The Role of Internal Variability, SST and Land Feedbacks in Decadal Drought in Western North America

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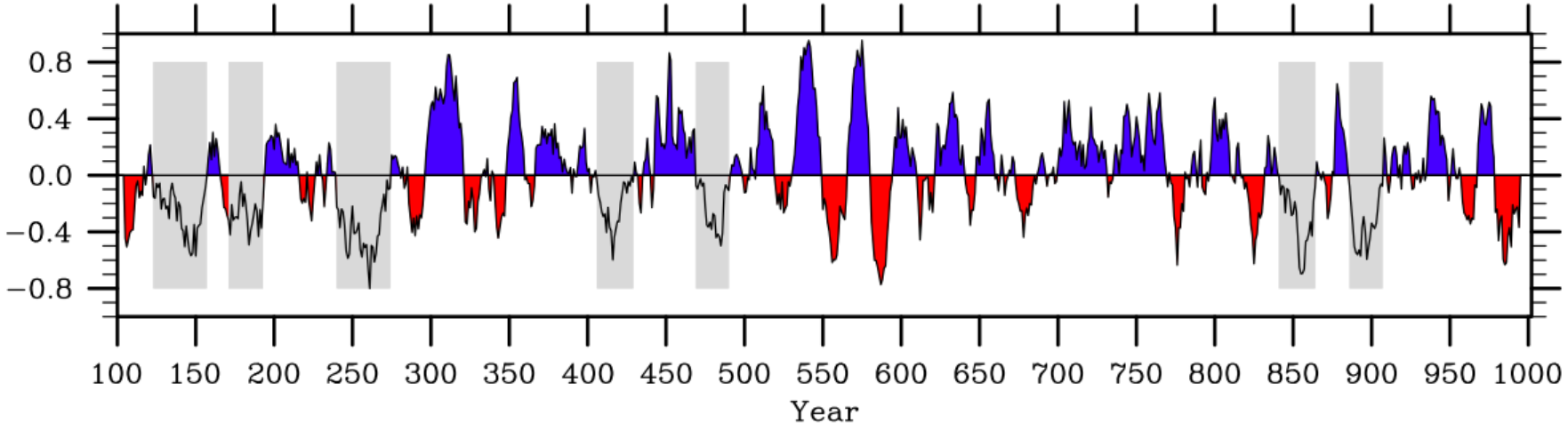
NCAR Community Earth System Model (CESM) v1.0.3 T31x3

- pre-industrial CO_2 with no volcanic or variation in solar forcing
- fully coupled control simulation for 900 years (after 100 years spin-up)

11 yr running mean standardized Great Basin precipitation anomaly



Megadrought -

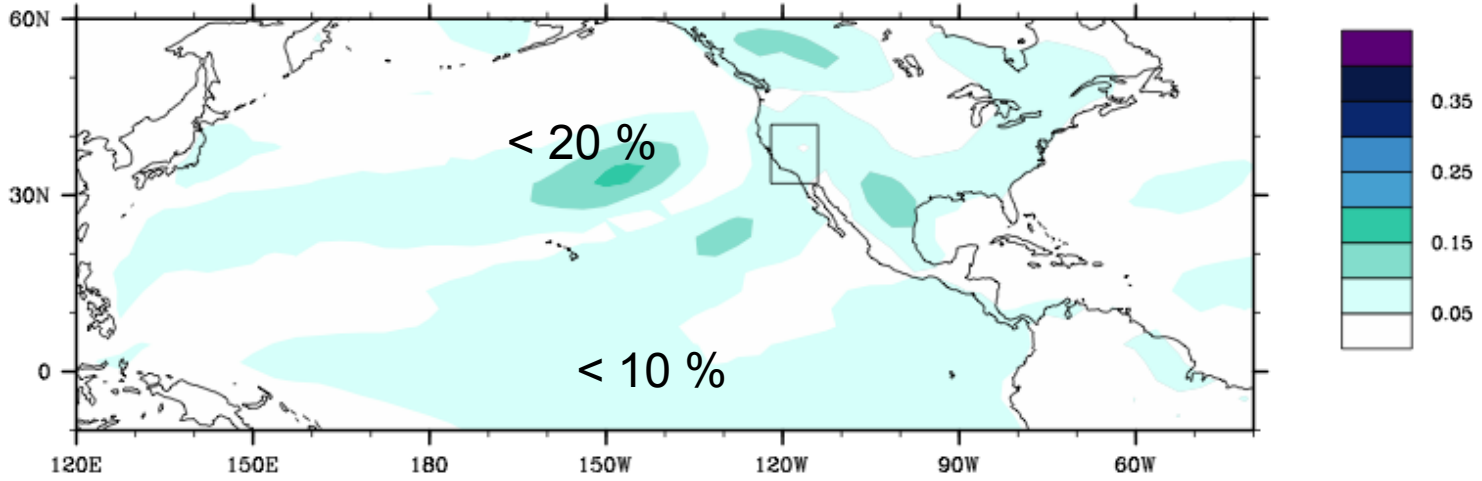
Longer than 20 yrs negative 11yr running mean precipitation anomaly

(Woodhouse and Overpeck 1998, Meehl and Hu 2006)

Langford et al. 2014 J Clim, in press

CMIP5 historical simulations

- consistent 5-yr running mean winter teleconnections from Pacific Ocean SST anomalies to western North America precipitation
- Less than 20% of low-frequency California winter precipitation variability associated with Pacific SST anomalies
- Observations show less than 30% for a shorter timeseries



Fraction of variance in 5 year running mean standardized precipitation anomalies over California in DJF associated with 5 year running mean surface temperature. Average of 47 CMIP5 historical simulations.

Long-term precipitation anomalies in western North America can occur in absence of SST anomalies in CMIP5 models.

