Report 12621
Appendix D
29 Jul 2002

ALGORITHM AND DATA USER MANUAL FOR THE SPECIAL SENSOR MICROWAVE IMAGER/ SOUNDER (SSMIS)

Appendix D: SSMIS LOWER AIR HUMIDITY SOUNDING ALGORITHM

Northrop Grumman
Contract No: F04710-00-C-0001

TECHNICAL REPORT

Prepared by:

Northrop Grumman Corporation
Space Systems Division
1100 West Hollyvale Street
Post Office Box 296
Azusa, California 91702-0296

1 INTRODUCTION AND SUMMARY

The SSMIS system is required to determine relative humidity and specific humidity at 6 pressure levels (1000, 850, 700, 500, 400, and 300 mb) as well as the water vapor mass in the intervals surface (SFC)-850, 850-700, 700-500, 500-400, 400-300, and above 300 mb. If the surface is below the 1000mb level, the SFC-850 interval is replaced by two intervals, SFC-1000 and 1000-850mb. The total water vapor mass (the integral of the profile) is also determined. The algorithm used for obtaining these products from SSMIS-measured brightness temperatures is the same as that currently in use with the SSM/T-2 (T2) [Aerojet, 1990; 1991], except regression coefficients are required for one scan angle only.

2 PHYSICAL CONSIDERATIONS

Four of the 24 SSMIS channels (channels 8-11) were included expressly for the purpose of humidity sounding. Why these frequencies were chosen can be seen from the weighting functions shown for a calm sea background in Figures 1 and 2. The peak sensitivity of each channel to water vapor variations (Fig. 1) occurs at different heights, allowing profiling up to ~ 300 mb (approximately 10 km in height). The weighting function for Ch18 (92 GHz) is also shown. For the atmospheric profile used here, both channels 8 and 18 receive large surface contributions. However in more humid atmospheres, the weighting functions for channels 8-11 are shifted upward, and in this case channel 18 alone provides information on low-level moisture and surface variations.

Figure 2 shows that these "humidity" channels are also very sensitive to temperature variations in the atmosphere. To account for the effect of this sensitivity on the brightness temperatures, temperature sounding channels 1-4, which sense the same portion of the atmosphere (see Fig. 1 in the lower air temperature algorithm description) are also included in the regression algorithm.

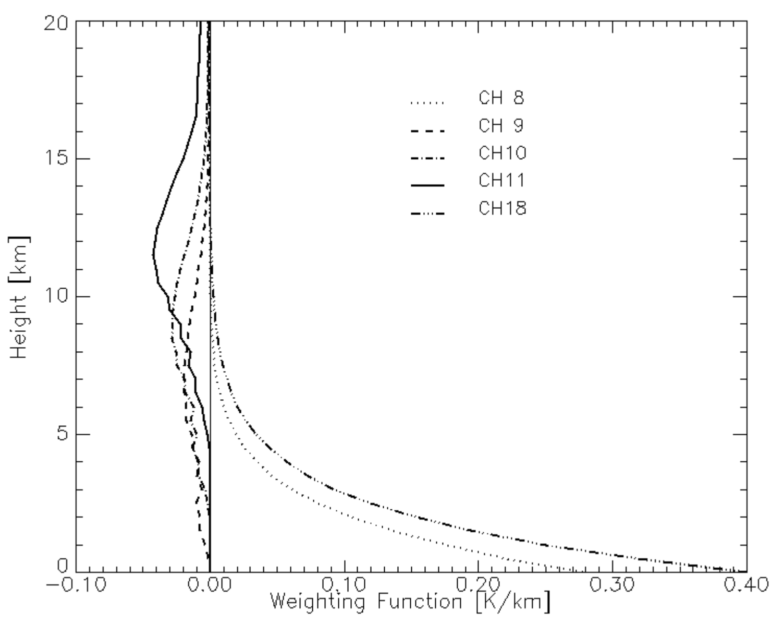


Figure 1. Relative humidity weighting functions for a moist mid-latitude standard atmosphere.

