VOL I #5

Royal Meteorological Society

R.M.S. CENTENARY

by

W. L. GODSON

CANADIAN

BRANCH

VOL. I May 1950 NO. 5

Published By

ROYAL METEOROLOGICAL SOCIETY, CANADIAN BRANCH

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"THE ROYAL METEOROLOGICAL SOCIETY CENTENNIAL CELEBRATIONS AND PRESENT TRENDS IN METEOROLOGICAL RESEARCH IN THE UNITED KINGDOM," *

(An account of a recent visit to England to participate in the Centennial activities of the Parent Society)

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Mr. Chairman, Ladies and Gentlemen,

When approached to give a talk on the Society's Centenary and on English Meteorological research I was at first rather hesitant to deliver a general address on such a large number of meteorological topics. Perhaps I was influenced by a few lines in a Punch of some years ago, stating: "No subject would appear to be too gruesome to be treated of in a modern book: a volume entitled 'Our Weather' has just appeared."

The occasion of our Parent Society's Centenary, nevertheless, is a good one to take stock of the many advances in Meteorology which are now taking place. It was on the 3rd of April, 1850, that Dr. G. Lee held a meeting of some 'friends of science' at his house at Hartwell. At this meeting the British Meteorological Society was established. In 1883 the society was renamed the Royal Meteorological Society and it is today a flourishing and virile organization with a membership exceeding 1600. From the first, the Quarterly Journal of the society has taken a prominent place in the dissemination of information and ideas; at first the emphasis was largely on observations and descriptions of meteorological phenomena, today the emphasis is chiefly on theories and descriptions of meteorological processes.

To mark the centenary of the Royal Meteorological Society the Science Museum in London is at present staging an exhibition entitled "The Science of Weather". The exhibition was officially opened on March 27 by the Rt. Hon. Herbert Morrison, Lord President of the Council. During his address he related his search of the Oxford Dictionary for a definition of the word 'forecast'. It was defined as a conjecture of a future event, usually the weather. Conjecture was in turn defined as a guess based on meagre evidence. Mr. Morrison suggested that in view of

* (Presented at the regular monthly meeting of the Royal Meteorological Society, Canadian Branch, held in Toronto, April 27th, 1950).

the word 'forecast' no one should take exception to the present accuracy of British forecasts, rated as 90% for rain in London on the next day.

The exhibition itself had evidently been very carefully planned. The Science Museum official most directly concerned was Mr. Chilton, whom many will remember as the Liaison Officer from the British Meteorological Office stationed in Canada during the war years. Among the exhibits was a display of Canadian instruments, including a thermometer filled with a mercury-thallium alloy which freezes at -73°F, and may therefore be used to measure accurately much lower temperatures than is possible with the ordinary mercury thermometer, since mercury itself freezes at -38°F. An interesting section of the Science Museum display dealt with the effects of weather on our daily lives, including a model of a windmill which is to be installed in the Orkneys and will generate 100 kilowatts of alternating current power. There was also a section of the exhibition devoted to meteorological research. One very popular exhibit dealt with cloud physics and contained a small refrigerated chamber in which a water droplet cloud could be formed by breathing into the chamber, even with temperatures well below 32°F, the normal freezing point of water. On introducing a small piece of 'dry ice', or solid carbon dioxide as chemists would have it, the cloud could be seen to precipitate out as minute ice crystals, illustrating the artificial seeding of clouds. This demonstrates very effectively the theory now widely held that condensed water can and usually does exist in the atmosphere in the liquid state with temperatures as low as -40°F. Any cooling below this point (as, for example, locally with dry ice) produces ice crystals which grow rapidly at the expense of the super-cooled water droplets until they are large enough to fall out of the cloud, reaching the ground as snow or rain, if they do not evaporate into the drier air below the cloud.

During the meetings at Oxford accommodation and meals were provided at Christ Church College, which was founded in 1525 and is the largest and in a sense the most important of the colleges. The college chapel is also the cathedral of the diocese and actually dates from 1004.

