Climate Data Record (CDR) Program

Climate Algorithm Theoretical Basis Document (C-ATBD)

Global Precipitation Climatology Project (GPCP) Daily Analysis

Precipitation – GPCP Daily CDR

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1. Introduction

1.1 Purpose

The purpose of this document is to describe the algorithm submitted to the National Centers for Environmental Information (NCEI) by the University of Maryland (PI Robert Adler) that will be used to create the Global Precipitation Climatology Project (GPCP) Climate Data Record (CDR) Daily analysis, which spans the time period October 1996 to the near present. The GPCP Daily analysis is a companion to the GPCP Monthly analysis, as many users need precipitation estimates at finer space and time scales than the GPCP monthly analysis provides. The GPCP Daily V1.3 analysis is currently computed by the University of Maryland and submitted to NCEI. The routine update of the product takes place two months after the end of the month, once all input data sets become available. If all data sets are not available or do not pass quality control tests, the calculation and submission are postponed. The data set is part of World Climate Research Program (WCRP) and GEWEX activities, being part of the array of data sets describing the water and energy cycles of the planet under the auspices of the GEWEX Data and Assessment Panel (GDAP). Up to now (2016) the GPCP analysis has been produced by a consortium of individual scientists at various government and university institutions. Incorporating the GPCP daily production and distribution into the CDR Program will formalize its production under NOAA's commitment for continued production and distribution. The GPCP daily product blends data from polar-orbit passive microwave satellites (SSMI, SSMIS), polar orbit IR sounders (TOVS, AIRS), geostationary infrared satellites (GOES, MeteoSat, GMS, MTSat) and the GPCP monthly analysis. The actual algorithm is defined by the computer program (code) that accompanies this document, and thus the intent here is to provide a guide to understanding that algorithm, from both a scientific perspective and in order to assist a software engineer or end-user performing an evaluation of the code.

1.2 Definitions

Symbols are defined where used.

1.3 Document Maintenance

This document describes the initial submission of the Precipitation - GPCP Daily CDR ATBD.

2. Observing Systems Overview

2.1 Product Generated

This document describes the GPCP Daily CDR. The primary output of this algorithm is daily surface precipitation starting in October 1996 on a 1°, globally complete grid obtained by merging precipitation estimations from satellites and adjusting the merged result to the GPCP Monthly analysis. The GPCP Daily product is described in detail in Huffman et al. (2001). The evolution of the companion GPCP Monthly analysis is described in Huffman et al. (1997), Adler et al. (2003), Huffman et al. (2009) and Adler et al. (2017).

2.2 Instrument Characteristics

The daily GPCP precipitation product is based on data from polar orbiting satellites, geostationary satellites, and monthly GPCP precipitation product. The actual data used is described in section 3.3.1. The following gives information on satellite sensor characteristics that are relevant for this climate data record.

SSM/I

The Special Sensor Microwave/Imager (SSM/I) is a multi-channel passive microwave radiometer that has flown on selected Defense Meteorological Satellite Program (DMSP) platforms since mid-1987. The DMSP is placed in a sun-synchronous polar orbit with a period of about 102 min. The SSMI provides vertical and horizontal polarization values for 19, 22, 37, and 85.5 GHz frequencies (except only vertical at 22) with conical scanning. Pixels and scans are spaced approximately 25 km apart at the suborbital point, except the 85.5-GHz channels are collected at approximately 12.5 km spacing. The channels have resolutions that vary from 12.5x15 km for the 85.5 GHz (oval due to the slanted viewing angle) to 60x75 km for the 19 GHz.

The polar orbit provides nominal coverage over the latitudes 85°N-S, although limitations in retrieval techniques prevent useful precipitation estimates in cases of cold land (scattering), land (emission), or sea ice (both scattering and emission). Further details are available in Hollinger et al. (1990).

SSMIS

The Special Sensor Microwave Imager/Sounder (SSMIS) is a multi-channel passive microwave radiometer that has flown on selected Defense Meteorological Satellite Program (DMSP) platforms since late 2003 as a follow-on to the SSMI instrument. The DMSP is placed in a sun-synchronous polar orbit with a period of about 102 min. The SSMIS provides vertical and horizontal polarization values for the SSMI-like 19, 22, 37, and 91 GHz frequencies (except only vertical at 22) with conical scanning, as well as other channels with a heritage in the Special Sensor Microwave/Temperature 2 (SSMT2) sensor. The SSMI/like frequencies use three separate feed horns: one for the 91 GHz channels, another for the 37 GHz channels and a third for the 19 and 22 GHz channels. This means that there is not a 1:1 co-location of channel values, as there is for SSMI. The SSMI-like channels have the resolutions 46.5x73.6 km (19, 22 GHz) 31.2x45.0 km (37 GHz) 13.2x15.5 km (91 GHz) with the slanted viewing angle and in-line processing determining the oval shape.

