Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

Additive covariance inflation in KENDA

Towards a climatological error covariance matrix from COSMO

Claire Merker, Daniel Leuenberger, Harald Anlauf, Roland Potthast, Marco Arpagaus
03 Sept. 2018, St. Petersburg

COSMO EPS at MeteoSwiss

High resolution NWP over the Alpine area

COSMO-E

21 members

2.2 km grid spacing

2 x a day, 120h forecast

SPPT

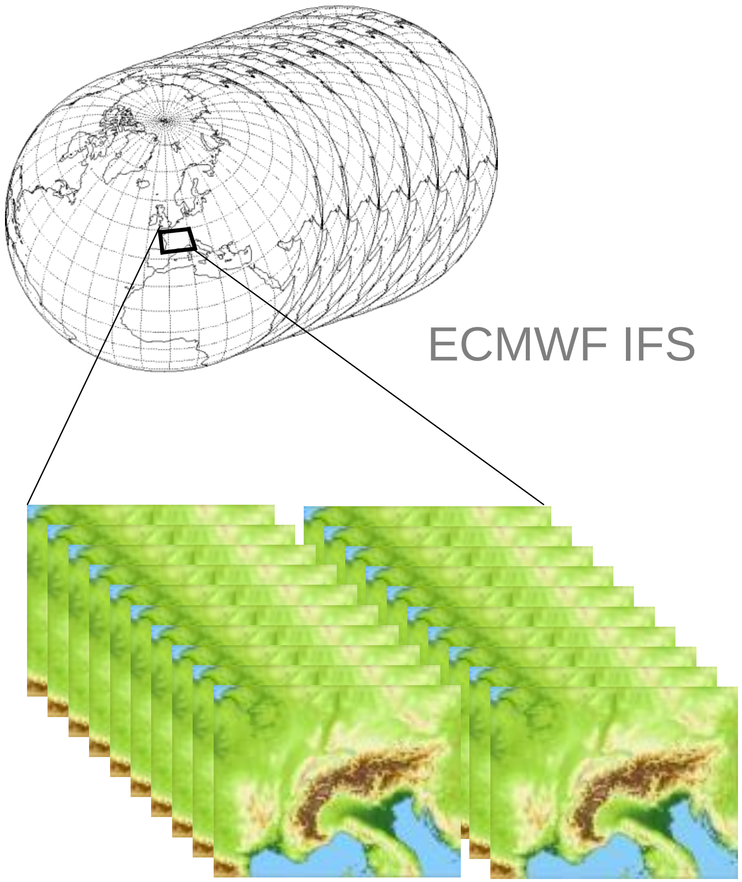
- **KENDA**

40 members

Hourly cycling

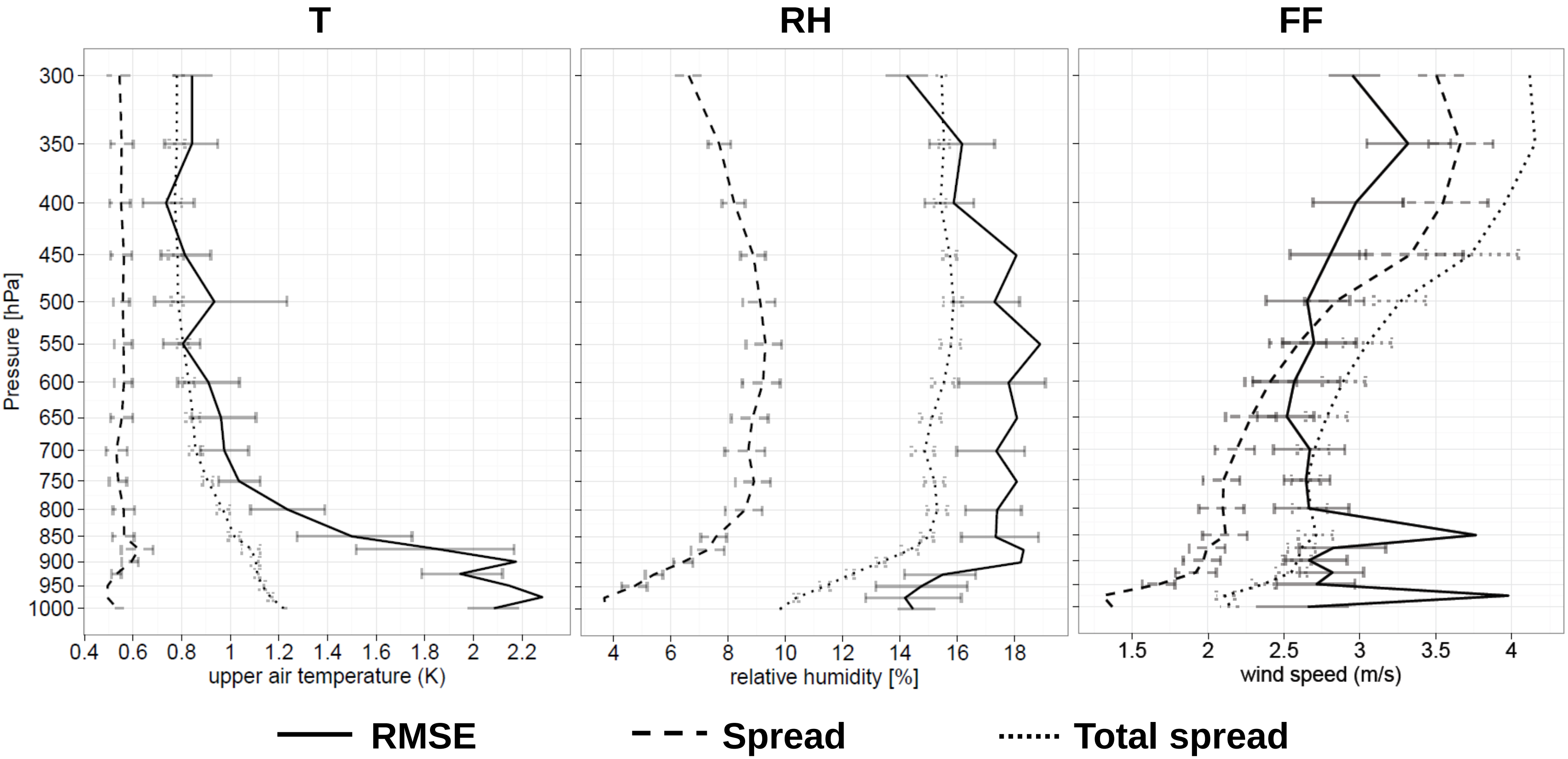
SPPT

RTTP, adaptive mult. inflation

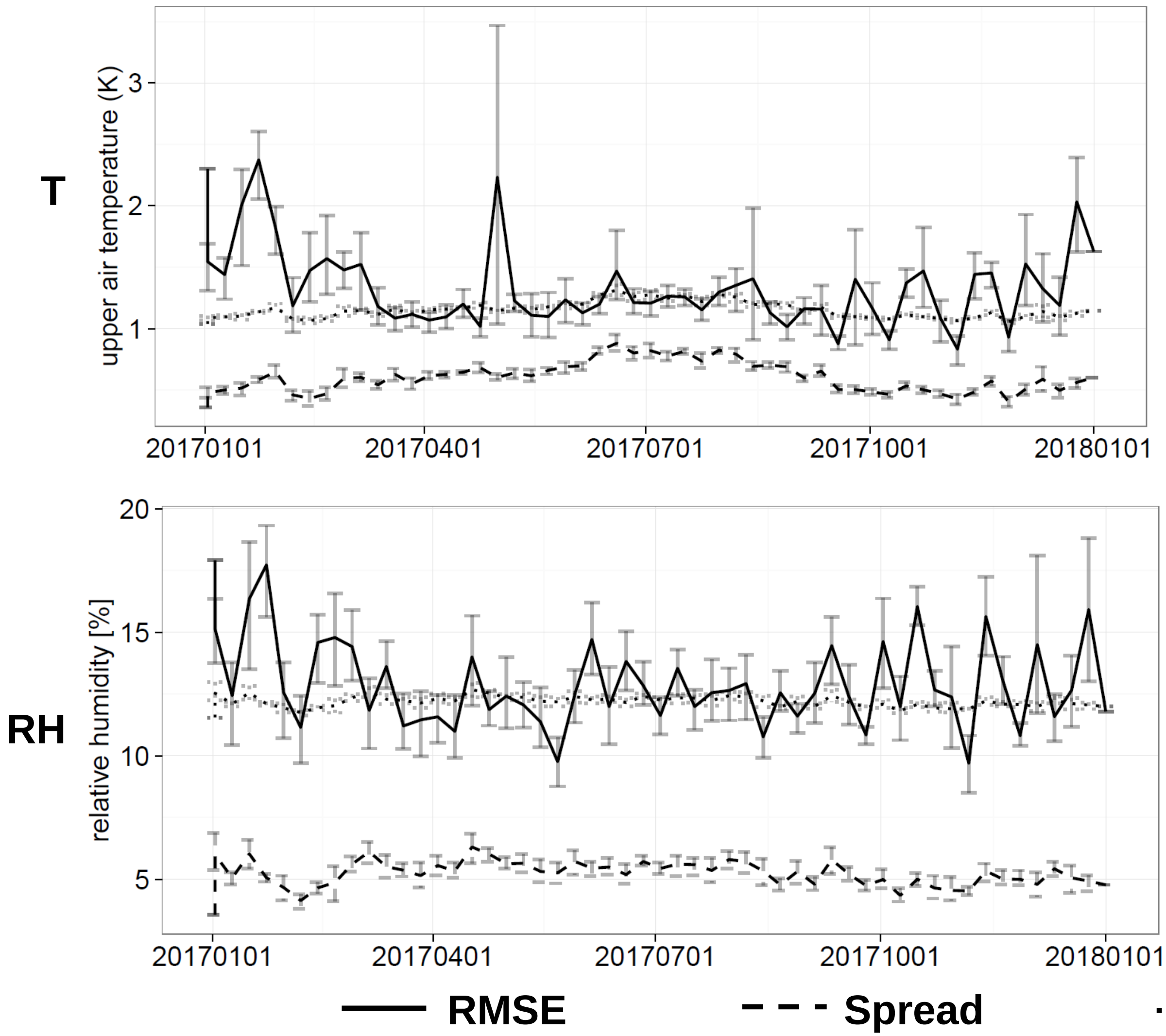


Underdispersive ensemble

Verification of first guess (det.) vs. radiosoundings, January 2017



Underdispersive ensemble



Annual cycle in the RMSE in the lower boundary layer (900hPa): larger RMSE in Winter

COSMO-E current situation

