P3.16 IMPROVEMENTS TO U.S. AIR FORCE CLOUD FORECAST MODEL, ADVECT CLOUD

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1. INTRODUCTION

Advect Cloud is an Air Force model that predicts the short-range movement of cloud cover. The model initialization is based on polar orbiting satellite imagery and has a long history at the Air Force Weather Agency (AFWA). The first numerical cloud forecast model was designed by Jensen during the early 1960s (Collins, 1970). This model was used operationally at the then Strategic Air Command Global Weather Central, from 1962-1964, and showed skill over persistence in forecasting macro-scale cloudiness. In 1964, the model was replaced by a condensation pressure spread (CPS) and trajectory model (Collins, 1970). CPS is defined as the number of hectopascals an air parcel must be lifted to become saturated. This model is the basis of the present Advect Cloud.

The initial cloud field is developed using AFWA's Real-Time Nephanalysis Model (RTNEPH) (Hamill, 1992). The RTNEPH combines DMSP and NOAA satellite data, rawinsonde data, conventional surface observations, and aircraft reports to provide an automated cloud analysis on a 25 nm horizontal resolution, bi-hemispheric grid (Kiess and Cox, 1988). Figure 1 shows the grid for the Northern Hemisphere. Each grid point is assigned a percent cloudiness at up to four levels. Since 1999, AFWA has produced developmental 12.5 nm hemispheric and 3 nm limited area cloud forecasts (Bieker, 2001).

Advect Cloud forecasts percent cloudiness for five fixed levels: 300, 500, 700, 850 hPa, and 60 hPa above the surface (defined as the gradient level). In addition, the total cloud in the column is forecast.

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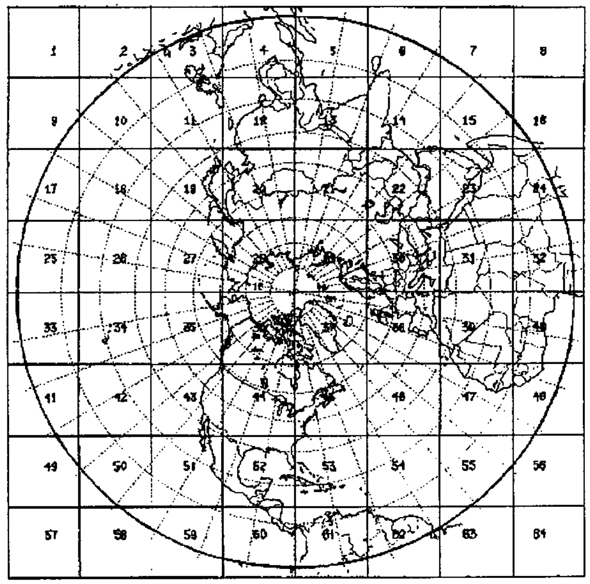

Figure 1. Advect Cloud uses a bi-hemispheric grid system. The Northern and Southern Hemispheres are run independently. Points off the hemisphere traditionally have been unused. This has caused continuity problems near the equator.

The first step in Advect Cloud is to convert the cloud analysis to a moisture amount. This is done through a cloud amount to CPS conversion table. Figure 2 shows the empirically derived relationship between CPS and cloudiness (Edson, 1965). In cloud-free areas, AVN or NOGAPS are used to initialize the model's moisture.

The next step is to develop trajectories to advect the moisture field. Advect Cloud uses a quasi-Lagrangian technique in its trajectory development (Crum, 1987). At the end of each one hour time step, the parcels are assumed to have advected to each grid point. This is accomplished by calculating trajectories (u, v, ω) that pass through each grid point at the end of the hour (McDonald, 1993). The advected parcel is initialized with the properties of the nearest grid point to the beginning of the trajectory.

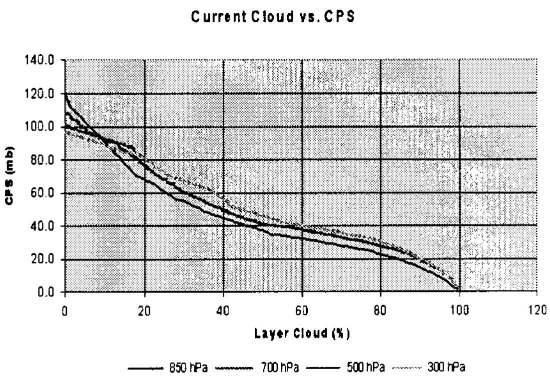

Figure 2. Advect Cloud uses empirically derived CPS to cloud amount values for 850, 700, 500, and 300 hPa. This has limited Advect Cloud to those layers

Finally, the moisture fields are advected with the trajectories and the CPS values are updated due to vertical displacement. CPS values are reconverted to cloud amount.

