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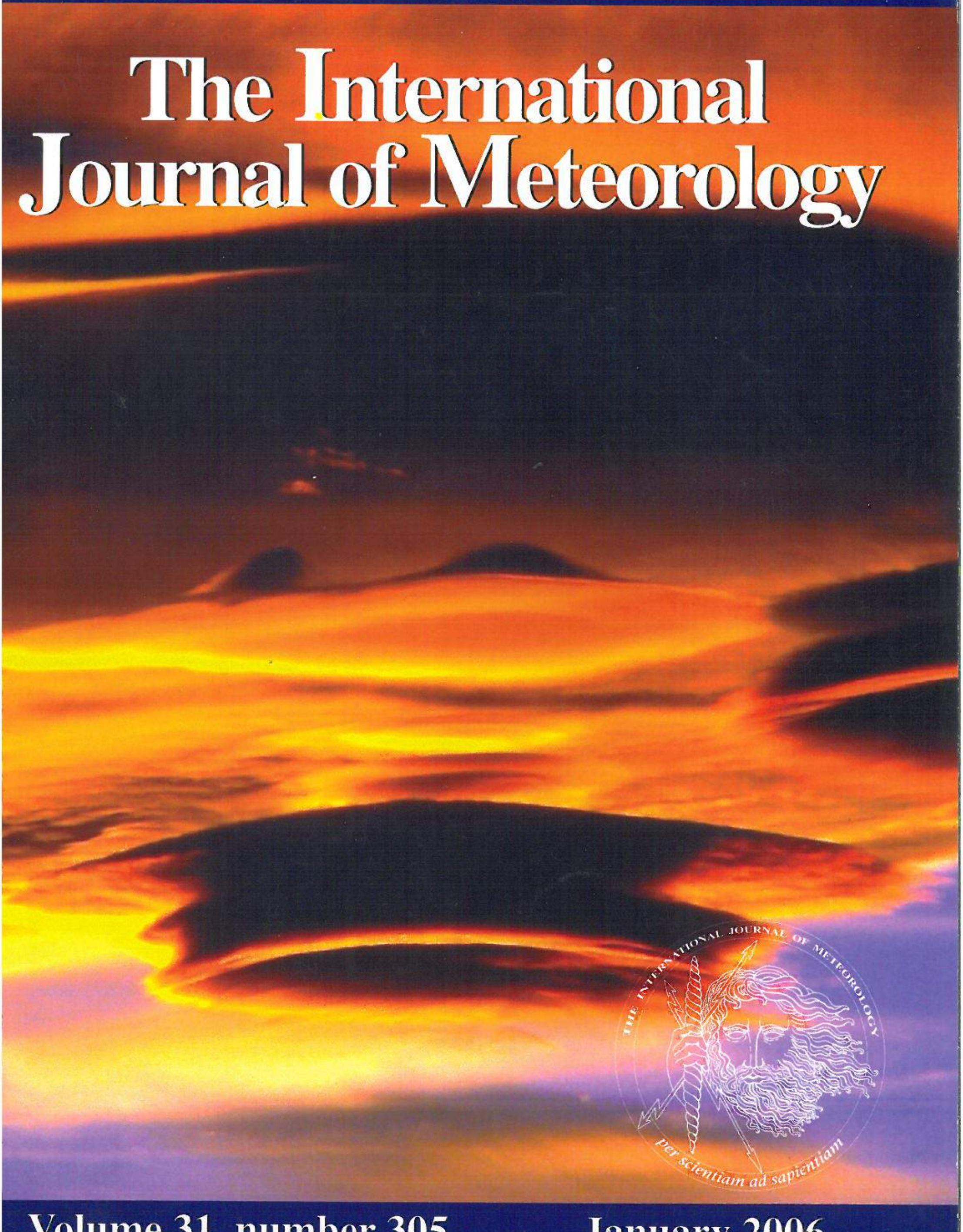

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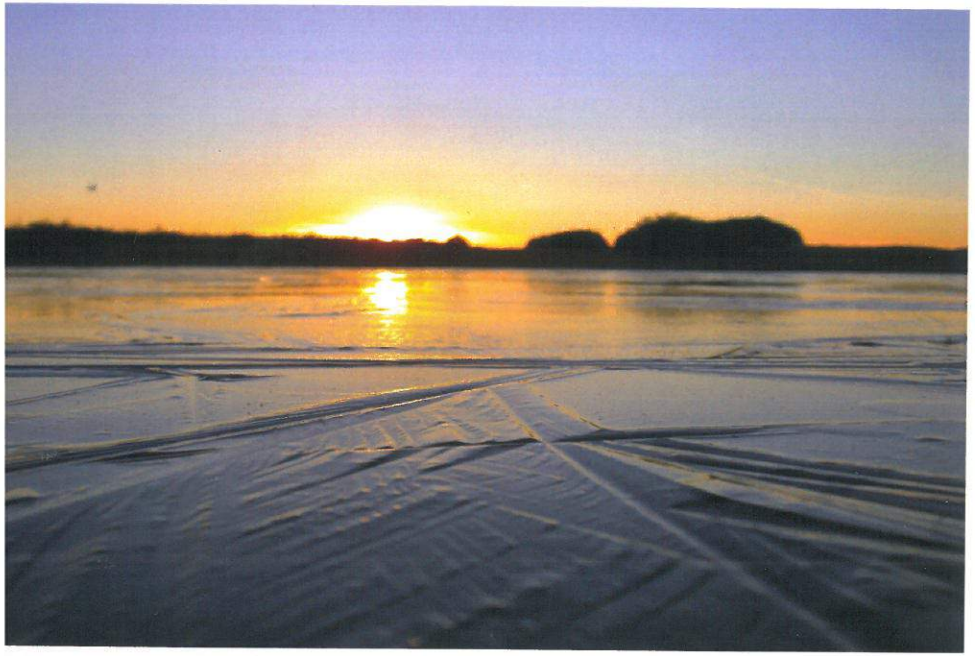

(*top*) Oxford canal, nr. Rugby, Warwickshire, U.K. November 2005 © Fernando Osborne
(*bottom*) Sunset, Hergest Ridge, Herefordshire, U.K. November 2005 © Howard Kirby

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Front cover and rear cover: Lenticular clouds at sunset, Blakey Ridge, North Yorkshire Moors, U.K. 11 December 2005
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THE INTERNATIONAL
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NUMERICAL SIMULATION OF PRECIPITATION SYSTEMS AT THE SERRA DO MAR REGION IN SOUTH-EAST BRAZIL: A CASE STUDY

By A. M. RAMOS[1], F. C. CONDE[1], P. S. LUCIO[1],
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Abstract: Rainfall convective systems in the Serra do Mar region of south-east Brazil have been investigated through a numerical simulation of regional circulation and cloud structure using the Regional Atmospheric Modelling System (RAMS). São Paulo weather radar maps and the National Center for Environmental Prediction (NCEP) data sets, as well as the meteorological ground station data, have been used in order to validate the RAMS output. The observed meteorological parameters were obtained during March 1993, as part of the German-Brazilian Project ENV-III (Air Pollution and vegetation damage in the tropics - the Serra do Mar as an example). The meteorological ground-station data and radiosonde data were the inputs for the modelling. The overall results showed agreement with the observed data. Rainfall system structure and displacement, air temperature and wind fields were reasonably compatible with the observed weather station data, the NCEP reanalysis and the weather radar data.

Keywords: numerical modelling, rainfall systems, liquid water content, industrial zone

INTRODUCTION

Several authors have described the effect of clouds and rainfall on air (e.g., Junge, 1963; Pruppacher & Klett, 1997 and Seinfeld & Pandis, 1998). That effect is considered important not only for the atmosphere, but also for vegetation and water quality. There are significant long-term climate implications as well. The quantification of this effect involves an integrated view of the whole system: the formation of droplets, their fall and scavenging properties in an atmosphere with thermal properties and wind fields of considerable complexity - as well as the specification of several chemical species and their individual lifecycles in the atmosphere.

Numerical modelling, in this case, represents a powerful tool, in as much as the problem can be separated into components, better understood, and some links provided to connect the parts. In the literature, there are many articles dealing with observational and modelling data set validation with respect to cloud development. Cloud development is, in fact, considerably difficult to analyse via observational data. Therefore, modelling becomes quite a useful tool to describe it. On the other hand, weather radar maps give the best observational data concerning rainfall amount and time resolution. Cloud modelling and radar together provide an important validation tool for studying many atmospheric processes. In particular, RAMS, developed initially by Tripoli & Cotton (1982), is one of these models which can be validated with weather radar data. Cautenet & Lefeivre (1994) used numerical modelling to evaluate the gas and aerosol scavenging processes. For instance, SO_2, $SO_4^=$ and NH_4^+ have been studied in convective rainfall in the African equatorial forest. The model examined the relationship between liquid water content and the trace elements in the convective precipitation and the results from numerical models compared well with the observed data set evaluated by the ABLE 2B (Amazonian forest) and DECAFE (African forest) experiments. The modelling also verified the reduction of aerosol scavenging efficiency with an increase in rain intensity and a strong impact of vertical profile of atmospheric trace elements on the ground rain concentrations. Gonçalves *et al.* (2002) presented a scavenging modelling with similar results at Amapá State.

Uno (2000) simulated sulphur transport and deposition using RAMS and an on-line long-range transport model, including chemical reaction and deposition processes to examine the transport and deposition from the East Asian mainland towards Japan and the Pacific Ocean. The results indicated that simulated regional meteorological parameters show a very good agreement with surface observations, satellite data for precipitation and cloud indices. The calculated wet deposition amount is strongly affected by the local precipitation (including in-cloud scavenging rate) and the sulphate concentration field and numerical results explained most of the important meteorological conditions favourable for trans-boundary pollution in East Asia and indicated the dramatic changes of chemical composition concentration with the season.

The objective of this research was to present a numeric simulation of the circulation and cloud associated features in the region shown in Figure 1. This was presented and validated against the available São Paulo weather radar and ground data with RAMS, parameterised to capture the synoptic and mesoscale details, using the technique of nested grids. In particular, the cloud liquid-water content, with its respective cloud droplet spectrum, time evolution and vertical dimensions are herein analysed. The research focused on the 15 and 16 March 1993 and it was organised as follows: the general features of the sites and data is described, a brief description of the RAMS options is presented and results and conclusions are shown.

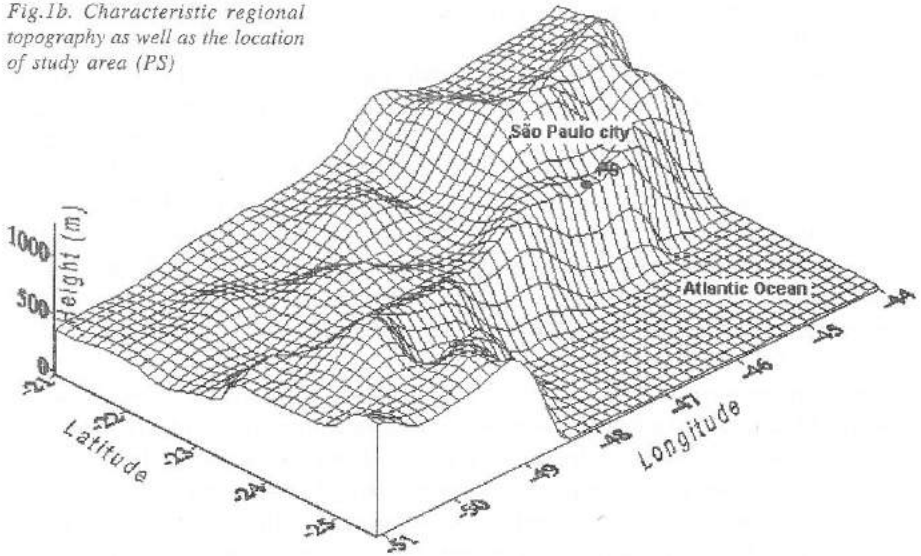
Fig.1a. São Paulo weather radar (R), Paranapiacaba meteorological station (PS) and the MASP

EXPERIMENTAL SITES

Figures 1a and b show the target area, both the locations of stations and radar (Fig. 1a) and topography (Fig. 1b). This region was the object of a six-year German/ Brazilian program ENV-III to study air pollution and its effect on tropical vegetation (Klockow *et al.*, 1998). The area possesses local industrial complexes, which produce high amounts of air pollution, and has been described in Klockow *et al.* (1996). For the study area, Gonçalves *et al.* (2000) addressed the scavenging modelling to identify the transferences in a much polluted area. Collection of rainfall water and the measurement of airborne concentrations of several gases provided data regarding the beginning and end result of the scavenging process and thus a means to validate numerical simulations of the whole process. The steep terrain shown in Fig. 1b and the proximity to the Atlantic Ocean are important cloud-generating factors in the region (Silva Dias *et al.* (1995) and Silva Dias & Machado (1997)).

