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SIMULATING CLOUDS WITHIN A SPACE-BASED DOPPLER LIDAR WIND SOUNDER SIMULATION MODEL

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ABSTRACT

An end-to-end performance simulation model for space-based Doppler lidar wind sounders is being developed under a Phase II SBIR contract. The Defense Lidar Simulation Model (DLSM) uses operational weather forecasting models (ECMWF/T106 and ETA/28 km) to generate LOS atmospheres for individual lidar shots. In addition to providing shot-by-shot aerosol backscatter, molecular attenuation, and atmospheric turbulence, the DLSM atmosphere generation model (AGM) produces cloud coverage, backscatter and porosity.

The AGM cloud model is, in general, based on the Slingo cloud parameterization scheme[1]. The Slingo approach provides distinctions between high and mid-tropospheric stratiform clouds, convective clouds with and without anvil cirrus, and low level clouds driven by weak vertical motion or inversion capped moist boundary layers.

1. CONVECTIVE CLOUD

The convective cloud is inferred, for example, from 3 hour integrated precipitable water from the 3-D model meteorological profiles. A critical threshold value of 0.14 mm/day must be met for a convective cloud to be present. The top of the convective cloud layer is a function of the base layer convective cloud amount and the tropopause height. If the top of the convective cloud is above the 400 mb layer and the integrated precipitable water more than 3.4 mm/day, then an anvil is defined. All anvil clouds are considered to be optically thick cirrus layers.

2. HIGH NON-CONVECTIVE CLOUDS

All non-convective high clouds are derived as a function of relative humidity from the 3-D model meteorological profiles. A high layer cloud is only derived when the tropopause height is higher than the 400 mb layer. All high non-convective cloud is considered to be thin cirrus and thus semi-transparent to the laser beam.

3. MIDDLE NON-CONVECTIVE CLOUDS

All non-convective middle clouds are derived as a function of relative humidity from the 3-D model meteorological profiles. If there was a convective cloud or a high layer cloud, the AGM drys out the relative humidity profile and thus reduces the likelihood of middle cloud. Like the high cloud algorithm, the AGM finds the highest relative humidity in the profile and uses a relative humidity threshold for cloud occurrence.

4. LOW NON-CONVECTIVE CLOUDS

The estimate of low level non-convective clouds is based upon two parameters: vertical velocity and the potential temperature profile. From vertical velocity, the AGM finds the layer with the largest negative vertical velocity and computes the critical relative humidity for the layer.

5. GLOBAL STATISTICS AND EMPIRICAL ADJUSTMENTS

We expect that clouds will be in the field-of-view (FOV) of a space-based lidar 70-80% of the time. This estimate is based upon the reported analysis of two years of HIRS data[2], the cirrus climatology derived from SAGE data[3] and the ISCCP global cloud climatology[4]. Much (30-40%) of this cloud coverage is high cloud (above 400-500 mb) and is semi-transparent. Very thin or subvisual cirrus ($\tau < .07$) not detected by HIRS or AVHRR may be occasionally represented in the SAGE observations. We conclude that the occurrence of very thin to subvisual cirrus is underestimated in current global cloud climatologies.

Of particular interest to any program involving space-based lasers are the semi-transparent and optically thin cirrus clouds, since they may provide strong returns without full extinction. When one considers that the statistics given above are, in most cases, exclusive - i.e., they do not provide a good representation of coincident clouds at different altitudes, it is very likely that there are many occasions when there are multi-layers of thin clouds underlain by opaque clouds (e.g., the recent WWW pictures on the LITE home page (http://arbs8.larc.nasa.gov/LITE/litehome.html)).

The distribution of clouds (over a 1° x 1° area) based upon the ECWMF total cloud coverage as a function of latitude are shown in Figure 1. The total coverage is quite reasonable and compares well with the satellite statistics. While not evident in the figure, the amount of midlevel cloud forecast for the tropics is considerably less than the 30-40% reported using the satellite data. This discrepancy is an ongoing point for discussion and study within the modeling community, with some researchers suggesting that the interpretation of midlevel cloud in satellite imagery may be faulty.

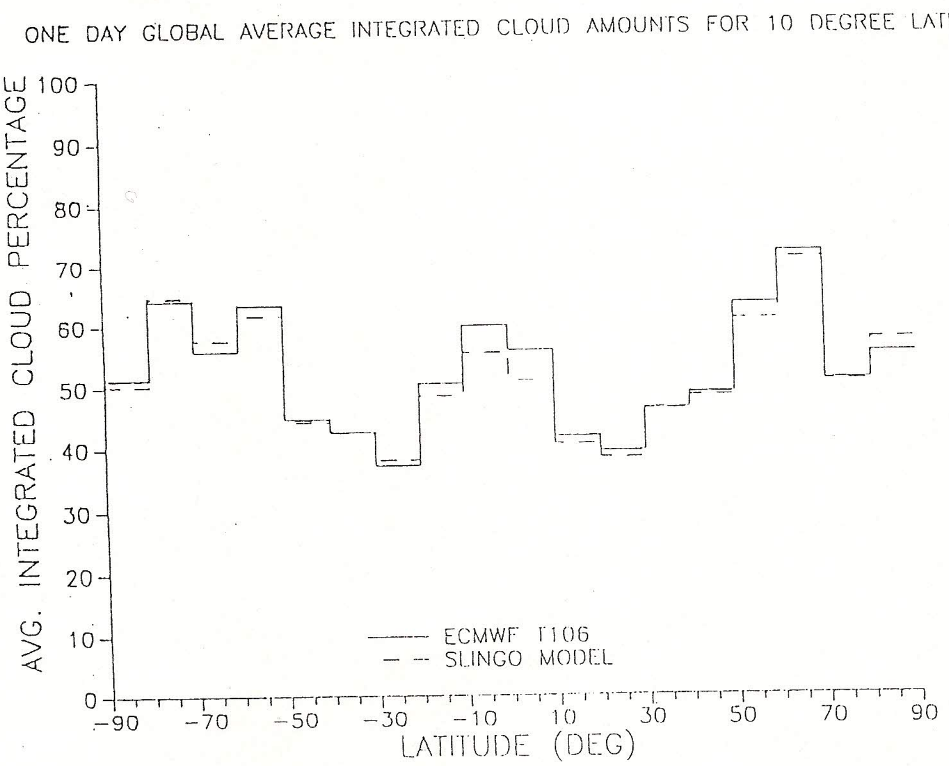

Figure 1. Comparison of the global average integrated cloud cover from the Slingo model to the AGM integrated cloud amount.

6. CLOUD OPTICAL PROPERTIES

All opaque cloud backscatter values are defaulted in the AGM to be 10^{-06} m^{-1} sr^{-1}. We believe this value is properly conservative, since recent midlayer cloud backscatter, measured with a lidar in the Antarctic, range from 10^{-06} to 10^{-04} m^{-1} sr^{-1} [5]. Once a lidar shot gets a return from an opaque cloud, the shot is considered to be fully attenuated and its propagation terminated. Cirrus cloud backscatter is computed using the LOWTRAN[6] cirrus model. For cirrus cloud layers, however, we allow all the shots a finite probability to pass through to the next model layer. The cirrus cloud attenuation model is a modified version of the analytical LOWTRAN cirrus algorithm[6],

$$\tau = e^{-0.14*L2}$$

where

τ = the cirrus transmittance

L = the cirrus cloud thickness .

Since the AGM is restricted to a coarse vertical resolution, it uses the Slingo algorithm cirrus cloud percentage as a surrogate for cirrus cloud optical thickness. The major assumption is that while the Slingo model derives a percent cirrus cloud coverage (e.g., 30%) from an average relative humidity within a grid volume, it is just as reasonable to interpret an optical thickness tendency from the same fields. Validation of this approach is ongoing. Instead of using the percent coverage as literally meaning that 30% of the grid has cirrus cloud and 70% is totally cloud-free, the AGM assumes that the whole grid area is covered by a cirrus cloud that has an optical thickness that scales to the percent coverage. The cirrus cloud attenuation is defined as

$$ci_{att} = 10^{\alpha} * (CLD_{\%} * 10)^2$$

where

ci_{att}	=	the cirrus cloud attenuation
α	=	the LOWTRAN cirrus attenuation coefficient for a 1 km thick layer
$CLD_{\%}$	=	the cirrus cloud percentage cover .

7. CLOUD POROSITY

Experience with airborne lidar systems has shown that visually dense and unbroken cloud fields are often fractionally (0-30%) transparent to a laser beam[7]. Detailed analysis of SPOT and LANDSAT imagery[8] also revealed that scenes (multi-pixel) classified as 100% covered, were more likely 10-30% porous for 10-20 m diameter beams. While the supporting data is rather sparse, the DLSM does allow the users to assign a porosity to model clouds based upon their type and physical thickness. A porosity of 25% for stratiform clouds makes a significant difference in the number of times a space-based lidar can make measurements in the PBL. We are currently evaluating techniques for validating the porosity assignments.

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