OPTRAN VERSION 7

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1. ABSTRACT

OPTRAN (Optical Path TRANsmittance) is a regression-based model used for calculating the channel (or band) transmittances, which is a core component of the NCEP fast radiative transfer (RT) model for simulating radiometric measurements and calculating radiance Jacobians with respect to the state variables. Since 1999, when OPTRAN version 6 was presented at the Tenth International TOVS conference, a number of important improvements have been made and implemented in OPTRAN version 7, including a constrained regression to improve Jacobian profiles, a reduction of the number of layers from 300 to 100 and a new way to handle polychromatic effects in channel transmittance calculations. In this presentation, we will review the algorithms that contribute to the improvements and demonstrate the accuracies of OPTRAN's forward and Jacobian models.

2 ALGORITHMS

2.1 Correction-factor Approach

Definition of correction factor τ_c : $\bar{\tau}_{tot} = \bar{\tau}_{wet}\bar{\tau}_{ozo}\bar{\tau}_{dry}\tau_c$ (1)

$\bar{\tau}_{tot}$: total channel transmittance

$\bar{\tau}_{wet}, \bar{\tau}_{ozo}, \bar{\tau}_{dry}$: individual transmittances of water vapor, ozone and dry gas

$\bar{\tau}_x = \int_{\Delta\nu} \tau_x(\nu)\phi(\nu)d\nu$ x = *tot, wet, ozo, or dry*; $\phi(\nu)$: spectral response function

2.2 Estimate of Absorption Coefficient

Absorption coefficient at layer *i*: $k_{x,i} = -\ln(\bar{\tau}_{x,i}/\bar{\tau}_{x,i-1})/(A_{x,i} - A_{x,i-1})$ (2)

$A_{x,i}$: column amount of an absorbing gas from space to the *i-th* level

x = *tot, wet, ozo, or dry*

Correction coefficient at layer *i*: $k_{c,i} = -\ln(\bar{\tau}_{c,i}/\bar{\tau}_{c,i-1})/(A_{wet,i} - A_{wet,i-1})$ (3)

Equations to estimate $k_{wet}, k_{ozo}, k_{dry}, k_{c,i}$

$$k_{x,i} = b_{x,i,0} + \sum_{j=1}^{5} b_{x,i,j}u_{x,i,j} \qquad (4)$$

$u_{x,i,j}$: predictors, such as temperature, pressure, etc.

$b_{x,i,j}$: constants obtained through regression

2.3 Absorber Space

The set of layers $\{\Delta A_{x,i}, i = 1,100\}$, at which the set $\{k_{x,i}, i = 1,100\}$ is computed, is a subset of the set defined as

$$\Delta A_{x,m} = \Delta A_{x,m-1}\exp(\alpha_x), \quad m = 1, 300 \quad \text{for wet, dry and correction-factor}$$

$$\begin{cases} \Delta A_{ozo,m} = \Delta A_{ozo,m-1} + (d_1 * m + d_2), & m = 1, 160; \\ \Delta A_{ozo,m} = \Delta A_{ozo,m-1} + d_3, & m = 161, 300 \end{cases} \quad \text{for ozone} \qquad (5)$$

where α_x, d_1, d_2 and d_3 *are constants*. Different channels may have different layer subsets.

2.4 Constraints to improve Jacobians

Eq. (4) may be written as

$k_x = U_x b_x$, where $k_x = \{k_{x,1}, k_{x,2}, k_{x,M}\}^T$,

$b_x = \{b_{x,1,0}, b_{x,1,1}, ..., b_{x,1,5}, b_{x,2,0}, b_{x,2,1}, ..., b_{x,2,5}, ..., b_{x,100,5}\}^T$ and

matrix U contains predictors $u_{x,i,j}$ (6)

By applying the following constraint,

$$q = \sum_{j=0}^{5}\sum_{j=1}^{M-1}(b_{x,i+1,j} - b_{x,i,j})^2$$

Eq. (6) is solved for *b* as

$$b_x = (U_x^T U_x + \gamma H)^{-1} k_x$$

where *H* is a band matrix and γ is a Lagrangian multiplier determined in the training process. Figure 1 shows an example of the effect of applying the constraint to improve Jacobian profiles

