Assessing the El Niño Southern Oscillation in development versions of the Community Earth System Model (CESM)

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Atmospheric Model Working Group

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El Niño Southern Oscillation (ENSO)

- Dominant source of interannual variability in the climate system *(McPhaden et al.* 2006; *Yeh et al.* 2018)
- Warm (El Niño) and cool (La Niña) sea surface temperature (SST) anomalies drive important teleconnections (e.g., *Ropelewski & Halpert* 1986*; Hoerling & Kumar.* 2002*)*
- Variability may not be stationary in time *(Diaz et al.* 2001; *Meehl et al.* 2006; *Li et al.* 2013; *Yeh et al.* 2018)

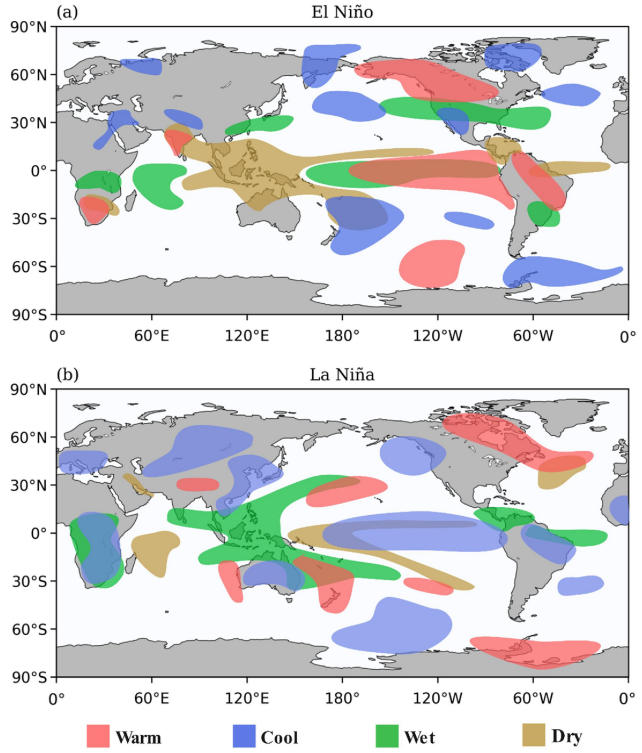

Fig. 8 of Alizadeh 2023

Earth System Models continue to show some persistent biases in their representation of ENSO

- ENSO amplitude continues to be either too strong or too weak in most models (Capotondi et al. 2015)
- ENSO diversity is limited; SST anomalies extend too far west (Capotondi et al. 2015)
- Complicated by relatively short observational record (Trenberth 1997; Wittenberg 2009; Capotondi et al. 2015)

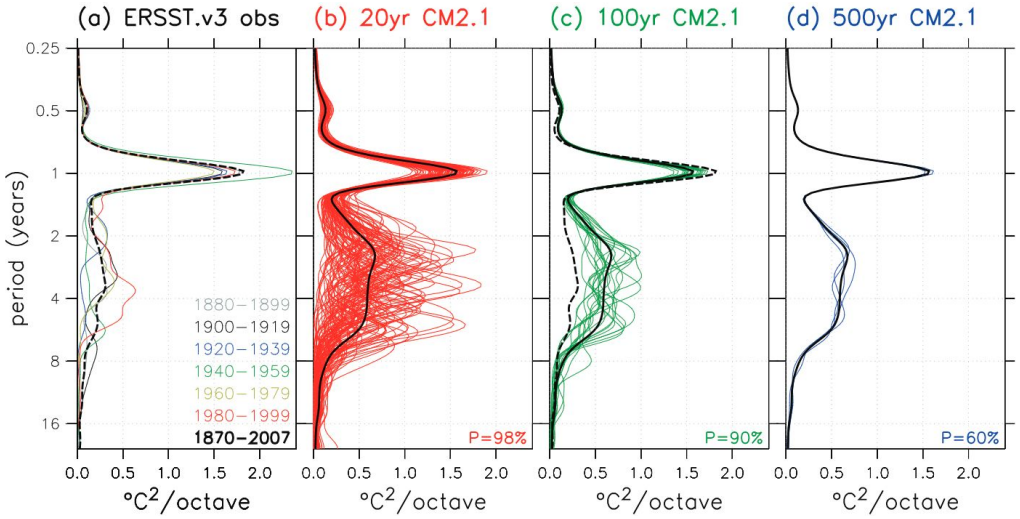

Fig 2. of Wittenberg 2009*: Nino 3 power spectra computed over various periods in observations and a long-running simulation of CM2.1.*

CESM2 had a number of ENSO biases as well;
A new parameterization was added to mitigate some

A convective gustiness parameterization aims to reduce ENSO biases

Gust fronts from deep convection enhance turbulence & surface fluxes

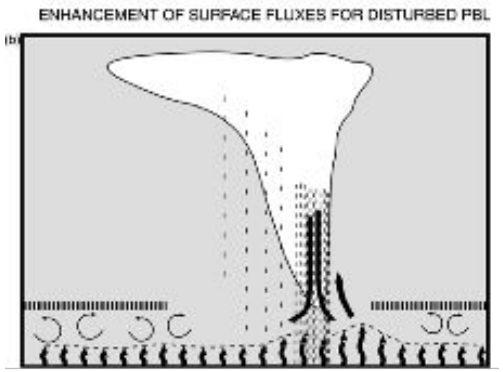

Fig. 1 of Redelsperger et al. (2000)

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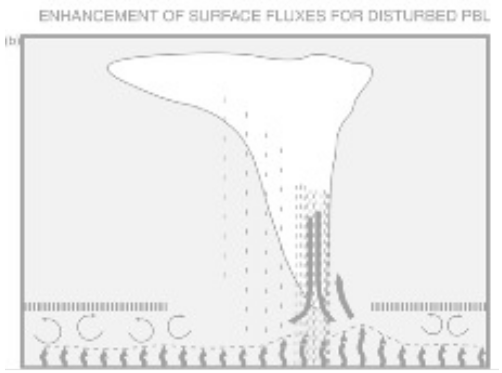

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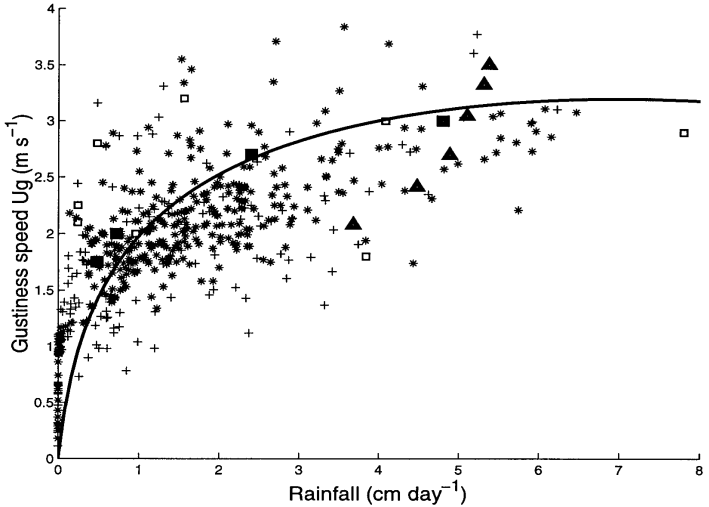
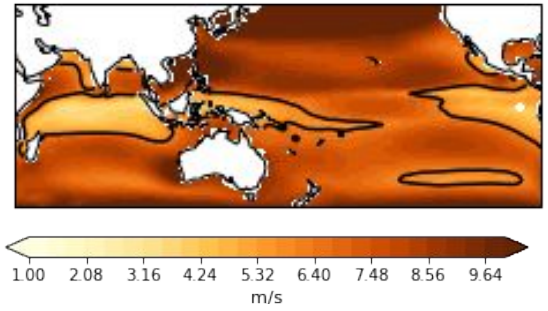


