Geo Factsheet

www.curriculumpress.co.uk Number 162

Hurricanes: A Predictable Hazard?

Hurricanes, (tropical cyclones/typhoons) are powerful tropical storms capable of unleashing tremendous destruction in the form of strong winds and torrential rainfall. Every year they result in death, homelessness and loss of livelihood from Japan in the east, through India and Bangladesh, to America and the Caribbean in the west.

Despite their ferocity and awesome power, many people would argue that hurricanes are, to a large extent, predictable hazards.

What is the hurricane hazard?

Annual average:	50 - 60 in Nothern Hemisphere
	20 - 30 in Southern Hemisphere
	15,000 killed or injured each year
	15% coastal population at risk

Hurricanes bring exceptionally strong winds and very heavy rainfall. The very strong winds, which often gust to over 200km/h, destroy homes, flatten crops and trees, and damage overhead power and telephone lines. In countries dependent on tree crops such as bananas, a hurricane can be absolutely devastating economically. Hurricanes can dump huge quantities of rainfall, often in excess of 200mm, in a matter of a few hours, leading to widespread flooding and often triggering landslides. It is these secondary hazards – the floods and the landslides – which are responsible for most of the deaths and damage associated with hurricanes (Table 1).

What is a hurricane?

Viewed from space, hurricanes characteristically exhibit a catherine-wheel spiral of cloud around a central 'eye' (Fig 1).
- 300 - 500 km across
- wind speed 120+ km/h

Fig 1. Hurricane

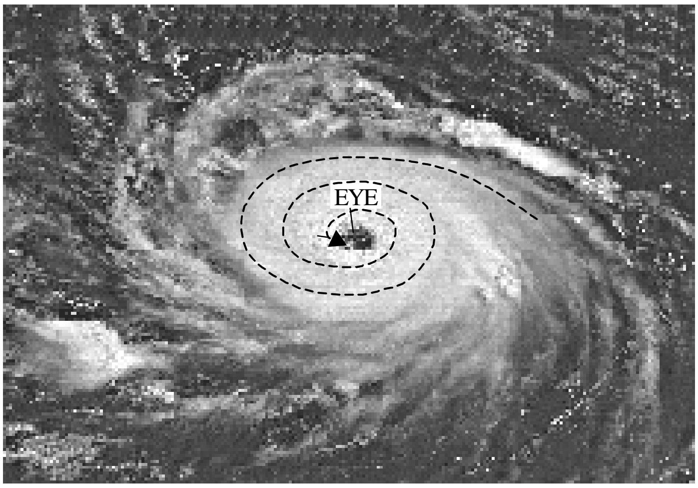


Table 1. Top twenty global hurricane disasters

	DATES	AREA	CASUALTIES (000)	PARTICULARS
1970	12-13 Nov	East Pakistan	200	Cyclone and storm surge; 100 thousand missing
1991	30Apr	SE Bangladesh	131	Cyclone; left as many as 9 million homeless. Thousands of survivors died from hunger and water-borne disease
1864	5 Oct	Calcutta, India	70	Cyclone
1965	11-12 May, 1-2 Jun	East Pakistan	47	Cyclone
1942	16 Oct	Bengal, India	40	Cyclone
1963	28-29 May	East Pakistan	22	Cyclone
1780	10-16 Oct	Barbados, West Indies	20-22	"The Great Hurricane of 1780"completely flattened Barbados, Martinique & St Eustatius; deadliest western hemisphere Hurricane on record
1977	19 Nov	Andhra Pradesh, India	20	Cyclone and storm surge
1998	26 Oct - 4 Nov	Honduras, Nicaragua, Guatemala	11	MITCH. Deadliest Atlantic storm in 200 years. Left 2-3 million people left homeless
1906	18 Sep	Hong Kong, China	10	Typhoon with storm surge
1965	15 Dec	Karachi, Pakistan	10	Cyclone
1971	29 Sep	Orissa State, India	10	Cyclone and storm surge off the Bay of Bengal
1996	29 Oct	Orissa State, India	9.5	Supercyclone swept in from Bay of Bengal. Left over 10M homeless
1930	3 Sep	Dominican Republic	8	Hurricane
1974	14-19 Sep	Honduras	8	FIFI. Struck northern part of Honduras and left 100,000 homeless
1963	2-7 Oct	Caribbean	7	FLORA. Casualties in Haiti and Cuba
1949	5 Dec	Off Korea	7	Typhoon struck fishing fleet
1900	10-21 Sep	Galveston, Texas	6-8	Galveston Hurricane. Hurricane and tidal surge. Deadliest in US history
1960	10 Oct	East Pakistan	6	Cyclone and storm surge
1959	27 Sep	Honshu, Japan	5	VERA left 1.5 million homeless

