Projections of Summertime Hot and Dry Compound Extremes in North America Using SPEAR Large Ensemble Simulations

Jonathan Lee[1,2], Liwei Jia[1], Colleen McHugh[1], Thomas L. Delworth[1]

[1] Geophysical Fluid Dynamics Laboratory (GFDL), Princeton, NJ, [2] Dept. of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY

Introduction

- **Hot-dry compound extremes (HDCEs)**: co-occurrence of hot and dry extremes
- Hazards are more impactful in combination; univariate approaches underestimate impact
- More frequent extremes, including HDCEs, with a warming climate, in global trends & projections

Focus of study on summer months in North America:

- How do the characteristics of HDCEs (frequency, duration, intensity) vary by month?
- What are their future projected changes?

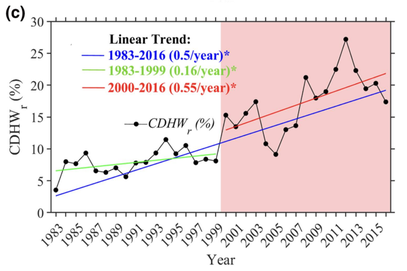

Fig. 1. Time series of ratio of global compound hot-dry extremes to all heat waves (Mukherjee and Mishra 2021)

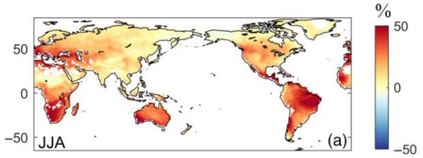

Fig. 2. Change in % of seasons with HDCEs in 2050-2099 vs 1950-1999 (Wu et al. 2020)

Methods and Data

Variables
- Months: June, July, August (JJA)
- Daily resolution max 2-m temperature (T2m)
- Monthly resolution total precipitation

Reanalysis: ERA-5, JJA 1980-2014

Model: GFDL SPEAR-MED (SPEAR)
30 members, 0.5° x 0.5°
Historical: JJA 1980-2014
Mid-century: JJA 2030-2064
Late-century: JJA 2065-2099
RCP 8.5 projections

HDCE definition. Define a *HDCE day* if, for that month:
- max daily T2m > 90th percentile T2m
- total precip < 10th percentile precip

Frequency: % of all days meeting HDCE criteria
Duration: average length of HDCE events
Intensity: average index per HDCE day (defined below)

Monthly precip ranking (percentile)	Daily max temp percentile relative to month									
	≥90	≥91	≥92	≥93	≥94	≥95	≥96	≥97	≥98	≥99
4th driest (10)	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
3rd driest (7.1)	1.29	1.419	1.548	1.677	1.806	1.935	2.064	2.193	2.322	2.451
2nd driest (4.3)	1.57	1.727	1.884	2.041	2.198	2.355	2.512	2.669	2.826	2.983
Driest (1.4)	1.86	2.046	2.232	2.418	2.604	2.79	2.976	3.162	3.348	3.534

HDCE climatologies: observed & modeled

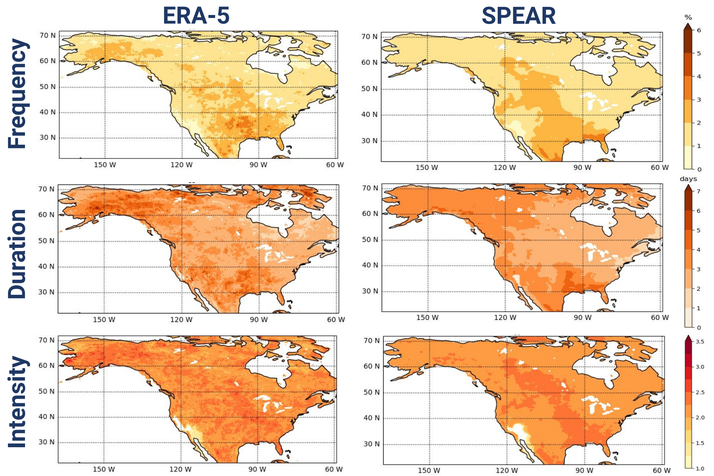

Fig. 3. Reanalyzed and modeled climatologies of HDCE characteristics for JJA 1980-2014.

