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A MESOSCALE, CLIMATOLOGICALLY-BASED FORECAST TECHNIQUE FOR COLORADO

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1. INTRODUCTION

Triggering of deep convection in mountain/high plains regions, particularly during the late spring and summer months, has long been known to be dominated by topographic effects (e.g. Hallenbeck, 1922). Various orographic convection mechanisms have been suggested which include the role of mountains as "high level heat sources" and the opportunity for higher terrain to force "orographic lift" (Braham and Draginis, 1960). There may also be favored regions of convection due to topographically induced convergence zones, but such effects remain speculative. During other times of the year, while topography may still influence convection, it may not dominate, because synoptic patterns are stronger. Dynamic flow and vertical mixing often combine to mask the so-called mountain/valley breeze cycle.

A study by Henz (1974), and an earlier report by Dirks (1969) establish the diurnal cycle of storms in Colorado. In this cycle, storms form in the afternoon along the front range of the Rockies. A preference is exhibited for one or more of ten favored triggering locations known as "hot spots". As the afternoon passes into the early evening, the thunderstorms travel eastward into the plains and intensify--reaching extreme eastern portions of Colorado near, or after, nightfall. Maddox (1980) found frequent instances when these eastward moving storms intercepted the low-level jet near the Kansas border, and went on to form large thunderstorm complexes that traversed the central plains throughout the night. Synoptic influences in this diurnal cycle, and their relation to severe versus non-severe storms, are discussed by Henz (1974) and in more detail by Doswell (1980).

With the advent of the PROFS* initiative to improve the quality of short term forecasting, such climatological results may find practical use. However, to utilize these findings in an operational environment, tools must be developed which provide the line forecaster with an expeditious means of applying them. One of the most useful information sources available to the short range forecaster is satellite imagery--where an actual photo of the weather in progress arrives at the forecast office every half hour. This paper presents some of the initial results of combining climatological features, identified via satellite photos, into a format useful to the short range forecaster.

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*For a more complete description of PROFS see Reynolds, 1982 (these proceedings).

2. Data Synthesis

The satellite data used in this study were processed through Colorado State University's All Digital Video Imaging System for Atmospheric Research (ADVISAR) II. The ADVISAR II is a multi-purpose image processing and computational system, geared toward research and development. The main processor is a DEC VAX 11/780, with a DEC PDP 11/60 being used primarily as a communications, front-end processor. Image processing is done using a two station COMTAL Vision One/20 system. Both stations have a CRT connected to the VAX, a keyboard, and a high-resolution television monitor. Station 1 is equipped with a data tablet, while Station 2 has a trackball and a video camera input devise. (For a more detailed description of this system see the paper by Green and Kruidenier elsewhere in these proceedings). In this study hard copy, LASERFAX visual satellite photos from GOES-W (which were obtained from Denver and Cheyenne WSFO's, and from Offutt AFB, Nebraska) were read into the system through the video input devise, and digitized by brightness values at each picture element (PIXEL).

Before a photo is entered into the system and digitized, a renavigation is performed to eliminate gridding errors. Briefly stated, this renavigation is accomplished by entering a reference image into one of the image planes, televising the COMTAL's image being digitized onto a second image plane, then rapidly 'flickering' back and forth between the two. By adjusting the position of the televised image, the operator can align actual landmarks such as lakes, rivers, etc. When the landmarks match precisely, the new picture can then be entered and digitized, and the process repeated for the next. Comparison between extremely-well versus extremely-poor gridded images for the summer of 1981, reveals errors in the placement of geographical borders that ranged from 0-60 km. Renavigated images match to within less than 10 km (as judged from making composite images, and studying the 'bluriness' of landmarks).

Following the renavigation and digitizing of the data, a computer routine was applied (to groups of images) which performs a pixel by pixel brightness average. For the portion of the study reported here, the pictures were stratified according to hour of the day, for the month of July, and an hour by hour "average satellite-cloudfield" was generated.

3. First Results.

a. 1800 GMT Composite.

Figure 1 is the average visual satellite image for 1800 GMT (1100 Local Standard Time) for July 1981, centered over the state of Colorado (CO). The cloud fields depicted in the image appear rather diffuse due to the averaging. However, some features are immediately evident. Notice, for example, that a large part of the cloud field seems to align with the highest terrain. This is not unexpected in a region where topography is a major convective forcing mechanism. Another feature, which might go unnoticed on an individual case basis, is that the convectively favored regions are somewhat isolated.

