Easterly wave contributions to seasonal rainfall over the tropical Americas in observations and a regional climate model

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Abstract

Easterly waves (EWs) are important moisture carriers and their variability can impact the total May–November rainfall, defined as seasonal precipitation, over the Tropical Americas. The contribution of EWs to the seasonal precipitation is explored over the tropical Americas using rain gauge stations, reanalysis data and a regional model ensemble during the 1980–2013 period. In the present study, EWs are found to produce up to 50% of seasonal rainfall mainly over the north of South America and contribute substantially to interannual regional rainfall variability. An observational analysis shows that the El Niño Southern Oscillation (ENSO) affects EW frequency and therefore, their contribution to seasonal rainfall. In recent years, tropical cyclone (TC) activity over the Main Development Region (MDR) of the tropical North Atlantic has a negative impact on regional seasonal precipitation over northern South America. High TC activity over MDR corresponds to below-normal precipitation because it reduces the EW activity reaching northern South America through the recurving of TC tracks. Recurving TC tracks redirect moisture away from the tropical belt and into the mid-latitudes. However, this relationship only holds under neutral ENSO conditions and the positive phase of the Atlantic Multidecadal Oscillation. A 10-member regional model multi-physics ensemble simulation for the period 1990–2000 was analyzed to show the relationships are robust to different representations of physical processes. This new understanding of seasonal rainfall over the tropical Americas may support improved regional seasonal and climate outlooks

Data and methods

1. Reanalysis and TRACK technique

The EW contribution to summer rainfall is estimated using the ERAI precipitation dataset. Following Thorncroft and Hodges (2001), the TRACK technique is implemented to objectively identify EW tracks over the 1980–2013 period. The criteria to define vorticity centers as EWs are: **1. Westward movement, 2. Lifetime of at least 2 days, 3. First detected points are over the oceanic domain 5°–20°N, 4. Vorticity centers are 2.0×10^{-5} s^{-1} or greater, 5. Systems travel at least 1000 km.**

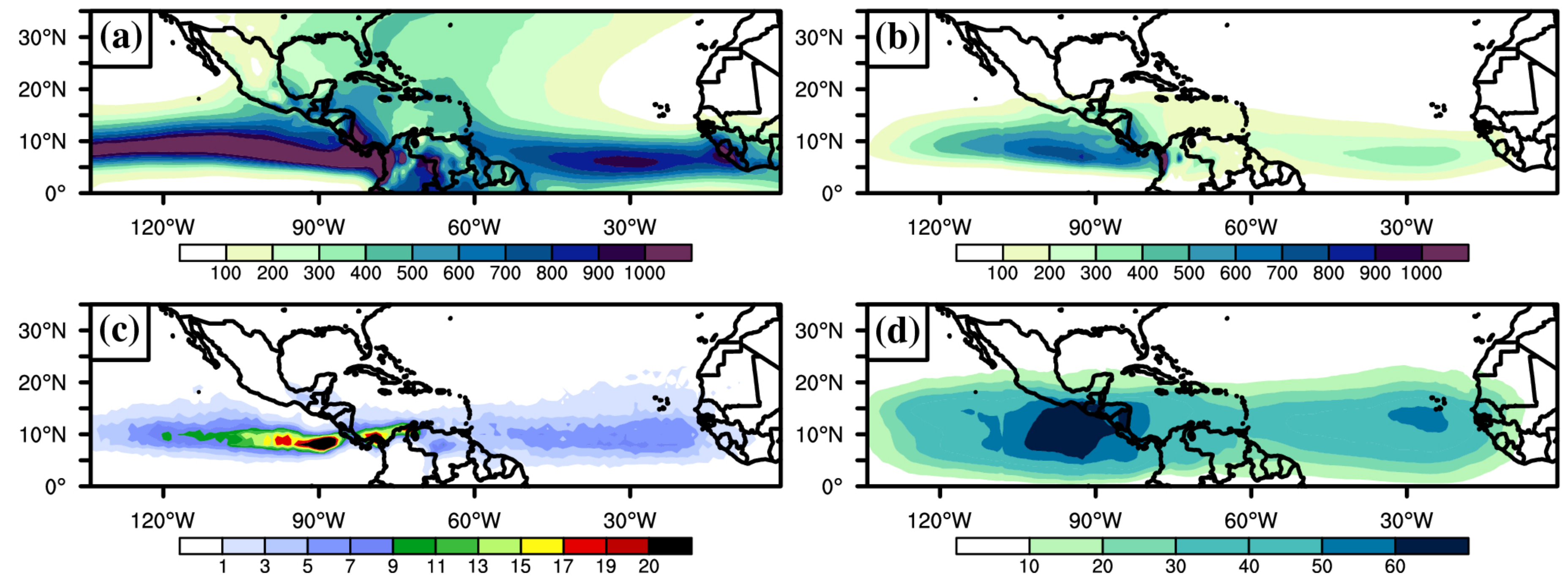
To identify TC tracks, hurricane matching is carried out by following the TC centers defined by the best-track database HURDAT of the National Hurricane Center in a grid of 2° × 2°. This helps to define which TCs came from EWs and remove the portions of TC tracks from our EW track database. Agudelo et al. (2011) suggested that a 15° × 15° region around the center of the wave can be used to capture the EW features.

