A Fundamental Climate Data Record of SSM/I, SSMIS and Future Microwave Imagers

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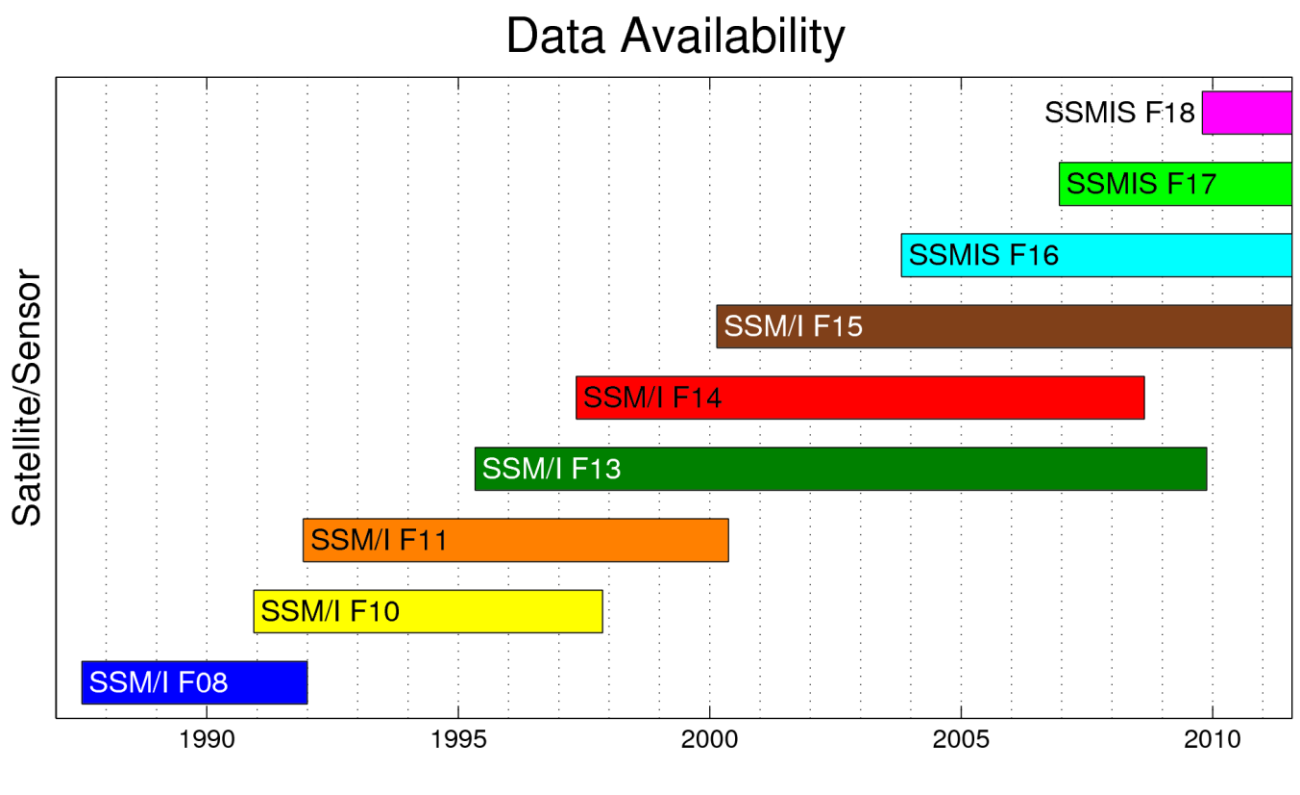
Outline

- Brief Project Overview
- Approach (1-2 slides)
- Results/Accomplishments (1-3 slides)
- Validation Strategy/Results (1-2 slides)
- Algorithm/Product Maturity
- Issues/Risks & Work-Off Plans
- Schedule
- Transition Plan
- Societal Benefits (2 slides)
- Resources (1-2 slides)

Overview
(Goals)

- Generate a transparent and documented Fundamental Climate Data Record (FCDR) of SSM/I and SSMIS brightness temperatures from 1987 - Present.
- Develop/implement code that is sufficiently clear and modular to serve as the historical record of what has been done to the original data as well as the starting point for any subsequent work.
- Intercompare and examine calibration procedures and results to provide not only the best possible product, but also an assessment of its uncertainty.

