Eurasian Heat Waves and Short-term Droughts*

Attribution of Weather and Climate Extremes Workshop:

9-11 September 2014

Boulder, Colorado

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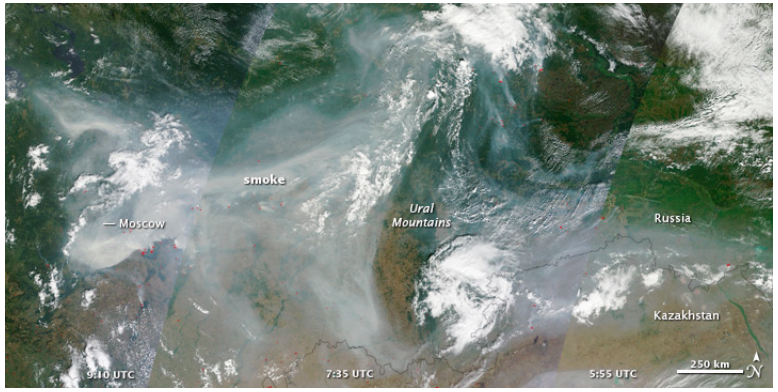
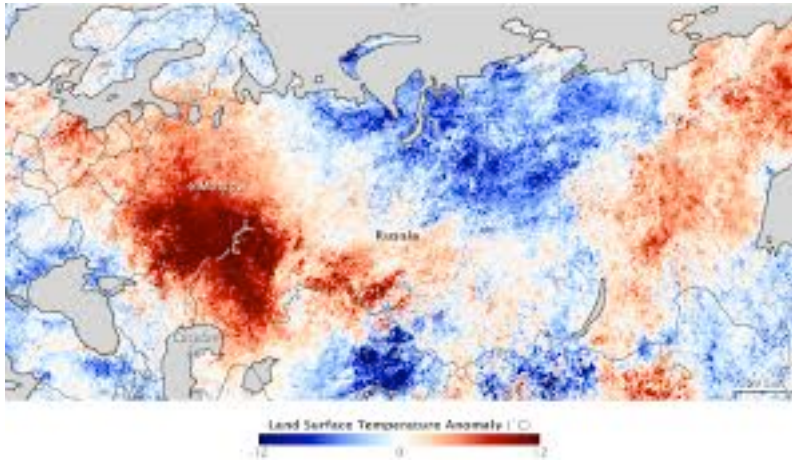
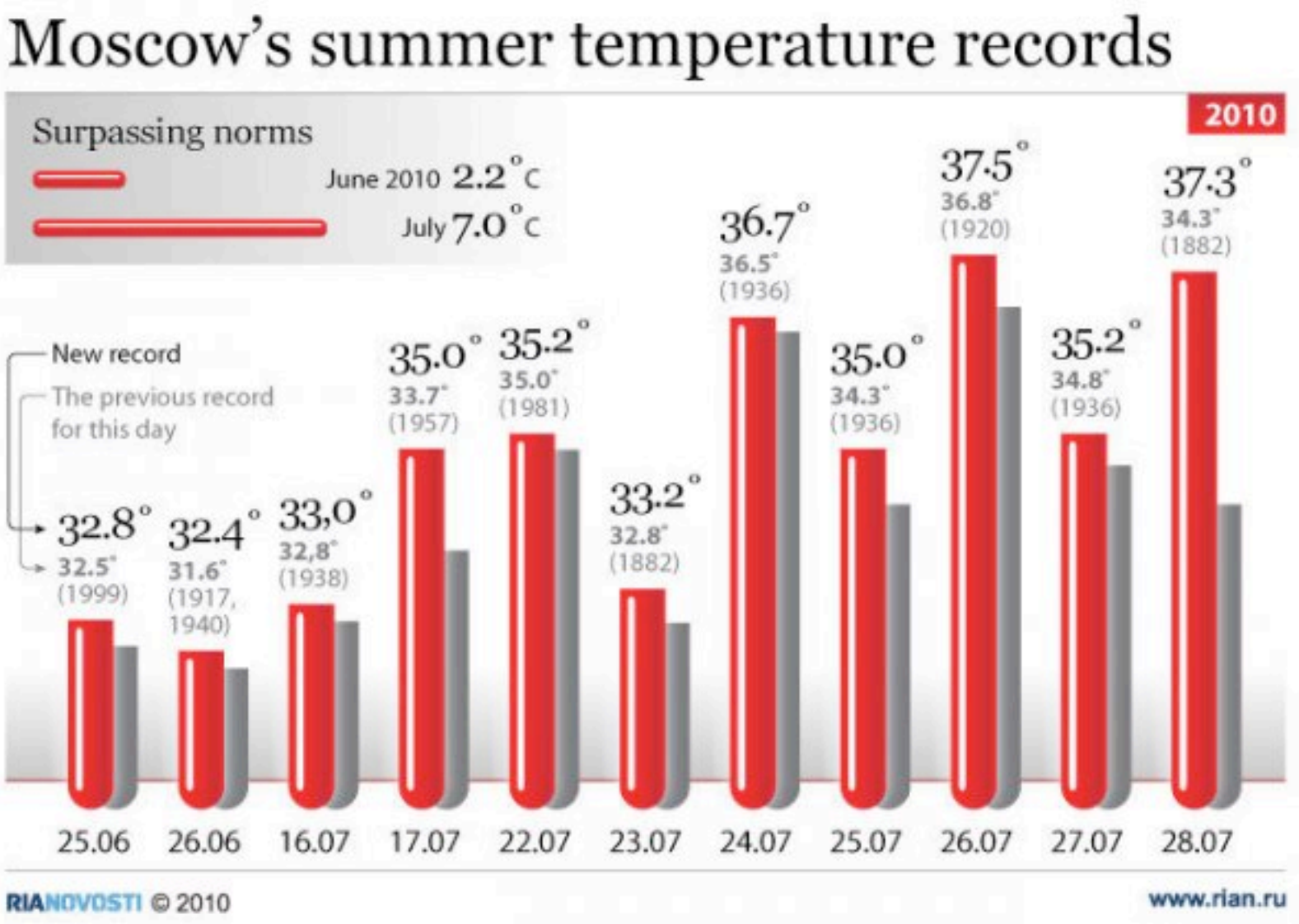
*Northern Eurasian Heat Waves and Droughts, Schubert, S., H. Wang, R. Koster, M. Suarez, and P. Groisman. *J. Climate*, 27, 3169-3207, 2014.

2010 Russian Heat Wave







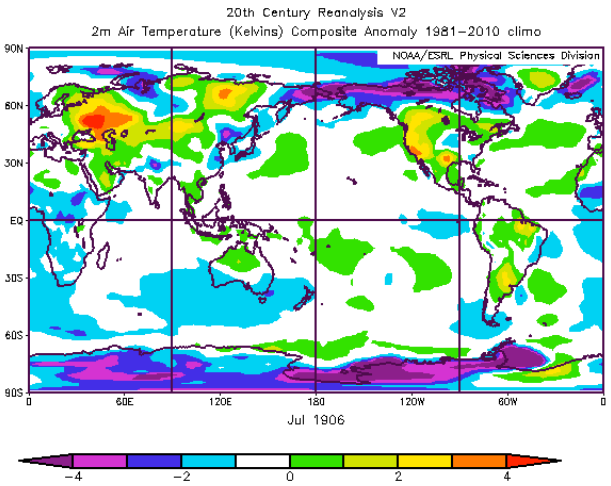
National Yearbooks (Letopisi) prepared by Russian monks: Moscow summary for 1092 says: "*Huge circle was in the sky in this summer, a drought was so strong that soil was burned and many forest and swamps were set in fire themselves*".

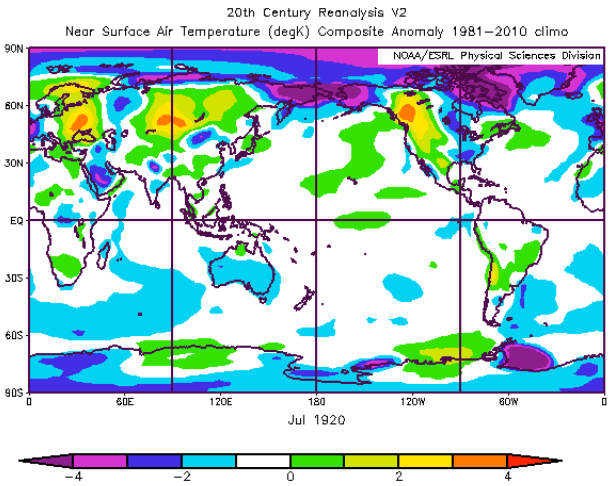
20th Century Reanalysis V2

July 1882

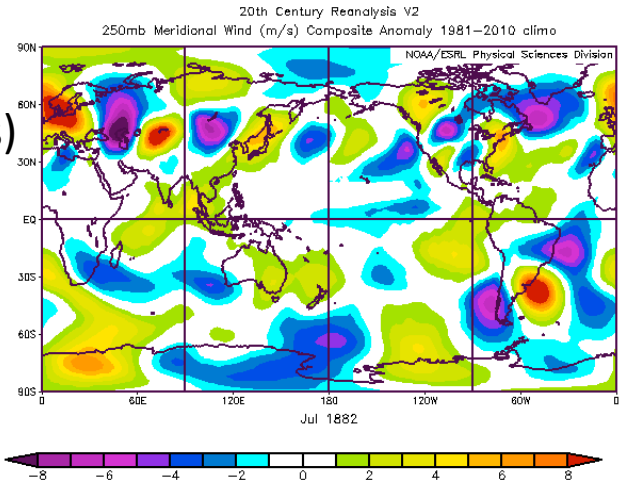
July 1920

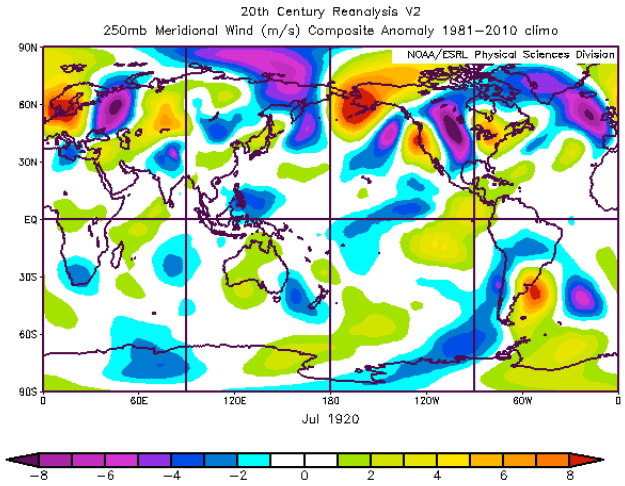
T2m (°C)





V250mb (m/s)



