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CONTENTS

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SIZE FUNCTIONS IN THE STUDY OF THE EVOLUTION OF CYCLONES

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Abstract: This paper describes a framework for studying the structural evolution of tropical cyclones based on geometrical topological shape descriptors known as size functions. The most widely used technique to interpret different cyclone patterns from satellite images is the Dvorak technique. This technique relies on human judgment and is, therefore, subjective. Size functions are proposed for automating this technique. The advantages are twofold: size functions are robust and can be determined from the qualitative aspects of shape; the second advantage lies in its modularity.

Keywords: Cyclone, Cloud Intensity Patterns, Dvorak technique, Size Functions.

INTRODUCTION

In the past few decades, the advancement of satellite technologies has vastly improved our understanding of distant objects like the identification of cyclonic cloud intensity patterns. The morphological characteristics of these patterns provide invaluable insight into the physical processes involved in their formation and subsequent evolution. However, these objects are poorly observed by conventional data sources. Remote sensing is the only available method to study their morphological properties. The full morphological description of these objects requires an understanding of both geometrical and topological characteristics. Shape descriptors have been used to characterize the morphology of different objects. Fourier descriptors and chain codes are conventional shape descriptors for identifying 2D shapes. However, natural objects like cyclonic cloud intensity patterns (Figure 1) do not have a well defined shape (Figure 2) and, therefore, are not amenable to characterization using such simplistic measures.

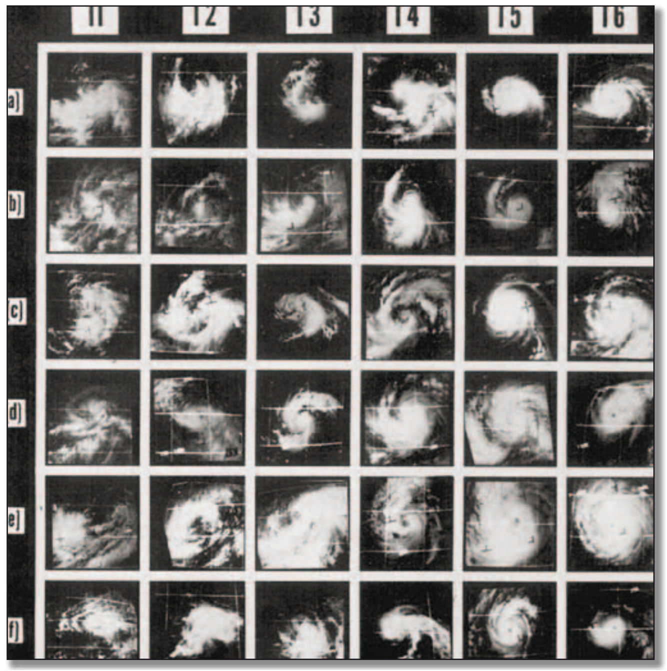

Figure 1. Cyclone evolution images (adapted from Dvorak,1975).

In this note, the author attempts to use a new type of shape descriptor, namely the size function (Frosini, 1991; Verri *et al.,* 1993) to identify the characteristic shapes of the cyclonic cloud at different stages of its evolution. Size functions are based on geometrical-topological characteristics of shapes and can thus handle qualitative rather than quantitative aspects of shape description. An additional advantage is its strong modularity. Size functions are defined with the help of a measuring function which maps the 2D shape to the domain of natural numbers. The choice of measuring functions is essentially problem dependent - thus one has the flexibility of using a new shape descriptor every time. Size functions have been employed in leukocyte classification (Ferri, Lombardini and Palloti, 1994) and tumor cell identification (Micheletti and Landini, 2003).

A brief overview of cyclone cloud intensity patterns and the technique for classifying its evolution follows. Then, an overview of related work is portrayed. The basic theory of size functions is then given, followed by a discussion of size functions. The experimental details are then provided and a discussion of the results and future work concludes the paper.

CYCLONE INTENSITY ANALYSIS: DVORAK TECHNIQUE

Tropical cyclones, or hurricanes or typhoons are low pressure systems that form in the tropical regions having well defined clockwise wind circulations in the southern hemisphere and anti-clockwise in the northern. The circular eye of a tropical cyclone is an area characterized by light winds and often clear skies. The eye is surrounded by a dense ring of cloud known as the eye wall where the heaviest winds and seas are located.

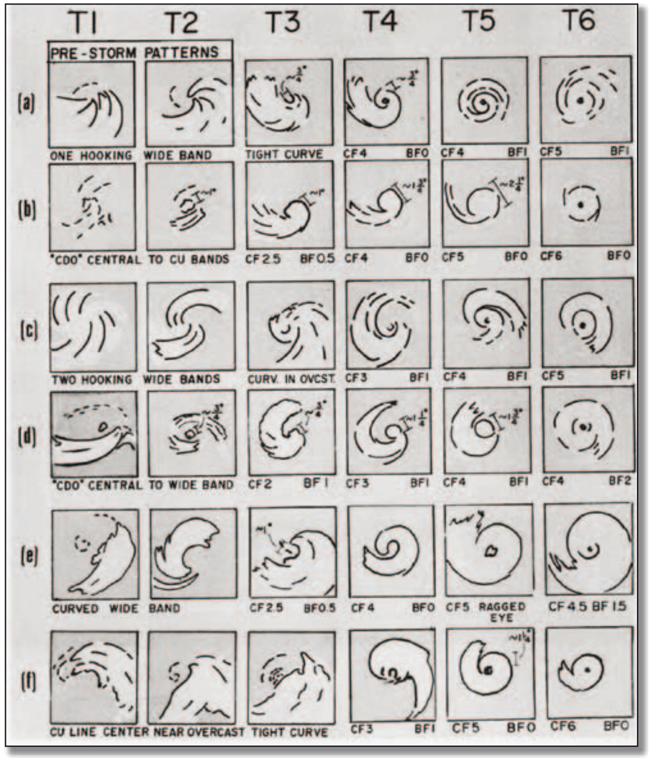

Figure 2. Contours of images of Figure 1 (adapted from Dvorak, 1975).

One of the widely used techniques to estimate the movement and intensity of tropical cyclones from satellite images is the Dvorak technique (Dvorak, 1975), which assigns a wind intensity value (called TC number) based on the size, shape and vorticity of the dense cloud shield adjacent to the centre of the storm. Due to the high variation of cloud patterns and lack of efficient scene analysis techniques for the isolation and extraction of cloud systems from satellite pictures, the TC pattern matching jobs have been mainly done so far by subjective human justification, although the automation of this technique is an active area of research (Griffin *et al.,* 1992; Woods, 1994; Wong *et al.*, 2004; Yip and Wong, 2004; Wong, Yip and Li, 2007; Lai *et al.*, 2004; Zhang, Lai and Sun, 2006; Li and Liu, 2001; Pineros, Ritchie Tyo, 2008; and Pao and Yeh, 2008). Efforts to automate or semi-automate the TC eye fix process fall into two categories: pattern matching and wind field analysis. In pattern matching, a TC eye is fixed by finding the best match between predefined TC models and remote sensing data. The model consists of a set of curves depicting tropical cyclone intensity change with time and cloud feature descriptions of the cyclone at intervals along the curves. Although the tropical cyclones viewed in satellite pictures appear in a variety of patterns, most can be described as having a comma or a rotated comma configuration.

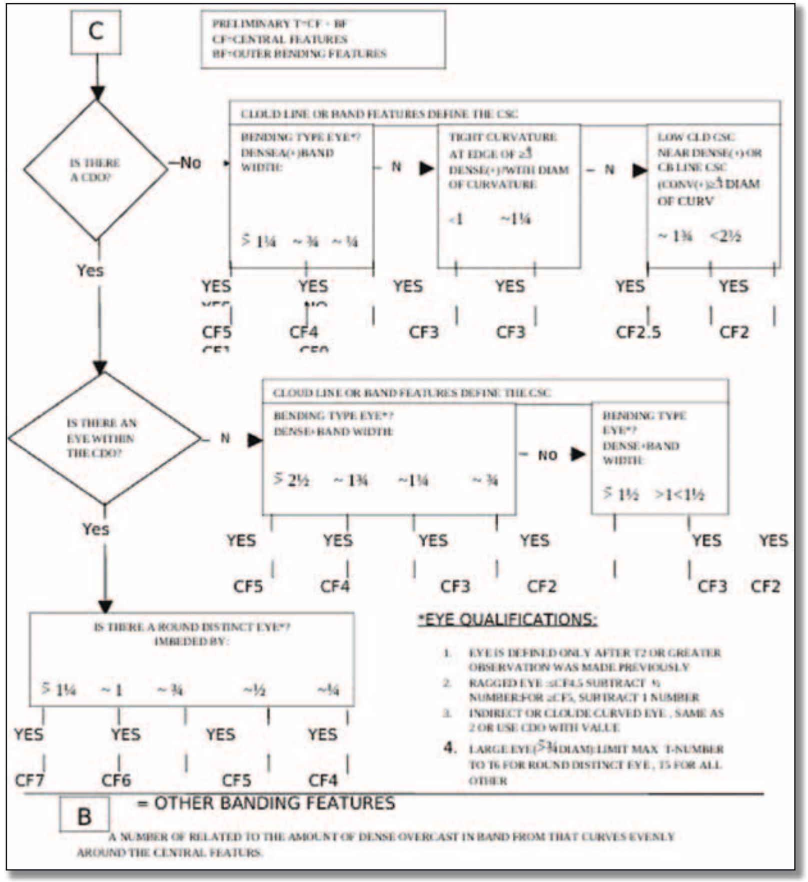

Figure 3. Dvorak Analysis of cyclonic cloud intensity patterns Dvorak (1975).

The cloud feature descriptions contained in the model describe the characteristics of the cyclone that are used to estimate both its present and future intensity. The cloud features used to estimate cyclone intensity at a time are the "central features" and "outer banding features" (Figure 3). Analysis of these features comprise a three stage procedure to assign T numbers to a disturbance using a qualitative description from Figure 2 and a quantitative description from Figure 3. The pattern of the comma usually consists of a combination of convective cloud lines that cluster and merge together, and cirrus clouds. The merging end of the comma either hooks inwards or curves broadly around a central core of clouds. These core clouds may be regarded as the head of the comma or may appear as curved cloud lines, or another smaller comma configuration or a dense overcast cloud mass. With the increase in intensity of the cyclone, this configuration appears to be more circular with the core clouds increasing in amount and density.

The cloud features related to cyclone intensity are the central features (CF) and outer band features (BF). CF appears within the broad curve of the comma and can either surround or cover the cloud system center (CSC). BF refers to only that part of the comma cloud band that is overcast and curves evenly around the central features. CF, BF and an implied cloud depth parameter taken together comprise the T-number description of the cyclone.

Central Features (CF)

The CF portion of the intensity estimate depends on the size, shape and definition of the central features as well as the amount of dense overcast associated with them. Three cases might arise (Figure 3), as described below.

(a) When the innermost cloud lines of the disturbance are visible, indications of cyclone intensity are inferred from cloud features showing the definition of the CSC and its association with deep layer convection. These include the distance between the low cloud centre and adjacent dense cloud mass, the pattern and depth of convection in the curved cloud lines defining the centre, the radius of curvature of the innermost deep layer convective cloud lines or bands, and in the characteristics of the eye and band encircling it.

(b) When a central dense overcast (CDO) covers the cyclone's central cloud lines, its characteristics are used in the intensity estimate. CDO is the mass of clouds embedded within the curvature of the comma cloud band. The CDO can be angular or oval shaped or irregular. As the cyclone intensifies the CDO becomes rounder and smoother in texture.

