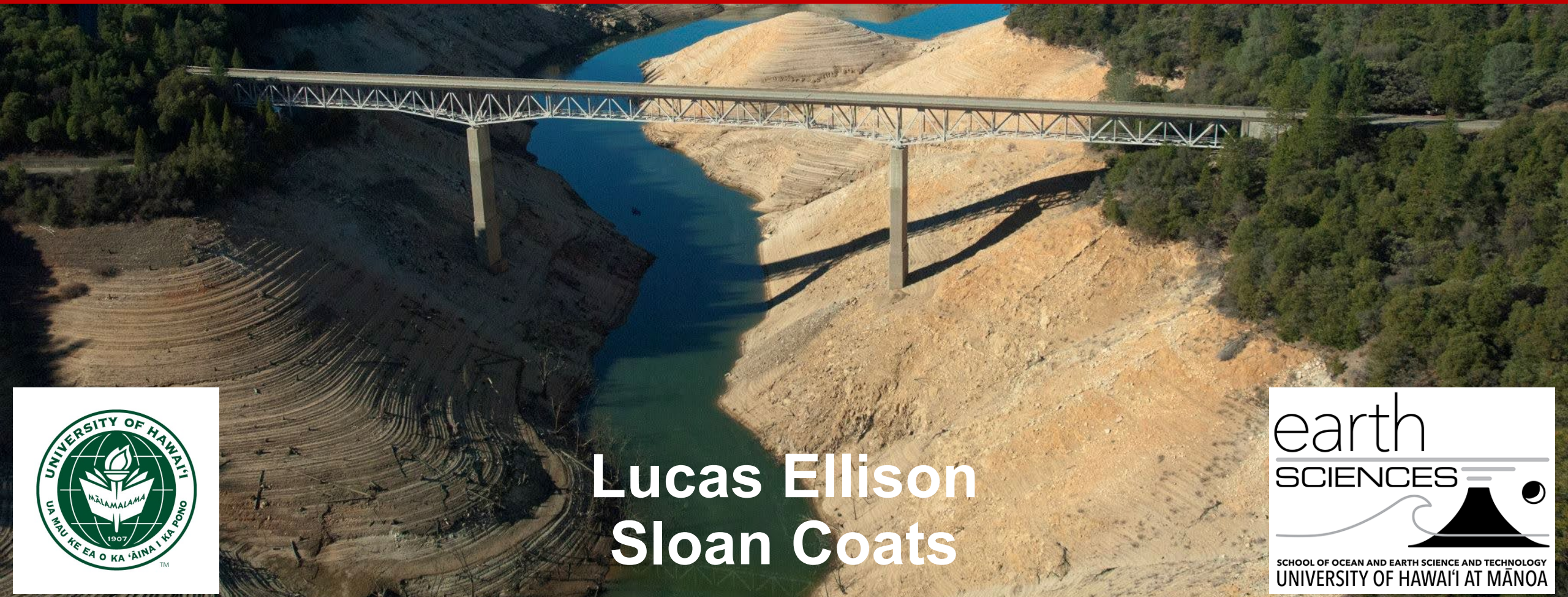
Quantifying the roles for structural uncertainty and intrinsic variability in determining the ocean-atmosphere conditions that drive western and central North American drought



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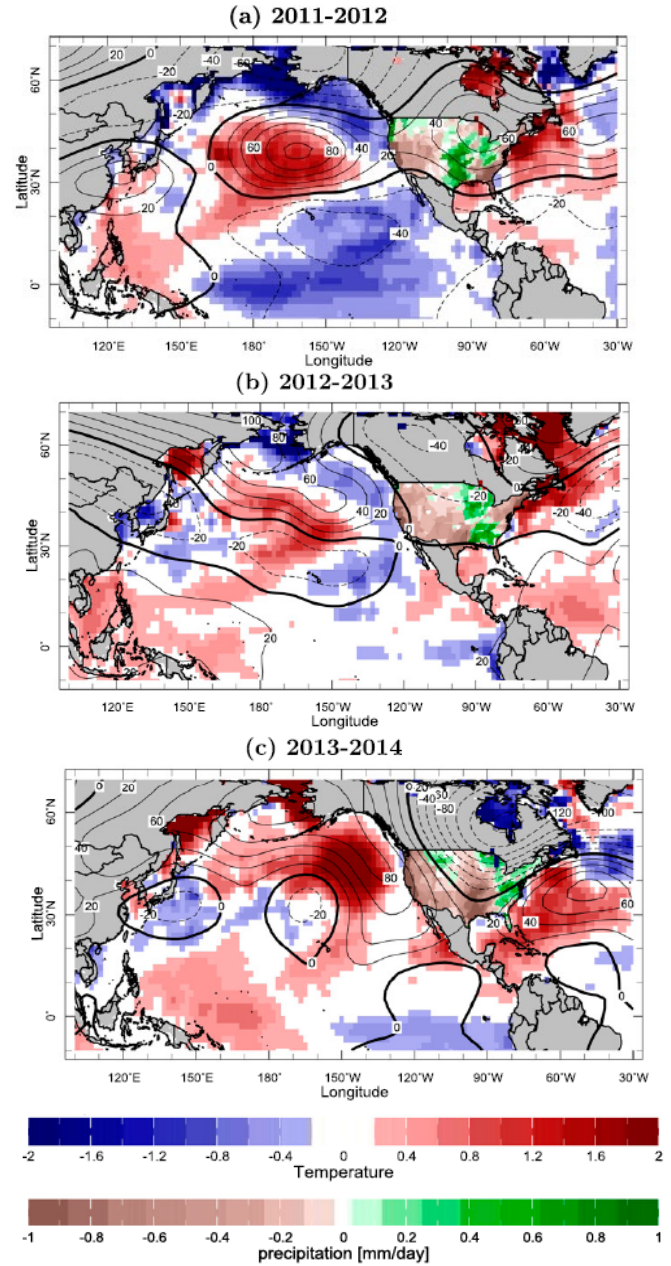
2011–2014 Western and central North American drought

- 2011 – 2014 was the driest 3-year period since 1895, and the warmest on record at the time

- Extensive cold SSTs in the first year of the drought, characteristic of strong La Niña conditions, helped form high pressure ridge in the North Pacific and stretched over southern North America

- Impacts include an estimated surface water shortage of nearly 10.7 billion m^3 (48% decrease relative to base-level years) and total economic loss of $2.7 billion.