- **COSMO-E is overconfident** in some situations which can lead to low analysis and forecast quality, especially in Winter (fog cases…).
- The quality of the analysis/forecast is highly sensitive to the accurate representation of the model error.
- Lack of spread in the ensemble (ensemble covariance too small)
  - ➢ too much weight on model, **observation impact too low** in KENDA
  - ➢ needs **artificially increase** of the ensemble spread for the assimilation process

Increase ensemble spread

- Larger ensemble spread: expected improvement of the analysis and forecast quality

- **Additive covariance inflation (ACI)**:

  - 40 members sample cannot always represent system's uncertainties (**low-rank estimation**)
  - add random draw of climatological forecast error distribution to the flow-dependent error from the ensemble spread

➢ **climatological error covariance matrix $\mathbf{B_0}$** is needed

ACI in KENDA and plans

- Implemented in KENDA, operational at DWD
  - Post analysis ACI
  - Inherited from global forecasting system
  - Implementation expects variables: geopotential, relative humidity, **stream function**, **velocity potential**
  - Climatological $\mathbf{B_0}$ matrix obtained from global ICON model
- Determine $\mathbf{B_0}$ for **limited area COSMO**
  - Ongoing work together with DWD

Implementation regional $\mathbf{B_0}$

What is needed:

- Proxy for (unknown) **model errors**: NMC method (used for global models, adequate for local model, short-range)
- Computation of **stream function** and **velocity potential** (solve Poisson equation on a limited area)
- Proper approach to compress $\mathbf{B_0}$ matrix for regional model (separation of horizontal and vertical correlations? resolution of auxiliary grid? representation of balances important in LAM?)

