A Comparison of the Daily Cycle of Lower-Tropospheric Winds Over the Open Ocean and Those Above a Small Island

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Introduction

The Nauru99 Intensive Operational Period (IOP) took place from June 16, 1999, (Day 167) to July 15, 1999, (Day 196) on and near the Republic of Nauru (0.5° S, 166.9° E). Nauru is a small (4 km by 6 km) island surrounded by a reef that is exposed at low tide (Figure 1). A narrow coastal belt encircles a sparsely vegetated 30 to 60 m high plateau comprised of coral pinnacles and phosphate-bearing rock.

Figure 1. The Republic of Nauru. The 915-MHz profiler was located at "**P**"; the Atmospheric Radiation Measurement (ARM) Atmospheric Radiation and Cloud Station (ARCS) site is indicated by an "**A**".

One of the goals of Nauru99 was to improve our understanding of the effects small islands have on atmospheric processes. Data from wind profilers operated on the southern edge of the island's plateau as well as on two research vessels (R/Vs) is being analyzed, with the focus being the daily cycle of both the lower-tropospheric winds and the boundary layer (BL) height.

Data and Methods

Two ship-based 915-MHz wind profiling Doppler radars were deployed during the Nauru99 IOP, one aboard the R/V *Mirai* and another aboard the R/V *Ronald H. Brown*. In addition, a 915-MHz profiler has been collecting data on Nauru since 1992, first during the Tropical Ocean Global Atmosphere-Coupled Ocean Atmosphere Response Experiment (TOGA-COARE) IOP (Parsons et al. 1994) and since then as part of the Trans-Pacific Profiling Network (TPPN) operated by the University of Colorado and the National Oceanic and Atmospheric Administration (NOAA) Aeronomy Laboratory (NOAA/AL). Some specifications for the three systems are shown in Table 1.

Table 1. Nauru99 915-MHz profiler parameters.

# Beams	5	3	3
Recurrence Time	2 min 43 sec	6 min 2 sec	4 min 52 sec
Platform Stabilization	Gyrostabilized	Gyrostabilized	N/A
Mode 1		60 m (vertical beam only)	60 m (vertical beam only)
Minimum Height		0.192 km ASL	0.192 km ASL
Maximum Height		6.372 km ASL	6.372 km ASL
Pulse Coding		None	None
Dwell Time		40 sec	40 sec
Mode 2	105 m	105 m	105 m
Minimum Height	0.130 km ASL	0.162 km ASL	0.304 km ASL
Maximum Height	6.325 km ASL	6.778 km ASL	6.919 km ASL
Pulse Coding	8-bit	4-bit	4-bit
Dwell Time	29 sec	43 sec	43 sec
Mode 3	495 m (vertical beam only)	420 m	495 m
Minimum Height	0.120 km ASL	0.485 km ASL	0.519 km ASL
Maximum Height	10.065 km ASL	17.495 km ASL	17.529 km ASL
Pulse Coding	None	None	None
Dwell Time	30 sec	45 sec	45 sec

The horizontal wind data from Nauru has been post-processed and quality controlled using algorithms developed at NOAA/AL (Riddle et al. 1996). The data from the two ships is being processed in the same manner. A mean daily cycle of winds during June 16 to July 15 has been computed from the half-hourly Nauru data for 1999, as well as for the same period during years 1993 to 1998. Mean wind profiles have also been constructed for the same periods.

In addition, data from the Nauru and R/V *Ronald H. Brown* profilers' 60-m vertical beam has been used to determine BL depth during the Nauru99 IOP. (None of the R/V *Mirai*'s operating modes lend themselves to this type of analysis.) Half-hourly values of BL depth are estimated by visually identifying a peak in the raw reflectivity (Angevine et al. 1994; Grimsdell and Angevine 1998; Cohn and Angevine 2000). If no reasonable peak is evident, the BL depth is flagged as missing. The accuracy of the result is believed to be ± 1 pulse length (± 60 m for these data).

