Recent progress and challenges in applying data assimilation for tropical weather systems

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Group meeting, Aug 18, 2015

Motivation

Can we extent the practical predictability of tropical weather systems by assimilating available observation?

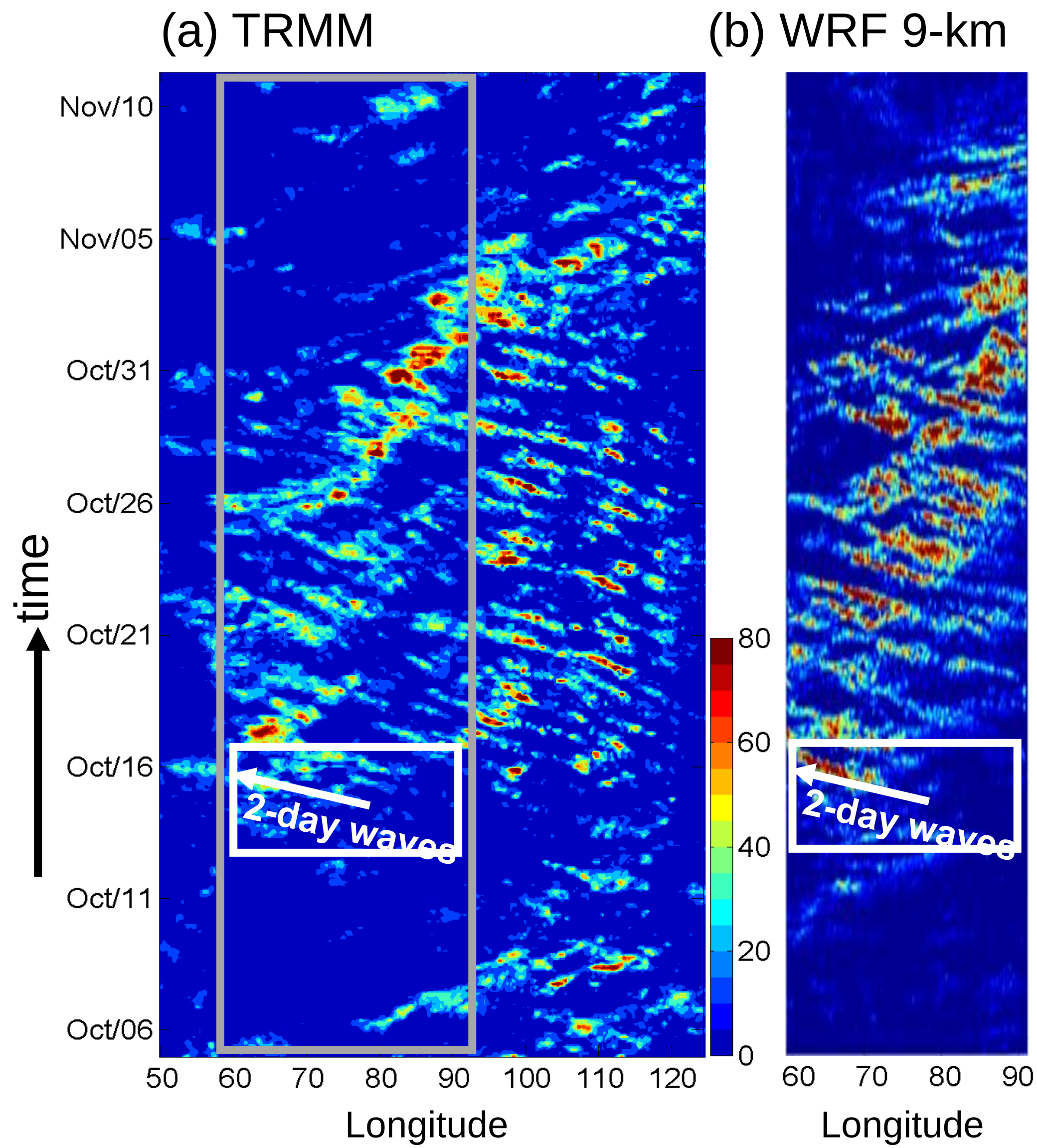
Tropical weather systems:

- MJO, convectively coupled waves, clusters of convection

Data assimilation methods need to take in to account

- Different dynamics compared to mid-latitude systems
- Different observation availability

Observing System Simulation Experiments



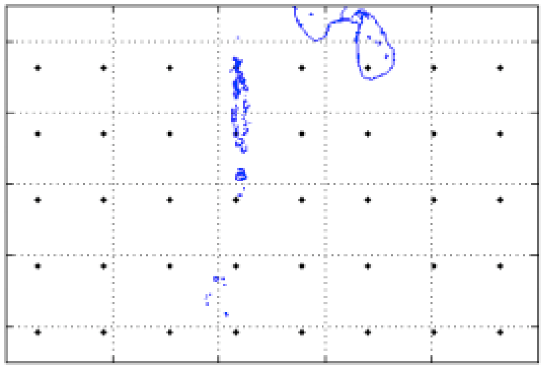
A WRF 9-km simulation by Wang et al. (2015) set as truth

Assimilate synthetic observation (UVTQ) using EnKF every 3 h

Challenge: too costly to run experiment through the whole wet phase.