The metropolitan area of São Paulo (MASP) is located on the south-west of the Paranapiacaba meteorological station (PS). The PS is located at approximately 23.7 °S and 46.3 °W at an altitude of 800 m, near the Atlantic coast (Fig. 1a and Fig. 1b). The MASP is quite a large area with about 17,000,000 inhabitants, 6,000,000 vehicles and many industries. Fig. 1 shows the study area, the location of both the stations and the radar, (Fig.1a) and the topography (Fig.1b). PS is located about 10 km northeast of the industrial complex, which is in the Mogi valley in the Serra do Mar mountain range. The continuous monitoring of the rainfall structures was accomplished by the use of São Paulo weather radar, which generates CAPPI (Constant Altitude Plan Position Indicator) reflectivity maps, at a height of 3 km, every 10 minutes.

Fig.1b. Characteristic regional topography as well as the location of study area (PS)



The radar is located at Ponte Nova (23°36'00"S, 45°58'20"W), and covers an area with a radius of about 180 km (Fig. 1a) - presenting a pixel resolution of 2x2 km^2. The data from the meteorological instruments and fractionated rain samplers at the ground station are described in Vautz *et al.* (1995) and Gonçalves *et al.* (2000).

MODEL DESCRIPTION

The simulations were made by the atmospheric model RAMS. The model is often used as a limited area model, and many of its parameterisations have been designed for mesoscale or high resolution cloud scale grids, as well as RAMS may also operate as a global scale model for simulating large-scale systems by configuring two hemispheric grids, which use a polar stereographic projection and continually exchange boundary data between them Walko and Tremback (1991).

The atmospheric model was constructed around the full set of non-hydrostatic, compressible equations for atmospheric dynamics and thermodynamics, plus conservation equations for scalar quantities such as water vapour and liquid and ice hydrometeor mixing ratios. These equations are supplemented with a large selection of parameterisations for turbulent diffusion, solar and terrestrial radiation, moist processes including the formation and interaction of clouds and precipitating liquid and ice hydrometeors, kinematics effects of terrain, cumulus convection, and sensible and latent heat exchange between the atmosphere and the surface, which consists of multiple soil layers, vegetation, snow cover, canopy air and surface water. A detailed overview discussion of RAMS and these options is given in Tripoli & Cotton (1982), Walko & Tremback (1991), Pielke *et al.* (1992) and Walko *et al.*, (2000). The following parameters were generated: the rainwater and cloud liquid-water contents, their vertical and horizontal profiles, the cloud, the cloud base and the cloud spatial distributions.

The main options and parameterisation used in these simulations, for our goal, are described as follows:

1. The homogeneous initialisation used the radiosonde data acquired at Congonhas Airport, which is inside São Paulo city. The simulation covered 48 hours beginning 15th March at 0000 UTC. Three tri-dimensional grids were used around PS, which is situated about 30 km southeast of Congonhas Airport. The coarse grid specification was defined with 20 km grid spacing, the other two with 4 km and 1 km horizontal resolutions respectively. The vertical grid stretched from 100 m of vertical spacing close to the surface, increasing by a factor of 1.2, and reached 500 m of vertical spacing. This was kept constant up to the model top, which is located above the tropopause at 14 km. The time step was 20s for grids 1, and 4s and 2s for grids 2 and 3 respectively.
2. The full microphysics package was activated in three grids. This scheme includes the use of generalised gamma distributions as the basic function for all hydrometeor species; the use of a heat budget equation for hydrometeor classes, allowing heat storage and mixed phase hydrometeors; partitioning hydrometeors into seven classes (including separate graupel and hail categories); the use of stochastic collection rather than continuous accretion approximations and the extension of the ice nucleation scheme to include homogeneous nucleation of ice from haze particles and cloud droplets (Walko *et al.*, 1995). Flatau *et al.* (1989) developed two schemes in order to simulate cloud physics. The first scheme was applied to the water categorical discretization (the categorical discretization is a prerequisite to the formulation of causal alternatives via numerical classification algorithms) and the second to the volumetric water, with a continuous distribution.
3. A modified Kuo-type cumulus parameterisation scheme, improved by Tremback (1990), was activated only over the coarser grid (20 km); solar radiation parameterisation (Chen & Cotton, 1983); turbulence parameterisation (Smagorinsky, 1963); soil, using seven levels (Tremback & Kessler, 1985) was activated in three grids.
4. Topography (from the U.S. Geological Survey at 1 km horizontal resolution) and vegetation, type 6 (evergreen broadleaf trees, as conditions inferior boundary) were used as input to characterise the Serra do Mar, following Mahrer & Pielke (1977).
5. The vertical and horizontal profiles of cloud water content were used in order to obtain the cloud droplet spectra to integrate the in-cloud scavenging processes along their vertical profiles.

All illustrations and discussions in the following section will be concerned with the simulations on grid 3 (1 km), in order to obtain a better representation of cloud microphysics processes that can be applied to any water phase, including the precipitation process. Figure 2 shows nested domains used in the model as well as the location of Paranapiacaba (PS) and São Paulo (SP) cities (a) and (b) the topographic characteristic generated by the model in the grid spacing 3 km.

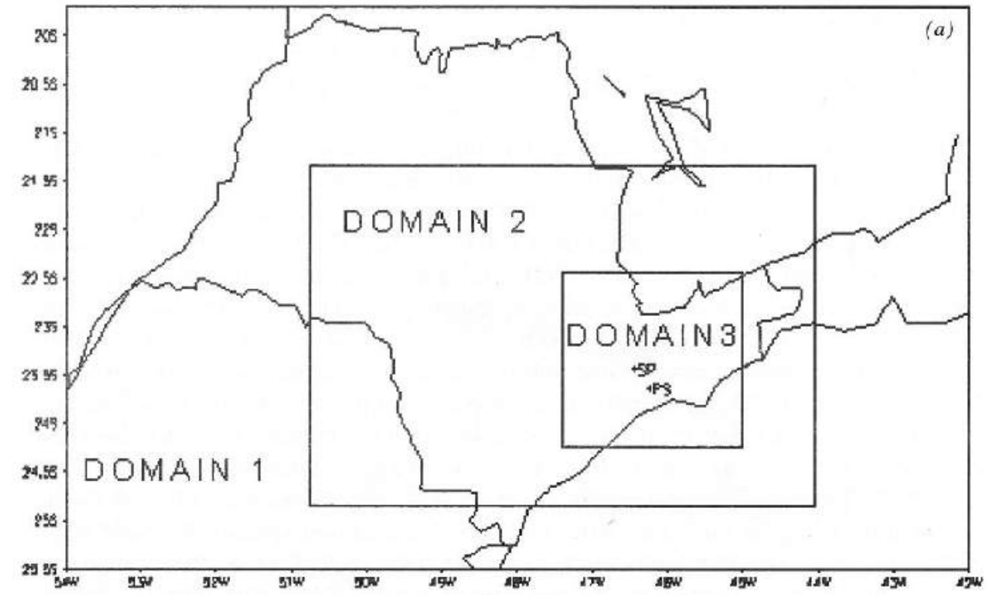
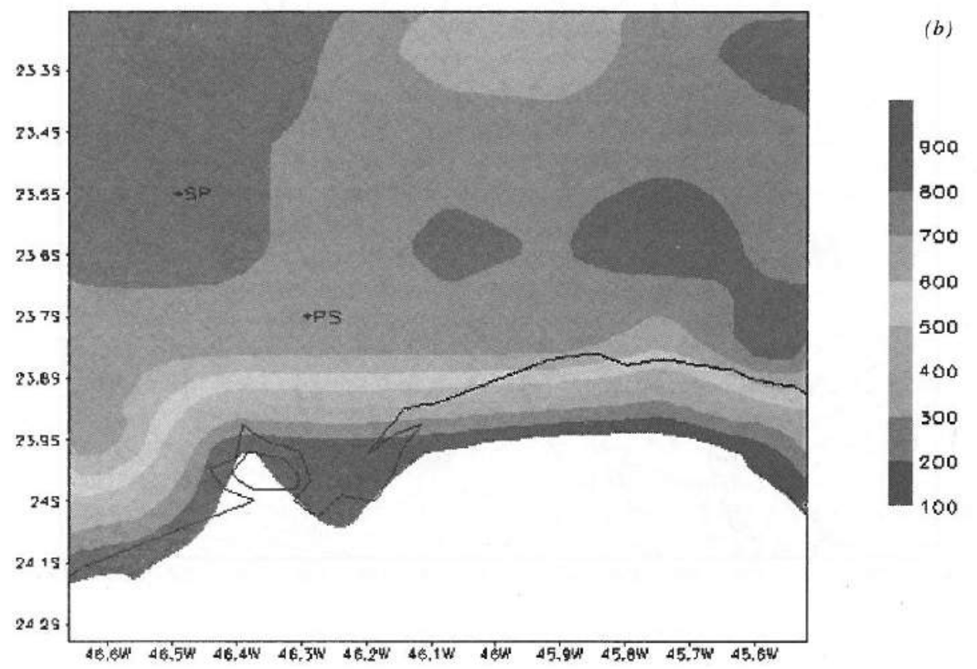


Fig.2. Nested domains used in the model simulations, with 20 km (domain 1), 4 km (domain 2) and 1 km (domain 3) respectively (a) (above) and (b) (below) a topography map generated by the model near the locations of São Paulo (SP) and Paranapiacaba (PS), contour increment 100 m



RESULTS AND DISCUSSION

Large-scale meteorological description: The sea-level pressure analyses on the 15 and 16 March 1993 at 1200 UTC are shown in Figure 3a and 3b respectively. A semi-stationary front seen on the morning of the 15th March was in a dissipating phase. Furthermore, on the 15th March, the South Atlantic high pressure area was located at the climatological position, i.e., close to the Southern Brazilian coast, and a low pressure system was located over Southern Brazil and Northern Argentina, moving in an easterly direction toward the Atlantic Ocean. The 1,000 hPa wind fields from NCEP reanalysis in São Paulo showed northeast wind at 1200 UTC, changing to east in the afternoon (1800 UTC). This analysis has been corroborated by the geopotential and wind fields, at the 500 hPa and 200 hPa levels, which presented zonal flow over the state of São Paulo on both days, with no influence from temperate zones on either day (Climanálise, 1993). On the 16th March the situation was influenced with low pressure in the coast from the state. This day showed a different synoptic situation, with wind blowing initially from the north and changing in the afternoon to north-west. This denotes a typical pattern presenting a wind field on the warm side of the low system, which was located over the southern Atlantic Ocean, influencing the study area, with convergence of relative moisture by around 80 %. The weak surface wind for both events, measured at the ground station PS (as shown in Fig. 6a and Fig. 6b with a small arrow), was from the southeast during the afternoon, which enhanced rainstorms in the interior of the State.

