Modes of Variability in the E3SM and CESM Large Ensembles

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The results a few highlights from a paper to be submitted to J. Climate. Full author list:

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Motivation:

- Modes of variability (MOVs) play a critical role in seasonal prediction and climate projection
- Historically many MOVs have been poorly simulated by coupled climate models
- We use recently produced large ensembles (LEs) with successive versions of both E3SM and CESM to assess the simulated MOV
- LEs:
  - E3SM1: 20 members, 1850-2100
  - E3SM2: 21 members, 1850-2100
  - CESM1: 40 members, 1920-2100
  - CESM2: 50 members, 1850-2100

- For this study, we use the period 1920-2020 (E3SM1 1920-2014)

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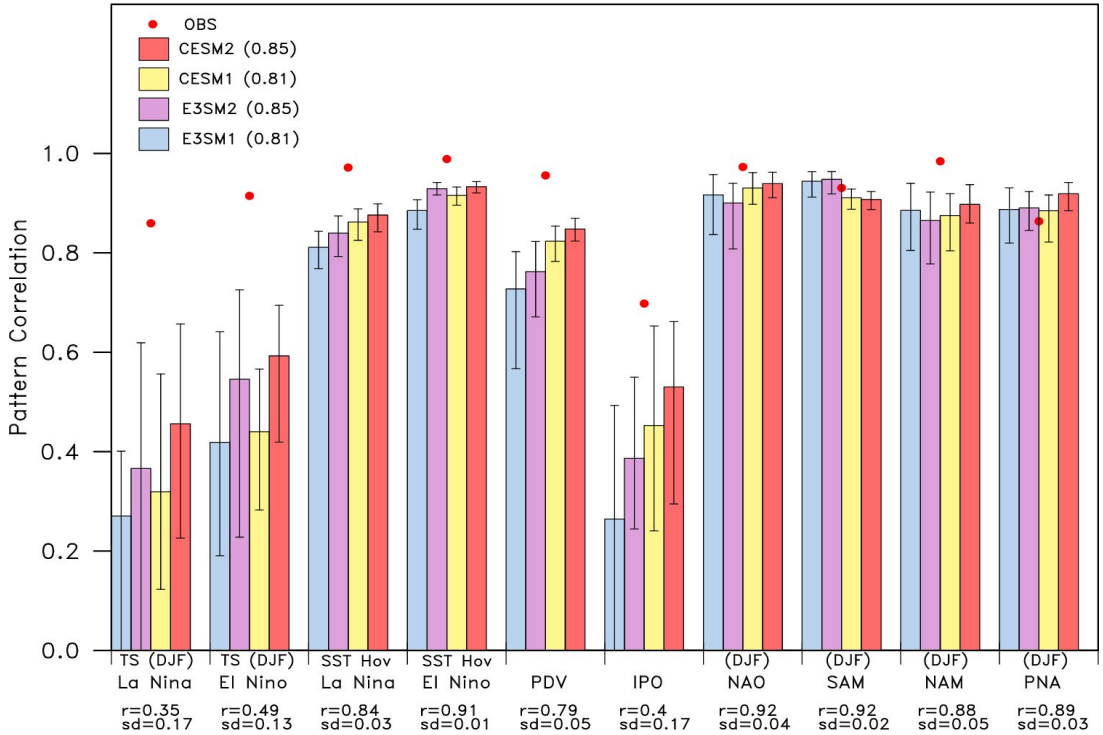
Are Observations a Useful Constraint on Simulated Modes of Variability?



- Overall the models do well representing extratropical modes which show correlations of 0.9 or above, and model uncertainty encompassing obs in many cases
- For global modes, PDO better represented than IPO which has large uncertainty and small correlation
- ENSO temperature composite patterns also have small correlations and large uncertainty
- However the ENSO hovmollers exhibit high correlations and certainty
- So it's important to note that some modes are not well-constrained because they have too much intrinsic noise between members

