Ensemble initial conditions targeted at the convective scale

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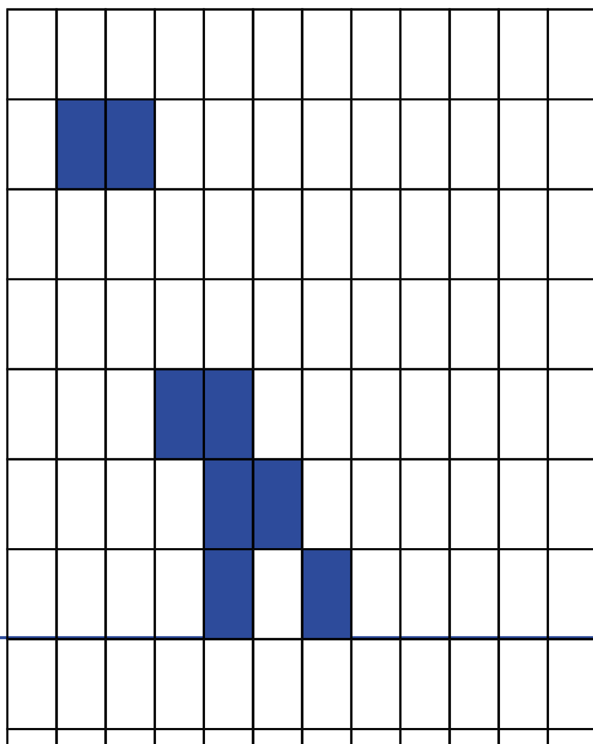
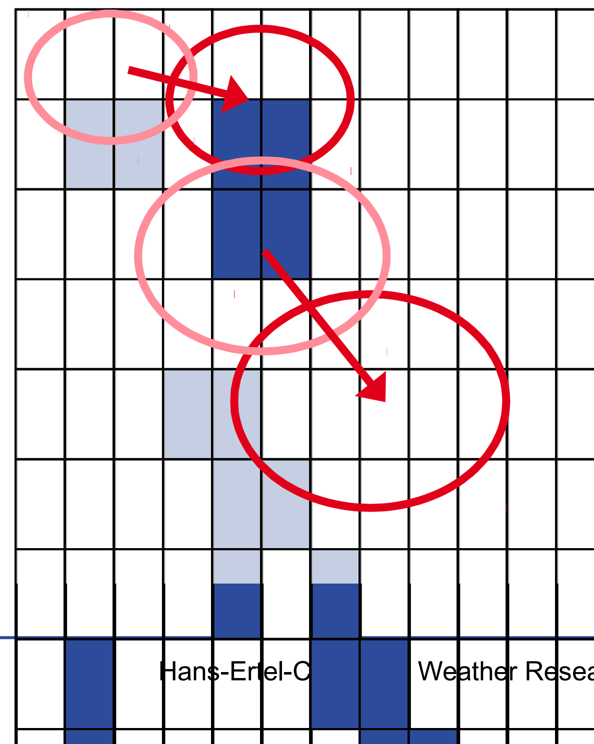
Motivation

- Convective events in LAMs
  - Forecasting has significantly improved
  - Correctly predicting location is largest issue





Motivation

- Convective-scale data assimilation
  - Observations, e.g., radar, satellites
  - Covariance structures and uncertainties

✉ Enhance the representation of convective-scale uncertainties

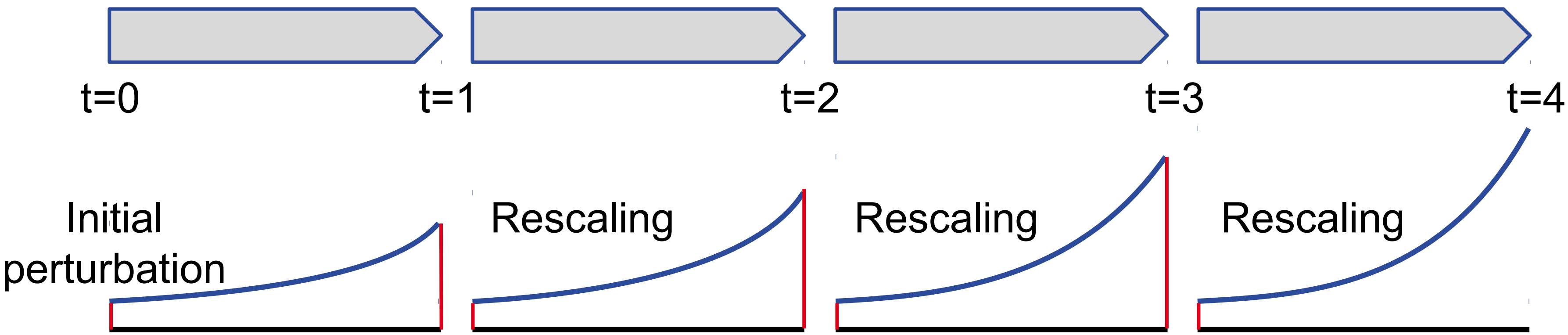
- Previous work indicated self-breeding perturbations and ensemble transform methods to work well in extreme cases

Approach

- Methods to estimate uncertainty
  - Simple Bred Vectors from Self-Breeding (SBV)
  - Ensemble Transform Bred Vectors (ETBV)
  - Ensemble Singular Vectors (ESV)

