Observation of 4-5 Day Meridional Wind and Surface Stress Oscillations During Nauru99

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Introduction

The existence of the easterly wave disturbances in the Tropical Western Pacific (TWP) has been recognized since early studies in the 1940s and 1950s (e.g., Riehl 1945). These synoptic-scale disturbances are westward propagating organized structures moving parallel to the equator. They are observed within the intertropical convergence zone (westward direction is associated with the trade winds) and propagate vertically into the stratosphere. Until the early 1980s, knowledge of these westward traveling wave disturbances was based on meteorological in situ observations. Recent accumulation of satellite data and remote sensing measurements revealed that these disturbances are closely associated with cumulus convective activity. Cloud clusters are clearly visible in cloudiness plots viewed from satellites. Spectrum analysis based on the satellite-observed outgoing longwave radiation is a proxy for cloudiness and a useful method for time-longitude analysis of the tropical disturbances (Wheeler and Kiladis 1999).

There are several types of tropical oscillations with different scales and different maintenance mechanisms. The waves range from lower-frequency Rossby and Kelvin waves, with periods on the order of a week, to the higher-frequency mixed Rossby-gravity and inertio-gravity waves, with periods of a day or a few days. Traditionally, “easterly waves” are associated with organized convection. Morphology of the convectively coupled equatorial waves can be found in Wheeler et al. (2000).

In this paper, we examine near-surface manifestations of atmospheric waves. The waves propagated to the west during 3- to 5-day periods and were identified as a mixed Rossby-gravity (MRG) waves. Perhaps the MRG waves received the most attention in literature (e.g., Takayabu and Nitta 1993, Dunkerton and Baldwin 1995).

Nauru99 Measurements

In this study, we describe observations of 4- to 5-day meridional wind and surface stress oscillations in the marine surface layer. The study is based on the direct measurements made by the National Oceanic and Atmospheric Administration (NOAA) Environmental Technology Laboratory (ETL) air-sea interaction group on board the NOAA Research Vessel (R/V) *Ronald H. Brown* during the Nauru99 experiment. The Nauru99 cruise took place from June to July 1999 in the TWP. The ship departed Darwin June 15 and arrived at atoll Kwajalein July 19. The main measurement sites were centered around the island of Nauru. The R/V *Ronald H. Brown* ship track is shown in Figure 1. The ETL ship-based air-sea interaction system was used for bulk meteorology, radiative, and turbulent flux measurements with additional measurements provided by the ship's operational instruments. The turbulent sensors were mounted on a forward-facing boom on the ship's jackstaff (17.5 m above sea surface) at the most forward and best exposed location on the ship. In situ observations from the ship were accompanied by the remote sensing of the lower atmosphere and the radiosonde measurements. Between 4 and 8 sondes were released per day providing wind structure, temperature, and humidity profiles. The measurements made on board the NOAA R/V *Ronald H. Brown* were accompanied by similar measurements from the Japanese R/V *Mirai*. Preliminary results of the surface flux measurements made in Nauru99 are described in Fairall et al. (2000).