Model errors – NMC method

- Developed for global models
- Proxy for model error: **differences between pairs of forecasts** of different lengths, but valid at the same time:

  $\mathbf{x}^{48} - \mathbf{x}^{24}$ (NCEP)

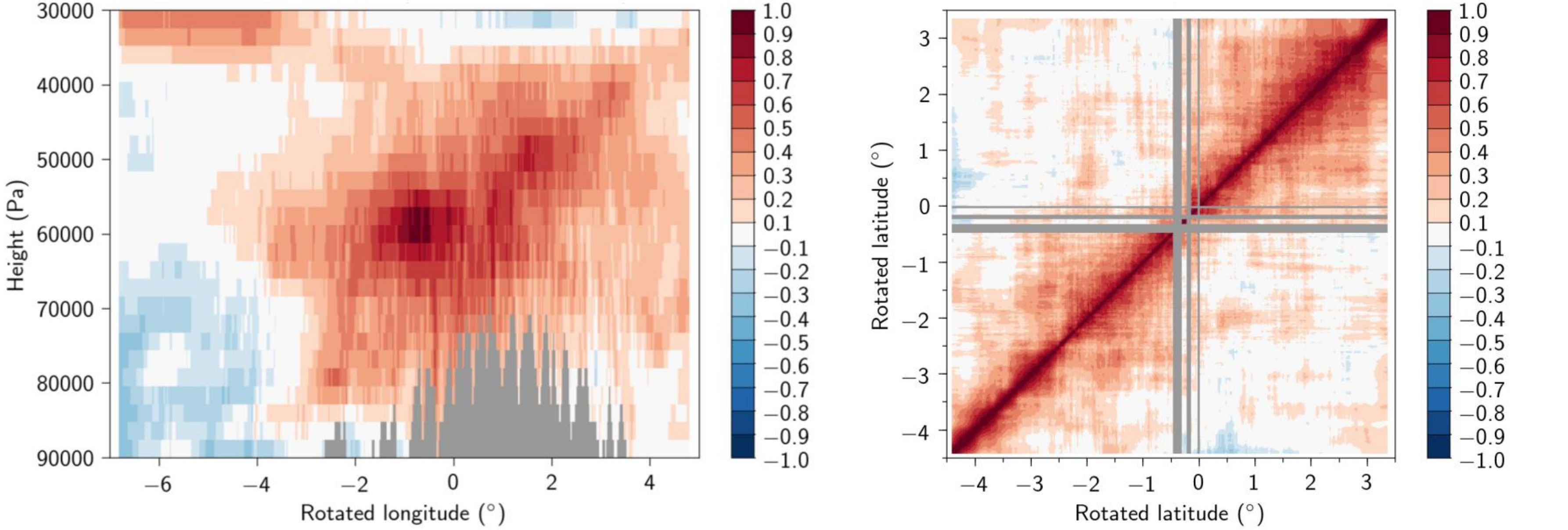
  $\mathbf{x}^{30} - \mathbf{x}^{6}$ (Met Office)
- Climatological error covariance for geopotential height, velocity potential, stream function, relative humidity

  $\mathbf{B_0} \approx \alpha\langle(\mathbf{x}^{48} - \mathbf{x}^{24})(\mathbf{x}^{48} - \mathbf{x}^{24})^{\mathrm{T}}\rangle$ α: tuning/scale factor
- For KENDA, $\mathbf{B_0}$ should represent the large scale error covariance, small scale features are still represented by the ensemble covariance

