Irish Meteorological Society

Newsletter

Number 36 **February 1993**

with:

Society News
Richardson's forecast factory
Global Atmospheric Watch

President: P. Lynch *Secretary: A. Kelly*

Irish Meteorological Society, c/o Meteorological Service, Glasnevin Hill, Dublin 9

Irish Meteorological Society

The Irish Meteorological Society was founded in 1981 with the object of promoting an interest in meteorology in Ireland and disseminating meteorological knowledge, pure and applied. Membership is welcomed from those with an interest in meteorology, climate and the environment. The Society organises lectures,.seminars, oùtings and an annual dinner for members and guests. An A.G.M. takes place, usually in April to coincide with the annual one-day seminar.

Summaries of lectures and other articles of meteorological interest are published in the Society's Newsletter. Articles and comments on articles are welcomed from members for publication.

The address of the Society is : Irish Meteorological Society,
c/o Meteorological Service,
Glasnevin Hill,
Dublin 9

As of 12/91, annual subscription rates are as follows: Greater Dublin Area £12,
elsewhere £8.

Students are welcomed at half the stated rates.

The officers and committee members for 1992/1993 are as follows:

President	Dr. P. Lynch
Vice-President	Ms. E. Cusack
Secretary	Mr. A. Kelly
Assistant-Secretary	Mr. J. Doyle
Treasurer	Mr. S. McCarthy
Assistant-Treasurer	unfilled
Committee members:	Capt. K. Tormey
	Dr. P. Shannon
	Mr. G. Fleming
	Mr. K. Commins
	Mr. S. Walsh
	Dr. M. Joyce

Members of the Society may subscribe to the Monthly Weather Bulletin published by the Climate and Applications Division of the Irish Meteorological Service at the preferential (as of 12/91) annual subscription of £15 , by kind permission of the Meteorological Service. The Society gratefully acknowledges the assistance and facilities which it enjoys from the Meteorological Service.Members may also receive "Weather" magazine, published by the Royal Meteorological Society, again at preferential rates. Details from the Treasurer at the above address.

Society News

The finishing touches are being applied to the schedule for the **One-Day** meeting on April 24th.

It takes place in the Tara Tower Hotel on the Merrion Road in Dublin. With the theme of "Diverse Aspects of Meteorology, topics will include planetary weather systems, the temperature regime in Dublin in summer, holiday weather, computer forecasting, the relevance of weather to peat harvesting and a talk on Irish Lighthouses and their contribution to meteorology. Details and schedule will follow later.

The ***A.G.M.,*** *which will immediately follow the One-Day meeting, will see a number of vacancies arising on the committee. The Secretary, Assistant-Secretary and two committee members will see their terms of office come to an end and nominations will be required for the vacant positions.*

oooOOOooo

Some of you have spoken of meteorological phenomena you have seen in your own local area and put questions to various committee members about these occurrances. Perhaps you would consider putting these on paper to the Secretary who will then delegate an appropriate 'expert' to make a reply and all will be published in the Newsletter.....?

Indeed, if you see any unusual weather--related phenomena why not drop the Newsletter a few lines with all the details?

Lectures

Dr. J.R. Bates, the founder of the Irish Meteorological Society, will speak on "Atmospheric Research at N.A.S.A. Goddard Space Flight Center" on a date to be arranged in **April.**

A lecture we had intended to schedule for **March** has, due to circumstances beyond our control, been deferred to later in 1993.

Outing

Observations by Naval Service vessels have been a valuable source of marine data and this year, by kind permission of the Minister for Defence, we will visit the Naval Base (and a ship) at Haulbowline, Cobh, Co. Cork on ***May 15th.*** *The train to Cork, connecting with the local Cork-Cobh train service should provide for a leisurely and enjoyable day out! The event is currently being organised by John Doyle.*

Boat Show 1993

Continuing with the marine theme, the Meteorological Service will be at the Boat Show in the Point Depot, Dublin from **March 3rd-7th.**

Apart from charts and photos, you will also be able to see computer-model forecasts and the latest in Weather-radar at the Met. Office stand on the mezzanine level. Come along and visit!

