University of Wisconsin-Madison

TRMM RESEARCH STATUS REPORT

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INTRODUCTION

This document reports on TRMM activities at the Space Science and Engineering Center. SSEC's contribution to TRMM is outlined in the table on the next page.

Our major goal is to extend TRMM calculations of diabatic heating over the tropical oceans from the climatologic scale to the synoptic scale. TRMM will measure the radiative energy losses of the planet, as well as the rainrate which is related to the condensational heating of the atmosphere. Our task is to extend the space and time coverage of these TRMM measurements through observations from geostationary satellites. The steps involved are conceptually depicted in the accompanying table.

The approach is to develop, using coincident measurements, statistical relationships between the TRMM measured parameters (e.g., rainrate and radiation balance) and the geostationary observations (e.g., visible and infrared radiances). These statistical relationships, along with additional observations (e.g., sea surface temperature) will then be used to derive the diabatic heating rates over geographic regions that are not observed by TRMM. Prototype relationships are presently being developed using the GOES and SSM/I observations.

Step 1: Observe Atmospheric Heating

↑ **Upwelling energy at the top of the atmosphere**	Can be estimated from CERES data.
Net radiative heating of the atmosphere ←	The “difference” between CERES and NESDIS SST
Upwelling energy at the bottom of the atmosphere ↑	can be estimated from NESDIS SST products or the Reynolds blended product.

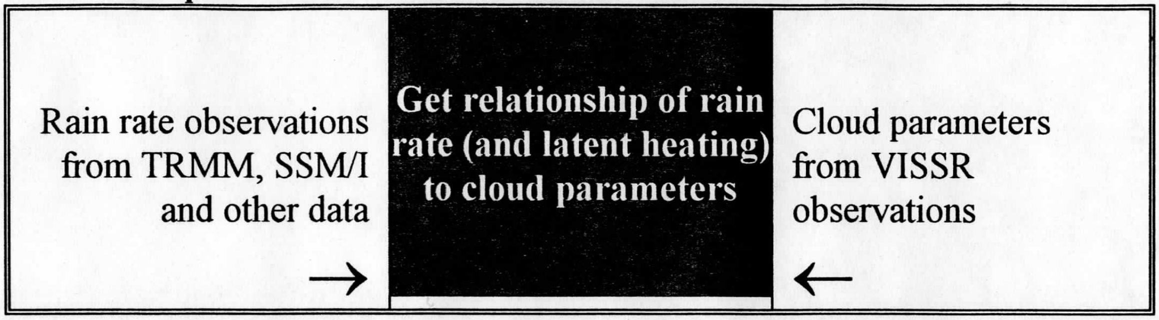
Step 2: Relate Heating to Clouds

Net radiative heating using CERES and SST observations →	**Get relationship of net radiative heating of the atmosphere to cloud parameters**	Cloud parameters from VISSR observations ←

The Result: Goal Realization— Extended Space-Time Coverage Using Cloud Parameters

Net radiative heating between CERES observations ←	Relationship of net radiative heating of the atmosphere to cloud parameters	Cloud parameters from VISSR observations ←

Step 3: Relate Rain Rates to Cloud Parameters

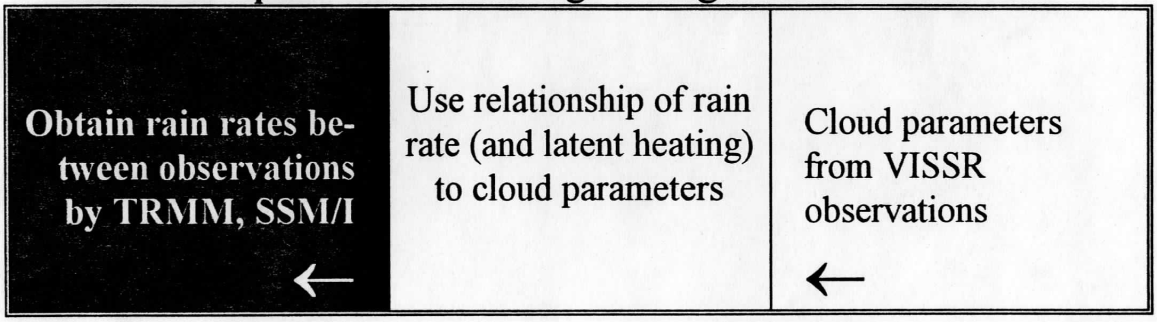


Rain rate observations from TRMM, SSM/I and other data →

Get relationship of rain rate (and latent heating) to cloud parameters

← Cloud parameters from VISSR observations

The Result: Goal Realization—
Extended Space-Time Coverage Using Cloud Parameters



