movement of those discontinuities in the atmosphere called "fronts" with which many of our weather changes are associated. Thunderstorms, also, will probably be located by wireless.

The "Climate of Wireless."

WE must pass on to the second aspect of our subject, namely, the atmospheric conditions affecting wireless transmission.

When intercommunication over long distance by wireless had been successfully achieved, it was soon found that the rate of attenuation of signals depended on many factors such as the type of intervening surface, time of day, time of year, wavelength, and so on. Superimposed on these rather regular features, which Watson Watt has called the "climate of wireless," were found fluctuations of a rapid and more erratic nature which may be likened to weather. Prominent among these are the phenomena of fading.

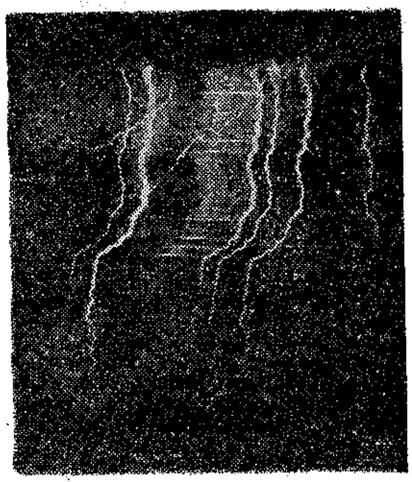
Though these phenomena have been a source of trouble to the wireless engineer, they offer a very promising means of learning something of the nature and condition of the atmosphere at high levels and especially of the electricity of the atmosphere.

In order to understand what is known of the climate and weather of wireless, one must remember that the energy from the transmitting station travels to the distant receiver along two different routes. The first is that followed by the direct wave, which travels along the surface, and the second that which is mainly in the upper atmosphere and is traversed by the indirect wave.

Atmospheric Electricity.

IT is necessary, also, to have some idea of the electricity of the atmosphere. Unfortunately, neither from the theoretical nor the observational view have we an adequate knowledge of atmospheric electricity. Indeed, one of the most acute of the present needs in geophysics is for active research in this subject. Its bearings on meteorology, radio-telegraphy and terrestial magnetism are both varied and important.

It has long been known that the atmosphere is normally in a state of



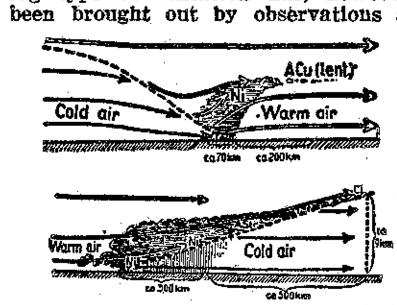
A photograph of a thunderstorm showing the length of the flashes of lightening.

electrical stress, there being an electric force directed downwards. The potential gradient due to this force, near the surface, is generally about 100 to 150 volts per metre. To maintain this gradient, the earth must be charged with 30,000 electrostatic units of negative electricity per sq. cm., or one-thousandth of a coulomb per sq. km.

The potential gradient is continually varying, the variations being to a large extent accounted for by irregular changes in the meteorological conditions. The loading of the gaseous ions with moisture, the consequent reduction of their mobility and hence the reduction of the conductivity of the atmosphere, is the chief means by which these variations are effected. The effect, as a rule, is only local and the total potential difference between top and bottom of the atmosphere and the air-earth current are practically unchanged. Consequently, as the mobility of the ions increases or decreases, so the potential gradient decreases or increases. Dust and smoke particles are even more effective than moisture in decreasing the mobility of the ions. Heavy and slow-moving ions, though taking small part in atmospheric currents, may possibly have important effects in absorbing or deflecting radio waves.

There is a decrease in the potential gradient as the height above ground increases. Therefore, the air must be positively charged. At about 10 km. the potential gradient probably vanishes so that the charge on the air below that must be about equal and opposite to that on the earth. The effect described is due to the increasing conductivity of the atmosphere with height. It is probable that the electrical resistance of the lowest 5 km. exceeds that of all the air above it, and that at 50 km. the conductivity is very high. The difference of potential between the earth and the upper conducting layer is of the order of 1,000,000 volts.

