Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology

Climate Change and Hydrological Extremes

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CHR Workshop, Bregenz, April 18, 2005

Motivation – Weather versus Climate

Lorenz's definition of climate:

"Climate is what you expect, weather is what you get."

Updated for the 21st century (Myles Allen):

"Climate is what you affect, ~~weather~~ is what gets you."

extreme events

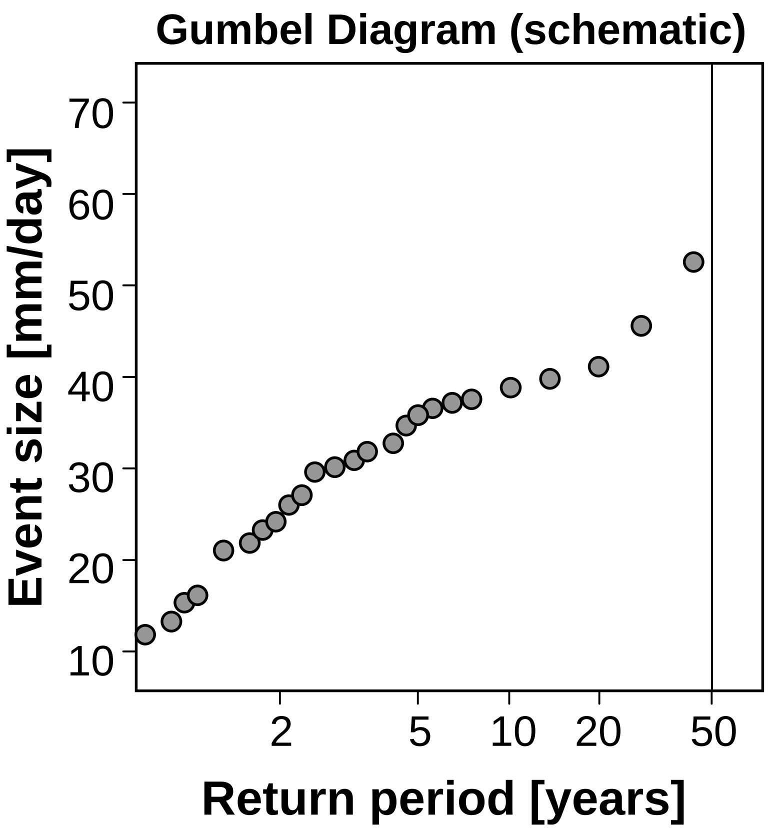
Outline

INTRODUCTION
Estimating extremes in a changing climate

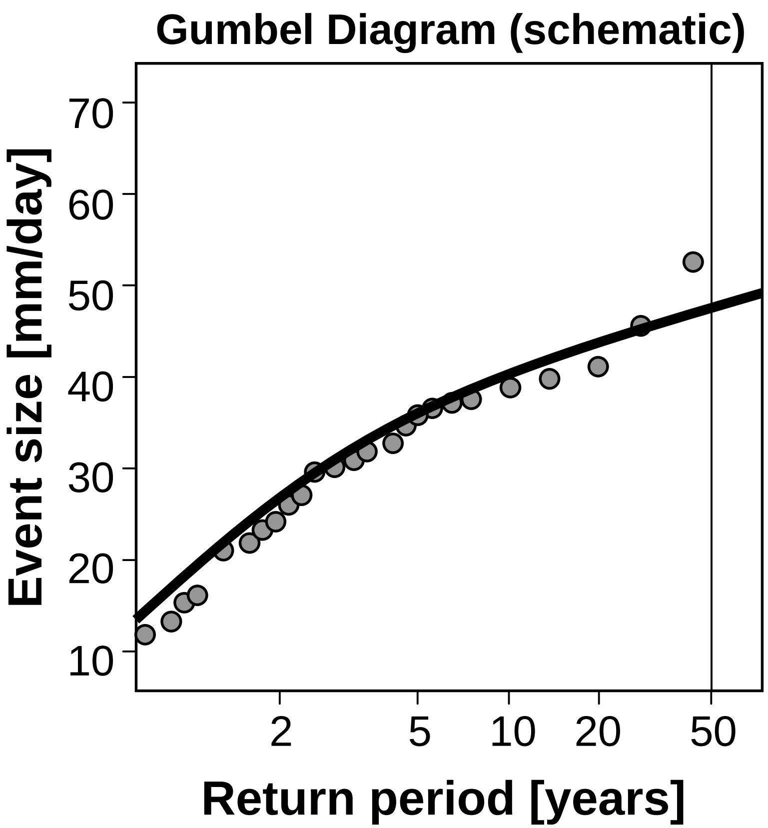
APPLICATION
European Summer Climate

CONCLUSIONS

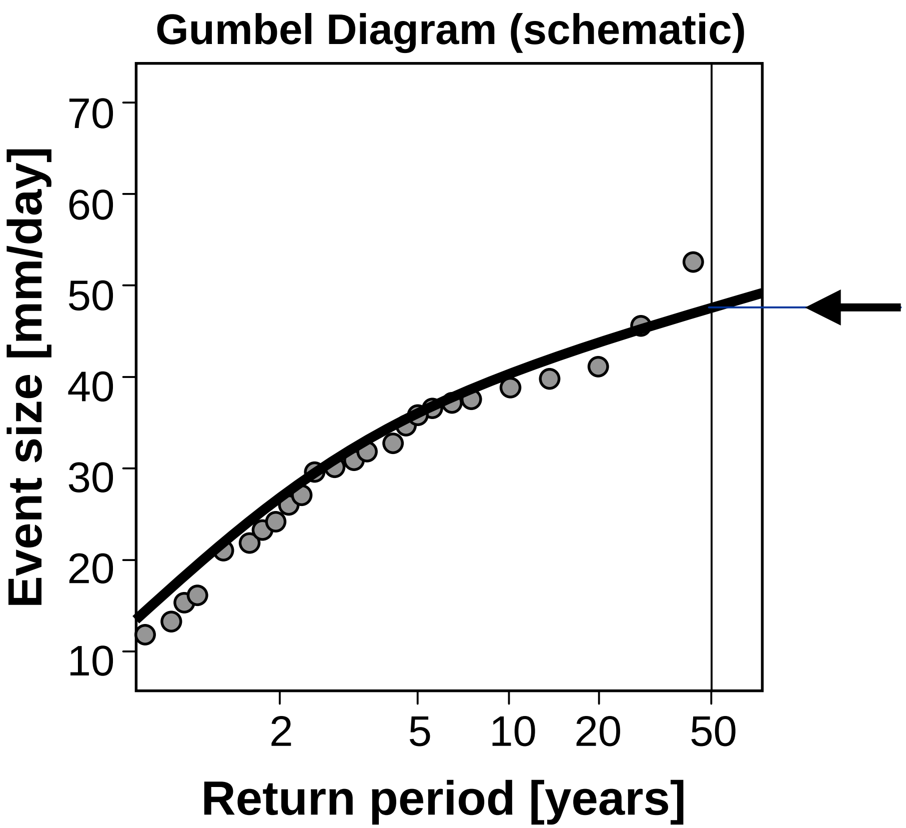
The role of climate change in estimating extremes