From Seager et al. 2014

Motivation

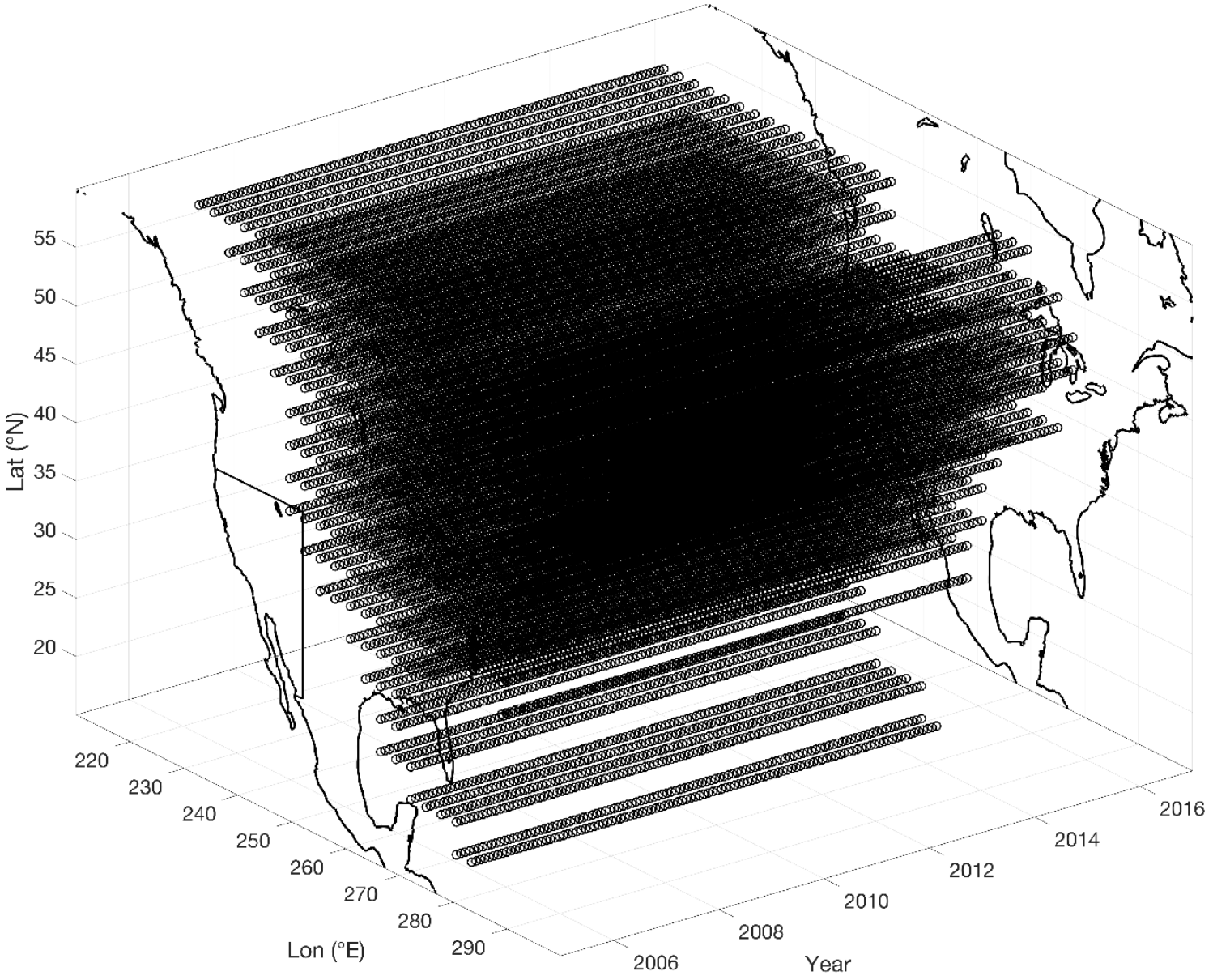
- Are simulated droughts effectively representing observed droughts?

- Are the large-scale drivers of the droughts (ocean-atmosphere conditions) consistent in simulated droughts?

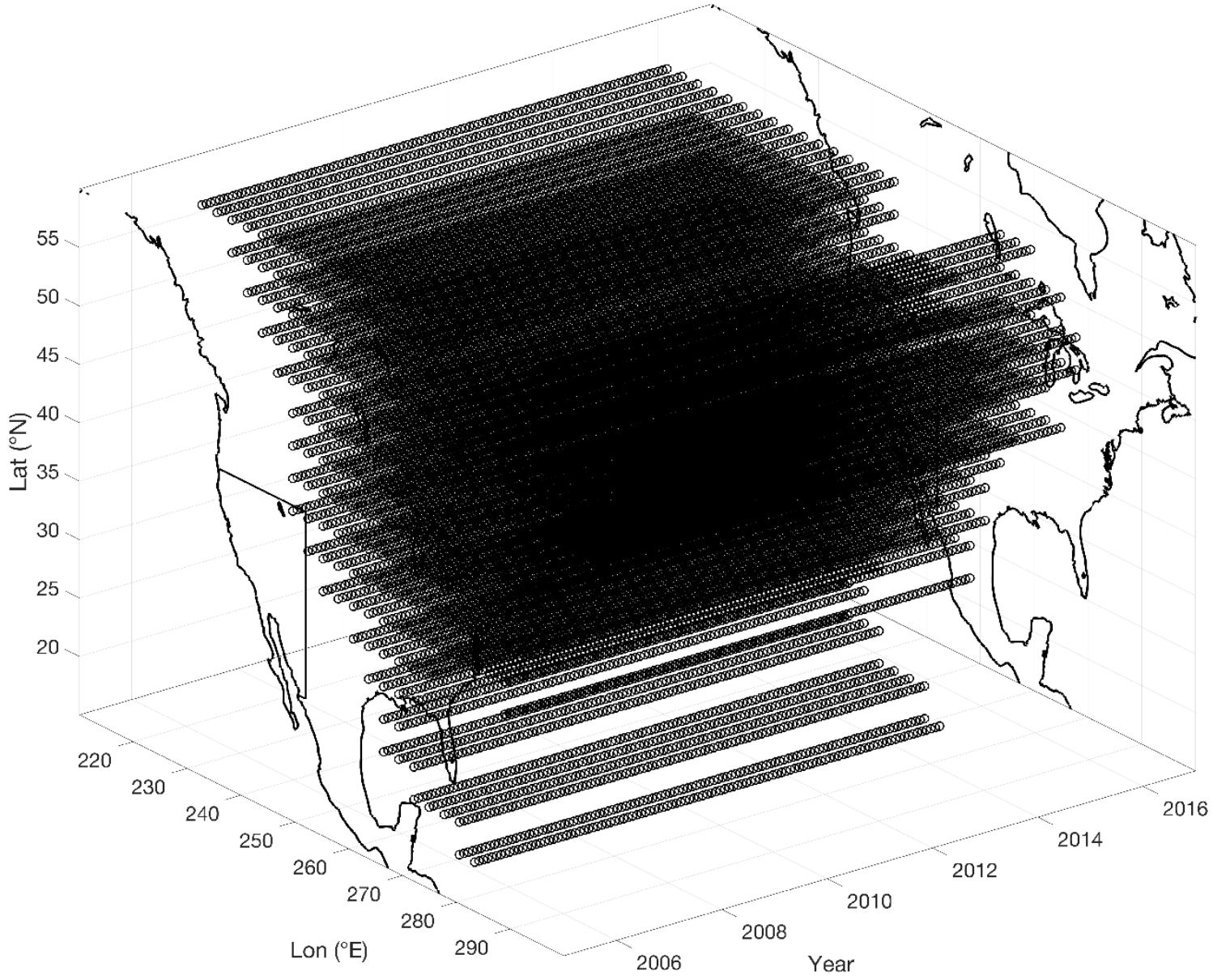
- How much of the inconsistency across droughts can be explained by randomness (intrinsic climate variability) and how much can be explained by differences in climate models (structural uncertainty)?