(c) There might be an eye within the CDO. The cyclone eye can either be a banding type eye or an eye embedded within a CDO. In both cases, there is an increase in the amount of dense overcast surrounding the eye and is decreased for ragged, large or cirrus-covered eyes.

Outer Banding Features (BF)

The BF adds to the intensity estimate of the cyclone in proportion to the amount and circularity of the dense overcast in band form that curves around the central features. When the cloud features of a cyclone are poorly defined in the imagery, changes in the overall cloud pattern can be used to infer variations in cyclone intensity. An increase in intensity is revealed in an increase of circularity of the CF and BF.

The features described in this section are summarized in a flow chart in Figure 3.

RELATED WORK

Efforts to automate the TC determination process fall under two categories: pattern matching and wind field analysis. This section describes the pattern recognition based efforts.

One of the earliest attempts have been to automate the TC detection technique by Griffin *et al*. (1992), where the TC centre was defined as the geometric centre of the TC eye wall. Woods (1994) used an axisymmetric hurricane vortex flow model to locate the ideal TC. Wong *et al.* (2004) modeled the spiral rain-band of a TC by a polar equation:

$$r = \theta e^{\cot \alpha}$$

Yip and Wong (2004) improved this model using additional parameters to limit the extent of rain-bands and used Genetic algorithms to speed up the search of the parameter set for the best match. A novel motion field structure analysis method to locate TC eyes more accurately (Wong, Yip and Lee, 2007), has also been described in the literature. Lai *et al.* (2007) have used feature based matching and neural networks to perform the location of a tropical cyclone centre automatically and intelligently. After pre-processing of satellite images, Zhang, Lai and Sun (2006) used some helix matching based procedures and models to detect the centre of a tropical cyclone according to its natural shape. Subsequently, they employ a rotation matching method based on the spiral movement feature of cyclone clouds. Pineros, Ritchie and Tyo (2008) propose a technique using gradient vectors for obtaining features associated with the shape and dynamics of cloud structures embedded in tropical cyclones. Lee and Liu (2001) have proposed an elastic graph dynamic link model (EGDLM) based on elastic contour matching to automate Dvorak's technique. Morphology and statistical image classification techniques have been used by Pao and Yeh (2008) to locate the centre and contours of typhoons.

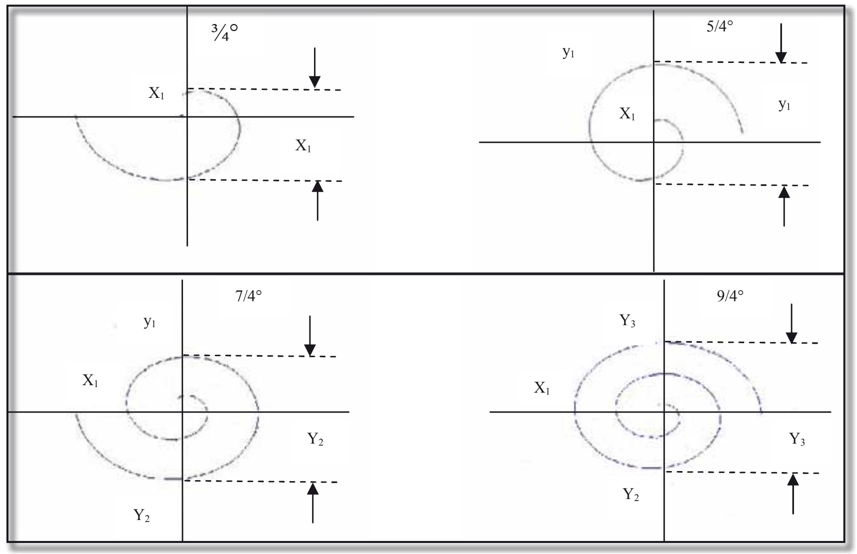

Figure 4. Computation of Size Functions.

SIZE FUNCTIONS

Size functions are (Frosini, 1991; Verri *et al.*, 1993) shape descriptors which are integer valued. The idea underlying the concept of size functions is that of setting metric bounds to the classical notion of homotopy, i.e., of continuous deformation. Representation of size functions can be tailored to suit the quantitative and qualitative invariant properties of the shape to be studied.

The goal of the theory is to produce a representation of the shape of a planar curve. The theory is based on two fundamental concepts: a real valued function defined along the curve, called a measuring function and an integer-valued function of two real variables called a size function. The size function encodes information about the shape of the curve by looking at the behaviour of the measuring function along the curve itself. A size function has a number of interesting properties:

1. It can be used to distinguish the shape of topologically equivalent curves.
2. It is robust against small continuous changes of the underlying curve.
3. It can be used to establish a distance between shapes.
4. It can be computed from a discrete approximation of a curve.
5. It can be generalized from curves to surfaces of arbitrary dimension.

SIZE FUNCTIONS USED FOR CYCLONE IMAGE ANALYSIS

The two measuring functions are used in this framework. The first one corresponds to the comma configuration representing the CF and surrounding the eye and is modeled as a spiral helix:

$$p = \alpha e^{b \cot \theta}$$

where a and b are constants determined from the helical configuration. This configuration is bounded by an eye wall. The bounds (metric obstructions) are obtained as follows: The right half plane is considered and the bounds are decided by the intercepts of the comma and associated banded configurations on the y-axis. Thus, when the curve has covered ¾° the intercept is x_1; the lower bound. When the curve has covered 1¼° the intercept is y_1; the upper bound. There is one connected component within these bounds and so the CF size function is $l_1(x,y) = 1$. When the curve spirals further to 1¾°, the intercept is y_2, and $l_1(x,y)=2$, and so on. These concepts are illustrated in Figure 4. The corresponding size function graph is given in Figure 5.

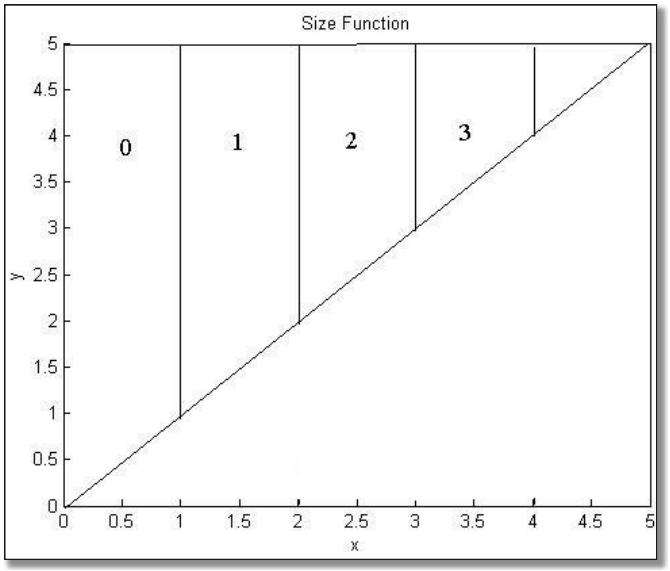

Figure 5. Size Functions.

The second measuring function related to BF, which is a number related to the amount of dense overcast clouding in band features. The bounds of the measuring function are determined by concentric circles with a barycentre corresponding to the centre of the cyclone's eye. The inner circle corresponds to the eye wall of the CF comma configuration whereas the outer circle corresponds to the outer boundary of the cyclone. Thus for BF0 (i.e. when little or no banding occurs) there are no connected components observed the BF (for BF1) size function is $l_2(x,y)=0$, when one band is observed $l_2(x,y)=1$ and for BF2, $l_2(x,y)=2$.

RESULTS AND FUTURE WORK.

This framework has been applied to the test contours (Figure 2) of the cyclone images (Figure 1). Table 1 summarizes the results and gives values for size functions and corresponding T numbers (T=CF+BF).

Table 1. Size Function for CF patterns
(corresponding to the patterns of rows a-f of Figures 1 and 2).

Row number	T number	l_1	l_2	$l = l_1+l_2$
a	4	1	0	1
a	5	2	1	3
a	6	3	1	4
b	4	2	0	2
b	5	4	0	4
b	6	1	0	1 (CDO central)
c	4	2	1	3
c	5	3	1	4
c	6	4	1	5
d	4	2	1	3
d	5	3	1	4
d	6	3	2	5
e	4	3	0	3
e	5	3	0	3 (Ragged eye)
e	6	3	1	4 (Irregular band)
f	4	1		2 (No eye)
f	5	3	0	3
f	6	4	0	4

Results indicate that there is a correspondence between size functions and T-numbers except in the three cases where there are irregularities as indicated in the table. In 80 % of the contours, there is an unit increase in the size function for unit increase in the T number, and there is an increase of 2 units of 10 % in the size function value for the unit increase in T-numbers. In the remaining cases, corresponding to CDO (Cloud Dense Overcast) and ragged eye/irregular band, there is no increase in the size function. This is to be expected, as the presence of CDO or irregular eye potentially leads to a fading of the cyclone intensity. Thus preliminary results are encouraging. These size functions can, therefore, be used to help automate the process of the cyclone shapes during its various stages of evolution. As size functions are based on qualitative descriptions of shape, they are robust to noise and possess the feature of modularity. Hence, they are very useful for modeling the irregular shapes.

Future work will be aimed at experimenting with numerous cyclone image sequences to standardize the procedure. Also, since a cyclone is a natural phenomenon, there are many variants of the above structures. Experiments will be performed with these shapes too, to develop a unifying framework.

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SHORT COMMUNICATION

ORISSA TORNADOES: SELECT DISCUSSIONS

By DR. DEEPAK BHATTACHARYA[1], DR. DWITIKRISHNA PANIGRAHI[2], and DR. PRAHALLAD, C. NAIK[3]

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In May, during the year 2005, a tornado was recorded in the western fringe of Bhubaneswar city (20.15°N/85.52°E), Odisa, known as Ghatikiya. No loss of life or property was reported. Farm land was marginally affected. Figure 1 is a scanned image of the said member when it had full scope form *(©The Dharitree,* 2008*)*. On that date in the following hours, a severe storm had hit the city centre, which was to the southeast of this tornado's location. This is the visual record of the said tornado (land born, of short duration land-to-land wind storm, and virtually bereft of rain) in an otherwise very severe cyclone prone coastal area of Orissa which suffers severe rain associated events. We can see the background is bereft of cumulus clouds, while the stem of the tornado is connected to a patch of black cloud. The base is churning up large volumes of dust/sand and is rainless. The top mid-portion is visually less opaque i.e., it is the less dynamic region in the whole system, which is why, the structure bends therein. Although the tornado is around a kilometer away from the camera, the structure of the tree does not suggest a wide wind-field. The event progressed over near-flat land which is covered with deciduous shrubs. Bhubaneswar is a core cyclone region.

Figure 1. The Odisa tornado fully formed, May 2005. (© The Dharitree, 2005).

The tornado is a completely different meteorological structure to cyclone which often strike land in this area and not much is known about tornadoes in this area of the world.

Figures 2 and 3 are that of another more well recorded event of 31 March 2010 in the village of Ganga, in the district of Jagatsingpore, Orissa (*The Samaya,* 2009). In Figure 2 we see a diesel jeep has been hurled away from the road with its rear lifted. In this event, there were extensive human and veterinary casualties, along with property loss. Both the tornado events were less than 15 minutes in duration. In Figure 3 we see a tractor has turned upside down. Both are iron made machines and weigh over half a metric tonne each. To the naked eye there is an apparent visual dimension in Figure 1 that suggests a narrow cross section.

The results one can conclude from Figures 2 and 3 suggest that inspite of a narrow cross section, a tornado (within the stem) inflicted a 'lift' to the object(s) irrespective of their weight. Such 'lift' phenomena was not encountered even during the event of the Super Cyclone of October 1999, but this is because tornadoes are indeed more localized events with the power to cause such damage to heavy mechanical devices (is the known position).

