Predictability Sources for Droughts Associated with the Midlatitude Wave Trains

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Acknowledgement: Grant Branstator, Ahmed Tawfik, Patrick Callaghan, Andy Mai, Jerry Meehl , Warren Washington, CESM / CESM1 large ensemble / CCR production team

January 2014

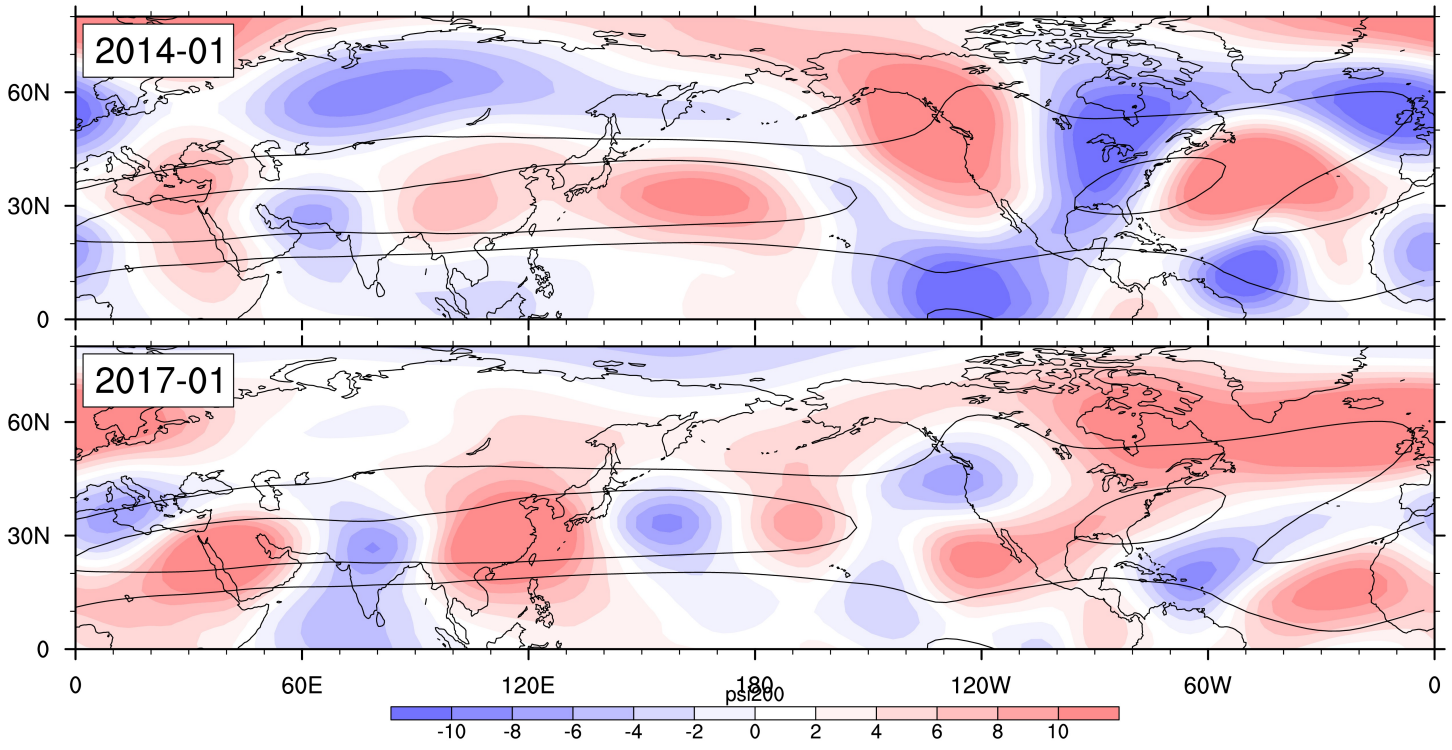
The Almaden Reservoir in San Jose, CA

January 2017

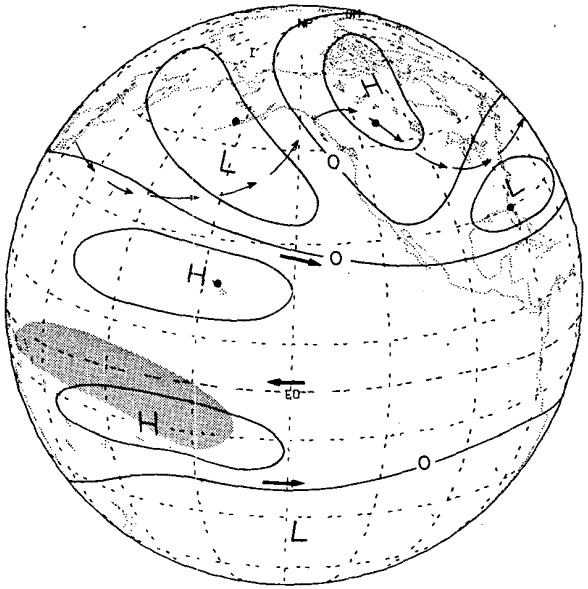
Monte Rio, CA

Recurrent persistent circulation patterns

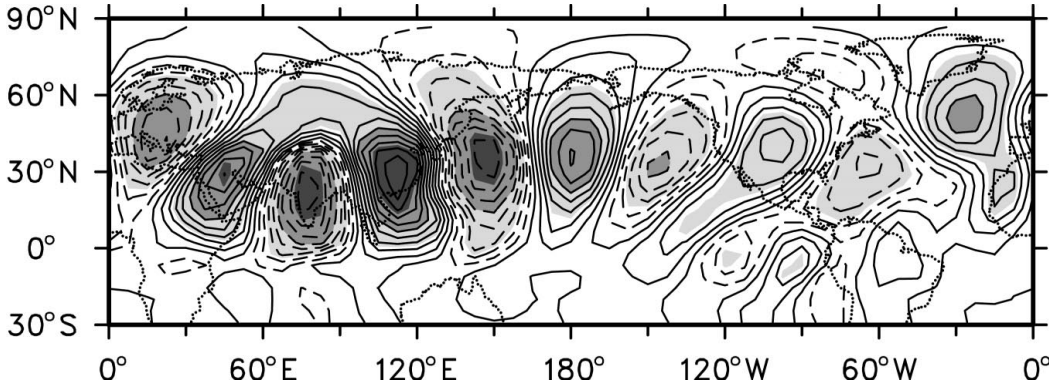
200 hPa streamfuction anomalies (shading)
and zonal wind climatology during 1979-2016



