Projected change in climatic drivers of extreme forest productivity, and the impacts on water availability in the western US

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Forest Vulnerability in a Changing Climate

On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene

Craig D. Allen, David D. Breshears, and Nate G. McDowell

Consequences of widespread tree mortality triggered by drought and temperature stress

William R. L. Anderegg, Jeffrey M. Kane and Leander D. L. Anderegg

Research frontiers for improving our understanding of drought-induced tree and forest mortality

Drought & Temperature Stress
- decrease productivity
- increase vulnerability to mortality
- biotic and abiotic interactions

(Buotte et al., 2019; Global Change Biology)
Forest productivity extremes in a large ensemble

(1) How are low summer NPP extremes projected to change?

(2) What are the climatic drivers of low summer NPP extremes, and are they projected to change?

(3) What are the impacts of changes in NPP extremes on soil moisture?
Modeling Framework

Global Climate Model (1.875°x1.25°)
HadAM3p – MOSES2

Regional Climate Model (25km)
HadRM3p – MOSES2

1–way 20-min coupling
Prescribed SST’s
Modeling Framework

Global Climate Model (1.875°×1.25°)
HadAM3p – MOSES2

Regional Climate Model (25km)
HadRM3p – MOSES2

Reducing climate model biases by exploring parameter space with large ensembles of climate model simulations and statistical emulation

Sihan Li, David E. Rupp, Linnia Hawkins, Philip W. Mote, Doug McNeall, Sarah N. Sparrow, David C. H. Wallom, Richard A. Betts, and Justin J. Wettstein

Less warming projected during heavy winter precipitation in the Cascades and Sierra Nevada

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Seasonal spatial patterns of projected anthropogenic warming in complex terrain: a modeling study of the western US

Ensemble Design

**Historical**
(1987-2016)
- 3 model parameterizations
- 80 initial land-atmosphere conditions
- 7200 model years

**Future RCP 8.5**
(2047-2076)
- 3 model parameterizations
- 80 initial land-atmosphere conditions
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Ensemble Design

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1987    1988
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Projected Change in Forest Productivity

Retains Snowpack

April 1\textsuperscript{st} SWE \textgreater{} 100mm

Loses Snowpack

100mm < April 1\textsuperscript{st} SWE < 10mm
Diagnosing climate drivers of low summer NPP

Retains Snowpack

Loses Snowpack

NPP (gC/m²/day)

Historical
Diagnosing climate drivers of low summer NPP

Retains Snowpack

Historical

Future

Loses Snowpack

Historical

Future

NPP (gC/m²/day) vs. Time (April to August)

NPP (gC/m²/day) vs. Time (April to August)
Diagnosing climate drivers of low summer NPP

Winter – precipitation

Spring – precipitation
  – temperature
  – NPP
  – soil moisture

Summer – precipitation
  – soil moisture
  – VPD
Change in climate drivers of extremes

Loses snowpack

Retains snowpack
Impacts on water availability

**Loses snowpack**

- Historical
- Future

**Retains snowpack**

- Historical
- Future
Take Away

(1) Projected change in mean summer NPP is larger than low NPP extremes – interaction with snowpack decline

(2) Cool temperature constraints on growth are relaxed at high elevations. Increased summer VPD and decreased soil moisture intensify low NPP extremes.

(3) Changes in vegetation functioning impacts projected changes in soil moisture.

Future directions

(1) Perturbed parameter experiments in regional dynamic downscaling? AGU session: GEC – PPE’s in Earth System Modeling

(2) Influence of vegetation/soil state on internal variability?
Thank you