
The Relationship between Forest Fire Occurrence and 500 mb Longwave Ridging

M.J. Newark

*Toronto Weather Office
Atmospheric Environment Service*

[Manuscript received 3 February 1975; in revised form 10 April 1975]

ABSTRACT

In general terms the probability of forest fires is increased by weather conditions that:

- (a) maximize the drying of forest fuels,
- (b) give a minimum of rain and yet still allow enough convective activity to produce lightning and spread going fires.

The hot sunshine and dry weather of summer high pressure systems fulfill these conditions. At the earth's surface however high pressure is transitory while at the 500 millibar level, ridging is much more persistent. Such longwave ridges aloft may persist for as

long as 80 days or even more but show oscillations in their strength. For the severe forest fire season of 1974 in northwestern Ontario, the changes in amplitude of the persistent longwave ridge over the area were examined. Using a diagnostic Hovmöller diagram, periodic oscillations of eleven days were discovered in its intensity which agreed closely with the periodicity in the Fire Weather Index, a measure of the forest's potential for fires. If such longwave behaviour is predictable then long term general statements about forest fire occurrence can be made.

1 Introduction

During the 1974 forest fire season 1,591 fires were recorded in Ontario with 1,288,170 acres burned. This season qualifies as one of the worst on record if only fire number and acreage are considered. The section of the province suffering the most was the area bordering on Manitoba. The greatest majority of fires in fact occurred in the Ontario Ministry of Natural Resources' northwestern fire region (fig. 1). A protracted dry spell which persisted from early June until the middle of August resulted in high to extreme values of Fire Weather Index (FWI) throughout much of the period. An emergency situation arose on July 7th and 1,700 people were evacuated from Vermilion Bay. Around the second week in August, nature took a hand and frequent rainfalls finished off the job that the firefighters had struggled with for nearly seven weeks.

It has been known for some time that longwave ridging at the 500 mb level over a particular longitudinal zone spells trouble for the firefighters in that

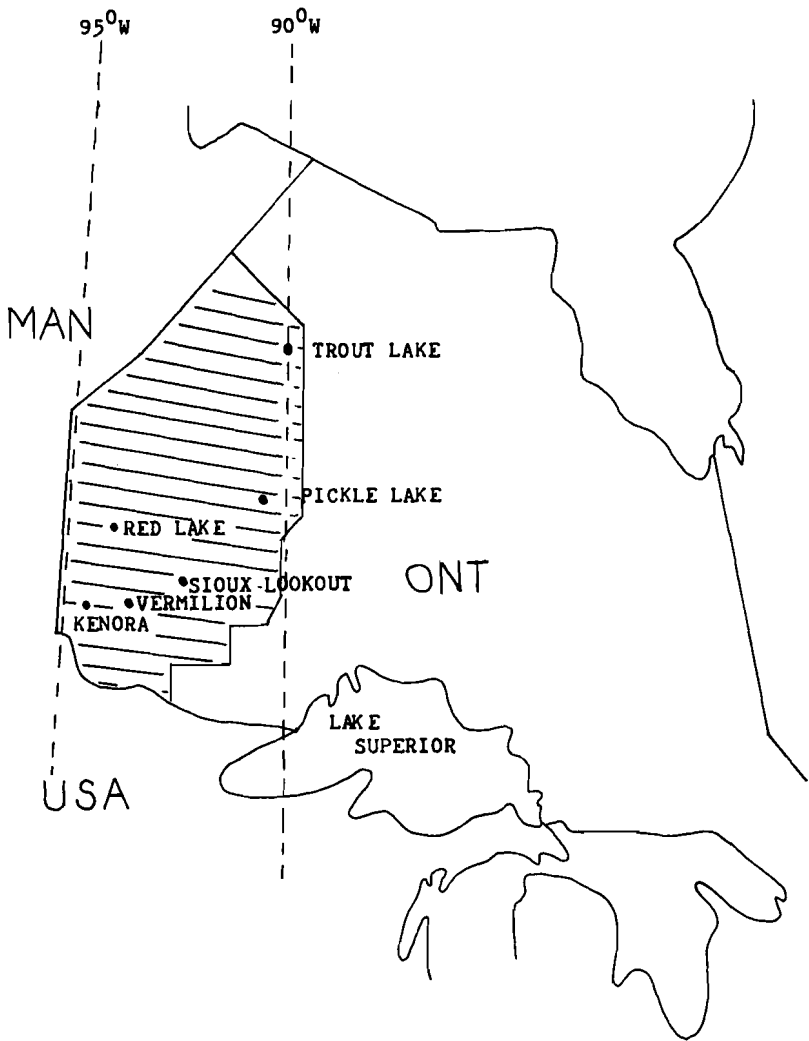


Fig. 1 The Northwest Fire Region of the Ontario Ministry of Natural Resources.

area. In order to determine what kind of relationship exists between the occurrence of forest fires and longwave ridges, an analysis was made of the 1974 season.

