Performance of the multiscale alignment ensemble filter in reducing vortex position errors

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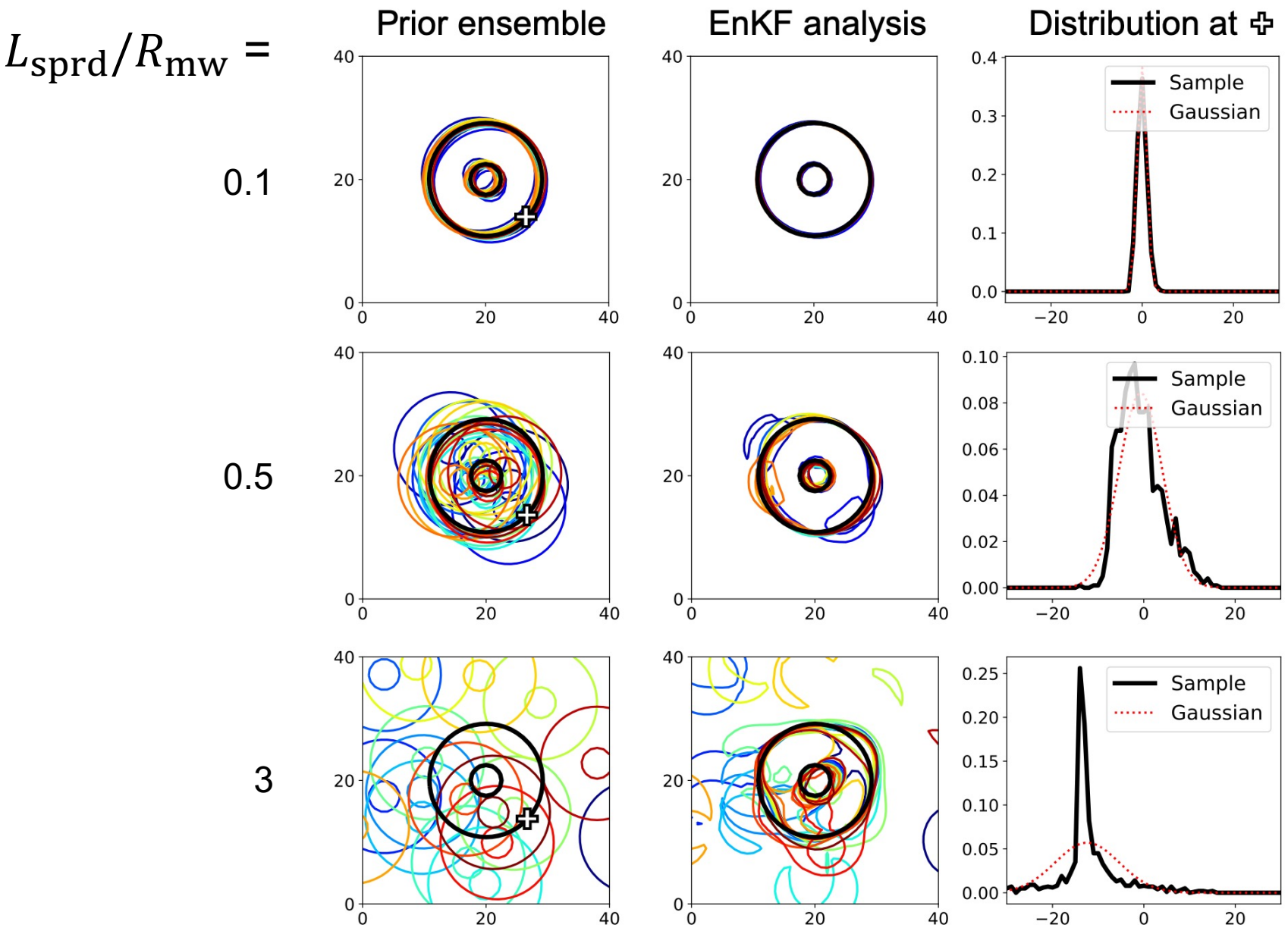
Nonlinearity due to vortex position errors

