European hydrological drought patterns: simulations by Global Hydrological Models, and future projections

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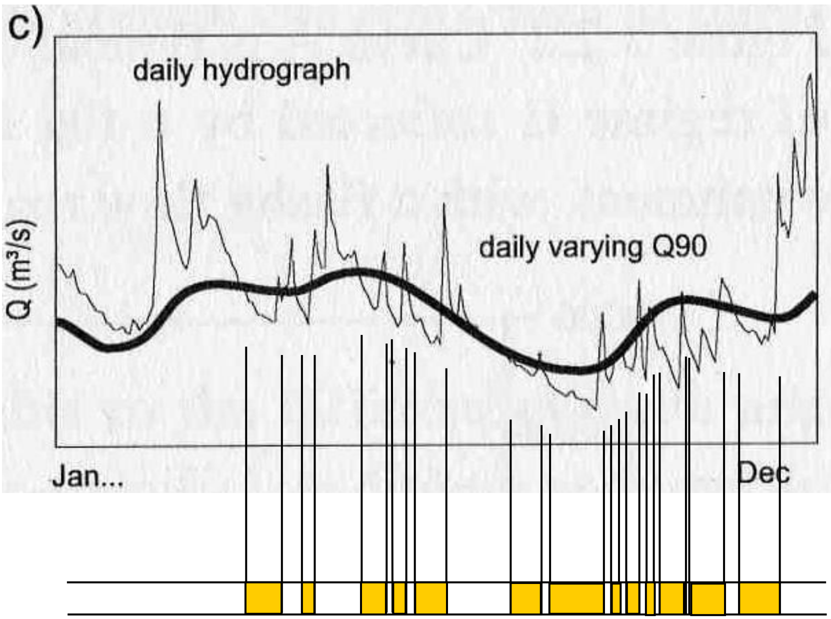
Research questions

- How well do Global Hydrological Models (GHM) reproduce droughts at the regional scale in Europe?
- How sensitive are GHMs to climate drivers?
- How large is the uncertainty in GHMs-simulated large-scale hydrological extremes? How does it compare with GCM uncertainty?

Droughts at the regional scale: the RDI

- For daily time series at each station, compare the measured river flow with a daily-varying Q90 threshold



Flow time series transformed into binary series, or **Deficit Index**:

1 for deficit, or flow below threshold: yellow periods

0 for non deficit, or flow above threshold: white periods

- For a region, the **Regional Deficiency Index (RDI)** is the proportion of stations which are below the threshold on any one day

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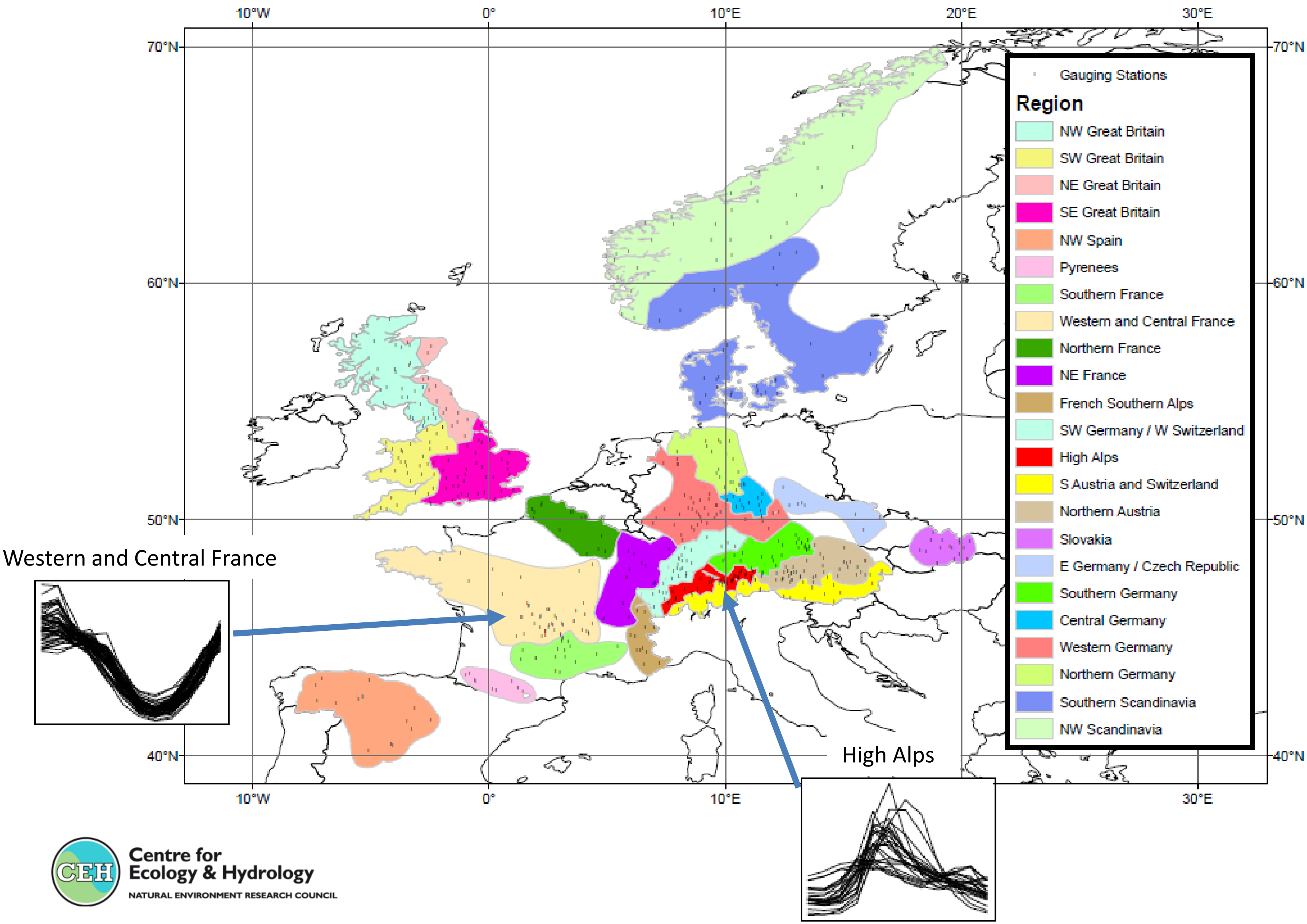
Homogeneous Drought Regions



