Poster 516

Preliminary evaluation of CESM 1.0 (CCSM4) 20th century climate runs within the Intra-Americas Sea region

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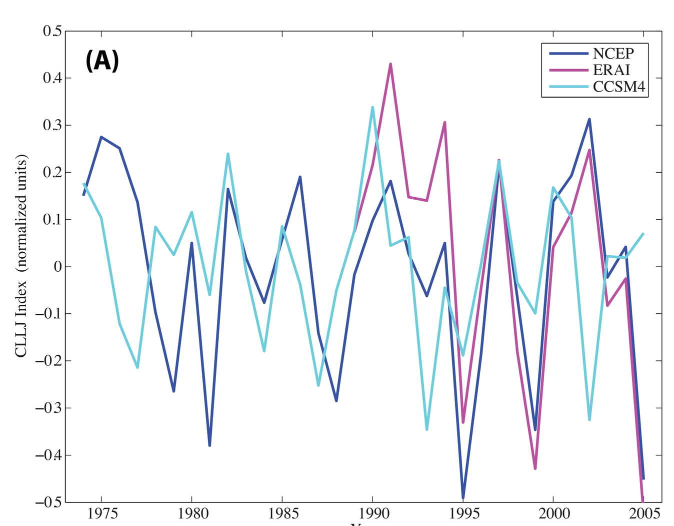
Abstract

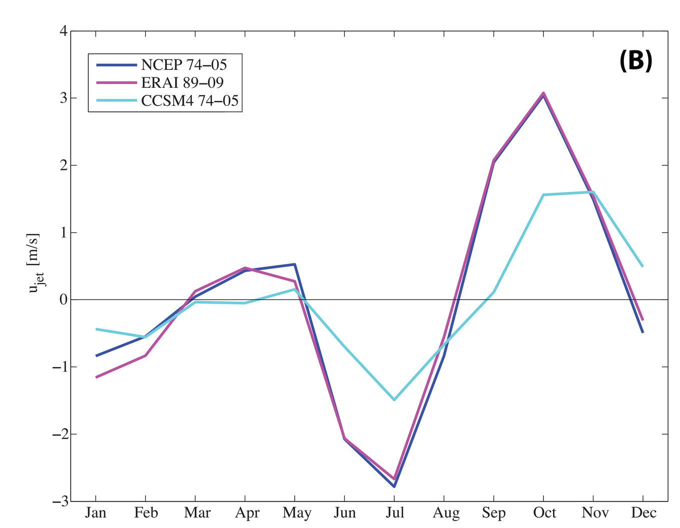
Several studies point out the critical role that orography plays in present day mid-latitude and tropical storm tracks. Recent work also suggests that the Madden-Julian Oscillation (MJO) and Caribbean low-level jet (CLLJ) influence storm track activity within the IAS, including Northeastern Pacific and North Atlantic tropical cyclone activity. Studies of tropical storm tracks for the projected warmer conditions of the 21st century find reduced storm track activity in the N. Atlantic and a shift of the Northeastern Pacific storm track southward. The intensity of tropical storms overall appears to remain unchanged in studies that have accounted for a mean shift in the tropical mean sea surface pressure due to warmer temperatures. However, storm intensity is more dependent on model resolution than storm frequency making these predictions more difficult. We present preliminary analyses of the Community Climate System Model (CCSM) 4.0 1 degree 20th century simulations to examine the general characteristics of the tropical storm track in the IAS during boreal summer for the 1974-2005 time period. Future analyses will dynamically downscale such runs and their corresponding 2005-2100 future climate runs (as well as other AR5 future climate runs) to assess changes in the location of the tropical storm track in the region and the affects on regional precipitation patterns including tropical storm frequency and intensity.

