5.4 MERIDIONAL WIND AND SURFACE STRESS OSCILLATIONS IN THE MARINE BOUNDARY LAYER INDUCED BY EASTERLY WAVES OVER THE TROPICAL PACIFIC

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1. INTRODUCTION

Determining the wind stress, sensible and latent heat fluxes over oceans is a fundamental problem in the modeling of the coupled atmosphere-ocean system. Understanding of the air-sea fluxes at different temporal and spatial scales is of obvious relevance for climate modeling, weather forecast, and other applications. The wind stress exerted on the ocean surface is a key parameter for physical processes in both atmospheric and oceanic boundary layers, including generation of the surface waves and local ocean currents. Traditionally fast-response instruments such as sonic anemometers and infrared (or Lyman α) hygrometers with sampling rates of 10 – 20 Hz are used to derive fluxes via eddy-correlation method based on the 1 hour averaging. In this study, we used 1-hr averaged statistics to study oscillations of the wind speed and surface stress in the marine boundary layer on scales 4–5 days based on the measurements made in the Western Pacific.

The existence of the easterly wave disturbances in the Tropical Western Pacific has been recognized since early studies in 1940–50s. 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 close 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 the 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.

2. MEASUREMENTS

In this study, we describe observations of 4–5 day meridional wind and surface stress oscillations in the marine boundary layer. The results are based on the direct measurements made by the NOAA Environmental Technology Laboratory (ETL) air-sea interaction group onboard NOAA R/V *Ronald H. Brown* during the Nauru99 experiment. The Nauru99 cruise took place in June – July 1999 in the tropical Western Pacific. The ship departed Darwin June 15 and arrived to atoll Kwajalein July 19. The main measurements sites were centered around the island of Nauru.

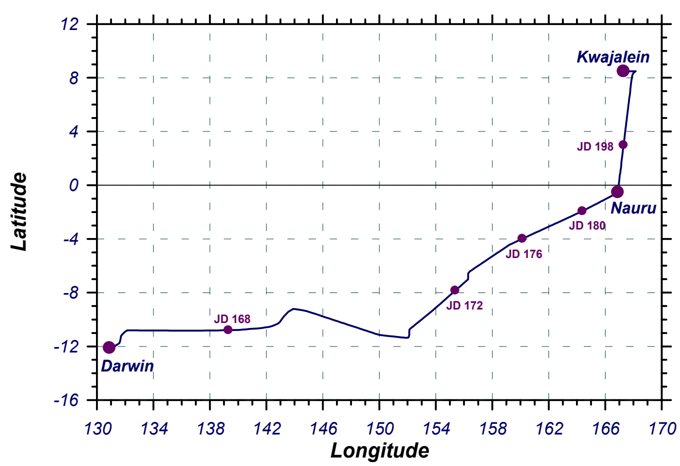

Fig.1. The R/V *Ronald Brown* ship track in the Nauru99 Experiment.

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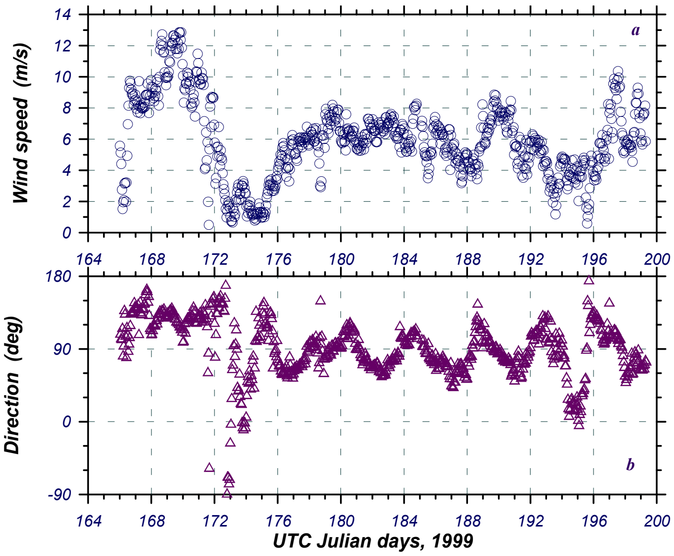

Fig.2 Time series of (*a*) the wind speed and (*b*) the true wind direction obtained onboard R/V *Ronald Brown* during the Nauru99 Experiment. Measurements were made by a sonic anemometer located 17.5 m above the sea surface.

