CORRELATION OF RAIN RATE AND RAIN HEIGHT: A STUDY RELATING TO CORRECTION OF SEAWINDS SCATTEROMETER DATA FOR RAIN

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Radar measurement of winds on the ocean surface uses multilook scatterometers. A duplicate of the SeaWinds scatterometer now on QuickSCAT will fly in late 2002 on the Japan-U.S. satellite ADEOS-II along with the AMSR (Advanced Microwave Scanning Radiometer). Rain attenuation and backscatter corrupt the scatterometer signal, but the presence of the radiometer will allow corrections for low to moderate rain rates and data discarding for high rain rates.

We developed methods for correction of the QuickSCAT signal based on radiometric brightness temperature, but they require estimates of the heights of the rainstorms. Since no direct measurements of rain height will be made by ADEOS-II, we propose to use estimates of the rain height based on radiometer rain-rate measurements that will be possible on ADEOS-II. The Tropical Rainfall Measurement Mission (TRMM) precipitation radar provides statistics on rain rates and heights in different oceanic regions and times of year, but it only covers the latitude range between 35 S and 35 N.

One possibility for such corrections is to use measurements of rain rate to help extrapolate the heights obtained using TRMM statistics to higher latitudes, since radiometer rain rates are available for several satellites in polar orbits. This study aims at determining the feasibility and limitations of this approach. We have over 3 years of TRMM data, including both En Niño and La Niña periods. Here we compare the TRMM rain heights with the TRMM rain rates from different ocean regions and present the correlations between them.

Another possibility for such corrections is to use measurements of sea-surface temperature (SST) to help extrapolate the heights obtained using TRMM statistics to higher latitudes. We also compared the TRMM rain heights with the sea-surface temperature in different ocean regions and will present some of the correlations in a separate paper. This approach is not as promising as that using the rain rates. For sea-surface temperature, correlations differ widely in the northern and southern hemispheres and in the eastern and western parts of the ocean basins. In the Pacific Ocean during January, one must separate the intertropical convergence zone (ITCZ) region and the equatorial region just south of it from other parts of the sea because of the different conditions that prevail in these special areas. Although some regions show good positive correlations with SST, others sometimes correlate negatively, so the SST approach cannot be used throughout the world's oceans.

RAIN RATE VS. RAIN HEIGHT

The correlations between rain heights and rain rates are always positive and usually exceed 0.5 for all regions. A notable exception is the data since September, 2001, where correlations are quite low in some regions for stratiform rain; we are reexamining the data source to see if there was either an instrumental or data-formatting problem for these months.

The two TRMM instruments of interest are the precipitation radar (PR) and the TRMM microwave imager (TMI) [1]. The PR has a surface footprint about 4.5 km in diameter and a range resolution of 250 m. It scans ± 17° to achieve a swath of about 215 km. The TMI [2] has 9 channels at 5 frequencies between 10.7 and 85 GHz.. Its effective field of view depends on frequency, but is elliptical and varies from 5 x 7 km at 85 GHz to 63 x 37 km at 10.7 GHz. However, data are delivered at cross-track intervals of about 4.5 km and along-track intervals of 13.9 km. It has a circular scan at an angle of incidence of 52.8°, resulting in a swath width of 759 km.

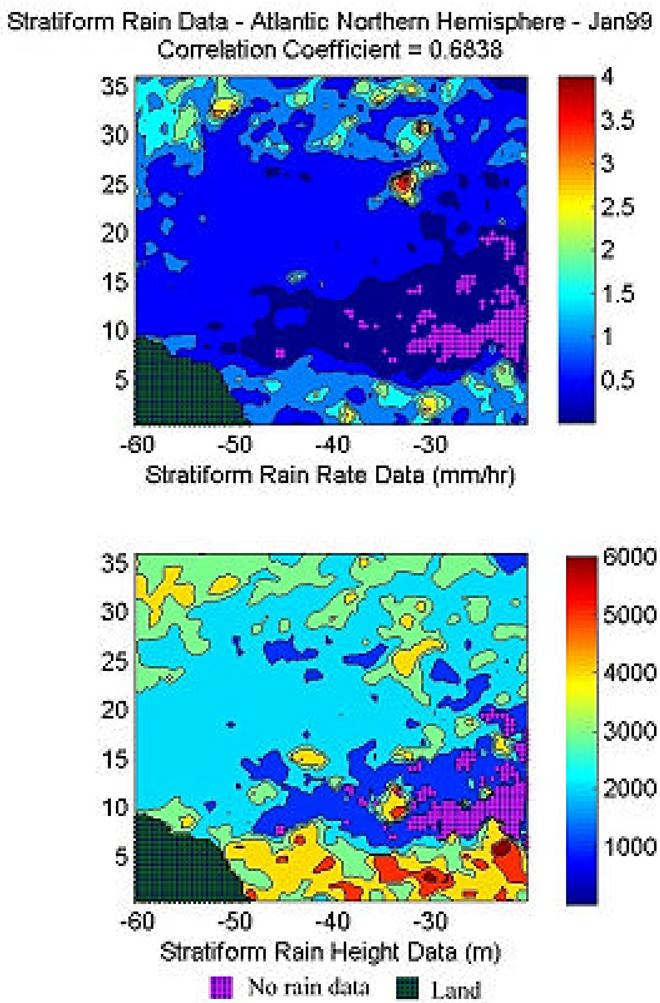
The TRMM project provides data in many forms, from Level 1 with actual measurements to various Level 3 averaged products. Key to this study are the PR rain-height and rain rate products that result from applying algorithms to the measured data based on backscattered signals from the rain and attenuation calculated through the rain. A special algorithm separates the measurements into stratiform rain, convective rain, and "other". The "other" data are for situations where the algorithm is unable to select stratiform or convective.