1. CLLJ Scales of Variability

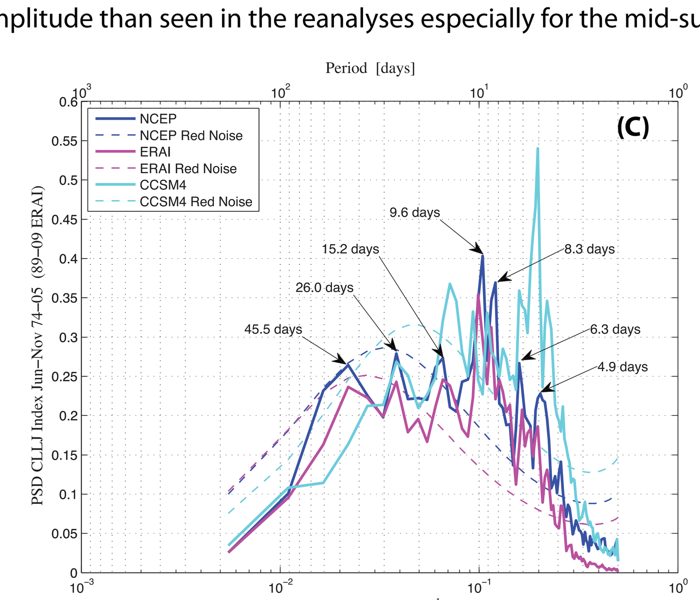
Variability in the CLLJ has been shown to impact moisture convergence and precipitation in the IAS (e.g. Magaña and Caetano 2005), as well as easterly wave activity and tropical storm frequency within the vicinity (e.g. Serra et al. 2010). Thus, a key element of understanding the impact of climate change on the IAS is to understand its impact on the variability and strength of the CLLJ. Here, we evaluate the CCSM4's ability to capture the current variability of the CLLJ to inform future downscaling efforts.

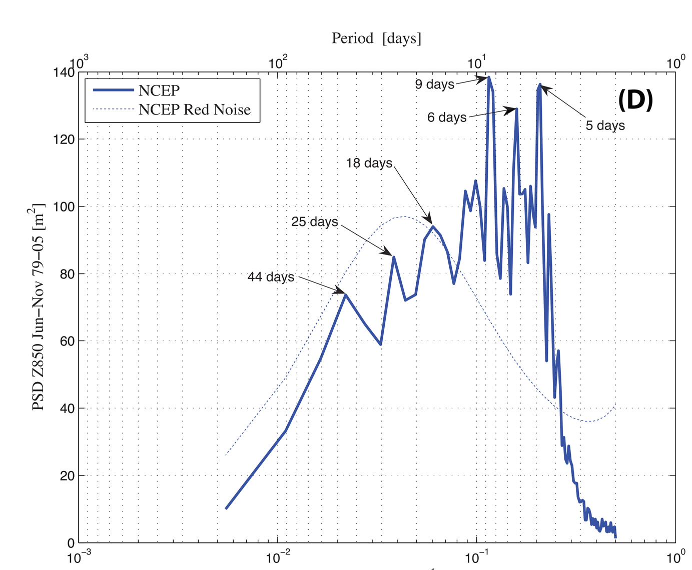
Using NCEP/NCAR Reanalysis 1 daily zonal wind at 925 hPa for the 1979-2005 time period averaged within the box defined by 70.5°-81.5°W, 12°-18°N, we calculate a normalized CLLJ Index. A similar procedure is also followed for the ERA Interim 925 hPa zonal wind but for the 1989-2009 time period. These indices are then compared to the CCSM4 CLLJ Index, calulated using the 930 hPa level from the model and using the 1974-2005 time period from the 20th century simulations.





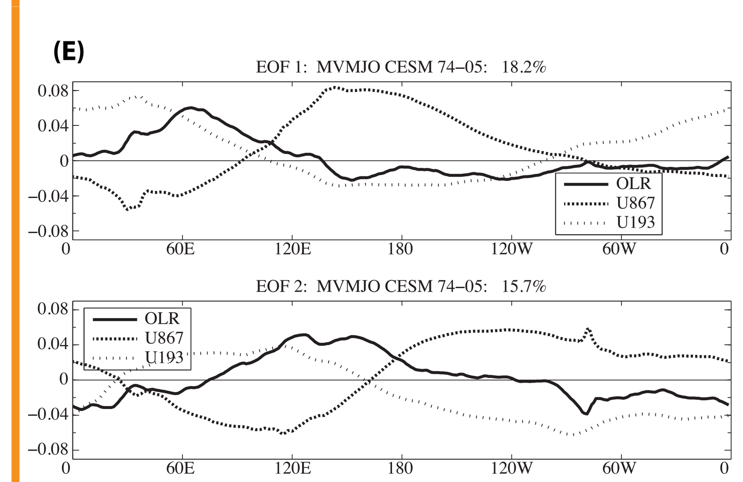
The interannual and seasonal variability of the jet are shown in **(A)** and **(B)**, respectively. Overall, the CCSM4 tracks the reanlyses reasonably well with the exception of the period prior to about 1982 and specific years such as 2003 and 2005. Interannual variability of the jet is primarily influenced by ENSO and the NAO (e.g. Wang 2007). The seasonal cycle of the jet, where a maximum in the jet is shown here by a minimum in the zonal wind (July and January), is well simulated by the CCSM4 but with a weaker amplitude than seen in the reanalyses especially for the mid-summer maximum and fall minimum.