The role of climate change in estimating extremes

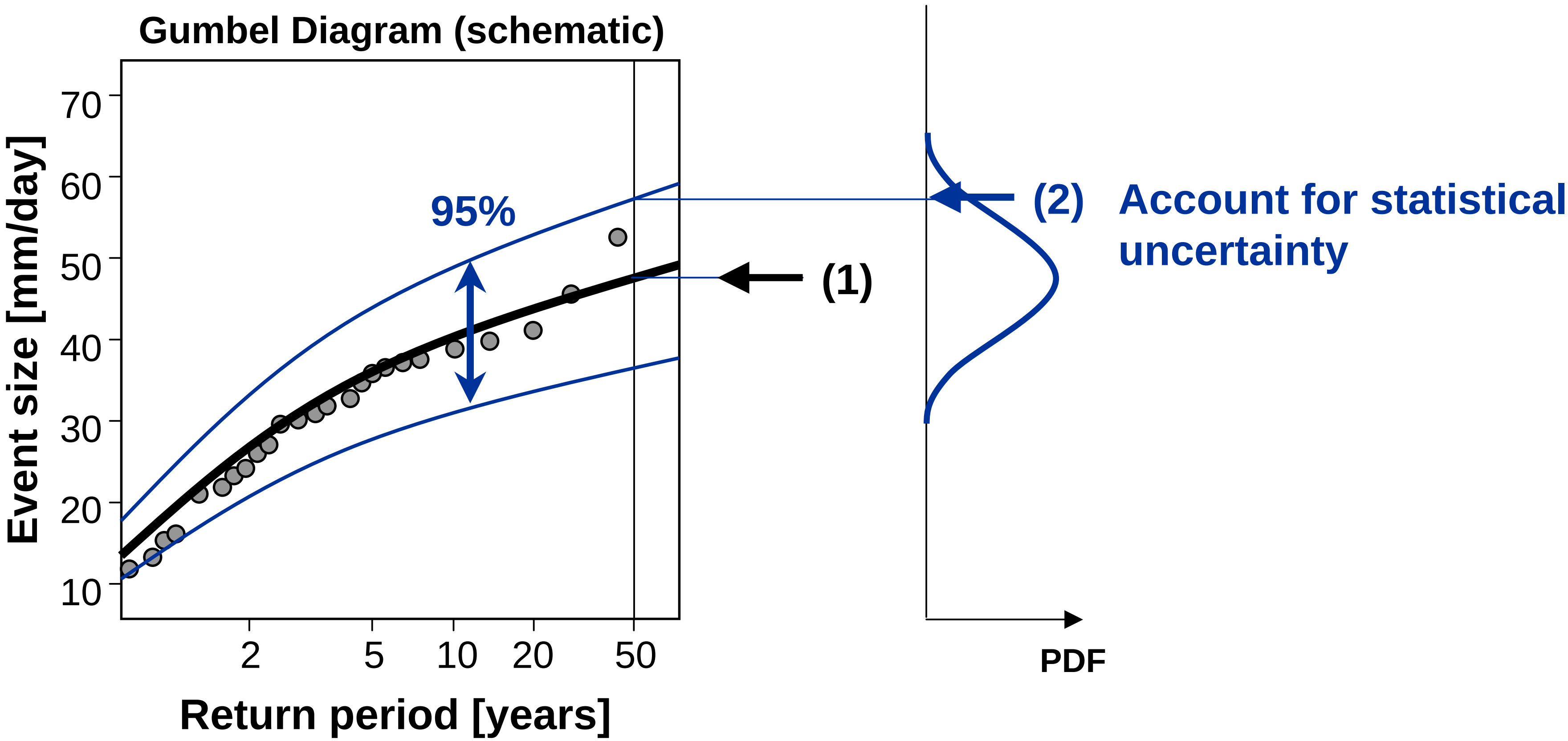


The role of climate change in estimating extremes



(1) Estimate size of event, say with 50-y return period

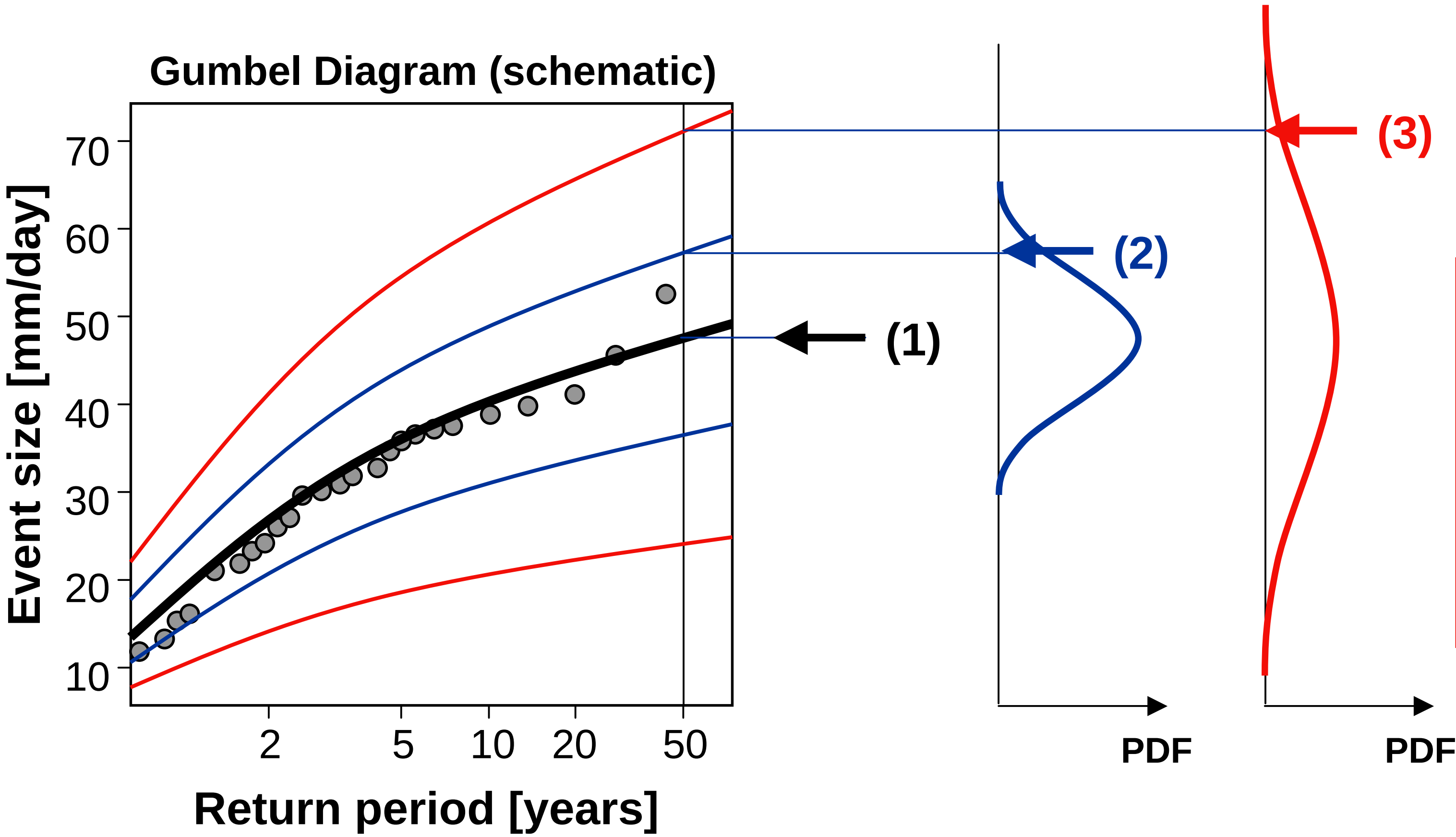
The role of climate change in estimating extremes



(1) Estimate size of event (with given return period) for current climate

(2) Account for statistical uncertainty

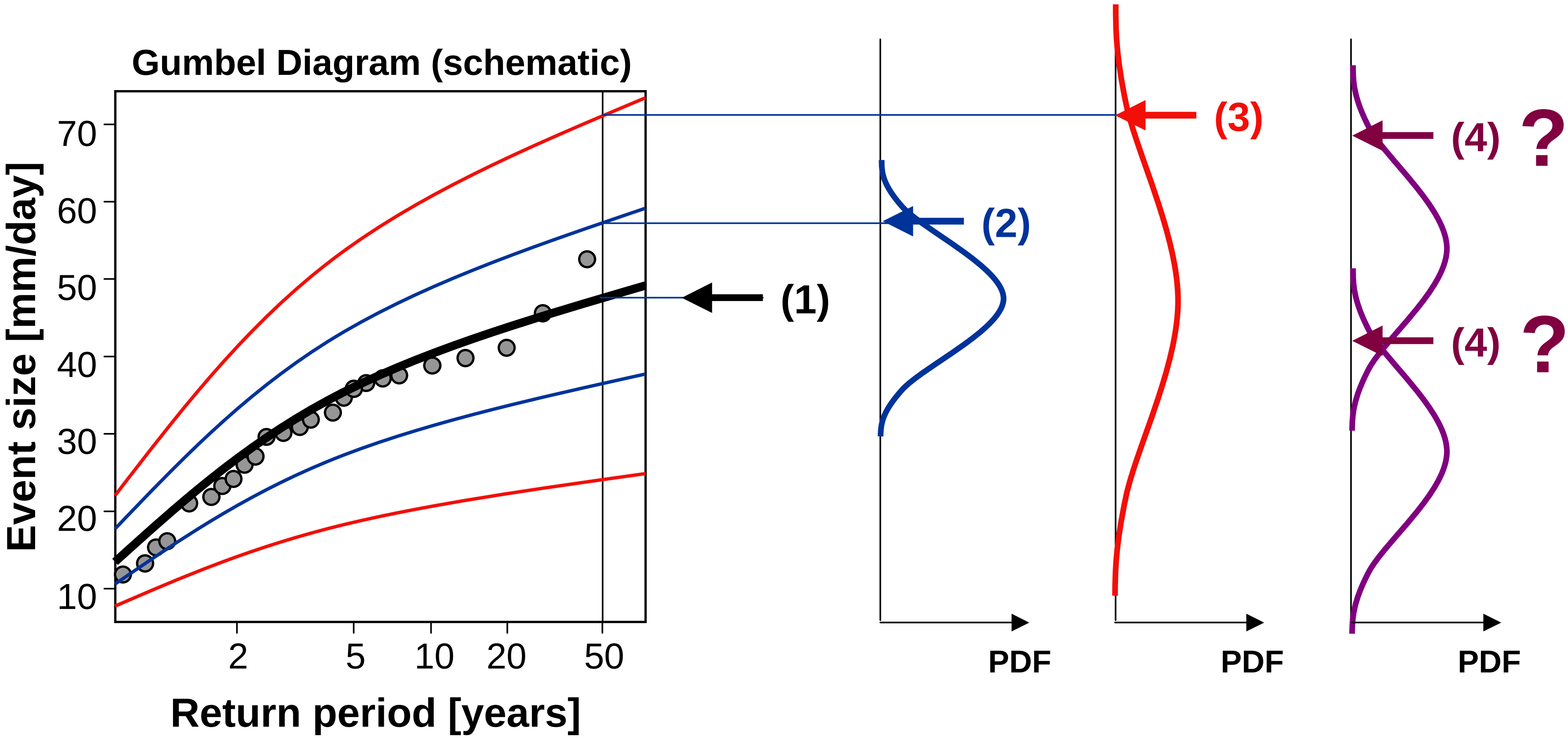
The role of climate change in estimating extremes