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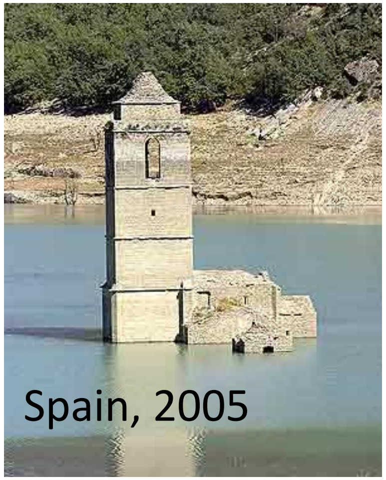
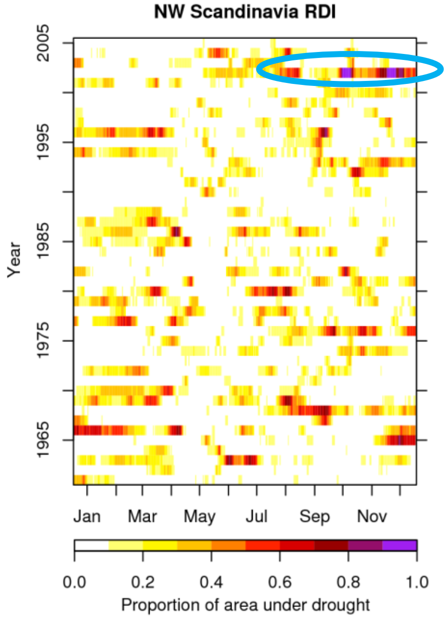
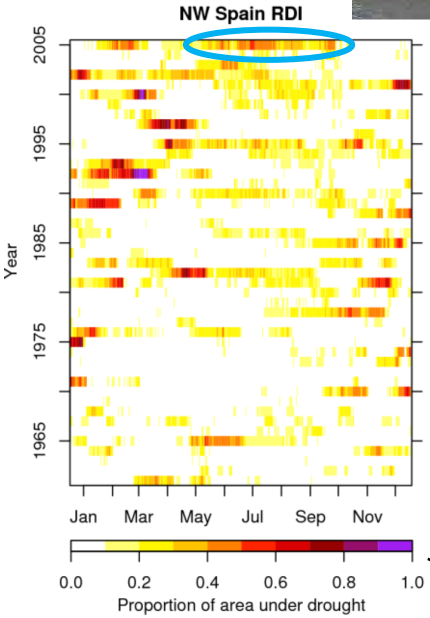
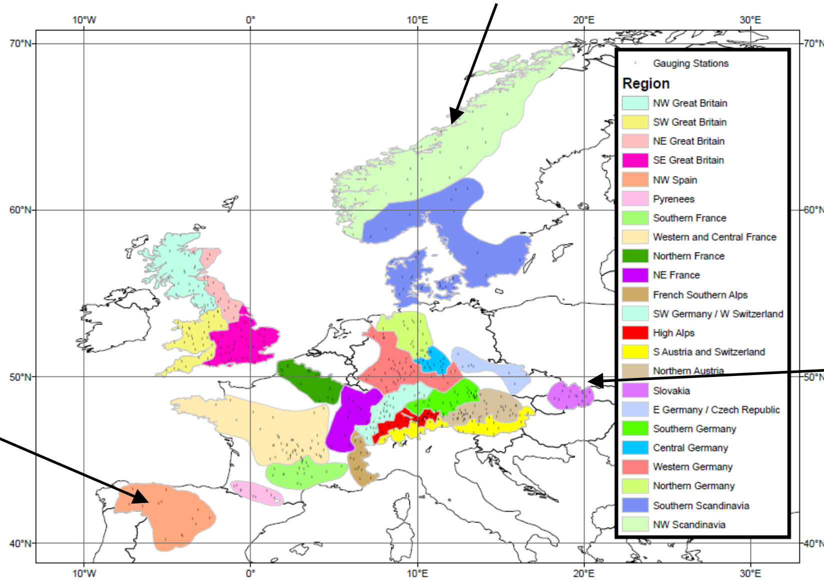
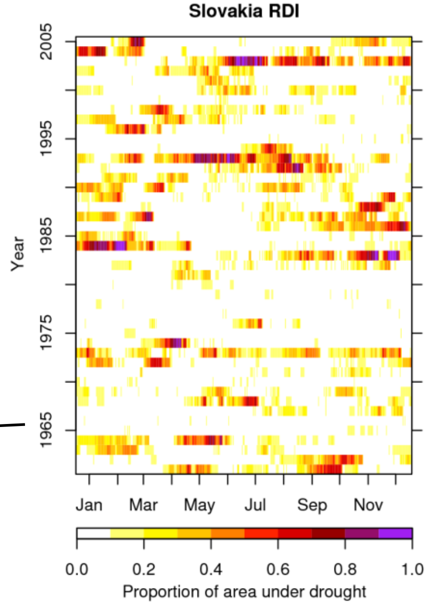
Observed Data: European drought catalogues











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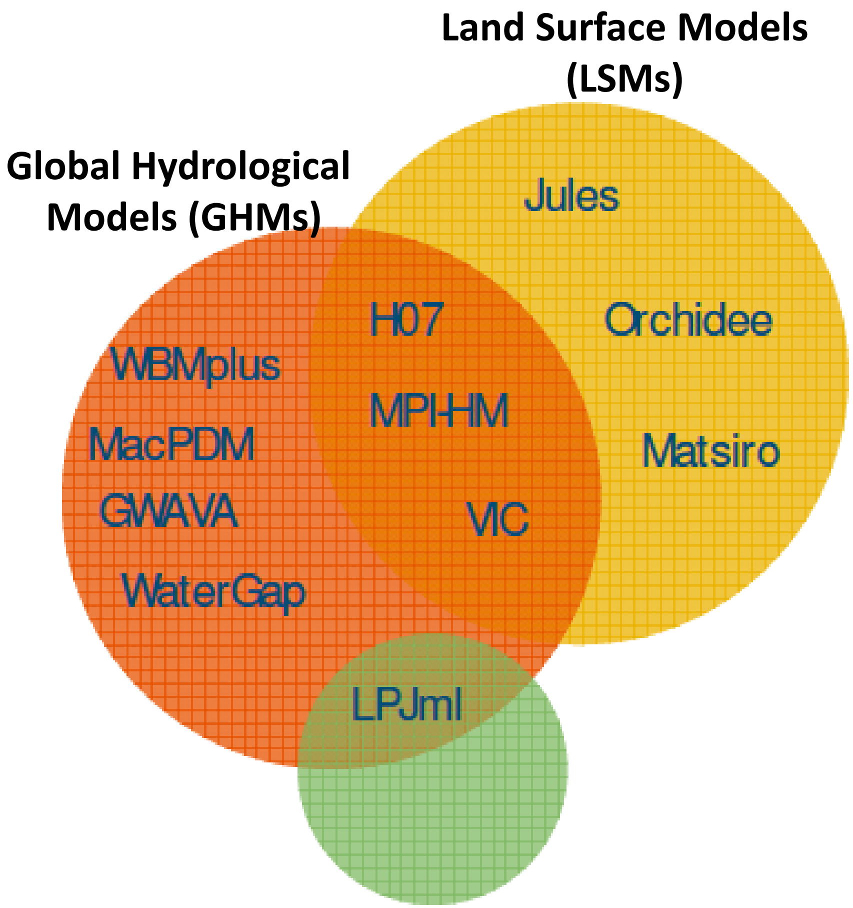
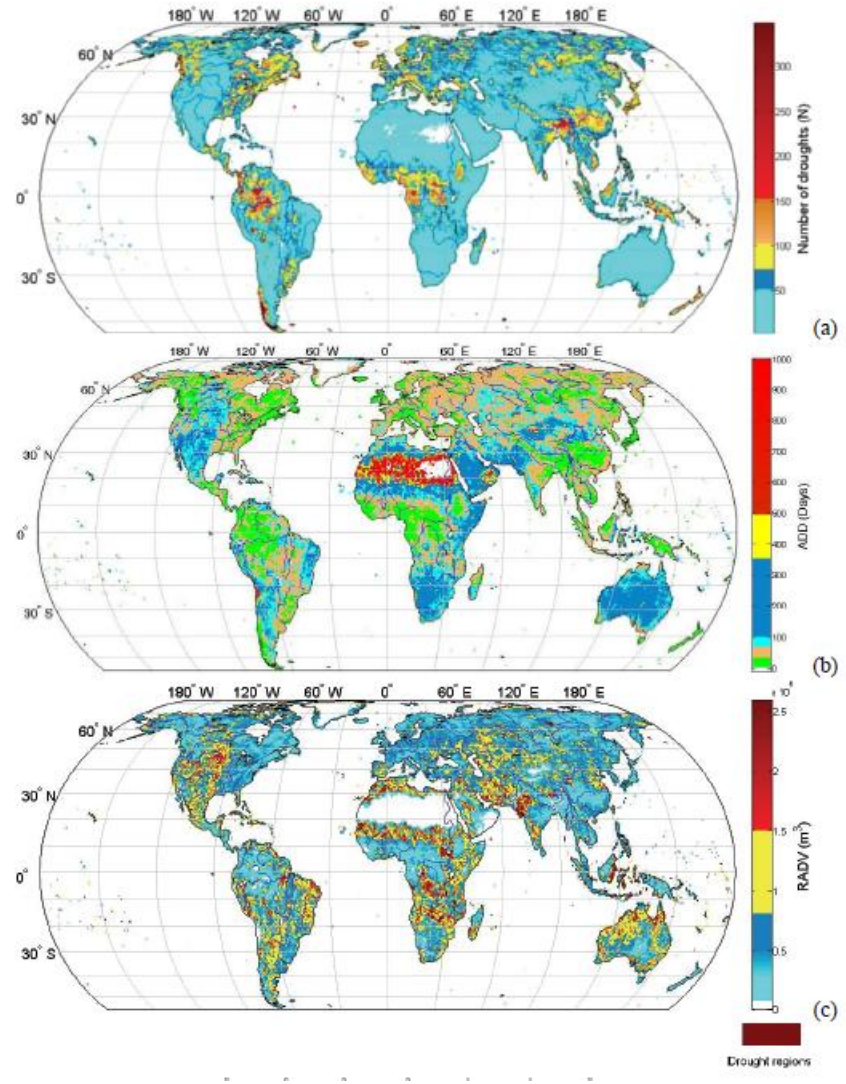
Hannaford et al. 2011. Parry et al. 2012

