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CLIMATE CHANGE RESEARCH

Droughts in the last two millennia: Challenges in its definition and connection to modes of variability

Christoph C. Raible

Juan Jose Gomez-Navarro, Oliver Bärenbold, Flavio Lehner

Climate and Environmental Physics, Physics Institute and Oeschger Centre for Climate Change Research,
University of Bern, Switzerland

Outline

- Framework of drought indices
- Model simulation
- Which index is suitable in which region?
- Connection to modes of variability?
- Conclusions / open issues

Framework of drought indices

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1. Choose fluxes entering in the water balance:
   Precipitation, PET, ET, runoff, snow, …
2. Determine the water balance

$$d(\mathbf{r},t) = M\left(a_1(\mathbf{r},t), a_2(\mathbf{x},t), \ldots, a_n(\mathbf{r},t)\right)$$

3. Select memory

$$D(\mathbf{r},t) = R\left(d(\mathbf{r},t), d(\mathbf{r},t-1), \ldots, d(\mathbf{r},t-m+1)\right)$$

4. Apply a normalization

$$I(\mathbf{r},t) = Z\left(\mathbf{r}, D(\mathbf{r},t)\right)$$

Ex.: Standardized Precipitation index SPI

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1. Choose fluxes entering in the water balance:
   Precipitation *P*
2. Determine the water balance

$$d(\mathbf{r},t) = M\big(P(\mathbf{r},t)\big) = P(\mathbf{r},t)$$

3. Select memory:
   Block mean
4. Apply a normalization
   Mapping *D* to a normal distribution via fitting a gamma distribution to *D*

New index

1. Choose fluxes entering in the water balance:
   Flexible depending on the data available
2. Determine the water balance
   Flexible depending on the data available
3. Select memory
   Exponential decay (flexible)
4. Apply a normalization
   Quantile mapping of *D* to a normal distribution

Model simulation

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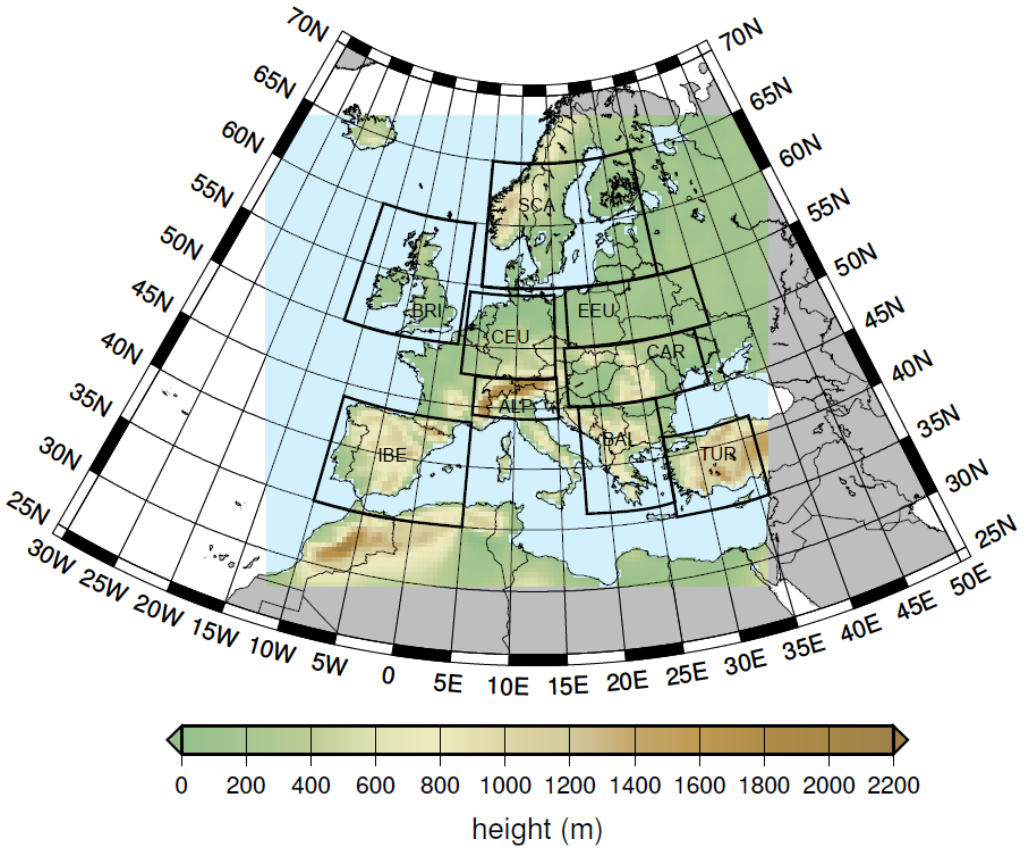
Global model:

- ECHO-G
- T31, 2.8x2.8

Regional model:

- MM5
- 45 km resolution



Simulation

- 0-2000 AD transient forcing
- Analysis is based on 0-1800 AD.

(Gomez-Navarro et al. 2013; 2015; Raible et al. in revision)

Which index is suitable in which region?

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- Potential evapotranspiration PET versus evapotranspiration ET?
  - Precipitation (SPI)
  - SPI + Potential Evapotranspiration (SPPEI)
  - SPI + Evapotranspiration (SPLEI)
- Increase complexity of the water balance
  - SPI + Potential Evapotranspiration (SPPEI)
  - SPI + Evapotranspiration + Snow (SPPEI_snow)
  - SPI + Evapotranspiration + Snow +runoff (PDSI_snow)

PET versus ET?

