Development and seasonal predictability of European heat waves

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Special thanks to colleagues

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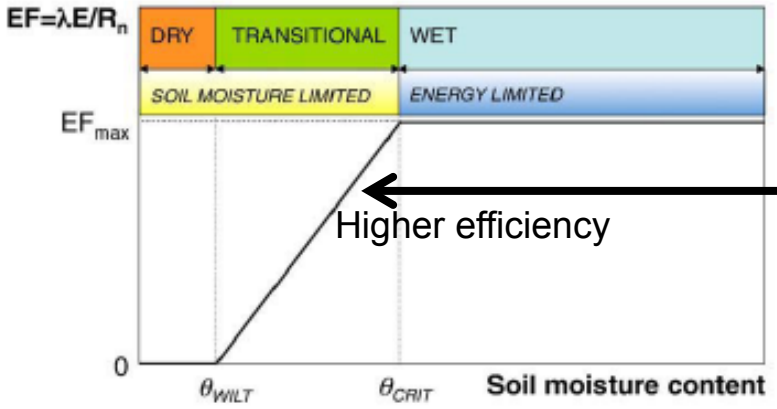
Issues about heat waves

- Understand key regional processes
  - Soil moisture memory, evapotranspiration regimes and feedbacks
- Identify seasonal predictability
  - Are there early warnings?
- Evaluate long-term climate simulation
  - Do current climate (GCM+RCM) models simulate key processes?

Summer Heat waves in Europe: Key drivers

- Dynamics
  - Summertime weather regimes, but: less « geostrophic turbulence » ➔ less dynamical influence and more predictability from long-term drivers?
- Tropical SST
  - Tropical SST anomalies favor certain weather regimes (Cassou et al., 2005)
- Soil moisture & feedbacks
  - Drier soils initiate larger positive feedbacks (see eg., Seneviratne et al., 2006, 2010; Fischer et al., 2007)



- larger SH flux → increased T
- less clouds → increased SWR and T
- more anticyclonic weather → increased SWR and T