Other Service news....Ms. Edel Carroll has been promoted S.M.O. in Instruments and Observations Division.

One of the Meteorological Officers recruited last year has completed his training course and transferred to Malin Head. The two recruits to the meteorologist grade have returned to Ireland, having completed their stint at the British Met. Office training college in Reading.

Richardson's Forecast-factory: the $64,000 Question
by
Peter Lynch, Meteorological Service, Dublin
[To appear in *The Meteorological Magazine*, March 1993]

Lewis Fry Richardson served as a driver for the Friends' Ambulance Unit in the Champagne district of France from September 1916 until the Unit was dissolved in January 1919 following the cessation of hostilities. For much of this time he worked near the front line, and during the Battle of Champagne in April 1917 he came under heavy shelling (Ashford, 1985). It is a source of wonder that in such appallingly inhuman conditions he had the buoyancy of spirit to carry out one of the most remarkable and prodigious calculational feats ever accomplished. During the intervals between transporting wounded soldiers back from the front he worked out by manual computation the changes in the pressure and wind at two points, starting from an analysis of the condition of the atmosphere at 0700 UTC on 20 May 1910. Richardson described his method of solving the equations of atmospheric motion and his sample forecast in what has become the most famous book in meteorology, his *Weather Prediction by Numerical Process* (Richardson, 1922). The unrealistic values which he obtained are a result of inadequacies and imbalances in the initial data, and do not reflect any flaw in his method, which is essentially the way numerical forecasts are produced today.

How long did it take Richardson to make his forecast? And how many people would be required to put the method to practical use? The answers to these two questions are contained in §11/2 of his book, but are expressed in a manner which has led to some confusion. On p. 219 under the heading 'The Speed and Organization of Computing' Richardson wrote

> It took me the best part of six weeks to draw up the computing forms and to work out the new distribution in two vertical columns for the first time. My office was a heap of hay in a cold rest billet. With practice the work of an average computer might go perhaps ten times faster. If the time-step were 3 hours, then 32 individuals could just compute two points so as to keep pace with the weather ... .

Could Richardson really have completed his task in six weeks? Given that 32 computers working at ten times his speed would require 3 hours for the job, he himself must have taken some 960 hours — that is 40 days or 'the best part of six weeks' working flat-out at 24 hours a day! At a civilized 40-hour week the forecast would have extended over six months. It is more likely that Richardson spent perhaps ten hours per week at his chore and that it occupied him for about two years, the greater part of his stay in France.

Now to the question of the resources required to realize Richardson's dream of practical forecasting. Quoting again from p. 219 of the book:

> If the co-ordinate chequer were 200 km square in plan, there would be 3200 columns on the complete map of the globe. In the tropics the weather is often foreknown, so that we may say 2000 active columns. So that $32\times2000=64{,}000$ computers would be needed to race the weather for the whole globe. That is a staggering figure.

It is indeed staggering, when we recall that these 'computers' were living, feeling beings, not senseless silicon chips. Richardson proposed taking 128 chequers or grid-boxes around each parallel and 100 between the poles. This gives a grid cell which is roughly a square of side 200 km at 50° North and South. He outlined a scheme for reducing the number of chequers towards the poles but made no allowance for that in the above reckoning. His claim that 3200 columns or chequers would cover the globe has been questioned by Sydney Chapman in his Introduction to the Dover Edition of *Weather Prediction by Numerical Process*:

> As to Richardson's estimates of the time and cost of full application of his methods, he made an uncharacteristic error in giving 3200 as the number of squares ... to cover the globe. His number is only a quarter of the true value, so that his required staff and his cost estimate must be quadrupled.

So, Chapman's estimate of the staff required is $4 \times 64{,}000 = 256{,}000$. However, this is not entirely correct. The envisaged computational grid would indeed have required $128 \times 100 = 12{,}800$ chequers for global coverage — four times the value stated by Richardson. But Richardson considered the grid-boxes in pairs, one for mass and one for momentum, and it was such a pair for which he made his sample forecast and upon which he based his estimates. Thus, 6400 pairs of chequers would cover the globe and, with 32 people working on each pair, a total horde of 204,800 would be involved in a bid to race the weather for the whole globe. That is a stupendous figure!

