IRISH METEOROLOGICAL SOCIETY

Newsletter

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This issue of the Newsletter contains a summary of a lecture "Ice in the Atmosphere" given to the Society by Dr. A.F. Roddy on 12 April 1985.

Also included is the Programme for the Society's One-day Meeting on Sunday 8th September. Members are welcome to invite their friends. I look forward to seeing you there.

Shane Tierney

Shane Tierney
President

ICE IN THE ATMOSPHERE

by

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The appearance of ice in natural clouds can be easily observed from the ground. The outline of a cumulus cloud becomes gradually diffuse and fibrous as glaciation proceeds. Cirrus clouds consisting of ice crystals are found at high levels in the troposphere. The contrails which are sometimes formed by high flying aircraft and which are ice clouds can sometimes persist for quite long periods. Noctilucent clouds are formed at very high altitudes averaging 82.5 km, far above normal clouds. They can be seen from high latitudes during a short season each year. Noctilucent clouds may consist of particles of cubic ice Ic, having a different structure from normal hexagonal ice Ih. Further afield, clouds in the atmosphere of Mars may involve water ice and/or solid carbon dioxide.

A typical cloud drop has a radius of the order of 10μm and a terminal velocity of about 1cm s^{-1}. Concentrations, although varying widely, may be of the order of 10^6 per litre of cloud. A typical raindrop has a radius of about 1 mm, a terminal velocity of 6.5 ms^{-1} and concentrations are of the order of 1 per litre of air. The water from 10^6 cloud drops must be brought together to form one raindrop, in a time limited to several tens of minutes. There are two main ways in which this can occur in nature. One way is through the collision - coalescence mechanism and this is the only possible way in clouds whose tops do not reach beyond freezing level in the atmosphere. Another mechanism, very important in our latitudes, is the freezing or Bergeron-Findeisen mechanism. Typically, droplets in a natural cloud do not freeze at 0°C, but exist as supercooled droplets at temperatures down to -15°C or lower. When, however a few ice crystals appear in such a cloud, they grow rapidly at the expense of the droplets. The terminal velocity of the growing crystals increase and they continue to grow as they fall more and more rapidly through the cloud. Eventually, if the cloud is sufficiently deep they may reach precipitation - particle sizes. The crystals become raindrops when they melt after passing through the 0°C level, on their journey to the earth's surface.

Ice crystals formed in a cloud grow by water vapour diffusion, also frequently by riming and/or by aggregation. Riming involves collision with and collection of supercooled cloud droplets that normally freeze on impact. Aggregation of single crystals to form snowflakes occurs at warmer temperatures, near 0°C. Painstaking work on the typing and classification of natural snow crystals has been carried out, particularly by Japanese scientists who also have grown snow crystals artificially in the laboratory. Replicas of natural snow crystals can be made using simple techniques which involve the use of formvar dissolved in a suitable solvent. A glass slide coated with the solution is exposed to the snowfall. A captured snow crystal sinks into the solution, in a short time interval the solvent evaporates and a plastic replica of the crystal remains. The main variables determining snow crystal habit (or shape) are temperature and humidity (amount of supersaturation). The basic habit is hexagonal and ranges from needles to hexagonal columns to plates to sector-like crystals and to the flower-like or dendritic crystals. The intricate dendritic crystals are formed at about -15°C when the supersaturation is relatively high, and when therefore the crystal growth rate is most rapid. Hailstone formation is an extreme case, in which heavy riming is occurring. When the collection of supercooled cloud droplets by the growing crystal is rapid (i.e. when the liquid water content of the cloud is high) the latent heat released cannot be transported away quickly enough; therefore the surface of the growing ice particle warms up and further collected drops do not freeze immediately on impact but spread out in thin layers over the whole ice particle surface which then freeze due to contact with the cold surrounding atmosphere. A similar situation occurs with drops subsequently collected and thus the typical layered "onion skin" structure of the hailstone is produced. Hailstones are polycrystalline, with the sizes of the crystallites varying from one layer to another. This can be shown by examining hailstone sections in transmitted polarized light, under a microscope. In a vigorous cumulonimbus cloud the growing hail particles may be carried up and down several times by updrafts and downdrafts, thus occasionally leading to the formation of golf-ball or even tennis-ball sized hailstones.

Ice has an important role in thunderstorm electrification. Thunderclouds are usually highly active cumulonimbus clouds in which hail particles have been formed. There is as yet no agreement among scientists concerning the exact mechanism chiefly responsible for the charge separation - indeed several different mechanisms may make significant contributions. Some mechanisms involve the thermoelectric effect in ice. This is an effect in which a temperature gradient across an ice particle results in charge separation. Positive charges are probably carried to the top of the cloud by small ice crystals/splinters, whereas hail particles/raindrops carry negative charges to the cloud base.

