Stratosphere- Troposphere Coupling:

Relationship of ENSO to stratospheric sudden warmings

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Introduction

We consider the effect of El Niño-Southern Oscillation (ENSO) on the strongest manifestation of stratosphere-troposphere coupling: stratospheric sudden warmings (SSWs). We find in the observational record that both El Niño and La Niña winters are associated with an increased frequency of SSWs relative to ENSO-neutral winters. We then examine the frequency of SSWs in relation to ENSO in a suite of Chemistry Climate Models (from the CCM Validation 2 Project) forced with observed sea surface temperatures from 1960-2004 (REF B1). Most models fail to capture the low frequency of SSWs during ENSO-neutral winters, and tend to simulate more frequent SSWs during El Niño winters than La Niña winters.

Observed Relationship

Table 1 shows that the frequency of SSWs in the NCEP-NCAR reanalysis from 1960-2004 during El Niño and La Niña winters is approximately equal, and nearly double the frequency during ENSO-neutral winters (*Butler and Polvani* 2011).

1960-2004	Number of Winters	Number of SSWs	SSWs per winter
El Niño	14	10	0.71
La Niña	15	11	0.73
Neutral	16	6	0.38
All	45	27	0.60

Table 1. SSWs are found as in Charlton & Polvani 2007. ENSO phase is defined by the NDJFM-mean of the Nino-3.4 time series greater than +/- 0.5C.

Figure 1 (from *Butler and Polvani* 2011) shows that although there is a statistically significant relationship between ENSO and DJF polar stratospheric temperature anomalies, SSWs occur during both phases of ENSO with equal frequency.

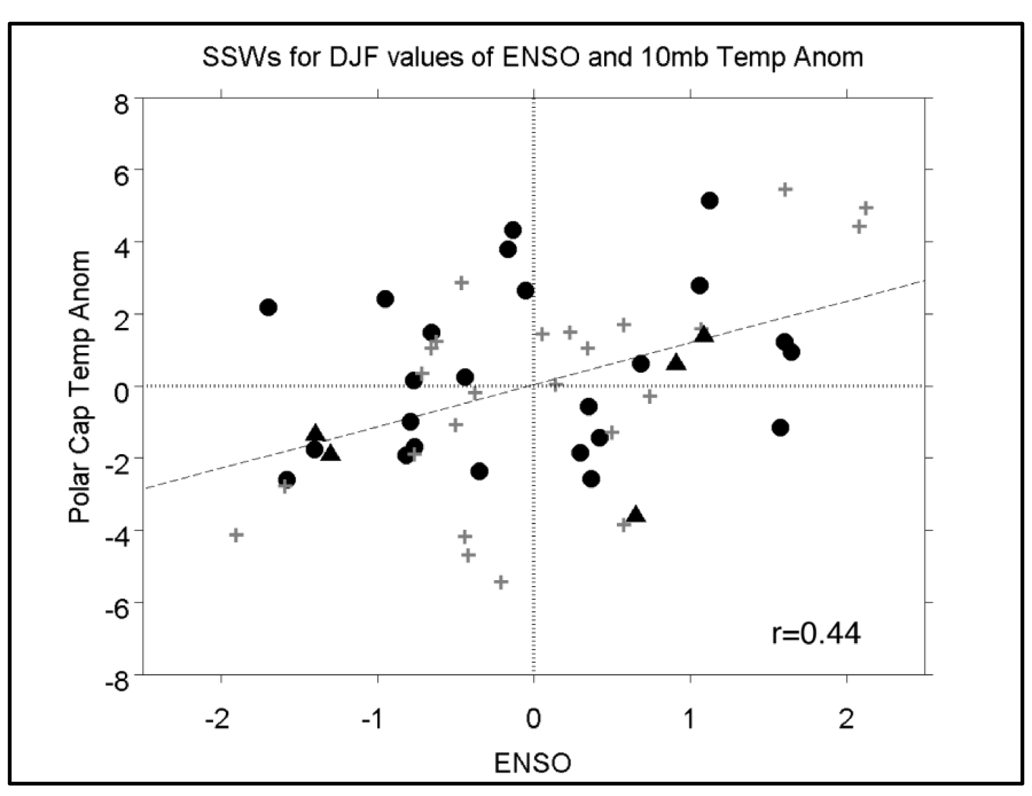

Figure 1. Standardized DJF ENSO index vs 60-90N DJF temperature anomalies at 10 hPa. Winters with one warming are indicated by black circles; winters with >1 warming are indicated by black triangles; winters with no warmings are indicated by grey crosses. From Butler & Polvani 2011.