Overview
(Source Data)



TDR (Temperature Data Record) data from DMSP SSM/I
F08, F10, F11, F13, F14, and F15 (July 1987 – Present)
TDR data from DMSP SSMIS
F16, F17, and F18 (October 2003 – Present)

Overview
(Deliverables)

- FCDR of SSM/I and SSMIS Brightness temperatures (TBs)
  - Standard NetCDF4 files; full QC applied
  - Recalculated geolocation (adding Earth incidence and solar beta angles)
  - Calibrations will be adjusted to be physically consistent for entire time series
  - Uncertainty estimates for geolocation and Tb
- Complete documentation
  - Stewardship Code: documented and commented, modular C code
  - Theoretical basis documents: Geolocation, Intercalibration

Overview
(ECVs and Current/Expected User Communities)

- FCDR Users are primarily algorithm developers (i.e. Used as input to CDRs). Examples include:
  - GPCP – Global Precipitation Climatology Project
  - Air-Sea flux datasets (Clayson/FSU)
  - NVAP – NASA Vapor Project (Vonder Haar/CSU)
  - Sea Ice products (Meyer/NSIDC)

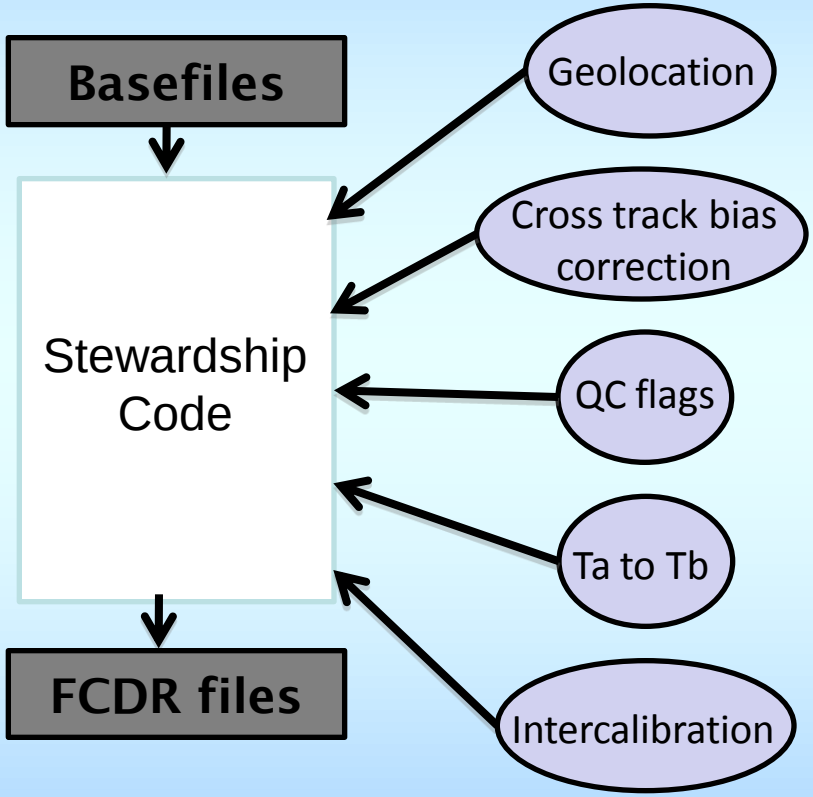
Overview
(Product Description Matrix)

- Description of project is slightly out-of-date now; the following is an updated set of text:

