Testing the adaptive covariance relaxation method with the Hurricane Karl (2010) case

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Group meeting 2014-12-11

Covariance relaxation

Relax-to-prior-perturbation (RTPP)
(Zhang et al. 2004)

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

Relax-to-prior-spread (RTPS)
(Whitaker and Hamill 2012)

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

Covariance relaxation

Adaptive covariance relaxation (ACR)
(Ying and Zhang 2014)

→ determines *α* from innovation statistics for RTPS

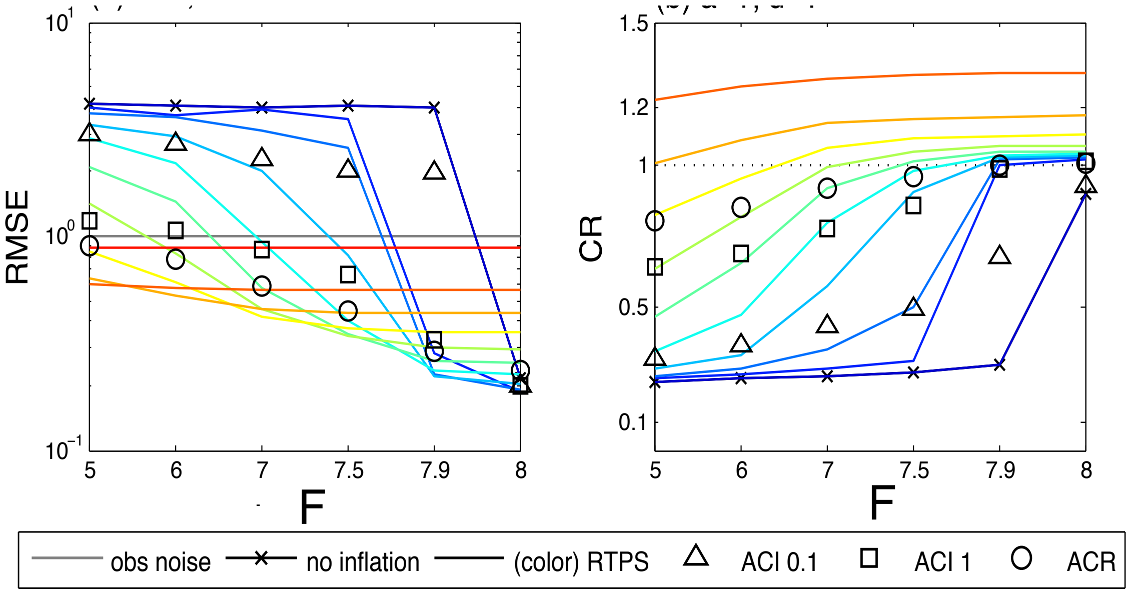
$$x'^{a,new} = x'^{a} \frac{(1-\alpha)\sigma^a + \alpha\sigma^b}{\sigma^a}$$

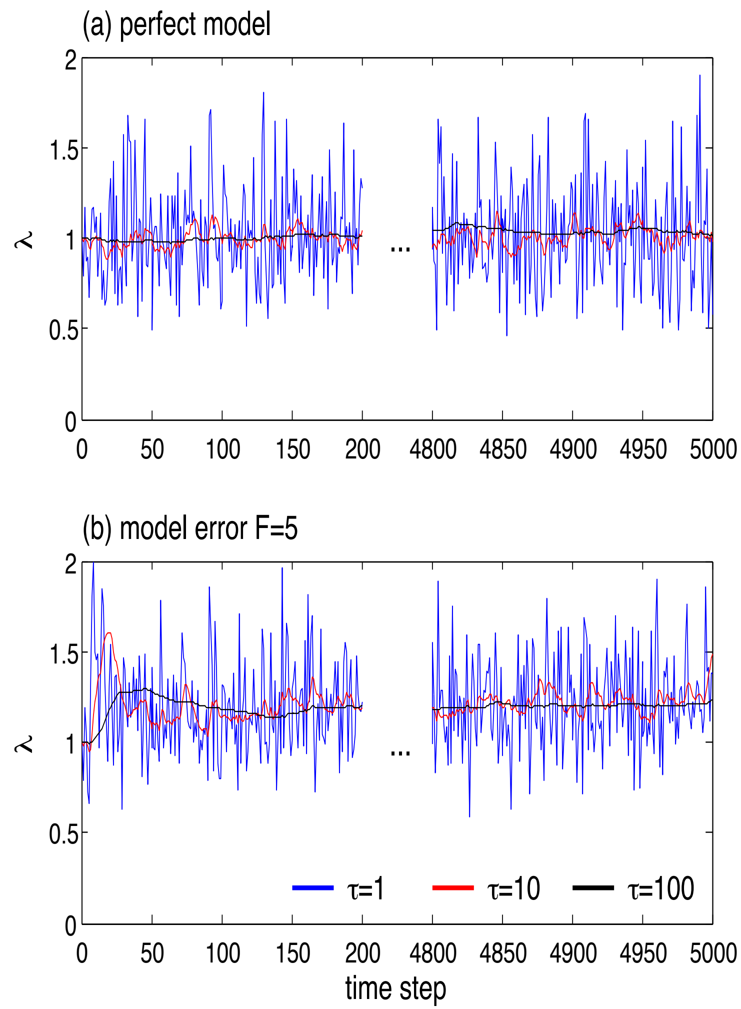
In observation space:

$$\frac{(1-\alpha)\overline{\sigma^b} - \alpha\overline{\sigma^a}}{\overline{\sigma^a}} = \sqrt{\frac{\langle \mathrm{d}^{a-b}\mathrm{d}^{o-a}\rangle}{\overline{\sigma^a}}}$$