So where did Richardson come by the figure of 3200 chequers to cover the globe? The error is inescapable but is not, I believe, a numerical slip. Richardson intimated that the weather in the tropics was sufficiently steady for variations to be neglected. But in such a case the global forecasting problem falls neatly into two parts and it is natural to consider each hemisphere separately. The Northern hemisphere can be covered by 3200 *pairs* of columns. Assuming with Richardson that the values at 1200 pairs may be prescribed and assigning 32 individuals to each of the remaining pairs, one finds that $32 \times 2000 = 64{,}000$ souls are needed to race the weather *for the extra-tropical Northern hemisphere.*

If this is what Richardson intended, his 'uncharacteristic error' was not an arithmetical howler but a lapse of expositional precision. For his staggering figure of 64,000 is clearly stated to refer to *the whole globe.* Later in the paragraph he speaks of a forecast-factory for the whole globe (in fact, the word 'globe' occurs five times on p. 219). In his wonderful fantasy of a theatre full of computers, the tropics 'in the upper circle' are treated on an equal footing with the temperate and frigid zones. Given that Richardson's assumption of constancy of tropical weather was over-optimistic, a full complement of 32 computers for each pair of columns in his *forecast-factory for the whole globe* would have provided work for 204,800 people.

Even this vast multitude could compute the weather only as fast as it was evolving. To obtain useful and timely predictions, the calculations would need to go several times faster than the atmosphere. Allowing for a speed-up factor of five, the establishment of a 'practical' forecast-factory would have reduced the ranks of the unemployed by over a million.