There are various more or less regular variations in potential gradient which can be dedeuced statistically, but it is difficult to say to what extent they are merely local and due to meteorological conditions, the prevalence of fires, dust, etc. One very interesting type of variation has, however, been brought out by observations at



Meterological conditions obtaining during a thunderstorm. Upper diagram, a cold frontal wind, and lower, a warm frontal wind.

sea and in polar regions. This is a diurnal variation of which the phase is the same at all parts of the world. It may be due to a diurnal variation in the frequency of thunderstorms; to the fact that the magneic poles are not at the ends of the geographical axis of the earth, and hence there may be some consequent effect on ionisation by solar radiation; or to some unknown cause.

In wet weather, and especially during thunderstorms, conditions are very different from those we have described. There are large fluctuations in potential gradient, both positive and negative values occurring. C. T. R. Wilson has made measurements of the electric field in the neighbourhood of thunderstorms. He finds a preponderance of negative gradients, and at a distance of 3 km. or 4 km. from the storm the gradient may be as high as 10,000 volts per metres. The lightning discharge usually restores the field to a more normal value.

The Phenomena of Thunderstorms.

NOW, the thunderstorm is a phenomena of considerable importance to those interested in wireless communication, and it will be worth while considering it in some detail. The only complete theory of the thunderstorm is that of Dr. G. C. Simpson, Director of the London Meteorological Office.

First, we must understand the meteorological conditions in a thunderstorm. Here the important point is that warm air flows in under the front of the approaching storm, and then upwards into it, being wedged up by cold air from behind. Condensation is produced through the cooling of the air owing to its pressure decreasing as it rises. In the forward part of the cloud there is a space in which the ascending current is so rigid that no raindrop can fall through it to the ground. We know that this is the case because, firstly, if conditions were otherwise, hailstorms could not be formed, and secondly, other evidence may be produced in support of this theory. The water drops rise and fall above this region in the ascending currents, and grow in size through continued condensation until they reach a diameter of 5mm. when they become unstable and break up, sending off smaller droplets. This process is repeated continuously, but many drops are continually reaching the boundaries of the violent upward current, and are thrown out and fall as rain.

Simpson experimented with water drops under the conditions described, and he found that the water drops became positively charged, i.e., they contained positive ions, while the air was negatively charged or contained an excess of negative ions. In the free air the negative ions would soon be caught by the small droplets or cloud particles, and carried upward with the ascending currents. The large drops will thus be positively and the small negatively charged. Observations of the charges carried by rain are in accordance with Simpson's theory.

In the region of the thunderstorm, where the ascending currents exceed 8 m/s, there is no accumulation of electricity. Above it there is an accumulation of large drops, which are continually breaking up, and therefore attain a high positive charge. The negative charge is carried by smaller drops to the more distant portions of the cloud.

The effect would be similar wherever rain is falling, but it requires the ascending currents of 8 m/s to produce electrical fields of sufficient magnitude to cause lightning.

It will be clear, therefore, that about the active region of rapid ascending currents, strong electrical fields will develop, the upper portion of the cloud being negatively and the lower positively charged. For sparking to take place it is necessary for the field in some part to reach 3×10^6 volts per metre.

According to Simpson, and I have not seen his ideas disputed, the mechanism of the discharge is as follows:—When the field has reached the limiting value there is a sudden production of ionisation. A highly conductive channel is thus produced, and the negative ions rush to the seat of the positive charge, and annul a large part of it. A strong field is left, however, at the further end of the conducting channel, that near the negative charge, and the ionising process continues there. The conducting channel extends towards the negatively charged area, and, owing to irregularities in the field, it branches, the branches finally dying out.

The discharge, therefore, is due almost entirely to the movement of electrons, the positive ions being too slow-moving in air to produce any large effect. The discharge may take place from the positively charged area to that with a negative charge within the

(Continued on page 29.)