PART I

DETERMINATION OF WIND DIRECTION FROM CLOUD FORMS

PART II

NOTES ON WEATHER IN THE LOS ANGELES BASIN WITH SPECIAL REFERENCE TO TOPOGRAPHIC EFFECTS

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INTRODUCTION

Since flow is evidenced in the lithosphere and hydrosphere, it seems reasonable to expect that similar information could be gained from the troposphere. Knowledge of air flow gained from observations of motions or results of motions in the air while moving in that medium would be of material aid to the pilot or aerial navigator. Clouds being perhaps the easiest thing to see in the troposphere, it was upon this basis that observations of the motions of clouds and the resulting shapes was begun in Hawaii in 1932.

Being located in the Trade Wind belt of the Northern Hemisphere, the prevailing wind in the Hawaiian Islands is from the northeast. The Koolau Mountains form a great barrier along the northeastern side of the Island of Oahu. The Trade Winds blowing against them keeps them almost continuously cloud covered, these clouds usually dissipating over the southwestern slopes. Similar clouds form over the Waianae Mountains on the southwestern side of the island. From the United States Army Air Corps station at Luke Field on Ford's Island in Pearl Harbor, it is possible to look in all directions with relation to the Trade Winds and their associated clouds formed by the Koolau and Waianae Mountains. Nature has thus provided a laboratory in which clouds may be observed almost continuously in relation to their direction of motion since the wind direction at cloud levels is almost constantly known.

Approximately two years of ground and airplane observation at this station led to the conclusion that it was possible to determine wind direction from cloud shapes and their orientation. This conclusion was presented to a recognized authority on air navigation but it was refuted with the argument that since the clouds are formed within the wind and have essentially the same specific gravity as the surrounding air, they therefore move with the wind, and hence no determination of wind direction could be made by observing their form or orientation.

Observations were continued at Crissy Field, Presidio of San Francisco, during 1934 and 1935. Conditions at San Francisco were very different from those in Hawaii, especially in regard to the constancy of wind direction. Correlation of wind direction and cloud forms must be made originally on the basis of knowing the wind direction at cloud levels and this became a constant problem, even with all of the available aids. Cloud types were much more varied in distribution and number than in Hawaii with the result that much progress was made. Certain ideas had been clearly evolved by this time and a most encouraging feature was that a pilot could be taught in a few minutes to estimate wind direction with a fair degree of accuracy by only using cloud shapes and their orientation.

During flights made from March Field, Riverside, California, in 1935 and 1936, while a student taking the Meteorological course at the California Institute of Technology, and having additional information concerning atmospheric processes, it was possible to make more detailed observations of the motions, orientation and shapes of clouds as well as the motions within clouds.

Airplane observation of motions within clouds is not entirely satisfactory, in that the relative motion between an airplane and clouds cannot be less than the stalling speed of the airplane. These motions could be observed from mountain stations but these observations would be considerably limited as to the times when they could be made and the angle of view, as well as being influenced by the effect of the mountains. The ideal place to observe motions within clouds would be from the basket of a free balloon. Moving pictures made from such a vantage point would accurately record cloud motions so that they could be studied by others as well as the photographer or observer. Still pictures or motion pictures made from an airplane would be a step in the right direction.

In PART II, ground study of the synoptic situations described is combined with observations made during airplane flights over the Los Angeles Basin and immediate vicinity. The airplane used was a single seater, so it was necessary to record the observations from memory after the completion of a flight. It would have been much more desirable to record the observations at the time that they were made. The use of airplane flights in connection with the ground study of synoptic situations affords the opportunity to see and experience conditions and processes that possibly would escape detection from the use of tools that the meteorologist normally has at hand.

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PART I

DETERMINATION OF WIND DIRECTION FROM CLOUD FORMS

The wind varies with height both in velocity and direction. This forms an infinite number of shearing planes in the flying regions of the atmosphere and these in turn cause a force which changes in magnitude and direction with elevation to act upon all particles forming the atmosphere. This variation in magnitude and direction is so small that it often escapes observation, however, it is frequently evidenced in the clouds since the clouds make some of the forces acting in the atmosphere visible. Visible gradients in the character of and forces acting upon any fluid reveal the motions within that fluid. Here we are concerned chiefly with the vertical change in the magnitude of the force acting upon air and cloud particles since a knowledge of the change in the direction of action of this force follows.

It has long been known that due to surface friction the wind does not reach its geostrophic value below an elevation of about three-hundred meters and one must need only read the record of a few pilot balloon runs to see that wind velocity usually increases with elevation above this level. Observational data show that normally there is an increase of wind velocity with altitude up to the tropopause. In other words, there is normally a vertical velocity gradient in the atmosphere which is directed down in the troposphere. The inevitable result of such a vertical velocity gradient is that any property of the atmosphere uniform in a given volume and dissimilar in intensity from the surrounding air will be streamed out in the direction of the wind with the upper portion of an original cubical unit being ahead of the lower part. Excluding vertical motions which are of probably small values at cirrus levels, there is at once an explanation of the long slender streamers of cirrus clouds with these streamers running parallel to the wind direction. As the vertical velocity gradient is up, above the tropopause, the lower layers of any clouds in the stratosphere areprobably ahead of the upper but the determination of wind direction remains unchanged.

The introduction of vertical velocities such as is required for the formation of cumulus clouds requires consideration of the resultant velocity that is produced by the interaction of the vertical velocity and the horizontal velocity and its vertical gradient. Cumulus type clouds from their inception to their decay are probably the best and most useful indicators of the wind direction. Their convections must be accompanied by compensating down currents to preserve continuity. In calm air, the falling currents would be expected to be distributed uniformly around the up currents, but this condition is rarely realized in nature. The vertical currents associated with convections are superimposed upon a field of translation in which there is a vertical velocity gradient. The combination of these motions from the ground to the top of an average cumulus cloud produces multitudinous vortices, the majority of which have horizontal axes perpendicular to the direction of translation. The diameter of these vortices is apparently inversely proportional to the steepness of the lapse rate, the rate of convection, the wind velocity and the vertical velocity gradient. These factors very throughout a convection column with the result that the diameters of the vortices in a single column are not uniform. Within a single cloud many different sized vortices may be seen. The diameter is also apparently inversely proportional to the rate of rotation of the vortex or vorticity. The vorticity is low in stable air or near the base of an inversion, usually of the order of half a minute for half a revolution. Fast whirling vortices having diameters of approximately six feet have been observed to make a complete revolution in five seconds.

That the vortices exist below the condensation level was clearly shown by observations made of thick haze in which the vortices were plainly visible while the upward extension of the convection column was forming a cumulus cloud several hundred feet above the lowest visible haze vortices. On the surface of an active cumulus cloud, the vortices may be readily seen although it is much easier to see them if they are outlined against the sky. There they appear as an upward rising portion of the main cloud mass, the upward extension gradually turning over and thinning out to point in the direction that the wind is blowing and thenturning downward to usually dissipate completely, leaving a curl of cloud bent to the lee. A large curl of this type reminds one of a bull ready to make a strike with its horns at an object on the ground. Often the vortical cloud mass makes a complete revolution leaving an almost perfect circle of cloud particles through the center of which the sky may be seen. The rules that may be derived from these observations are as follows: 1) The direction of motion at the top of a cloud vortex is usually the prevailing wind direction; 2) Curled portions of a cloud usually thin out and point in the direction of the prevailing wind.

The nature of origin of the vortices precludes the possibility that all of them in an average sized cumulus cloud will whirl with their axes perpendicular to the true wind. In a cloud undergoing strong convective activity a few of them may be rotating in the direction opposite to that normally observed.

Of more than a thousand vortices observed, less than ten were rotating in a reverse manner. It was only possible to observe the motions after they reached the surface of the cloud and the individual vortices are not distinctly seen until they become somewhat detached from the main cloud body so the motions inside a cloud are not exactly known but it is likely that motion against the wind is at a maximum there. Some motion of this nature is necessary to give a cumulus cloud its cauliflower appearance and strong convections have been seen to emerge at the surface of a cloud with cloud particles mushrooming in all directions. Reverse vortices would be expected to persist on the windward side of a cloud, yet in this favored location, numerous curls obeying the rule were observed while reverse curls were rare.

When the vertical velocity gradient is upward or when the wind reverses with altitude, the vortices rotate in a reverse manner with respect to the lower wind. This is readily seen when cumulus clouds form at the top of a sea breeze or by noting how the frayed portions at the top of an advective ocean fog bend back toward the ocean.

The net effect of the vortical activity and the vertical velocity gradient beside producing individual vortices is to give the entire cloud a swept over appearance with the action coming from the windward side. The windward edge slants up, and downwind and is smooth in outline, while the lee side usually has an uneven forward slant with the upper portion appearing somewhat frayed due to the exposed action of the vortices. This action at the forward edge is apparently what prevents cumulus type clouds from streaming out under the influence of the vertical velocity gradient. The downward motion of the curls on the forward side of a cloud combines adiabatic heating andmixing of the colder cloud particles with the drier surrounding air to dissipate the projected portion of the cloud considerably above the condensation level.

Decaying cumulus type clouds are exposed only to the action of the vertical velocity gradient so they are stretched out until they appear to lean forward with the upper forward edges being frayed out by being mixed with the surrounding air. When viewed cross wind, this effect produces many parallel forward tilting surfaces in a horizontal cloud layer. Often the vertical velocity gradient is not sufficient to make this effect pronounced and then it may be necessary to get the effect from a survey of the entire sky rather than from an individual cloud or small group of clouds.

