A PHYSICAL BASIS FOR LONG-RANGE WEATHER FORECASTS

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The economic importance of long-range weather forecasts has long been recognized, and many attempts have been made to solve the problem. Until very recently, however, most of them were rather unsuccessful, due in general to a lack of observational data and to the fact that the methods of attack were not, in many cases, well founded. A method of approach to the problem, which is beginning to yield encouraging results, has been developed by the writer during the past few years. It utilizes the principal that the positions of the air streams in the general circulation of the atmosphere, which controls the long-period weather trends, are predictable for periods of a month or more.

In the latitudes of the United States, the principal storms are the result of a continuous conflict between cold polar air and warm tropical currents along a boundary surface separating these two dissimilar air bodies. The storms are wavelike ripples which progress eastward along these boundaries, causing them to oscillate simultaneously north and south across the country. The storms arise along a boundary of separation between warm and cold currents either from a southward surge of polar air or from a northward thrust of the tropical current. At present it is not posisble to determine the weather for long periods day by day. However, if the average positions of the zones of interaction between the air currents are known, regions of maximum storm frequency can be determined, and therefore the trend in the weather for fairly long periods.

Fig. 1 illustrates the normal position of the principal air streams in the atmosphere and the active portions of their zones of separation during the fall and early months. The heavy lines indicate regions where warm and cold streams of air are brought together and, therefore, where storms are most apt to develop. It will be noted that the principal zone of separation between the cold and warm currents at this time of the year extends east and west across a large part of the north Pacific Ocean and through the center of the United States. Whenever a warm current of air from low latitudes meets a cold polar current, it is forced to ascend the forward edge of the cold mass. It is on these occasions that widespread precipitation occurs, for, as the warm current rises, it cools by expansion owing to the reduction in atmospheric pressure encountered aloft. This allows its moisture to condense to form clouds and precipitation. The lighter lines show the average flow patterns of the principal air currents.

The oceans form the principal sources of moisture for precipitation in the United States. The rain-bearing air currents of the storms occurring at this season of the year in the eastern part of the United States originate over the Atlantic Ocean southeast of the Carolinas and Florida, and over the Gulf of Mexico, while the moist currents producing the major part of the precipitation on the Pacific Coast may either move across the Pacific from Siberia or Alaska, ultimately invading the Pacific Coast, or they may come northward from subtropical latitudes to interact with the colder polar air to the north. These currents have been indicated on the map in Fig. 1, their average flow being shown by the long curved arrows.

Cold waves in any part of the country at this season of the year are the result of the invasion of cold air from Canada. It will be noted from Fig. 1 that this air usually converges with a dry current from the southwestern United States. Owing to their lack of moisture, no important precipitation results from this interaction, thus explaining the characteristic dryness of the Great Plains area and the regions between the Pacific Coast ranges and the Rocky Mountains at this season of the year.

Since the long-period weather trends are obtained by averaging day-to-day changes, they depend primarily upon the air currents which predominate during the period and the frequency of the storms occurring along the zones of separation between them. We may conclude, then, that the determination of the seasonal temperature and precipitation trends depends, to a large extent, upon the correct anticipation of the average position of the zones of interaction between the air currents. Since these are the regions where the storms develop, any shift in their location from year to year can cause significant departures from the normal in the observed weather changes. The position of these zones of interaction appears to be a function of the location and intensity of areas of relatively high atmospheric pressure centered in the subtropical latitudes. Owing to their importance in the control of the weather, these systems have been called the "centers of action" of the atmospheric circulation. They are marked in Fig. 1 by CA. They are the most stable systems in the general circulation of the atmosphere and, although they tend to migrate eastward from day to day, the average position is fairly stationary so that they materially influence not only the location of the zones of interaction between the principal air streams of the atmosphere but also the paths followed by the most important rain-bearing air masses of the atmosphere which normally have their origin within these high-pressure systems.

In a year when the atmospheric conditions illustrated in Fig. 1 prevail, one may expect the precipitation and temperatures throughout the country during the late fall and early winter to closely approximate the normal. However, in a year when the conditions show a deviation from the average, significant departures from normal will be observed in these quantities. For example, this year all of the centers of action are several hundred miles north and west of their usual position at this season, and therefore the paths of the storms controlled by them are north of their usual track. On the Pacific Coast practically all of the precipitation at this season of the year results from storms crossing the Pacific Coast which have developed along the zone of separation over the north Pacific between cool, moist, polar currents and warm, moist, tropical currents. This zone being north of its usual position this year has caused these storms to pass inland several hundred miles to the north of their usual course, and rains are less frequent along the Pacific Coast than in a normal year, particularly in the southern half of California.