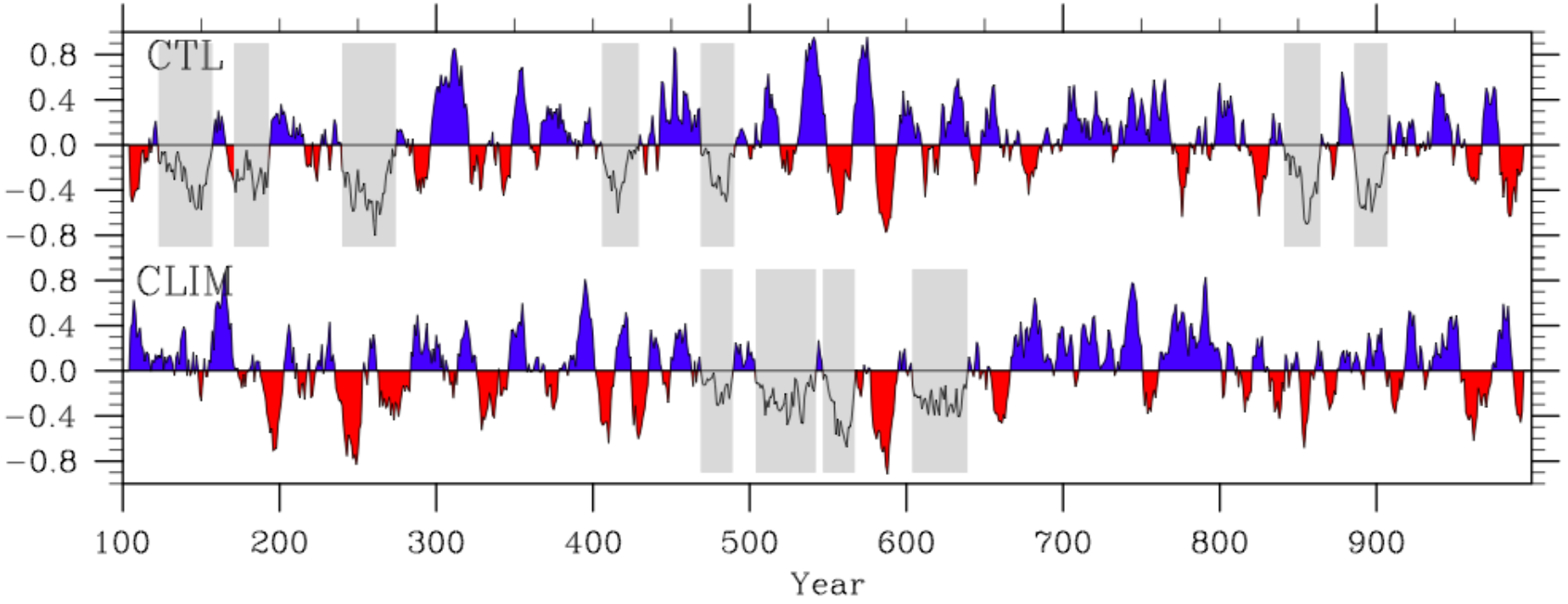
Stevenson et al. J Clim in review

CESM1.0.3 T31x3 1000 year simulation

11 yr running mean standardized Great Basin precipitation anomaly.

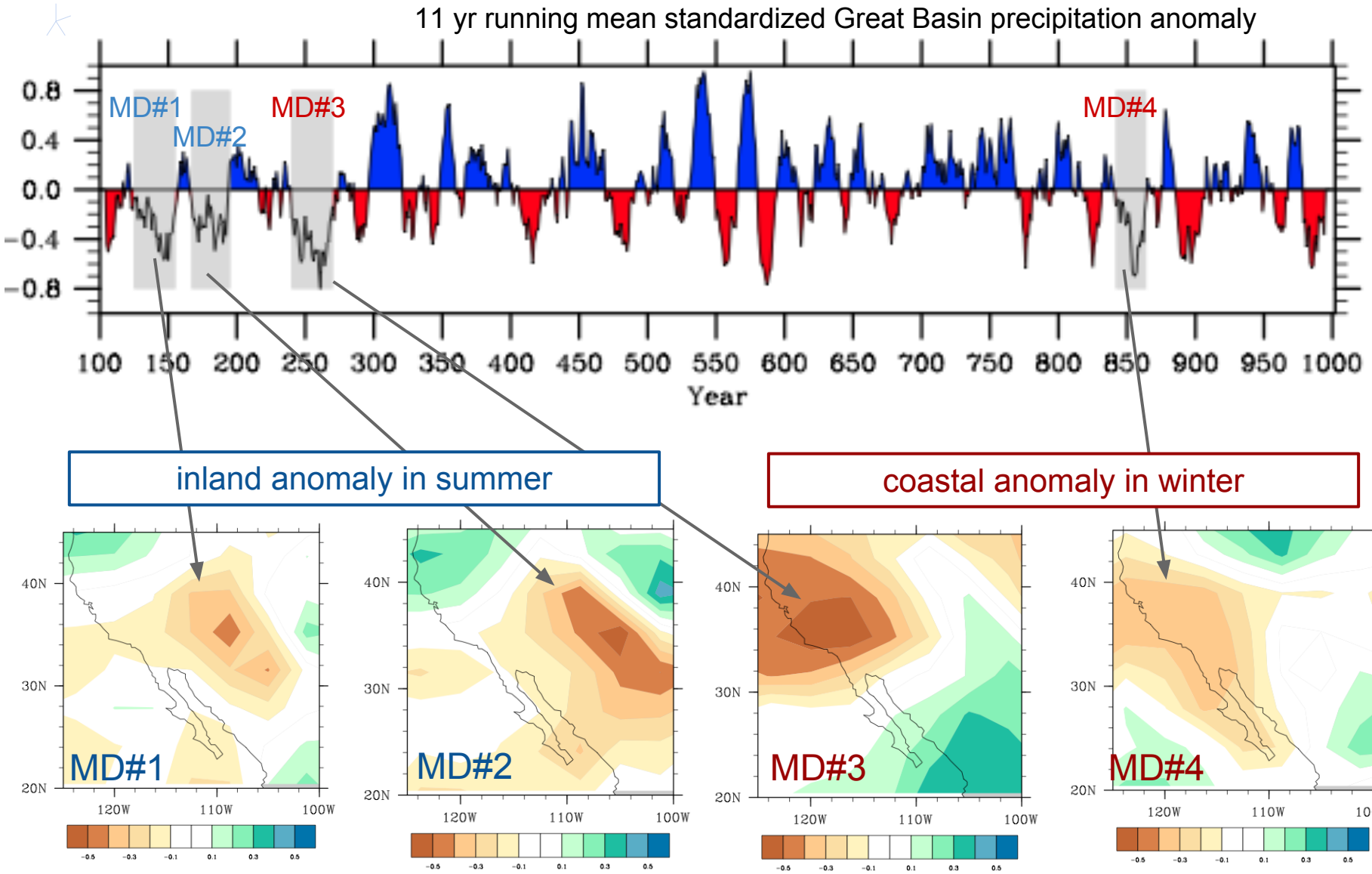
CTL - fully coupled simulation

CLIM - climatological SST forcing from CTL; no feedback to the ocean (12 month cycle)