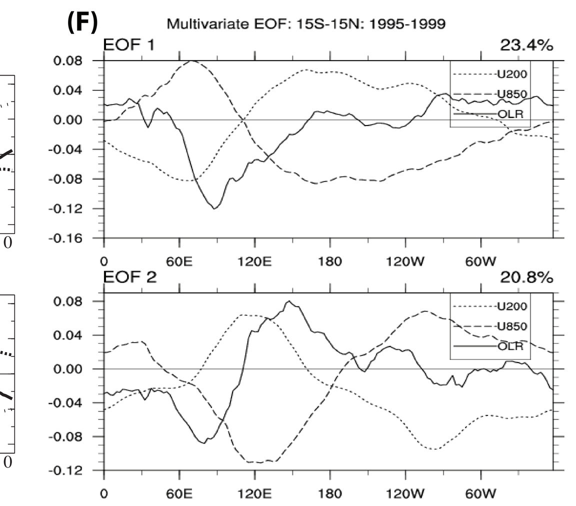


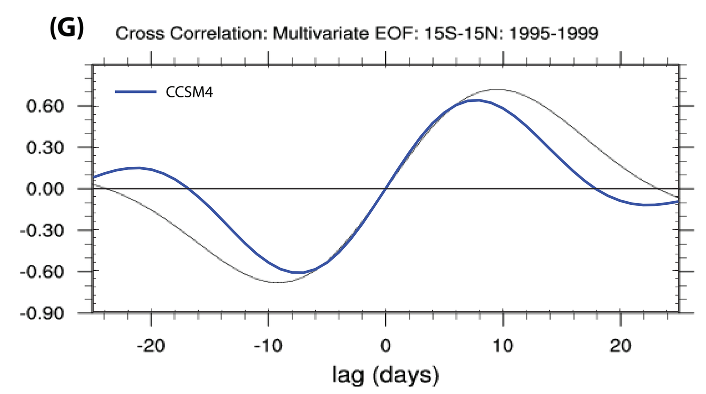


To examine the sub-seasonal variability in the jet we calculate a power spectrum of the CLLJ Index for the June-November season using 1974-2005 for NCEP and CCSM4 and 1989-2009 for ERAI. The seasonal cycle and interannual variability have been removed from the daily index prior to calculation of the power spectral density shown. The power spectrum of this index indicates significant variability at around 45 days (not significant), 26 days (not significant), 15 days, and 5-10 days **(C)**. This variability closely matches that of the daily sub-seasonal 850 hPa geopotential height anomalies **(D)**, suggesting, not surprisingly, that the jet variability is strongly contolled by sub-seasonal variability of the Bermuda High. The CCSM4 geopotential height sub-seasonal variance is an order of magnitude less than that of NCEP shown in **(D)** and has none of the same characteristics. Given the good agreement between the CCSM4 jet sub-seasonal variance with that of the reanalyses, this is surprising. We are currently investigating this issue further.