In addition to the shift observed in the centers of action, the sporadic outbreaks of cold air from Canada, which invade the Middle West during this season of the year, are developing less frequently than in a normal year and are moving southward into the United States several hundred miles west of their usual course. This is causing temperatures to remain above normal in the Middle West but occasionally to drop below normal in the western part of the country as the air invades the regions west of the Rocky Mountains. However, since, in the western part of the country, the storm frequency is less than in a normal year and more clear days occur, the temperature averaged over a long period will not show much departure from normal.

Abnormally large amounts of precipitation during the winter season and early spring along most of the Atlantic Coast will be a further consequence of the shift that has occurred in the centers of action this year, since air from the deep tropics will tend to move northward more frequently during the winter season, invading the southeastern part of the country and over-running cold air from Canada in the Ohio Valley. This interaction will produce rather heavy rains which, as they progress eastward, will affect all the Atlantic Coast areas. The heavy snowfall late in November, which occurred along the Atlantic seaboard, was the result of just such an interaction between warm tropical air, heavily laden with moisture, moving northward along the Atlantic Coast, as it converged upon a southward moving mass of extremely cold air from Canada.

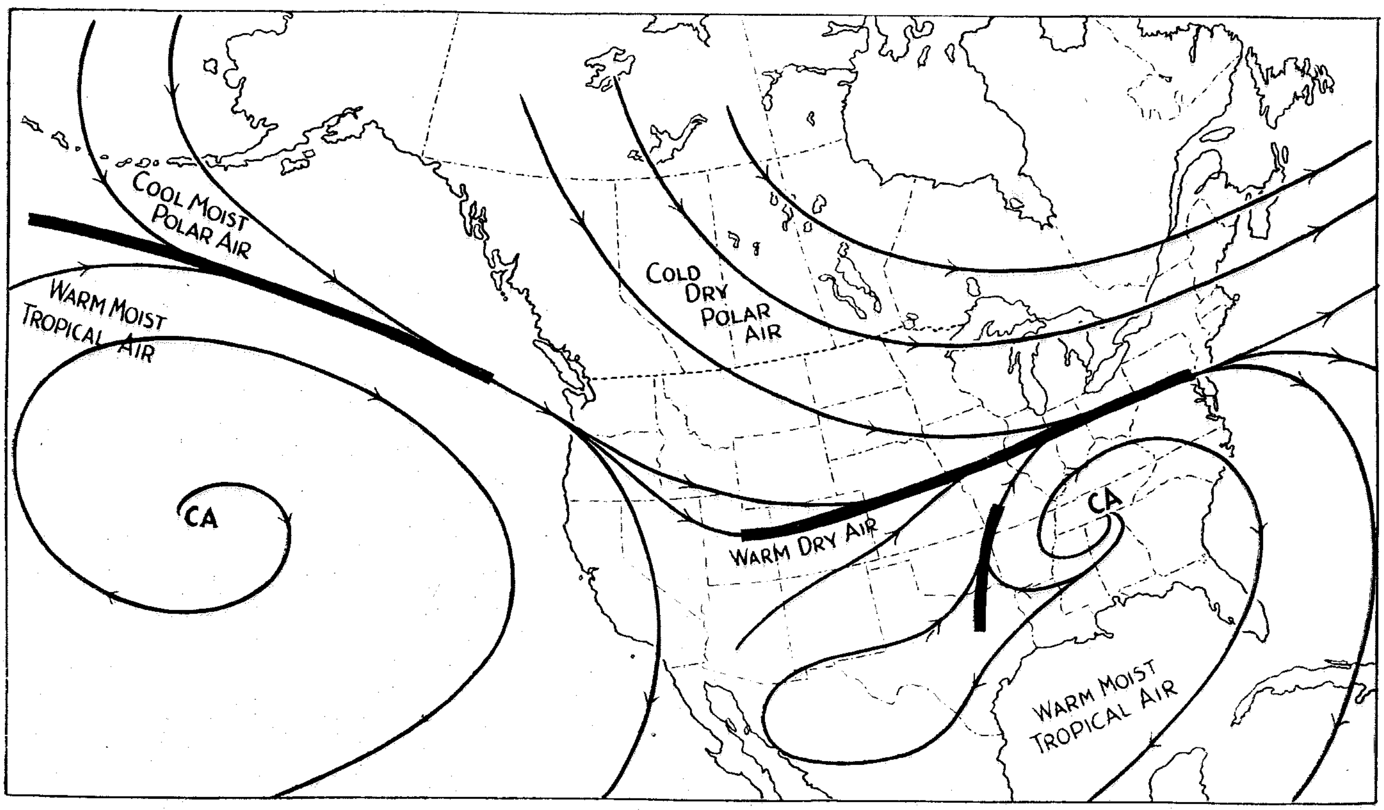

FIGURE No. 1
Normal position of Centers of Action (CA) and principal air currents for late fall and early winter.