SOME PRELIMINARY RESULTS FROM THE POLAR-ORBITING SATELLITE DATA RETRIEVAL

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## 1. Introduction

The Institute of Atmospheric Physics, Academia Sinica built a very simple system for receiving satellite APT pictures from ITOS series in 1969. Since then, the science of satellite meteorology has been developed rapidly in China. Now there are more than one hundred APT stations and at least ten HRPT/GMS stations are in operation. Scientists of IAP cooperated with the meteorologists from State Meteorological Administration and Beijing University in the interpretation of the satellite cloud pictures. Some theoretical research and numerical experiments in various aspects of remote sounding such as calculation of transmittance, channel selection, study of the retrieval algorithms have been done. Unfortunately, due to the absence of a computer facility we did not have much experience in dealing with the quantitative satellite sounding data. Thanks to the help from the Space Science and Engineering Center, University of Wisconsin-Madison, a system called Interactive Data Processing and Research System (IDPRS) was set up in mid April, 1983. Actually, IDPRS is a PRC version of McIDAS (Man-computer Interactive Data Access System) based on the IBM 4331/2 computer. Although we only have very basic applications software for satellite and conventional data so far, it is proving to be very valuable to our research. The tested retrieval technique (Zhao, 1980) has been implemented on our system with real satellite data for the first time. Several ALPEX orbits have been processed interactively, also one of the Tasman Sea orbits has been processed.

## 2. Retrieval Algorithm

A non-linear Taylor expansion method is used for both temperature and moisture inversion. The radiative transfer equation for the ith channel is written

$$I_i = B_i(T_s)\tau_{is} + \int_{\tau_{is}}^{1} B_i(T)d\tau_i \quad . \qquad (1)$$

It can be approximated by

$$I_i = \sum_{j=1}^{n+1} B_i(T_j)W_{ij} \qquad (2)$$

where j refers to the atmospheric level, and

$$W_{i,1} = (\tau_{i,1} - \tau_{i,2})/2$$

$$W_{i,j} = (\tau_{i,j-1} - \tau_{i,j+1})/2$$

$$W_{i,N} = (\tau_{i,N-1} - \tau_{i,N})/2$$

$$W_{i,N+1} = \tau_{is},$$

$$T_{N+1} = T_s \quad .$$

a. Temperature Retrieval

Using a first order Taylor expansion of $B_i(T_j)$ in terms of $T_j$ in (2), we have

$$\begin{aligned} \Delta I_i^{(k)} &= I_i - \sum_{j=1}^{N+1} B_i(T_j^{(k)}) W_{ij}^{(k)} \\ &\simeq \sum_{j=1}^{N+1} \frac{\partial B_{ij}}{\partial T}\Big|_{T_j^{(k)}} W_{ij}^{(k)} \Delta T_j^{(k)} \\ &= \sum_{j=1}^{N+1} A_{ij}^{(k)} \Delta T_j^{(k)} \qquad i=1,2,\ldots,M \, . \end{aligned} \tag{3}$$

Here M is the number of channels for temperature retrieval. In this study M=8 (i.e., HIRS channels 1 to 8) and N=40 are used. k is the iteration order, k=0 refers to the first guess.

In matrix notation, (3) can be written as

$$\Delta \underline{I}^{(k)} = \underline{A}^{(k)} \Delta \underline{T}^{(k)} \tag{4}$$

and the solution will be

$$\Delta \underline{T}^{(k)} = [(\underline{A}^{(k)})^* \underline{A}^{(k)} + \gamma \underline{D}]^{-1} (\underline{A}^{(k)})^* \Delta \underline{I}^{(k)} \tag{5}$$

where $\underline{D}$ is an identity matrix, $\gamma$ is a smoothing factor. We use 0.008 as the value of $\gamma$.

The iteration equation employed is

$$\underline{T}^{(k+1)} = \underline{T}^{(k)} + \Delta \underline{T}^{(k)} \quad . \tag{6}$$

When the condition

$$|\Delta I_i^{(L)}| \le \varepsilon I_{im} \quad , \quad i=1,2,\ldots,M.$$

is satisfied, the temperature iteration is stopped. L usually takes 3 or 4 and is forced to 5. The value of $\varepsilon$ is 0.003. $I_{im}$ is the measured radiance.

b. Moisture Retrieval

To determine a moisture profile, we assume the temperature profile as constant. It is obtained from the temperature retrieval. The changes of radiance in three HIRS water vapor channels (10,11,12) are caused by the moisture variation in the air.

