Remote Sensing Observations from MTI Satellites and GMS Over Tropical Island of Nauru

W. M. Porch, P. Chylek, and B. Henderson
Los Alamos National Laboratory
Los Alamos, New Mexico

Introduction

The observations of island cloud trails have revealed a strong relationship between the character and frequency of occurrence of island cloud trails and the Tropical Ocean Southern Oscillation (MacFarlane et al. 2004 a, b). Island cloud trails from the U.S. Department of Energy's (DOE) Atmospheric and Radiation Measurement (ARM) facility of Nauru persist for more than 50 km (Nordeen et al. 2001) and resemble ship trail clouds found in the Eastern Ocean Margins (Porch et al. 1999). Island trail clouds are much more frequently observed during La Niña periods than El Niño periods (Figure 1). This

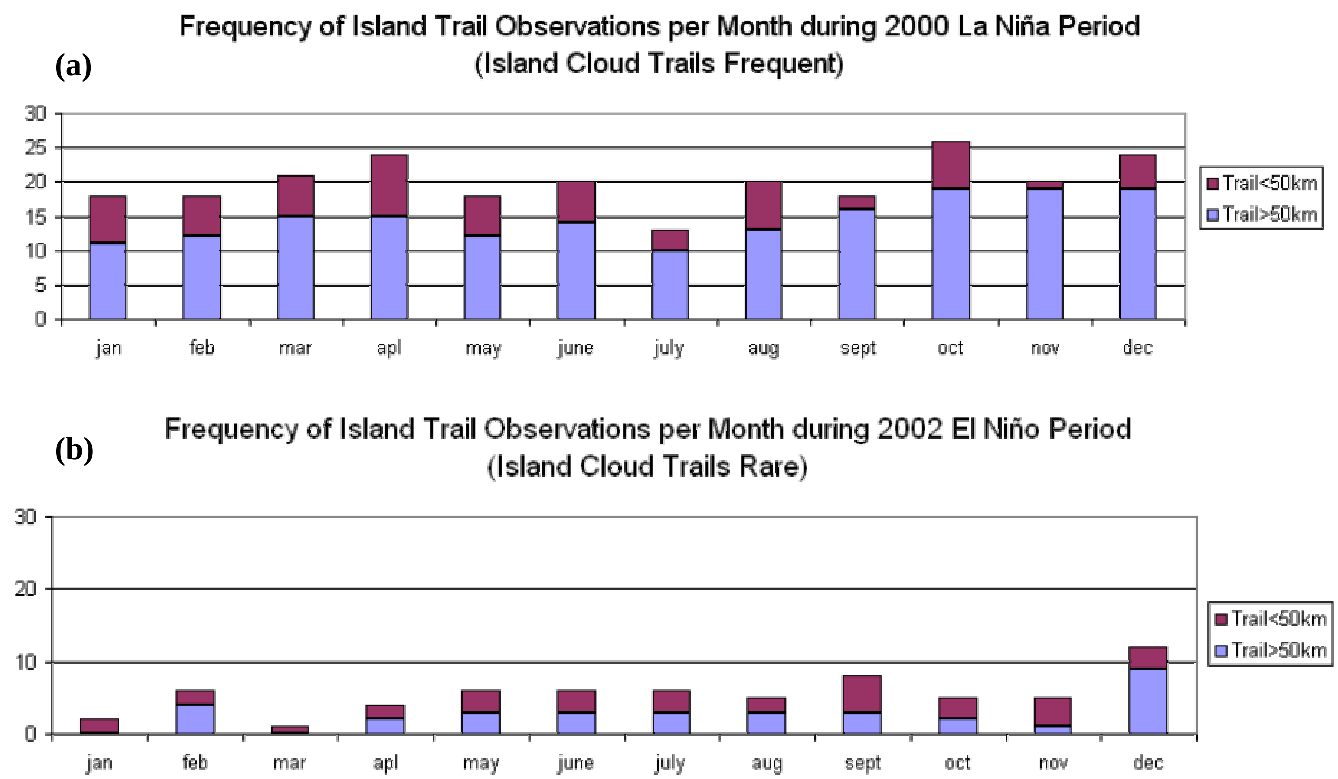


Figure 1. Frequency of observed Nauru Island cloud trails during (a) 2000 and (b) 2002. The highest peak in 2002 is 26 per month (blue > 50 km in length) in October. The frequency of island cloud trails shows the influence of the El Niño-Southern Oscillation (ENSO) on boundary layer cloud properties.

suggests that subsidence at the margins of the Tropical Warm Pool strongly affects the persistence of boundary layer clouds and may help contribute to the Tropical Ocean sea surface temperature cooling during La Niña periods.