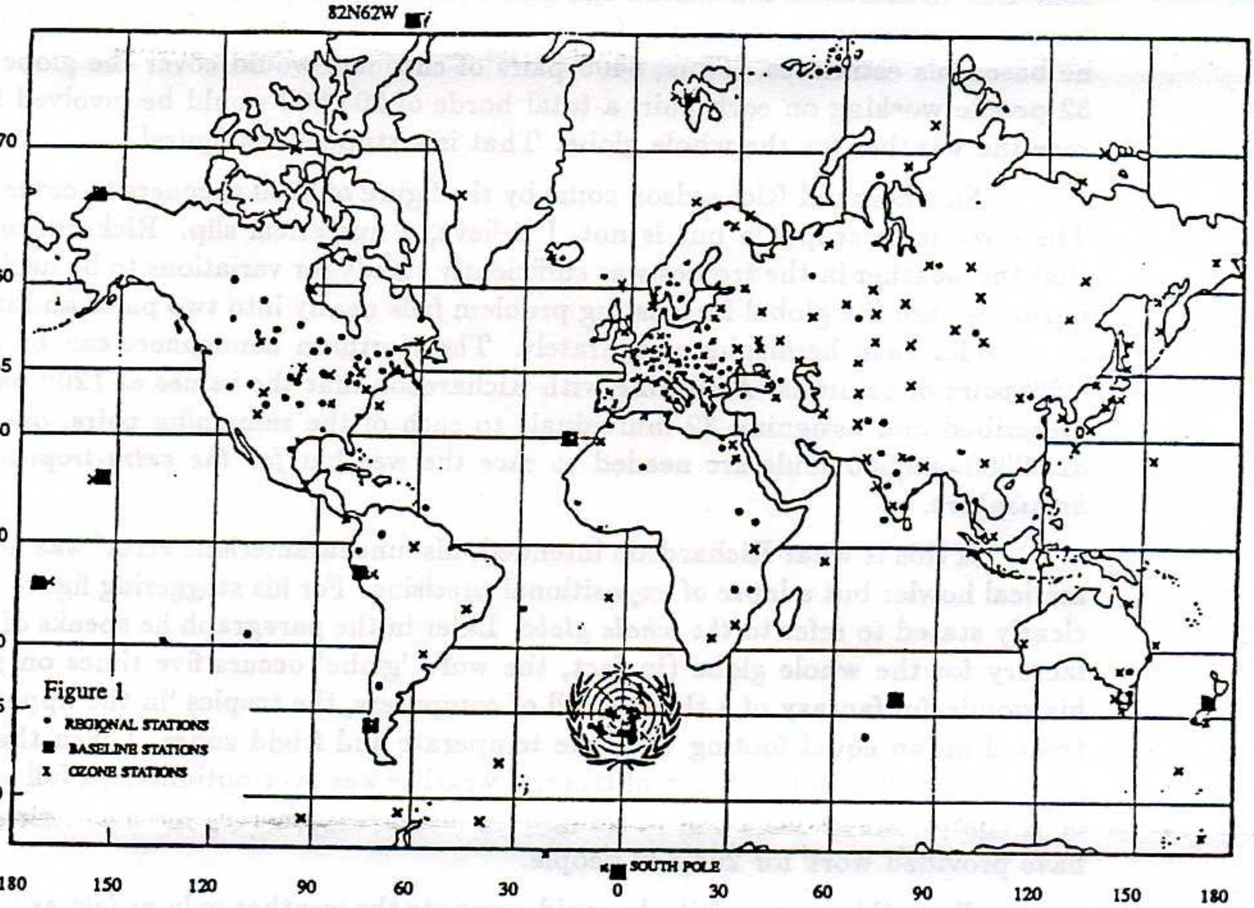
References

Ashford, Oliver M., 1985: *Prophet—or Professor? The Life and Work of Lewis Fry Richardson.* Adam Hilger, Bristol and Boston, xiv+304 pp.

Richardson, Lewis F., 1922: *Weather Prediction by Numerical Process.* Cambridge University Press, xii+236 pp. Reprinted by Dover Publications, New York, 1965, with a New Introduction by Sydney Chapman, xvi+236 pp.

World Meteorological
Organization

THE GLOBAL ATMOSPHERE WATCH



WHY WE NEED IT

Measurements in WMO's networks show that pollutants accumulating in and being transported through the atmosphere are changing its composition and its radiative balance, and are causing a change in the climate of the Earth. Pollutants are affecting the health of human beings and animals, damaging vegetation and soil, and causing stone, concrete and metals to deteriorate. The depletion of the stratospheric ozone layer, the increase in tropospheric ozone (ozone near the ground), the rise in carbon dioxide and methane concentrations, higher levels of acidity in rain and changes in the radiative balance of the Earth-atmosphere energy system; all of these changes, measured by 160 Member countries — partners in the World Meteorological Organization — directly reflect the increasing influence of human activity on the global atmosphere, the life-support system of the planet Earth.

WMO's *Global Atmosphere Watch* integrates many monitoring and research activities involving the measurement of atmospheric composition. The *GAW* serves as an early warning system to detect further changes in atmospheric concentrations of greenhouse gases, changes in the ozone layer and in the long-range transport of pollutants, including acidity and toxicity of rain as well of atmospheric burden of aerosols (dirt and dust particles). This new system, approved in June 1989 by the WMO Executive Council, will strengthen and

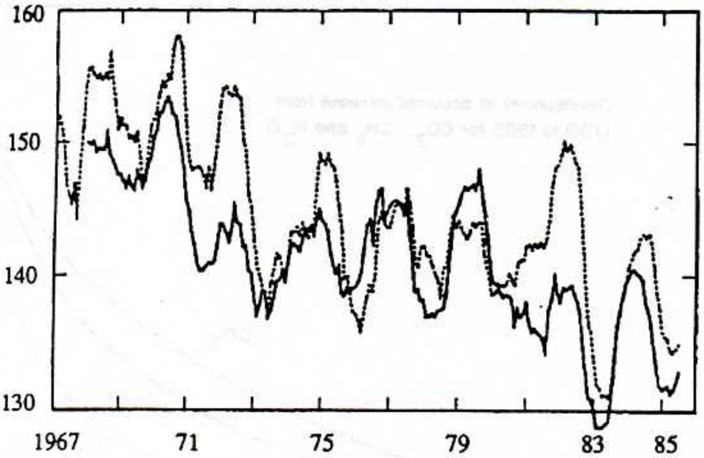


Figure 2: 12-month running means of the ozone partial pressure (nbar) at the ozone maximum (~ 21 km) from nearly 2000 ozone-soundings each made at the GO_3OS stations at Payerne (Switzerland) and Hohenpeissenberg (Germany, F.R. of) show very pronounced ozone decrease of about 0.5% per year.

