Preliminary Examination of Island Effects on Near-Surface Bulk Meteorology and Air-Sea Fluxes from the Nauru99 Field Program

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Introduction

The National Oceanic and Atmospheric Administration (NOAA) research vessel Ronald H. Brown conducted a series of measurements in transit to and in the vicinity of the U.S. Department of Energy's Atmospheric Radiation Measurement (DOE/ARM) Program's Cloud and Radiation Testbed (CART) Atmospheric Radiation and Cloud Station (ARCS) on the island of Nauru in June-July 1999. Among the various instruments deployed on the Ron Brown during Nauru99 were those necessary to measure the bulk meteorological conditions (wind speed and direction, air and sea surface temperature, solar and infrared downwelling irradiance, relative humidity, and rain rate) and a suite of instrumentation for the direct measurement of the turbulent fluxes of heat, moisture, and momentum. In addition, the bulk meteorological variables were used as input to the newest generation of the Tropical Ocean Global Atmosphere-Coupled Ocean Atmosphere Response Experiment (TOGA-COARE) Bulk Flux Algorithm. See http://www.etl.noaa.gov/nauru99/ for more information about Nauru99.

One purpose of the siting of the Nauru99 expedition was to characterize the island as an appropriate platform for remote sensing of the open-ocean marine atmosphere, as there is some concern about the possibility that the island-induced effects may contribute to biases in the climatological measurements made from the ARCS site. Toward this end, the Ron Brown made numerous circumnavigations of the island over the course of several days, and each circuit required 2 hours to 2.5 hours to complete. It is anticipated that the upwind versus downwind sampling of the local meteorology will serve to assist in the characterization of the island effect on the structure of the marine boundary layer.

In order to accomplish this characterization, means were computed for all of the relevant meteorological variables and inferred bulk fluxes for each circuit. These means were then subtracted from all the one-minute mean measurements and five-minute flux estimates within that circuit in order to create a common reference atmospheric state and to reduce diurnal effects for subsequent comparison. Then, all measurements were segregated into one of eight wind direction-referenced averaging bins as shown in Figure 1. As seen in Figure 3, the mean wind direction for much of the experiment period was from the northeastern quadrant. For those periods in which the wind direction deviated from this sector, the coordinate system was rotated so that the bins remained consistently referenced to wind direction. There is a noticeable upwind/downwind signature in both air and sea temperatures as shown in Figure 4a, although the modulation is less clear in subsequent circumnavigations (Figure 4b).

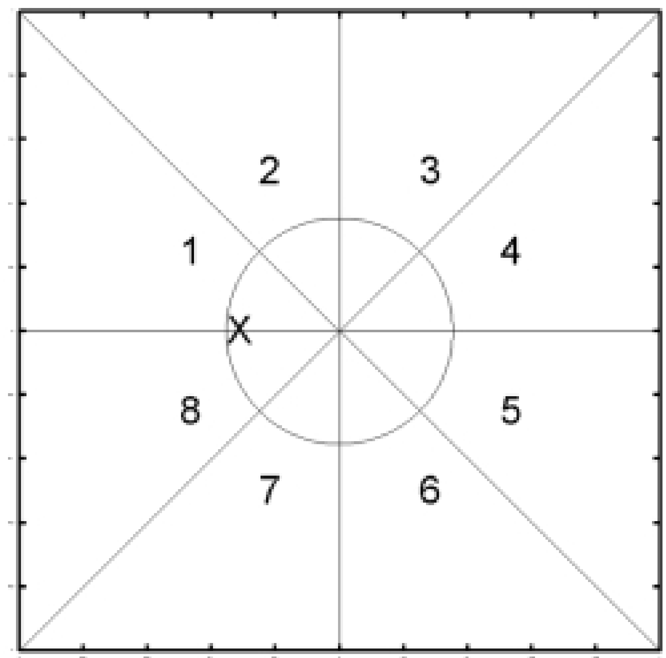

Figure 1. Schematic of the averaging bins surrounding Nauru. The ARCS site is approximately indicated by the 'X', and is climatologically located in the downwind direction. All measurements were rotated such that sectors 1 and 8 are downwind.