The freezing of supercooled droplets in natural clouds is triggered by relatively rare particles called ice nuclei. The small proportion of natural aerosol particles which can nucleate ice increases rapidly with decreasing temperature. A typical concentration of natural ice nuclei active at -20 °C would be one per litre of air. The concentration increases by an order of magnitude for each additional fall in temperature of about 4°C. Ice nuclei concentrations can be measured by forming a cloud in the air under investigation, at a selected temperature, and measuring the concentration of ice crystals produced. For this purpose an expansion cloud chamber or mixing cloud chamber can be used and ice crystals can be detected acoustically or by other means. Another technique for ice nuclei measurements involves the growth of ice crystals in a thermal diffusion chamber, on particles captured on membrane or Nuclepore filters. What is the composition of natural ice nuclei? There is much evidence that clay mineral particles form a significant fraction of them. There was much controversy at one stage concerning the possibility of an important role for particles of meteoric origin. Most investigators would now discount such a major role but the question is not completely resolved. Some of the most interesting research work carried out over the last decade concerns particles of biogenic origin. It has been found that some very active ice nuclei are associated with biogenic sources such as decaying leaves and leaf litter, phytoplankton blooms on the ocean surface, and particular types of bacteria. Bacteria of particular interest are Pseudomonas syringae and Erwinia herbicola. Much of the research on the ice nucleating characteristics of these bacteria has been carried out in the context of frost damage to plants. Ice nucleation active bacteria found on plant surfaces can trigger the freezing of plant water at relatively small supercoolings. This freezing can cause serious damage to some plants. When the leaves of these plants are sterilized they can be supercooled to temperatures of the order of -15 °C without freezing. One application of this research has led to a method for the prevention of such frost damage to high-value citrus plants. Evidence has been presented to show that biogenic ice nuclei may form a significant fraction of natural atmospheric ice nuclei. Substances not found naturally in the atmosphere can be active as "artificial" ice nuclei. Examples of the more active nucleating substances are silver iodide, lead iodide and the organic materials phloroglucinol and metaldehyde. Silver iodide and lead iodide were chosen on the theoretical basis that their crystal structures are similar to that of ice. With regard to anthropogenic sources, some steel mills have been found to be prolific sources of ice nuclei. There has been a suggestion that lead in motor vehicle exhaust would combine with iodine in the atmosphere to produce lead iodide, a good ice nucleant. However, the chemistry involved is very complicated. Dry ice (solid carbon dioxide) and propane are examples of materials that when injected into clouds produce severe localised cooling. Temperatures below -40 °C, at which spontaneous or homogeneous freezing occurs, are reached.

The basis of attempts to modify weather in order to achieve increased precipitation is that nature is deficient in ice nuclei and that if "artificial" ice nuclei are introduced into suitable clouds that precipitation, initiated by the Bergeron - Findeisen mechanism, can be increased. Most weather modification work has involved cloud seeding with dry ice from an airborne dispenser or with silver iodide from ground-based or airborne generators. Too much of this work, carried out over the last four decades has been unscientific, however, some good controlled large-scale experiments have been organised. There are great difficulties involved in the statistical evaluation of even well-designed experiments, one reason being that natural precipitation is so variable. Very few precipitation augmentation experiments have produced even modest increases whose validity are accepted by the scientific community. The Israeli weather modification programme is one such example. Other weather modification work involving cloud seeding with artificial ice nucleating materials has included hail suppression experiments (USSR scientists claimed a high success rate in this area), supercooled fog clearance (used operationally at some airports), layer-cloud clearance and hurricane modification experiments. Interesting but limited work has been carried out with the aim of redistributing precipitation.

Several interesting optical effects are caused by ice crystals in the atmosphere, some of them frequent and some very rare. The most common effect is the 22° (radius) halo observed around the sun or moon, which is formed by refraction in randomly oriented ice crystals. Other effects include a 46° halo, "sun dogs" or "mock suns", sun pillars, and several arcs including the circumzenithal arc, like a small inverted rainbow high in the sky. It has been suggested that a very rare 28° halo, Scheiner's halo, may be caused by refraction in octahedral crystals of ice Ic which has a cubic crystalline structure.

One-day meeting, Sunday 8 September 1985

Grand Hotel, Malahide, Co. Dublin

Programme

11.00 - 11.30	:	Dr. Ray Bates (Meteorological Service) "L.F. Richardson: A Pioneer in Numerical Weather Prediction"
11.30 - 12.00	:	Mr. Michael Bailey (An Foras Forbatha) "Acid Rain in Ireland".
12.00 - 12.30	:	Mr. Kare Breivik (Meteorological Service, Retired) "Wind and Weather at Dublin Airport".
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2.30 - 3.00	:	Mr. Michael Mansfield (Meteorological Service) "Television Weather Presentations around the World".
3.00 - 3.30	:	Dr. John Farrell (Geography Dept. U.C. Cork) "Weather Hazards in County Cork".
3.30 - 4.00	:	Dr. Shane Ward (Agricultural and Food Engineering Dept. U.C.D) "Weather Dependence of Forage Harvesting operations"
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Lunch	:	The Hotel will reserve a section of the dining room for members taking lunch provided prior notice is given. If you intend having lunch (from the normal lunch menu), please inform Dick Breen, Irish Meteorological Society, Glasnevin Hill, Dublin 9 by 2 September. Send no money. A booking slip is included on page 6.
Overnight accommodation	:	Overnight accommodation at the reduced rate of £17.50 per person for bed and breakfast is being offered by the hotel to members of the Society and their friends. Please contact Mr. John McMahon at 01 450633 to avail of this offer.