Source: Bojkov and Attmannspacher, 1988 (*Proc. Ozone Symp. 1988*, Deepak Publ.)

co-ordinate WMO data-gathering activities begun in the 1950s under the separate *Global Ozone Observing System* and the *Background Air Pollution Monitoring Network* with other smaller measurement networks.

The WMO *Global Atmosphere Watch* will provide framework design, standards, intercalibrations and data collection systems for global monitoring and data evaluation. *GAW* will ensure the continuing participation of WMO Member countries and will facilitate contributions from developed and developing countries' scientists. The programme is an essential means of improving understanding of atmospheric behaviour and its interactions with the oceans and the biosphere. It will enable prediction of future states of the atmosphere and related earth systems and will also serve as a framework to plan, design, advise, co-ordinate and scientifically evaluate global atmospheric-composition monitoring activities that will affect decisions on the environment in the 21st century.

COMPONENTS OF THE GLOBAL ATMOSPHERE WATCH

The *GAW* system evolved from WMO experience with the two existing systems — the *Global Ozone Observing System (GO_3OS)* and the *Background Air Pollution Monitoring Network (BAPMoN)* — and other global observing systems. When fully implemented, it will consist of about two dozen observatories of global importance, a few hundred stations of regional importance and a mechanism for co-ordination with several other WMO and non-WMO background atmosphere composition networks.

In the mid-1960s WMO planned and established the *Background Air Pollution Monitoring Network (BAPMoN)* to provide information for continuous assessment of the atmosphere's changing chemistry. Major alterations in background concentrations of atmospheric consitituents will signal forthcoming changes in weather and affect climate on a global scale. *BAPMoN*, for example, provides the only continuous measurement made of carbon dioxide and registers changes in the relevant gaseous components at strategic locations around the Earth. The data from WMO *BAPMoN* is the major source of information for the *Global Environmental Monitoring System (GEMS)*.

At present the network consists of 196 stations, 152 of which have the capability of carrying out sampling for measurements of precipitation chemistry (rainfall and snow). Other measurements recorded in the observation programme are: turbidity (transparency or clarity of the air) at 90 *BAPMoN* stations; suspended particulate matter at 84; carbon dioxide at 23; surface ozone at 22; methane at seven; and chlorofluorocarbons at five. The atmosphere is sampled according to agreed criteria by specially trained staff, using recommended instruments and standard procedures.

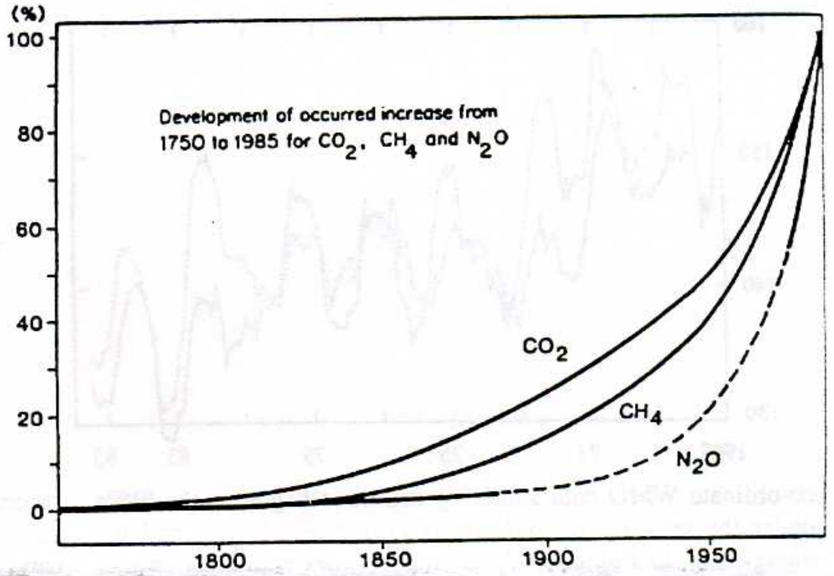
Baseline measurements of global importance are made at observatory-type stations in remote locations entirely free of the effects of local pollution and nearly free from the influence of regional pollution sources at least 60% of the time evenly distributed over the year. Air that does arrive contains in diluted form various chemical components carried for thousands of kilometres by long-range transport. Regional measurements are those of air pollution concentrations obtained in rural areas where the effects of local sources of air pollution are absent for most of the year. They are of primary importance for the assessment of regional environmental problems such as acid rain, increasing surface ozone, the deterioration of ecosystems and air pollution in rural areas remote from urban developments. The baseline stations carry out a complete range of measurements relevant to climate change, atmospheric ozone changes and other global-scale environmental issues. They will serve as reference stations for regional networks. A few, such as Mauna Loa in Hawaii and Cape Grim in Tasmania, have been in operation for nearly two decades. The *Global Atmosphere Watch* will endeavour to establish more observatories in data-sparse areas like Africa, South America and South-east Asia.

