Ocean-Atmosphere Characteristics of Tropical Instability Waves Simulated in the NCEP Climate Forecast System Reanalysis

Caihong Wen
Climate Prediction Center, NCEP/NWS/ NOAA, Camp Springs, Maryland,U.S.A
Yan Xue
Climate Prediction Center, NCEP/NWS/ NOAA, Camp Springs, Maryland,U.S.A
Arun Kumar
Climate Prediction Center, NCEP/NWS/ NOAA, Camp Springs, Maryland,U.S.A

Abstract

Tropical instability waves (TIWs) are commonly observed mesoscale eddies as westward-propagating wavelike oscillations of SST front along the equatorial cold tongue in the Pacific and the Atlantic oceans. TIWs involve active air-sea coupling. There is an increasing need to understand and monitor TIWs due to their significant roles in modulating ocean momentum and heat exchanges as well as upwelling and nutrient supplies. However, the historical reanalysis data sets are incapable of adequately representing TIWs variability owing to their coarse resolution and lack of air-sea coupling. The NCEP Climate Forecast System Reanalysis (CFSR) represents a new effort with first guess from a high-resolution coupled system, and offers prospects for improved simulation, and monitoring of TIWs. This study aims to describe the climatological aspects of ocean-atmosphere co-variability associated with TIWs in the equatorial Pacific for the CFSR, and to assess how well they agree with in situ and satellite observations.

Multiyear daily high-resolution CFSR data is used to describe the temporal and spatial features of variability associated with TIWs. Results show that TIW-induced SST variations exhibit pronounced seasonal and interannual variability which are tightly connected with variations in the cold tongue. The analysis illustrates coherent patterns associated with TIWs both in ocean and atmosphere. An in-phase relationship between SST and wind speed is found in the CFSR, and the wind speed response to SST is on the order of 0.6 $ms^{-1o}C^{-1}$. Moisture and air temperature maximums are located west of SST maximums, leading to downstream displacement of surface pressure minimums to SST maximums. The magnitude of pressure perturbations reaches -10 $Pa^{o}C^{-1}$. The expected pressure-driven flow is in phase with SST, similar to the regression pattern of surface wind in the CFSR. The wind convergence and pressure field, together with changes in static stability set up a thermally direct circulation cell. The resultant vertical motion causes large variations in water vapor. Significant signals are observed in low-level cloud cover, which is closely in phase with surface wind convergence.

CFSR data also allows for a detailed investigation of thermodynamic feedback of surface heat fluxes associated with TIWs. Both latent and sensible heat fluxes are approximately out of phase with SST perturbations. TIW-induced water vapor perturbation is the primary factor contributing to changes in latent heat flux, while SST-induced wind perturbation plays a secondary role. The net surface heat flux is further modified by the formation of low-level clouds over warm water. The total surface net heat fluxes associated with TIWs are dominated by latent heat fluxes and have a large negative feedback on TIW SSTs (~40Wm^{-2} $^{o}C^{-1}$).

Comparisons with in situ observations reveal that the temporal variations of SST and wind anomalies are accurately replicated in the CFSR, although magnitudes are underestimated by about 25%. The magnitude of surface wind, surface pressure, and cloud cover response to TIW-induced SST agree well with in situ and satellite observations. It indicates that air-sea coupling processes associated with

TIW-induced SST and winds are well represented in the CFSR and the weak wind response might be attributed to weaker SST signals.

Our results highlight the capability of CFSR in capturing small-scale features involving ocean-atmosphere coupling associated with the tropical Pacific TIWs. The high resolution and long record (1982-2009) of CFSR provides an unprecedented opportunity to study the physical mechanisms of TIWs, as well as their influence on climate system.

Corresponding Author:

Name: Caihong Wen

Organization: Climate Prediction Center, NCEP/NWS/ NOAA, Camp Springs, Maryland, U.S.A

Address: 5200 Auth Road, 605A, Camp Springs, MD, 20745, USA

Email Address: Caihong.Wen@noaa.gov