A Survey of C-Band RFI in the Chesapeake Bay Region using WindSat Radiometry

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1 Introduction

One of the instruments participating in the 2004 Soil Moisture Experiment ("SMEX04") [1] will be NOAA's airborne Polar Scanning Radiometer (PSR), augmented with an advanced radio frequency interference (RFI) monitor developed at the Ohio State University. One of the bands targeted for observation using this hybrid system is the "C" Band around 6.8 GHz, which is already known to be severly limited by RFI [2]. For the purposes of planning flight lines, it is helpful to have advanced knowledge of from where to expect RFI, so that it can be either avoided or observed, depending on the circumstances. This advance information on RFI distribution can be obtained from an analysis of radiometry from exisiting systems in Earth orbit, as described in [2]. We are fortunate to have access to radiometry from the WindSat instrument [3], which can be used for this purpose. In a previous report [4], a dataset of limited duration (October 2003) was analyzed to determine the spatial distribution of RFI in the 6.8 GHz band in the region of SMEX04.

Prior to SMEX04, a check flight will occur in the Chesapeake Bay area. In this report, the same data set is analyzed in the same manner, for the purpose of assisting in the planning of flight lines for this check flight.

2 WindSat

A detailed description of the WindSat polarimetric microwave radiometer is available in [3]. Here, the details relevant to the analysis in this report are summarized.

WindSat is the primary payload on the U.S. Air Force's *Coriolis* satellite, which was launched in January 2003 and is now in an 840 km circular sun-synchronous orbit. The 6.8 GHz radiometer has a bandwidth of 125 MHz and integration time of 5 ms, yielding an absolute accuracy of about 0.75 K. WindSat measures brightness temperature in a footprint approximately 0.5° (in latitude and longitude) in diameter as travels over the Earth. For this reason, the "duty cycle" of observation for any given point on the Earth is very low; on the order of twice per day.

After ground-based post-processing, radiometry in fully-calibrated vertical ("V") and horizontal ("H") polarizations are provided. ("H" refers to the polarization parallel to the ground, whereas "V" refers to the polarization perpendicular to both "H" and the direction of incidence.) Brightness temperatures observed over land in the 6.8 GHz band typically fall in the range 250–330 K. For the purposes of this report, temperatures greater than 330 K are considered RFI, which also corresponds the highest brightness temperature the WindSat radiometer can accurately measure.

The basis of this report was one month of WindSat observations corresponding to the month of October 2003.

3 Analysis

The first analysis attempted was to determine the "max hold" brightness temperatures in the Chesapeake Bay area over the observing period. "Max hold" in this case means the maximum brightness temperature in either polarization ever observed at a certain location. This analysis requires the definition of a grid over the surface of the Earth. Each point in the grid defines a pixel for which the brightness temperature statistics are computed. The grid used initially in this report is shown in Figure 1. The grid spacing is set equal to four times the mean spacing of the swath data obtained from WindSat. This grid spacing is approximately one-half of a beamwidth, so there is significant spatial overlap in both the WindSat data as well as the observations presented here.

Figure 2 shows the probability distrubution function (PDF) of the number of observations per grid point. An "observation" is defined as follows: For each measurement from WindSat, the grid point nearest the center of the beam is determined, and then this grid point (and no other) is then declared to have been observed. Note that each grid point is observed at least 51 times over the one month period, with a typical value being closer to twice a day over that period.

Using this approach, Figure 3 shows the max-hold brightness temperature, displayed as a flat-shaded contour plot. Note that some caution is required in interpreting this plot since the graphing

