Air–Sea Measurements from Moored Surface Buoys During the 2010 Pacific Typhoon Season

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INTRODUCTION

It is recognized that there is a lack of knowledge of the physics of air-sea exchange at wind speeds above gale force (Black et al., 2007). In order to try and fill this void in our understanding two pairs of buoys were deployed in the Philippine Sea, ~740 km east of Southern Taiwan, as part of the Impact of Typhoons on the Ocean in the Pacific (ITOP) experiment. Each mooring consisted of an Extreme Air-Sea Interaction (EASI) buoy, (Drennan and Williams 2008), and an Air-Sea Interaction Spar (ASIS) buoy, (Graber et al. 2009).

The northern mooring was located at 21.23°N, 126.96°E in 5608 m water depth and the southern mooring was located at 19.63°N, 127.23°E in 5128 m water depth. EASI buoys were anchored to the seafloor via ~800 m of line allowing them to move freely upon the surface. ASIS were tethered to their respective EASI with a horizontal separation of ~60 m. Distance between moorings was approximately 180 km. The north mooring collected data from August 3rd to November 15th, 2010 (DOY 213–326), while the south mooring collected data from August 4th to November 22nd, 2010 (DOY 216–326). ASIS south and north broke loose on October 19th and September 19th, respectively, and were subsequently recovered. Figure 1 shows a typical ASIS-EASI mooring configuration.

Both moorings were in place and operational during the passage of four major storms: tropical storm Dianmu, typhoon Fanapi, super typhoon Megi, and typhoon Chaba. Corresponding storm tracks were as close as 68 km from the buoy locations according to the Joint Typhoon Warning Center, (Angrove and Falve, 2010). See Figure 2. Significant wave heights over 10 m were recorded as were maximum wind speeds exceeding 25 m/s (30 minute average) with instantaneous gusts exceeding 35 m/s.

OCEAN TEMPERATURE MEASUREMENTS

A combined thirty-seven subsurface temperature sensor/data loggers were connected intermittently to the mooring line in the upper ~150 m of the ocean. Sensors sampled at rates from 4 seconds to 8 minutes and were calibrated pre- and post-deployment in a high precision bath.

The sensor arrays included RBR-TDR200 dual channel temperature, pressure loggers from which depth was determined. Fitting a quadratic to the mean depths of these loggers, as a function of their position on the mooring line, the mean depth of all sensors was determined.

Of the thirty-seven original bottom surface sensors thirteen failed during the experiment. This was likely due to intense vibration of the near-surface mooring line. The depth of the remaining sensors, as a function of time, for the north (left) and south (right) moorings are shown in Figure 3.

Profiling Sea Surface Temperature, Mixed Layer Depth

• Upper ocean temperature profiles were created by linearly interpolating through the water column between adjacent sensors.
• Sea surface temperature was assumed to be equal to temperature recorded by the shallowest sensor at each mooring (~1 m).
• Mixed layer depths (MLD) were estimated to be the depth where temperature is ~0.5°C below SST, following the work of Levitus (1982), amongst others.

Figure 4 show SST, ocean temperature with MLD, and wind speed (red) for the north and south moorings. Timing of the named storms are also shown.

REFERENCES


CONCLUSION

The deployment of EASI and ASIS in the Philippine Sea during the 2010 typhoon season resulted in a unique and varied data set which reflects the interaction between the ocean and atmosphere at high wind speeds. Further investigation will focus on fluxes of heat and momentum, the evolution of the wave field, and aerosol component analysis. Results from this work will help to develop a clearer understanding of air-sea interaction at high wind speeds and improve forecasting of tropical storms.

WAVE MEASUREMENTS

Operating Principles

ASIS buoys measure wave periods of periods >8s and remain relatively stable for values of period >8s. These shorter waves are measured using an array of capacitance wave wires which sense the surface elevation. These are transformed to earth-reference surface elevations by adjusting for the buoy’s motion (Anctil et al., 1993) using the onboard motion sensing system. EASI is a surface follower, all degrees of freedom are recorded (local buoy reference frame) along with compass heading. The heave is tilted corrected and double integrated to produce sea-surface elevation. The compass heading is used to transform pitch and roll to an Earth-fixed coordinate frame and integrated to produce sea-surface slopes.

Measurements

Figure 5 displays some of the parameters that can be determined from EASI wave measurements. These include: wave frequency spectrum (a), inverse wave age (b), significant wave height (c), peak period (d), and direction at the peak period (e).

Figure 7 shows 20 minute averaged significant wave height (a), wind direction (b), wind speed (c), and surface temperature (d), wave spectra (e), and significant wave height (f) at the north mooring during these storms.

TYPHOONS MEGI AND CHABA

Typhoons Megi and Chaba had maximum sustained wind speeds of 82m/s and 59m/s, 19km and 28km radius of maximum winds, and passed 284km and 94km from the northern mooring, respectively. Figure 8 shows atmospheric pressure (a), U10 (b), wind direction (c), air- and sea surface temperature (d), wave spectra with peak frequency (e), and significant wave height (f) at the north mooring during these storms.

Figure 8 shows (a) significant wave height, (b) wind direction, (c) wind, (d) air temperature, (e) wave spectra, and (f) significant wave height at the north mooring during Typhoon Megi and Chaba. It is recognized that there is a lack of knowledge of the physics of air-sea exchange at wind speeds above gale force (Black et al., 2007). In order to try and fill this void in our understanding two pairs of buoys were deployed in the Philippine Sea, ~740 km east of Southern Taiwan, as part of the Impact of Typhoons on the Ocean in the Pacific (ITOP) experiment.

Each mooring consisted of an Extreme Air-Sea Interaction (EASI) buoy, (Drennan and Williams 2008), and an Air-Sea Interaction Spar (ASIS) buoy, (Graber et al. 2009). The northern mooring was located at 21.23°N, 126.96°E in 5608 m water depth and the southern mooring was located at 19.63°N, 127.23°E in 5128 m water depth. EASI buoys were anchored to the seafloor via ~800 m of line allowing them to move freely upon the surface. ASIS were tethered to their respective EASI with a horizontal separation of ~60 m. Distance between moorings was approximately 180 km. The north mooring collected data from August 3rd to November 15th, 2010 (DOY 213–326), while the south mooring collected data from August 4th to November 22nd, 2010 (DOY 216–326). ASIS south and north broke loose on October 19th and September 19th, respectively, and were subsequently recovered. Figure 1 shows a typical ASIS-EASI mooring configuration.

The deployment of EASI and ASIS in the Philippine Sea during the 2010 typhoon season resulted in a unique and varied data set which reflects the interaction between the ocean and atmosphere at high wind speeds. Further investigation will focus on fluxes of heat and momentum, the evolution of the wave field, and aerosol component analysis. Results from this work will help to develop a clearer understanding of air-sea interaction at high wind speeds and improve forecasting of tropical storms.

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