From Seager et al. 2014

Identifying droughts

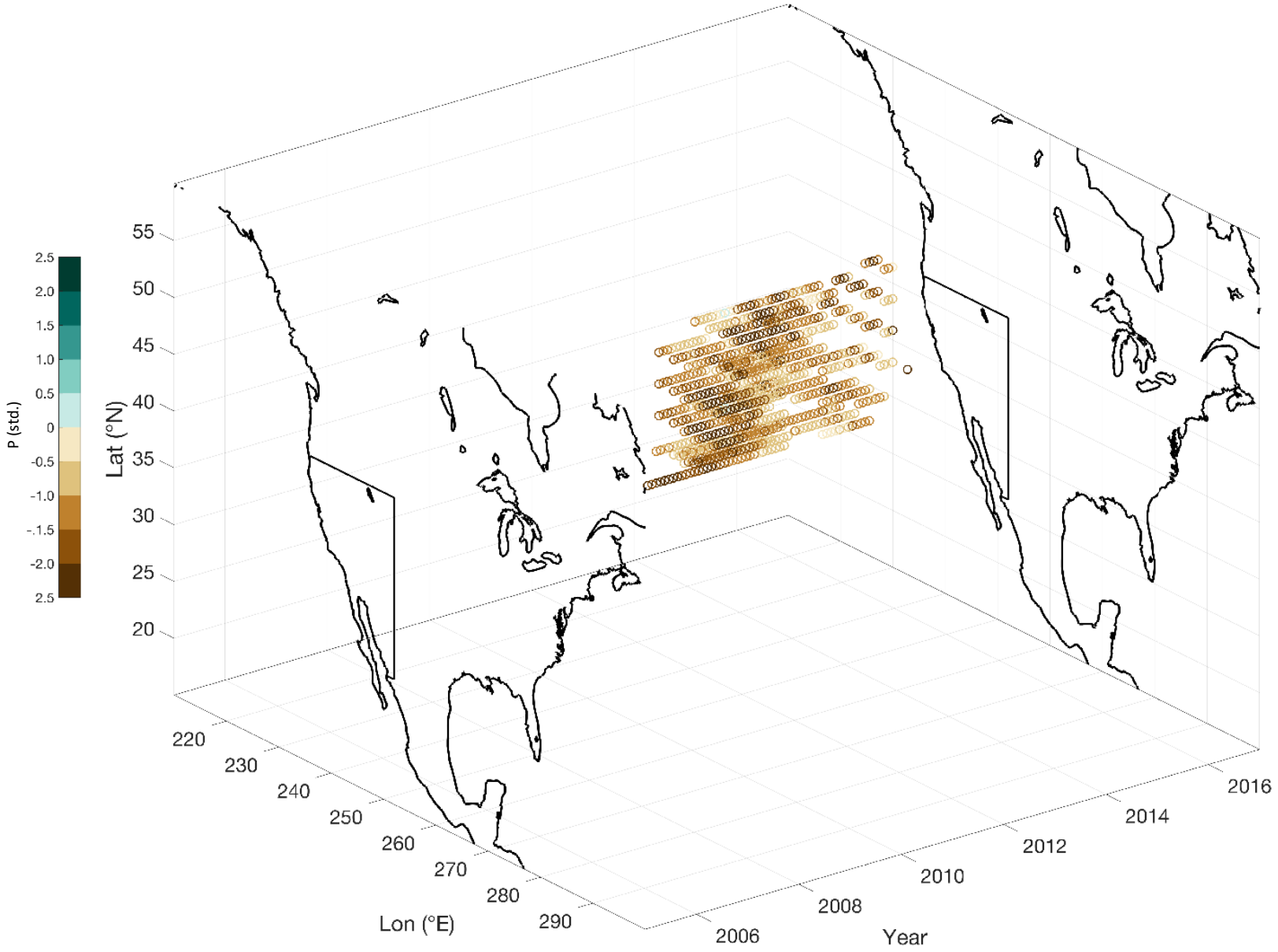


Identifying droughts

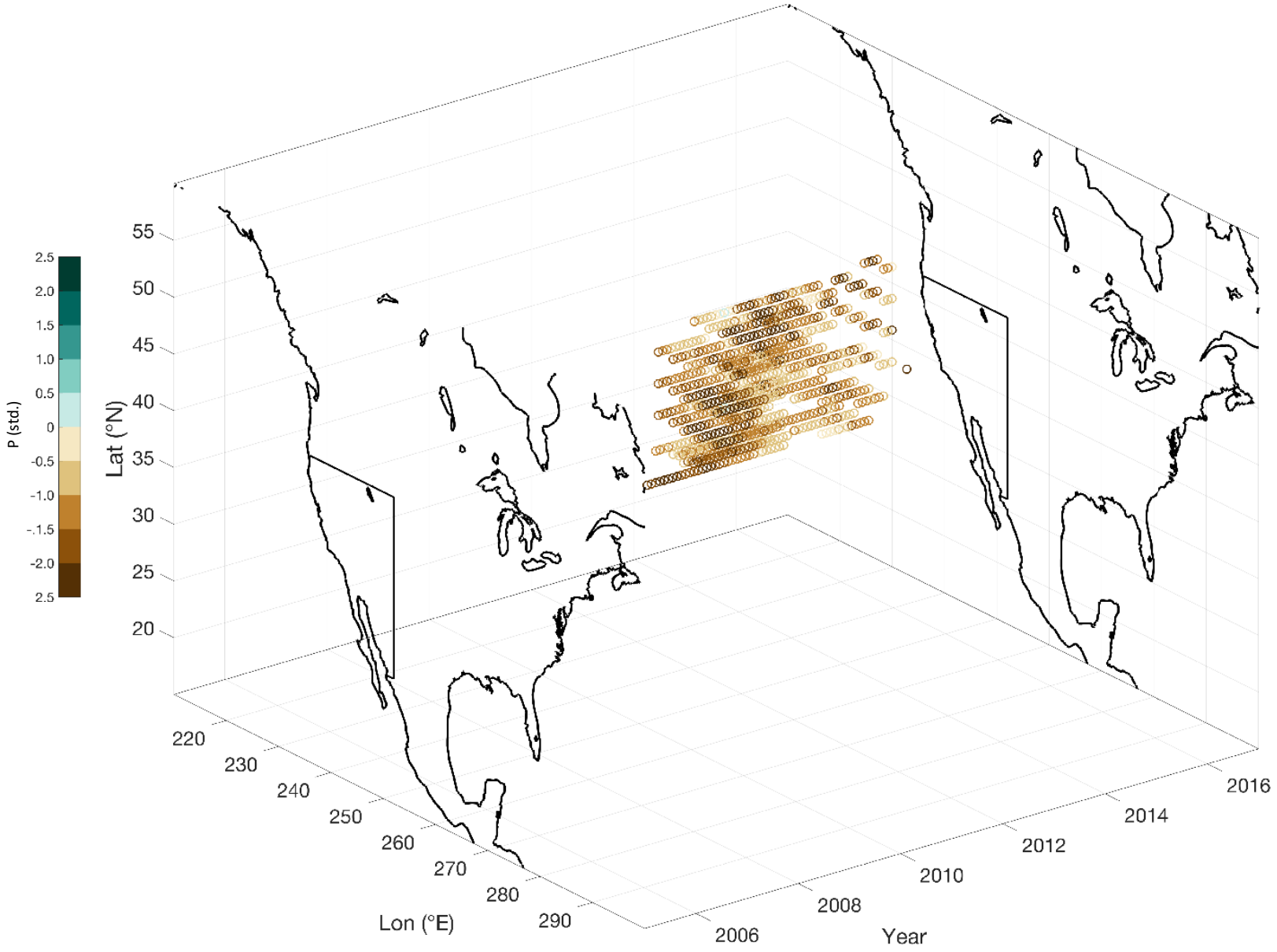


Assign each point as drought state or normal state

Identifying droughts

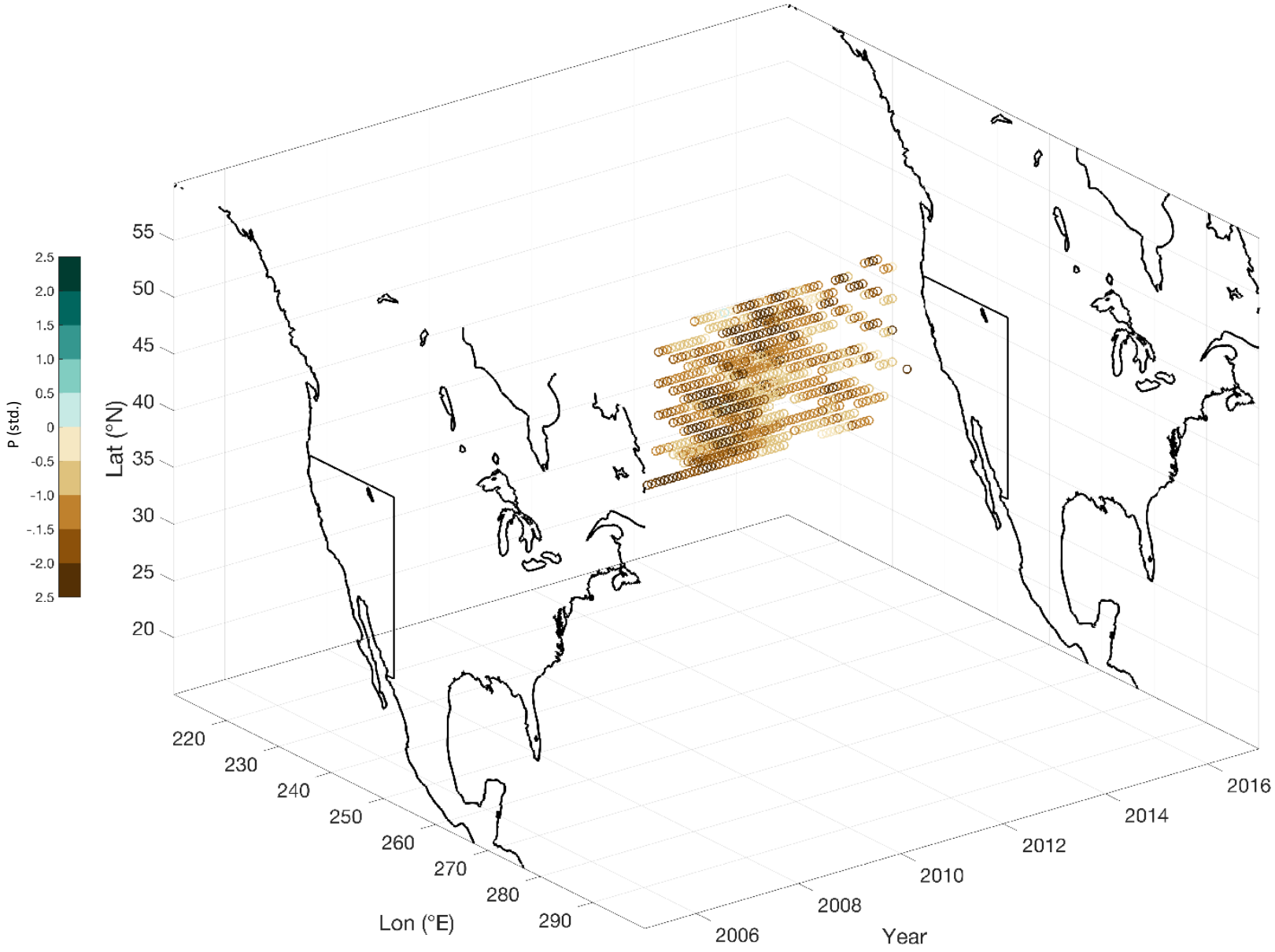


Drought characteristics



Size = total # space time grid points = 818

Drought characteristics



Size = total # space time grid points = 818

Spatial extent = 42

