Analogues de circulation atmosphérique: un peu de théorie, quelques applications

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Motivations

- Study climate events and relate them to large-scale atmospheric circulation
- If there is a climate attractor, how to measure a qualitative alteration?
  - Link with forcings (solar, volcanoes, GHG…)
- Detection, attribution and emergence?

Circulation analogues (1)

- *Reference* database **R**, containing consistent pressure (SLP and/or geopotential heights), temperature, precipitation etc. data during a reference period of observations
  - E.g. Reanalysis data for a fixed period, model control simulation
- *Target* dataset **T**, with only pressure data (SLP or geopotential height)
  - E.g. Observation during a period outside of the reference

Circulation analogues (2)

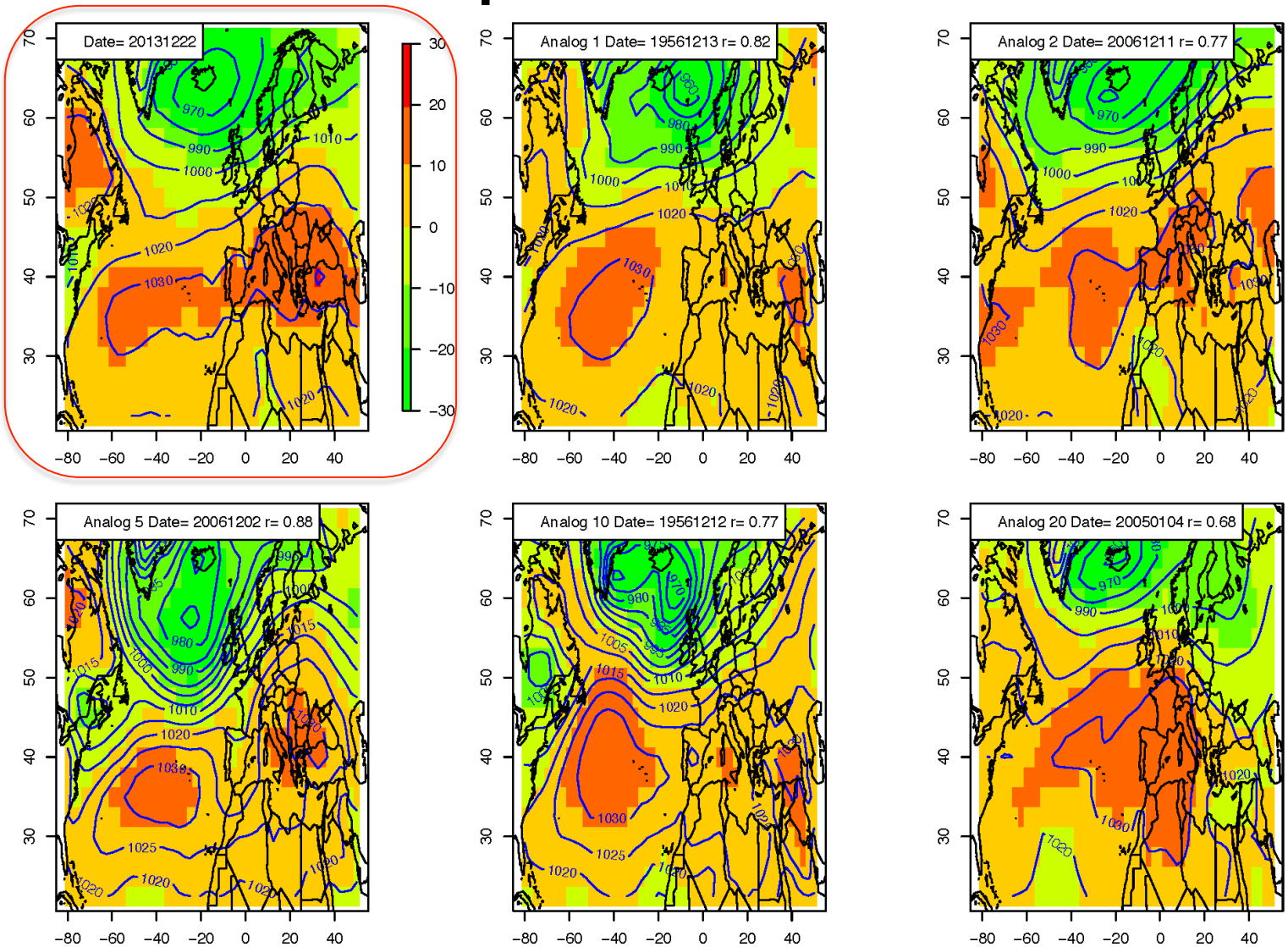
- We want to infer the value of climate variables (e.g. T, Prec., Wind speed) in the dataset **T**, from information in the database **R**.
- For each day in **T**, find best analogues of pressure in **R**.
  - Minimize distance (Euclidean, Mahalanobis…)
  - Maximize spatial correlation (rank)

Circulation analogues (3)

- Use of daily sea-level pressure (SLP) from NCEP reanalyses
- For all days between Jan. 1st 1948 and March 31st 2013, pick the 10 days within 30 calendar days but different year with the closest SLP:
  - largest correlation (rank or linear)
  - Smallest Euclidean distance

- NOTE: analogues for day d, or sequences of (d-1, d, d+1) to preserve local trajectories

Example: Storm Dirk



Temperature analogues

- Average daily minimum temperature (TN) anomalies over Europe
  - ECA&D database
- Compute the median temperature for 10 circulation analogue days
  - Analogue temperature & spread of analogues