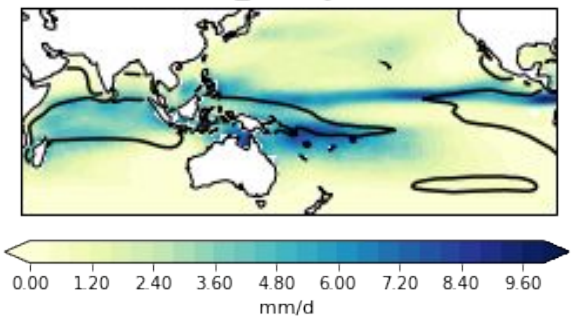
Figure 10 of Redelsperger et al. (2000): Observations (open square), and a series of CRM simulations from current study (,+, ^), and Jabouille et al. (solid squares).*

A convective gustiness parameterization aims to reduce ENSO biases

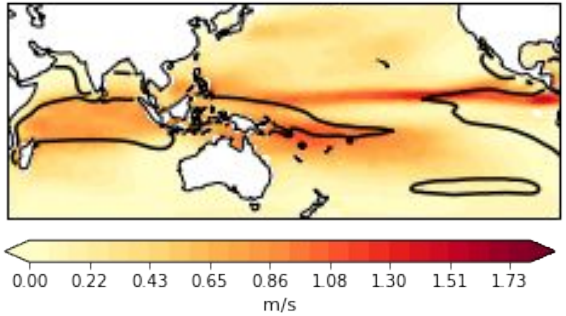
DJF 10m Wind (CTRL)



DJF Convective Rain Rate (CTRL)



DJF Gust Speed (GUST)



Initial tests of convective gustiness parameterization in development
CESM; 1996-2014 AMIP simulations

But more broadly…
How has the representation of ENSO evolved?

Leveraging a variety of development simulations

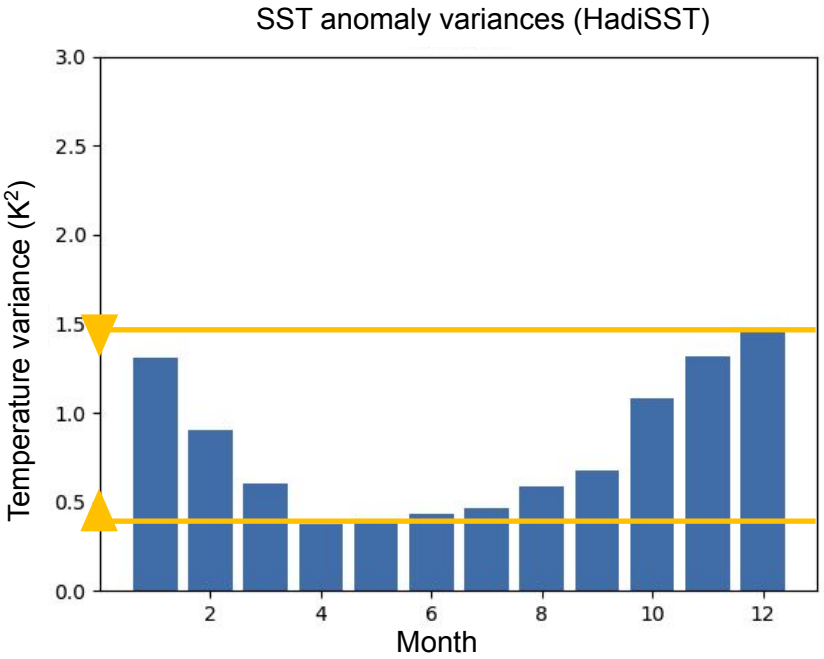
- Fully coupled model simulations (atm+land+ocean) with pre-industrial climate
  - Minimum of 40 years used for analysis
- Validated against HadiSST and ERA5
  - Context added from CESM1 and CESM2 pre-industrial ensembles (40 year periods)
- Some key new developments:
  - New hybrid vertical ocean coordinates
  - New radiation scheme
  - New “convective gustiness” parameterization (based on *Redelsperger et al.* 2000 and *Jabouille et al.* 1996)

How has the representation of ENSO evolved during development of CESM3?

Are there characteristics of ENSO that have improved?

Strength of ENSO events

Monthly SST anomaly variances



Observed SST anomalies in each month within the Nino3.4 region

Strength of ENSO events

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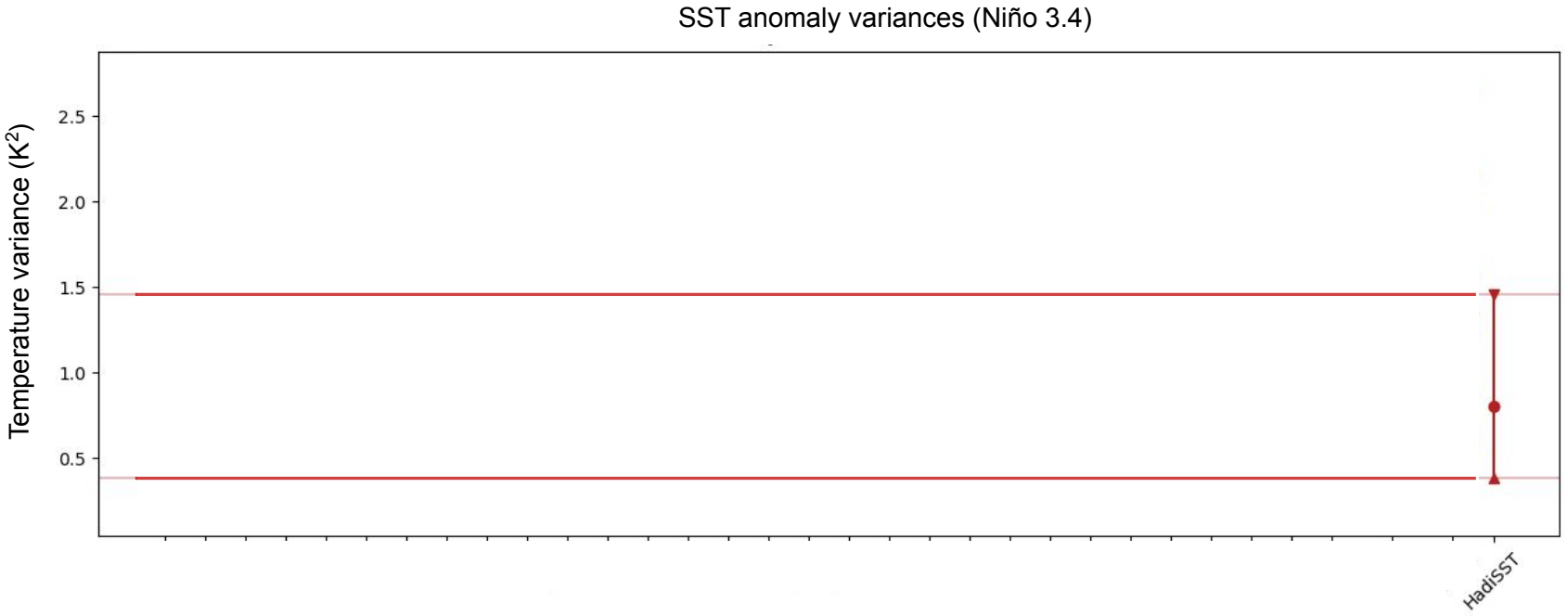

