



Weather and event generators based on analogues of atmospheric circulation

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Introduction & Motivation

- A large part of the variance of climate variables of the extra-tropics are controlled by the large-scale atmospheric circulation
 - E.g. temperature & precipitation vs. NAO
- For given atmospheric circulation patterns, we want to investigate a *plausible* range for other variables (T, Prec, Wind speed)
 - Use for diagnostics & modelling

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

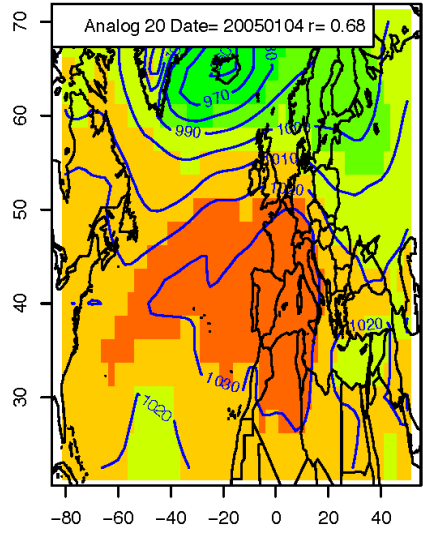
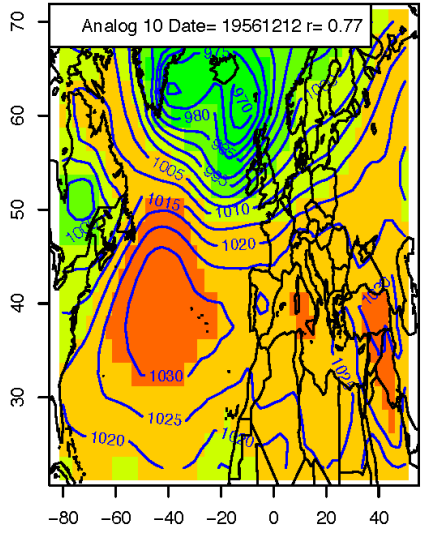
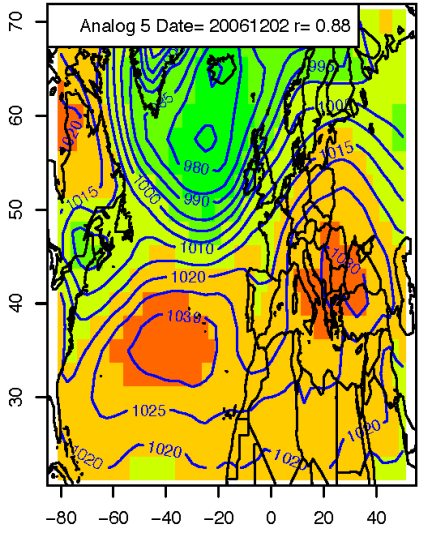
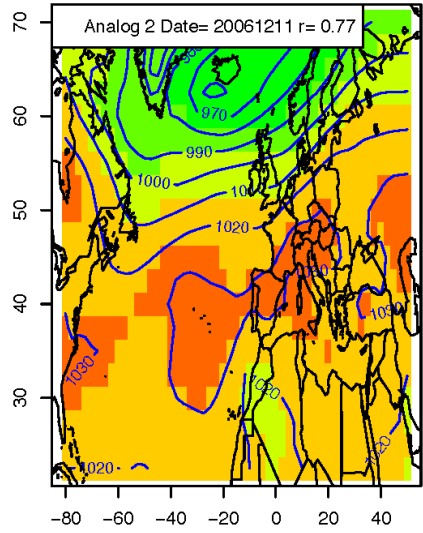
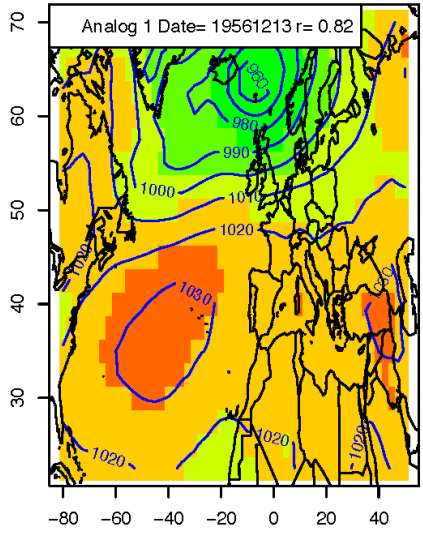
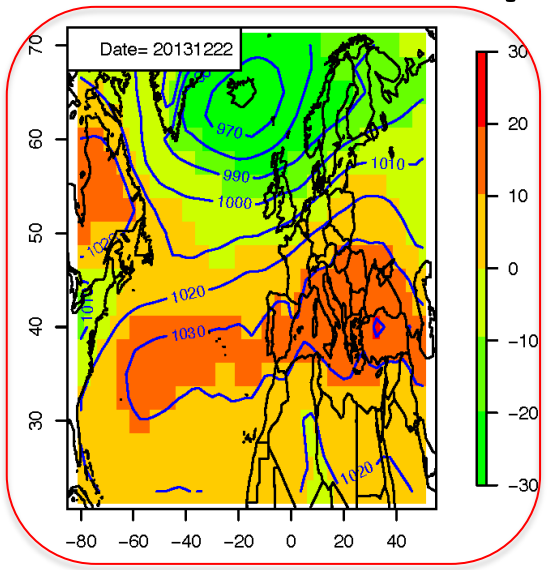
Circulation analogues (2)