Approach

- Simple Bred Vectors



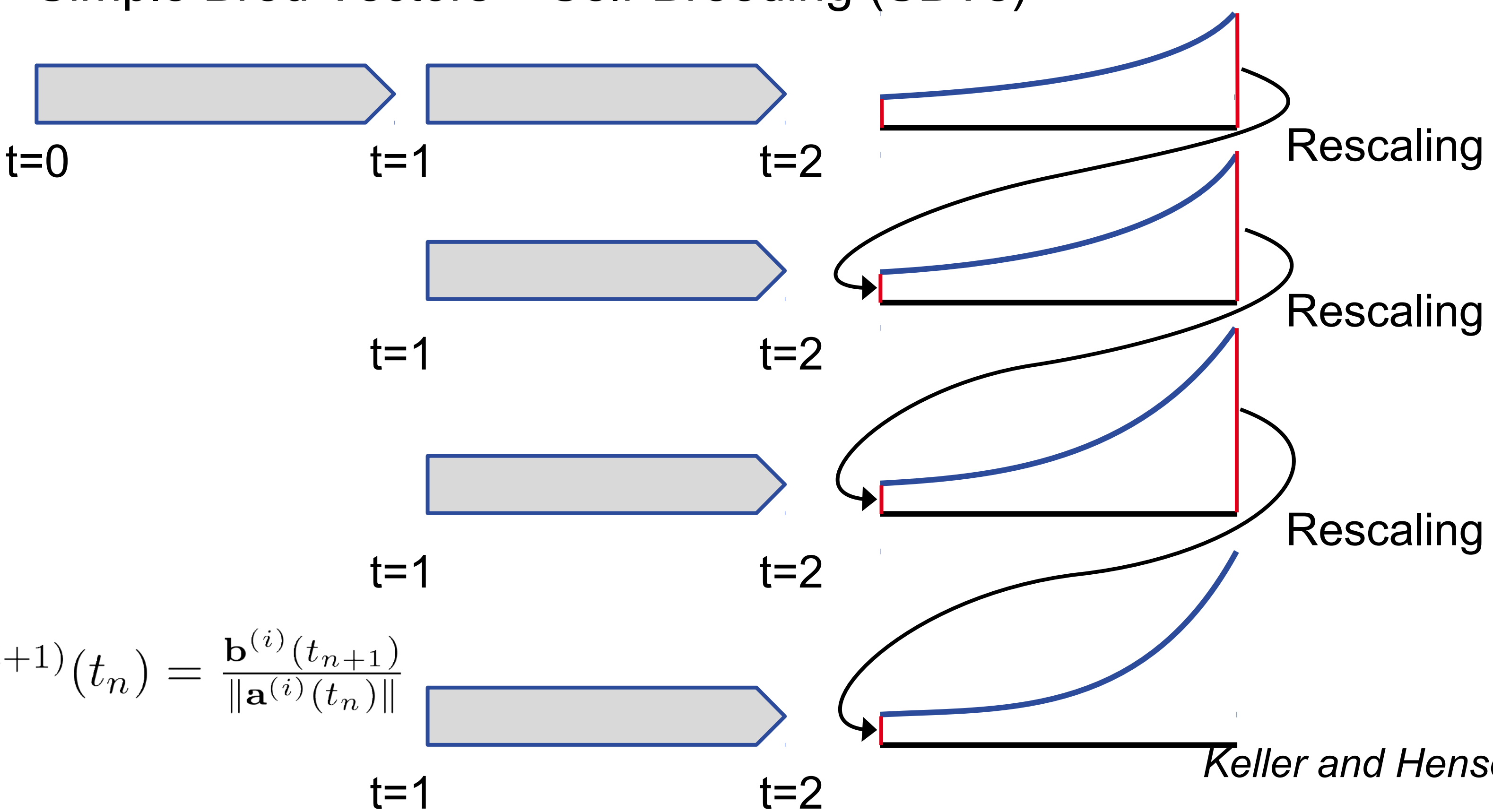
let $\mathbf{a}(t) = \mathbf{x}(t) - \hat{\mathbf{x}}(t)$ and $\mathbf{b}(t) = \mathbf{y}(t) - \hat{\mathbf{y}}(t)$ with $\mathbf{y}(t_{i+1}) = \mathcal{M}\mathbf{x}(t_i)$

then $\mathbf{x}(t_n) = \hat{\mathbf{x}}(t_n) + \mathbf{a}(t_n) = \hat{\mathbf{x}}(t_n) + \frac{\mathbf{b}(t_n)}{\|\mathbf{a}(t_{n-1})\|}$

e.g., Toth and Kalnay, 1993; 1997

Approach

- Simple Bred Vectors – Self-Breeding (SBVs)



$$\mathbf{a}^{(i+1)}(t_n) = \frac{\mathbf{b}^{(i)}(t_{n+1})}{\|\mathbf{a}^{(i)}(t_n)\|}$$

Keller and Hense, 2014

Approach

- Ensemble Transform

$$\mathbf{Z}_{\mathrm{ET}} = \mathbf{Z}\mathbf{T}$$

Ensemble Transformation is designed to make optimal use of the ensemble space as provided by $\mathbf{Z}$

e.g., Bishop and Toth, 1999

- Ensemble Transform Bred Vectors (ETBVs)

$$\mathbf{A} = \mathbf{B}\widetilde{\mathbf{E}}\mathbf{\Lambda}^{-1/2}\mathbf{I}$$

ETBVs can be easily derived from BVs by applying an Ensemble Transformation with the transformation matrix given as solution to

$$(\mathbf{B}^T\mathbf{M}\mathbf{B})\widetilde{\mathbf{E}} = \widetilde{\mathbf{E}}\mathbf{\Lambda}$$

Keller et al., 2010

Approach

- Ensemble Singular Vectors (ESVs)

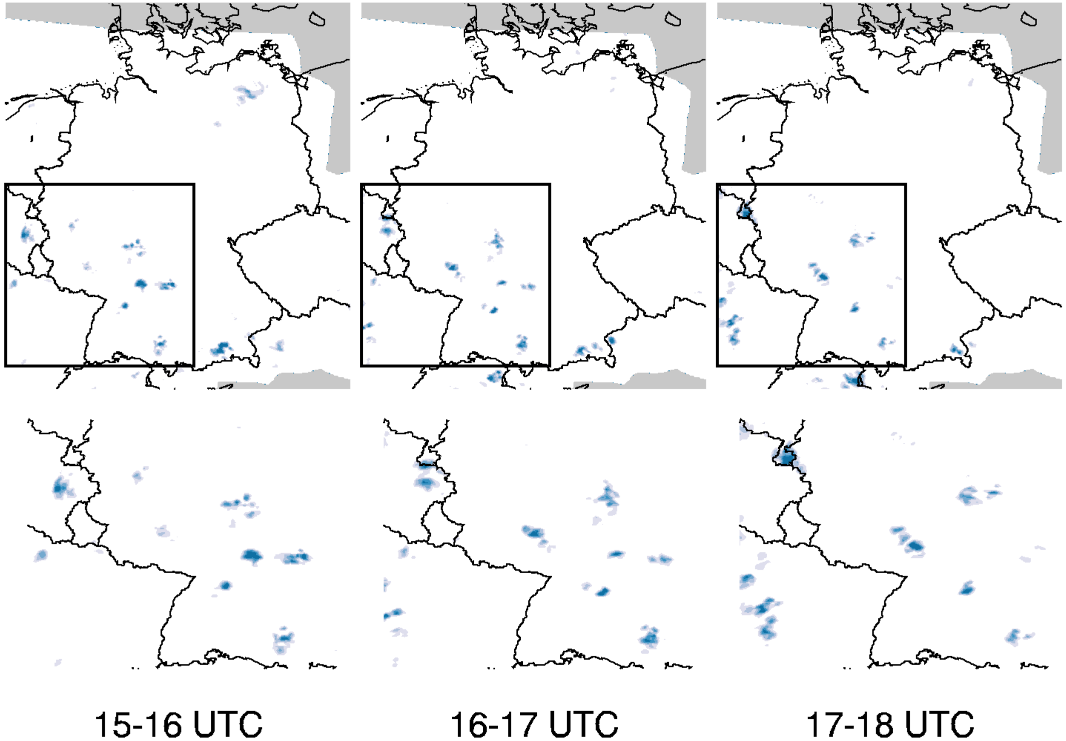
$$(\mathbf{A}^T\mathbf{M}\mathbf{A})^{-1}(\mathbf{B}^T\mathbf{M}\mathbf{B})\mathbf{E} = \mathbf{E}\mathbf{\Lambda}$$

  - Initial and forecast perturbations are used
  - Determines the singular vectors in ensemble space
    i.e. fastest growing perturbations wrt the given ensemble