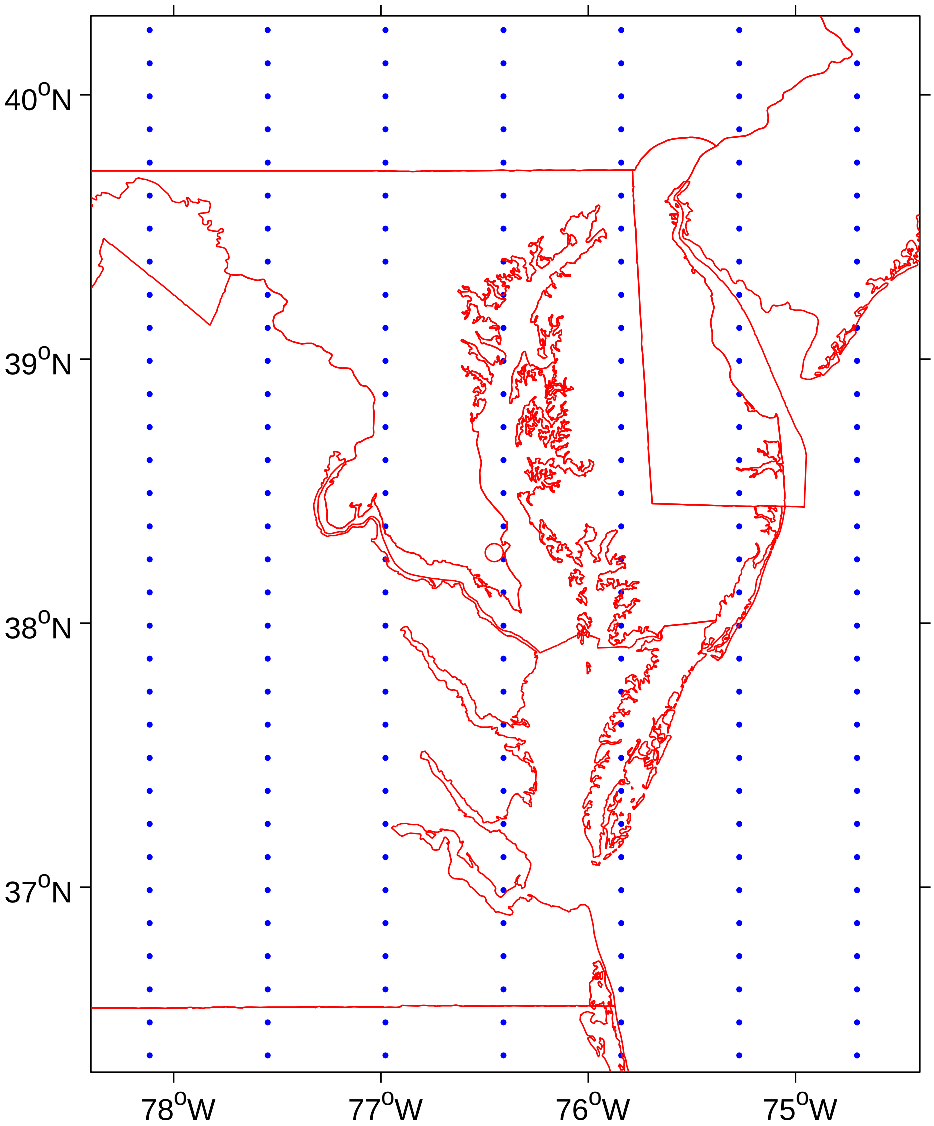

Figure 1: Grid used to compute max-hold and average brightness temperture distributions. The red lines denote borders of U.S. states. The circle marker located near the center of the figure shows the position the Patuxent River Naval Air Station, from which the check flight will originate.

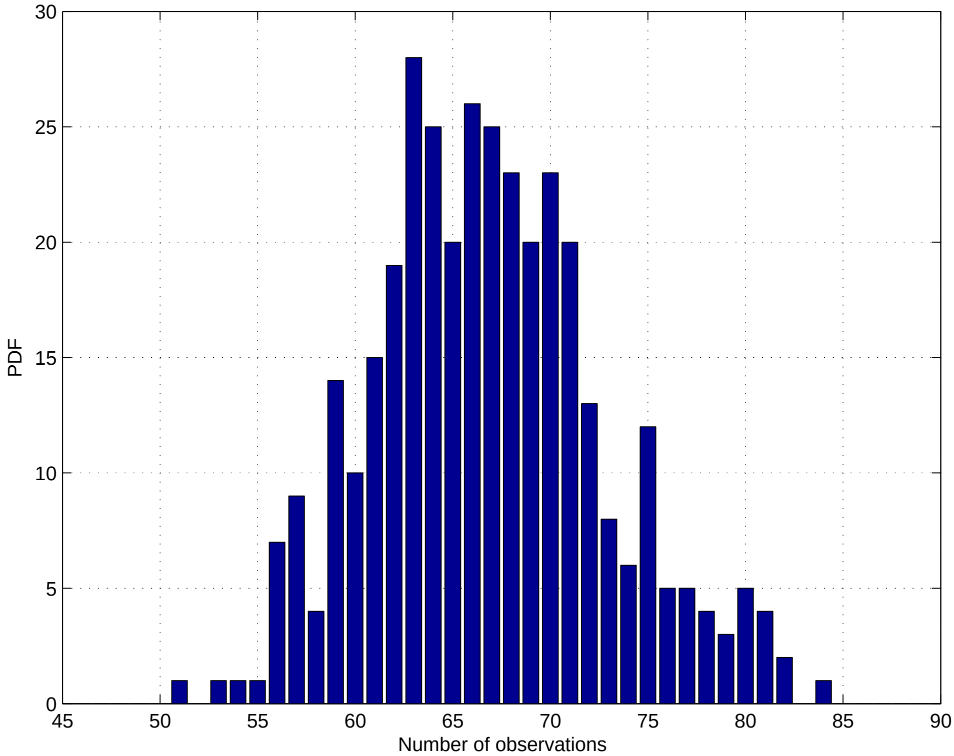

Figure 2: Distribution of the number of observations per grid point.

routine is essentially interpolating between the points shown in Figure 1 to obtain the temperatures at all other points. Nevertheless, a large area centered on Washington, DC and another large area centered in South-Central Pennsylvania exhibit brightness temperatures in excess of 330 K, strongly suggesting the presence of RFI. In addition, a localized region around Petersburg, VA exhibits levels which peak around 325 K, which are quite likely due to to RFI.

