

Nowcasting by analogues: a generalization using radar data sequences

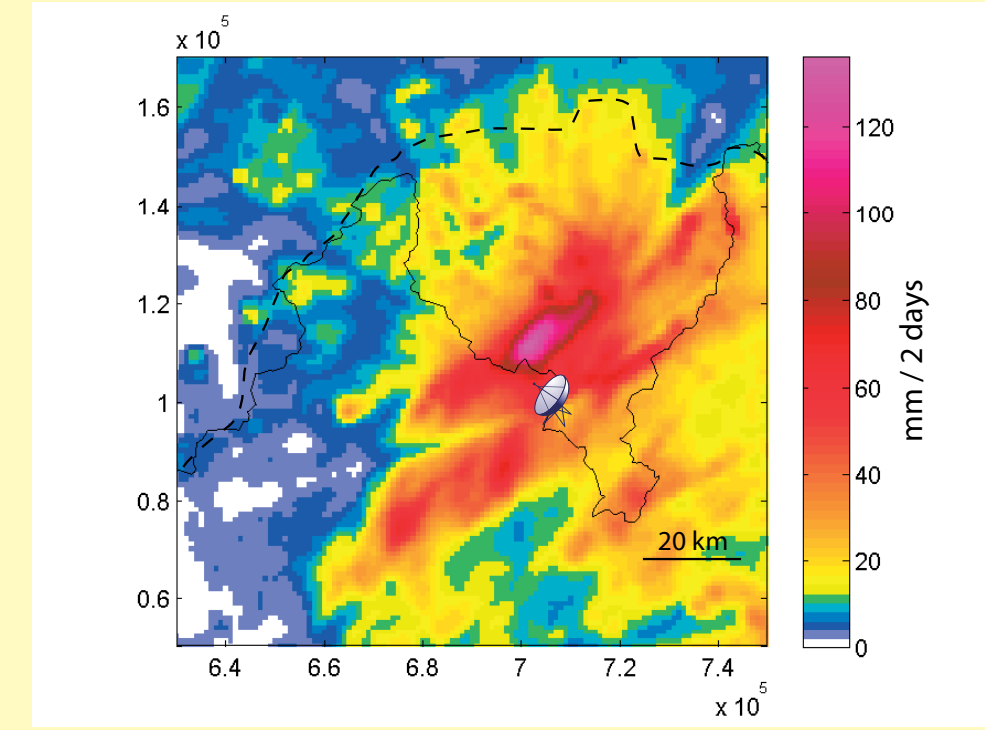
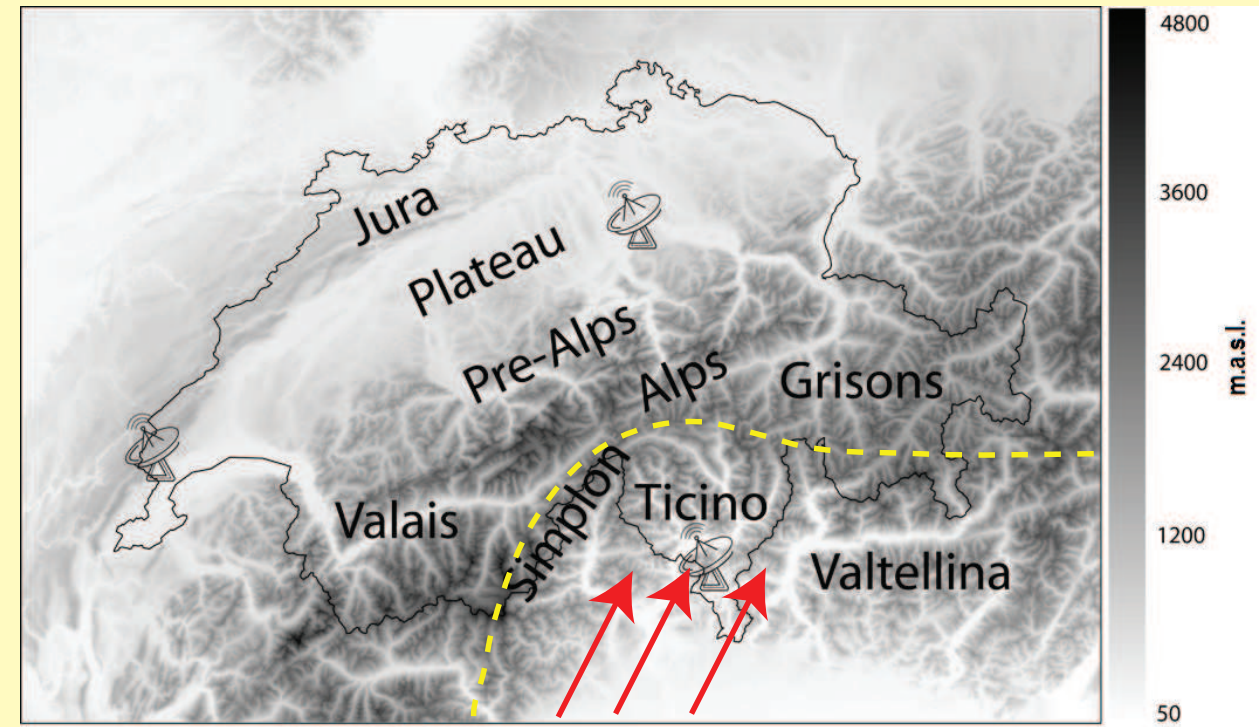
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Motivation