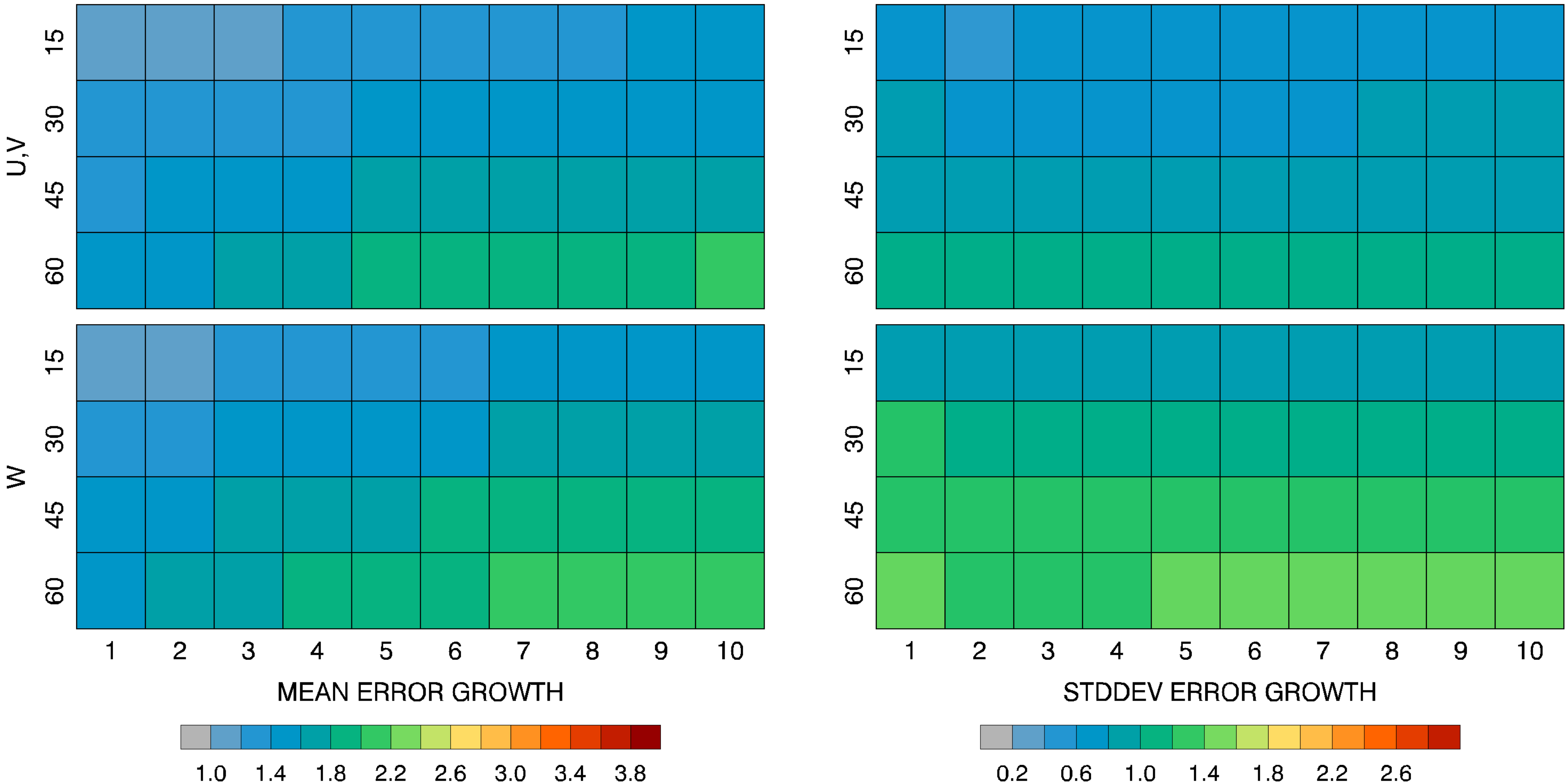
Yang et al., 2015

Case-Study Setup (1)

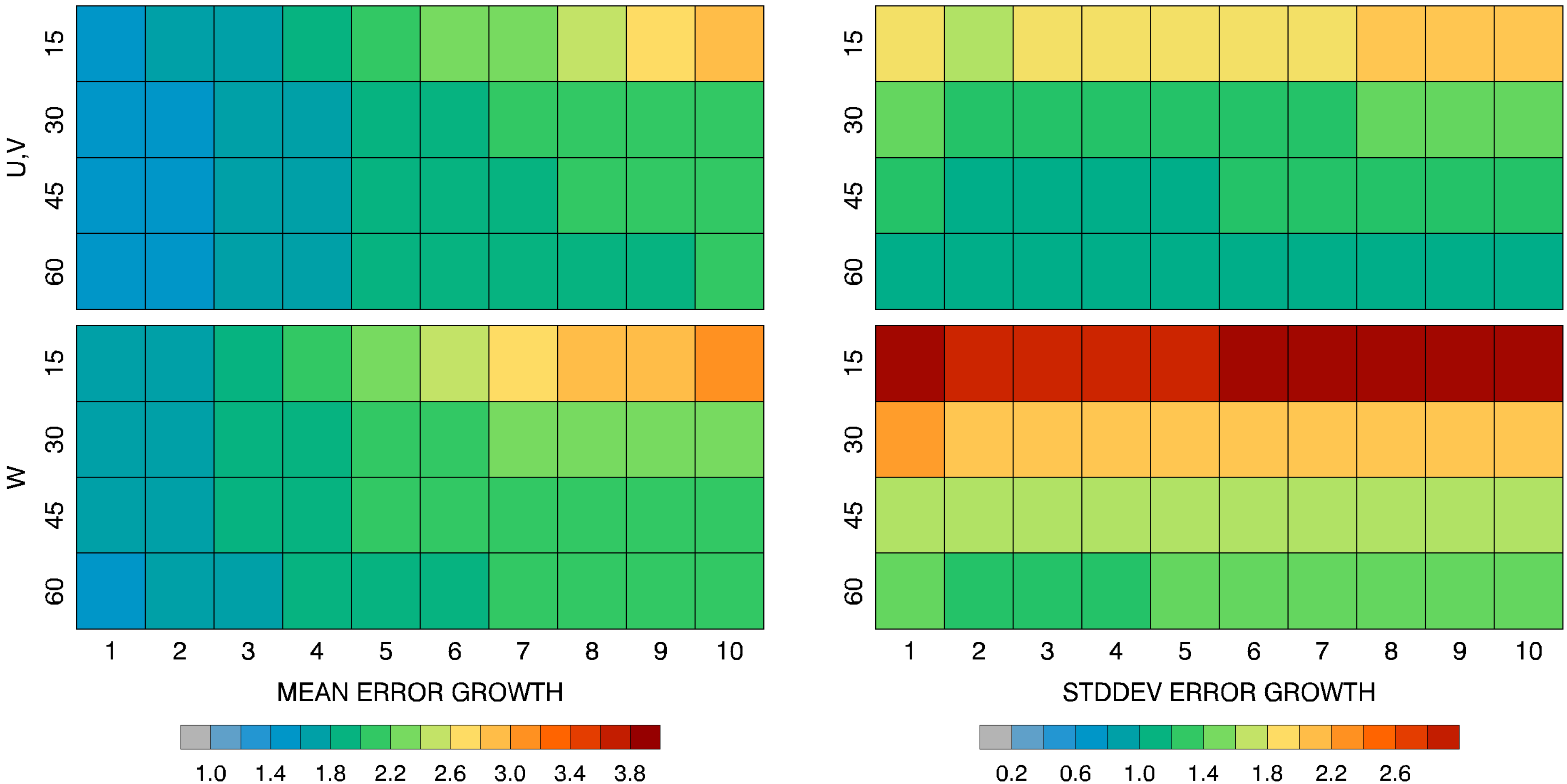
- COSMO LAM model at 2.8km (convection-permitting)
- 3 June 2014 - afternoon with scattered convective cells
- Initial cond … rs)
- Self-Breed
  - 1 rando
  - Recyclir
  - Norm: k



