



Towards spatially coherent statistical downscaling

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18 December 2013

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Outline

1. Motivation and approach
2. Statistical downscaling method: SANDHY
3. Predictor domain optimisation
4. Validation
5. Towards spatially coherent statistical downscaling
6. Outlook



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Motivation

Applications of precipitation downscaling in hydrology

- Medium-range forecasting from NWP models
- Climate change impact studies from GCMs
- Historical reconstructions from long-term global reanalyses

Research Question

To simulate extreme events (floods, droughts), hydrological applications require:

- a high local skill
- a spatial coherence of precipitation fields

How to reconcile the two constraints over large river basins?



Statistical downscaling approach over France

Perfect Prog with analogue method

Context (Lorenz, 1969)

Similar large-scale atmospheric circulation situations (ERA-40, Uppala et al., 2005) lead to similar local precipitation (SAFRAN, Vidal et al., 2010)

Reformulation of the research question

Different subcatchments of large river basins:

- are exposed to different climatic influences (possibly different analogue dates)
- but all contribute to the basin river flow (need for same analogue dates)

How to deal with the fact that the best analogue situations are not the same for different subcatchments of large river basins?



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Analogue method

History of PhD theses

- 1997: Sophie Guilbaud
→ analogues on geopotential fields
- 2004: Guillaume Bontron
→ humidity variables added
- 2010: Aurélien Ben Daoud
→ preselection on temperature instead of calendar proximity,
additional variables tested and optimised over two river basins
(Saône and Seine)

→ Use of the method proposed by Ben Daoud (2010)

| Predictor: ERA-40 | Pressure level [hPa] | Similarity criterion | Predictor domain | Number of analogues |
|-------------------|----------------------|----------------------|------------------|---------------------|
| Temperature | 925, 600 | E. d. | nearest | 2000 |
| Geopotential | 1000, 500 | TWS | optimised | 170 |
| Vertical velocity | 850 | E. d. | nearest | 70 |
| Humidity (TCW*rh) | 850 | E. d. | nearest | 25 |

Predictand: Safran

daily precipitation 608 climatologically homogeneous zones in France



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Optimising geopotential predictor domains

Objective function

- Continuous Rank Probability Score (CRPS)
- Skill score: CRPSS with climatology as reference

Optimisation period: 1982-2002

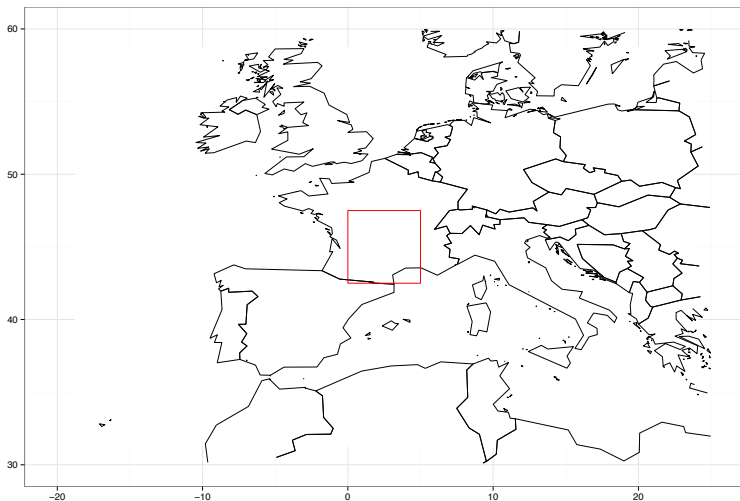
- Common period for optimisation and archive of analogue dates (best case)
- More recent period common between ERA-40 and SAFRAN

