Use of TRMM PR Measurements to Validate High-Resolution QuikSCAT Rain Estimates

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Summary

SeaWinds on QuikSCAT, a spaceborne scatterometer launched in 1999 by NASA and currently operating, provides daily coverage of near-surface ocean vector winds. Although QuikSCAT was designed only for ocean wind measurement, and while it does not have vertical resolution capability like the TRMM PR, it can provide rain measurements.

Collocated TRMM PR data has been used to derive a wind/surface rain model function assuming that rain results in both an additional attenutation and an additional backscatter value. The resulting wind/rain model function is shown in Fig. 2. This model function can be used in processing algorithms to simultaneously retrieve vector wind and surface rain rate from SeaWinds data [1,2]. The resulting SeaWinds surface rain rate measurements are noisier than TRMM PR measurements but have broad global coverage.

Conventionally, SeaWinds observations are reported at 25 km resolution. Figure 3 compares averaged 25km SeaWinds rain estimates to TRMM TMI monthly averaged rain rates for the month of October in 1999. However, the raw radar measurements support much finer spatial resolution. Recently, a new SeaWinds simultaneous wind/rain retrieval algorithm has been developed that is based on enhanced resolution SeaWinds backscatter measurements. The new high resolution wind/rain algorithm produces vector wind and rain rates estimates posted at 2.5 km resolution.

Although this improved algorithm reports wind and rain at 2.5 km resolution, the true resolution is somewhat lower. To most effectively compare SeaWinds and TRMM PR rain rates we first spatially smooth the TRMM PR measurements using a low pass filter. Figure 1 shows a scatter density plot of the TRMM PR and QuikSCAT rain rate for each colocated location after smoothing. Although Fig. 1 illustrates a high variance between the two rain rates, due to the noisy QuikSCAT measurements, it also shows the high correlation between the data sets. The QuikSCAT rain estimates are biased high compared to TRMM rain rates though this offset can be corrected.

In addition to the pointwise comparison of the colocated data sets shown in Fig. 1 we illustrate the capability of the SeaWinds SWR algorithm using several case studies. Figures 4-6 show the TRMM rain rate, the SeaWinds rain rate and the SeaWinds wind speed for a single colocation. In this case wind speeds are relatively low, rain rates are low as well and rain is limited to a small segment of the SeaWinds swath. The rain features in Fig. 4 are concentrated and result in spreading of the SeaWinds rain estimates. Despite the spreading, the SeaWinds estimates resolve the rain features including accurate estimates of the rain rate quite well.

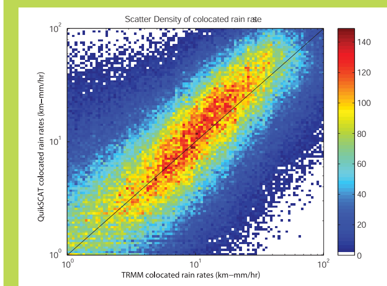

Figure 1. TRMM PR rain rates versus QuikSCAT rain rates for the colocated data set. The data set has been artificially enhanced to better represent high rain rate cases by including a disproportionate number of hurricanes.

Figures 7-9 show the TRMM rain rate, the SeaWinds rain rate and the SeaWinds wind speed for a second colocation. Although wind speeds for this case are comparable to those in Fig. 6, this case has more pervalent rain features with higher rain rates throughout. Despite the differences, the SeaWinds estimates still resolve the major rain features although they are noisier than the TRMM estimates. The largest differences between the TRMM and SeaWinds estimates occur over land where SeaWinds cannot estimate wind or rain. In addition to differences in the rain field, the widespread rain features cause enough attenuation of the wind backscatter that wind estimates are impossible in location with high rainrates as indicated by gray areas in Fig. 9.

Figures 10-12 show the TRMM rain rate, the SeaWinds rain rate and the SeaWinds wind speed for a hurricane off the western coast of Central America. In this case both rain rates and wind speeds vary from moderate to extremely high. The TRMM PR rain rates shown in Fig. 10 clearly indicate the structure of the rain bands surrounding the hurricane eye. As in the previous cases algthough the SeaWinds estimates are not as high resolution they also accurately discern the structure of the rain bands. SeaWinds is incapable of making rain estimates in the outermost parts of the swath indicated on the left edge of Fig. 11. A significant difference between the TRMM PR and SeaWinds rain estimates is the maximum detectable rain rate. SeaWinds is limited by computation efficiency to rain rates below 100 km-mm/hr while TRMM has a maximum detectable rain rate that is much higher. In the hurricane case where rain rates are extremely high SeaWinds reaches the maximum rain rate many times. Once again there are gaps in the wind field in Fig. 12 due to the rain attenuation caused by the highest rain rates.