Maximum (^), Minimum (v), and mean (o) of monthly SSTa variances

Strength of ENSO events

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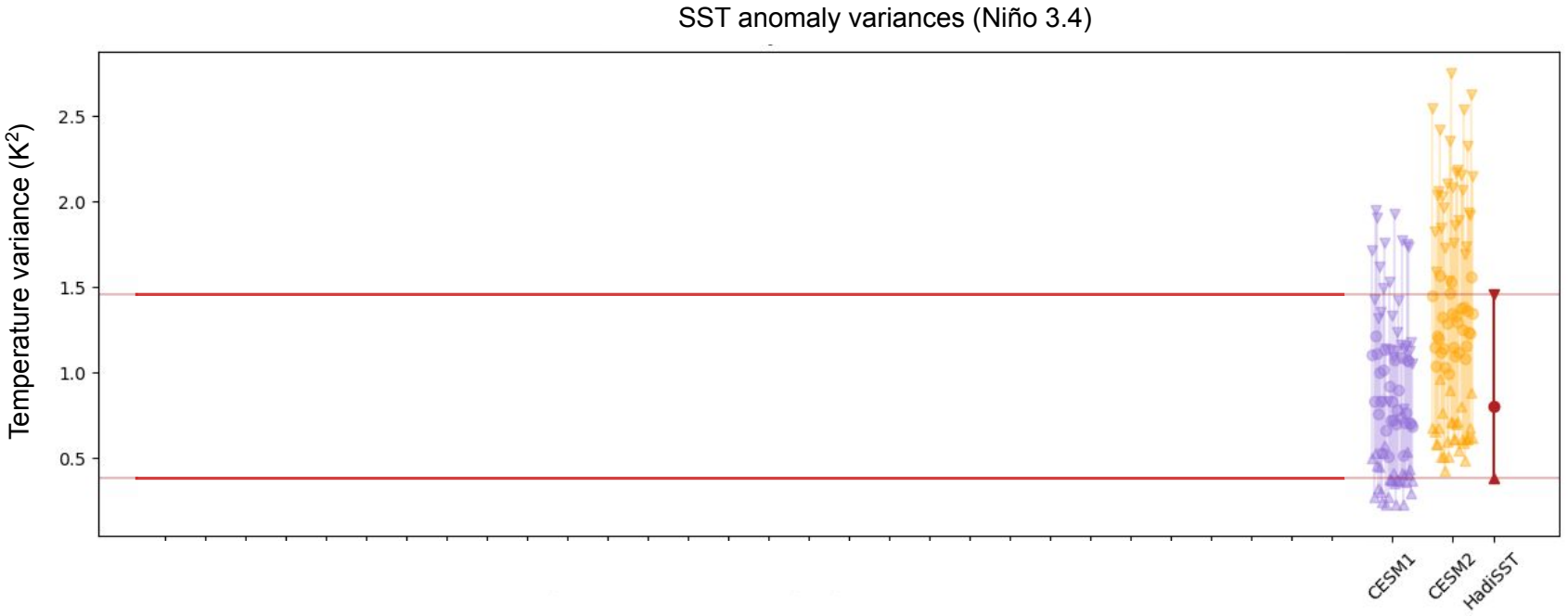

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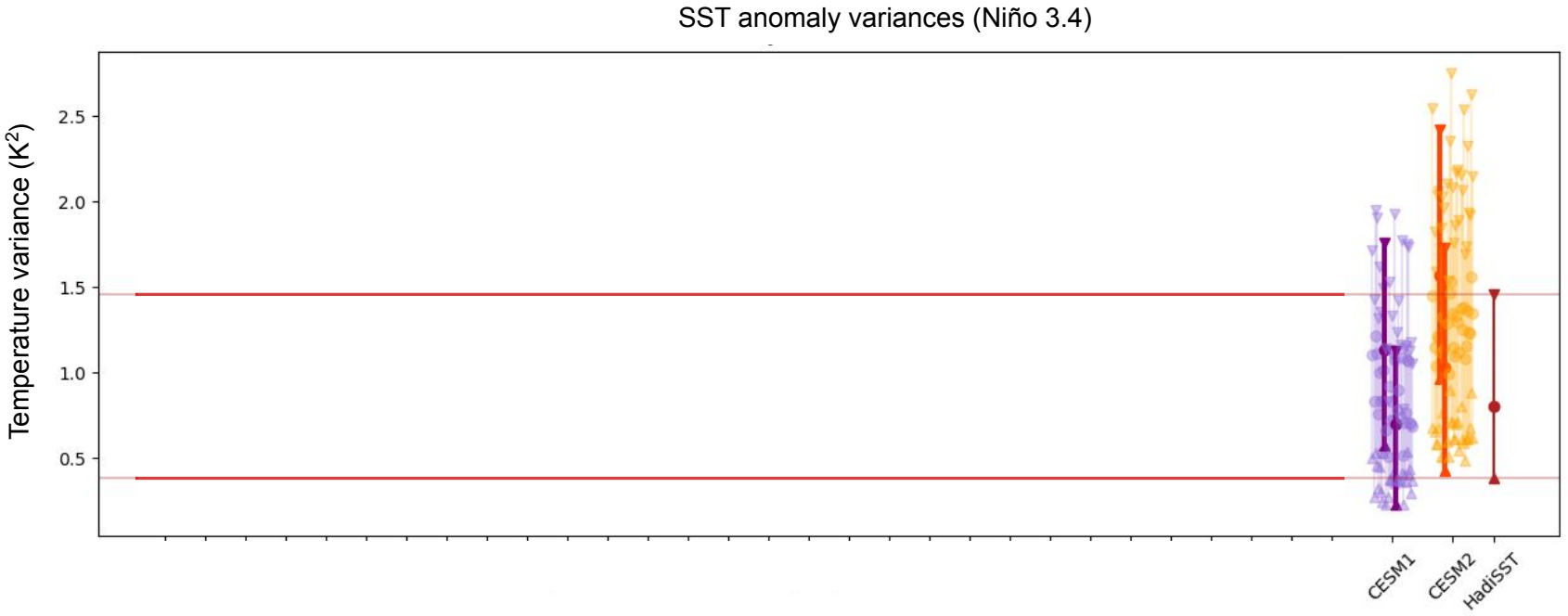

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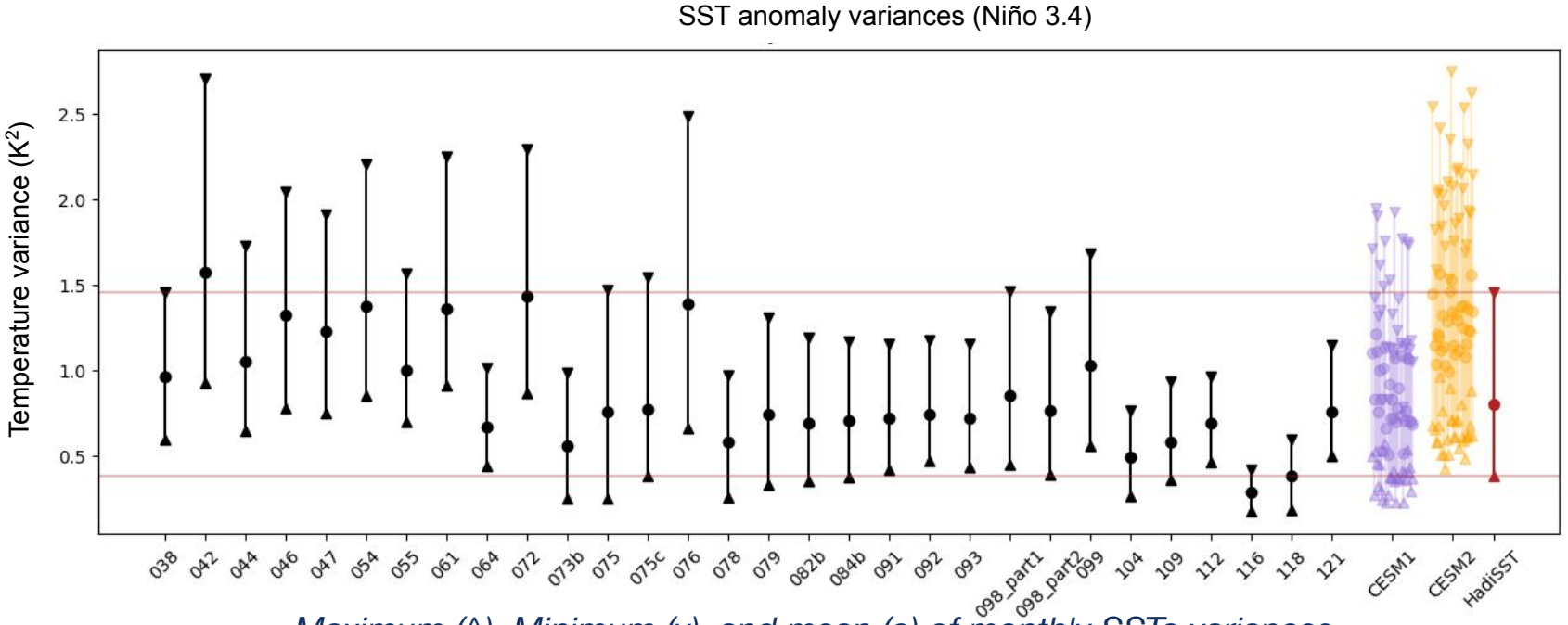

