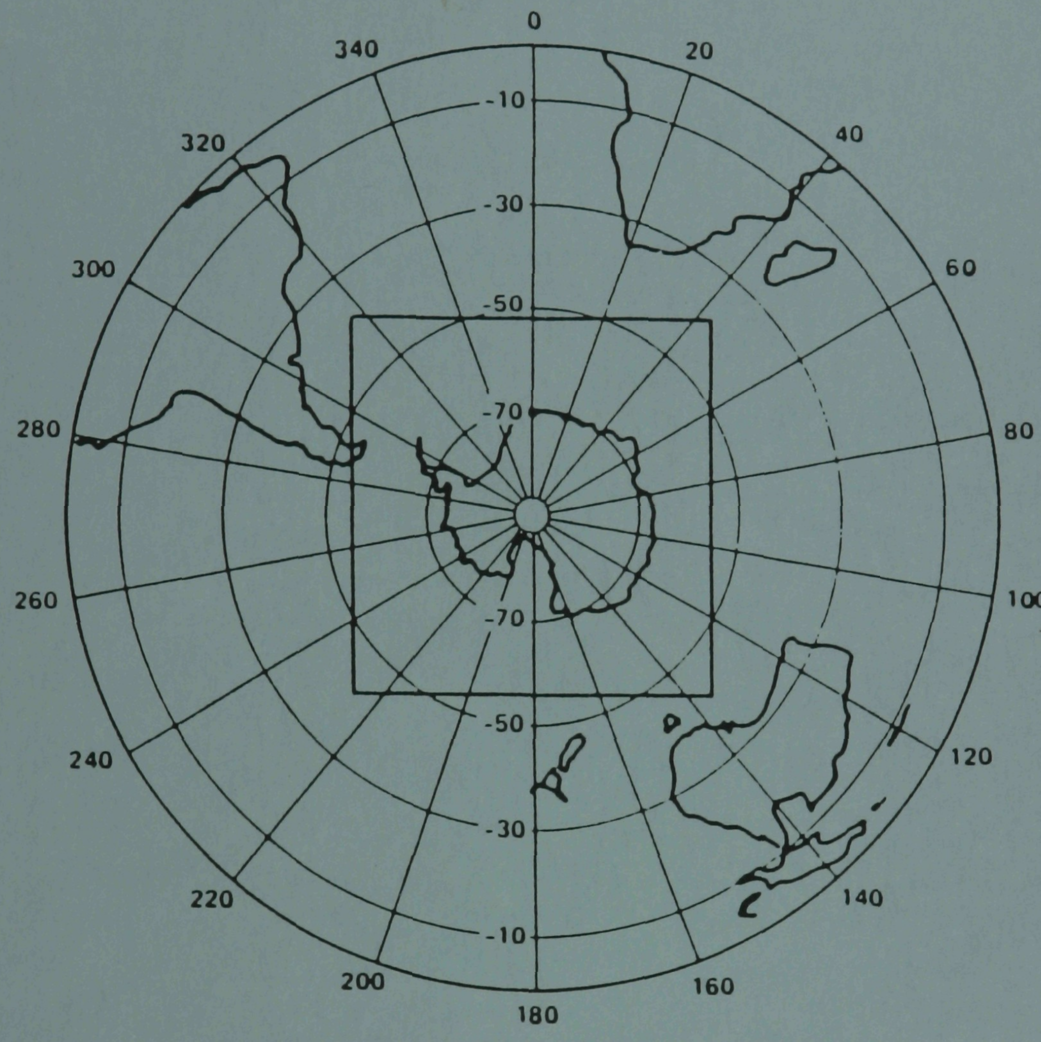
Comparison Between SMMR and SSM/I Passive Microwave Data Collected over the Antarctic Ice Sheet



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COMPARISON BETWEEN SSMR AND SSM/I PASSIVE MICROWAVE DATA COLLECTED OVER THE ANTARCTIC ICE SHEET

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Cover art depicts geographic area over which SSM/I data are processed by the Cryospheric Data Management System (from the NASA Science Working Group Report for the Special Sensor Microwave/Imager, 1984)

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SUMMARY

Passive microwave brightness temperature data collected during the overlap period between the Scanning Multichannel Microwave Radiometer and the Special Sensor Microwave Imager are compared. Only data collected over the Antarctic Ice Sheet are used in order to limit spatial and temporal complications associated with the open ocean and sea ice. Linear regressions are computed from scatter plots of complementary pairs of channels from each sensor revealing highly correlated data sets. That a simple linear model can be used to correlate the data is used to support the argument that there are important relative calibration differences between the two instruments.

1. Introduction

Global data sets collected from spaceborne sensors are considered to be a principal component of global change studies. Indeed, several types of spaceborne data are becoming sufficiently extensive spatially and sufficiently lengthy over time so as to provide important gauges of global change. Obviously, if those data sets are to fulfill their promise, careful calibration and validation are essential over the life of individual sensors used to acquire the data (eg. Comiso and Zwally, 1989; Cavalieri and Swift, 1987). It is equally important to provide for cross-calibration between a succession of similar sensors when long baselines of observations are required.

Data from NASA's Scanning Multichannel Microwave Radiometer (SMMR) and the Navy's Special Sensor Microwave Imager (SSMI) (Hollinger and others, 1987), as well as predecessor instruments such as the Electrically Scanning Microwave Radiometer, provide an opportunity for a case study of the issues faced by the earth remote sensing community when attempting to establish long-base-line data sets. Data from each of these passive microwave instruments separately were and are routinely processed to derive estimates of sea ice concentration and multiyear ice fraction (Zwally and others, 1983). Along with operational utility, sea ice geophysical products from SMMR are being studied extensively for trends in total and hemispheric ice concentrations that might evidence changes in global temperatures. Time series of SMMR brightness temperature data have also been used to investigate relative trends in surface physical temperature between different sectors of the Antarctic Ice Sheet. Along with strong seasonal trends, those data reveal important differences in the timing of temperature anomaly events between East and West Antarctica (Jezek and others, 1990).

It is natural to attempt combining data from the successive satellite programs into a single, long record of measurable geophysical variables. Two approaches are possible, the first being to 'match' values of a derived variable obtained near the end of one sensor's useful life with values obtained near the beginning of the follow-on sensor's mission. A second approach is to compare lower level data products and develop a procedure for relative calibration. This later is the method adopted here wherein gridded brightness temperatures are compared during the brief overlap between SMMR and SSMI.

2. Approach

Data sets used in this study were gridded SSMI brightness temperature data obtained on CDROM from the National Snow and Ice Data Center (Weaver and others, 1987). A multiplicative constant (set equal to 10) is incorporated in the CDROM data. We rescaled the data by simple division, preserving the result as a real value. Gridded SMMR TCT data for the same period were obtained from the Goddard Space Flight Center (Gloersen, 1987). A multiplicative constant equal to 5 was incorporated in those data. The constant was removed as part of our analysis but the resulting brightness temperatures were retained only to the nearest degree. While in retrospect, it would have been desirable to retain fractional values of the SMMR brightness temperatures, we do not believe this changes the results of our analysis.

Only complementary pairs of channels were compared, namely the SMMR 18v, 18h, 37v, 37h and SSMI 19.35v, 19.35h, 37v and 37h channels during the period of overlap The period of overlap began on July 7, 1987 and lasted till August 20, 1987. Because SMMR acquired data every other day, this resulted in 20 days of nearly simultaneous observations by both sensors.

Initially, the SMMR and SSMI gridded data were compared by simply differencing like channels. Raster images of difference maps so generated revealed strong differences in the vertical channels (-4 to +10 degrees K) and lesser differences in the horizontal channels (only a few degrees K). Patterns in temperature differences closely mimicked the spatial patterns in the original brightness temperature data for the vertical channels. Spatial patterns evident in the brightness temperature data for the horizontal channels were mostly absent in the difference maps.

Several hypothesis were tested to explain these results. Because of the proximity of the SSMI 19.35 Ghz channels to the 22 Ghz water vapor absorption line, we first assumed that water vapor in the atmosphere might be causing the spatial patterns of brightness temperature differences between the lower frequency SMMR and SSMI channels. However, the observation that difference maps of the 37 Ghz channels also showed similar spatial patterns refuted the importance of the water vapor argument.

The pointing angles of the two instruments are different (SSM/I points at 53.1 degrees; SMMR points at 49.0 degrees) and a second hypothesis was developed to test the effect of differing angles of incidence. This seemed a promising hypothesis because the pointing angles are close to the brewster angle for polar firn. This fact would argue for stronger spatial variations in the vertical channels as compared to the horizontal channels which was observed in the difference maps. However, simple Fresnel reflection coefficient calculations using typical values for the density of polar firn (0.35 to 0.5 g/cc) showed that angle of incidence differences account for less than one degree K of variation.

The remaining hypothesis was simply to allow for variations in the relative offset and gain between the various channels. A purely additive offset would account for much of the difference while a multiplicative gain difference would explain the observation that patterns in brightness temperature were preserved when differences in brightness temperature were mapped.

We tested this hypothesis by correlating the SMMR and SSMI gridded brightness temperature data during the overlap period (figures 1 and 2). A distinct correlation was observed between data from each pair of complementary channels. The correlation was obviously complicated by unexplained factors that caused large variances in the comparison. To improve the analysis, we limited the data geographically to include observations taken only from over the Antarctic Sheet (figure 3). Ocean

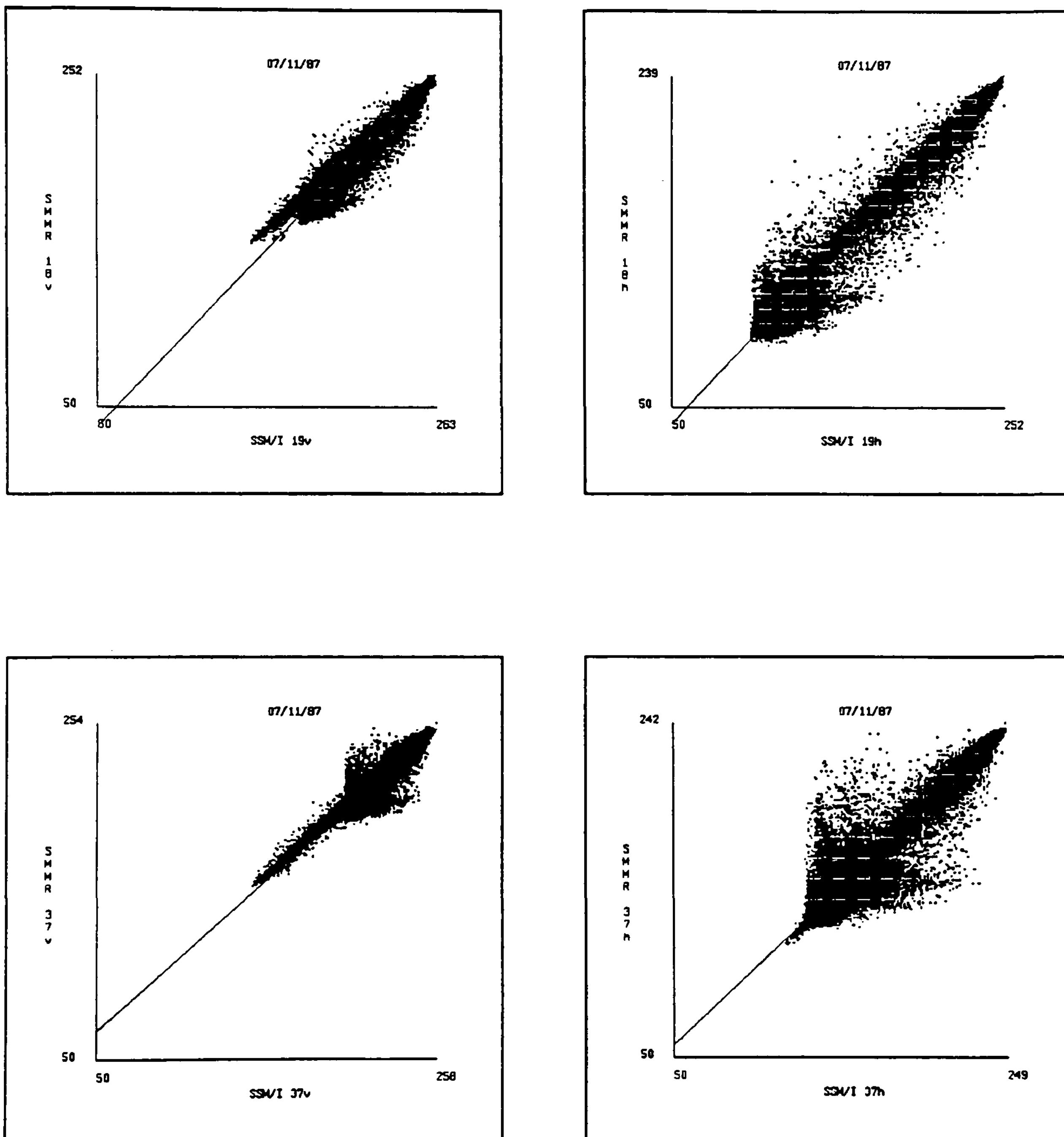


Figure 1. Regression plots for the 4 pairs of complementary channels. Data are from the first day of overlap between the two sensor (July 7, 1987) and all data accumulated within the SSMI southern hemisphere grid (NSIDC, 1990) are included.

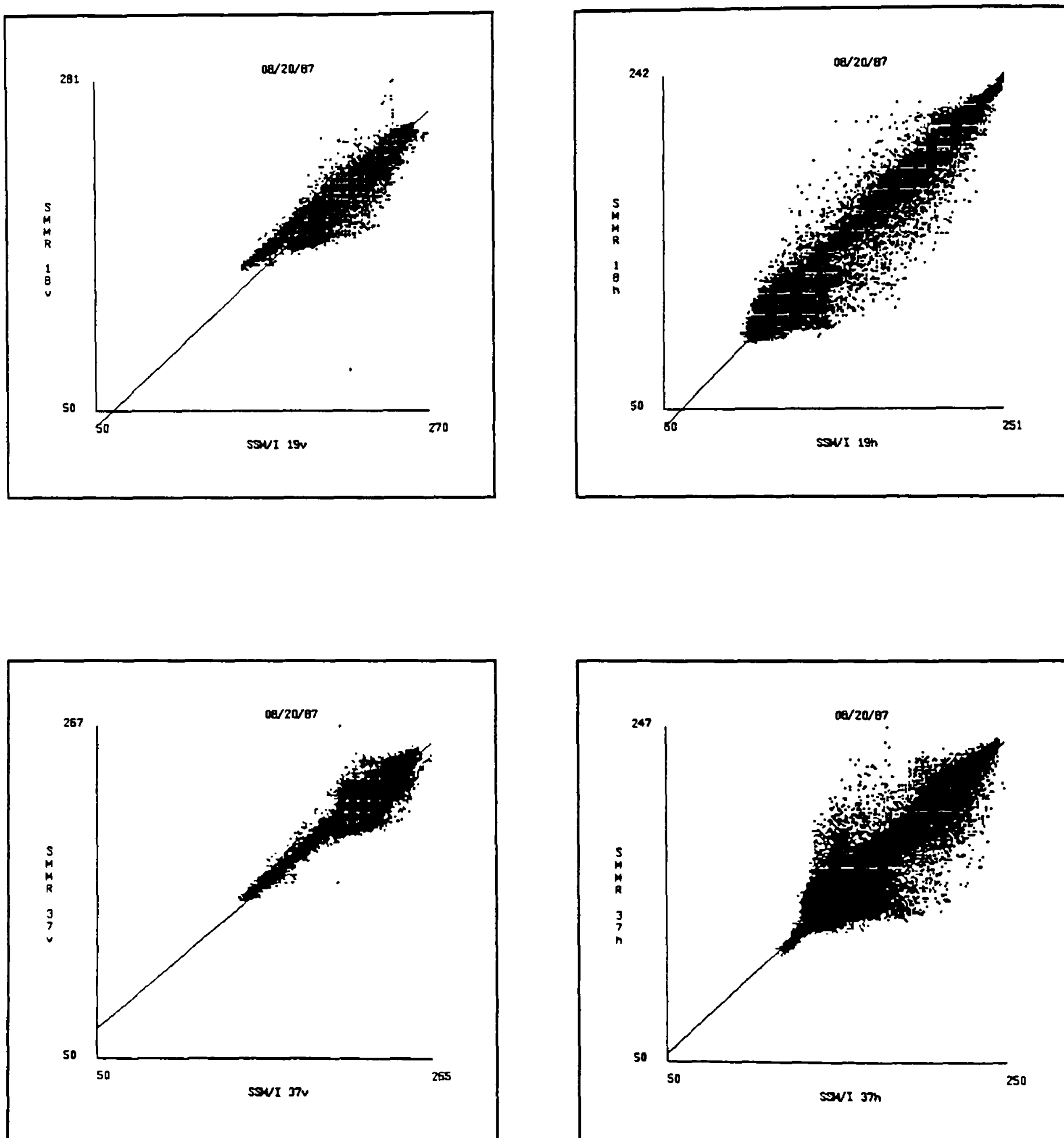


Figure 2. Regression plots for the 4 pairs of complementary channels. Data are from the last day of overlap between the two sensor (August 20, 1987) and all data accumulated within the SSMI southern hemisphere grid (NSIDC, 1990) are included.

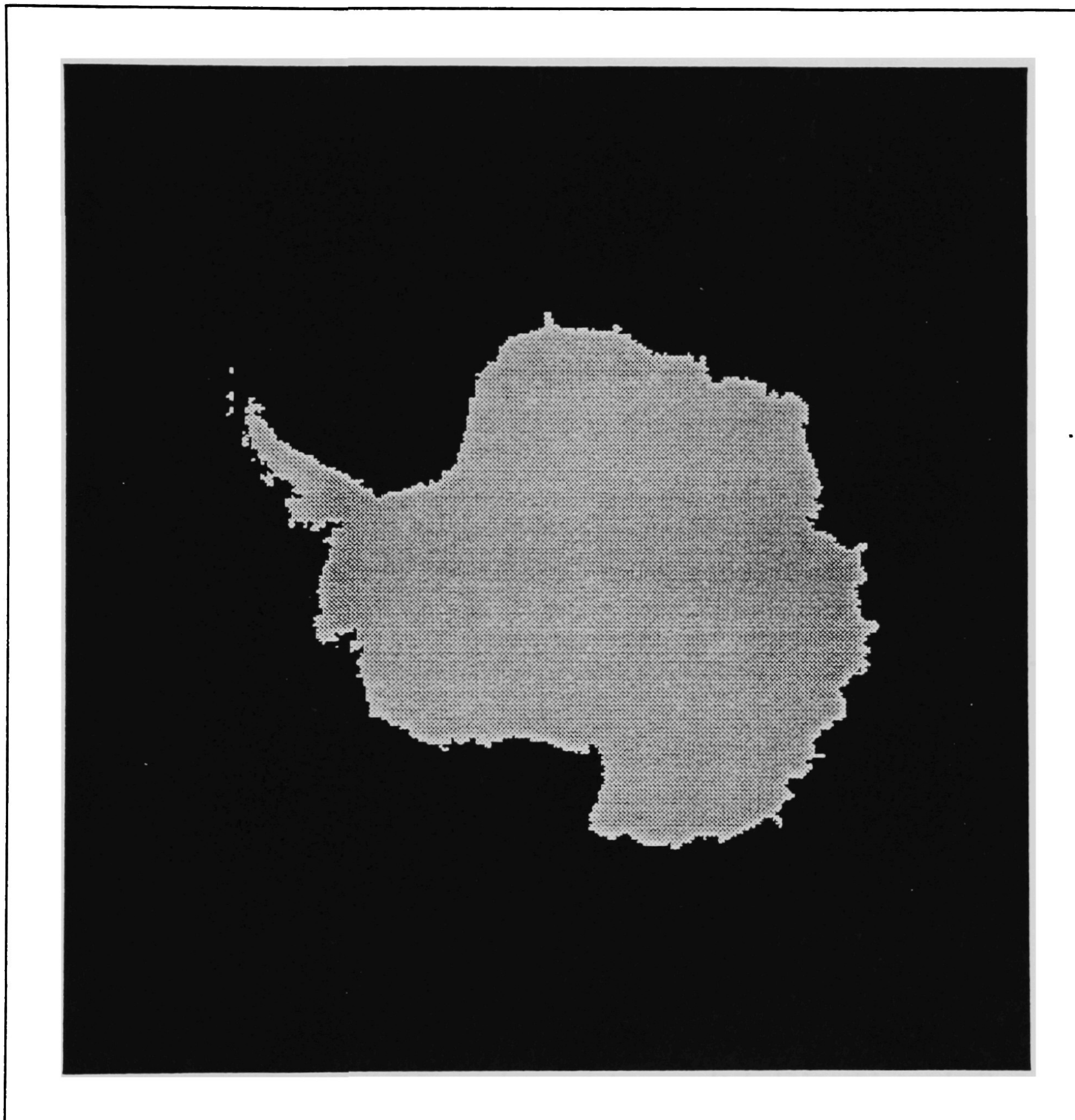


Figure 3. Ocean mask applied to the SMMR and SSMI data to eliminate all but the Antarctic Ice Sheet data from the regression analysis.

and sea ice data were masked to avoid the complexities of the temporally more volatile seaward conditions. Example of the correlations for the 4 pairs of channels for the first and for the last day of overlap are shown in figures 4 and 5 (all correlation plots are presented in appendix 1).

3. Results

A linear regression of the form

$$SMMR(Tb) = g*SSMI(Tb) + dc$$

was applied to each correlation plot where g is the slope of the regression line, dc is the intercept and SMMR and SSMI are the brightness temperature pairs. Coefficients and intercepts for each pair of data are presented in appendix 2. Figures 6 and 7 show the slopes and intercepts for each pair of channels plotted as a function of time. Because there is no consistent trend in the time series of slopes and intercepts, we feel justified in computing average values of the slopes and intercepts of the channel pairs. These are given in table 1.

Table 1

Average slopes and intercept values determined by regressing SMMR and SSMI brightness temperature data collected over the Antarctic Ice Sheet

Channel Pair	Average Slope	Average Intercept (degrees K)
18v/19v	0.870	21.9
18h/19h	0.940	2.62
37v/37v	0.861	30.2
37h/37h	0.954	2.85

As recorded in appendix 2, the correlation coefficients for each regression exceeded 0.99.

