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The future of the El Niño-Southern Oscillation: Using large ensembles to illuminate time-varying responses and inter-model differences

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Robert Jnglin Wills, Pedro DiNezio, Jeremy Klavans, Sebastian Milinski, Sara Sanchez, Samantha Stevenson, Malte Stuecker, Xian Wu



ENSO projections - CMIP3 → CMIP6

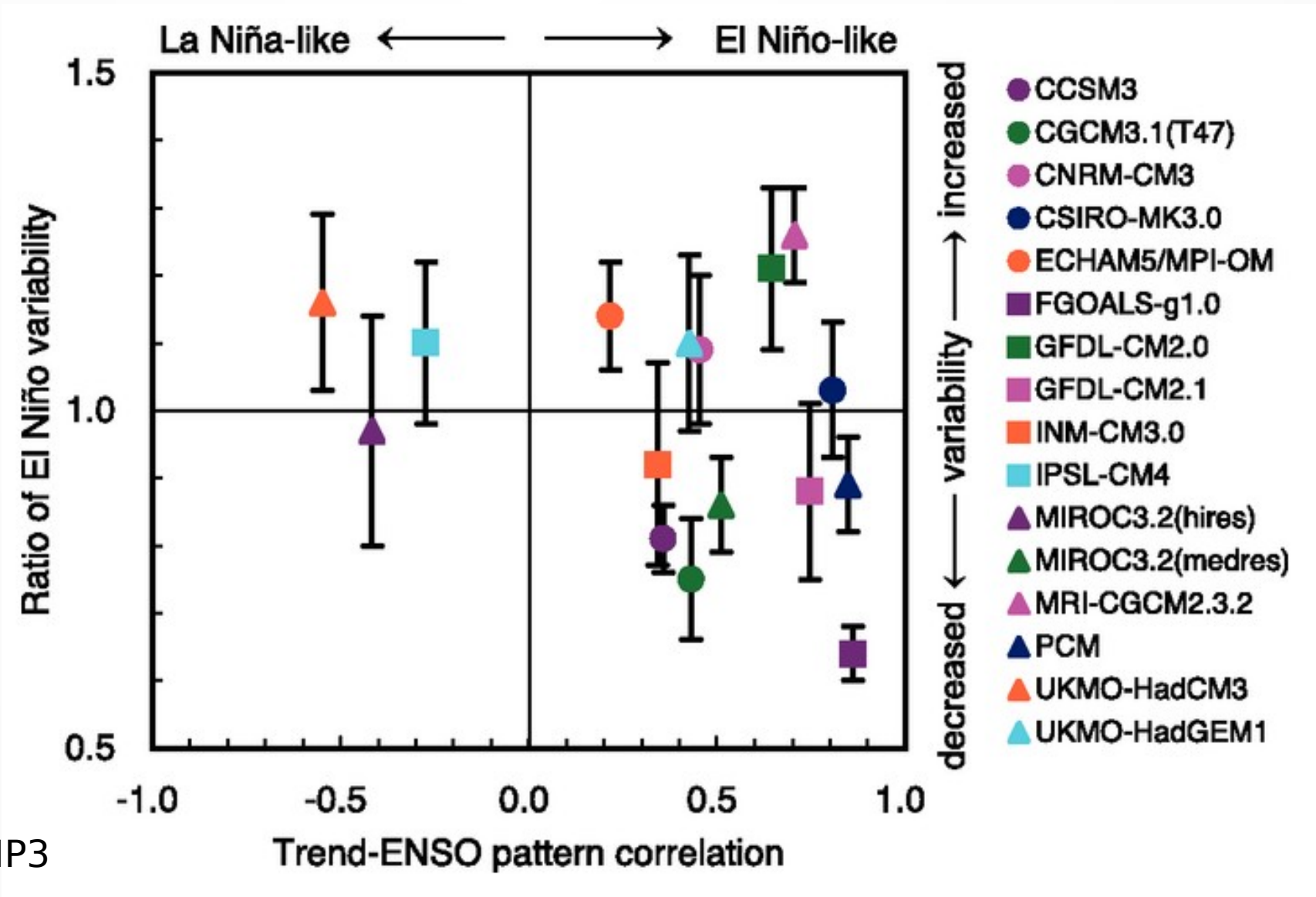


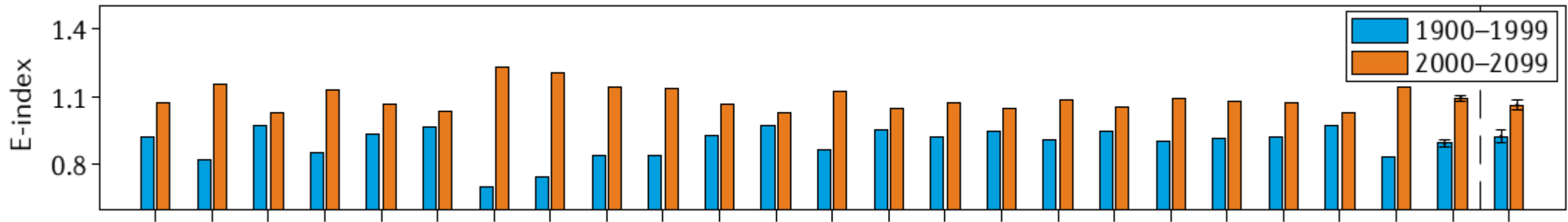
Figure 10.16 AR4 CMIP3



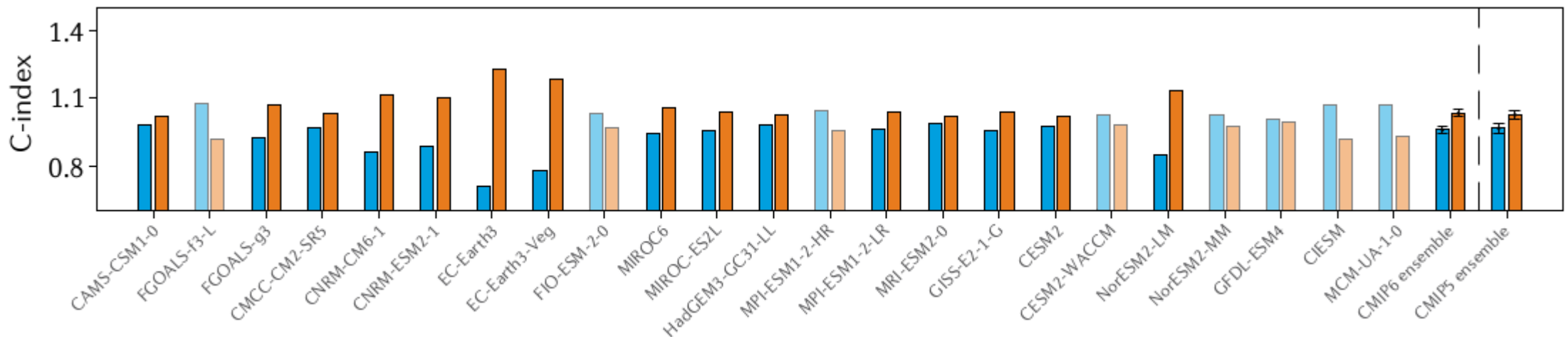
ENSO projections – CMIP3 → CMIP6



a Projected change in E-index variability

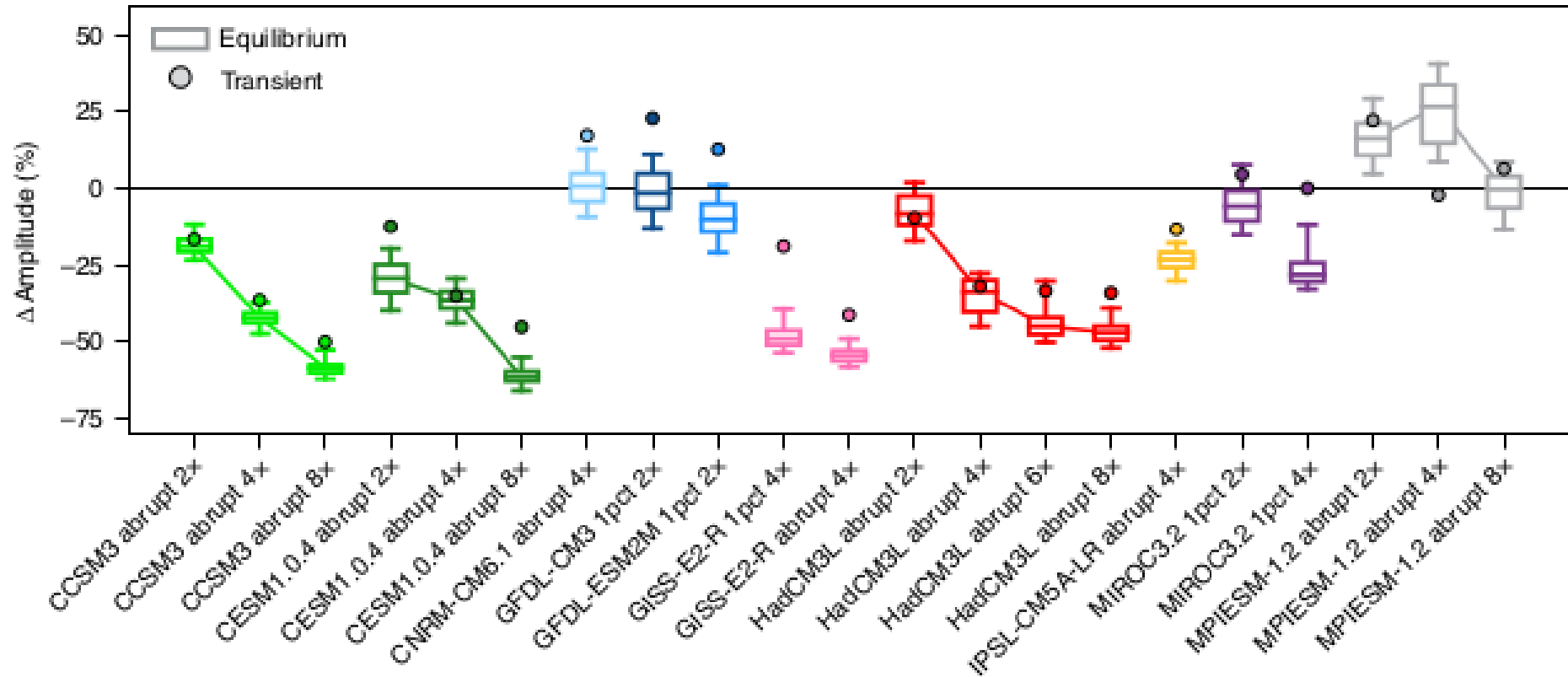


b Projected change in C-index variability





ENSO projections - LongRunMIP

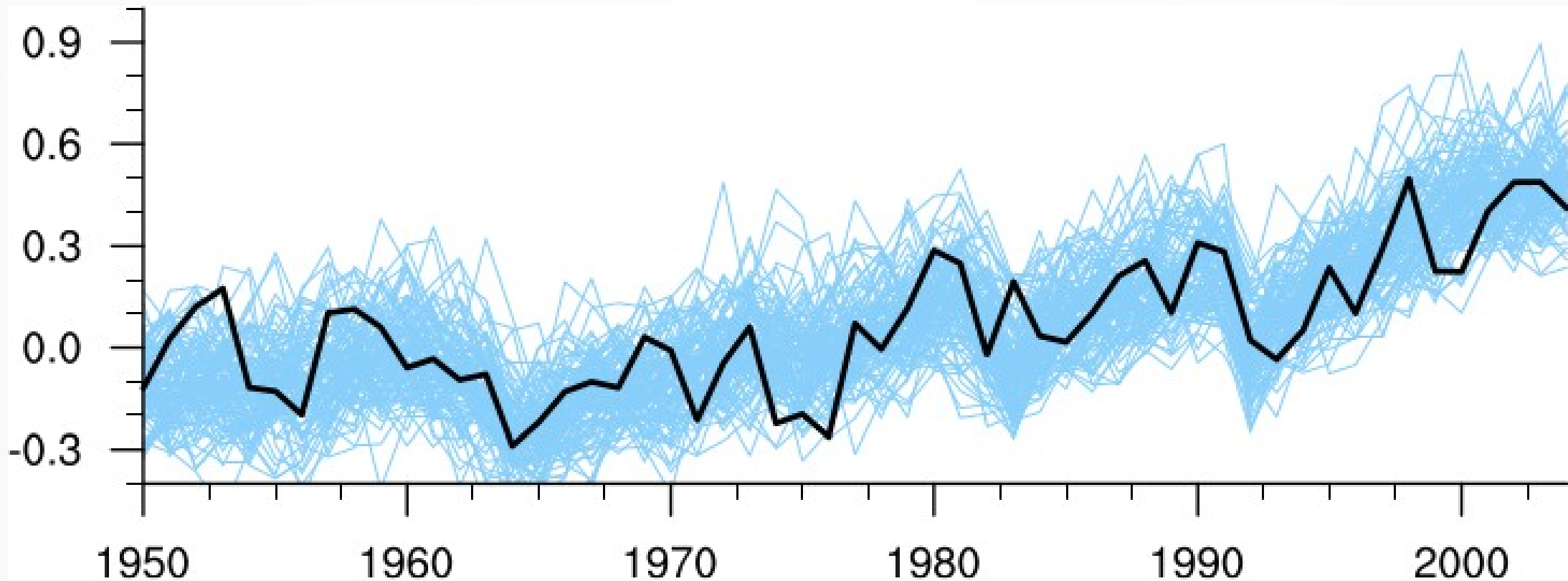




What is a SMILE?



