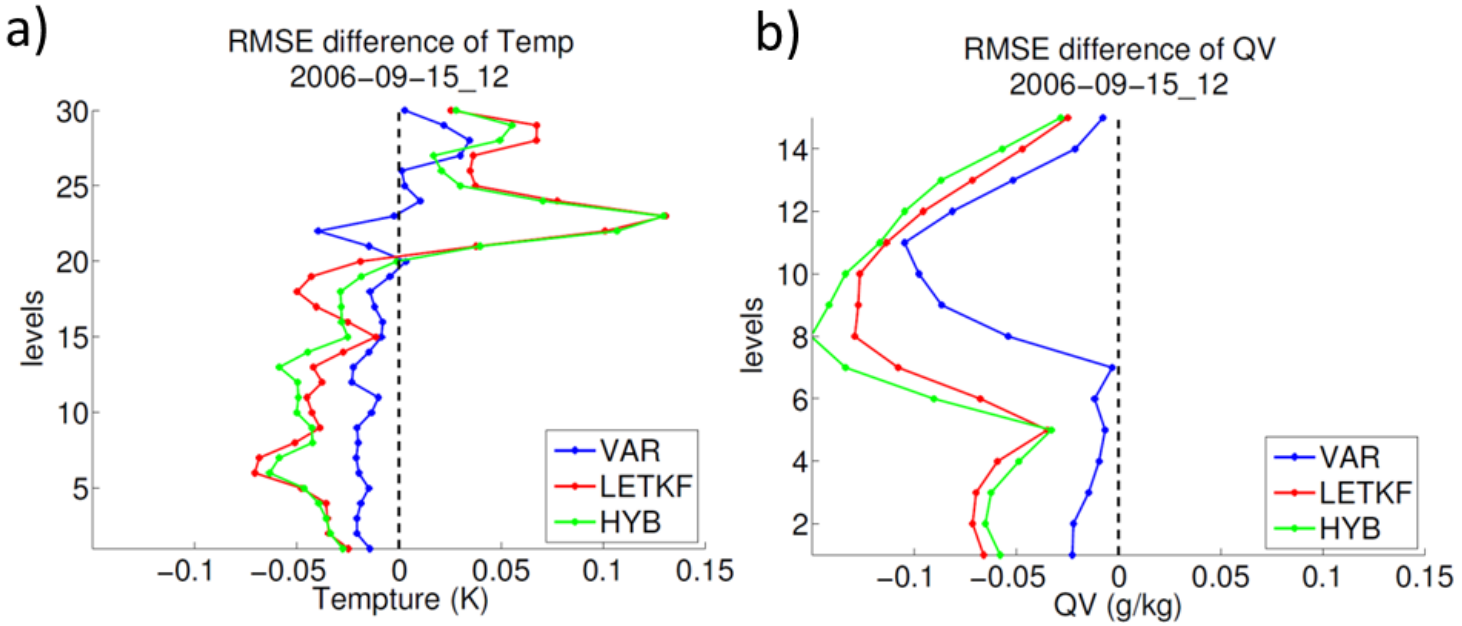


- For QV field, the RO impact is significant in LETKF and KHYB, but less significant with WRF-VAR.

- An advanced DA system can increase the impact of RO data. Mainly, attributed to the use of the flow-dependent error covariance.