WMO's responsibility within the United Nations system is to provide the authoritative scientific voice on the state and behaviour of the atmosphere and climate of our planet. Regarding the ozone layer, as early as 1957 WMO established international procedures to assure standardized and co-ordinated ozone observations, their publication and related research. Since then, in collaboration with the International Ozone Commission and over 60 Member countries, continuous measurements of atmospheric ozone have been carried out by the *Global Ozone Observing System (GO_3OS)*. It now has approximately 140 stations around the world — complemented during the last decade by satellite remote-sensing . It is the only network in the world that provides information on total ozone content, its vertical distribution and changes. It not only provides data but also ensures preparation of research assessments.

In 1975 the first WMO Statement on Modification of the Ozone Layer due to Human Activities was prepared in response to public concern at threats to the ozone layer from supersonic

Figure 3: Relative increase of the atmospheric CO_2, CH_4 and N_2O concentrations. CO_2 and CH_4 were determined by measurements on ice samples from Antarctica. Development of N_2O is not yet known in detail. The values for the year 1750 (0%) and 1985 (100%) are CO_2—280 ppmv and 340 ppmv, CH_4—800 ppbv and 1700 ppbv, and N_2O—285 ppbv and 307 ppbv.

Source: Stayffer and Weftek, 1988 (*The Changing Atmosphere*, Wily & Sons Publ.)



aircraft. The statement concluded that the threat came more from man-made pollutants responsible for reducing the quantity of ozone in the stratosphere than from the very few supersonic aircraft which only occasionally flew in the stratosphere. Since 1975, more than 18 substantial scientific reports have appeared. It is only through WMO's co-ordination and guidance and thanks to the patient work of many scientists that we know what constitutes a *normal* ozone layer and how much the ozone in the stratosphere has declined over the past two decades.

A number of WMO Member countries provide vital *centralized data collection* points and services for the *GAW*: Canada operates the WMO World Ozone Data Centre and publishes ozone data every other month; the United States provides a home for data on precipitation chemistry analyses, acid rain and atmospheric turbidity measurements; and the USSR is responsible for the collection of solar radiation data. Czechoslovakia and the Federal Republic of Germany provide the laboratory analysis of rainfall samples from stations in other countries and also provide training in chemical analysis. Special emphasis is now being given to an arrangement with Japan for the collection and analysis of data on greenhouse gases.