Lorenz-96 model test results

Analysis RMSE   Consistency ratio

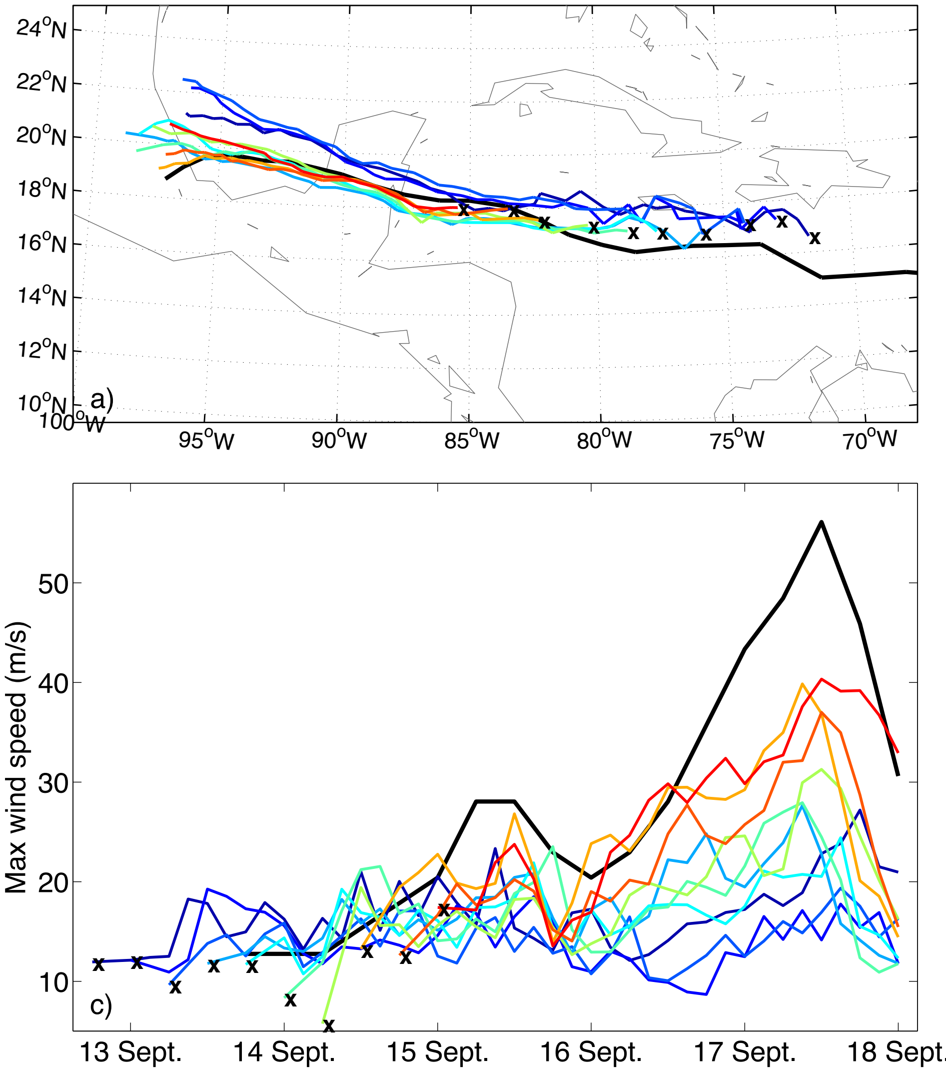




The ACR method is able to find suitable *α* value for different error severity regimes!

Application to hurricane case

Jon's EnKF_PREDICT case



Model setup:

- 13.5 km single domain, 35 levels
- WRF 3.4.1
  w/ Ben's modified surface flux scheme
- Fixed SST

