OBSERVING AIR-SEA EXCHANGE WITH A FREE-DRIFTING SPAR BUOY

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ABSTRACT

Understanding of climate change ultimately relates to how well we understand the Earth's energy balance, and changes to it. The fluxes of heat, moisture, and momentum between the ocean and atmosphere constitute a significant fraction of the global energy budget. Yet current *in situ* observations are simply not adequate to accurately evaluate atmosphere-ocean exchange, especially at the weather scales, and insufficient in certain locations to even constrain models and satellite observations. To address this shortcoming of the global observing system, a drifting spar buoy system capable of directly measuring air-sea turbulent fluxes and bulk parameters in remote, inhospitable regions has been conceptualized and prototyped. It is argued that the measurements from these spars will complement those made from moored buoys and ships, and potentially return more accurate observations owing respectively to greater measurement height above the wave boundary layer and minimal flow distortion.

INTRODUCTION

The fluxes of heat, moisture and momentum between the ocean and atmosphere constitute a significant fraction of the global energy budget (e.g. Stephens et al. 2012). Air-sea interactions occur from time scales of minutes to hours, through synoptic variability, to interannual and decadal periods. Current *in situ* observations are simply not adequate to accurately evaluate atmosphere-ocean exchange, especially at the weather scales, and not sufficient in many locations, such as the high-latitudes, to even constrain models and satellite observations (e.g. Risien and Chelton, 2008; Gille et al. 2010; Fig 1). A number of national and international groups (such as the World Climate Research Programme and CLIVAR) have published reports that describe the lack of data in remote, hard-to-reach locations.

Addressing this shortcoming in the global environment observing system and motivated by the performance of the ASIS buoy (Graber et al., 2000) in high sea states (Marshall et al., 2009), Clayson and Toole conceived and oversaw prototype development of a freely-drifting spar buoy instrument system to return near-surface meteorological and oceanographic observations over time periods of a year or longer in remote, inhospitable regions of the ocean. Spar buoys are long, thin structures that float vertically in the ocean spanning the air-sea interface. Owing to their small cross-sectional area, spar buoys tend not to heave vertically with smaller-scale waves, making them ideal platforms for meteorological observations. Being relatively low-cost and because all data are telemetered ashore, the system may be considered expendable: hence the device's name "X-Spar."

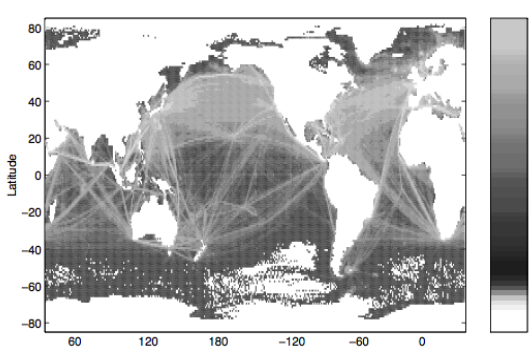

Figure 1. Global distribution of the number of latent heat flux estimates per 1° x 1° square used to form the average climatological monthly mean for the period 1980 – 1993 in the SOC flux atlas database from ship of opportunity data. White areas in the Southern Ocean indicate that there were no observations over the entire period considered. From Josey et al., 1999.