Model errors – NMC method

High resolution allows orographic effects, domain resolves effect of Alps

Temperature error correlations

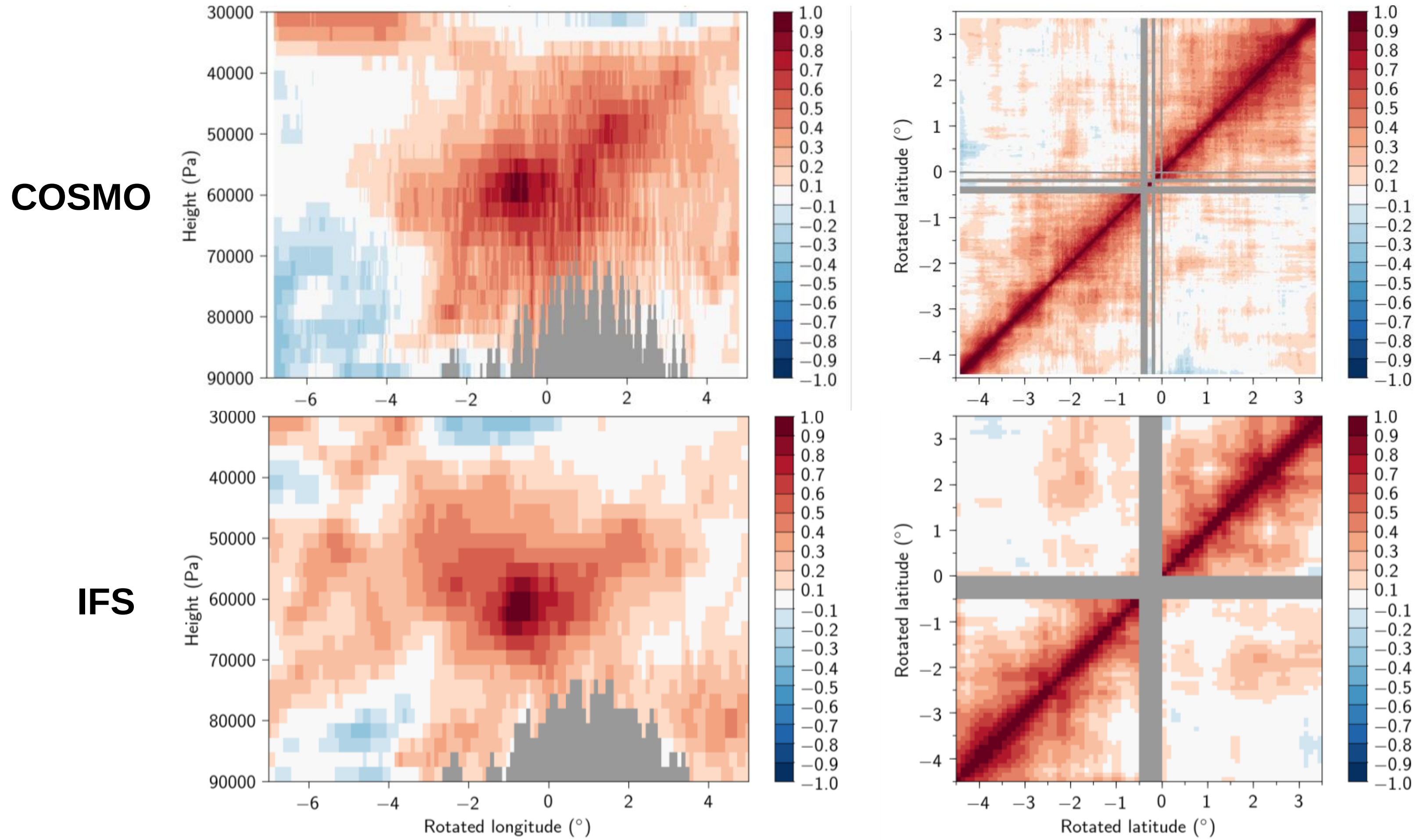


- **West-East cross-section (point at 47.00°N, 8.97°E and 600hPa with surroundings)**
- **March 2017**

- **South-North transect at 800hPa (each point with every other)**
- **July 2017**