The measurements were then bin-averaged to create the plots shown in Figures 6 through 13, which also include standard error bars. Some of the variables were also separated into day/night conditions to further reduce the diurnal effect. As described by Figure 1, the downwind averages are described in bins 1-2 and 7-8, and it should be noted that the ARCS site is located in the climatological downwind direction. It is readily seen from some of the figures that an apparent downwind/upwind bias does exist, as shown in Figure 7. In other examples, the downwind/upwind variability is quite small. In Figure 10, a clear-sky model was employed to provide a further baseline for interpretation of the results for downwelling shortwave irradiance.

Although these results are meant to assist in the characterization of the marine boundary layer surrounding Nauru, it is hoped that further elucidation will occur with the processing of the various remote sensing systems deployed during Nauru99. Note that due to the complications of making covariance turbulence measurements during ship maneuvers, it is anticipated that a similar analysis of the directly measured turbulent fluxes will not yield meaningful results.

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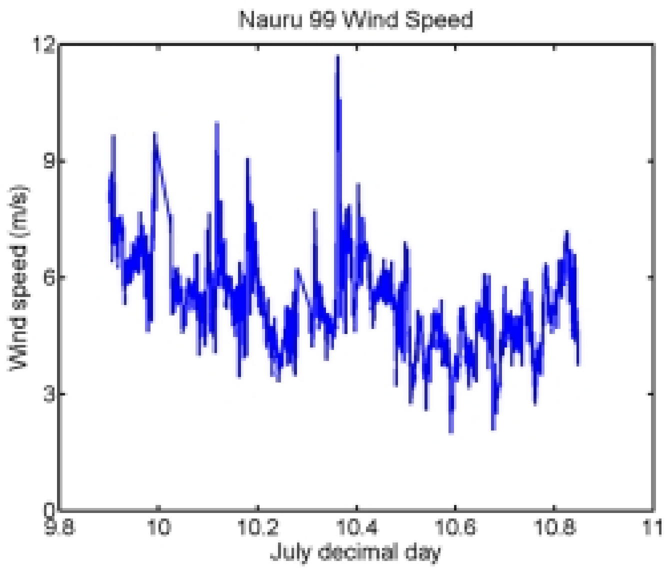
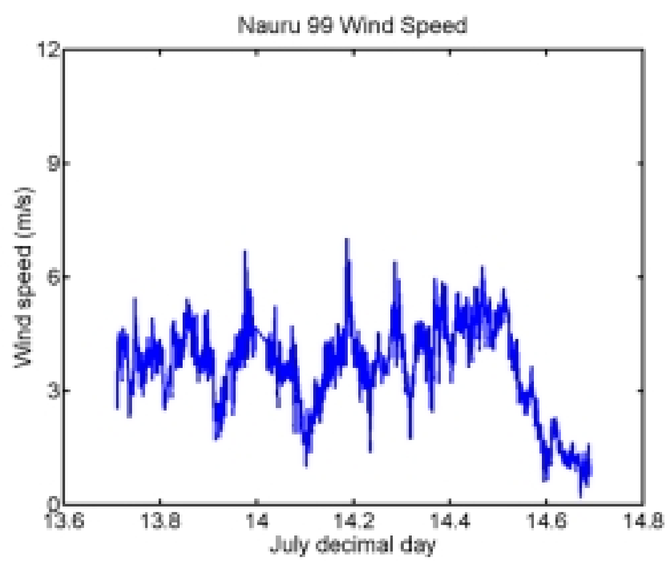
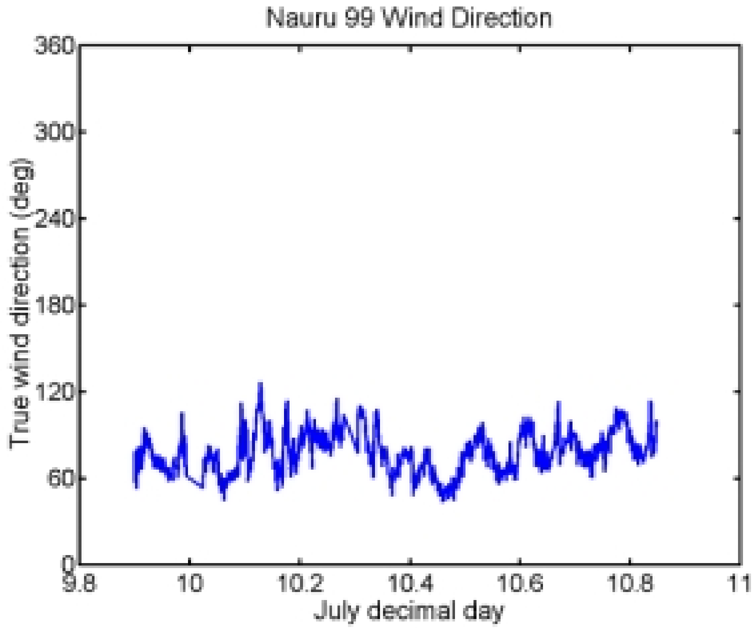