The most immediate effect of climate change is to increase the uncertainty

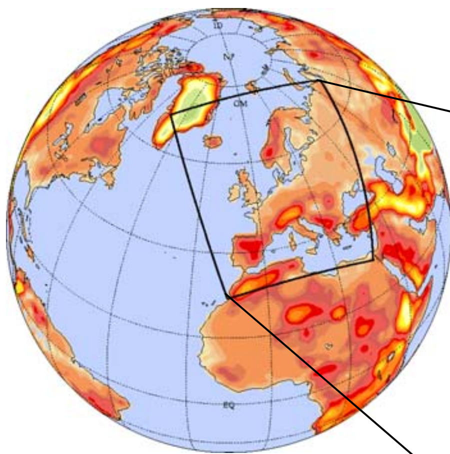
(1) Estimate size of event (with given return period) for current climate
(2) Account for statistical uncertainty
(3) Account for non-stationarity

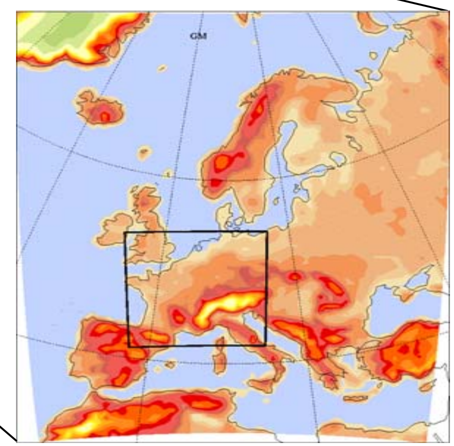
The role of climate change in estimating extremes



(1) Estimate size of event (with given return period) for current climate
(2) Account for statistical uncertainty
(3) Account for non-stationarity
(4) Account for predictions / scenarios

Climate Change Scenarios





Greenhouse-Gas Scenario
(IPCC SRES A2)

Coupled GCM
(HadCM3, ~300 km)

Atmospheric GCM
(HadAM3, ~120 km)

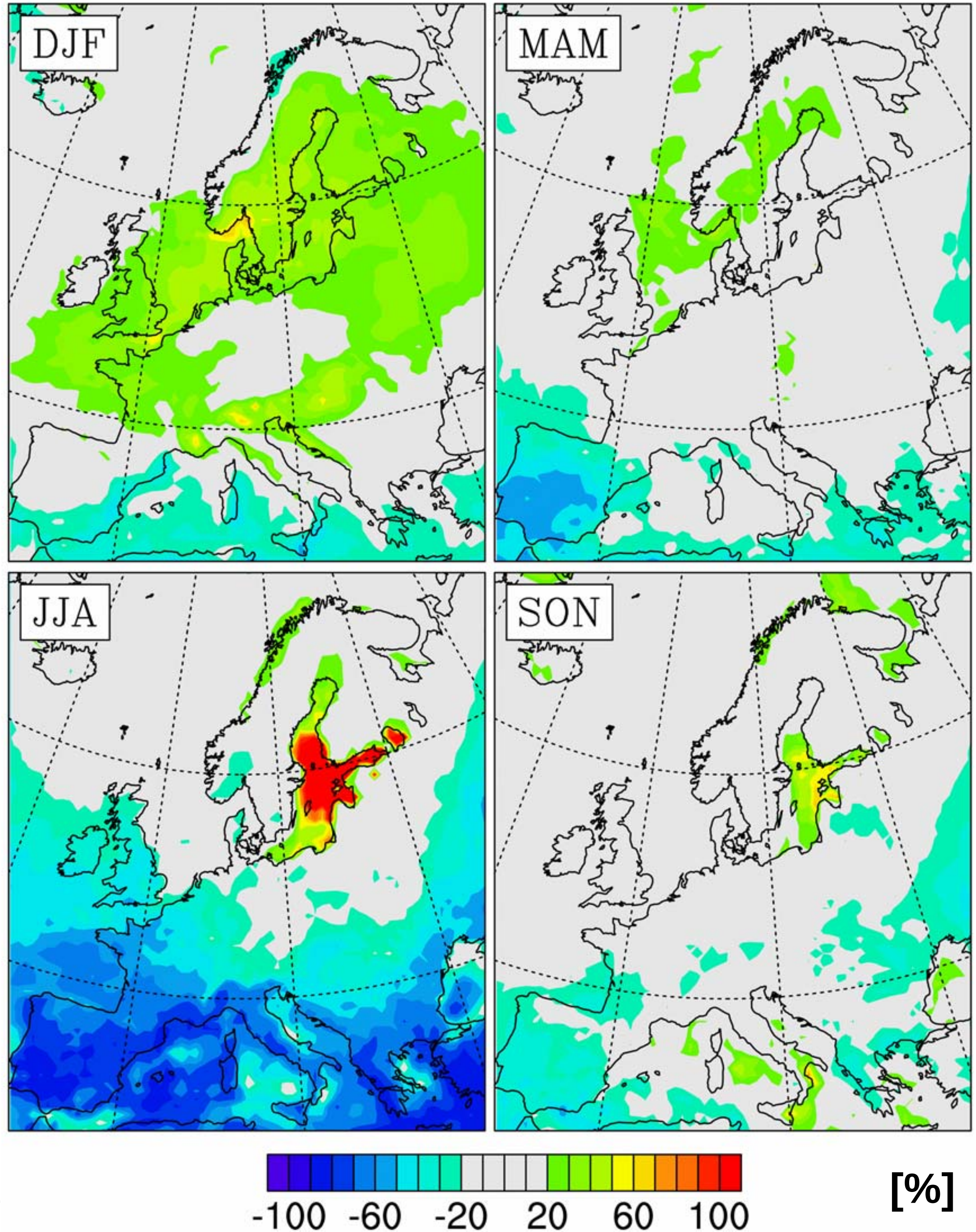
Regional Climate Model (RCM)
(CHRM / ETH, 56 km)

Time slice experiments
CTRL (1961-1990)
SCEN (2071-2100)

(EU-Project PRUDENCE, NCCR Climate)

Precipitation Change, Climate Scenarios

Relative Changes
2071-2100 versus 1961-1990



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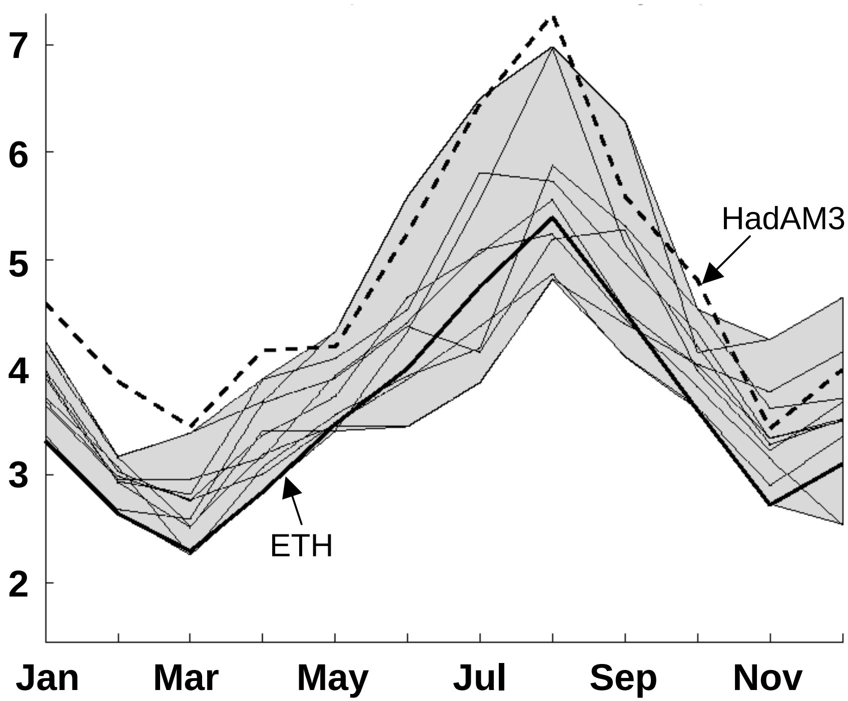
(ETH, EU-Project PRUDENCE