The polar orbit provides nominal coverage over the latitudes 85°N-S, although limitations in current retrieval techniques prevent useful precipitation estimates in cases of cold land (scattering), land (emission), or sea ice (both scattering and emission).

The SSMIS is an operational sensor, so the data record suffers some gaps in the record due to processing errors, down time on receivers, etc. Over time the coverage has improved as the operational system has matured.

GPCP Monthly Analysis Version 2.3

The GPCP monthly product blends data from gauges (from the Global Precipitation Climatology Center), precipitation estimates from polar-orbit passive microwave satellites (SSMI, SSMIS) polar orbit IR sounders (TOVS, AIRS) and geostationary infrared satellites (GOES, MeteoSat, GMS, MTSat). This product starts in January 1979 on a 2.5°, globally complete grid.

TOVS

The TIROS Operational Vertical Sounder (TOVS) dataset of surface and atmospheric parameters is derived from analysis of High-Resolution Infrared Sounder 2 (HIRS2) and Microwave Sounding Unit (MSU) data aboard the NOAA series of polar-orbiting operational meteorological satellites. The precipitation estimates from TOVS are derived as a secondary product utilizing various retrieved sounding parameters, including atmospheric temperature and water vapor profiles, cloud-top pressure and radiatively effective fractional cloud cover.

For the period October 1996 - February 1999, the TOVS estimates are based on two NOAA satellites. Beginning in March 1999, the TOVS estimates are based on a single NOAA satellite. This occurred as the result of the failure of NOAA-11. More information can be found in Susskind et al. (1997)

AIRS

The Atmospheric Infrared Sounder (AIRS) aboard the NASA Aqua polar-orbiting satellite is the source of precipitation estimates to follow-on after TOVS (in 2005). The precipitation estimates from AIRS are derived in a very similar way to those from TOVS as a secondary product utilizing various retrieved sounding parameters, including atmospheric temperature and water vapor profiles, cloud-top pressure and radiatively effective fractional cloud cover.

IR Data from Geosynchronous Satellites

Precipitation estimates from mainly geosynchronous and some polar-orbit data are made using the Geosynchronous Precipitation Index (GPI) (Janowiak and Arkin, 1991) for the latitude band 40N-40S. The infrared (IR) data are collected from a variety of sensors. The primary source of IR data is the international constellation of geosynchronous-orbit meteorological satellites – the Geosynchronous Operational Environmental Satellites (GOES, United States); the Geosynchronous Meteorological Satellite (GMS), then the Multifunctional Transport Satellite (MTSat, both Japanese); and the Meteorological Satellite (Meteosat, European Community). . Gaps in geosynchronous coverage (most notably over the Indian Ocean before METEOSAT-5 began imaging there in June 1998) are filled with IR data from the NOAA-series polar-orbiting meteorological satellites. The data are accumulated for processing from full- resolution (roughly 4x8 km) images.

3. Algorithm Description

3.1 Algorithm Overview

The algorithm to produce the daily 1° GPCP product takes inputs from several different sources and merges them to create the most consistent and accurate daily precipitation estimates. An overview of the procedures, inputs and outputs of the GPCP Daily analysis can be found in Huffman et al. (2001). The algorithm as described is Version 1.3. In terms of inputs, the GPCP Daily uses the "best" quasi-global observational estimators of underlying statistics to adjust the observational datasets that have desirable time/space coverage. Specifically,

1. SSMI, then SSMIS (0.5°x0.5° by orbit, GPROF algorithm) provides fractional occurrence of precipitation, and

2. GPCP monthly analysis Version 2.3 (2.5°x2.5°) provides monthly accumulation of precipitation to algorithms applied to

3. Geosynchronous-orbit IR (geo-IR) T_b histograms (1°x1° grid in the band 40°N-40°S, 3-hourly),

4. Advanced Very High Resolution Radiometer (AVHRR) low-orbit IR (leo-IR) GPI (same time/space grid as geo-IR), and

5. TIROS Operational Vertical Sounder, then Atmospheric Infrared Sounder (TOVS, AIRS; 1°x1° on daily nodes, Susskind algorithm).