EnKF:

- Multi-physics ensemble (60 members)
- Spin-up period:
  Sep 8, 06Z to Sep 12, 18Z (18 cycles)
- MADIS + PREDICT soundings every 6 h

(Fig. 4 from Poterjoy and Zhang 2014)

First, reproduce Jon’s result!

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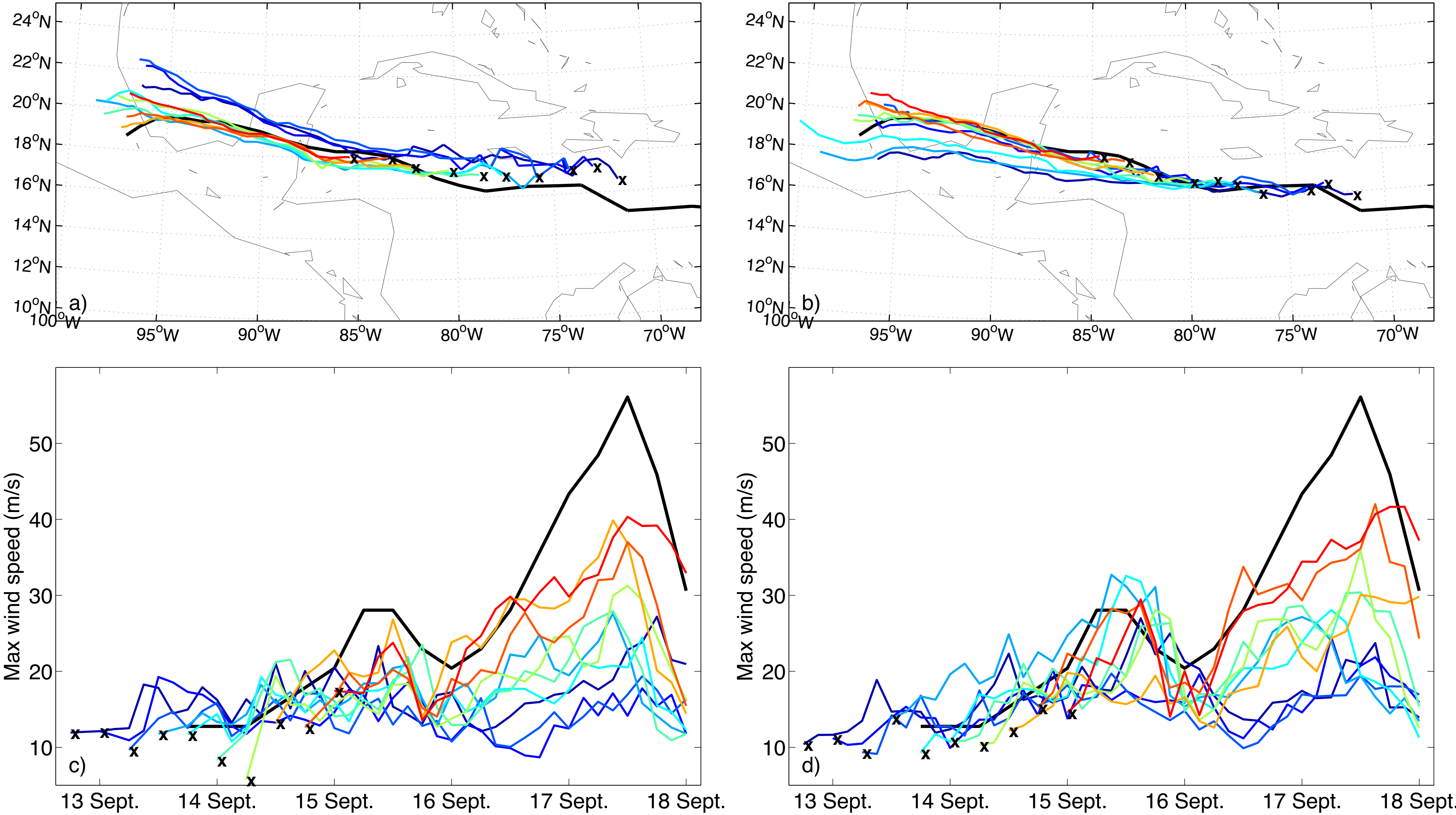
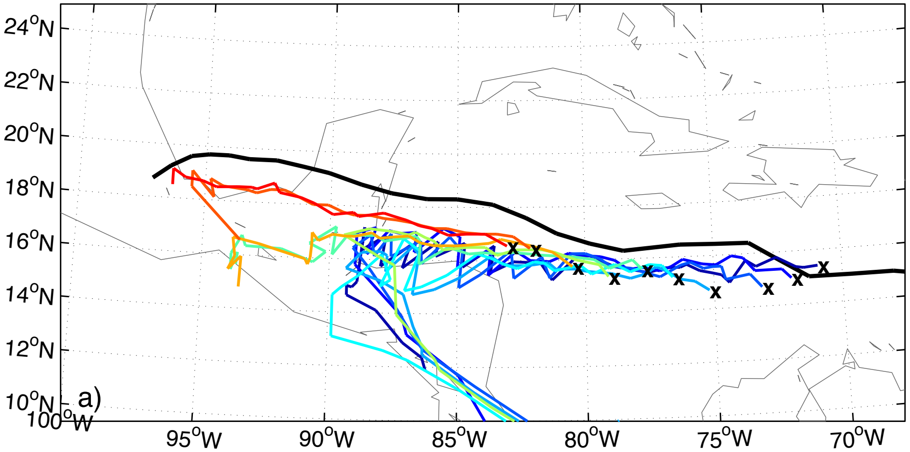
Jon’s results | Reproduced

