Short-Period Climatic Fluctuations

The nature and cause of climatic abnormalities lasting from a month to a few years are discussed.

Jerome Namias

The *nature* of climatic fluctuations on various time scales has received a great deal of attention for at least the past century. It has frequently been pointed out that weather events are serially correlated from day to day, week to week, month to month, year to year, decade to decade, and so on, so that spells of weather of the same prevailing character arise, the persistence often surprising both meteorologists and laymen. Thus, the standard deviations of mean values of continuous meteorological elements do not decrease as rapidly as the number of observations in a random series would suggest. It is unlikely that the large standard deviations observed over seasons, for example, can be attributed solely to day-to-day coherence. But even if they could, one would have to explain how the day-to-day coherence was brought about. The *causes* of climatic fluctuations, both short and long, have on the other hand received much less attention in the literature than their description—a fact not surprising in view of the seemingly infinite complexities involved.

In the course of almost 30 years' work with extended and long-range forecasting for periods from a week to a season, I have noted certain associations between branches of the atmospheric circulations and between these and the character of the land and ocean surfaces. For short periods —pentads, for example—, how and why one center of action may affect others has become classical knowledge. For almost a century, statistical methods (mainly correlation) pointed to simultaneous teleconnections, but later Rossby (*1*) and Charney *et al.* (*2*) developed satisfactory and testable theories for explaining large-scale changes over short time intervals, based on the concept of vorticity redistribution. For longer time scales—for example, a month or season—while it is obviously impossible to apply precisely the same reasoning, it is known that if one center of action (one trough-ridge complex) is in some way forced, others are likely to fall into certain positions.

Thus, one apparently logical attack would be to try to find evidence for the factors leading to the establishment of an anomalous position and orientation of one center of action and attribute the behavior of others to this primary abnormality. Such an attack is, unfortunately, a great oversimplification, because the fluid atmosphere operates in a manner such that all its perturbations are interactive. Nevertheless, practical work in long-range forecasting suggests that frequently some anomalous areas of the general circulation are persistently reestablished or reinforced and that other areas respond to these. Not too long ago the Rocky Mountains were considered to be the primary forcing agent for the normal circulation pattern over North America, and the Atlantic and European normal flow patterns were believed to be almost completely responsive features (*3*). While a good deal of truth probably resides in this thesis, it is abundantly clear that for periods of a month or a season the forcing influence of the Rocky Mountains must often be secondary to other influences. An example is shown in Fig. 1, where the observed mid-tropospheric flow pattern over North America is out of phase with the normal pattern: a trough, not a ridge, is observed over the western mountains and a ridge, not a trough, dominates the east. Similar aberrations from normality may also be seen on mean seasonal charts, and even in annual means the normal western ridge may be greatly suppressed. Therefore, it seems that other influences on the general circulation can be strong enough to overpower and to some extent mask even the strong geographically engendered forces. To me it seems unlikely that this circumstance results from random combinations of meteorological data, or, in other words, from *internal* aspects of behavior of the atmospheric system, because of the chaos of daily or weekly wind and weather patterns.

The alternative is to seek factors *external* to the atmosphere as causative agents for its abnormality. The most obvious are variations in the ocean and land surfaces on the one hand and variations in solar activity on the other. The case for the latter is presented elsewhere (for example, by Willett, *4*), and I shall not enter into this controversial domain. Rather, I shall try to show by circumstantial evidence (statistical, synoptic, and qualitatively physical) the reasonability of the thesis that the atmosphere and the surface that underlies it work jointly to favor prevailing (or prevailingly recurrent) abnormal wind and weather patterns. In what follows, it must be continually borne in mind that the longevity of abnormalities in the two media, sea and air, is quite different, so that heat reservoirs in the ocean may continue to exist long after perturbations in the atmospheric system, whether cyclones or cyclone families (short- or long-wave), have passed.

Cooperative Ocean-Atmosphere Effects

Although the concept that air-sea interactions lie at the root of the problem of short- and possibly long-period climatic fluctuations is an old one, it is only during the past 5 or 10 years that the subject has been resuscitated since its popularity around the turn of the century (*5*). In 1959 I discussed (*6*) the joint nature of atmosphere-ocean behavior on a large scale over the North Pacific. Here I pointed out that sea-surface temperature anomalies were of the same scale as sea-level pressure

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(wind) anomalies when both were averaged over seasons, and that the anomalous wind components appeared to induce the sea-surface temperature anomalies largely through the transport in the Ekman layer.

Although further practical work along these lines has strengthened the conviction that there is a general relationship between anomalous wind components (over months or seasons) and sea-surface temperature, this is a much more complex relationship than was originally supposed.

In general, the extensive pools of warmer-than-normal surface water are found between anomalously deep mean cyclonic centers of action and the adjacent anticyclones to their east, while colder-than-normal surface water is generally found in, and to the west of, deeper-than-normal cyclones. Isopleths of pressure anomaly bring into sharp focus these anomalous components of air flow, because the mean resultant (geostrophic) anomalous wind component bears the same relation to the isopleths of pressure anomaly that the mean resultant wind bears to the mean isobars. The isopleths of mean anomaly also afford a good picture of the abnormal frequencies of wind directions.

Two examples are shown in the upper rows of Figs. 2 and 3, where, for October 1959 and July 1958, roses for normal and observed surface winds are given for the shaded square shown in the graph at top left. (The charts reproduced are for the 700-millibar level, but the *anomalies* at the surface are similar.)

It is clear that, in these 2 months, winds with southerly components frequently replaced the more usual winds from more westerly and other quadrants. This biased wind distribution apparently set up a chain of events leading to warmer-than-normal surface water to the east, as indicated by the observed sea-surface temperature