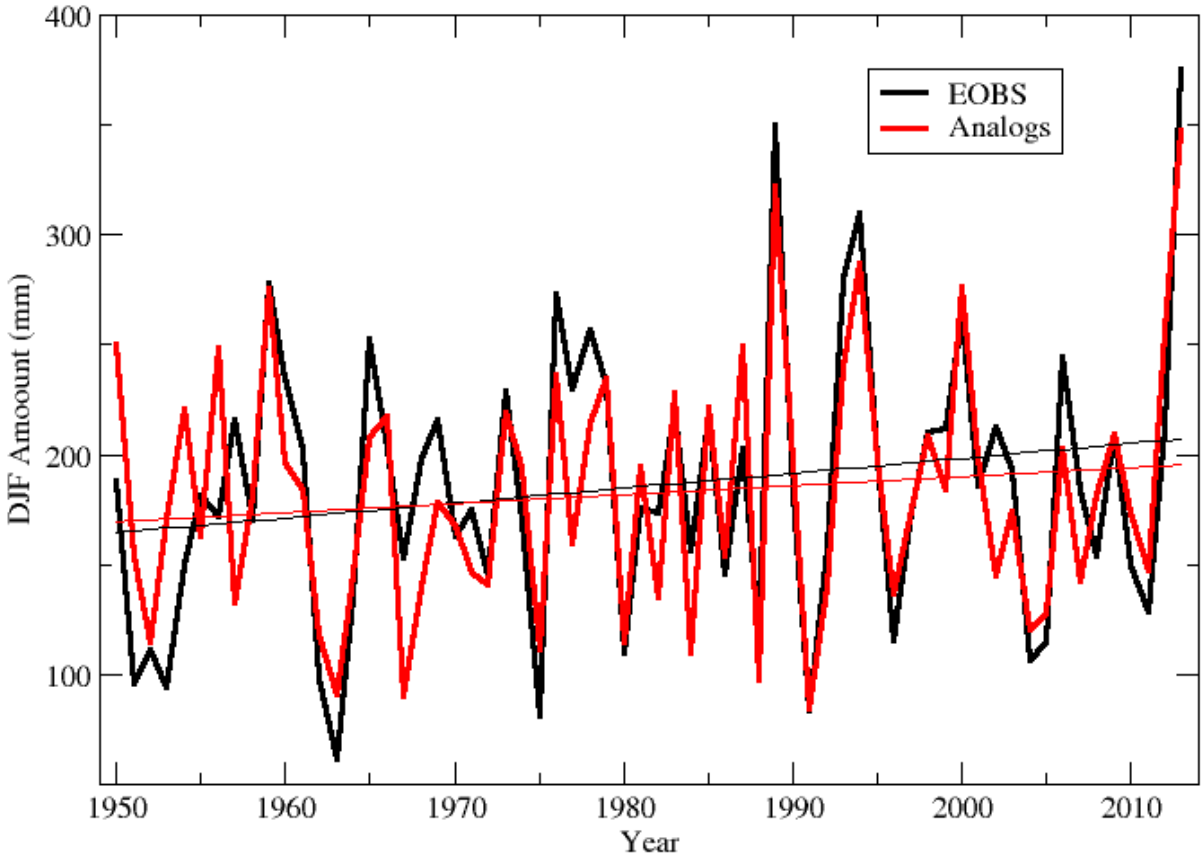
- Same thing for precipitation

“Black Swans” & Extremes

- Contribution to BAMS special issue on extreme events
- Providing a long time perspective of observed extremes
  - Year 2011 in Europe
  - Wet winter in 2012 in Northern Europe
  - Wet winter in 2013 in Southern Europe
  - Warm and wet winter in 2014 in UK and Brittany (in progress)

Extreme Precip in South UK

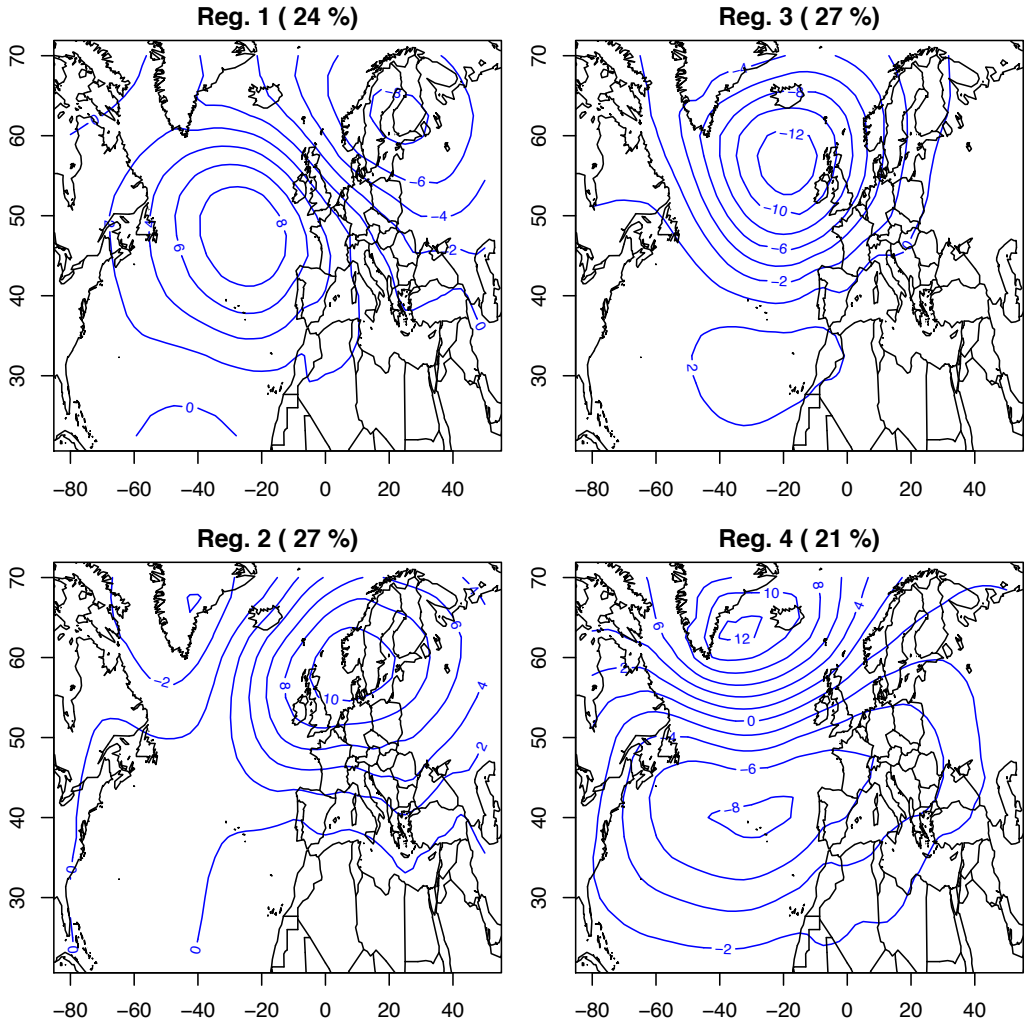
Comparaison des cumuls saisonniers avec les cumuls reconstruits par analogues



Tendances de régimes DJF?

