RSS Tech. Memo. 122095 Issued: December 20, 1995

Interim Report for JPL Contract 960132

Error in Estimating 14-GHz Atmospheric Attenuation from Climatology for the Case of No Rain

Principal Investigator: Frank J. Wentz

Prepared for:
NSCAT Project
Jet Propulsion Laboratory
National Aeronautics and Space Administration
Pasadena, CA 91109

Prepared by:

Remote Sensing Systems
1101 College Ave., Suite 220, Santa Rosa, CA 95404 (707) 545-2904

1. Error in Estimating Atmospheric Attenuation from Climatology

Remote Sensing Systems' Technical Memorandum 093095 described the generation of a climatology for the 14-GHz atmospheric attenuation over the world's oceans. This climatology was computed from SSM/I observations for the time period from June 1991 through May 1995. The climatology is represented as monthly global maps, with each map corresponding to an average over 4 years. The spatial resolution of the monthly maps is 1° in latitude and longitude. We suggest that during the NSCAT Level-1 processing, an attenuation be found for each NSCAT ocean observation using these climatology lookup tables.

In this memorandum, we estimate the error in specifying the attenuation from climatology. Herein, all attenuation values are defined as the 2-way attenuation for an incidence angle of 40° in units of decibels. The attenuation error ΔA is defined as the difference between the actual attenuation for the NSCAT footprint and the value estimated from the climatology tables:

$$\Delta A = A - A_{CLM} \quad (1)$$

where A is the footprint attenuation and A_{CLM} is the climatology value. In this analysis, we only consider rain-free (rain < 0.2 mm/h) observations. Thus the attenuation error we compute is just due to variations in the atmospheric water vapor and non-raining clouds relative to the monthly climatology.

To estimate ΔA, we treat the F11 SSM/I as if it were NSCAT. For each F11 SSM/I footprint, we compute the 14-GHz attenuation using the expressions in RSS Tech. Memo. 093095. The spatial resolution of the SSM/I footprint is about 50 km. If the SSM/I rain rate retrieval exceeds 0.2 mm/h, the SSM/I footprint is excluded from further analysis. Using a 0.2 mm/h cutoff threshold excludes about 5% of the footprints.

The climatology attenuation A_{CLM} is found from a tri-linear interpolation of the climatology tables. The three dimensions of the interpolation are time (months), latitude (degrees), and longitude (degrees). In this way, the climatology attenuation is interpolated to the exact time and location of the SSM/I footprint. Note that the climatology tables were calculated just from the F10 SSM/I observations, which have an ascending node time near 9 PM.. Thus, in some sense, the F11 observations, which have an ascending node time near 6 PM, are independent of the climatology.

One year of F11 data is processed, and ΔA is found for each footprint. For a given year, there are approximately 200 million footprints. These 200 million values of ΔA are binned into 1-month, 1°-latitude, 1°-longitude bins. For each bin, the following averages are computed:

$$\langle \Delta A \rangle_{i,j,k} = \tfrac{1}{N} \sum_{n=1}^{N} \Delta A \quad (2)$$

$$\langle \Delta A^2 \rangle_{i,j,k} = \tfrac{1}{N} \sum_{n=1}^{N} \Delta A^2 \quad (3)$$

where $\langle \Delta A \rangle_{i,j,k}$ is the monthly mean attenuation error and $\langle \Delta A^2 \rangle_{i,j,k}^{\frac{1}{2}}$ is the monthly rms attenuation error. The summation is over the N observations in the 1-month, 1°-latitude, 1°-longitude bin. The subscripts i,j,k denotes month, latitude, and longitude, respectively.

For each 1°-latitude and 1°-longitude cell, we next find the annual-averaged mean attenuation error ε_1 and the annual-averaged rms attenuation error ε_2, which are defined by

$$\varepsilon_1 = \tfrac{1}{12} \sum_{i=1}^{12} \langle \Delta A \rangle_{i,j,k} \tag{4}$$

$$\varepsilon_2 = \tfrac{1}{12} \sum_{i=1}^{12} \langle \Delta A^2 \rangle_{i,j,k}^{\frac{1}{2}} \tag{5}$$

where the summation is over the 12 months in the specified year. In addition, for each 1°-latitude and 1°-longitude cell, we find the maximum value of the monthly mean error and the monthly rms error. These maximum values are given by