SMILE = **S**ingle **M**odel **I**nitial-**C**ondition **L**arge **E**nsemble

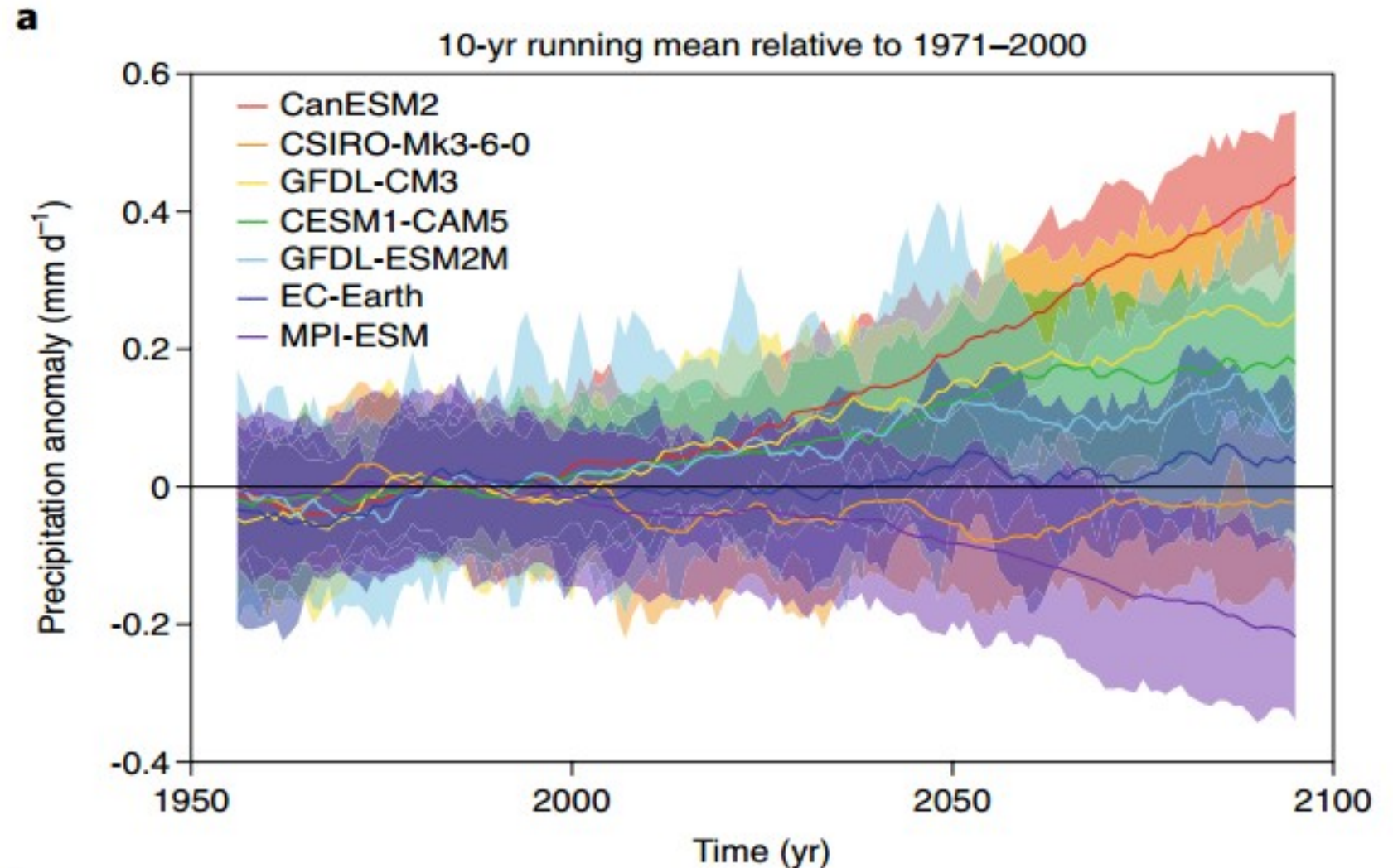




What is a SMILE?