Results - Winds

The mean daily cycle of the lower-tropospheric winds during the Nauru99 IOP is shown in Figure 2. Vector wind anomalies for alternate half-hours are plotted; only levels for which the each half-hourly average was based on at least 50% of the total possible days are included. The anomalies are generally less than 1 m s^{-1} and are somewhat disorganized. There is some indication of a sea breeze, with northerly (southerly) anomalies below 1.5 km during the middle of the day (night) and weak return flow aloft from 1.5 to 3 km. This is in marked contrast to the results found by Gutzler and Hartten

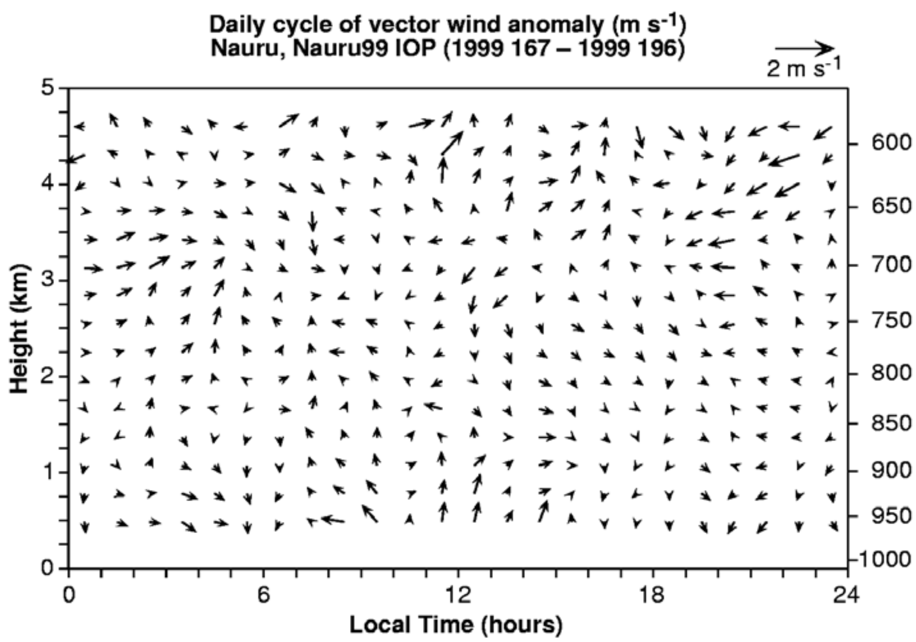

Figure 2. The daily cycle of vector wind anomalies at Nauru during the Nauru99 IOP (June 16 through July 15,1999) as a function of height (or pressure). Arrow sizes are proportional to speed; a 2 m s^{-1} reference vector is shown above the upper right-hand corner.

(1995), who saw no sign of a sea breeze in winds collected by this same profiler during the TOGA-COARE IOP (November 1992 through February 1993). The atmospheric semidiurnal tide is also evident, most clearly at about 09 and 15 LT. (The phase of this tide is invariant with height; maximum westerly anomalies are expected at 0344 and 1544 LT, with the maximum northerly anomalies lagging by 3 hours in the Southern Hemisphere and vanishing at the equator [Whiteman and Bian 1996].)

The mean June/July daily cycle during the 3 years before the Nauru99 IOP is shown in Figure 3. There is considerable year-to-year variability. The semidiurnal tide is clearly visible during 1996 and 1997, but is only weakly seen at a few levels in the 1998 data. The daytime (nighttime) northerly (southerly) anomalies are very weak in 1996, but are stronger in 1997 and 1998 than during Nauru99. Possible correlations with the phase of the Southern Oscillation Index (SOI) are not immediately apparent; the 5–month running mean SOI was -1.57 in June 1997 and 0.32 to 0.55 in 1996, 1998, and 1999.

