Nature of Heat Waves in Western Russia as Simulated with CCSM4.0

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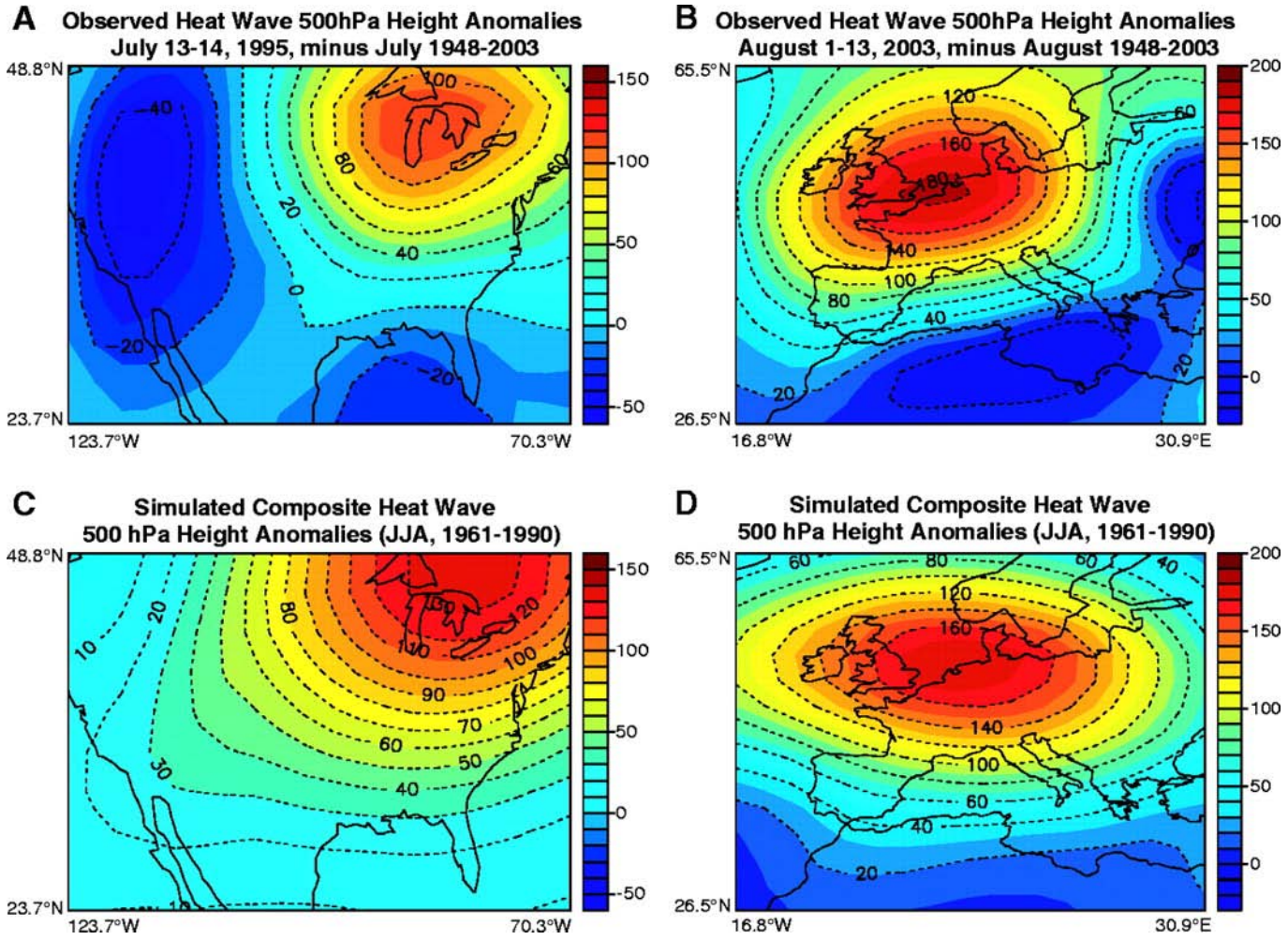
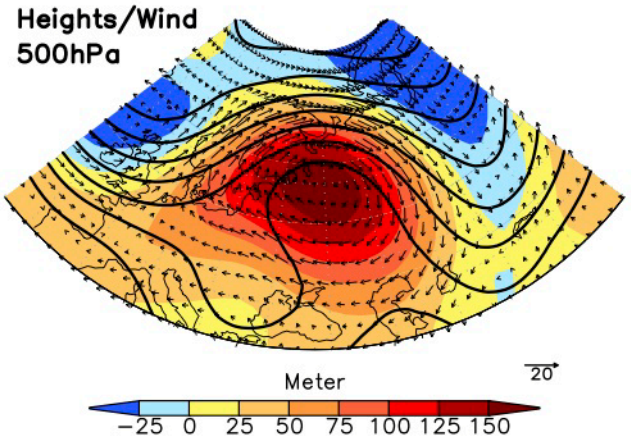
Many thanks to Jim Hurrell for giving access to the CCSM output

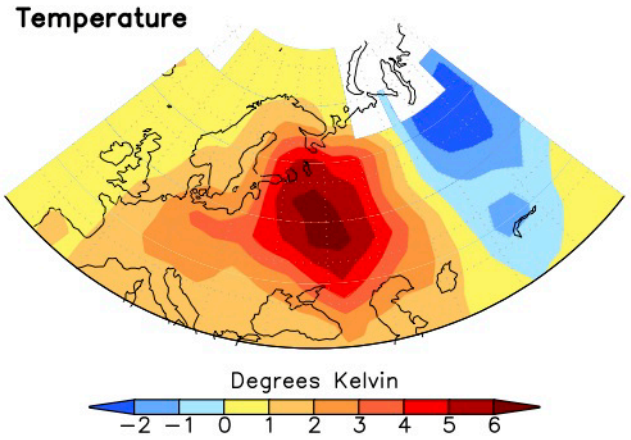
Meehl and Tibaldi 2004 study "More Intense, More Frequent, and Longer Lasting Heat Waves in the 21st Century"



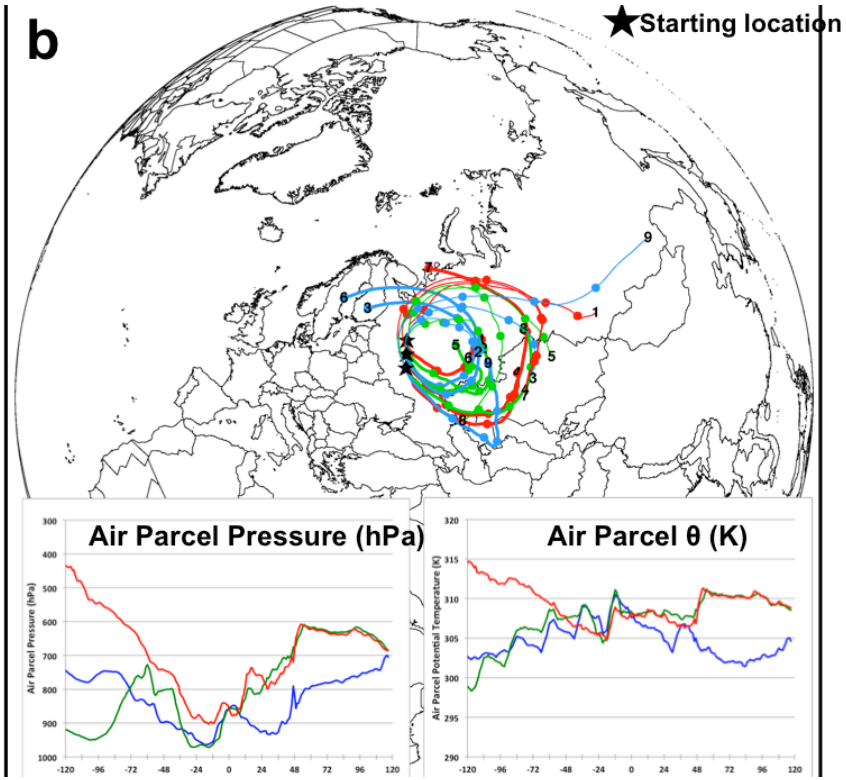
2010 Russian Heat wave is closely related to strong blocking event

Reanalysis/OBS 2010





120h backward (thick) and 120h forward (thin)
Trajectories starting at 0000UTC 27 July 2010

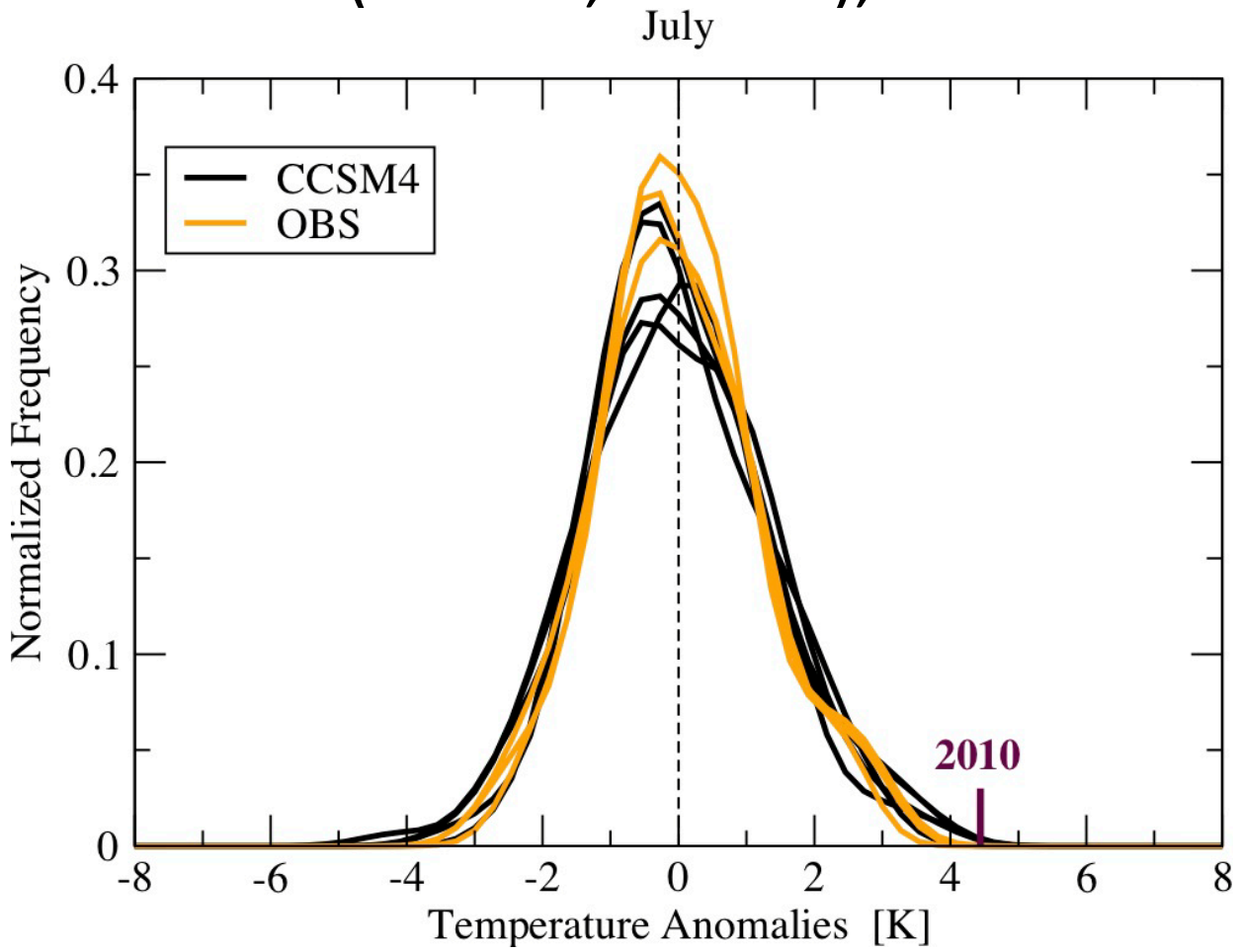


Courtesy of Tom **Galarneau**

Outline

- Evaluate occurrence of Western Russia heat waves in CCSM4
- Nature of Western Russia temperature extremes in changing climate
- Potential role of land-surface feedbacks

OBS and CCSM exhibit similar summertime temperature variability in the Western Russia region (30-55E,45-60N), 1900-2009