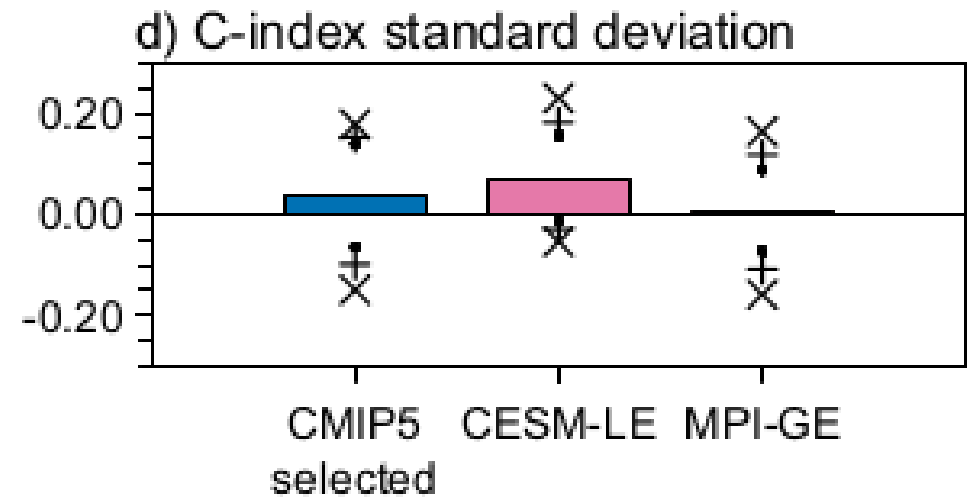
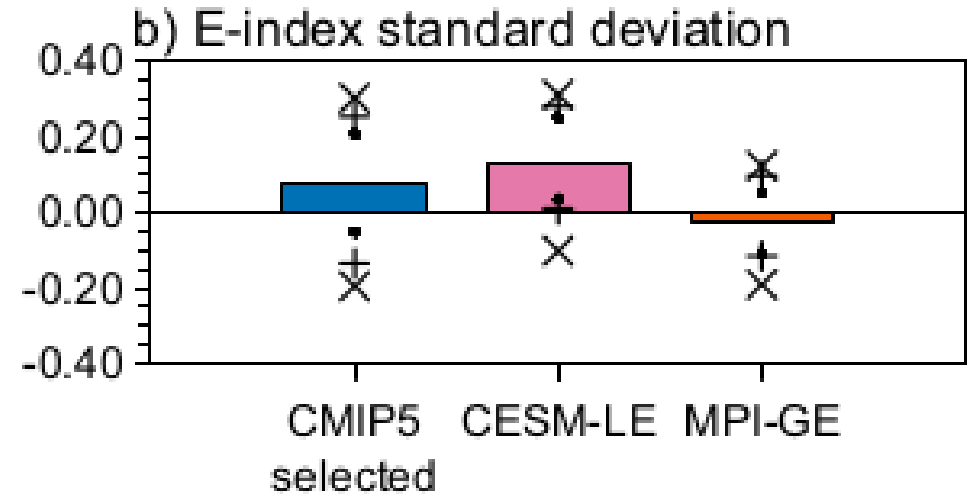
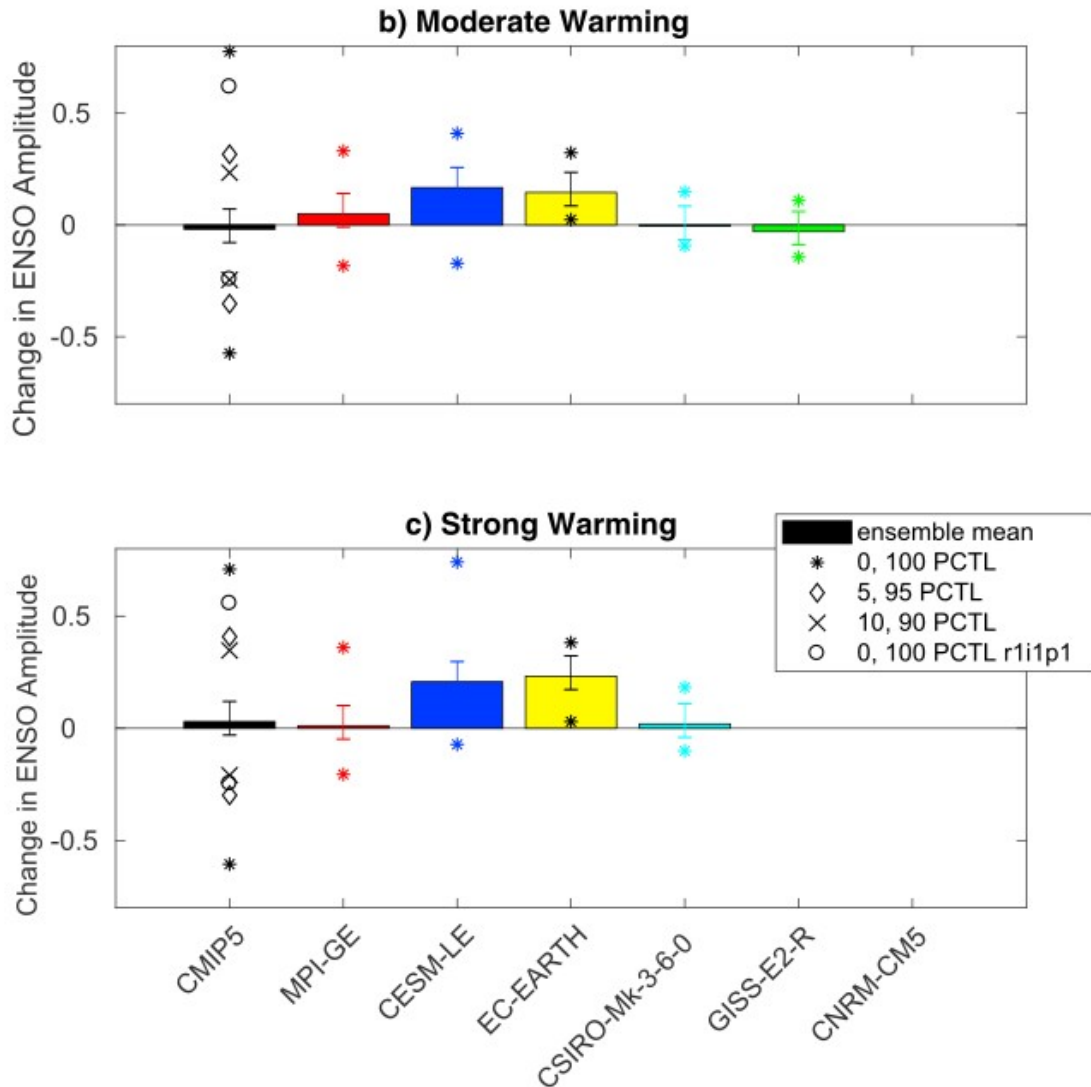


- Key value of SMILEs comes from precisely quantifying forced response and internal variability
- We can compare the internal variability and forced response between SMILEs





ENSO projections – SMILEs vs CMIP





Research Question



Assess the temporal evolution of ENSO SST variability in individual SMILEs

- Previous studies are limited by use of single ensemble members:
- Cannot look at time dependence of ENSO changes
- Difficult to separate forced response from internal variability
- Use 14 SMILEs with CMIP5/6 forcing



ENSO indices in many SMILEs



Nino DJF stddev.
temporal statistics over 30 years and averaged over the ensemble