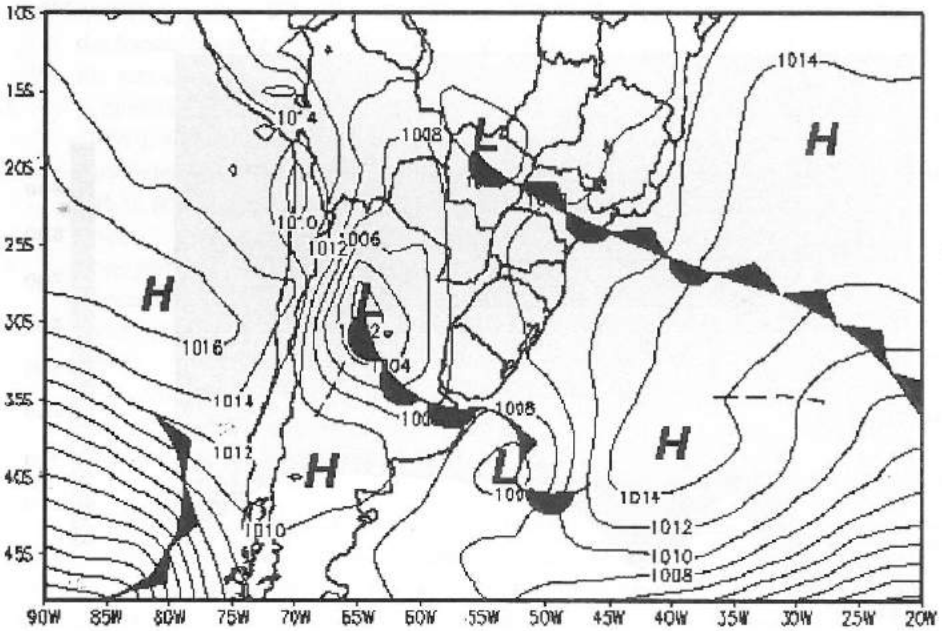


Fig. 3a. Synoptic chart (isobars in hPa) for 1200 UTC on the 15 March 1993

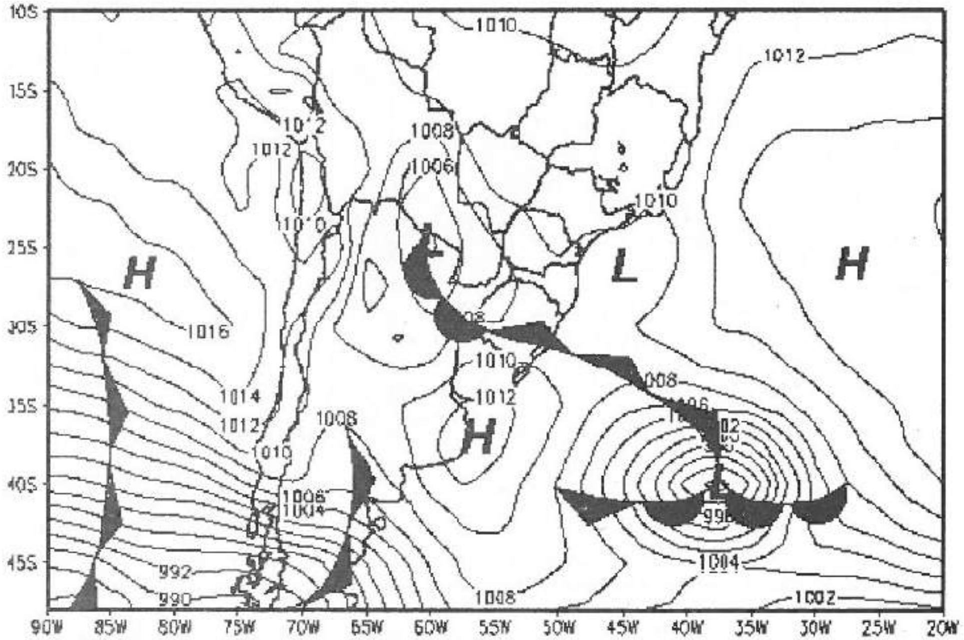


Fig.3b. Synoptic chart (isobars in hPa) for 1200 UTC on the 16 March 1993

Wind direction Simulation: Figure 4a and 4b show wind direction simulations (with 1 km grid resolution) at 57 m and 3 km above the surface respectively. These figures describe the sea breeze configuration, i.e., southeast winds through the continent (Fig. 4a) and northwest winds through the Atlantic Ocean (Fig. 4b). This configuration stayed during the whole target period. Observe that the ground stations corroborate the wind simulations at PS and other weather stations for both events. The NCEP reanalysis shows similar wind direction as described above. At 3 km, there is a general agreement between the rainfall system displacement, NCEP reanalysis and simulation as shown in Figure 6b (large arrow) and Figure 4b respectively for the 16th March event.

Simulation of temperature: During the 15th March event, at 1530 LT (Local Time), the observed air temperature reached 24 °C at PS. The PS simulated air temperature (ground level) was 25 °C, close to the observed one (Fig. 5a). Other recorded air temperatures were also close, such as the MASP presenting a recorded temperature of about 26 °C, and a simulated temperature of about 25 °C. During the 16th March event, at around 1600 LT, the observed temperature reached 26 °C at PS. The simulated PS air temperature was between 24 °C and 24.3 °C (Fig. 5b), also close to the observed one. Other locations showed similar results. Therefore, the RAMS simulations were able to reasonably predict the ground-level air temperature fields.

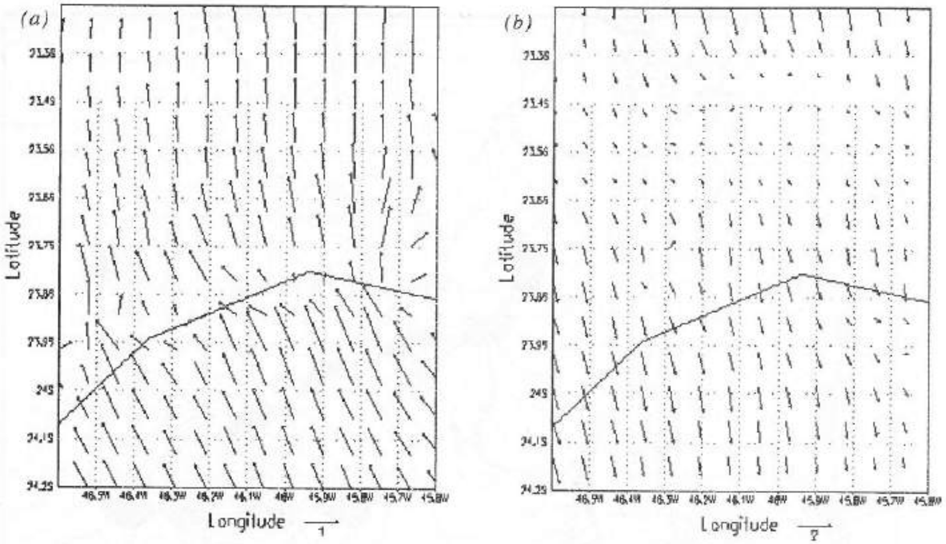


Fig.4. RAMS wind (in m.s^{-1}) sea breeze simulations for (a) at 1600 LT for the 16 March 1993 event at 57 m and (b) at 1600 LT for the 16 March 1993 event at 3 km height.

Simulation rainfall: The weather radar CAPPI maps are shown in Figure 6a and Figure 6b for the March 1993 events. The 15 and 16 March 1993 precipitation event RAMS simulations are shown in Figure 7a and Figure 7b. Both events presented characteristics of convective systems through rain intensity and cloud development variables as shown in RAMS simulations. During the 15th March event (Fig. 6a and Fig. 7a), a large rainfall pattern was advected towards the southeast, through the MASP.

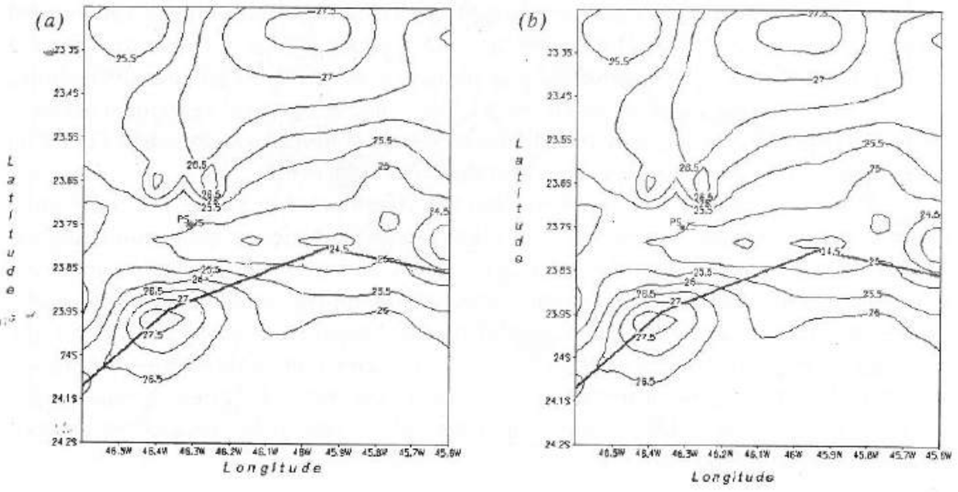


Fig.5. Simulated temperature field for the times of precipitation corresponding (a) at 1453 LT for the 15 March 1993 (b) at 1553 LT for the 16 March 1993

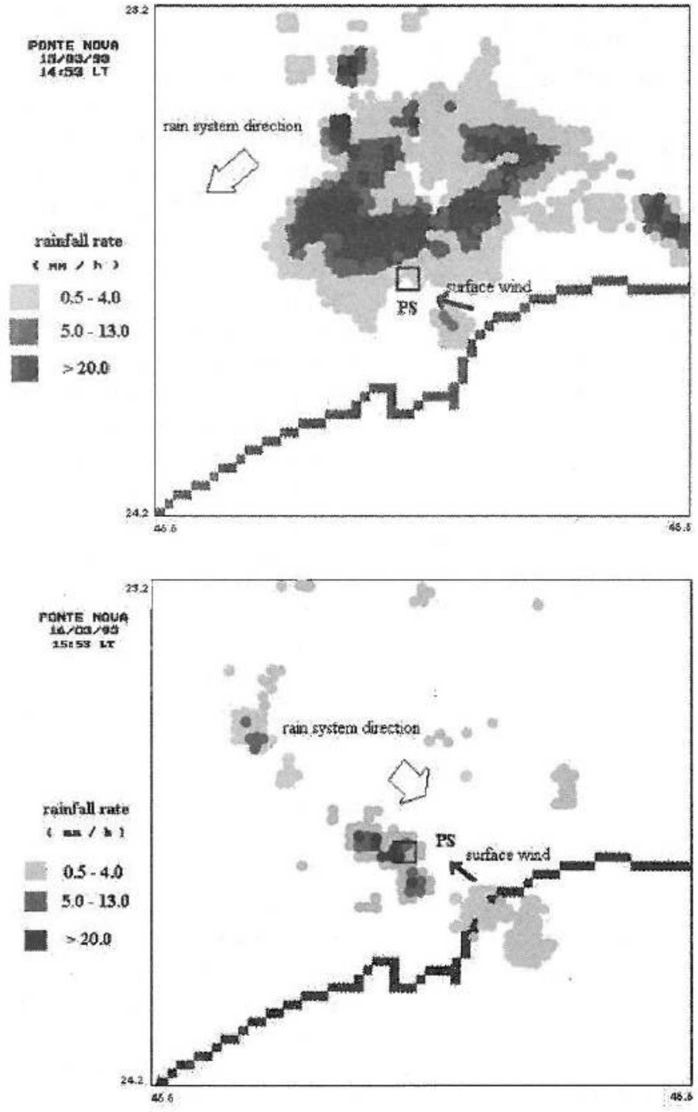


Fig.6. Weather radar CAPPI maps (a) at 1453 LT for the 15 March 1993 event, at 3 km height, including the surface wind (narrow arrow) and rain system direction (large arrow) and (b) at 1553 LT for the 16 March 1993 event, at 3 km height, including the surface wind (narrow arrow) and rain system direction (large arrow)

(a)

(b)

The study area was not directly affected by the heaviest rainfall (presenting rates of about 2 mm/h), where the convective core (cloud band region with rainfall rate > 20 mm/h) is positioned to the north of PS, although the rainfall core reached more than 100 mm/h. The simulated rainfall (Fig. 7a) shows the convective core over the northeast (around 7 mm/h) PS, with rainfall for every area.

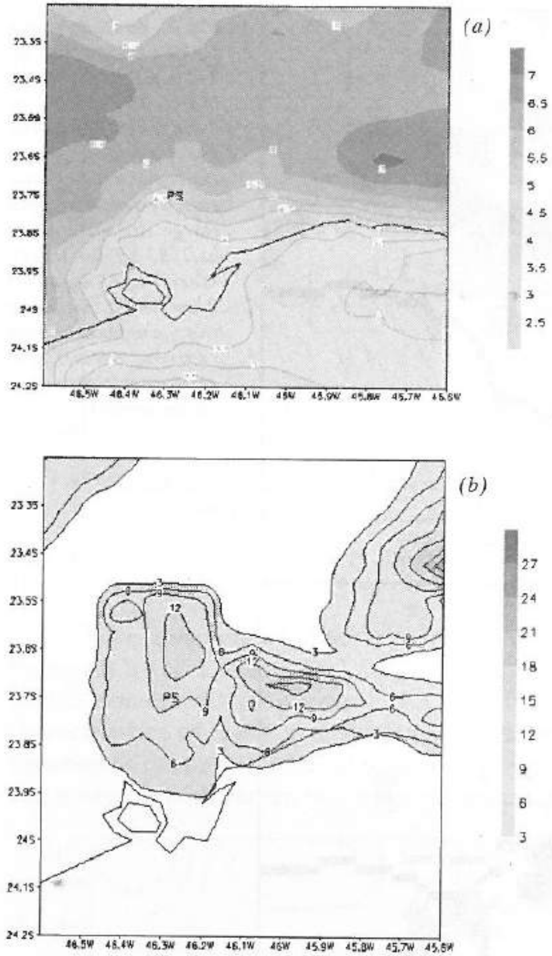


Fig.7. Rainfall (mm) simulated by RAMS at 1600 LT: (a) at 1500 LT 15 March 1993 event and (b) at 1600 LT 16 March 1993 event.