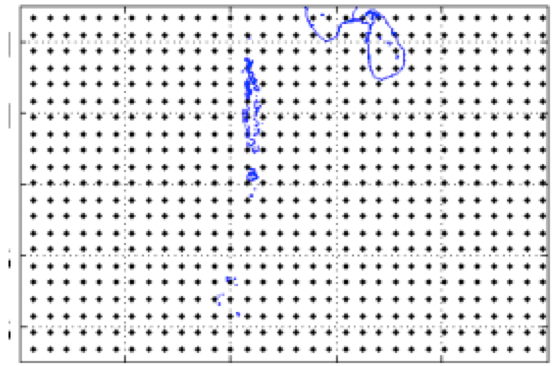
Observing systems used in EnKF

radiosonde **UVTQ**



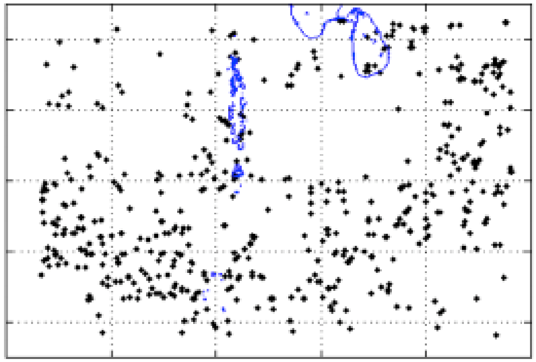
(all model levels)

Satellite **TQ** retrievals



(T: all levels; Q: below 200 hPa)

Satellite **AMV**



(wind: 200~700 hPa)

observation error:

U,V ~1 m/s; T ~1 K; Q ~1 g/kg

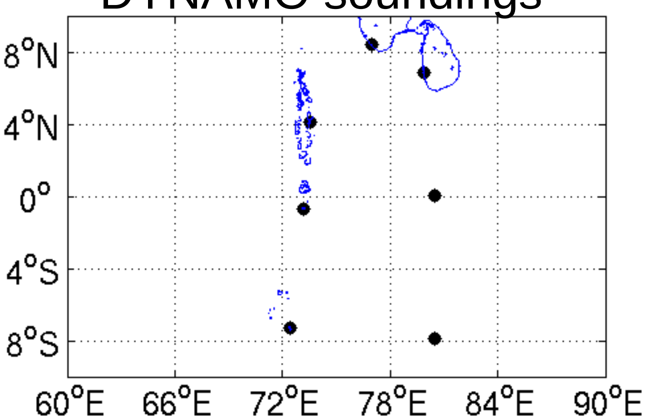
T ~2 K, Td ~4 K

ATOVS validation
(Li et al. 2000)