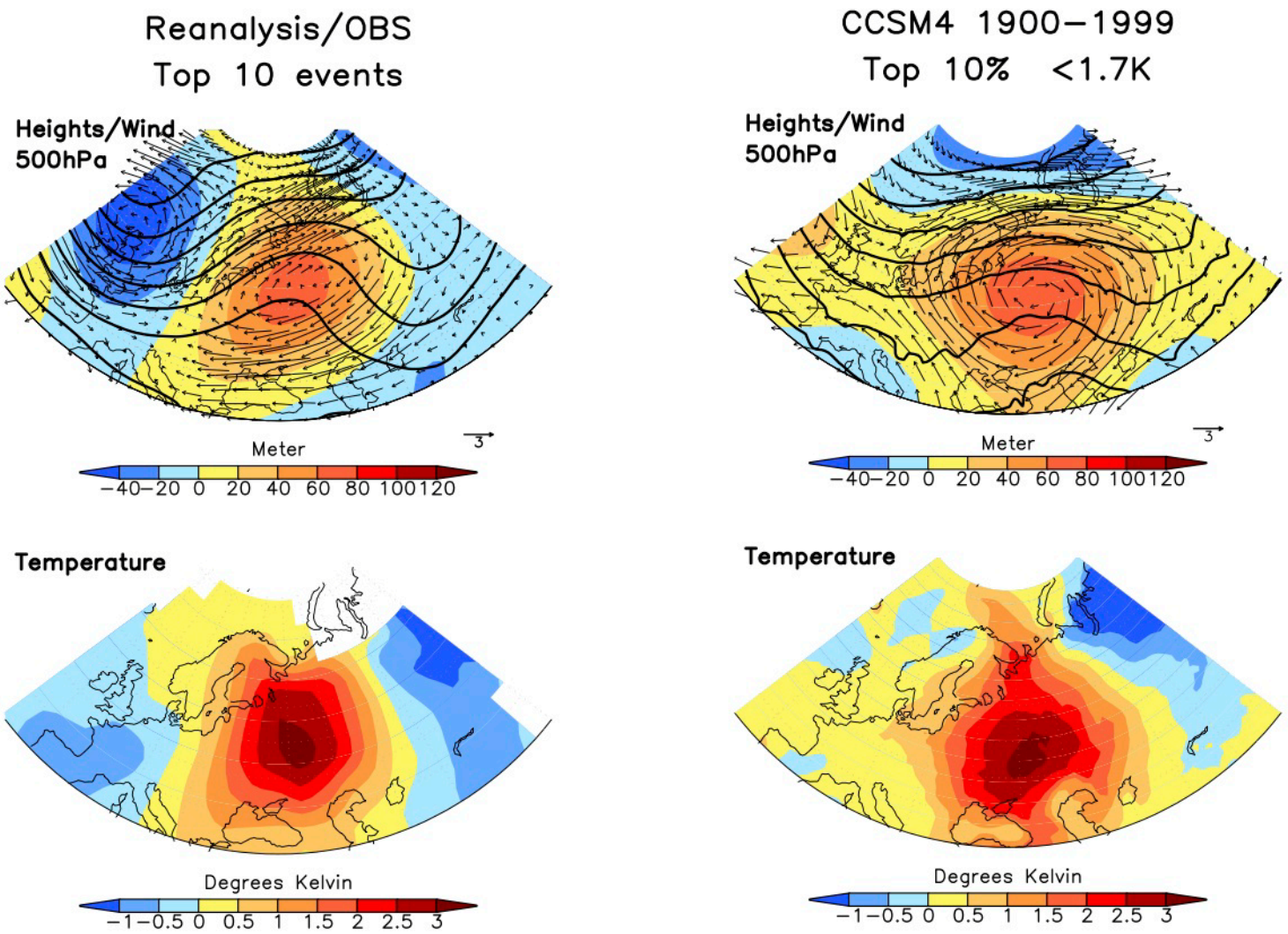


$1.07K<\sigma_{OBS}<1.22K$

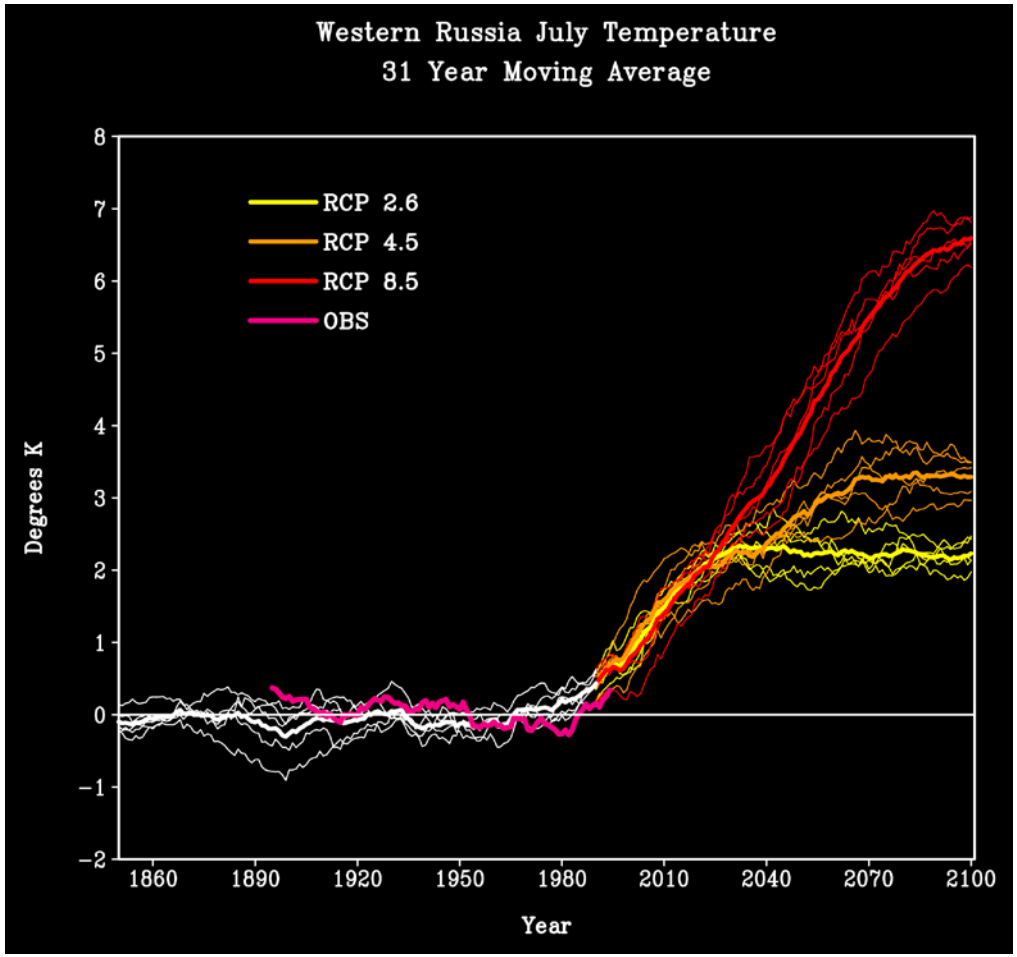
$1.17K<\sigma_{CCSM}<1.37K$

Similar results for August

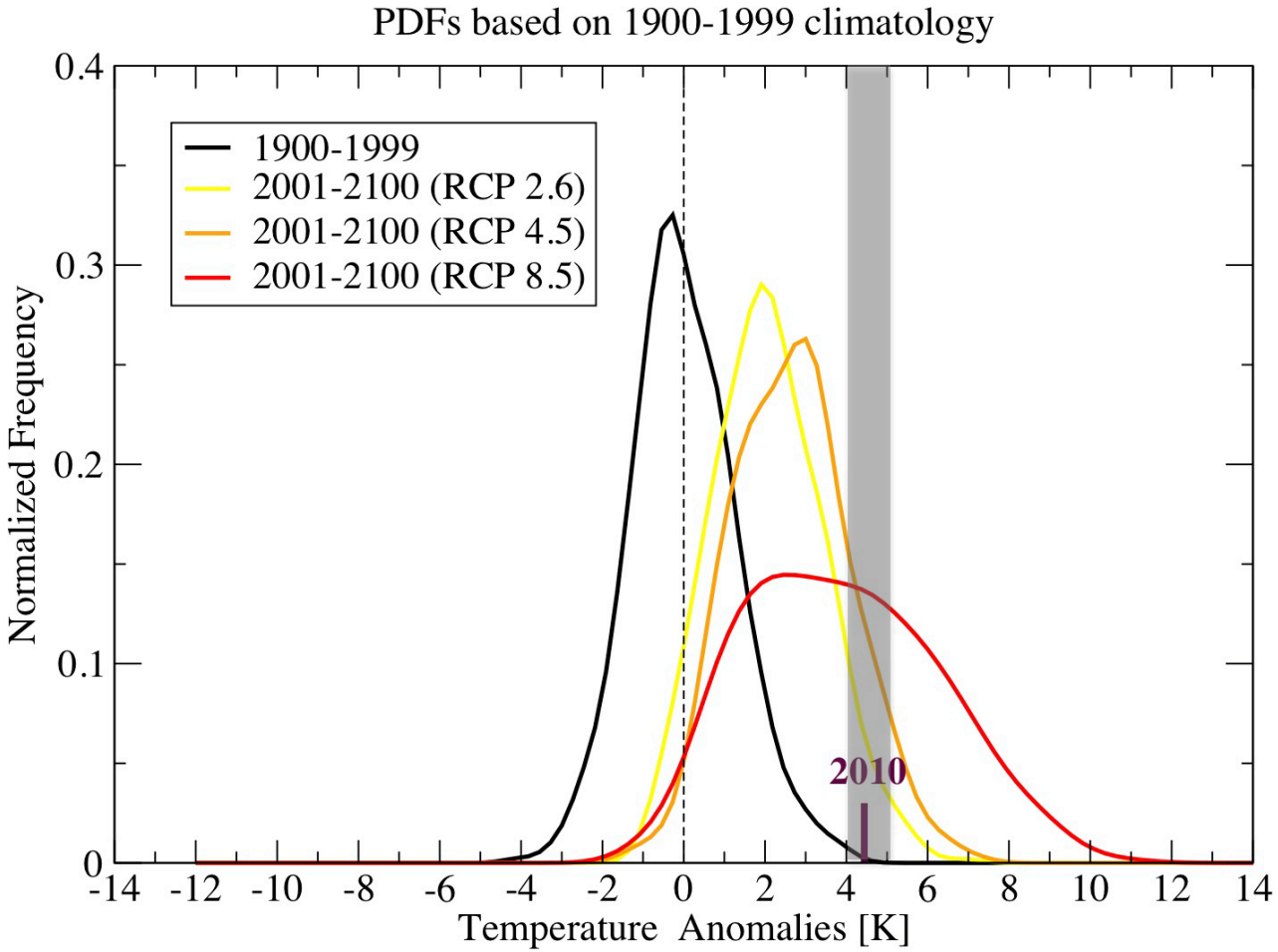
Observed and simulated events



Western Russia July Temperature Evolution in Dependence of Representative Concentration Pathways (RCPs)



20th and 21st Century PDFs of July Western Russia Temperatures



Mean ± σ

0.00±1.20

2.07±1.34 (1.16)

2.64±1.43 (1.27)

3.87±2.35 (1.47)

"One in 100 yr event"