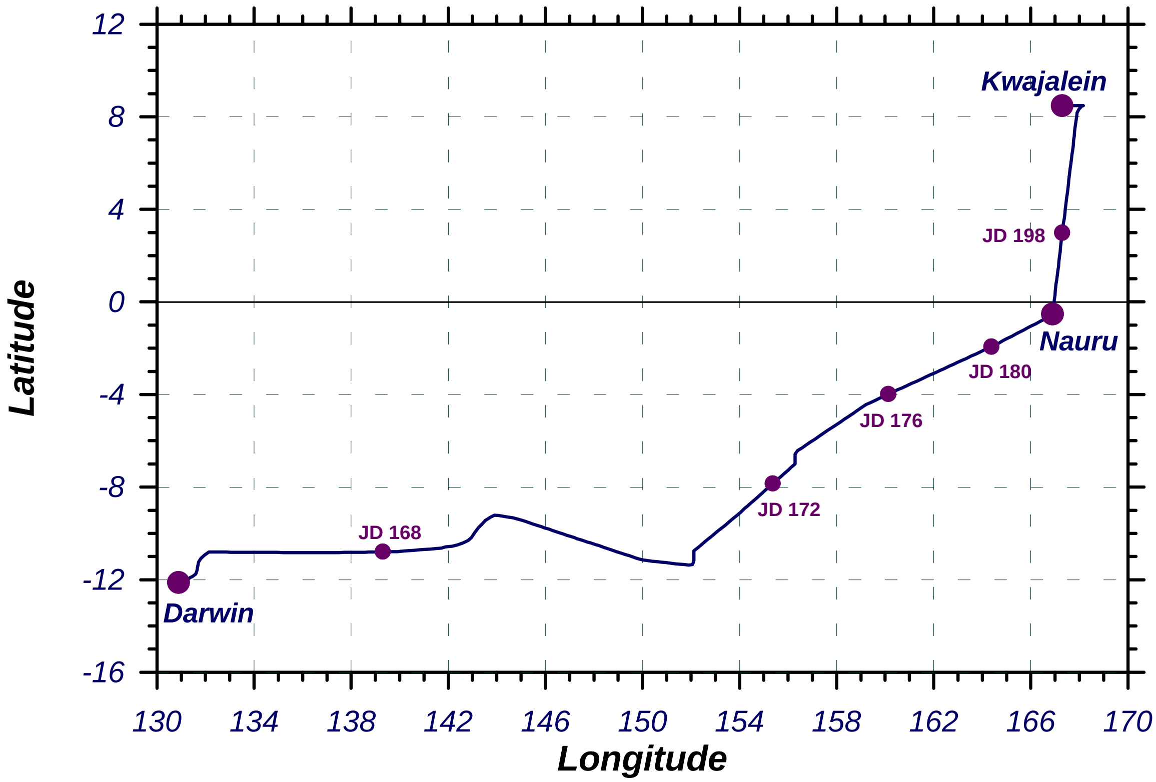

Figure 1. The R/V *Ronald H. Brown* ship track during Nauru99.

Data Analysis

Figure 2 shows the entire time series for wind speed (a) and wind direction (b). Data are based on the individual 1-hour-averaged observations made with a sonic anemometer. The most prominent result from Figure 2 is that the true wind direction oscillates between about 60° and 120° within a period of 4-5 days. All angles are calculated using the meteorological convention ("from"), e.g., 90° means wind (or stress) is from the east. Practically the same behavior of wind speed and direction is obtained by the ship's meteorological slow response sensors. Four-to five-day-period oscillations of the wind direction are also observed in the meteorological data obtained on board the R/V *Mirai*. However, these oscillations are not as regular as in the R/V *Ronald H. Brown* case. This may be because of the different locations of the two ships. Because measurements were made from a moving platform, we may estimate the area where the oscillations have been observed (cf. Figures 1 and 2). After the ship departed Darwin Port and sailed near Australia, Papua New Guinea, and the Solomon Islands wind direction was about