U,V ~ 5 m/s

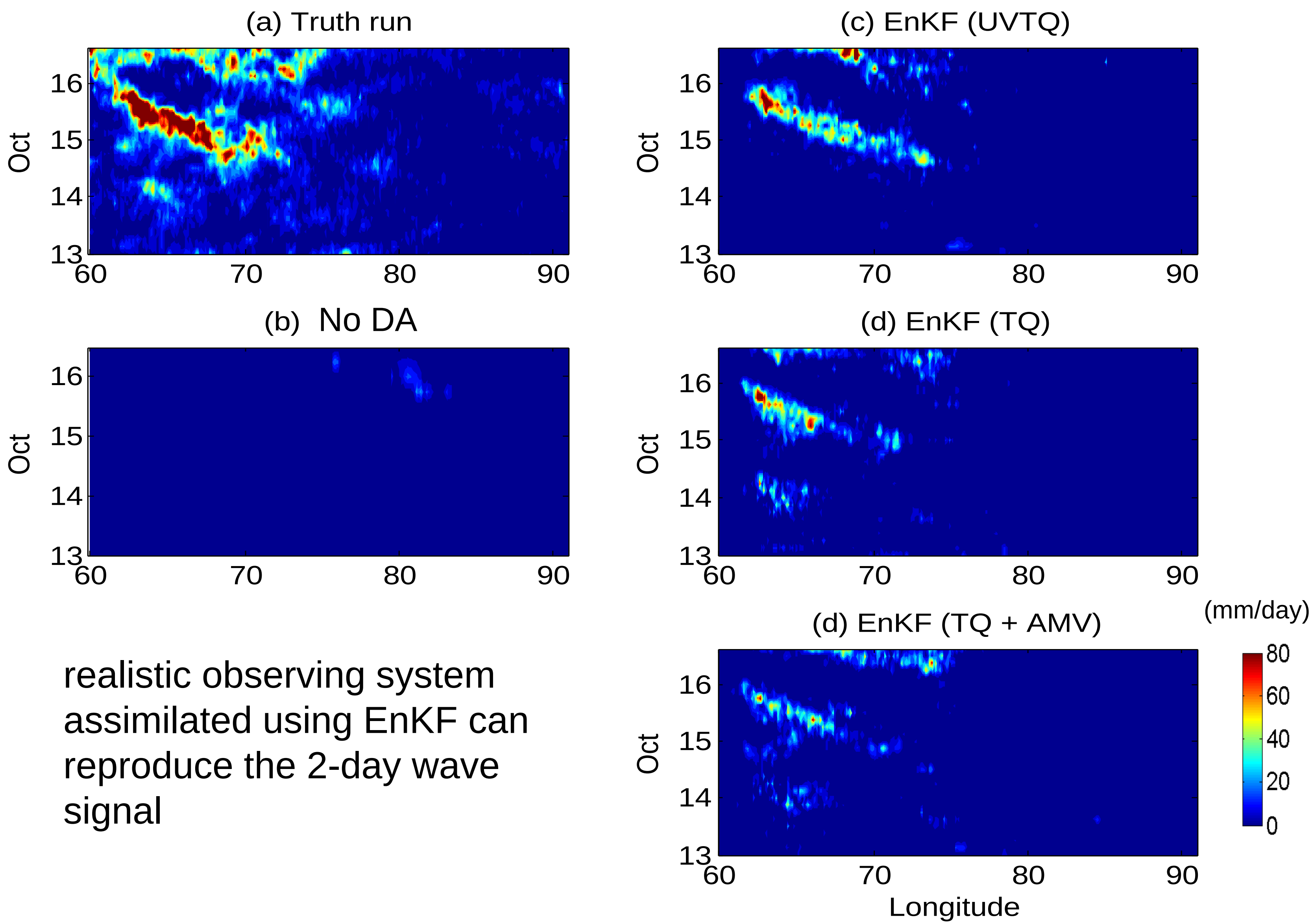
(Velden and Bedka 2009)