Only optimization of geopotential domains

- Application to all zones in France
- Taking account of several “best” domains

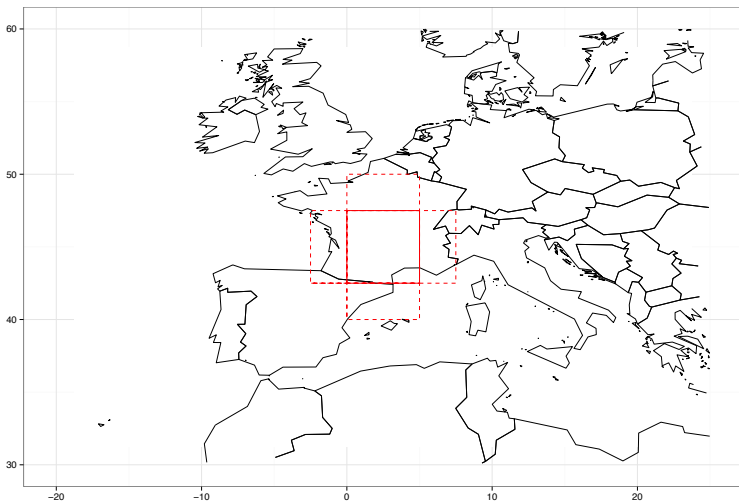
Growing rectangular domains algorithm

Keeping the 5 best geopotential predictor domains



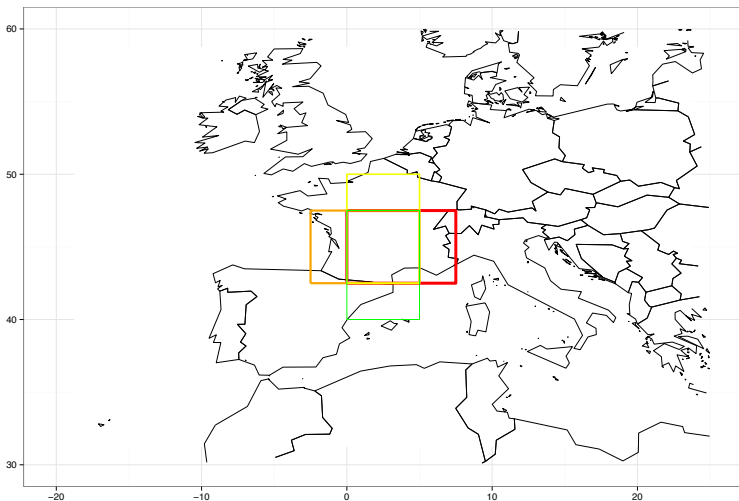
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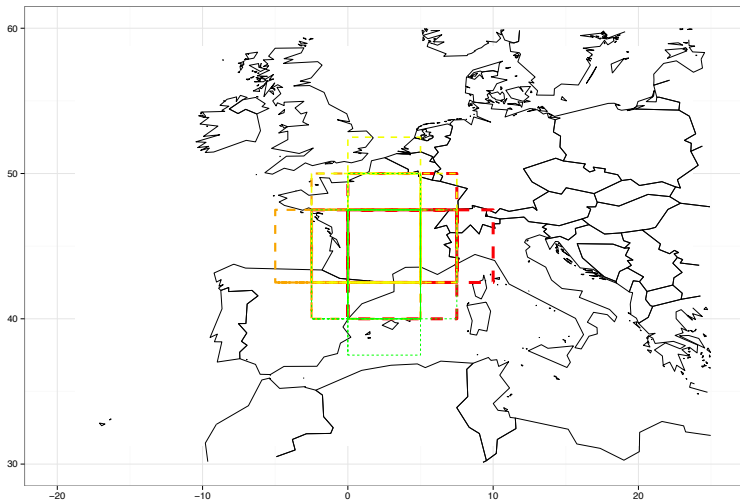
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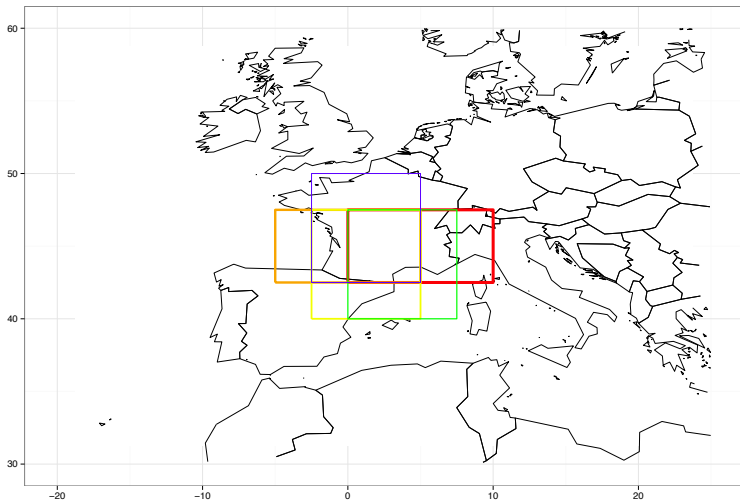
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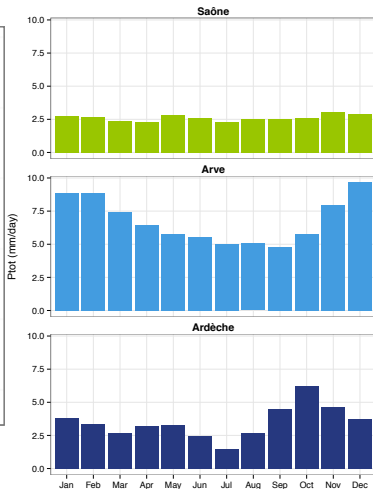
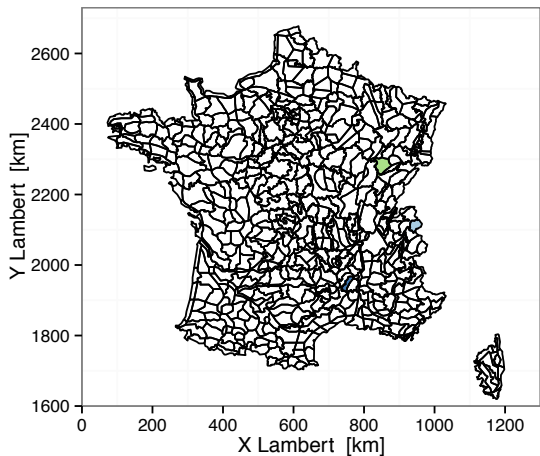
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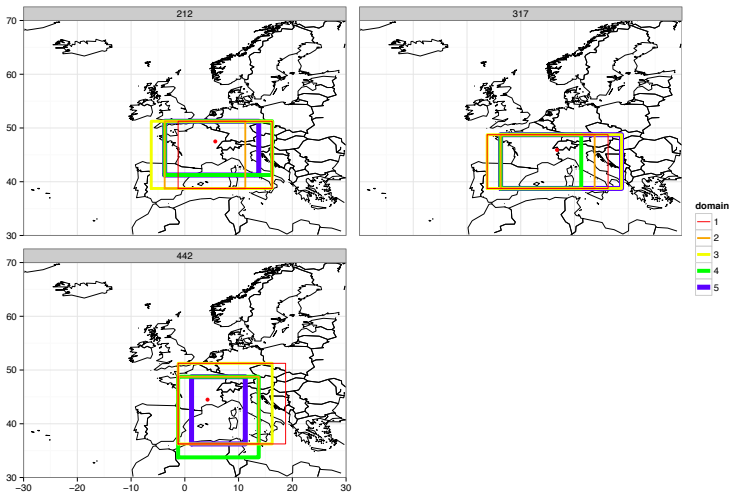
Case study zones

