Regional Cooperation for
Limited Area Modeling in Central Europe

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Flow dependent SPP

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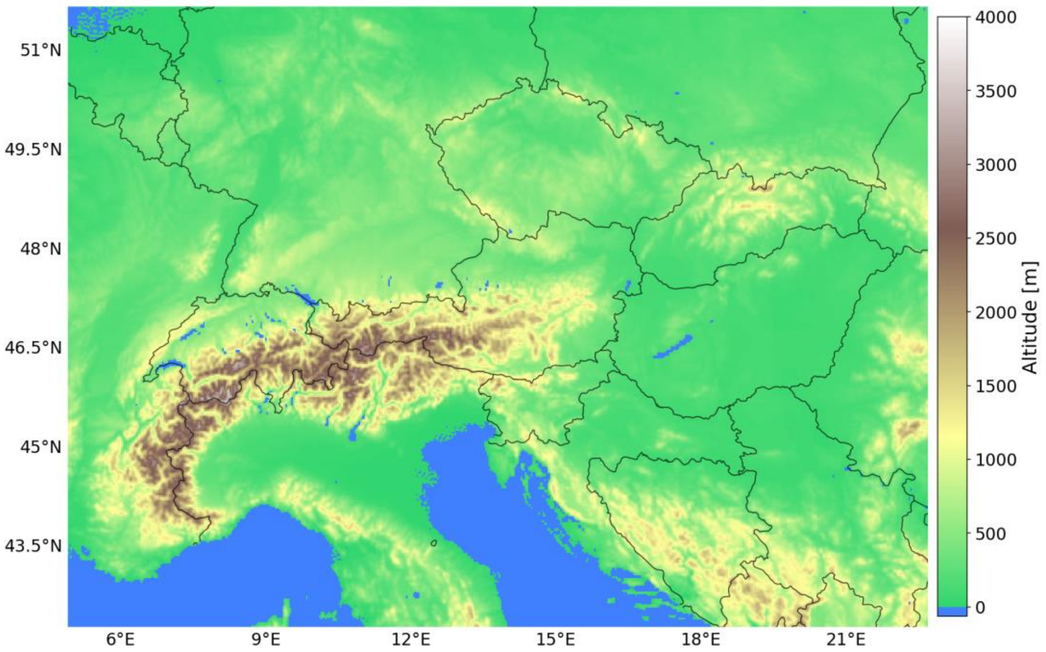
Introduction

- Stochastic perturbation pattern in SPP is random
  - Weather or flow situation is not considered
- Can a stochastic perturbation pattern in SPP be adjusted to reflect the state of the flow?
  - Focus perturbations to the areas of high uncertainty
  - Make sure that perturbations are added to sensitive areas in the domain
    - Flow dependent SPP (FD-SPP)

Model

- C-LAEF
  - cy43t2
  - Grid size: 2.5 km
  - 90 vertical levels
  - 3-h cycling
  - 16 perturbed + 1 control
  - Coupling: ECMWF-EPS (1-h)
  - EnsJk, SPP, LBC and surface perturbations



- Implemented for CLAEF1k
  - cy46t1
- cy46h1 by Ulf Andrae

SPP

- Parameters considered
  - C-LAEF operational implementation
- 6 physics schemes
- 12 parameters

Scheme	Parameter	Description
Microphysics	ZRDEPSRED	Snow reduction factor
	ZRDEPGRED	Graupel reduction factor
	RCRIAUTI	Snow autoconversion threshold
	RCRIAUTIC	Rain autoconversion threshold
	VSIGQSAT	Saturation limit sensitivity
Radiation	RSWINHF	Short-wave cloud thickness inhomogeneity factor
	RLWINHF	Long-wave cloud thickness inhomogeneity factor
Turbulence	XCTP	Constant for temperature and vapour pressure correlations
	XCEP	Constant for wind and pressure correlations
	XCED	Constant for dissipation of TKE
Shallow convection	XCMF	Closure coefficient at bottom level for convective mass flux
Surface	XFRACZ0	Coefficient of orographic drag

SPP

- Following Ollinaho *et al.* (2017), in C-LAEF, SPP-perturbed parameters $\hat{P}$ are obtained:

$$\hat{P} = P\, e^{c+w\varphi} \qquad (1)$$

- Where P is the original constant parameter, φ is normally distributed stochastic pattern and c and w are distribution parameters
  - Log-normal distribution for $\hat{P}$
  - φ varies in space and time independently for each variable and ensemble member
- c, w and clipping values are adjustable
  - Tune the impact of the pattern φ

FD-SPP methodology

- Existing pattern will be modified by some weights
- Diagnose areas in the model which are the most uncertain for each parameter
  - Modify the pattern to perturb more there (i.e., amplify perturbations)
- The weights are then added to the perturbation field as w in (1)
  - Where w>1 (w<1), the perturbations will be amplified (attenuated)
    - $w \in [1, W_{max}]$ ⟶ goal is to amplify the perturbations in targeted regions

FD-SPP methodology

- How to find sensitive areas in the domain?
- Pragmatic approach
  - For each of the 12 parameters, a particular model variable will be used to diagnose sensible areas for that parameter
  - Microphysics and radiation – Cloud fraction
  - Turbulence and shallow convection – TKE
  - Orographic drag – 10 m wind speed

Microphysics and radiation

- Cloud fraction is between 0 and 1 and is available for each model level
  - Average over all model levels to obtain CF_{mean}
- Final weights:

$$w_{CF} = MIN[CF_{mean} \times N + 1, W_{max}]$$

  - N = multiplication factor to increase the impact
    - Determines how strongly chosen model variable influences the weights