Obtain rain rates between observations by TRMM, SSM/I ←

Use relationship of rain rate (and latent heating) to cloud parameters

← Cloud parameters from VISSR observations

RECENT WORK

Our cloud classification scheme is rooted in the algorithm developed by Louis Garand for the north Atlantic. The method uses visible (VIS) and infrared (IR) images from a geostationary satellite to classify cloud conditions in a box roughly one degree on a side. Departures of the present algorithm from the original Garand algorithm include the following:

1. The VIS observations can have a ~~nominal~~ spatial resolution of either 2 km (as in the original scheme) or 4 km. Because GMS resolution is approximately 4 km and Meteosat resolution is approximately 5 km, allowing 4 km resolution should enable us to produce a more consistent global analysis.
2. NESDIS composite "real time" sea surface temperature (SST) data is imported into the algorithm to set the clear sky IR temperature threshold. Presently the threshold for cloud is $T_{11} \leq (SST-11.5°)$. Because the original scheme relied on climatological SSTs, this change should improve the IR cloud product.
3. The algorithm can run with IR and SST data alone. Although the result is degraded, this change allows cloud classification at night.

To date we have conducted preliminary tests of this algorithm on images from approximately a dozen days in the eastern tropical Pacific. An example of the frequency of occurrence of the twenty original cloud classes of Garand is shown in Figure 1. As expected, certain cloud classes (e.g., 7--cloud streets) rarely occur over the tropical oceans. If confirmed in additional tests, this result would favor a reduction in the number of classes. On the other hand, our interest in diabatic heating and rainfall may indicate an increase in the number of classes.

To supplement the VIS/IR cloud classification, we incorporate information from two GOES Multi-Spectral Image channels, 12 μm and 6.7 μm. The 12 μm channel has a nominal resolution of 8 km at nadir; the 6.7 μm channel has a resolution of 16 km. Box by box, for each channel we compute brightness temperature mean, maximum, minimum and standard deviation. We do not believe that either channel will add any additional information on cloud pattern and therefore do not compute class discrimination features such as the two-dimensional power spectrum for the boxes.

These measurements should aid in classifying the atmospheric structure. Specifically, if used with the 11 μm channel in a manner analogous to the split window cloud classification of Toshiro Inoue, the 12 μm data will aid in the determination of the total precipitable water (PW). The brightness temperature difference between the 11 and 12 μm channels will be used to identify convective cells. The 6.7 μm data will provide estimates of upper tropospheric relative humidity.

The GOES multispectral data provides information about the cloud top. We also require information, such as PW and liquid water content (LWC), within and below the cloud. For this reason our analyses incorporate DMSP SSM/I measurements and products derived from them. Tropical SSM/I data within 10 minutes of a GOES image are remapped into the GOES projection. Figure 2 employs color to illustrate the remapping. SSM/I data (here, a product, PW) are colored; the GOES image is grey. In this example pink indicates large values of PW; green, small values. As would be expected, larger values of PW are associated with colder clouds. Individual SSM/I values are averaged for each box. While all the SSM/I spectral observations are available and are recorded, to date we have focussed on the derived products, including rainrate (RR). We use the NESDIS algorithm to obtain these products. Some very preliminary results of combining the GOES and SSM/I observaions are given below.

As a first step we combine related classes to obtain three cloud groups. These are low cloud (classes 1-5), mid-level cloud (classes 12-15) and high and thick cloud (classes 16-20). The histogram of LWC as a function of cloud group is shown in Figure 3 for two days in November 1992. The large LWC values are generally associated with high and thick clouds. The area averaged LWC for the low cloud group is generally less than 3 g/m^3. A similar analysis of the SSM/I rainrate (mm/hr) is shown in Figure 4. Heaviest rainrates occur for the high and thick group. It is important to note that these results are for two days only and the distribution may change as we analyze more cases.

The GOES split window value is depicted in Figure 5 as a function of cloud groups. Negative values of the split window are almost exclusively associated with the high and thick clouds. They do not occur for the low cloud group.

For low cloud and clear boxes there does appear to be a relationship between PW and 6.7 μm brightness temperature (Figure 6). Drier upper tropospheric conditions (warmer brightness temperature) tends to be associated with the smaller values of PW. This implies that very moist atmospheres must also have a moist upper troposphere.

