1. Introduction

ENSO affects weather, ecosystems, and economies worldwide. Instrumental records, paleo proxies, and coupled GCM simulations all exhibit strong intrinsic modulation of ENSO behavior, which factors into future climate risks and confounds detection of forced changes (see refs). Here we examine variations in ENSO teleconnections, arising from both intrinsic modulation and radiative forcing changes.

2. Canonical Teleconnection Patterns

Two coupled GCMs, GFDL-CM2.1 (2° atm, 1° ocean) and GFDL-CM2.5 (0.5° atm, 0.25° ocean), produce reasonable simulations of global climate, ENSO, and ENSO teleconnections:

- As CO2 doubles (yellow dots) and quadruples (red dots) relative to 1860, the climate warms. For CM2.1, the 4xCO2 warming relative to 1860 is easily detectable with a single annual-mean over Indonesia, while at Galapagos it takes several years to detect reliably. At high CO2, the CM2.1 ENSO weakens and the teleconnections become more linear. These changes are not easily detectable in a 30yr record, like those currently available from TAO & satellites.

3. Noise, Nonlinearity, and Climate Change

Focusing on the black-boxed regions in the above figure, we examine scatterplots of annual-mean temperatures vs. NINO3 SST (gray box). The CM2.1 1990 control run (green dots) generally mimics the observed (black dots) climate & teleconnections. SSTAs in the equatorial Pacific vary in tandem with NINO3, while Indonesian & SE U.S. temperatures have weaker links to NINO3. A 4000yr run of CM2.1 with 1860 forcings (blue dots) exposes the nonlinear structure of the teleconnections: (1) Galapagos responds only to strong El Niños; (2) the equatorial Pacific temperature sensitivity to NINO3 is strong for La Niñas or moderate El Niños, but weaker for strong El Niños; and (3) Indonesia cools when NINO3 SST is neutral, and warms during either El Niño or La Niña. Similar effects are seen in a 500yr 1860-forced run of CM2.5 (gray dots).

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4. The ENSO Continuum and Local Vulnerability

To shed light on these nonlinear relationships, the figure at left shows the 4000 June-May annual-means of equatorial surface temperature & rainfall from the CM2.1 1860 simulation, sorted by NINO3 SSTAs and smoothed by 100yr along the quantile axis. The dashed green line (repeated all panels) marks the longitude of peak equatorial Pacific SST. In CM2.1, NINO3 is evidently a good proxy for both the strength & peak longitude of equatorial SSTAs. The peak rainfall anomaly sits 20-30° west of the peak SSTA, sliding eastward with the peak SSTA as NINO3 warms.

CM2.1 exhibits a continuum of ENSO events, with SSTAs that can peak at any longitude. But the strong El Niños are rather distinct from moderate events and La Niñas. During strong El Niños, heavy rain expands across the entire Indian & Pacific oceans at the equator. Galapagos (at 90W) gets substantial annual rainfall only during the strongest El Niños, while Indonesia dries during strong events of either sign. Such nonlinearities can produce counter-intuitive relationships between teleconnection strength and decadal ENSO amplitude. During strong-ENSO epochs, when a linear regression model poorly fits the teleconnection curves, the regression coefficient can shrink despite a stronger signal-to-noise ratio. This motivates the use of nonlinear methods to characterize teleconnections. However, such methods may be hard to constrain with the short instrumental records currently available.

5. How Uncertain are the Teleconnections?

Because instrumental records are short, and extremes are rarely sampled, historically-observed teleconnections may not accurately reflect ENSO’s full repertoire. The CM2.1 1860 run can be used to compute maps of temperature & rainfall correlations with NINO3 SST, using the full 4000yr simulation (rtrue), or subsampled N-yr chunks (rρ). Binning rρ by rtrue we find that for rtrue = 0 there is a 10% chance that |rρ| ≥ 0.35, and a 10% chance that |rρ| > 0.2. For rtrue = 0.7, there is a 5% chance that rρ < 0.5. The confidence intervals for rainfall are nearly identical to those for temperature, and these intervals can be used to assess uncertainties of teleconnections diagnosed from short climate records, and to evaluate risks of proxy selection biases & overfitting in paleo reconstructions.

References


