AN IMPROVED CLOUD RETRIEVAL ALGORITHM USING HIRS2/MSU RADIANCE MEASUREMENTS

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1. INTRODUCTION

Cloud heights and cloud amounts have been produced with an improved method as part of the operational processing of polar orbitting satellite data at the National Environmental Satellite, Data, and Information Service(NESDIS) since 1984. The cloud parameters for each 3 by 3 array are obtained by placing the clouds at one of 9 pressure levels(100,150,200,250,300,400,500,700, or 850mb) with the final amount determined by the cloud amounts for the 9 individual HIRS2 spots. Details of the improved method were described by Nappi et al.(1988). The method relies on a basic technique called "radiance-slope method", which was discussed by McCleese and Wilson (1976) and later expanded by Smith and Platt (1978) as the CO2 Method, and still later by Wielicki and Coakely (1981). These approaches rely heavily on principles used to derive clear-column radiance by Smith (1968).

The NESDIS operational cloud products were compared with similar products from the Air Force Real-Time Nephanalysis(RTNEPH) (Kiess and Cox, 1988; Hamill et al. 1991), from the NASA Goddard's processing of NOAA TOVS radiance data (Susskind et al. 1987), and from the International Satellite Cloud Climatology Project(ISCCP) (Rossow et al. 1988). The comparisons showed that the amount of high level cloud (above 400mb) produced by the NESDIS operational system was underestimated, and the amount of low level cloud(below 800mb) was overestimated, and the effective total cloud amount seems to be larger compared with the other cloud data sets (McMillin et al. 1991).

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2. INVESTIGATION

The previous comparisons showed that two questions need to be answered: 1) Why does the NESDIS operational cloud retrieval algorithm produce too much low level cloud and too little high level cloud?; 2) Why does the effective total cloud amount Produced by the operational system seem to be larger compared with the other cloud data sets?

To investigate these questions, the cloud retrievals from the NESDIS operational system for the day of November 11, 1990 were separated to 4 categories by specific flags appended to the retrievals. Each of these categories contains the retrievals for a particular combination of channels. The combinations are HIRS2 channel 8 and 18 for partly cloudy/night, channel 6 and 8 for partly cloudy/day, MSU channel 2 and skin temperature for overcast/sea, and HIRS2 channel 6 and 7 for overcast/land. Figures 1-4 show the distribution of effective cloud amount as a function of cloud top pressure for each of these 4 categories. The distributions shown in figures 1-3 are similar. Each displays too much low level cloud and too little high level cloud. This indicates the pairs of channels used by the NESDIS operational algorithm for cloud retrieval for those categories are less sensitive to high level cloud. An opposite trend is shown in figure 4, which shows no low level cloud. This means the pair of channels is not sensitive to low level cloud (a similar problem was mentioned by Wylie and Menzel, 1990). As a result of the above analysis, it can be concluded that different pairs of HIRS2 15 um CO_2 and window channels respond to different cloud levels.

In order to investigate the characteristics of the pairs of channels used for cloud retrieval, different pairs of channels were used to retrieve cloud parameters for all of the 4 situations as mentioned above. Figures 5 and 6 show the same parameters as figures 1-4, but use HIRS2 channels 6 and 8(figure 5), and 6 and 7(figure 6) for all situations for the 2nd orbit of March 21, 1991. The distribution of effective cloud amount as a function of cloud top pressure in figure 5 is closer to the expected distribution than the one in figure 2, but a trend similar to that shown in figure 2 still exists. Figure 6 shows a distribution of cloud amount that is very similar to the one displayed in figure 4. Both of these two figures further confirm our earlier conclusion that the use of different level 15 um CO_2 and window channels is necessary for cloud parameter retrieval using HIRS2/MSU radiance measurements.

3. IMPROVED CLOUD RETRIEVAL ALGORITHM

The basic method used by the improved cloud retrieval algorithm is the "radiance-slope method" as mentioned before. The same iterative procedure (known as the Newton-Raphson method) as that used by the NESDIS operational cloud retrieval algorithm is used for cloud top temperature calculation.