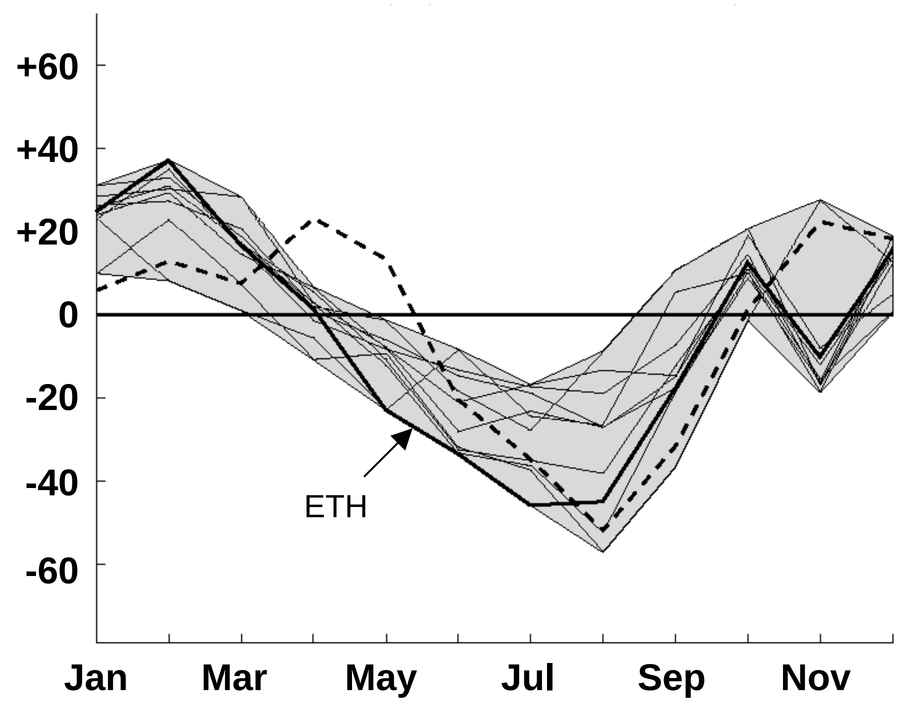
Scenarios for Alpine region

2071-2100 versus 1961-1990
Changes in seasonal cycle (9 models)

Temperature [ºC]



Precipitation [%]



(Jacob et al. 2005, PRUDENCE)

Models agree on mean changes in seasonal cycle
(Note: uncertainty is not fully represented)

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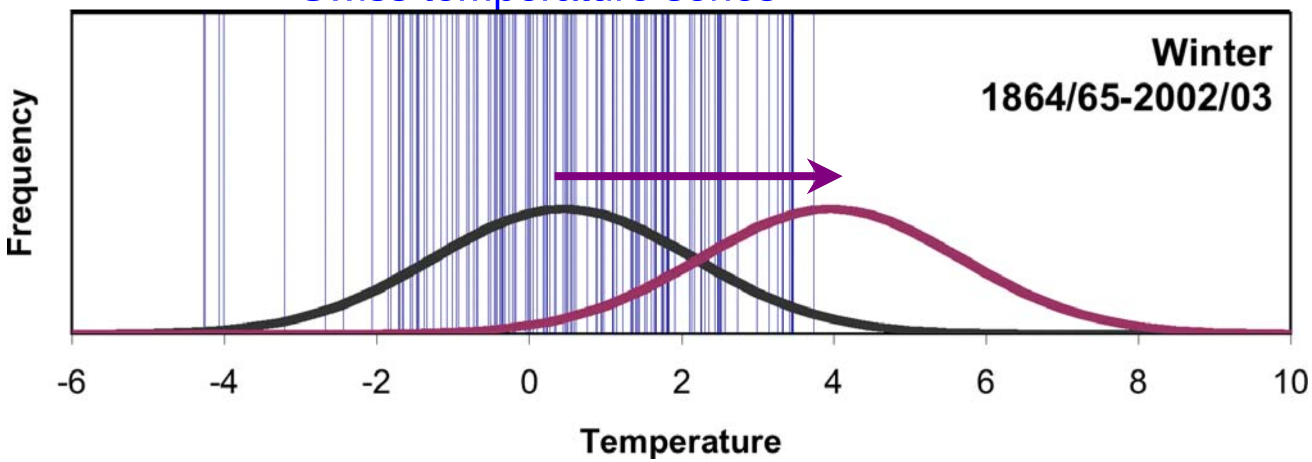
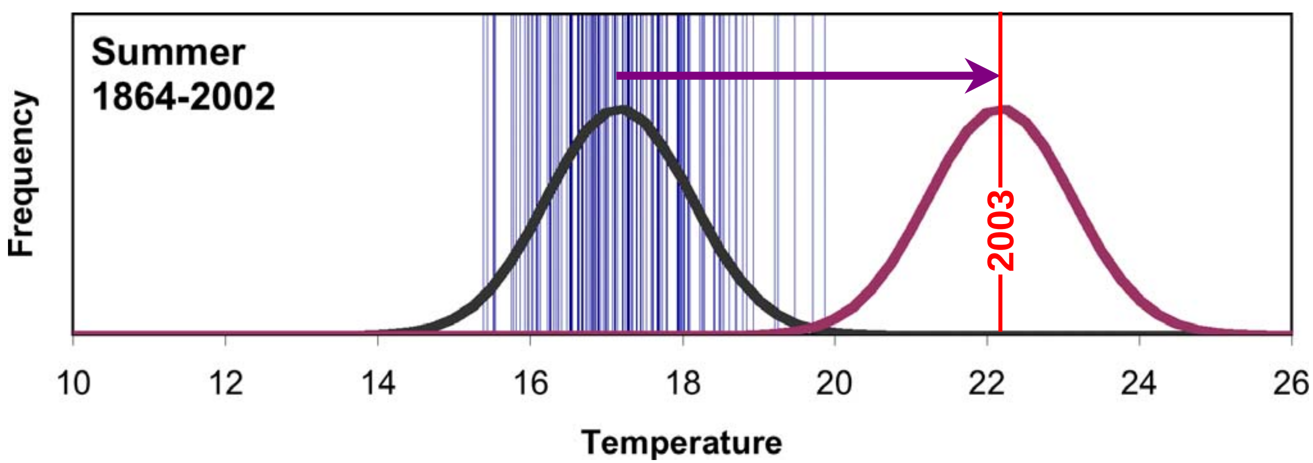
Climate Change in the Alps – Basic Considerations

Swiss temperature series



Warming until 2100: +3 K

About every second winter should fit the warm winters of the past.



Stronger warming: +4.5 K
Smaller interannual variability

Yields an essentially new climate!