In conclusion, this comparison of colocated TRMM PR and SeaWinds high-resolution rain rates indicates that the SeaWinds model function derived using TRMM PR rain rates allows for simultaneous wind and rain retrieval from SeaWinds measurements. Although the SeaWinds estimates are noisier and lower resolution than the TRMM measurements they do allow for wind and rain estimates to be made around the world.

[1] D.W. Draper and D.G. Long, Simultaneous Wind and Rain Retrieval Using SeaWinds Data, IEEE Trans. Geoscience and Remote Sensing, Vol. 42, No. 7, pp. 1411-1423, 2004.

[2] D.W. Draper and D.G. Long, Assessing the Quality of SeaWinds Rain Measurements, IEEE Trans. Geoscience and Remote Sensing, Vol. 42, No. 7, pp. 1424-1432, 2004.

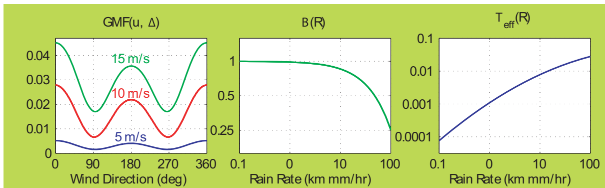

Figure 2. SWR GMF.
Left: Wind/backscatter model. Center: Rain Attenuation model. Right: rain backscatter model.

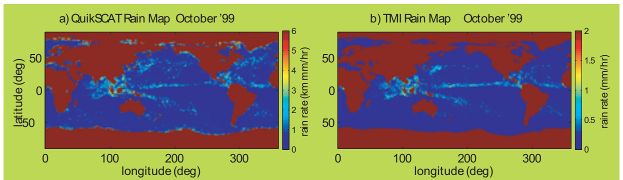

Figure 3. Comparison of SeaWinds-derived rain with TMI-derived rain rates averaged over one month. Note that TMI has tropical coverage only.

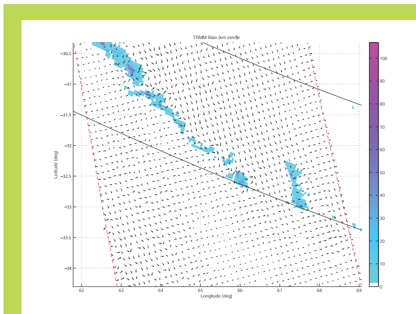

Figure 4. TRMM PR rain rates (km-mm/hr) plotted together with QuikSCAT wind direction vectors. In this case the wind speeds are relatively low and the rain rates are lower as well.

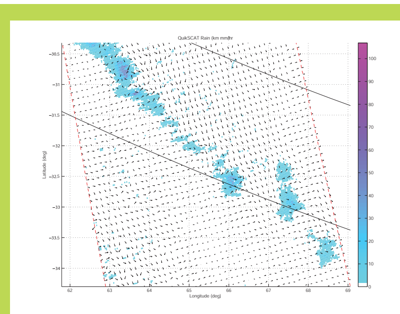

Figure 5. QuikSCAT SWR high-resolution rain rates(km-mm/hr). Note that although the QuikSCAT rain rates are not as high resolution they do accurately resolve the rain front illustrated by the TRMM PR measurements in Fig. 5.

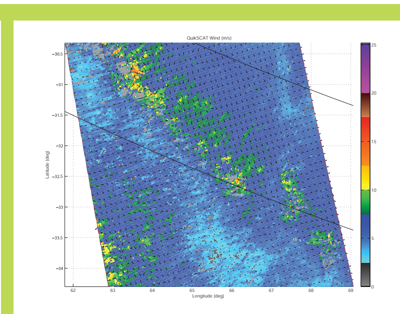

Figure 6. QuikSCAT SWR high-resolution wind speed and direction (m/s). In the locations with the highest rain rates QuikSCAT is unable to make an accurate estimate of the wind vector resulting in holes in the wind field. Wind vector cells without wind vector estimates are plotted gray.