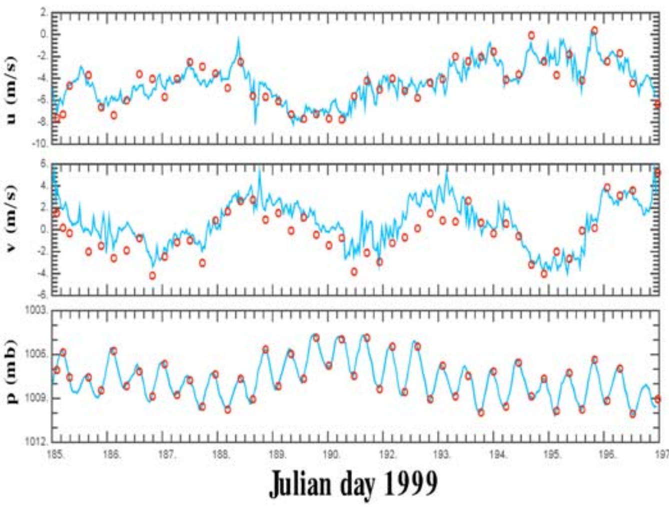

Fig.3 Time series of the zonal (upper panel) and meridional (middle panel) wind speed components, and the air pressure (bottom panel) obtained onboard R/V *Ronald Brown* during the Nauru99 Experiment. Dots are data obtained from the radiosondes near the surface and the solid lines from the ship's meteorological sensors.

The R/V *Ronald 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. Preliminary results of the flux measurements made in Nauru99 and some other ETL expeditions are described in Hare et al. (2000). The measurements made onboard NOAA R/V *Ronald Brown* were accompanied by similar measurements from Japanese R/V *Mirai*.

3. 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 fast-response sonic anemometer. The most prominent result from Figure 2 is that the true wind direction oscillates between about 60° and 120° with a period of 4–5 days. All angles are calculated using the meteorological convention ("from"), e.g. 90° means wind (or stress) is from east. Practically the same behavior of the wind direction is obtained by the ship's meteorological slow response sensors and radiosondes launched from the ship (Fig. 3). Note that 4–5 day oscillations were also observed in the pressure time series (Fig. 3). Since measurements were made from the moving platform we may estimate the area where the oscillations have been observed (cf. Figs. 1 and 2). After the ship departed port Darwin and sailed near Australia, Papua New Guinea, and the Solomon Islands wind direction was about constant and predominantly from SE. 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 increased to 6–8 m/s. During JD 174–181 the ship was located at coordinates about 2°S and 164.5°E. For about two weeks, JD 182–197, the ship was in the vicinity of the island (0.5°S and 167°E) including special examination of island effects during JD 191–192 and JD 194–195. It is worth mentioning that Nauru Island effect has minimal impact on the observed meridional wind oscillations. 4–5 day-period oscillations of the wind direction are also observed in the meteorological data obtained onboard R/V *Mirai* (Fig. 4). However, these oscillations are not quite so regular as in the R/V *Ronald Brown* case (Figs. 2 and 3). This may be because of different locations of the two ships. During JD 168–170 R/V *Mirai* sailed around Nauru Island and than moved to the observation point with coordinates 0° and 165°E. Thus the effect is observed to be stronger in the belt 0.5°S–2°S rather at the equator. Boehm and Verlinde (2000) are also discussed this effect in connection with