WATCH Simulations: large-scale models





Driven by:

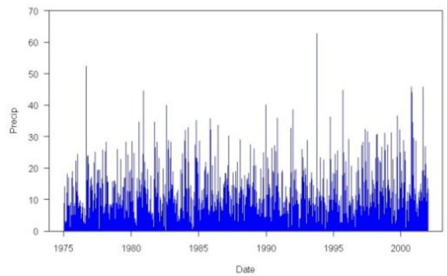
-- WATCH Forcing Data for 20th Century

-- Three Climate Models for 20th Century

-- Three Climate Models for 21st Century

1) Simulation of past from observed climate

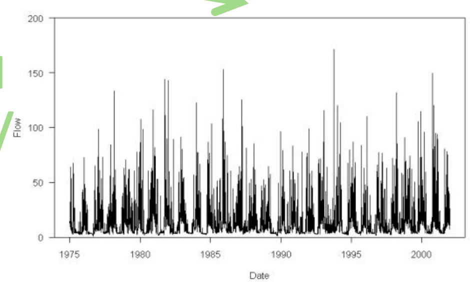
WATCH Forcing data (Gridded observations)



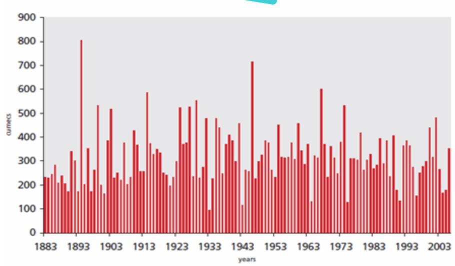
River discharge databases (e.g. FRIEND)

Global model

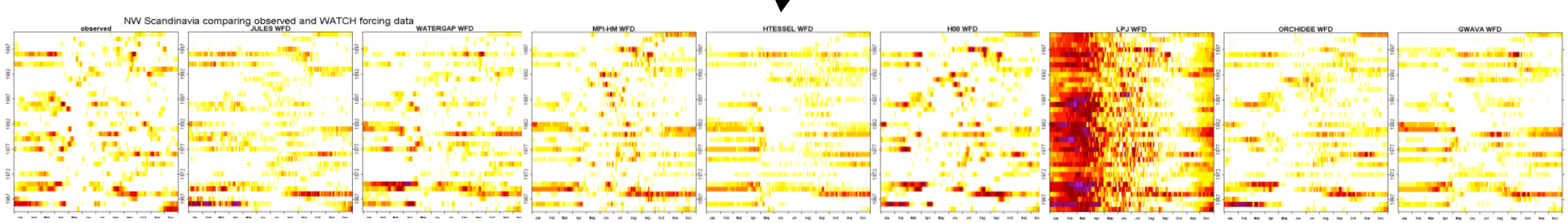
Simulated discharge/ runoff time series (gridded)



Observed river flow time series

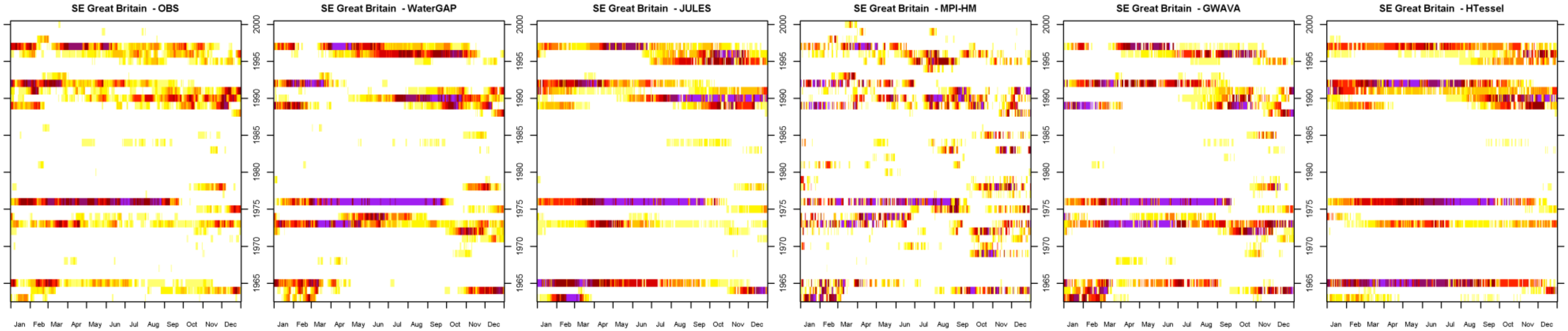


Data analyses (e.g. RDI)

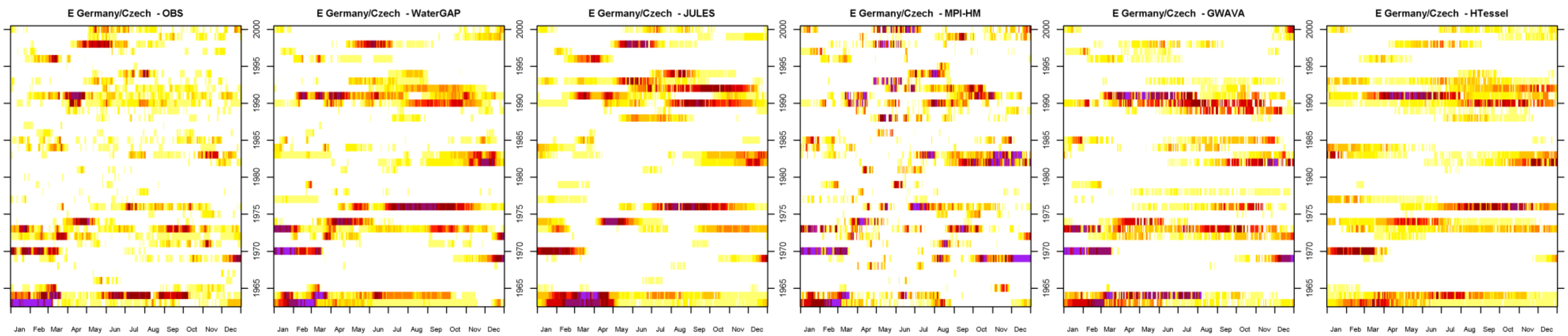


Observed droughts vs. Simulated droughts

SE Great Britain



E Germany/ Czech



Observed **WaterGAP** **JULES** **MPI-HM** **GWAVA** **HTESSEL**

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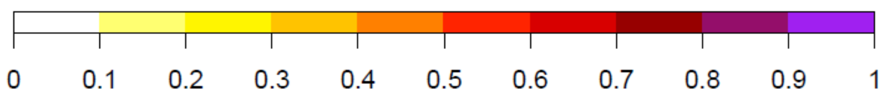
RDI



Observed droughts vs. Simulated droughts

- Spearman correlations between observed and simulated RDI for 1963-2000)
- Dark shades: highest correlations
- Results vary amongst GHM and regions

