CALCULATION OF THE TRANSMISSION FUNCTION FOR REMOTE SENSING BY METEOROLOGICAL SATELLITE (EXTENDED ABSTRACT)

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At Syowa Station, Antarctica, the data of TIROS-N and NOAA series meteorological satellites have been received by the Japanese Antarctic Research Expedition (TANAKA *et al.*, 1982). In order to derive a vertical temperature profile from satellite radiation measurements, it is often necessary to know the transmission functions, especially for the polar atmosphere.

The equation of radiative transfer is written as

$$I_j=\varepsilon_j B_j(T_s)\tau_j+\int_{x_s}^{0} B_j(T)\frac{\partial\tau_j}{\partial x}\mathrm{d}x\,, \tag{1}$$

where I_j is the observed radiance at a certain channel j, ε_j is the emissivity of the earth's surface, B_j is the Planck function with T_s the surface temperature and T air temperature, τ_j is the transmission function, x is a monotonically increasing function of pressure and x_s is that at the earth's surface. The mean transmission function τ_j is given by

$$\tau_j=\int_0^{\infty}\phi_j(\nu)\exp\left(-k_\nu u\right)\mathrm{d}\nu\,, \tag{2}$$

where $\phi_j(\nu)$ is the normalized response function of the radiometer for the j-th channel (WERBOWETZKI, 1981), k_ν is the absorption coefficient at wavenumber ν and u is the absorber amount. The profile of the Planck function, and accordingly of the temperature, can be found by inverting eq.(1), knowing I_j from measurements and the weighting function $\partial\tau_j/\partial x$ namely the transmission function τ_j, from calculations.

Calculations of the transmission functions for Ch. 1 to 7, which are in the CO_2 15 μm band, of the HIRS/2 of TOVS, loaded on TIROS-N, were made and the coefficients of the polynomial representation for the transmission function were given in the present paper.

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1) Transmission function of a homogeneous atmosphere and its polynomial representation

Before calculating the transmission functions of the real atmosphere, the transmission functions of a homogeneous atmosphere were calculated using the absorption coefficients of the Lorentz line. The absorption coefficient k_ν is given by the summation of the contributions of all lines as

$$k_\nu = \sum_i^N \frac{S_i}{\pi} \frac{\alpha_i}{(\nu - \nu_{i0})^2 + \alpha_i^2}, \tag{3}$$

where S_i, α_i and ν_{i0} are the line strength, the line half width and the wavenumber of the line center, respectively. After substituting eq.(3) into eq.(2), the transmission function of each channel was calculated by line-by-line integration. In the calculations, line parameters S_i, α_i and ν_{i0} were derived from the magnetic tape of the AFCRL-line parameters compilation (MCCLATCHEY *et al.*, 1973). In the case of Ch. 1, a large portion of absorption occurred above the level of 30 mb, and the effect of the Doppler broadening could not be neglected. Though very time consuming, calculation of the transmission function for the Voigt profile, which contains the effect of Lorentz and Doppler broadening, was attempted for this channel using the method by PIERLUISSI *et al.* (1977).

In order to express the transmission funcfions τ thus obtained in an analytical form, the following polynomial representation proposed by SMITH (1969) was adopted:

$$\tau = \exp\{-\exp(\sum_i^N C_i \cdot A_i)\}. \tag{4}$$

A_i are terms of the power of ln P, ln T and ln u, and the number of terms N was chosen as 17. The coefficients C_i were determined by a least-squares fit to the

Table 1. Coefficients of the polynomial representation for HIRS/2 channels and fitting errors.

Channel number	1	2	3	4	5	6	7	1 (Voigt)	
Channel central wavenumber (cm^{-1})	668	679	691	704	716	732	748	668	
C_1	0.822	0.243	-0.227	-1.399	-2.138	-2.971	-3.894	0.886	$A_1 = 1$
C_2	0.437	0.670	0.675	0.763	0.778	0.847	0.933	0.472	$A_2 = \ln(u(273/T))$
C_3	0.251	0.499	0.459	0.306	0.170	0.167	0.127	0.309	$A_3 = \ln(P/1000)$
C_4	0.501	0.801	1.609	3.157	3.827	3.840	5.393	0.720	$A_4 = \ln(T/273)$
C_5	0.0154	0.0483	0.0396	0.0667	0.0723	0.0819	0.0662	0.0293	$A_5 = A_2 A_3$
C_6	-0.172	-0.0692	0.0741	-0.131	-0.348	-0.321	-0.346	-0.119	$A_6 = A_2 A_4$
C_7	-0.152	-0.0790	0.0194	0.122	0.152	0.0818	-0.0271	0.0394	$A_7 = A_3 A_4$
C_8	-0.0262	-0.0262	-0.0125	-0.0262	-0.0207	-0.0168	-0.0291	-0.0227	$A_8 = A_2 A_2$
C_9	-0.0231	-0.00446	-0.00432	-0.0220	-0.0185	-0.0172	-0.0118	-0.00562	$A_9 = A_3 A_3$
C_{10}	0.258	0.493	0.476	-0.424	-1.530	-1.702	-1.397	0.292	$A_{10} = A_4 A_4$
C_{11}	-0.00536	-0.00915	-0.00400	-0.00641	-0.00276	-0.00192	-0.000878	-0.00190	$A_{11} = A_2 A_2 A_3$
C_{12}	-0.0108	-0.00953	0.00291	-0.00106	0.0209	0.0167	-0.0132	-0.00884	$A_{12} = A_2 A_2 A_4$
C_{13}	0.00118	0.00682	0.00193	0.00343	0.00234	0.00245	0.000871	0.00267	$A_{13} = A_2 A_3 A_3$
C_{14}	-0.0162	0.00466	0.0131	0.00163	-0.0243	-0.0459	-0.0751	0.0103	$A_{14} = A_3 A_3 A_4$
C_{15}	-0.00869	-0.00519	-0.0521	-0.0210	0.216	0.160	0.0715	-0.0225	$A_{15} = A_2 A_4 A_4$
C_{16}	-0.00534	-0.0452	-0.0127	0.0230	0.0365	-0.0834	0.453	0.0354	$A_{16} = A_3 A_4 A_4$
C_{17}	-0.0351	-0.0252	0.0239	-0.0214	-0.0346	-0.0405	-0.0178	-0.00974	$A_{17} = A_2 A_3 A_4$
Root mean square error	0.023	0.0062	0.0028	0.0032	0.014	0.013	0.0075	0.023	
Maximum error	0.059	0.018	0.010	0.014	0.042	0.038	0.055	0.067	

u (atm cm), P (mb), T (K)

transmittance data calculated from line-by-line integration for about 200 homogeneous paths and listed in Table 1. The conditions of pressure P, temperature T and absorber amount u for all paths were carefully selected to correspond to the range of conditions encountered in downward sensing of real atmospheres.

2) Application to an inhomogeneous atmosphere

As the next step, calculations of the transmission functions of an inhomogeneous atmosphere were performed, based on transmission functions of homogeneous atmospheres and their analytical expressions. The atmosphere was divided into 100 layers distributed on a $P^{2/7}$ scale, and the pressure, temperature and absorber amount of each layer were given by assuming typical atmospheres. Calcula-

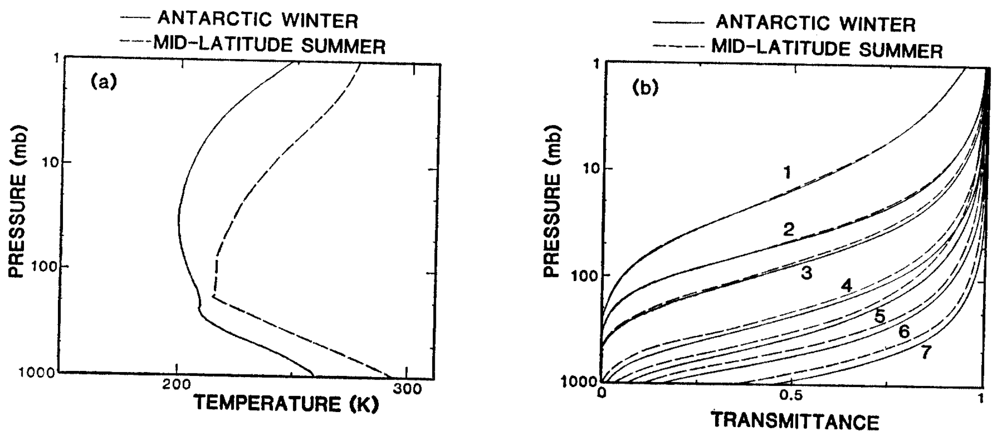

Fig. 1. Temperature profile of atmosphere (a) and transmission functions (b) in mid-latitude summer and Antarctic winter.

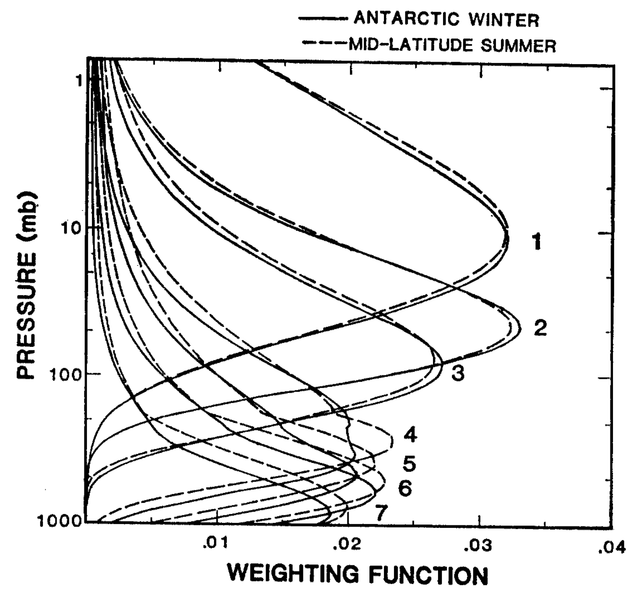

Fig. 2. Weighting functions in mid-latitude summer and Antarctic winter (Lorentz profile).

tions were performed by the method of GODSON (1953)—WEINREB and NEUENDORFFER (1973). Fig. 1a shows the temperature profile of the model atmospheres and Fig. 1b shows the corresponding transmission functions. The atmospheric model for the mid-latitude summer was derived from the U.S. Standard Atmosphere (MCCLATCHEY *et al.*, 1972), and that for the Antarctic winter was derived from the average of radiosonde measurements at Syowa Station in 1980 (JAPAN METEOROLOGICAL AGENCY, 1982).

The weighting functions $\partial\tau/\partial\,(P^{2/7})$ in the $P^{2/7}$ scale were also calculated and shown in Fig. 2. From the figure we can see that it is necessary to calculate the weighting functions specially for use in the polar region, because there are considerable differences below the layer of about 100 mb. Finally, we can improve the accuracy of the temperature profile obtained from the above procedures, as follows: after obtaining the vertical temperature profile from the transmission functions calculated for a model atmosphere, the transmission functions are recalculated from the obtained temperature profile; from them, a new temperature profile is retrieved, and so on.

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