European Summer 2003 looks like a glimpse of the future

Recent Summers …

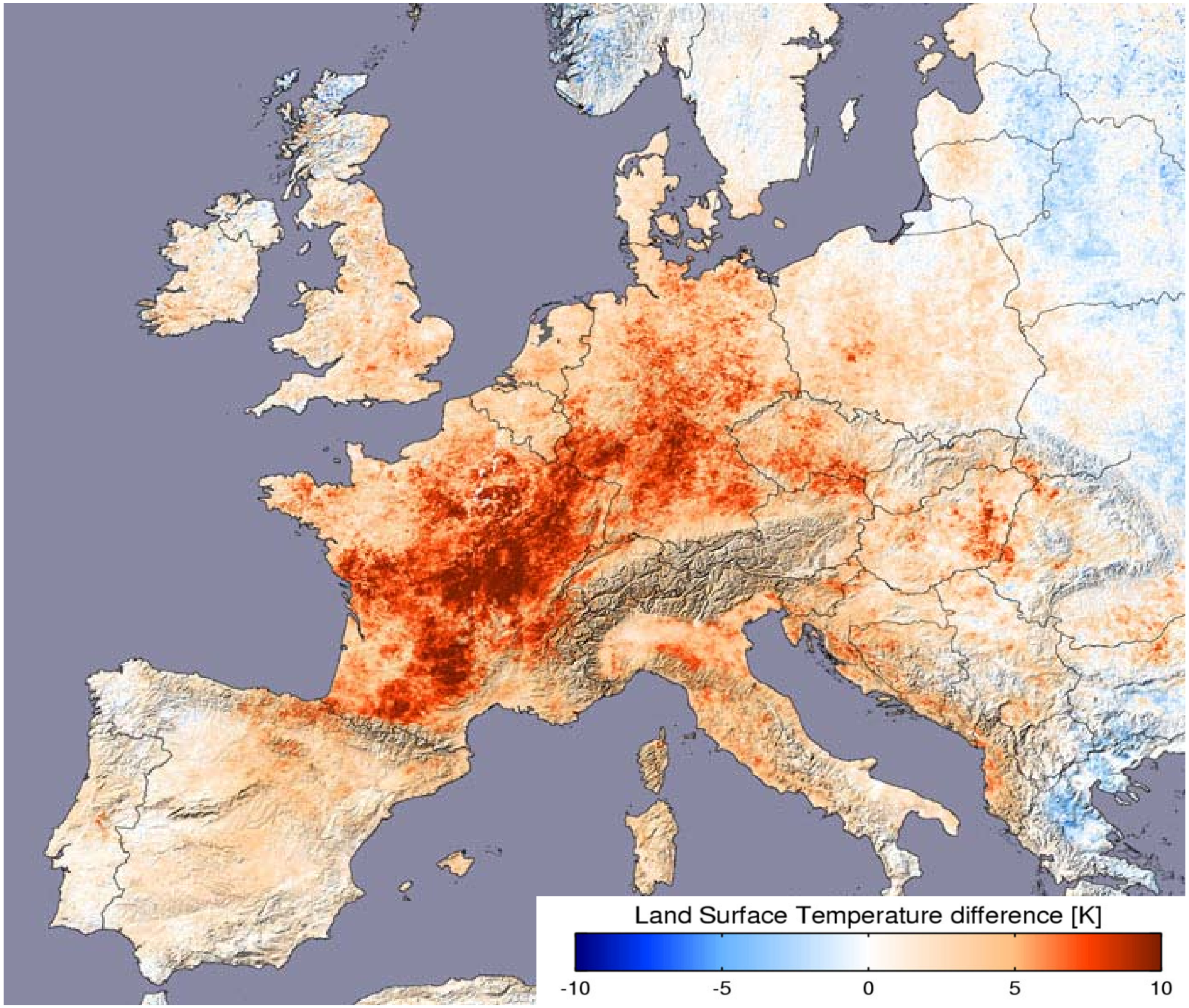
2002

Dresden, August 2002

2003

River Töss, 28. August 2003

Impact of the summer 2003 in Europe



August 2003 temperatures relative to 2000-2002, 2004
(Reto Stöckli, ETH/NASA, MODIS)

Agricultural losses:
12.3 Billion US$ (SwissRe)

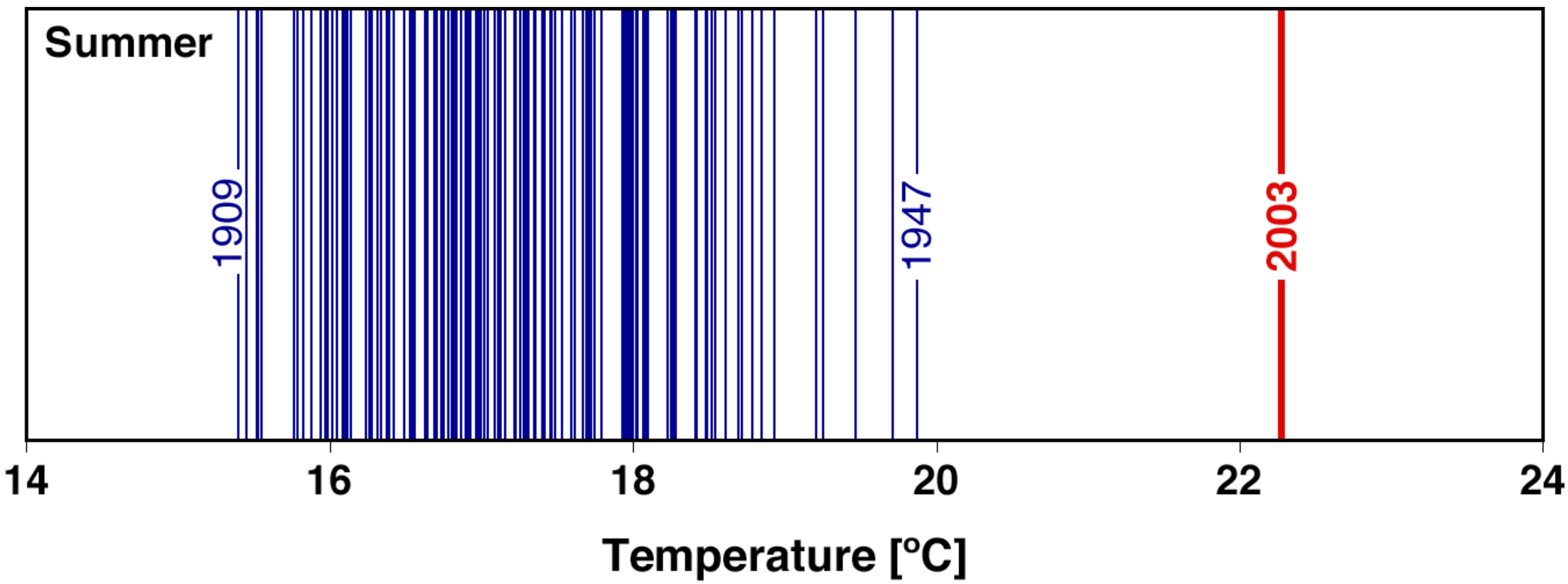
Shortage of electricity,
peak prices on spot market
(EEX, Leipzig)

Serious problems with
- **freshwater resources (Italy)**
- **forest fires (Portugal)**
- **freshwater fish (Switzerland)**

Estimated 22,000 to 35,000
heat deaths (excess mortality)