Though island cloud trails themselves do not have a major effect on clouds in the Tropics, they can be used to understand the meteorological conditions under which they and the surrounding stratocumulus clouds form and dissipate. Figure 2 shows a comparison of high resolution images from DOE's Multi-spectral Thermal Imaging (MTI) satellite and 1-km resolution images at the same time from the geostationary meteorological satellite (GMS) in December 2000. There are no clouds in the region on December 12, 2000. On December 13, on the other hand, an island cloud trail is formed that extends over 100 km and has cloud-free regions on the sides of the island cloud trail.

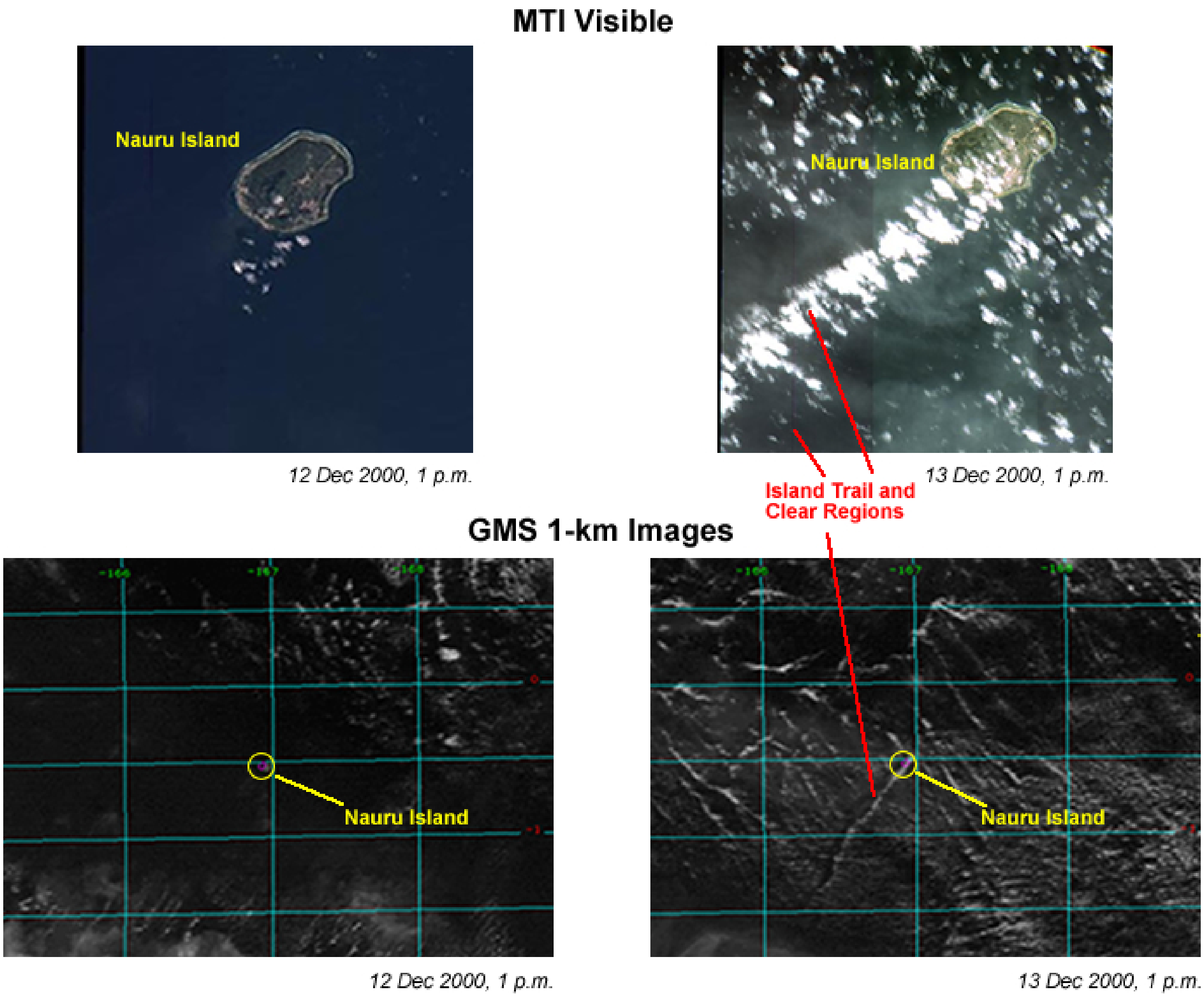


Figure 2. Island cloud trail comparison with two satellite images, DOE MTI and GMS. These images show how sensitive the island cloud properties are to regional subsidence. A small amount of subsidence makes persistent cloud trails. Too much subsidence inhibits the initial island cloud formation.