(a)

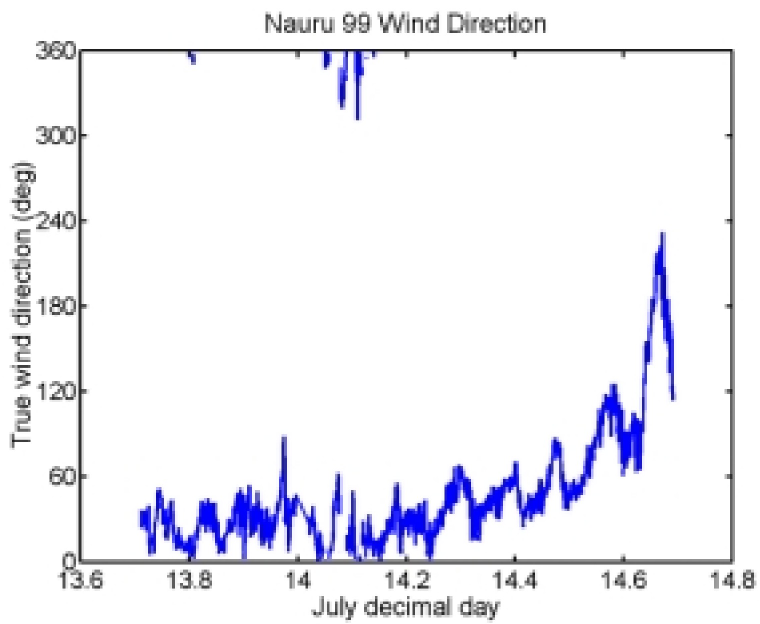


(b)

Figure 2. Wind speeds measured during the two circumnavigation periods analyzed here.