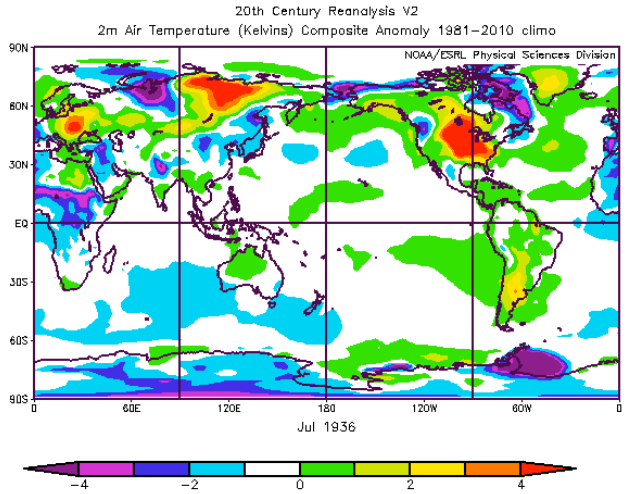


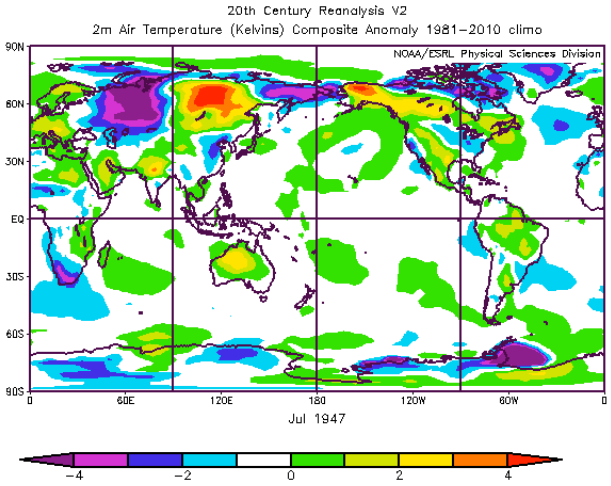
20th Century Reanalysis V2

July 1936

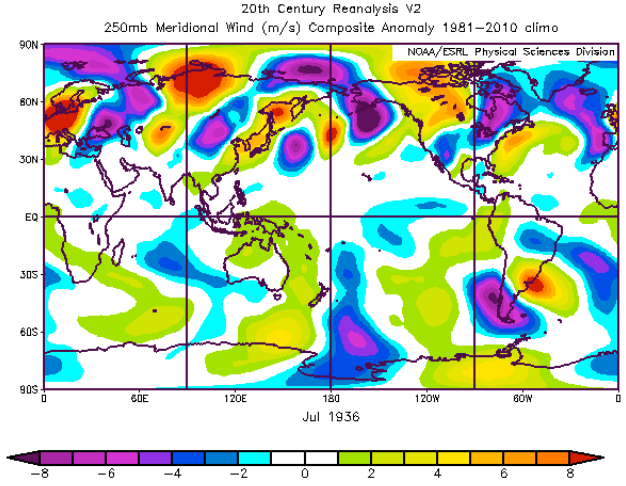
July 1947

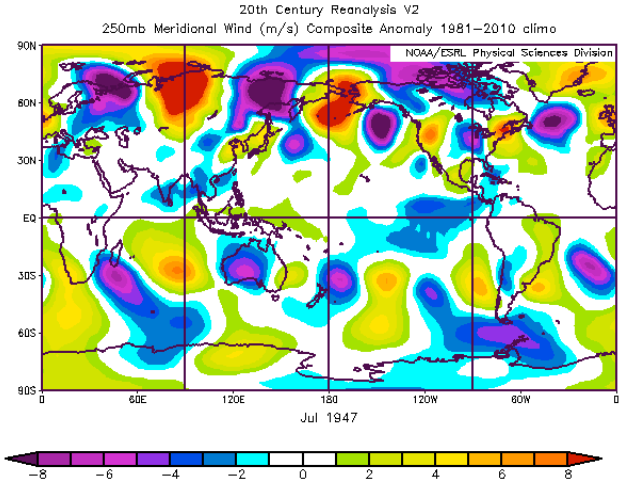
T2m (°C)





V250mb (m/s)

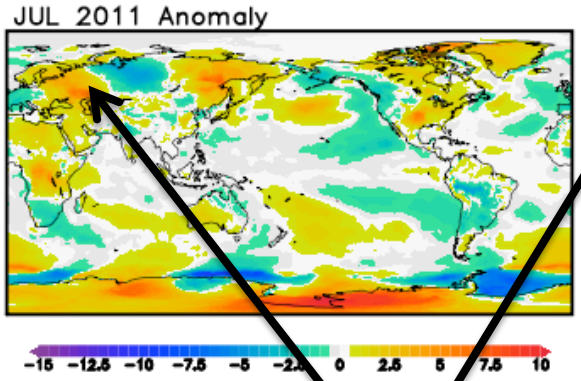




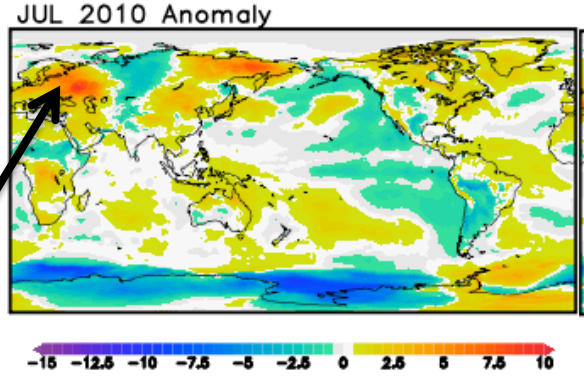
MERRA

Temperature at 2 meters (T2m)

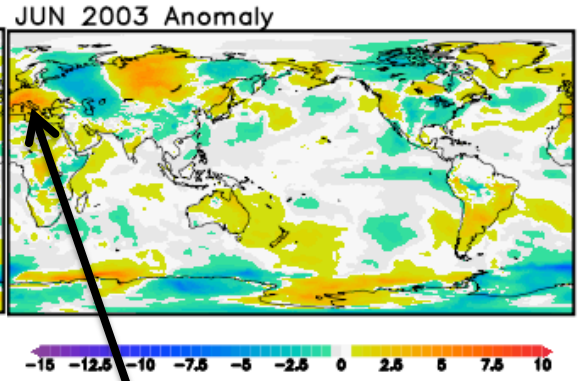
July 2011



July 2010



June 2003

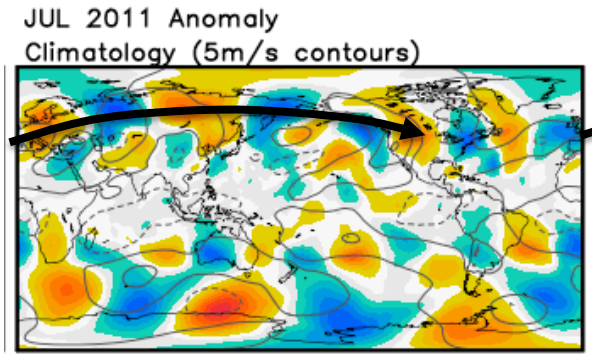


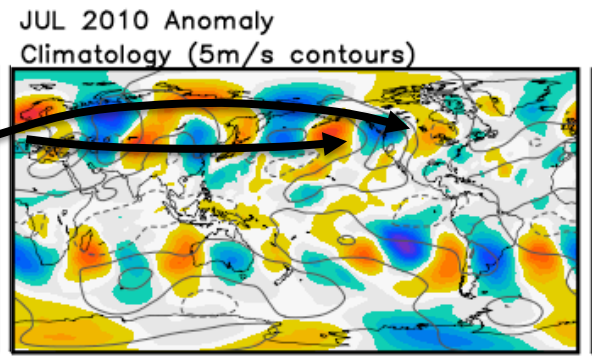
°C

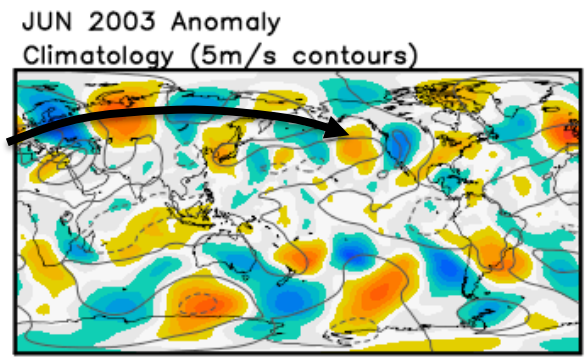
Russian Heat Waves

European Heat Wave

V250mb Anomalies (m/s)

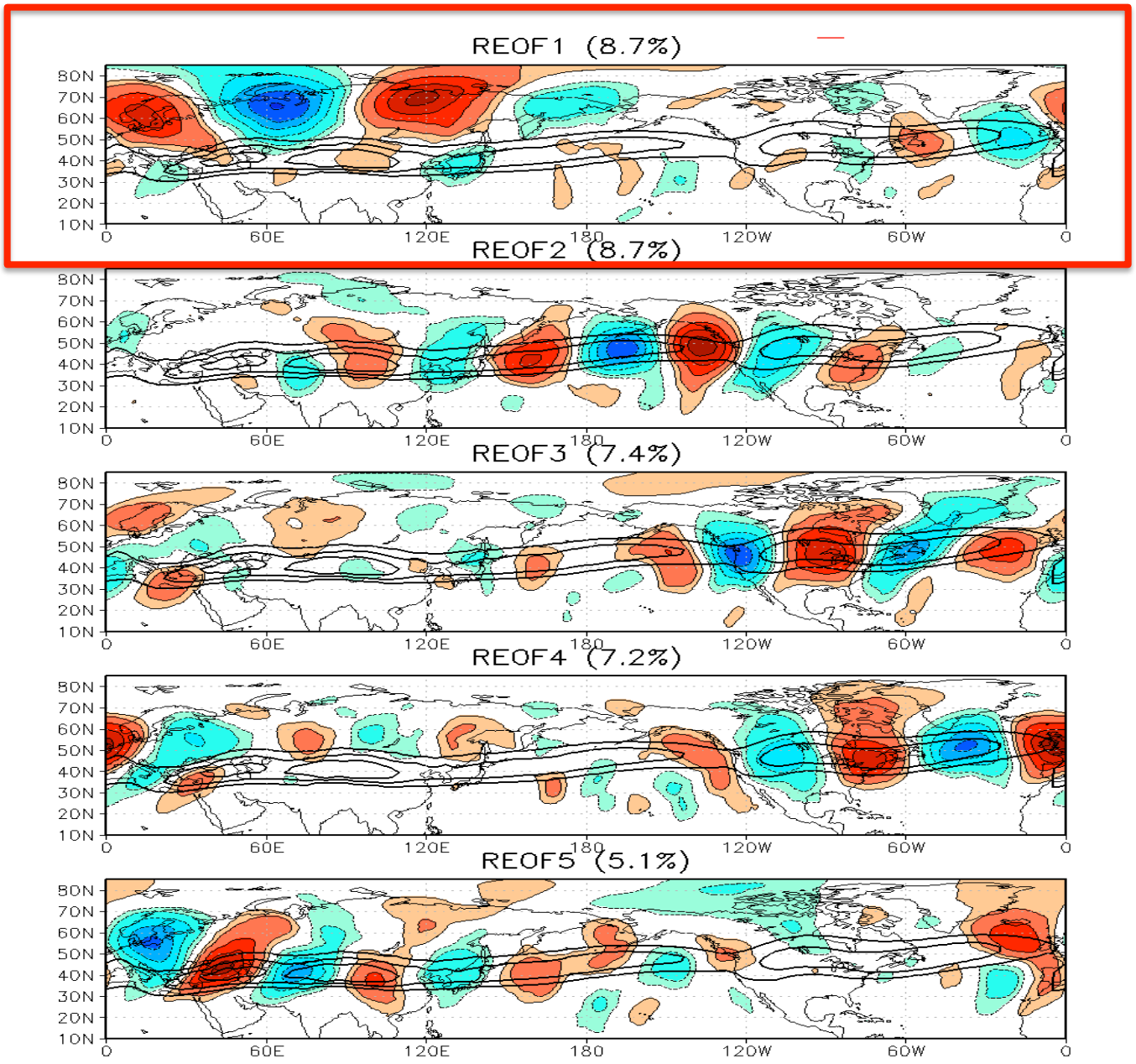






−20 −14 −8 −2 4 10 16

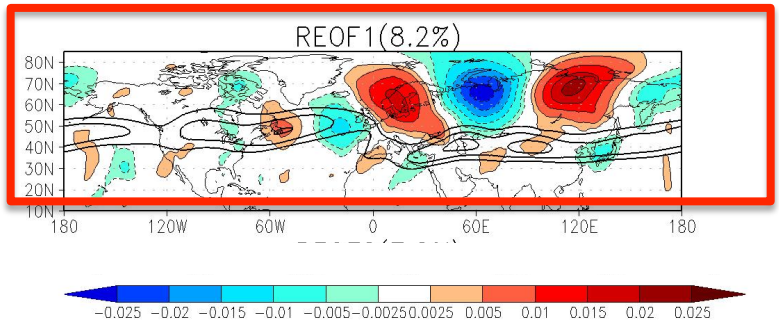
Leading Rotated EOFs of Intraseasonal (Monthly JJA) V250mb

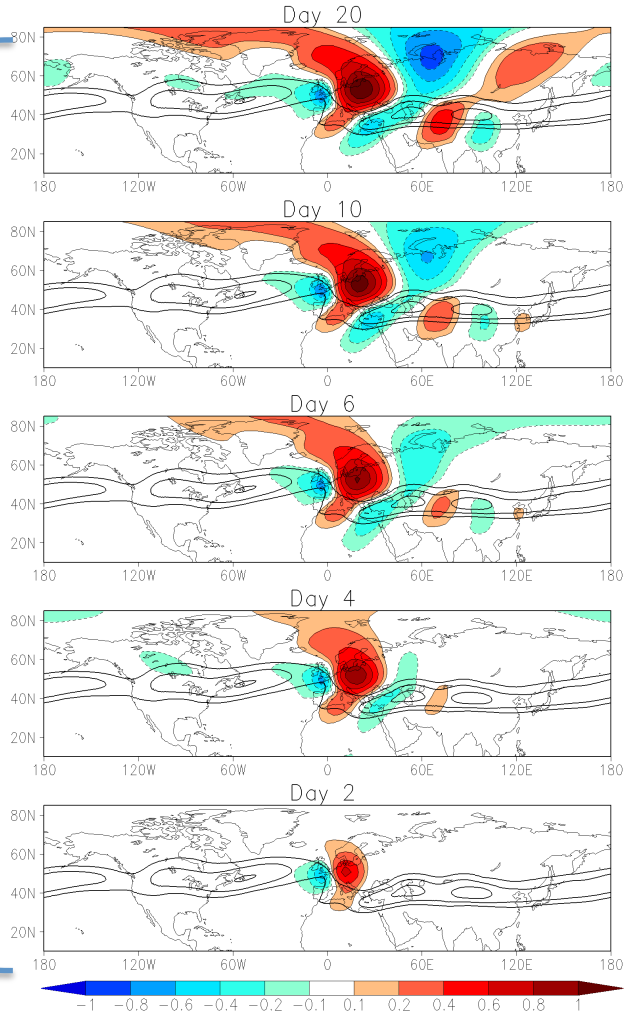


Based on MERRA: 1979- 2010

Stationary Wave Model response of the eddy v-wind at σ=0.257 to an idealized vorticity source at 0E, 50N

