The chief conclusions drawn by Simpson from his observational data, and supported by numerous subsequent observations by other persons at widely separated places, are:

(*a*) That the charge on thunderstorm rain, amounting often to 5 to 10 electrostatic units per cubic centimeter, usually is positive.

(*b*) That, on the whole, the quantity of positive electricity brought down is more than three times greater than the negative.

While these observations were being secured a number of well-devised experiments were made to determine the electrical effects of each obvious process that takes place in the thunderstorm.

Freezing and thawing, air friction, and other things were tried, but none produced any electrification. Finally, on allowing drops of distilled water to fall through a vertical blast of air of sufficient strength to produce some spray, positive and important results were found, showing:

(1) That breaking of drops of water is accompanied by the production of both positive and negative ions.

(2) That three times as many negative ions as positive ions are released.

Now, a strong upward current of air is one of the most conspicuous features of the thunderstorm. Experiment also shows that raindrops of whatever size can not fall through air of normal density whose upward velocity is greater than about 8 meters per second, nor themselves fall with greater velocity through still air; that drops large enough—4.5 millimeters in diameter and up—if kept intact, to attain through the action of gravity a greater velocity than 8 meters per second with reference to the air, whether still or in motion, are so blown to pieces that the increased ratio of supporting area to total mass causes the resulting spray to be carried aloft, or, at least, left behind, together with, of course, all original smaller drops. * * * [The larger drops] fall as positively charged rain, because of the processes just explained. The negative electrons, in the meantime, are carried up into the higher portions of the cumulus, where they unite with the cloud particles and thereby facilitate their coalescence into negatively charged drops. Hence the heavy rain of a thunderstorm should be positively charged, as it almost always is, and the gentler portions negatively charged, which also very frequently is the case.

Such in brief is Doctor Simpson's theory of the origin of the electricity in thunderstorms, a theory that fully accounts for the facts of observation and in turn is itself abundantly supported by laboratory tests and imitative experiments.

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The foregoing are only a selected few of the many recent contributions to the physics of the air, but they are sufficient, it is hoped, to show that meteorology is indeed a progressive branch of physics, and one eminently suitable to every type of scientific talent. The close observer, the clever experimentalist, and the keen analyst all can find in the phenomena of the atmosphere inexhaustible material and endless opportunities. But in science opportunity is only a synonym for duty, and of all words duty is the noblest.

SUBJECTS FOR RESEARCH IN METEOROLOGY.

It seems well at the present time for the Weather Bureau to take the lead in suggesting fundamental problems for research in meteorology—problems the solution of which, in part at least, may be undertaken by university post-graduate students in meteorology and by others who have opportunity for research. With this in view, the following subjects are proposed by the staff of the Central Office of the Weather Bureau.

Instruments and Observations.

1. Apparatus for recording the total radiation received from the sun and sky.

2. The measurement of the intensity of daylight.

A campaign to determine the intensity of daylight illumination in different latitudes under different atmospheric conditions is contemplated. Suitable apparatus for recording light intensities is highly desirable, but not yet available.

3. Methods of obtaining the directions and velocities of the winds at different elevations: (*a*) By direct observation with various forms of anemometers; (*b*) by observations of pilot and other balloons with one or two theodolites; (*c*) by observation of the movements of clouds by triangulation, or possibly by observations of the form, direction, and size of cloud waves.

4. Development of apparatus for determining soil temperature, soil moisture, and intensity of solar radiation as affecting plant growth.

Physical Properties of the Atmosphere.

5. Origin and maintenance of the outgoing current of negative electricity.

6. Source and effects of the penetrating radiation in the upper atmosphere.

7. The absorptive power of water vapor for long-wave-length radiation.

8. The absorption and radiation properties of the different constituents of the atmosphere.

Temperature.

9. A theoretical study of the cause of the altitude to latitude relation of the height of the stratosphere.

10. Diurnal variation in height and intensity of nocturnal inversions of temperature and their relation to "air drainage" and other phenomena.

This could be studied by means of frequent nocturnal soundings of the air in valleys with a small captive balloon carrying a meteorograph. Data of this kind will be of use in forecasting frost.

Atmospheric Pressure.

11. Reduction of surface pressures to those of stated levels in the free air.

Such reduced pressures would make possible the construction of fairly accurate weather maps for different levels. To obtain as nearly as possible the pressures aloft without direct observations at the required levels requires a close study of the vertical temperature gradient at each place, in order that for any type of weather at any time of day and season a proper temperature factor may be used in the hypsometric formula.

12. Diurnal temperature changes in the free air and their relation to the surface semidiurnal variations of pressure.

Winds.

13. Over- and under-running of differing winds, and attending phenomena.

14. Studies of atmospheric turbulence.

This may be done directly and indirectly in several ways; smoke movements, sound irregularities, irregular movements of balloons, internal movements in clouds, gustiness, cloud waves, temperature oscillations, temperature contrasts between neighboring fields.

Moisture.