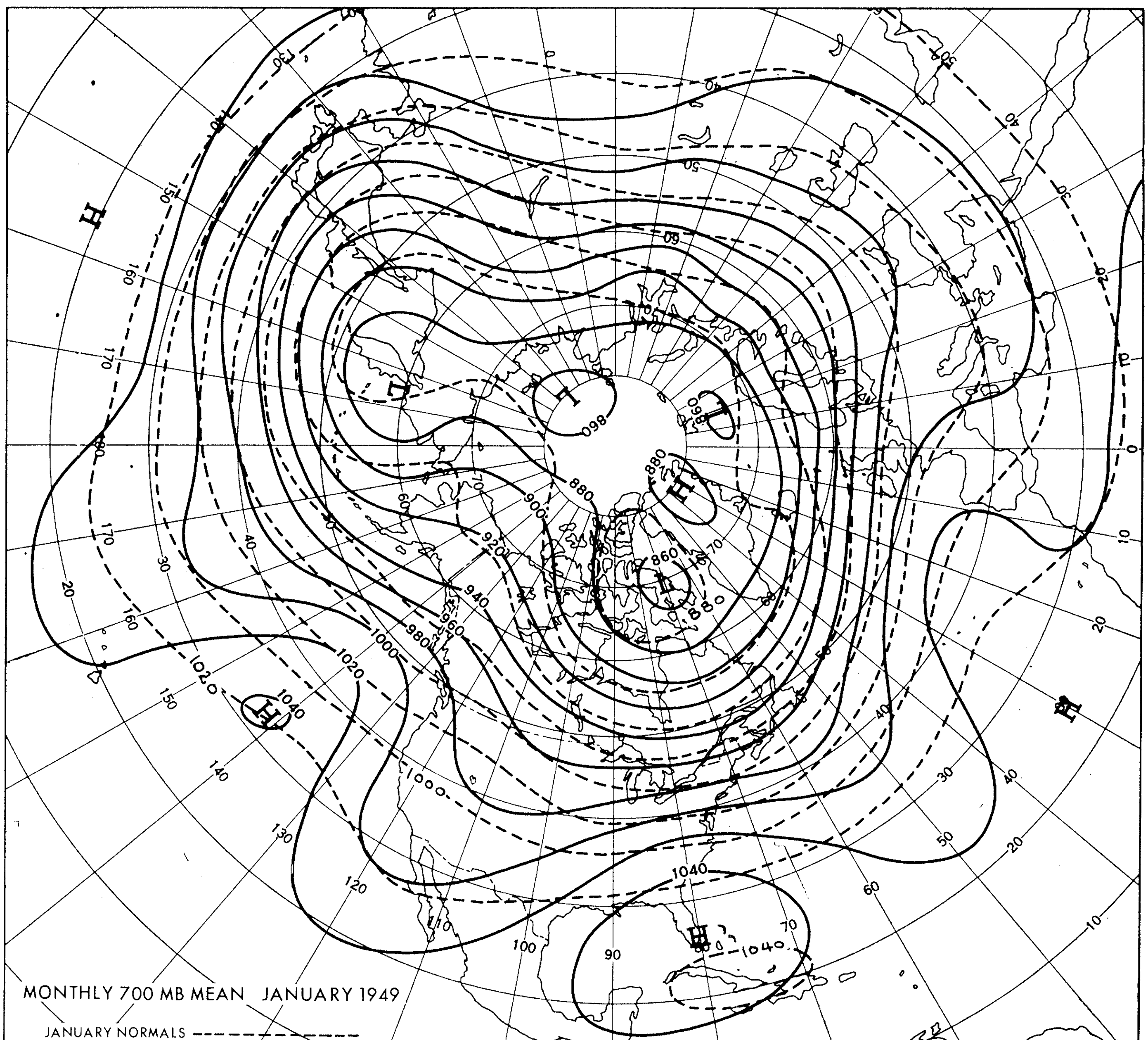


Fig. 1. (Solid lines) Monthly mean 700-mb contours for January 1949; (dashed lines) normal contours for January (contours labeled in tens of feet).

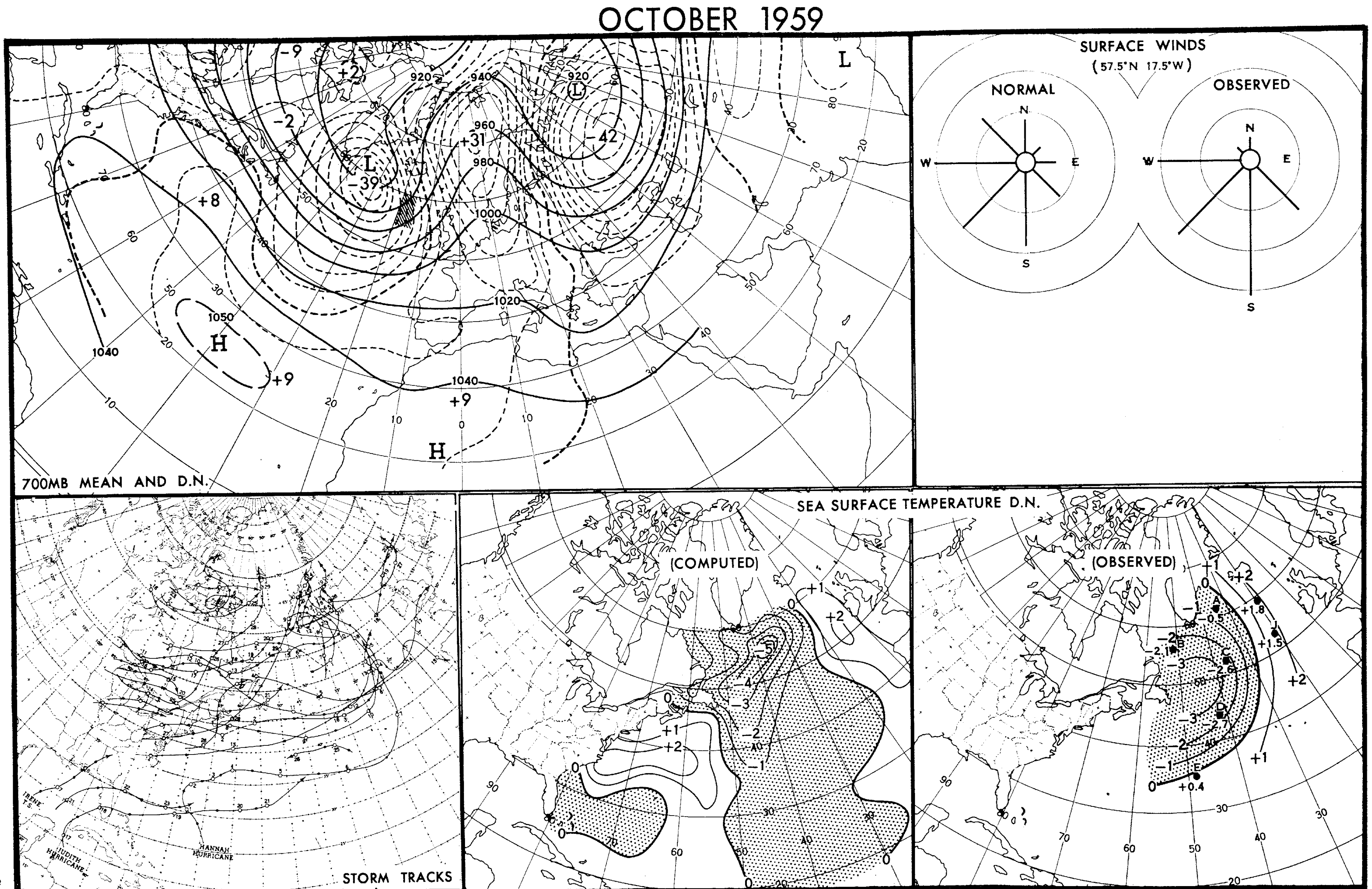


Fig. 2. (Top left) (Solid lines) Mean 700-mb contours for October 1959; (dashed lines) isopleths of departures from normal for October 1959. Centers of the isopleths are labeled in tens of feet. (Top right) Normal-surface-wind rose for October and observed-surface-wind rose for October 1959 as computed from surface-weather-map analyses for the hatched 5-degree square shown in chart at top left. (Bottom left) October 1959 cyclone tracks (numbers refer to days of month). (Bottom middle) Sea-surface temperature anomalies (in degrees Fahrenheit), computed from a formula for advection in the Ekman layer for October 1959. (Bottom right) Observed sea-surface temperature anomalies (in degrees Fahrenheit) for October 1959.

