P5.39 SSMIS UPPER ATMOSPHERE SOUNDING CALIBRATION AND VALIDATION PLANS

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1. Introduction

The Defense Meteorological Satellite Program (DMSP) is presently scheduled to launch the first of five Special Sensor Microwave Imager/Sounder (SSMIS) in November 2001. The SSMIS is a joint United States Air Force/Navy multi-channel passive microwave sensor that combines and extends the current imaging and sounding capabilities of three separate DMSP microwave sensors, SSM/T, SSM/T-2 and SSM/I. Built by Aerojet, the SSMIS measures the earth's upwelling partially-polarized radiances in 24 channels covering a wide range of frequencies (19–183 GHz) in an SSM/I-type conical scan geometry (53 degree earth incidence angle), maintaining uniform spatial resolution, polarization purity and common fields-of-view for all channels across the entire swath.

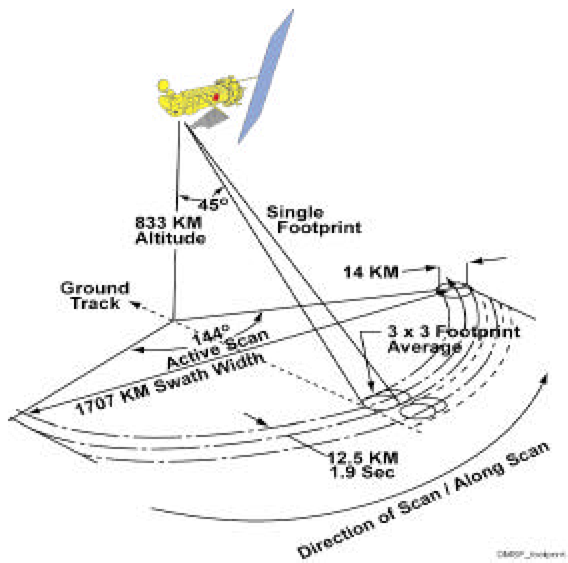
The DMSP System Program Office (SPO) in conjunction with the Office of Naval Research (ONR) is conducting a comprehensive end-to-end calibration/validation (Cal/Val) of the first SSMIS, to begin shortly after launch. The Naval Research Laboratory has been selected to lead the technical efforts of the Cal/Val with support and guidance from DMSP and ONR.

The SSMIS Upper Atmosphere Sounding (UAS) capabilities offer a unique opportunity to provide real-time stratospheric and mesospheric temperature observations. However, supporting measurements for the calibration and validation of the sensor and retrieved soundings are quite limited in comparison to tropospheric and lower stratospheric sounding sensors. A wide reaching combination of lidar, rocketsonde and NWP model fields will be used to calibrate the SSMIS UAS channels and retrieved temperature profiles. Plans for the utilization of these data sources and their limitations are presented.

2. SSMIS Sensor Characteristics

The SSMIS hardware characteristics and retrieval algorithms for the temperature and humidity retrievals have been described in Swadley and Chandler (1991, 1992). A thorough discussion of the background theory and approach to the SSMIS mesospheric temperature retrievals are discussed in Stogryn (1989a, 1989b). Figure 1 and Table 1. describe the SSMIS scan geometry and channel characteristics.

Figure 1. SSMIS scan geometry



3. SSMIS Calibration and Validation Plans

The Cal/Val approach taken for the SSMIS is divided into four major phases. In Phase I, the foremost task is the calibration of the instrument itself. This includes the instrument health, general operation and verification that it is working as designed and within specification. It also includes calibration of the sensor-related algorithms and of the absolute power level at the input to the feed-horn (antenna temperature) and the correction for antenna reception pattern effects to obtain the absolute brightness temperature of the scene. The calibration of the SSMIS instrument and verification that the accurate absolute scene brightness temperatures are being measured is the essential first step of the Cal/Val Plan. The verification of the Doppler shift correction in the SSMIS hardware will also be carried out.

The second step of Phase I involves validation of the retrieval algorithms encoded in the GPS used

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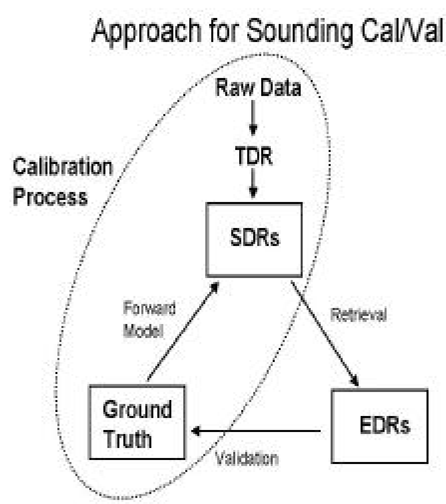
Table 1. SSMIS channel characteristics.