DYNAMO soundings



EnKF performance with different observing systems

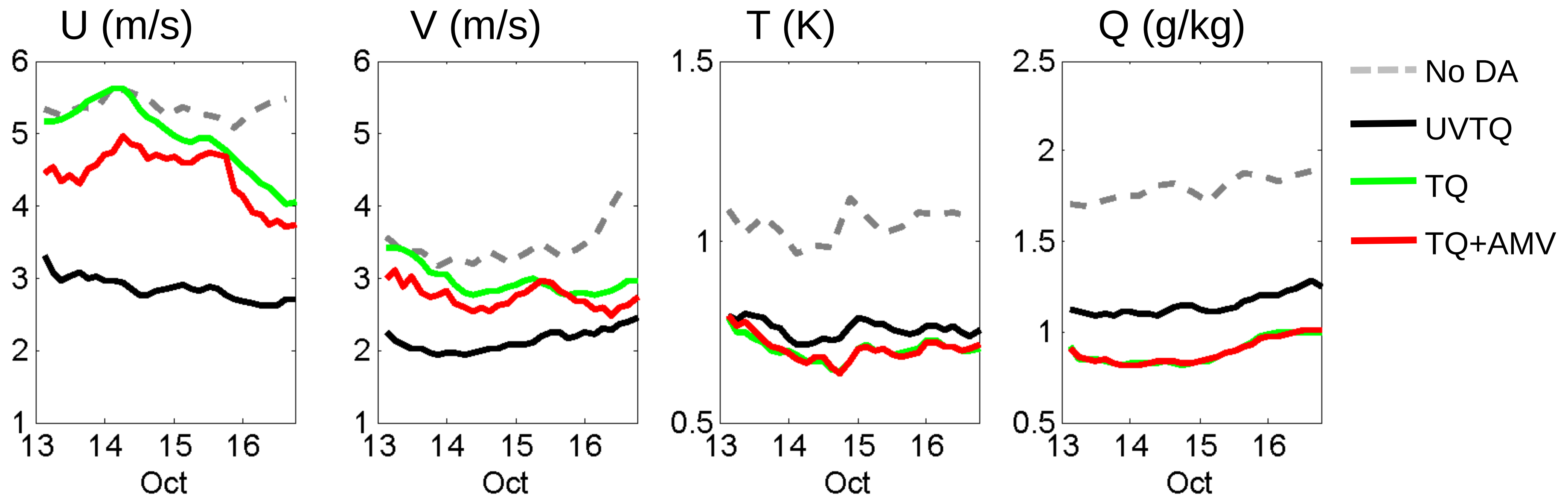
6-h rain forecast from analysis



realistic observing system assimilated using EnKF can reproduce the 2-day wave signal

EnKF performance with different observing systems

analysis RMSE time series



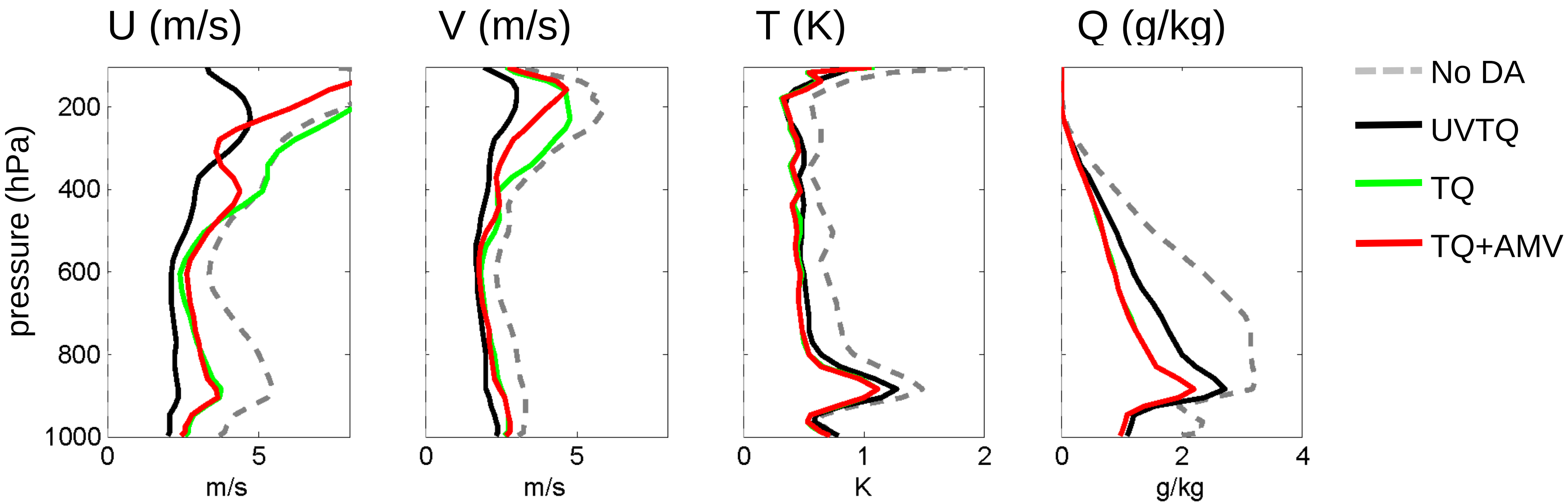
TQ+AMV improves U, V less than **UVTQ** due to partial observation

TQ improves T, Q more than **UVTQ** because of higher resolution

Although **TQ** does not observe wind, it can still improve U, V.

