TOGA Notes

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TOGA Notes

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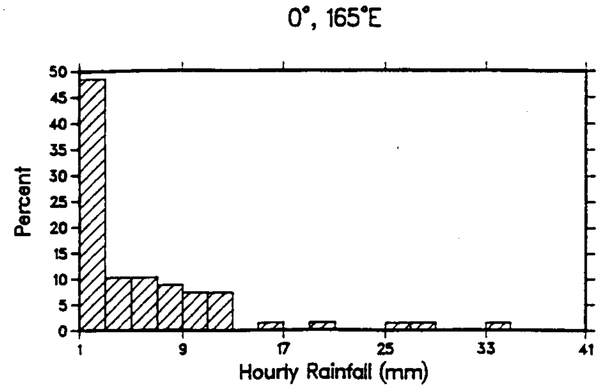

Figure 7. Histogram of hourly moored rain rate data based on 68 nonzero values between 7 August and 7 September 1991.

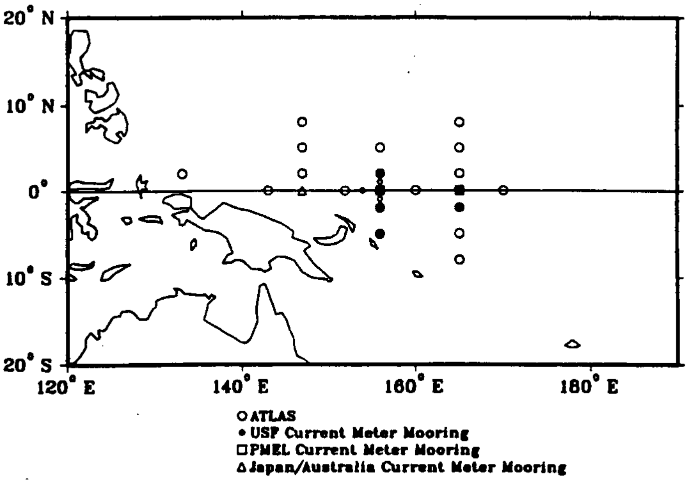

Figure 8. Array of moored measurements for enhanced monitoring in the COARE domain, 1992-1993. Solid symbols indicate rain gauge sites.

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Satellite-observed Cloud Clusters in the TOGA-COARE Domain

The Intensive Observation Period (IOP) for the TOGA Coupled Atmosphere-Ocean Response Experiment (TOGA-COARE) will take place in the extreme western equatorial Pacific from November 1992 through February 1993. As described in the Experiment Design (TCPO, 1991), numerous fixed atmospheric and oceanic observing platforms will be located near 2°S, 156°E during the IOP. The focus of the observations will be the Intensive Flux Array (IFA), which consists of several ships with surface flux measurement, atmospheric sounding, and oceanographic measurement capabilities. The central ships in the IFA will be equipped with meteorological radars, which will measure precipitation in circular areas of ~ 100 km radius. Measurement of fluxes at the air-sea interface can thereby be related to precipitating atmospheric convection. In addition to the fixed platforms in the IFA, a number of aircraft will be available during the IOP. Most of the aircraft will be staged out of Noniara, 1000 km (~ 2 h flying time) southeast of the IFA (see Figure 1).

As background information for the planning of the TOGA-COARE aircraft program, we have constructed a three-year (1986-87, 1987-88, 1988-89) climatology of southern summer (November-February) cold cloudiness from GMS infrared satallite data. These data serve as a proxy for deep convective cloud and precipitation systems. For the same three years, Janowiak and Arkin (1991) presented seasonal (DJF) mean rainfall maps based on the observed climatological correlation between cold cloudiness coverage and rainfall. These years span an ENSO cycle, with unusually high sea surface temperature (SST) in the equatorial western Pacific in 1986-87, unusually low SST in 1988-89, and intermediate conditions in 1987-88. Figure 1 shows seasonal-mean maps of cold-topped cloud coverage, expressed as percentage high cloudiness (PHC) for the data used in this study. In each year, the region of the planned TOGA-COARE IFA lay in a zone with a mean gradient of PHC, with significantly higher values to the east and southeast, as well as island-induced maxima to the west.