Although microwave precipitation estimates and gauge analyses are not explicitly used due to sampling limitations, the calibration of the Daily to the GPCP Monthly Version 2.3 ensures that they do have a strong influence on the overall scaling. The differences between the IR and TOVS (AIRS) datasets required that the Daily be formulated in two parts, with smoothing over the latitude band 40° to 50° in each hemisphere to help transition across the data boundary.

In the latitude band 40°N-S the Threshold-Matched Precipitation Index (TMPI) produces approximate instantaneous precipitation from the geo-IR T_b with fill-in by rescaled leo-IR GPI. It is a GPI-type algorithm with locally calibrated T_b threshold and rainrate. To do this, time/space-matched geo-IR T_b and GPROF-SSMI (SSMIS) estimates of fractional coverage by precipitation are used to set the IR T_b threshold such that instantaneous geo-IR fractional coverage equals that of the GPROF-SSMI (SSMIS) estimation. Then a single rainrate for "raining" geo-IR pixels is computed for each grid box that makes the full month of TMPI sum to the local GPCP Monthly value. Mismatches in geo-IR and GPROF-SSMI (SSMIS) precipitation cause some unrealistic TMPI conditional rain rates, so an "auditing" technique was developed to fill in reasonable values and re-estimate the geo-IR Tb threshold. A less tractable problem is that the warmest geo-IR histogram bin starts at T_b=270K, which prevents correctly setting the threshold in regions with warm-top clouds. In parallel, individual leo-IR GPI values used for fill-in are scaled by the (local) ratio of the GPCP Monthly value to the monthly sum of all available leo-IR GPI estimations.

The original TOVS and AIRS datasets tend to exhibit a very high number of rain days and a correspondingly low conditional rain rate. To overcome this, for each month in each hemisphere the local number of TOVS (AIRS) rain days was reduced by the ratio of the total number of TMPI and TOVS (AIRS) rain days at latitude 40°. The remaining non-zero daily rain amounts are rescaled to start at zero and sum over the month to the local GPCP Monthly value.

A study for the period from 1997 to 2002 indicated the instantaneous TMPI estimations showed good consistency from one time to the next and with the daily TMPI, GPI, and rescaled TOVS fields. A month of GPCP Daily estimates correctly sum to the monthly product, except in the subtropical highs where geo-IR threshold saturation becomes a problem. Even before smoothing, there is good continuity across the 40° N and S data boundary, perhaps in part because the IR and TOVS datasets both largely represent clouds. This dependence on scaled cloud information implies that users should expect larger errors in the individual daily values, and preliminary validation results support this view. Space and/or time averages should be more reliable.

3.2 Processing Outline

The processing for the daily 1° GPCP CDR is split into five different steps referred to as m1-m5.

m1. The first step is a simple diagnostic step where checks of inputs are carried out and listings of input files are made. The details of the inputs (blue and orange boxes) data are described in Section 3.3.1.

m2. The second step includes pre-merge algorithms, involving the processing of SSMI and SSMIS data.

m3. The third step is another diagnostic step; simple checks are performed to ensure that the input precipitation datasets exist.

m4. The fourth step is the merger step where the satellite gauge data are produced.

m5. The fifth step is the output step where the outputs are checked and the NetCDF file is created.

The strategy and method of calculations in steps m2-m5 are described in section 3.4.3.

3.3 Algorithm Input

3.3.1 Primary Sensor Data

Table 1: Inputs to GPCP Daily Analysis

Name	Data type	GPCP time period	Data source	Notes
RSS SSMI Tb CDR	Tb	1996 to 2008	NCEI	F13: 1996 to 2008
RSS SSMIS Tb CDR	Tb	2009 to present	NCEI	Replaces SSM/I Tb; data only from F17
GPCP Monthly Analysis V2.3	Precip	1996 to present	NCEI	
TOVS	Precip	1996 to 2002	GPCP/GSFC	
AIRS V6	Precip	2003 to present	GSFC DISC	Replaces TOVS
IR 3 hourly files	Tb	1996 to present	CPC	

The SSMI/SSMIS era of July 1987 to the present provide a near homogeneous set of input data and analysis technique with the ocean precipitation estimates of the SSMI/SSMIS adjusting the GEO-IR estimates, over both ocean and land, with the gauge analysis adjusting the satellite bias over land and blending with the adjusted satellite analysis. The TOVS/AIRS estimates provide the information at higher latitudes with a smooth transition from the microwave-driven lower latitude estimates and the final blending with the gauge information.

