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Atmospheric Manifestation of Tropical Instability Wave Observed by QuikSCAT and Tropical Rain Measuring Mission

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Abstract. Observations from two new spaceborne microwave instruments in 1999 clearly reveal the atmospheric manifestation of tropical instability waves north of the Pacific equatorial cold tongue. A unique zonal-temporal bandpass filter enables the isolation of the propagating signals and the determination of their phase differences. The phase differences between the propagation of wind and sea surface temperature (SST) signals observed from space and the vertical wind profiles measured from a research ship are consistent with the hypothesis that the coupling between wind and SST is caused by buoyancy instability and mixing, which reduces the wind shear in the atmospheric boundary layer. The coupling causes higher evaporative cooling over the warm phase and infers a negative thermal feedback.

1. Introduction

Tropical instability waves (TIW) vary in exact location and phase velocity. Such waves were best observed by radiometers on geostationary satellites as meanders of the temperature front between the cold upwelling water of the Pacific equatorial cold tongue and the warm water to the north [e.g., Legeckis, 1977; Yoder et al., 1994]. The waves propagate westward, with period of approximately 30 days, wavelength of 1100 km, and phase speed of 0.5 m/s. The waves are stronger from June to November and during La Nina episodes. Sea surface temperature (SST), however, is often obscured from visible and infrared radiometers by cloud cover. When such sensors are on polar orbiting spacecraft, many days of data are need to form a composite map of TIW.

The ocean circulation associated with TIW has been well studied using in situ measurements [e.g., Hansen and Paul, 1984; Halpern et al., 1988; Qiao and Weisberg, 1995; Flamant et al., 1996; Baturin and Niiler, 1997]. The TIW is believed to be generated by the shear of ocean currents and not by local winds. The atmospheric manifestations of the TIW were observed and inferred in a number of studies [e.g., Hayes et al., 1989; Deser et al., 1993]. The sparsity of historical ship data may have limited their use to seasonal and interannual variations of air-sea coupling. The studies of Halpern et al. [1988] and Hayes et al., [1989] were based only on mooring data at fixed locations.

Xie et al. [1998] identified TIW in the wind variations observed by the radar scatterometer on the European Remote Sensing (ERS-1) satellite. They found that the wind divergence patterns propagate westward with their centers sandwiched between the warm and cold poles of the SST. A scatterometer measures both wind speed and direction near the ocean surface. The ERS-1 scatterometer scans a 479 km swath and covers only 40% of the global ocean daily and the wind vector retrieved has a resolution of 50 km. The weekly averaged winds used by Xie et al. [1998] can barely resolve TIW and is not adequate for reliable determination the relative phase between wind and SST, which is key to infer physical mechanism.

Because the atmosphere and the clouds are transparent to microwave, the coincident measurements of two spaceborne microwave instruments during the La Nina episode in the second half of 1999 provided the unprecedented opportunity to observe the influence of the SST front on atmospheric parameters, under both clear and cloudy conditions. The microwave imager on the joint US/Japan Tropical Rainfall Measuring Mission (TRMM) has provided measurements of SST, surface wind speed (WS), and integrated water vapor (WV) in the atmosphere since November 1997. The low-inclination orbit of TRMM is designed to give an optimal sampling rate for monitoring diurnal variations. A radar scatterometer called SeaWinds was launched in June 1999 on NASA's QuikSCAT mission. It has a continuous swath of 1,800 km, providing wind vector measurements at 25 km resolution over 90% of the global ocean daily.

The satellite data also aided the planning of a research cruise on Japan Fishery Agency's R/V Shoyo Maru to observe the vertical structures of the TIW-induced atmospheric waves for the first time. This paper reports briefly on the analysis of the satellite and in situ data with respect to hypotheses on the atmospheric manifestation of oceanic TIW.

2. Hypotheses

There are two hypotheses on the relation between SST and surface winds over tropical oceans. As illustrated by

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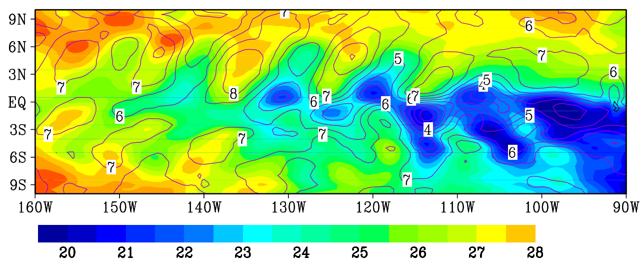
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satellite data. The standard deviation of the wind averages at the surface are 0.5 m/s over warm water and 0.8 m/s over cold water; standard deviations in the lowest 300 m are very consistent with these values. Without band-pass filtering, high-level winds are more susceptible to the influences of non-local circulation. The model simulation by Xie et al. [1988] indicated a vertical phase-shift in the profiles of wind anomalies. The one-time cruise section may not have sufficient sampling to reveal two-dimensional changes.

6. Conclusion

Coincident all-weather observations by a spacebased microwave scatterometer and a microwave radiometer during a La Nina episode reveal clearly the atmospheric manifestation of TIW in surface wind vectors and integrated water vapor. The phase differences between wind components and SST determined from the spacebased data and the wind profiles measured on a research cruise are consistent with the hypothesis that buoyancy instability over warm region of TIW reduces vertical wind shear in the atmospheric boundary layer. LH is found to be in phase with SST and WS with possible negative feedback.

The TIW-induced wind fluctuation is about 2 m/s. The ability to detect the spatial structure of this fluctuation on a daily basis as demonstrated in Section 4 attests unprecedented accuracy and time-space resolution of SeaWinds measurements.

This study was confined to the TIW north of the equator in the Pacific, but similar air-sea coupling is obvious south of the equator in Fig. 1, 3, 4 and 5. Atmospheric responses to the TIW in the South Pacific and the Atlantic were investigated by Hashizume et al. [2000].

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