Results - Selfbreeding



Results - Selfbreeding



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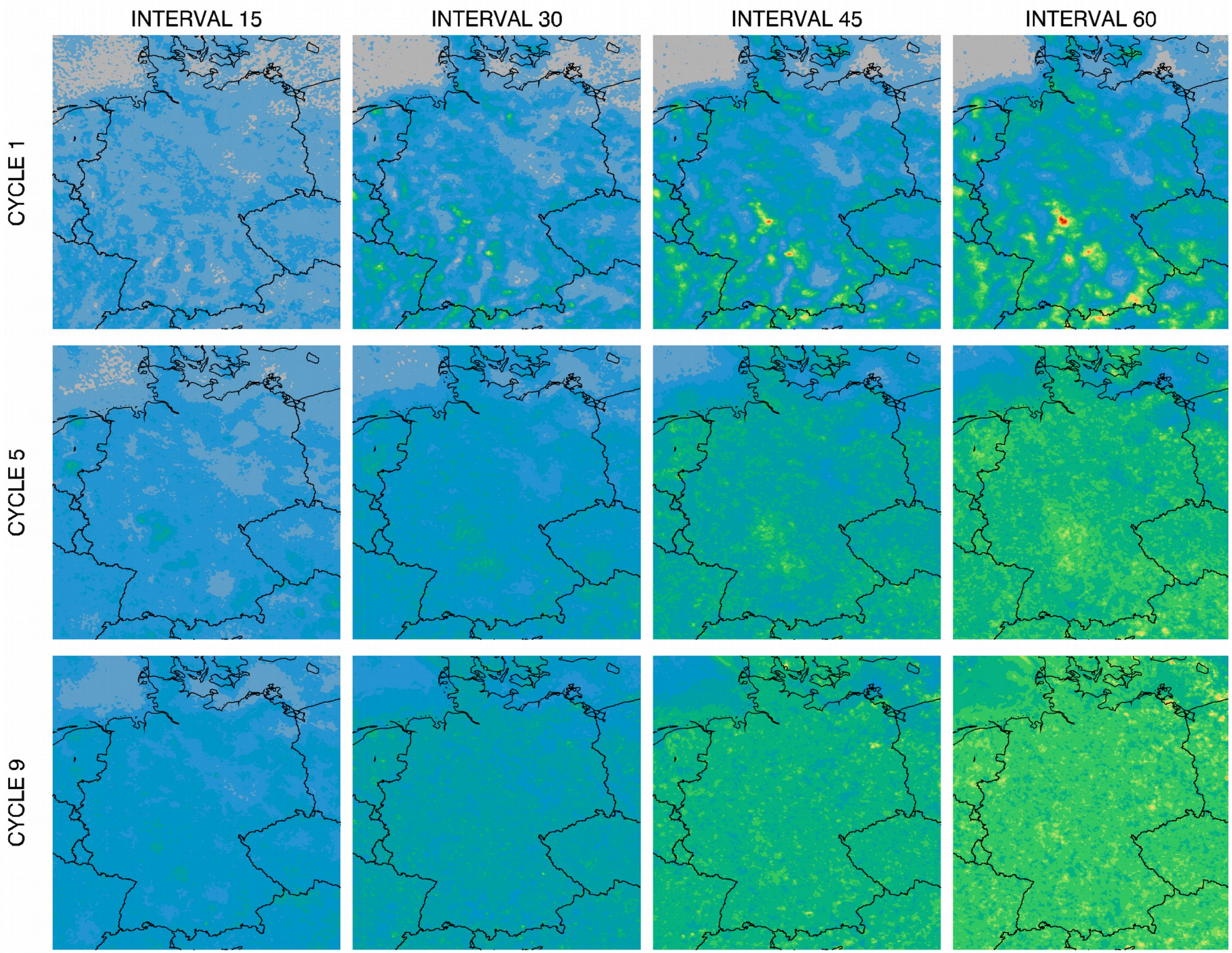
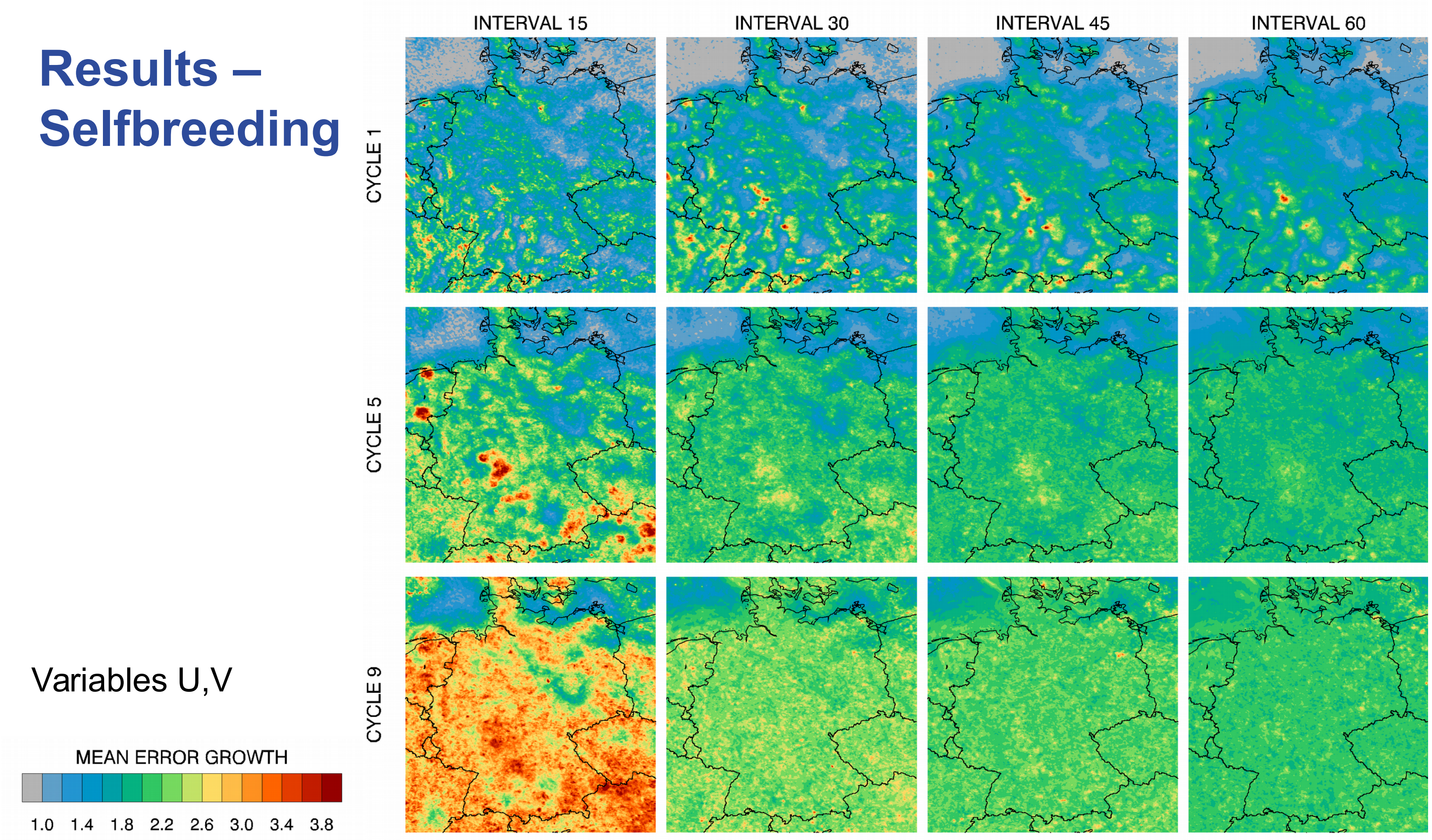


