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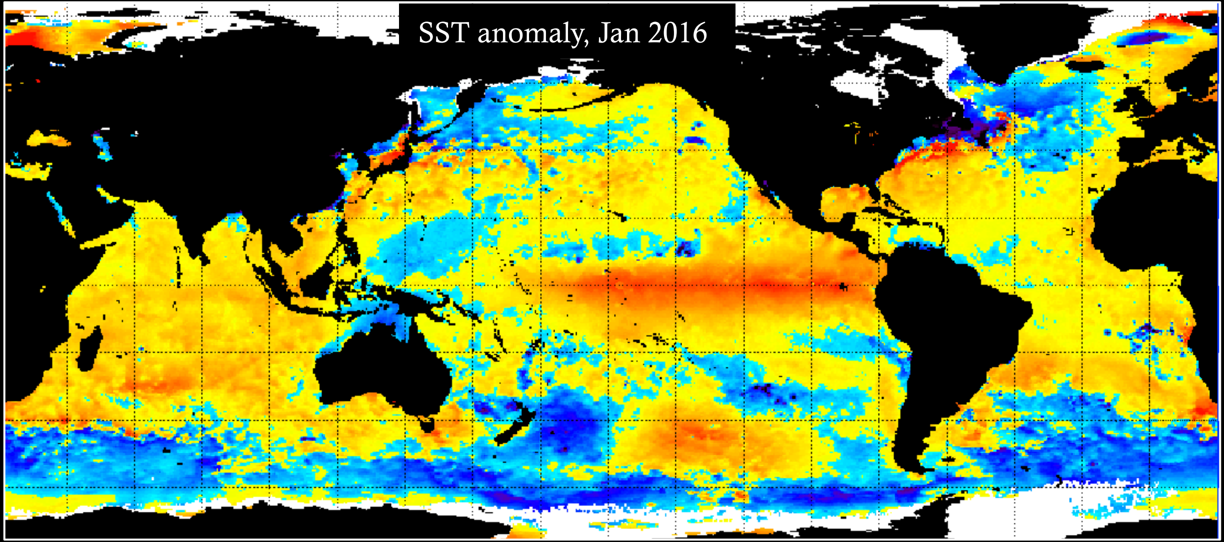
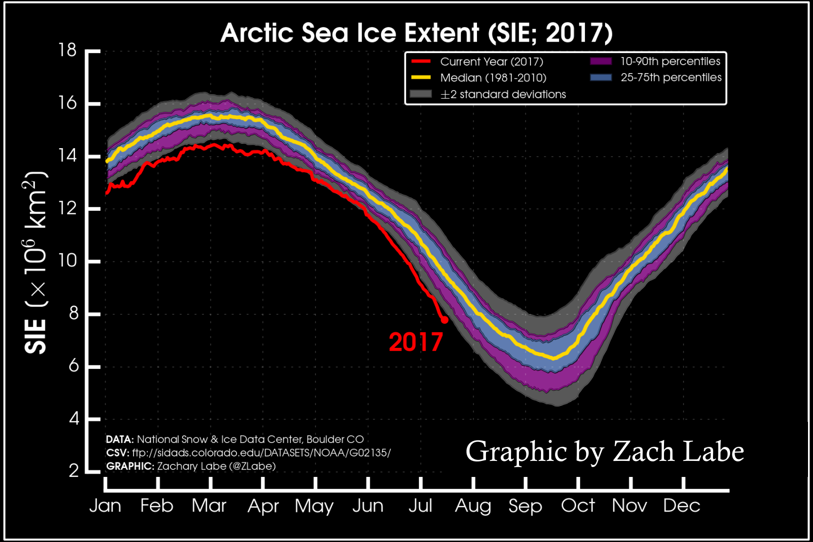
Teleconnections & regional impacts under anthropogenic forcing





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Outline

- California as a case study in regional impacts:
  Drought, flood, & the 2015-2016 El Niño event
- Embracing complexity in regional impacts:
  Internal variability, state-dependence, & nuanced metrics
- Considerations in a warming climate:
  (Non) stationarity of impacts; potential emerging predictors