15. Relation between meteorological factors and evaporation from soil and water surfaces.
16. The theory of evaporation.
17. Nucleation of the atmosphere. What is the nature of condensation nuclei, apart from ordinary dust.
18. Quantitative studies of fog, with respect to depth, density, water content, etc.
19. Cloud forms and their origin.
20. The cooling of the air by falling rain or snow, and atmospheric processes resulting from such cooling.

Cyclones and Anticyclones and Attendant Phenomena.

21. The origin, mechanism, and maintenance (1) of the tropical cyclone, (2) of the extratropical cyclone, and (3) of the migratory anticyclone.
22. The vertical extent of cyclones and anticyclones as rotary wind systems.
23. The connection (if such exists) between temporary changes in the general circulation of the atmosphere (if these can be localized and observed from day to day), and the development and movement of cyclones and anticyclones.
24. The connection between the temporary changes aloft from day to day at a given point or points, as determined by kite or balloon observations, and the development of cyclones and anticyclones.
25. Use of free-air winds, as measured by means of kites and balloons, in forecasting the movements of HIGHS and LOWS.
26. The temperature, wind direction, and velocity from the surface of the earth up to the greatest attainable altitudes (*a*) in the various portions of the extra-tropical migratory cyclone, (*b*) in the various portions of the "permanent lows," (*c*) in the different portions of the tropical cyclone, (*d*) in the different classes of anticyclones.
27. Cloud heights, directions, and velocities in different quadrants of HIGHS and LOWS, and their seasonal and latitudinal variations.
28. Horizontal and vertical distribution of temperature and humidity in different quadrants of HIGHS and LOWS and their significance in forecasting.
29. Temperature gradients in rainless cyclones compared with those of anticyclones.
30. Effects of differences in temperature upon wind velocities in and around cyclones.
31. The processes accompanying the origin, growth, and decay of thunderstorms.

Forecasting.

32. Weather maps at the 1,000 m. level as a basis for daily forecasts. (The sea-level maps now used show hypothetical, not actual, pressure distribution.)
33. An intensive study of cloud formations, movements, etc., with reference to their possible use in increasing the accuracy of weather forecasts.

This would probably involve primarily the question of cloud observations as an index to the development and direction of movement of cyclones and anticyclones. It is recognized that such studies may be of great value in forecasting in the western United States where phenomena of cyclones and anticyclones are not well defined. Particular attention should be given to formation and diurnal changes with reference to types of weather, and to certain forms, such as lenticular strato- or alto-cumulus, of frequent occurrence west of the Rockies.

34. Forecasting the occurrence of precipitation in a quantitative manner.
35. The relation between short and long interval changes in solar radiation and terrestrial weather.
36. Changes in atmospheric transmission in relation to world-wide changes of the weather.

For instance, changes resulting from volcanic dust veils.

37. Ocean temperatures in long-range forecasting. (See MONTHLY WEATHER REVIEW, Nov., 1918, 46: 510–512.)
38. Periodicity in climatic or weather changes; application of mathematics.

To what extent is harmonic analysis permissible?

Agricultural Meteorology.

39. Correlation of weather and crops.

Mathematical correlation of monthly mean temperature and total monthly precipitation with crop yield.

40. Effect of temperature, rainfall, and sunshine on plant development.

Intensive and direct comparison between weather factors and plant growth.

Other Applications of Meteorology.

41. Effect of sunshine on the melting of snow on (*a*) level ground; (*b*) slopes; (*c*) in forests.
42. Effect of the wind on the melting of snow.
43. Determination of temperatures injurious to perishable products in transit.

Climatology.

44. Distribution of rain and cloud through the day and night, and month by month, at various stations.
45. Neglected factors in climate.
46. The importance of evaporation in climatology.
47. Comparative climatology.

Classification of climates from various points of view, and especially a comparison of the climates of the United States with those of foreign countries.

48. City climates compared with those of the open country.
49. Climatic distribution of certain crops.

For example, there is a region along the California coast near Carmel where the weather conditions are eminently best for lima beans.

50. Physiological and psychological relations of climate and weather.

One topic under this head that has been conspicuously neglected is the susceptibility of certain individuals to the effects of thunderstorms ("astrophobia"). This and kindred topics are discussed in W. Hellpach's "Geophysiche Erscheinungen."

The subjects contained in this list have, in many cases, been investigated to a considerable extent already. They are mentioned here because the investigations have by no means given a full understanding of these matters. In view of the previous work which has been done, needless duplication of effort will be avoided if those who undertake to study these problems familiarize themselves with the whole existing body of knowledge in the particular branch of meteorology in which they intend to specialize. The results, also, when published, should be fully articulated with previous literature, either as extending, confirming, refuting, or otherwise modifying the same. A preponderant part of such literature is, as a rule, European, and much of it in foreign languages. The facilities of the Weather Bureau library, which contains the most extensive collection of meteorological literature in the United States, are available to those who ask.—C. F. B.