→ Increased evaporative demand

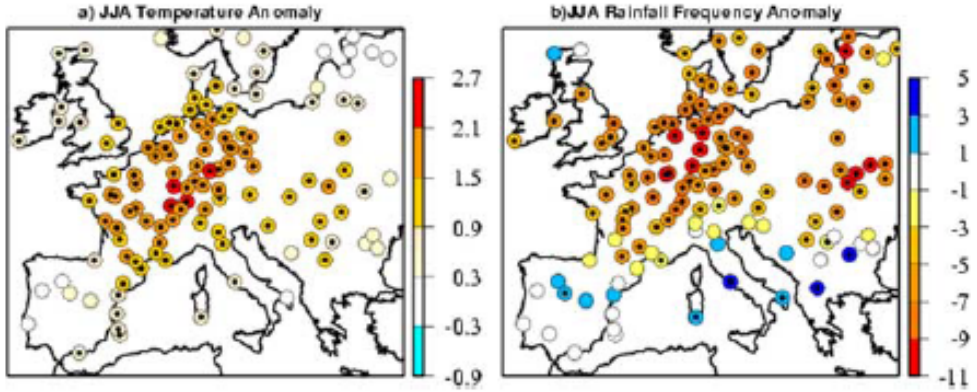
Seneviratne et al., 2010

Precipitation frequency before hot summers

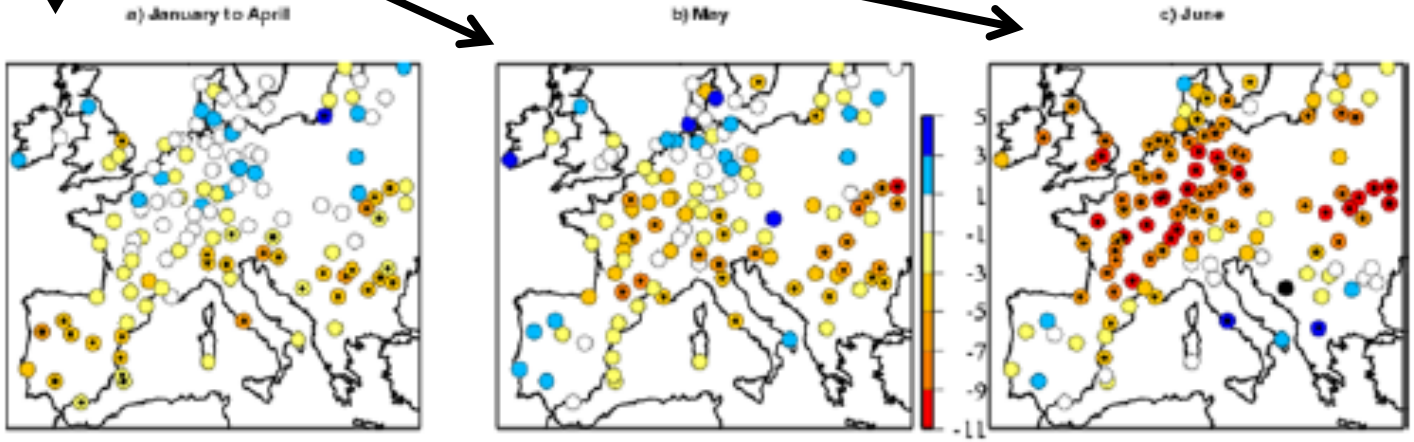
Temperature

Rainfall frequency

JJA anomalies



Rainfall frequency anomalies evolution



Jan-Apr

May

Jun

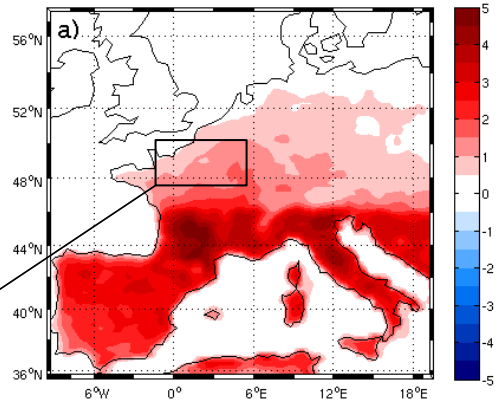
Vautard et al., 2007, GRL

Sensitivity experiments with MM5

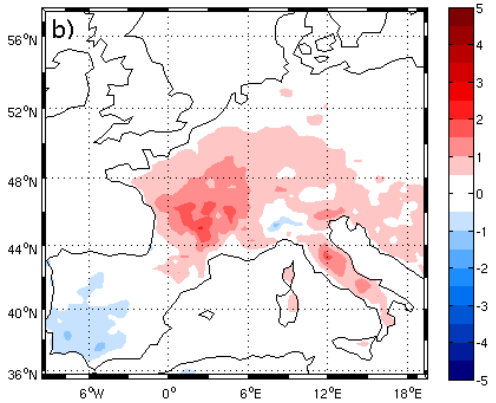
- European area, 36 km resolution, NCEP analysis forcing
- Simulate the 10 hottest summers
- DRY and WET experiments with SM=0.15 and 0.3 South of 46°N

Northward diffusion of drought and heat : Regional climate model 2-month twin experiments : dry – wet soils in Southern Europe