Temporal extent = 34

Data

19 CMIP6 models

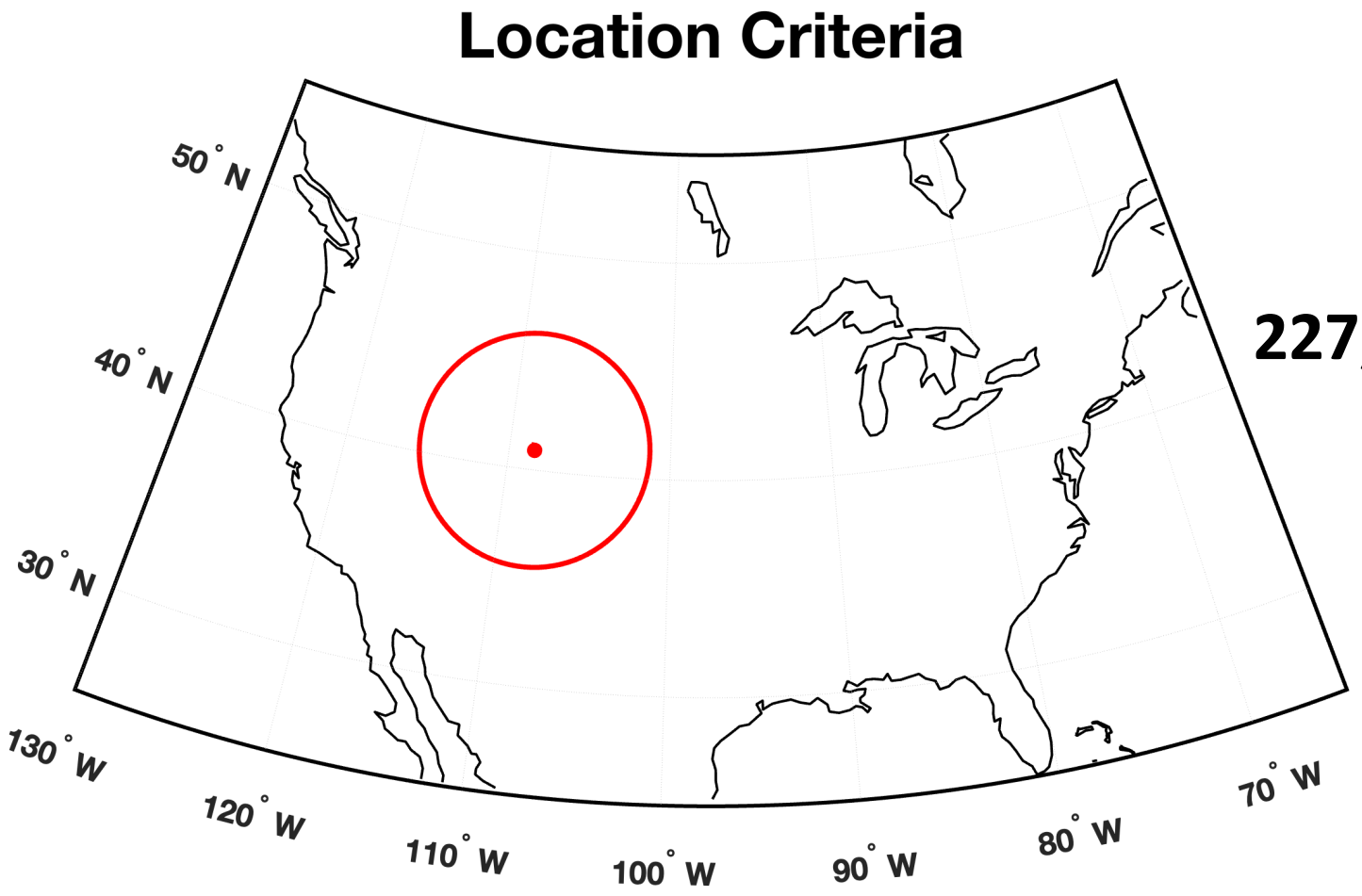
570 Individual Simulations

85,500 Simulation Years

227,716 droughts

Model	Simulations
ACCESS-ESM1-5	40
CESM2	11
CMCC-CM2-SR5	11
CanESM5	65
CanESM5-1	72
E3SM-1-0	22
E3SM-2-0	21
GISS-E2-1-G	46
GISS-E2-1-H	25
HadGEM3-GC31-LL	55
INM-CM5-0	10
IPSL-CM6A-LR	33
MIROC-ES2L	30
MIROC6	49
MPI-ESM1-2-HR	10
MPI-ESM1-2-LR	26
MRI-ESM2-0	12
NorCPM1	14
UKESM1-0-LL	18