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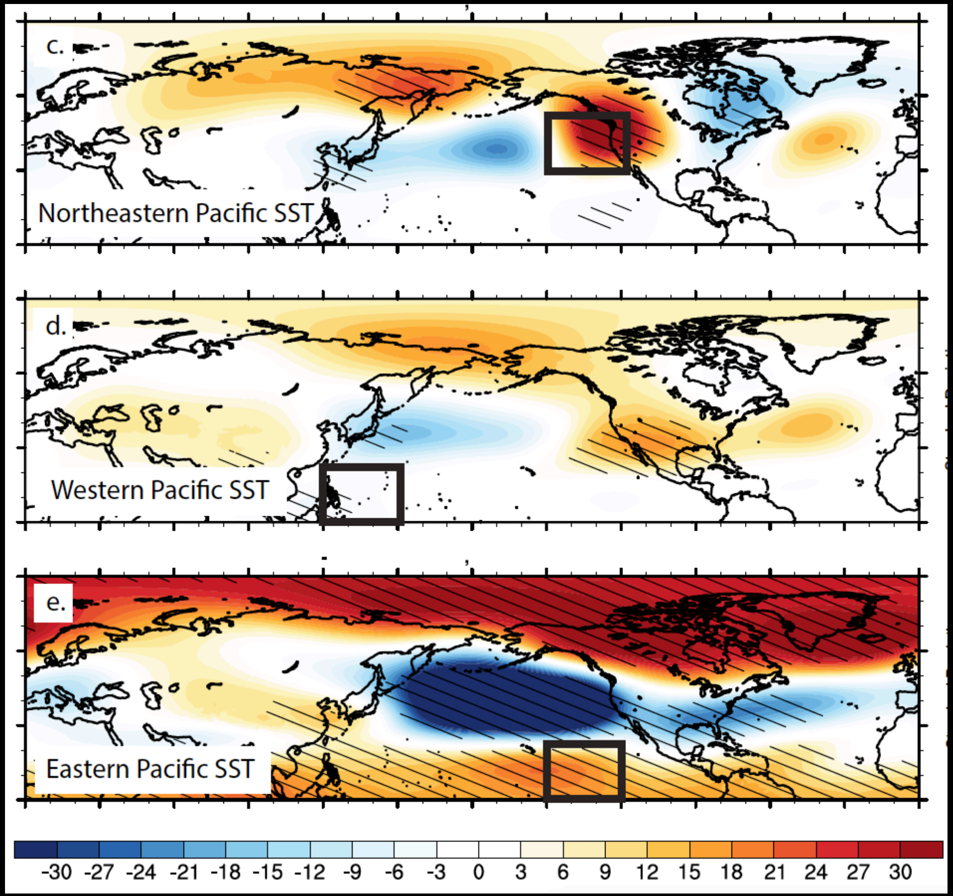
California as a case study: 2012-2016 drought



Multiple linear regression between regional SST and 500 hPa geopotential heights in CESM-LENS (Swain et al. 2017a, in revision)

- Severe drought between 2012-2016 (Griffin et al. 2014 ,Williams et al. 2015)
- Proximal cause: anomalous, seasonally-persistent NE Pacific ridging (Swain et al. 2014, 2016; Wang et al. 2014, 2015)
- Evidence for both internal & ocean-forced causes of North Pacific ridging
  - Extreme ridges can arise randomly (Seager et al. 2015, 2016; Teng and Branstator 2017)
  - Warm tropical SST can also trigger (Hartmann 2015, Seager et al. 2016, Teng and Branstator 2017, Swain et al. 2017a, in revision)
  - Possible extratropical feedbacks? (Lee et al. 2015, Swain et al. 2017a, in revision)