Region	WaterGAP	JULES	MPI-HM	GWAVA	HTessel
NW Great Britain	0.50	0.52	0.60	0.52	0.34
SW Great Britain	0.64	0.62	0.69	0.64	0.52
NE Great Britain	0.63	0.49	0.62	0.59	0.42
SE Great Britain	0.77	0.77	0.63	0.68	0.74
NW Spain	0.50	0.48	0.60	0.44	0.35
Pyrenees	0.46	0.35	0.40	0.45	0.30
S France	0.60	0.57	0.60	0.57	0.42
W & C France	0.61	0.59	0.67	0.55	0.49
N France	0.63	0.55	0.47	0.54	0.55
NE France	0.64	0.56	0.57	0.55	0.48
French S Alps	0.45	0.43	0.44	0.53	0.37
SW Germany/W Switz	0.65	0.60	0.62	0.59	0.53
High Alps	0.55	0.54	0.51	0.50	0.39
S Austria & Switz	0.56	0.51	0.57	0.51	0.47
N Austria	0.59	0.52	0.61	0.47	0.37
Slovakia	0.61	0.54	0.51	0.46	0.46
E Germany & Czech	0.59	0.53	0.53	0.53	0.49
S Germany	0.66	0.52	0.57	0.58	0.55
C Germany	0.59	0.56	0.57	0.51	0.51
W Germany	0.72	0.57	0.66	0.65	0.60
N Germany	0.63	0.53	0.58	0.59	0.54
S Scandinavia	0.62	0.63	0.67	0.61	0.53
NW Scandinavia	0.62	0.61	0.59	0.49	0.39

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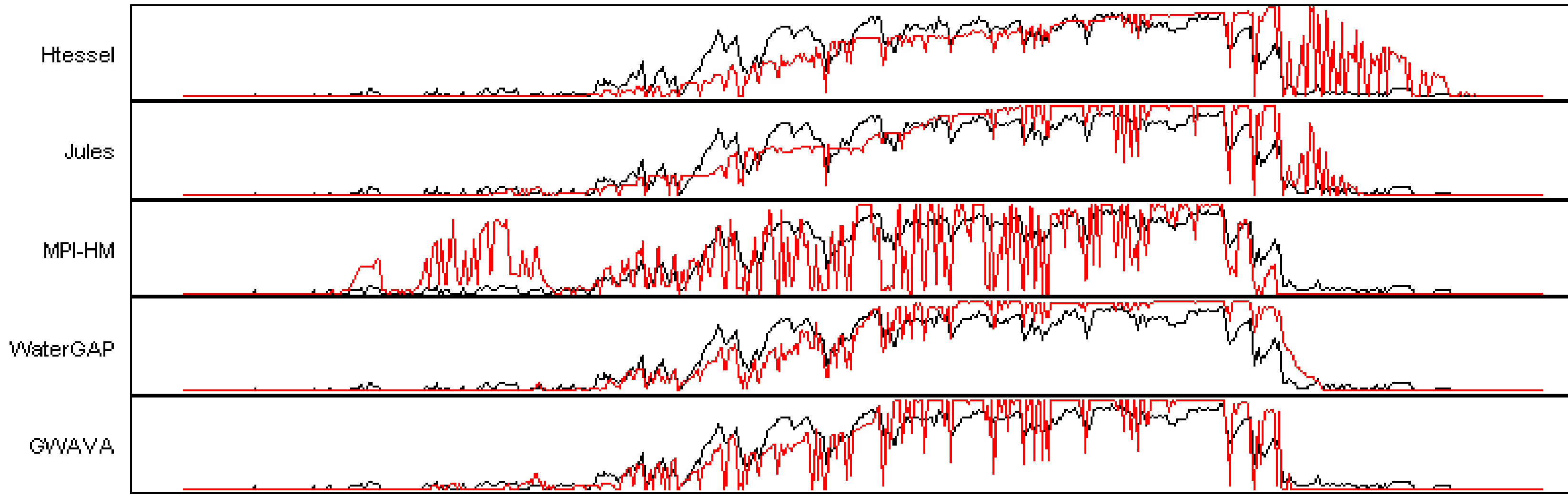
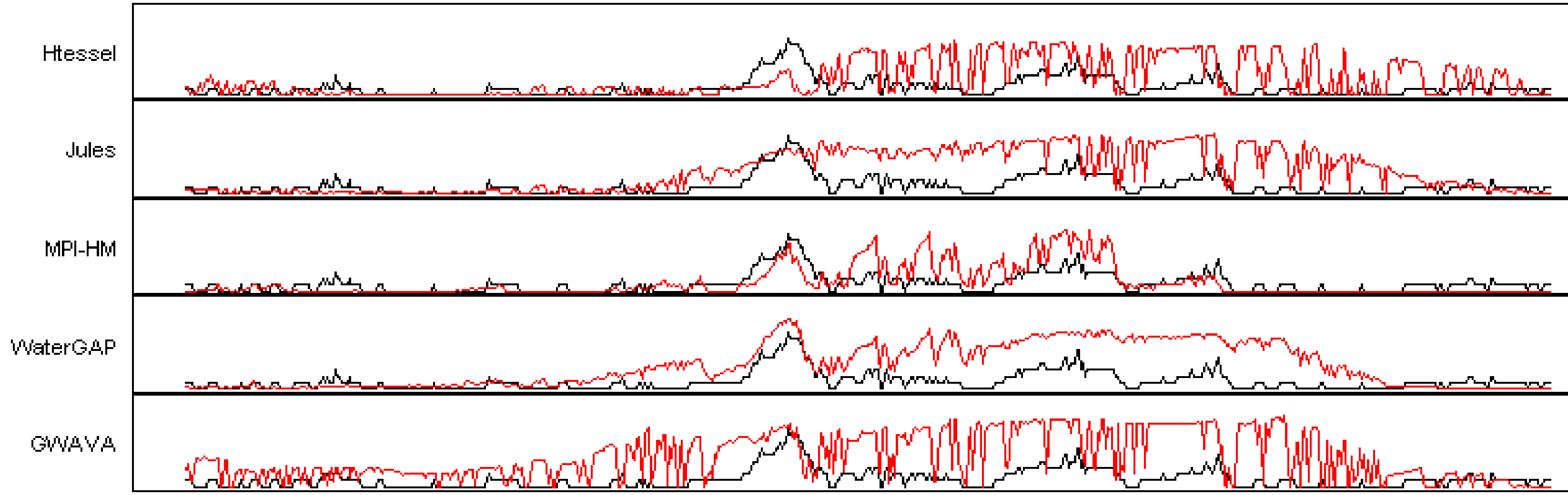
1975-76 drought: simulated vs. observed