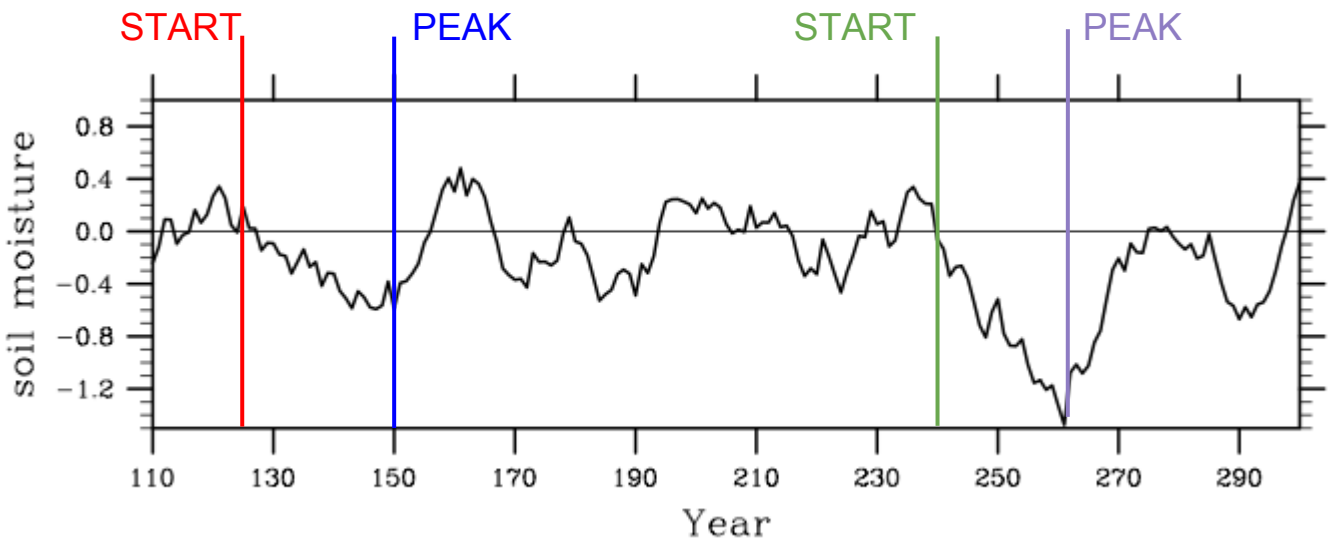


Megadroughts can occur without ocean feedbacks.