REOF 1





Day 20

Day 10

Day 6

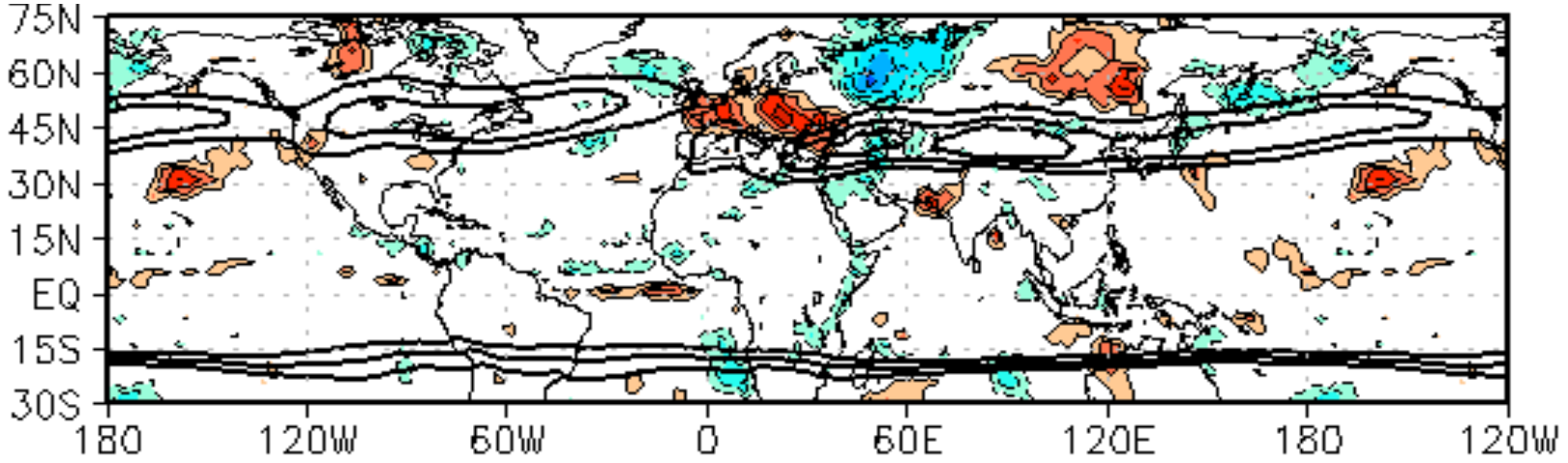
Day 4

Day 2

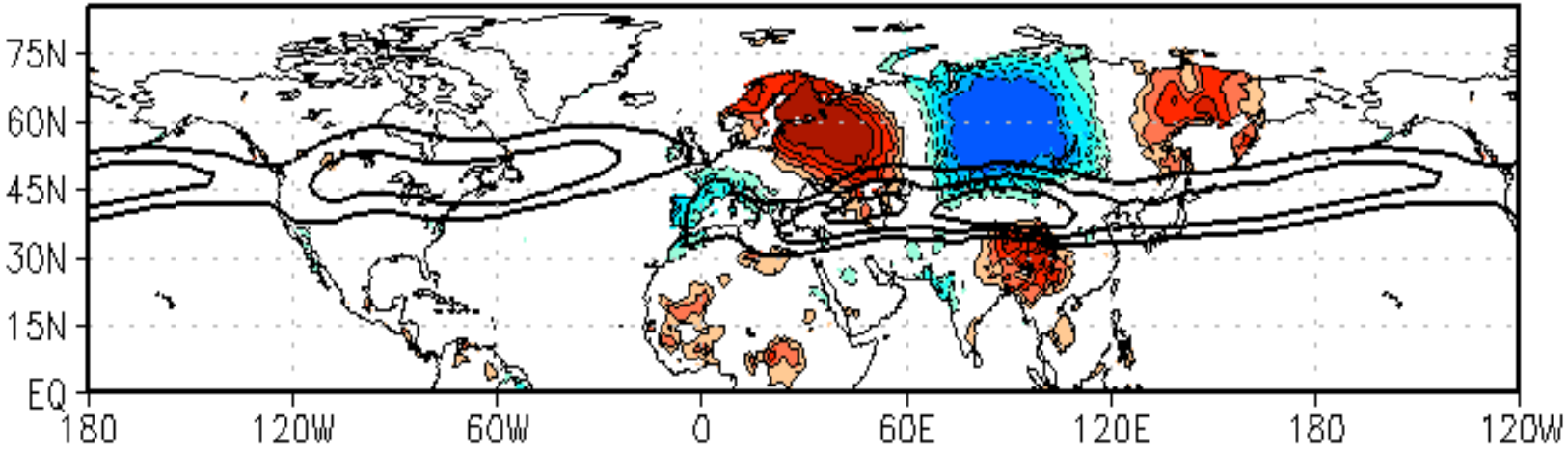
MERRA Base State: JJA 1979-2010

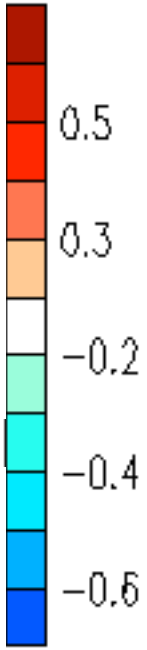
Correlation Between V250 REOF 1 and T2m

GPCP Precipitation



HADCRU Gridded Station Data T2m





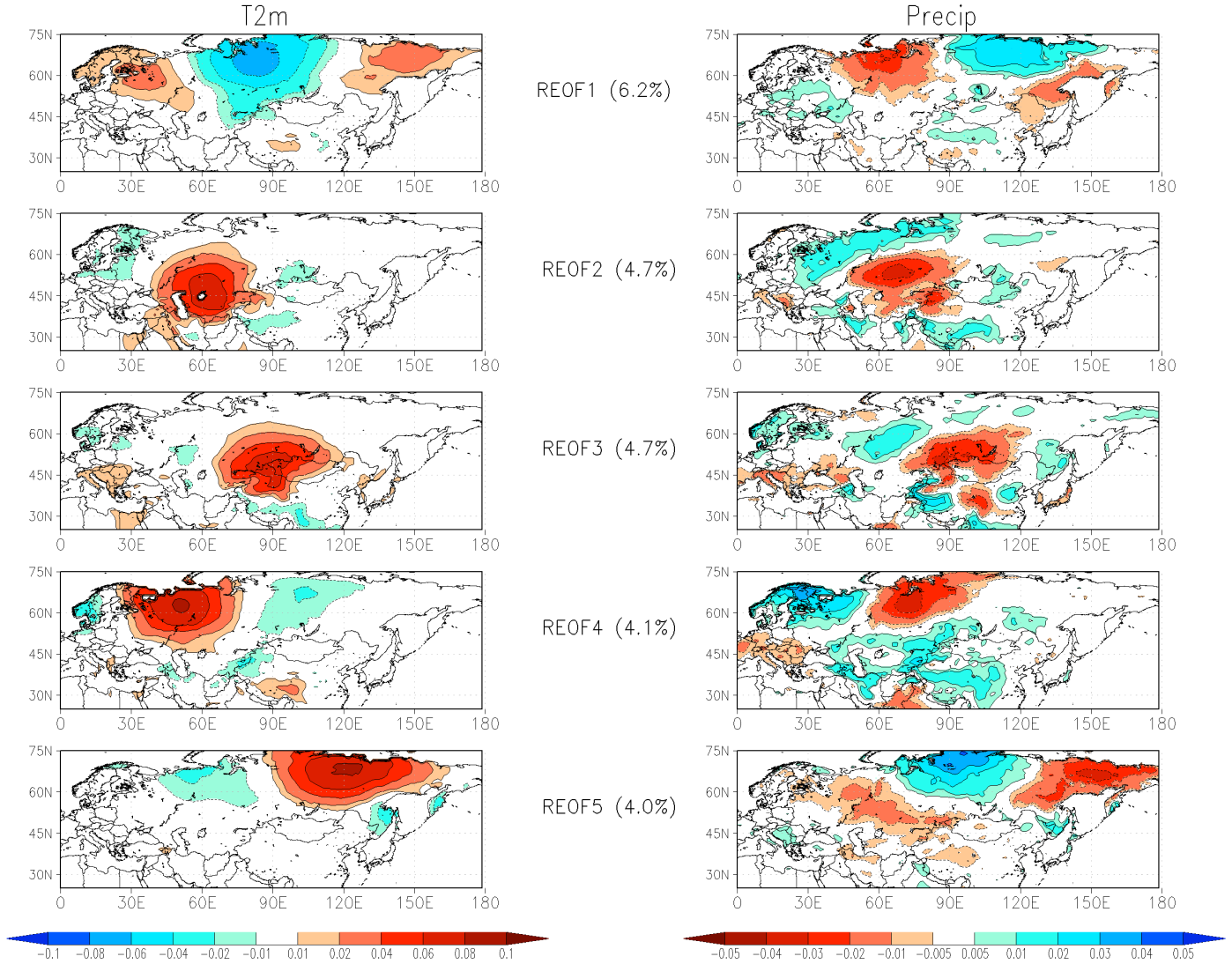
Based on Monthly (subseasonal) data JJA (1979-2008)

Leading Eurasian Patterns of Subseasonal (Monthly, JJA) T2m and Precipitation

GEOS-5 AGCM

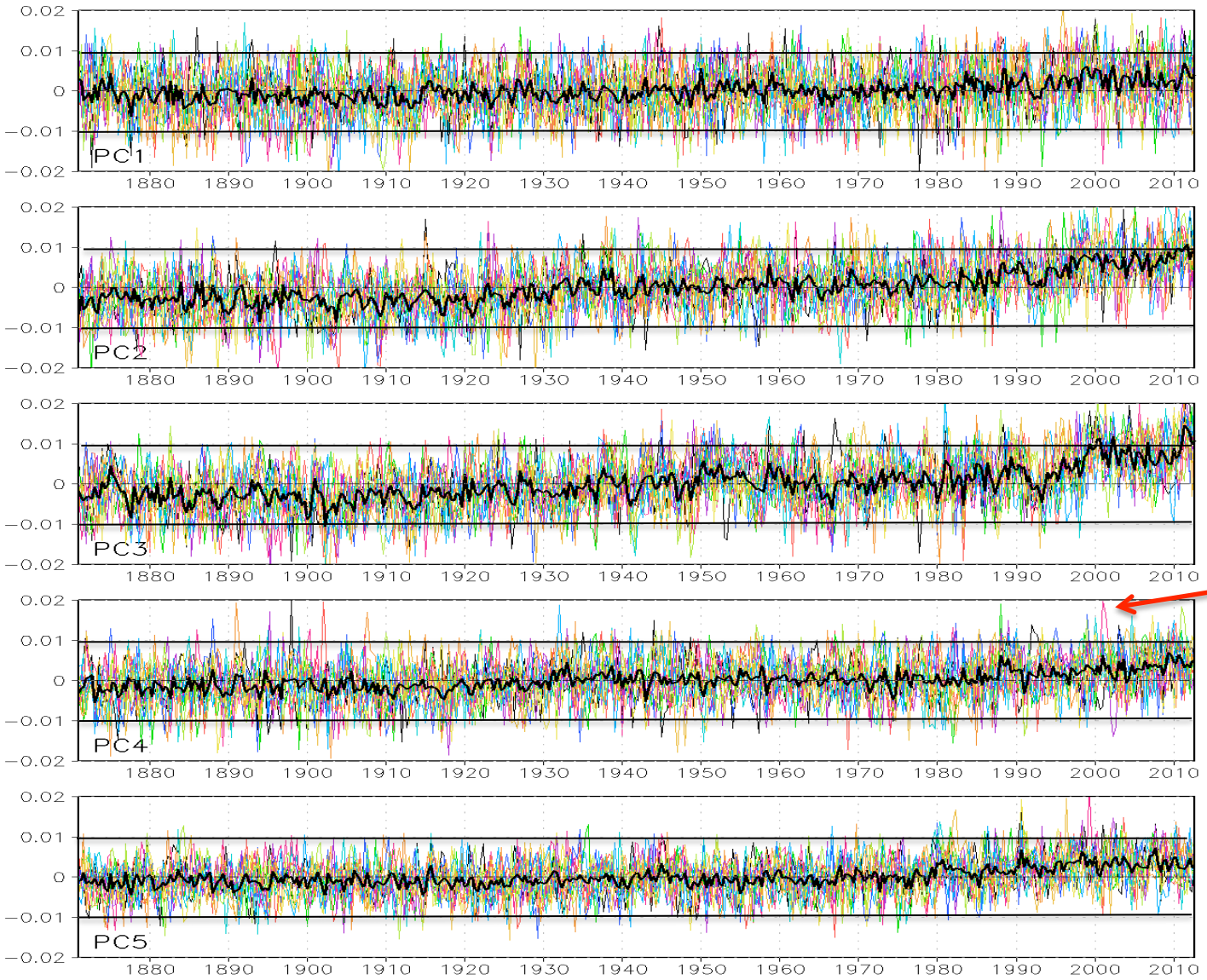
- 12 ensemble members (1871-2012)