Atl Ridge

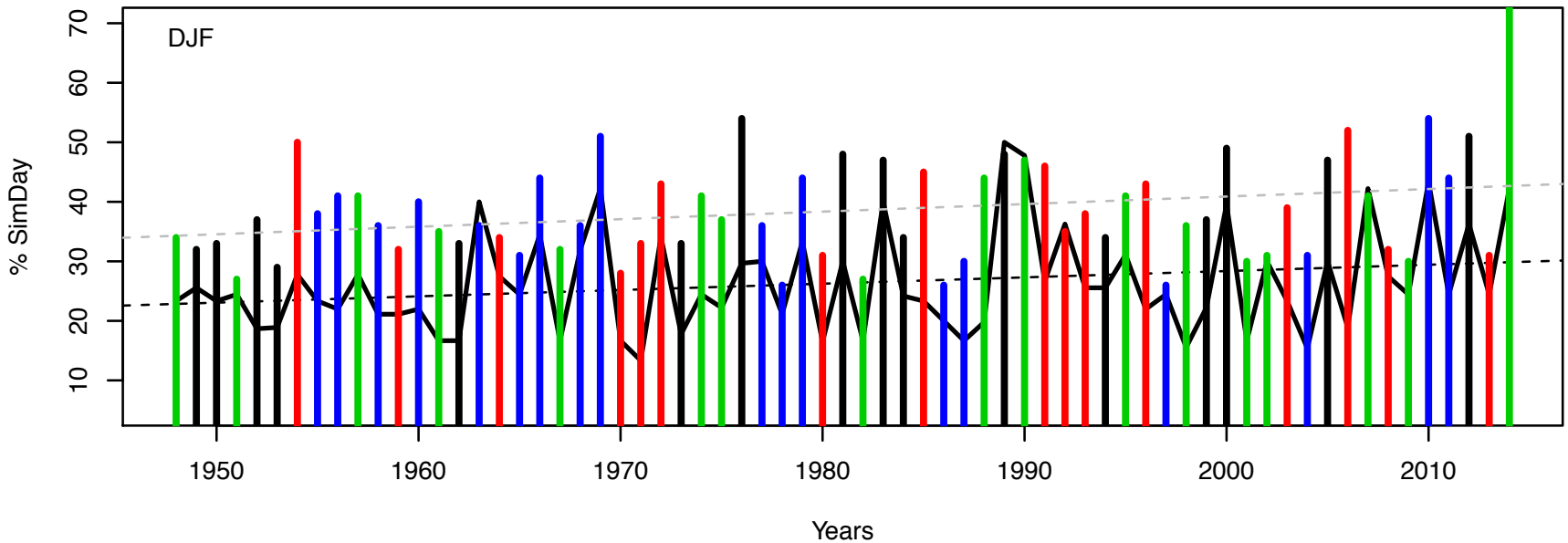
Zonal



Blocking

NAO-

Régimes & Analogue Clusters



Couleurs: Fréquence des régimes dominants pendant une saison
Ligne: Nombre max de jours “semblables” pendant d’une saison

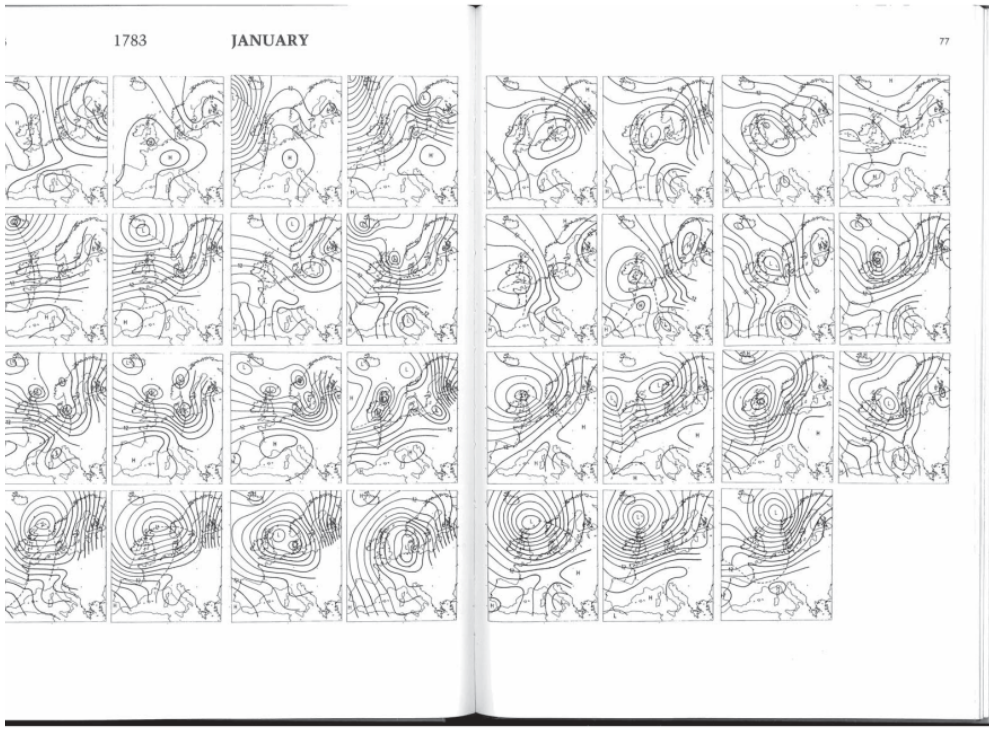
Vers une augmentation de la persistence des structures atmosphériques en hiver (l’inverse en été)?

Application: Atmospheric Reconstructions

- Reconstruct daily atmospheric fields (pressure, temperature, wind) compatible with surface SLP observations
- Compare with historical meteorological observations
- Focus on the years 1781-1785 (incl. Laki eruption in 1783)

Input SLP data

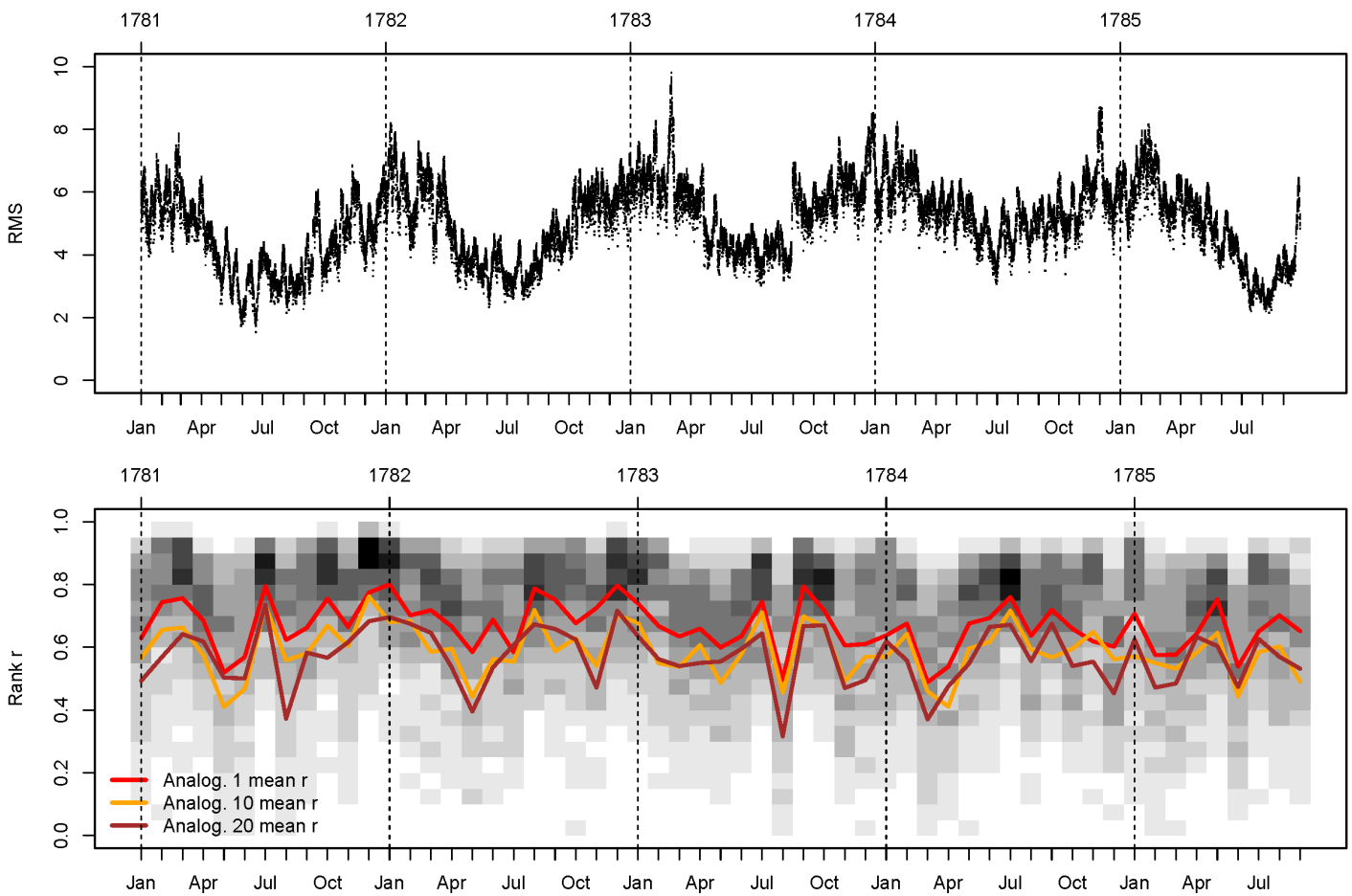
- Daily pressure observations in Europe
  - converted to SLP
  - Gridded
- From J. Kington (1988)
  - The Weather of the 1780s in Europe, Cambridge University Press
  - Data file provided by P.D. Jones (UEA)
  - Various QC