ENSO-SSW Relationship in CCMVal-2 Models

We consider REF-B1 simulations provided to the Chemistry-Climate Model Validation project phase 2 (CCMVal2) [CCMVal, 2010], which are forced by observed sea surface temperatures from 1960-2004. **Figure 2** shows the SSW frequency for CCMVal2 model runs compared to reanalysis (black bar). Many models reasonably simulate the total number of SSWs, though some have far too few (AMTRAC3, SOCOL, CCSRNIES) or too many (CMAM).

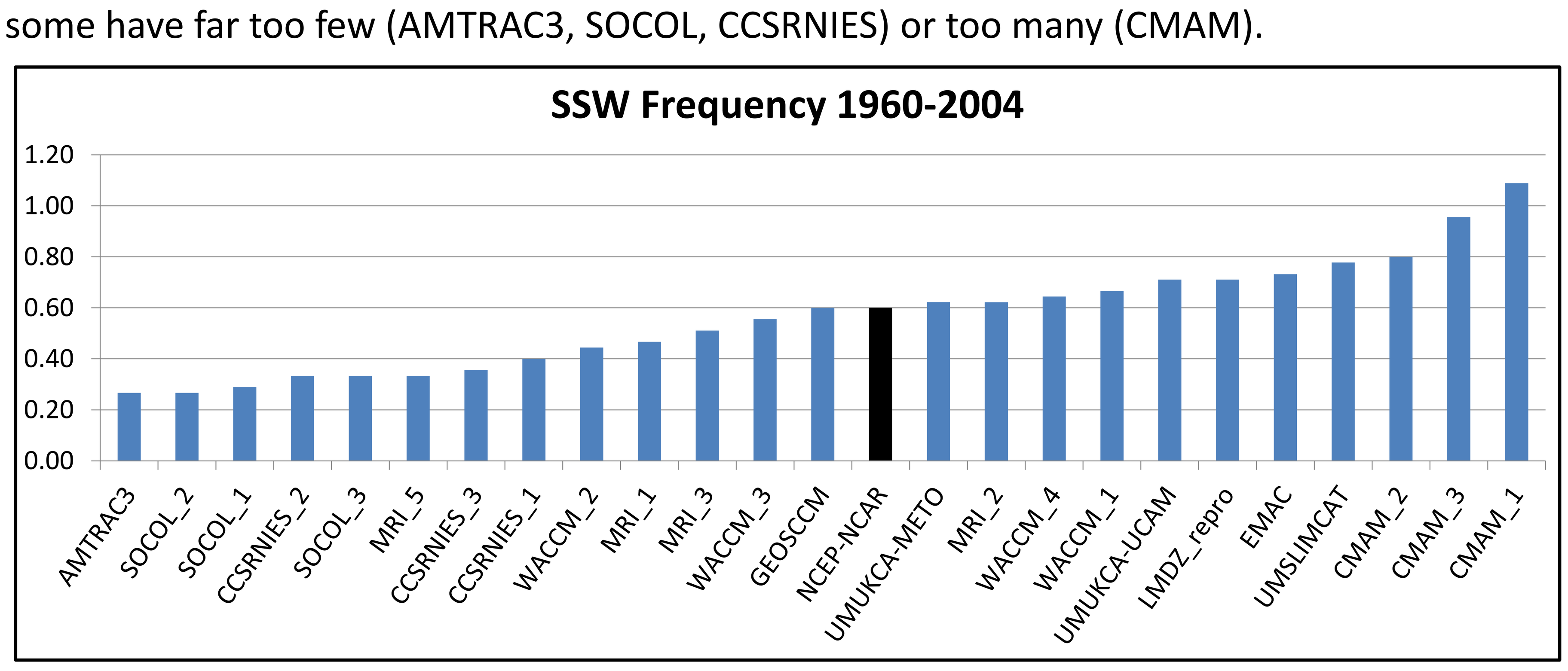

Figure 2. Frequency of SSWs (number per year) from 1960-2004. Some models have multiple runs.