- Need for probabilistic nowcasting models for hydro-meteorological warning systems in complex Alpine orography
- Exploration and exploitation of weather radar data archives

Orographic rainfall



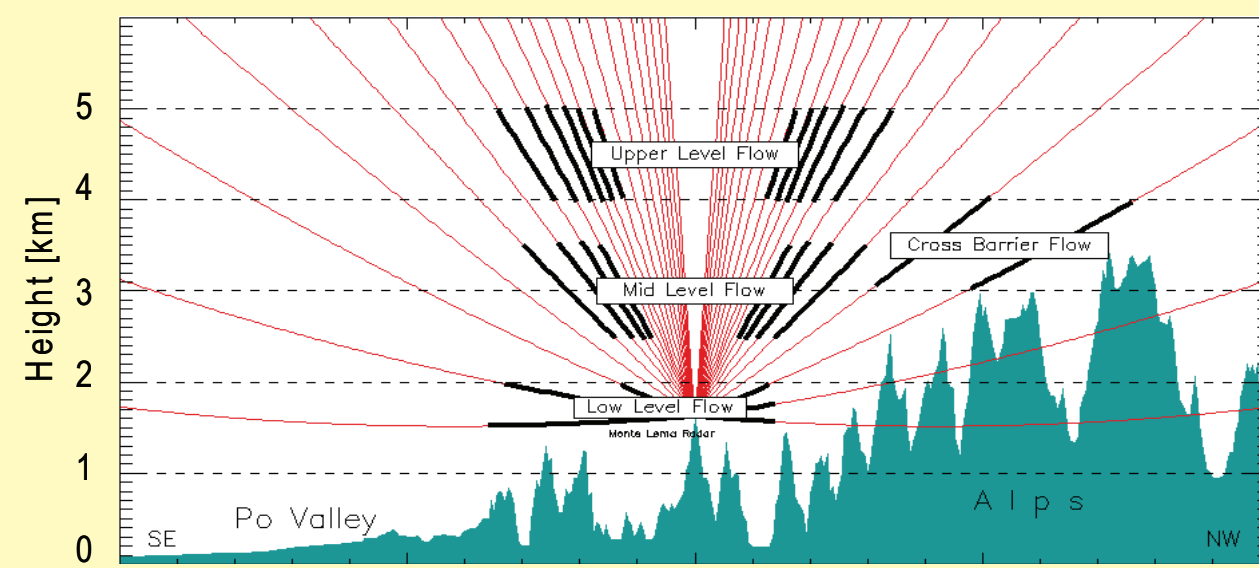
- Causes:
- Flow $\perp$ mountain range
 - Sufficient air moisture
 - Air instability
 - Lifting of air masses

- Consequences:
- Stationarity and persistence of rainfall
 - Large rainfall amounts in a few hours
 - High spatial gradients

NORA

NORA is a tool recently developed at MeteoSwiss for nowcasting of orographic rainfall by means of analogues