- We want to infer the value of climate variables (T, Prec.) 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 SLP from NCEP reanalyses
- For all days between Jan. 1st 1948 and September 16th 2014, pick the 20 days within 30 calendar days but different year with the closest SLP:
 - Smallest Euclidean distance

Example (1) Storm Dirk



SWGEM (Avignon 2014)

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



Stochastic Weather Generator(s) LSCE

- 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

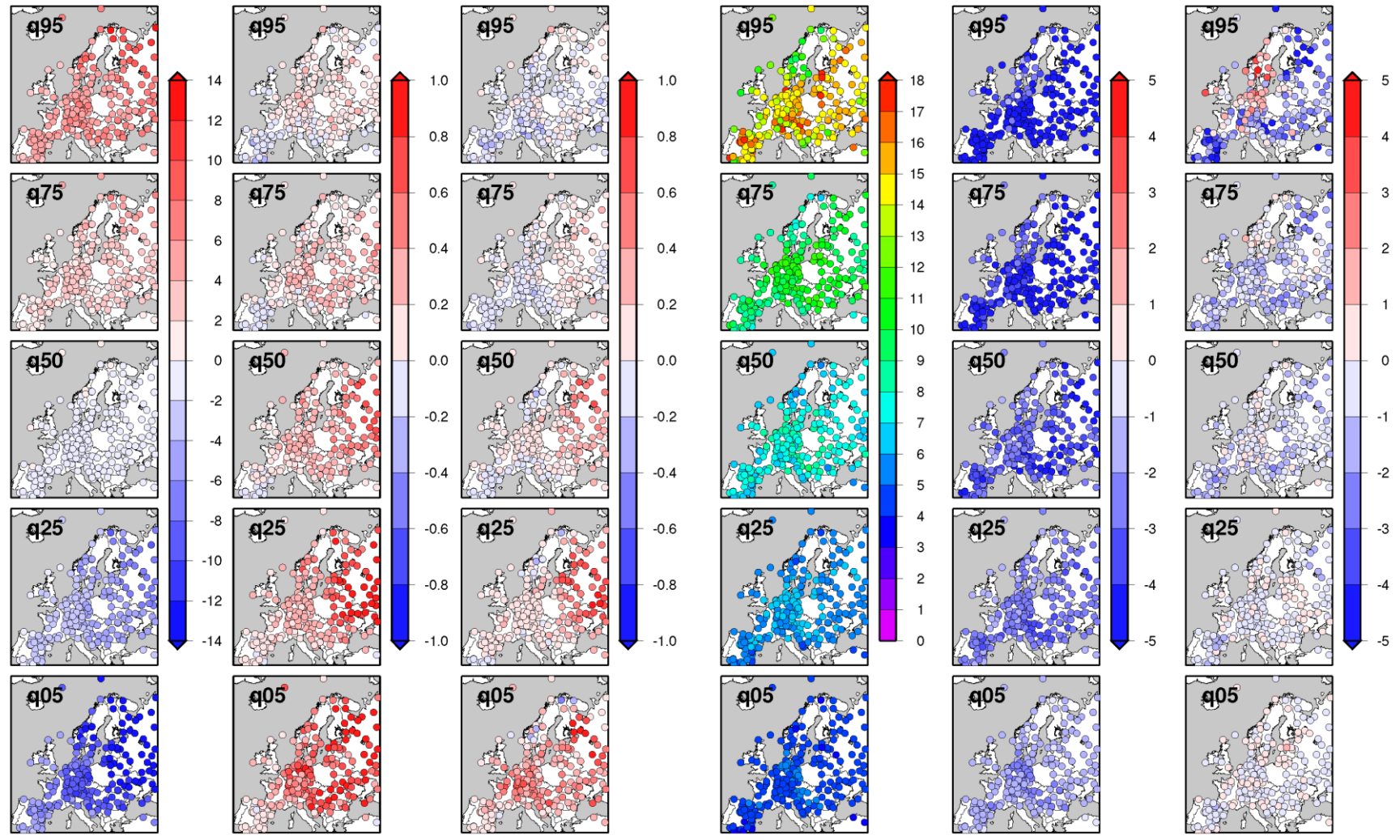


Winter initial conditions

Temperature

Decorrelation time

Bias estimates



