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THE UNIVERSITY OF CHICAGO

DEPARTMENT OF METEOROLOGY

PRELIMINARY REPORT ON THE DEVELOPMENT OF THE ANIMATED MOTION PICTURE IN MESOMETEOROLOGY

by

Tetsuya Fujita

Technical Report Number 6

to

United States Weather Bureau
(Contract Number Cwb 9530)

June 1959

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1. INTRODUCTION

Since August, 1953, the writer has been investigating mesoscale systems and features, such as squall lines, organized convective systems, tornadoes, hurricane rainbands, etc. Hundreds of charts and diagrams have been analyzed so far for the purpose of describing the behavior of the atmosphere in two- or preferably three-dimensional representations.

Standardization of analysis charts and time section sheets was introduced a few years ago; thereafter the standard size $8\frac{1}{2}$ x 11 inch tracing paper was used, unless other sizes were required for some reason. This standard size, first considered too small, now appears to be a very handy size for handling and analyzing the charts. These charts are kept flat, without being rolled or unrolled, in standard size folders from which they are easily pulled out at the time of use. Meteorologists and plotters were continuously trained to do fine and artistic meteorological work on sheets of such small size.

The writer learned that character animation and background painting are made on very small sheets, such as 10 x 15 inches in size, which are filmed for the use of commercial 35 mm movies. Therefore, it seemed justifiable to use $8\frac{1}{2}$ x 11 inch charts for 16 mm animated pictures. Although it was known that hourly charts, when filmed, would look too jumpy and too fast on a screen, a test film of three sequences of such charts was made with the use of a tripod-fixed movie camera. The result, although it turned out as expected, led the writer to take one step toward the production of animated weather charts by adding in-between charts.

This report will include a description of the animation instrument and techniques being developed by the writer.

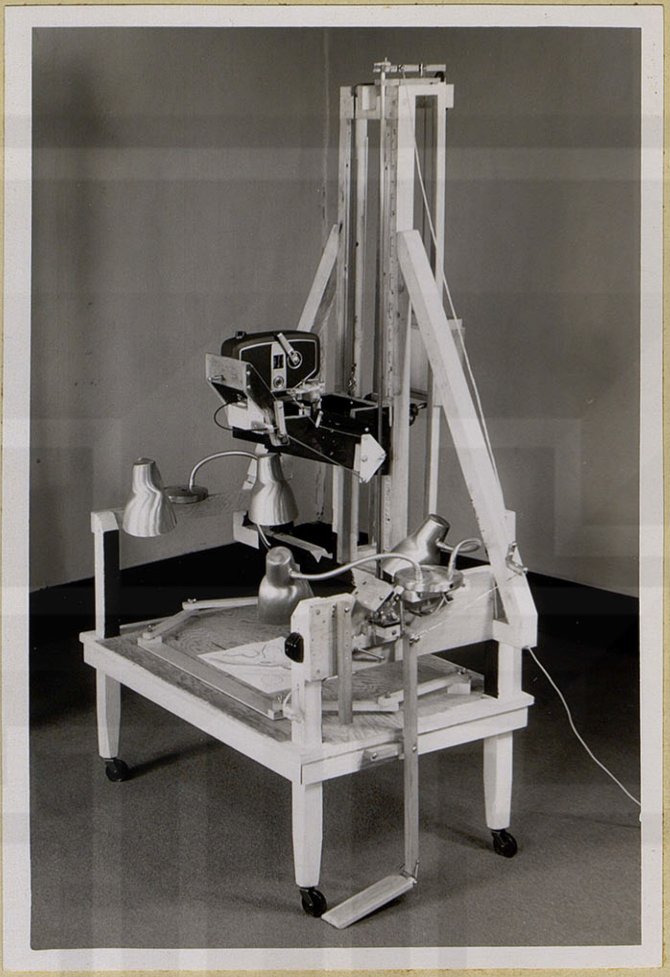
2. ANIMATION EQUIPMENT

An animation titler designed and constructed by the writer is shown in Fig. 1. This titler is capable of mounting either an 8 mm or a 16 mm movie camera in horizontal position, and consists of an electric switch to control light intensity on the animated chart and of a mechanical system to operate the camera shutter. The height of the camera above the chart to be filmed may be changed continuously between 10 and 36 inches.

This titler can be operated by using the hand lever or the foot lever designed to pull the electric switch down, lighting four hundred-watt photoflood light bulbs, and, after a few tenths of a second, pressing the camera shutter. The adjusted time lag between the electric contact and shutter operation is about 15 microseconds during which the color temperature of the bulbs goes up to 3400° F.

The mechanical parts of the titler are designed to be very firm and absolutely dependable; even a single mistake in an entire operation should be avoided. The time lag adjustment loop allows a very short delay before the mechanical connection to the connecting rod is set in motion. When the connecting rod, counterweighted by the balancing spring, is depressed, the connecting screw, adjustable but tightened, turns the shutter plate which operates the camera shutter. Either 8 or 16 mm cameras can be used.

The electrical system of the titler is operated by a lever to which a spring is connected which pulls a knife switch down. This switch, in its "up" position, connects the 100-watt bulbs in their series connections, $L_1 - L_2$ and $L_3 - L_4$, exert-



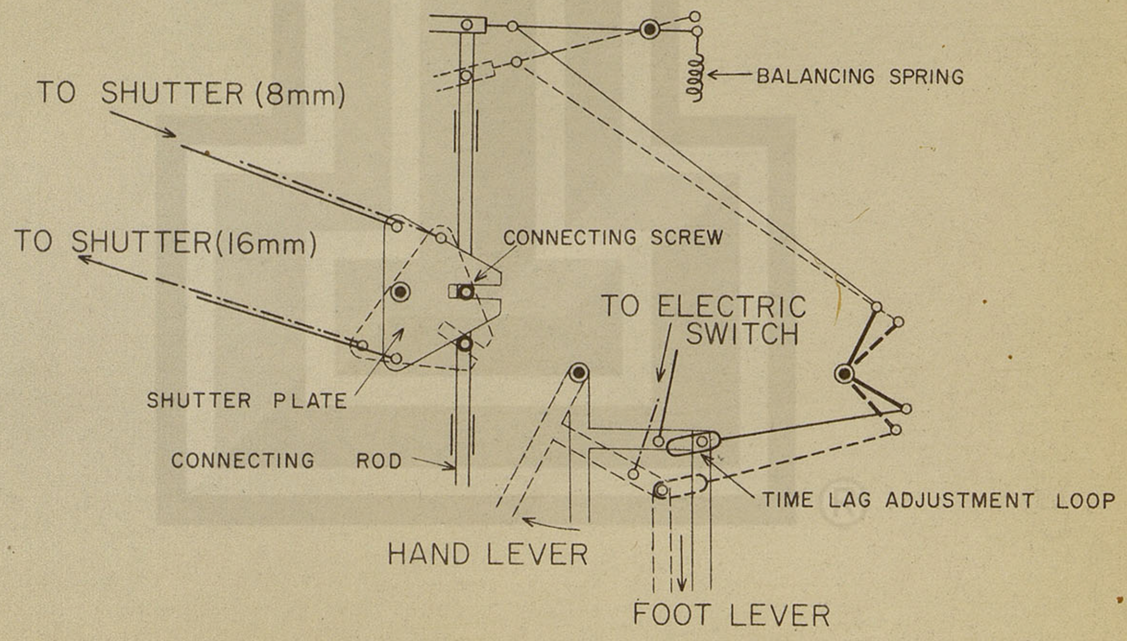
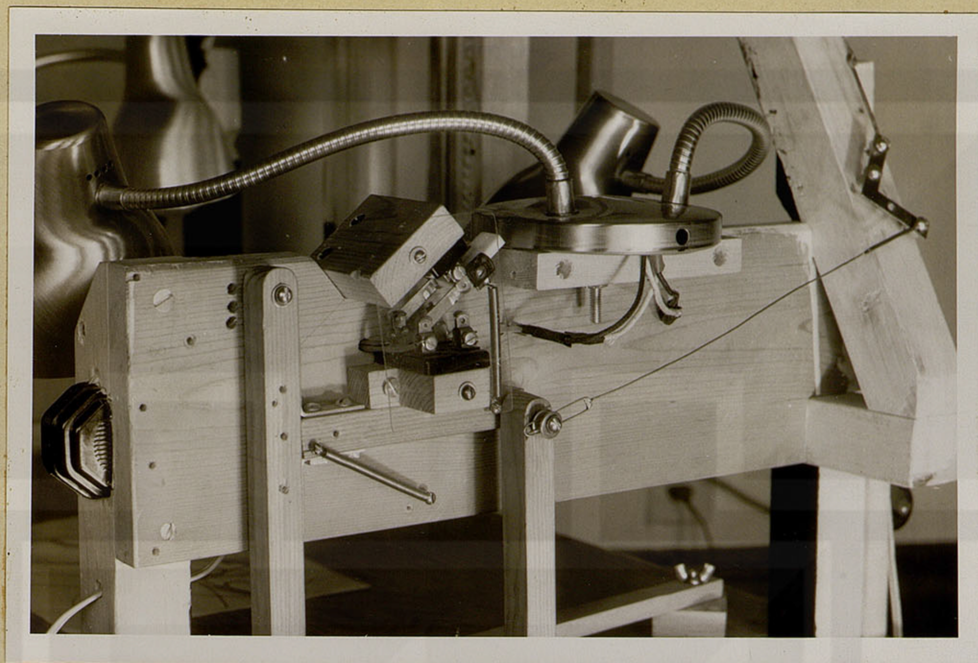


FIG. 1 ANIMATION TITLER



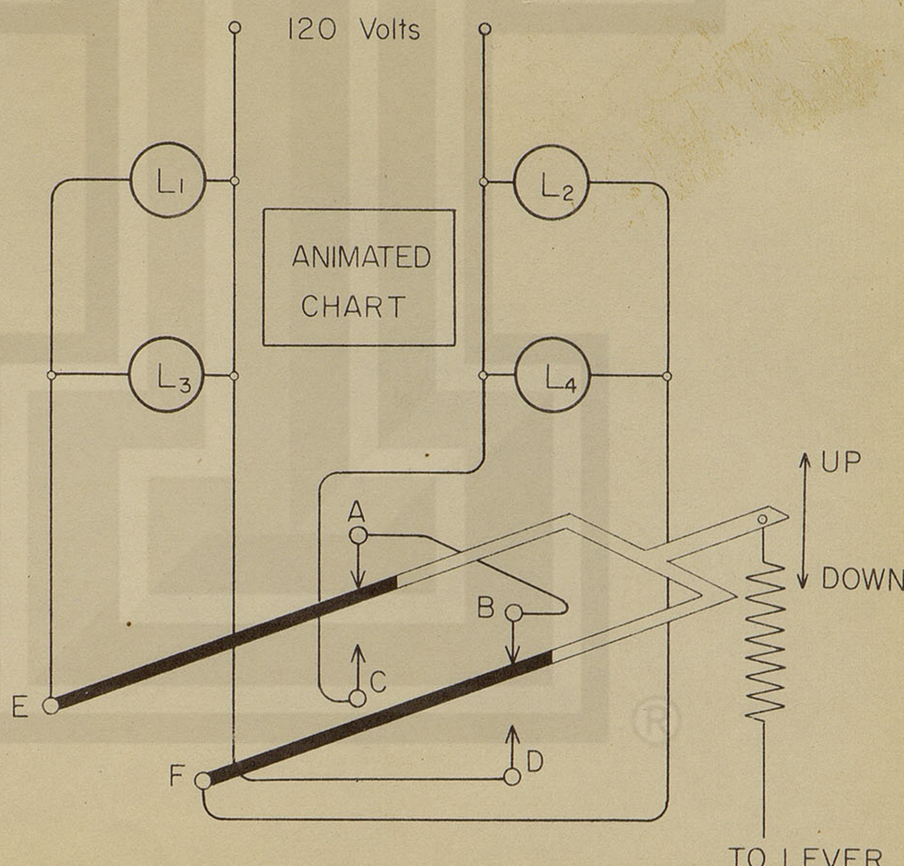


FIG. 2 ELECTRIC SWITCH

ing 60-volt pressure on each of the bulbs. Because of the increase in resistance of tungsten filament with rising temperature, each of the four bulbs will be lighted with a power of about 40 watts. The titler is thus illuminated by four 40-watt bulbs when its lever is left untouched. The color temperature of the bulbs at this time is very low, with yellowish light quality; this is, however, an ideal illumination while changing charts for the following shot.

The "down" position of the switch is reached by stepping on the foot or by pulling the hand lever forward. This contact immediately changes the series connection into parallel connection, exerting 120 volts on each of the four bulbs. The color temperature rises to 3400° F within one-tenth of a second.

The life of the photoflood bulbs is very short, on the order of hours under normal operation, and it is not practical to use them to their full brightness. The electric system does prevent the bulbs from burning out, and at the same time the series circuit illumination gives the photographer a complete picture of how a chart or drawing would appear under intensified illumination. The images of bulbs or other shiny objects attached to the titler, which might appear as a result of reflection from the surface of a plastic sheet or a glass plate, will not appear on the film if the images are carefully eliminated under the illumination of the four 40-watt bulbs.

The height of the camera above the chart to be photographed is scaled not only in inches, but also in a series of numbers which are used when the height of the camera is lowered or lifted. The vertical scale with these numbers was computed so that the successive charts, after being filmed, expand or contract at a constant rate.

Let f be the focal length of the camera lens and h the height of the lens above the chart to be filmed. Geometric optics gives the relations:

$$\frac{1}{h} + \frac{1}{b} = \frac{1}{f} \qquad (1)$$

$$\frac{r}{R} = \frac{b}{h} \qquad (2)$$

where b is the distance between lens and film, r and R the radius vectors shown in Fig. 3.

Assuming that the rate of time change in r, the vector on the film, is proportional to R, the length of the vector on the chart, we have:

$$\frac{dr}{dt} = k\,R \qquad (3)$$

where k is a constant expressing the expansion rate of the filmed charts. Assuming that b is approximately equal to f, and differentiating equation (2) with respect to t, we have:

$$\frac{dr}{dt} = -R\,f\,h^{-2}\,\frac{dh}{dt} \qquad (4)$$

Next we eliminate $\frac{dr}{dt}$ by using equation (3):

$$-h^{-2}\,dh = \frac{k}{f}\,dt$$

After integrating both sides, we determine the integration constant; thus the height may be expressed by:

$$h^{-1} = \frac{k}{f}\,t + h_o^{-1} \qquad (5)$$

where h_o is the initial height of the camera lens.

The titler designed by the writer has dimensions of h_o = 100 cm and f = 2 cm. Putting these values in equation (5), we arrive at:

$$h^{-1} = \frac{1}{2}\,k\,t + \frac{1}{100} \quad \text{(cm)} \qquad (6)$$

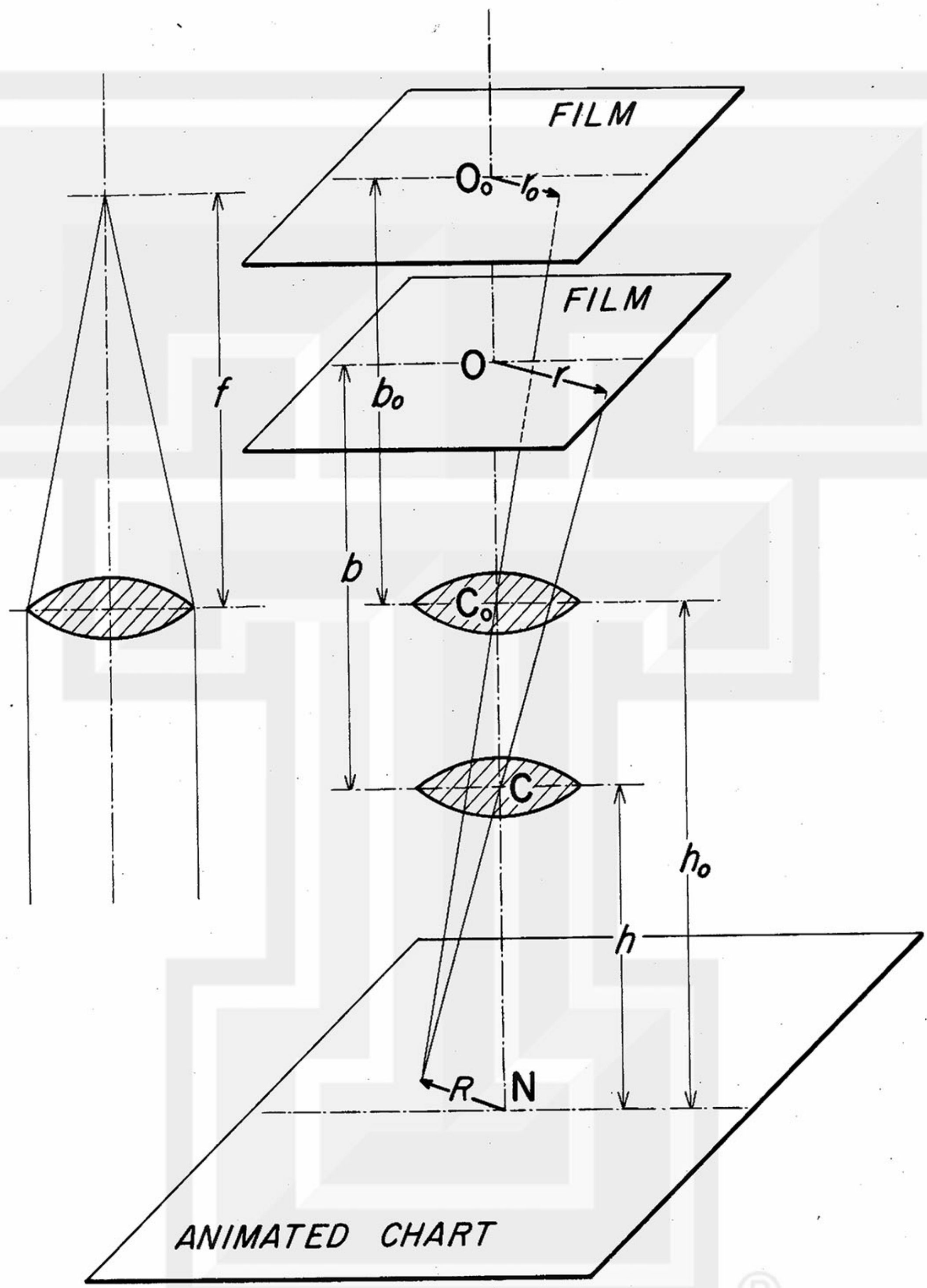


FIG. 3

The time required to lower the camera from its highest position, h_o, to 30 cm, the lowest position, is obtained as:

$$\frac{1}{30} = \frac{1}{2} k\, t_m + \frac{1}{100}$$

$$t_m = \frac{7}{150} k$$

Experience showed that tm = 5 sec gives fairly smooth expansion of the chart on a screen. This rate, therefore, was used as a standard scale. Actually, 76 pictures will be taken during a descent from 100 cm to 30 cm. The height of the camera lens at intervals of 1/16 sec is tabulated in Table I.

Pictures of both 8 mm and 16 mm cameras in operation are shown in Fig. 4. The single frame shutters of these cameras are connected to the shutter plate by means of a metal wire which pulls (8 mm camera) or pushes (16 mm camera) to open the shutter. A test operation showed that the mechanical links are very dependable: not a single erroneous operation occurred in 3,000 repeated tests.

A size conversion gadget was designed and made. A photograph appears in Fig. 5. By using this gadget with attachments, black and white negatives can be made from:

A. 35 mm color slides

B. 35 mm movie films

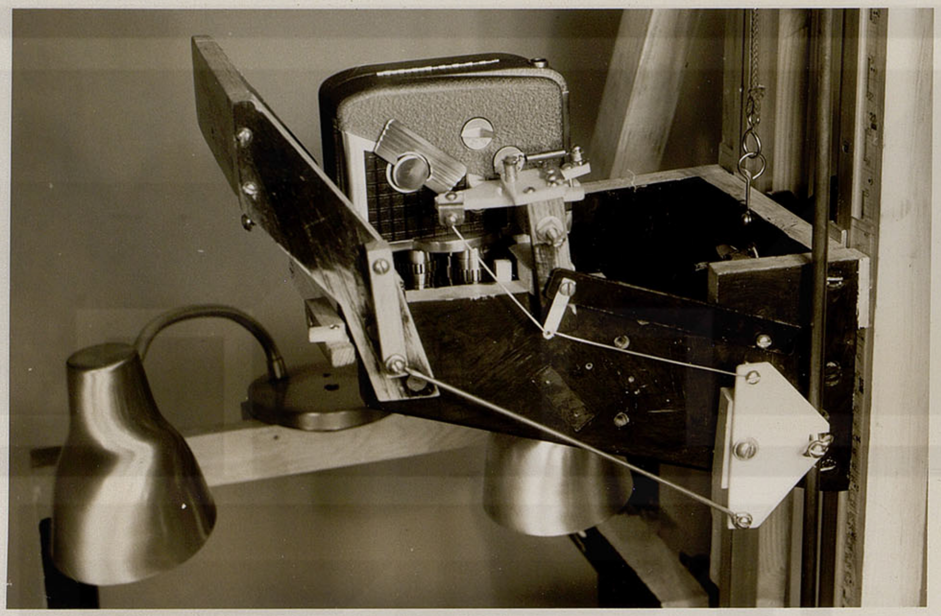
C. 16 mm movie films

D. 8 mm movie films

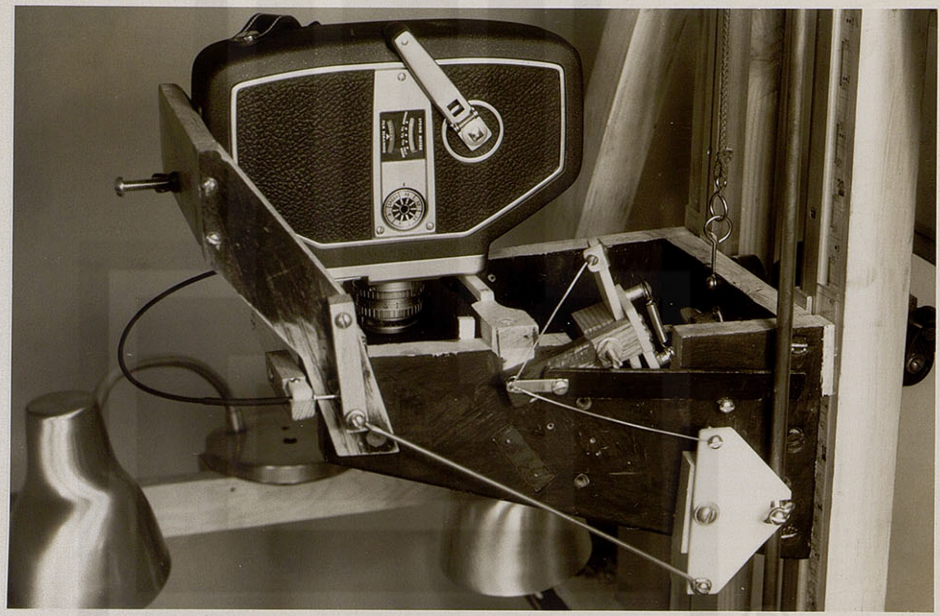
Conversion of the film size is required in animating meteorological characters, such as tornadoes, waterspouts, etc. Most of the Fargo tornado pictures have been converted into 35 mm negatives.

3. CHARACTER AND CHART ANIMATION

The result of this chapter was presented at the A.M.S. National Meeting in



8 MM CAMERA



16 MM CAMERA

FIG. 4 MOVIE CAMERAS IN OPERATION

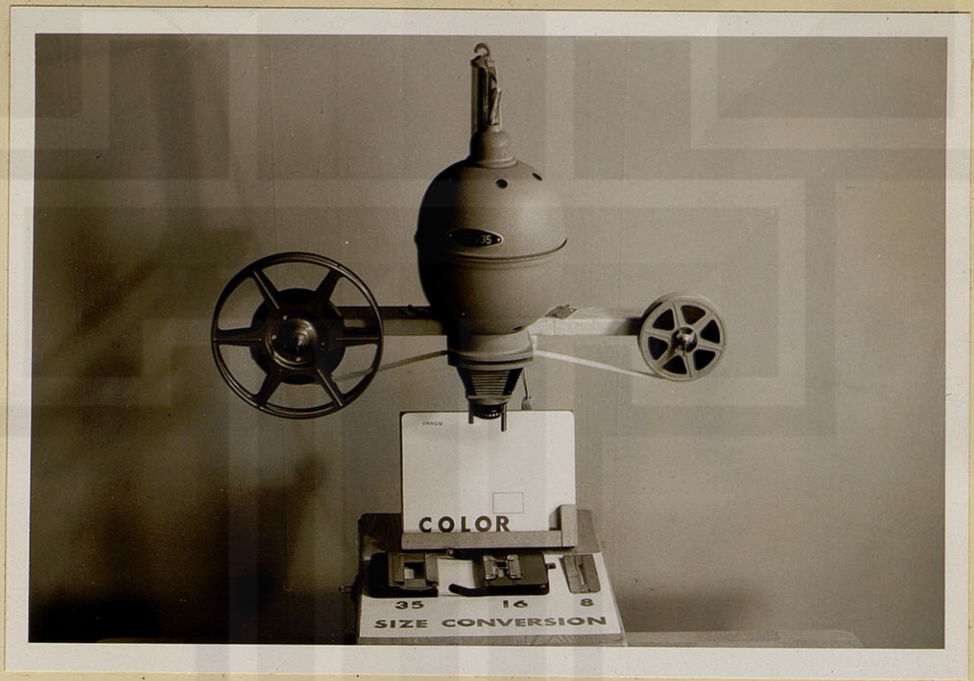


FIG. 5 SIZE CONVERSION EQUIPMENT

Time	0 sec	1 sec	2 sec	3 sec	4 sec
0/16 sec	100.0	66.7	50.0	40.0	33.3
1/16	97.2	65.4	49.2	39.5	33.0
2/16	94.5	64.1	48.4	39.0	32.7
3/16	91.9	62.8	47.7	38.5	32.4
4/16	89.5	61.6	47.0	38.0	32.1
5/16	86.2	60.4	46.3	37.6	31.8
6/16	84.0	59.3	45.6	37.2	31.5
7/16	81.9	58.2	45.0	36.8	31.2
8/16	79.9	57.1	44.4	36.4	30.9
9/16	78.0	56.1	43.8	36.0	30.6
10/16	76.1	55.1	43.2	35.6	30.3
11/16	74.5	54.2	42.6	35.2	30.0
12/16	72.8	53.3	42.0	34.8	29.7
13/16	71.2	52.4	41.5	34.4	29.4
14/16	69.6	51.6	41.0	33.0	29.1
15/16	68.1	50.8	40.5	33.6	28.8

Table I. The height of the camera lens above the chart, in cm, tabulated as a function of time.

Washington, D.C., on May 5, 1959.

The 16 mm film, lasting about ten minutes when projected 16 frames per second, consists of:

(A) 24 surface charts at one-hour intervals. (Winds and isobars in black, hourly precipitation in blue.)

Eight frames, four frames, two frames and one frame were photographed per chart. These hourly charts appear in Figures 6 - 31.

(B) 80 surface isotherm charts at 7.5-minute intervals. (Isotherms in orange.)

These charts were photographed one frame, two frames and three frames per chart. It was found that two frames per chart gives the best result.

(C) 196 surface charts at 7.5-minute intervals. (Station winds in black, isobars in purple, mesoscale systems in green, and isotherms in orange.)

The film is made by taking two pictures of each chart covering the period 12 CST, June 20, through 12 CST, June 21, 1957. After the end of the series, the charts were photographed in reversed order in which time runs backward.

(D) 196 700 mb charts at 7.5-minute intervals.

These charts consist of about 30 red circles, originally placed at grid points, which are displaced with the 700 mb wind pattern. The direction of the 700 mb height contour and the observed wind speed were used in determining the displacement vector of each circle. A detailed description of these charts appears in Technical Report No. 7, 1959, to the United States Weather Bureau.

(E) 196 surface and 700 mb charts.

Both the 700 mb wind charts, drawn on thin plastic sheets, and the surface charts, were photographed by superimposing the former upon the latter. This film, when projected on a screen, showed an interesting relationship between surface and 700 mb charts.

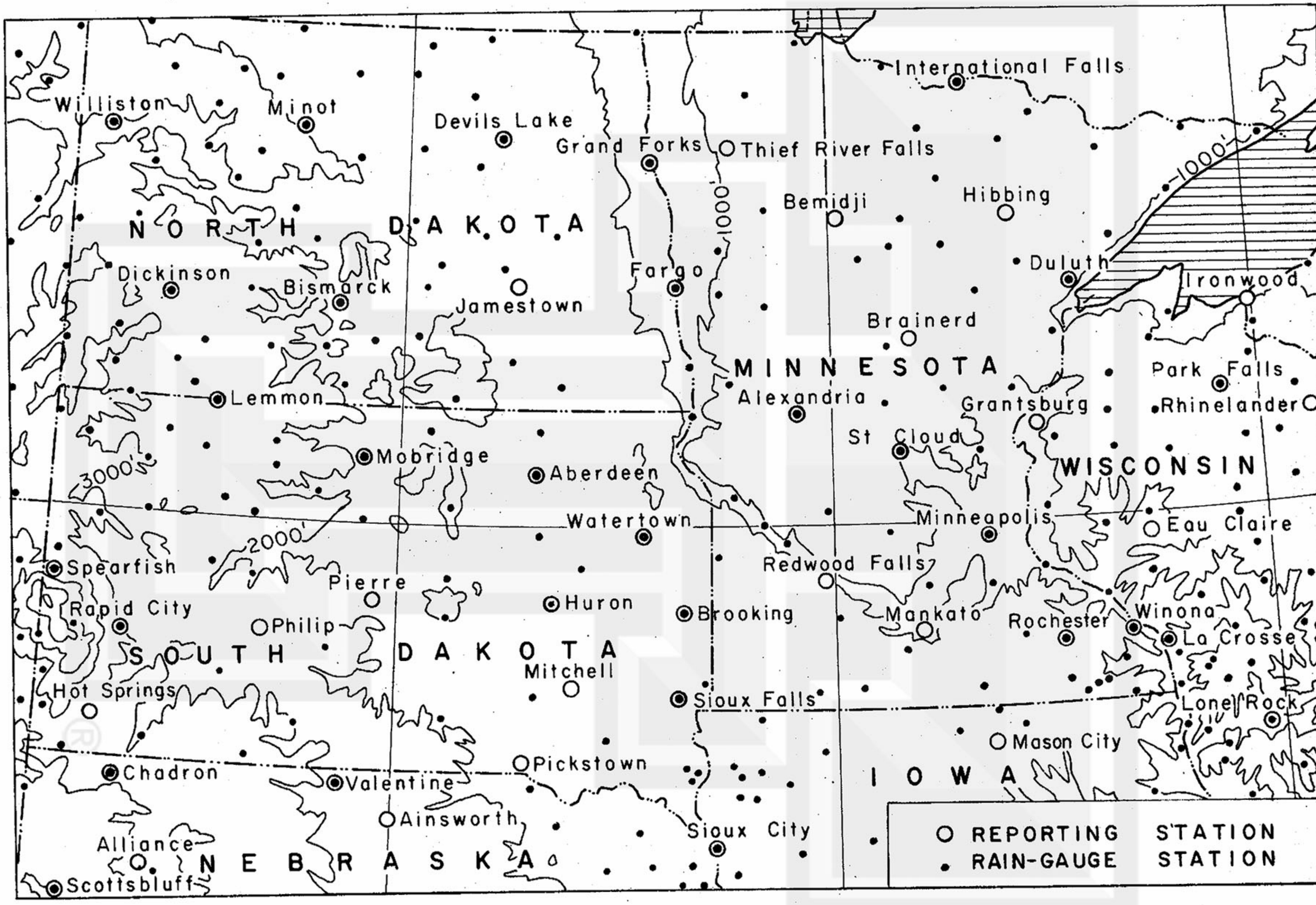
CONCLUSIONS

As a result of this preliminary investigation of weather chart animation, it became evident that a movie is capable of representing continous changes in isobars, isotherms, winds, etc. In addition to the three-dimensional analysis dealing with x, y and z, "time", the fourth dimension, now appears to be very important.

As has been well recognized, mesometeorological phenomena change with time so fast that their descriptions, by means of charts or drawings, at long time intervals such as one, three or six hours, are not satisfactory. The introduction of time continuity will, therefore, permit us to study the mesometeorological phenomena by using a "four dimensional technique". This technique can be carried out by trained assistant-level personnel under the direction of senior meteorologists. Of course, it is absolutely necessary to develop objective techniques in making in-between charts from either one-hour or 30-minute interval charts analyzed by senior meteorologists.

Another important use of this animated motion picture is to observe "dynamical relationships" between two or more meteorological elements. Each element, drawn on plastic sheets, can be photographed by superimposing it upon the others, thus enabling all to display their individual movements simultaneously on a movie screen.

FIG. 6



NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
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IOWA
NEBRASKA
Williston
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Grand Forks
Thief River Falls
International Falls
Bemidji
Hibbing
Duluth
Ironwood
Dickinson
Bismarck
Jamestown
Fargo
Brainerd
Park Falls
Rhinelander
Lemmon
Alexandria
Grantsburg
St Cloud
Mobridge
Aberdeen
Watertown
Minneapolis
Eau Claire
Spearfish
Pierre
Redwood Falls
Rapid City
Huron
Brooking
Mankato
Rochester
Winona
La Crosse
Philip
Mitchell
Hot Springs
Sioux Falls
Lone Rock
Mason City
Chadron
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REPORTING STATION
RAIN-GAUGE STATION

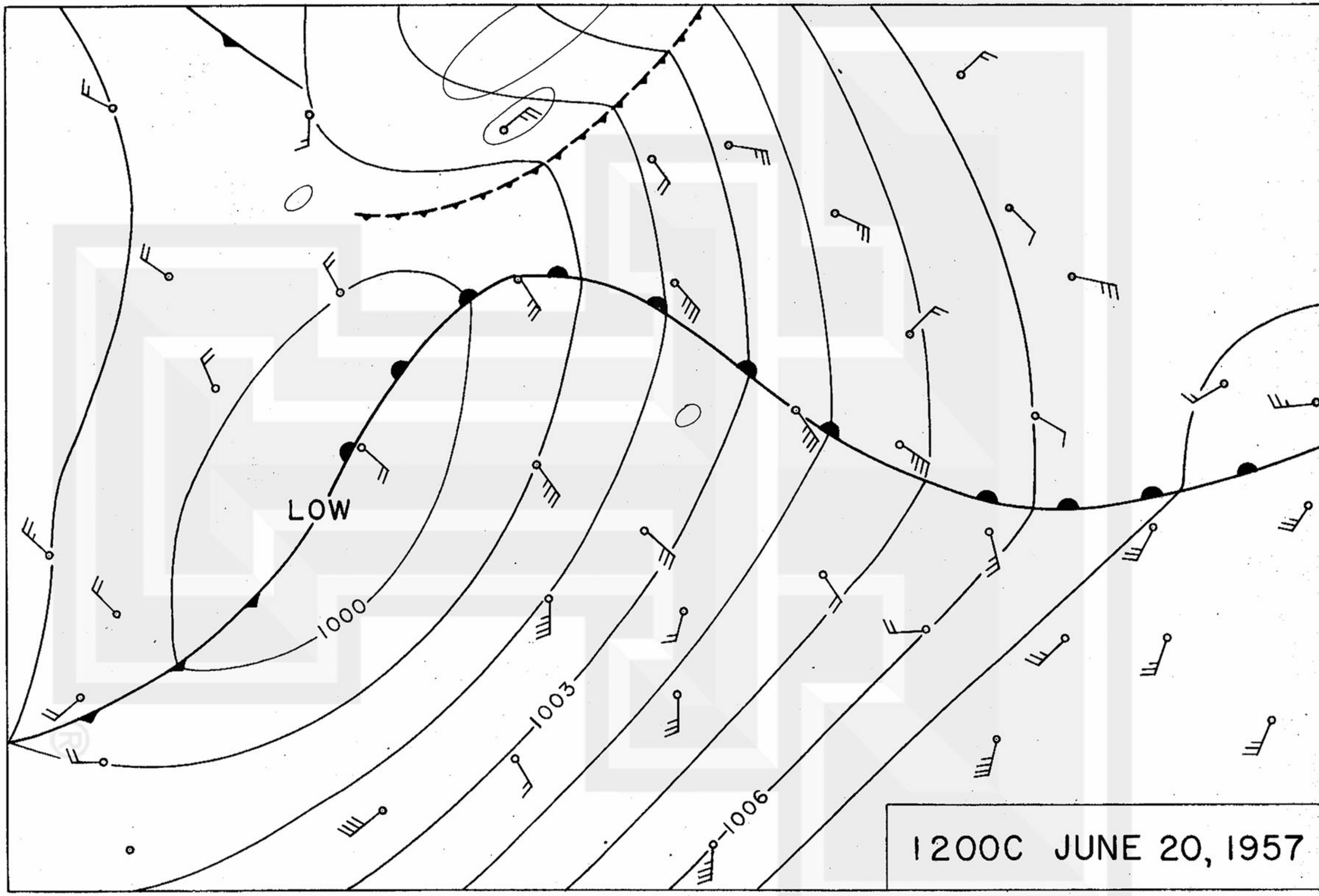


FIG. 7

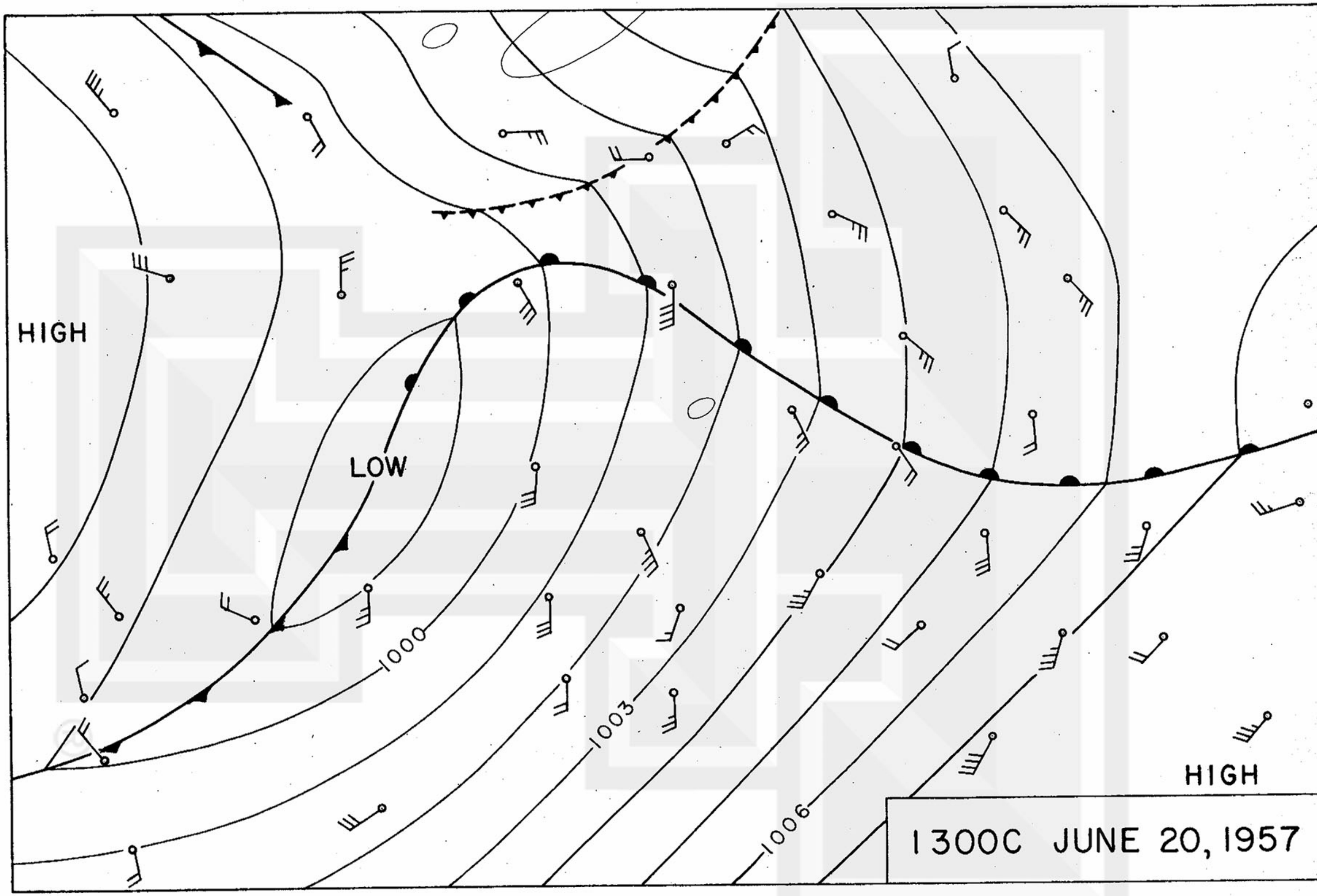


FIG. 8

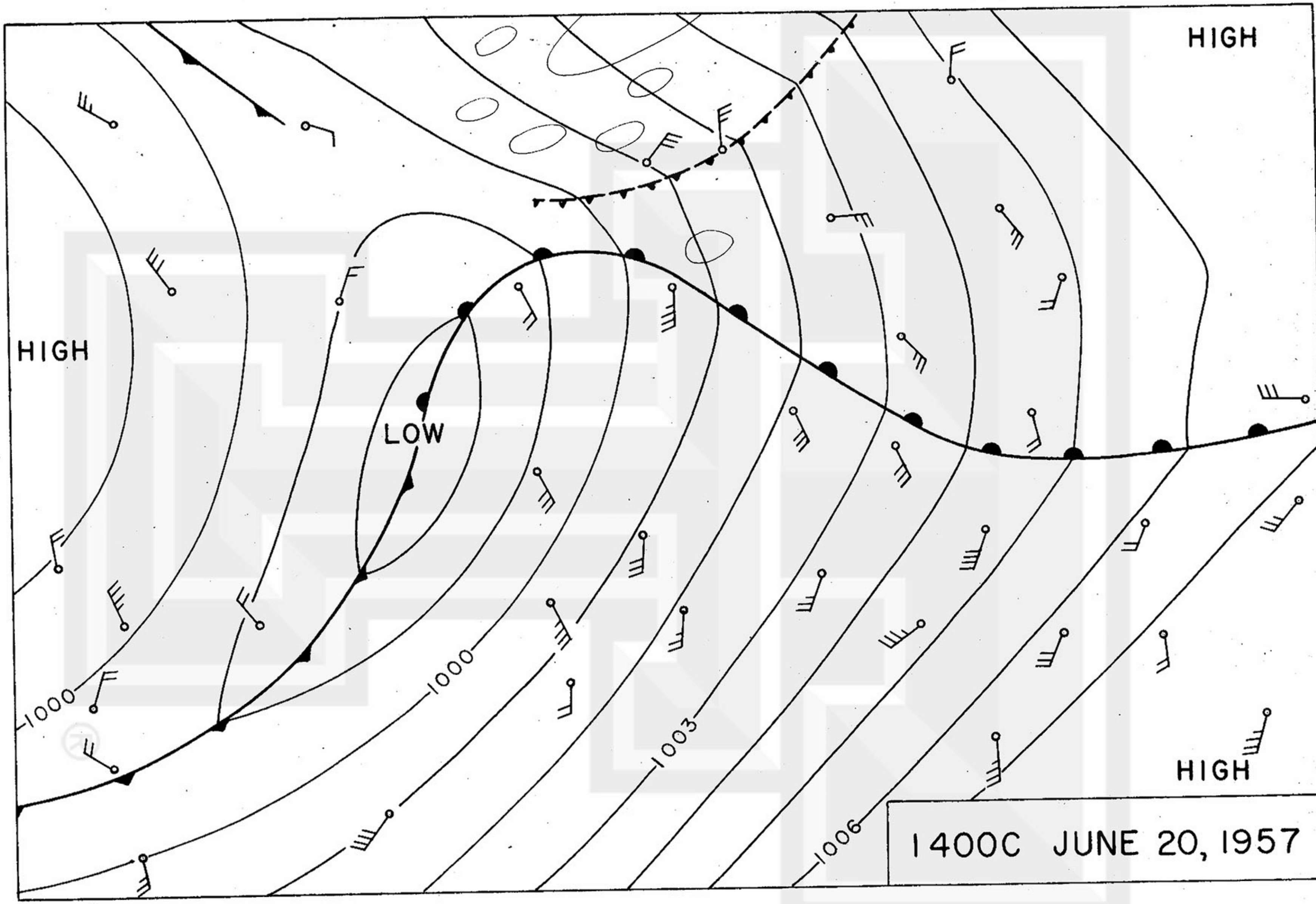


FIG. 9

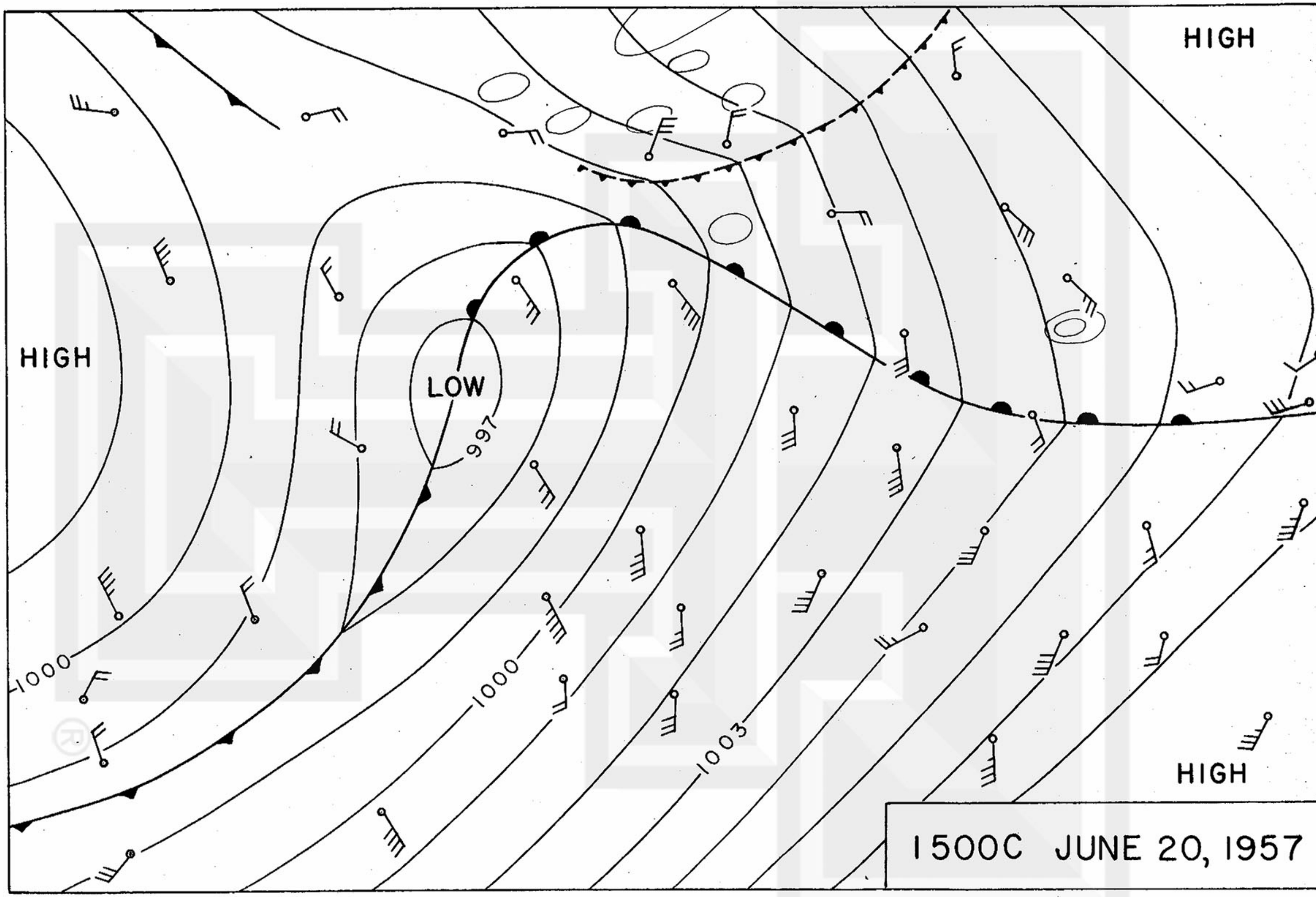


FIG. 10

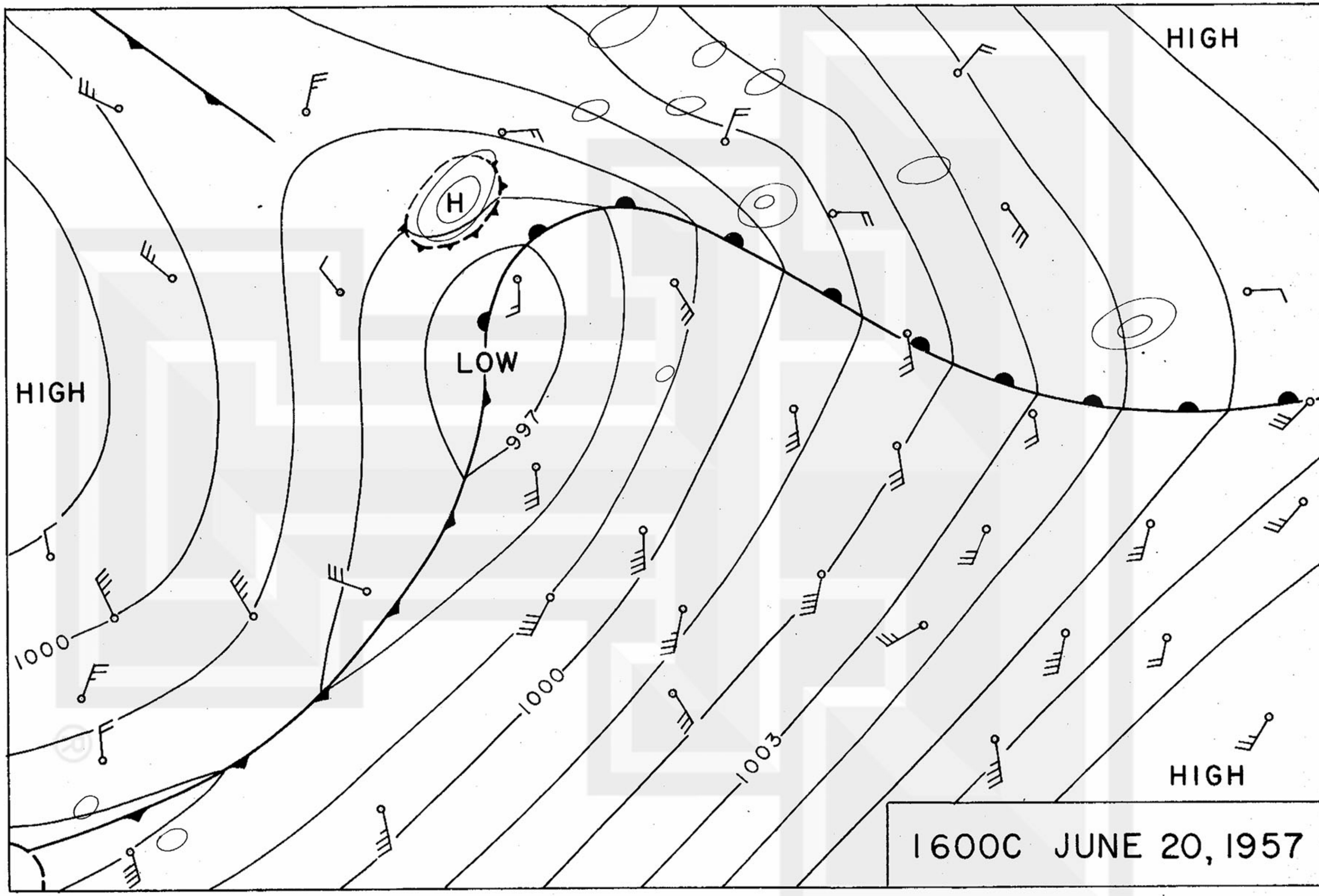


FIG. 11

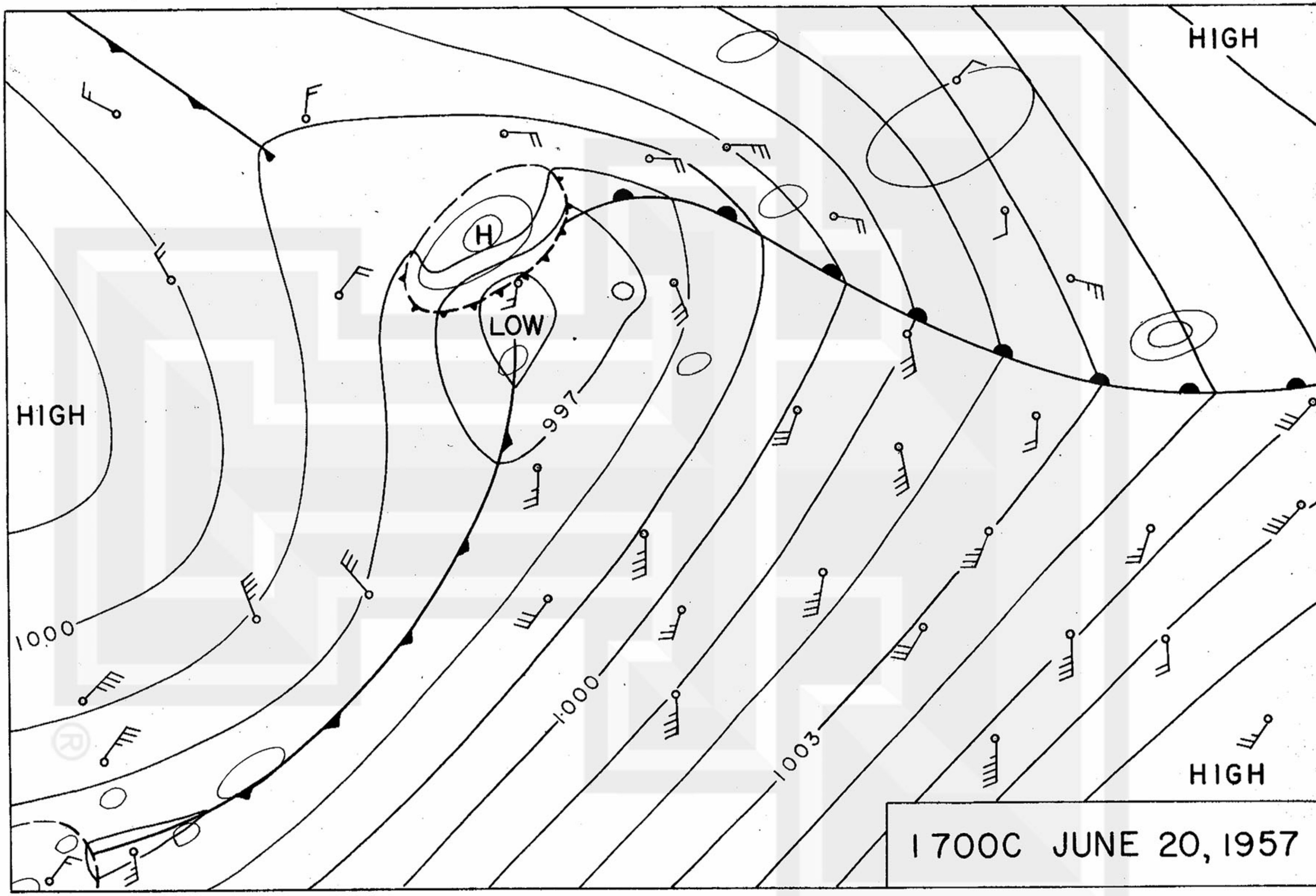


FIG. 12

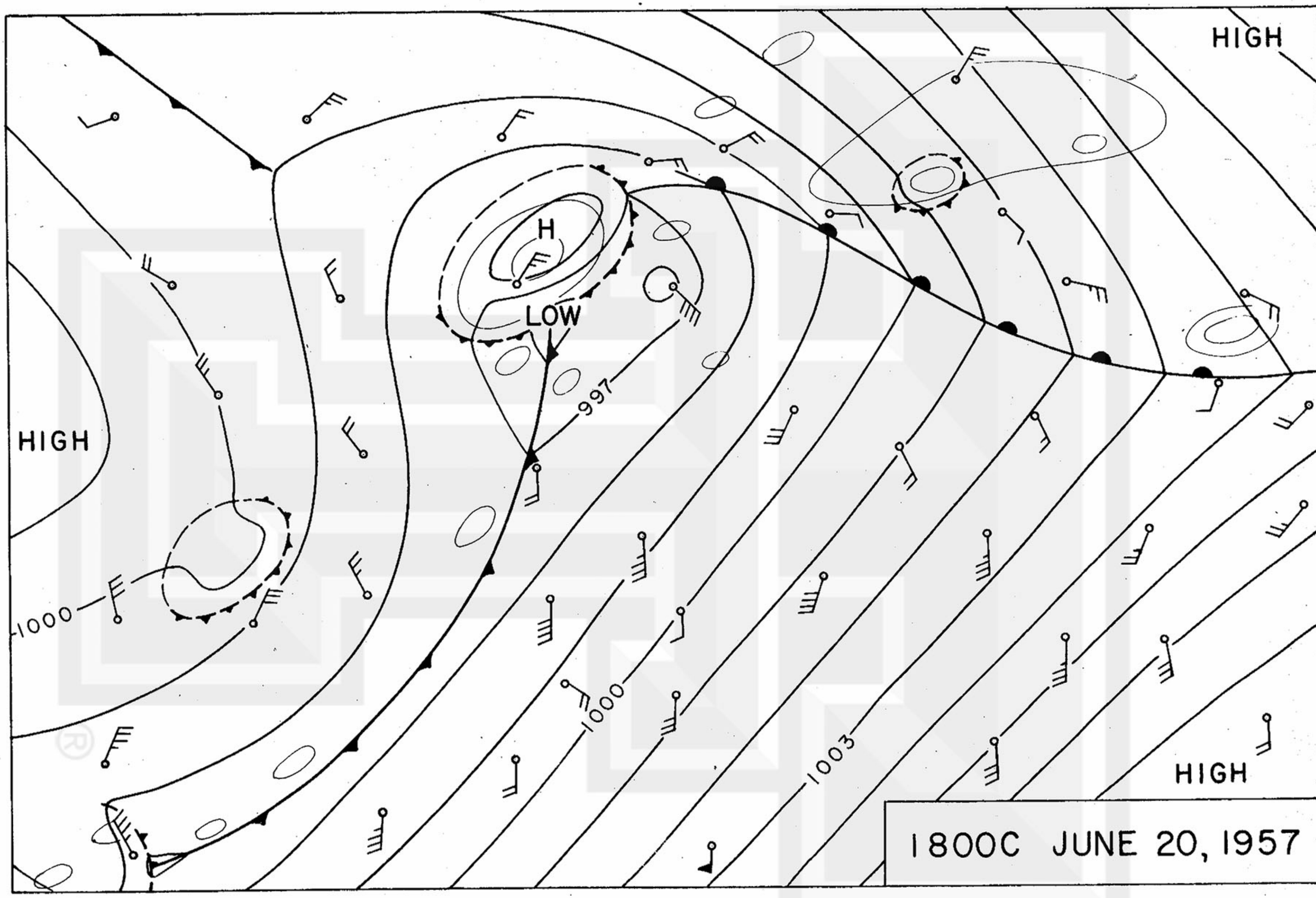


FIG. 13

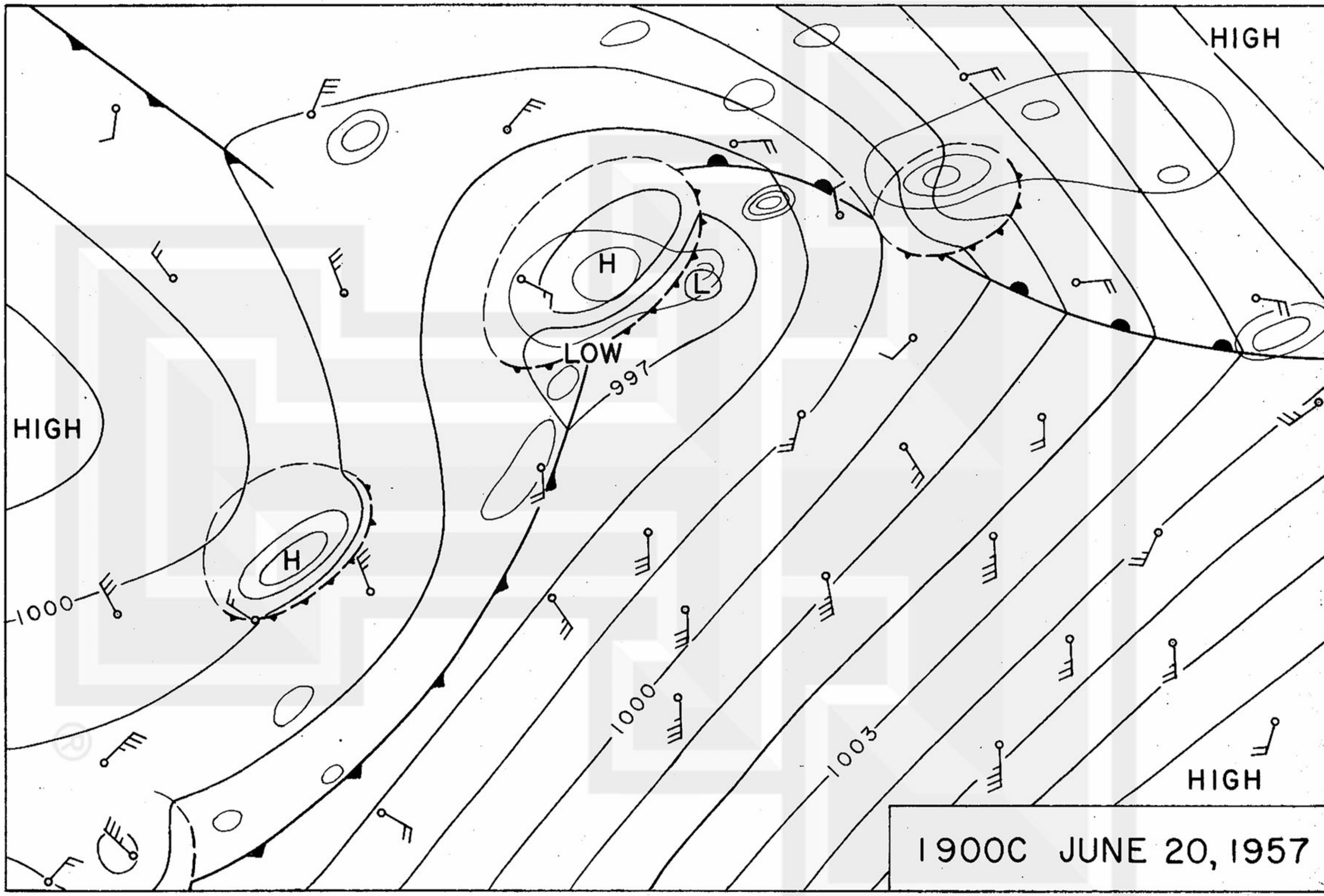
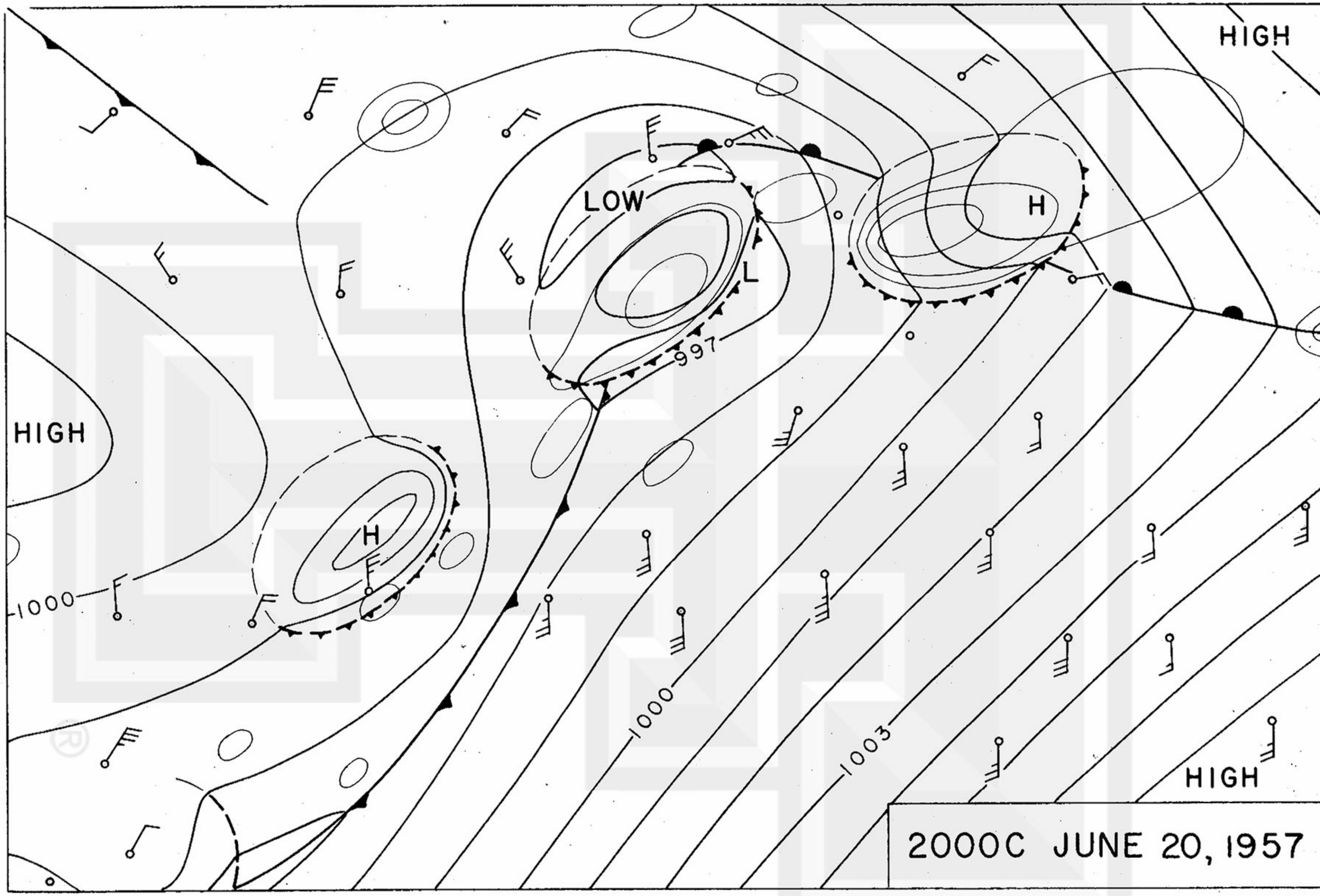


FIG. 14



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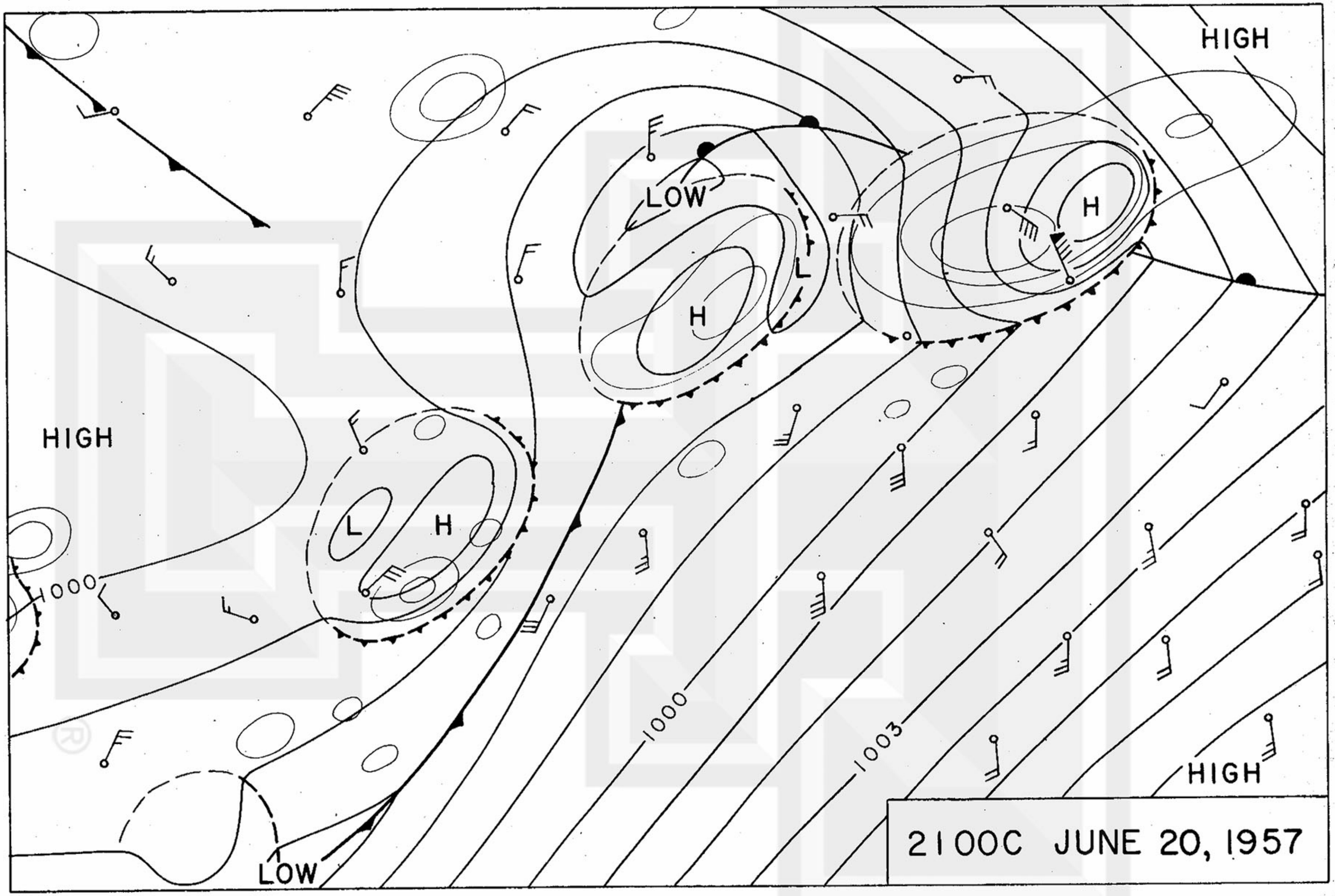
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FIG. 16

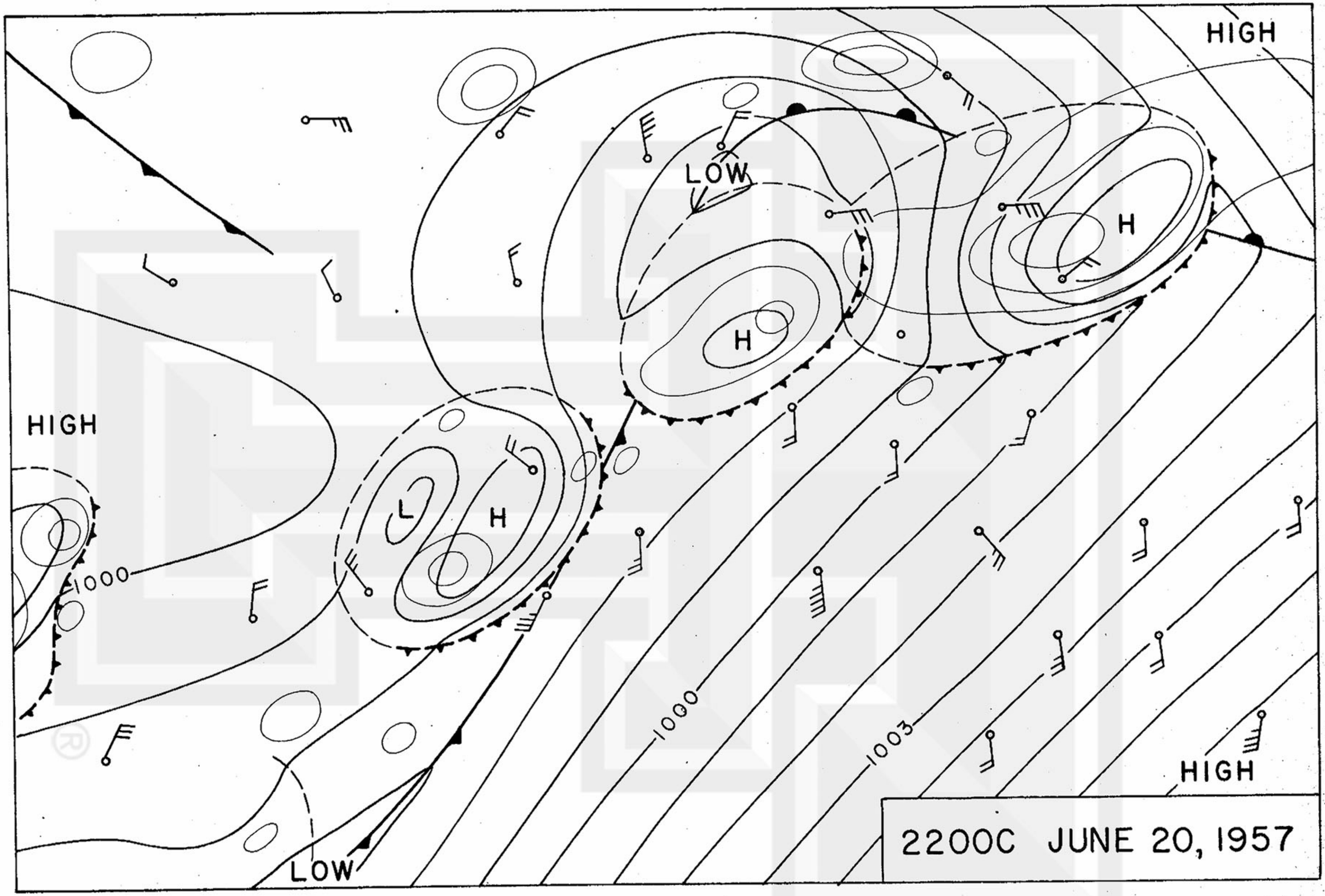
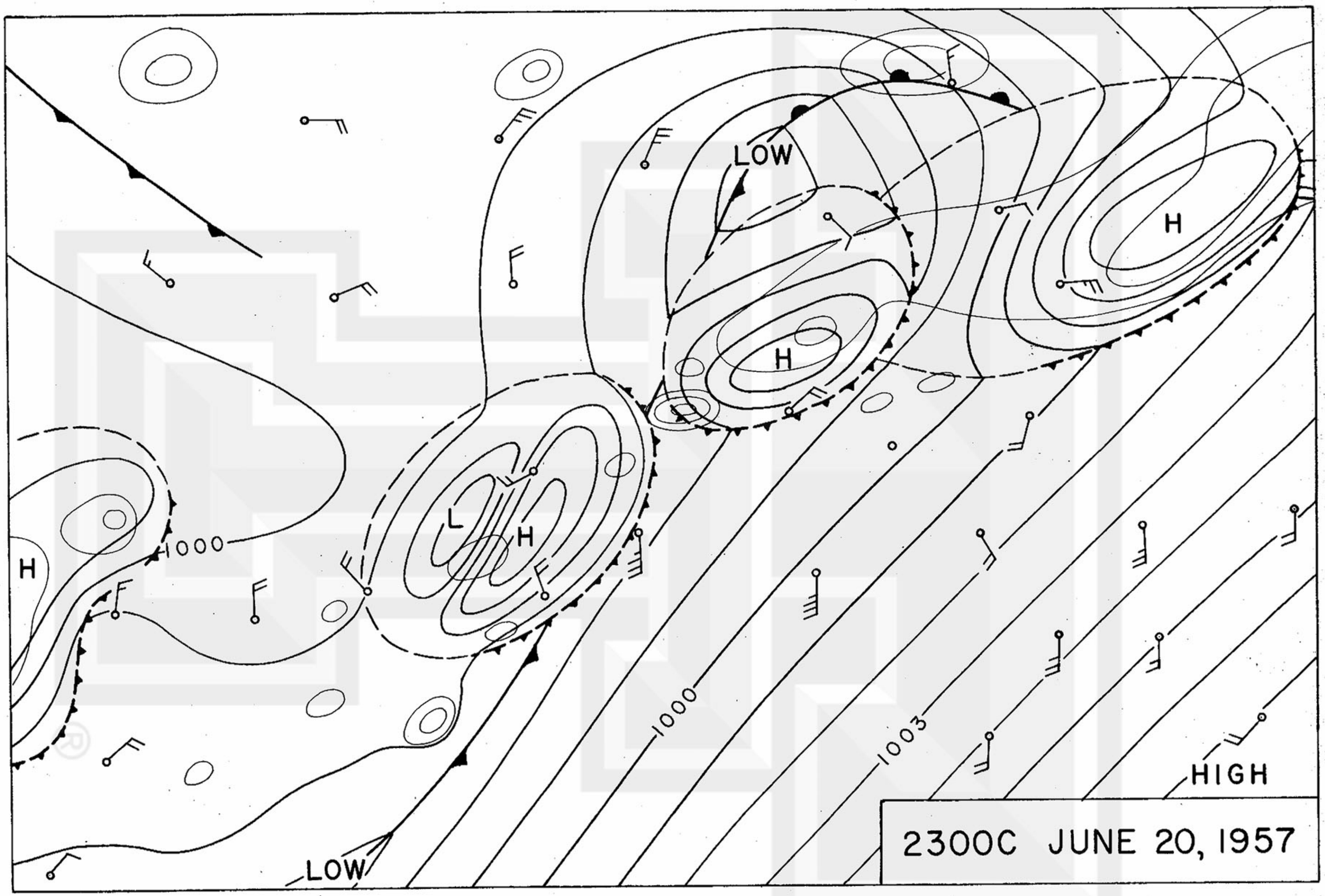


