THE SSM/T2 AS A PREVIEW OF THE AMSU-B

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ABSTRACT. Data from the SSM/T2 microwave radiometer carried on the the DMSP F-11 and F-12 satellites provide an opportunity prepare the algorithms for processing the AMSU-B data from the NOAA-K,L,M satellites. Of particular interest is the potential application of the 183 j 7 GHz channel to filter precipitation over both land and sea with equal facility. Seasonal variations show expected areas of persistent low humidity, but also show some interesting deviations from anticipated climatological norms.

1. Introduction.

The Advanced Microwave Sounding Unit, Model B (AMSU-B) will be carried on the NOAA series of satellites beginning with NOAA-K scheduled for launch in 1996. It is a radiometer that will measure in five narrow spectral intervals in the range 89-190 GHz. A cross-track scanning device, it will take 90 measurements of the earth in 1.1 seconds and will have a nadir spatial resolution of 15 kilometers.

The Defense Meteorological Satellite Program (DMSP) carries the Special Sensor/Meteorological/Temperature, Model 2 (SSM/T-2) on the F11 and F12 satellites launched in 1993 and 1994. It has essentially the same spectral channels as the AMSU-B, and measures 28 times in its cross-track scan with a wavelength-dependent spatial resolution of 50-100 kilometers in the nadir direction. Table 1. campares the two instruments.

Table 1. Characteristics of the AMSU-B and the SSMT-2 instruments. Channels are listed in order of atmospheric opacity.

AMSU-B						SSMT-2					
Freq. (GHz)	Ch. no.	Scan (sec)	Steps	Resolution Angle (deg)	Resolution Dist. (km)	Freq. (GHz)	Ch. No.	Scan (sec)	Steps	Resolution angle (deg)	Resolution dist. (km)
183.31±1.0	3	8/3	90	1.1	15	183.31±1.0	2	8	28	3.0	50
183.31±3.0	4	8/3	90	1.1	15	183.31±3.0	1	8	28	3.0	50
183.31±7.0	5	8/3	90	1.1	15	183.31±7.0	3	8	28	3.0	50
150.00±0.1	2	8/3	90	1.1	15	150.00±1.25	5	8	28	3.7	60
89.00±0.1	1	8/3	90	1.1	15	91.03±1.25	4	8	28	6.2	100

2. Limb adjustments.

To make all observations have a common viewing angle, adjustments must be made to the observations. This takes the form of a linear combination of radiance temperatures for two or three channels, including the primary channel. These channels are called "associated" channels in the vernacular of Reference [1]. Following the procedures given in Reference [1], the associated channels for the SSM/T2 given in Table 2. have been adopted. During the time beginning in June 1993, Channel 5 on the F11 satellite failed and the channels indicated in parentheses were deleted.

Table 2. Associated channels for the SSM/T2 satellite maked by X. Channels marked with parentheses are deleted during the period of failure of Channel 5 on the F11 satellite and the channel marked by Y is substituted.

Primary channel	Associated Channel 1	2	3	4	5
1	X	X	X		
2	X	X			
3		X	X		(X)
4			Y	X	(X)
5			(X)	(X)	(X)

The SSM/T2 Channels 4 and 5 have different spatial resolutions from Channels 1-3. This results from the use of a single horn for all frequencies. Thus, Channel 4 has twice the diameter of Channels 1-3 and Channel 5 has 1.2 the diameter. Where significant non-uniformities of the fields of view of those two channels occur, they represent different regimes from Channels 1-3 and the limb adjustments are therefore in error. The effects are small and will not be encountered with AMSU-B, which has separate horns for the different frequencies.

3. Observations.

Figures 1-4 show limb-adjusted measurements in the five channels of the SSMT-2 for four seasons at intervals of about three months during April 1994 through January 1995. The first two periods are from the F-11 satellite and the last two periods from the F-12 satellite.

A catch-up processing of orbits earlier than July 1994 allowed the capture of the F-11 April 1993 data.

Beginning in June 1993, Channel 5 (150 GHz) on the F-11 satellite failed. Data from the F-12 satellite have been received since October 1994.