SE Great Britain



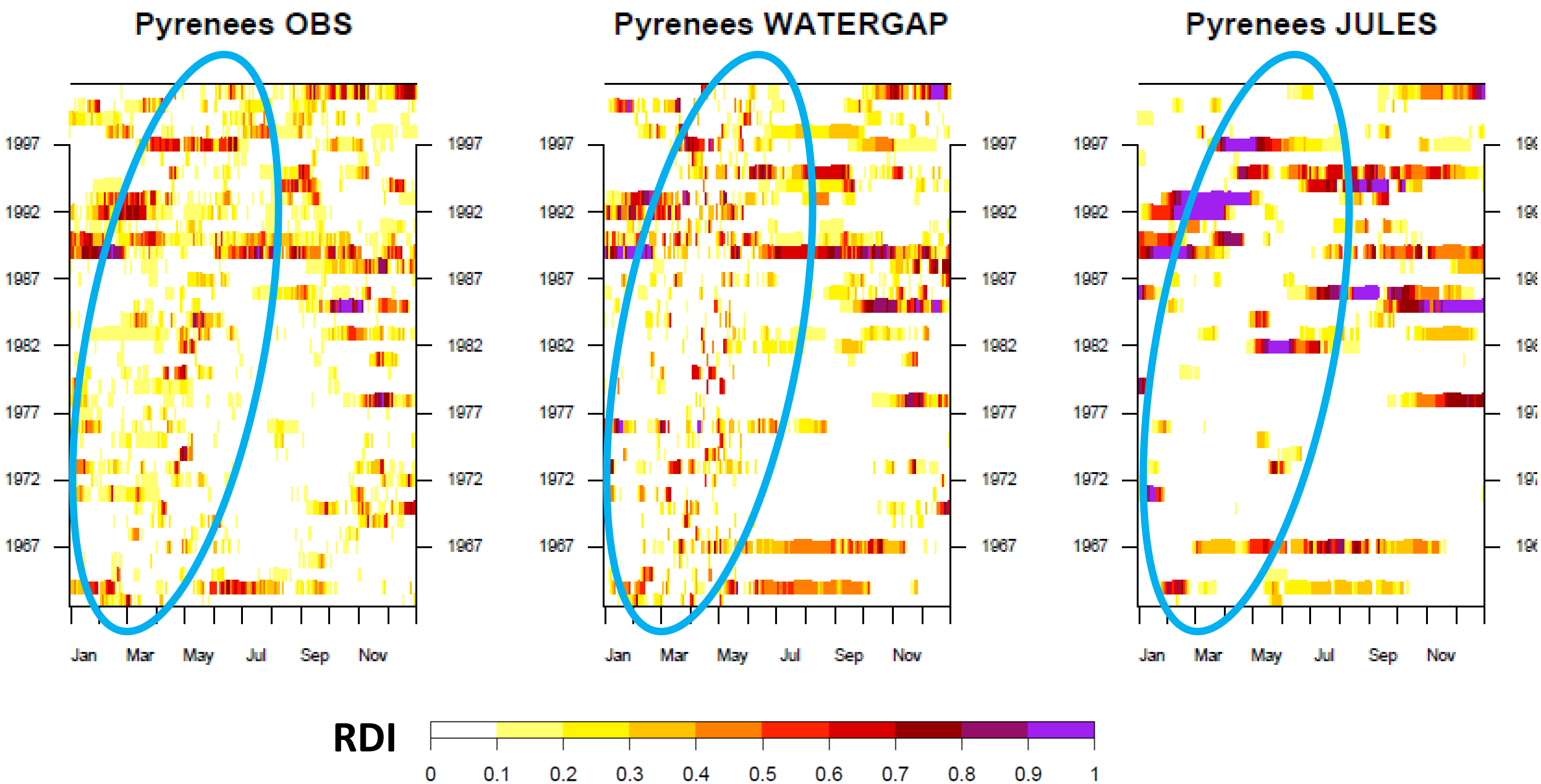
NW Spain

Black = Observed **Red = Modelled**



Implications of process base of models?

Snow melt processes?



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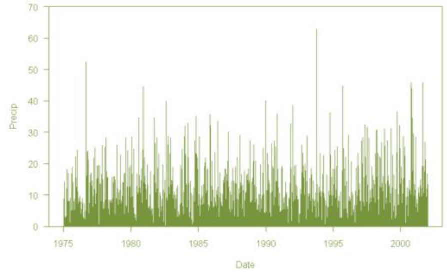
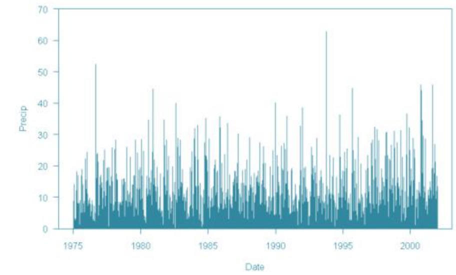
Prudhomme *et al*. (submitted), Journal of Hydrometeorology

2) Simulation of past from modelled climate

WFD data (Gridded observations)



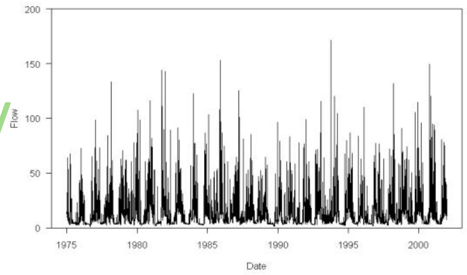
GCM baseline runs bias-corrected (Gridded simulations)



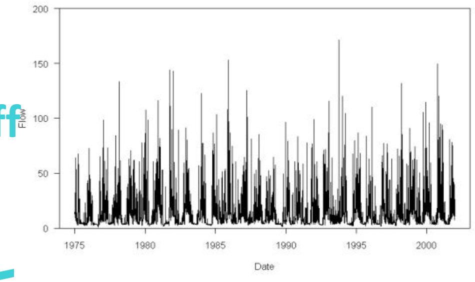
Global hydrological model

Global hydrological model

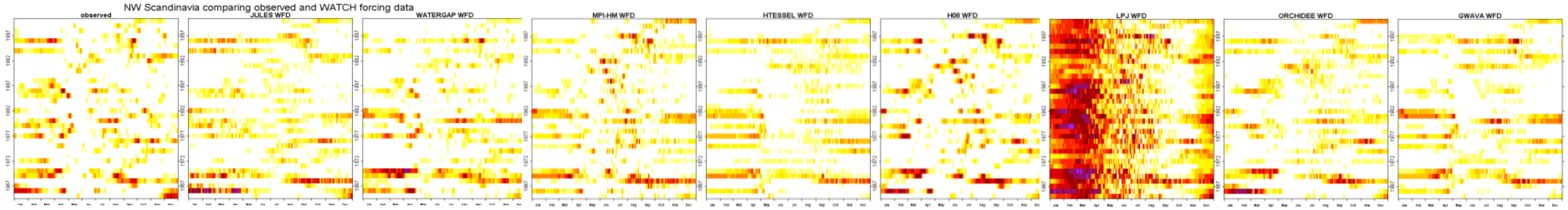
Simulated discharge/runoff time series (gridded)



Simulated discharge/runoff time series (gridded)