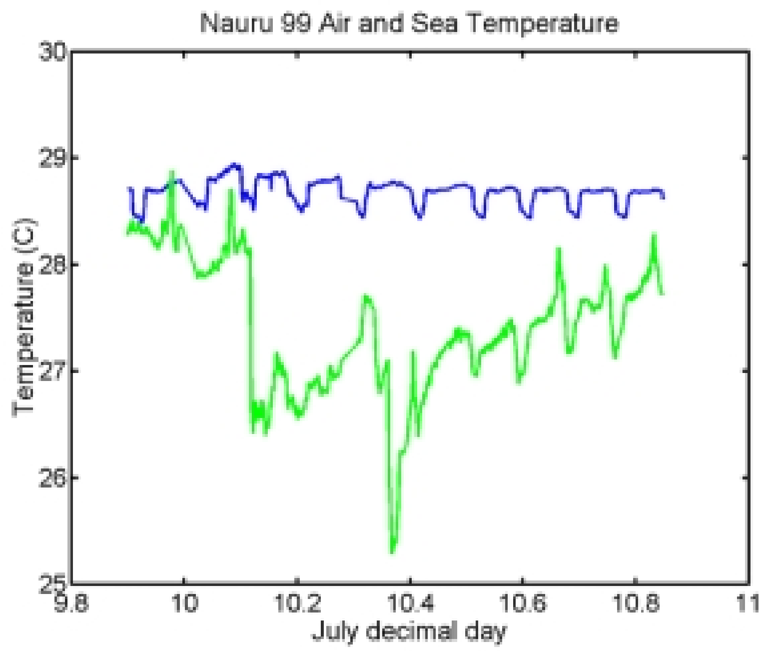


(a)



(b)

Figure 3. Wind direction measured from the Ron Brown.



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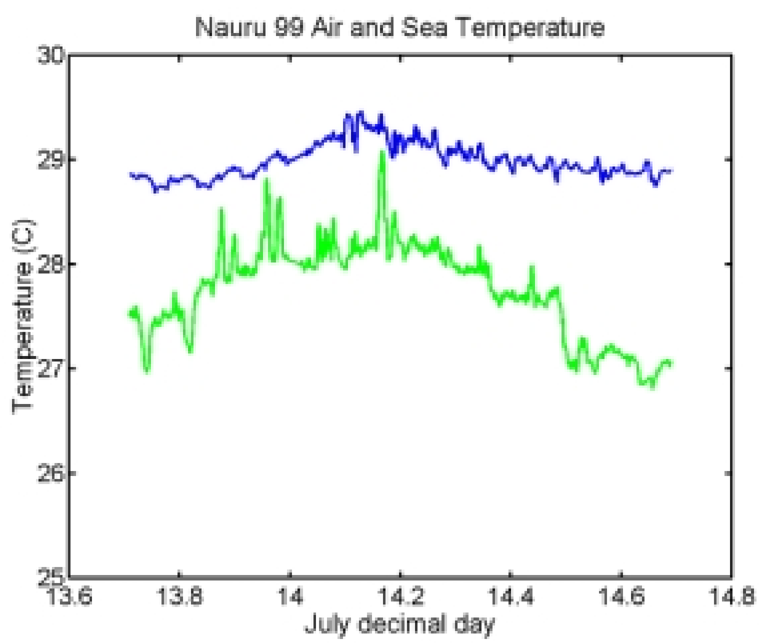
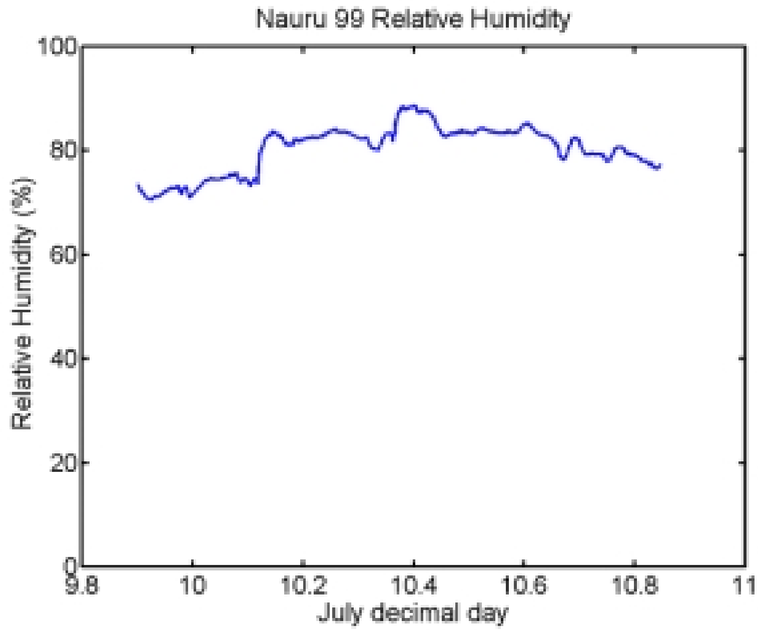
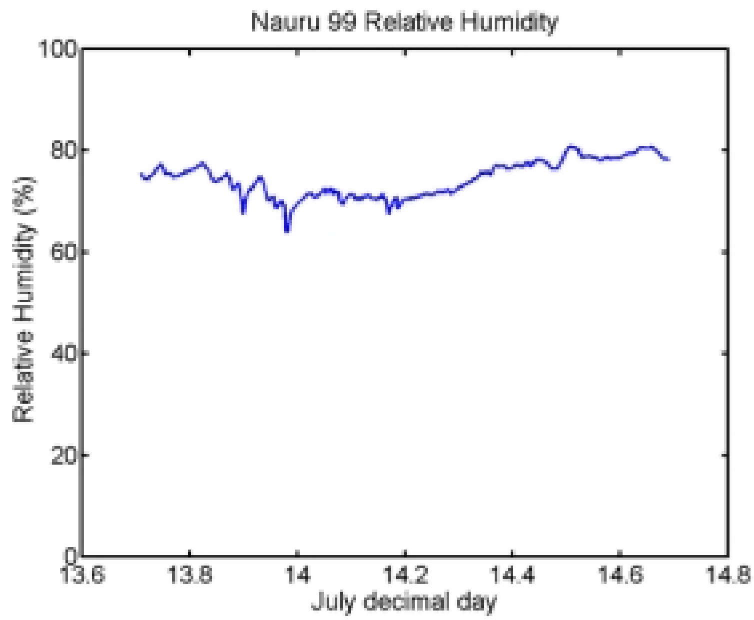