Figure 3 shows that most models fail to capture the observed relationship of SSWs to ENSO phase. All models show the highest frequency of SSWs during El Niño winters, and most models show the lowest frequency of SSWs during La Niña winters.

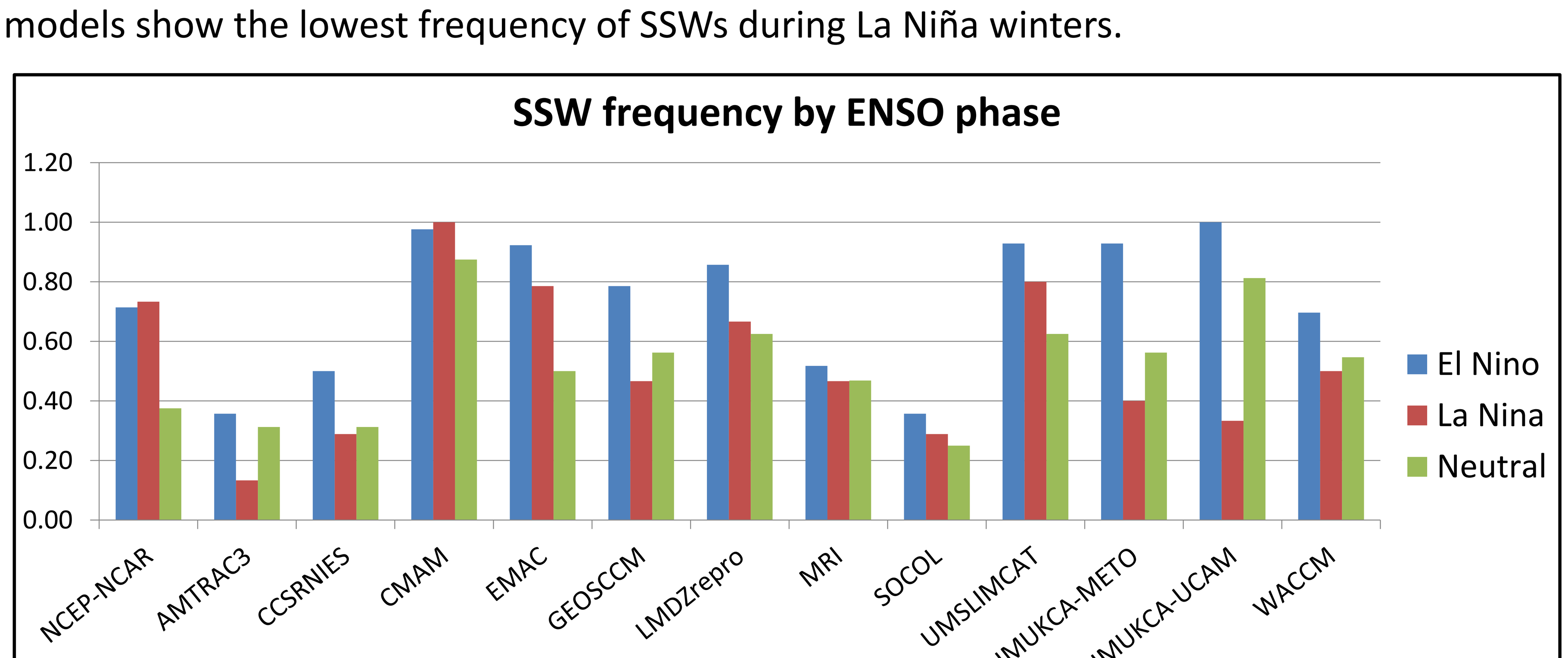

Figure 3. SSW frequency as a function of ENSO phase. Ensemble means of models with more than one run are shown.

Figure 4 shows that some models have 2-3x higher frequency of SSWs during El Niño relative to La Niña, even though the observed ratio is ~1. **Figure 5** shows that most models also overestimate the frequency of SSWs during neutral ENSO.