Figure 2. A photograph of the lifted car, displaying the power of the tornado. © The Samaya (2009).

Mechanics of roof blow-out has been explained by Bhattacharya (2010). In this instance two rooms, hutments and even concrete structures with ajar door and windows suffered, while those which were all firmly shut from within (by owners), were not affected. However, the vehicles that were overturned remains to be explained. We examined published literature, interviewed a wide range of experts and field examined the events. Though a fair knowledge is known about damage caused by tornadoes, in this instance, much is still confusing in terms of what actually happened in this particular event. However, we may conclude the following: Firmly grounded vehicle implements (excluding *Sagadas* - bullock carts), fishes, bovines and other ruminants were lifted and thrown and damaged into many parts. Those which did not have inflated tyres or large air-way systems, however, were not affected. Human casualties indicated extensive pulmonary rapture, cerebral hemorrhage and asphyxiation.

It is known that the stem of a tornado develops an atmospheric low, sometimes in the order of 800-600 hPa. The tyres have a positive pressure ~ 32 psgi (normal atmosphere). 1 psgi=6.894757 (say 7) hPa. So the gross contrast between the inflated tyre's interior coupled with that of the transient low created by the tornado works out as (32 x 7) = 224 hPa + 200 (1000-800) = 424 psgi less than that of the mean sea level pressure. This therefore could make the trapped air within the tyres act as compressed air bubble(s) locked in a fluid bed. Compressed air tries to come out at a force of 424 psgi.

This imparts very high buoyancy to the inflated wheels and inflicts a rotary motion in order to gain the preferred positioning (in relation to the atmospheric column pressure). Bulk mass modulus shifts and the centre of gravity alters in a reverse manner along the vertical. The item then becomes airborne. In the case of the jeep, the rear becomes relatively more buoyant. In the case of the tractor, the large wheels could play this decisive role. A combined play of the principles of Pneumatics, Fluid Mechanics and Brownian motion manifests in nature.

Items of high weight/specific-gravity cannot become buoyant in boundary conditions with no boundaries. Boundaries are needed for Newton's Third Law to operate which in non-compressible fluid manifests as Pascals. Acute barometric gradient generates cylindrical boundaries around a conical stem, with fluid motion in inertia, towards the enstrophy point, as 'updraught' (top dark hood - Figure 1). Psgi force then acts upon and assumes the weight (for instance, the tractor's). This then seeks redistribution centrifugally (weight versus thrust), more intently due to the 'low' and the 'Newtonian fluid bed'. Firm boundary limits centrifugal distribution of weight; vectors vertically (2nd Law). Inertia additionally fails redistribution; and is also an antidote to the 3rd Law. Psgi thrust gets conserved as propulsion, the item becomes aerodynamic and 'lifts'. Mechano-structural alteration results in 'throw' and a 'smooth landing', respectively (the jeep's hind/trailer). High psgi force with relative large mass down-regulates gravity efficiently (e.g. a space shuttle).

Figure 3. Picture showing the over-turned and highly damaged field machinery. © The Samaya (2009).

Tornadoes can occur along coastal Odisa during and extending from the spring equinox to the onset of severe summer (May). The Orissa coastal region thus is possibly prone to either form of atmospheric phenomena. This suggests the creation of meteorological fronts, about which there are no known records or knowledge of their causes. All such findings delight the scientists' minds. This is first time an event of this nature has been reported and recorded.

In March (2010) a tornado with a prominent damage track was reported to have struck the northern coast of Orissa (Balasore) in the *Dak* editions of the vernacular newspapers. We believe therefore that the entire coastal belt of Orissa (the eastern seaboard of India) is as prone to both forms of atmospheric severe weather events individually: cyclones and tornadoes.

From these short examinations of the tornado event in Orissa, we strongly advise that more research of this nature should be conducted in order to understand the nature of tornadoes and cyclones in India which in turn should aid forecasting these events, and education, especially considering the fact this is the first known report of a tornado of this magnitude (not dissimilar to USA events) to be recorded in any journal world-wide. In this article we have aimed to lay an explanation to the physics of 'lift and throw' of such heavy material in this instance by such a small bodied cross-section of compressible turbulent flowing fluid system(s). India is much more commonly struck by cyclones than tornadoes, and any tornado event that has ever occurred previously have not been researched and did not have the 'lift and throw' characteristics of the tornado examined here. The Super Cyclone of 1999 occurred in the same region, but being different meteorological phenomena, showed no comparable 'lift and throw'.

This event was so unique to Pan India historically, that even Apex Indian National Leaders visited the affected area and were immensely shocked by their findings. On the whole, our population is educated about the much more frequent danger of cyclone activity and a tornado is much less understood.

In this light, such physics as put forth in this article, hope to help make predictions about the timing of tornadoes as well as their genesis; life and intensity; and the track of the tornado - a task that has defied all mental and instrumental efforts so far with respect to the scientific basis of 'lift and throw'. Therefore, Orissa itself could be offered as a candidate for commencing such research work to make tornadoes more understood for the Indian population, just as cyclones are already.

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NATURAL HAZARDS IN RELATION TO LANDSLIDES

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Abstract: Natural disaster like floods, tornadoes, tropical cyclones, heat and cold waves and landslides causes tremendous loss of property all over the world. Nearly 80 % of these natural disasters are related to weather directly or indirectly and damage from this is of meteorological and hydrological origin. Fatalities reported during the last decade due to extreme weather events complied by the WMO showed India as one of the five worst affected countries in the world. The present study aim at bringing out the essential pattern and features of hazard associated with landslides due to heavy rain over India. The synoptic factors shows that major events are occurring due to Land slides associated with heavy rain in Mumbai during July 2000 killing 65 persons and water logging.

Keywords: Natural disasters, Landslides, floods, Extreme weather events.

INTRODUCTION

Landslides are slippery masses of rock, earth or debris, which move by force of their own weight down mountain slopes or riverbanks. They are due to Geological weak material, erosion, intense rainfall, human excavation; earthquake shaking, volcanic eruption etc. The Indian subcontinent, with diverse physiographic, seismotectonic and climotological conditions is subjected to varying degree of landslide hazards. Removal of vegetation and toe erosion have also triggered slides torrential monsoon on the vegetation cover removed slopes was the main causative factors in the Peninsular India namely in Western Ghats and Niligiris, Human intervention by way of slope modification has added to this effect. Landslides are a major hydro-geological hazard affecting large parts of India from Himalayas to Northeastern hill ranges, Western and Eastern Ghats and Vindhayas. In the Himalayas alone, one could find landslides of every fame, name and description – big and small, quick and creeping, ancient and new. Similarly most of the northeastern region is bristling with landslides of a bewildering variety. Then, there are landslides in the Western Ghats in the south, along the steep slopes overlooking the Konkan coast. Landslides are also very common in the Nilgiris, characterized by a lateratic cap, which is very sensitive to mass movement. Land slides are often the cause of dislocation of traffic and casualty over in accessible areas in the Northwestern and Northeast parts of the country, associated with heavy rains causes extensive damage of crops, road/rail, and communication disrupted and deaths. De et al (2004) from worldwide data for the period 1967 to 1991 reported 238 events of landslides due to which 41,992 persons killed. According to them landslides comes under the category of Natural disasters indirectly related to weather events. In India, about 1,500 human lives are lost annually due to floods and heavy rains.

Landsliding is a general term applied to all surface movement of earth material under direct influence of gravity. Slides are initiated by events such as wave action, earthquake, heavy rains, artificial excavations etc. When a landslide occurs, it results in sudden translocation of earth materials from a higher to a lower elevation. Human activities such as disturbance of vegetative cover, excavations for buildings, highways and appurtenances, gravel pits and washing plants, mining and other activities may cause serious disturbance to the natural conditions.

This provides an important source for destabilizing the earth cover on slope. In India most of the landslides occur during the rainy season of the southwest monsoon. The passage of rainwater increases the soil porosity and sufficient amounts of soil particles are washed out. This creates unbalancing along the slopes, which subsequently culminates in landslides. A huge landslide occurred at village Gona on river Birehi Ganga on 22 September 1893, and 4 February 1968 at Reni on the bank of river Rishi Ganga. (Ray, *et al*., 2001). About 50 % of the occurrences of the landslide are found associated with loss of human lives.

Natural disaster like floods, tornadoes, tropical cyclones, heat and cold waves and landslides causes tremendous loss of property all over the world. Nearly 80 % of these natural disasters are related to weather directly or indirectly and damage from this is of meteorological and hydrological origin (Obassi, 2001). As per recent World Meteorological Organisation (WMO) review the total global losses (economical) as a result of natural disasters US $50-100 billion per year with loss of life about 250,000 (De, *et al*., 2005, a). During the period 1977-2001, India suffered significant loss of property and human lives each year due to weather related hazards such as floods, droughts, tropical storms, heat and cold waves (De, *et al*., 2005 b).

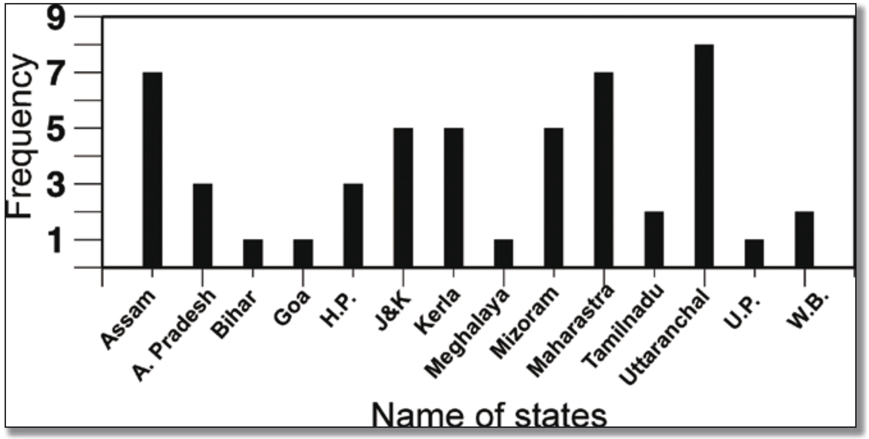

Figure 1. Frequency of landslides in India

DATA AND METHODOLOGY

Data on incidence of landslides are collected from the Annual Reports of Disastrous weather Events published by India Meteorological Department, Pune (IMD) for the year 1991 to 2005. The associated synoptic systems were also collected from the records of IMD. (i.e. Indian Daily Weather Reports). The India Meteorological Department (IMD) gives the weather forecasts in the spatial domain known as meteorological subdivisions. The daily weather reports are published on weekly basis for each of these subdivisions. The authors have compiled the data from annual reports of disastrous weather events and tried to find out their impacts and causes for their happening.

RESULTS AND DISCUSSIONS:

Landslides are generally reported from May to October with highest incidence in June and July. It is much less in May and is generally reported from northeastern state of India. The incidence gradually decreases in August, September and October. In the present study a total 51 cases of severe damages/death due to landslides were reported during the period 1991 to 2005.