Turbulence and shallow convection

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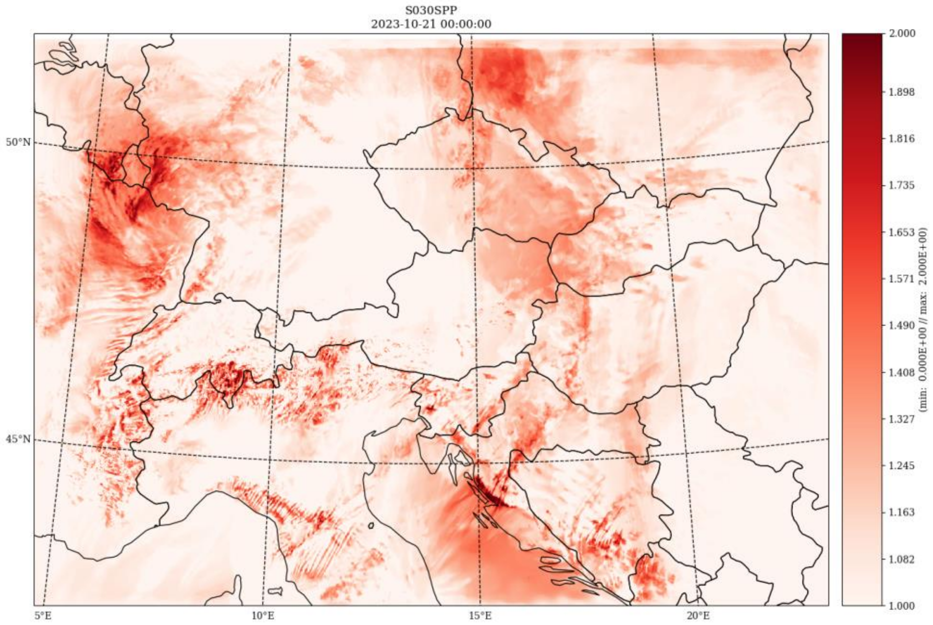
- TKE is given for all levels and has unbounded values greater then 0
  - Maximum value of TKE over the whole domain needs to be calculated
- Final weights:

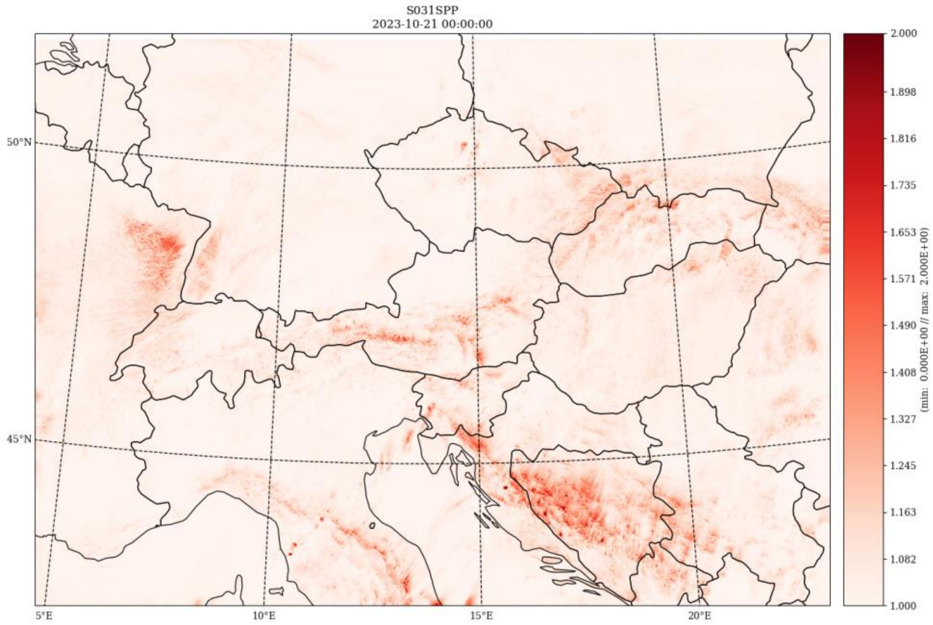
$$w_{TKE} = MIN\left[\frac{MAX(TKE_{levs})}{TKE_{max}} \times N + 1, W_{max}\right]$$

  - *N* = multiplication factor to increase the impact
- For wind field, the same procedure is implemented

Example of weights



Cloud fraction



TKE

Impact on stochastic pattern

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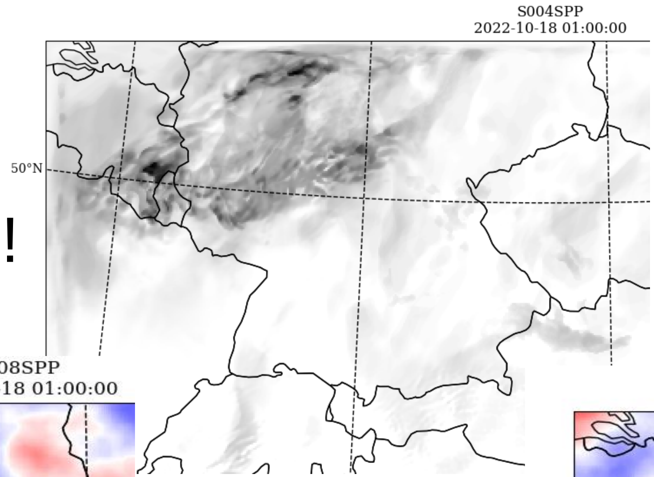
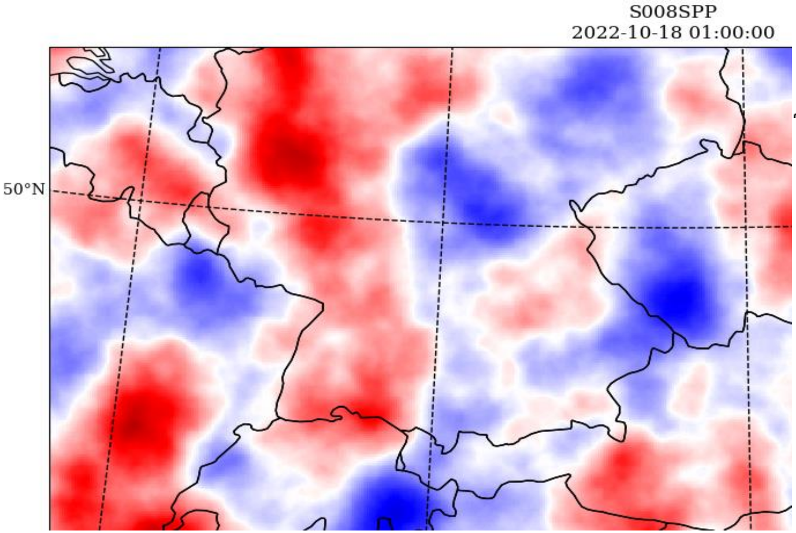
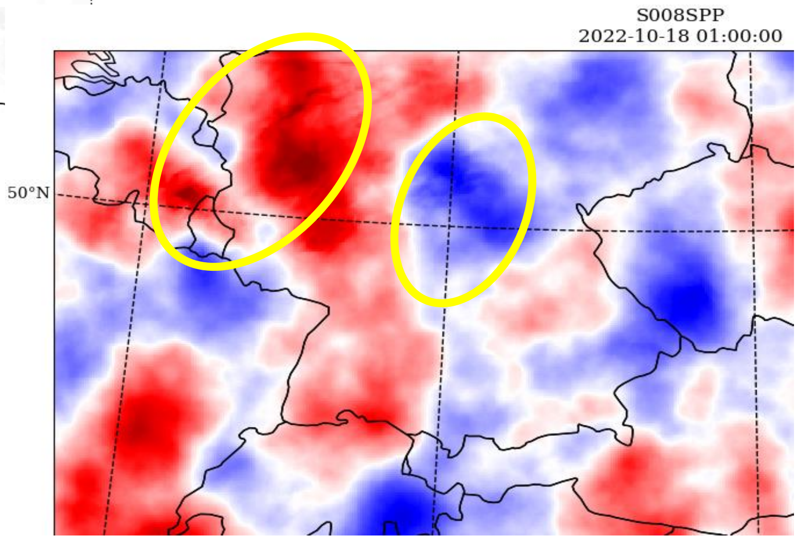
It behaves as it should!