2. Regional climate model experiment design

The Weather Research and Forecasting model was driven by the ERAI reanalysis for the 1990–2000 period. The Reynolds optimum interpolated analysis was used to force the RCM ensemble. Ten members have different physical parameterization schemes: ***(1) radiation scheme (CAM and RRTMG), (2) cumulus convection (Kain Fritsch, New Simplified Arakawa-Schubert, and Tiedtke); (3) microphysics (WRF Single-Moment 6-Class, and Thompson) and (4) planetary boundary layer (PBL) (Mellor-Yamada-Janjic, and Yonsei University). The Noah scheme was the only land surface scheme used for the experiments.***

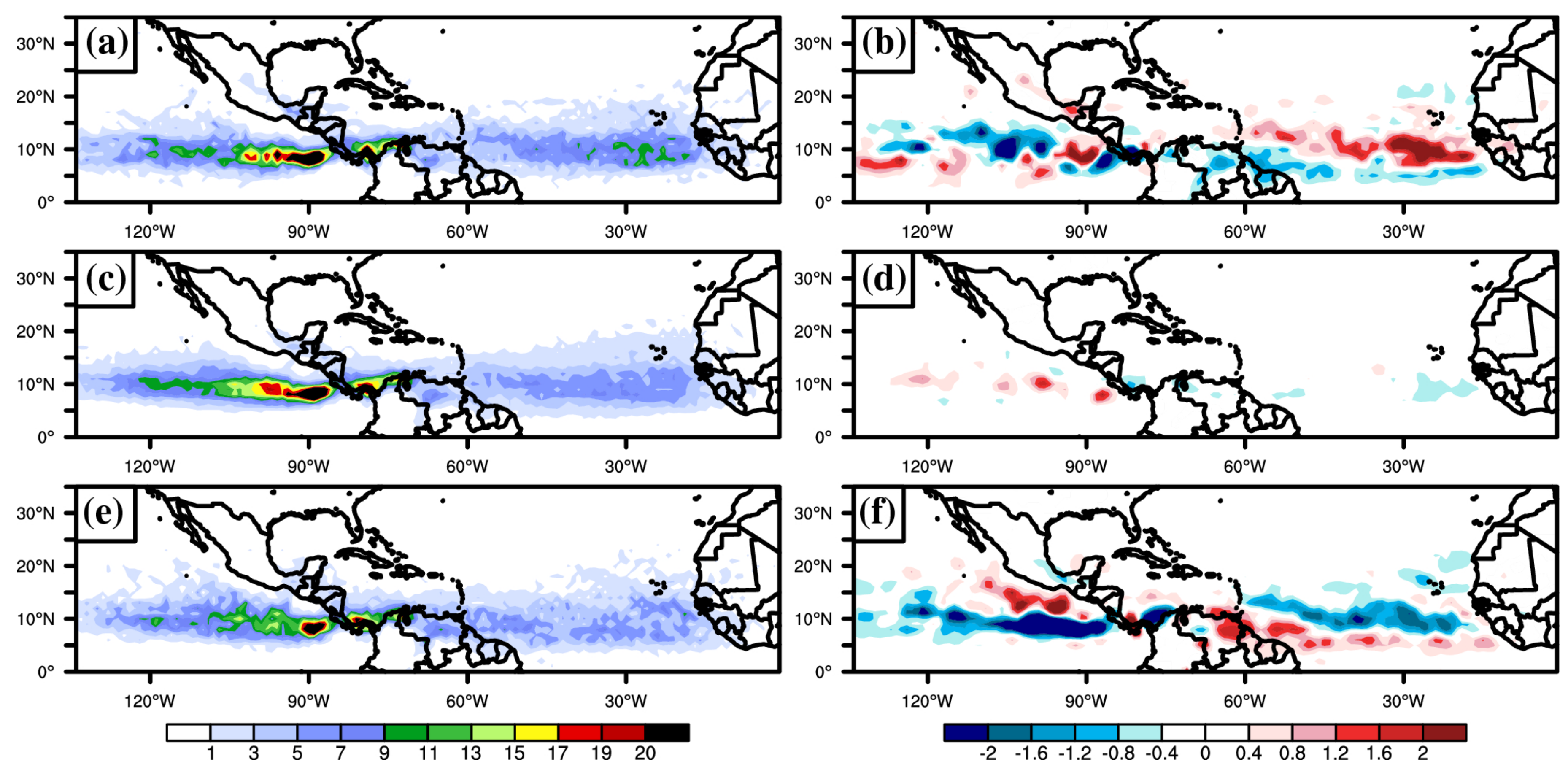
Results from observations