There are two mechanisms that are necessary for an island cloud trail to form. First, the local conditions must be favorable for forming an island cloud. The convection provided by the island can result from daytime heating of the island (or possibly the mechanical lifting associated with the interception of the prevailing winds by the island land mass). Second, very small regional subsidence (a few cm/sec) is necessary to keep the cloud from spreading and dissipating. Too much subsidence leads to warming and drying at the top of the boundary layer and inhibits cloud formation. The sensitivity of regional stratocumulus to small changes in meteorological parameters, e.g., subsidence, turbulence, and aerosol (or lack thereof), can be studied better when the source is known to be a small island and that island is well instrumented. The ability of the boundary layer clouds to cool the surface during the La Niña period can come from both how they persist for hours once formed reflecting sunlight during the day, and from their ability to dissipate at night leaving the night sky clear for radiation cooling.

MacFarlane et al. (2004a) describes the diurnal behavior of Nauru clouds during the La Niña period. In Figures 3 and 4, we compare the La Niña (2000) and the El Niño (2002) years by comparing the hourly cloud liquid water (CLW) from the microwave radiometer (MWR) observation frequency above 0.006 cm and the infrared thermometer (IRT) observed down-welling temperatures, respectively. These data demonstrate the higher cloud activity and the ability of the cloud characteristics to cool at night during the La Niña period. The applicability of these data depends on the assumption that nighttime clouds generated by the island are not significant.