  The data record of operational microwave imager observations from SSM/I spans over two decades from 1987 to 2010. The follow-on to this successful series of sensors is the SSMIS, which is currently operational and will extend this record for at least the next decade. The SSM/I sensors have a long history of climate applications from the early detection of the Arctic Sea ice decline to confirmation of the coupling between sea surface temperature and total precipitable water. Indeed, the robust retrievals of water vapor, surface wind speed, cloud water and precipitation from SSM/I make it a cornerstone for global hydrologic cycle research. The current proposal combines efforts from NESDIS and CSU that have experience in dealing with climate quality SSM/I brightness temperature records. NESDIS started in the early 1990s the developments of SSM/I operational products and made the product operational for NOAA and DoD users, and recently created new procedures for climate quality time series. CSU has created a L1C dataset of passive microwave sensors intercalibrated to data from the TRMM microwave imager.

  Drawing on the expertise from both of these groups, the goal of this proposal is to identify and use the best approach from each group where this can be identified, or to fully understand and document differences in order to generate a completely transparent and documented Fundamental Climate Data Record (FCDR) of SSM/I and SSMIS brightness temperatures. Key to this effort will be the intercomparison and examination of calibration procedures and results that will provide not only the best possible product, but also an assessment of this product.

Approach
(from TDR to FCDR Files)



1. Reformat SSMI/SSMIS TDR files into NetCDF "**Base files**". These files contain **all** the original data and **nothing is modified** except to make orbit granules, add ephemeris, reformat time to YYYYMMDD_HHMMSS, and reformat to NetCDF.
2. Create a **well documented software** package ("**Stewardship code**") that ingests the Base files, applies corrections (i.e QC, cross-track bias, TA-TB, geolocation, calibration) and outputs the final FCDR in NetCDF for use by the broader community.
3. Expert users can be given access to the Base files and the "stewardship code". This gives them access to the beta versions without confusing the general users.

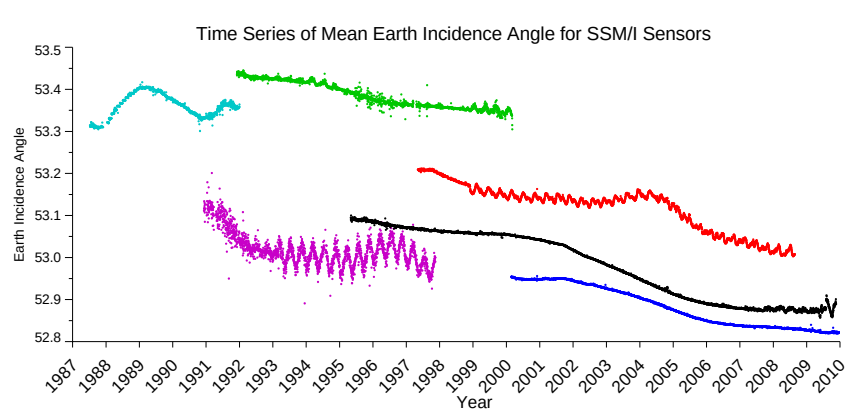
Approach
(Stewardship Code)

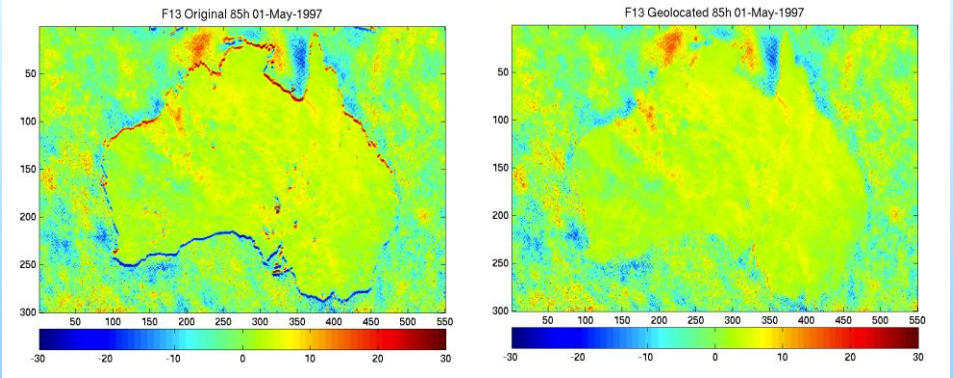
Stewardship code contains several modular components