In order to clarify the scales of the actual deep convective systems contributing to the mean cloudiness maps, the data have been objectively processed, in the manner of Williams and Houze (1987), to reveal spatially connected areas (at 10 km resolution) of cold cloudiness (with blackbody temperature T_{BB} < -65°C), which for the purposes of this note we will call "cloudiness elements" (CEs). The -65°C temperature threshold is arbitrary, but it is our impression that CEs so defined correspond well with radar echo areas (precipitation areas) in mesoscale convective systems (MCSs) near northern Australia, as sampled by airborne radars in EMEX (Webster and Houze, 1991). Temperatures this low are *not* associated with the radiatively important cirrus anvil clouds, which shear off of the convection and cover areas much larger than the precipitation area.

The size spectra of all the CEs in the domain of Figure 1 are shown in Figure 2, with the accumulated area coverage shown against a logarithmic size scale. The abcissa is the accumulated normal distribution function; lognormally distributed variables appear as straight lines on such a diagram. The properties describing populations of tropical convective systems (area covered, duration, rainfall etc.) tend to be lognormally distributed (Houze and Betts, 1981). The 1986-87 and 1987-88 spectra are quite similar, while the 1988-89 spectrum is lower on the diagram. In other words, less area was covered by very large CEs in 1988-89 (the largest CE was only $2x10^5$ km^2 compared to $4x10^5$ km^2 in the other years). Figure 2 indicates that 25% of the cold cloud area is accounted for by CEs with areas less than ~ 6,000 km^2, 50% by

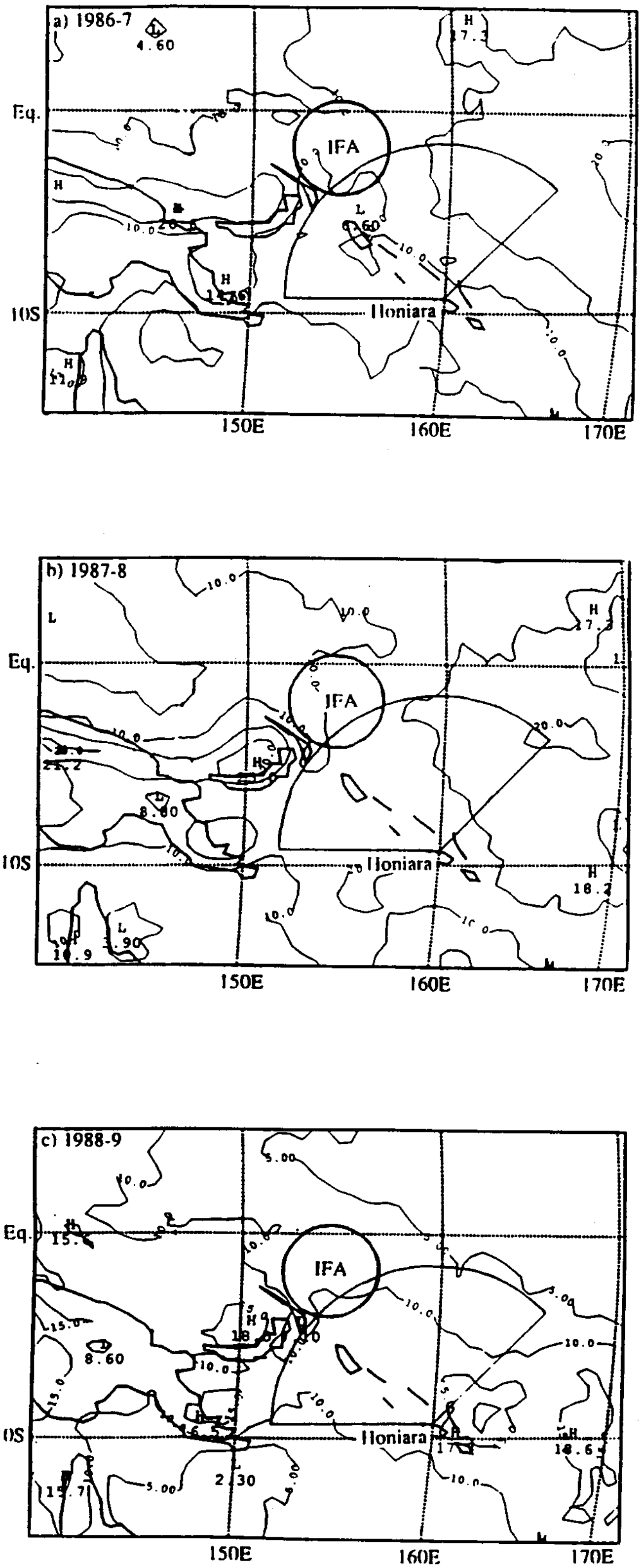

Figure 1. Percentage High Cloudiness (PHC), defined here as the fractional coverage of cloudiness with IR blackbody temperature T_{BB} < 288K. The spatial pattern is not very sensitive to the arbitrary threshold temperature. a) November 1, 1986, to February 28, 1987. b) November 25, 1987, to February 29, 1988. c) November 16, 1988, to January 24, 1989.

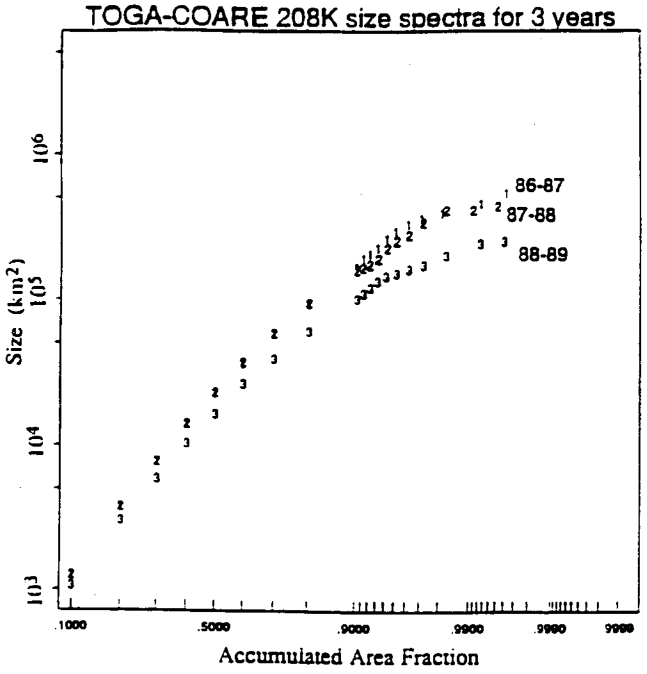

Figure 2. Year-by-year size spectra of the cloudiness elements (CEs), as defined by the 208K threshold, within the domain of Figure 1.

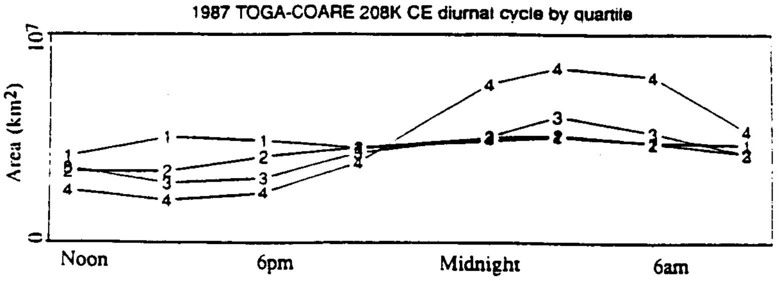

Figure 3. Diurnal cycle of area, within the domain of Figure 1, covered by CEs in each of the four size quartiles 0-6000 km², 6000-22500 km², 22500-65000 km², > 65000 km² (derived from Figure 2). Only data from 1986-87 are shown; other years are similar.

CEs smaller than ~ 20,000 km², and 75% by CEs smaller than ~ 65,000 km². Thus, these sizes define quartiles (with respect to area coverage) of the size spectrum of CEs in the region. In order to meet the TOGA-COARE objectives, *the aircraft program will be organized so that comparable attention is paid to convective systems in each size quartile (as well as to no-deep-convection conditions).*

The four size quartiles have different diurnal variability. As shown in Figure 3, the smallest CEs cover nearly equal amounts of area at all hours of the day. Near land, there is an oscillation of the small CEs between the land (daytime) and an offshore zone ~ 300 km in width (nighttime), but in the IFA region and over the open ocean, the incidence of small CEs is nearly independent of time of day. By contrast, the larger CEs, especially the fourth quartile, have a pronounced (4:1) diurnal cycle, with maximum coverage just before sunrise. More importantly, this diurnal cycle of large CE coverage reflects the life cycle of the associated mesoscale convective systems, which have lifetimes of ~ 12 h. The convective phase of the life cycle occurs from midnight to 6 A.M. LST, and then the systems begin to dissipate after dawn. As a result, *night flights will be necessary in order to sample adequately the systems responsible for these largest CEs.* A similar diurnal cycle prevails in all years.

The number of opportunities available to sample the CEs of various sizes in a given spatial domain is shown in Figure 4. The points represent CEs of various sizes (expressed as equivalent radius $R_{eq} = (A/\pi)^{1/2}$, where A is the CE's area), at 3 A.M. LST only, which overlap the IFA (upper panels) and the larger domain in Figure 1 (lower panels). The larger domain is that portion of the circle 1000 km (~ 2 h flying time) in radius, centered on the aircraft base in Honiara, which lies within the larger-scale TOGA-COARE IOP sounding network. Overlap is defined by the centroid of a CE lying within a distance R_{eq} of the areas indicated in Figure 1. The radii R_{eq} corresponding to the quartile boundaries discussed above are shown as horizontal lines.

In the 4 months from November 1986 to February 1987, only 2 fourth-quartile CEs overlapped the IFA, while the larger domain contained 15. In 14 weeks during 1987-88, the corresponding numbers are 3 and 12, while 10 weeks of 1988-89 offered 2 and 6 opportunities, respectively. It is apparent that in order to sample adequately the large CEs, not only are night flights a necessity, but *the aircraft will probably have to operate outside the IFA area.* This is particularly true if the large CEs must be sampled within a more limited time window, such as January 1993, when the full fleet of specialized aircraft will be available. Similar concerns may apply to the third size quartile, although the diurnal modulation is not quite so severe. Fortunately, the CEs at the smaller end of the size spectrum probably can be sampled adequately within the confines of the IFA, maximizing the overlap of measurements from diverse platforms.

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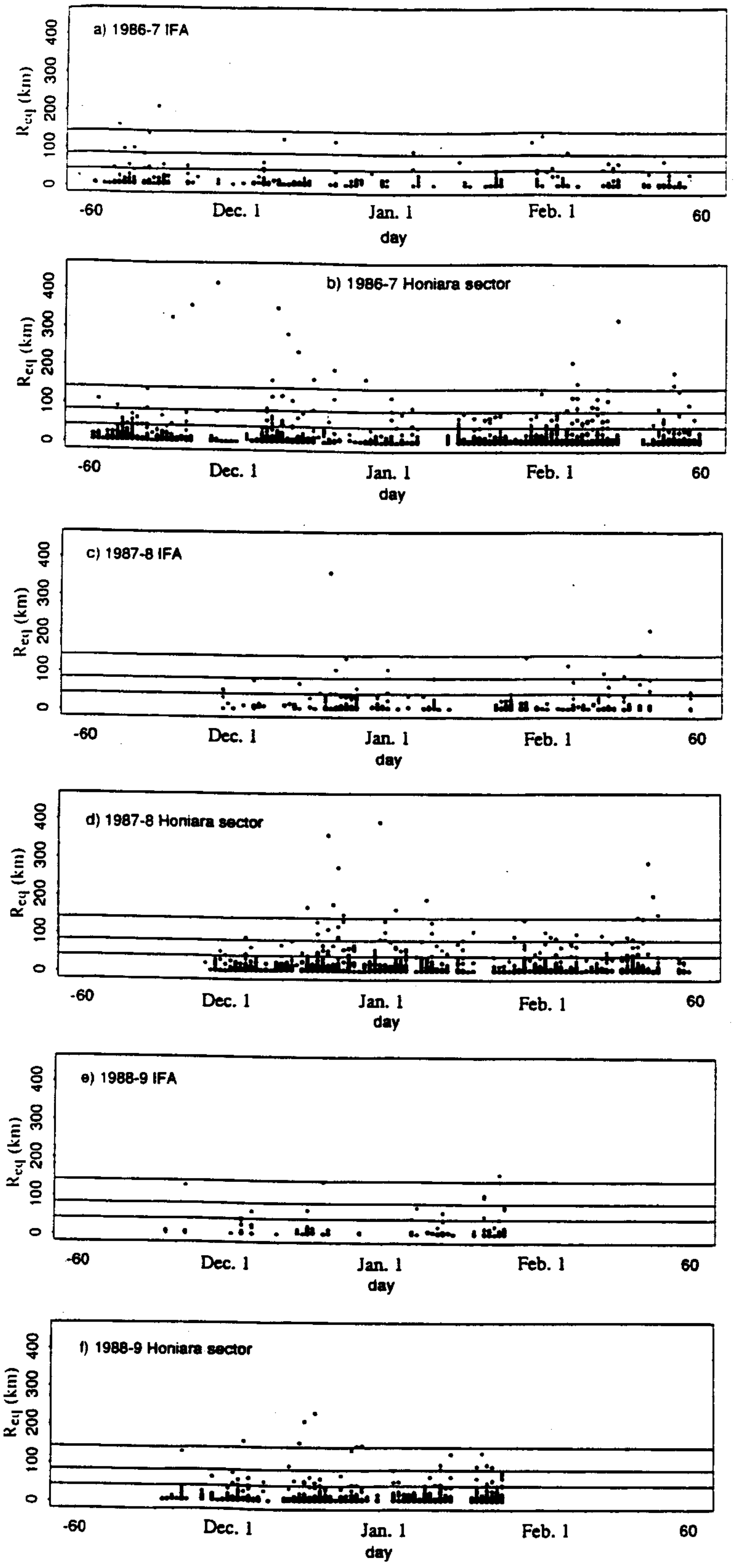

Figure 4. Time-size series of CEs in the IFA circle and larger Honiara sector shown in Figure 1, at 3 A.M. LST only (peak of diurnal cycle in Figure 3). Each dot represents one CE, characterized by its equivalent radius $R_{eq} = (A/\pi)^{1/2}$*, whose centroid is within a distance* R_{eq} *of the areas shown in Figure 1. The horizontal lines denote the boundaries of the size quartiles.*

Prediction of Northeast Brazil Rainfall Anomalies from Coastal Mean Sea Level

Introduction

It is now recognized that the occurrence of droughts in Northeast Brazil (Nordeste) corresponds to an unusually well-defined, large-scale atmospheric circulation pattern (Hastenrath and Heller, 1977) which is correlated to sea surface temperature anomaly (SSTA) distributions (e.g., Moura and Shukla, 1981) in the tropical Atlantic.

Much less is known about the large-scale ocean dynamics at interannual time-scales which correspond to this atmospheric anomaly pattern. At these scales, we can expect a close relationship between thermocline depth, sea surface dynamic topography and SST fields in the western Atlantic (Houghton, unpublished manuscript). Recent work (Vianna and Holvorcem, 1992; Holvorcem and Vianna, 1992; Vianna, 1992) indicates a way to obtain the two-dimensional (2D) sea-surface topography from the one-dimensional (1D) coastal mean sea-level (MSL) field. In fact, one may substitute the 2D wind-stress forcing field by a functional of the 1D coastal MSL field forcing. In summary, these theoretical results suggest that coastal MSL in the western Equatorial Atlantic may well be correlated with precipitation anomaly fields in Nordeste. A similar kind of correlation study is also being made in Australia, with encouraging results (Allan *et al.*, 1990).

To test this idea in the tropical Atlantic, we decided to take a close look at the available monthly MSL data from Fortaleza, to determine the relationship, if any, between MSL and Fortaleza precipitation anomalies (PRECIP). We have found that PRECIP and MSL time series between 1962 and 1968 exhibit the same spectral peaks up to seasonal frequencies. Also, the cross-correlation between MSL and PRECIP displays oscillations with a 26-month period, that MSL precedes PRECIP by roughly one year. In this work, we present a preliminary time domain analysis. We plan to apply more rigorous statistical techniques to the analysis when we finish the digitalization of MSL data set for Fortaleza.