Revisiting the analog method to obtain uncertainty estimates for proxy surrogate reconstructions

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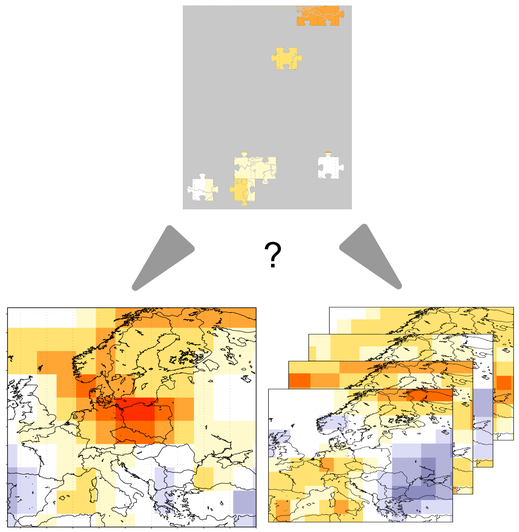
I. The analog method

Analog search algorithms allow to combine information from simulations and reconstructions at low computational costs. Simulated spatially complete and "dynamically consistent" fields complement the puzzle pieces provided by the spatially sparse paleo-observations according to certain criteria of compatibility.

An effective criterion is the Euclidean distance between the proxy series and appropriate grid-point data. Thus, one obtains, e.g., the single best analog or a number of suitable analogs.



If one is certain about the puzzle pieces, one may use the single best analog. What if I am uncertain about the puzzle pieces?

Obviously the proxy series explain only part of the local or regional variability. The unexplained variance allows to screen the pool of fields for compliance within a certain interval around the proxy values.

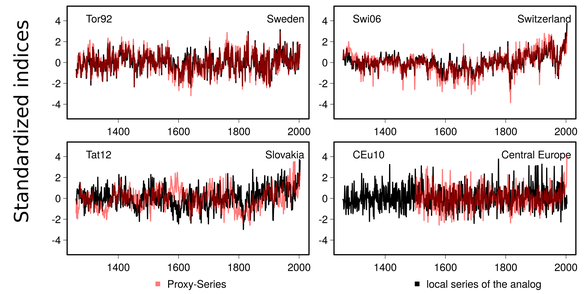
This ensemble of analogs provides a credible interval for local and field estimates.

The credible interval depends obviously on the source of the analogs. Different pools of analogs may give different intervals.

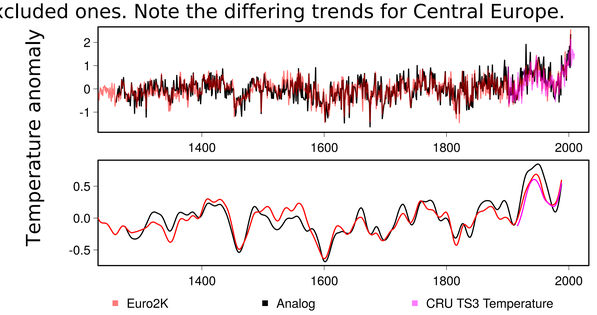
II. Data and data handling

- Proxy data: Euro2K excluding Albania, Slowakia & Central Europe
- Simulation pool: MPI-ESM COSMOS ensemble
- Data is locally normalized over 1260-2003. Analogs are scaled with standard deviation from one simulation over this period.
- Criteria:
  - I. single best Euclidean distance;
  - II. analogs within an uncertainty margin for each proxy. One standard deviation margin derived from correlation between proxy series and grid point CRU TS3.

III. The single 'best' analog



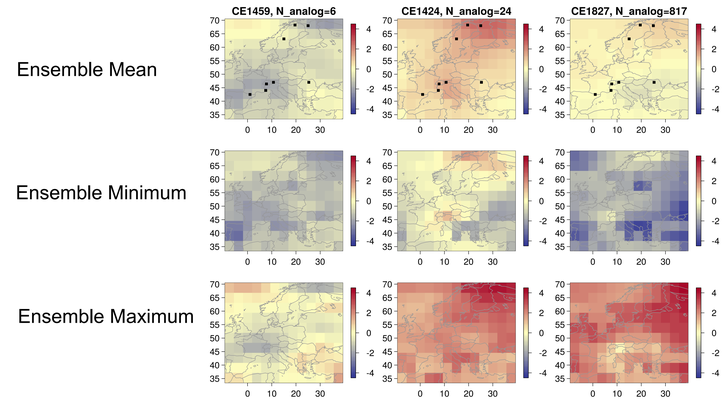
Analogs capture the proxies from the analog-search. Differences can be large for excluded ones. Note the differing trends for Central Europe.



The good match is transferred to the temperature reconstruction. The chosen scaling seems to overestimate multi-decadal variability and centennial trends since ~1600.

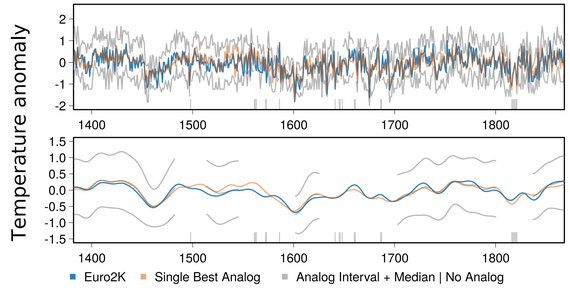
Observations (magenta) are arbitrarily shifted. Lower panel uses a 31 point Hanning Filter.

IV. A credible interval of analogs



Choosing only all those analogs compliant with the uncertainty of the proxy data results in different sample sizes. There may be very high numbers of potential analogs and there may be no analogs at all.

For average conditions, temperature is only loosely constrained even at the proxy locations.



Cold conditions, are hard to capture with the used pool of analogs. The interval for area-averages of analogs is very similar throughout. The ensemble median is close to the result of the single best analog selection.

V. Conclusions

Considering uncertainty of paleo-observations in analog searches provides **credible intervals** for the reconstructions, helps to **validate** other reconstructions, and **highlights differences** in spatio-temporal variability between simulation and proxies.

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