- Geolocation - from NORAD TLEs; calculate EIA, solar beta and pixel geolocation
- Cross track bias correction
- QC procedures - climatology checks; check based on geolocation; flags for known periods
- TA to TB (from published method)
- Intercalibration

Approach
(Geolocation)

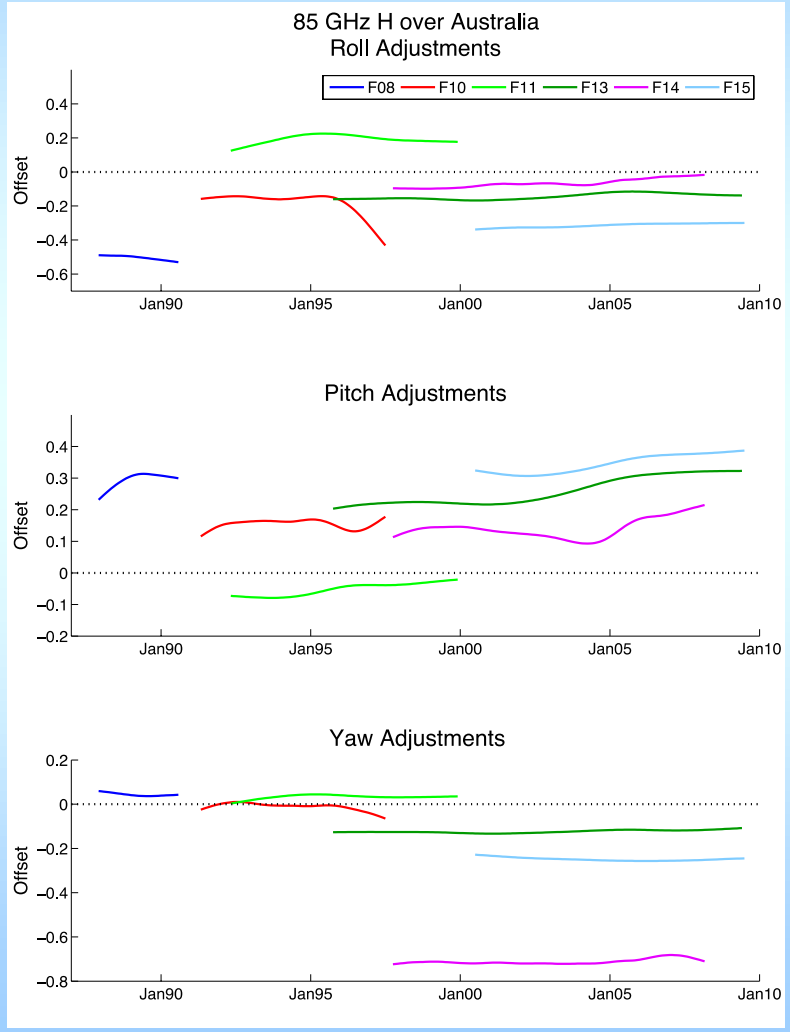
- Geolocation needs to be recalculated to obtain Earth Incidence Angle for each pixel
- Changes in EIA can have an important impact on climate trends
  - Only know nominal values for SSM/I
  - Top plot shows trends in our estimated EIA





Results/Accomplishments (Coastline analysis)

- Original SSM/I geolocation information did not include EIA
  - Need Earth Incidence Angle (EIA) for Intercalibration and as an input to geophysical algorithms
- Impact on climate is potentially large since EIA differences can lead to false trends
- Wrote geolocation code to calculate EIA from TLEs
  - C Code is available to other SDS projects
- Used a coastline analysis to estimate Roll, Pitch, Yaw for each satellite (within 0.1°)
  - Used this to get accurate (within 0.1°) pixel-resolution EIA



