Verification of clustering methods for hydrological ensemble forecasts

Joris Van den Bergh, RMI Belgium

HEPEX Tenth Anniversary Workshop
24-26th June 2014, Maryland, USA

Collaboration with
A. Deckmyn, A. Duerinckx, G. Smet (RMI)
B. Pannemans (IMDC)
Outline

- Introduction.
- Clustering & representative ensembles.
- Verification.
- Hydrological verification.
- Conclusions.
Introduction

- Project with Flemish environment agency (VMM, end user), Royal Meteorological Institute Belgium (RMI) and International Marine and Dredging Consultants (IMDC).
- Aim: reduce an ensemble of precipitation forecasts to a smaller set of “representative members” (scenarios) for use as input for the detailed hydraulic model used by VMM.
- ~50 → 5-10 ensemble members.
VMM

- Responsible for water management of Flemish non-navigable rivers. Website: WATERINFO.be
Introduction

• Our solution: **clustering algorithm**.
• Literature study of available methods.
• Development of new methods.
• Evaluation of some proposed methods, using GLAMERPS and ECMWF ENS ensembles.
• Verification for Dijle catchment ($\approx 900 \text{ km}^2$) for two 1-month periods (winter and summer).
ECMWF ENS

- 51 member ensemble (global).
- Forecast range: 10 days, resolution ~30km (up to 14 days at ~50km resolution). N320 grid.
- Runs at 00 and 12 UTC.
- Singular vectors, stochastic physics perturbations, ensemble data assimilation.
- Postprocessing to be performed by end users.
GLAMEPS (v1), www.glameps.org

- 54 limited area ensemble members:
  - ECMWF ENS, ECMWF DET (downscaled),
  - AladEPS, HirEPS-K, HirEPS-S.
- Forecast range: 54 hours, ~11 km resolution.
- Runs at 06 and 18 UTC.
- Postprocessing with BMA.
GLAMEPS gridpoints, Dijle catchment
Clustering

- Clustering: partition objects into clusters such that objects with similar characteristics are clustered together and dissimilar objects end up in different clusters.

- Form of unsupervised learning: little or no prior information on object classification.
Clustering

• Many different algorithms and applications.
• Main ingredient to define “similarity”: distance measure for n data vectors in K-dimensional space:
  - Euclidean
  - Karl-Pearson
  - “City block distance”, …
• Computation of n(n-1)/2 pairs of distances.
Clustering

Hierarchical
- Single Link
- Complete Link

Partitional
- Square Error
- Graph Theoretic
- Mixture Resolving
- Mode Seeking

k-means

Expectation Maximization
Hierarchical clustering

- Partition objects into tree of nodes.
- Iterative procedure, object cannot change cluster once assigned.
  - Agglomerative: "bottom up", start with n clusters, iterative merging of pairs.
  - Divisive: "top down", start with 1 cluster and iteratively decompose (computationally expensive).
- After cluster assignment, methods allow to assign "most representative" members.
Partitioning clustering

- Non-hierarchical, objects can be re-assigned to new clusters during procedure.
- Number of clusters $k$ chosen a priori.
- Most well-known algorithm: k-means.
Clustering in Meteorology

- Classify into weather regimes, climate zones, ...
- Clustering of ensemble forecasts to generate representative members (RM) for downscaling:
  - Based on meteorological variables such as MSLP, wind speed, relative humidity, ...
  - Typically at synoptic scale.
  - Example: COSMO-LEPS (Marsigli et al, 2005).
- Most used method: hierarchical clustering.
Problems/issues for our application

- Clustering at synoptic scale not always suitable for clustering at local scale.
  - Small scale catchments.
  - We are only really interested in precipitation.

- Clustering should not select different ensemble members on different days → temporal consistency and avoidance of “double counting”
Our approach

- **Main idea**: use precipitation directly to classify, no other meteorological fields.
- Precipitation at k different lead times → clustering on k dimensional space.
- **Sub-ensemble taken from full ensemble**.
  - Classify into 5-10 clusters,
  - take RM from each cluster,
  - associate prob. weight according to cluster size.
Tested methods

- Hierarchical agglomerative clustering method, based on Ward's method (e.g. Wilks, 2004).
- Our own developed “Optimal distance (OPT)” method, taking members that are the most different from each other (similar to Sattler and Feddersen, 2005).
- Quantiles of total accumulated precipitation.
- Quantile method that selects using “most active period” (bin with most precipitation).
Verification setup

- Verification periods:
  - 1 month during summer 2012,
  - 1 month during winter 2012-2013.

- Comparison of observed areal precipitation with full ensemble forecast and sub-ensemble with representative members.

- Comparison of a hydrological model forced with full ensemble vs. forcing with sub-ensemble.

- Performance evaluation: visual, probabilistic scores.
Dijle catchment & ENS/GLAMEPS gridpoints
Dijle: observed areal precipitation for two test cases. Summer 2012 (left), winter 2012 (right).
Verification example, GLAMEPS, hierarchical method
Probability plot using 5-member ensemble plus weights
Verification example, ECMWF ENS, hierarchical method
Hydrological Verification

- Complete GLAMEPS and ENS precip ensembles used as input for conceptual hydrological model.
- Sub-ensembles generated by our main 4 clustering methods with “best” parameter choices tested.
- Evaluation by comparison with full ensemble:
  - Peakflow probability distribution,
  - Probability of exceedance for thresholds.
Hydrological verification example: peakflow probability

![Graph showing hydrological verification example](image)

- **Optimal**
- **Cluster**
- **Quantile**
- **Mixed6h**
- **All members**

**Forecast:** 2012-12-20 00 / **Peak of event:** 23 Dec 2012
Hydrological verification example: probability of exceedance
Some Conclusions

- All methods are “competitive”, there is not one that clearly stands out.
- Single peaks usually included in cluster, multiple peaks can be missed in sub-ensemble.
- Quantile method works quite well (CRPS score), and very simple to implement.
- Going from 5 to 10 members gives a large improvement, and is recommended if possible.
Further investigation & Work in progress

- Test clustering on more catchments and longer time period.
- Use of distance measure taking spatial structure into account.
- More detailed investigation of quantile method with selection of “active precipitation periods” (accumulation time, dependance on forecast range,...).
Questions?