The equator to pole asymmetry in surface warming across the seasonal cycle and temperature percentiles

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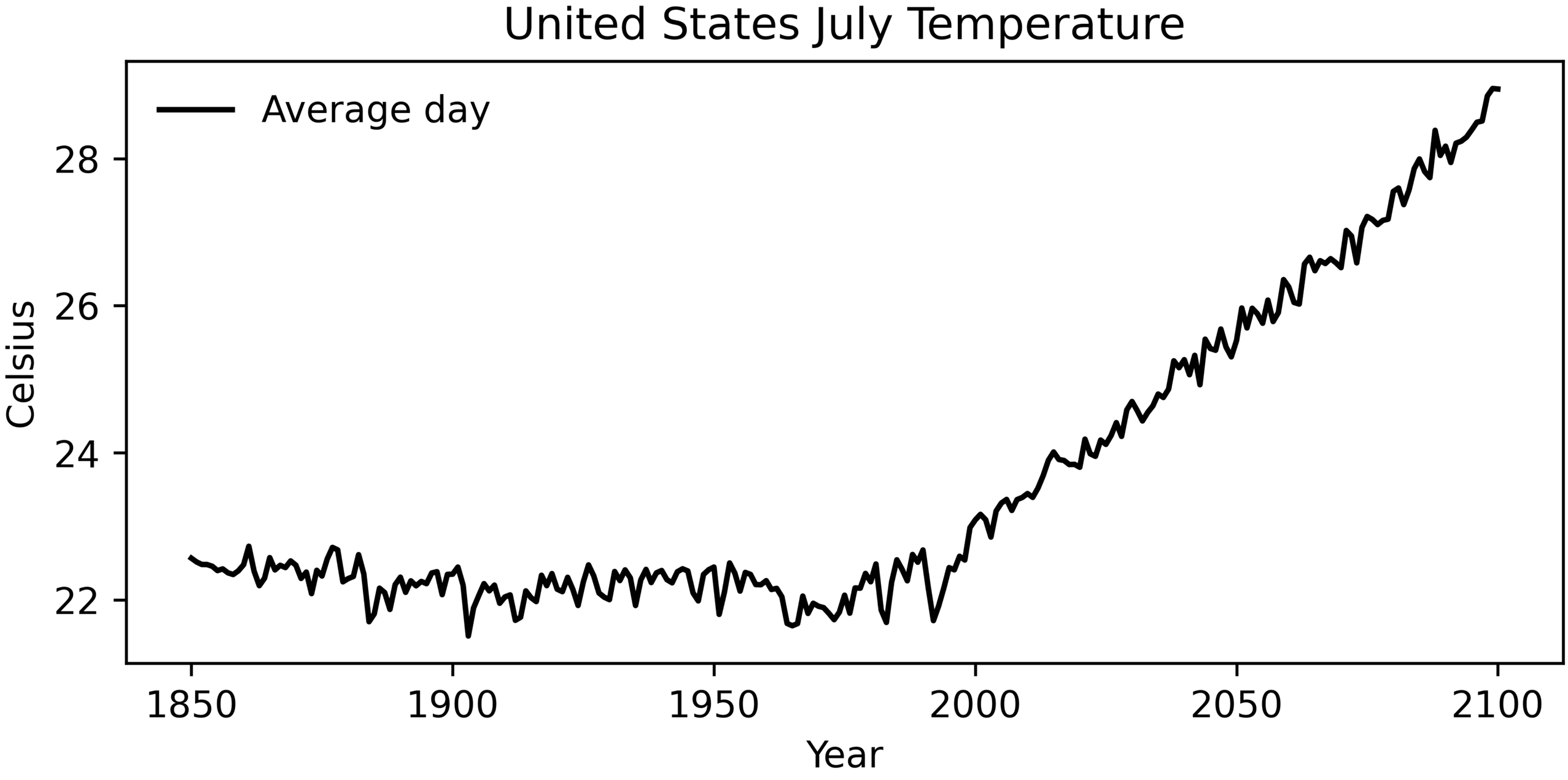
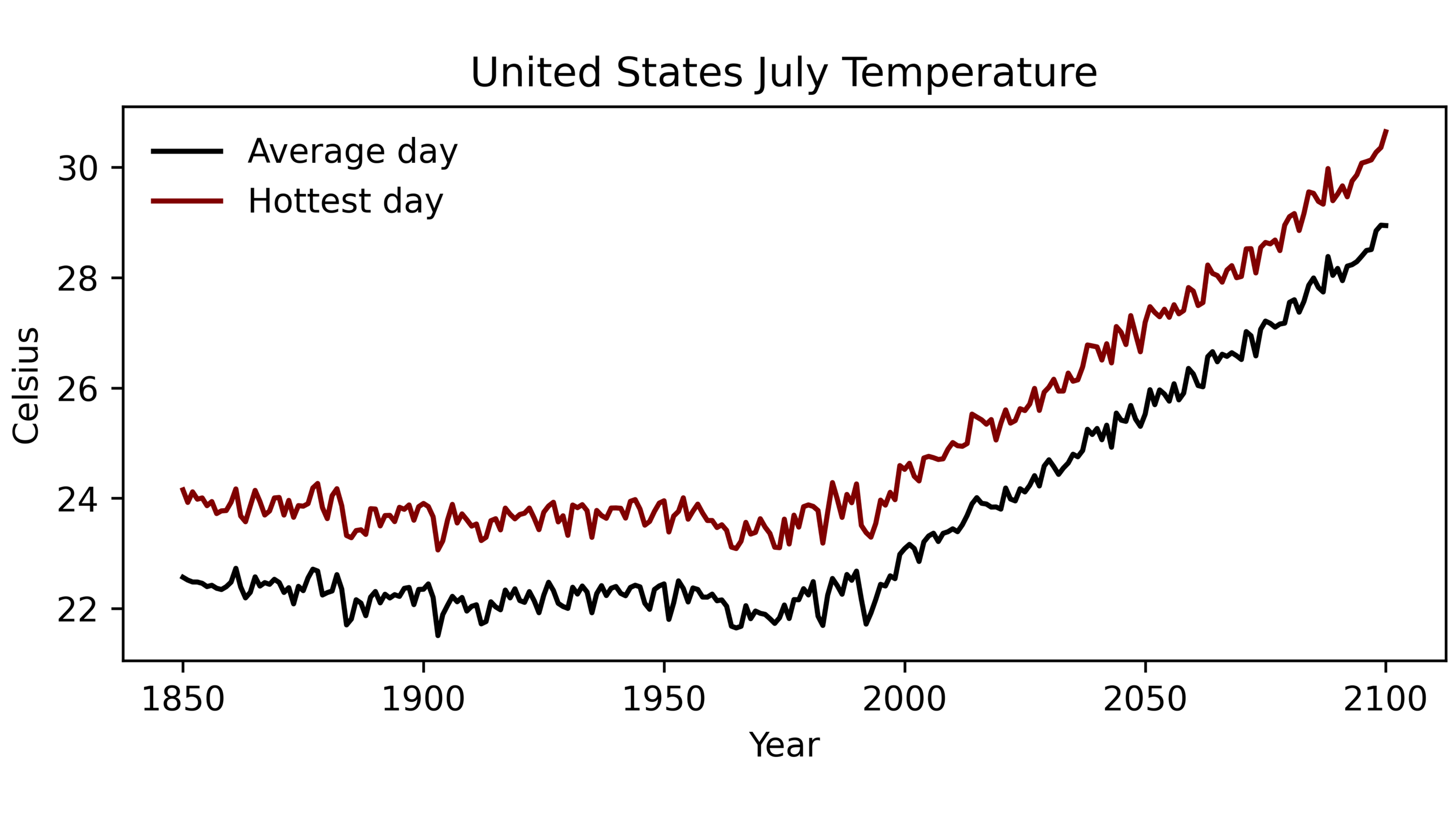
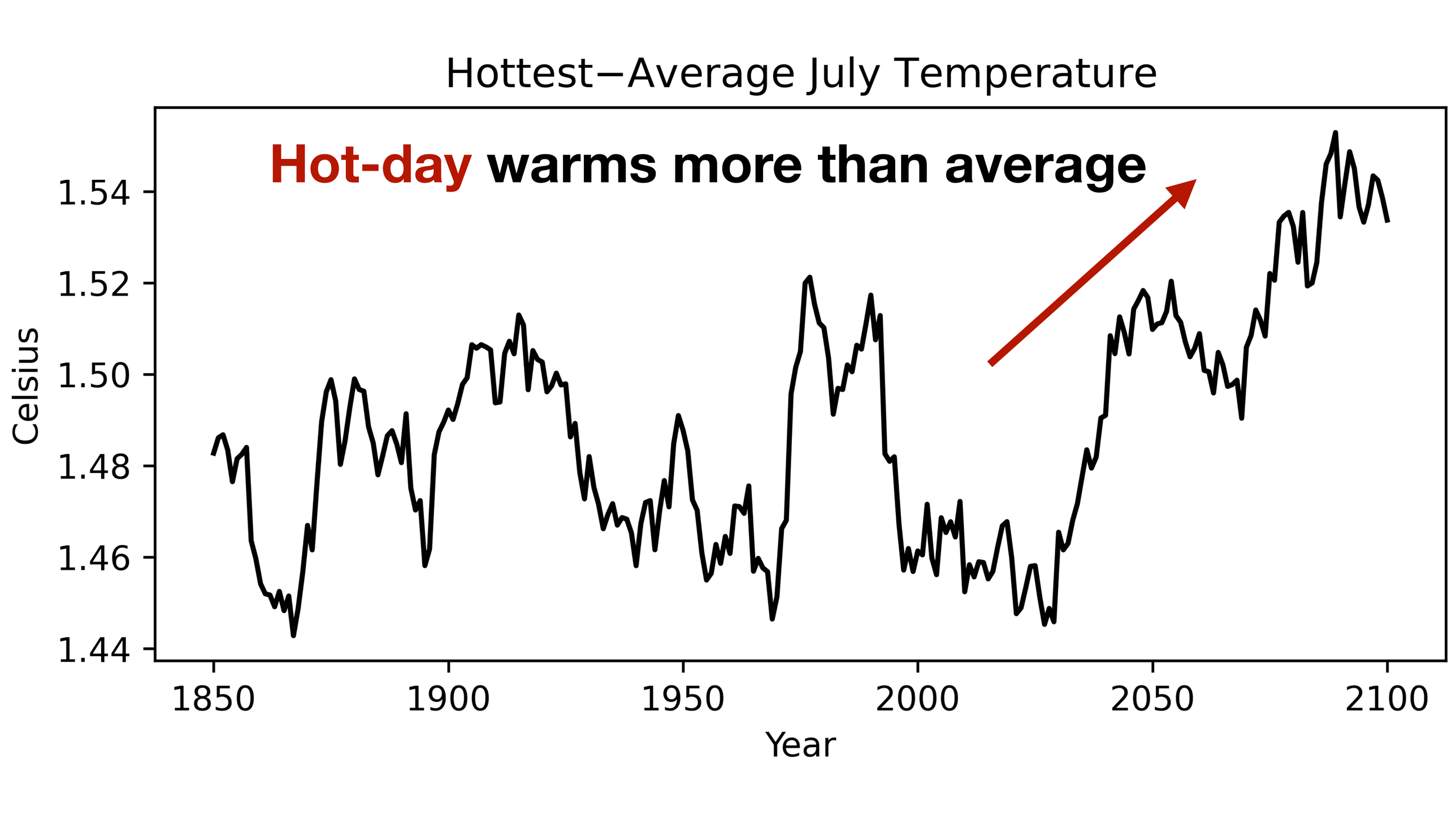
CVCWG Meeting
March 6, 2024

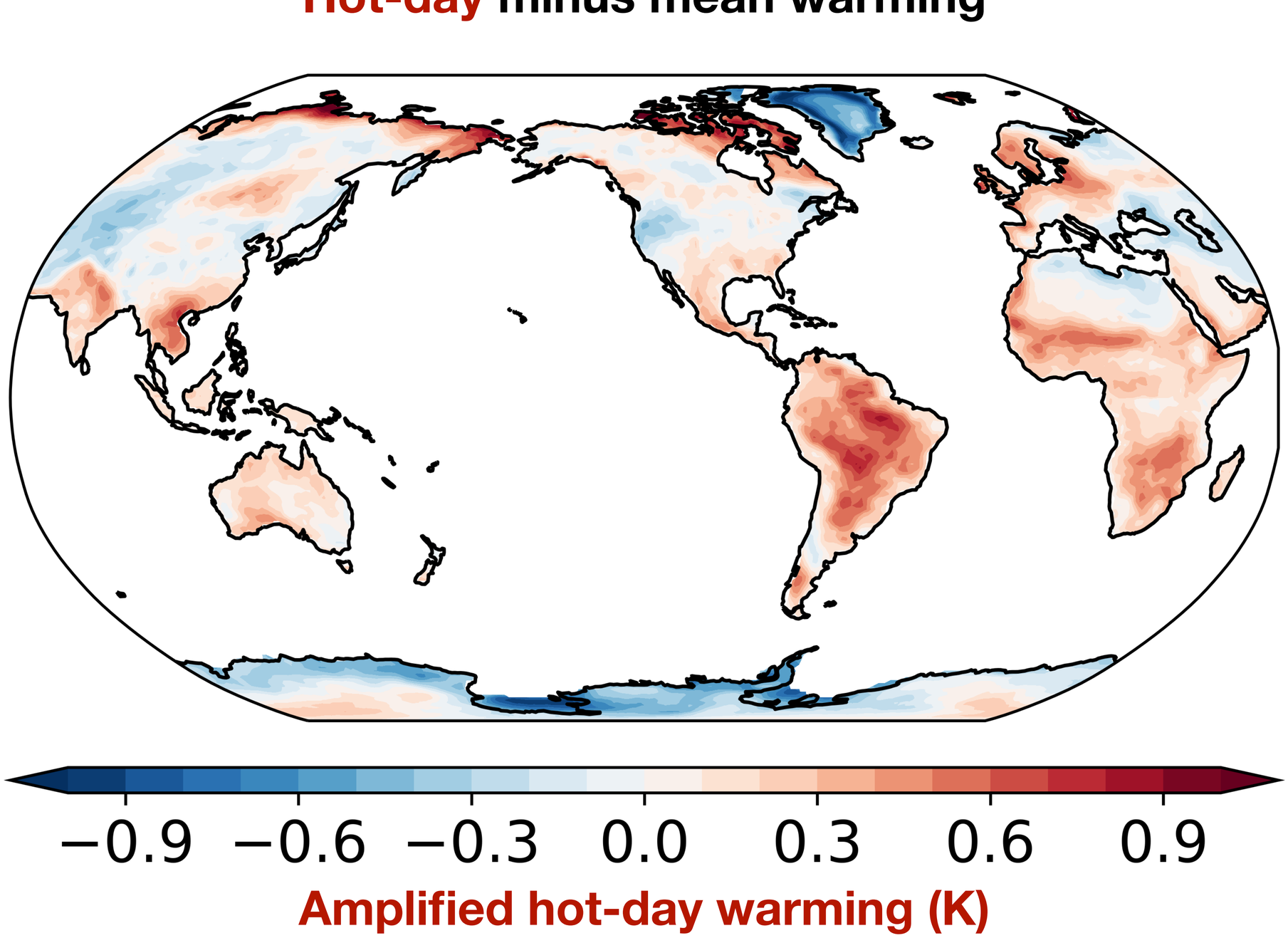

United States July Temperature
Average day
28
26
24
22
Celsius
1850
1900
1950
2000
2050
2100
Year

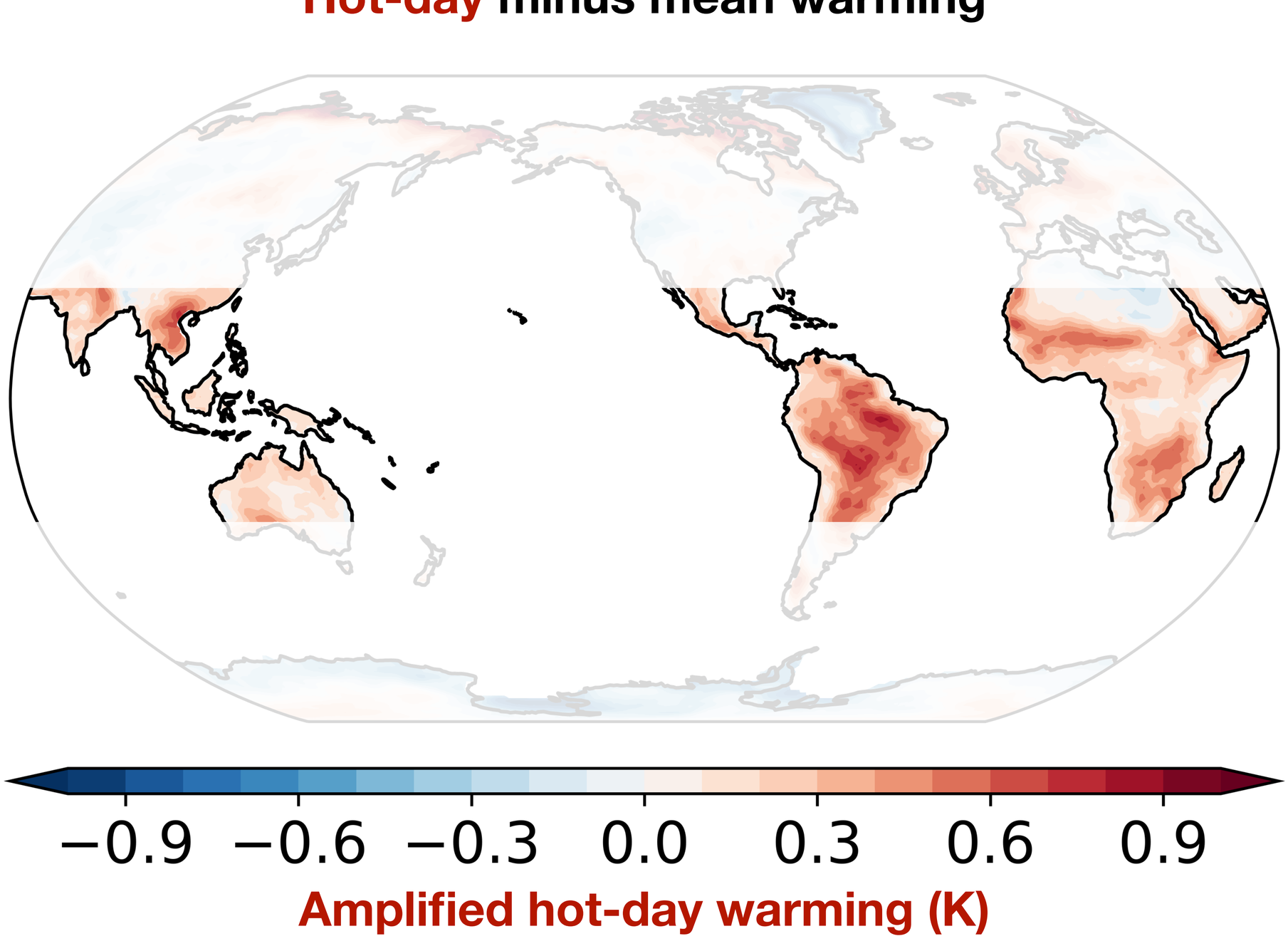

EXTREME HEAT
SAVE POWER 4-9PM
STAY COOL

High Temperatures
June 28, 2021
Bellingham
104°
Mount Baker
93°
Friday Harbor
92°
Concrete
110°
Mount Vernon
105°
Neah Bay
87°
Darrington
109°
Port Angeles
94°
Port Townsend
90°
Everett
107°
Forks
108°
Hurricane Ridge
86°
Monroe
113°
Stevens Pass
94°
Seattle
107°
Queets
91°
Quinault
106°
Bremerton
109°
North Bend
113°
Kent
113°
Snoqualmie Pass
102°
Shelton
111°
Tacoma
111°
Aberdeen
101°
Olympia
112°
Westport
79°
Paradise
88°
Chehalis
110°
Mossyrock
111°
White Pass
93°
65 70 75 80 85 90 95 100 105 110 115
Created: 04:52 AM PDT 06/28/2021
Temperature (F)
weather.gov/Seattle

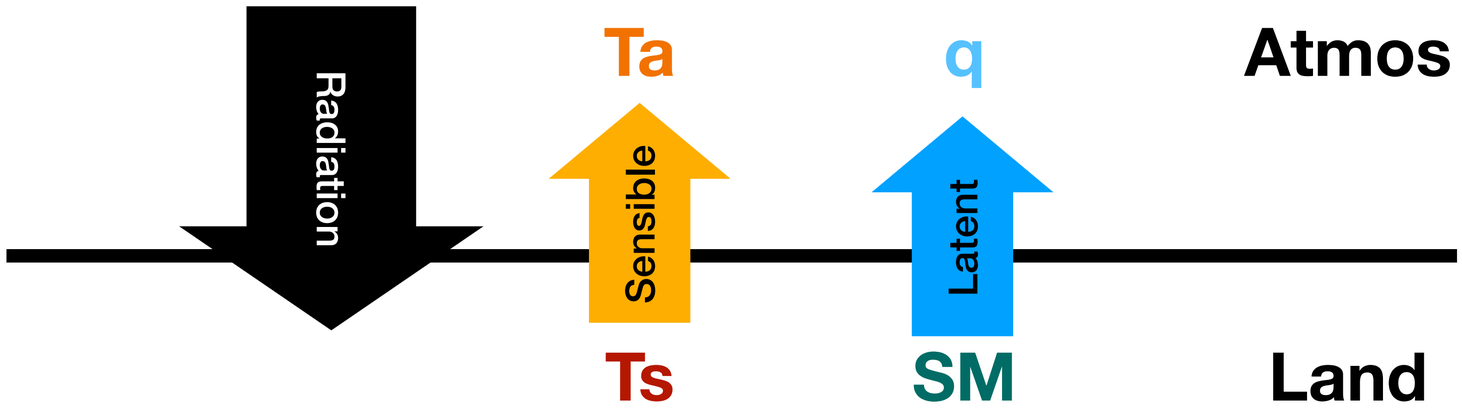

United States July Temperature
Average day
Hottest day
30
28
26
24
22
Celsius
1850
1900
1950
2000
2050
2100
Year


Hottest−Average July Temperature
Hot-day warms more than average
1.54
1.52
1.50
1.48
1.46
1.44
Celsius
1850
1900
1950
2000
2050
2100
Year

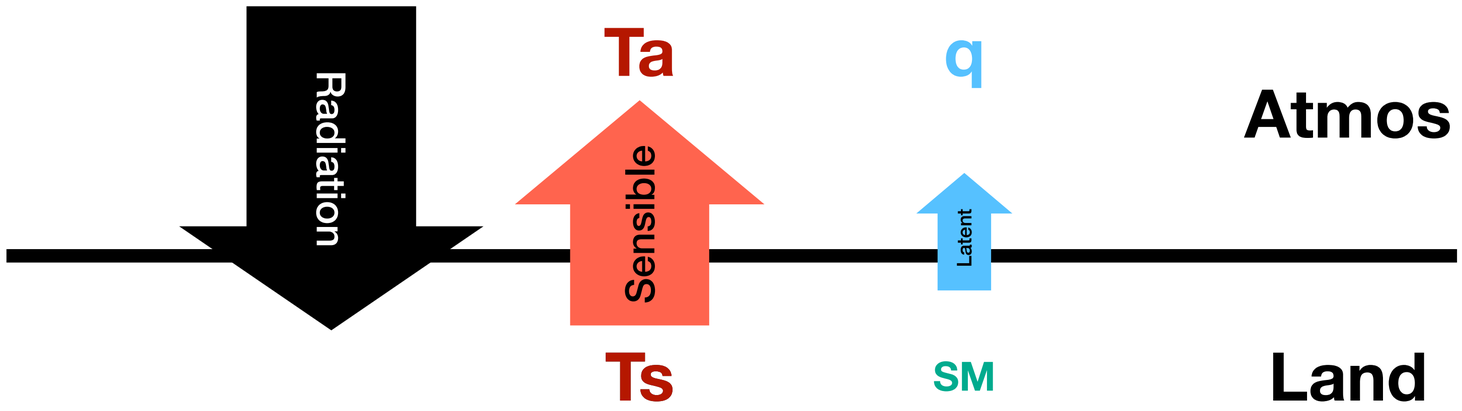

Hot-day minus mean warming
−0.9
−0.6
−0.3
0.0
0.3
0.6
0.9
Amplified hot-day warming (K)


Hot-day minus mean warming
−0.9
−0.6
−0.3
0.0
0.3
0.6
0.9
Amplified hot-day warming (K)

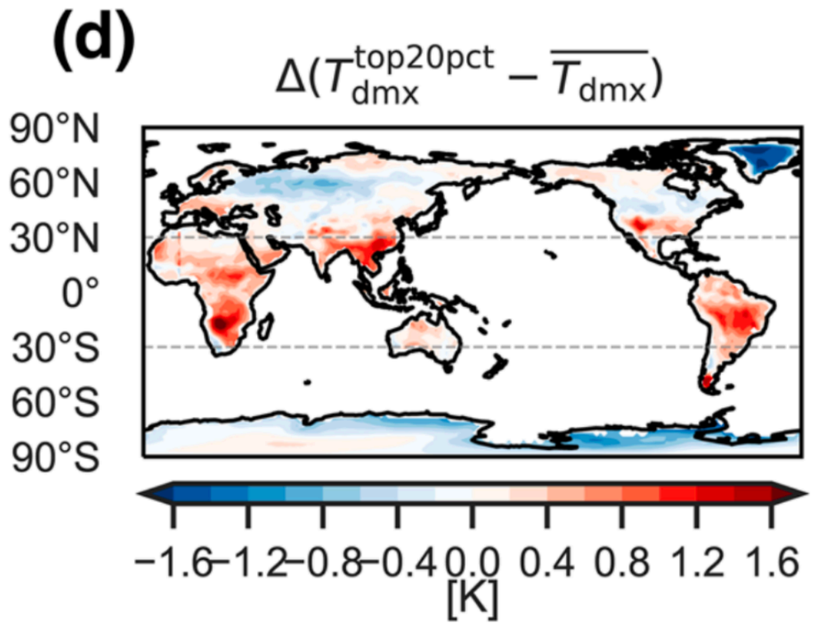
In equilibrium, surface radiative heating is balanced by surface sensible and latent heating



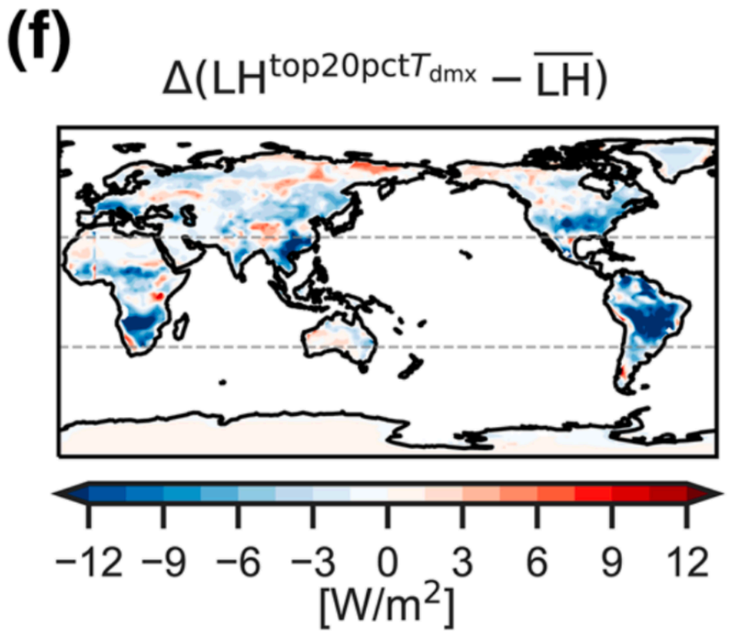
On hot days, latent heating weakens so sensible heating compensates to maintain energy balance



Amplified hot-day warming



Reduced hot-day latent heating

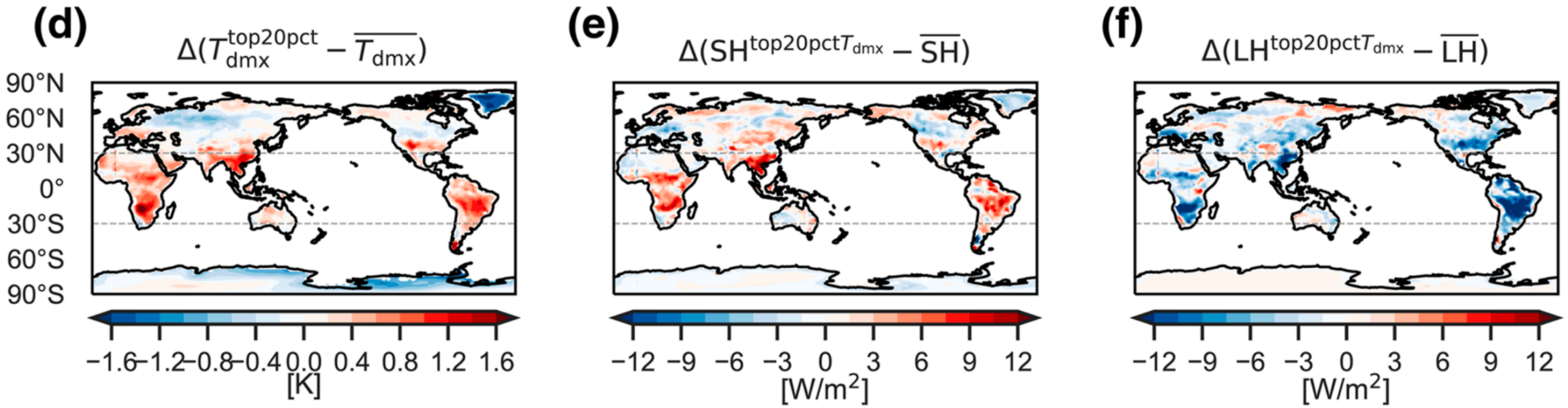


Duan et al. (2020)

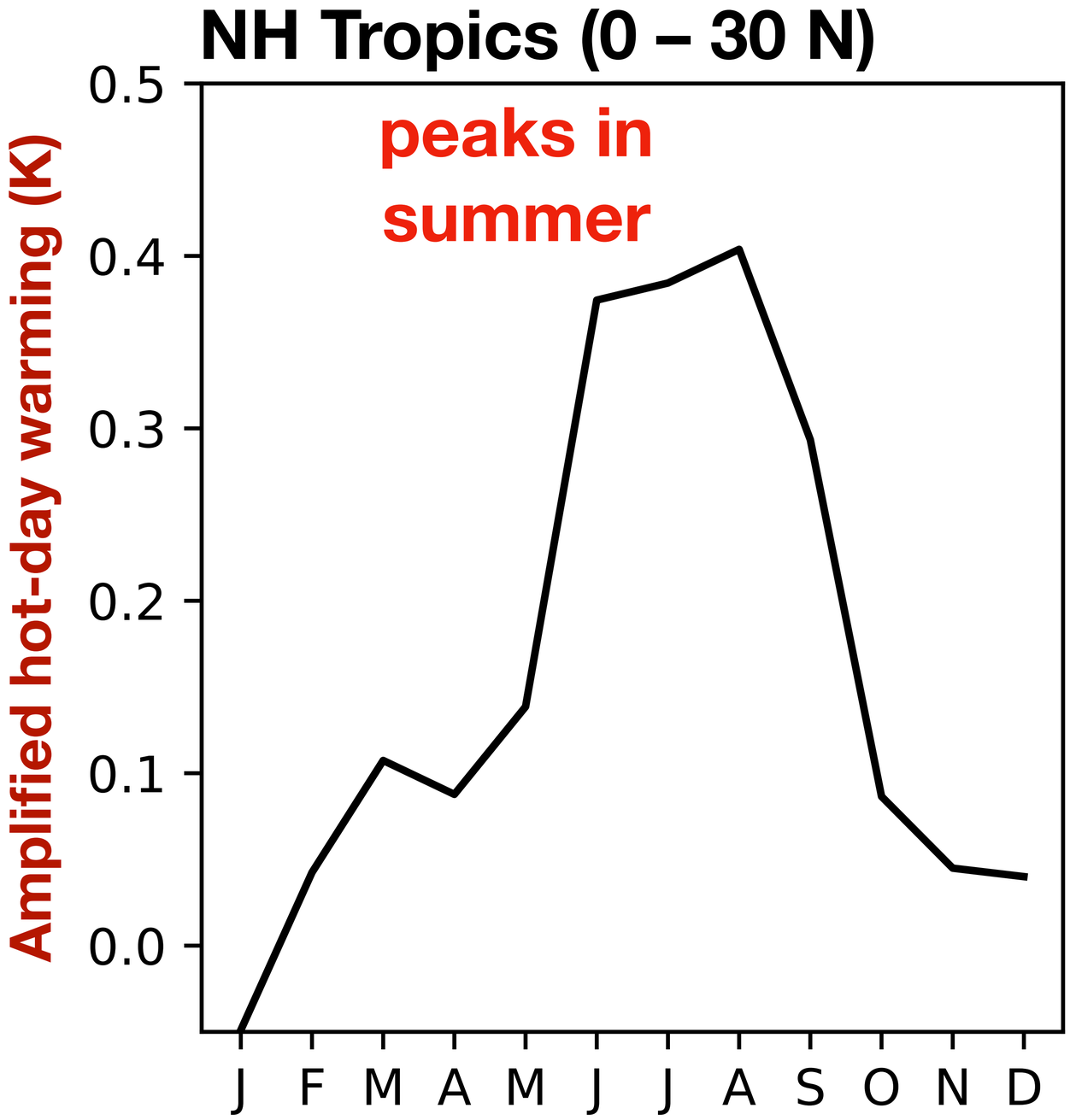
Amplified hot-day warming

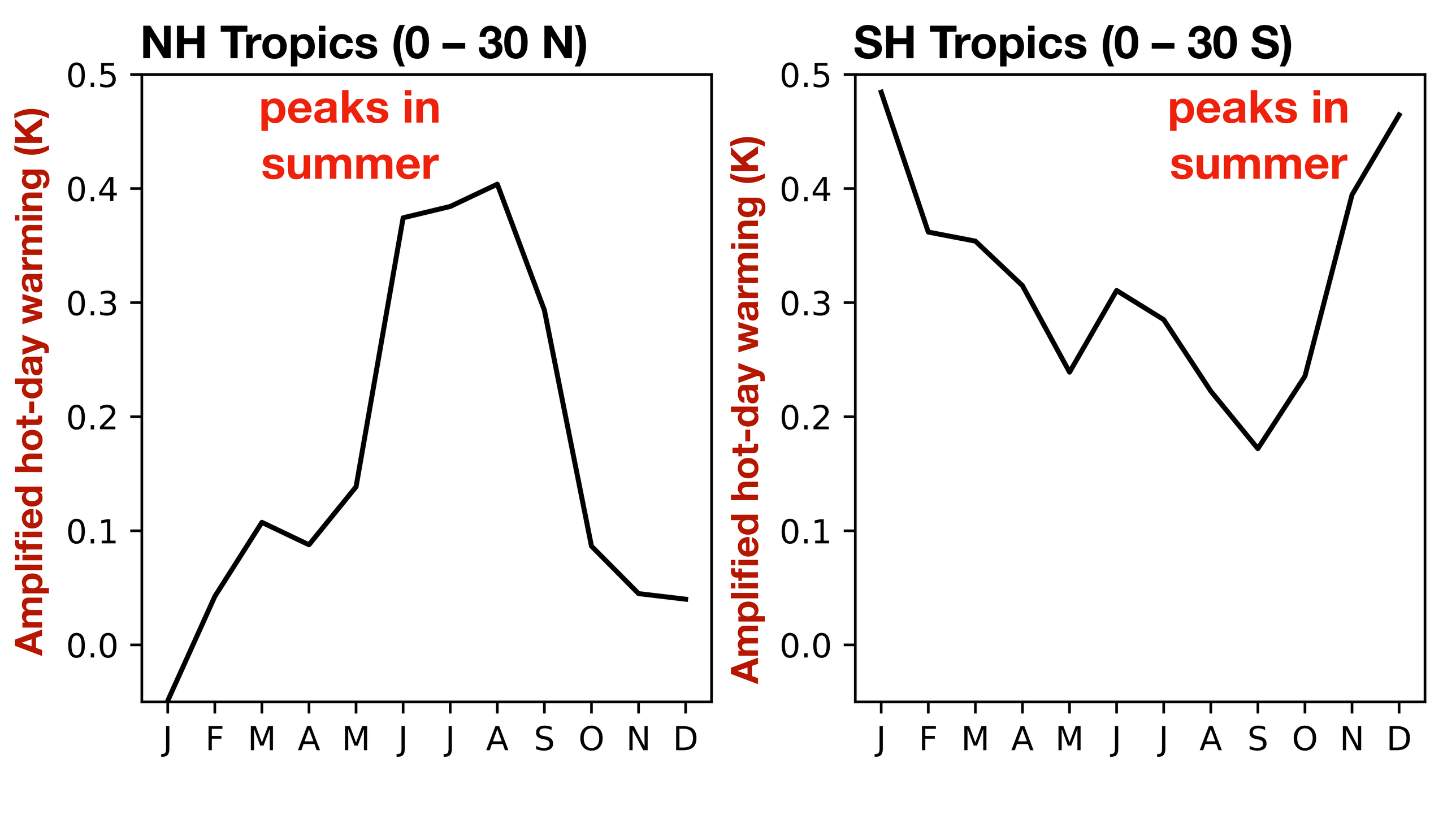
Amplified hot-day sensible heating

Reduced hot-day latent heating

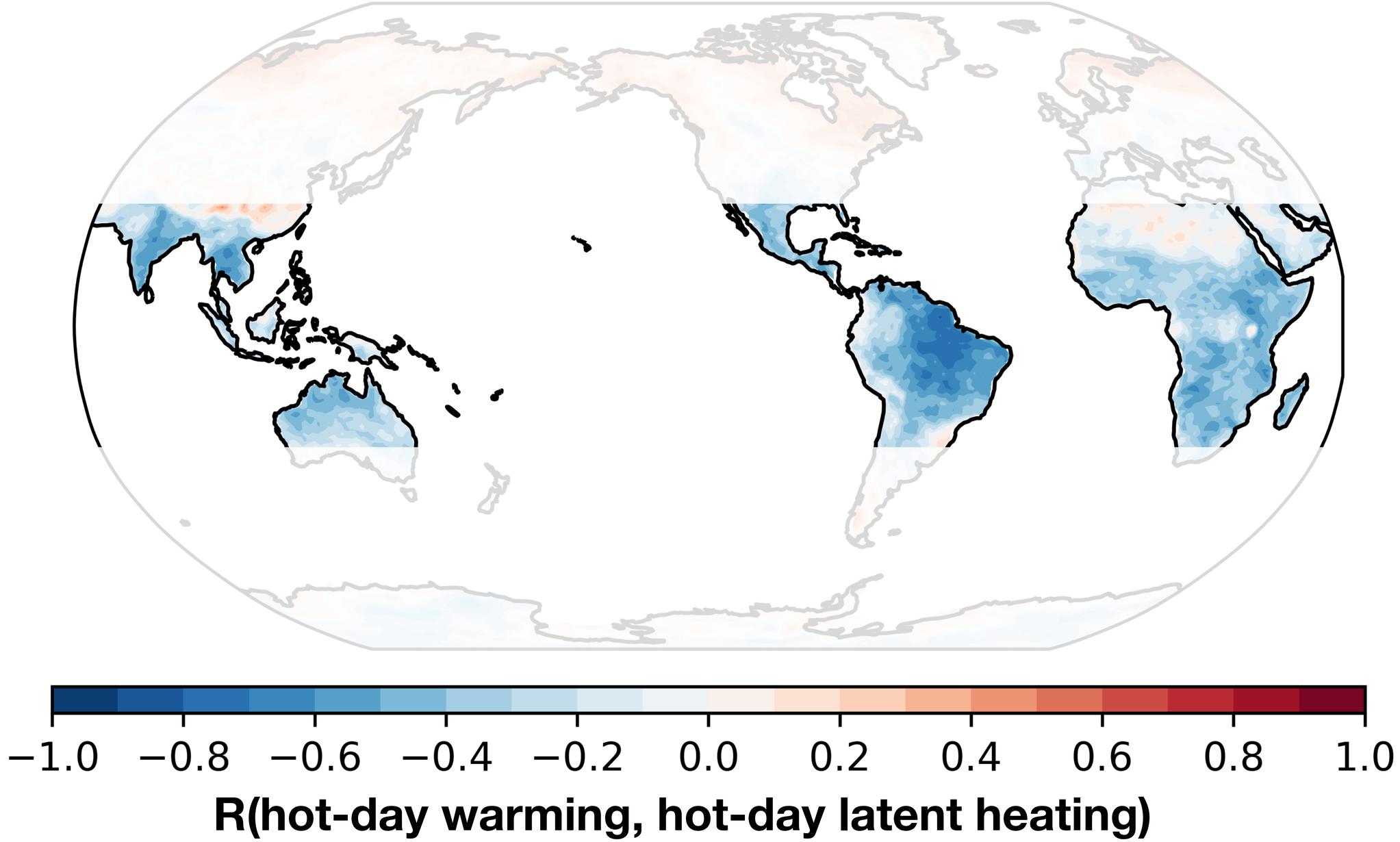


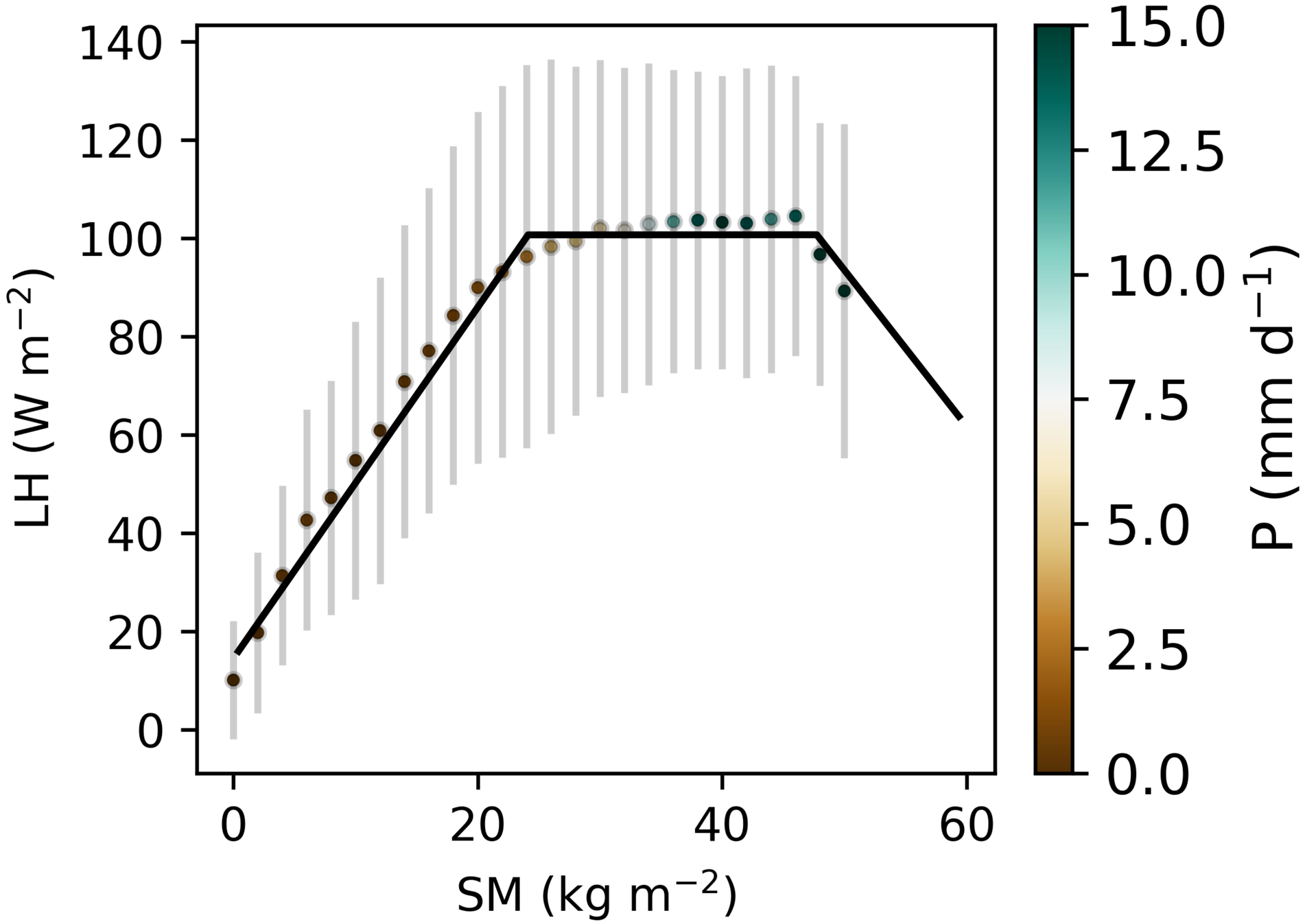
Duan et al. (2020)

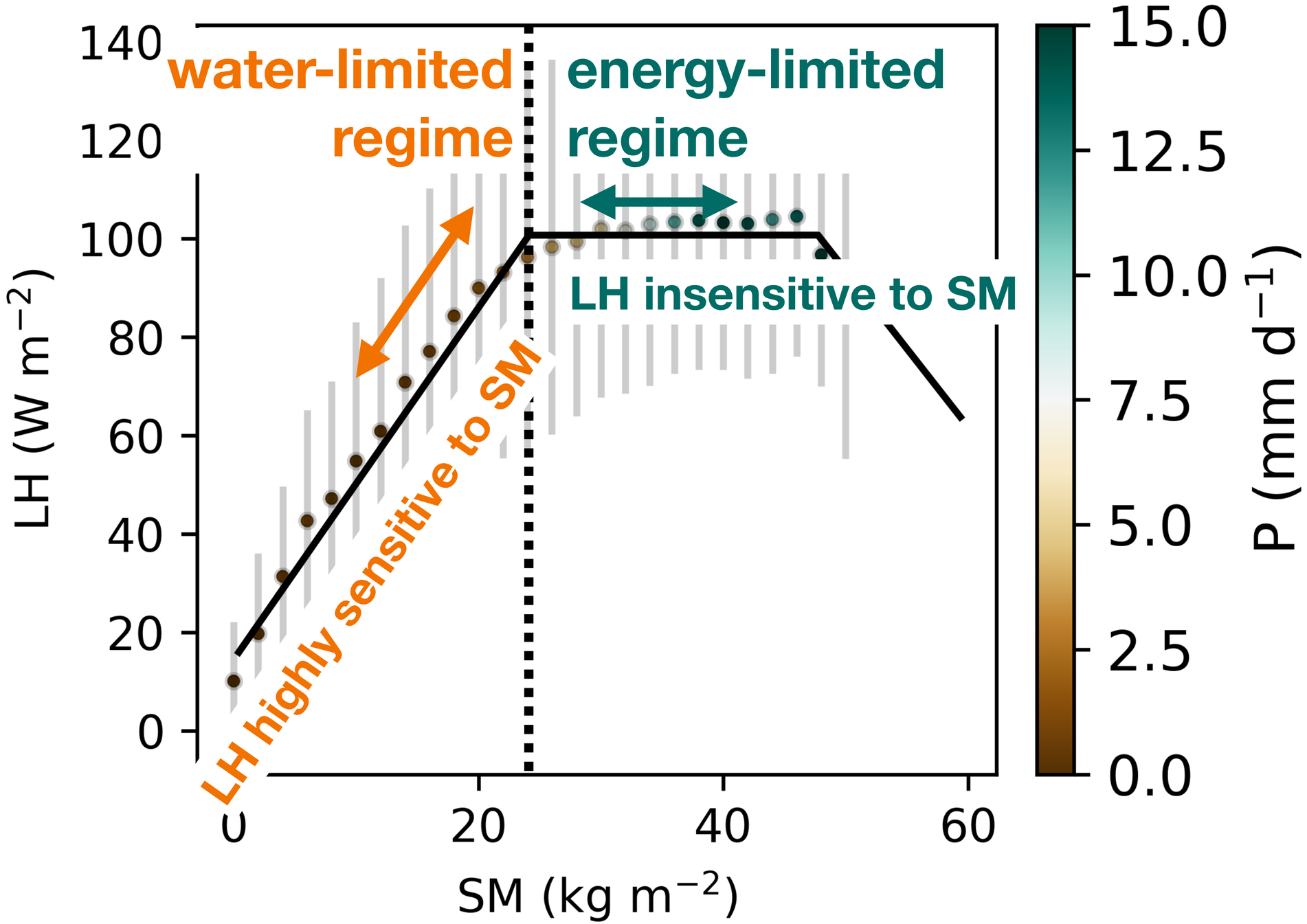

NH Tropics (0 – 30 N)
peaks in summer
Amplified hot-day warming (K)
0.5
0.4
0.3
0.2
0.1
0.0
J F M A M J J A S O N D

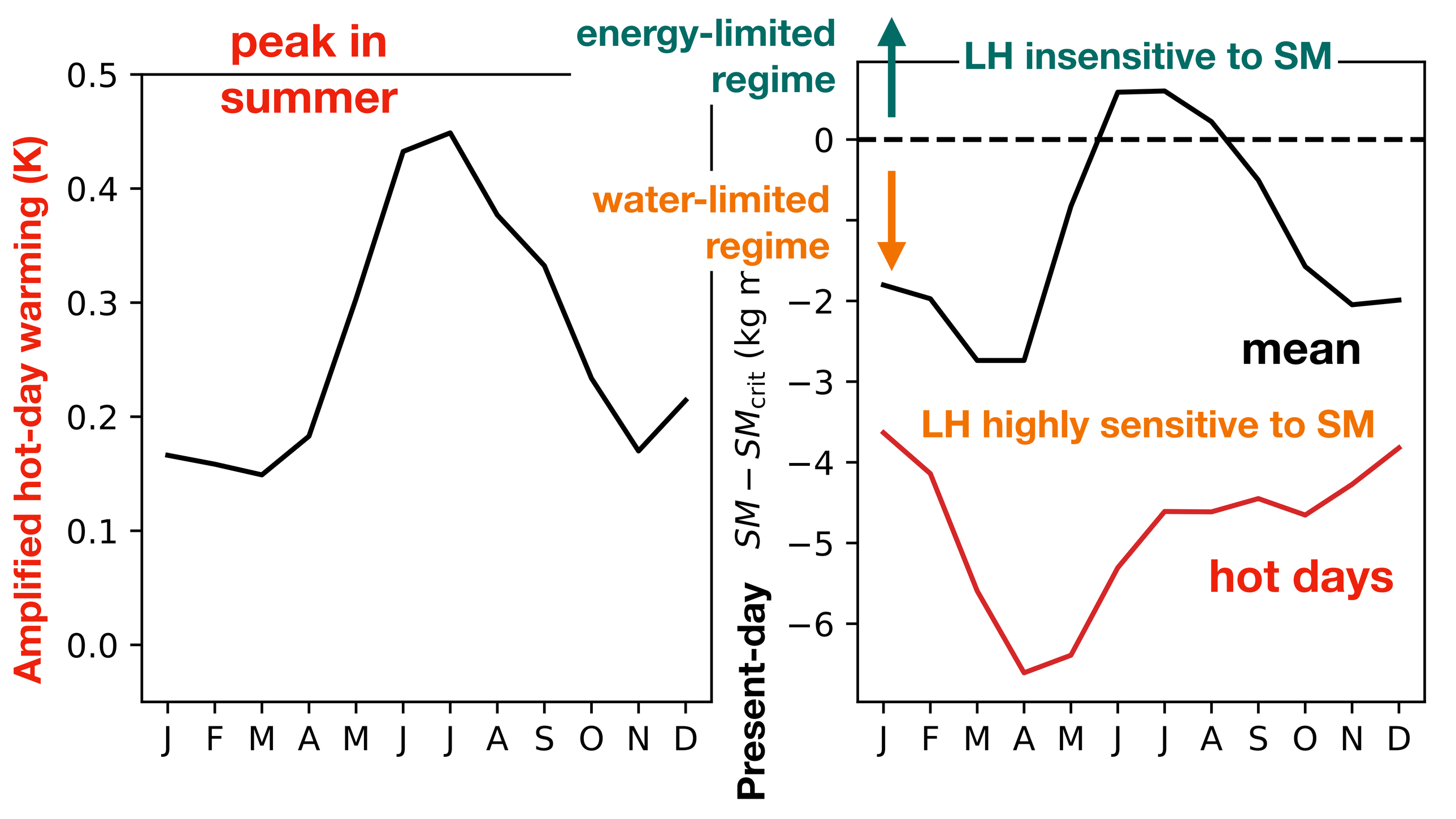

NH Tropics (0 – 30 N)
peaks in summer
Amplified hot-day warming (K)
0.5
0.4
0.3
0.2
0.1
0.0
J F M A M J J A S O N D
SH Tropics (0 – 30 S)
peaks in summer
Amplified hot-day warming (K)
0.5
0.4
0.3
0.2
0.1
0.0
J F M A M J J A S O N D

Correlation across the seasonal cycle

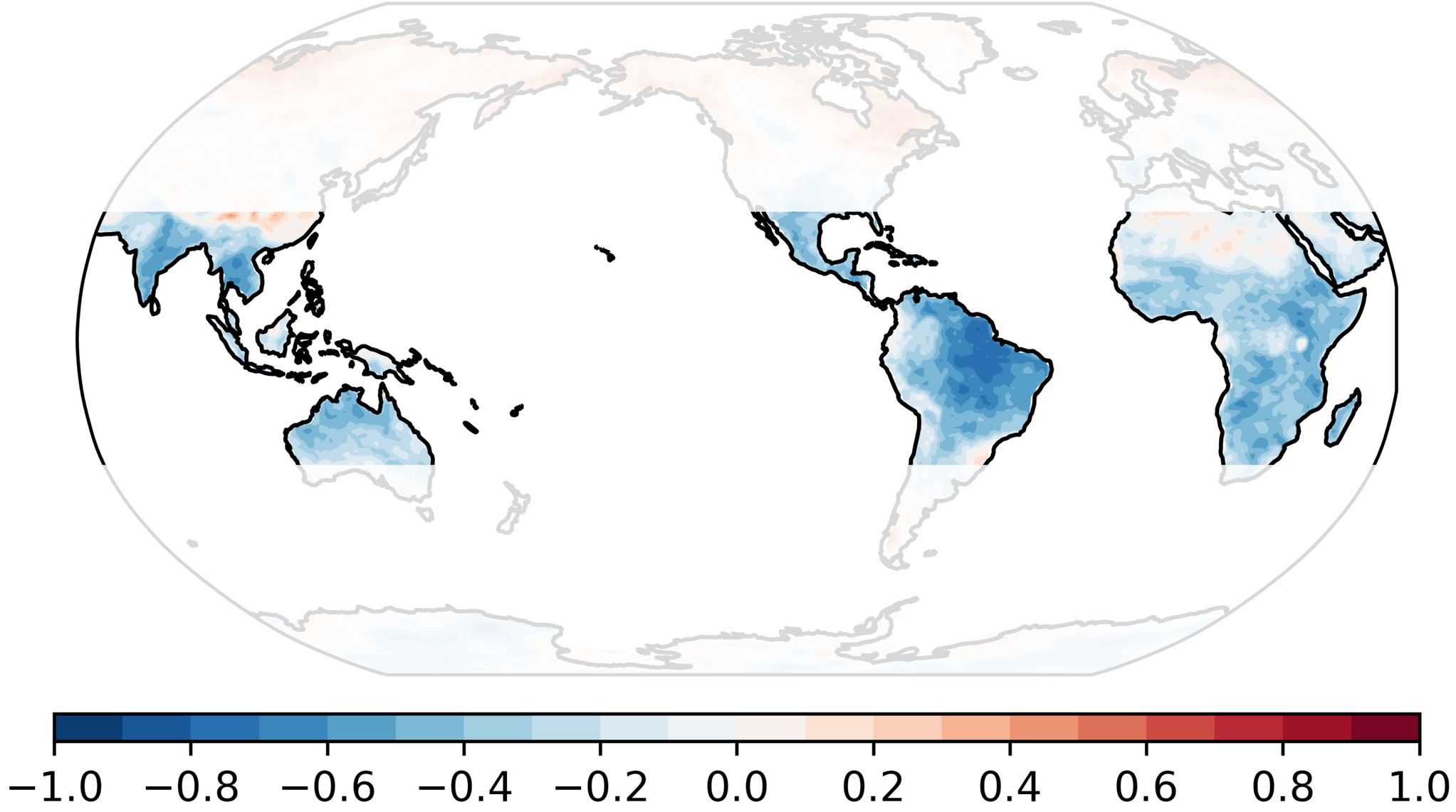



140
120
100
80
60
40
20
0
LH (W m^{-2})
0
20
40
60
SM (kg m^{-2})
15.0
12.5
10.0
7.5
5.0
2.5
0.0
P (mm d^{-1})

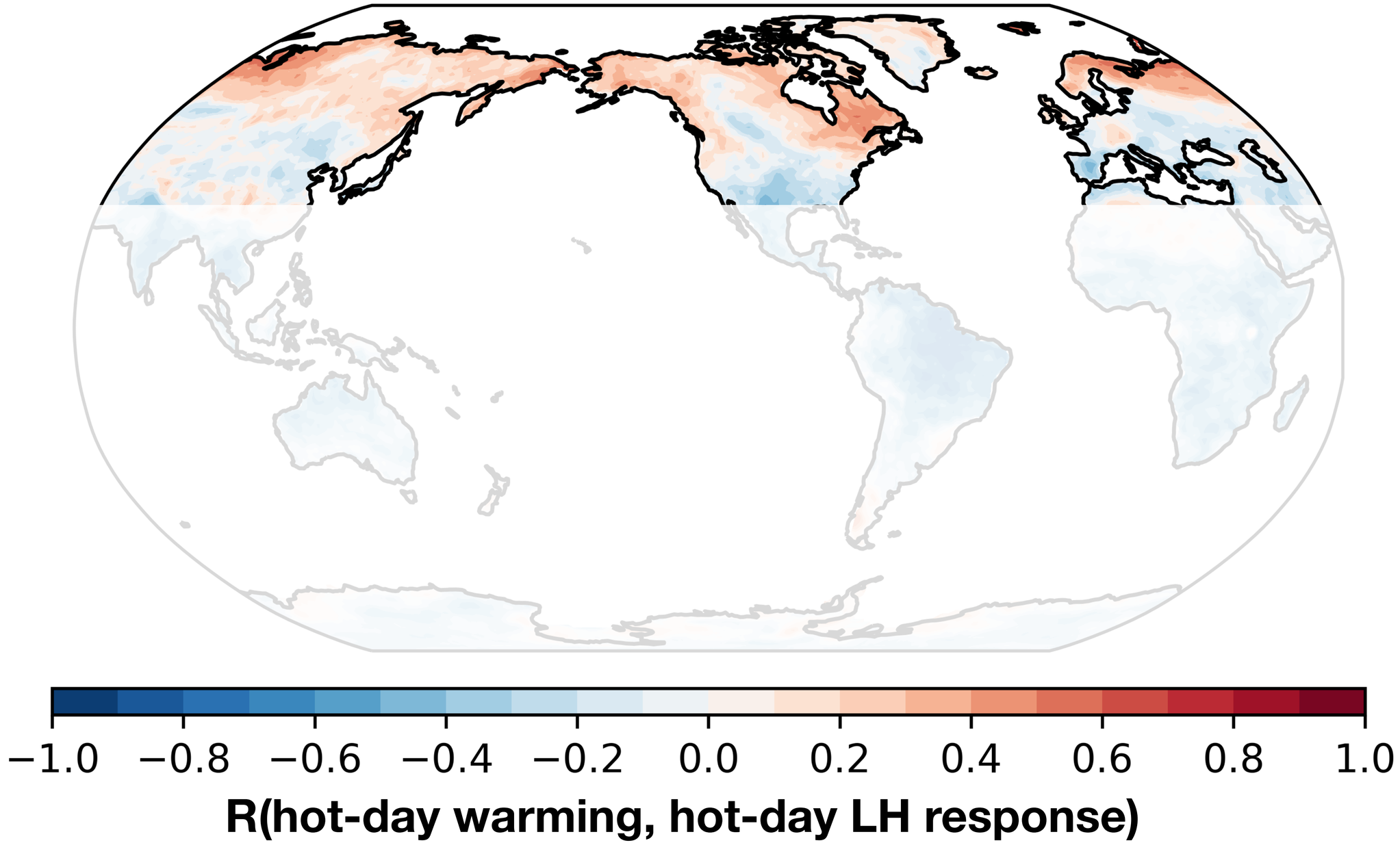

water-limited regime
energy-limited regime
LH insensitive to SM
LH highly sensitive to SM
LH (W m^{-2})
SM (kg m^{-2})
P (mm d^{-1})
0
20
40
60
80
100
120
140
0
20
40
60
0.0
2.5
5.0
7.5
10.0
12.5
15.0

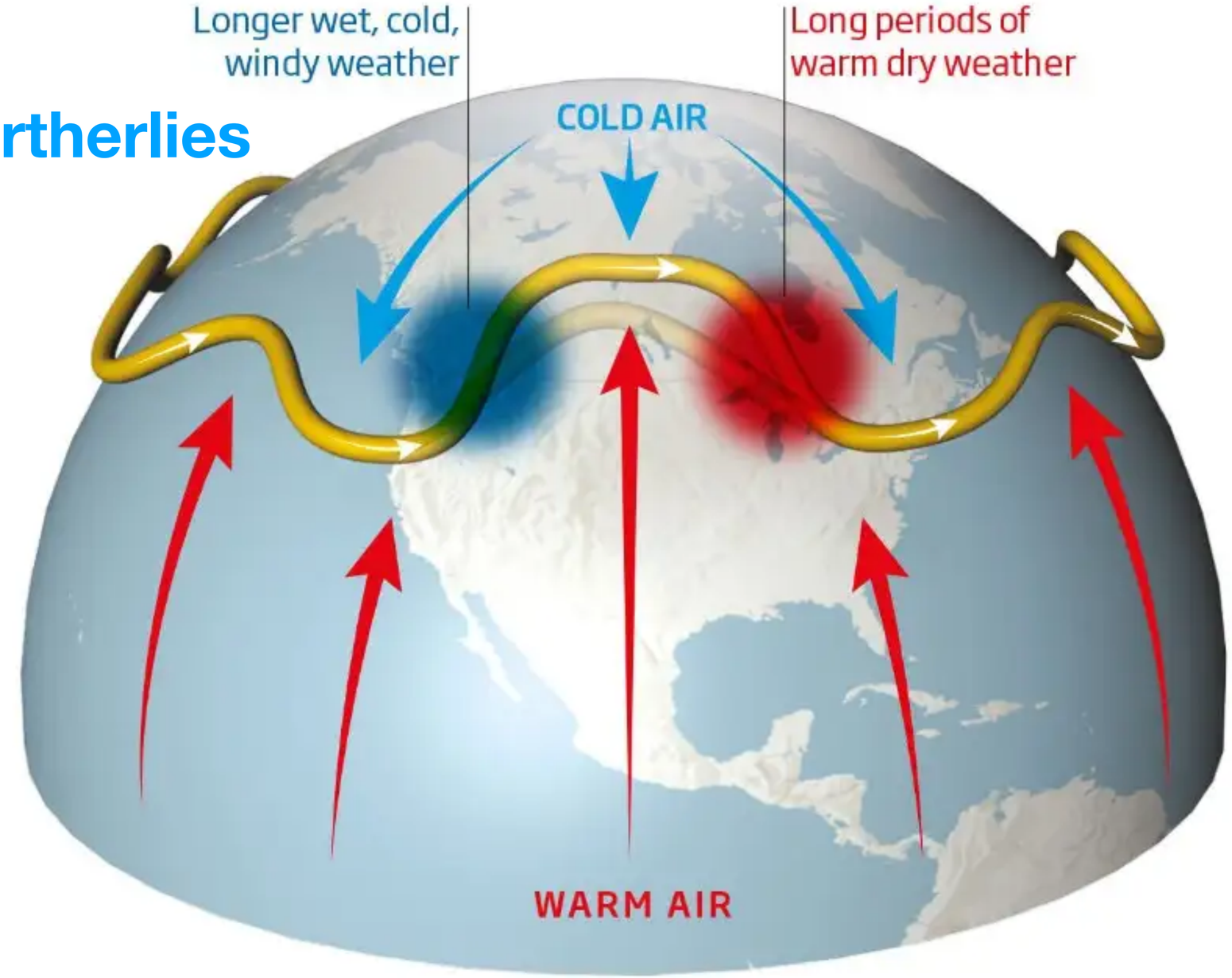

peak in summer
Amplified hot-day warming (K)
0.5
0.4
0.3
0.2
0.1
0.0
J F M A M J J A S O N D
energy-limited regime
water-limited regime
Present-day $SM - SM_{crit}$ (kg m
LH insensitive to SM
0
−2
−3
−4
−5
−6
mean
LH highly sensitive to SM
hot days
J F M A M J J A S O N D

Correlation across the seasonal cycle



Correlation across the seasonal cycle

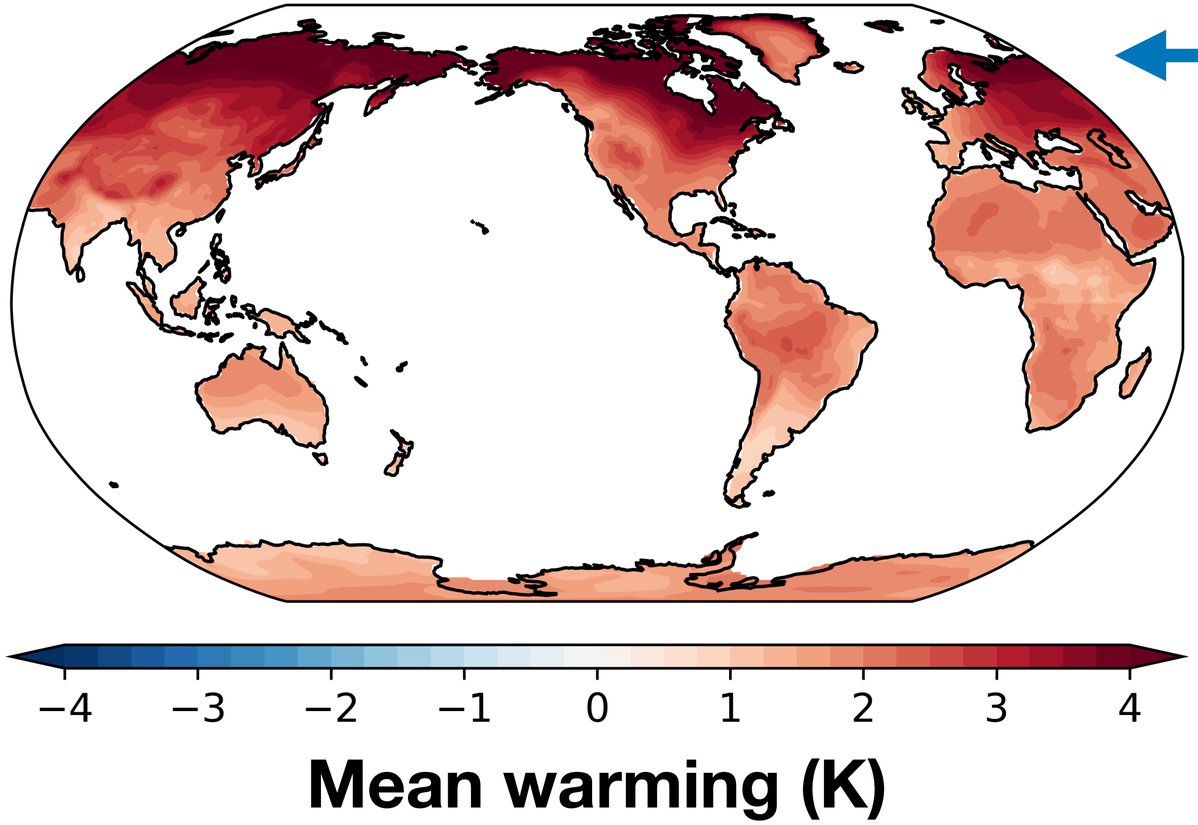




Northerlies

Southerlies

New Scientist. https://www.newscientist.com/article/dn26278-crazy-weather-traced-to-arctics-impact-on-jet-stream/

