A STUDY OF SEVERAL DIFFERENT NUMERICAL ITERATION SOLUTIONS OF THE RADIATIVE TRANSFER EQUATION (RTE)

W. P. Menzel
NOAA/NESDIS
1225 W. Dayton Street
Madison, WI 53706
USA

1. Introduction

TOVS data from the ALPEX region and the Tasman Sea were processed to determine temperature profiles at locations where time coincident radiosonde data were also available. This work was accomplished on an IBM personal computer. Radiance data was calibrated, located, and limb corrected before it was ingested into the IBM personal computer for the retrieval calculations. Two modifications of the Chahine relaxation method (Chahine, 1970) and the Smith iteration method (Smith, 1970) are the numerical methods that were studied.

2. Description of Processing Algorithms

The Chahine relaxation method and the Smith iteration method are documented in the literature and therefore are not described here. In the Chahine method, temperature information from the different sounding channels is placed where the maximum of the weighting function for that spectral channel occurs and temperature profiles are determined by linear interpolation with respect to the logarithm of the pressure. The Chahine method is less dependent of the first guess, but represents the profile by line segments; the Smith method does create a temperature profile, but is often very dependent on the initial guess through the averaging process. The one modification of the Chahine method is to weight the temperature information from each spectral channel by the weighting function and derive the temperature profile from this weighted mean, as is done in the Smith iteration method. This alleviates the problem that the temperature profile is usually not well represented by a series of line segments between pressure levels where the weighting functions peak, particularly when dealing with only a small number of spectral channels. A second modification is to iterate for three cycles with the original Chahine method and then to implement the aforementioned modification until convergence is reached. This allows freedom to move away from the initial guess profile and then to determine a mean temperature profile that best satisfies the RTE.

3. Results

In this study, the performance of the three methods (Smith, Chahine mod1, and Chahine mod2) are compared when initialized by a statistical first guess or a standard atmospheric temperature profile. Transmittances for the radiative transfer calculations are generated from the NOAA operational TOVS software package. Surface temperature is estimated by the 11 μm brightness temperature. Convergence of the numerical iterations was achieved when the residuals were less than .1 degree centigrade. The regression coefficients for the generation of the statistical first guess temperature profiles are the operational TOVS coefficients calculated from matched radiosonde observations in that latitude zone from the previous 30 days. Radiosonde determined temperature profiles were used as a reference of the true atmospheric profile.

The ALPEX data were gathered on 4 March 1982 at 1344GMT and the clear sky conditions in the Mediterranean area allowed TOVS soundings to be compared with about ten 12 MGT radiosondes. Figure 1 shows a typical comparison from this set. When using the standard atmosphere as a first guess (Figure 1a), both the Smith and Chahine modl methods improve the guess profile rather modestly above 250 mb while moving it further from the raob values below 500 mb. The Chahine mod2 demonstrates difficulties above 300 mb because the linear interpolation in the first three iterations removed any tropopause information that the first guess had (since none of the HIRS spectral bands has a weighting function that peaks at the tropopause) and subsequent iterations cannot adjust the profile enough in this region. When using the statistical temperature profile as a first guess (Figure 1b), the same behavior was observed while the retrieved profiles show an improved agreement with the raob values (although not as good as the initial statistical guess!).

Figure 2 demonstrates the dependence of the retrieved profile on the initial first guess profile. Starting with the statistical or the standard profile leads to a different retrieved profile. This is found for both the Smith and Chahine modl methods (the profiles from these two methods were usually within .2 degrees Centigrade of one another throughout this study). The Chahine mod2 was much less dependent on the first guess; the profiles derived from the two different initial guesses were within .5 degrees Centigrade of one another.

The Tasman Sea data was gathered on 28 October 1982 at 431GMT and the TOVS soundings over the sea are compared with one raob released at OOGMT. Figure 3 displays the results; similar conclusions as with the ALPEX comparisons can be drawn. Again, the Chahine mod2 never recovers from the first iterations. The standard atmosphere profile is improved below 300 mb by Smith and Chahine modl. The statistical profile is the best representation of the radiosonde observation.

