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FREQUENCY OF CLOUD-FREE CONDITIONS BELOW VARIOUS FLYING ALTITUDES OVER CANADIAN FORESTS IN SUMMER

by

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1. Introduction

Statistics on the frequency of clouds preventing a clear view of the ground from aircraft flying at various altitudes have not been readily available. Such information would be useful when planning reconnaissance flights in order to estimate the best month, time of day and cruising altitude to fly. It would be useful when assessing whether an aerial survey system found practicable in one part of Canada could be used elsewhere without serious cloud interference. In particular such information has application in assessing the potential usefulness, or planning the operational use of infrared scanning equipment which is now available for forest fire detection and fire-line mapping.

To help fill this information gap cloud data from hourly weather observations of the Atmospheric Environment Service (formerly the Canadian Meteorological Service), have been processed to derive the frequency of hours when clouds did not obscure more than:

(a) one-tenth, or

(b) three-tenths of the sky.

The results are presented in this report, in graphical form, hour by hour through the day, and month by month April through October.

Precise specifications of the procedures used in data selection and analysis and comments on how these affect the results are given in the next two sections.

2. Data Selection and Processing

The bulk of the available weather data for Canada is made up of intensive observations from (relatively few) individual stations; techniques for obtaining area - average values (by radar or satellite), are just beginning to be developed. To represent cloud conditions over Canada's forest land for this report, 18 stations were selected (see Table 1) and 10 years (1957-66) of hourly observations from each were used. Court's* work suggests that a 10-year average is as good as a 30-year average as an indicator of future conditions.

First, the observations were sorted by month. For each hour of the day there were, nominally, 300 or 310 observations (for a 30 or 31 day month). From this number were subtracted the hours when either:

(a) precipitation was occurring, or

(b) more than one-tenth of the sky was covered with cloud whose base was below aircraft cruising level.

The remainder, divided by ten, was taken as the number of days for that month which would be suitable for reconnaissance at that hour of the day. This calculation was performed for cruising altitudes

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* Court, Arnold. 1968. Climatic Normals are Inefficient. Paper presented at American Meteorological Society Conference & Workshop on Applied Climatology in Asheville, October 31, 1968.

of 1,000, 2,000, 4,000, 8,000, and 12,000 ft above the elevation of the weather observing station.

Then the calculations were repeated with three-tenths in place of one-tenth as the maximum acceptable cloud cover below aircraft cruising altitude.

As is likely in any long series of observations, there were a few gaps in the 10-year record. The largest number of observations missing from any one total was 8 observations out of the nominal 300; this was for 15:00 hours in April at Killaloe. There were also six observations missing for each of 09:00 and 10:00 hours in May at Killaloe. The largest number missing from an individual total at any of the other stations was four. These gaps would make less than one days' difference in the results plotted in the graphs, so they have been ignored.

Information relevant to flight levels higher than 12,000 ft was made available by the Photogrammetry Division, Surveys and Mapping Branch, Department of Energy, Mines and Resources from a tabulation of photo weather it had commissioned, based on the same 10 years of Atmospheric Environment Service weather observations. This tabulation showed the number of days per month for each hour when:

(a) horizontal visibility was 10 miles or more, and

(b) there was less than one-tenth of the sky covered with cloud (except up to two-tenths of thin Cirrus was accepted).

To show these data in the same graphs as the other data, they have been given a nominal cruising altitude designation of 40,000 ft.

3. Looking Up Versus Down

Observations of cloud amount made by an observer looking up at the sky are used here to indicate what can be seen by an observer up in the air looking down at the earth. The ground-based observer has considered the whole sky, from horizon to horizon. If the air observer is similarly interested in the full 180° below him, then the ground-based observations should be precisely related to his need. If, however, the air observer is only interested in, say, $\pm 60^{\circ}$ from the vertical, then he should experience slightly less cloud obstruction on the average than the ground observer reports; the amount less, will depend on the vertical thickness of the clouds in relation to the spacing between them.

4. Summary of Results

Gander had the fewest suitable days and Penticton the most. But, apart from these the data show surprisingly little variation across Canada. There is a slight increase in suitable days from eastern to western Canada. Killaloe data is exceptional in ranking with Alberta and British Columbia rather than the east. This may be due to dissolution of clouds through subsidence (whenever the wind is other than easterly), since Killaloe is almost surrounded by higher ground; one hopes it is not due to less assiduous observing.

Looking at the diurnal pattern, a large dip reaching its lowest point in the early afternoon is obvious in the 4,000 and 8,000 ft lines at nearly all stations. This is clearly due to convective type (Cumulus) cloud. The convection starts in the morning. If the relative humidity near the ground is high enough, cloud will form below 1,000 or 2,000 ft and show as dips in those lines (as well as the higher lines) of the graph. Other days when the surface humidity is not so high, cloud does not form until convection reaches above 2,000 ft later in the day, causing a dip in the 4,000 ft and higher lines. Fredericton lines for June, July and August clearly show the minimum point at a later hour the higher the altitude (from 2,000 to 8,000 ft). The Greenwood charts (June, July, and August) suggest that whenever convective cloud forms there, its base is below 2,000 ft initially but as the surface humidity decreases during the morning (primarily due to rising temperature but assisted by mixing of the surface air with drier air from aloft) the base rises above 2,000 ft. Hence, the 4,000 ft line remains low while the 2,000 ft line rises during the morning.

Since convection giving a cloud base above 2,000 ft almost guarantees freedom from any kind of cloud below 2,000 ft, the diurnal maximum for 2,000 ft occurs at about the same hour as the diurnal minimum for 8,000 ft (particularly at eastern stations).

At Penticton the humidity is apparently so low that convective cloud hardly ever forms below 4,000 ft.

The seasonal variation in intensity of convection can also be seen. Convective cloud increases in frequency from May to June, generally, then begins to decrease after July. By October the convective dip is much weaker; at the higher latitude stations it has almost disappeared.

Besides the major dip (due to convection) many of the stations show a minor dip at about 04:00 in the morning in the 4,000 ft and higher lines. On closer inspection this dip is seen to migrate from 04:00 to 06:00 between July and October, which indicates it is a dawn-related phenomenon. Part of the reason for the dip may be that clouds are detected in daylight which were not noticed at night. But, to the extent that the lines rise again after the dip, the phenomenon must be real. There are meteorological reasons why the change-over from night to day should favour temporary cloud formation.

5. Conclusions

For stations and months where there is an appreciable diurnal variation, maximum frequency of cloud-free conditions below aircraft altitude is usually found:

for 1,000 ft, in the afternoon;

for 2,000 ft, in late afternoon;

for 4,000 ft and up, at night.

If reconnaissance flights at altitudes above 2,000 ft are to be made during daylight hours, late evening and early morning are about equally cloud free, but note differences at individual stations.

6. Acknowledgements

All the machine processing for these tabulations was done under contract by the Climatology Division of the Atmospheric Environment

Service. Appreciation is expressed to Mr. B.S.V. Cudbird for discussions which facilitated this project, to Mr. J. Fleming for making the photo weather tabulation available, to Graphics Services, C.F.S. for preparing the charts (including the plotting of 18,144 points) and to Mr. R.E. Donnelly for checking them.

7. Sequel

The need for forest fire detection flights varies with the weather; in general it increases with the Fire Weather Index. Frequency of cloud-free conditions might also be expected to vary with the Fire Weather Index. A sequel study, which is nearing completion, has found that there is a positive correlation. A report will be published soon.

Table 1

Stations for which cloud-free frequencies are shown.

NAME	LATITUDE	LONGITUDE	ELEVATION (feet above sea level)
Gander, Nfld.	48°57'	54°34'	482
Greenwood, N.S.	44°59'	64°55'	82
Fredericton, N.B.	45°52'	66°32'	72
Seven Islands, Que.	50°13'	66°16'	190
Bagotville, Que.	48°20'	71°00'	536
Val d'Or, Que.	48°03'	77°47'	1,108
Killaloe, Ont.	45°34'	77°25'	571
White River, Ont.	48°36'	85°17'	1,243
Sioux Lookout, Ont.	50°07'	91°54'	1,227
The Pas, Man.	53°58'	101°06'	894
Prince Albert, Sask.	53°13'	105°41'	1,414
Fort Smith, N.W.T.	60°01'	111°58'	665
McMurray, Alta.	56°39'	111°13'	1,216
Whitecourt, Alta.	54°08'	115°40'	2,430
Fort Nelson, B.C.	58°50'	122°35'	1,230
Prince George, B.C.	53°53'	122°41'	2,218
Penticton, B.C.	49°28'	119°36'	1,121
Comox, B.C.	49°43'	124°54'	75

Graphs for the main fire season May through October are grouped together on facing pages: a pair of pages for each station. Graphs for April are shown separately, at the back, grouped 3 stations to a page. Stations are shown in geographical order, east to west, across Canada as in Table 1.

Graphs show

number of days per month

(for each hour of the day)

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below specified height

(in feet above ground)

covers 1/10 or less

of the sky.

Digits above graph points

for even numbered hours

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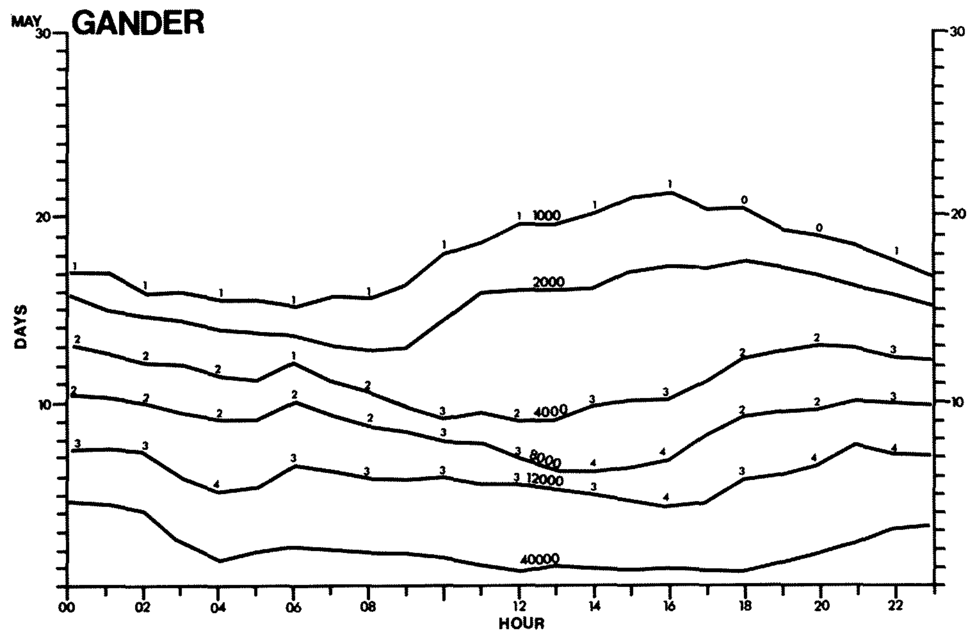
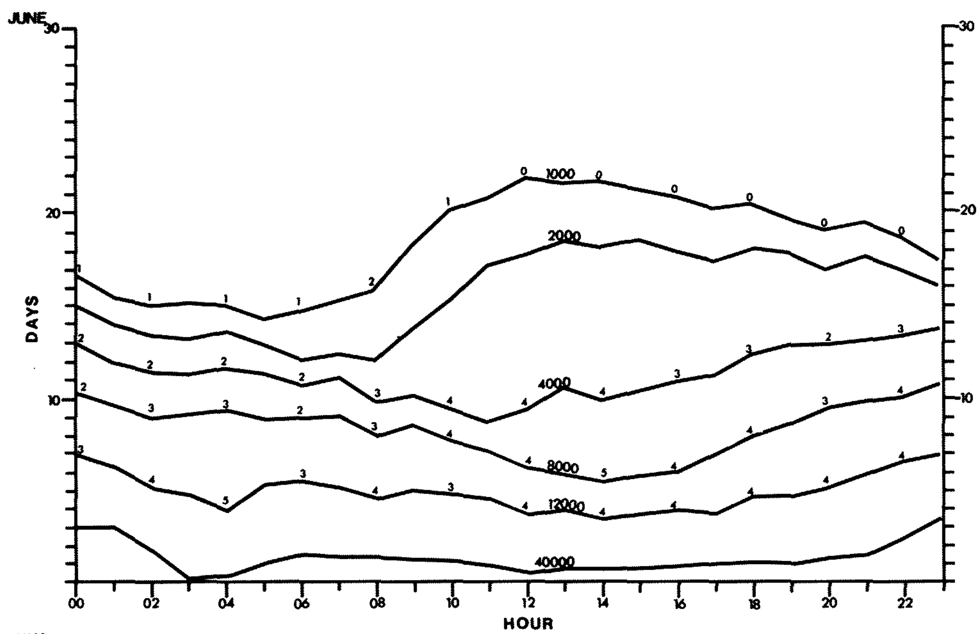
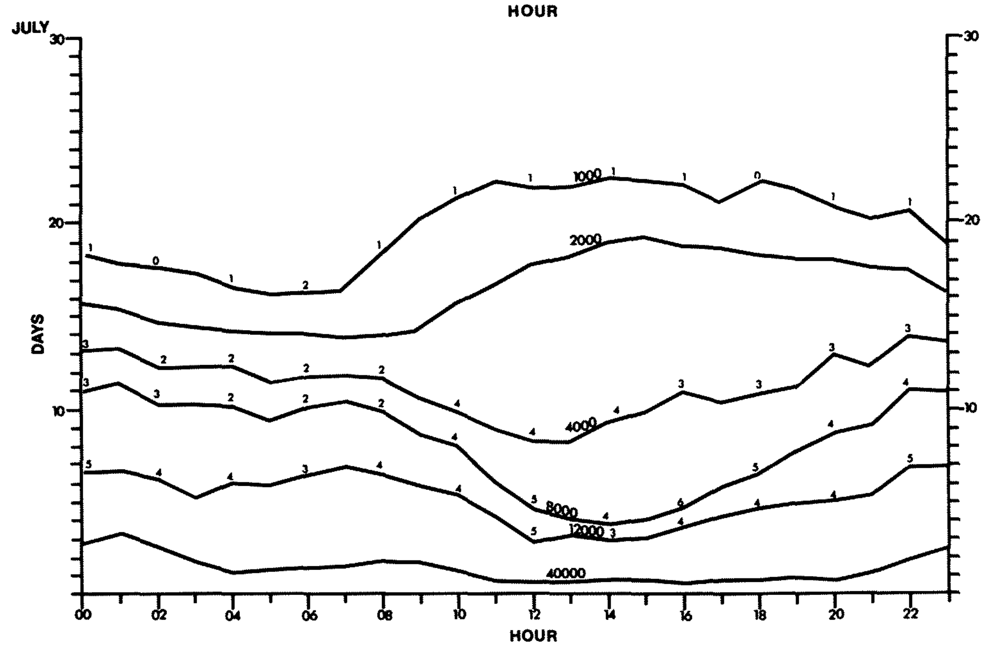
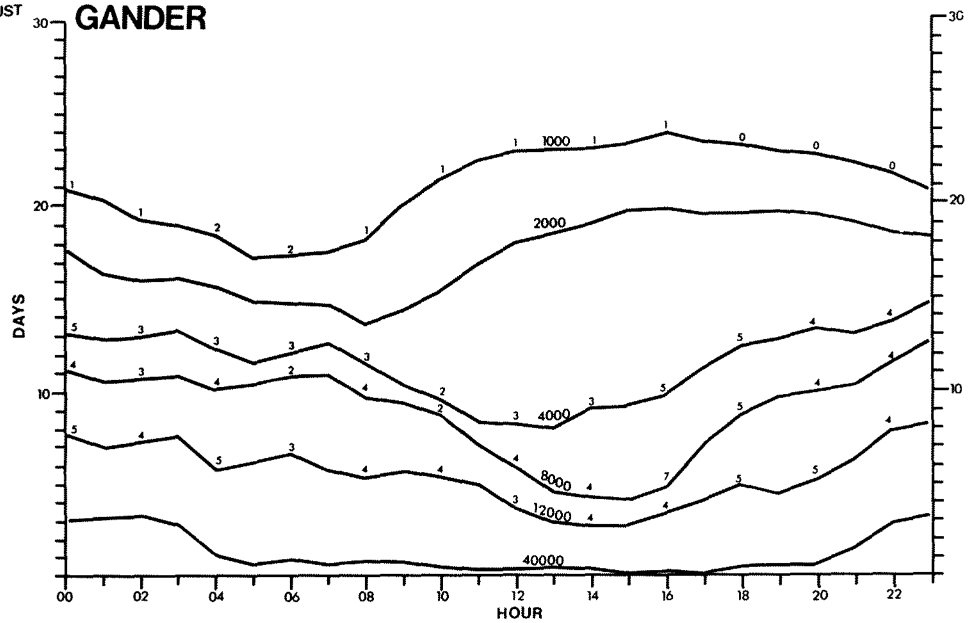






GANDER

AUGUST



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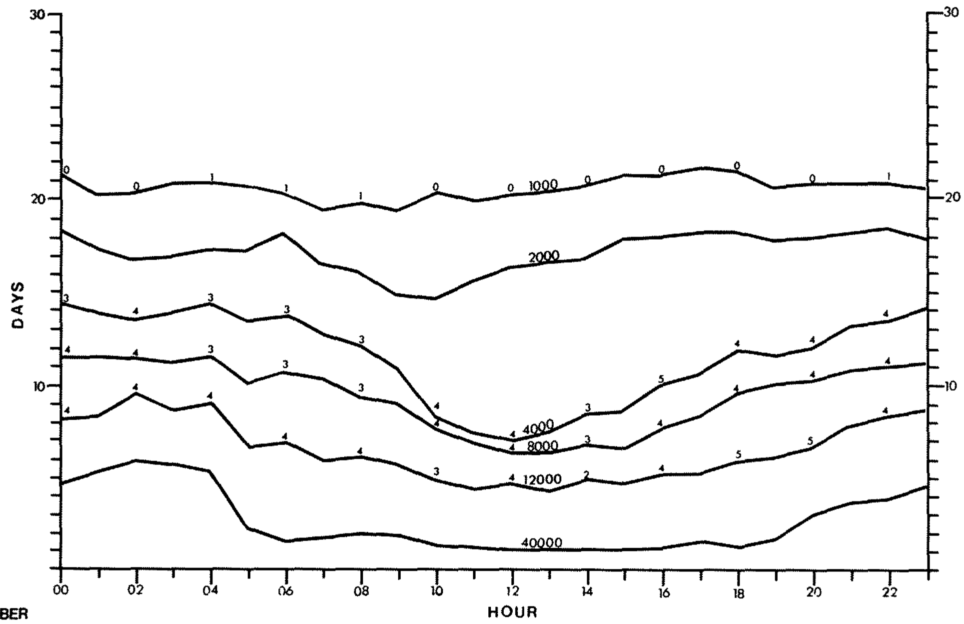
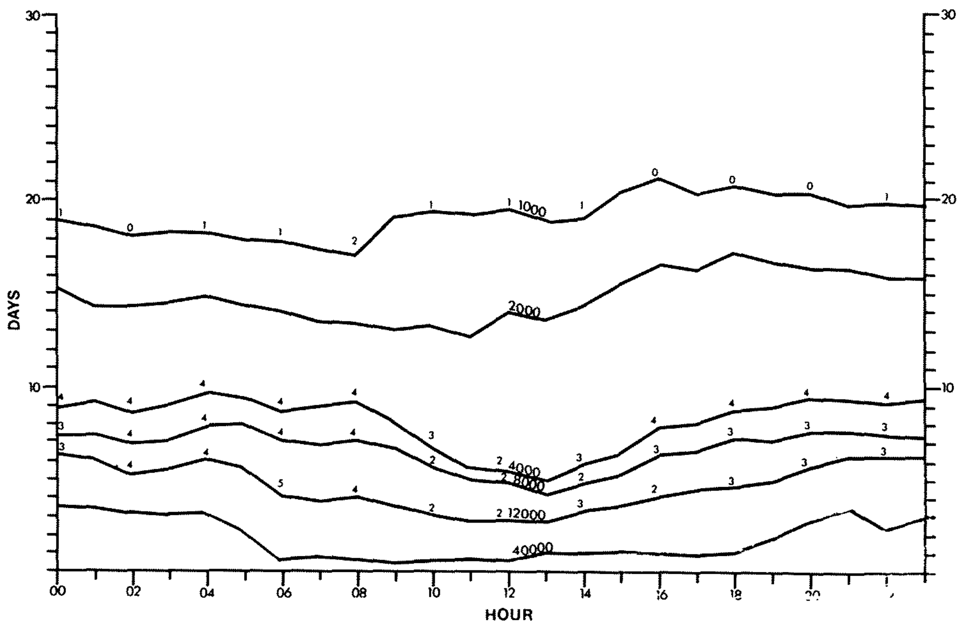


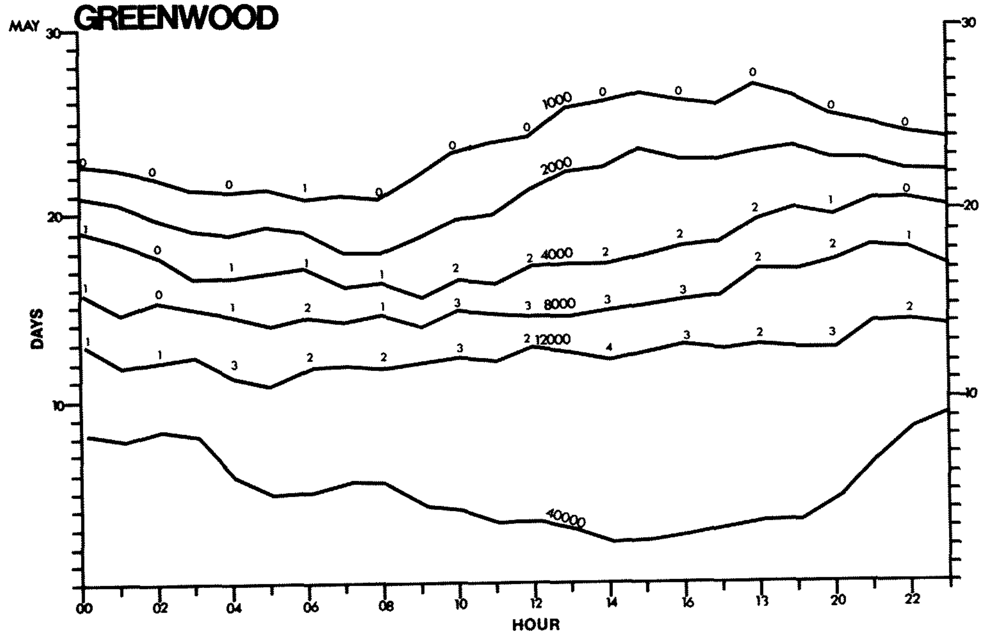
OCTOBER

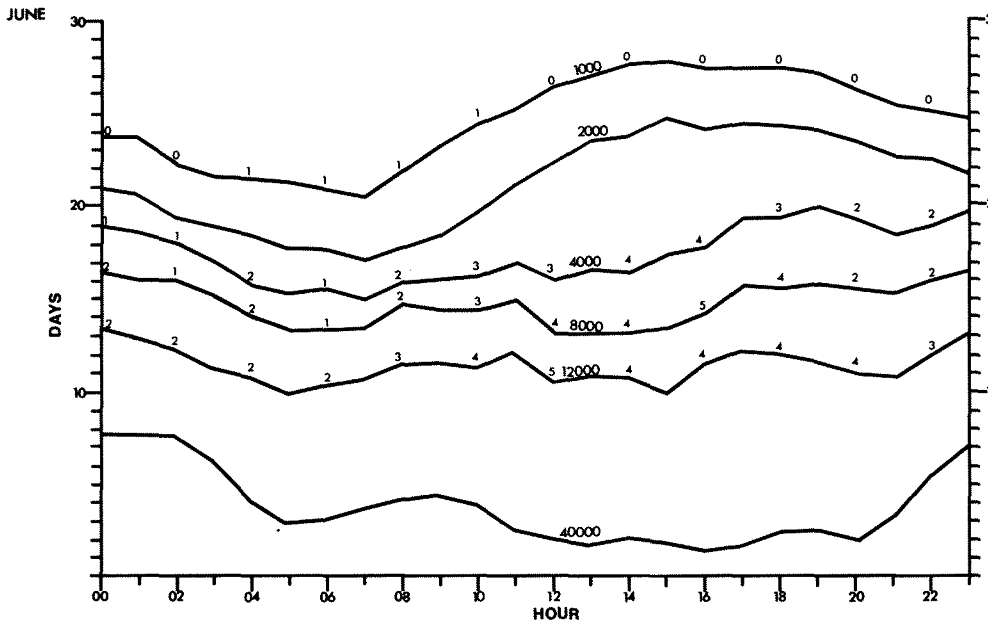


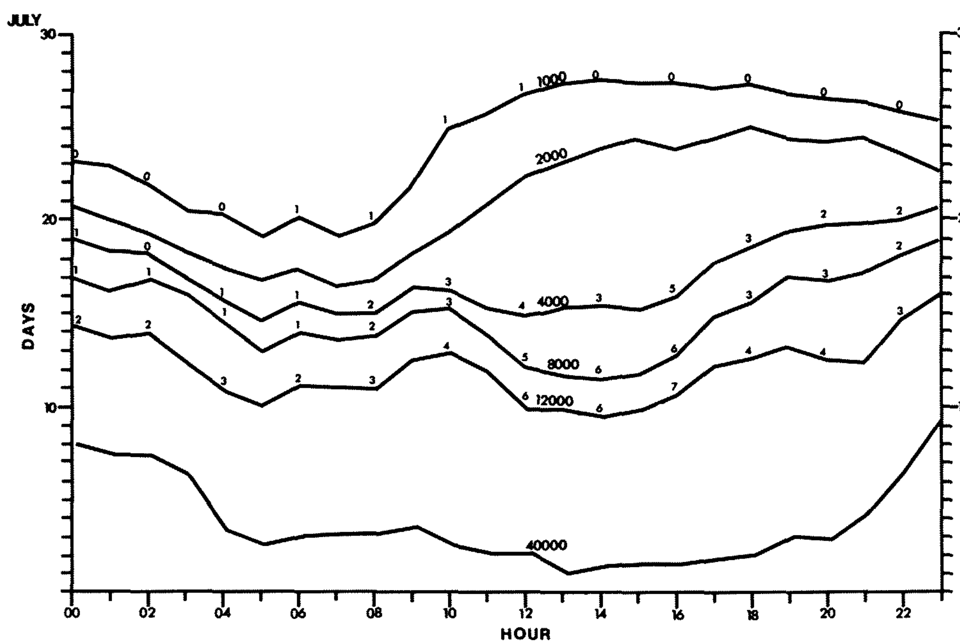
Graphs show number of days per month (for each hour of the day) when cloud amount below specified height (in feet above ground) covers 1/10 or less of the sky. Digits above graph points for even numbered hours show number of days cloud below specified height covers 2/10 or 3/10 of the sky.

GREENWOOD

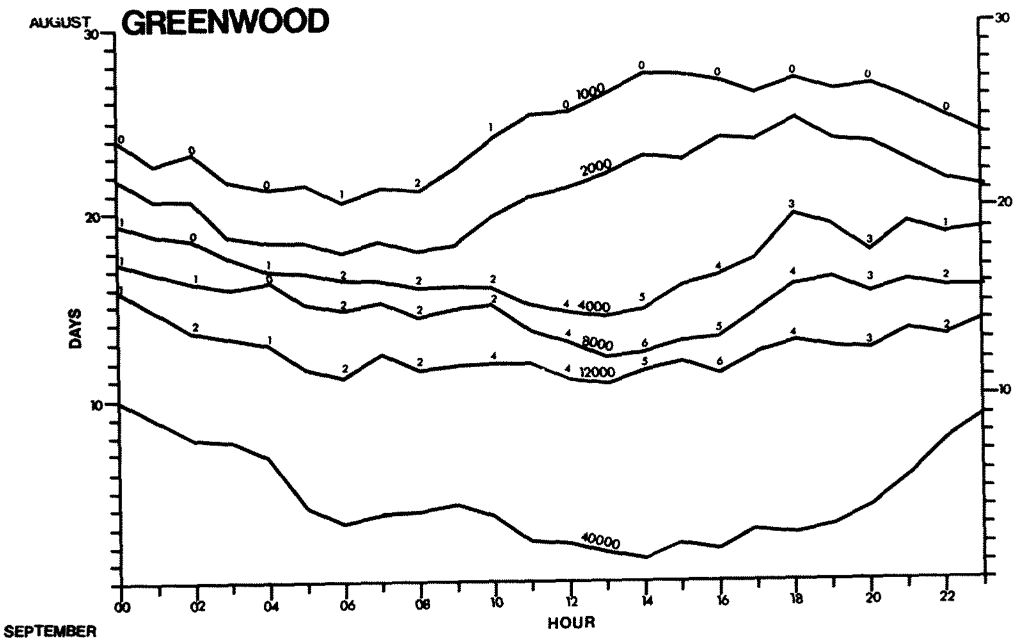
Graphs show number of days per month (for each hour of the day) when cloud amount below specified height (in feet above ground) covers 1/10 or less of the sky. Digits above graph points for even numbered hours show number of days cloud below specified height covers 2/10 or 3/10 of the sky.