Leading REOFs of Combined T2m and Precipitation GEOS-5 (JJA, 1979-2012, 12 members)



linked to western Russia heat waves

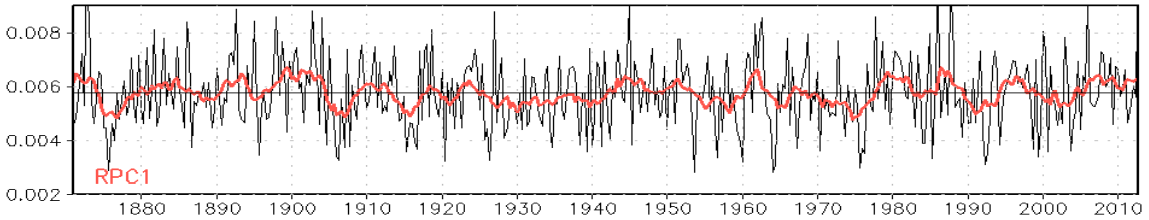
12 Ensemble members (Leading 5 RPCs)



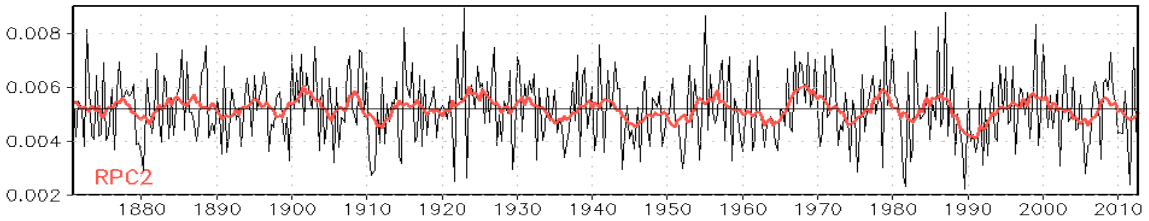
Any Trends in Variance?