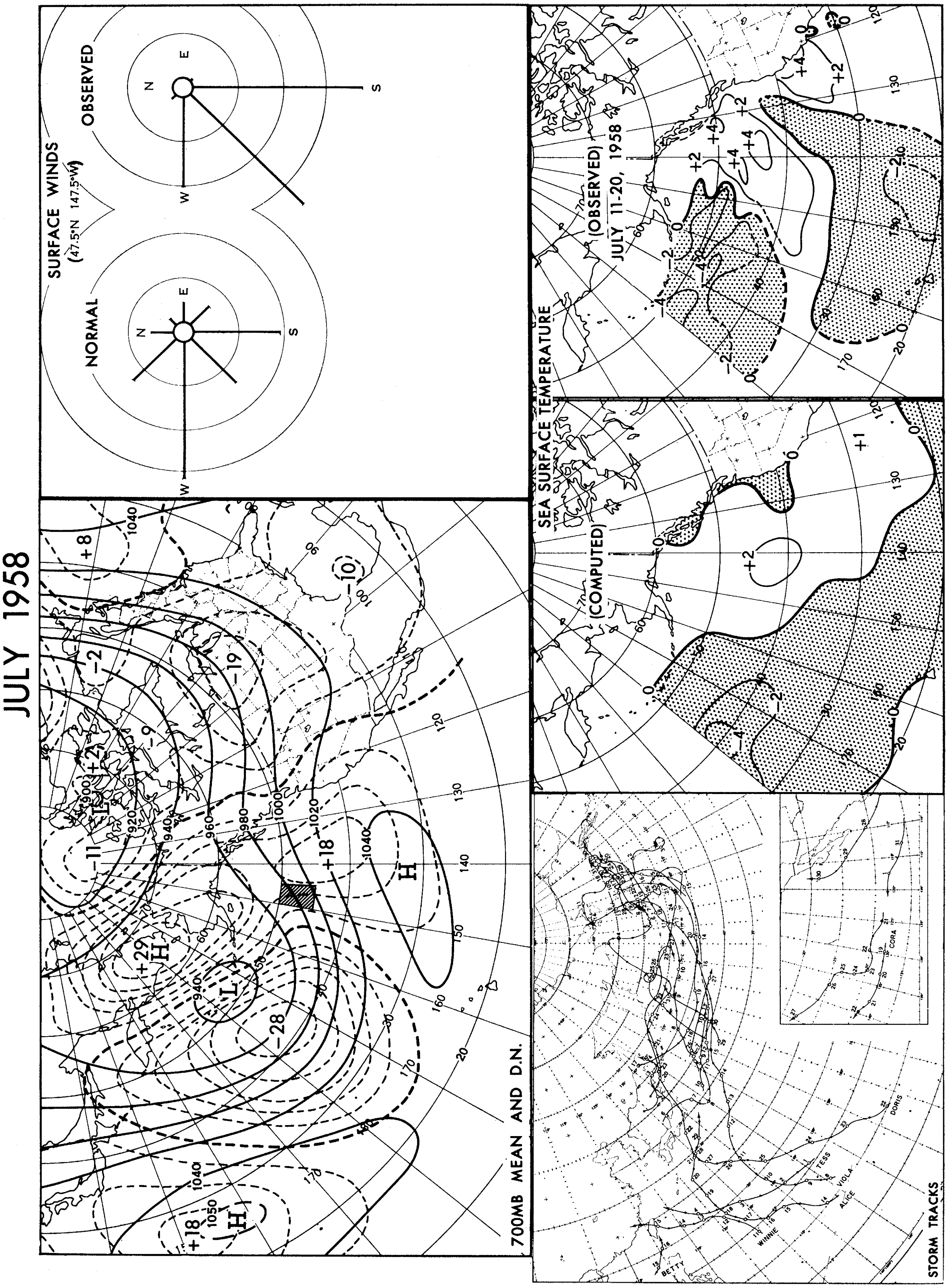


Fig. 3. Charts analogous to those of Fig. 2 for July 1958 rather than October 1959.

anomalies shown in Figs. 2 and 3, bottom right. It is also clear that surface water near and to the rear of the center of negative pressure anomaly was colder than normal.

With such biased surface-wind components as are suggested by the anomalies, it seems probable that several factors play a role in creating anomalous sea-surface temperatures. In the first place, if we compute an "anomalous" Ekman drift such as that described in (*6*), where the surface water is displaced 45° to the right of the wind, it is clear that a substantial part of the departure of water temperature from the normal pattern is accounted for as suggested in the middle charts of the bottom rows of Figs. 2 and 3. At least the gradients are in the proper sense. However, it is highly unlikely that advection alone can account for many observed patterns of sea-surface temperature, for it is well known that the exchange of sensible and latent heat, as well as radiation and upwelling, are important. Bjerknes (*7*) has demonstrated that upwelling may account for the anomalously cool water frequently found near anomalously deep mean cyclonic centers, while horizontal convergence and "downwelling" may explain some of the warmth often recorded under mean anticyclonic circulations.

It appears that other factors frequently operate in the same sense as advection and upwelling, producing cooling of surface water when there is abnormal flow of air from the north, warming of surface water when there is abnormal flow of air from the south, cooling of water in abnormally deep cyclones, and warming in anticyclones. Over most of the year, and especially in the areas dominated by the Aleutian and Icelandic lows, an increase in the frequency and strength of northerly air streams implies more than the normal transport of cold air masses. In the case of the Aleutian Low these air streams emanate from the Bering Sea, Alaska, and the Arctic Basin; in the case of the Icelandic Low they emanate from Greenland. These masses of cold dry air extract great amounts of sensible and latent heat from the water. An idea of the magnitude of such heating is given by Winston (*8*), who computed that as much as 1000 langleys per day are lost from the sea to the air when the Gulf of Alaska cyclone develops strongly. Of course, the great vertical instability created in these air masses facilitates upward transport of heat and water