Static

Dynamic

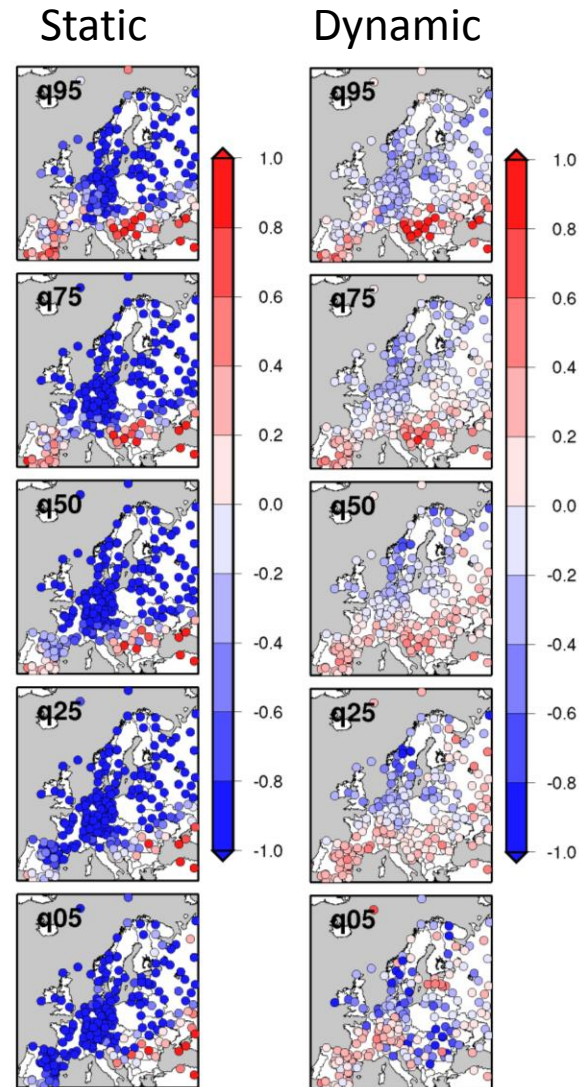
Static

Dynamic

Cold winter initial conditions

Initial conditions on Dec. 21
2009

Mean DJF temperature
bias (K) with respect to
2009/2010 DJF
conditions



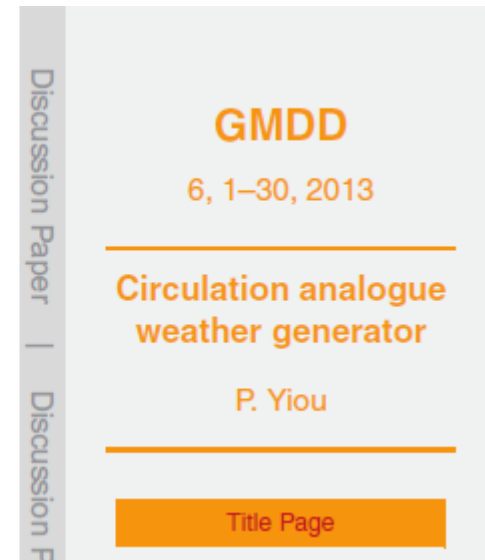
Description in GMDD

Geosci. Model Dev. Discuss., 6, 1–30, 2013
www.geosci-model-dev-discuss.net/6/1/2013/
doi:10.5194/gmdd-6-1-2013
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This discussion paper is/has been under review for the journal Geoscientific Model Development (GMD). Please refer to the corresponding final paper in GMD if available.

