Annual Report

Project Title: Error Estimates for AMSR-E Rainfall Data

(P.I. Thomas L. Bell)

Project Objectives

The main objectives of the current project that are relevant to the AMSR-E data validation plan are:

(i) Produce estimates of the sampling error in the monthly area-averaged rain rate on a global 5° × 5° grid as measured by AMSR-E. This error arises from the intermittent and often incomplete observation of a grid box on the earth by the satellite. It is determined by the rain statistics and the total area sampled by the satellite in course of the month. The rms error gives the 95% confidence interval for the satellite retrieval error.

(ii) Carry out a comparative study of the rain statistics derived from collocated satellite and ground-based radar images at Kwajalein and other ground validation sites.

The error estimates are themselves essential for utilizing the data in scientific investigations, such as, comparison with other data sets and numerical climate model predictions. Extracting modulating signals like the diurnal cycle and other longer term trends also require knowledge of the error distribution. Inter-comparison of ground radar and satellite-derived rain statistics can reveal systematic differences. These differences are indicative of the presence of retrieval errors and can lead to improvement of the rain retrieval algorithms.

Model of Sampling Error

The validation problem involves comparing two estimates of the monthly grid-box averaged rain rate, one obtained with ground-based techniques ("ground truth") and the other obtained with satellite remote sensing. If the satellite could observe the entire grid box continuously over the month, the difference would be the so-called retrieval error. However, since the satellite estimate is actually obtained from an average over the footprints that fall within the observed area of the box during the satellite overpasses in course of a month, the error estimate provided by the satellite data is the sum of the retrieval error and a contribution from the error due to intermittent sampling.

The mean squared sampling error σ_E^2 depends primarily on the variability of precipitation within the box and the total area sampled by the satellite. As described in Bell et al (2001), this quantity is given by the empirical formula

$$\sigma_E^2 = \gamma \, \sigma_A^2 / S \qquad (1)$$

where σ_A^2 is the variance of the instantaneous rain rate averaged over the grid box of area A, S is the total area fraction sampled by the satellite and γ is a numerical factor of the order unity whose value depends on the time correlation present in the data. If γ is known, then the other two quantities on the right hand side of Eq. (1), and consequently the sampling error, can be directly calculated individually for each grid box for the month. In this work we analyzed data from two SSM/I satellite F10 and F11 whose local visit times were roughly 0930/2130 and 0530/1730 respectively. This allowed us to compute the lagged autocorrelation function over a range of time lags starting at 4 hours and obtain an accurate estimate of the correlation time. The value of γ computed from our theoretical model was in good agreement with the value 0.7 calculated directly from data. The AMSR-E observations are by themselves not closely enough spaced in time to yield a reliable estimate of the correlation time. It is however possible to achieve this if data from other satellites, such as TRMM and the current SSM/I satellites are utilized to fill in the temporal gaps.

Accomplishments during the Reporting Period

While awaiting the accumulation of a substantial amount of level 2 rainfall data from AMSR-E, we examined a number of aspects of rain statistics from the TRMM Microwave Imager (TMI) version 5 data over the Equatorial Pacific between 10° N - 10° S and 150° E - 90° W taken during 1998. Figure 1 illustrates the dependence of the fractional error σ_E/R as a function of the monthly mean rain rate R computed for January 1998.

For Rain rates $R > 0.1$ mm h^{-1}, the fractional error was found to be well approximated by the simple formula $\sigma_E/R = 0.2\, R^{-0.28}$. At lower rain rates the error leveled off at about 40% of the mean. A number of other statistics that we studied also showed simple power law dependence on the mean rain rate. For example, the area fraction containing nonzero rain p – a statistic that expresses the intermittent or "patchy" character of the rain field – was found to obey the relation $p = 0.29\, R^{0.65}$ over the entire range of R for January 1998 data over the Equatorial Pacific (Figure 2). Some systematic geographical trends seemed to emerge when the full year's worth of data was examined. For example, the fraction p(R) at a certain R was consistently larger in the Eastern Pacific than in the Western Pacific, especially during the period September-December 1998. We have now undertaken a much more extensive project of studying the full multi-year global TMI data in conjunction with the recently initiated TRMM data mining efforts at the Goddard DAAC. This will allow us to investigate geographical and seasonal trends in the rain statistics in greater depth than has been possible until now because of the enormous amount of archived data that would otherwise be needed to be transferred over the networks.

In the context of TRMM data validation, we have been particularly interested in investigating how the rain statistics retrieved from two different instruments, specifically the TMI and the precipitation radar (PR), with widely differing physical characteristics, spatial resolution and retrieval algorithms may differ. To this end, we have carried out an inter-comparison study of TMI and PR rain statistics over the Tropical Western Pacific during the period January-April 1998 from the version 5 data. We examined statistics area-averaged rain rate computed from a sequence of rectangular areas roughly of the same area as a 2.5° × 2.5° square box that lie within the overlapping region of the TMI and PR swaths. The statistics of this collocated data can yield valuable insight into response of each instrument to the same rain field. From a plot of monthly area-averaged rain rates (Figure 3) we find that the TMI rain rates are systematically larger than the corresponding PR values by about 50%. However, remarkably the plot of the dimensionless ratio σ_A/R of TMI vs. PR shows that the values of this quantity are very nearly equal (Figure 4). Broadly speaking this means that the rainfall variability detected by the two instruments are the same even though they see differing total amounts.

Future Work

As more level 2 rainfall product from AMSR-E becomes available, we expect to be able to carry out investigations of the rain statistics and generate error estimates for the gridded global AMSR-E precipitation data set along the lines outlined above. The future goals of the project are to generate monthly error maps for each grid box on the globe seen by AMSR-E and carry out an inter-comparison study of the satellite data with collocated ground radar and/or rain gauge data to explore any systematic differences in their statistical properties.