Evidence for Island Effects and Diurnal Signals in Satellite Images of Clouds Over the Tropical Western Pacific

S. A. Barr-Kumarakulasinghe
Marine Sciences Research Center
State University of New York
Stony Brook, New York

R. M. Reynolds and P. J. Minnett
Oceanographic and Atmospheric Sciences Division
Brookhaven National Laboratory
Upton, New York

Introduction

Instruments to measure atmospheric radiation and ancillary meteorological variables will be set up on Manus Island as the first site of the tropical western pacific (TWP) locale of the Atmospheric Radiation Measurements (ARM) program. Manus is in the "warm pool" region of the TWP. This region is critical in establishing global atmospheric circulation patterns and is a primary energy source for the Hadley and Walker cells (Webster 1994; Skinner and Trapper 1994; Keenan et al. 1989). The myriad islands and enclosed seas in the immediate vicinity of Manus have been referred to as the "maritime continent" (Ramage 1968), which has the deepest convective activity in the world (Skinner and Trapper 1994; Keenan et al. 1989). Manus is in a region having a global impact on climate and where island effects on clouds are likely to be important. In this preliminary analysis we have sought evidence of island effects in the cloud fields around Manus and have studied the variability of the diurnal cycles of cloud cover over Manus and over other islands and areas of open sea in the region.

Methods

The data we have used are hourly images from the thermal infrared channel ($\lambda \sim 11\,\mu m$) of the GMS-4 (Meteorological Satellite Center 1989), at 10-km resolution for the time interval of November 1992 to February 1993. These data are now available on CD-ROM (Japanese Pacific Climatic Studies 1993). Hovmuller diagrams are used here to depict the longitudinal variation in time of the infrared channel brightness temperatures (T_b) at 2.1°S, the latitude of Manus (Figure 1). From this, and other evidence, it is clear that there were three distinct regimes during this period. Two regimes represent "undisturbed conditions" (December 1-18, 1992, and January 1-31, 1993), and one represents "disturbed conditions" during which a Madden-Julian event occurred (December 19-31, 1992) (Madden and Julian 1971).[a] For these time periods we created images of average brightness temperature fields and diurnal cycles of probabilities of the occurrence of low, mid-level, and high clouds. These cloud divisions are determined using only infrared brightness temperature ranges: $T_b < 273°K$, $220°K < T_b < 273°K$, and $T_b < 220°K$. These are not the thermodynamic temperatures as they are not corrected for emissivity effects, nor for the intervening atmosphere. A comparison was made of diurnal cycles of cold clouds over the center of the Bismarck Sea and over three islands of varying size, Manus, Luf (Hermit Islands) and Mussau (Figure 2, Table 1).

Results and Discussion

The Hovmuller diagrams show a regular series of lower cloud temperatures around 147°E (lighter color), especially during December 1-7 and January 12-17 (Figure 1). These regular occurrences of convection are suppressed (or at least masked) during the periods when the cloud fields are associated with larger scale meteorological features. This suppression of diurnal cloud formation by large-scale features has been identified over Melville Island by Skinner and Tapper (1994), who ascribe the suppression of diurnal convection to both the reduction of the land-sea temperature differences resulting from the diminished surface insolation.

(a) D. Waliser, 1994, personal communication.

