

DATA RESCUE AND QUALITY CONTROL OF
SPECIAL SENSOR MICROWAVE/IMAGER (SSM/I) DATA

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ABSTRACT

Satellite measurements from the Defense Meteorological Satellite Program's (DMSP), Special Sensor Microwave/Imager (SSM/I) have been produced since July 1987 and continue to function operationally today. National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) has served as the active archive of SSM/I data which are produced by the Navy's Fleet Numerical Meteorological and Oceanic Center. SSM/I data measurements have been used extensively to generate climate data sets (including rain, snow, ice, cloud liquid water, and total precipitable water) in support of both national and international programs. Due to the incomplete archive of SSM/I data at NCDC, this study will explain the data rescue efforts currently being undertaken to find SSM/I data before 1993 (mainly F-8, F10 and F11 satellites). This study will also identify and provide a solution to some of the major data quality issues of SSM/I data before February 4, 1997, which has made it unreliable for use by potential customers. In order to devise a data quality algorithm that is more comprehensive than simple threshold algorithms and preserves the original data, an appended file containing a data flag classification scheme was determined to be most effective. Data quality flags address error caused by sun glint, climatology quality control checks, geolocation checks, nonphysical distance between pixels, temperature threshold checks, unrealistic latitude/longitude values, non-linear or disconnected time values, and erroneous adjacent/cross-polarization pixel values. Complete archiving of SSM/I data and the application of data quality algorithms will be the first step in reaching a critical level of data maturity and preservation.

1. INTRODUCTION

The use of passive microwave measurements to retrieve global products of various hydrological parameters has been demonstrated for nearly 30 years: research sensors such as the Electrically Scanning

Microwave Radiometer (ESMR) and the Scanning Multichannel Microwave Radiometer (SMMR), which operated in the 1970's on board NASA research satellites clearly demonstrated the near all weather capability that passive microwave sensors possess, thus offering regular measurements of features such as snow cover and sea-ice concentration, despite the presence of cloud cover (Zwally et al, 1981; Chang et al., 1987).

The real breakthrough came about with the launch of the first Special Sensor Microwave Imager (SSM/I) on board the Defense Meteorological Satellite Program (DMSP) F-8 satellite in June of 1987 (Hollinger et al., 1987); this operational sensor, designed primarily to support the day-to-day operations of the U.S. Department of Defense, has proven to be extremely reliable and continues to provide excellent measurements of the Earth's surface and atmosphere (now entering its twentieth year of continuous operation from a series of six satellites – F-8, F-10, F-11, F-13, F-14, and F-15, the latter three which are still operating). This sensor series continues with an enhanced sensor; the Special Sensor Microwave Imager Sounder (SSMIS), which combines the entire suite of original DMSP microwave sensors (e.g., SSM/I, SSM/T and SSM/T-2) into a 24 channel instrument. The DMSP satellites are designed to operate at two nominal overpass times: approximately 6 am/6 pm local time and 10 am/10 pm. The "early morning" satellites are F8, F11 and F13 while the "mid-morning" satellites are F10, F14, F15 and F16.

1.1 *Establishing a Complete and Uniform SSM/I Time Series*

The SSM/I was first placed into operation in June 1987 on board the DMSP F-8 satellite. Since then, five other SSM/I sensors have operated, with three still functioning. Figure 1 documents the time series; note that beginning in 1990, there have been at least two SSM/I sensors in operation and beginning in 1999, there have been three in operation. Also, note that the F-16 has the first SSMIS.

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Month, Year	F8	F10	F11	F13	F14	F15	F16
1987	•	•	•	•	•	•	•
1988	•	•	•	•	•	•	•
1989	•	•	•	•	•	•	•
1990	•	•	•	•	•	•	•
1991	•	•	•	•	•	•	•
1992	•	•	•	•	•	•	•
1993	•	•	•	•	•	•	•
1994	•	•	•	•	•	•	•
1995	•	•	•	•	•	•	•
1996	•	•	•	•	•	•	•
1997	•	•	•	•	•	•	•
1998	•	•	•	•	•	•	•
1999	•	•	•	•	•	•	•
2000	•	•	•	•	•	•	•
2001	•	•	•	•	•	•	•
2002	•	•	•	•	•	•	•
2003	•	•	•	•	•	•	•
2004	•	•	•	•	•	•	•
2005	•	•	•	•	•	•	•
~07/2006	•	•	•	•	•	•	•

Figure 1. Summary of SSM/I and SSMIS (F16) time series. The red dots indicated the years where data are available; gray indicates that the sensor was not in operation while both dots indicate the year the data first became available. (Ferraro and Weng, 2006).