JJA Monthly Intraensemble Variance of Each RPC

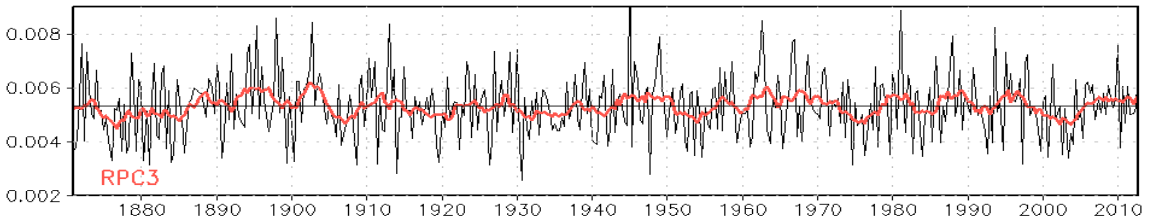
RPC 1



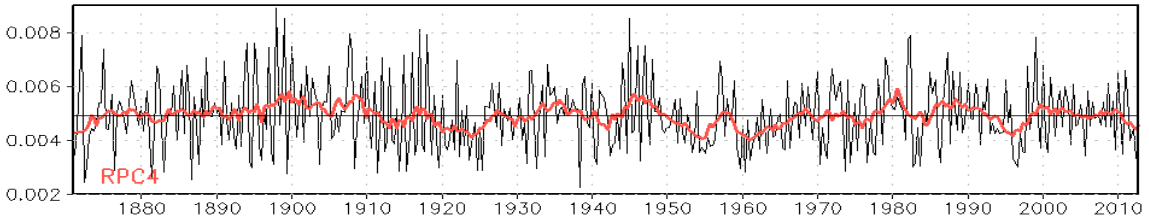
RPC 2



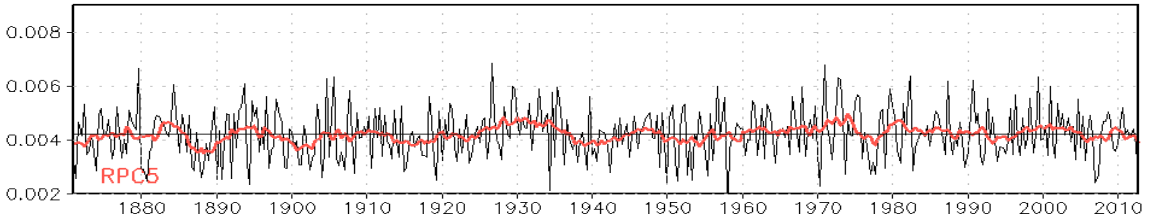
RPC 3



RPC 4



RPC 5



12 Ensemble members (Leading 5 RPCs)

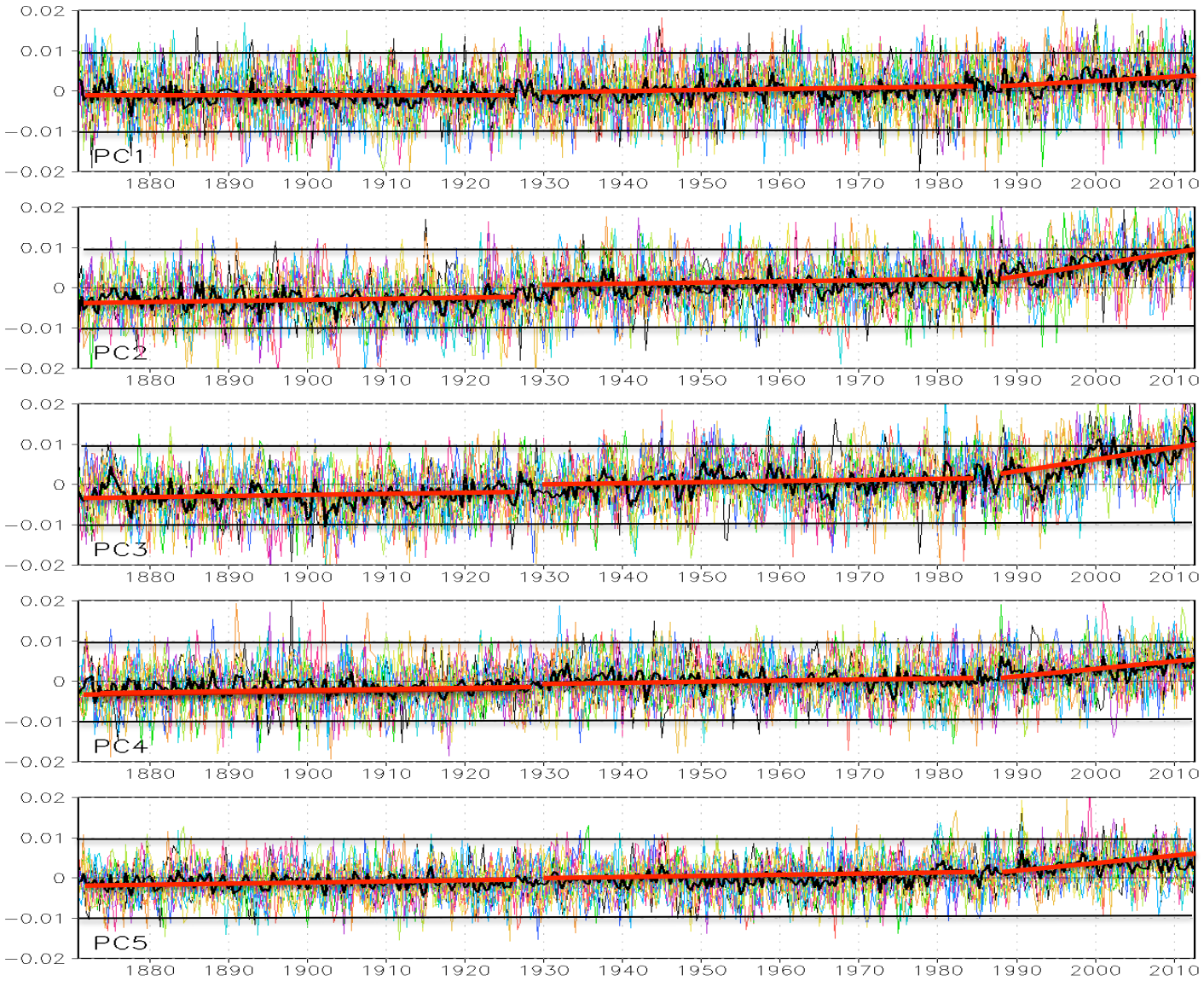
RPC 1

RPC 2

RPC 3

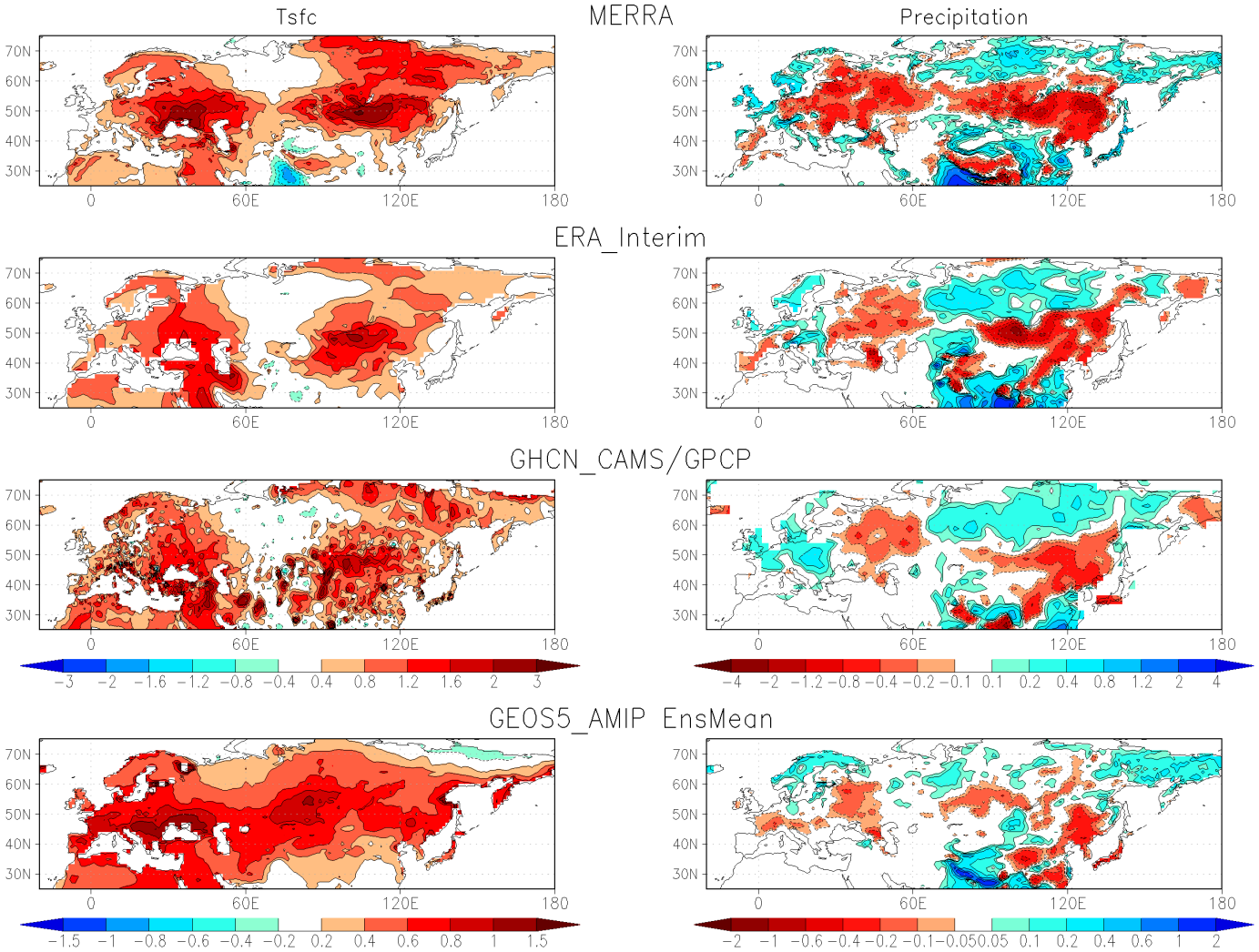
RPC 4

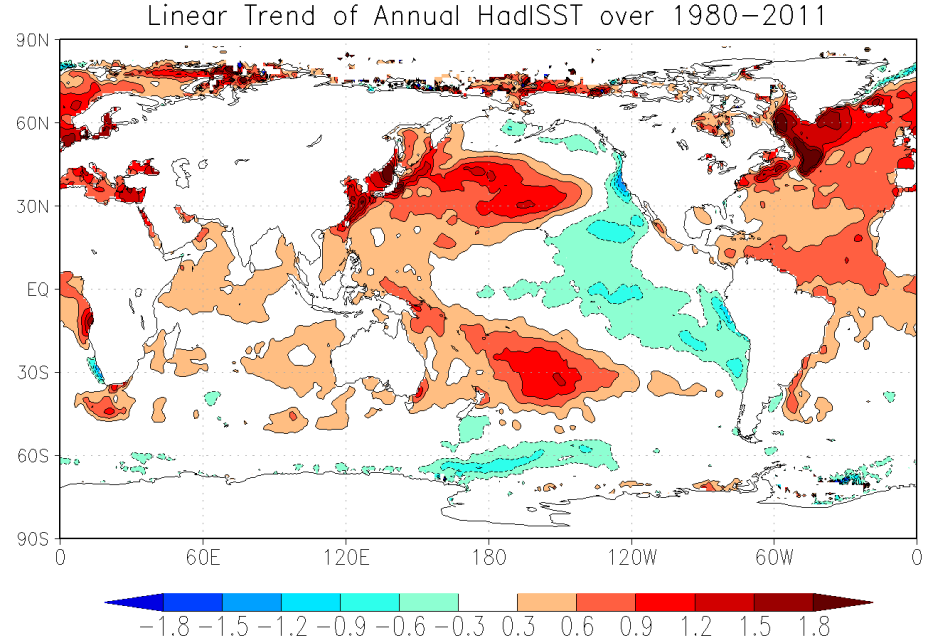
RPC 5

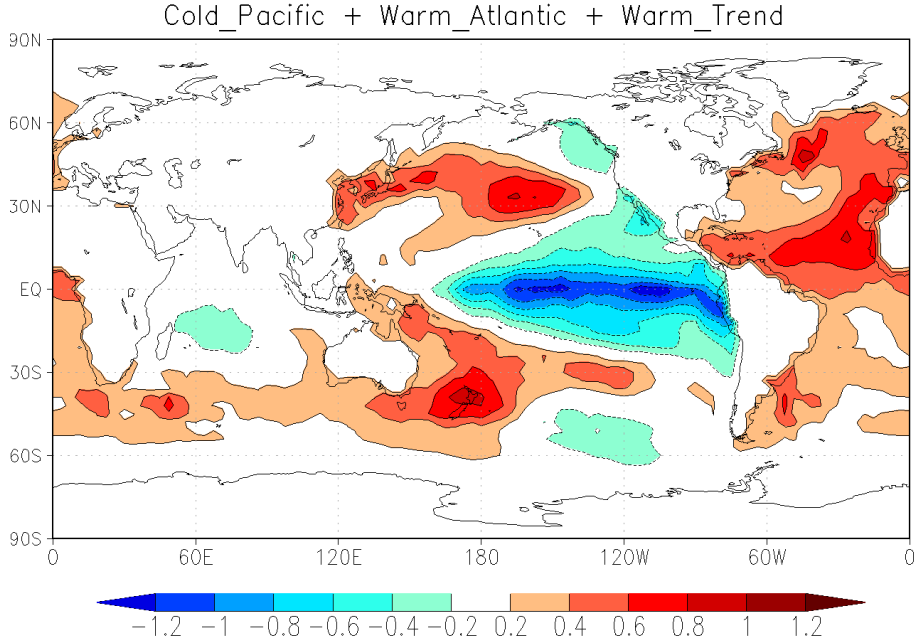


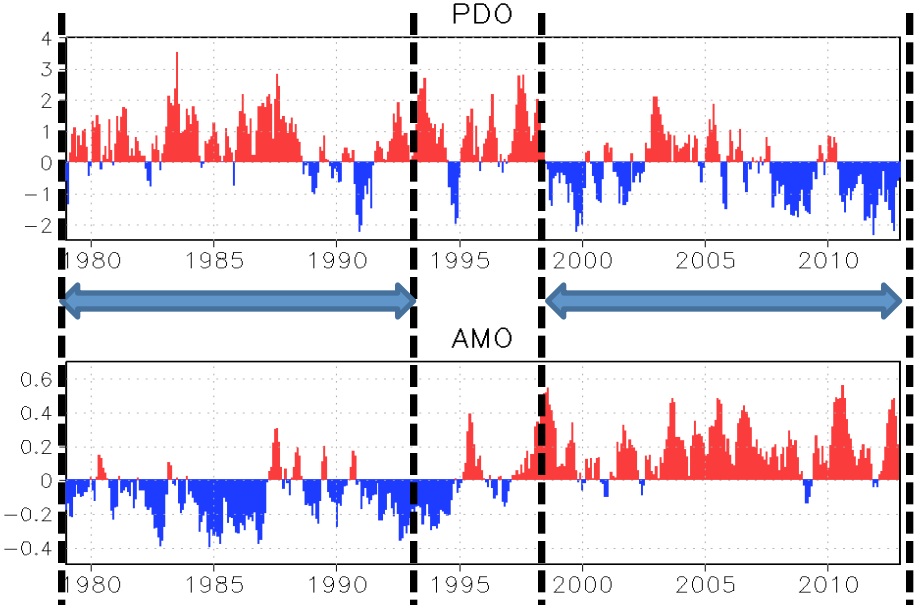
Nature of Recent “Trends” (1979-2012)

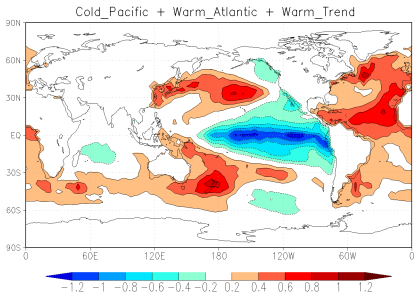
JJA means (1996-2011 minus 1980-1995)




Linear Trend of Annual HadISST over 1980–2011
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
−1.8 −1.5 −1.2 −0.9 −0.6 −0.3 0.3 0.6 0.9 1.2 1.5 1.8

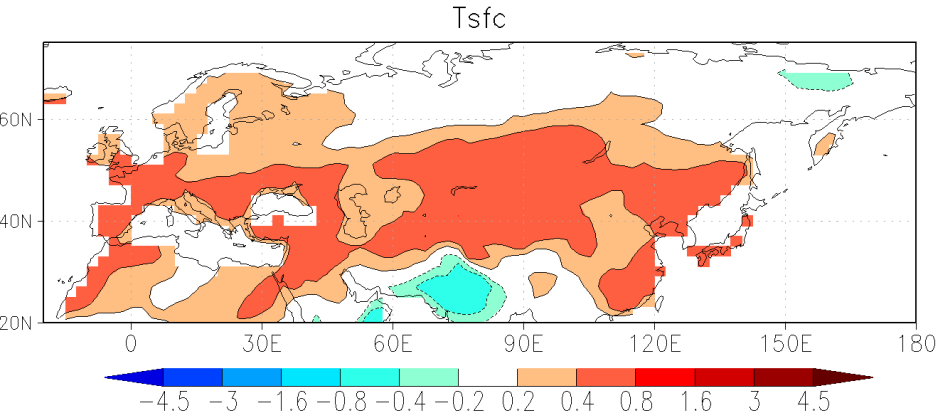

Cold_Pacific + Warm_Atlantic + Warm_Trend
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
−1.2 −1 −0.8 −0.6 −0.4 −0.2 0.2 0.4 0.6 0.8 1 1.2

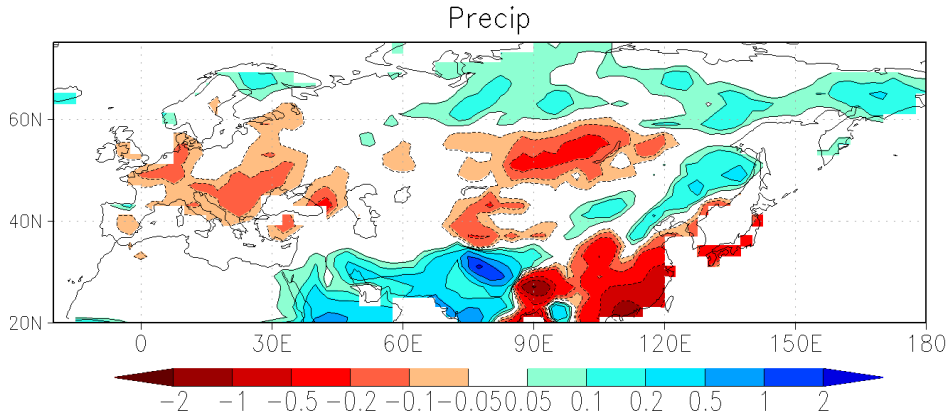

PDO
4
3
2
1
0
−1
−2
1980
1985
1990
1995
2000
2005
2010
AMO
0.6
0.4
0.2
0
−0.2
−0.4
1980
1985
1990
1995
2000
2005
2010

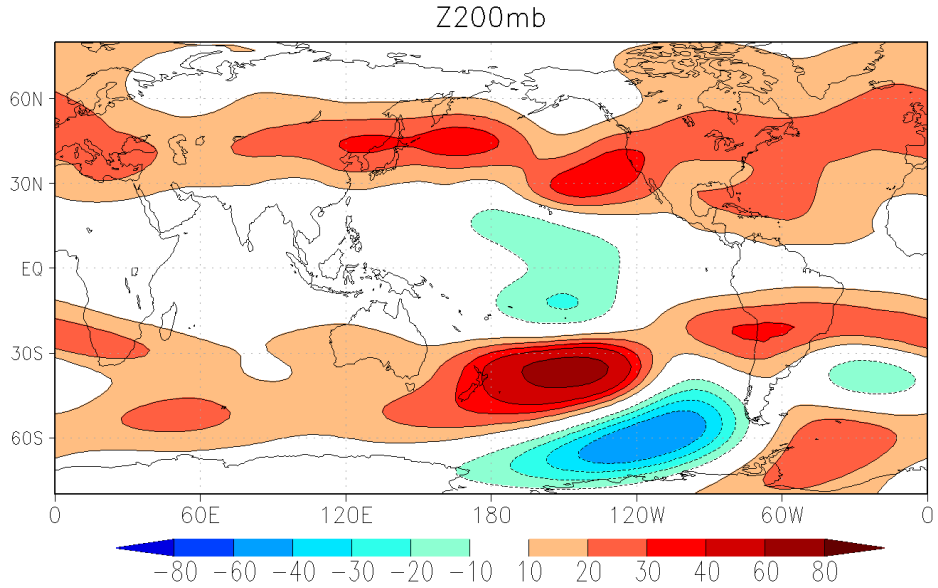


JJA Responses to idealized SST forcing pattern

(CCM3, GEOS-5, GFS, and GFDL).