What is hazard prediction?

Scientists strive to reduce the impact of natural hazards by attempting to predict or forecast when, where and how large an event will occur. People can then be warned or evacuated to safety. Defence measures can be put in place to reduce the impact of the event.

Prediction works well for some natural hazards, but less well for others. For example, there are usually several weeks or months warning of an impending volcanic eruption. Minor earthquakes, steam eruptions, increases in surface heat flow indicated by melting snow and ice, and the physical bulging of the volcano all help to provide scientists with evidence that a volcanic eruption is imminent. However, earthquake prediction is much more unreliable and as yet no universally accepted precursors exist.

Hurricanes are generally considered to be a predictable hazard because they can be clearly seen and tracked by radar and satellite, and warnings can be issued. However, as this Factsheet will show, hurricane prediction is not as straightforward as it may seem, which is why so many people are adversely affected by them.

In what ways are hurricanes predictable?

There are several reasons why hurricanes can be considered to be predictable hazards.

1. **Hurricanes are formed in the Tropics over oceans (Fig 2)**

- Hurricanes are only formed when the water temperature exceeds 26.5°C. At this temperature and above, the air is unstable and has the potential to rise. This explains why they are found in the Tropics. It also explains why they are not found, for example, off the west coast of Africa where the cold Benguela ocean current keeps the water temperature well below 26.5°C.
- Hurricanes derive their energy from the sea. Rapidly rising moist air cools and condenses, releasing latent heat. This heat 'fuels' the storm, increasing its power and intensity. Without the moist oceanic air hurricanes lose their fuel supply and becomes less powerful.
- Hurricanes are thought to be triggered by disturbances in the lower atmosphere. In these low latitudes a belt of unstable conditions exists called the Inter-tropical Convergence Zone (ITCZ). Formed by the convergence (meeting) of warm tropical air at the surface, the ITCZ is characterised by a discontinuous area of low pressure with associated thunderstorms (Fig 3).
- In cross-section a hurricane is a spinning vortex of rapidly rising air. The 'spinning' motion results from the **coriolis effect**, which is caused by the rotation of the Earth about its axis. The coriolis effect is zero at the Equator and increases poleward. This explains why the source areas for hurricanes tend to lie either side of the Equator, generally between 5° and 25° north and south.

Given the requirements for hurricane formation – warm, tropical oceans between 5-25 degrees north and south of the Equator – it could be stated that at least spatially hurricanes are fairly predictable.