RSS SSM/I Tb

SSM/I was a seven channel, conically scanning microwave radiometer that flew aboard the Defense Meteorological Satellite Program polar orbiting satellites. The SSM/I possessed four different frequencies (19, 22, 37 and 85 GHz) three of which had vertical and horizontally polarized channels (there was no 22H channel). GPCP daily analysis makes use of data from the F13 satellites. SSM/I Tb is obtained from NCEI from the CDR produced by Remote

Sensing Systems (RSS; Santa Clara, CA). These data have been extensively quality controlled by RSS and have been inter-calibrated using the methods described by Wentz (1997).

RSS SSMIS Tb

SSMIS is a 24 channel, conically scanning microwave radiometer that replaced the SSMI and flies aboard DMSP polar orbiting satellites. Only the 7 SSM/I-like channels are used for GPCP although the 85GHz channel on SSM/I was replaced with a 91GHz channel. At present, only data from F17 is used in GPCP. SSMIS data is also obtained from the NCEI CDR produced by RSS. The RSS SSMIS Tb are produced with the RSS V7 calibration, so a correction is applied in the GPCP CDR software to calibrate these data to the RSS V6 intercalibration standard.

TOVS precipitation

The Television Infrared Operational Satellite (TIROS) Operational Vertical Sounder (TOVS) instrument flew aboard the NOAA series of polar-orbiting platforms. Susskind and Pfaendtner (1989) and Susskind et al. (1997) described the process for estimating precipitation from TOVS The TOVS precipitation estimates infer precipitation from deep, extensive clouds. The technique uses a climatological multiple regression relationship between collocated FGGE precipitation gauge measurements and several TOVS-based parameters that relate to cloud volume: cloud-top pressure, fractional cloud cover, and relative humidity profile. This relationship is allowed to vary seasonally and latitudinally. Furthermore, separate relationships are developed for ocean and land.

The TOVS data are used for 1999 - 2002 and are provided as daily 1° gridded estimates. The data covering the span October 1996 - February 1999 are based on information from two satellites. For the period March 1999 - December 2002, the TOVS estimates are based on information from one satellite due to changes in satellite data format. TOVS data were obtained directly from Joel Susskind and are supplied as part of the GPCP CDR source data.

AIRS precipitation (V6)

The Advanced Infrared Sounder (AIRS) instrument flew aboard the Earth Observing System Aqua polar-orbiting satellite and was used to replace TOVS data. The same algorithm applied to TOVS to produce precipitation was also applied to AIRS (Susskind and Pfaendtner, 1989; Susskind et al., 1997). The AIRS data are also obtained in daily mean 1° gridded format. AIRS data are available from May 2002 and used for the period from January 2003 – present. The AIRS precipitation estimates have been bias-adjusted to the TOVS estimates to minimize the TOVS/AIRS data boundary. Matched histograms of precipitation were computed between the TOVS and AIRS data for the months January, April, July, and October 2004. These seasonal calibrations are applied accordingly to the corresponding seasonal months of data.

Geostationary Data

The geostationary IR data used for the GPCP Daily product is the same as used for the Monthly product. However, whereas for the Monthly product the GOES Precipitation Index

(GPI; Arkin and Meisner, 1987) is used and then adjusted, for the Daily product the TMPI procedure is used (see below). The data is processed and provided by Pingping Xie at NOAA CPC. The geostationary data includes inputs from the Geosynchronous Operational Environmental Satellites (GOES, USA), the Geosynchronous Meteorological Satellite (GMS, Japan), the Multifunctional Transport Satellite (MTSat, Japan) and the Meteorological Satellite (Meteosat, European Community). The data is three-hourly channel 4 ~10.7 micron thermal infrared (IR) imagery that is merged and zenith angle corrected at NOAA CPC.

Starting with October 1996 the geostationary IR data were accumulated on a 1° grid for individual three hourly images. Gaps in geostationary data are filled with leo-IR data from the NOAA series of polar orbiting meteorological satellites. The Indian Ocean sector routinely lacked geo-IR coverage until Meteosat-5 was repositioned to that region starting 06 UTC 16 June 1998.