FIG. 17



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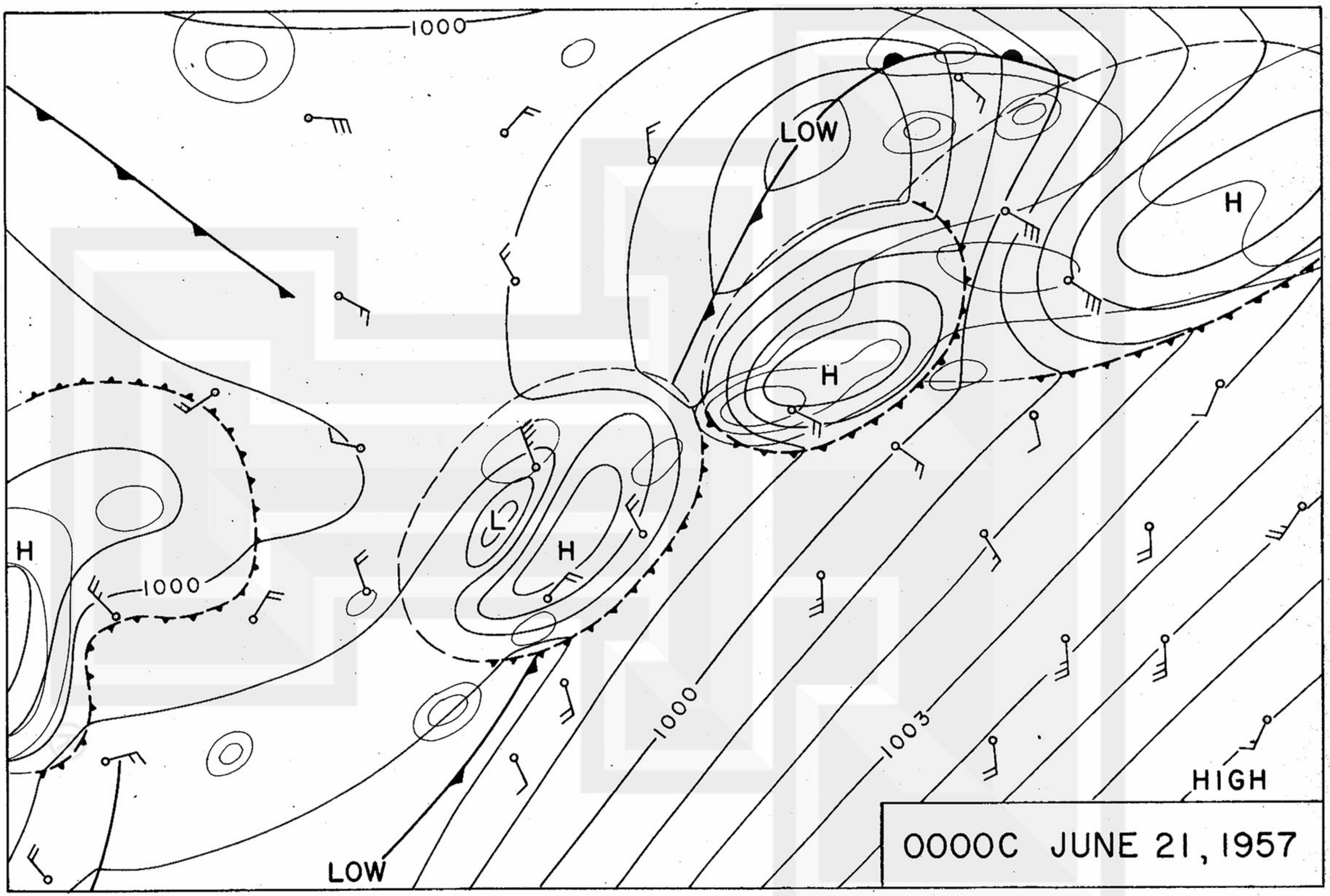

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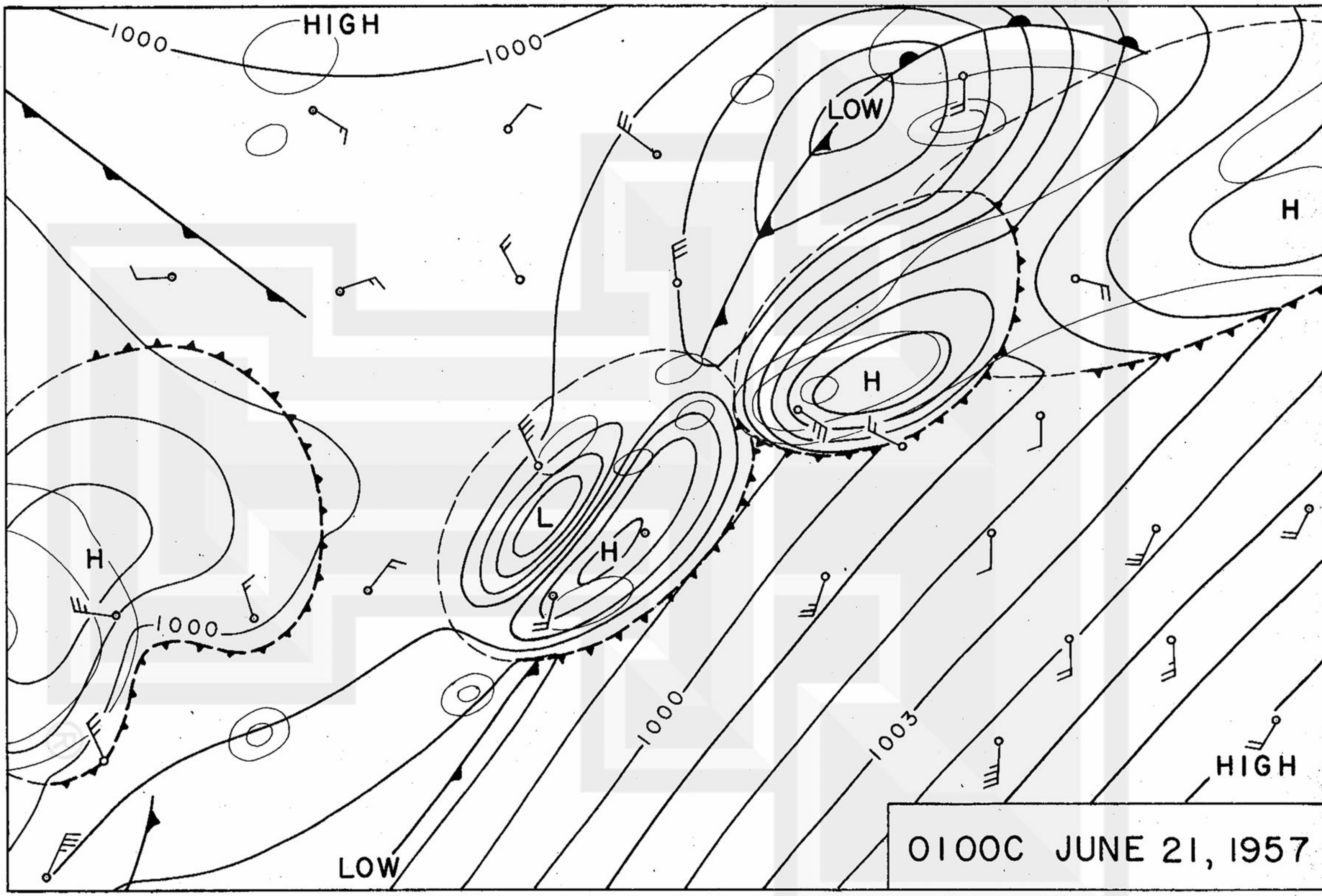
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FIG. 20

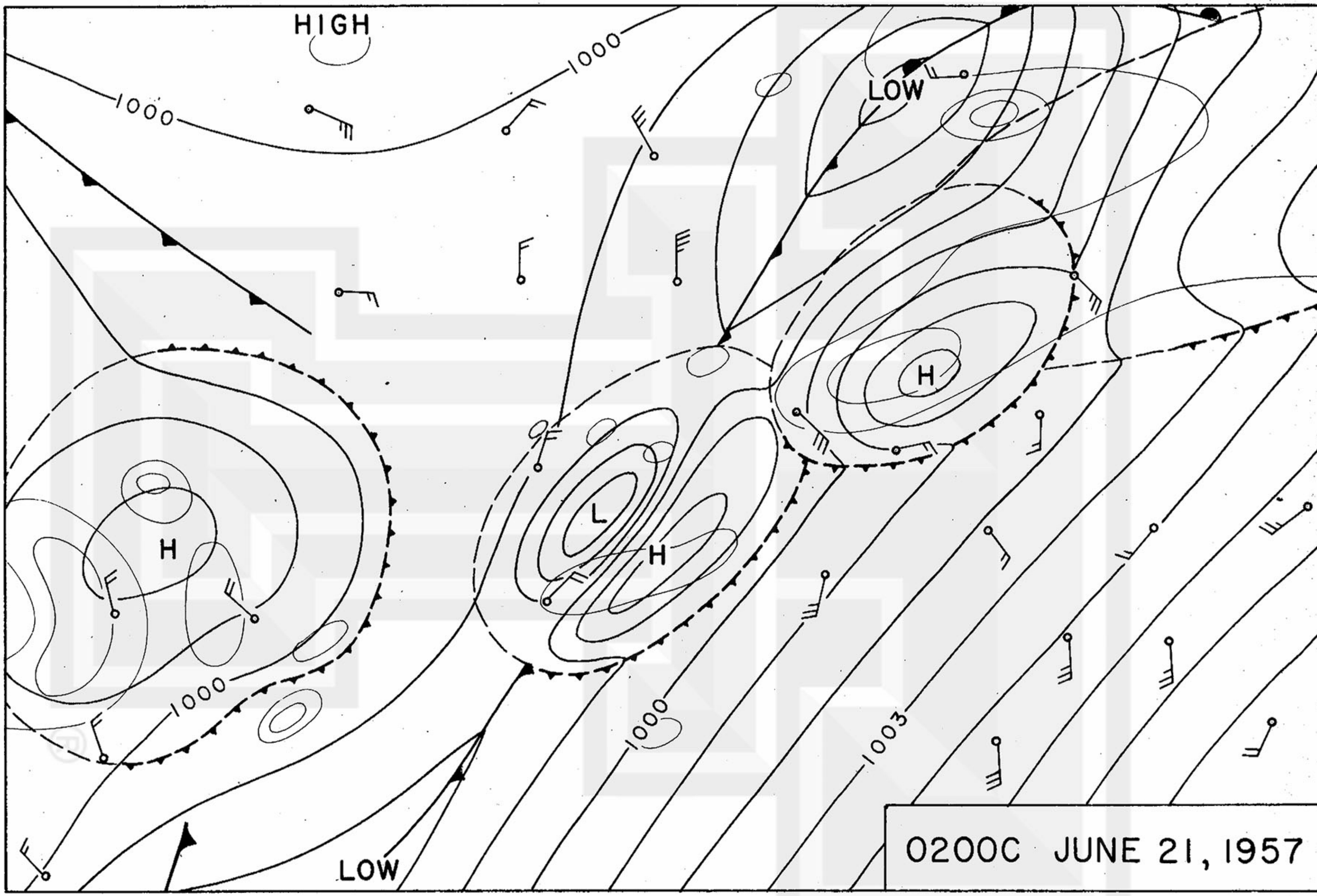

FIG. 21

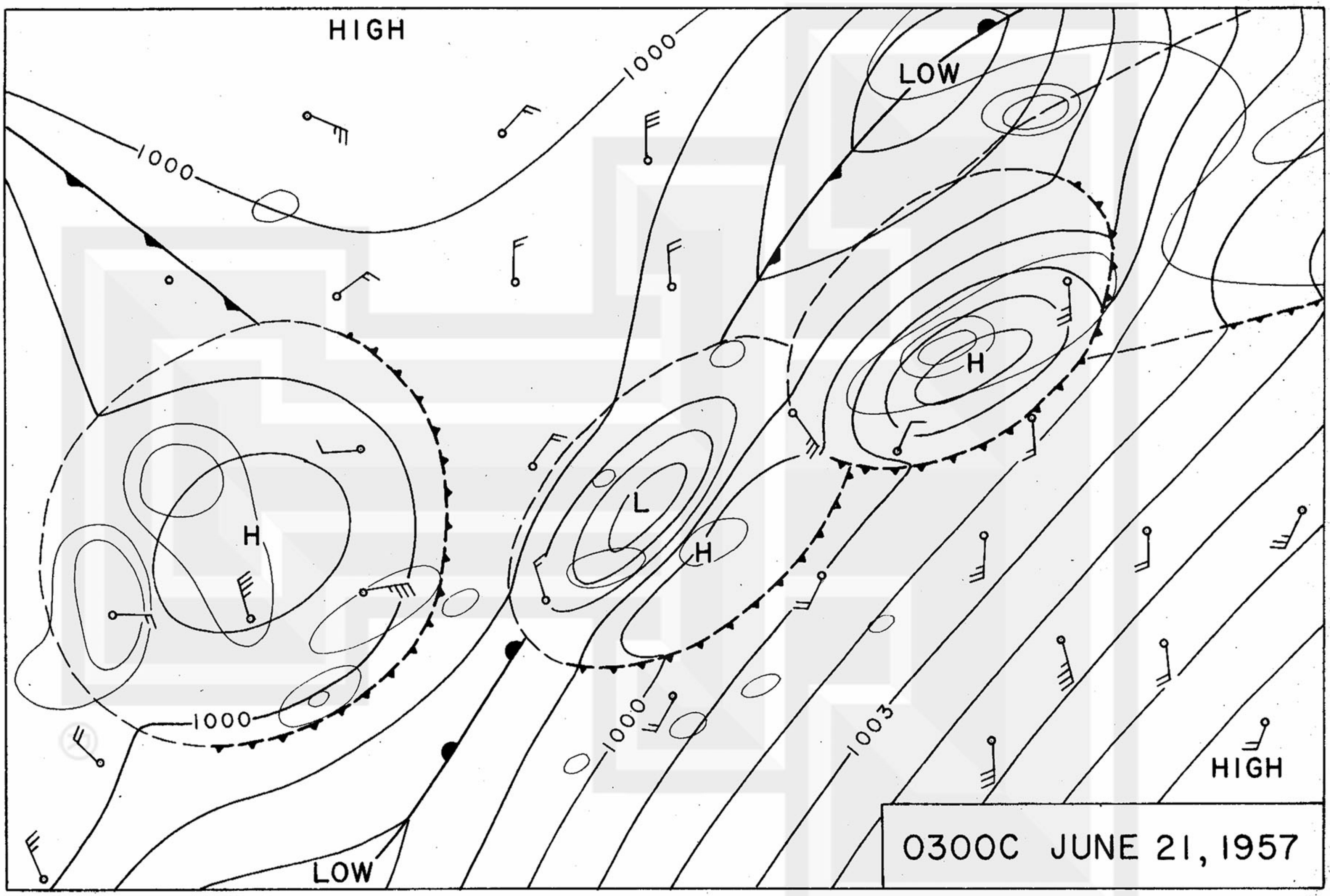
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FIG. 22

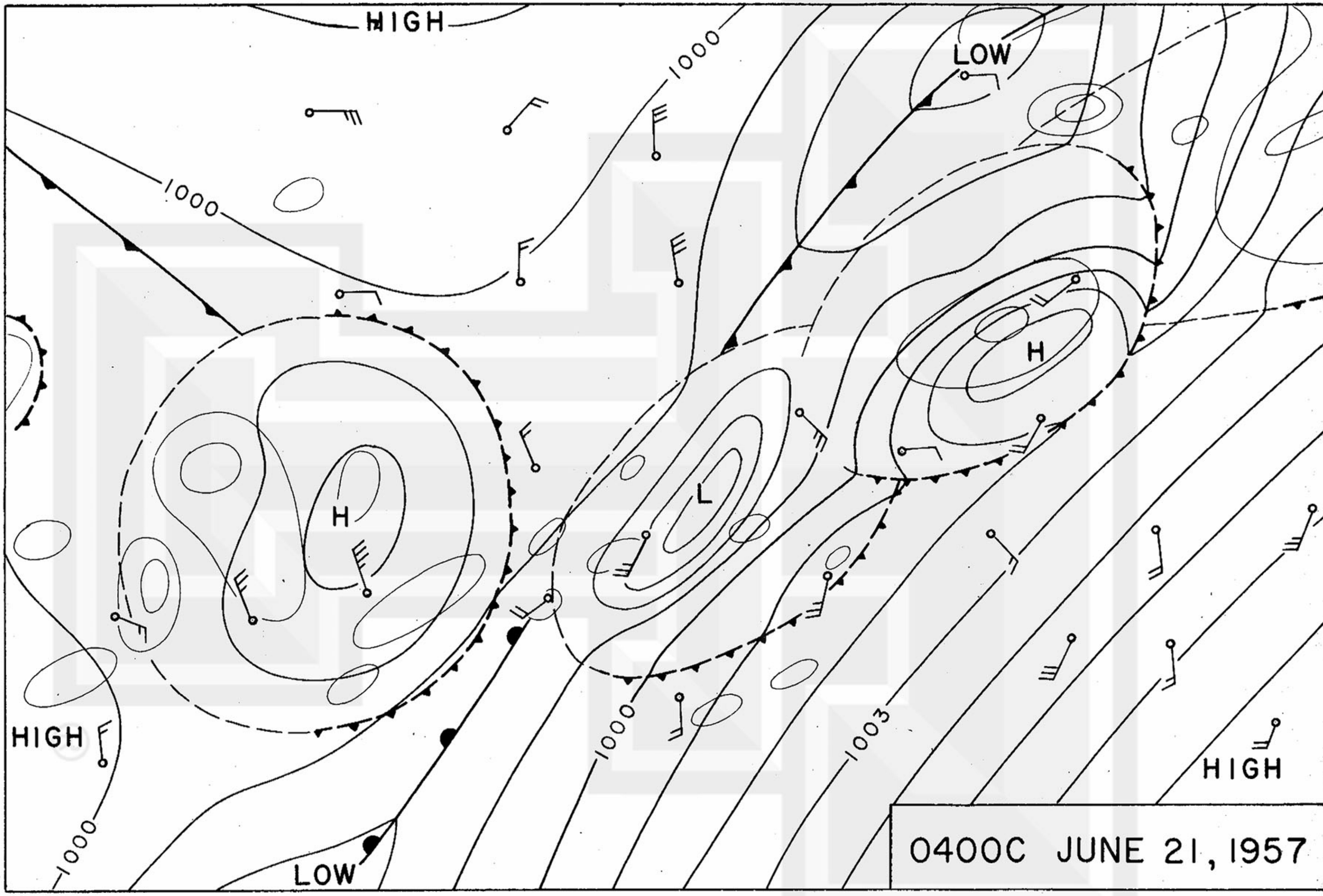
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FIG. 23

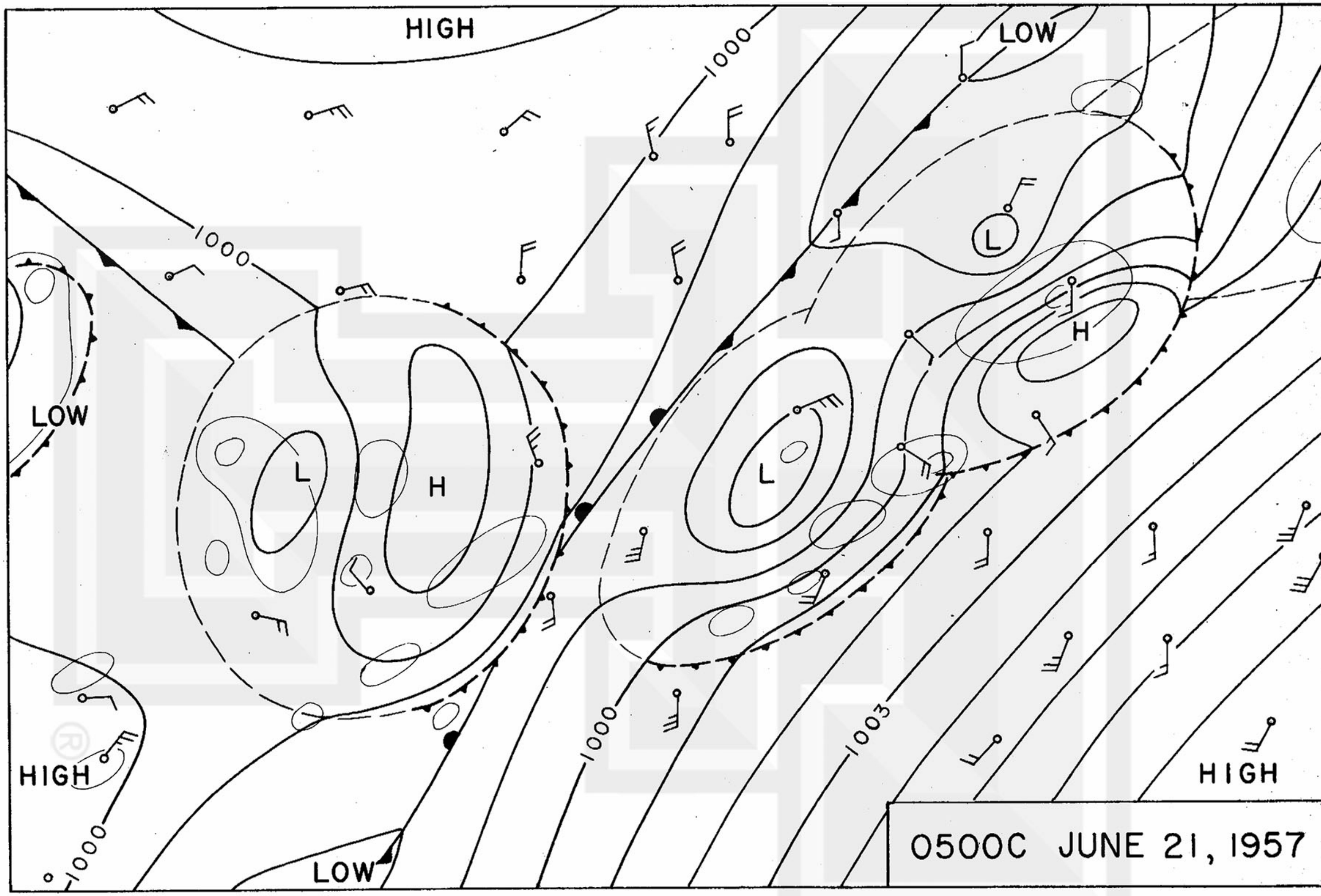
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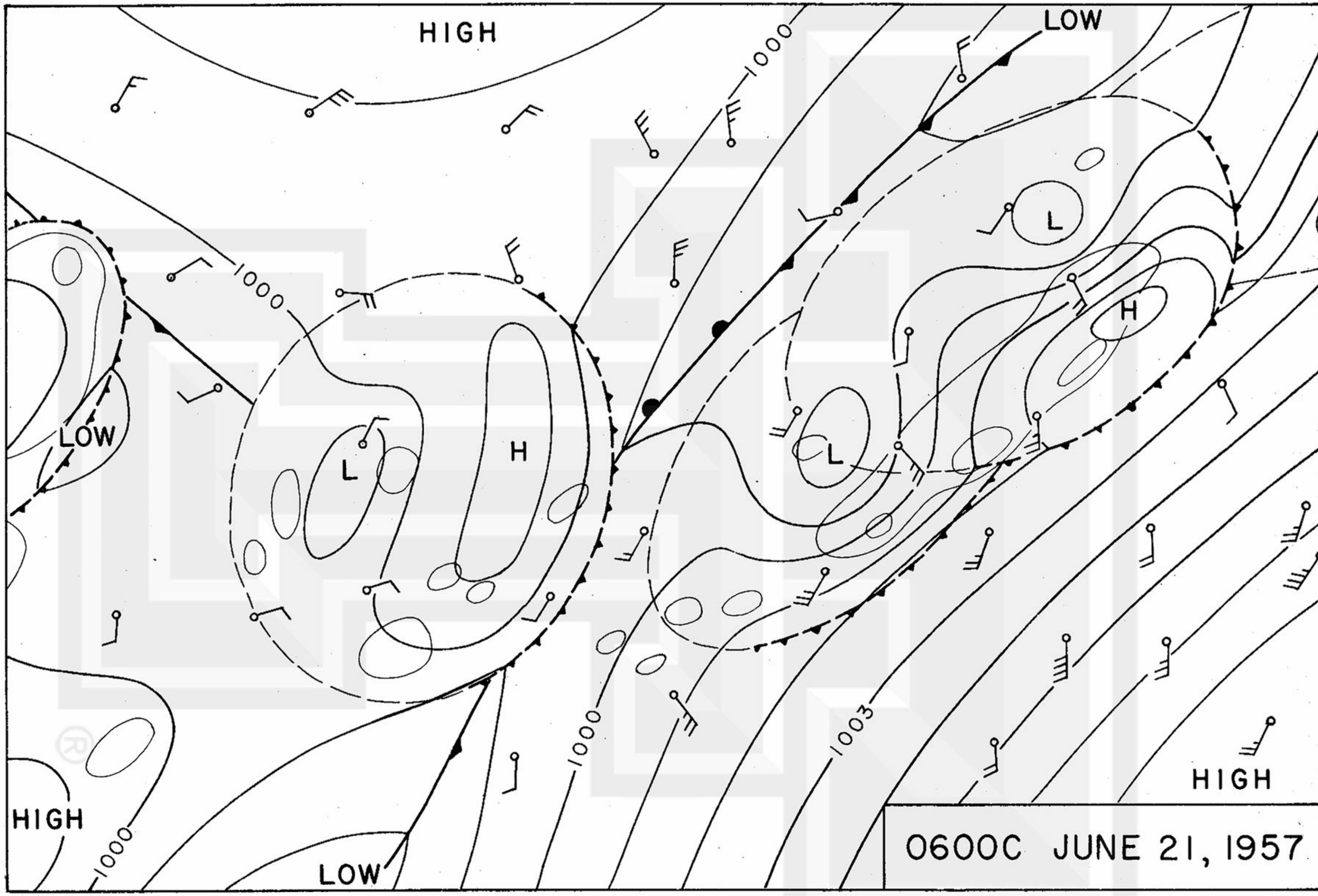
FIG. 24



0600C JUNE 21, 1957

FIG. 25

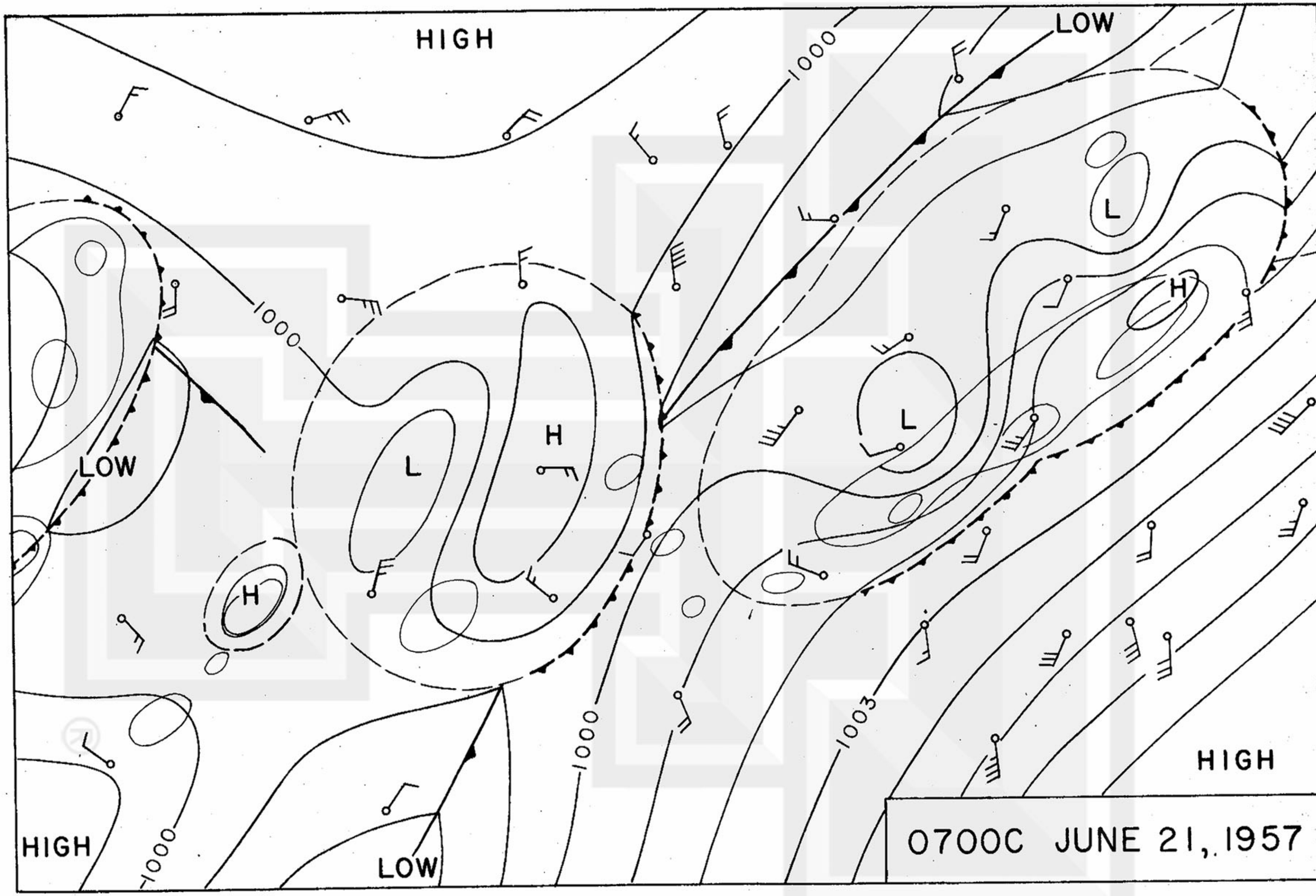


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FIG. 26

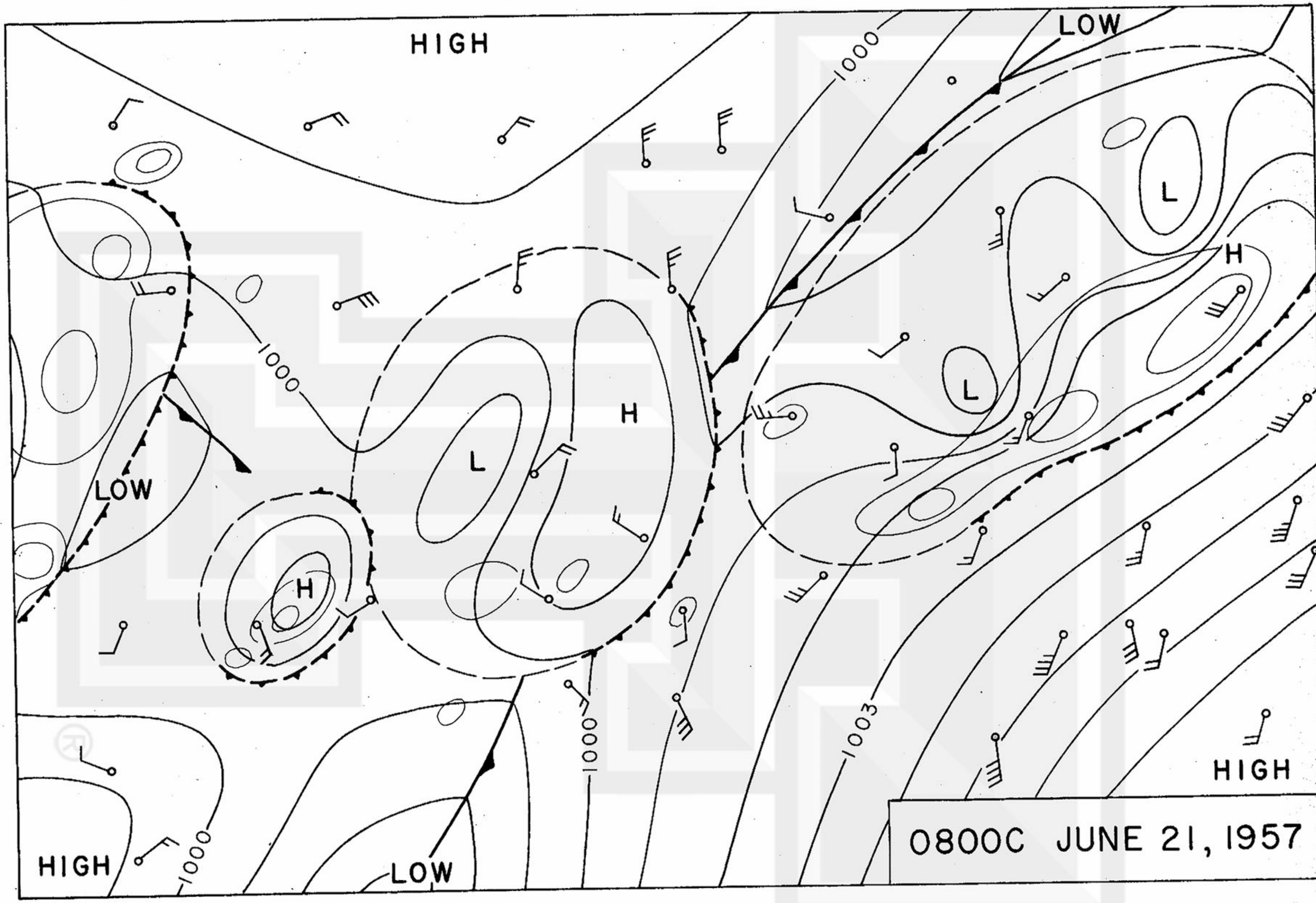
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FIG. 27

