TOGA COARE Satellite Data Summaries Available on the World Wide Web

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Abstract

Satellite data summary images and analysis plots from the Tropical Ocean Global Atmosphere Coupled Ocean–Atmosphere Response Experiment (TOGA COARE), which were initially prepared in the field at the Honiara Operations Center, are now available on the Internet via World Wide Web browsers such as Mosaic. These satellite data summaries consist of products derived from the Japanese Geosynchronous Meteorological Satellite IR data: a time–size series of the distribution of contiguous cold cloudiness areas, weekly percent high cloudiness (PHC) maps, and a five-month time–longitude diagram illustrating the zonal motion of large areas of cold cloudiness. The weekly PHC maps are overlaid with weekly mean 850-hPa wind calculated from the ECMWF global analysis field and can be viewed as an animation loop. These satellite summaries provide an overview of spatial and temporal variabilities of the cloud population and a large-scale context for studies concerning specific processes of various components of TOGA COARE.

1. Introduction

The Tropical Ocean Global Atmosphere Coupled Ocean–Atmosphere Response Experiment (TOGA COARE) was designed to achieve a better understanding of the physical mechanisms of the coupling of the ocean and the atmosphere in the western Pacific warm-pool region. One of the goals of TOGA COARE is to describe and understand the processes that organize convection and the effects of convection on the large-scale atmospheric and upper-oceanic circulations in the warm-pool region (Webster and Lukas 1992).

The population of convection over the warm-pool region is closely related to the large-scale circulation and exhibits variations over a broad spectrum of temporal and spatial scales (Nakazawa 1988; Lau et al. 1991; Sui and Lau 1992; Mapes and Houze 1993; Chen et al. 1995). During the intensive observation period (IOP) of TOGA COARE (1 November 1992–28 February 1993) the circulation and cloudiness over the warm-pool region underwent two cycles of the intraseasonal oscillation (ISO) that were characterized by alternating periods of suppressed and active convective activity (Chen et al. 1995). Because of these variations, it was necessary to maintain a real-time overview of the population of clouds over the oceanic region of the Tropics stretching from the Indian Ocean eastward across the western Pacific.

During the daily operation of the project, particularly in the aircraft program, the general pattern of cloudiness shown by satellite was used to indicate and monitor the evolution of the ISO and other large-scale circulations that affected the TOGA COARE domain. Aircraft and shipboard measurements in TOGA COARE were designed to observe critical aspects of the warm-pool convective clouds and to document the structure of the atmospheric and oceanic boundary layers. Summaries of the satellite data were constructed and used in the daily aircraft planning meetings at the TOGA COARE Honiara Operations Center in the Solomon Islands. The satellite summaries were derived and updated daily from hourly infrared images of the Japanese Geosynchronous Meteorological Satellite (GMS). The GMS images were received at the Honiara Operations Center via the Australian Bureau of Meteorology.

Since the field phase of TOGA COARE, the satellite summaries have been checked and edited. These satellite summaries remain useful as an overview of the cloud population that was observed in TOGA COARE. They provide a large-scale context for studies concentrating on specific processes such as air–sea fluxes or mesoscale organization of the convective systems. The summary images and analysis plots that were constructed during the field phase of TOGA COARE are now available to all researchers in electronic form on the Internet via World Wide Web browsers such as the National Center for Supercomputing Applications's (NCSA) Mosaic software. The images

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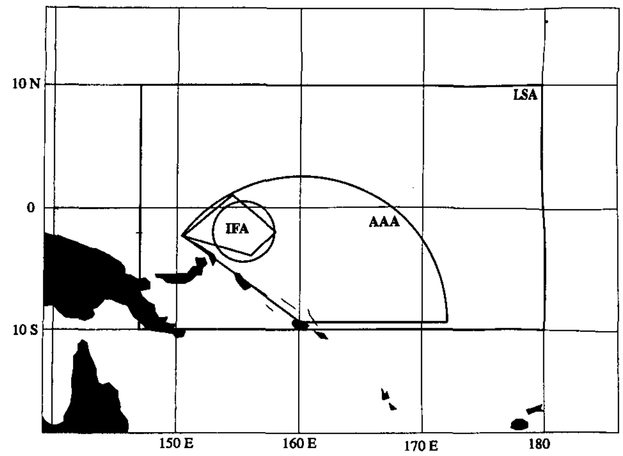