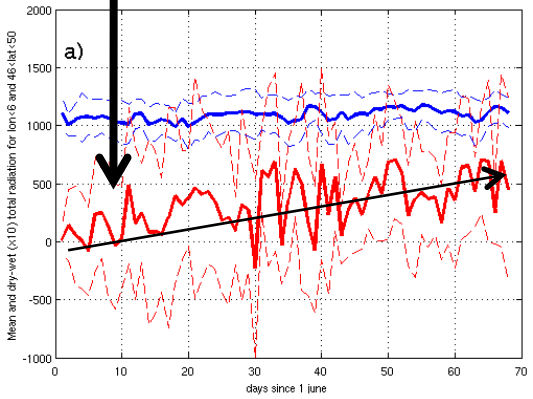
Summer mean temperature difference



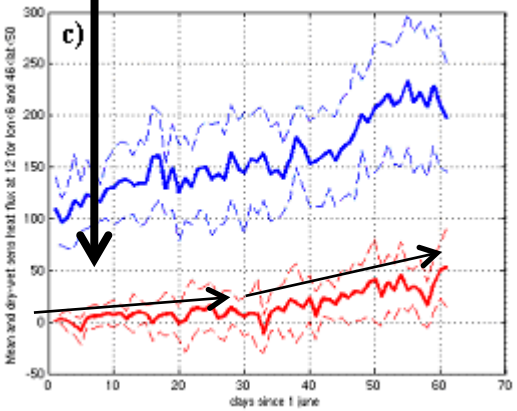
July minus June temperature difference



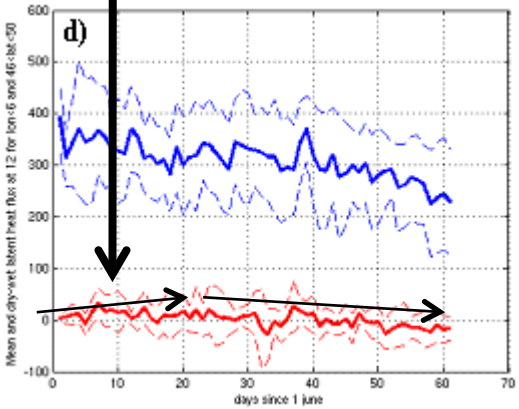
Excess Radiation



Excess Sensible HF

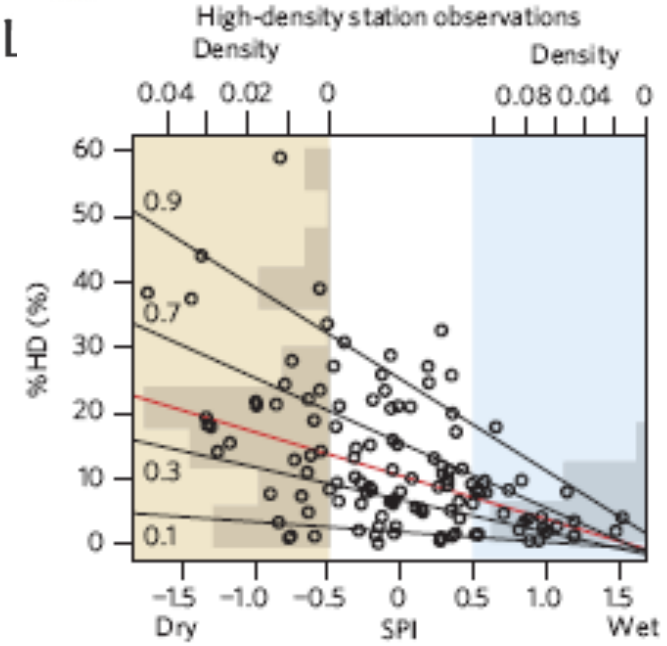


Excess Latent HF



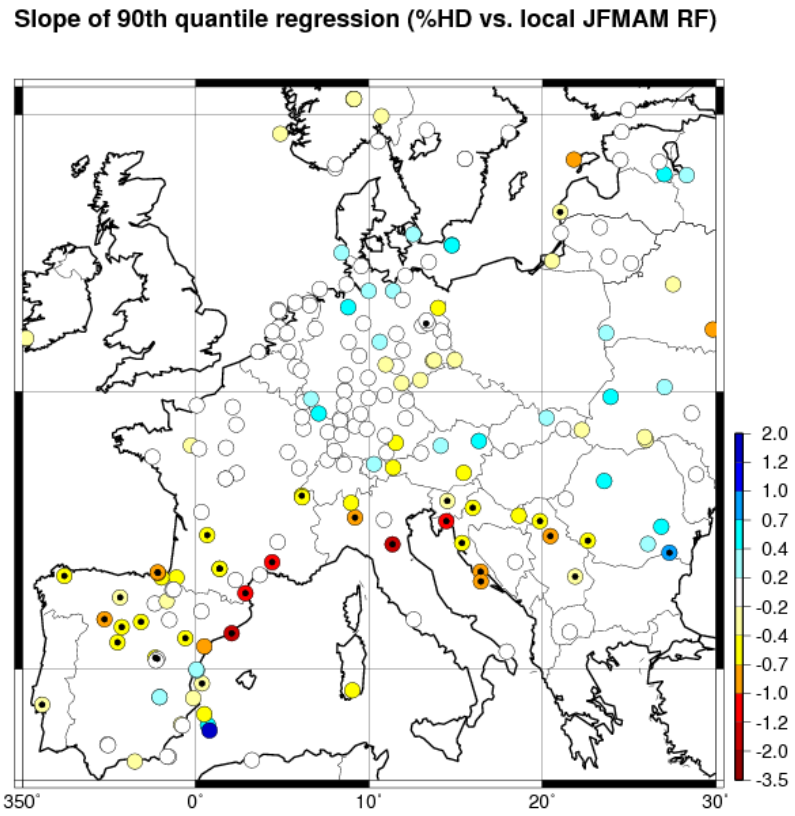
Zampieri et al., 2009, JGR

Variability in predictability of % Hot Days



Wet → few hot days
Dry → unpredictable

More sensitivity
in Southern subregions

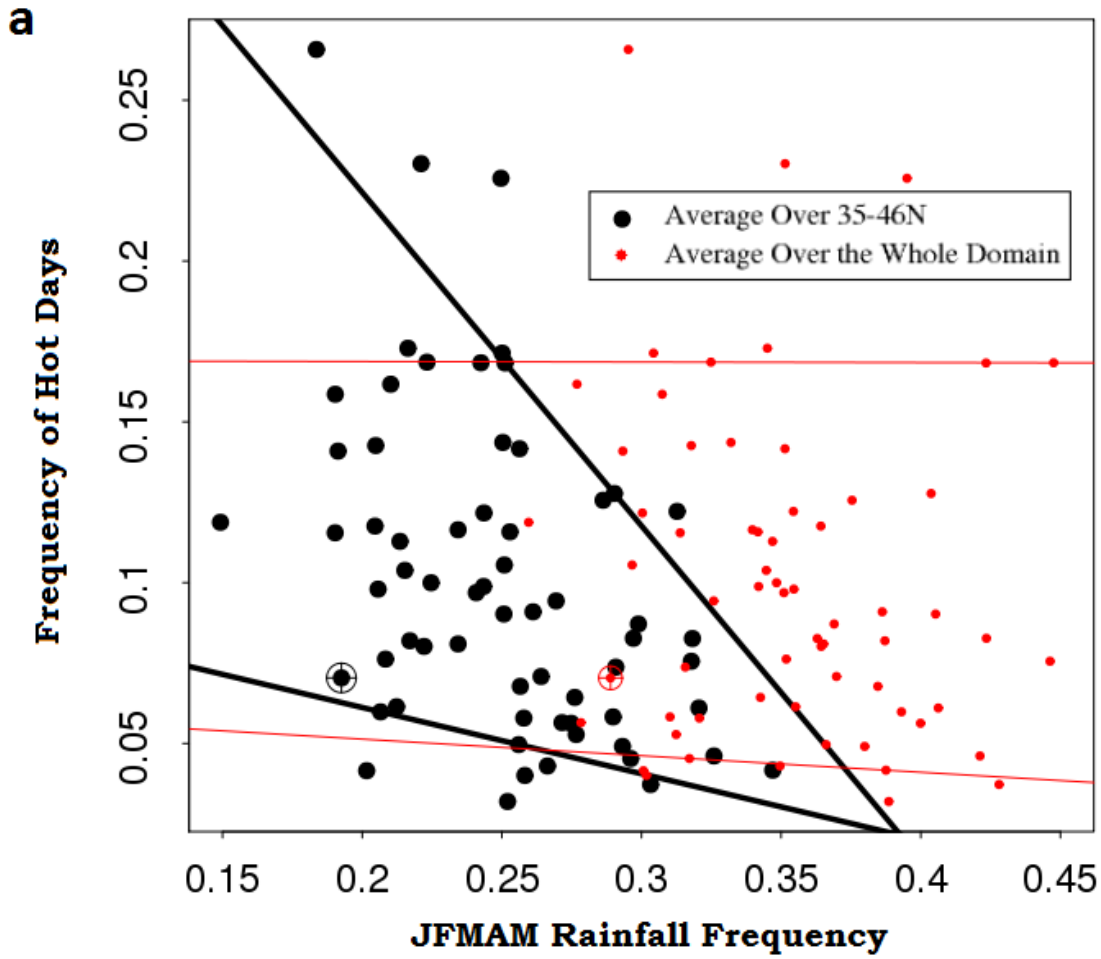


Dry / Wet in-situ widening of hot days freq. distribution
Quesada et al., in preparation

Hirschi et al., 2011

Hot Day = Day with Tm>90th temperature centile

Average european frequency of summer hot days vs. Winter/spring precipitation frequency

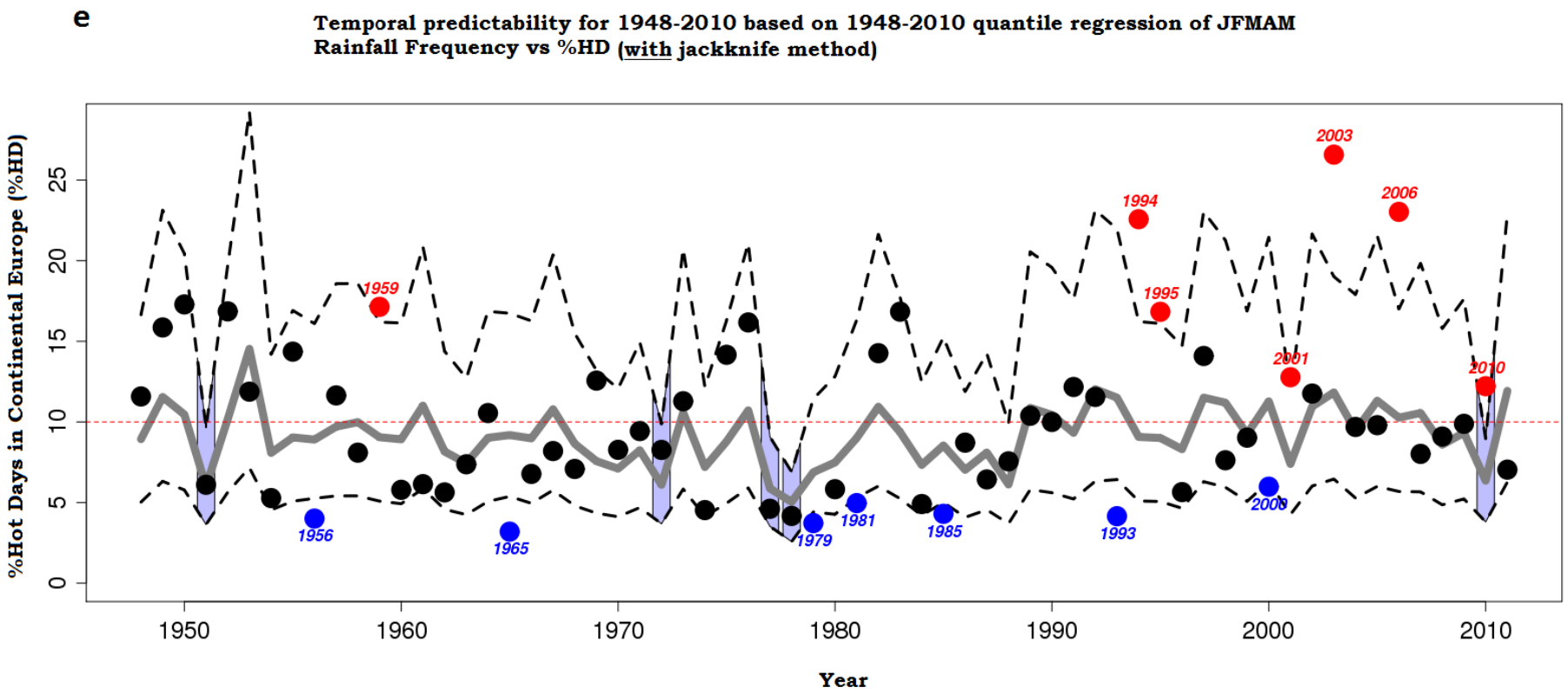


Predictive precipitation information is located in Southern Europe

Quesada et al., in preparation

Consequence for predictability

Hindcast experiment using the leave-one-out method



Quesada et al., in prep.

LSCE

How do climate models simulate the precipitation – temperature relation and related processes ?

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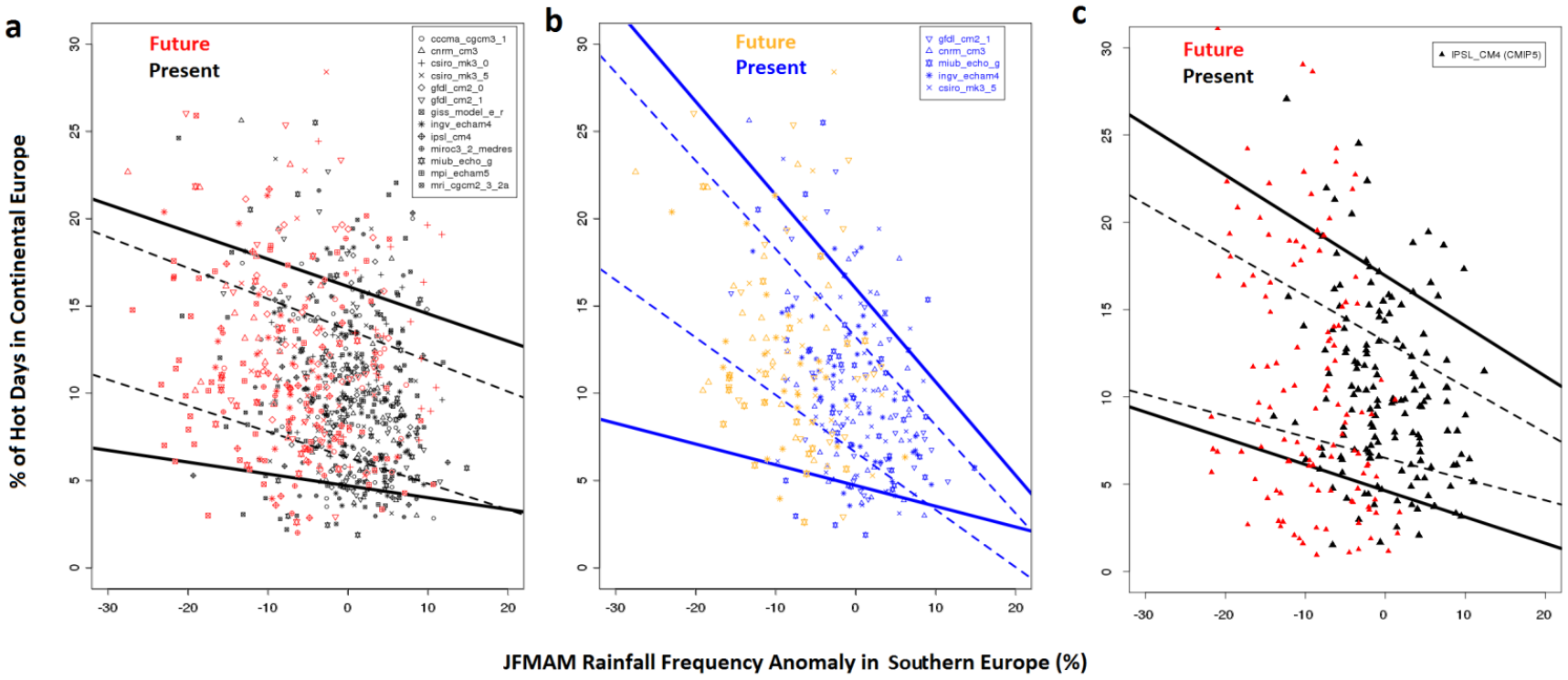
GCMs T-P diagrams present / future

CMIP3 ensemble

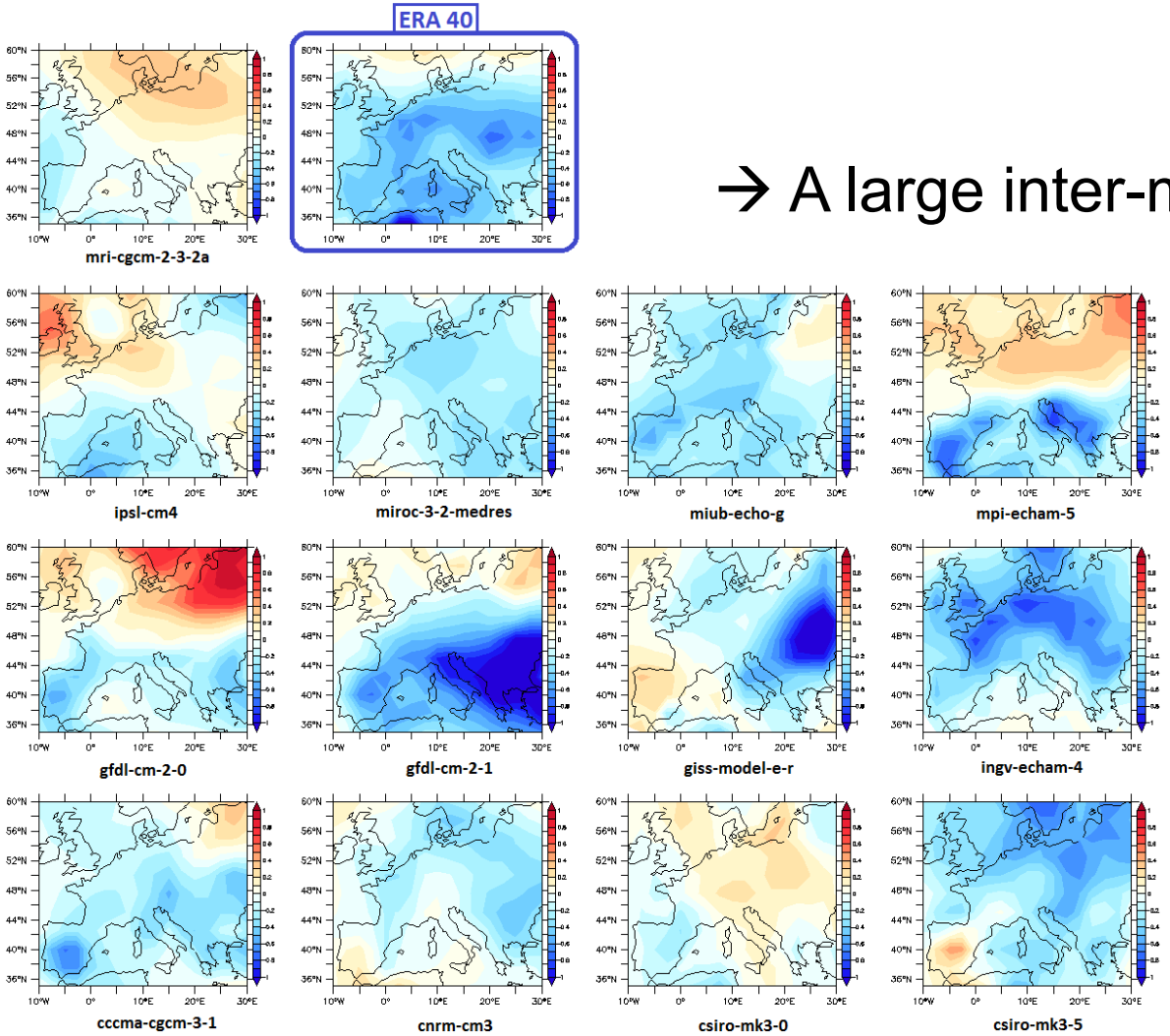
CMIP3 Selected ensemble

CMIP5 IPSL model



Quesada et al., in prep

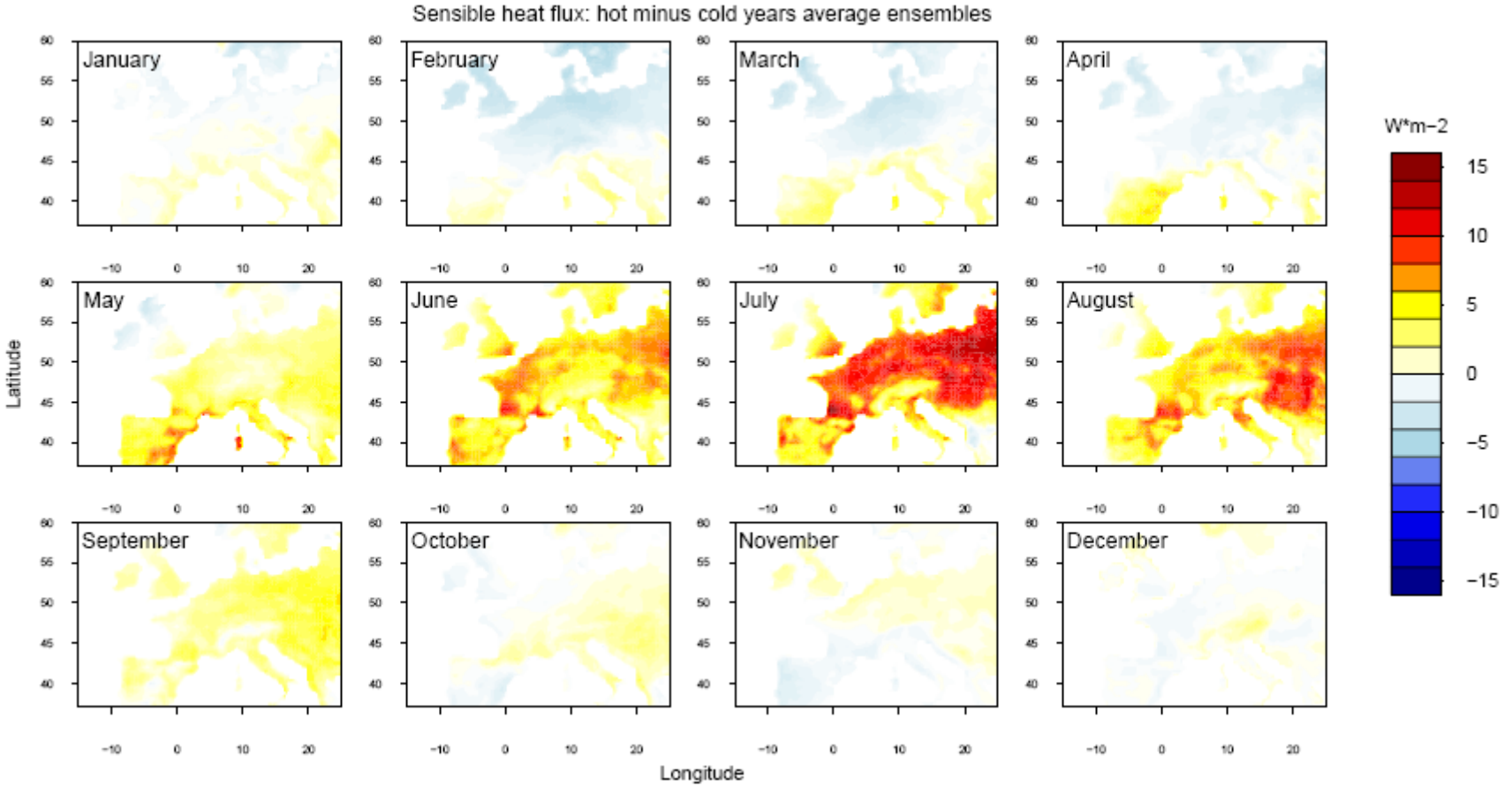