4. The influence of precipitation.

Perhaps the most interesting channel of the SSMT-2 is Channel 3 (183.13±7 GHz). It is largely opaque to surface effects except at high latitudes where the moisture is extremely low. However, even though cloud droplets have only small effects, precipitation is a strong absorber and scatterer at this frequency.

Over oceans the effects of precipitation appear prominently in Channel 4 (91 GHz) because of the contrast with ocean areas free of precipitation. On the other hand, Channel 3 reveals these effects because of its independence from surface influences. Therefore, precipitation over land and over ocean are indistinguishable.

To understand this phenomenon, one needs only to consider the weighting functions for a normal atmosphere with normal humidity. The function for Channel 3 is very small at the surface, but it reaches a peak in the lower troposphere, where precipitation occurs in the form of rain under most meteorological conditions, and the effect on the radiation is stronger from rain than from frozen particles.

In Channel 4, the combination of surface radiance and atmospheric radiation yields radiance temperatures of 200 K, whereas precipitation (particularly rain) is at a much higher temperature and therefore causes the radiance temperature to be higher. Over land, the surface radiance temperature is much nearer the temperature of the precipitation, and although there are minor decreases they as often as not cannot be distinguished from surface effects. Only the strongest thunderstorms provide incontrovertible evidence of precipitation over land.

The result is that precipitation appears everywhere in Channel 3 just as strongly as in Channel 4 over oceans, but in the reverse sense (decrease in radiance temperature rather than an increase. Being universal (except in extremely dry conditions), Channel 3 provides a tool for filtering of precipitation areas which is not otherwise available.

The attention of the reader is directed to the following:

a. In the Inter-Tropical Convergence Zone (ITCZ) all four seasons demonstrate the effects of showers and thunderstorms by the lower temperatures. These occur as frequently over South America and Africa as over ocean areas. In many cases precipitation can be traced to a higher altitude in the atmosphere with Channels 1 and 2.

b. Fronts.

(1). The front in Figure 4 in the South Atlantic intersecting the South American coast continues inland in Channel 3, but disappears in Channel 4 (not shown).

(2). In every figure there are fronts which are easily identified. Mostly these are in relatively warm air masses where the humidity is higher and the radiance temperatures in clear areas are higher. In colder air masses the fronts provide less contrast and are more difficult to identify.

c. The very dry sub-tropical anticyclonic regions west of South America, west of southern Africa, and southwest of California persist through all four seasons. This is what is expected. In addition, there are numerous dry regions which are transitory, indicating seasonal or other variations. Among these are the dry and wet seasons of India, and the changes over the Sahara and Australia.

5. Statistical behavior of the SSM/T2.

To demonstrate the nature of of the observations of the SSM/T2, the data for a 24-hour period on January 8-9, 1995 were separated into land and sea. To exclude most data in which Channel 3 was not opaque at the surface, data were excluded where that channel had a radiance temperature less than 260 K (this cutoff value was found not to be critical). The effect was to exclude all of the high-latitude observations, some data over the eastern North Pacific and over the Tibetan Plateau, and particularly in areas of significant precipitation.

Means, standard deviations, and correlations between channels were then formed. Data were accumulated in 2-degree latitude belts to form the means. To keep the separation between land and sea unambiguous, data were deleted where either group of latitudinal means had less than one-quarter of the average non-zero population. The result was a sample limited to 48 degrees north to 48 degrees south latitudes. The covariances were then formed for this reduced sample for sea and for land. Table 3. shows the results.

Table 3. Statistical parameters of SSM/T2 data from the F12 DMSP satellite. Channels are given in descending order of atmospheric opacity.