Illustrative impact of flow dependency

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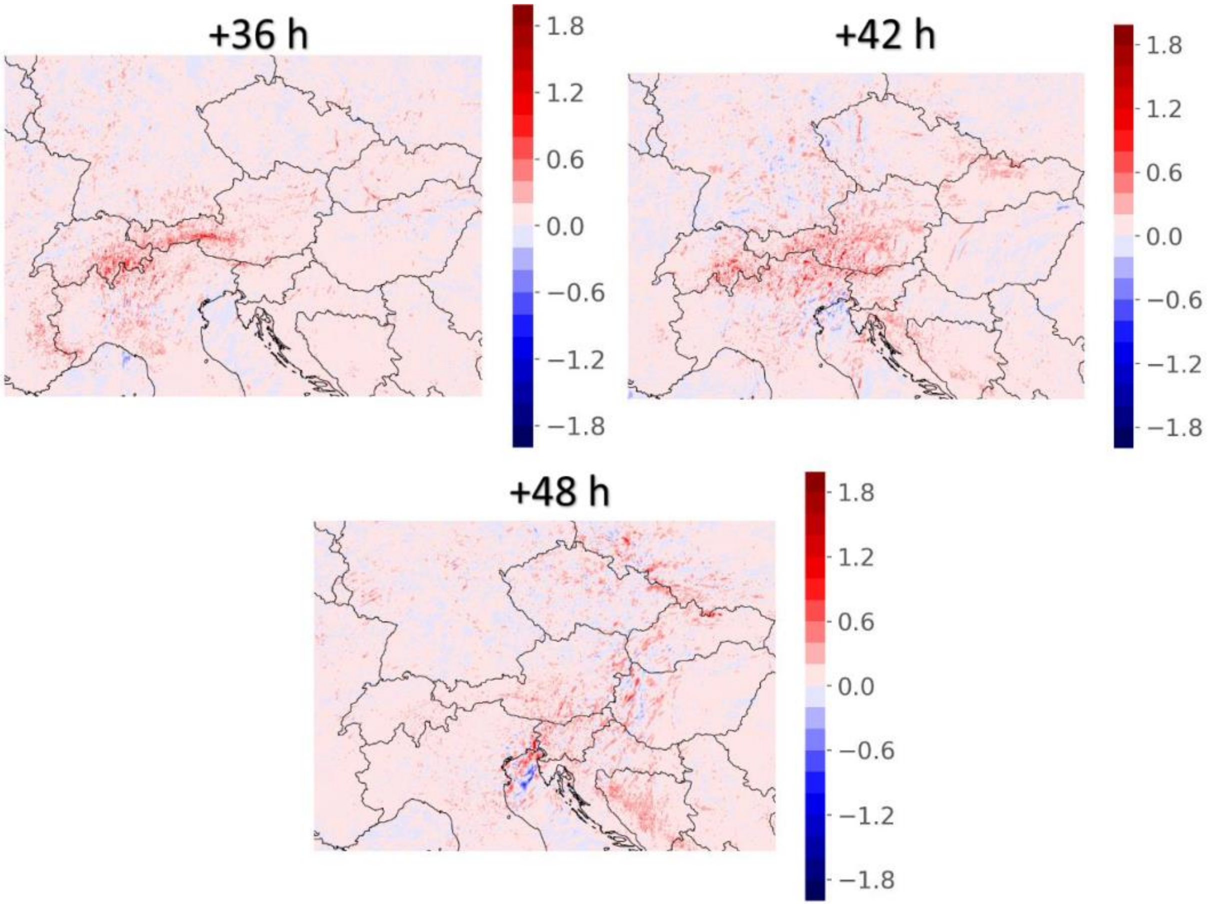
- Spread difference
  - **FD-SPP – SPP**
- Difference „moves” with the incoming front
- Last three slides show that FD-SPP behaves expectedly