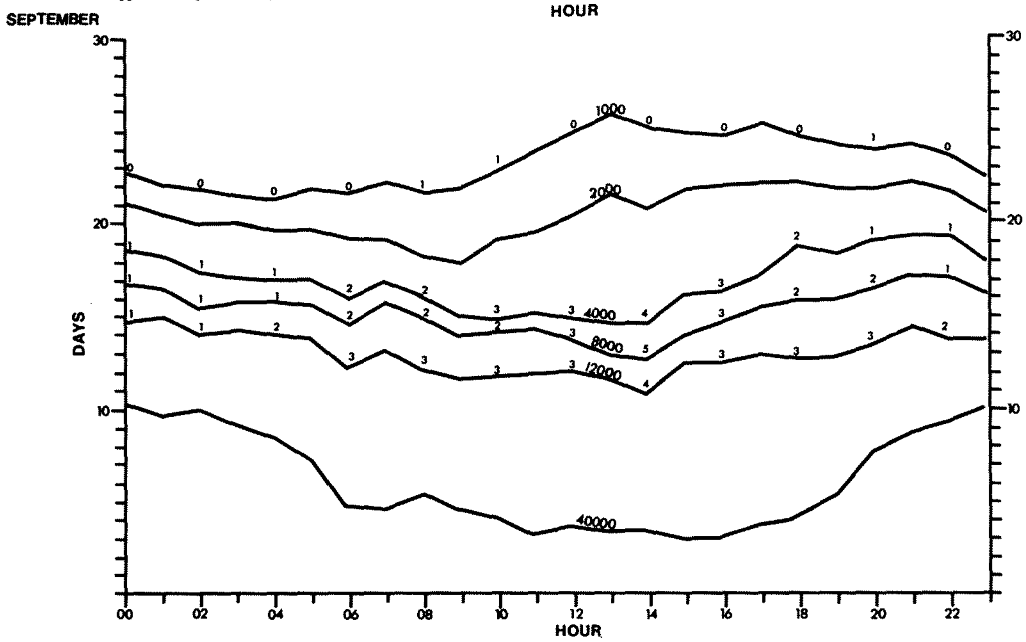


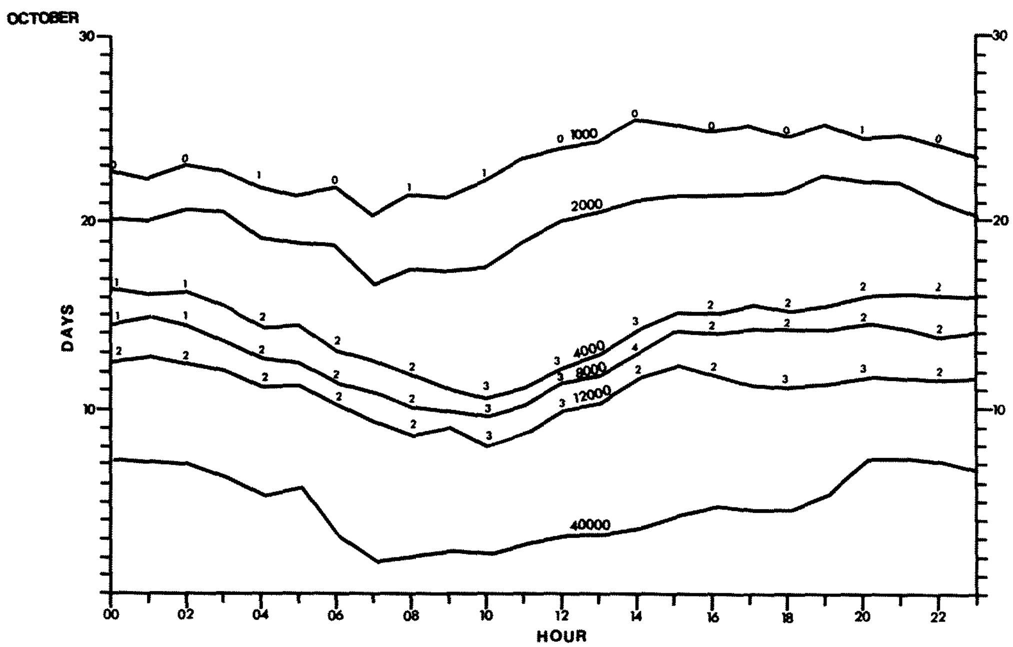




GREENWOOD







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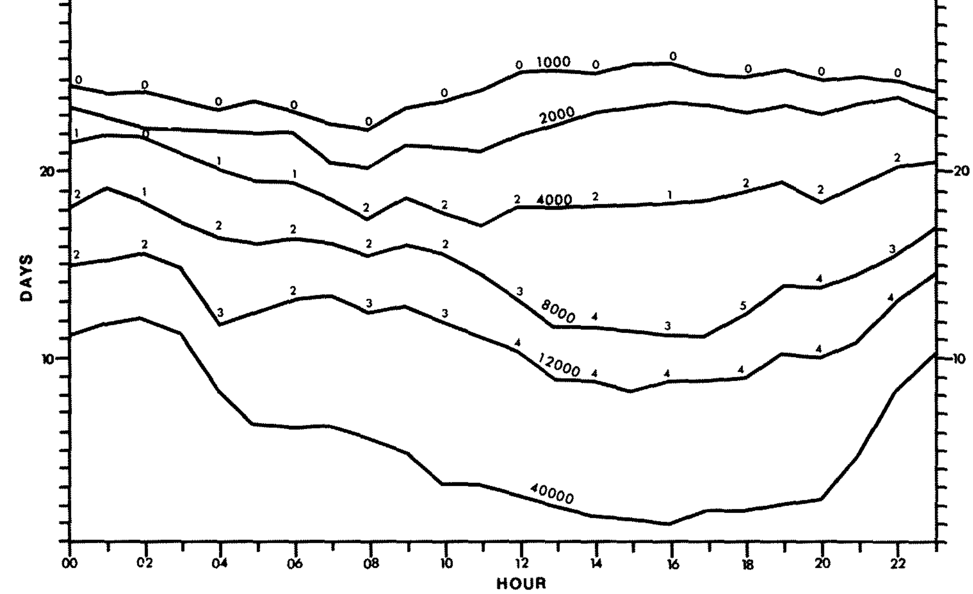
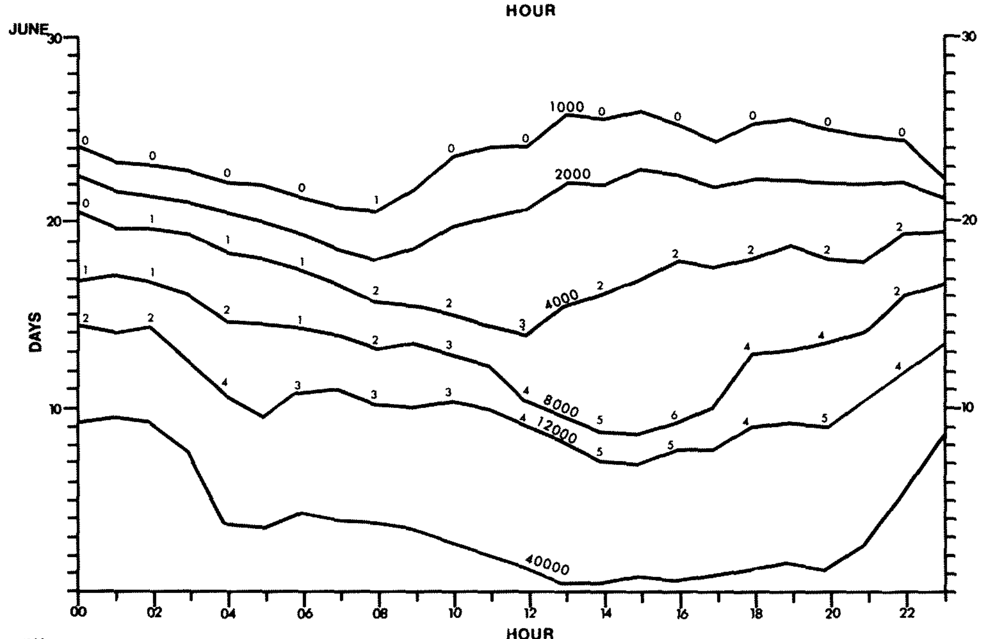
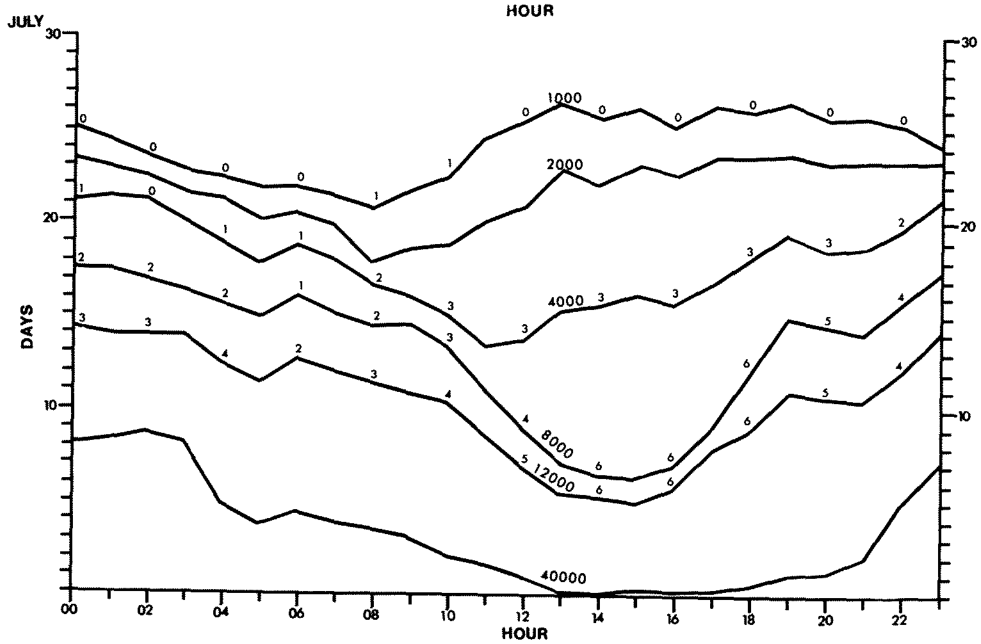
FREDERICTON







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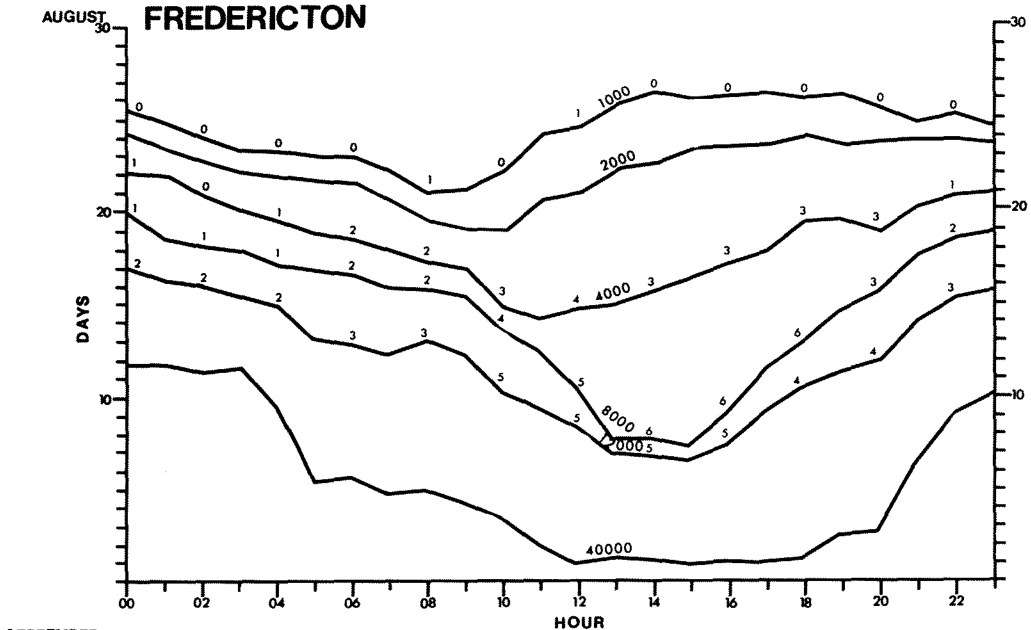

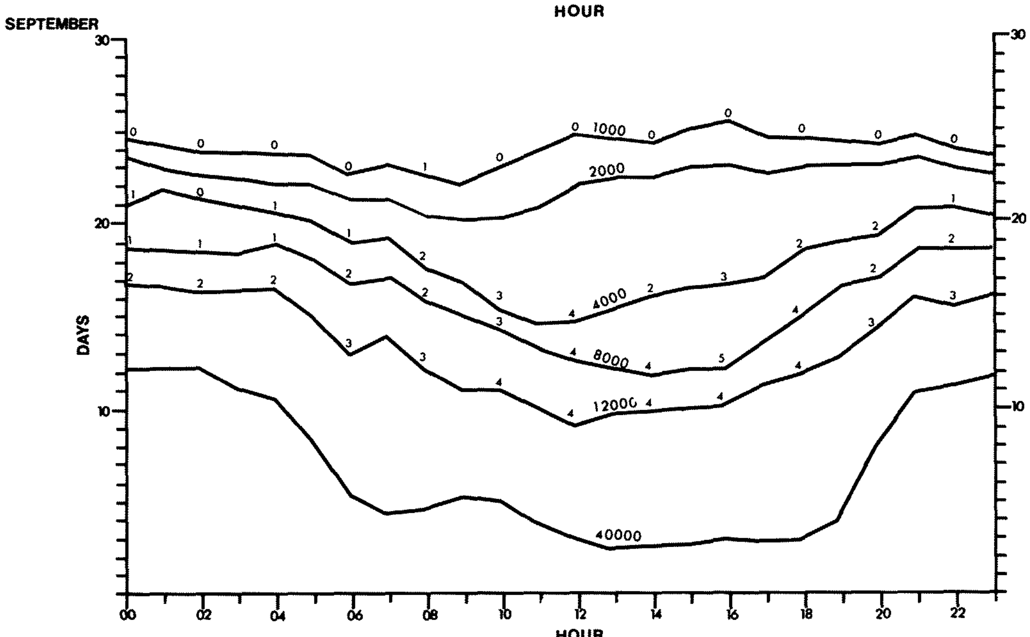

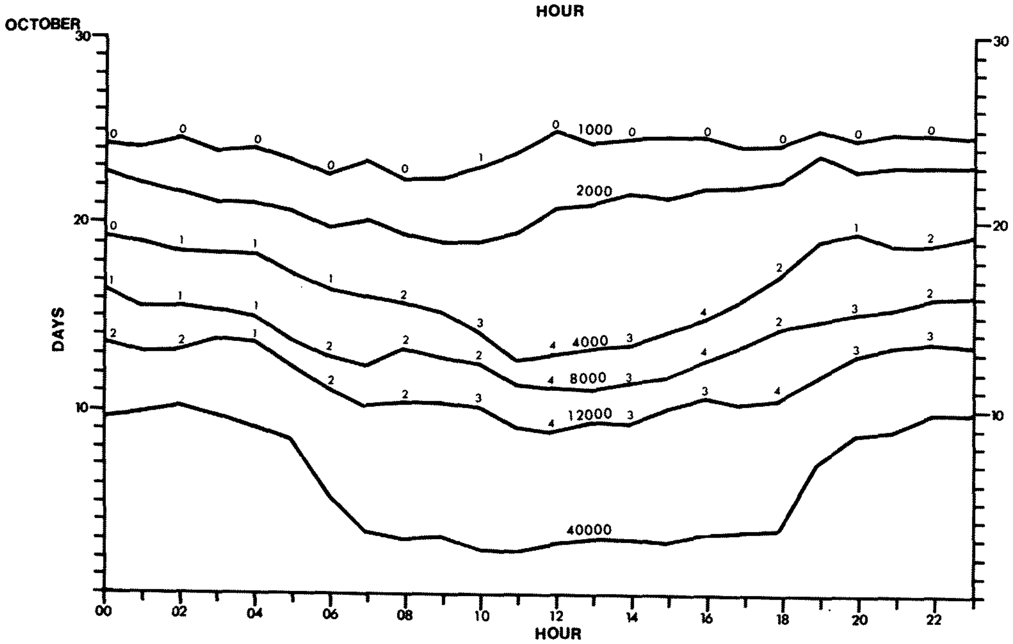

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SEVEN ISLANDS

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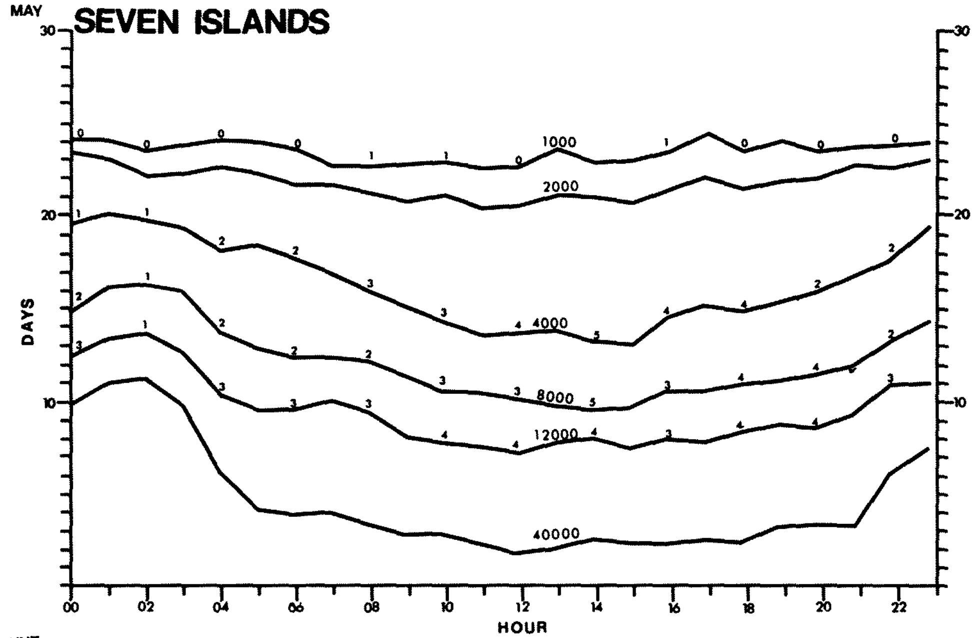
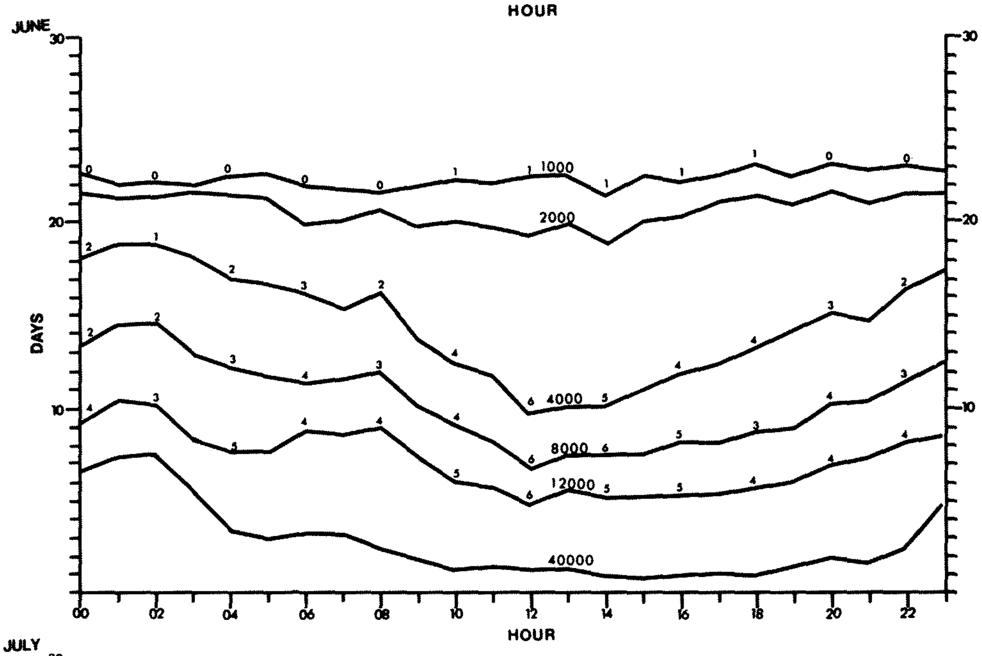
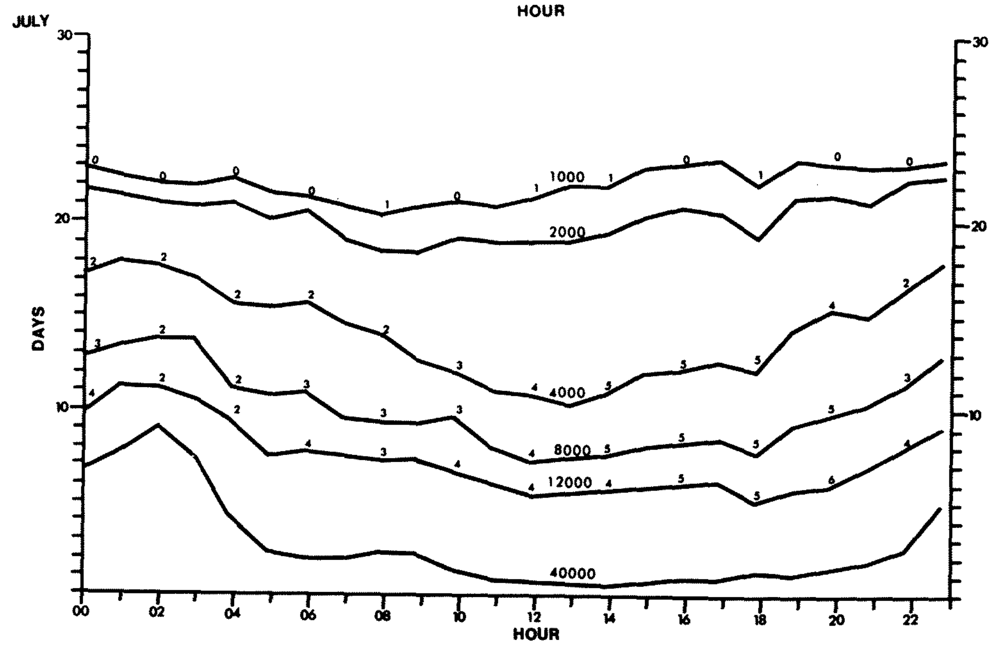
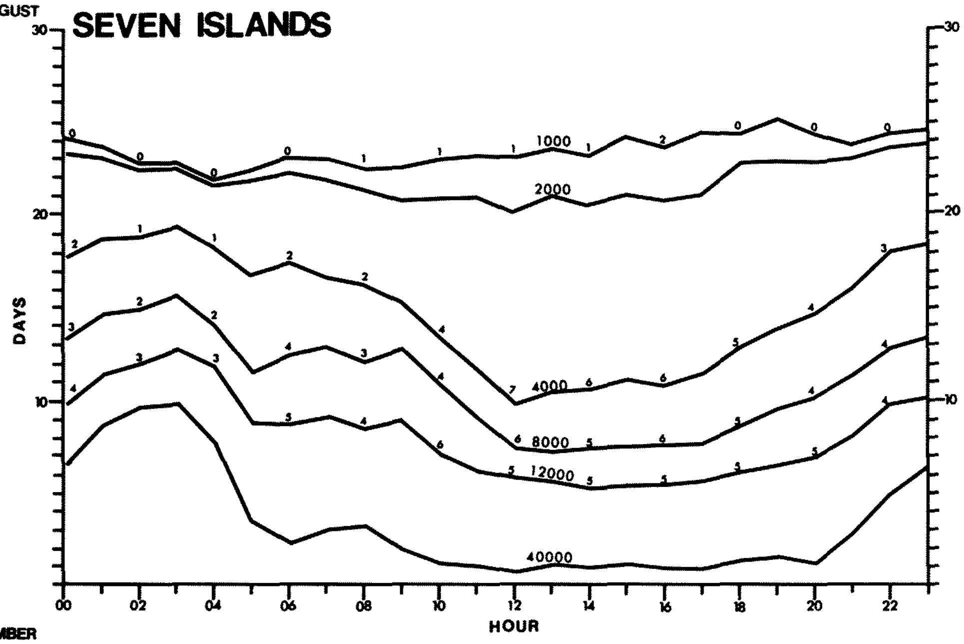






AUGUST

SEVEN ISLANDS



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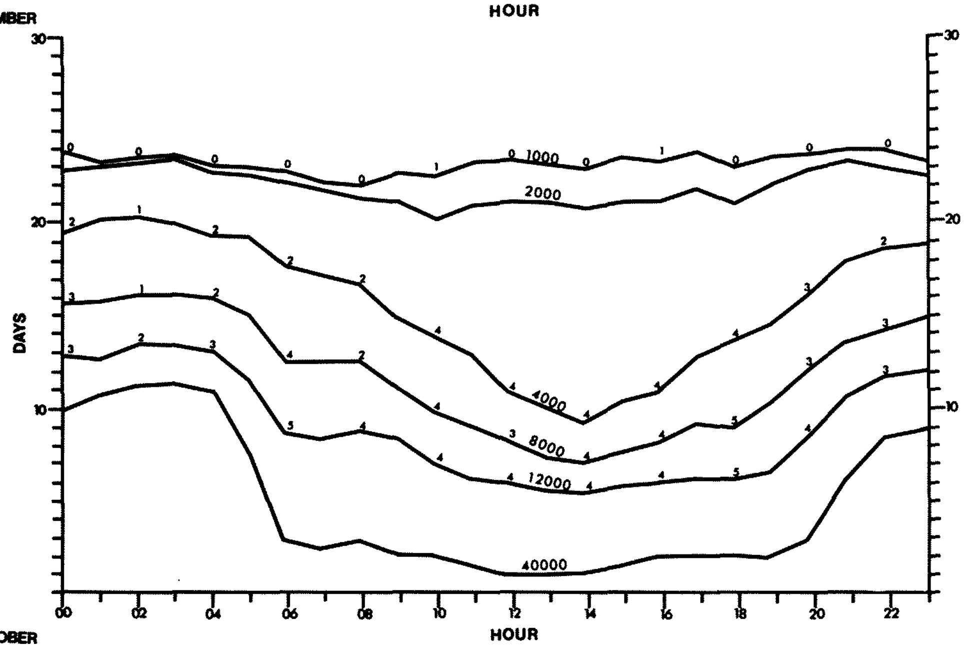
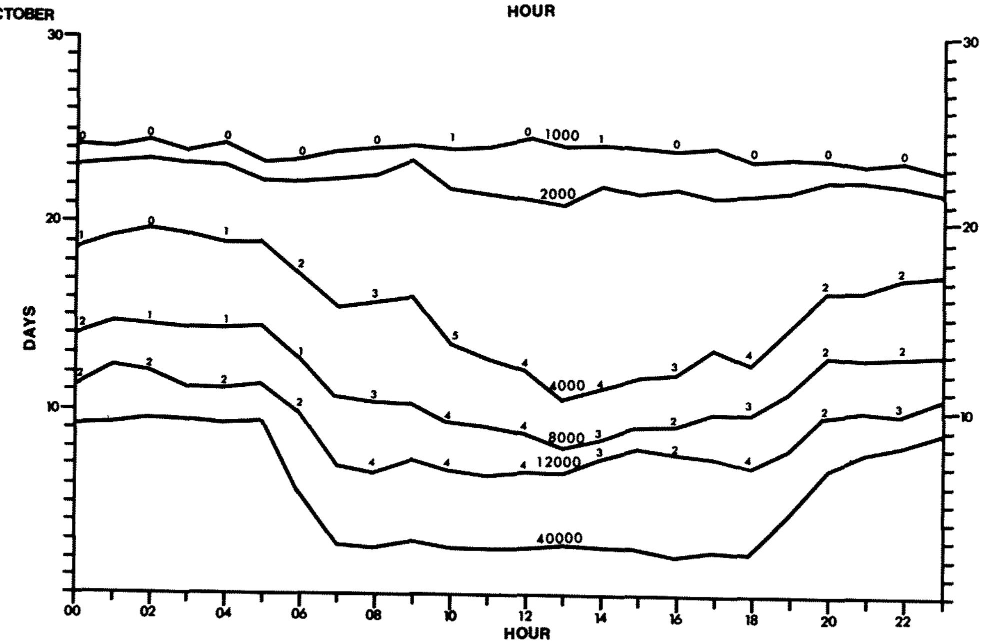


OCTOBER



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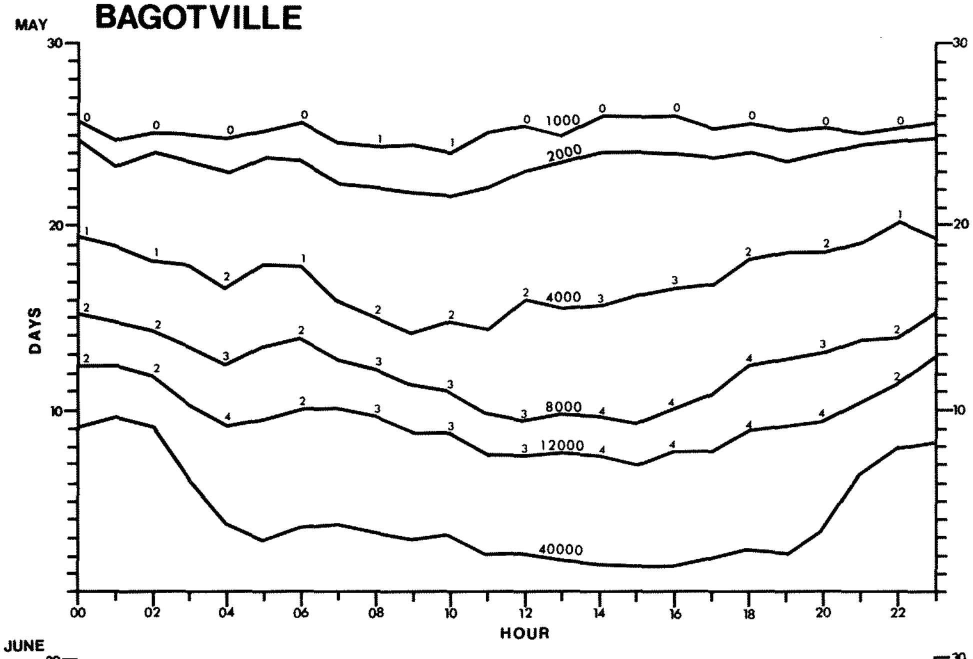
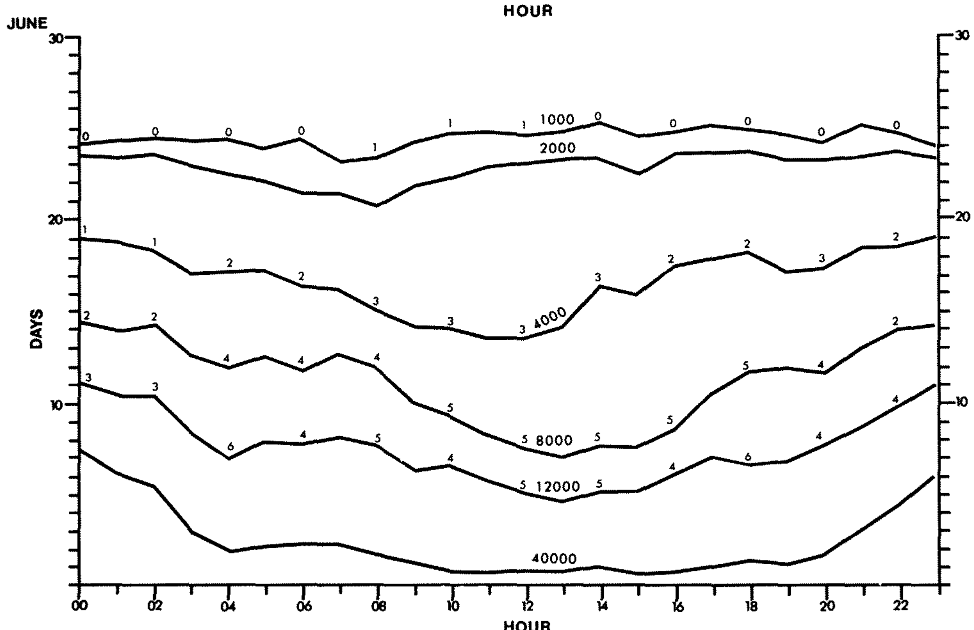
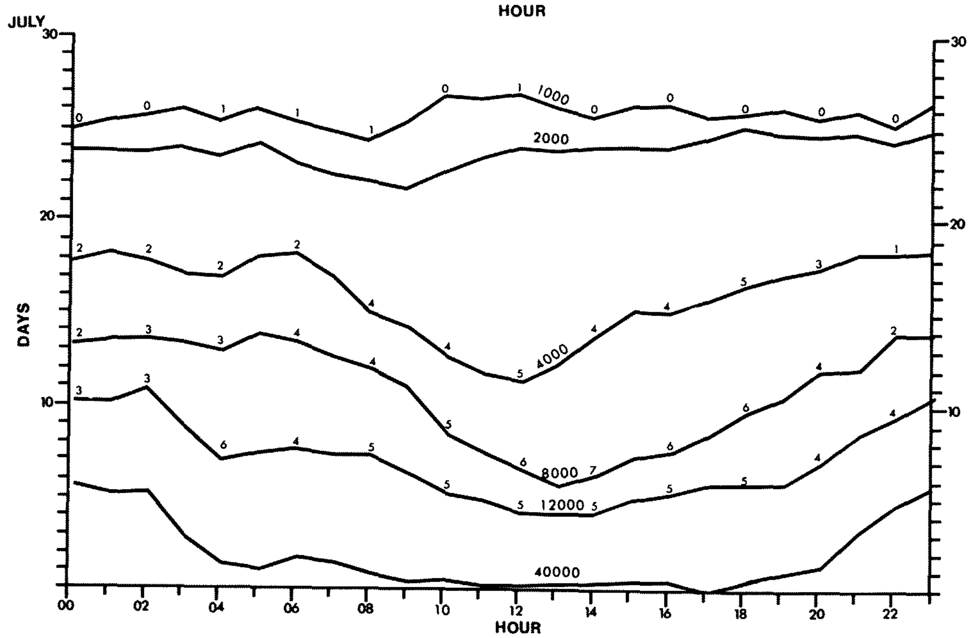
BAGOTVILLE