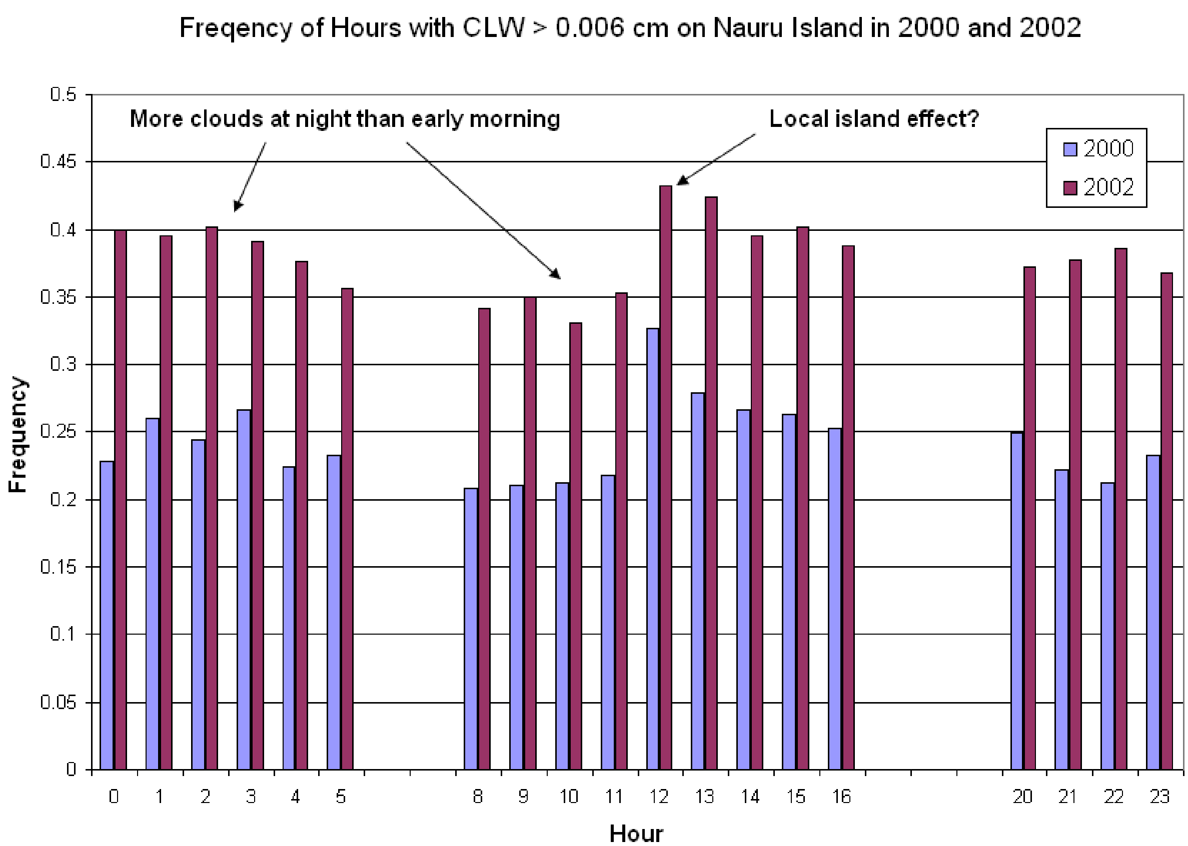


Figure 3. Relative frequency of hours observed with CLW content above 0.006 cm for the years 2000 and 2002.

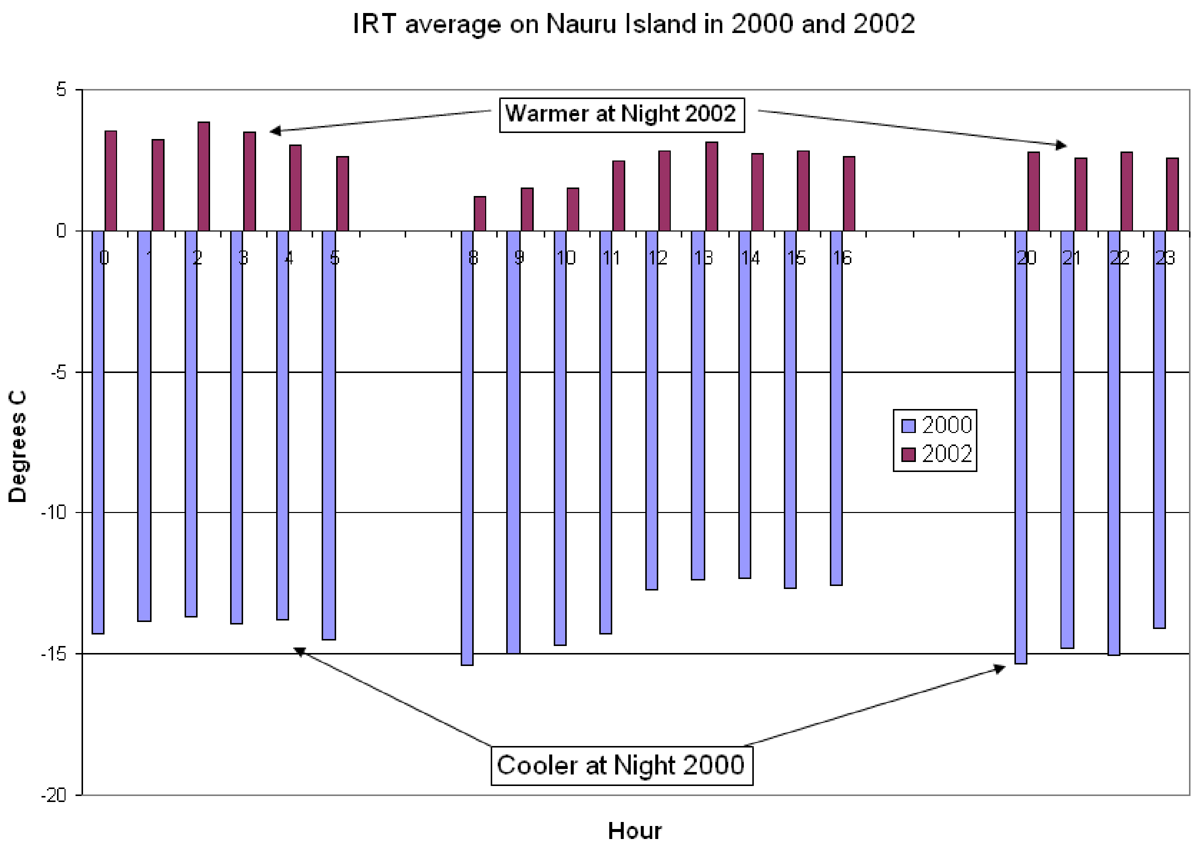


Figure 4. Mean hourly averaged upward looking temperatures for the years 2000 and 2002.

