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OPERATIONAL TEST OF A LIGHTNING FORECAST MODEL

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INTRODUCTION

Accurate forecasting of lightning activity could be an aid to forestry managers involved in deployment of fire fighting resources during the fire season. The Pacific Weather Centre in Vancouver is attempting to improve the accuracy of lightning forecasting in order to make the forecasts more usable to forecasters in both government and industry. Lightning generally develops over British Columbia in association with synoptic scale features of the atmosphere that can be identified and their short-term movement and forecast positions can be determined. A model was developed at the Pacific Weather Centre that attempts to link these synoptic-scale features with areas of expected lightning activity. This paper describes the use of this model in lightning forecasting in the summer of 1985.

LIGHTNING FORECASTING MODEL

The lightning forecasting model relies on the analysis of satellite imagery film loops to identify the locations of five types of synoptic-scale features:

1. The jet stream, a core of very strong winds usually travelling in a general west-to-east direction between 7000 and 12000 metres above sea level.

2. Vorticity centres, a point around which the higher level clouds appear to rotate.

3. A vorticity trough, a line ahead of which the atmosphere is ascending.

4. An upper ridge line, a line ahead of which the atmosphere is descending.

5. A deformation zone, a line where the upper winds tend to deform or split apart towards a general west and east direction.

Figure 1 shows these five features superimposed on an idealized cloud system. Figure 2 shows the relationship between these synoptic-scale features and areas where lightning can occur when a number of other atmospheric criteria are met. Four distinct lightning areas: A, B, C and D are defined. These lightning areas can be described as follows:

1. Area A is bounded by the jet stream, vorticity trough, deformation zone and upper ridge line. The majority of thunderstorms develop in this area and almost always are accompanied by showers and high humidities.

2. Area B lies to the south of the jet stream between the vorticity trough and upper ridge line. Thunderstorms that develop here frequently are more violent and often are based at such high levels that no significant precipitation reaches the ground and humidities remain low.

3. Area C lies along or near the deformation zone. Thunderstorms developing here are generally accompanied by precipitation.

4. Area D refers to isolated thunderstorms that occur well to the south of the jet stream and to the west of the upper ridge line. These thunderstorms generally develop late in the day and frequently continue well into the evening. They are associated with subtropical moisture that moves in from the southwest and are also based at such high levels (above 3000 metres) that little or no precipitation reaches the ground. Thunderstorm development in area D is not as common as in the other areas and is the most difficult to accurately forecast.

APPLICATION OF LIGHTNING FORECASTING MODEL DURING 1985 FIRE SEASON

During the 1985 fire season, the satellite meteorologist routinely analysed daily satellite imagery by identifying the relevant synoptic-scale features and their historical movements. Figure 3 shows a satellite analysis for June 26, 1985 and is typical of the chart produced twice each morning in support of the lightning forecasting project. This analysis shows a jet stream lying in a northeast-southwest line through British Columbia with a vorticity centre north of Williston Lake and a vorticity trough curving southward to Prince George. The upper ridge line lies in a northwest-southeast line through the extreme northeastern tip of the province and the deformation zone lies over the Yukon. Lightning areas A,B,C and D were also outlined by the satellite meteorologist.

The movement and final afternoon and evening positions of the synoptic-scale features and the associated "lightning areas" were made by the forestry meteorologist based mainly on extrapolative techniques and computer modelling. Atmospheric stability was also assessed to determine the likelihood of thunderstorm development. Regions were then outlined where lightning was expected to occur that afternoon and evening and the fire weather zones included in those regions were recorded. Subsequently, daily lightning strikes counts for each fire weather zone were recorded in order to verify the accuracy of the forecasting technique.

Figure 4 shows the location of cloud to ground lightning strikes on June 26, 1985. In this case, most lightning activity appears to have occurred in area B with lesser amounts in areas A and D. Lightning data over the Yukon is not received at the Pacific Weather Centre so it is not known if any lightning was associated with the deformation zone in this case.

LIGHTNING FORECAST VERIFICATION

Lightning forecasts issued from June 1 to September 15, 1985 were verified by comparing the forecast for each zone on each day with the number of strikes recorded. Figure 5 shows an example of the contingency table produced for southeastern British Columbia for the month of August.