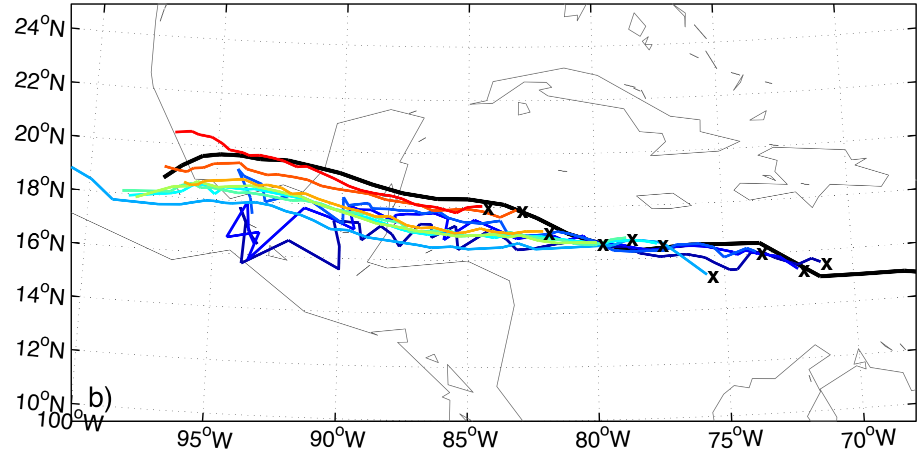


Performance of relaxation methods: Track deterministic forecasts

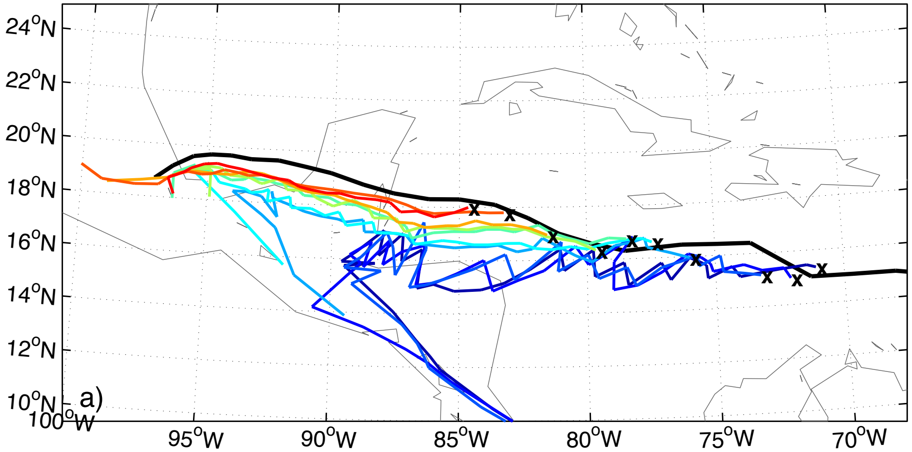
No inflation



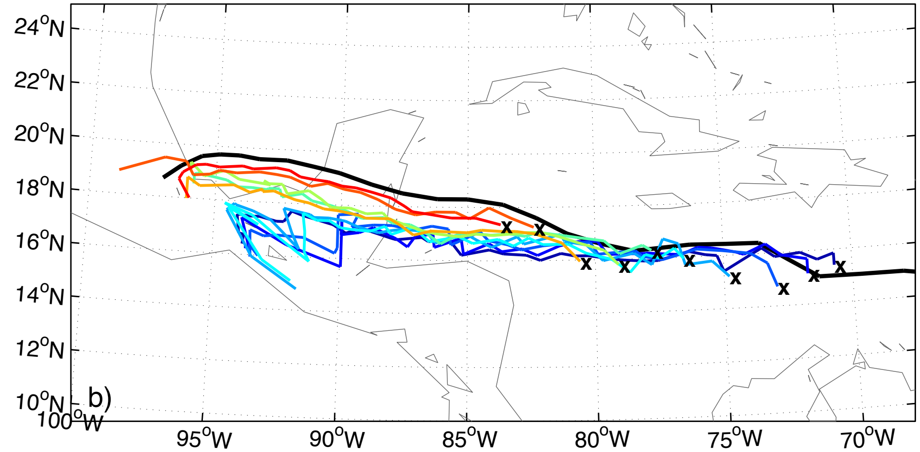
RTPP 0.8



RTPS 0.8



ACR



Performance of relaxation methods: Intensity deterministic forecasts

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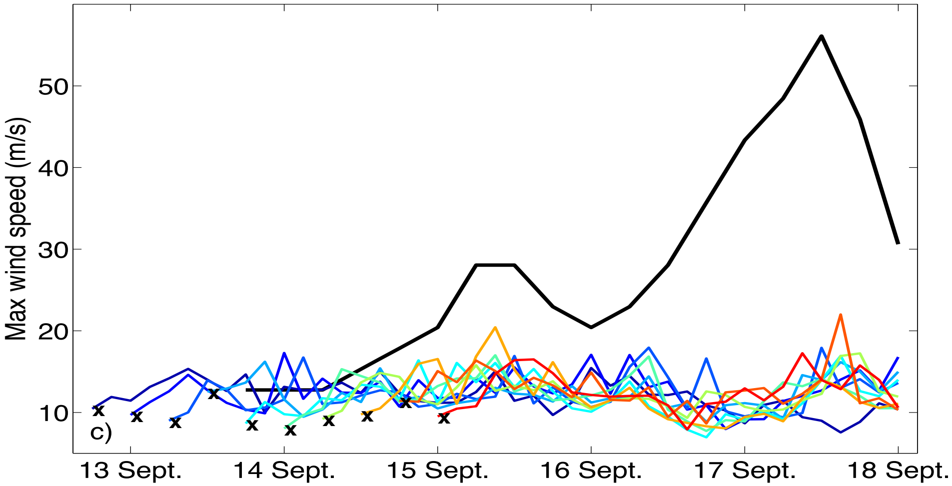
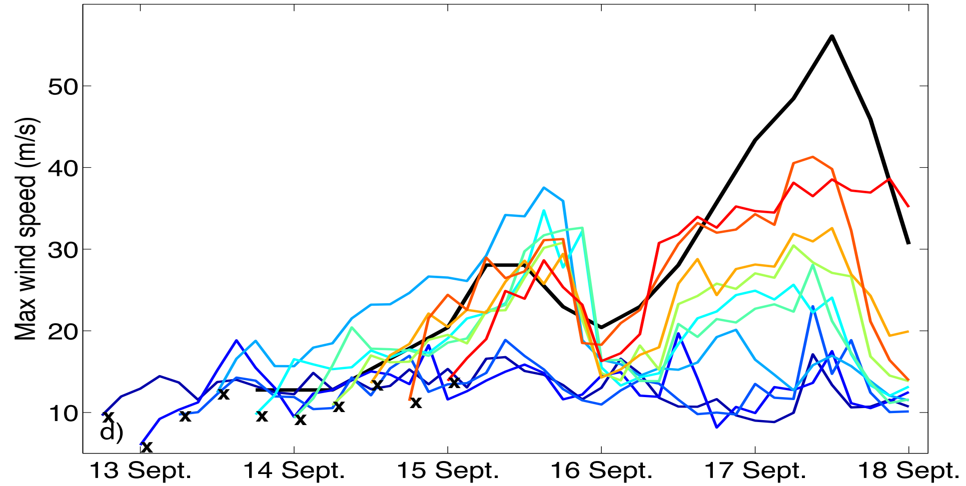
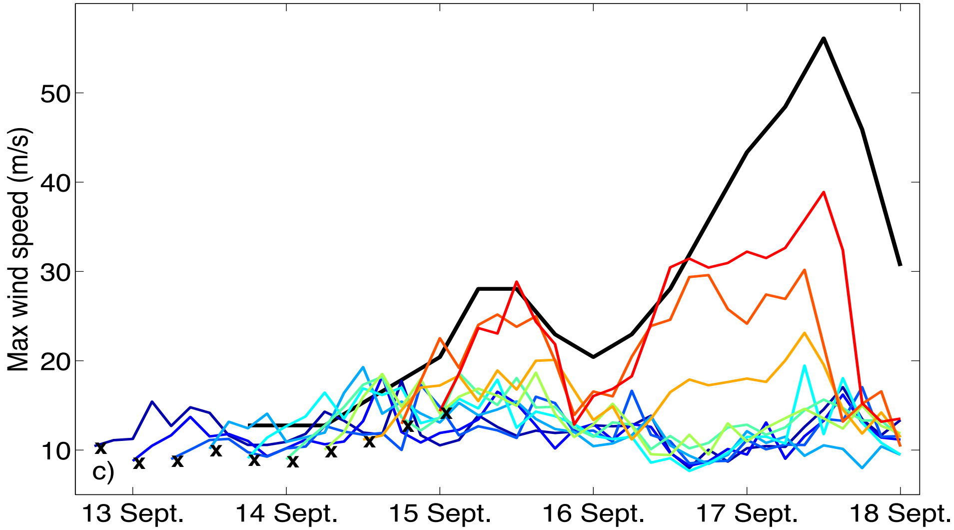
No inflation