4 megadroughts examined as case studies in 1000 yr CESM1.0.3 T31x3 CTL run



11-yr running mean standardized Great Basin 2m soil moisture anomalies



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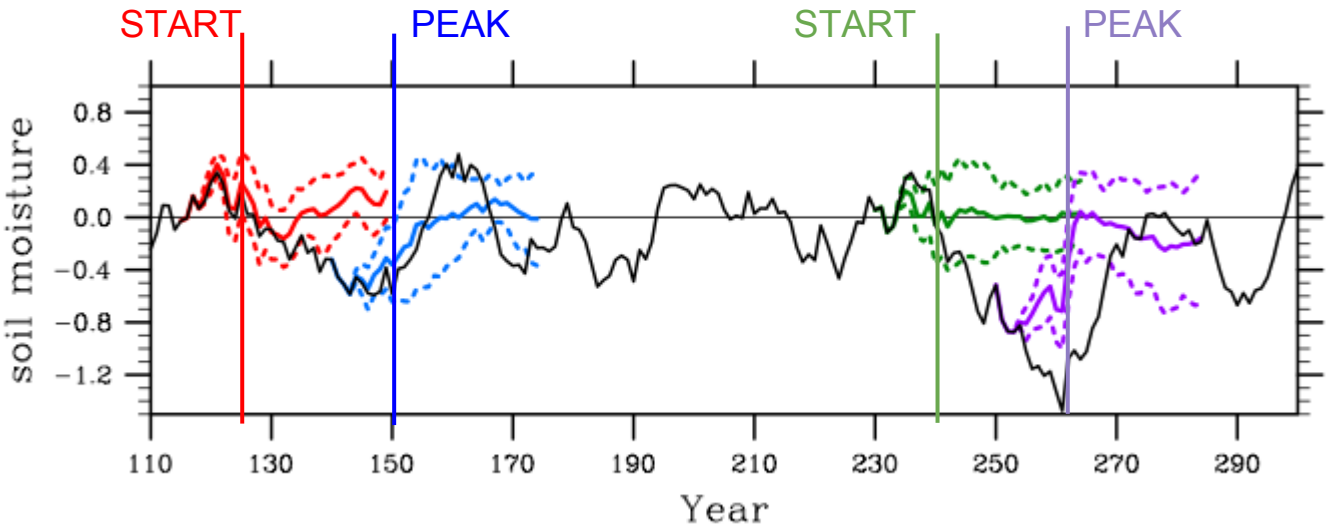
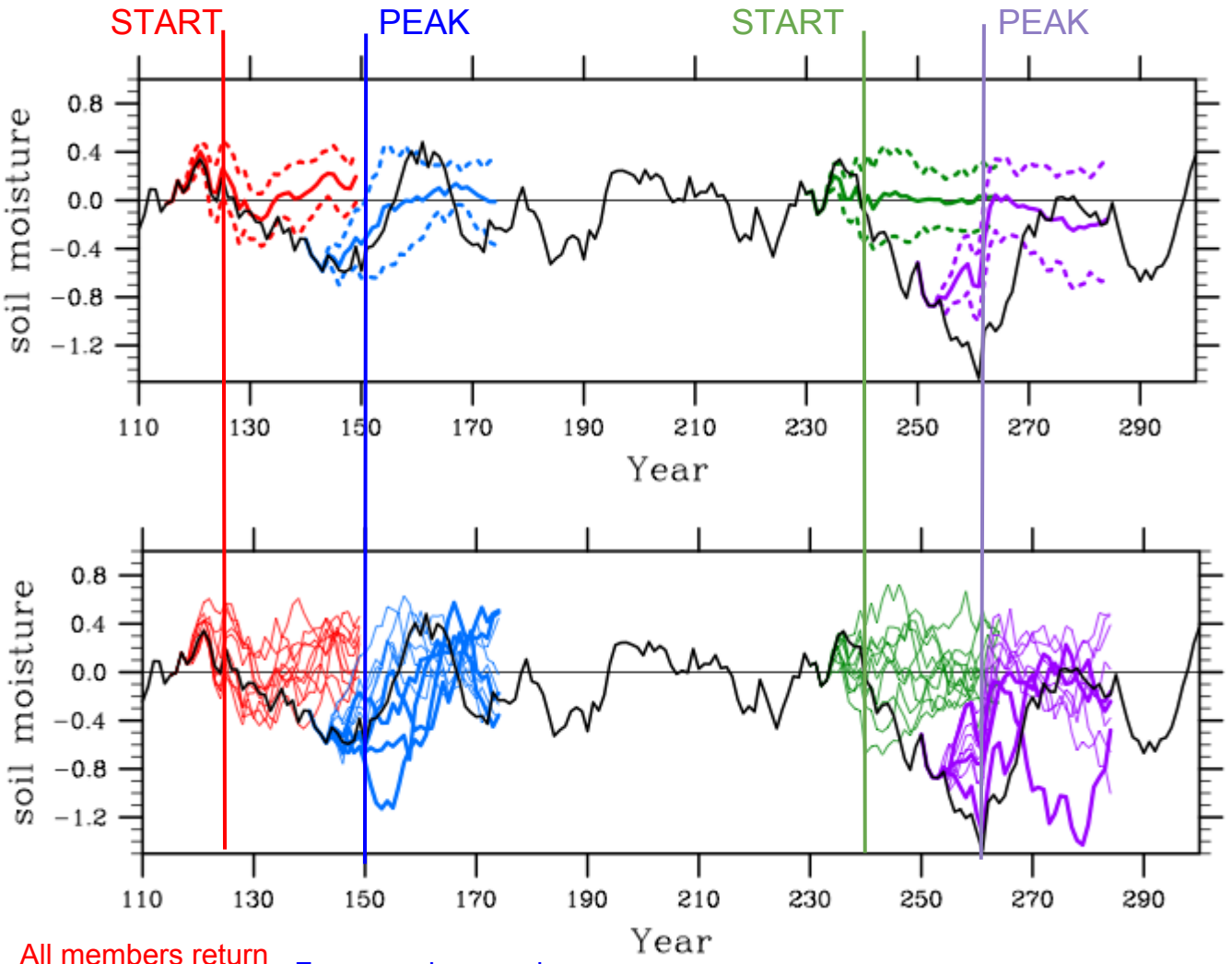