On the other hand, during the 16th March event (Fig. 6b and Fig. 7b), started the formation of an intense convective cell, but this was a smaller convective rain cell than of the previous day, a heavy rainfall core was observed crossing the PS study area, advected from the north-west, and presented rainfall rates higher than 20 mm/h. (Fig. 7b). Considering Fig. 6 and Fig. 7, it is possible to verify that the RAMS event simulations for both events presented spatial distribution and rainfall intensity similar to that shown on the weather radar maps, although overestimating the rainfall rates for both events.

The liquid water content profiles: The simulated vertical water profiles over PS are presented in Fig. 8a and Fig. 8b for the measured rainfall time, 1500 LT and 1600 LT for the event on the 15th and 16th March respectively. For presenting characteristics of convective development as expected, both events presented similar results. The 16th March event presented lower water concentration, reaching a maximum value of only 1.5 g/kg (though in a deeper layer), while the 15th March event shows higher amounts, up to 4.5 g/kg (though in a shallower layer). This result can be partially confirmed in Fig. 5a and Fig. 5b, which display the horizontal liquid-water content fields. The 15th March event presented a broader horizontal area of higher concentration, although the maximum value reached just 5 g/kg, while the 16th March event exceeded 8 g/kg (Fig. 7a and Fig. 7b). That result means that the convective system in the 16th March event was stronger, yet smaller. As previously described, this was also confirmed by the CAPPI maps. Therefore, the simulations are comparable with the observed data.

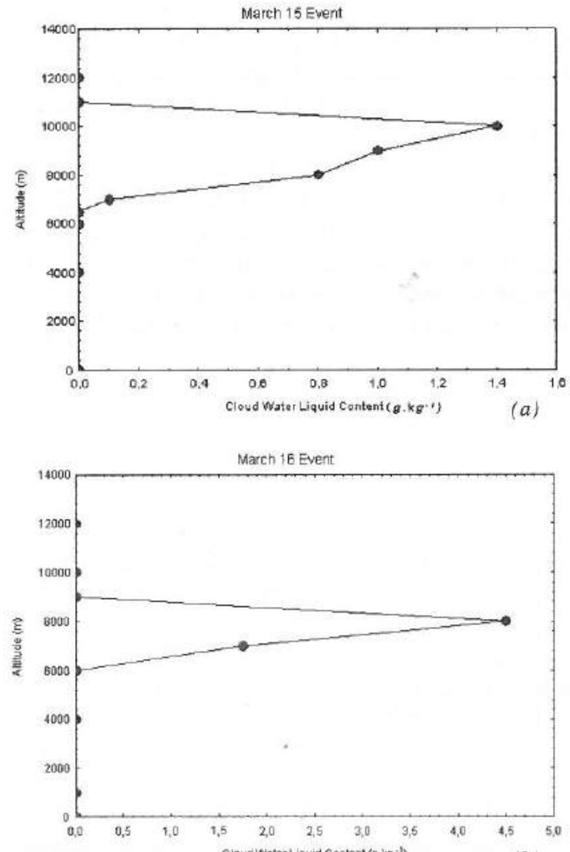


Fig.8. RAMS simulation for (rain + cloud) liquid-water content profiles in Paranapiacaba (PS) city for (a) at 1500 LT 15 March 1993 and (b) at 1600 LT on the 16 March 1993

As the scavenging process is a function of the droplet spectrum and that parameter is, for its part, a function of liquid water content, in Gonçalves *et al.* (2002) the results obtained by RAMS were coupled with a one-dimensional (1-D) below-cloud scavenging model based on Gonçalves *et al.* (2000) in order to simulate the in-cloud and below-cloud scavenging processes for three chemical species found in rainwater $SO_4^=$, NO_3^- and NH_4^+, scavenged from the atmosphere, besides comparing the modelled and the observed rainwater and determine the variability in concentration. The numerical modelling was primarily divided into two main mechanisms: below-cloud and in-cloud scavenging processes. Below-cloud modelling was based on Gonçalves *et al.* (2000) and in-cloud using the equations proposed by Volken (1994), Pruppacher & Klett (1997) and Seinfeld & Pandis (1998). The results show a general agreement with the observed data, e.g., the same magnitude of rainwater concentration and similar concentration curve behaviour. Sulphate and ammonium presented an overestimation for the average observed rainwater concentrations and nitrate presented the opposite. The wet deposition in the Cubatão and Serra do Mar, during deep rainfall cells, which crossed the MASP (Fig. 1a), could also have crossed over the sample ground station.

CONCLUSIONS

The above sections have aimed at validating numerical simulations of convective systems and the associated regional circulation around the Paranapiacaba meteorological station (PS) and MASP on 15 and 16 March 1993. The main results show that a sea breeze cell, compatible with observed meteorological data at a ground station and rainfall cell displacement evaluated by the weather radar maps, was successfully simulated. The temperature fields are compatible with the observed data, the numerical modelling of the region also approximated the main features associated with the rain systems, evaluated by São Paulo weather radar maps, and when the two events are compared, the cloud liquid-water content horizontal and vertical profiles obtained from the RAMS simulation were in qualitative agreement with the data set of rainfall rates and total disdrometer-collected amounts.

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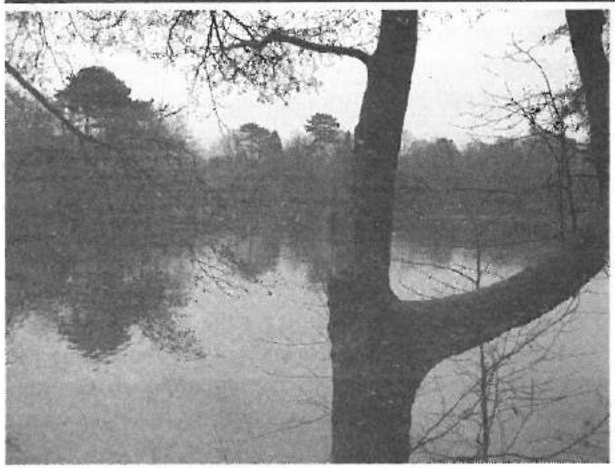

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SNOW IN NORTHERN ENGLAND DURING THE 1760s

By LANCE TUFNELL

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Abstract: By using a variety of sources, it is demonstrated that in northern England* the 1760s was a time of quite frequent and occasionally heavy snowfalls. The picture contrasts with that given by Pearson (1976) of a largely snow-free Scotland. [*defined as the area from Manchester and Sheffield to the Scottish border]

Keywords: snow (falling/lying), winters 1759-60 to 1768-9, northern England

INTRODUCTION

Progress in understanding the climatic changes of recent centuries depends heavily on the successful identification of trends. Yet, few of the trends proposed have been rigorously verified. This is undoubtedly true of a snowstorm curve which Pearson (1976) compiled for the winters 1729-30 to 1829-30 in Scotland. The first of its three principal elements covers the thirty-five years up to the mid-1760s and suggests a time of infrequent snowfall. Next is a part of the curve which implies growing snowstorm activity between about 1765 and 1785, mirrored by a decrease until around 1805. Thereafter, the curve rises gently towards the winter of 1829-30 and indicates a snowstorm frequency somewhat greater than in its first thirty-five years.

Interestingly, Pearson's curve suggests that the late 1750s and early 1760s was the period of his study with the lowest snowstorm frequency. The beginning of an upward trend in the second half of the 1760s he ascribed largely to a month of snow which commenced in late December 1766. This was the only long period of snow in Scotland during the 1760s which he identified.

Pearson's curve is largely derived from one source, a newspaper known as *The Caledonian Mercury*. By contrast, *The Leeds Intelligencer*, a newspaper used in the present research, tells a different story. It describes a number of snowfalls throughout the 1760s in northern England, but gives little information about snow events during the 1770s. According to a third perspective (Manley, 1978), both the 1760s and, more especially, the 1770s were fairly snowy in east-central Scotland. Again, the reconstruction for the 1760s used only one source, a meteorological register from near Perth. Because each of the above sources offers a different point of view, it was decided that the only satisfactory approach towards understanding snow events of the 1760s in northern England would be to consult as wide a range of material as possible.

The most useful sources for this work appear to be diaries and newspapers. For present purposes, the former category is taken to include not only descriptive and often intermittent weather details of the type Williamson (1742-81) and Fletcher (Winchester, 1994) have given for Cumbria, but also continuous daily and partly instrumental records, such as Hutchinson (1768-93) provided for Liverpool. The word 'newspapers' is also used in a broad sense, so that it includes weekly publications, such as *The Leeds Intelligencer*, together with the monthly *Gentleman's Magazine* and the so-called *Annual Register*. These, plus a number of other, minor sources, have furnished three grades of data about snow events of the 1760s in northern England. The most important consists of references to snow (falling or lying) on specific days. Then, there are other times when snow is almost certain to have occurred, despite there being no actual mention of it in the literature. For example, a group of snow records with just the occasional day missing is surely evidence of an uninterrupted period of cover. One such sequence happened in February 1760, when snow was noted in Cumbria on the 15th, 16th, 17th, 19th, 20th, 21st and 23rd (Williamson, 1742-81; Winchester, 1994), making it highly likely that it also existed on 18th and 22nd. A third grade of detail relates to times when snow might have occurred (e.g. immediately after a period when it has been recorded, as in the days following 23 February 1760). This type of day is, however, not included in the record discussed below, owing to uncertainty about how long the snow persisted.

THE SNOWINESS OF THE 1760s IN NORTHERN ENGLAND

Some parts of Europe enjoyed relatively high temperatures during the 1760s. For example, in Hungary the winters of 1761-8 were "particularly mild" (Racz, 1992). It might be supposed that favourable winters also affected Scotland, given Pearson's (1976) claim that the 1760s was largely snow free. Yet, Manley has suggested that not only was east-central Scotland fairly snowy at the time, but also that temperatures in central England over the five months November to March were below the long-term average (Manley, 1953, 1978). Furthermore, he has pointed to a "broad agreement between the [snowfall] fluctuations in Pennine Yorkshire and east-central Scotland" (Manley, 1978). Reconstructing the history of snow in northern England ought therefore to shed light on conditions in Scotland.

Using the first two grades of data mentioned above, 288 days have been identified when snow was either falling or lying in northern England. The sequence begins on 9 November 1759 and ends on 13 April 1769. As expected, the gap between the earliest and latest days with snow varies from year to year and was apparently greatest in the 1767-8 season. On this occasion, snow was recorded as early as the 7th October and as late as the week beginning the 17th July. These were also the earliest and latest times when snow was reported in any winter of the decade. As, however, the July observation is from very late in the season, it should be treated with caution. The same is perhaps true for the report of snow near Pateley Bridge on 14 June 1768 (*Leeds Intelligencer*, 21.6.1768). Were both these observations to be proved inaccurate, the winter with the longest interval between the earliest and latest reports of snow would be 1760-1 (20th October - 2nd May) (Table. 1).

During the 1760s, the time between the earliest and latest snow dates appears to have had little bearing on the frequency with which snow occurred. Thus, records for the winters of 1759-60 and 1763-4 show only minor differences in the timing and length of their snow seasons (Table. 1). Yet, the former had twice as many days with snow (Table. 2). Likewise, the winter of 1761-2 was the fourth snowiest of the decade, yet all but five of its 35 days with snow were within the period 11th February to 19th March. By contrast, the least snowy winter of the decade (1762-3) had its first snow on 12th November and its last on 4th May. At the other extreme, the decade's snowiest winter (1766-7) had 45 of its 59 days with snow restricted to the period 2nd January to 15th February.

1759-60; 9th November [*Gentleman's Magazine*] - 23rd February [F]: **1760-1**; 20th October [F] - 2nd May [F]: **1761-2**; 16th January (1762) [W] - 30th April [W, F]: **1762-3**; 12th November [W] - 4th May [F]: **1763-4**; 19th November [F] - 28th February [W]: **1764-5**; 27th October [W] - 20th April [F]: **1765-6**; 2nd November [F] - 28th March [W]: **1766-7**; 5th December *[York Courant]* - 19th April [W, Carlyle]: **1767-8**; 7th October [W] - week beginning 17th July *[Leeds Intelligencer]:* **1768-9**; 12th November [W] - 13th April [Hutchinson].