The maximum frequency of landslides observed in Uttaranchal followed by Assam, Maharashtra, Mizoram, Kerala and Jammu and Kashmir (Figure 1) whereas sever damages/maximum deaths related to landslides due to rain have been observed in the state of Assam, followed by Uttaranchal, Meghalaya, Kerala, Maharashtra etc. (Figure 2). From the Figure 3, it is noticed that during the study period the maximum events of landslides (14) were reported in the year 2004 with maximum deaths (443) followed by 2005. In the years 1996, 1999 and 2002 not a single incidence was reported. Figure 4 shows the map of subdivisions used by IMD. The maximum incidences of landslides were reported during June and August followed by July. The most vulnerable areas to landslides are Himalayas and Western Ghats, due to tectonically unstable geological formations in Himalayas and having uplifted plateau margins respectively. A few typical cases of landslide and synoptic situations are discussed below:

i) A landslide in Assam in July 1991, 300 persons died, road and building damaged due to heavy rain and landslides. The main synoptic situations were as follows:

A trough between 1.5 and 3.6 km asl was extending from western Assam to north coast Andhra Pradesh. The embedded cyclonic circulations - one over northwest Bay and neighbourhood and another over east Arabian sea off north Maharashtra coast were located between 3.6 and 5.8 km asl. The trough on the sea level chart extended from south Uttar Pradesh to northwest Bay and thence to east central Bay. Another trough on sea level chart extended from south Uttar Pradesh to northwest Bay and thence to east-to-east runs from Uttar Pradesh to south Assam. Axis of monsoon trough on sea level chart was located through Anupgarh-Agra-Sidhi- Balasore and thence to east central Bay through center of low-pressure area. Under the influence of cyclonic circulation over north Bay low pressure area of the same area, associated cyclonic circulation extended up to 7.6 km asl. It is likely to concentrate in deep depression. Low-pressure area over northwest Bay and neighbourhood has concentrated in to depression and lay centred at 0830 hrs IST.

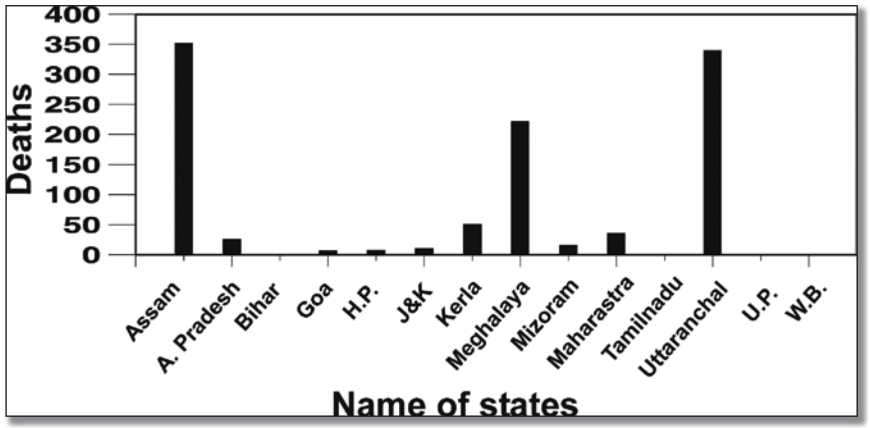

Figure 2. Deaths due to landslides.

A landslide occurred near East Khasi hills West garo hills and entire Meghalaya state during 7-25 October 2004, 209 persons died, 2256 cattle lost. The main synoptic situations responsible for this were as follows:

The depression close to Bankura moved in northeasterly direction and lay close to Sriniketan last evening, it now lay over Bangladesh and centered at 0830 hours IST of 8.10.2004 near 24.0°N / long. 90.0°E.

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The associated cyclonic circulation extended up to mid tropospheric levels over Uttaranchal and neighbourhood persists. The western disturbances as an upper air system extending up to 4.5 km asl lay over north Pakistan and adjoining Jammu and Kashmir. Low-pressure area lay over north parts of Bangla Desh and neighbourhood. The cyclonic circulation in the lower levels lay over west central Bay and adjoining north Andhra coast.

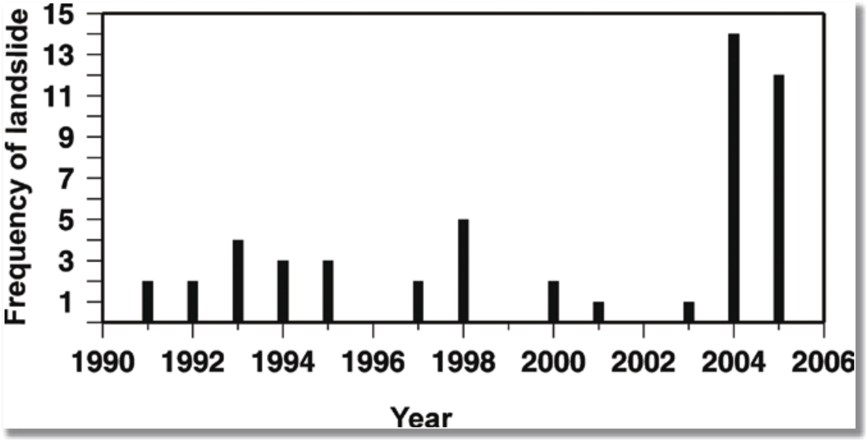

Figure 3. Yearly frequency of landslides.

Landslide at Malpa, Kali river on 18 August 1998: 210 persons killed. The heaps of debris created were about 15 m high. The two villages were wiped out the event. The synoptic situations were:

A cyclonic circulation was located over west Uttar Pradesh and adjoining areas of northwest Madhya Pradesh, east Rajasthan and Haryana. A western disturbances an upper-air system was located over north Pakistan and Jammu and Kashmir. The axis of monsoon trough on sea level passed through Ganganagar, Baharich, Rexaul, Dhubri and Khasi.

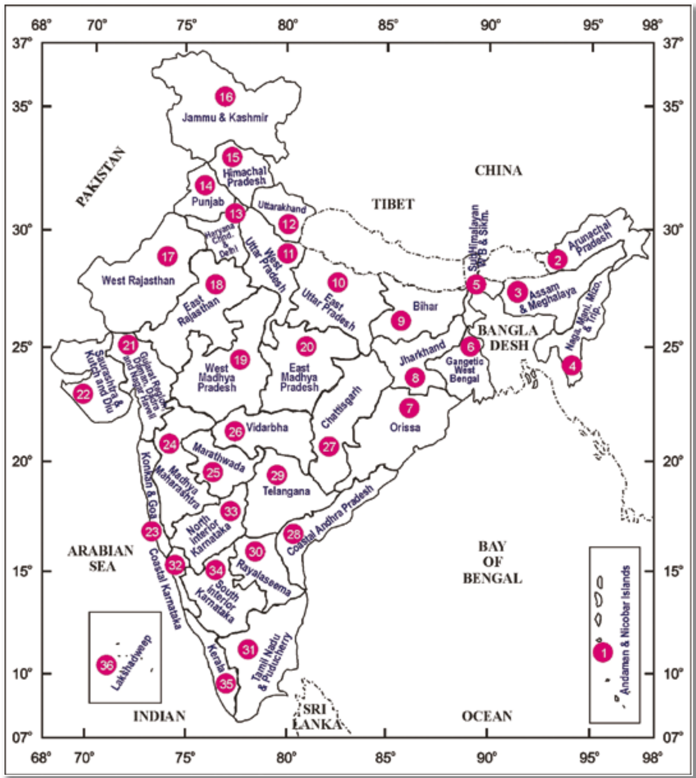

Figure 4. Map of sub division used by IMD (from weekly weather report).

© John Cameron
Ice on Rannoch Moor
(January 2011)

Both pictures © ***Dick McGowan***, USA
Bottom picture - "December Ice"

Landslide at Mumbai, Pune and Thane during 26 July – 5 August 2004: 33 people died and more than 50 injured. The main synoptic situations were as follows:

An off shore trough at sea level from Maharashtra coast to Karnataka coast persisted. The cyclonic circulation over north Maharashtra and adjoining Gujarat now lay over Gujarat region and neighbourhood between 1.5 and 7.6 km asl tilting southwest with height.

Mitigation

i) Hazard mapping will locate areas prone to slope failures. This will permit to identify avoidance of areas for building settlements. These maps will serve as a tool for mitigation planning.
ii) Land use practices,
iii) Retaining walls can be built to stop land from slipping.
iv) Surface drainage control works
v) Engineered structures with strong foundations can withstand or take the ground forces.
vi) Increasing vegetation cover is the cheapest and most effective way of arresting landslides.
vi) Insurance will assists individuals whose homes are likely to be damaged by landslides or by natural hazards. For new constructions it should include standards for selection of the site as well as construction technique.

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TORRO TORNADO DIVISION REPORT: JANUARY - MAY 2010

By PAUL R. BROWN and G. TERENCE MEADEN

January 2010 was a cold month with a good deal of frost and snow, especially in the first half: there were two reports of waterspouts and one of a funnel cloud. February was another cold month, but despite a very cyclonic second half, there were no confirmed whirlwinds. The first half of March was anticyclonic, but the second half was unsettled; this was another very quiet month for whirlwinds, having just one probable tornado. The first few days of April were cyclonic, but high pressure dominated the weather for most of the month, and the strong sunshine coupled with very low humidities produced several land devils; there was also one waterspout and three reports of funnel clouds (one of which was in the Irish Republic). May, characteristically, had a high proportion of northerly winds, but there was a westerly spell in mid-month, and an anticyclonic spell just after that: there was one probable tornado, one report of waterspouts, six funnel clouds, and again several land devils.

2WS2010Jan06/I *Firth of Forth (c 56° 11' N 2° 32' W, NT 6799)*

A photograph of this pair of waterspouts was published by *BBC Scotland*. It was taken from the coastguard station at Fife Ness at 1230 GMT, and shows two slender spouts descending from a shower cloud, from which dense precipitation shafts are also visible. They were said to have been travelling west towards the Isle of May. An account was also published in the *Courier* of the 7th January.

At 1200 GMT a cold northeasterly airstream covered the British Isles between a low, 997 mb, near the Channel Islands and a high, 1029 mb, in mid-Atlantic. There were wintry showers in the east, and some longer spells of snow in the south.

WS+2FC2010Jan06/II *Jersey (to NNE), Channel Islands (c 49° 20' N 2° 10' W)*

A vertical funnel cloud was photographed from Jersey Airport at 0930 GMT, which was estimated to be seven or eight miles (c 12 km) to the northnortheast, and confirmation was later received that it reached the sea; two smaller funnels were also reported (but not seen from the airport) – information from Mr Frank Le Blancq. Weather at the time was: temperature 2 °C, dewpoint 0 °C, sea temperature 8.5 °C, with scattered Cb clouds and showers of snow and soft hail.

FC/TN2010Jan31 *Paul, near Mousehole, Cornwall (c 50° 05' N 5° 33' W, SW 4626)*

The *Western Morning News* of the 2nd February reported that Ms Jenna Matthews had photographed a 'tornado' from the A30 road outside Penzance 'on Sunday afternoon', which she described as "… coming down to the right [i.e. south] of Paul …". We have not seen the picture, but John Pask of TORRO obtained a copy, which he described as "… a long, very well-defined, and very thin funnel/possible tornado. The base of the funnel is hidden from view behind the crest of a hill …". He considered that it must have come very close to touching down, if not actually doing so. At 1200 GMT a cold northwesterly airstream covered the British Isles between a complex low, 990 mb, near southwest Norway, and a ridge of high pressure in mid-Atlantic. There were wintry showers in the north and west, but other areas were mostly dry.

tn?2010Feb27 *Throop, Bournemouth, Dorset (50° 45' N 1° 52' W, SZ 1095)*

Information was received that the *Bournemouth Daily Echo* (1st March?) had reported the occurrence of tornado damage to roofs and aerials in the Throop district of

Bournemouth on the 27th February, but as no details have come to light (and we have not seen the original report), we cannot substantiate this. No time of day is known for this occurrence, but rainfall radar showed quite heavy showers passing through Bournemouth about 0600 GMT (on a minor trough), and again between 0730 and 0800 GMT. At 1200 GMT a complex area of low pressure covered the British Isles, with main centre, 985 mb, near northwest Ireland, and minor fronts and troughs moving north over England and Wales.

tn2010Mar25 *South Ockendon, Essex (51° 31' N 0° 17' E, TQ 5882?)*

Paul Sherman of TORRO reported that his brother-in-law had observed a probable tornado at 1730 GMT in Arrowdale Road*, South Ockendon. There were reports of a funnel having been seen, and of empty 20-foot containers moved about 50 feet. Force T1. At 1800 GMT a large low, 971 mb, was slow-moving to the southwest of Ireland, and a secondary of 991 mb was moving north over Wales. Its cold front, accompanied by a band of heavy rain, was crossing Essex.