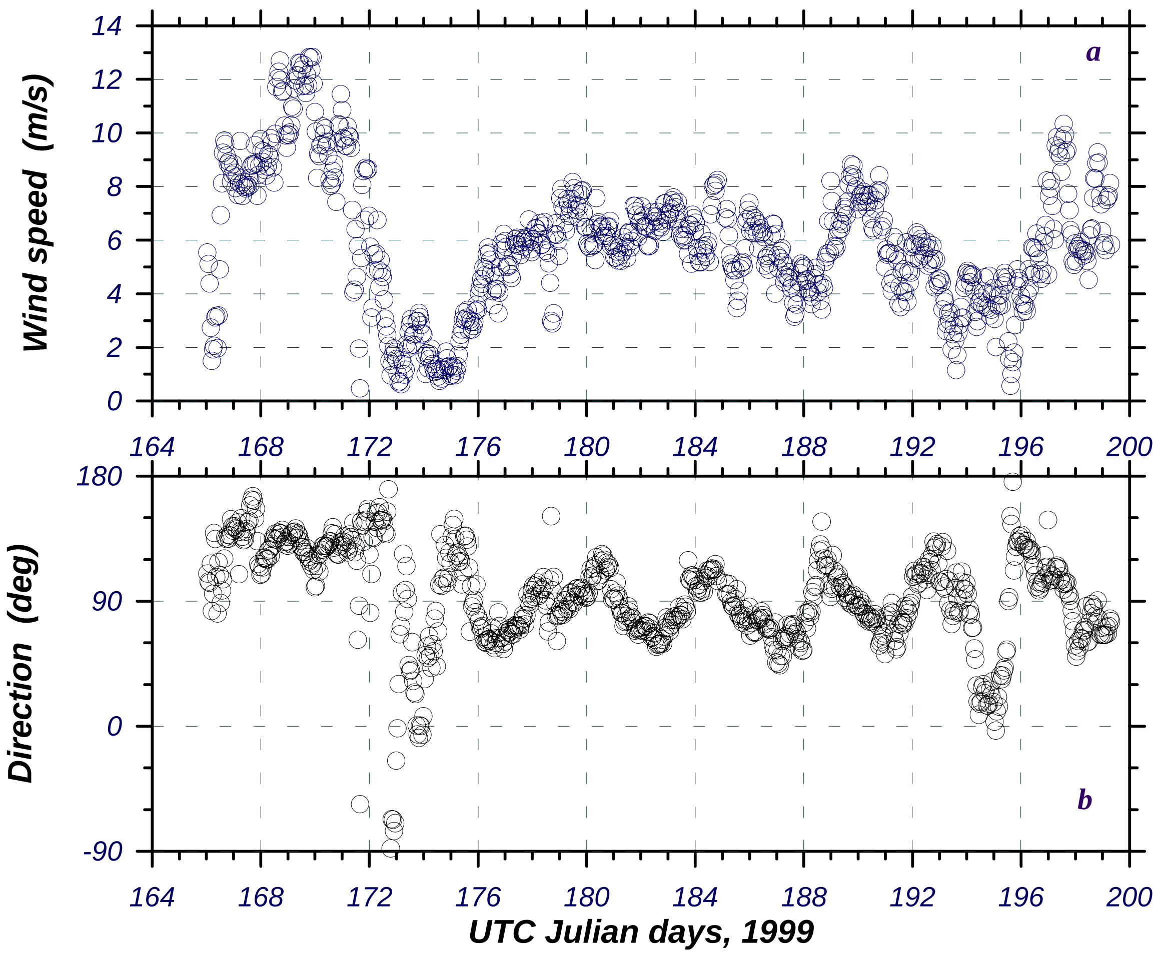

Figure 2. Time series of the (a) wind speed and (b) true wind direction obtained on board the R/V *Ronald H. Brown* during Nauru99. Measurements were made by a sonic anemometer located 17.5 m above the sea surface.

constant and predominantly from the southeast. During Julian days (JD) 173-175, the weather conditions were calm. The oscillations were observed when the ship crossed north of about 5° S and 160° W and wind had risen to 6-8 m/s. It is worth mentioning that the Nauru Island effect has minimal impact on the observed meridional wind oscillations. For about 2 weeks the ship was in the vicinity of the island including special examination of island effects during JD 191-192 and JD 194-195. Note that 4- to 5-day wind oscillations were also observed from the data obtained by radiosonde launched from the ship (Westwater et al. 2000). We suggest that observed 4- to 5-day meridional wind oscillations are associated with MRG waves. This issue is also discussed by Boehm and Verlinde (2000) in connection with observed periodic cloud clusters during Nauru99.

Figure 3 presents a time series of the downwind stress component and direction of the stress vector, based on the eddy-correlation measurements with a sonic anemometer. Figure 3 shows that wind speed oscillations cause similar variations of the wind stress exerted on the sea surface. One may suggest that oscillations of the surface stress vector may cause similar oscillations of the surface currents in the