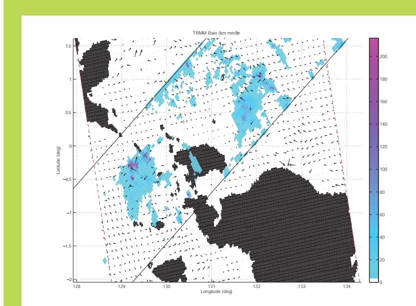

Figure 7. TRMM PR rain rates (km-mm/hr) plotted together with QuikSCAT wind direction vectors. In this case the wind speeds are relatively low and the rain rates are high. TRMM PR is capable of estimating rain rates over land as well.

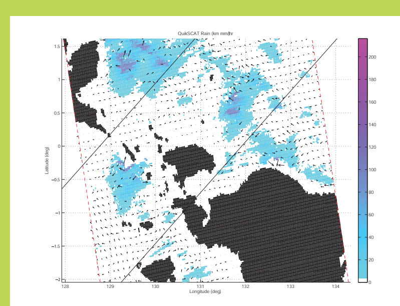

Figure 8. QuikSCAT SWR high-resolution rain rates(km-mm/hr) and QuikSCAT wind direction vectors. Note that although the QuikSCAT rain rates are not as high resolution, they do accurately resolve the rain features that are not near land. QuikSCAT is incapable of wind or rain measurements over land.

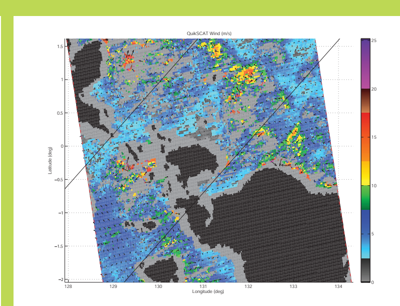

Figure 9. QuikSCAT SWR high-resolution wind speed and direction (m/s). For locations near land or with high rain rates QuikSCAT is unable to make an accurate estimate of the wind vector resulting in holes in the wind field. Wind vector cells without wind vector estimates are plotted gray.

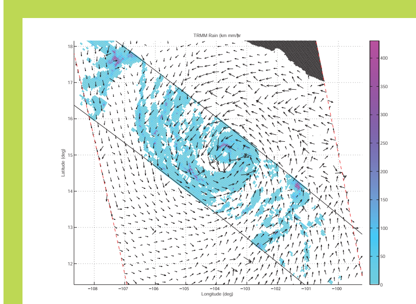

Figure 10. TRMM PR rain rates (km-mm/hr) plotted together with QuikSCAT wind direction vectors. In this case the both wind speeds and rain rates are extremely high. The TRMM PR rates clearly show the hurricane rain bands.

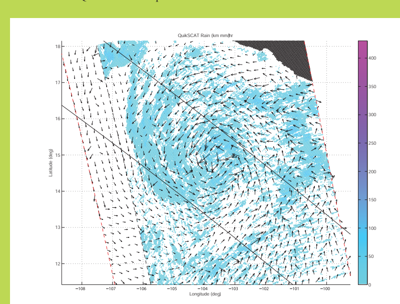

Figure 11. QuikSCAT SWR high-resolution rain rates(km-mm/hr) and QuikSCAT wind direction vectors. Note that although the QuikSCAT rain rates are not as high resolution, they do accurately resolve the hurricane rain bands although the rain rate estimates are low.

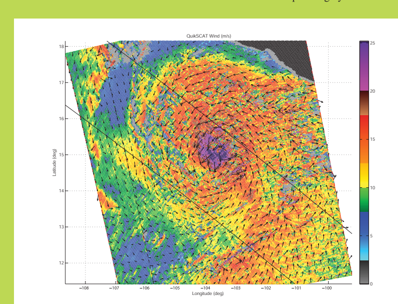

Figure 12. QuikSCAT SWR high-resolution wind speed and direction (m/s). For locations near land or with high rain rates QuikSCAT is unable to make an accurate estimate of the wind vector resulting in holes in the wind field. Wind vector cells without wind vector estimates are plotted gray.