The 1930s Dust Bowl heat waves: Were they Atlantic forced, and did anthropogenic climate change play a role?

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Dust storm in Stratford, Texas, 1935

(NOAA Photo Library)

Oklahoma, 1936

Taylor, Texas. April 1939

Devastating dust storms in 1933, 1934, 1935; 65% of Great Plains damaged by erosion in 1934(Cook et al. 2014 *GRL*);

Texas Panhandle, March 1936

Oklahoma Panhandle, 1936

Dalhart, Texas. June 1938

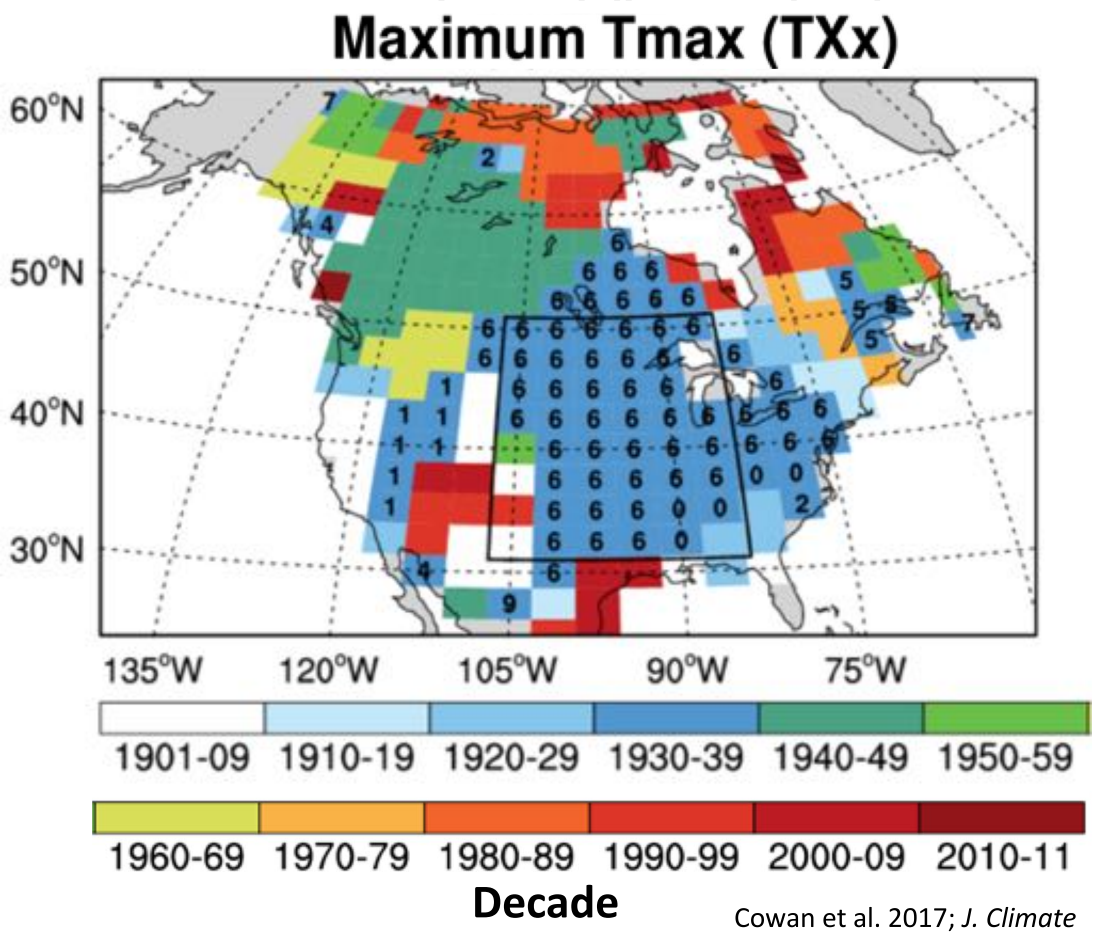
Coincided with The Great Depression (~1929 – late 1930s);

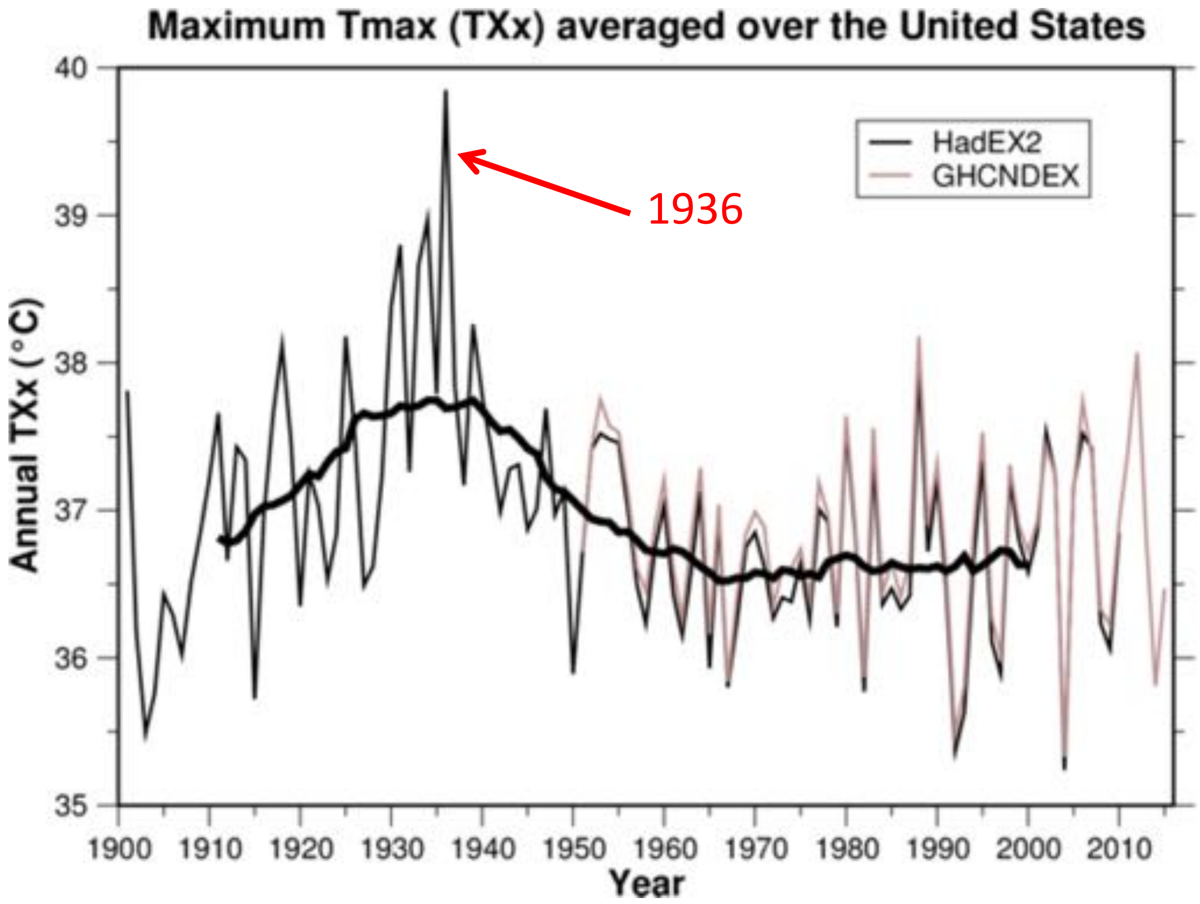
- Wheat price dropped by two-thirds in 2 years (1929-1931) with oversupply.
- Drought/dust impacts: over 2 million residents displaced (20-30% migration), dust pneumonia, rioting, crime sprees, starvation, madness.

Photo credits: Russell Lee, Arthur Rothstein, Dorothea Lange (The Library of Congress, Prints & Photographs Division), Matt Loughre (The Sun UK)

Breaking heat records during the Dust Bowl

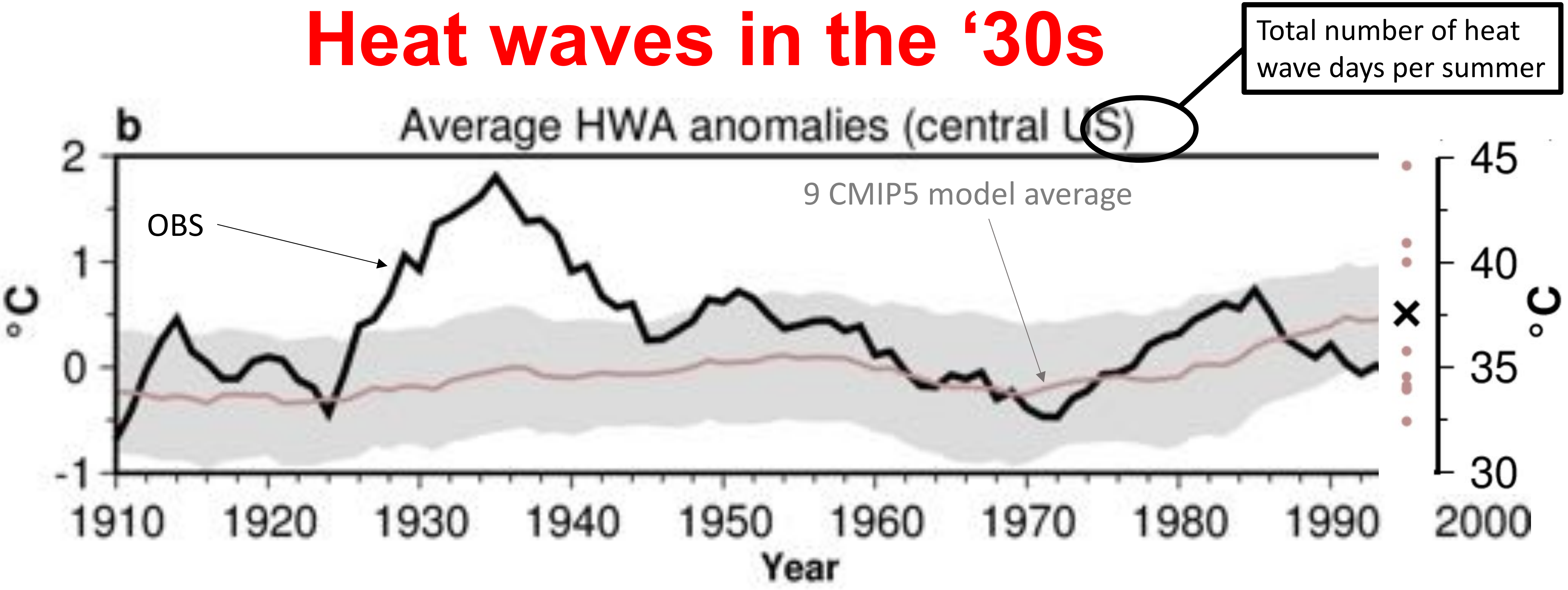
- Hottest day/night for central US, southern Canada;
- Largest areal extent of hot days in the 1930s (**45%** of US; Abatzoglou & Barbero, 2014 *GRL*).





Cowan et al. 2017; *J. Climate*

Heat waves in the '30s

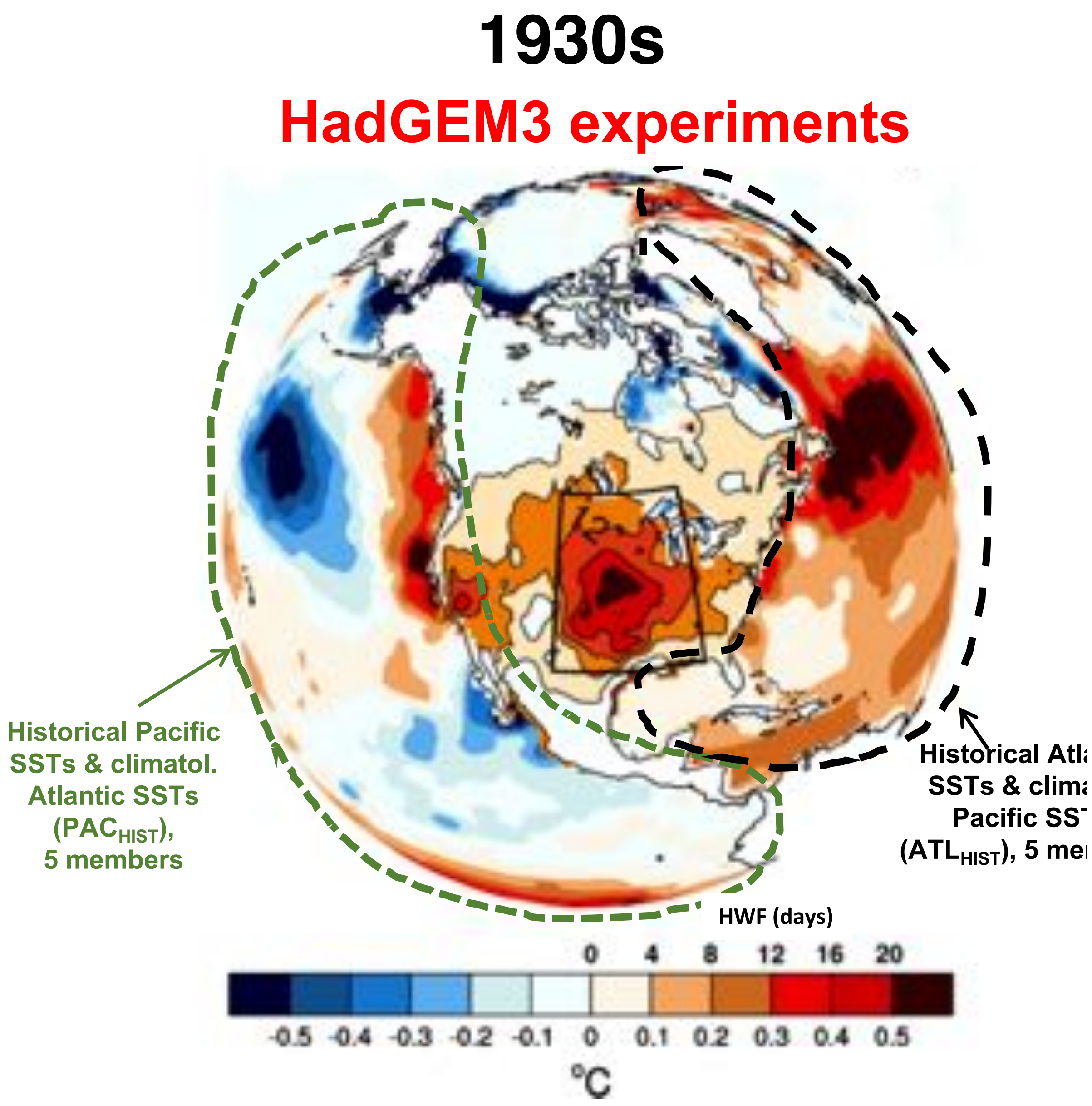


- **What role did SST anomalies play?**
- **Was the summer circulation important?**
- **How sensitive are the heat waves to devegetation?**

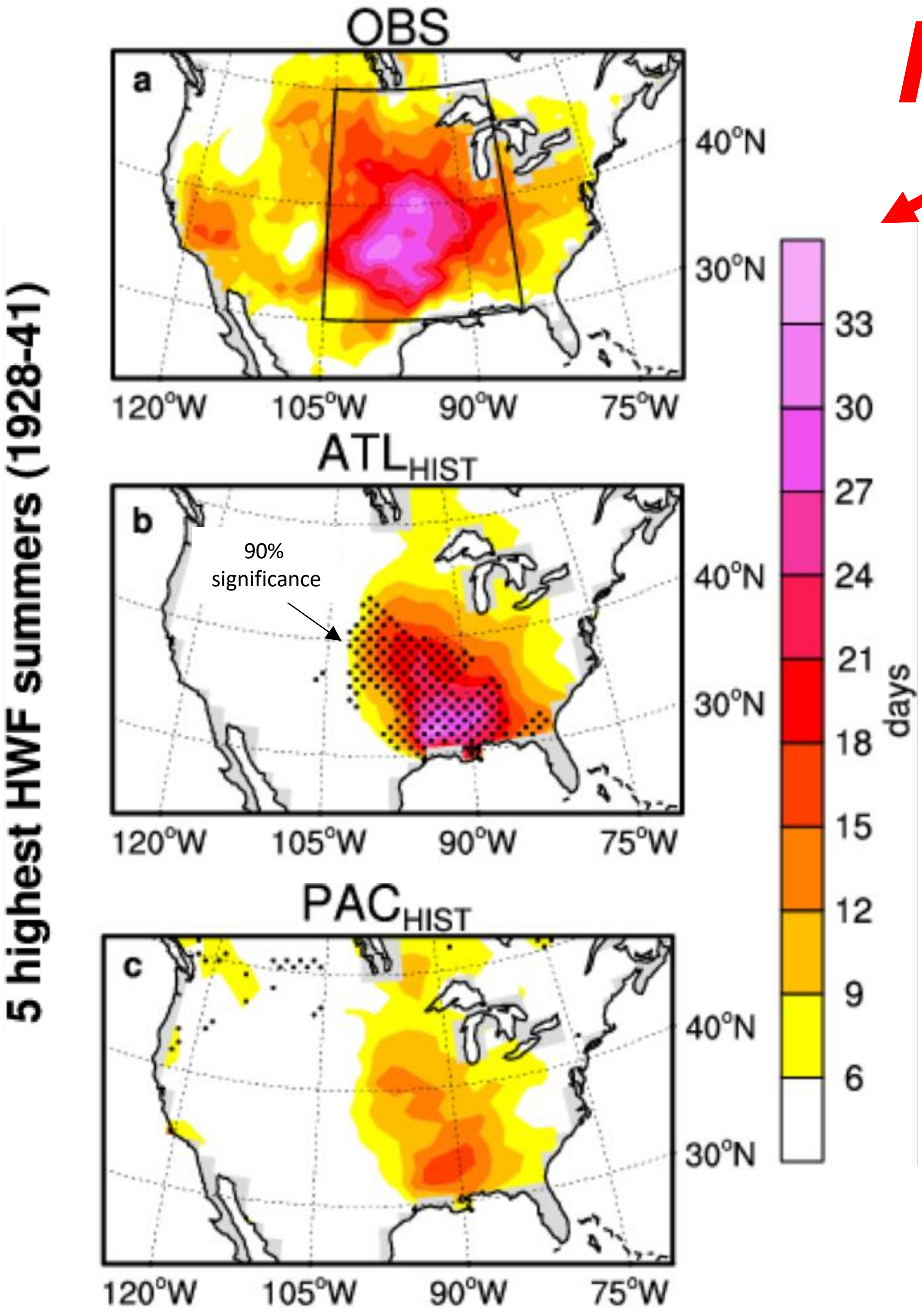
→ **HadGEM3 atmosphere-only model (idealised, sensitivity runs)**

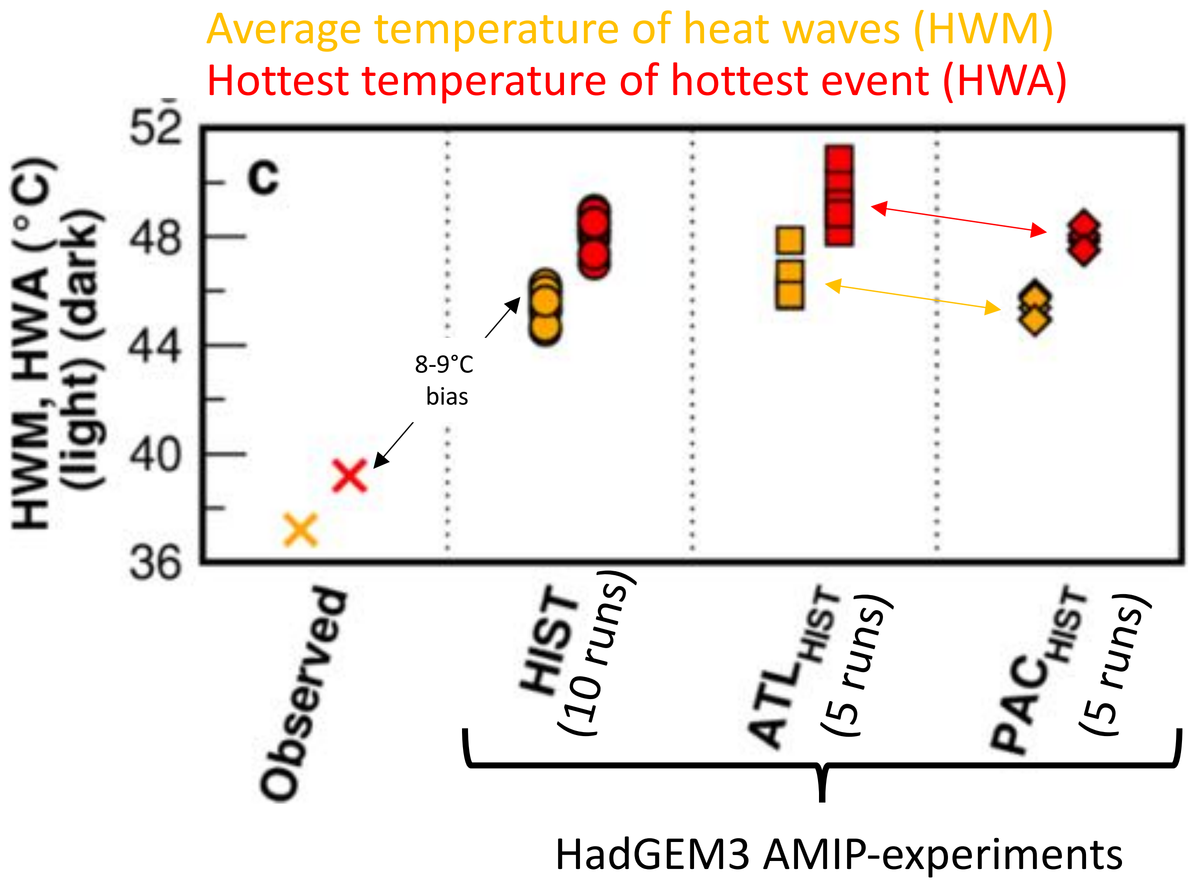
- **Was there a greenhouse gas signal in the 1930s?** → **weather@home2 simulations**

Sea surface temperatures and heat wave activity



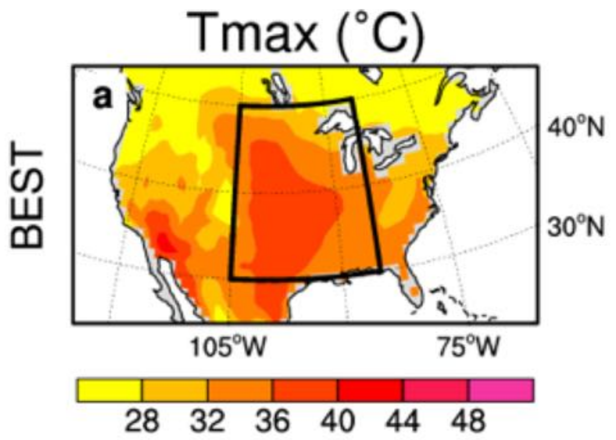
Five most active heat wave summers in the 1930s





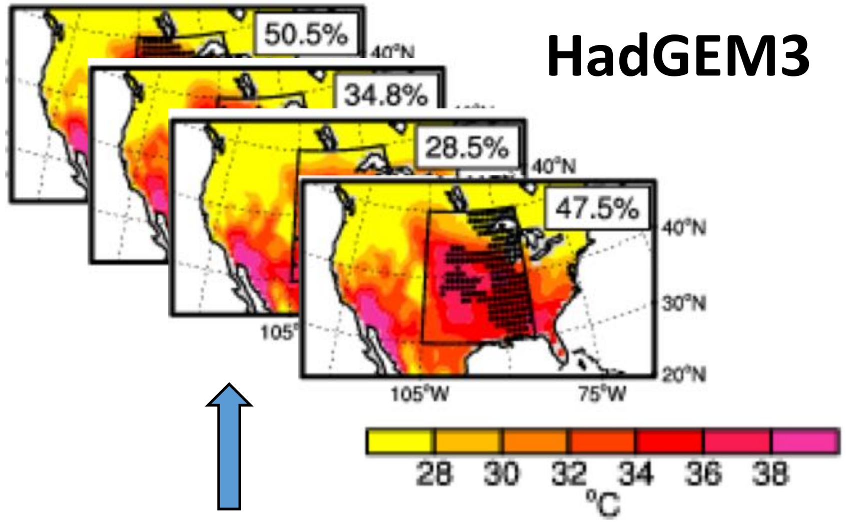
Summer circulation (analogue technique)

Observed (7 days)