Figures 4 and 5 show the *mean* brightness temperatures over all observations in the vertical and horizontal polarizations respectively. In both cases, the region around Washington, DC is still visible as a source of elevated brightness temperture, and the vertical polarization appears to be significantly stronger than the horizontal polarization. However, the fact that the mean levels are much lower than the max hold levels indicates that any RFI observed in this region is intermittent, with low "duty cycle." The PDFs of the mean brightness tempertures in Figures 4 and 5 is shown in Figure 6.

To better resolve the spatial and temporal statistics of the RFI, a different analysis was attempted using grid similar to the one showed in Figure 1 but four times finer; i.e. spatial sampling approximately equal to that of the original data. Of course, the number of observations per grid point is greatly reduced in this approach, because there is a higher density of grid points available to "accept" observations. As shown in Figures 7 and 8, the number of observations per grid point is reduced to an average of about 4 (i.e., about once a week) and a few points are never observed. The latter are relatively few and are plotted in Figure 9 to show that they are unlikely to significantly bias the results.

Using the fine grid, Figure 10 shows all grid points experiencing at least one observation of RFI (i.e., at least one recorded brightness temperature greater than 330 K in either polarization). We see that these are primarily concentrated around Washington, DC and South-Central Pennsylvania, as previously noted.

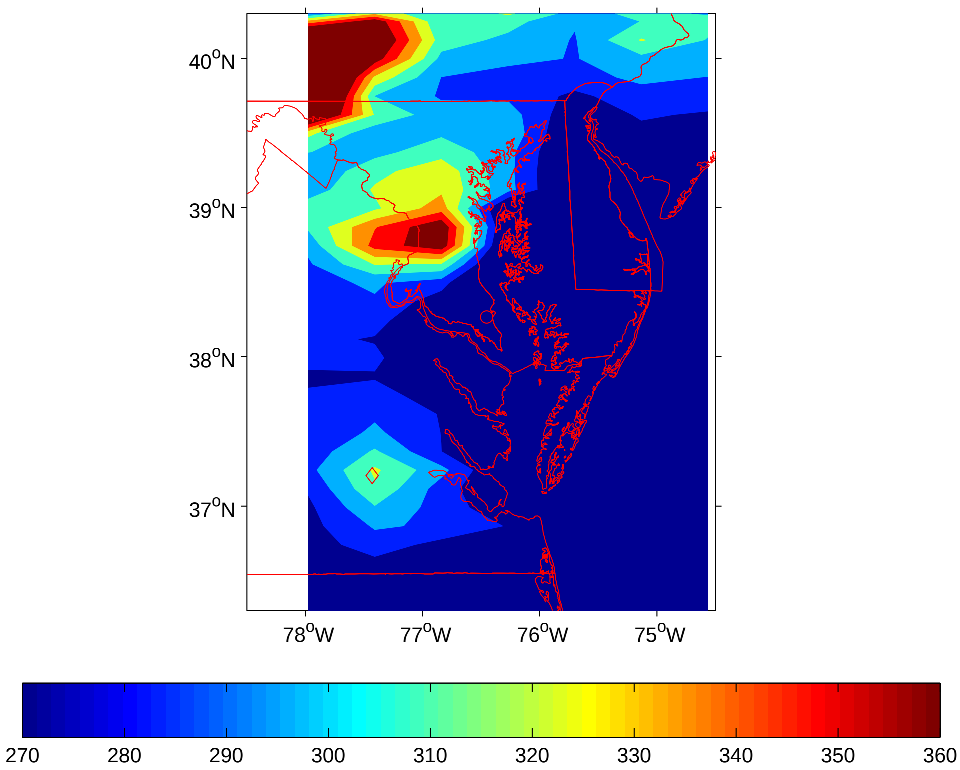

Figure 3: "Max Hold" Brightness Temperture. The red diamond denotes Petersburg, VA (longitude 77.4303° W, latitude 37.2042° N).