Results - BL Heights

Figure 4 shows the height of the atmospheric BL (in km above sea level [ASL]) above Nauru and the R/V *Ronald H. Brown* during the entire Nauru99 IOP. All available half-hourly values have been plotted, and no smoothing has been performed. Overall, the results are very similar; the correlation between the two timeseries is 0.8663. The range of values is slightly larger over the ship, while the mean (median) height is 24 m (20 m) greater over Nauru than over the R/V *Ronald H. Brown*. Both timeseries show evidence of a slow, large-scale modulation of BL heights.

The IOP-mean daily cycle of BL heights above both profilers is shown in Figure 5. Error bars indicate the standard error of each average value, and range from 11 to 13 m. The mean daily cycles are very similar, with the Nauru BL generally slightly deeper than the oceanic one; the mean difference between the two daily cycles is 26 m, and the correlation is 0.7814. Over both locations the BL is shallowest just before dawn and deepest around sunset, with a secondary maximum just after noon. Further analysis will be required to determine whether the BL structure is more complex, for example, if the profiler reflectivity peak is at times occurring at an elevated inversion not coupled to the surface.

Future Work

The preliminary results presented here point to several intriguing questions and the following avenues for future research:

- Identify the amplitude and timing of the diurnal and semidiurnal wind variability by performing a harmonic analysis on the mean daily cycle of lower-tropospheric winds.

- Identify the larger-scale patterns of variability affecting the dynamics of the lower troposphere by doing a spectral analysis on the entire 30-day wind timeseries.

- Repeat all these analyses using profiler winds collected by the R/Vs *Mirai* and *Ronald H. Brown*.