2. The MJO and Its Modulation of Easterly Waves



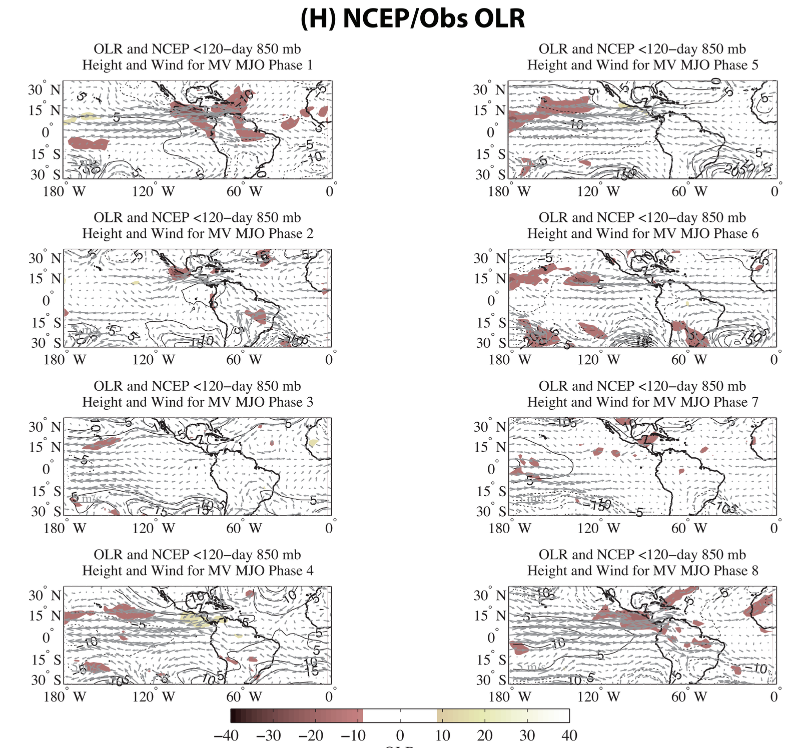




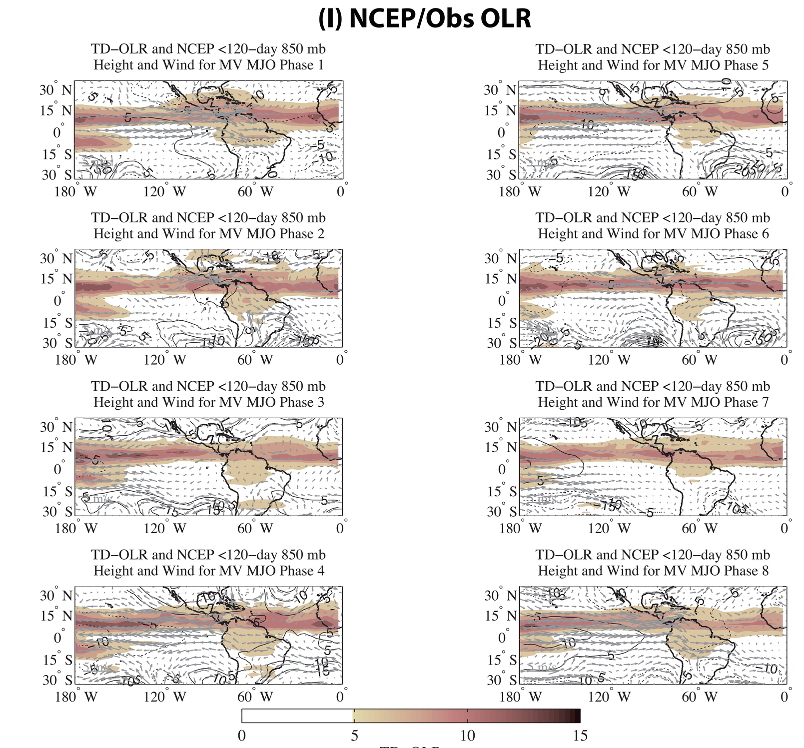
The MJO is a significant peak in the CLLJ Index power spectrum shown in **(C)**, indicating its modulation of the jet. The MJO is also linked to enhanced eddy activity and increased tropical storm frequency during its westerly phase in the tropical eastern Pacific (Maloney...). To examine the characteristics of the MJO in the CCSM4, we follow the methodology of Waliser et al. (2009) to create a Multivariate MJO Index using CCSM4 OLR and 193 and 867 hPa winds. This methodology is similar to that of Wheeler and Hendon (2004, WH2004). The first two CCSM4 multivariate EOFs for each variable are shown in **(E)**, results of Waliser et al. (2009) for observed OLR and NCEP winds are shown for comparison in **(F)**. EOF1 indicates that cloudiness is in phase with upper-level easterlies and low-level westerlies, with the maximum in the low-level westerlies to the west of the OLR minimum in both data sets. This pattern shifts to the east for EOF2, indicating an eastward propagation. These results suggest that the CCSM4 has captured the general character of the MJO in its 20th century simulations. The lagged correlations between the multivariate PC 1 and 2 are also in good agreement with Waliser et al. (2009), however the time scales associated with the MJO in the CCSM4 are a few days shorter than in the observations **(G)**.

