Future heat waves in the US Great Plains in the CESM1 large ensemble experiment

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Motivations

✔ How does climate change affect the future heat waves by changing the temperature variability?
Meehl and Tebaldi 2004
Katz and Brown 1992, Schär et al. 2004,
Schneider et al. 2015, Screen 2014, Screen et al. 2015

✔ Would future climate enhance midlatitude extremes through amplification of planetary waves trapped in the waveguide?
Francis and Vavrus 2012:
slower/weaker jet stream => slower Rossby waves with larger amplitude
Barnes 2013, Screen and Simmonds 2013:
FV2012 has no observational evidence

Petoukhov et al. 2013, Coumou et al. 2014
Resonant amplification of synoptic eddies trapped in the stationary waveguide
“double jet”-> quasi-resonance
Coumou et al. 2015:
lower EKE’ -> persistent blocking -> heat waves

Barnes and Screen (2015): “links between Arctic warming and wave amplitudes, blocking anticyclones, heat waves, cold snaps, hurricanes, and extreme precipitation events….the precise mechanisms remain uncertain and thus, the proposed linkages should be viewed with extreme caution”
CESM LENS JJA 2070-2100 relative to 1980-2010

(a) mean

(b) 20-90day stddev

(c) 97.5th percentile
CESM1 LENS JJA zonal wind 2070-2100 minus 1980-2010

Black contour: 1980-2010 JJA u clim

Shading:
u anom m/s
CESM1 LENS JJA 2070-2100 relative to 1980-2010

Dashed line: 10m/s contour of u200 seasonal mean
Hatching: 95% confidence level

U200 mean

20-90day v200 stddev
Zonal wave variance of 20-90day v200

wavenumber
A linear stochastic stationary wave model (linclin, Branstator 1990)

- Time mean states \( \rightarrow \) Subseasonal variability

- 10σ level primitive equation model truncated at R15
- U, V, T, PS
- Topography implicitly represented by PS

\[
\psi' = \psi - \bar{\psi} \\
\frac{\partial \tilde{X}}{\partial t} = -L\tilde{X} + r
\]
Zonal wave variance of 20-90day v200
Composite of the heat waves at the Great Plains
psi200, TAS and Plumb flux

anticyclone strength = v200 diff in the box avg
Surface energy balance for the Great Plain heat waves

Results consistent with Fischer et al. 2007, 2012...
summary

• In the CESM1 LENS, the 20-90 day stddev of JJA TAS increases by ~15% over the US great plains and some other “hot spots” by the end of the 21stC. The variability change is secondary compared to change in the mean.

• The increased subseasonal variability in TAS can be partly caused by enhanced atm-Ind interaction under the future warmer climate.

• Subseasonal variability in the planetary waves is slightly reduced in the midlatitude, which is confirmed by a linear stochastic stationary wave model forced with the CESM1 LENS mean states.

• Cautions are needed when linking possible changes in extremes and planetary waves to climate change. Stationary wave model is an useful tool for testing the hypotheses.