(b)

Figure 4. Bulk air and sea-surface temperatures obtained from the Ron Brown. Note the apparent downwind/upwind signature due to the circumnavigations of the island.



(a)



(b)

Figure 5. Relative humidity.

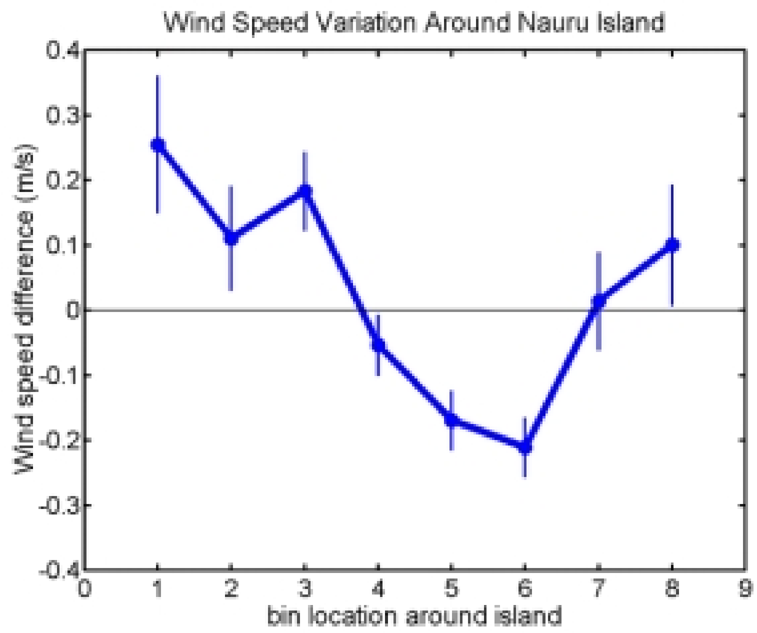


Figure 6. Bin-averaged wind speed around the island. Notice that winds are reported here to be accelerating in the lee of the island.