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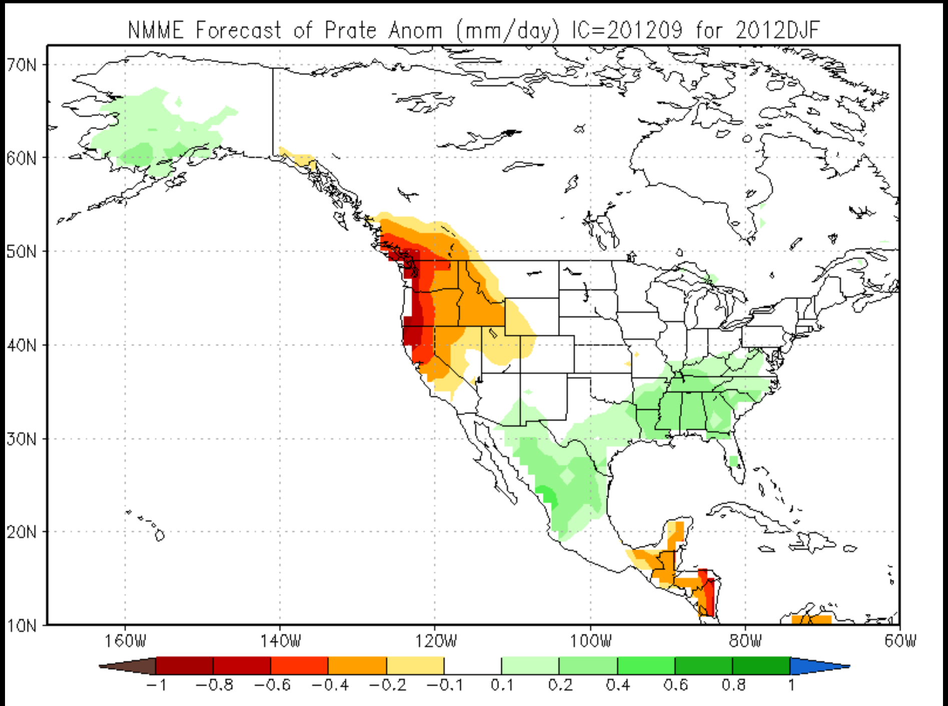

Animation of DJF precipitation anomaly forecasts from NMME using Sept IC (2012-2016). Via Climate Prediction Center

- Multi-year persistence & subsequent transition to flood not well captured by multi-model ensemble
- Relevant questions:
  - Fundamentally unpredictable sequence of random variability?
  - Linked to potentially traceable Earth system processes, but coupled models did not capture?

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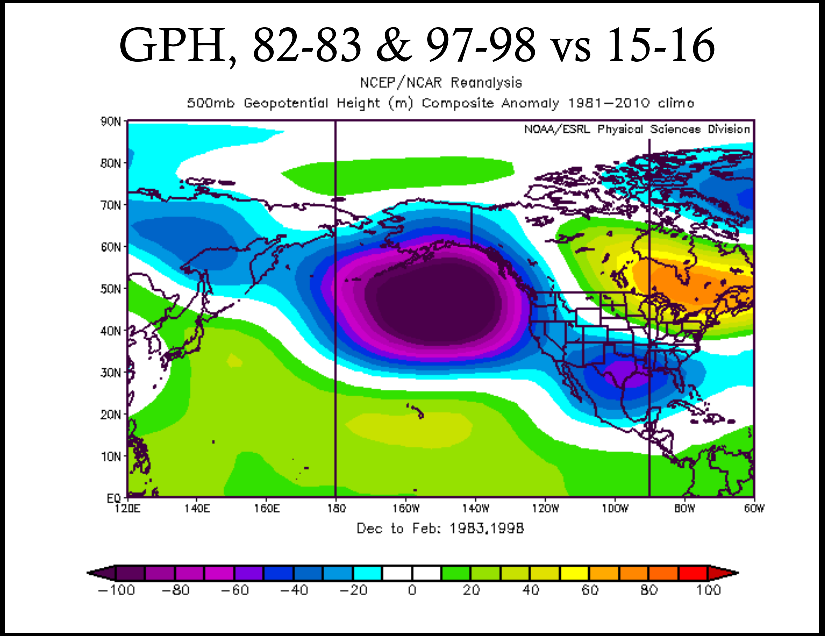
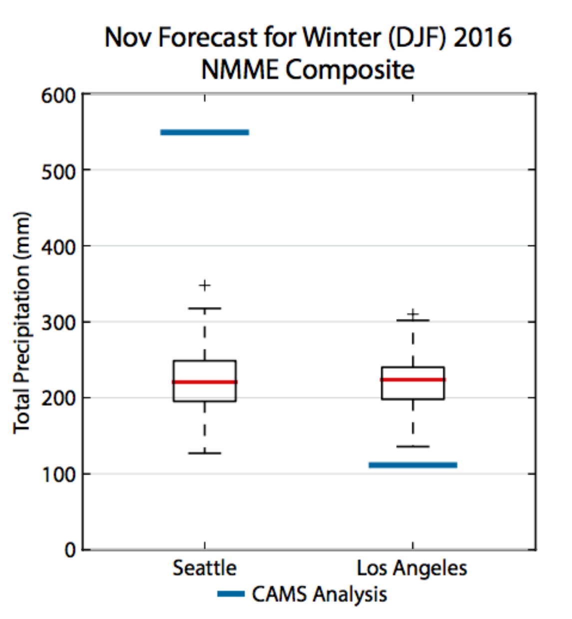
California as a case study: 2015-2016 El Niño