Data archive: 62 events of orographic rainfall (~ 2165 hours)



- Step 1:** retrieval of forcing analogues (mesoscale flows + air-mass stability)
- $\min \{ \text{dist}[\text{MLF}, \text{ULF}, \text{CBF}, \text{LLF}, N_m^2] \}$
 - N_m^2 : Brunt-Väisälä frequency
 - 120 forcing analogues

Step 2: retrieval of rainfall analogues (radar image features)

- $\min \{ \text{dist}[\text{IMF}, \text{WAR}, \Delta \text{IMF}(\text{t-2hrs}), \Delta \text{WAR}(\text{t-2hrs})] \}$

IMF: image mean flux, WAR: wet area ratio

- 12 rainfall analogues selected from 120 forcing analogues

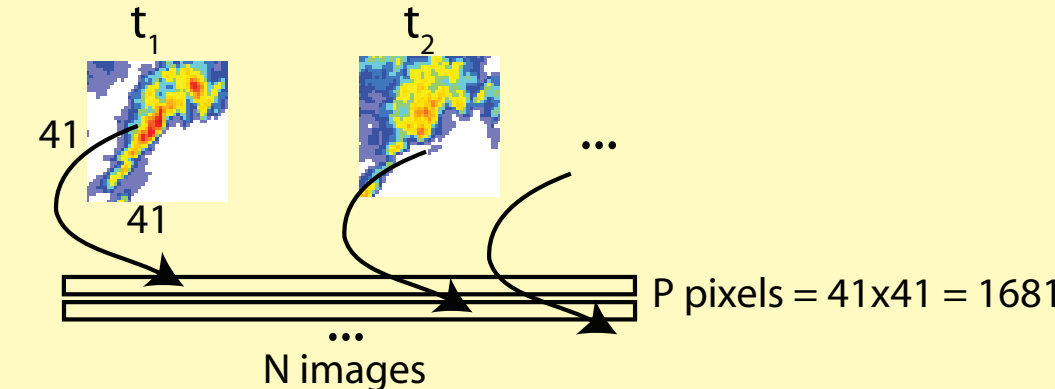
Step 3: construction of the forecast by using the future evolution of the analogues

- NORA outperforms Eulerian persistence after 1 hour lead time
- NORA outperforms NWP COSMO-2km model up to 3-4 hours lead time

A new idea for retrieving rainfall analogues

- 1: Prepare $N \times P$ data matrix of radar rainfall rates $\mathbf{R} = \{R_{ij}\}$, $i, j = 1, \dots, 41$