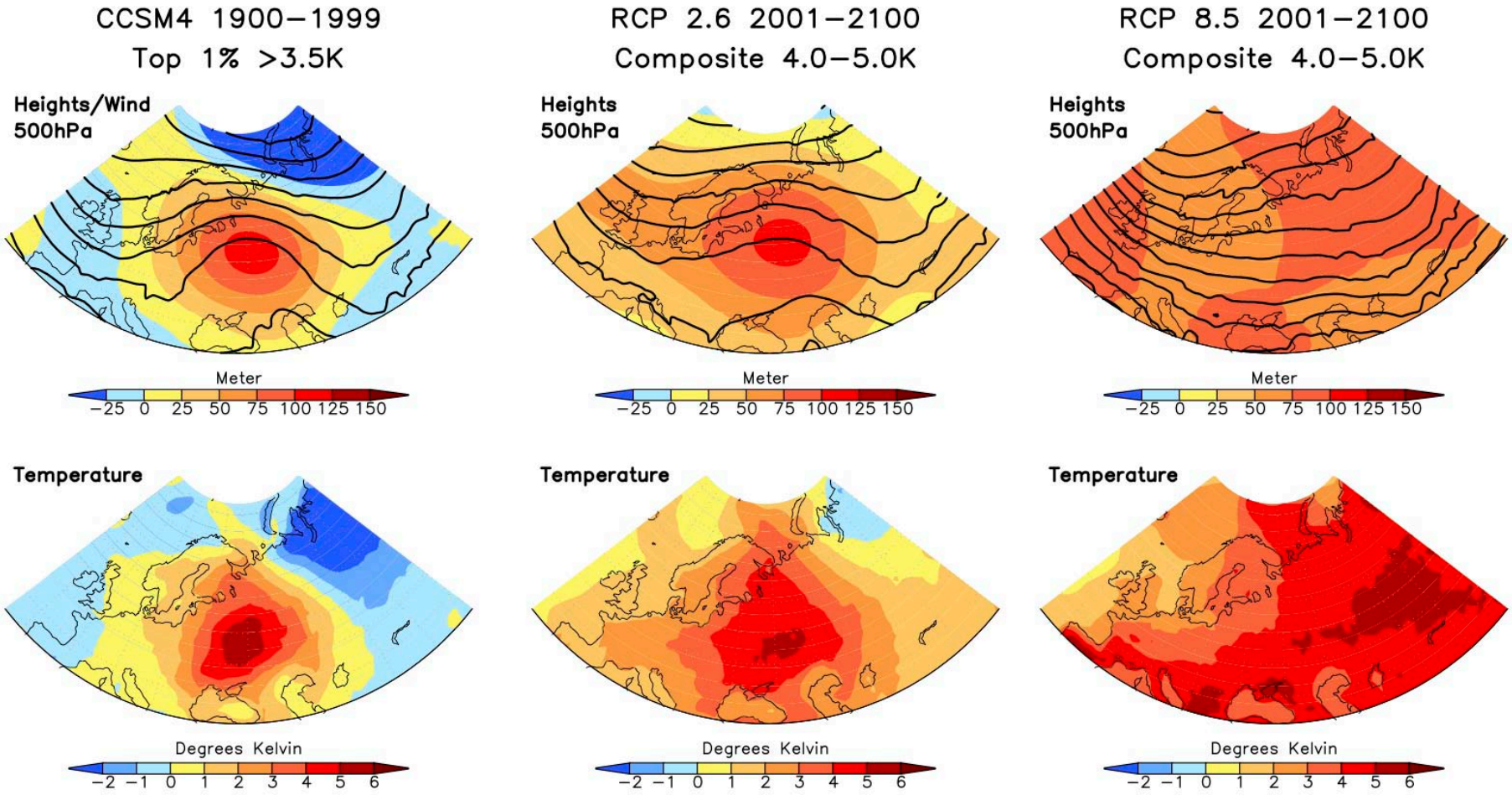
3.52<T<4.06

5.35<T<6.88

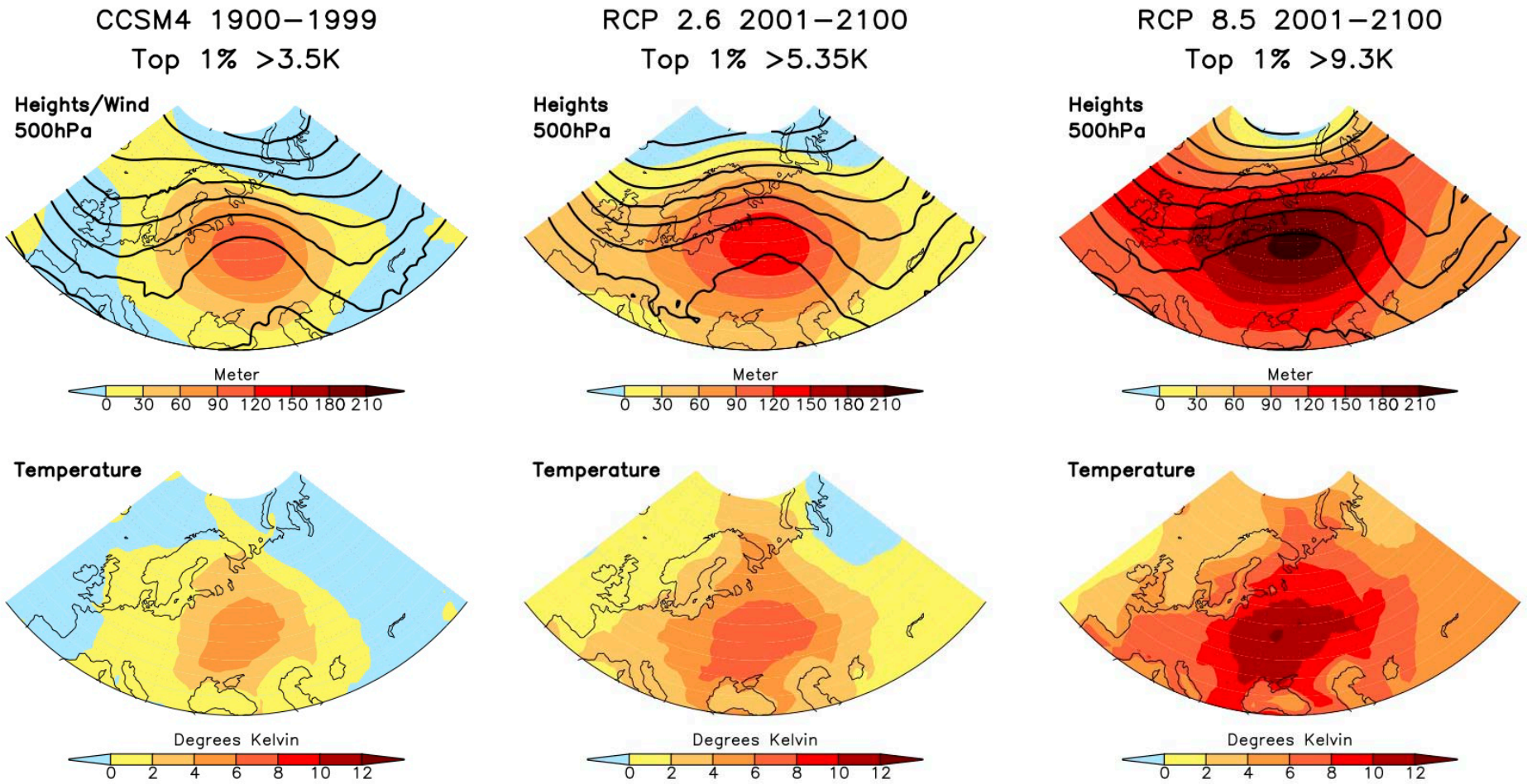
6.48<T<7.27

9.36<T<10.98

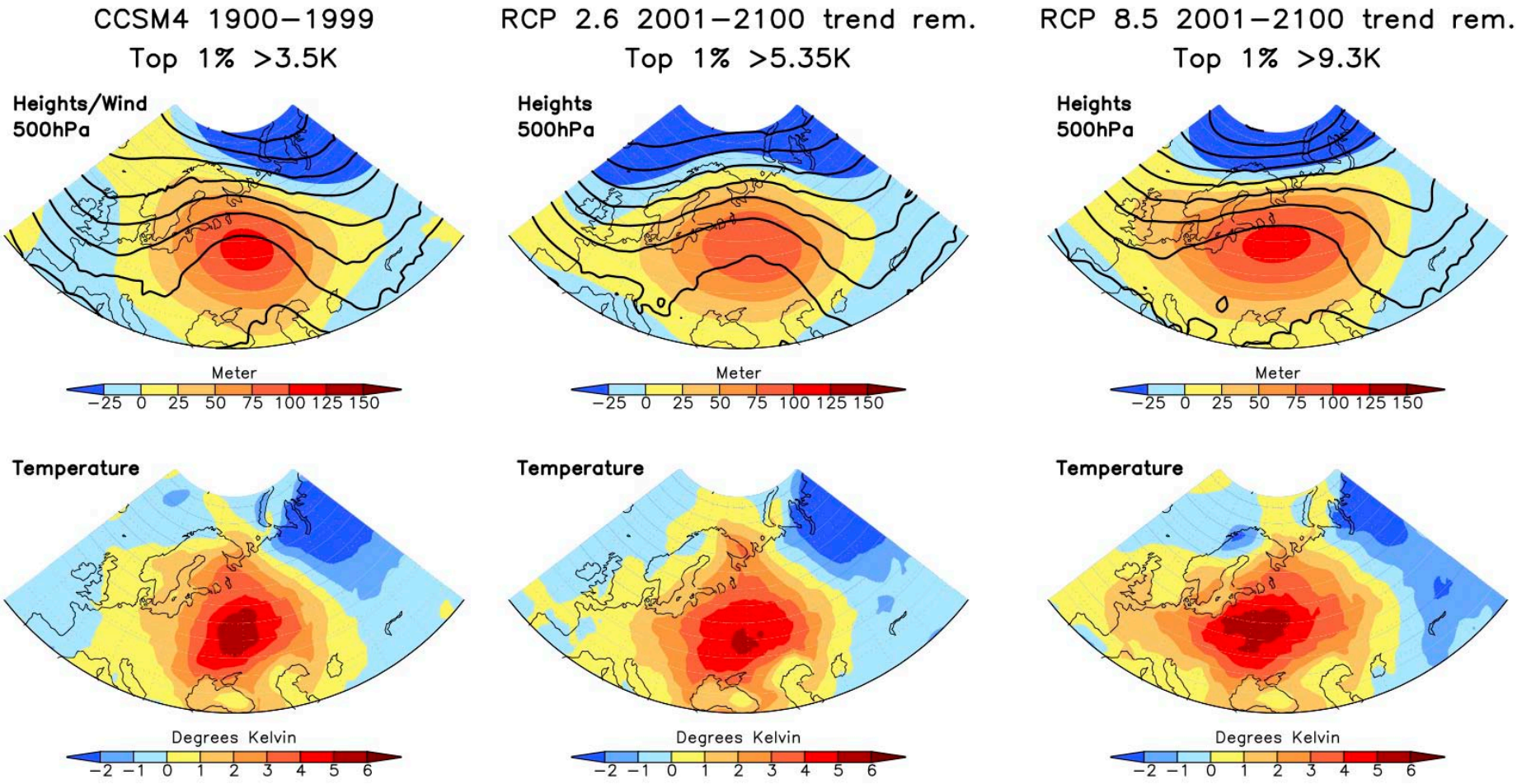
Comparison between 20th century events and 21st century 4-5K composite



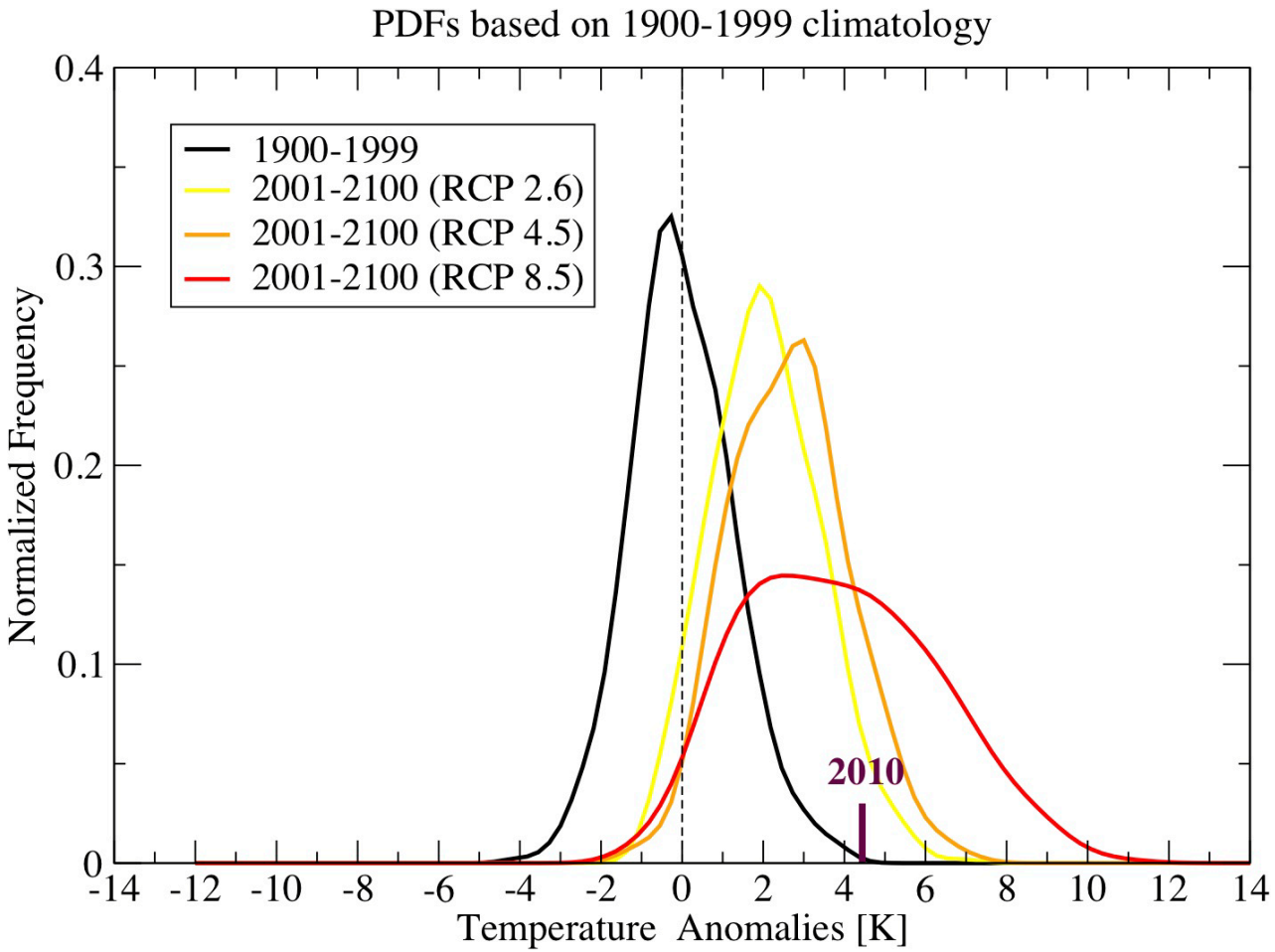
Comparison of “one in 100 year events”



Comparison of “one in 100 year events” (trend removed)



20th and 21st Century PDFs of Western Russia Temperatures



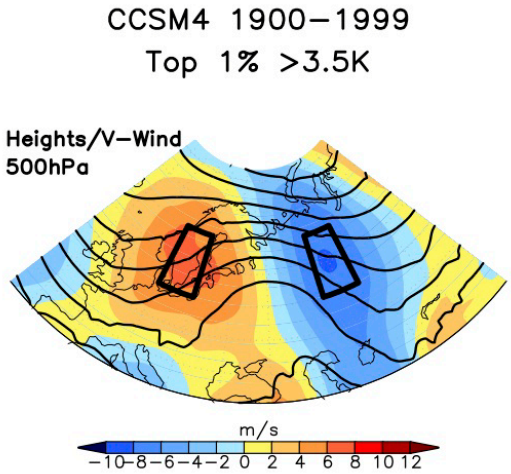
Mean ± σ
0.00±1.20
2.07±1.34 (1.16)
2.64±1.43 (1.27)
3.87±2.35 (1.47)

At the end of the 21st century, 2.5σ heat wave events occur more often and last longer in RCP 8.5

	Obs 1950-2010 (61 years)	2005-2034 (150yr ensemble)	2071-2100 (150yr ensemble)
≥ 4 days	2	7	16
≥8 days	1	1	5
≥ 12days	1	0	1

Model July-August statistics is calculated by removing respective 30 year mean and normalized based on 2005-2034 standard deviation

Are longer lasting heat waves and increase in summertime temperature variability related to an intensified regional circulation pattern?