Summer temperature following the 10 wettest winter/spring in Southern



→ A large inter-model spread

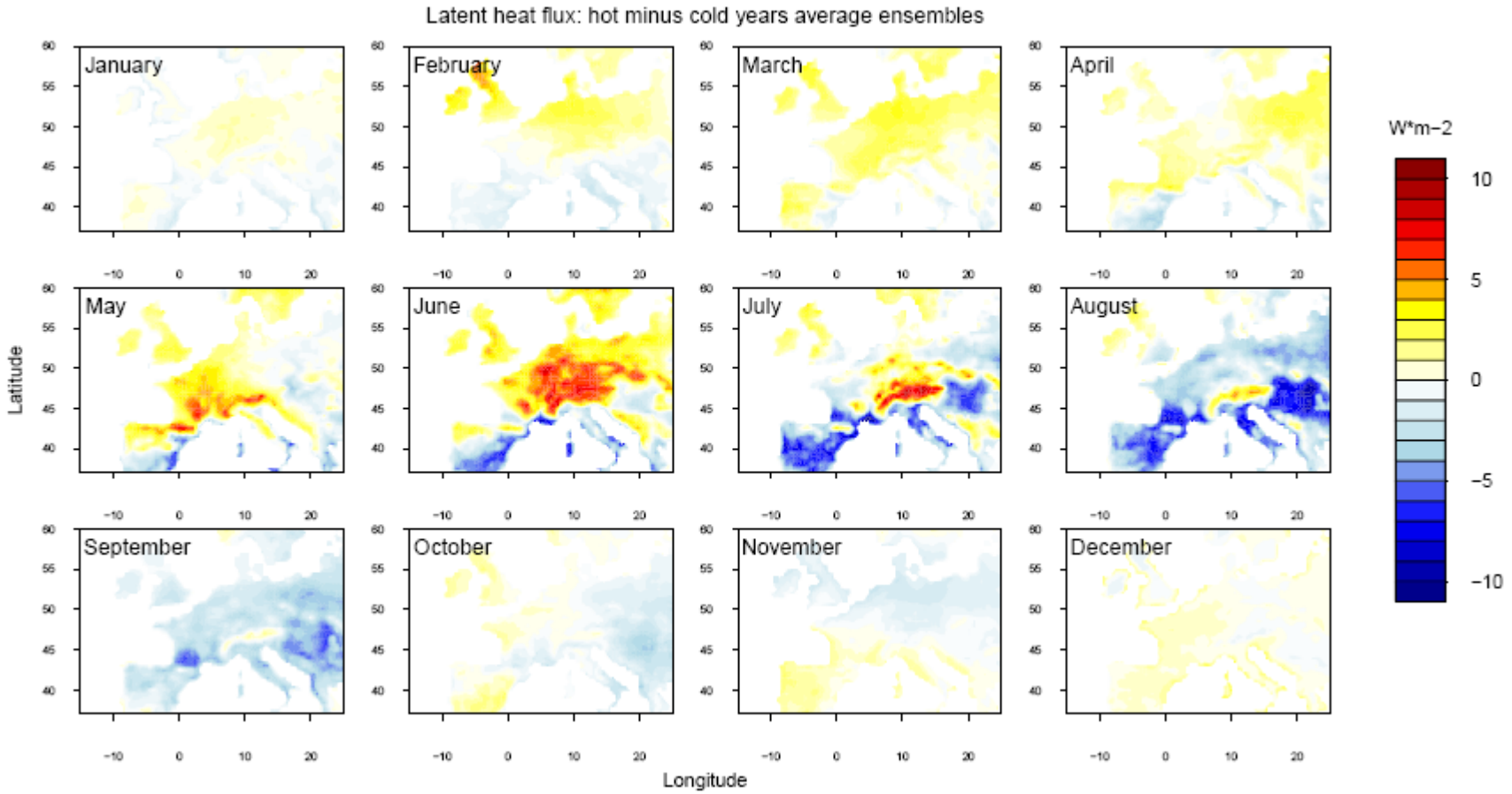
Quesada et al., in prep.