During the La Niña period between 1999 and 2001, the hourly mean wind directions measured at Nauru were almost exclusively from east with no indication of an island breeze effect. After 2001, the wind directions have included a westerly component on most days (Figures 5a, b).

Nauru Island Aerosol

Prospero conducted mineral dust collections on Nauru in the early 1990s, during periods when the winds were blowing into the island. These observations (Zender 2003) show that Nauru has very little mineral aerosol when the winds blow from east. Mineral dust may be very important to ocean fertilization of microorganisms; however, it is a negligible component of the aerosol optical depth. We have observed aerosol plumes generated by the island of Nauru in MTI channel-E images (Figure 6), and the aerosol optical depths observed by the MTI satellite have been compared to Aerosol Robotic Network (AERONET) data from Nauru.

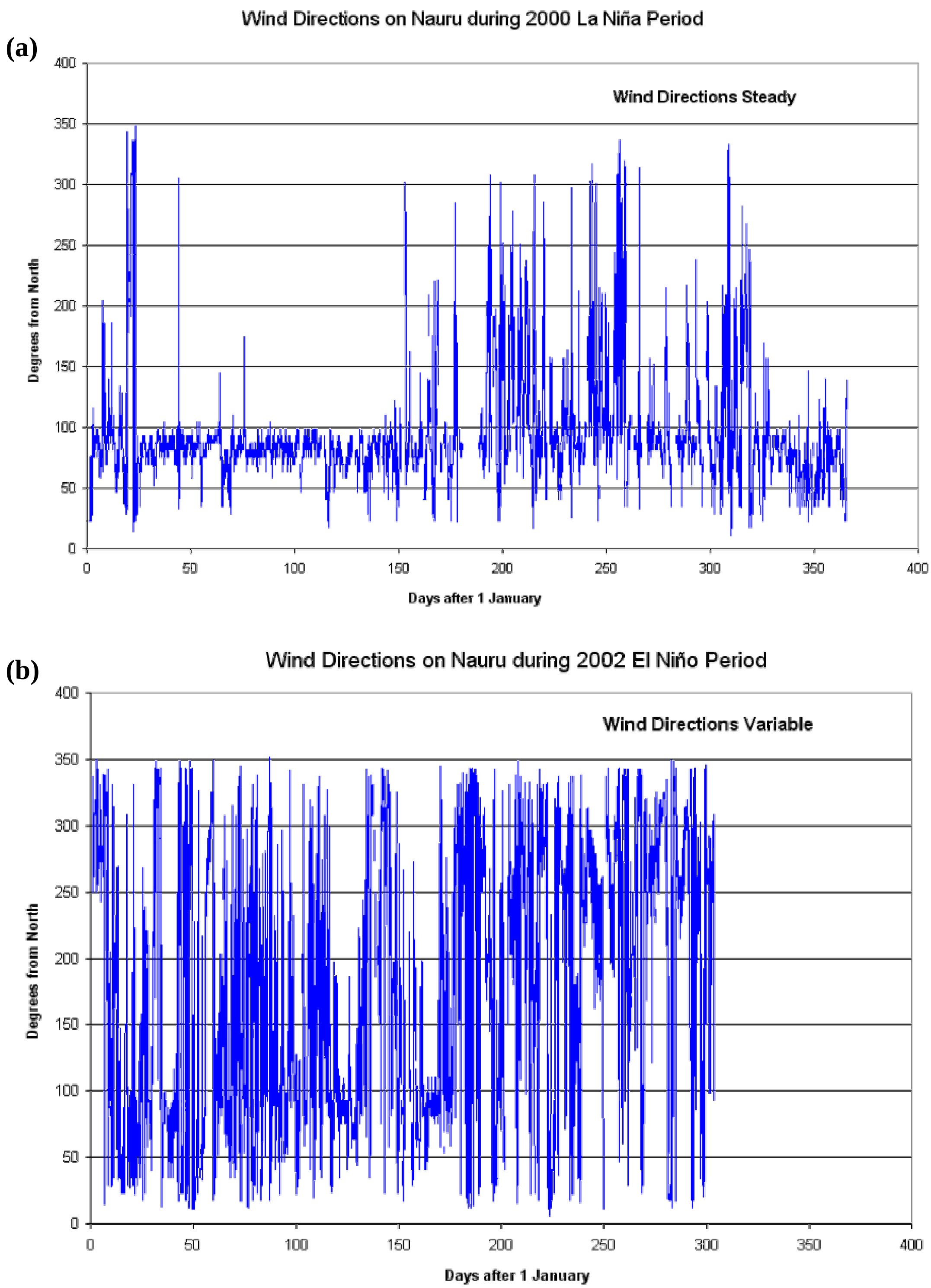
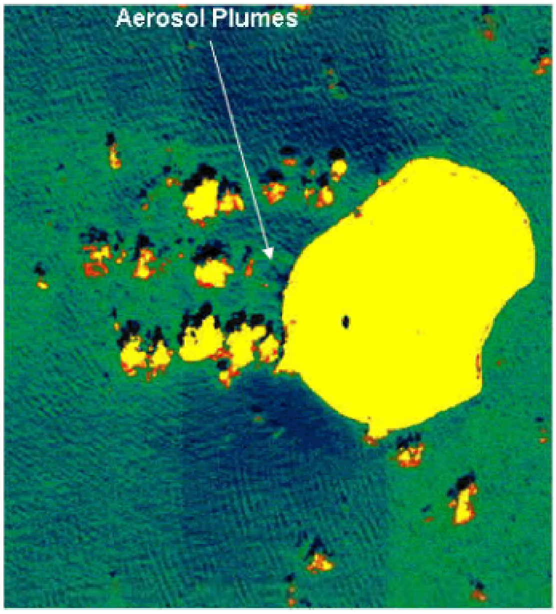