1. Easterly wave contributions to rainfall over the tropical Americas



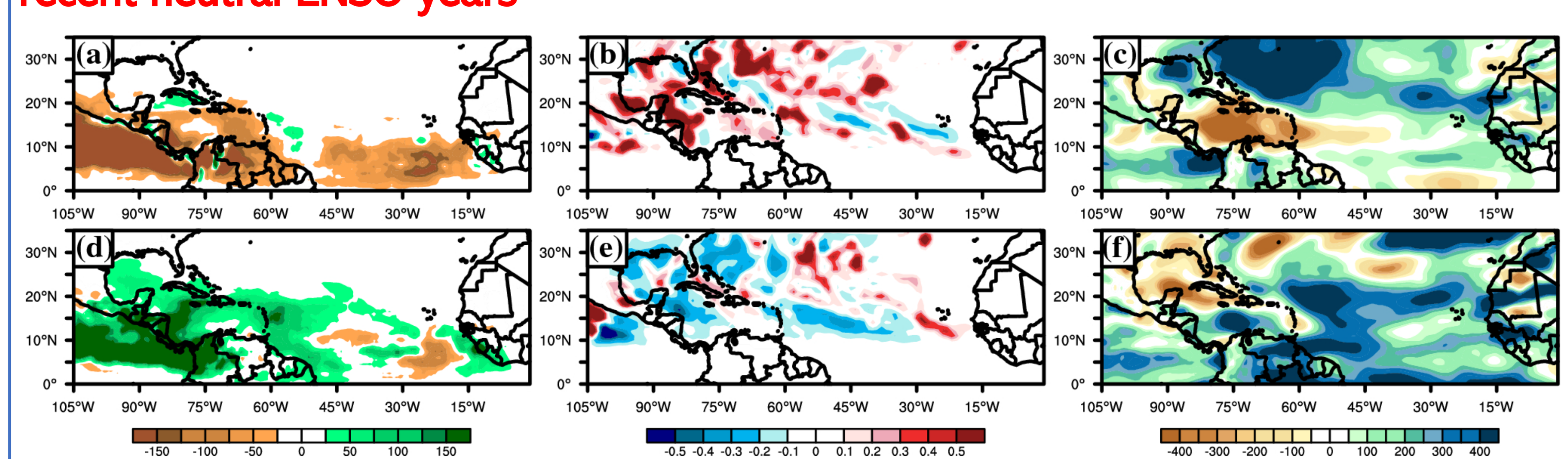
a Summer rainfall (mm), **b** summer rainfall (mm) produced by easterly waves, **c** annual average easterly wave track density, and **d** contribution (%) of easterly waves to summer rainfall. Data are shown for the 1980–2013 period using ERAI data

2. Relationship between ENSO and easterly wave activity over the tropical Americas



Annual average easterly wave track density for: **a** El Niño years, **c** neutral years, **e** La Niña years during the 1980–2013 period and the anomalies of easterly wave track density for **b** El Niño years, **d** neutral years and **f** La Niña years