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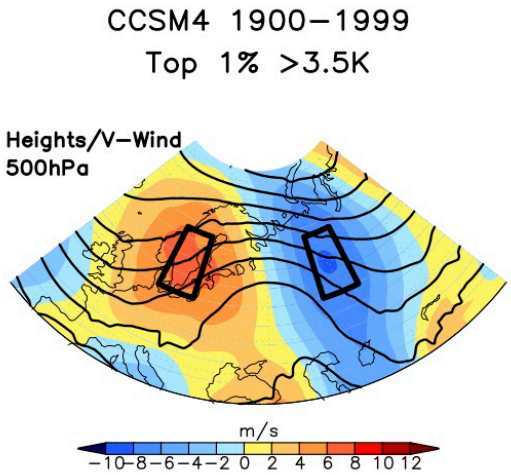
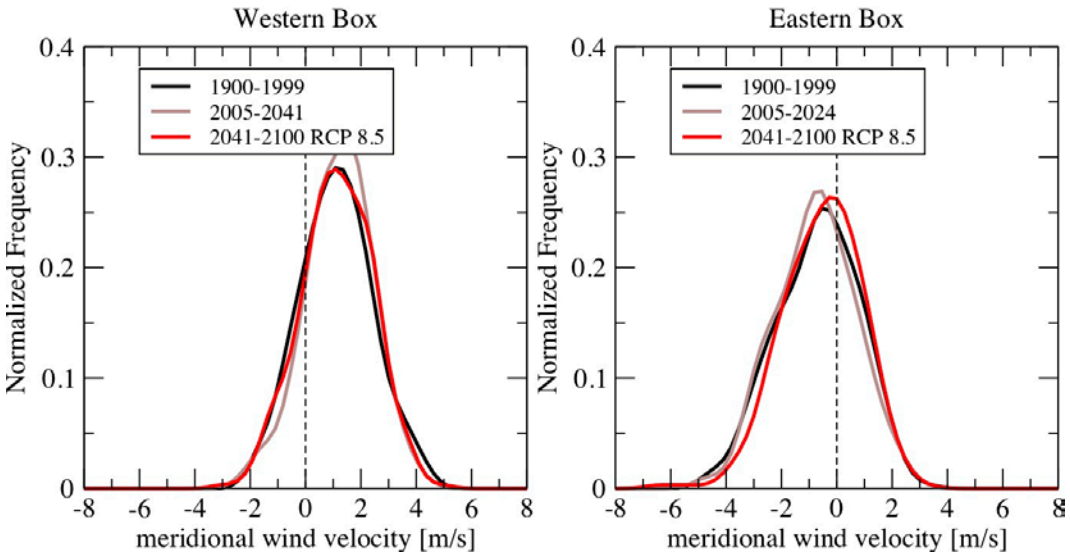
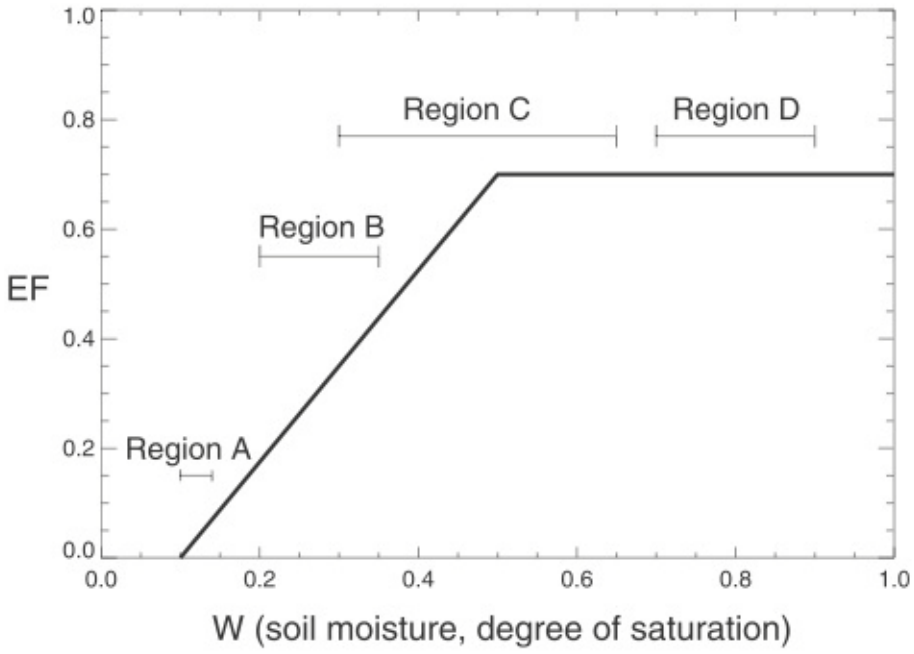




Evaporative Regimes - Idealized and simulated with CCSM4

Idealized (Koster et al)



Dry regime (Soil moisture controlled): Increase (decrease) in soil moisture leads to corresponding increase (decrease) in evaporative fraction

Wet regime (Energy-controlled): Evaporative fraction is insensitive to soil moisture changes

Evaporative Regimes - Idealized and simulated with CCSM4

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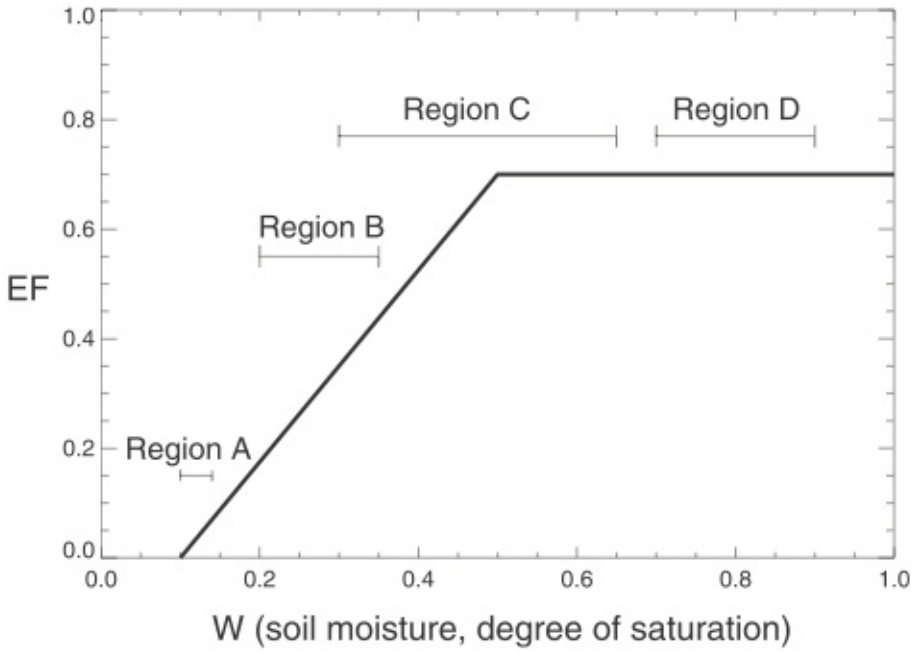
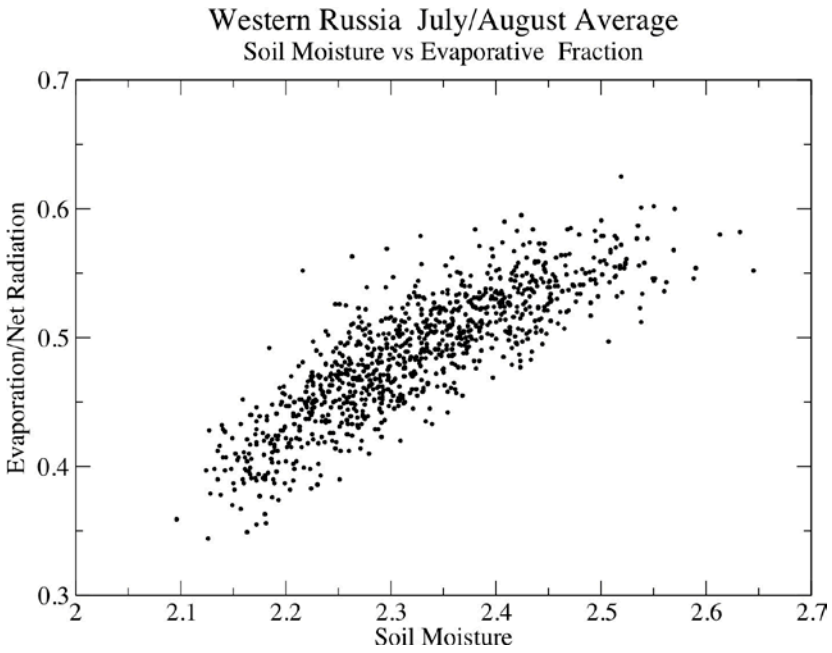