Table. 1: Earliest and latest dates when snow is known to have been recorded in northern England during the winters 1759-60 to 1768-9 (data from Fletcher [F] and Williamson [W], unless stated otherwise).

1759-60 32: **1760-1** 15: **1761-2** 35: **1762-3** 11: **1763-4** 16: **1764-5** 18: **1765-6** 23: **1766-7** 59: **1767-8** 43: **1768-9** 36.

Table. 2. Number of days per winter when snow is known to have occurred in northern England during the 1760s

Of the 288 days from the 1760s with snow in northern England, 92% were during the five months, November to March. These may, therefore, be regarded as forming the main snow period. Over the decade, a clear majority of the months from this period (i.e. 38 out of 50) are known to have experienced snow. This was reported on 265 out of just over 1500 days in the period (i.e. during nearly 17.5 % of the time). February recorded the highest number of snow days and was also the only month that registered snow in every winter of the 1760s (Table. 3). The months of the November to March period when snow has not been identified are March and November 1760, January, March, November and December 1761, January and March 1763, March and December 1764, January 1765 and November 1766. As these are mostly in the first half of the decade, it is not surprising that the winters from 1759-60 to 1763-4 recorded only 109 days of snow compared with 179 for the rest of the decade. In northern England, the worst period of snow during the 1760s was that of January 1767. Its most severe phase occurred on the 10th and 11th, when there was very heavy snow and strong winds. Several observers thought it the greatest snowfall in living memory (Hutton, 1754-1812; Carlyle, 1768; Hutchinson, 1794-7; Noble, 1904).

November 23: **December** 38: **January** 74: **February** 87: **March** 43.

Table. 3. Number of days during the 1760s when snow is known to have occurred in northern England over the period November to March

Yet, the distinguished meteorologist, Thomas Barker, believed that in Rutland it was the greatest only since the fall of 1 December 1747 (Kington, 1988). Even so, January 1767 appears to have been particularly snowy, not only in northern England, but in places as far apart as Blairgowrie in the north (Perth & Kinross District Council, Archive 466), Bletchley in the south (Stokes, 1931) and Looe in the west (Bond, 1767).

According to Barker, there had been another "great snow" in February 1762 (Kington, 1988). This occurred on the 21st and was widely reported in northern England, as well as further south (Lincolnshire - Anon c. 1867; Somerset - Greg, 1905; Bedfordshire, Gloucestershire, Oxfordshire - *Leeds Intelligencer* 9.3.1762; *Manchester Mercury* 9.3.1762). Observers in northern England seem to have been more impressed by the strength of the wind and the damage it caused than they were when recording the other major snowfalls of the 1760s (Mayors Book, Doncaster, 1493-1947; Ismay, 1722-66; *Newcastle Journal* 20-27.2.1762; *Leeds Intelligencer* 23.2.1762, 2, 9.3.1762; *York Courant* 2.3.1762; Carlisle Quarter Sessions Rolls, Easter, 1762; Winchester, 1994). A report from Newcastle, on the 13th March, described the weather since the blizzard of the 21st February as "very unsettled" and noted that further heavy snow on the 8th and 9th March had "filled the roads, as to render them impassable" (*Leeds Intelligencer,* 16.3.1762).

A third of Barker's "great snows" occurred in February 1766 (Kington, 1988). On the 18th, the *Leeds Intelligencer* reported that locally, snow had begun to fall around 1 AM the previous Wednesday [2 AM at York - *York Courant*, 18.2.1766] and had continued until Friday night. Records from north-west England confirm that the days mentioned in the *Intelligencer* were the 12 and 14 February 1766. On 12th, Fletcher noted "A great snow ... last night" near Cockermouth (Winchester, 1994) and Williamson reported "deep Snow" near Appleby (Williamson, 1742-81). Both men also recorded snow on the 13th and 14th February. However, much further south, at Bletchley, there was "Rain & Wind" on the 12th, "Rain & Snow with it" on the 13th and "freezing ... Snow & Rain", that greatly damaged vegetation, on the 14th (Stokes, 1931). These observers give the impression that, despite their importance, the snowfalls in February 1766 were less severe and widespread than those of the following January.

A fourth "great snow" was recorded by Barker in January 1768 (Kington, 1988). Northern England had snow throughout the first 24 days of this month. Liverpool's heaviest falls were on the 8th and 10th (Hutchinson, 1768-93), while near Cockermouth "severe frost and snow" occurred on the 1st and 11th (Winchester, 1994). On the 12th, the *Leeds Intelligencer* described the previous week's weather as "uncommonly severe" and said that on the 9th and 10th "more snow... stopped all communications with several parts of the country". The 9th was "stormy" around Appleby and snow fell there again on the 11th (Williamson, 1742-81). Though snow continued to be noted for some time after this, records suggest that the most significant falls were during the first half of the month. January 1768 seems, however, to have been less snowy than 12 months earlier, at least in northern England.

Further deep snow was reported throughout northern England in 1763, particularly between the 10th and 12th February (*Leeds Intelligencer* 15, 22.2.1763; *York Courant* 15.2.1763; Ismay 1722-66; Winchester, 1994).

There were other heavy falls just over a year later, on 26 and 27 February 1764 (Ismay, 1722-66; Williamson, 1742-81; *Leeds Intelligencer* 28.2.1764; Winchester, 1994) and again in March 1765, at least on higher ground (*Leeds Intelligencer* 26.3.1765; Richardson, 1956). Observers also noted much snow on 9 February 1768, though this was quickly followed by heavy rain and a rapid thaw (*Newcastle Journal* 6-13.2.1768; *Leeds Intelligencer* 16.2.1768; *Manchester Mercury* 16, 23.2.1768; *York Courant* 16, 23.2.1768; *Drax parish register* 1768; Hutchinson, 1768-93; *Annual Register,* 1786b; Law, 1985; Winchester, 1994). While these last four events appear to have been less extreme than the "great snows" previously described, they nevertheless add to the picture of the 1760s as a time when most winters in northern England experienced at least one snowfall which was reported to be heavy and deep.

Anyone wishing to discover exactly what eighteenth century observers meant by "deep snow" is, however, faced with problems. These arise from the often - displayed tendencies of vagueness and exaggeration, as well as from the practical difficulty of obtaining a truly representative figure for snow depth. How, for example, is one to interpret the claim that in late March 1765 snow was "14 or 15 yards deep" on parts of Alston Moor (Richardson, 1956)? Equally, suspicions must be aroused by reports in the *Leeds Intelligencer* (15.2.1763 and 28.2.1764) that describe two different snowfalls in identical terms. Both give "Snow upon the Plains" in the Leeds area as "upwards of a Foot deep", while "in the Lanes" it was "drifted two or three Yards". Almost identical wording was again used by the paper on 18 February 1766. It also reported snow depths in vague terms on 16 March 1762, 26 March 1765, 17 December 1765, and on 6 and 13 January 1767. Vagueness similarly characterises Fletcher's remarks that on 12 February 1766 snow was "above a foot deep" near Cockermouth and that 11 months later, on 12 January 1767, it was "above a yard deep" (Winchester, 1994).

Fortunately, some observers attempted to provide a more accurate indication of snow depth (Table 4). These point to a maximum snow thickness on the level of around 18 inches.

Date	Locality	Snow depth (inches)	Source
12.2.1766	Newcastle	8 (ML)	*Newcastle Journal* 8-15.2.1766
14.2.1766	York	about 18 (ML)	*York Courant* 18.2.1766
11.1.1767	Carlisle	14 (ML)	Carlyle 1768
8.10.1767	Manchester area Alston-Barnard Castle area	6 near 12	*York Courant* 13.10.1767
8.1.1768	Liverpool	8	Hutchinson 1768-93
c. 17-23.7.1768	Wensleydale	7	*Leeds Intelligencer* 26.7.1768

Table. 4. Some 'precise' values for snow depths in northern England during the 1760s. ML = source indicates that snow depth was measured on the level

Another indication of snowiness is provided by meltwater floods. These were described by Fletcher from near Cockermouth on 7 December 1760 and 12 March 1762 (Winchester, 1994). They were also noted towards the end of December 1763 in the Leeds area (*Leeds Intelligencer* 3.1.1764) and at York (*York Courant* 3.1.1764). Further examples were recorded near Leeds and at Carlisle in the latter part of January 1767 (*Leeds Intelligencer* 3.2.1767; Carlyle, 1768) and at several places after the snow of 9th February 1768 (*Newcastle Journal* 6-13.2.1768; *Leeds Intelligencer* 16.2.1768; *Manchester Mercury* 16, 23.2.1768; *York Courant* 16, 23. 2 1768; *Drax parish register* 1768; *Annual Register* 1786b; Law, 1985). In all cases, rain, which was often heavy, combined with melting snow to exacerbate the flooding.

DISCUSSION

According to Pearson's (1976) record from Scotland, the 1760s were one of the least snowy periods to have occurred between the winters of 1729-30 and 1829-30. In northern England, by contrast, the decade experienced snow quite often, including times when falls were obviously heavy and had a major impact on people and the environment. While the reports so far identified are unlikely to provide a complete picture of what happened, they nevertheless indicate a level of snowiness in northern England which was not unlike that described by Manley (1978) for east-central Scotland. They also point to an increase of snowfall activity during the second half of the decade, though the true picture may have been somewhat distorted by the availability or otherwise of source material (e.g. the years 1761 and 1763 are missing from Williamson's diary). Above all, the current information for northern England strongly suggests that the 1760s ought not to be regarded as a low point in the history of snowiness in Britain. Significantly, this is a view confirmed in the diary of Janet Burnet, a family heirloom published by Pearson in 1994. During the three years, 1766-8, the diarist noted snow fairly often at Kemnay, near Aberdeen, thus recording conditions similar to those being observed in northern England.

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THE WEATHER AT OXFORD IN 2005

By HANG GAO
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Abstract: After a very warm year in 2004 which we reported as the warmest year on record, 2005 was again much warmer than expected and turned out to be the 2nd warmest year on record with an annual mean air temperature of 11.1 °C which was 0.1 °C lower than in 2004 and 1.5 °C higher than normal.

Keywords: Oxford, weather, 2005, annual summary

January has been well above average across all temperature measures, with a mean air temperature of 6.5 °C placing this month in the top 10 warmest Januaries. Minimum temperatures have not been severe, with only 2 air frosts and an absolute minimum grass temperature 5.7 °C above average - the 3rd highest on record. With sustained high pressure featuring this month, there was very little rain in comparison with the long period mean. After a warm January, this winter has ended with temperatures close to average for **February**. With just 20.0 mm recorded, precipitation was again well below normal, in keeping with the winter as a whole, and a seasonal total of 75.9 mm makes this the 13th driest winter on record. The final week of February brought a wintry mixture of snow and sleet, although conditions were a little too warm to allow the snow to lie. **Winter** as a whole was warmer and drier than expected. The mean temperature of 5.6 °C was 1.2 °C above the average and there was 73.1 mm of precipitation less than expected.

March has been warm and dull. Mean air temperature was 1.8 °C above average for March, and there were only 10 ground frosts this month, 6.2 fewer than expected from the long period mean. The sunshine total of 79.3 hours was a disappointing 34.0 hours below the average. Rainfall in **April** was close to normal for the month and the total sunshine was somewhat below average at 136.3 hours. Temperatures were in general well above expected for April, although there were some large fluctuations, indicated by the minimum and maximum air temperatures. Like March, there were again far fewer incidences of ground frost in April than expected from the long period mean.

Mean maximum temperature in **May** was a little above average, but there was a wide range of daily maximum temperatures, from a low of 12.9 °C on the 10th to 28.5 °C on the 27th. 28.5 °C is the 5th highest temperature recorded in May at the Radcliffe and the highest since 1953. Total amount of sunshine was well above the average at 226.4 hours and rainfall was low this month too, with 31.5 mm collected.

Spring was warmer than expected from the long period means. Mean air temperature for the season was 1.3 °C above average and the 7th highest on record. The season was relatively frost-free. A record of 17 days with ground frost was the 4th lowest record since 1881.

Mean temperatures in **June** were all well above the average, but maxima and minima have been more extreme than expected from the long period means. The absolute minimum air temperature was 1.2 °C below average, and the absolute maximum of 31.2 °C, reached on the 19th, was 4.7 °C above average and the 7th highest temperature recorded at the Radcliffe in June. It has been a rather dull month, with a total of just 177.6 hours bright sunshine, 19.3 hours below normal for June. The beginning and end of **July** were characterised by low daily sunshine totals and relatively cool temperatures - a maximum of 15.8 °C on the 25th is disappointing for July. In contrast, there was a period of sustained fine, dry, sunny weather in the middle of the month, with temperatures reaching a maximum of 29.6 °C. After a wetter than average June, July saw a return to the dry conditions that have been a feature in southern England over the past six months, with 34.9 mm precipitation recorded, 24.6 mm below the expected for the month.

A good number of very fine, dry and sunny days in **August** brought the sunshine total up to 235.7 hours, 55.4 hours more than expected for the month, making this the 15th sunniest August on record. Rainfall was well below average with just 31.3 mm recorded. An absolute maximum of 29.9 °C was reached on the last day of the month before thunder and lightning storms in the evening reduced temperatures and humidity. **Summer** was warm, at 1.4 °C above the seasonal norm of 15.8 °C. Mean minimum temperature of 5.9 °C was the 7th highest on record.

September 2005 was, as a whole, a very warm month in Oxford. Mean air temperatures were over 2.0 °C above the expected from the long period means. A mean air temperature of 16.1 °C was the 5th warmest on record, and the mean maximum (21.1 °C) and mean minimum (11.9 °C) temperatures were both the 4th warmest recorded at the Radcliffe in September.

October 2005 was the 2nd warmest October in Oxford on record. The mean air temperature was 13.7 °C which is 3.7 °C higher above the long period means. The warmest October was in 2001 with a mean temperature 13.8 °C. The mean maximum air temperature of 17.1 °C was the same as that for 2001 and the 4th highest on record. With many mild nights during October the absolute minimum air temperature of 5.7 °C was the 3rd highest on record and the mean minimum air temperature of 10.9 °C was the 2nd highest on record. Although the mean air temperature for **November** was the same as normal, the absolute maximum air temperature of 18.0 °C was the 3rd highest on record, and the highest since year 1946. Ground and air frosts were experienced this month, more frequently than normal for November. Fog had been a feature of the morning on 8 occasions this month, 7 of them were consecutive from the 18th to 24th. The number of days with fog was 4.1 days higher than normal. However, the fog did not reduce hours of sunshine which were well above normal.

Radcliffe recorded its warmest **autumn** on record since we commenced records in 1815. Mean air temperature was 2 °C higher than the seasonal norm of 10.1 °C. Mean minimum temperature of 8.7 °C was the same as last year, and the 2nd highest on record. Mean maximum temperature of 16.0 °C was the 3rd highest on record.

Annual Summary of Weather at Oxford for 2005, Radcliffe Meteorological Station,
Oxford University Centre for the Environment, University of Oxford

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Mean air temperature (°C)	6.5	4.4	7.5	9.7	12.1	16.6	17.6	17.3	16.1	13.7	6.4	4.7	11.1
Difference from long period mean	2.8	0.2	1.8	1.4	0.5	1.8	1.1	0.8	2.5	3.7	0	0.2	+1.5
Absolute maximum air temperature (°C)	14.2	12.7	17.4	20.7	28.5	31.2	29.6	29.9	28.3	22.3	18.0	11.2	31.2
Difference from long period mean	2.1	0.0	1.1	1.0	4.4	4.7	1.6	2.6	4.0	2.9	3.1	-0.6	+1.6
Lowest maximum air temperature (°C)	4.6	2.2	4.2	8.8	12.9	16.0	15.8	17.6	15.2	13.6	0.9	1.0	0.9
Mean maximum air temperature (°C)	9.4	7.3	11.2	14.5	17.2	21.6	22.3	23.1	21.1	17.1	9.9	7.7	15.2
Difference from long period mean	2.6	-0.1	1.0	1.5	0.5	1.8	0.6	1.9	2.6	2.9	0.1	0.3	+1.3
Absolute minimum air temperature (°C)	-0.8	-4.0	-2.7	-1.7	0.2	4.0	9.9	8.6	3.5	5.7	-4.2	-3.7	-4.2
Difference from long period mean	4.8	0.6	0.7	-0.5	-1.3	-1.2	2.3	1.5	-0.2	5.9	-1.3	1.2	+3.6
Mean minimum air temperature (°C)	4.0	2.1	4.6	5.7	7.5	12.0	13.4	12.2	11.9	10.9	3.2	1.8	7.4
Difference from long period mean	3.6	0.7	2.2	1.4	0.3	1.8	1.2	0.3	2.1	4.1	-0.6	-0.3	+2.3
Absolute minimum grass temperature (°C)	-3.4	-6.5	-5.6	-2.6	-1.6	0.2	4.0	4.3	-1.2	1.7	-6.6	-8.1	-8.1
Difference from long period mean	5.7	2.0	1.8	2.8	1.1	-1.3	0.2	1.2	-1.1	5.6	-0.2	0.1	+3.2
Mean minimum grass temperature (°C)	0.8	0.0	2.2	3.7	5.1	9.9	11.0	8.1	8.2	8.1	0.1	-1.4	4.7
Difference from long period mean	2.5	1.0	2.4	2.2	0.5	2.0	1.0	-1.3	1.1	4.2	-1.1	-1.0	+1.1
Mean minimum concrete temperature (°C)	1.6	0.4	3.0	4.8	7.0	11.8	12.5	11.1	10.5	9.2	0.2	-0.3	6.0
Difference from long period mean	0.8	-0.9	0.6	0.8	-0.6	1.3	0.1	-1.1	1.2	3.6	-2.6	-1.3	+0.2
Absolute minimum concrete temperature (°C)	-3.6	-6.3	-4.8	-3.0	0.1	3.5	6.5	7.4	1.8	3.2	-7.0	-6.2	-7.0
Difference from long period mean	0.7	1.5	-0.6	-0.5	-1.8	-1.5	-0.9	0.6	-1.6	4.7	-3.1	-0.2	+0.1
Mean soil temperature at 30 cm (°C)	5.6	5.4	6.6	10.4	14.1	17.6	19.4	18.6	17.3	14.1	8.8	5.4	11.9
Difference from long period mean	1.6	1.4	0.7	1.3	1.2	1.2	1.2	0.5	1.6	2.4	1.0	0.2	+1.1
Mean soil temperature at 100 cm (°C)	7.2	6.9	6.7	9.8	12.5	15.3	17.5	17.6	17.1	14.9	11.7	7.7	12.1
Highest daily rainfall (mm)	2.8	3.6	22.5	11.0	13.5	26.9	13.4	6.5	9.1	14.9	10.4	14.9	26.9
Total rainfall (mm)	18.2	20.0	44.5	50.2	31.5	93.4	34.9	31.3	38.5	92.0	38.6	50.2	543.3
Difference from long period mean	-34.4	-21.0	3.4	6.3	-19.1	40.1	-24.6	-27	-21.8	26.7	-23.2	-5.6	-100.2
Total bright sunshine (hours)	65.4	66.3	79.3	136.3	226.4	177.6	192.0	235.7	155.4	92.0	83.5	55.7	1565.6
Difference from long period mean	11.1	-4.0	-34.0	-15.5	36.1	-19.3	0.4	55.4	17.1	-10.8	19.1	6.9	61.3
Mean daily bright sunshine (hours)	2.1	2.4	2.6	4.5	7.3	5.9	6.2	7.6	5.2	3.0	2.8	1.8	4.3
Mean wind speed (knots)	12.5	9.4	7.8	8.0	9.0	7.2	7.3	6.6	6.7	8.9	8.7	6.5	8.2
Difference from long period mean	2.4	-0.5	-1.9	-1.4	0.6	-0.8	-0.5	-1.1	-1.1	0.6	-0.3	-3.3	-0.6
Highest gust speed (knots)	56	47	41	41	37	32	32	34	35	42	46	40	56
Difference from long period mean	5.4	0.1	-8.6	-2.5	-0.7	-5.2	-1.2	-0.4	-4.3	-4.3	2.2	-9.5	-3.6
No. of rain days (0.2 mm or more rainfall)	13	12	12	15	12	9	10	10	13	13	10	8	137
Difference from long period mean	-3.9	-1.6	-2.1	1.2	-1.5	-2.8	-2.6	-3.2	0.4	0.4	-5.9	-9.1	-33.5
No. of wet days (1.0 mm or more rainfall)	9	7	9	13	6	8	7	8	12	11	8	6	104
No. of days with minimum temperature less than 0°C	2	10	6	1	0	0	0	0	0	0	11	11	41
Difference from long period mean	-8.5	0.1	-1.5	-1.9	-0.4	0	0	0	0	0	5.8	2.3	-5.5
No. of days with ground temperature less than 0°C	15	17	10	3	4	0	0	0	1	0	15	20	85
Difference from long period mean	-2.8	0.4	-6.2	-7.6	0.4	-0.4	0	0	-0.2	-0.2	2.8	3.2	-16.9
No. of days with fog at 0900 GMT	0	5	5	3	0	0	0	0	3	5	8	6	35
Difference from long period mean	-3.6	1.9	3.1	2.6	-0.1	-0.1	-0.1	-0.2	2.3	2.2	4.1	1.8	+14.1
No. of days with snow lying at 0900 GMT	0	2	0	0	0	0	0	0	0	0	0	2	4
Difference from long period mean	-3.8	-1.2	-0.9	-0.1	0	0	0	0	0	0	-0.2	0.3	-5.9

After a relatively dry November, there was not much rainfall in **December**. A total of 37.7 mm precipitation was 17.8 mm below the long period means. 8 rain days was the 2nd lowest record since 1881. In terms of temperature, December 2005 was relatively unremarkable with recorded values generally falling within 0-2 °C of the long period mean for most temperature measures.

CONCLUSION

2005 was the 2nd warmest year on record, following 2004 as the warmest. In terms of mean minimum temperatures equal 3rd warmest with 2002, 1997 and 1998. Fog occurred on 35 days this year, the 6th foggiest year on record.

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THE WEATHER AT DURHAM IN 2005

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Abstract: 2005 was another very warm year at Durham, 6th highest on record since 1850, another in a sequence of very warm years that have made the last 10 years the warmest 'decade' on record at Durham. It was drier than normal, but not notably so.

Keywords: Durham, weather, 2005, annual summary

January was a mild month with all measures of temperature well above average. Mean air temperature for January was 9th highest since 1850, the warmest since 1989. It was a dry month, with rainfall total well below average, continuing the pattern of the previous two months – the 3-month total is well below average therefore. Perhaps most notable was the wind – it was generally a very windy month, with mean speeds well above average. Extremely high gusts on the morning of the 8th caused havoc on the A1 and brought down a large chimney at St Cuthbert's Society on the Durham peninsula. The maximum gust of 137 km/h (86 mph) is the highest recorded since the new anemometer was installed in 1999. Despite feeling rather cold at times, **February** was, overall, a mild month, well above the long-term average and ranking 101st in a series of 156 years. Perhaps a run of very mild winters has made us overly sensitive to colder months, imagining them to be more extreme than is the case; in fact, one only has to go back to 2003 to find a much colder February! Rainfall was, once again, below average and all three long-term cumulative totals fell below average at this time. Sunshine was close to average, although there were only two days in the month with no bright sunshine at all. For the **winter** as a whole, it was both very mild and very dry. It was the 10th warmest winter on record since 1850, although 0.2 °C cooler than in 2004. Perhaps more unusually, it was one of the driest winters on record - the 11th driest since 1853 and the driest since 1973. Five of the ten driest winters were experienced in the 19th Century, when summers tended to be much wetter than winters; in recent decades, winters have tended to be wetter than summers, so a winter as dry as this one is now something of a rarity.

March was another mild month, with maximum temperatures well above average and minimum temperatures even more so (the highest mean minimum for March since 1997). Overall, mean air temperature was the same as last year and the highest since 1998 (equal 19th highest since records began). There were 12 ground frosts and 7 air frosts, but all in the first half of the month.

Rainfall was just below average, a dry month generally but with 20 mm on the 27th raising the total to near average. It was a dull month too, with sunshine hours well below average, the 10th dullest March since 1882 and the worst since 1996. There were 9 days recorded with no bright sunshine, again the lowest number since 1996. There was a particularly gloomy end to the month over the Easter weekend which was both wet and sunless. Mean air temperature in **April** was above average, but this masked a contrast between mean daily maximum – a little below average – and mean daily minimum – well above average. This suggests a relatively cloudy month – certainly sunshine was only a little above average and it was, overall, a wet month. In fact, there were only 10 rain days, and the large total was accounted for by two very wet days – 14th and 15th when a total of 58.8 mm fell, a notably large two-day total for Durham. The 3-month and 12-month rainfall totals were now back to average levels but the 6-month total remained well below average, reflecting the dry winter. Although of above-average temperature, **May** was nevertheless somewhat disappointing, the coolest since 1997. That the warmest day was on the 3rd and the sunniest day was on the 12th suggest that the expected heat and sun towards the end of the month did not materialise. It was, however, a dry month: exactly the same total as a year ago but both Mays being only the driest since 2001. There was a notable gust on the afternoon of Saturday 28th of 87 km/h. With an average of 8.4 °C. **spring** ranks =19th highest with 1949 and 2000. Of the other years this decade, only 2001 has had a cooler spring; 2003, 2004 and 2002 rank 1st, 3rd and 4th respectively.

June started in a very disappointing manner, with some very cool days, including a maximum on the 6th of only 12.4 °C and one of 12.8 °C on the 7th. However, the second half of the month was notably warm and so, overall, the month ended up above average, more so because of warm nights than warm days. The maximum of 26.7 °C on the 20th was very welcome indeed. It was only the coolest June since 2002, however, so again memories (of a below-par June in this case) proved short! Perhaps the most notable event was the downpour on the early evening of Sunday 19th. Though less dramatic than elsewhere in the region, it was nevertheless exceptional, with 21 mm falling in an hour (18:00 – 19:00 BST), most of that in about 40 minutes, accompanied by thunder and lightning. There was localised flooding in Durham City, including in Hatfield College where the chaplain's valedictory sermon was accompanied by thunder and lightning! June was less sunny than May, and just below average. **July** was warmer than average, but not exceptionally so, lying just within the interquartile range, 117th in a series of 156. Minimum temperatures were well above average, more so than maximum temperatures, reflecting the relatively cloudy and wet month. Total sunshine was just below average and total rainfall was above average. The 5th, 6th and especially the 28th were wet days. In between there were some warm days, with daily maxima exceeding 20 °C from the 9th to the 19th. One must go back to 1968 to find a July with more days without any bright sunshine at all. In all, therefore, July was a somewhat mixed month but at least with some warm, sunny summer weather in the middle of the month. **August** temperature was a little above average, but not greatly so. It was a dry month, with only just over half the normal amount of rainfall. By now, all long-period totals had fallen below average, the 12-month total significantly so [By contrast, August 2004 was a very wet month indeed].

Sunshine was above average but the running total for the year remained well below average. It should be mentioned here that the automatic weather station at the Observatory failed to operate after a power cut on the 14th. This fault was not discovered until 7th September. Mean temperatures for August and September were therefore interpolated from maps on the Met Office website; daily rainfall figures are based on the Environment Agency record from Barker's Haugh Sewage Treatment Works in Durham City.

Summer was drier than normal (148 mm against an average of 182 mm) but still considerably wetter than the preceding winter (75 mm). The 1990s were characterised by winters being wetter than summers, but this pattern has reversed in the 2000s. The winter:summer ratio was 0.51 in 2005, the 23rd lowest on record since 1852. As noted above, summers tended to be wetter than winters in the 19th Century and of the 22 lower ratio values, 12 date from the period between 1852 and 1900. At 15.1 °C, the summer of 2005 ranks equal 17th with 2001 and 2002. 2004 ranks =11th and 2003 1st, indicating just how warm summers at Durham since this decade have been.

The (estimated) mean air temperature of 14.1 °C for **September** makes it one of the warmest on record at Durham since 1850. It ranks 8th highest on record, the highest since 1999 (which ranks 3rd). Unusually, apart form 1999, none of the other very warm Septembers have been recent: three years from the 1890s and two from the 1940s rank above September 2005, plus 1865. The warmest September at Durham was in 1949 (15.3 °C). September was a little wetter than average. The wettest day was the 8th with 15.2 mm with 30 mm on the 7th and 8th combined. Despite the rainfall, sunshine was a little above average too, with the cumulative sunshine total approaching the average figure for the first time since January. **October** was a mild, wet month, typically autumnal except perhaps for being less windy than normal. All measures of temperature were well above average. Mean daily maximum was the 5th highest on record since 1950 while mean daily minimum was the 2nd highest on record since1950. Overall, mean air temperature was the 3rd warmest on record since 1850, beaten only by 1969 and the record holder, 2001, which was a whole degree Celsius warmer than October 2005. October rainfall was well above average, though not exceptional by any means. Not surprisingly, sunshine was below average. The wettest day was the 13th with 13 mm, but 12.8 mm on the 12th must also be noted, falling in a very short time and causing localised flooding. **November** was a cool month by recent standards, still a little above the 1961-90 average, but nevertheless the coolest since 1998. It was, in many ways, a more traditional November, some colder air mixed in with the milder westerlies. An indication of the variable weather was that, in addition to 16 ground frosts, there were also 16 rain days. It was mild at the beginning of the month, but very cold later on. The daytime maximum on the 23rd was only 2 °C! The changeable weather was also reflected in the rainfall: wet at the beginning and very end of the month, but dry during the cold period. The three- and six-month totals rose above average for the first time in several months (since April and January respectively), but the 12-month total remained well below average (where it had been since August). Sunshine was above average; indeed there were more hours of bright sunshine than in October. This brought the cumulative sunshine total for 2005 almost back to the average level. There was a notable gust on the afternoon of the 11th which was a very windy day indeed: 107.4 km/h [58 kt] from a southerly direction.

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Mean maximum	8.3	7.2	9.5	11.6	14.9	18.4	19.8	20.1	18.2	14.8	9.6	7.3	20.1
Mean minimum	2.7	1.3	3.7	4.1	6.2	10.0	11.8	10.8	10	8.9	2.4	1.2	1.2
Mean air temperature	5.5	4.3	6.6	7.9	10.6	14.2	15.8	15.3	14.1	11.9	6	4.3	9.7
Absolute maximum	13	13.2	15.7	16	19.4	26.7	28.2	22.1	22.9	19.4	15.6	12.7	28.2
Absolute minimum	-2.2	-2.4	-2.7	-1.2	-0.8	1.4	7.9	7.6	2.9	1.9	-4.6	-9	-9
No. ground frosts	8	17	12	11	1	0	0	0	1	1	16	18	85
Rainfall	34.2	32.4	45.6	66.4	19.8	38	72.8	37.1	63.8	74.0	73.2	34.8	592.1
Highest daily rainfall	6.6	11.6	20	39.8	7	22.4	26.8	11	15.2	13	11	9	39.8
No. rain days	11	12	12	10	12	8	12	8	10	13	16	13	137
Sunshine hours	56.7	60.9	64.9	144	164.6	152.8	135.4	180	145	81.8	92.8	53.2	1332.1
Max daily sunshine	4.6	5.2	7.6	10.8	11.9	14.1	12	6.9	9.8	7.3	6.6	5.2	14.1
Mean windspeed (kph)	20.7	15.9	15.0	16.1	14.1	10.2	9.1	10.6	13.7	10.7	14.1	11.1	13.4

Autumn rainfall (211 mm) was a little above average (44th wettest in a series of 156). In contrast, the April-October rainfall total (298 mm) was a little below average (333 mm), reflecting drier months in late spring and summer. In terms of temperature, autumn 2005 ranks =5th at 10.7 °C; 2001 lies 1st with 11.1 °C. The warmest 30 autumns include 10 since 1990; as with other seasons, recent warming is clear to see in the Durham record.

Like November, **December** was a mixed month: some very mild days in the middle but extremely cold after Christmas. The absolute minimum of -9 °C on the 29th was the coldest day in Durham since 4 March 2001 and the lowest December temperature for a decade. The temperature only reached -0.7 °C on the 7th. Overall, the temperature in December was above average, mainly because daytime temperatures were well above average, night-time temperatures being only marginally so. It ranks 99th warmest in a series of 156 years, but was the coolest this decade. December was a dry month, with only 61% of the normal amount. Sunshine was a little over average, but it was a calm month, with mean wind speed well below average.

Overall, **2005** was a warm year, 1.1 °C above average. Every single month of the year was above the 1961-1990 average. 2005 was the 6th highest on record since 1850, although the coolest since 2001. For the record, the warmest years on record at Durham (to two decimal places) are now:

2005	9.71
1990	9.75
2002	9.80
1949	9.83
2003	9.88
2004	9.96

Only 1990 and 1949 have rivalled the last four years therefore. The extraordinary warmth of the last few years is reflected in the fact that, if we take the average of every 10-year period (1850-59, 1851-60, etc.), then the last decade (1996-2005) is the warmest on record and the first to average 9.5 °C.

As it happens, the coldest 'decade' on record at Durham is 1879-1888 (7.7 °C); an increase of just over 1 °C in a little over a century does not sound much, but is in fact a huge increase compared to the 'historical' record. Moreover, an increase of 1.1 °C has occurred since the 1960s, a remarkable rate of warming. The mean maximum temperature for 2005 was 8th highest since 1950, while the mean minimum was 3rd highest. 2005 was a dry year, but not remarkably so, only 112th driest in 154 years, and some 40 mm wetter than the rather drier 2003. Sunshine hours ended up just above average, having lagged behind for most of the year. It was a little windier than normal, but in this regard the most remarkable event was the damaging winds on 8th January.

WEATHERVIEW: JANUARY 2006

RADNOR FOREST, MID WALES, U.K. 8 JANUARY 2006

By HOWARD KIRBY

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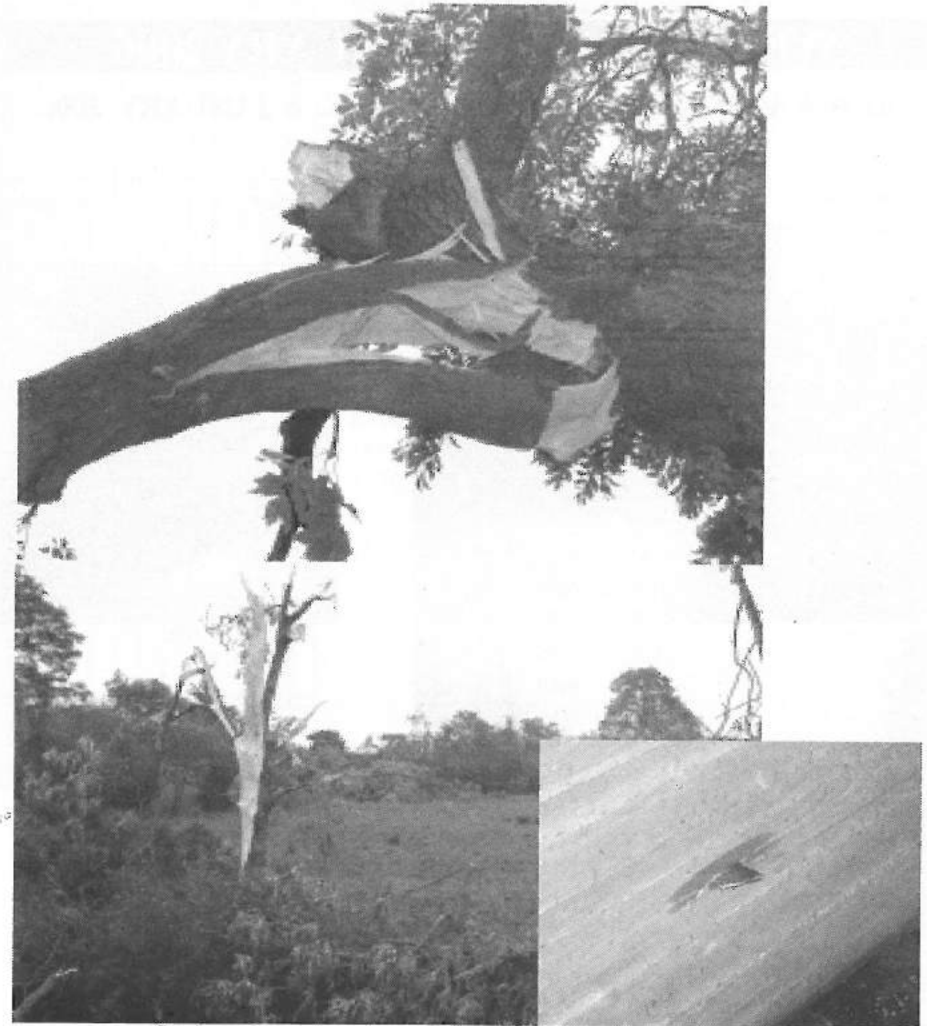

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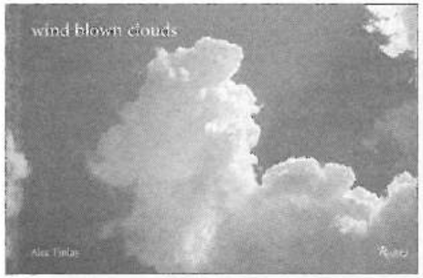
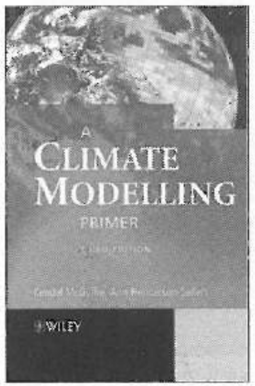


WIND BLOWN CLOUDS by Alex Finlay (2005) Rizzoli International Publications, Inc. New York. ISBN 0847827119 hb 175 colour photographs, 224pp £9.99

The author Alex Finlay began collecting photographs of clouds in 1999, inspired by the seventeenth century Japanese poet Basho's *The Road to the Far North*, with its beautiful description of being 'drawn like a wind blown cloud' on a wandering spring journey. *Wind Blown Clouds* is a collection of poetic images collected from people all over the world, from photographers young and old, experienced and amateur. The concept of the book is a very good one and I agree with the author that from time to time we need a reminder that we are all living under the same sky. However, this is not the best collection of cloud pictures I have seen. Even the sporadic 'poetic' annotations are not as poignant as one would have hoped considering the 'inspiration'. I am not sure this will be of great interest meteorologists as there is no reference to either cloud species or locations. In fact, this was never an intention, "*The archive appears as if it were a scientific project, gathering data that awaits classification; but there will be no such rational arrangement, for its purpose is poetic, utopian.*" This is art. Art, just like a thing of beauty, is in the eye of the beholder – the pictures are worth a browse if only to make up your own mind and form opinion on this collection. (RD)



A Climate Modelling Primer by Kendal McGuffie and Ann Henderson-Sellers (2005) John Wiley & Sons, Ltd. ISBN 047085751X pbk 280pp £34.95

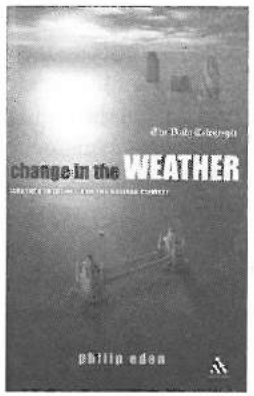
The third edition of this popular text has been thoroughly revised and updated and is designed to explain the basis and mechanism of all types of current physical-based climate models. This revised text does live up to expectation in helping the reader to understand the complexities and applicabilities of today's wide ranging climate models. Topics covered include the latest techniques for modelling the coupled biosphere-ocean-atmosphere system, information on current practical aspects of climate modelling and ways to evaluate and exploit the results.

Other model discussion includes Earth System Models of Intermediate Complexity (EMICs) and interactive exercises based on Energy Balance Model (EBM) and the Daisyworld model.

There are six chapters and three appendices. Chapter 1. *Climate* – examines the components of climate and climate change assessment along with the internal and external influences of climatic change. Chapter 2. *A History of and Introduction to Climate Models* – provides an introduction to climate modelling and the types of history of particular models. Chapter 3. *Energy Balance Models* – is entirely devoted to these aspect of climate modelling. Chapter 4. *Intermediate Complexity Models* discusses radiative-convective models and EMICs. Chapter 5. *Coupled Climate System Models* - looks at modelling the atmosphere, the ocean, the cryosphere, and land surface as well as elements of atmospheric chemistry. Chapter 6. *Practical Climate Modelling* – provides useful information in helping the reader work with climate models and model evaluation. All chapters have both recommended reading and suggested web resources.

Appendix A presents a very clear and reference list divided into appropriate sections and Appendix B is a glossary of key terms and abbreviations. Appendix C is a short paragraph about the accompanying CD ROM. The CD ROM is one of its greatest strengths and is a perfect accompaniment to this text. The CD is a well composed collection of images, movies, links and programs which will help the reader apply and understand the concepts discussed in the text further. All the figures which illustrate the book are on the CD and there are movie animations of the ocean circulation and atmosphere along with results from the GENESIS climate model which all make fascinating viewing.

It's always good to find a text on climate and modelling that is designed to be thoroughly used. This text is ideally priced, easy to read and is accompanied by an excellent CD ROM and Internet links for further reference. This text and CD are perfect for undergraduates studying meteorology and climate modelling, economic forecasting, computer science, environmental science and geography and oceanography - it is perfect for both students and teachers. It also has very high relevance to professionals working with climate models and those with a keen and general interest in climate. Well recommended. (RD)

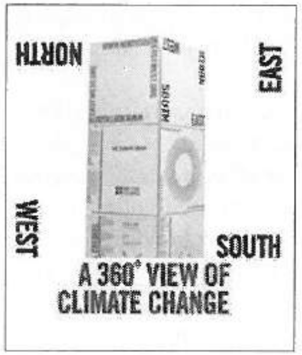


CHANGE IN THE WEATHER; WEATHER EXTREMES AND THE BRITISH CLIMATE by Philip Eden (2005) ISBN 0-8264-7973-1 Continuum, London hb pp214 £16.99

The Sunday Telegraph has long been my Sunday paper of choice because of Philip Eden's weekly weather items. This book, sponsored by *The Daily Telegraph*, is based on those articles. The vast majority of the book is devoted to a survey of the four seasons. For each month, the author has tabulated the average mean temperature, rainfall sunshine, and snowfall/thunderstorms (depending on whether it is a winter or summer) for each decade of the 20th century as well as for the last two decades of the 19th century, and the first half-decade of the 21st century.

He then details the *Disaster, Heatwave, Flood* etc of the century that fell in that particular month. The book starts with two introductory chapters on British climate generally, and ends with two chapters on the important weather events of the first five years of this century, and a series of articles Philip has written over the years about global warming. There is an excellent *Index* and the book is up to date enough to deal with the Boscastle Flood.

This is an attractive and informative way of describing climate change and written in a non-technical style for non-specialists, this book nevertheless very clearly paints a picture of an ever changing, but undoubtedly warming, climate over the UK. I unreservedly recommend this book to all readers of this Journal. (PR)



NorthSouthEastWest A 360° VIEW OF CLIMATE CHANGE published by THE CLIMATE GROUP, MAGNUM AND THE BRITISH COUNCIL (2005) (No ISBN quoted) hb pp184 £35

This large format book has been sponsored by those mentioned above, together with HSBC, DEFRA, The United Nations Foundation, the Rockefeller Brothers Fund and others and was published in order to raise public awareness of the increasing problems posed by Climate Change. The result is a book consisting of contributions from ten guest contributors, writing about 12 locations illustrated by both black and white and colour photographs taken by ten photographers from the celebrated Magnum Agency. The contributors include some very distinguished names: Kofi Annan, the UN Secretary General; Tony Blair, Mary Robinson and Sir. Arthur, C. Clarke. The topics range from *Physical Environment*, through to *Human Rights*, *Food*, *Health*, *Urban Life* and *Economy to Leadership*, and the countries used to illustrate these themes range from Greenland, The Marshall Islands, Japan, China and India to Mexico City, California, the UK/Germany/New York City.

Each of these invited contributions are short - usually a page or two at the most but there is a valuable linking commentary from Paul Brown. The photographs are stunning, as is to be expected from Magnum photographers. Apparently, those used to illustrate the book were chosen from the 1,000 or so that were taken for the project. Some of the facts unearthed by Paul Brown are extremely disturbing. For instance, he tells us that the rapid increase in the size of Mexico City during the last fifty years has raised average temperatures between 4° and 5° C. On the other hand, it is encouraging to realise how hard Japan is striving to find viable alternatives to the burning of fossil fuels by the development of technology. This book is clearly intended to be a "wake-up call" for the world's decision makers, but, beautifully produced though it is, the format is difficult to handle, with both text and photographs printed at right-angles to the conventional way for no good reason that I can see, and the price (£35) is certainly high. At present the book can only be ordered direct from The Climate Group at www.theclimategroup.org. or The British Council at www.britishcouncil.org though doubtless it will soon become available at other places online or booksellers. (PR)

THE INTERNATIONAL JOURNAL OF METEOROLOGY
"An international magazine for everyone interested in weather and climate, and in their influence on the human and physical environment."

MEDIA REVIEW
by PAUL DOMAILLE

Running Time: 51 mins
Format: DVD
Requires multi regional player

For Aficionados of severe super cellular weather, Mike Hollingshead's "The Dream" is a must to watch. Highlights of Mike's 2004 chase season cover a number of locations in "Tornado Alley", mainly in Nebraska and Iowa.

The producer has successfully turned a number of video clips into something more than just a documentary. A clever introduction, subtle use of background music and good editing transport the viewer onto the Great Plains and right into the action. My only negative comment would be the shortage of spoken commentary, but having said that you are drawn into the hunt for tornadoes just as much as the cameraman was. Searching the base of massive supercells, seeking out any earthbound vortices, looking for the hint of a debris cloud, watching and waiting for the tornado chasers Holy Grail.

Amazing cloud structures are abundant, huge banded supercells with wall clouds seeming to touch the ground, trying to suck up all and sundry, rotating under the proverbial "Mother Ship", are accompanied by the surreal sound of birds twittering in the background. Baseball size hail, with the accompanying din from the car roof takes the viewer into the heart of the storm, thunder and lightning just adds to the atmosphere.

Tornadoes, which are the ultimate players in this fantasia, are certainly well accounted for. Ranging from the messy rain wrapped wedge, the archetypal fat cylinder to the slender rope tornado.

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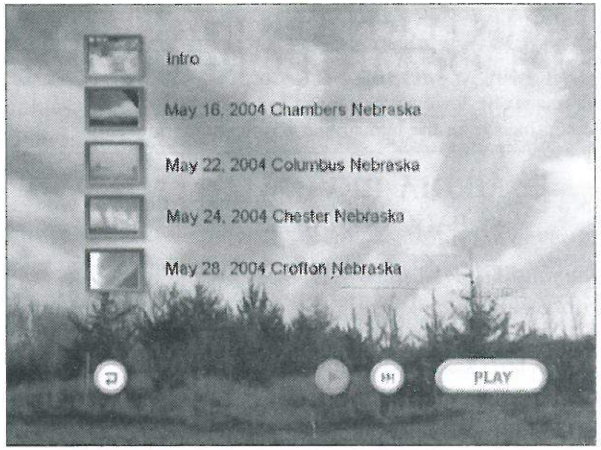
January 2006, Vol.31, No.305

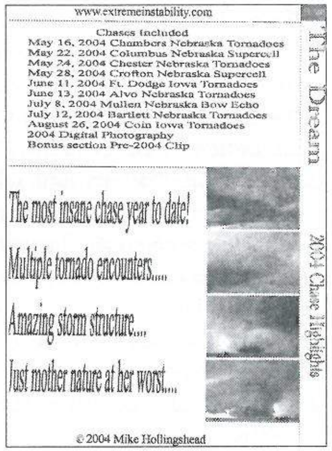


One scene shot in Alvo, Nebraska on the 13th June shows the brief appearance of three tornadoes, one disappearing leaving two "sisters" to form into a spectacular short lived double helix.

The film also hints at the dangers of chasing tornadoes through areas of heavy precipitation, when visibility is reduced to 20 or 30 metres and also highlights the importance of being strategically placed to catch the best action.

The penultimate 10 minutes are devoted to a sequence of still shots including all the cloud features one could wish for and as an added bonus some spectacular aurora images. The final 3 minutes cover highlights of pre 2004 chase trips including one wonderfully eerie scene when day was turned into night.

I think Mike would consider 2004 a successful chase season and that his dream came true, however, I am sure he has been out there again looking for bigger and better if that is possible! The DVD is available online at http://extremeinstability.com or by post from: Mike Hollingshead, 1304 Grant #7, Blair, NE 68008, USA. Price $25 p&p free



THE INTERNATIONAL JOURNAL OF METEOROLOGY

(*top*) Frost and mist, nr. Rugby, Warwickshire, U.K. November 2005 © Fernando Osborne
(*bottom*) Lenticular sunset, North Yorkshire, U.K. November 2005 © Laura Gilchrist

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