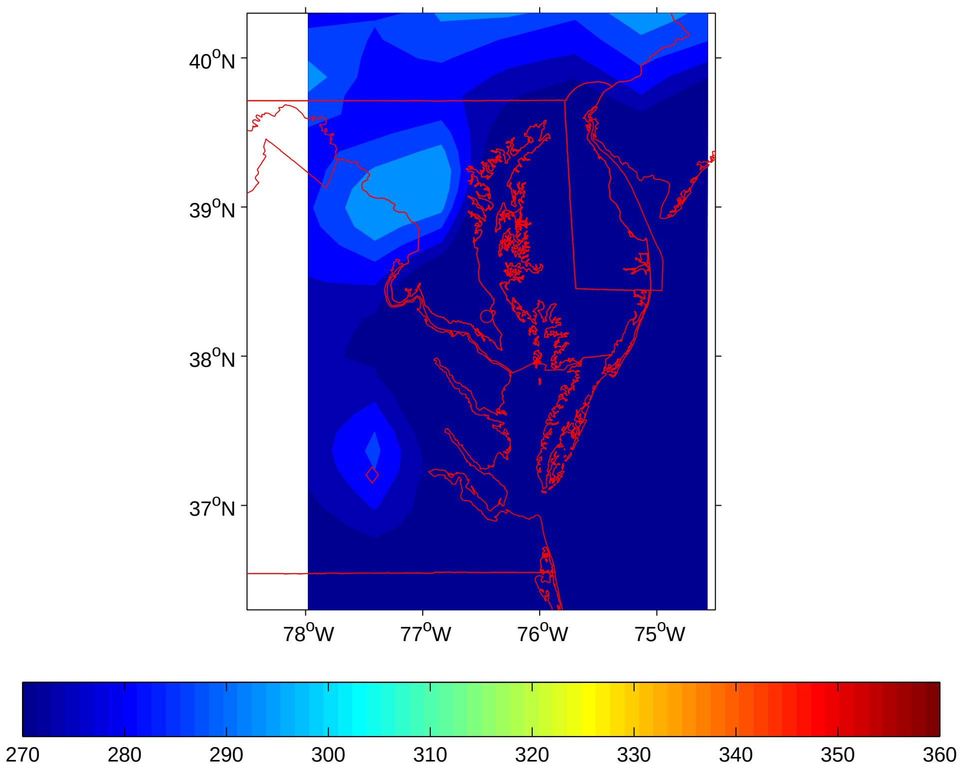

Figure 4: Mean Brightness Temperture, Vertical Polarization.

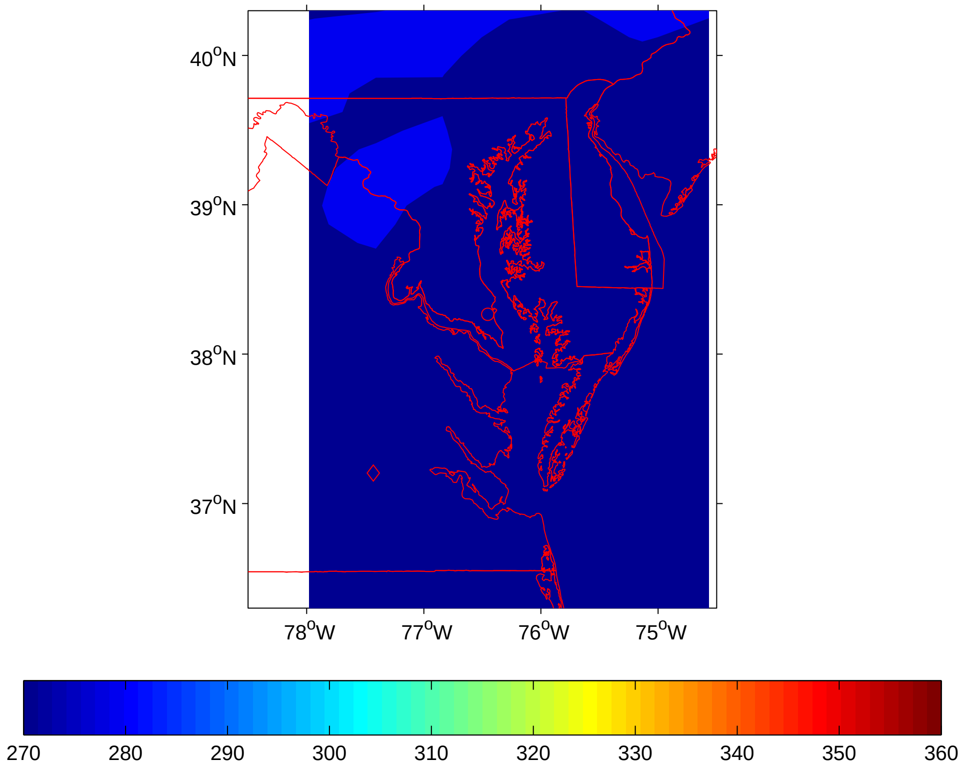

Figure 5: Mean Brightness Temperture, Horizontal Polarization.

Finally, Figure 11 shows all grid points for which RFI was observed during *every* observation. Note that there is no significant region which exhibits this property. This further suggests that the RFI is intermittent, or perhaps too weak to be detected consistantly using the 330 K criterion.