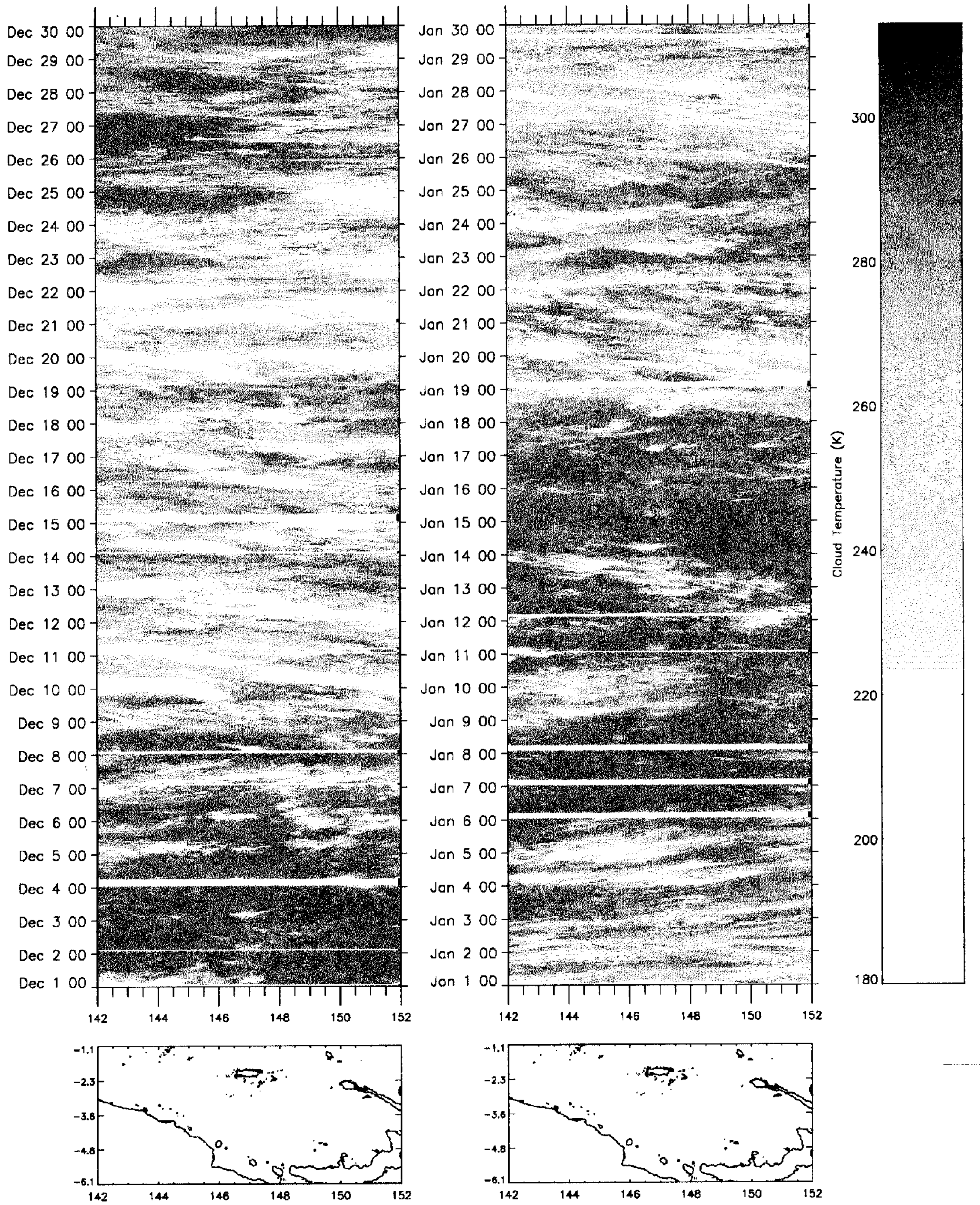

Figure 1. Hovmuller diagrams of satellite infrared channel brightness temperatures measured along the line of latitude 2.1°S, through the island of Manus, for the months of December 1992 and January 1993. The diurnal influence of Manus on the clouds is most apparent in conditions where the surrounding area is cloud free.