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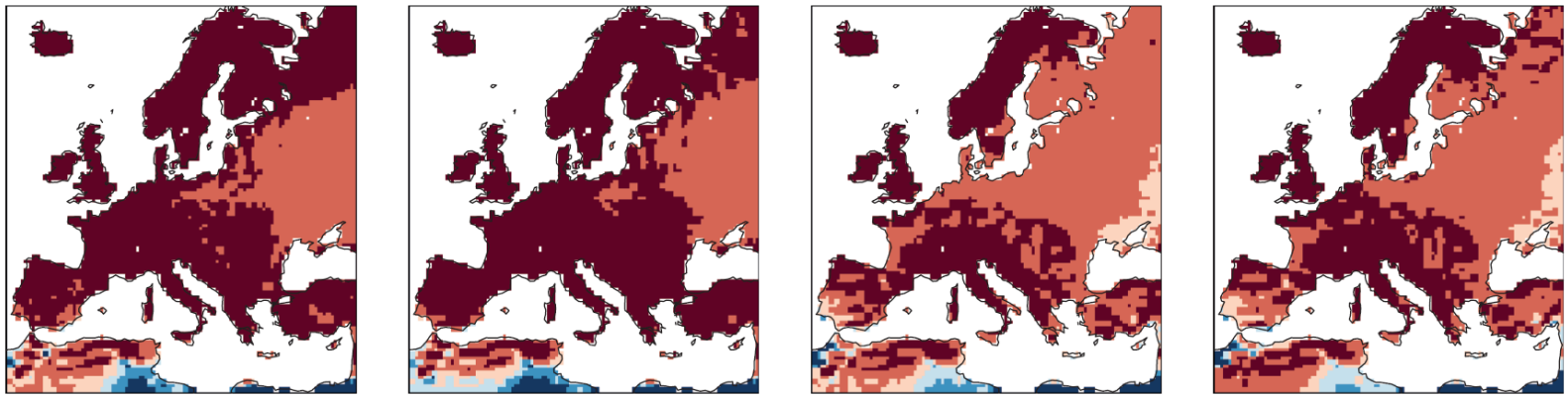
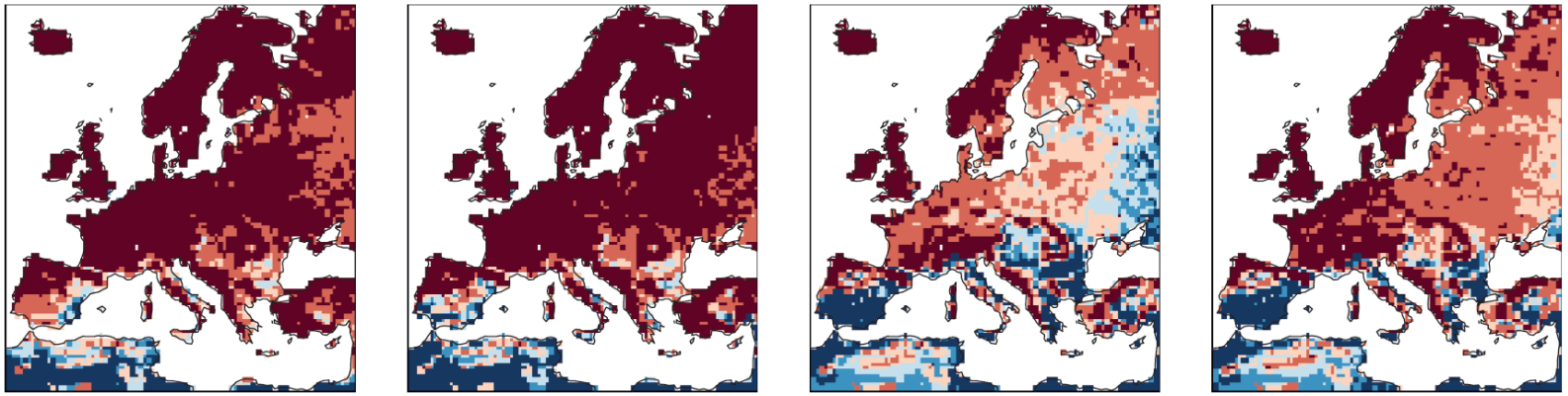
SPI – SPPEI

DJF MAM JJA SON



SPI - SPLEI



PET versus ET?

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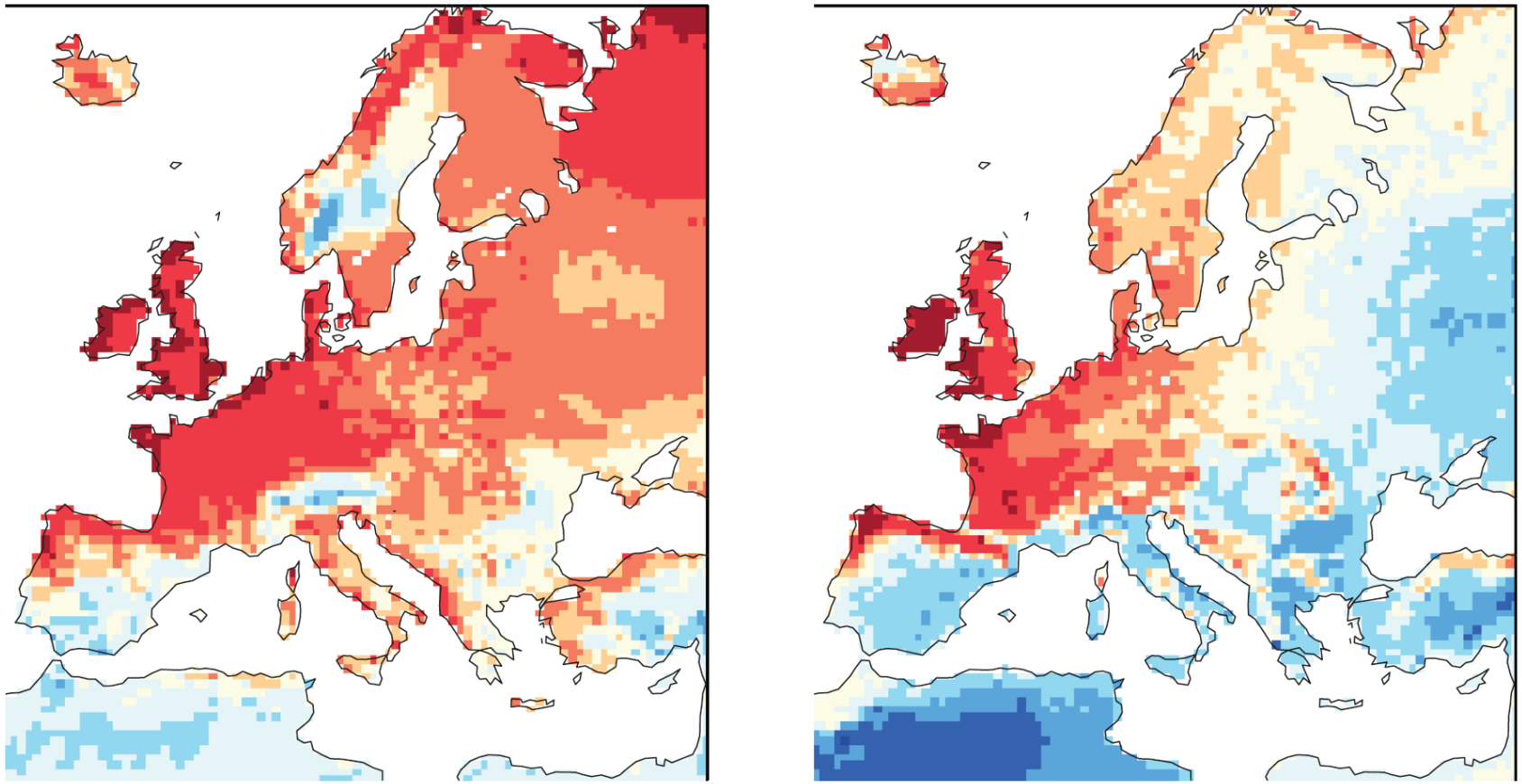
(a) DJF

