NUMERICAL MODEL PREDICTIONS FOR THE ALBERTA HAIL PROJECT

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INTRODUCTION

During the summer of 1975, the Alberta Hail Project utilized two steady-state, one-dimensional cloud models routinely to assist the forecaster with his daily forecast.

One model was the Loaded Moist Adiabatic (LMA) model, the other the Hirsch model.

The LMA model has been used on the project since 1970 (Renick, 1970) and is simply parcel theory with water loading taken into account (Chisholm, 1970). According to Chisholm (1970), the storm tops computed with the LMA model agreed within ± 0.8 km with the radar storm tops in 75% of the cases he analyzed. Combined with the Maxwell nomogram (Renick, 1975), the LMA model predicted the category of the maximum hail size correctly 63% of the time that hail was forecast during the summer of 1974 (Maxwell, 1974). (Hail size categories are shot, peak, grape, walnut, golfball and larger than golfball.)

The Hirsch model is somewhat more plausible, physically, than the LMA model since it takes entrainment into account and also includes some microphysics, although in a very simple form (Hirsch, 1971). Data from the South Dakota School of Mines and Technology's Project Cloud Catcher was used by Hirsch (1971) to verify the model; he reports correlation coefficients near 0.8 between model predictions and cloud top heights and radar reflectivity maxima. Since then, the Hirsch model has been used on a number of hail projects around the world, for example the Swiss project (Atlas, 1975), the South African one (Simpson, 1975) and in the Dakotas (Simpson, 1975).

Comparison of the Two Models

The two models sometimes differ considerably in their predictions. Since both models predict liquid water content and updraft speed as a function of height, these parameters can give an indication of differences in the models.

Figure 1 shows the maximum total water substance content predicted by the Hirsch model versus that predicted by the LMA model for a number of soundings and surface conditions. The data points for this diagram, as well as for the following two diagrams, are derived from all soundings available on seven days on which hail was observed (i.e. haildays) and do not constitute a sample representative for the whole summer. Therefore the results shown here should be considered to merely give a suggestion on the trends of the final results. Thus Figure 1 indicates that generally the Hirsch model predicts a considerably lower total water substance content than does the LMA model. This is to be expected, since the Hirsch model allows for entrainment of drier environmental air. No measurements of the water substance content of clouds were made during the project and so it is not possible to determine which of the two models gives more realistic values.

The maximum updraft speed from the same soundings is given in Figure 2. Again, the Hirsch model often gives lower updraft speeds, but there are a number of occasions when it gives the higher maximum updraft speed. Presumably, on these occasions, the lower water loading in the Hirsch model more than compensates for the loss in buoyancy due to the entrainment of cooler environmental air. Again, no in-cloud measurements of updraft speed are available for verifying the model results.

One parameter that can easily be verified is the storm top height. Figure 3 shows the storm top height predicted by the Hirsch model plotted against that predicted by the LMA model. In a number of cases, both models gave the same storm top height but sometimes there was considerable difference in the two values. The diagram suggests that there may be as many occasions when the Hirsch model predicts the higher top as there are occasions when the LMA model gives the higher top.

Correlation coefficients were calculated for all three diagrams. Both maximum water content values and maximum updraft speed values from the two models are highly correlated, the correlation coefficient being 0.84 in each case. Storm top heights from the two models are somewhat less correlated, the correlation coefficient being 0.71. All correlations are statistically significant at the 1% level.

Verification of the Models

During the summer, plots of the radar echoes were made routinely at intervals of about 15 min. and at the same time the maximum echo top height was measured for each storm; errors in these measurements were about 1 or 2 km. A plot of the maximum (for a given day) echo top height (called maximum observed storm top in the diagram) versus the storm top heights predicted by the two models for six of the seven haildays considered to date is shown in Figure 4. No models were run on the seventh day because of insufficient instability in the morning soundings. In all cases the forecast sounding, derived in the morning by the forecaster, was used to calculate the predicted storm top height. Again, correlation coefficients have been calculated and there are 0.62 for the LMA model and 0.55 for the Hirsch model. Neither of these correlations is statistically significant.