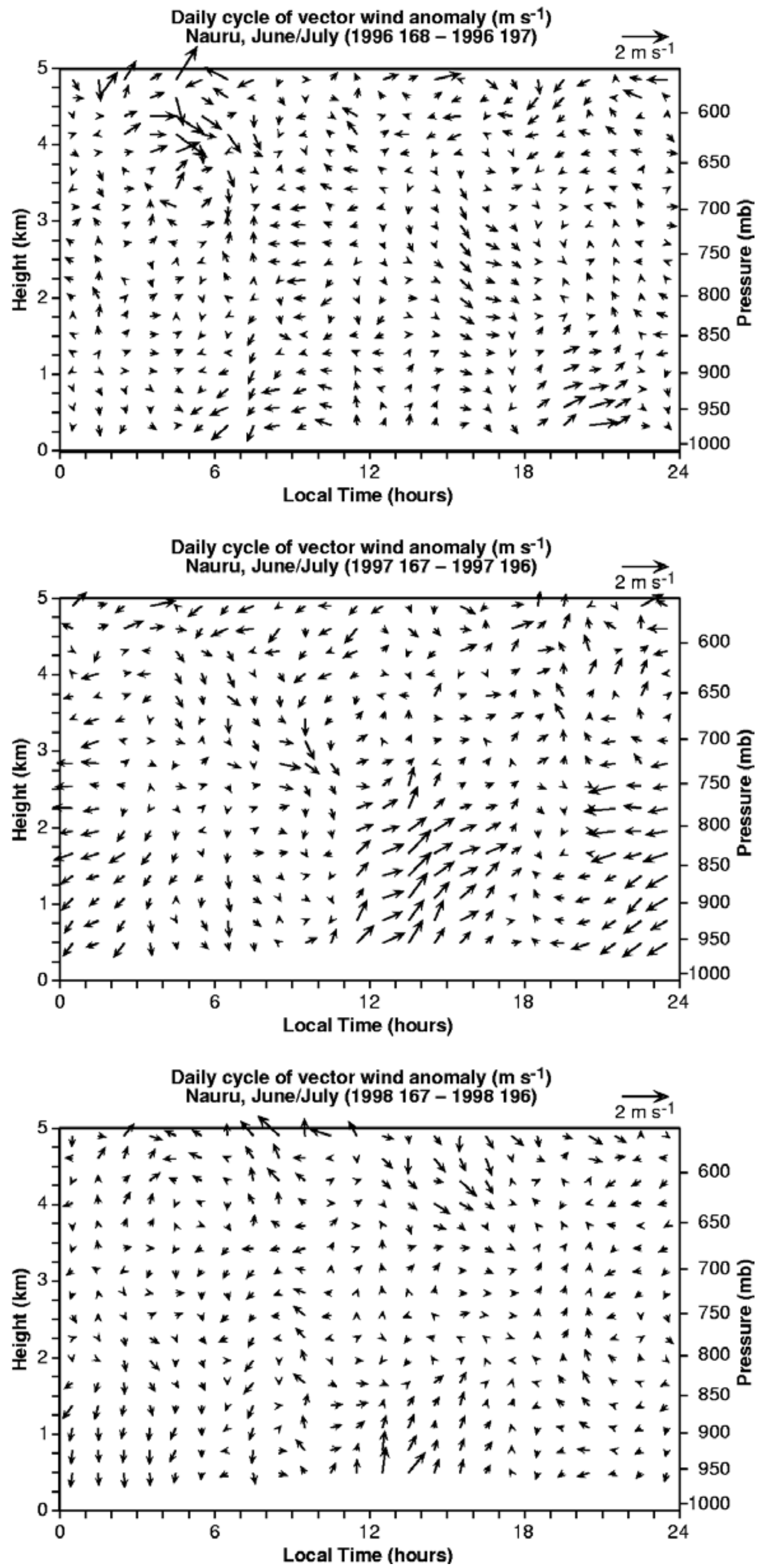

Figure 3. As in Figure 1 but for June 16 through July 15 in 1996 (top), 1997 (middle), and 1998 (bottom).