Selecting the droughts

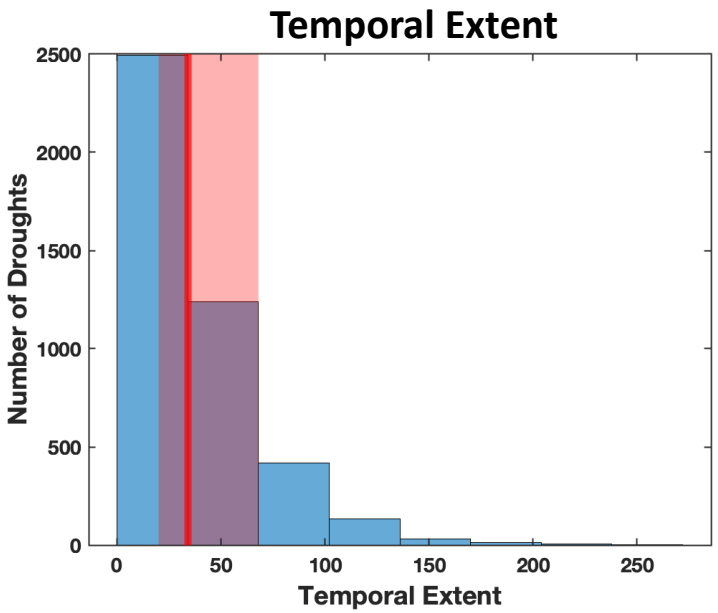


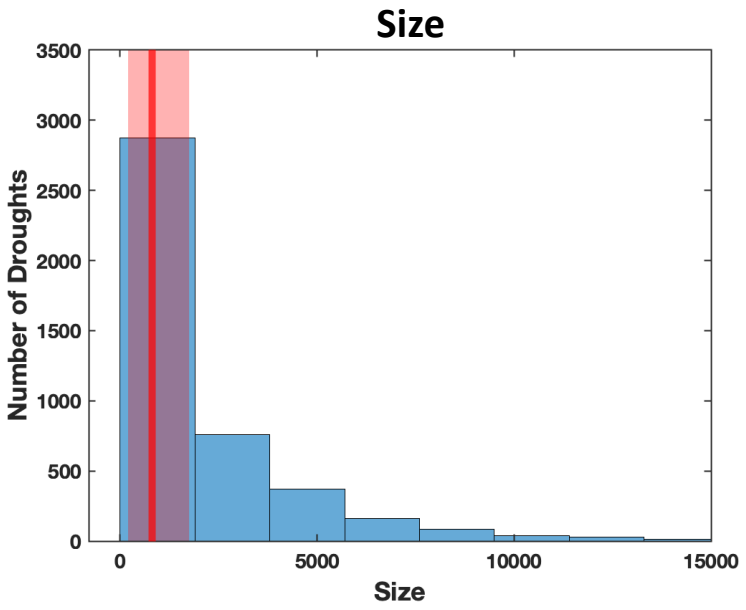
227,716 droughts → 4,337 droughts

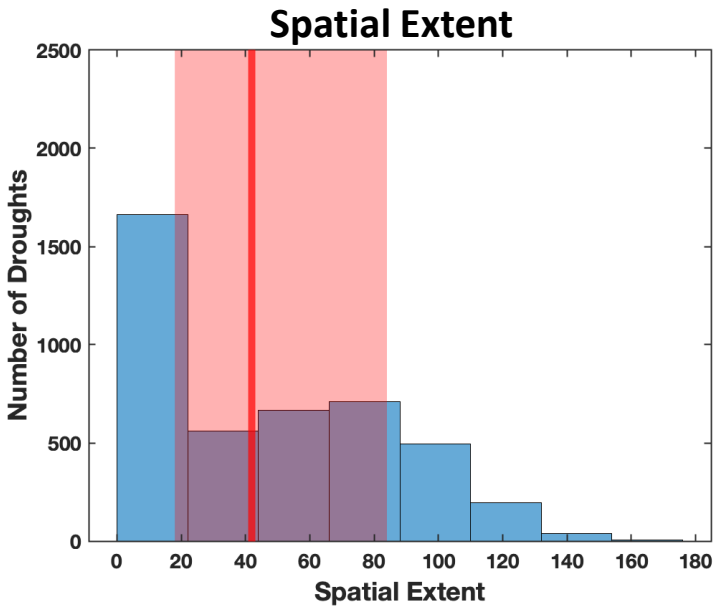
Selecting the droughts

- For a drought to be selected, it must have a size, spatial, and temporal extent value that is within the 30% closest values to the observed drought