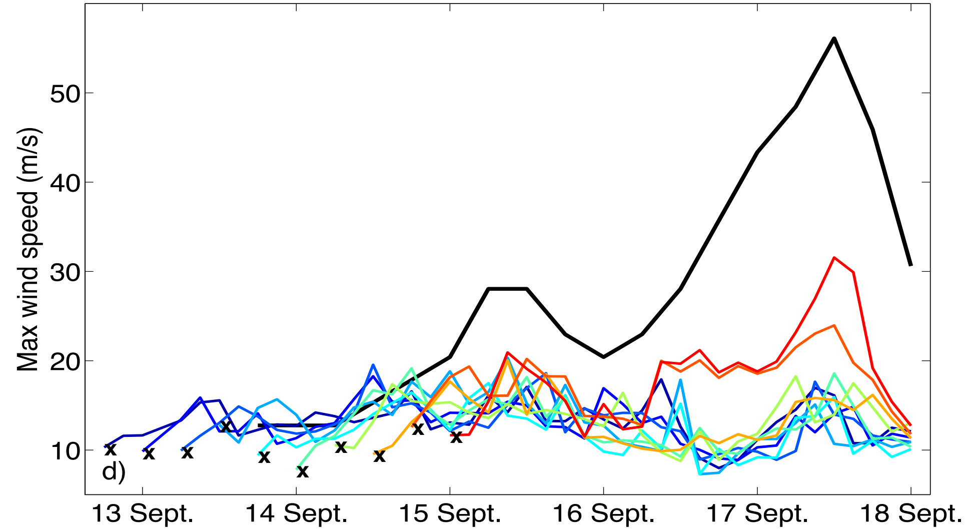
RTPP 0.8



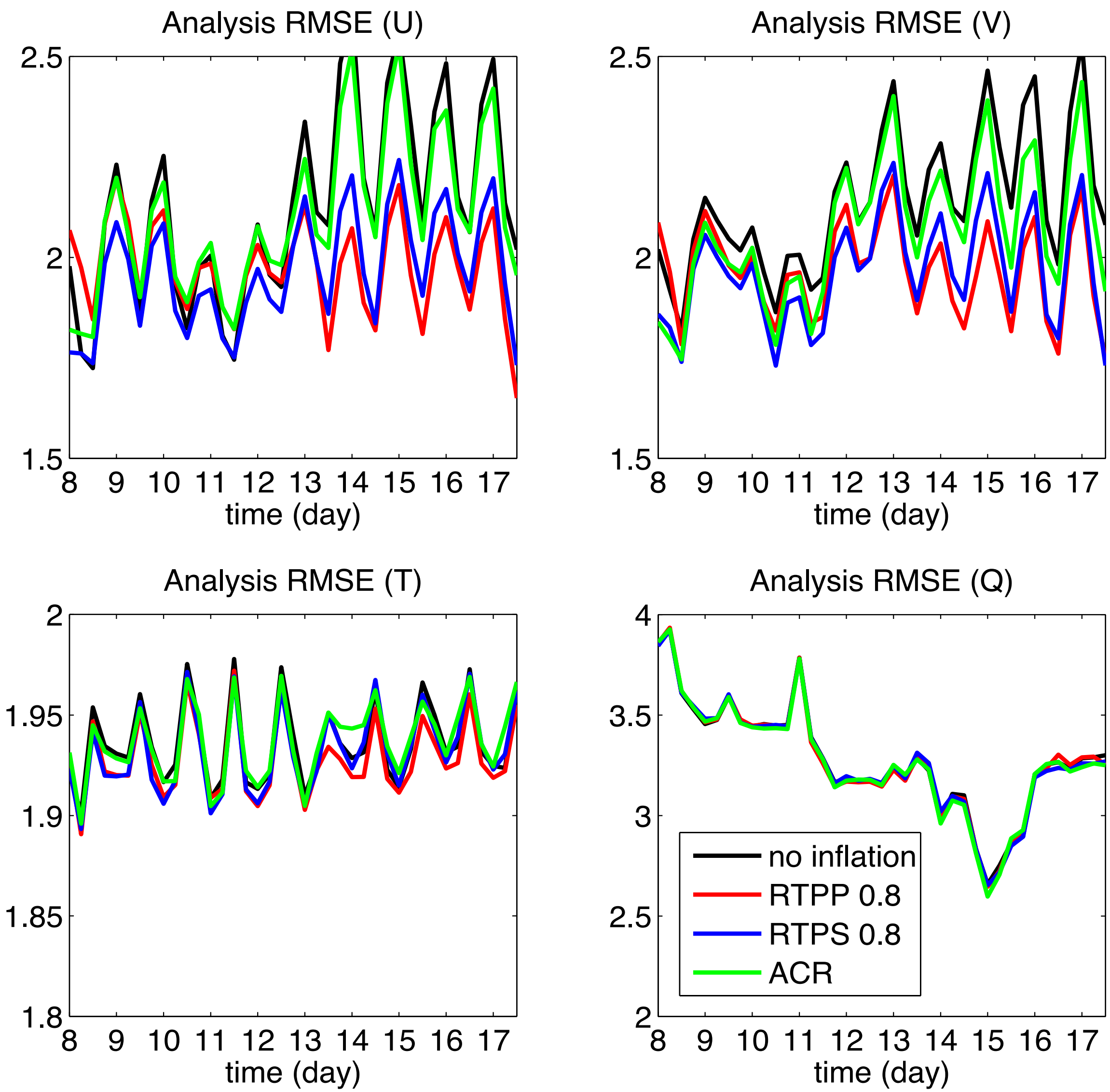
RTPS 0.8



ACR

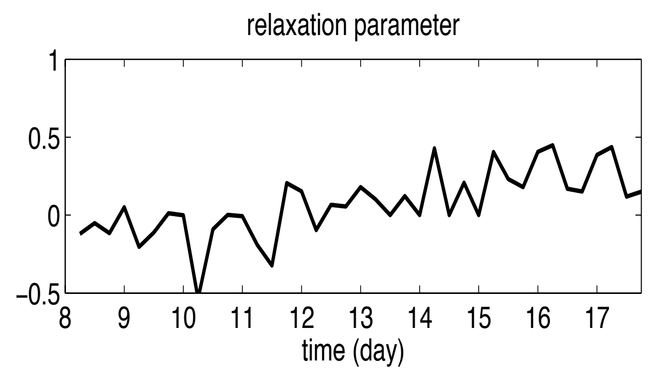


Performance of relaxation methods: Analysis RMSE

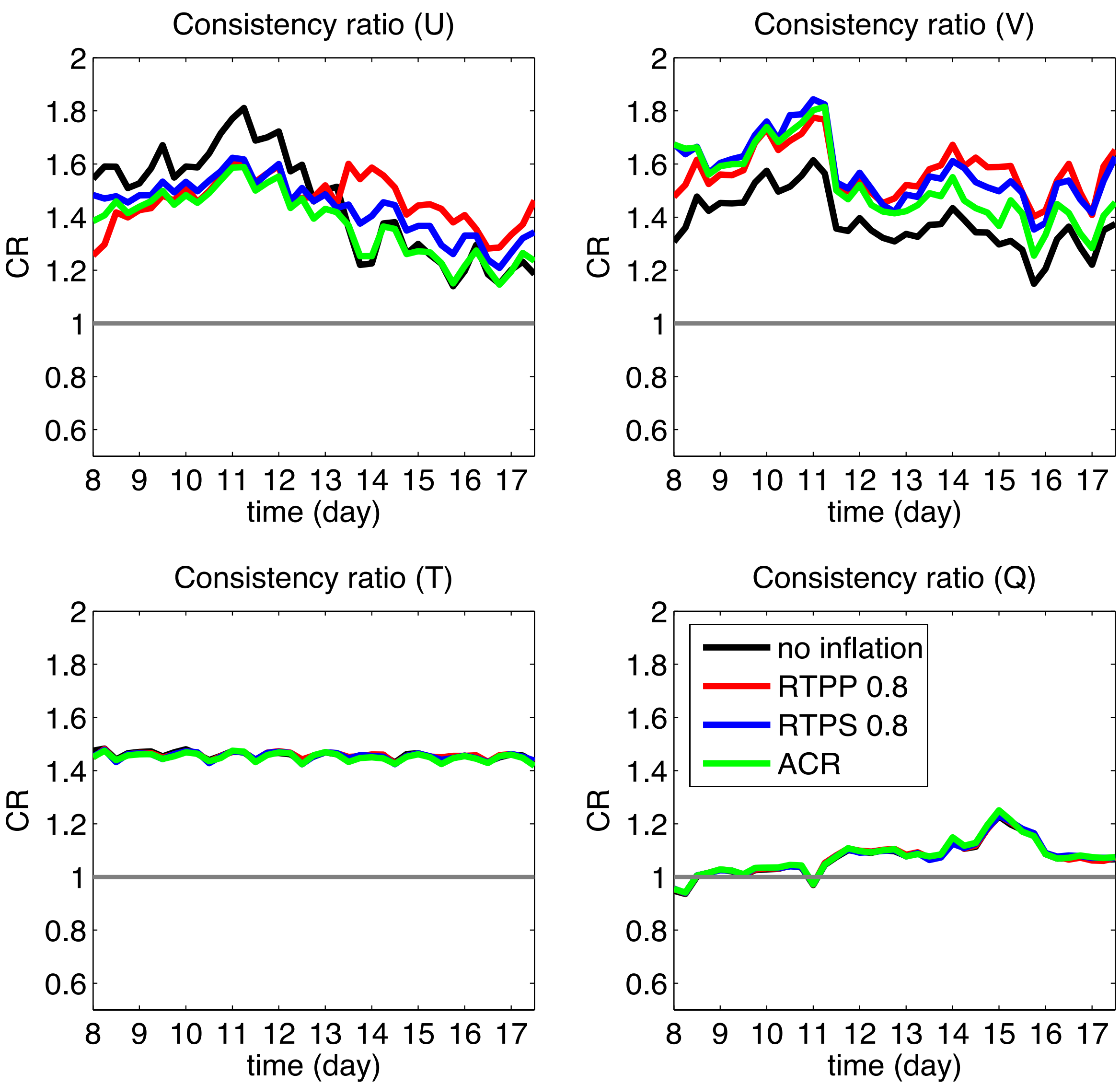


Most impacts in U,V