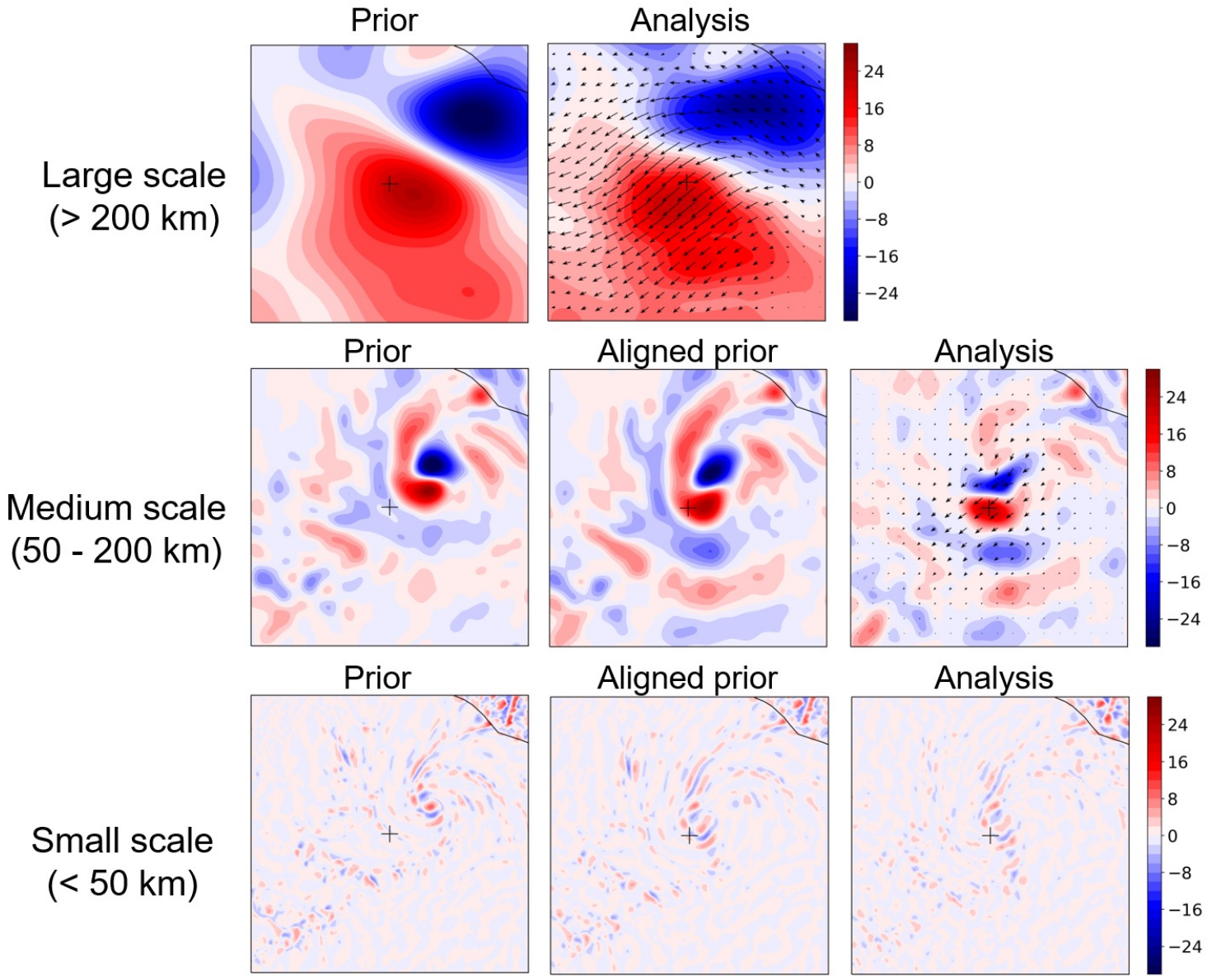


Contours of constant wind speed from vortices:
black: truth
colors: ensemble members

As position error L_{sprd} increases,

- error distribution becomes more non-Gaussian,
- EnKF analysis becomes more suboptimal

The multiscale alignment ensemble filtering idea



Example: Hurricane Patricia (2015)

blue/red shadings: *u*-wind for the *Ns* = 3 scale components.