4. Conclusions

These comparisons, while limited in number, suggest several conclusions. (a) The IBM personal computer has a considerable capability for analyzing the TOVS data. (b) The Chahine mod2 method is vulnerable when the spectral channels used in the retrieval calculation exhibit no weighting function maxima in the tropopause. (c) The Chahine modl and Smith methods provide very similar results. (d) The statistical temperature profile is often a good representation of the atmospheric state.

References

Chahine, M. T., 1970: A general relaxation method for inverse solution of the full radiative transfer equation. Journal of Atmospheric Science, 27, 960.

Smith, W. L., 1970: Iterative solution of the radiative tranfer equation for temperature and absorbing gas profiles of an atmosphere. Applied Optics, 9, 1983.

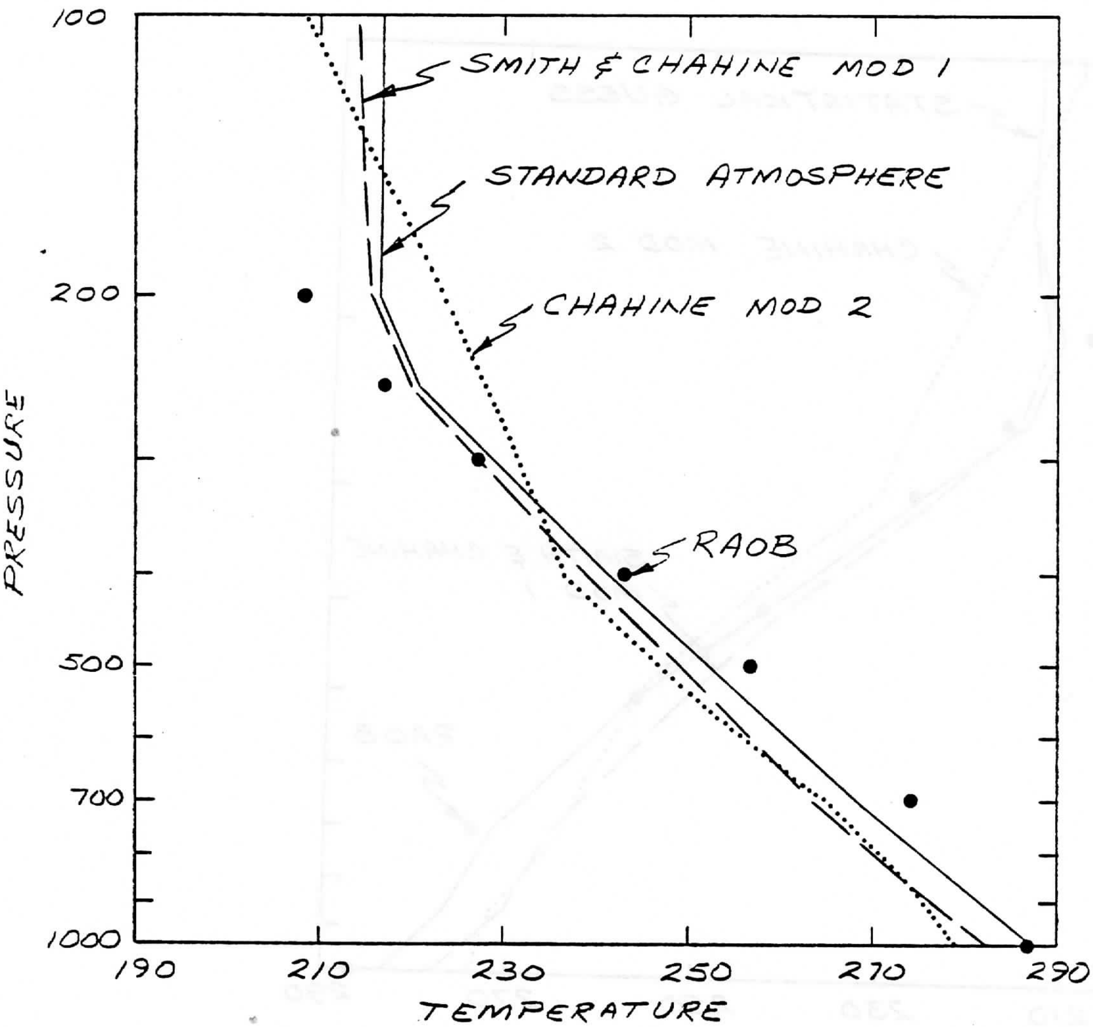


FIGURE 1a 4 MARCH, 1982 NORTH AFRICA
ALPEX DATA

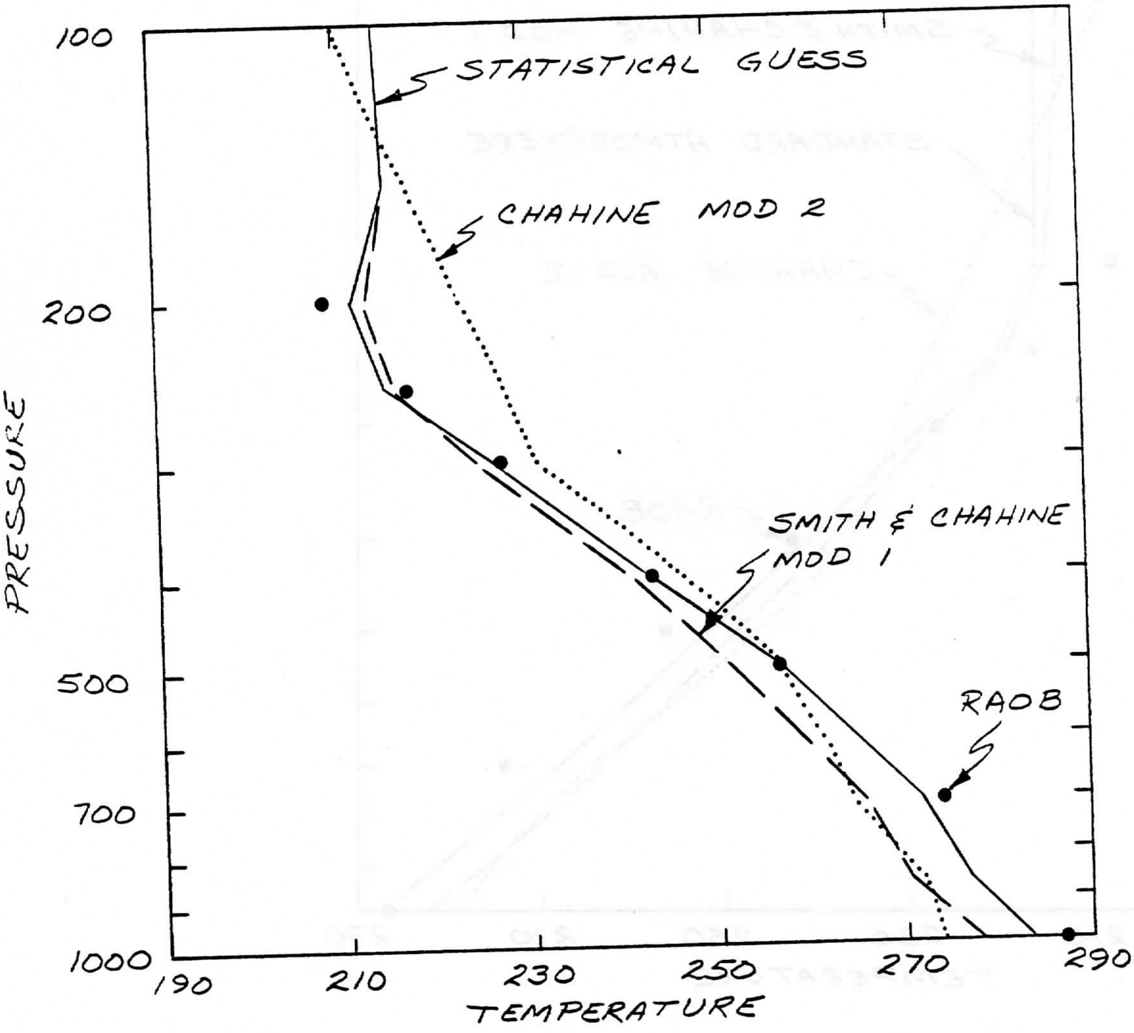
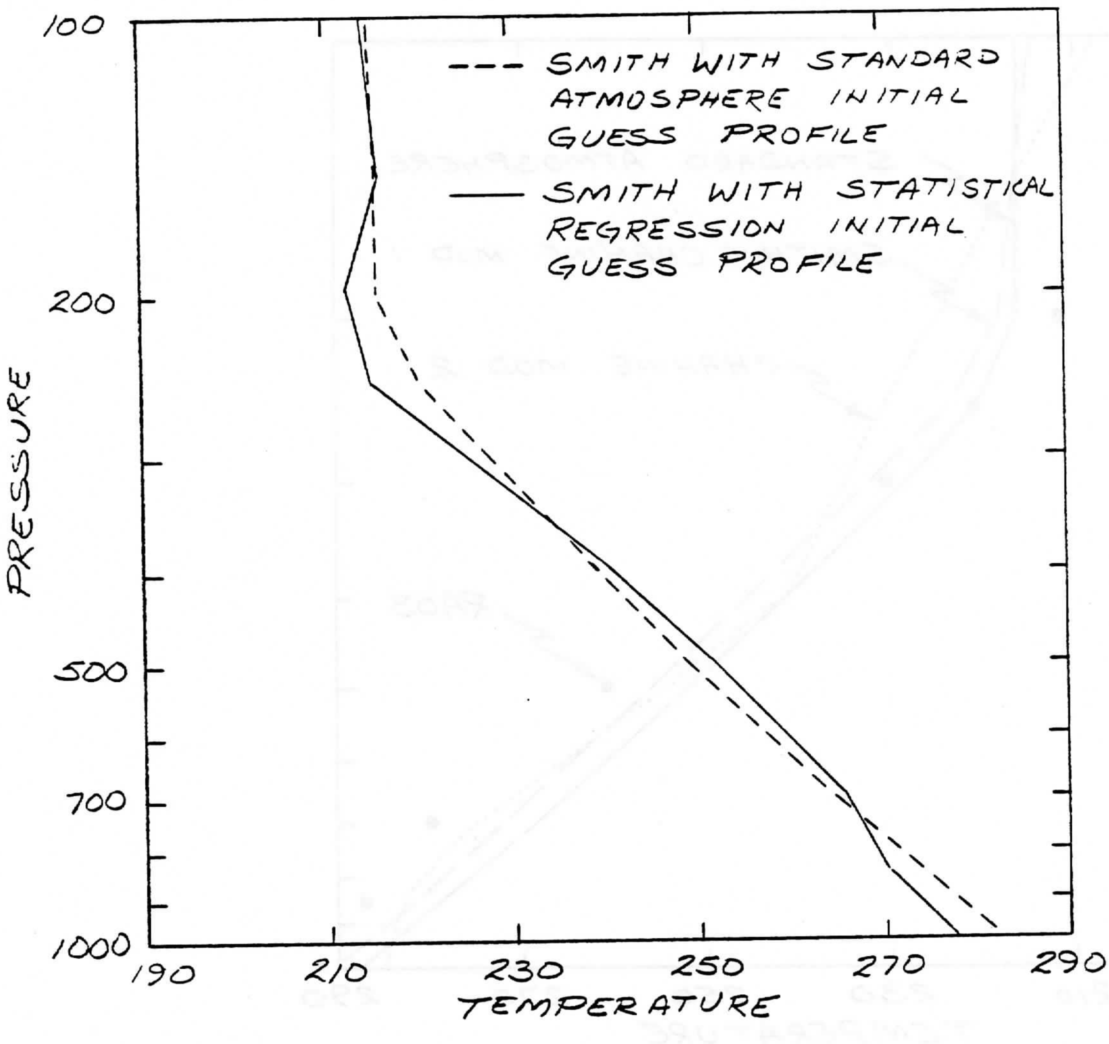


FIGURE 1b 4 MARCH, 1982 NORTH AFRICA ALPEX DATA



100
200
500
700
1000
PRESSURE
190
210
230
250
270
290
TEMPERATURE
SMITH WITH STANDARD ATMOSPHERE INITIAL GUESS PROFILE
SMITH WITH STATISTICAL REGRESSION INITIAL GUESS PROFILE

FIGURE 2

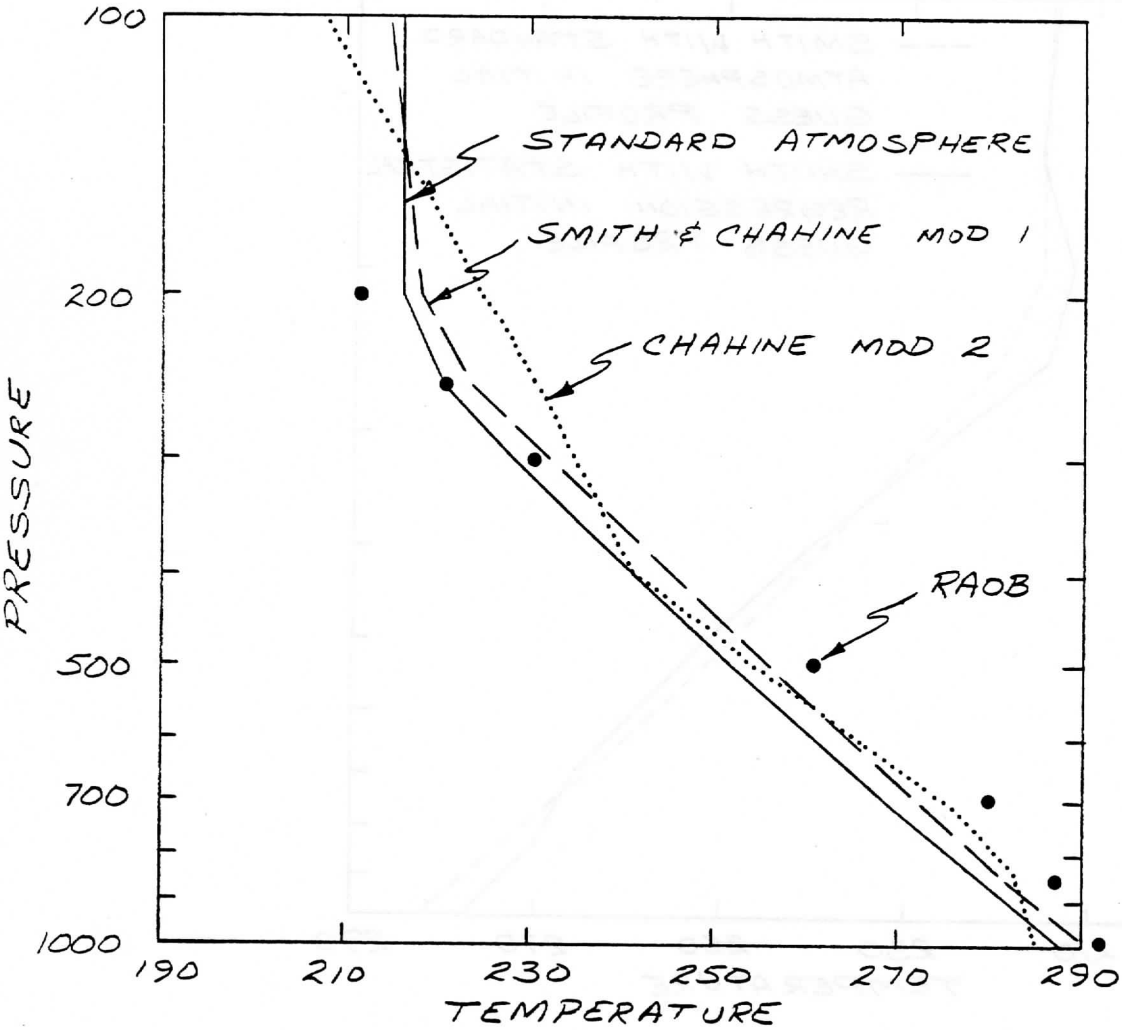


FIGURE 3a 28 OCTOBER 1982 LORD HOWE ISLAND TASMAN SEA DATA

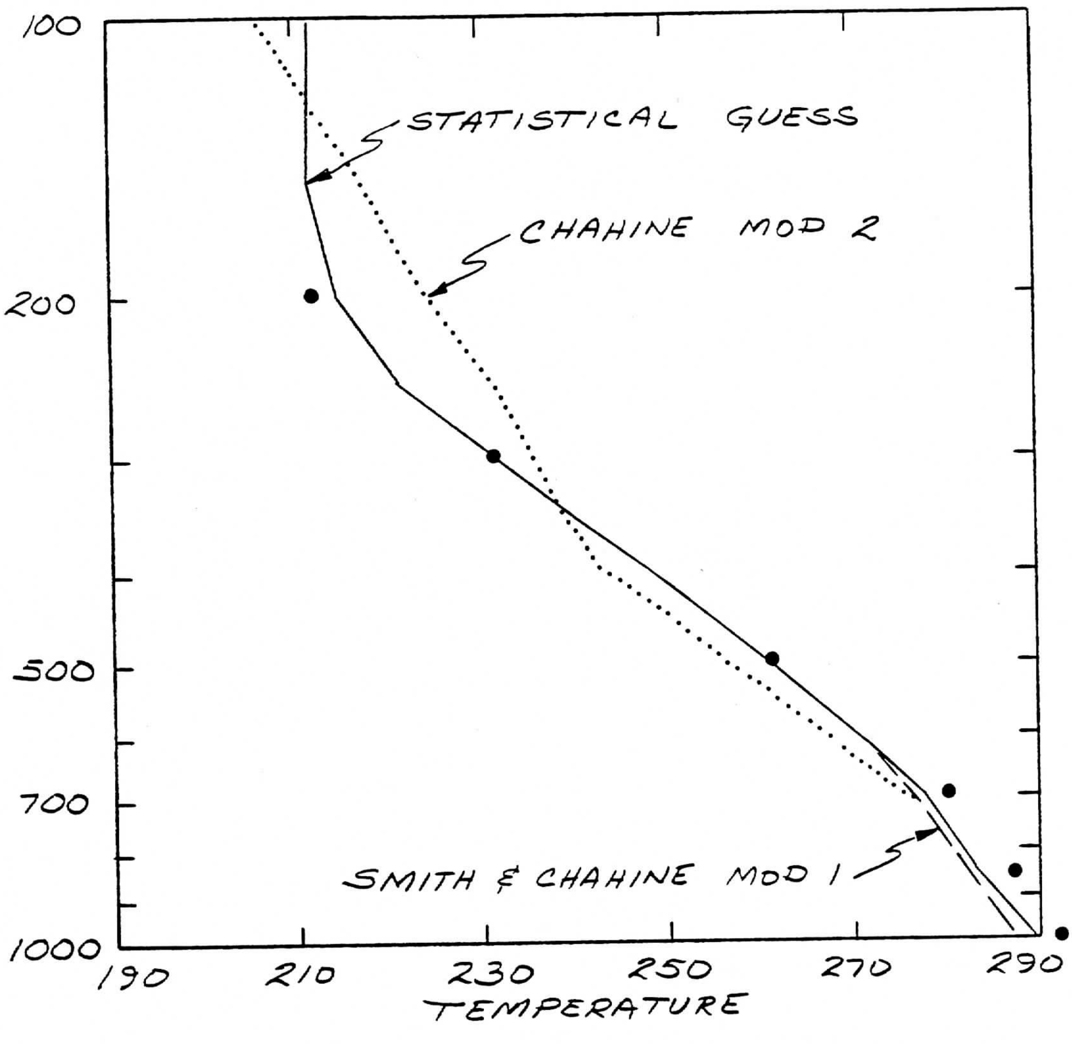


FIGURE 3b 28 OCTOBER 1982 LORD HOWE ISLAND TASMAN SEA DATA

The Technical Proceedings of

The First International TOVS Study Conference

Igls, Austria

29 August through 2 September 1983

Edited by

W. P. Menzel

Cooperative Institute for Meteorological Satellite Studies
Space Science and Engineering Center
University of Wisconsin
1225 West Dayton Street
Madison, Wisconsin 53706
(608)262-0544

March 1984