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Lightning Area Locations Within An Organized Cloud System - A Model -

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INTRODUCTION

A model that identifies areas of high lightning potential is described below. This model was constructed after study of the relationship of lightning data with dynamic features evident on GOES imagery. The dynamic parameters have been chosen so that longer range outlooks can be prepared by "boxing" key areas on numerical analysis and prognosis.

THE MODEL

There are distinctly favoured lightning areas with respect to organized cloud systems. By evaluating and isolating the dynamic features inherent in these cloud structures it is possible to construct a model that isolates high probability lightning areas. This model is based, in part, on Weldon (1979).

The model in figure 1 represents an idealized cloud system structured with respect to a vorticity maxima, deformation zone and thickness ridge. Most of these features have been well documented in the satellite-meteorology literature, however, the thickness ridge as used here does require some clarification. In a developing situation the classical 500 mb thickness ridge lags, by a few degrees, the contour ridge and the anticyclonic axis of the comma cloud head. However, significant convective activity is found behind the coldest cloud shield tops and ahead of the supporting vorticity trough. Thus the model thickness ridge is placed just behind the coldest cloud tops in the comma head and extrapolated across the jet and into the warm sector. The model ridge has been found to fit quite well with the classical thickness ridge as seen on the numerical products.

The following are characteristics of the respective sectors:

Area A

- This region is bounded by the local wind maxima or jet, the vorticity trough, deformation zone, and thickness ridge as defined above (figure 2).
- The air over this region is cooling and drying aloft while low level moisture remains trapped in mountain valleys and inlets. This creates an unstable situation with low convective temperatures.

- This region encompasses most of the lightning occurrences. However this may not be all that significant for forest fire ignition, as much of the convective activity in the area is also accompanied by showers or thundershowers.

- Lightning has been recorded over the ocean within this region. This occurs when a cold and unstable airmass moves from the Gulf of Alaska southward over the relatively warm waters of the eastern Pacific.

- There is a strong diurnal tendency for lightning activity over land with a maximum in the late afternoon and early evening. This tendency is not as evident along the coast.

- The region covered by lightning can be quite large or small depending on the amplitude of the comma cloud system.

- It appears that the regions near the jet and vorticity center itself are the most active.

- Small scale vorticity troughs moving into this area can be associated with extremely active lightning events, as they are concentrated areas of lifting motion within a general area of lift.

- Lightning in this area can occur under relatively warm tops. The tops are often warmer than minus 20°C. This is likely due to the fact that the bases, troposphere and convective temperatures are all low in this area.

- Morning solar heating appears to be a necessary criteria for the initiation of strong afternoon convection over land. Subsidence breaks in the clouds to the lee of the mountains are sometimes associated with afternoon lightning outbreaks. A thin veil of cirrus acts as an inhibitor.

- Winds within this area are generally from the southwest. This makes southwest to northeast orientated valleys susceptible to thunderstorm and lightning activity.

Area B

- This area lies along the leading edge of the comma cloud tail. It is bounded on the right by the thickness ridge. The area extends a few degrees into the leading and thinner portion of the cloud band (figure 3).

- This area is particularly significant in a strong southerly flow situation as warm moist air funnels northwards into the constricting valleys of southern British Coloumbia (see Funk, 1984).

- The lighting activity in this region appears to be initiated by daytime heating, however the heating and initial development may begin well upstream.

Area C

- This area lies along and parallel to the cloud deformation zone (figure 4).
- The lightning is usually high based, quite isolated and associated with "subtropical overrunning".

Area D

- This is not really an area but refers more specifically to small isolated hard cloud cells or lines that appear on either the infrared or water vapour imagery (figure 3).
- The region of concern is within the warm sector but behind the thickness ridge.
- The cells or lines in this area can develop explosively and result in associated hail and heavy rains.
- These features are particularly significant when they move northwards from Puget Sound or the Washington Plateau into southern B.C.
- These cells or lines tend to "blow up" late in the day then continue through the night.

AN EXCEPTION

There is one situation that deserves special attention as the associated lightning can be quite intense, widespread and highbased. This occurs during the midsummer months when an extended band of high level subtropical air moves up from the south. In this case, individual vorticity troughs and ridges are masked by a dense deck of cirrus. The whole band with the cloud edges in particular should be treated as potential areas for lightning activity. As well, lightning associated with the subtropical cloud is greater in an area ahead of an approaching maritime front or shortwave. This shortwave or front need not intersect or move under the subtropical clouds before explosive development occurs.

FUTURE WORK

A procedure is being developed to outline and forecast areas of high lightning potential. This procedure is based on observed relationships of lightning data with dynamic and topographical features. Key dynamic areas outlines in the lighting model are "boxed" then extrapolated At the same time particular attention is given to potential terrain induced lightning corridors and convergence zones (for more details see Funk, 1984).

ILLUSTRATED CASES

Figure 1. Favoured lightning areas with respect to an organized cloud system.

Figure 2. An example of Area A.

Figure 3. Examples of Areas B and D.

Figure 4. An example of Area C.

REFERENCES

Funk, L., The Effects of Terrain and Moisture Channeling on Regional Lightning Activity, Pacific Region Technical Note 84-009.

Weldon, R., Cloud Patterns and the Upper Wind Field, Satellite Training Course Notes, Part IV, (NESS), 1979.

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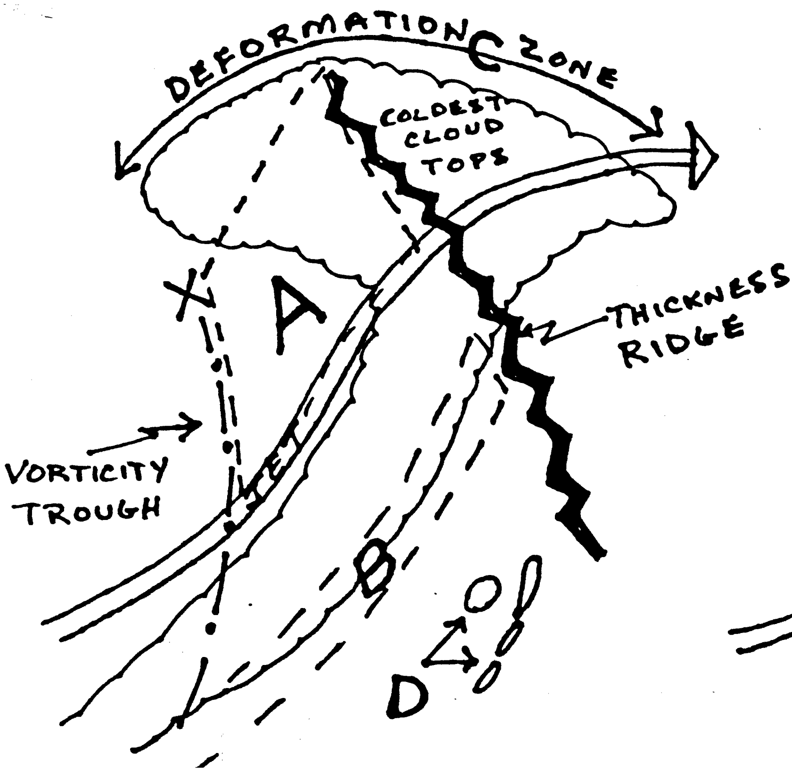
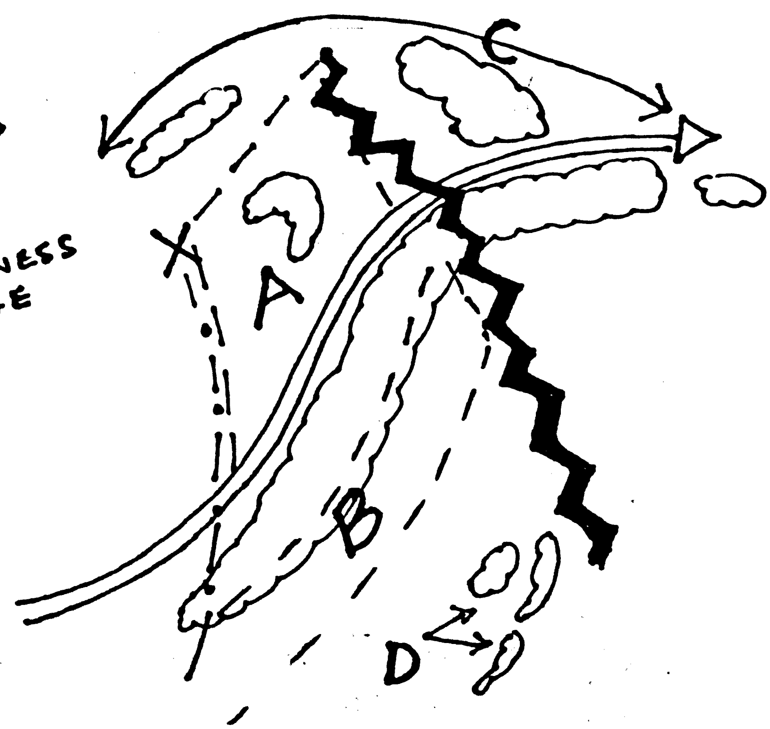
FIGURE 1. FAVOURED LIGHTNING AREAS WITH RESPECT TO AN ORGANZIED CLOUD SYSTEM

Idealized Cloud System



Usual Summer Cloud System



Figures 2. An example of Area A.
Figure 2A has the synoptic features such as jets, vorticity centers and thickness ridges labelled. Figure 2B is a "zoom" of the Area A region over southwest B.C.
The X's are the lightning strike locations that occured within the half hour time window centered at image time.

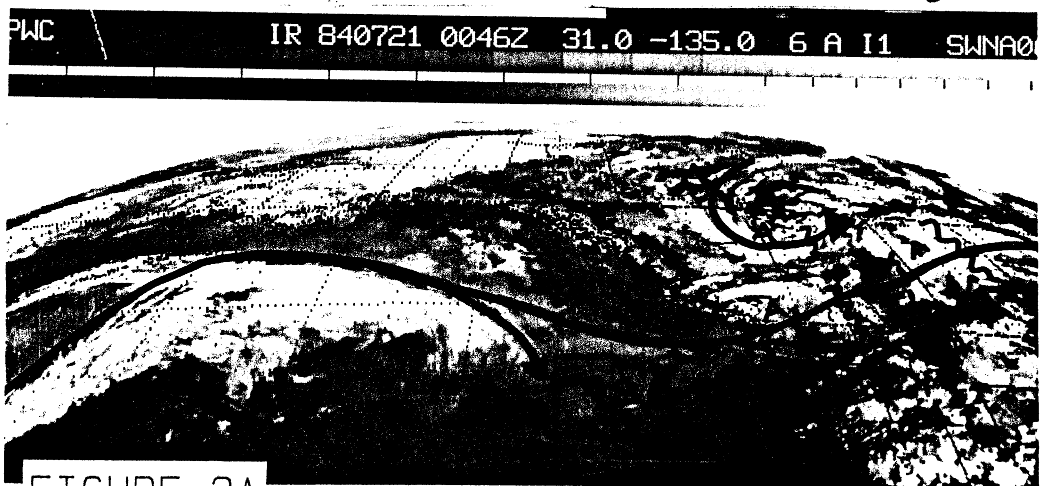


FIGURE 2A

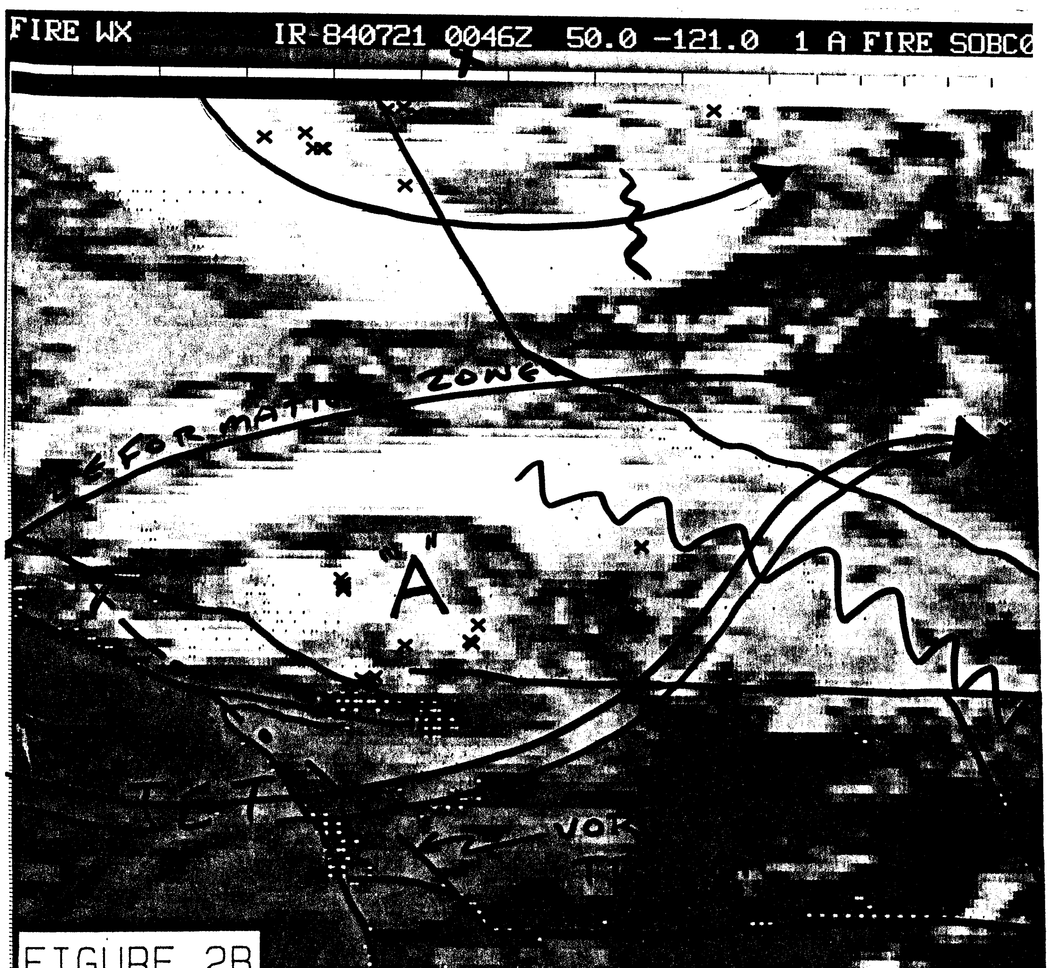
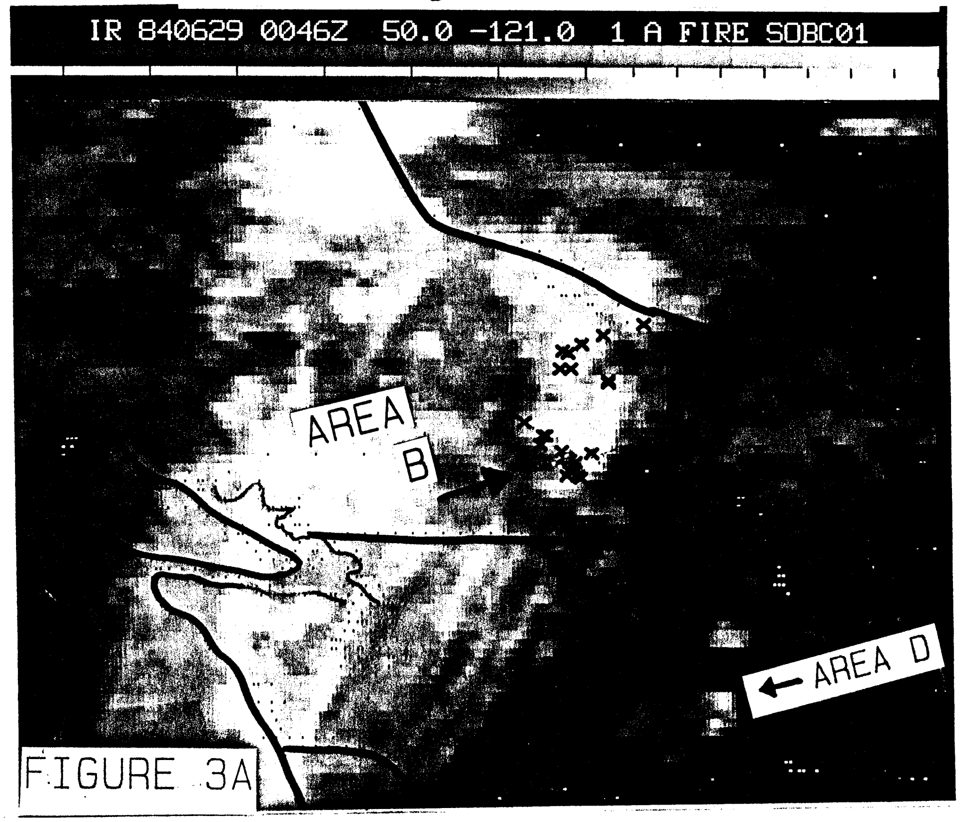


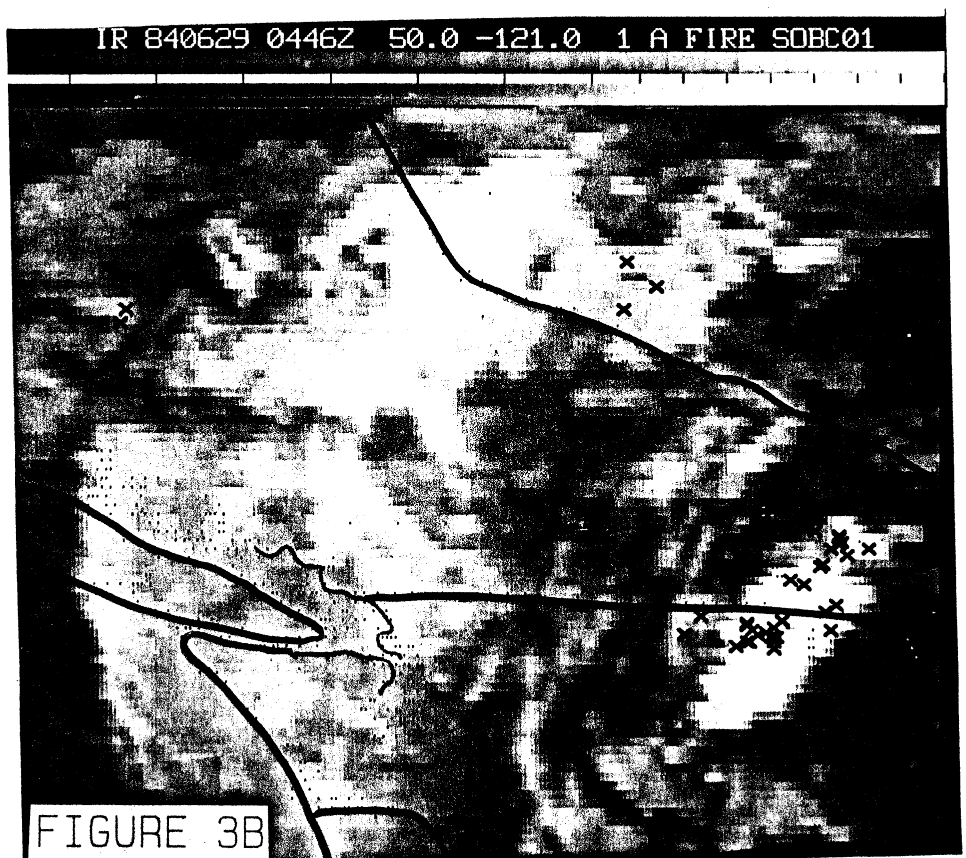
FIGURE 2B

Figure 3. Examples of Areas B and D.

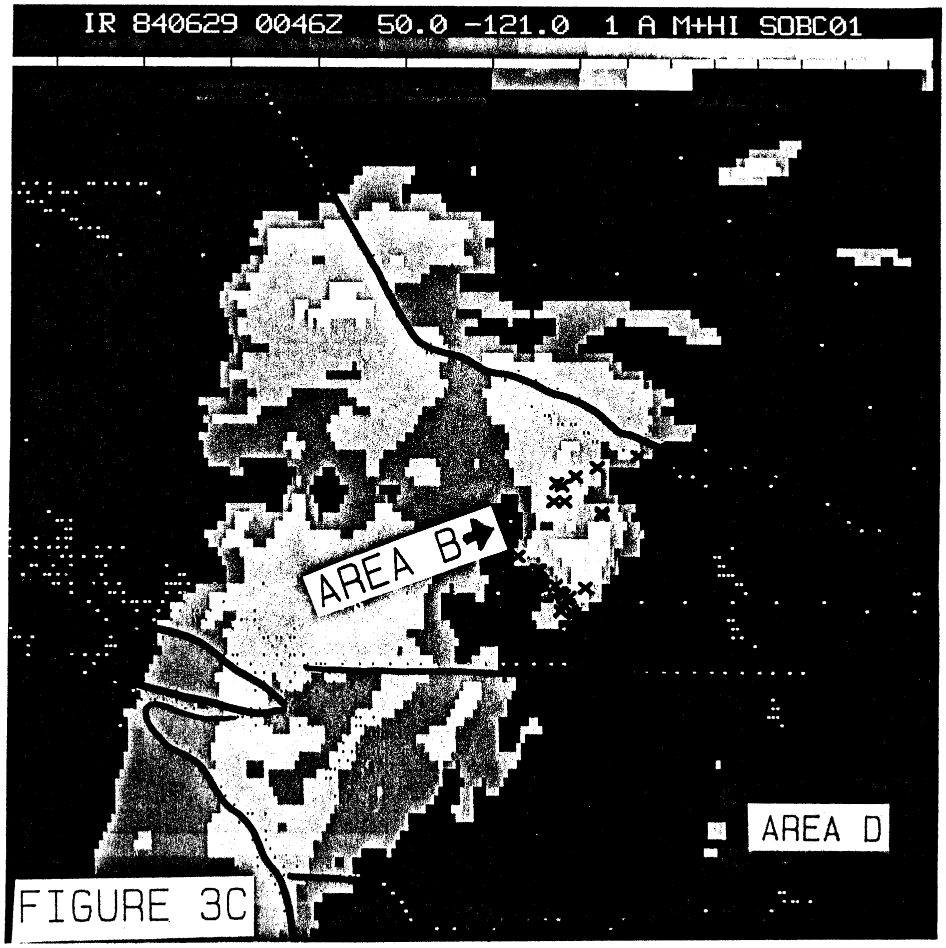
3A. An infrared Image and lightning strikes associated with a leading frontal cloud edge (Area B) and a cell (Area D) developing over the Washington Plateau.



3B. Four hours later - Lightning is still associated with the leading cloud edge while significant strikes have occured with the cell and moved northward into southeast B.C.



3C. Same image as 3A with a "cold top" enhancement



3D. Same image as 3B with a "cold top" enhancement

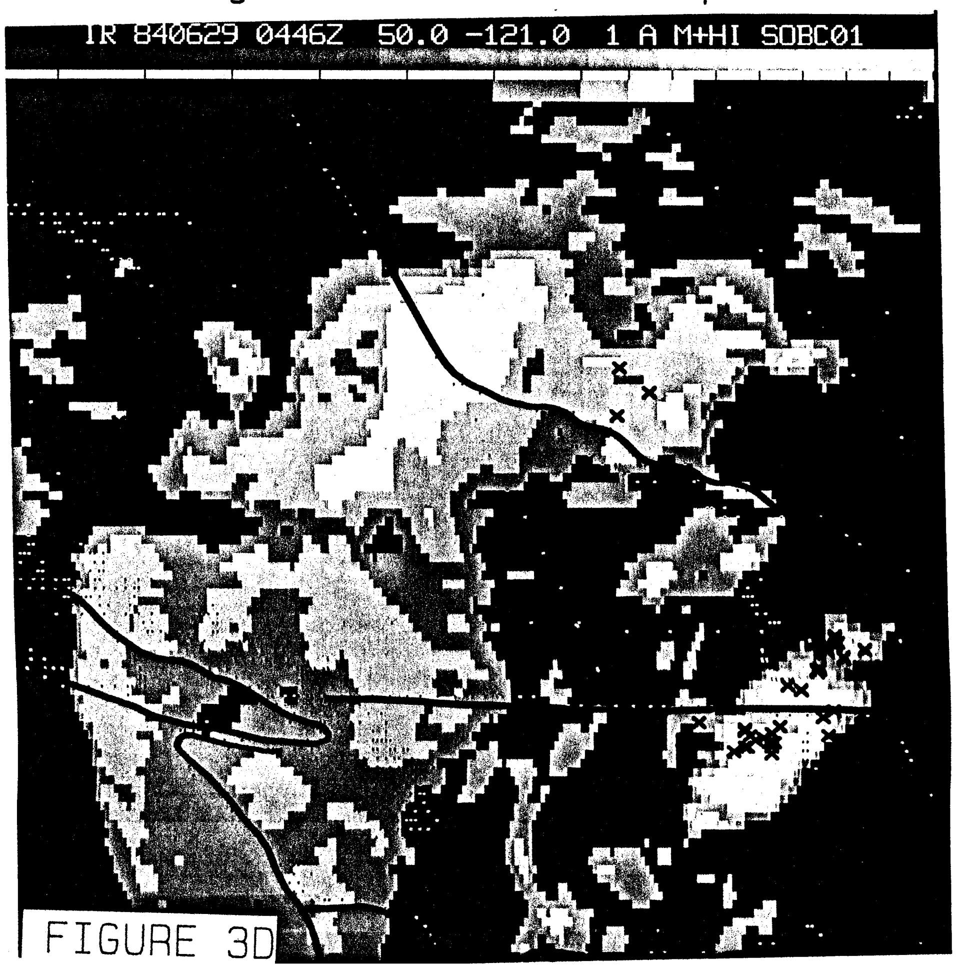


Figure 4. An example of Area C.

4A. Highlights of the lightning activity associated with the western end of the deformation zone indicated on the enhanced infrared image of 4B.

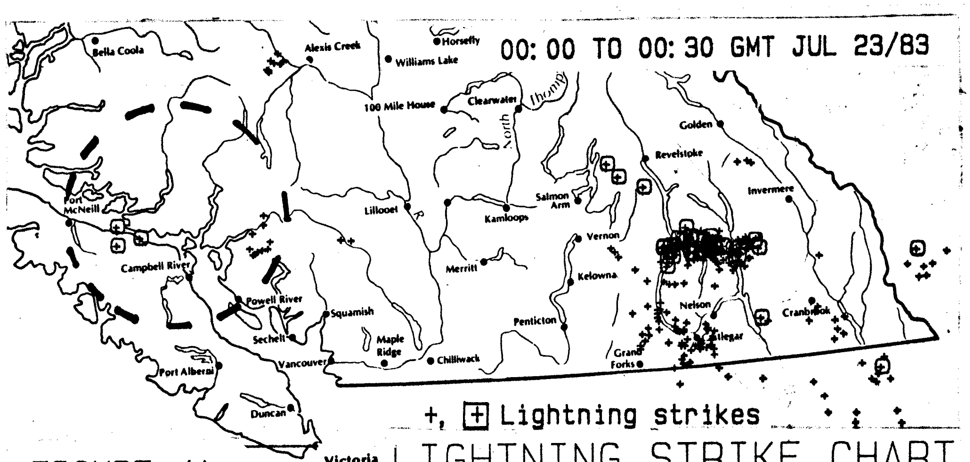


FIGURE 4A

4B. Enhanced infrared image corresponding to 4A and showing the model features.

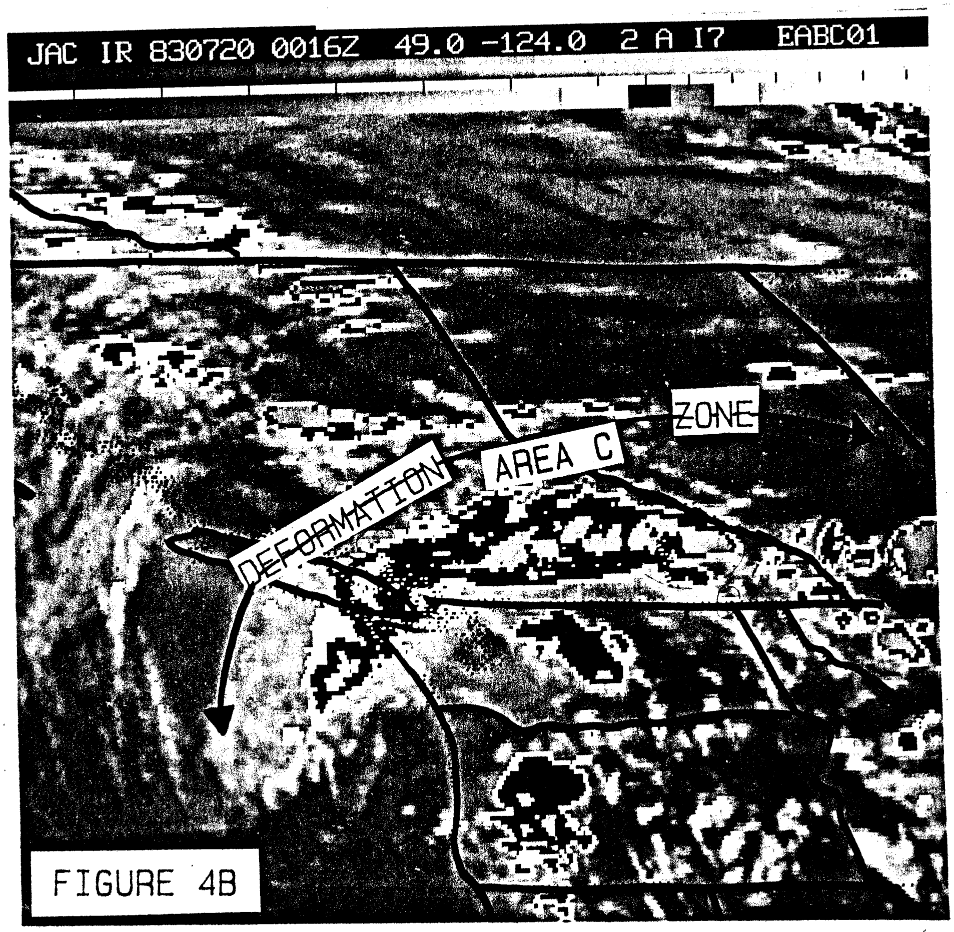


FIGURE 4B