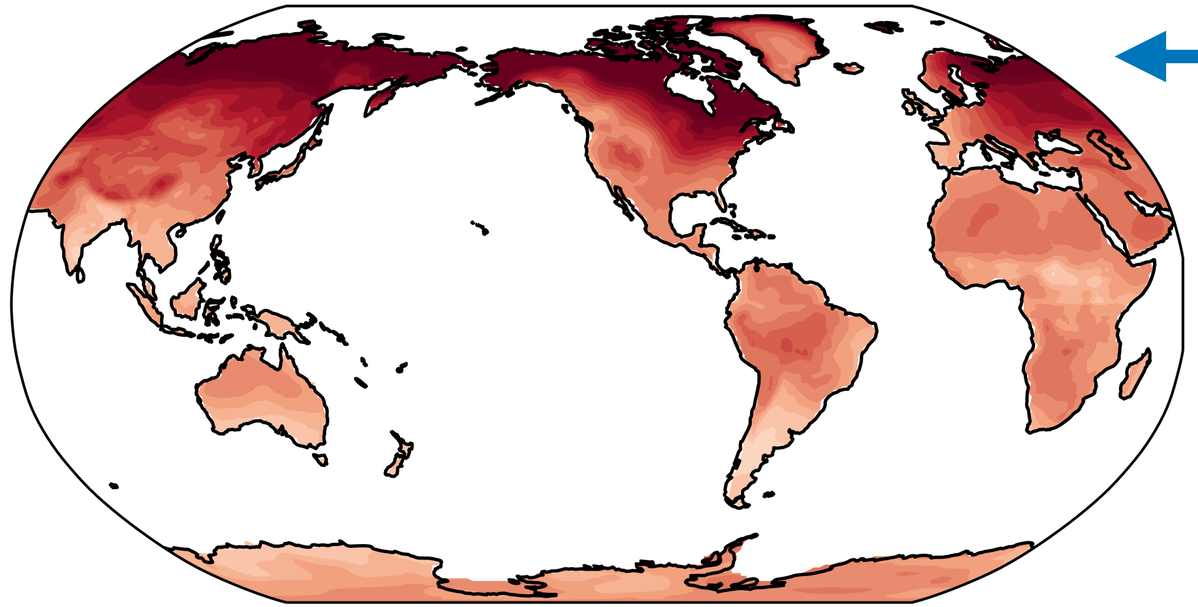


Winter:

Arctic Amplification

=

Amplified cold-day warming equatorward of max warming



−4 −3 −2 −1 0 1 2 3 4

Mean warming (K)