* The only name we can find that bears any resemblance to this is Arisdale Avenue.

WS+FC2010Apr04 *Dunseverick (offshore), near Bushmills, County Antrim (c 55° 14' N 6° 27' W, C 9944)*

The *Belfast Telegraph* of the 6th April published a photograph taken by Mr Geoff Dunlop showing a pair of funnel clouds over the sea, one of which reached the water surface. The time was about 0745 GMT, and they remained visible for 15 minutes. At 0600 GMT a low, 1002 mb, was centred in the southern North Sea, and a ridge of high pressure was moving into Ireland; a frontolysing occlusion lay through the Irish Sea. There were scattered showers, mainly in northern and eastern Britain, but also near the north coast of Ireland.

LD2010Apr16 *Lymm, Cheshire (53° 23' N 2° 29' W, c SJ 676875)*

We heard from the Editor, Samantha Hall, that her mother witnessed a dust devil in Statham Avenue during the afternoon (probably between 1400 and 1500 GMT). It only lasted 10 seconds, but blew over a heavily-weighted canopy and dragged it a short distance. At 1200 GMT a large anticyclone covered the British Isles, with one centre, 1031 mb, in the Irish Sea, and another in mid-Atlantic. The weather was dry with a good deal of sunshine (although a veil of volcanic ash from Eyjafjallajökull in Iceland covered much of the country).

LD2010Apr18 *Bromesberrow Heath, near Ledbury, Herefordshire (51° 59' N 2° 23' W, SO 738315)*

Mr Craig Reynolds saw this land devil from a position south of Bromesberrow Heath (grid reference supplied by the observer) at about 1500 GMT. It lasted 10 minutes and caused damage to plant coverings in farm fields. At 1200 GMT a ridge of high pressure covered the British Isles from an anticyclone, 1031 mb, south of Greenland. Inland parts of England and Wales were warm and sunny, but coasts were much cooler (as was the north generally).

LD2010Apr21 *Rotherham, West Riding of Yorkshire (c 53° 25' N 1° 21' W, SK 4392)*

The Editor, Samantha Hall, received a report from a local radio station to say that a 'mini-tornado' had been seen in Rotherham (no further details known). At 1200 GMT a high, 1025 mb, was centred near northwest Ireland. The weather was fine and sunny, but rather cool.

LD2010Apr22 *Fakenham, Norfolk (52° 50' N 0° 52' E, TF 933305)*

A brief report in the *Lynn News* of the 22nd April said that a 'mini-tornado' had been observed that afternoon in the car park of a shopping store in Enterprise Way. At 1200 GMT a ridge of high pressure extended from Greenland to central Europe, with a small high centre, 1021 mb, in the southern North Sea. England and Wales were again dry and sunny.

FC2010Apr25 *Slieve Gallion Mountain, County Derry (c 54° 44' N 6° 46' W, H 7988)*

Mr Conor McDonald submitted a report of 'quite a large long funnel cloud' seen at 1400 GMT from the top of Slieve Gallion Mountain. It lasted about two minutes. At 1200 GMT a southwesterly airstream covered most areas between a high, 1028 mb, near northwest Spain and a low, 1007 mb, south of Iceland. Scattered heavy showers affected many central and western parts (including Ireland) during the afternoon.

FC/TN2010Apr30 *Slemish, near Ballymena, County Antrim (c 54° 53' N 6° 06' W, D 2205)*

TORRO member Martin North saw a well-formed funnel cloud at 1220 GMT. It was in the distance over the moorland east of Ballymena. He went up to the area later and found fresh tree damage, but it could not be confirmed that this had been caused by the funnel cloud. At 1200 GMT an unstable westerly airstream with shower troughs covered most of Britain, associated with a low, 993 mb, over Scandinavia. Showers, locally thundery, occurred widely during the afternoon.

fc2010May01/I *Near Shaftesbury, Dorset (c 51° 00' N 2° 15' W, ST 82)*

The *Blackmoor Vale Magazine* (7th May), while giving an account of a local food festival, mentioned in passing that there was "rain in all directions, and even a twister coming towards Shaftesbury, but everything veered away leaving Shaftesbury dry for the festival". At 1200 GMT a slack area of shallow low pressure covered much of Britain, with centres of 1008 mb over Ireland and 1009 mb over southern England. There were showers in many areas (especially the south and west), a few of which were heavy and thundery.

FC2010May01/II *South of Melksham, Wiltshire (c 51° 19' N 2° 03' W, ST 9757)*

Alan Whitewick, TORRO's local coordinator, photographed this funnel cloud to the south of Melksham at 1315 GMT. The picture shows a well-formed funnel reaching a third of the way to the ground. Mr David Obrien submitted a report of a funnel cloud seen to the south of Devizes at 1300 GMT, which was no doubt the same one. It was visible for 10 minutes, and he estimated that it would have been over Worton, approximately. Another photograph, apparently of the same funnel, appeared on the *BBC Gallery* web site, taken by Ms Nicola Miles.

3FC2010May11 *New Quay area, Cardiganshire (c 52° 13' N 4° 22' W, SN 3860)*

Matthew Leese of TORRO photographed a funnel cloud at 0655 GMT. From his viewpoint it appeared to be either over New Quay or just off the coast. In the picture it extends no more than a third of the way from the base of a shower cloud, but was much longer just before the photograph was taken. He saw another two funnel clouds in the next half-hour. At 0600 GMT a weak northerly airstream covered the British Isles between a high, 1036 mb, in mid-Atlantic, and a low, 1000 mb, in the Norwegian Sea; a shower trough lay from North Wales to Cornwall. There were scattered showers, mainly near north-facing coasts, but also near the trough over Wales.

WS+2FC2010May12 *Great Orme (offshore), Caernarvonshire (c 53° 20' N 3° 53' W, SH 7584)*

Mr Marc Buzzard filmed a well-formed waterspout out to sea from Great Orme. This was one of three that were seen drifting west between 0600 and 0610 GMT; the other two were said to have been smaller, and are here classified as funnel clouds. At 0600 GMT the synoptic pattern was similar to that of the previous day, with a weak northeasterly airstream across England and Wales between complex low pressure over the Continent and a ridge of high pressure off northwest Ireland. There were showers in the Irish Sea, and a few elsewhere.

fc2010May13 *Coleraine, County Derry (55° 07' N 6° 39' W, C 8630)*

Mr Darren Shaw contacted us to report that he had seen a lowering of the cloudbase and condensation funnel from Newbridge Park at 1645* GMT during a shower; the event lasted about six minutes. At 1800 GMT a low, 995 mb, was slow-moving between Scotland and Iceland; its occlusion, accompanied by outbreaks of rain, was moving very slowly east across Ireland, and was passing through Coleraine about this time.

* Reported as 1745, presumably BST, but internal evidence suggests it might have been GMT.

LD2010May13 *Jersey (Grouville), Channel Islands (49° 11' N 2° 03' W)*

This was reported to us by Mr Frank Le Blancq of Jersey Meteorological Office. It was seen by a Mr Chambers at 1345 GMT about 200 m southeast of Grouville Parish Church, picking up dust and loose paper, which swirled round in the column (described as 'a large grey cloud'). Weather at Jersey Airport at the time was fine with small amounts of cumulus; sea breezes developed on the island.

LD2010May18/I *Eastham, Cheshire (c 53° 19' N 2° 59' W, SJ 3580)*

Reported on the UKWeatherworld forum, and said to have been seen at 'lunchtime'. At 1200 GMT a long ridge of high pressure extended from near the Azores across England to the Norwegian Sea. Some areas were rather cloudy, but northwest England had good breaks.

LD2010May18/II *Irlam (Chat Moss), Lancashire (c 53° 28' N 2° 26' W, SJ 7196)*

A correspondent to the UKWeatherworld forum photographed a well-developed dust devil. It was seen looking across Chat Moss from Irlam at about 1330 GMT.

FC/TN2010May21 *South of Wick, Caithness (c 58° 24' N 3° 07' W, ND 3547)*

The *John O'Groat Journal* of the 9th June published this under the headline 'Disbelief as tornado twists at Wick'. It was seen by Ms Rosalind Mills at about 1500 GMT, and her photograph shows a well-developed funnel descending below the near horizon from a dark cloud above. From her viewpoint it appeared to be a few miles south of the town, about Hempriggs, and it lasted just a couple of minutes from when first seen. It is impossible to say from the picture whether it reached the ground, but a local weather expert, Mr Keith Banks, was quoted as saying he thought it could have done. At first sight the synoptic situation did not seem suitable for tornado formation: at 1200 GMT the whole of Britain was under a large high, 1034 mb, centred in the North Sea; but convergence zones led to the development of thundery showers over the north Pennines and northeast Scotland in the afternoon, while a slow-moving front gave outbreaks of rain in the far northwest of Scotland.

LD2010May23 *Gloucester (Longlevens), Gloucestershire (51° 53' N 2° 13' W, SO 853210)*

This was reported in the *Gloucester Citizen* of the 25th May, and was said to have happened about 1430 GMT 'on Sunday'. It passed over an allotment in Innsworth Lane, and caused slight damage to a motor car. At 1200 GMT a declining high, 1025 mb, was centred over southern England. England and Wales were fine and very warm with sea breezes on some coasts.

LD2010May24 *Highworth, Wiltshire (51° 38' N 1° 43' W, SU 202929)*

This is Wiltshire of the 25th May reported that a 'mini-tornado' carried a garden umbrella up onto the roof of a house in Turnpike Road the previous day (time not stated). At 1200 GMT a very weak northerly airflow covered England associated with a ridge of high pressure from Greenland to west of Ireland. The south was still very warm, with temperatures in the mid-twenties Celsius, but other areas had become cooler.

tn2010May27 *Neyland, Pembrokeshire (51° 43' N 4° 57' W, SM 961062)*

The *Western Telegraph* of the 28th May reported that a 'mini-twister' was thought to have occurred in the Honeyborough district of Neyland 'last night', and a slightly more detailed account appeared in the *Milford & West Wales Mercury* of the 4th June. Mr Derek Brockway, the local weather forecaster for Wales, provided some further details via John Mason of TORRO, following which Nicky Lambert of TORRO interviewed one of the witnesses, Mrs Dawn Delahaye of Elm Grove, and her findings were as follows. At about 2035 GMT, during a spell of rain (not heavy), the sky darkened and there was a loud roar; debris in the garden began to swirl, tree branches and garden furniture were hurled about, and roof tiles came flying down onto a parked motor car. This lasted no more than a few seconds, and was followed by torrential rain. The press reports indicated that several other homes, including some in Wood Lane, had suffered slight damage to roofs and gardens; there was also some damage at the cemetery. Force T1.

At 1800 GMT a shallow depression of 1004 mb was drifting slowly southeast across northeast Scotland, with various minor troughs in its circulation; one of these was crossing Pembrokeshire at the time of the tornado.

fc2010May27 *Feniscowles, Lancashire (53° 43' N 2° 33' W, SD 6425)*

David Smart of TORRO received information that a 'rotating cloudbase' and funnel cloud were seen at Feniscowles at 2045 GMT.