ACR finds $\alpha < 0.5$

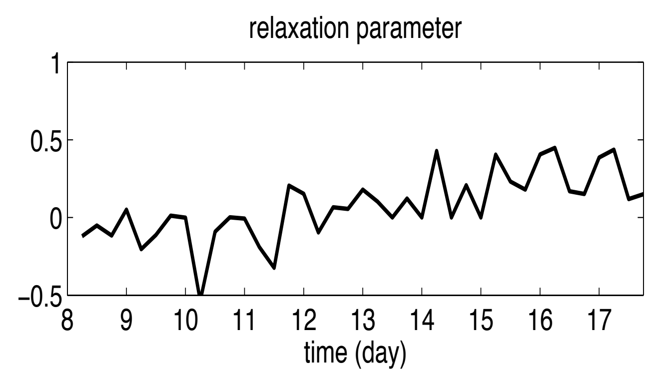


Performance of relaxation methods: Consistency ratio



Ensemble is over-dispersive

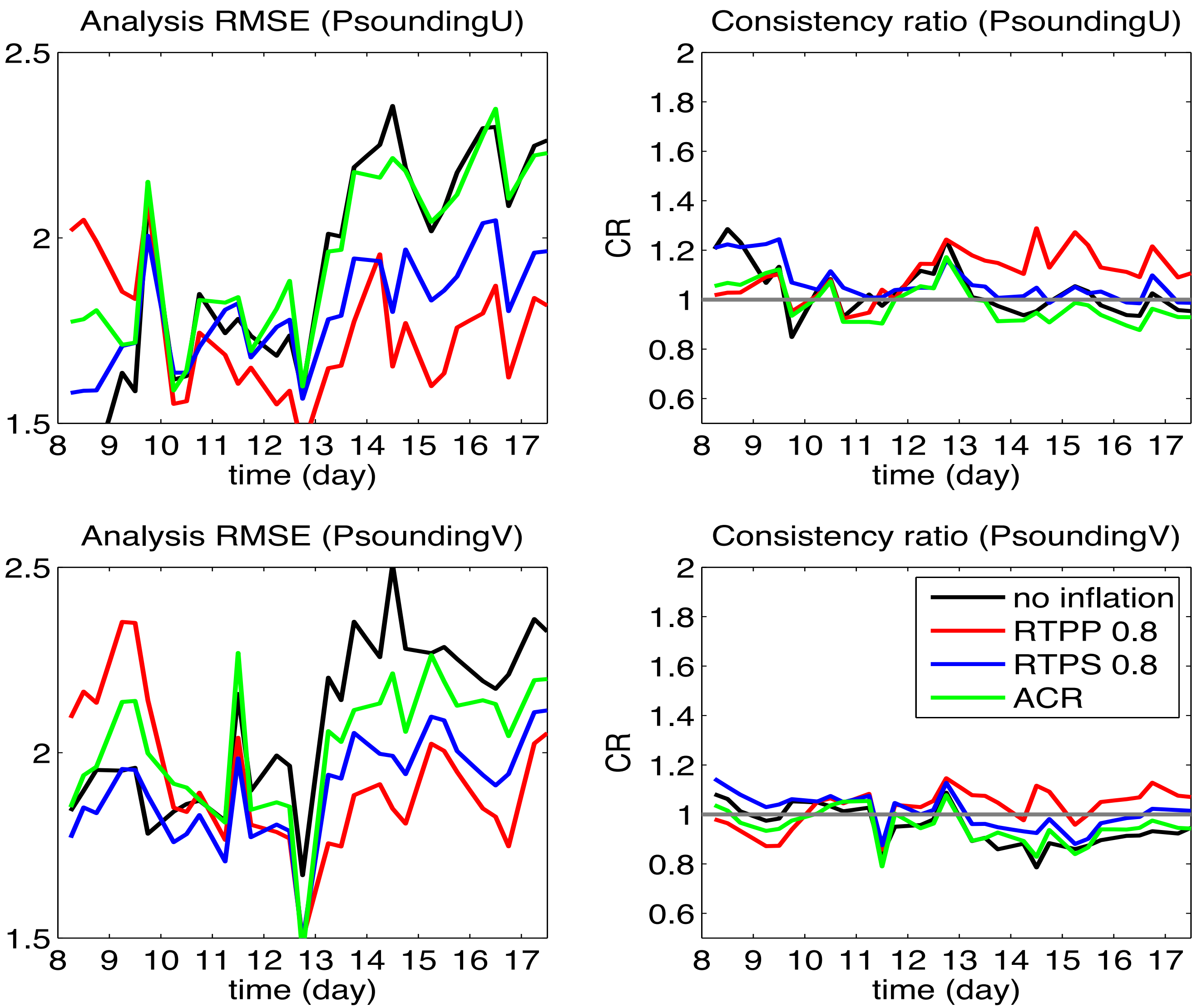
ACR finds $\alpha < 0.5$



Why does ACR not find the needed inflation (at least α=0.8)?