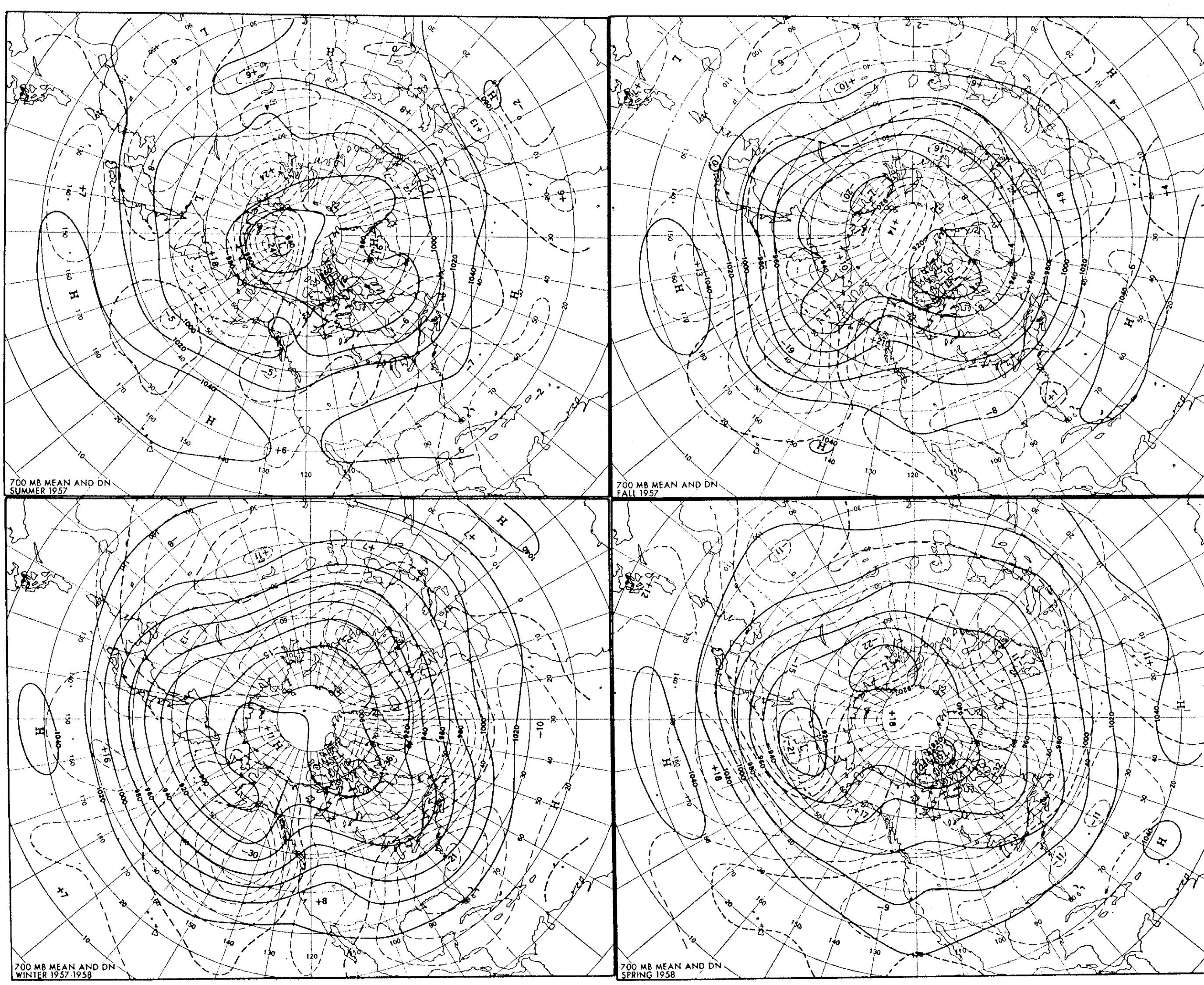


Fig. 4. (Solid lines) Seasonal mean 700-mb contours for the seasons indicated; (dashed lines) departures from normal. Contours are labeled in tens of feet and isopleths of departures are drawn for intervals of 50 feet with centers in tens of feet.

vapor to considerable elevations. On the other hand, in association with greater-than-normal frequency and strength of southerly winds, one usually finds relatively small temperature contrasts between sea and air, greater-than-normal vertical stability in the mixed layer of the lower atmosphere, and therefore lower-than-normal loss of sensible and latent heat from the ocean. During the cold season the radiation balance may also cooperate by providing greater cooling in northerly than in southerly air streams, since the latter are generally characterized by more clouds than the former, and hence trap the outgoing long-wave radiation more effectively.

For all these reasons, it is not surprising that colder-than-normal surface waters are often found to the west of negative anomalies on monthly or seasonal charts and that warmer-than-normal waters are found to the east.

With positive pressure anomalies, frequently associated with semipermanent anticyclones, other effects besides warm advection in the Ekman layer and downwelling often tend to create extensive warm pools of water. For example, in strong anticyclones, surface winds are light and subsidence generally leads to a shallow mixing layer; neither factor favors much upward transport of latent and sensible heat. In such cases the radiation balance may show a net loss somewhat greater than normal during the cold season, but a net gain during the warm season, when days are long, the solar angle is large, and the cloudiness is diminished because of the subsidence. It is such warm-season quasi-permanent anticyclones which seem to generate extensive pools of warm water in the central and eastern Pacific and maintain them for long periods (*9*).

Of course, such phenomena become complicated in the vicinity of coastlines, especially off the coast of California, where upwelling plays a dominant role.

Effects of Abnormal Patterns of Water Temperature

Once the temperature in the Ekman layer departs from normal over large areas, vast amounts of heat are stored in the ocean. Moreover, it is well known that rates of movement and change for the ocean are only a small fraction of those for the atmosphere, so the heated or cooled water areas may be considered reservoirs to be drawn upon by new atmospheric circulations. In other words, the atmosphere is continually in a state of turmoil, with cyclones, anticyclones, and fronts sweeping over the ocean in time intervals too short for these phenomena to materially affect the water temperature. Thus, there is high coherence of sea-surface temperatures from week to week and often from month to month.

In an earlier article I computed that the loss of heat to the air from a warm-water pool in the central Pacific would not be sufficient to reduce the temperature of the pool to its normal temperature for several months! Of