Variables U,V

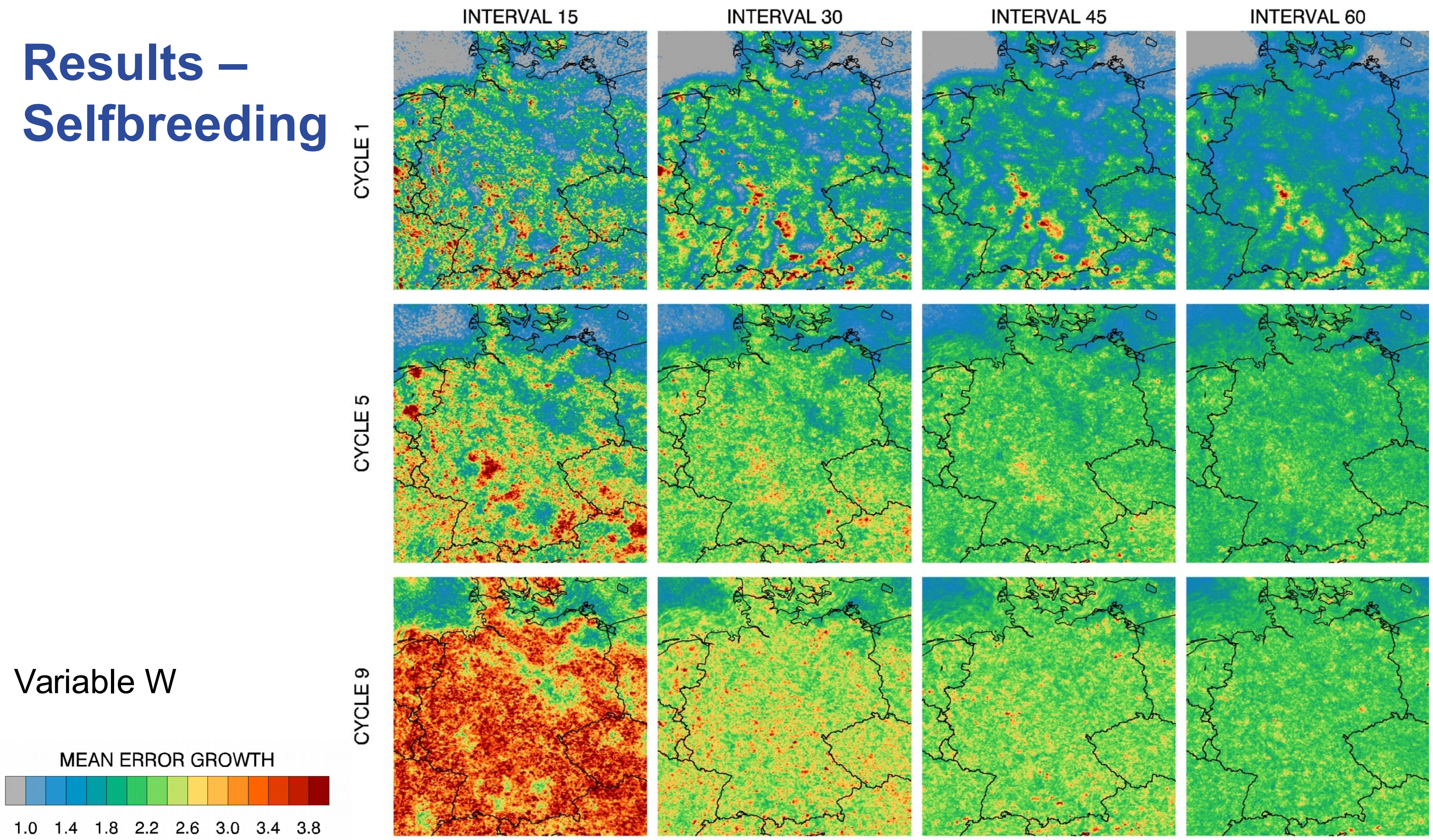
Results – Selfbreeding

Variables U,V



Results – Selfbreeding

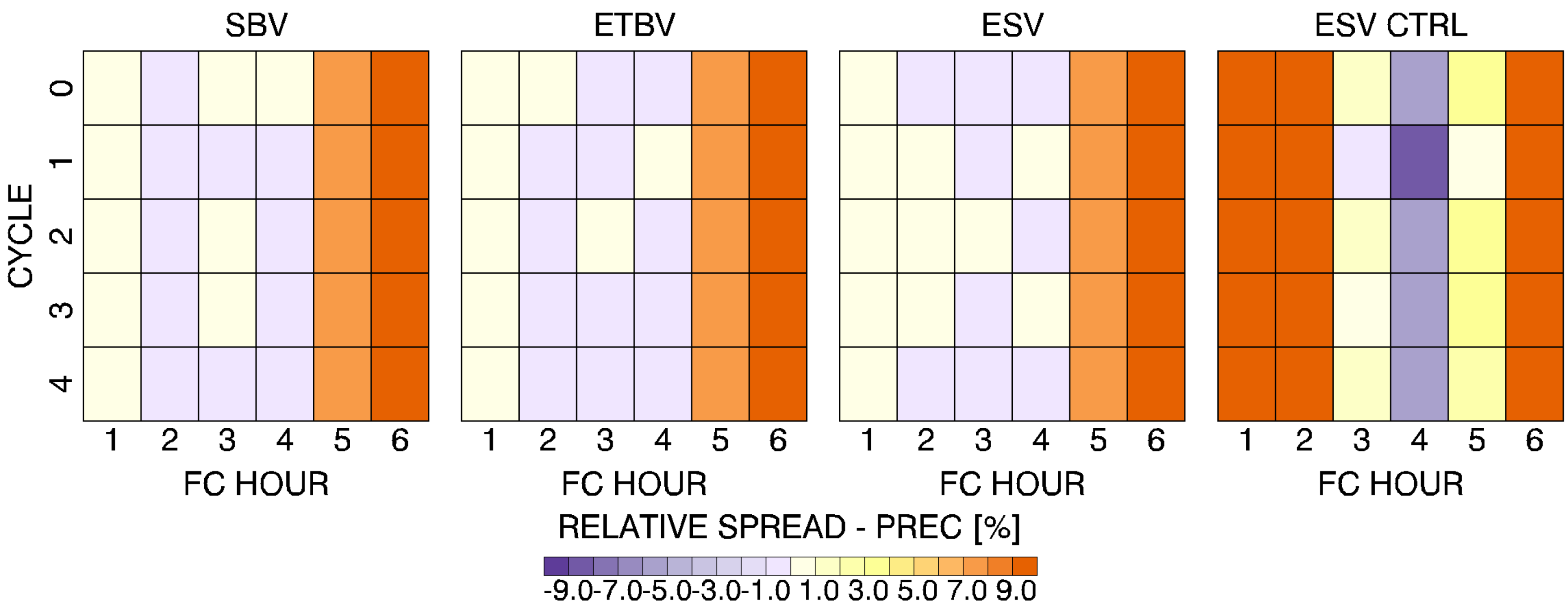
Variable W



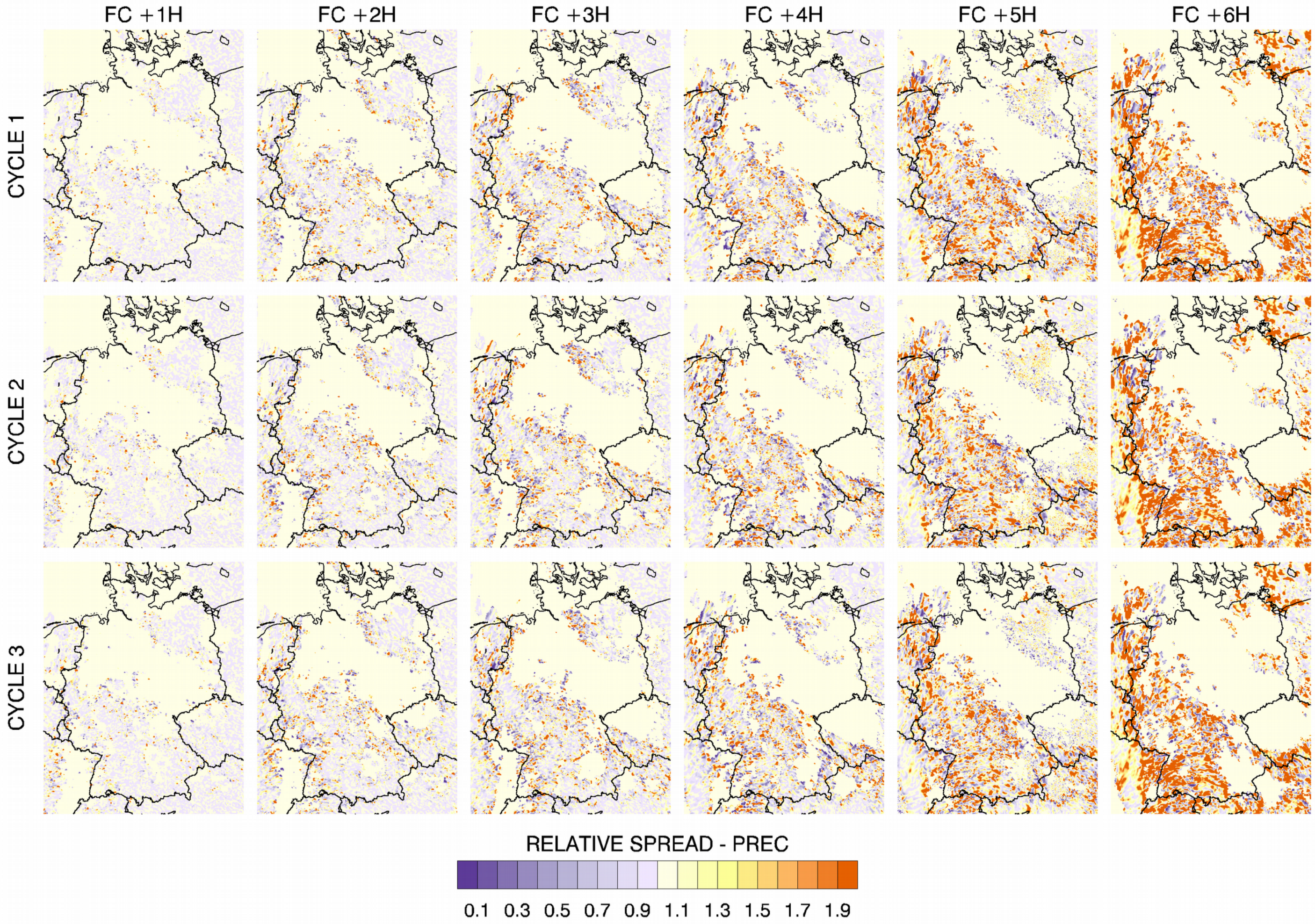
Case-Study Setup (2)

- Perform 6-hour forecasts
- Initial conditions from self-breeding cycles
- Perturbations of the single ensemble members were used as
  - SBVs
  - ETBVs
  - ESVs