PLANS

Plans for the next quarter are as follows:

- Continue collecting GOES, SSM/I and SST data. SSM/I data are collocated with GOES data. (To reduce costs all data are recorded from the real-time stream of McIDAS). We plan to collect 2-4 cases per week over the next 3-4 months.
- Continue evaluation of the cloud classification technique in a milieu which includes sunglint as well as tropical storms. Test the effect of halving visible resolution. Evaluate the utility of an IR-only classification.
- Develop relationships between the cloud classes and PW, LWC and RR. Explore the relationship of 6.7 μm brightness temperature to PW.
- Design an algorithm to specify the longwave radiative cooling of the Garand box. One possibility is to specify the top of the atmosphere fluxes using the algorithm of Patrick Minnis and his colleagues. Because, atmospheric cooling is correlated to the net radiative flux at the tropopause, a top of the atmosphere flux estimate should give a first order approximation to the total atmospheric cooling. With an estimate of sea surface temperature, we can determine the atmospheric greenhouse effect as the ratio of the outgoing flux at the top of the atmosphere to the blackbody flux leaving the surface.

- Extend the cloud classification to include GMS observations. This will allow us to participate in the third Algorithm Intercomparison of the Global Precipitation Climatology Project.
- Through the TRMM office, share the set of SSM/I and GOES data with the TRMM community.

FIGURE CAPTIONS

Figure 1. Frequency of occurrence of cloud classification for three days in the tropical Pacific Ocean

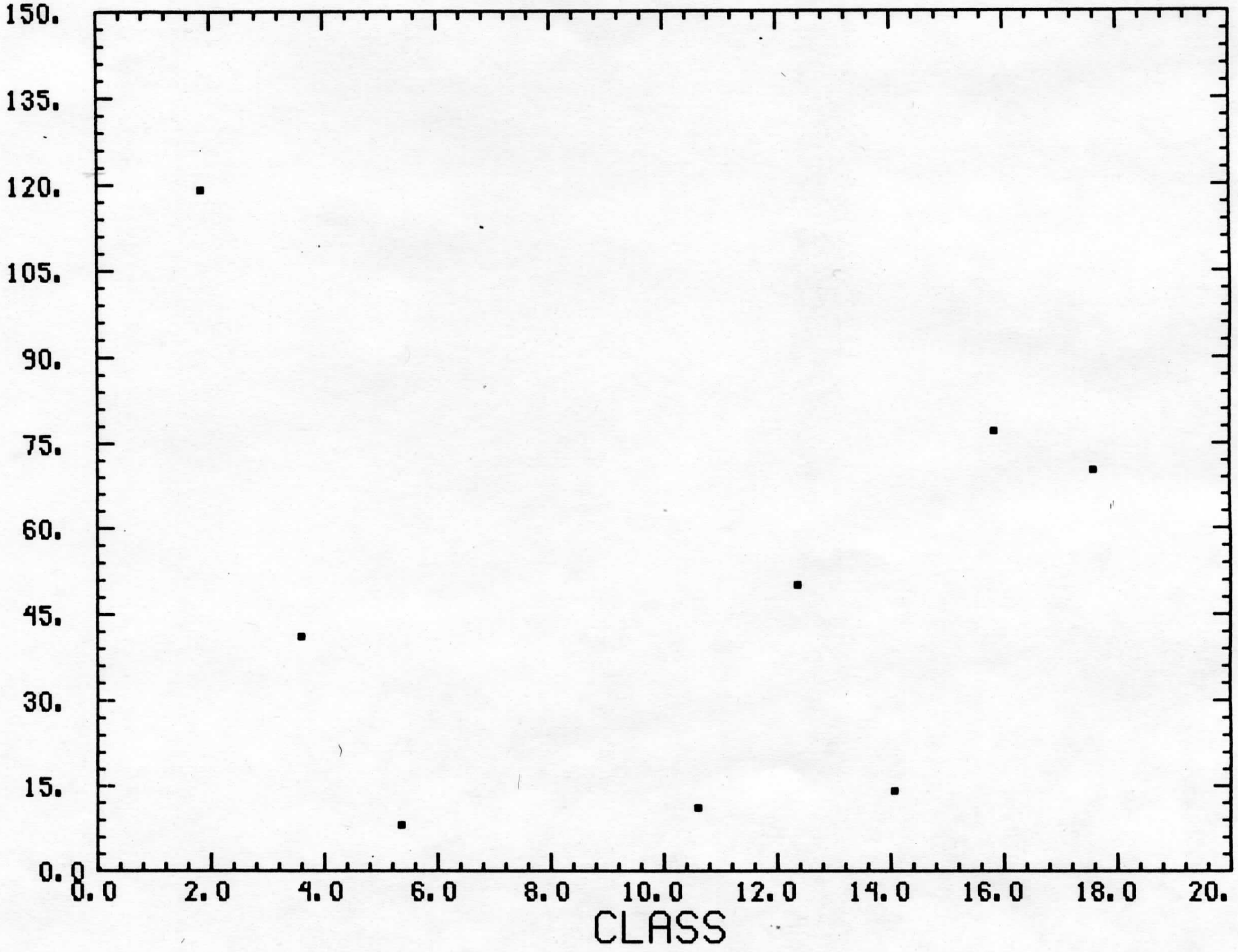
Figure 2. A composite image of GOES IR and remapped SSM/I observations

Figure 3. A sample histogram of the number of occurrences of the SSM/I derived liquid water content as a function of classification.

Figure 4. A sample histogram of the number of occurrences of the SSM/I derived rainrate as a function of classification.

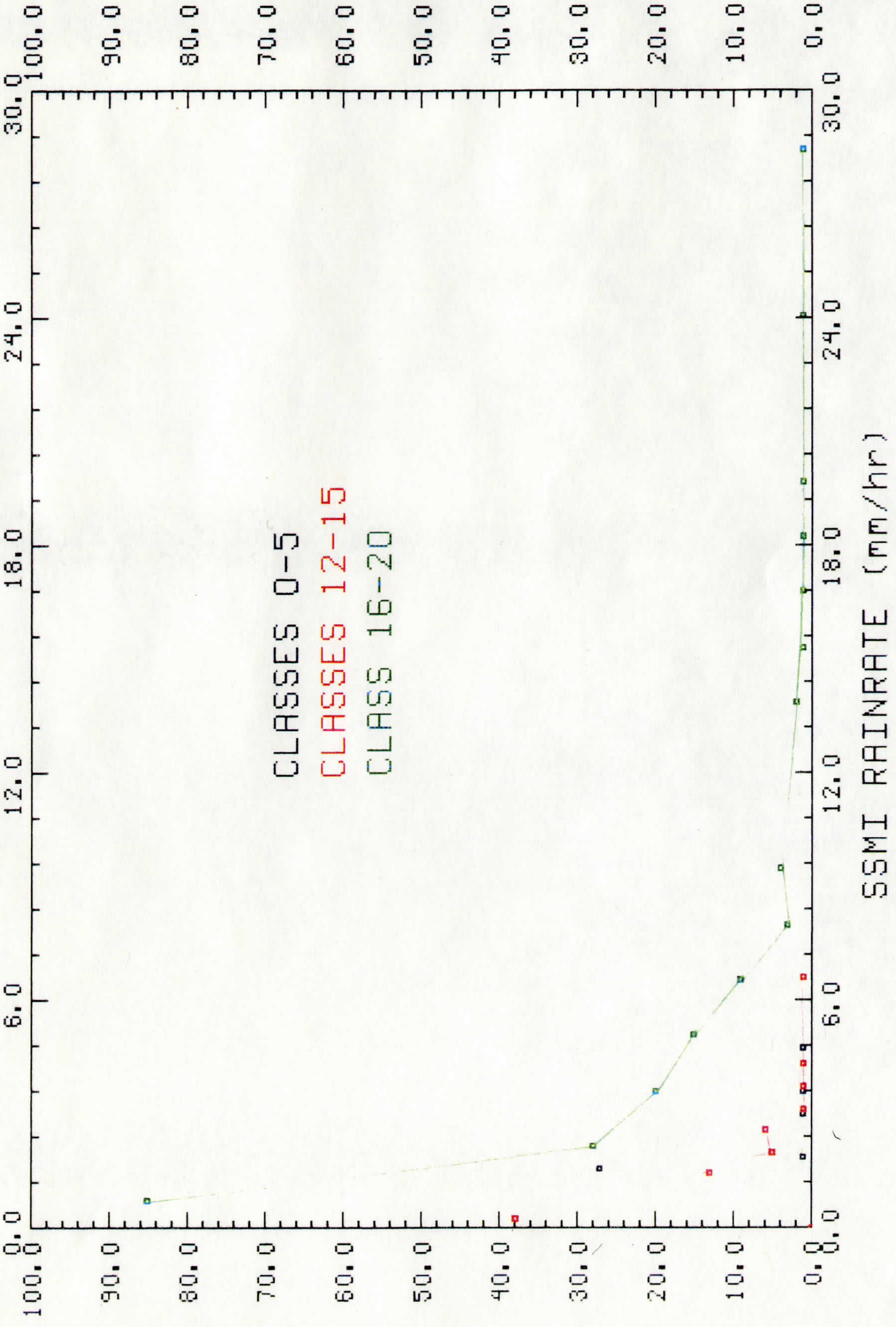
Figure 5. GOES spilt window brightness temperature difference (DTM4) versus the SSM/I derived precipitable water (STM8). Each color represents a cloud classification as indicated in the legend.