We have identified three major concerns with our analysis. SSMI and SMMR data were not collected simultaneously and there is as much as a 6 hour difference between observation times. We do not consider this a serious problem over the ice sheet for two reasons. At the lower frequency, several meters of firn contribute emitted energy and the temperature response of that bulk layer of snow to reasonable changes in air temperature over the period of several hours is likely to be small (a degree or two at most). Air temperature variations may affect the

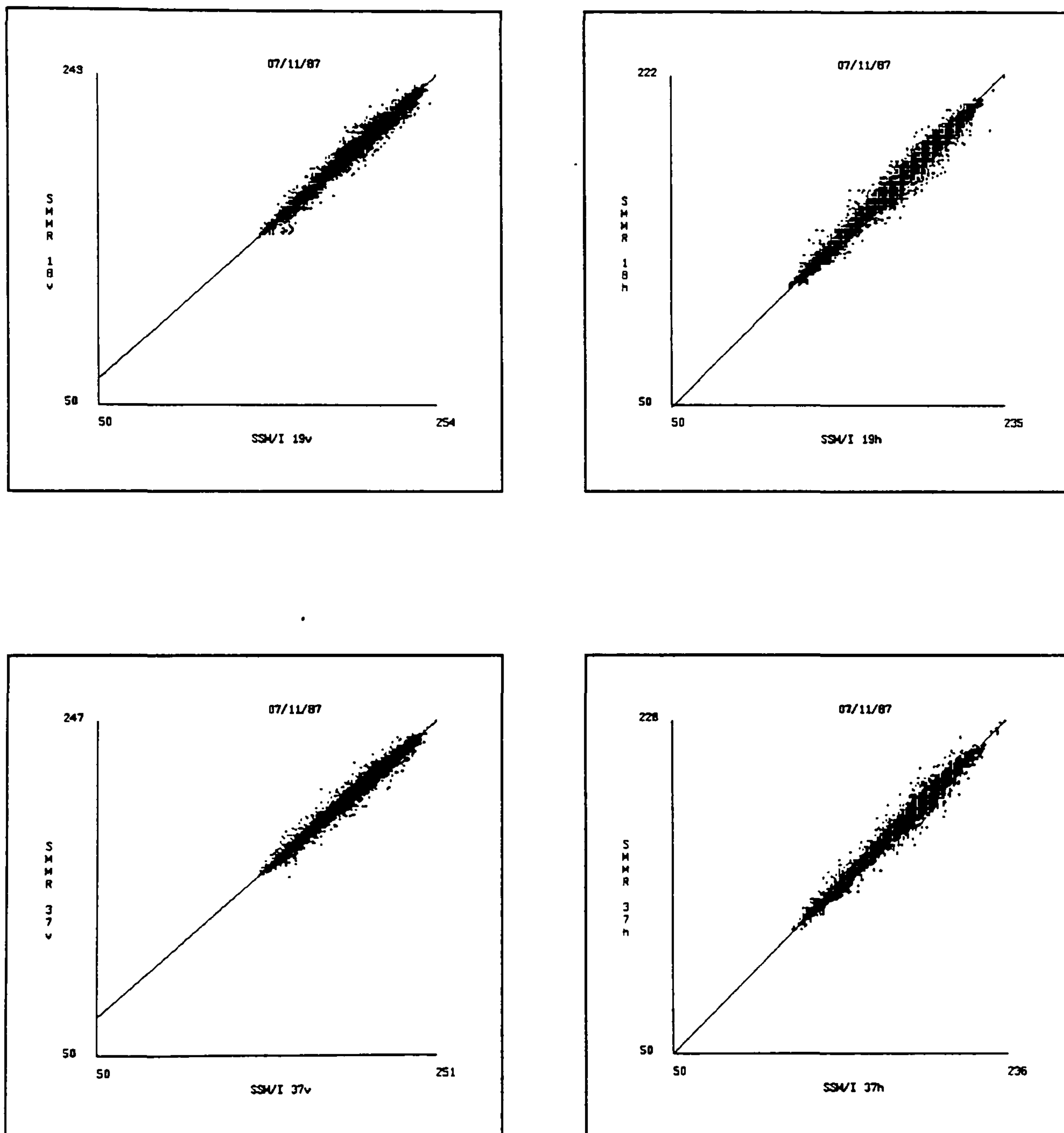


Figure 4. Regression plots for the 4 pairs of complementary channels. Data are from the first day of overlap between the two sensor (July 7, 1987). Only data accumulated over the Antarctic Ice Sheet are included.

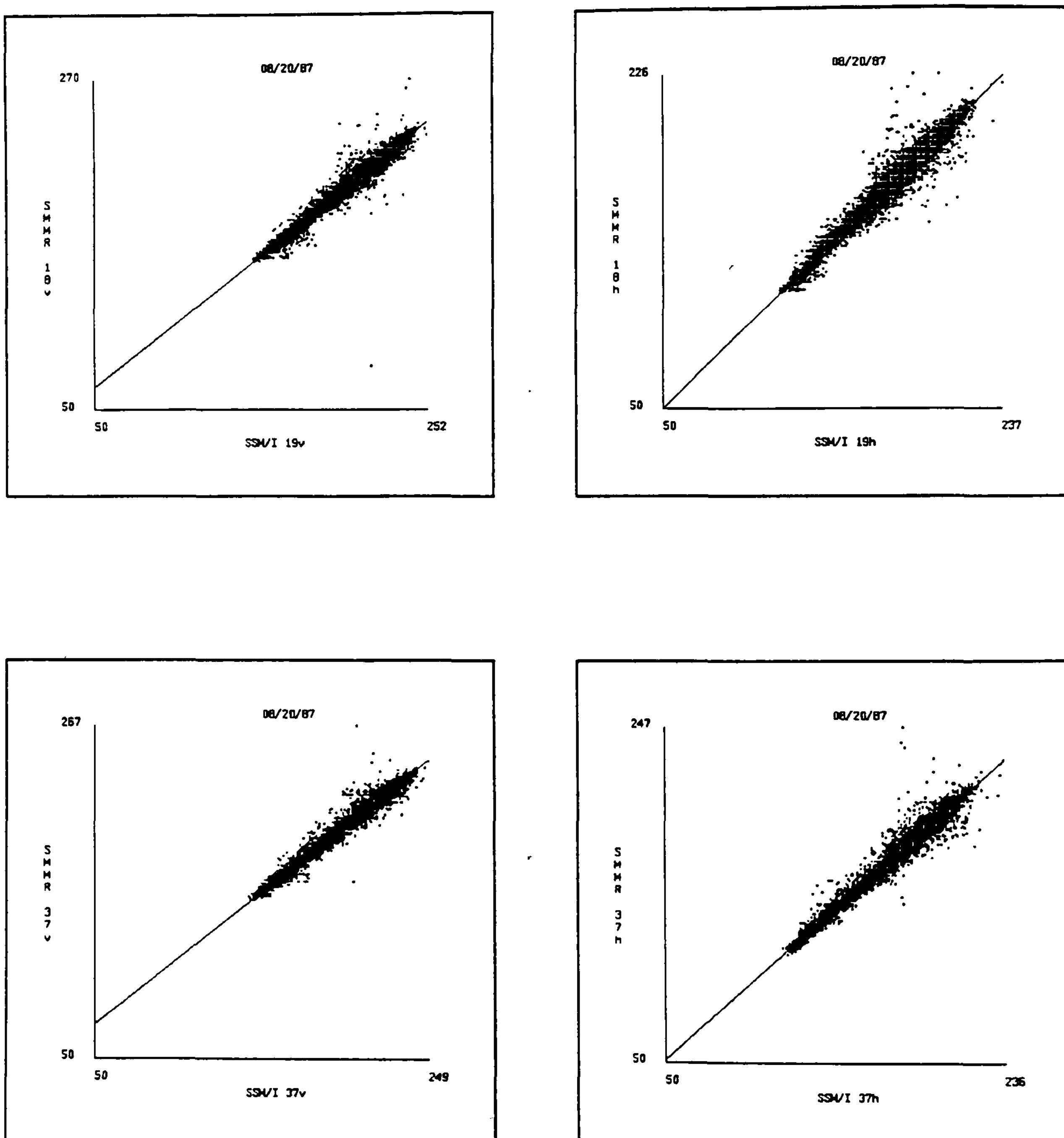


Figure 5. Regression plots for the 4 pairs of complementary channels. Data are from the last day of overlap between the two sensor (August 20, 1987). Only data accumulated over the Antarctic Ice Sheet are included.

interpretation of the higher frequency data but temperature records acquired from Automatic Weather Stations at several locations in Antarctica indicate that diurnal variations over much of the continent during the dead of winter are only a few degrees (data from Automatic Weather Station Program, University of Wisconsin-Madison).

During the early part of the SSMI mission a geolocation problem was discovered with a magnitude of 25 km or about 1 pixel. We have not attempted to improve the co-registration of the data primarily because the gradients in brightness temperature across the ice sheet are on average less than 2 degrees per pixel though in some coastal areas and in mountainous areas the gradient can be as high as 5 degrees per pixel. We note that increased brightness temperature gradients and a stronger diurnal cycle of physical temperature near the coast may explain the slight broadening of the variances about the regression lines at higher brightness temperatures. There is some suggestion (figures 4 and 5) that the variances at higher temperatures increase with time possibly coinciding with the seasonally lengthening diurnal cycle.

Finally, there may be a diurnal difference in the amount of atmospheric radiation emitted directly to the sensors and reflected off the surface that might corrupt the regression of non-simultaneous data. We do not measure strong trends in the regression coefficients during the overlap time period even though the average surface air temperature in August, 1987 at Byrd Station was 7 degrees cooler than in July and about 4 degrees cooler at Dome C. Consequently, we do not believe that sky radiation is an important issue in this analysis.

4. Discussion

Figures 6 and 7 demonstrate that slopes of regression lines are significantly different from unity and that intercepts are significantly different from zero. In fact, the intercepts can be quite large exceeding 30 degrees K for the 37v channel comparison. It seems reasonable to ask why such apparently large offsets would go unnoticed during the initial inspection of each data set. The answer lies with the fact that the relative difference between SMMR and SSMI brightness temperatures changes with the magnitude of the temperature. That point is demonstrated in figure 8 where predicted differences are plotted as a function of SSMI brightness temperature. The functions plotted in figure 8 are the derived from the regression analyses and the equation

$$\text{Delta} = (\text{SMMR} - \text{SSMI}) = \text{DC} - (1-g)*\text{SSMI}$$

Using figure 8, it can be seen that in the SSMI temperature range from 150 to 250 degrees K, corresponding deltas span over a range from about +10 to -10 degrees K depending on the channel Thus while the differences at these temperatures may be reduced relative to the intercept values, geophysical analysis at only these temperatures would tend to overlook the details of the relative calibration differences.

Figure 6. Slopes derived from the regression analysis for each pair of complementary channels plotted for each day of overlap

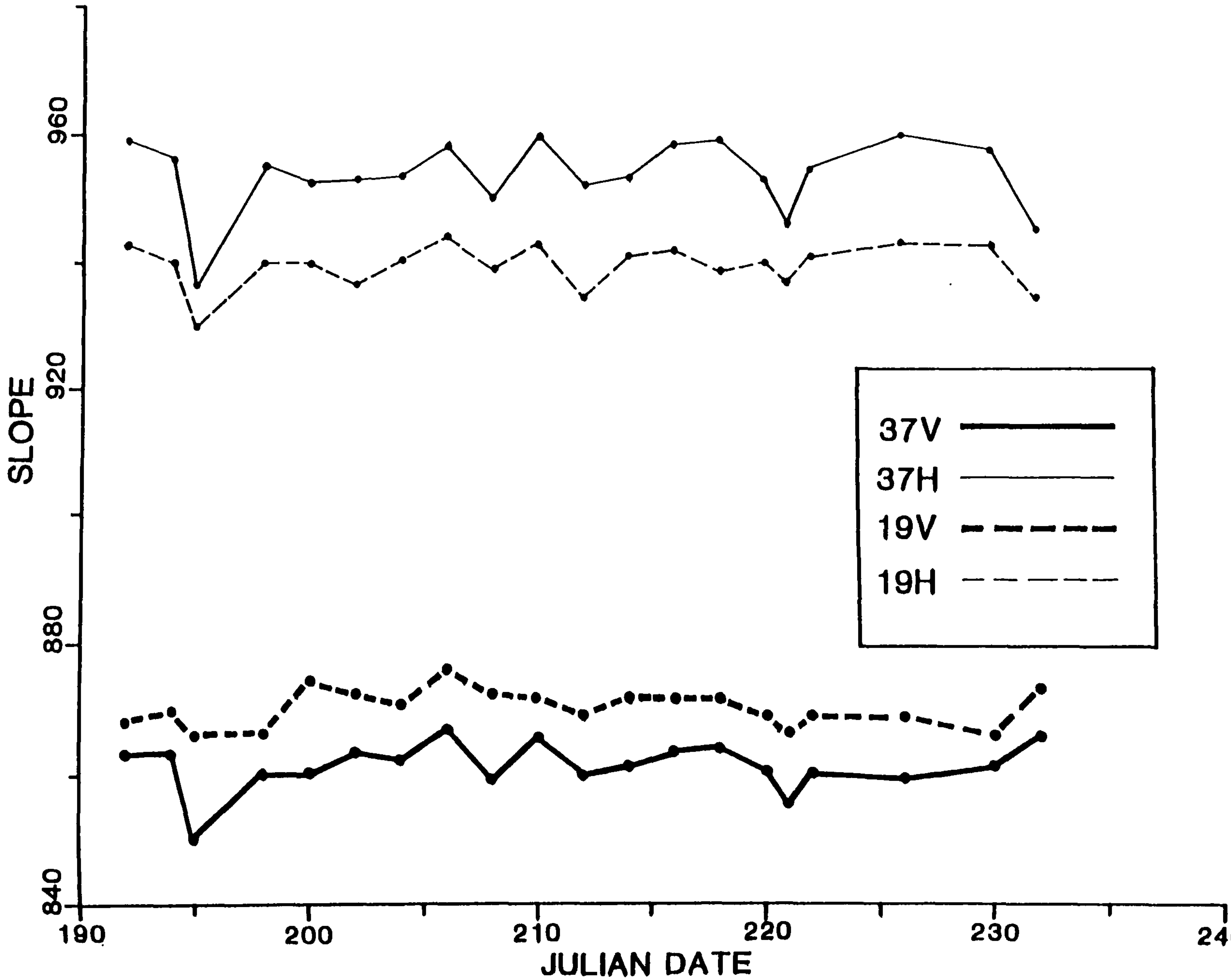


Figure 7. Intercepts derived from the regression analysis for each pair of complementary channels plotted for each day of overlap

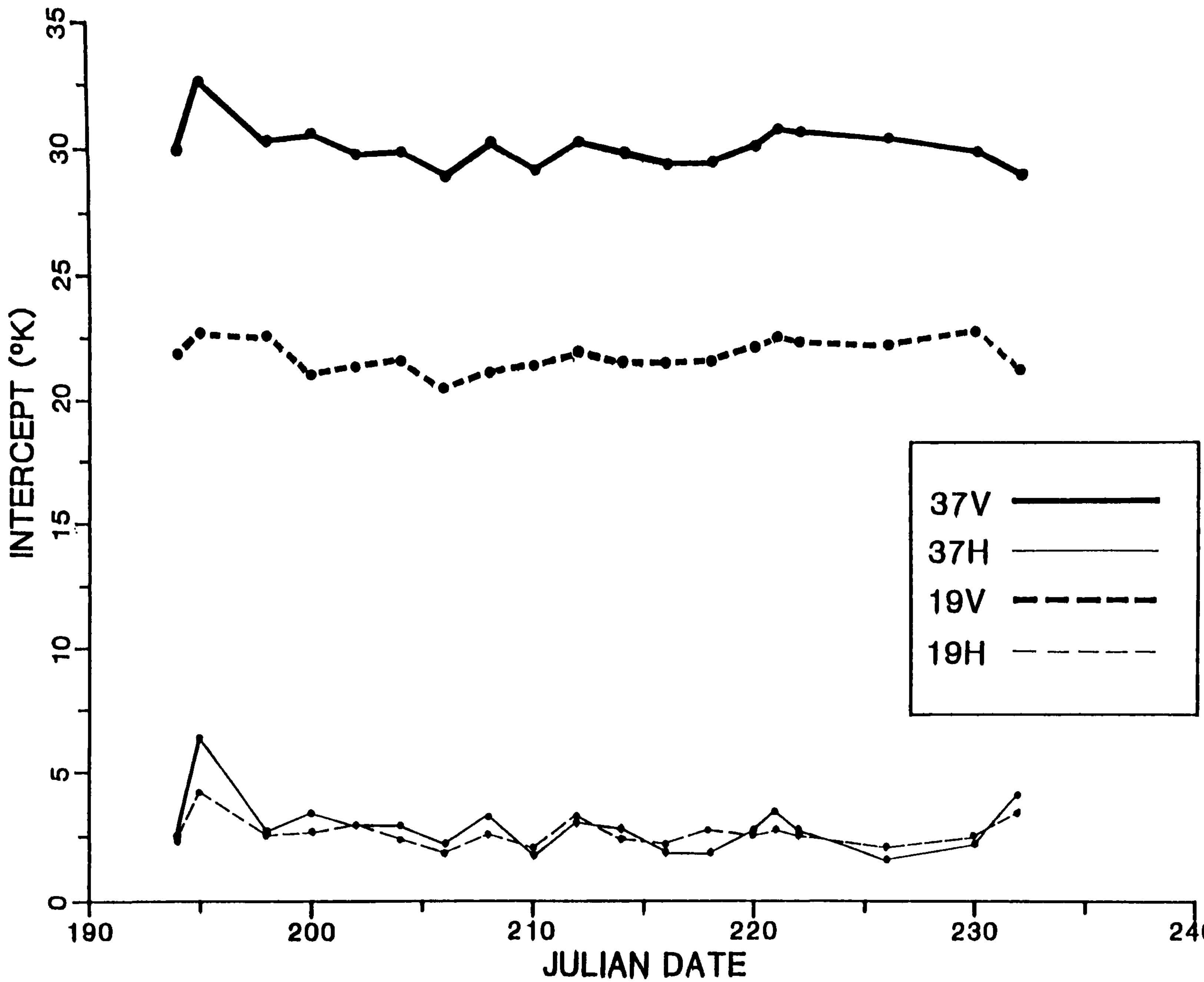
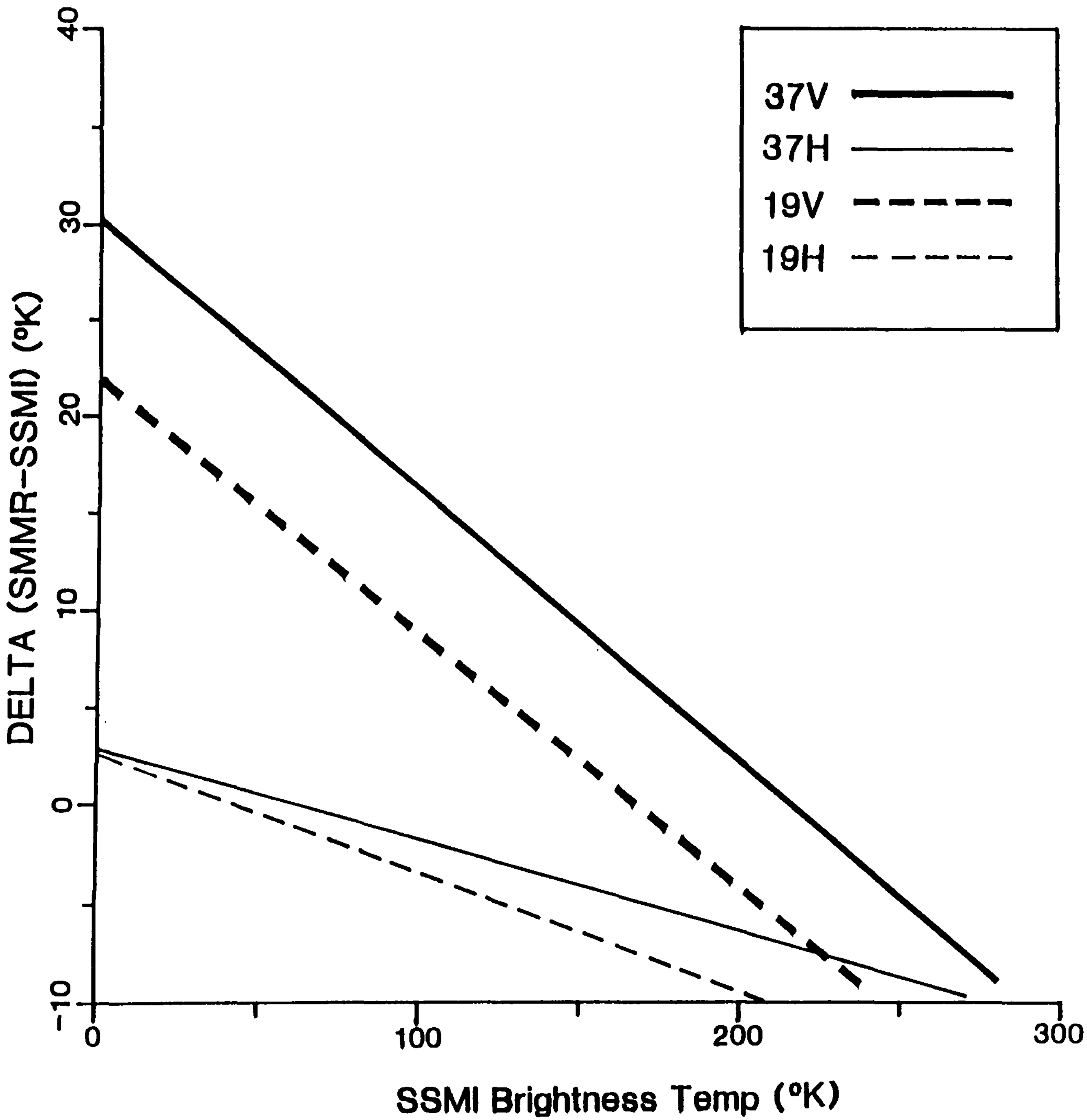


Figure 8. Differences between SMMR and SSMI brightness temperatures predicted using the regression coefficients listed in table 1 plotted against SSMI brightness temperatures.



5. Conclusions

We attribute the strong linear nature of the correlation plots compiled between complementary pairs of SMMR and SSMI data collected over the Antarctic Ice Sheet as strong support of the hypothesis that there are important relative calibration differences between the two sensors. Calibration differences in the brightness temperature data have an obvious and important impact on derived geophysical properties such as changes in relative physical temperature, estimates of melting (based on absolute brightness temperatures) and calculated emissivities. Calibration differences may also complicate the derivation of other geophysical variables wherein the quotients of the differences and the sums of channels are used (Swift and Cavalieri, 1985).