As before, we use the Taylor expansion to get

$$\Delta I_i^{(k)} = \sum_{n=1}^{N} \sum_{j=n}^{N} B_i(T_j) \frac{\partial W_{ij}^{(k)}}{\partial \ln q_n} \Delta \ln q_n^{(k)} \tag{7}$$

$$= \sum_{n=1}^{N} A'^{(k)}_{in} \Delta \ln q_n^{(k)} , \quad i = 10,11,12 .$$

$q_n$ is the mixing ratio at the level n.

In matrix notation it is

$$\Delta \underline{I}^{(k)} = \underline{A}'^{(k)} \Delta \ln \underline{q}^{(k)} \tag{8}$$

and the iterative equation is

$$q_n^{(k+1)} = q_n^{(k)} (1 + \Delta \ln q_n^{(k)}) . \tag{9}$$

The criteria of convergence for moisture profile is $|\Delta I_i^{(k)}| \leq \varepsilon' I_{im}$ ,where $\varepsilon' = 0.01$ is used.

After getting the moisture profile, the temperature retrieval is determined again, and then the moisture, ... The procedure is repeated until both converge. Usually one or two loops is enough. At present, the climatological temperature and moisture profiles are used as the first guess, because the analysis or forecast field is not available to date. Also no surface observations are available for the retrieval.

## 3. Some Preliminary Results

Four NOAA-7 orbits over the ALPEX area and one orbit over the Tasman Sea were processed. Each retrieval contains 1000 mb to 100 mb temperatures, heights, 1000mb to 300 mb dew points, three-layer relative humidities, geopotential thicknesses, precipitable water and so on. It takes about thirteen seconds on the IBM4331/2 computer to get one retrieval. The temperatures fit well with the radiosonde observations in middle and lower troposphere but are not so good around 200 mb. The retrieved temperatures are good over clear ocean areas and bad in cloudy or mountainous regions. Due to the shortness of time (we started the case study in early July), it is not possible to consider more factors at this time. Our proposed plan is to get the program working first, then try to improve and speed it up later. The bad retrievals are deleted by use of a manual editing program according to the horizontal consistency and cloud contamination. Comparisons were made between the analyses of the satellite soundings and the upper air observations. Some samples for showing the analyzed fields of the atmospheric parameters can be found in Figures 1 to 4. Single retrievals are also compared with the closest Raob data. The RMS error of satellite temperatures with respect to radiosondes is about 4 degrees from 1000 mb to 100 mb and reduced to 1.5 degree between 1000 mb and 300 mb.

## 4. Conclusion

As indicated earlier, the results are very primitive. Our further effort will be devoted to improve the retrieval technique and use it over the Tibetan plateau and south-east ocean regions where almost no Raob stations exist. We are also interested in nowcasting studies.

Our TOVS study benefits from collaboration with the Cooperative Institute for Meteorological Studies in Madison, WI. It is impossible to do this research on such short notice without their help. The retrieval program is based on the applications software developed by the CIMSS (Smith, 1982). Many of those subroutines and coefficients are used in our research. The authors wish to express sincere thanks to Prof. V.E. Suomi, Drs. R. Fox, W. L. Smith, H. M. Woolf, C. M. Hayden and their colleagues for the generous help with both McIDAS hardware and software.

## References

Zhao, Gaoxiang, 1980: A possible scheme for improving vertical resolution and accuracy of satellite temperature retrieval. KEXUE TONGBAO (A monthly Journal of Science) Vol. 25, No. 12, 1019-1024.

Smith, W. L., V.E. Suomi, F.X. Zhou and W.P. Menzel, 1982: Nowcasting applications of geostationary satellite atmospheric sounding data. 'Nowcasting' edited by K.A. Browning.

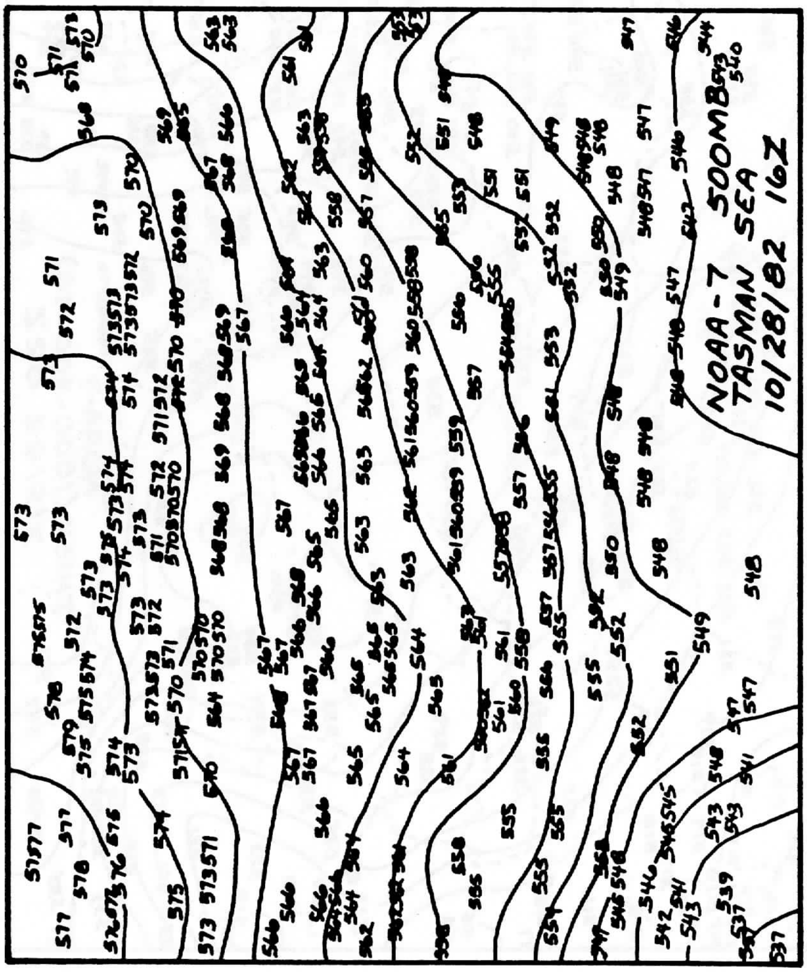


Figure 1

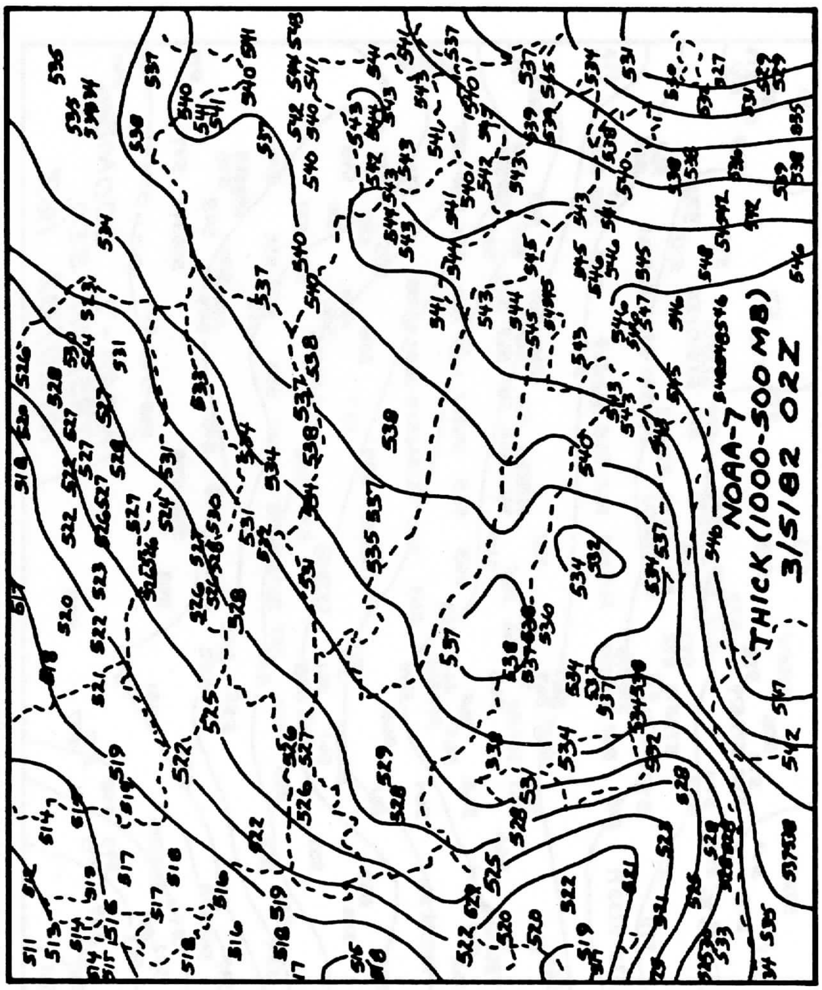


Figure 2

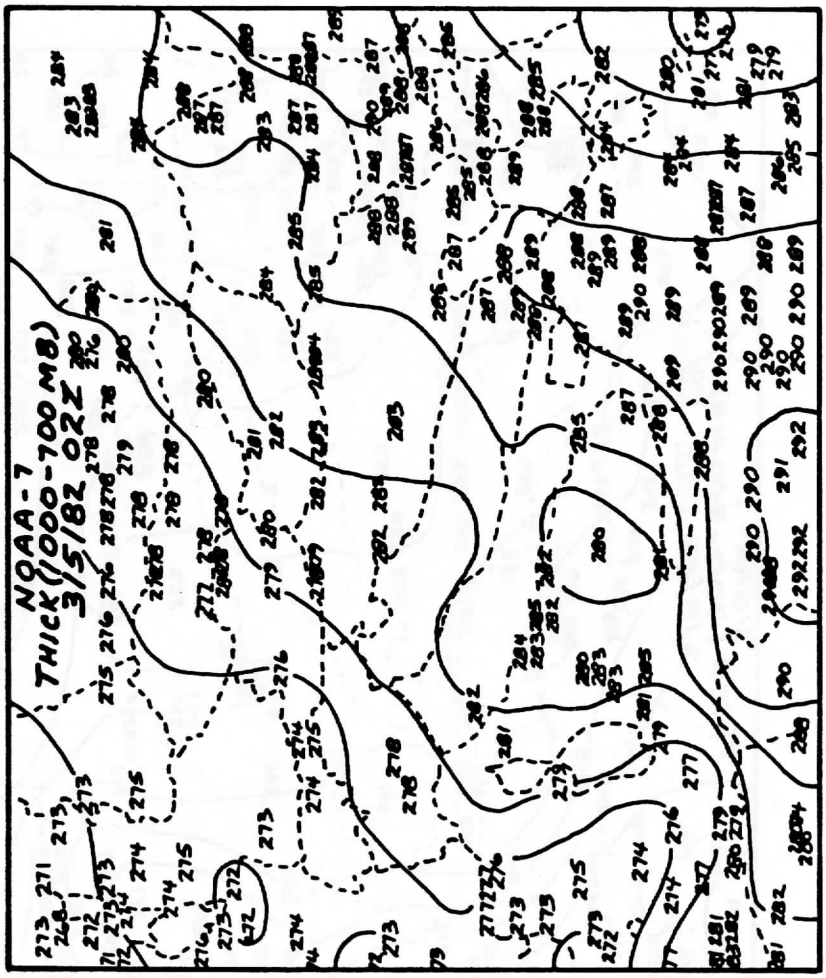


Figure 3

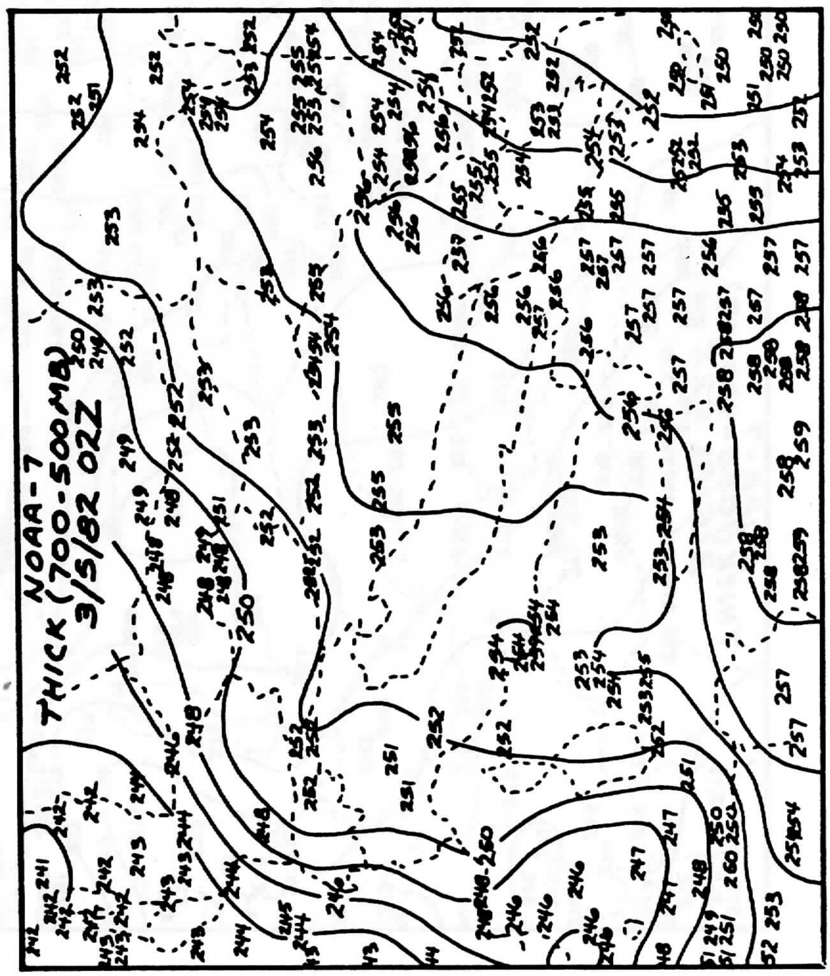


Figure 4

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