AnaWEGE: a weather generator based on analogues of atmospheric circulation



With free and open source code and data in R

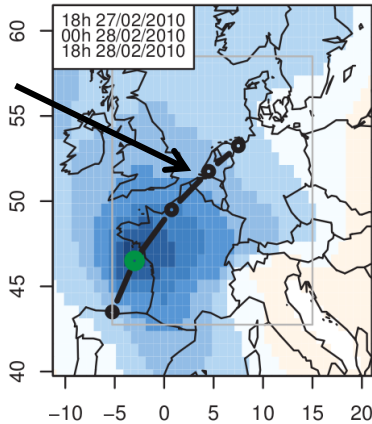
Catalogues of Storms

- Request of insurance companies
 - Feed into risk estimates and portfolios
 - Generate a catalogue of ~10000 events & estimate probability distributions of relevant variables



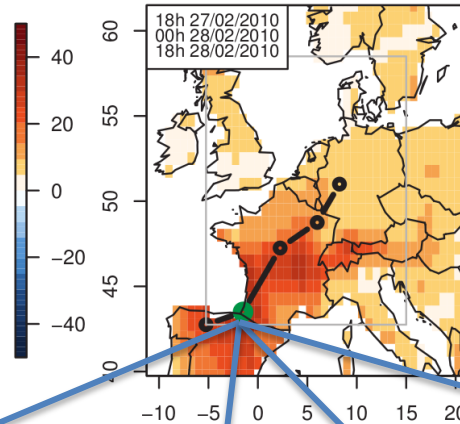
Detecting example : Xynthia

Sea level pressure anomaly (hPa)

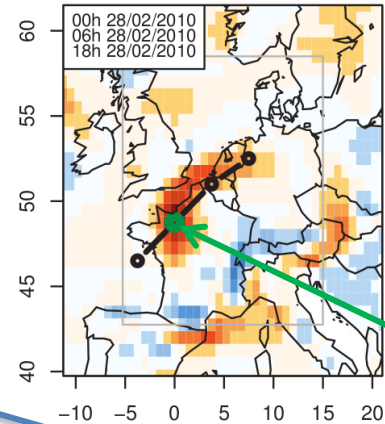


Storm track

Ratio of 10m wind speed to its 98th percentile

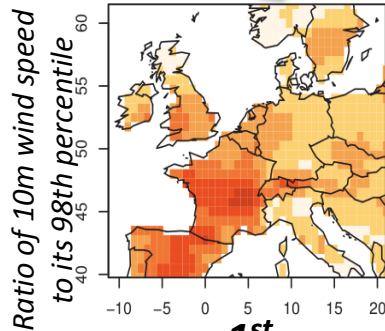


Vorticity at 850 hPa (s⁻¹)