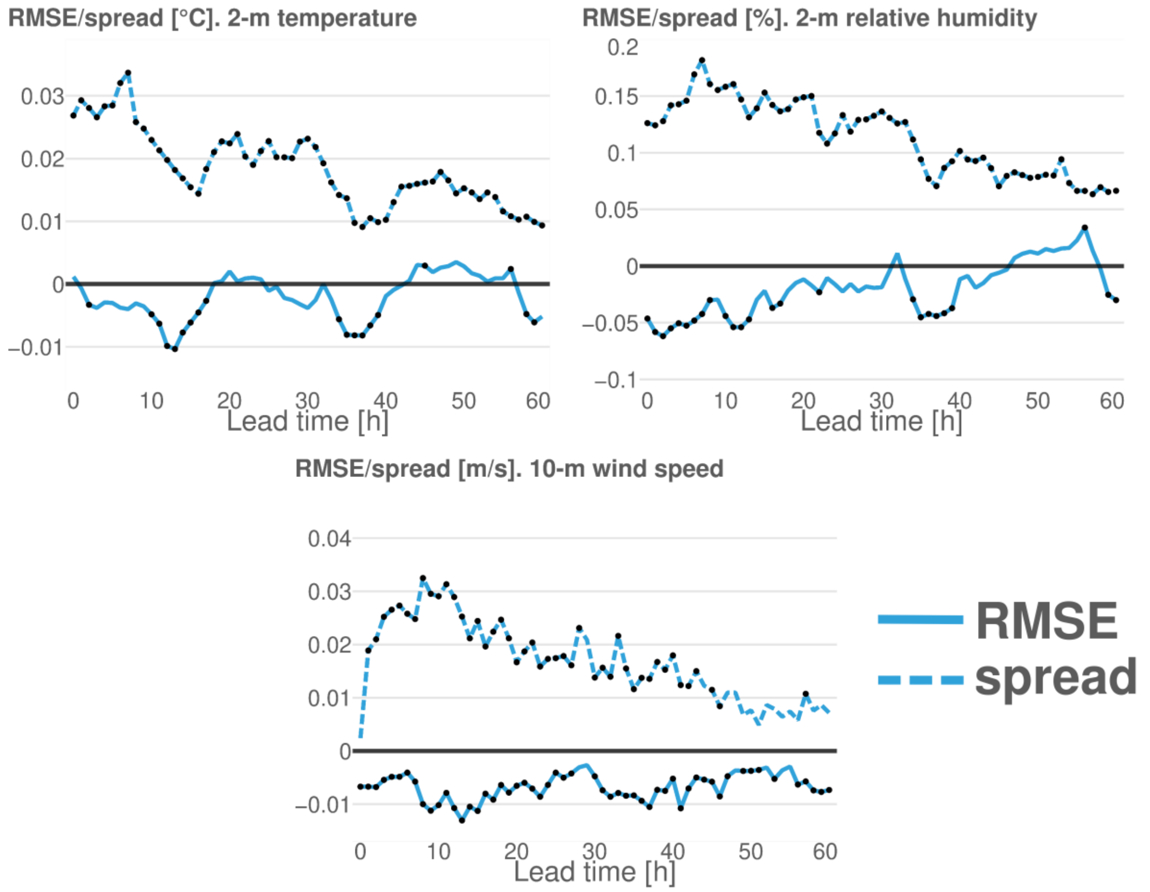


Evaluation

- Experiments
  - **SPP** – standard SPP configuration used
  - **FDSPP** – flow dependent perturbations with W_{max} = 3 and N = 1.5
- Verification
  - February 2024
  - 225 Austrian stations for surface verification (hourly)
  - 25 radiosonde stations for upper-air verification (12-hourly)
  - Paired t-test at a 95% confidence level (black dots)

Surface verification – RMSE/spread

- Plotted relative to SPP
- Spread is increased and RMSE decreased
  - Good because C-LAEF is under-dispersive
  - Increased accuracy and reliability



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Upper-air verification – RMSE/spread

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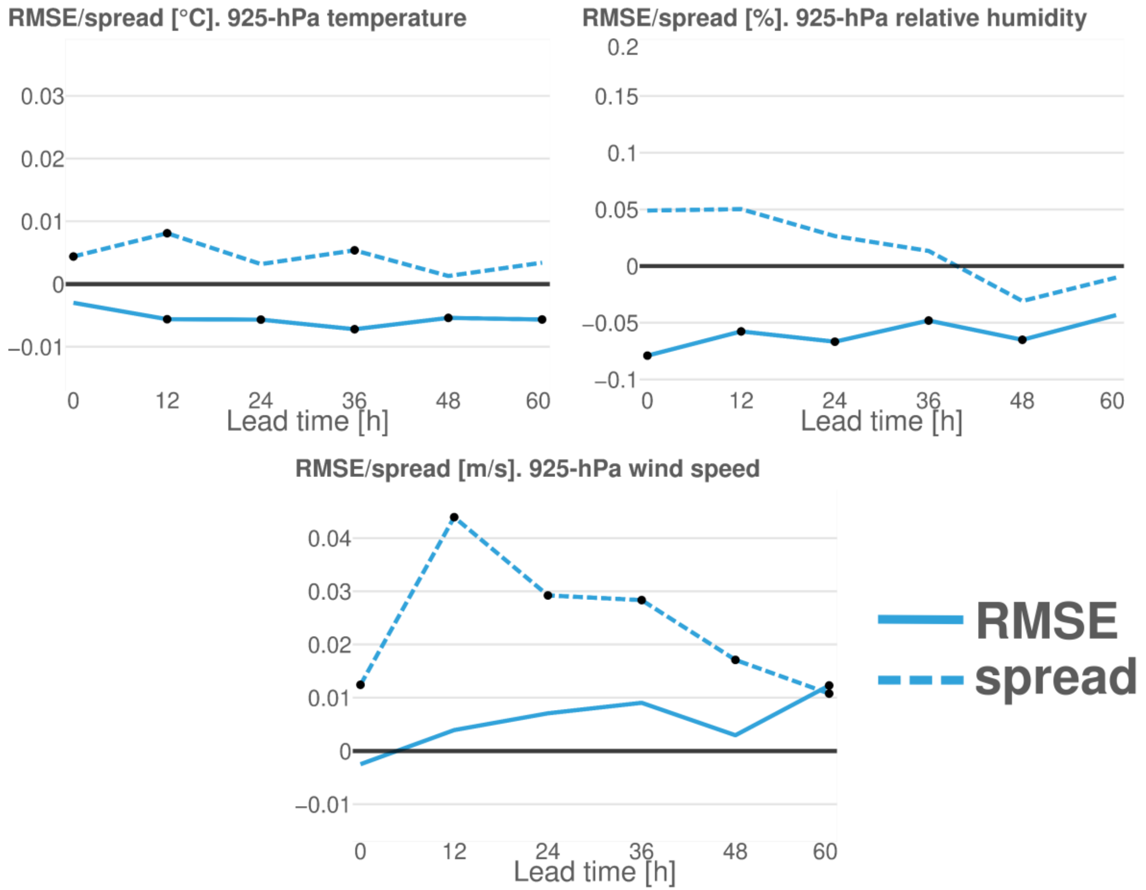
- 925 hPa
- Spread is increased and RMSE decreased
  - Good because C-LAEF is under-dispersive
  - Increased accuracy and reliability



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Upper-air verification – RMSE/spread