The principle of the new algorithm is the use of different pairs of HIRS2 channels to retrieve cloud top temperature for different cloud levels. In practice, the pair of HIRS2 channels(Ch. 7 and 8) is used to get the first estimate of cloud top temperature, and the first estimate of cloud top pressure is evaluated using the calculated cloud top temperature and the retrieved temperature profile from operational sounding processing system. Based on the first estimate, a second pair of HIRS2 channels (Ch. 3 and 4, Ch. 4 and 5, ... or Ch. 6 and 8) is used to refine the estimate of the cloud top temperature. The overcast radiance is calculated with the Planck function using the refined estimate of the cloud top temperature. The clear radiances for partly cloudy areas were taken directly from the cloud clearing step (McMillin and Dean, 1982). The clear radiances for HIRS2 channel 4-8 for overcast areas, where the cloud clearing step failed, were predicted from HIRS2 channel 1-3 and MSU channel 2-4 radiance measurements with a standard regression technique. Finally, the window channel (HIRS2 channel 8) is used for effective cloud amount calculation. An important advantage of the new algorithm is the fact that a single numerical procedure is used to retrieve cloud parameters for all of the 4 situations.

4. PRELIMINARY RESULTS AND COMPARISON

The HIRS2/MSU radiance measurements and the retrieved atmospheric temperature profiles for March 21, 1991 were used to test the improved cloud retrieval algorithm. Cloud heights and cloud amounts were retrieved with the new algorithm. The distribution of effective cloud amount as a function of cloud top pressure for the retrievals with the new algorithm is shown in figure 7. The daily global averaged effective total cloud amount is 42%. The cloud retrievals from the NESDIS operational system are shown in figure 8, and the daily global averaged effective total cloud amount is 53%. The comparison between these two figures shows that the distribution of effective cloud amount produced by the new algorithm is in better agreement with other cloud data than the one from the operational system. The daily global averaged effective total cloud amount produced by the new algorithm is reduced by 20% compared with the operational result, and is consistent with NASA Goddard's result (McMillin et al. 1991).

5. SUMMARY AND SUGGESTION

The improved cloud retrieval algorithm produces cloud parameters that are in agreement with NASA Goddard's, ISCCP and Air Force RTNEPH data. The investigation discussed in section 2 demonstrated that the combination of different level 15 um CO2 and window channels is necessary for cloud parameter retrieval using HIRS2/MSU radiance measurements.

Since the first guess of cloud top temperature was evaluated using the pair of HIRS2 channels 7 and 8, and the cloud height retrieved using the pair of HIRS2 channels 6 and 7 never goes below the 700mb surface, the low level cloud retrieved with the new algorithm mainly depends on the pair of HIRS2 channels 7 and 8. The possibility that the temperature of the coldest AVHRR spot within the HIRS2 field of view may provide a better first guess of cloud top temperature should be investigated.

The procedure used for predicting the clear radiance for the lower level channels from the upper level HIRS2 channel and MSU channel radiance measurements for overcast areas needs to be investigated and modified in order to get more reliable clear radiances than the regression results used to retrieve the cloud parameters. Alternatively, the radiance computed from NMC forecast files may be used in place of the clear value for overcast areas (McMillin et al. 1991).

The improved cloud retrieval algorithm is being evaluated. When the evaluation is complete, it will be used to produce cloud parameters that will be compared with the other cloud data sets.

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REFERENCES

Hamill, T.M., J.T. Bunting, and R.P. d'Entrement, 1991: A Description of the Real-Time Nephanalysis Model. (in preparation).

Kiess, R.B. and W.M. Cox, 1988: The AFGWC Automatic Real-Time Nephanalysis Model. AFGWC Tech. Note-88/001, U.S. Air Force Global Weather Center, Offutt AFB, Nebraska 68113, 82 pp.

McCleese, D.J. and L.S. Wilson, 1976: Cloud Top Heights from Temperature Sounding Instruments. Quart. J. Roy. Meteor. Soc., Vol. 102, pp. 781-790.