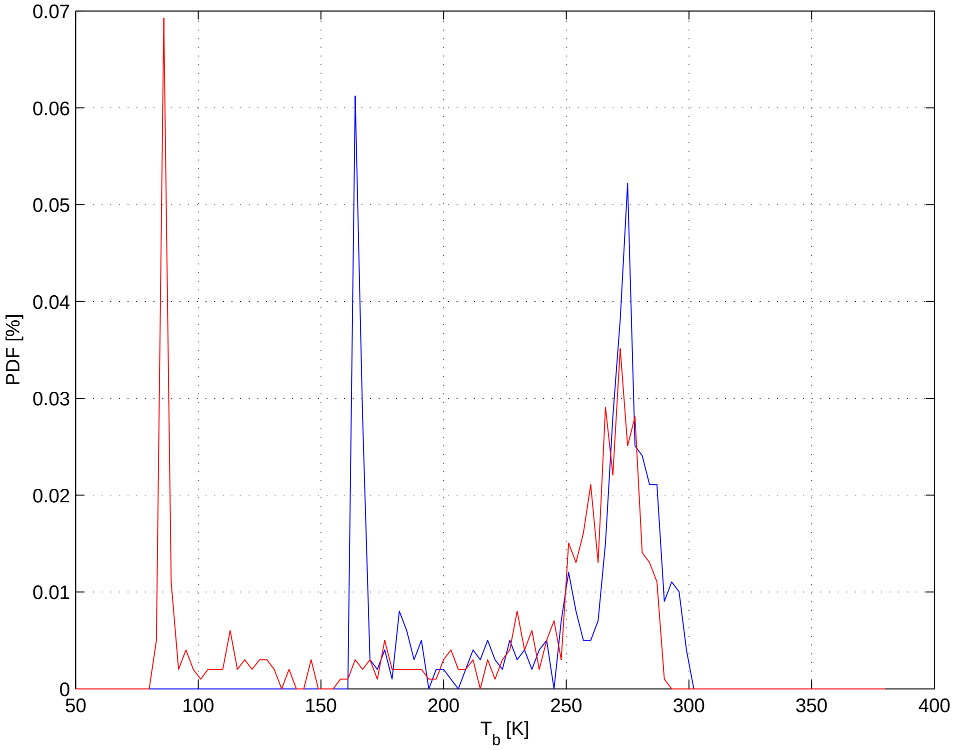

Figure 6: PDF of mean brightness temperature. *Blue:* Vertical polarization, *Red:* Horizontal polarization. The portion around 275 K is the expected geophysical signal associated with land, whereas the single peak in each polarization at lower temperatures is the geophysical signal associated with the ocean. No persistent signal is apparent which can be unambiguously associated with RFI.

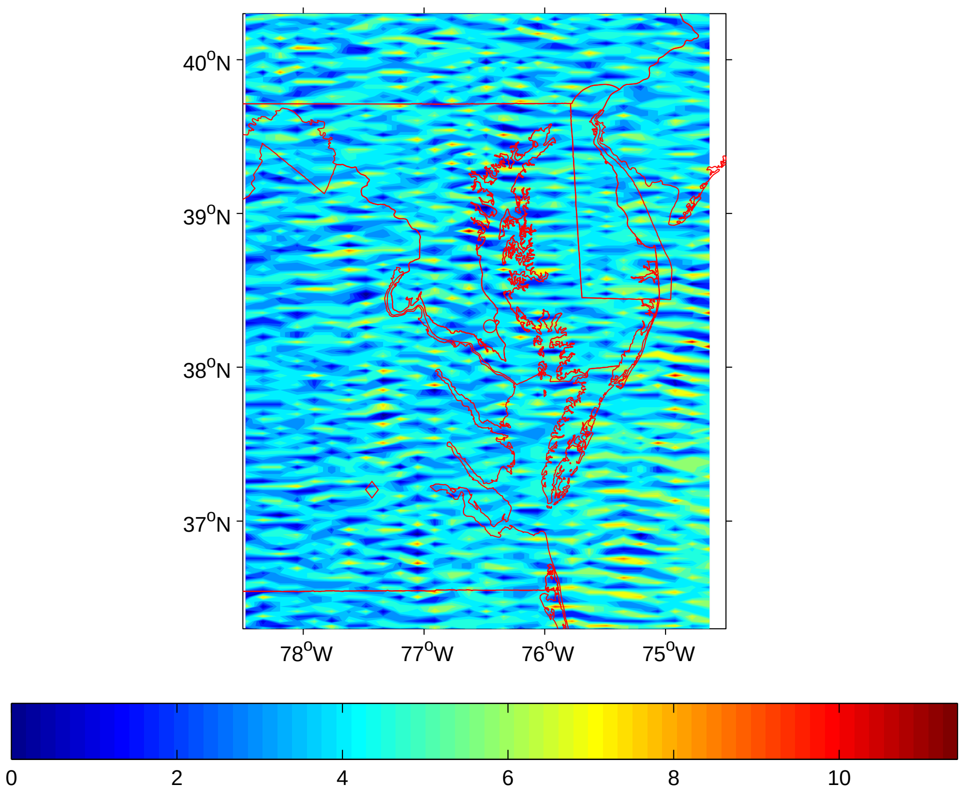

Figure 7: Number of observations per grid point using the second (fine) grid.