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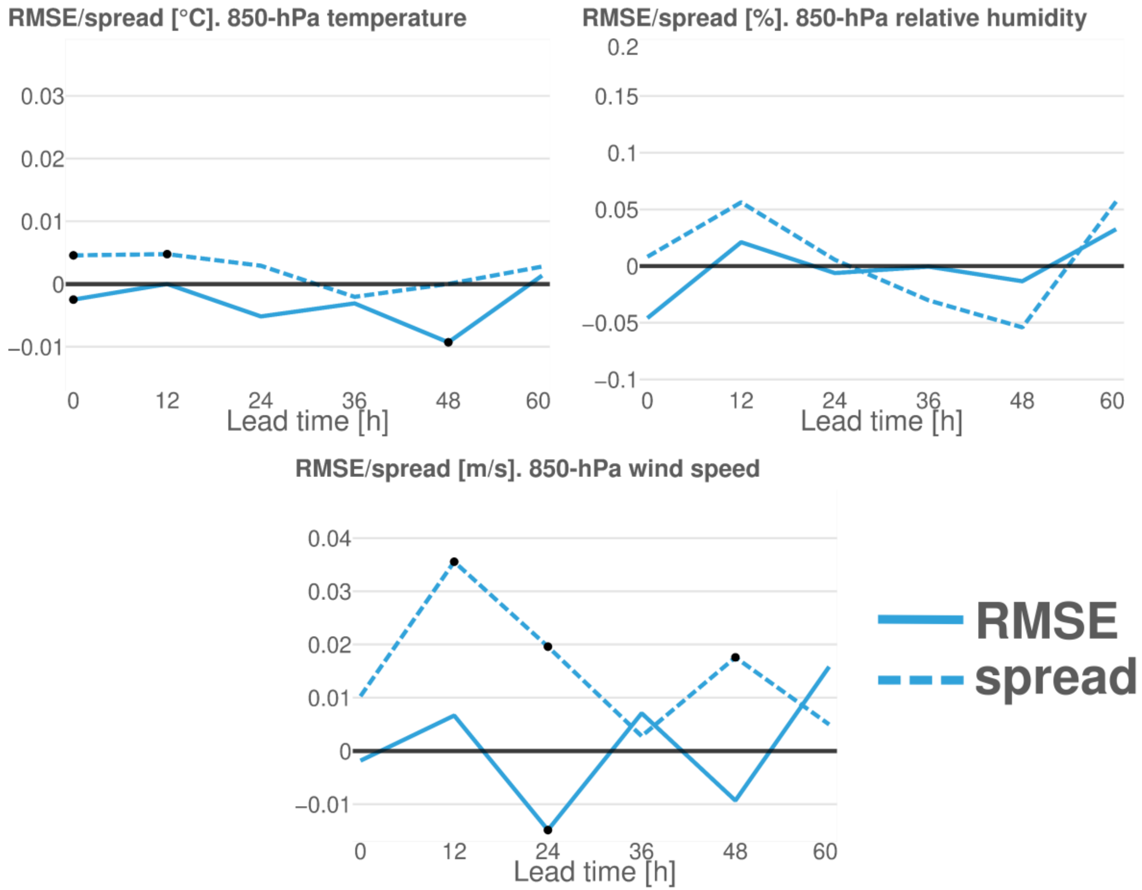
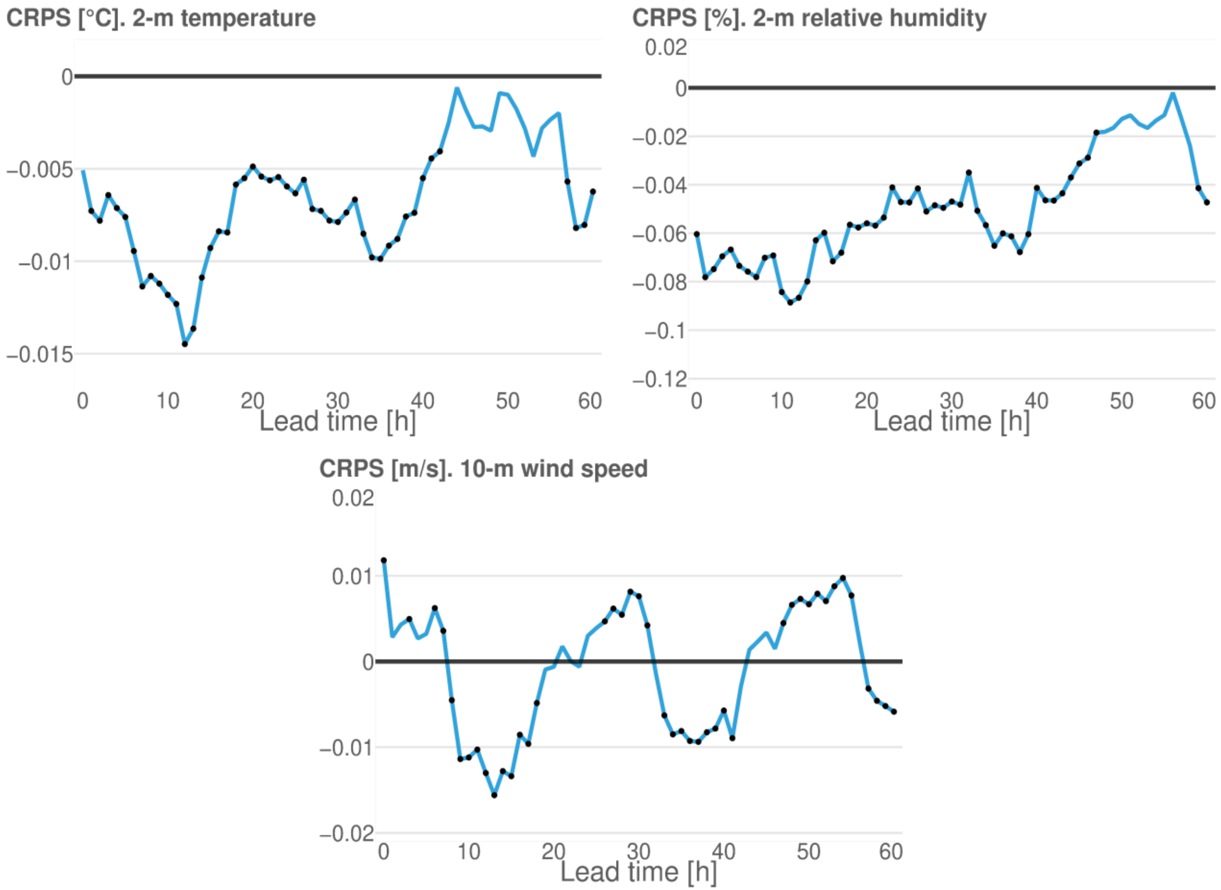
- 850 hPa
- More neutral results but still slightly positive
  - Expected as model physics plays more dominant role closer to the surface