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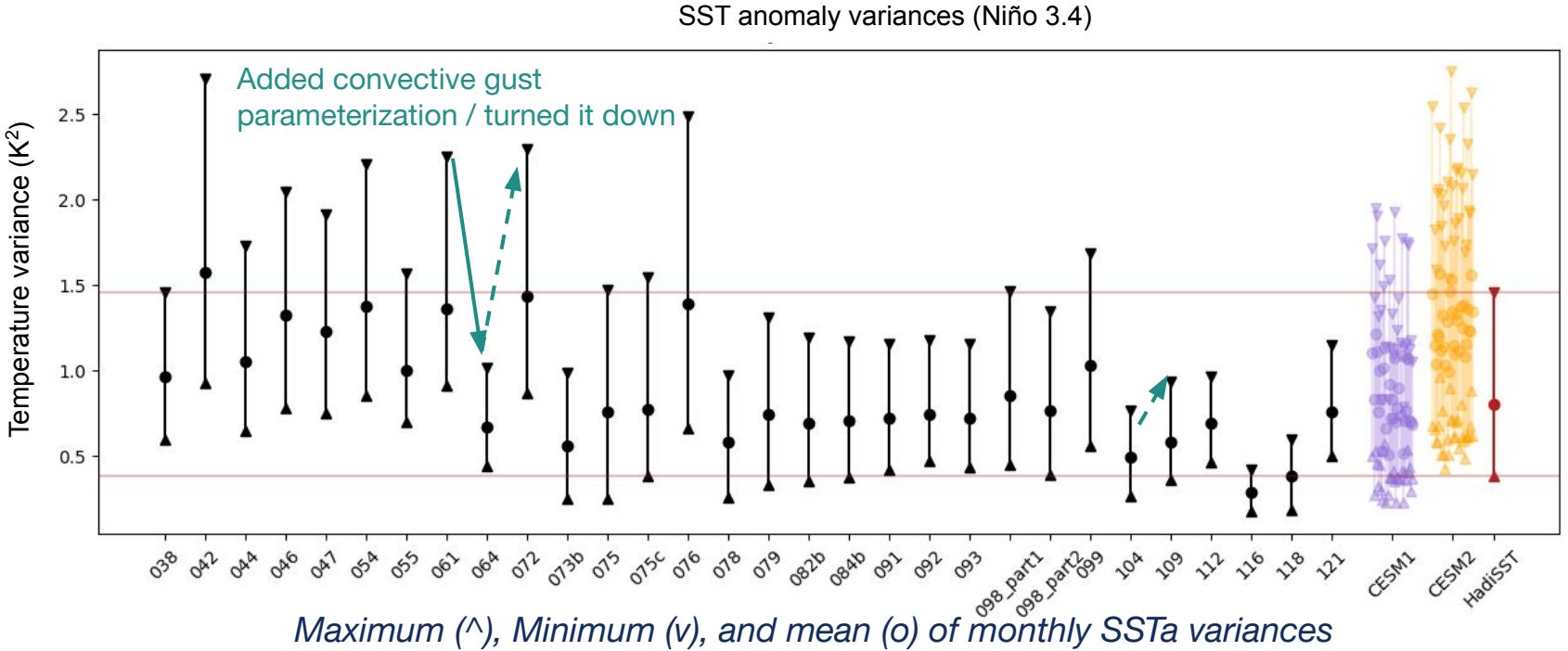

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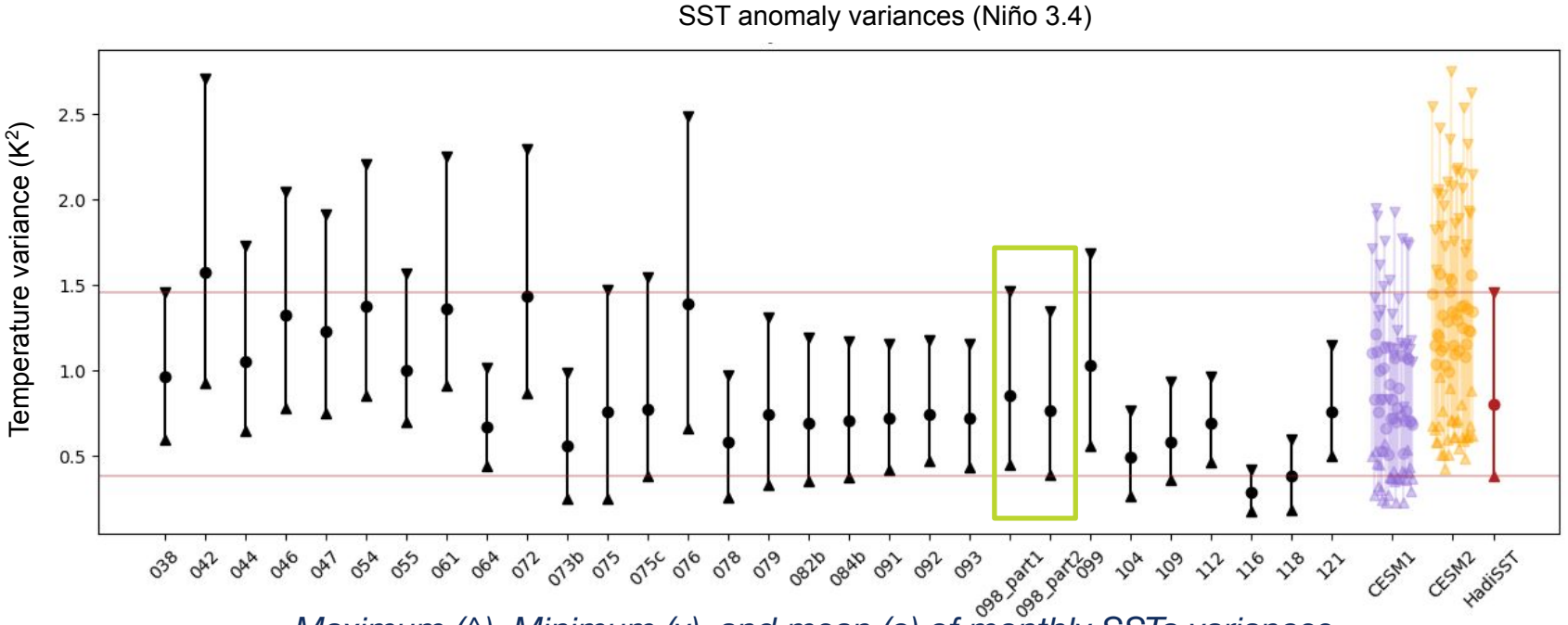