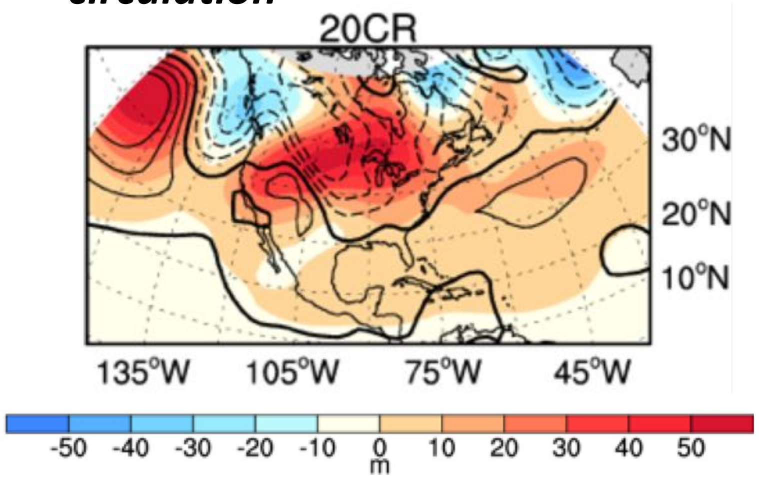


Comparison

HadGEM3



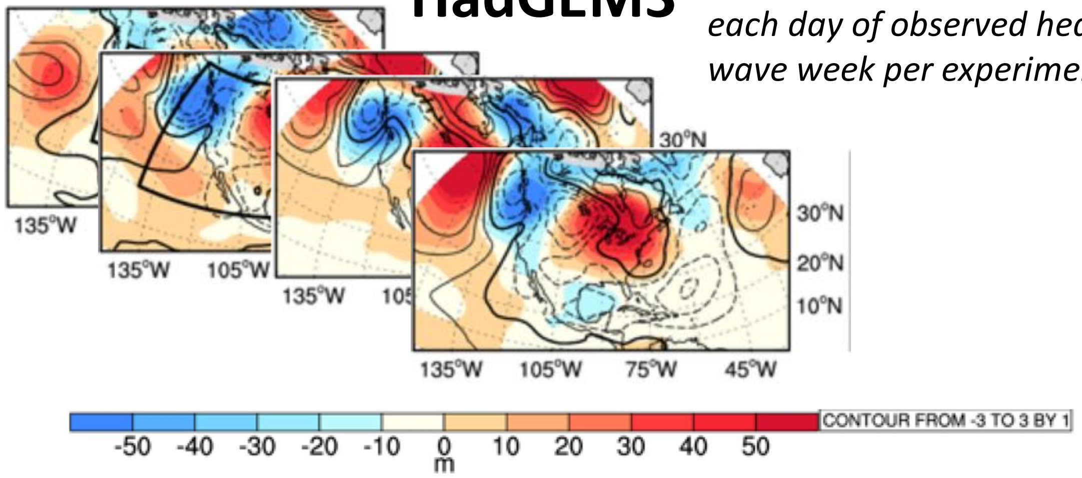
Corresponding circulation



Best matching model circulations

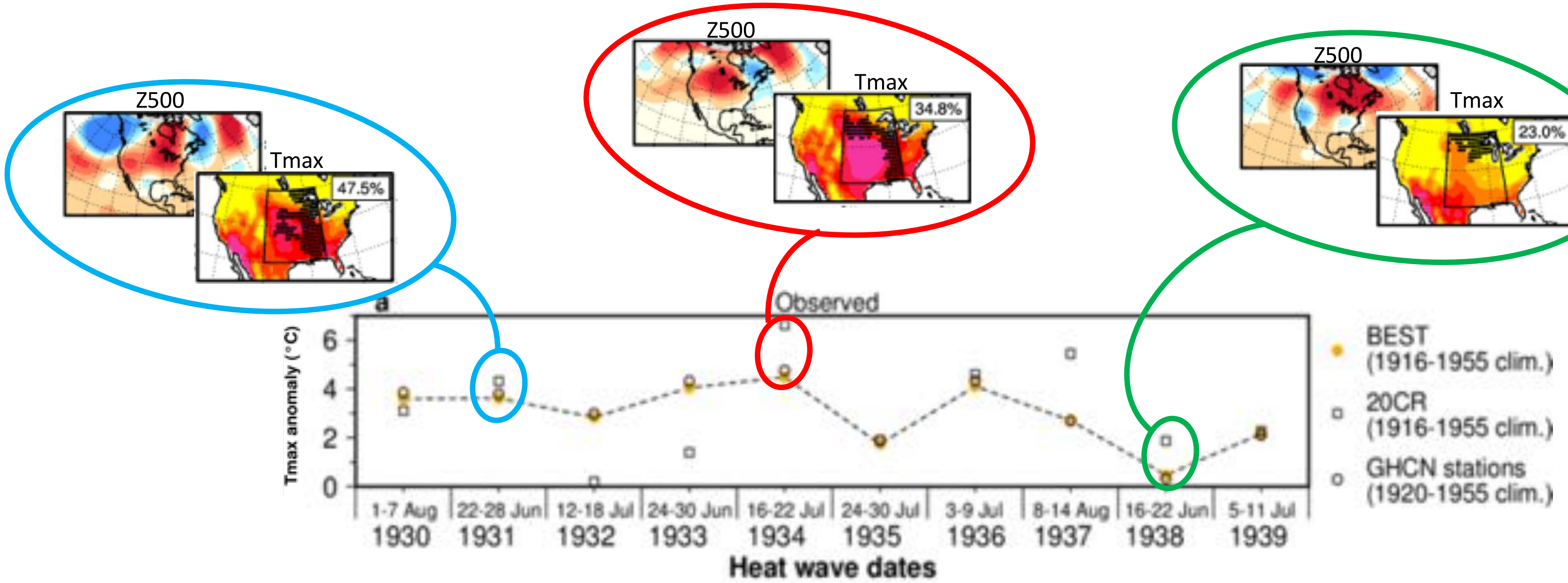
HadGEM3

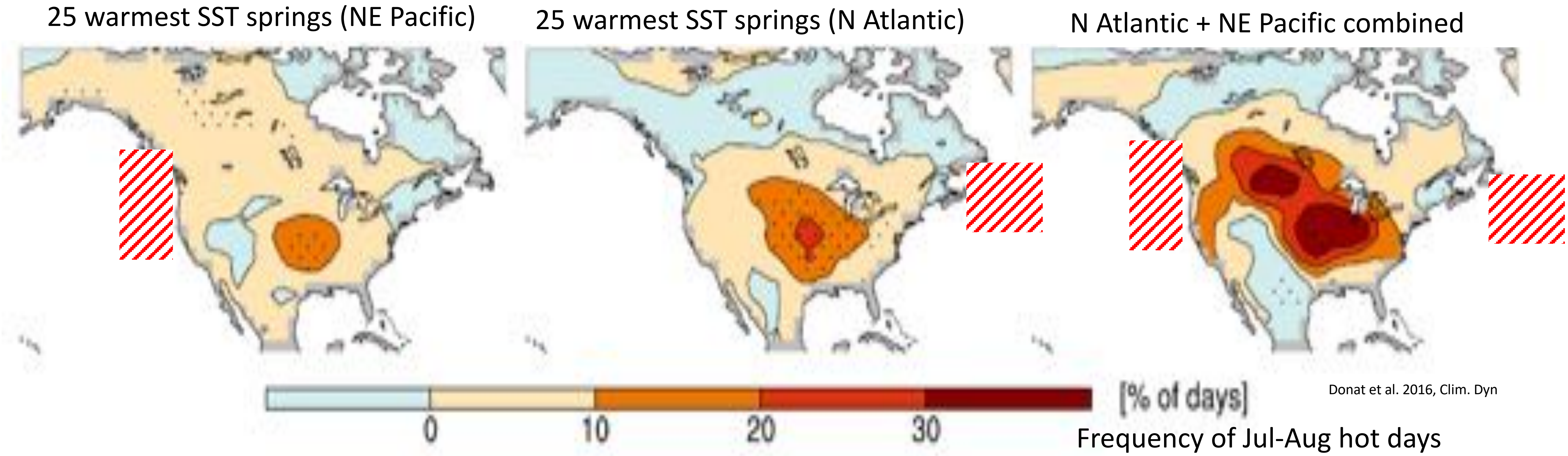
N=20 best analogues of each day of observed heat wave week per experiment



Adapted from Jézéquel et al. 2017, *Clim. Dynamics*

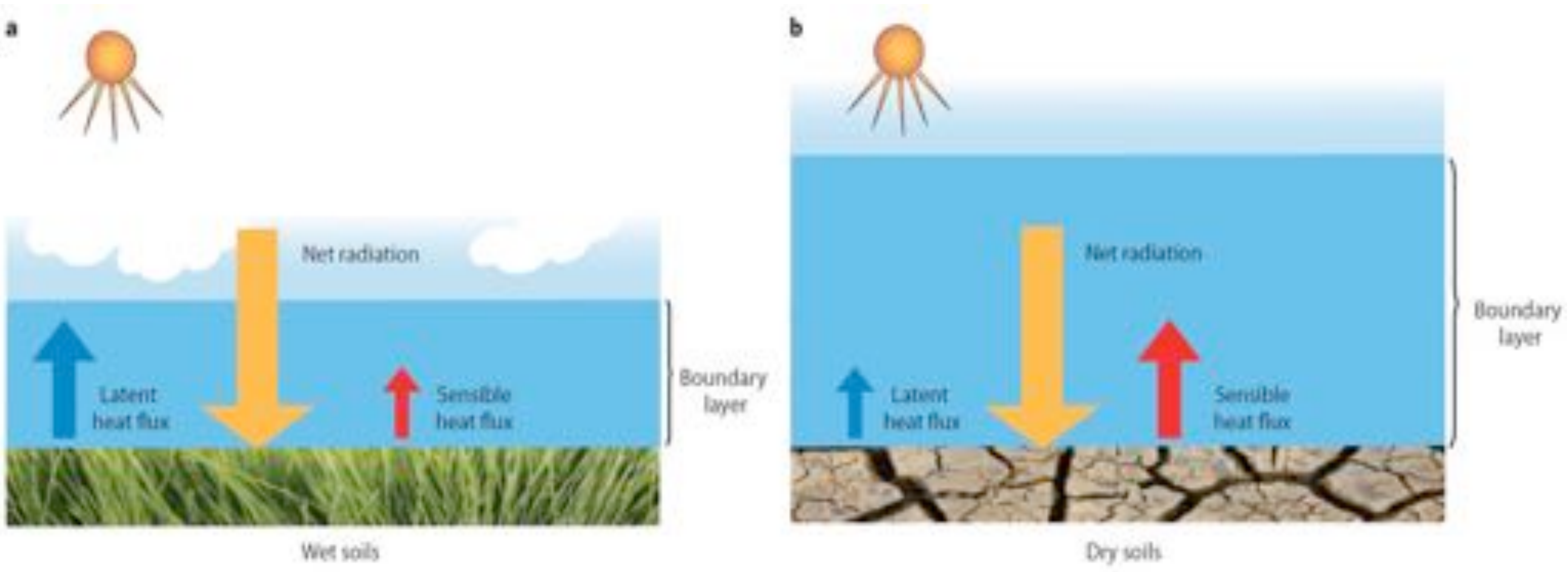
Contribution of atmospheric circulation to daily Tmax during the hottest summer heat waves in the 1930s





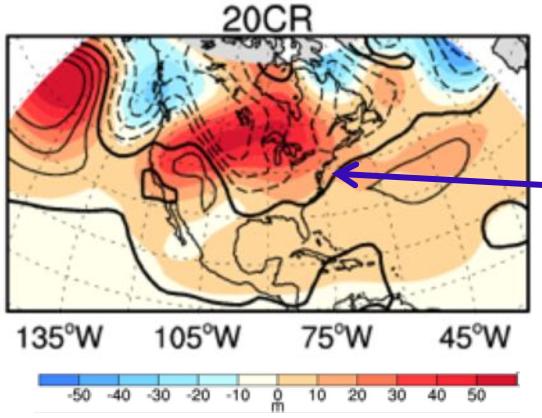
Donat et al. 2016, Clim. Dyn

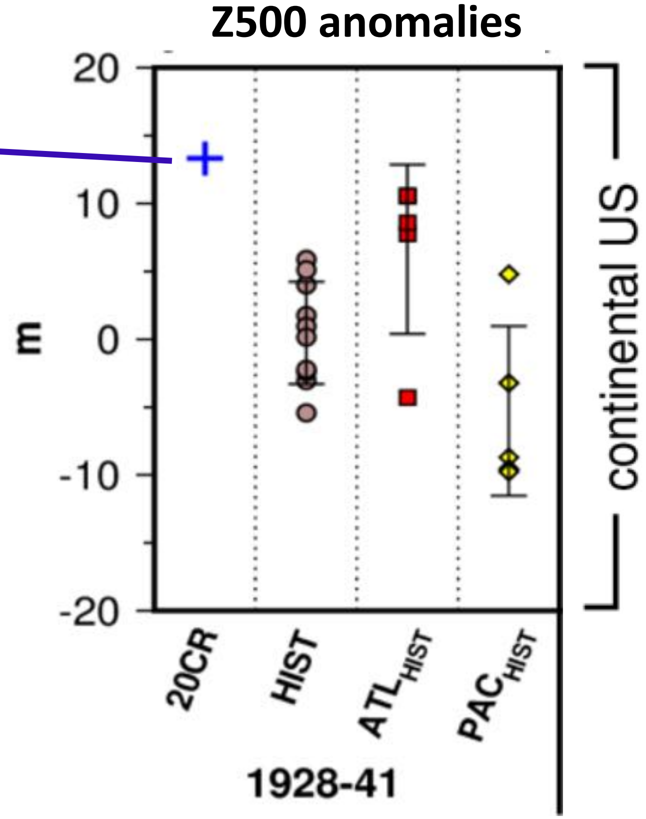
Spring drought (pre-conditioning)