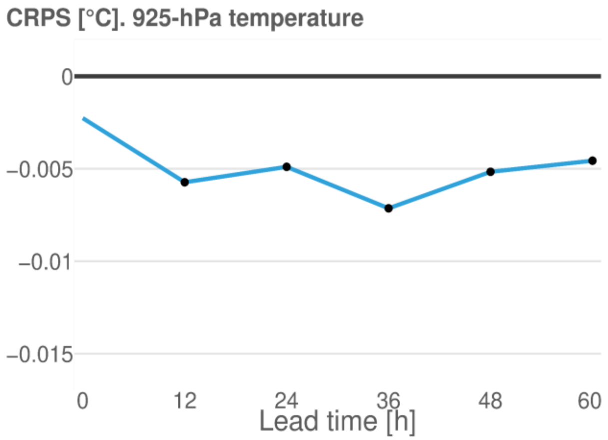
Surface verification – CRPS

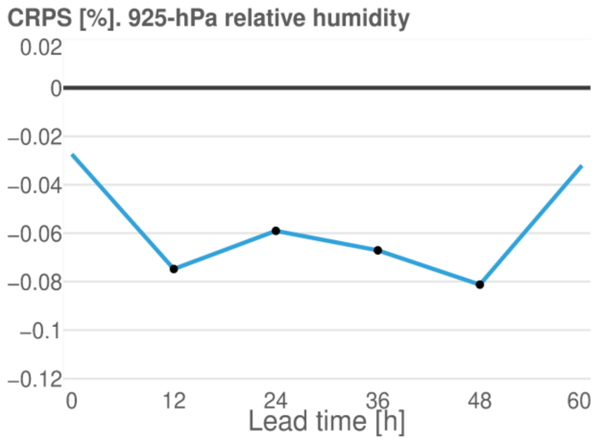
- Significantly positive impact for T and RH, and more neutral for WS
- FDSPP is more skilful

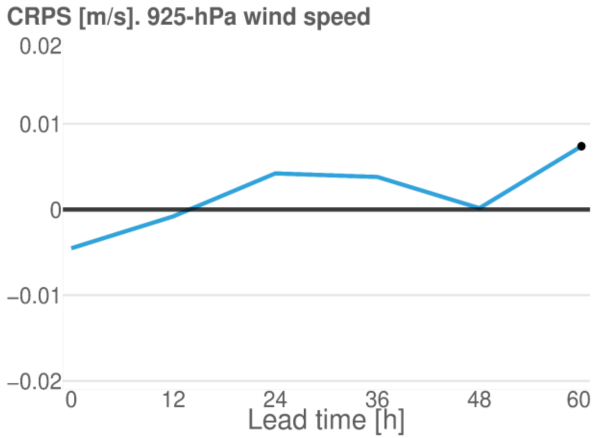


Upper-air verification – CRPS

- 925 hPa
- Similar as for surface







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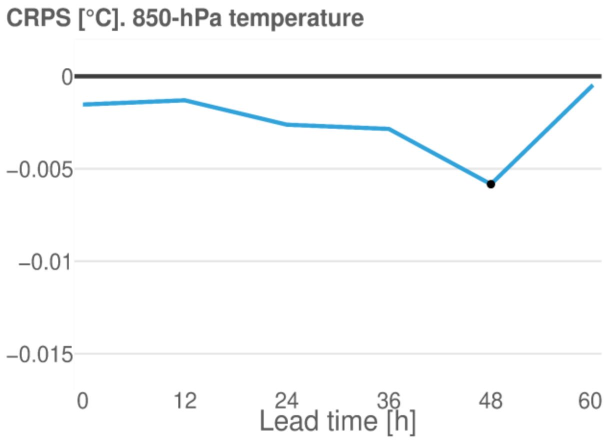
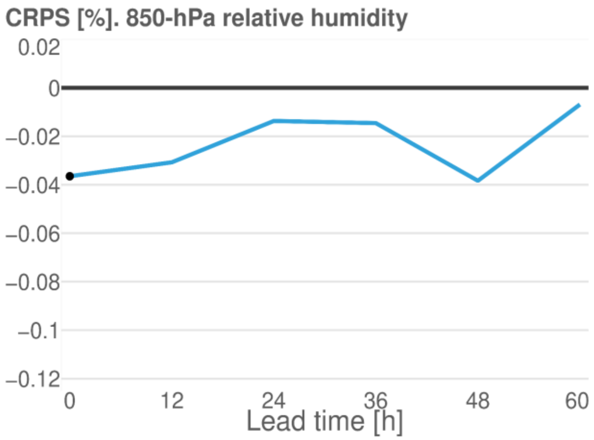
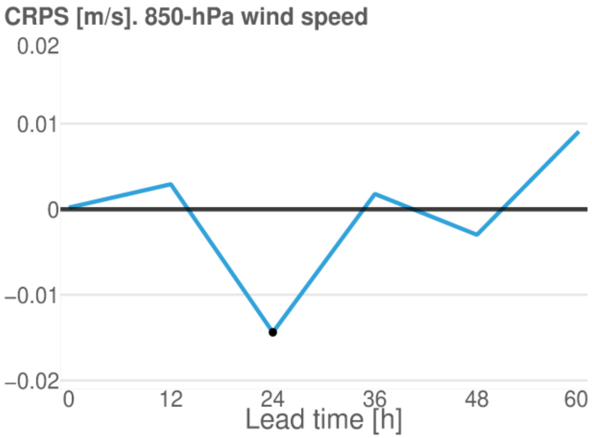
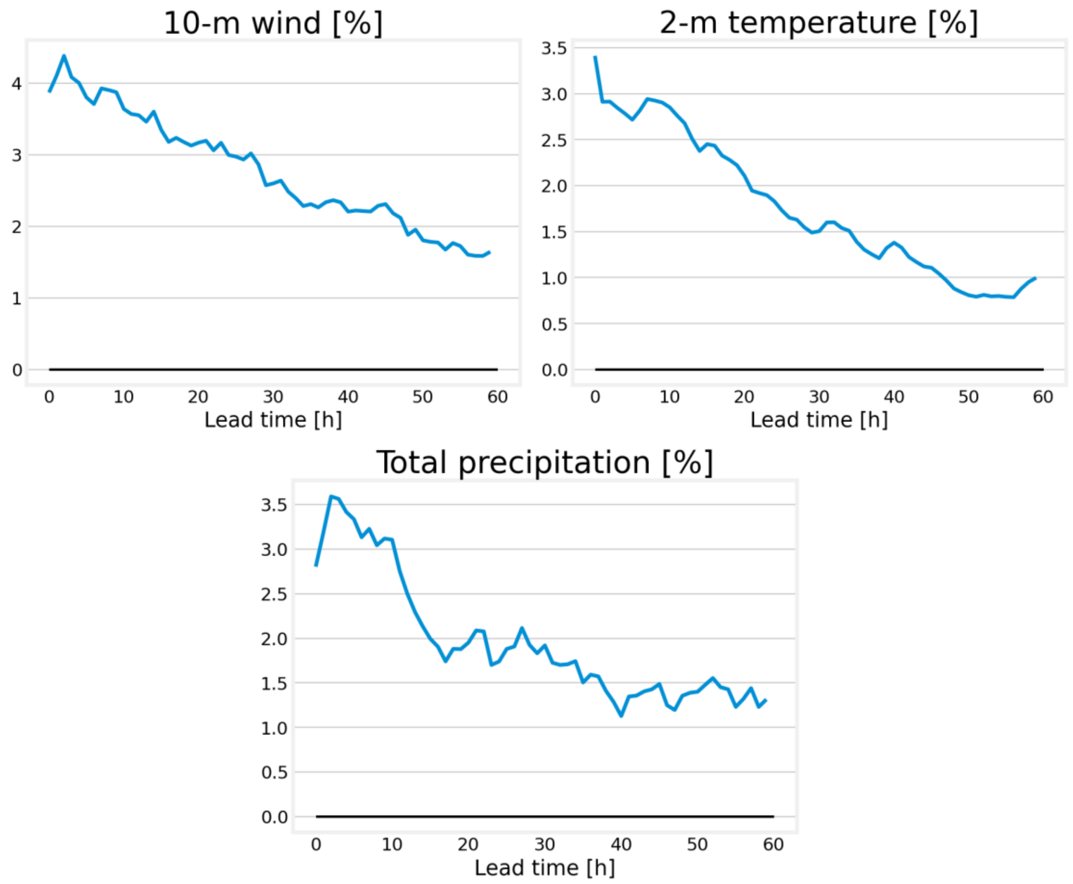