Students are expected, except for one night a week, to be in by 10 p.m., and no effort is spared to make the walls and gates quite unsurmountable - to the extent of jagged broken bottles cemented to the tops of walls and several rows of iron spikes on gates. The living quarters are naturally old and, as a result, the heating and sanitation conveniences were, to put it mildly, inadequate.

The symposia themselves were held in the Claredon Physics Laboratory, by the kind permission of Prof. Lord Cherwell, who was Churchill's scientific advisor during World War II. The lecture theatre and the building itself are very modern. An electrical system raised and lowered metal blinds when slides were to be shown, and blackboard sections worked on the continuous roller system, giving endless scope even to a mathematician (close to 800 square feet available).

Full accounts of the symposia at Oxford, including all papers and all oral discussions, will be published this summer in a special Centenary issue of the Quarterly Journal. It would be almost impossible to overestimate the value and significance of this Centenary volume; not only will it be a monument to the Society's progress in the past hundred years but also it will summarize and crystallize the present ideas and theories of meteorologists from the entire world. I am empowered to state that all meteorologists who are not already members of the Royal Meteorological Society will be able to obtain the Centenary issue if their applications and fees are received in London by June. In addition to this issue, summaries of symposia will probably appear in Weather in the very near future, so that I shall dwell only briefly on the papers and discussions presented at Oxford.

The first symposium dealt with "Radiation and its effect on the troposphere and lower stratosphere." Prof. Adel, of Arizona State College, drew attention to the presence in the atmosphere of small amounts of Nitrous Oxide, once known as laughing gas because of its peculiar properties when inhaled. Spectroscopic measurements in New Mexico suggested that the mean temperature in spring of the layer containing nitrous oxide was of the order of $+5^{\circ}C$, so that this gaseous component must be present almost entirely in the lowest layers. Dr. Wormell of Cambridge University corroborated these results and pointed out that nitrous oxide concentrations are of the same order as those of ozone, a component known to be significant in the radiative processes of the stratosphere. Dr. Robinson of Kew Observatory presented evidence showing that a clear day at noon the ground temperature, with short grass, exceeded the screen temperature, roughly at eye-level, by twenty degrees on the average. This is a significant factor in the heat interchange in the lowest layers of the atmosphere.

The second symposium dealt with "The Physics of Clouds and Precipitation". The chief contribution to this symposium was undoubtedly that of Dr. Schaefer, of the General Electric Co., who showed a large number of slides, chiefly in color, illustrating the effects produced by seeding super-cooled clouds with dry ice and silver iodide. Cumulus clouds in the New Mexico region have been made to give significant amounts of precipitation as a result of such seeding operations, even when similar clouds not seeded gave absolutely no rain. One aspect of the seeding process, hitherto not understood, is the very rapid change in the state of a super-cooled layer cloud when seeded with less than 1 pound of dry ice per mile. In less than half an hour the water droplets are converted to ice crystals which slowly fall out, leaving a gap in the cloud several miles wide.

Mr. Mason, of Imperial College, London, reported on some theoretical investigations which showed that the ice crystals once formed would grow by deposition of vapour from the water droplets only on certain edges or corners of the crystals. This results in the formation of long needles which readily splinter, producing hundreds of new nuclei. Dr. Frith, of the Meteorological Research Flight, South Farnborough, spoke on the value of seeding in labelling a sector of a cloud. On one occasion a long rift or clear band, about 1/4 mile wide, had been observed in a layer cloud and the cloud was thereupon seeded at right angles to, and across, this rift. The two cleared sectors, on opposite sides of the rift, subsequently drifted apart, in a direction parallel to the rift at a rate of about 10 miles per hour, demonstrating the remarkable horizontal variation or shear of the wind in that vicinity. An interesting experiment, which is undoubtedly related to the generation of electricity in thunderstorm clouds, was described by Prof. Gill, of Oxford University. A slow stream of water droplets was blown by an air blast against a surface of ice. The ice surface became strongly charged the water receiving an equal and opposite charge. With an air stream of 30 miles per hour and a temperature of -35°C, 1 cubic centimetre of water received a positive charge of 100 electrostatic units. In the vicinity of 0°C, the results indicated that the ice would take a positive charge, the net effect being much weaker than at -35°C. It appears that this process is of the right order of magnitude to account for the electrostatic field required for lightning flashes.