We use products based on monthly averages, with the rain heights and rates recorded on a 0.5° x 0.5° grid. We have not attempted to use instantaneous rain rates and heights for comparison because of the large size of such a data set. Rain rates are also provided by the TMI, but the poorer resolution makes them incompatible for our purposes with the PR observations. With the AMSR radiometer to fly on ADEOS-II the resolutions are comparable with those of the SeaWinds scatterometer, so radiometer rain rates will be useful.

Fig. 1 shows an example of the mapping of rain rate and rain height for part of the North Atlantic Ocean. Note Brazil in the lower left corner and areas with too little rainfall to report of the west coast of Africa near longitudes up to -40° and latitudes around 10° north.

Although we have data for all months, our study concentrates on months at quarterly intervals, starting with January, 1998, and ending with January, 2002. Meteorological conditions vary in different parts of the world, so we subdivided the oceans into regions and checked the correlation between rain height and rain rate in each region. Table 1 lists the results for stratiform rain. As an example, Fig. 2 shows the variation in correlation coefficients for the Atlantic regions. Note that nearly all correlation coefficients are above 0.6 except for October 2001 and January 2002. We do not know if this is real or is some problem with the instrument or data, but we suspect the latter.

A characteristic of the data is that rain rates below about 0.5 mm/hr seem to have an unrealistically wide range of heights for the stratiform case, especially since September, 2001. Indeed, many of the reported heights exceed values that are physically possible for such light stratiform rains. Examples of scatter plots showing this for stratiform rain for January, 1999, and October, 2001, is in Fig. 3. This situation does not exist for convective conditions. Trilinear regression lines also shown are typical in that the slope is steep from 0.7 to 1.5 mm/hr and more gradual for higher rain



rates.

Fig. 1. Illustration of mapping of rainfall rates and heights in the North Atlantic showing their spatial correlation.

Table 1. Correlation coefficients between stratiform rain height and rain rate for different oceanic regions.

Region	Jan-98	Apr-98	Jul-98	Oct-98	Jan-99	Apr-99	Jul-99	Oct-99
IndianNorth	0.85	0.68	0.63	0.54	0.79	0.76	0.62	0.64
IndianSouth	0.74	0.69	0.76	0.76	0.73	0.65	0.76	0.83
AtlSouth	0.80	0.81	0.83	0.79	0.82	0.78	0.86	0.81
AtlNorth	0.57	0.68	0.81	0.66	0.68	0.76	0.81	0.72
PacSoutheast	0.79	0.80	0.79	0.77	0.80	0.78	0.82	0.78
PacSouthwest	0.68	0.72	0.77	0.63	0.69	0.49	0.49	0.67
PacNortheast	0.82	0.77	0.69	0.82	0.71	0.65	0.80	0.80
PacNorthwest	0.81	0.64	0.65	0.67	0.68	0.65	0.61	0.66

Region	Jan-00	Apr-00	Jul-00	Oct-00	Jan-01	Apr-01	Jul-01	Oct-01	Jan-02
IndianNorth	0.78	0.73	0.64	0.53	0.74	0.78	0.55	0.28	0.28
IndianSouth	0.71	0.76	0.76	0.78	0.78	0.65	0.73	0.62	0.67
AtlSouth	0.85	0.83	0.90	0.82	0.83	0.84	0.89	0.17	0.32
AtlNorth	0.57	0.66	0.75	0.75	0.79	0.71	0.69	0.39	0.40
PacSoutheast	0.81	0.75	0.80	0.76	0.82	0.74	0.79	0.36	0.55
PacSouthwest	0.59	0.62	0.50	0.68	0.63	0.68	0.52	0.37	0.60
PacNortheast	0.72	0.73	0.79	0.82	0.77	0.78	0.79	0.30	0.41
PacNorthwest	0.65	0.65	0.62	0.67	0.75	0.68	0.67	0.63	0.57