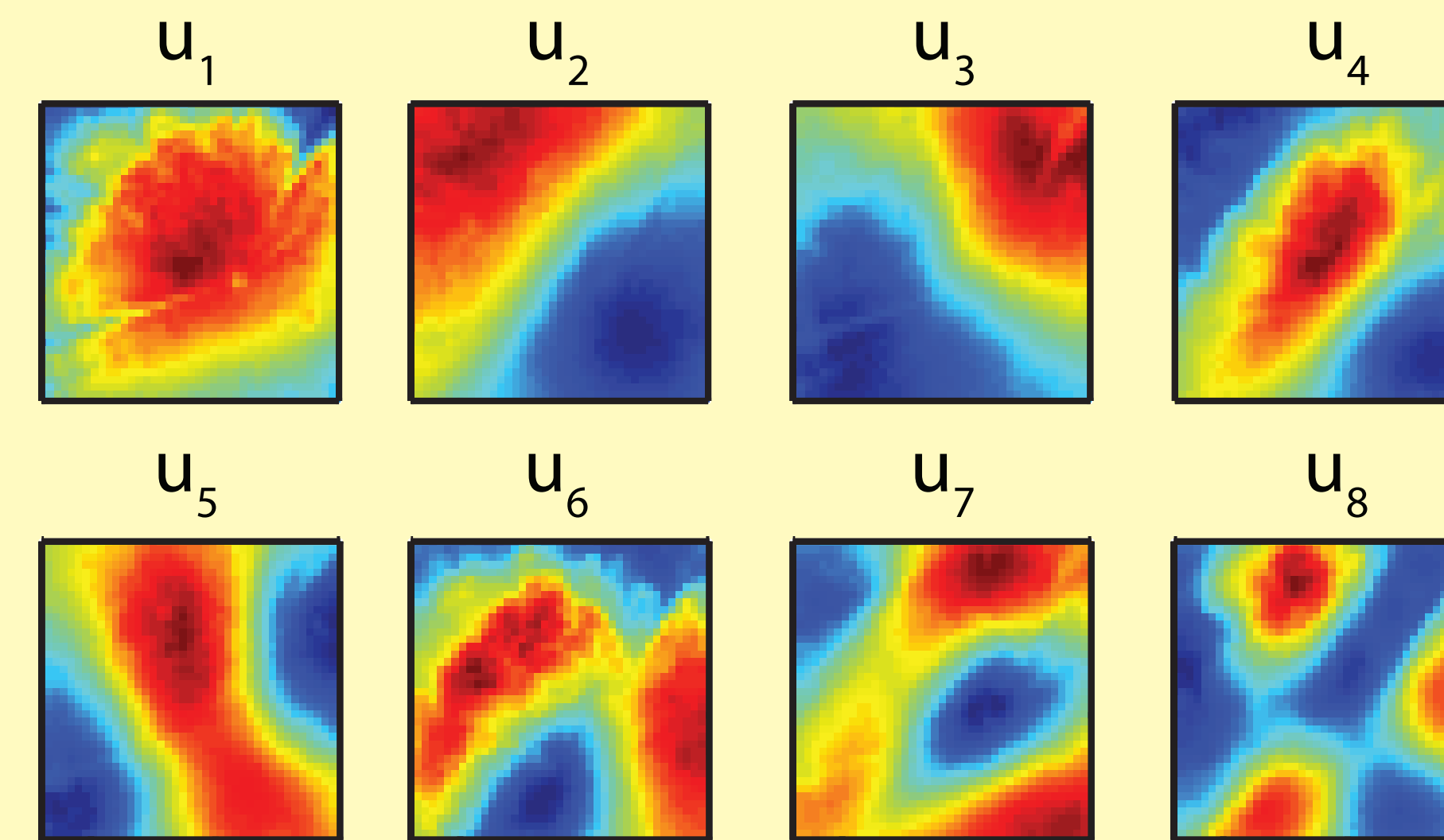
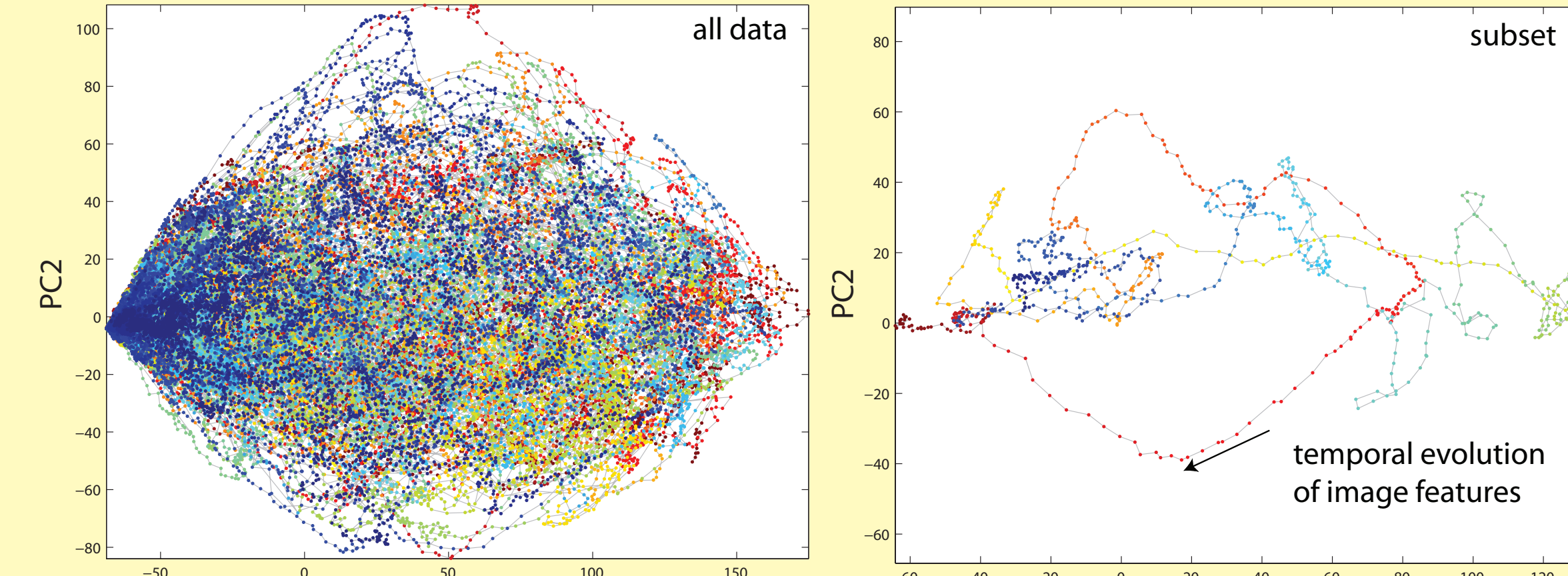
N : 47603 radar images,
 P : 1681 radar pixels