3.3.2 Ancillary Data

Not Applicable

3.3.3 Derived Data

Not Applicable

3.3.4 Forward Models

Not Applicable

3.4 Theoretical Description

3.4.1 Data Merging Strategy

GPCP is created by merging precipitation estimates in several different stages. Each of these stages leads to the creation of interim products, some of which are given as outputs. Each stage of processing is described below. All the merging of data is done in processing step m4.

Threshold-Matched Precipitation Index (TMPI)

The geo-IR histograms are interpolated to a 1-K interval (Joyce and Arkin 1997) and corrected for zenith angle effects (Joyce et al. 2001), providing an estimate of the true nadir-view IR *Tb*s. Both steps tend to broaden the geo-IR histograms because both involve estimating sub-bin histogram structure. Such broadening occurs equally in the calibration and estimation steps, so it likely introduces additional random error, but not bias. The revised geo-IR histograms are matched within 1.5 h to the microwave-based frequency of precipitation and each is accumulated for the month. To further ensure stability, the monthly matched accumulations are smoothed with a 7-3-7 grid-box boxcar filter. In each grid box, the geo-IR histogram is summed starting with the coldest bin until the cumulative fraction of total pixels matches the microwave-based fractional coverage, and *Tb*(rain) is set to the corresponding *Tb* . This *Tb*(rain) is applied to the 7 3 7-box-smoothedsum of *all Tb* histograms in the box for the month, yielding the fractional occurrence of rain in the full geo-IR dataset for the month, f_{IR} . The single local conditional rain rate for all raining pixels during that month is computed as

$$R_c = r_{mon}/f_{IR},$$

Where R_c is daily conditional rainrate, r_{mon} is monthly precipitation from GPCP monthly analysis, and f_{IR} is the fractional occurrence of rain.

Holes occur in individual geo-IR images, most routinely in the Indian Ocean sector, where no geo-IR data were available until June 1998. To compensate, leo-IR estimates from NOAA–series polar-orbiting satellites are processed to fill in holes as necessary.

Because the TMPI is required to sum to the monthly product over the month to maintain consistency between daily and monthly products, all computations are carried out in millimeters per day, although Rc is discussed in millimeters per hour to conform to the usual representation of pixel-level precipitation.

Daily TOVS

Outside the latitude band covered by the merged IR dataset (40°N–40°S) it is necessary to base the GPCP Daily on the precipitation estimates that are computed as part of the Susskind et al. (1997) TOVS Pathfinder Path A dataset. The TOVS Path A algorithm uses an atmospheric model to generate a first guess for retrieval of various atmospheric parameters, including cloud-top pressure, fractional cloud cover, and relative humidity profile from NOAA-series satellite data. The precipitation algorithm is a regression between these parameters and surface data stratified by latitude, month, and land/ocean surface type. The result is instantaneous pixel-by-pixel precipitation estimates. TOVS precipitation was chosen for the Daily based on global coverage, reasonable performance, and we previous experience with monthly accumulations of this product in developing the GPCP monthly product. The TOVS precipitation estimates are provided as daily averages on a 1° x 1° global grid.

3.4.2 Numerical Strategy

Not applicable.

3.4.3 Calculations

The GPCP Daily code is made up of around 150 individual code files, which are distributed among 6 modules of code plus another 4 codes to create file listings and perform pre- and post processing diagnostics. The code is run by a single driver code (shell script)in the main directory that mirrors the monthly code (GPCPcdr_ECPd_Process1month.sh) that performs a check that all data is present and then calls each of the constituent parts of the processing code.

Once the data is ready, GPCPcdr_ECPd_Process1month.sh can be used to produce one month of daily GPCP NetCDF files. The code is broken into steps with code stored in the following directories:

a. GPCPcdr_d1
All the data required to run the GPCP daily analysis should be already produced after the initial run of the GPCP monthly analysis. This is the directory for pre-processing steps and tests, including following shell scripts:
GPCPcdr_d1_ChkL1files.sh - checks that all files are in place for given month
GPCPcdr_d1_GetInputFiles.sh - obtains file listings required for processing

b. GPCPcdr_d2
This is the directory containing the pre-merge algorithms.
GPCPcdr_d2_GPROFv2004_SSMI - run algorithm GPROF V2004 algorithm for SSMI
GPCPcdr_d2_GPROFv2004_SSMIS - run algorithm GPROF V2004 algorithm for SSMIS