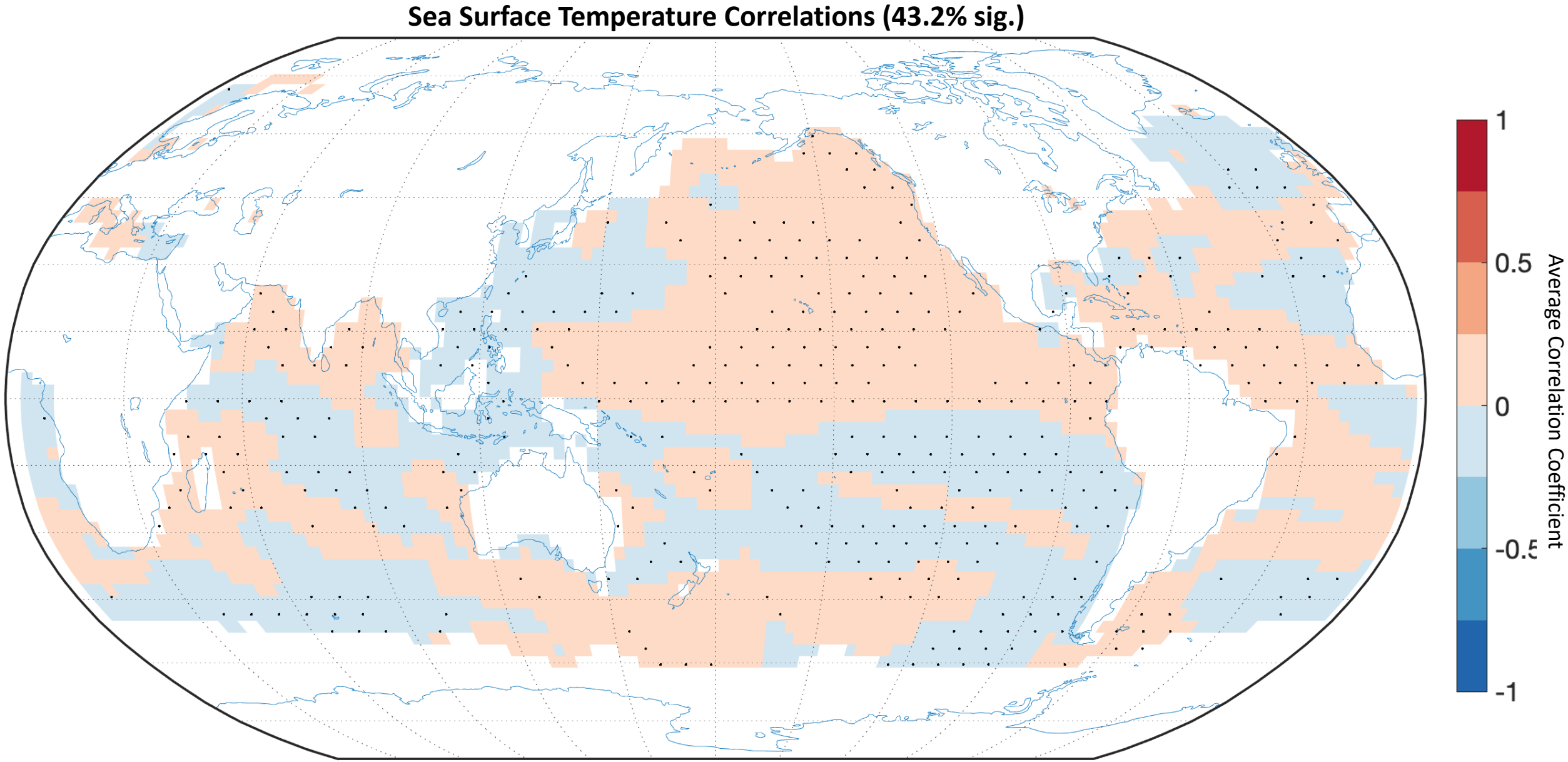
Ex/ 30% threshold







Average correlation for all models

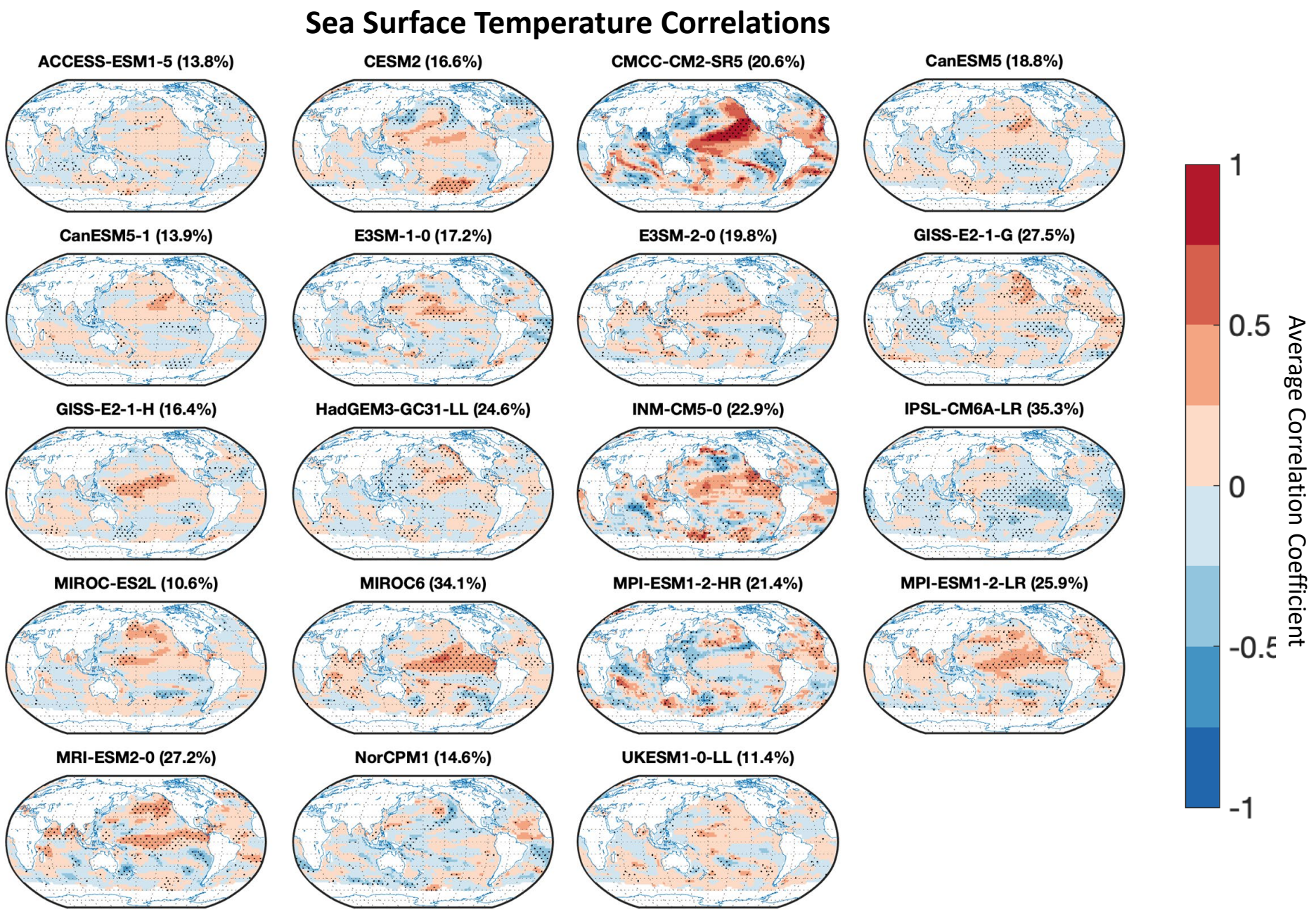


Two significance tests

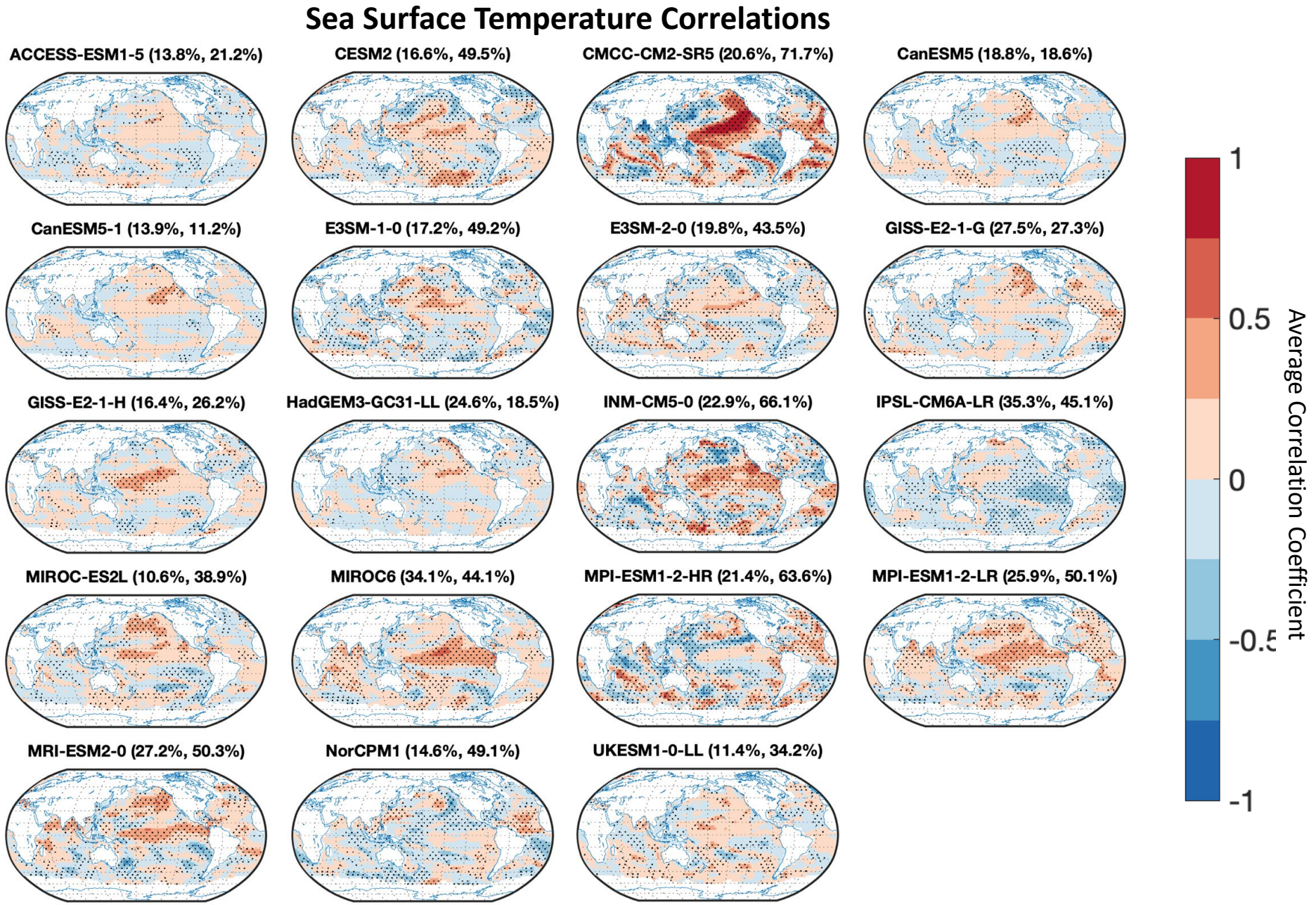
- First test: compared the consistency of each individual model to the consistency of 1000 randomly selected sets of droughts **from the same model** that met the distance criteria