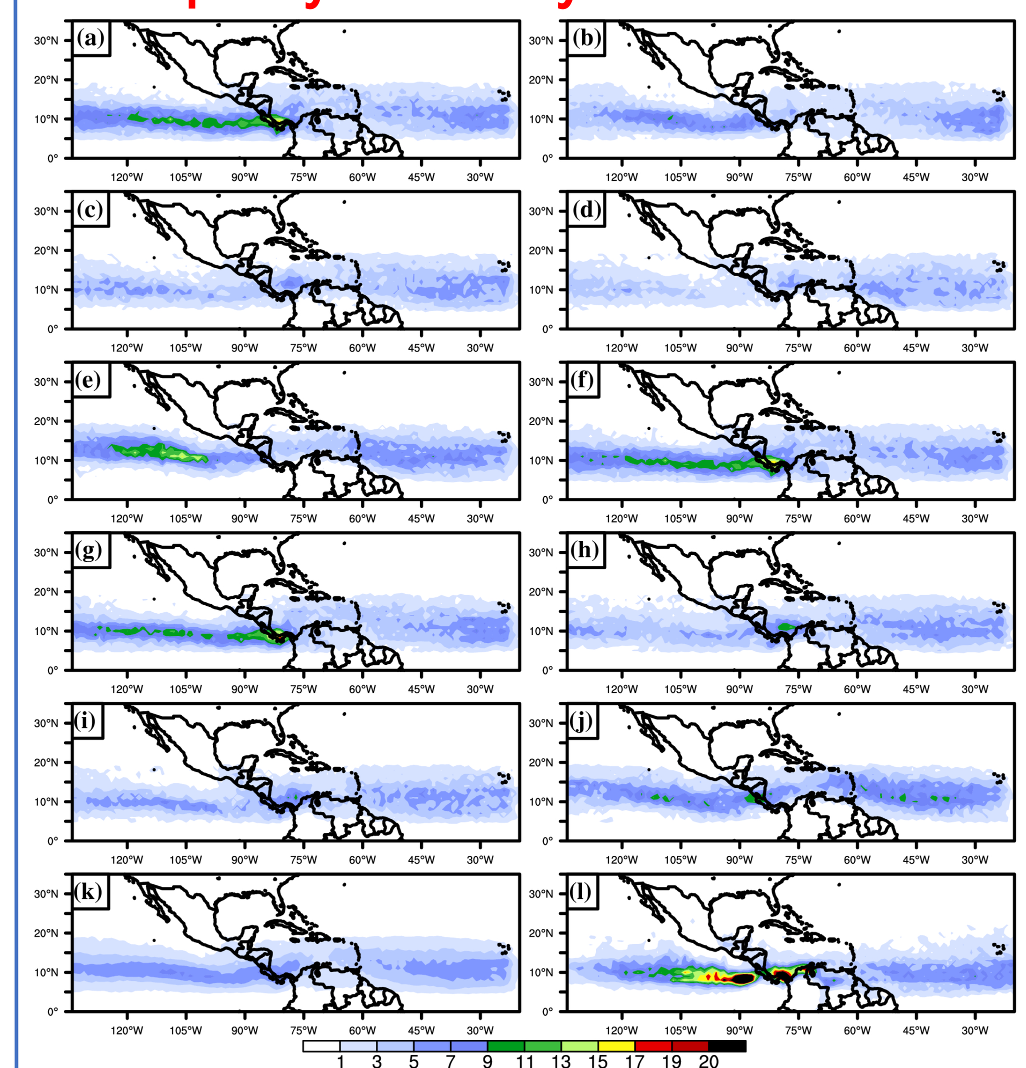
3. Relationships between easterly waves, TCs and regional precipitation during recent neutral ENSO years



Anomalies of seasonal rainfall (mm) associated with easterly wave tracks (**a**, **d**), anomalies of TC density (**d**, **e**), and anomalies of vertically integrated moisture flux (**c**, **f**, kg/m² s) for years of high TC activity: 2005, 2011 and 2012 (upper row), and years of low TC activity: 2006, 2008 and 2013 (bottom row) over the main development region