$$\varepsilon_3 = \operatorname*{Max}_{i=1}^{12} \left(\left| \langle \Delta A \rangle_{i,j,k} \right| \right) \tag{6}$$

$$\varepsilon_4 = \operatorname*{Max}_{i=1}^{12} \left(\langle \Delta A^2 \rangle_{i,j,k}^{\frac{1}{2}} \right) \tag{7}$$

where the Max function finds the month that has the maximum value of $\left| \langle \Delta A \rangle_{i,j,k} \right|$ or $\langle \Delta A^2 \rangle_{i,j,k}^{\frac{1}{2}}$.

Figures 1 through 3 show ε_1, ε_2, ε_3, and ε_4 for the three years 1992, 1993, and 1994, respectively. The annual-averaged mean attenuation error ε_1 is very small, having a maximum range of about ±0.03 dB. The annual-averaged rms attenuation error ε_2 is also small, range from 0 to 0.06 dB. The maximum value of the monthly mean attenuation error ε_3 is largest in the inter-tropical convergence zone (ITCZ), where it reaches an extreme value of about 0.10 dB. The maximum value of the monthly rms attenuation error ε_4 is also largest in the ITCZ, where it reaches an extreme value of about 0.12 dB. ε_4 also shows relatively high values just south of Japan.

In conclusion, these results show that the rms error in estimating the 14-GHz attenuation from climatology tables is typically about 0.05 dB (2-way, 40° incidence angle). Certain small regions of the ocean (the ITCZ and just south of Japan) for certain months show larger monthly rms attenuation errors, which can reach maximum values of 0.10 to 0.12 dB. Thus the typical rms error is 0.05 dB and the extreme rms error is 0.12 dB.

2. Upcoming Work

The following work is being proposed for calendar year 1996. Task 2.1, 2.2, and 2.3 will be completed April 30, 1996. Task 2.4 will be completed December 31, 1996.

2.1. Extend the Time-Base for the Attenuation Climatology

Currently, the attenuation climatology is based on the time period from June 1991 through May 1995. In order to make this data set more representative of a true climatology, we will extend the time base to January 1988 through December 1995. Averaging over a time period of 8 years should smooth out the effect of most interannual anomalies such as the ENSO.

2.2. Expanding the Ocean Attenuation Climatology to Cover the Entire Globe

The attenuation climatology maps that were delivered with RSS Tech. Rpt. 093095 only have values for the open-ocean. There are no attenuation values for coastal ocean zones and land area. To avoid geographical discontinuities when applying the attenuation correction, attenuation values must be available for the entire globe. Accordingly we will expand the ocean attenuation fields to completely cover the continents and islands. This expansion will be done by first finding the zonal average attenuation for the world's oceans. For land areas that are far from the oceans (>1000 km), the zonal average will be used. For coastal zones, the attenuation will be a smooth blend of the zonal average and the ocean values.

We will also investigate the possibility of obtaining a land-based water vapor climatology derived from radiosonde observations. If such a data set exists and is reliable, then we will convert it to a 14-GHz attenuation and blend it with the ocean attenuation. This would provide a more accurate over-land attenuation than simply expanding the ocean attenuations into land area.

2.3 Tri-Linear Interpolation Routine for Accessing the Climatology Attenuation Tables

We will supply the NSCAT Project with a relatively simple interpolation routine for accessing the climatology attenuation tables. The three dimensions of the interpolation are time (months), latitude (degrees), and longitude (degrees). In this way, the climatology attenuation can be interpolated to the exact time and location of the NSCAT footprint.

2.4 Rain Likelihood Indicator for NSCAT

The report on the Rain Likelihood Indicator (RLI) for NSCAT is due December 31, 1995. Unfortunately, we have not yet completed our analysis, and are hereby requesting a 1-month extension, with the report being delivered January 31, 1996. To analyze the practicality of using an RLI for NSCAT, we are calculating rain fields from F11 SSM/I and then treating the F10 SSM/I as if it were NSCAT. F10 has an ascending node time near 9 PM, which is about 3 hours later than F11. The question being addressed is how well can one predict the occurrence of rain in the F10 footprint given the F11 rain maps. This problem of specifying an RLI is proving to be rather difficult, and we are proposing to continue the RLI analysis through 1996.