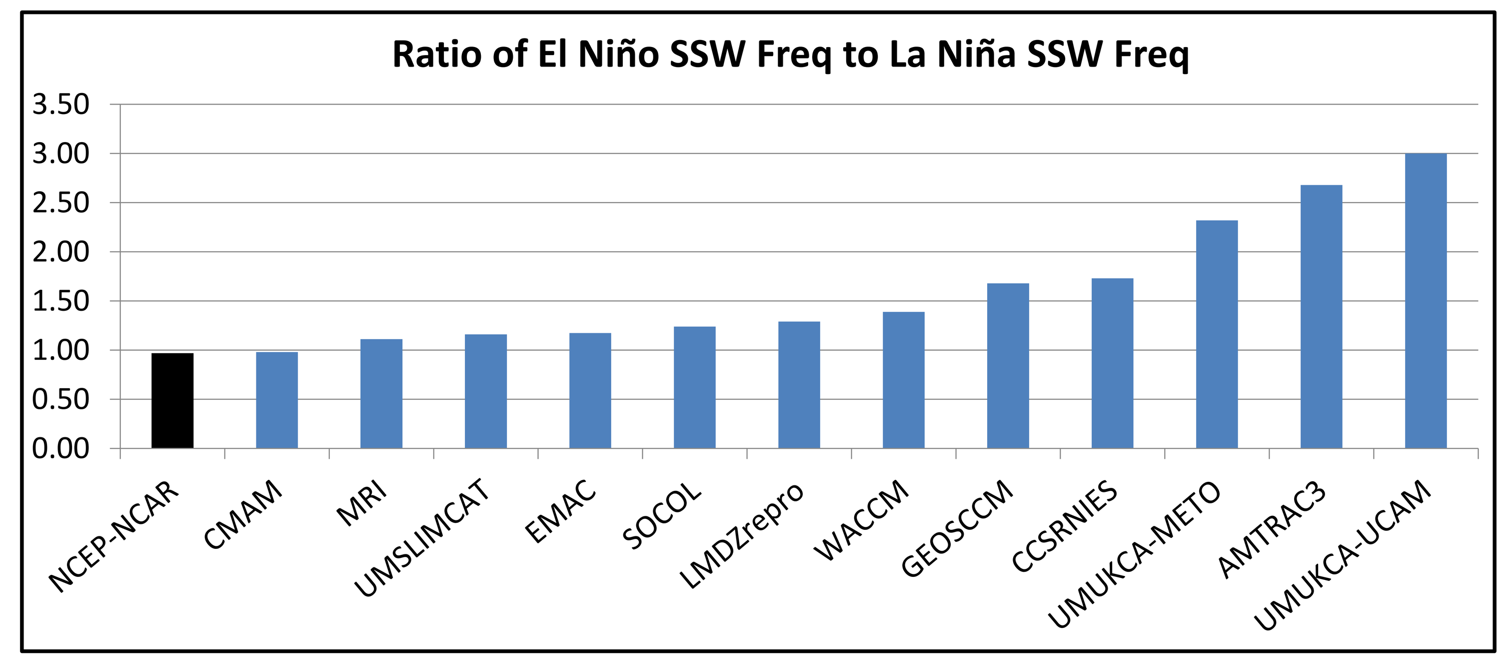

Figure 4. Ratio of SSW frequency in El Niño winters to frequency in La Niña winters.