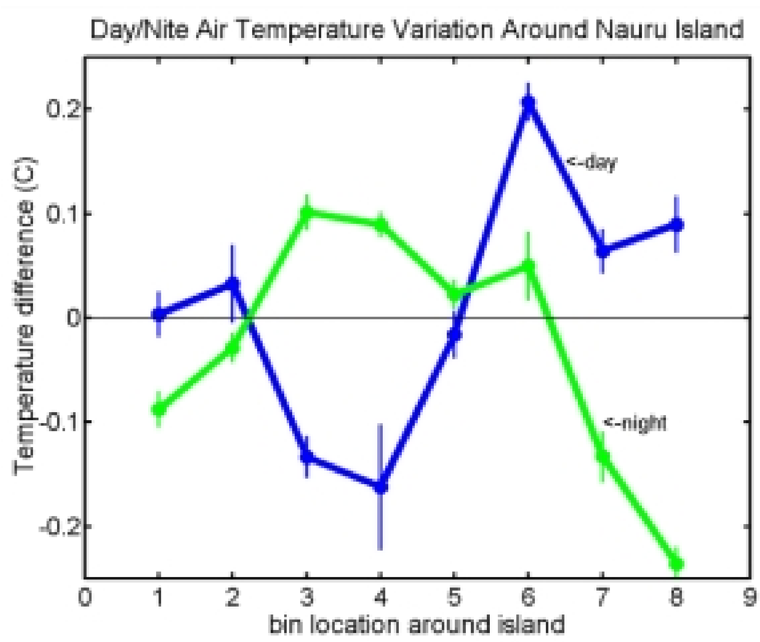


Figure 7. Both daytime and nighttime bin-averaged temperature around the island. Note that the relatively strong daytime warm air in the lee is reversed at night.

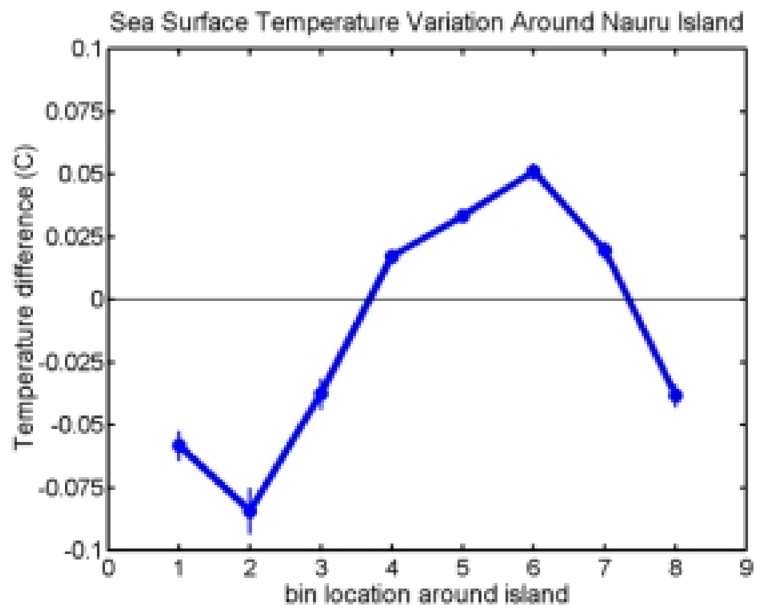


Figure 8. Bin-averaged bulk sea surface temperature measured from the Ron Brown. Current direction dependencies are not accounted for in this figure.