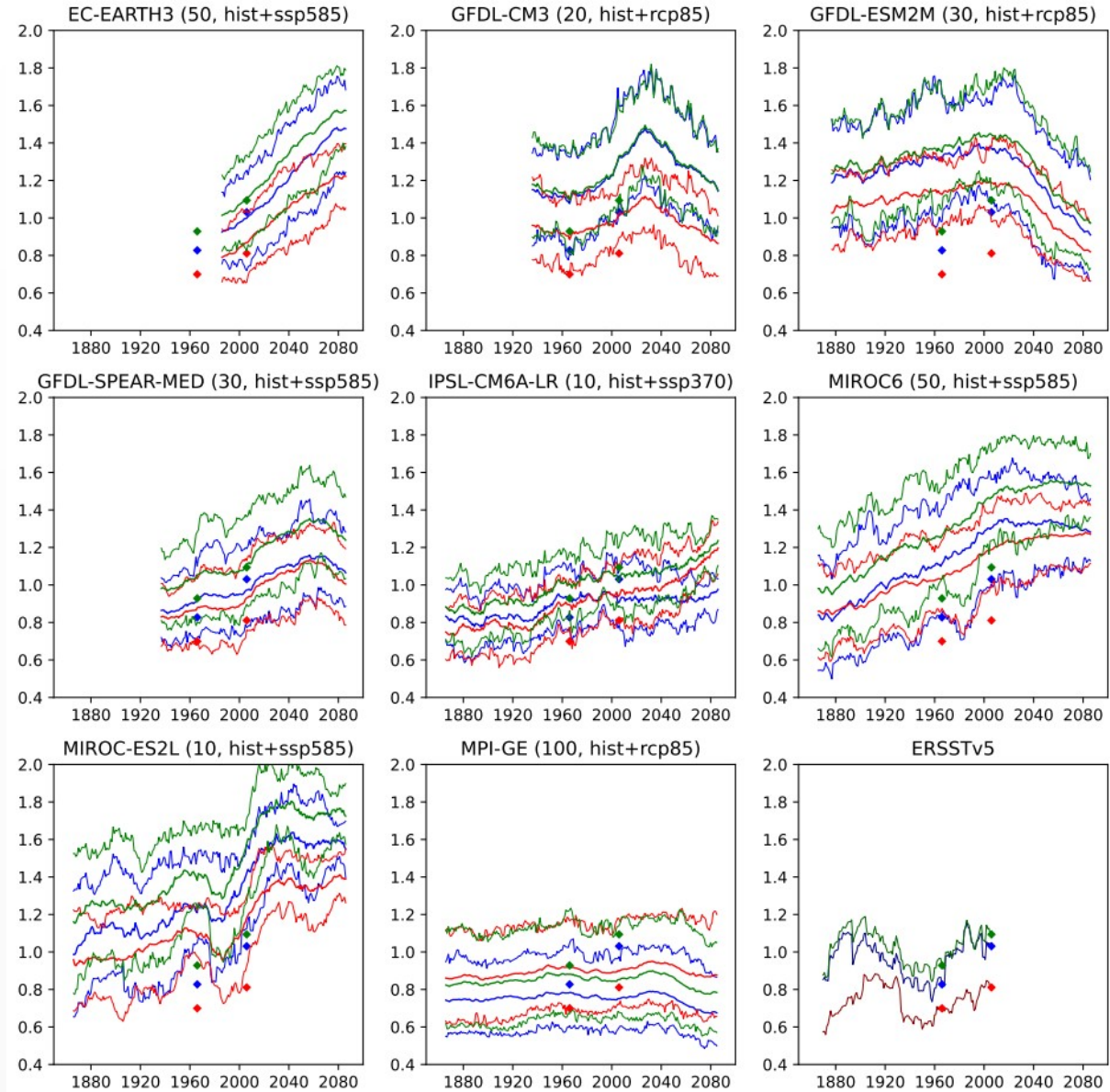
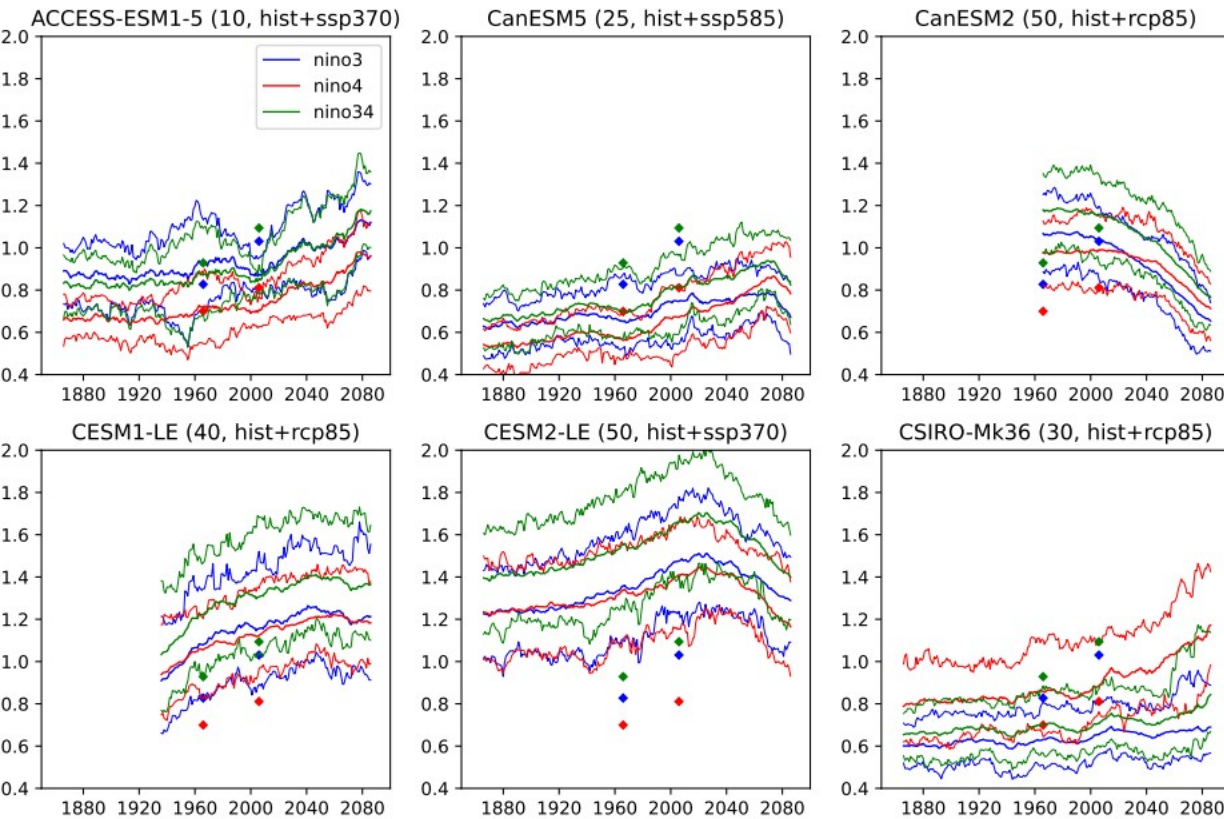


Image credit: Sebastian Milinski & Malte Stuecker



Pattern changes in the tropical Pacific (2-7yr frequencies)



2021-2050 compared to 1951-1980

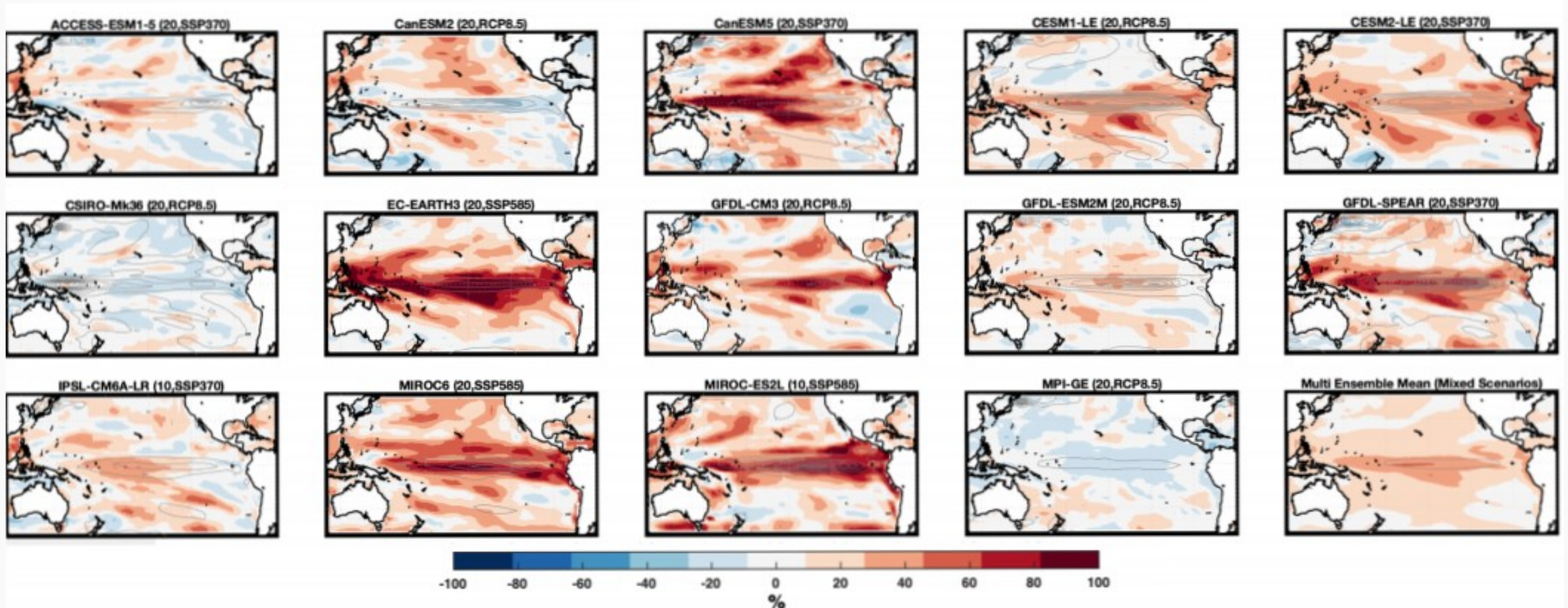


Image credit: Sara Sanchez



Pattern changes in the tropical Pacific (2-7yr frequencies)