McMillin, L.M. and C. Dean, 1982: Evaluation of a New Operational Technique for Producing Clear Radiances. J. Appl. Meteor., 21, 1005-1014.

McMillin, L.M., S.S. Zhou, and S.K. Yang, 1991: An Initial Evaluation of TOVS Cloud Products Based on Comparisons with Other Cloud Retrievals. (in preparation).

Nappi, A.J., A. Swaroop, and L.M. McMillin, 1988: An improved Method for the Retrieval of Cloud Height and Cloud Amount from satellite radiance Measurements. Preprint Volume of the Third Conference on Satellie and Oceanography, Feb. 1-5, Anaheim, California, American meter. Soc., pp. 338-391.

Rossow, W.B., L.C. Garder, P.J. Lu, and A.W. Walker, 1988: International Satellite Cloud Climatology Project(ISCCP) Documentation of Cloud Data. WMO/TD-No. 226, World Meteor. Organization, Geneva, 78 pp. plus two appendices.

Smith, W.L., 1968: An Improved Method for Calculating Tropospheric Temperature and Moisture from Satellite Radiometer Measurements. Mon. Wea. Rev., 96, 387-396.

-----, and C. M. R. Platt, 1978: Comparison of Satellite-Deduced Cloud Heights with Indications from Radiosonde and Ground-Based Laser Weasurements. J. Appl. Meteor., Vol. 17, PP. 1796-1802.

Susskind, J., D. Reuter, and M. Chahine, 1987: Cloud Fields Retrieved from Analysis of HIRS2/MSU Sounding Data. J. Geophys. Res., 92, 4035-4050.

Wielicki, B.A. and J.A. Coakely,Jr., 1981: Cloud Retrieval Using Infrared Sounding Data: Error Analysis, J. Appl. Meteor., Vol. 20, pp. 157-169.

Wylie, D. and W.P. Menzel, 1990: Cloud Climatology from GOES/VAS/HIRS. Presentation in OPSAT'90, October 16-19, Washington D.C.