LIGHTNING FORECAST VERIFICATION FROM AUGUST 1 TO AUGUST 31, 1985 FOR SOUTHEASTERN BRITISH COLUMBIA

FIRE WEATHER ZONES 22 23 24 25 26 AND 27

CONTINGENCY TABLE

		LIGHTNING FORECAST YES	LIGHTNING FORECAST NO
OBSERVED	YES	65	13
	NO	43	65

TOTAL FORECASTS:	186	
PERCENT CORRECT:	70%	
BIAS	1.38	(#Forecast/#Observed)
POST AGREEMENT:	.60	(#Correct/#Forecast)
PREFIGURANCE:	.83	(#Correct/#Observed)
THREAT:	.54	(#Correct/#Forecast & Observed)

Figure 5. Contingency Table for Lightning Forecast Verification for southeastern British Columbia in August 1985.

This example shows that during August 1985 in southeastern British Columbia, 186 forecasts were made of whether or not lightning would occur in each fire weather zone; (31 days, 6 zones).

Of the 186 forecasts:

- 65 forecasts correctly predicted lightning occurrence.
- 65 other forecasts correctly predicted no lightning occurrence.
- Lightning occurred 13 times but was not forecast.
- Lightning was forecast 43 times but did not occur.

Figure 5 also lists a number of scores associated with the contingency table describing the accuracy of the lightning forecasts.

Contingency tables for each area of British Columbia for the fire season were produced. These tables show a number of regional differences in forecast accuracy:

1) The ability to forecast lightning occurrence was highest in the southern interior of the province, though there was a tendency to overcast lightning.

2) The ability to forecast lightning was lowest in northwestern British Columbia and the north coast, due mainly to the relatively rare occurrence of lightning.

3) There was either no forecast bias or a bias towards overforecasting through most of the province. The exception was northeastern British Columbia where more lightning occurred than was forecast.

FORECAST ACCURACY OF LIGHTNING MODEL

In general, the lightning model worked well, as lightning almost always occurred in one or more of the "lightning areas" A,B,C, or D. Forecast inaccuracies occurred primarily due to the difficulty in accurately predicting the location, size and shape of these "lightning area" later in the day. Sources of lightning forecast errors appear to fall into one of the following categories:

1) The motions of the synoptic-scale features identified on the satellite analyses were sometimes incorrectly forecast due to unexpected changes in their speed, direction and/or intensity.

2) New synoptic-scale features appeared later in the day that were not apparent early in the morning.

3) Lightning activity sometimes began and/or ended earlier or later in the day than expected, possibly due to an inaccurate assessment of the atmospheric stability.

4) Lightning forecast areas were sometimes too narrowly defined so that minor lightning activity outside the area was not forecast.

CONCLUSION

A lightning forecast model based on synoptic-scale atmospheric features analysed from satellite imagery was tested during the 1985 fire season in British Columbia. Satellite imagery both in hard copy and in animated loops was examined to define the positions of up to five distinct types of synoptic-scale atmospheric features. The lightning forecast model defined specific areas linked to these features within which lightning was likely to occur in an unstable atmosphere. Forecasting the movement of the synoptic-scale features and the associated lightning areas enabled the forestry meteorologist to delineate regions of expected lightning occurrence during the day.

The lightning forecast model worked well in general. Inaccuracies developed in some cases due to incorrect prediction of the movement of synoptic-scale features, or to incorrect assessments of the atmospheric stability.

REFERENCES

Funk, L. 1984, 'Lightning Area Locations Within an Organized Cloud System - A Model', Pacific Regional Technical Note, Atmospheric Environment Service, Vancouver.

