PLANS FOR NESDIS OPERATIONAL WATER VAPOR RETRIEVALS

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1. INTRODUCTION

The results provided by NESDIS for this study are the values obtained from the routine processing and are not reprocessed. Although there are several reasons for this, a significant one is that the operation uses fields that are continually updated. Unless these fields are captured at the right instant and stored, reprocessed data do not exactly match the operational ones. The other reason is that the operational program has not been designed to reprocess historical data. One of the impacts of this that is particularly significant for this comparison is that NESDIS has an improved water vapor model that will soon become operational. It is not being used now only because the operational programs are being switched to a new computer and no changes are allowed during the changeover. The tape prepared for this intercomparison does not reflect the improvement. It should also be mentioned that the format in which water vapor is stored does not allow much precision.

The current water vapor retrieval, and the one used for this intercomparison, is a multiple linear regression in which the mixing ratio $q$ is predicted from satellite measurements of brightness temperatures $BT_i$ using the relationship

$$q = C_0 + \sum_{i=1}^{21} C_i BT_i$$

where $C_i$'s are the regression coefficients and the subscript $i$ denotes channel. The channels used are HIRS 1-16, 18, 19 and MSU 2-4. Water vapor values are produced for the clear (A) and N* (B) retrievals because clear column HIRS radiances are not available for the microwave (C) retrievals.

The new method will produce water vapor from the relation

$$T_d = C_0 + \sum_{i=1}^{21} C_i ABT_i$$

where $T_d$ is the dewpoint temperature and the values of $ABT_i$ are atmospheric brightness temperatures obtained from the radiative transfer equation

$$I = B_s T_s + \int_{T_s}^1 B_d T$$

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where \( I \) is the observed radiance, \( B_S \) is the Planck surface radiance, \( \tau_S \) is the surface transmittance, and \( B \) and \( d\tau \) are the Planck radiance and change in transmittance for a given layer. The integral is the atmospheric term which, from the mean value theorem, may be written as

\[
\bar{B}_a(1-\tau_S) = \int_{\tau_S}^{1} B d\tau
\]  

(4)

where \( \bar{B}_a \) is the average atmospheric radiance used to obtain values of \( ABT_i \). Values of \( \tau_S \) are obtained by a separate regression and constrained to be between the maximum and minimum values for the particular channel. It should be noted that the new method is an adaptation of one described by Hayden et al. (1981).

A comparison study of several water vapor methods was recently conducted at NESDIS. Besides these methods, one other alternative is of interest. It is given by

\[
q = k_0 + \sum_{j=1}^{n} k_j T_j
\]  

(5)

where \( k \)'s are coefficients, \( T_j \) are retrieved atmospheric temperatures, and the subscript \( j \) denotes level. This method contains no direct information about water vapor but represents a minimum that should be achievable. It gives surprisingly accurate results when compared to the other methods.

2. RESULTS

In the process of evaluating an operational change, several successive tests are typically made, each of which is increasingly more expensive and closer to the operation. In this case, three successive comparisons are shown in Tables 1, 2 and 3. Tables 1 and 2 are based on a simulation.

The data used in this test consisted of 1000 sets of TOVS radiances matched with corresponding radiosondes. In the matches, the distance varies slightly with latitude even within a 30 degree latitude zone so the exact upper limit is difficult to define. However, all matches had locations that agreed to within ± 1 degree of latitude or better. In addition, two radiosondes 12 hours apart were interpolated to the radiosonde time. These data were collected during the period of 11/23-12/30, 1983, and were between 20 to 50 N latitude. Every third sounding was selected as an independent observation and grouped together to form the independent data set which was used to determine the statistics given in this paper. The other two thirds were grouped to form a dependent data set which was used to determine the coefficients.

It should be noted that this division of dependent and independent data differs from the operation which produces new coefficients every week from data collected over the previous two to four weeks. Because
of this difference, method 2, which is the operational method, does not produce results which exactly duplicate the actual operation. However, for this comparison it was important for all methods to be identical except for the changes being evaluated. The relative performances of the various methods should be independent of the selection procedure for the dependent sample, provided that all methods are treated equally.