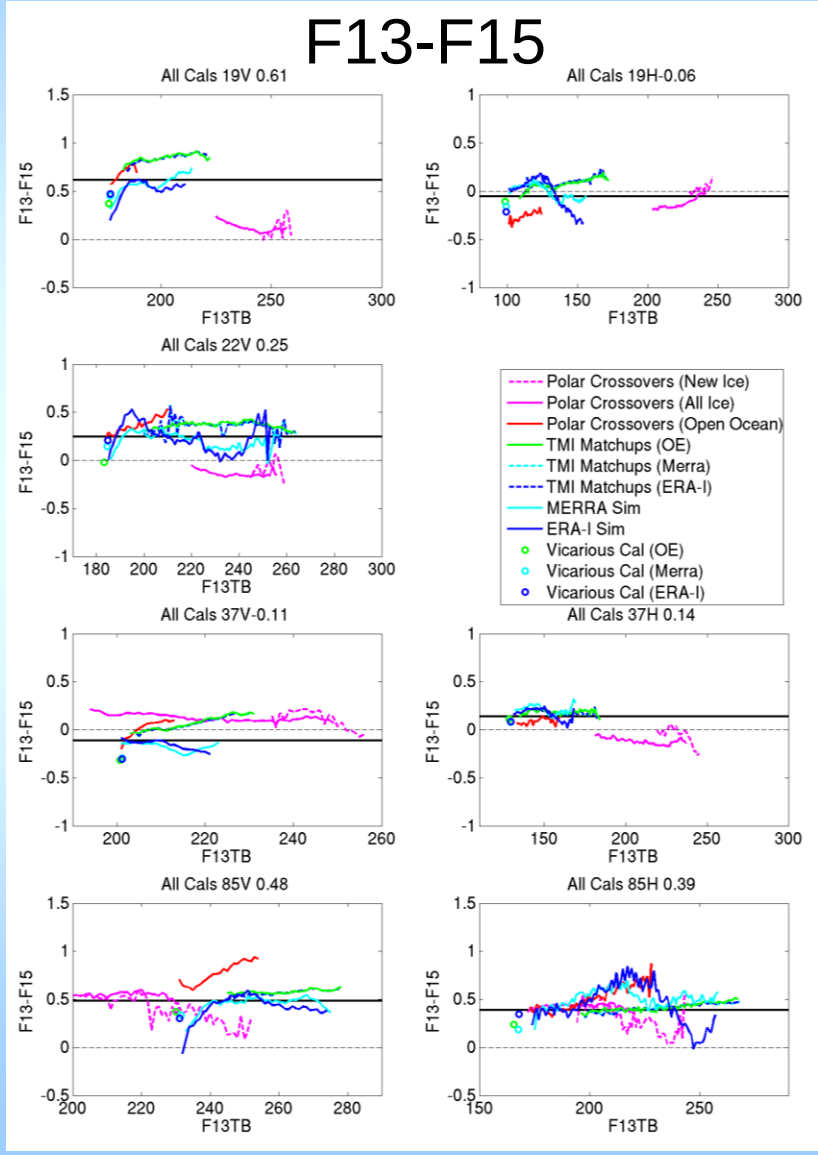
Approach
(Intercalibration)

- Investigate calibration differences using multiple approaches. Consistency/inconsistency between approaches will provide insight into methods as well as estimate of the uncertainties.
  - Coincident overpasses with TMI
  - Coincident overpasses over polar regions
  - Model double difference approach
  - Vicarious Calibration (cold and warm end)
- Goal is to understand differences and use sensor information to select correct solution.
- Techniques will then be combined using information about relative errors

Results/Accomplishments (SSM/I Intercalibration)

- Applied four techniques for Intercal, with several implementations of each technique
  - Model double difference
  - Polar Crossovers
  - TMI matchups
  - Vicarious calibration (Cold and Warm)

F13-F15	19V	19H	22V	37V	37H	85V	85H
PolarCross (Ocean)	-0.57	0.1	-0.22	-0.88	-1.03	-1.65	0.06
ModelSim	0.06	-0.2	-1.21	0.79	-0.06	-0.88	-1.13
TMIMatch	0.03	-0.19	-1.24	0.25	-0.41	-0.34	-0.08
VCC	0.13	0.06	0.02	-0.39	-0.39	0.65	1.24



Results/Accomplishments (SSM/I beta release)

- Beta Version of SSM/I released to beta testers July 2011
  - Includes QC, geolocation (EIA) and beta calibration
  - Available to small community. Contact Kummerow/Berg/Sapiano
- Used beta calibration
  - Simple additive offset based on mean of four techniques

SSM/I Beta Cal	19V	19H	22V	37V	37H	85V	85H
F08	0.38	0.04	1.41	0.48	1.48	1.89	-0.18
F10	-0.19	0.14	1.19	-0.40	0.45	0.24	-0.12
F11	-0.13	-0.06	-0.02	0.39	0.39	-0.65	-1.24
F13	0	0	0	0	0	0	0
F14	-0.01	0.17	0.07	-0.58	0.11	0.06	0.21
F15	0.62	-0.08	0.26	-0.09	0.14	0.52	0.42

Results/Accomplishments (SSMIS)

- Have obtained all available SSMIS data and created preliminary BASE files
- SSMIS has several problems that were addressed by the F16 Calibration/Validation exercise
  - Solar Intrusions into the warm load
  - Lunar intrusions into the cold load
  - Emissive antenna
- Corrections developed for these issues that are used in the FNMOC processing code were obtained from Aerospace Corp. and implemented in the SSMIS stewardship code as modules
- Currently applying coastline analysis to establish roll, pitch, yaw for geolocation
- Once these elements are in place, the same intercalibration techniques that were used for SSM/I will be applied to SSMIS
  - Only planning to intercalibrate 19, 22, 37 and 91 GHz channels, but will include other channels in FCDR

Validation Strategy

- Consistency Checks
  - Calibration -> Multiple approaches
  - Geolocation -> Ascend/descend coastline diff.
- Related Calibration Activities
  - NASA PMM XCAL
  - Comparisons with RSS Data
- Work with CDR Developers now that beta SSM/I version is available
  - GPROF Precipitation Alg. (CSU)
  - NVAP (CSU)
  - GPCP (Adler/Huffman)
  - Air-Sea Flux products (Clayson/FSU)
  - Sea Ice (Meyer/NSIDC)

Issues/Risks & Work-Off Plans

- Problems with SSM/I appear to be addressed
  - Possible that unforeseen issues may arise from beta testing
  - Always the possibility of other issues such as calibration nonlinearity, RFI, unknown errors that are difficult/impossible to quantify/correct.
- Still a number of potential issues with SSMIS
  - Data (particularly F16) are expected to have QC issues; may lose substantial amount of data if quality is low (especially pre-operational data)
  - It is unknown how the corrections for emissive antenna and intrusions will work with the APC
- Ultimately stewardship must allow for continued stewardship after delivery of code. Need continued monitoring and plans to develop new/improved techniques/approaches.

Schedule

- 6 Months (End of 2010)
  - Work with Beta version users to identify problems and correct as appropriate
  - Complete testing on SSMIS and calculate intercalibration
- 12 Months (End of project)
  - Write remaining ATBDs and Documentation; ensure code is well documented and CF compliant
  - Deliver final version of Base files, FCDR files, and stewardship code, along with all documentation to NCDC.

Transition Plan

- DOCUMENTATION (Delivery expected Summer 2012)
  - Climate Algorithm Theoretical Basis Document (C-ATBD)
    - Not yet complete; expect to do an ATBD including Intercal, geolocation and QC procedures
  - Data Flow Chart and Maturity Matrix
    - Data flow chart not yet complete

- DATA SET(S)
  - Format: NETCDF4 with internal compression
  - Metadata is mature but needs to be checked for CF compliance
  - Size of data set: currently around 4.1TB including BASE and FCDR
    - SSM/I Base Files: 1.2 TB FCDR: 1.4 TB
    - SSMIS (up to 2010 data) Base Files: 1.1 TB FCDR: 1.4 TB
    - Note: SSMIS is still operational and expect data size to grow considerably

- SOURCE CODE
  - Modular, written in C

- CONCERNS (Risks): None so far

CDR Maturity Matrix

Level	Sensor Use	Code Stability	Metadata & QA	Documentation	Validation	Public Release	Science & Applications	IV&V
1	Research Mission	Significant changes likely	Incomplete	Draft ATBD	Minimal	Limited data availability to develop familiarity	Little or none	
2	Research Mission	Some changes expected	Research grade (extensive)	ATBD Version 1+	Uncertainty estimated for select locations/times	Data available but of unknown accuracy; caveats required for use.	Limited or ongoing	ATBD Review
3	Research Missions	Minimal changes expected	Research grade (extensive); Meets international standards	Public ATBD; Peer-reviewed algorithm and product descriptions	Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood.	Data available but of unknown accuracy; caveats required for use.	Provisionally used in applications and assessments demonstrating positive value.	NOAA Operations Review
4	Operational Mission	Minimal changes expected	Stable, Allows provenance tracking and reproducibility; Meets international standards	Public ATBD; Draft Operational Algorithm Description (OAD); Peer-reviewed algorithm and product descriptions	Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood.	Source code released; Data available but of unknown accuracy; caveats required for use.	Provisionally used in applications and assessments demonstrating positive value.	
5	All relevant research and operational missions; unified and coherent record demonstrated across different sensors	Stable and reproducible	Stable, Allows provenance tracking and reproducibility; Meeting international standards	Public ATBD, Operational Algorithm Description (OAD) and Validation Plan; Peer-reviewed algorithm, product and validation articles	Consistent uncertainties estimated over most environmental conditions by multiple investigators	Source code portable and released; Multi-mission record is publicly available with associated uncertainty estimate	Used in various published applications and assessments by different investigators	CDR Certification Review
6	All relevant research and operational missions; unified and coherent record over complete series; record is considered scientifically irrefutable following	Stable and reproducible; homogeneous and published error budget	Stable, Allows provenance tracking and reproducibility; Meeting international standards	Product, algorithm, validation, processing and metadata described in peer-reviewed literature	Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation	Source code portable and released; Multi-mission record is publicly available from Long-Term archive	Used in various published applications and assessments by different investigators	

Benefit to the Science Community

- CDRs will have access to open dataset to determine if trends are real or possibly due to data issues
- Prepares stewardship data that can be incrementally improved over time

Benefit to Society

- SSMI and SSMI data record is one of the longest time series available (1987 - present). It is use to create multiple climate data records related to the global hydrologic cycle, including surface wind speed, water vapor and cloud water, as well as evaporation and precipitation. Preserving the data and ensuring a full descriptions of its heritage are essential to interpret climate signals.

  For instance, evaporation products including SeaFlux and HOAPS have a noticeable positive trend. It is not clear if this trend is real (implying more precipitation globally) or artificial due to subtle trends in SSM/I data. This work should help resolve the problem.

Resources

- Number of personnel employed for project: 2
- Key equipment used:
  - Workstation (8 processor linux)
  - Disk raid (13 TB)
- Key collaborating projects or personnel
  - Bob Adler/George Huffman (NASA/GPCP)
  - Carol Anne Clayson (FSU/Air-Sea Flux)
  - Walt Meyer (NSIDC/Sea Ice)
  - Tom Vonderhaar (CSU/NVAP)
  - Dongsoo Kim (NOAA/Precip CDR)
- NOAA points-of-contact or collaborators
  - Fuhzhong Weng (NOAA/NESDIS)
  - Hilawe Semunegus (NOAA/NCDC)
- Target NOAA Data Center (if known)
  - NCDC