Projections: mid vs. late century

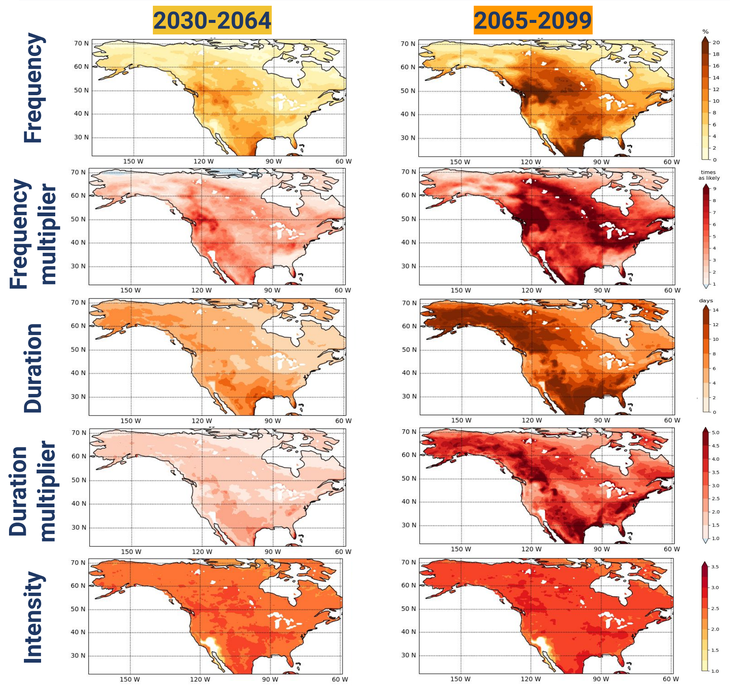

Fig. 4. Projections of HDCE characteristics for JJA 2030-2064, 2065-2099. Multipliers are relative to modeled climatologies (1980-2014).

Late-century projections by month

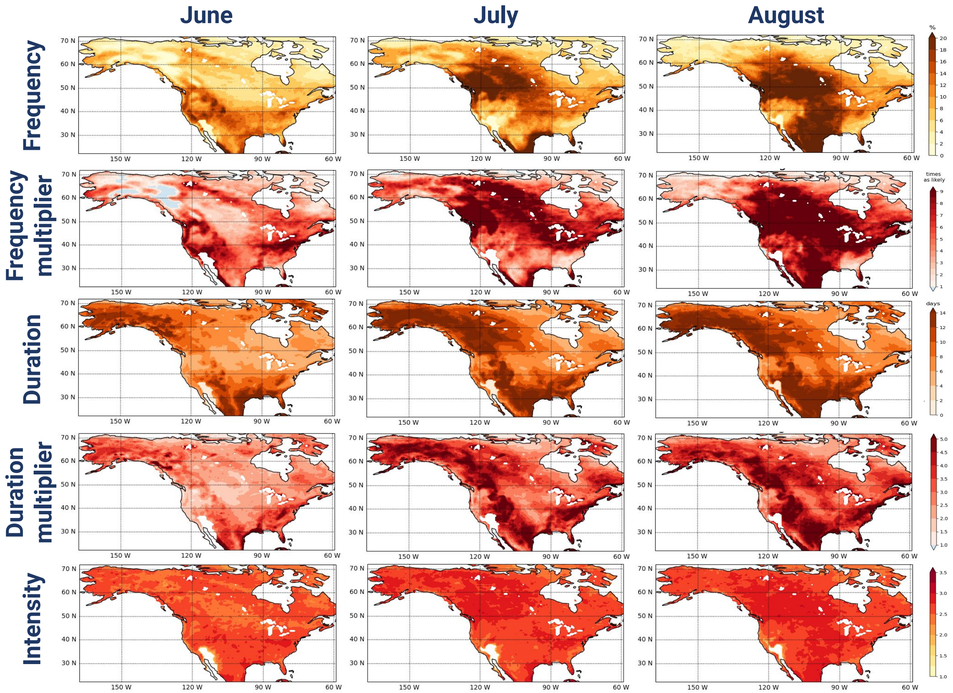

Fig. 5. As in Fig. 4, but only late-century RCP 8.5 projections in 2065-2099 and projected characteristics for each summer month.

Conclusions and Future Research

- SPEAR reasonably simulates spatial pattern + magnitude of the climatology of HDCE events (Fig. 3)
- **Accelerated increases** in HDCE frequency, duration, and intensity are projected in late-century relative to mid-century in RCP 8.5 runs (Fig. 4)
- HDCE characteristics are **more pronounced later in the summer** compared to June (Fig. 5)
- *Pacific Northwest, west-central Canada,* and *south-central US and Mexico* have the greatest projected increase in HDCE frequency (Fig. 4, 5)
  - Greatest duration increases in *Alaska*, much of the *southern US*, plus above areas (Fig. 4, 5)
  - Several-fold frequency, duration increases possible in parts of eastern US
  - Intensity increases are relatively uniform
- **Future directions**: analyze projections across more emissions scenarios/ precip. metrics, compare with preindustrial control, conduct significance tests
- Investigate changes in the dependence between extreme heat and drought; assess mechanisms/roles of each factor behind projected increases