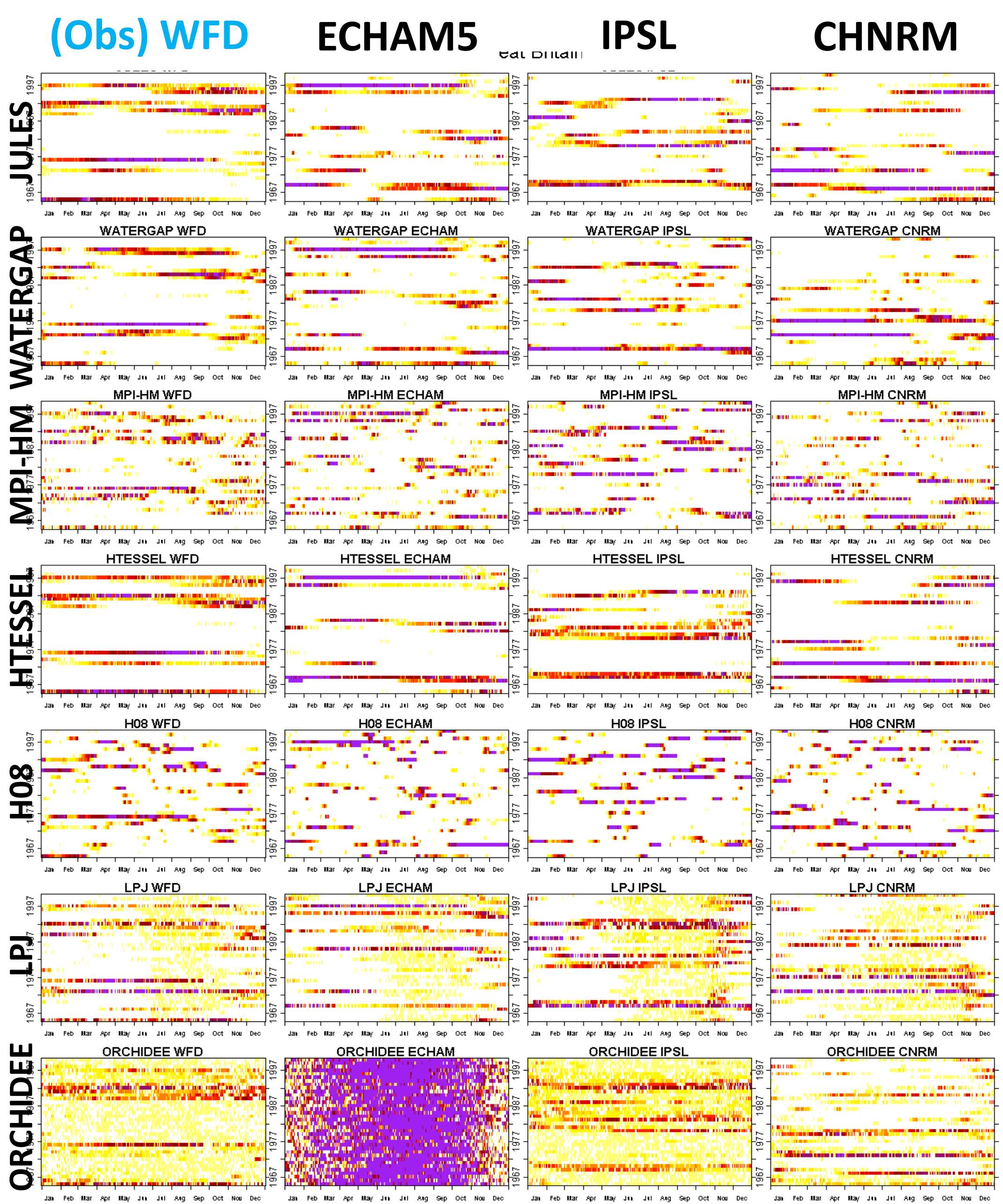


Data analyses (e.g. RDI)



Watch Forcing Data vs GCM Control

- Events not expected to occur at same time, but with same **characteristics**
- Generally good reproduction of RDI



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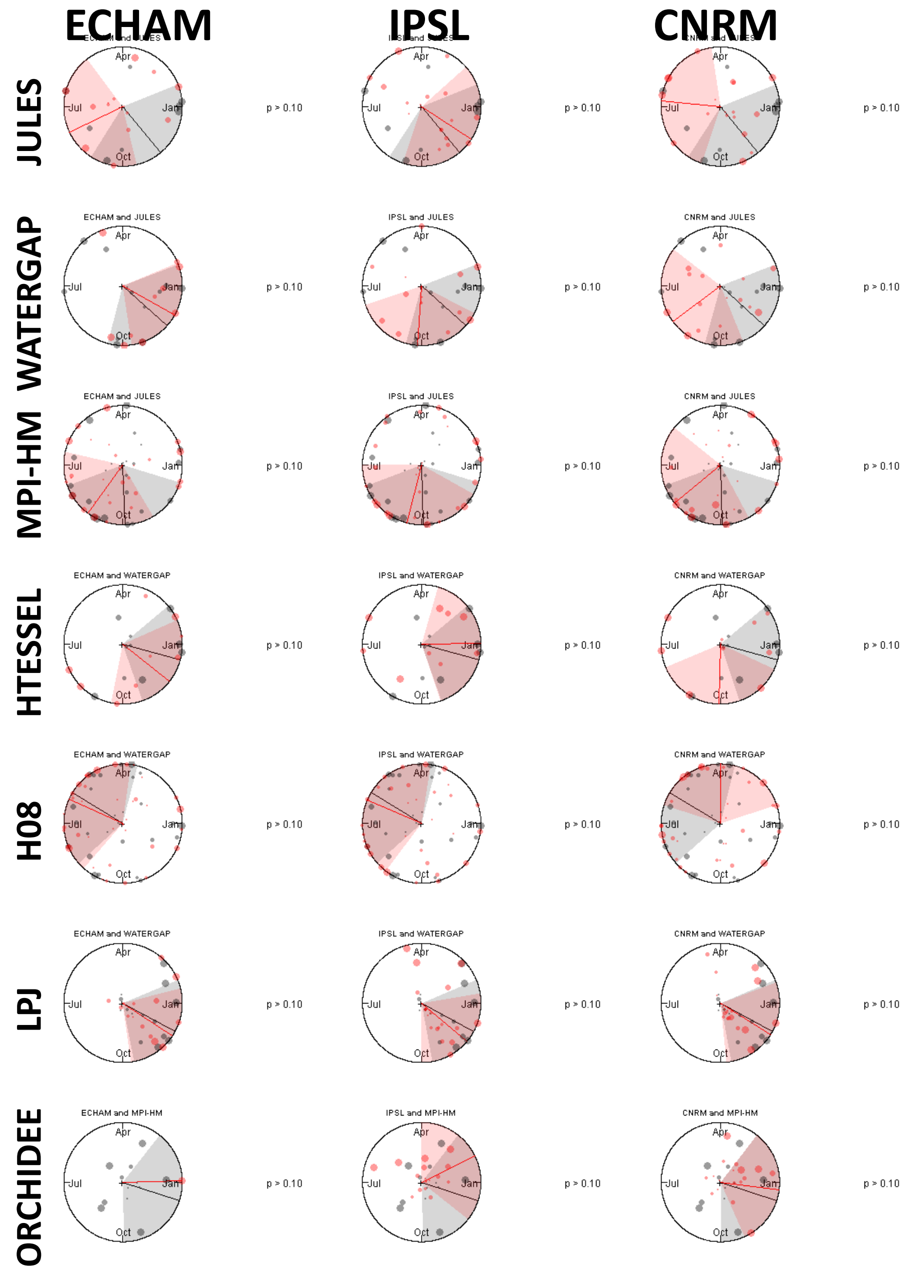
SE GB: comparing WFD & GCM CTL

- Different seasonality between WFD & GCMs strongest for **JULES & WATERGAP**

- Large **variability** in month start event; smallest for LPJ

- Long events JULES, WATERGAP, HTESSEL

- Short events MPI-HM,H08



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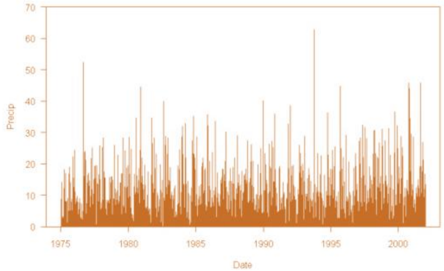
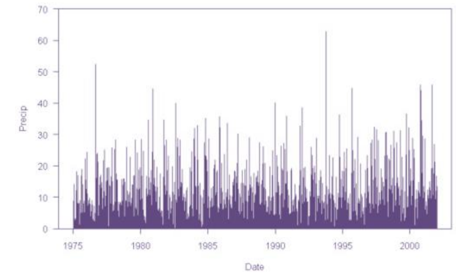
3) Simulation of future from modelled climate

GCM control runs bias-corrected (Gridded simulations)



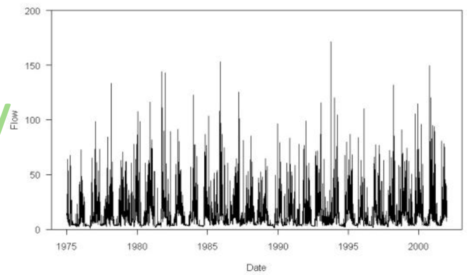
GCM future runs bias-corrected (Gridded simulations)



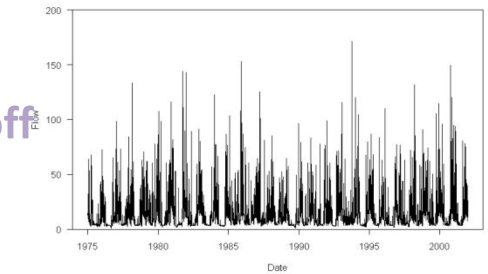
Global hydrological model

Global hydrological model

Simulated discharge/ runoff time series (gridded)