Fig 2. Hurricane formation areas and typical tracks

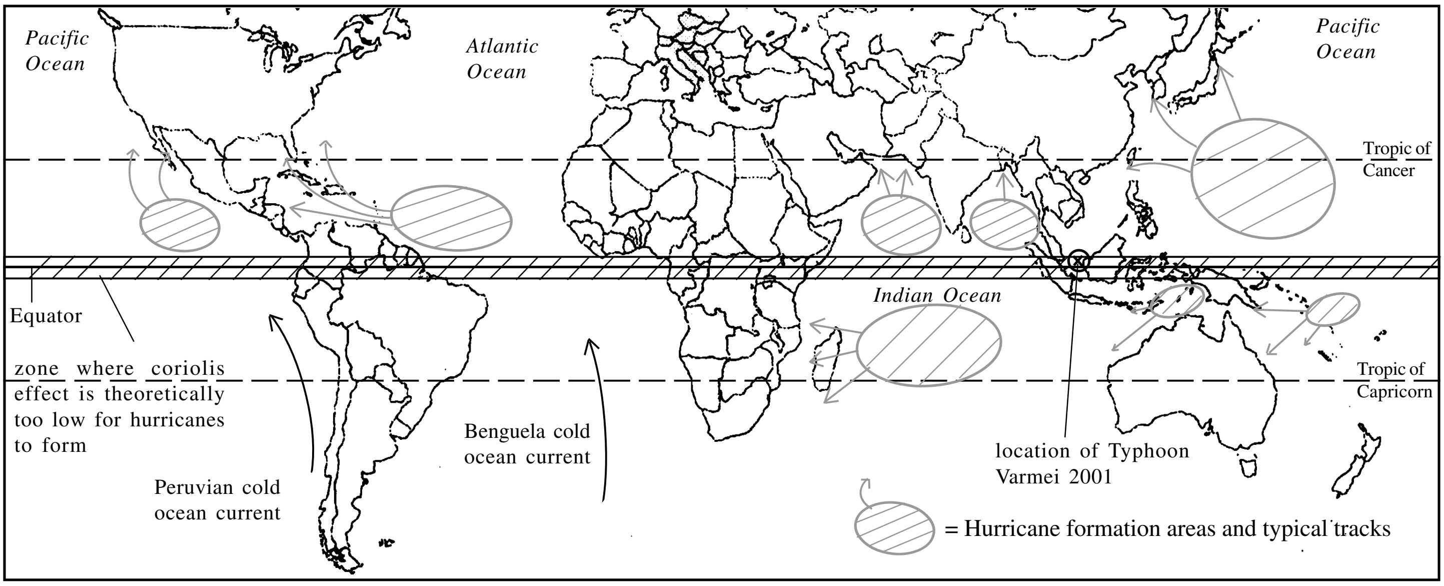
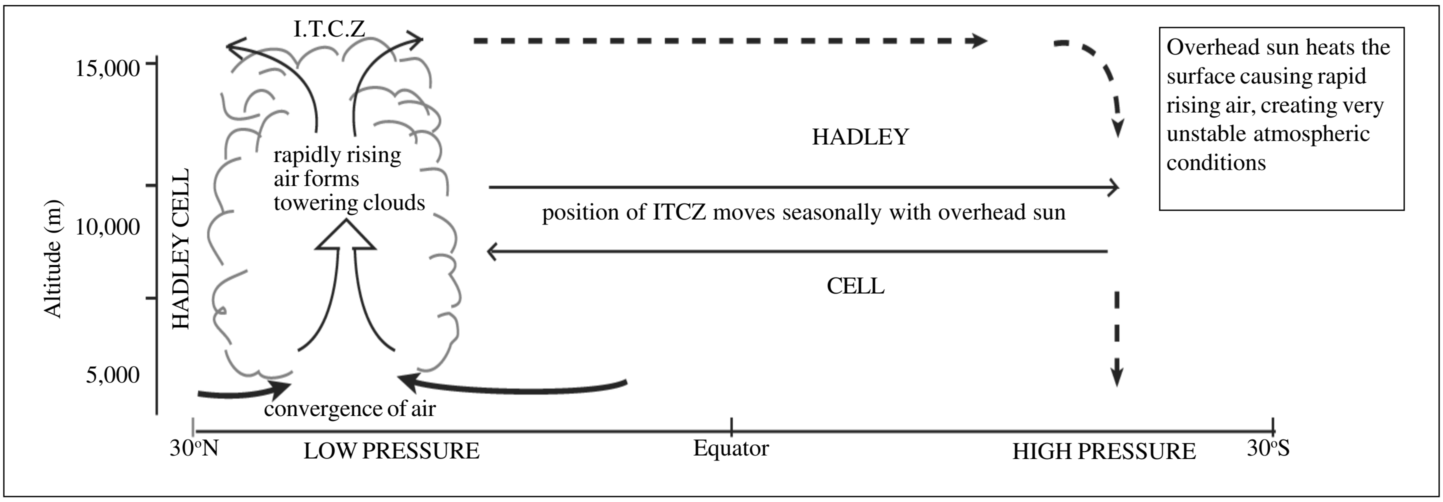


Fig 3. Inter-tropical convergence zone (ITCZ) in June (summer in northern hemisphere)



Typhoon Varmei, South China Sea, 2001

In December 2001, Typhoon Varmei, with winds in excess of 140km/h, hit several unsuspecting US Navy ships in the South China Sea to the south of the Malay Peninsular. Typhoon Varmei passed between Malaysia and Borneo just 150km north of the Equator in a zone where hurricanes are not expected to exist due to the absence of a marked coriolis effect. So, why did it form outside the expected hurricane formation zone?

Scientists believe that the hurricane resulted from a freak sequence of events with a recurrence interval of one in every 400 years. A strong blast of air from Asia, called a 'monsoon surge', funnelled rapidly down the South China Sea towards the Equator. Typically, the surge winds change direction as they cross the equator in response to the change in the coriolis effect, which is positive (deflects to the right) in the northern hemisphere and negative (deflects to the left) in the southern hemisphere. In December 2001, a winter monsoon weather system with a cluster of thunderstorms happened to be located in the area where the monsoon surge winds change direction and scientists believe that this combination created enough spin to initiate Typhoon Varmei.

(A more detailed report on Typhoon Varmei can be found at ***www.jpl.nasa.gov/earth/features/typhoon varmei.cfm*** *)*

On rare occasions, tropical cyclones (or storms that appear to be similar in structure to tropical cyclones) can develop in the Mediterranean Sea. These have been noted to occur in September 1947, September 1969, January 1982, September 1983, and, most recently, during 13 to 17 January 1995. Scientists believe that despite being very similar to hurricanes in their features, their formation is more to do with the mid-latitude atmospheric circulation than the intense oceanic heating that occurs within the Tropics.

2. Hurricanes usually only occur in the summer

Given that one of the key requirements for hurricane formation is high water temperature, hurricanes themselves tend to be seasonal phenomena concentrated particularly in the summer months. In the northern hemisphere, where the majority of damaging hurricanes are spawned, the 'hurricane season' lasts from July to October (Table 2). Whilst the majority of the powerful hurricanes occur during these months, it is worth noting that some storms do occur in May and June and also through to November. Nevertheless, in terms of prediction, it is generally the case that hurricanes are summer events.

Table 2. Tropical storms and hurricanes in the Atlantic, Caribbean and Gulf of Mexico by month

	1944 - 2000 Tropical storms & Hurricanes		1944 - 2000 Hurricanes	
Month	Total	Average	Total	Average
January - April	3	0.1	0	0.0
May	8	0.1	2	<0.05
June	31	0.5	11	0.2
July	50	0.9	22	0.4
August	151	2.6	95	1.6
September	198	3.5	129	2.3
October	100	1.8	60	1.1
November	26	0.5	16	0.3
December	4	0.1	2	<0.05
Year	571	10.0	337	5.9

In the Southern Hemisphere, the majority of hurricanes affecting Australia and south eastern Africa are formed during the summer months of December to March

Winter hurricanes

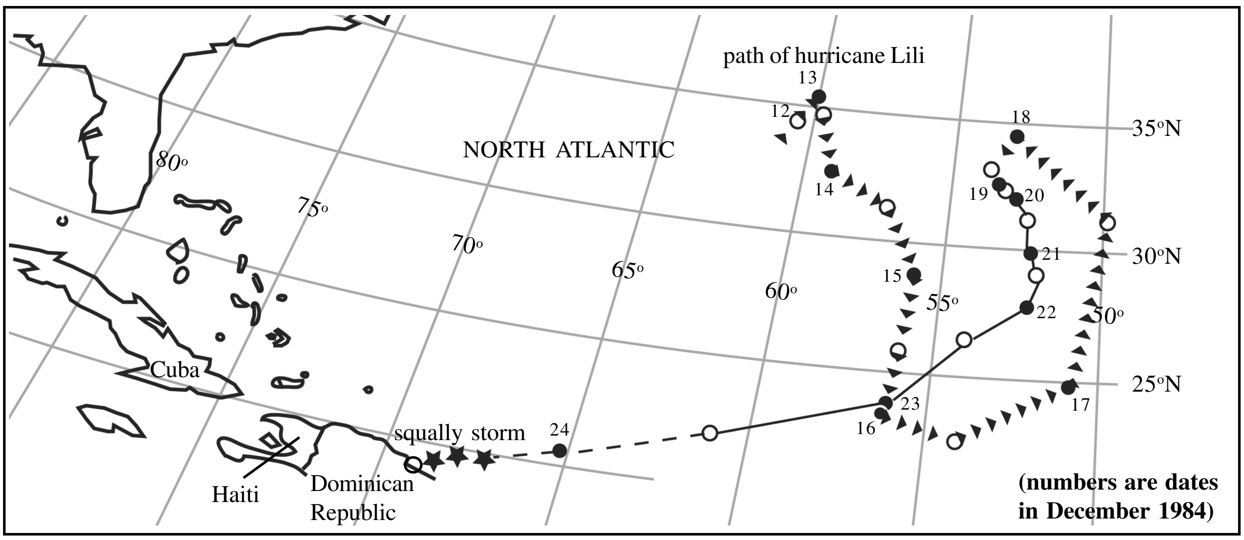
In 1984 Hurricane Lili became the third December hurricane since records began in 1886. The previous two hurricanes occurred in 1887 and 1954.

Hurricane Lili started unusually as a developing wave on an old cold front. Upper level disturbances in the westerly airflow helped to initiate the storm on 9 December and it gradually intensified as it followed an erratic course before heading south-west towards the Caribbean. As it speeded up after 23 December it lost its energy and was downgraded to a tropical storm.

When it made landfall on the Domincan Republic on 24 December it was no more than a squally storm and it caused only limited damage.

More recently, in 2001 Hurricane Olga roamed the Atlantic Ocean for about a week at the end of November. It didn't make landfall.

(For further information on Hurricane Olga access ***www.nhc.noaa.gov/2001olga.html****)*



In recent years, scientists have become aware of significant oscillations in Pacific Ocean sea surface temperatures, which affect global weather patterns. Increasing evidence now suggests a link between these events – known as El Niño and La Niña - and the frequency of hurricanes.

Do El Niño and La Niña events affect hurricanes?

El Nino and La Nina are terms applied to changes in the large scale ocean-atmospheric climate resulting from changes in sea surface temperatures in the Pacific Ocean. Together, they form the ENSO (El Niño Southern Oscillation). El Niño represents a relative warming of the Pacific Ocean sea surface temperatures and La Niña represents a relative cooling. Temperatures oscillate between these two extremes every few years.

One of the requirements for hurricane formation is a fairly uniform vertical profile of winds in the atmosphere. This will produce what is called a low 'wind shear'. High wind shear is when there is considerable variation in winds with altitude. When there is a high wind shear, hurricanes are less likely to form.

Winds are largely determined by pressure patterns, which are in turn affected by surface temperatures. As surface temperatures oscillate as part of the ENSO, it is logical to expect pressure patterns and winds to vary also from the normal pattern. During the extremes of temperature variation (El Niño and La Niña events), the 'normal' vertical profile of winds becomes altered and this influences the likelihood (and therefore the frequency) of hurricanes.

Research has shown that during an El Niño event, wind shear is increased over the tropical Atlantic thereby suppressing hurricane formation. Over the eastern Pacific the opposite occurs, with wind shear decreasing and hurricane formation being promoted.

During a La Niña event, the exact opposite occurs. There tend to be more Atlantic hurricanes (due to a lower wind shear) and fewer eastern Pacific hurricanes (due to a higher wind shear).

El Niño and La Niña also influence where the Atlantic hurricanes form. During El Niño fewer hurricanes and major hurricanes develop in the deep Tropics from African easterly waves. During La Niña more hurricanes form in the deep Tropics from African easterly waves. These systems have a much greater likelihood of becoming major hurricanes, and of eventually threatening the U.S. and Caribbean Islands.

Therefore, the chances of the U.S.A. and the Caribbean Islands experiencing a hurricane increases substantially during a La Niña event, and decreases during an El Niño event.

Whilst monitoring techniques are still to be perfected, it is interesting to note that during the last strong El Niño episode in 1997 there were only 3 Atlantic hurricanes compared to 10 in 1998, 8 in 1999, 8 in 2000 and 9 in 2001. In 2002, during a moderate El Niño episode, there were only 4 hurricanes. It therefore seems reasonable to predict fewer Atlantic hurricanes during an El Niño episode than at other times.

(For further information on the affect of the ENSO on hurricanes access the Climate Prediction Center at ***http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensofaq.html#NINA*** *)*

3. Hurricanes can be tracked and their courses predicted

As Fig 2 indicates, hurricanes tend to follow curved paths away from their source areas. The direction of movement (generally from east to west) is determined by the easterly Trade Winds that dominate in the low latitudes. The curvature of the hurricane paths is due to the coriolis effect.

Meteorologists have developed powerful computer tracking programmes to help forecast hurricane paths, and satellite and radar systems help to maintain a careful watch on a hurricane's progress. Tracking stations exist in the main hurricane 'hot spots' such as Miami in the USA, Hong Kong, Australia and Japan.

Hurricane Isabel (2003) came ashore exactly wher it was predicted (Outer Barrier Islands) and at almost exactly the time. It was a caergory 2 storm by the time it came ashore (again exactly as predicted). Vastly improved computer models, very easy tracking and the position of other weather systems which controlled its path also contributed to the successful prediction.

Hurricane tracking in Hong Kong

Hurricanes are monitored by scientists at the Hong Kong Meteorological Office using enhanced infra-red satellite images produced every hour and radar images when the storm is within 500km of the territory. In the past, reconnaissance aircraft have provided accurate wind speed data but flights were stopped in 1987.

Weather charts are plotted every six hours to place the hurricane in the context of large scale weather systems, which can have a profound effect on the future intensity and course of a hurricane.

Over the western North Pacific, most of the tropical cyclones form along the southern or southwestern flank of the subtropical ridge of high pressure where the 'steering current' flows to the northwest. This explains the predominant north-westward storm tracks observed in this part of the world. However, fluctuations in the 'steering current' caused by changes in the high pressure area, together with internal changes within the storm itself, can lead to unexpected and eccentric hurricane tracks.

Forecasting and prediction make use of past records to predict likely courses of hurricanes approaching Hong Kong. Additionally, numerical computer models are used to help predict both the course and the intensity of hurricanes. However, each hurricane is essentially unique both in its own structure and dynamics and in its meteorological setting. The science of tropical cyclone forecasting is by no means perfect.

Another problem related to Hong Kong concerns its geographical setting. Most tropical cyclones approach the coast of southern China on a west-northwestward track. With the orientation of the coastline at such an oblique angle to the storm track and Hong Kong being such a small target, a deviation of only 10 degrees in the direction of storm movement is enough to divert the storm to Hainan Island instead of a direct hit on Hong Kong.

Faced with an uncertain and ever-changing situation, forecasters need to keep a close watch and be prepared to make timely updates and intelligent decisions. By the same token, the public should be aware of the uncertainties involved and be prepared to respond to the latest development as indicated by the warning bulletins.

(Additional information about forecasting hurricanes in Hong Kong can be accessed at the Hong Kong Meteorological Office at **http://www.hko.gov.hk/informtc/tc.htm**)

Coastal communities at risk from hurricanes are informed about the potential dangers associated with hurricanes and advised what to do in the event of an approaching storm. Warnings are issued over the radio and television and people may be encouraged to evacuate their homes to move to hurricane shelters on higher ground (as in Bangladesh) or inland away from the coast (as in the case of the USA).

In many instances hurricanes do follow 'typical' curved paths thereby making it relatively straightforward to forecast which areas are at risk. However, this is not always the case as Hurricane Mitch demonstrated in 1998 (see Factsheet 62). Furthermore, as hurricanes approach populated coastal areas, forecasters can only identify a broad area at risk, which is perfectly understandable given the size of hurricanes and the possibility that they might alter their course as they approach the coast.