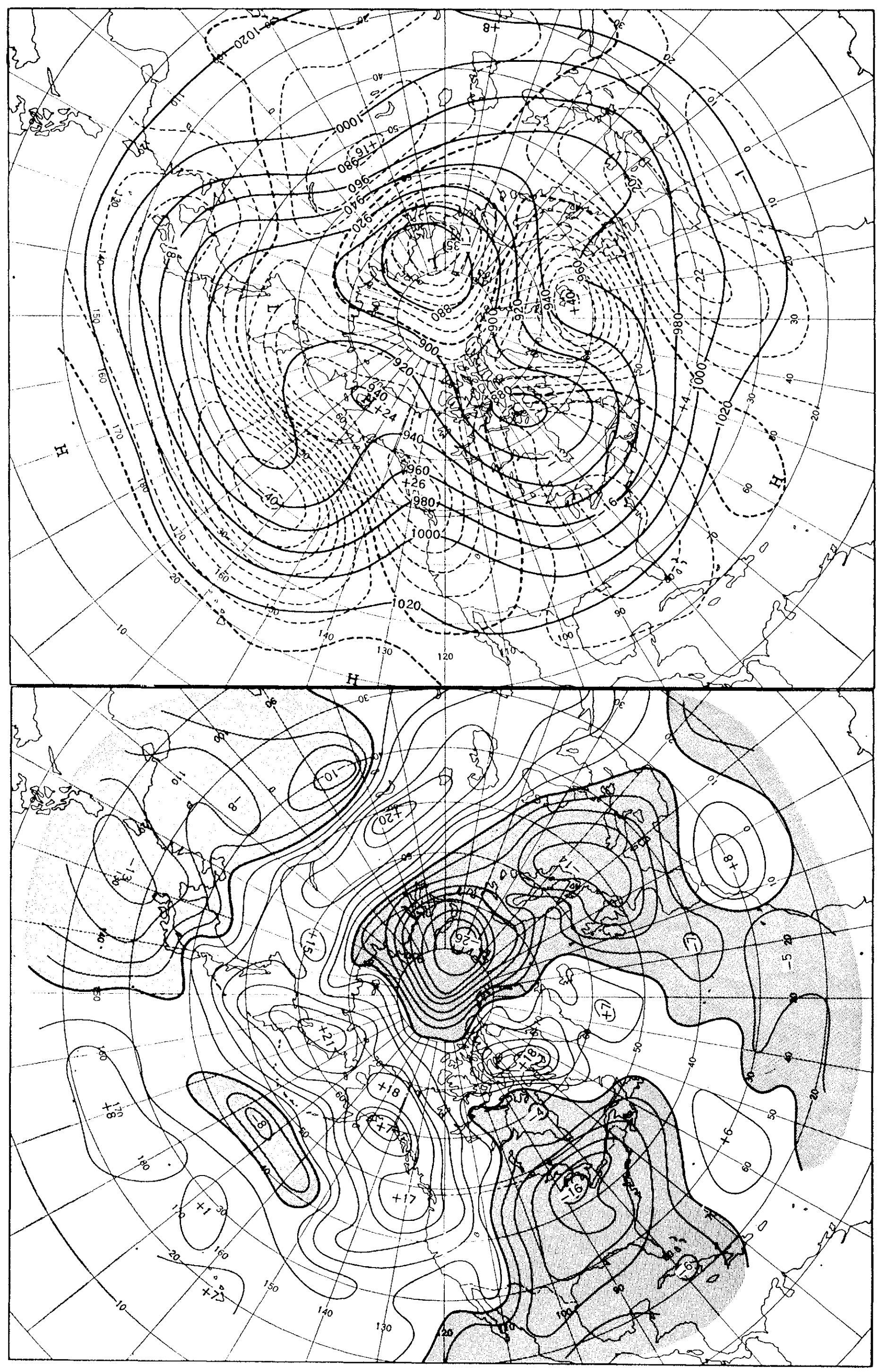


Fig. 5. (Top) (Solid lines) Mean 700-mb contours for winter (December, January, February) 1962–63; (dashed lines) isopleths of anomaly. (Both are given in tens of feet.) (Bottom) Corresponding departure from normal (in tens of feet) of thickness of the 1000- to 700-mb layer.

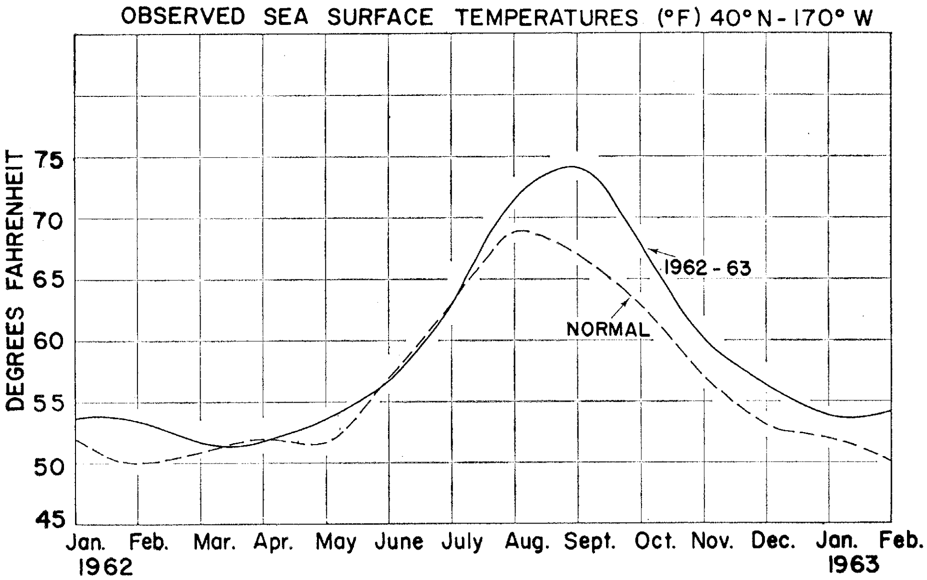


Fig. 6. Observed and normal monthly mean temperature of the sea surface at 40°N, 170°W for the period January 1962 through February 1963.

course, for such longevity certain special conditions, enabling the atmosphere and the ocean to collaborate, must be present.

It not infrequently happens that ocean-temperature abnormalities assist in restoring synoptic activity of the sort that may have been responsible for establishing them. We do not yet know precisely enough how these self-perpetuating systems operate to use such knowledge in long-range forecasting, but a number of suggestive clues are coming to light.

For example, the water transmits heat to the overlying air rapidly, so that if a large pool of warm water has been generated east of a quasi-stationary cyclone, with cold water at its center and to its rear, the anomalous *gradient* of water temperature is rapidly transmitted to the air masses. In this manner a field of increased baroclinicity is established in the air, and new cyclones arriving in the area may acquire an additional (anomalous) energy source. Similarly, properly oriented fronts may sharpen in the zone of water-temperature contrast, and the additional contribution of water vapor to warm sectors of passing cyclones may assist in their development. The more rapid occlusion of these systems may also affect their paths, producing more northward rather than eastward motion. Also, the anomalous thermal gradient tends to create a direct (anomalous) circulation favoring more southerly steering currents along the zone of east-west contrasts in water temperature.

Some mechanism of this sort is implied in the storm tracks shown in Figs. 2 and 3, bottom left, where cyclones rarely crossed the zone of surface-water contrast, pursuing instead a course parallel to the isopleths of sea-temperature anomaly. Of course, the cyclone tracks are related to the mean steering flow indicated by the 700-mb contours, and it is not possible to say definitely what causes what. I emphasize here that one is dealing with coexisting, probably cooperating, air and sea systems. The families of cyclones are maintaining abnormalities of water temperature (established earlier), while the abnormalities of water temperature are encouraging the cyclonic action to repeat time after time.

Other cyclogenetic effects may occur when very cold air masses are forced to move over abnormally warm water masses. Recurrent instances of this kind occurred during the exceptional winter of 1962–63, discussed elsewhere in some detail (*9*).

Another type of oceanic influence on the atmosphere is that observed when the water in certain areas is abnormally cold at certain times of the year. Thus, off the east coast of North America in spring, frequent formation of anticyclones (anticyclogenesis) may be favored if the off-shore waters are colder than normal—a condition which seemed to prevail in 1964. Wexler (*10*) has suggested that, when there is cold underlying water, the "leakage" of air in the friction layer may be lessened because of the shallowness of this layer, associated with the great vertical stability. This in turn would per-