Model errors – NMC method

Temperature error correlations

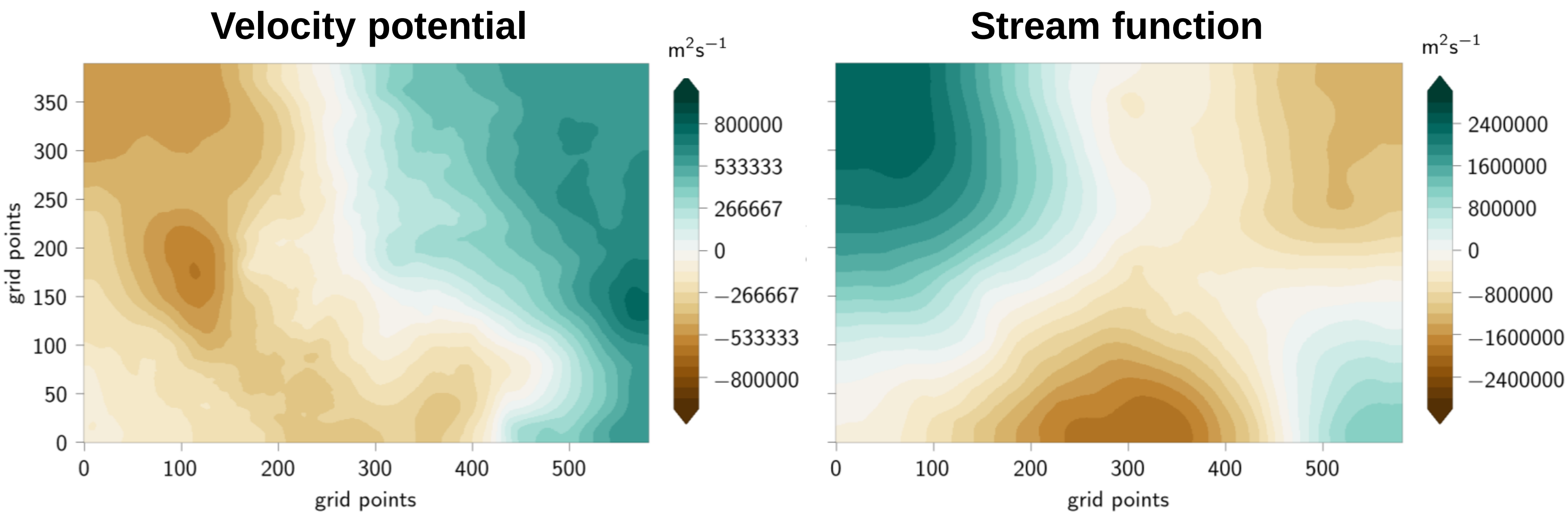


- **West-East cross-section**
- **South-North transect**

Potentials for COSMO (in progress)

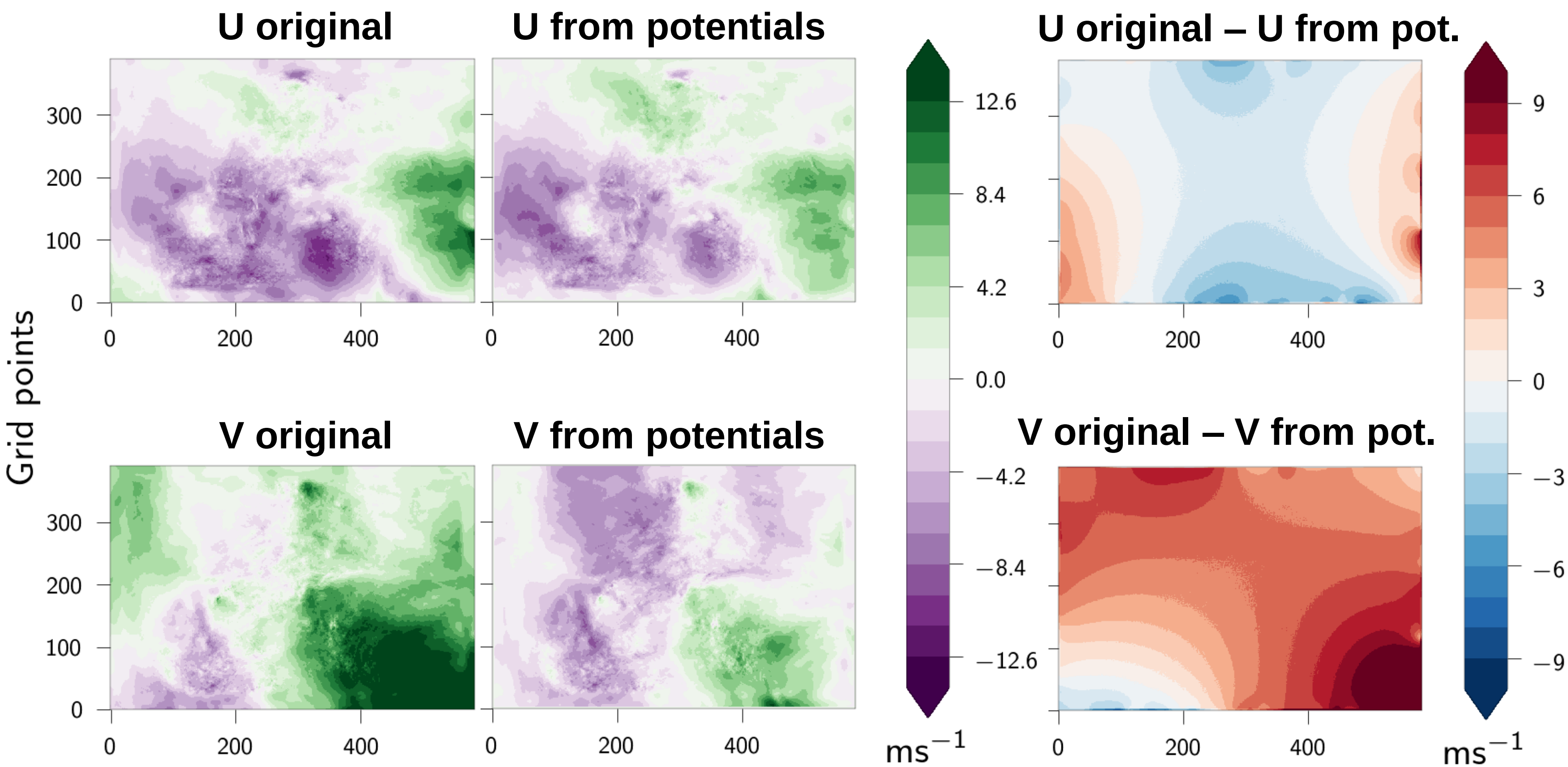
Stream function and velocity potential for a limited area

