Stepwise analogue downscaling for hydrology (SANDHY): validation experiments over France

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Challenge
- Statistical downscaling relates large scale prediction from general circulation models (GCMs) to local predictors
- A necessary condition for downscaling is a climate change context in which the predictor-prediction relationship is still valid under past climate variability

Objective
- Testing the performance of SANDHY on independent data under current climate conditions.
- Testing the dependence of the performance on the archive for searching analogue dates and on the predictor domains optimized for a given period.

SANDHY
- Principle: Similar large scale circulation leads to similar local precipitations (Fig. 1)
- Downscaling by selecting four types of predictor variables: temperature, geopotential, vertical velocity and humidity (Fig. 2)
- The precipitation on the 25 best analogue days gives an empirical distribution reflecting the uncertainty in the downscaling step
- Predictor domains for geopotential optimized individually for 608 target zones using a variant of the growing rectangular domain algorithm and retaining the best five domains found (Radanovics et al., 2013)

ERA-40 Reanalysis data (Uppala et al., 2005) are used as large scale predictors and daily precipitation from the French near surface meteorology SAFRAN (Vidal et al., 2010) as predicted local data

Results
1. Reference simulation: CRPSS and bias show a spatial distribution similar to the one of the mean precipitations with high skill and positive bias where mean precipitations is high, and lower skill and very small or slightly negative bias in dry regions. (Fig. 4 and 7 top left)
2. Out-of-sample validation: The average skill loss compared to reference simulation is a reasonable (Fig. 5) with some more skill loss in the northern part of the country and no loss in the southeastern part. (Fig. 6) The bias is somewhat stronger than for the reference simulation. (Fig. 7)
3. Alternative archive: Using the alternative archive leads to small and spatially uniform skill loss (Fig. 6), but changes the bias (Fig. 7) compared to the out-of-sample simulation.
4. Imperfect predictor domains: The skill loss is very similar to the out-of-sample validation, while the bias is rather similar to the reference simulation.

Experiments
1. Reference simulation: Simulation of the late period using the late period as an archive for searching the analogue dates, that is, representing the best possible case scenario (Fig. 3)
2. Out-of-sample validation: Simulations of the early period using the late period as an archive. The idea is to simulate a period whose local data is not "known" by the model as it would be the case in any application
3. Alternative archive: The late period is simulated using the early period as archive
4. Imperfect predictor domains: The early period is simulated using the early period as archive

Conclusions
SANDHY is quite robust in terms of downscaling skill at most locations (experiment 2)
- Changing the archive has only small impacts on the skill but changes the bias at some locations. (experiment 3)
- The skill loss observed in experiment 2 stems rather from the imperfect predictor domains than from the imperfect archive (experiment 4)
- The bias tends to be positive in regions with high mean precipitation and slightly negative in dry regions
- We can not expect to have a constant bias if the archive period differs from the simulation period
- Overall the results increase the confidence in applying SANDHY skillfully for downscaling in various contexts over France

Figure 1: For a large scale target situation the N most similar situations are searched in the analogue archive. The local precipitation recorded on these analogue dates gives an estimate of the target day.

Figure 2: Analogue selection starts off with a 20-year archive (7305 days), from which a subset is selected. (temperature at 500hPa and 850hPa, (2) geopotential shape at 850hPa and 500hPa, (3) vertical velocity at 850 hPa and (4) relative humidity at 850hPa full column water.

Figure 3: Time periods used in the different experiments. Predictor domains have been optimized over the late period for all experiments.

Figure 4: CRPSS for the reference simulation versus CRPSS for the alternative archive for every zone in France

Figure 5: CRPSS for the reference simulation versus CRPSS for the other experiments for every zone in France

Figure 6: Spatial distribution of CRPSS for between the four experiments and the reference simulation.

Figure 7: Spatial distribution of bias for the four experiments.