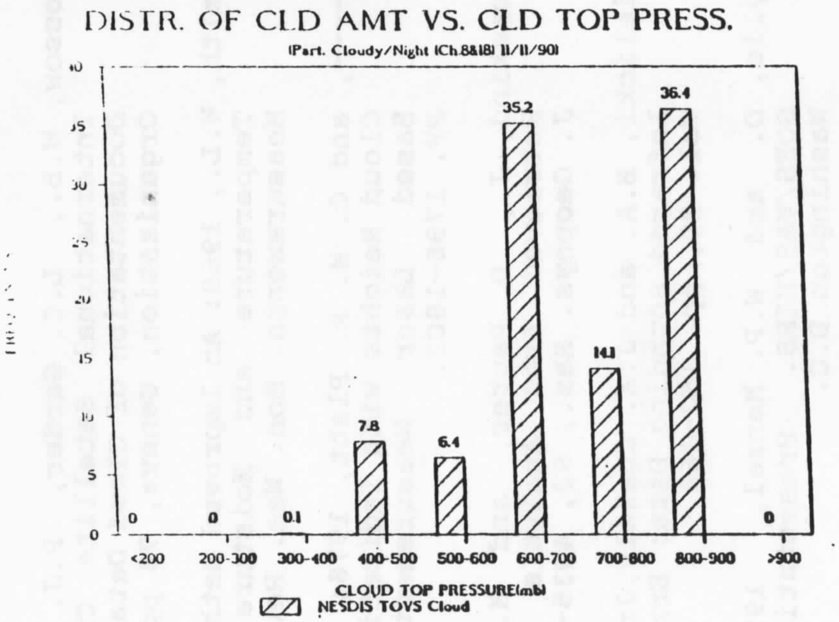


Figure 1

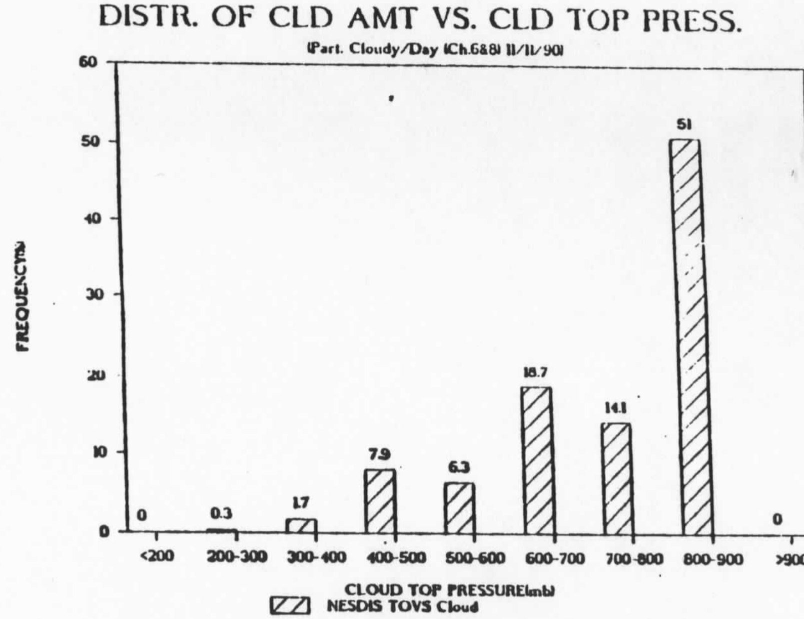


Figure 2

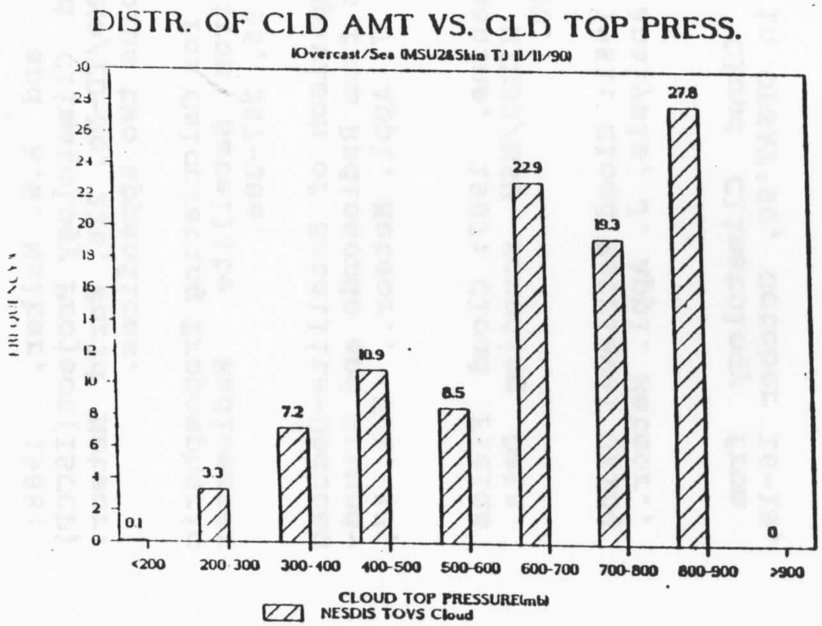
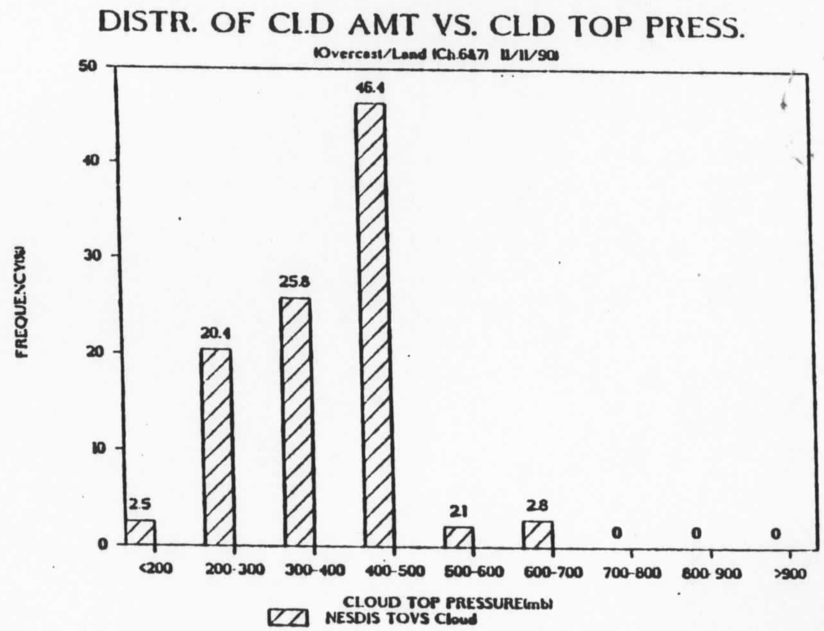


Figure 3



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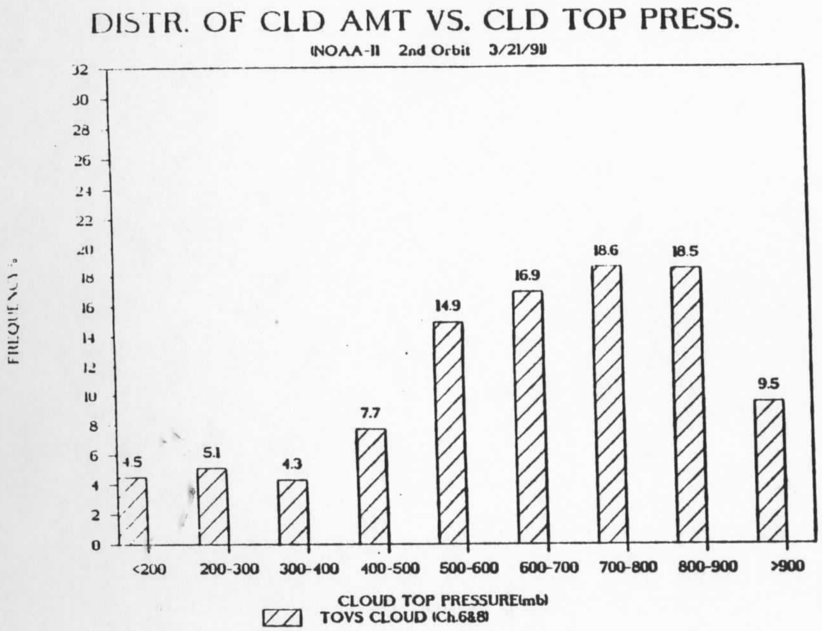
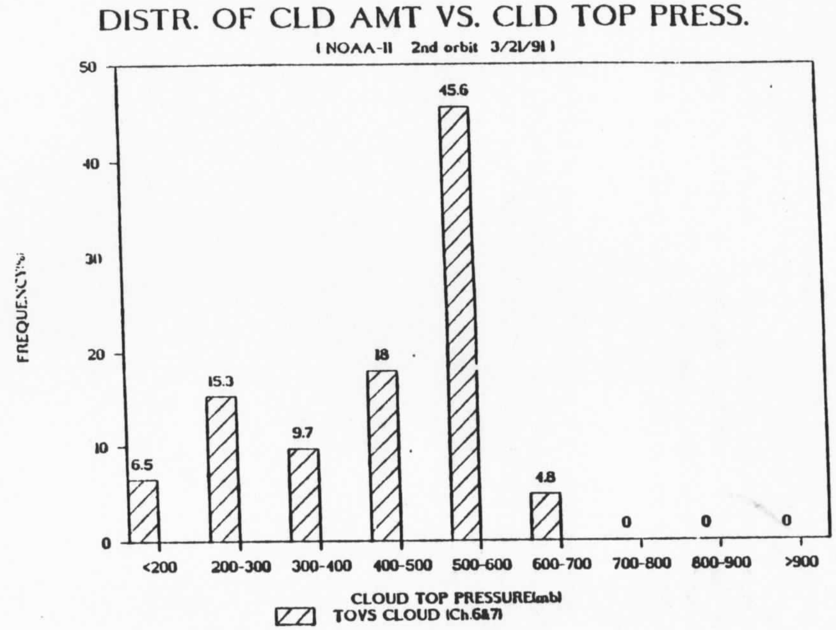


Figure 5



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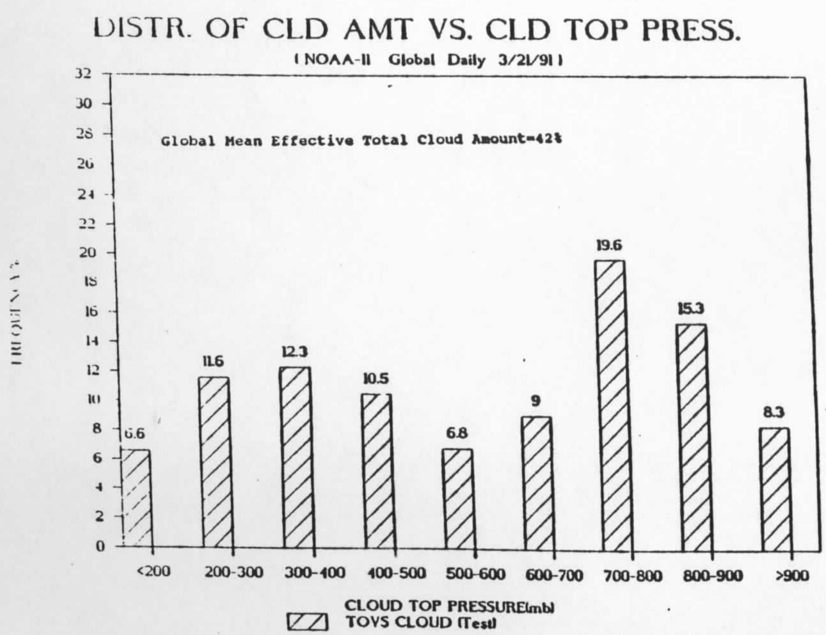

Figure 7

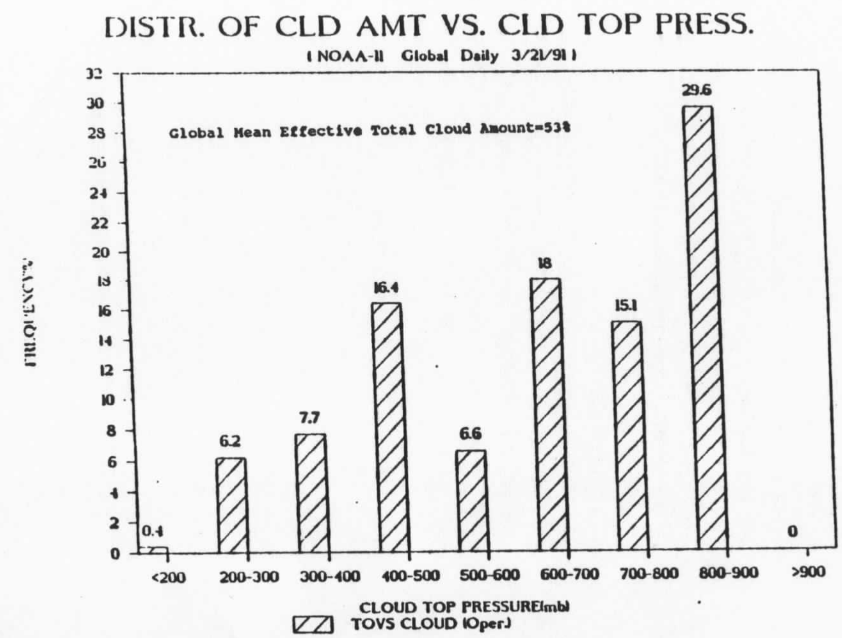

Figure 8

TECHNICAL PROCEEDINGS OF THE SIXTH INTERNATIONAL TOVS STUDY CONFERENCE

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