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The Northern Hemisphere Extratropical Atmospheric Circulation Response to ENSO: How Well Do We Know It and How Do We Evaluate Models Accordingly?

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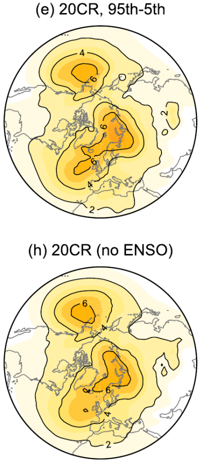
How well do we know the observed atmospheric circulation response to ENSO?

Is the atmospheric sea level pressure (SLP) variability during ENSO due to ENSO variability or to natural (non ENSO) variability?

Is the atmospheric variability captured in atmospheric-oceanic coupled climate models?

Key Results

- Sea level pressure (SLP) variability in the Northern Hemisphere (NH) during ENSO is independent of ENSO variability and likely atmospheric in origin
- No significant non-linearities between El Nino and La Nina SLP response
- Approach to evaluate true model biases and forced ENSO responses in models



5% and 95% confidence interval (CI) of sampled SLP composites in the NH

Observation Data

- the sea level pressure (SLP) dataset is the Twentieth Century Reanalysis (20CR)
- ENSO composites:
  boreal winter (DJF) average of SLP in the Northern Hemisphere for El Nino (EN) and La Nina (LN) events (which are identified by Nino3.4 SST index)
- observation period 1920 to 2013 corresponds to 18 distinct EN and 14 distinct LN

Climate model data

DJF average of SLP in the Northern Hemisphere for EN/LN events from

1. Tropical Pacific pacemaker coupled model simulations
   - full atmospheric and oceanic coupling considered
   - SST data nudged to NOAA reconstruction SST
   - compare CESM to MIROC, GFDL

2. TOGA simulation
   - only one way ocean-atmosphere coupling

3. Atmosphereic control simulation
   - atmospheric variability in the absence of ENSO

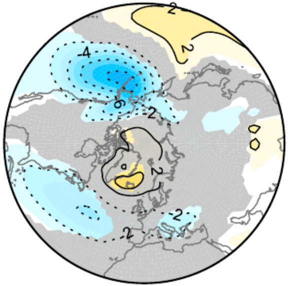
ENSO composite sampling

Bootstrapping method:

1. Randomly sample (with replacement) 18 EN and 14 LN SLP maps from observation (model) data
2. Average EN samples and LN samples, respectively
3. Subtract the LN average SLP map from the EN average SLP map

   ⇒ One member of the observed ENSO composite

Repeat 2000 times



One member of the observation ENSO composite. Values not significant at the 5% confidence level based on a two-sided t test are shaded in gray.

Sampling distribution of observational data

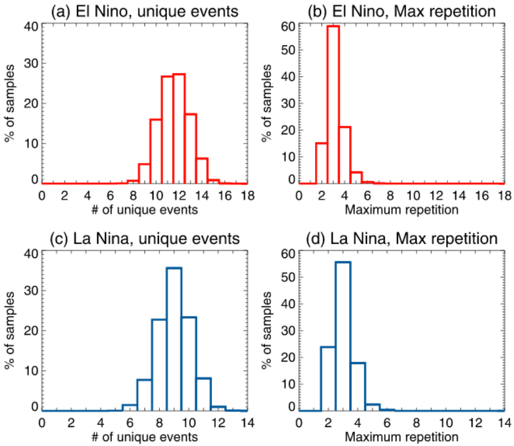
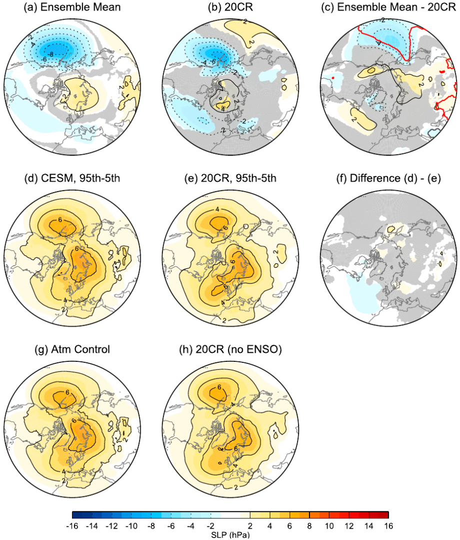


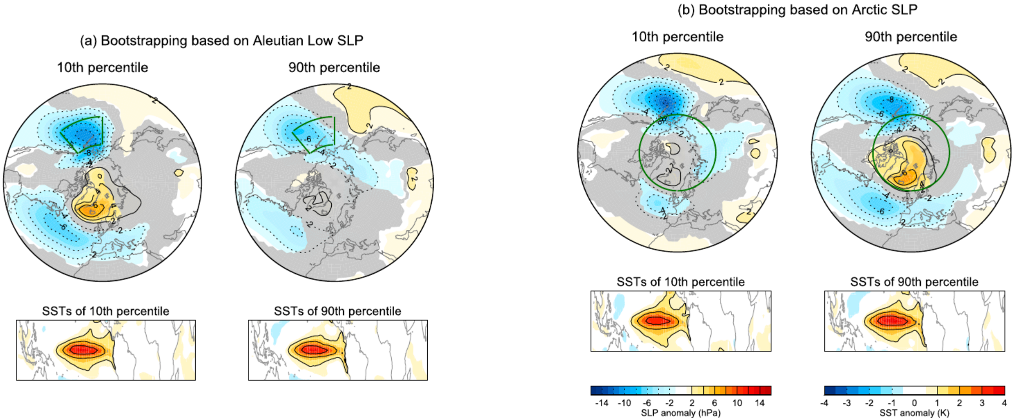
FIG. 1. Distribution of (a) the number of unique El Niño events, (b) the maximum number of times a single El Niño event is repeated, (c) the number of unique La Niña events, and (d) the maximum number of times a single La Niña event is repeated, in the 2000 synthetic ENSO composites based on observations. See text for details.