Previous studies have shown that the CLLJ strong phase also coincides with enhanced easterly wave activity (Serra et al. 2010), so we examine composites of sub-seasonal OLR and standard deviations of TD-filtered (easterly wave band) OLR and sub-seasonal 850 hPa heights and winds for the phases of the MJO **(H & I)**. NCEP composites are based on the May-Nov 1979-2007 time period. While the westerly phase of the MJO in the Northeast Pacific coincides with greater convective activity, especially along the west coasts of Mexico and Central America, the easterly phase corresponds to greater convective activity associated with easterly waves consistent with Serra et al. (2010). We show the same composites for the CCSM4 OLR and TD-OLR along with that model's 867 hPa heights and winds in **(J)** and **(K)**, respectively, for the May - Nov 1974-2005 time period. While the MV MJO phases of Waliser et al. (2009) are roughly opposite from those of WH2004, the CCSM4 shows a similar modulation of the TD-OLR as that seen in the observations. It is also evident that while the amplitude of the OLR, height, and wind anomalies in the CCSM4 are generally weaker than those in the observations, the TD-OLR anomalies are somewhat larger suggesting the TD-filter encompasses a larger fraction of the overall CCSM4 OLR variance than for the observations.

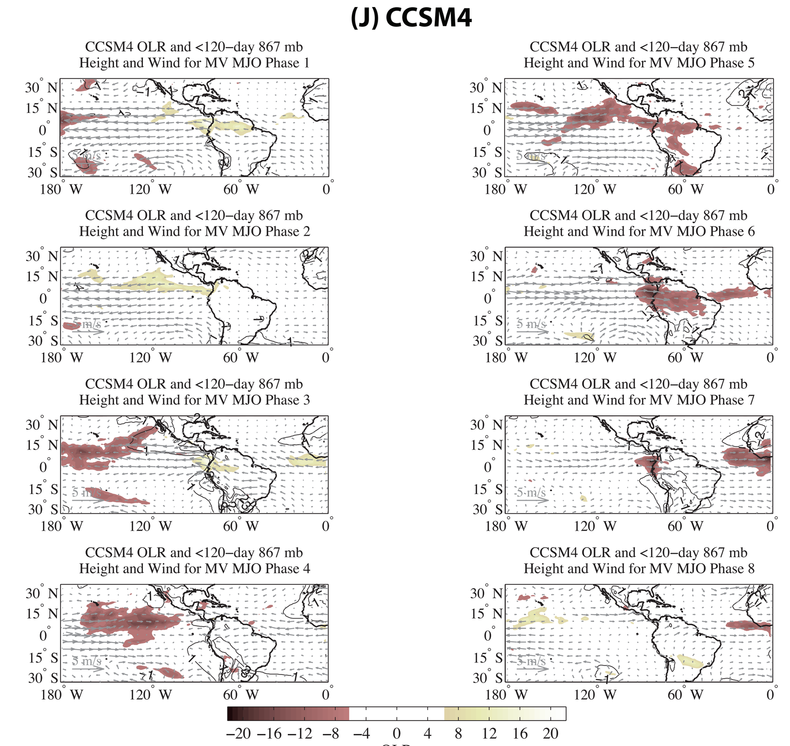
(H) NCEP/Obs OLR



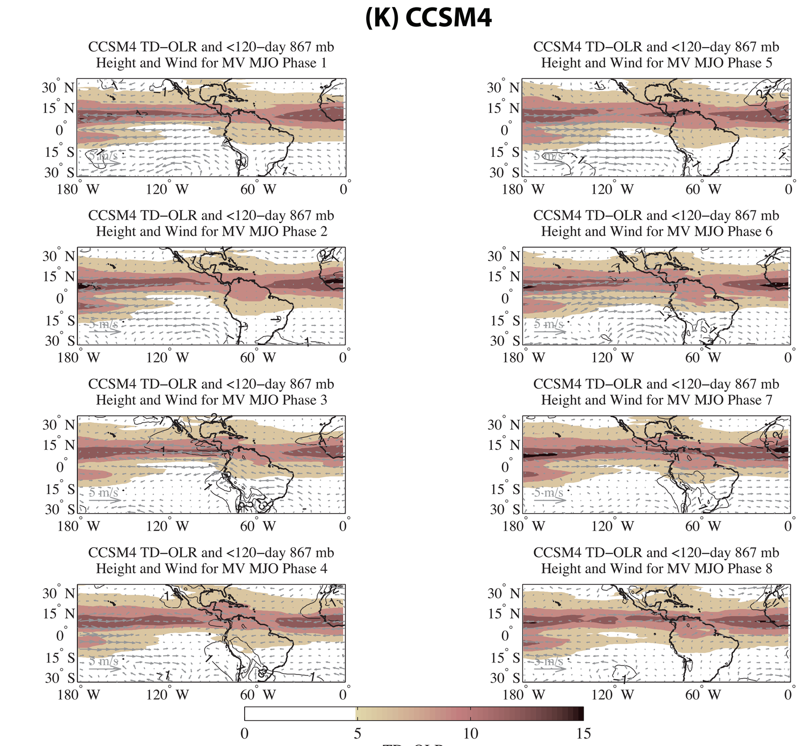
(I) NCEP/Obs OLR



(J) CCSM4

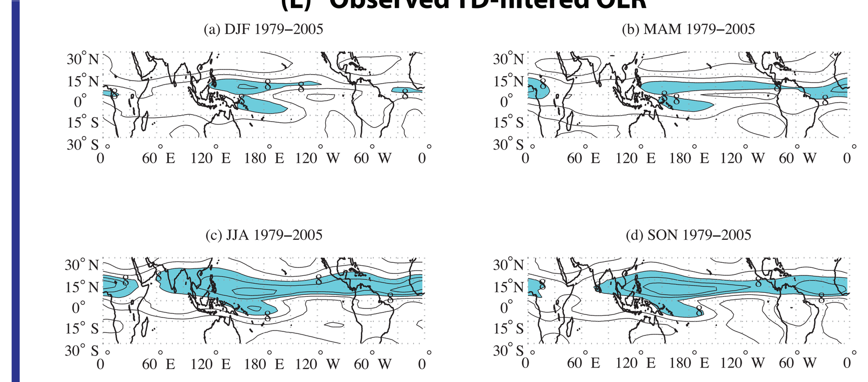


(K) CCSM4

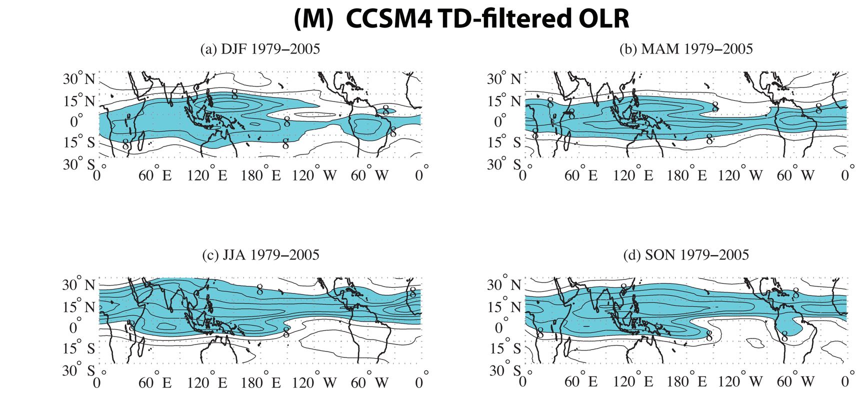


3. Tropical Storm Track

(L) Observed TD-filtered OLR

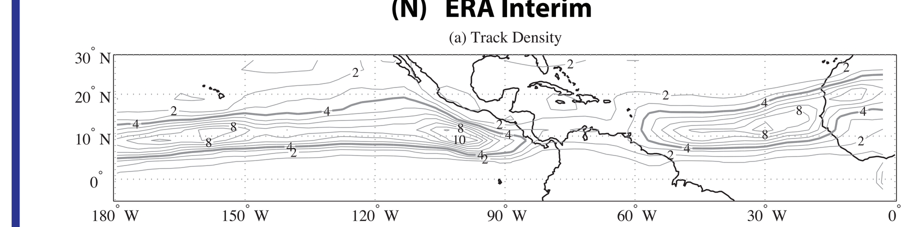


(M) CCSM4 TD-filtered OLR

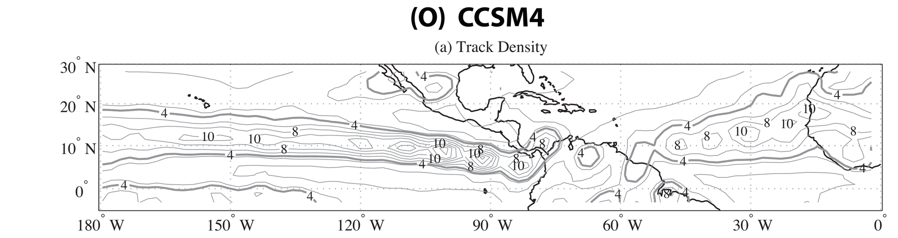