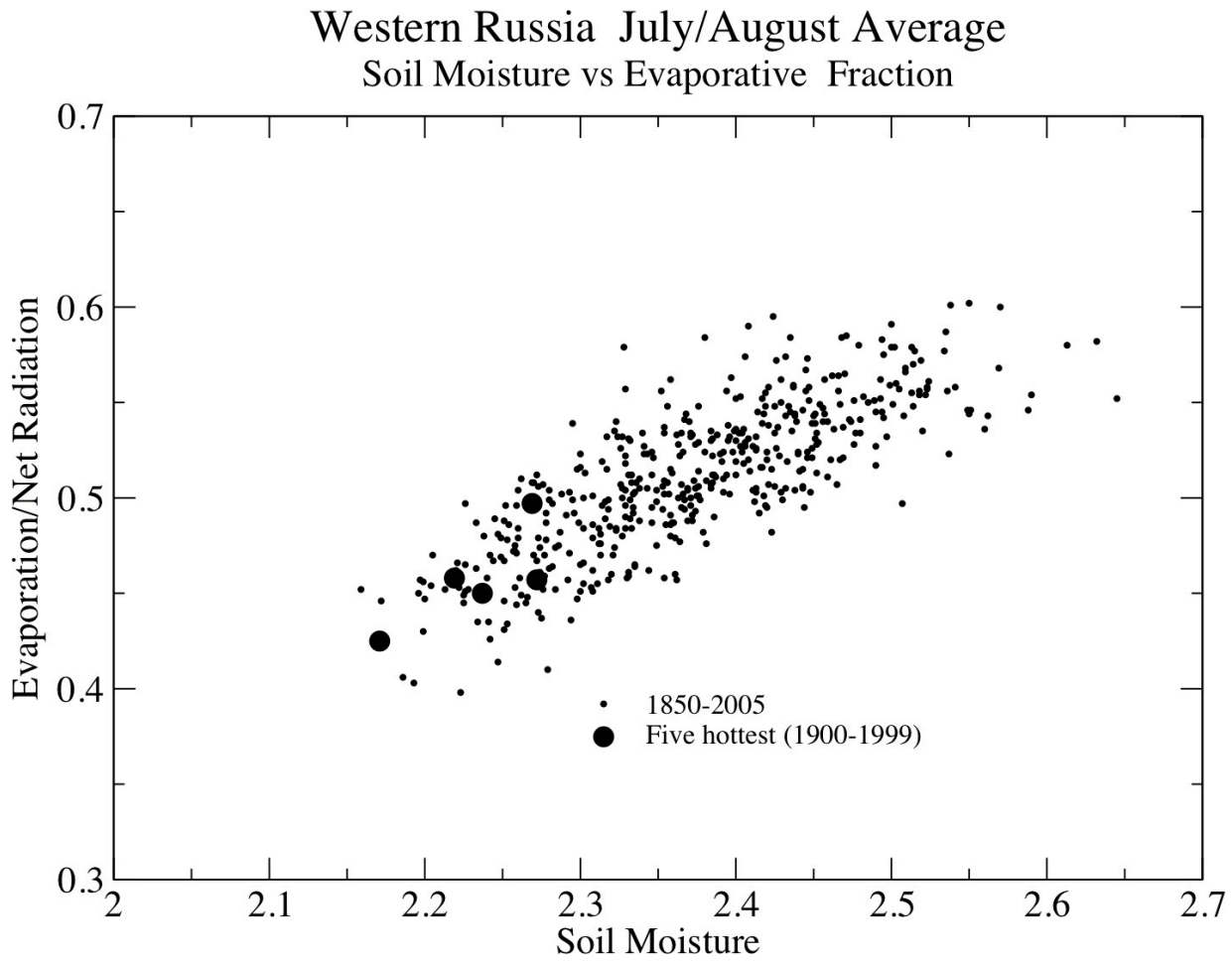
Simulated



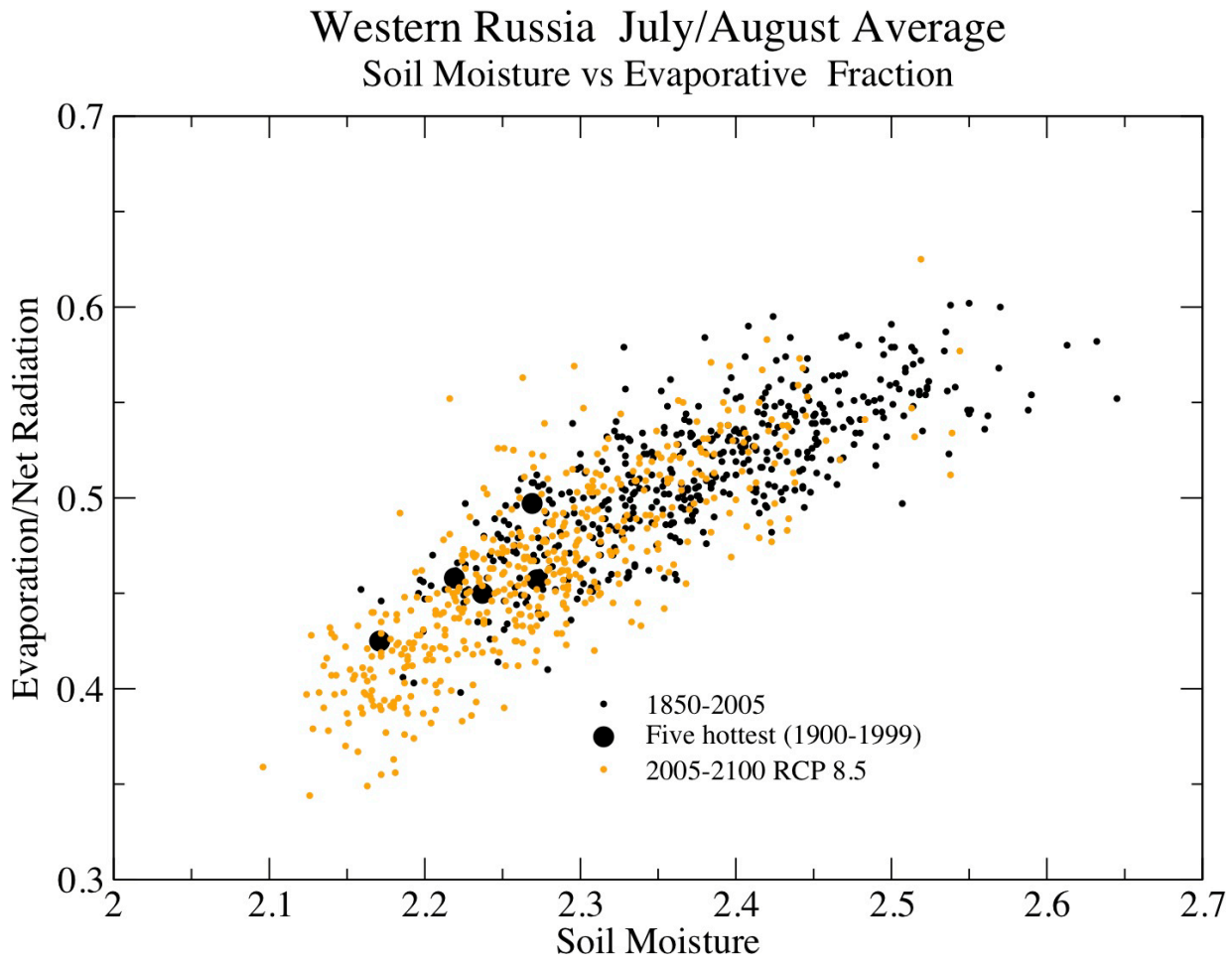
Dry regime (Soil moisture controlled): Increase (decrease) in soil moisture leads to corresponding increase (decrease) in evaporative fraction

Wet regime (Energy-controlled): Evaporative fraction is insensitive to soil moisture changes

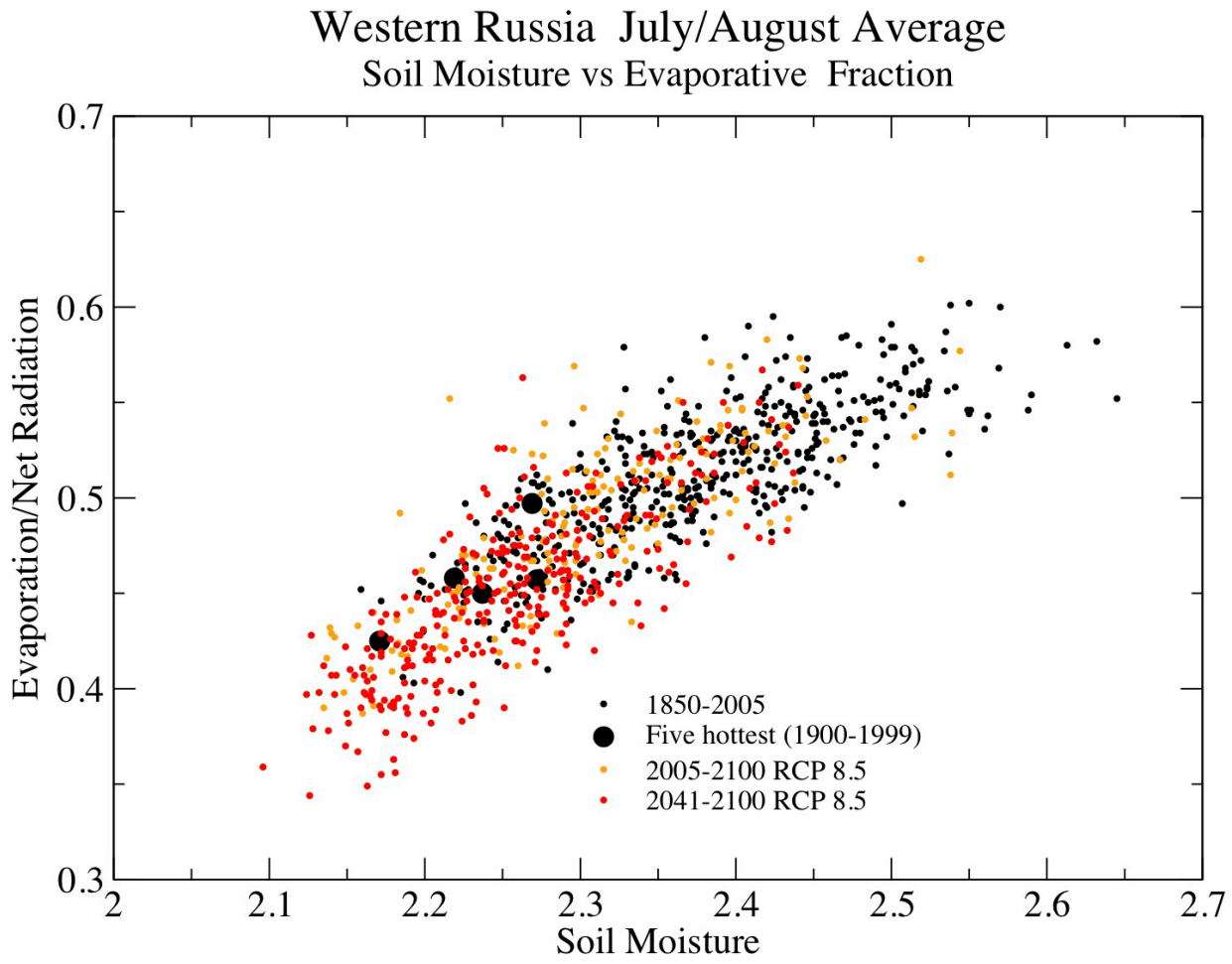
Simulated hottest summer during 20th century are characterized by relatively low soil moisture and small evaporative fraction



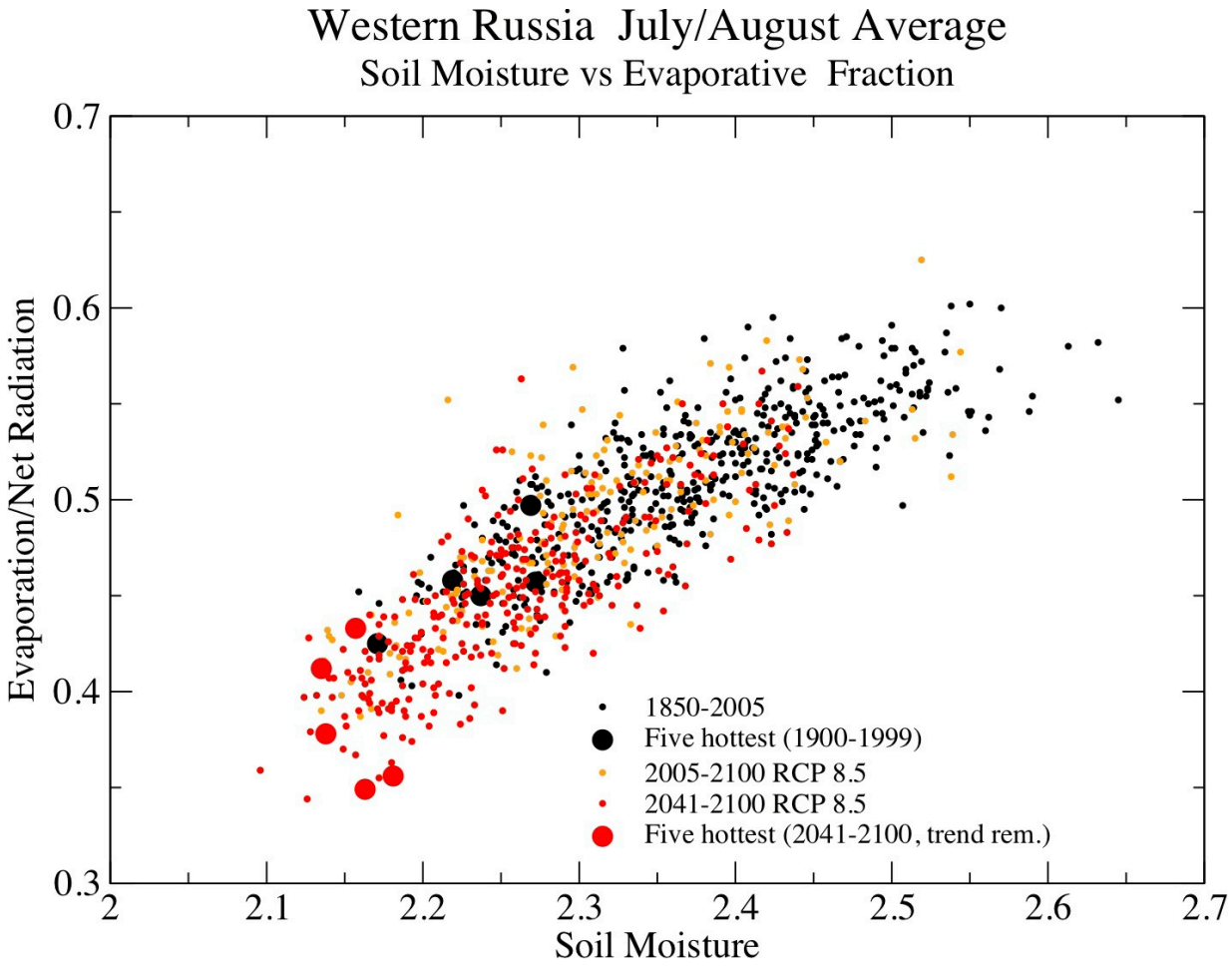
Shift to reduced soil moisture and lower evaporative fraction in the 21th century for RCP 8.5



Shift towards even less soil moisture and lower evaporative fraction in the 21th century for RCP 8.5



Shift to less soil moisture and lower evaporative fraction in the second half of 21th century for RCP 8.5

