*B* and *C* take a marked drop at times when spots continue to be abundant in the sun's central area for 4 or 5 days. In the south, *C*, however, the drop is far more marked and begins earlier than in the north, *B*. The reversal between *C* and *A* is striking. It serves strongly to reenforce the idea that *storminess accompanies a lack of balance among the sun spots in the marginal portions of the sun, while quiet weather free from storms occurs when a balanced condition is produced either by the absence of disturbed areas on the sun's surface or by the concentration of such areas in the sun's center.*

(To be continued.)

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## CHANGES IN OCEANIC AND ATMOSPHERIC TEMPERATURES AND THEIR RELATION TO CHANGES IN THE SUN'S ACTIVITY.[1]

By Professor FRIDTJOF NANSEN, University of Kristiania.

[*Author's abstract* reprinted from Jour., Wash. Acad. Sci., Mar. 4, 1918, 8: 135-138.]

The primary aim of the research was to find the relations existing between oceanic and atmospheric temperatures. The surface temperature of the water in various parts of the North Atlantic at the coldest time of the year formed the foundation of the first study. When the region covered by the data is divided into approximately equal areas, the temperature curves of these areas are found to be parallel, it is evident from the form of the curves that these changes of temperature, taken as a whole, are not due to changes in the water-masses transported. A relation does appear, however, between these changes and the prevailing direction of the wind, as deduced from atmospheric pressure gradients. Where the wind turns south of (i. e., is directed south of) its average direction over a period of years, the temperature of the water is lower than the average for the same period, and vice versa. A similar parallelism between wind direction and water temperature appears along the coast of Norway; the effect near the coast is based on the direction of the wind with respect to the land, as well as on the season of the year. The air temperature variations on land appear earlier than the variations in water temperature.

Certain periodicities appear in all the curves of oceanic and atmospheric temperatures, but they vary in type. At the same time a relation also appears between these curves and curves of sun-spot activity and magnetic elements. The 11-year period is prominent. An oceanic type and a continental (Eurasian) type can be distinguished. The latter follows the sunspot curve directly, whereas the former type follows the sunspots inversely. There is also a third and very remarkable type in which the curve changes more or less suddenly from direct to inverse. This sudden inversion is brought out in many curves, comparing stations in different parts of the earth, and the inversion occurs in very many cases at about the year 1896.

When the temperature curves for different months of the year are compared with the sunspot curves, these three types of agreement again appear in very puzzling and unexpected combinations.

In addition to oceanic and atmospheric temperatures, other meteorological elements (air pressure, wind velocity, rainfall, cloudiness, mean daily temperature-amplitude) show a relation to the sunspots, sun prominences, and magnetic variations, and show not only the 11-year period, but also shorter periods of two, three, and five and one-half years.

The fluctuations of the temperature at the earth's surface do not follow directly the variations in the energy received from the sun as determined by the measurements of Abbot and Fowle. The daily and yearly temperature-amplitudes are believed to furnish sufficient refutation of hypotheses based on supposed variations in the absorbing and reflecting power of the atmosphere, as well as of Humphreys' hypotheses as to formation of ozone or effects of volcanic dust. Blandford's hypothesis of the effect of increased evaporation in lowering continental temperatures at sunspot maxima is also not supported by the facts of tropical land and ocean stations.

The mistake of most authors when they have discussed the causes of temperature changes, has been that they took for granted that the average temperature at the earth's surface was directly dependent on solar radiation, and would give a direct indication of heat received. They have not considered sufficiently the fact that a very great proportion of the sun's radiation is absorbed by the higher layers of our atmosphere and that the distribution of heat in the atmosphere is of the greatest importance for the temperatures at the earth's surface. They seem very often to have forgotten that the variations in the sun's activity, and in the so-called "solar constant," and also in the sun's electric radiation, may primarily influence the higher layers of the atmosphere, thus indirectly guiding the distribution of atmospheric pressure and the circulation not only of these higher layers, but also of the lower parts of the atmosphere. In this manner the temperature of the higher latitudes may be influenced more than that of the Tropics where the conditions are so stable.

