Estimation of Large-Scale Oceanic Rainfall for TOGA

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1. Introduction

The Global Precipitation Climatology Project (GPCP) of the World Climate Research Programme (WCRP) is responsible for producing global analyses of large-scale monthly rainfall through the use of a mix of satellite and conventional data. Over the tropical oceans, the primary information source is rainfall estimates derived from geostationary IR digital data using a simple thresholding algorithm, supplemented by polar-orbiting IR and microwave observations. Estimates using IR data are now available for the tropics for 5-day periods beginning in January 1986 using data from GOES East and West, Meteosat, GMS and NOAA-9, 10 and 11. In this paper we will describe the GPCP and the interannual variability in tropical oceanic precipitation during 1986-1988 depicted by its analyses.

2. The global precipitation climatology project

The need for analyses of large-scale areally-averaged precipitation for periods of 5 days to monthly covering at least the tropics to satisfy the requirements of the WCRP became clear in early 1985, as the Tropical Ocean-Global Atmosphere (TOGA) Programme was beginning. A workshop on Global Large-scale Precipitation Data Sets for the WCRP was held in Camp Springs, MD, USA in July 1985, and recommended (WCRP, 1986) that a GPCP be instituted to use available algorithms and data to produce these analyses. Its objectives include :

a. the production of estimates of tropical precipitation from areas of 2.5° latitude x 2.5° longitude for periods of 5 days using geostationary satellite data;
b. the derivation of rainfall estimates for similar spatial scales and for months from passive microwave radiometric data;
c. the use of these data together with conventional rainfall data to produce analyses of monthly rainfall on a near-global scale; and
d. the development of a capability to validate and calibrate the various satellite estimates.

The organization of the GPCP is shown in Fig.1. The production of estimates from geostationary data requires the routine production of statistics, including histograms, means and spatial variances, of IR brightness temperatures for 5-day periods from each of the available satellites. This activity is carried out at the several Geostationary Satellite Data Processing Centers (GSDPCs). The integration of these data into rainfall estimates for the global tropics is done by the Geostationary Satellite Precipitation Data Centre (GSPDC). Data from the SSM/I (Special Sensor Microwave/Imager) instrument on the U.S. Defense Meteorological Satellite Program polar-orbiting satellite is processed at the Polar Satellite Data Processing Centre (PSDPC) and sent to the Polar Satellite Precipitation Data Centre (PSDPC), where it is used to obtain estimates of monthly oceanic precipitation. Both of the Precipitation Data Centres use calibration and validation information provided by the Surface Reference Data Centre (SRDC), where developmental work on new methods of measuring rainfall over the oceans is also coordinated. The Global Precipitation

Climatology Centre (GPCC) receives the various satellite estimates and, by combining them with conventional rainfall measurements, produces monthly analyses of near-global rainfall.

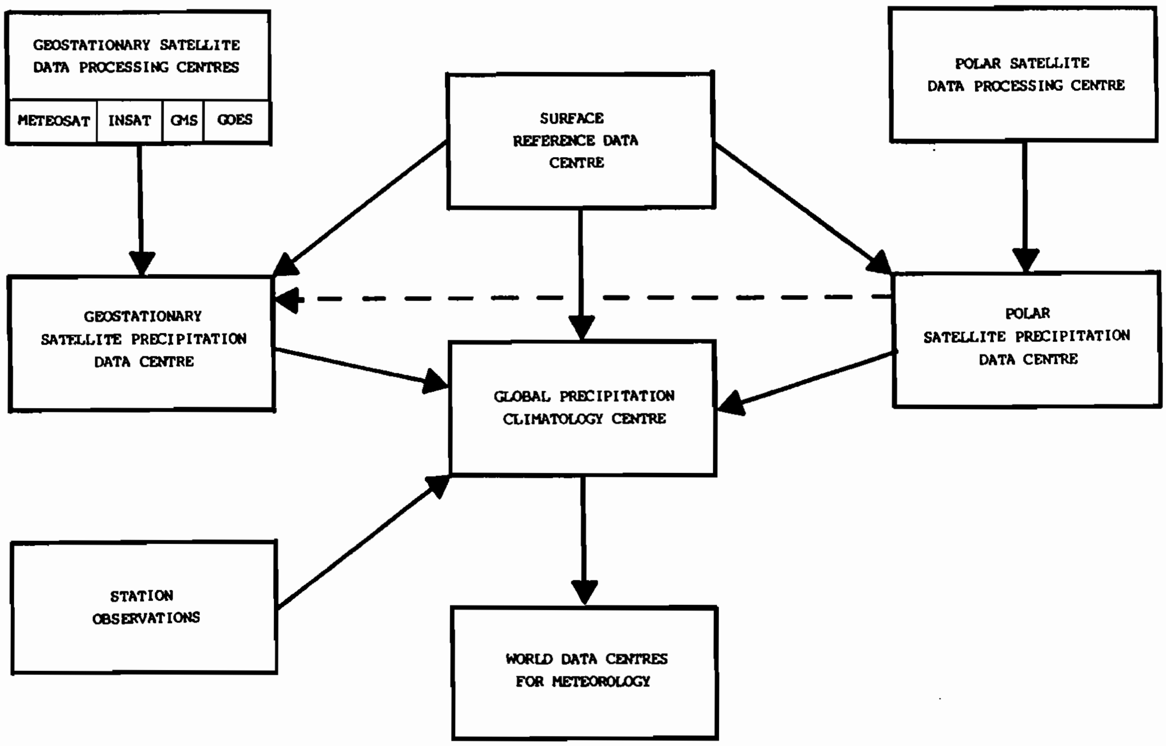

FIG.1. Organization and data flow of the Global Precipitation Climatology Project.

The GSDPCs for each of the geostationary satellites are currently producing the statistics required by the GPCP and, with the exception of that for INSAT, are regularly deliverying data. Figure 2 shows the status of geostationary data for the GPCP as of May 1989. The GSDPC for GOES is colocated with the GSPDC and has been producing data routinely for both satellites since July 1987. The GSDPCs for Meteosat and GMS, operated by the European Space Agency (ESA) (under contract from Eumetsat) and the Japan Meteorological Agency (JMA), respectively, have been delivering data since late 1987. Both JMA and ESA have completed post-processing and delivery of older data. While, India has not yet agreed to participate in the GPCP, the functional duties of an INSAT GSDPC have been carried out since June 1, 1986, by the India Meteorological Department as a result of a collaborative effort under a joint Indo-U.S. research program.

The GSPDC has developed preliminary merging and quality control algorithms, and analyses have been obtained for all pentads from January 1986 through December 1988. Rainfall estimates are computed from each satellite for each 5-day period, and then merged into an analysis covering the global tropics. Data from the NOAA polar-orbiting satellites are used to fill spatial and temporal gaps. The experience gained by the Global Processing Center of the International Satellite Cloud Climatology Project has proven very useful. Figure 3 shows an example of estimated tropical rainfall for a 30-day period during June 1988 in which data from GOES West, GOES East, Meteosat, GMS, NOAA-9 and NOAA-10 were used.

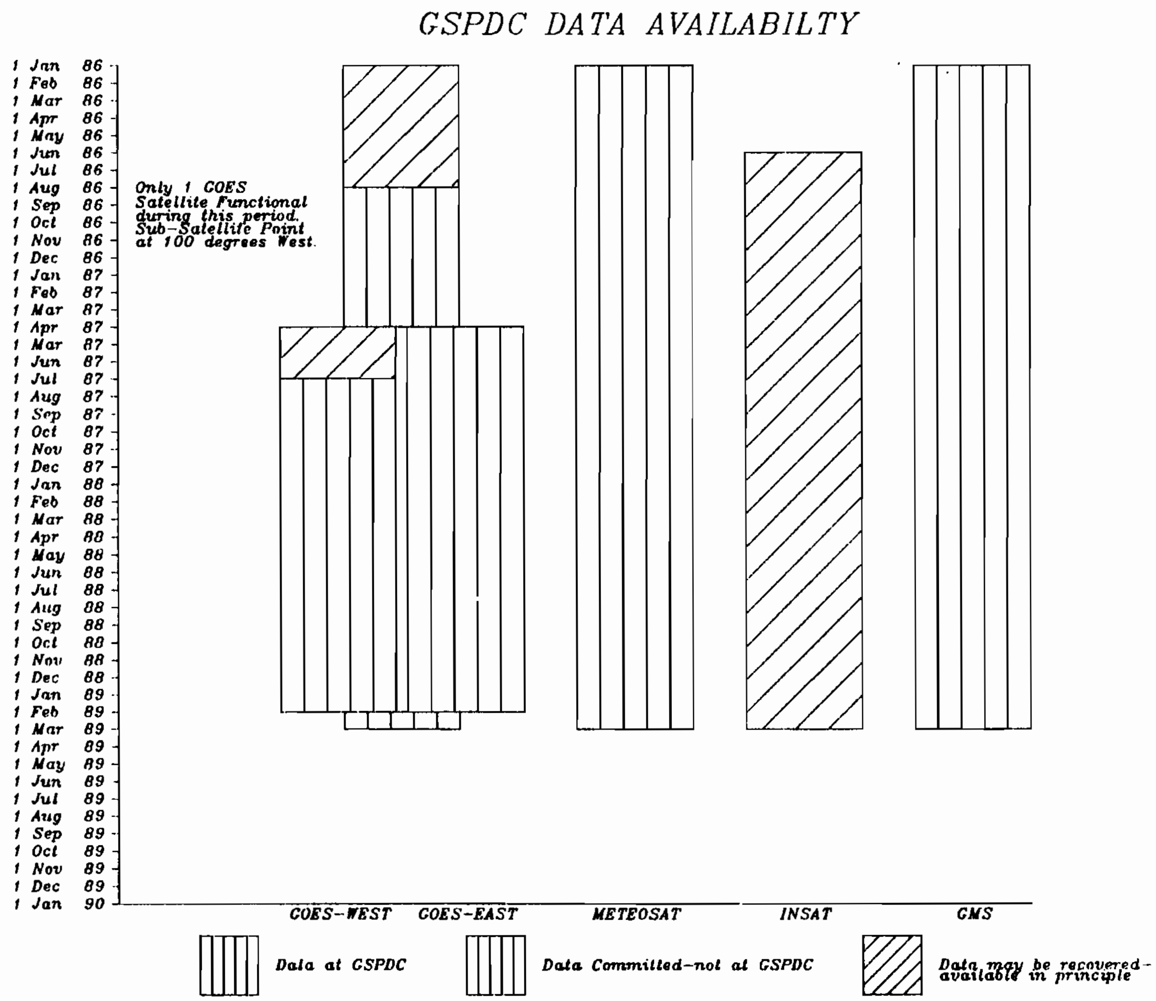

FIG.2. Availability of geostationary satellite Data at the Geostationary Satellite Precipitation Data Center as of May 1989.

Estimates of rainfall based on passive microwave observations from the SSM/I instrument on a polar-orbiting satellite of the Defense Meteorological Satellite Program offer considerable potential for supplementing and improving the geostationary estimates. The satellite was launched on June 19, 1987, and data began to be produced near the end of that month. No formal commitments for either the PSDPC or the PSPDC have been received, although initial data processing, as well as development and testing of estimation algorithms, is under way.

SSM/I data will be archived at NOAA/NESDIS, and the possibility that the Satellite Data Services Division of NESDIS could provide the PSDPC is being explored. In the interim, data are being supplied by a NASA/NESDIS contractor to a group headed by T. Wilheit and A. Chang at NASA/Goddard Space Flight Center. This group has agreed to furnish the PSPDC provided a satisfactory arrangement for supply of the data can be made. They have presently applied their preliminary estimation algorithm to data for the period from July 1987 to May 1988 (see example, Fig. 4). This algorithm, which uses 18 GHz data and a physically-based model of the absorption due to raindrops, appears to give plausible patterns over the tropical oceans, but with amounts which are systematically less than those estimated from IR data. Other microwave algorithms are being developed in a number of locations.

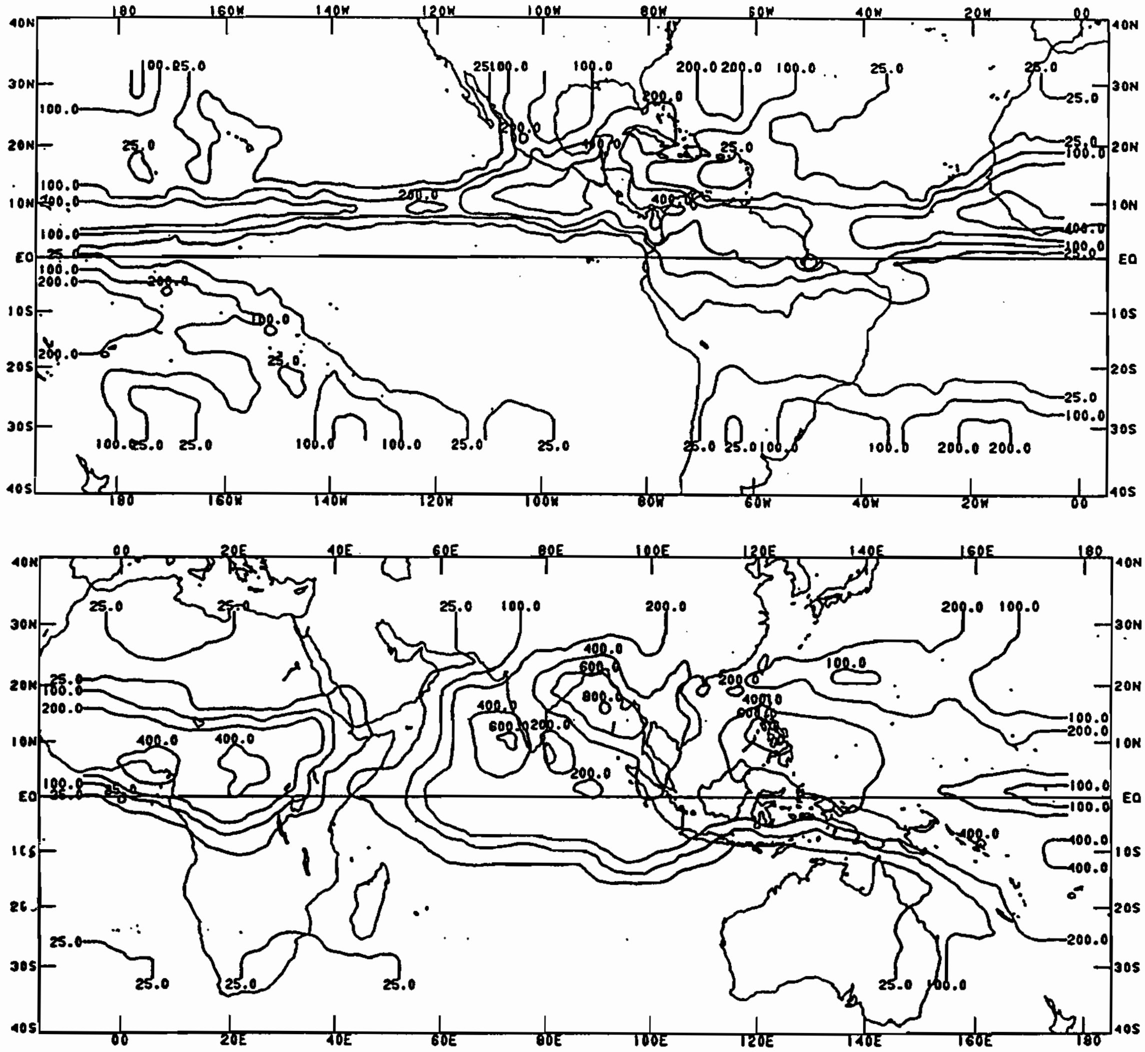

FIG.3. Merged IR-based estimates for May 31-June 29, 1988 using data from GOES-E, GOES-W, GMS, Meteosat, NOAA-9 and NOAA-10. Contours at 200 mm intervals beginning from 200 mm and at 25 and 100 mm.

The use of indirect estimates of rainfall (such as those based on observations of clouds or ice particles) requires calibration and validation in order to be used with confidence (WCRP, 1988). The Calibration/Validation (Cal/Val) Program of the GPCP consists of three principles efforts: the acquisition and organization of surface observations of rainfall from areas representing different climatic regimes; sponsorship and coordination of efforts to develop new methods of observing rainfall over the oceans; and the execution of an Algorithm Intercomparison Program which will use detailed, relatively short-term rainfall analyses and satellite observations to refine existing algorithms and develop new ones.

The first algorithm intercomparison project will be conducted during June-August 1989 in an area of the northwest Pacific Ocean encompassing the main islands of Japan (Fig. 5). It will use GMS visible and IR data with SSM/I observations, and will compare estimates with a composite rainfall analysis constructed by JMA from automated raingauge

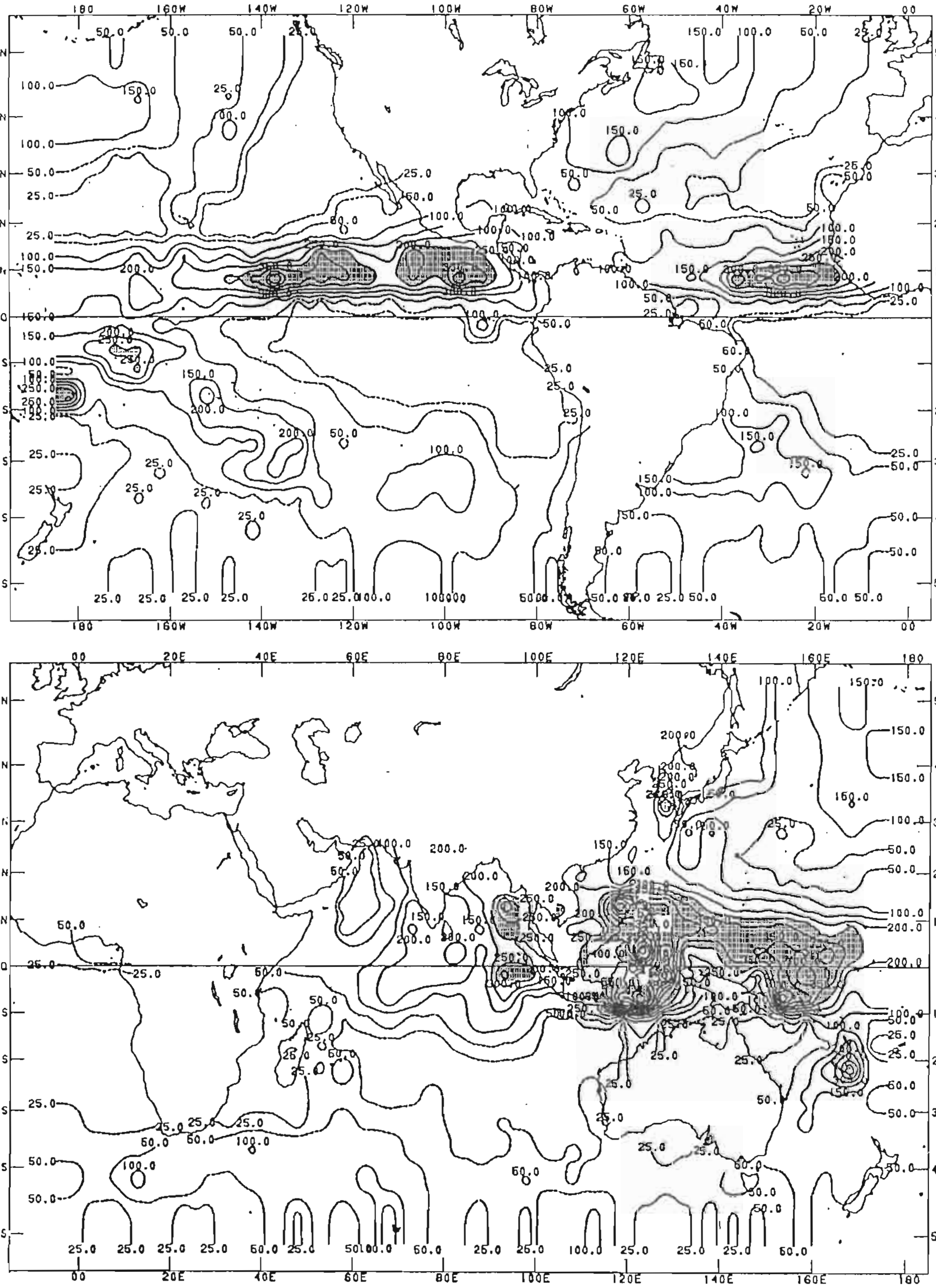

FIG.4. Estimated rainfall for August 1988 using 19 GHz data from SSM/I and an absorption algorithm (see text).

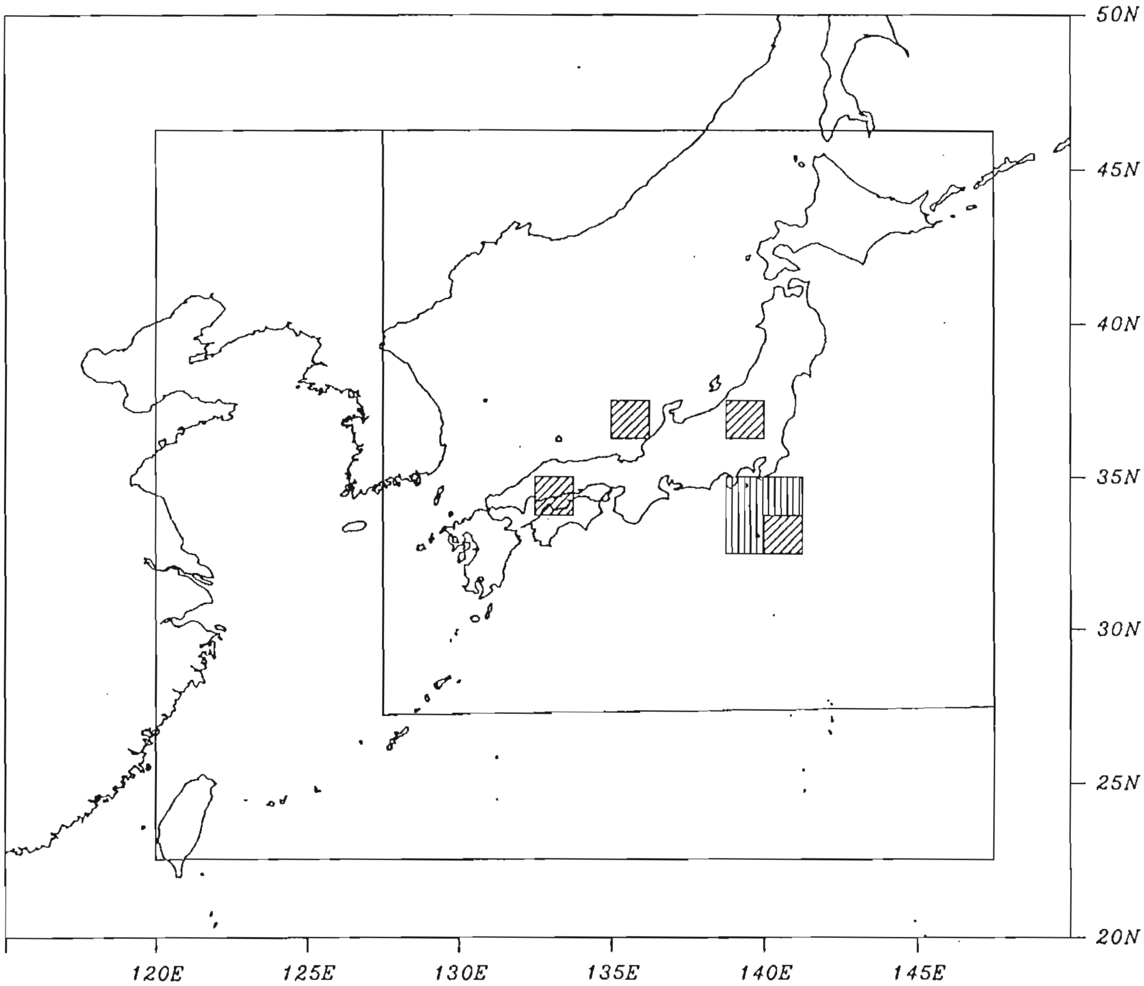

FIG.5. Area of the first project of the Algorithm Intercomparison Programme. Large open boxes represent areas for which satellite data are to be available; hatched boxes are regions where detailed comparisons between radar and satellite estimates are to be made.

observations over Japan and digital radar data for the nearby ocean regions. The proposed TOGA Coupled Ocean-Atmosphere Response Experiment (COARE) is expected to provide the data for an algorithm intercomparison in the western Pacific.

3. Oceanic precipitation during 1986-88

During late 1986, a warm episode of the El Nino/Southern Oscillation (ENSO) began. The warmest surface water in the equatorial Pacific shifted eastward to near the date line, and the maximum in convective activity moved eastward, as well. Near the beginning of 1988, the warm episode ended. Warmer than normal sea surface temperatures (SSTs) disappeared from the central and eastern equatorial Pacific and were, within a few months, replaced by below normal SSTs. This cold episode was characterized by less than normal convective activity in the central Pacific, with a pronounced westward extension of the equatorial dry zone.

The interannual change in SST can be seen in Fig. 6, where seasonal SST has been taken from the blended analysis of Reynolds (1988). Note the change in the eastward extent of the 29° isotherm in the central and western equatorial Pacific. The estimated precipitation for the December-February (DJF) and June-August (JJA) seasons during this period (Fig. 7 and 8) clearly shows the large decrease in rainfall near the intersection of the equator and the dateline from the warm episode to the cold episode.

Estimated seasonal totals of more than 1 meter during the warm episode are replaced by totals than 25 mm during DJF 1988-89.

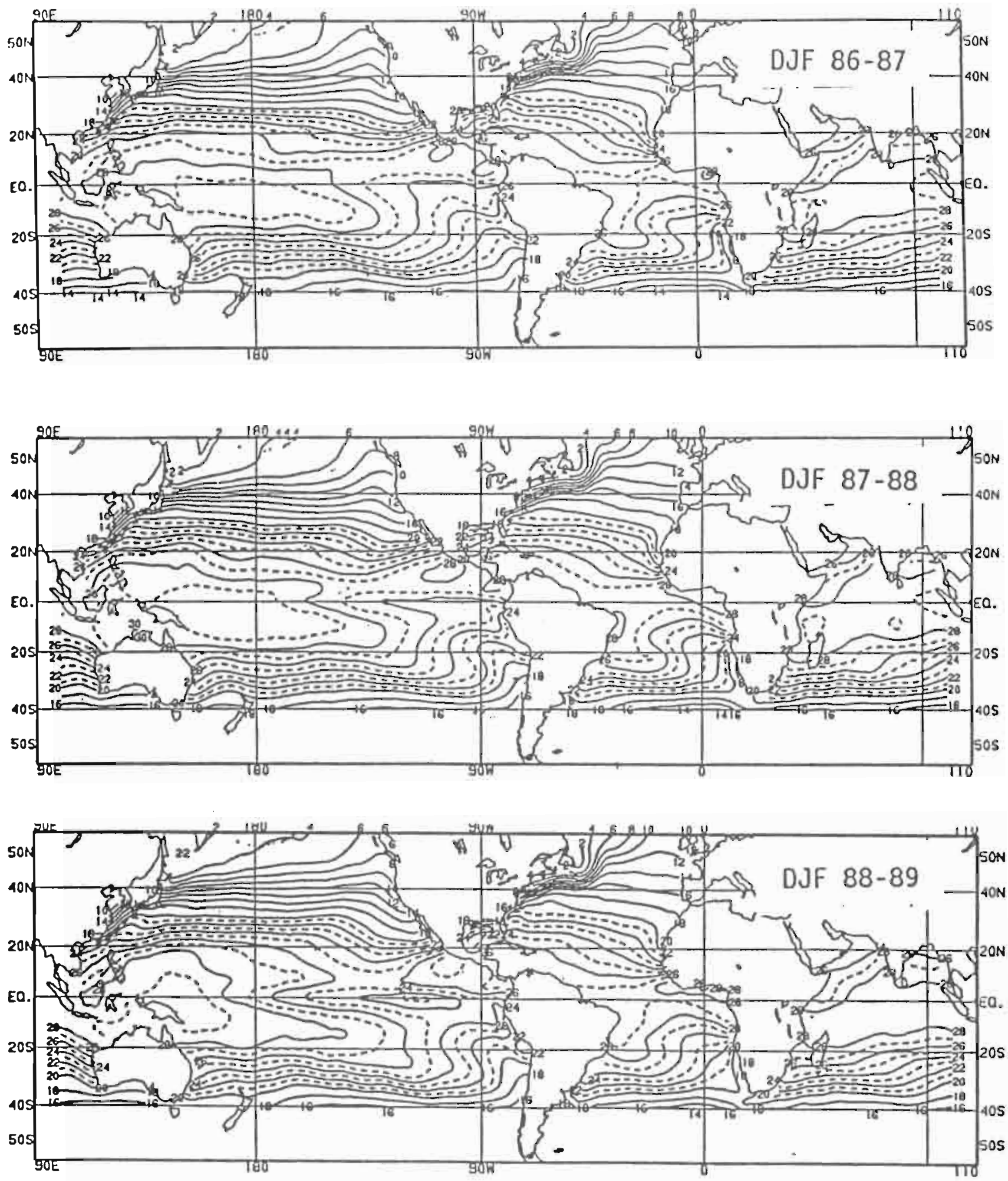

FIG..6. Mean sea surface temperatures for the indicated seasons from the blended analysis of Reynolds (1988).

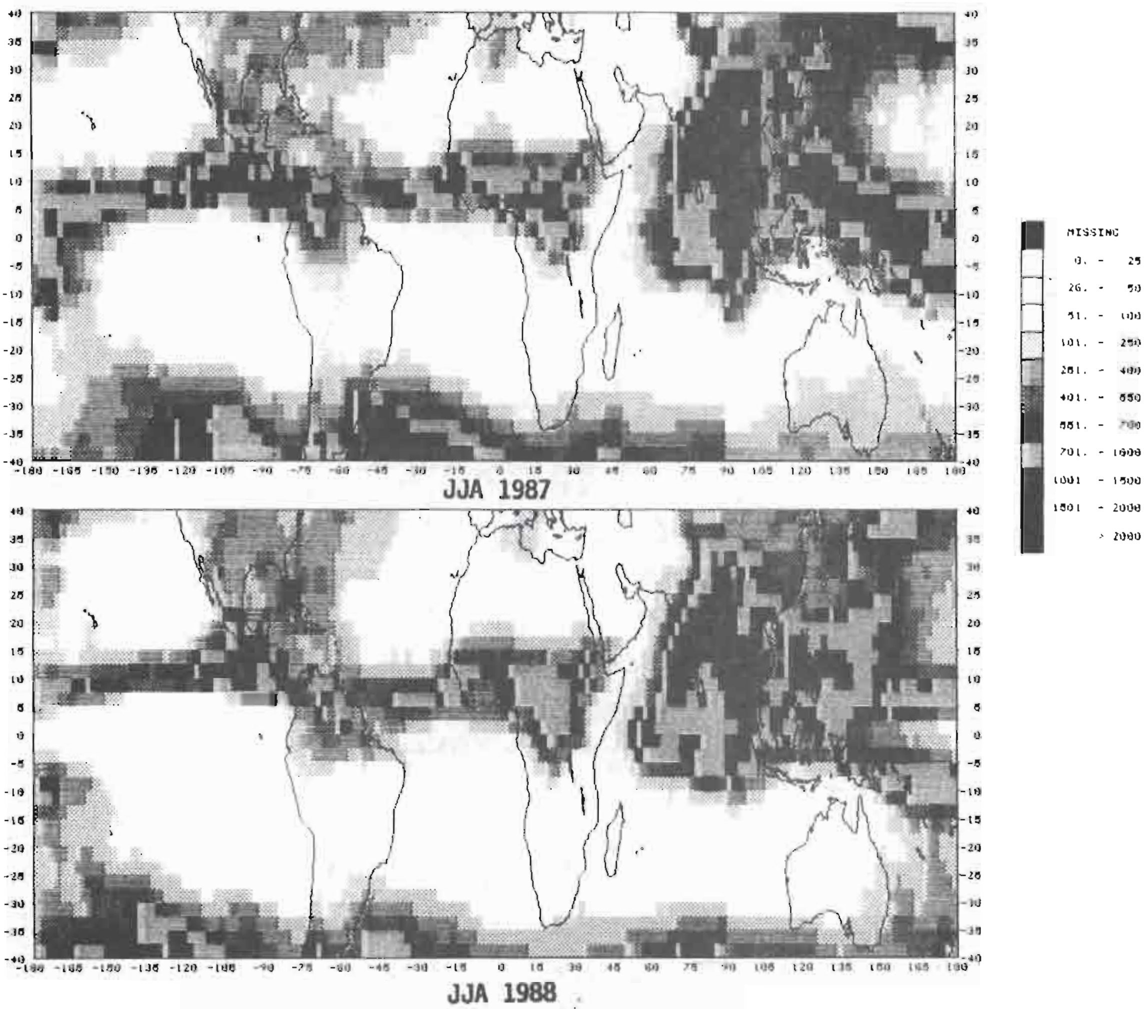

FIG.8. As in Figure 7, except for JJA (top) and JJA 1988 (bottom).

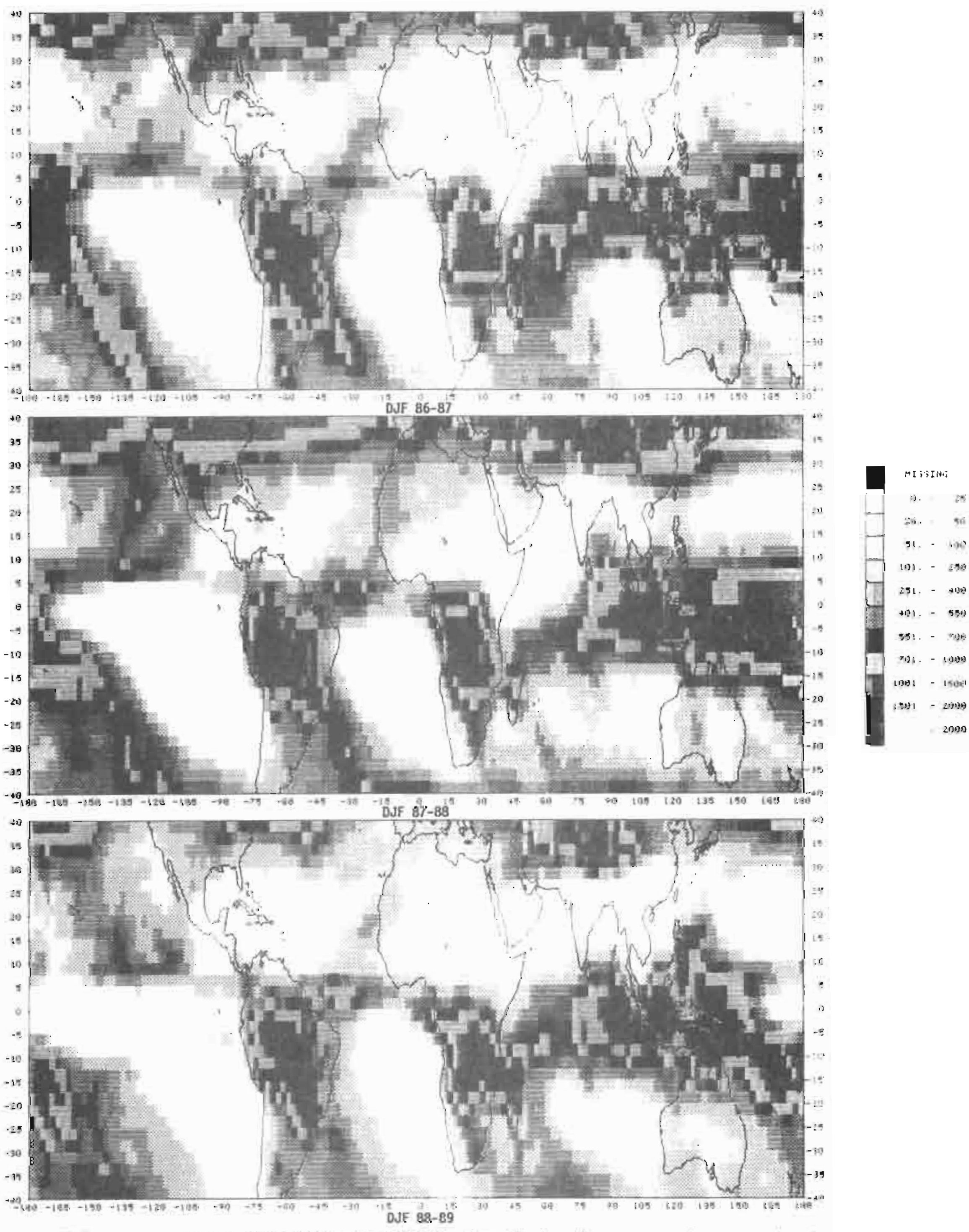

FIG.7. Precipitation estimated by the GPCP using IR data from geostationary and polar-orbiting satellites for the seasons DJF 1986-87 (top), DJF 1987-88 (middle) and DJF 1988-89 (bottom). Values are total accumulations in mm; estimates are quantitatively valid only in the tropics.

4. Conclusions

The GPCP of the WCPR is in operation and is producing analyses of tropical rainfall for the TOGA period. It uses a variety of satellite data and algorithms but, for the tropical oceans, presently relies primarily on estimates from geostationary satellite observations. Seasonal rainfall totals for the period 1986-88 show that the large interannual change in oceanic precipitation associated with the change from warm to cold episode conditions was qualitatively quite well depicted in these analyses.

In order to improve our confidence in the quantitative accuracy of the estimates, a variety of calibration/validation activities are planned. Of these, the Algorithm Intercomparison Program is of particular significance for TOGA/COARE. It is hoped that high-quality, quantitatively-accurate rainfall analyses for COARE can be obtained using a combination of radar and satellite data, and that improved estimation techniques can be developed with these products.

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