Why does RTPS gives worse deterministic forecast than RTPP, when they both reduced analysis error?

Why does ACR gives less than needed inflation?



PREDICT dropsonds

Why does ACR gives less than needed inflation?

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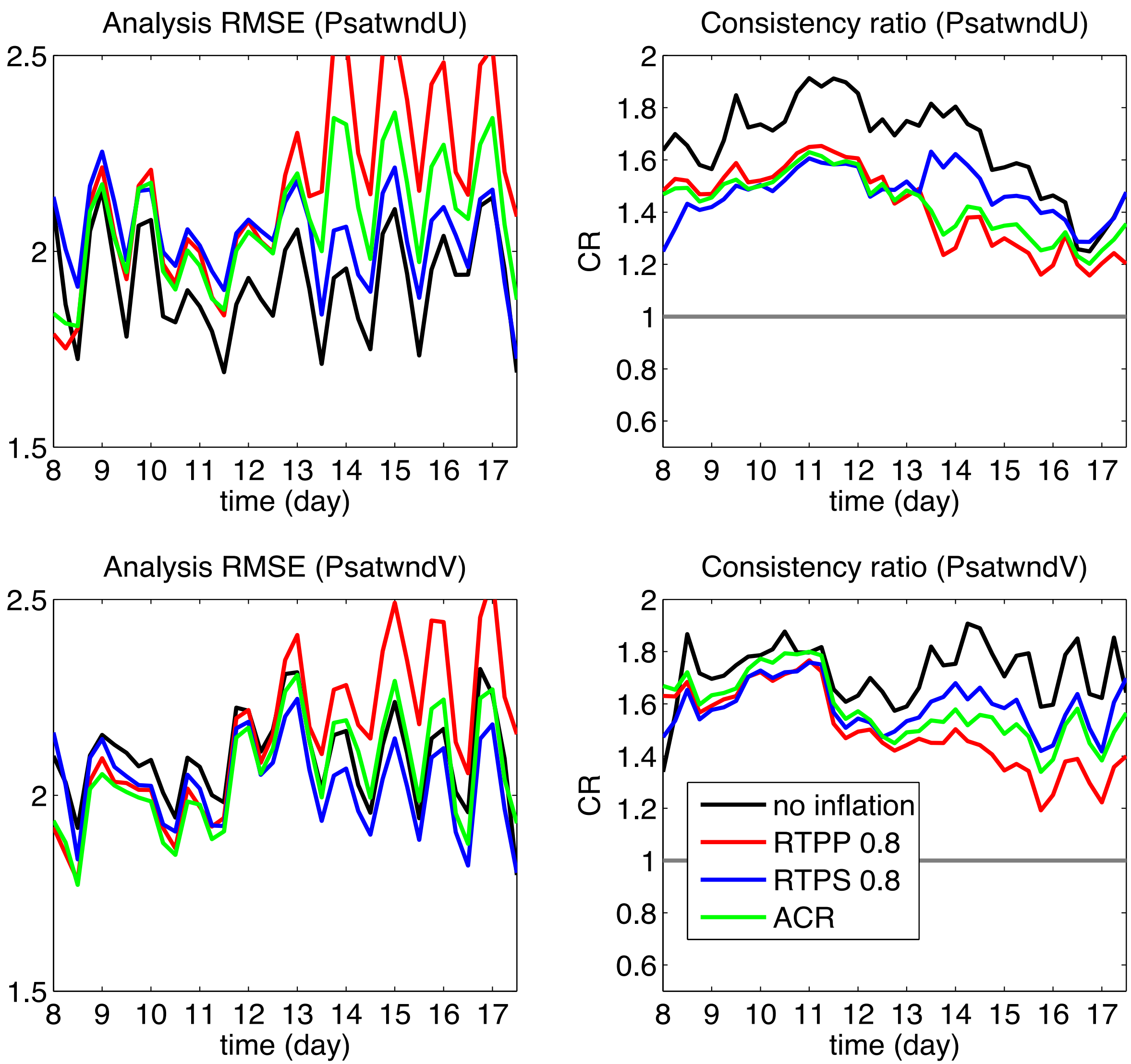
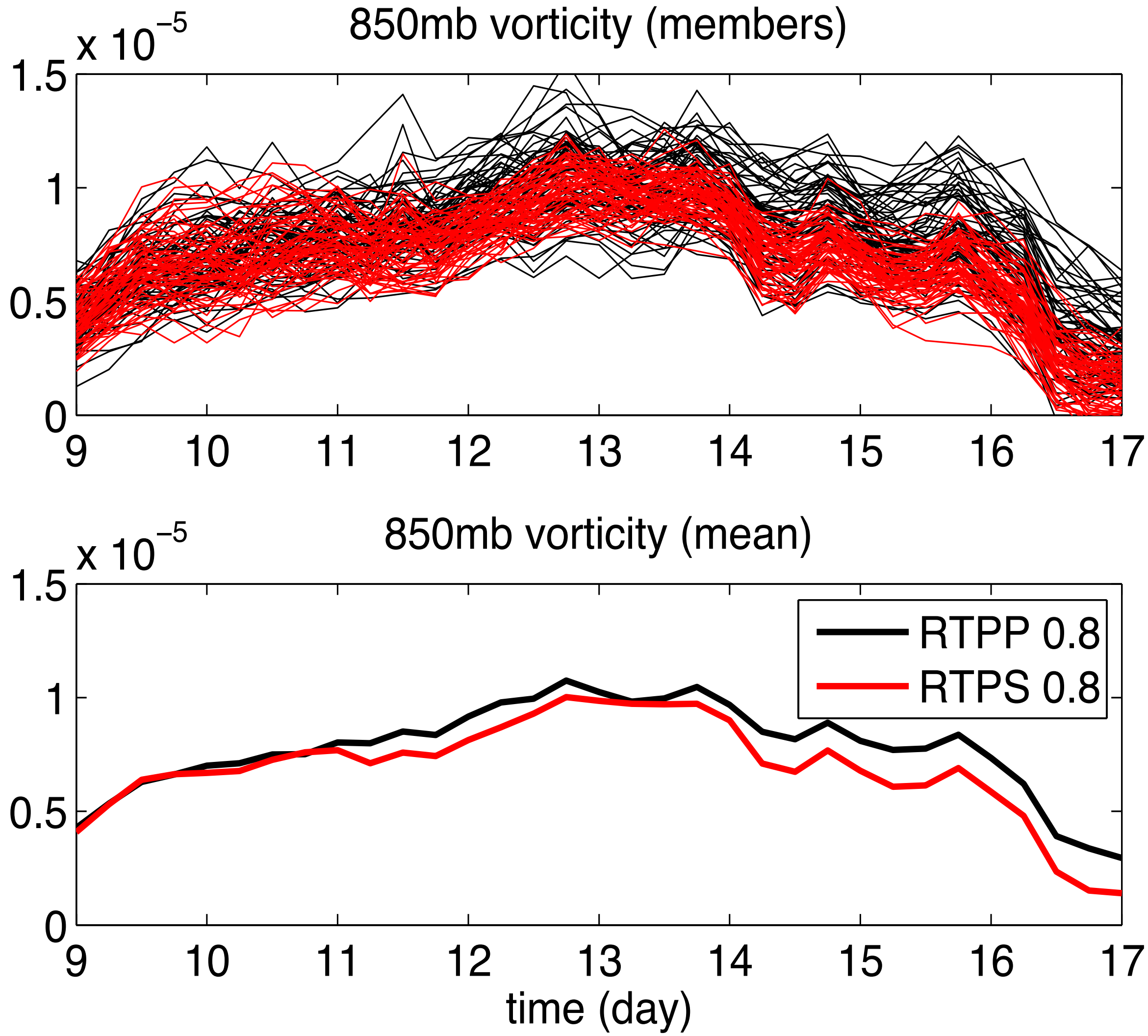