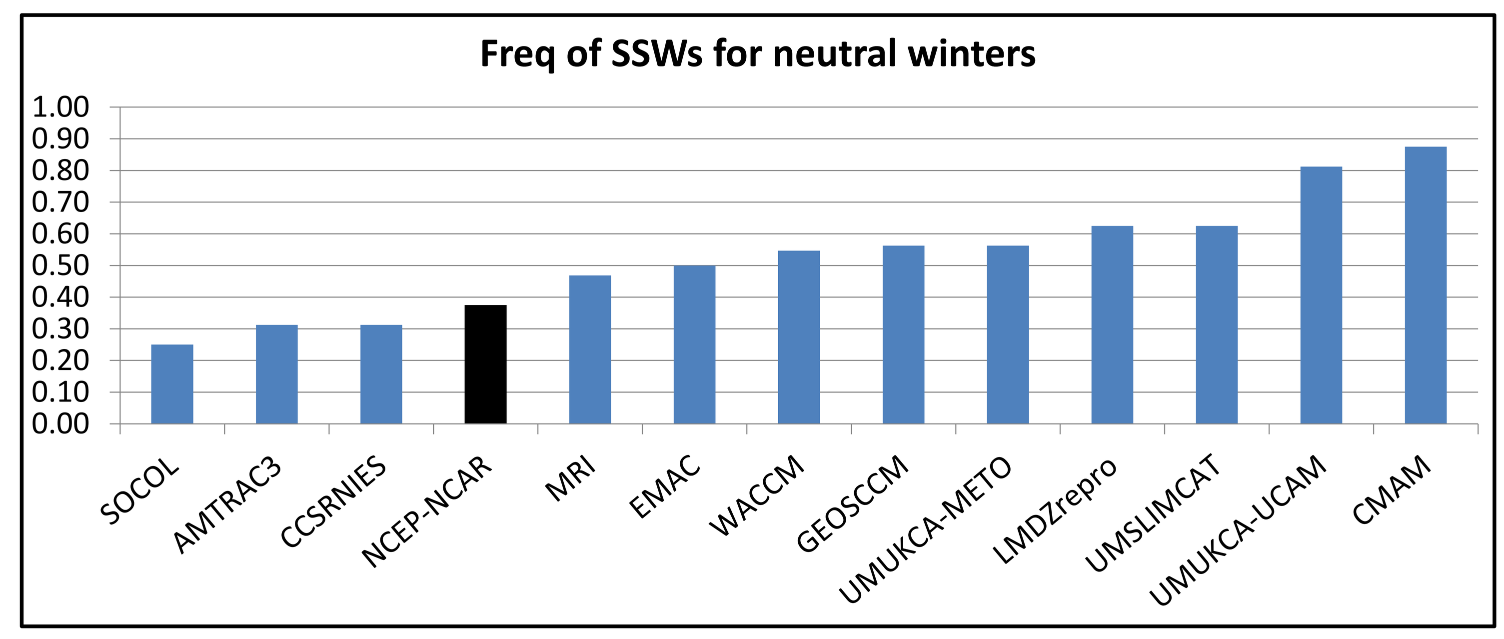

Figure 5. SSW frequency (number per year) for ENSO-neutral winters in reanalysis and CCMVal2 models.

Figure 6 shows that in the reanalysis the wintertime polar vortex winds are stronger during La Niña than during El Niño, but the number of days with easterly winds is nearly the same in both phases, and higher than during ENSO-neutral winters. Models generally do not capture this relationship (only select models shown here).