- 2: Consider nonlinear transformations of $\mathbf{R}$ (ex: Box-Cox)
- 3: Reduce dimensionality of $\mathbf{R}$ with PCA: construction of phase space

Phase space trajectories of radar images

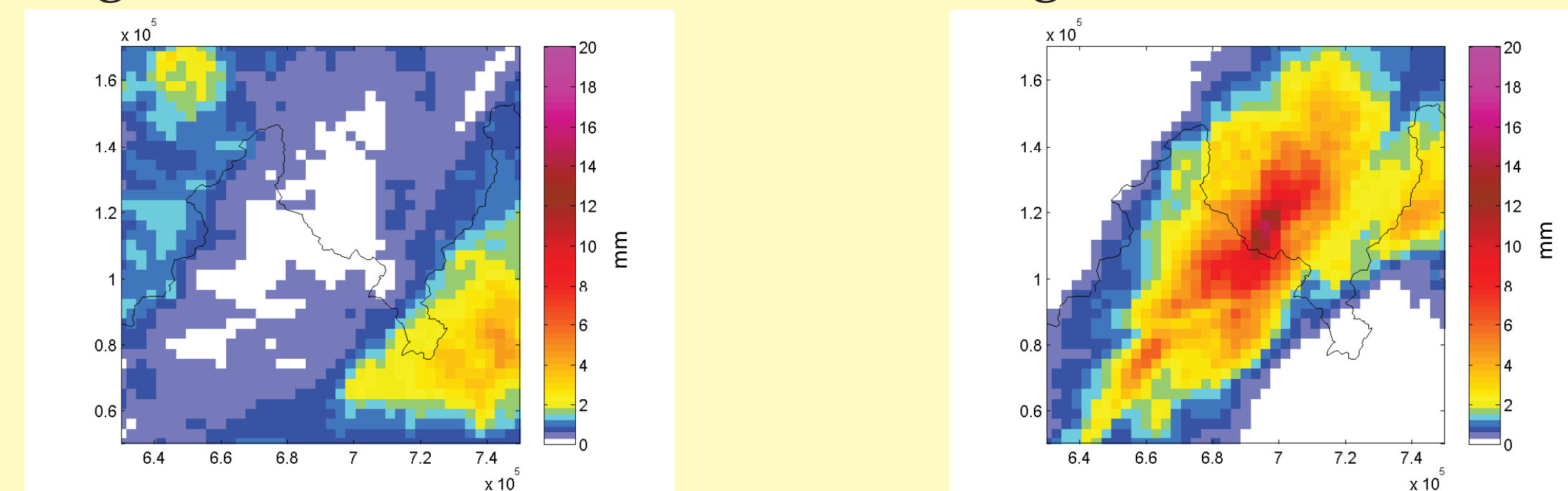
Points = radar images projected in first 2 principal components



→ Eigenvectors explain spatial rainfall patterns

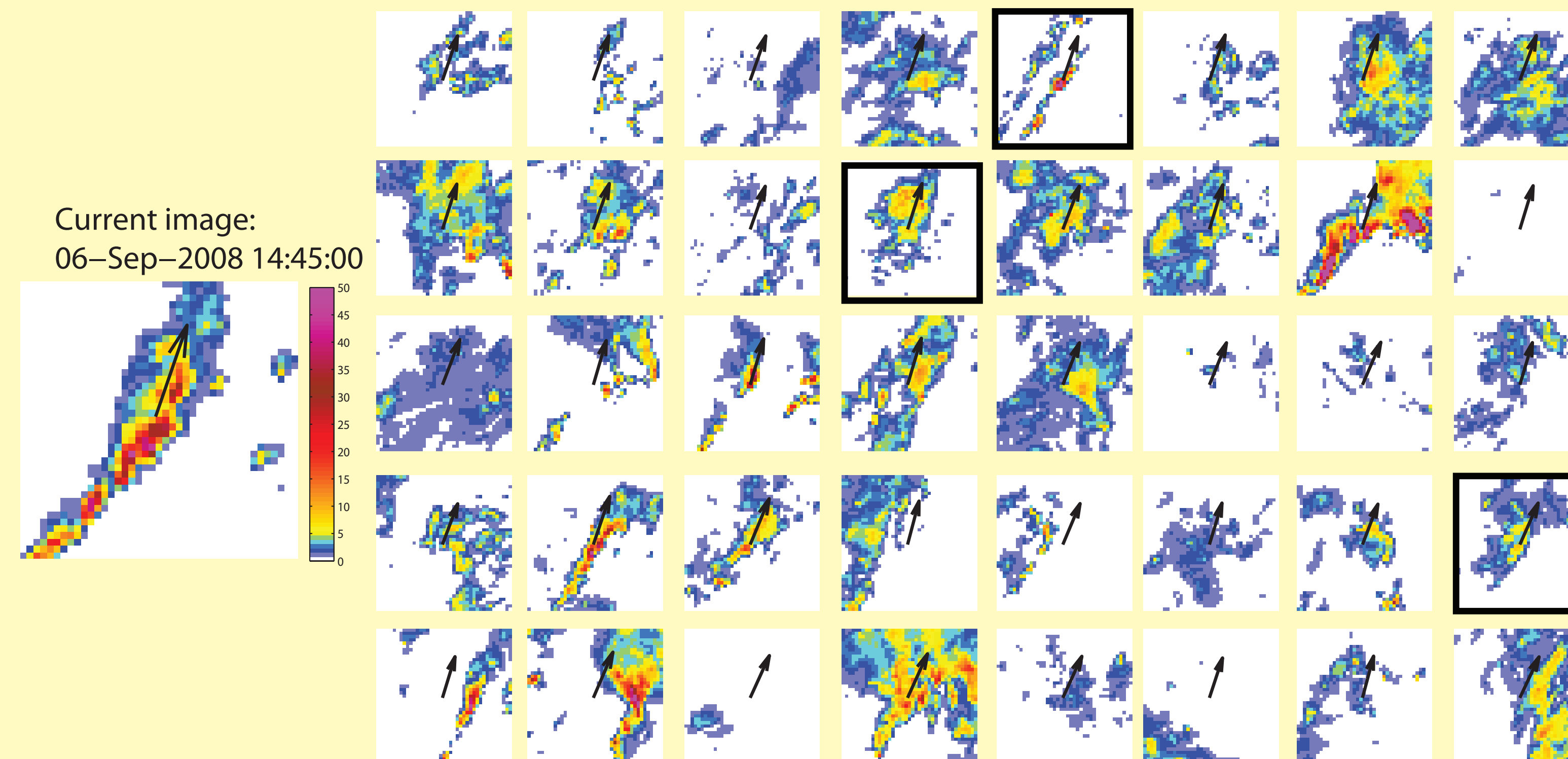
Rainfall fields are compared in terms of “major features”