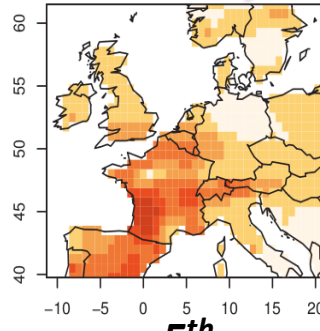
Maximum of the event

Analogues



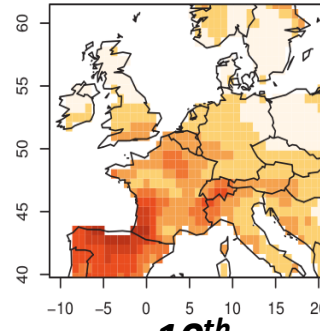
1st

7/12/2000 @18h



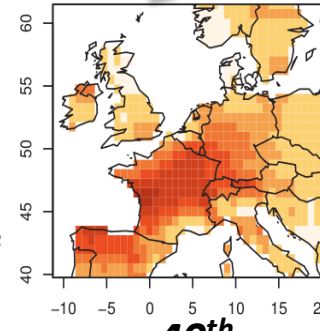
5th

26/2/2004 @12h



10th

4/10/1984 @18h



40th

16/12/2011 @6h

Find N analogues



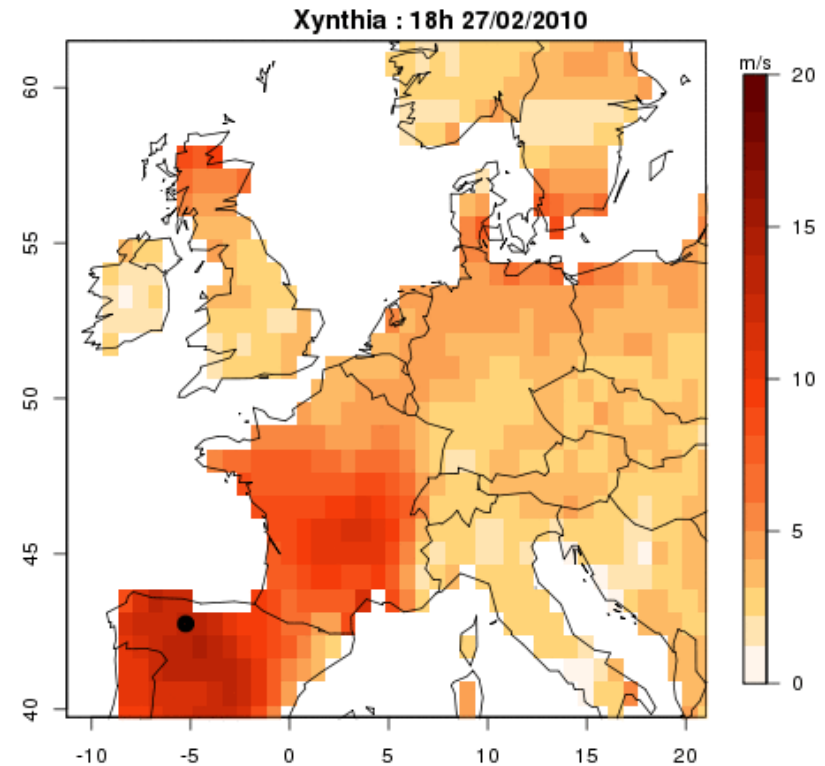
Reasonable "tweak"
(primarily a matter of intensity)