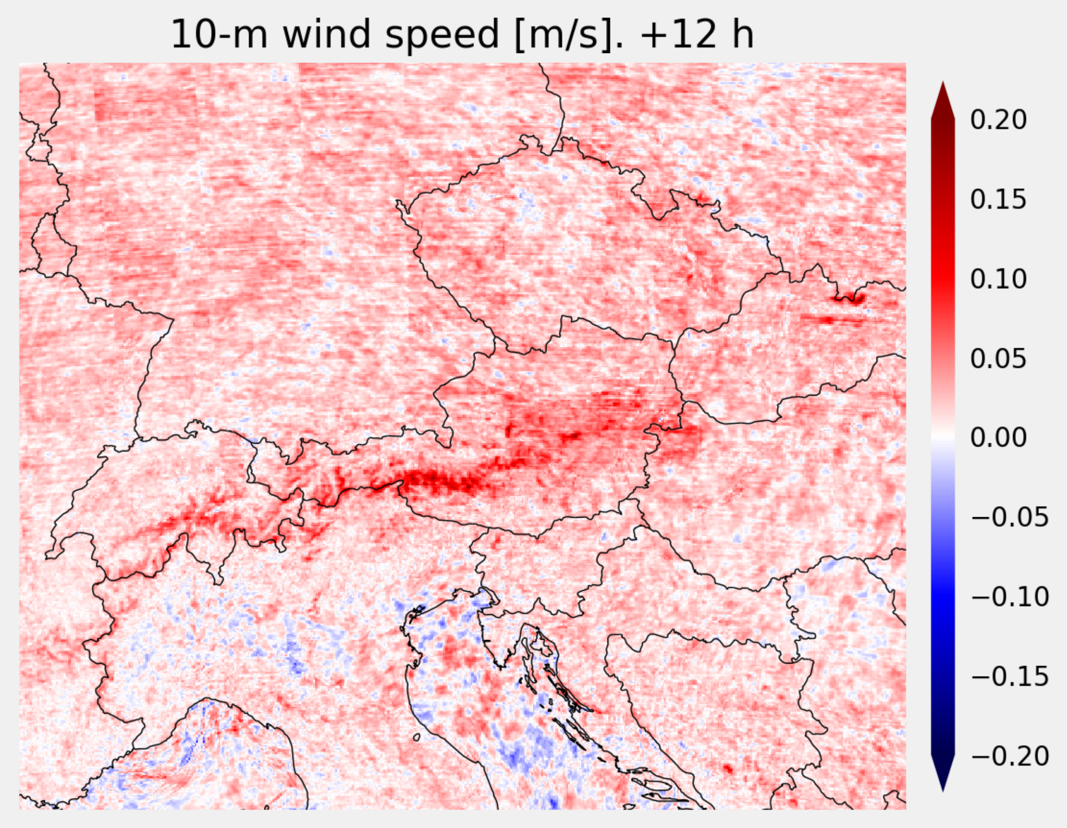
Domain averaged spread

- Go beyond station locations
  - Domain averaged spread with respect to SPP for February 2024
- Spread increased for all lead times