Several problems have been identified in Advect Cloud over the years. 1) The zero-hour forecast initializes with incomplete or old satellite data. 2) The conversion between moisture and cloud is based upon an old limited study and the results are for only four fixed levels. 3) Bi-hemispheric grids have caused a discontinuity at the equator. 4) Clouds develop excessive smoothing and linear artifacts later in the forecast.

2. IMPROVEMENTS TO ADVECT CLOUD

Since 1999, AFWA has applied the Advect Cloud model to 12.5 and 3 nm horizontal resolution cloud analyses. The increased resolution magnified the shortcomings of the original Advect Cloud model and indicated a need for greater vertical resolution. In 2000, we began a rewrite of Advect Cloud to address these problems.

2.1 FIRST GUESS FIELD

The cloud analyses contain areas of aged or incomplete satellite data that are assumed to be current. These areas are mitigated by initializing Advect Cloud with the previous forecast in areas where satellite data are more than 30 minutes old. The one hour forecast moisture field is advected, over time, to the target analysis time. At each time step during this advection process, any timely (± ½ time step) analyzed cloud is assigned to one of the five layers, converted to moisture, and overwrites the forecast moisture at those points (figure 3). The end result is an updated moisture field, representing the best guess of conditions at the analysis time.

An advantage of this technique is it provides a method to estimate model performance. Each time new moisture amounts derived from current satellite data are written over the first-guess forecast field, the two are compared and error statistics are computed.

2.2 Moisture Conversion

The moisture conversion method represents two problems: 1) the validity of the actual conversion and 2) the lack of flexibility to apply the conversion at an arbitrary level. The solution presented corrects the flexibility issue and lays the ground work to address the validity issue.

To correct the flexibility issue and begin to address the validity problem, the current cloud to moisture tables were fitted to a nonlinear function

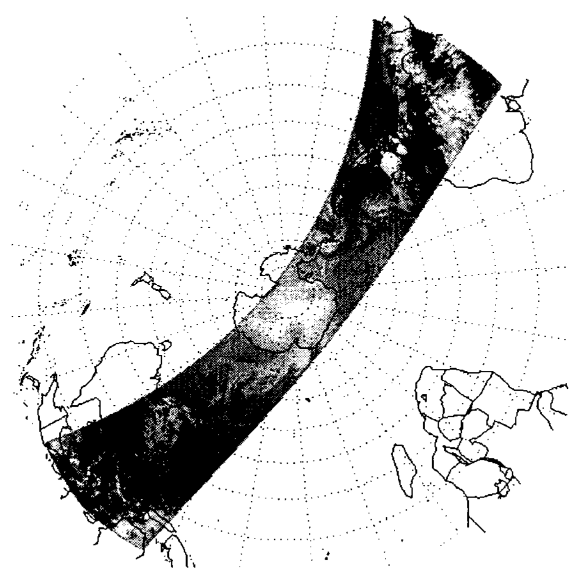

Figure 3. The improved Advect Cloud model uses the previous forecast (indicated by the white area) instead of old satellite data as the first guess. It overlays new satellite data where available. In practice, data from several satellites are available.

relating cloud amount to relative humidity:

$$Ln\left(-Ln\left(r\cdot\frac{RH}{100}\right)\right)=\beta_0(T)+\beta_1(T)\cdot Ln\left(-Ln\left(\frac{Cloud-C_L}{C_U-C_L}\right)\right).$$

The values C_L and C_U are offset and scaling factors allowing the function to be evaluated under the conditions of 0% and 100% cloud. The value *r* is a scaling factor that allows evaluation for 100% relative humidity.

Based on the fitted equation, new moisture – cloud conversion tables were created. The tables relate the cloud amount with *standardized* CPS (the ratio of CPS over pressure); temperature is used as the second variable. See figure 4 for an example.

The advantage of fitting a generalized function to the empirical CPS values is it enables us to increase the number of levels in Advect Cloud in the future.

2.3 CROSS-EQUATORIAL FLOW

In the current version of Advect Cloud, the equator is a boundary and cross-equatorial flow is not allowed. This was a natural outgrowth of the forecasts originally being made on an extra-tropic polar-stereographic grid. When the model was last rewritten, the forecast area was extended to the equator, but Northern and Southern hemisphere forecasts remained independent. To avoid boundary problems, moisture (*i.e. clouds)* was held constant within one degree of the equator; this constraint caused streamers of clouds to be advected from the equator. Figure 5 is an example of the equatorial discontinuities at 850 hPa.

We solved the equatorial discontinuity by linking the Northern Hemisphere and Southern Hemispheres. The hemispheres are linked, *each time step*, by mapping opposite hemisphere points to the off-hemisphere grid points of the polar stereographic grid. Filling the off-hemisphere points (see figure 1) with moisture amounts provides a source for the quasi-lagrangian advection. Thus, the two hemispheric polar-stereographic grids are linked and cross-equatorial flow is possible. The result is a continuous forecast across the equator. Figure 5 shows a comparison between the current and improved model near the equator.

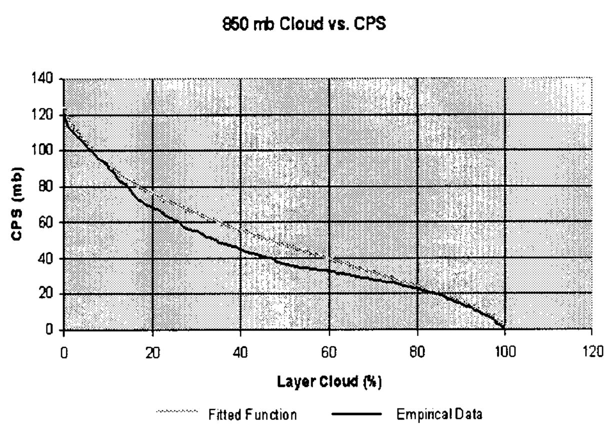

Figure 4. Comparison of the empirical and fitted CPS – Cloud conversion curve for 850 hPa in a standard atmosphere.

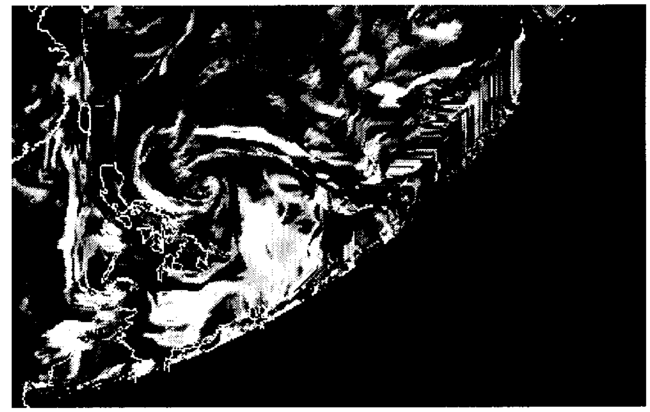

Figure 5. Clouds are held constant within one degree of the equator. This causes streamers from the equator, seen here on the 850 hPa level over the Northwestern Pacific.

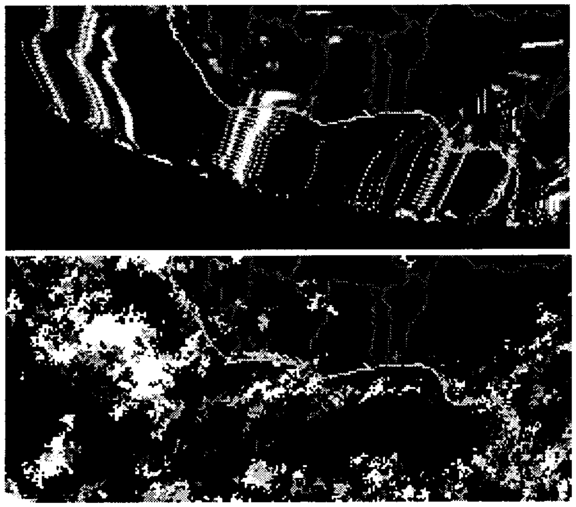

Figure 6. The standard model 30 hour 850 hPa forecast on the top shows streamers near the equator. The improved model on the bottom fills off-hemisphere points with cloud data from the opposite hemisphere. The resulting 30 hour forecast appears more meteorologically realistic.

2.4 ASSIGNMENT OF CPS TO START POINTS

The current Advect Cloud model assigns the trajectory start point CPS to equal the nearest gridded CPS. Tests showed *any* interpolation of CPS, either in the vertical or horizontal, resulted in excessively smooth forecast clouds.

In low-wind areas, assigning the nearest-grid moisture to the trajectory start resulted in repeated use of the same moisture value; this caused straight line and right angle artifacts in the clouds.

To eliminate excessive smoothing and correct the linear cloud artifacts, we use a probabilistic approach based upon the idea that moisture values of the points surrounding the trajectory starting point represent a *sample of area moisture values*. The probability that the starting point moisture equals the moisture at a given grid point is inversely proportional to the squared distance from the grid point. The technique gives more granularity to the cloud forecasts (see figure 6).

3. CONCLUSIONS

Improvements to the AFWA's Advect Cloud model address the model's weaknesses due to aged satellite data, limited cloud-to-moisture conversions, equatorial boundaries, and grid limitations. The improvements produce forecasts that appear more meteorologically reasonable than the current version of the model. Error comparisons between the two versions are still unavailable; however, these improvements bring us closer to our goal of producing an accurate, three-dimensional forecast of global cloud cover.

We are prepared to increase the vertical resolution and re-evaluate the cloud to CPS conversion process.

4. FUTURE DEVELOPMENT

AFWA expects further improvements to Advect Cloud with the next cloud analysis system. This system will use data from both geosynchronous and polar orbiting satellites to improve timeliness of the cloud analysis.

5. REFERENCES

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