EnKF performance with different observing systems

analysis RMSE vertical profiles



UVTQ improves all variables throughout the column

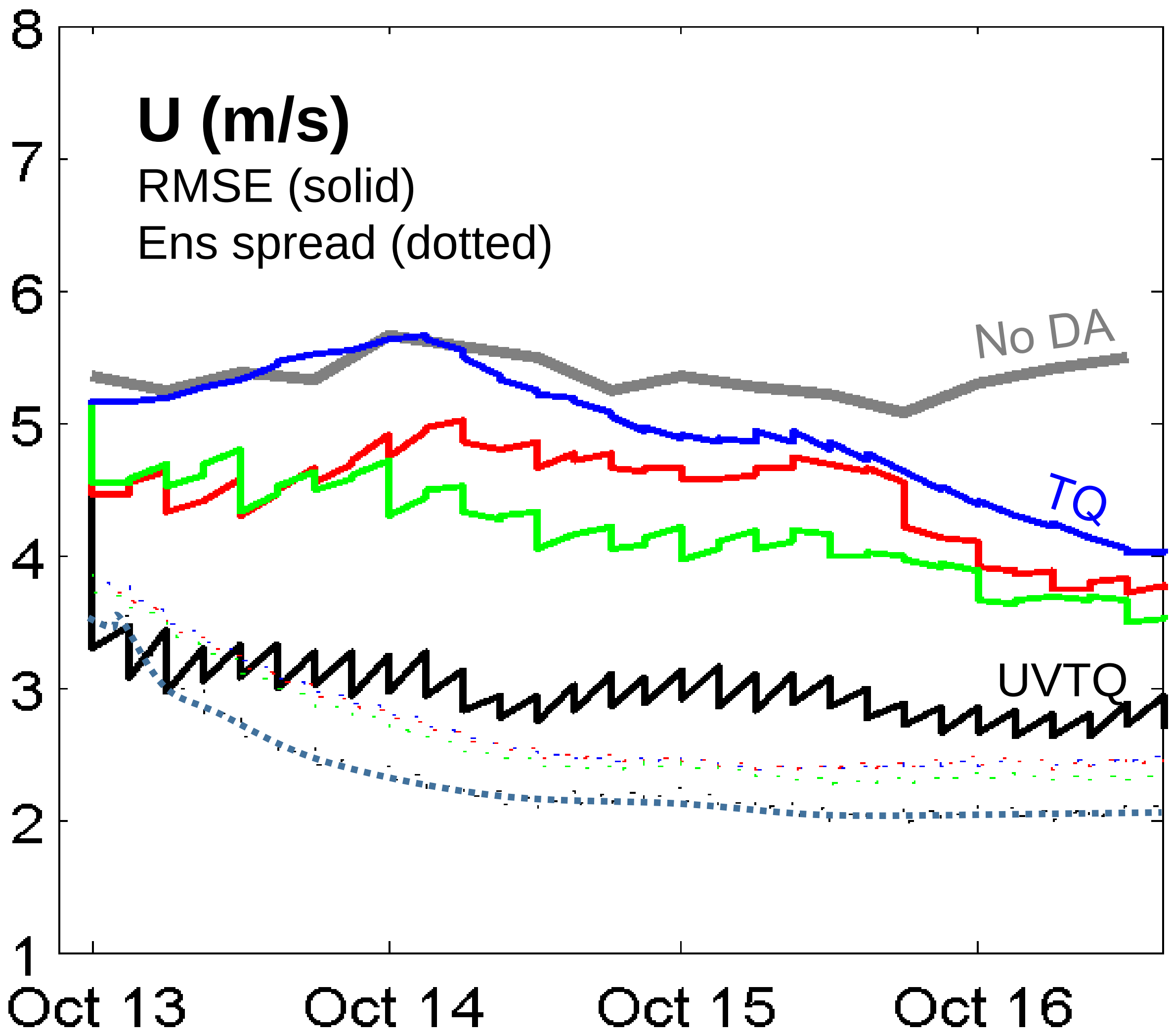
TQ only improves mid- to low-level winds, while **AMV** improves high-level wind.

Conclusion and future work

Current satellite-based observing network can help extent practical predictability of MJO-related tropical wave events.

Consider comparing direct assimilation of satellite BT observation versus using retrieved TQ profiles.

Challenge: under-dispersive ensemble



Ensemble spread keep decreasing no matter how large initial perturbations are.

Relaxation coef = 0.8 (optimal for mid-latitude)