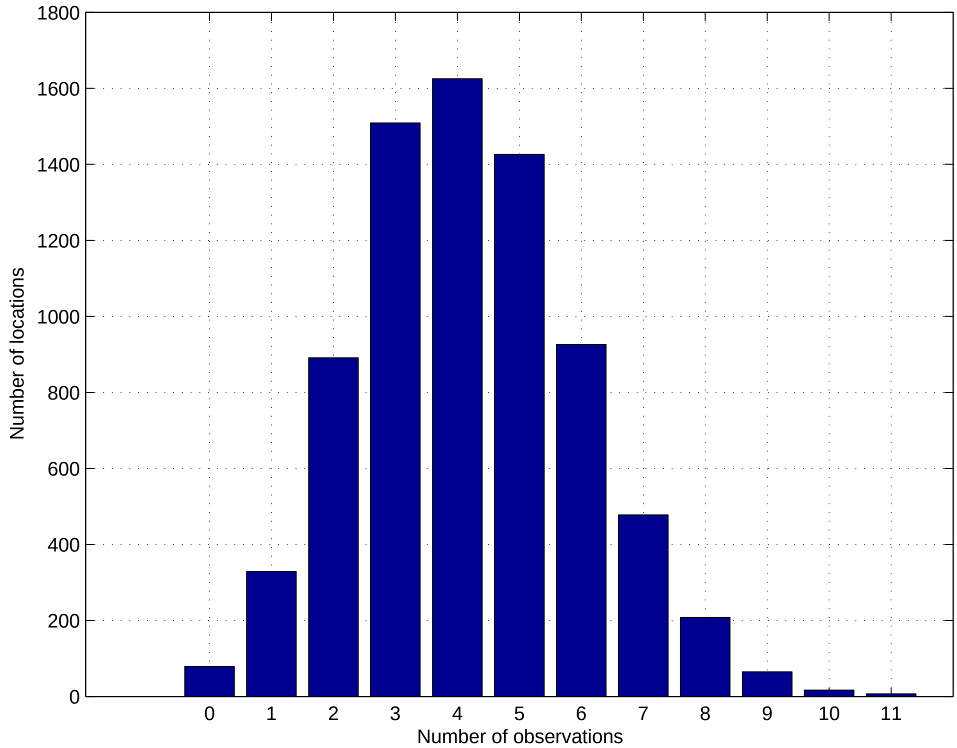

Figure 8: PDF of the number of observations per grid point using the second (fine) grid.