WD2010May28 *River Bure (near Upton), Norfolk (52° 40' N 1° 34' E, TG 409131)*

A detailed description of this water devil was provided by Ms Mary Gibbs and Ms Peggy Twyman, who were sailing on the River Bure near Upton (grid reference supplied by the observers) on a fine day with a light-moderate westerly wind. At about 1330 GMT the wind suddenly shifted to southerly and, quoting Ms Gibbs, "... About a yard from the edge of the water I saw water leap up in ... a sort of double rosette of outward splashes about 3-4 feet across, and I should think about 18 inches high ... I saw it was rotating fast and getting faster (I am really not sure about the direction ... but in my memory it is rotating anti-clockwise, also I think it was getting a bit larger), and heading straight for us ... We both ducked, and a moment later it hit us, drenching us and the cockpit ... The boat rocked to starboard and seemed to round up to port as the whirlwind went through us, but only a little ... Peggy saw [the whirlwind] continue across the river and fade out as it hit the reeds on the other side ... the wind came back westerly and we bore away on to a reach again ...I would estimate that the whole thing from the first appearance of the whirlwind to it dying away took about 15 seconds".

MsTwyman described it as "like a huge bubble rising up and there was a hissing noise ... the water was circulating in a whirlpool and getting faster and faster with a white foaming crest round the outside, which seemed to be rising up. It must have been about one metre in diameter". At 1200 GMT a weakening westerly airstream covered the British Isles between a complex low, 1006 mb, in the northern North Sea and a high, 1020 mb, in the Bay of Biscay. England had a dry day with sunny periods; sea breezes developed locally near the east coast, and it is possible that the water devil was triggered by the arrival of such a breeze at Upton (it reached Norwich Airport, further inland, about three hours later).

Whirlwinds in the Irish Republic

EWs2010Mar18 *Dugort, Achill Island, County Mayo (54° 01' N 10° 02' W, F 6709)*

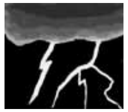
Ms Laura Cleary, when reporting the eddy whirlwinds at Kylemore Abbey (see below), mentioned that she had seen similar whirlwinds off the coast from Dugort on Achill Island two weeks earlier on another windy day. They "were quite wide, again with no funnel cloud, but it looked like the water was being sucked around in a wide circle and up slightly into the clouds. They did not last longer than two minutes". At 1200 GMT a strong south to southwesterly airflow covered Ireland in association with a low, 974 mb, moving northeast off the west coast. Rain crossed the country in the morning, giving way to scattered showers in the afternoon.

EWs2010Apr05 *Kylemore Abbey, near Letterfrack, County Galway (53° 33' N 9° 57' W, L 7157)*

Ms Laura Cleary was at Kylemore Abbey at 1000 GMT, when "suddenly a huge gust came with a very loud noise … The water was lifted out from the lake, I felt as though I was in a whirlwind with a wide base maybe 10 metres wide. There was no funnel cloud, just a really loud noise … Initially I got blown away a couple of feet but I did not fall over". Afterwards she saw other small whirlwinds on the lake, about five metres wide sucking water up in a spiral to a similar height. They lasted about 30 seconds at a time. At 1200 GMT the synoptic situation was similar to that of the 18th March, with a strong southwesterly warm sector over Ireland, associated with a low, 972 mb, moving northeast on the Atlantic. The weather was mostly dry before the cold front moved in later.

FC2010Apr25 *Dublin (Artane), County Dublin (53° 23' N 6° 14' W, O 1839)*

This was reported by Mr Darren Roe. The time was 1430 GMT, and it lasted less than five minutes. He took a film of it, and although it was past its best by then, it still appears as a distinct, slightly ragged, funnel descending at least a third of the way to the ground. See the *Slieve Gallion* entry above for the synoptic situation.



TORRO THUNDERSTORM REPORT FOR THE BRITISH ISLES: MAY AND JUNE 2010

By BOB PRICHARD

MAY

The quiet start to 2010 continued. There were two or three days with thunder in parts of eastern Scotland, but none over vast swathes of the United Kingdom

On the 1st, as the boundary between warm air in the south and cold air advancing from the north intensified in a weak pressure gradient, showers broke out and became heavier during the afternoon and evening. There were some prolonged downpours, locally thundery for a time in the evening, across London, parts of East Anglia, the Midlands, Wales and northwest England. Local flooding was reported from London and around Worcester.

On the 12th, there may have been isolated thunder in showers in the dawn period near some northern Irish Sea coasts. A frontal system crossed the country from the west during the 16th: most places had only small amounts of rain from it, but ripples running along the cold front as it crossed the southeast during the afternoon led to outbreaks of heavy rain here, with thunder briefly in the early evening over parts of London and near Ipswich. There was also thunder in a shower in the early evening in the Grampians, and during the middle of the 17th in a few districts from The Wash to Thanet.

High pressure covered the country from the 20th to the 23rd, but this period also brought the month's most notable storms. On the 20th, thundery showers affected parts of central Ireland in the evening, in response to high temperatures (c. 25 °C) in humid air: pressure was around 1030 mb at the time. On the 21st, heavy showers developed during the afternoon over the Pennines and Cheviots and turned thundery briefly as they edged into southeast Scotland. There was also a notable, lengthy, thundery outbreak during the afternoon and evening over and around the Grampians – all this with pressure around 1031mb! Flooding affected parts of the area, and two houses were struck by lightning at Westhill, near Aberdeen: a hole was ripped in the roof of one of them, and telephone lines and electrical boxes were melted and blown off the wall, resulting in a fire in the second house – where a woman was on a landline telephone, which was ripped out of her hand. Finally in this spell, on the 23rd, west-east bands of convective cloud developed over the hills of northern England and Scotland in very warm air ahead of a cold front edging southwards into northern Scotland in the afternoon. The showers turned thundery over the Grampians and along parts of the east coast as far south as about Redcar.

Chilly air then returned from the north. On the 26th, there were thundery showers in the eastern English Channel in the early hours, and distant thunder was (possibly) heard at Eastbourne. One or two thundery showers also affected central areas late in the day, including around the England/Scotland border (west end) and around Dundee/Leuchars (with hail). Four walkers in the Lake District were hurt by nearby lightning strikes in three separate incidents: a man was knocked unconscious and thrown 30 feet, a couple were knocked off their feet and a woman suffered singed hair in the incidents. Next afternoon, the Leuchars area was affected again (with hail), and there was isolated thunder in one or two other northern districts during a showery afternoon and evening near a depression under deep cold air. The spire of a historic church in Broughty Ferry on Tayside suffered major damage after being struck by lightning. The 28th again brought isolated thunder in showers in the north, especially over south Lancashire in the early hours, and it accompanied showers developing over North Yorkshire and moving across north Lincolnshire and the

north Norfolk coast during the middle of the 30th.
Finally, this month, there was thunder in parts of western and central Ireland during the late afternoon and early evening of 31st on the leading edge of a large area of frontal rain. A

JUNE

This was another month with below-normal thundery activity over most of the British Isles: parts of southern England were thunder-free throughout the first half of 2010 - a very rare occurrence. Just a few scattered locations across the country reported three days of thunder – and it is possible that one or two places in Nottinghamshire and Lincolnshire may have heard it on four days.

On the 4th, as an area of high pressure declined off northeast Scotland and a frontal trough edged closer to our western shores, sferic reports indicated a small thundery outbreak around the coast of northwest Scotland during the late afternoon and early evening. Next day, there were thundery showers in parts of the east and north during the afternoon and evening as pressure continued to fall in very warm air: there were also a number of very heavy showers without thunder. In the late evening, under the centre of a small depression, active thunderstorms developed over areas of the east Midlands and Lincolnshire, with localised flooding in the Nottingham area. These storms continued through the early hours of the 6th in parts of Lincolnshire – and even as this outbreak cleared away, a further crop of thunderstorms appeared over areas of the north Midlands and Lincolnshire for an hour or two soon after daybreak, when lightning struck a building at Nottingham City Hospital. Meanwhile, in association with a cold front developing southeastwards from the depression, storms also moved northeast over extreme southeast England early in the day. The roof of a house at Hastings was set ablaze after it was struck by lightning. Thundery showers became more widespread on the afternoon of the 6th, affecting parts of southwest Scotland and extreme southeast England, but especially drifting east and becoming increasingly active across the Midlands and East Anglia. There were reports of two tornadoes in Norfolk, with roofs torn off buildings, trees toppled and a power blackout to 300 homes between Marshland St James and Stradsett. In the evening, a bungalow was hit by lightning at Clacton, and roads were flooded at nearby Jaywick.

After the weekend's activity, a weak area of low pressure remained over central regions of the British Isles on the 7th, and thunder was reported in a few parts of northern England and southwest Scotland from late morning to late afternoon. 32 mm of rain fell in one hour at Penrith, with severe flooding in the town centre. There was also thunder briefly in the late afternoon in southwest Ireland behind the next frontal rain-band; as this cleared northwards over Britain during the 8th, showers soon broke out in the south, and these turned thundery in the afternoon in a zone from southeast Wales through the south and east Midlands to Cambridgeshire, Norfolk and south Lincolnshire. At Calthorpe (Norfolk), an intense thunderstorm gave 14 mm of rain in 15 min; there was continuous thunder when the storm was overhead and also some hail. There was also some thunder in southern Ireland. On the 9th, the old depression off southwest Britain became absorbed in a new development over north Spain, and showers in the resulting southeast to easterly airflow turned thundery in the afternoon over parts of the Midlands and, especially,Wales.

Between the 10th and the 25th, there was thunder only on the 13th, when, as a depression slipped southeast across the country, isolated activity appeared across southern and eastern Ireland, Wales and the south Midlands, with more significant storms over the north Midlands. An active storm developed and drifted northeast across south Lincolnshire in mid-evening; a lightning strike put clocks and traffic lights out of action near Lincoln cathedral.

As pressure fell after the heatwave that characterised the fourth week of June, destabilisation in a warm southerly airflow resulted in thunder developing around the north coast of Ireland as showers drifted north in the mid-afternoon of the 26th. Showers also developed over the Pennines in the late afternoon and continued through the evening, with a fair amount of thundery activity from near Bradford on a track to the coast from Middlesbrough to Newcastle. The next day saw showery outbreaks move northeast across northern regions, with isolated thunder near the north coast of Ireland in the afternoon and rather more widely over central and northern Scotland during the late afternoon and evening. Thunder broke out over parts of Ireland around dusk on the 28th, and an outbreak of thunderstorms and very heavy rain then moved northeast during the night, close to the track of a small depression, across the Irish Sea and northernmost Wales and the more northerly regions of England. At Waunfawr, on the northwest edge of Snowdonia, prolonged lightning and thunder was reported for 90 minutes early on the 29th with some vivid forked lightning; there was a similar report from Llansadwrn, not far to the north on Anglesey. Electricity supplies were cut by the storm to thousands of homes across north Wales. A separate thundery outbreak, linked to the cold front, developed in the dawn period (29th) near Nottingham and tracked across Lincolnshire. In the afternoon, isolated small thundery showers briefly affected some eastern coastal districts of England.

Reporting Severe Weather

TORRO rely on members and general public for reports on severe weather events to carry out this pioneering research into severe weather in Britain and ireland. If you witness, hear of, see any articles anywhere (etc) about any event, please do get in touch with us and give us as much detail as you possibly can. If the event was recent, please try and report it to us as quickly as possible as often site investigations are required to establish what type of weather phenomena caused the damage and it is important if our volunteers who carry out site investigations arrive at the scene as soon as possible so that the bulk of the damage has not yet been cleared away, thus ensuring a more accurate account of what happened.

Site Investigation Results

Anyone who kindly undertakes an investigation for TORRO please do write up your findings to enable us to disseminate this important research to thousands of readers worldwide through online libraries, other subscriptions, and so on.
For help in writing reports, email editorial@ijmet.org. Thank you.