Pilot studies have initiated the process of an SSM/I data “rescue” as a first step in developing SSM/I CDRs. Such a step is necessary as the SSM/I data was not initially archived at NOAA National Environmental Satellite Data and Information Service (NESDIS) due to complications in the Shared Processing agreement between NOAA and the Department of Defense. It was not until the early-1990’s that the SSM/I Temperature Data Records (TDR), Sensor Data Records (SDR) and Environmental Data Records (EDR) were even made available at NESDIS while it was several years later before they were archived. Significant progress has been made at NCDC and NOAA Center for Satellite Applications & Research (STAR) on recovering much of these data; it is assumed that this project will leverage off such continued activities and that the majority of the SSM/I radiance data and corresponding metadata will be available to this project. As part of this data rescue effort, the F-8 data set was obtained from an archive maintained at Colorado State University and additional F10 and F11 data were obtained from NOAA Environmental Technology Labs (ETL). This study is a collaborative effort with NOAA STAR and their proposal to the Scientific Data Stewardship program that will address the accurate characterization of the calibration targets, intersensor biases and non-linearities in the conversions from antenna temperatures to brightness temperatures (Ferraro and Weng, 2006). Current plans at NCDC are to have all of the SSM/I data sets available through CLASS within the next few years.

1.2 Identify SSM/I Data Processing Issues before February 1997

NCDC and STAR have been working to improve the quality of SSM/I (Special Sensor Microwave Imager) data that has been archived before February 1997. This study focuses mainly on the lack of reliable SSM/I data and will attempt to identify all the data processing problems that have been identified before February 4, 1997. This study will also suggest a solution to deal with the array of data quality issues that have been found in the course of reading and displaying SSM/I data for the same period.

As the producer of DMSP SSM/I data, Navy’s Fleet Numerical Meteorology and Oceanography Center (FNMOC) has supplied NOAA NESDIS with SSM/I TDR, SDR and EDR data since 1992. These datasets are accessible to customers through NOAA’s Comprehensive Large Array-data Stewardship System (CLASS). At Navy FNMOC, the processing of SSM/I data has improved drastically starting in early 1997 (Personal Communication, Jeffrey Haferman, Navy FNMOC, Monterey, CA). It was stated that FNMOC had an inadequate quality control system set up in the operational processing codes prior to early 1997 and that these earlier data scans got dropped on a regular basis and the remainder of the orbit were either continued as normal, discarded, assigned zero values, or assigned unrealistic values that were one order of magnitude higher than expected. Also, FNMOC did not reship complete data to NESDIS when a short dataset was created, so only portions of an orbit were being sent, and the rest were discarded. It was indicated that more rigorous operational data processing systems were implemented after on and after February 4, 1997 (Figure 2).

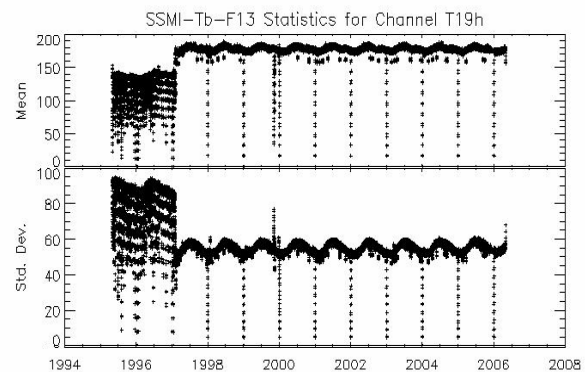


Figure 2. SSM/I F-13 19 GHz horizontal brightness temperatures from SDR data sets and corresponding statistics showing erroneous data before 2/4/1997 and other noisy trends at the end of every year.

2. APPLYING QUALITY CONTROL

Figure 3 shows the “improvement” in SSM/I data after a simple brightness temperature (Tb) threshold check is applied ($100K < Tb < 325K$) compared to Figure 2.