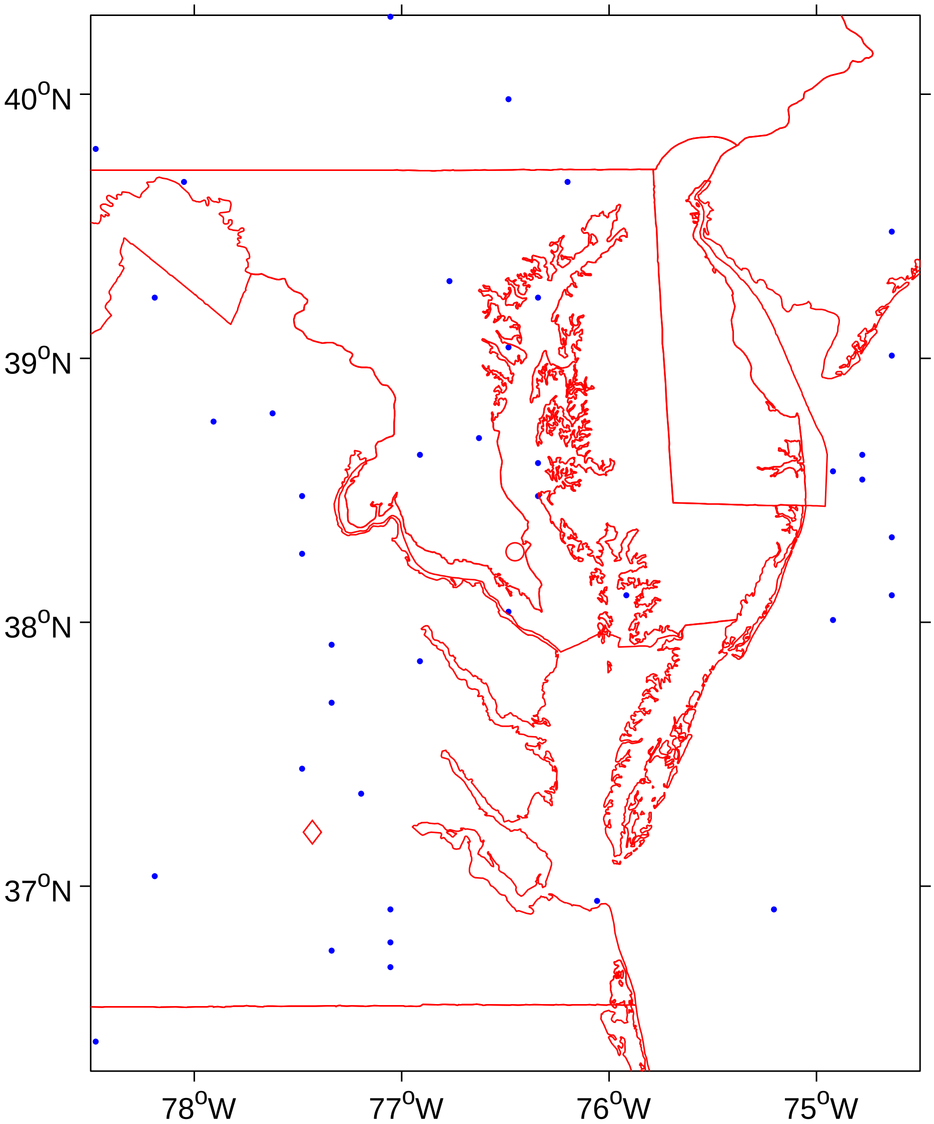

Figure 9: Locations of unobserved grid points using the second (fine) grid.

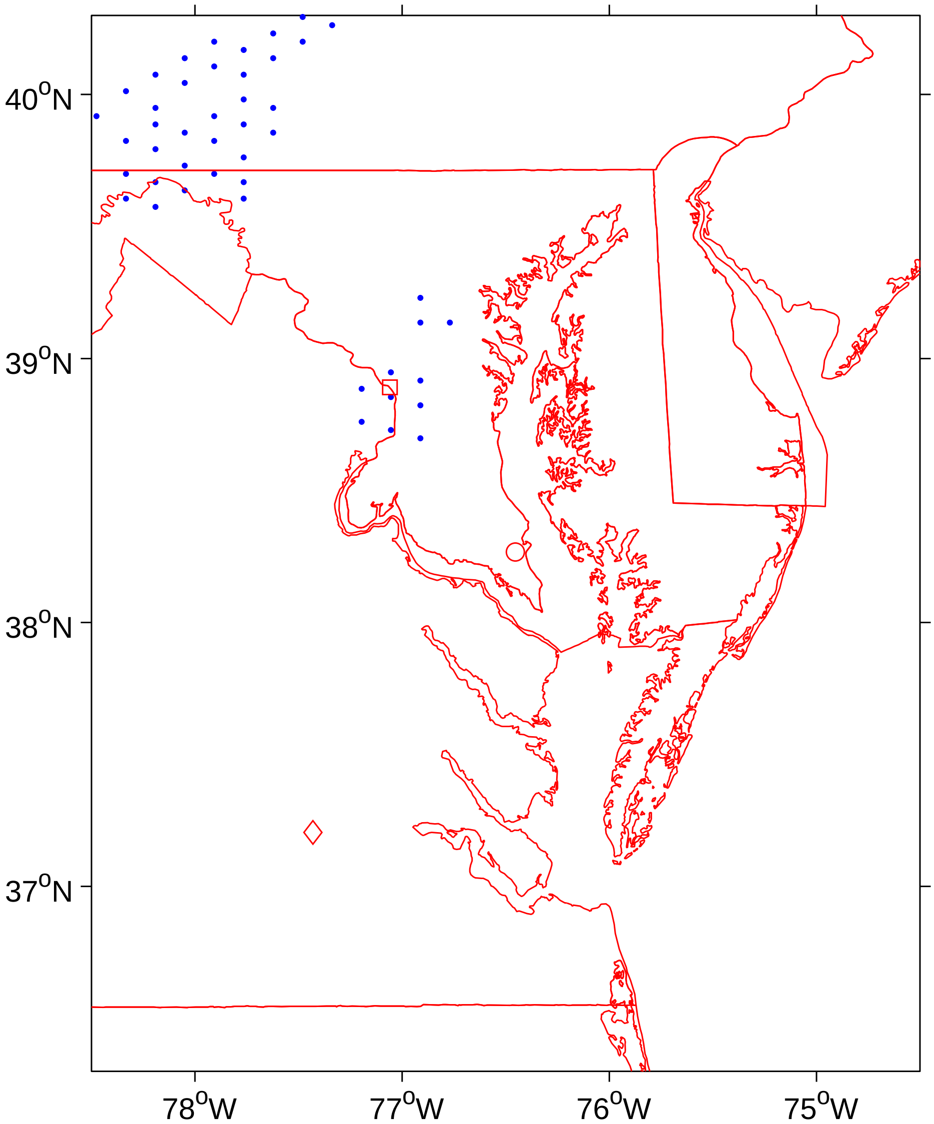

Figure 10: Grid points experiencing at least one observation of RFI, using the 330 K criterion.