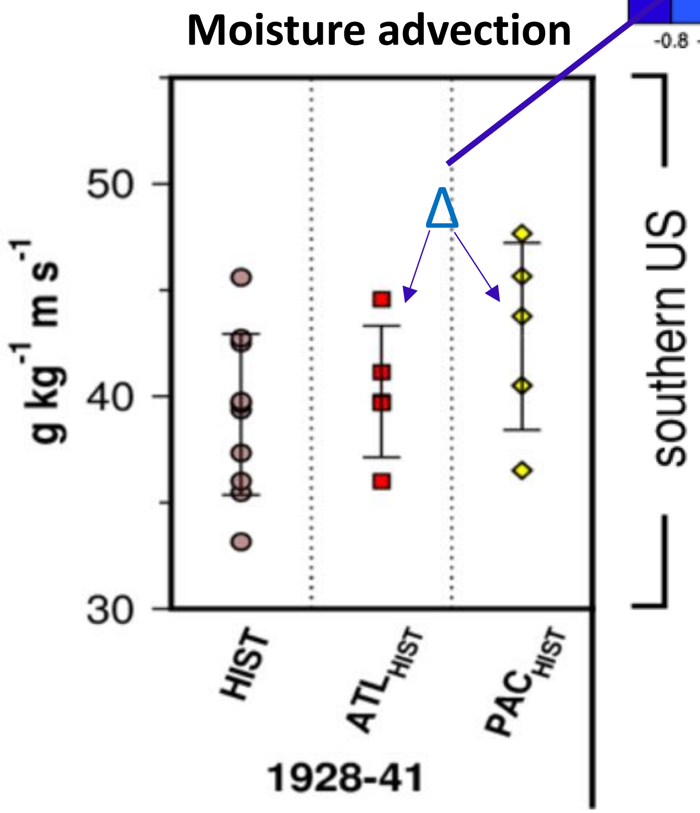


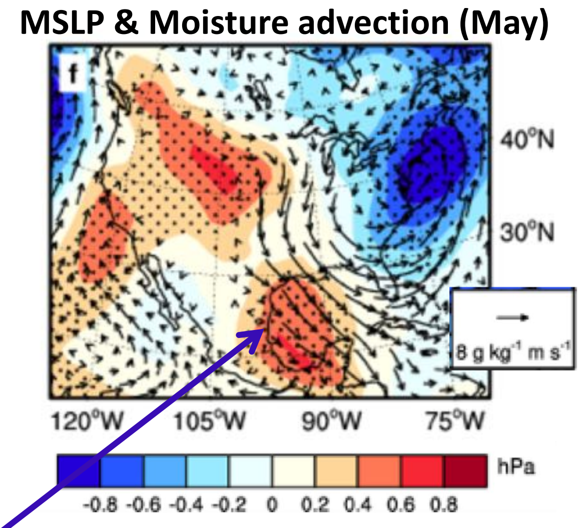
Alexander (2011),
Hirschi et al. 2011,
Nature Geoscience

Spring drought (pre-conditioning)



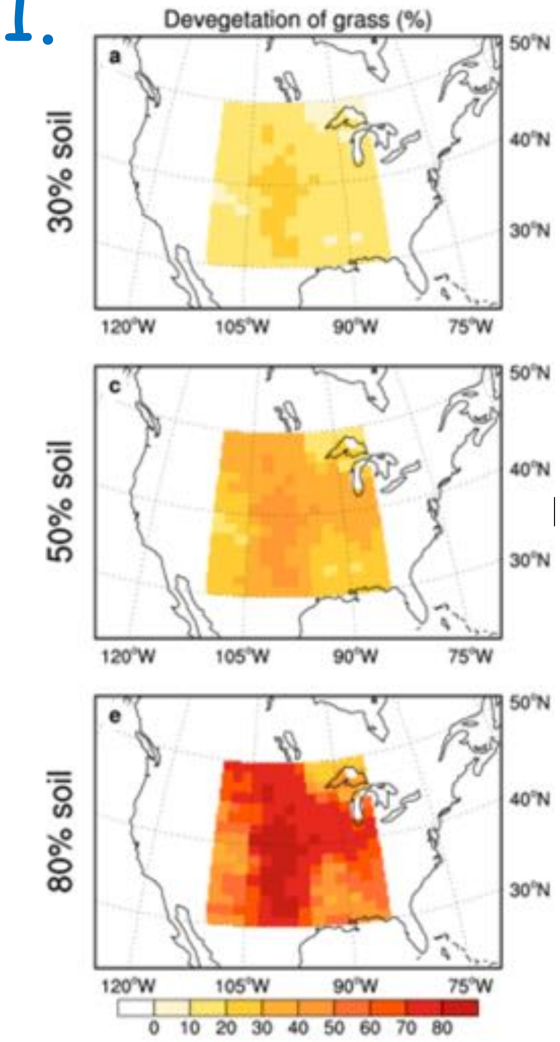




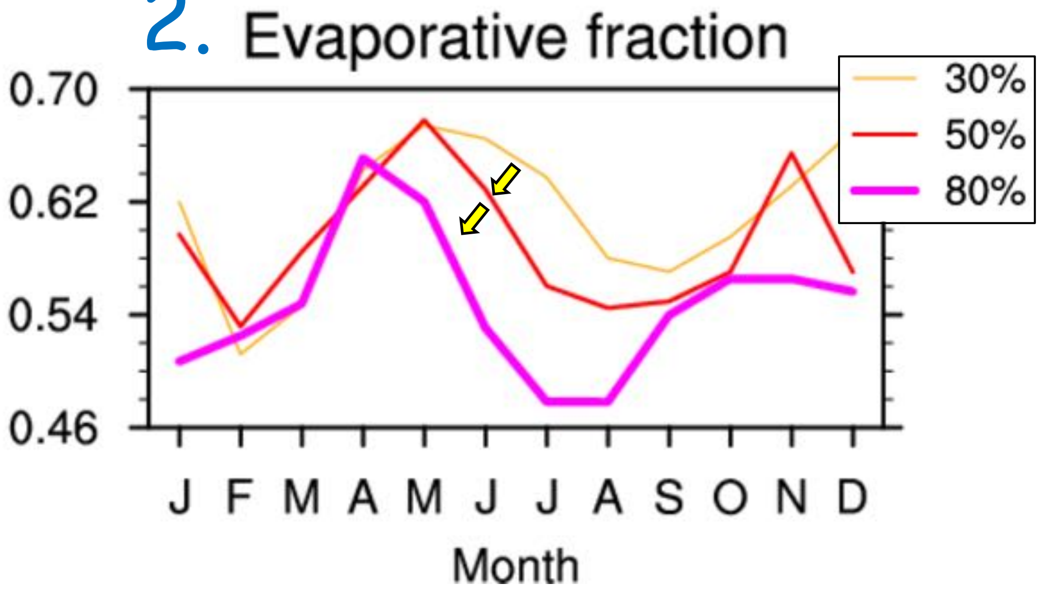


Land cover changes

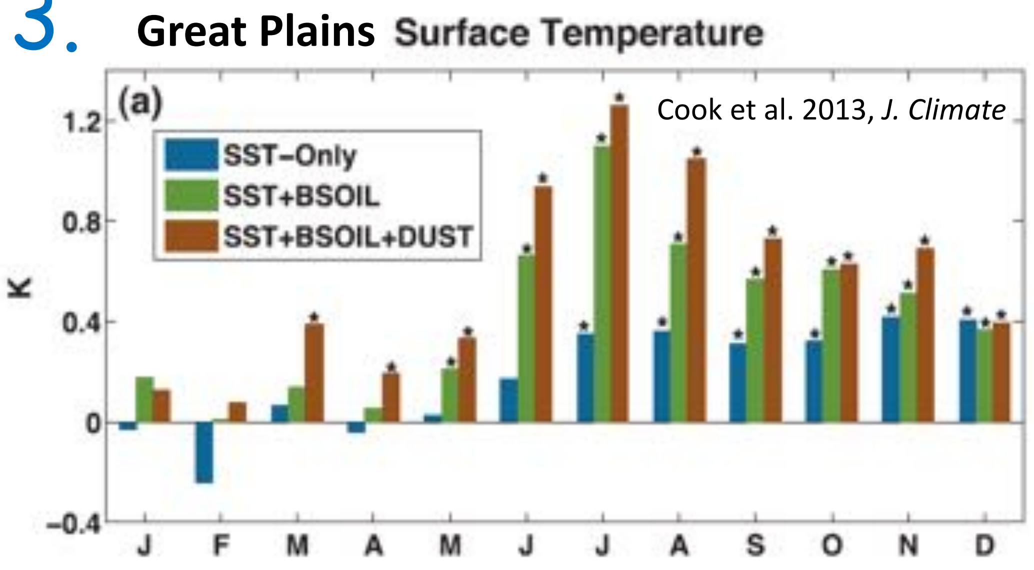
1.



2.

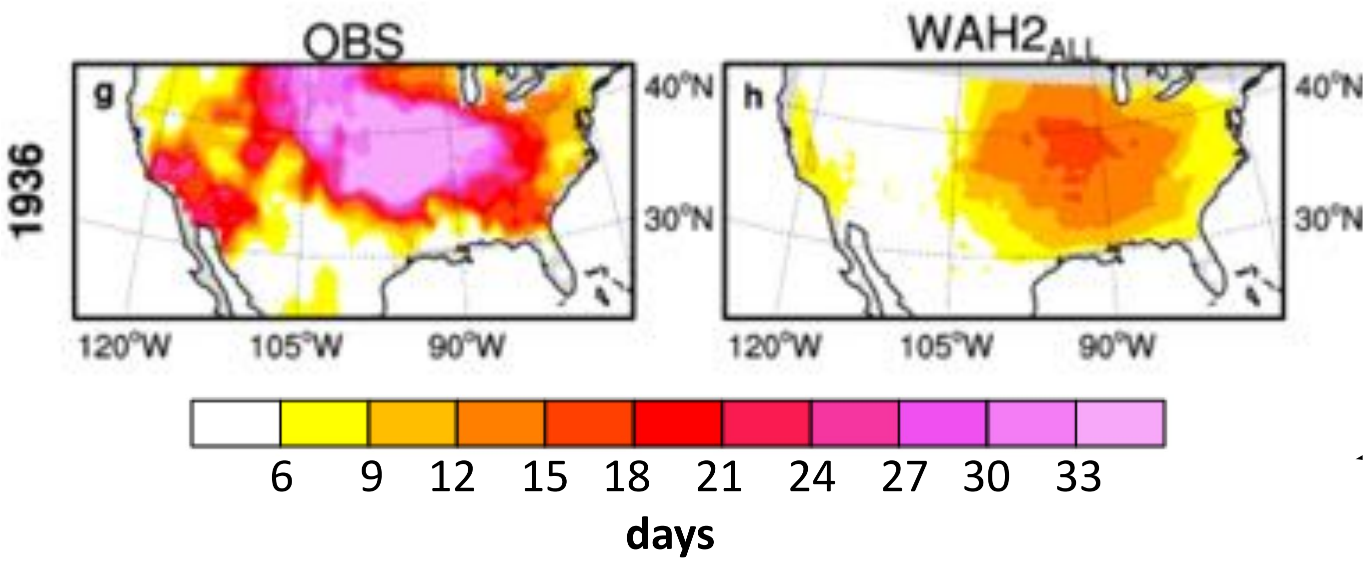


3.



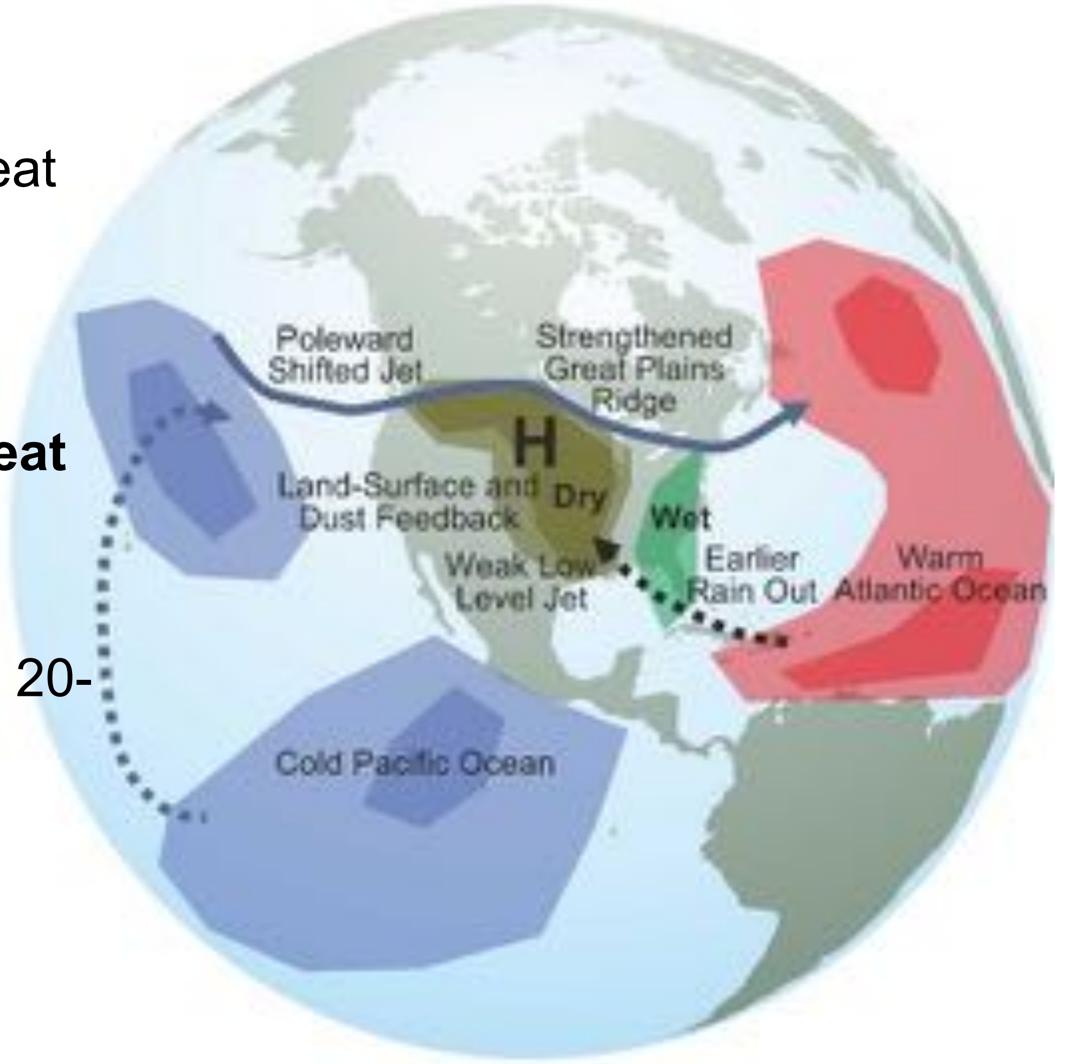
Impact of greenhouse gases (using weather@home2 experiments)

Heat wave frequency



Conclusions

- **Atmosphere-only experiments:**
  - Atlantic SSTs produce hotter, more active Dust Bowl heat waves;
  - Summer differences between experiments arise from spring drying.
- **Devegetation leads to significantly hotter and longer heat waves;**
  - Most likely underestimated in CMIP5 experiments;
  - HadGEM3 highly sensitive to grass removal exceeding 20-30% over central US.
- **Anthropogenic climate change played a small but significant role;**
  - Caution using "absolute" metrics of heat waves (i.e., amplitudes) due to overly warm model biases.



Brönnimann (2015), *Advances in Global Change Research*

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Thank-you

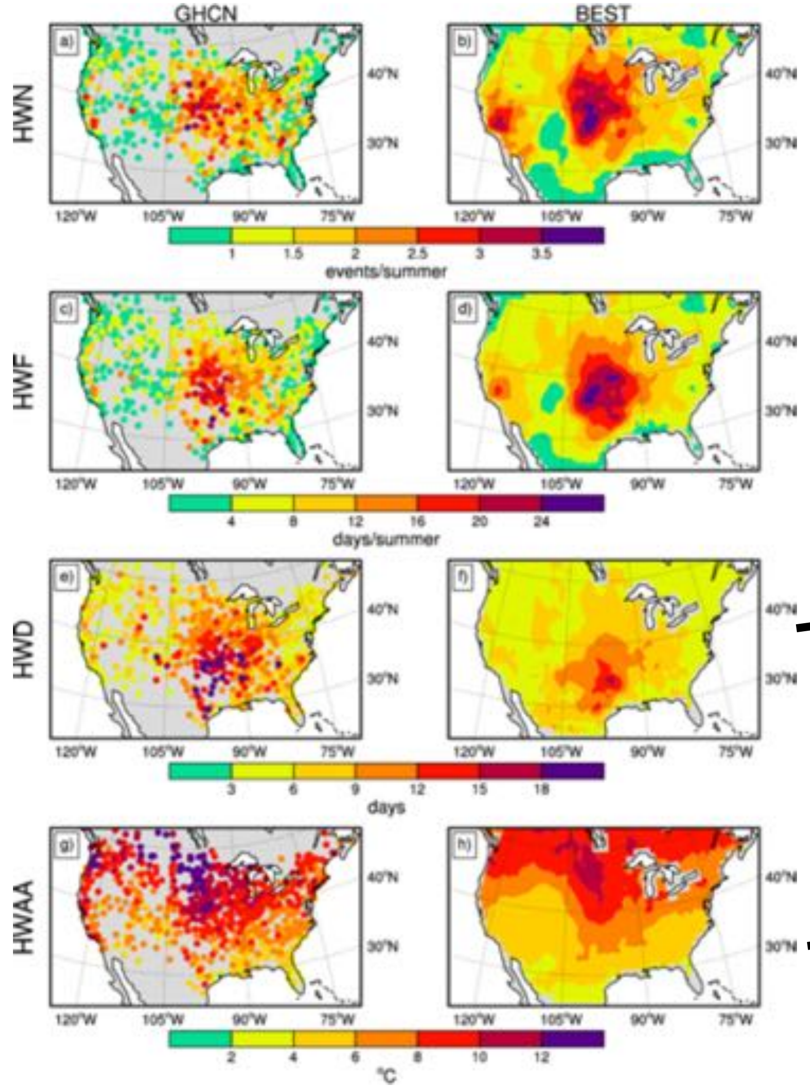
EXTRA SLIDES

Defining heat waves

Simple percentile definition

- **Tmax > 90th percentile 3 consecutive days**
- **Tmin > 90th percentile on 2nd and 3rd (consecutive) nights**
- ➢ Use daily percentiles, using a 15-day sliding window (Perkins & Alexander 2013, *J. Climate*).
- ➢ Similar to Excess Heat Factor (combines heat excess + stress)

Stations | Berkeley Earth Surface Temp.



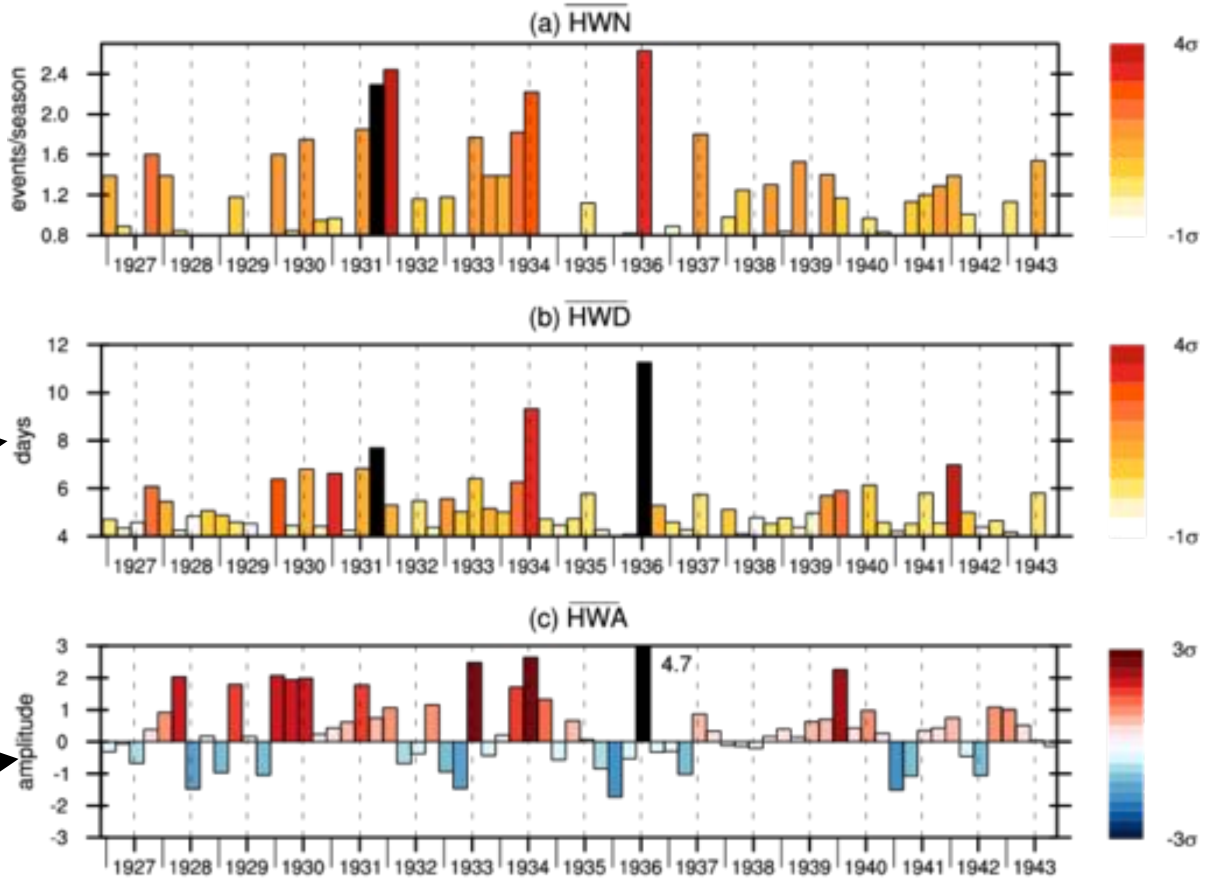
Number (HWN) (events per season)

Frequency (HWF) (total days per season)

Duration (HWD) (longest event per season)

Amplitude (HWAA) (Temp. anomaly of hottest day of hottest event)

Time series over the Great Plains (105-85W, 30-50N)



Season in year

Cowan et al. 2017, *J. Climate*

Schubert et al. 2004 - Science

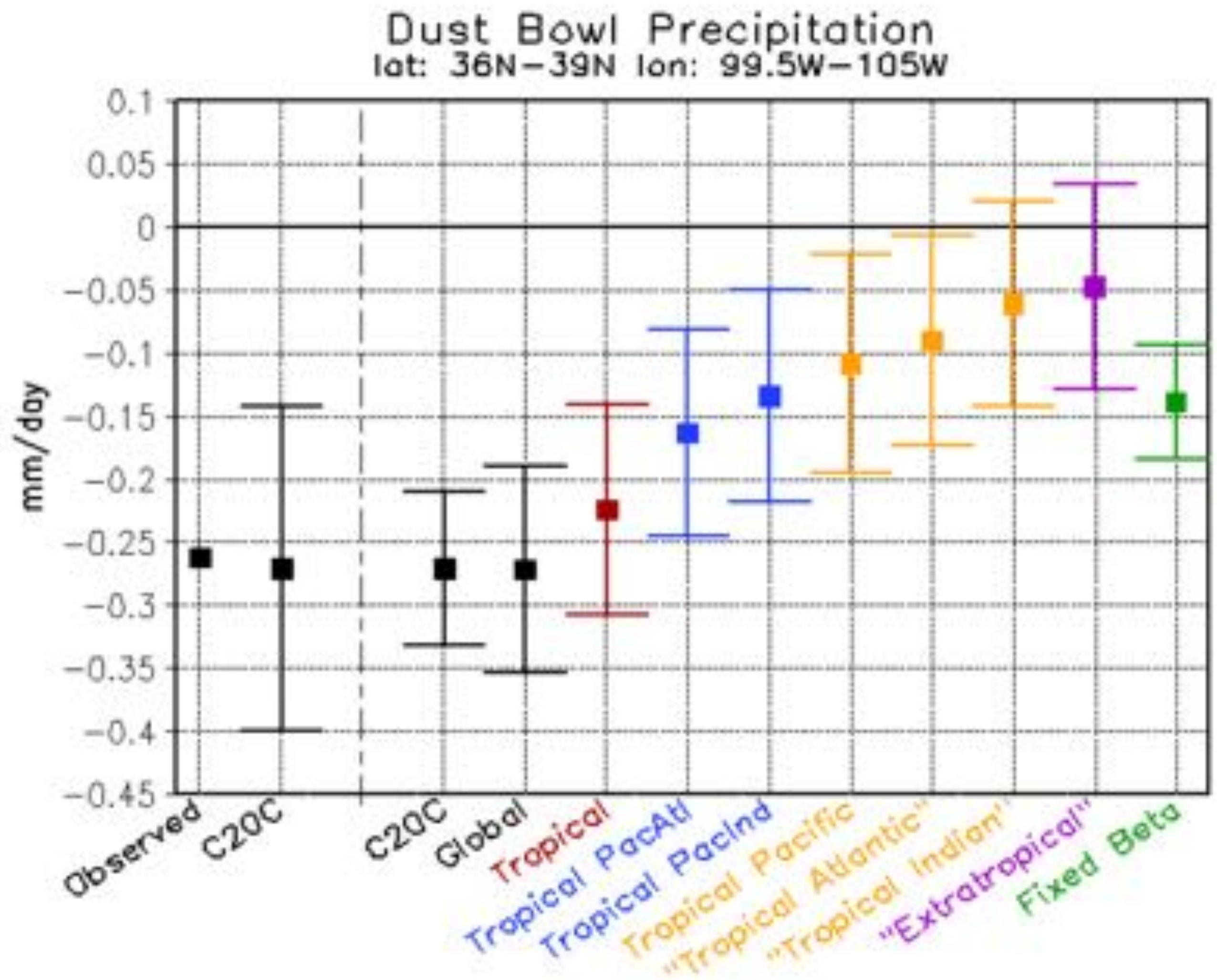
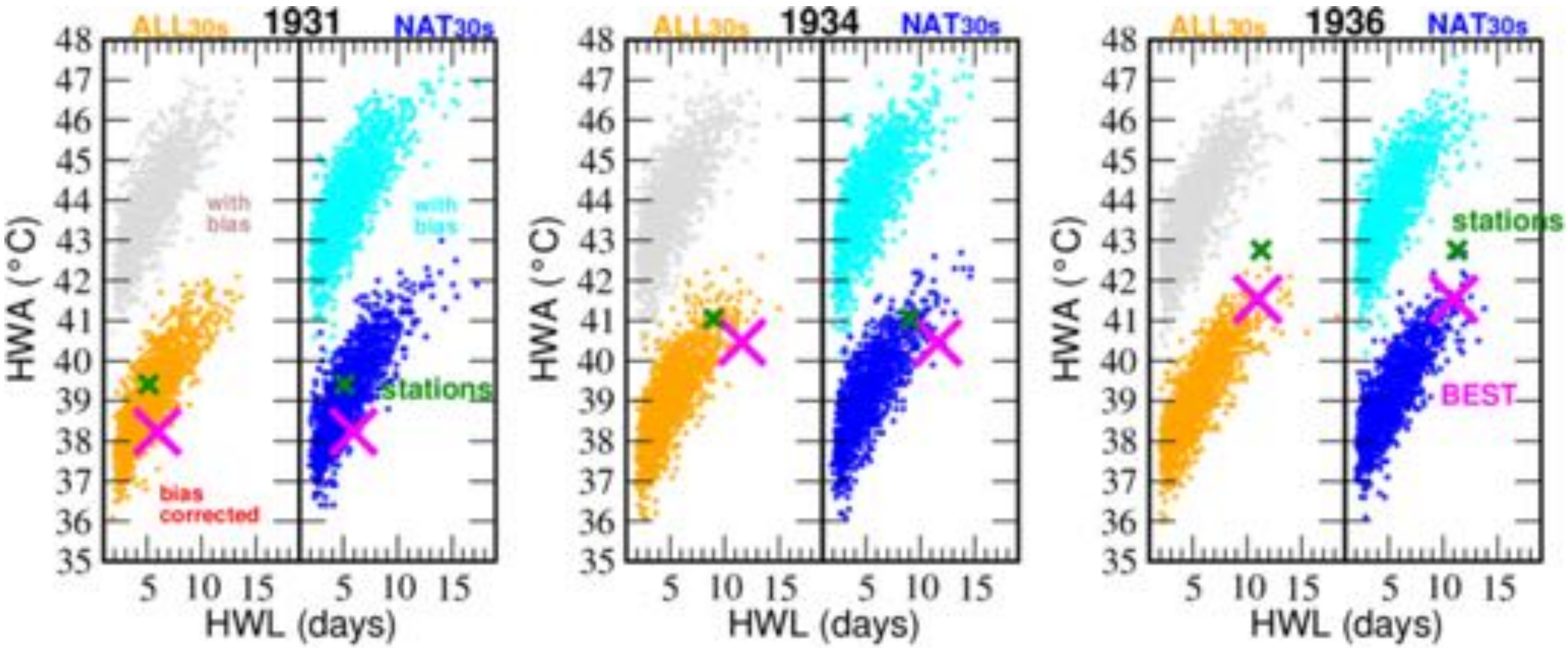
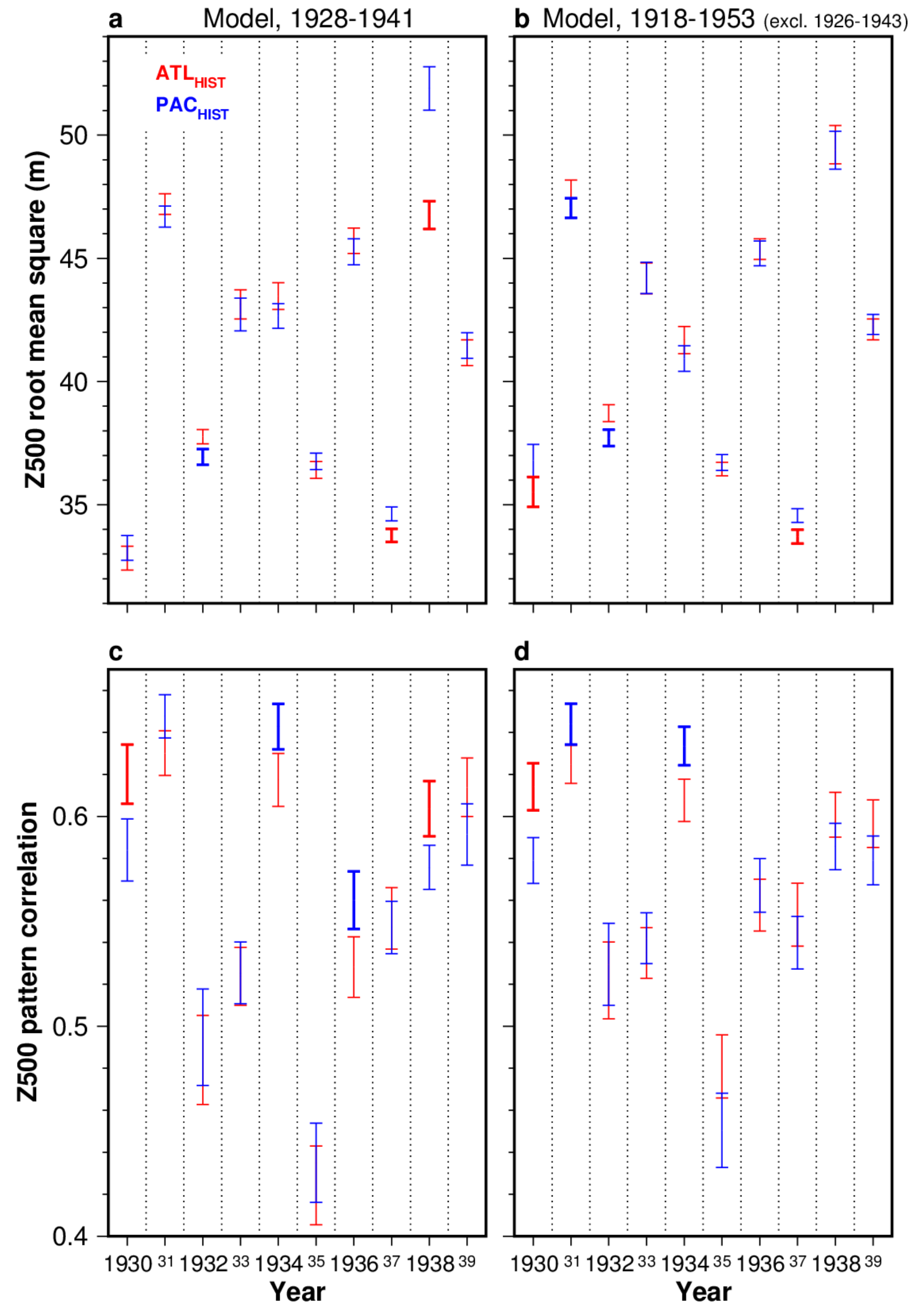


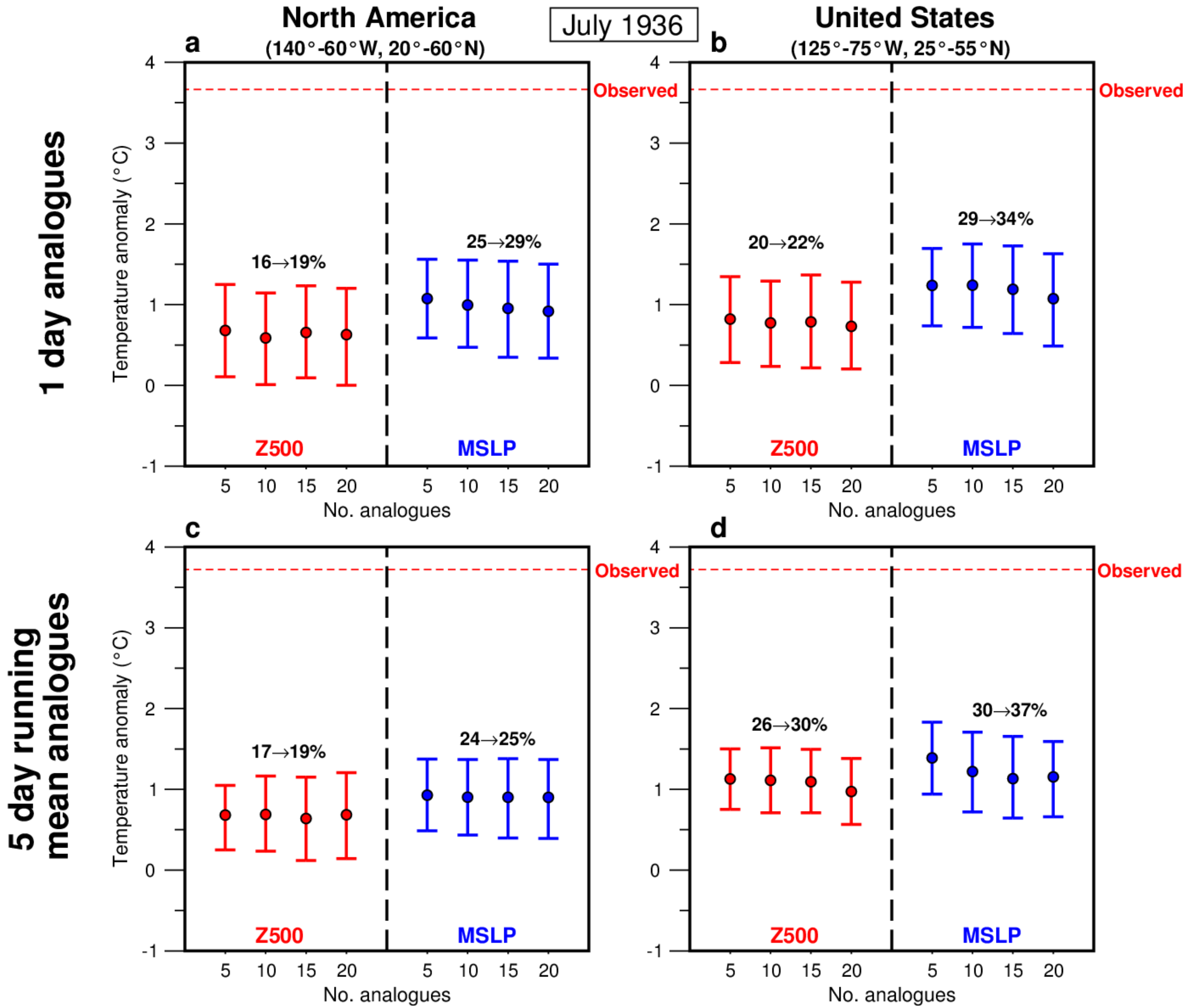
Figure S1: The precipitation anomalies averaged over the core Dust Bowl region (36°N-39°N, 99.5°W-105°W, see boxes in Fig. 4) for the period 1932-1938. The first two points compare the observed and C20C results (the bar denotes the ensemble spread measured by +/- one standard deviation). Points to the right of the dashed vertical line show the results from the various idealized SST runs and a repeat of the C20C value. Here the bars denote the 90% confidence intervals. Units are mm/day