The third symposium dealt with "The Structure of Weather Systems". Dr. Bleeker of the Netherlands postulated the great significance of differential surface heating for the development of frontal and jet-stream systems. He pointed to the surface trough of low pressure so often found off the East coast of North America in winter as an example; over the snow-covered continent little heat could be absorbed, the snow reflecting back to space roughly 80% of the incoming solar radiation, whereas over the Gulf Stream large amounts of heat could be taken up by a cold air stream. This theory was attacked by several meteorologists including Dr. Rossby, of the University of Chicago, who pointed out that frontal troughs frequent the same region in summer even though the differential heating effect was then completely reversed. Dr. Nyberg of Sweden drew attention to the importance of large-scale vertical motions in the free atmosphere and showed a case over the North Atlantic of marked cooling at 30,000 ft. over a large area, even though the horizontal wind field was bringing in warmer air. I spoke on some aspects of three-dimensional synoptic structure, with emphasis on frontal configurations and their prognostic significance.

The fourth symposium dealt with "The General Circulation". Many of the contributions to this colloquium were highly mathematical and will not be mentioned further. The general idea held by most meteorologists seems to be that the processes of radiation alone tend to set up a simple flow system with westerly winds around the world. Such a system is, however, unstable and must breakdown, with cold air surging southward and warm air northward, probably in preferred regions dictated by distributions of land and sea and mountain ranges. This interchange of vast masses of air then changes the overall temperature distribution, which is now no longer in equilibrium with processes of radiation. The atmospheric machine is then set into motion again, maintaining the broad scale features of the general circulation while allowing for meridional transport of atmospheric properties.

The fifth symposium dealt with "Climate Change". This included papers by Dr. Willett, of M.I.T., and Dr. Lysgaard, of Denmark, both of whom dealt with climatic changes in the last 100 years. There has been a decided warming trend in the last 50 years, averaging about 2°F for the entire world but especially marked in the north polar regions. Some diagrams produced by Dr. Lysgaard showed this feature very clearly, even when applied to 30-year means. At the other extreme of the time scale Mr. Ovey, of the Natural History Museum, London, dealt with climatic changes in the last 15,000,000 years. It has been found that the types of shells observed on the ocean bottom are representative of the water temperature, and hence of the mean air temperature. By analyzing core samples from ocean beds it is thus possible to deduce the mean temperatures at various periods in the past, making use of the fact that 1 cm. of deposit will be laid down in 1000 years.

The final symposium had as its subject "Meteorology and the Community". While none of the problems of the meteorologist were answered in this colloquium, it was pointed out that many problems of special groups can be answered by the meteorologist, and, in fact, are being answered by him. Several rather obvious fields of application are still relatively in their infancy, as for example, agricultural meteorology. It was urged that more meteorologists should devote time to these specialized branches of our weather science, so that the general public may derive greater benefits from the skill and experience of the forecaster. The meteorologist should also stimulate the interest of special groups in the services and type of information available else he is in danger of suffering the fate depicted by C.R. Benstead in the lines.

"The weather-man dreamed he was dead,
That he stood by his monument tall and read
The message there - and he hung his head,
For 'Probably Warmer' was all it said."

At the end of the week of Symposia I had an opportunity to visit Prof. Dobson's home a few miles from Oxford where he has installed his Ozone Spectrophotometer for measuring the amount and distribution of ozone in the atmosphere. Since the Meteorological Division has recently purchased one of Prof. Dobson's instruments it may be of some interest to consider its operation briefly. Even though the total amount of ozone in the atmosphere is very small it is sufficient to absorb, and hence filter out, virtually all of the radiation from the sun in the far ultra-violet and a large proportion in the near ultra-violet. More is absorbed at the shorter wave lengths, the relative amounts at two wave lengths being a function of the total ozone concentration. The Dobson instrument contains a prism which breaks up sunlight into a wide spectrum and by a system of variable slits two narrow wave-length bands alone are permitted to continue. A revolving slotted disk alternately allows light from each slit to fall on a photo-multiplier tube where it is amplified 100 times. The result is essentially a direct current on which is superimposed an alternating current. The alternating current is rectified, further amplified, and measured as a direct current on a micro-ammeter. An optical wedge is inserted in front of the slit through which the most light passes and by adjustment of the wedge the rectified direct current may be reduced to zero. The reading on the optical wedge can then be calibrated directly in terms of total ozone. By taking a series of measurements on the zenith sky during the hours of sunlight it is now possible to deduce the distribution of ozone with height - information of vital interest to any student of the stratosphere.