Results of the comparison are shown in Table 1. The units used in the table require some explanation. The computer runs provided results in terms of mixing ratios for individual levels. Because of the number of levels and a tendency for the relative accuracies to oscillate with height, it was difficult to get a clear picture from these numbers. Since water vapor is output in terms of precipitable water in three layers, it was decided that an evaluation based on the three layers would be less confusing than one based on the 15 levels. To accurately determine the errors for the layers, it would have been necessary to rerun all the results. Actually, the final case and a couple of comparisons were rerun. However, the results shown in Table 1 were obtained from the level values. They were obtained by summing the rms errors of the individual levels, then dividing the total by the average precipitable water for the layer as given by the radiosonde to obtain a percent. Although this method provides a slight overestimate of the retrieval error, the relative performances of the various methods are still valid. The magnitude of the approximation can be determined from a comparison of Tables 1 and 2.

Although the other methods are generally better, method 1, which uses only the correlation between temperature and water vapor, produces a surprisingly good retrieval, especially when compared to the other methods. Three factors limit the improvements of the other methods over method 1. One is that since radiosondes are subject to measurement errors, they are not a true measurement of water vapor. Because of this, even a perfect satellite instrument would produce differences from radiosondes that are significantly greater than zero. A second is that the atmospheric temperature is highly correlated with water vapor and thus is a good predictor. Finally, when inversions are present, there are layers for which the incoming radiation is matched by the emitted radiation, making the outgoing radiation insensitive to water vapor.

Comparison of the three methods shown in Table 1 shows that the current operation is better than the results from temperatures only and the proposed method is better still. In the important 1000-850 mb layer, the errors, expressed as percentages of the average, are 54.6%, 44.6%, and 41.0%, respectively. Table 2 gives a more accurate calculation of the errors for the operational and proposed methods. Again there is significant improvement, especially in the 1000-850 mb layer, which contains most of the water vapor.

Table 3 contains the results of a limited operational test. Results are shown as percentages at the TOVS levels between 300 and 1000 mb. A plus denotes improvement and a simple average is given at the bottom. It is clear from the table that while there are selected
zones and levels for which current operational results are better, the
dominant pattern favors the new method.

Recently, Smith & Woolf (1984) proposed a simultaneous solution
for water vapor which retrieves water vapor and temperature together.
NESDIS at Suitland has plans to evaluate the new method. It is likely
that some form of a simultaneous solution will be adopted, but until
results are obtained, conjecture is premature.

3. RESULTS OF THE CURRENT MODEL

Figures 1-6 show the results of the current operational retrieval
model for the two European cases. Lines of longitude are 3E, 13E,
etc., and the latitudes are 30, 40, 50 and 60N. The values shown are
precipitable water over the layer bounded on the high side by the given
pressure. Values shown on the figures are plotted by the computer and
analyzed by hand. Comparisons at the conference will establish the
validity of the patterns shown. Currently, water vapor is being out-
put, but it is unclear if anyone is using it as extensively as the tem-
perature soundings. However, it is clear from Figs. 3 and 6 that the
formats for at least the 300-500 mb layer need to be modified to allow
more resolution.

4. SUMMARY

In summary, it should be noted that the results for water vapor
are from a model that has remained essentially unchanged from the ini-
tial implementation. Recently, a rather extensive evaluation of alter-
native methods was made. As a result of that evaluation, a new water
vapor retrieval system has been developed and will soon be implemented.

5. REFERENCES

Hayden, C.M., W.L. Smith and H.M. Woolf, 1981: Determination of
Moisture from NOAA Polar Orbiting Satellite Sounder Radiances.

Smith, W.L., and H.M. Woolf, 1984: Improved Vertical Soundings from an
Amalgamation of Polar and Geostationary Radiance Observations.
Conf. on Satellite/Remote Sensing and Applications, American
Meteorological Society, 45-48.
Table 1. Accuracies of Water Vapor Retrieval Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>1000-850 (% of avg)</th>
<th>850-500 (% of avg)</th>
<th>500-300 (% of avg)</th>
<th>total (% of avg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>54.6</td>
<td>49.8</td>
<td>34.6</td>
<td>40.3</td>
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<tr>
<td>2</td>
<td>44.6</td>
<td>43.6</td>
<td>35.1</td>
<td>38.2</td>
</tr>
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<td>3</td>
<td>41.6</td>
<td>40.7</td>
<td>29.7</td>
<td>34.4</td>
</tr>
</tbody>
</table>

Table 2. RMS errors for true layer averages

<table>
<thead>
<tr>
<th>Layer (mb.)</th>
<th>Method 2 (% of avg)</th>
<th>Method 3 (% of avg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000-850</td>
<td>37.6</td>
<td>32.3</td>
</tr>
<tr>
<td>850-500</td>
<td>34.0</td>
<td>30.5</td>
</tr>
<tr>
<td>500-300</td>
<td>29.6</td>
<td>27.4</td>
</tr>
</tbody>
</table>

Table 3. Improvements of method 3 over the current operation in units of percent of operational error for the week of July 1, 1984

<table>
<thead>
<tr>
<th>level</th>
<th>pressure (mb.)</th>
<th>60-90N (%)</th>
<th>30-60N (%)</th>
<th>30S-30N (%)</th>
<th>60-30S (%)</th>
<th>90-60S (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>300</td>
<td>9.3</td>
<td>1.5</td>
<td>14.6</td>
<td>26.7</td>
<td>12.5</td>
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<tr>
<td>27</td>
<td>350</td>
<td>16.7</td>
<td>10.1</td>
<td>23.0</td>
<td>24.0</td>
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<td>28</td>
<td>400</td>
<td>17.3</td>
<td>12.6</td>
<td>14.2</td>
<td>21.1</td>
<td>9.5</td>
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<tr>
<td>29</td>
<td>430</td>
<td>15.8</td>
<td>13.6</td>
<td>14.8</td>
<td>18.3</td>
<td>22.2</td>
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<tr>
<td>30</td>
<td>475</td>
<td>14.2</td>
<td>7.9</td>
<td>14.1</td>
<td>9.0</td>
<td>35.0</td>
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<tr>
<td>31</td>
<td>500</td>
<td>11.9</td>
<td>5.2</td>
<td>12.3</td>
<td>4.9</td>
<td>39.6</td>
</tr>
<tr>
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<td>7.2</td>
<td>1.9</td>
<td>2.1</td>
<td>29.0</td>
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<td>-1.0</td>
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<td>780</td>
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<td>-0.3</td>
<td>-11.0</td>
<td>3.7</td>
<td>18.7</td>
</tr>
<tr>
<td>37</td>
<td>850</td>
<td>2.6</td>
<td>1.1</td>
<td>-9.2</td>
<td>2.5</td>
<td>22.7</td>
</tr>
<tr>
<td>38</td>
<td>920</td>
<td>-0.2</td>
<td>23.7</td>
<td>25.0</td>
<td>8.4</td>
<td>23.8</td>
</tr>
<tr>
<td>39</td>
<td>950</td>
<td>6.4</td>
<td>41.1</td>
<td>27.4</td>
<td>6.9</td>
<td>14.8</td>
</tr>
<tr>
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<td>1000</td>
<td>44.4</td>
<td>54.4</td>
<td>33.5</td>
<td>28.4</td>
<td>16.7</td>
</tr>
</tbody>
</table>

AVG.  | 8.8            | 21.6       | 11.9       | 10.1        | 20.1       |
Figure 1. Precipitable water vapor for the 1000-700 mb layer for March 4, 1982.
Figure 2. Precipitable water vapor for the 700-500 mb layer for March 4, 1982.
Figure 3. Precipitable water vapor for the 500–300 mb layer for March 4, 1982.
Figure 4. Precipitable water vapor for the 1000-700 mb layer for March 5, 1982.
Figure 5. Precipitable water vapor for the 700-500 mb layer for March 5, 1982.
Figure 6. Precipitable water vapor for the 500–300 mb layer for March 5, 1982.
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