11-yr running mean standardized Great Basin 2m soil moisture anomalies

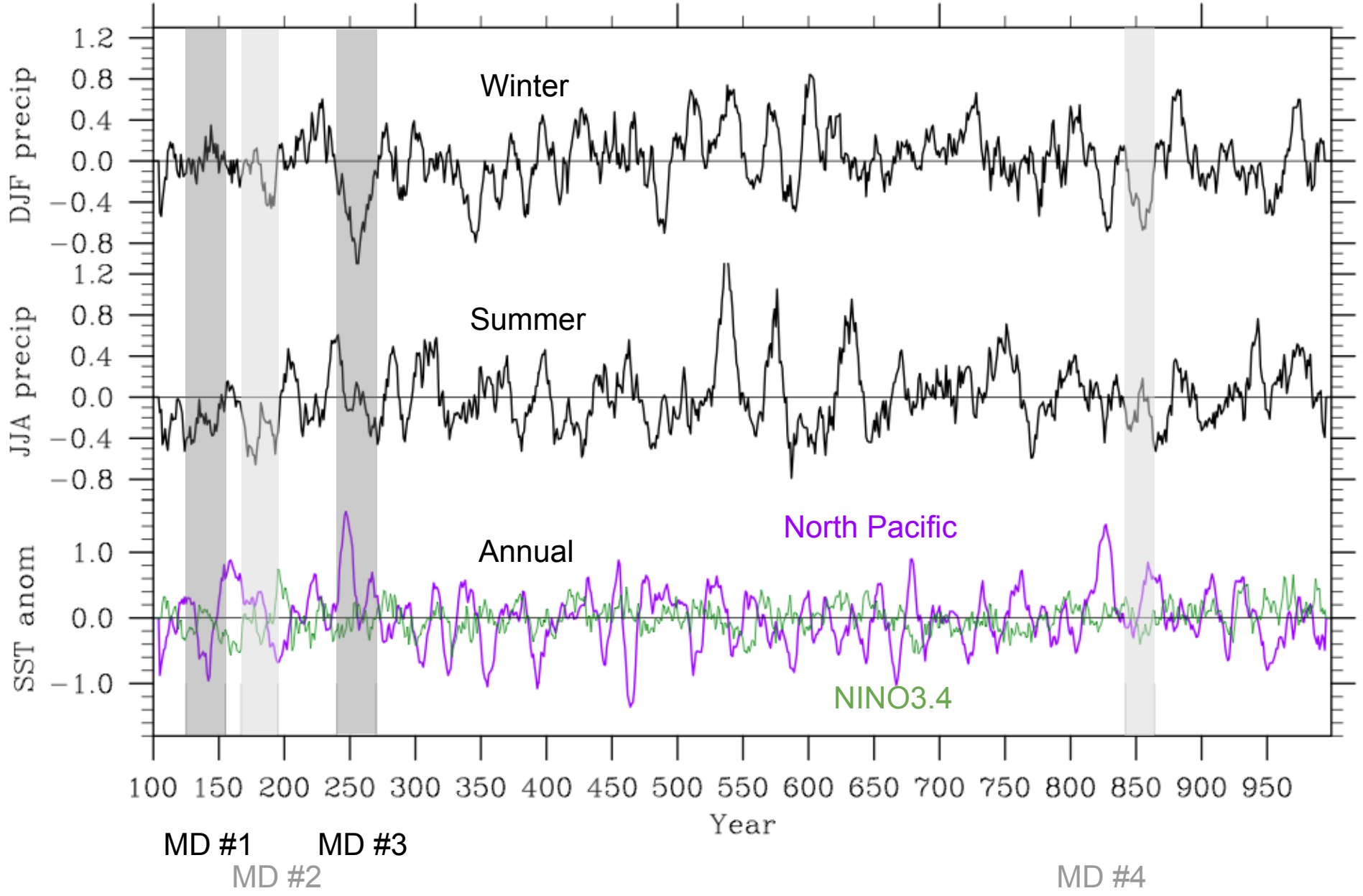


All members return to climatology

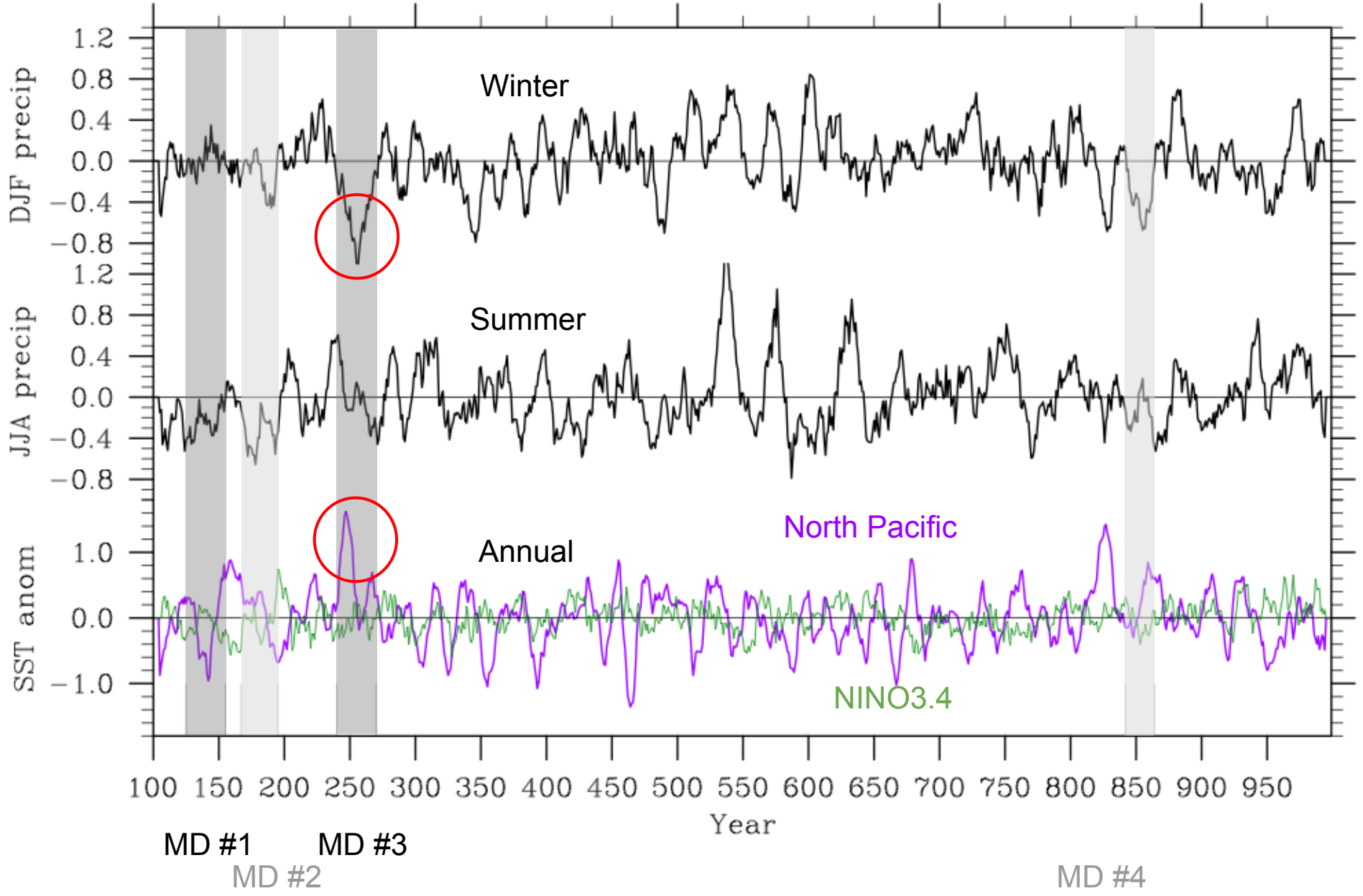
Four members prolong the drought compared to CTL run

Antecedent soil moisture anomaly may increase potential predictability of the termination of drought