On the last evening before leaving Oxford all those at the meetings attended a play produced by the Oxford Repertory Players. All that I will say about the play is that its title was "The Man with a Load of Mischief", it was written by Ashley Dukes, and it would most certainly be banned in Boston.

On the Saturday afternoon of our return to London there was arranged a visit to the Meteorological Office at Harrow. This office houses the instrument development, testing and calibration section, the Marine Meteorological section, and the Climatology section, including the main library of the British Meteorological Office. Numerous exhibits illustrating the activities of these sections had been prepared, only a few of them can be mentioned here. The Marine section makes great use of Hollerith techniques and machines were shown sorting punched cards to find all the occasions of certain values of meteorological elements and obtaining monthly totals of various elements, simultaneously printing the individual records from the punched cards and their sums. A photo-electric visibility meter was demonstrated, which should improve the subjective and approximate nature of purely visual estimation. One interesting new instrument was a gadget attached to a captive balloon which could register the top of a fog layer photo-electrically by indicating the cessation of light scattering. In addition to such new instruments there were displays of historical and present-day instruments for recording pressure, temperature, humidity, wind and rainfall.

That evening the Royal Meteorological Society held a conversazione, featuring a musical concert by the Occasional Wind Players and some meteorological films. Dr. Schaefer showed a colored film illustrating the growth of a New Mexico cumulus into a cumulonimbus or thunderstorm cloud after seeding, individual pictures being taken every 2 minutes and then projected at normal speed.

On the following Monday morning there was a visit to the Dept. of Meteorology of the Imperial College of Science and Technology in London. This is the only full Dept. of Meteorology in Great Britain and consists of a large teaching staff, with numerous students working towards their M.Sc. or Ph.D degrees. Under Prof. Sheppard a group is working on turbulence and the vertical transport of heat and water vapour in the lowest layers over land and sea. Other active investigations include studies of vertical velocities of the air, studies of freezing nuclei, droplets in clouds, and the growth of ice crystals, and theoretical studies of the general circulation. That noon a special luncheon was provided by the Whitely Electrical Radio Co., who manufacture British radiosondes. This was a very elaborate affair, with wine and cocktails flowing like water in Toronto. In the afternoon the Royal Meteorological Society held its centenary meeting. On this occasion honourary fellowships were awarded to: Dr. Banerji, of India; Dr. Bureau, of France; Prof. Ficker, of Austria; Dr. Reichelderfer, of the United States; and Prof. Vening Meinesz, of the Netherlands. The centenary dinner was held in the evening and was attended by the Secretary of State for Air, the Rt. Hon. Arthur Henderson. This ended the official celebrations of the Society's Centenary. The remainder of my stay in England was spent in visits to various meteorological centres, especially those where research was being conducted.

I also visited the Physical Society's annual exhibition of scientific instruments. The chief item of interest to meteorologists was the new radar-sonde developed by the Telecommunications Research Establishment, a branch of the Ministry of Supply. In this new scheme of upper-air sounding a ground station transmits narrow electrical pulses regularly on a wave length of 2 metres, the pulses being returned by the balloon-borne unit (resembling a normal radiosonde) on a wave length of 10 cm. By measuring the transit time of the pulses to and from the unit, the distance of the balloon from the ground station can be found, and is very accurate up to a range of 100 miles. The receiving antenna system, esentially a parabolic mirror, can be homed automatically on to the airborne unit so that the elevation angle and the horizontal or azimuth angle of the balloon are always known. All this information is fed into an electronic computer which stores it up for 15 seconds and then calculates the mean horizontal velocity of the balloon, which is simply that of the air itself at that level. The resulting figures for wind speed and direction are then printed on a paper tape as well as displayed on dials, the entire process being completely automatic. In addition the balloon unit carries a normal radiosonde assembly to measure pressure, temperature and relative humidity. The magnitude of these elements is telemetered to the ground station over the same pulse channel as is used for the wind determination. This system is designed with an accuracy of 0.1%. The frequencies corresponding to each atmospheric variable in turn are analysed automatically by the ground station and values printed on a paper tape.