ENSO Teleconnection
Horel and Wallace 1981



Circumglobal/waveguide Teleconnection
Branstator 2002



- Midlatitude intrinsic pattern
- Certain forcings can affect the intensity and persistence of the waveguide patterns

Some recent work

- **Intrinsic variability**

*Branstator, G. and **H. Teng**, 2017: Tropospheric waveguide teleconnection and their seasonality, J. Atmos. Sci., DOI:10.1175/JAS-D-16-0305.1.*

- **Response to tropical diabatic heating (non-ENSO related)**

***Teng, H.** and G. Branstator, 2017: Causes of extreme ridges that induce California droughts. J. Climate, DOI:10.1175/JCLI-D-16-0524.1.*

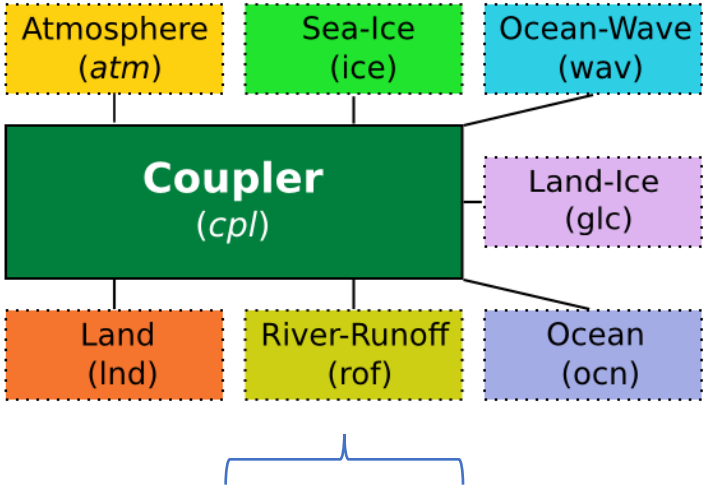
- **Response to anthropogenic forcing**

***Teng, H**., G. Branstator, G. A. Meehl, and W. M. Washington, 2016: Projected intensification of subseasonal temperature variability and heat waves in the Great Plains. Geophy. Res. Lett., doi: 1002/2015GL067574.*

- **Response to soil moisture forcing**

***Teng, H**., G. Branstator and A. Tawfik, 2018: Circumglobal response to prescribed soil moisture over North America, to be submitted.*

CESM & experiments

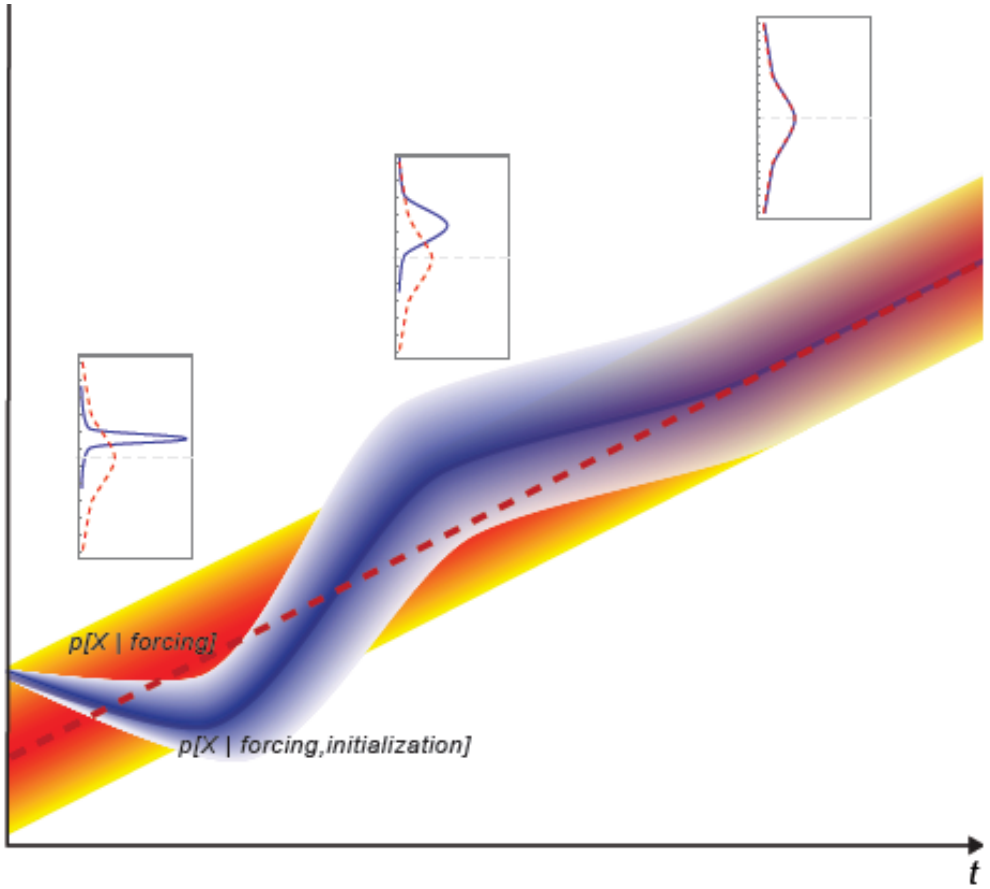


- 1800 yr pre-industrial control run
- 2600 yr CAM5 atm/lnd stand-alone control run
- 40-member large ensemble climate change simulation 1920-2100