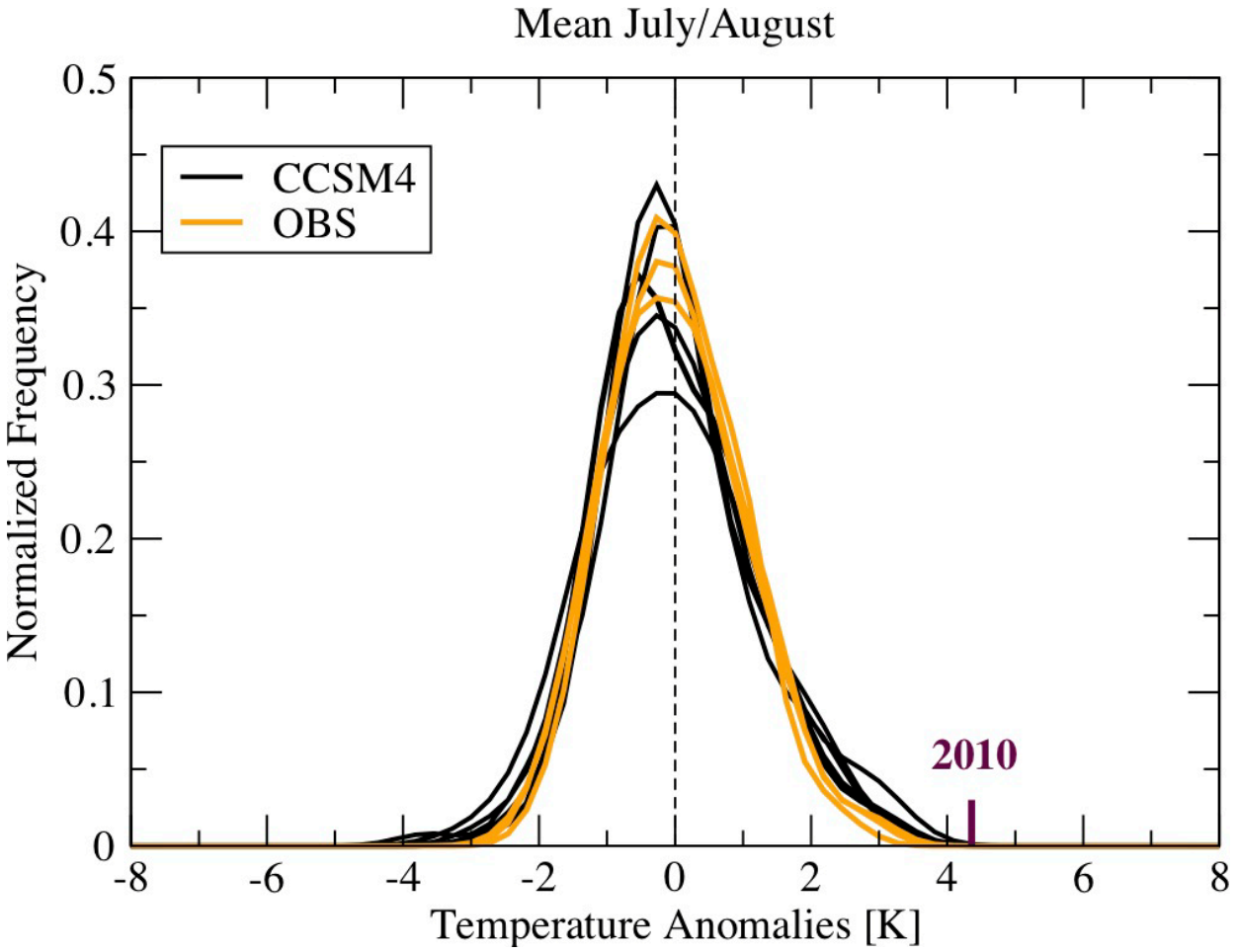


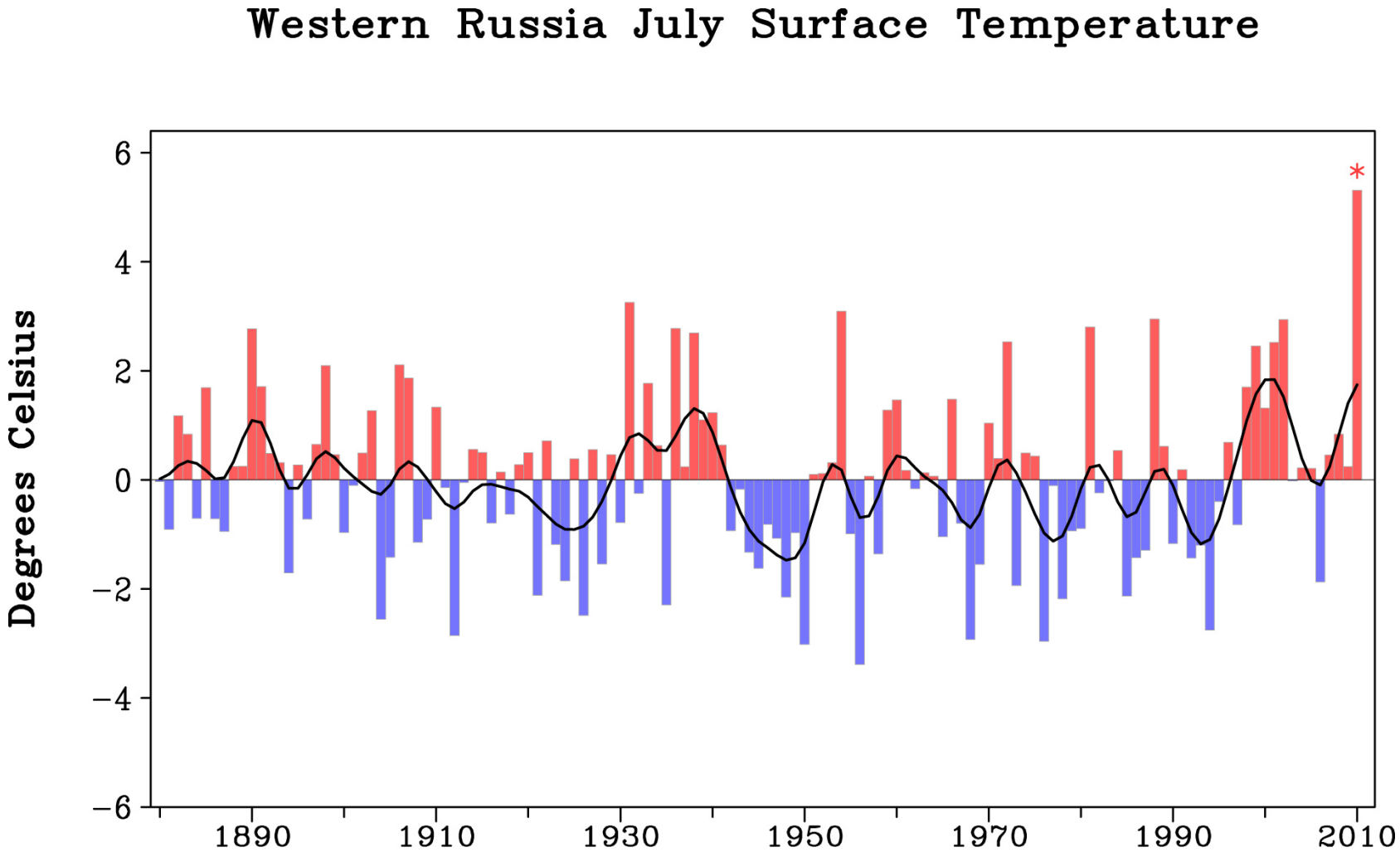
Take home messages

- CCSM4 produces heat waves during the 20th century with similar magnitude and related regional circulation features as observed.
- Character of 21st century events of observed 2010 magnitude (4-5K) differs between RCP 2.6 and RCP 8.5:
  - In RCP 2.6: temperature anomalies require dynamical processed to evolve.
  - In RCP 8.5: Dynamic processes become less important with increasing GHG concentrations.
- "One in 100 year events", however, will have similar regional character as 20th century events and are involving atmospheric internal dynamics.
- Increased summertime temperature variability in the second half of the 21st century in RCP 8.5 is very unlikely a result of a strengthening of the regional circulation pattern, but is more likely a result of land surface feedbacks.