The British Meteorological Office has a very active research programme directed, actually, by the Meteorological Research Committee, which contains all of the prominent British Meteorologists, at Universities and elsewhere, as well as representatives of other scientific and governmental bodies. This committee assigns a priority to every research problem suggested and allocates the problem to some branch of the Meteorological Office, often in collaboration with some outside group. The Committee receives reports of all research activities and prints the more significant of these reports as Meteorological Research papers, a certain number of which are authorized for general distribution and are received, for example, in Toronto. The research projects are divided into three main groups and it might be instructive to list the various topics to which the highest priority rating has been assigned - problems which are considered extremely vital and urgent. Many of these will be referred to later under the actuvities of various research groups.

In the field of instrument research the high-priority projects are:

(1) Determination of air speed corrections for thermometer elements,
(2) development of a thermometer suitable for high speed aircraft,
(3) development of a fully automatic recording frost point hygrometer,
(4) development of an instrument to evaluate the vertical visibility by day or night utilizing the light scattered from a searchlight beam,
(5) development of meteorological elements for radar-sondes,
(6) development of radar-sonde theodolites, and
(7) application of radar methods for detecting and investigating cloud, precipitation and turbulence.

In the fields of synoptic and dynamical research the corresponding subjects are:

(1) studies of large scale circulation types, their classification and changes,
(2) studies of zonal, meridional and other indices,
(3) studies of the development, movement, and decay of major synoptic features, according to season and location in the Northern Hemisphere.
(4) studies of the early stages of anticyclogenesis,
(5) studies of upper winds and contour patterns, and jet streams in particular,

(6) studies of temperature changes and the relative importance of advection, dynamical and non-adiabatic processes,
(7) studies of the three-dimensional structure of fronts in relation to temperature, humidity and wind, with special reference to clouds and rainfall,
(8) development and use of regression equations for forecasting upper winds,
(9) statistical studies of the temperature distribution at standard pressure levels, and
(10) studies of the incidence, duration, and intensity of frontal rain over the British Isles.

In the field of physical meteorology the high-priority investigations are:

(1) studies of the physical structure of rain-producing clouds,
(2) studies of the meteorological factors affecting ice accretion on aircraft,
(3) studies of the velocity and dimensions of gusts associated with CB clouds
(4) studies of clear air, or high level, turbulence,
(5) studies of the relation between vertical and horizontal visibility,
(6) studies of the temperature and humidity of the troposphere and lower stratosphere under various conditions, and
(7) studies of the formation of single and multiple tropopauses, types of tropopause, and the exchange of mass between the stratosphere and the troposphere.

In the British Meteorological Office research is carried out either by the Forecast Research Section, under Dr. Sutcliffe, which is a branch of the Forecast Division or by the Research Division itself, under Dr. Goldie. Many of the activities of the research division are carried out at special research establishments and observatories, several of which I was able to visit. A small group is stationed in the headquarters in Victory House, London.