The variation in *pressure gradient* seems much more closely related to the temperature of land stations than is the variation in air pressure itself. For instance, the Colombo-Hyderabad gradient runs parallel to the temperature in the Himalayas but opposite to the temperature at Batavia, while Bombay forms an example of those strange reversals occurring about 1896. The Iceland-Azores gradient has exactly opposite effects in Norway and in mid-Atlantic. An increase of air circulation may thus have opposite effects in different regions. The sunspots and magnetic elements sometimes oppose and sometimes agree with the variations in pressure gradients.

Various periodicities appear in the sunspots as well as in the terrestrial phenomena. In the sunspots there is an 8-month period corresponding with the conjunction or opposition of the planets Venus and Jupiter with the sun. This same period occurs in the North Atlantic gradient, and was found by Krogness in the magnetic declination at Kristiania. There are also periods of six and twelve months in the magnetic elements, due to the position of the earth. The combination of these 6-, 8-, and 12-month periods gives a 2-year period for the magnetic and meteorological elements on the earth. But in the fluctuations of the sunspots a similar period of two years is also discovered, and specially noticeable are indications of minima every second year. Before 1896 there is an agreement between the 2-year minima of temperature at certain stations and the corresponding sunspot minima, but the agreement is remarkable in that the greatest depressions in the sunspot curve

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[1] Illustrated review, before the Washington Academy of Sciences, Jan. 8, 1918, of the recent book.

*Helland-Hansen, Bjørn, & Nansen, Fridtjof.* Temperatur-Schwankungen des Nordatlantischen Ozeans und in der Atmosphäre. Einleitende Studien über die Ursachen der klimatologischen Schwankungen. Videnskapsselskapets Skrifter, I Mat.-naturv. Kl., 1916, No. 9. Kristiania, 1917. [viii, 341 p. charts. tables. 27½ cm.] This work is now in the Weather Bureau library.

coincide with the smallest depressions in the temperature curve; this relation ceased about 1896, hence the peculiar inversion already referred to.

Other periodicities have been recognized. A 32-33-month period at Batavia may be a combination of the 2-year period already referred to and a 3.7-year period suspected by Lockyer. Secular changes of relatively long period (35 years and over 100 years) also are probable. The researches of Clayton have recognized correlations in daily temperature and pressure fluctuations at various stations over the earth and the fluctuations in the daily heat radiation of the sun as measured by Abbot and Fowle, the same three types appearing in these meteorological variations as have been noted in the long-time variations. Krogness recognizes 14-day and 27-day periods in magnetic storms, as well as in air-pressure gradients, wind, and temperature, in northern Norway.

To summarize the results of these investigations: In different groups of areas on the earth the meteorological elements (temperature, barometric pressure, rainfall, etc.) fluctuate or pulsate, so to speak, in time with one another, while in other groups of areas the fluctuations or pulsations are exactly inverted, and finally, some areas show transition stages between the two. The result of all this is a very complicated picture of the meteorological fluctuations. But by means of appropriate analyses we see that from this complicated and apparently chaotic set of fluctuations there arises a clear picture of the very intimate relation between all these variations and the variations in the sun's activity. We have seen that even changes of very short duration in the sun's radiation (of heat as well as electricity) are distinctly repeated in our meteorological conditions and in the surface temperature of the ocean. The effects of the solar variations are probably transferred by means of variations produced in the distribution of pressure in our atmosphere. Changes in solar radiation probably first affect the higher layers of our atmosphere, and thus create an unrest which in turn is transmitted to the lower strata near the earth's surface.

Such dynamic changes will produce different effects in different regions of the earth. But by thorough and complete analyses of the great meteorological material now at hand it may be possible to find the general rules. This will be an important step forward toward understanding the laws ruling our atmosphere.

For this purpose it will also be of the greatest importance to have the wonderful researches of Abbot and Fowle continued with the greatest possible efficiency. These investigations of the sun's radiation of heat, which they have been carrying on for a long series of years at Washington, Mount Wilson, Mount Whitney, and in Algeria, have given us the remarkable revelation that our sun is a variable star, the most important discovery that has been made in this field in many years.