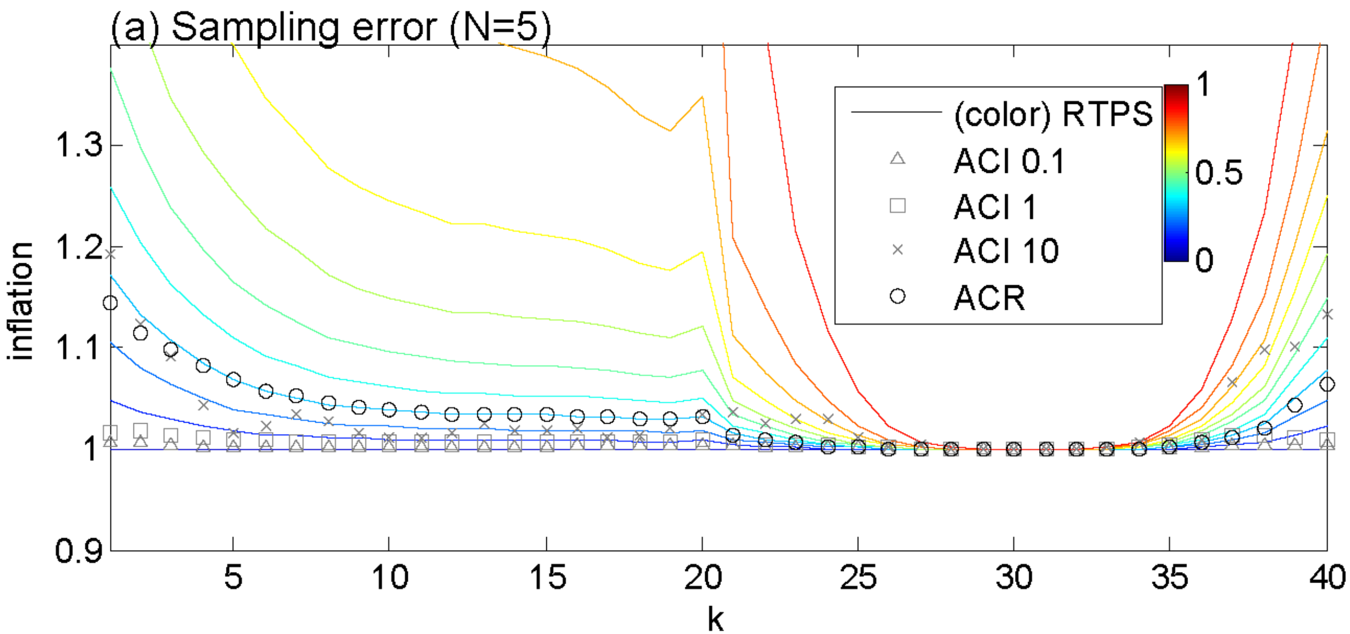
Adaptive covariance relaxation
Test with Lorenz-96 model

RTPP $x'^{a,new} = (1-\alpha)x'^{a} + \alpha\, x'^{b}$

Zhang et al. 2004

RTPS $x'^{a,new} = x'^{a}\dfrac{(1-\alpha)\sigma^{a} + \alpha\sigma^{b}}{\sigma^{a}}$

Whitaker and Hamill 2012

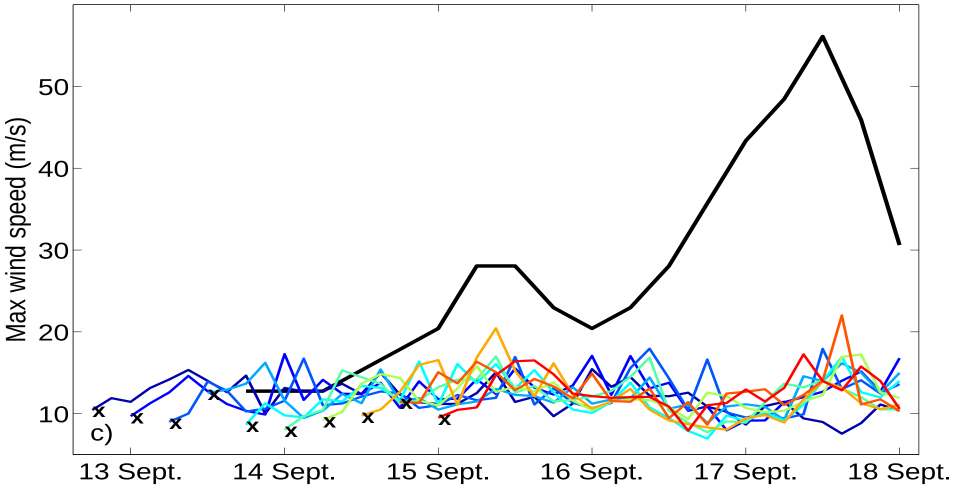


Handles partial observation well: Inflation factor larger for observed than unobserved

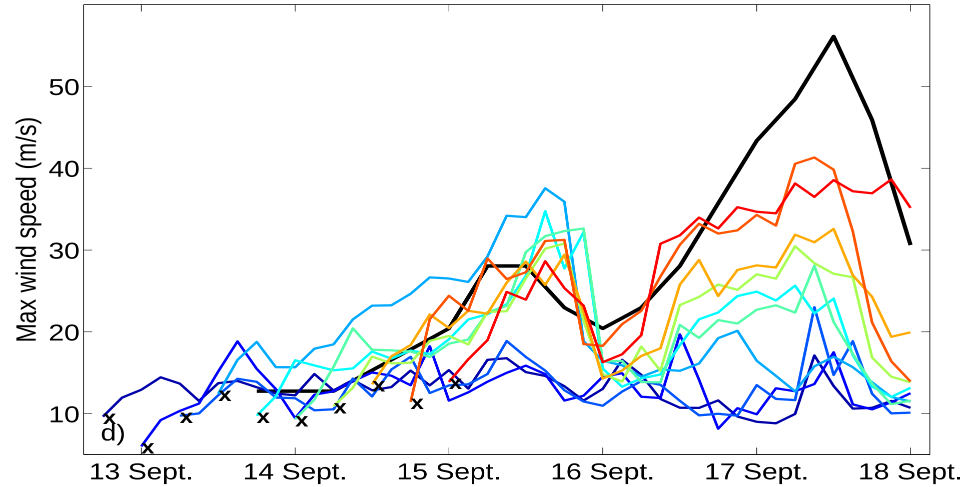
Determines relaxation coef adaptively according to ensemble spread deficiency.