It is doubtful if the motions within a cloud may be seen from a modern airplane moving at cruising speed, so then the effects of the curls must be evaluated rather than the motions within them. In pronounced instances, it is possible to see their effect for distances of the order of thirty miles on a clear day. The action of a vortex as well as its result may be distinctly observed from the ground.

Accurate results are difficult to obtain from stratus clouds. The absence of convections with them and their stability gives them a uniform smooth appearance especially when viewed from anywhere except above them. From above, it is possible to detect small wisps which are bent forward by the action of the vertical velocity gradient. The stability often lends to the development of waves and rolls which have their long axes perpendicular to the wind. The development of Helmholtz waves in thin stratus decks may create long parallel cloud bands with clear spaces inbetween where the wave has a downward component and the adiabatic heating and mixing with warmer air dissolves the cloud along the trough of the wave.

At times, a quick glance at a cloud may give an accurate determination of wind direction while at others a study of an entire cloud studded sky will be necessary before an accurate decision can be made. Clouds look quite different when looking down or up wind compared to cross wind and it is the cross wind view that gives the most information. Care should be taken to avoid optical illusions, and it is averages that give best results.

CONCLUSIONS

1. The atmosphere exhibits its motions chiefly through the clouds.

2. Atmospheric movements of wind direction may be determined from:

   a. Motions within clouds

   b. Cloud forms

   c. Cloud orientation

3. Cirrus clouds string out in the direction of the prevailing wind.

4. Wind direction may best be determined from cumulus type clouds.

5. Vortices normally exist in the free air from the surface of the earth to high levels.

6. Cloud vortices usually have their axes perpendicular to the wind.

7. Cloud vortices apparently develop in number and size directly and inversely proportional to the wind velocity, the vertical velocity gradient, the lapse rate, and the rate of convection respectively.

8. Cloud vortices are best seen when outlined against the sky.

9. The direction of motion at the top of a cloud vortex is usually the prevailing wind direction.

10. Curled portions of a cloud usually thin out and point in the direction of the prevailing wind.

11. An upward vertical velocity gradient or wind reversal with altitude will produce vortices rotating opposite to the usual sense with respect to the lower wind.

12. Cumulus clouds often present many parallel forward tilting surfaces in a horizontal cloud deck.

13. The windward and lee edges of cumulus clouds usually slant upward and downwind.

14. Cumulus clouds usually have a swept over appearance.

15. The upper lee edge of a cumulus type cloud is usually the most frayed portion of the cloud.

16. Cloud curls may be seen from airplanes moving at cruising speed.

17. Large cloud curls may be seen for about forty miles on a clear day.

18. The study of cloud vortices should be undertaken from free balloons with the aid of cameras.

19. Stratus clouds give the least information as to wind direction.

20. The crests and troughs of Helmholtz waves are usually perpendicular to the wind direction.

21. Small wisps of cloud pointing downwind may be seen from above stratus decks.

22. Clouds look differently when viewed crosswind, upwind, or downwind.

23. The crosswind view is best for the determination of wind direction from clouds.

24. The observation of one cloud may quickly give the correct result, however, averages from a number of clouds usually give the best results.

25. Avoid optical illusions.

PART II

NOTES ON WEATHER IN THE LOS ANGELES BASIN

WITH SPECIAL REFERENCE TO TOPOGRAPHIC EFFECTS

For the purposes of this paper, the Los Angeles Basin is defined as the area bounded by the Pacific Ocean and the higher mountains to the north, northeast, east, and southeast of Los Angeles, California. This region is noted for its mild Winter climate, one of the contributing factors to which is the surrounding mountains.

During the Winter, a limb of the Pacific anticyclone frequently moves in over Oregon and Washington, breaks from the Pacific high forming a new center which moves to the Great Basin where it stagnates or remains semi-permanent. This movement brings comparatively fresh Polar Pacific (Pp) air into the Great Basin in the lower levels while tropical air is moved northward over the area in the higher levels. The stagnation, which Dr. Krick has explained to be the result of tropopause waves caused by the centering of deep cyclones in the Gulf of Alaska, produces an air mass differing in many essentials from the other air masses frequenting the western United States, and he has chosen the name "Polar Basin" (Pb) to signify this type of air.

Subsidence in the Great Basin anticyclone increases the potential temperature of the air mass and further dries out a fresh maritime air that already had a low water content, especially in the upper levels. The subsidence produces a strong inversion which holds the new and cold polar air to the lower levels even to the extent that the lower layers cannot flow over the mountains that surround the Great Basin. Being at an average elevation of four to five thousand feet, the Great Basin with its surrounding mountains forms a great saucer which holds the enclosed air and causes the subsiding air from above to spill away over the mountains to the surrounding areas. The average elevation of the mountains in the direction of the Los Angeles Basin is well over six thousand feet, hence when this already warmed and dry upper air from the Great Basin descends adiabatically to the valleys of California, which are only slightly above sea level, the adiabatic heating and further drying is considerable. Assuming an adiabatic lapse rate of ten degrees Centigrade per kilometer, descent of five thousand feet would heat the air about fifteen degrees Centigrade or twenty seven degrees Fahrenheit. Consequently, when air is flowing out of the Great Basin, lower surrounding areas such as the Los Angeles Basin, experience a warming Foehn effect and temperatures aremarkedly higher than in the source region, due entirely to the effects of the inversion, adiabatic heating, and subsidence rather than the small difference in latitude or the condition of the surface.

Polar Basin air that flows into the Los Angeles Basin has relative humidities of the order of twenty to thirty per cent and in extreme cases as low as five per cent. Temperatures frequently reach as high as 85 degrees Fahrenheit during the coldest Winter months. This very dry, clear air is almost wholly transparent to terrestial radiation which allows rapid cooling at night and hence the diurnal temperature variations are large, usually being between 30 and 40 degrees Fahrenheit. The days are warm, the nights are cool, the air is dry and the sky is cloudless except possibly for very high clouds.

The high mountains to the north of the Los Angeles Basin cause Pp air brought down directly from the north to be adiabatically heated on descent to the Basin floor, thereby raising minimum temperatures to such an extent that frost is infrequent. Air that comes into the Basin from the Pacific Ocean has usually had a long trajectory over that body of water and has been heated sufficiently by contact with the ocean to keep minimum temperatures relatively high for the Winter months. On an average of less than once a year, when a strong cyclone centered in the northwest causes fresh Polar Continental (Pc) air to be swept out over the ocean from British Columbia, and rapidly brought down to the Los Angeles area, do temperatures fall much below freezing and the possibility of snow at valley stations does exist.

THE SANTA ANA

A strong building up of the Great Basin anticyclone sufficiently increases the velocity of the stable air flowing out of the Basin to cause strong winds to develop in the low, narrow mountain passes leading out of the area. Rapid movement through Cajon Pass, across the Los Angeles Basin, near or over the town of Santa Ana and on to the Pacific Ocean has long been known as a "Santa Ana". Rapid movements through Cajon Pass often do not reach Santa Ana and these have been locally called "Fontanas" after the name of the town at the mouth of Cajon Pass. The "Santa Ana" is a special type of "Fontana" and develops only when east winds through San Gorgonio Pass are sufficient to deflect the course of a "Fontana" to the southwest. Cajon Pass is oriented roughly NNW-SSE with a low promontory turning the southern extremity to the southeast, and transmits most readily a flow of air from the northeast because of the distribution of the mountains on the Mojave Desert side of the pass. San Gorgonio Pass is oriented E-W, so that in order to get maximum flow across Santa Ana, the prevailing wind must be from the northeast since the flow through San Gorgonio Pass acts not so much as the main source of air but more as a deflecting force.

The phenomenon of simultaneously strong flow through these passes, which are almost at right angles toeach other, requires a combination of factors which probably explains the relatively short duration of a "Santa Ana", which is usually from about nine to twenty hours, while a "Fontana", although usually also of short duration, may blow for several consecutive days with varying force. The first requirement is an originally strong anticyclone over the Great Basin or a similar anticyclone combined with a cyclone over Arizona to give the necessary pressure gradient, otherwise the air from the interior will never reach the ground in the Los Angeles Basin. Secondly, exceptionally strong flow from the interior requires strengthening of the system, and, in the third place, there must be movement. This movement does not require a movement of the center or centers, which may or may not occur, but does require a movement of a portion of the system, or, in other words, a movement of certain isobars that will give a steep pressure gradient northeast of the Basin combined with the proper orientation of these isobars to produce strong northeast winds. In the lower levels, the energy behind this movement and build up, in this system of stable air, is stored up as potential energy by the mountains that surround the Los Angeles on the north, northeast, and east, and is released in the form of kinetic energy as the air flows through the low mountain passes. Since the necessary strength or energy is attained by a combination of movement and build up of pressure gradient at the edge of the Los Angeles Basin, it follows that this combination in its proper relations should last for a limited period and be accompanied by a veering of the associated winds.