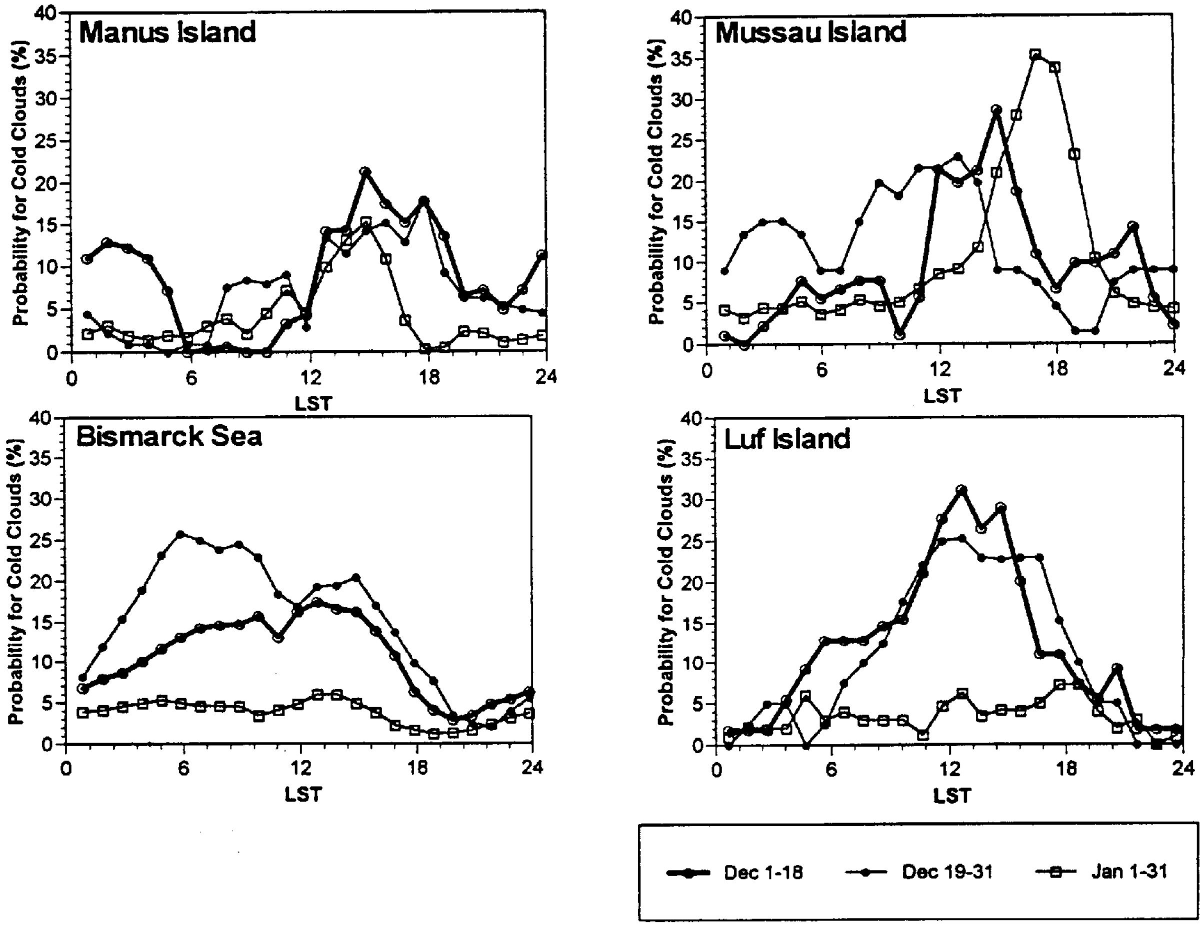

Figure 2. Diurnal cycles of the probability of the occurrence of high clouds $(T_b < 253°K)$ over Manus, Mussau and Luf Islands, and over the Bismarck Sea. Diurnal cycles for the three regimes discussed in the text are shown.

Table 1. Islands used in this study.

Island	Location	Topography [a] (m)	Area [b] (km^2)	Perimeter [b] (km)
Manus	2.1S, 147.0E	718	1925	475
Luf	1.5S, 145.0E	111-244	7	20
Mussau	1.4S, 149.6E	651	346	102

(a) Defense Mapping Agency (1992).
(b) Calculated from coastline data of the World Vector Shoreline.

In the presence of extensive cloud cover and the inhibition of sea-breezes by the strong large-scale surface winds.

The average temperatures over Manus are lower than the surrounding area as are the probabilities of low clouds. The probabilities of mid clouds and high clouds are increased over the island. The diurnal cycles for the cold, mid-level, and high clouds surrounding 2° x 2° have approximately the same shape but with somewhat reduced amplitudes as that over Manus island, and this appears to reflect the island's influence on the surrounding region (approximately 100 km). The shape of the diurnal cycles over and around Manus are different from those over the Bismarck Sea (Figure 2).

The diurnal cycles of the cold clouds show that Manus Island changes from having two peaks, one early in the morning and one in the afternoon for cold clouds in December 1-18, to a single peak in the afternoon during January (Figure 2). Mussau, an island a sixth the size of Manus has three times the probability of high clouds over it during the evening. Even Luf Island, a small island has a higher probability of high clouds over it compared with Manus.

These results indicate that convective activity over even small islands can be significant. The possibility of small islands inducing considerable convection has also been observed elsewhere.[a] Published studies indicate that cloud structure over an island is primarily controlled by its size and relief (Gray and Jacobson 1977), with large islands typically showing morning and evening maxima and small islands only a morning maximum in their diurnal cycles of rainfall and convection. Our preliminary analysis shows that the characteristic forms of the diurnal convection may be determined also by the influence of large-scale meteorology, with the same island displaying single or double peaks dependent on the larger-scale atmospheric features.

Conclusions

Based on our study, the following conclusions can be reached:

- Island effects are discernable in satellite thermal infrared images.
- Diurnal cycles of clouds are sometimes different over islands than over the open sea.
- Diurnal effects are influenced, probably suppressed, by larger-scale cloud fields or meteorological structures.
- Island effects will have consequences on the analysis of ARM surface radiometric and meteorological measurements as these are localized and subject to small, island-scale influences. When used with measurements covering the larger scale features, such as from satellite and aircraft, there is the potential for systematic discrepancies resulting from scale-mismatch.

(a) J. Simpson, 1994, personal communication.

References

Defense Mapping Agency. 1992. *Sailing Directions (Enroute) for the Pacific Islands*. Publication 126, Defense Mapping Agency Hydrographic/Topographic Center, Bethesda, Maryland.

Gray, W. M., and R. W. Jacobson. 1977. Diurnal variation of deep cumulus convection, *Mon. Wea. Rev.*, **105**, 1171-1188.

Japanese Pacific Climatic Studies. 1993. *GMS-4 Infrared images over the TOGA-COARE region*. Japan Meteorological Agency and Science and Technology Agency, Ibaraki, Japan.

Keenan, T. D., B. R. Morton, M. J. Manton, and G. J. Holland. 1989. The island thunderstorm experiment (ITEX)-A study of tropical thunderstorms in the maritime continent, *Bull. Am. Met. Soc.*, **70(**2), 152-159.

Madden, R., and P. R. Julian. 1971. Detection of a 40-50 day oscillation in the zonal wind in the tropical Pacific, *J. Atmos. Sci.*, **28**, 702-708.

Meteorological Satellite Center. 1989. *The GMS Users Guide*. Meteorological Satellite Center, Tokyo 204, Japan.

Ramage, C. S. 1968. Role of a tropical "maritime continent" in the atmospheric circulation, *Mon. Wea. Rev.*, **96**, 365-370.

Skinner, T., and N. Trapper. 1994. Preliminary sea breeze studies over Bathurst and Melville Islands, Northern Australia, as a part of the Island Thunderstorm Experiment (ITEX), *Meteorol. Atmos. Phys.*, **53**, 77-94.

Webster, P. J. 1994. The role of hydrological processes in ocean-atmosphere interactions, *Rev. Geophys.*, **32**(4), 427-476.