Ch. No.	Center Frequency (GHz)	Pass Band (MHz)	Polarization	NE?T (K)
1	50.3	400	H	0.4
2	52.8	400	H	0.4
3	53.596	400	H	0.4
4	54.4	400	H	0.4
5	55.5	400	H	0.4
6	57.29	350	*	0.5
7	59.4	250	*	0.6
8	150.0	1500	H	0.88
9	183.31±6.6	2500	H	1.2
10	183.31±3	100	H	1.0
11	183.31±1	500	H	1.25
12	19.35	400	H	0.7
13	19.35	400	V	0.7
14	22.235	400	V	0.7
15	37.0	1500	H	0.5
16	37.0	1500	V	0.5
17	91.655	3000	V	0.9
18	91.655	3000	H	0.9
19	63.283248 ±0.285271	3	V+H	2.4
20	60.792668 ±0.357892	3	V+H	2.4
21	60.792668 ±0.357892 ±0.002	6	V+H	1.8
22	60.792668 ±0.357892 ±0.0055	12	V+H	1.0
23	60.792668 ±0.357892 ±0.016	32	V+H	0.6
24	60.792668 ±0.357892 ±0.050	120	V+H	0.7

to derive the EDR products. A team of specialists selected for their experience and expertise in microwave radiometer remote sensing and their knowledge of the particular EDR will be conducting the initial assessment. Depending on the results of the early EDR assessment, recommendations will be made for Phase II efforts that range from simple refinement of the algorithm coefficients to the development of new algorithms to bring the EDR performance within specification.

The Cal/Val for the upper air sounding channels represents a unique challenge because it is the first time such observations will be made and there is very limited independent data on which to base a comparison of either SDRs or EDRs. Therefore, we have developed a combined approach, Figure 2. Raw sensor data is transformed by the GPS calibration algorithm into SDRs, which are subsequently converted to sounding EDRs by the GPS retrieval algorithm. The collection of "ground truth" or validation data sources consisting of coincident rocketsondes, Lidar observations and NWP analysis fields are then processed and compared with the SSMIS sounding EDRs to form the validation component. The cycle is completed when the "ground truth" is used as input to the forward model to generated SDRs, which may then be compared to the calibration component. Clearly, a successful upper air Cal/Val depends on having an intimate knowledge of the sensor-related performance parameters (e.g. Doppler correction), an understanding of the approximation and limitations of radiative transfer theory, thorough knowledge of the retrieval algorithms and their performances and an in-depth understanding of the errors occurring in the validation data.

Figure 2. Schematic of the SSMIS Cal/Val approach



The SSMIS UAS retrieval error can be decomposed into several components (see e.g. Rodgers (1996); Burns (1998)). These include the brightness temperature measurement error, the error in the forward model used to generate simulated brightness temperatures and regression coefficients, errors due to the simplifying approximations made in the algorithm, and the error due to the limited samples contained in the RAOB/ROCOB/LIDAR profile database used to derive the UAS algorithm coefficients. The measurement error can be estimated from the predicted calibration accuracy and NE?T; the actual measurement error will be determined from the calibration phase. Quantifying the other errors as far as possible prior to launch will facilitate identifying the part of the UAS algorithm responsible for residual discrepancies with the validation data.

Immediately after launch, the first step toward UAS validation will be a qualitative assessment of the retrieved temperature profiles by a meteorologist. Such large-scale qualitative assessments are important as they provide an overall impression of algorithm performance and indicate possible deficiencies. For this purpose the SSMIS upper atmosphere retrievals will be gridded to and 1.0 degree spherical coordinate system. Ascending and descending passes will be analyzed separately to limit diurnal/semi-diurnal effects. The gridded retrievals then will be examined for the classic meteorological patterns of horizontal and vertical variations expected for the hemisphere and time of year of observation. The large-scale temperature features of the stratosphere will be verified. Qualitative assessment of smaller scale features must also differentiate real meteorological from noise effects. This qualitative view of UAS performance will provide a meteorological context for the quantitative statistics to be derived from comparison with the validation data. Figures 3 and 4 demonstrate some of the analysis tools available to the SSMIS Cal/Val Team for such qualitative assessments.

Comparisons of the SSMIS gridded upper atmosphere temperatures with NWP temperature analyses from operational centers (FNMOC, ECMWF and NCEP) will also aid in this initial qualitative assessment. The temperature analyses will also be used as background profiles for input into the forward radiative transfer models

Figure 3. Temperature profile comparisons from ECMWF, NOGAPS and ATOVS.

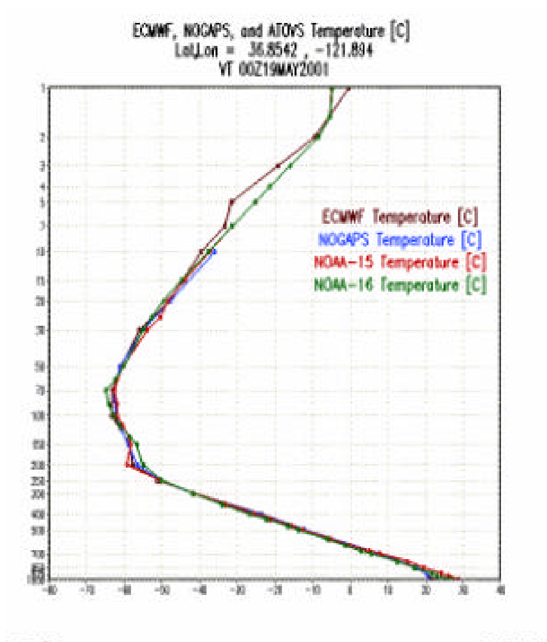
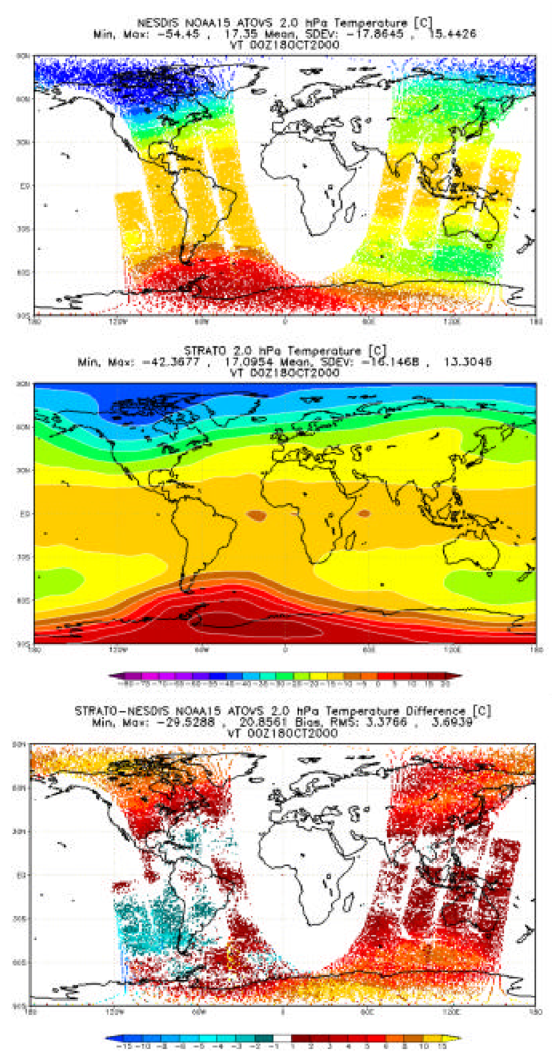


Figure 4. Global comparisons of the NOGAPS and ATOVS temperatures at hPa.



4. Upper Atmosphere Observation Campaigns

The primary sources of temperature profiles in the altitudes 30-80 km are Rayleigh LIDAR and ROCOBs. These observations will be combined with RAOBs to form profiles extending to the surface. Profiles will be assembled throughout the Cal/Val period, with several intensive observation periods (IOPs) for intercomparison of the validation data sources. Analysis fields from NWP models will be used to supplement the RAOB/ROCOB/LIDAR databases to provide a firmer basis for statistical analyses on a global scale.

The SSMIS Cal/Val team has made plans for three lidar IOPs and one coincident ROCOB/LIDAR IOP in direct support of the upper atmosphere sounding calibration and validation Phase I efforts. These campaigns are detailed in Table 2. They include IOPs using a Rayleigh lidar at the NASA JPL Table Mt. Facility (TMF) and a combined

Raman and Rayleigh lidar facility at Mauna Loa, HI (MLO) (Leblanc, et. al. 1998); the Geophysics Institute (GI) of the University of Alaska Fairbanks's Poker Flat Research Range (PFRR) lidar observatory (Cutler, 2000); and the Aerospace Mobile lidar observatory deployed at the Pacific Missile Range Facility (PMRF).

Table 2. SSMIS Upper Atmosphere Observational campaigns

Team	Site	Dates	Lidar	Rocob
NASA/JPL	TMF	Feb '02	X	
NASA/JPL	MLO	Oct '02	X	
Geophys. Institute U. of A.	PFRR	Jan-Apr '02	X	
PMRF and Aerospace	PMRF	Jan-Apr '02	X	X

Once the measurement and retrieval error statistics have been derived through the intercomparisons, the analysis framework used to characterize the UAS retrieval error sources will be applied. This allows the total observed retrieval error to be broken down into its components. With the errors associated with measurement, forward model, and database already quantified, an estimate of the error due to the algorithm formulation itself can be obtained. The relative magnitude of these contributors then indicates where improvements to the retrieval system are required. A proposal for algorithm improvement and/or development of alternative algorithms (e.g. physical-statistical retrievals), and associated validation studies, will be produced, and will form the basis for the efforts in Phase II of the SSMIS Cal/Val.

5. Summary

The SSMIS upper atmosphere sounding calibration and validation effort has been presented. The level of effort in Phase II of the calibration and validation will be determined by the results of Phase I. Results of the SSMIS Upper Atmosphere Sounding Calibration and Validation efforts will be presented at a future AMS conference.

6. Acknowledgements

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