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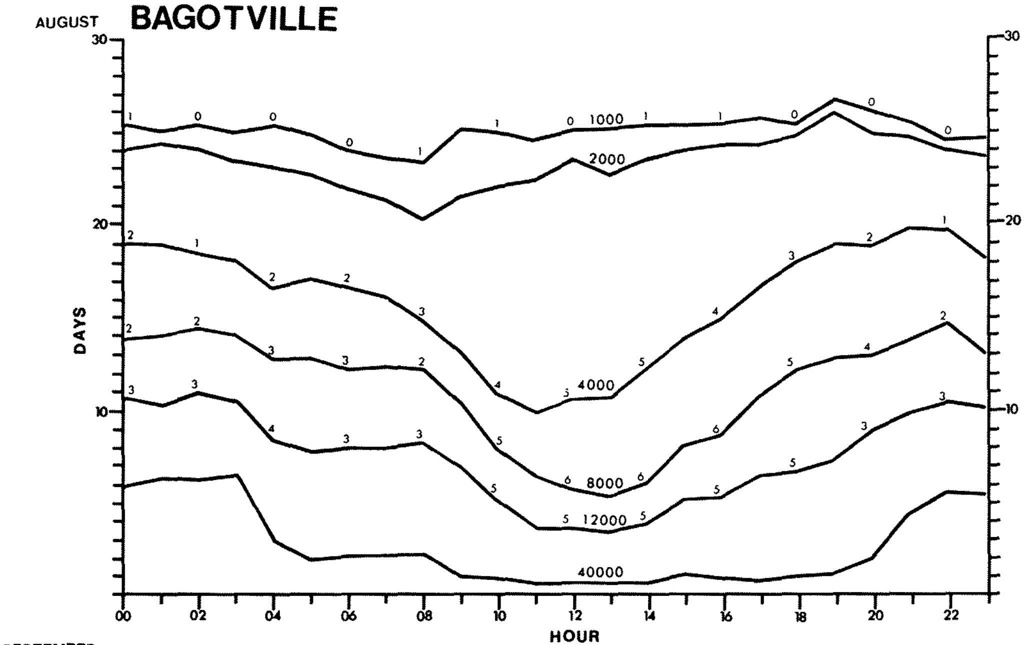

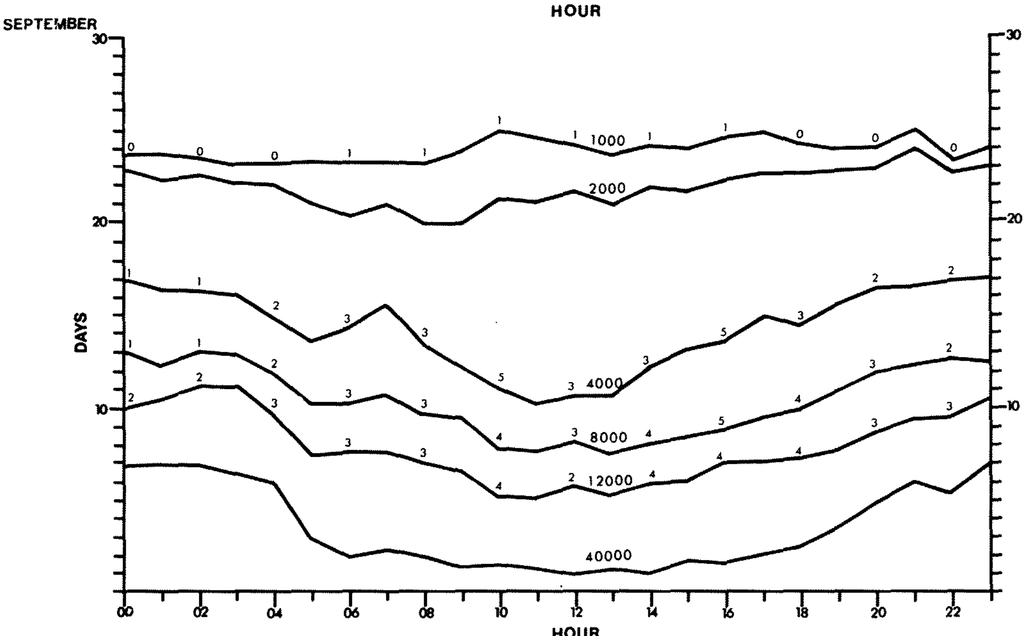

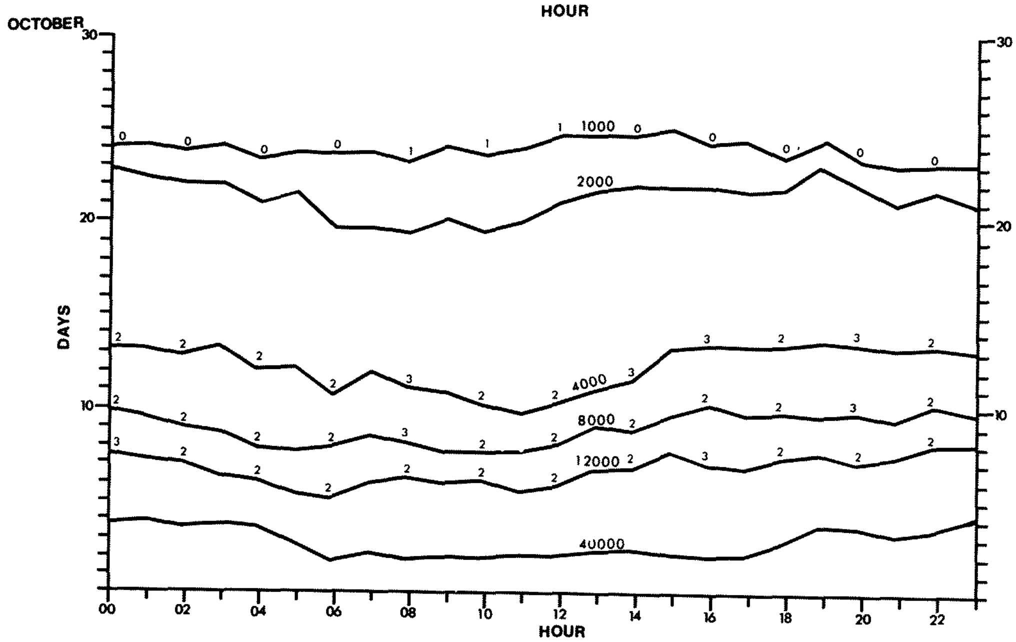

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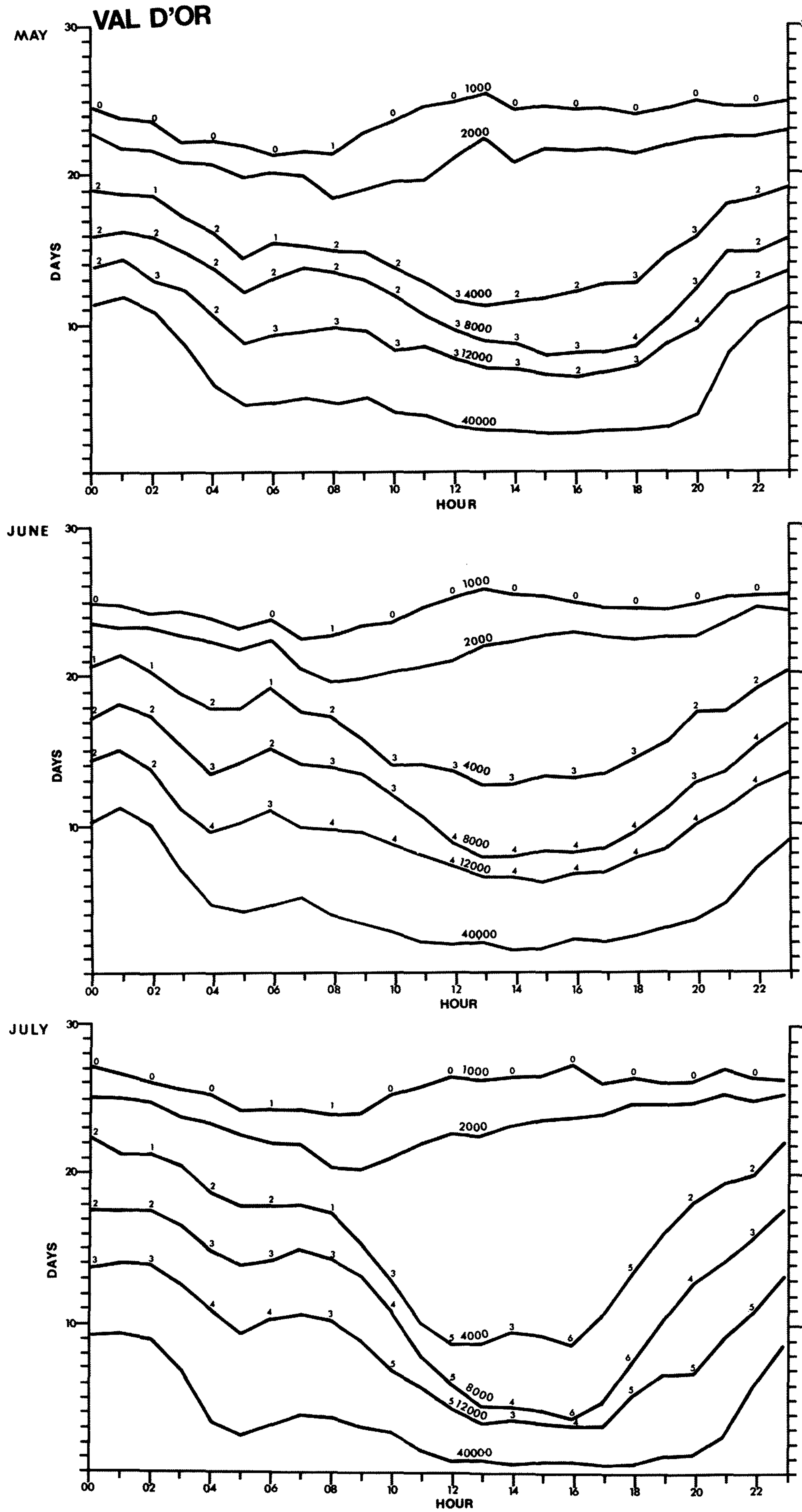

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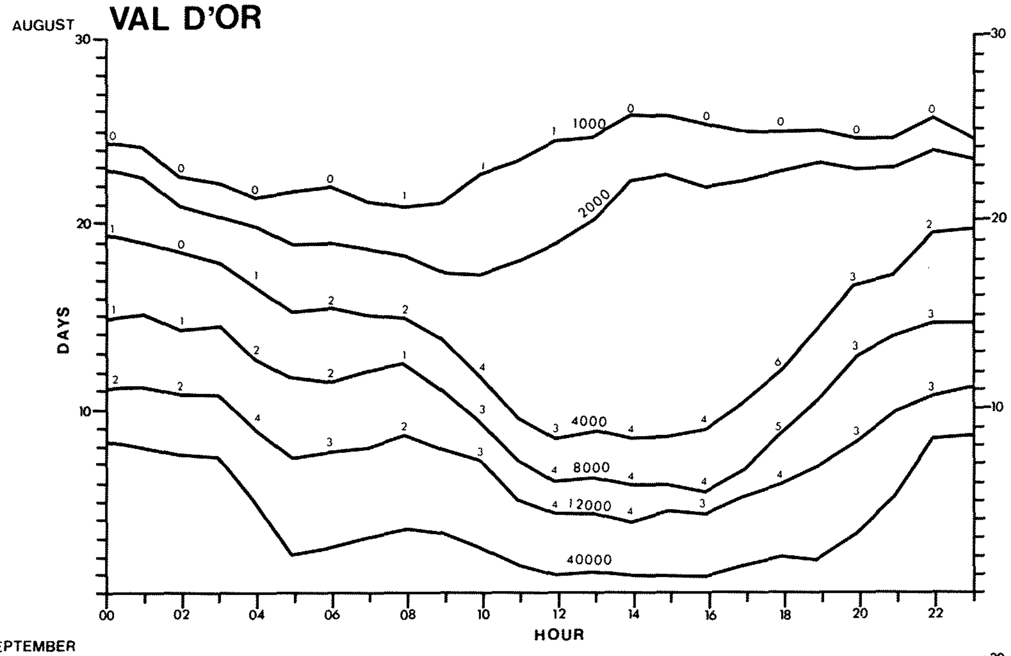

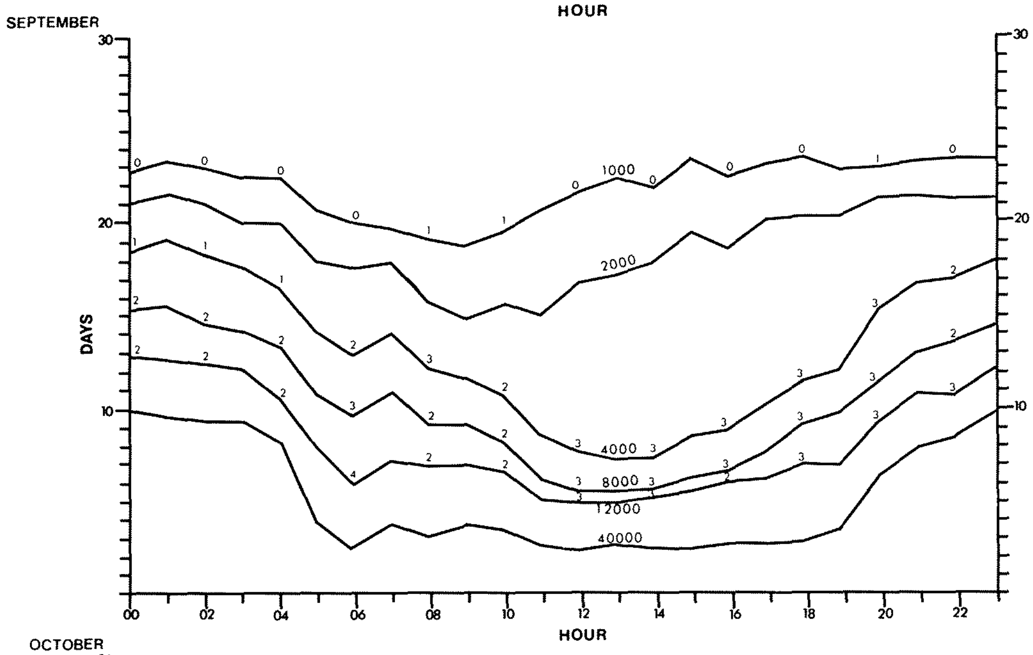

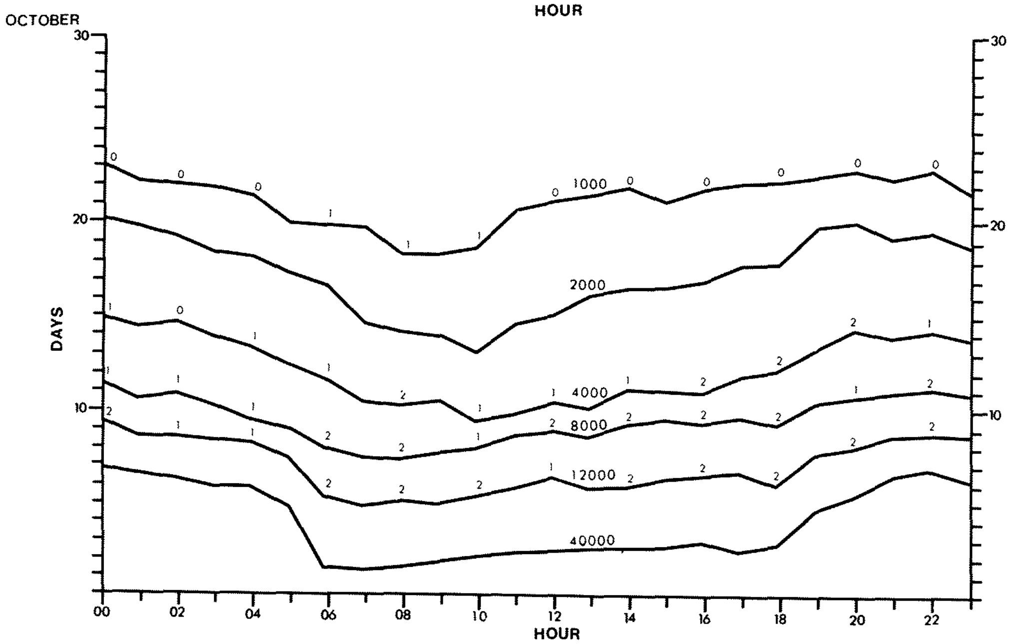

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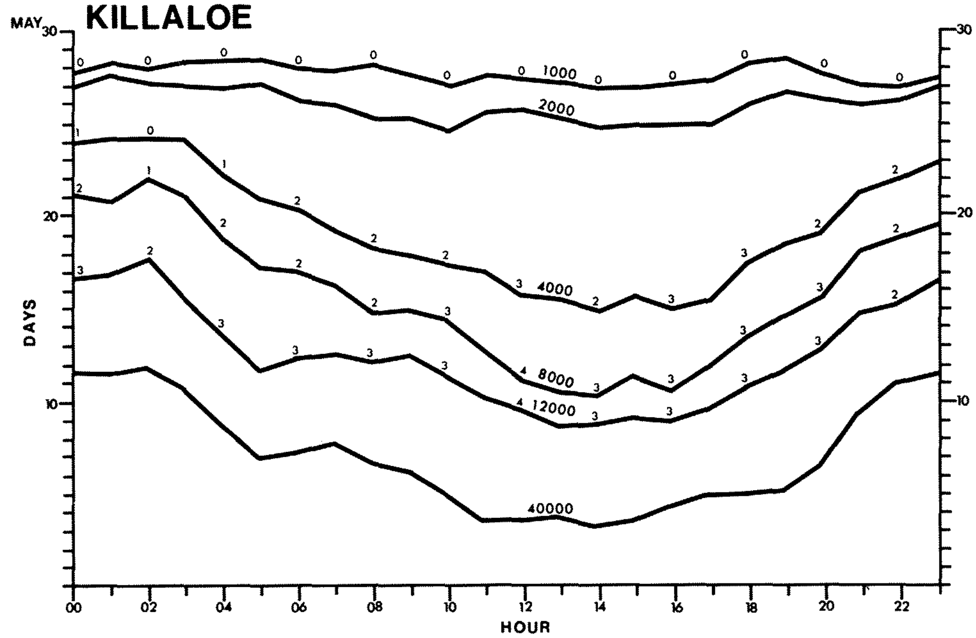
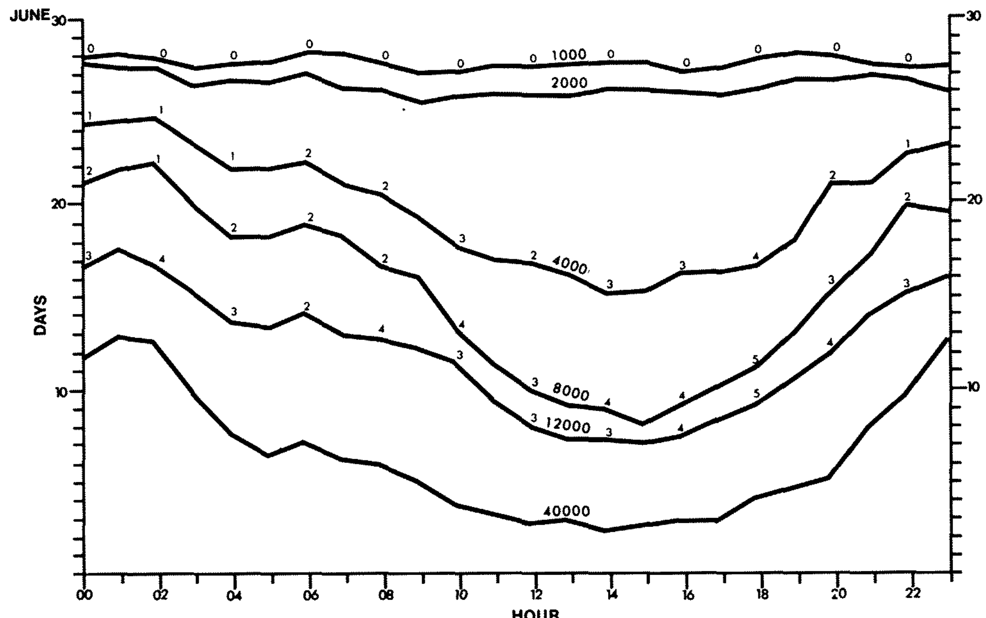
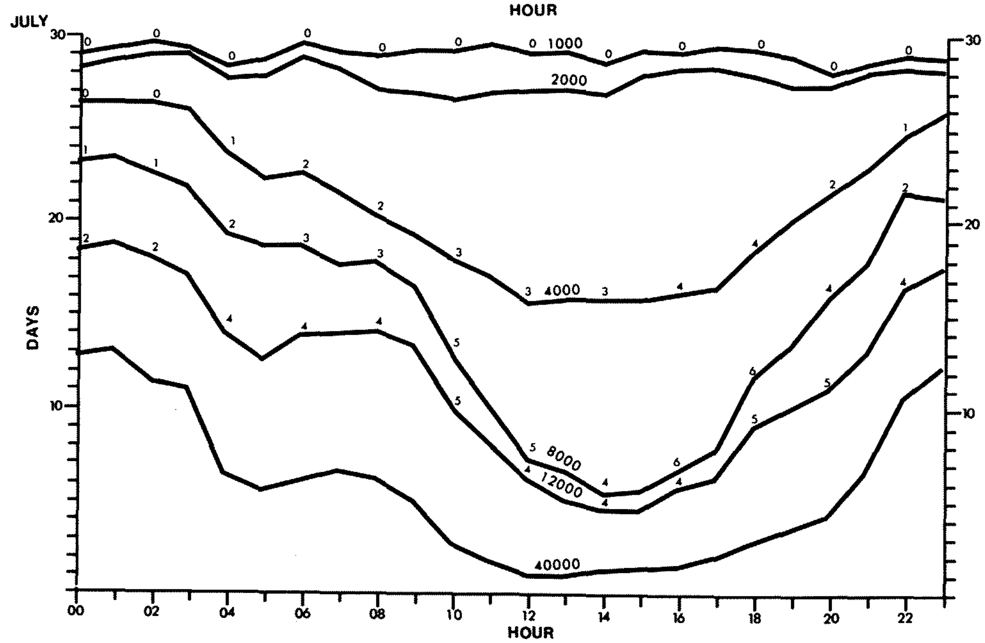
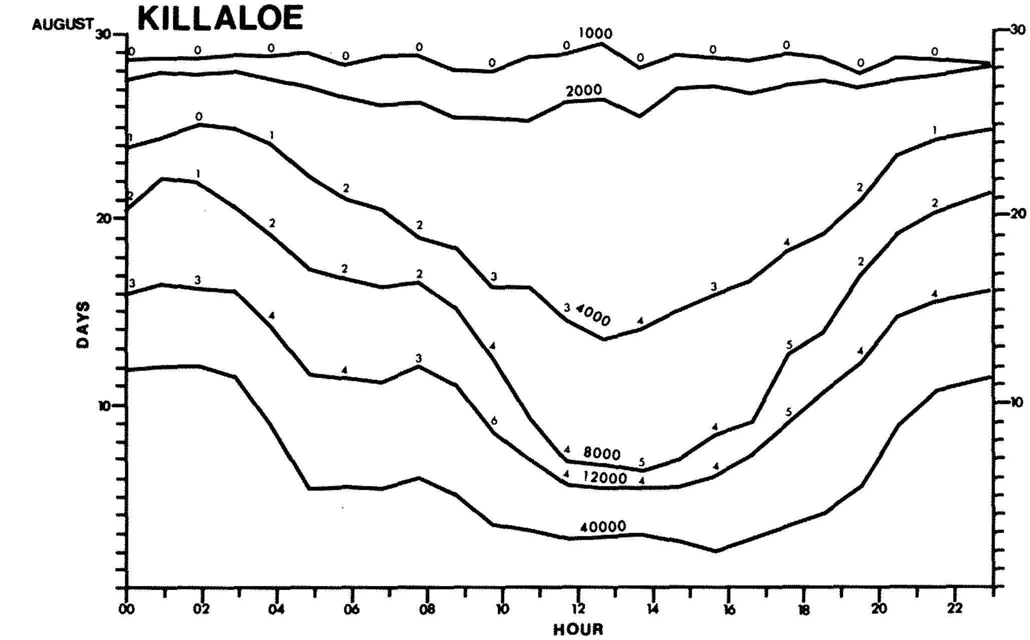
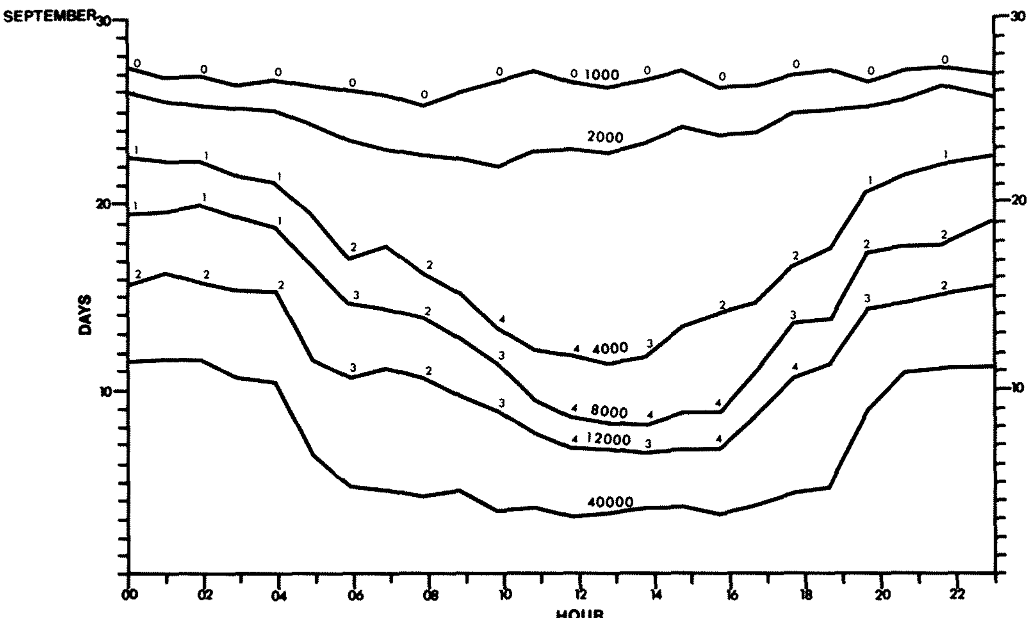


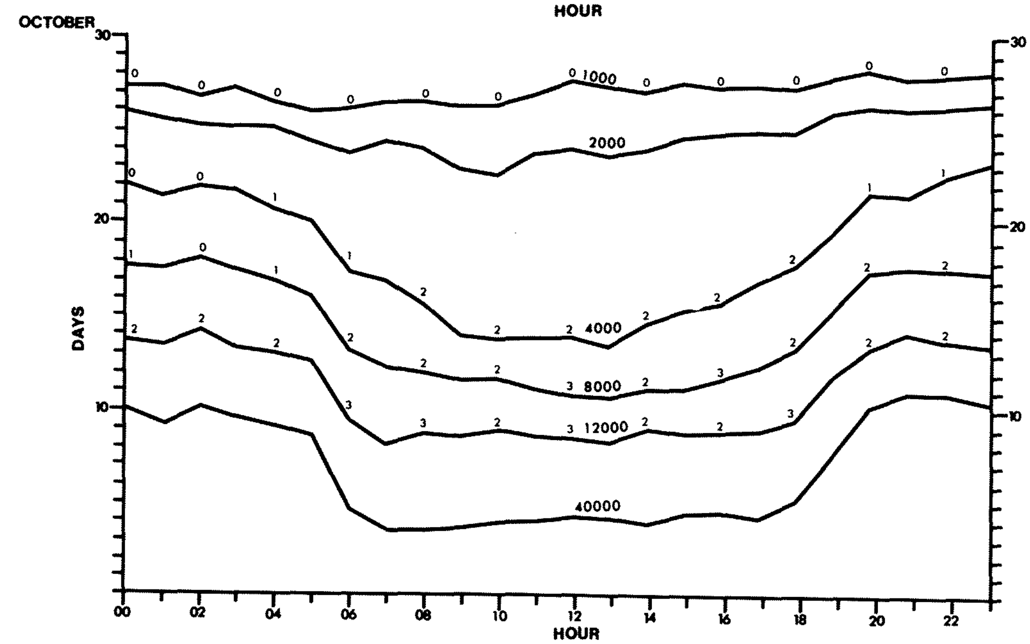




KILLALOE







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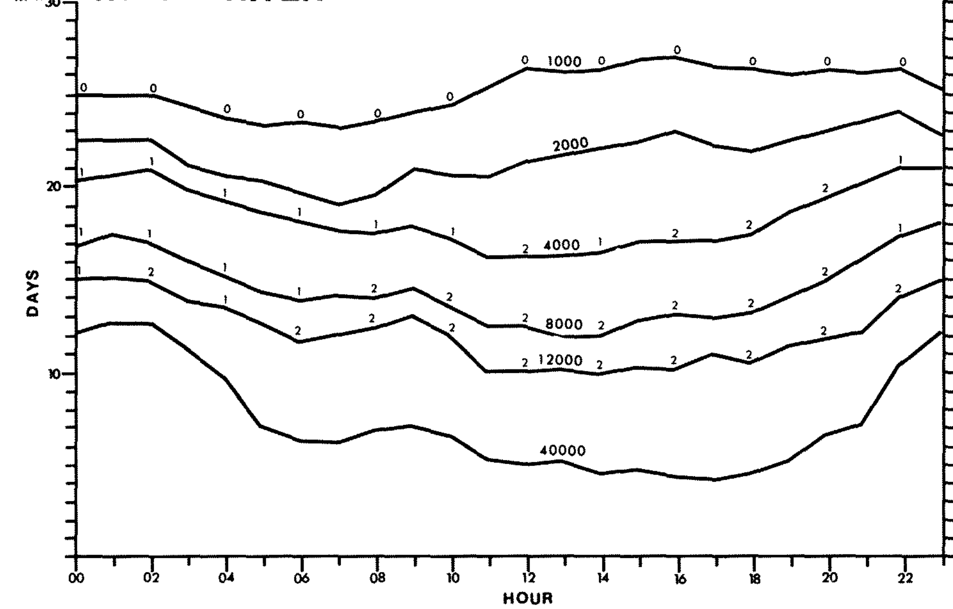
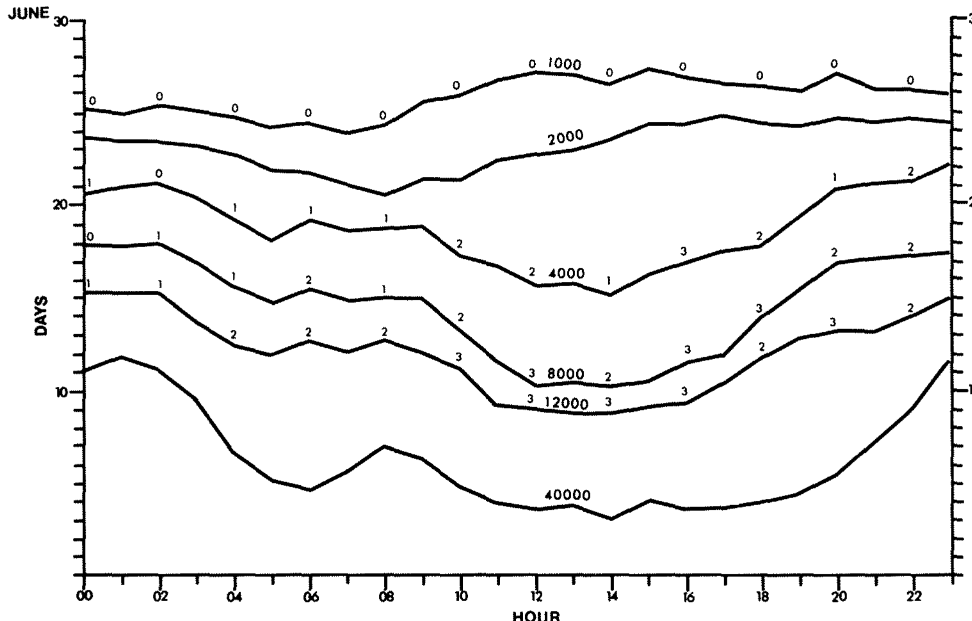
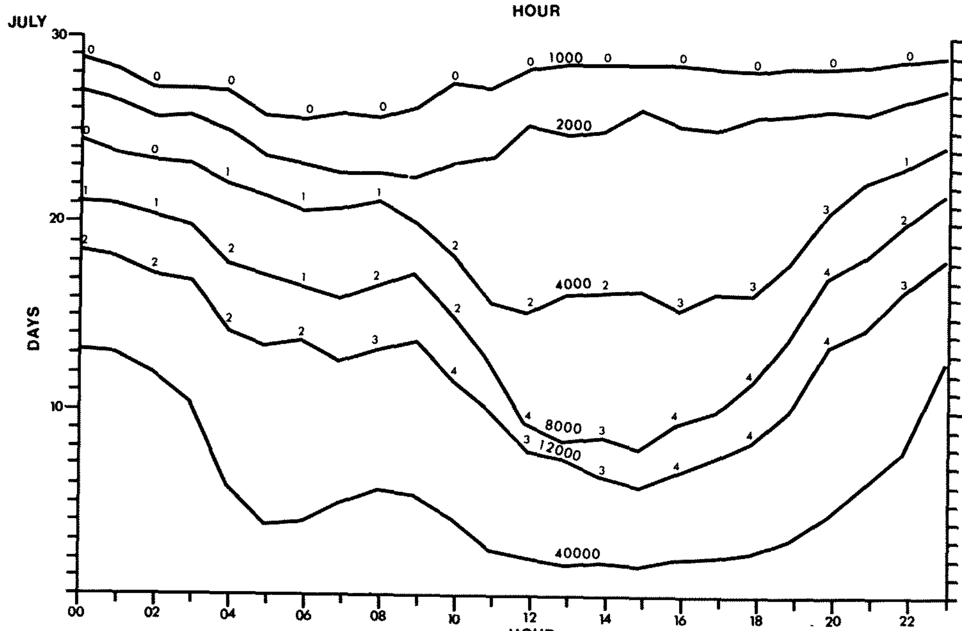
WHITE RIVER







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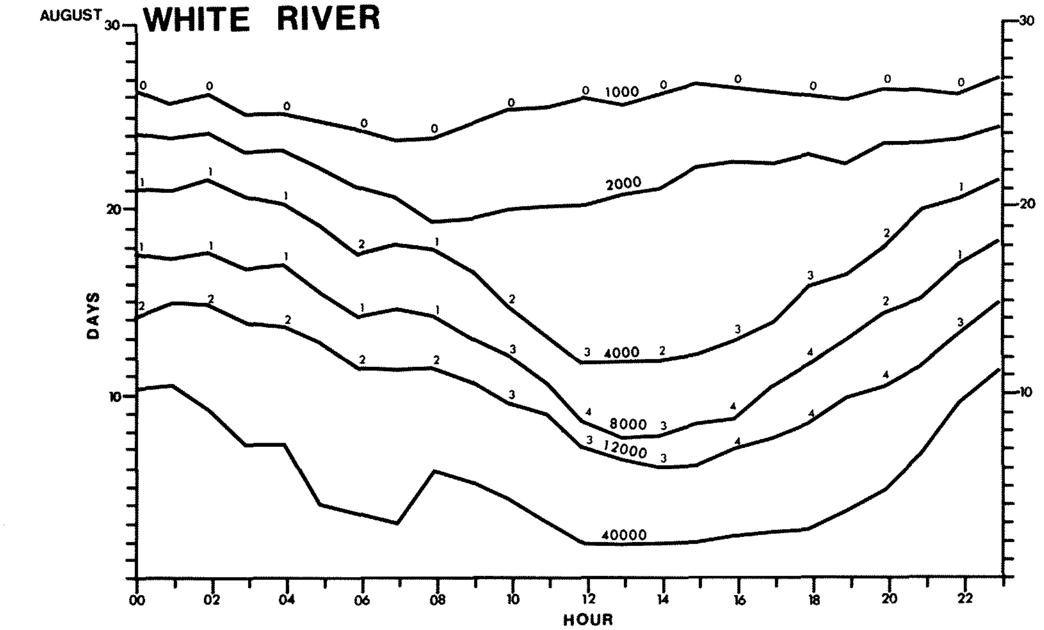

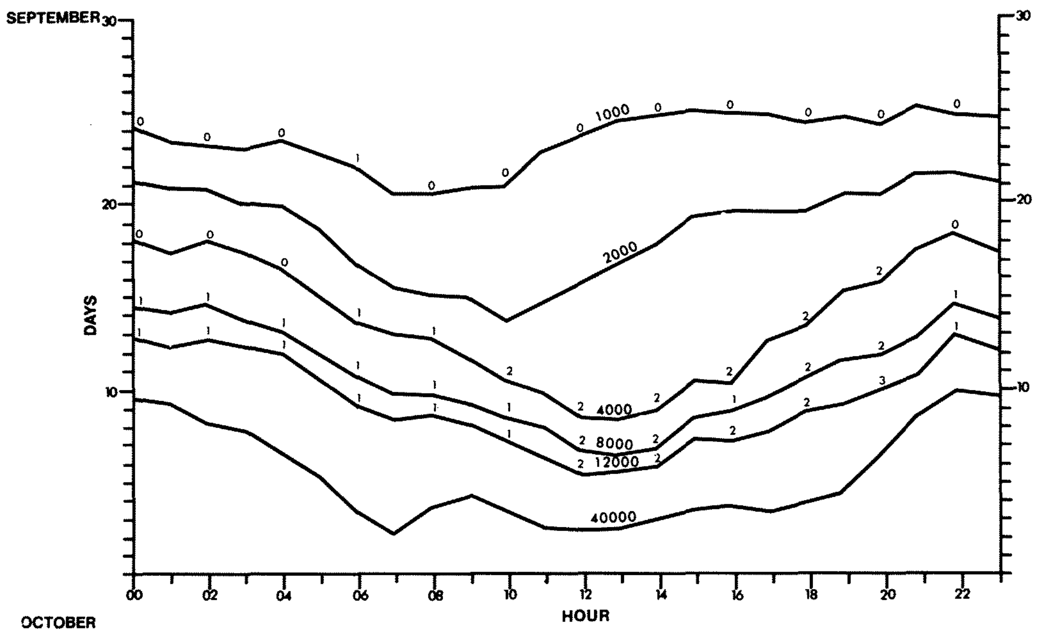

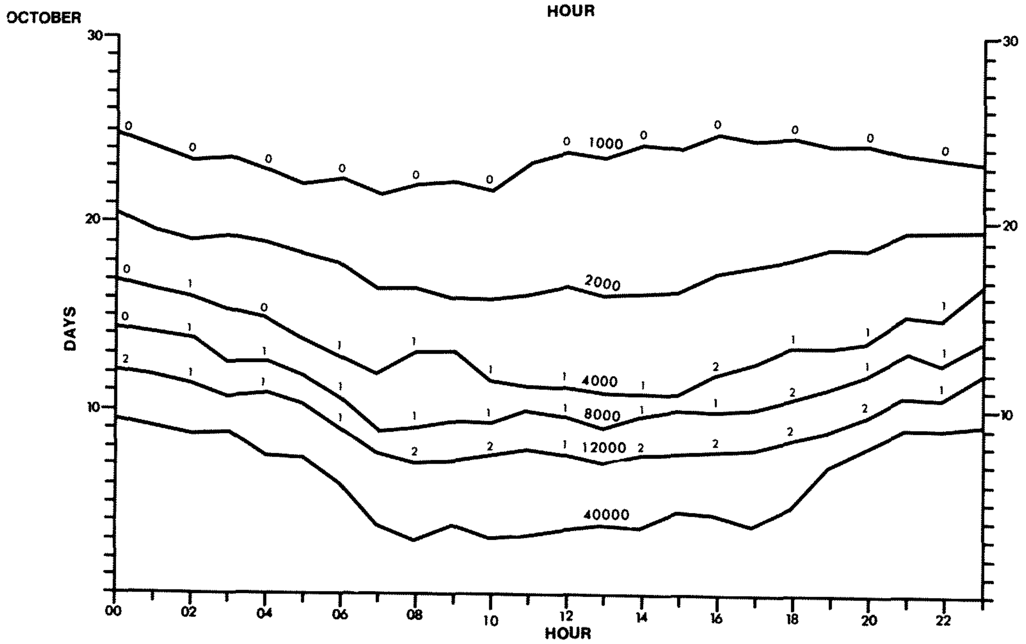

Graphs show number of days per month (for each hour of the day) when cloud amount below specified height (in feet above ground) covers 1/10 or less of the sky.

Digits above graph points for even numbered hours show number of days cloud below specified height covers 2/10 or 3/10 of the sky.

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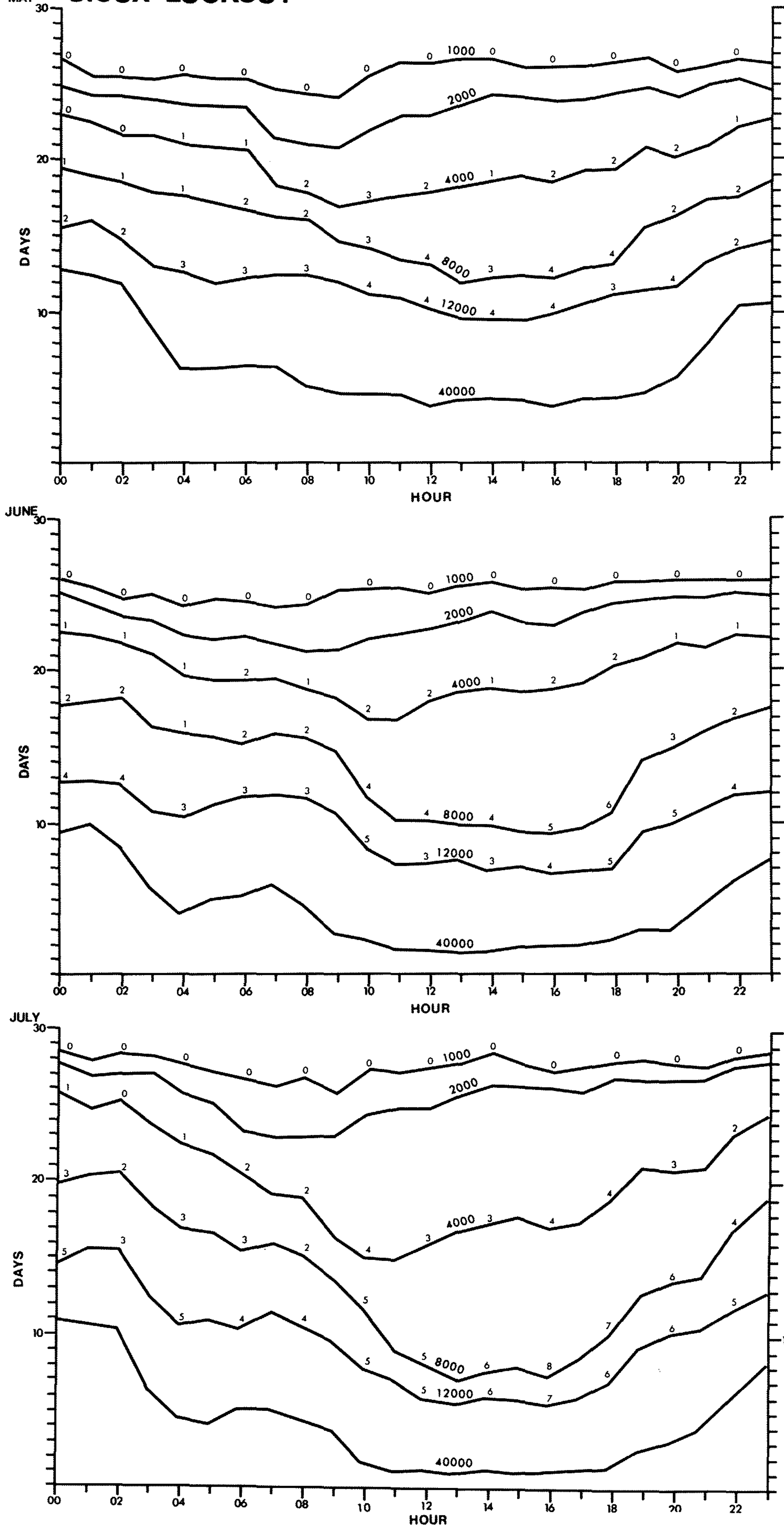
SIOUX LOOKOUT



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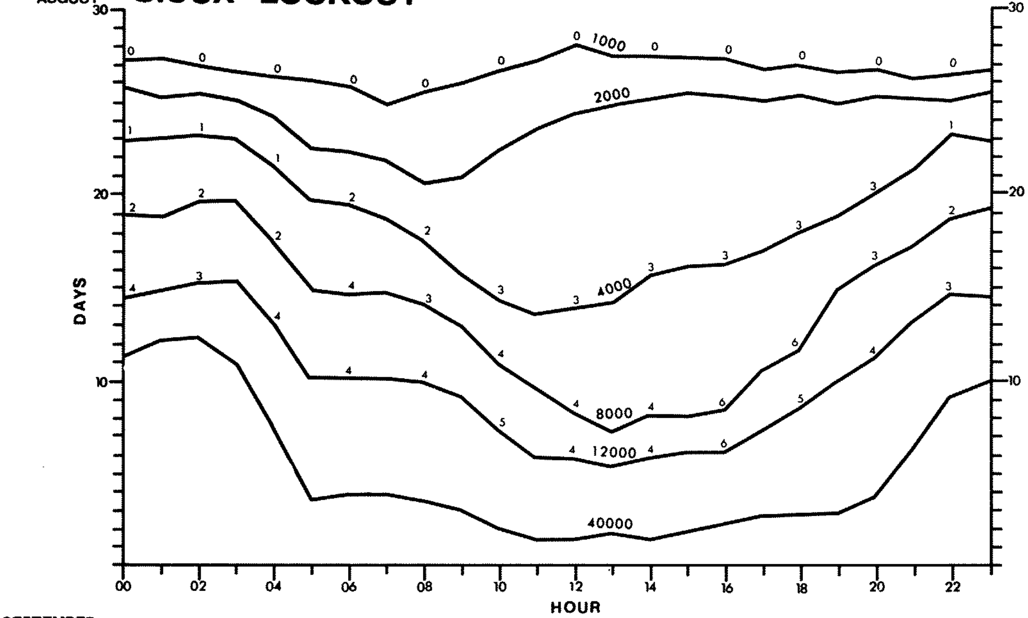

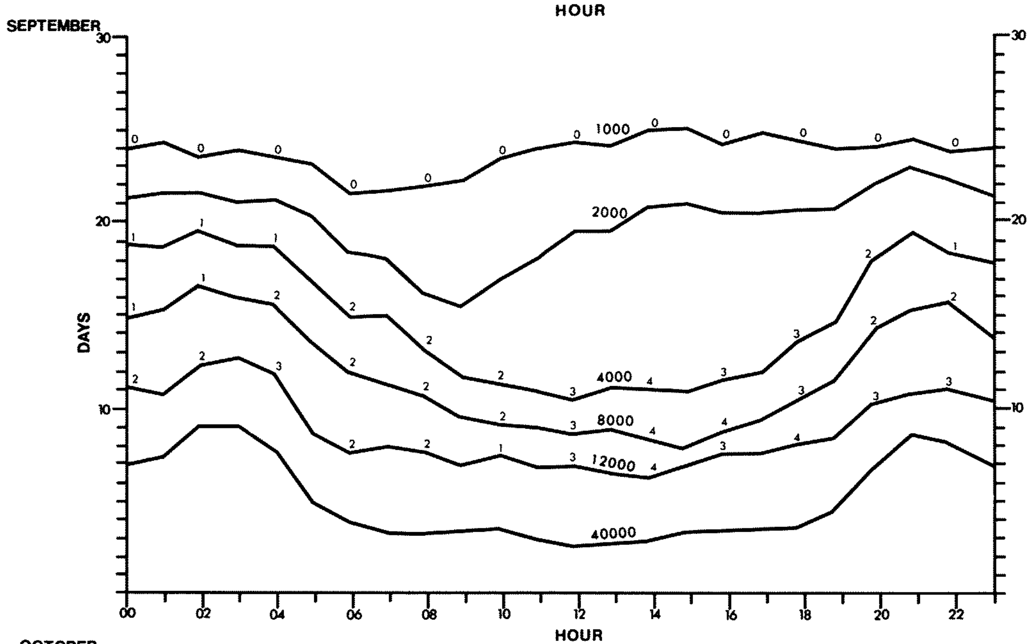

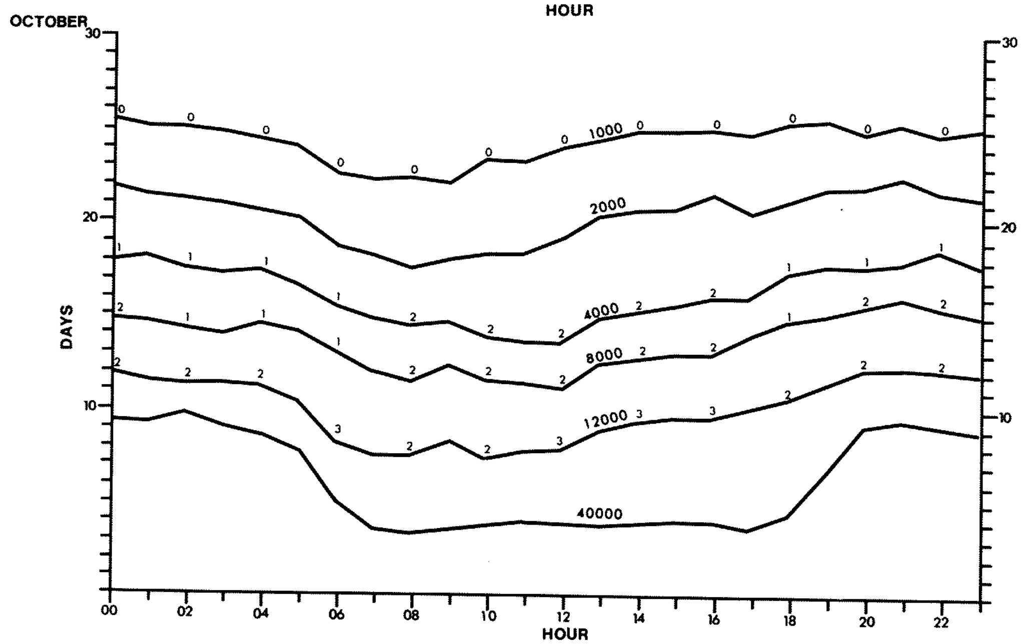

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Digits above graph points

for even numbered hours

show number of days

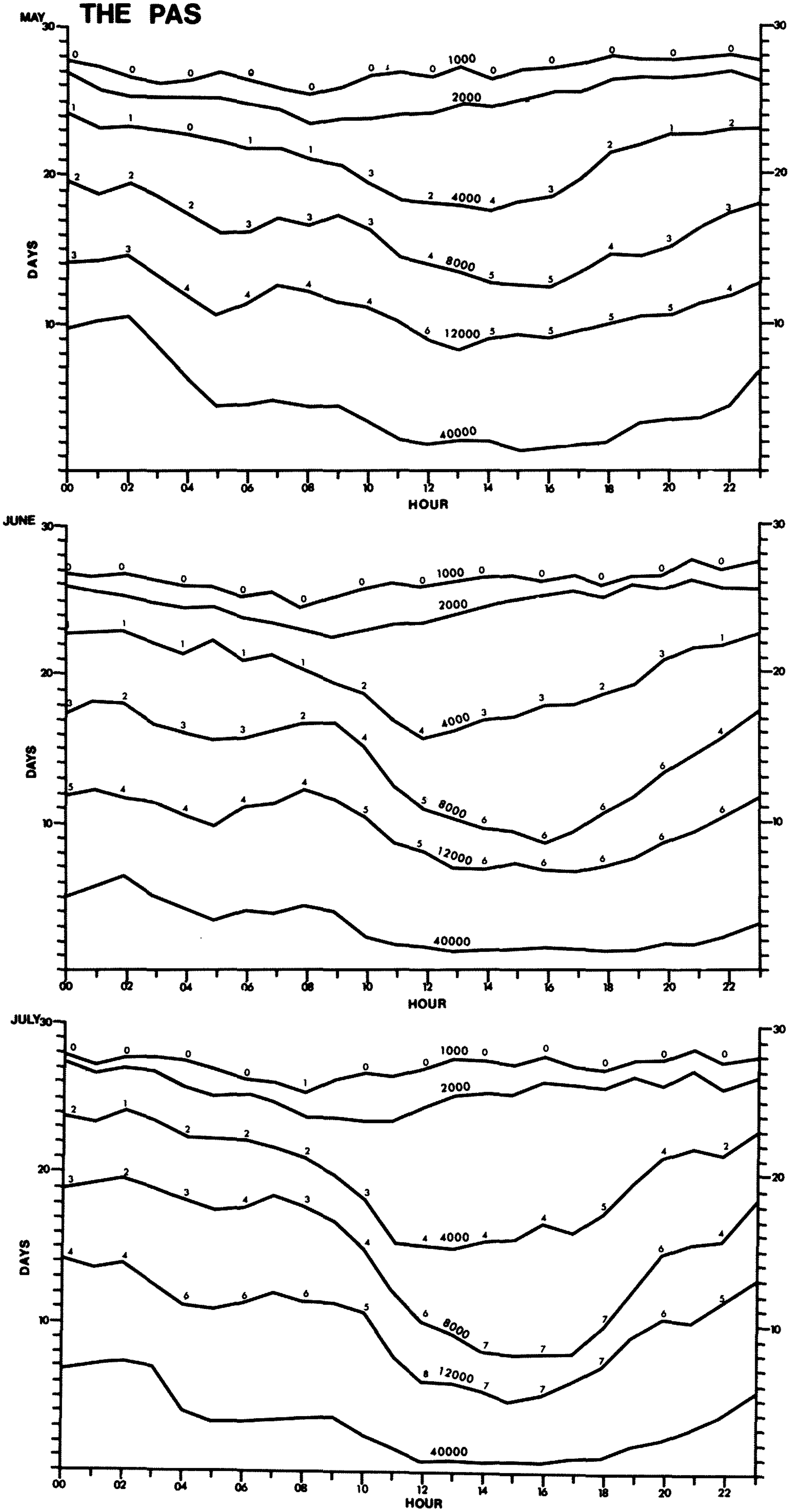
cloud below

specified height

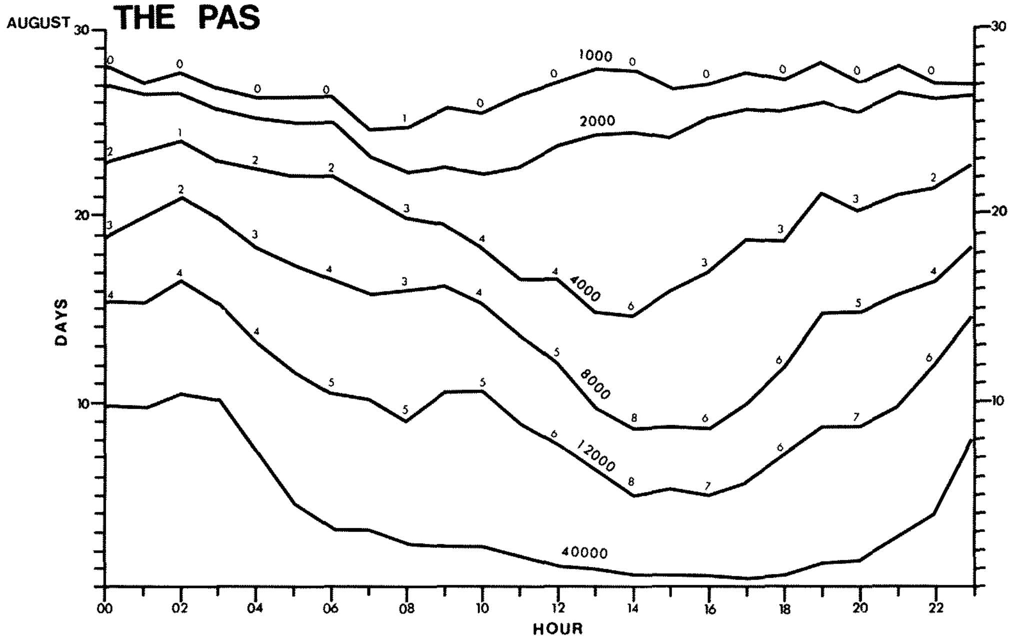
covers 2/10 or 3/10

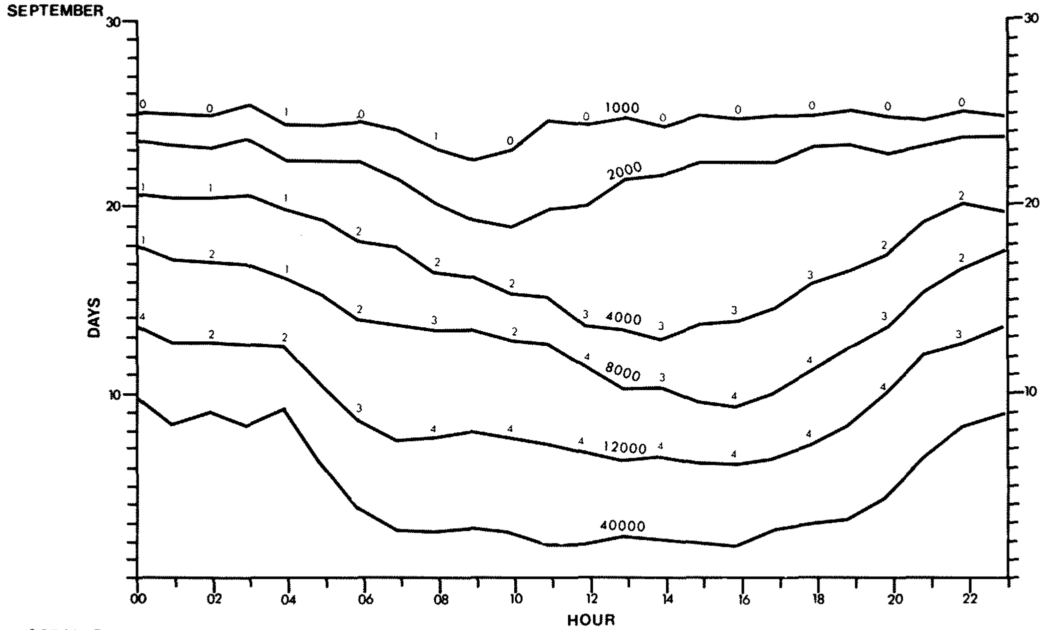
of the sky.

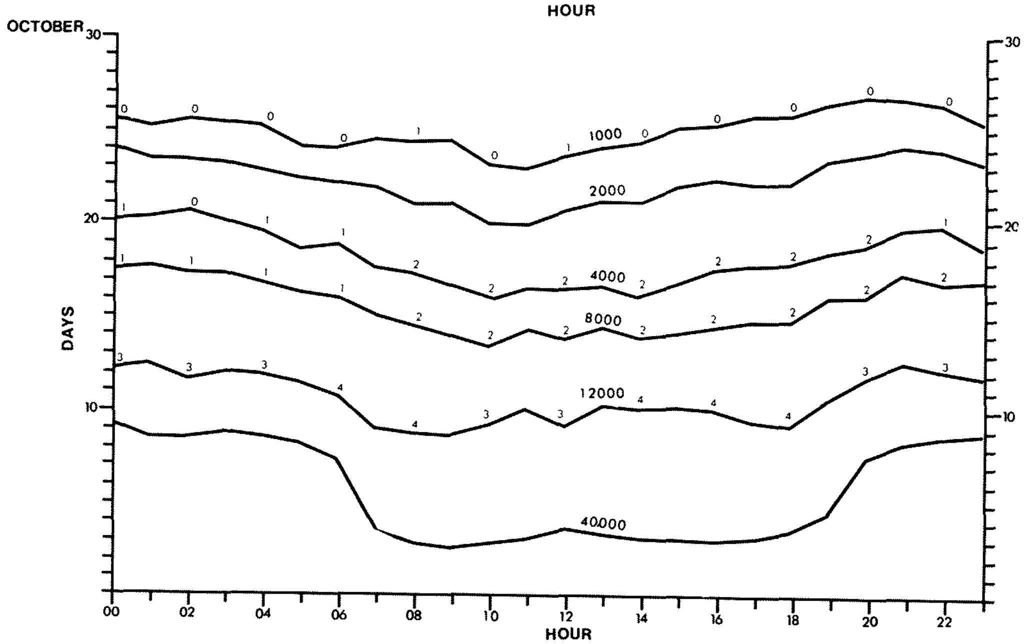
THE PAS



THE PAS







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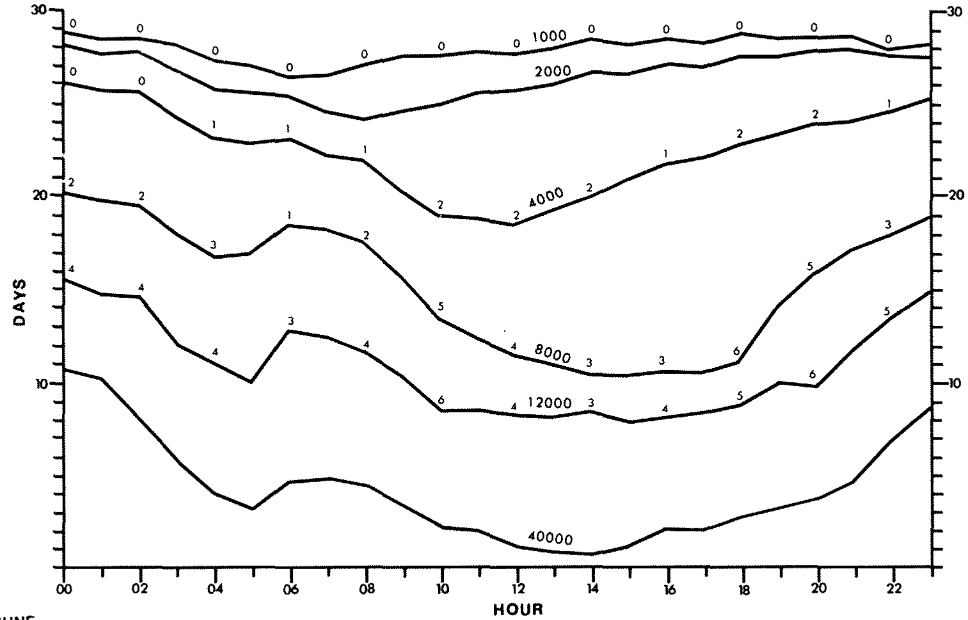
PRINCE ALBERT

MAY



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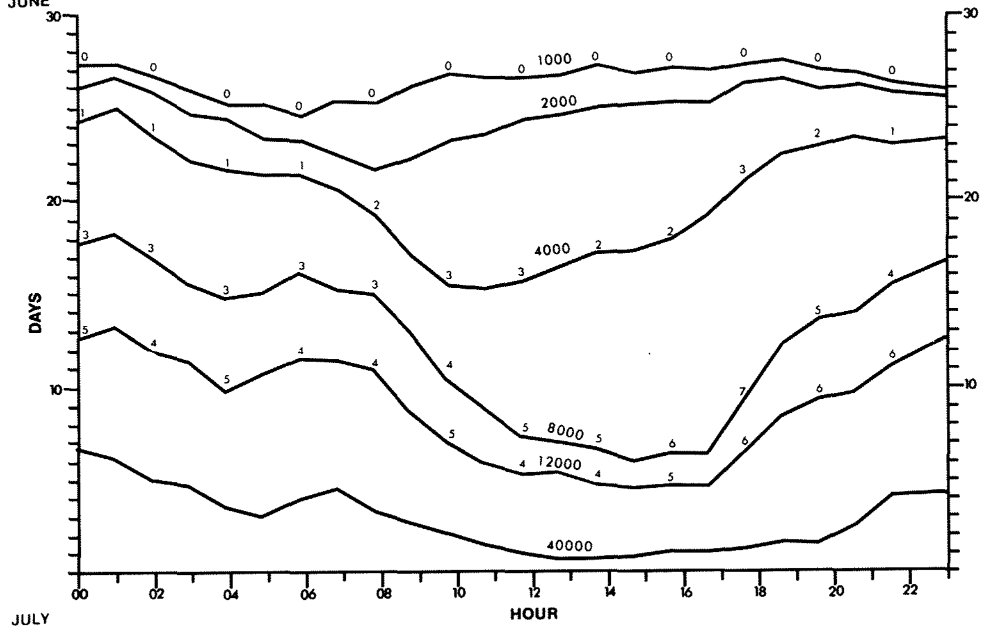

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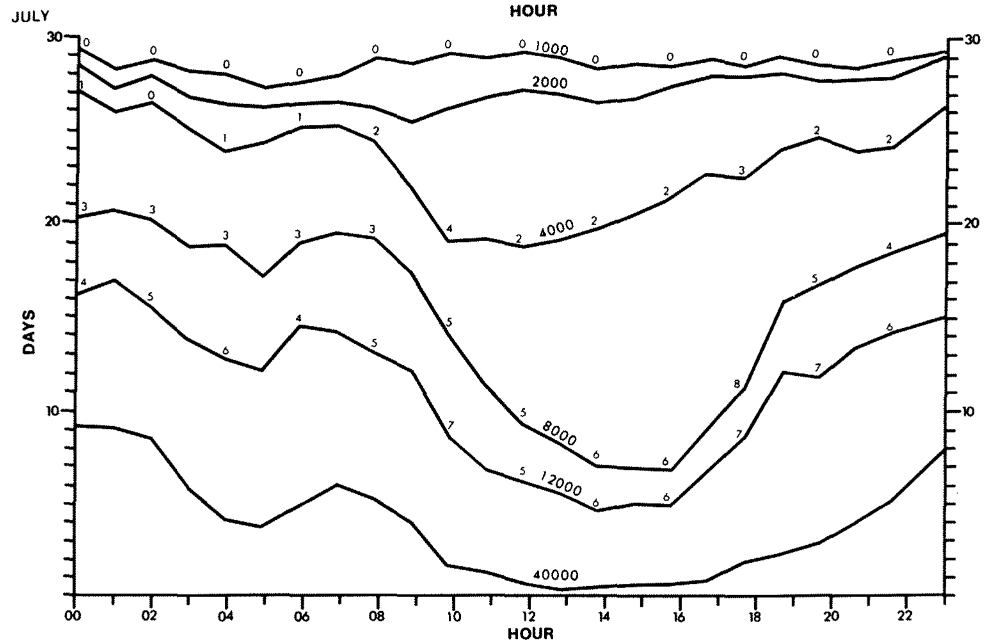
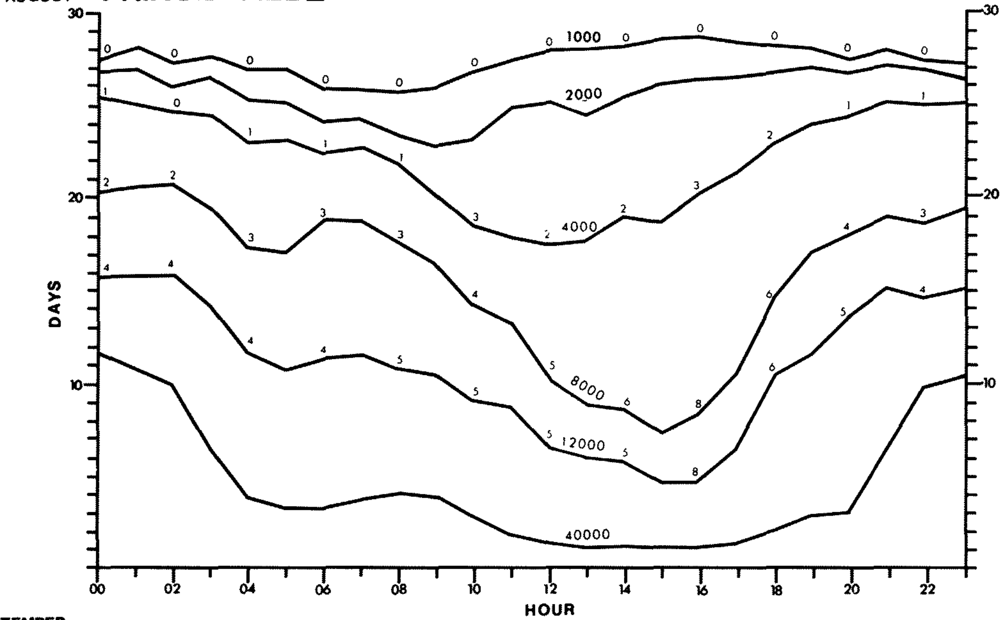
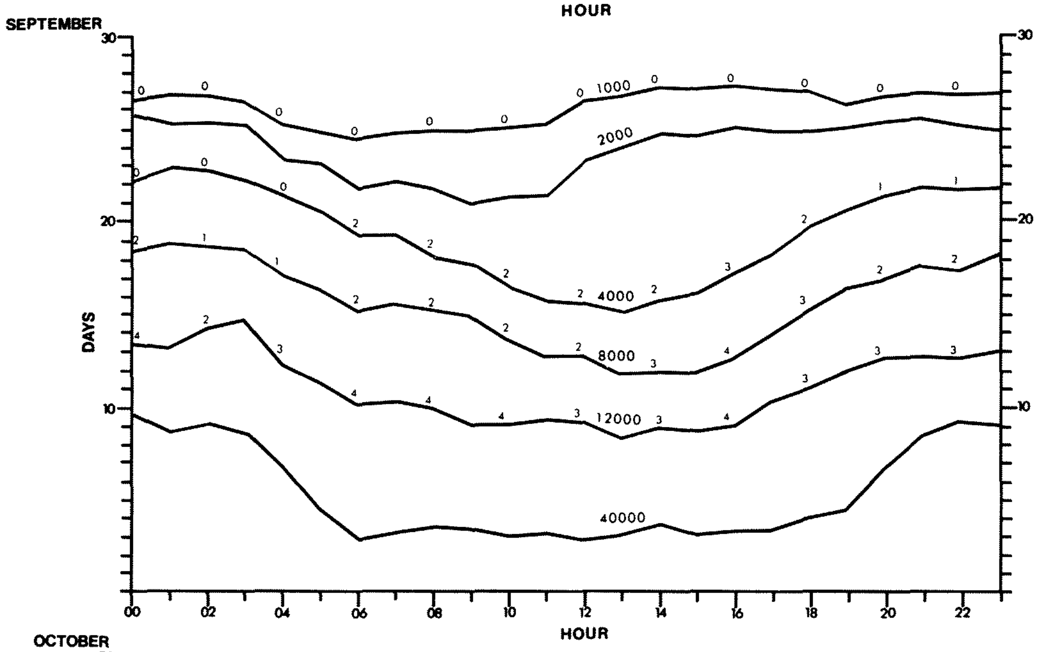
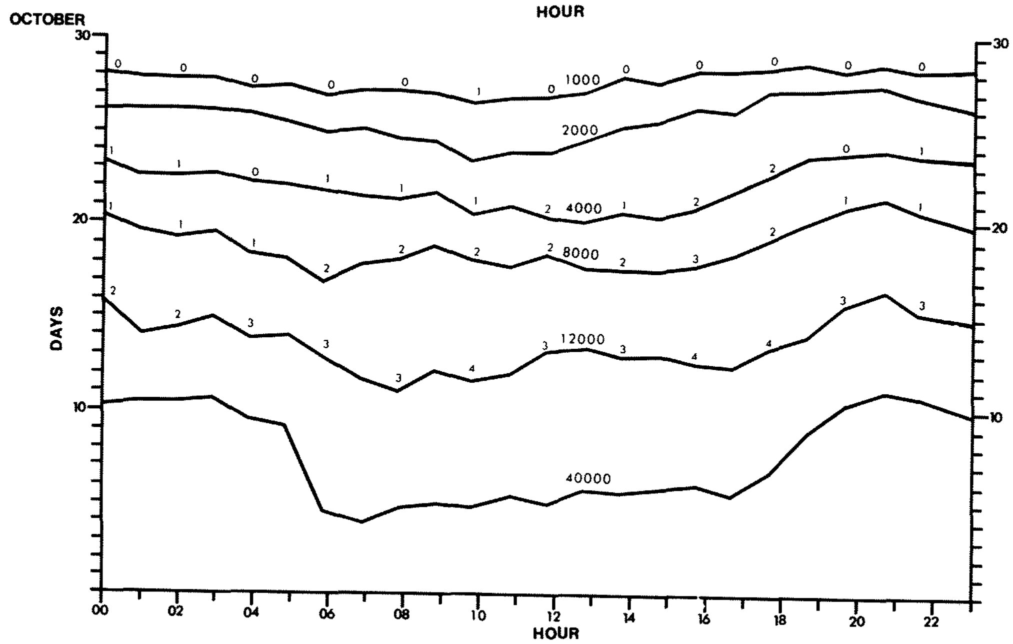


PRINCE ALBERT







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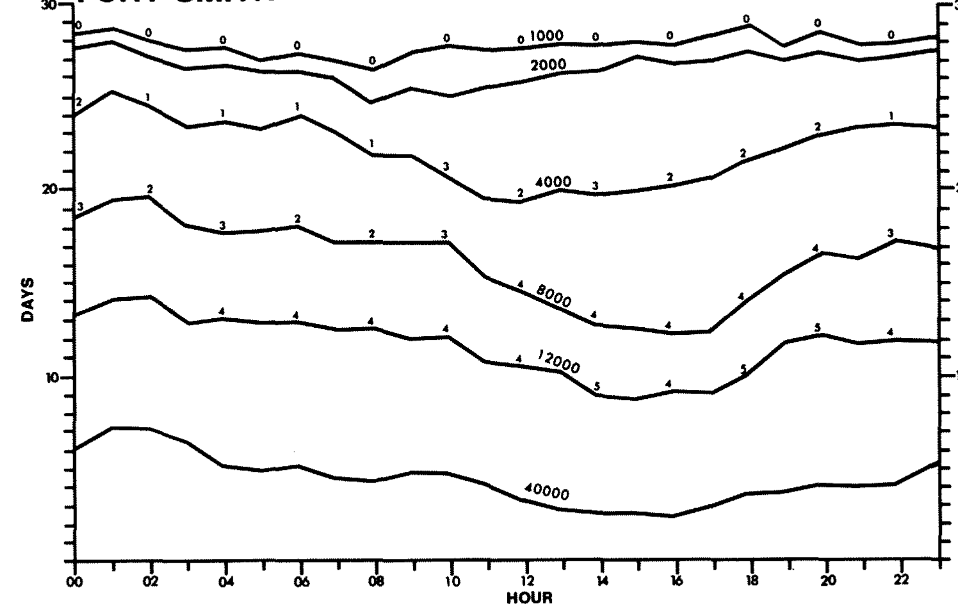
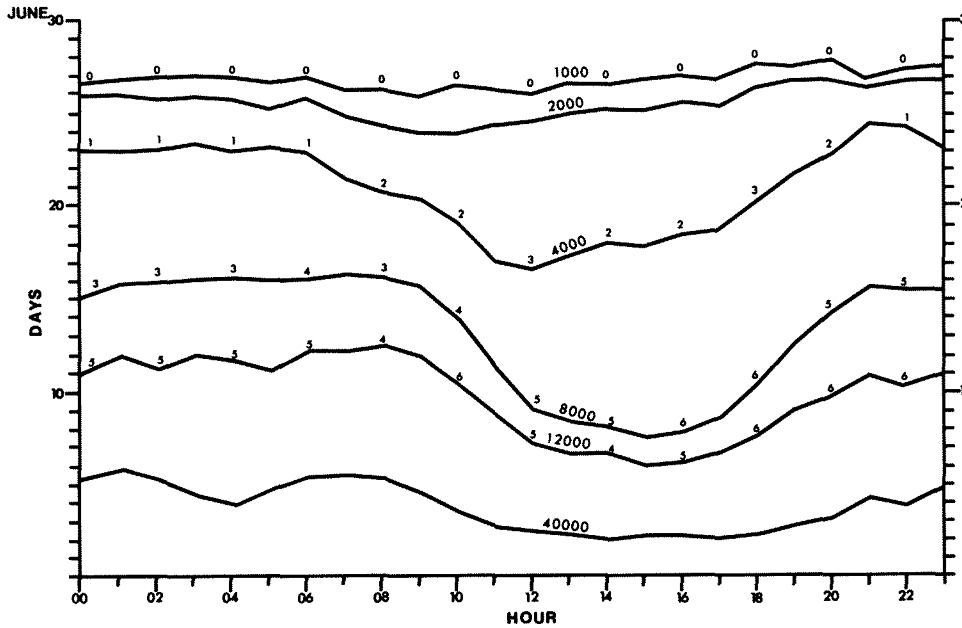
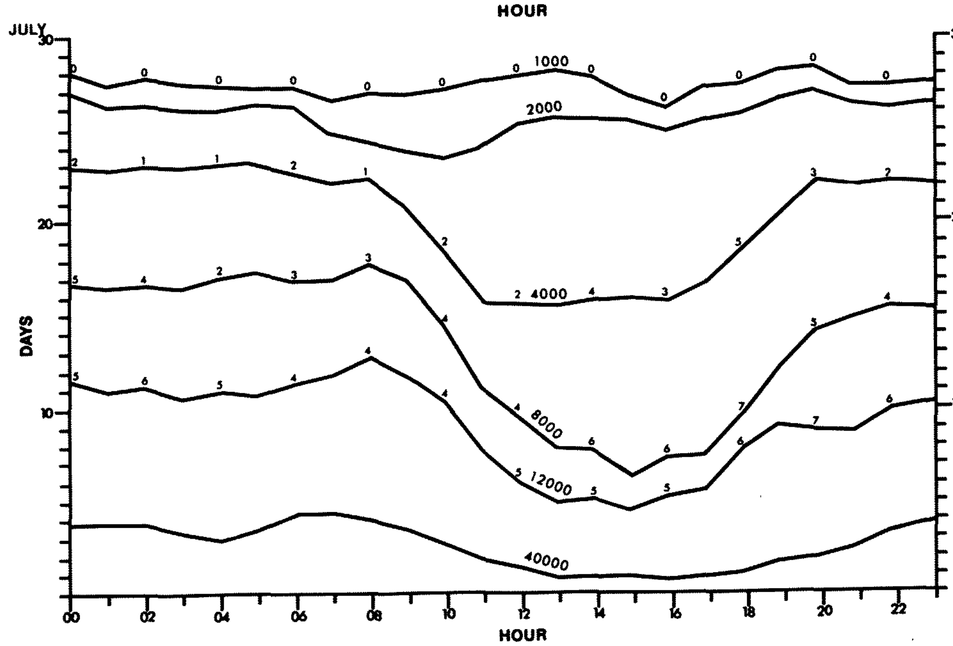
FORT SMITH







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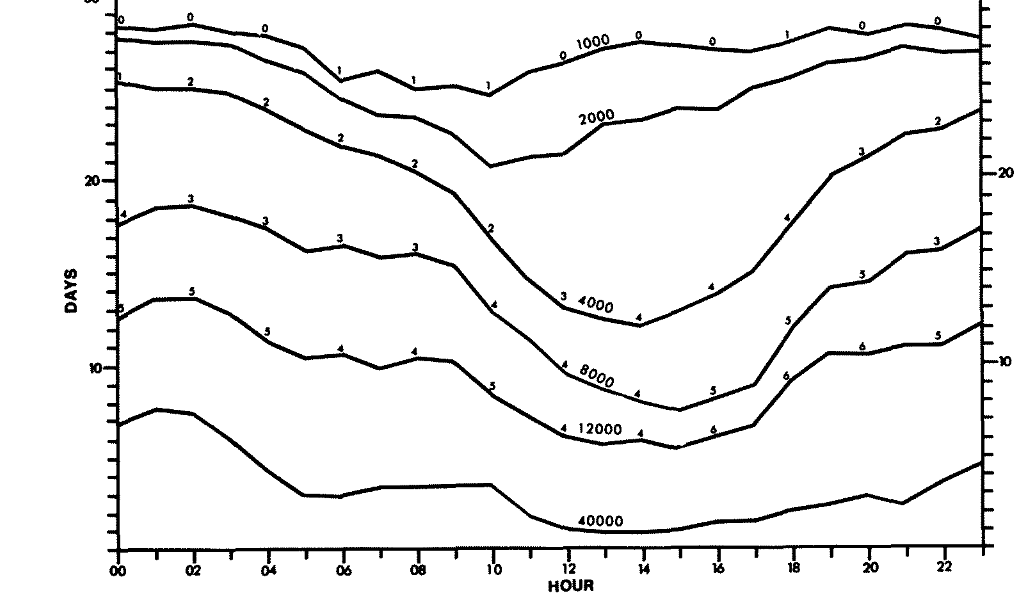

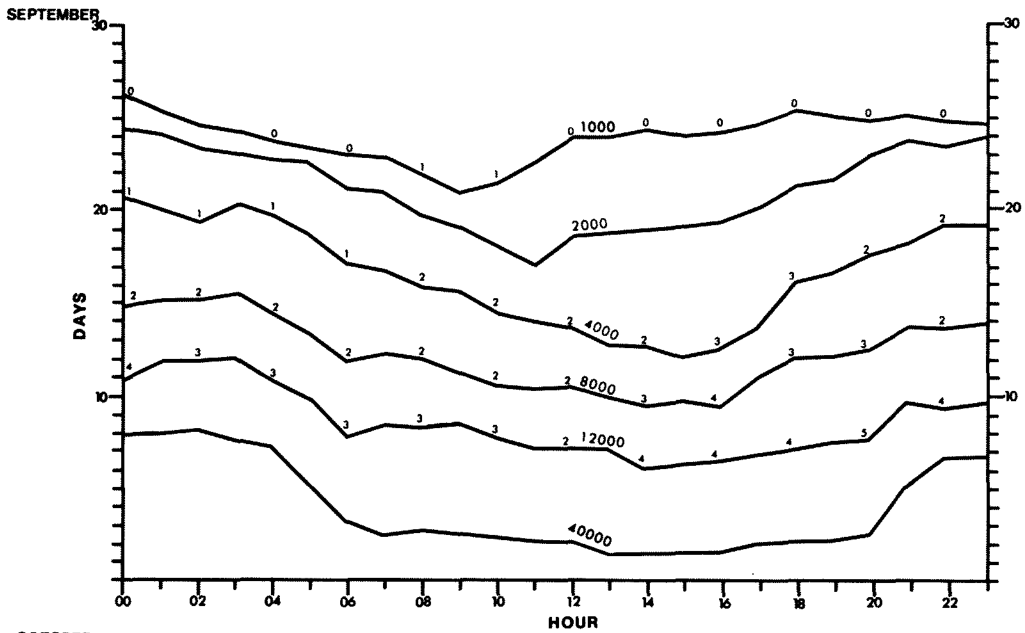

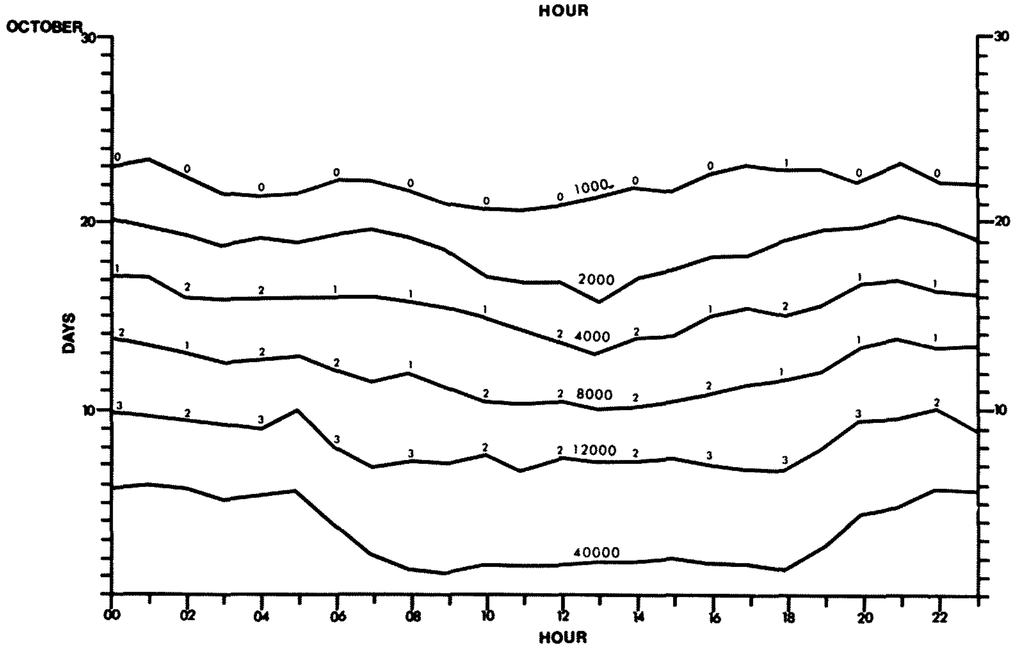

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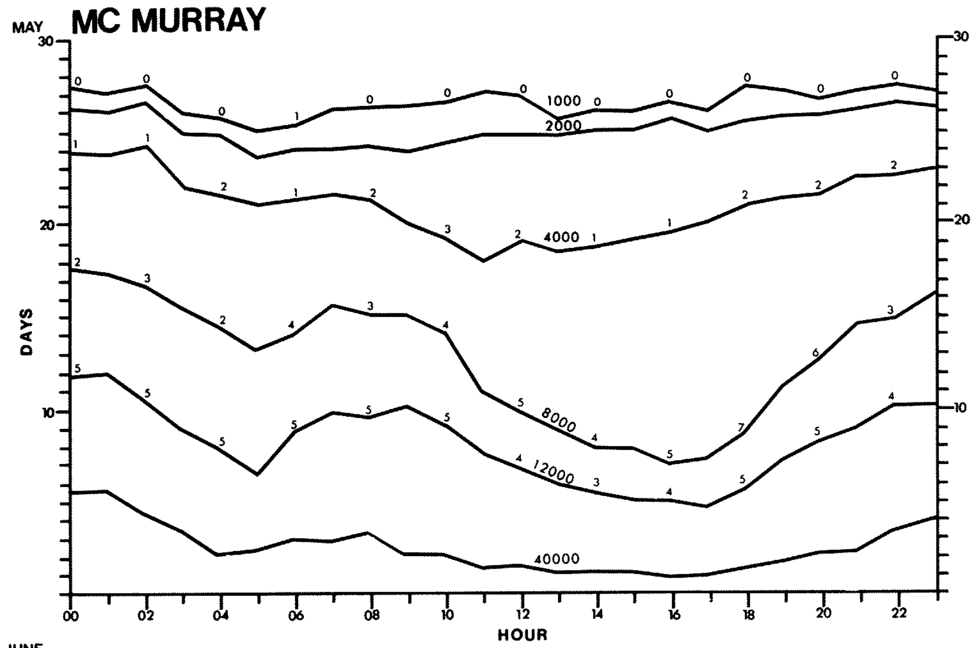
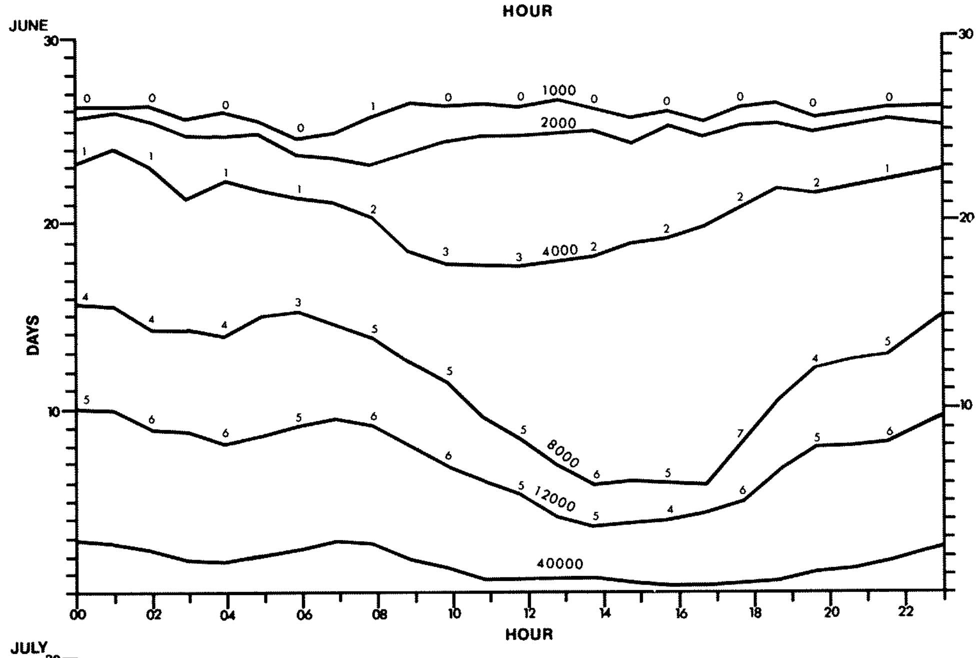
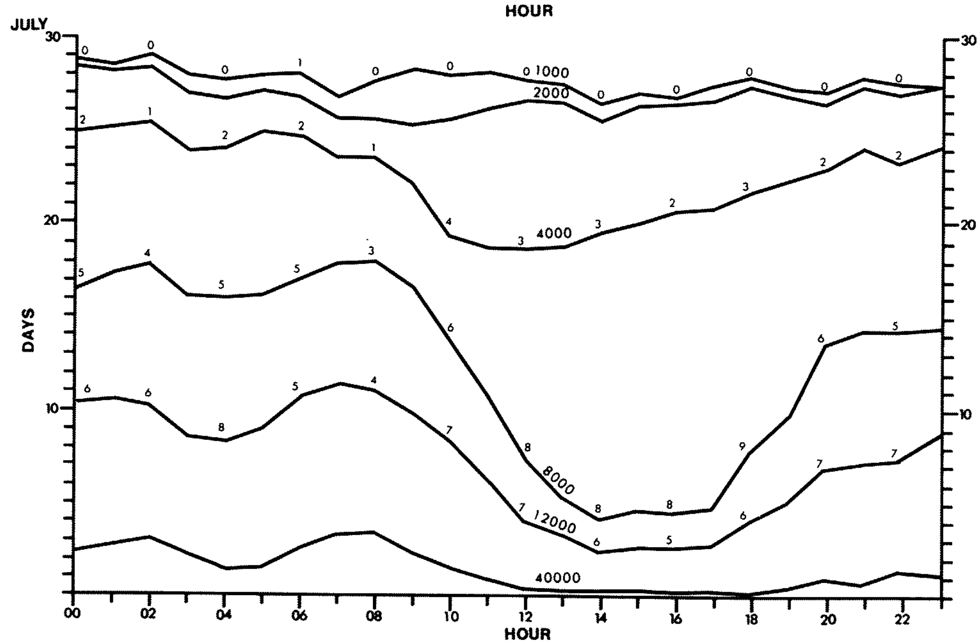
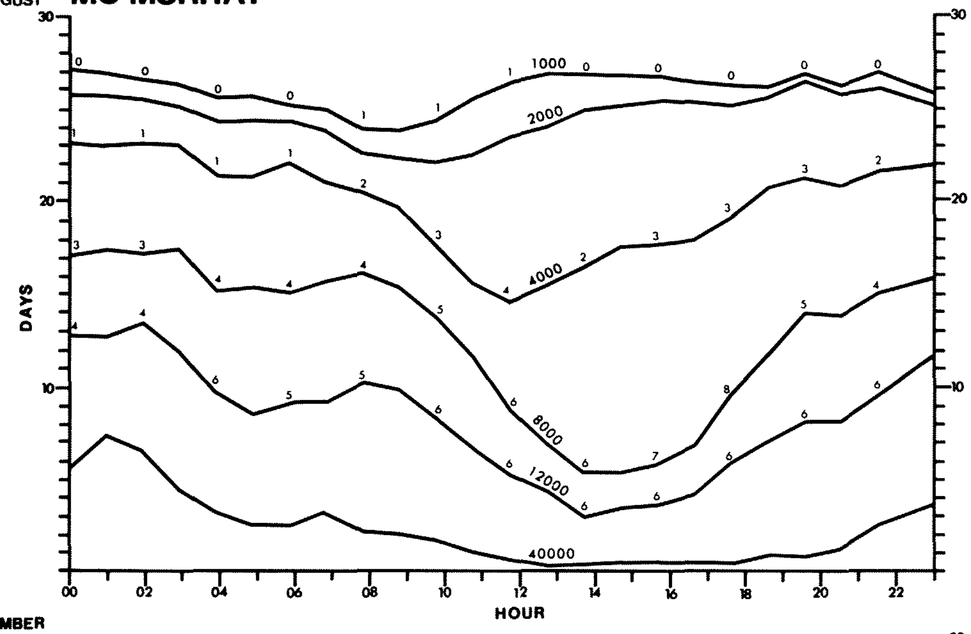


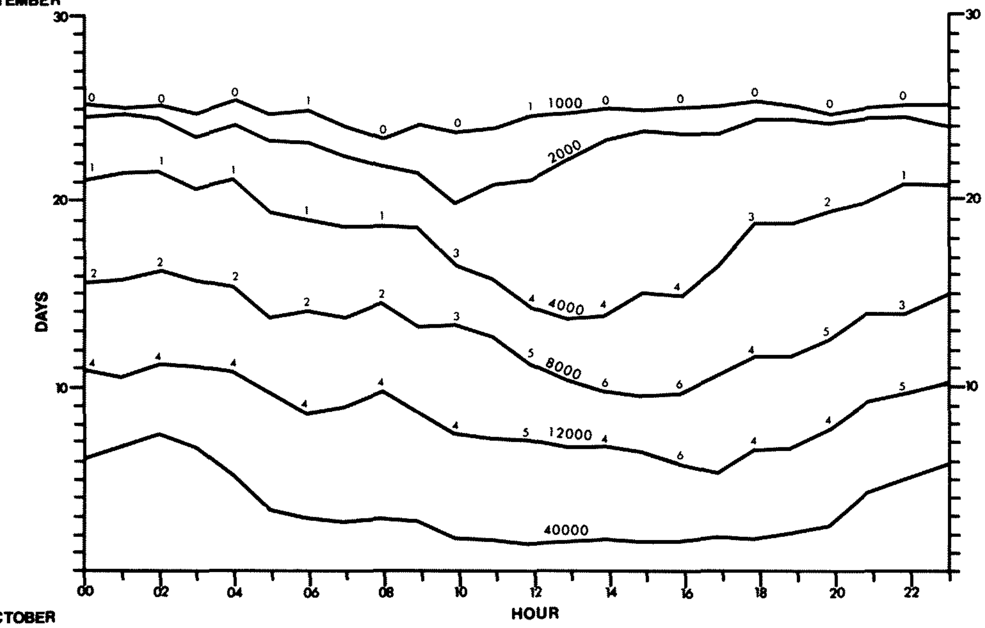




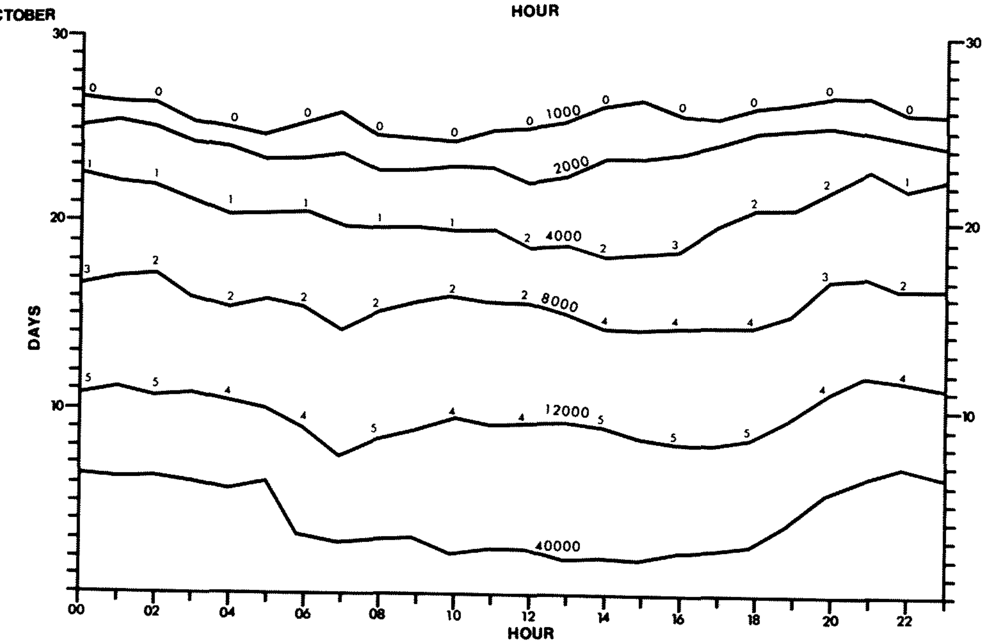
AUGUST **MC MURRAY**



SEPTEMBER



OCTOBER



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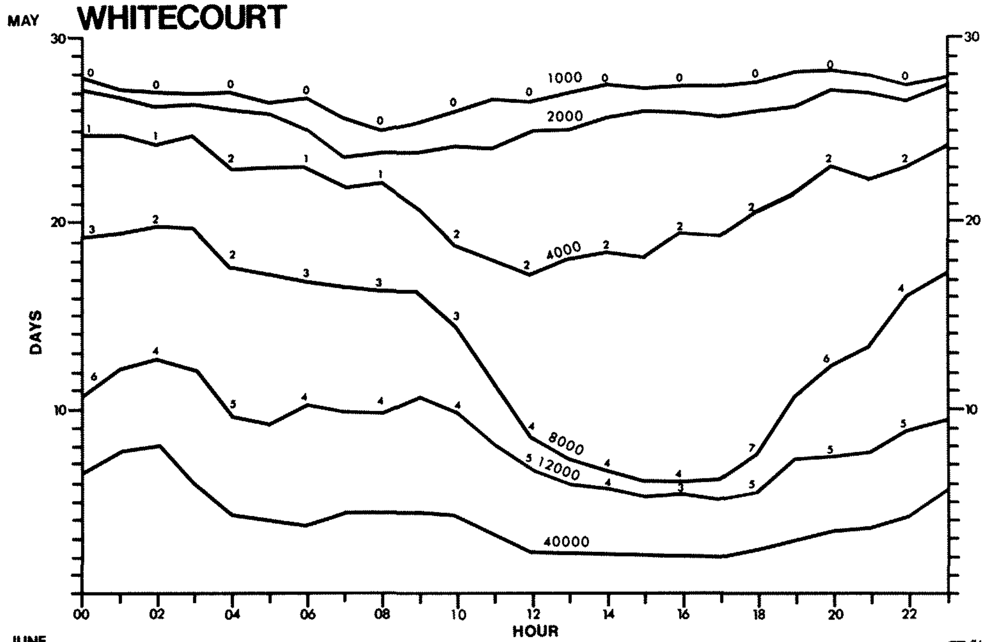
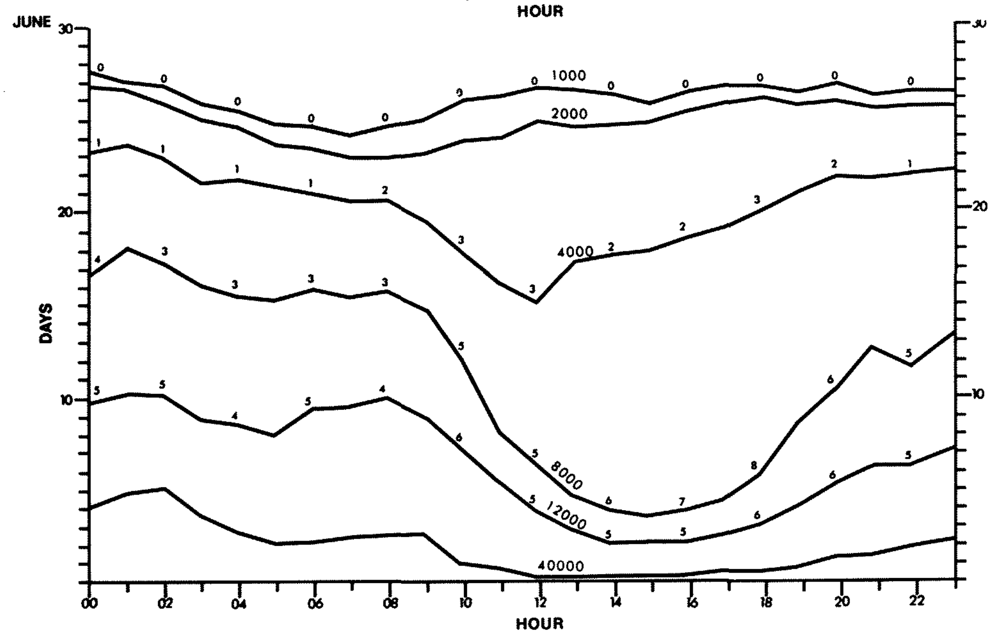
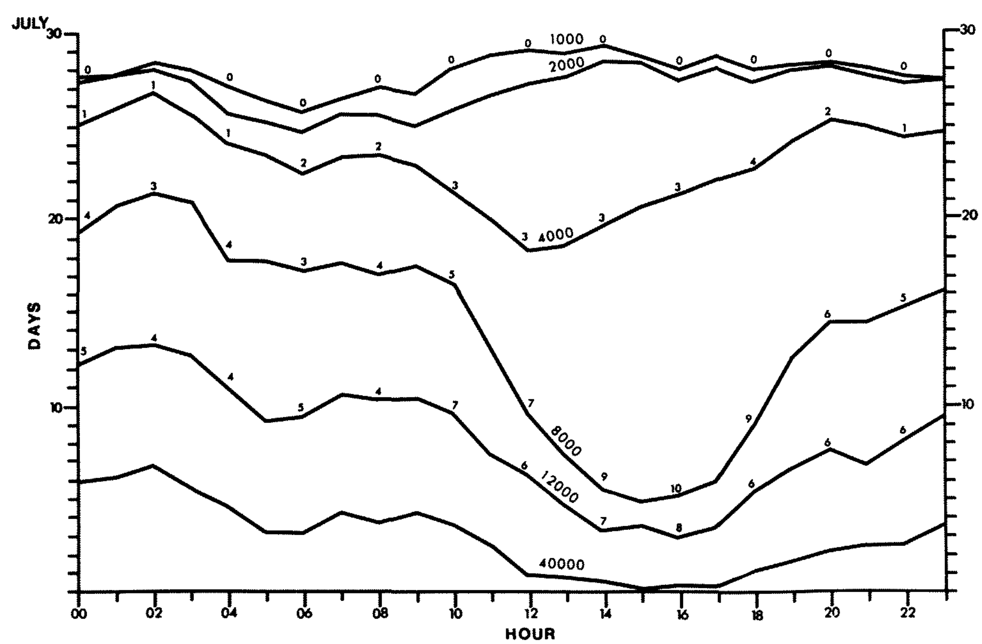
WHITECOURT







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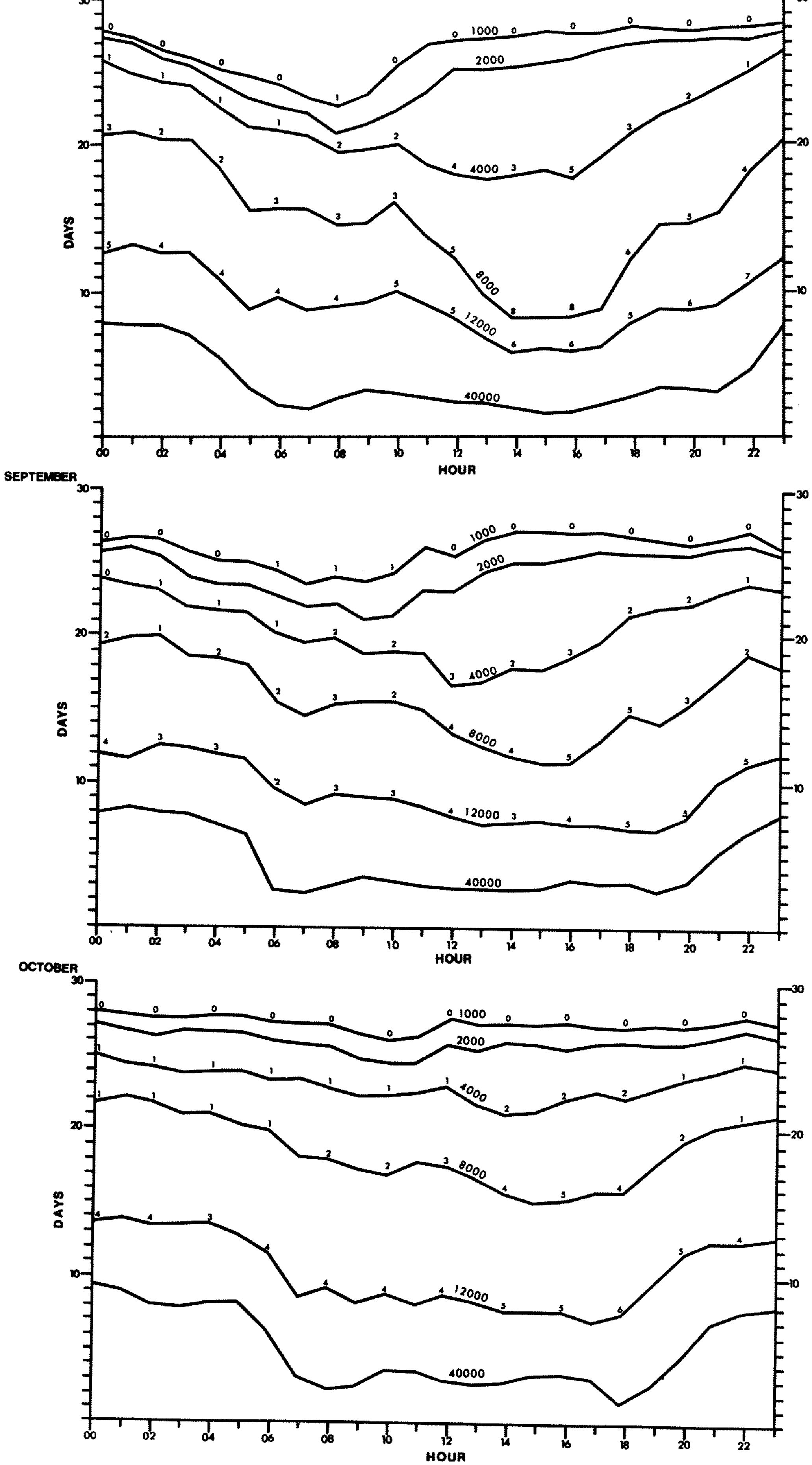

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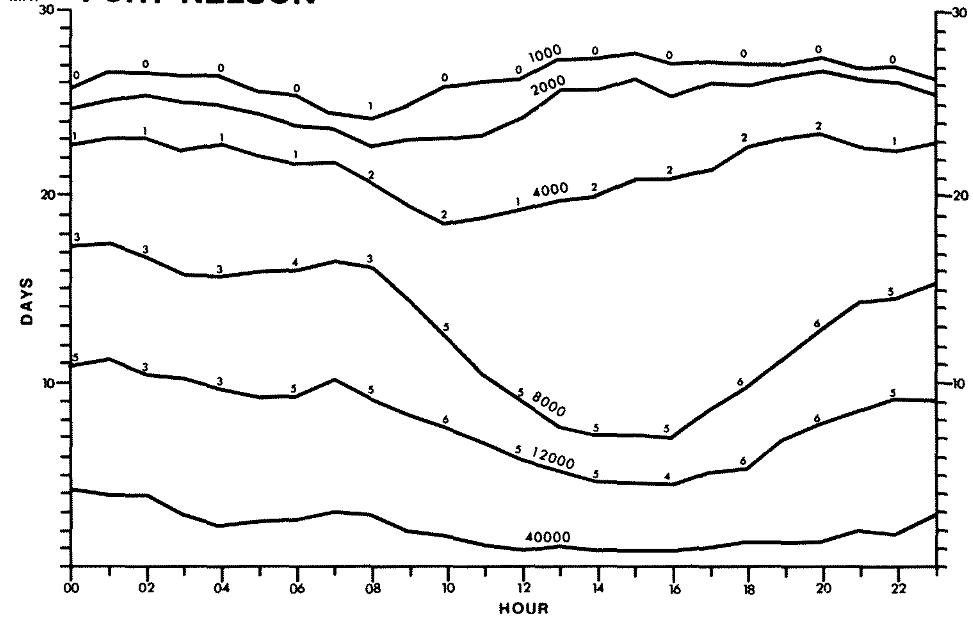

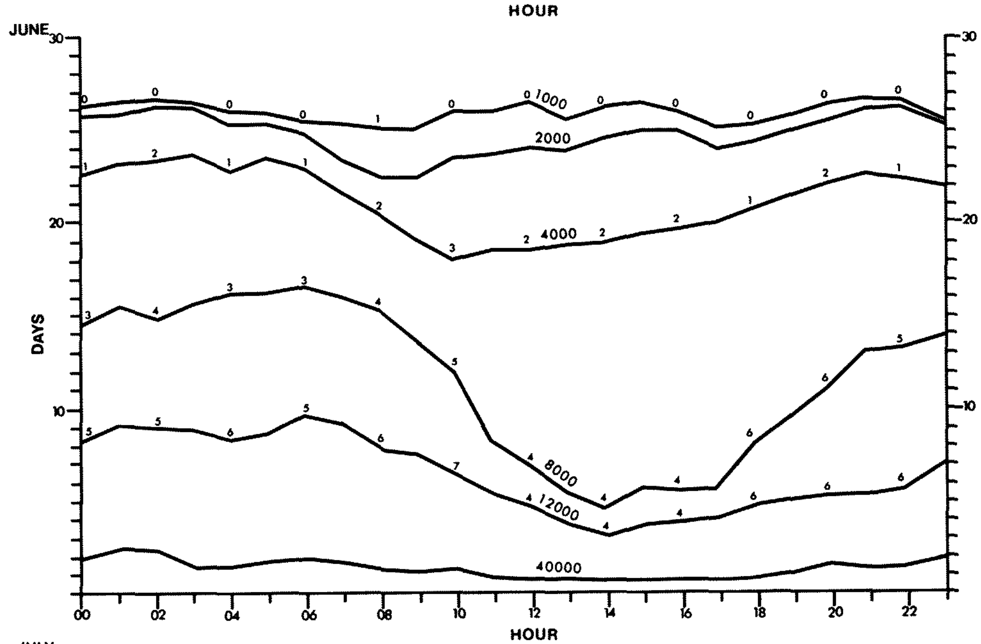

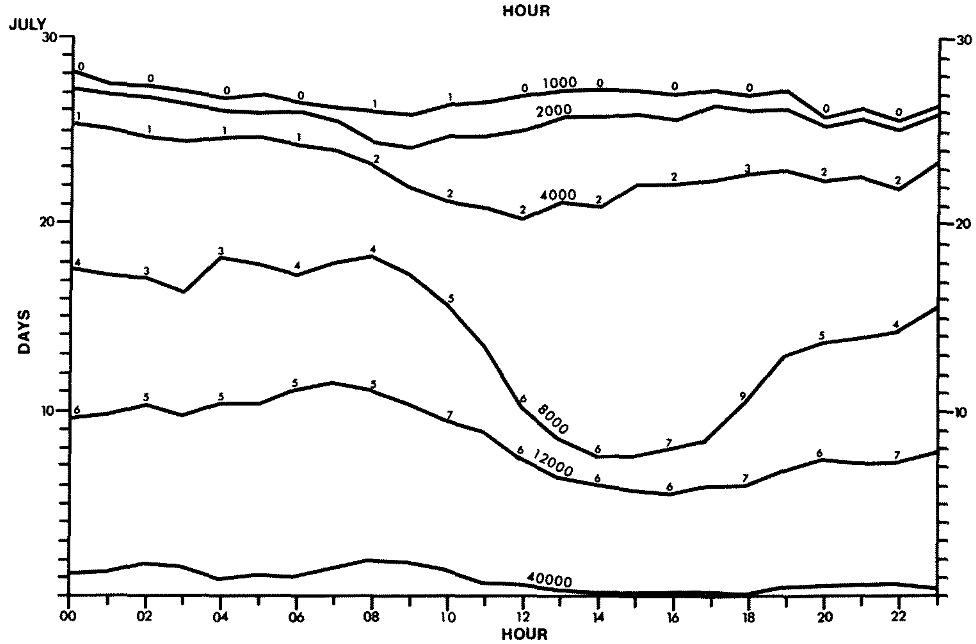

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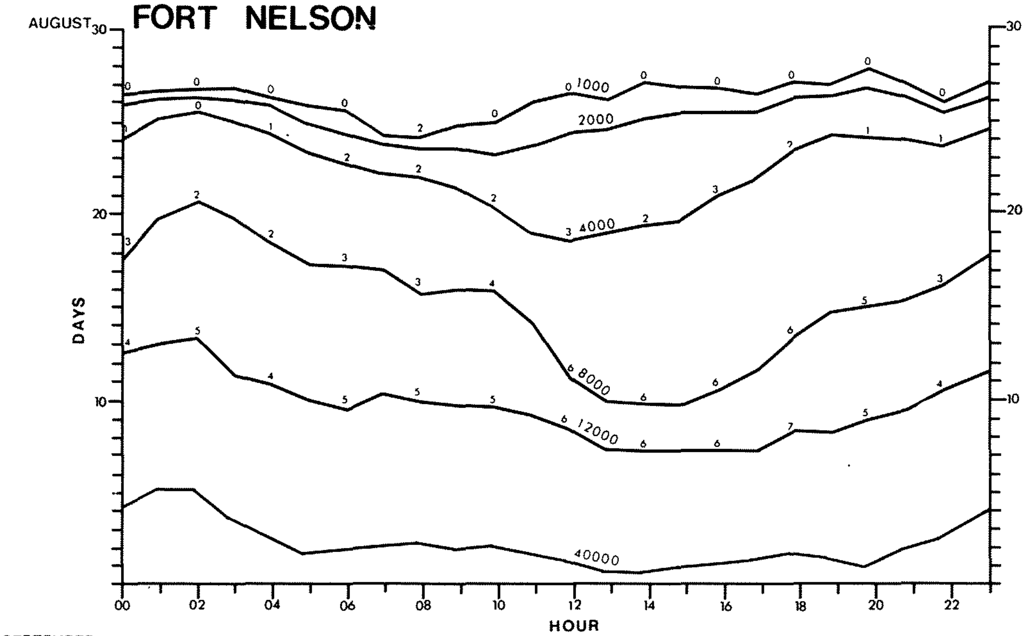

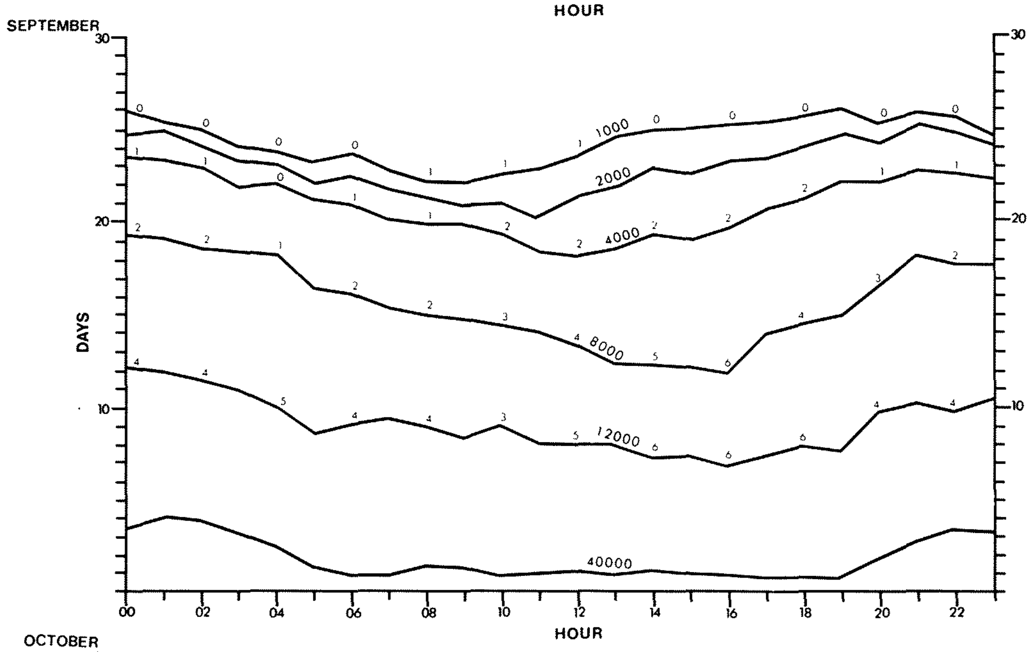

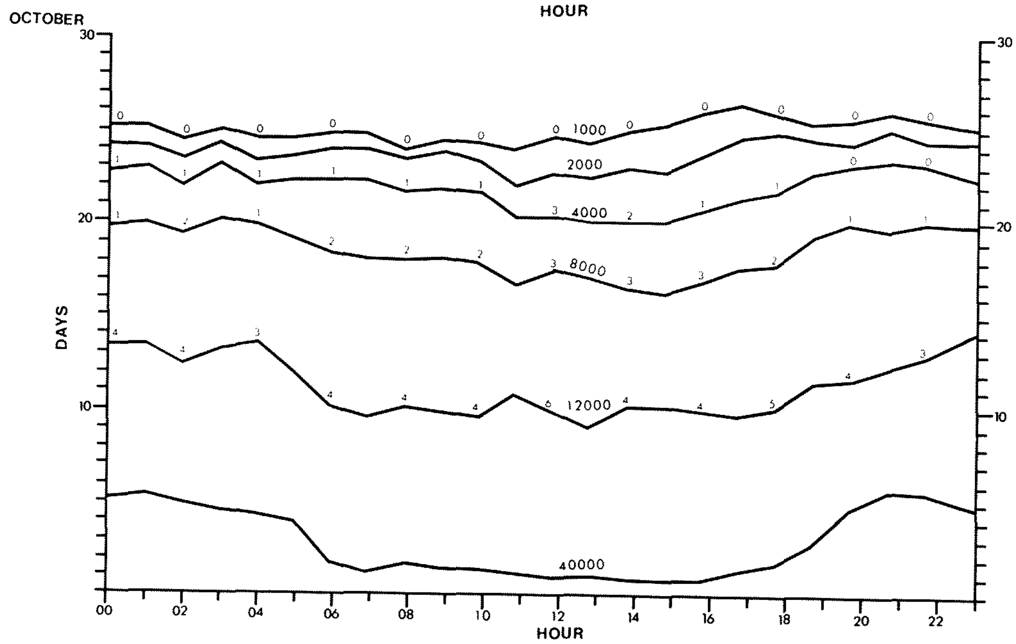

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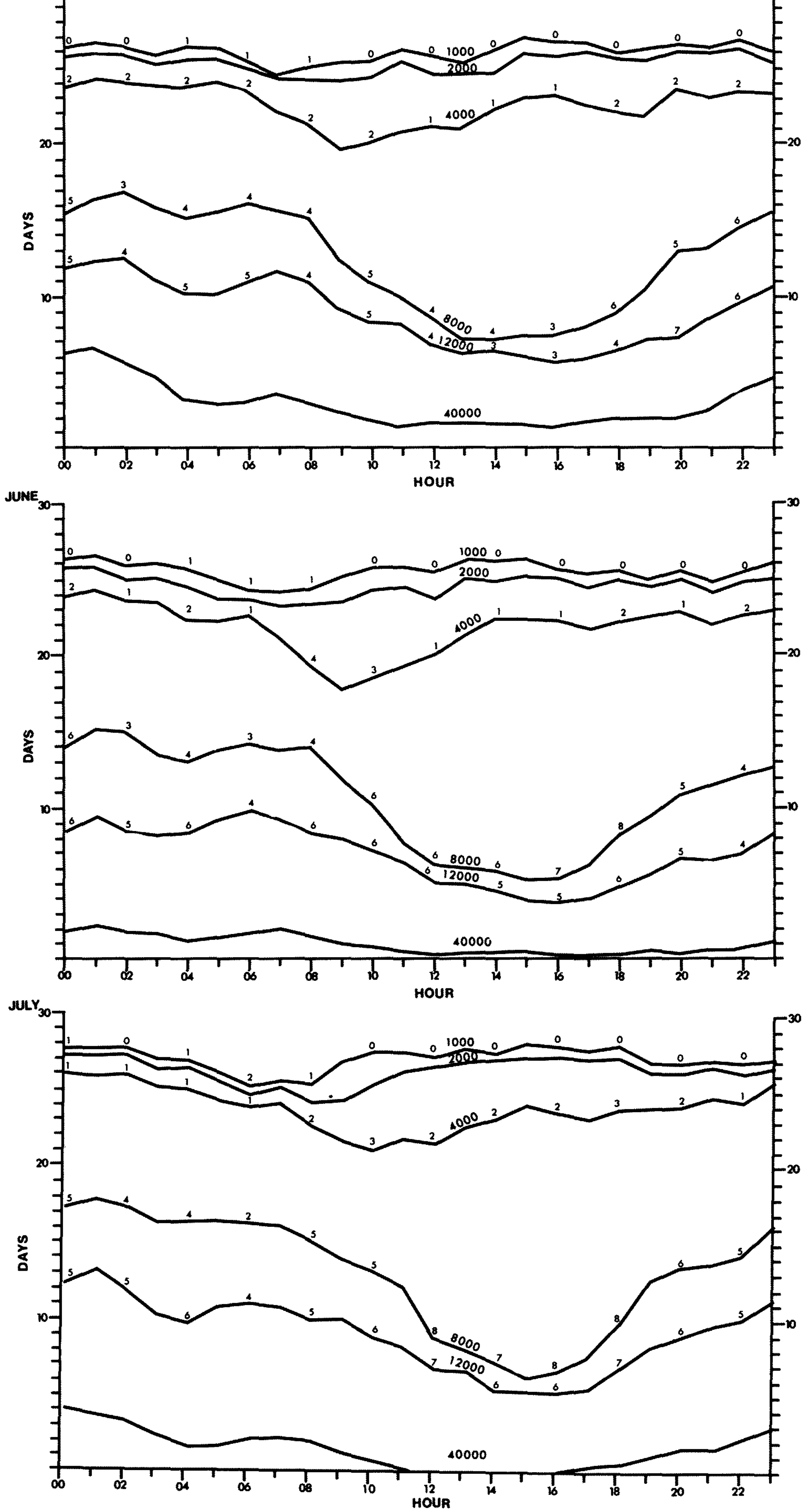

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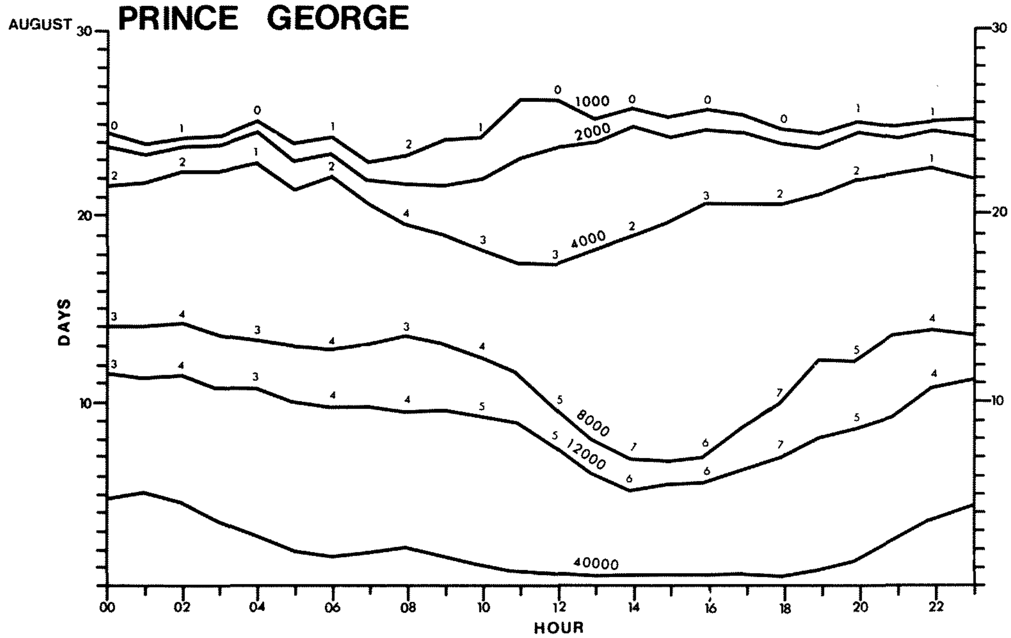

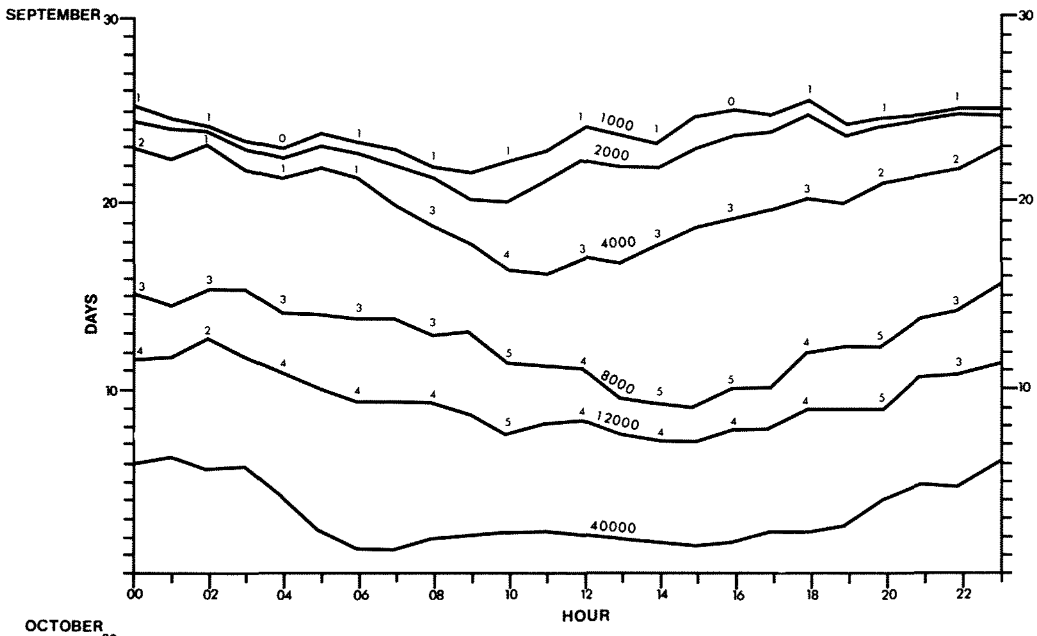

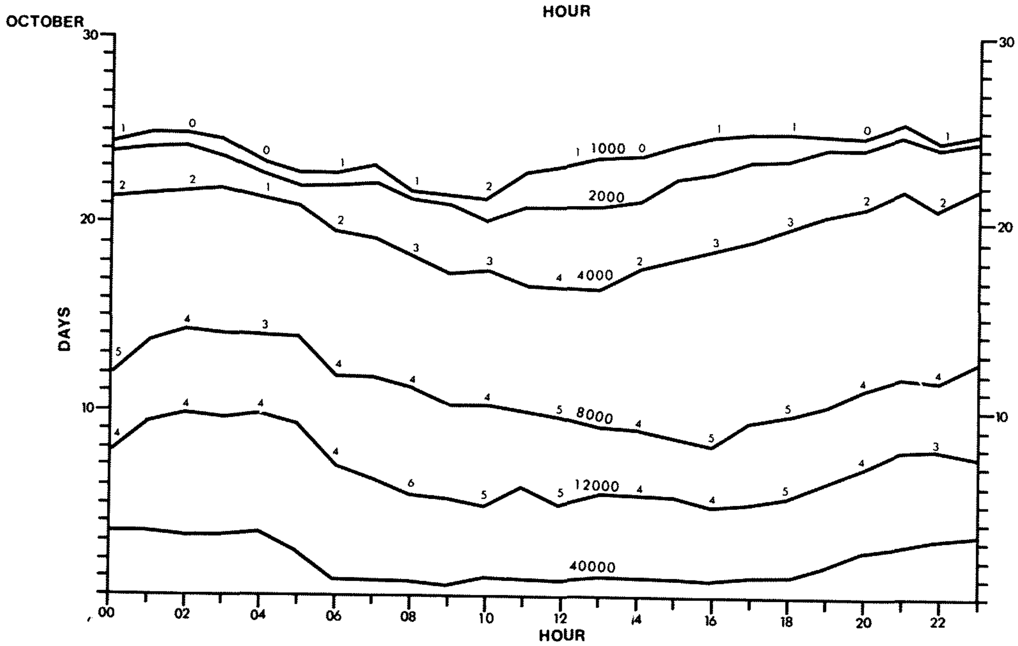

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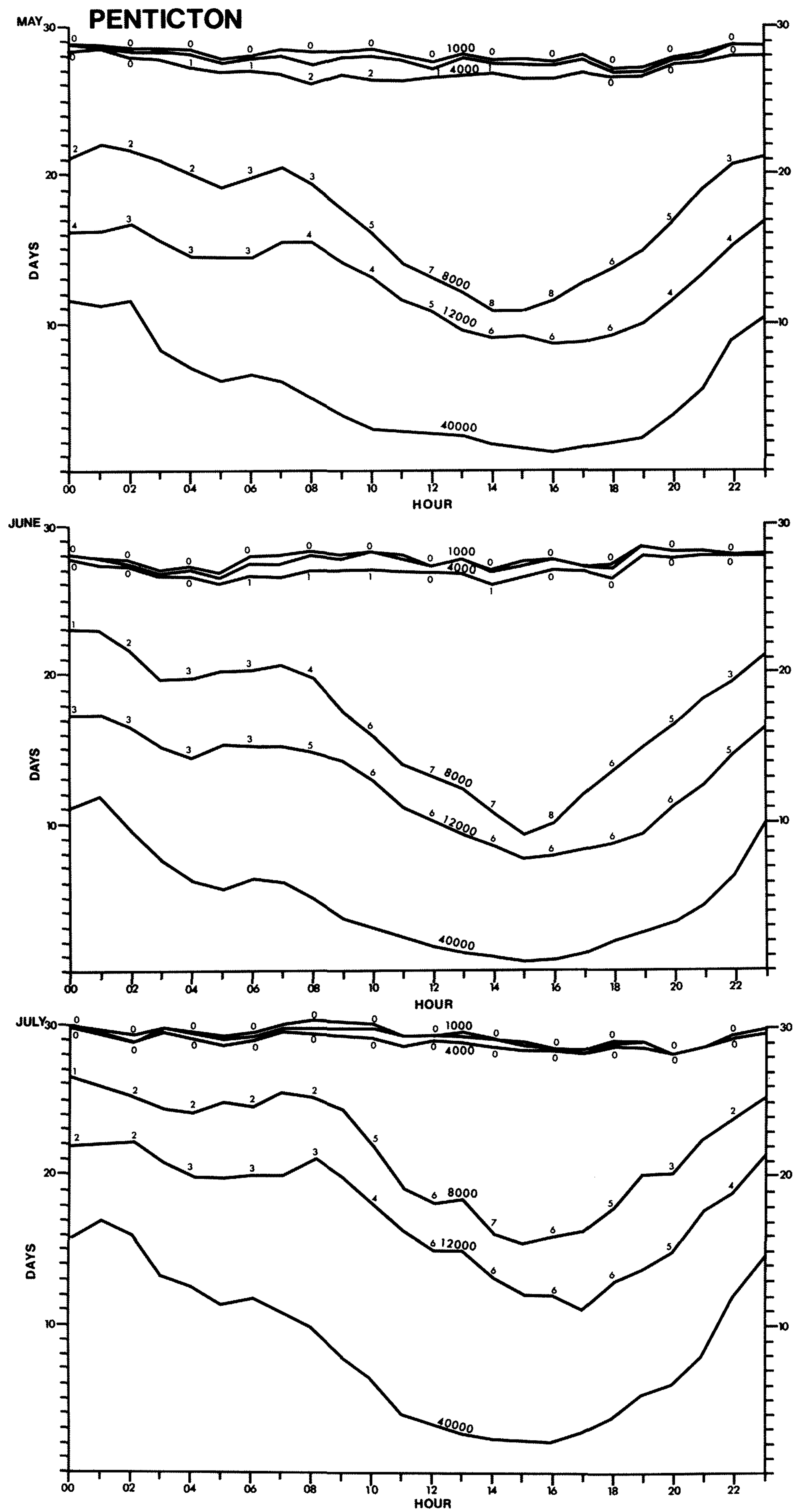
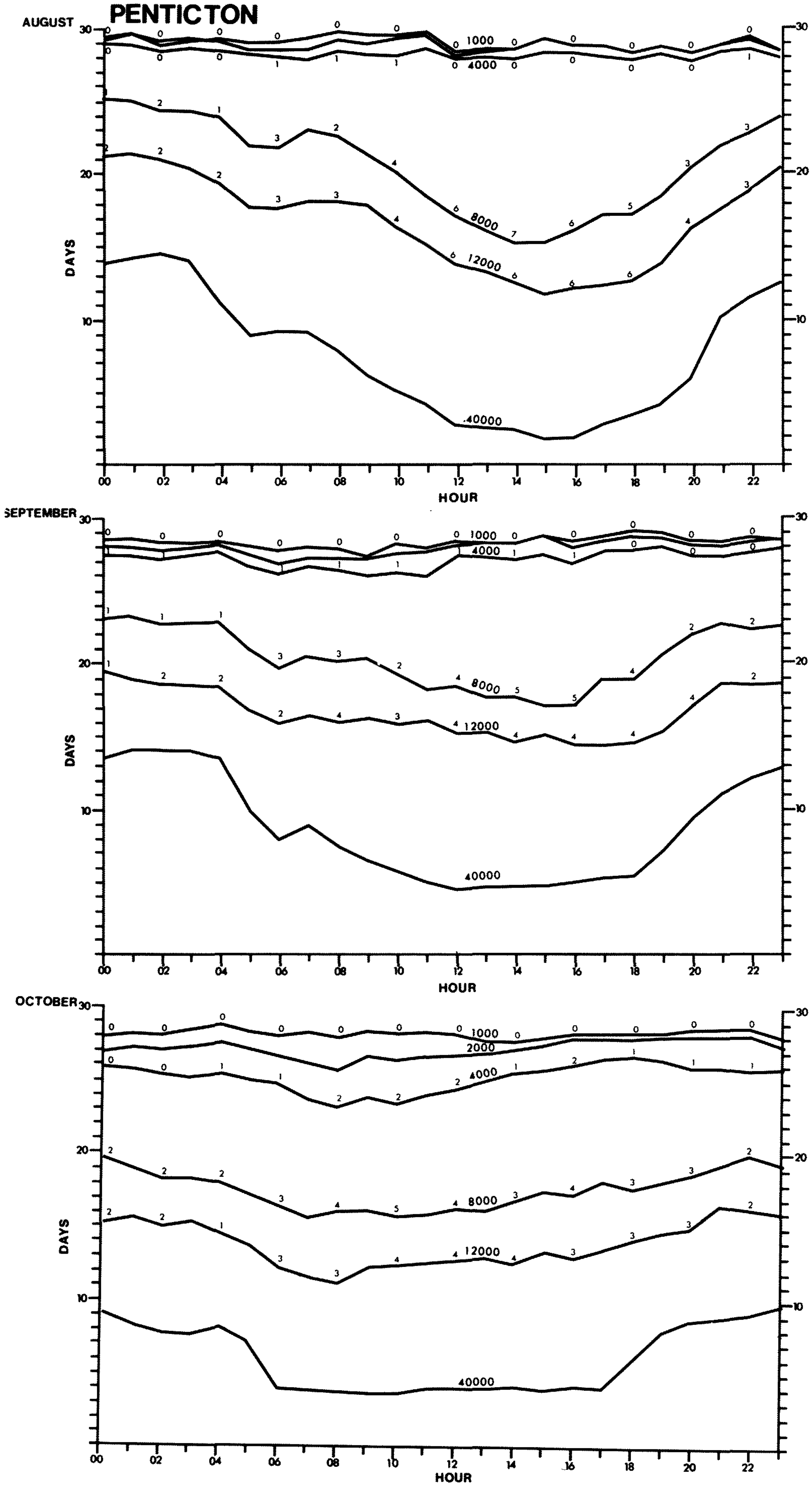


PENTICTON



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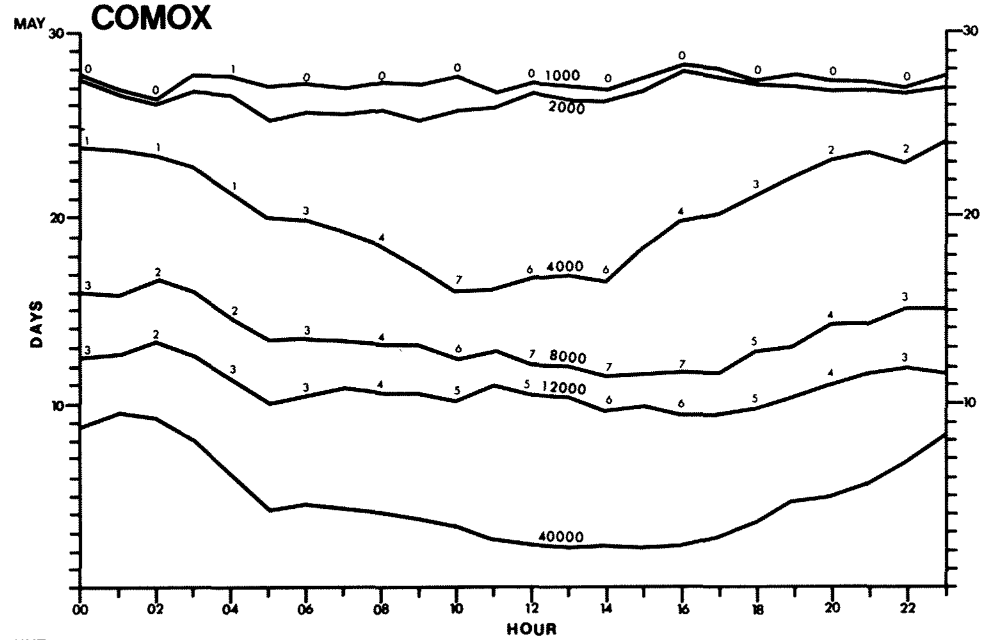
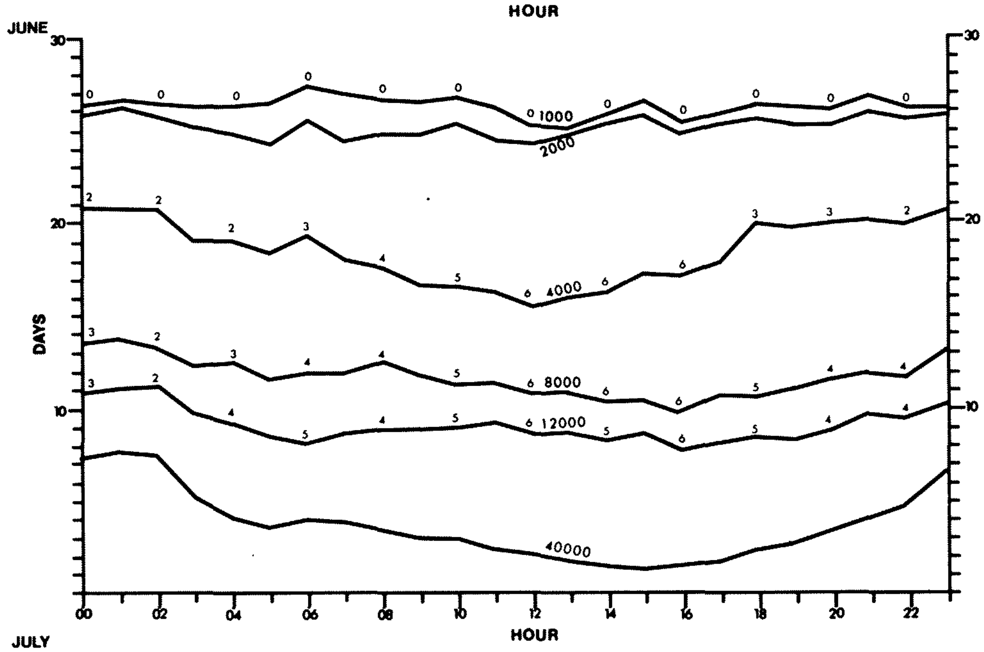
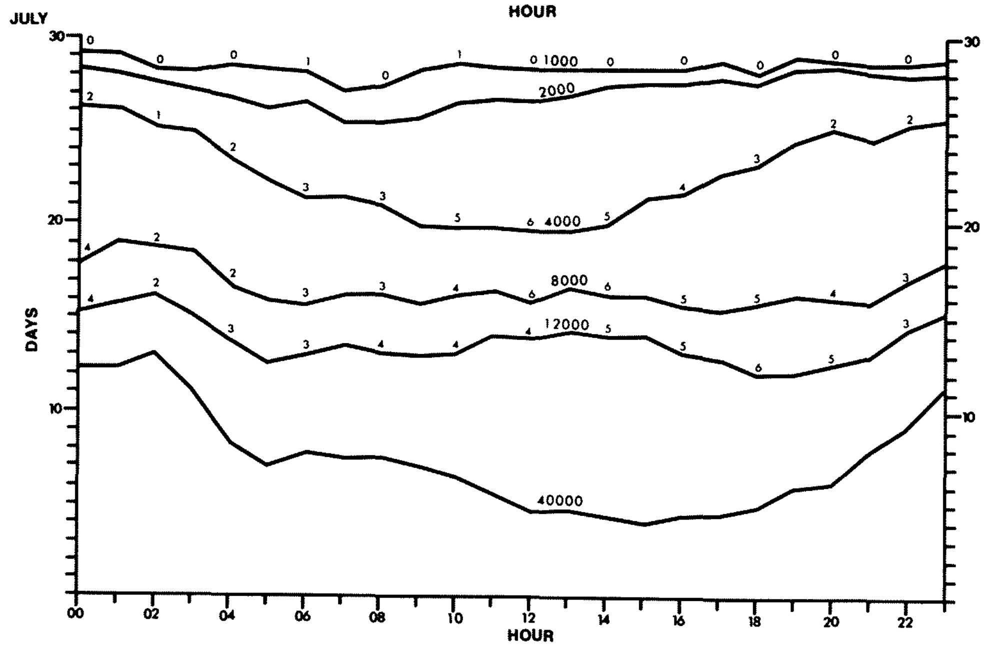
COMOX







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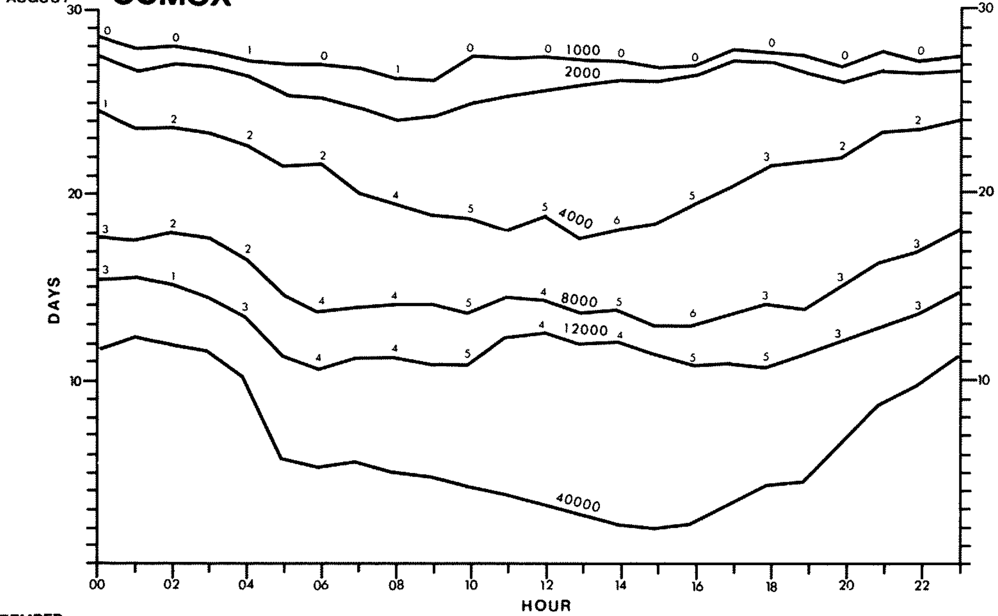

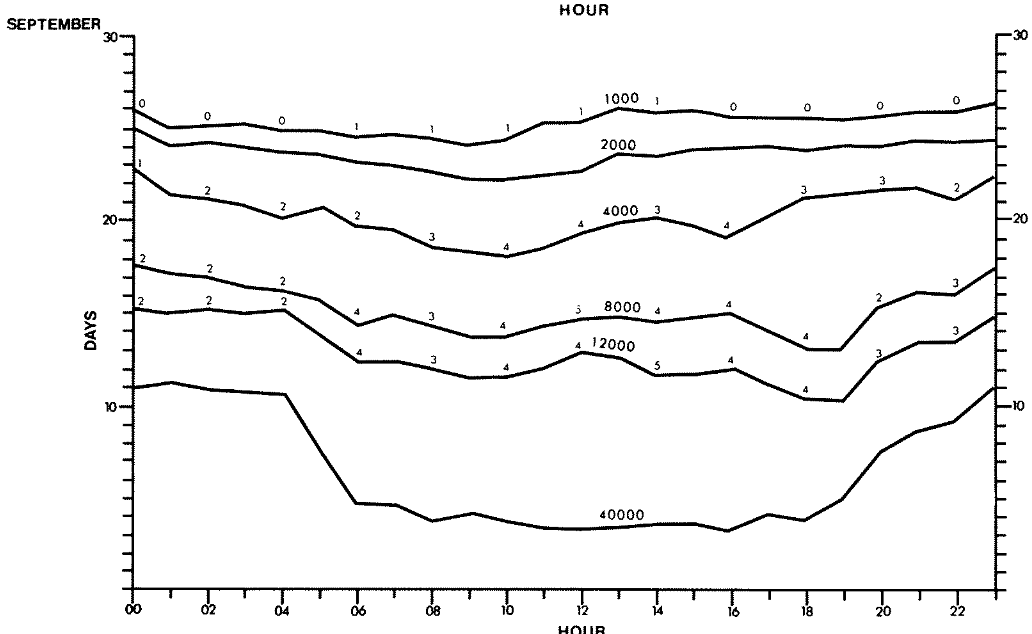

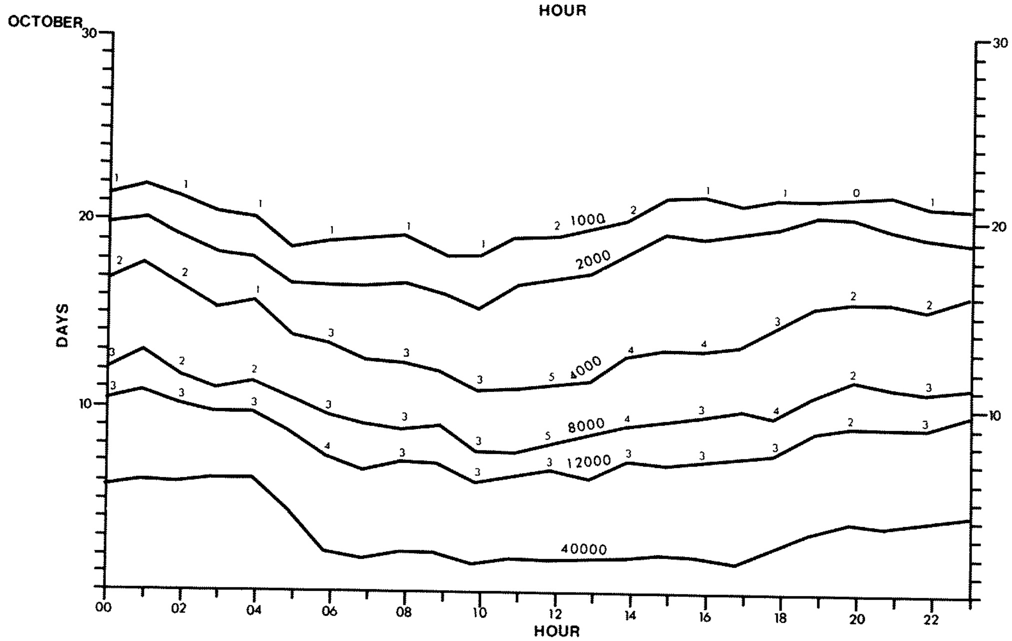

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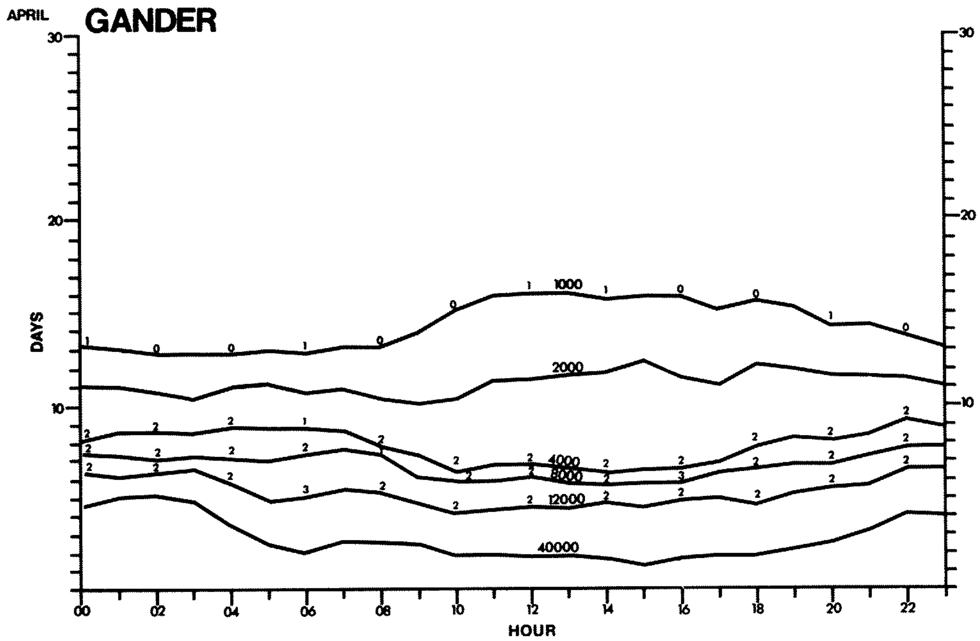

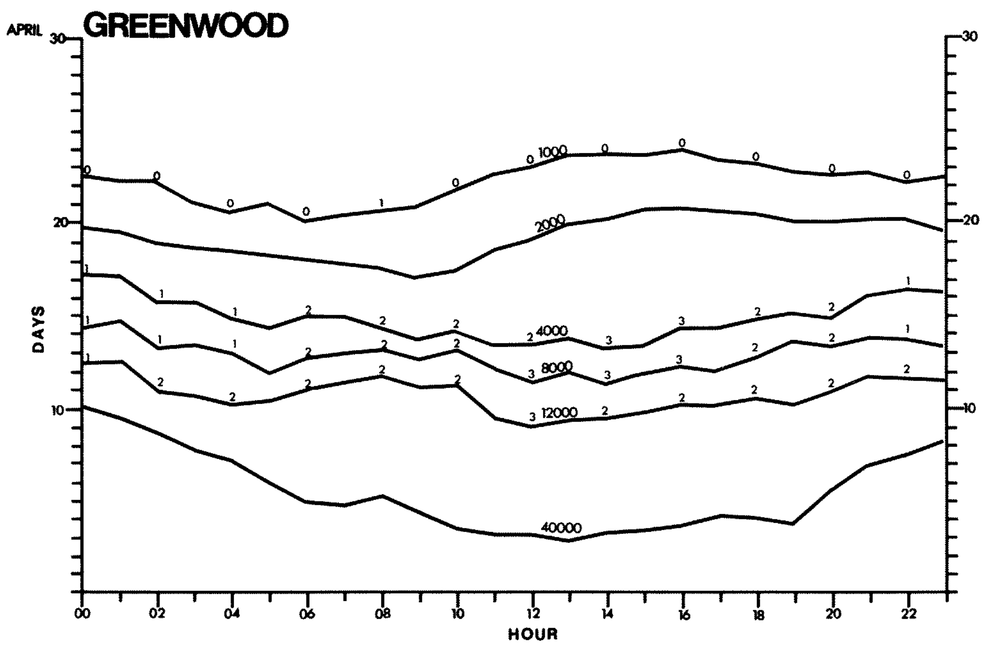

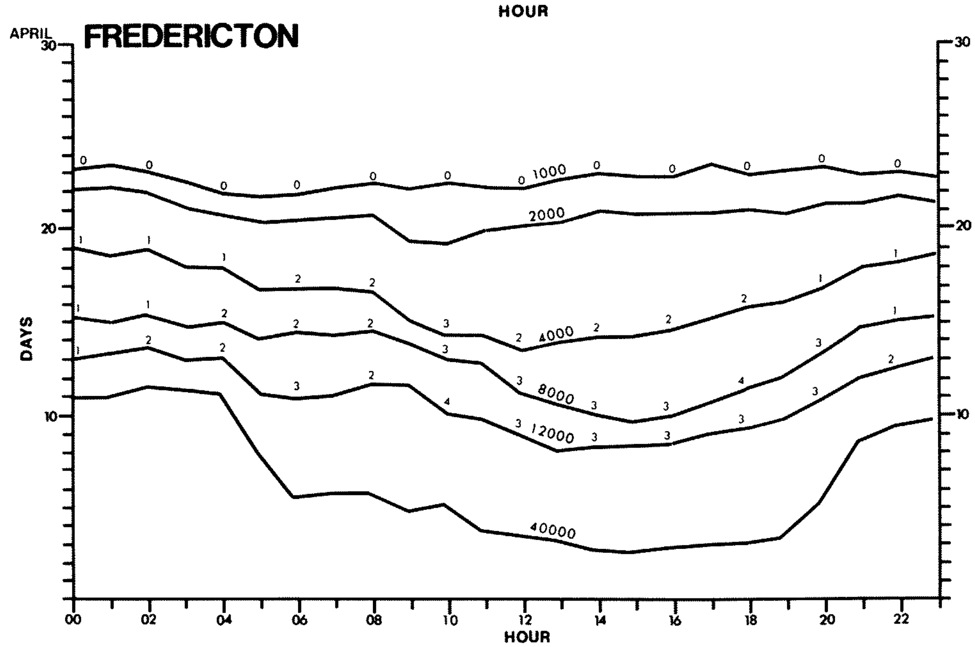

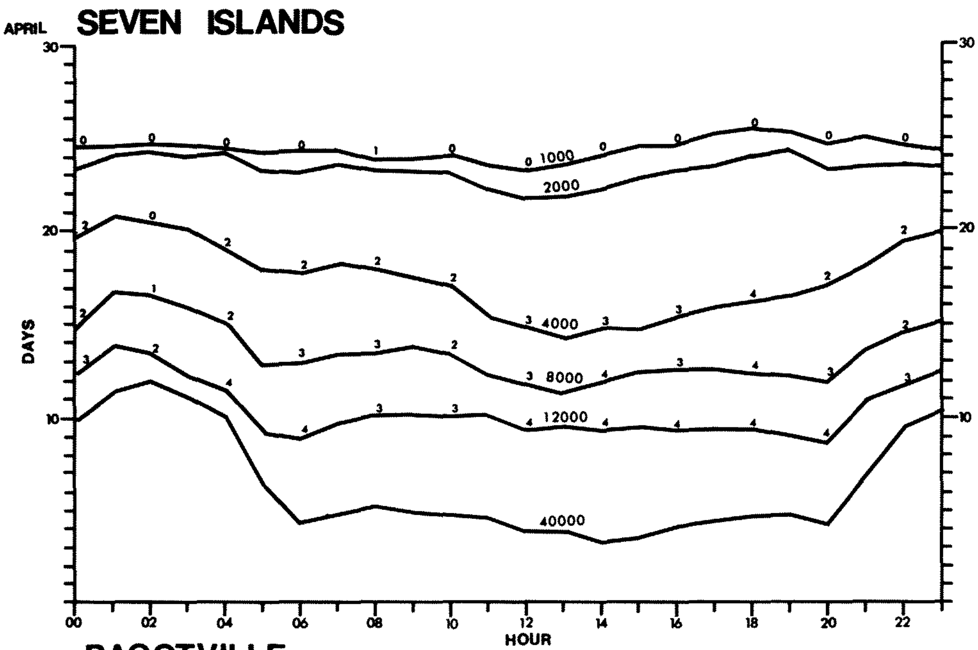

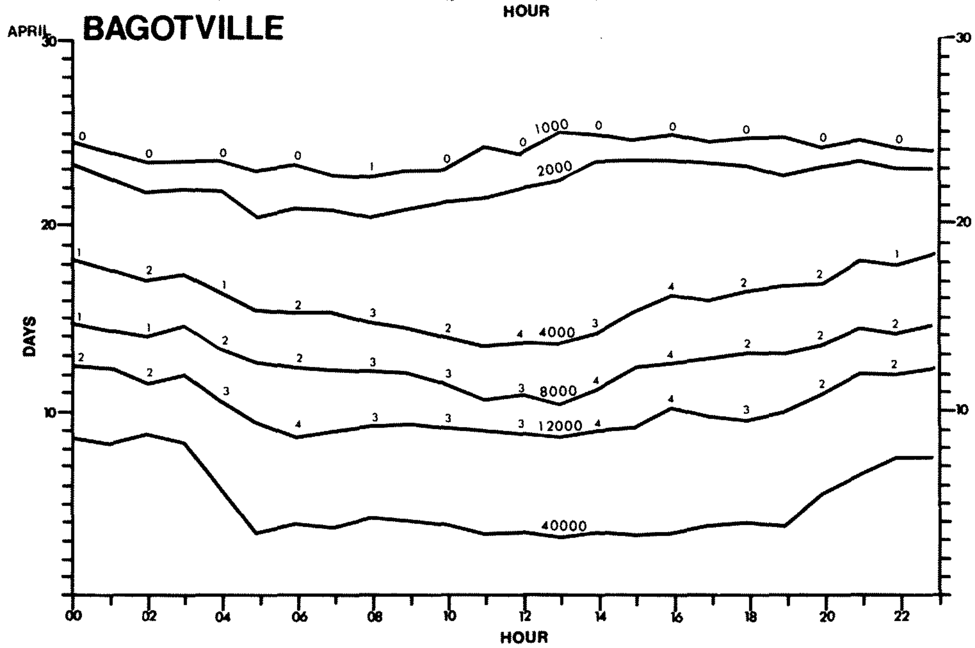

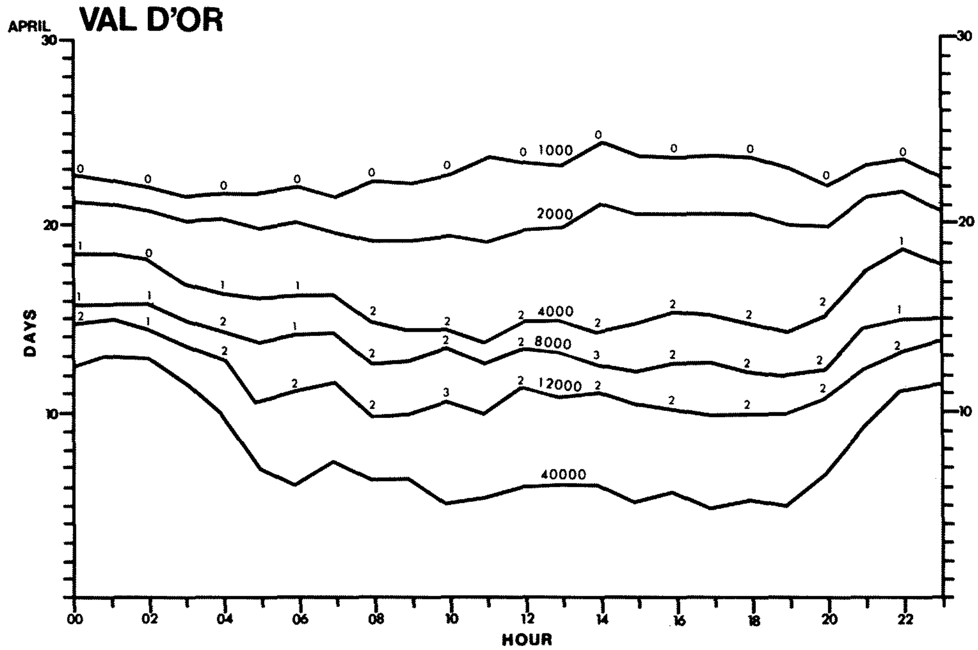

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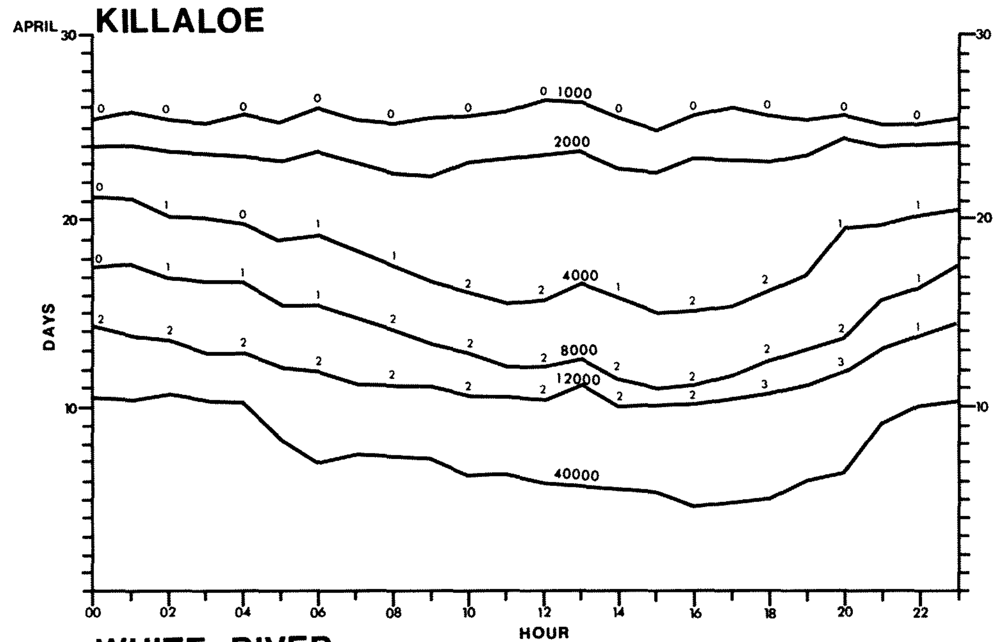
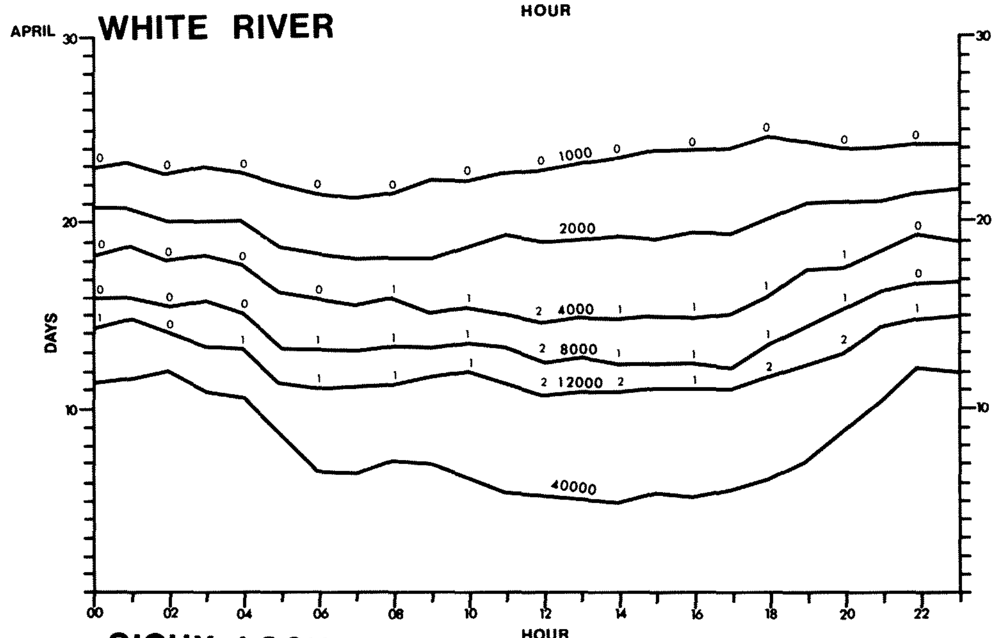
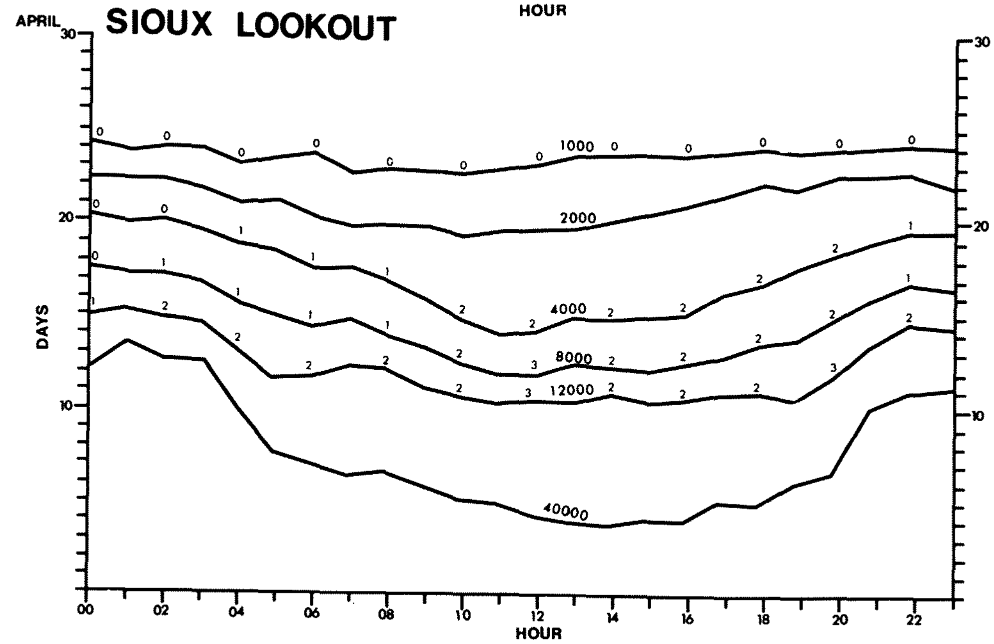
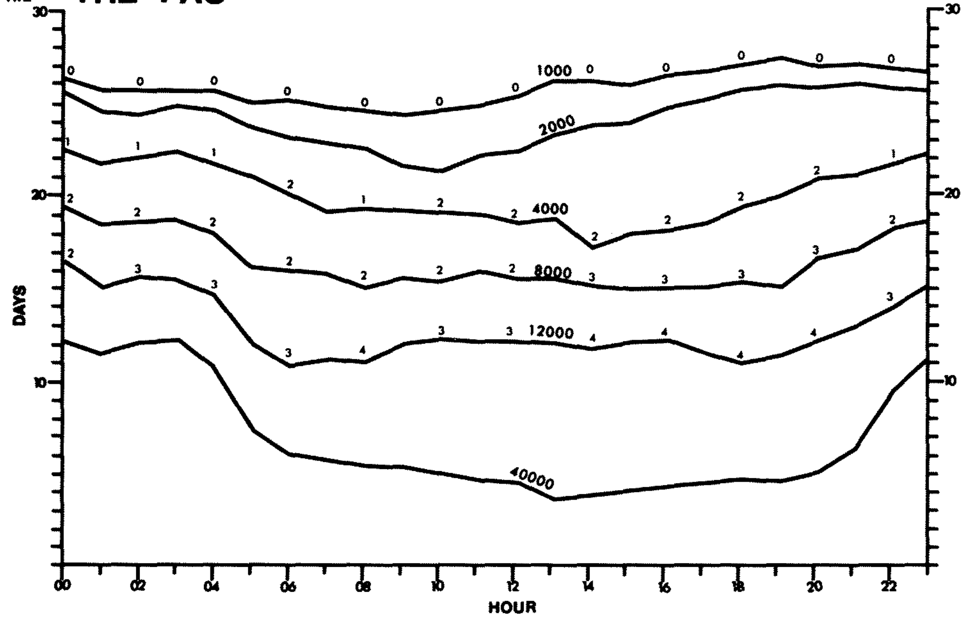






APRIL **THE PAS**



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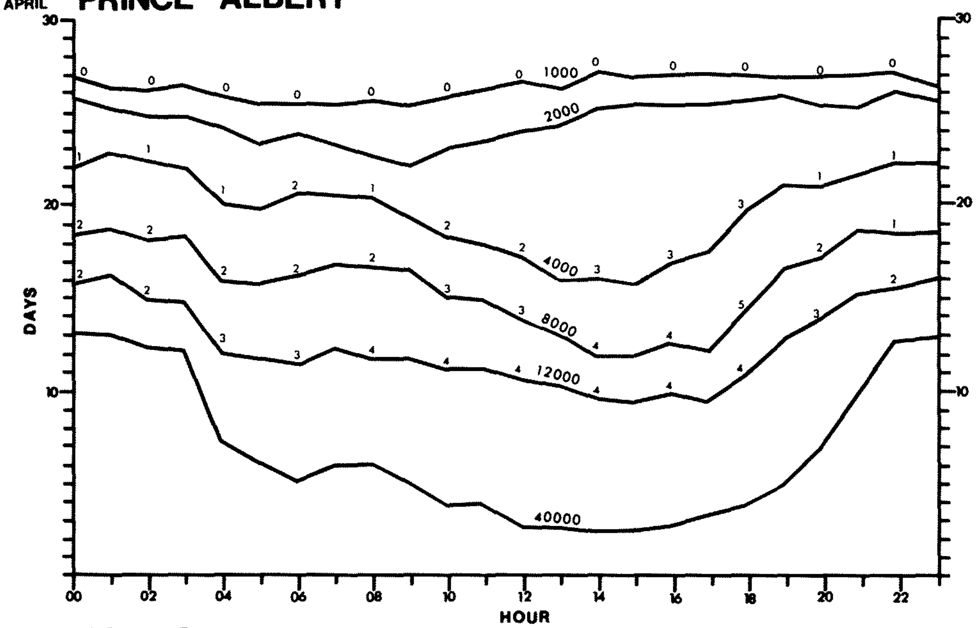

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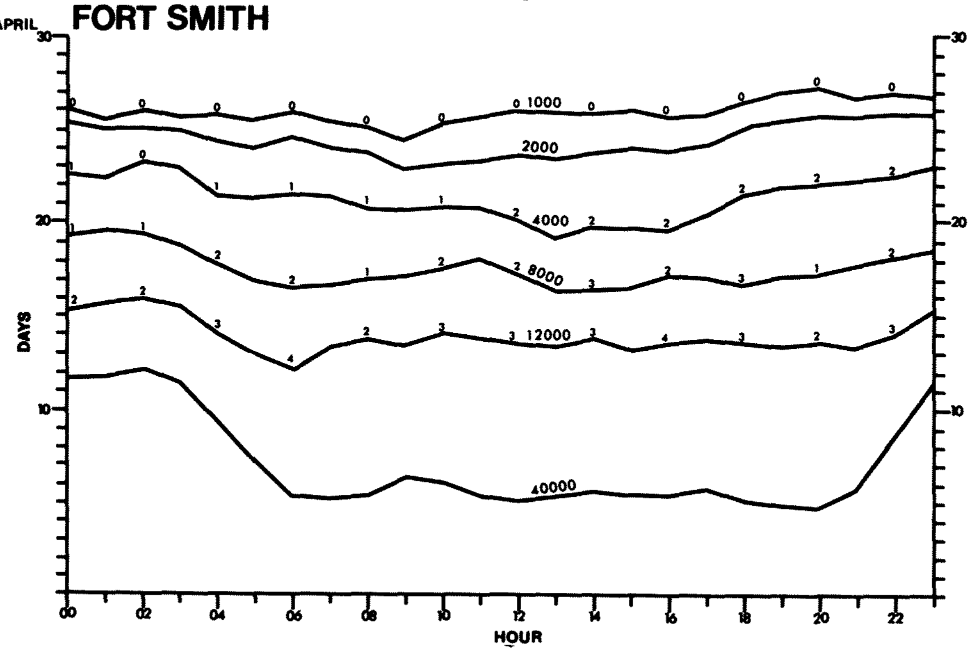

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(for each hour of the day)

when cloud amount

below specified height

(in feet above ground)

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of the sky.

Digits above graph points

for even numbered hours

show number of days

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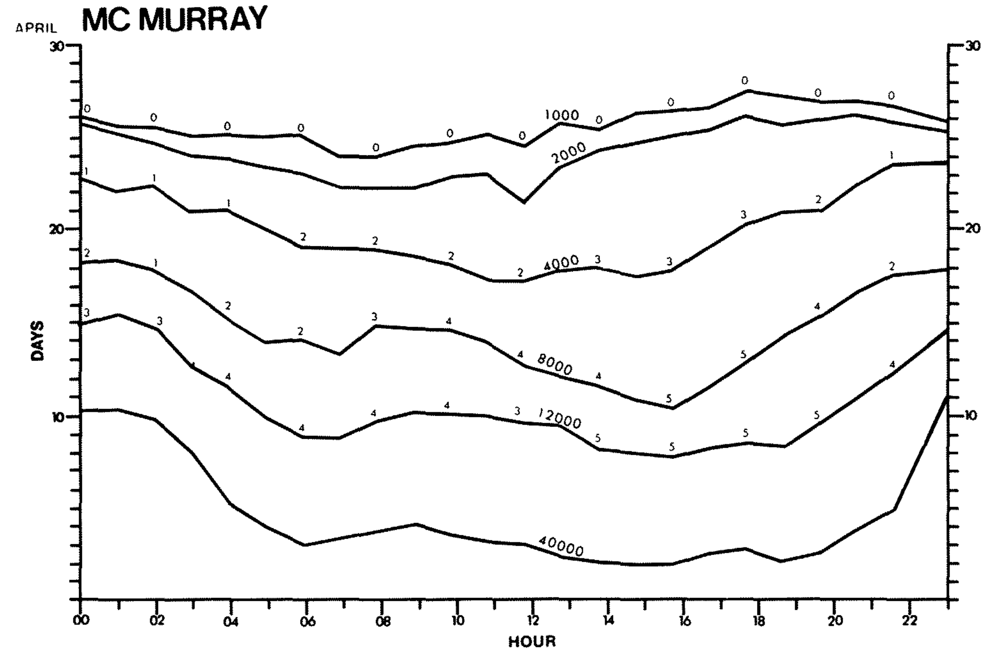
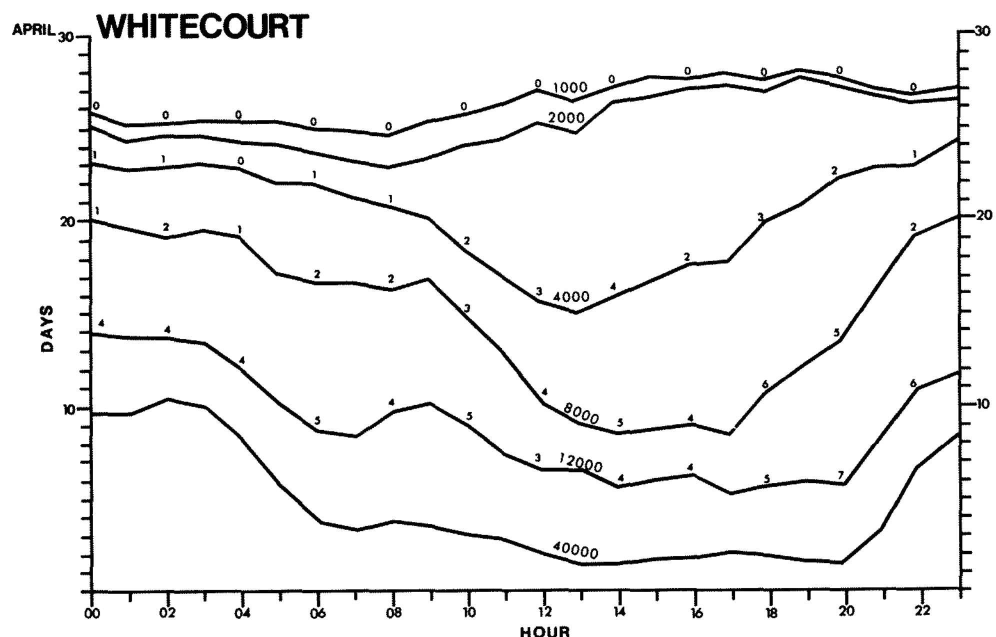
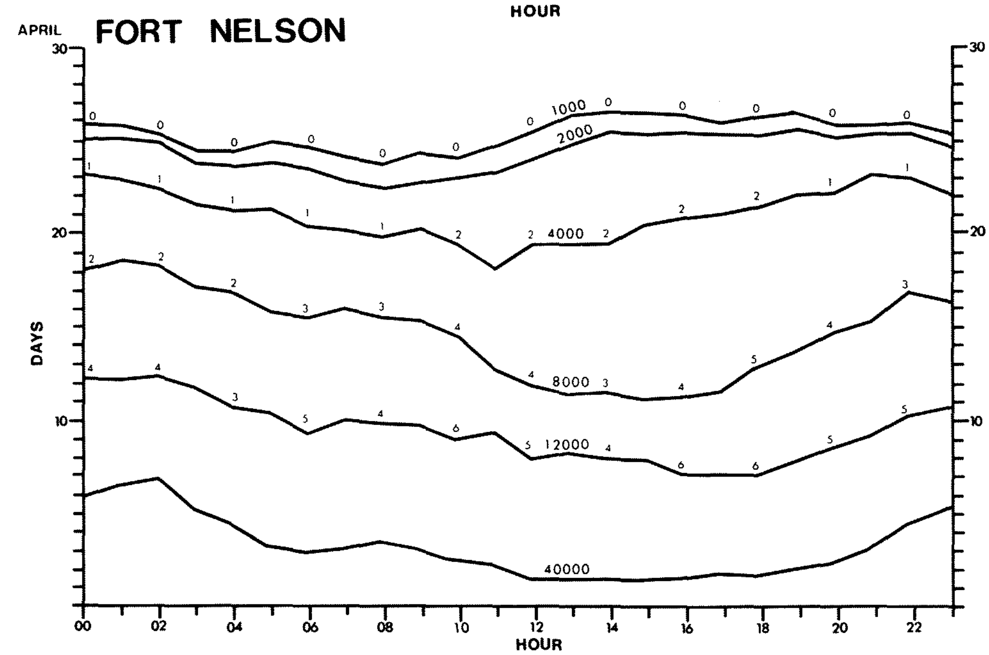
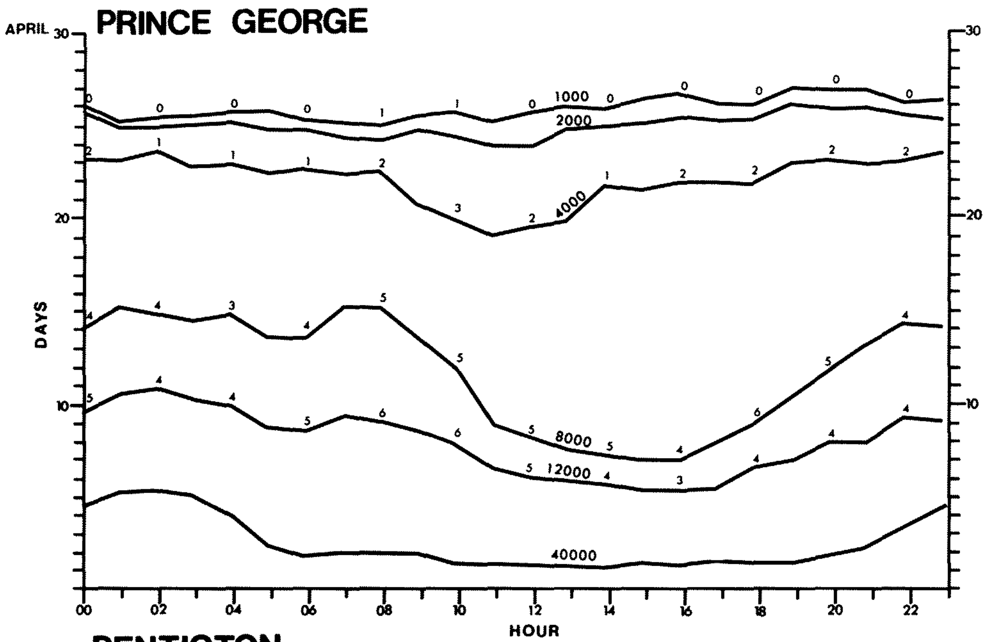
covers 2/10 or 3/10

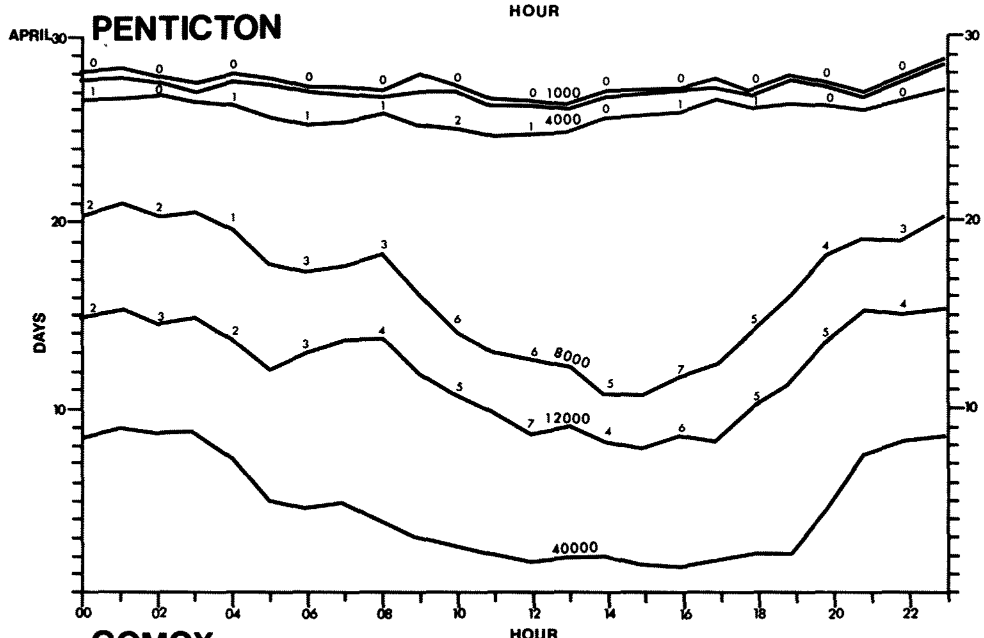
of the sky.

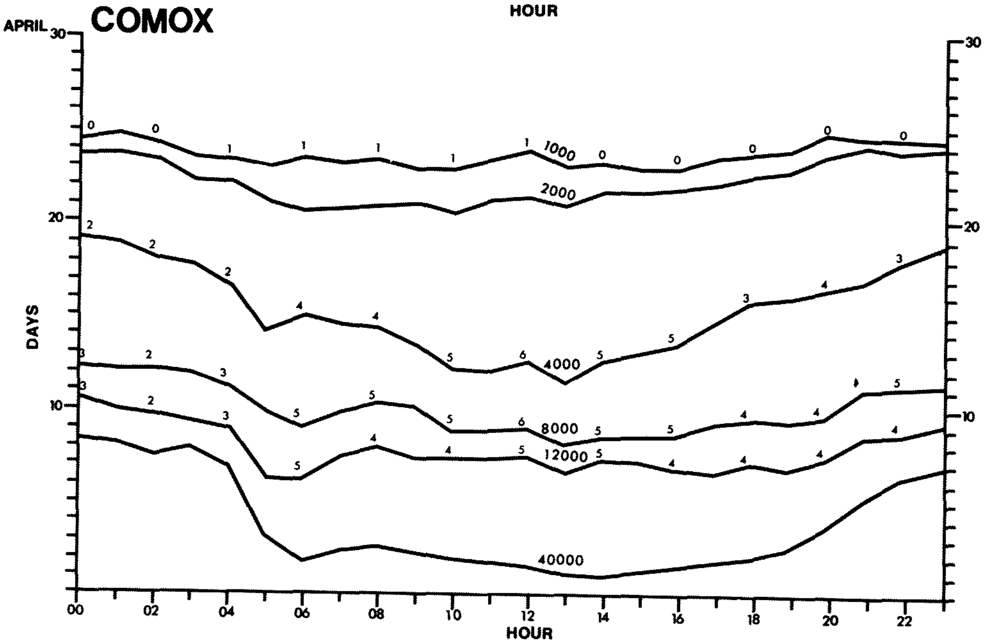












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