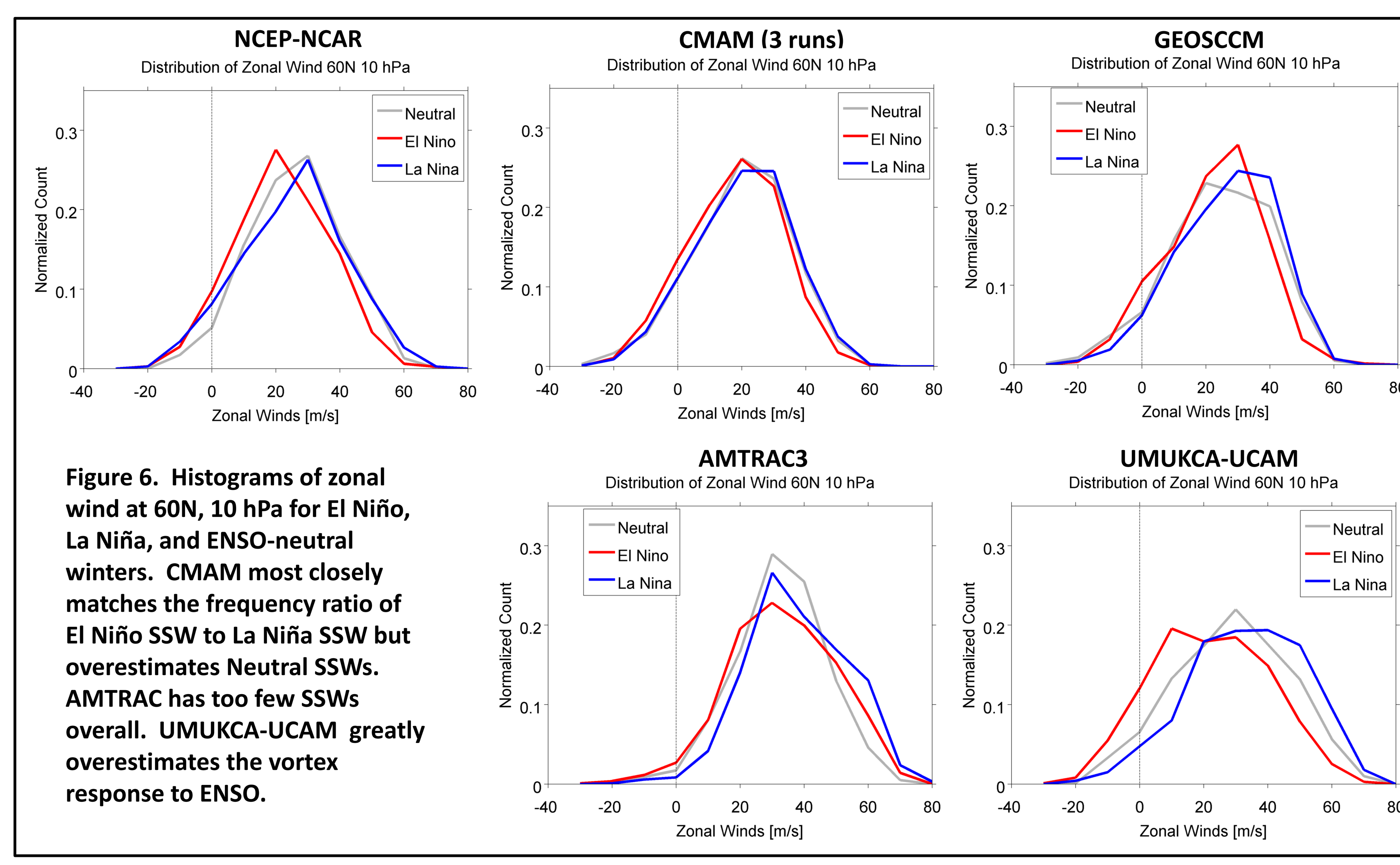

Figure 6. Histograms of zonal wind at 60N, 10 hPa for El Niño, La Niña, and ENSO-neutral winters. CMAM most closely matches the frequency ratio of El Niño SSW to La Niña SSW but overestimates Neutral SSWs. AMTRAC has too few SSWs overall. UMUKCA-UCAM greatly overestimates the vortex response to ENSO.

Discussion

One possible explanation for why SSW frequency is similar in both El Niño and La Niña phases in the reanalysis is that the region in the North Pacific where waves are most likely to grow in amplitude with height and break in the stratosphere is actually distinct from the region where ENSO teleconnections are strongest (*Garfinkel et al*., in prep). In many models, however, ENSO teleconnections are often zonally elongated, meaning that the anomalous ridge that forms in the North Pacific during La Niña would extend into the region of SSW formation and prevent vertical wave growth. We acknowledge that the reanalysis record is relatively short, and that this analysis does not account for other factors like the Quasi-Biennial Oscillation (though we note that La Niña SSWs occur during both phases of the QBO).

Conclusions

In the reanalysis, SSWs occur with equal frequency during El Niño and La Niña, and with nearly double the frequency as during ENSO-neutral winters. This relationship is not captured in most CCMVal-2 models, which generally show more warmings during El Niño compared to La Niña and too many warmings during ENSO-neutral. More work is being conducted to understand these results.

Acknowledgements

We acknowledge the modeling groups for making their simulations available for this analysis, the Chemistry-Climate Model Validation (CCMVal) activity for WCRP's SPARC project for organizing and coordinating the model data analysis activity, and the BADC for collecting and archiving the CCMVal model output.