(b) JJA



-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8

Correlation coefficient

Increase complexity of the water balance

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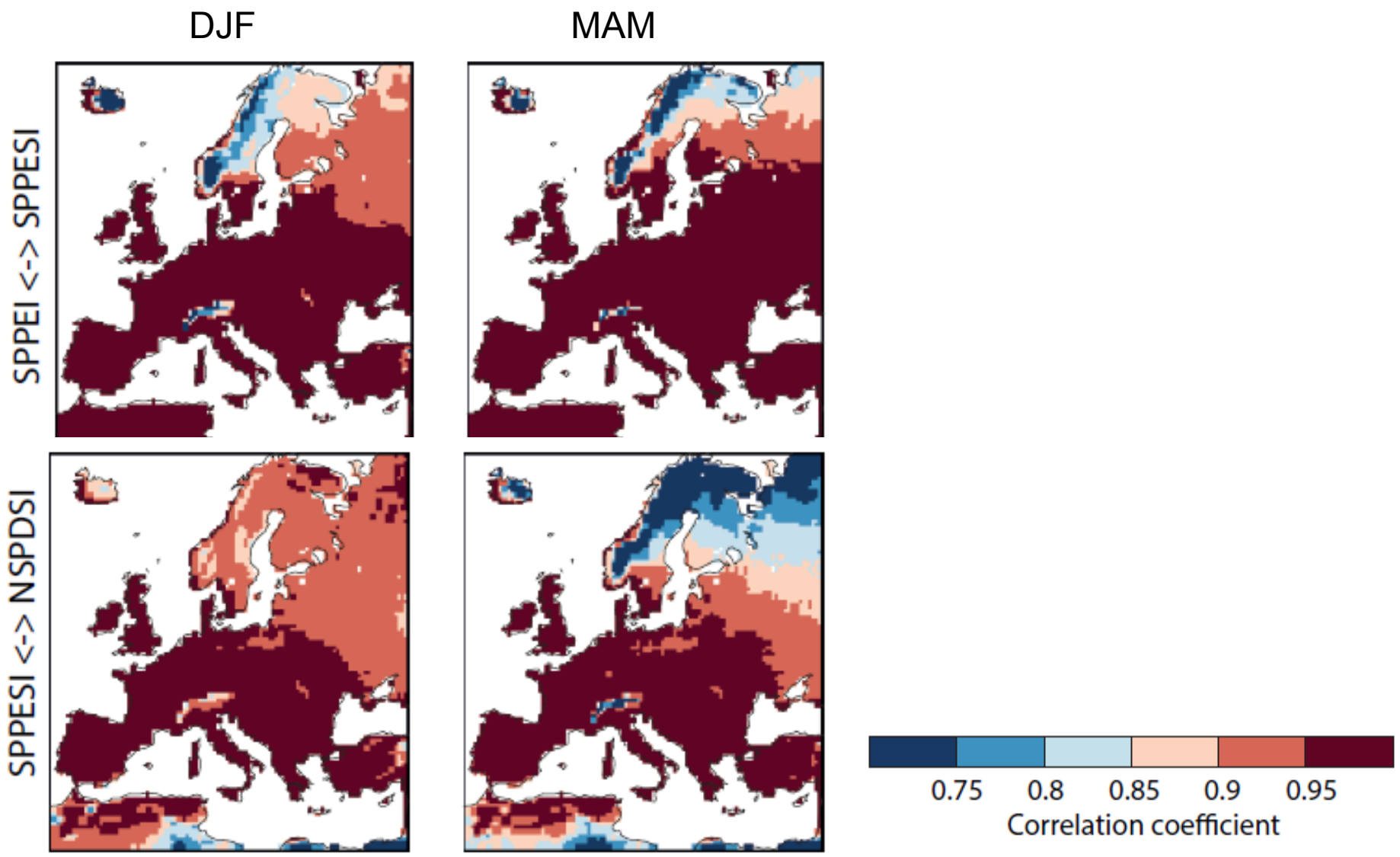
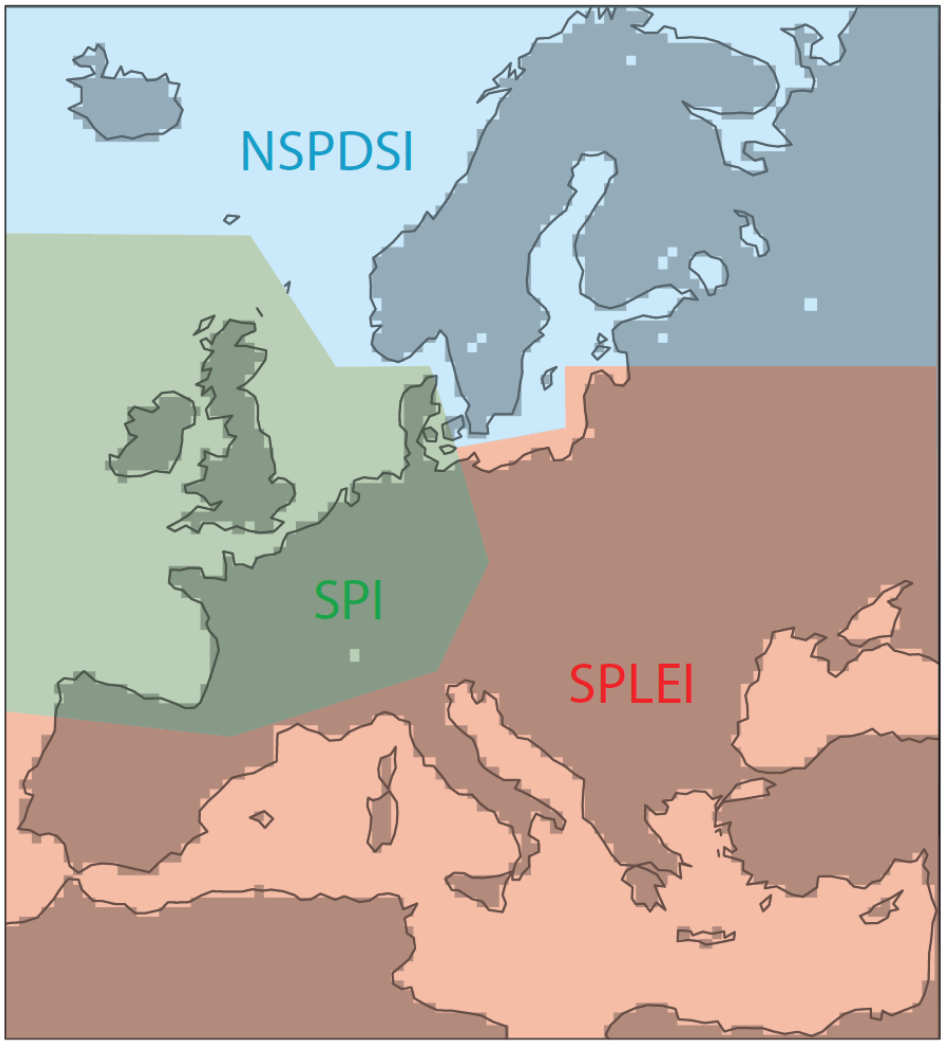


Conclusions:

Which index is suitable in which region?



Connection to modes of variability?