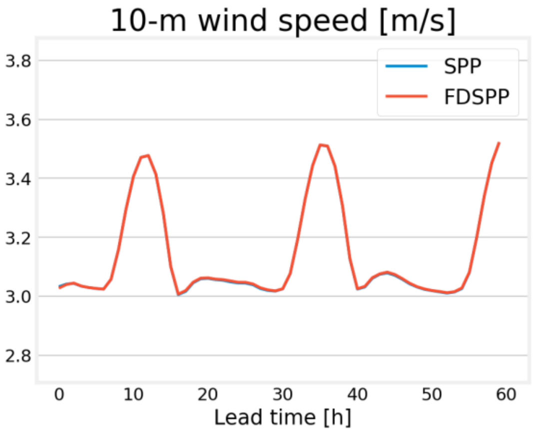
Monthly averaged spread difference

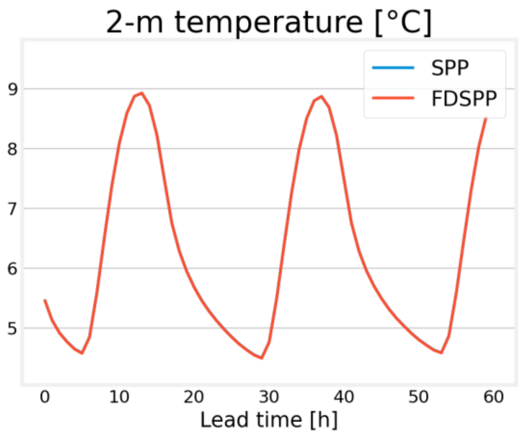
- Difference of monthly averaged spread
  - FDSPP - SPP
- Spread is consistently increased for all variables
- Example for 10-m wind speed at +12 h

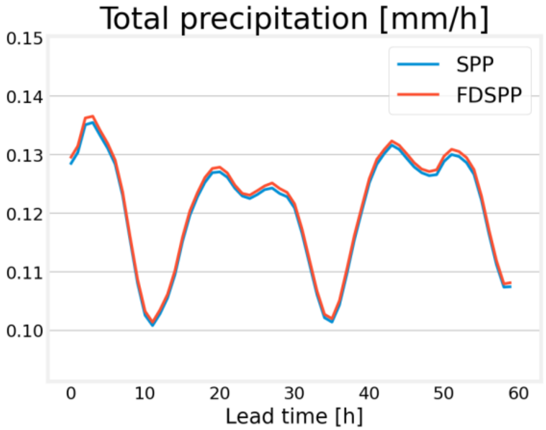


Domain averaged values

- Impact on mean values
  - We do not want to change the mean state
- Mostly unaffected

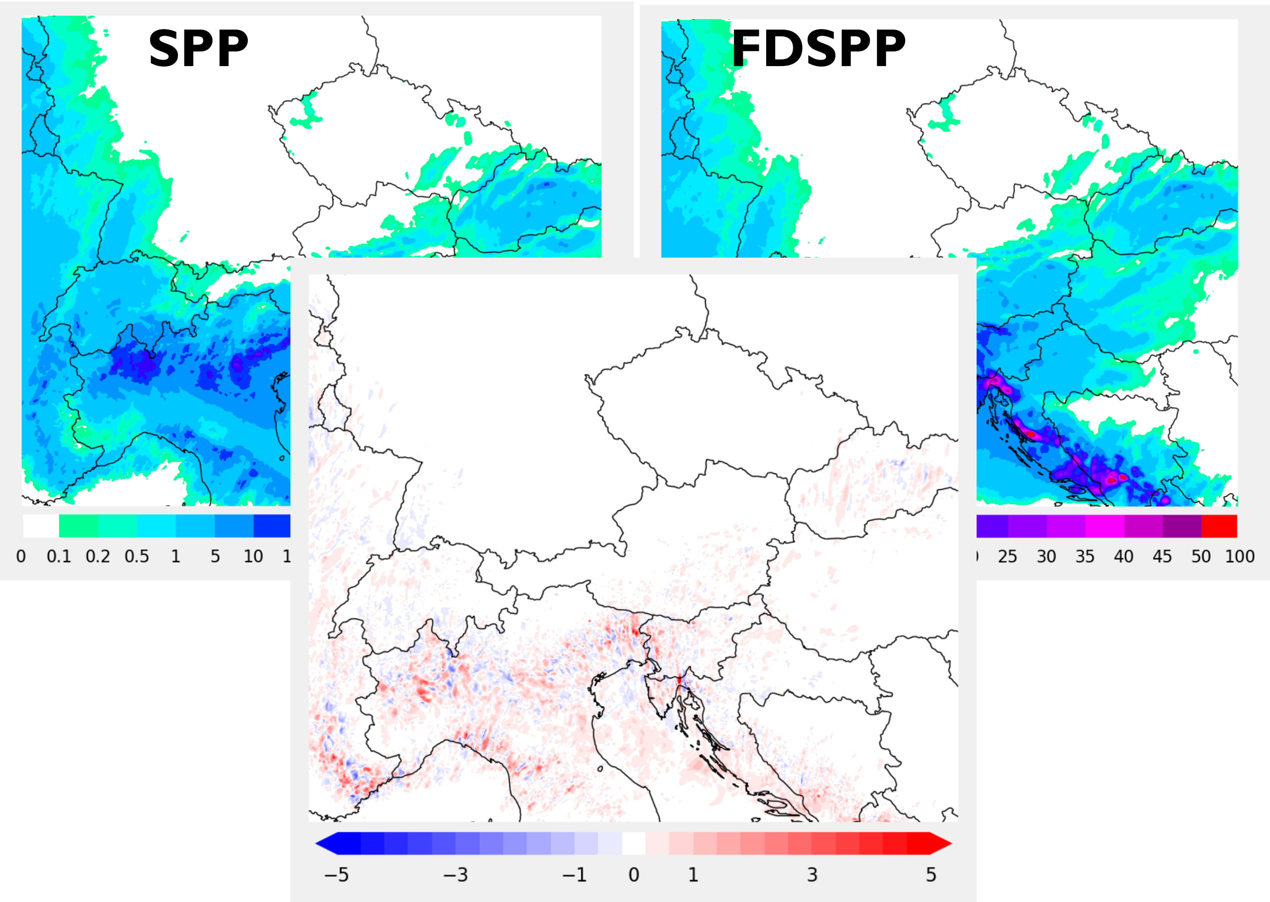






Precipitation

- Example
  - 10 February 2024
  - 18-24 h accumulation
- SPP vs FDSPP
- Very small impact on spatial distribution
- Small impact on precipitation amounts



Conclusion

- New perturbation method – flow dependent SPP
  - *LSPP_FLOWD* namelist switch
- FD-SPP behaves expectedly
  - Perturbs more in targeted areas
- Spread is increased, RMSE decreased
  - RMSE/spread ratio is improved
- CRPS decreased
- To do
  - FSS for precipitation should be calculated
  - Summer period should be included