2070-2099 compared to 1951-1980

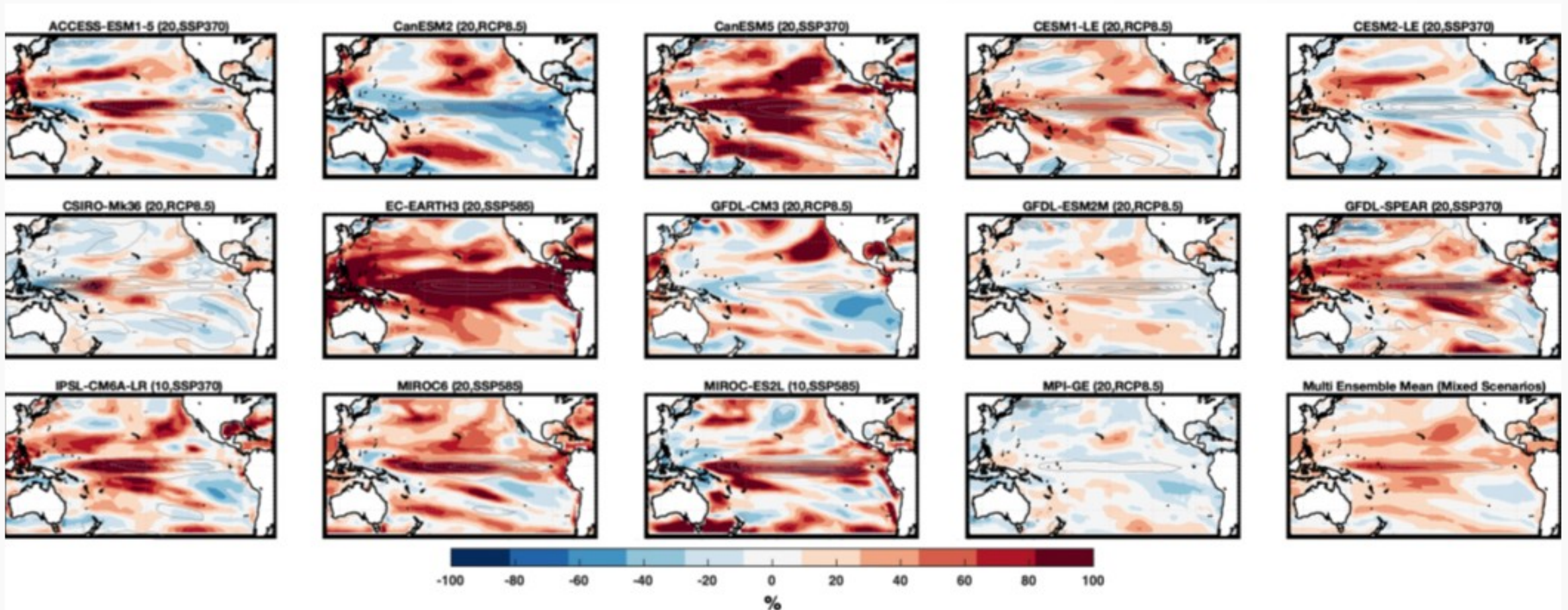


Image credit: Sara Sanchez



Future changes in El Niño SST anomalies



2070-2099 compared to 1951-1980

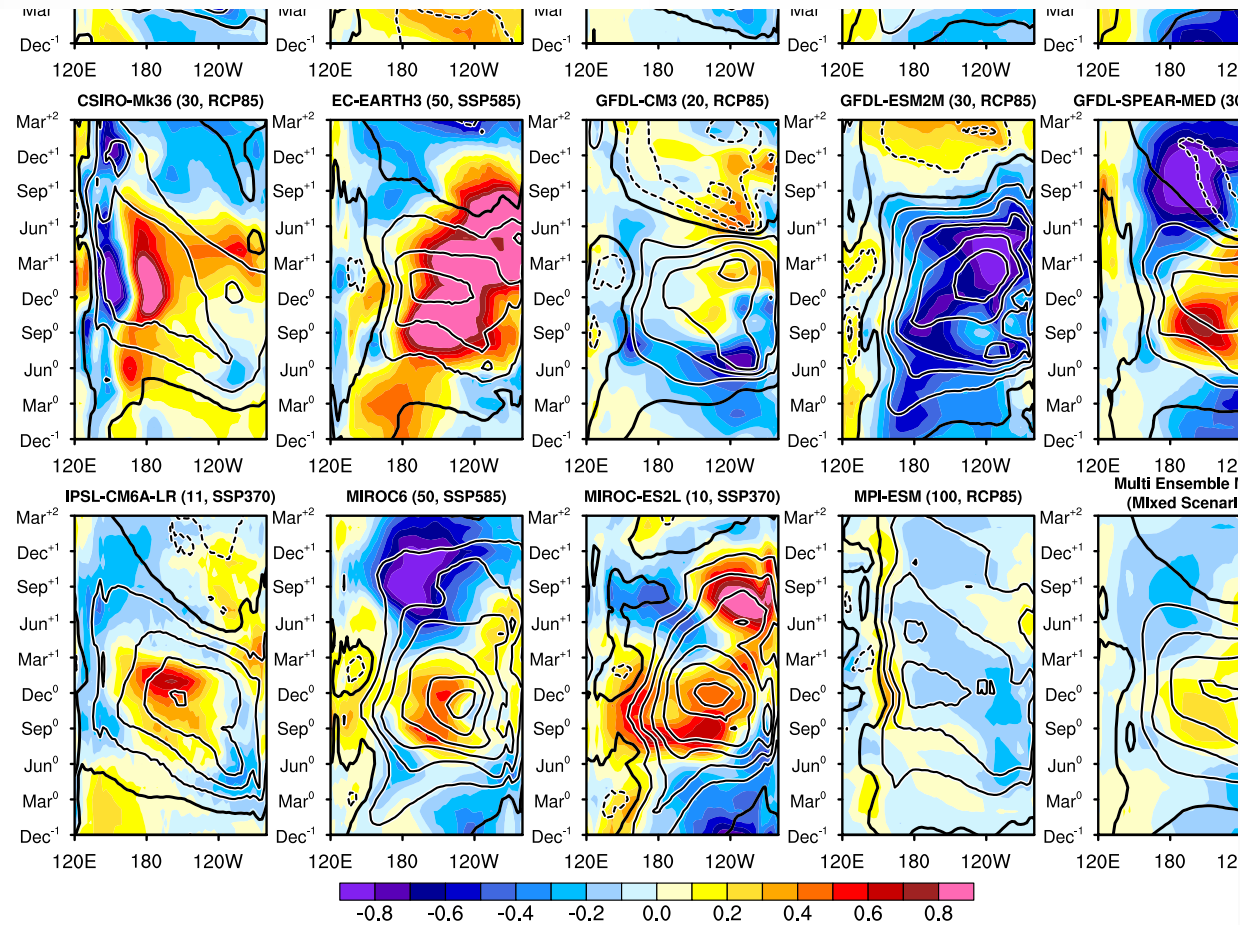


Image credit: Xian Wu



Seasonal synchronization



2071-2100 compared to
1951-1980

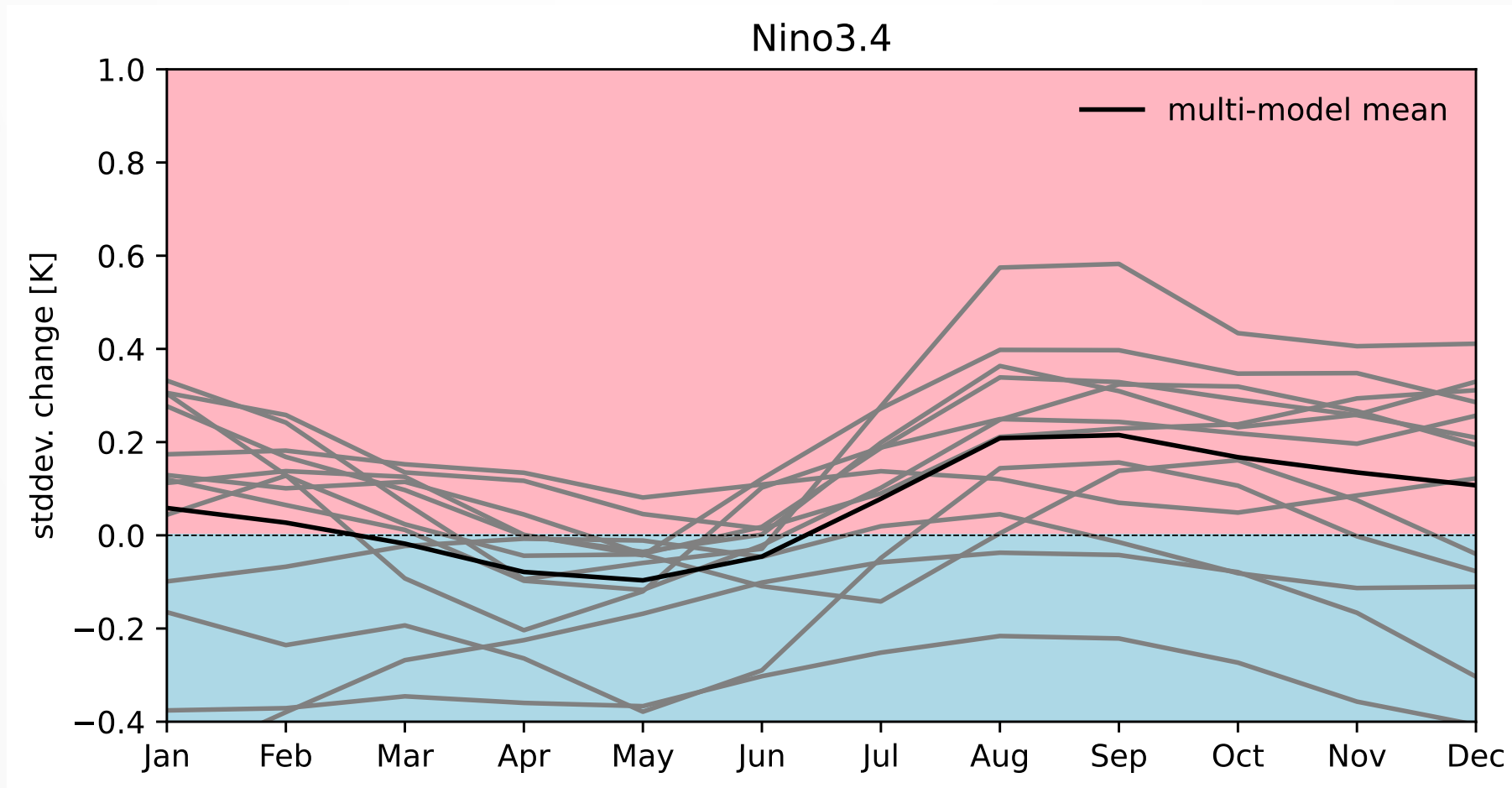


Image credit: Sebastian
Milinski & Malte Stuecker



Seasonal Changes in the E-W gradient