Average rainfall for PC4 < -50 Average rainfall for PC4 > 50



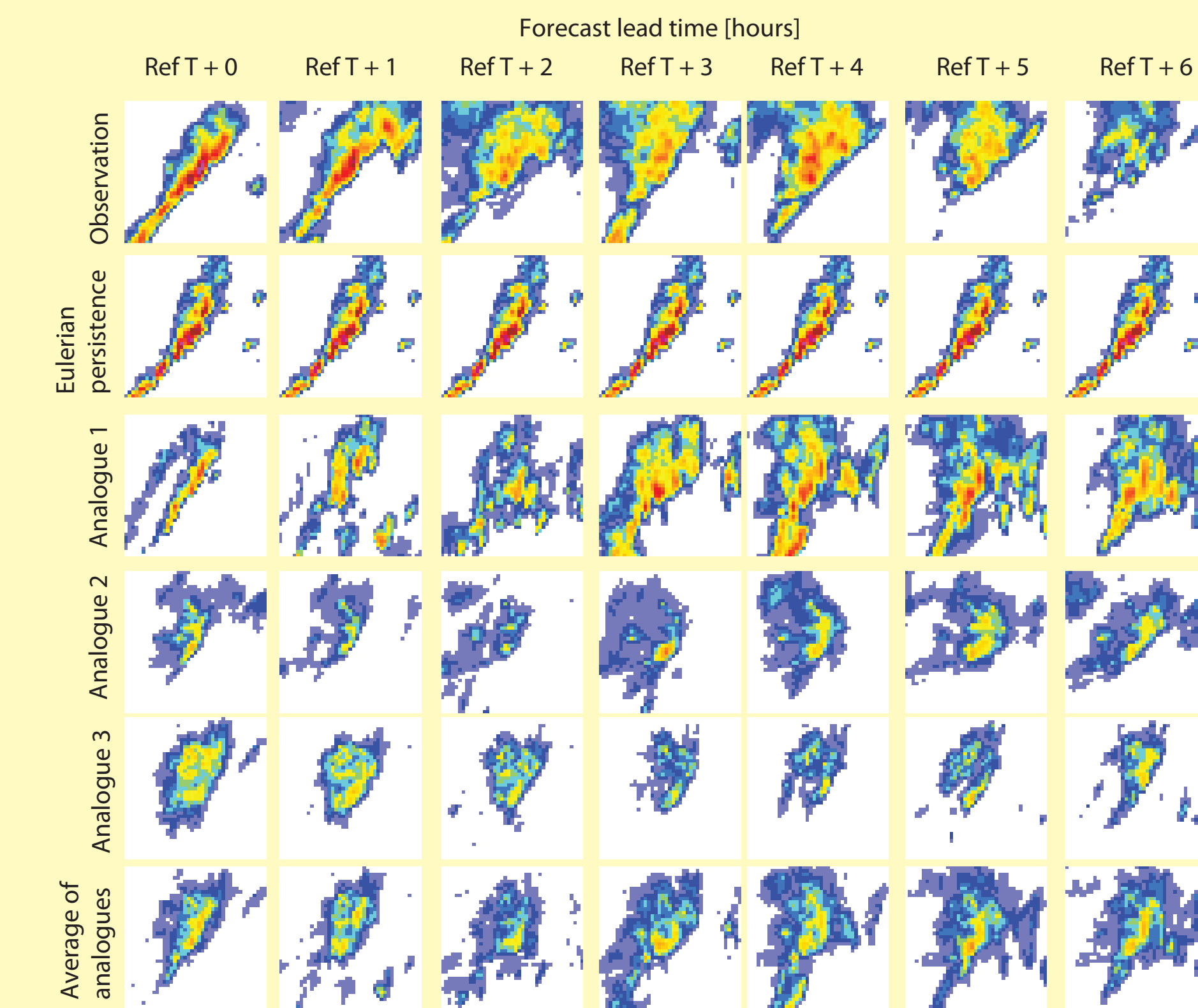
Retrieval of analogue trajectories/sequences

40 forcing analogues based on MLF and 3 rainfall analogues based on PCA trajectories



→ 3 closest trajectories of 12 images (1 hour) in 10 dimensional eigen space
A temporal constraint of 3 hours is set to avoid sampling redundant sequences