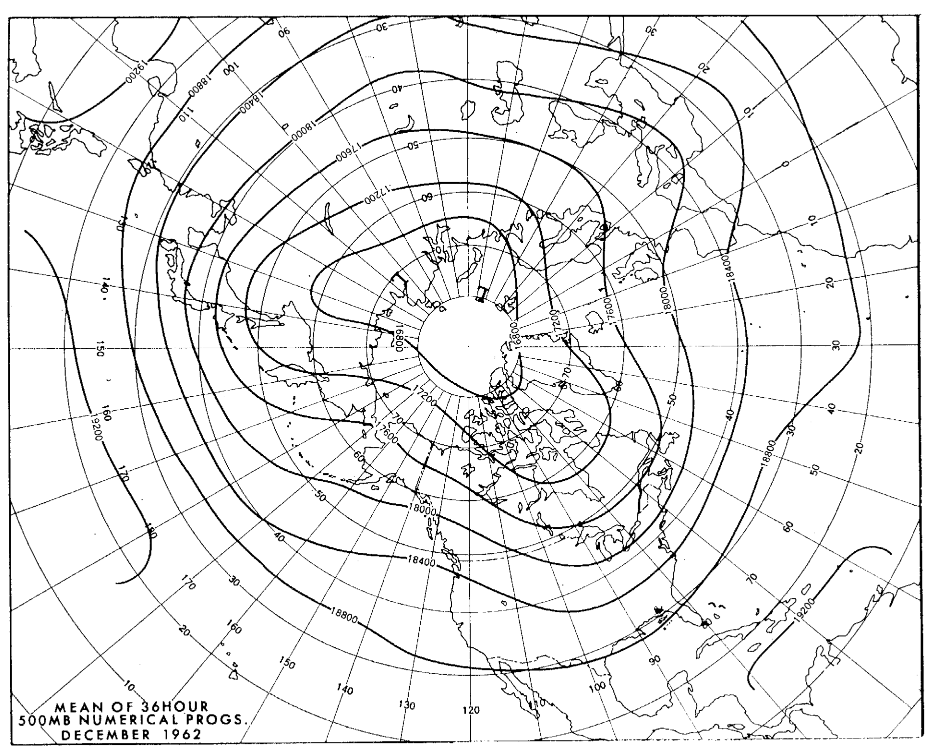
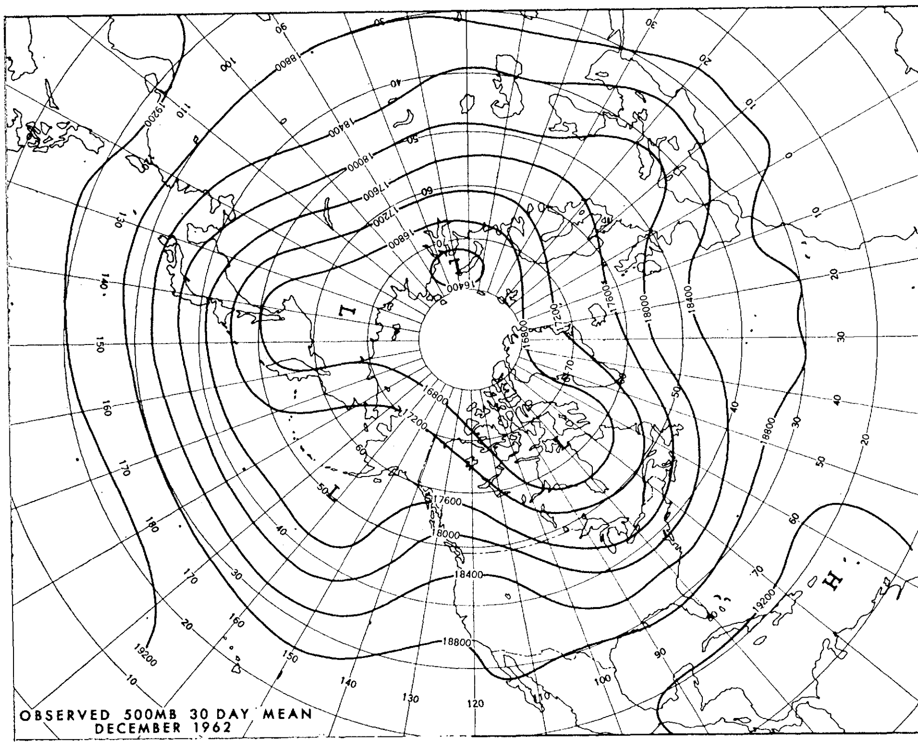


Fig. 7. (Above) Mean contours of 36-hour numerical (baroclinic) prognoses, for the 500-mb level, for all days in December 1962. (Top right) Observed mean contours, for the 500-mb level, for December 1962. (Bottom right) Isopleths of mean error (drawn for 200-foot intervals) of the numerical 36-hour prognoses for all days in December 1962—that is, above graph minus top right graph.

mit other anticyclogenetic factors, perhaps operating aloft, to be more effective.

It must be stressed that, in order for sea-temperature anomalies to affect the atmospheric circulations to any considerable degree, the atmosphere must set up the proper systems. For example, a warm pool of water in central latitudes of the eastern North Pacific during summer would not encourage cyclogenesis for the simple reason that climatological constraints hardly ever place cyclones (even embryonic ones) over this area, which in summer is dominated by one great and persistent anticyclone. Atmosphere and ocean must be properly "tuned" in order for the atmosphere to draw on these additional sources of energy.

Once a region becomes characterized by persistently recurrent formation of cyclones or anticyclones, responses in remote areas are established through inertial effects. Hence, a forced, deep, quasi-stationary, long wave trough in the mid-Pacific, leading to and nurtured by cyclones, which feed on abnormal distributions of sea-surface temperature, can create a quasi-stationary strong ridge over northwest Canada and a trough over eastern North America. This responsive (barotropic) wave may then induce contrasting air masses and develop storms (and abnormal snows in winter), which can create vast positive-feedback loops in the general circulation. It apparently is not uncommon for a series of such long-wave systems to develop harmoniously in such a way that the abnormal heat sources created at the surface continue to force recurrent wind and weather patterns of the same type over periods of weeks and even months. In the next section I briefly describe some interesting cases, detailed studies of which may be found in the cited references.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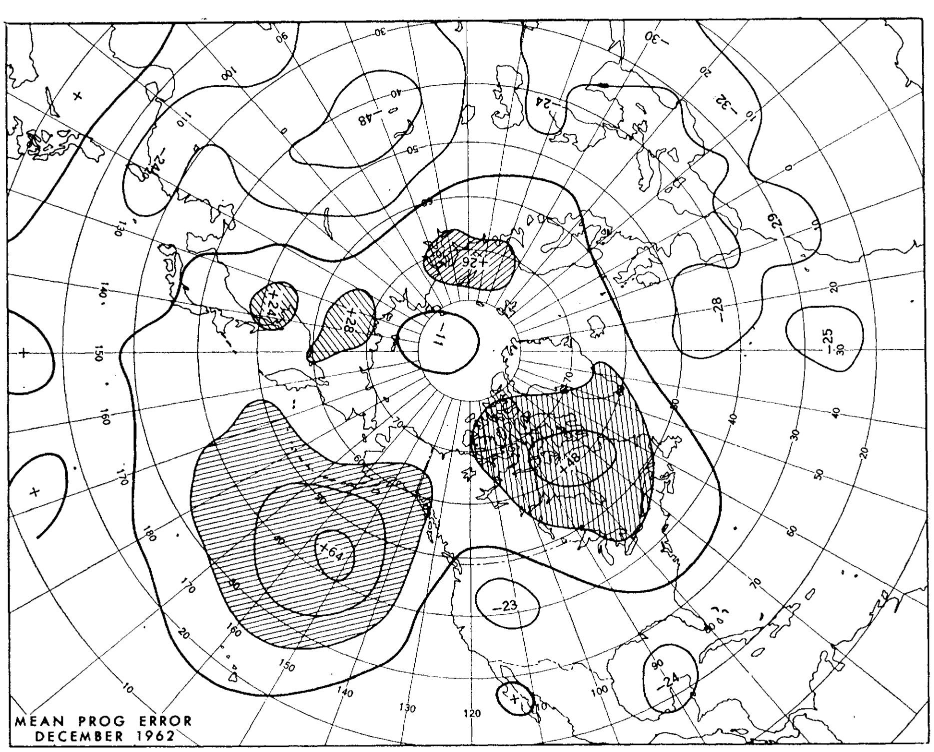
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Examples