Winter

Arctic Amplification

=

Amplified **cold-day** warming

equatorward of max warming

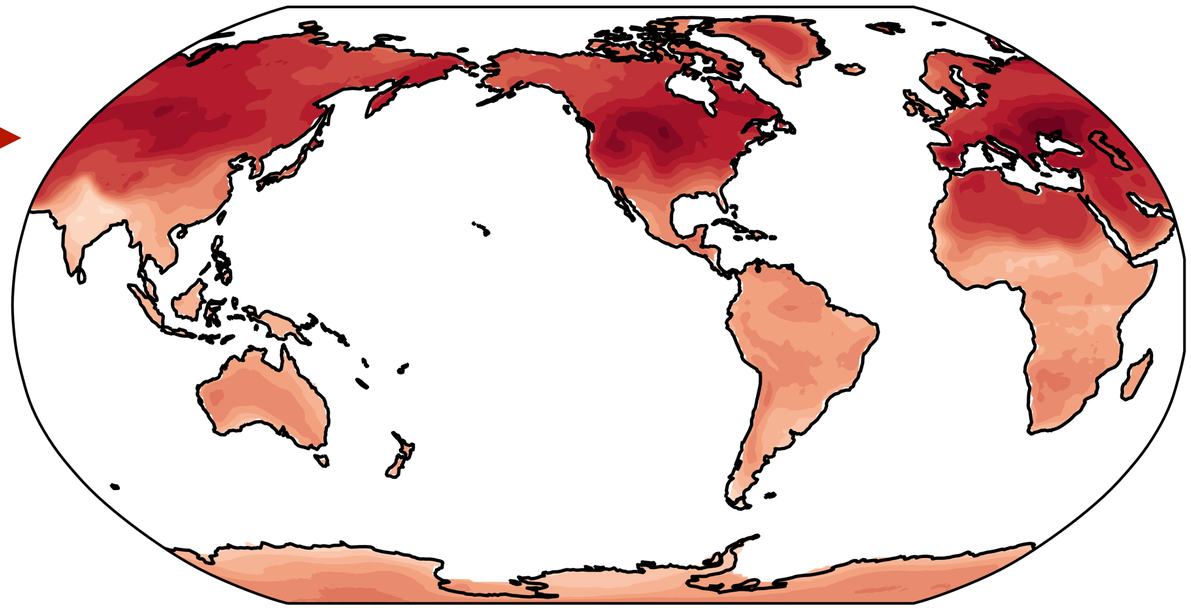
Summer

Midlatitude Amplification

=

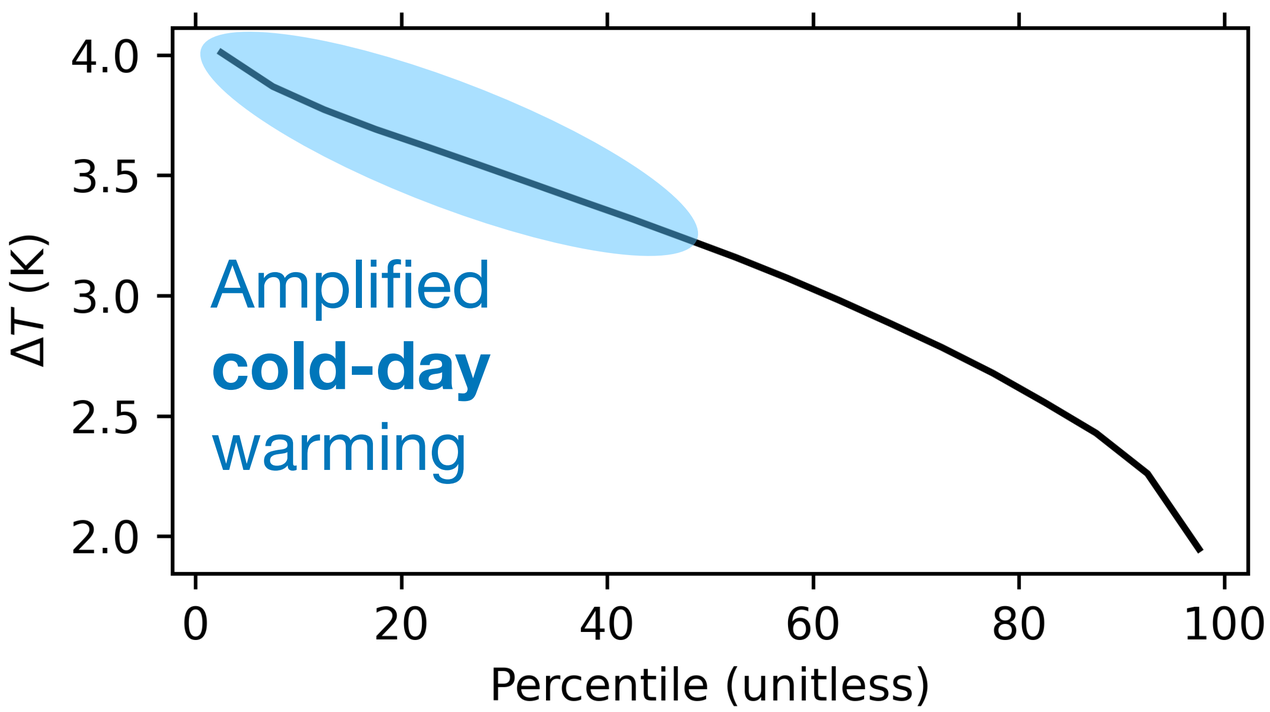
Amplified **warm-day** warming

poleward of max warming

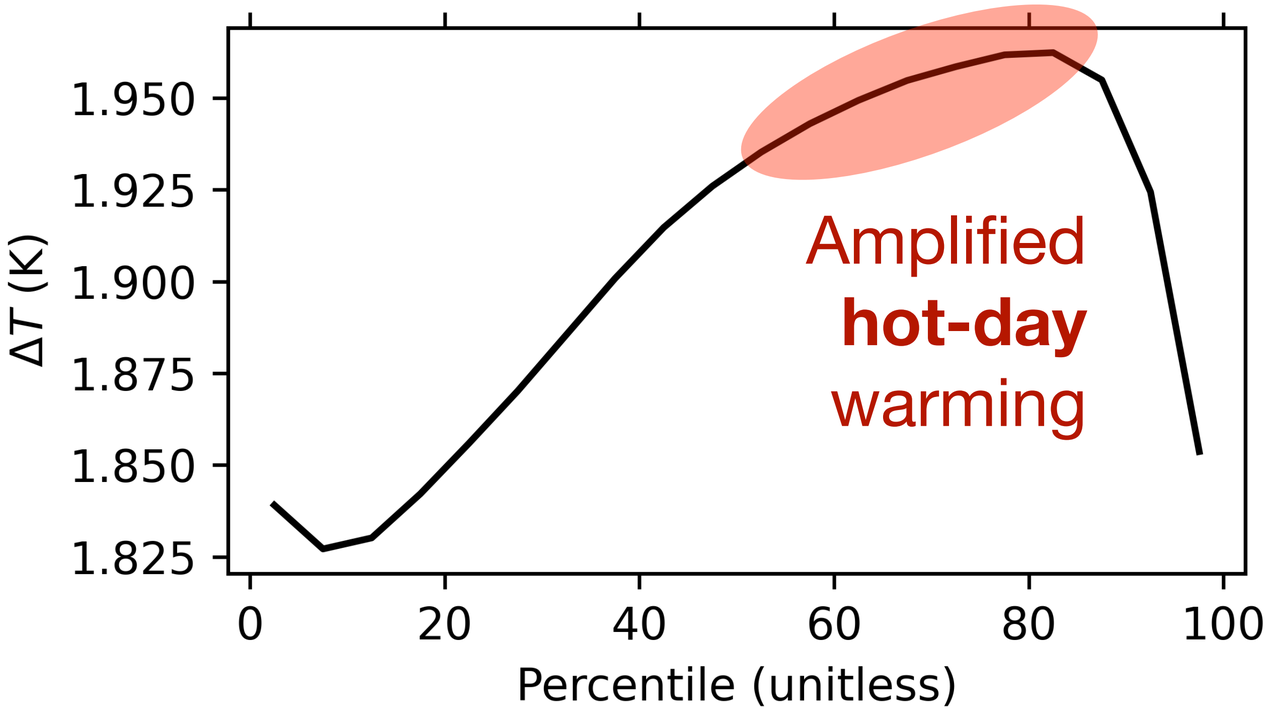


Poleward of 50º

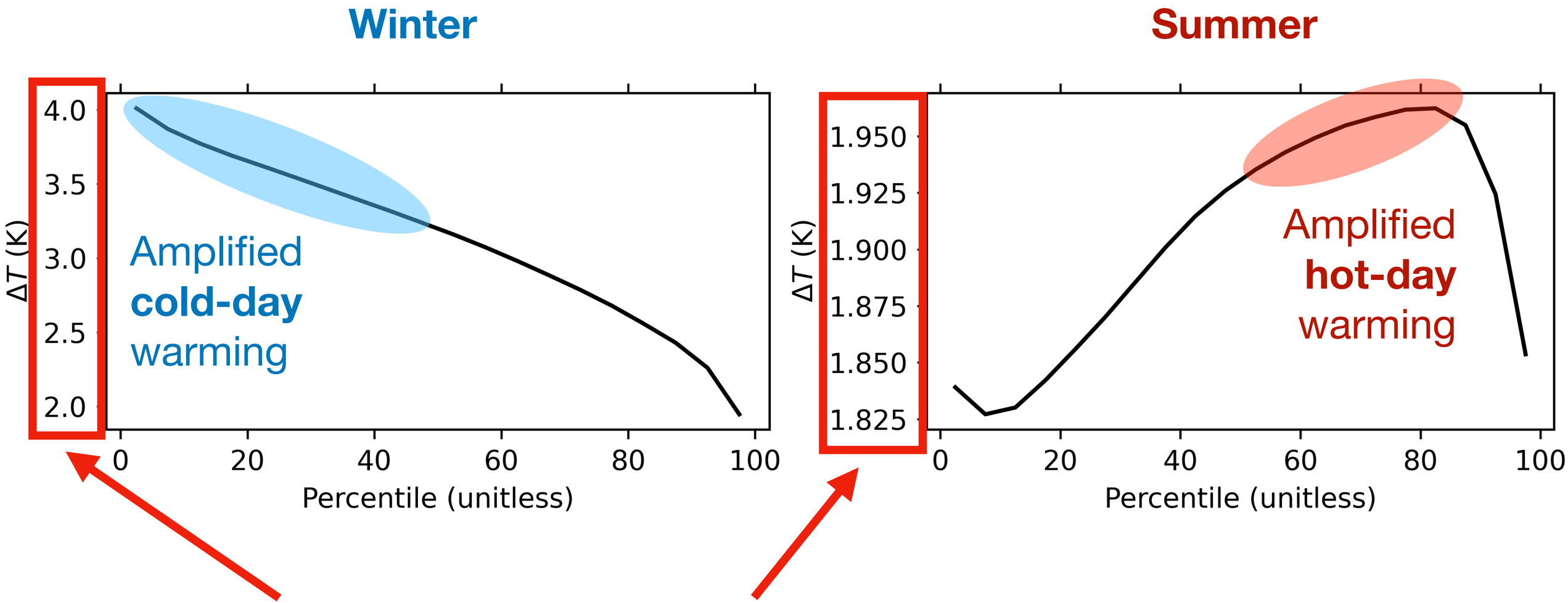
Winter



Summer



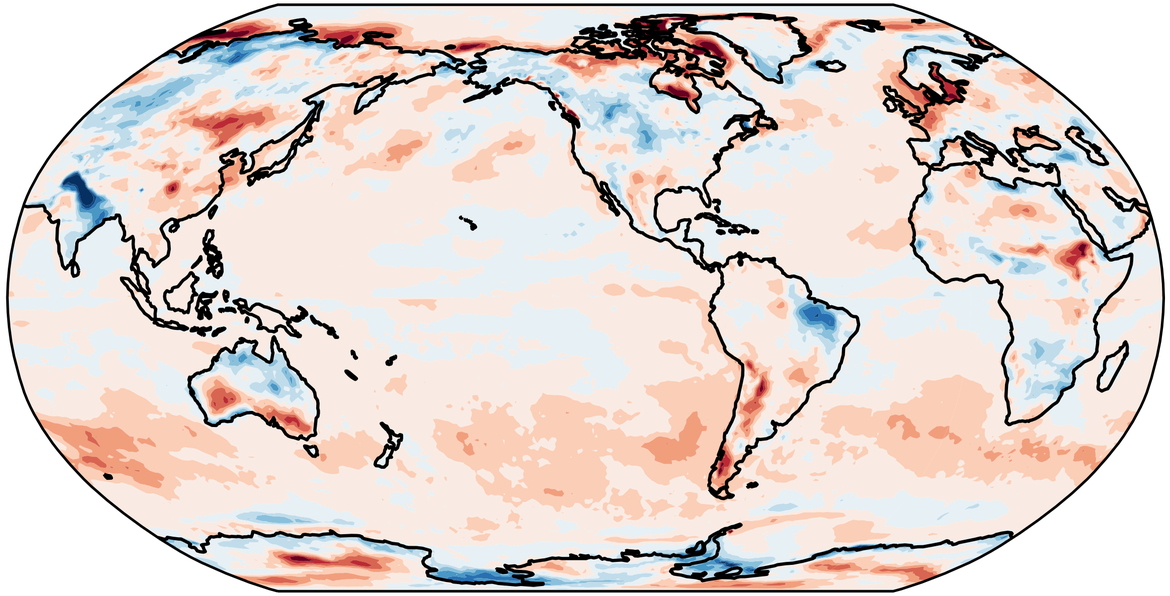
Poleward of 50º

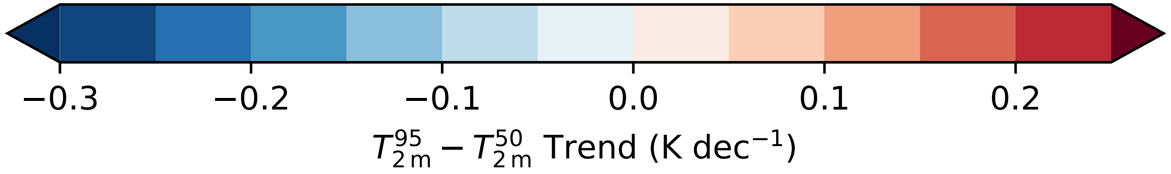


Why is summer amplification much weaker?

ERA5
Historical Trend

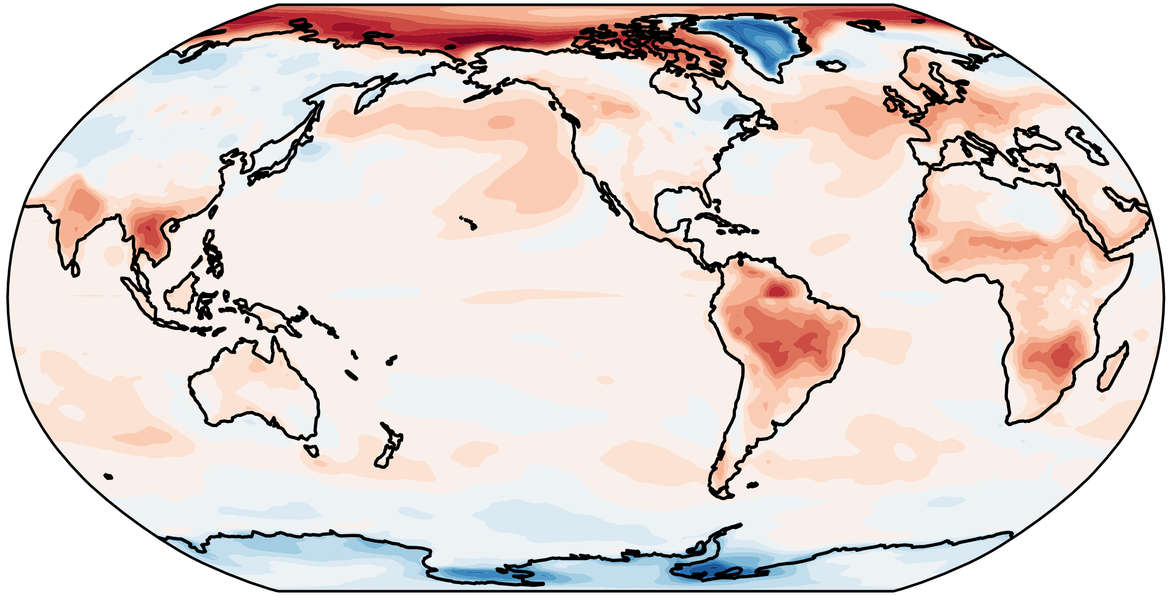
SUMMER ERA5 (1950 – 2020)

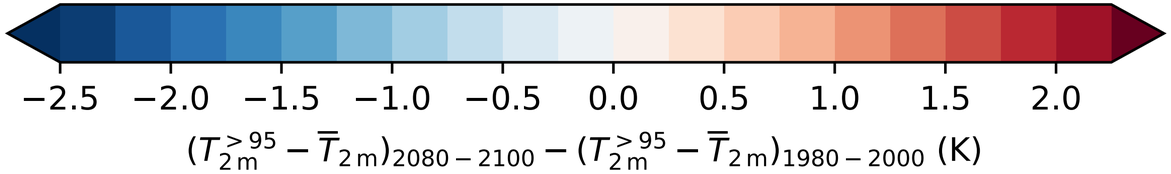


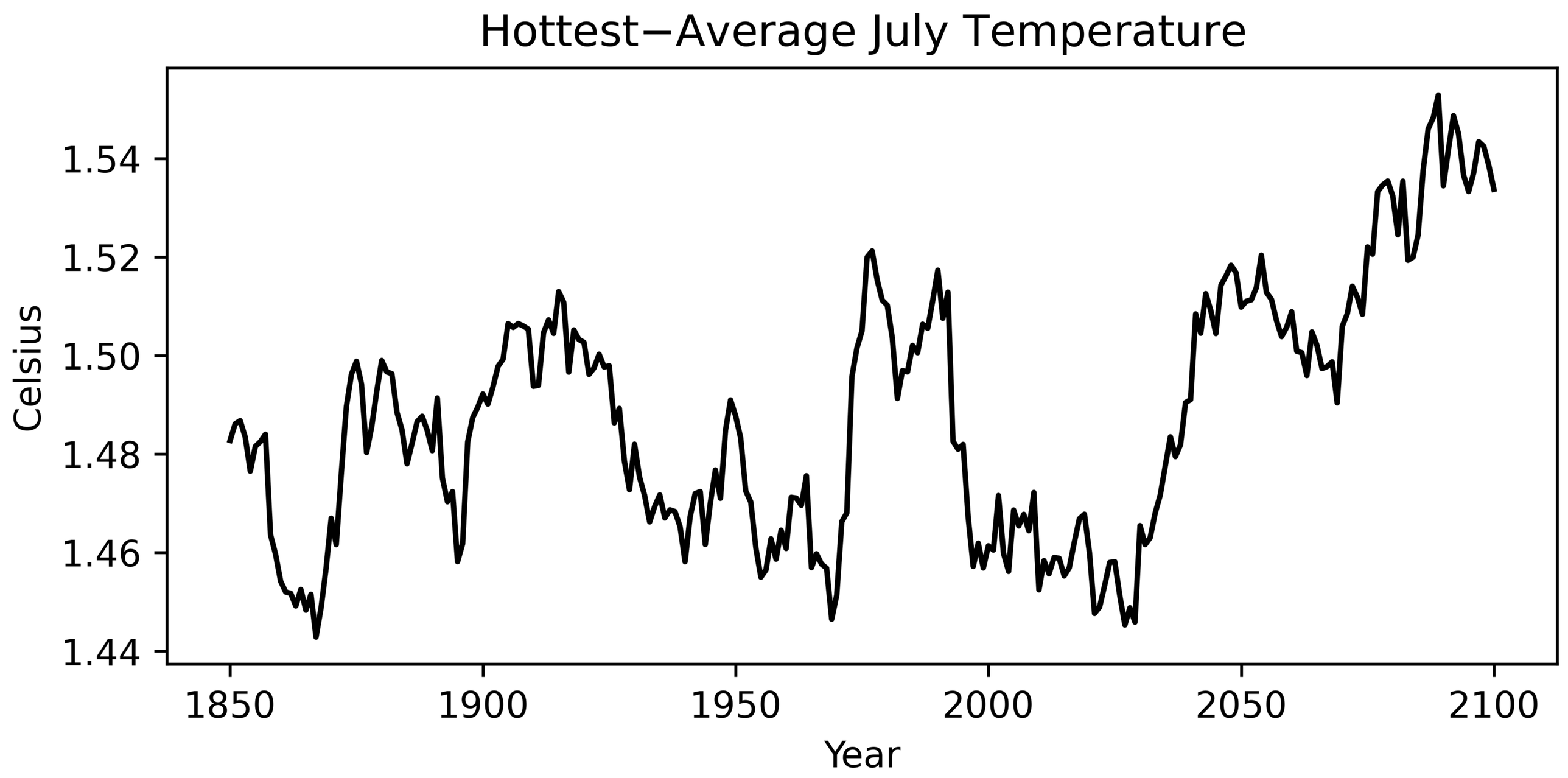


CMIP6
2 K Global Warming

JJA+DJF MMM SSP370







If the models can be trusted, when will the signal emerge?