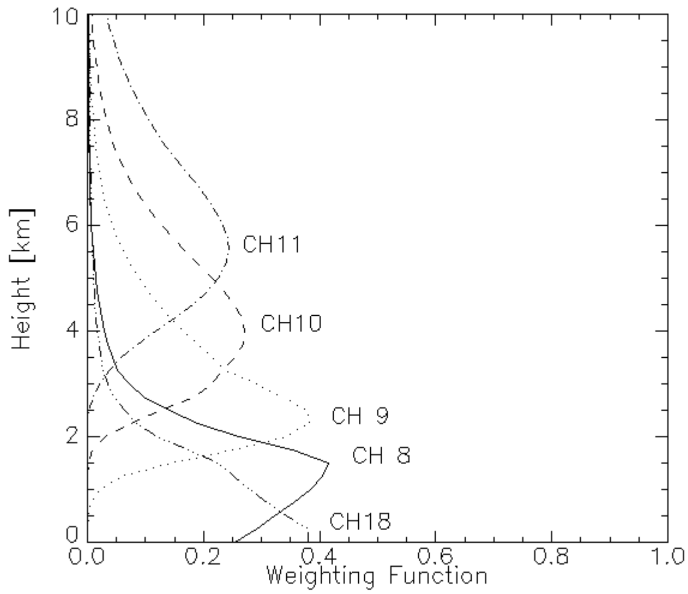


Figure 2. Temperature weighting functions for a moist mid-latitude standard atmosphere.