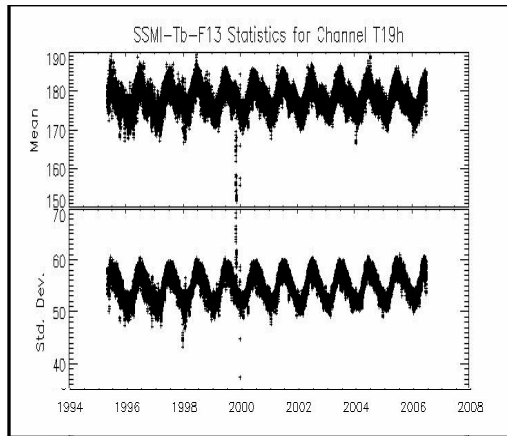


Figure 3. SSM/I F-13 19 GHz horizontal brightness temperatures from SDR data sets and corresponding statistics after a simple temperature threshold check is applied ($100\text{K} < T_b < 325\text{K}$). A few interesting features to note are a few periods of "noisy" data in early 1998 and late 1999 associated with calibration errors and/or data processing errors.

Time disconnection and orbit files that end with zeroes are illustrated in Figure 4.

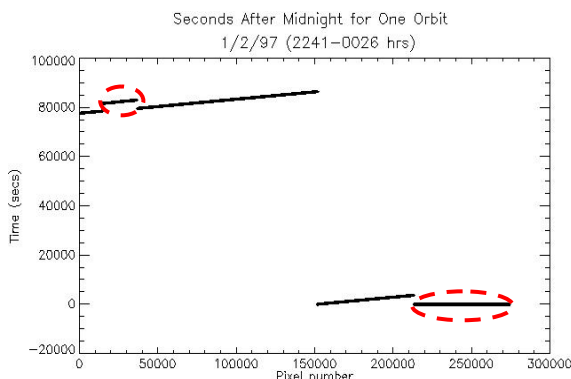


Figure 4. SSM/I F-13 time values for one orbit from SDR dataset. Note the short jump in time shown in the top left red circle and the zeroes toward the end of the orbit shown in bottom right red circle.

However, threshold checks are inadequate for the purpose of handling systematic errors that occur in SSM/I data. In determining the best method of characterizing these errors, it was important to leave the original orbital data unchanged. Data quality flags appended to each orbit file was chosen as the best option for users who prefer to test the quality flags, independently and preserves original data. A flag classification scheme based on a Colorado State University "level 1c" radiance database for NASA's Global Precipitation Measurement (GPM) mission (Berg and Kummerow, 2005) was used to characterize the non-physical error and warnings to potential users.

In this flag classification scheme, a zero value indicates good temperature values. Values from 1 to 9

indicate cautionary flags, so temperatures are not set to the missing value. Values from 10 to 90 indicate major issues for at least one channel. Flags are set in the following order of priority: 10, 20, 30, 40, 50, 60, 70, 1, 2, 0. Specific flag values are:

0 = Good data in all channels in the swath

1 = Possible sun glint

2 = Climatology QC check warning

10 = Data is missing from input file or unreadable

20 = Geolocation check flagged pixel as bad

30 = Climatology check flagged pixel as bad

40 = Distance between pixels is nonphysical

50 = Antenna temperatures are $< 50\text{K}$ or $> 325\text{K}$

60 = Lat/lon values are out of range

70 = Adjacent/cross-polarization pixel flagged as bad

Another quality control issue that is being addressed presently is the existence of SSM/I TDR and SDR NESDIS data filenames that claim to have 105 minutes of data, for example, but the physical size of those files indicate that there are only 30 kilobytes of data, when they should have file sizes that are more than 4 megabytes. Data files with such discrepancies are currently being identified and placed in a separate location.

3. SUMMARY AND CONCLUSIONS

This study is part of a Scientific Data Stewardship proposal to intercalibrate and reprocess SSM/I data from its inception in 1987. The acquisition of all data from 1987 is crucial in moving forward with this goal. The data processing issues before February 4, 1997 will be important to identify using a flag classification scheme, until it is eventually replaced in the next few years with reprocessed and intercalibrated SSM/I data. This study is a first step in providing accurate and quality controlled data to users of SSM/I data

4. REFERENCES

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