FIG. 1. The TOGA COARE experimental area. The LSA, AAA, and the IFA are outlined. The actual IFA is the quadrilateral. The 2.5° radius circle, which has the same area as the IFA, was used in counting the "IFA cloud clusters" in Fig. 2.

will be periodically added to and updated as further information becomes available. This paper presents examples of the summary images and plots and provides instructions for accessing them over the Internet.

2. Time–size plot of cloud clusters for aircraft sampling evaluation of the cloud population

For the purpose of monitoring the spectrum of convection sampled by the TOGA COARE aircraft, the areas of cold cloud top in the TOGA COARE domain at each hour were measured, their centroids were located, and they were partitioned into four classes (<6000, 6000–20 000, 20 000–60 000, and >60 000 km^2) numbered 1–4, according to the sizes of areas of contiguous cold cloud-top temperatures below 208 K. Climatologically, the area covered by each of these four classes accounts for approximately one-quarter of the total <208 K cloudiness. These categories were suggested by Mapes and Houze (1992) and adopted for operational use in the TOGA COARE experiment design plan [TOGA COARE International Project Office (TCIPO) 1992]. Each aircraft mission was assigned a class designation according to the largest contiguous area of cold cloud-top temperatures <208 K present in the region sampled by the mission. Class 0 missions had no cloud-top area less than 208 K, while class 1–4 missions investigated cloud systems with progressively larger areas of cold cloud top.

To evaluate how well the aircraft missions were sampling the spectrum of cloudiness, a running count of the number of cloud areas in each category was maintained and plotted throughout the experiment. These counts were made for the three nested regions of TOGA COARE operations shown in Fig. 1. These regions are described in the following sections.

a. Intensive flux area (IFA)

This was the region of most concentrated observations taken on islands, ships, and buoys. It is shown by the quadrilateral enclosing the point 2°S, 155.4°E, which was the central buoy location in the array. For the purpose of identifying the satellite cloud clusters, the circular region in Fig. 1 was used as a proxy for the actual IFA.

b. The aircraft accessible area (AAA)

This region is the partial circle radiating out in Fig. 1 from Honiara. The outer boundary of the circle was approximately the 3-h flight distance for the turboprop aircraft stationed at Honiara.

c. The TOGA COARE large-scale array (LSA)

This region encompasses the primarily oceanic area (147°–180°E, 10°S–10°N) of the TOGA COARE domain. The longitudinal coordinates for the LSA have been modified from the coordinates defined in TCIPO (1992) and Webster and Lukas (1992) to remove most of the influence of the New Guinea landmass.

A cloud cluster is defined by a closed contour of 208 K temperature on an hourly satellite IR image. Each dot in Fig. 2 represents one cloud cluster. The cluster radius is the radius of a circle having the same area as the observed cloud cluster. The time period of the plot is from 1 November 1992 to 28 February 1993, the full duration of TOGA COARE operations. Horizontal lines in the figure mark the boundaries of size classes 1–4. The clusters whose centroids were in the three areas defined above are shown in Figs. 2a–c.

Figure 2a shows that the class 1 systems were present over the IFA nearly every day. However, class 4 systems were rare. For the TOGA COARE aircraft to sample such large systems often enough to obtain a representative sample, a region larger than the IFA had to be considered (the aircraft accessible area in Fig. 1). Figure 2b shows that a reasonable number of opportunities for sampling the larger systems occurred in the aircraft accessible area.

3. Weekly maps of percent high cloudiness and 850-hPa wind field over the TOGA COARE domain

The weekly percent high cloudiness (PHC) maps were created by calculating the percentage of time

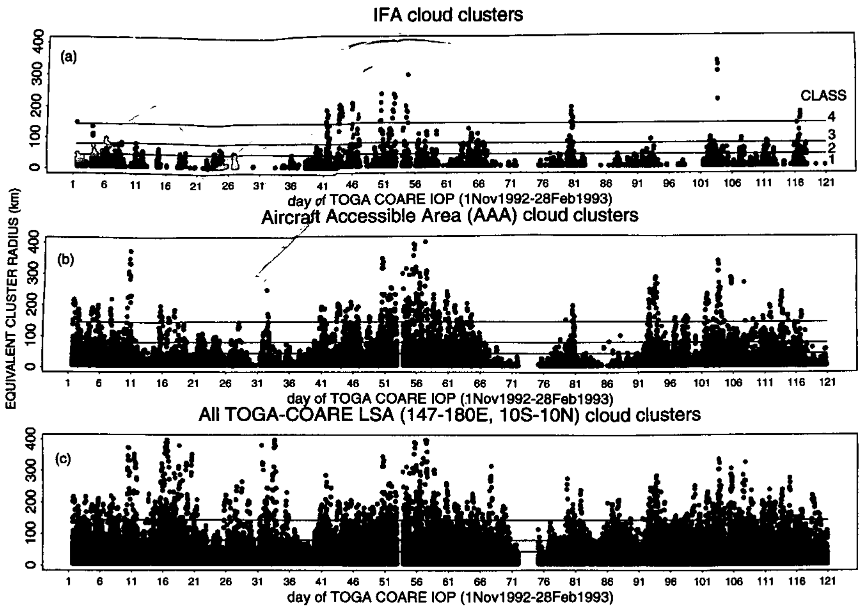

FIG. 2. Time series of occurrence of cloud clusters (closed contours of infrared temperature 208 K) as a function of their size for the period from 1 November 1992 to 28 February 1993. Horizontal lines are boundaries of size classes 1–4 referred to in the text. Panels (a)–(c) refer to cloud clusters in the IFA, AAA, and LSA shown in Fig. 1. Data are not available for 11–13 January 1993 (days 72–74).

during the week that each 10 km × 10 km pixel in the GMS IR image had a value of 235 K or less. PHC maps were constructed for the region between 20°S and 20°N for each week during the period 4 October 1992–27 February 1993. An example for the weeks of 27 December 1992–2 January 1993 and 10–16 January 1993 is in Fig. 3. The PHC values (in units of percent) are color coded in each map. Additionally, weekly mean 850-hPa winds calculated from the European Centre for Medium-Range Weather Forecasts (ECMWF) global analysis fields at 2.5° × 2.5° resolution are overlaid on each map. Wind vectors are scaled such that a 20 m s^{-1} wind is represented by a vector that would be 2.5° in length. The patterns of cold cloudiness illustrated in the weekly PHC maps are an indicator of the general locations of mesoscale convective systems and other deep convection during the week. The weekly PHC maps are displayed using SatView,[1] an interactive display and analysis tool for satellite and other meteorological data developed by the Department of Atmospheric Sciences at the University of Washington. By accessing the maps via Web browsers such as Mosaic (see section 5 for instructions), the user of these maps may view on demand any or all of the weekly PHC maps on her or his own workstation. The weekly PHC and 850-hPa mean wind maps can be viewed as an animation loop. The importance of these maps is to demonstrate the horizontal structure and evolution of the deep convection associated with the ISOs.

4. Time–longitude view of the percent high cloudiness in TOGA COARE

A time–longitude diagram of a PHC index (Fig. 4) was created from five months (1 October 1992–28 February 1993) of 0.5° × 0.5° resolution daily PHC maps. Each 1 day × 0.5°-long grid element in the time–longitude diagram is color coded according to the value of the PHC index, which is the meridional summation of the number between 20°S and 20°N of daily PHC values greater than 25%. The color thresholds are set so that dark blue represents fewer than 2 counts, light blue 2–9, green 10–19, yellow 20–29, and red ≥30. Patterns illustrated in the time–longitude diagram indicate the gross evolution and zonal migration of large areas of cold cloudiness across the longitudinal range 80°E–160°W. The diagram emphasizes deep convection that persisted longer than 6 h. More detailed discussions on deep convective activity and large-scale circulation during TOGA COARE are given in Chen et al. (1995).

Three episodes of the ISO, seen as an eastward propagating large-scale cloud ensemble, are included. The long-lasting westward propagating disturbances were three Northern Hemispheric tropical cyclones, Elsie, Gay, and Hunt (indicated in Fig. 4).

5. How to access satellite summary images via Mosaic

The satellite summary images are readily available to anyone with an appropriately configured computer

[1]SatView is an interactive tool for displaying satellite images and weather data. It runs under X Windows and was developed at the University of Washington as part of the National Aeronautics and Space Administration Earth Observing System Mission to Planet Earth. For further information or a copy of the software, e-mail satview@atmos.washington.edu.

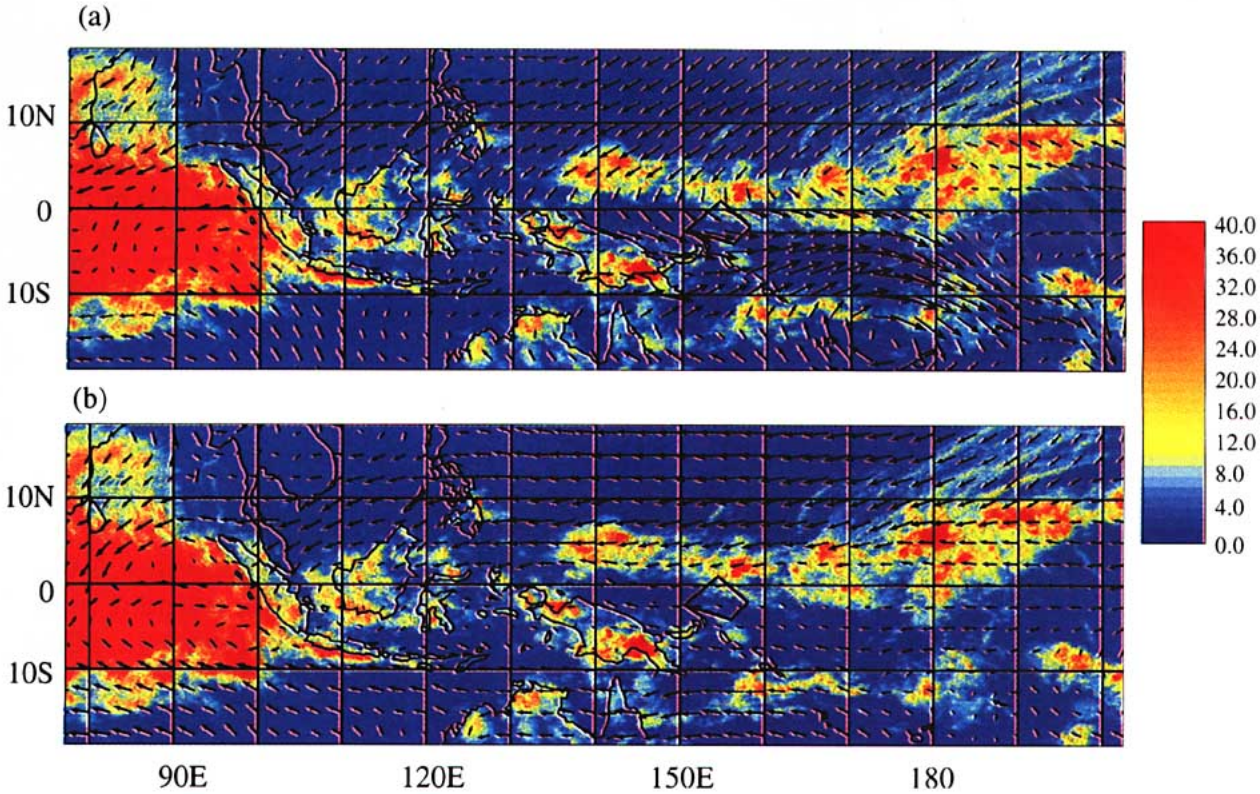

FIG. 3. Weekly PHC, calculated as the percentage of time during the week that each 10 km × 10 km pixel in the GMS IR image had a value of 235 K or less for the weeks of (a) 27 December 1992–2 January 1993 and (b) 10–16 January 1993. Also shown is the weekly mean wind from the ECMWF global wind analysis at 850 hPa with 2.5° × 2.5° grid resolution. Wind vectors are scaled such that a 20 m s^{-1} wind is represented by a vector that would be 2.5° in length.

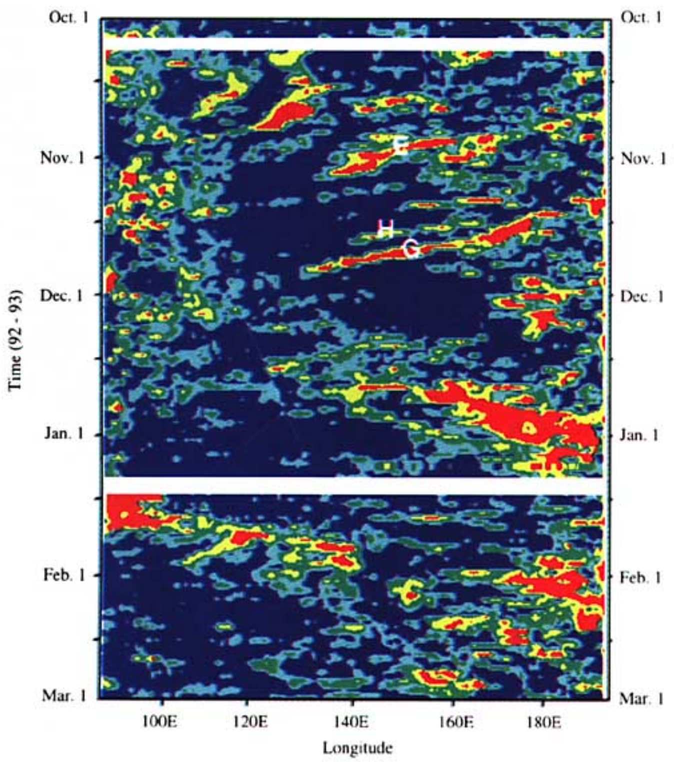

FIG. 4. Time–longitude section of daily PHC index. Each 1 day × 3 0.5°-long grid element is color coded according to the value of the PHC index, which is the meridional summation of the number of daily PHC values greater than 25% between 20°S and 20°N. The color thresholds are set so that dark blue represents fewer than 2 counts, light blue 2–9, green 10–19, yellow 20–29, and red ≥30. The three tropical cyclones (Elsie, Gay, and Hunt) are marked as E, G, and H. Blank areas (4–6 October 1992 and 11–13 January 1993) are missing data.

with access to the Internet. NCSA's Mosaic is a public domain (free), general purpose, mouse-driven interface to text and images, and is data accessible over the Internet. The Mosaic software is straightforward to install (see Yuter et al. 1995) and will run on a personal computer (PC) under Windows, the Apple Macintosh, and a wide variety of workstation platforms running the public domain X Windows system. We chose NCSA Mosaic as the distribution medium for the electronic atlas of satellite summary images since it requires minimal resources to install and its point-and-click interface is simple and easy to operate.

There are two different ways to access the satellite summary images on a system with Mosaic installed. The easiest way is to enter

> Mosaic http://www.atmos.washington.edu/togacoare/summaries.html

One can also perform a two-step process. First, get into Mosaic by entering the word **Mosaic.** Then, using the pull-down **File** menu in the top left corner of the window, choose **Open URL...** and type in

> http://www.atmos.washington.edu/togacoare/summaries.html

The Mosaic main document that will appear by following the instructions above is an annotated outline of available information. One can move between the main and subtopic documents containing additional information and/or images using the mouse.[2] The arrow slider on the right side of the window is used to scroll up or down to parts of the document not currently displayed in the window. Some words or phrases in the document are highlighted in blue and underlined. Highlighting in this manner indicates a hypertext link. Clicking the mouse on these hypertext links will either bring up additional textual information or perform an action similar to displaying an image or downloading software. Click on the blue text that says **Satellite summaries** to bring up the title page of the satellite summary document. The **Back** and **Forward** buttons at the bottom of the window are used to move back and forth between levels of text accessed via hypertext links. For additional information, use the **Help** pull-down menu in the top right corner of the Mosaic window.

6. Conclusions

The satellite data summaries used in the field in Honiara as part of the daily monitoring of the TOGA COARE field project provide a useful overview of the cloud field observed by the various instrumental platforms. The satellite summaries were used in aircraft operation planning in conjunction with the aircraft mission summaries, which are also being distributed via Mosaic (Yuter et al. 1995). We hope that the provision of these overview products electronically will aid researchers working on various components of TOGA COARE to put their analyses into context.

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References

Chen, S. S., R. A. Houze Jr., and B. E. Mapes, 1995: Multiscale variability of deep convection in relation to large-scale circulation in TOGA COARE. *J. Atmos. Sci.,* submitted.

Lau, K.-M., T. Nakazawa, and C.-H. Sui, 1991: Observations of cloud cluster hierarchies over the tropical western Pacific. *J. Geophys. Res.,* **96,** 3197–3208.

Mapes, B. E., and R. A. Houze Jr., 1992: Satellite-observed cloud clusters in the TOGA COARE domain. *TOGA Notes,* **1,** 5–7.

——, and ——, 1993: Cloud clusters and superclusters over the oceanic warm pool. *Mon. Wea. Rev.* **121,** 1398–1415.

Nakazawa, T., 1988: Tropical super clusters within intraseasonal variations over the western Pacific. *J. Meteor. Soc. Japan,* **66,** 823–839.

Sui, C.-H., and K.-M. Lau, 1992: Multiscale phenomena in the tropical atmosphere over the western Pacific. *Mon. Wea. Rev.,* **120,** 407–430.

TCIPO, 1992: TOGA COARE Operations Plan, 95 pp. [Available from UCAR, P.O. Box 3000, Boulder, CO 80307.]

Webster, P. J., and R. Lukas, 1992: TOGA COARE: The coupled ocean–atmosphere response experiment. *Bull. Amer. Meteor. Soc.,* **73,** 1377–1416.

Yuter, S. E., R. A. Houze Jr., B. F. Smull, F. D. Marks Jr., J. R. Daugherty, and S. R. Brodzik, 1995: TOGA COARE aircraft mission summary images: An electronic atlas. *Bull. Amer. Meteor. Soc.,* **76,** 319–328.

[2]The details of the Mosaic user interface implementation vary somewhat between the versions for X Windows, the Macintosh, and the PC. However, the same generic operations can be performed in all versions. The user-interface discussion in this paragraph refers to the X Windows version of Mosaic. Refer to the documentation accompanying the Mosaic distribution for specific information regarding the user interface on other platforms.