3 zones belonging to the Rhône basin



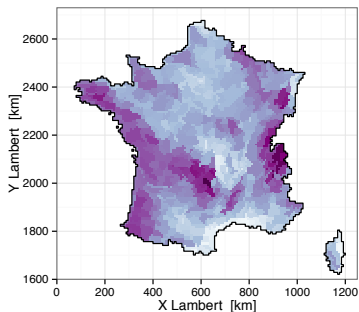
Case study zones

Best 5 domains

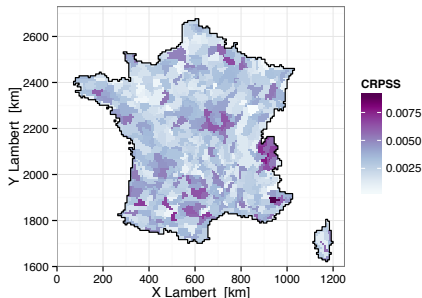


Skill of the statistical downscaling method

Locally optimized



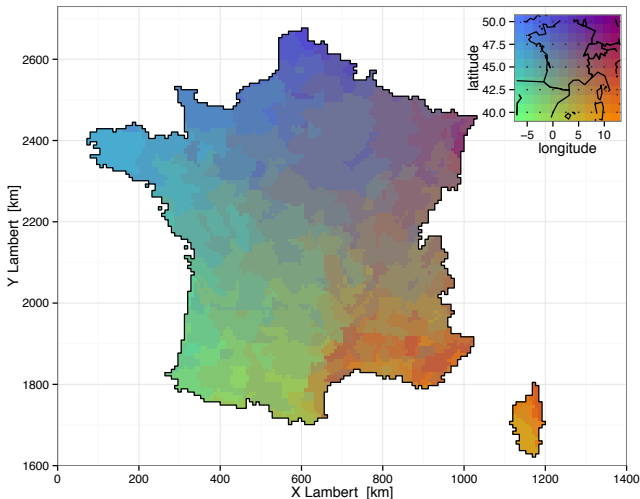
Mean CRPSS



CRPSS difference 1st-5th domain

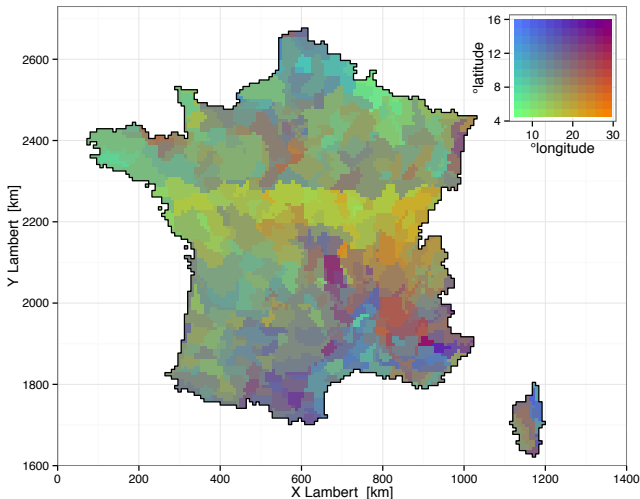
- Skill depends on precipitation regime
- Very small differences in skill → 5 near optimal domains

Mean domain center of near optimum domains



- Centers mainly distributed according to geographical locations
- Differences between windward and lee side of mountain ridges

Mean domain extent of near optimum domains

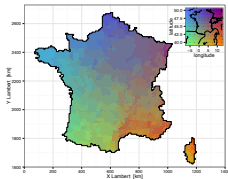


- Larger domains in the south, smaller domains in the north
- Small meridional extent in the center

Optimisation: take home messages

Where does the rain come from?

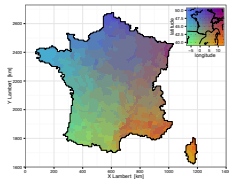
- If you're close to the Mediterranean, have a (broad) look to the South-East
- Otherwise, you'd better look to the West



Optimisation: take home messages

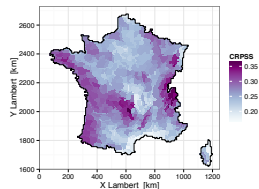
Where does the rain come from?

- If you're close to the Mediterranean, have a (broad) look to the South-East
- Otherwise, you'd better look to the West



How confident can one be about rain forecasts?

- Reasonably if you're close to the Atlantic or in the windward side of mountain ranges
- Much less if you're close to the Mediterranean or in the leeward side of mountain ranges



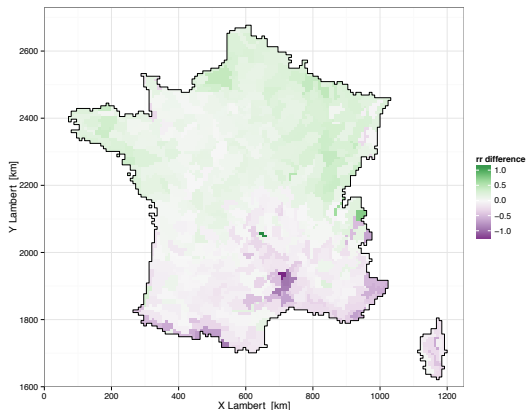


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Validation strategy

Split-sample approach: 1958-1978 (first) vs 1982-2002 (last)



Difference in
average
rainfall
(mm/day)

- Increase in the north, decrease in the south (mainly non significant, see Vidal et al., 2010)
- Plus some extremes values in each period...