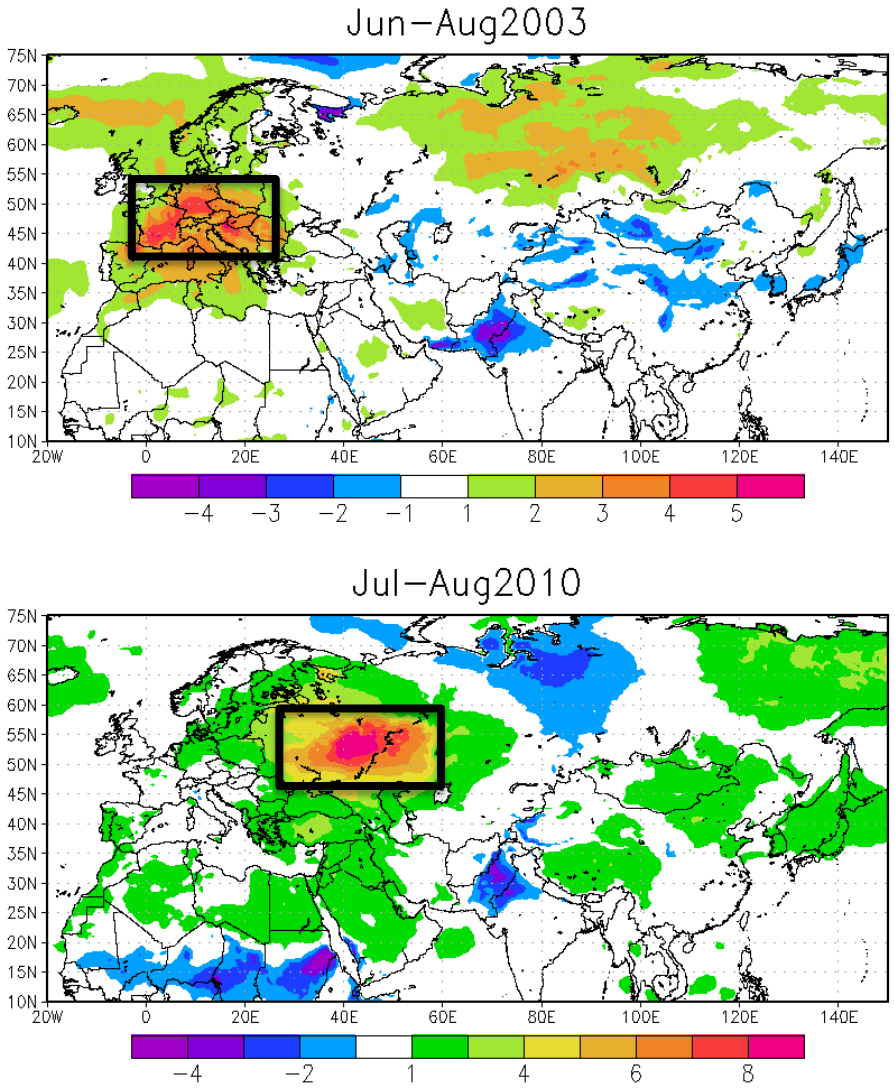






Another Look at Long Term Changes (1871-2012)

MERRA: T2m Anomaly (°C)

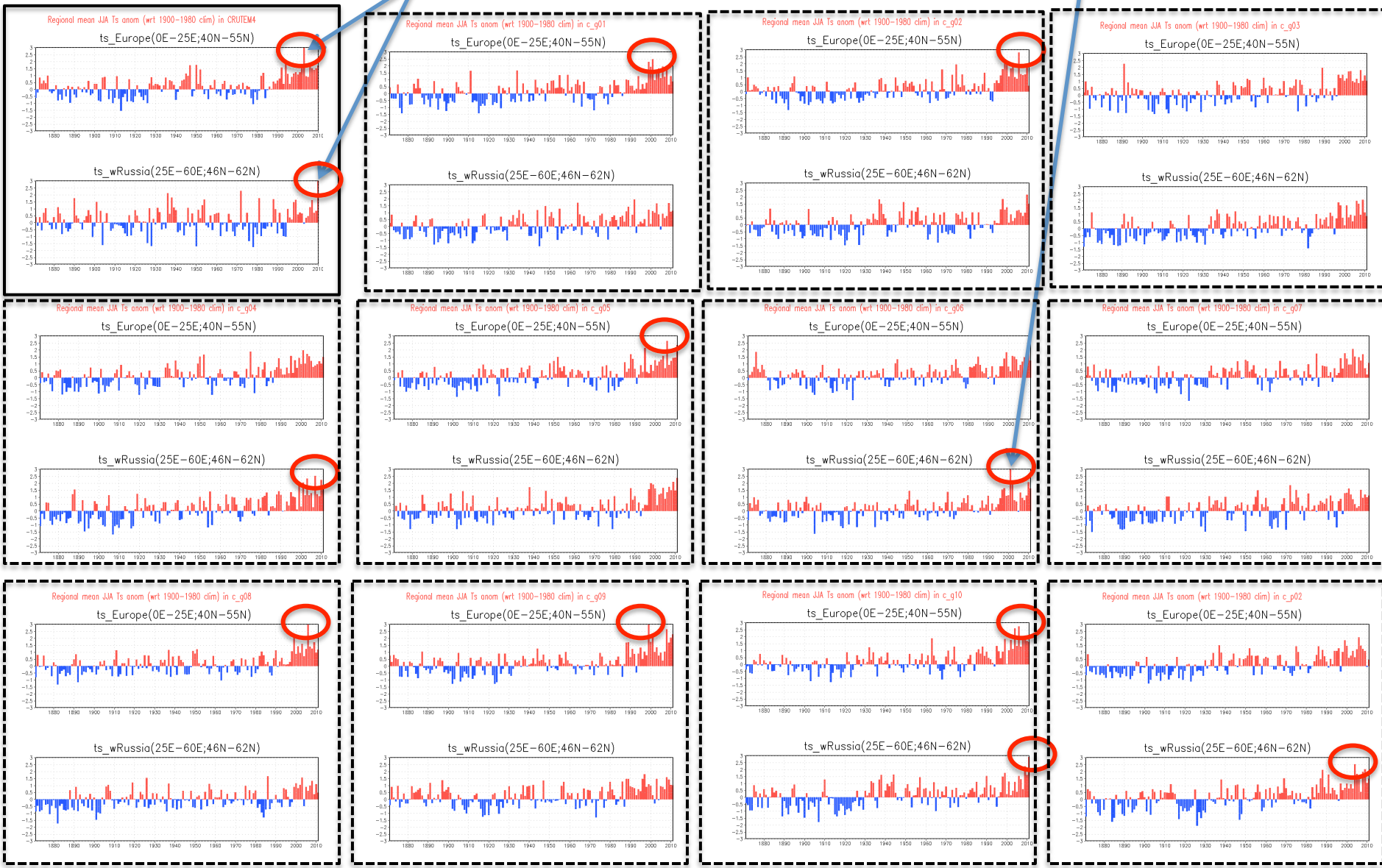


Area Averages: European region: 0-25E; 40N-55N;
western Russia region: 25E-60E;46N-62N

European and Russian T2m (1871-2010; Observed and Simulated)

Observed 2003 European and 2010 Russian Heat Waves

Simulated 2001 Russian Heat Wave

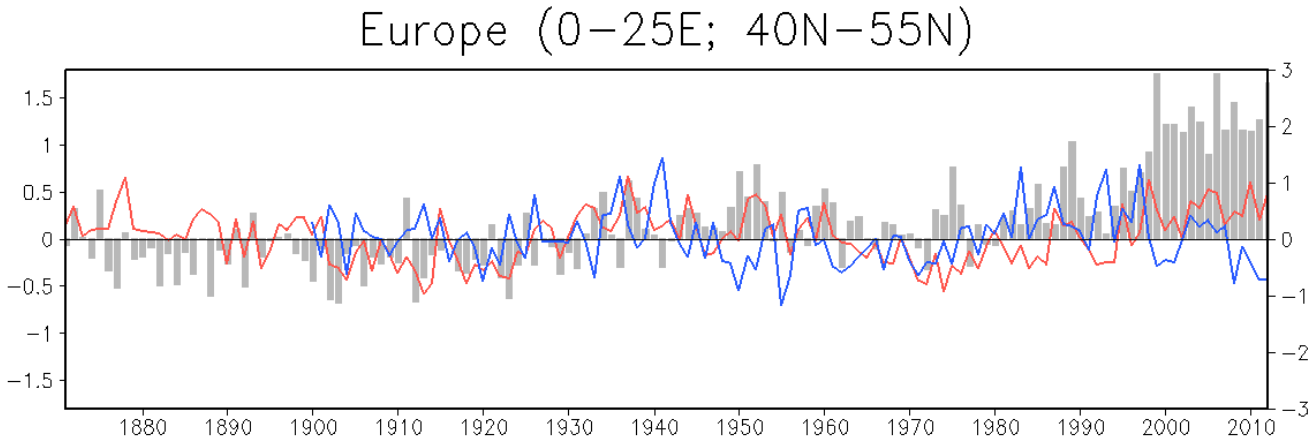


Simulations produce 4 western Russia and 6 European extreme heat waves

Ensemble Mean JJA T2m

(AMO index- red, PDO index- blue)

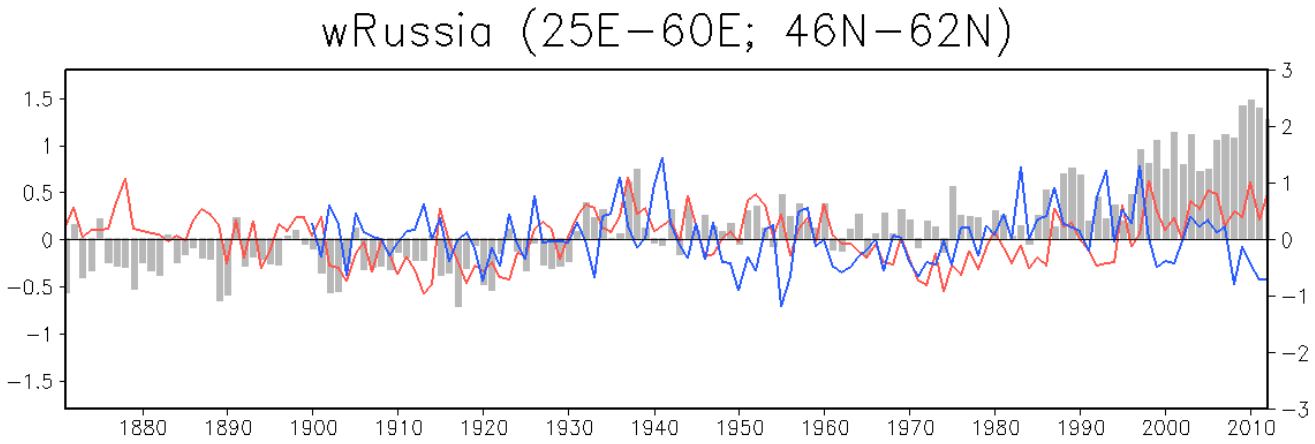
(Climatology is 1900-1980)



Temporal correlation for JJA1900-2012

Corr PDO= -.21

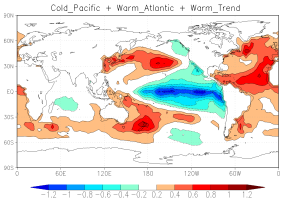
Corr AMO = 0.56



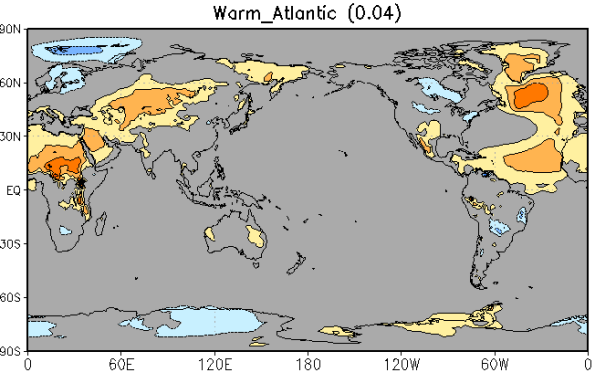
Corr PDO= -0.08

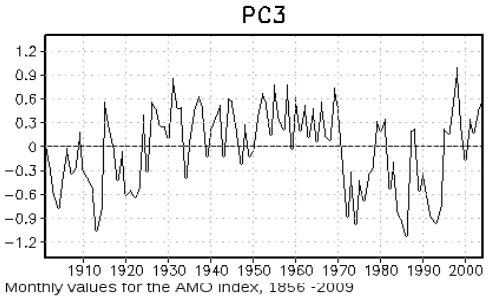
Corr AMO = 0.54

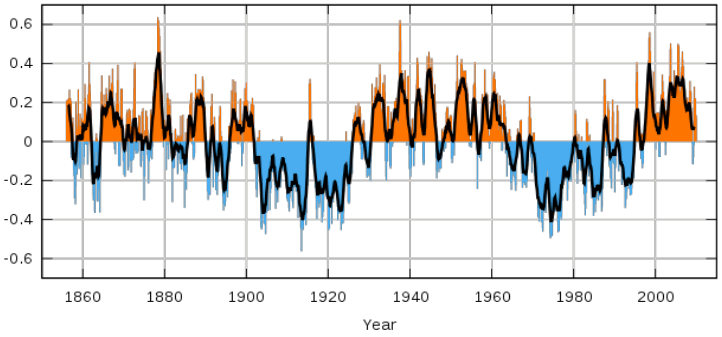
Response to Idealized SST Components
GEOS-5 AGCM (T2m °C)