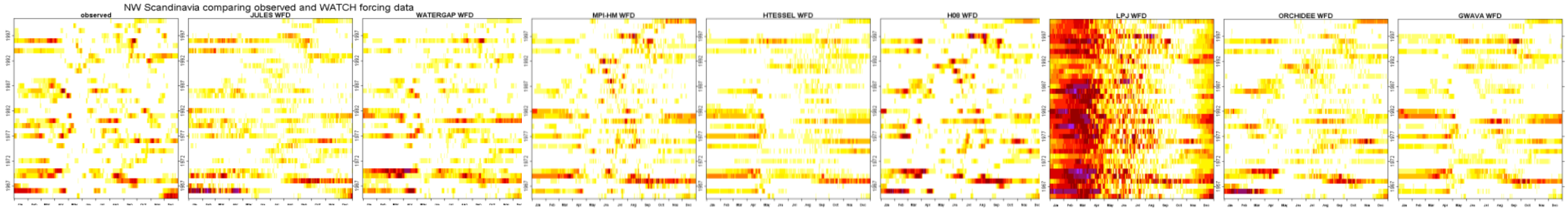


Simulated discharge/runoff time series (gridded)

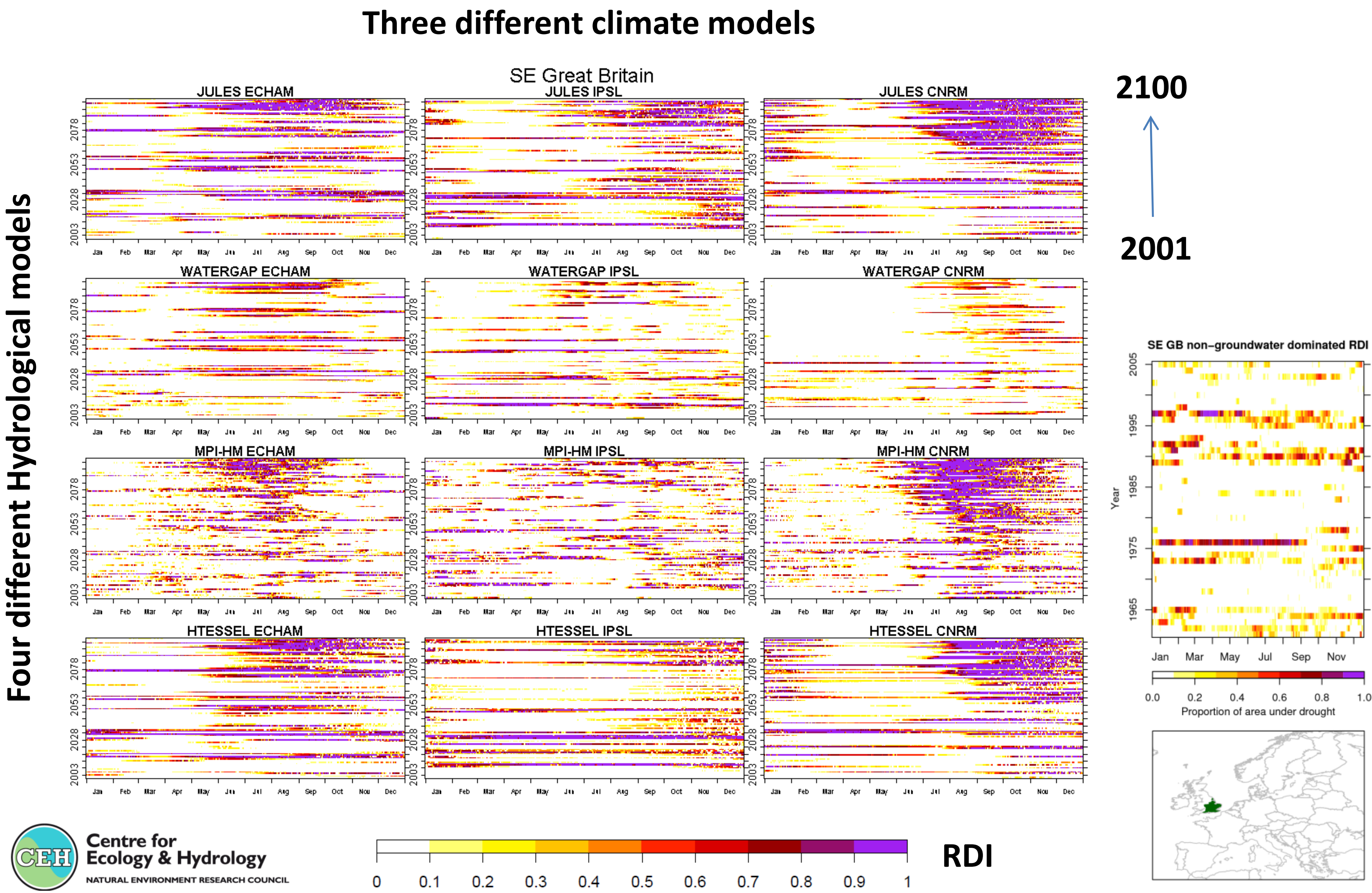


Data analyses (e.g. RDI)

Moving Threshold: same for historical and future - from CTL run



Uncertainty for 21st C GCMs and GHMs



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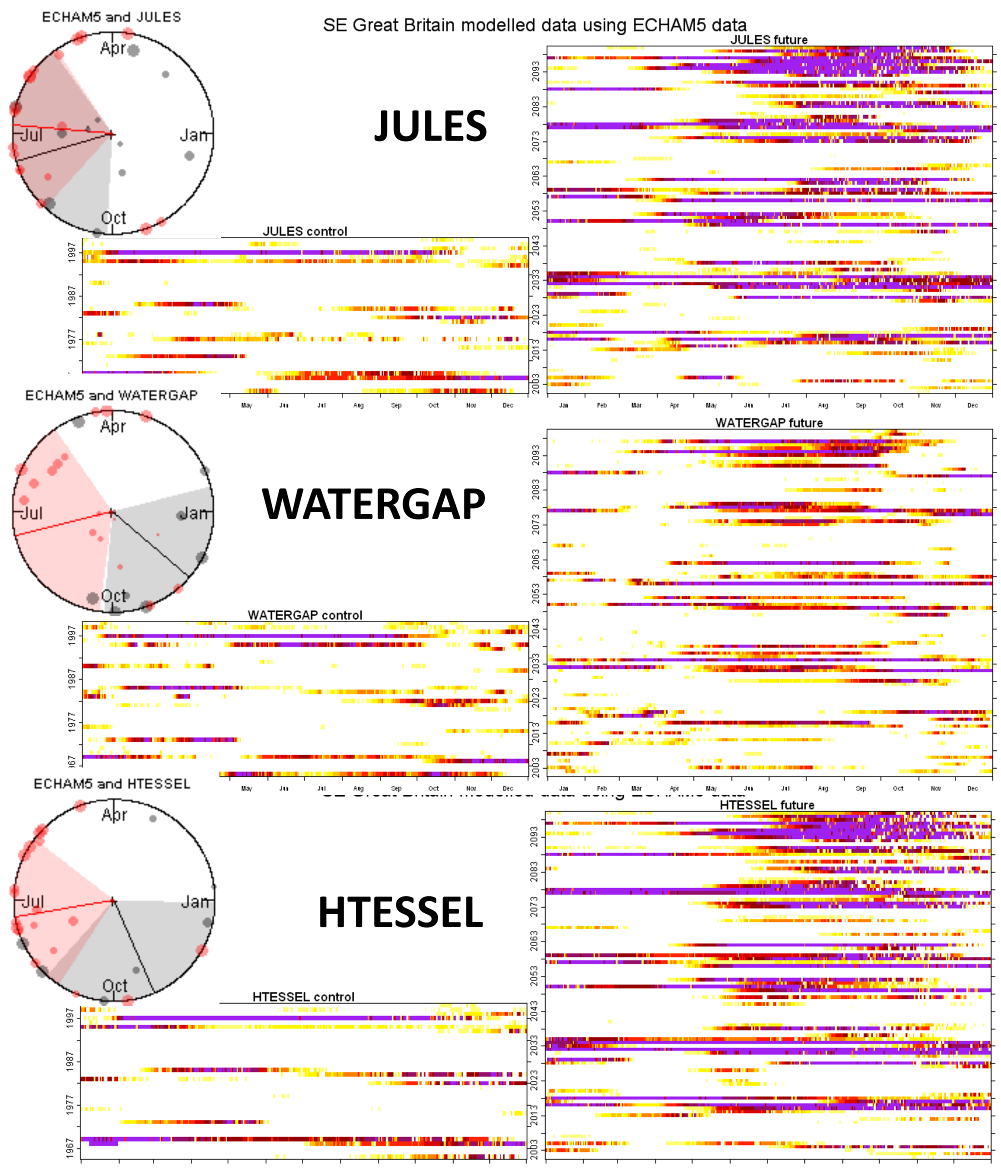
SE Great Britain: CTL & Future (ECHAM5)