The first discovery was that a longwave ridge persisted at approximately the longitude of northwestern Ontario from June 14th, to August 8th, during which time the most hazardous fire weather situation of the summer occurred. Secondly, the ridge exhibited an orderly oscillating behaviour. It is possible that this is a feature of other bad fire years and that case studies will not only reveal the key to the inception of the longwave ridge but will do so in time to use the periodicity as a forecasting tool.

2 Surface weather systems

From June 14th to August 8th, high pressure systems were the dominating feature on the surface weather map. They were interspersed with occasional outbreaks of fresh dry Maritime Polar or modified Maritime Arctic air. As the northwestern fire region was dominated by a longwave ridge pattern at mid levels of the atmosphere, the troughs associated with the leading edge of the outbreaks weakened as they moved eastwards from the Rockies. This meant that rainfall was sparse and almost exclusively the result of localized convective activity. In many cases, the precipitation was associated with lightning. With the air masses being very dry, the rain in some cases would evaporate before reaching the ground leaving "dry" lightning. New fire starts were naturally the result.

3 Upper air patterns

a *The 1974 pattern*

Early in the month of June a well developed omega blocking pattern formed in the airflow at middle levels of the atmosphere over North America. By the middle of the month the western arm of this pattern had moved to Quebec followed by a mid-continent ridge. This ridge-trough configuration then persisted as a stationary longwave feature until nearly the second week of August. Most importantly, the longwave ridge remained over the northwestern fire region.

The most interesting feature of this pattern is the periodicity with which troughs broke through the ridge. The cycle typically consisted of a slow building of the ridge with associated high pressure influence at the surface, followed by a fairly rapid collapse as the troughs penetrated.

b *500 mb heights over International Falls as a longwave indicator*

A smoothed curve of the 500 mb height at International Falls versus time clearly shows the periodic building and collapse of the ridge (fig. 2). The period from ridge to ridge averaged eleven days. However, the average period from trough to trough was fifteen days so that after five cycles the pattern broke down.

c *Maximum temperatures as a longwave indicator*

To reinforce the evidence for periodicity, a check was made on the maximum observed surface temperature within the region. Since this temperature is linked to 500 mb heights, by way of the layer thickness concept, it should also show some periodic variation. In addition, it is reasonable to expect that maximum temperatures will be lower during the unsettled weather of troughs and at a peak during times of fire weather associated with ridges. A smoothed curve of the maximum temperature observed anywhere in the region in fact follows the variation of heights very closely (fig. 2).