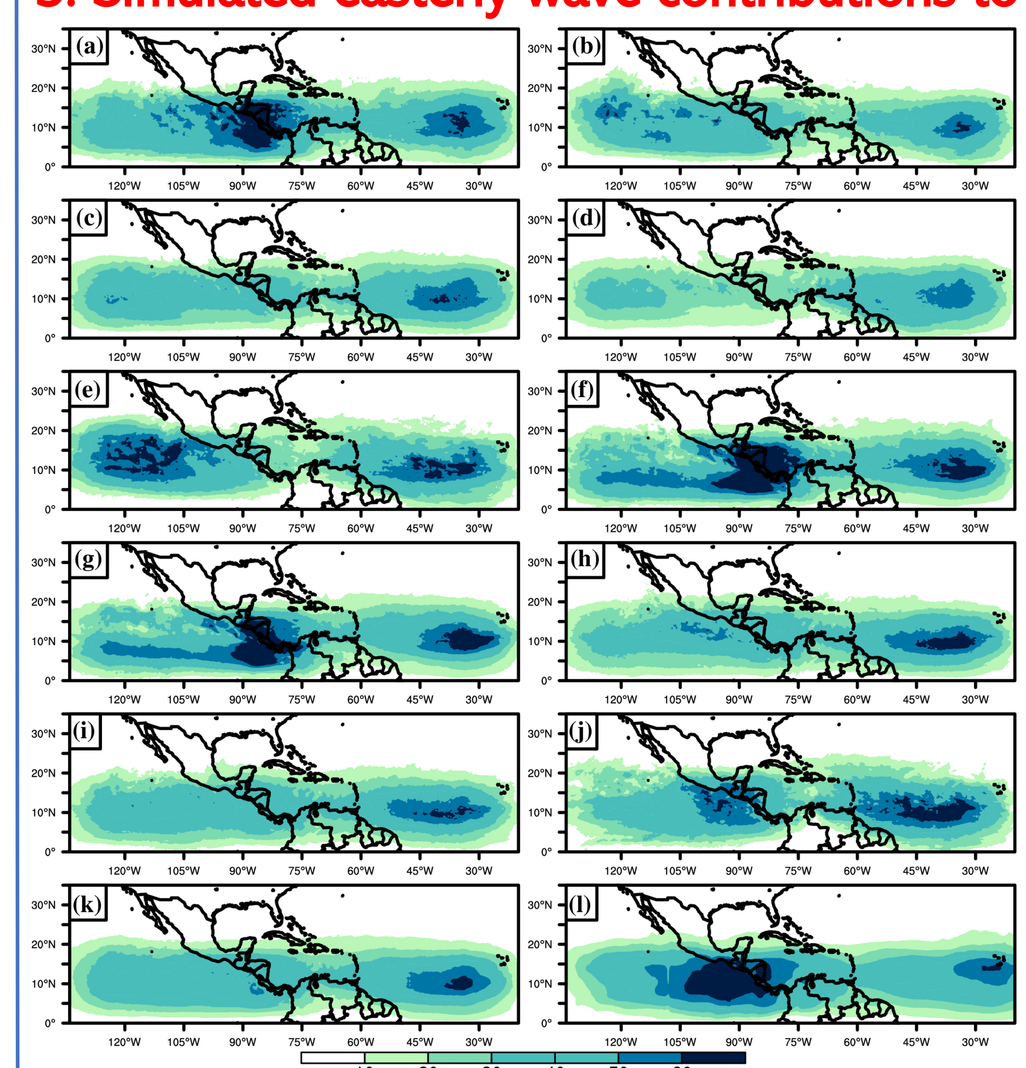
Results from RCM simulations

4. Frequency of easterly waves



Annual average density of easterly wave tracks in ten members of the RCM ensemble: **a** ck6m, **c** cktm, **e** cn6y, **g** cnty, **i** ctty, **b** rk6m, **d** rktm, **f** rn6y, **h** rnty, **j** rtty, **k** ensemble mean and **l** ERAI during the 1990–2000 period

5. Simulated easterly wave contributions to rainfall (%)



contribution (%) of easterly waves to summer rainfall in ten members of the WRF ensemble: **a** ck6m, **c** cktm, **e** cn6y, **g** cnty, **i** ctty, **b** rk6m, **d** rktm, **f** rn6y, **h** rnty, **j** rtty, **k** ensemble mean and **l** ERAI during the 1990–2000 period

Conclusions

- The accumulated seasonal rainfall depends on EW activity, since they produce up to 50% of the accumulated summer precipitation over TAs.
- ***More (less) TC tracks that curve into the mid-North Atlantic transport more moisture into the subtropics or mid-latitudes. This reduces (enhances) the chance of rain over the continental TAs because the number of EW days reaching this region is reduced (increased). This relationship is overwhelmed under strong El Niño or La Niña events and it is only valid after the year 2000 and under AMO+ conditions.***
- To complement the observational analysis, a multi-physics RCM ensemble simulation was used to (1) develop understanding of the extent to which RCMs can capture the EW–TC rainfall relationships, and (2) assess the strength of the physical mechanisms to different representations of physical processes.
- The simulated EW contribution to seasonal rainfall over TAs landmass is adequately captured by most of the members.

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