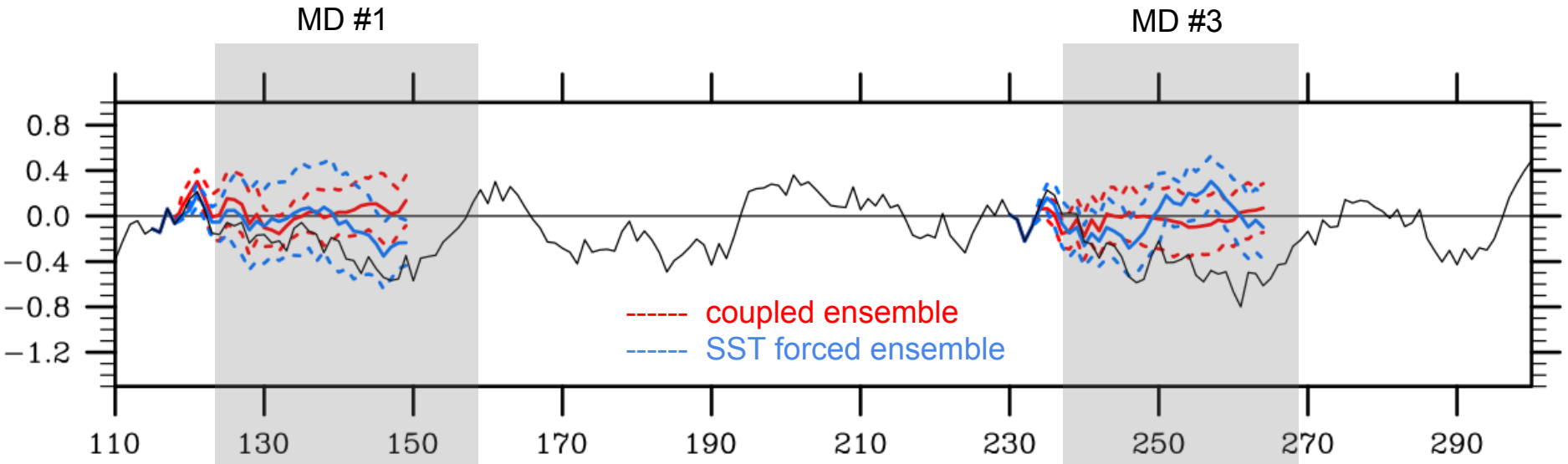
11 yr running mean standardized Great Basin precipitation or SST anomaly



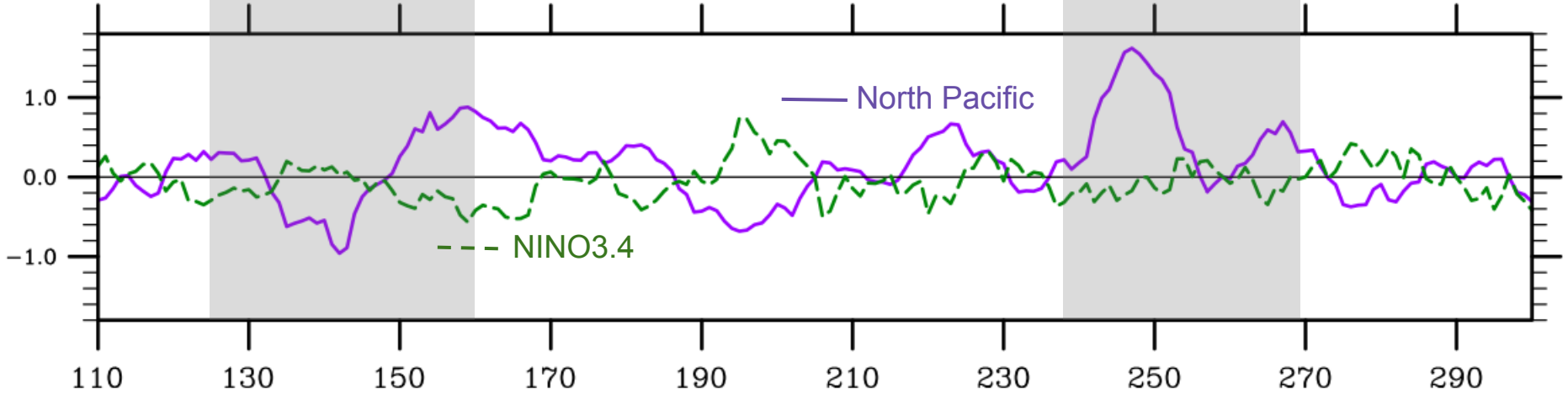
11 yr running mean standardized Great Basin precipitation or SST anomaly



11 yr running mean annual standardized Great Basin precipitation anomalies
with mean and 1 std dev spread for 10 ensemble members



11 yr running mean annual standardized SST anomalies



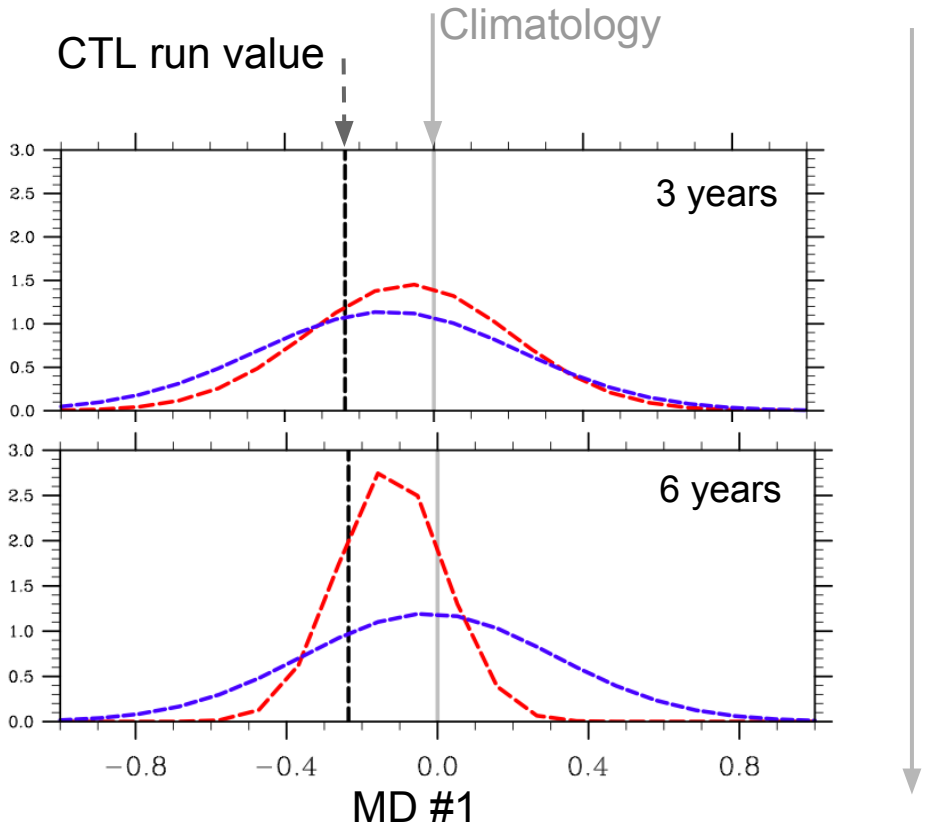
Year

PDF of 11 yr mean precipitation for 10 ensemble members (atmospheric perturbation)