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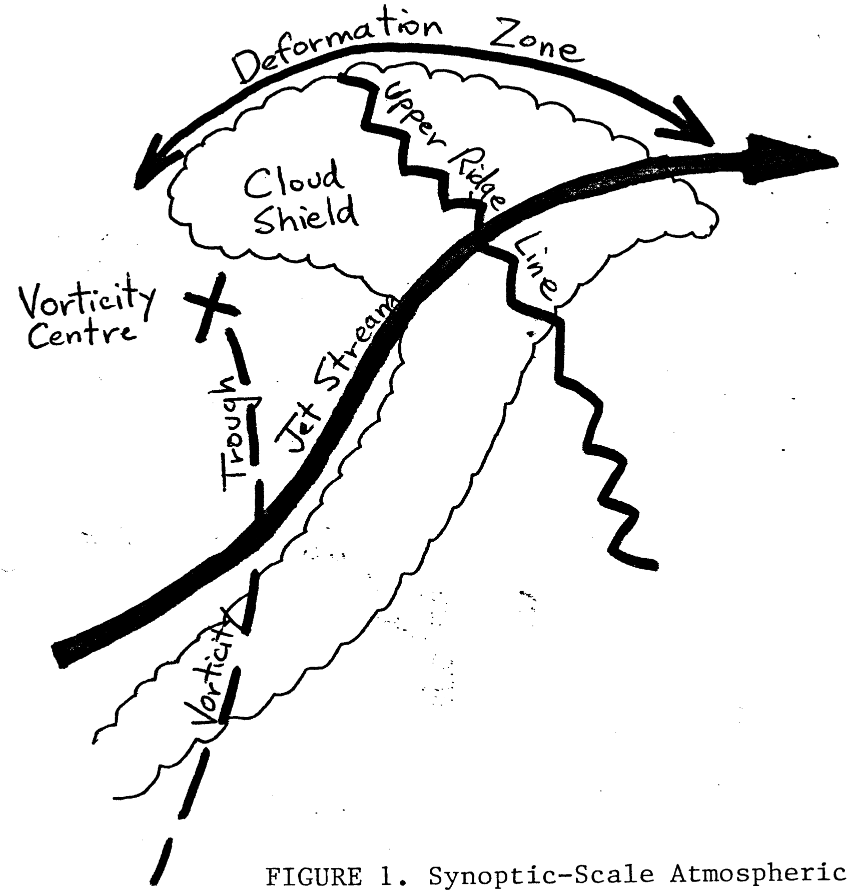

FIGURE 1. Synoptic-Scale Atmospheric Features.

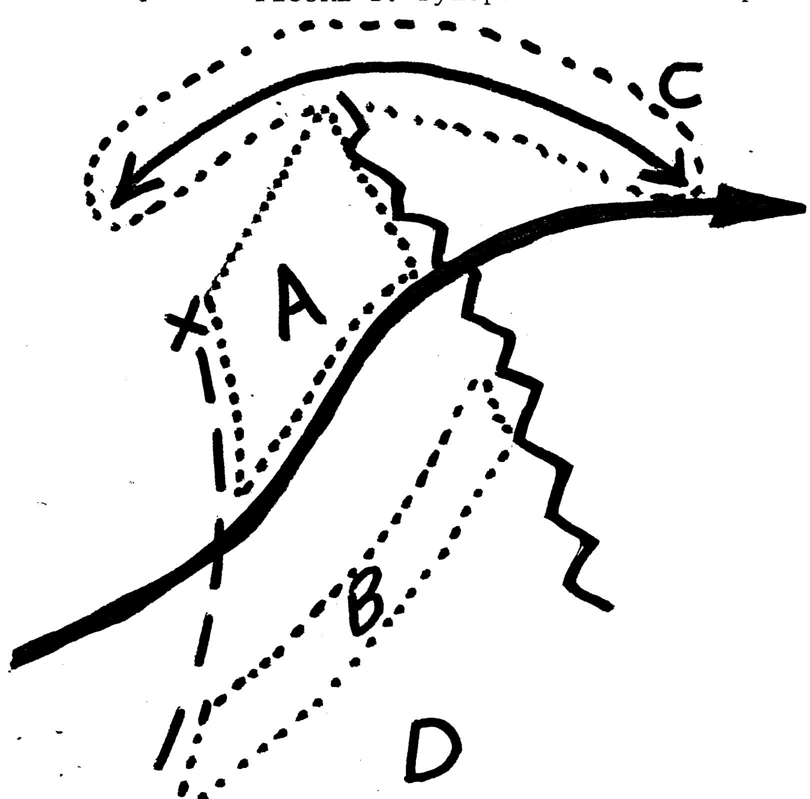

FIGURE 2. Lightning Areas A, B, C, and D.