Here we look at the seasonal average of TD-filtered OLR in the CCSM4 and compare it to observed TD-filtered OLR. As indicated in the MJO composites, the TD-band has greater variance in the CCSM4 than in the observations. This is especially true over Indonesia and the western Pacific, where variance remains high throughout the year between 15°S and 15°N in the CCSM4. Across the western hemisphere a seasonal cycle is more evident but the variance remains higher than that for the observations. MAM in the CCSM4 differs the most from observations, with the SPCZ extending across the Pacific while the ITCZ stretches only into the central Pacific **(M)**. This is essentially the mirror image of MAM in the observations **(L)**.

(N) ERA Interim



(O) CCSM4



To investigate the tropical storm track more we calculate the track density in 867 hPa vorticity from CCSM4 following the method based on Hodges (1999) and described in Serra et al. (2010). These track densities are compared with ERA Interim track densities calculated from 4xdaily 850 hPa vorticity. The 75th percentile value is highlighted and is the same for both the observations and model. This is primarily the result of setting the track parmeters on the daily analysis such that a similar number of tracks resulted as in the 4xdaily ERAI data. Once the 4xdaily AR5 simulations are available from NCAR, we will be better able to compare the number of tracks. This comparison is useful primarily to compare the spatial distribution of tracks, and as can be seen, CCSM4 does reasonably well. At the 850 hPa level, easterly wave tracks initiate on the north side of the African Easterly Jet due to the mechanisms forcing the waves at this level (e.g. Pytharoulis and Thorncroft 1999). The CCSM4 follows this general pattern suggesting these mechanisms may be captured by the model. In the Northeast Pacific the model tracks do not remain as close to the coast of Mexico and Central America as seen in the observations. Aiyyer and Molinari (2008) find that tropical storm tracks are shifted along the coast of Mexico and even into the Gulf of Mexico during the westerly phase of the MJO. Thus, the tendency for the tracks to remain off the coast in **(O)** may be the result of the model's weak MJO.