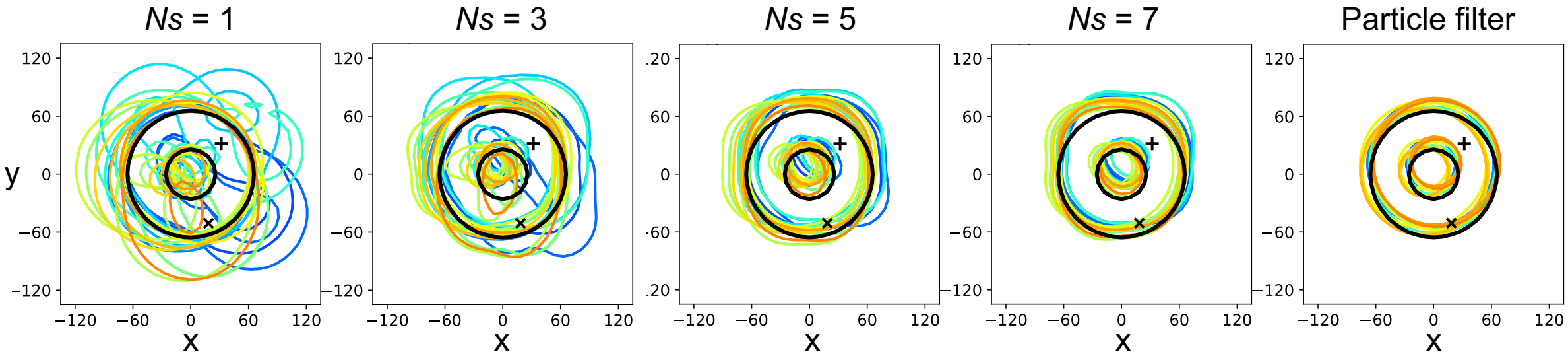
vectors: the displacement vectors computed from the analysis increments

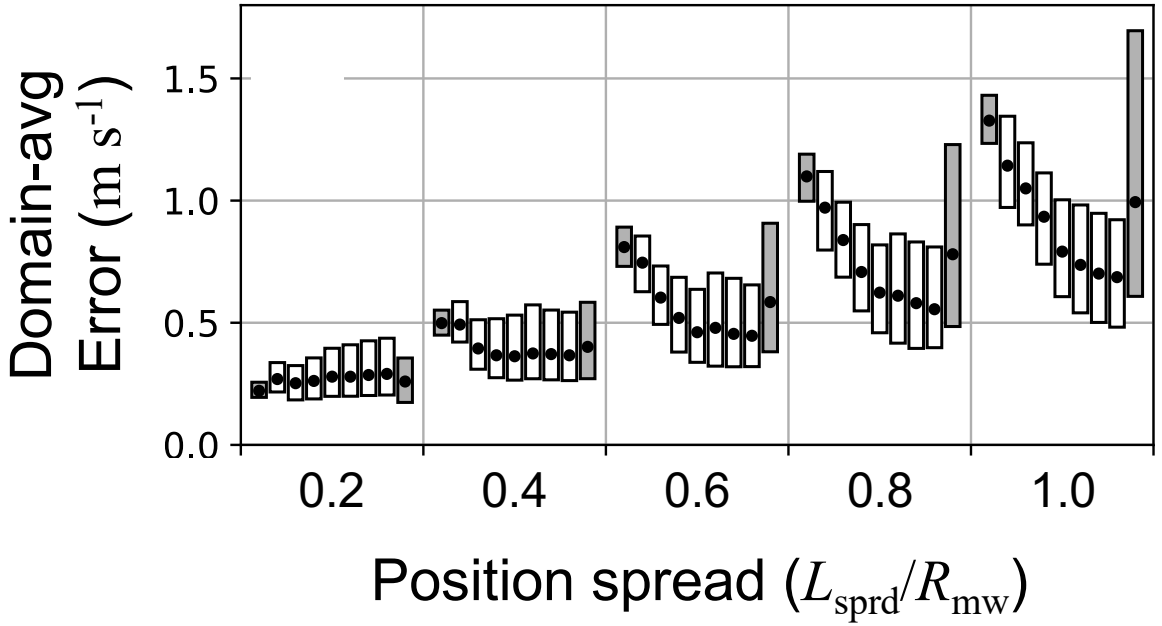
Iterate over scale components:

1. EnKF assimilate observations,
2. Find displacements (optical flows), which are applied to the smaller scales to align (precondition) the prior,
3. go to next scale …

(MSA; Ying 2019, MWR)

Asmptotic behavior as *Ns* increases



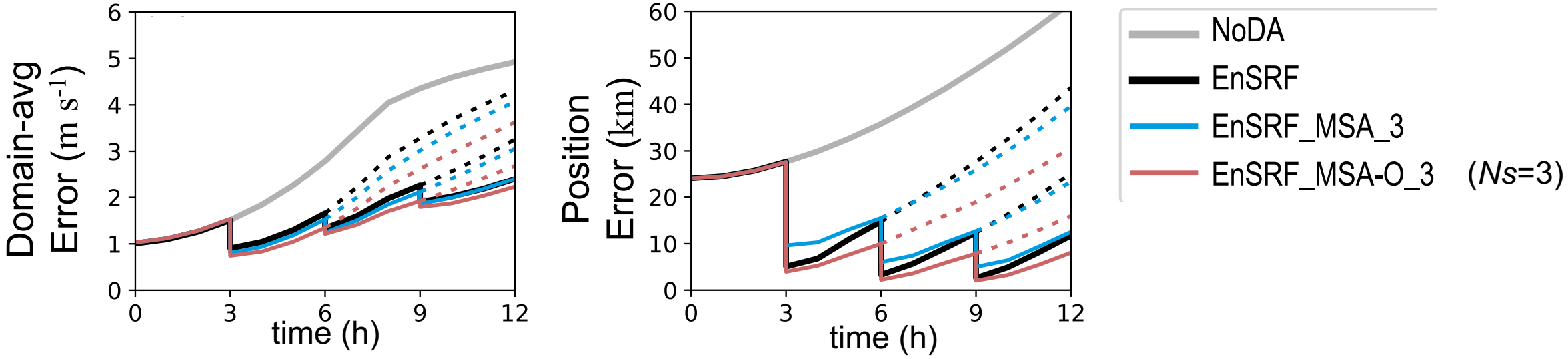


Domain-averaged RMSE from 1000 trials (boxplot)
(left-right: **NoDA**, **EnSRF** *Ns* = 1, 2, …, 7, **PF**)

- Performance improve as *Ns* increases in nonlinear regimes.
- For the quasi-linear regime, some degradation is due to smearing of sharp gradients in alignment.

(Ying, Anderson & Bertino, MWR, in review)

Performance in a cycling DA experiment



Assimilating filtered observation at corresponding scales (MSA-O) improves filter update and the overall performance.

MSA-O outperforms EnSRF in both analyses and forecasts
at equal cost! (MSA ensemble size is reduced to compensate for increased *Ns*)

(Ying, Anderson & Bertino, MWR, in review)

Issue when deviating from coherence assumption

background flow errors
and vortex position errors

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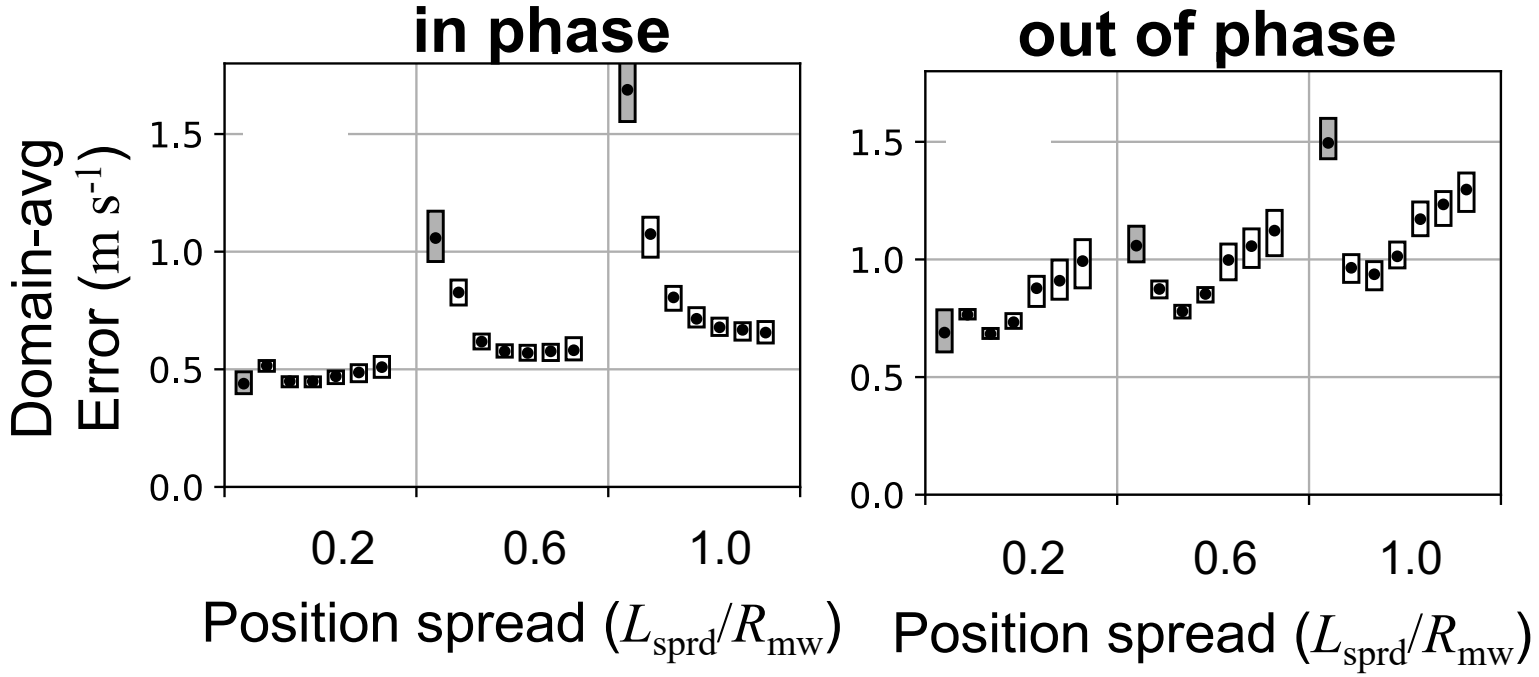

MSA makes **a coherence assumption** (large-scale pattern analysis increment → displacements → align the small-scale features)

If background flow errors are incoherent with the vortex position error (out-of-phase), the MSA performance degrades.

How often does this happen in real applications?

(Ying, Anderson & Bertino, MWR, in review)

Take home message

We performed stress test of the MSA method in a 2D vortex model:
MSA outperforms EnKF at equal cost (reduced ensemble size for large *Ns*)

Found/resolved issues:

- Sometimes alignment causes smearing of sharp gradients (high-res grid)
- Using filtered observation at corresponding scales improves filter update.
- Breaking the coherence assumption (caution when the large-scale pattern evolves independently from the small-scale features)

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