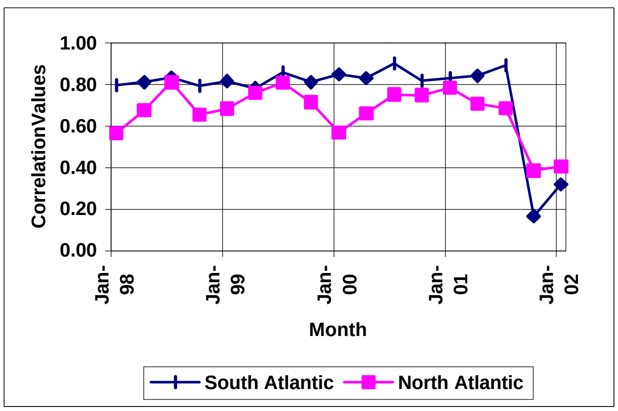


Fig. 2. Correlation coefficients between stratiform rain height and rain rate for the Atlantic Ocean

Note for October, 2001 the cluster of heights below 0.5 mm/hr that is nearly uniform to 8 km (in fact, the data points extend even higher than those plotted). This physically impossible set of points greatly reduces the correlation coefficient. The number of such points is much smaller in the January, 1999, plot as for most of the earlier cases Some such high points appear in most of the data, but their number is much larger for months since September, 2001..

CONCLUSION

We believe that the regressions based on stratiform rain rates above about 0.5 mm/hr can be useful in estimating the rain heights, and plan to extend the study to determine the degree to which regional and seasonal effects must be considered in developing a correction algorithm for the SeaWinds data. Fortunately, rain rates below 0.5 mm/hr do not significantly degrade SeaWinds measurements, so the problems with low rain rate data from TRMM are not important to the algorithm development, although they are of considerable interest scientifically. The correlations remain high for all periods with convective rain, so there is little question about their utility.

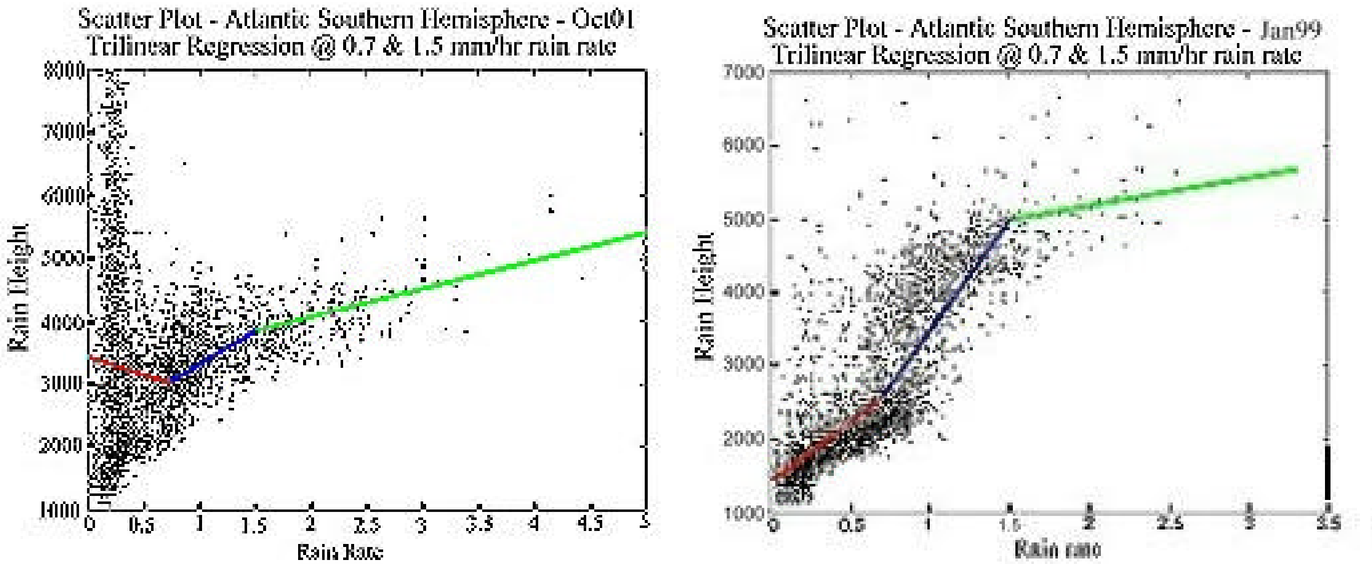


Fig. 3. Scatter plots relating stratiform rain height to rain rate for the South Atlantic Ocean in October, 2001 and January, 1999. The trilinear regression line shows a characteristic steep rise from 0.7 to 1.7 mm/hr, followed by the typical smaller slope for higher rain rates. Note the very large concentration of unrealistic heights for low rain rates in October, 2001.

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REFERENCES

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