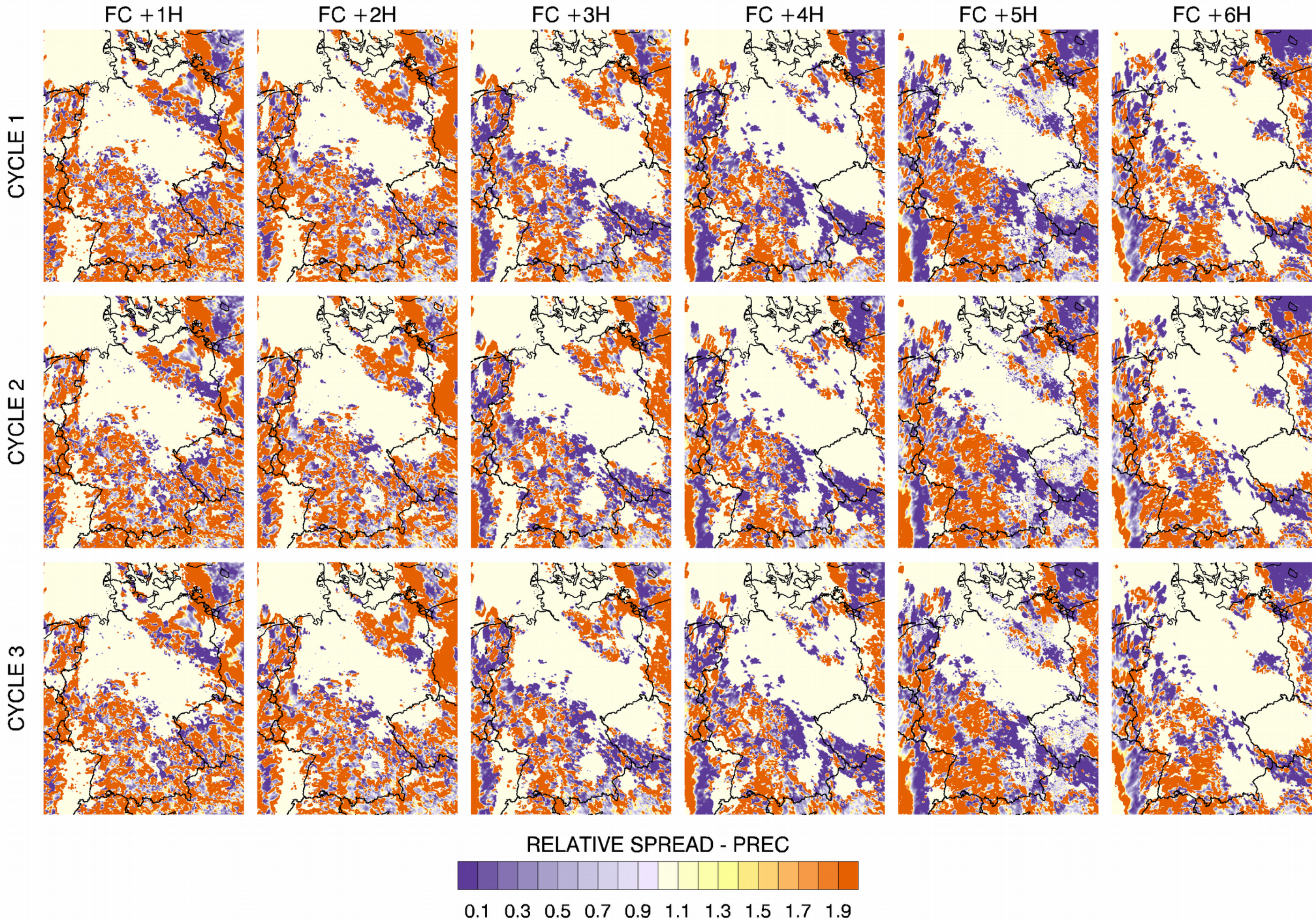
Results – Relative Forecast Spread



Results – Relative Forecast Spread – ESV



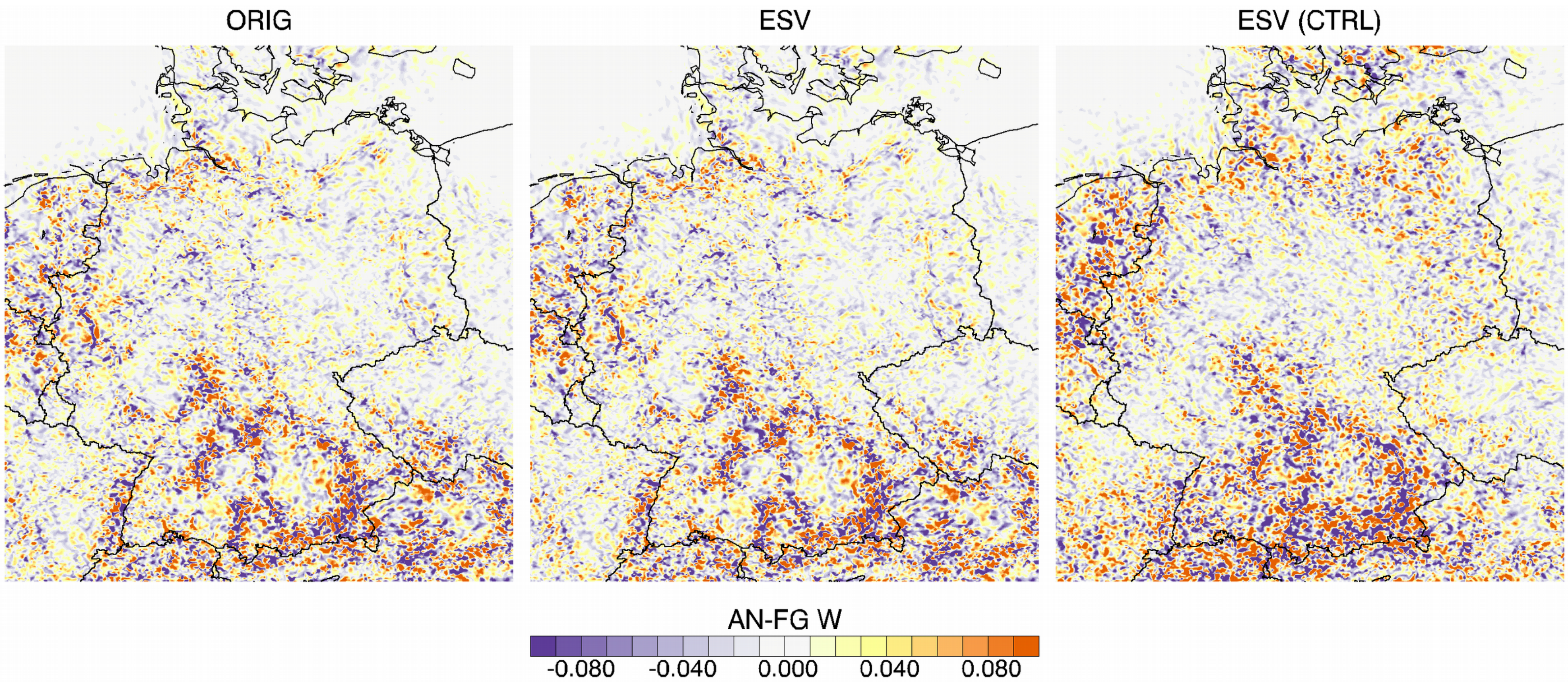
Results – Relative Forecast Spread – ESV (CTRL)



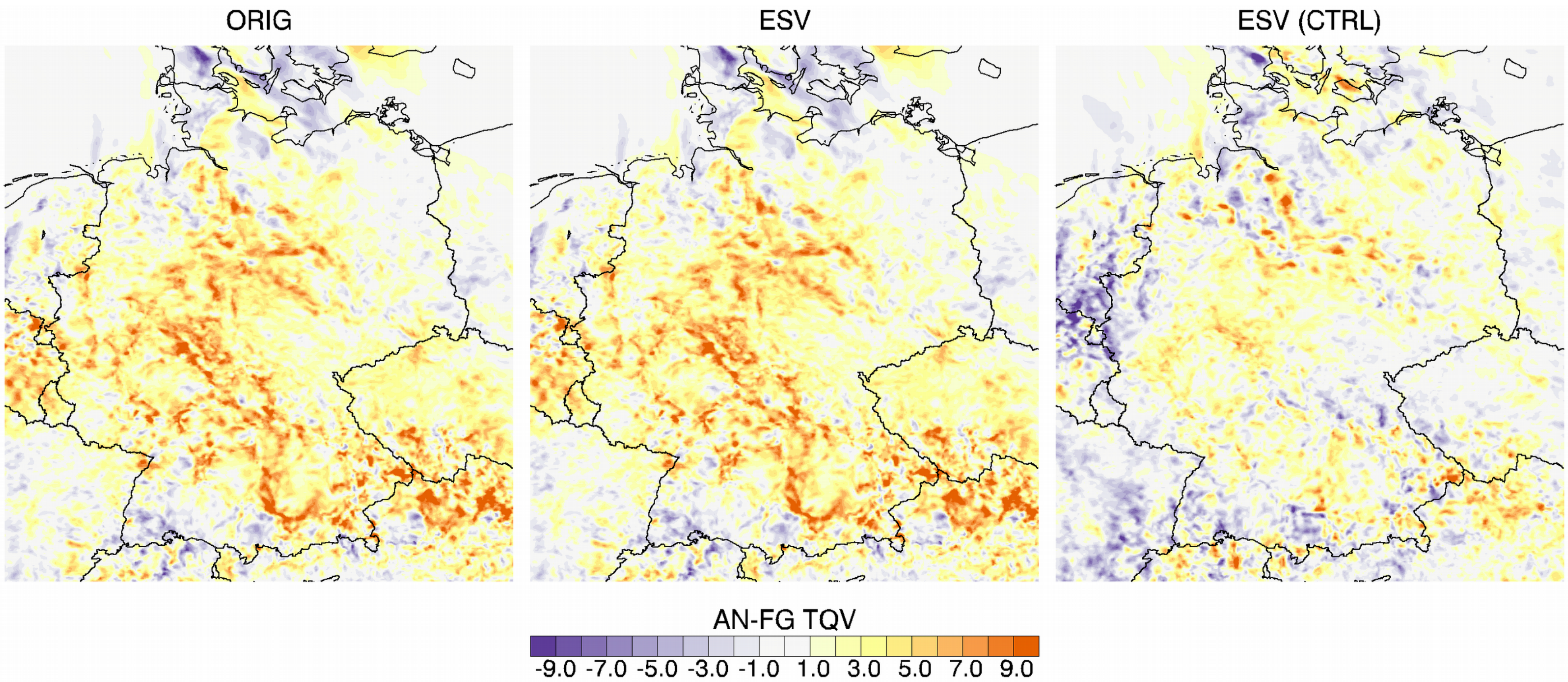
Case-Study Setup (3)