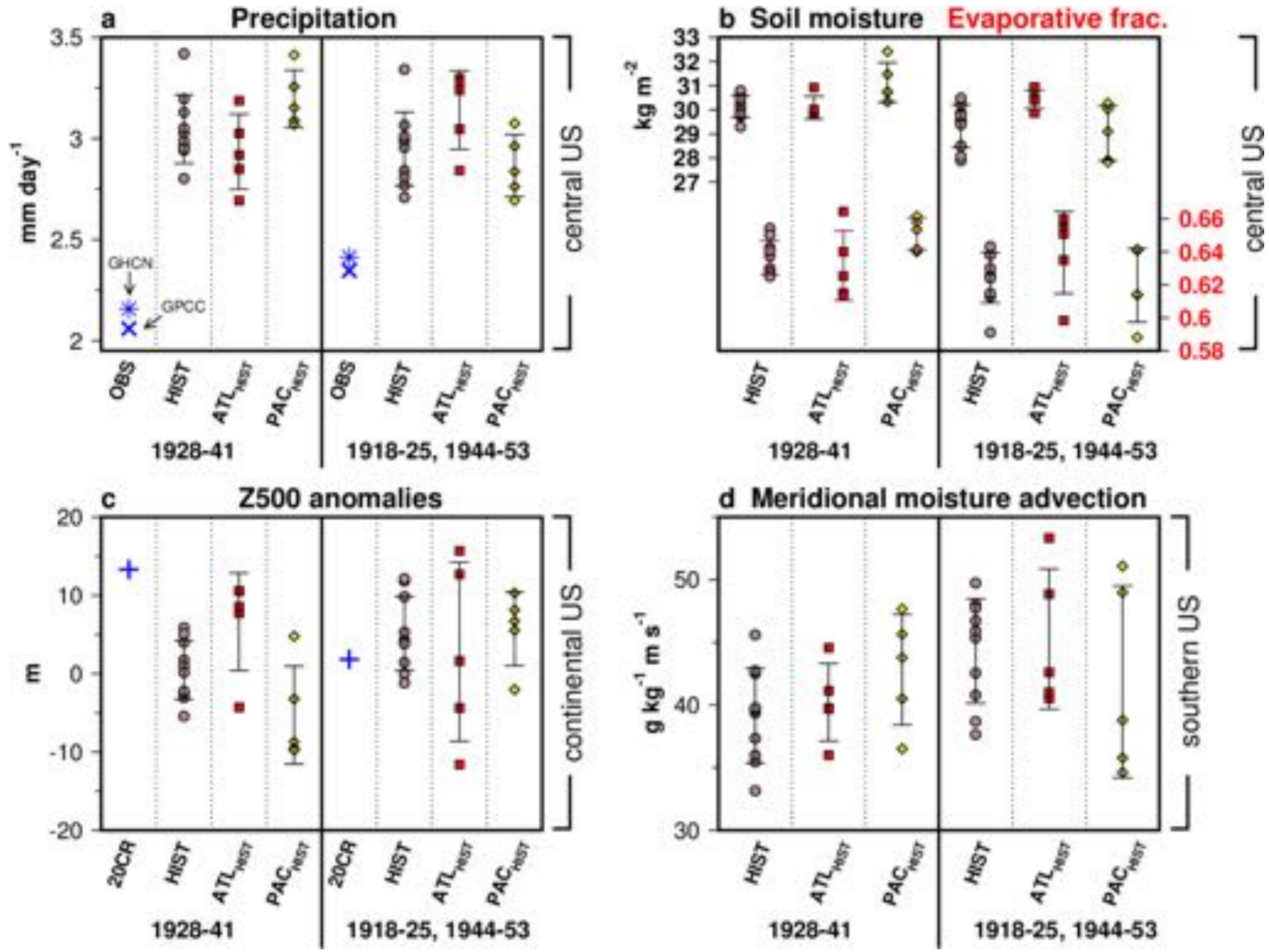
Simulating the Dust Bowl heat waves

- Oxford have carried out weather@home simulations over 1931, 1934 and **1936**, using an atmospheric model + a regional model over southern North America; each year has ~*1500-1600 simulations*.
- One simulation set are driven by observed SSTs with GHGs and aerosol composition set at 1930s levels (**ALL_{30s}**), one without anthropogenic forcing (**NAT_{30s}**), and one with observed SSTs with GHGs set at **p**resent **d**ay levels (**PD_{30s}**).
- Cautious of warm bias in the model.

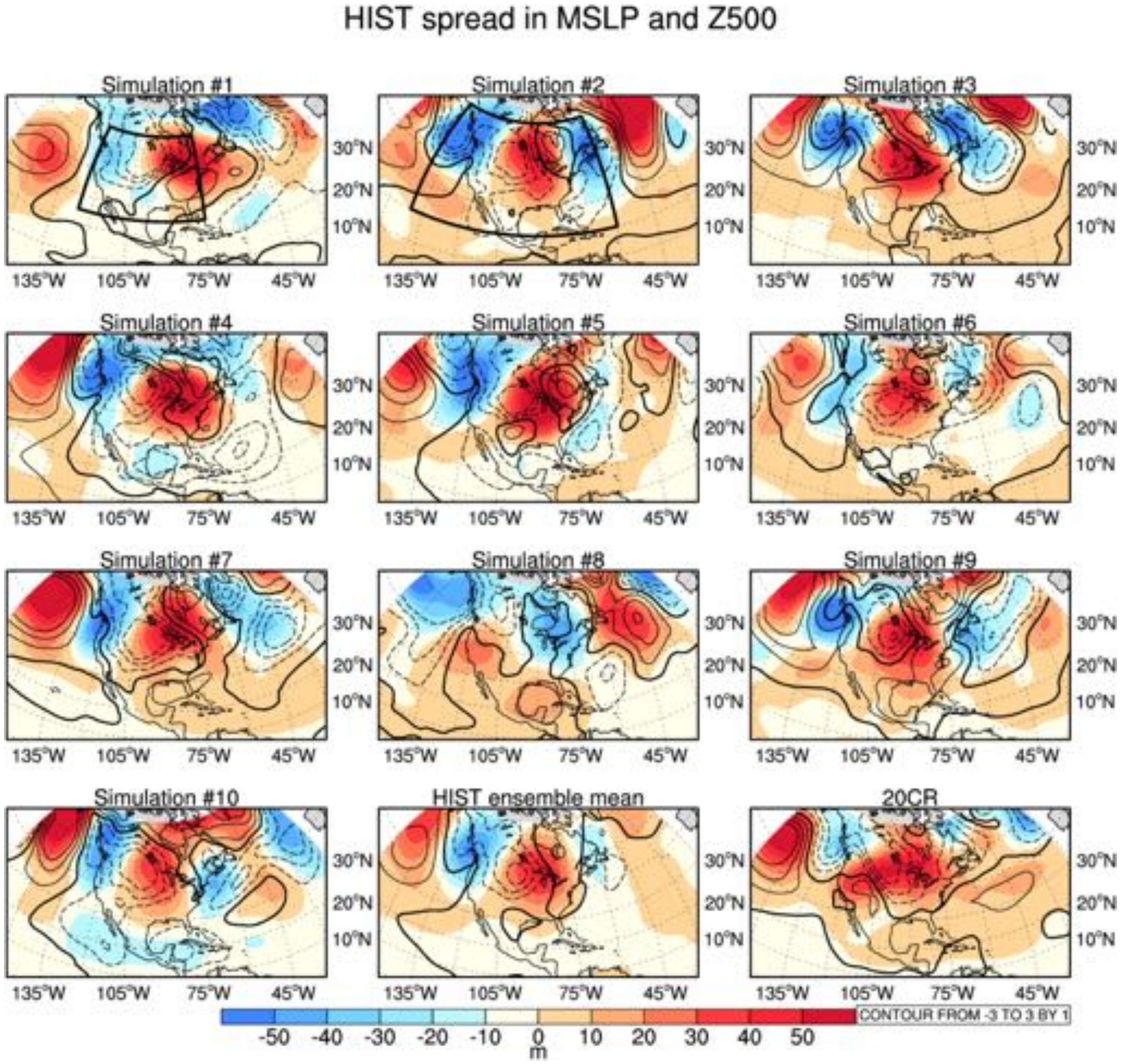


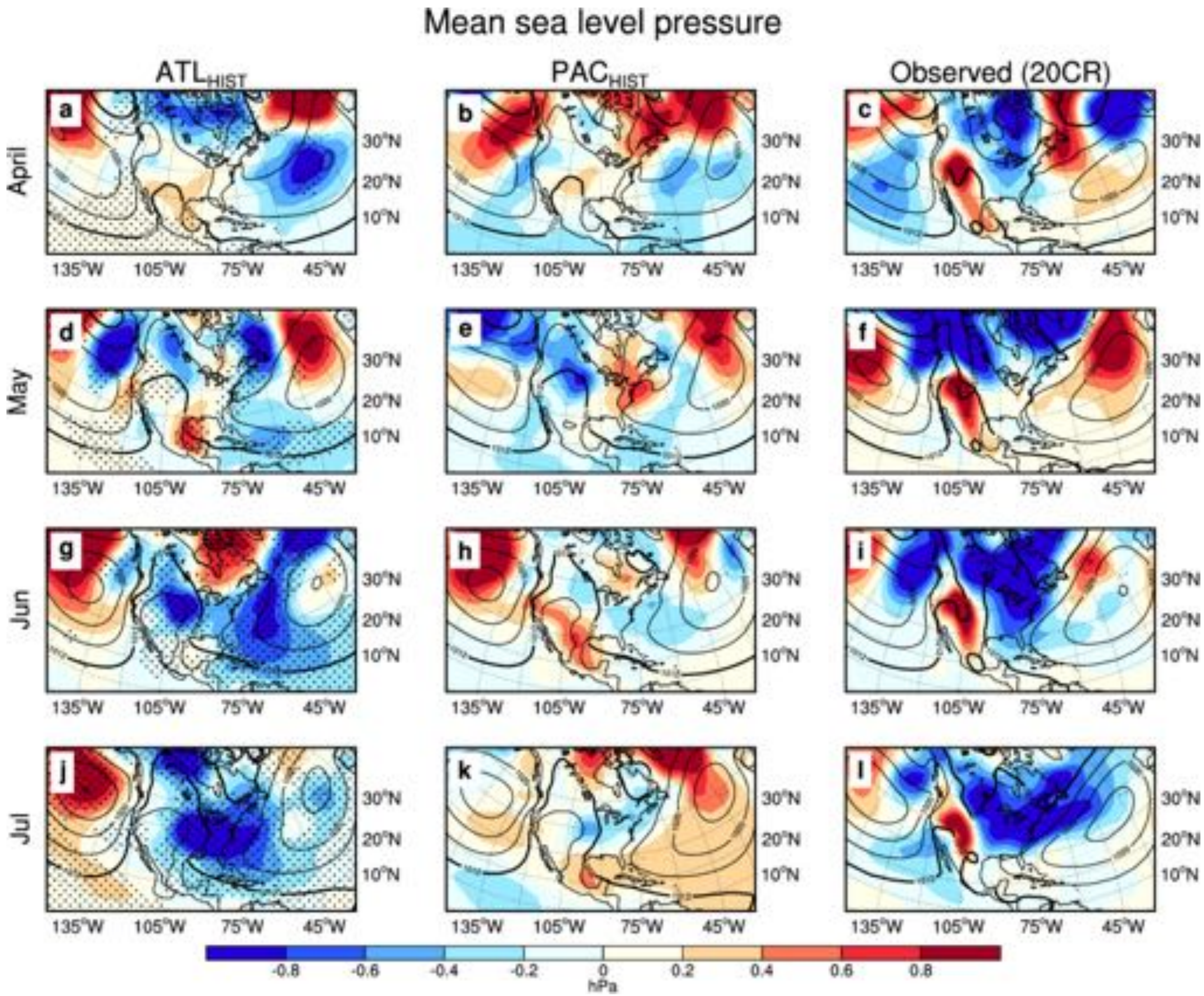

a Model, 1928-1941
b Model, 1918-1953 (excl. 1926-1943)
ATL_HIST
PAC_HIST
Z500 root mean square (m)
c
d
Z500 pattern correlation
1930 31 1932 33 1934 35 1936 37 1938 39
Year