500 hPa GPH anomaly, 1982-83 & 1997-98 composite vs. 2015-16 (R1 Reanalysis via ESRL Plotter)

- From oceanic perspective, strong El Niño event was well predicted
- Atmospheric response recognizably "El Niño-like"
- But regional impacts along U.S. west coast exact opposite of expectations! California dry; Pacific Northwest extremely wet



NMME predicted vs. observed precipitation, Seattle vs. Los Angeles (from Cohen et al. 2017)

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Quantifying regional impacts: Observations vs. models

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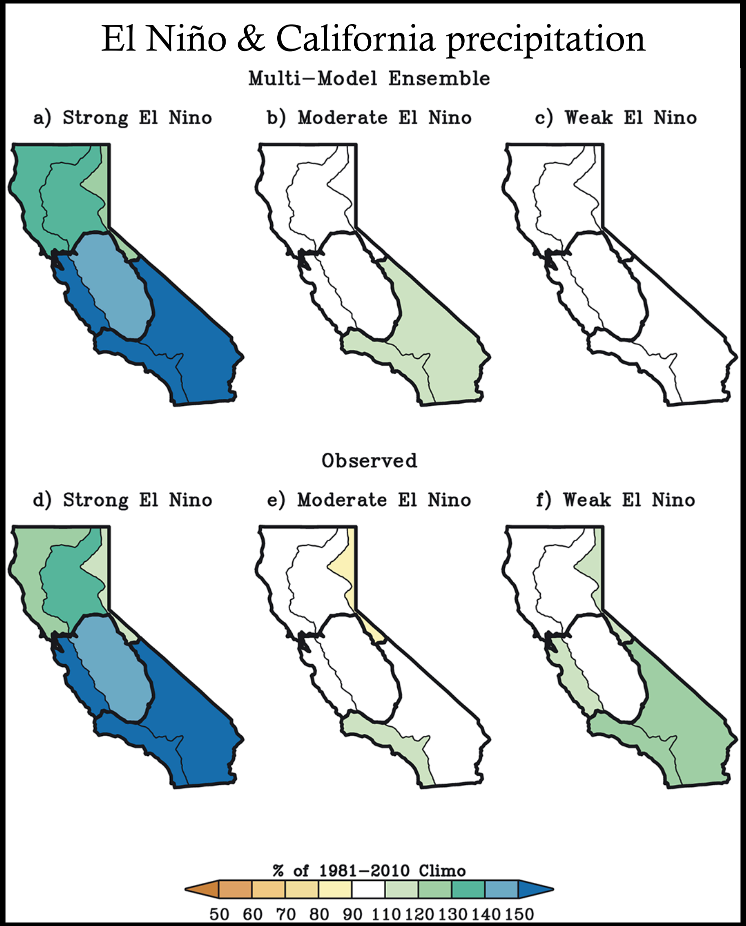

Simulated vs. observed precipitation in California during El Niño (from Hoell et al. 2016)

- Observational record often too short to make robust conclusions (esp. regional extremes) (Diffenbaugh et al. 2017)
- Climate model ensembles yield much larger sample size & physical insights
  - Large ensembles allow us to see "forest for trees" of internal variability (Deser et al. 2014, Thompson et al. 2014)
- Should the 2015-2016 regional forecast "failure" change our priors?
  - Probably not. However…