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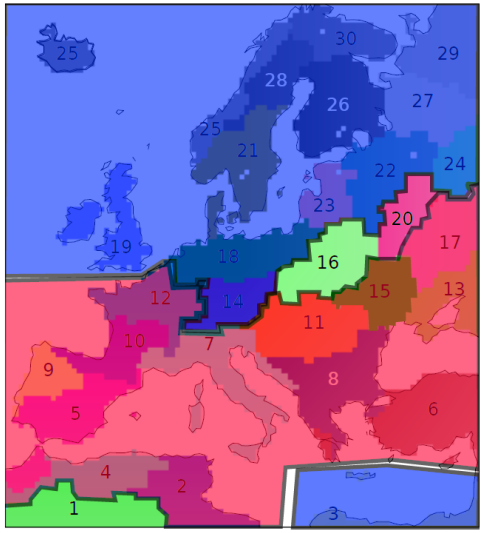
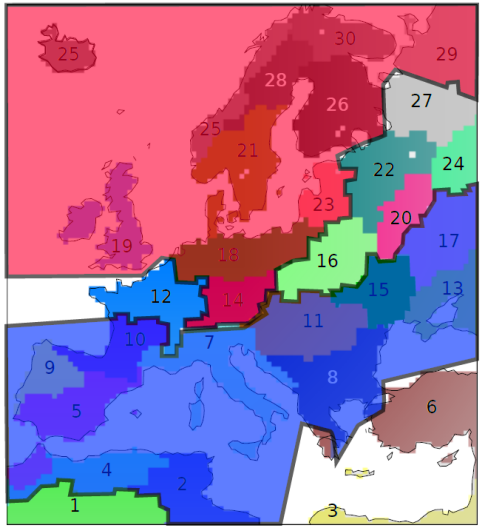
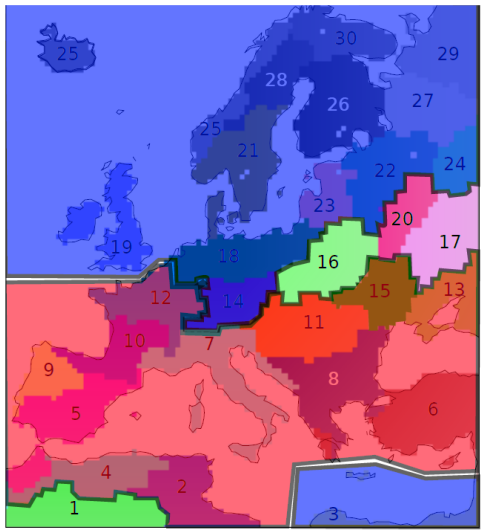
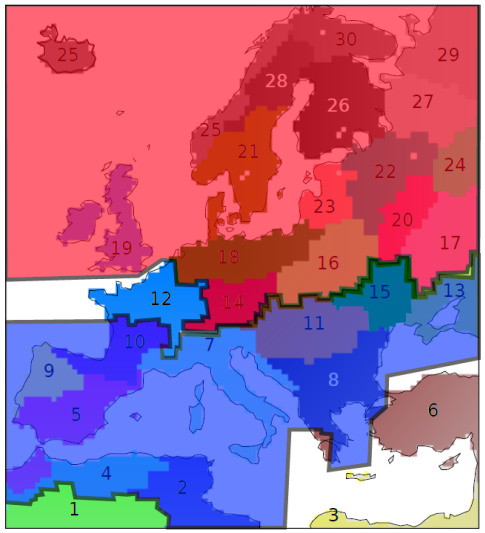
NAO response

	90th	10th
SPI		
PDSI_snow_ET		

Dry

Wet

Connection to modes of variability?

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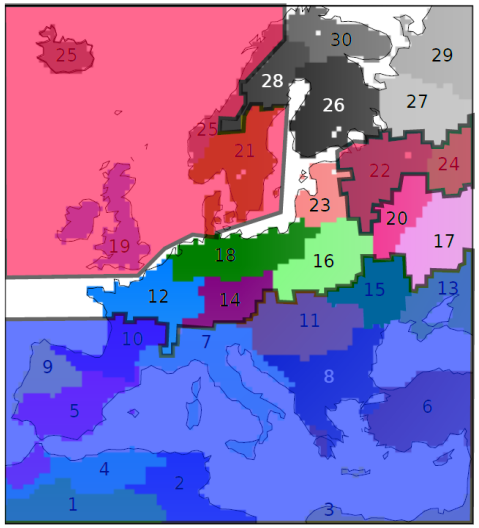
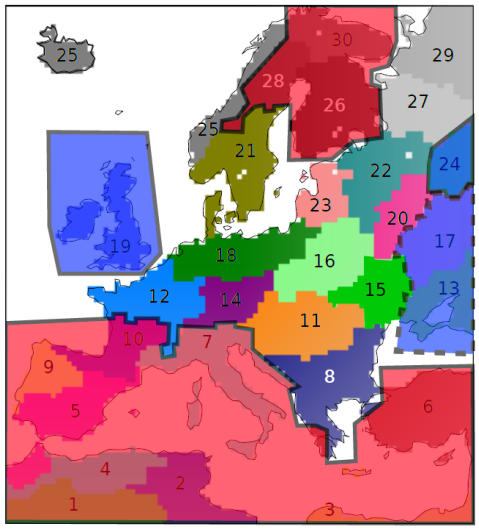
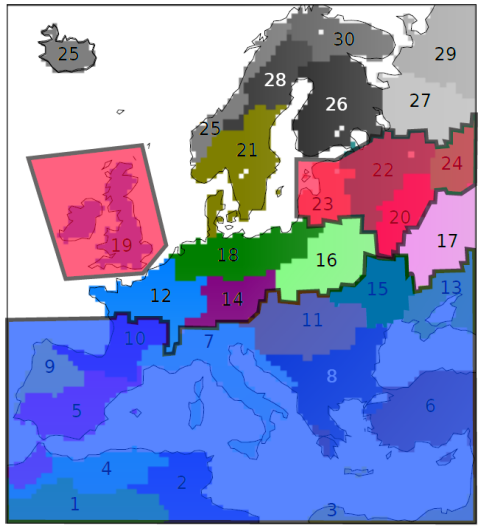
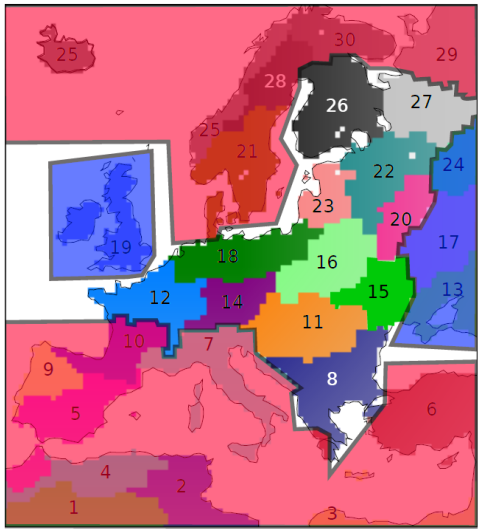
ENSO response

	90th	10th
SPI		
PDSI_snow_ET		

Dry

Wet

Conclusions

- NAO:
  - Linear connection
  - Follows the precipitation pattern associated to the NAO
- ENSO:
  - Nonlinear connection
  - Depends on the complexity of the water balance

Open issues

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- Analysis shows that ET is superior to PET, but ET is almost not observed
- What do proxy archives register?
- Enlarge the analysis to PMIP3 simulations

Publication: Raible, C. C., O. Baerenbold, and J. J. Gomez-Navarro, 2016: A generalized framework for different drought indices: Testing its suitability in a simulation of the last two millennia for Europe. **in revision**