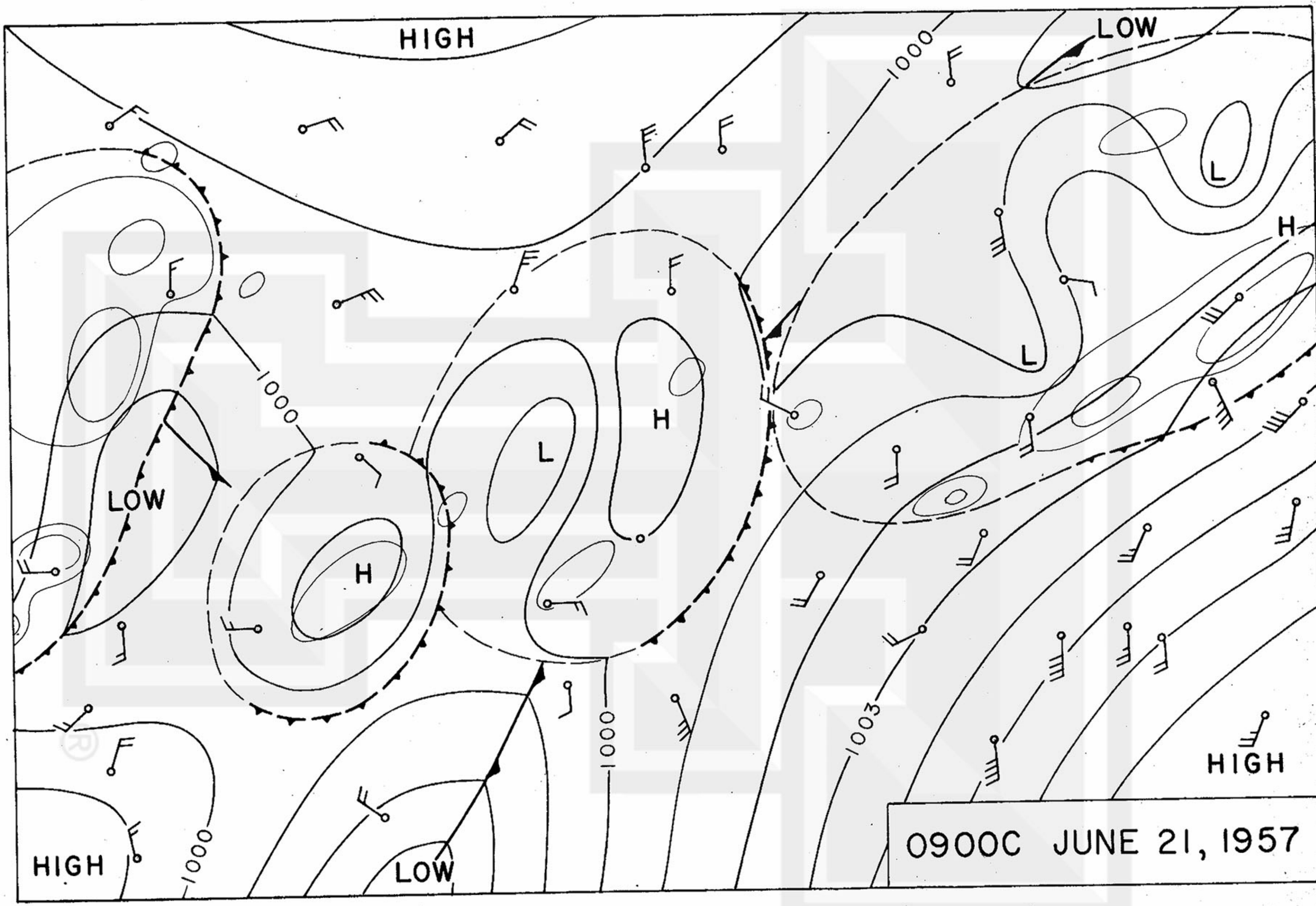
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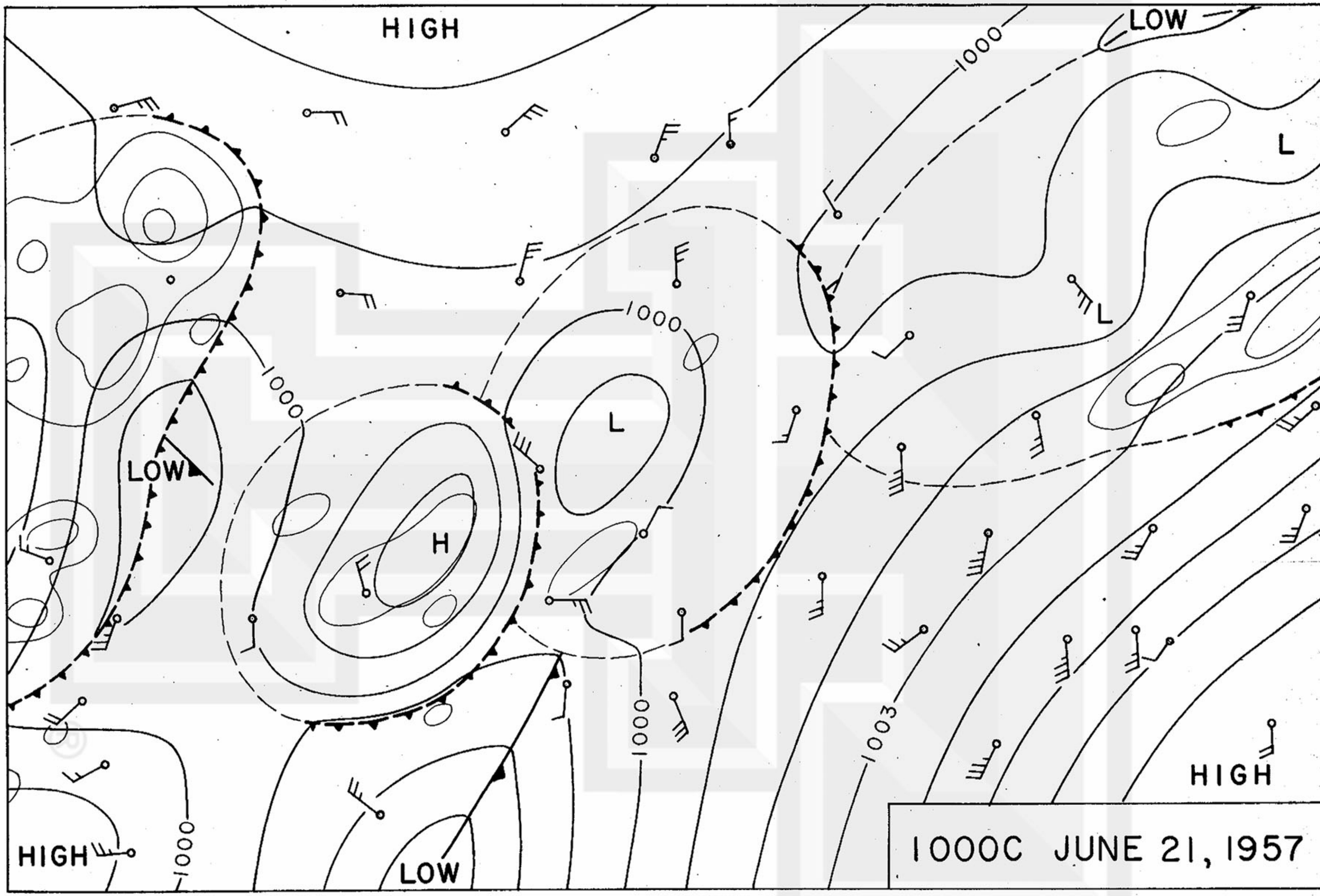
FIG. 28

FIG. 29



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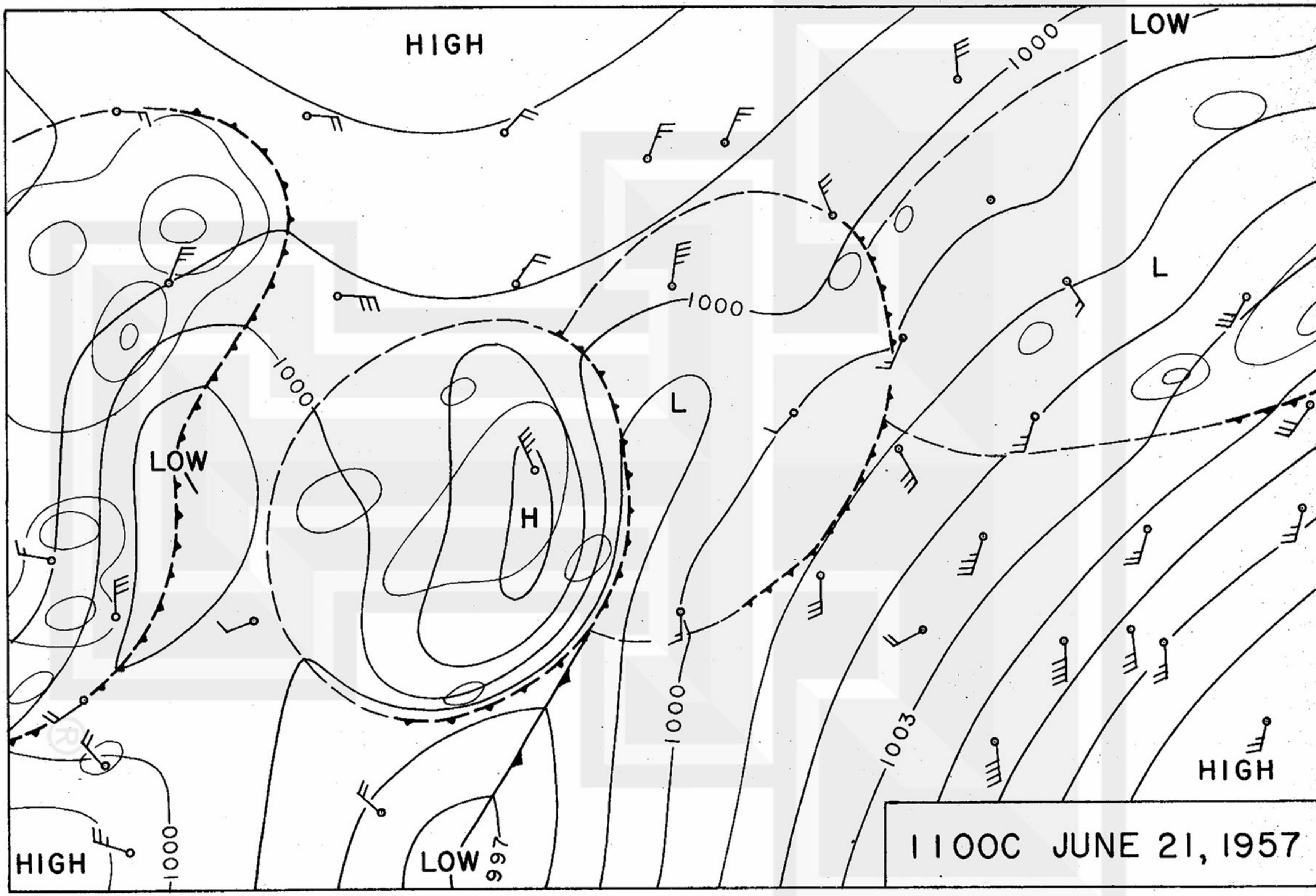
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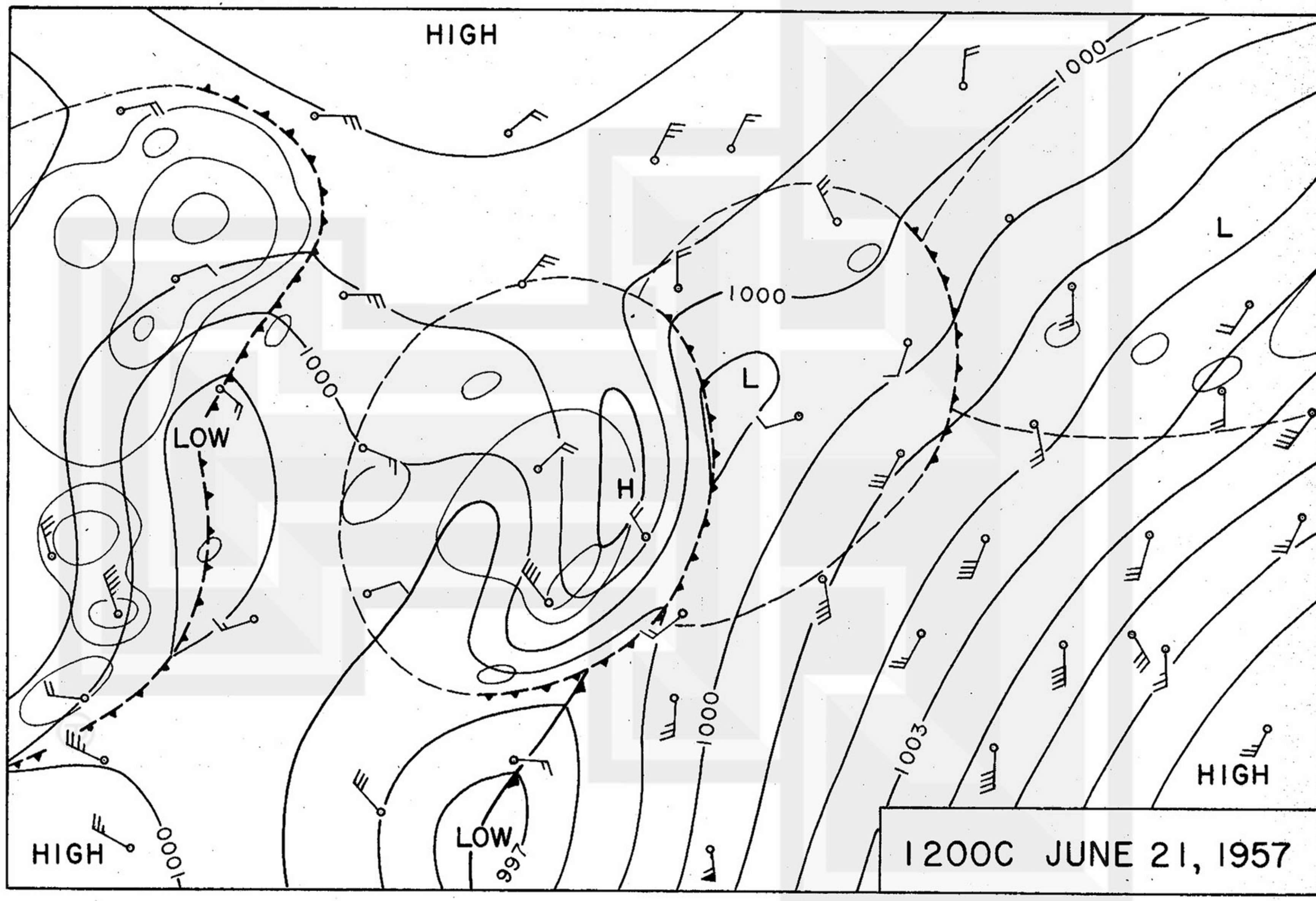
FIG. 30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1200C JUNE 21, 1957

FIG. 31