WEATHER STATION READINGS IN BERGENFIELD, NEW JERSEY, NEW YORK USA: SEPTEMBER 2010

By RUDY NICKMANN

Temperatures continued the warm pattern begun this past March. Bergenfield's average of 70.3 °F (27.3 °C) was 3.3 °F (1.8 °C) above the long-term mean. I recorded a maximum of 100 °F (37.8 °C) on the 1st. This set a new all-time record for September, breaking the old record of 97 °F (36.1 °C) reached in 2005 and 1983. Precipitation was a bit below normal. The month was quite dry overall but heavy rains associated with a tropical storm dropped 1.93 " (49.0 mm) of precipitation on the 31st. A cold front swept through the region on the 22nd resulting in brief heavy showers and a peak wind gust of 43 mph.

ENGLISH UNITS								METRIC UNITS					
	TEMPERATURE			PRECIPITATION			WIND		TEMPERATURE			PRECIP	
DAY	MAX	MIN	AVG	RAIN	SNOW	SC	GUST	DIR	MAX	MIN	AVG	RAIN	SNOW
1	100	69	85				11	SW	37.8	20.6	29.2		
2	99	72	86				17	SSW	37.2	22.2	29.7		
3	86	72	79				14	NE	30.0	22.2	26.1		
4	80	64	72				28	WSW	26.7	17.8	22.2		
5	80	54	67				21	W	26.7	12.2	19.4		
6	84	50	67				13	SSW	28.9	10.0	19.4		
7	94	65	80				17	SSW	34.4	18.3	26.4		
8	92	64	78	T			26	SSW	33.3	17.8	25.6	T	
9	70	58	64				24	WNW	21.1	14.4	17.8		
10	73	57	65				17	NW	22.8	13.9	18.3		
11	82	51	67				12	ESE	27.8	10.6	19.2		
12	67	59	63				14	E	19.4	15.0	17.2		
13	80	58	69	0.18			11	NW	26.7	14.4	20.6	4.6	
14	79	54	67				24	WNW	26.1	12.2	19.2		
15	75	50	63				22	WNW	23.9	10.0	16.9		
16	71	49	60	0.57			19	ESE	21.7	9.4	15.6	14.5	
17	73	55	64	0.16			18	NNW	22.8	12.8	17.8	4.1	
18	77	55	66				11	ESE	25.0	12.8	18.9		
19	86	55	71				10	SW	30.0	12.8	21.4		
20	76	54	65				20	N	24.4	12.2	18.3		
21	78	46	62				14	SSW	25.6	7.8	16.7		
22	92	61	77	0.41			43	SSW	33.3	16.1	24.7	10.4	
23	85	63	74				12	ESE	29.4	17.2	23.3		
24	89	64	77				13	SSW	31.7	17.8	24.7		
25	90	67	79				22	SSW	32.2	19.4	25.8		
26	72	58	65	T			16	E	22.2	14.4	18.3	T	
27	72	60	66	0.71			20	NE	22.2	15.6	18.9	18.0	
28	76	71	74	0.16			20	SE	24.4	21.7	23.1	4.1	
29	80	60	70				14	SW	26.7	15.6	21.1		
30	76	66	71	1.93			33	SE	24.4	18.9	21.7	49.0	
31													
AVG	81.1	59.4	70.3						27.3	15.2	21.3		
SUM				4.12								104.6	
MAX	100	72	85.5	1.93			43	SSW	37.8	22.2	29.7	49.0	
MIN	67	46	60						19.4	7.8	15.6		

Weather station datafor Bergenfield, New Jersey, USA for September 2010.
*Note, peak gusts are shown in mph. *SC = Snow Cover.*

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WEATHER STATION READINGS IN BERGENFIELD, NEW JERSEY, NEW YORK USA: OCTOBER 2010

By RUDY NICKMANN

October marked the 8th consecutive month with above normal temperatures here in Bergenfield, New Jersey. The average of 57.2 °F (14.0 °C) was 1.5 °F (0.8 °C) above the long-term mean. I recorded a maximum of 80 °F (26.7°C) on the 11th. The season's first frost usually occurs during the last half of October in Bergenfield but there were no freezing temperatures this month. I noted a minimum of 35°F (1.7°C) on the 23rd. There was some scattered ground frost on the 10th, 22nd and 23rd. Precipitation was a bit below normal. Heavy rains accompanied by gusty winds on the 1st brought 2.19 " (55.6 mm) inches of precipitation. I recorded a peak wind gust of 40 mph. This was the only stormy period throughout the month which was rather uneventful and benign.

*Weather station data for Bergenfield, New Jersey, USA for October 2010. Note, peak gusts are shown in mph. *SC = Snow Cover.*

ENGLISH UNITS									METRIC UNITS				
	TEMPERATURE			PRECIPITATION			WIND		TEMPERATURE			PRECIP	
DAY	MAX	MIN	AVG	RAIN	SNOW	SC	GUST	DIR	MAX	MIN	AVG	RAIN	SNOW
1	76	54	65	2.19			40	NW	24.4	12.2	18.3	55.6	
2	72	46	59				11	W	22.2	7.8	15.0		
3	65	48	57				18	NNE	18.3	8.9	13.6		
4	55	53	54	0.19			18	NNE	12.8	11.7	12.2	4.8	
5	59	53	56	0.01			16	NNE	15.0	11.7	13.3	0.3	
6	67	54	61	T			17	SW	19.4	12.2	15.8	T	
7	74	51	63	T			25	WSW	23.3	10.6	16.9	T	
8	77	47	62				19	WSW	25.0	8.3	16.7		
9	75	49	62				21	NW	23.9	9.4	16.7		
10	75	37	56				17	WSW	23.9	2.8	13.3		
11	80	49	65	0.20			22	SW	26.7	9.4	18.1	5.1	
12	72	50	61	0.07			13	NW	22.2	10.0	16.1	1.8	
13	70	41	56				8	N	21.1	5.0	13.1		
14	64	40	52	0.67			12	E	17.8	4.4	11.1	17.0	
15	57	48	53	0.02			32	W	13.9	8.9	11.4	0.5	
16	62	46	54				30	WNW	16.7	7.8	12.2		
17	73	39	56				19	WSW	22.8	3.9	13.3		
18	63	41	52				17	WSW	17.2	5.0	11.1		
19	67	47	57	0.01			11	SSW	19.4	8.3	13.9	0.3	
20	60	39	50				12	SSW	15.6	3.9	9.7		
21	66	42	54				26	SSW	18.9	5.6	12.2		
22	55	37	46				28	W	12.8	2.8	7.8		
23	67	35	51				14	WSW	19.4	1.7	10.6		
24	72	49	61				8	ESE	22.2	9.4	15.8		
25	75	50	63				16	SSW	23.9	10.0	16.9		
26	77	61	69	T			16	SSW	25.0	16.1	20.6	T	
27	75	62	69	0.22			20	SSW	23.9	16.7	20.3	5.6	
28	77	53	65				27	SSW	25.0	11.7	18.3		
29	56	45	51	T			28	WNW	13.3	7.2	10.3	T	
30	59	39	49				19	SSW	15.0	3.9	9.4		
31	58	39	49				28	WSW	14.4	3.9	9.2		
AVG	67.7	46.6	57.2						19.9	8.1	14.0		
SUM				3.58								90.9	
MAX	80	62	69	2.19			40	NW	26.7	16.7	20.6	55.6	
MIN	55	35	46						12.8	1.7	7.8		

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SHORT COMMUNICATION

A REPORT ON THE KASATOCHI VOLCANO-CLOUD OBSERVED FROM SALONTA, ROMANIA

By KÓSA-KISS

Abstract. The author of this article is engaged in the aerosols of Kasatochi volcano rising into the stratosphere, as well as in the optic phenomena of these aerosols.

Keywords: Kasatochi, volcano-cloud, Romania.

INTRODUCTION

Sky watchers across the USA and Europe began reporting unusually colourful sunsets and sunrises in 2008. The cause appears to have been the 7 August 2008 eruption of the Kasatochi volcano in the Aleutian-Islands. This volcano hurled a massive, 1.5 million tons of ash-cloud and sulfur dioxide into the stratosphere, where high winds have since carried the aerosols over parts of the USA and Europe, later this dense plumes of the material circled Earth's northern hemisphere.

OBSERVATIONS

I glimpsed the cloud of the Kasatochi volcano at first on 13 August 2008. I was on my way home from my place of work at dawn when I glimpsed the rising Sun. The sky was clear (without tropospheric clouds). Then all of a sudden I noticed a strange, but not unfamiliar cloud. At the low-edge of the eastern horizon there were developing thin, mostly straight striped lines of pearl mutter light. This was visible only around the Sun. (I used to encounter such phenomena for several months and years in the 80s and 90s due to the dust and gases erupted by the volcanoes of the Mount St. Helens, El Chichón and Mount Pinatubo).

The phenomenon would be seen again with the same characteristics and at the same time on the 14th and 15th August. The next favourable weather conditions for observing the phenomenon were on the 18th August with unaltered sight to be seen.

On the 30th August I had very clear weather and sky again over Salonta town. In the afternoon the cloud originating from the Kasatochi volcano completely covered the sky (mostly the western sky), which was shining like silver under the sunrays. The gently woven fibers, stripes and bands made up a continuous, uniform veil. The constituting elements of the veil were undulating, more or less in a parallel way, whereas they seemed to converge at their western and eastern edges of the horizon. I assumed the height of the silky cloud as reported to the earth surface of about 15-20 km. The silver-like threads hardly changed their position. A quarter of an hour after sunset, on the western half of the ever darker sky there appeared a huge, shapeless, cyclamen (purple – violet) colour light-table. In this strange optical condition the westward sides of the earth-surface objects got some kind of a bizarre light (alpine-light?). Thereafter the bottom of the western horizon was lit by an orange-like light that soon changed into scarlet-red.

On the 31st August after sunrise, the same pleasant, silky cloud began spreading in all directions covering the entire visible sky. Nevertheless it could not stop the sun-rays penetrating though it. It could not even weaken the azure light of the whole sky. The parallel threads of the stratospheric cloud tended to converge in both west and east.

A quarter of an hour after sunset the majority of the sky (mostly to the west) went cyclamen again, and the bottom edge of it on west was burning in crimson.

On the 1st September under favourable weather conditions the silver-like, silky cloud was still visible only around the Sun.

Figure 1. Cyclamen (purple-violet) colour in the sky. © Mark D, Marquette, USA).

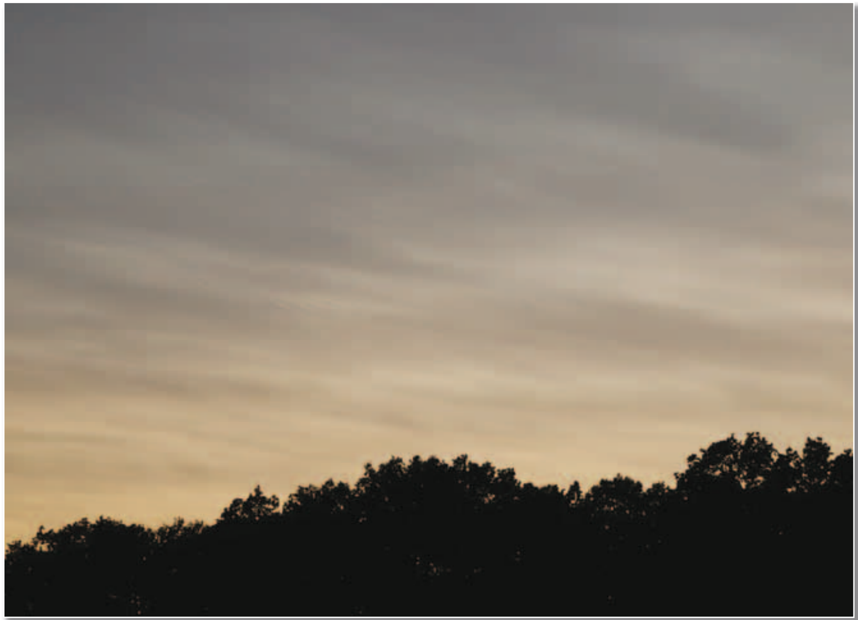


Figure 2. Striking feature of volcanic-cloud: silver-like, silly cloud covering the entire visible sky. © Radek Grochowski, Poland.