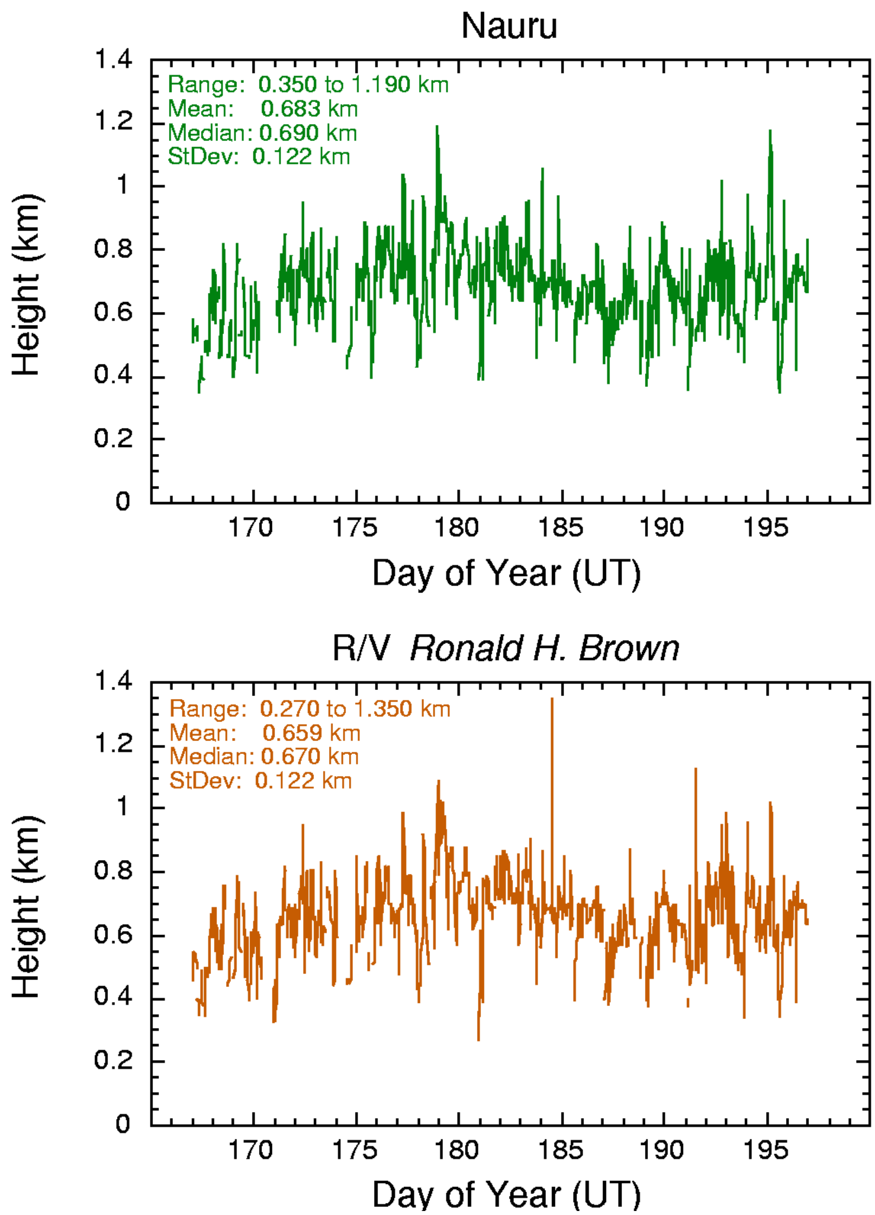

Figure 4. The height of the atmospheric boundary layer over Nauru (top) and the R/V *Ronald H. Brown* (bottom) during the Nauru99 IOP.

- Determine the conditions under which a sea breeze exists over Nauru by computing 30-day mean daily cycles at other times of the year.
- Refine the BL height determination by using ceilometer data to help interpret reflectivity peaks.
- Investigate the relationship of BL evolution under different wind conditions and ship positions.

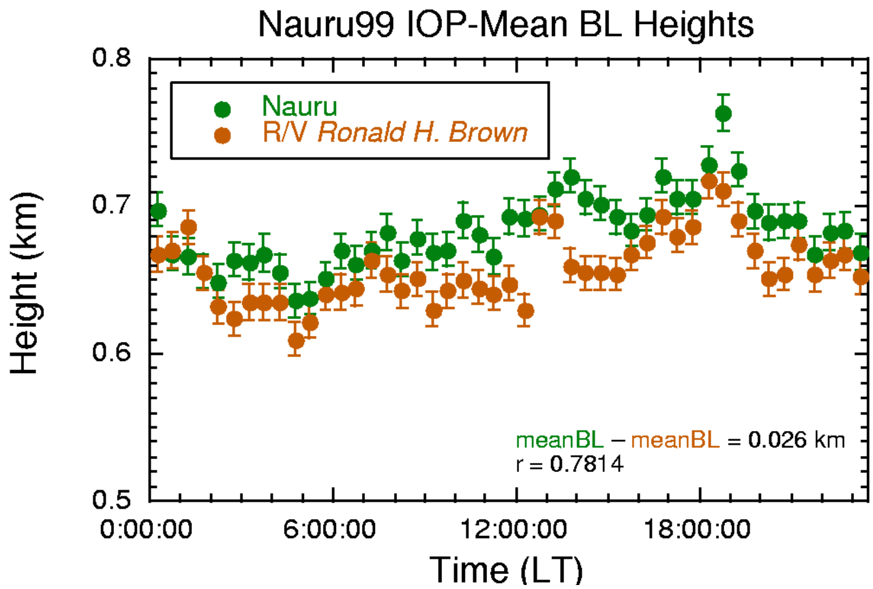

Figure 5. The mean daily cycle of BL heights over Nauru and the R/V *Ronald H. Brown* during the Nauru99 IOP. Error bars indicate the standard error of each value.

The results of these studies should help us place the lower-tropospheric dynamical conditions during Nauru99 in a larger context, and should also provide information on the effects of a small raised island on the flow over the open ocean.

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