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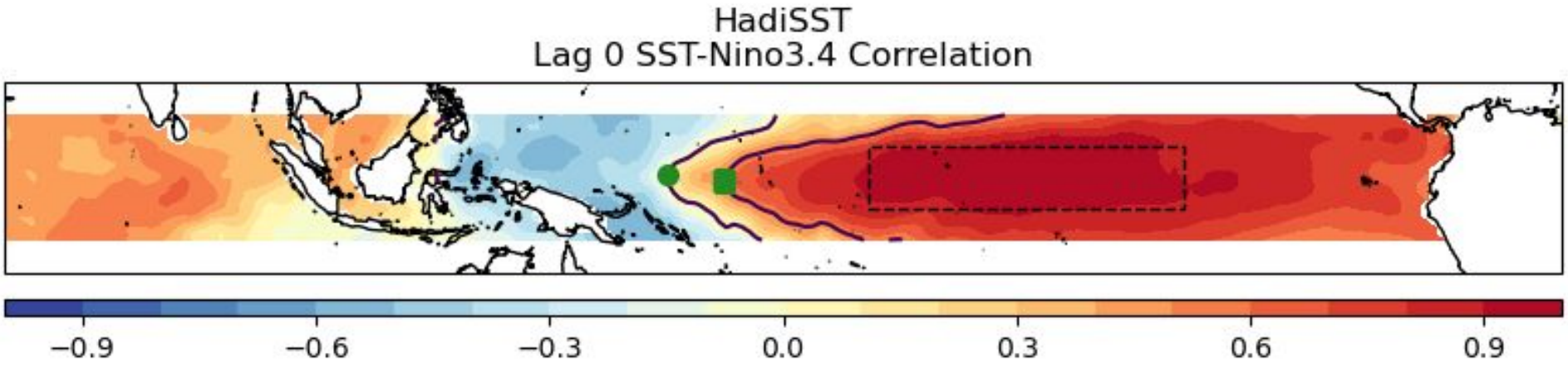
Are there characteristics that have not improved?

Spatial Extent of ENSO events

Correlation of SST anomalies with Niñ3.4 index



Observed correlation of SST anomalies with the Nino3.4 index

- Extent of 0 correlation contour
- Extent of 0.5 correlation contour

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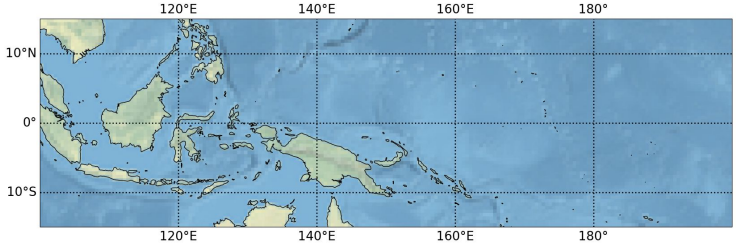

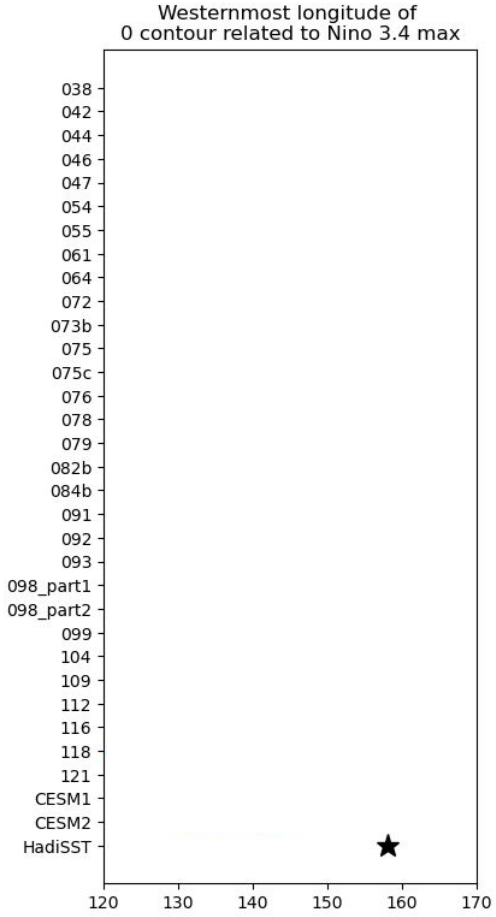

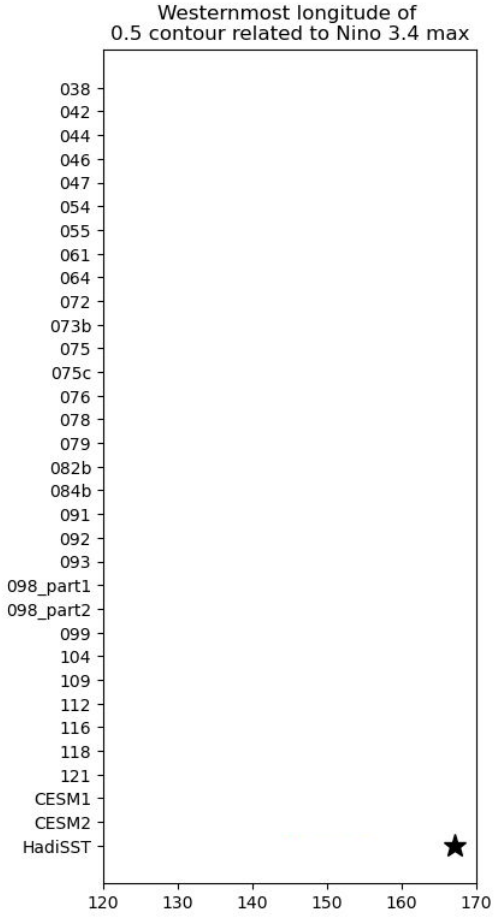

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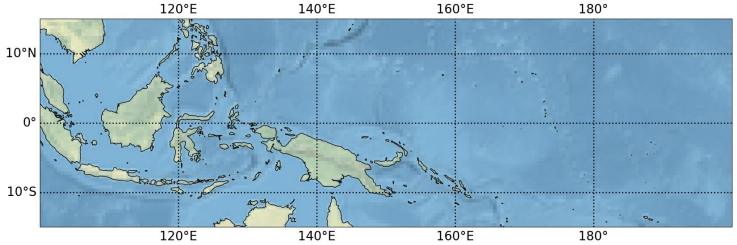