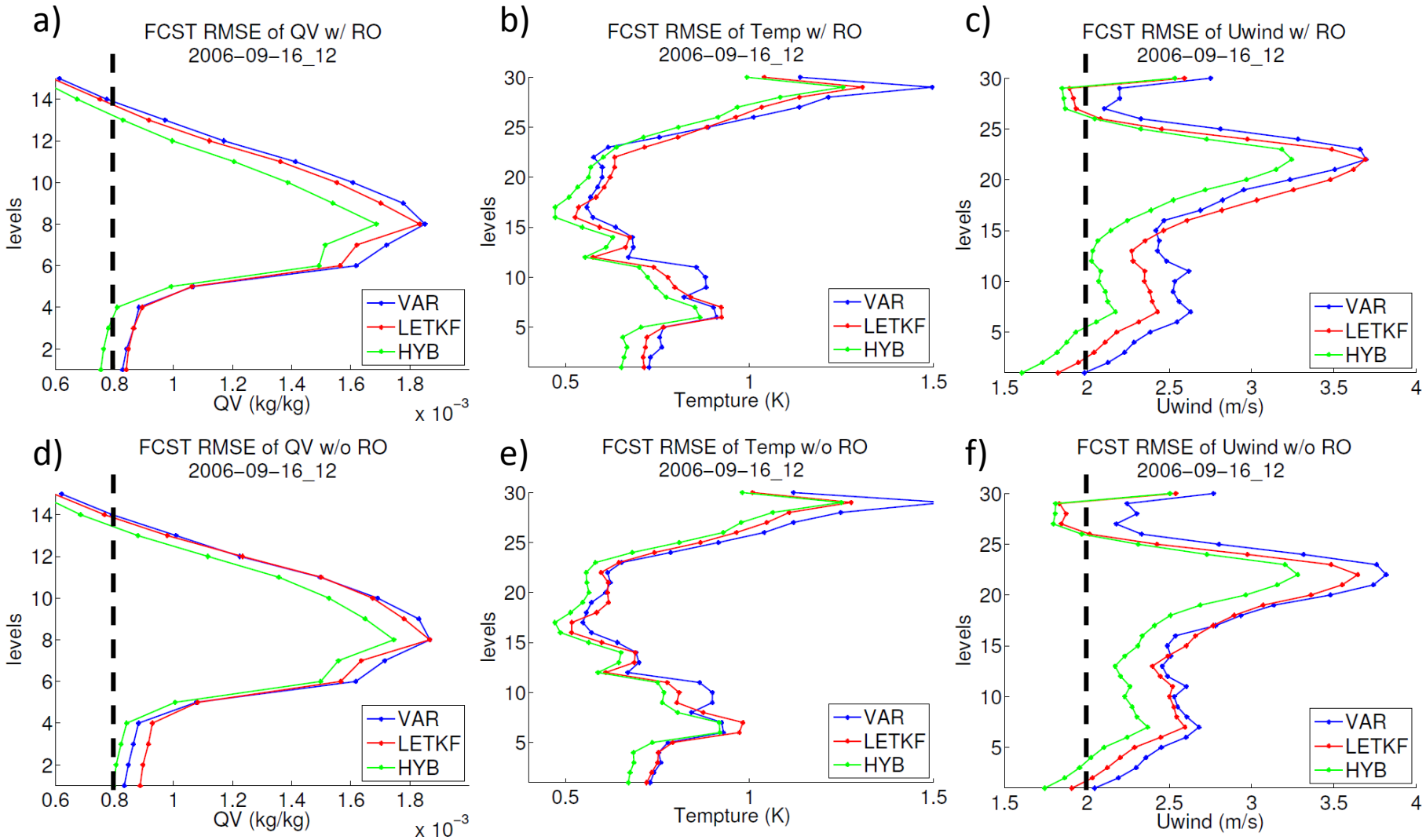
Impact from RO observation

Impact :$RMSE_{W/\ RO}$ - $RMSE_{W/O\ RO}$ (negative: improvement, positive: degradation)



- Higher impact on the mid-level Qv and T.
- KHYB negative impact on the high-level T might owing to the poor estimation of correlation in LETKF.

1-day forecast initialized from 7th Cycle



Conclusion

- WRF-KHYB system has been established via combining the WRF-LETKF and WRF-VAR systems.

- Results indicate that HYB outperform its component systems. The benefits of WRF-KHYB might owing to the improvement of Wind field, and then feedback to T and QV fields.

Average improvement (%) (compared with EPS)

	LETKF	VAR	KHYB
T	20.4	-3.1	20.5
Qv	15.8	2.6	20.0
U	23.7	11.3	29.9

Conclusion

- WRF-KHYB is able to use the RO observation more effective than WRF-LETKF and WRF-VAR, especially in the mid-level QV and Temperature fields.

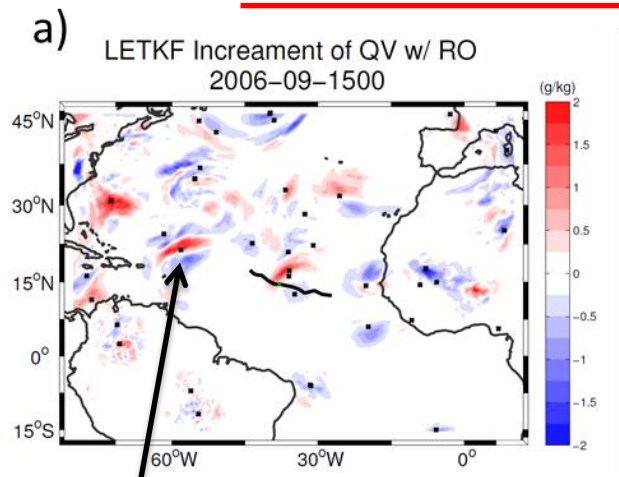
- The advantages of RO observation in KHYB are maintained after 1-day forecast.