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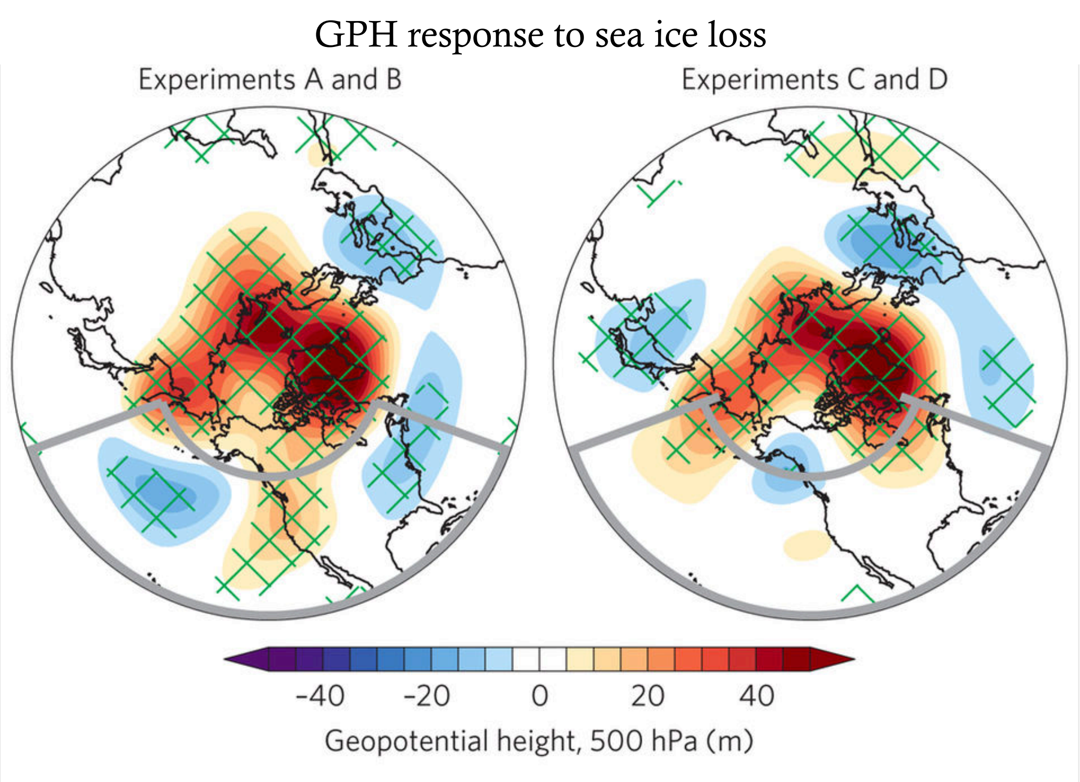
Quantifying regional impacts: Internal variability & state dependence



The circulation response to Arctic sea ice loss appears to depend on initial pattern of remote mid-latitude SST (Overland et al. 2016)

- …several factors complicate our understanding of regional impacts from models
- Distinct regimes arising from internal variability?
  - Evidence for distinct, but stochastic, El Niño "eras" (Capotondi et al. 2015)
- State dependence in response?
  - Regional response to sea ice loss may depend on N. Hemisphere SST pattern or atmospheric variability (Overland et al. 2016)