Tendrils of sulfurous ash have been drifting through the stratosphere ever since Alaska's volcano erupted on the 7th August. It became clear that another cloud of aerosols from Kasatochi was moving over my observing place. The sunsets and sunrises we have been experiencing are extremely amazing. However, we have spread out into a wide and thin layer that yields sunsets and sunrises of a more subtle beauty. The violet glow of volcanic aerosols could be seen 40-50 degrees above the western horizon.

At about 11:00 GMT, October 6, 2008, after having thoroughly examine the clear, cloudless sky, it seemed that the cloud of the Kasatochi volcano had returned. South from the Sun I saw a very pale, silver-like, silky cloud with stripes. The stratospheric cloud converged towards south-west.

On the 10th October at 16:00 GMT after sunset the sky became cyclamen coloured at a medium height, which lasted for about ten minutes. Shortly thereafter the lower edge of the sky dressed in bright pink. On the 11th and 12th October, before sunrise, respectively after sunset, at the similar times, the lower part of the sky was pale pink.

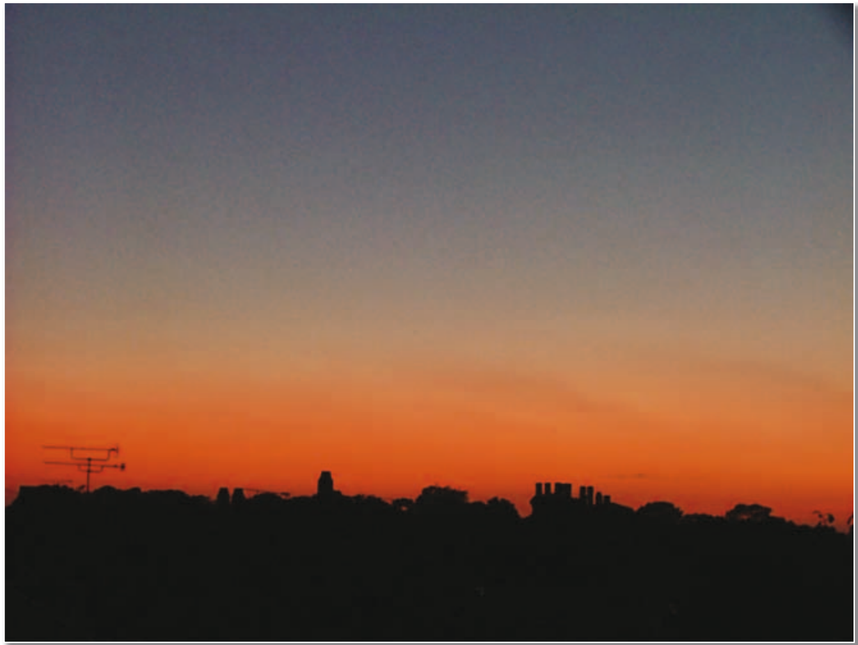


Figure 3. The burning red, scarlet or crimson sky before and after sunset in lower parts of the sky west and east. © Jeremy Housman, Great Britain.

A cold front was passing above my observing spot on 18th October at about 16:00 GMT westward at a medium height the sky became cyclamen again, with the lower edge of the sky being later pale pink. In the evenings of the 20th, 21st and 22nd October I observed the same colours in the respective parts of the sky.

EVIDENCE REGARDING THE CLOUD OF THE KASATOCHI VOLCANO

If the sky is cloudless (there are no clouds to be found in the troposphere), and besides it is clear, too (there are neither significant dust nor vapour in the lower atmospheric strata), the Sun rises and sets in greenish blue colour.

An excellent example in this respect is to be experienced in winter when one can witness both sunrise and sunset under the conditions after of a strong cold front.

On the contrary, if in the stratosphere there are to be found volcanic gases and dust, in case of a cloudless sky, soon after sunset and before sunrise one can witness a very characteristic cyclamen (purple-violet) colour in the west, and east part of the sky (Figure 1). The stratospheric cloud is illuminated by the Sun when the latter is to be found under the horizon.

Why is the sky characteristically colored in cyclamen if there is a volcanic cloud to be found above us? This is due the predominant short-wavelength light scattering.

Another characteristic and striking feature of the volcanic cloud is the silver-like, silky cloud covering the whole sky seen upon which there are thin threads, stripes and waves (Figure 2). This type of cloud keeps being of silver-like colour even when the Sun is already a little below the horizon, nevertheless the Cirrus clouds floating at a height of about 10-12 km at he same time is already in the shadow and is of dark gray colour.

What could have contained the material of the silky cloud observed during day-time? Usually are assumes that SO2 is rather rapidly converted to sulfate aerosol.

After sunset and before sunrise the lower parts of the sky westwards and respectively eastwards is explicitly burning in red, scarlet or crimson (Figure 3). This is the third piece of evidence that a volcanic cloud is floating above us in the stratosphere besides the specific or typical characteristics mentioned above.

Why can a volcanic cloud be floating so long in the stratosphere? There is no chemical decomposition and the air-streams are rather horizontal.

ACKNOWLEDGEMENTS
I express my deepest gratitude to Dr. Thomas Trickl (Forschungszentrum Karlsruhe, Germany) for his precious and valuable professional information. Many thanks to Mr. Mark D. Marquette (Tennessee, USA), Mr. Radek Grochowski (Poland), and Mr. Jeremy Housman (Great Britain) for their pictures.

RESPONSE LETTERS TO THE EDITOR OR SHORT ARTICLES

What are your thoughts on Kosa-Kiss's article above? Do you think volcanoes sometimes cause magnificent colours such as these beautiful pictures show? Have any volcanic eruptions coincided with these sorts of colours in your experience? Or, is it indeed simply usual meteorological phenomena that occur during specific atmospheric conditions?...

Weather Lore

Red sky at night, shepherd's delight,
Red sky in the morning, shepherd's warning...!
How often is this well known old weather lore poem correct?

Ask us your questions
Tell us your stories!

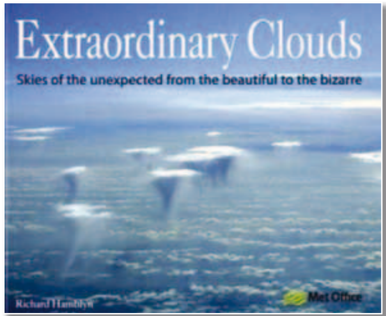
editorial@ijmet.org

BOOK REVIEWS

By PETER ROGERS

INSTANT WIND FORECASTING (3rd Edition) By Alan Watts. ISBN 978-1-4081-2291-4 *Adlard Coles Nautical* (2010) 112pp. pb. £12.99.

There is no doubt that the series of paperbacks about the weather by Alan Watts, primarily for users of inland waters, which he started in 1967, have been extremely popular as witnessed by the fact that virtually all of them have gone into several editions over that period. This volume, now in its 3rd Edition is no exception. The formula is the same: landscape sized paperbacks running to just over 100 pages each, with colour illustrations supported by informed but accessible text. It might be thought that pictures of the wind are difficult to capture, but the pictures in this volume are well-chosen to illustrate particular "wind situations". For example, Plate 30 illustrates a shower cloud and the caption warns of the gusts likely at its leading edge. This volume contains rather fewer photographs than some other volumes in the series, but this is more than made up for by the graphs, diagrams (your reviewer was particularly impressed by the two-page spread on *Local Winds*), and the extremely informative text. One minor criticism is that the page numbers are on the extreme left or right top edge of the page, and therefore tend to be masked by the gutter. Overall, though, this volume is well up to the high standard of this series, and should prove as popular as all the others. Your reviewer has little doubt that a 4th Edition will be required quite soon!



EXTRAORDINARY CLOUDS. Skies of the unexpected from the beautiful to the bizarre By Richard Hamblyn ISBN 13-978-071536-3281-8; 10:07153-3281-3 *David & Charles* (in association with the *Met Office*) (2009) pb. 144pp £9.99; US$14.99; Can$16.50.

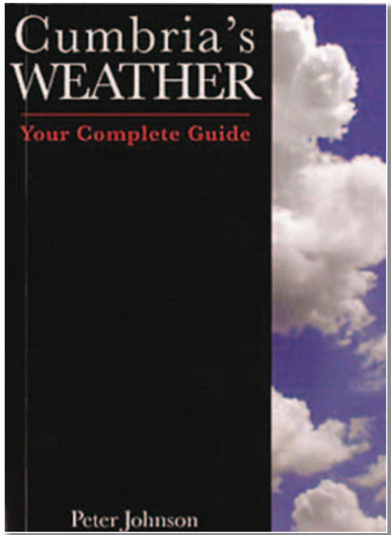
The market for albums of colour photographs of clouds and other phenomena has expanded greatly over the last few years, and with the very high quality of colour photography that has been reached even in the weekend magazine supplements, any new entrant to this crowded field needs something special in order to be able to make its mark. In this reviewer's judgment, this volume succeeds, the key being in the sub-title of the volume. After the *Foreword* and *Introduction*, there are five Chapters: *Clouds from the Air; Strange Shapes; Optical Effects; Theatrical Skies,* and *Man-Made Clouds*. The 144 page volume is completed by a two-page Index, a page of Picture credits and a useful page of *Further Reading*.

Some of the photographs are breathtakingly beautiful, the two that particularly impressed your reviewer being Mammatus at the Base of a Storm Cloud, and Lenticularis over Patagonia. Many extend across the page of this landscape volume which helps to give a better perspective than where the photograph appears to have been cropped to fit on to a single page.

Each chapter starts with a short Introduction opposite small-scale pictures of what is to appear on a bigger scale in the following pages, an interesting innovation. The chapter on Man-Made clouds is unusual, containing, in addition to the usual contrail pictures, two that may be unique: of a sonic boom cloud and a tornado fighter wing cloud.

This volume will in your reviewer's opinion more than hold its own amongst its competitors, and would make an ideal Christmas or birthday present (your reviewer's broad hint that his birthday was approaching bore fruit!), and is very reasonably priced.

CUMBRIA'S WEATHER: YOUR COMPLETE GUIDE By Peter Johnson ISBN 978-0-9549480-1-6 *Cinderbarrow Publishing* (2009) pb 64pp £5.95



Browsing through the Science section of a large London Bookshop, your reviewer discovered this thin volume almost hidden between two much larger hard-backs, and unearthed a real gem. The sub-title is perhaps a little exaggerated as the book is clearly designed for visitors to Cumbria, and, in the space available clearly cannot be comprehensive. It is divided into three Parts. Part 1 considers the history of Cumbria's weather and *Weather related Phenomena*; Part 2 considers what weather can be expected in the area in each of the four seasons, while Part 3 considers the effect of *Weather on Art and Literature*. All are interesting, though no single item is more than a few lines long. The real strength of this volume is however in the photographs. In addition to numerous small black and white photographs throughout the book, there are no less than eight pages of splendid colour photographs which are entirely appropriate to its content. Bearing this in mind, the price is a real snip, and the book should be bought by anyone thinking of visiting this beautiful area of the country. Hopefully, there will be a second edition which will enable the author to cover the record-breakingly heavy rains of November, 2009 that caused so much damage, and cost the life of a brave police officer.

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