Figure 6. The GOES 6.7 μm brightness temperature (HTM4) versus the SSM/I derived precipitable water (in mm) for clear and low cloud conditions.



FREQUENCY OF OCCURRENCE (THREE DAY COMPOSITE)

HISTOGRAM FOR DAYS 92310, 92314



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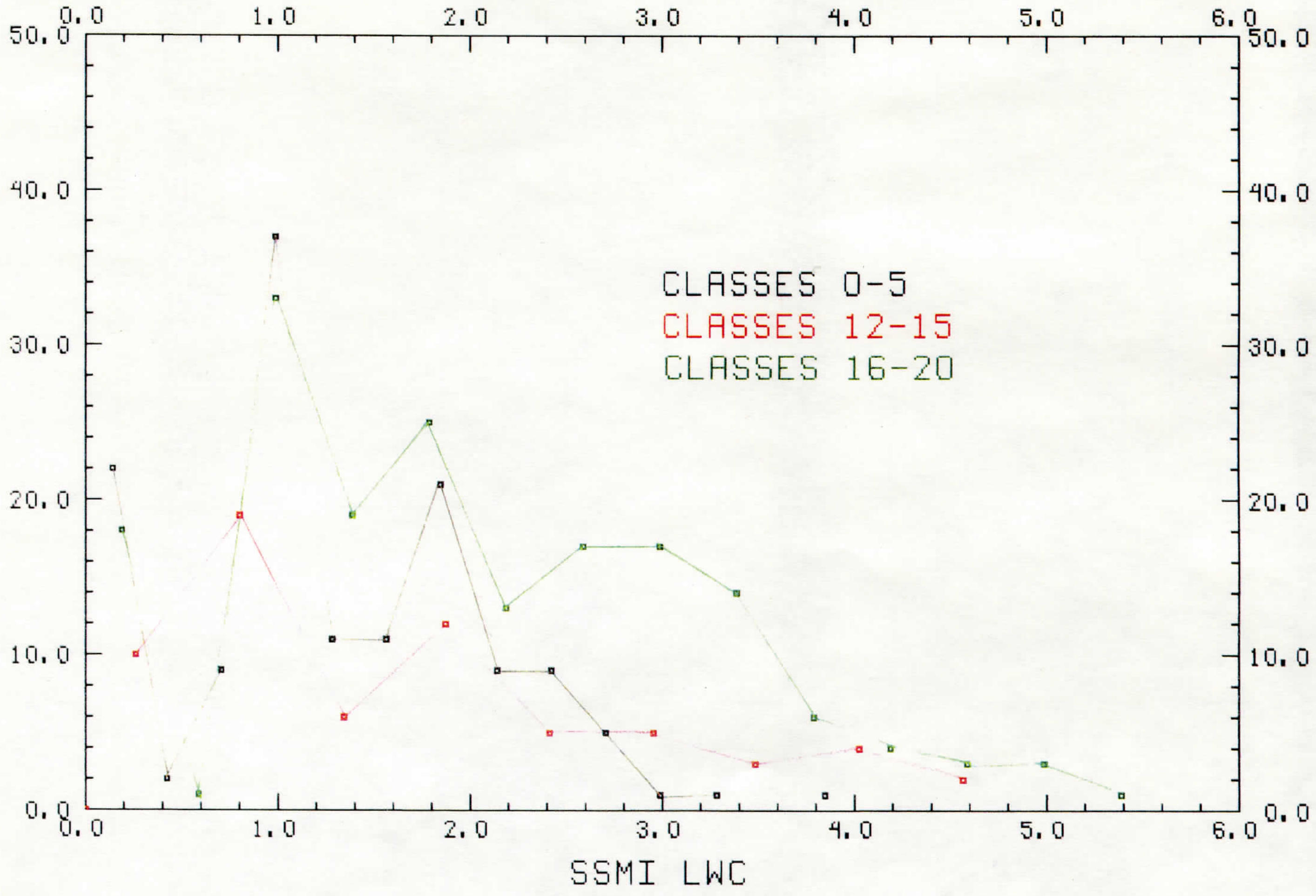
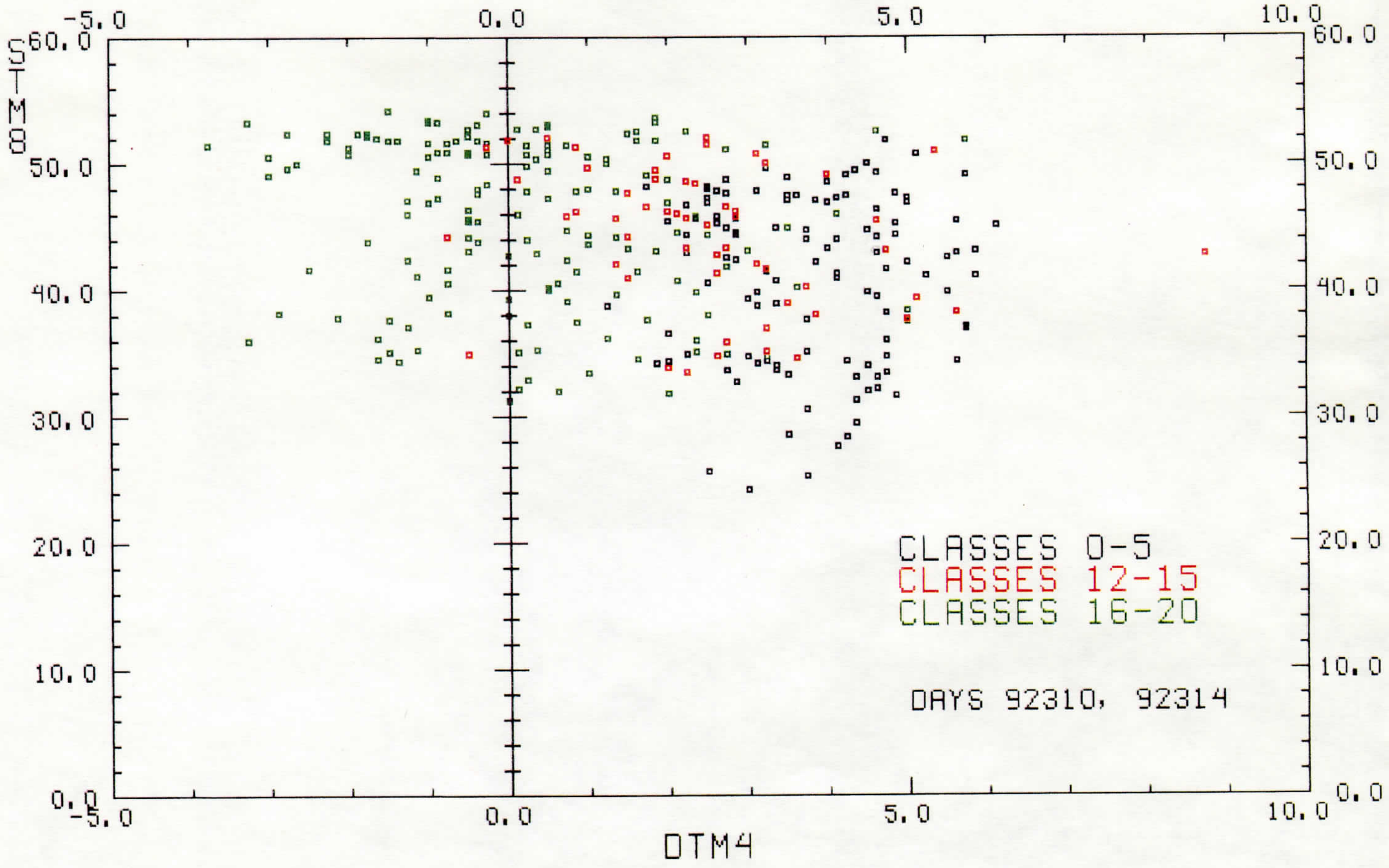


GOES SPLIT WINDOW vs SSMI PW



6.7 BBT vs SSMI PW