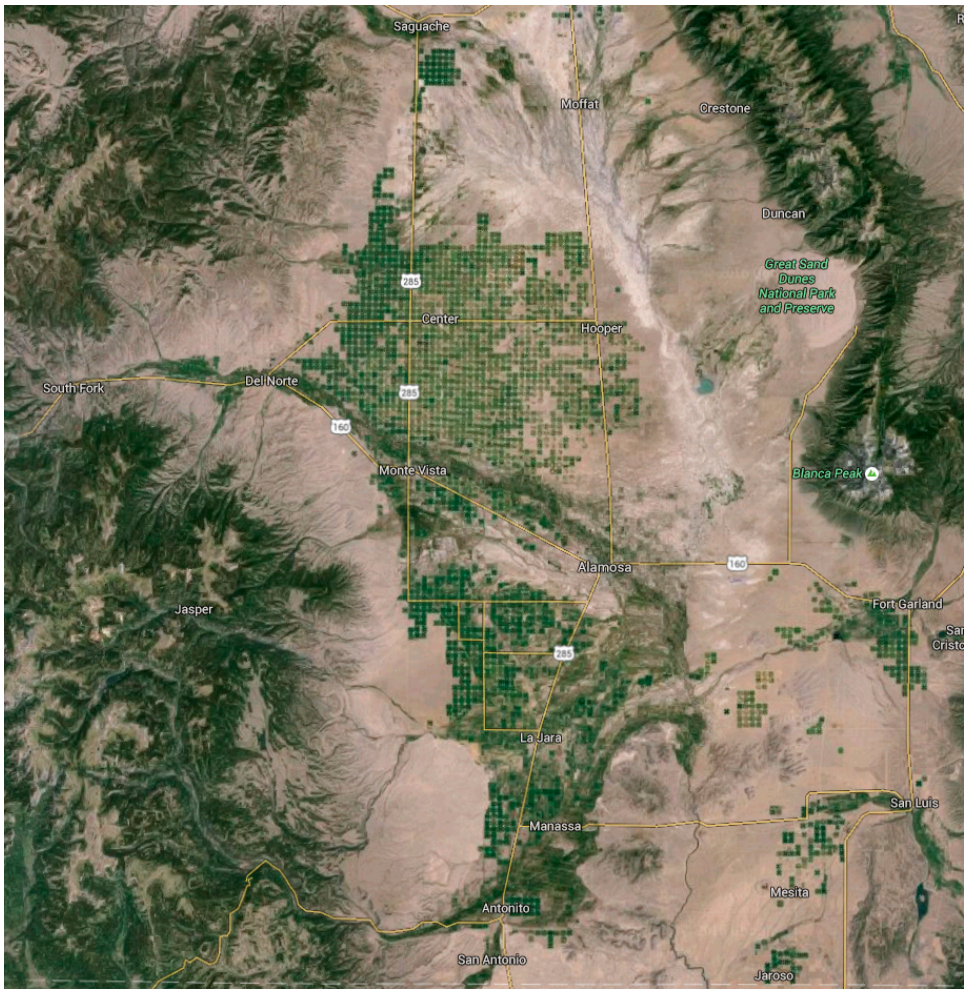
Runoff efficiency and climate in the American South-West

Flavio Lehner[1], Eugene Wahl[2], Andrew Wood[1]

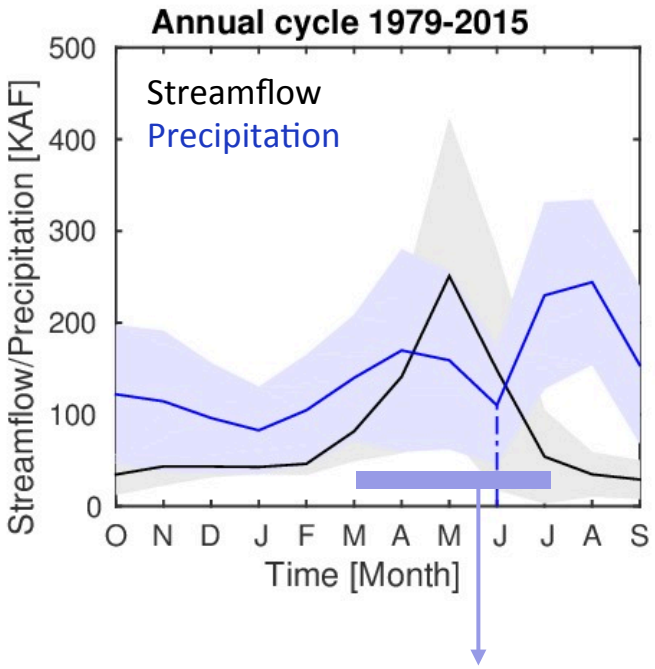
[1] *NCAR Research Applications Lab, Boulder, USA*