Occasionally, continuity of singular features is quite clear on a series of seasonal mean charts. An example is provided by the mean 700-mb charts and their departures from normal for the seasons from summer 1957 through spring 1958 (Fig. 4). Here the regularity of motion lies in the steady eastward displacement of a trough (with its associated negative deviation from normal heights) from the west-central Pacific in summer to the west coast of the United States in the following spring. This case was discussed in an earlier report (*6*). Here it was shown that the progressive eastward motion of the mean trough was probably associated with an increase in stationary wavelength as measured from the climatologically anchored Asiatic coastal trough as the westerlies over the Pacific strengthened from summer to winter. The longevity of the slow migratory trough, which was naturally associated with many cyclones, can reasonably be ascribed to the contrasts in sea-surface temperatures which the trough helped develop and maintain—that is, anomalously warm water to the east of cold water. The abnormal heat exchanges to the overlying air

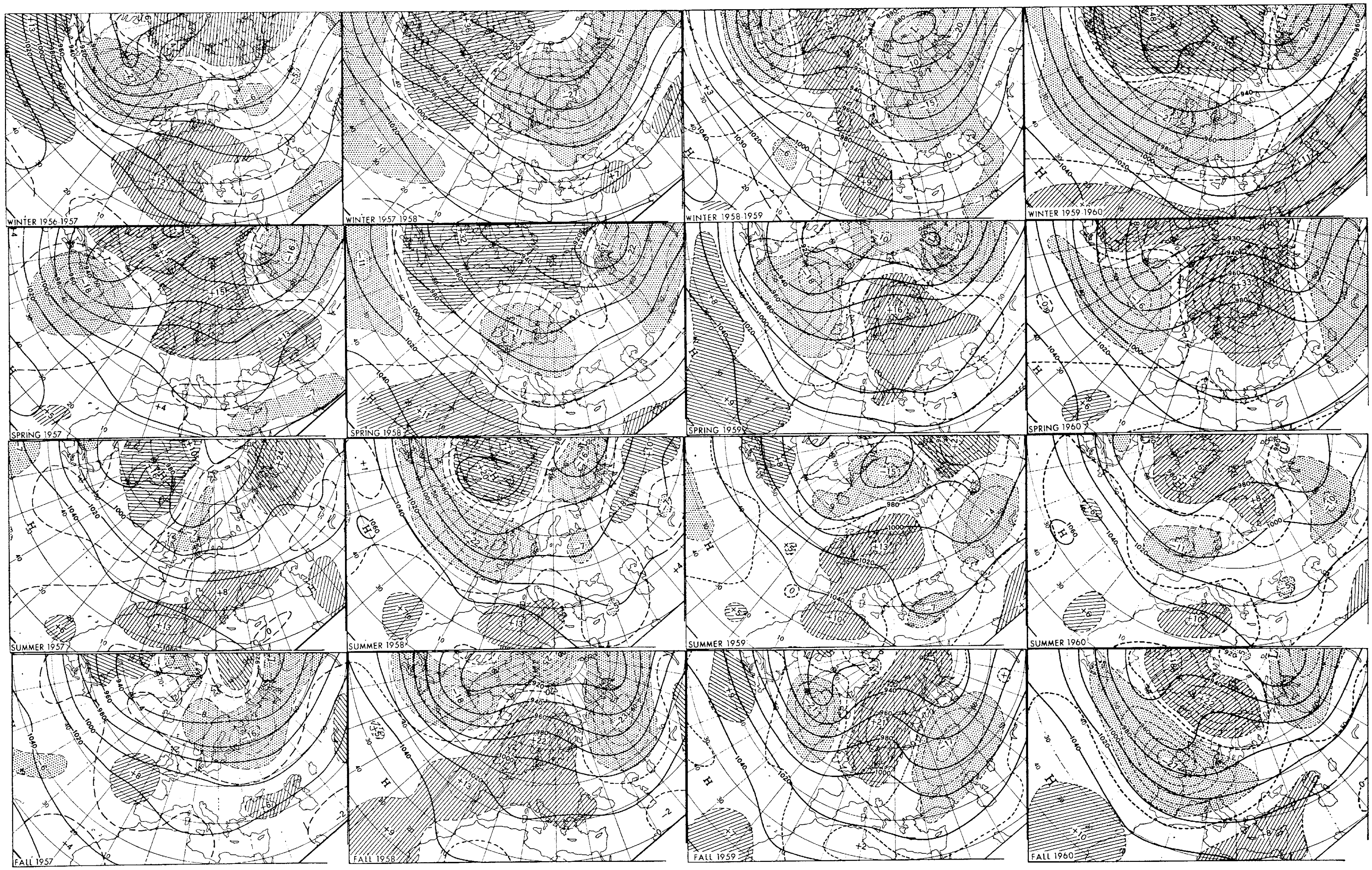

Fig. 8. (Solid lines) Seasonal mean 700-mb contours for winter of 1957–58 through fall of 1960; (dashed lines) isopleths of departure from normal.

masses would then provide the additional baroclinicity upon which individual cyclones could feed, thereby further maintaining a deeper-than-normal mean trough through the action of enhanced cyclogenesis. Some weight is lent to this hypothesis by the observed increase in strength of the eastward migratory anomaly, for it is during the cold season that abnormal heat exchanges would have their maximum effect.

The inertial response of the North America planetary wave (long wave), especially during the winter of 1957–58, is of interest. This amplified wave was associated with one of the coldest winters ever observed in Florida.

Also exemplifying anomalous cyclogenesis coupled with oceanic effects was the general circulation during the highly abnormal winter of 1962–63, a study of which is presented elsewhere (*9*). That winter was unusual in other respects, as the numerous statistics on energy conversions, given by Wiin-Nielson (*11*), indicate.

The observed mean seasonal 700-mb contours and anomalies are shown in Fig. 5, along with the associated thickness anomalies of the 1000- to 700-mb layer. The area where cyclonic activity deviated most from normal was in the central Pacific, where departures from normal at 700 mb for the entire winter averaged −120 meters, and −15 mb at sea level—values almost three times the winter standard deviations. This cyclogenesis appeared to be associated with a vast and persistent pool of appreciably warmer than normal surface water which had originated during the preceding summer. Figure 6 shows the annual course of sea-surface temperature near the center of this pool, together with the normal temperatures. Computations of heat exchange indicate that in this case the cyclonic activity, once generated, probably helped the water retain its warmth longer than it would normally have retained it, because backward radiation was entrapped by the persistent clouds, and because evaporation losses were small, since differences in vapor pressure between the damp, frequently rain-laden air and the water were small. The warmer-than-normal water, operating through complex processes associated with release of sensible and latent heat, seems to have been a major factor in encouraging cyclogenesis in the vicinity of the warm pool. This is suggested by the mean errors in short-range baroclinic predictions; errors in the predictions for 36 hours during January 1963 averaged +192 meters for areas near the warm-water pool (Fig. 7).