Seasonality of start events RDI>0.5

Control: long events starting in winter half year
Future: events becoming longer, more coherent and mostly in summer
Shift in seasonality of droughts

Control: long events starting any time; largest spatio-coherence in summer
Future: summer events more frequent
Strong shift in seasonality of droughts start

Control: long, multi-year events
Future: events more coherent/frequent summer
Strong shift seasonality towards summer



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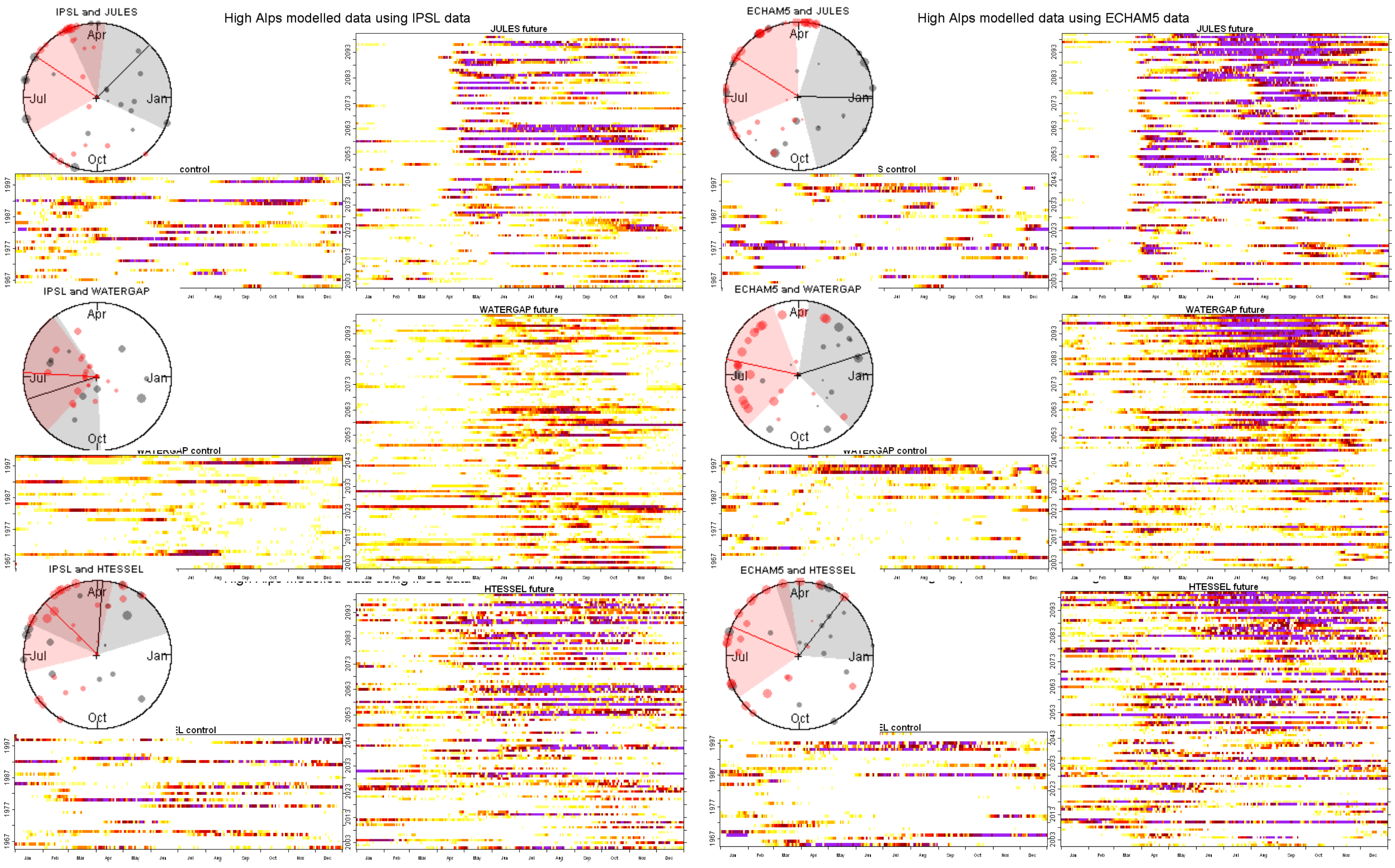
High Alps: CTL & Future IPSL & ECHAM5



Take-home messages

- Validation:
- GHMs can reproduce broad-scale regional drought characteristics
- Yet substantially different results from different models, and performance varies across the regions
- Spatial resolution of the models hampers performance in some regions
- Interception, infiltration and snow-melt process amongst possible differences between GHM sensitivity
- Future:
- Complex picture: some signal of stronger spatial coherence of droughts, but direction of change not always the same
- Strength and seasonality of change different, depends on GHM and region
- GHMs uncertainty as large as (or larger than) GCM uncertainty
- Increases in drought severity across Europe

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Open Research Questions

- What are the best indicators to use to compare observed vs. modelled drought characteristics when using large-scale models?
- How does observed data coverage affect the baseline observed RDI, and what can we do to develop a better observational dataset in Europe?
- Can we explain different performance in different regions due to subgrid heterogeneity, e.g. topography, snowmelt processes etc?
- What processes cause the differences between models (soil moisture, AE, runoff), and can modellers elucidate these differences?
- Can we quantify the role of GHM uncertainty vs. GCM uncertainty more explicitly?

Thank you...

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Water and Global Change

Read More

Read more:

Hannaford, J., Lloyd-Hughes, B., Keef, C., Parry, S., and Prudhomme, C. (2011) Examining the large-scale spatial coherence of European drought using regional indicators of precipitation and streamflow deficit. ***Hydrological Processes***, 25 (7). 1146 – 1162

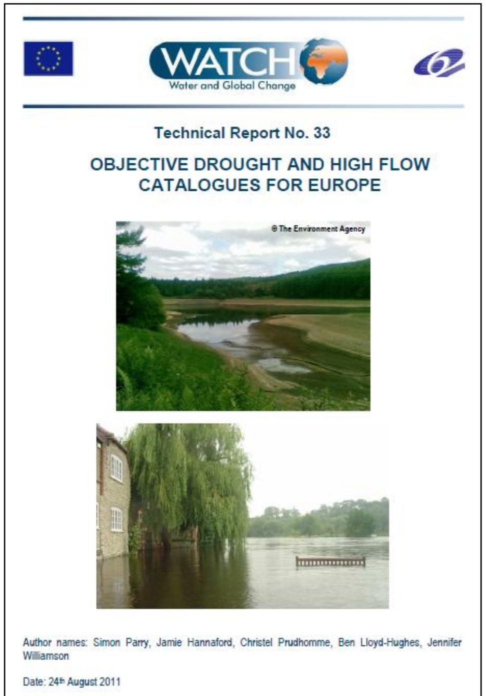
Parry, S., Prudhomme, C., Hannaford, J., and Lloyd-Hughes, B. (in press) Multi-year droughts in Europe: Analysis of development and causes. ***Hydrology Research***

Prudhomme, C., Parry, S., Hannaford, J., Clark, D.B., Hagemann, S., and Voss, F. (in press) How well do large-scale models reproduce hydrological extremes in Europe? ***Journal of Hydrometeorology***

WATCH Technical Reports:

Parry et al. – Drought Catalogues –***Number 33***

Williamson et al. – Model Validation and 21st Century Projections –***Number 29***


Technical Report No. 33

OBJECTIVE DROUGHT AND HIGH FLOW CATALOGUES FOR EUROPE

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