d *Hovmöller diagram as a longwave indicator*

The Hovmöller diagram (fig. 3) very clearly shows the persistence of the

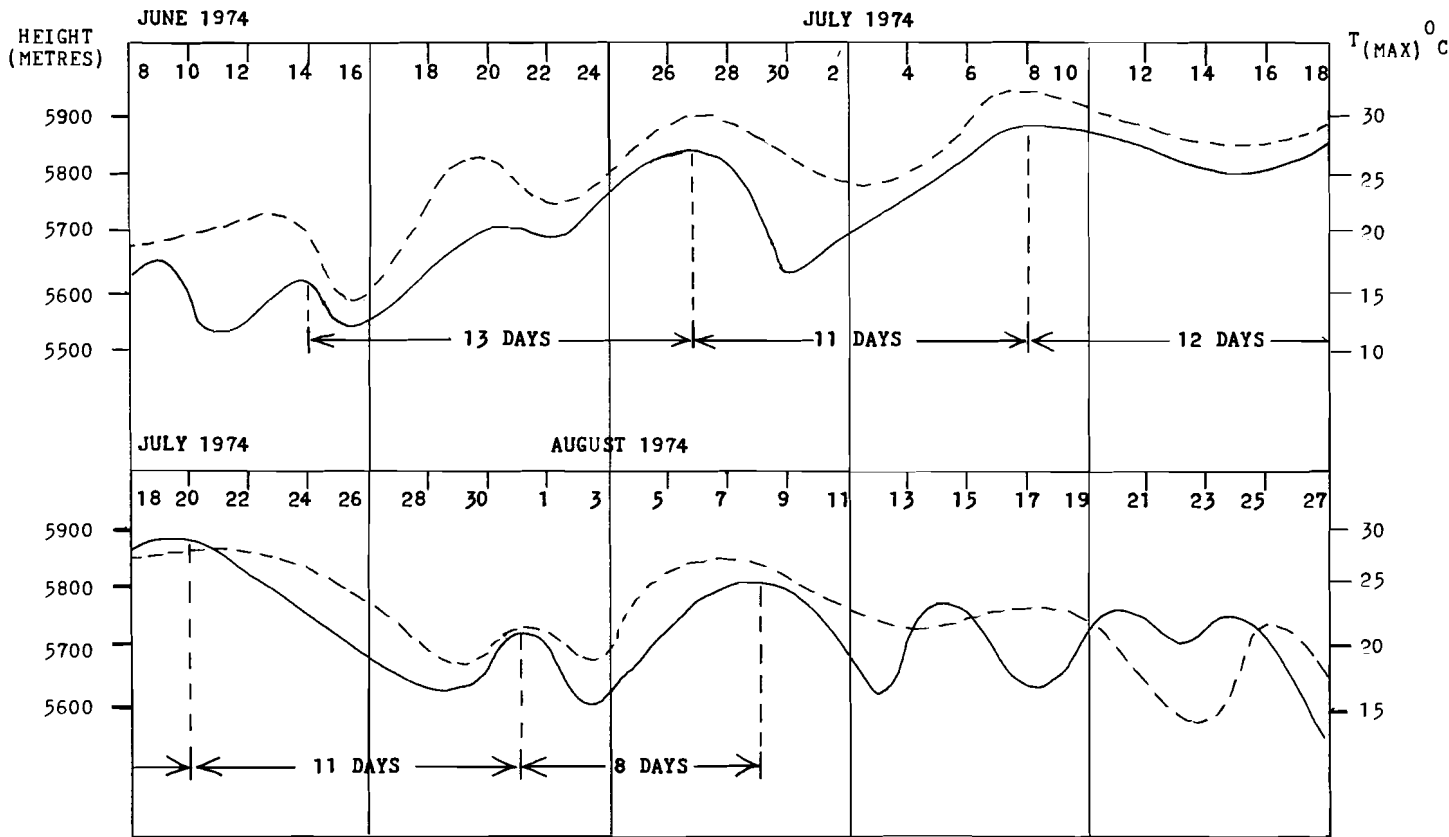


Fig. 2 Smoothed curve of 500 mb heights over International Falls compared to the smoothed curve of maximum observed temperature in the region (dashed curve). The period of each oscillation is shown in days.

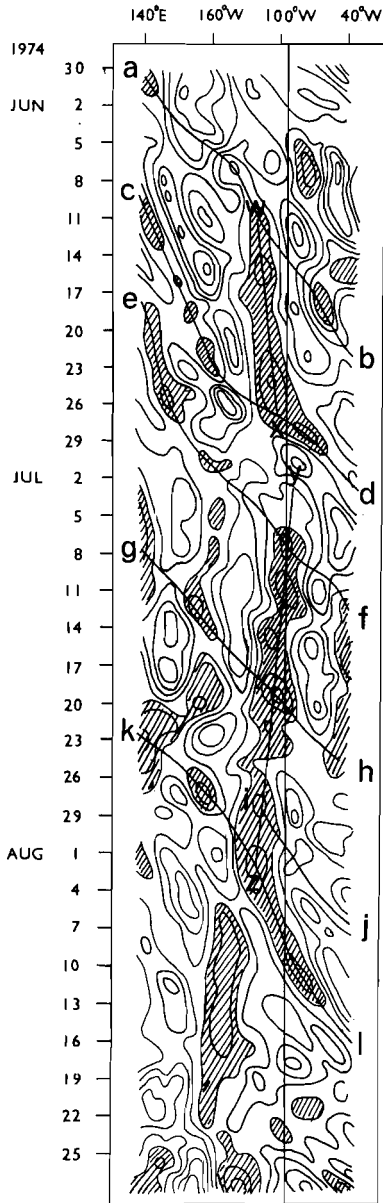


Fig. 3 Hovmöller diagram for 30th May to August 28th 1974. The unlabelled vertical line is the longitude (93°W) of the Northwestern Region. Shaded areas are ridges at 500 mb. Unshaded areas are troughs.