The insignificant correlation of 0.55 for the storm top height from the Hirsch model does not compare favorably with the 0.8 reported by Hirsch (1971). Neither do the data points for the LMA model (in Figure 4) agree with Chisholm's (1970) finding that the LMA model predicts storm top heights within $\pm$ 0.8 km in 75% of the cases. The poor correlation between observed storm top height and predicted storm top height could be due to a number of factors such as errors in the observed storm top height, an inability to forecast afternoon temperature and moisture profiles, the use of incorrect surface and cloud base parameters, or a possible inapplicability of the models to the storms analyzed. Determination of errors in the observed storm top height awaits a detailed analysis of radar data for the summer. But an estimate of the effect of the forecast sounding and the assumed cloud base parameters can be obtained. This year, the Alberta Hail Project had at its disposal a mobile radiosonde unit which was often directed into the vicinity of storms and was able to take soundings before, during and after the passage of the storm. Soundings in the region of the storms are available for each of the seven haildays considered here. In addition, the pilots of the seeding aircrafts were requested to estimate cloud base height, temperature, updraft speed and updraft size.

Model predicted storm top heights, based upon mobile radiosonde soundings (taken ahead of the storms) and pilots' estimated cloud base conditions, are plotted against maximum observed echo top height in Figure 5. The correlation coefficients between predicted and observed storm top heights have now increased to 0.73 for the Hirsch model and 0.72 for the LMA model. Both these values are statistically significant at 10% even though the sample size is very small. Probably, the correlation could be improved further by eliminating errors in the pilots' estimates of cloud base conditions and errors in the maximum observed storm top height. The horizontal bars in the diagram give the range of values obtained when all actual soundings for the day were considered. It appears, therefore, that using a representative sounding can result in significantly less error in the predicted storm top height.

Neither of the two models predicts hailstone size directly. But an empirical nomogram developed by Maxwell (shown in Renick, 1975) gives maximum hailstone size from maximum vertical velocity predicted by the LMA model and the temperature at which that maximum occurs. A similar nomogram could be developed for predictions from the Hirsch model.

Figure 6 shows predicted maximum hailstone size versus observed maximum hailstone size for five of the seven haildays considered above. The forecast soundings were used to derive the necessary parameters from the LMA model. A statistically insignificant correlation coefficient of 0.6 was obtained for these data. The maximum hailstone size predicted by the LMA model together with the Maxwell nomogram, when the more representative mobile radiosonde sounding and pilot-estimated cloud base were used as input into the LMA model, are shown in Figure 7. This diagram includes data for all seven haildays. The correlation coefficient between predicted and observed maximum hailstone size has now increased to 0.86 and this value is statistically significant at the 5% level.

The horizontal bars in Figure 7 show the range in predicted sizes obtained when all available soundings for the day are considered. Note that in some cases the range extends almost over the whole spectrum of sizes.

Conclusions

A fairly impressive correlation between predicted and observed maximum hail size is suggested above provided that a representative sounding is used with the LMA model. The value of the mobile radiosonde unit in providing representative soundings cannot be overemphasized. Thus the LMA model together with the Maxwell nomogram may be a useful tool for stratifying data for a statistical evaluation of the hail suppression program. As an operational tool, the LMA model and nomogram seem to be less dependable due to frequent difficulties in forecasting afternoon temperature and moisture conditions. A nomogram like that of Maxwell could be developed for Hirsch model results, but this may not be warranted in view of the good performance of the LMA model and Maxwell nomogram.

The only predictor from the Hirsch model that can presently be easily verified is the height of the storm top. The results given above suggest that the Hirsch model does no better in predicting this parameter than does the much simpler LMA model.

It must be remembered, though, that these conclusions are based on very limited data.

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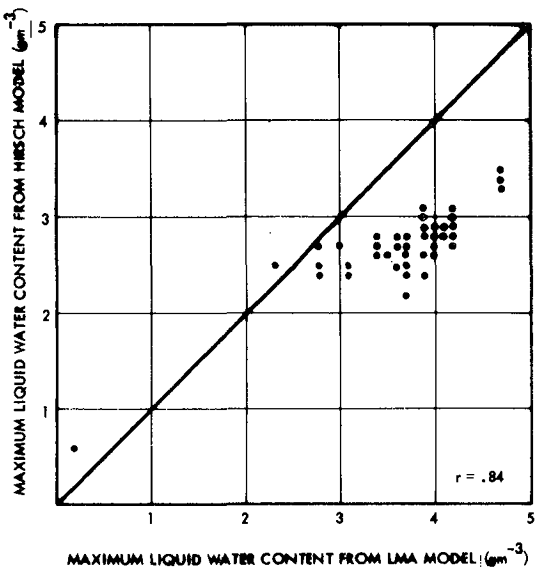

Figure 1: Correlation between maximum liquid water content predicted by the LMA model and that predicted by the Hirsch model for given soundings and sets of surface conditions. r is the correlation coefficient.

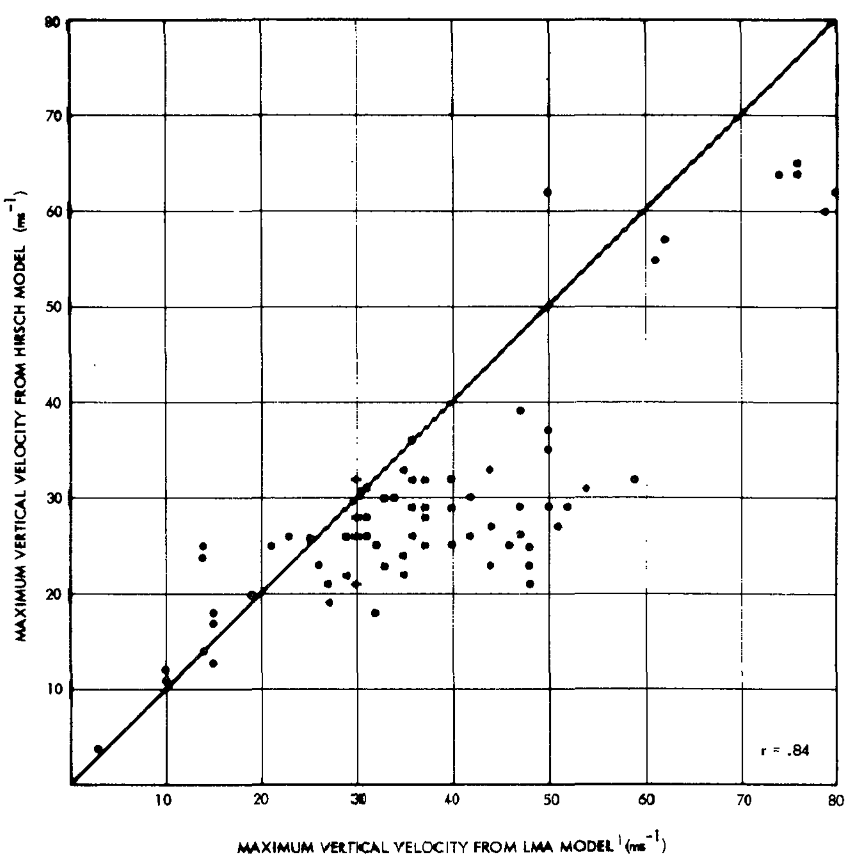

Figure 2: Correlation between maximum vertical velocity predicted by the LMA model and that predicted by the Hirsch model for given soundings and sets of surface conditions. r is the correlation coefficient.

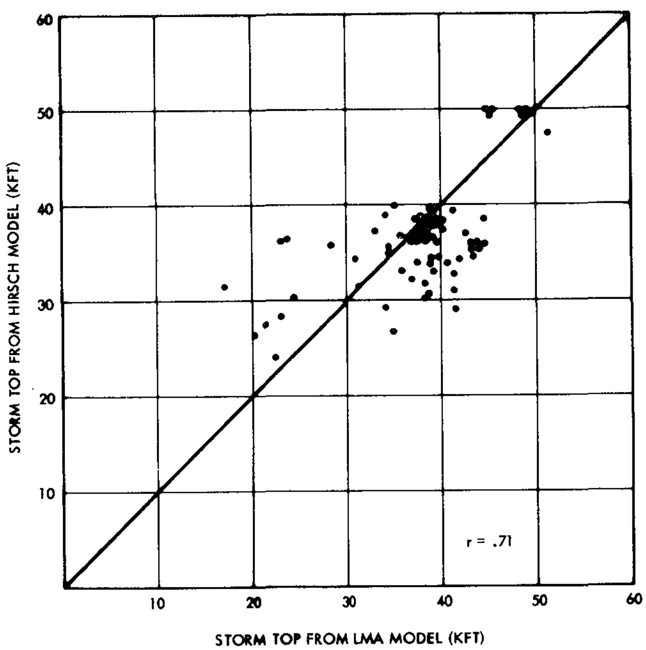

Figure 3: Correlation between predicted storm top from the LMA model and that predicted by the Hirsch model. r is the correlation coefficient.

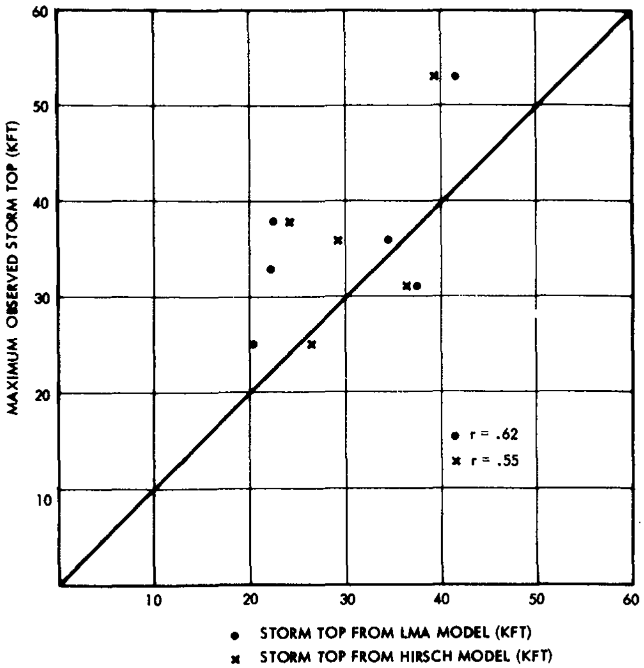

Figure 4: Correlation between maximum observed storm top and predicted storm top, using the forecast sounding, for seven haildays. r is the correlation coefficient.

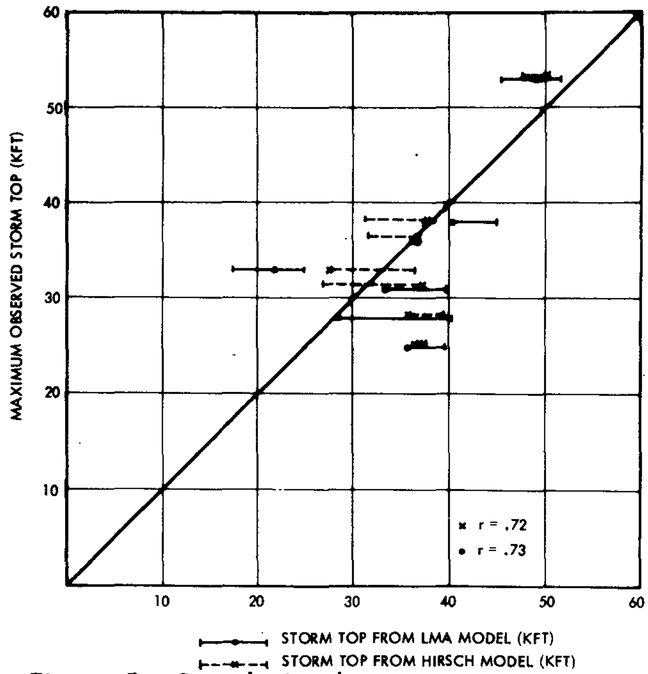

Figure 5: Correlation between maximum observed storm top and predicted storm top, using the more representative mobile radiosonde sounding and pilot-estimated cloud base parameters, for seven haildays. r is the correlation coefficient. The horizontal bars show the range of values obtained when all actual soundings for that day are considered.

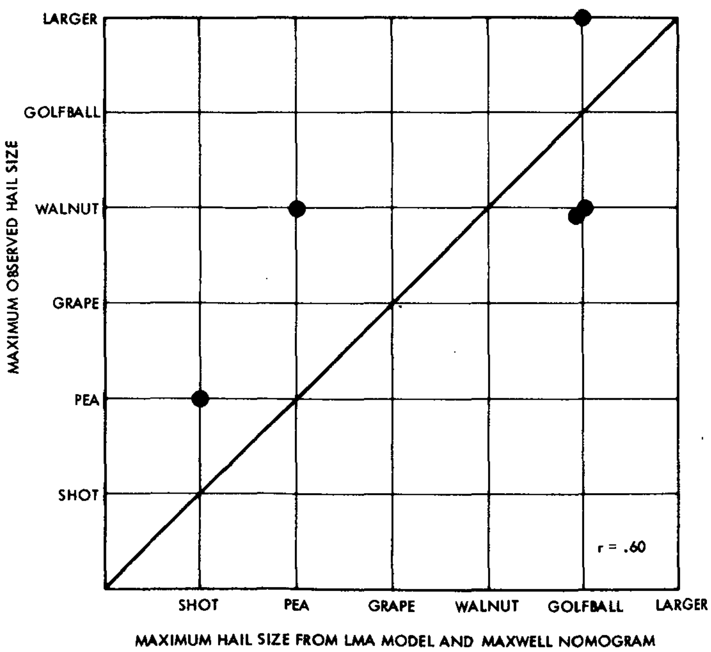

Figure 6: Correlation between maximum observed hail size and predicted maximum size, using the LMA model together with the Maxwell nomogram for five of the seven haildays. The forecast soundings were used as input into the LMA model. r is the correlation coefficient.

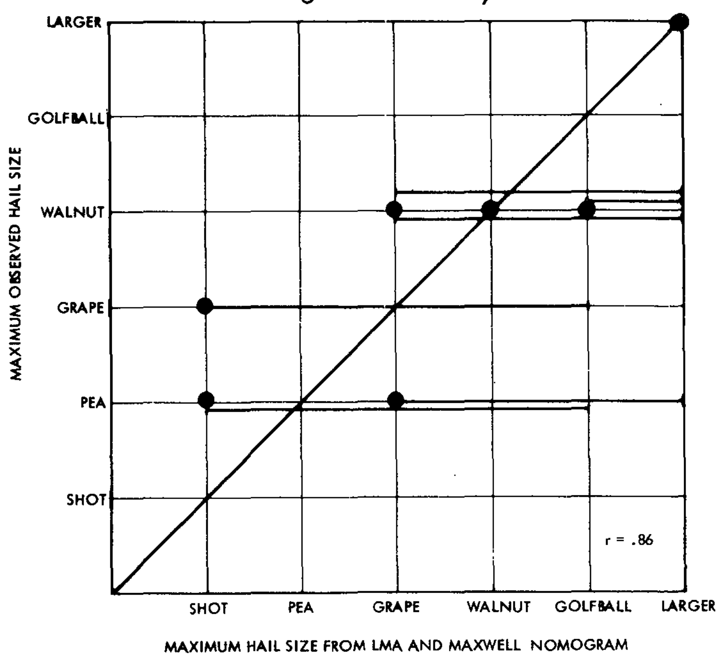

Figure 7: Same as Figure 6 except for the seven haildays and the use of the more representative soundings from the mobile radiosonde and of the pilot-estimated cloud bases as input into the LMA model. r is the correlation coefficient. The horizontal bars show the range of sizes obtained when all actual soundings for that day are considered.