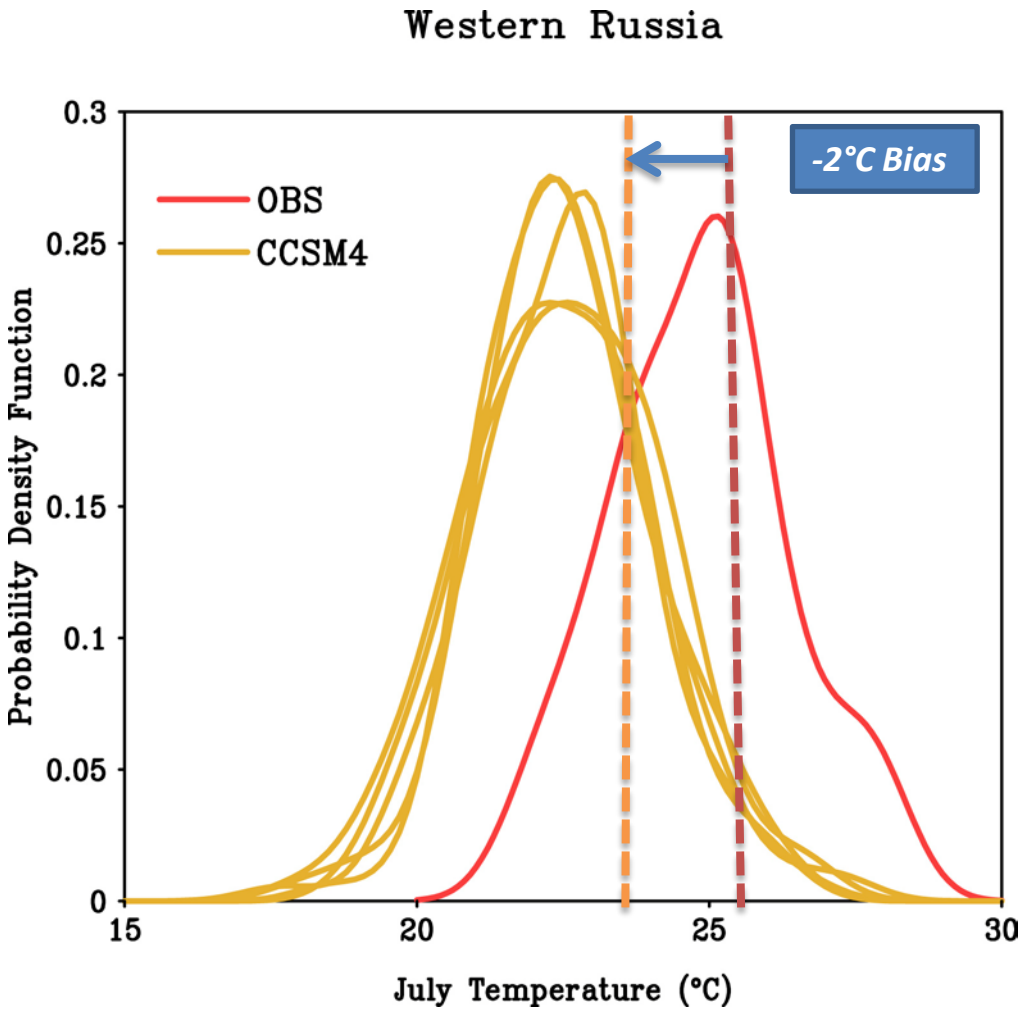
Backup slides

OBS and CCM exhibit similar temperature variability in the Western Russia region



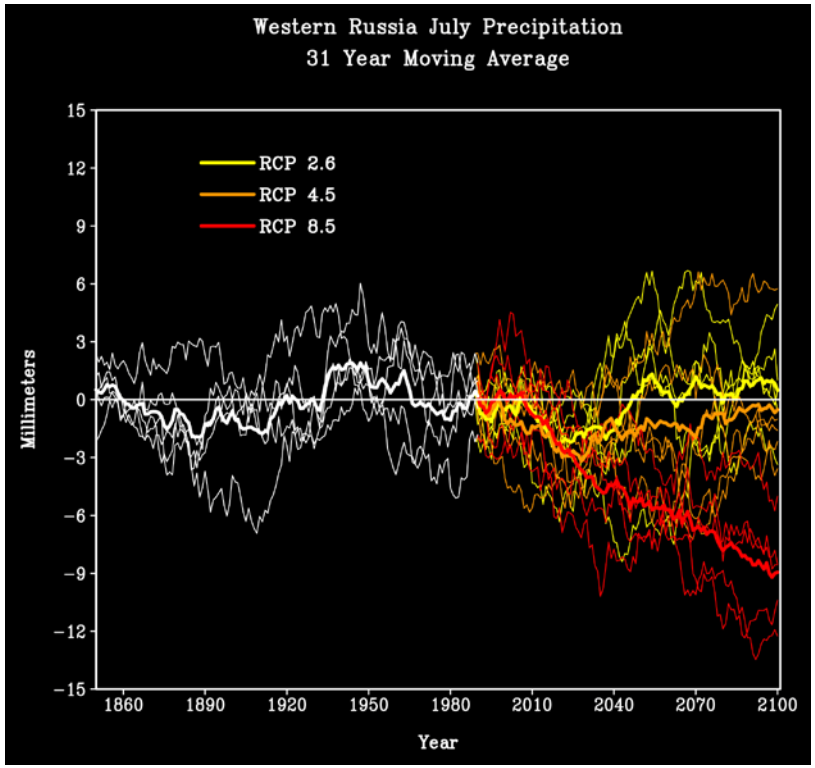


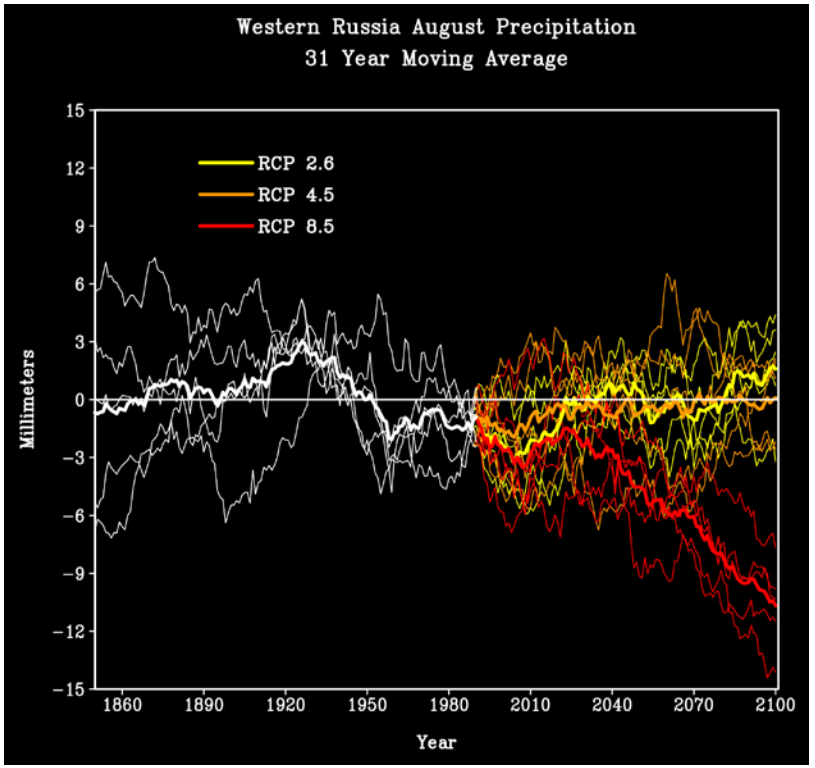
Dole et al. 2011



1900-2009 July SfcT

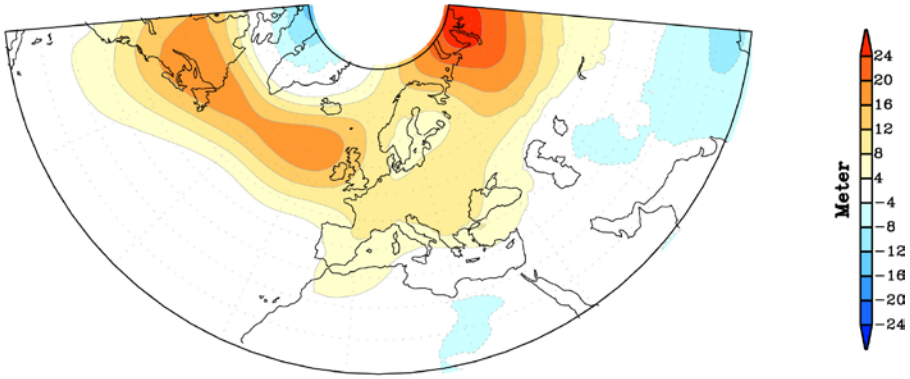
Precipitation changes in July and August



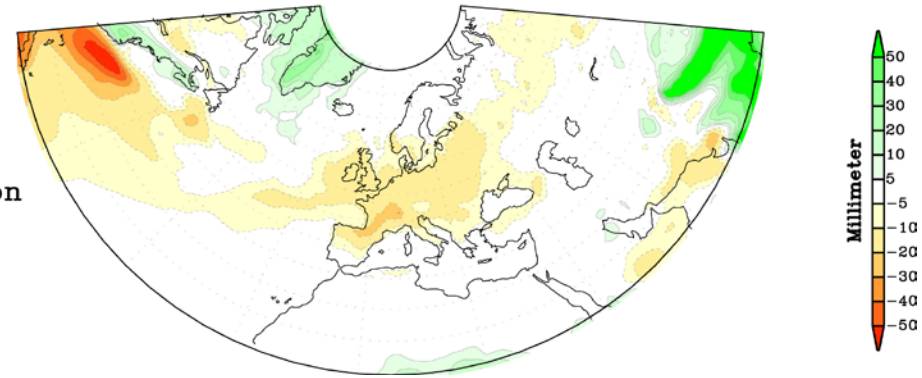


Ensemble CCSM4 July/August: RCP 8.5
(2081–2100) minus (2005–2024)

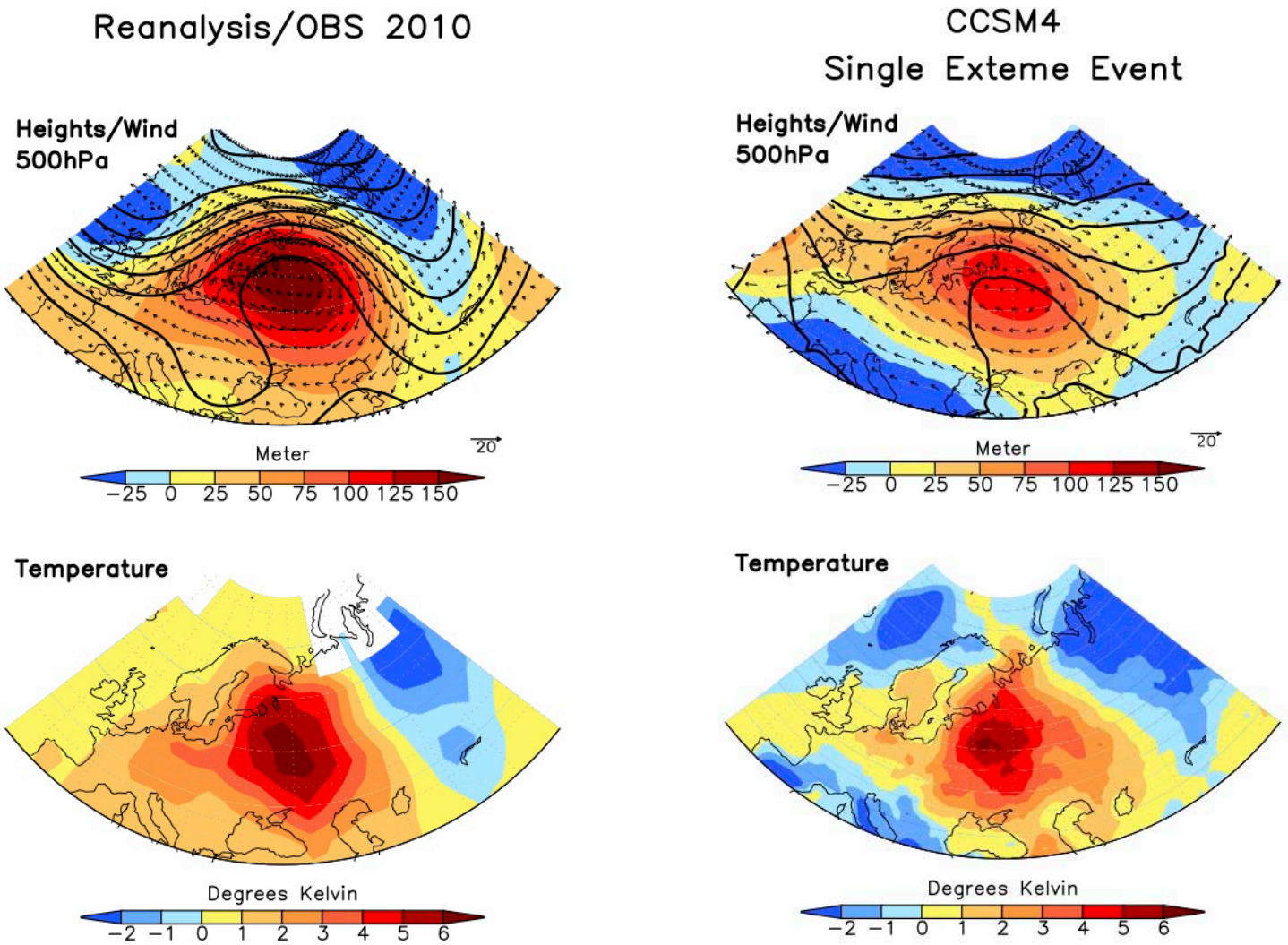
Z500



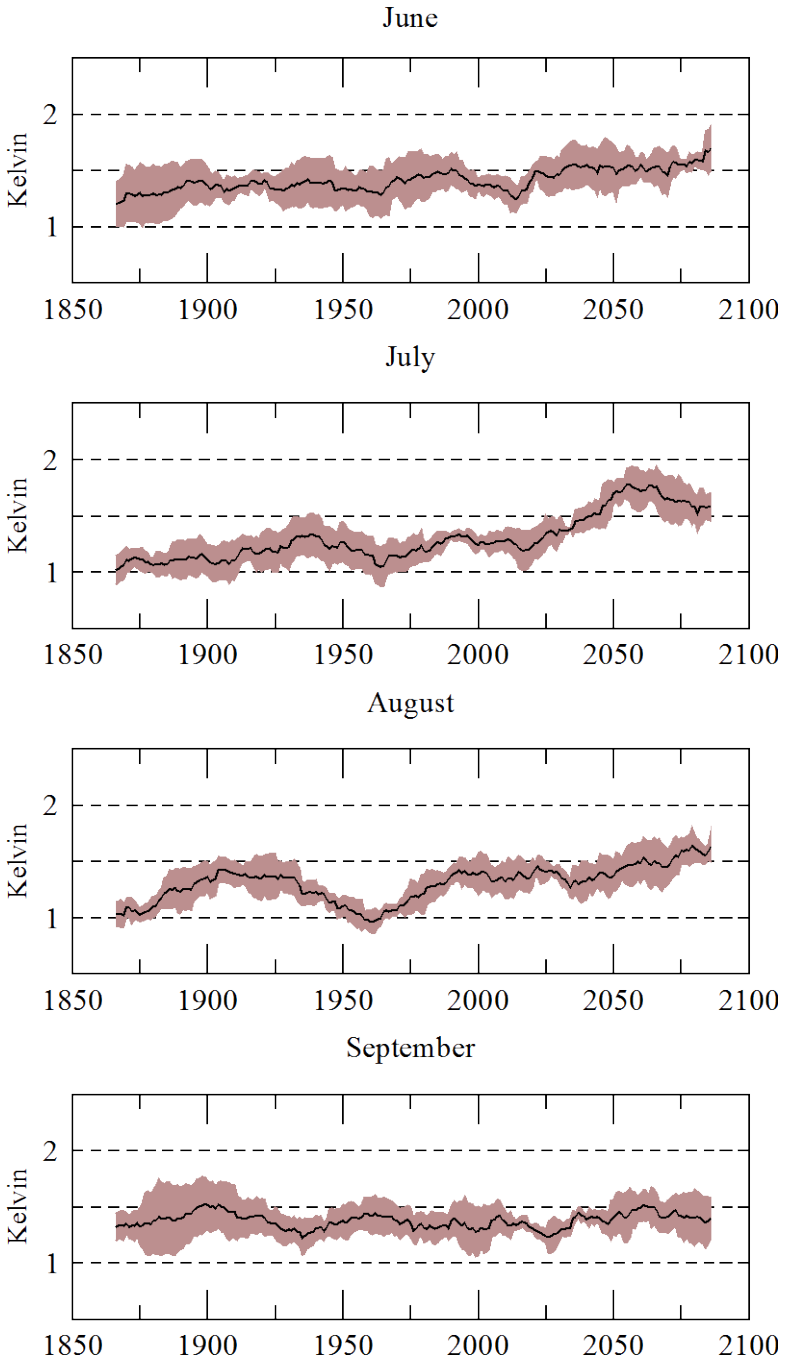
Precipitation



20th century simulated strongest events exhibit similar regional features as observed 2010 event