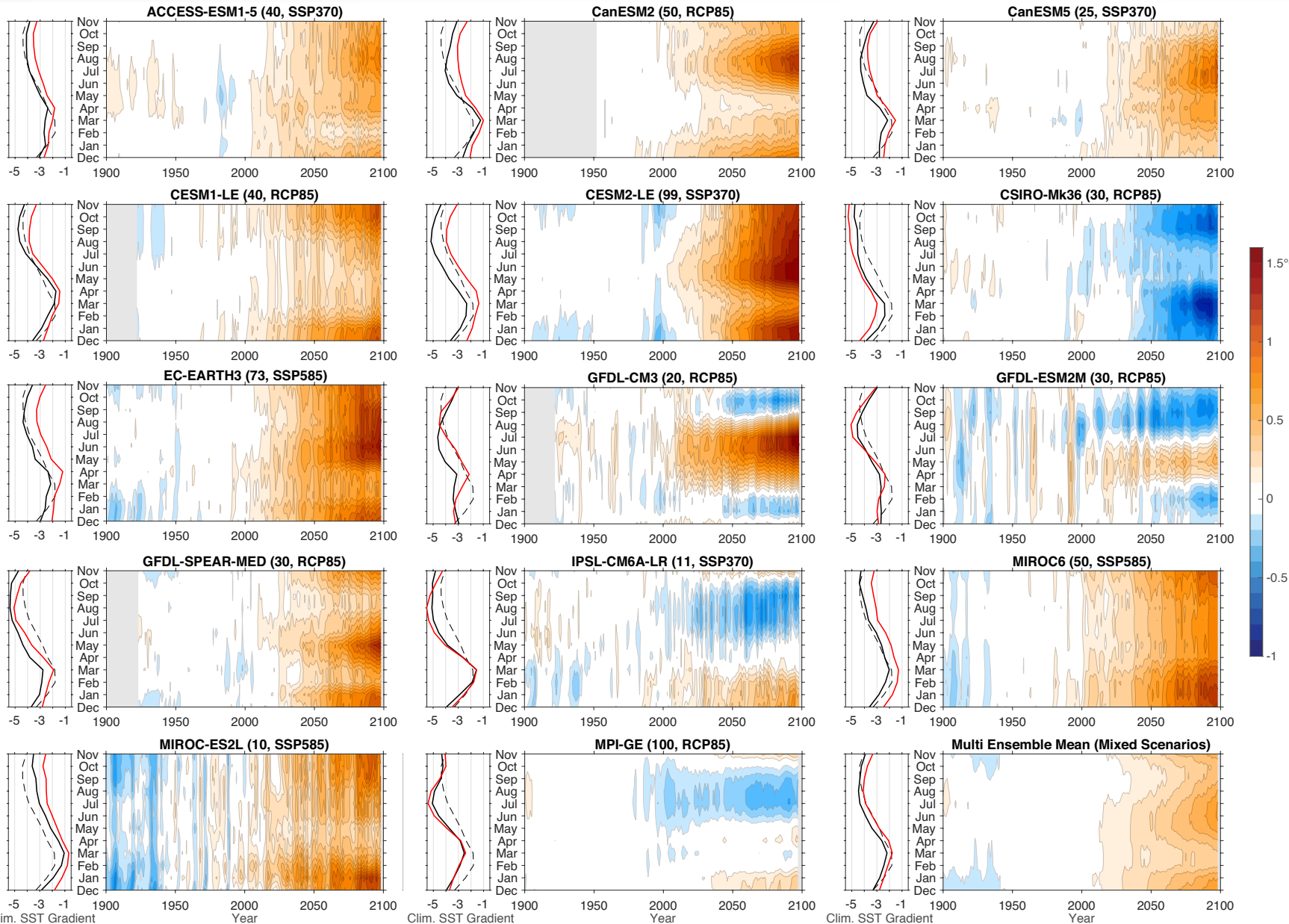
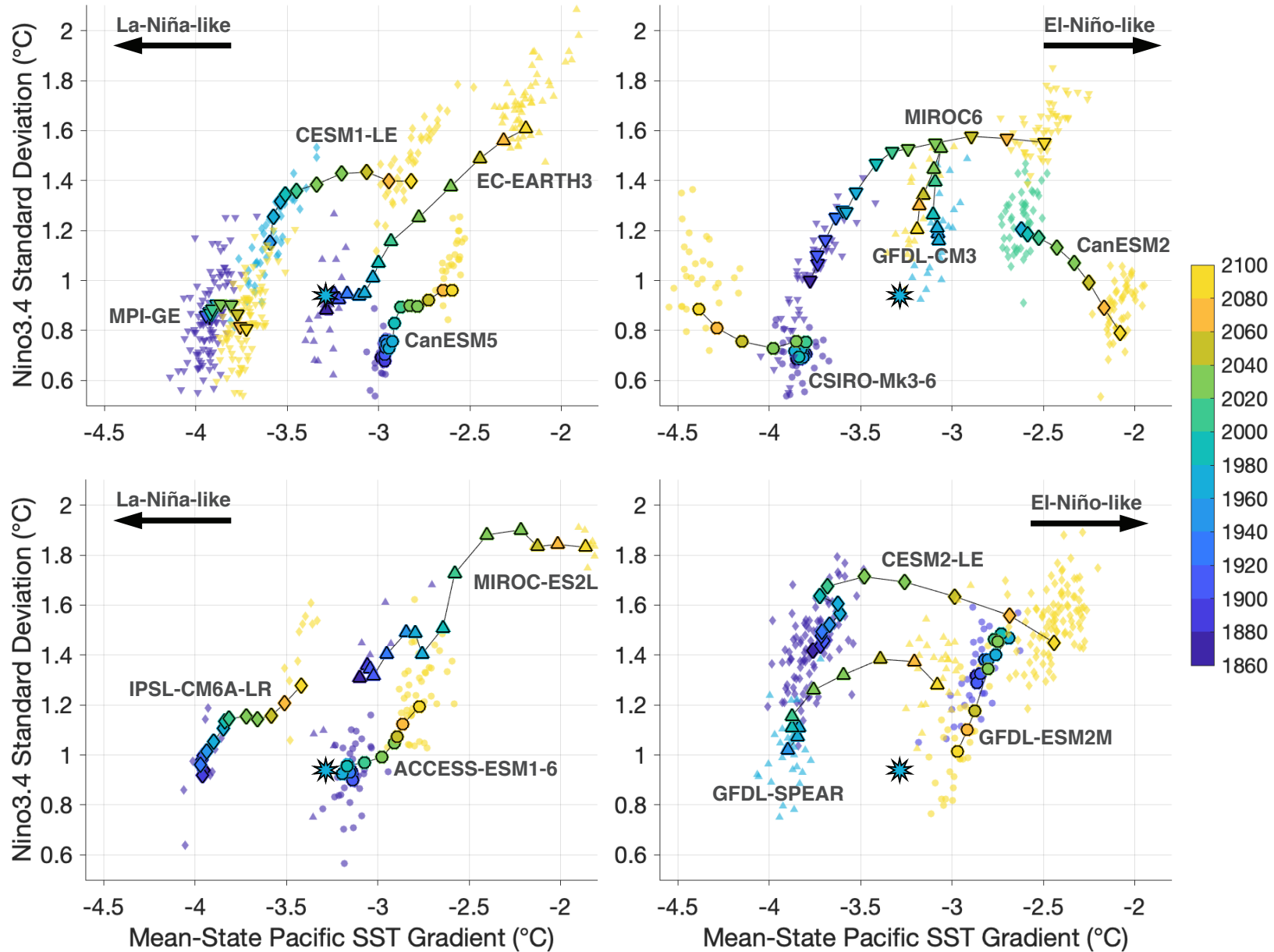
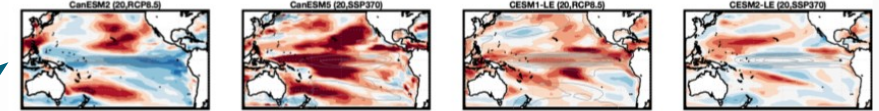
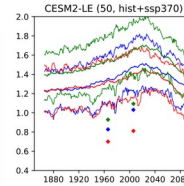


Image credit:
Robert Jnglin Wills 14



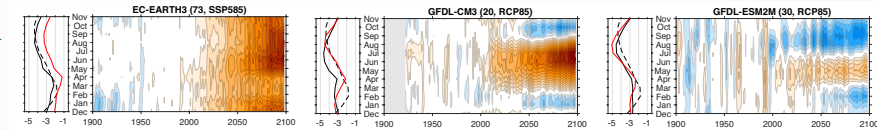
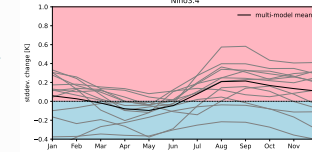
1 Projections of ENSO variability are

- Time dependent
- Pattern/evolution different between different models
- The seasonality increases - consistent across models



2 Mean state tropical Pacific shows a El Niño-like warming in most models

- When (season) this occurs differs between models
- There are models that have the opposite response and/or seasonal response



3 Many models show:

- Increase in ENSO variability concurrent with a small decrease in mean-state gradient
- Then a larger decrease in mean-state gradient, with no more change in ENSO
- Then decrease in ENSO variability → consistent with Cai et al, 2021 & Callahan et al, 2021