c. GPCPcdr_d4
This is the directory including all codes to merge data for GPCP daily output.
GPCPcdr_d4_CORR_G - compute threshold for calculation of IR precipitation
GPCPcdr_d4_ADJIR - match IR to GPROF and scale to monthly product
GPCPcdr_d4_CORR_T - compute correction coefficients for merger
GPCPcdr_d4_FUSE2 - combines SSMI/SSMIS, TOVS/AIRS and IR to produce the final satellite/gauge data (already adjusted to the monthly CDR)

d. GPCPcdr_d5
This directory has the codes to produce output files and diagnostics.
GPCPcdr_d5_WriteNC - write daily CDR NetCDF files for current month

3.4.4 Look-Up Table Description

Not applicable.

3.4.5 Parameterization

Not applicable.

3.4.6 Algorithm Output

The GPCP Daily Version 1.3 Combined Precipitation Data Set, covering the period October 1996 through the present (with 2+ months delay). The primary product in the dataset is a combined observation-only dataset, that is, a gridded analysis based on satellite estimates of precipitation and the GPCP Monthly analysis.

The data set archive consists of monthly unformatted REAL*4 binary files with ASCII headers, each of which holds 28-31 daily fields. Each file occupies almost 5 MB. The grid on which each field of values is presented is a 1°x1° latitude--longitude (Cylindrical Equal Distance) global array of points. It is size 360x180, with X (longitude) incrementing most rapidly West to East from the Prime Meridian, and then Y (latitude) incrementing North to South. Grid edges are placed on whole- and half-degree values:

First point center = (89.5°N, 0.5°E)
Second point center = (89.5°N, 1.5°E)
Last point center = (89.5°S, 0.5°W)

Missing values are denoted by the value -99999, and the unit of rainfall is mm/day.

4. Test Datasets and Outputs

4.1 Test Input Datasets

Initial test input data sets will consist of the next (or last) month of data inputs.

4.2 Test Output Analysis

4.2.1 Reproducibility

Reproducibility will be shown by comparison with results of parallel runs at UMD.

4.2.2 Precision and Accuracy

Precision of daily rainfall rates is given in units of mm/d.

4.2.3 Error Budget

Not applicable

5. Practical Considerations

5.1 Numerical Computation Considerations

Not applicable

5.2 Programming and Procedural Considerations

Not applicable

5.3 Quality Assessment and Diagnostics

The diagnostic analyses and plots of the output products are performed every month, with comparison to climatologies. Attention will be paid to any anomalies for further examinations.

5.4 Exception Handling

Not applicable

5.5 Algorithm Validation

Not applicable.

5.6 Processing Environment and Resources

The computer used to process the GPCP Daily product is Red Hat Enterprise Linux Server release 6.7 (version 2.6.32-573.7.1.el6.x86_64). The programming languages and software include: shell scripts to run the processing code; FORTRAN programs to perform most of the calculations; C programs to generate the outputs; MATLAB to make the diagnostic plots.

6. Assumptions and Limitations

6.1 Algorithm Performance

Not applicable.

6.2 Sensor Performance

Not applicable.

7. Future Enhancements

Not applicable.

8. References

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Appendix A. Acronyms and Abbreviations

Acronym or Abbreviation	Definition
AIRS	Atmospheric Infrared Sounder
C-ATBD	Climate Algorithm Theoretical Basis Document
CDR	Climate Data Record
GDAP	GEWEX Data and Assessment Panel
GMS	Geosynchronous Meteorological Satellite
GOES	Geosynchronous Operational Environmental Satellites
GPCP	Global Precipitation Climatology Project
HIRS2	High-Resolution Infrared Sounder 2
IR	Infrared
MSU	Microwave Sounding Unit
MTSat	Multifunctional Transport Satellite
NCEI	National Centers for Environmental Information
NOAA	National Oceanic and Atmospheric Administration
SSM/I	Special Sensor Microwave/Imager
SSMIS	Special Sensor Microwave Imager/Sounder
SSMT2	Special Sensor Microwave/Temperature 2
TIROS	Television Infrared Operational Satellite
TMPI	Threshold-Matched Precipitation Index
TOVS	TIROS Operational Vertical Sounder
WCRP	World Climate Research Program