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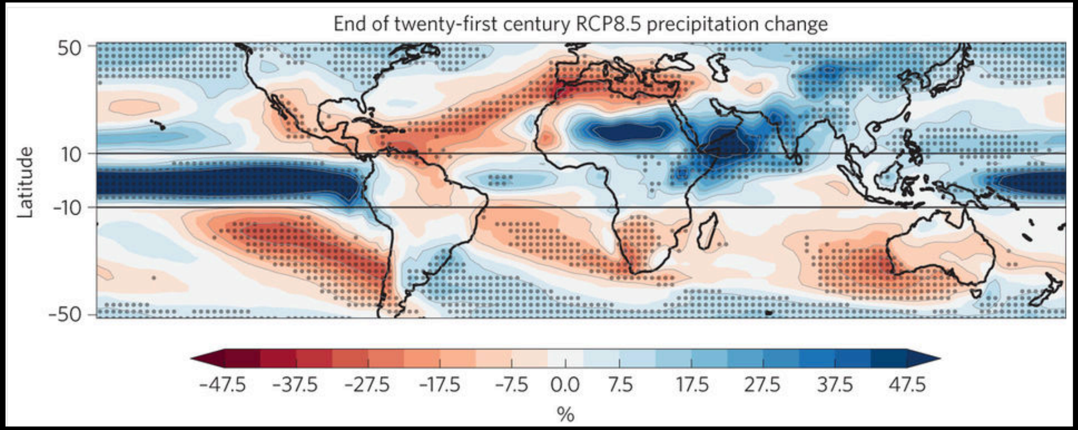
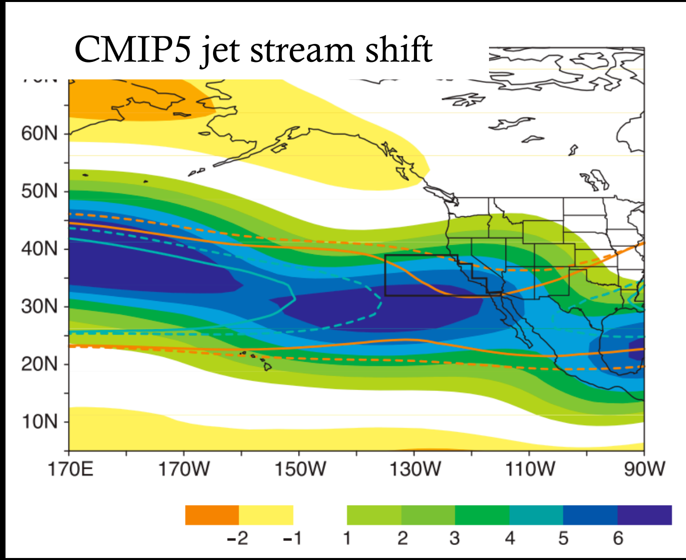
Spatiotemporal complexity in a warming world



Subtropical drying depicted in He and Soden 2016



Future strengthening on equatorward flank of winter jet stream (from Neelin et al. 2013)

- Climate models broadly suggest:
  - Asymmetrical expansion of Hadley cell; general subtropical drying (Karnauskas and Ummenhofer 2014)
  - Poleward shift in jet stream; mid-latitude wetting (Seager & Vecchi 2010)
  - "Mediterranean" climate regions exist near/within transition zone, but precip mostly declines
- But doesn't hold true in all regions/across all seasons!
  - Example: *Equatorward* shift in winter mean jet axis over N. Pacific (Neelin et al. 2013)

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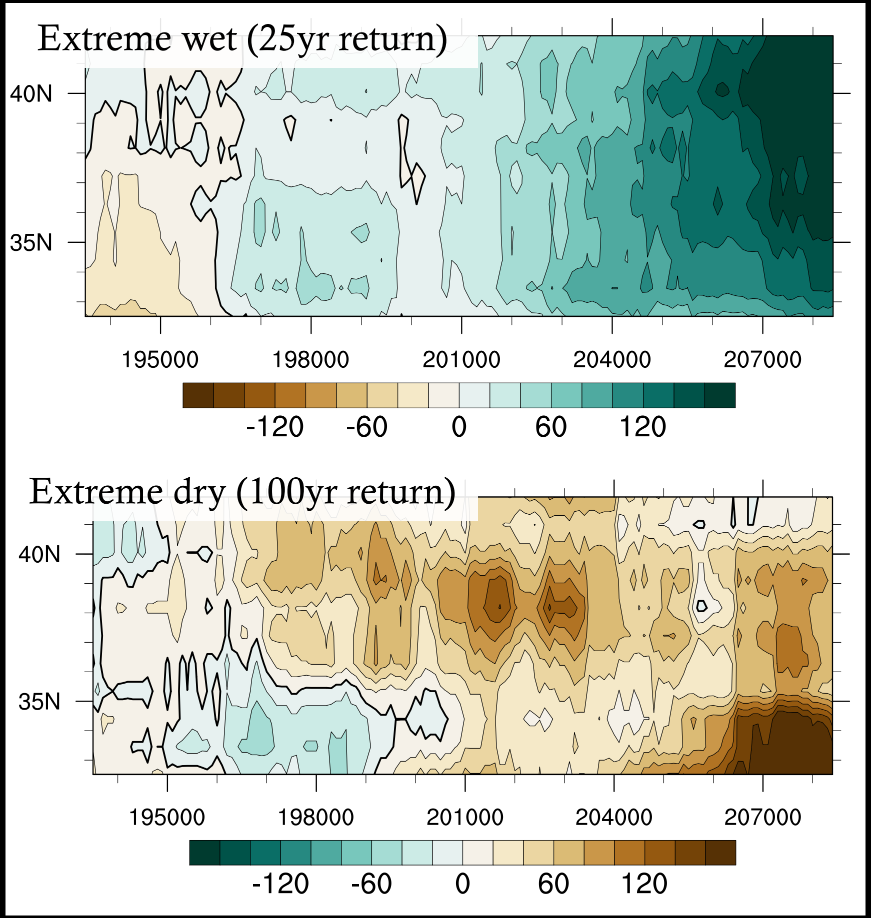