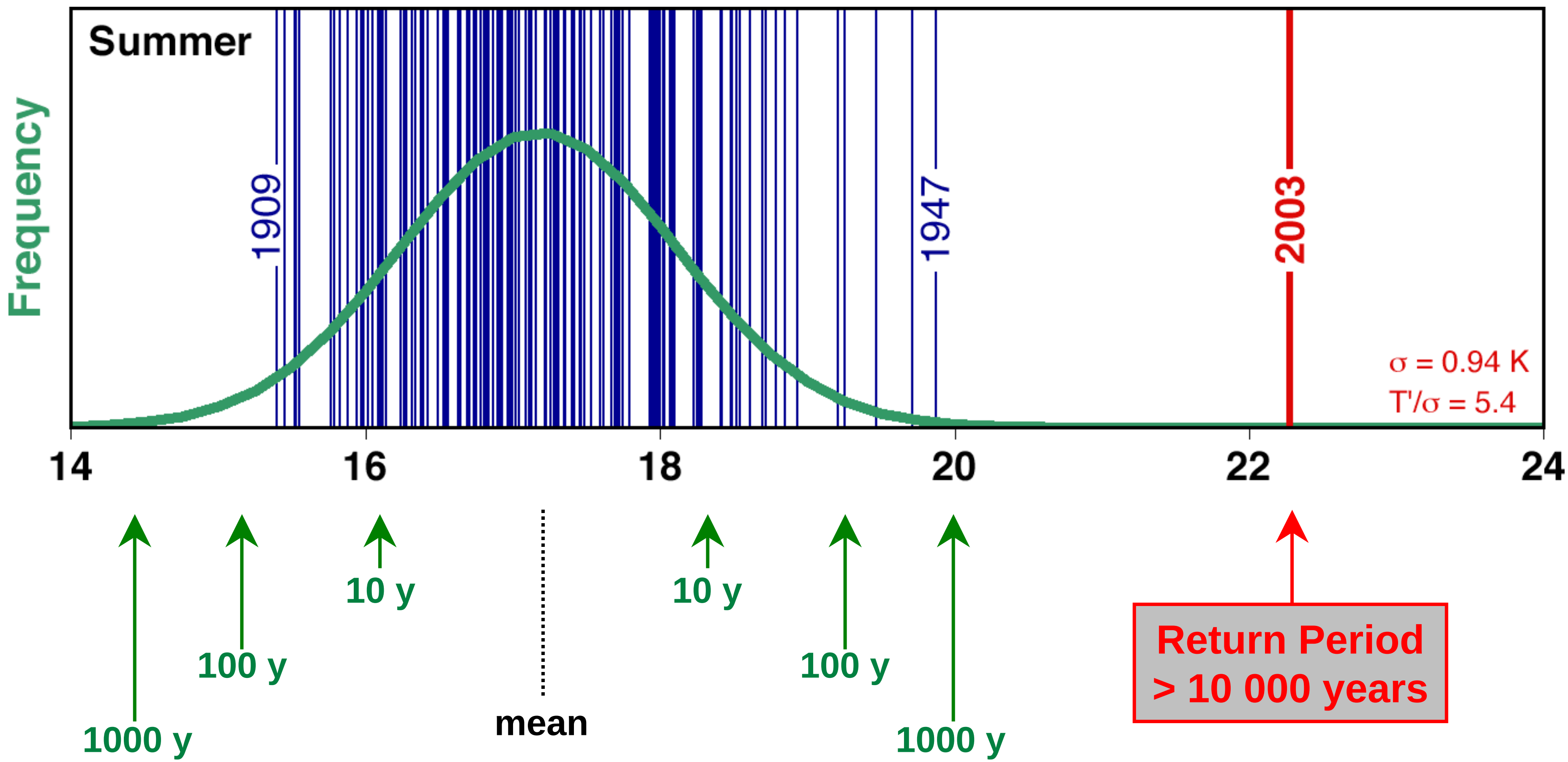
Swiss Temperature Series 1864-2003

Average of 4 Stations: Zürich, Basel, Berne, Geneva

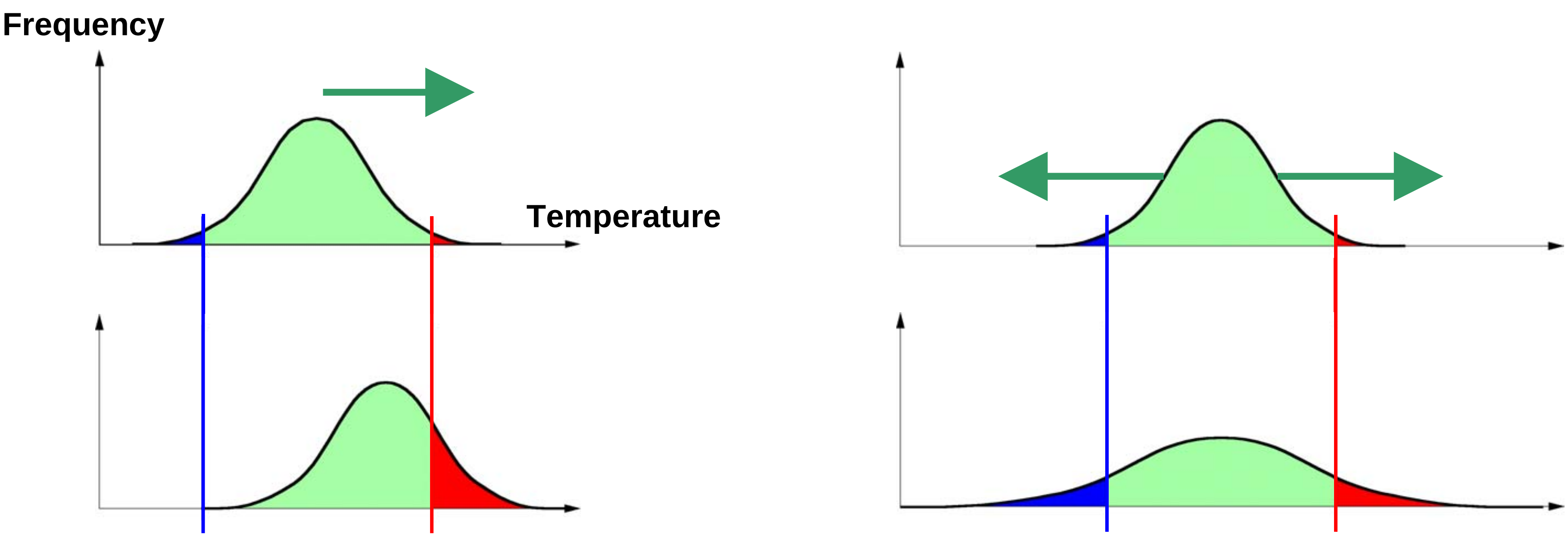


Estimation of Return Periods

Average of 4 Stations: Zürich, Basel, Berne, Geneva



Changes in Mean versus Changes in Variability



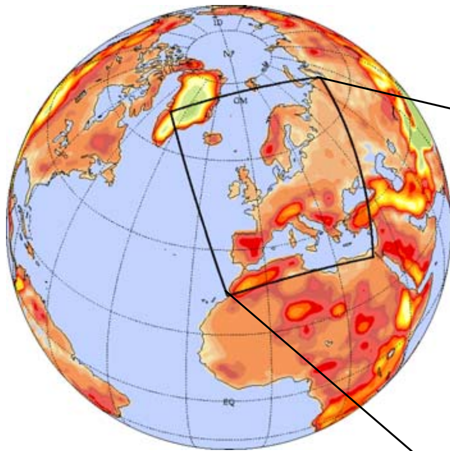
increase in the frequency of extreme warm conditions

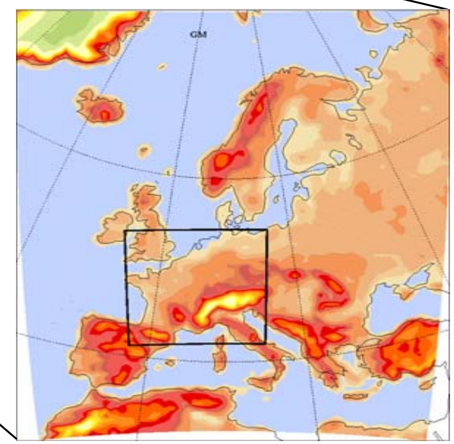
increase in the frequency of extreme warm/cold conditions

For extremes far away from mean,
“variability is more important than mean”

Katz and Brown 1992
Folland et al, IPCC, 2001

Climate Change Scenarios





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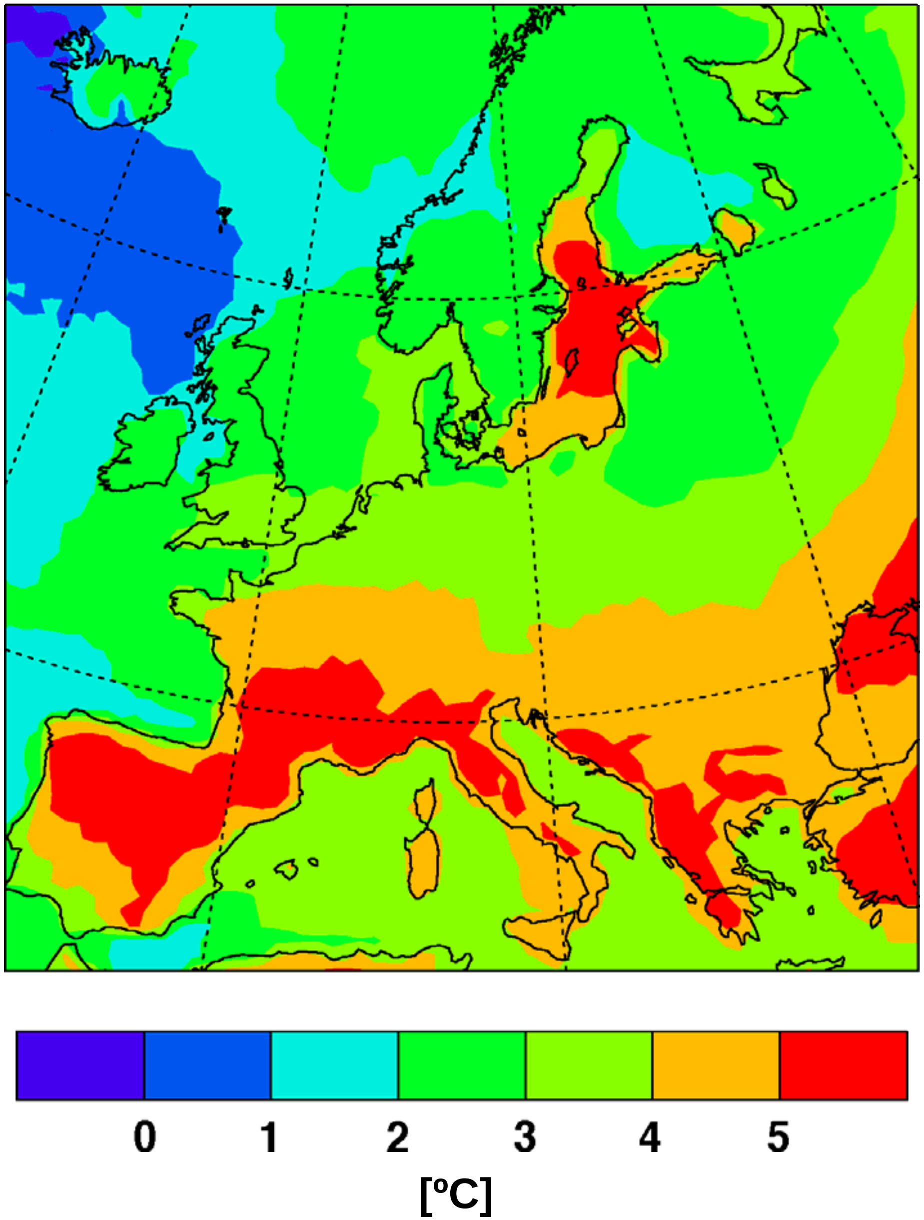
JJA Temperature Change