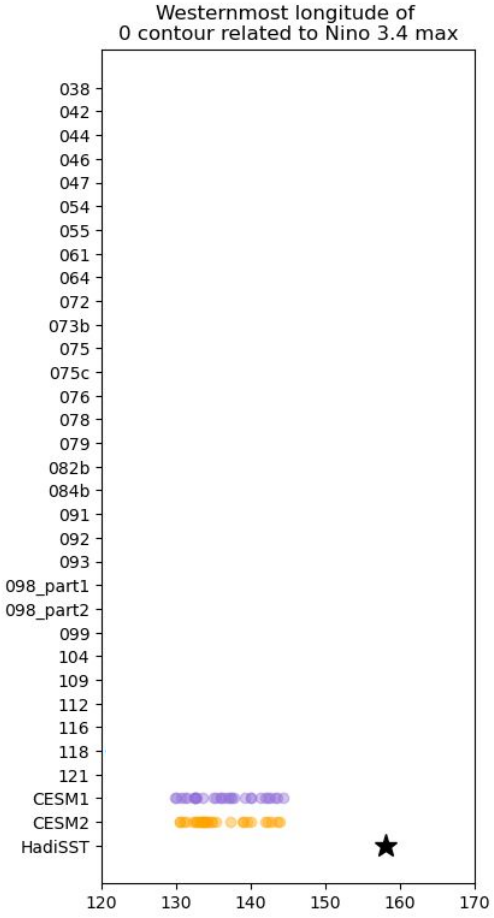

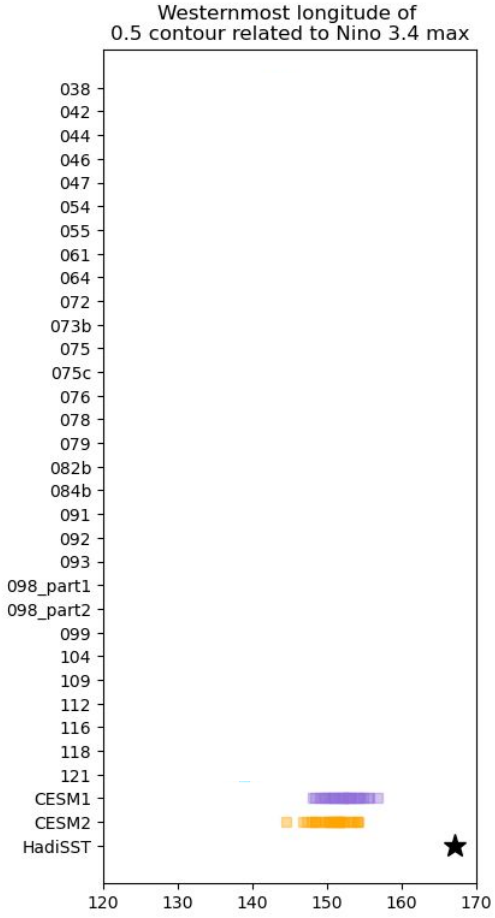

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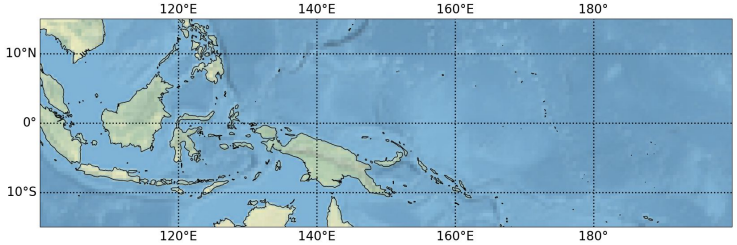

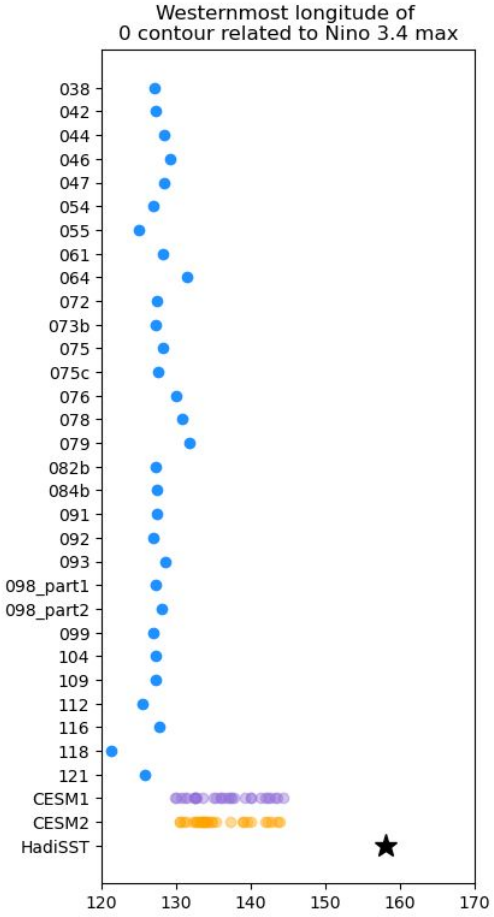

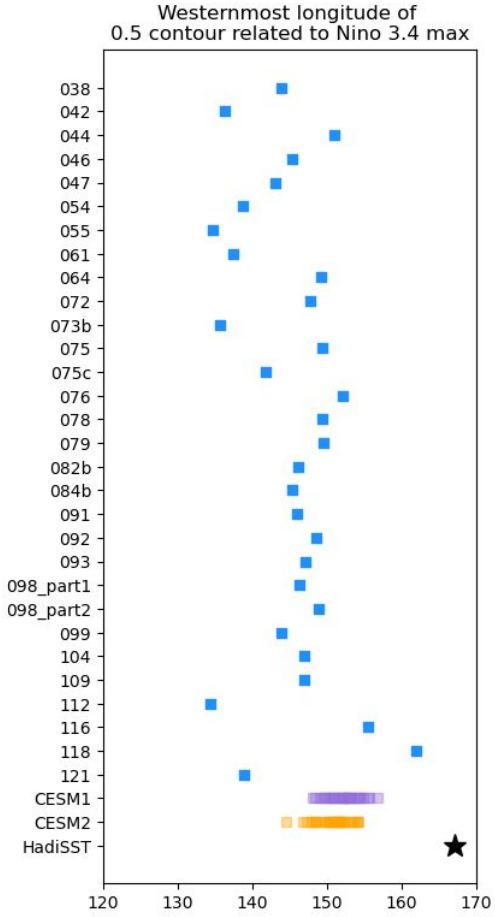

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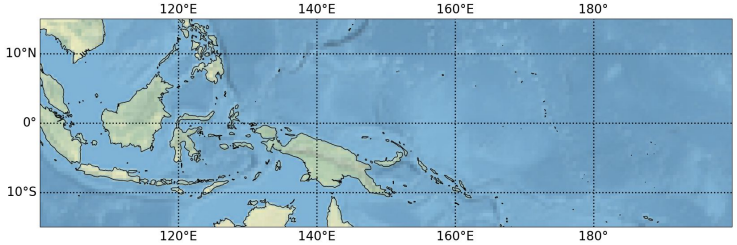