Initialized hindcast on daily to decadal time scales

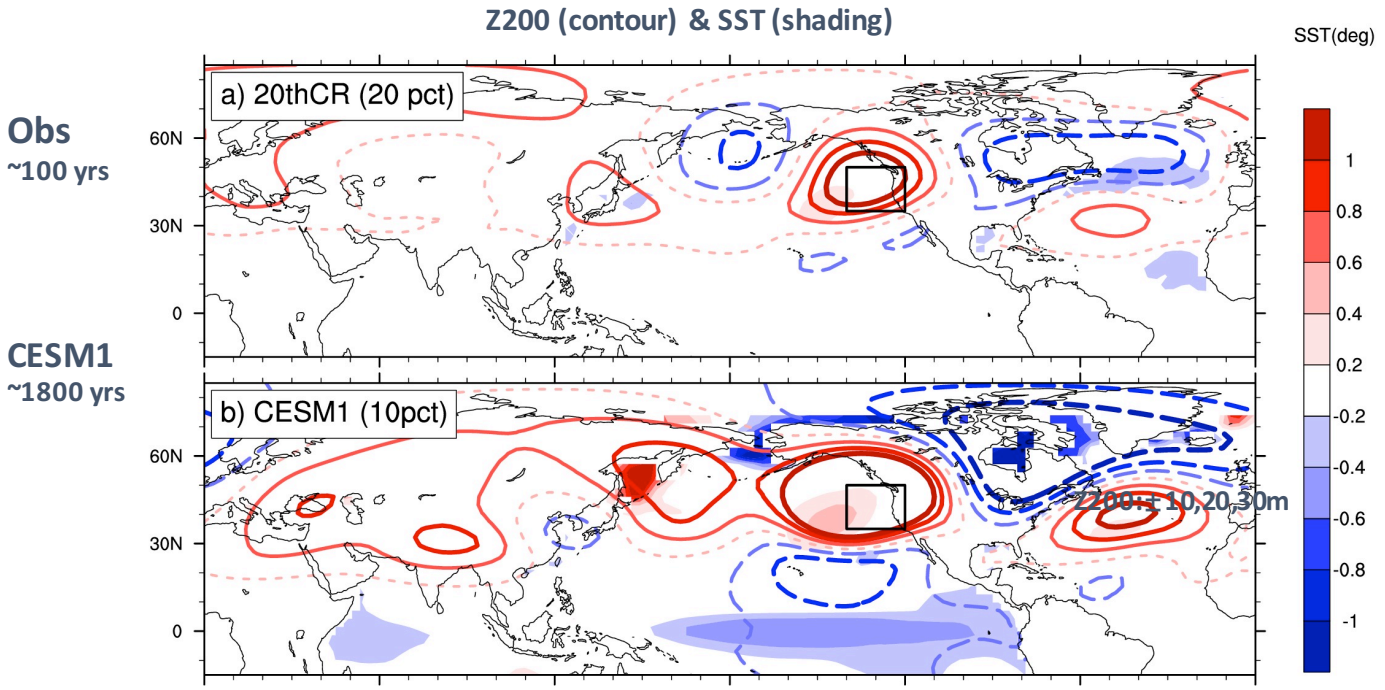
Initial-value vs forced predictability

Initial-value predictability: $P_e(t)$ vs. $P_c(t)$
Forced predictability: $P_c(t)$ vs. $P_c(0)$



Both mean and variance can contribute to predictability!

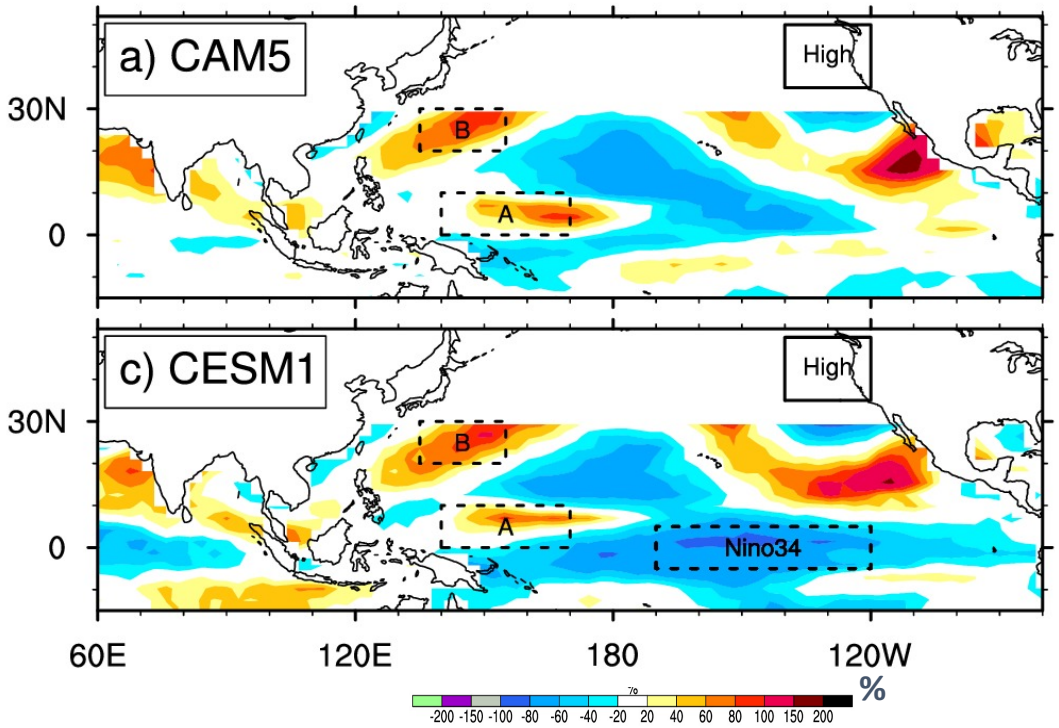
Causes of extreme west coast ridges



- Associated with a **continuum** of wavenumber-5 waveguide patterns which originate from **internal** dynamics in the midlatitudes
- Certain **persistent forcing** can affect the probability/persistence of extreme ridges