longwave ridge WXYZ at about the longitude of northwestern Ontario (denoted by the unlabelled vertical line at 93°W). It makes its appearance during the first week in June and persists until August 23rd. For part of this

TABLE 1. Dates that major 500 mb ridges crossed 93°W

Date of 93°W Longitude Crossing	Major Ridge Identification (Fig. 3)	Average Speed of Ridge (knots)
June 14th	A,B	11
June 27th	C,D	18
July 7th	E,F	16
July 20th	G,H	18
July 31st	I,J	12
August 8th	K,L	10

time it showed a steady retrogression of 0.83 degrees longitude per day (1.3 knots).

It is of interest to note that the wavelength of the longwave features of the circulation is approximately 65 degrees of longitude (wave number of about 6). The ridge crossed the 93°W longitude line on July 8th, just the time of the Vermilion Bay emergency! About August 5th, a particularly vigorous trough moved through the ridge destroying the comparatively stable pattern. Travelling waves then predominated at 93°W.

Throughout the lifetime of the ridge a series of major ridges and troughs moved through it. The passage of these groups across 93°W resulted in the periodicity in the fluctuation of heights at that longitude that has already been examined in fig. 2. The Hovmöller diagram (fig. 3) shows that major ridges crossed 93°W at times which are shown in table 1.

It should be noted that the peak of July 31st in fig. 2 appears as only a weak ridge in fig. 3. Apart from this, excellent agreement exists between table 1 and the times of the peaks shown in fig. 2.

The literature records several cases of periodicity in oscillations of the zonal index (Panofsky and Wolff 1957, Monin 1963, Julian 1966, Noar 1973). In this analysis, the eleven day period of oscillation relates directly to the change in amplitude of the real weather feature rather than to an index, but the similarity to the 12 to 13 day figure common in the literature suggests that they are related.

4 Fire Weather Index

The Fire Weather Index (FWI) is a numerical rating of potential fire intensity in a standard fuel type. By definition it is dependent on weather only, not on differences in fuels or topography. It is related to the ease of ignition of wild fires. The FWI combines the meteorological parameters upon which forest fires depend and forest fuel moisture content as well as a term to take account of the rate of spread of fire. The numerical value of the index is directly proportional to the potential fire intensity. In practice, various ranges of values are grouped into four fire-danger categories, namely "low", "moderate", "high" and "extreme".

Since the FWI is highly dependent on atmospheric temperature and rainfall it is reasonable to expect that its variations are somehow linked to 500 mb ridging.

