Nowcasting by analogues: a generalization using radar data sequences

Loris Foresti1, Luca Panzieri2, Pradeep Venkata Mandapaka2, Urs Germann3, Mikhail Kanevski1 & Alexei Pozdnoukhov4

1. Institute of Geomatics and Analysis of Risk, University of Lausanne, Switzerland 2. Radar and Satellite group, MeteoSwiss, Locarno-Monti, Switzerland 3. National Centre for Geocomputation, National University of Ireland Maynooth

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 → 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
→ min \( \text{dist}[\text{MLF, ULF, CBF, LLE, } N_\alpha] \)
→ 12 forcing analogues

Step 2: retrieval of rainfall analogues (radar image features)
→ min \( \text{dist}[\text{IMF, WAR, } \Delta \text{IMF}(t-2hrs), \Delta \text{WAR}(t-2hrs)] \)

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 \( R = \{ R_{ij} \} \) for \( i = 1, \ldots, 41 \) and \( j = 1, \ldots, 41 \)
2. Consider nonlinear transformations of \( R \) (ex. Box-Cox)
3. Reduce dimensionality of \( R \) with PCA: construction of phase space

Phase space trajectories of radar images

Points \( R \) 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

Forecast verification

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

Conclusions and future perspectives
→ The recurrence of radar sequences in orographic 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 = ~ (image features, dist. analogues, past performance, etc.)

The research is supported by the Swiss National Science Foundation projects No 200020-12185/1 + PBLAP2-12773/1 and the European FP7 project IMPRINTS. More information can be found at www.geokanels.org. Contact: Loris.Foresti@gmail.com

References: