Irish Meteorological Society

Newsletter

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Contents:

The renewal date for subscriptions was Jan. 1st 1991. Would those whose subscriptions are outstanding please forward them to the Treasurer as soon as possible.

J.A. Scott
President

A. Kelly
Secretary

CHAOS

Dr. D.J. Fegan,
Physics Department,
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What is chaos and where may it arise ? Chaos is a ubiquitous phenomenon of nature which may arise in any living, natural or man-made system where nonlinearity is present. Many systems are naturally linear and the mathematical models used to describe them show a linear interdependence of the characteristic variables used to specify these systems. The steady state features of such systems are mundane and absolutely predictable. However, many other systems are naturally nonlinear with characteristic variables exhibiting a nonlinear interdependence. The extraordinary sensitivity to the precise values of initial conditions highlights one of the hallmarks of dynamical chaos. The chaotic behavior of nonlinear systems is counter-intuitive and initially disturbing, as it appears to contradict reason. Once experienced however, the phenomena becomes recognised for what it is - robust, exotic and fascinating.

Chaotic behavior is observable in such diverse natural phenomena as fluid flow dynamics, the evolution of weather systems, patterns of smoke plumes, the dynamical motion within the great red spot of Jupiter, orbiting spacecraft and stellar mechanics, dripping taps and the long term patterns shown by the earths magnetic field. Chaos is also manifest in other disciplines such as biology, medicine, commerce and the social sciences where nonlinear behavior can sometimes arise. No doubt the pheonomenon has been with us since time began, fleetingly perceived but never recognised over the past two centuries, often being dismissed as extraneous unwanted noise which on occasions no doubt twarted the painstaking measurements of observers of past generations. However, in the past three decades all that has changed and new insights into the workings of nature have established a new branch of science. Deterministic classical chaos has been shown to exist in nonlinear dynamical systems where underlying symmetries exhibit order within the apparently random behaviour.

The advent of digital computers in the latter part of the 20th century has radically altered the complexity scale of problems which scientists, engineers, mathematicians and others have attempted to solve. Weather forecasting has proved to be no exception to this rule. In 1960 Edward Lorenz (1), a meteorologist at M.I. T., had just taken delivery of a vacuum tube technology digital computer. Motivated by a lifelong desire to understand the unpredictability of the weather, he constructed a simple mathematical model of the earths weather system. He hoped that by programming the model into the computers memory, the computer would predict impending weather patterns, based upon the model equations and the specific initial conditions pertaining to the models parameters. This was a very reasonable aspiration given the success that astronomers had in modelling the motion of planets and comets based upon simple models of solar system dynamics. The astronomical models also involve initial conditions which specify the locations and masses of all the planets in the solar system. In general, for all cases of practical interest, the outcome of the astronomical models are not especially sensitive to the exact values of all the initial conditions. After all, who could know precisely the exact velocities and masses of all the objects in the solar system at any instant of time ? The model equations are such that small uncertainties do not scale to larger proportions as the computer runs through several thousand successive iterations. If the input data to the computer as specified by the initial conditions is approximately accurate then so also will be the output data. This form of deterministic numerical forcasting is known to work well in accurately determining trajectories of spacecraft and missiles and also for a whole variety of other applications.

Differential equations are used to describe the way in which systems evolve continuously with time. Lorentz used a simplified set of three first order coupled differential equations which were hydrodynamical in form, describing Rayleigh-Benard convection in fluids. The simplified model treats the atmosphere as a giant fluid subject to heating, cooling and mixing. The equations model a sample of fluid of finite thickness which is heated from below with a fixed temperature difference maintained between the top cold surface and the bottom hot surface. Gravitational forces act downwards on the fluid. In the model, variables X, Y and Z refer to properties of the hydrodynamic system. Nonlinear terms appear on the right-hand sides of the second and third equations of the triad (the product terms XZ and XY are explicity formed).

In general, in mathematics, when faced with a set of time dependent differential equations of this nature we are interested in how the system described by such equations might evolve with time. The problem reduces to solving the equations for the variables X, Y and Z. The time dependent solutions tell what the expected permissible combinations of X, Y and Z might be as a function of time. Fortunately the system of equations is integrable. It is possible to write a computer program which will start with some initial values of X, Y and Z (the phase space coordinates) at some time t and compute the values at some later t + dt, where dt is a small positive increment of time. Since it is not possible to plot the evolving system in three dimensions, graphical output from the program has to involve some compromise in displaying the results on a computer graphics screen.

If the computer program is run through several hundred iterations remarkable features are discovered. The most intriguing feature of the model is the appearance of a new kind of attractor - Lorenz attractor Fig. (1).

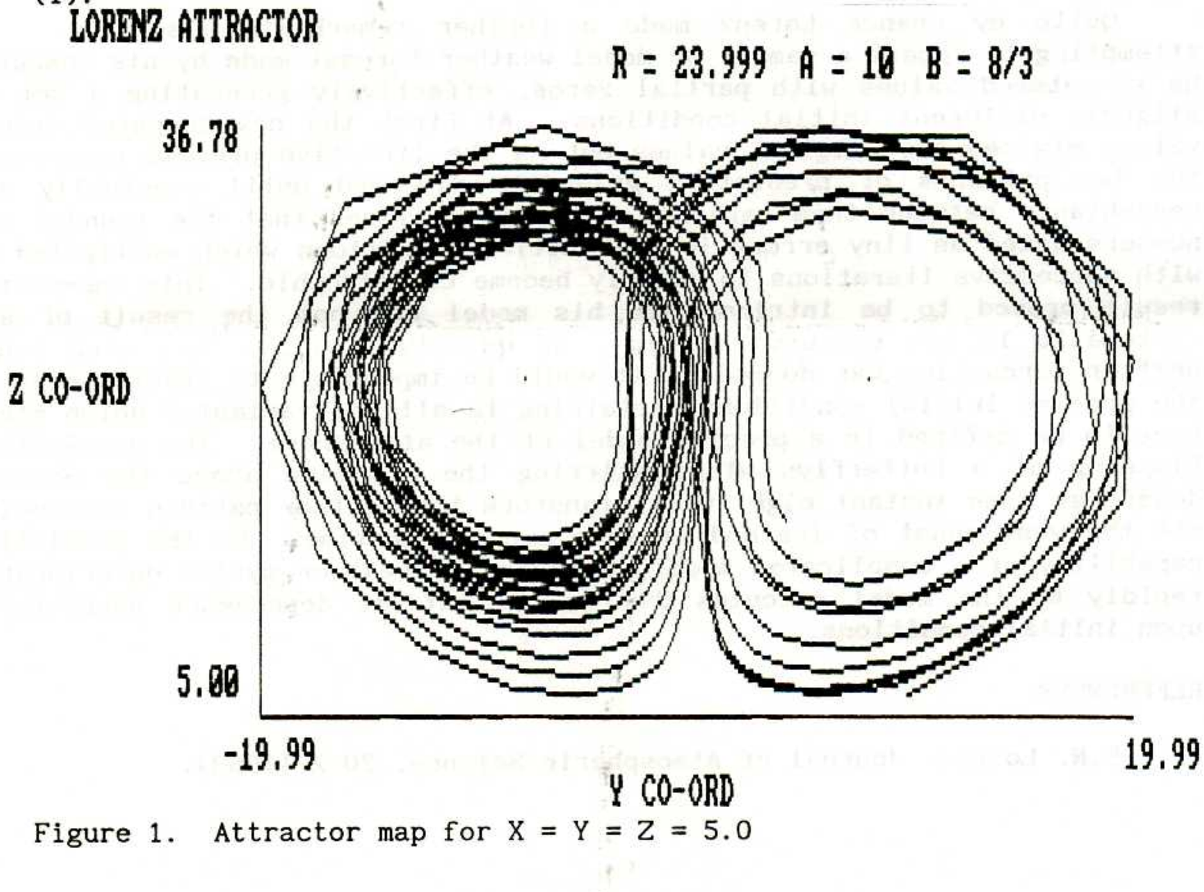


Figure 1. Attractor map for X = Y = Z = 5.0

Here a phase space plot shows how Z varies with Y for various successive intervals of time. This strange hypnotic picture, resembling a butterflys wings, has become a landmark symbol to the cartographers of the landscape of chaos. The relationship shows that the motion of the system in phase space in continuous but the trajectories never repeat themselves of self interact. The prediction of the model is that the motion of the fluid in real space is not one where the complexity of motion might be damped out and the fluid might settle and exhibit steady or regular patterns of motion but rather that the fluid motion becomes completely chaotic. We are witnessing dynamical chaos which is the appearance of apparently random motion in a deterministic dynamical system. The behavior is referred to as a strange attractor - it is bounded by non-periodic. Lorenz reasoned that the basic mechanism responsible for the random motion was one where the neighbouring orbits very close together at some instant of time begin to diverge apart exponentially fast and it soon becomes impossible to predict where the points might end up. The final states might be anywhere on the attractor phase space. The strange attractor is an attractor on which nearby orbits, though bounded, diverge in exponential fashion. Chaos mixes the orbits in phase space in a manner similar to that whereby a baker might mix two differently coloured samples of dough by a process of rolling the dough and then folding it over upon itself. If such a process is repeated twenty times the initial sample will have been stretched to more than a million times its original length and the individual layer thickness has been reduced to molecular levels. The sample of dough has been totally randomly mixed. The implication of the chaotic behavior in the atmospheric fluid problem is that since the motion is nonperiodic then it is unpredictable. Lorenz recognised that complicated dynamical systems possessed points of instability which produced chaotic behavor. Here was order masquerading as randomness, linking aperiodicity with undpredictability.

Quite by chance Lorenz made a further remarkable discovery. In attempting to repeat a sample of model weather forcast made by his computer he re-entered values with partial zeros, effectively generating a set of slightly different initial conditions. At first the new computer output values mimiced the original values but as the iterative process progressed the two patterns of prediction gradually diverged until eventually all resemblance between them vanished. Lorenz realised that the rounded off numbers acted as tiny errors in the initial conditions which multiplied up with successive iterations to quickly become catastrophic. This unexpected result proved to be intrinsic to his model and not the result of any systematic in his computer system. He quickly realised that long range weather forcasting was doomed ! It would be impossible to specify exactly the precise initial conditions pertaining to all the variables which might have to be defined in a precise model of the atmosphere. The unspecified flapping of a butterflys wings stirring the air-mass above the Sonoran desert at some instant might well transform the weather pattern developing off the west coast of Ireland at some subsequent time. So the predictive capability of a complicated model, such as the weather system deteriorates rapidly as the model executes due to the extreme dependence sensitivity upon initial conditions.

REFERENCES

1. E.N. Lorenz. Journal of Atmospheric Science, 20 2 (1963).

FEATURE

WEATHER OF 1990

1990 was a warm year. The most notable features were the storms of late January and February and the May to September period which was dry overall, especially in the south and east.

Percentage rainfall ranged from over 120% of normal in the north and west to less than 90% on parts of the south coast. At Belmullet and Malin Head it was the wettest year since the 1950s but in south Munster it was the driest year since 1975.

Mean annual temperatures were generally between 0.6°C and 1.0°C above normal with both maximum and minimum temperatures contributing almost equally. At most stations mean temperatures were equal to or slightly below those of the warm years 1983 and 1989, but at Kilkenny it was the warmest year since recording began in 1958, at Belmullet the warmest since 1959 and at Malin Head the mean equalled that of 1971. Some stations near the north, west and southwest coasts had their highest mean minimum temperatures for between 30 and 50 years.

Highest temperatures of the year occurred in early August: Dublin Airport had its highest temperature since recording began there in 1942, 28.7°C, and temperatures of 30°C or more were recorded on the 2nd of August in Dublin city, making it the hottest day in the city for more than a century. The lowest temperatures of the year occurred in late November when -5.4°C was recorded at both Birr and Clones.

Percentage sunshine ranged from 80% at Belmullet to 108% at Mullingar where it was the sunniest year since 1968: it was also the sunniest year since the 1960s at Cork Airport and Rosslare. The strongest winds of the year occurred in late January and February when gusts of 70 to 80 knots were widely recorded, with a gust of 86 knots at Roche's Point. There were also some gusts in the range 60-73 knots during October and in late December.

With the exception of a rather wet June, the summer was mainly dry and warm — good seaside weather. (photo courtesy Irish Independent)

SOCIETY NEWS

Dinner

The Society's Dinner took place on Jan. 26th in Barrels Restaurant, Grafton Street, Dublin.

Annual Outing

The Annual outing for 1991 has been confirmed. The venue this year will be Armagh Observatory and hopefully we can also arrange a visit to the Planetarium. The date is May 6th and we propose to travel by train from Dublin (Connolly Station) to Portadown and from there by coach to Armagh. Those of us who made the train journey to Galway for the outing to Mace Head in 1990 are looking forward to a similar experience in 1991 ! More details of times and costs later.

Lectures in February

The first lecture is on Friday, Feb.8th - lecture notice at end of Newsletter. The proposed launch of the European Space Agency's "MOP2" satellite takes place on Feb.21st In conjunction with this, the head of the Central Analysis and Forecast Office in Dublin, Mr. Tom Sheridan - recently returned from working with the European Space Agency - will speak speak to the Society on Feb.22nd.

Subscriptions for 1991

A gentle reminder that subscriptions for 1991 are due from Jan.1st. Those paying by standing order should make the appropriate adjustments to take account of the increased subscription rates i.e. £12 for the greater Dublin area and £8 elsewhere.

One-Day Meeting/A.G.M

Preparations are well under way for the meeting and A.G.M. Most speakers have confirmed and a full listing wil appear in due course.

SERVICE NEWS

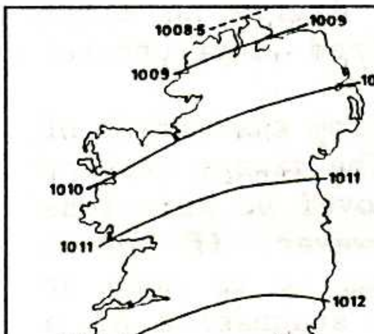
P.P. O'Briain , C.A.F.O., is transferring to Kilkenny as Officer-in-Charge. Ms. Phil Stokes will move to Casement Aerodrome from C.A.F.O. in March and Kieran Dollard, also from C.A.F.O. will transfer to Computer Division .

Snow and Strong Winds

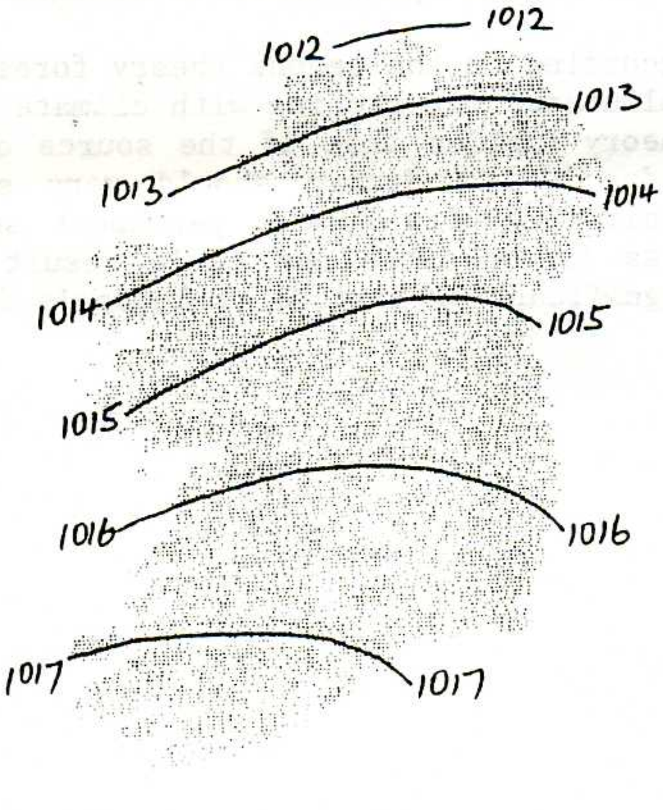
During the first five days pressure was high over Ireland. The anticyclone was centred to the south of Ireland on the 1st and 2nd but, with the passage of a weak cold front on the 3rd, the main centre of high pressure shifted to the west. During the following day this centre moved eastwards and crossed Ireland on the 5th and early on the 6th. Later that day and during the 7th an active cold frontal rainbelt moved southwards and a depression formed over England giving heavy snow there. Ireland escaped with between 4 and 16mm of rain or sleet as winds veered northwesterly and then northerly.

There was a very cold northerly flow on the 8th which gradually turned more northeasterly on the 9th; on both days there were occasional wintry showers, mainly near north- and east-facing coasts, where thunder was reported. Pressure rose on the 10th and there were only a few showers as the wind turned gradually northwesterly. During the 11th, as a deep depression moved from Iceland towards Scandinavia, a westerly airflow developed and a weak cold front came down from the northwest late in the day. Behind the front winds veered northwesterly again and pressure rose steadily over Ireland on the 12th.

There was a high pressure area over Ireland between the 13th and 17th which drifted very slowly eastwards. A slack south to southeast airflow brought hazy conditions with frost and fog at times. Late on the 18th there was a change of airmass as a cold front moved southwards and brought clearer, fresher conditions and a change in wind direction from southerly to northwesterly. For the rest of the month vigorous Atlantic depressions determined our weather.



MEAN ATMOSPHERIC PRESSURE



The pressure pattern in December was very similar to the normal pattern for this time of year, as a comparison between these two maps shows (the smaller map shows the 30-year average pressures for the month of December). However mean pressures were between 3 and 5 hectoPascals above normal, and the strong winds of the latter half of the month are reflected in the greater range of mean pressures - 5.5 hPa - as compared to the normal 4 hPa range between the highest and lowest values.

Acid Rain and Forest Decline in Europe

E.P. Farrell, Department of Environmental Resource Management.

Abstract.

The problem of forest decline in Europe has been a matter of serious concern for almost ten years now. Damage, previously observed on European silver fir, a species of limited commercial importance, spread to Norway spruce, the most important coniferous forest tree in Europe, in 1982. In subsequent years the extent and severity of the symptoms increased but more recently the situation has stabilized itself. However the spread of decline symptoms in broadleaved species has given rise to further unease.

The symptoms of forest decline vary from non-specific needle loss and yellowing in conifers to premature leaf abcission in broadleaved species. There is probably no single cause of this damage. There is still a great deal of controversy surrounding the issue, but most scientists agree that forest decline is, at least in part, pollution-induced. There are two principal schools of thought on the issue, both of them with their origins in Germany. One suggests that acid rain results in increased soil acidification leading to an increased rate of soil aluminium mobilization. Aluminium, toxic to plants, inhibits fine root development resulting in damage to trees which is most pronounced in drought years, due to impaired water uptake.

According to the second theory forest decline results from the effect of pollutants interacting with climate on tree foliage. The direct contact theory implies that if the source of pollution is removed or emissions reduced then damage should very soon decrease. However, if forest decline results from a permanent soil degradation then it is more or less irreversible and could result in the death or stagnation of a significant proportion of Europe's forests.

Irish Meteorological Society

"Drought in the Sahara"

Agricultural development and the reproduction of underdevelopment in the Sudan

by

Prof. Abduli Osman El-Tom
Professor of Rural Development,
University of Gizara, Sudan
and
currently visiting Professor of Anthropology
St. Patricks College , Maynooth

in

Lecture Theatre G33
Earlsfort Terrace (U.C.D.)
Dublin 2
on
Friday February 8th 1991
at 8.00 pm.

Admission Free *Open to the Public*