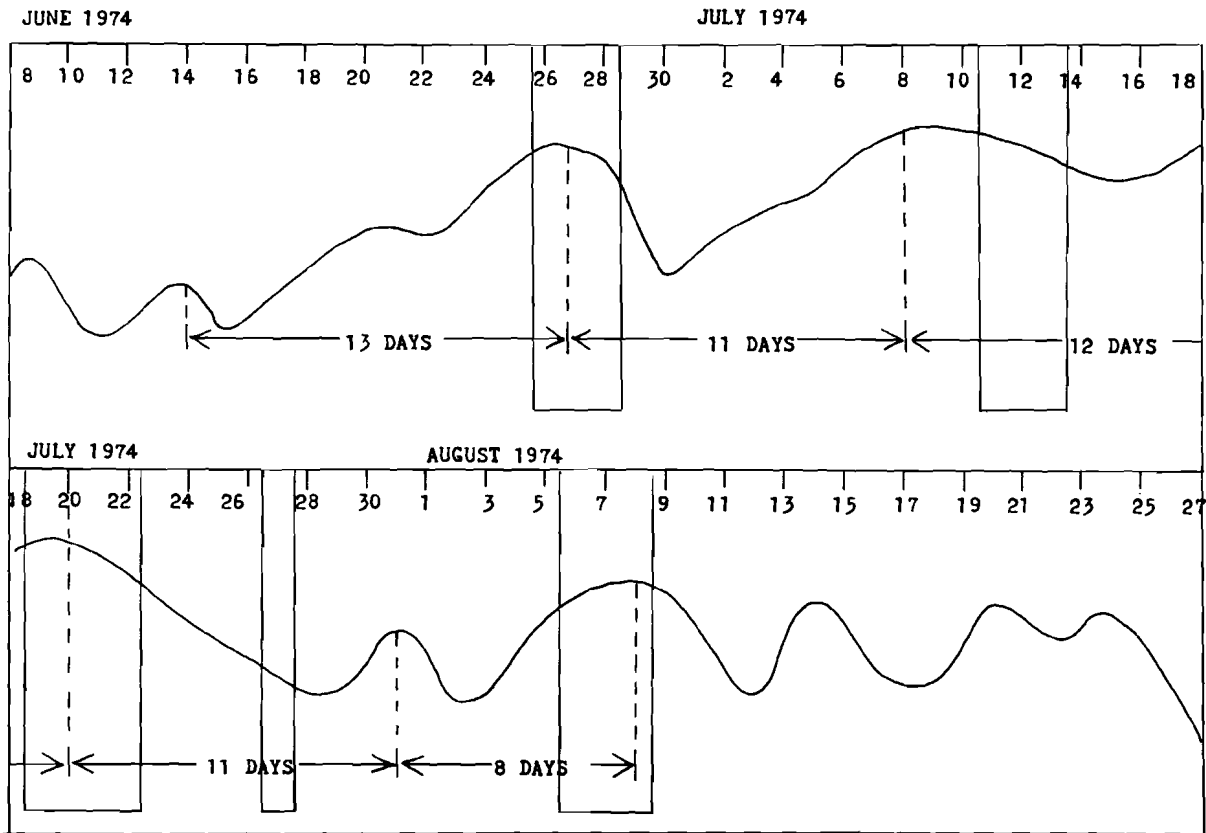


Fig. 4 Relationship between times of peak ridging (curve) and times of maximum fire weather index (rectangles).

In fact it shows an interesting and predictable relationship to the longwave ridge (fig. 4). Values of the FWI generally increase during the building half-cycle and decrease during the half-cycle of collapse. The times that "extreme" values of FWI were measured occur very close to the times of maximum ridging. The only exception is the "extreme" value centred on July 27th, which does not fit well with the ridge of July 31st.

In a practical sense, if the average period and lifetime of the longwave ridge cycle were known on June 14th, it would have been possible to predict the date of occurrence of "extreme" values of FWI in four cases out of five. The error in these cases would vary from 0 to 2 days. In the fifth case (the "extreme" FWI of July 11th), the prediction would have been five days too soon.

The forecast problem, and a very formidable one, is to recognize that a stable longwave ridge cycle has begun. While it is most probable that similar cycles have occurred in previous bad forest fire years, it would be too simplistic to believe that they have the same period and lifetime. Periodicity has been the goal at the end of the rainbow for many a meteorological researcher. Nevertheless, questions immediately arise concerning the feasibility of using such a regular variation as a forecasting device to predict times of high fire weather hazard.

5 Conclusions

- (a) The longwave ridge oscillation of 1974 over northwestern Ontario showed a marked tendency towards a stable repeating periodicity of eleven days.
- (b) The longwave ridge showed remarkable persistence, having a lifetime of 55 days.
- (c) A close relationship existed between the time of occurrence of peaks in the longwave ridge oscillation and the times of high Fire Weather Index.
- (d) A study of previous bad forest fire years is necessary in order to determine whether or not a common, predictable longwave ridge behaviour pattern exists.

References

- ANDERSON, R., 1961: Wave motion in the upper westerlies. *Techniques for High-Level Analysis and Forecasting of Wind and Temperature Fields* WMO No. 106 TP 45, 29-42.
- BJERKNES, J., 1957: Hovmöller diagram analysis Article II, *Large Scale Synoptic Processes*, Final report no. AF 19 (604)-1286, Dept. of Meteorology, UCLA. 27 pp.
- FRANK, V.V., 1965: A method for the determination of relationships between the occurrence and spread of forest fires and the characteristics of the barometric field, *Current Problems in the Protection of Forests from Fires and Forest Fire Fighting*. Proceedings Leningrad Scientific Research Institute of Forestry. LESNAYA promyshlennost. Moskva, 1965, 38-52. (In Russian.)
- HÖVMÖLLER, E., 1949: The trough and ridge diagram. *Tellus*, 1, 62-66.
- NOAR, P.F., 1973: Energy Dispersion and other Features of the Middle Latitude Circulation in the Australian Region. Meteorological Study no. 24, Australian Bureau of Meteorology, Department of Science.
-