Validation strategy

Split-sample approach: 1958-1978 (first) vs 1982-2002 (last)

Optimisation

- Optimisation: last
- Archive: last
- Simulation: last

Out-of-sample validation

- Optimisation: last
- Archive: last
- Simulation: **first**



Validation strategy

Split-sample approach: 1958-1978 (first) vs 1982-2002 (last)

Optimisation

- Optimisation: last
- Archive: last
- Simulation: last

Changing periods

- Optimisation: last
- Archive: first
- Simulation: first

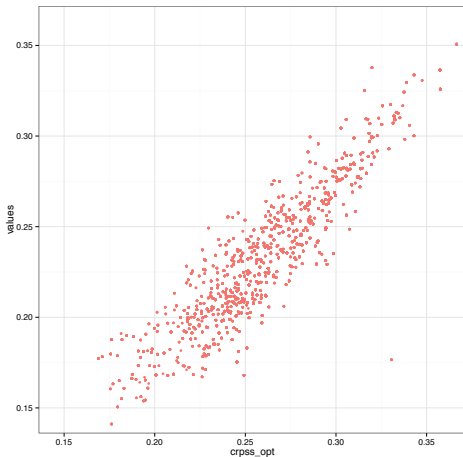
Out-of-sample validation

- Optimisation: last
- Archive: last
- Simulation: first

Alternative archive

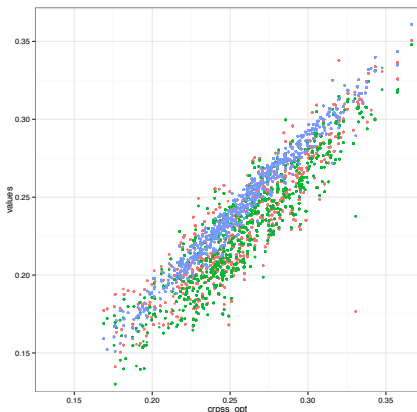
- Optimisation: last
- Archive: first
- Simulation: last

Out-of-sample validation vs optimisation



- Reasonable skill loss, except one zone
- Some zones even show a better skill

plus other experiments vs optimisation



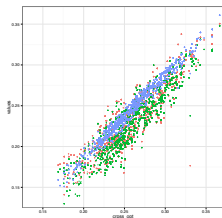
- out-of-sample validation
- alternative archive
- changing periods

- Narrow blue scatterplot
→ the two periods provide archives with similar information
- Green scatterplot similar to red scatterplot
→ out-of-optimisation skill loss \sim validation skill loss

Validation: take home messages

Periods and human generations

- You can use the weather knowledge of your parents with high confidence
- You could retrospectively forecast reasonably well the weather your parents experienced
- Your parents could have predicted the weather you experience equally well





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Towards spatially coherent downscaling

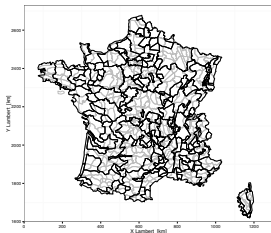
Proposition #1

Aggregate areas with common predictor domain

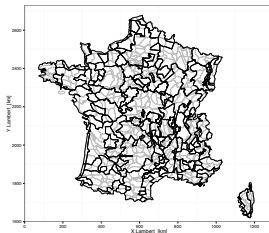
- same domain → same analogue dates
- **spatial coherence + high local skill**

#1 Aggregate areas with common domain

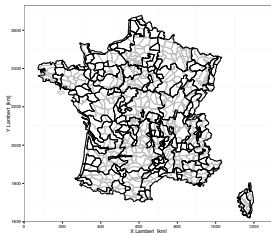
102 groups



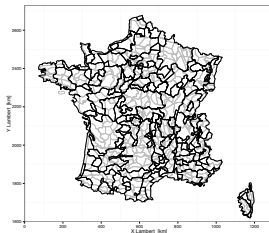
100 groups



120 groups



126 groups



- Alternative possible solutions with different algorithms
- Reduce the problem from 608 zones to ~100 clusters