Nowcasting example

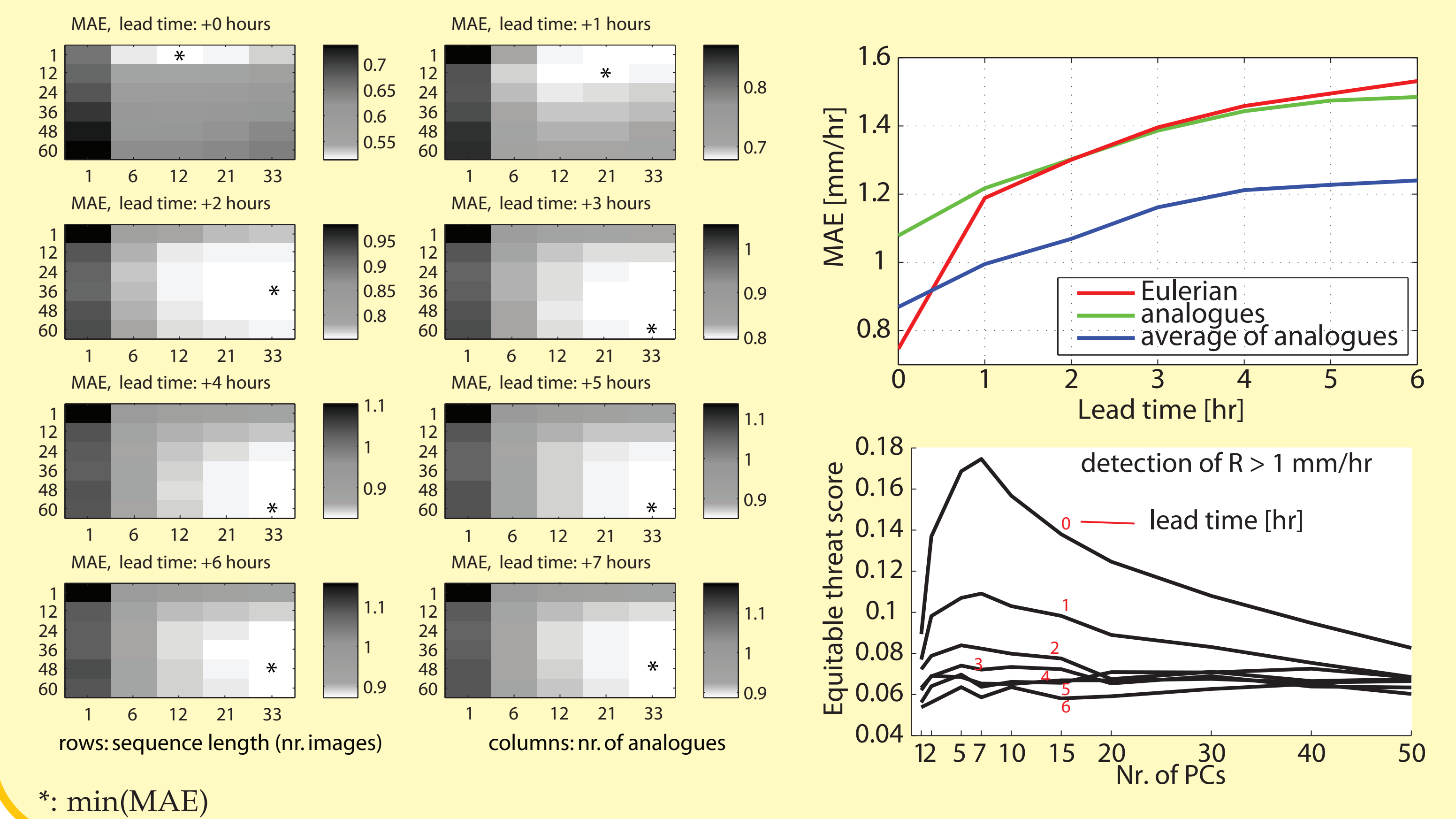


Eulerian persistence does not allow characterizing forecast uncertainty without explicit stochastic simulations

Analogues form a natural ensemble to produce probabilistic forecasts

Averaging of analogues produces a deterministic forecast

Forecast verification



*: min(MAE)

Conclusions and future perspectives

- The recurrence of radar sequences in eigen spaces provides a basis for nowcasting orographic rainfall
- The convexity of error surfaces and lead time dependence of parameters allow optimizing the system (nr. neighbors, seq. length, nr. PCs, etc)

Next steps:

- Comparison with NORA, MAPLE (Lagrangian persistence) and COSMO-2
- Predictability $\sim f(\text{image features, dist. analogues, past performance, etc})$

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References:

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