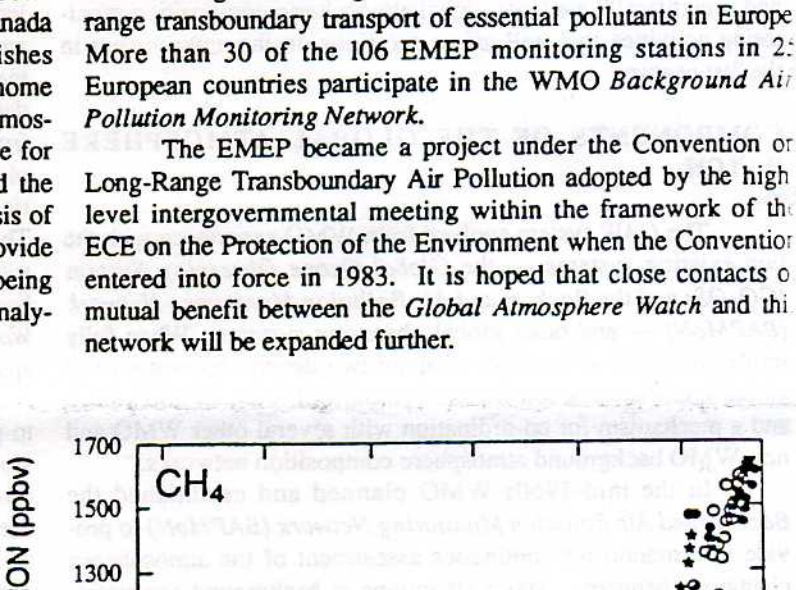
OTHER SYSTEMS AND THE GLOBAL ATMOSPHERE WATCH

In 1977 the UN Economic Commission for Europe (ECE), WMO and the United Nations Environment Programme (UNEP) launched the Co-operative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP). The EMEP involves the collection of daily data from measurement programmes of participating countries, the checking and storing of data, and calculations of the long-range transboundary transport of essential pollutants in Europe. More than 30 of the 106 EMEP monitoring stations in 2: European countries participate in the WMO *Background Air Pollution Monitoring Network*.

The EMEP became a project under the Convention on Long-Range Transboundary Air Pollution adopted by the high-level intergovernmental meeting within the framework of the ECE on the Protection of the Environment when the Convention entered into force in 1983. It is hoped that close contacts of mutual benefit between the *Global Atmosphere Watch* and this network will be expanded further.

Figure 4: Summary of methane concentrations in air bubbles extracted from ice cores in both Greenland and Antarctica measured by several investigators and by gas chromatographic measurements of ambient air during the last decades. Significant increase currently amounts to nearly 1% per year. It appears this increase is coupled with the human population growth and expanding agricultural activities.

Source: *NASA/WMO Ozone Trends Panel Report—1988*, WMO Ozone Report No. 18



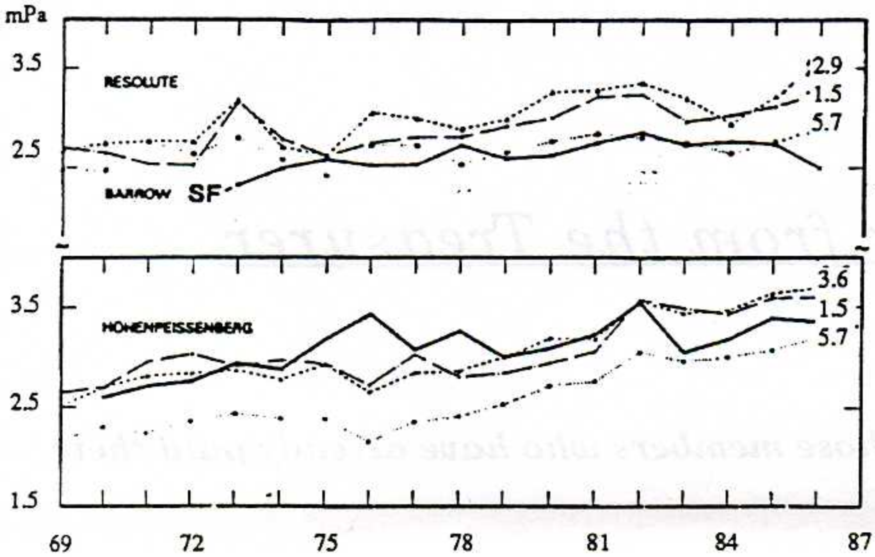


Figure 5: The course of annual average ozone partial pressure at the surface (the heavy continuous line) and the three tropospheric levels (their heights in km are indicated by the bold numbers on the right-hand side) at Hohenpeissenberg during the last two decades. The same information is given for Barrow (SF) with the tropospheric ozone values taken from Resolute. These indicate a steady increase in the surface ozone by 1.1 and 0.8% per year and increases in the lower and middle troposphere of 1.1 to 1.6% per year respectively.