A wedge from the Pacific anticyclone had entered the United States through Oregon and Washington and had, by the morning of January 21, 1936, separated from the parent high and developed a new center over southeastern Oregon which had built up rapidly to a pressure of 30.5 inches (See map for Jan. 21, 1936) and was still strengthening as shown by all of the tendencies within the forty isobar being positive. Good positive tendencies over a large area to the east, southeast, and south of the center with negative tendencies in Oregon and Washington indicated an expansion of the system as well as a southeastward movement. These indications were verified by the morning of January 22. (See map for Jan. 22, 1936). The high had expanded greatly and the thirty isobar had moved five hundred miles to the southeast but the center had only moved two hundred miles east while increasing to about 30.58 inches. Although the pressure at the center did not rise a great deal, the expansion of the system indicated considerable strengthening along the leading edges. A deep cyclonic system near Dutch Harbor, Alaska, probably helps explain the build up andmovement of the center in accordance with the tropopause wave theory.

Aerograph records from North Island, San Diego, were available for January 20 and January 25, 1936, but not for the intervening dates. A comparison of these soundings, given below, indicates the changes in the structure of the air mass during t at period as the system persisted until after January 25.

San Diego is about one hundred miles from the Los Angeles Basin but the same air mass covered all of Southern California between the above dates.

Abbreviations: ELEV-elevation in meters, S-surface, PRESS-pressure in millibars, TEMP-temperature in degrees Centigrade, RH-relative humidity in per cent, θ_E -equivalent potential temperatures in degrees Absolute, W-specific humidity in grams per kilogram, LIFT-lift in meters required for saturation.

0600 Pacific Standard Time

North Island, San Diego, January 20, 1936.

ELEV	PRESS	TEMP	RH	θ_E	W	LIFT	CLOUDS	AIR MASS
S	1016	7	79	293	5.0	400	Light haze	Pp
480	962	15	53	308	5.8	1200		
1210	882	12	40	308	4.0	1600		
1670	834	10	40	309	3.8	1500		
2070	794	7	38	308	2.8	1700		
2950	714	4	29	312	2.2	1800		
3920	634	-1	33	317	1.9	1700		
4450	594	-6	36	316	1.5	1400		
4660	578	-6	36	318	1.6	1400		
5040	550	-9	40	319	1.5	1200		
							0.2 cirro-stratus NW	

Table 1

0600 Pacific Standard Time

North Island, San Diego, January 25, 1936.

ELEV	PRESS	TEMP	RH	θ_E	W	LIFT	CLOUDS	AIR MASS
S	1013	8	86	296	5.9	200		
540	952	16	38	308	4.8	1700		
1020	900	16	23	307	2.8	2600		
1930	808	11	10	306	1.0	3600		
3400	676	2	12	310	0.8	3000		
4090	620	-3	11	310	0.5	3000		
4630	580	-7	10	312	0.5	2900		
5090	548	-9	10	316	0.5	2700		
5360	528	-11	10	316	0.5	2500		
							0.4 cirrus W 0.2 cirro-stratus W	

Table 2

The stability, inversion, drop in relative humidities, low water content, and the very high lifts required for saturation are the outstanding features. In Table 2, the influence of the sea breeze in the lower levels is plainly marked.

Early in the morning of January 21, the winds through Cajon Pass were from the north and as the development progressed, they moved towards the east. This was accompanied by a shifting during the day of the main flow from over Riverside and the hills to the west of Riverside, to west of these hills so that by mid-afternoon, they were aiding in the deflection of the main flow to a position over Wineville and the area immediately to its west. At the same time, the flow through San Gorgonio Pass was increasing and aiding in the westward deflection of the Cajon current. The air from the east flowed down the San Bernardino Valley to deflect and confine the main current as it emerged from Cajon Pass while farther south it flowed across the Perris Valley to help deflect the Cajon flow west of Corona and Arlington. The Santa Ana mountains aided in this by limiting its southward movement. Thus, an originally south to southwestward moving current from Cajon Pass was confined and deflected towards the west during its entire passage across the Los Angeles Basin. Its own inertia limited northward spreading from the central line of flow, aided in part by the air spilling over the Sierra Madre Mountains which did not reach the ground until it reached a line running east-west through Pomona. .

The winds at March Field were light northerly up to about 1:00 P.M., when they became NE 18 miles per hour showing that the San Gorgonio current did not reach the ground at that station until that time. A balloon run made at 11:00 A.M., showed light northerly winds up to eight thousand feet where they became NE 32 m.p.h., then diminished to NW 12 m.p.h., at twelve thousand feet with six tenths of the sky covered by cirro-stratus moving from the west. At 3:30 P.M., the last report on that date, the wind was NE 16 m.phh.

The air flowed out of Cajon Pass in the form of a trough covering an area approximately two miles wide as it left the pass. The width of the flow at the ground enlarged to about eight miles as it moved southwestward across the Basin to the Santa Ana Mountains where it was constricted again by the canyon of the Santa Ana River which runs almost east-west with its eastern end a little north of the western one. In accordance with Bernoulli's Theorem, the flow was accelerated through the passes so that it debouched on the coastal area with above normal velocities. The trough like shape of the flow from Cajon Pass was verified by locating the zones of turbulence along the flow boundaries. The high velocities picked up dust and sand making the streamlines plainly visible from an airplane. Groves and other vegetation near Fontana prevented the picking up of dust in that area but farther out in the valley, near Wineville and beyond, the path of the "Santa Ana" was plainly visible because of the dust stream. On days when there are normal winds in the Basin, the path of the "Santa Ana", when viewed from the air, is shown by strings of small sand dunes and the flow lines that have been imprinted on the terrain.

North of the east-west line through Pomona and east of Los Angeles, the winds outside the main flow path and to the west of it were light from the west and southwest due to the back-set eddy effect of the Sierra Madre Mountains to the north. Numerous small whirlwinds that were rotating anticyclonically helped to define the western boundary of the main current. These marked the contact between the light southwest and the strong northeast winds. Winds at Sandberg were northeast throughout the day and attained a maximum velocity of 33 m.p.h., at 11:30 A.M. Reports from Saugus showed that the wind was calm at 7:41 A.M., and had become northeast by 11:41 A.M., with a velocity of 12 m.p.h. The velocity increased to 22 m.p.h., during the afternoon, then dropped to 8 m.p.h., at 5:41 P.M., when the wind changed to north. Light southerly winds were maintained at Burbank throughout the day until 5:41 P.M., when they became north 3 m.p.h. A balloon run at that station at 2:00 P.M., gave the following data:

ELEV (feet)	DIRECTION	VELOCITY (m.p.h.)
700	SSE	10
2000	SE	6
4000	NNE	26
6000	ENE	20
8000	NE	18
10000	N	15
12000	NW	16
14000	NW	13
21100	W	2
Above run	W	0.2 cirrus

Table 3

This run as well as the March Field record shows that the flow of air causing the "Santa Ana" was confined to the lower levels, which, combined with a lack of an intense pressure gradient, may explain why this "Santa Ana" was not of destructive force as many have been.

The flows through Newhall Pass and Mint Canyon came down across Los Angeles, as shown by smoke from the city, and aided in confining the Cajon current as it emerged from the Santa Ana Mountains. The sea breeze from the direction of Santa Monica added its bit in confining the flow from the northern side. The high ground to the south of Santa Ana helped keep the flow near the ocean from spreading to the south. Together with the shifting of the source winds, the flow across the coast line of the "Santa Ana" shifted northward from between Newport Beach and Huntington Beach to between Huntington Beach and Long Beach.

In the vertical direction, the stability of the air prevented large vertical components so that the top of the dust cloud was at about six thousand feet when it reached the ocean. Dust in conditionally unstable air over the Mojave Desert was once observed to reach an altitude of fifteen thousand feet in about four hours.

It seems as though almost all contributing agencies were working to confine and thereby speed up the "Santa Ana" as it moved across the Los Angeles Basin, and it is believed that this is the reason why high velocities persist as far away from Cajon Pass as San Pedro. The dust continued as far southwest as Catalina Island and perhaps beyond.

A "FONTANA"

"Fontanas" often do not have sufficient strength to displace the air already in the Los Angeles Basin. The following is a description of such an instance. On March 10, 1936, old Polar Pacific air had been stagnating in the Basin for a week. Several weak cold fronts had passed the area in this time but none of them had sufficient energy to get to the surface in the Basin area and displace the stagnant air. The passing cold fronts approached the Basin from the interior, each followed by a weak anticyclone, and hence the air behind them was warmed by subsidence and adiabatic heating so that they did not remove the old air but left a cold layer approximately one thousand feet thick. The North Island sounding gave the following data:

0840 Pacific Standard Time

North Island, San Diego,
March 10, 1936.

ELEV	PRESS	TEMP	RH	θ_E	W	LIFT	CLOUDS	AIR MASS
S	1014	13	84	306	7.8	300	heavy haze	
340	973	8	99	302	6.7	0	0-210 Fp	
820	921	15	40	309	4.6	1700	0.4 stratus	
1040	897	14	46	312	5.3	1300	210-340	
1260	873	16	36	314	4.7	1800		
1860	813	11	30	311	3.1	2000		
2720	733	5	34	313	2.7	1700		
3650	653	-3	37	310	1.7	1500		
4740	569	-9	29	314	1.0	1700		
5300	529	-14	28	314	0.7	1600		

Table 4

The sounding shows a marked inversion at about a thousand feet above which there was an isothermal layer extending up to about six thousand feet. These conditions were made visible by a low thick haze below the one thousand foot level that cut visibilities to two to three miles in the thicker portions. The isothermal layer was characterized by less thick haze above which a thin haze extended to about fifteen thousand feet.

During the morning, a cold front from the interior, (See map for March 10, 1936) somewhat stronger than the ones mentioned previously, crossed the Los Angeles Basin and it was possible to see its effect which was most striking inthe lower levels near Fontana. After the frontal passage, winds blowing through Cajon Pass reached ground velocities as high as forty miles per hour. The force of this wind was sufficient to cut away the hazy, stagnant air at the mouth of the pass so that by 11:00 A.M., a clear fan shaped area extending fifteen miles out into the Los Angeles Basin from the mouth of the pass had been formed. The contact between the fresh, clear air behind the front and the old, stagnant, hazy air was sharply outlined. As the day progressed, the fan shaped area on the ground remained almost constant in size until about 3:00 P.M., when it began to diminish. In three dimensions, the contact area was similar in shape to a shallow bowl with the northern edge missing.

The clear air was adiabatically heated by its descent from the Mojave Desert so that by the time it reached the Basin floor, it was warmer than the surrounding hazy air. When its velocity decreased sufficiently after leaving the pass, it was forced on up over the older air and proceeded on in a southerly direction. This vertical component combined with increasing diurnal heating caused a strengthening of the sea breeze flowing in from the northwest at March Field. By late afternoon, the increase of the sea breeze and the decrease of velocities through the pass allowed the clear area to be destroyed and winds at Fontana changed to southwest fifteen miles per hour.

That the front came from the interior was evidenced by the sequence of events to the west. At 11:30 A.M., the hazy air in Mint Canyon and the Saugus Valley had not been completely cleared, although the calm air at Saugus had changed to NE 6 m.p.h., at 9:41 A.M., with a dew point drop from 47 to 35 degrees Fahrenheit. At 2:41 P.M., the Saugus wind was E 18 m.p.h., but it became calm by 4:41 P.M., and with a wind shift to the north, then to southerly, the dew point rose froma low of 28 to 41 degrees by 6:30 P.M. However, the resistance to displacement offered by the stagnant air, aided by the sea breeze, was so strong that the passage of the front caused no visible change in the haziness of the air in the San Fernando Valley.

The Sierra Madre Mountains became clear above four thousand feet early in the morning, but later in the day when convections behind the front increased, the medium haze re-established itself up to the six thousand foot level.

There were no clouds, with notable exceptions, associated with the passage of the front although this same front had caused considerable rain in the state of Washington. It had taken this front just two days to reach southern California from off the coast of Washington. The cloud exceptions were in the vicinity of the three peaks, San Antonio, San Gorgonio, and San Jacinto, all of which are approximately ten thousand feet high. About one thousand feet above and one half mile south of each of these peaks, a small flattened cumulus cloud remained constantly in the same position during most of the day. Close observation of one of these clouds showed that it was continually building on its windward edge and dissipating on the lee side, hence the constant position in the face of a twenty to thirty mile wind. These clouds clearly show that there is a vertical component upward extending some distance up and beyond a mountain peak in air flowing over it with a velocity of twenty to thirty miles an hour.

AN OCCLUDED COLD FRONT TYPE PASSAGE

The synoptic situation on March 23, 1936, (See map for March 23, 1936) consisted of a large anticyclone over the eastern Pacific Ocean and northwestern Canada with a broad, shallow, re-entrant trough extending along the western coast of Canada and down through the northwestern part of the United States. The cyclonic curl of the upper winds in the western states accompanied by small drops in pressure indicated that a cyclonic area was developing. By the morning of March 24, (See map for March 24, 1936) the cyclone was well developed with two waves, one of which had passed over Southern California while the other was in Northern California and southern Oregon, and had already started to occlude. The air behind the cold front of the second wave wasfresh Polar Continental that had recently come out of British Columbia and was approaching a fresh Polar Pacific type by its one day passage over the ocean. The air in advance of this front was Polar Pacific that had been over the water two days and was beginning to move inland from the southwest in Southern California.

The dynamic and convective components of this wave were additive so that it quickly moved down the coast of California. Since the velocities behind the cold front considerably exceeded the warm front velocity, the wave was rapidly occluding. The resulting deepening of the system caused pressure drops in Southern California with an attending increase in the onshore component in that area. As the wave progressed, the surface winds became southerly withthe upper winds veering.

The morning sounding from San Diego (Table 5) showed two kilometers of potentially unstable air just above the surface with another kilometer that was in equilibrium, and hence would offer no resistance to lift, above the unstable layer. The average lapse rate of equivalent potential temperature for the lower two kilometers was 5.5 degrees Centigrade per kilometer. The specific humidity was 6 grams per kilogram for the first kilometer, about 4 grams per kilogram for the second kilometer, and 2.5 grams per kilogram for the third kilometer. The average lift required to saturate the lower two kilometers was about two hundred meters. The ice crystal level was at about one thousand meters in the Los Angeles Basin.

0600 Pacific Standard Time — North Island, San Diego, March 24, 1936.

ELEV	PRESS	TEMP	RH	θ_E	W	LIFT	CLOUDS	AIR MASS
S	1014	11	79	301	6.5	300		
400	968	11	77	305	6.6	400		
880	912	6	91	303	5.8	200	0.2 stratus	P_p
1280	869	2	85	300	4.5	200	710-1010	
2010	793	-3	94	299	3.6	100	0.5 strato-cumulus	
2380	756	-2	70	303	3.0	600	1680-1990	
3100	690	-6	49	303	1.8	1000		
3600	648	-8	35	303	1.1	1500		
3890	623	-9	45	307	1.4	1100		
4080	608	-10	39	307	1.1	2000		
4320	590	-11	44	309	1.2	1200		
5220	526	-15	25	312	0.6	1700		
							0.1 cirrus SW	
							0.5 cirro-stratus SW	

Table 5

Under these conditions, relatively low topographic features would furnish sufficient lift to air flowing over them to produce showers. The temperature lapse rate in the first kilometer was almost that of the dry adiabatic, so, with the scattered clouds that existed in the morning, diurnal heating was sufficient to cause convections which materially aided in the formation of showers. The air over the ocean was so unstable that showers formed there during the night and early morning. Topographic lift, convective activity, and convergence due to the approaching cold front and the shape of the Los Angeles Basin combined to produce showers eight hours before the occluded front arrived. As early as 6:30 A.M., there were occasional sprinkles at San Diego and by 8:30 A.M., sprinkleshad occurred at Laguna and showers were developing in the Santa Ana Mountains.

The Department of Commerce teletype reports for the period from 7:41 A.M. to 7:41 P.M. March 10, 1936, are reproduced below for stations in and in the immediate vicinity of the Los Angeles Basin to show the reported, hourly sequence of events. Abbreviations: LU-Laguna, WMZ-March Field, GX-Glendale, BU-Burbank, SG-Saugus, FMF-Mines Field, ZB-Sandberg, PS-Pacific Standard Time, E-estimated, minus sign-thin or light, plus sign-thick or heavy, circle - clear, circle with cross - overcast, circle with two vertical lines - broken clouds, circle with one verticle line - scattered clouds, F - fog, Sp - sprinkling, R - rain, S - snow, ceilings are given in hundreds of feet, visibility in miles, temperature and dew point in degrees Fahrenheit, wind direction by arrows, wind velocity in miles per hour, pressure in hundredths of inches, tendency in hundredths of an inch, sky cover in tenths, ST - stratus, CU - cumulus, STCU - strato-cumulus, NB - nimbus, cloud movement by arrows, AST - alto-stratus, and GF - ground fog. Of two cloud layers reported, the first is the upper. No ceiling report indicates unlimited ceiling. The height of lower scattered or broken clouds is given after the cloud symbol. The sequence of a report is: 1. Station; 2. Ceiling; 3. Sky condition; 4. Height of lower clouds; 5. Visibility; 6. Precipitation; 7. Temperature; 8. Dew point; 9. Wind direction; 10 Wind velocity; 11. Pressure; 12. Tendency; 13. Sky cover; 14. Type of clouds; 15. Direction of movement of clouds; 16. Remarks. These reports are grouped so that the first group gives the station, the second group gives the ceiling, sky condition, height of lower clouds, visibility and precipitation, the third group contains the temperature and dew point, the fourth group gives wind direction and velocity, the fifth group gives pressure, the sixth group is given three-hourly and contains the tendency, sky cover, type of clouds, and their direction of movement. The infinity sign joins items of the second and third groups and is also used to indicate a fraction when the visibility is less than one mile. Time is given using the twenty-four hour system. Letters after the tendency indicate as follows: B is steady up then level, R is unsteady down, T is up then steady down. The writer's remarks are enclosed by infinity signs.