[2] *NOAA National Centers for Environmental Information, Boulder, USA*

Motivation – water resources and management

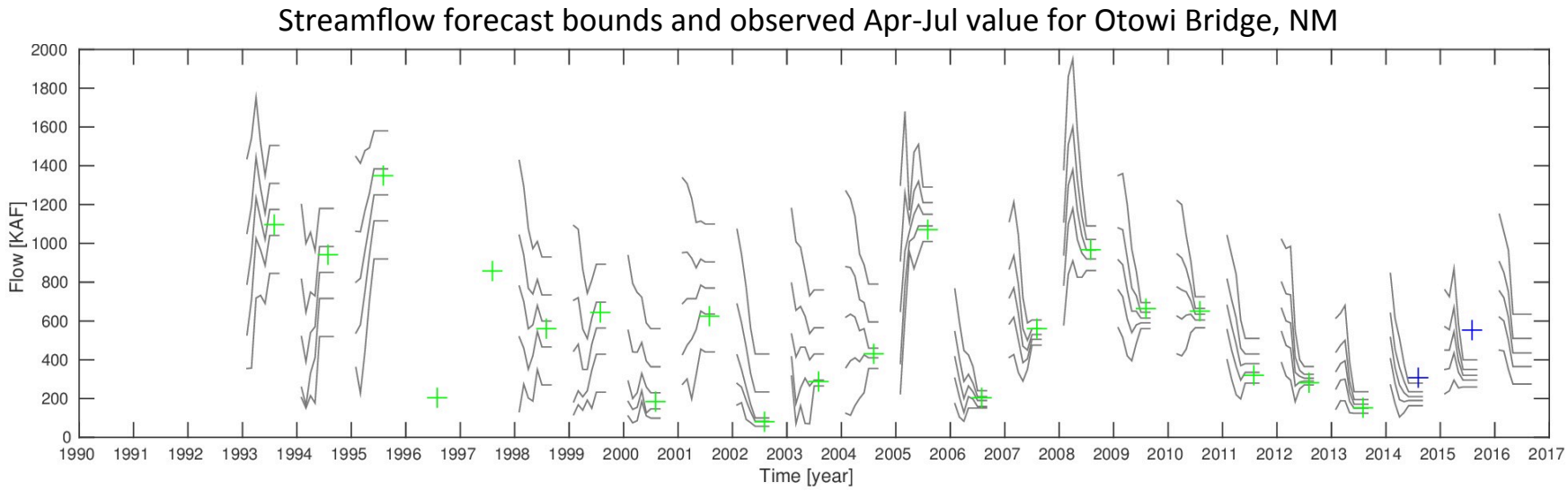


Motivation – water resources and management

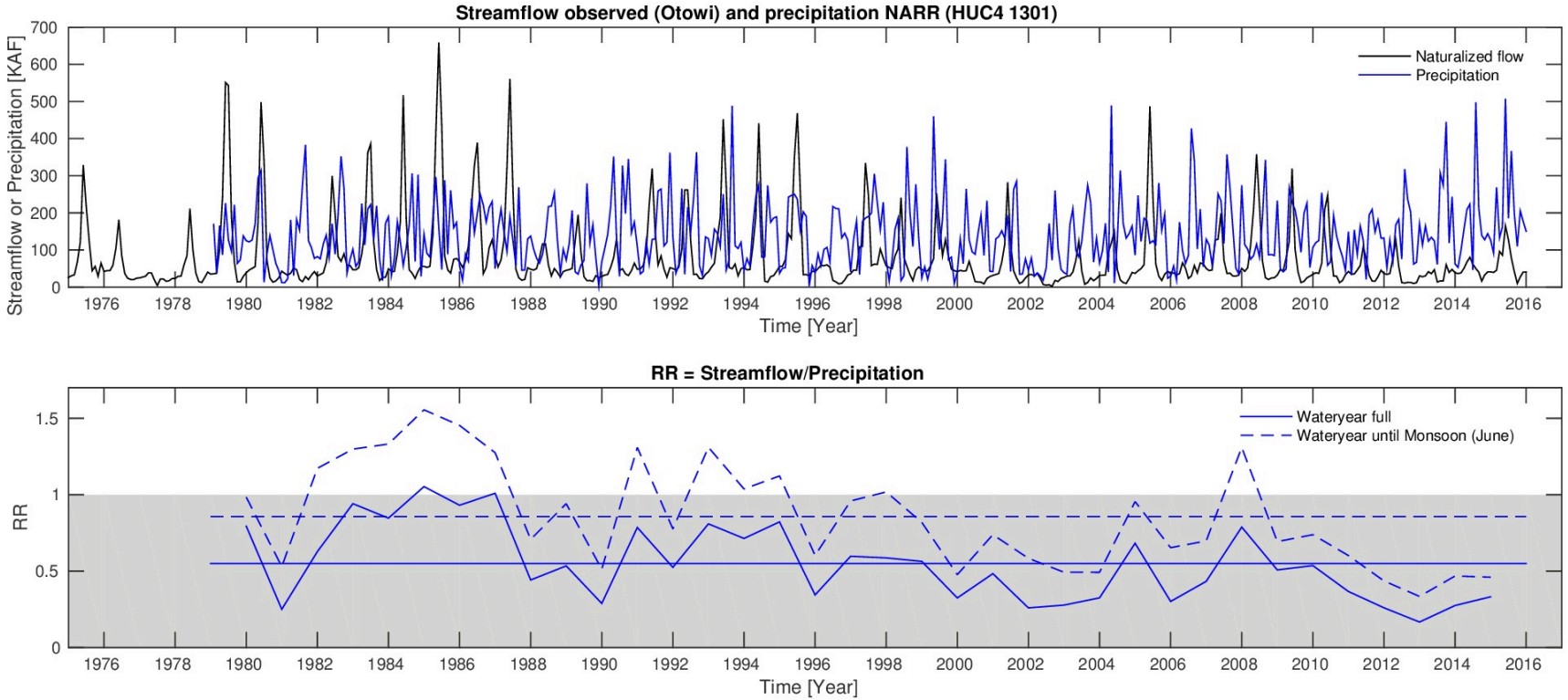


Main runoff amount → Streamflow of interest

Motivation – streamflow forecasting



Decreasing basin efficiency



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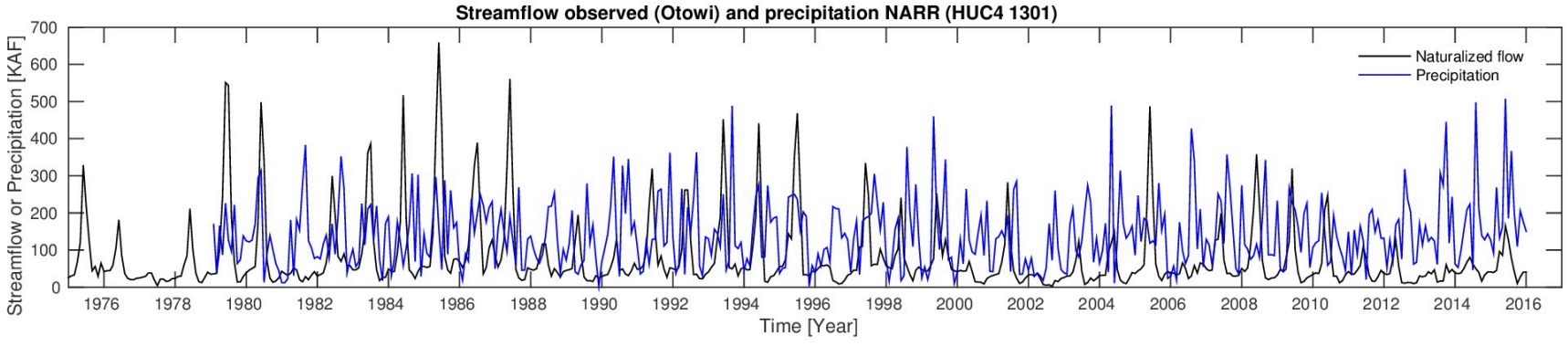
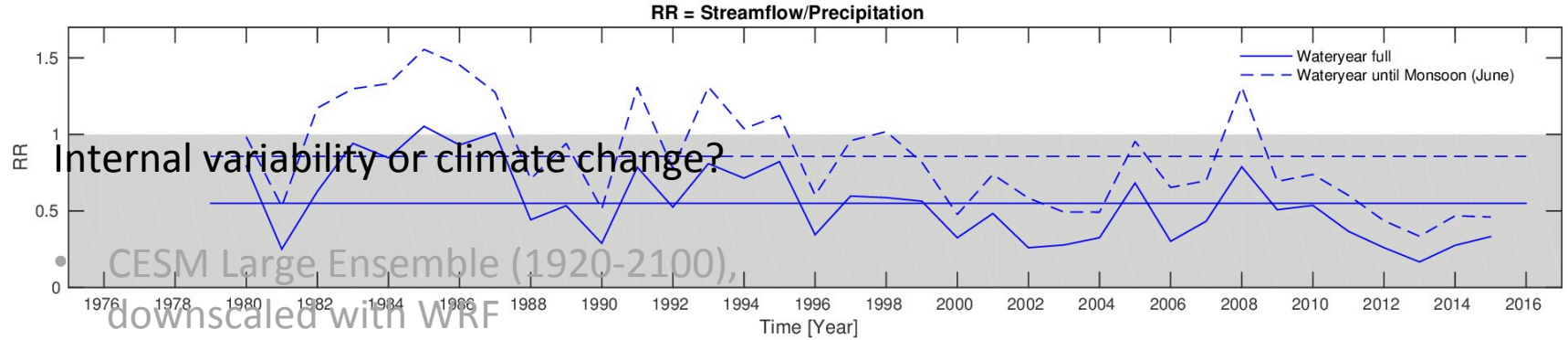
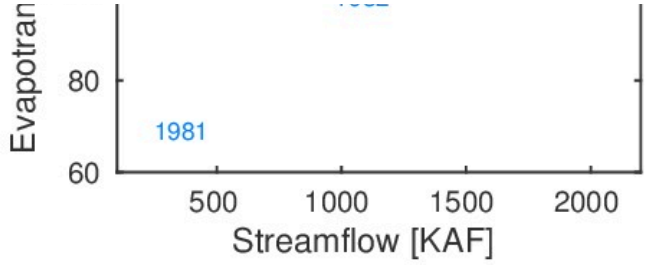