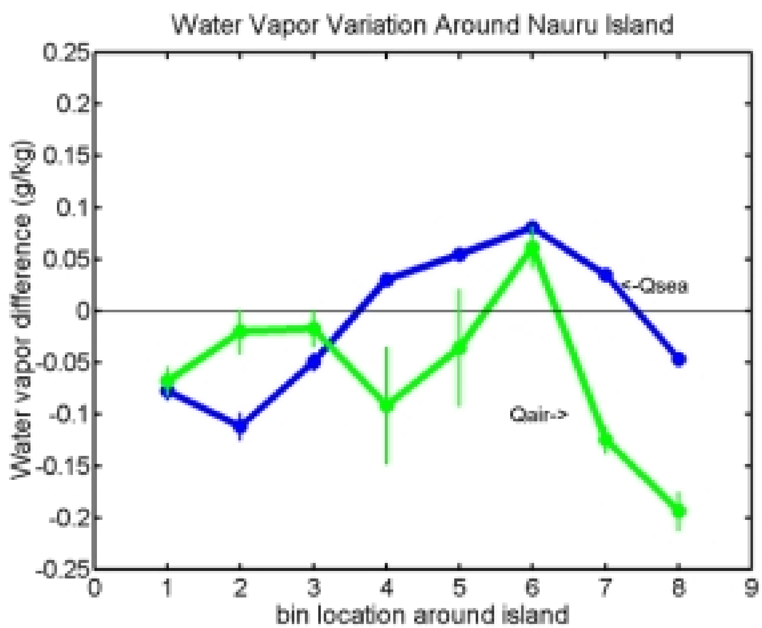


Figure 9. Saturation and air specific humidity, averaged with respect to the bins in Figure 1.

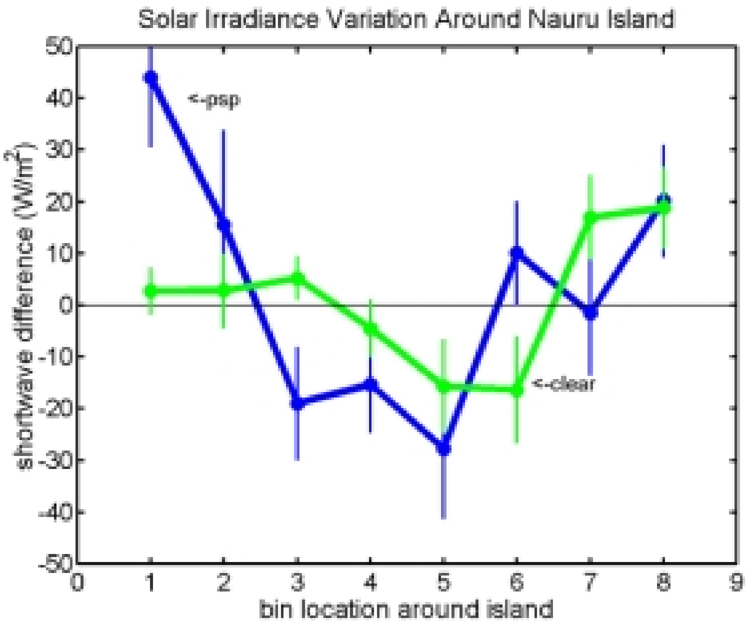


Figure 10. Bin-averaged downwelling solar irradiance measured from the Ron Brown. Also included is a clear-sky model to be used as a reference for interpretation of this figure.

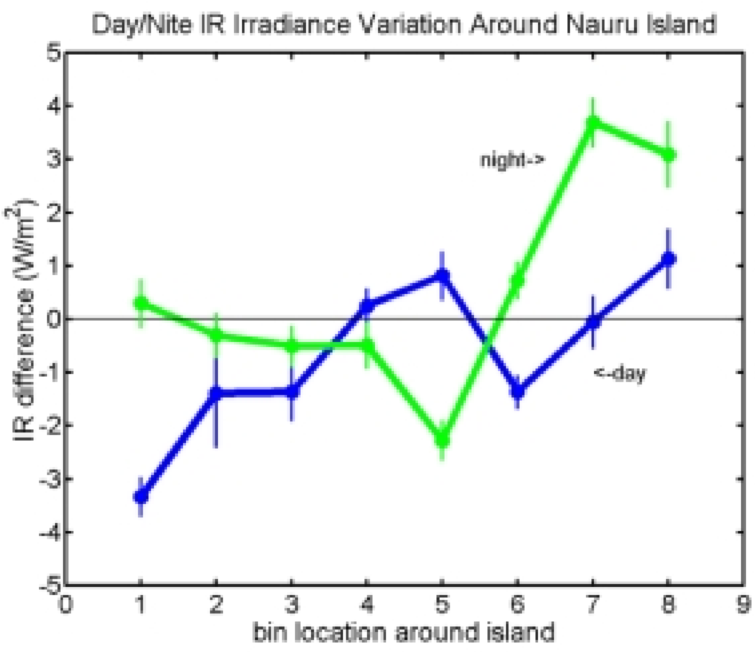


Figure 11. Daytime and nighttime bin-averaged downwelling infrared irradiance as measured from the Ron Brown during the circumnavigation periods.