- Solve the Poisson equation with source term vorticity and divergence: $\nabla^2\psi = \eta, \nabla^2\chi = div$
- Discrete cosine transform (DCT-II), Neumann BCs



Example: Computed potentials for COSMO-E ctrl, 600hPa, 08.06.2018

Potentials for COSMO (in progress)



Example: Original wind field and reconstructed wind field from potentials, 600hPa, 08.06.2018

$$\boldsymbol{u},\boldsymbol{v}\ (\text{original}) \rightarrow \boldsymbol{\eta}, \boldsymbol{div} \rightarrow \nabla^2\psi = \eta, \nabla^2\chi = div \rightarrow u = \frac{\partial\chi}{\partial x} - \frac{\partial\psi}{\partial y}, v = \frac{\partial\chi}{\partial y} + \frac{\partial\psi}{\partial x}\ (\text{rec.})$$

Next steps

- Finalise **computation of potentials**
- **Compute needed variables** for two months reforecasts
- Analyse **correlation structures and patterns**
- Analyse **relevant balances**/correlations between variables
- Decide on how to parameterise the $\mathbf{B_0}$ matrix
- **Compute a $\mathbf{B_0}$ matrix from COSMO** on the local domain
- Apply, run a test suite and evaluate

Outlook

- **Benefits** from $\mathbf{B_0}$ matrix from regional COSMO
  - Tailored to model and model domain
  - Catch small scale feature like orography, better resolution in lower boundary layer than matrix from global model

  - No need for expensive global model or EPS to obtain a model covariance matrix (also needed for var. methods)

Application at MeteoSwiss:

➢ **Expected improvement in forecast quality** especially in the lower boundary layer and short lead times

Outlook

- **Benefits** from $\mathbf{B_0}$ matrix from regional COSMO
  - Tailored to model and model domain
  - Catch small scale feature like orography, better resolution in lower boundary layer than matrix from global model

  - No need for expensive global model or EPS to obtain a model covariance matrix (also needed for var. methods)

Application at MeteoSwiss:

➢ **Expected improvement in forecast quality** especially in the lower boundary layer and short lead times

Thank you!

Implementation global $\mathbf{B_0}$

- Separability: vert. and hor. correlations independent
- Vertical correlations: nmc method
- Horizontal correlations: IO method (analytical description)

- Computation geopot., rel. humidity, stream function, velocity potential
- Interpolation to auxiliary grid (coarser)
- Spectral transformation (wavelet for sparse matrix representation)
- Forecast differences
- Coefficients for $\mathbf{B_0}$ matrix (in wavelet space, on aux. grid)

- Application of random perturbations matching $\mathbf{B_0}$ statistics