To summarise, hurricane tracking and the use of computer models linked to satellite and radar observation can be used to forecast and predict areas at risk. There can be no doubt that such predictions have reduced the potential death toll, especially in MEDCs where the wherewithal exists to react and respond to warnings. However, not all hurricanes follow predictable courses as Hurricane Mitch demonstrated, and even when predictions are made the sheer scale of the storms rules out precise pin-pointing of those areas at greatest risk.

Conclusion

To a large extent it is a reasonable assertion that hurricanes are predictable hazards. They are restricted to certain parts of the world, having distinct 'source' areas over tropical oceans. Their occurrence is also largely predictable in that they are summer phenomena, being concentrated between July and October in the Northern Hemisphere and December to March in the Southern Hemisphere. They tend to follow typical tracks in response to the prevailing winds and the coriolis effect enabling computer models to help predict the courses of individual storms.

However, there have been a number of historical exceptions to the rules; hurricanes are not absolutely predictable. Each storm has its unique set of characteristics and exists within a unique meteorological setting. It is therefore important not to become complacent and expect all hurricanes to follow an expected evolution. There is much to be done to improve hurricane tracking and forecasting and it is still very difficult for scientists to predict accurately the conditions associated with individual hurricanes or their likely effects upon communities.

Further research

Access the National Hurricane Center's website at www.nhc.noaa.gov/pastall.shtml to find archive data for past hurricanes. Click the most recent year to find detailed information about hurricanes affecting America. Conduct your own research on the predictability of hurricanes in your chosen year by examining the months when hurricanes occurred and the nature of the tracks taken by the hurricanes. Comment on the level of predictability and identify any exceptions to the general rules.

Internet websites

An internet search will reveal many sites. One of the best is the National Hurricane Center at www.nhc.noaa.gov , which has huge amounts of archive information about individual events and a great deal of general information about hurricanes.

The National Oceanic and Atmospheric Administration's website is at **http://hurricanes.noaa.gov**.

The Hong Kong Meteorological Office at http:**//www.hko.gov.hk/informtc/tcSmap.htm** also provides a good deal of useful information and gives a slightly different perspective for a different part of the world.

Eaxm Question

1. The table below lists the top twenty hurricane disasters ranked according to deaths in Hong Kong (1960-2002).
   Describe and suggest reasons for the patterns shown [10}

Year & Name		Dates	Dead	Injured
1962	Wanda	28/08 – 02/09	130	N/A
1971	Rose	10/08 – 17/08	110	286
1960	Mary	04/06 – 12/06	45	127
1964	Ruby	02/09 – 06/09	38	300
1976	Ellen	21/08 – 24/08	27	65
1964	Dot	07/10 – 13/10	26	85
1979	Hope	28/07 – 03/08	12	260
1983	Ellen	29/08 – 09/09	10	333
1964	Sally	04/09 – 10/09	9	24
1961	Olga	07/09 – 10/09	7	0
1989	Brenda	16/05 – 21/05	6	119
1964	Ida	02/08 – 09/08	5	56
1965	Agnes	25/09 – 28/09	5	3
1990	Nathan	15/06 – 19/06	5	1
1999	Sam	19/08 – 23/08	4	328
1961	Alice	04/06 – 12/06	4	20
1978	Agnes	24/07 – 30/07	3	134
1963	Faye	01/09 – 09/09	3	51
1995	Helen	07/08 – 12/08	3	35
1976	Ruby	22/06 – 04/07	3	2

Answer Framework

- seasonally predictable -(expect data analysis) Anomalies include Brenda in 1989 (May) and Dot in 1984 (October). Reasons are associated with ocean warming in the summer.
- Generally speaking fewer **deaths** in recent years but the injury relationship is less clear. (Sam in 1999 was particularly damaging)
  Lower death rate associated with improved hazard management, risk reduction, prediction, education etc.
  Anomalies such as Sam perhaps associated with magnitude, or where and what it struck.

Acknowledgements; *This Factsheet was researched and written by Simon Ross a well known author.* ***Curriculum Press, Bank House, 105 King Street, Wellington, Shropshire, TF1 1NU****. Geopress Factsheets may be copied free of charge by teaching staff or students, provided that their school is a registered subscriber.*