"AMO"

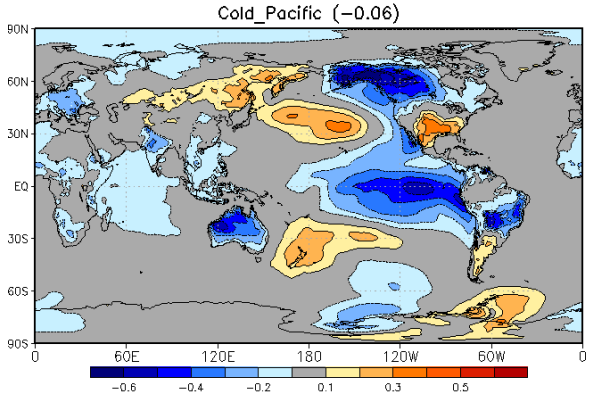


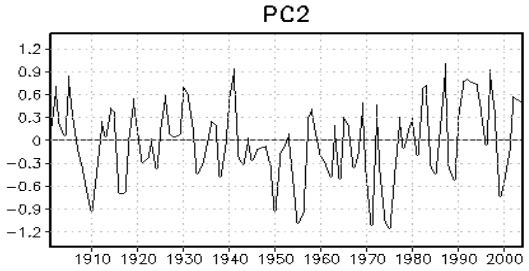


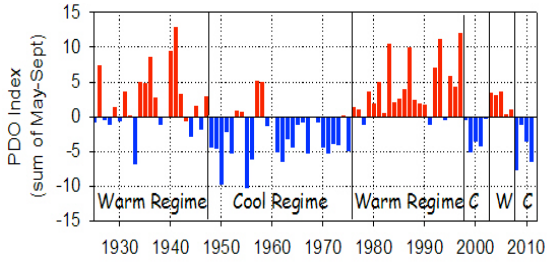


http://en.wikipedia.org/wiki/File:Amo_timeseries_1856-present.svg

"PDO"

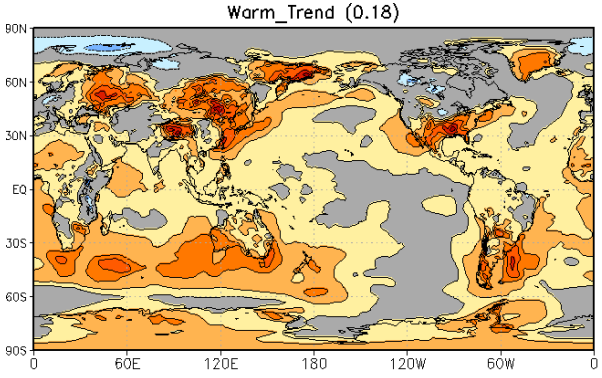


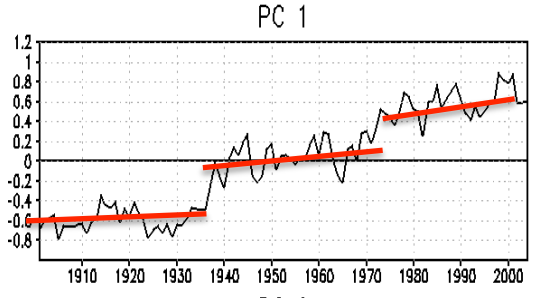




http://jisao.washington.edu/pdo/

"Trend"



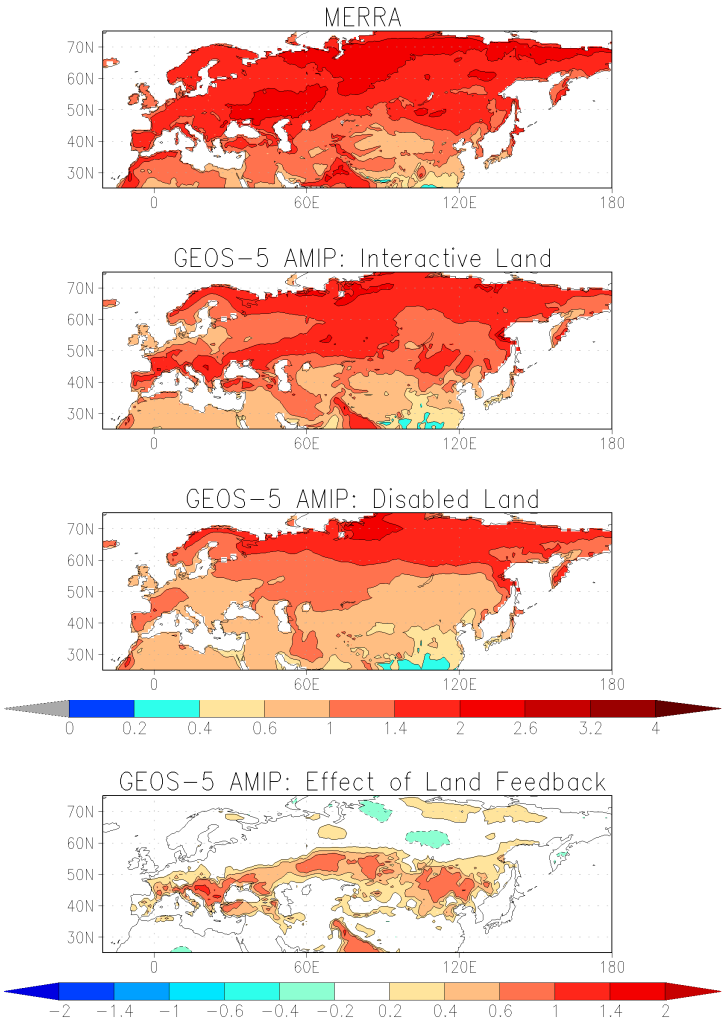


Schubert et al. 2009

Role of Soil Moisture

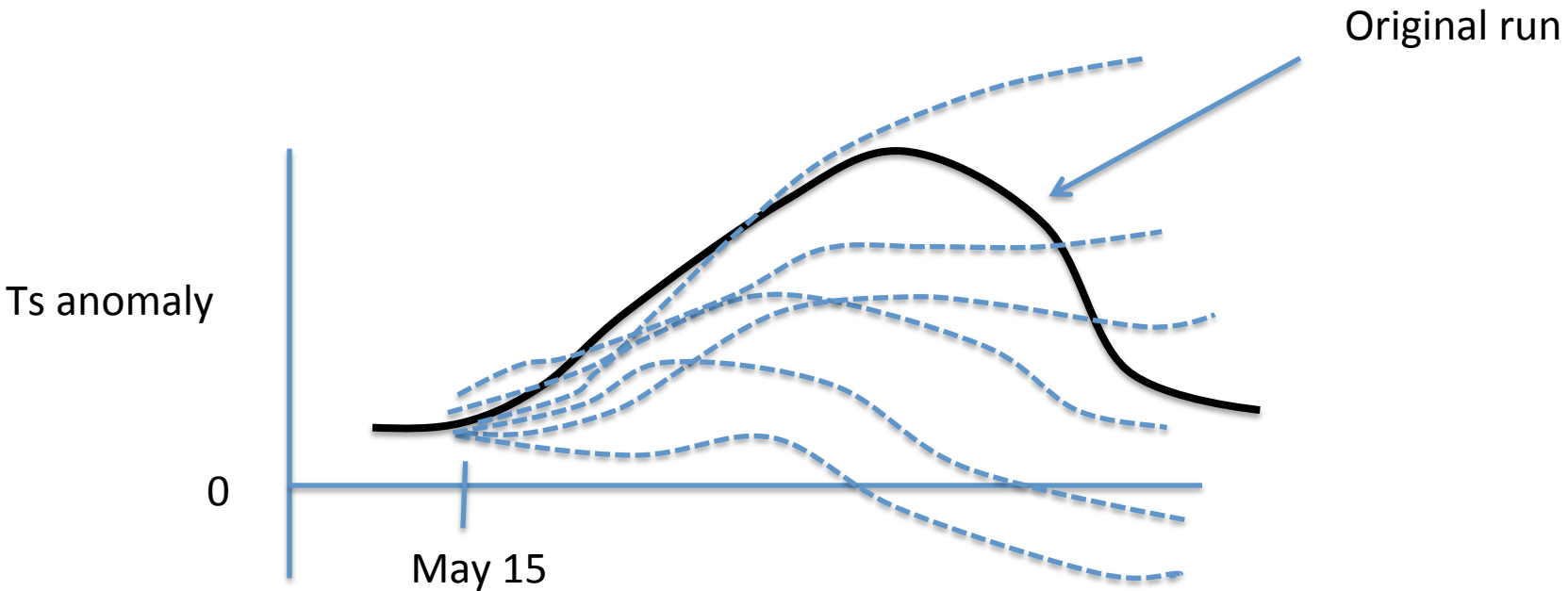
- Impact on T2m
- Impact on circulation

StDev of monthly JJA T2m (1980-2012)
°C

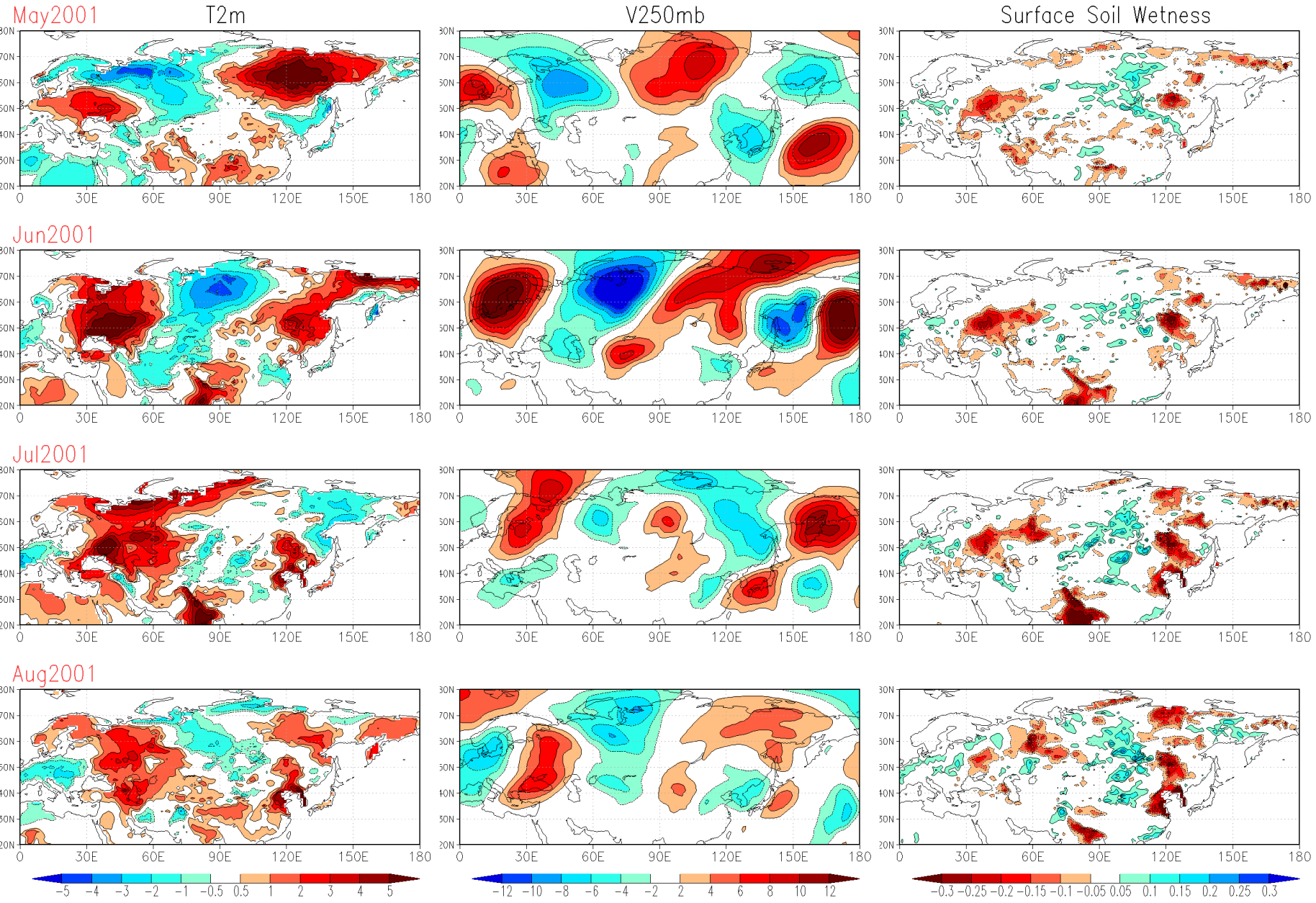


How Predictable is the 2001 Simulated Russian Heat Wave?