2070-2099 versus 1960-1989



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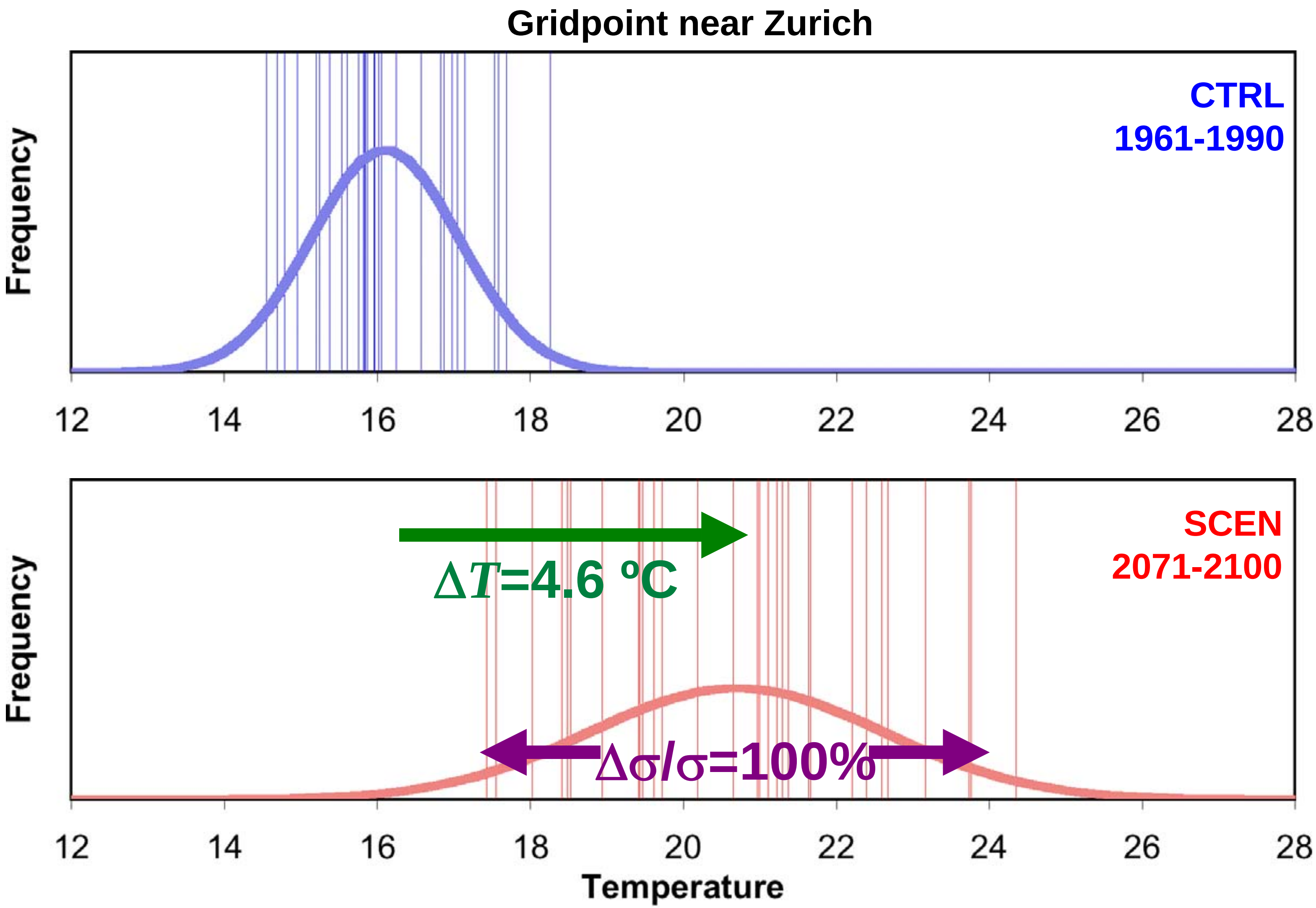
(Schär et al. 2004, *Nature*, **427**, 332-336)

Summer Surface Temperatures



Simulated:
T = 16.1 ºC
σ = 0.97 ºC

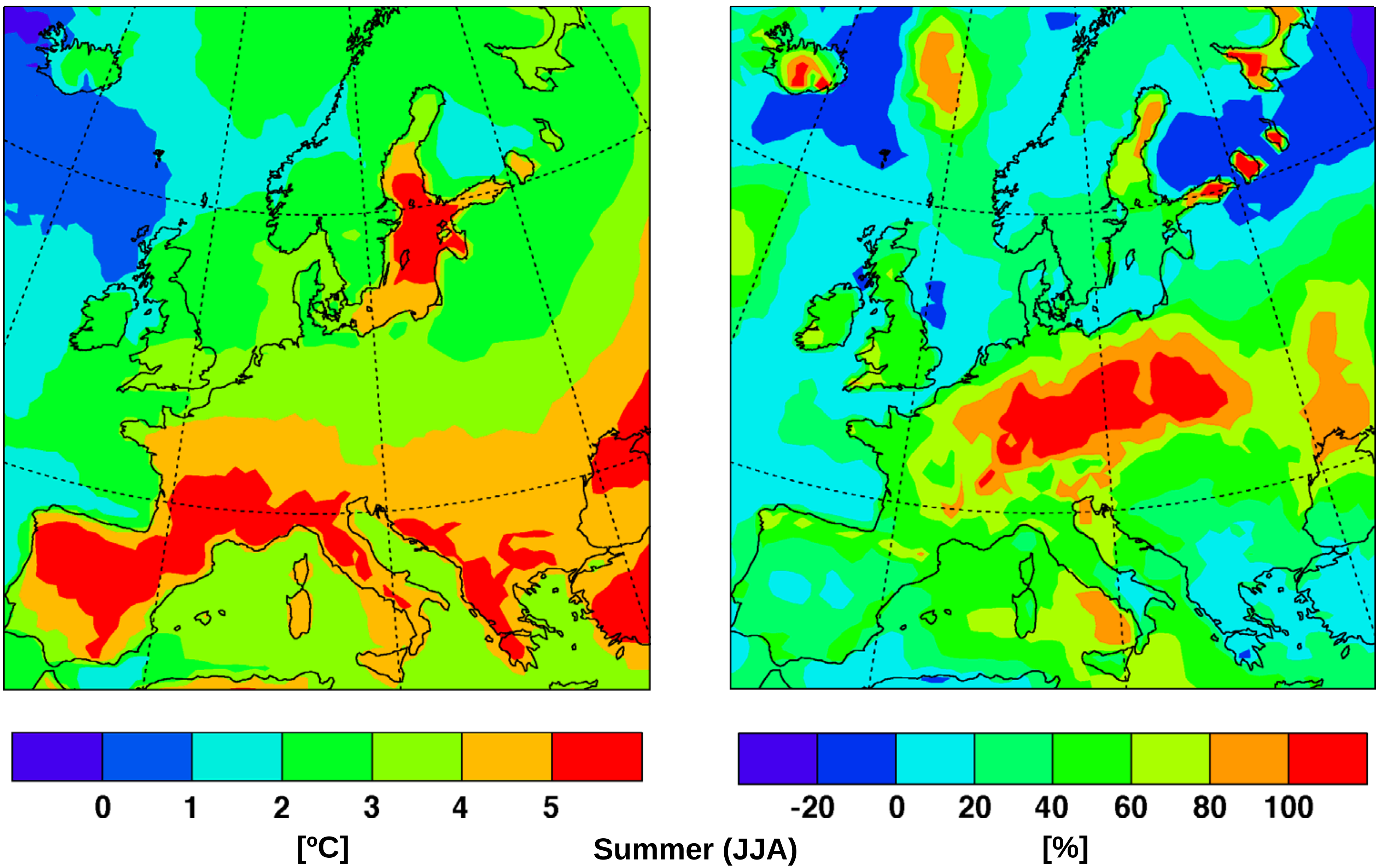
Observed:
T = 16.9 ºC
σ = 0.94 ºC

strong increase in variability

(Schär et al. 2004, *Nature*, **427**, 332-336)