Ensemble of reconstructions

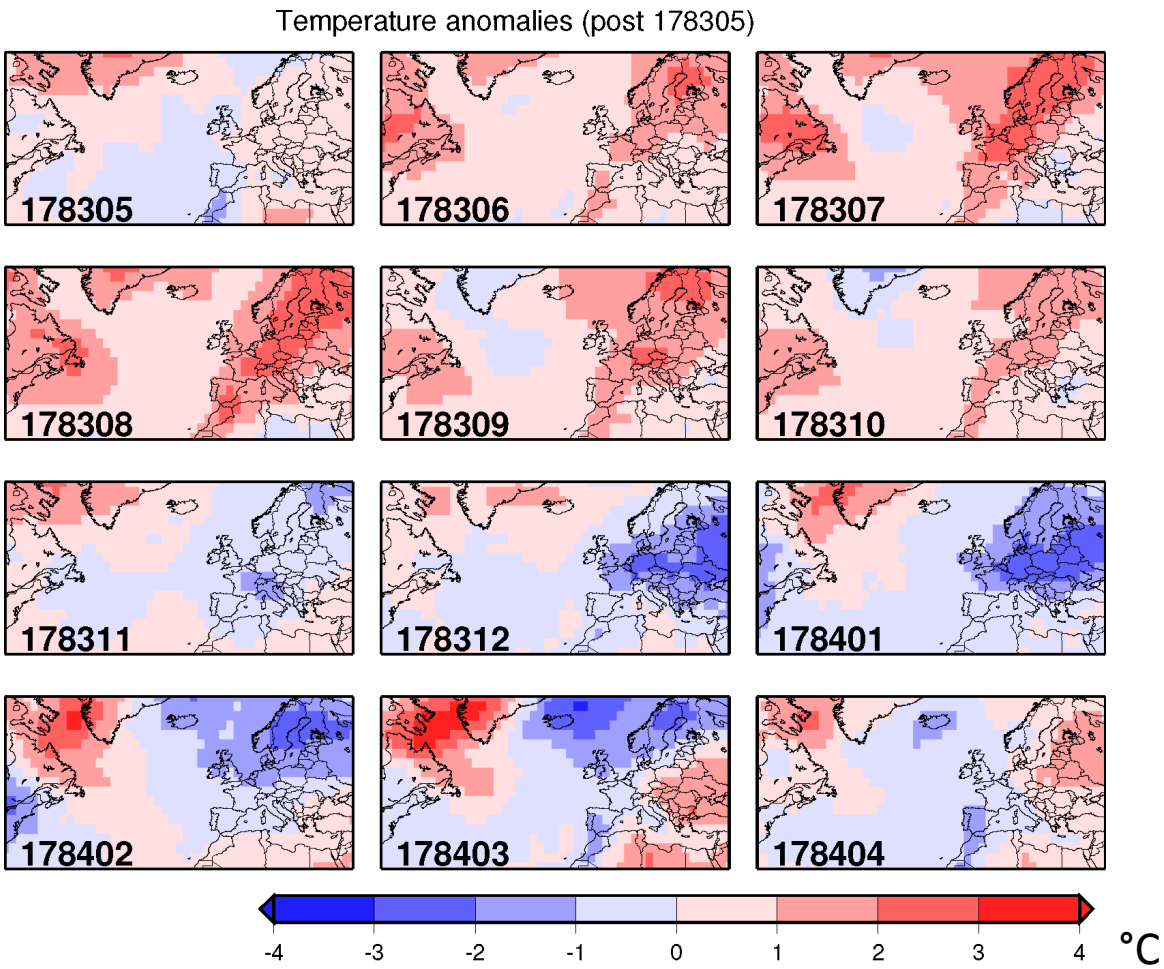
- NCEP SLP (daily)
  - Interpolated on Kington grid (5°x5°)
- 20 analogues of SLP, calibrated over Europe, extended over the North Atlantic
  - For each day in 1781-1785, computation of 20 best analogues of SLP from NCEP (1948-2012)
  - Computation of correlation
  - Computation of composites for T2m, wind speed