SYSTEM DESCRIPTION

With support from the WHOI Innovative Technology Program, supplemented by a grant from Eastman Chemical Co., a prototype X-Spar system was designed, fabricated and tested in February 2015 off the WHOI pier, followed in June of that year by a short open-ocean test conducted near the OOI Pioneer Array. X-Spar 1.0 was fabricated from commercially-available 10-foot sections of 8-5/8"-diameter schedule-80 PVC pipe as shown in Figure 2. Standard couplings were used to join 3 sections to form the main 10-m section of the spar. Closed-cell foam was injected into the pipe for reserve buoyancy in the event of tube leaks. A sealed aluminum battery case was joined to the lower end of the spar with a cable supplying power to the main controller and sensor package. For the first prototype, the controller was housed in an available watertight housing clamped to the top of the pipe section (Fig. 2, right) but in future, it will be integral to the main spar. A carbon-fiber mast was mounted to the top of the spar tube to support the meteorological sensor suite approximately 7 m above the air-sea interface. The first prototype was fitted with a Vaisala WXT520 weather package with sensors for wind speed and direction, barometric pressure, relative humidity and precipitation (http://www.vaisala.com/en/products/multiweathersensors/Pages/WXT520.aspx), a WHOI UOP electronic compass and interface for the WXT520, and a WHOI-designed controller to collect sensor and GPS position data and transmit those via Iridium cell phone to data servers ashore. A Sea-Bird SBE 37 conductivity and temperature sensor, mounted about 6 m below the sea surface and also integrated into the ITP surface controller, completed the sensor system.

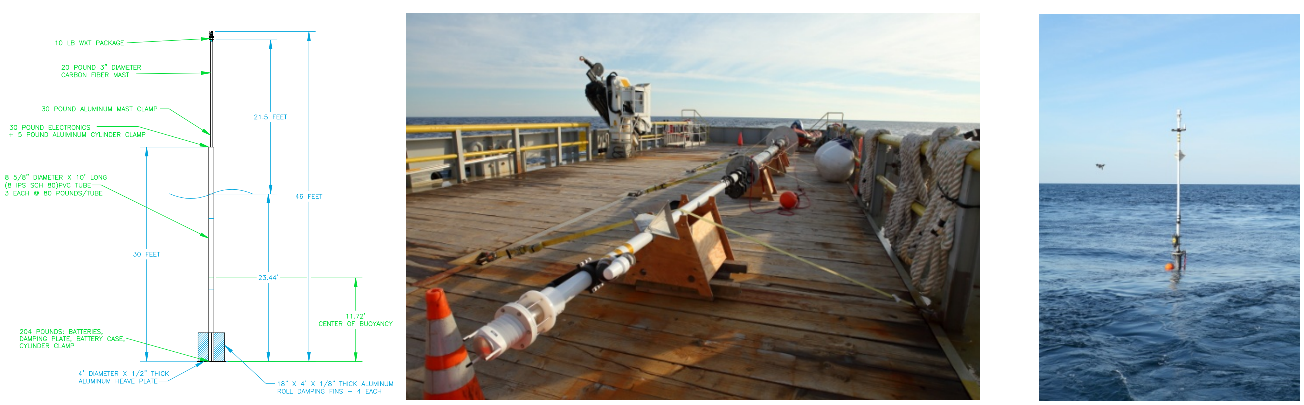

Figure 2. Schematic drawing of the first X-Spar prototype instrument and photographs of it on deck and deployed during a short sea trial.

FUTURE PLANS

The next steps in the X-Spar development program include redesigning the spar segment to handle higher sea state and integrating a sonic anemometer and radiation sensors to support full air-sea flux estimation, followed by longer-term sea trials. With data from the operational X-Spar systems, users will be able to collect direct estimates of the momentum, buoyancy and downwelling radiative (short and longwave) fluxes and associated means including air temperature, humidity, precipitation, and pressure all at roughly 7 m from the surface. With the addition of CTDs on the spar, near-surface ocean temperature and salinity may be observed. In turn, the near surface temperature may be combined with the meteorological data to compute bulk estimates of the momentum, sensible heat and latent heat fluxes. Those in turn may be verified with direct covariance measurements. And addition of capacitance wires will return estimates of surface wave characteristics. A key feature of X-Spar is that it will induce negligible flow distortion and sample relatively far above the wavy air-sea interface. As such, X-Spar may become the standard against which all other air-sea flux estimates may be compared. Identifying and securing support to take these next steps in the X-Spar instrument development effort is the immediate hurdle facing in the program.

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