Mr. Bannon of this group has made some interesting surveys of high-level clear-air turbulence. Until recently it had always been thought that the bumpiness observed on flights in the lower levels and in or near clouds of vertical development would be non-existent in the upper levels, especially in the stratosphere, in the absence of such clouds. This appears now to be not the case; in fact, for over 300 flights between 20 and 40,000 feet the bumpiest conditions were observed between 28 and 32,000 ft, about 1 flight in 4 reporting turbulence in this layer. The bumpiest layer in the upper troposphere actually rises from summer to winter, showing clearly that surface heating cannot be a controlling factor. Statistical studies showed that high-level turbulence was most probable if there were large wind velocities and if there were large rates of change of the wind speed in the vertical or in the horizontal. These criteria suggested that high-level bumpiness should be most frequent in the vicinity of the jet stream, which was verified by the observational data. This can be appreciated from a vertical north-south cross-section through the atmosphere on which are entered lines of equal wind velocity from west to east. In the vicinity of the region of fastest-moving westerlies, the so-called jet stream, rapid changes of the wind velocity in the vertical and horizontal are observed, and in this sector high level turbulence is very frequently encountered.

A small but active research group is stationed at South Farnborough, with the Royal Aircraft Establishment, which is under the Ministry of Supply and tests all aircraft parts and accessories. This group is named the Meteorological Research Flight and has 5 aircraft - 2 Halifaxes for investigations up to 25,000 ft. and 3 Mosquitoes for investigations from 25 - 40,000 ft. On the day of my visit only one mosquito was operative, which was apparently the typical case.

The high level flights have been used to study the temperature and the relative humidity up to the ceiling of the aircraft. Very dry air has been found in the stratosphere, the atmospheric region lying above the tropopause and marked by a constancy or slight increase of temperature with height rather than the normal decrease with height observed below the tropopause. The tropopause is at a mean height over the south of England of about 35,000 ft. and the mean relative humidity at the tropopause level is 42%. At a level of 40,000 ft, 5000 ft. into the stratosphere, the mean relative humidity has dropped to 5%, and the air at that level must be cooled from its mean temperature of -57°F to -100°F before hoarfrost will form.

Other investigations have dealt with the fine structure of the atmosphere and recently an aircraft thermometer has been developed which will accurately and instantaneously record air temperature fluctuations of as little as 0.01°F. An extensive cloud physics investigation is also pursued at South Farnborough, the seeding experiment across the cloud gap mentioned earlier having been performed there. Of particular interest is their study of atmospheric nuclei, those minute atmospheric particles on which it is believed water condenses to form the droplets observed in fogs and clouds. Two particular types which seem to be significant have been studied in some detail; both have been observed at all levels in the atmosphere but are much more numerous near the ground. One type may readily be collected on spider webs and consists of particles of the order of 0.01mm (1/2500 inch) in diameter. This type appears to be common salt, doubtless of marine origin. When viewed indoors under a microscope the individual particles have a roughly crystalline form, often in small aggregates.

When breathed upon they swell up instantly into spherical water droplets, which rapidly shrink and collapse to leave the original crystal, the entire process taking about 2 seconds. Such crystals undoubtedly serve as nuclei for water and supercooled water droplets. The other type of crystalline nucleus is far more mysterious and has not yet been identified chemically. Such crystals can be collected on very thinly greased slides exposed to the atmosphere and consist of flat transparent plates with dimensions up to 0.1 mm (1/250 inch). When observed under the microscope they have markings on their flat face which appear to represent a surface boundary of some sort. When a slide with such a crystal is breathed upon, the line on the crystal moves across the surface apparently corresponding to the spreading of a water film. In the dry room air, this line recedes to its original position rapidly, suggesting that a certain amount of water can stay on the crystal even at low relative humidity. These crystals are absolutely insoluble in water and so far they have crystallographers completely baffled.

The British Meteorological Office maintains at East Hill, north of London, a Radar Research Station, where considerable work has been done on the relation of radar weather echoes to the meteorological situation existing. Supplementary studies, using aircraft traverses, have been made of the turbulence dimensions, and internal structure of cumulonimbus clouds. The radar equipment most generally used at East Hill is a 10 cm set using an energy pulse with a duration of 2/1,000,000 second. On the radar screens, identical in nature with television screens, both horizontal and vertical sections through the atmosphere are displayed. Radar pictures are obtained of all reflecting objects, which include large ice crystals and snow flakes, water droplets of rain drop size, and, of course, airplanes. These radar pictures have been correlated with the weather and the vertical temperature distribution and the reflection-or echo- producing atmospheric agency. In addition, flights have been made by Spitfires through the entities viewed on the radar screen, which has led to a greatly increased understanding of the conditions attending cloud and precipitation, and thunderstorms in particular. The most interesting results have been obtained from the vertical sections, in which the horizontal axis represents distance from the station and the vertical axis represents height. The normal layer cloud type of echo is essentially a shallow horizontal entity on the radar screen. This echo is typical of clouds with small vertical currents and temperatures at the top of the echo 18°F or warmer; the echo is received from snowflakes and melting snowflakes.

