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SIMULATING THIN CIRRUS CLOUDS IN OBSERVING SYSTEM SIMULATION EXPERIMENTS (OSSE) FOR LAWS

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ABSTRACT

Pulsed Doppler lidars can be designed primarily to detect and measure the motion of atmospheric aerosols along the cloud-free lines of sight. Available literature suggests that a space-based lidar system will encounter clouds more than 50% of the time. Since the presence of very thin cirrus clouds is underestimated with today's passive systems, we can expect that lidar cloud return will be even greater.

In addition to realistically simulating the accuracy of a space-based Doppler lidar system such as LAWS, it is important to realistically simulate where measurements will be made. Current simulation studies with Goddard Space Flight Center (GSFC) and Florida State University are attempting to include first order estimates of optically thin ($\tau < 1.0$) clouds based upon grid point data from General Circulation Models (GCMs).

1. INTRODUCTION

A space-based Doppler Lidar Atmospheric Wind Sounder (LAWS) has been proposed by NASA as a facility instrument for the NASA Earth Observing System. A LAWS Simulation Model (LSM) has been developed that, coupled with Global Circulation Models (GCMs), evaluates the potential impact on the predictive skills of current forecast models. Simpson Weather Associates (SWA) is currently participating in Observing System Simulation Experiments (OSSE) by providing realistic LAWS simulation winds and errors for assimilation into NASA/GSFC and Florida State's GCMs (Atlas and Emmitt, 1991; Krishnamurti et. al., 1991). It is important to provide these experiments with winds at locations where LAWS measurements will be possible.

Previous studies have shown that, given current LAWS baseline orbital configuration and signal processing capabilities, obtaining mid-level wind information will be very difficult unless sub-visual cirrus is present (Wood and Emmitt, 1990, 1991). In fact, thin cirrus clouds will probably be the primary discriminator between marginal measurement accuracy and resolution in the upper troposphere and some of the best wind measurements made by LAWS.

2. GLOBAL CLOUD CLIMATOLOGIES

Most of our knowledge of global cloud coverage is derived from data obtained with space-based sensors. Climatologies such as those based upon Nimbus-7 data (Stowe et al., 1989) and, more recently those being generated by the International Satellite Cloud Climatology Program (ISCCP) all find an average global cloud coverage of 50-55%. These climatologies must be considered as climatologies of basically visible cloud. They are suspected of severely underestimating the amount of very thin clouds - clouds with optical depth less than .1 or .2.

To get some idea of the extent of thin cirrus, data taken during the SAGE (Stratospheric Aerosol and Gas Experiment) was processed to get statistics on the frequency of occurrence of upper tropospheric cirrus (Woodbury and McCormick, 1983). That study indicated that in some latitudinal bands, very thin cirrus occurred more than 25% of the time.

We have concluded that any OSSE that omits the contribution of thin cirrus will severely misrepresent both the frequency and accuracy of wind observation in the upper troposphere. For this reason, we are attempting to estimate the presence of such cloud by using model soundings in a cirrus cloud model.

3. MODELING CIRRUS IN THE LAWS SIMULATION MODEL

The LAWS Simulation Model (LSM) simulates LAWS' scanning/sampling and computes line-of-sight radial wind velocities. The model includes the effects of aerosol backscatter, molecular attenuation, atmospheric turbulence, opaque clouds and terrain. The line-of-sight velocity information is used to compute the horizontal wind components. In previous studies, the LSM has been used to address some key LAWS issues and trades involving accuracy and interpretation of LAWS information, data density, signal strength, cloud obscuration and temporal data resolution (Emmitt, 1991; Emmitt and Wood, 1989; Emmitt and Wood, 1988). Currently, SWA is providing global LAWS simulated winds for five days to NASA/GSFC to address the impact of three proposed LAWS orbital configurations. To insure that LAWS winds are represented in the upper troposphere in these simulations, we attempt to simulate the global presence of optically thin cirrus clouds.

The LSM cirrus cloud model is based upon a model obtained from Heymsfield (NCAR). The Heymsfield model computes a profile of cirrus cloud ice water content, along with cloud base and top altitudes, based upon a vertical atmospheric sounding taken with a rawinsonde. The LSM version of the Heymsfield model uses European Center for Medium Range Weather Forecasting (ECMWF) profile data to supply atmospheric soundings as input to determine the presence of cirrus clouds. While the rawinsonde profile may contain thin layers of near saturation, the ECMWF model rarely shows saturation because of the vertical averaging. Therefore, we have taken an approach which computes a proability of a cirrus layer from the (< 100%) relative humidity in the ECMWF layers above 500 mb. Currently we use a threshold of 70% RH for the probable occurrence of cirrus. As the RH increases so does the probability of a saturation layer. Figure 1 shows a typical ECMWF relative humidity profile depicting a high humidity aloft and thus the likely presence of a cirrus cloud.

Once a cirrus ice profile is detemined, the LSM assigns a subvisible cirrus backscatter from the baseline atmosphere library (Wood and Emmitt, 1990, 1991) as a function of cirrus base altitude. The baseline median cirrus backscatter ranges from E^{-9} to E^{-6} m^{-1} sr^{-1} for altitudes 7 to 14 km, respectively. The LSM uses the LOWTRAN 6 cirrus cloud model (Kneizy et. al., 1983) to approximate cirrus attenuation effects by utilizing the cirrus cloud thickness. The optically thin cirrus attenuation ranges from 0.0001 to 0.15 km^{-1} for cloud thicknesses 0.001 to 1 km, respectively. A future update of the cirrus model will provide thin cirrus optical properties using a radiative transfer model such as Liou et. al. (1990).

Figure 2 is an example showing the location of cirrus cloud profiles for 0000z 11/10/79 that the LSM generated over North America. Contours of the ECMWF 500 mb relative humidity inputs over North America are shown in Fig. 3.

4. CONCLUSIONS

It is too early in this study to conclude whether or not the simulated thin cirrus cloud is realistic. Without much "real" data we are left with primarily sensitivity studies. In the extremes we can assume no clouds other than those provided directly by the ECMWF model or we can generate 20-25% global coverage of additional thin cirrus. If larger differences in the model performance are found between these two extremes we will then be faced with developing a more rigorous algorithm.

5. ACKNOWLEDGEMENTS

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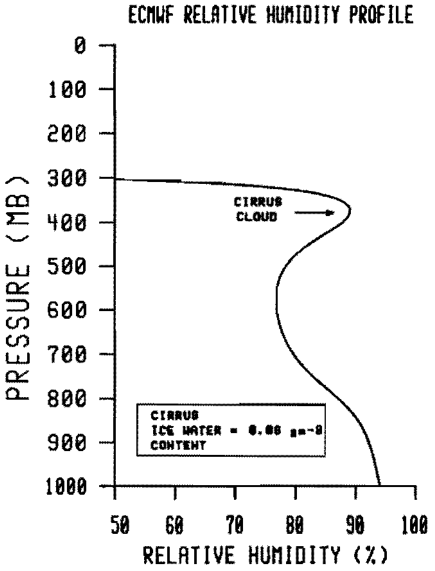

Fig. 1. A relative humidity profile from the ECMWF data set 11/10/79, 0000Z. The Heymsfield cirrus model was used to compute the cirrus ice water content at the higher relative humidities aloft.

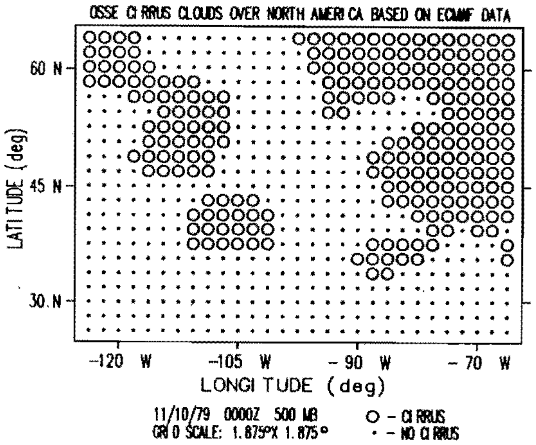

Fig. 2. Locations of cirrus cloud profiles over North America for 11/10/79, 0000Z. The profile locations were determined using the Heymsfield cirrus model and ECMWF gridded profile data.

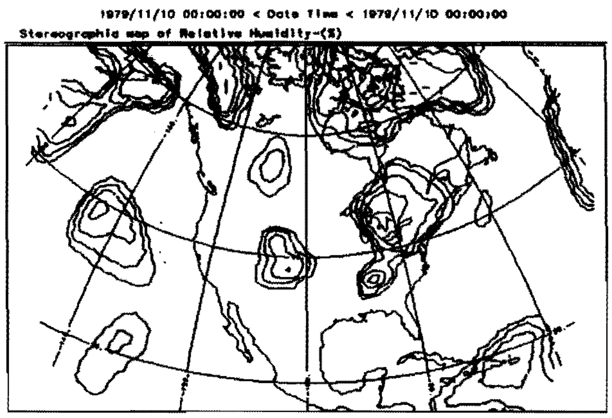

Fig. 3. 500 mb ECMWF relative humidity contour plot over North America for 11/10/79, 0000Z. The relative humidity contours are plotted from 70% to 100%.