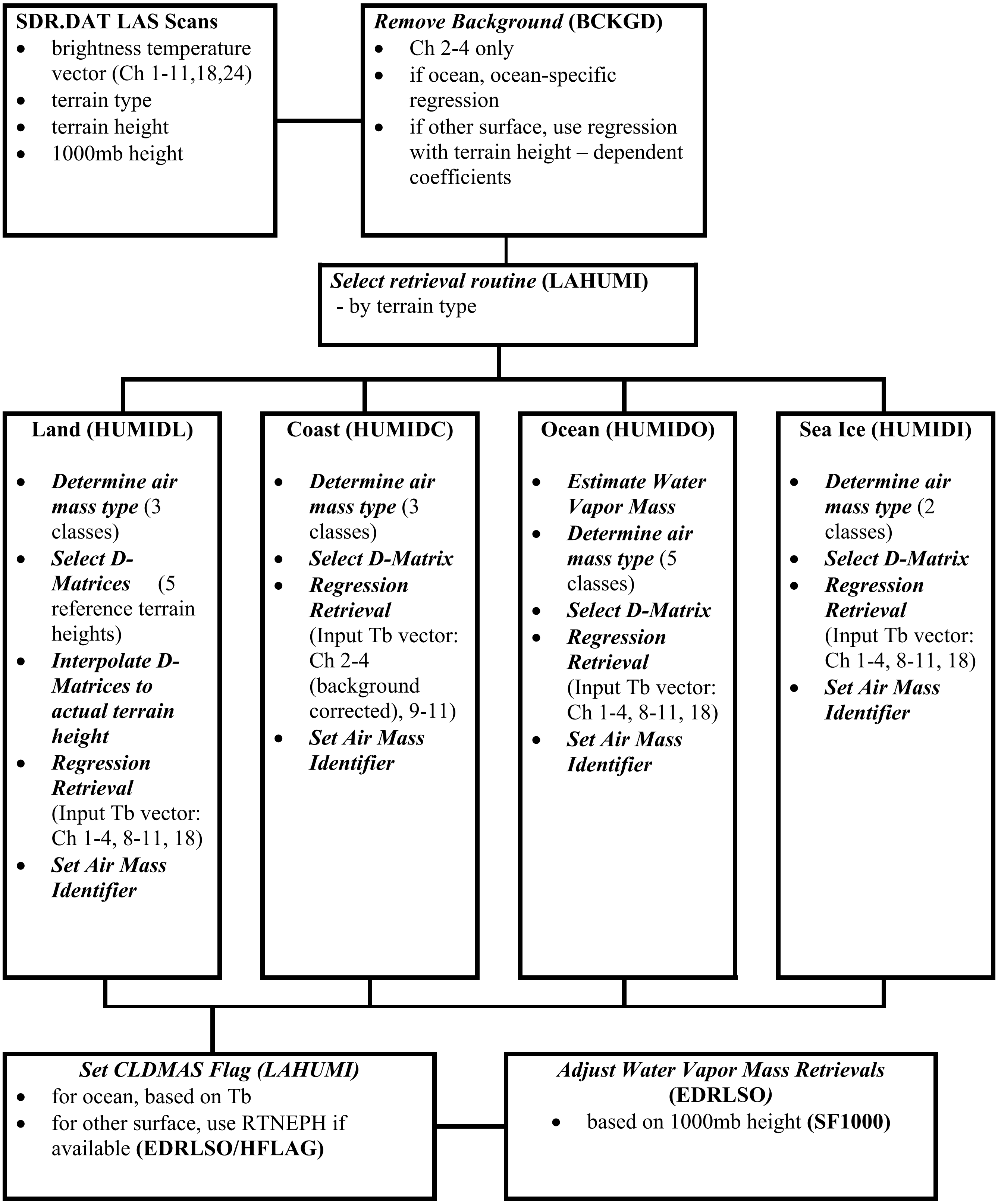
3 RETRIEVAL METHODOLOGY

The humidity sounding algorithm uses the same basic regression matrix approach used for lower air temperature retrievals. In this case, a nine element data vector (channels 1-4, 8-11 and 18) is required as input. These brightness temperatures are used without modification except for retrievals over coasts. In this case only six channels are used: the three 183 GHz channels (9-11) and temperature channels 2-4, from which the surface contribution has been removed as described in the lower air temperature algorithm description.

In order to achieve the required retrieval accuracy, a total of 25 D-matrices are used. In addition to stratification based on the static terrain type (ocean, land, sea ice, coast), the algorithm also applies a dynamical stratification according to air mass characteristics (temperature and vapor content) derived from the data themselves. Over land, further discrimination is made on the basis of terrain height (derived from a data base). Cloud effects are not explicitly accounted for in the retrieval algorithm. Retrievals in the presence of heavy cloud cover are flagged at the end of the retrieval process.

The basic structure of the retrieval system from SDR input to EDR output is illustrated in the flow diagram in Figure 3. The SSMIS Ground Processing Software routines are shown in capitol letters in each box. Note that BCKGD produces a separate vector of background-corrected brightness temperatures that are used in the air mass stratification tests, and in actual retrieval algorithm only for the "coast" terrain type.

Figure 3. Flow diagram of SSMIS humidity retrieval algorithm



4 DYNAMIC STRATIFICATION BY AIR MASS

In order to meet accuracy requirements, regression coefficients had to be derived for various atmospheric conditions above each of the four terrain types. The atmosphere is characterized in terms of total water vapor, high altitude vapor, and temperature. A preliminary estimate of total vapor mass Mv is calculated using a globally valid regression equation involving all 9 input brightness temperatures, whereas the brightness temperature at 183±1 GHz (channel 11) serves as a surrogate for high altitude vapor. Atmospheric temperature (in the altitudes of humidity retrieval) is represented by the brightness temperatures of channels 2 and 3, from which the surface contribution has been removed. These "corrected" brightness temperatures are denoted here as TB_{atm}. The atmosphere is considered COLD if TB_{atm}(Ch3) < 233K. And a large amount of high altitude vapor (HAV) is indicated if TB(Ch11) < TB_{atm}(Ch2)-8K.

Over oceans, soundings are placed in one of five categories:

Type 1: Mv < 10 kg/m^2 and COLD
Type 2: Mv < 10 kg/m^2 and NOT COLD
Type 3: 10 kg/m^2 < Mv < 26 kg/m^2
Type 4: Mv > 26 kg/m^2 and NOT HAV
Type 5: Mv > 26 kg/m^2 and HAV

Over land and coast, three categories are used:

Type 1: COLD
Type 2: NOT COLD and NOT HAV
Type 3: HAV

Over sea ice, there are only two categories:

Type 1: COLD
Type 2: NOT COLD

5 TERRAIN HEIGHT CORRECTION

Because close to half of the moisture in the atmosphere is found below 850 mb (~ 1.5 km altitude), corrections for terrain height variations over land are critical to accurate humidity retrievals. For each of the 3 over-land atmosphere types, regression matrices were computed for five reference heights: h_k = 0, 1500, 3000, 4500, and 6200 m. For a scene terrain height of h, the D-Matrix used in the retrieval is then given by

$$D(H) = D_k + (D_{k+1} - D_k) \bullet (h - h_k)/(h_{k+1} - h_k)$$

6 WATER VAPOR MASS ADJUSTMENT

The SFC-850 interval is the lowest layer output from the D-Matrix water vapor mass calculation. If the 1000mb height input from SDRP is above the surface ($h_{1000} > 0$), the water vapor mass in the intervals SFC-1000 and 1000-850 is calculated as follows

$$Mv_{SFC\text{-}1000} = C \bullet Mv_{SFC\text{-}850} \bullet h_{1000} / (h_{1000} + THICK_{1000\text{-}850})$$

and

$$Mv_{1000\text{-}850} = Mv_{SFC\text{-}850} - Mv_{SFC\text{-}1000}$$

where

C = constant determined from a regression analysis dependent on atmospheric type
$Mv_{SFC\text{-}850}$ = SFC-850mb water vapor mass from D-Matrix calculation
$THICK_{1000\text{-}850}$ = thickness determined from lower air temperature retrievals

The value for the SFC-850 interval ($Mv_{SFC\text{-}850}$) is then set to "undetermined". If the height of the 1000 mb level is < 0, the value of $Mv_{SFC\text{-}850}$ is left unchanged, and the values for the intervals SFC-1000 and 1000-850 are set to "undetermined".

7 HEAVY CLOUD DETERMINATION

Because the accuracy of the humidity retrieval can be compromised in the presence of heavy cloud, a quality flag containing a cloud mass value is set for each scene at the end of the retrieval algorithm. Over ocean, with its low emissivity, an indication of heavy cloud can be obtained from the near-surface temperature sounding channels. Over the other terrain types, which have relatively high surface emissivities and surface brightness temperature contributions, the algorithm relies on the cloud information contained in the RTNEPH analyses (AFWA database) if it is available.

Screening for heavy cloud over ocean is based on the results of an analysis of simulated brightness temperatures at channel 1 and channel 2 frequencies [see AESD Rpt.#8859, pg. 13-15, April 1985]. Three classes of atmospheric profiles were distinguished in that analysis: clear, cloudy with cloud mass (Mc) ≤ 0.15 kg/m^2, and cloudy with Mc > 0.15 kg/m^2. The screening algorithm that resulted is as follows:

$Mc > 0.15$ kg/m^2 if

$TB(Ch1) > 248K$

or

$[238.5K < TB(Ch1) \leq 248K]$ and $[TB(Ch2) > 260K]$

or

$[225K < TB(Ch1) < 238.5]$ and $[TB(Ch1) > 0.6167\ TB(Ch2)+78.17K]$

If this relationship is found true the CLDMAS flag is set to 15 (100 x 0.15 kg/m^2). If false CLDMAS = 1 (100 x 0.01 kg/m^2) to represent clear or light cloud conditions.

For the other terrain types, if the RTNEPH analysis is available, CLMAS is set equal to 100 x total cloud mass of the 4 cloud layers. If not available, CLDMAS=-100.

[End of Appendix D]