An Improved OPTRAN Algorithm

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1. ABSTRACT

Presented here is an improved algorithm for the fast and accurate transmittance-calculation procedure, referred as Optical Path TRANsmittance, or OPTRAN. It combines two techniques that have been developed separately at NOAA NESDIS and NCEP and implemented in OPTRAN version 7 and 8, respectively. The first technique removes the effective-transmittance approach used in OPTRAN-V6 by applying a correction factor to account for the band-averaging effect, making OPTRAN more efficient. The second technique reduces the number of regression coefficients for predicting the absorption coefficients. It applies a 10th order polynomial to fit the absorption coefficients along optical depth, and as a result the number of regression coefficients is reduced by a factor 23. This is especially useful for hyper-spectral sensors such as AIRS. The improved algorithm also includes other approaches to increase the computational efficiency and accuracy as OPTRAN-V8 shows poor computation efficiency due to the need to compute the polynomial functions.

3. Correction and Polynomial Approaches into OPTRAN

3.1 Correction approach

Definition of correction factor τ_c:

$$\tau_{tot} = \tau_{wet}\tau_{ozo}\tau_{dry}\tau_c \qquad (1)$$

τ_{tot} : total channel transmittance
τ_{wet}, τ_{ozo}, τ_{dry} : transmittances of water vapor, ozone and dry gas

τ_c is given as

$$\ln(\tau_c) = c_0 + \sum_{i=1}^{12} \delta_i c_i Z_i \qquad (2)$$

c_0, c_i : constants; Z_i: predictors
δ_i : = 1 if Z_i is used; = 0, if Z_i is not used

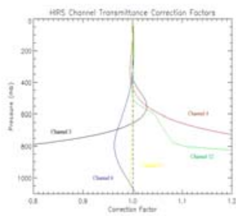

Fig. 3 Correction factors for selected HIRS channels computed using LBLRTM.

i	1	2	3	4	5	6	7	8	9	10	11	12
Z_i	A_{wet}	A_{wet}^2	A_{wet}^3	A_{wet}^4	A_{ozo}	A_{ozo}^2	A_{ozo}^3	A_{ozo}^4	$P^{1/4}$	PT	$A_{wet}PT$	$A_{ozo}PT$

Table 1 The set of predictors, from which a subset is selected for estimating the correction factors. *A*: integrated space-to-layer absorber amount; *P*: pressure; *T*: temperature

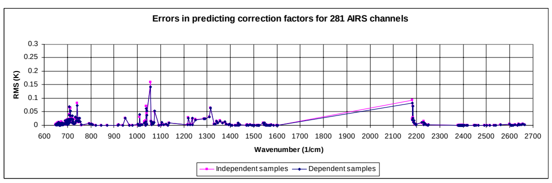

Fig. 4 RMS brightness temperature differences between OPTRAN and LBLRTM. In the OPTRAN calculations, τ_c in (1) is estimated using the Correction approach and the other three components on the right side of (1) are exact, computed using LBLRTM. The independent and dependent data sets are based on the CIMSS 32 and UMBC 48 profiles, respectively

3.2 Polynomial approach

τ_{wet}, τ_{ozo}, τ_{dry} are estimated as,

$$\ln(k(A)) = \sum_{i=0}^{6} c_i(A) X_i, \text{ and } c_i(A) = \sum_{j=0}^{10} a_{i,j} A^j \qquad (3)$$

K: absorption coefficient, corresponding to τ_{wet}, τ_{ozo}, or τ_{dry}
A : integrated absorber amount;
X_i : predictors
c_0, a_0, a_j : constants.

For each channel, the 6 atmospheric predictors {X_i, i=1,6} are selected from a set of 17.

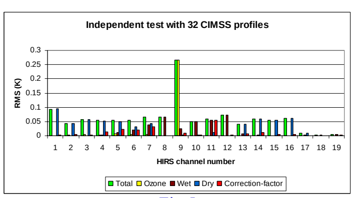

Fig 5a

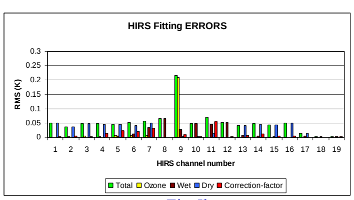

Fig 5b

Fig. 5 RMS brightness temperature between OPTRAN and LBLRTM for HIRS channels. Both correction and polynomial approaches are applied in OPTRAN. Fig. 5a, the independent test with data from CIMSS 32 profiles and Fig. 5b, the fitting errors with data from UMBC 48 profiles.

2. Description of OPTRAN-V7 & OPTRAN-V8

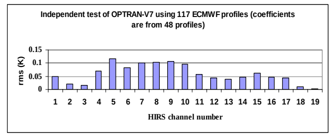

Fig. 1 RMS differences between OPTRAN-V7 predicted HIRS channel brightness temperatures and those of a line-by-line model. OPTRAN-V7 applies the correction-factor approach to account for the band-averaging effect.

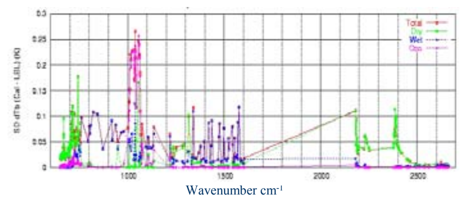

Fig. 2 OPTRAN-V8 fitting errors at the selected 281 AIRS channels. OPTRAN-V8 applies a 10th order polynomial to fit the absorption coefficients along optical depth and thus reduces the number of regression coefficients by a factor 23 for each channel and absorber.

In the following sections we present the improved OPTRAN algorithm that combines the Correction technique in OPTRAN-V7 and the Polynomial technique in OPTRAN-V8, as well as the approaches to improve the efficiency and accuracy.

4. Improvement of Efficiency and Accuracy

Although the polynomial approach in OPTRAN-V8 greatly reduces the number of the regression coefficients, its computation efficiency is also reduced due to the need to compute the polynomial functions. In addition, it appears that the accuracies at a few AIRS channels are not as good as its predecessors. This section shows some preliminary results of the efforts to improve the efficiency and accuracy.

4.1 Efficiency Improvement

Several approaches have been studied. One of the approaches is to lower the order of the polynomial function from the original 10 to a number that still satisfies a specified accuracy. For the selected 281 AIRS channels, Figure 6 shows the distribution of the number of channels with the minimal order of the polynomial function that matches a fitting error < 0.05 K. Table 2 shows a comparison of the computation speed between the improved OPTRAN and OPTRAN-V8. Fig. 7 shows the AIRS fitting errors with the approach applied in OPTRAN. These figures demonstrate that the computation efficiency has been significantly improved without reducing the accuracy that OPTRAN-V8 provides.

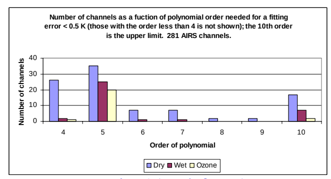

Fig. 6 (see left text)

Computation	Varied order	Fixed 10th order
Forward	26 sec	10 min 30 sec
Jacobian	2 min 43 sec	37 min 29 sec

Table 2 (see left text)

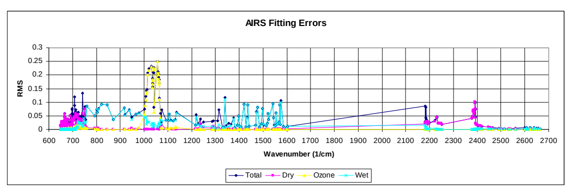

Fig. 7 (see above text)

4.2 Accuracy Improvement

In OPTRAN-V8, the regression coefficients $c_i(A)$ *in Eq. (3)* is represented by a polynomial function which includes all polynomial modes. Here, the polynomial modes with little contributions are dropped, and the maximum order of the polynomial mode for any channel is limited to 3. In addition, the maximum number of the predictors {X_i} is increased from 6 to 17. Fig. 8 shows the HIRS fitting accuracy of the improved OPTRAN. Comparing it with Fig. 5, one sees that the accuracy has been significantly improved, especially for the ozone channel.

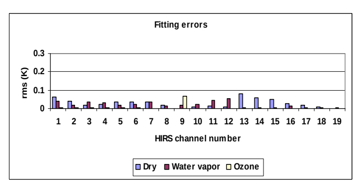

Fig. 8 (see left text)

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