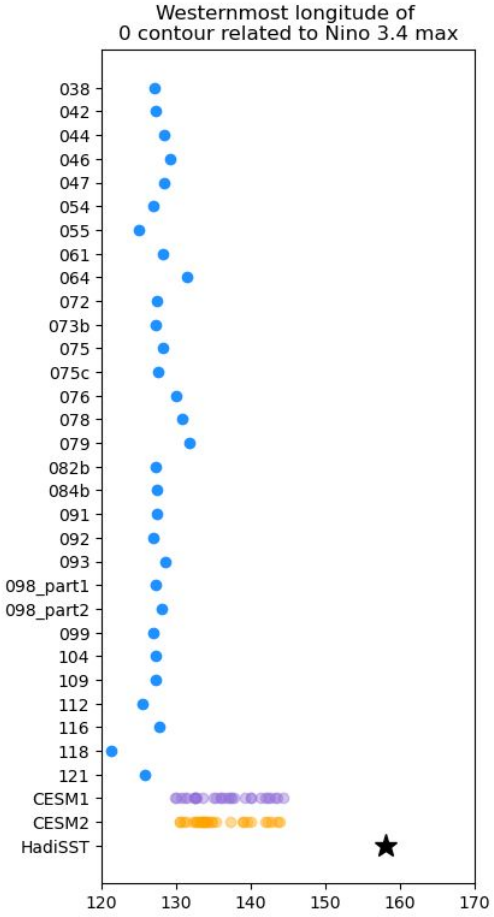

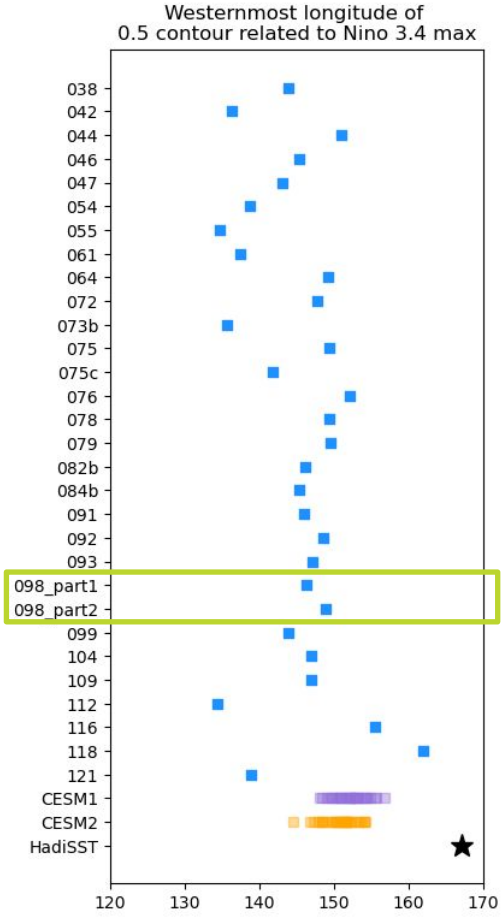

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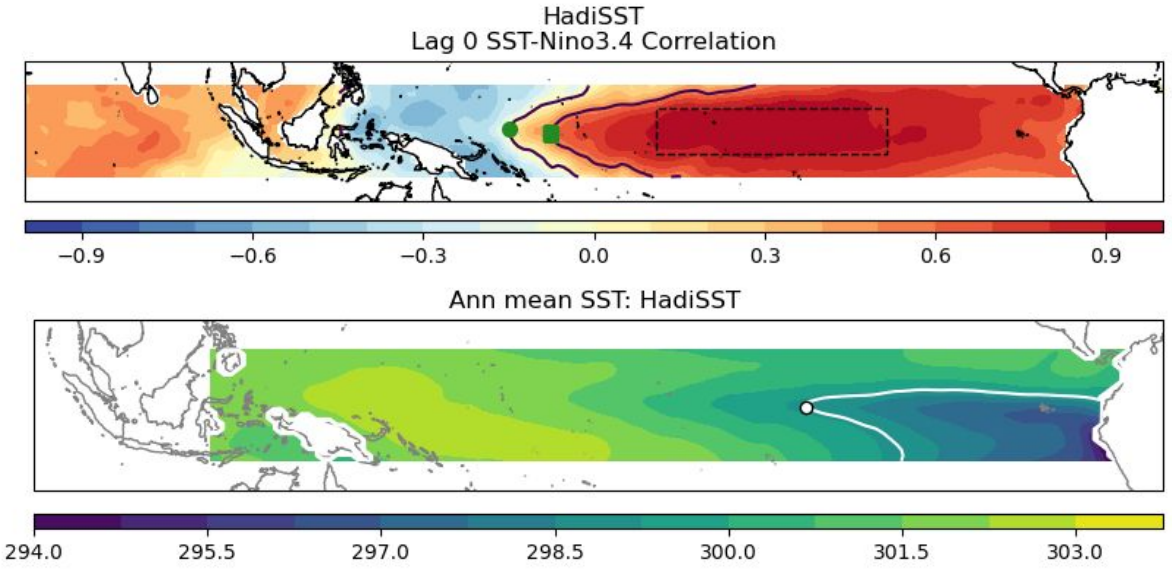
What are some factors driving these characteristics?

Possible connections with East Pacific Cold Tongue



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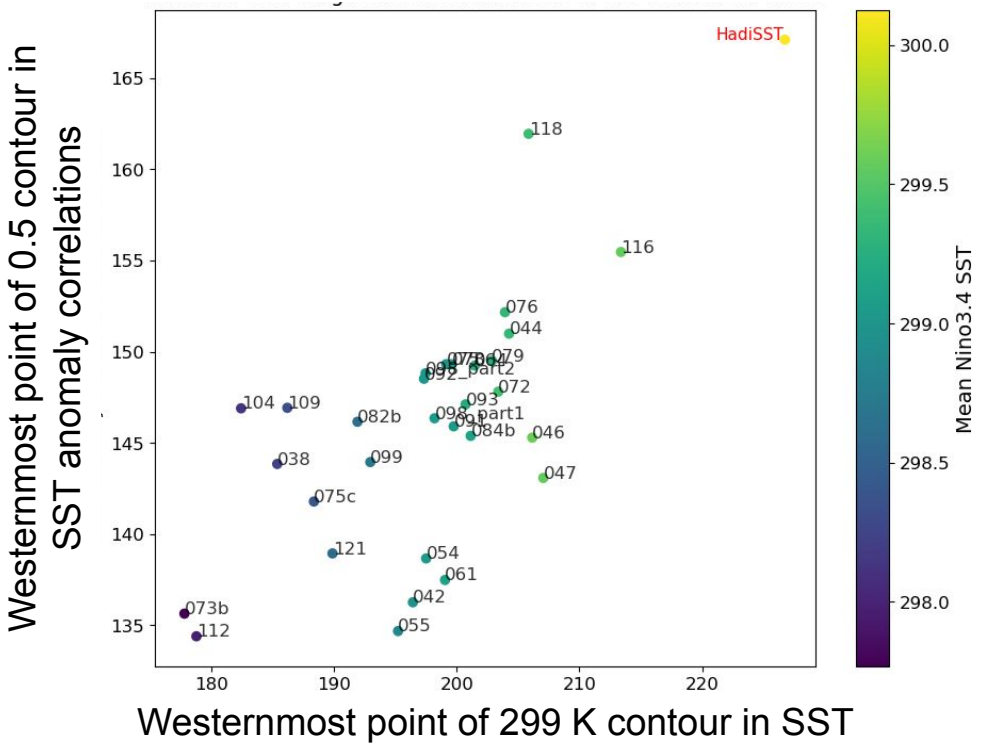

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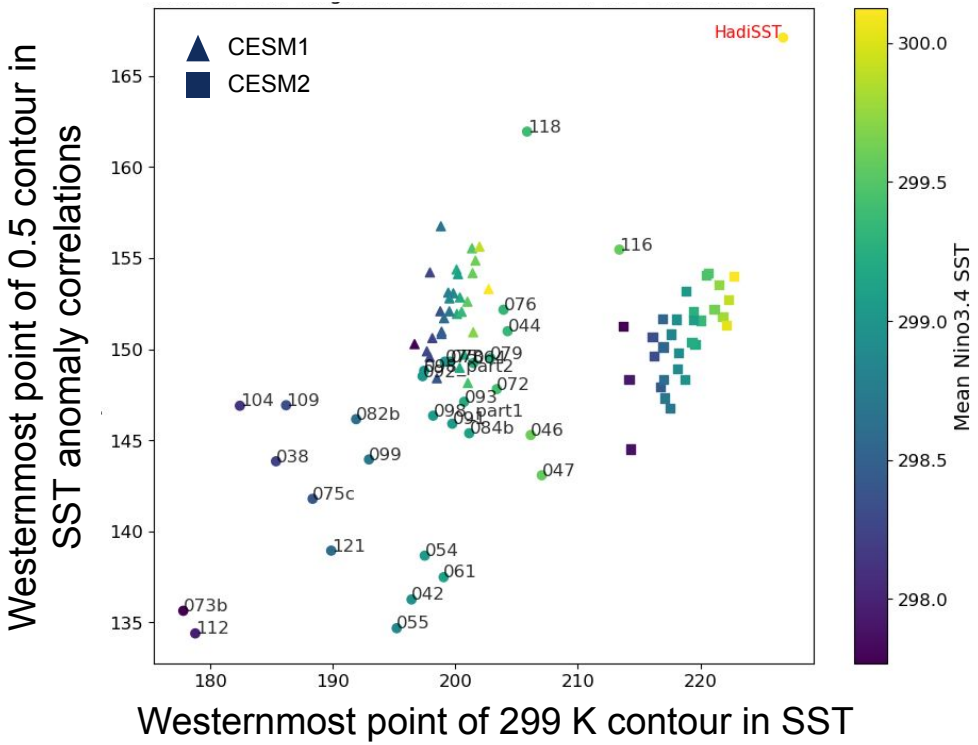

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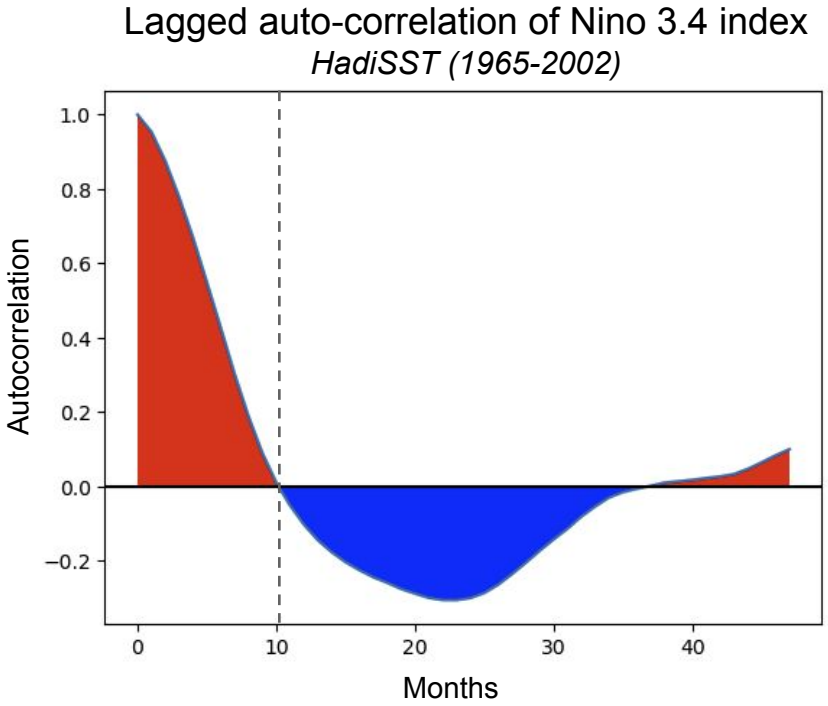
Extra Slides

How long do ENSO events persist?