With a more active precipitation system echoes are received from much greater heights, although the horizontal stratification is still pronounced. The echo in the upper levels is interpreted as coming from large individual ice crystals which have grown to the necessary size for reflection by a slow fall through a considerable depth of cloud. At the freezing level the large ice crystals and snowflakes melt, producing large water droplets which later break up. Thus a much greater response is obtained from the cloud near the freezing level, giving what is known as the "bright band" effect.

On the day of my visit an occlusion was giving continuous rain and the corresponding radar picture was very similar to this latter type, with a level echo top at 10,000 ft and a pronounced 'bright-band' effect near the freezing level at 2000 ft. I was informed that I was very fortunate to be able to observe anything on the radar screen since the well-known law of the 'perversity of inanimate objects' almost invariably operates so that the arrival of visitors clears the radar screen of everything except echoes from an occasional aircraft.

There are two typical types of echo from cumulonimbus cloud. Such clouds are characterized by strong vertical columns of echo with clear-cut vertical edges and no indication of any 'bright band' phenomena. Such echoes must therefore come from liquid water at all levels. On one such occasion the Spitfire pilot reported aircraft icing from 26,000 ft. (-39^{o}F) to 18,000 ft (-7^{o}F), in the form of a fine mist freezing to form a very thin ice layer on the plane, and he observed rain from 10,000 ft ($+ 22^{o}$F) to 8000 ft ($+30^{o}$F) - all at levels with temperatures well below the freezing point.

For single column echoes of this sort the mean echo width is $3\frac{1}{2}$ inches and the mean cloud width 6 miles, largely independent of the vertical extent of the cloud or of height itself. In the outer regions of the clouds the droplets present are not large enough to give a reflected signal.

Frequently there is observed a multiple column CB echo and this is typical of a thunderstorm situation. Thunderstorms are associated with well-developed CB clouds, and echoes in such cases extend upwards to much lower temperatures and are more intense than the normal CB which produces showers without the occurrence of thunder or lightning. Thus in a thunderstorm the vertical currents and raindrop size must be greater than in an ordinary CB cloud. This may lend support to the "breaking drop" theory of separation of electrical charges within a thunderstorm. It may also be significant that the temperature at the top of the thunderstorm echo is usually below about -40^{o}F and is therefore in the region where, according to Dr. Langmuir and Dr. Schaefer and many others, any type of atmospheric nucleus will act as a freezing or sublimation nucleus, and where supercooled droplets will be transformed into ice crystals. This suggests that at least a contributory factor to the generation of a thunderstorm may be the introduction of a number of supercooled raindrops into a volume containing large numbers of ice crystals, especially in the light of the Oxford report that at such low temperatures the impact of water droplets on ice produces a large separation of electrical charge.

Vertical sections of this sort show a number of strong columns separated at least at the upper levels, by well-marked troughs.

From a horizontal picture of atmospheric echoes at a time when typical CB clouds were present, it can be seen that the echoes associated with single column returns are isolated and sharp-edged, with approximately circular cross-section. Multiple column echoes, on the other hand, appear to be derived from masses of echo of all shapes, although sometimes forming a line of echo, which show units of cellular structure. The individual cells are associated with a single column of echo and are approximately circular in cross-section. For multiple column echoes the mean total echo width observed was about $6\frac{1}{2}$ - 7 miles, and the mean cloud width 9 miles. Individual column widths averaged $1\frac{1}{2}$ - 2 miles with clear intervals about 1 mile wide, corresponding to individual cells, inside the cloud, of roughly 3 miles in diameter.