Overlapping 31 year standard deviation of Western Russia temperatures



In RCP 8.5 scenario temperature variability increases during summer months

Variability of July Western Russia Temperatures increases in the RCP8.5 scenario

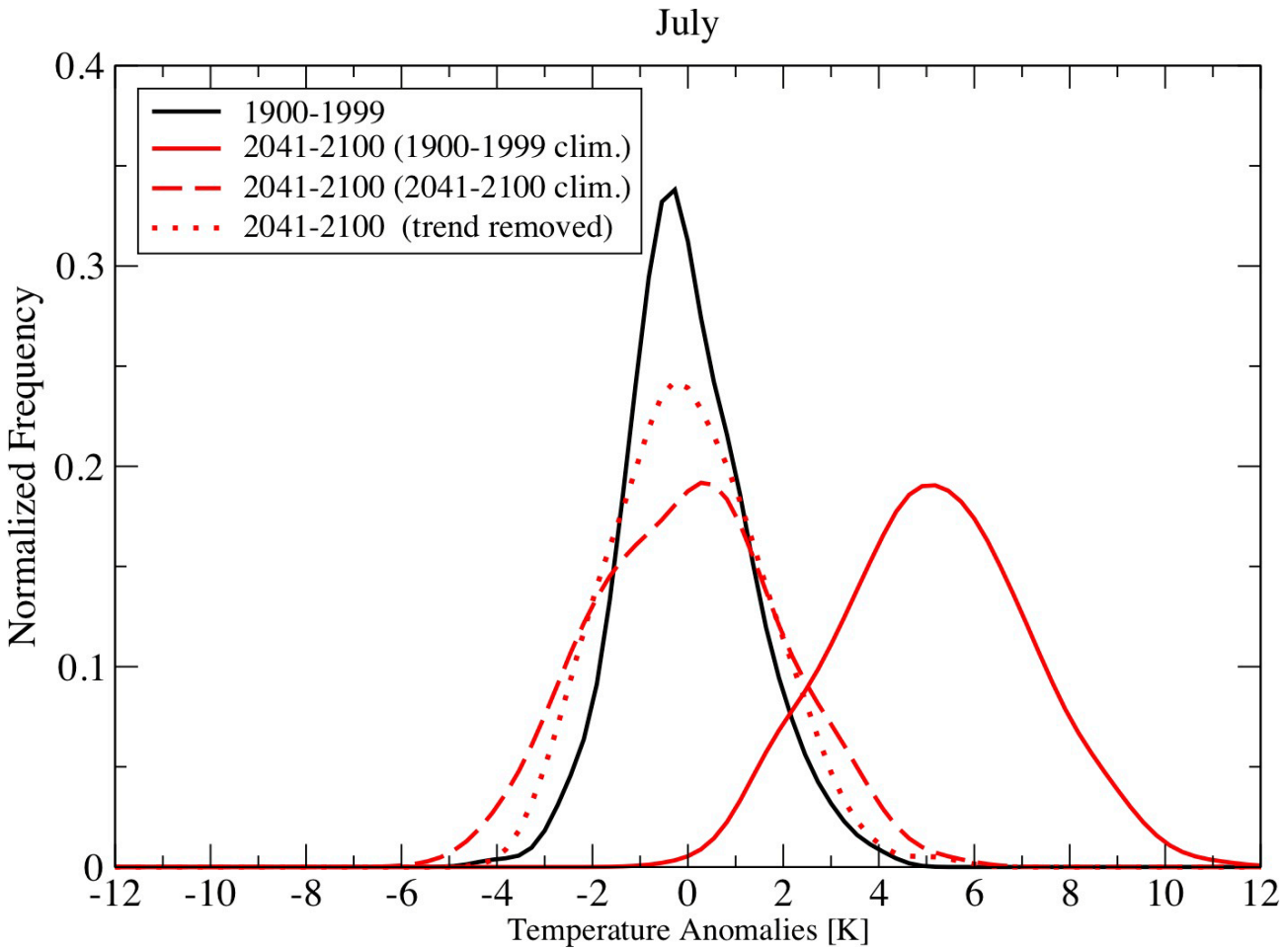
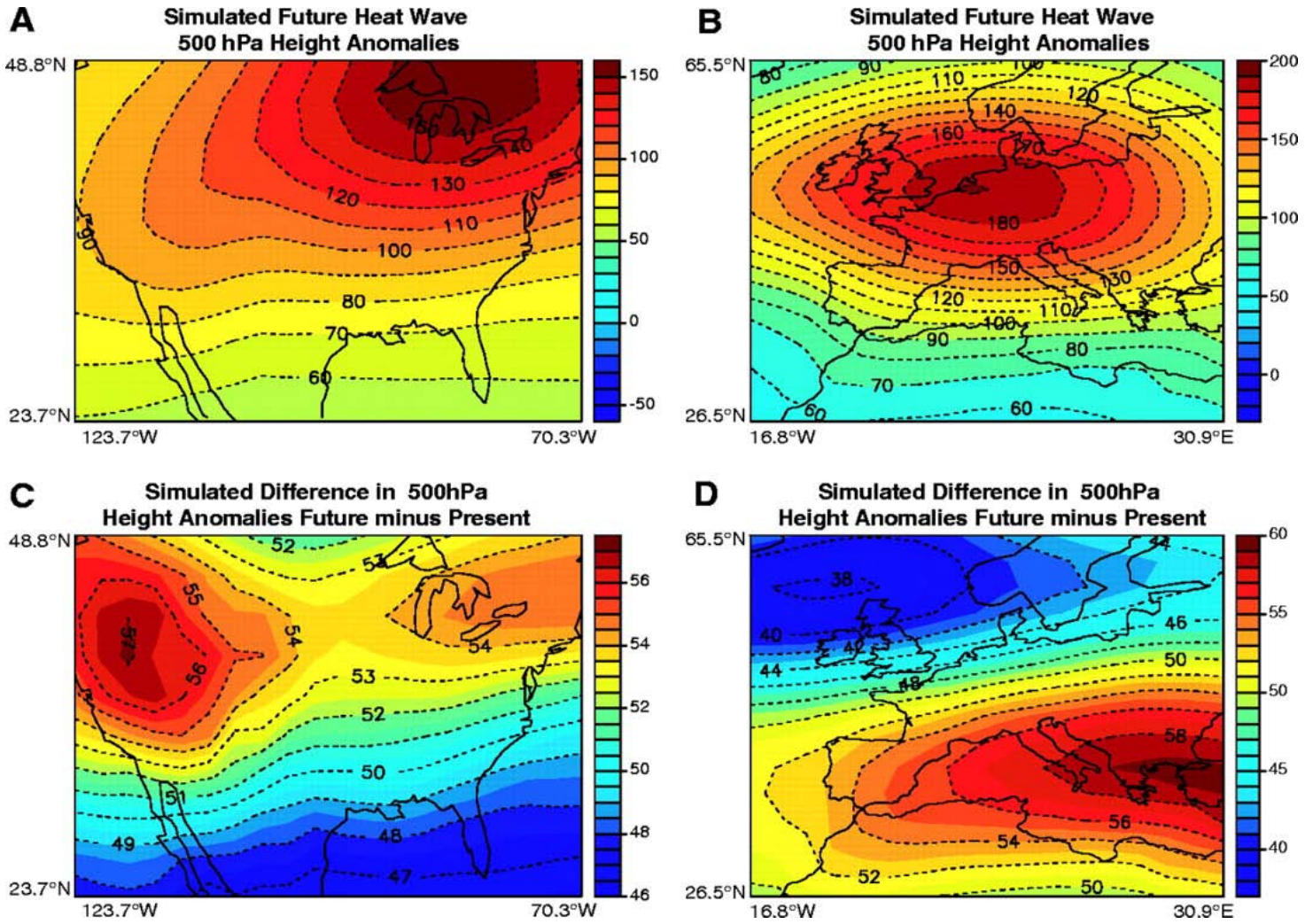
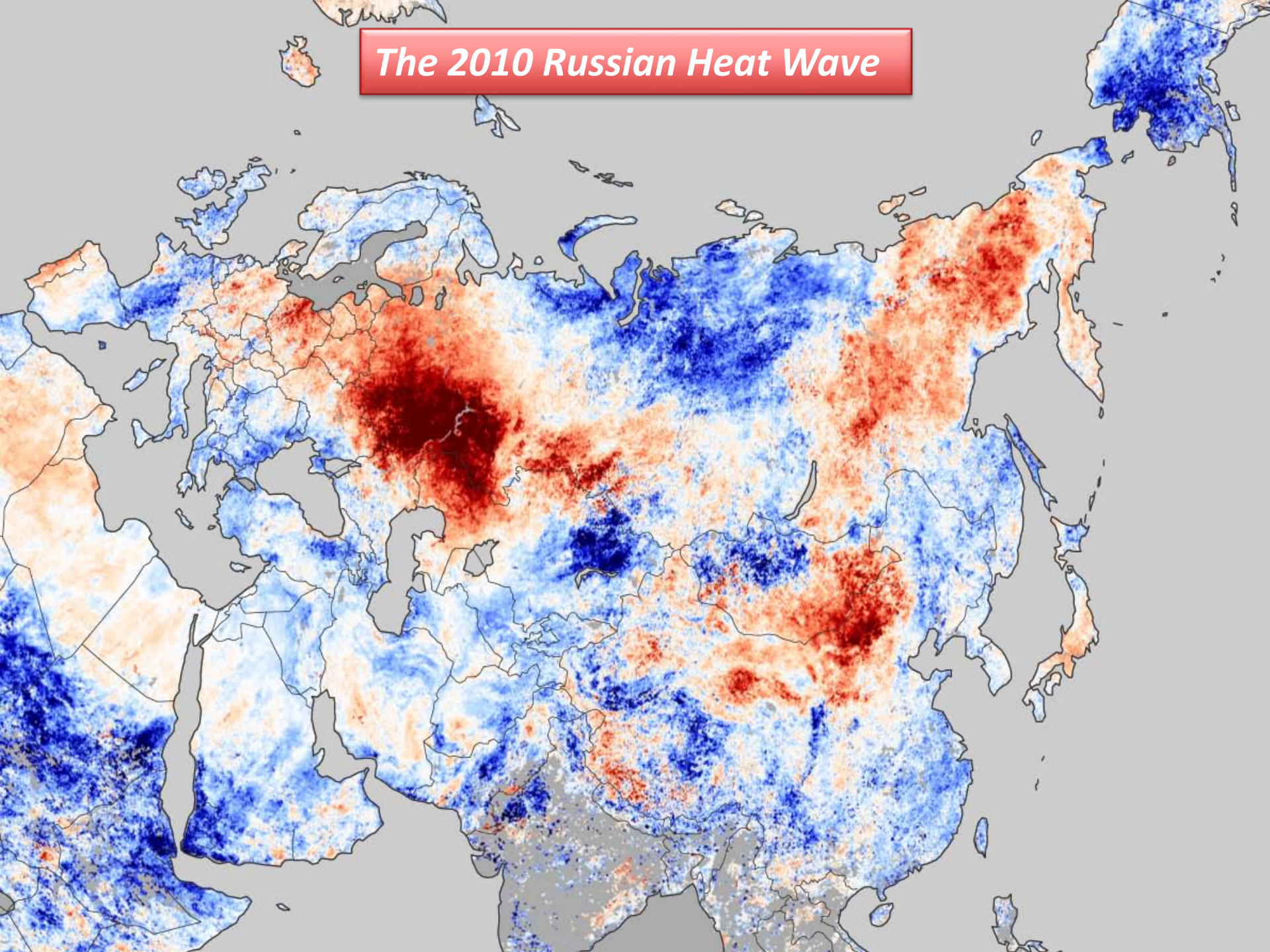


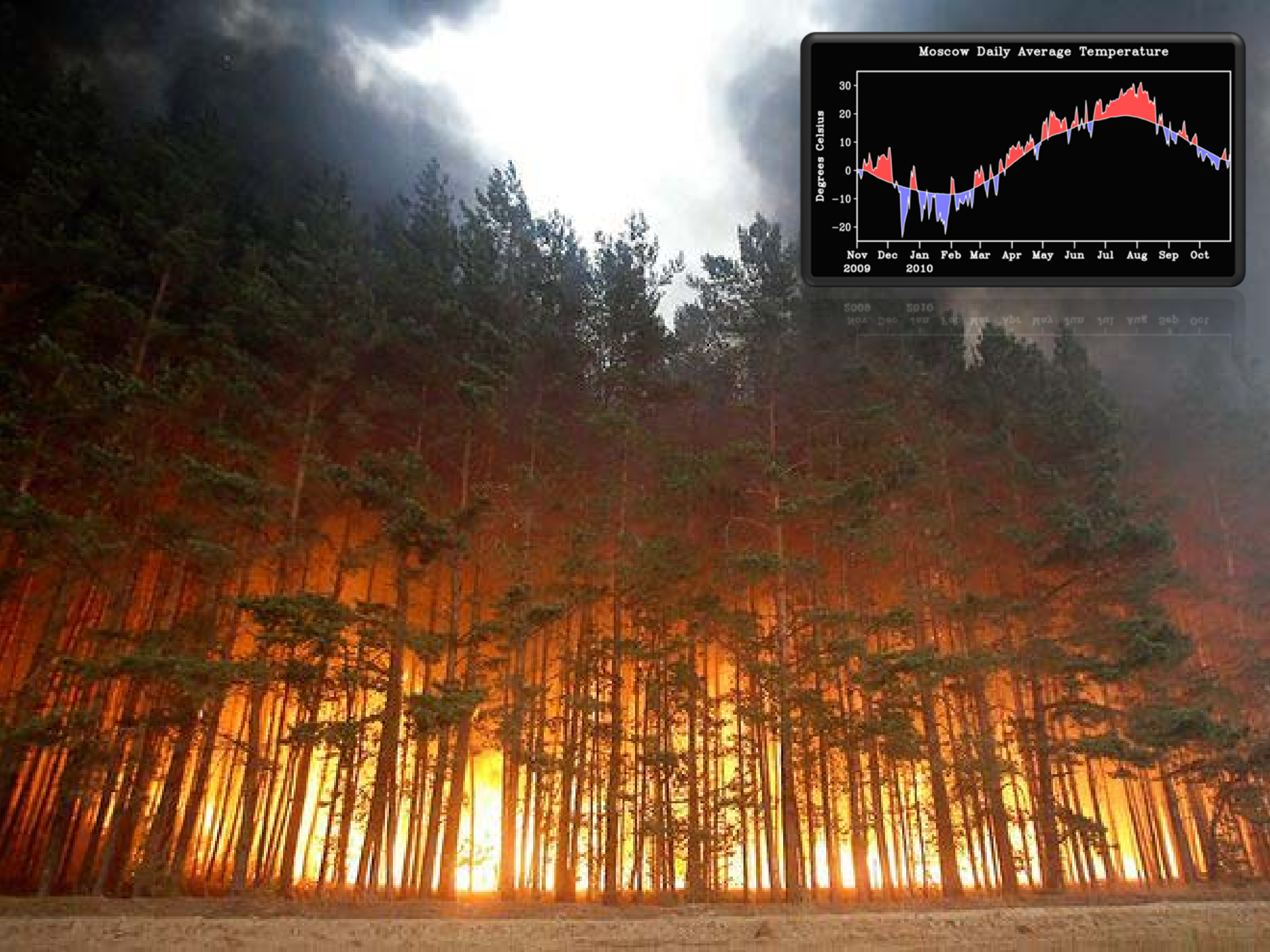
Fig. 4. Height anomalies at 500 hPa (gpm) for events that satisfy the heat wave criteria in the model in future climate (2080 to 2099) for grid points near Chicago (A) and Paris (B), using the same base period as in Fig.



G A Meehl, C Tebaldi Science 2004;305:994-997

The 2010 Russian Heat Wave




Moscow Daily Average Temperature
Degrees Celsius
30
20
10
0
−10
−20
Nov
2009
Dec
Jan
2010
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct