Seasonal Oceanic Precipitation Frequencies 
From Nimbus 5 Microwave Data

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Microwave brightness temperature data from the Nimbus 5 satellite have been analyzed by using threshold brightness temperatures to yield tropical oceanic precipitation frequencies for several classes of rainfall rates during the season December 1972 through February 1973. Data taken near local noon and near local midnight were analyzed. The overall results are consistent with both climatological precipitation frequencies and with concurrent satellite-derived frequency of highly reflective clouds. The difference between the local noon and the local midnight frequency is small, but the heavier rainfall rates tend to occur more frequently near local noon. The ratios of the frequencies of light, moderate, and heavy rain were observed to be relatively constant over the tropical oceans. Passive microwave measurements from space seem to be an important step toward accurate measurement of oceanic precipitation.

INTRODUCTION

Knowledge of oceanic precipitation is of fundamental importance to meteorology. Approximately 80% of the earth's precipitation falls in the ocean [Sellers, 1965], where fewer than 10% of the world's weather stations exist. Yet latent heat released over the ocean plays a major role in the maintenance of the general circulation and affects almost everything known as 'weather.'

Many ingenious attempts to determine oceanic precipitation from surface observations have been made [e.g., McDonald, 1938; Tucker, 1961; Jacobs, 1968; Allison et al., 1969], but such observations have not the spatial nor temporal resolution necessary for accurate measurement of anything except long-term climatological precipitation. Satellite data offer much better resolution, but until the launch of Cosmos 243 in 1968 and Nimbus 5 in 1972, all satellite data were from the visible or infrared portions of the electromagnetic spectrum in which precipitation cannot be observed directly because of the opacity of clouds. (See Martin and Scherer [1973] and Dittberner and Vonder Haar [1973] for a review of precipitation estimation techniques using visible and infrared satellite data.)

Several authors have shown the usefulness of microwave imagery from the Nimbus 5 electrically scanning microwave radiometer (ESMR) in depicting oceanic precipitation zones [Theon, 1973; Sabatini and Merritt, 1973; Allison et al., 1974a, b; Wilheit et al., 1976]. The present study uses Nimbus 5 ESMR data to infer tropical oceanic precipitation frequencies for the season December 1972 through February 1973. This approach is a first step toward measuring seasonal precipitation amounts, and the results may be of interest to modelers of the general circulation.

THE RADIOMETER

Nimbus 5 is a sun synchronous satellite which crosses the equator at 1130 and 2330 LT and has an orbital period of 107 min. The ESMR receives radiation in a 250-MHz band centered at 19.35 GHz (1.55 cm), with a noise equivalent temperature difference of approximately 2 K. The antenna electrically scans across the spacecraft track from 50° left to 50° right in 78 steps every 4 s. In this study, only data within 30° of nadir were used. The radiometer half-power resolution is 25 × 25 km at nadir and degrades to 42 km crosstrack by 30 km downtrack at 30° from nadir.

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not be detected and (2) local atmospheric and surface conditions may deviate from those used to calculate the brightness temperature versus rainfall rate curves. However, comparison of radar data and ESMR data shows that the 170 K brightness temperature contour (which corresponds to a 0.25 mm h\(^{-1}\) rainfall rate when the freezing level is 4 km) closely follows the radar echo [Allison et al., 1974a].

**DATA ANALYSIS AND RESULTS**

Data from the period December 22, 1972, through February 26, 1973, were stratified by position (5° latitude-longitude squares) and local time. The data in each category were first corrected for scan angle, and then the fraction of the observations above each of the brightness temperature thresholds was calculated. Figure 3 shows the fraction of observations above the 0.25 mm h\(^{-1}\) threshold, which may be interpreted as the frequency of precipitation regardless of intensity. Noon and midnight frequencies have been averaged. Figure 4 shows, for comparison, the precipitation frequencies of McDonald [1938] compiled from ship observations.

The microwave precipitation frequencies reproduce the expected general pattern: (1) narrow convergence bands, (2) dry eastern oceans, and (3) the splitting of the ITCZ in the mid-Pacific. The precipitation frequencies in the northwest oceans may be biased upward by the more frequent occurrence of strong winds in those areas [McDonald, 1938]. Strong winds, by forming foam on the sea surface, increase the surface emissivity and thus the observed brightness temperature [Nordberg et al., 1971].

The microwave precipitation frequencies are generally lower than those of McDonald, and the mid-Pacific precipitation maximum seems to be about 20° further west. These findings are in agreement with Ramage [1975], who in his study of the 1972–1973 El Niño found that the frequency of highly reflective clouds was generally less in December 1972 than in the more normal period of December 1971 and that the position of maximum cloudiness had shifted westward in December 1972.

Figures 5–7, showing the frequencies of light (0.25–1.0 mm h\(^{-1}\)), moderate (1.0–2.5 mm h\(^{-1}\)), and heavy (>2.5 mm h\(^{-1}\)) precipitation, indicate that the ratios of the frequencies in these categories do not vary appreciably over the tropical ocean.

Finally, an indication of the diurnal variation of precipitation frequency was obtained by comparing the noon and midnight frequencies. Table 1, showing the percentage of the total of noon and midnight precipitation events occurring near
TABLE 1. Percentage of the Total of Noon and Midnight Precipitation Events Occurring near Local Noon in Oceanic Regions Between 20øN and 30øS During the Season December 1972 through February 1973

<table>
<thead>
<tr>
<th>Rainfall Category, mm h⁻¹</th>
<th>Precipitation Frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry Regions (0-5%)</td>
</tr>
<tr>
<td>Light (0.25-1.0)</td>
<td>47</td>
</tr>
<tr>
<td>Moderate (1.0-2.5)</td>
<td>48</td>
</tr>
<tr>
<td>Heavy (2.5-5.0)</td>
<td>49</td>
</tr>
<tr>
<td>Very heavy (&gt;5.0)</td>
<td>53</td>
</tr>
<tr>
<td>All rain</td>
<td>49</td>
</tr>
</tbody>
</table>

local noon in oceanic regions between 20øN and 30øS, indicates that there is little difference between noon and midnight precipitation frequencies. Although a diurnal variation of tropical oceanic precipitation with an early morning maximum and a late afternoon minimum has been observed, little difference is to be expected between noon and midnight frequencies [Lavoie, 1963; Jacobson and Gray, 1976]. However, the increasing tendency, shown in Table 1, for the heavier precipitation events to occur near local noon supports the early morning maximum.

CONCLUSIONS

Nimbus 5 ESMR data have yielded reasonable seasonal precipitation frequencies over the tropical oceans by use of preliminary calibration curves. Other investigators are working on obtaining oceanic precipitation amounts [Rao et al., 1976] and on improving the calibration curves. Soon we will be able to accurately measure this important atmospheric parameter and its interannual variation.

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