The analysis of the gust or accelerometer records of Spitfires making traverses through CB clouds has provided not only information on the distribution of turbulence and bumpiness in such clouds but also a qualitative picture of the vertical velocities present. Because of the increase in both terminal velocity of fall and echo return with increase in drop diameter it is logical to assume that the well-marked columns in the echo are associated with strong upward currents in which the drop sizes are greater than in the neighbouring weaker and probably downward currents. The close proximity of up-and-down-currents would explain the sharp edge which is peculiar to the active CB type of echo and leads one to expect the greatest turbulence in the edges of the echoes where the vertical current is changing most quickly. Such views are definitely supported by the analysis of simultaneous radar and flight records. These data also suggest that a large proportion, if not all, of the air which ascends in an active CB cloud must be balanced by down currents within the cloud itself, rather than between or around clouds as was the view until recently.

It is interesting to note how little the average horizontal dimensions of a single-cell CB cloud change with increasing vertical extent of the cloud and to note the little change in horizontal extent at different heights in a particular cloud. These results indicate that once a developing cumulus contains water droplets of raindrop size any further growth of the cloud takes place only in the vertical without any appreciable lateral spread of the cloud, as long as the cloud remains a single cell. If lateral development does take place the cloud splits into separate cells each having approximately the same diameter, but this diameter will be appreciably less than that of the original single cell. This suggests that lateral development takes place by the initiation of new cells on the perimeter of the old cell, and this has often been observed to happen on radar screen representations.

A lengthy visit was also made to the Central Forecast Office and the Forecast Research Section at Dunstable. The Forecast Office and the Communications Centre, both the most important of their type in the British Isles, are housed in old sprawling buildings. The Research group, on the other hand, has just moved into a new building to be named The Sir Napier Shaw Laboratory. Here are all the facilities for research that could possibly be required and the conditions of work appeared ideal. Ample provision has been provided for storage of all past charts and work tables for ready reference to old data; there are large analysis and plotting rooms for the larger projects, a large lecture room, a photographic dark room, a drafting room, a small library with reading rooms, and numerous offices, - all arranged around a centre court to provide the maximum natural illumination. The building is even provided with central heating although this is appreciated chiefly by visitors from abroad — the native residents find it too warm. I was reminded of the story of a hotel keeper during a heavy thaw at a popular Swiss winter resort who stated that Englishmen were to blame for the warm Chinook-type wind. When asked how this could be, he replied: "Because zey opens all ze windows and so, alas! lets ze'ot air outside".

The Forecast Research Section studies both synoptic and dynamical problems, individual researches being as significant as, but probably less interesting than the physical investigations considered hitherto. Due to limitations of time only a brief outline of a few of these activities will be attempted.

The Forecast Research Section is divided into two units, one under Mr. Sawyer being concerned with short-range forecasting problems (up to 48 hours), and the other under Dr. Forsdyke dealing with extended period forecasting problems, at present chiefly in the range of 2-4 days. Personnel from both units participate in the preparation of experimental 4-day forecasts. These forecasts are based on a sequence of Northern Hemisphere charts, two per day, for the surface and 500 mb and for the total thickness from 1000 to 500 mb. The greatest use is made of the thickness chart, interpreting it in the light of Dr. Sutcliffe's recently-derived equation relating development in the pressure field to the properties of the thermal wind field. The results indicate definite skill for the first three days, but very little for the fourth day, on the average.

Mr. Lamb, of the extended-range forecast research unit, has made some interesting studies of persistence of weather types over England. He considered all long spells, characterized by a predominant weather or circulation type, which lasted for at least 25 days. Over a 50-year period 158 such lone spells have occurred, the probability being about 30% on the average that any given day will be included in a long spell.

This probability is far from uniform throughout the year, however. Certain periods in the year show a decided minimum probability; at such times long spells either do not occur or soon come to an end — for example, early June (16% probability) and early September (12% probability). Other periods show maximum probabilities — long spells remain or are instituted if not present - for example, July (46% probability) and early October (52% probability). These studies are at present being extended to larger geographic areas.