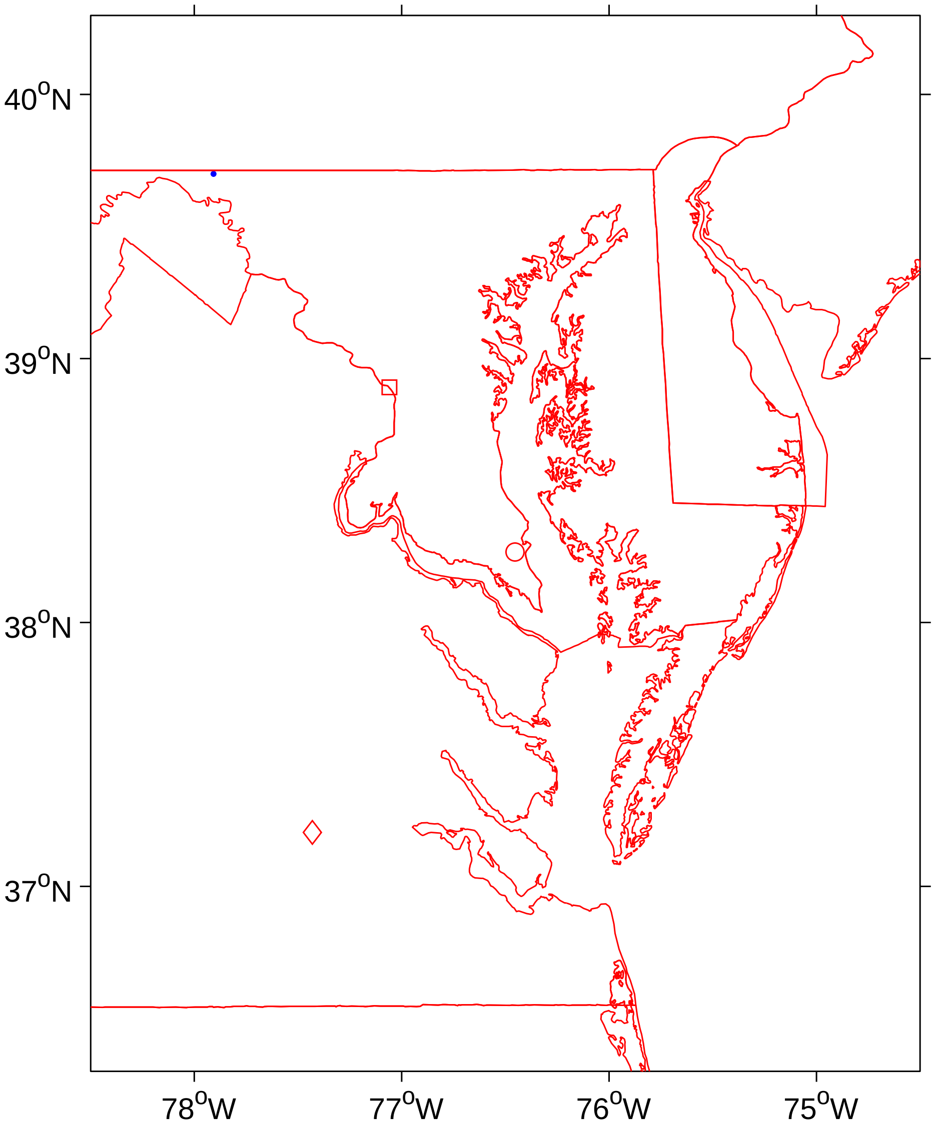

Figure 11: Grid points exhibiting RFI during *every* observation, using the 330 K criterion.

References

[1] "Soil Moisture Experiment 2004 (SMEX04) and the North American Monsoon Experiment (NAME): Preliminary Experiment Plan", November 2003.

[2] L. Li *et al.*, "A Preliminary Survey of Radio-Frequency Interference over the U.S. in Aqua AMSR-E Data," *IEEE Trans. Geoscience & Remote Sensing*, **42**, 380, 2004.

[3] P.W. Geiser *et al.*, "The WindSat Space Borner Polarimetric Microwave Radiometer: Sensor Description and Early Orbit Performance", Submitted to *IEEE Trans. Geoscience & Remote Sensing*, February 10, 2004.

[4] S.W. Ellingson, "A Preliminary Survey of C-Band RFI in the SMEX04 Area of Operations using WindSat Radiometry," Informal Report, May 28, 2004. (Contact author at ellingson@vt.edu.)