Evolution of SH fluxes in RCMs: ENSEMBLES simulations Hot – cold year difference



Courtesy of A. Stegehuis

Evolution of ET fluxes: excess in spring, then spread in summer



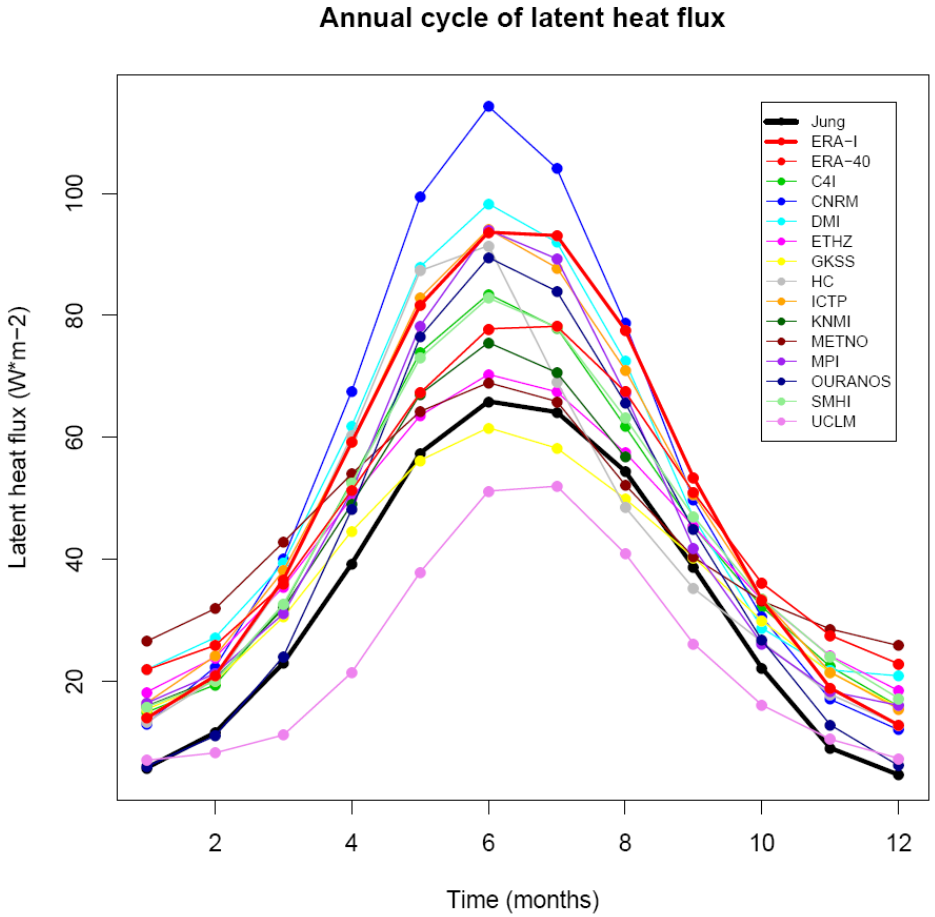
Courtesy of A. Stegehuis

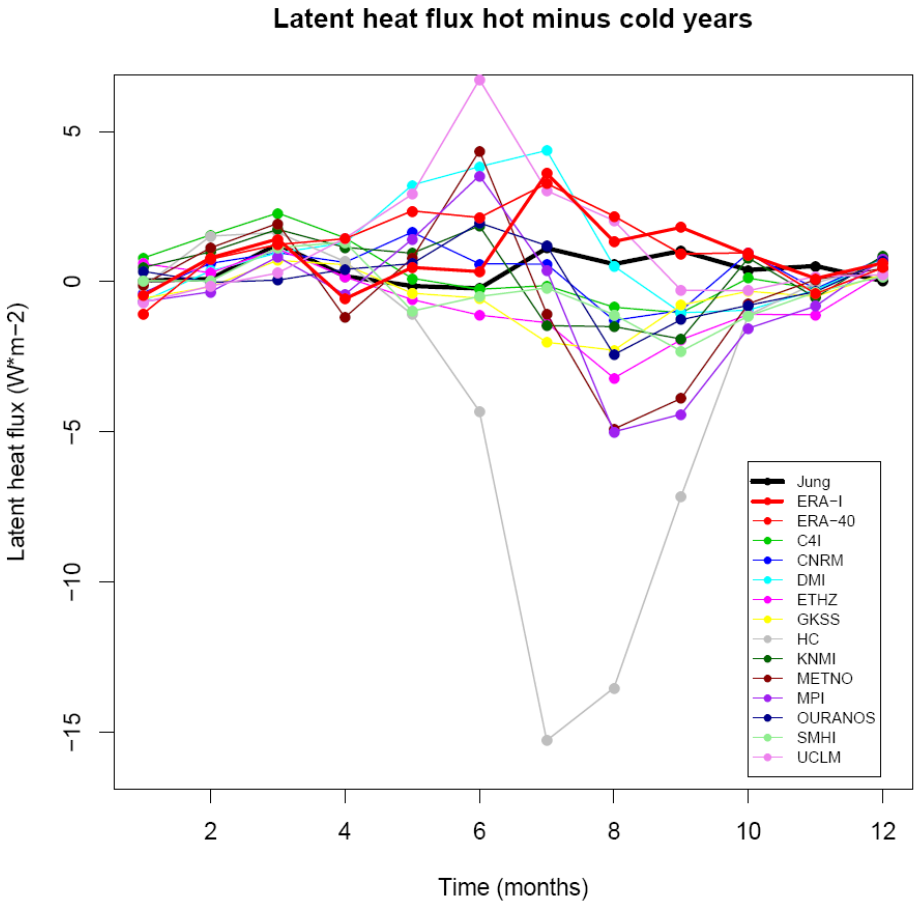
Conclusions

- Hot summers preceeded by rainfall frequency deficit in Southern Europe
- Wet springs in SE inhibit hot summer days, but dry springs in SE do not always induce heat waves
- GCMs hardly simulate detailed behaviour and have a large spread, however predict drier, less predictable situations in the future