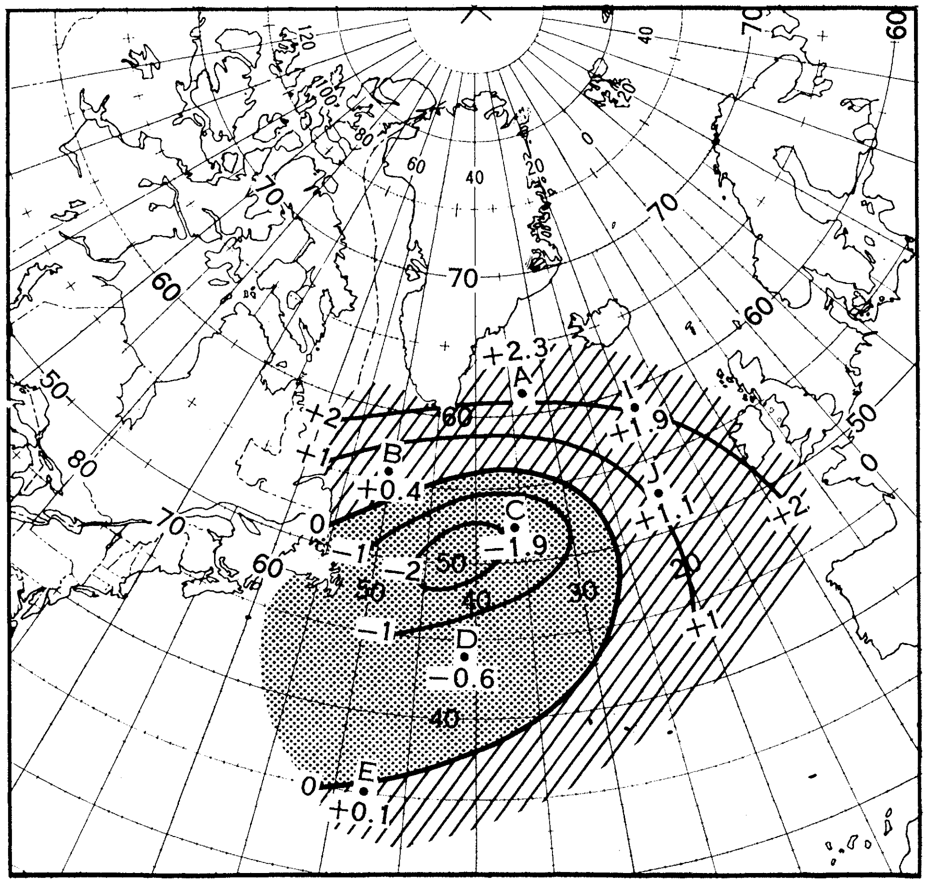

Fig. 9. Departure from normal of mean sea-surface temperature (in degrees Fahrenheit) for the period September 1958 to November 1960.

As in the previous case, the apparently responsive mean-long-wave pattern set up over North America is of interest.

A third example of long-period interactions between air and sea is the persistent recurrence of blocking (that is, formation of anticyclones at high latitudes) over Europe for a period of almost 2½ years (see *12*). The blocking led to a decline in seasonal precipitation over western Norway from 1957 through 1960, especially in the autumn seasons. Rough indices of blocking, expressed as anomalous height differences, at the 700-mb level, between 70°N, 20°E (northern Scandinavia) and 50°N, 10°W (near Ireland) and also between 70°N, 20°E and 60°N, 80°E (south of Novaya Zemlya) showed the slow increase in blocking over a few years, with special regularity in the fall seasons.

The individual seasonal 700-mb charts for the 4 years are shown in Fig. 8. Each row represents charts for the same season in successive years and illustrates the gradual emergence of the north European block in the form of increasing ridge and positive height anomalies. It appears that persistent blocking was initiated by the fall of 1958 and probably in late summer of that year.

Greater-than-normal cyclonic activity is apparent in the Icelandic Low off southern Greenland and also in Russia to the south of Novaya Zemlya. These features are associated parts of an amplified long-wave system, and it is difficult to ascribe one feature to another, since they are mutually dependent. Yet it seems reasonable to hypothesize that the deep Icelandic Low off the tip of Greenland may have been the primary forcing element in the trough-ridge-trough complex. This is an area of great variability (*12*), where cyclogenesis may easily produce inertial responses of a barotropic nature in European flow patterns—long known to be sensitive to the behavior of Icelandic pressure systems. An analogy can be drawn with the Aleutian Low, the responsive Canadian ridge, and the downstream North American trough.

In view of the air-sea interactions described earlier, it is perhaps not surprising that anomalous sea-surface temperatures were found over the North Atlantic, with colder-than-normal water in and to the west of the Icelandic quasi-stationary depression and warmer-than-normal water to the east. The mean anomalies in sea-surface temperature for the nine seasons from September 1958 to November 1960, as indicated by weather ship observations, are given in Fig. 9. Actually, this pattern of water temperatures became established by late spring and summer of 1958, preceding inception of the blocking.

Here again is the suggestion of an external forcing agent producing anomalous cyclogenesis (and cyclonic vorticity), forcing storms more to the north than to the east, thus providing more frequent and stronger southerly components of wind than normally occur at upper levels east of the Icelandic Low. These winds, in turn, helped create a ridge over northern Europe, in contrast to the flat westerly flow normally found there (see *13*).

Finally, attempts are being made in the Extended Forecast Division of the U.S. Weather Bureau (*14*) to develop quantitative physical methods for testing the validity of these ideas.

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Science in Mainland China: A Tourist's Impressions

Visits to universities and research institutes show significant efforts to bring science to the people.

C. H. G. Oldham

In 1958 J. T. Wilson, professor of geophysics at the University of Toronto, spent a month in China as a guest of the Academia Sinica in Peking. He went in his capacity as president of the International Union of Geodesy and Geophysics to see scientific work in geology and geophysics, and he has reported on his observations (*1*). I had studied under Professor Wilson, and one by-product of his visit was an intensification of my interest in scientific developments in Asia and in studying the Chinese language. Despite several requests to Chinese scientists and the Academia Sinica, it has never been possible for me to visit China in my capacity as a geophysicist. So, when, in the spring of 1964, a Canadian travel agency was invited by the Chinese Government to send a group tour, I applied to join, to visit China as a tourist. Ultimately all other members of the tour withdrew, and I was able to visit China on my own.

Initially the tour was for 2 weeks in mid-October 1964, but once in China I had no difficulty in extending my stay to a month. I spent a week in Peking, 5 days in Nanking, 3 days in Soochow, a week in Shanghai, 3 days in Hangchow, and 3 days in Canton. I flew from Canton to Peking but made the return journey by train.

In Peking I saw all the classic tourist attractions, but my requests to visit the Academia Sinica, the university, and the Museum of Peking Man were refused. Nanking was quite different. There my requests to see the university, research institutes, a commune, and a scientific instrument factory were approved, and only my request to see the Purple Mountain Observatory was rejected—on the grounds that the road was under repair and impassable. In the other cities I visited I was able to visit schools, universities, and communes, although nowhere else was I able to visit a research institute.

From the point of view of my scientific specialty of geophysics the trip was disappointing. In fact I saw no scientific research work on which I am qualified to pass a professional judgment. But from the point of view of the study of scientific development in Asia the visit was quite rewarding. My visit was in many ways superficial, and although previous study, in Hong Kong, of Chinese scientific developments added some depth to my observations, it would be quite wrong to conclude that the conditions I saw are typical of China as a whole. But first-hand reports of Chinese science are fragmentary at best, and my impressions may add a few more pieces to the jigsaw puzzle of Western knowledge of Chinese science.

My visits to institutions followed a set pattern. I would arrive at the appointed time accompanied by an interpreter supplied by Luxing She (China International Travel Service). Invariably there would be a "reception committee" waiting on the steps of the institution—usually consisting of a professional man, an administrator, and a secretary. We would go into a committee room and, after an official welcome, I would be given a "brief introduction." This introduction was frequently political and gave a Before and After Liberation comparison (*2*). I found that interruptions were not wel-

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