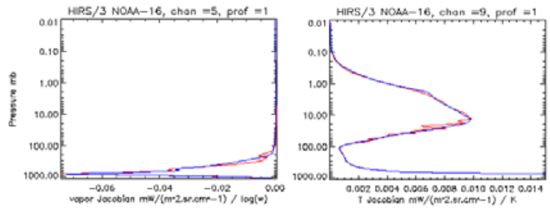

Fig. 1 Water vapor (left) and temperature (right) Jacobians before (red curve) and after (blue curve) applying constraint in the regression

3. COMPARISONS BETWEEN OPTRAN-V7 AND LBL MODELS

3.1 Forward model comparisons

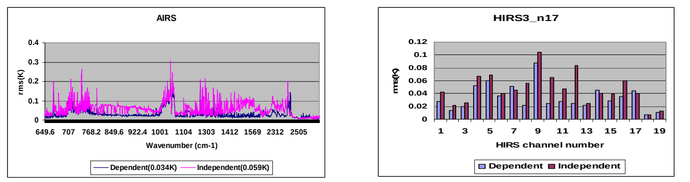

Fig. 2 RMS differences of brightness temperatures between OPTRAN-V7 and LBLRTM: blue curve - dependent test and red curve – independent test, with UMBC 48 profiles as dependent data set and ECMWF 52 profiles as independent data set.

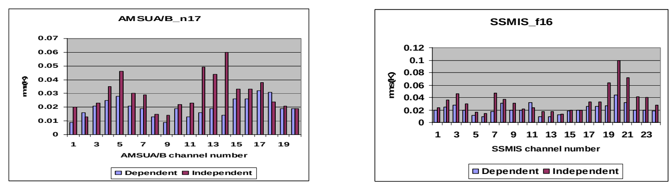

Fig. 3 RMS differences of brightness temperatures between OPTRAN-V7 and the microwave line-by-line radiative transfer using the Rosenkranz-2003 absorption models: blue curve - dependent test and red curve – independent test, with UMBC 48 profiles as dependent data set and ECMWF 52 profiles as independent data set. Zeeman effects are not taken into account.

3.2 Samples of Jacobian comparisons

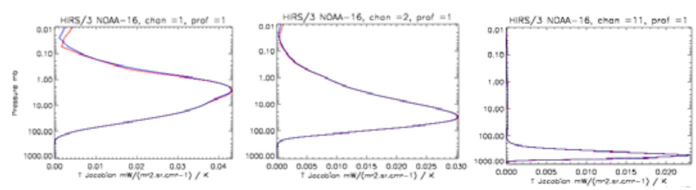

Fig. 4 Temperature Jacobians of HIRS/3-NOAA16 at channel 1, 2 and 3: Red curve – OPTRAN-V7; blue curve – LBLRTM (Finite-Difference).

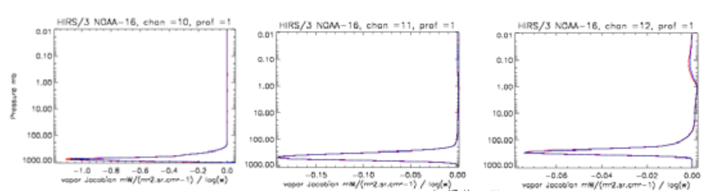

Fig. 5 Water vapor Jacobians of HIRS/3-NOAA16 at channel 10, 11 and 12: Red curve – OPTRAN-V7; blue curve – LBLRTM (Finite-Difference).

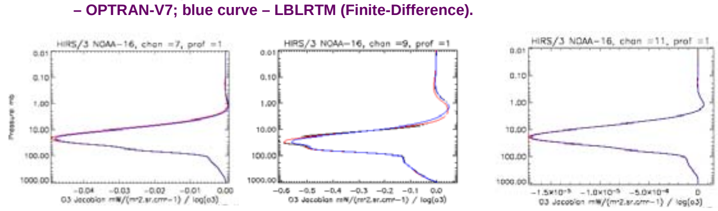

Fig. 6 Ozone Jacobians of HIRS/3-NOAA16 at channel 7, 9 and 11: Red curve – OPTRAN-V7; blue curve – LBLRTM (Finite-Difference).