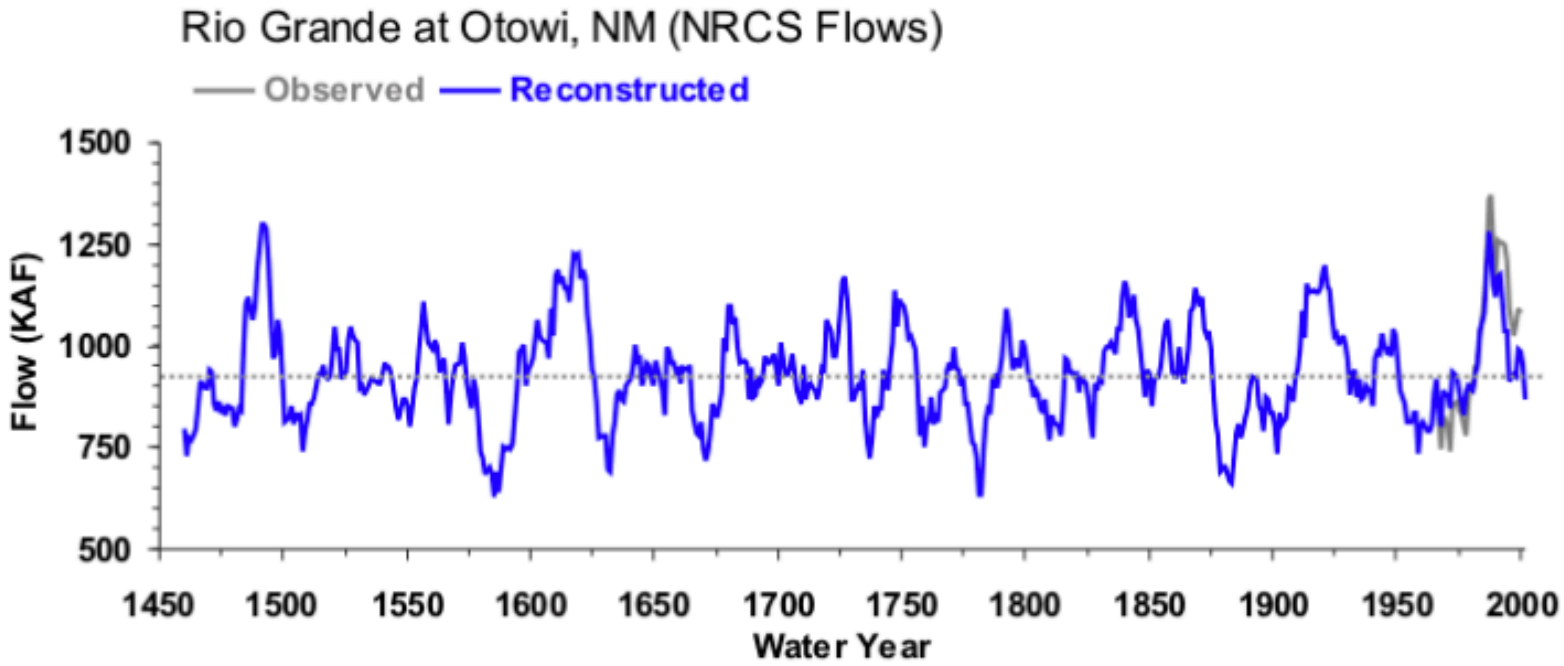


Internal variability or climate change?

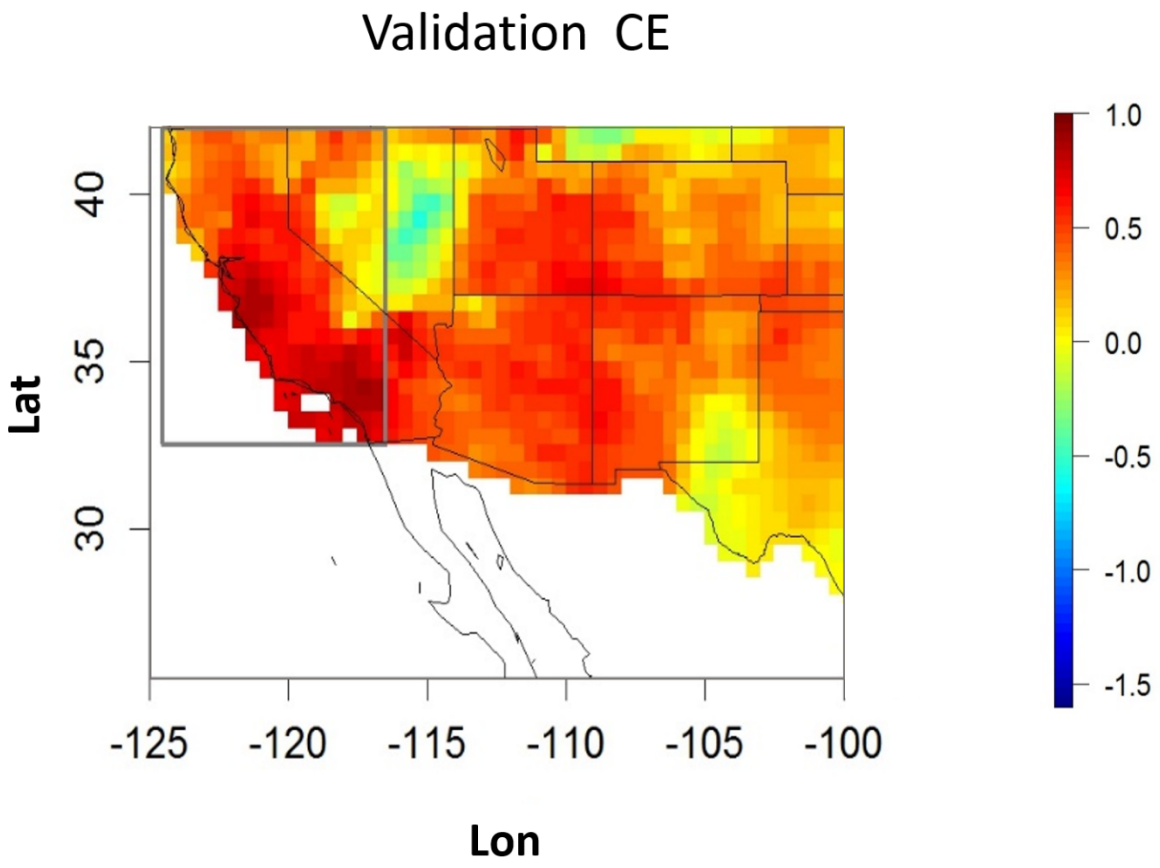
- CESM Large Ensemble (1920-2100), downscaled with WRF
- CESM Last Millennium Ensemble and PMIP3
- Reconstructions: streamflow, precipitation, drought atlas