N new storms

Catalogue of storms

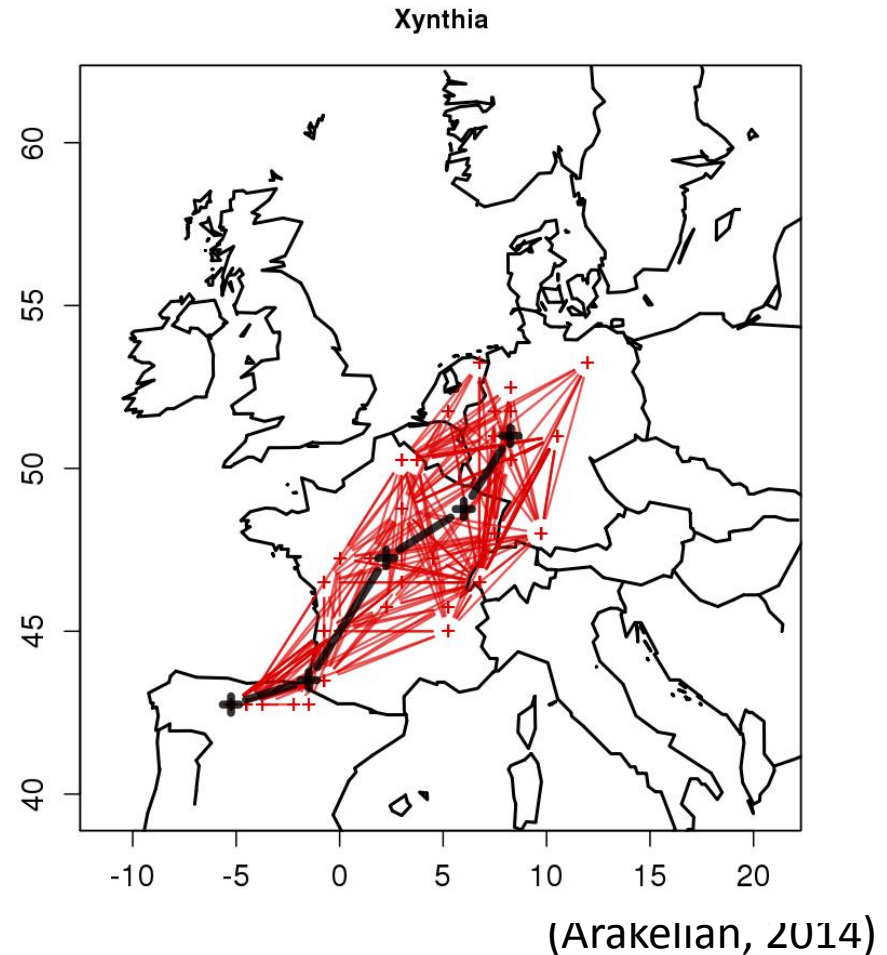
- ERA-I (1989-2013)
 - 31 reference events
- Simulation of ~600000 random plausible storms in 3h (max)
- Example with Xynthia (2010):
 - Windspeed V
 - Trajectories of max V



(Arakelian, 2014)

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Conclusion & Perspectives

- Flexible approach to investigate the likelihood of some extreme events from atmospheric variability
 - Special issues of the BAMS (2012, 2013, 2014)
- Analysis of the probability of “black swans” (i.e. events with no analogues in the past)
- Continuous time analysis of events for D/A conditional to atmospheric circulation
- Simulation of catalogues of extreme events (e.g. storms)

Acknowledgement

- Applications to climate reconstructions:

- CHEDAR



- Mathematical and statistical developments:

- A2C2: <https://a2c2.lsce.ipsl.fr>



- Applications to energy sector

- E3P: <http://e3p.lsce.ipsl.fr>



- Application to insurance sector

- OASIS: <http://www.oasislmf.org/>





- School in Cargèse Institute of Physics on “Mathematics, Statistics for Climate Extremes” in Corsica
- Save the date: 9-13 November 2015
- Speakers include:
 - D. Allard, M. Vrac, P. Naveau, E. Masiello, A. Ribes, M. Ribatet...