Tropical forcing

*nonessential, but may **double** the **probability** of extreme ridges*



- ***Ridge index***=

avg<Z500, 35-50N, 140W-120W>

- $P_0(E_{xtreme}\ R_{idges})$=10%
- $P_1(E_{xtreme}\ R_{idges} | E_{xtreme}$ local rain)=
- $100*(P_1-P_0)/P_0$
- ***rainAB index***=

regress<rainA,rainB>to Ridge index

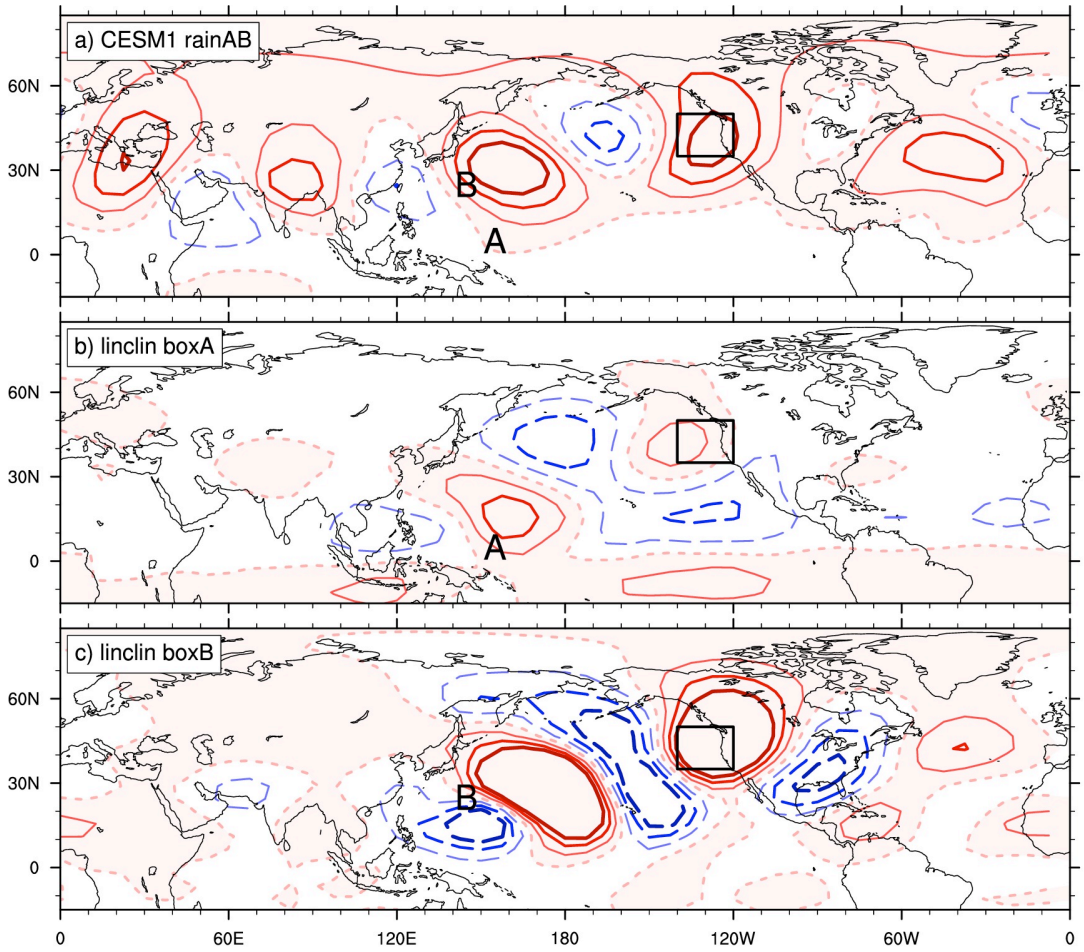
***P1(*$E_{xtreme}\ R_{idges}$**|E_{xtreme} rainAB)= 19% ~ doubling of P_0**

Heating response in a linear planetary wave model (Branstator 1990)