Model & Observation comparison



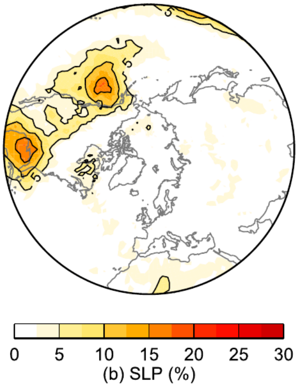
- model variability (d) is in good agreement to observational variability (e)
- (c) shows model biases in the North Pacific, over the Atlantic, parts of northeast Asia, and the southeastern United States
- model and observational variability are attributed to atmospheric variability (not ENSO variability) (g+f)

Observational range of variability



- Variability of SLP magnitudes differ by approximately a factor of 2

ENSO response to variability

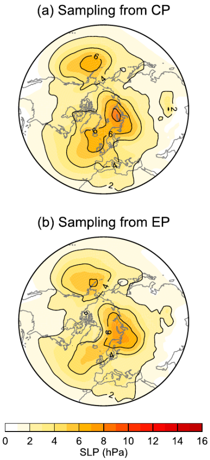


Linear contribution of the Nino-3.4 SST index to the CI of the SLP ENSO composites

- given a value of the Niño-3.4 SST index, the AL index range from 212 hPa to 23 hPa
- removing dependency of Nino-3.4 SST index by linear regression

⇒ yield ENSO response of SLP variability

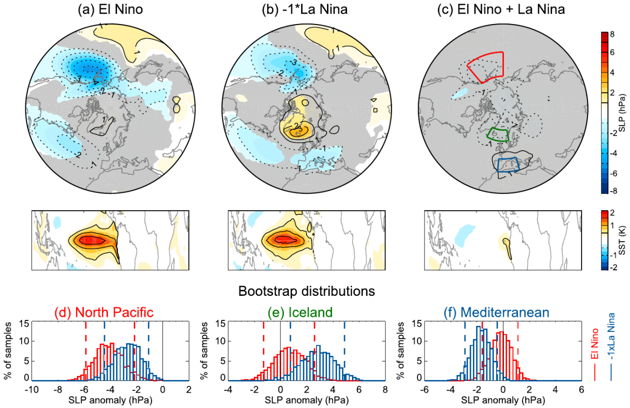
Effect of ENSO flavors to SLP variability



CIs of CP-type composites and EP-type composites

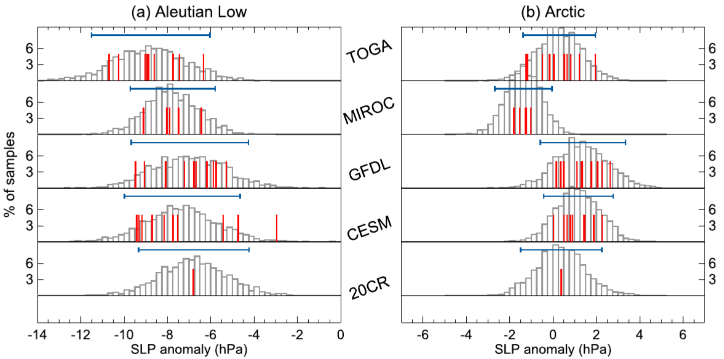
’flavors’ of El Niño have no appreciable effect on uncertainty of ENSO SLP composite

El Nino and La Nina composites



- EN and LN composites show regional differences in amplitude
- EN and LN SLP composites have a linear relationship (no non-linearities)

ENSO composites across models



"need for large model ensembles, since a single simulation from a particular model can alter the mean value of the distribution just by chance"

Summary

Results of observational composites

- SLP variability during ENSO is independent of ENSO variability and likely atmospheric in origin
- El nino diversity (CP, EP type) has only minor contribution to the SLP uncertainty
- No significant non-linearities between El Nino and La Nina SLP response

Results of model composites

- Model composites show similar diversity than observational composites
- Since model do not capture ENSO complexity, their SLP response uncertainty can only be related to atmospheric processes
- Approach to evaluate true model biases and forced ENSO response in models

Discussion

Problems:

The different EN and LN events are assumed to be independent from another. This omits dependencies and trends (interdecadel effect by PDO).

Ideas:

- Generating EN and LN samples with GANs or Variational Autoencoders might be a more rigerous approach.
- Trace back reasons for model biases.
- What might be reasons for atmospheric variability?