Scores of analogues

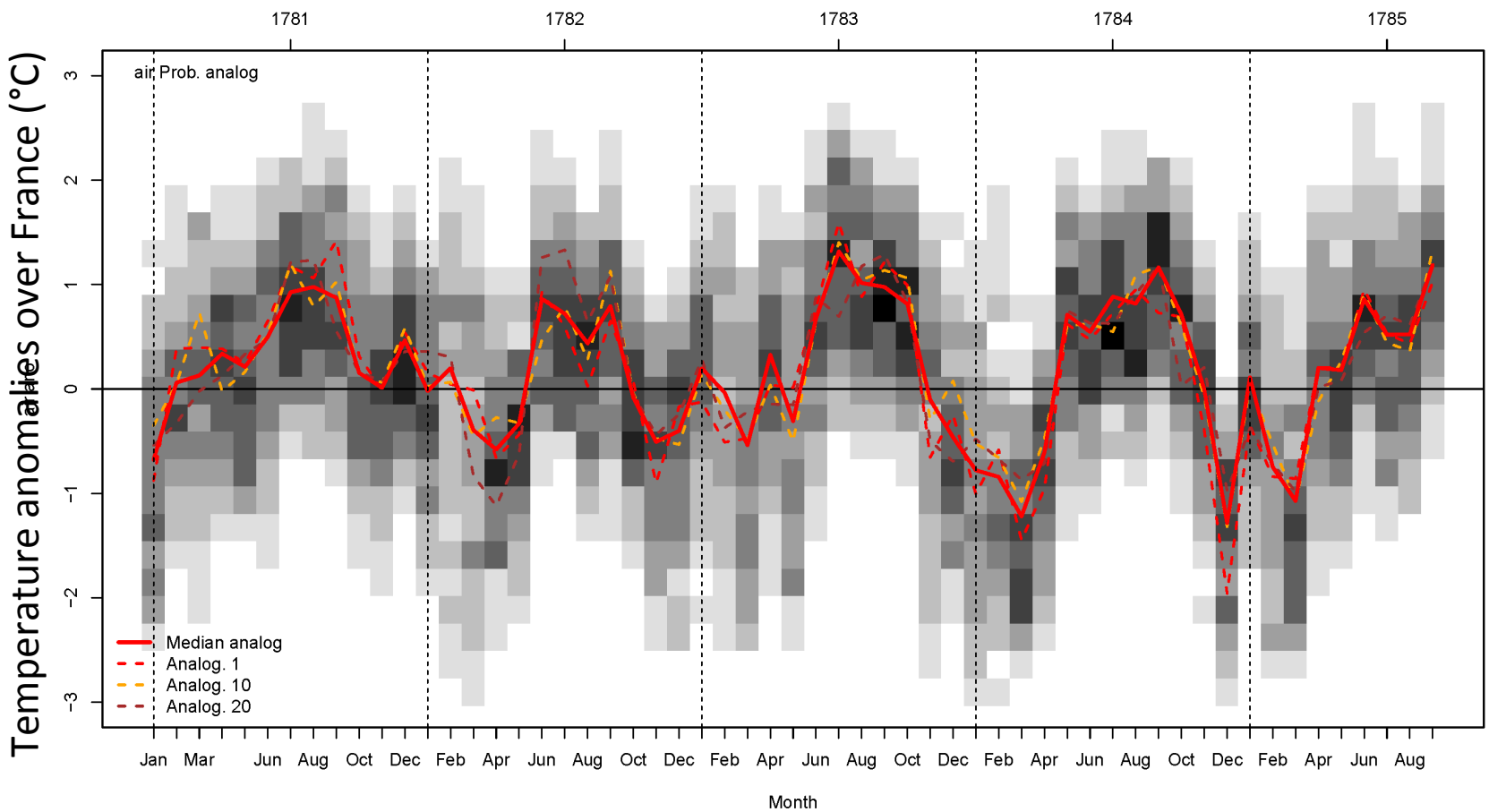


Probability distribution of correlations

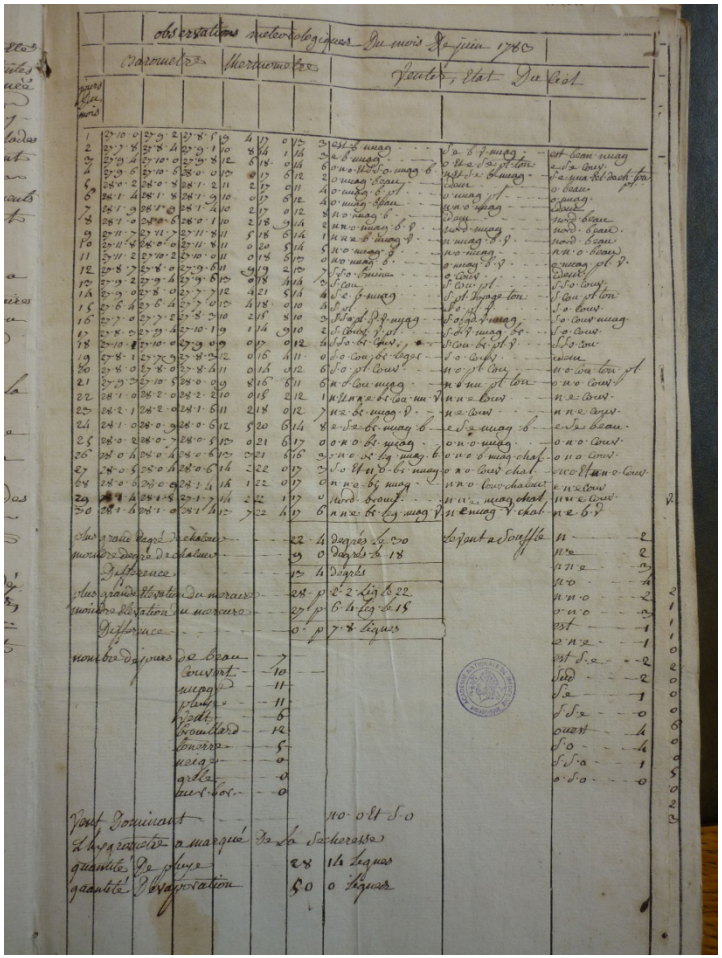
Surface temperature reconstructions



Temperature over France

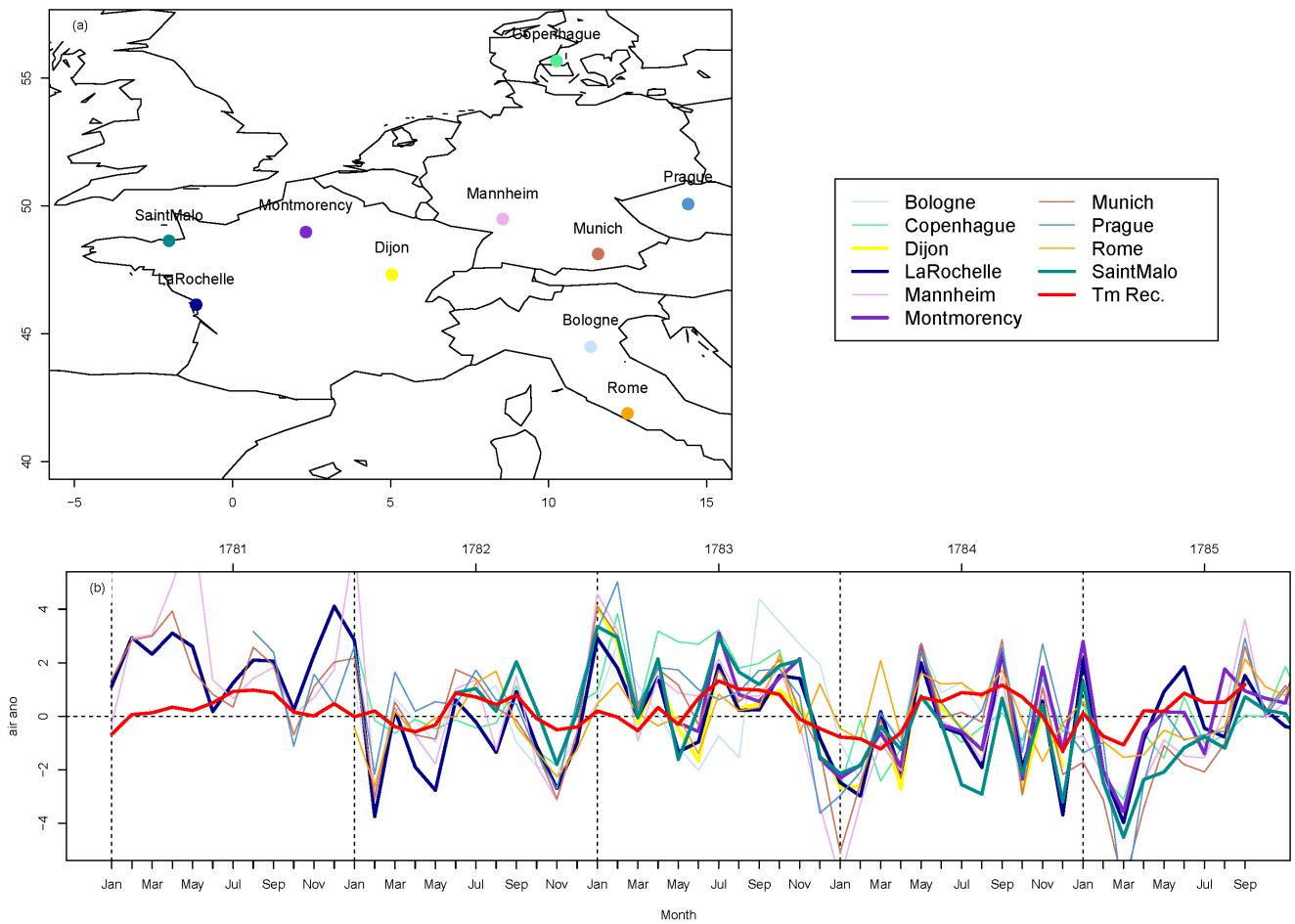


Historical temperature data

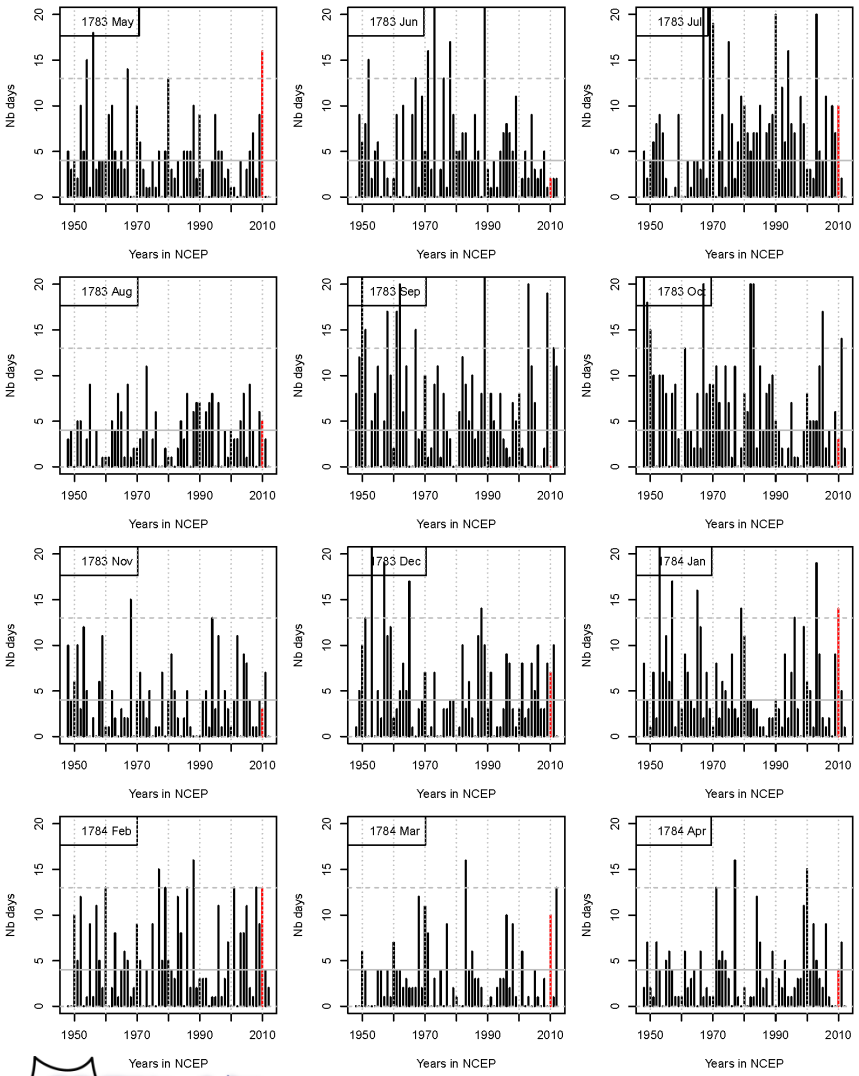


- Société Royale de Médecine (Paris) & Palatina Society (Mannheim)
- Digitized by Météo France (S. Jourdain, DCLIM)
- Use for verification

Comparison with observations



Years of analogues after the Laki



- Which recent years resemble 1783-1784?
- Is the spring of 2010 a proxy for 1783?
- Is the winter of 2009/2010 a proxy for 1783/1784?

Summary

- Atmospheric variability roughly explains temperature variability (hot summers, cool winters) in 1782-1785
- The ensemble of atmospheric reconstructions can be used to force air quality model (e.g. CHIMERE and INCA) for 1783

Butterflies

- Sensitivity to initial conditions
  - Chaotic climate system
- Ensembles of trajectories to estimate a probability density for key variables

Stochastic Weather Generator(s)

- Simulate ***many and long*** sequences of climate variables with plausible statistical and physical properties
- Use of analogues to generate random sequences of dates (in reference dataset **R**)
  - Generate large ensembles of seasons (~90 days) from random or chosen initial conditions
  - Generate long sequences of a stationary climate

Analogue weather generators

- Randomized initial conditions
- *Static* weather generator
  - Perturbation of observed trajectories with random trials of best analogues
- *Dynamic* weather generator
  - Iterative computation of new trajectories from best analogues
- The WGs essentially determine random sequences of dates in the NCEP reanalysis

Analogue weather generators

- Static

Each day (d=yyyymmdd) is replaced by one of its 20 best analogues. The probability of drawing an analogue d' is proportional to the correlation of SLP(d) and SLP(d')

- Dynamic

For each day d (=yyyymmdd), the next day is chosen among yyyymm(dd+1) and its 20 best analogues

Weight of probabilities proportional to correlation and calendar distance to desired simulated date

Simulation of temperatures

- Temperature observations from ECA&D
  - Choice of 291 stations with few missing data between 1948 and 2012
- WG simulates the sequences of temperature for each station, with a global constraint from the atmospheric circulation patterns
- Possibility of adding a GPD "residual" when the temperature exceeds a threshold
  - E.g. 90th quantile

Main uses

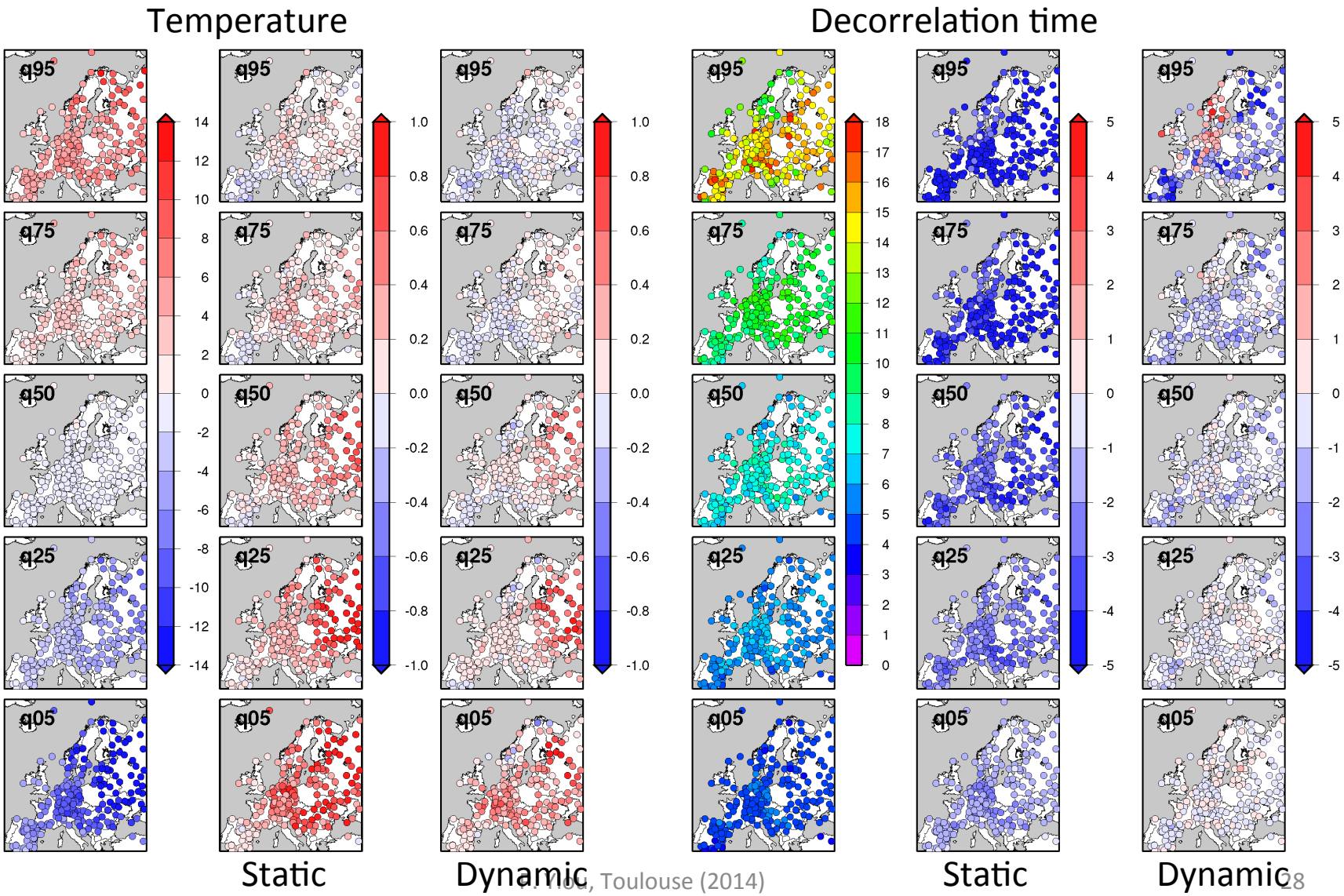
Static weather generator

- Simulate surrogates of observed sequences
  - Events, seasons or years

Dynamic weather generator

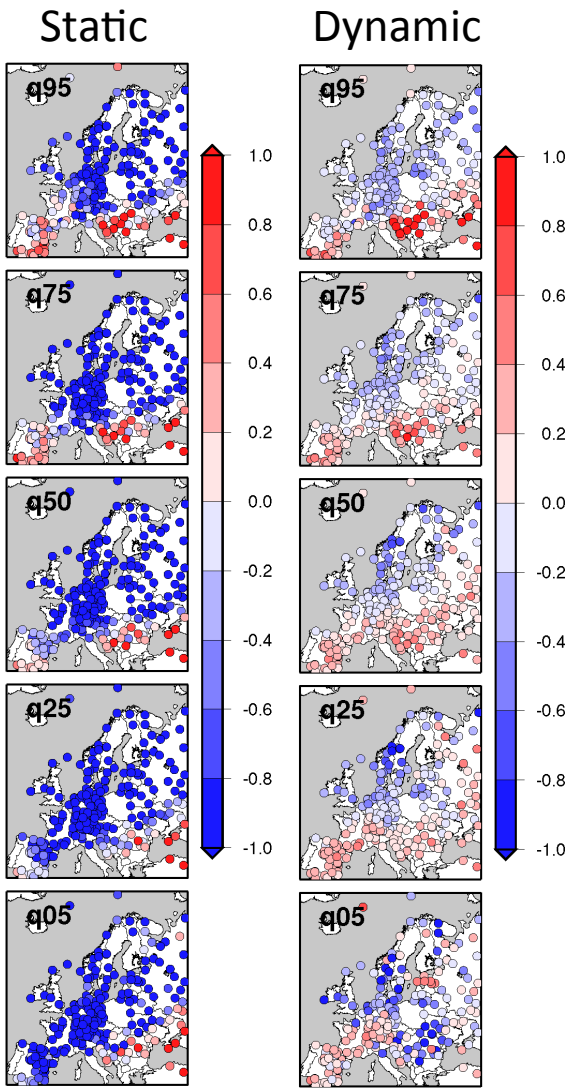
- Simulate new sequences (from observed data)
  - Events or seasons
- Low cost seasonal prediction

Winter initial conditions



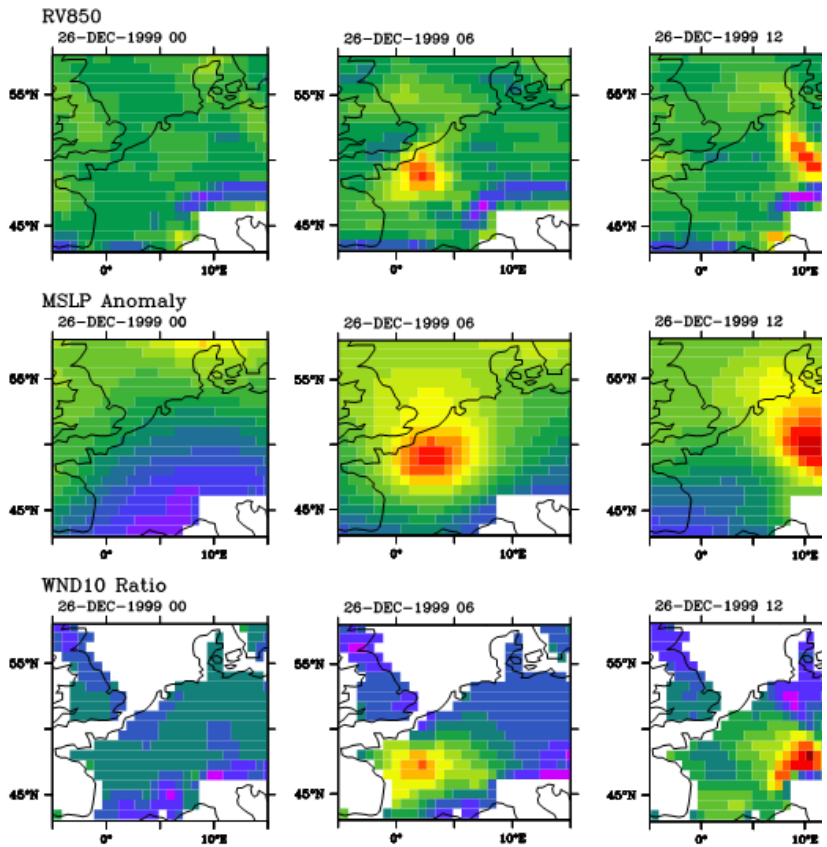
Cold winter initial conditions

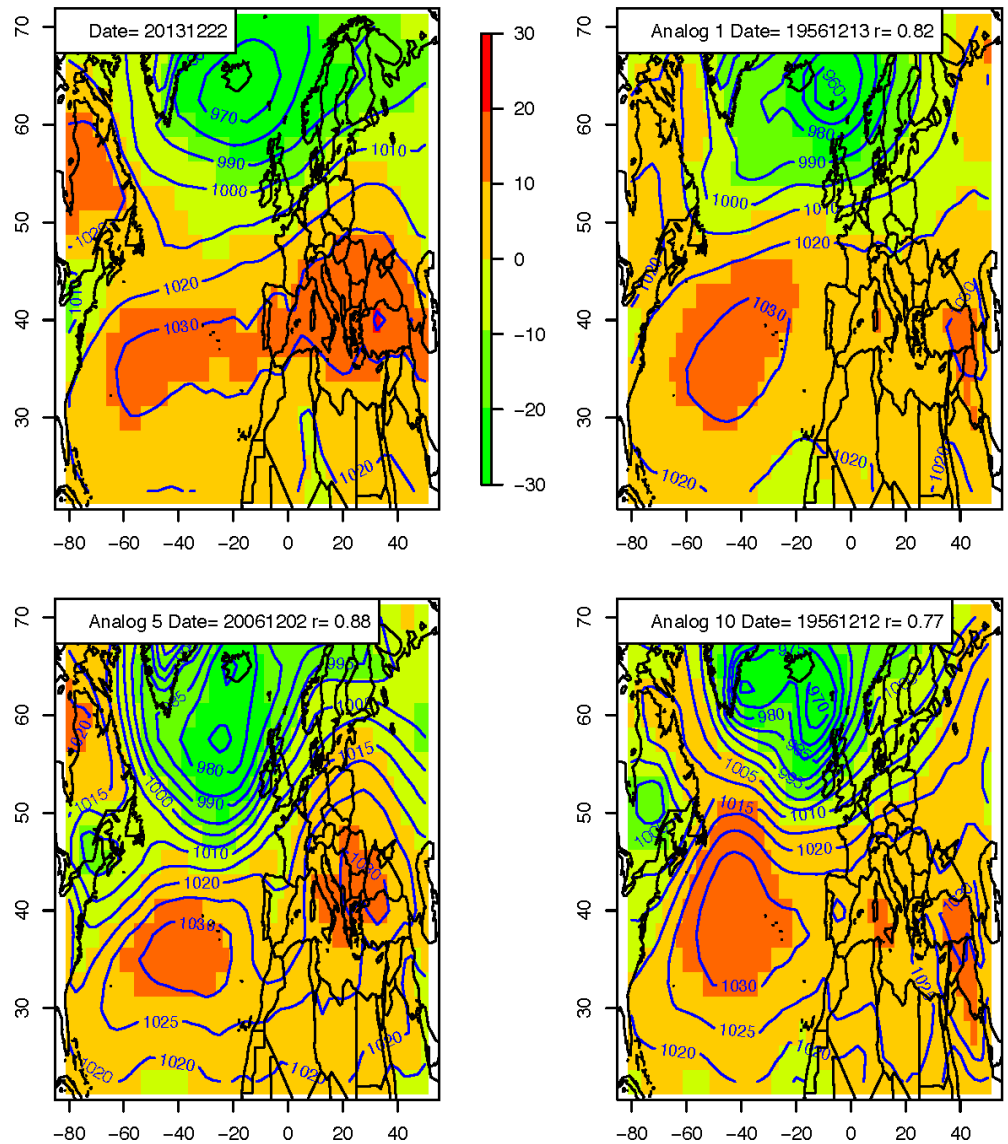
Initial conditions on Dec. 21 2009



A Catalogue of Storms

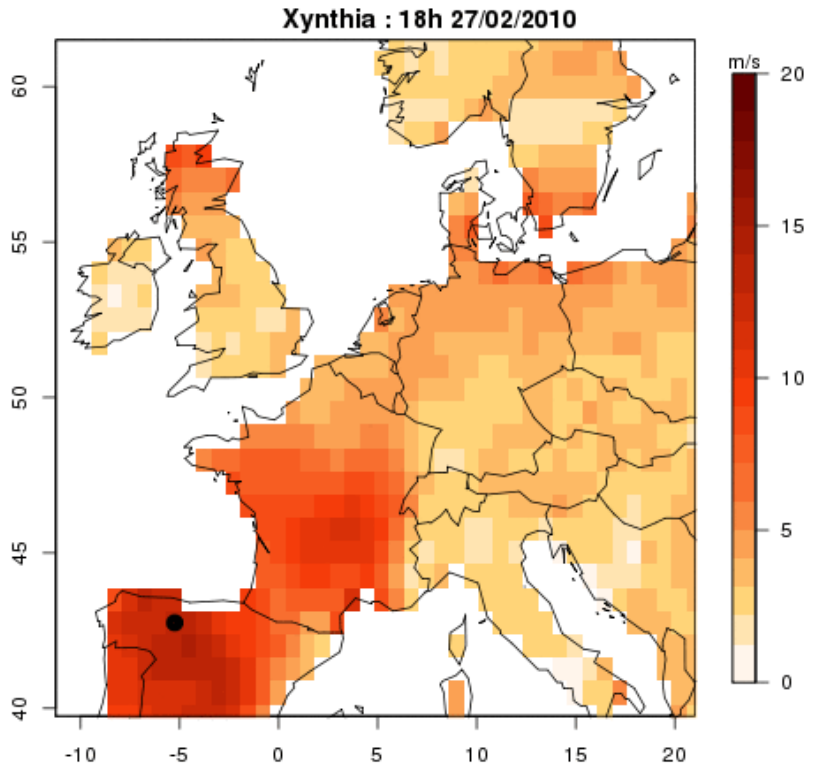
- Algorithm of storm detection in ERA-I





An Analogue Storm Catalogue

- ERA-I (1989-2013)
  - 31 reference events
- Simulation of ~600000 random plausible storms in 3h (max)
- Example with Xynthia (2010):
  - Windspeed V
  - Trajectories of max V



(A. Arakelian, 2014)

Analogues of circulation

- What is a good analogue? (*butterflies*)
  - Hypothesis of recurrent patterns in a phase space to be defined
  - Probability distribution of distances of analogues
- Cases without analogues (*black swans*)
  - Extremes of the probability distribution of distances
- Re-construction of 3D field from the constraint on a boundary of the domain?

Conclusion & Perspectives

- Computation of analogues in "real time" from NCEP reanalysis (once a week) and delivery on LSCE dods server
  - 1d and 3d windows
- Computation of analogues from other data sets (CMIP5, PMIP3…) for attribution (conditional to atmospheric pattern) studies in progress

Thank you