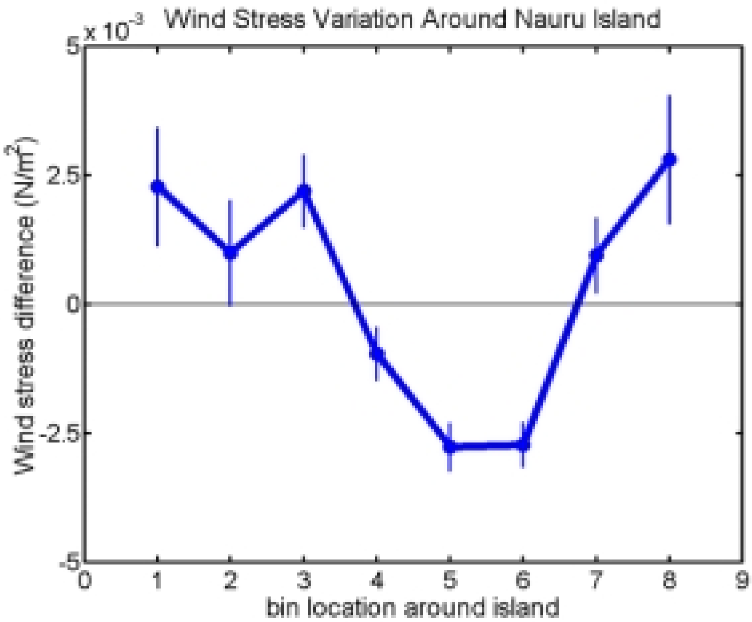


Figure 12. Bin-averaged wind stress as determined from the TOGA-COARE Bulk Flux Algorithm.

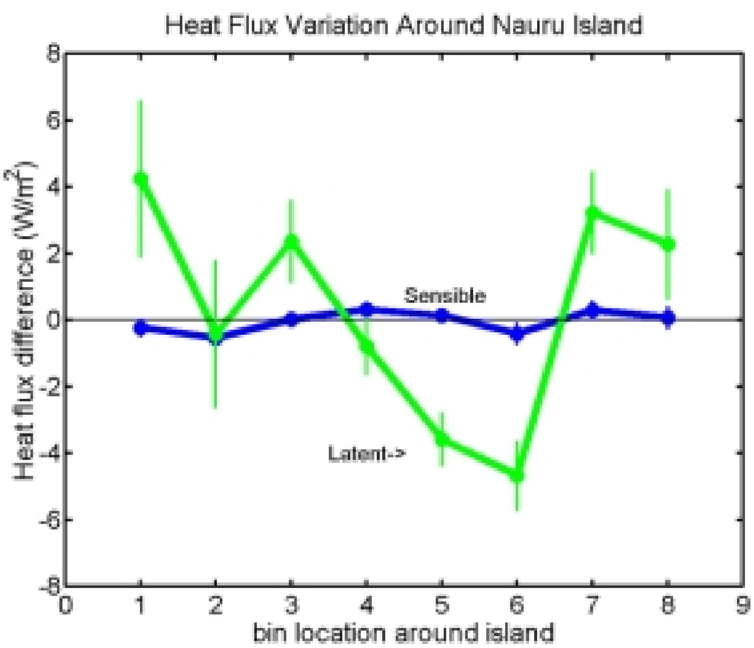


Figure 13. Bin-averaged sensible and latent heat fluxes as determined from the TOGA-COARE Bulk Flux Algorithm.