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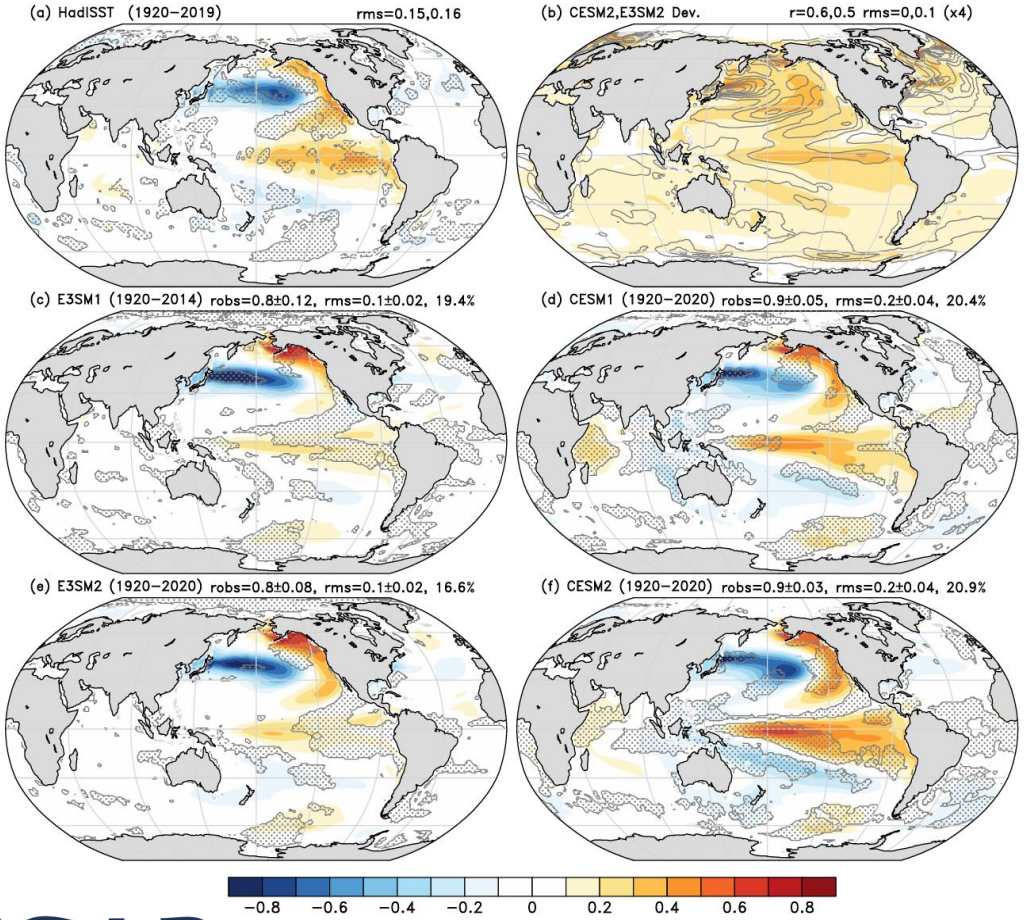

Pacific Decadal Oscillation (PDO)

- E3SM is notably deficient in the tropical signature of the PDO
- While in the N. Pacific, E3SM is too strong
- CESM simulates the PDO with more fidelity but is too strong in regions like the Western N. Pac.
- And extends too far into the tropical W. Pac.

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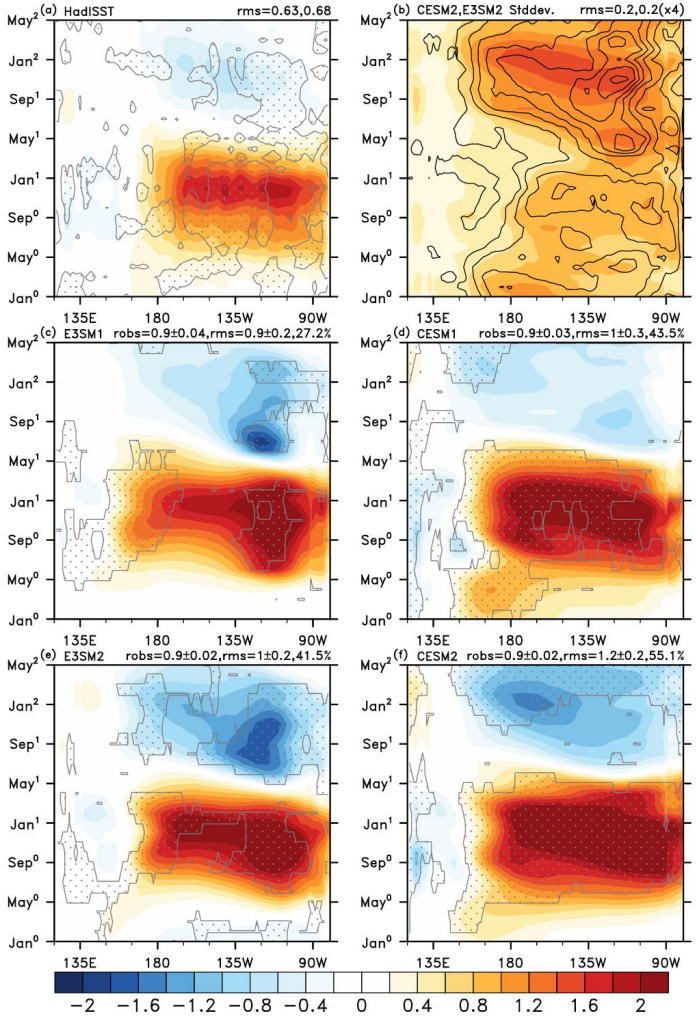
Zonal Structure

El Nino Hovmollers:

- The models overestimate the warm anomalies, and have rapid growth of and longer-lived warming than observed (esp near 115W in E3SM)
- The subsequent La Nina anomalies are too strong, and the models' El Nino too biennial
- There also appears to be a westward propagation in CESM SST anomalies
- Warm anomalies extend too far west



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Conclusions:

- The ENSO TS composites and IPO have low pattern correlations and more intrinsic noise between members, so they are not well represented by the models
- The extratropical modes are well represented in the large ensembles, as are the PDO and the ENSO hovmollers
- However, the PDO pattern shows clear areas of model bias, including E3SM's very weak tropical signal, tropical pattern extending too far west in all models, and overestimation of pattern in N. Pacific
- Model bias is also seen in the zonal structure for El Nino, including rapid warm anomaly growth, warming which is too strong, lasts too long, warm anomalies extending too far west in the tropical Pacific, and apparent westward propagation of warming in CESM.

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