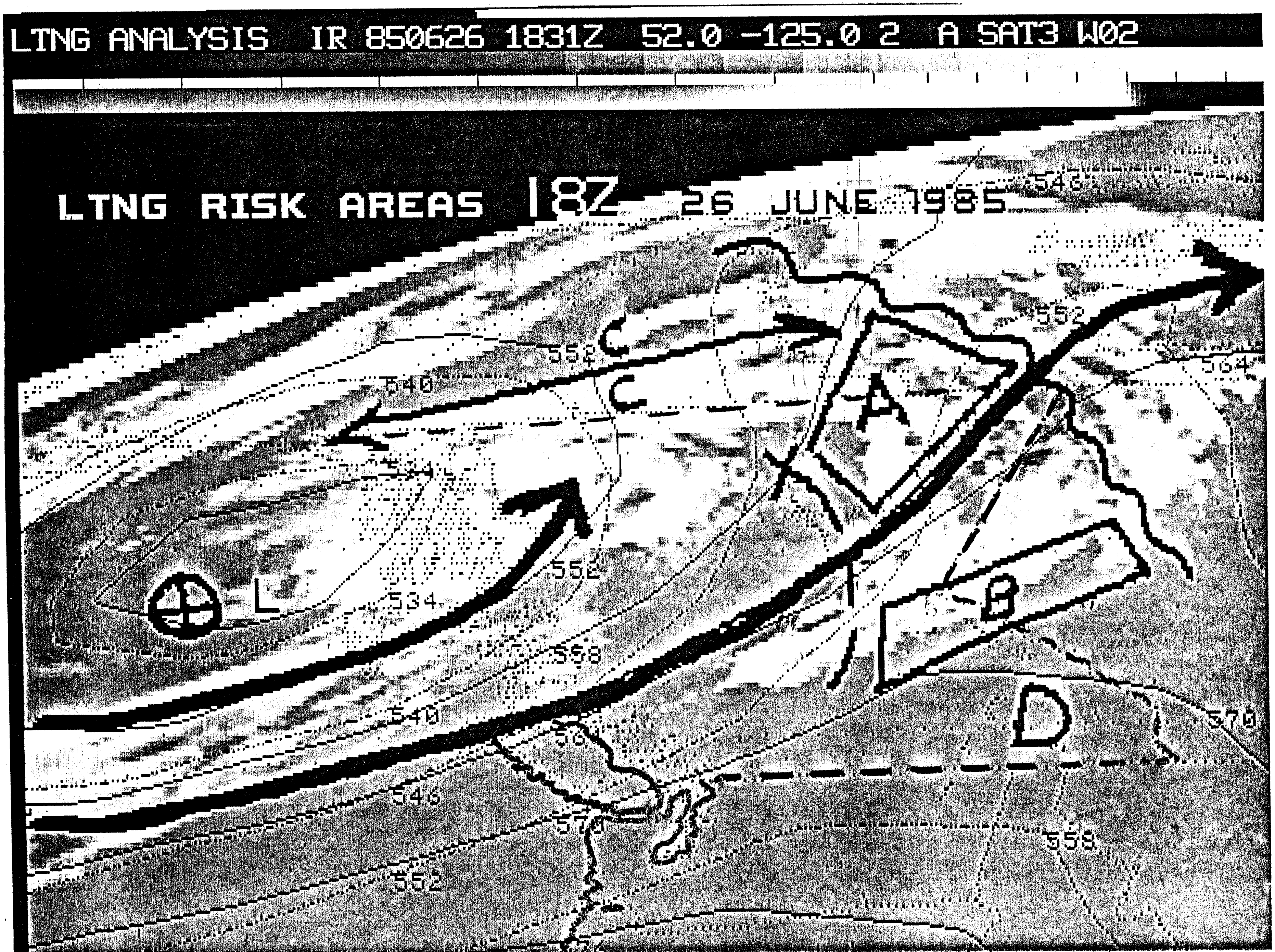

Figure 3. Satellite Analysis with the associated Lightning Areas superimposed on an Infra-Red image for 1131 PDT, June 26, 1985.