Change in extremely wet (top) and dry (bottom) Nov-Mar periods in CESM-LENS (from Swain et al. 2017b, in prep)

- Despite modest mean precip change, large projected increases in California extremes (wet & dry)
  (Berg & Hall 2015; Yoon et al. 2015; Gao et al. 2016; Dettinger 2016; Gao et al. 2016, Swain et al. 2017b (in prep))
- Linked to increasing frequency of *extreme* (vs. mean) ENSO?
  (Wang et al. 2015; Yoon et al. 2015)
- Serious implications for decision-making & climate adaptation:
  1. "Slightly wetter" / "more El Niño-like"
  2. "Large increase in extremes" / "more ENSO variability, tilt toward +EN"

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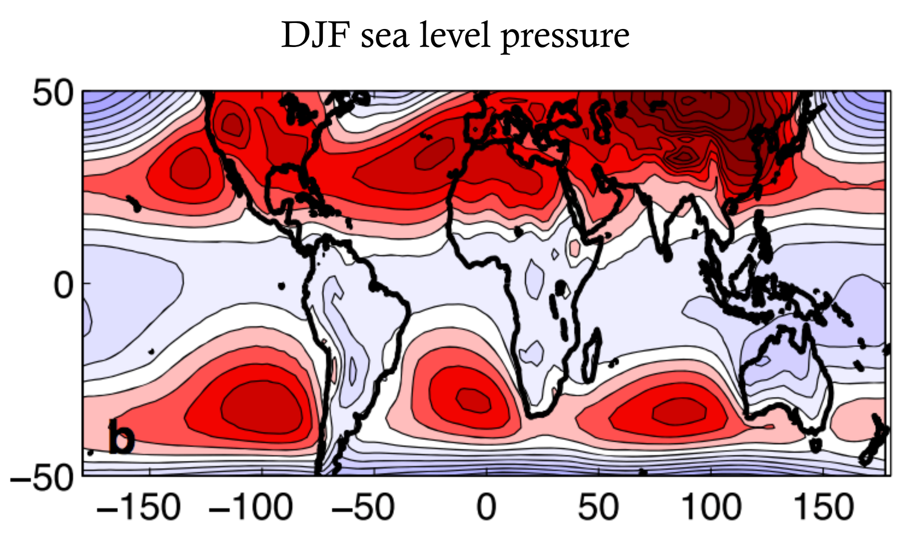
Stationarity of teleconnections vs. regional impacts



Zonal asymmetries likely to modulate Hadley Cell changes & regional subtropical impacts (From Karnauskas and Ummenhofer 2014)

- Typically assumed that coupled processes underlying teleconnections are themselves stationary
- Indeed: evidence that existing modes of variability easiest to excite, rather than novel ones (Shepherd 2014)
- But for regional impacts, interactions with mean state may affect outcomes
    - Continentality, ocean upwelling zones
    - Increasing land-sea thermal contrasts
    - Zonally asymmetric storm tracks