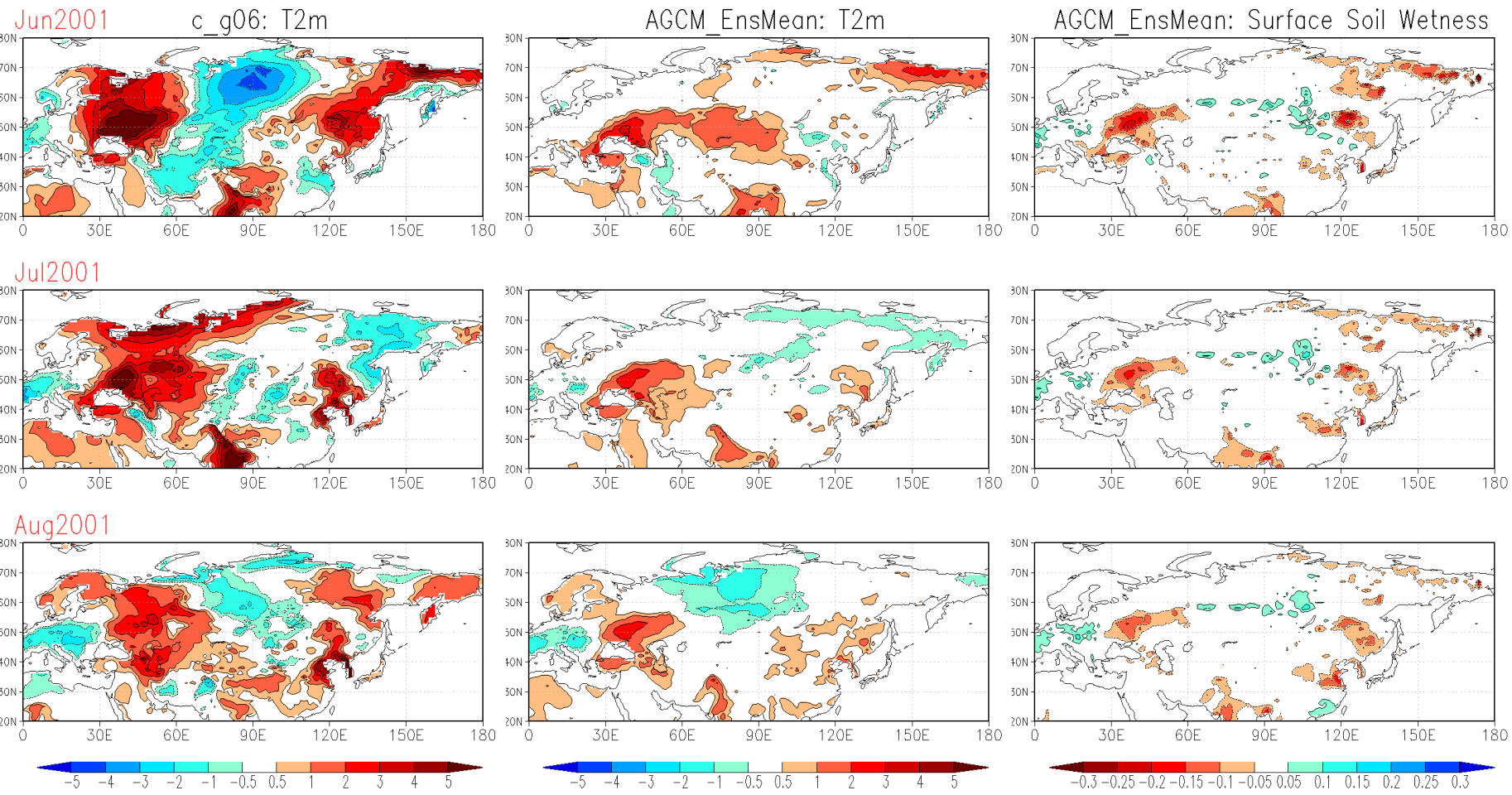
- Examine sensitivity to initial conditions
- Restart runs on May 15th 2001 with small perturbations in the atmosphere
- 20 ensemble members



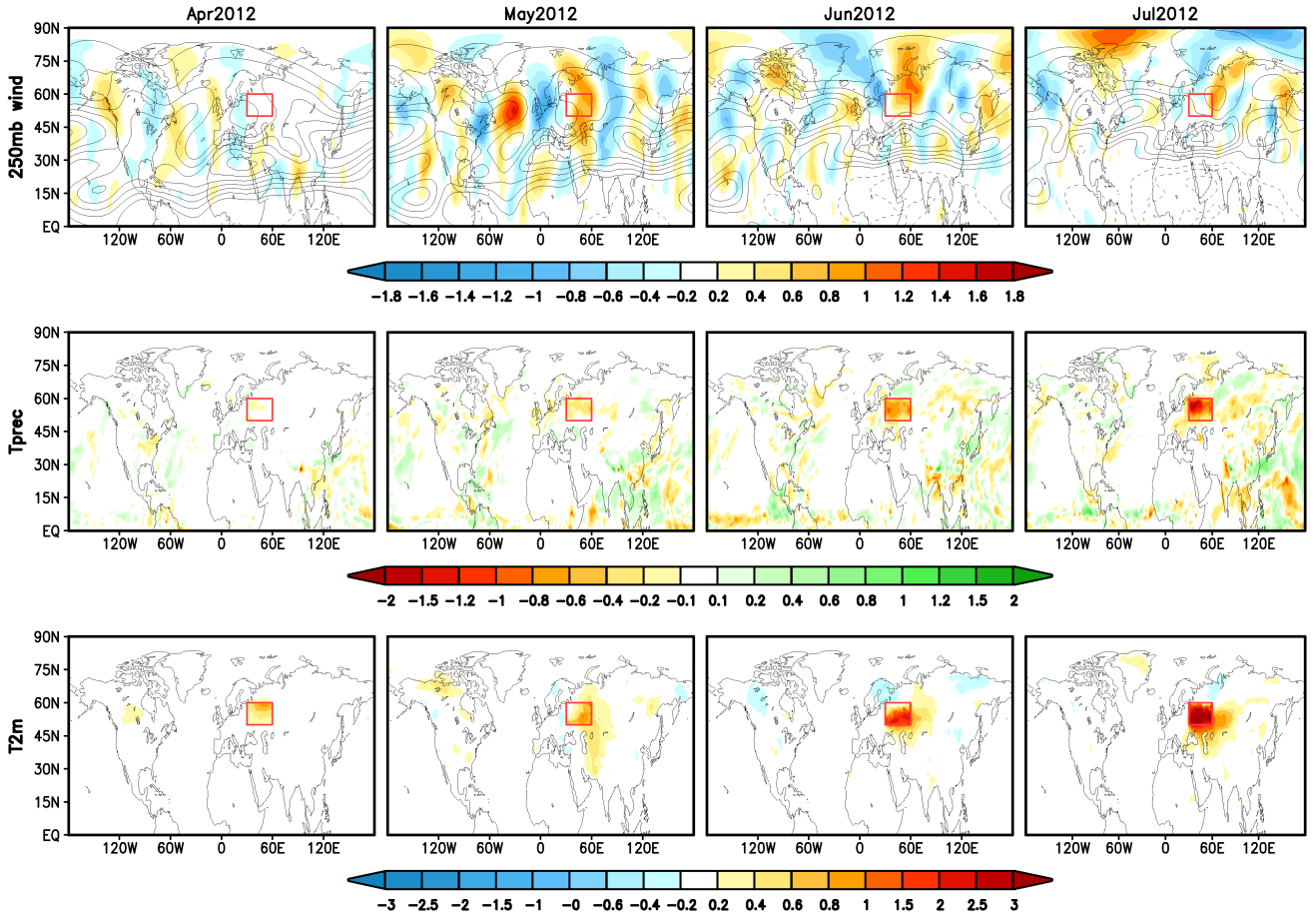
Case Study – 2001 Simulated Russian Heat Wave



Case Study – 2001 Simulated Russian Heat Wave - Predictability



Response of GEOS-5 AGCM to Idealized Soil Moisture Anomalies



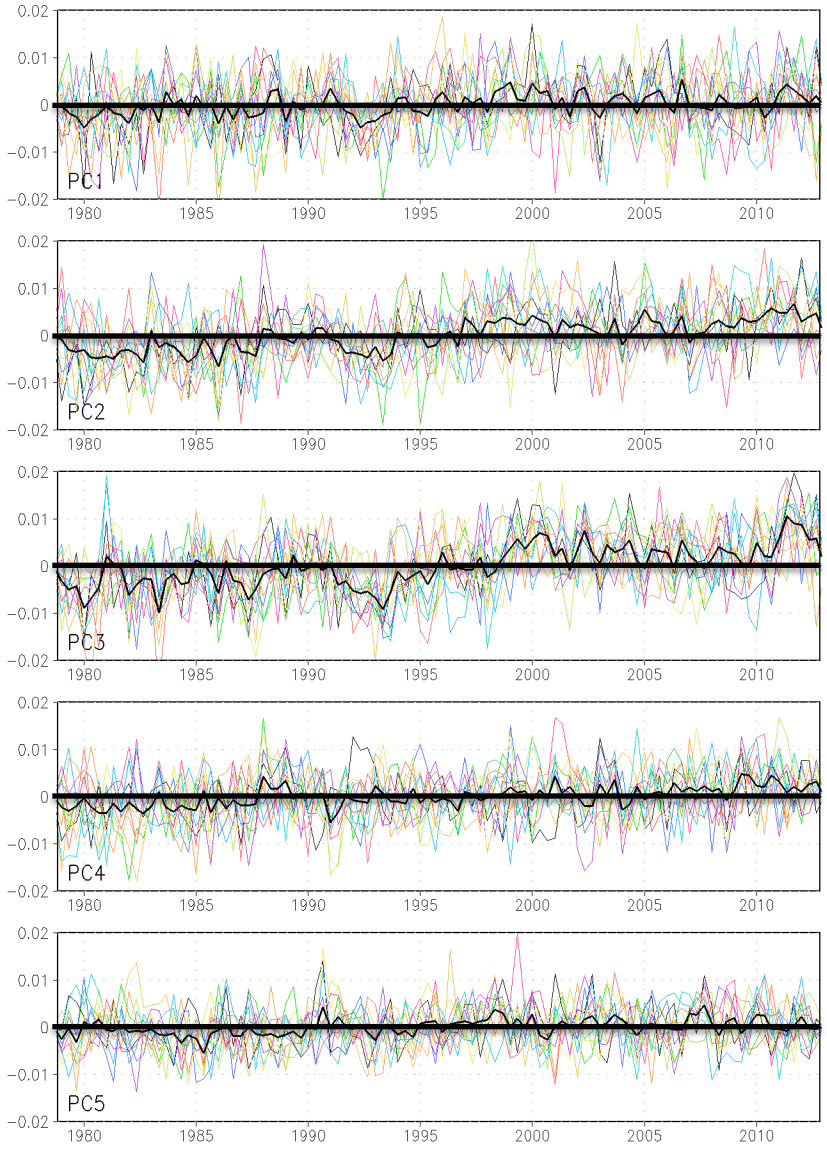
Koster, Chang and Schubert

Conclusions

Eurasian extreme heat waves and short term droughts:

- have occurred throughout recorded history (e.g., 1092)
- often have surface anomalies (temperature, precipitation) with distinctive wave-like structures
- often linked to Rossby Wave patterns that at times span the hemisphere (primarily forced by vorticity transients)
- surface anomalies are more extreme in recent decades because occurring on top of overall warming over Eurasia linked primarily to the AMO and warming trend in SST
- wave structures show no obvious trends in characteristics over last 100 years or so (e.g., frequency, amplitude)
- unclear what causes waves to occasionally reach large amplitude and persist – soil moisture preconditioning and feedbacks appear to be important

RPCs


0.02
0.01
0
−0.01
−0.02
PC1
PC2
PC3
PC4
PC5
1980
1985
1990
1995
2000
2005
2010