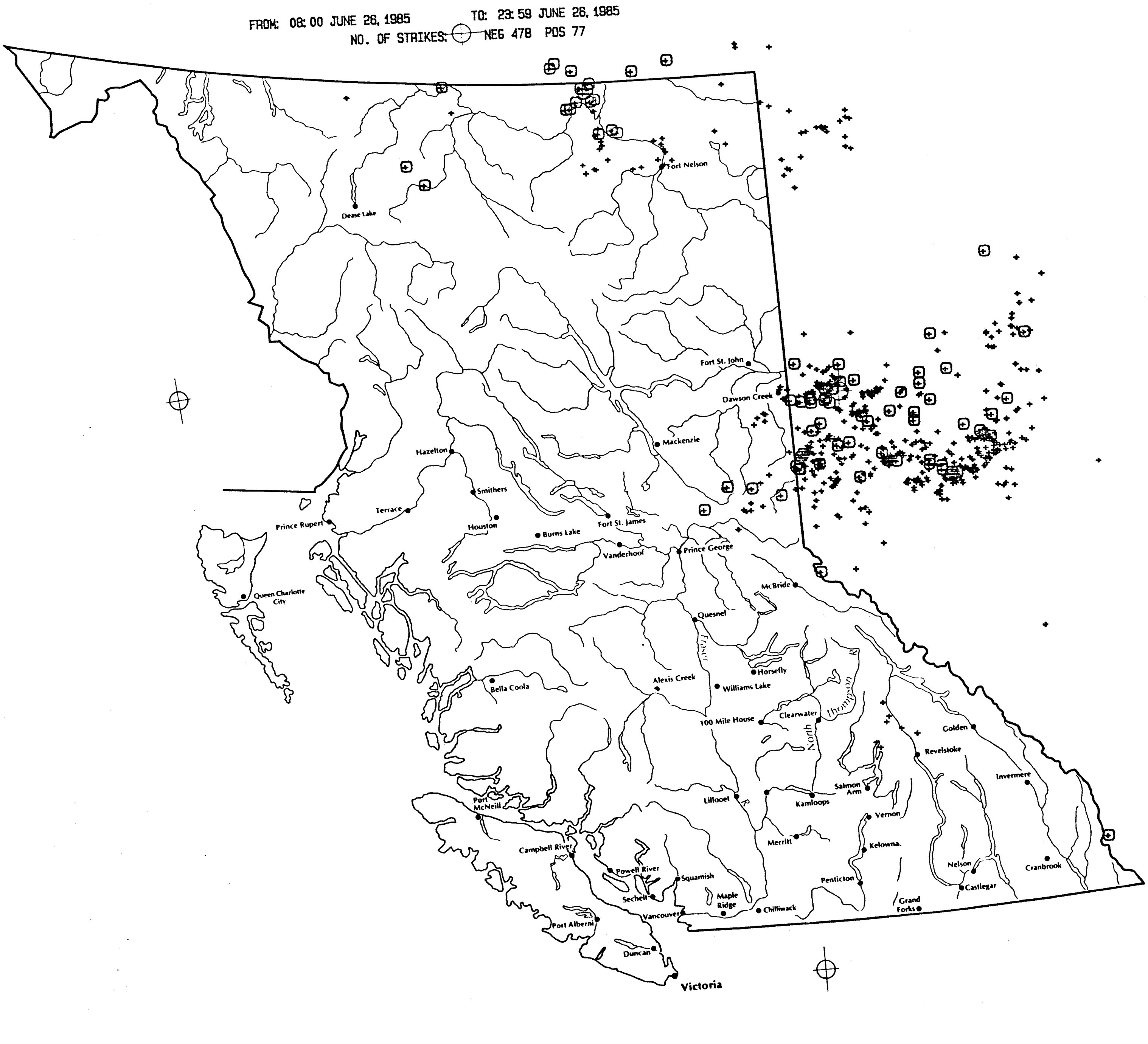

FIGURE 4. Cloud to Ground Lightning Stikes for June 26, 1985. Negative strikes are crosses. Positive strikes are circled crosses.