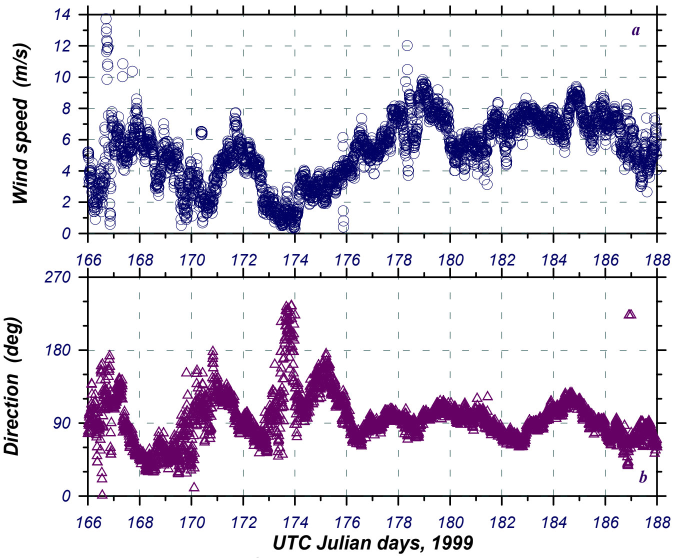

Fig.4 Time series of (*a*) the wind speed and (*b*) the true wind direction obtained onboard R/V *Mirai* during the Nauru99 Experiment. Measurements were made by a convention slow-response anemometer (10-min data).

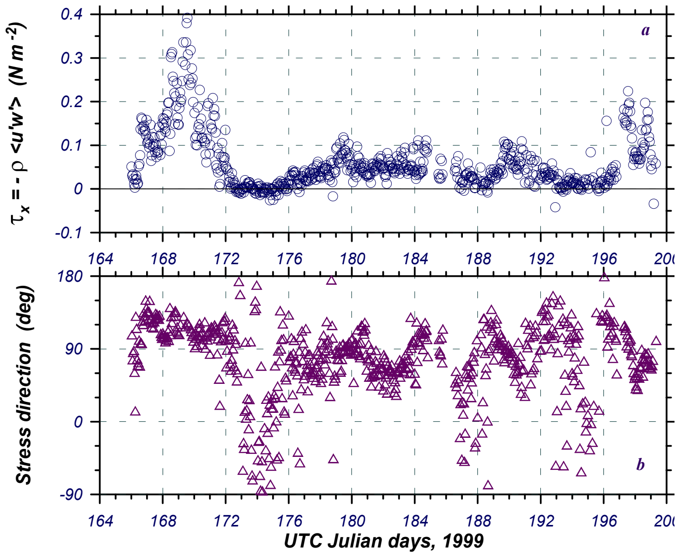

Fig.5. Time series of (*a*) the downwind stress component and (*b*) the true direction of the stress vector obtained onboard R/V *Ronald Brown* during the Nauru99 Experiment.

observed periodic clouds cluster during Nauru99 Experiment.

Figure 5 presents time series of the downwind stress component and direction of the stress vector, based on the 1-hr eddy-correlation measurements with a sonic anemometer. Figure 5 shows that wind speed oscillations results in the similar 4–5 days 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 ocean. Some scatter of the stress vector direction is associated with 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 accelerate air (wave-driven wind). Figure 4a shows that this is occurred during JD 171–175, 188, 194–195.

4. CONCLUSIONS

Data collected during the Nauru99 program were used to investigate synoptic-scale disturbances in the Tropical Western Pacific. Measurements made onboard the NOAA ship *Ronald 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° with 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 surface. Eddy-correlation measurements show that wind speed oscillations cause similar variations of the wind stress exerted on the sea surface. Previous research has shown that these tropical oscillations are responsible for the development of organized cumulus cloud clusters in the tropical Pacific. Nauru Island effect has minimal impact on the observed meridional oscillations of the wind and the stress.

4. REFERENCES

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