Coupled ocean

SST prescribed from CTL

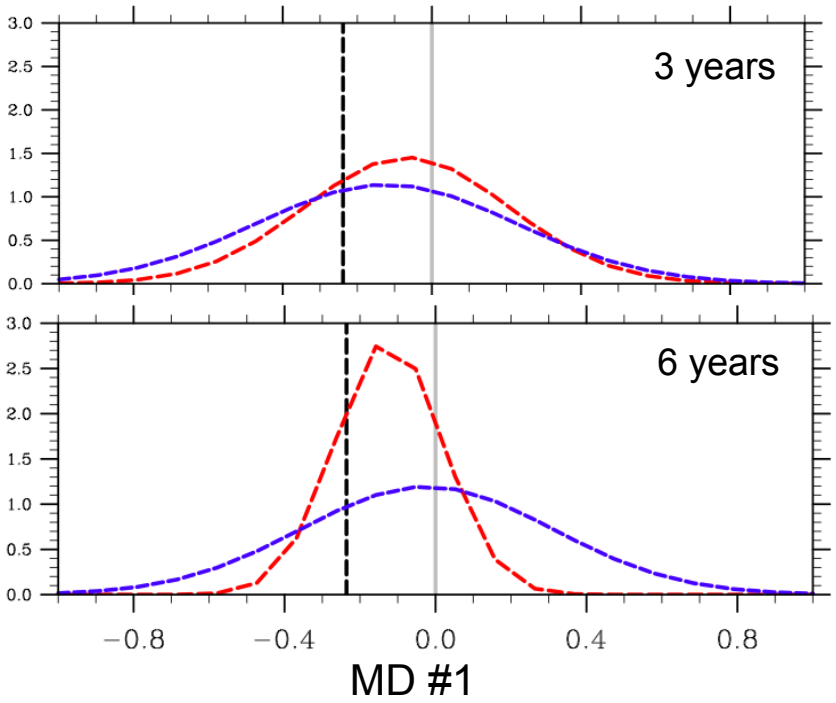
Time since ensemble initialization

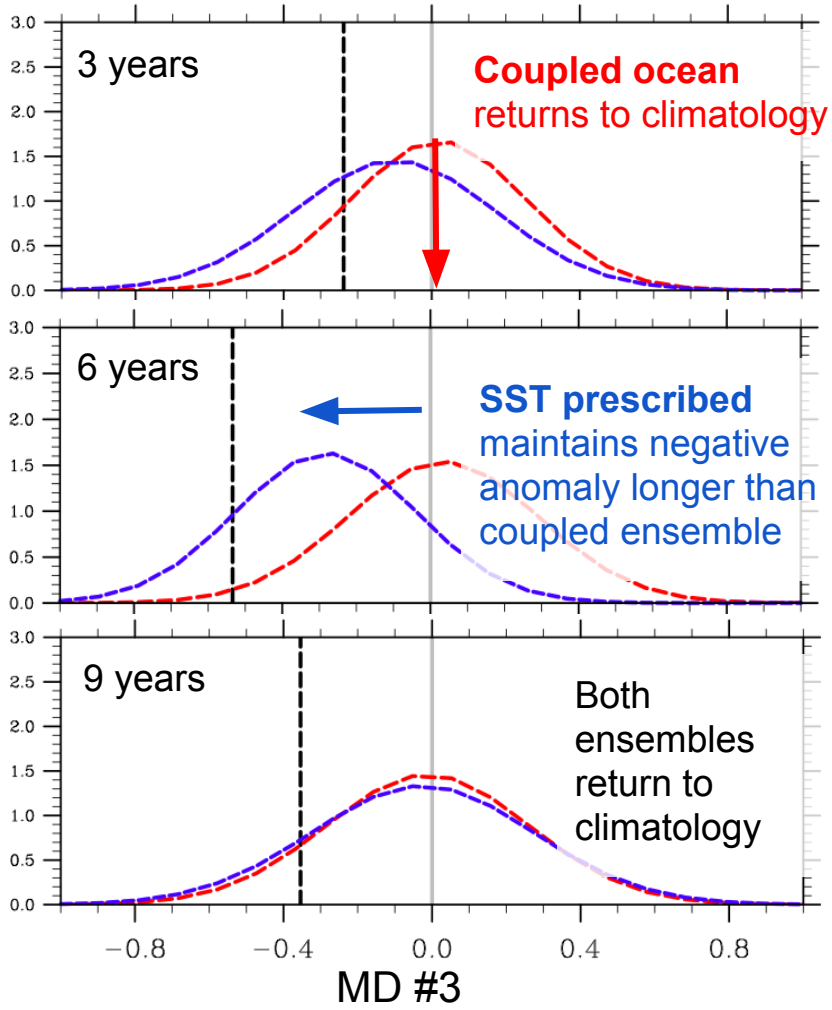


MD #1 - ensemble mean persists climatology in both ensembles

PDF of 11 yr mean precipitation for 10 ensemble members (atmospheric perturbation)