Adaptive covariance relaxation Applied to WRF model (Karl 2010):

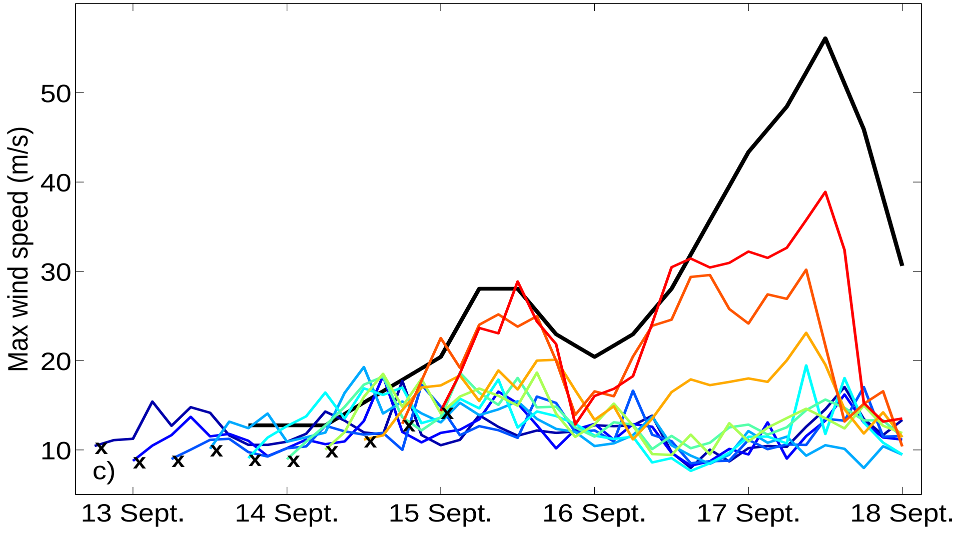
No inflation



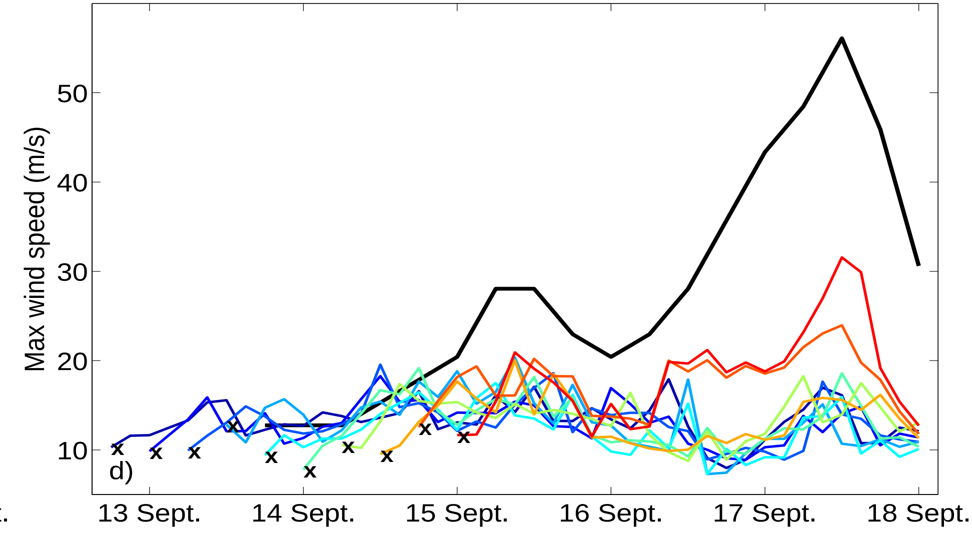
RTPP 0.8



RTPS 0.8



ACR



Challenge: Assimilation-induced imbalance

$x'^{a}_{(t)}$ → model → $x'^{b}_{(t+1)}$ → EnKF → $x'^{a}_{(t+1)}$

RTPP

$$x'^{a,new} = (1-\alpha)x'^{a} + \alpha\, x'^{b}$$

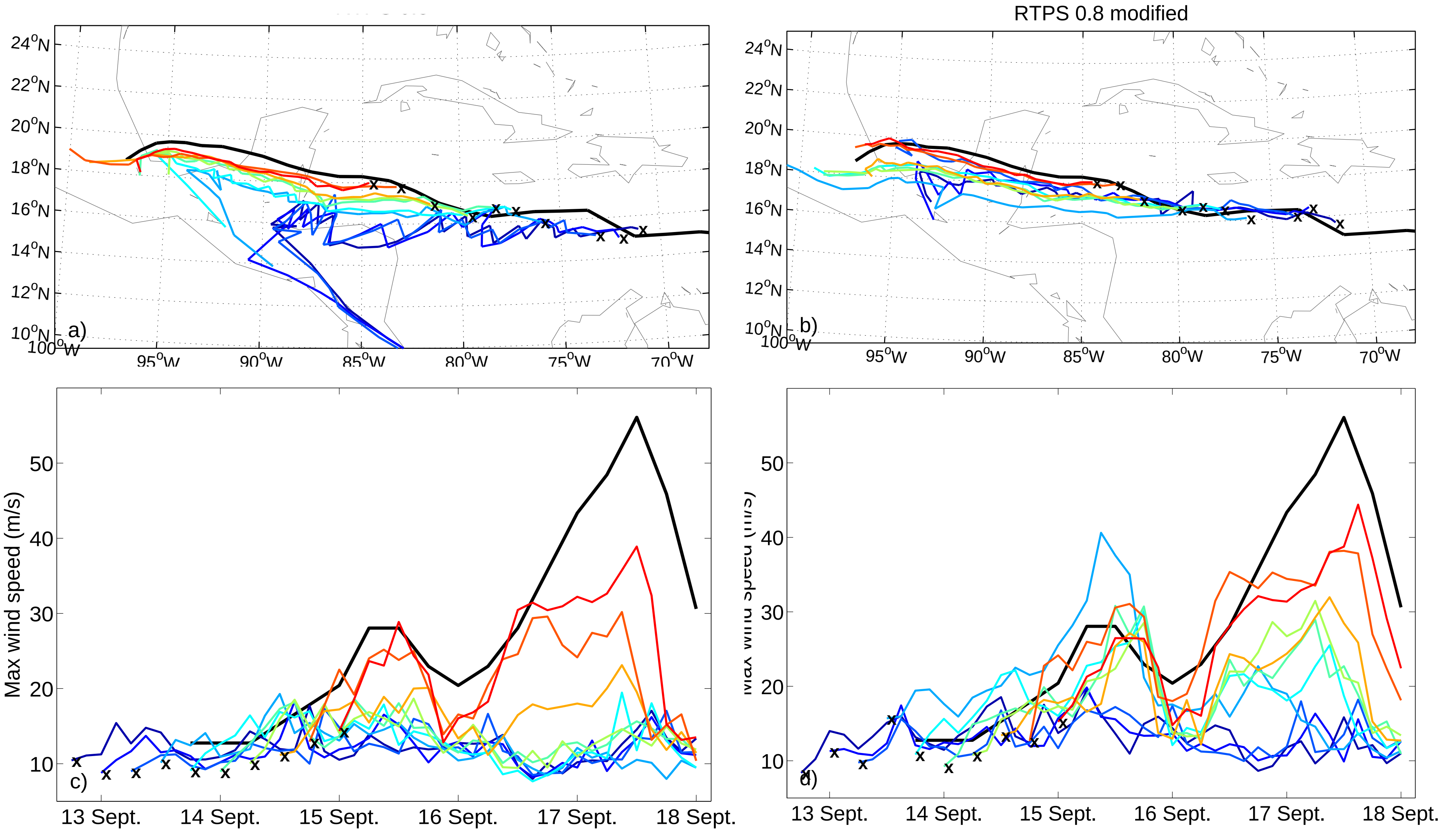
RTPS

$$x'^{a,new} = x'^{a}\frac{(1-\alpha)\sigma^{a} + \alpha\sigma^{b}}{\sigma^{a}}$$

Modified adaptive covariance relaxation

$$x'^{a,new} = x'^{a}\frac{(1-\alpha)\sigma^{a}+\alpha\sigma^{b}}{\sigma^{a}}$$

$$x'^{a,new} = x'^{b}\frac{(1-\alpha)\sigma^{a}+\alpha\sigma^{b}}{\sigma^{b}}$$



Conclusion and future work

The adaptive covariance relaxation can handle irregular observing system well.

The modified version retains balanced ensemble perturbations.

Apply this method to the MJO EnKF experiments and test its performance