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## WHIRLWIND OF JANUARY 26, 1918, AT PASADENA, CAL.

By Ford Ashman Carpenter, Meteorologist.

[Dated: Weather Bureau, Los Angeles, Cal., Apr. 18, 1918.]

On the afternoon of January 26, 1918, a whirlwind of considerable severity, showing many of the characteristics of a tornado, visited the city of Pasadena, Cal. Although the storm attained considerable violence and damaged property to the extent of about $10,000, no lives were lost and no one was injured. The material loss was widely distributed among one hundred or more persons. The storm was interesting from a meteorological viewpoint as it was the first of its kind reported from southern California.

*The topographic features of Pasadena.*—The topographical features of Pasadena should be taken into consideration in studying this storm.[1] The city is located 25 miles from the Pacific Ocean at the southern base of the Sierra Madre. These mountains rise abruptly to an average elevation of 5,000 feet above sealevel; an idea of the wall-like character of the northern background to the city may be gained from the fact that within four miles of Pasadena one of the crests of the range reaches an elevation of 5,000 feet above the city.

*General and local weather conditions preceding the storm.*—The morning weather map of January 26, 1918, showed a belt of high atmospheric pressure over the northern part of the country and a double-centered low

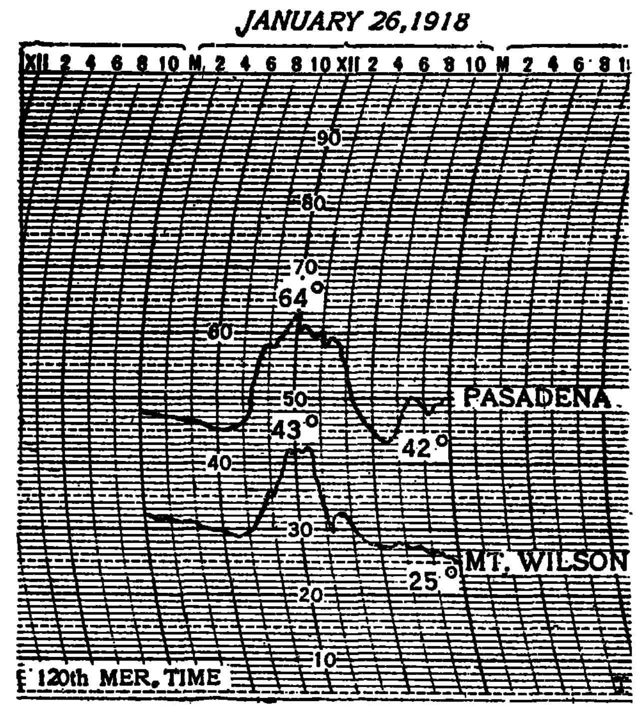


Fig. 1.—Thermograms from Pasadena, Cal., and Mount Wilson for Jan. 26, 1918, when hail and a whirlwind visited Pasadena in the afternoon.

area in Arizona, New Mexico, and Oklahoma. It was in the southwestern quadrant of this depression that the Pasadena storm occurred.

The first indication of unusual weather was the appearance of a solitary cloud which formed with great suddenness in that vicinity. The writer observed this huge convectional cloud from the Los Angeles station about 1:30 p. m. January 26, 1918, and it rapidly assumed the proportions and character of the cumulo-nimbus type. Within an hour this structure underwent rapid changes, but in three hours the sky was clear again. This cloud was observed from Mount Wilson (4 miles distant horizontally and 1 mile vertically) the upper edges appearing as a misting fog, boiling up 3,000 feet or more above that mountain. The temperature differences between the base and the top of the mountain amounted to about 20° F., as the thermograph traces from Pasadena and Mount Wilson show (fig. 1).

*Course of the storm.*—In many respects this whirlwind failed to follow the usual easterly course characteristic of

[1] For a topographic map of Los Angeles, Pasadena, and vicinity see this Review, June, 1914, 42: 387.—C. A. Jr.