- Second test: compared the consistency of each individual model to the consistency of 1000 randomly selected sets of droughts **from different models** that met the distance criteria

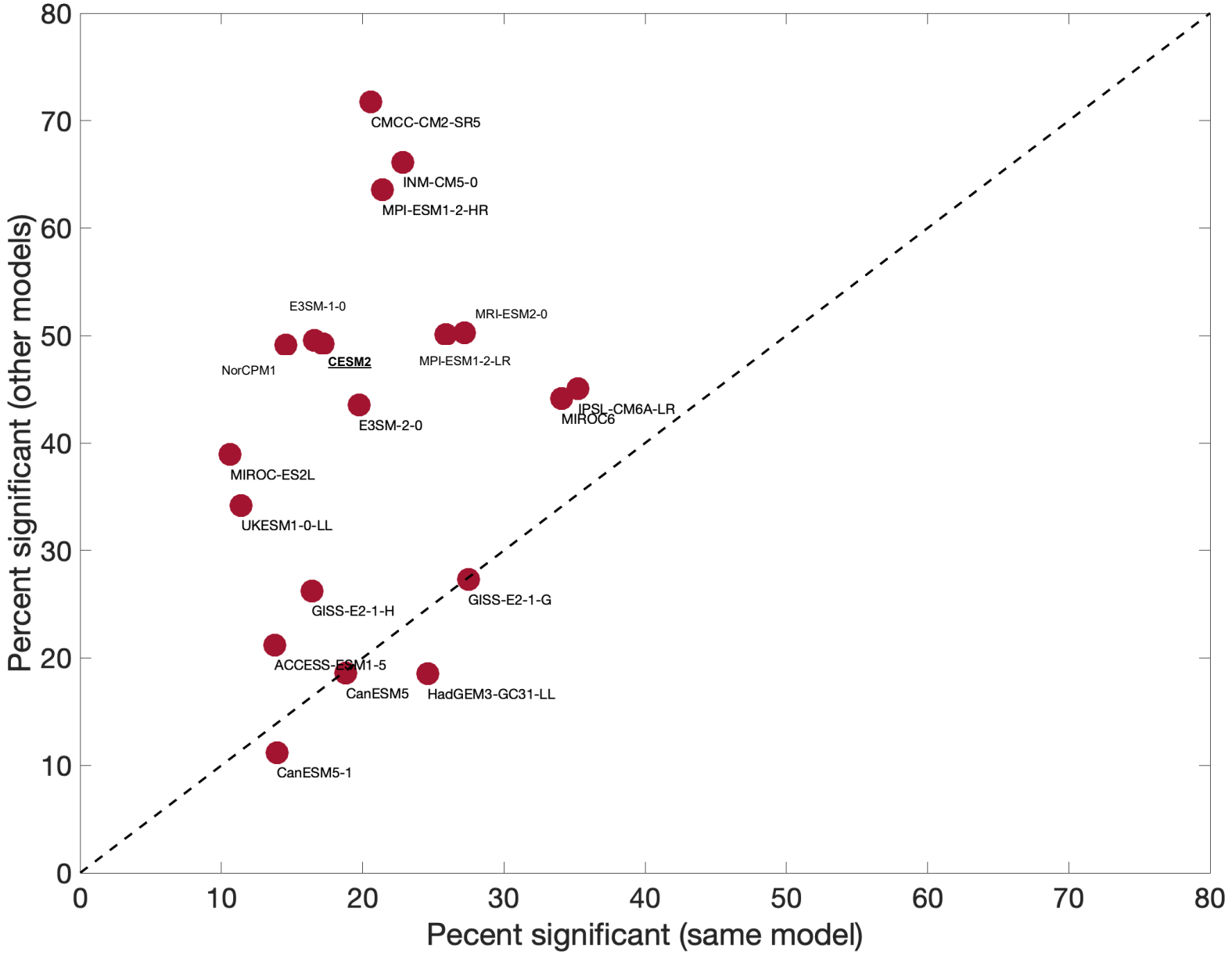
Significance compared to the **same model**



Significance compared to the **other models**



Differences in the significance tests



Conclusions

- Droughts were identified in climate models using only the precipitation data of each grid point and the neighboring grid points
- Droughts in climate models are associated with a wide range of ocean-atmosphere conditions
- Most model simulations show an increased structural uncertainty compared to intrinsic climate variability, suggesting there is the possibility of reducing uncertainty and increasing predictability of drought events in the future

References

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Current Work

Previous Work:	Current Work:
17 Climate Models	19 Climate Models
67 Individual Simulations	570 Individual Simulations
10,653 Simulation Years	85,500 Simulation Years