Towards spatially coherent downscaling

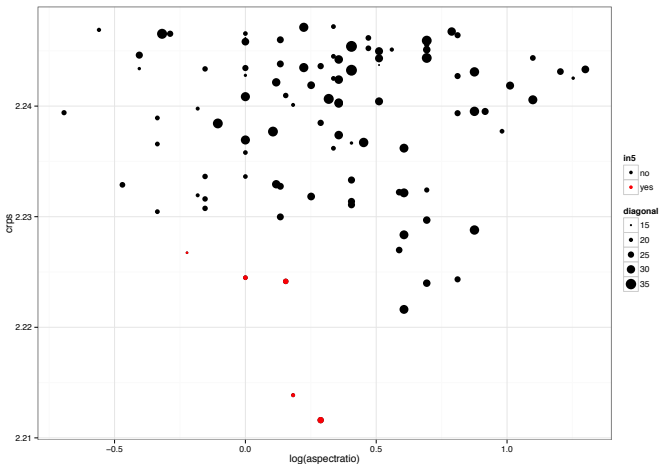
Proposition #2

Extend ensemble of locally near-optimal domains

- Retain more near-optimal domains
- potentially better spatial coherence + potentially better local skill

#2 Extend ensemble of near-optimal domains

99 best domains for the Ardèche zone: CRPS vs. logarithm of aspect-ratio





Towards spatially coherent downscaling

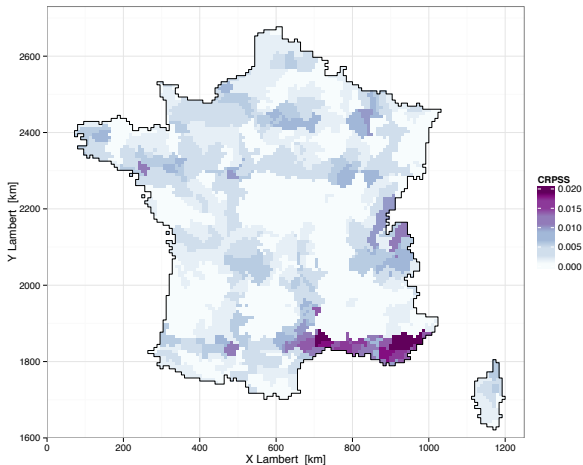
Proposition #3

Consider domains optimised for other zones

- Consider the ensemble of optimized domains found over France
- Look at domains leading to a higher local skill
- **potentially better spatial coherence + better local skill**

#3 Consider domains optimised for other zones

Higher CRPSS found within the overall 848 domains founds





Towards spatially coherent downscaling

Proposition #4

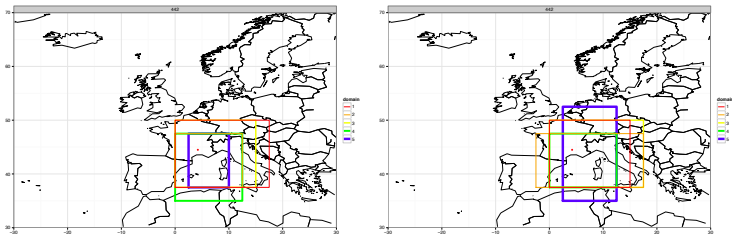
Consider less skewed predictand variable

- Scaled precipitation: $\sqrt{\frac{p}{p_j \times a_{10}}}$
- potentially better spatial coherence + high local skill

#4 Consider less skewed predictand variable

Ardèche case study zone

Domains optimised with raw (left) and scaled (right) precipitation



- Tendency to larger domains with transformed precipitation



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Methodological framework

- Taking account of spatial coherence with Perfect Prog downscaling
- Impact on hydrological features
- PhD thesis Sabine Radanovics (2011-2014)

Application in historical reconstructions

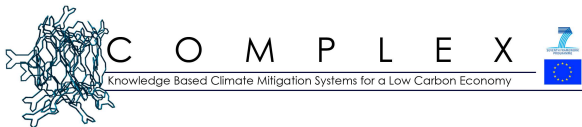
- Hydrometeorological reconstructions of historical low flows and droughts in France: 1871-2010
- PhD thesis Laurie Caillouet (2013-2016)



Outlook (cont'd)

Extension to multivariate downscaling

- FP7 COMPLEX project
- Work Package on Climate Related Energies (with LTHE, U. Padova, SINTEF, EDF, BC3)
- Issue: spatio-temporal coherence of CRE sources (hydro, solar, wind)
- www.complex2050.eu





Thank you for your attention

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