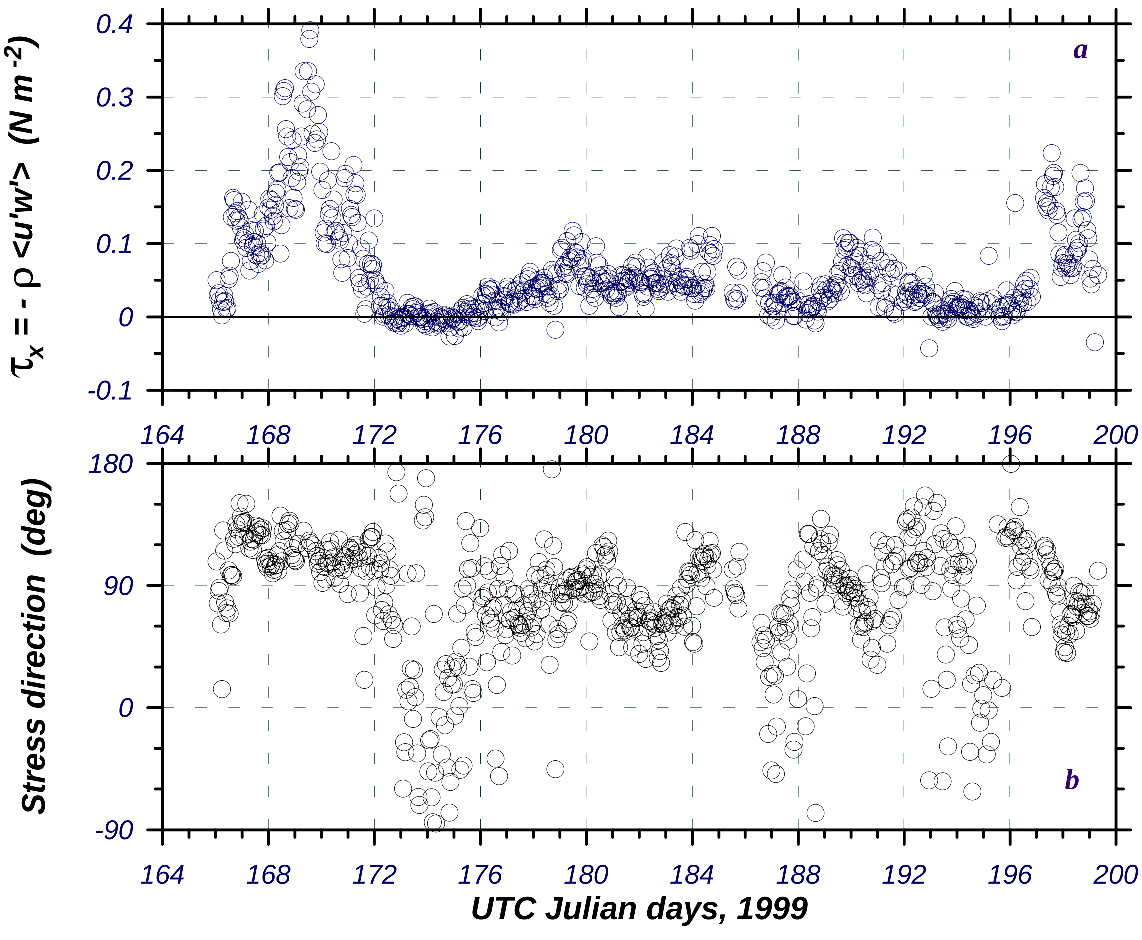

Figure 3. Time series of the (a) downwind stress component and (b) true direction of the stress vector obtained on board R/V *Ronald H. Brown* during Nauru99.

ocean. Some scatter of the stress vector direction is associated with the influence of waves during light wind periods. The stress vector direction during light winds is governed by both the swell direction and the wind direction. Grachev and Fairall (2001) showed that the light wind-speed regime at sea is frequently characterized by an inverse (upward) momentum flux when momentum is transported from ocean to atmosphere and accelerated air (wave-driven wind). Figure 3a shows that this has occurred during JD 171-175, 188, and 194-195.

Conclusions

Data collected during Nauru99 were used to investigate synoptic-scale disturbances in the TWP. Measurements made on board the NOAA ship *Ronald H. Brown* near Nauru Island, between 2° S and the equator clearly reveal westward propagating organized structures moving parallel to the equator. It is found that the true wind direction oscillates between about 60° and 120° within a period of 4-5 days. The typical mean wind speed was about 4-8 m/s at the measurement height 17.7 m above the sea surface. Eddy-correlation measurements show that wind speed oscillations cause similar variations of the wind stress exerted on the sea surface. Previous research shows these tropical oscillations are associated with MRG-wave type disturbances. It is suggested that MRG waves are responsible for the development of organized cumulus cloud clusters in the tropical Pacific. The Nauru Island effect has minimal impact on the observed meridional oscillations of the wind and the stress.

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