- ENSEMBLES RCMs simulate northward propagation, but with large spread of ET in later summer

Additional slides

Evapo-Transpiration evolution

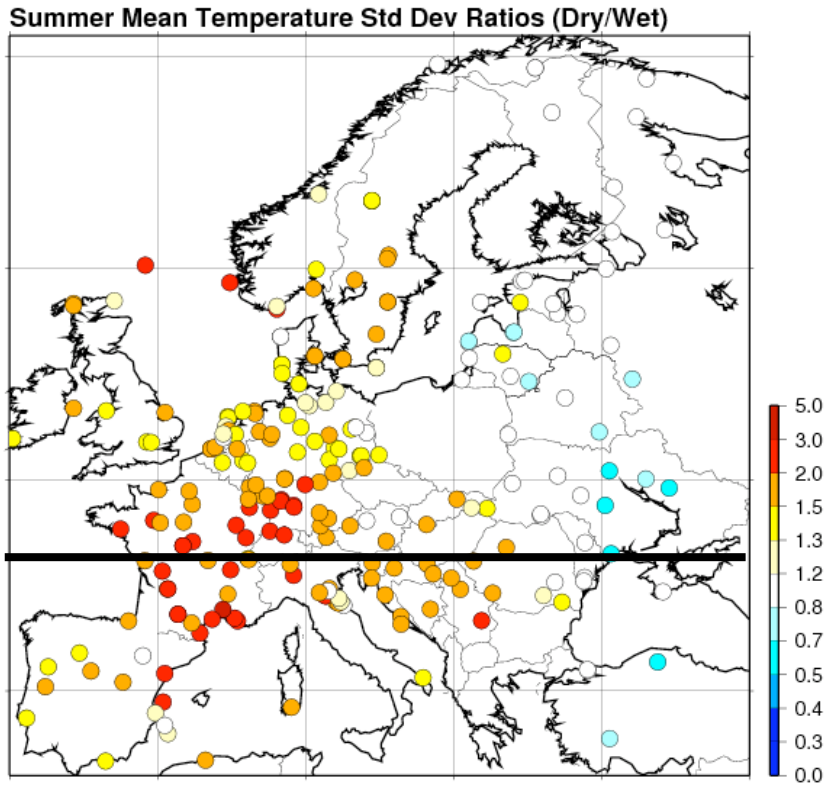


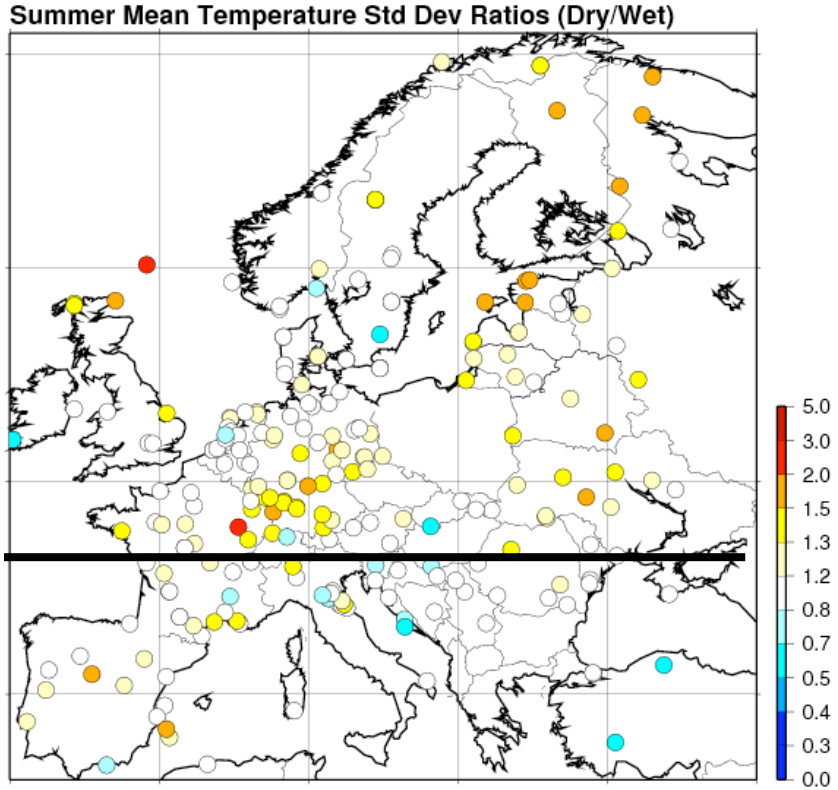


Reconstructed gridded observations from M Jung
Jung et al., 2009, 2010

Variability in predictability : Information in Southerm regions

Temperature STDev ratios DRY/WET





Initially wet summers in Southern Europe give a range of hot days 2xless wide

Quesada et al., in preparation