Ch	Sea							Land						
	Mean (K)	σ (K)	Correlation (ch.)					Mean (K)	σ (K)	Correlation (ch.)				
			2	1	3	5	4			2	1	3	5	4
2	264.69	6.70	1.00	.90	.65	-.15	-.39	263.50	5.75	1.00	.89	.61	.12	-.08
1	251.85	5.71		1.00	.87	-.15	-.48	250.82	5.28		1.00	.84	.18	-.04
3	273.99	4.63			1.00	-.06	-.52	272.88	4.46			1.00	.39	.16
5	267.70	7.53				1.00	.76	275.01	7.20				1.00	.86
4	233.07	12.25					1.00	272.07	7.72					1.00

The following are some characteristics noted by the author:

a. For Channels 1-3 the means and correlations differ little over land and sea, indicating that humidity profiles are, in general, independent of surface type. This, of course, does not imply that the same conclusion holds true in specific areas.

b. The degree to which the correlations of Channels 4 and 5 with Channels 1-3 are more negative over water is exactly what one would expect from the emissivities of oceans and land and from the consequent means. That is, the statistics agree with the physics.

c. The standard deviations hold no surprises. It cannot be judged from this small sample whether or not the slightly smaller values over land are significant.

d. The manner in which the correlations among Channels 1-3 decrease with with differences in height in the atmosphere is indicative of the independence of information contained in each channel.

6. Algorithms for AMSU-B.

The derivation of humidity profiles from AMSU-B will follow a physical retrieval algorithm in the NOAA operational processing. The most important step in preparation for the retrieval is the elimination of observations badly contaminated by precipitation and the adjustment of moderately contaminated observations. Any of several algorithms might be employed, some of which would entail the use of observations from other instruments, AMSU-A, HIRS-3 or AVHRR. No decision has yet been reached concerning the algorithm to be used in the NOAA operational processing.

7. Reference.

Wark, D. Q., 1994: Adjustment of TIROS Operational Vertical Sounder Data to a Vertical View. NOAA Technical Report NESDIS 64, NTIS Springfield, VA, 36 pp.

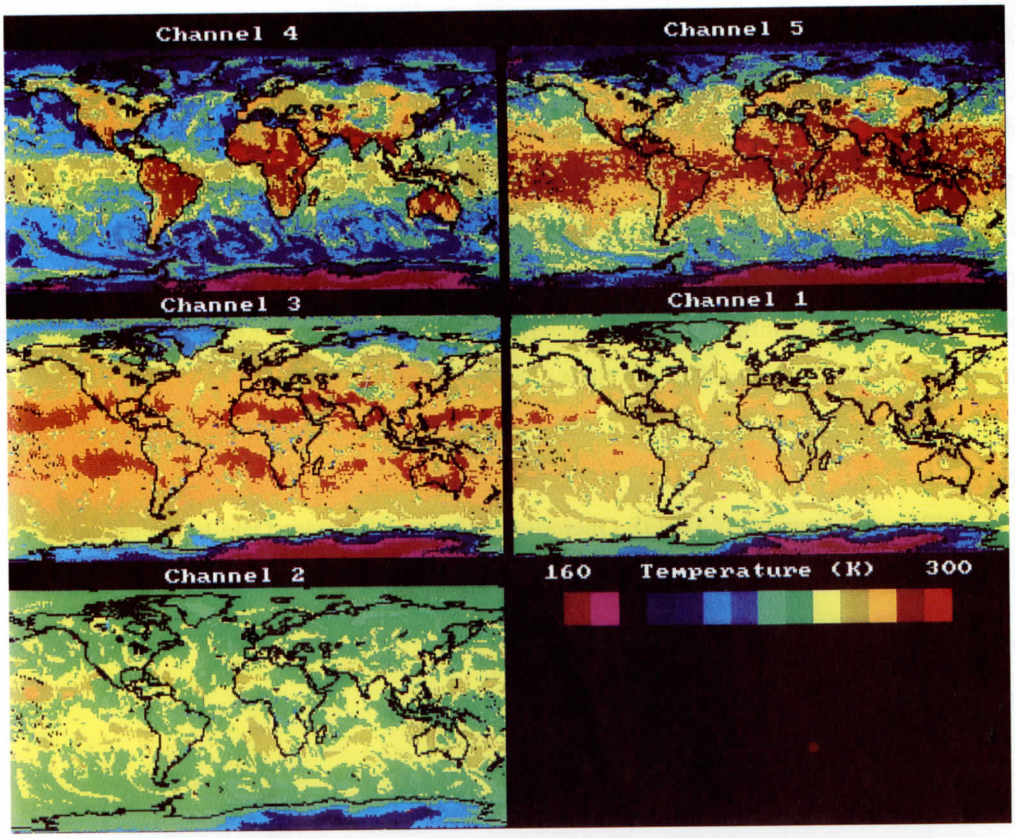

Figure 1. SSM/T2 data from the DMSP satellite F11 for the period April 16- 21, 1994. The channels are presented in ascending order of atmospheric opacity.

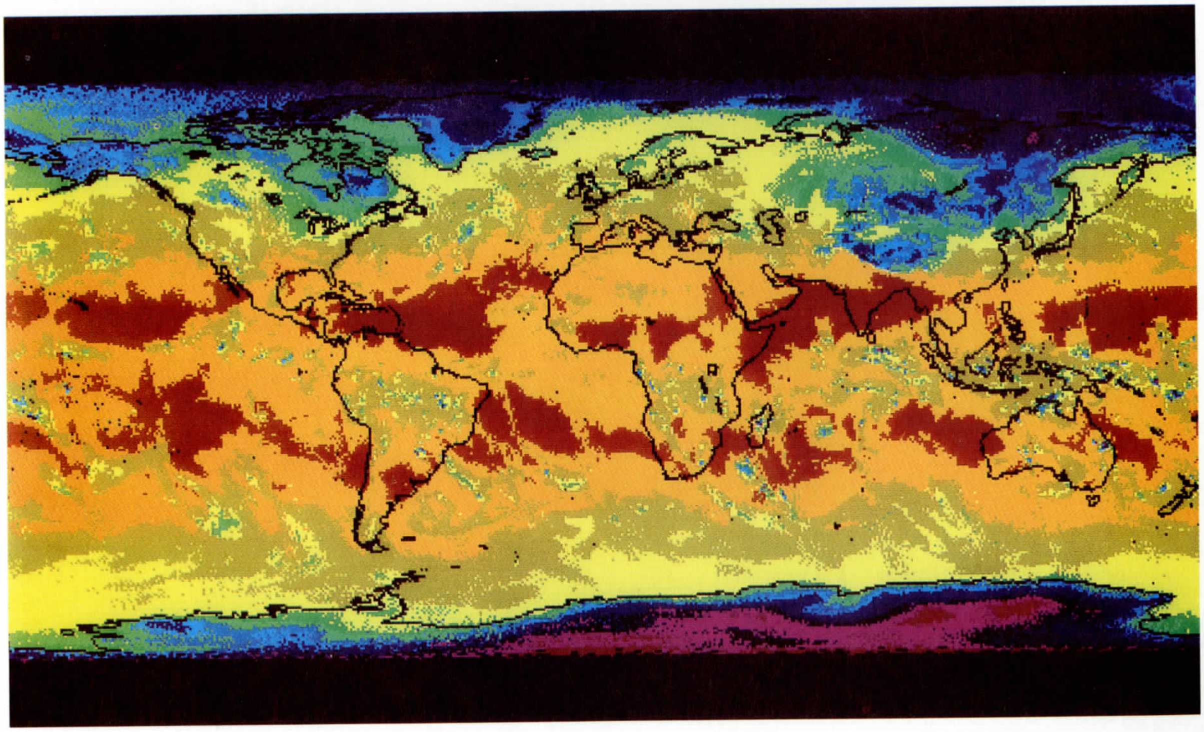

Figure 2. Channel 3 SSM/TW data from the DMSP satellite F11 for the period April 16-21, 1993.

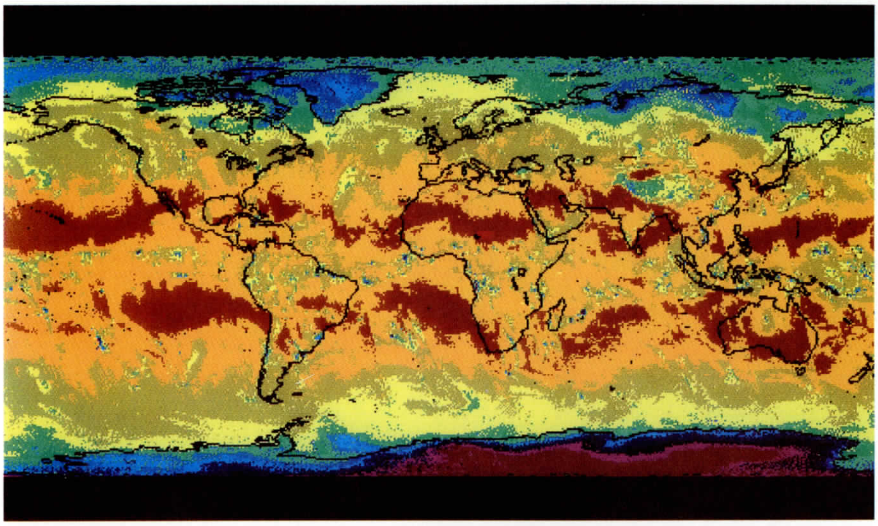

Figure 3. Channel 3 SSM/T2 data from the DMSP satellite F12 for the period July 10-15, 1994.

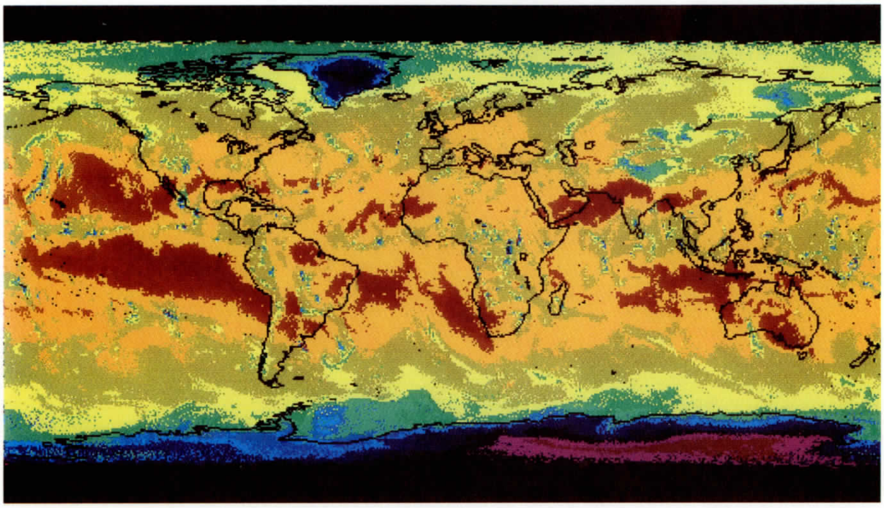

Figure 4. Channel 3 SSM/T2 data from the DMSP satellite F12 for the period October 13-18, 1994.

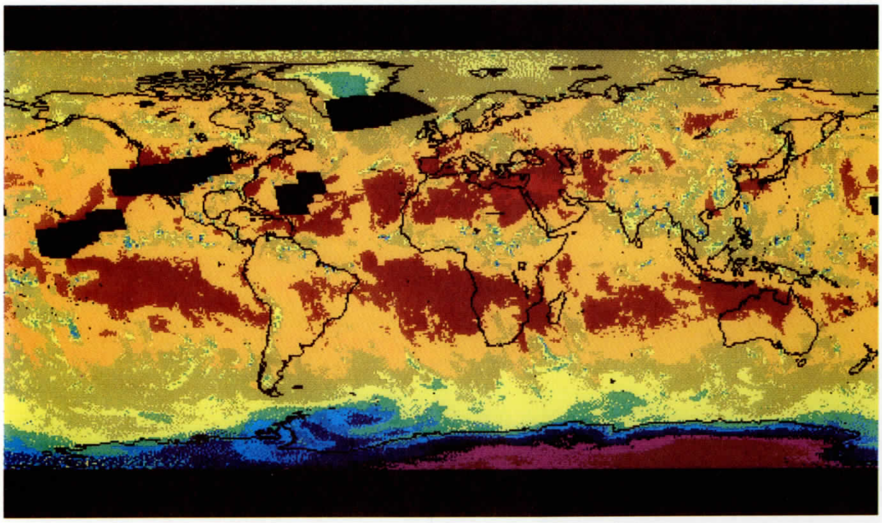

Figure 5. Channel 3 SSM/T2 data from the DMSP satellite F12 for the period January 25-30, 1995.

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