Streamflow reconstructions

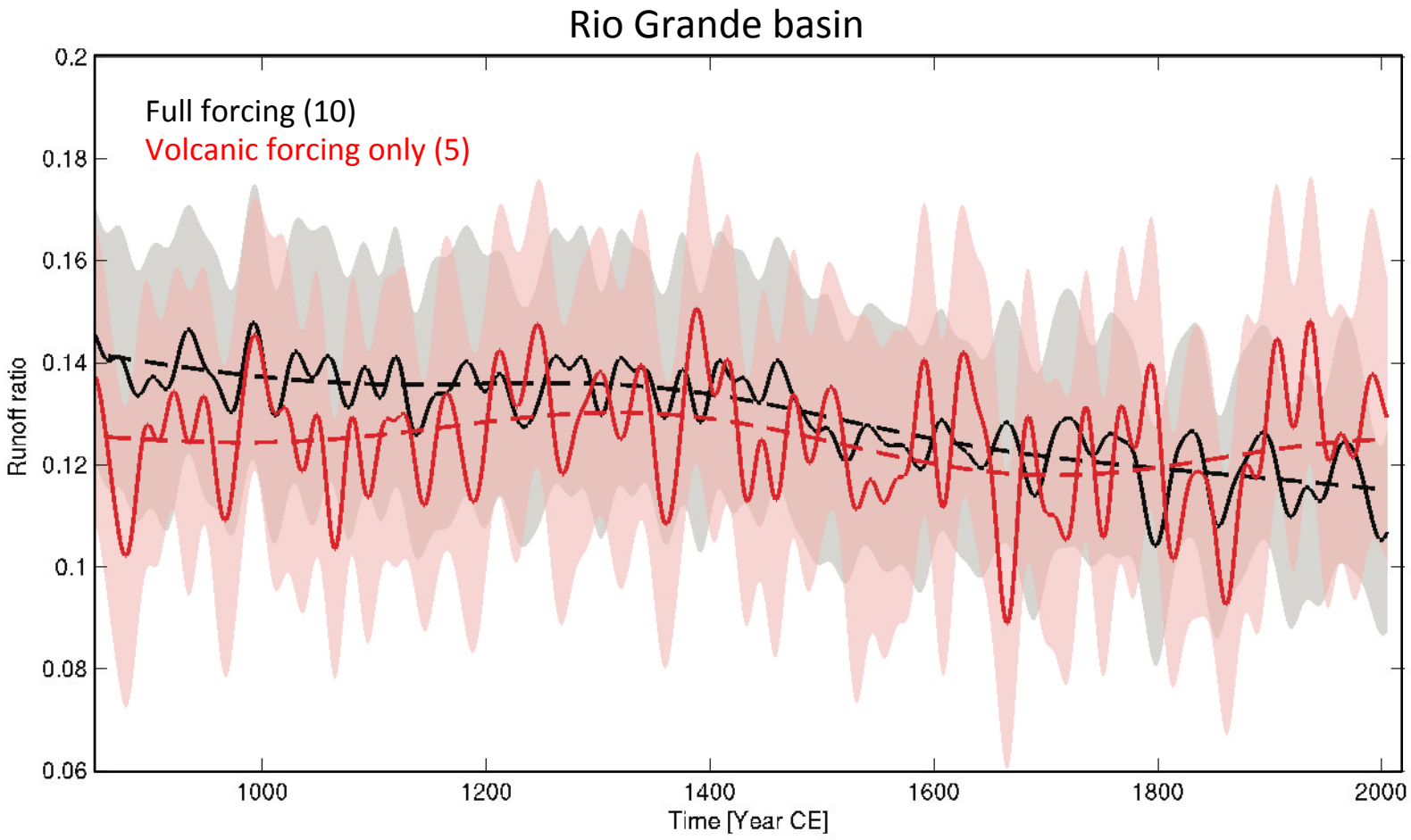


Precipitation reconstruction



Diaz and Wahl (2015, J. Climate)

CESM Last Millennium Ensemble – runoff efficiency



Ideas and next steps

- Reconstruct runoff efficiency for Rio Grande and Colorado basin (others?)
- What is the natural range of trends in runoff efficiency?
- Compare with variability in models – are models adequate?
- What are the drivers of such trends? Are there modes of variability that project onto these trends or is it just noise? Can something be learned that is useful for present-day streamflow forecasting?

Ideas and next steps

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flehner@ucar.edu

Thank you, PAGES!

PAST GLOBAL CHANGES

Memory

Correlation between exponential approach with an *e*-folding time of 6.6 months and

Water balance	Block mean memory (in mon)							
	1	3	6	9	12	18	24	48
SPI	0.43	0.68	0.84	0.90	0.92	0.89	0.82	0.61
PDSI	0.44	0.68	0.84	0.91	0.93	0.91	0.84	0.64

Memory

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Correlation between exponential approach with an e-folding time of 6.6 months and

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PDSI	0.44	0.68	0.84	0.91	0.93	0.91	0.84	0.64

For moderate droughts (index < -2): 63% agreement

For severe droughts (index < -3): 48% agreement

Quantile mapping: SPI, 1 mon memory

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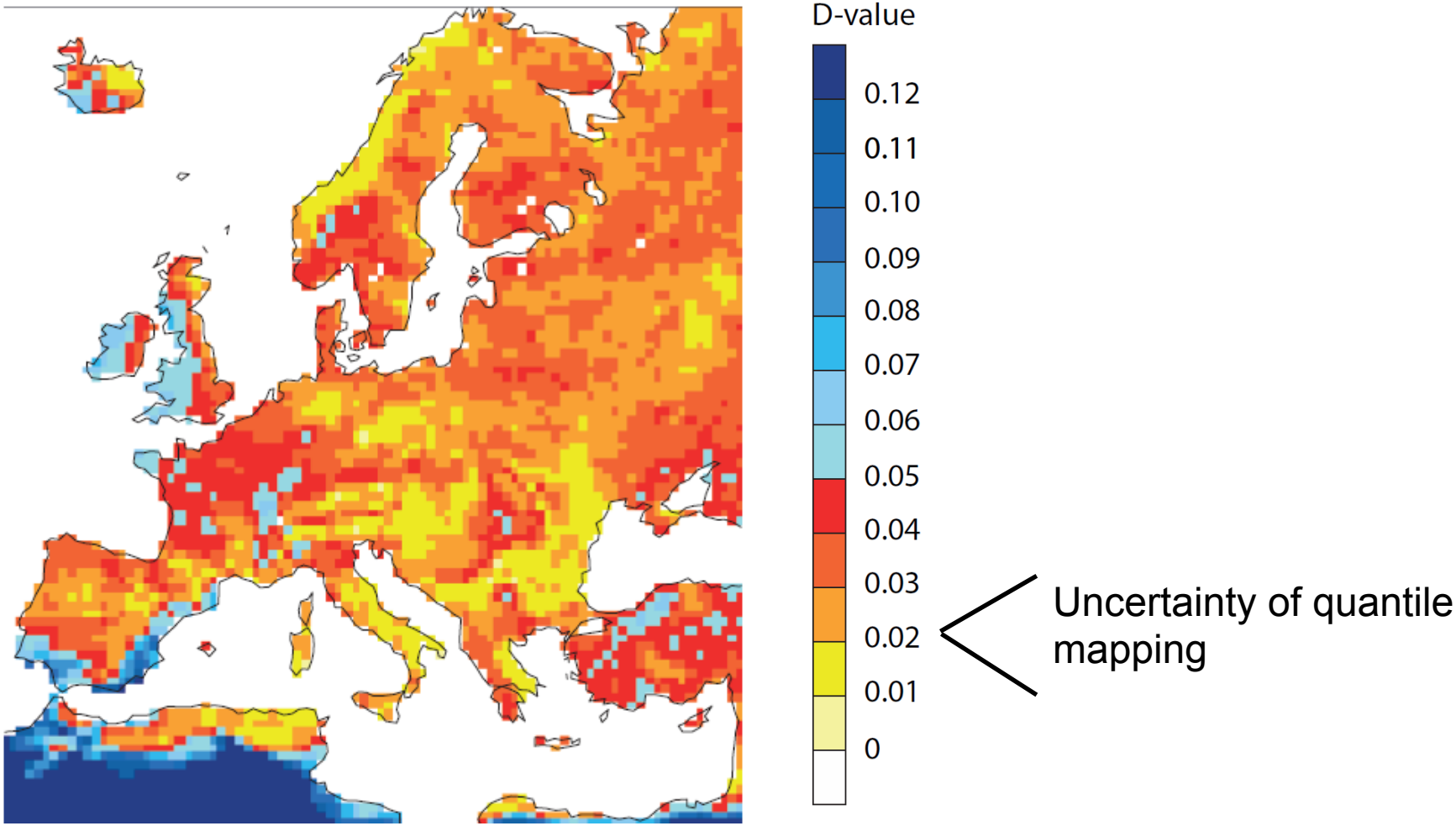
Maximum distance between the empirical cumulative distribution and the cumulative gamma distribution for January



PET versus ET?

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