- Use uncertainty structures in KENDA (LETKF)
  - Observations: Radar, Aircraft
- Perform 1-hour forecasts for collecting observation increments from
  - Original perturbations
  - ESVs in relation to single members as well as the control
- Perform free forecasts from new analysis

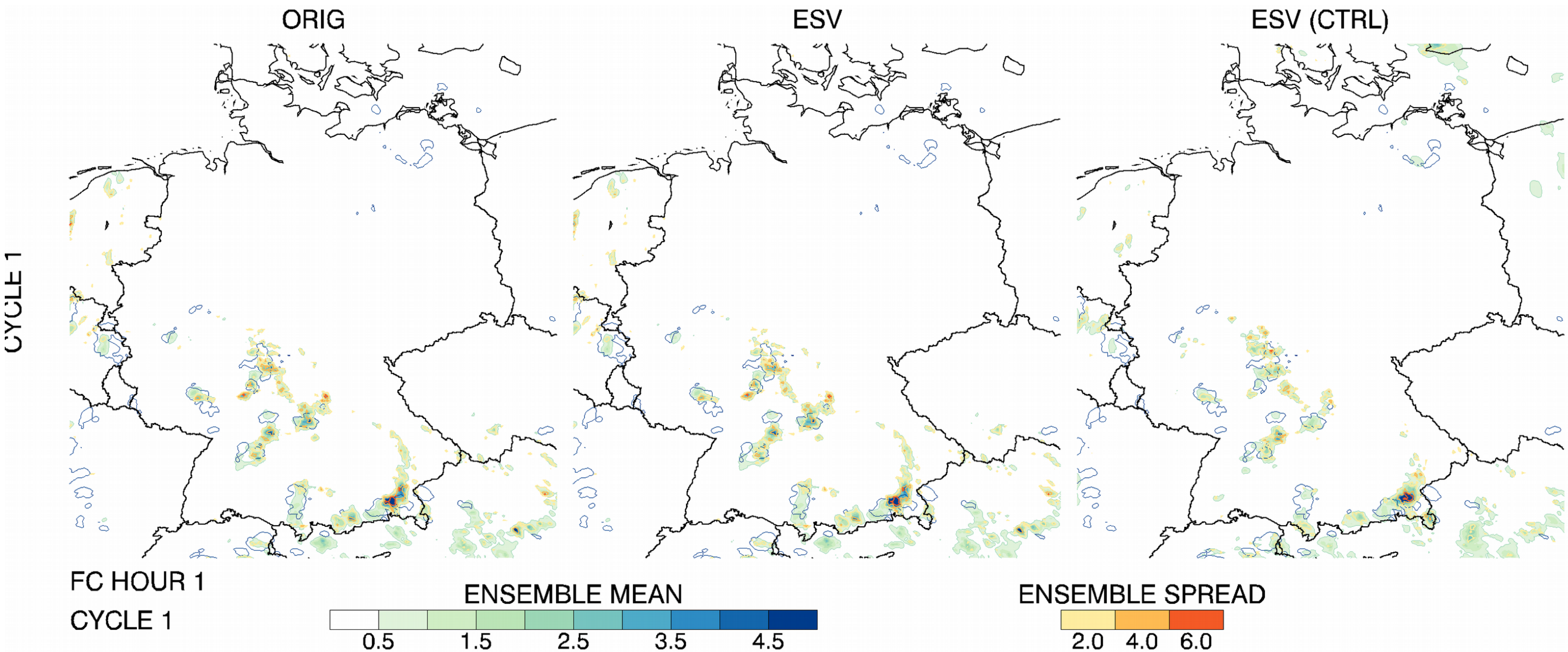
Results – AN-FG from LETKF DA



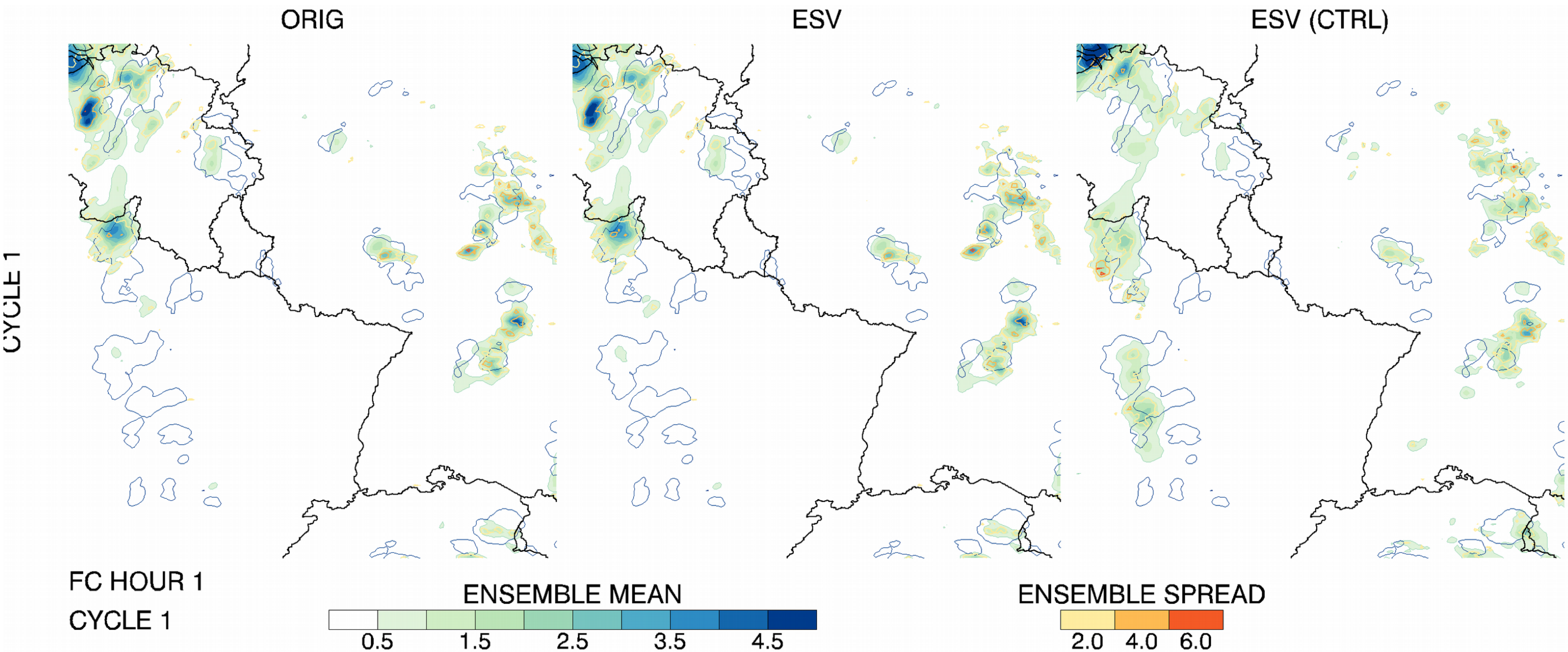
Results – AN-FG from LETKF DA



Results – Forecasts from LETKF DA



Results – Forecasts from LETKF DA



Conclusions

- Current implementation of SBVs
  - Weak effect on ensemble spread for the first hour
  - Impact on spread after 4 hours of free forecast
- ESVs from control show much stronger impact on ensemble spread in the first 2 forecast hours
- For DA purposes in LETKF:
  - SBVs from single members (and their transformations) do not benefit LETKF DA
  - ESVs from control have a much bigger impact and indicate potential to enhance the short term forecast

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