At 7:00 A.M., strato-cumulus clouds were generally scattered over the basin. By 8:30 A.M., the sky was half overcast with a solid bank of strato-cumulus clouds along the flanks of the mountains bordering the area to the north, northeast and east. By 9:30 A.M., sprinkles occurred at March Field with numerous showers visibly approaching from the Santa Ana Mountains. Showers were beginning along the edges of the mountains bordering the Basin. At 10:30 A.M., the base of the strato-cumulus clouds was twenty-five hundred feet above March Field, the sky was eight tenths overcast, and many of the clouds extended up to eight thousand feet. Showers were occurring underneath all of the clouds that had a thickness greater than about four thousand feet. The relative humidity of the first kilometer of air averaged about eighty per cent so that evaporation prevented considerable rain falling from the smaller clouds from reaching the ground. Six thousand feet above the tops of the strato-cumulus clouds was a deck of alto-cumulus having a thickness of about one thousand feet. This layer broke and disappeared east of March Field whereas to the west, it became increasingly solid to entirely solid covering the sky at the coast. These clouds had some-

0741PS
LU E25◑25 50/44 ←3 000 RAINING OFFSHORE
PMF O40 47 ↙4 991 /CLEAR SKY/
WMZ E45◑10 44/40 ↙1 994 /NORTH WIND/
GX Φ30/10 50/40 ↑4 995
BU Φ/10 47/39 ↖5 994 HAZE SE VISIBILITY 6
SG ◑/Φ15/10 45/37 ↑12 989 /TWO LAYERS OF CLOUDS/
ZB O1/5GF+ 30/30 ↑16 981 DRIFTING GROUND FOG

0841PS
LU E25◑25 51/43 ↘3 001 FEW SPRINKLES LAST HOUR
GX Φ/Φ30/20 56/37 ↖3 996 /TWO CLOUD LAYERS/
WMZ E45Φ15 46/40 ↓6 994 CLEARING FEW LOWER CLOUDS
BU ◑/Φ30/15 51/38 ↖7 995
SG Φ/Φ25/35 47/36 ↑↖11 991
ZB OF1/5 32/32 ↑22 979 CLEAR OVER ANTELOPE VALLEY CLOUDS
TOPPING TEHACHAPIS /ICE CRYSTAL LEVEL/

0941PS
LU Φ30/30 52/43 ↘5 001 /GOOD VISIBILITY/
WMZ E40Φ15 49/34 ↓4 993 /PRESSURE FALLING DESPITE DIURNAL RISE/
GX E35⊕/◑20 56/37 ↑9 996 /CLOUDINESS INCREASING RAPIDLY
BU E35⊕/◑20 50/37 ↑↖8 994
SG E25⊕/◑30 48/36 ↑↖14 989 /CEILING LOWERING/
ZB E1⊕5S- 31/31 ↑↗18 982 /FIRST REPORTED PRECIPITATION IN MTS/

1041PS /THREE HOURLY REPORTS/
LU E18⊕15SP 54/43 ↘5 000 NONE 10STCU↗RAINING OFFSHORE
WMZ E40⊕12SP 47/41 →4 993 1B 10STCUX→ /WIND BACKING/
GX E35/⊕/◑20 56/37 ↑10 995 1- 3AST/U 7STCU↗
BU E80⊕Φ30/20 50/40 ↑↖10 993 1T 9AST→↗ 1STCU↑
PMF E20⊕◑25 56 ↗8 991. /UPPER CLOUDS CONTINUOUS WEST TO FRONT/
SG E20⊕6R-47/39 ↑↖9 987 4-/VISIBILITY ONE FIFTH FORMER VALUE/
ZB OF+OS- 31/31 ↑↗21 980 2R

1141PS
LU E30Φ/◑25 57/48 ↑6 999 OCCASIONAL LIGHT SHOWER /SOUTH WIND/
WMZ E35⊖12SP 49/39 ↖8 990 /SHOWERS BECOMING GENERAL/
GX E35⊕20R- 53/47 ↑↖5 993 /PRESSURE FALLING/
BU E70⊕Φ/30/12R- 49/40 ↖10 991 /CEILING LOWERING/
SG E12⊕4R- 44/40 ↗9 985 /MINIMUM CEILING AND VISIBILITY/
ZB OF+OS- 31/31 ↑19 976 /BAROMETER FALLING RAPIDLY/

1241PS
LU E30⊕15/10R- 54/43 ↗9 996 DARK OVERCAST SEAWARD
/OBSERVER SEES FRONT APPROACHING/
WMZ E25⊕6R-F- 46/40 ↗13 987 /VISIBILITY LOWER IN SHOWERS/
GX E25⊕10R- 48/46 ↗5 992 /VISIBILITY CUT IN HALF/
BU E45⊕Φ20/8R- 47/42 ↑↖5 990 /CEILING LOWERING RAPIDLY/
SG E12⊕4R- 44/41 ↑9 983 PASS OBSCURED /PRESSURE FALLING/
ZB OF+OS- 30/30 ↑14 977

1341PS

LU E10⊕⊙7R- 49/47 →9 994 /WIND SHIFTING FRONTAL ZONE/
BU E15⊕⊙10 49/46 ↑4 986 SHOWERY CONDITIONS LARGE BREAK SW /FRONT CLOSE OBSERVER SEES BREAK BEHIND FRONT/
PMF 10⊕20R 50 ↗24 984 /WIND SHIFTING AND PICKING UP/
GX E30⊙Φ20/20R- 51/47 ↖3 990
WMZ E25⊕6R- 45/43 ↑7 984
SC E15⊙10SP 48/45 ↖7 977 BAROMETER DROPPING VISIBILITY SE TO S 5 DUE TO FOG CEILING RAGGED
ZB OF+1/5S- 31/31 ↑↗11 975

1441PS

LU E20⊕Φ10/12SP 50/44 →↘8 991 RAINING OFFSHORE /FRONT HAS PASSED/
GX E30⊙Φ20/15 54/46 ↗15G- 984 /GUSTY WIND BEHIND FRONT BAROMETER DROPPED RAPIDLY/
BU E15⊕⊙20 53/43 →19 983 FEW LARGE BREAKS /FRONT PASSED/
SG E20⊙10SP 50/45 →9 975 PASS OPEN CEILING RAGGED AND CHANGEABLE /FRONT HAS PASSED BAROMETER STILL FALLING/
ZB OF+1/5S- 30/30 ↑11 972 GRAUPEL TYPE SNOW

1541PS

LU E30Φ30 52/46 ↘11 989 CEILING RAGGED
WMZ E12⊕3R-F- 41/41 →8 980 /LOW VISIBILITY FRONTAL ZONE/
GX E30Φ15R- 51/45 →↘18G- 983 /STRONGER GUSTY WINDS BEHIND FRONT/
BU E20Φ20 49/44 →17 982 /CLEARING/
SG E20Φ/Φ15 45/40 ↗11 974 VISIBILITY N 34 NEWHALL PASS OPEN
ZB E50⊙Φ0/10 32/32 ↑↗20 970

1641PS

LU E35Φ25 53/43 →↘12 989 4- 6STCU→
DMF O40 53 ↗32 979 LOW CLOUDS ALL HORIZONS /WIND STILL STRONGER
WMZ E10Φ7 45/43 →21 979 10S 8STCU→ /FRONT HAS PASSED/
BU 25Φ30 51/39 →17 981 4S 7CU→↗ /MINIMUM PRESSURE/
SG Φ/Φ15/30 47/39 ↗19 973 4- ALL MOUNTAINS CLOUD CAPPED CLOUDINESS CHANGEABLE DARK NW TO N /SHOWERS BEHIND FRONT/
ZB E10⊕15 34/30 ↗11 972 2R 10STCU→ SNOWING N TO W

1741PS

LU Φ35/30 52/40 ↘11 989
WMZ E20Φ/Φ8 46/41 →24 978
GX E35Φ15 52/36 ↘15G- 983
BU Φ30/30 49/37 →↘12 981
SG Φ20/30 45/36 ↗20 975 CLOUDINESS CHANGEABLE SHOWER NE
ZB E10Φ30 30/25 →↘12 972 /FRONT HAS PASSED/ MINIMUM PRESSURE/

what the appearance of alto stratus but their elevation was insufficient for this type. They were what is often called "false cirrus" and were the high clouds known to exist in advance of the idealized cold front. There was enough vertical motion within this layer to produce small vortices and the wisps on top of the deck all pointed in the direction of the prevailing wind.

At 11:00 A.M., rain was continuous at Beaumont and Banning. The ceiling in San Gorgonio Pass had dropped to eight hundred feet, this being due in a large part to the higher elevation of the ground there than at March Field. The rain area stopped halfway through the pass. Beyond in the Coachella Valley, the sky was clear, no clouds persisting beyond just east of the crest of the mountains that bound the valley on the west and northwest. The absence of clouds in the Coachella and Imperial Valleys and northeast of the San Bernardino Mountains indicated that the rain in the Los Angeles Basin was chiefly orographical during the morning and early afternoon.

There was a marked increase in wind velocity over the mountains forming the northeast rim of the Basin. The countour of the Basin is such that winds from the south and southwest are converged towards the northeast and frequently doubled or tripled in velocity as they pass out of the area. The resulting greater volume of air flowing over the San Bernardino Mountains would cause the precipitation to be exceptionally heavy there in situations similar to the one being described, were it not for the Santa Ana Mountains to the southwest. These mountains average about three thousand, five hundred feet in elevation and cause a large amount of precipitation to fall there that otherwise would fall on the San Bernardino Mountains. The convergence caused six inches of snow to fall on the San Bernardino Mountains, while four inches of snow was falling on the freely exposed Sierra Madre Mountains to the west.

The strong velocities over the rough country on the northeastern slopes of the San Bernardino Mountains created sufficient turbulence to make flying uncomfortable. In many places, a crab of thirty-five degrees was required to make a given track, and in others the down component was about two thousand feet a minute. Such down components do not extend down to the surface, but the downward momentum given to an airplane by such a current might force an airplane to the ground because of the momentum established in the plane itself.

There were lower scattered cumulus clouds over the Mojave Desert to the east, becoming overcast to the west with an upper deck of "false-cirrus", the eastern edge of which extended in a north-south direction through Victorville at noon. No rain was visible at that time over the desert, but a blinding snowstorm was in progress in Cajon Pass where the ceiling remained at two thousand, five hundred feet. Velocities through the pass were not as high as they were over the mountains to the east, yet they were sufficient to cause severe turbulence, especially on the desert side where the terrain is quite rough and the outflow occurred. Turbulence due to topography alone is rarely found on the windward side of a mountain or ridge. The main turbulent zone lies to the lee, starts below the top of the ridge, and slopes downward roughly parallel to the surface. The turbulence is greatly increased if the ridge has a rough or uneven surface on top and on the lee slope.

By noon, the eastern portion of the Basin was overcast with intermittent rain falling over the entire area. This showery condition continued until the approach of the frontal zone. The occluded cold front reached the western edge of the area about 1:30 P.M., and continued to move eastward at about forty-five miles per hour. Surface winds immediately in advance of the front increased from about ten to twenty miles per hour and with the passage of the front, shifted from south and southwest to west and northwest. Heavy rain preceded the front in a narrow band. A thunderstorm of about three minutes duration with accompanying moderate hail and heavy rain occurred at Pasadena at 3:10 P.M. The pre-frontal precipitation changed type at Ontario where light snow occurred while a little farther south and east at Wineville, it was a two-minute heavy rain.

Ceilings dropped to about fifteen hundred feet on the approach of the front where they remained for an hour until after the frontal passage when the sky became broken, ceilings lifted and only scattered clouds remained by late afternoon. Ceilings over the Tehachapis were zero most of the day up to 3:00 P.M., when they rose considerably. Visibilities were cut in half during the passage of the frontal zone and became only one quarter mile in the heavy pre-frontal rain. Surface winds maintained their increased frontal velocity for several hours after the front had gone by. Visibilities increased after the passage to higher values than had existed early in the morning. The air both in front of and behind the front was so fresh that it was unusually clear. No appreciable haze developed in the Basin for two days after the frontal passage. Temperatures were greatly changed by the frontal passage. They dropped a little at coastal stations but at Burbank they actually rose, due probably to adiabatic heating caused by the low mountains to the west of that station when the wind shifted from south to west northwest. Pressures dropped rapidly on the approach of the front but did not rise sharply after the passage due to the diurnal variation and a general deepening of the whole system. Minimum were pressures at sea level stations two to three hours after the passage of the wind shift whereas at Sandberg, a four thousand, five hundred foot station, the wind shift and minimum pressure occurred simultaneously. The front passed Sandberg about three and a half hours after it passed sea level stations on the same meridian, indicating that the front was retarded somewhat by the Coast Range Mountains to the west. Study of the wind data in connection with the passage of this and other fronts indicates that Sandberg gives more representative data than any other station in the Los Angeles Basin or its immediate vicinity. A rule might be suggested, "Watch Sandberg for frontal passages in Southern California."

The frontal zone when viewed from the rear showed a marked north and south line of nimbus and cumulo-nimbus clouds. There were large breaks immediately to the west with clearing in the distance. Showers at valley stations persisted for only about half an hour after the frontal passage. The precipitation at the base of the Sierra Madre Mountains was about twice that at coastal stations.

CONCLUSIONS

1. Topography plays an important role in the weather and climate of the Los Angeles Basin.

2. The high surrounding mountains materially aid the existence of the mild Winter climate.

3. Strengthening and movement of the Great Basin anticyclone alone, or combined with similar action of a cyclone over Arizona, which causes a steep pressure gradient and strong northeast winds at the northeastern edge of the Los Angeles Basin, are essential to the formation of a "Santa Ana".

   a. The northerly flow through Cajon Pass is confined and deflected to the west by a simultaneous flow through San Gorgonio Pass.

   b. All elements seem to combine in confining and thereby maintaining the velocity of the main current as it flows across the Basin.

4. To replace stagnant air in the basin, a front approaching from inland must have considerable strength or precede potentially colder air.

5. A cyclonic system that brings fresh Polar Continental air out of central, western North America, rapidly transports it over the Pacific Ocean, and brings it into the Los Angeles Basin from the west is the only agency that will produce snow at low Basin stations.

6. Annual precipitation is largely orographical.

7. In the San Bernardino area, convergent flow caused by the mountains increases precipitation which is somewhat limited by the screening effect of the Santa Ana Mountains.

8. With south and southwest winds in the Basin, velocities over the northeast rim show a marked increase.

9. The air stream over a mountain or ridge separates to the lee with an upward component extending some distance above and beyond the crest, this distance varying with the velocity. The down component follows the contour with eddies and turbulence in the separation zone. Maximum turbulence lies to the lee in a zone sloping down parallel to the surface.

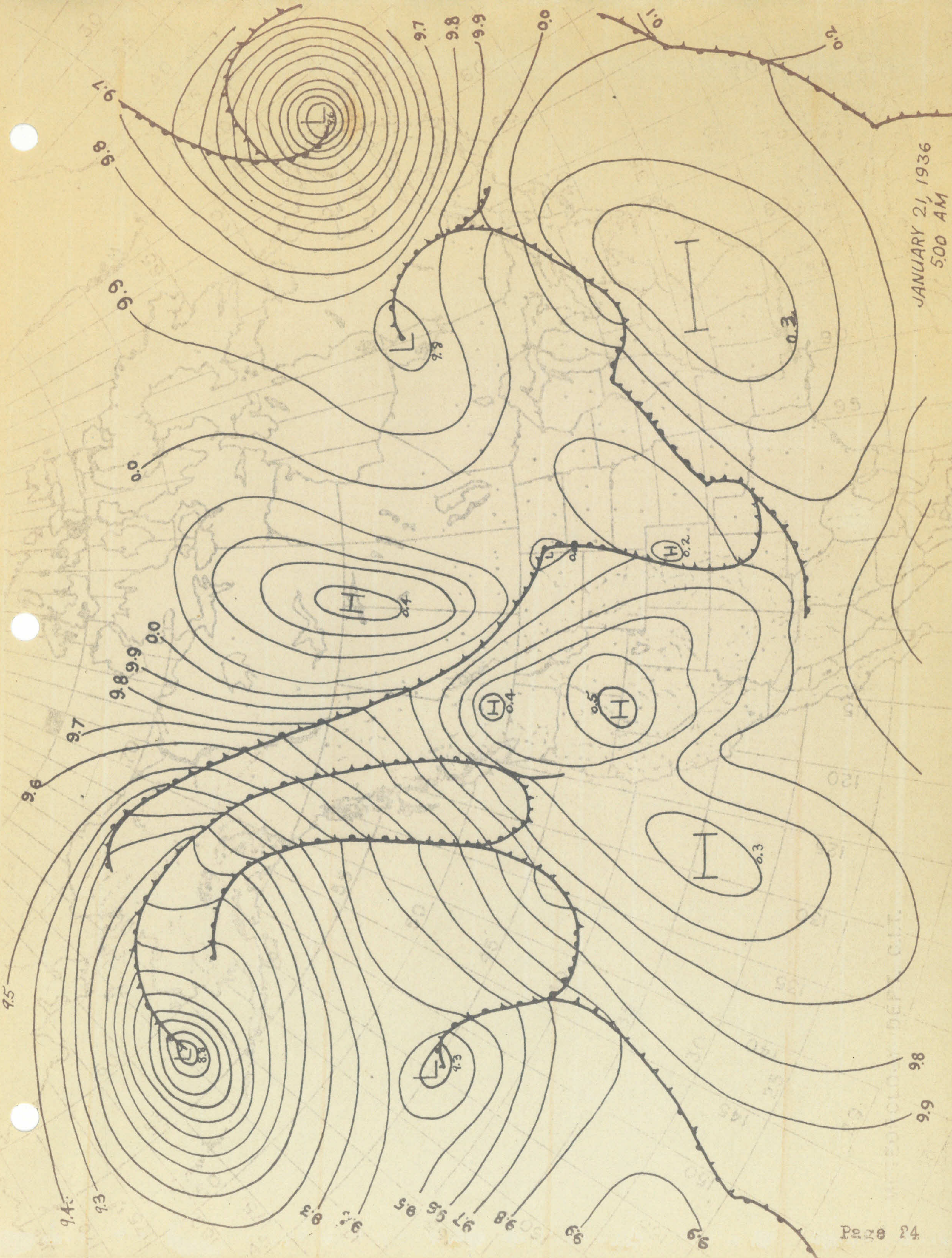
10. Flying altitudes should be kept above a certain minimum in strong down drafts.

11. Central flow through smooth passes is slightly disturbed. Turbulence results from irregular flow caused by promontories or canyons, is more pronounced to the lee, and is directly proportional to the wind velocity.

12. Sandberg gives the most representative wind data in or near the Basin.

13. Rainfall at the base of the Sierra Madre Mountains should be about twice that at coastal stations.

14. Frontal passages are rarely marked in all of their essentials in the Los Angeles Basin.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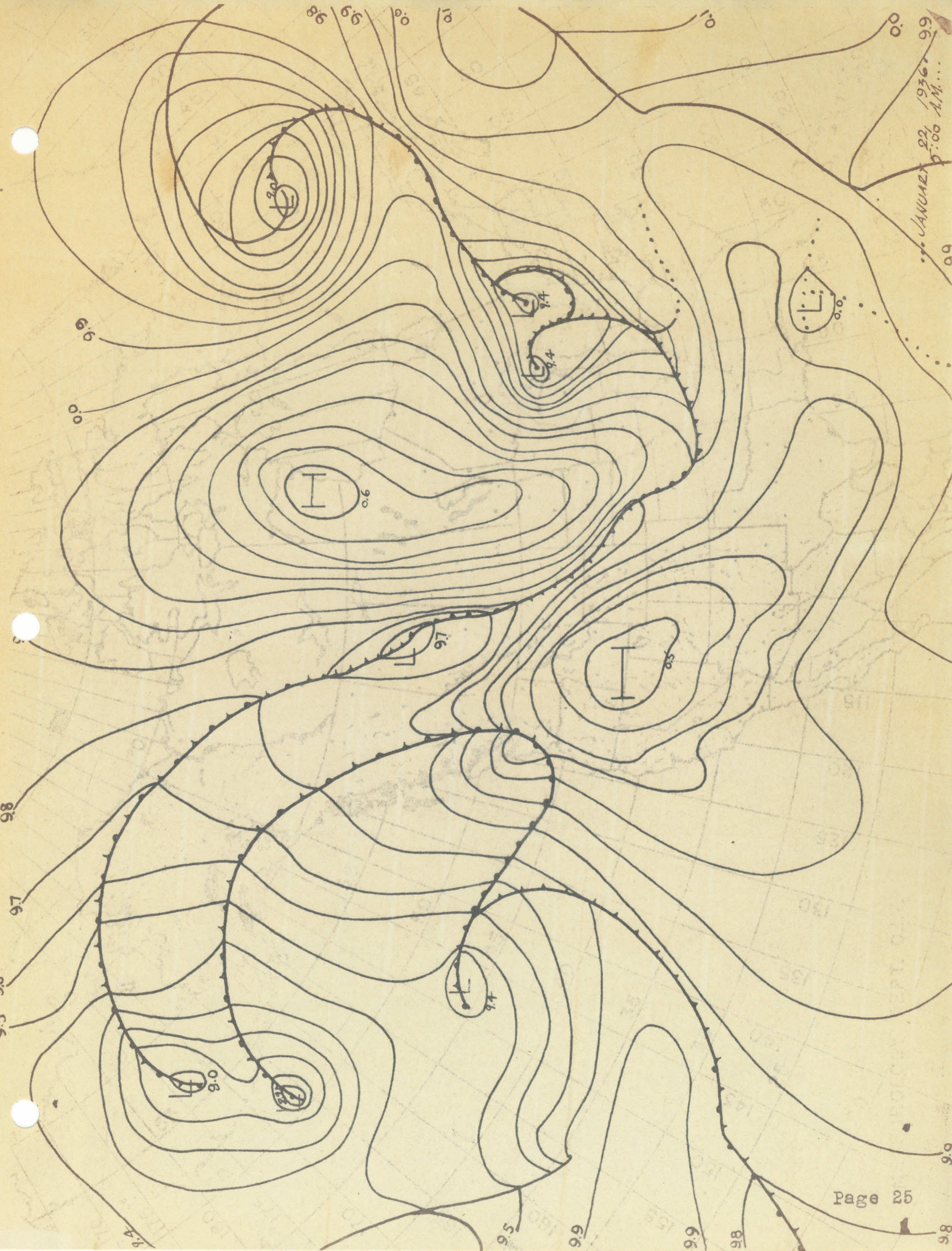