4. Discussion

This study presents an evaluation of the CCSM4.0 20th Century simulations of the tropical storm track, with a focus on the Inter-Americas Sea. The purpose of this work is to inform future dynamic downscaling efforts of AR5 simulations in the region to investigate changes in easterly wave and tropical storm genesis mechanisms and in precipitation patterns associated with a warming climate.

Our evaluation of the CCSM4.0 1deg simulations suggests the following:

The model captures the primarily modes of seasonal and sub-seasonal variability of the CLLJ but with somewhat weaker amplitude.

The model has difficulty capturing the interannual variability of the jet. This may be associated with the model ENSO or NAO and needs to be further investigated.

The model MJO has a slightly higher frequency and weaker amplitude than the observations, but the phase of the sub-seasonal OLR with the upper- and low-level winds is encouraging and produces the general spatial and propagation features of the observed MJO.

Metrics of the tropical storm track suggest that the CCSM4 produces more convection in the easterly wave band than in the observations, but, with the exception of MAM, reproduces the seasonal variability rather well.

Track density statistics must be interpreted loosely since we are using daily time resolution model output. That being said, the model reproduces the spatial characteristics of the tropical storm track density over Africa but has difficulty over the Northeast Pacific. This difficulty may be associated with the model's weak MJO.

Future work will focus on evaluating other AR5 model 20th Century simulations and selecting the best performing models for dynamic downscaling studies focused on understanding furture climate forcing on the region.

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