July 1936
North America
(140°-60°W, 20°-60°N)
United States
(125°-75°W, 25°-55°N)
1 day analogues
5 day running mean analogues
Temperature anomaly (°C)
Observed
16→19%
25→29%
20→22%
29→34%
17→19%
24→25%
26→30%
30→37%
Z500
MSLP
No. analogues

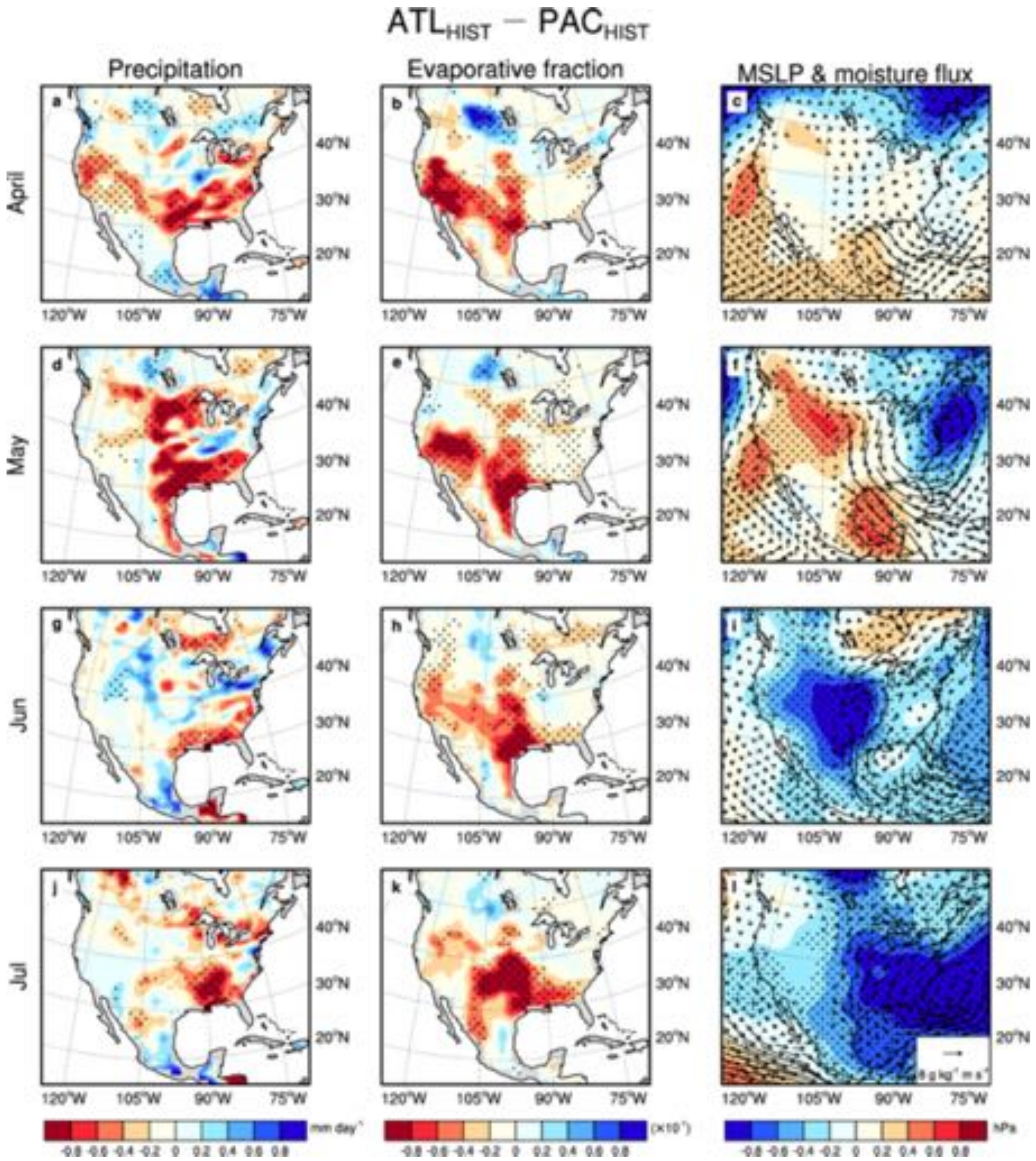


Spread in HadGEM3


HIST spread in MSLP and Z500
Simulation #1
Simulation #2
Simulation #3
Simulation #4
Simulation #5
Simulation #6
Simulation #7
Simulation #8
Simulation #9
Simulation #10
HIST ensemble mean
20CR
30°N
20°N
10°N
135°W
105°W
75°W
45°W
CONTOUR FROM -3 TO 3 BY 1
-50 -40 -30 -20 -10 0 10 20 30 40 50
m

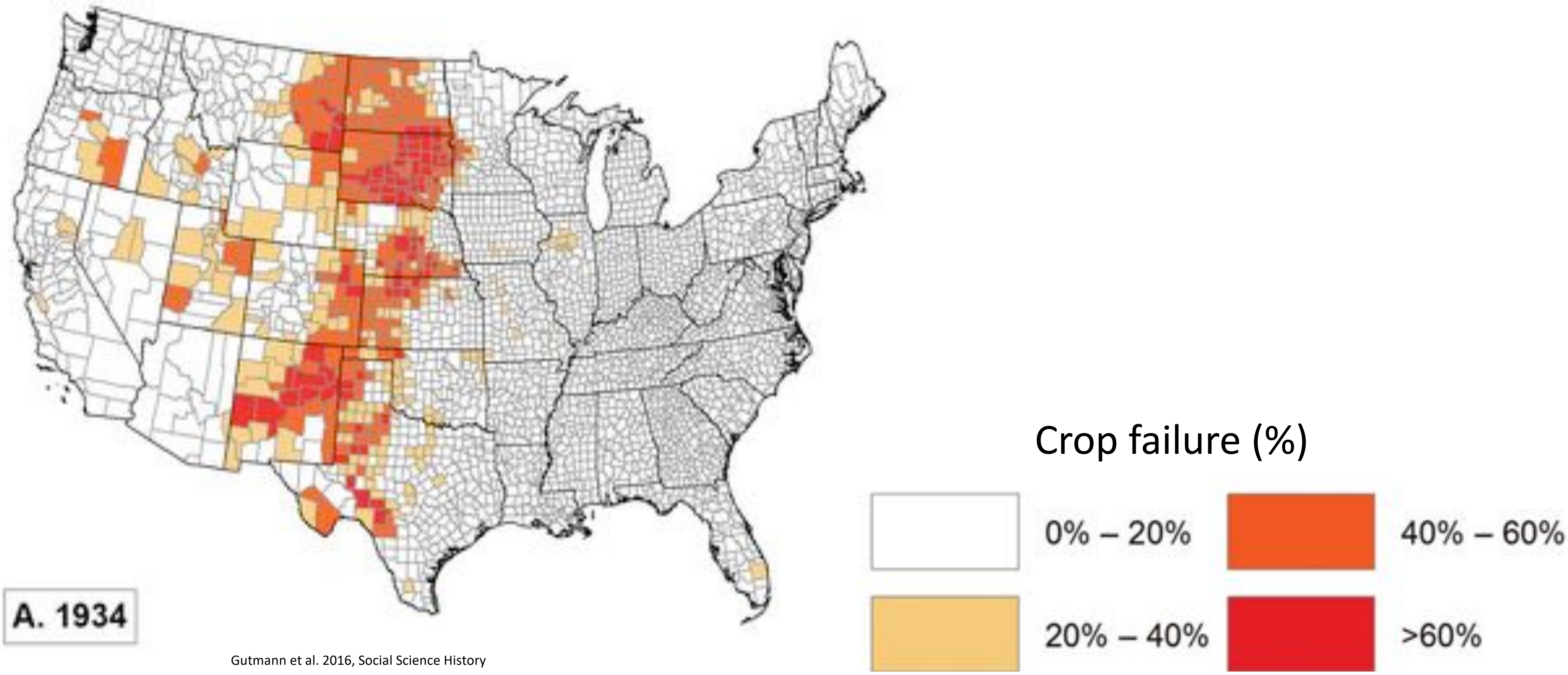


Spring/summer conditions in HadGEM3 & 20CR

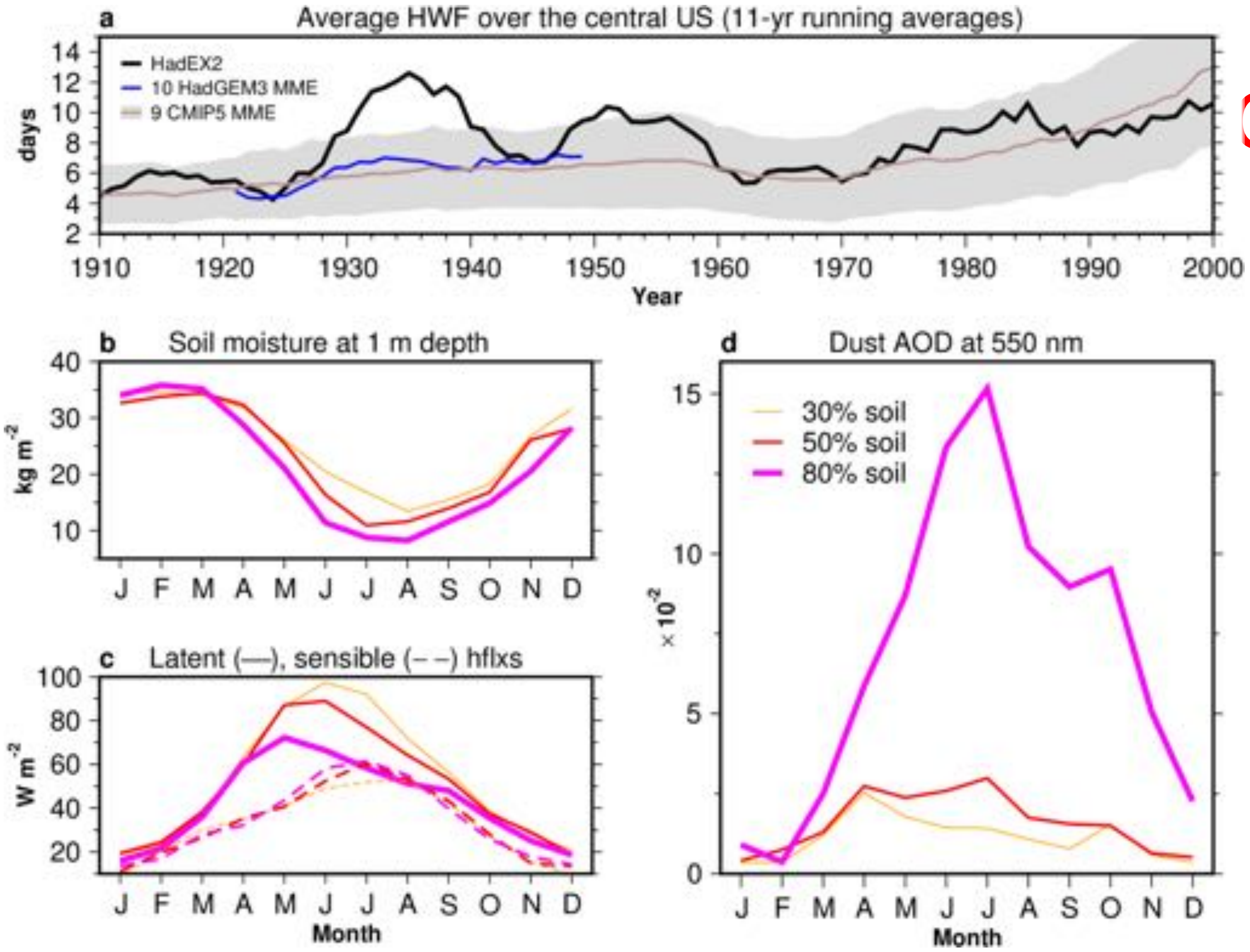


Spring/summer Differences btw ATL and PAC.

1934 crop changes



Gutmann et al. 2016, Social Science History



CMIP5 historical

Bare soil runs

HadGEM3

Weather@home2 simulations