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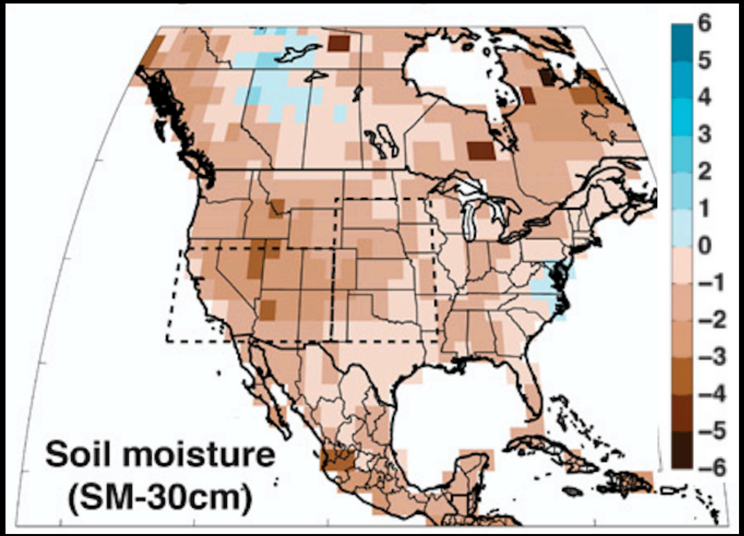
Emerging teleconnections: Looking beyond the tropics



Profound drying of continents likely during 21st century (30cm soil moisture anomaly, 2050-2099, under RCP8.5 from Cook et al. 2016)

- Historically, strong focus on tropical ocean variability as predictor (Baxter and Nigam 2015)
- Arctic changing rapidly & profoundly
  - At some point this century, we will effectively have a new summer/autumn ocean basin
- Warming may induce continental-scale soil drying & vegetation shifts
  - Potential for feedbacks to large-scale circulation, not just local moisture balance
- Difficult but critical challenges!
  - Opportunities for increased predictability?

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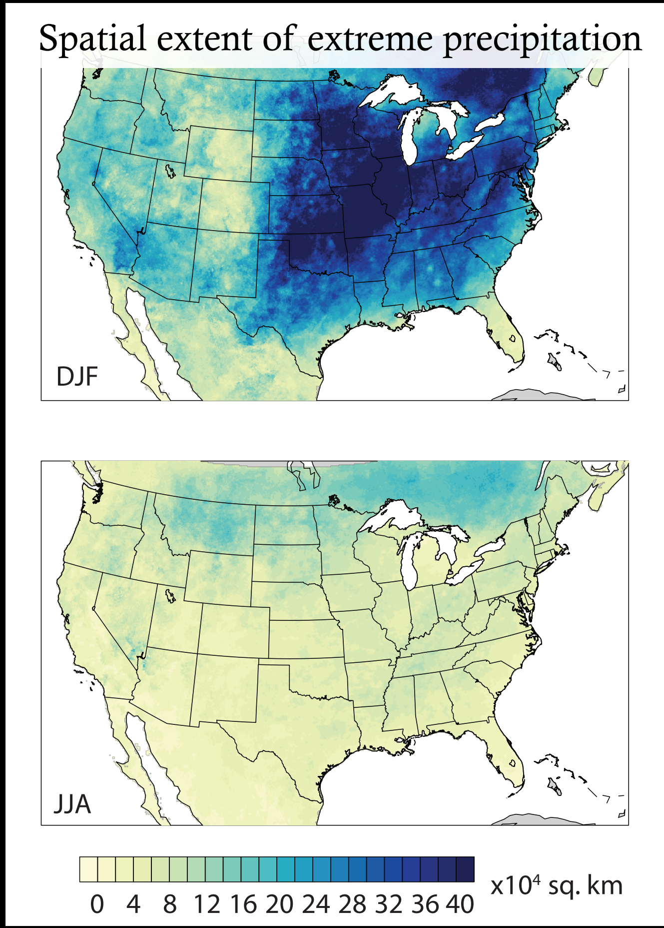
Key points



Spatiotemporal variability of contiguous extreme precipitation events, 1980-2014.
From Touma et al. 2017 (in prep)

- Metrics matter: spatial, temporal, & magnitude “smoothing” can mask critical teleconnection impacts & nonlinearities
- Stationarity of teleconnections ≠ stationarity of regional impacts
- As climate warms, new sources of predictability may emerge

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