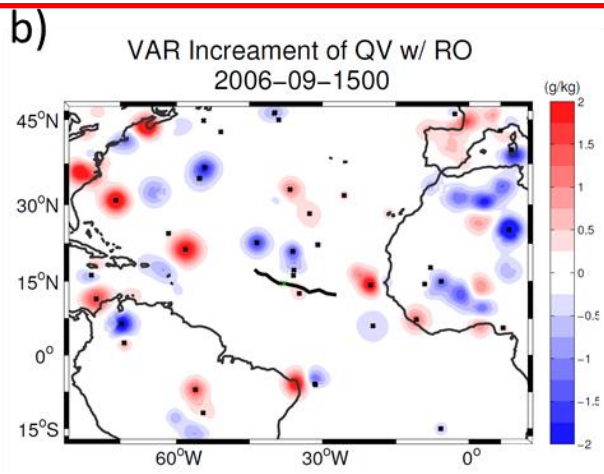
Average improvement (%) with assimilation of RO

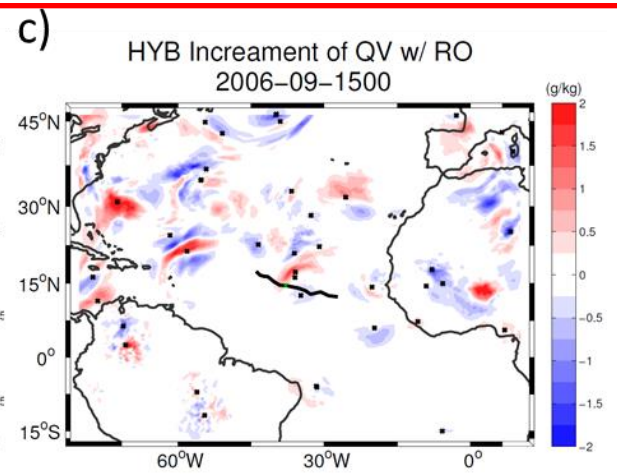
	LETKF	VAR	KHYB
T	5.5	-0.7	5.4
Qv	5.0	2.6	5.6
U	3.2	1.2	4.2


Thank you !

QV increment @ 5th Cycle

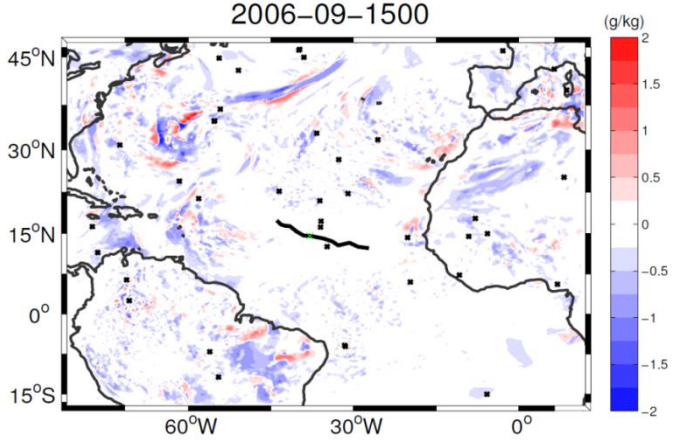




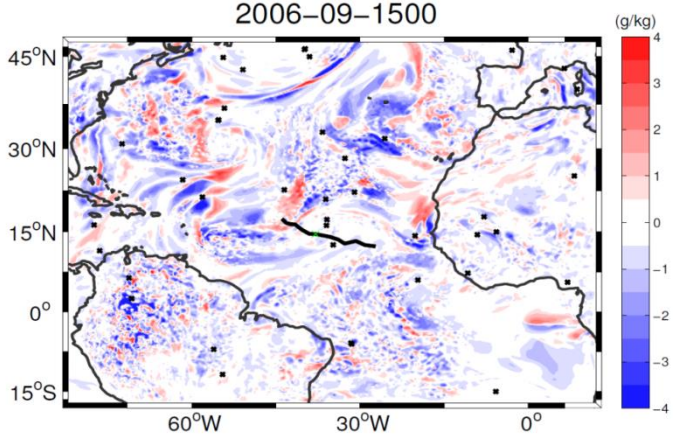


Flow-dependent

- Negative value indicates positive impact.



$RMSE_{KHYB} - RMSE_{LETKF}$



$RMSE_{KHYB} - RMSE_{VAR}$

Hybrid Gain algorithm

$$\widehat{\overline{x_a}} = (1-\alpha)\overline{x_a} + \alpha\overline{x_a}^{v}$$

$$\begin{aligned}
(1-\alpha)\ \overline{x_a} &= (1-\alpha)[\overline{x_b} + \delta_x] \\
+ \quad \alpha\ \overline{x_a}^{v} &= \alpha\,[(\overline{x_b} + \delta_x) + \delta_{xv}] \\
\text{----------} & \\
&= [\overline{x_b} + \delta_x + \delta_{xv}] \\
&= [\overline{x_b} + (K_{LETKF} + K_{var}) * innovation]
\end{aligned}$$

Gain combination!!

- NO DOUBLE use of observation.
  The K matrixes times the same innovation separately!!