Acknowledgements

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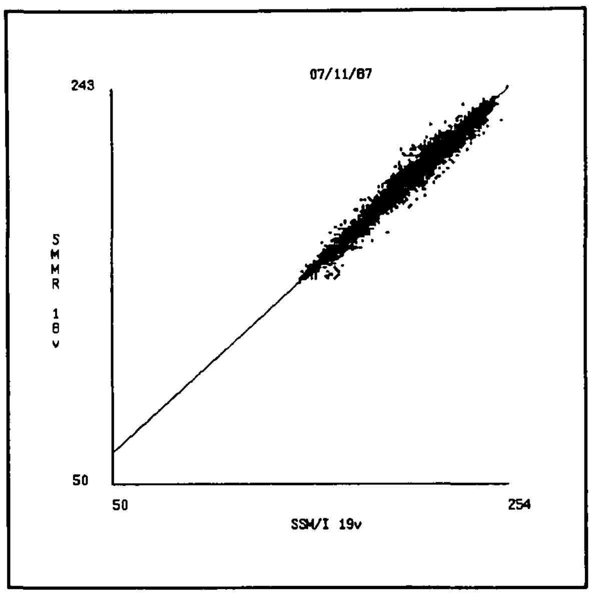
Appendix 1: Regression plots between SMMR and SSMI data for the period of instrument overlap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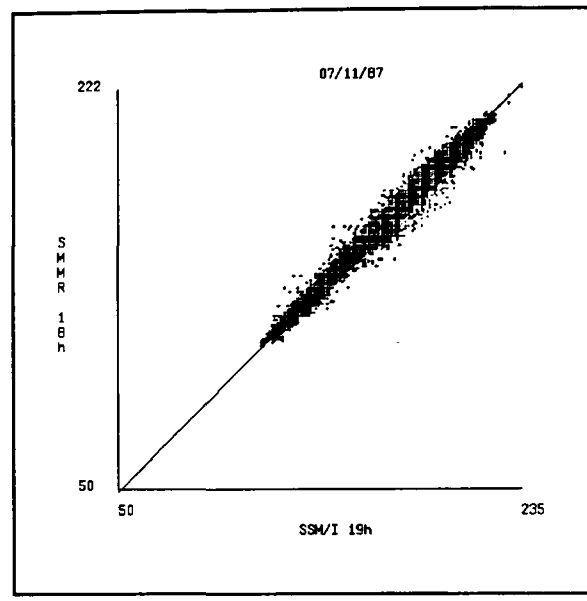
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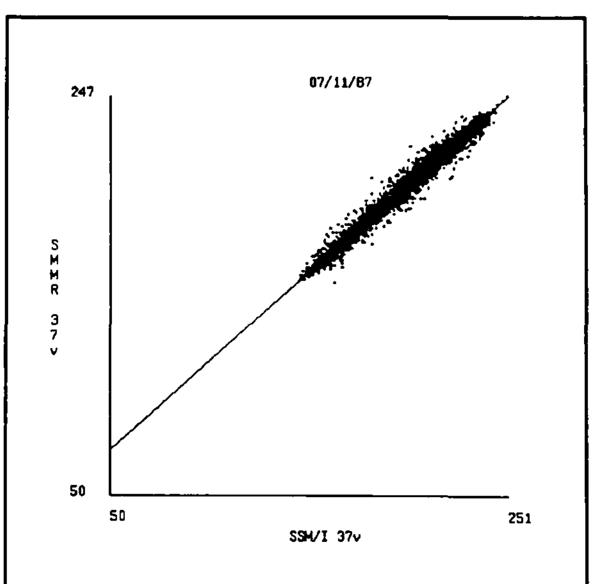
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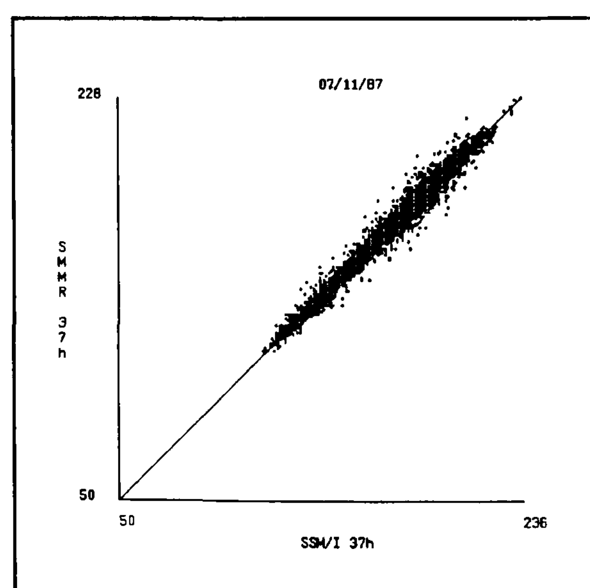
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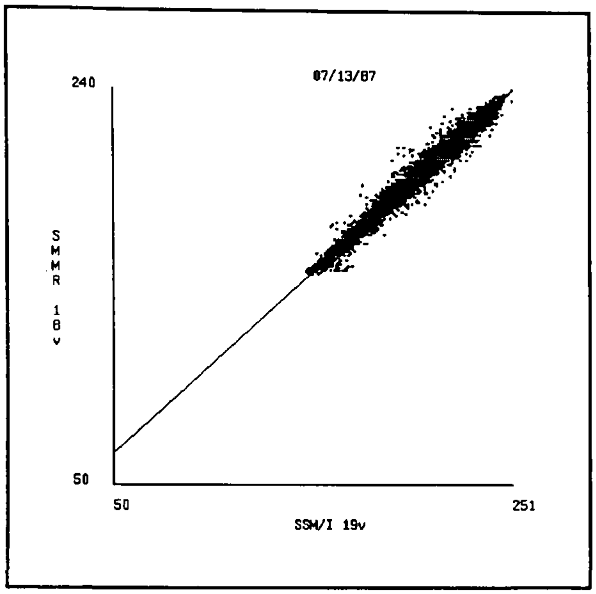
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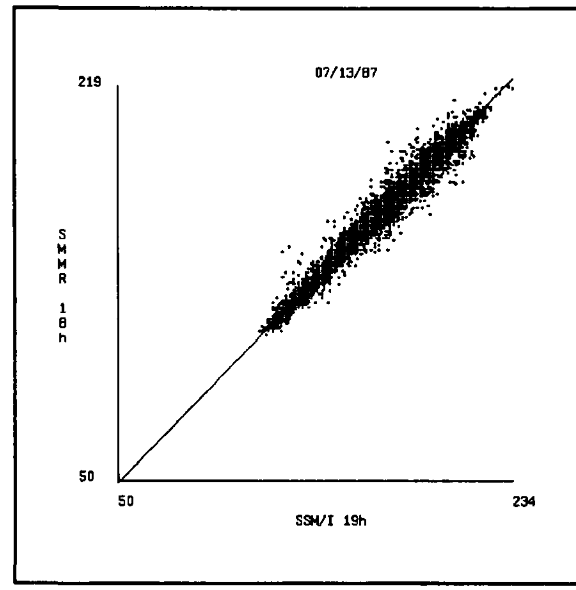
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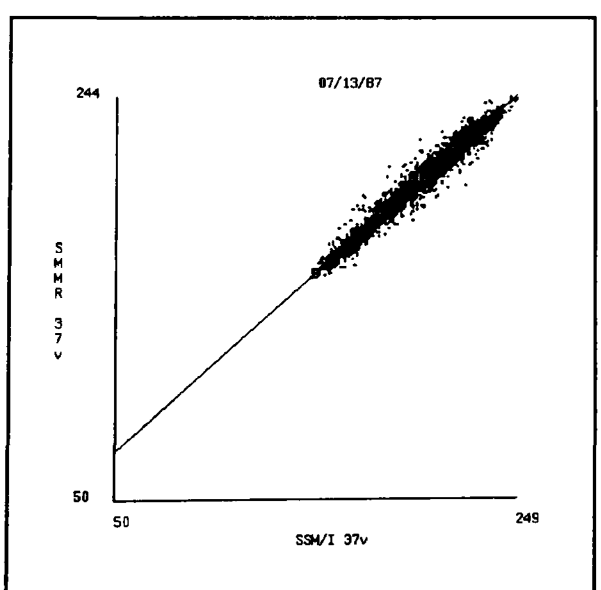
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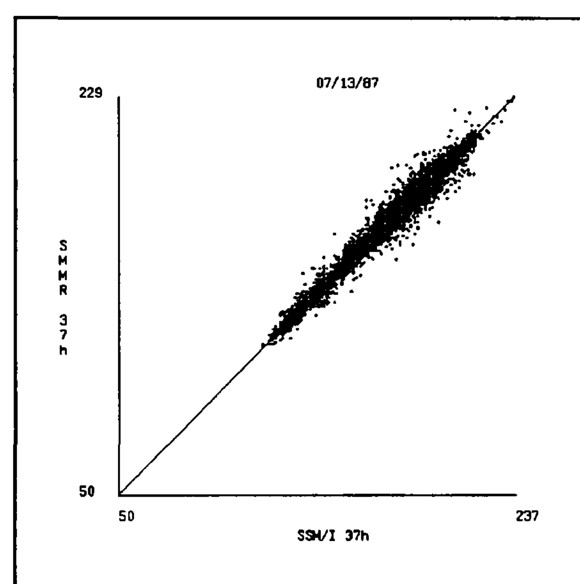
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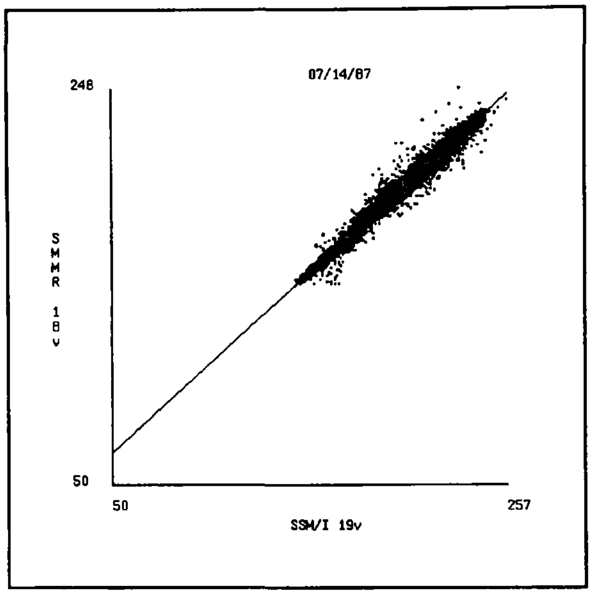
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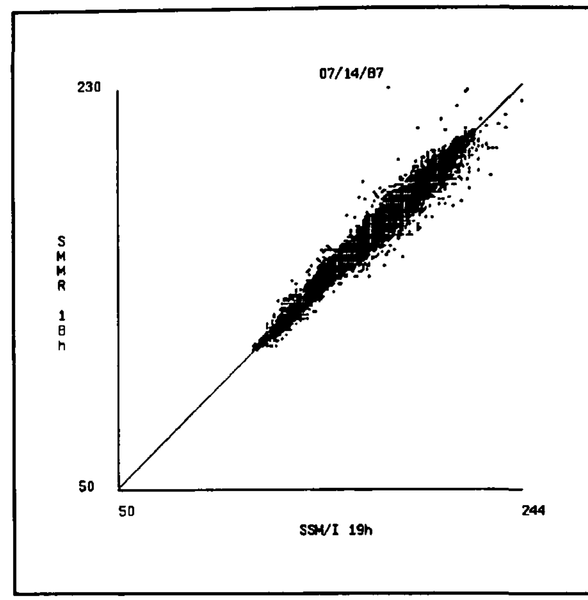
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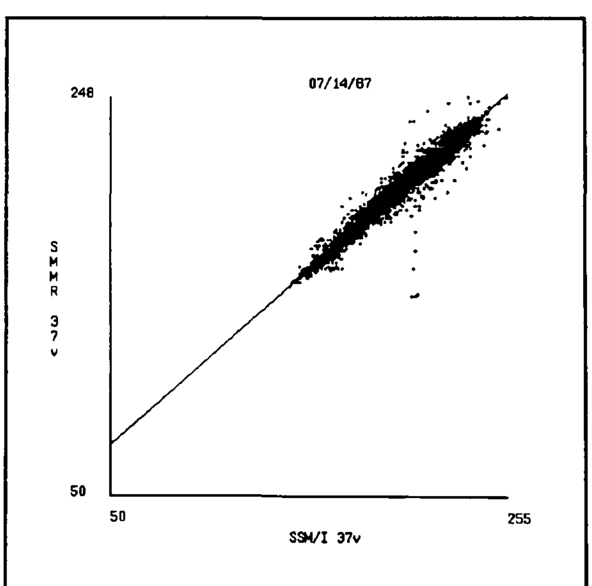
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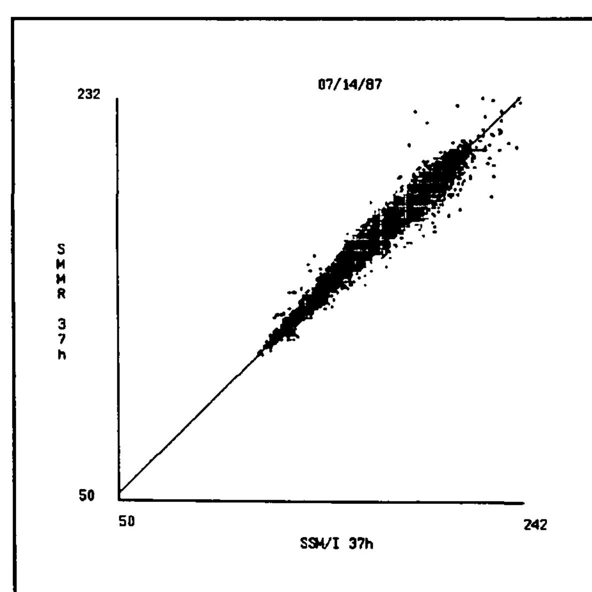
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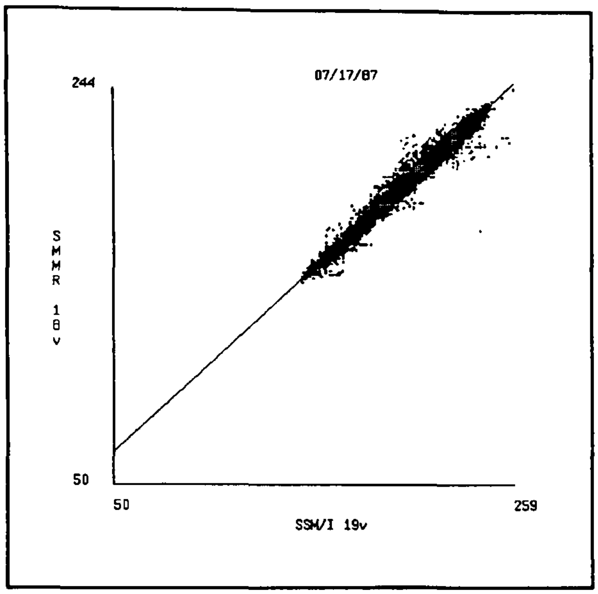
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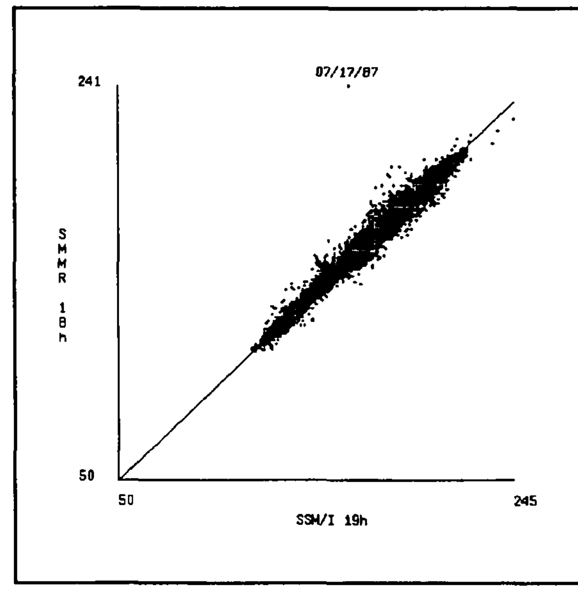
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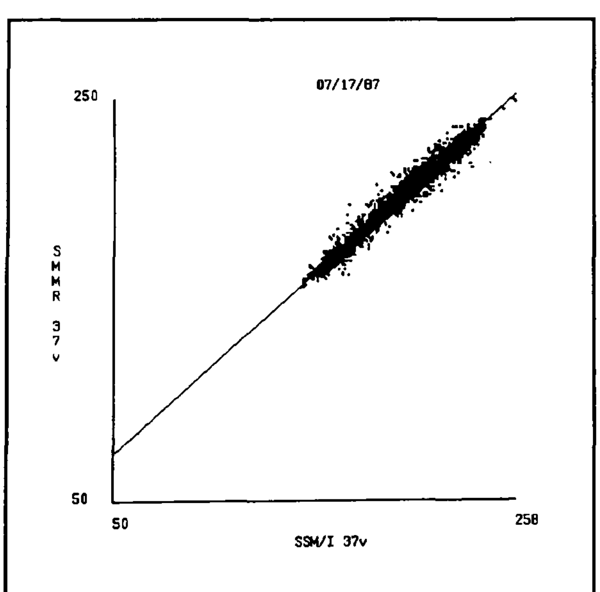
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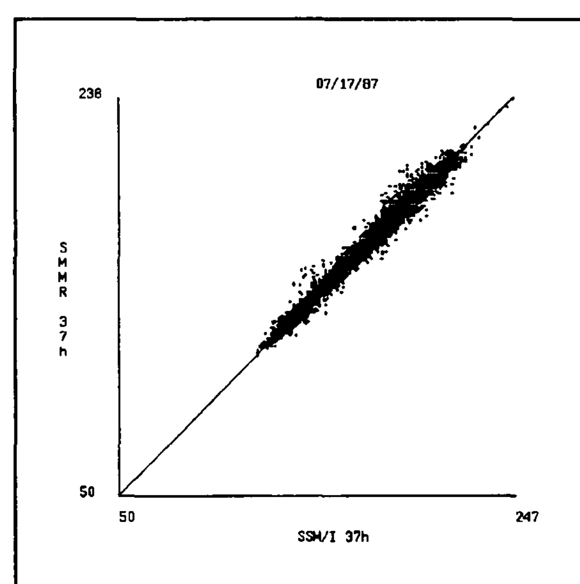
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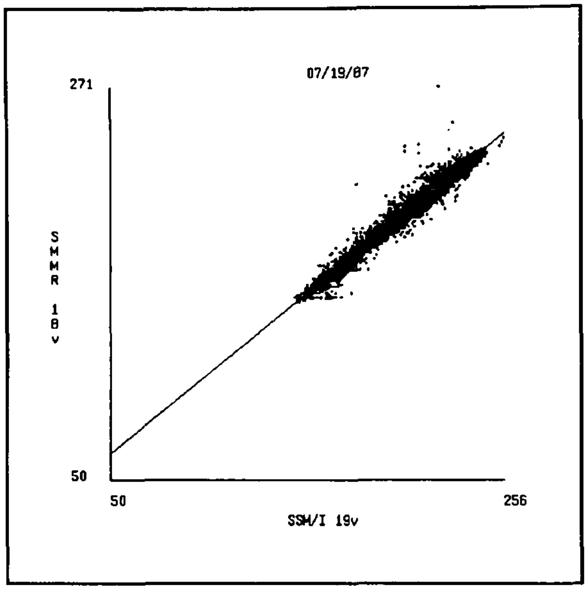
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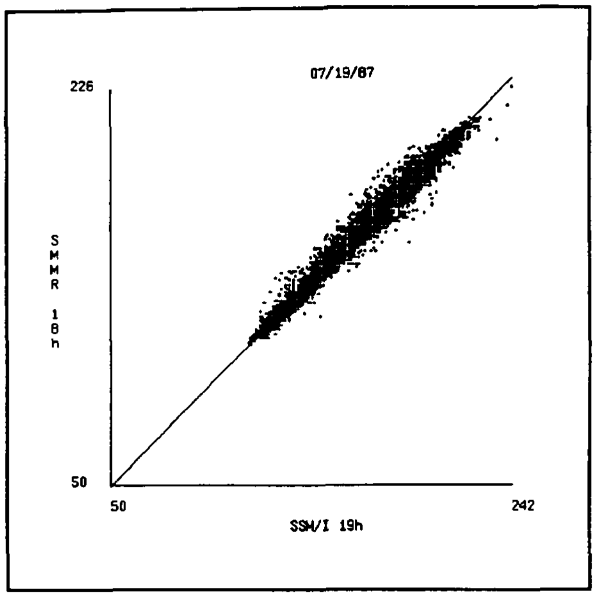
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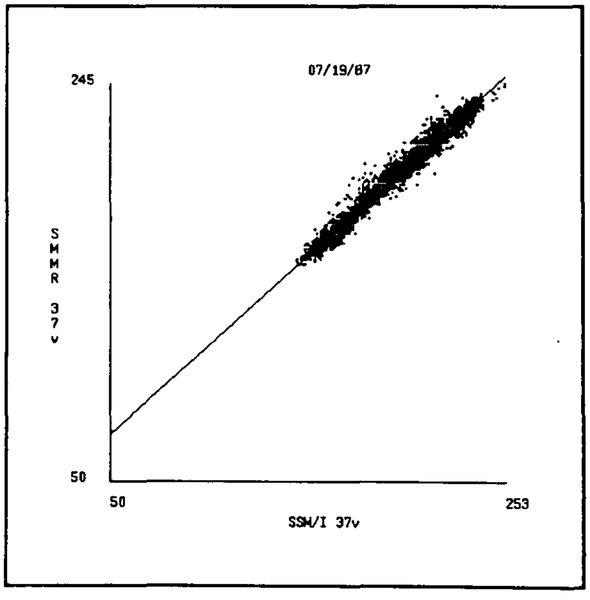
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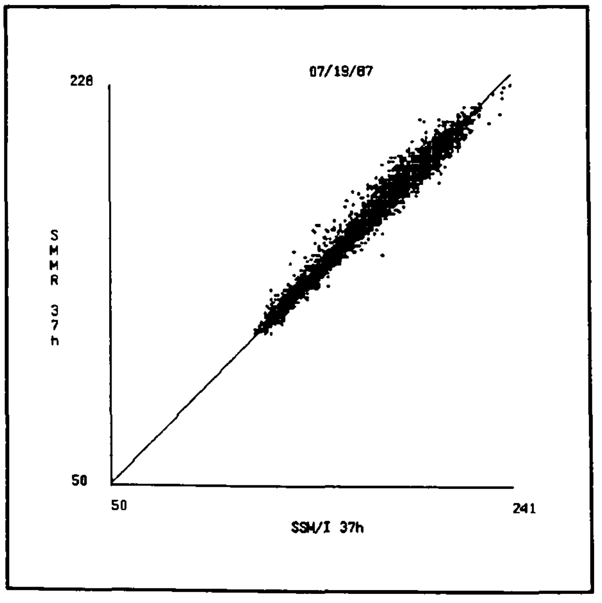
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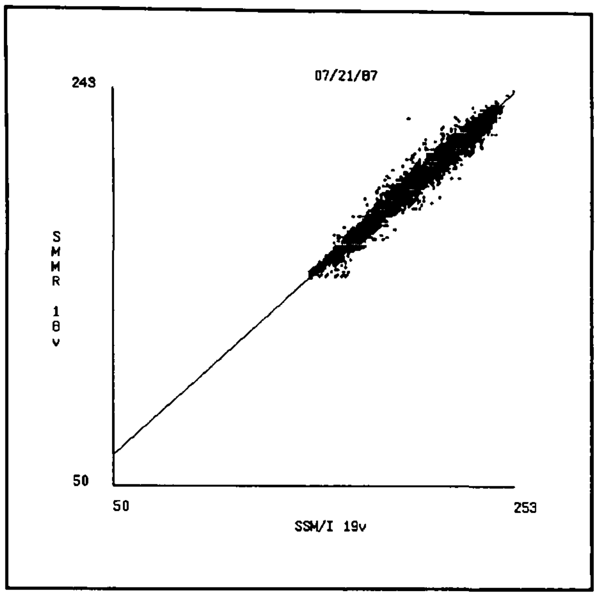
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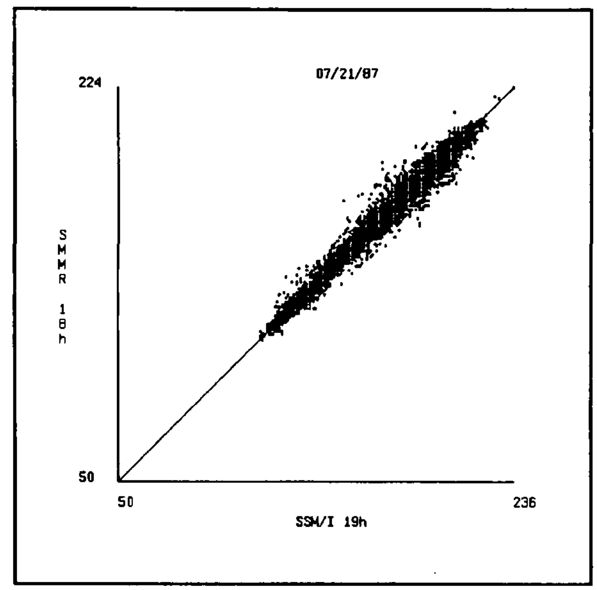
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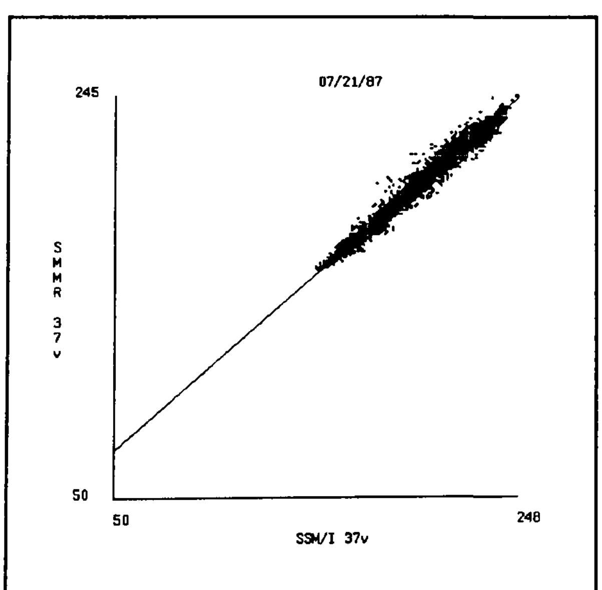
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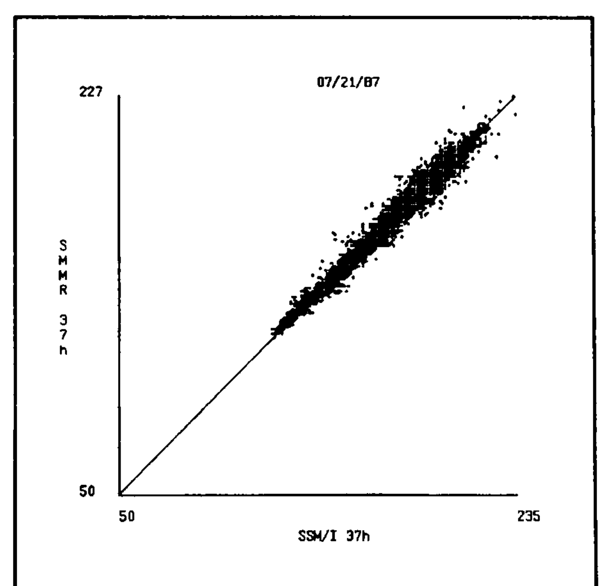
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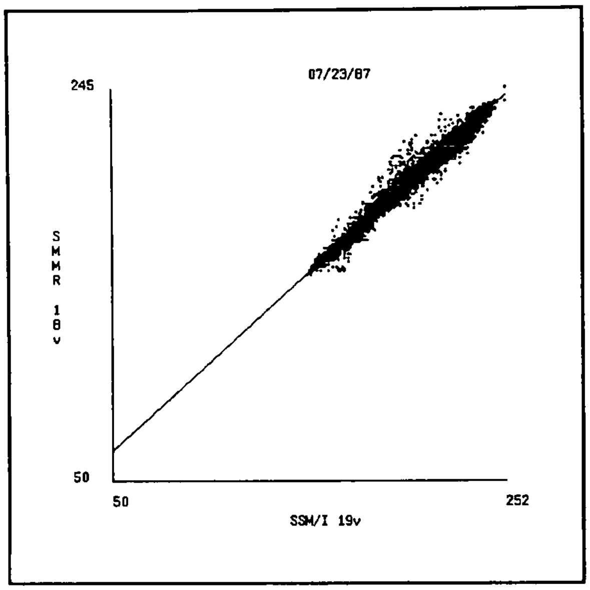
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SMMR 18v
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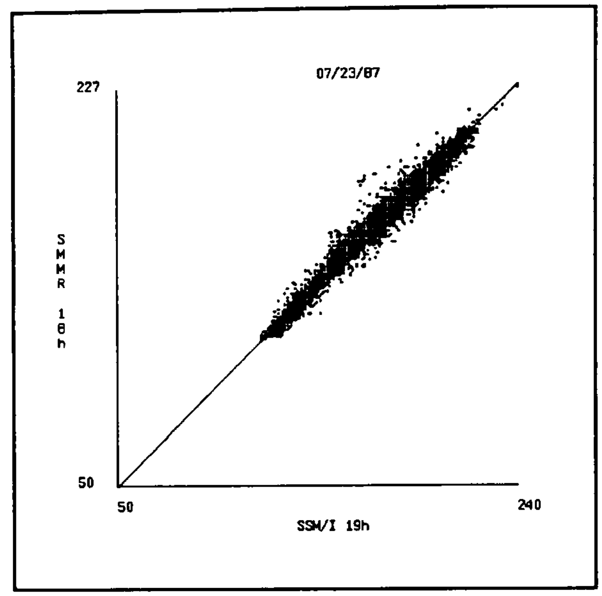
SSM/I 19v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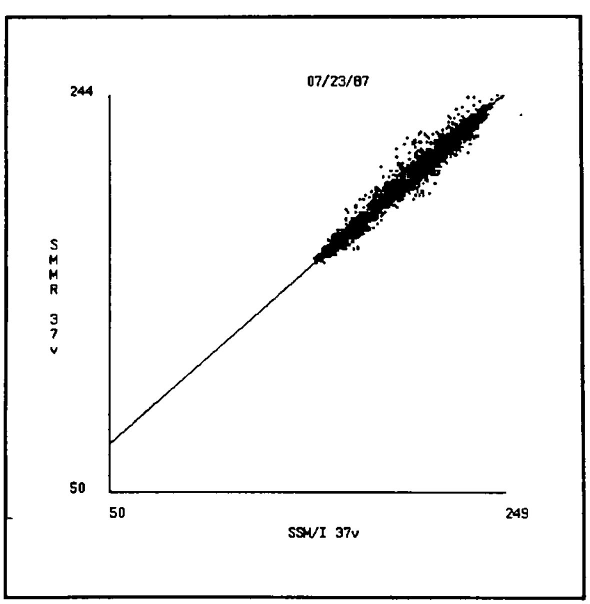
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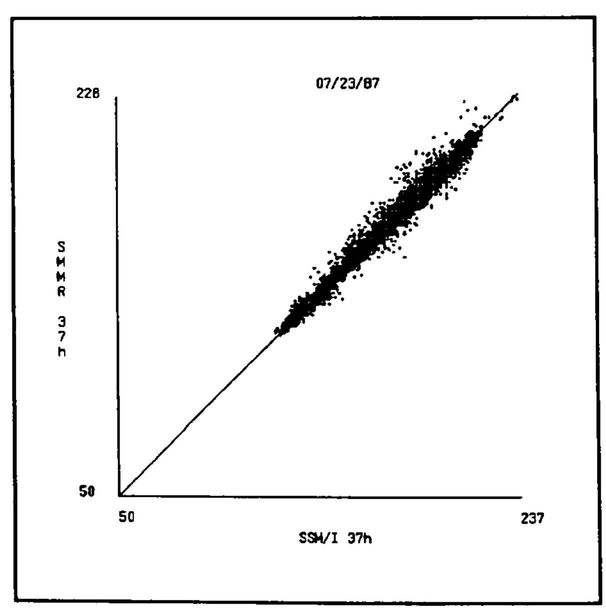
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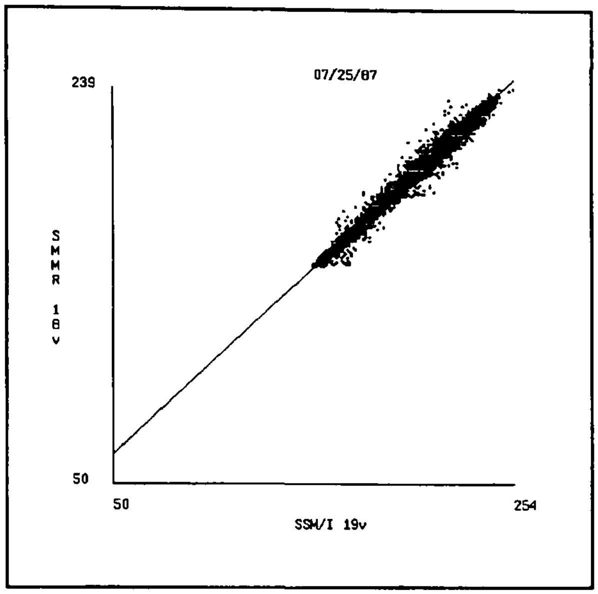
SSM/I 37h



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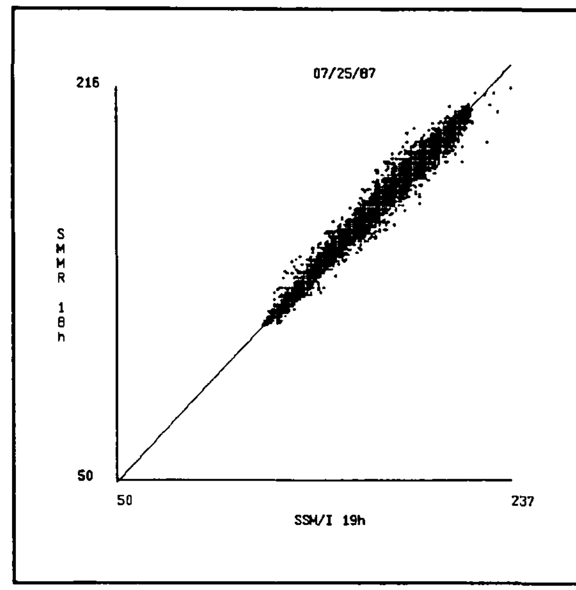
SSM/I 19v



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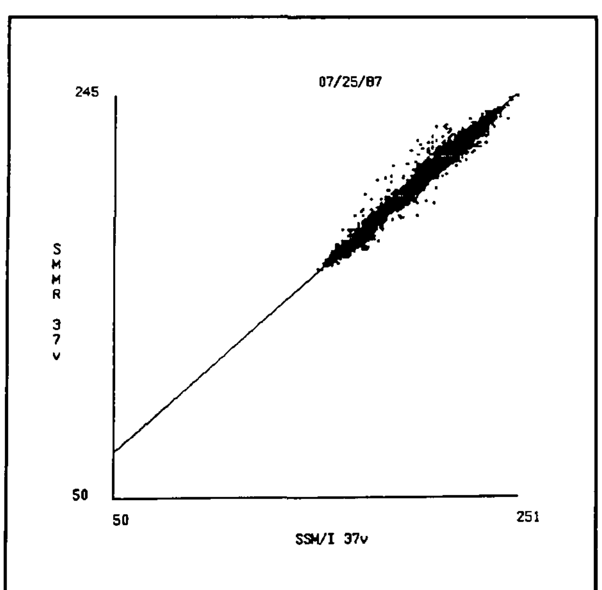
SSM/I 19h



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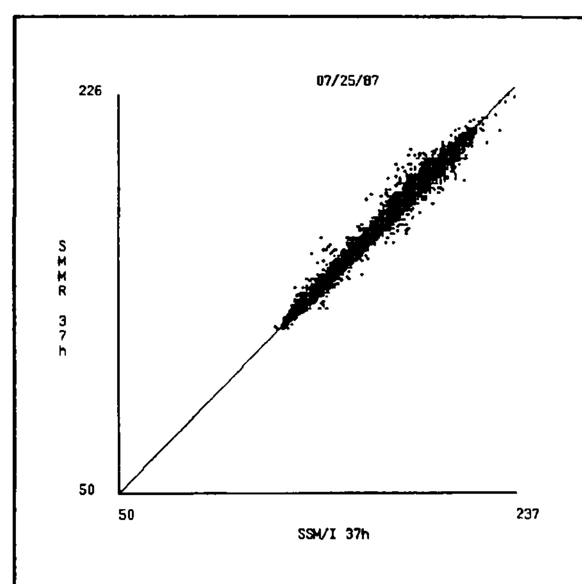

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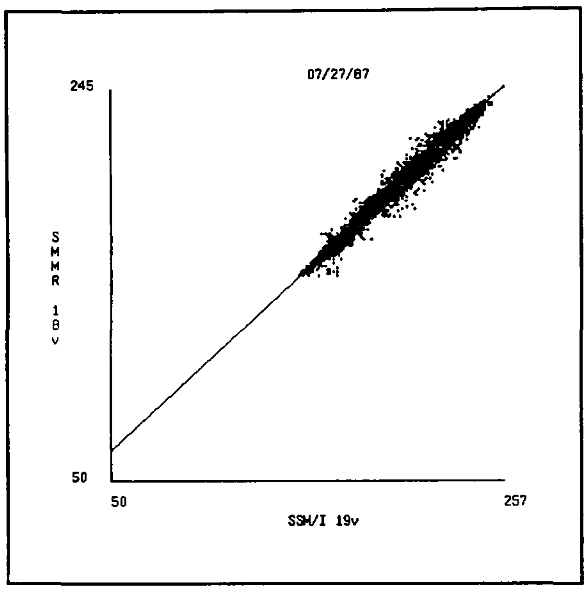
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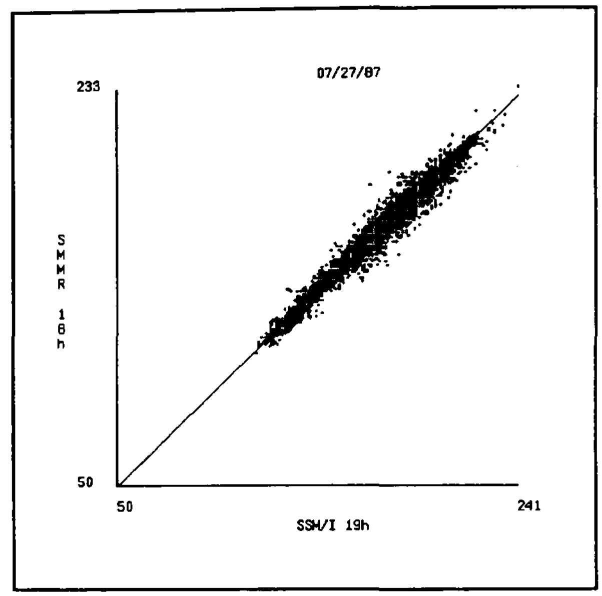
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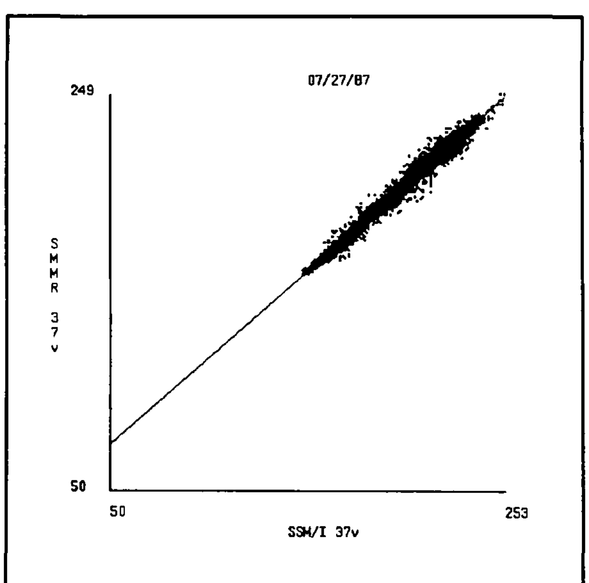
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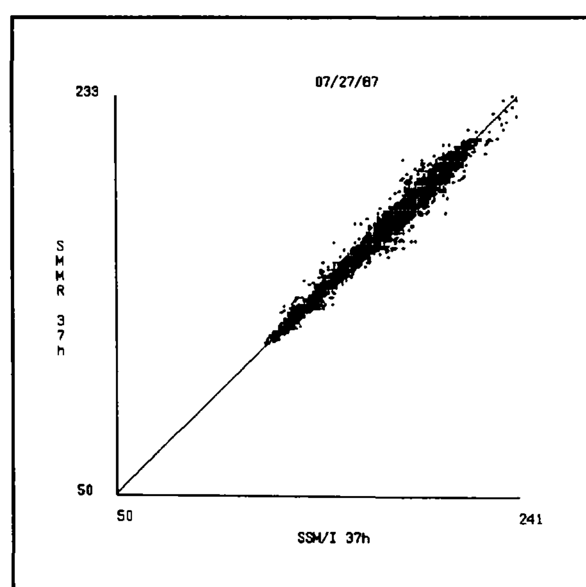
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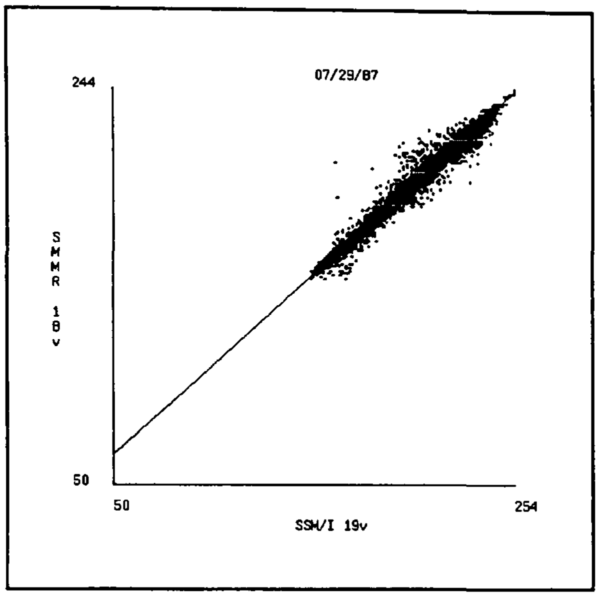
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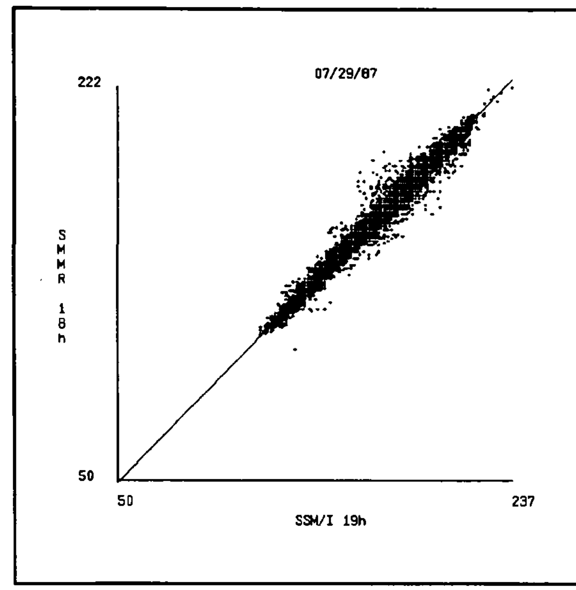
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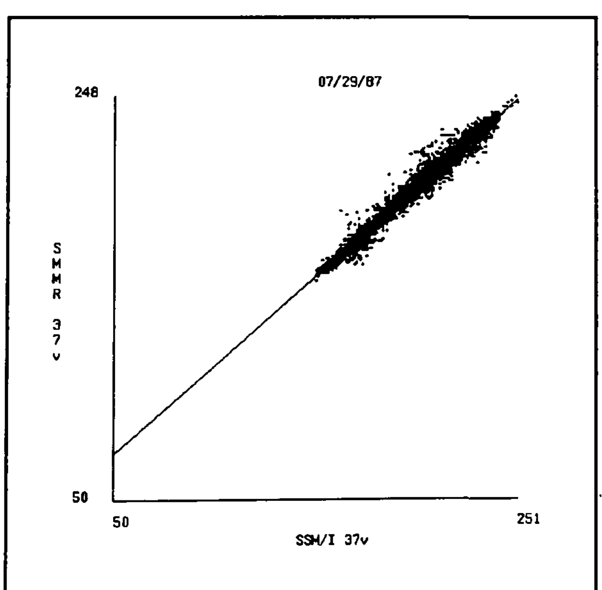
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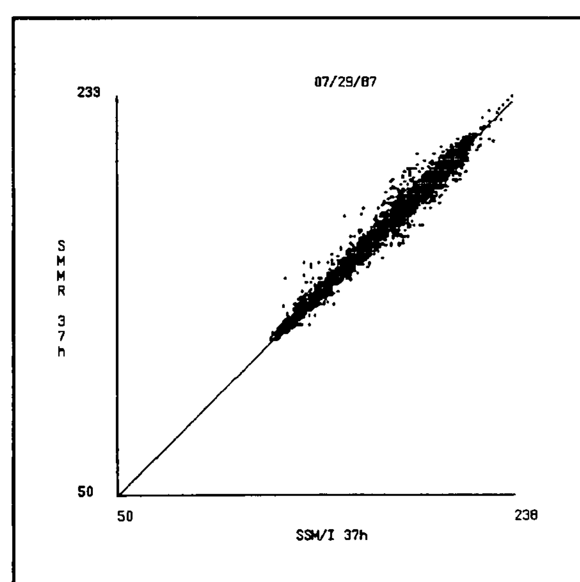
SSM/I 37v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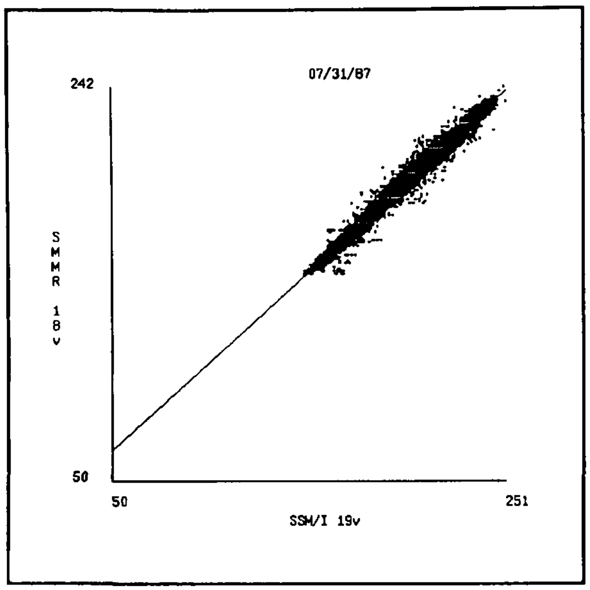
SSM/I 37h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SMMR 18v
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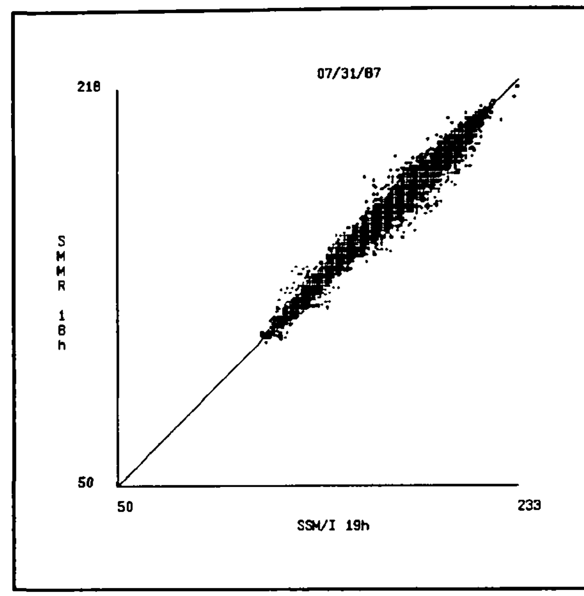
SSM/I 19v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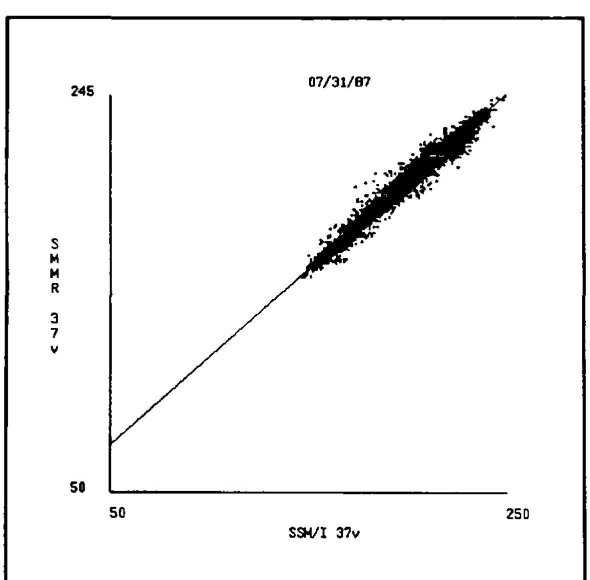
50
233
SSM/I 19h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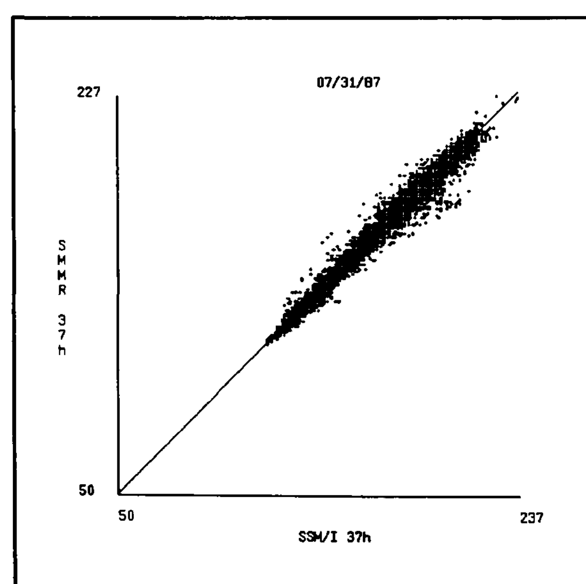
SSM/I 37v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SMMR 37h
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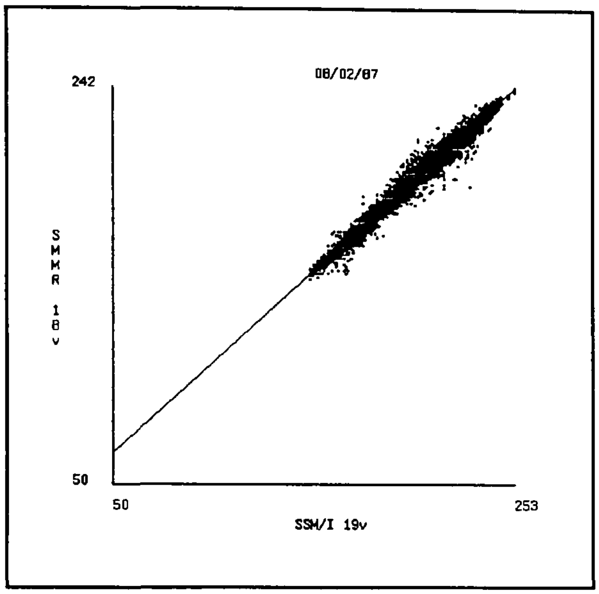
50
237
SSM/I 37h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SMMR 18v
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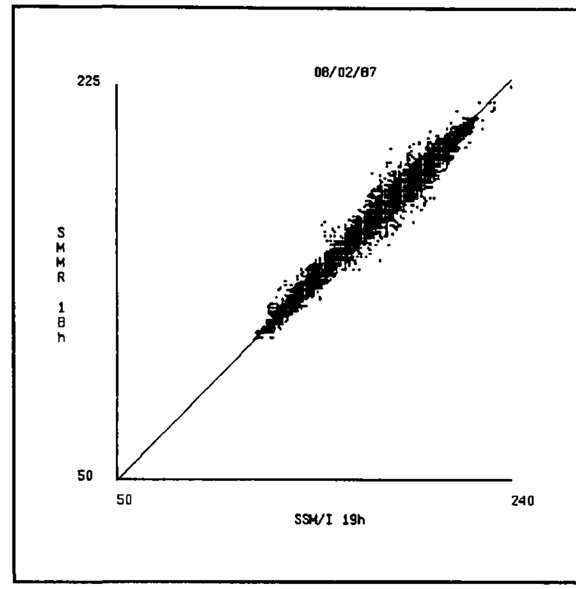
253
SSM/I 19v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SMMR 18h
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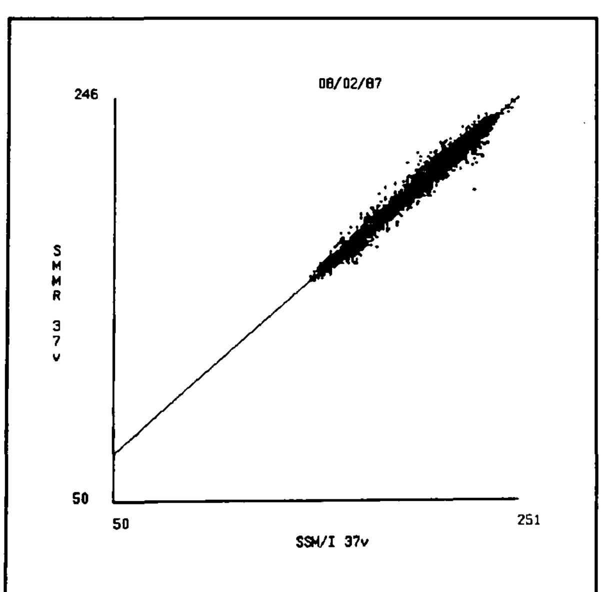
50
240
SSM/I 19h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SMMR 37v
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50
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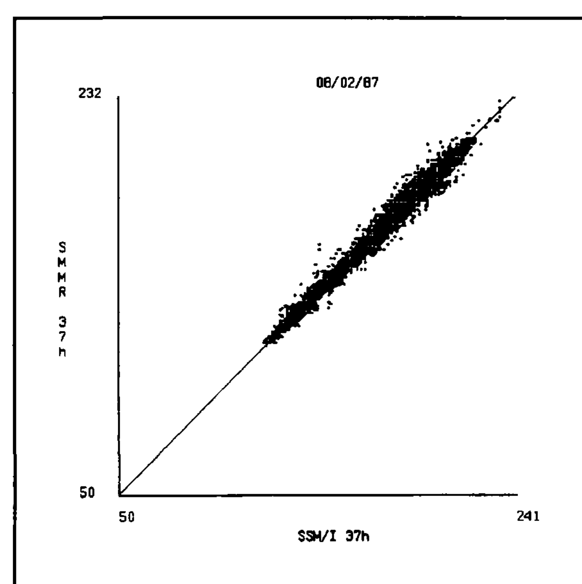
SSM/I 37v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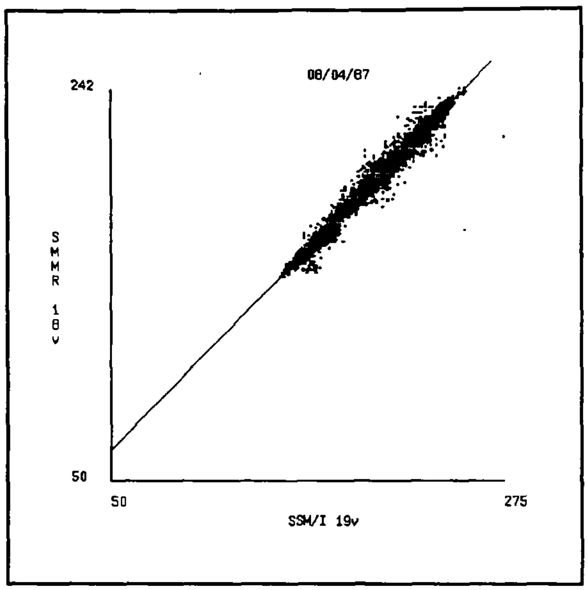
SSM/I 37h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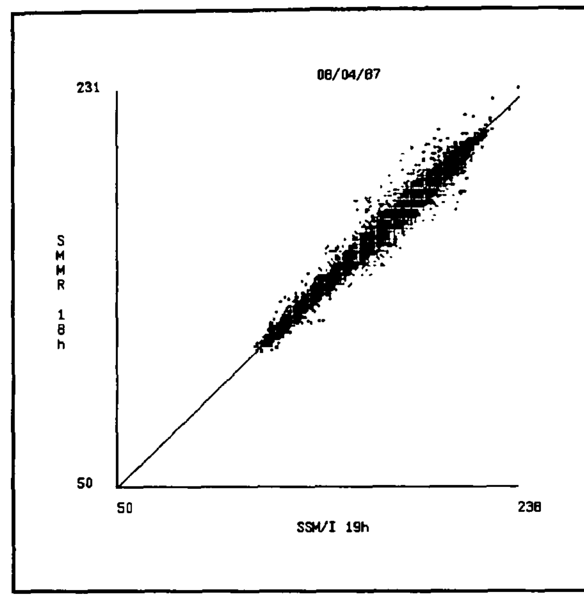
50
275
SSM/I 19v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50
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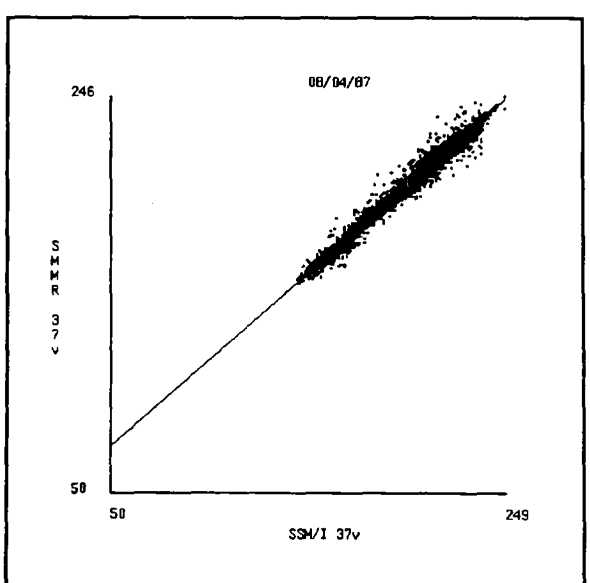
SSM/I 19h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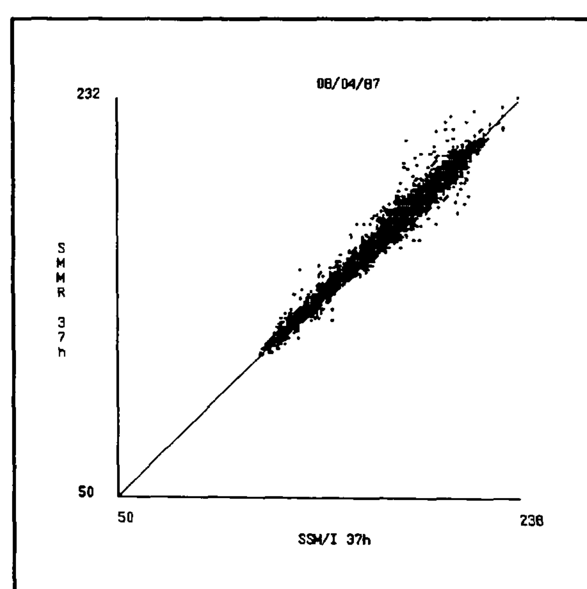
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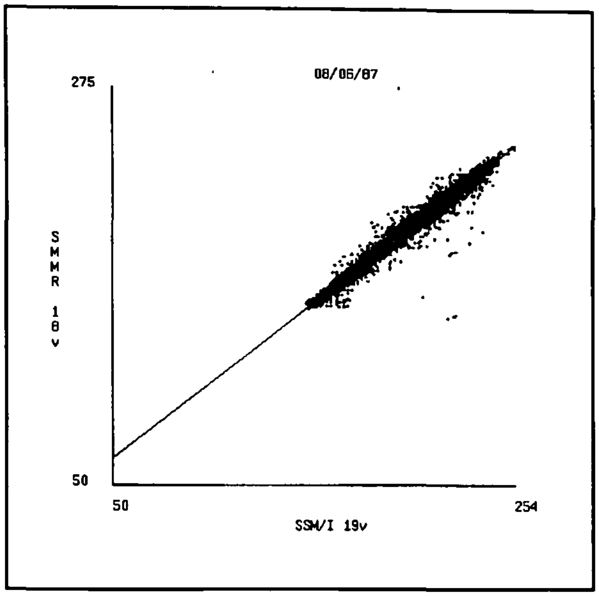
SSM/I 37h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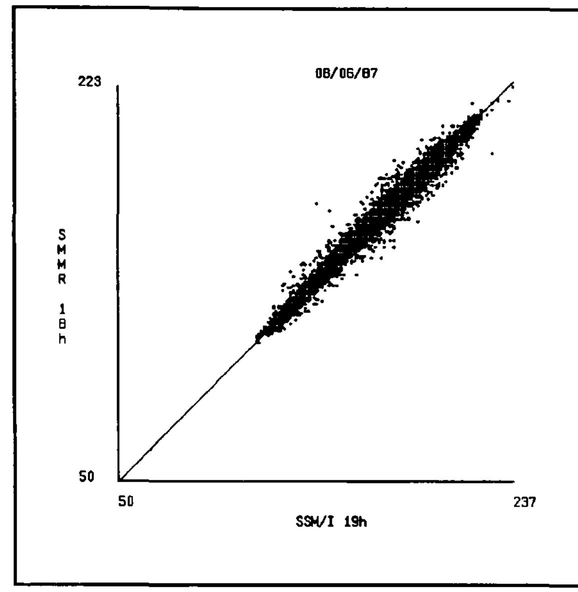
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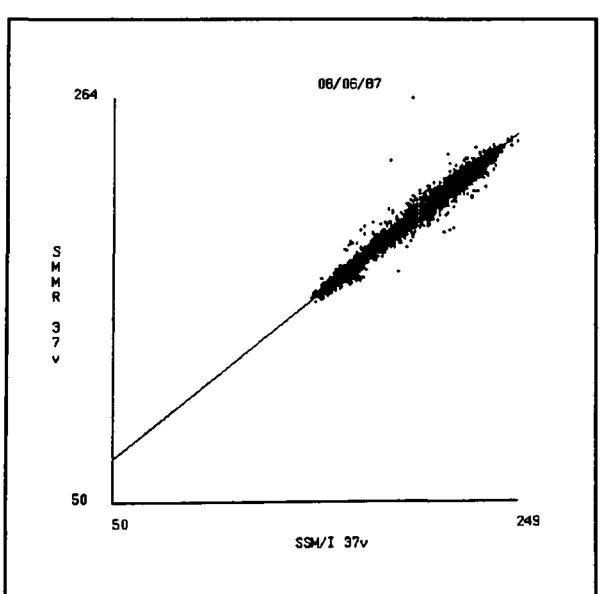
SSM/I 19h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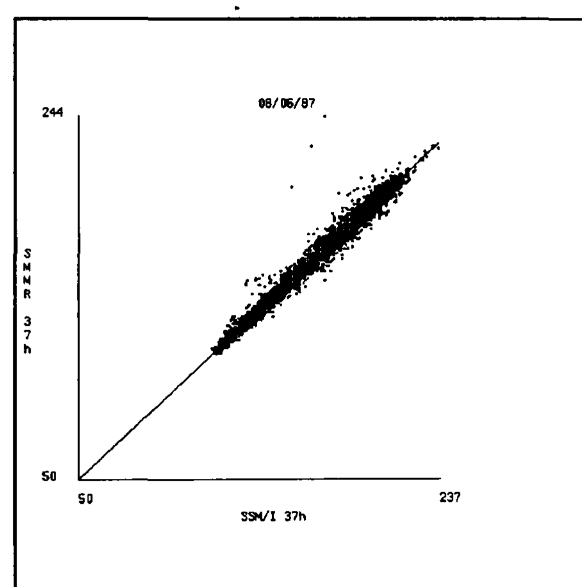
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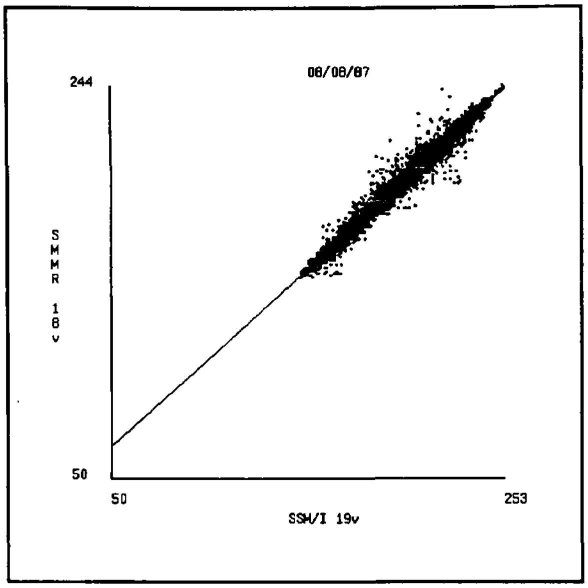
SSM/I 37h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SMMR 18v
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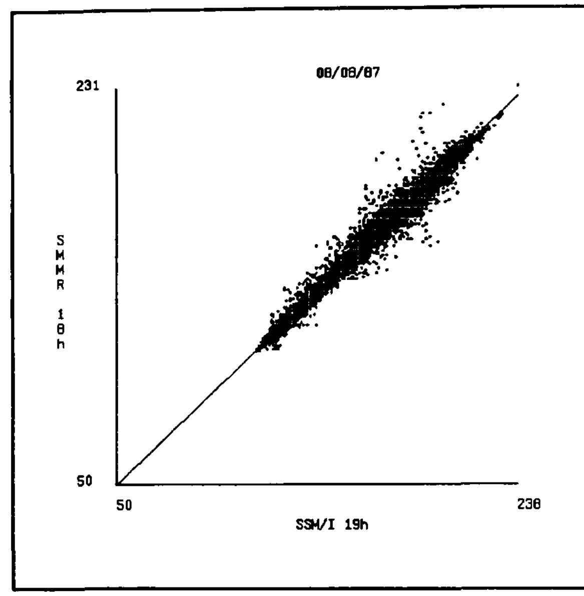
SSM/I 19v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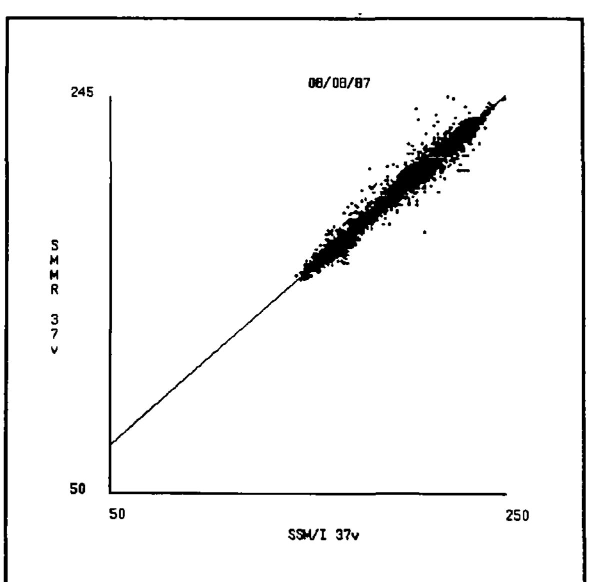
SSM/I 19h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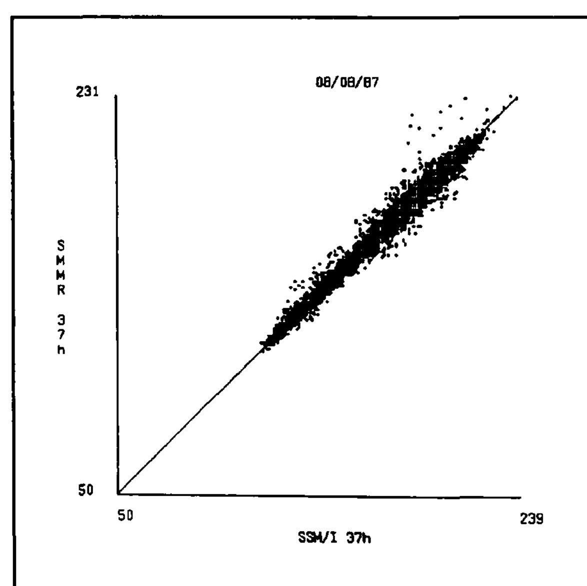
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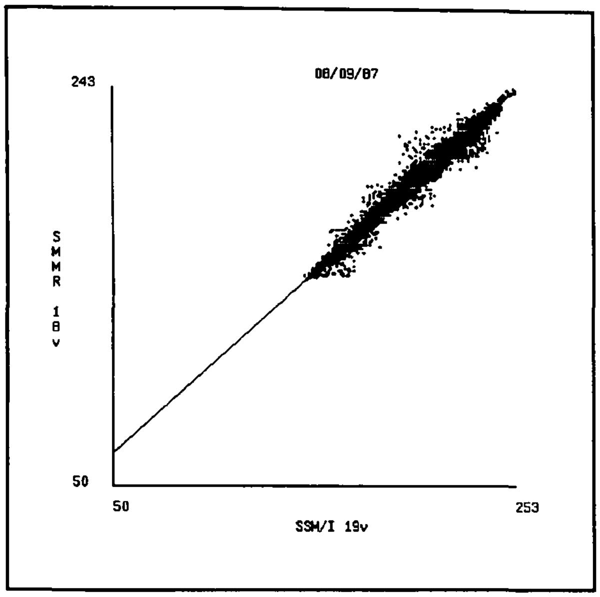
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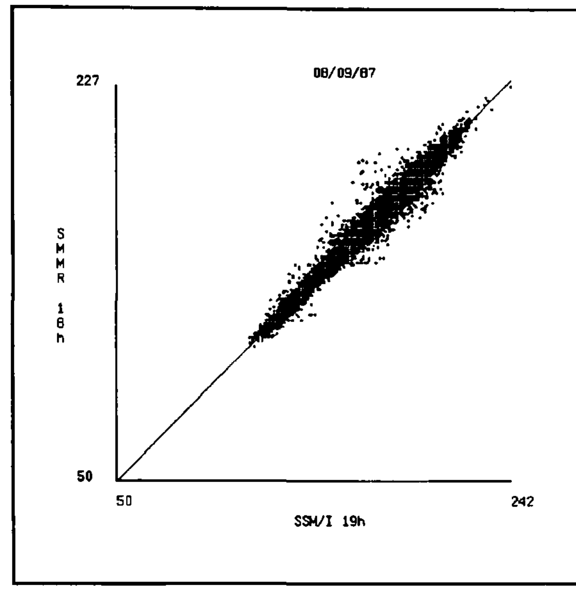
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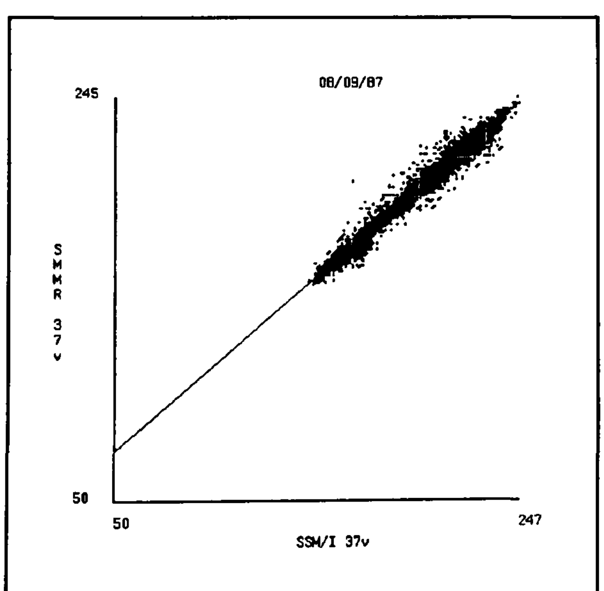
SSM/I 19h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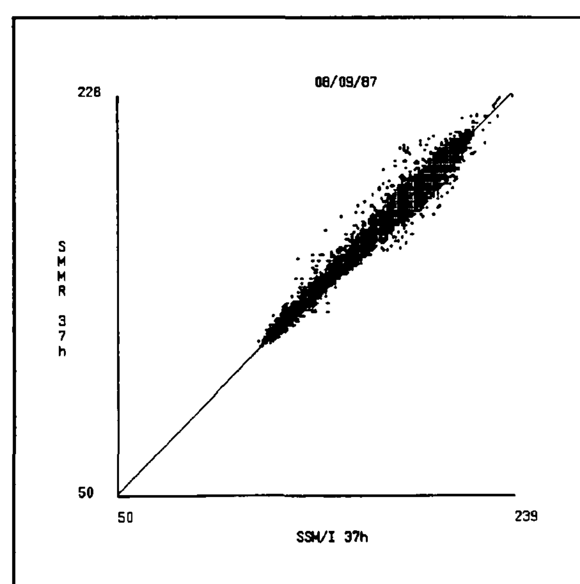
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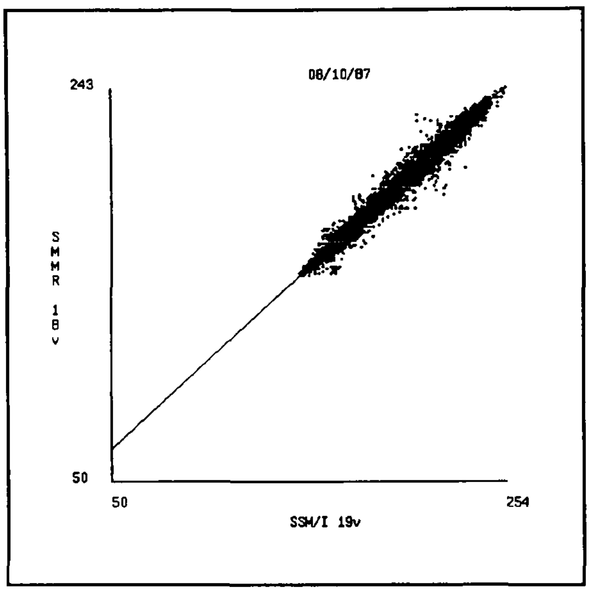
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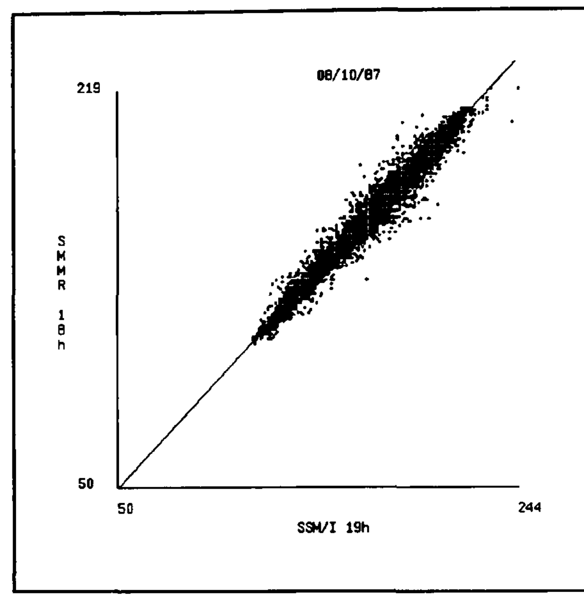
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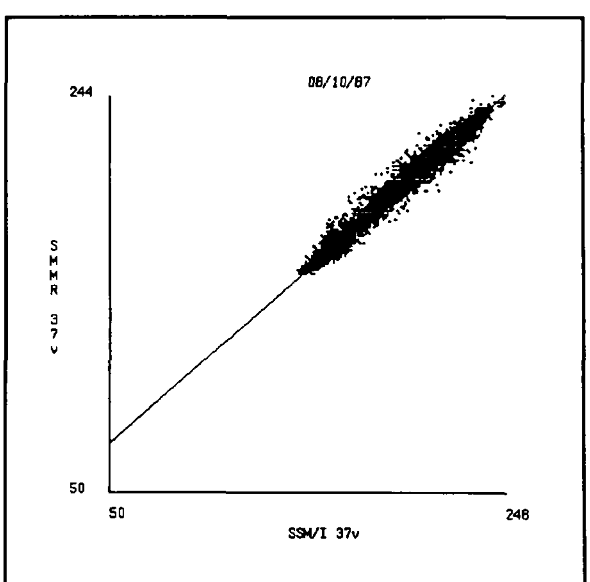
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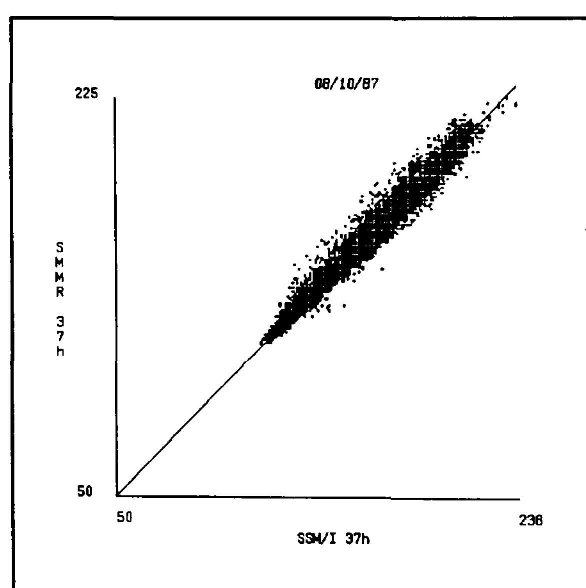
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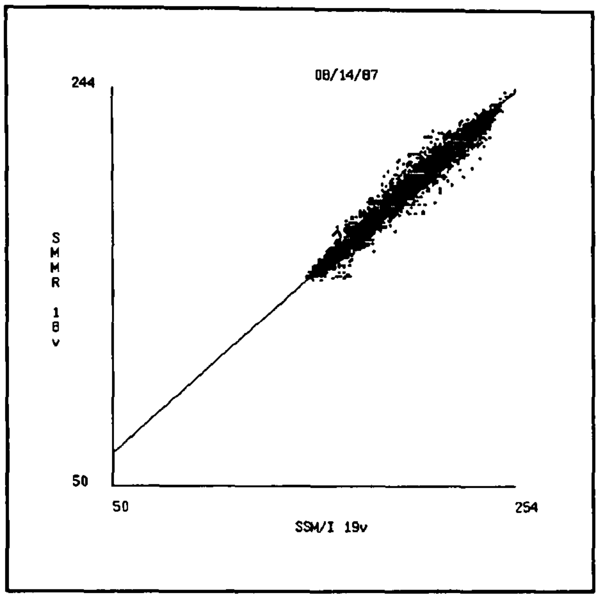
SSM/I 37h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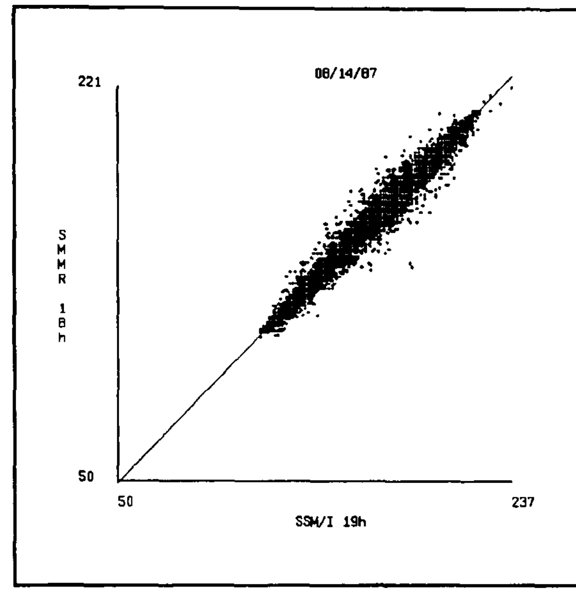
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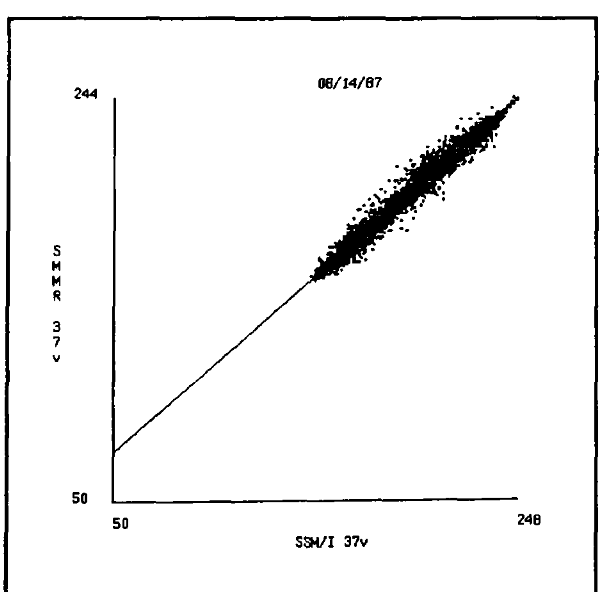
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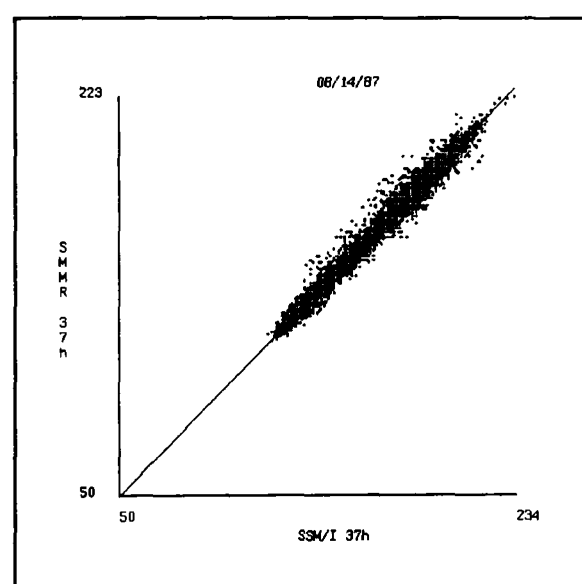
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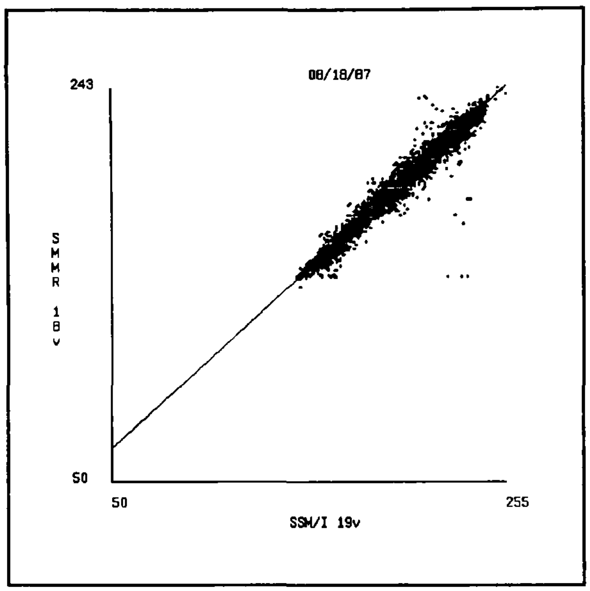
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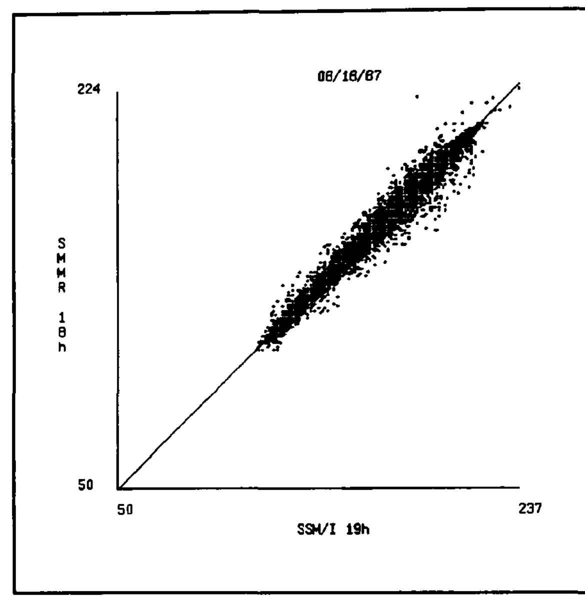
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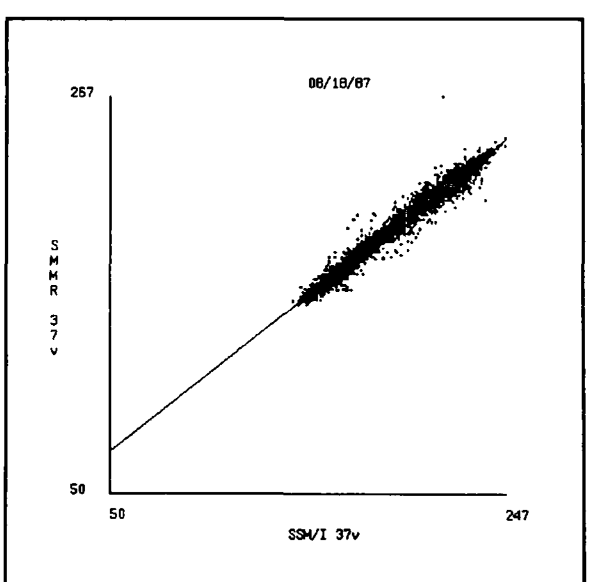
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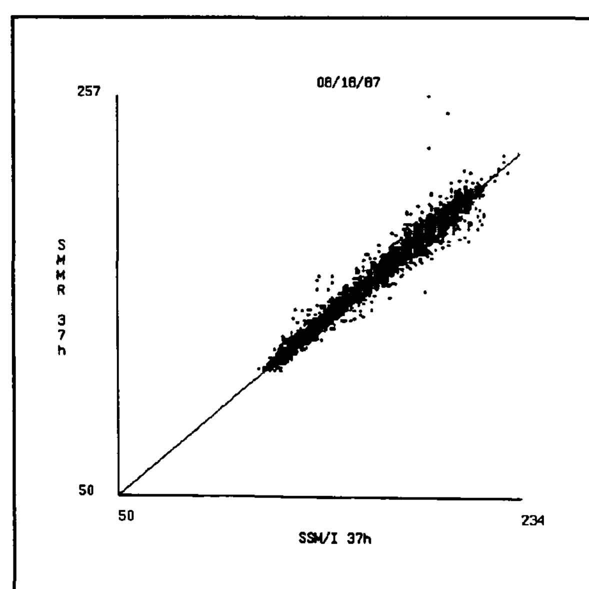
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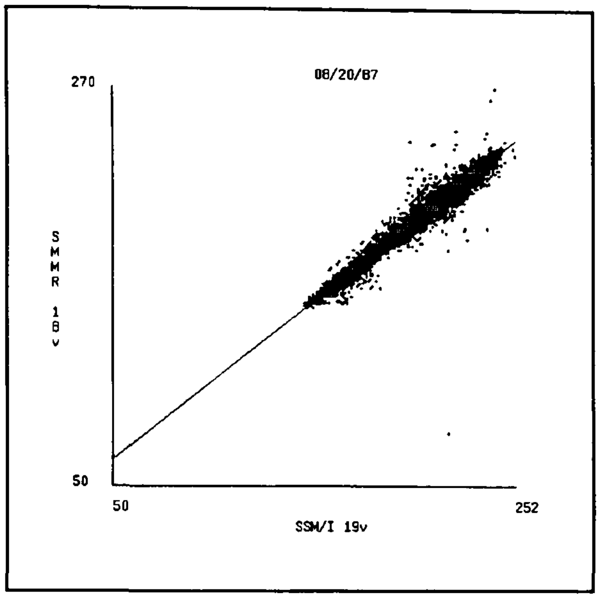
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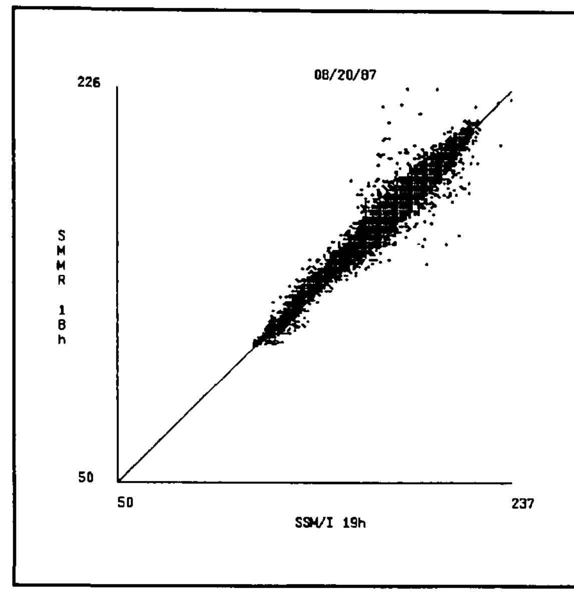
SSM/I 19v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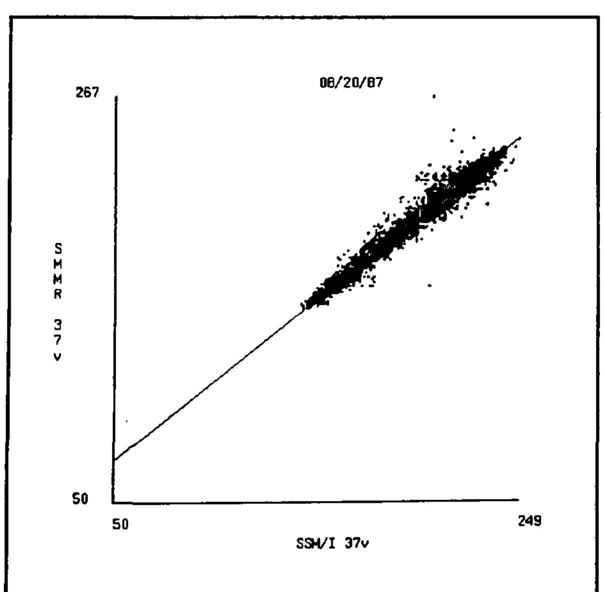
SSM/I 19h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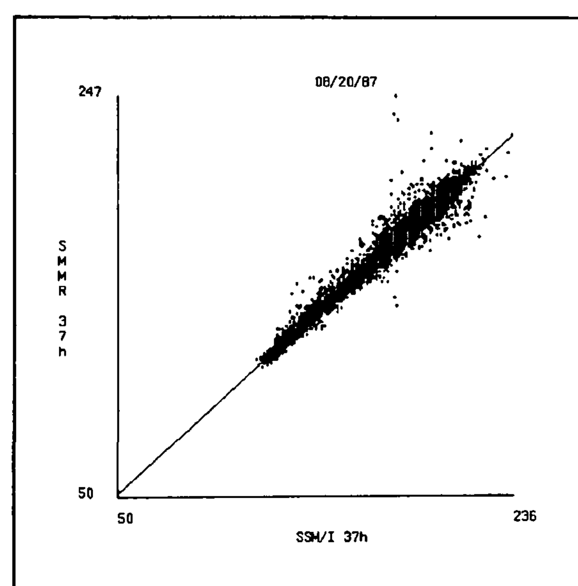
SSM/I 37v


08/20/87
247
S M M R 37 h
50
50
236
SSM/I 37h

Appendix 2: Regression coefficients, standard deviations and correlation coefficients for the SMMR and SSMI overlap period

CHANNELS 19v/18v

Date: 07/11/87
Julian Date: 192
Equation: Smmr=0.868006*Ssmi+(22.126473)
Std. Dev. of g : 0.000751
Std. Dev. of dc: 0.155132
Correlation Coefficient: 0.992879

Date: 07/13/87
Julian Date: 194
Equation: Smmr=0.869618*Ssmi+(21.875949)
Std. Dev. of g : 0.000805
Std. Dev. of dc: 0.166162
Correlation Coefficient: 0.991893

Date: 07/14/87
Julian Date: 195
Equation: Smmr=0.865755*Ssmi+(22.713962)
Std. Dev. of g : 0.000864
Std. Dev. of dc: 0.178369
Correlation Coefficient: 0.990727

Date: 07/17/87
Julian Date: 198
Equation: Smmr=0.866251*Ssmi+(22.609591)
Std. Dev. of g : 0.000817
Std. Dev. of dc: 0.168821
Correlation Coefficient: 0.991574

Date: 07/19/87
Julian Date: 200
Equation: Smmr=0.874235*Ssmi+(21.107558)
Std. Dev. of g : 0.000849
Std. Dev. of dc: 0.175387
Correlation Coefficient: 0.991083

Date: 07/21/87
Julian Date: 202
Equation: Smmr=0.872341*Ssmi+(21.434023)
Std. Dev. of g : 0.000875
Std. Dev. of dc: 0.179933
Correlation Coefficient: 0.991737

Date: 07/23/87
Julian Date: 204
Equation: Smmr=0.870847*Ssmi+(21.657953)
Std. Dev. of g : 0.000788
Std. Dev. of dc: 0.163167
Correlation Coefficient: 0.992207

Date: 07/25/87
Julian Date: 206
Equation: Smmr=0.876189*Ssmi+(20.573244)
Std. Dev. of g : 0.000735
Std. Dev. of dc: 0.151854
Correlation Coefficient: 0.993287

(continued)

CHANNELS 19v/18v (continued)

Date: 07/27/87
Julian Date: 208
Equation: Smmr=0.872436*Ssmi+(21.287238)
Std. Dev. of g : 0.000745
Std. Dev. of dc: 0.154024
Correlation Coefficient: 0.993050

Date: 07/29/87
Julian Date: 210
Equation: Smmr=0.871899*Ssmi+(21.563166)
Std. Dev. of g : 0.000807
Std. Dev. of dc: 0.166594
Correlation Coefficient: 0.991840

Date: 07/31/87
Julian Date: 212
Equation: Smmr=0.869214*Ssmi+(22.065195)
Std. Dev. of g : 0.000782
Std. Dev. of dc: 0.161219
Correlation Coefficient: 0.992309

Date: 08/02/87
Julian Date: 214
Equation: Smmr=0.871829*Ssmi+(21.641341)
Std. Dev. of g : 0.000774
Std. Dev. of dc: 0.159368
Correlation Coefficient: 0.992510

Date: 08/04/87
Julian Date: 216
Equation: Smmr=0.871645*Ssmi+(21.680726)
Std. Dev. of g : 0.000761
Std. Dev. of dc: 0.156499
Correlation Coefficient: 0.992751

Date: 08/06/87
Julian Date: 218
Equation: Smmr=0.871613*Ssmi+(21.789630)
Std. Dev. of g : 0.000886
Std. Dev. of dc: 0.181981
Correlation Coefficient: 0.990210

Date: 08/08/87
Julian Date: 220
Equation: Smmr=0.869119*Ssmi+(22.357432)
Std. Dev. of g : 0.000796
Std. Dev. of dc: 0.163336
Correlation Coefficient: 0.992026

Date: 08/09/87
Julian Date: 221
Equation: Smmr=0.866383*Ssmi+(22.718934)
Std. Dev. of g : 0.000827
Std. Dev. of dc: 0.169607
Correlation Coefficient: 0.991377

Date: 08/10/87
Julian Date: 222
Equation: Smmr=0.869072*Ssmi+(22.538849)
Std. Dev. of g : 0.000839
Std. Dev. of dc: 0.171770
Correlation Coefficient: 0.991176

Date: 08/14/87
Julian Date: 226
Equation: Smmr=0.868945*Ssmi+(22.381813)
Std. Dev. of g : 0.000818
Std. Dev. of dc: 0.167492
Correlation Coefficient: 0.991600

Date: 08/18/87
Julian Date: 230
Equation: Smmr=0.866296*Ssmi+(22.985748)
Std. Dev. of g : 0.000905
Std. Dev. of dc: 0.185069
Correlation Coefficient: 0.989663

Date: 08/20/87
Julian Date: 232
Equation: Smmr=0.873380*Ssmi+(21.386583)
Std. Dev. of g : 0.001093
Std. Dev. of dc: 0.223508
Correlation Coefficient: 0.986778

Date: 07/11/87
Julian Date: 192
Equation: Smmr=0.942653*Ssmi+(1.778075)
Std. Dev. of g : 0.000809
Std. Dev. of dc: 0.139088
Correlation Coefficient: 0.992966

Date: 07/13/87
Julian Date: 194
Equation: Smmr=0.939942*Ssmi+(2.325736)
Std. Dev. of g : 0.000884
Std. Dev. of dc: 0.151949
Correlation Coefficient: 0.991606

Date: 07/14/87
Julian Date: 195
Equation: Smmr=0.929905*Ssmi+(4.285499)
Std. Dev. of g : 0.000979
Std. Dev. of dc: 0.168003
Correlation Coefficient: 0.989684

Date: 07/17/87
Julian Date: 198
Equation: Smmr=0.939925*Ssmi+(2.566501)
Std. Dev. of g : 0.000877
Std. Dev. of dc: 0.150847
Correlation Coefficient: 0.991733

Date: 07/19/87
Julian Date: 200
Equation: Smmr=0.940096*Ssmi+(2.652004)
Std. Dev. of g : 0.000851
Std. Dev. of dc: 0.146326
Correlation Coefficient: 0.992224

Date: 07/21/87
Julian Date: 202
Equation: Smmr=0.936710*Ssmi+(2.983378)
Std. Dev. of g : 0.000899
Std. Dev. of dc: 0.153843
Correlation Coefficient: 0.992407

Date: 07/23/87
Julian Date: 204
Equation: Smmr=0.940608*Ssmi+(2.428030)
Std. Dev. of g : 0.000796
Std. Dev. of dc: 0.136910
Correlation Coefficient: 0.993162

Date: 07/25/87
Julian Date: 206
Equation: Smmr=0.944113*Ssmi+(1.856899)
Std. Dev. of g : 0.000783
Std. Dev. of dc: 0.134263
Correlation Coefficient: 0.993424

(continued)

Date: 07/27/87
Julian Date: 208
Equation: Smmr=0.939194*Ssmi+(2.591795)
Std. Dev. of g : 0.000773
Std. Dev. of dc: 0.132623
Correlation Coefficient: 0.993536

Date: 07/29/87
Julian Date: 210
Equation: Smmr=0.943190*Ssmi+(2.022759)
Std. Dev. of g : 0.000808
Std. Dev. of dc: 0.138606
Correlation Coefficient: 0.992992

Date: 07/31/87
Julian Date: 212
Equation: Smmr=0.934719*Ssmi+(3.339743)
Std. Dev. of g : 0.000836
Std. Dev. of dc: 0.142981
Correlation Coefficient: 0.992390

Date: 08/02/87
Julian Date: 214
Equation: Smmr=0.941118*Ssmi+(2.411967)
Std. Dev. of g : 0.000832
Std. Dev. of dc: 0.142426
Correlation Coefficient: 0.992544

Date: 08/04/87
Julian Date: 216
Equation: Smmr=0.942238*Ssmi+(2.235417)
Std. Dev. of g : 0.000820
Std. Dev. of dc: 0.140058
Correlation Coefficient: 0.992781

Date: 08/06/87
Julian Date: 218
Equation: Smmr=0.939105*Ssmi+(2.787673)
Std. Dev. of g : 0.000807
Std. Dev. of dc: 0.137930
Correlation Coefficient: 0.992961

Date: 08/08/87
Julian Date: 220
Equation: Smmr=0.940542*Ssmi+(2.581242)
Std. Dev. of g : 0.000875
Std. Dev. of dc: 0.149330
Correlation Coefficient: 0.991771

Date: 08/09/87
Julian Date: 221
Equation: Smmr=0.937214*Ssmi+(2.822305)
Std. Dev. of g : 0.000910
Std. Dev. of dc: 0.155216
Correlation Coefficient: 0.991077

(continued)

Date: 08/10/87
Julian Date: 222
Equation: Smmr=0.941310*Ssmi+(2.569920)
Std. Dev. of g : 0.000943
Std. Dev. of dc: 0.160597
Correlation Coefficient: 0.990482

Date: 08/14/87
Julian Date: 226
Equation: Smmr=0.943465*Ssmi+(2.092288)
Std. Dev. of g : 0.000920
Std. Dev. of dc: 0.156555
Correlation Coefficient: 0.990953

Date: 08/18/87
Julian Date: 230
Equation: Smmr=0.943057*Ssmi+(2.537536)
Std. Dev. of g : 0.000868
Std. Dev. of dc: 0.147134
Correlation Coefficient: 0.991931

Date: 08/20/87
Julian Date: 232
Equation: Smmr=0.934945*Ssmi+(3.465172)
Std. Dev. of g : 0.001165
Std. Dev. of dc: 0.198583
Correlation Coefficient: 0.986834

Date: 07/11/87
Julian Date: 192
Equation: Smmr=0.862724*Ssmi+(29.742364)
Std. Dev. of g : 0.000630
Std. Dev. of dc: 0.126468
Correlation Coefficient: 0.994873

Date: 07/13/87
Julian Date: 194
Equation: Smmr=0.863181*Ssmi+(29.919394)
Std. Dev. of g : 0.000697
Std. Dev. of dc: 0.139674
Correlation Coefficient: 0.993764

Date: 07/14/87
Julian Date: 195
Equation: Smmr=0.850237*Ssmi+(32.703826)
Std. Dev. of g : 0.000829
Std. Dev. of dc: 0.166093
Correlation Coefficient: 0.991094

Date: 07/17/87
Julian Date: 198
Equation: Smmr=0.860023*Ssmi+(30.368848)
Std. Dev. of g : 0.000671
Std. Dev. of dc: 0.135040
Correlation Coefficient: 0.994174

Date: 07/19/87
Julian Date: 200
Equation: Smmr=0.860205*Ssmi+(30.613109)
Std. Dev. of g : 0.000664
Std. Dev. of dc: 0.133625
Correlation Coefficient: 0.994308

Date: 07/21/87
Julian Date: 202
Equation: Smmr=0.863222*Ssmi+(29.854093)
Std. Dev. of g : 0.000727
Std. Dev. of dc: 0.145577
Correlation Coefficient: 0.994111

Date: 07/23/87
Julian Date: 204
Equation: Smmr=0.862117*Ssmi+(29.937989)
Std. Dev. of g : 0.000659
Std. Dev. of dc: 0.133239
Correlation Coefficient: 0.994384

Date: 07/25/87
Julian Date: 206
Equation: Smmr=0.866965*Ssmi+(29.042883)
Std. Dev. of g : 0.000627
Std. Dev. of dc: 0.126344
Correlation Coefficient: 0.994966

(continued)

Date: 07/27/87
Julian Date: 208
Equation: Smmr=0.859274*Ssmi+(30.330078)
Std. Dev. of g : 0.000596
Std. Dev. of dc: 0.119923
Correlation Coefficient: 0.995371

Date: 07/29/87
Julian Date: 210
Equation: Smmr=0.865539*Ssmi+(29.331982)
Std. Dev. of g : 0.000639
Std. Dev. of dc: 0.128247
Correlation Coefficient: 0.994754

Date: 07/31/87
Julian Date: 212
Equation: Smmr=0.860300*Ssmi+(30.399226)
Std. Dev. of g : 0.000674
Std. Dev. of dc: 0.134770
Correlation Coefficient: 0.994117

Date: 08/02/87
Julian Date: 214
Equation: Smmr=0.861638*Ssmi+(30.026945)
Std. Dev. of g : 0.000611
Std. Dev. of dc: 0.122157
Correlation Coefficient: 0.995167

Date: 08/04/87
Julian Date: 216
Equation: Smmr=0.863790*Ssmi+(29.624217)
Std. Dev. of g : 0.000594
Std. Dev. of dc: 0.118354
Correlation Coefficient: 0.995459

Date: 08/06/87
Julian Date: 218
Equation: Smmr=0.864301*Ssmi+(29.672895)
Std. Dev. of g : 0.000646
Std. Dev. of dc: 0.128225
Correlation Coefficient: 0.994649

Date: 08/08/87
Julian Date: 220
Equation: Smmr=0.860871*Ssmi+(30.317367)
Std. Dev. of g : 0.000653
Std. Dev. of dc: 0.129265
Correlation Coefficient: 0.994485

Date: 08/09/87
Julian Date: 221
Equation: Smmr=0.855696*Ssmi+(30.991045)
Std. Dev. of g : 0.000705
Std. Dev. of dc: 0.139425
Correlation Coefficient: 0.993522

(continued)

Date: 08/10/87
Julian Date: 222
Equation: Smmr=0.860600*Ssmi+(30.857812)
Std. Dev. of g : 0.000824
Std. Dev. of dc: 0.162550
Correlation Coefficient: 0.991277

Date: 08/14/87
Julian Date: 226
Equation: Smmr=0.859525*Ssmi+(30.597545)
Std. Dev. of g : 0.000674
Std. Dev. of dc: 0.133266
Correlation Coefficient: 0.994106

Date: 08/18/87
Julian Date: 230
Equation: Smmr=0.861564*Ssmi+(30.152191)
Std. Dev. of g : 0.000663
Std. Dev. of dc: 0.130816
Correlation Coefficient: 0.994312

Date: 08/20/87
Julian Date: 232
Equation: Smmr=0.866207*Ssmi+(29.176564)
Std. Dev. of g : 0.000833
Std. Dev. of dc: 0.164623
Correlation Coefficient: 0.992032

Date: 07/11/87
Julian Date: 192
Equation: Smmr=0.958958*Ssmi+(1.884326)
Std. Dev. of g : 0.000700
Std. Dev. of dc: 0.121722
Correlation Coefficient: 0.994873

Date: 07/13/87
Julian Date: 194
Equation: Smmr=0.956224*Ssmi+(2.494463)
Std. Dev. of g : 0.000776
Std. Dev. of dc: 0.134756
Correlation Coefficient: 0.993707

Date: 07/14/87
Julian Date: 195
Equation: Smmr=0.936502*Ssmi+(6.434096)
Std. Dev. of g : 0.000961
Std. Dev. of dc: 0.166910
Correlation Coefficient: 0.990136

Date: 07/17/87
Julian Date: 198
Equation: Smmr=0.955418*Ssmi+(2.663708)
Std. Dev. of g : 0.000720
Std. Dev. of dc: 0.125541
Correlation Coefficient: 0.994566

Date: 07/19/87
Julian Date: 200
Equation: Smmr=0.952629*Ssmi+(3.403744)
Std. Dev. of g : 0.000766
Std. Dev. of dc: 0.133739
Correlation Coefficient: 0.993825

Date: 07/21/87
Julian Date: 202
Equation: Smmr=0.953107*Ssmi+(2.909900)
Std. Dev. of g : 0.000836
Std. Dev. of dc: 0.144876
Correlation Coefficient: 0.993627

Date: 07/23/87
Julian Date: 204
Equation: Smmr=0.953903*Ssmi+(2.950334)
Std. Dev. of g : 0.000712
Std. Dev. of dc: 0.124502
Correlation Coefficient: 0.994649

Date: 07/25/87
Julian Date: 206
Equation: Smmr=0.958484*Ssmi+(2.234629)
Std. Dev. of g : 0.000669
Std. Dev. of dc: 0.116511
Correlation Coefficient: 0.995305

(continued)

Date: 07/27/87
Julian Date: 208
Equation: Smmr=0.950241*Ssmi+(3.310646)
Std. Dev. of g : 0.000669
Std. Dev. of dc: 0.116561
Correlation Coefficient: 0.995224

Date: 07/29/87
Julian Date: 210
Equation: Smmr=0.960253*Ssmi+(1.739535)
Std. Dev. of g : 0.000689
Std. Dev. of dc: 0.119861
Correlation Coefficient: 0.995038

Date: 07/31/87
Julian Date: 212
Equation: Smmr=0.952371*Ssmi+(3.080021)
Std. Dev. of g : 0.000780
Std. Dev. of dc: 0.134903
Correlation Coefficient: 0.993575

Date: 08/02/87
Julian Date: 214
Equation: Smmr=0.953830*Ssmi+(2.790900)
Std. Dev. of g : 0.000685
Std. Dev. of dc: 0.118447
Correlation Coefficient: 0.995051

Date: 08/04/87
Julian Date: 216
Equation: Smmr=0.959172*Ssmi+(1.922468)
Std. Dev. of g : 0.000706
Std. Dev. of dc: 0.121767
Correlation Coefficient: 0.994796

Date: 08/06/87
Julian Date: 218
Equation: Smmr=0.959725*Ssmi+(1.863408)
Std. Dev. of g : 0.000742
Std. Dev. of dc: 0.127830
Correlation Coefficient: 0.994267

Date: 08/08/87
Julian Date: 220
Equation: Smmr=0.953547*Ssmi+(2.797268)
Std. Dev. of g : 0.000746
Std. Dev. of dc: 0.128207
Correlation Coefficient: 0.994127

Date: 08/09/87
Julian Date: 221
Equation: Smmr=0.946348*Ssmi+(3.553627)
Std. Dev. of g : 0.000842
Std. Dev. of dc: 0.144456
Correlation Coefficient: 0.992455

(continued)

Date: 08/10/87
Julian Date: 222
Equation: Smmr=0.955400*Ssmi+(2.828288)
Std. Dev. of g : 0.001039
Std. Dev. of dc: 0.177776
Correlation Coefficient: 0.988770

Date: 08/14/87
Julian Date: 226
Equation: Smmr=0.960536*Ssmi+(1.644079)
Std. Dev. of g : 0.000747
Std. Dev. of dc: 0.127861
Correlation Coefficient: 0.994197

Date: 08/18/87
Julian Date: 230
Equation: Smmr=0.958262*Ssmi+(2.236586)
Std. Dev. of g : 0.000758
Std. Dev. of dc: 0.129311
Correlation Coefficient: 0.993987

Date: 08/20/87
Julian Date: 232
Equation: Smmr=0.945384*Ssmi+(4.219609)
Std. Dev. of g : 0.001022
Std. Dev. of dc: 0.175156
Correlation Coefficient: 0.989947

Appendix 3: Computer code used to perform the linear regression analysis

```
#include <math.h>
#include <stdio.h>
#include <stdlib.h>

#define numofiles 80

FILE                *ssmi, *smmr, *smask, *filelist, *fp4;
unsigned short int  *Smaskdat,*Ssmidat,*Smmrdat,*Ssmidat3,*Smmrdat3,*Ssmigraph,*Smmrgraph;
float               Ssmifloat[104912],Smmrfloat[104912],Ssmishort[104912],Smmrshort[104912];
char                *File1,*File2;
char                Filename1[20],Filename2[20],Filename3[20],Filename4[20],Filename5[20];

/**********************************************************************************/
/*                                                                                */
/*  PROGRAM REGRESS.C - Performs a linear regression analysis on SSM/I and SMMR passive  */
/*                      microwave data.                                           */
/*                                                                                */
/*  INPUTS - all input files should be loacted in the same directory as the executeable  */
/*                                                                                */
/*  list.all - ASCII file containing pairs of SSM/I and SMMR input files          */
/*                           This file has the following format:                  */
/*                                  870711.19v 870711.s3                          */
/*                                  870711.19h 870711.s4                          */
/*                                  870711.37v 870711.s5                          */
/*                                  870711.37h 870711.s6                          */
/*                                  870713.19v 870713.s3                          */
/*                                  870713.19h 870713.s4                          */
/*                                                                                */
/*  Data files -  The binary SSM/I and SMMR input files have the nomenclature     */
/*       870711.19v where:                                                        */
/*                                                                                */
/*       year    - digits 1 and 2                                                 */
/*       month   - digits 3 and 4                                                 */
/*       day     - digits 5 and 6                                                 */
/*       channel - located after the period.                                      */
/*                                                                                */
/*       Channel codes for SSM/I are:        Channel codes for SMMR are:          */
/*          19v - 19 MHz vertical               s3 - 19 MHz vertical              */
/*          19h - 19 MHZ horizontal             s4 - 19 MHz horizontal            */
/*          37v - 37 MHZ vertical               s5 - 37 MHz vertical              */
/*          37h - 37 MHZ horizontal             s6 - 37 MHz horizontal            */
/*                                                                                */
/*  s3bmask - binary file containing values of 1 over the Antarctic Sheet         */
/*            and values of 0 elsewhere                                           */
/*                                                                                */
/*                                                                                */
/*                                                                                */
/*                                                                                */
/* OUTPUT - all output files                                                      */
/*                                                                                */
/*   table.all - ASCII file containing the comparison equations and error analysis  */
/*                                                                                */
/*   xxxxxx.graph - binary file containing data to be used by the plotting program  */
/*                                                                                */
/*   xxxxxx.output - binary file which is byte swapped to be used on the IBM PC   */
/*                                                                                */
/*   xxxxxx.badata - ASCII file containing a list of all Tb > 300.0               */
/*                                                                                */
/*                                                                                */
/**********************************************************************************/
```

```
/*****************************************************************************************/
/*   Procedure which opens the file containing the names of the files to be compared     */
/*****************************************************************************************/

void open_list_file()

{
   if((filelist = fopen("list.all","r")) == NULL)
       {
        printf("\nError opening list file for input");
        exit(1);
       }
}

/*****************************************************************************************/
/*    Procedure which:                                                                   */
/*                 1) Opens the ocean mask file                                          */
/*                 2) Allocates memory for the arrays:                                   */
/*                        Smaskdat,Ssmidat,Smmrdat,Ssmi3dat,Smmr3dat,Ssmigraph,Smmrgraph */
/*****************************************************************************************/

void initialize ()

{
   if((smask = fopen("s3bmask.dat","rb")) == NULL)
       {
         printf("\nError opening smask file for input");
         exit(1);
       }

  if ((Smaskdat = (unsigned short int *) malloc(104912*sizeof(short int))) == NULL)
     printf ("\nError allocating storage for smask data");

  if ((Ssmidat = (unsigned short int *) malloc(104912*sizeof(short int))) == NULL)
     printf ("\nError allocating storage for ssmi data");
  if ((Smmrdat = (unsigned short int *) malloc(104912*sizeof(short int))) == NULL)
     printf ("\nError allocating storage for smmr data");

  if ((Ssmidat3 = (unsigned short int *) malloc(104912*sizeof(short int))) == NULL)
     printf ("\nError allocating storage for ssmi3 data");
  if ((Smmrdat3 = (unsigned short int *) malloc(104912*sizeof(short int))) == NULL)
     printf ("\nError allocating storage for smmr3 data");

 if ((Ssmigraph = (unsigned short int *) malloc(104912*sizeof(short int))) == NULL)
     printf ("\nError allocating storage for ssmigraph data");
  if ((Smmrgraph = (unsigned short int *) malloc(104912*sizeof(short int))) == NULL)
     printf ("\nError allocating storage for smmrgraph data");

  if ((File1 = (char *) malloc(15*sizeof(char))) == NULL)
     printf ("\nError allocating storage for File1");
  if ((File2 = (char *) malloc(15*sizeof(char))) == NULL)
     printf ("\nError allocating storage for File2");
}
```

```
/*********************************************************************************************/
/*    Procedure which:                                                                       */
/*              1) Reads the file names from the list file                                   */
/*              2) Creates the file names for the output files                               */
/*********************************************************************************************/

void read_list_file ()

{
    fread(File1,sizeof(char),11,filelist);          /* reads the name of the ssmi file       */
    strcpy(&File1[10],"");                          /* deletes the space between filenames   */
    fread(File2,sizeof(char),10,filelist);          /* reads the name of the smmr file       */
    strcpy(&File2[9],"");                           /* deletes the carraige return           */

    printf("\nFiles: ");printf("\n");               /* writes to the screen the names of     */
    printf("Ssmi:   ");puts(File1);                 /* the files that were read              */
    printf("Smmr: ");puts(File2);

    fprintf(fp4, " %s",File1 );
    fprintf(fp4, " %s: \n",File2 );

    strcpy(Filename1,File1);                        /* creates the names of the files that   */
    strcpy(&Filename1[10],".output");               /* can be used with ibm pc's             */
    strcpy(Filename2,File2);
    strcpy(&Filename2[9],".output");

    strcpy(Filename3,File1);                        /* creates the name of the file to be    */
    strcpy(&Filename3[10],".graph");                /* used by the plotting program          */

    strcpy(Filename4,File1);                        /* creates the name of the files that    */
    strcpy(&Filename4[10],".badata");               /* report bad Tb values                  */
    strcpy(Filename5,File2);
    strcpy(&Filename5[9],".badata");
```

```
/**********************************************************************************************/
/*   Procedure which opens the binary SSM/I file and the binary SMMR file to be compared    */
/**********************************************************************************************/

void open_data_files()

{
  if ((ssmi = fopen(File1,"rb")) == NULL)
    {
      printf ("\nError opening ssmi file for input");
      exit (1);
    }

  if ((smmr = fopen(File2,"rb")) == NULL)
    {
      printf ("\nError opening smmr file for input");
      exit (1);
    }
}




/**********************************************************************************************/
/*   Procedure which reads the data from the input files                                    */
/**********************************************************************************************/

void read_data_files ()

{
  char ch [104912];
  int i;

  fread(Ssmidat,sizeof(short int),104912,ssmi);
  fread(Smmrdat,sizeof(short int),104912,smmr);
  fread(ch,sizeof(char),104912,smask);
  for (i=0; i<104912; i++)
    {
    Smaskdat [i] = (short int) ch [i];
    }
}
```

```
/*******************************************************************************/
/*                                                                             */
/*    Procedure which:                                                         */
/*              1) Byte swaps the SSM/I and SMMR files                         */
/*              2) Multiplies the SSM/I and SMMR files by the ocean mask       */
/*              3) Divides the Tb values in the SSM/I file by 10               */
/*******************************************************************************/

void process_data_files()

{
  FILE *fp1,*fp2;
  int i;
  unsigned short int left,right,left2,right2;

  fp1 = fopen(Filename1,"wb");
  fp2 = fopen(Filename2,"wb");

  for (i=0; i<104912; i++)                      /* loop to put values into the arrays    */
    {

      left = right = Ssmidat[i];
      left = left << 8;                         /* byte swaps the 16 bit data to be      */
      right = right >> 8;                       /* used on the SUN SPARC2                */

      Ssmidat[i] = ((left | right))*Smaskdat[i];   /* multiply by the ocean mask,        */
      Ssmifloat[i] = ((float)Ssmidat[i])/10.0;     /* divide the SSMI data by ten and    */
                                                   /* store as real values               */

      left2 = right2 = ((int)(Ssmifloat[i]+.5));   /* round to integer values and        */
      left2 = left2 << 8;                          /* byte swap back to be output as     */
      right2 = right2 >>8;                         /* xxxxxx.output files so they can be */
      Ssmidat3[i] = (left2 | right2);              /* checked on the IBM 386             */

      left = right = Smmrdat[i];
      left = left << 8;                         /* byte swaps the 16 bit data to be      */
      right = right >> 8;                       /* used on the SUN SPARC2                */

      Smmrdat[i] = (left | right)*Smaskdat[i];     /* multiply by the ocean mask and     */
      Smmrfloat[i] = (float)Smmrdat[i];            /* store as real values               */

      left2 = right2 = ((int)(Smmrfloat[i]+.5));   /* round to integer values and        */
      left2 = left2 << 8;                          /* byte swap back to be output as     */
      right2 = right2 >>8;                         /* xxxxxx.output files so they can be */
      Smmrdat3[i] = (left2 | right2);              /* checked on the IBM 386             */

    }

    fwrite(Ssmidat3, sizeof(unsigned short int), 104912, fp1);
    fwrite(Smmrdat3, sizeof(unsigned short int), 104912, fp2);
    fclose(fp1);
    fclose(fp2);

}
```

```
*****************************************************************************************/
*   Procedure which calculates the least squares fit of SSM/I vs.SMMR                   */
*****************************************************************************************/

void linreg(k)
int *k;

int i, j, npts;
double sumx,sumy,sumx2,sumy2,sumxy,delta,sum,sigma2,sigma_a,sigma_b,temp,a,b,r;
npts=0;sumx=0.0;sumy=0.0;sumx2=0.0;sumy2=0.0;sumxy=0.0;delta=0.0;
sum=0.0; sigma2=0.0; sigma_a=0.0; sigma_b=0.0; temp=0.0; a=0.0; b=0.0;

for (i=0; i< *k; i++)
   {
    npts =npts+1;
    sumx  = sumx+Ssmishort[i];
    sumy  = sumy+Smmrshort[i];
    sumx2 = sumx2+(Ssmishort[i]*Ssmishort[i]);
    sumy2 = sumy2+(Smmrshort[i]*Smmrshort[i]);
    sumxy = sumxy+(Ssmishort[i]*Smmrshort[i]);
   }
 delta=(((float)npts)*sumx2) - (sumx*sumx);
 a=((sumx2*sumy) - (sumx*sumxy))/(delta);         /* calculation of the y intercept       */
 b=((sumxy*((float)npts)) - (sumx*sumy))/(delta); /* calculation of the slope             */

 for (j=0; j<*k; j++)
   {
   temp = Smmrshort[j]-a-b*Ssmishort[j];
   sum = sum+(temp*temp);
   }

 sigma2=(1.0/(npts-2.0))*sum;
 sigma_a=sqrt((sigma2*sumx2)/delta);             /* calculation of the std. dev. of dc    */
 sigma_b=sqrt((sigma2*npts)/delta);              /* calculation of the std. dev. of g     */
 r=((npts*sumxy)-(sumx*sumy))/sqrt(delta*((npts*sumy2)-(sumy*sumy)));
                                                 /* calculation of the correlation coeff.  */

/********************************** Print Results ****************************************/
 fprintf(fp4,"\n");
 fprintf(fp4,"    Equation: ");
 fprintf(fp4,"Smmr=");
 fprintf(fp4,"%f",b);
 fprintf(fp4,"*Ssmi+(");                         /* print the equation, std deviations,   */
 fprintf(fp4,"%f)\n",a);                         /* and correlation coefficient to the    */
 fprintf(fp4,"    Std. Dev. of b: ");            /* output file 'table.all'               */
 fprintf(fp4,"%f\n",sigma_b);
 fprintf(fp4,"    Std. Dev. of a: ");
 fprintf(fp4,"%f\n",sigma_a);
 fprintf(fp4,"    Correlation Coefficient: ");
 fprintf(fp4,"%f\n",r);
 fprintf(fp4,"\n");
 printf("\nThe equation of the least-squares fit to a straight line is:");
 printf("\n ");
 printf("\n             Smmr= %f * Ssmi + %f", b, a);printf("\n ");
 printf("\nThe form of this equation is Smmr= b * Ssmi + a");printf("\n ");
 printf("\n             The standard deviation of a is %f ",sigma_a);
 printf("\n             The standard deviation of b is %f ",sigma_b);
 printf("\n             The linear correlation coefficient is %f ",r);
 printf("\n ");
}
```

```
/**********************************************************************************************/
/*    Procedure which generates the arrays to be input to the plotting program              */
/**********************************************************************************************/

void create_graph_arrays()
{
   FILE *fp3,*Ssmibadata,*Smmrbadata;
   int r;
   fp3=fopen(Filename3,"wb");
   for(r=0; r<104912; r++)
    {
       Ssmigraph[r] = ((int)(Ssmifloat[r]+0.5));
       Smmrgraph[r] = ((int)(Smmrfloat[r]+0.5));
    }
    fwrite(Ssmigraph, sizeof(unsigned short int),104912, fp3);
    fwrite(Smmrgraph, sizeof(unsigned short int),104912, fp3);
    fclose(fp3);
}

/**********************************************************************************************/
/*    Procedure which checks for bad Tb values (ie >300) and                                 */
/*                    writes the values to the xxxxxx.badata files                           */
/**********************************************************************************************/

void check_bad_data()
{
   FILE *Ssmibadata,*Smmrbadata;
   int s;
   Ssmibadata=fopen(Filename4,"w");
   Smmrbadata=fopen(Filename5,"w");
   for (s=0; s<104912; s++)
     {
        if (Ssmifloat[s] > 300.0)
          {
            fprintf(Ssmibadata,"Ssmi[");
            fprintf(Ssmibadata,"%d]: ",s);
            fprintf(Ssmibadata,"%f\n",Ssmifloat[s]);
          }
        if (Smmrfloat[s] > 300.0)
          {
            fprintf(Smmrbadata,"Smmr[");
            fprintf(Smmrbadata,"%d]: ",s);
            fprintf(Smmrbadata,"%f\n",Smmrfloat[s]);
          }
     }
   fclose(Ssmibadata);
   fclose(Smmrbadata);
}
```

```
/*****************************************************************************************/
/*   Function created in order to speed up the linear regression process                 */
/*   This function shortens the Ssmifloat and Smmrfloat arrays by disposing of           */
/*       those elements which are either both zeros or both bad Tb values                */
/*       in the Smmifloat and Smmrfloat arrays                                           */
/*   This function also returns the length of the array to be used be the procedure linreg */
/*****************************************************************************************/

int create_short_arrays()
{
   int m,n;
   n = 0;
   for (m=0; m<104912; m++)
    {
      if((Ssmifloat[m]>1.0) && (Smmrfloat[m]>1.0)&&(Ssmifloat[m]<300.0) &&(Smmrfloat[m]<300.0))
         {
          Ssmishort[n] = Ssmifloat[m];
          Smmrshort[n] = Smmrfloat[m];
          n++;
         }
    }
  return(n);
 }
```

```
/*****************************************************************************************/
/*                                    THE MAIN PROGRAM                                   */
/*****************************************************************************************/

void main()

{
    int j, k;
    k=0;
    open_list_file();

    fp4 = fopen("table.all","wt");                    /* open a file to write the output       */
    fwrite("\n", sizeof(char), 2, fp4);               /* equations from the linear regression  */

    for (j=0; j<numofiles; j++)                       /* loop through each pair of input files */
      {
        initialize ();
        read_list_file ();
        open_data_files();
        read_data_files ();
        process_data_files ();
        create_graph_arrays();
        check_bad_data();
        k = create_short_arrays ();
        linreg(&k);

        free(Smaskdat);                                /* free the memory allocated             */
        free(Ssmidat);                                 /* to the arrays and close all           */
        free(Smmrdat);                                 /* input files                           */
        free(Ssmidat3);
        free(Smmrdat3);
        free(Ssmigraph);
        free(Smmrgraph);
        fclose(ssmi);
        fclose(smmr);
        fclose(smask);
      }

    fclose(fp4);
    exit(0);
}
```

****

THE PLOTTING PROGRAM

****

```c
#include <stdio.h>
#include <stdlib.h>
#include <strings.h>
#include <math.h>
#include <suntool/sunview.h>
#include <suntool/canvas.h>

FILE *fp;
unsigned short int *Datax, *Datay, Maxx, Maxy;
Frame frame;
Canvas canvas;
Pixwin *pw;
int Number;

char filename[20],str1[20],str2[20],str3[20];

/*********************************************************************************************/
void initialize()

{

  printf("Enter file name to graph ");
  scanf("%s",filename);
  if ((fp=fopen(filename,"rb"))==NULL)
  {
    printf("\nError opening file for input");
    exit(1);
  }
  Number = 104912;
  Datax= (unsigned short int *) malloc(Number*sizeof(short int));
  Datay= (unsigned short int *) malloc(Number*sizeof(short int));
}

/*********************************************************************************************/
void plot_line()
{
  float a,b,x1,x2,y1,y2;
  int ptx1,pty1,ptx2,pty2,temp;

  printf("Enter the slope ");
  scanf("%f",&b);
  printf("Enter the intercept ");
  scanf("%f",&a);

  x1 = 50;
  x2 = Maxx;
  y1 = (b*x1)+a;
  y2 = (b*x2)+a;
  temp = 400;

  x1 =100.0+(float)(x1-50)/(float)(Maxx-50)*(temp);
  y1 = 500-(float)(y1-50)/(float)(Maxy-50)*(temp);
  x2 =100.0+(float)(x2-50)/(float)(Maxx-50)*(temp);
  y2 = 500-(float)(y2-50)/(float)(Maxy-50)*(temp);
  ptx1 = (int)((x1)+0.5);
  ptx2 = (int)((x2)+0.5);
  pty1 = (int)((y1)+0.5);
  pty2 = (int)((y2)+0.5);
  pw_vector(pw,ptx1,pty1,ptx2,pty2,PIX_SRC,2);
}
```

```
/****************************************************************************************/
void get_data()
{
  fread(Datax,sizeof(short int),Number,fp);
  fread(Datay,sizeof(short int),Number,fp);
}

/****************************************************************************************/
void plot_data()
{
  int i,minx,miny,xi,yi;
  float x,y,temp;
  char string[10];

  miny = minx = 9999;
  Maxx = Maxy = 0;
  for (i=0;i<Number;i++)
  {
    if ((Datax[i] != 0)&&(Datay[i] !=0)&&(Datay[i]<300)&&(Datax[i]<300))
     {
       if (Datax[i] > Maxx)
          Maxx = Datax[i];
       if(Datax[i] < minx)
          minx = Datax[i];
       if (Datay[i] > Maxy)
           Maxy = Datay[i];
       if (Datay[i] < miny)
           miny = Datay[i];
       if ((miny == 0) || (minx == 0))
           printf("Error");
     }
    minx = 50;
    miny = 50;
  }

  for (i=0;i<Number;i++)
  {
    if ((Datax[i] != 0)&&(Datay[i]!=0)&&(Datax[i]<300)&&(Datay[i] < 300))
    {
       temp = 400.0;
       x=100.0+(float)(Datax[i]-minx)/(float)(Maxx-minx)*(temp);
       y = 500-(float)(Datay[i]-miny)/(float)(Maxy-miny)*(temp);
       xi = (int)(x+.5);
       yi = (int)(y+.5);
       pw_put(pw,xi,yi,1);
       pw_put(pw,xi-1,yi,1);
       pw_put(pw,xi+1,yi,1);
       pw_put(pw,xi,yi-1,1);
       pw_put(pw,xi,yi+1,1);
     }
   }
```

```
/******************************************************************************/
/*                          PRINT THE DATE                                    */
/******************************************************************************/
    strcpy(str1,&filename[2]);
    strcpy(&str1[2],"/");
    strcpy(&str1[3],&filename[4]);
    strcpy(&str1[5],"/");
    strcpy(&str1[6],&filename[0]);
    strcpy(&str1[8],"            ");
    pw_text(pw,300,90,PIX_SRC,0,str1);

/******************************************************************************/
/*                          PRINT THE X AXIS LABEL                            */
/******************************************************************************/
    strcpy(str2,"SSM/I");
    strcpy(&str2[5]," ");
    strcpy(&str2[6],&filename[7]);
    strcpy(&str2[9],"          ");
    pw_text(pw,280,545,PIX_SRC,0,str2);

    gcvt((float)(minx),5,string);
    pw_text(pw,100,525,PIX_SRC,0,string);
    gcvt((float)Maxx,5,string);
    pw_text(pw,500,525,PIX_SRC,0,string);
    gcvt((float)(miny),5,string);

/******************************************************************************/
/*                          PRINT THE Y AXIS LABEL                            */
/******************************************************************************/
    strcpy(&str3[0],"S");
    pw_text(pw,40,255,PIX_SRC,0,&str3[0]);
    strcpy(&str3[1],"M");
    pw_text(pw,40,270,PIX_SRC,0,&str3[1]);
    strcpy(&str3[2],"M");
    pw_text(pw,40,285,PIX_SRC,0,&str3[2]);
    strcpy(&str3[3],"R");
    pw_text(pw,40,300,PIX_SRC,0,&str3[3]);
    strcpy(&str3[4]," ");
    pw_text(pw,40,315,PIX_SRC,0,&str3[4]);
    strcpy(&str3[5],&filename[7]);
    strcpy(&str3[6],"\n");
    pw_text(pw,40,330,PIX_SRC,0,&str3[5]);
    strcpy(&str3[6],&filename[8]);
    if(str3[6] == '9')
      {
        strcpy(&str3[6],"8");
      }
    strcpy(&str3[7],"\n");
    pw_text(pw,40,345,PIX_SRC,0,&str3[6]);
    strcpy(&str3[7],&filename[9]);
    strcpy(&str3[8],"\n");
    pw_text(pw,40,360,PIX_SRC,0,&str3[7]);

    pw_text(pw,60,500,PIX_SRC,0,string);
    gcvt((float)Maxy,5,string);
    pw_text(pw,60,100,PIX_SRC,0,string);
```

```
/*****************************************************************************************/
main()
{
  initialize();
  frame = window_create(NULL,FRAME,WIN_WIDTH,900,WIN_HEIGHT,900,
  WIN_X,0,WIN_Y,0,0);
  canvas = window_create(frame,CANVAS,
  CANVAS_WIDTH,900,
  CANVAS_HEIGHT,900,
  WIN_X,0,
  WIN_Y,0,
  WIN_VERTICAL_SCROLLBAR, scrollbar_create(0),
  WIN_HORIZONTAL_SCROLLBAR,scrollbar_create(0),0);
  get_data();
  pw = canvas_pixwin(canvas);
  pw_vector(pw,100,100,100,500,PIX_SRC,1);
  pw_vector(pw,100,500,500,500,PIX_SRC,1);
  plot_data();
  plot_line();
  window_main_loop(frame);
}
```