MADIS
Satellite-derived
Winds

More than
half the data

Innovation stats.
could be over-
whelmed by
Psatwnd

Why does RTPS gives worse deterministic forecast than RTPP, when they both reduced analysis error?



Mean vorticity from a 1350*1350 km^2 storm-following slab

As a measure of dynamic structure / balance?

Hypothesis

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The prior ensemble perturbation x'^{b} has better balance/structure (after model integration).

Assimilation-induced imbalance in x'^{a} is harmful for the prediction of Hurricane Karl genesis.

If prior ensemble perturbations have good dynamic balance, why not use them (instead of posteriors) in RTPS?

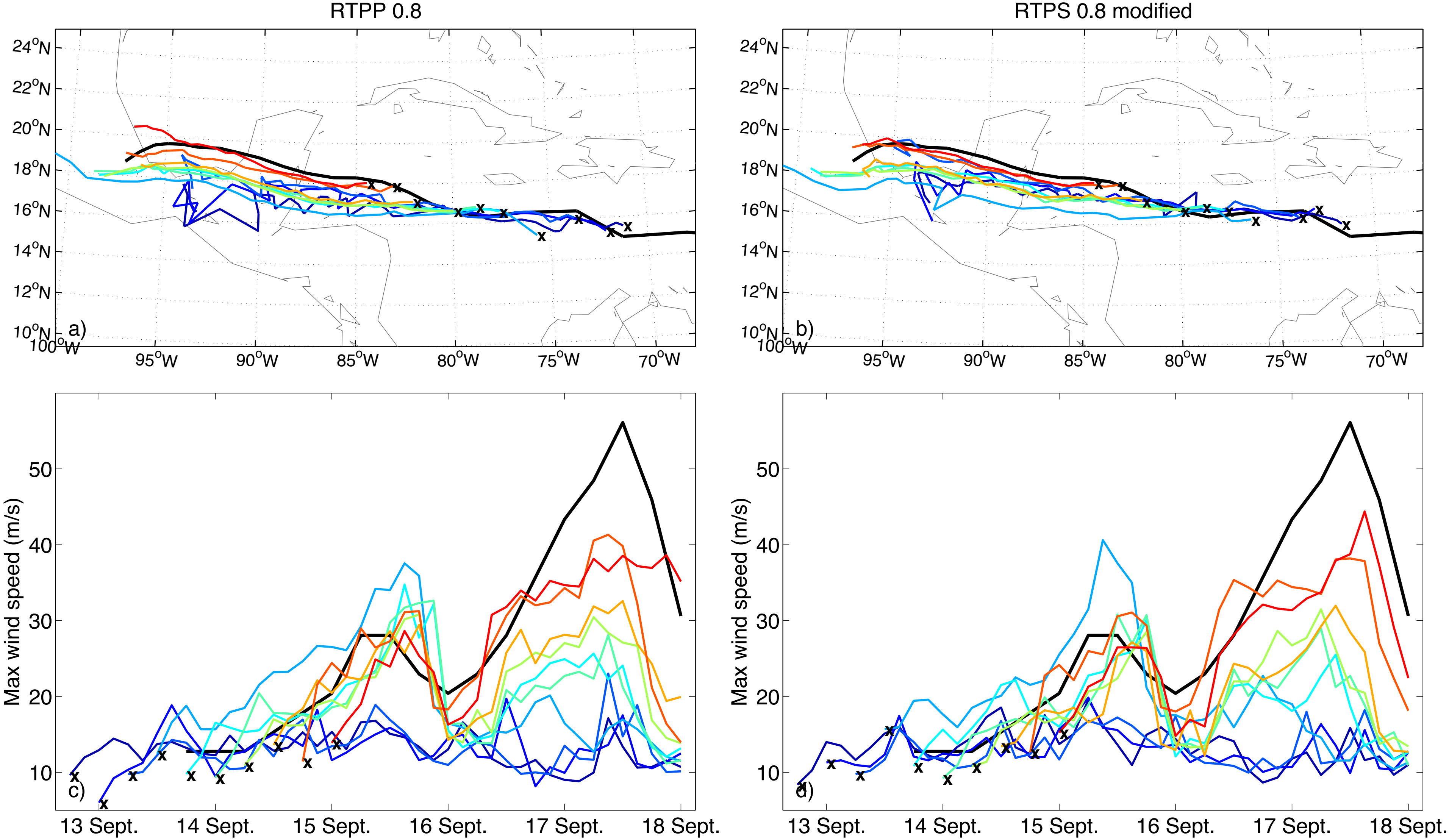
RTPS:

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

RTPS modified:

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

Modified RTPS method



Concluding remarks

In mixed-type observation case, innovation statistics could be dominated by certain observation, which results in failure of getting the desired inflation factor.

Prior perturbations contains valuable dynamically balanced structure so that keeping them helps improve deterministic forecasts.

On-going:
Reformulate ACR to take advantage of prior perturbations