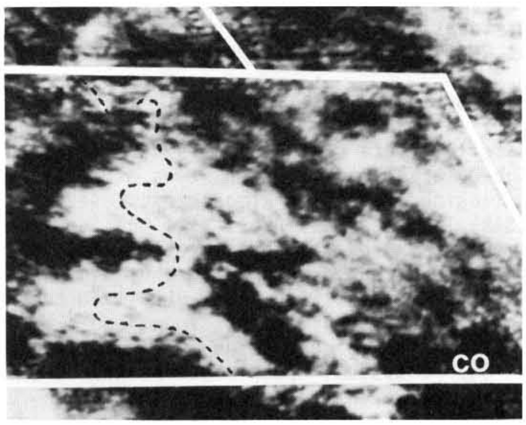

Figure 1. Computer derived average of all GOES-W visible images taken at 1745 GMT during July 1981. Picture composite encompasses most of the state of Colorado. North is in the direction of the short border segment at the top of the photo. Dashed line is the Continental Divide.

There are two large areas, one in southwestern, the other in central CO which appear to be separated by non-convective regimes. The pattern can be directly related to topography, For example, the western clear slot between the two convective regions is an area known as the Gunnison Valley. It is situated in a valley some 4,000 feet lower than the surrounding mountains. Other clear areas reflect similar topographic influences. It should also be mentioned that the clouds in extreme eastern CO are generally not convective--a fact determined from study of individual photos comprising the average. In fact, most of the resulting brightness in that sector comes from persistent stratiform cloudiness. On the composite this point is not clear. Additionally, the amount of cloudiness over the state in figure 1, results in a somewhat confusing picture. This is because it represents an average for a large number of days, while an individual day will generally have less cloudiness that is much sharper in appearance. To alleviate the problem, a brightness-dependent, gray scale enhancement was applied (Figure 2). In this version, the convection over the Rocky Mountains (central CO) stands out as the brightest. Much of the low-level cumulus just east of that region (along the so-called "Front Range") has been eliminated. However, there still exists a bright area in extreme eastern CO. Even though this cloudiness is mostly stratiform, the persistence of the feature from day to day, leaves a small bright patch on the enhancement which could easily be confused with convective areas to the west. An attempt will be made in the ongoing research to enhance this region differently. It should not be eliminated, as its very persistence indicates climatological significance.

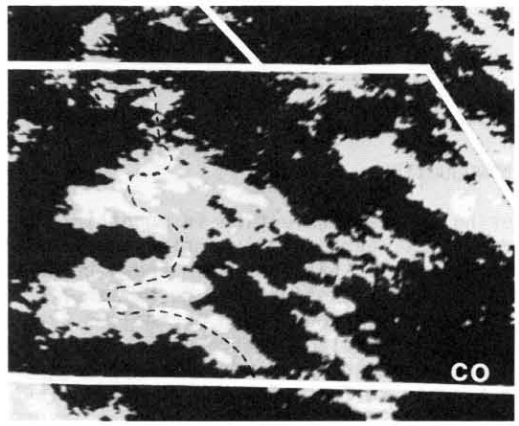

Figure 2. Same as Figure 1 except an artifical, brightness-dependent, gray shading enhancement is added for clarity.

b. 2100 GMT Composite.

Figure 3 is the result of similar compositing and enhancing as that in figure 2, except the hour is 2100 GMT. Several features appear important. First, notice that the stratiform brightness in eastern CO has disappeared. This occurred in most of the individual cases due to diurnal heating.

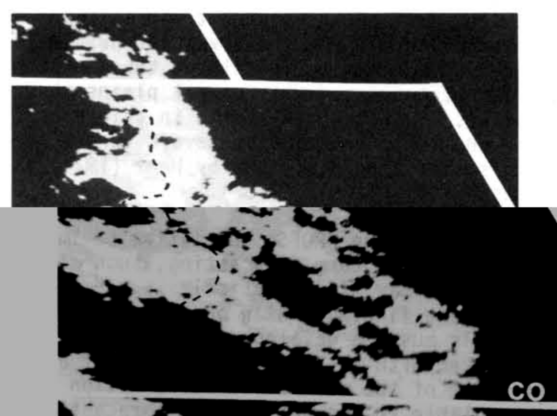

Figure 3. Same as Figure 2 except for 2100 GMT, July 1981.

The convective region in southwest CO has moved off the Continental Divide (or, "the Divide"), out over Gunnison. This evolution is an important point from a forecast perspective. It suggests that the area of the divide in southwest CO has convection very frequently during July. However, the convection most often forms early in the day, and moves out over the valleys by mid-afternoon.

The convective region in central CO has both expanded and propagated northward. Of particular interest is the rather sharp line delineating cloud/no cloud in northcentral CO. This line, in fact, demarcates the foothills of the front range. The important implication here, from a forecast point of view, is that, the population centers (which are situated just east of the foothills) should expect, on the average, that convective activities will remain to the west at least until 2100 GMT.

The single exception seems to be a region in central CO (near Colorado Springs) which has substantial convection by this time. As it happens, this area is located at the western edge of a ridge (the Palmer Divide) that extends eastward into the central CO plains.

Finally, a fourth area of convective activity is evident in southcentral CO. This area is also at the western extreme of an east-west ridge (the Raton mesa). Comparing figure 3 with figure 2, we note that convection had already begun in the area by 1800 GMT.

c. Further Stratification.

As a refinement to the above procedure, the data were stratified. It was found that various convective initiation patterns seem to be repetitive. For example, on many convective days, activity initiates on the divide in south-western CO, and in a broad region of higher terrain in central portions of the state. On those days, no initiation occurs on the front range (as opposed to the mean tendency, figure 2), the stratiform area is further south, and northeast CO is mostly clear at the early time. The composite for this configuration (16 cases) is shown in figure 4. This composite was based on various times corresponding to initiation, but all of the photos range between 1645-1745 GMT. Figure 5 is a composite of photos three hours beyond those averages for figure 4--on the same days.

Several differences between the two perspectives are evident. In the stratified case, the convection along the divide in southwest CO remains there longer than in the mean. The composites also indicate that development in the latter case is not as dramatic. Later photos (not shown) show that the activity eventually moves off, but later in the afternoon. The activity in central CO is also slower to develop, and does not expand northward. Lastly, note that the front range in central and southern CO appears more active--possibly due to the moisture which had, in the early part of the day, been moving up the Arkansas Valley (i.e. in southeast CO).

d. Short Term Forecast Application.

To illustrate the utility of these products consider figures 6 and 7. The photos are from a randomly selected case from the Summer 1981, CO convective season. Figure 6 is the 1648 GMT visual satellite image from 25 June 1981. Figure 7 was taken at 2045 GMT on the same day. The 1648 GMT, photo bears a striking resemblence to both figure 2 and 4, regarding the convectively cloudy areas over the mountains. However, the similarity seems greater for figures 6 and 4 than for figures 6 and 2. A marked difference is, that while the mean composite (figure 2) indicates development in northcentral CO, there is none on the 1648 picture (figure 6). This region of the state looks more like the stratified composite (figure 4). Indeed, figure 7 shows that northcentral CO developed in a manner consistent with the stratified case.

On the other hand, in northeast CO the 1648 image is quite similar to the overall mean (figure 2), and is different than the stratified data (figure 4). Thus, one might expect the evolution in this region to proceed more like the average--namely, to become clear. This is what occurs (figure 7).

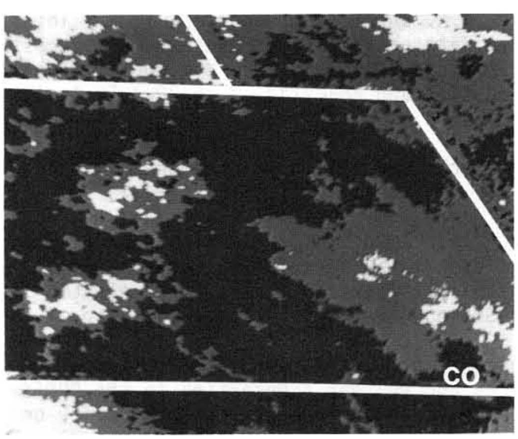

Figure 4. Computer derived average of GOES-W images taken at times corresponding to convective initiation in central and southern Colorado, June thru August 1981. Artifical, brightness-dependent, gray shading enhancement is added for clarity.

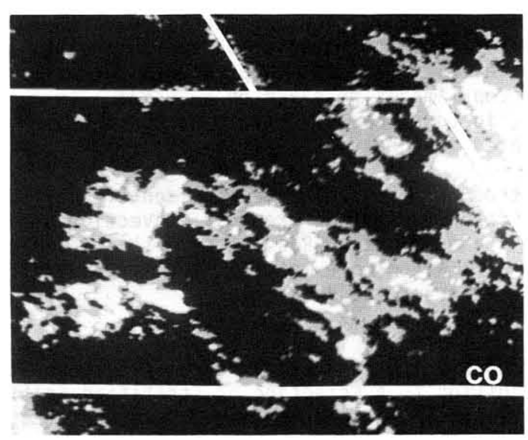

Figure 5. Same as figure 4 except images averaged are initiation times plus three hours.

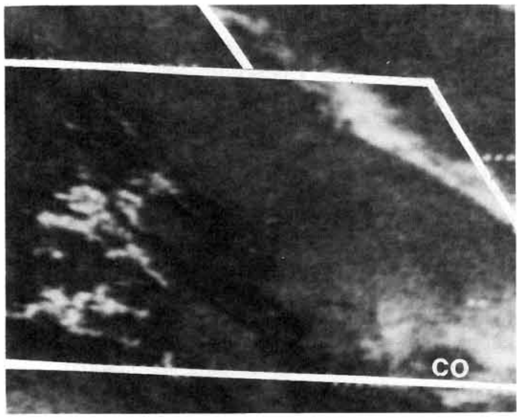

Figure 6. GOES-W visible image for 1648 GMT, 25 June 1981.

Finally, note that the convection in central CO appears more wide spread than that in the southwest. This combination is represented best by the overall climatological average. One might expect, to find strong convection to the east of the initiation area in three hours (as opposed to the moderate development in the same region which occurs in the stratified case). Again, this is what happens (figure 7).

4. Discussion.

As may be seen from the results described above, satellite data can be composited to form the basis for a mesoscale forecast tool. Results at this point require refinement. Currently, composites for other months and other initiation pattern stratifications are being constructed. Additionally, synoptic and subsynoptic meteorological data are being stratified in an effort to strengthen the utility of the product. One very promising data set is the hourly surface winds from the PROFS surface mesonetwork (see Johnson and Toth, these proceedings). Another refinement will be to construct the same composites from digitized data received directly through Colorado State University's Direct Readout Satellite Ground Station. It is intended to collect data in sufficient quantity to do so in 1982. These directly received data will likely improve the quality of the composites substantially, since photographic density varies on hard copy images received on LASERFAX. This variation, in turn, causes certain pictures to be weighted more heavily than others in the averaging.

A method is being developed to identify regions of stratus/fog versus areas of convection using both visual and IR data. Results from this differentiation will allow more meteorologically significant enhancements to be designed.

The final product is envisioned as furnishing the forecaster with mean hourly satellite composites, in addition to a selection of stratified initiation averages. The forecaster may choose the stratification most similar to what is then occurring, and use it, along with the mean image, in a manner similar to that described above. Stratified meteorological data will also be available to help the forecaster couple the satellite imagery with the dynamic processes occurring.

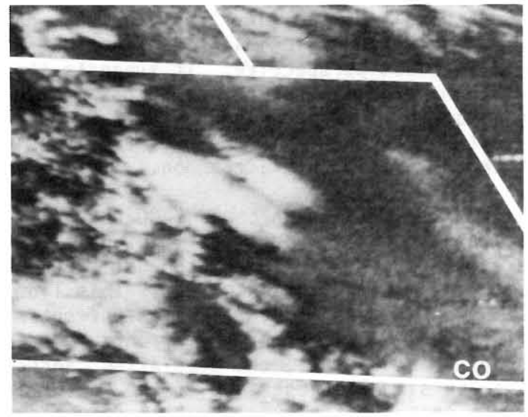

Figure 7. GOES-W visible image for 2045 GMT, 25 June 1981.

5. Acknowledgements

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