CESM1
extreme rainAB
Psi500
$\pm 1,2,3 \times 10^6\ m^2 s^{-1}$

Linear model
boxA
psi450

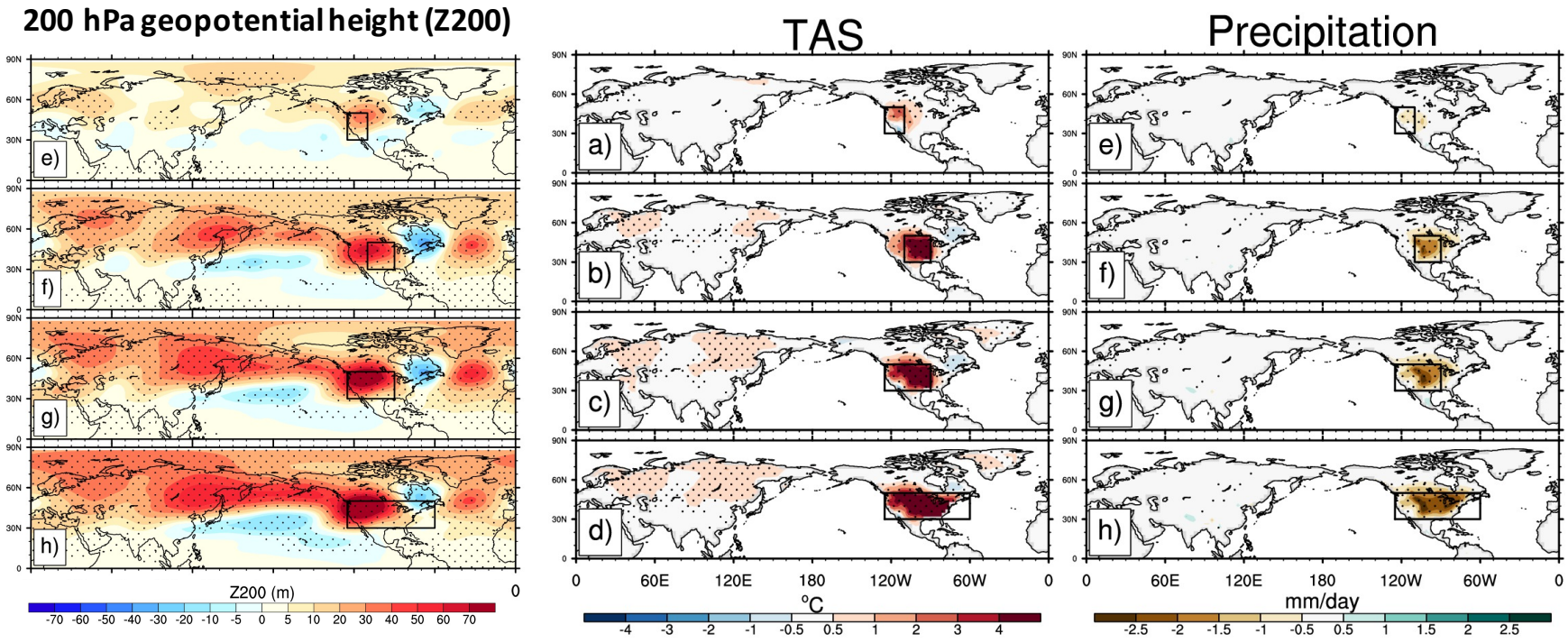
Linear model
boxB
psi450



heating rate =2.5C/day, ~2mm/day precip anom

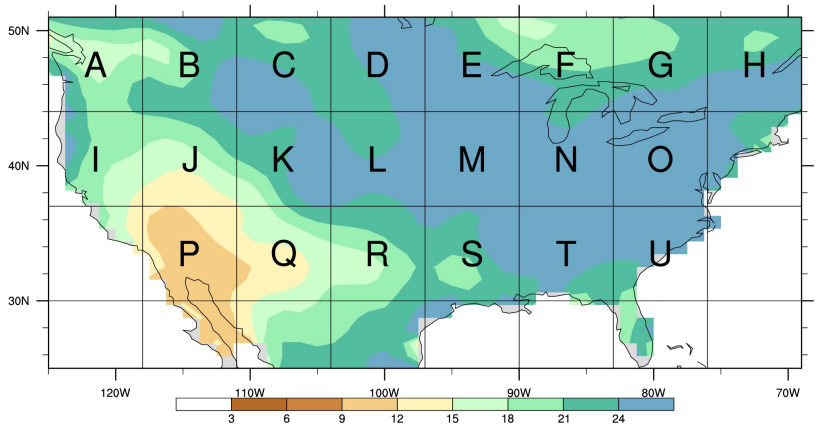
CAM5 prescribed soil moisture experiments

- Prescribe soil water at selected domains
- Run 100-member CAM5 atm/lnd stand-alone simulation for a season/year
- CESM1-LE tag (2600-year CAM5 & 1800-yr fully coupled control run & the large ensemble climate change experiments)



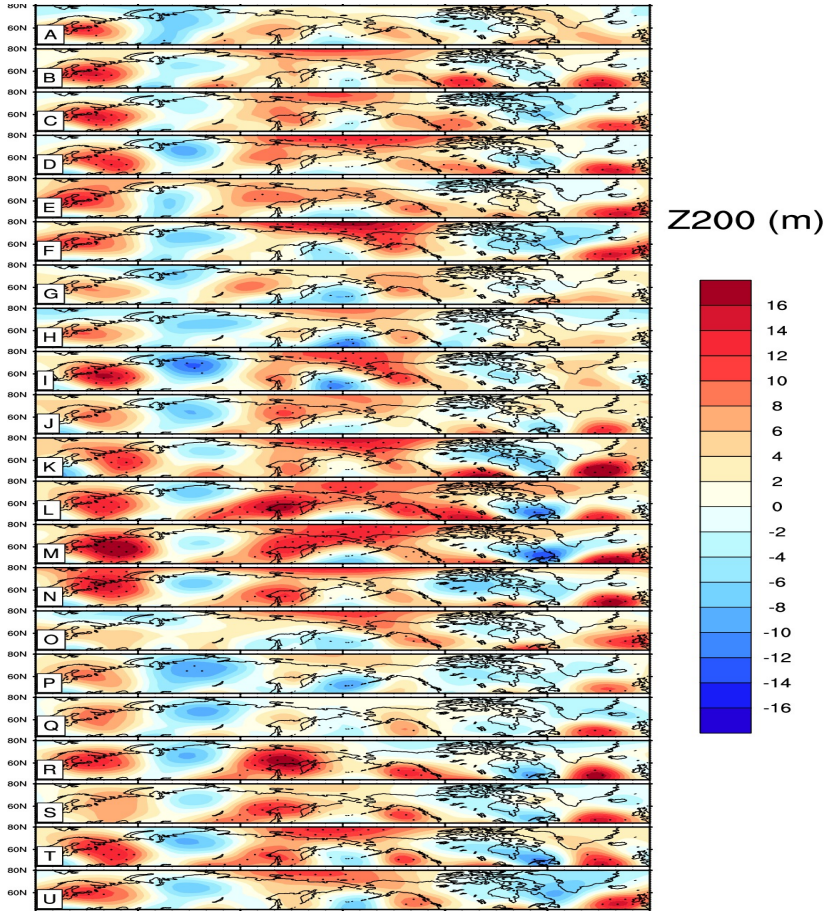
Planetary wave response
… phase insensitive to the location of the forcing