Source: Bojkov, 1988 (*Tropospheric Ozone*, Reidel Publ.)

The International Council of Scientific Unions is designing the International Geosphere-Biosphere Programme which is concerned with the processes that change the Earth on time-scales of decades to centuries. Activities are planned that will document the slow but persistent changes in the state of vegetation cover on land, the chemical state of the atmosphere, and the effects of those changes on climate and life. One particular project of direct interest to the atmospheric change question is the International Global Atmospheric Chemistry Project. The *GAW* will provide the data and assessments that will be essential to investigations on how the disappearance of the equatorial rain forest is changing the concentrations of greenhouse gases in the atmosphere, the changing chemistry of the troposphere, the nature and fate of the spring ozone hole in the Antarctic, and Arctic ozone layer perturbations.

THE GLOBAL ATMOSPHERE WATCH AND GLOBAL CHANGE

Global emissions of carbon dioxide increased from 1639 to 5330 million metric tons (as carbon) per year from 1950 to 1984. Concentrations of CO_2 increased from approximately 315 parts per mil in volume (ppmv) in the mid-1950s to more than 350 ppmv in 1988. Chlorofluorocarbons (CFC F-11 and F-12) are powerful greenhouse gases and a serious threat to the stratospheric ozone layer. Production and release increased from zero in 1930 to a total of over 1,100 thousand metric tons in 1988.

Scientists studying past climates of the Earth know that there have been fluctuations in the surface temperature before. Thanks to WMO networks, humanity now has information indicating that the changes in the atmospheric concentrations of gases and pollutants will have an impact on climate, and thus on the environment of the Earth, of a magnitude unprecedented in human experience. The observed drastic springtime reduction in the Antarctic ozone is a vivid indication of sudden changes that can occur.

Stations from the *Global Ozone Observing System*, *BAPMoN* and other networks of global and regional importance that participate in the *Global Atmosphere Watch* will measure most of the following:

(a) Greenhouse gases — carbon dioxide, the chlorofluorocarbons, methane, nitrous oxide, tropospheric ozone;
(b) Ozone — surface, total column, vertical profile and precursor gases, using ground-based instruments such as spectrophotometers, sondes, lasers, microwaves, as well as satellites;
(c) Radiation and the optical depth or transparency of the atmosphere, including: turbidity, solar radiation, UV-B, visibility, total aerosol (dirt and dust particles) load, water vapour;
(d) Chemical composition of rainfall and snow;
(e) Reactive gas species such as: sulphur dioxide and the reduced sulphur species; nitrogen oxides and the reduced nitrogen species; carbon monoxide;
(f) Particle concentration and composition characteristics, including mineral aerosols; and
(g) Radionuclides, including krypton-85, radon, tritium, and the isotopic composition of selected substances.

By creating the *Global Atmosphere Watch* and by improving and expanding the observation networks, scientists can begin to address policy-makers' questions, such as: "What is the greenhouse future of the Earth?" "Is the ozone problem manageable?" and, "Is acid rain increasing or declining?"

Reminder from the Treasurer

1. Thank you to all those members who have already paid their 1993 subscription.

2. Would all other members please forward subscriptions as soon as possible for book-keeping purposes.

3. A special reminder to those members who have yet to submit subscriptions for 1992. If you have any doubts contact me at the Met. Office. To any members who haven't paid for 1991 and 1992, you have just received your last bulletin from the Society.

4. To subscribers of the Royal Met. Soc, "Weather Magazine" I still await subscription for 1993 from some, which I'm sure is an oversight ,again contact me if you are unshure

The subscription rates remain unchanged at £12 for Dublin, £8 for Country and 1/2 price for Student members. The 1993 subscription to "Weather" is 24 stg and the subscription to Irish Monthly Weather Bulletin remains at £15, which is great value.

Regards from the Treasurer

Sean McCarthy

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