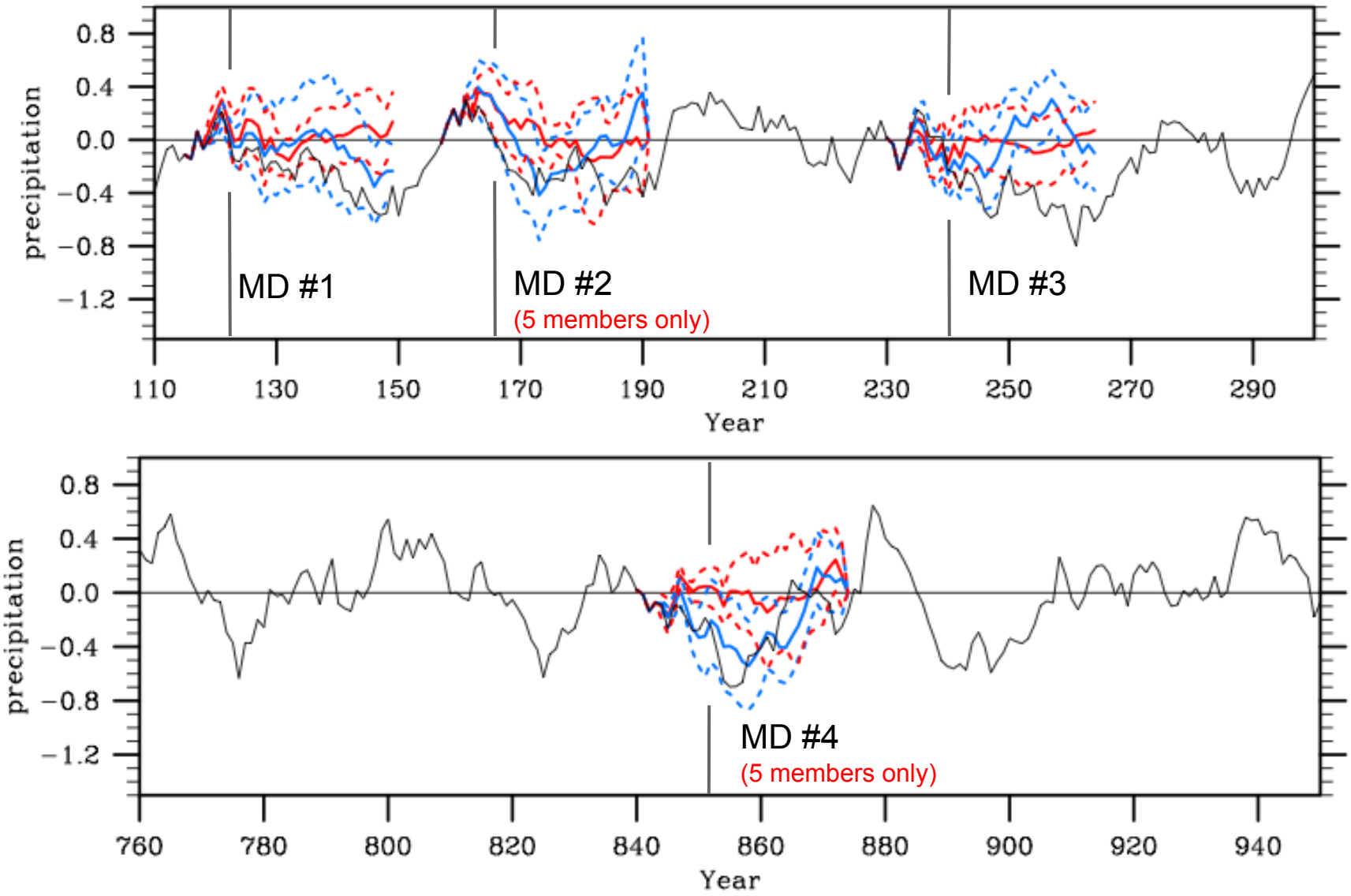
Coupled ocean
SST prescribed from CTL
CTL run value
Climatology





MD #3 - SST forced members persist anomaly for first 10 years

11 yr running mean annual standardized Great Basin precipitation anomalies with ------ coupled ensemble
mean and 1 std dev spread for 10 (or 5) ensemble members ------ SST forced ensemble



Summary - megadrought case studies have many different characteristics:

MD #1
- Summer, inland precipitation anomaly
- Not reproducible with SST forcing
- Termination reproduced from antecedent soil moisture anomaly

MD #2
- Summer, inland precipitation anomaly
- Reproducible with SST forcing for around a decade
- Drought continues in CTL for around a decade

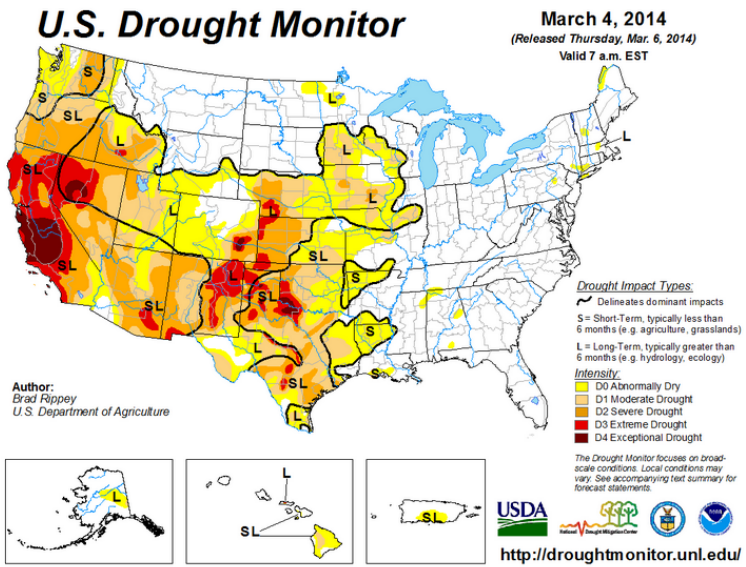
MD #3
- Winter, coastal precipitation anomaly
- Reproducible with SST forcing for around a decade
- Drought continues in CTL for 2 decades (after North Pacific SST anomaly ends)
- Termination not reproduced from antecedent soil moisture anomaly

MD #4
- Winter, coastal precipitation anomaly
- Reproducible with SST forcing for around 2 decades (full duration of drought)

- potential predictability of initiation of megadroughts linked to positive North Pacific and negative equatorial Pacific SST anomalies
- potential predictability of termination of megadroughts may be linked to antecedent soil moisture anomaly in the interior of the continent

Potential economic and social cost of long-term drought-like conditions motivates understanding mechanisms in order to develop effective forecasts

- SST anomaly not always present during decadal drought
- Prescribed SSTs reproduced anomalous 11 year running mean precipitation during megadroughts for around a decade
- Soil moisture anomaly may influence potential to predict the termination of a megadrought



Current drought conditions in US

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