21 subdomains in the US

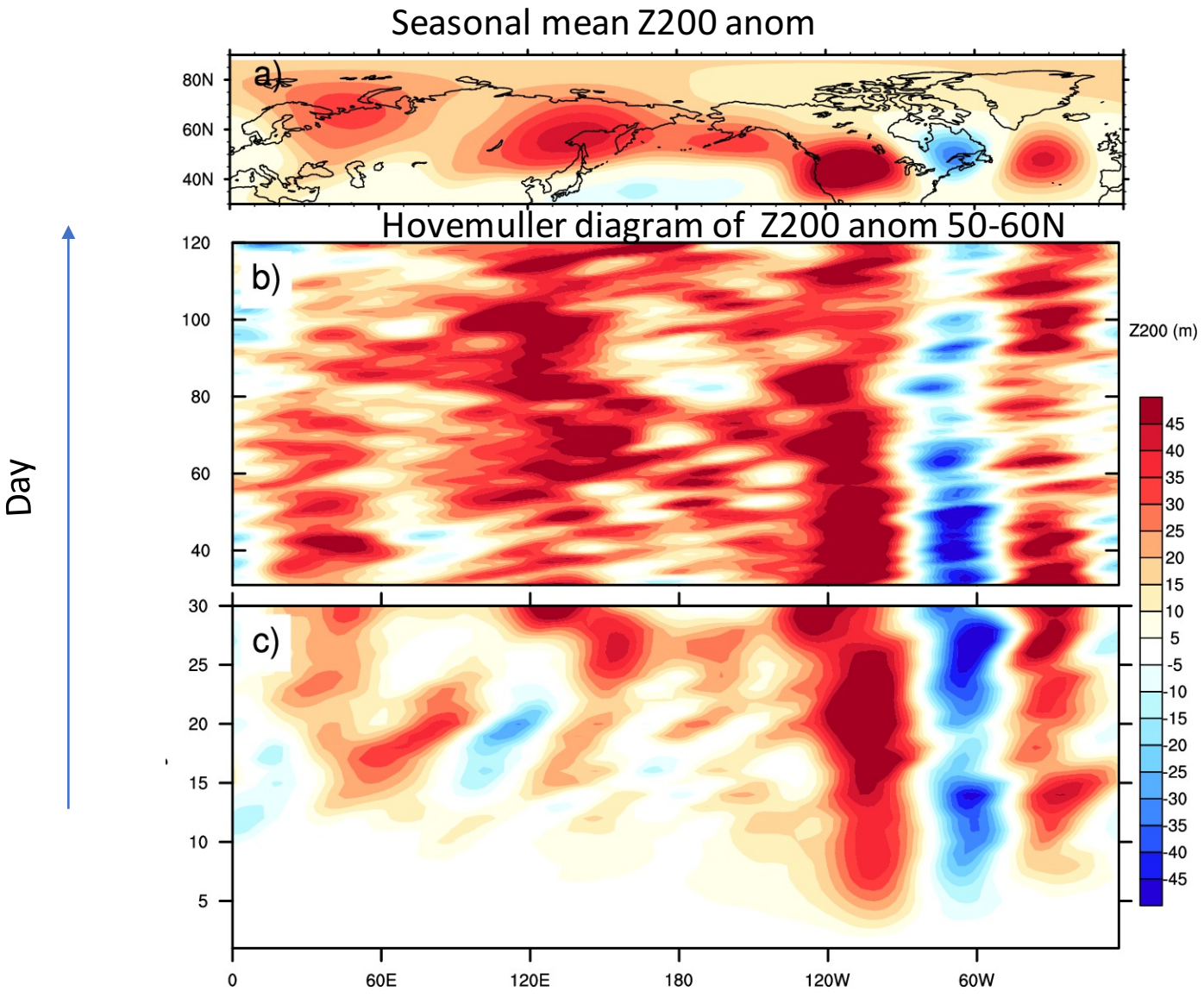


Koster et al. 2016

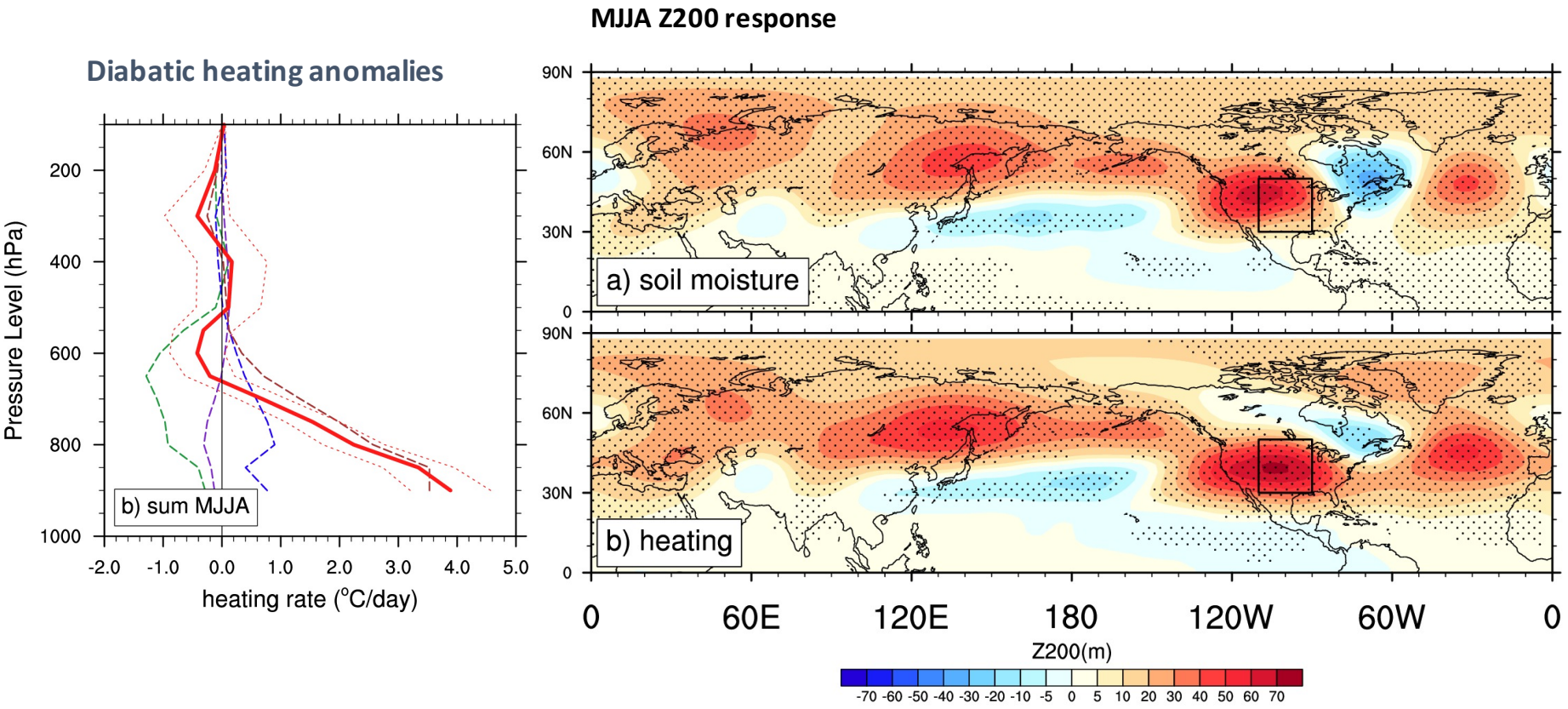
Z200 response 50-80N



I have investigated other "hot spots" in Europe and Asia and find consistent results.


Seasonal mean Z200 anom
a)
80N
60N
40N
Hovemuller diagram of Z200 anom 50-60N
b)
c)
120
100
80
60
40
30
25
20
15
10
5
Day
0
60E
120E
180
120W
60W
Z200 (m)
45
40
35
30
25
20
15
10
5
-5
-10
-15
-20
-25
-30
-35
-40
-45

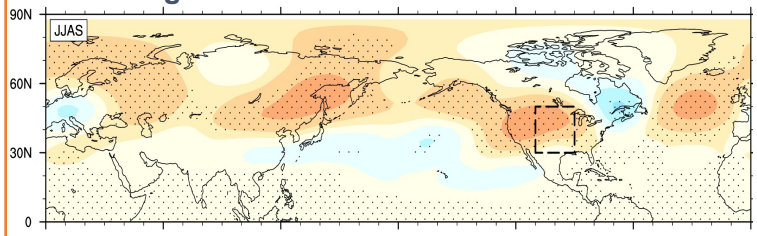
CAM5 response to surface drying very similar to response to the near surface heating



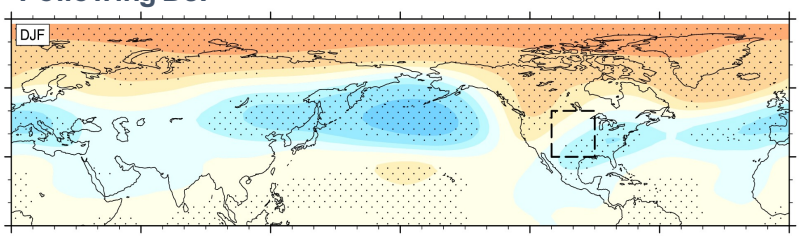
Delayed response in the pulse experiments

Deplete surface SM@GP for a month on May1, Jun1, and Jul1, turn it off, run through the following winter

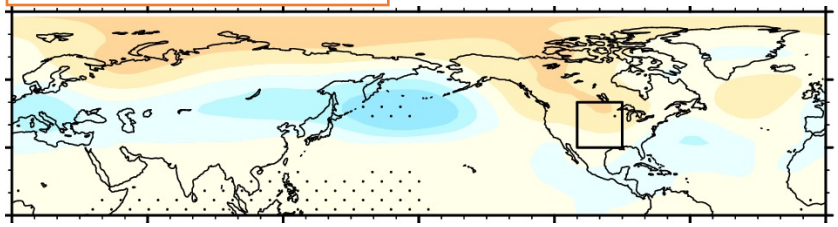
Following *summer*

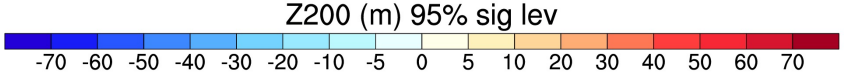


Following *DJF*



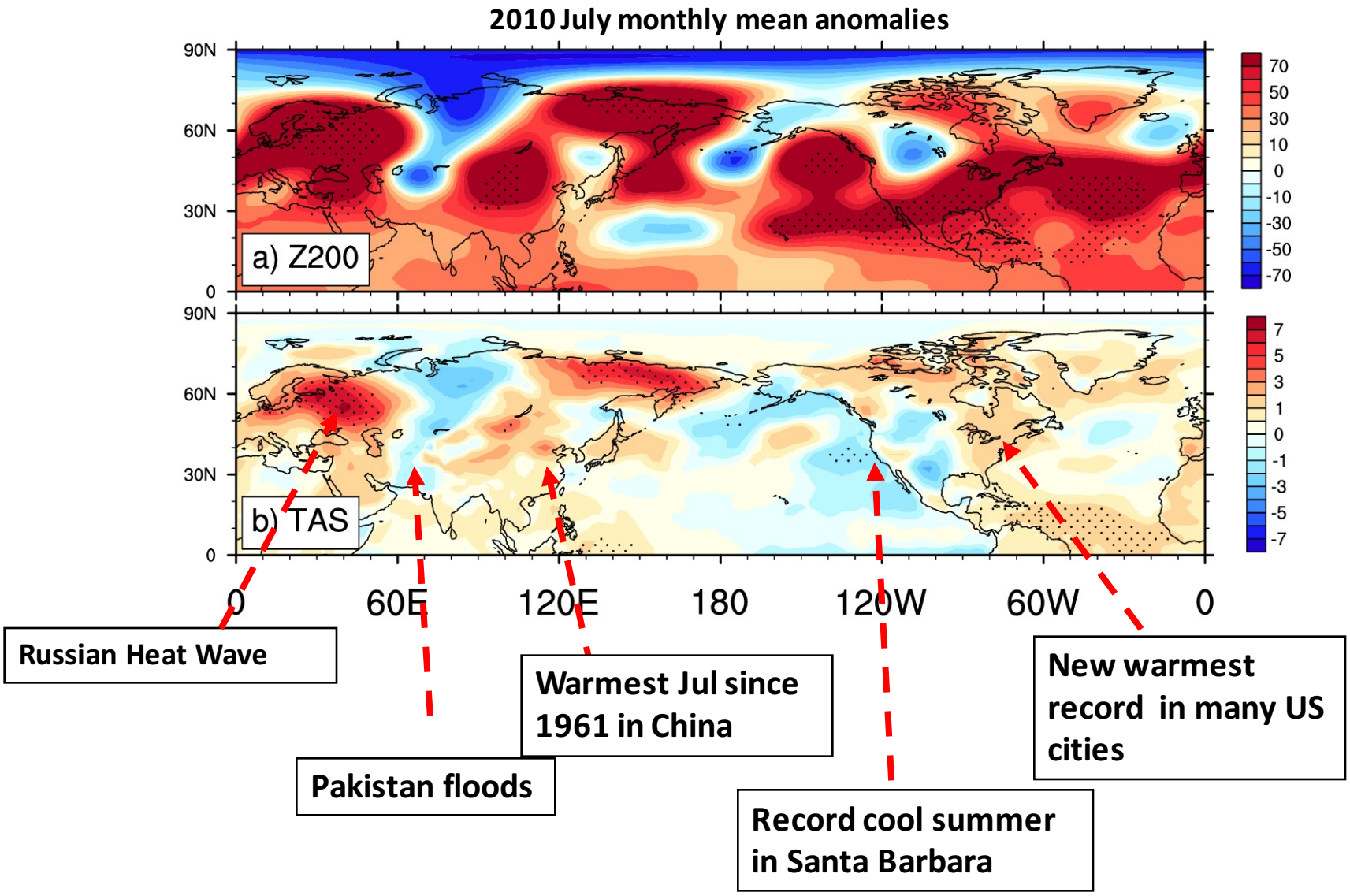
Deplete SM@GP in NDJF

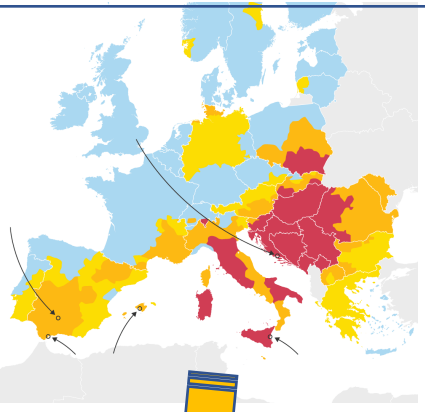




- *Midlatitude extremes are often associated with strong Rossby wave trains*

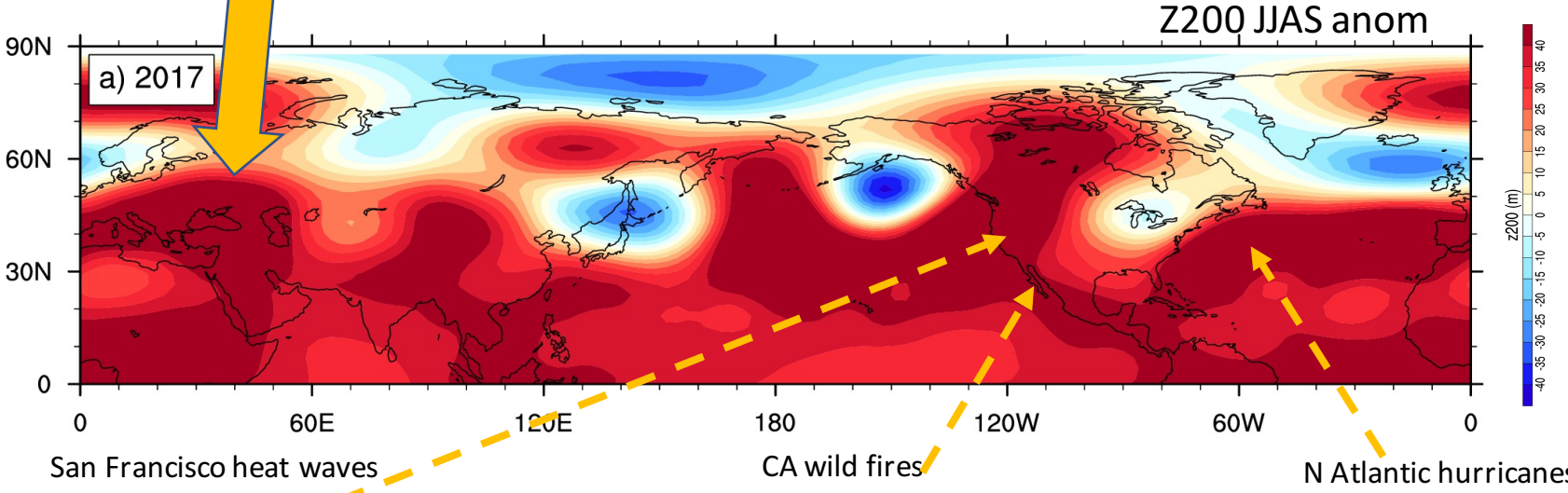
"A stubborn, stagnant upper-air pattern"





Authorities in 11 European countries warn residents and tourists to take precautions amid region's most intense heatwave – nicknamed Lucifer – since 2003

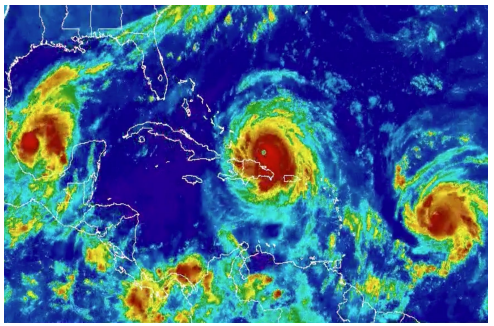
Summer of 2017



San Francisco heat waves

CA wild fires

N Atlantic hurricanes



Take home

- Think globally (keep circulation in the game)
- Atmosphere – land coupling

We could use earth system model to:

- *Explore predictability sources & quantify predictability limit of low-frequency atm circulation patterns*
- *Provide climate change projection …. a kind of early warning*
- *Help to design global soil moisture ground obs system*