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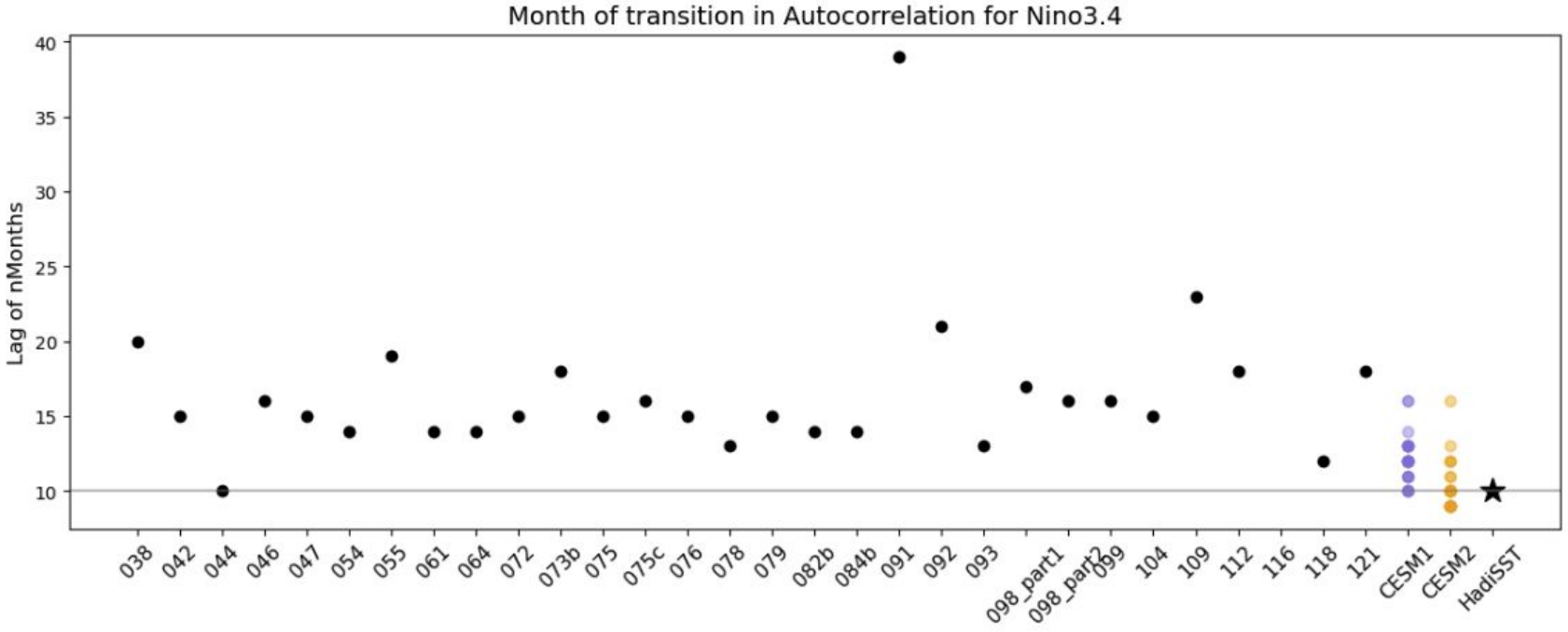
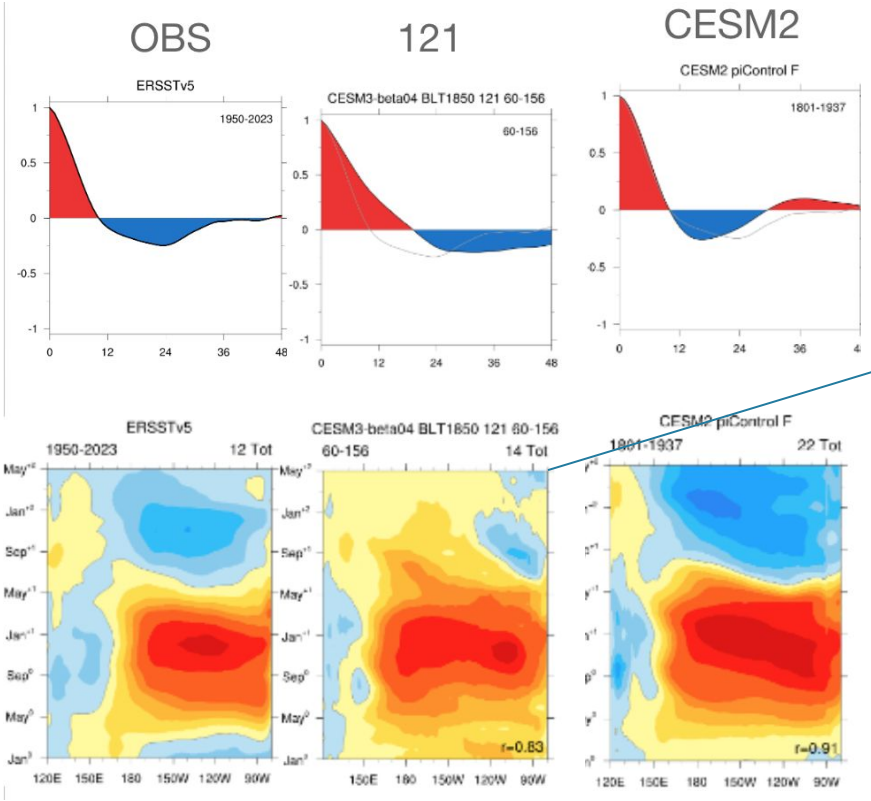
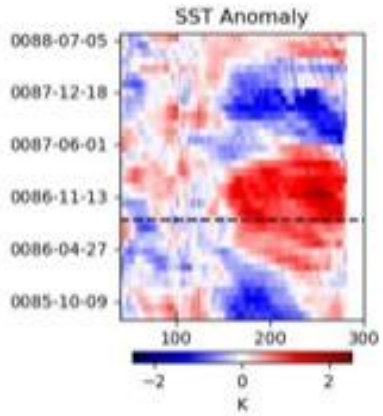
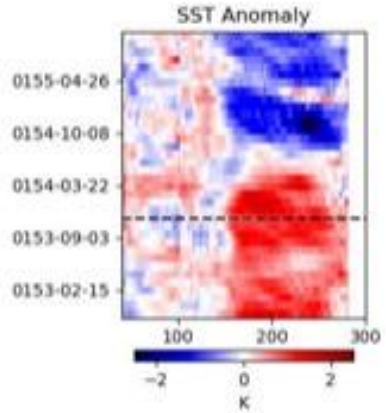


Compositing masks some good events too







Figs from Isla/Adam P.

How long do ENSO events persist?

- Duration: ENSO events may last a bit too long, though not necessarily outside the CESM1/2 range ** Depending on the period selected…

One simulation (112), extended 50 vs. 90 years: