PACIFIC REGION TECHNICAL NOTES

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The Role of Low Level Topographical Convergence and Moisture Channeling on Regional Lightning Activity

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INTRODUCTION

The Pacific Weather Centre relies heavily on lightning data and satellite imagery for its Fire Weather Forecast Program. This is necessary due to the mountainous terrain and lack of conventional meteorological data within the forecast area.

The lightning strike network, operated by the B.C. Ministry of Forests, can detect and position cloud to ground lightning strikes. This information can be transmitted in near real time to the Pacific Weather Centre for analysis. As well, the interactive satellite analysis and display system at the Weather Centre produces automatic output of high resolution GOES imagery, complete with specialized enhancements. These two data sets were studied independently then correlated during the course of a PWC Satellite Lightning Strike project conducted during the summer of 1984.

In the past, conventional theory suggested a random occurrence of heavy convection and lightning activity when strong surface heating, high dew points, and orographic lift were deemed significant. Random thunderstorms were forecast in coastal areas when a cold unstable airmass moved onshore from the Pacific and was subjected to coastal lift and differential heating. From the study of lightning and satellite data it became apparent strong convective activity was more ordered than previously believed.

GENERAL OBSERVATIONS

During the course of the Satellite Lightning project, the following were observed:

1. Towering cumulus form readily along mountain ridges in a convective situation. However, it seems that the significant convection with its associated lightning activity has a different development mechanism.

2. It was found that the initial development and subsequent axis of lightning activity tends to align with the valleys and inlets of southern British Columbia. The lightning activity did not normally cross over mountain ranges but "jumped" or developed from valley to valley and inlet to inlet (figure 1). The resolution of the data

prevents discrimination between the valley bottom or walls, but the common belief is that higher elevations are favoured.

3. Lightning was enhanced when the middle and low level winds ran parallel with a valley or inlet. In many cases there was a marked decrease in lightning activity when the flow ran perpendicular to a mountain range.

The above general observations were not all that surprising. Weaver (1979) presented cases to show that severe thunderstorm activity could be linked and anchored to strong boundary layer convergence zones.

Unlike most areas of the country, where low level convergence zones and low level moisture tongues translate with a disturbance or a cell, these features remain relatively fixed along steep mountain valleys or inlets in a given flow pattern.

It should be noted at this point that the lightning-valley relationship is only a general rule. The higher the base of the convective storm, the less the reliance on low level moisture. For example, with high based thunderstorms such as those that occur with "overrunning" subtropical air, the valley effects may not be that significant.

REGIONAL OBSERVATIONS

Because of the large variation of topography, the province below 56 degrees north was divided into three study areas; the Coast, the Central Interior, and the Southern Interior.

1. Coastal Lightning. The coastal inlets generally have a southwest to northeast orientation, with a natural discontinuity along the Coast Mountain Range. However, the lower Fraser Valley is aligned more east to west with sharp steep valleys extending north from it. These inlets and valleys form natural convergence lines and moisture funnels when the low and mid-level wind field aligns with them. As well, there are at least two well defined convergence zones. The first is the general area between Johnstone and Georgia Straits where Vancouver Island juts towards the mainland coast. Winds from either the northwest or southeast result in forced convergence and support convective activity. The other significant zone lies in the vicinity of the B.C.-Washington border along the mainland coast. A southerly flow pattern through Puget Sound and inflow through Juan de Fuca Strait can produce strong convergence and lightning activity if the airmass involved is unstable and relatively cloud free.

Abundant moisture for coastal convection is readily available and dew points generally run quite high. However, critical convective temperatures are not normally reached because of the moderating effect of coastal waters and low cloud.

In a significant convective situation the valleys and inlets form corridors for lightning activity (figure 2). The convergence zones are also key areas to watch for thunderstorm/lightning initiation and intensification.

2. Southern Interior Lightning. The valleys of the southern interior generally run north to south between steep mountain ranges. Significant exceptions are: the South Thompson Valley through Kamloops and eastwards into the Shuswap Lakes and the stretch of the Columbia River between the B.C./ U.S.A. border and Kootenay Lake. These valleys tend to align more east-west. Several north-south valleys converge with the South Thompson River system.

Coastal moisture penetrates into the Southern interior by several routes. The principal moisture source area is the Washington Plateau which is in turn fed from the coast by the Columbia River valley. From the plateau, moisture and convective cloud funnels up through the north-south valleys. The Skagit and Fraser canyon also steer coastal moisture into the southwest interior.

The valleys act as corridors for lightning activity (figures 3 and 4) especially when the winds below 500 mb are aligned with them. Thunderstorms moving up from the plateau tend to develop, often explosively when forced to push northwards through the constricting valleys and convergent zones of southern B.C. (figure 5).

3. Central Interior Lightning. Central B.C. is dominated by a high plateau which is bounded to the west by the Coast range, to the east by the Rockies, and to the south by a more disorganized set of mountains. The North Fraser and North Thompson valleys are the principal north to south orientated features through this region. The upper Fraser, Nechako, Quesnel, and system of rivers and lakes from Williams lake through Wells Grey Park are the principal east to west valleys.

The coastal mountains to the west are not as high nor as continuous as those further south. As a result coastal moisture can better penetrate the plateau. As well moisture can infiltrate the area via the North Fraser and North Thompson River systems. The prevailing wind directions for heavy thunderstorm and lightning activity was found to lie between the south and west with little directional shear between levels. Broad scale upslope winds were not found to be a significant factor. In fact upslope often had a marked dissipative effect on convective and lightning activity. For example, westerly winds did not produce increased lightning activity along the western slopes of the Rockies. In some westerly flow cases, most of the activity was found on the western plateau (downslope area).

The Central Interior valleys did show some tendency to steer thunderstorm and lightning activity, but not to the extent evident with the southern B.C. valleys. (Lu, 1984, has indicated that there are well defined valleys in which power lines have repeatedly experienced damage because of lightning.) In general, it appears that significant convective activity is more affected by the dynamic situation and daytime heating than by any terrain features.

SUMMARY

Low level convergence zones and moisture channels induced by southern B.C. valleys are significant factors in regional lightning production.

Illustrated Cases

REFERENCES

Weaver, J., Storm Motion as Related to Boundary-Layer Convergence, Monthly Weather Review, 1979.

Lu, I., B.C. Hydro Working Group Presentation, November 6, 1984.

w/p C407

FIGURE 1.
LIGHTNING JUMPING DOWN SUCCESSIVE SOUTH COAST INLETS

LIGHTNING ACTIVITY ALONG THE SOUTHCOAST MAINLAND (FIGURE 1A) IN A SOUTHWEST FLOW SITUATION DEVELOPS OR JUMPS SOUTHWARDS ALONG SUCCESIVE INLETS (FIGURE 1B).

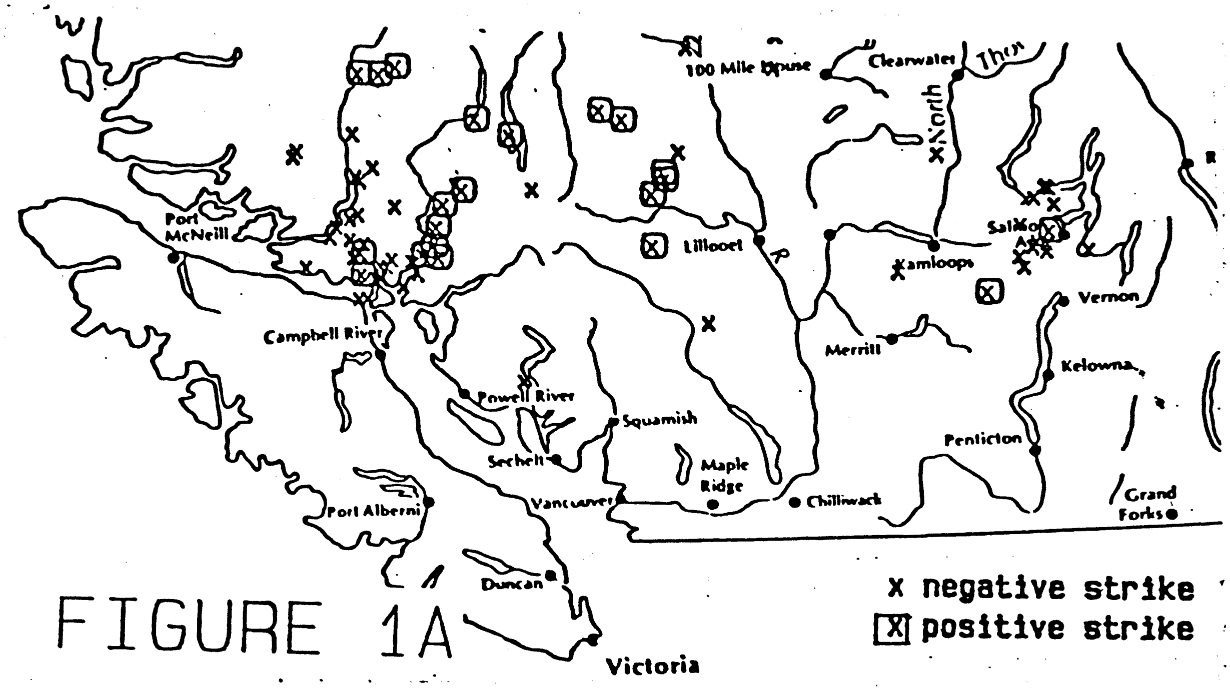

FIGURE 1A

FROM: 14:00 JULY 13, 1983 TO: 15:00 JULY 13, 1983

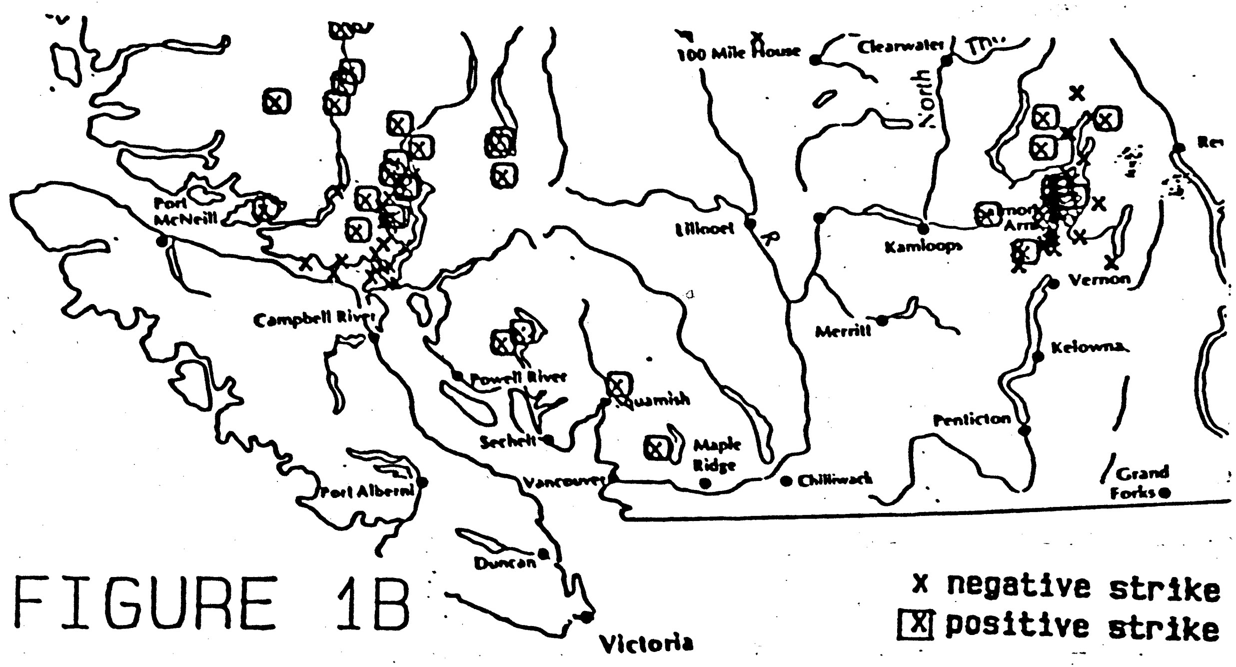

FIGURE 1B

FROM: 15:00 JULY 13, 1983 TO: 18:00 JULY 13, 1983

FIGURE 2.
LIGHTNING STEERED BY A MOUNTAIN VALLEY.

LIGHTNING INITIALLY ALONG THE LOWER FRASER VALLEY AND NORTHERN PUGET SOUND (FIGURE 2A), ADVANCES NORTHWARDS UP HARRISON LAKE (FIGURE 2B).

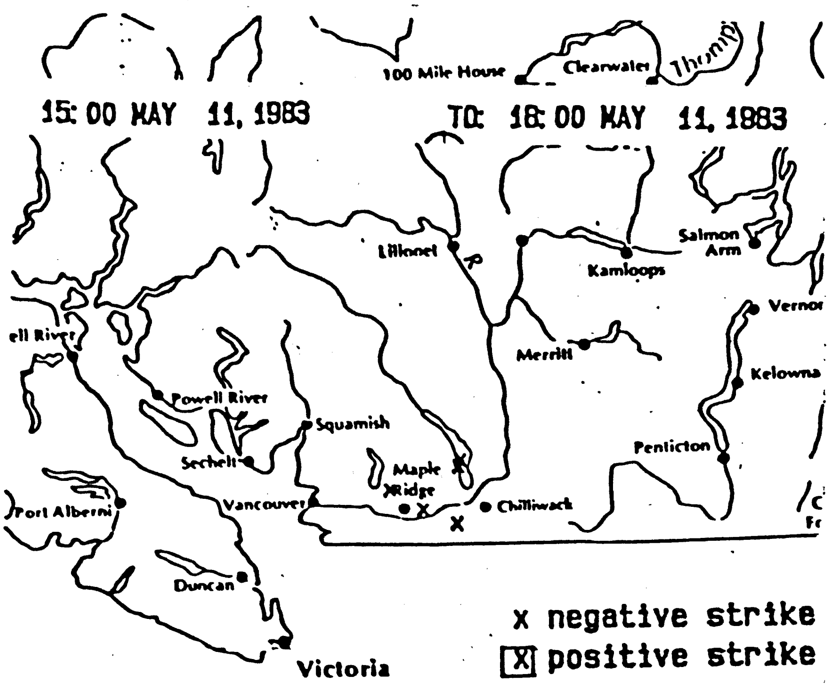

FIGURE 2A

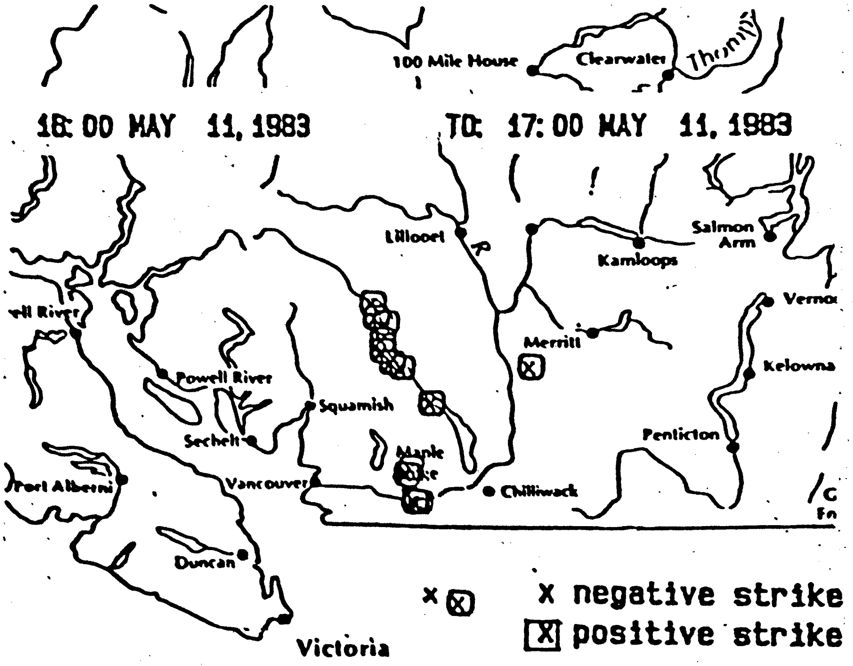

FIGURE 2B

FIGURE 3.
THE OKANAGAN CORRIDOR

LIGHTNING ADVANCING UP THE OKANAGAN VALLEY FROM THE WASHINGTON PLATEAU IN A SOUTHERLY FLOW SITUATION

11:00 JUNE 17, 1983 TO: 12:00 JUNE 17, 1983

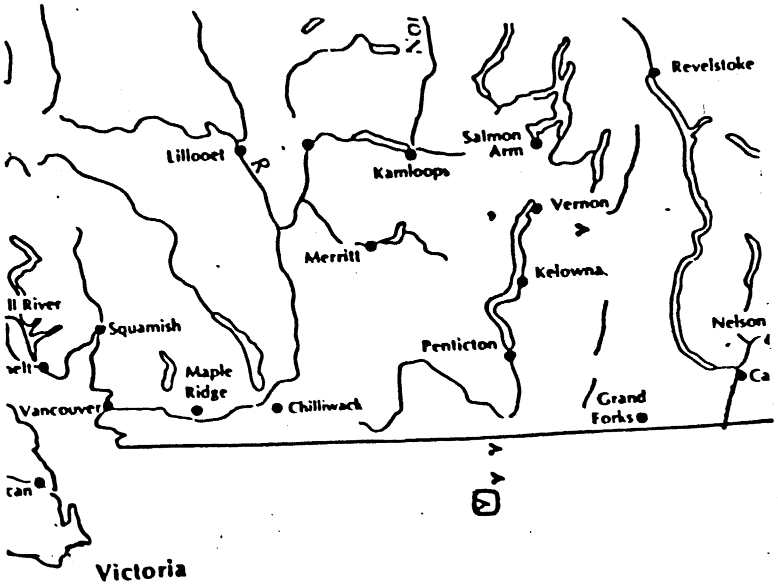

FIGURE 3A

^ negative strike

☒ positive strike

12:00 JUNE 17, 1983 TO: 13:00 JUNE 17, 1983

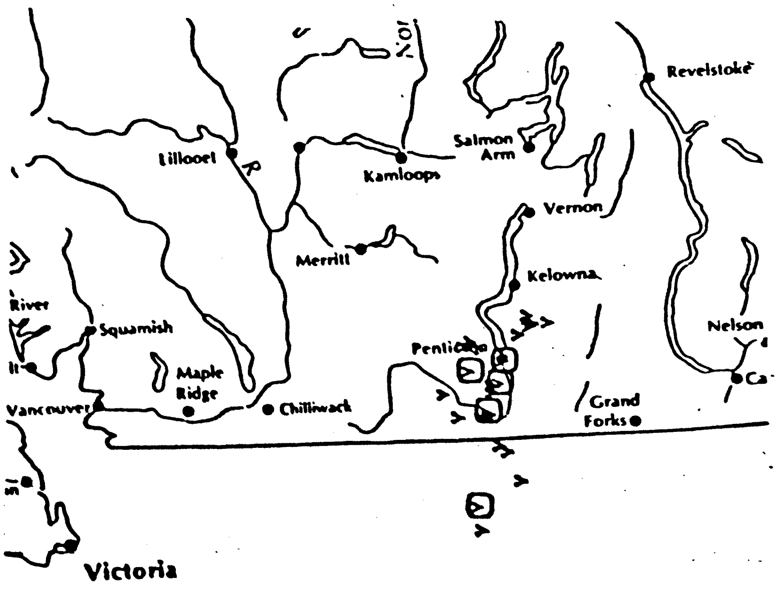

FIGURE 3B

> negative strike

☒ positive strike

FIGURE 4.

THE VALLEY CORRIDOR EFFECT

LIGHTING MOVING UP THE COLUMBIA RIVER FROM WASHINGTON STATE TOWARDS CASTLEGAR. AT THE SAME TIME LIGHTNINGIS OCCURING SIMULTAINOUSLY OVER THE ARROWS, SLOCAN, AND KOOTENAY LAKE VALLEYS.

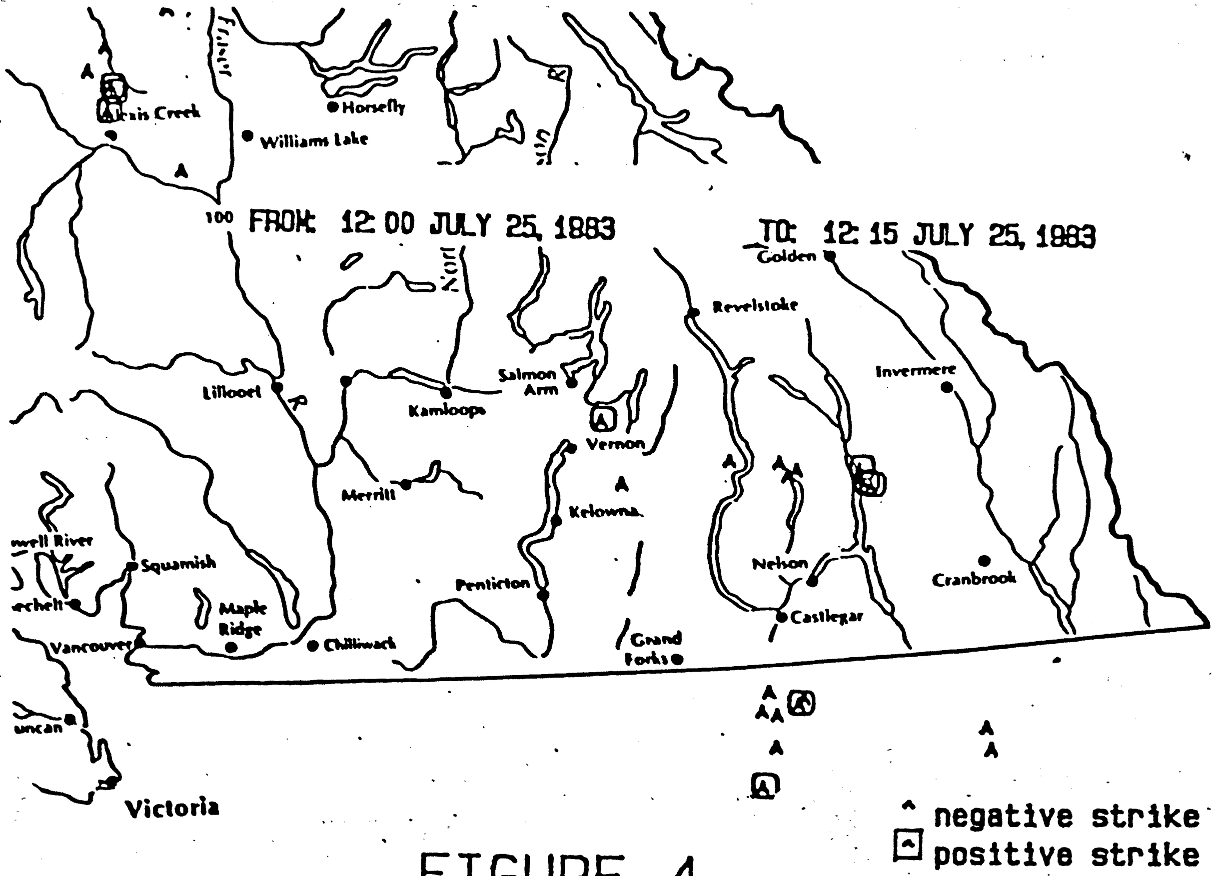

FIGURE 4

THE VALLEY-CORRIDOR EFFECT FIGURE 5.

ENHANCED COLD CLOUD TOPS AND THE ASSOCIATED LIGHTNING (FIGURE 5A) INCREASE AS CB CELLS MOVE NORTHWARDS FROM THE WASHINGTON PLLATEAU AND UP THROUGH THE COLUMBIA CORRIDOR INTO SOUTHERN BC (FIGURE 5B).

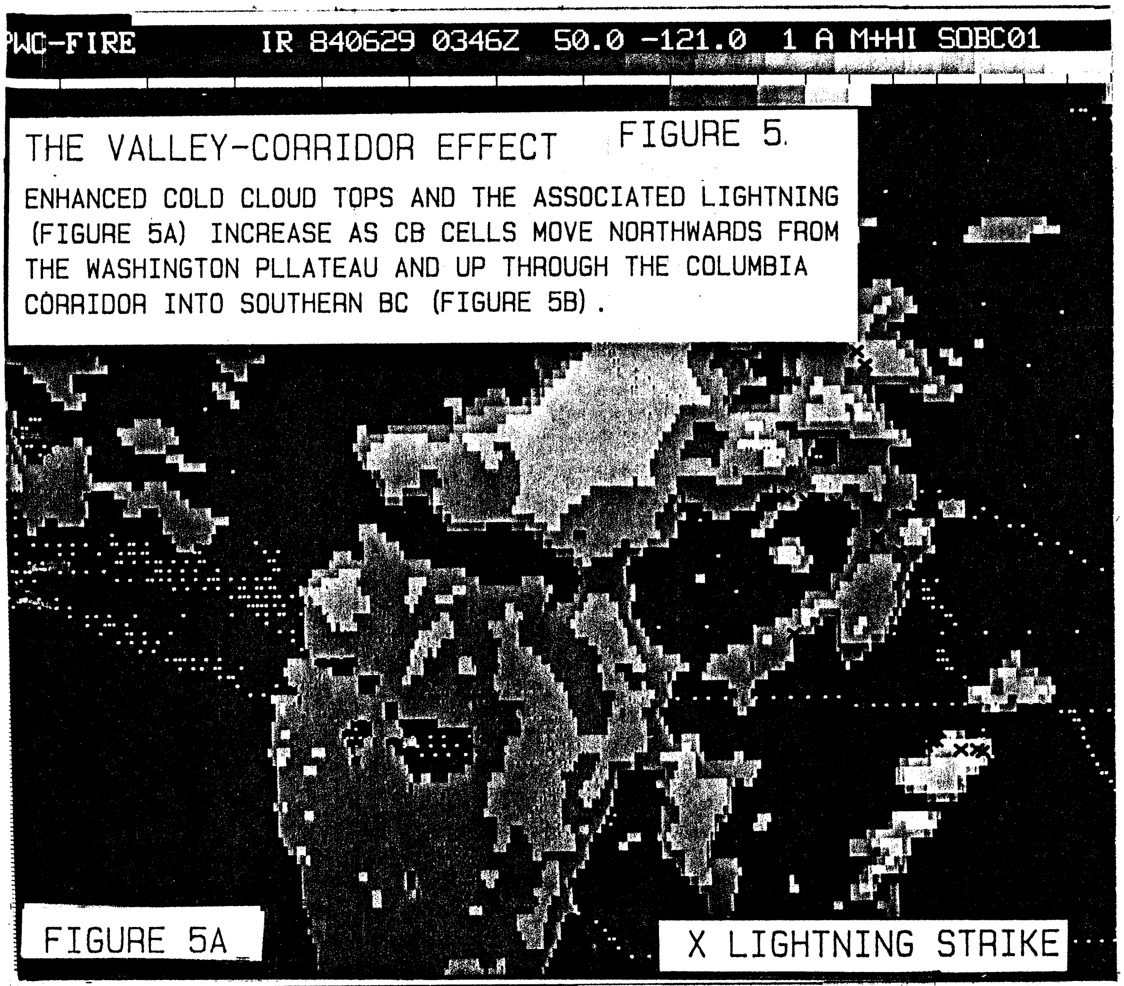

FIGURE 5A

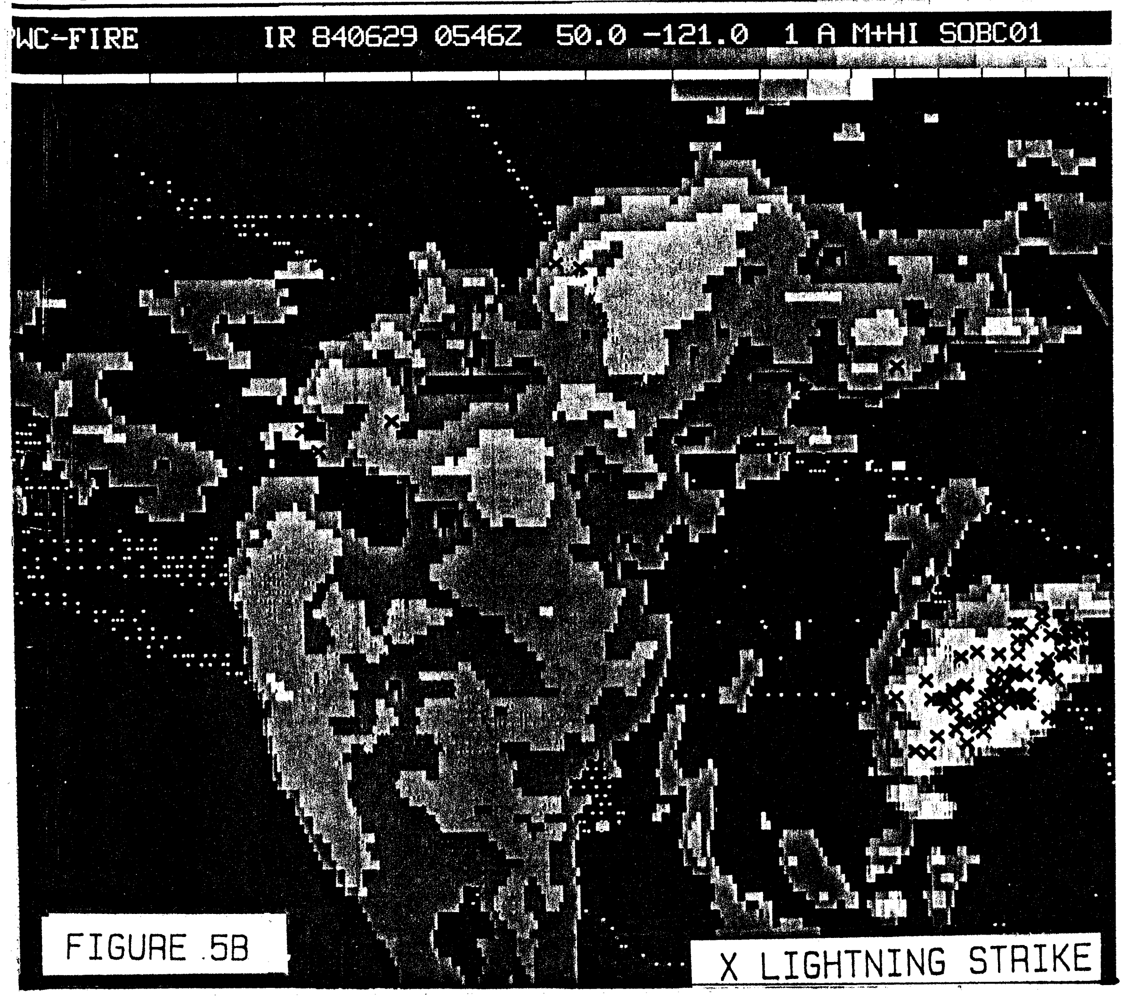

FIGURE 5B