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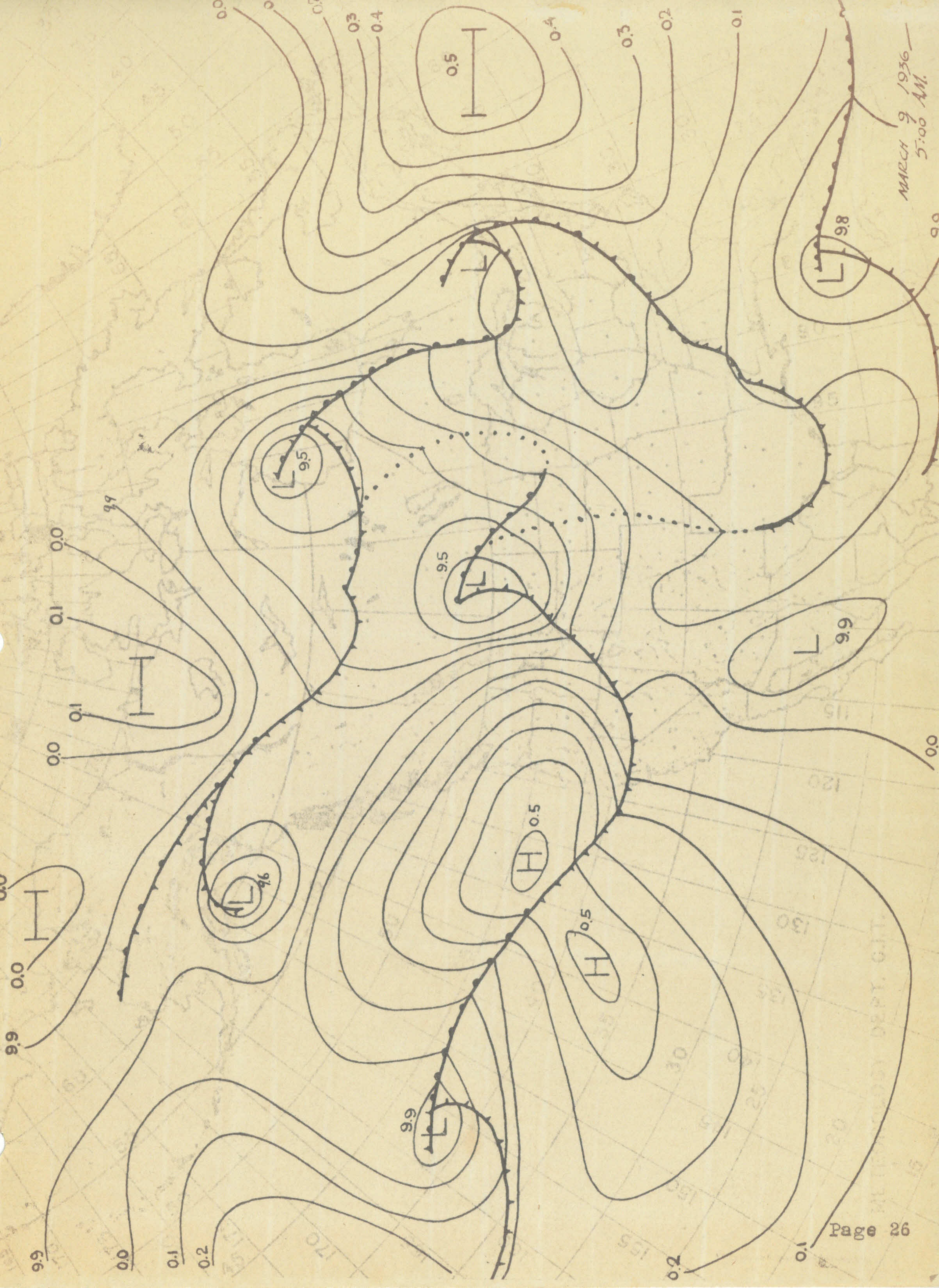
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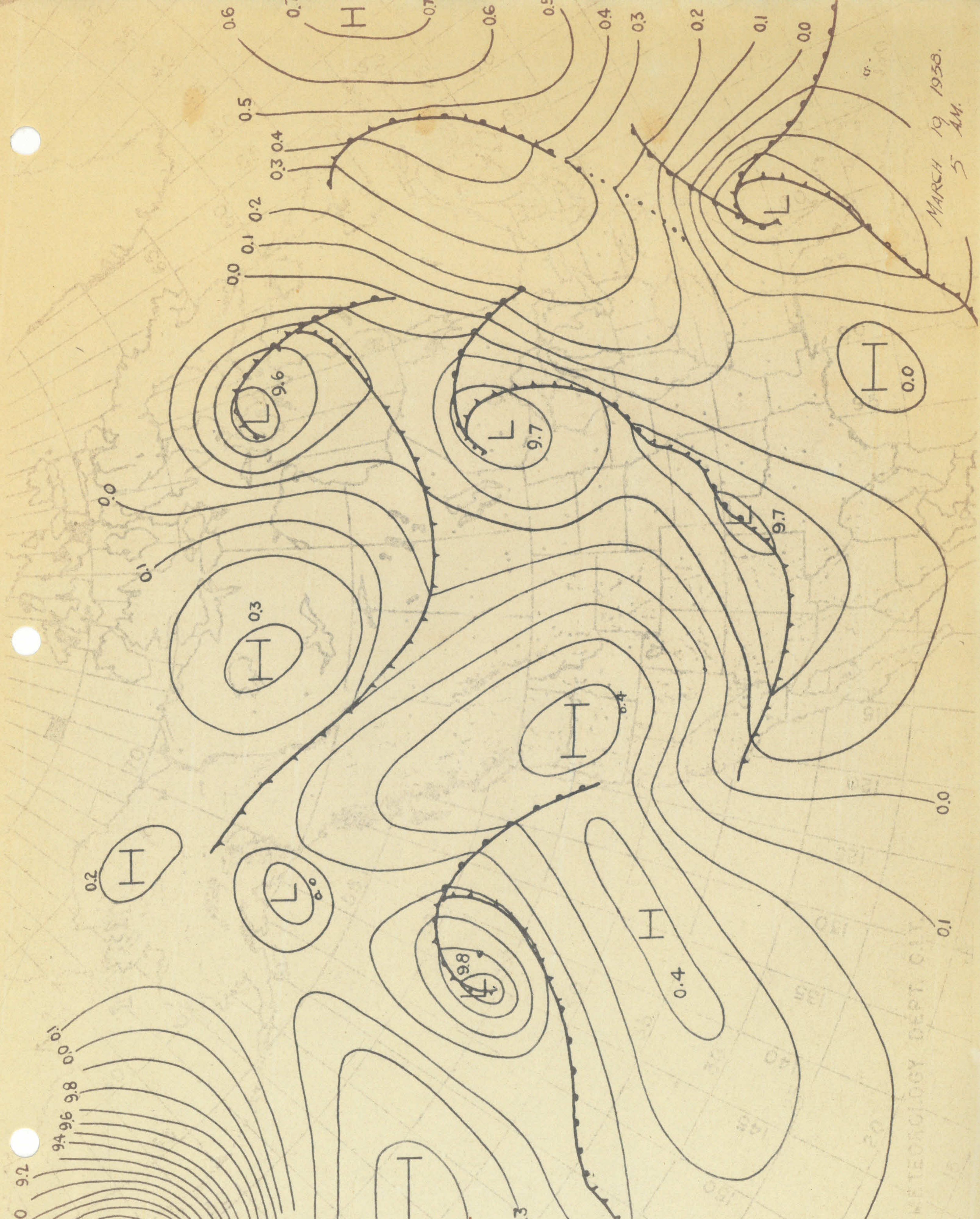
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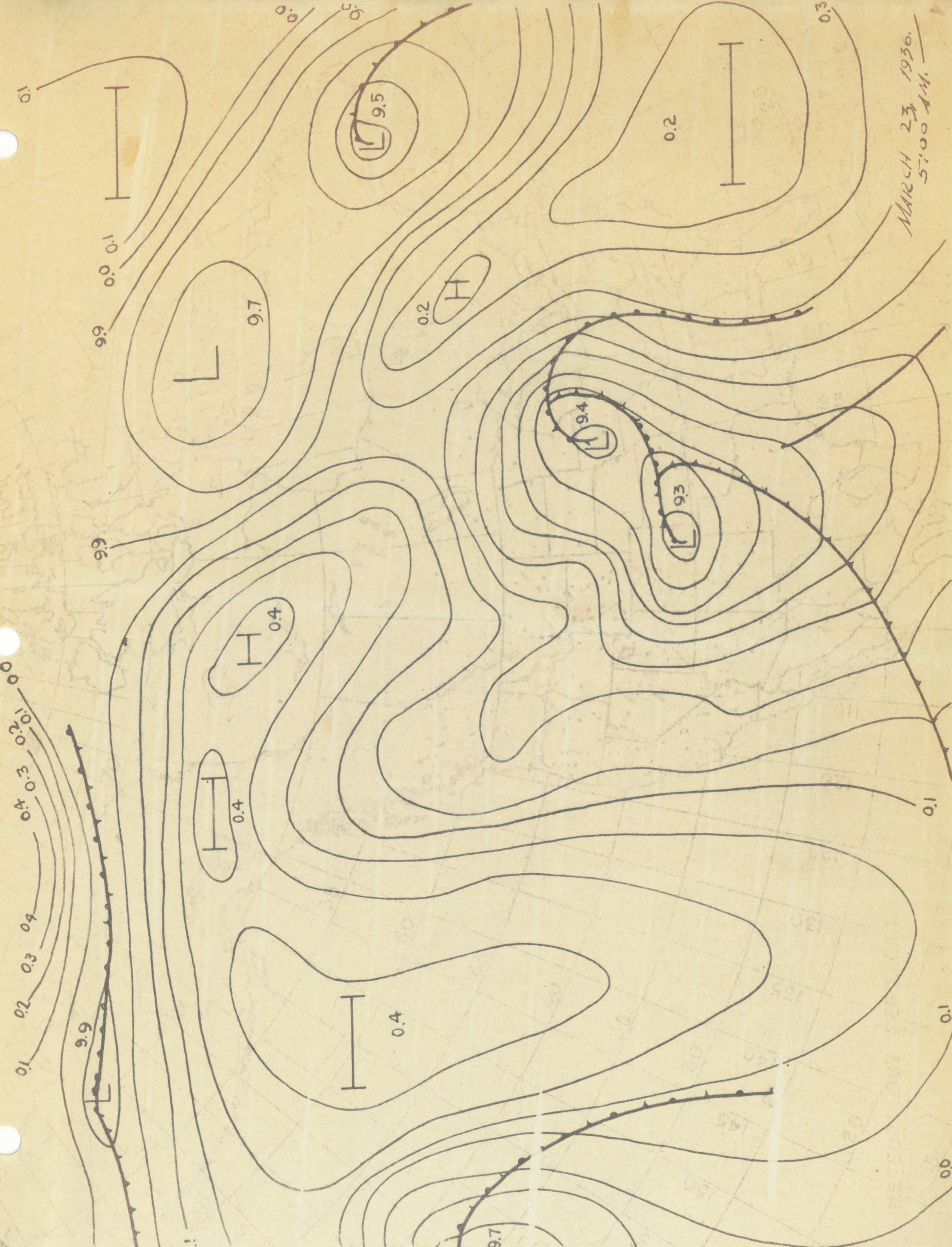
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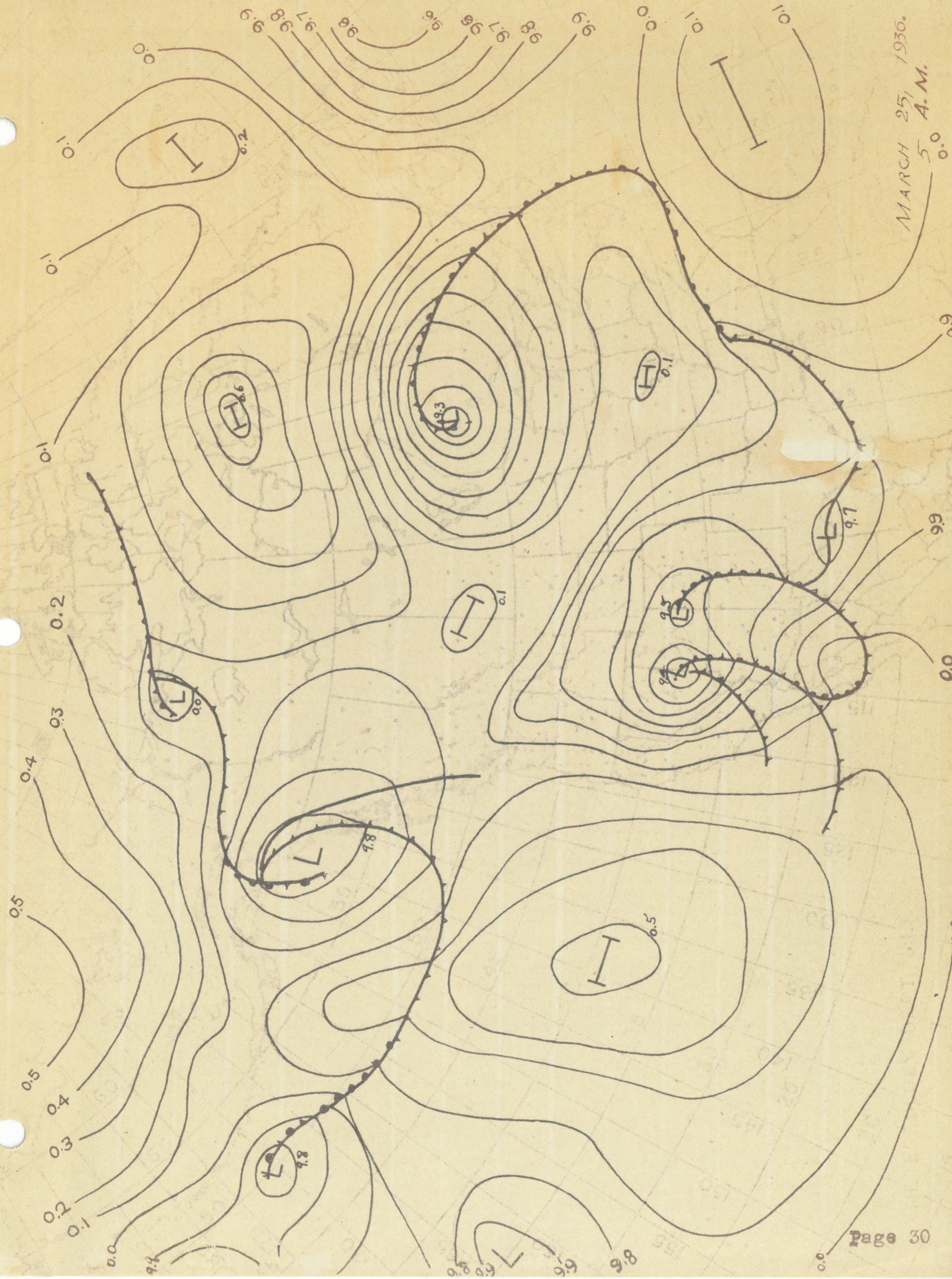
5:00 A.M.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