

Pacific Coastal Niños —
Drivers of Divergent Evolution and the Connection to
Westward Propagating El Niño Events

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Abstract

In the tropical Pacific, variability on interannual timescales is dominated by the El Niño-Southern Oscillation (ENSO). The warm phases of ENSO - El Niño events - are of importance for weather patterns around the world but differ strongly from one another. Warm El-Niño-like events along the South American coast, so-called Coastal Niños, can have similar impacts on the local precipitation but do not engage basin-wide air-sea dynamics. An extreme Coastal Niño occurred in February-March-April (FMA) in 2017, causing torrential rainfalls and flooding in Peru.

In this thesis, global climate models and reanalysis products are used to derive general mechanisms important for Coastal Niños. Most Coastal Niños do not show consequences as severe as the 2017 event. This can be attributed to the timing of the events. The event in 2017 occurred earlier (FMA) than other events observed, which tend to peak in boreal summer. This is found to be of great importance, as the 2017 events coincided with the climatologically warmest temperatures along the coast. Only during this season, warm anomalies can trigger strong atmospheric responses, causing strong convection and rainfall. During boreal summer, the sea surface temperature (SST) is too low and the cloudiness is dominated by stratiform clouds instead of convective clouds. Thus, the 2017 event represents an outlier among other Coastal Niños in terms of strength and timing.

Another distinct feature of Coastal Niños is the state of the central Pacific. During the 2017 event, the central Pacific was in a neutral state and turned into a weak La Nina state towards the end of the year. In contrast, in 2023 the central Pacific warmed following the Coastal Niño and by the end of the year a basin-wide El Niño was observed. This divergent evolution is well represented in the Community Earth System Model-Large Ensemble (CESM-LE). While reanalysis products suggest differences in oceanic heat content (OHC) as a key factor for the evolution, the CESM-LE suggests that large-scale background conditions and westward propagating equatorial Rossby waves are the main factors. Positive SST anomalies in the equatorial western Pacific and the Subtropical northeastern Pacific that go along with weaker northern hemispheric trade winds, favor the development of Coastal Niños into basin-wide events. Furthermore, a negative wind stress curl south of the equator in the eastern Pacific during the coastal events enhances the westward propagating Rossby wave, enabling it to disperse the anomalies from the coastal area.

Coastal Niños that develop into basin-wide El Niños can also be considered as westward propagating El Niño events, as they were predominantly observed before 1980. The El Niño event in 2023 closely resembles those events which occurred before 1980. Within this work, a new metric to track SST anomalies in the equatorial Pacific is defined for the clear definition of eastward and westward propagating events. Westward propagating events are the norm, driven by the climatological westward surface currents in the eastern equatorial Pacific. During eastward propagating events, these currents are reversed and the eastward propagating Kelvin waves are the main driver of zonal SST anomaly propagation. The decadal variability in the propagation of ENSO events can be attributed to the Pacific Decadal Oscillation (PDO). Between the late 1970s and 2000, the PDO was in its positive phase. This is associated with a warmer central Pacific, weaker trade winds and weaker zonal mean currents, which favors reversal of the currents. According to earlier studies, this current reversal is an exclusive feature of the extreme events in 1982/83 and 1997/98. In contrast, this study additionally shows reversed currents during two medium events in

1991/92 and 1994/95, which are identified to be westward propagating. In addition to the weaker mean current, the sensitivity of the current to the zonal wind is enhanced during the positive phase of the PDO. Thus, also weaker events can cause strong current anomalies, which possibly lead to a current reversal. Further, it is shown that equatorial Kelvin waves during boreal spring can effectively contribute to the westward propagation by causing a coastal warming at the onset of the El Niño event. Kelvin waves in boreal fall cause an immediate warming in the central Pacific, which is associated with the eastward propagation of El Niño events.

Overall, this thesis puts the warm events in the tropical Pacific of 2017 and 2023 into a broader context. It highlights the role of the 2017 Coastal Niño as an extreme event and strong outlier in terms of seasonality. The El Niño event in 2023 and its differences to other very strong events during the last decades are explained by decadal variability and the timing of equatorial Kelvin waves.