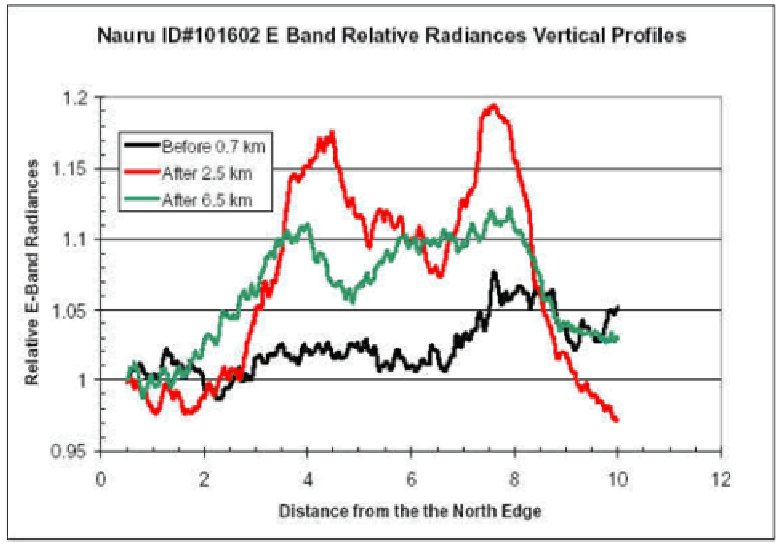
Figure 5. Hourly average wind directions from the 10-m tower at the ARM Nauru Facility during (a) 2000 (La Niña) and (b) 2002 (El Niño).

MTI E Band Image Shows Aerosol Plumes Coming from Nauru



MTI E band radiances show more aerosols downwind of Nauru (east winds from the right)

There are higher aerosol concentrations toward the edge of the island.



E-band radiances at several transects upwind (Before) and downwind (after) the island.

Figure 6. Aerosol Observations from Nauru from the DOE MTI Satellite.

AERONET aerosol optical depths observed at Nauru (Figure 7) have shown that prior to 2002, the aerosol optical depths were steady and typical of tropical ocean locations with some evidence of periodic local aerosol generation. Toward the end of 2001, the general level of aerosol optical depth increased, and subsequent years showed periodic peaks of aerosol extinctions lasting several days with background aerosol levels similar to earlier years (except for a small aerosol extinction level increase in the November-January period, which may be due to ocean micro-organism aerosol generation).

Figure 7 seems to imply that during the years dominated by easterly winds and a La Niña Southern Oscillation, the aerosol level was very steady; however, after 2001, when the Southern Oscillation switched to El Niño conditions and more frequent periods of westerly winds, periods of high aerosol may have been transported from land masses west of Nauru. Therefore, both Nauru island clouds characteristics and island aerosol appear to be affected by the Southern Oscillation.

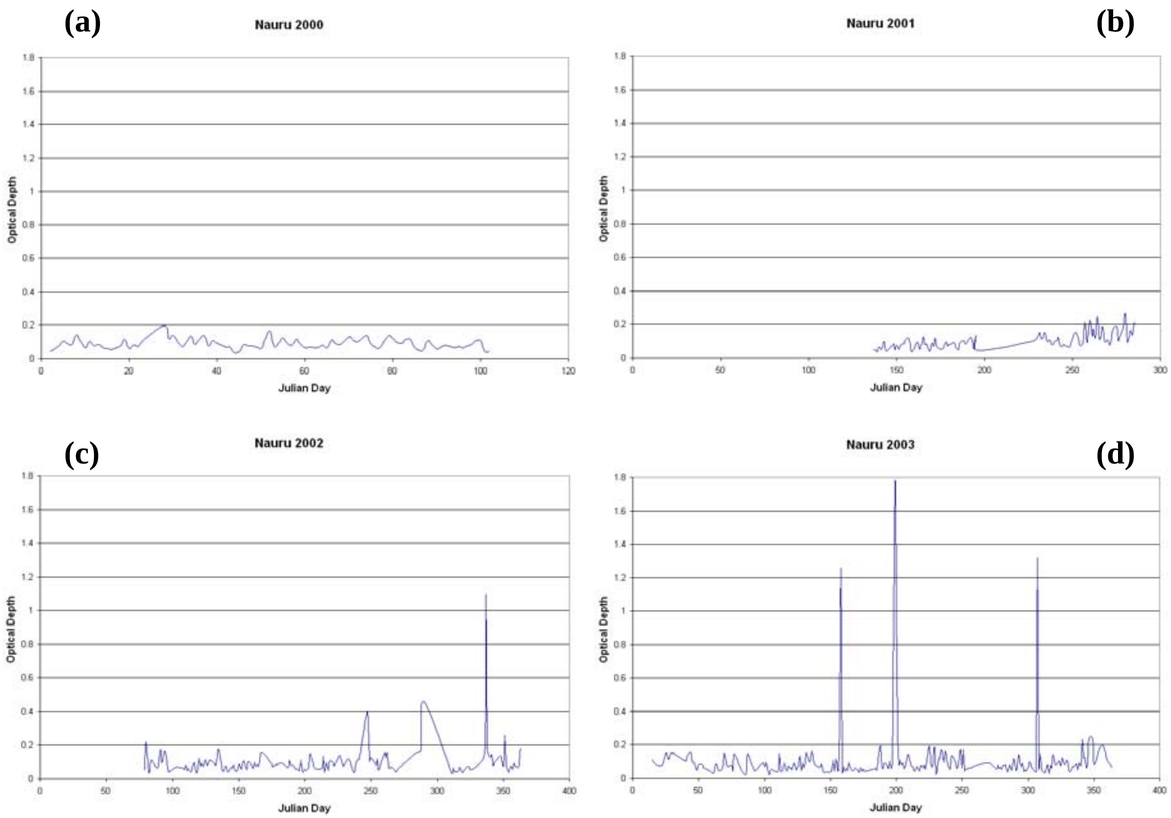


Figure 7. Aerosol optical depth measurements at visible (500 nm wavelength) made at Nauru using a sun-photometer from (a) 2000, (b) 2001, (c) 2002, and (d) 2003.

Corresponding Author

William M. Porch, wporch@lanl.gov, (505) 667-0971

References

McFarlane, S. A., and K. F. Evans, 2004a: Clouds and shortwave fluxes at Nauru. Part I: Retrieved Cloud Properties. *J. Atmos. Sci.*, **61**, 733-744.

McFarlane, S. A., C. N. Long, and D. Flynn, 2004b: Nauru Island Effect Study. This Proceeding.

Nordeen, M. L., P. Minnis, D. R. Doelling, D. Pethick, and L. Nguyen, 2001: Satellite observations of cloud plumes generated by Nauru. *Geophys. Res. Lett.*, **28**, 631-634.

Porch, W. M., R. Borys, P. Durkee, R. Gasporivic, W. Hooper, E. Hindman, and K. Nielson, 1999: Observations of ship tracks from ship-based platforms. *J. Applied Meteorol.* , **3**8, 69-81.

Zender, C. S., H. Bian, and D. Newman, 2003: Mineral Dust Entrained and Deposition (DEAD) Model: Description and 1990s Dust Climatology. *J. Geophys. Res.*, **108**, AAC8-1, 19.