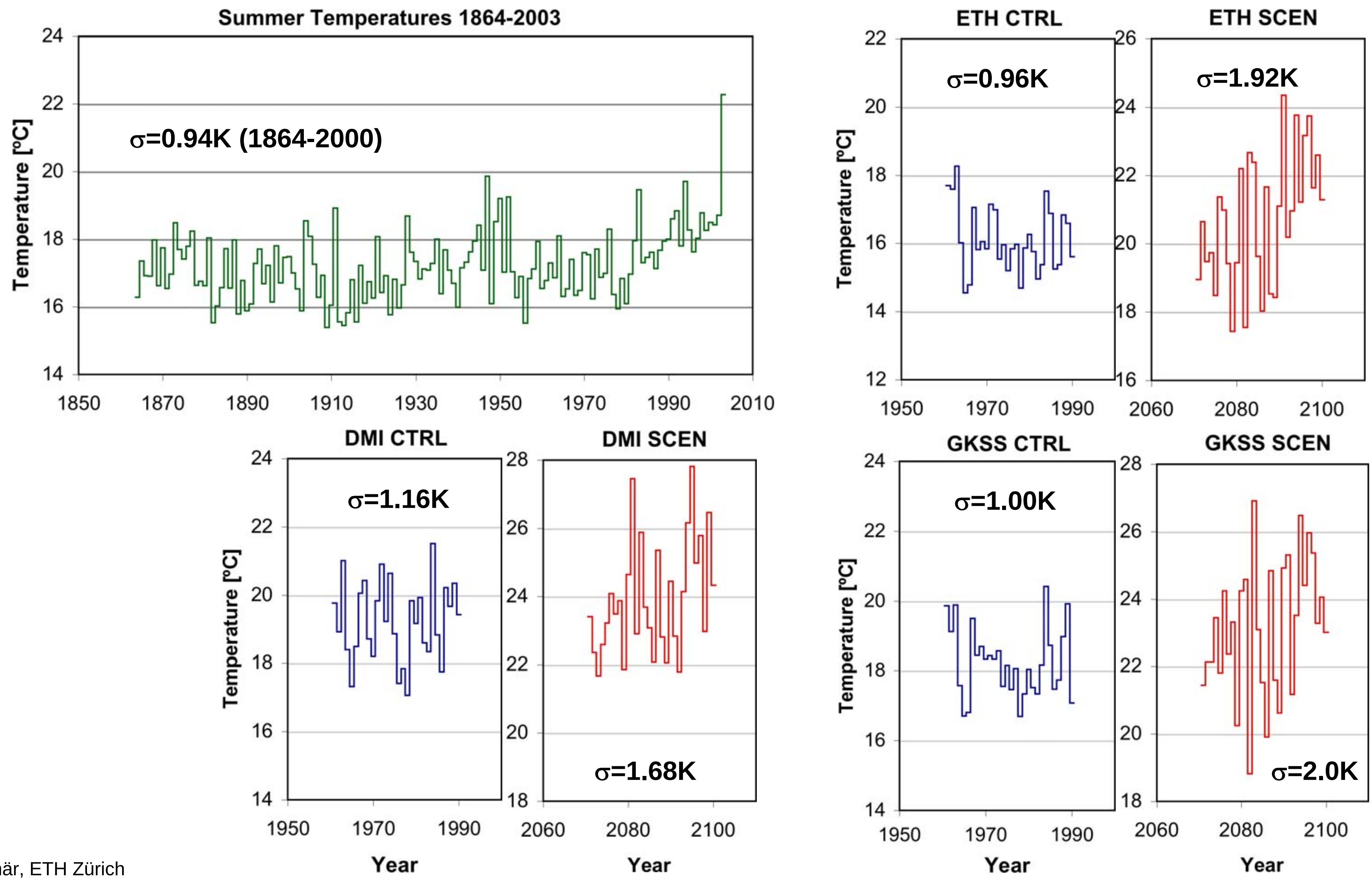
Change in Mean Temperature ΔT

Change in Variability Δσ/σ

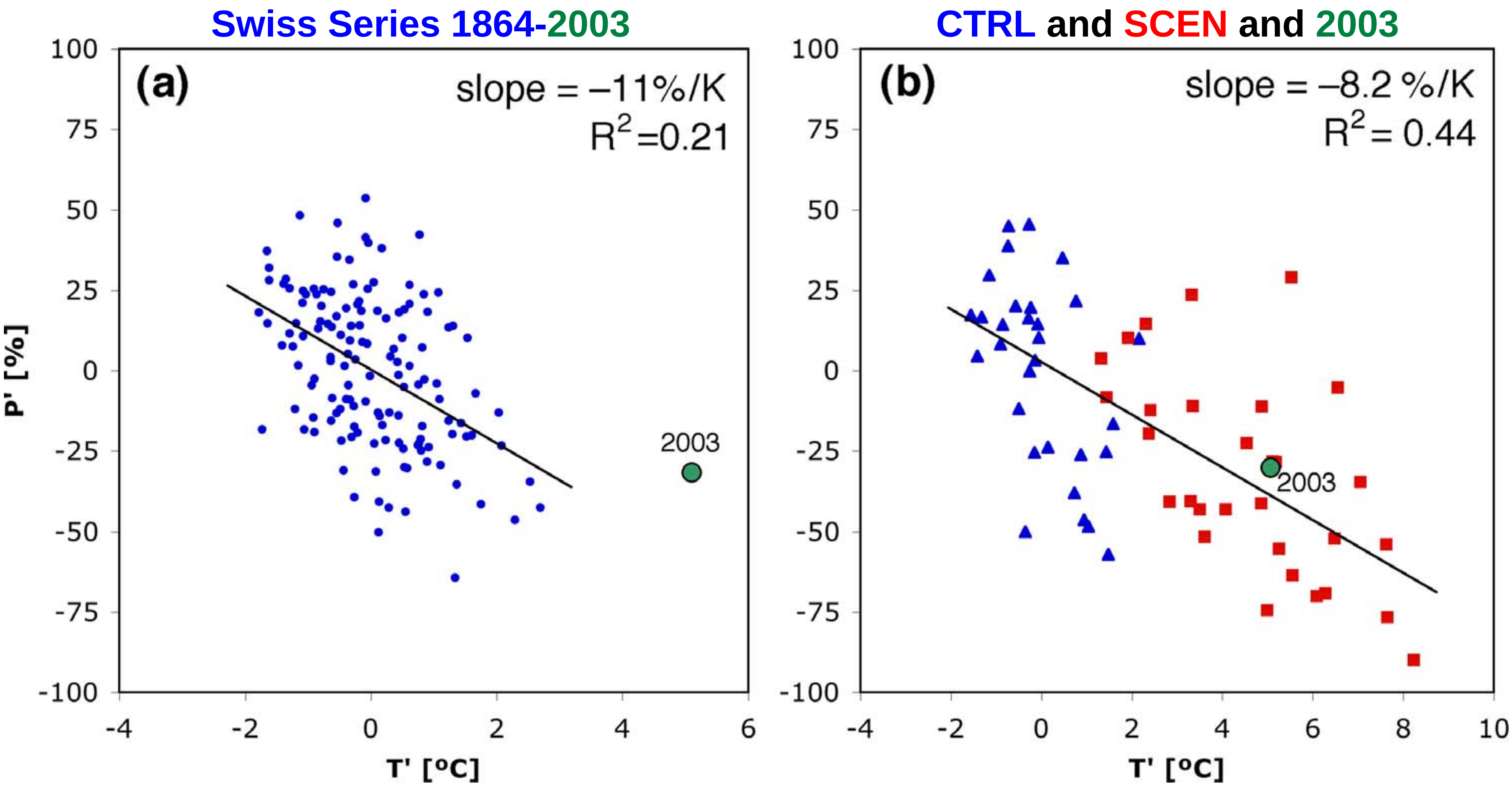


(Schär et al. 2004, *Nature*, **427**, 332-336)

Timeseries Zürich

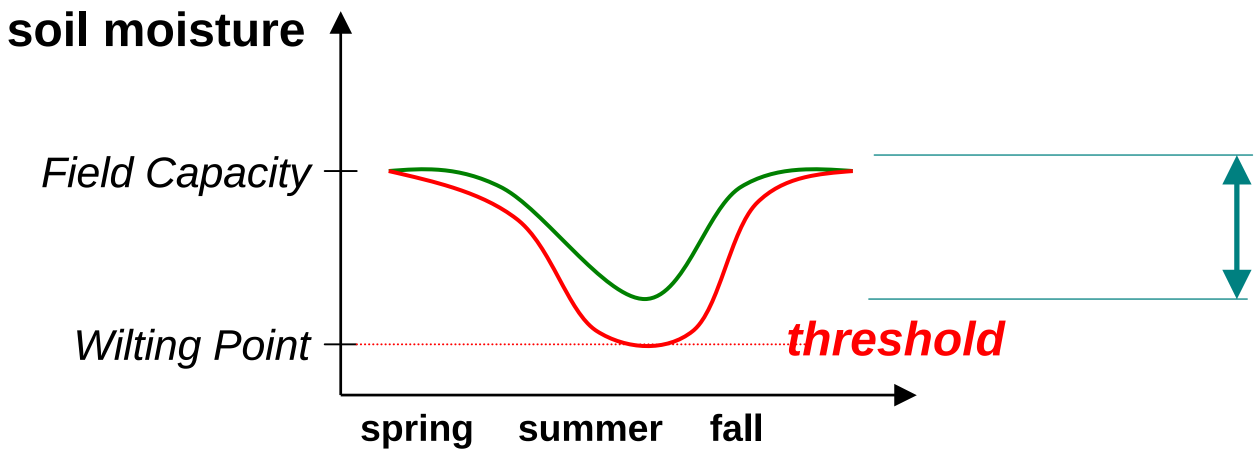


Comparison of T and P anomalies



Physical Mechanism

- **land-surface processes important for extratropical summer climate**
  (Koster et al. 2004, Betts et al. 2004, Schär et al. 1999)
- **climate change increases potential for mid-latitude summer drought**
  (Wetherald and Manabe 1995)
- **soil-moisture depletion nonlinearly amplifies temperature anomalies**
  (e.g. Hartmann 1994)



Δ ~ 150 mm

latent cooling corresponds to ~43 W/m^2

Conclusions

1. The most immediate effect of climate change is to increase the uncertainty. Protection with same safety margin becomes more expensive.

2. Estimating extremes in a changing climate requires combining observations and climate change scenarios.
   Recent progress evident, but still large uncertainties.

3. For extremes far away from mean,
   changes in variability are more important than changes in mean.

4. European summer climate might face fundamental changes,
   which would strongly involve land-surface processes and hydrology.
   Many simulations predict an increase in interannual variability.