Natural Hazards:
Climate & Weather-related Hazards

Lectures & practical

- **Lecture 1 (Tuesday 4 Oct)** DS
  Introduce climate & weather related hazards; Tropical cyclones.

- **Lecture 2 (Friday 7 Oct)** RD
  Floods (including introduction to the practical)

- **Lecture 3 (Tuesday 11 Oct)** DS
  How does climate variability influence meteorological hazards?

- **Lecture 4 (Friday 14 Oct)** DS
  Will meteorological hazards be affected by climate change?

- **Lecture 5 (Tuesday 18 Oct)** RD
  Storm hazards in the UK

- **Lecture 6 (Friday 21 Oct)** RD
  Heat-waves and droughts

- **Flood practical (13/14 Oct, 20/21 Oct)**
  Floods in the UK – likely impacts from climate change over the next century
  Please look at documents handed out/on WebCT in advance
Reading/Further info

- Course book: E.A Keller & RH Blodgett, Natural Hazards; some chapters on WebCT
- Old Course book: E. Bryant, Natural Hazards, 2nd Ed. (2005)
- Many useful web-sites (general):
  
  http://naturalhazards.org
  http://earthobservatory.nasa.gov/NaturalHazards
  http://www.ipcc.ch

Flooding in India, September 2011

- http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=52089
Floods

Mozambique, 2000

High-magnitude, regional floods – prolonged heavy rain over large area

York Floods, Autumn 2000

Regional floods, due to prolonged heavy rain (compare to flash floods)
Flash-flooding in the UK

Boscastle, Cornwall: Summer 2004

A total of 75 mm - the August average rainfall - fell in two hours

Cornwall is prone to these sort of events; e.g. Polperro, 1993

Rainfall intensity & local hydrology are the crucial factors

Land precipitation is changing significantly over broad areas

Increases

Decreases

Smoothed annual anomalies for precipitation (%) over land from 1900 to 2005; other regions are dominated by variability.

IPCC (2007)
Drought

Drought destroyed the corn crop of this farmer in Lisutu, Zambia, in 2002. Climate research suggests that drought may intensify across southern Africa in future.

The UK in 1976.

2004-2006, SE England experienced its worst drought on record; Summer 2007’s rain ended this.

Drought is increasing most places

The most important spatial pattern (top) of the monthly Palmer Drought Severity Index (PDSI) for 1900 to 2002.

The time series (below) accounts for most of the trend in PDSI.

IPCC (2007)

Mainly decrease in rain over land in subtropics, but enhanced by increased evaporation with warming
Regions of disproportionate changes in heavy (95\textsuperscript{th} percentile) & very heavy (99\textsuperscript{th} %-tile) precipitation

Proportion of heavy rainfalls (1951-2003): increasing in most land areas

**IPCC(2007)**

---

**Storms**

**Large-scale storms (>\sim 100 km across)**
- Tropical cyclones
- Extra-tropical cyclones
  - Both associated with:
    - Storm surges (short-term increase in sea-levels)

**Small-scale storms (<100 km across)**
- Thunderstorms (lightning, hail)
- Tornadoes
  - [not discussed further in this course]

*Keller and Blodgett, Chapters 9 & 8*
Meteorological Hazards in context

<table>
<thead>
<tr>
<th>Rank</th>
<th>Hazard</th>
<th>Deaths/ millions</th>
<th>Cost/ US$bn</th>
<th>Homeless/ millions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (1)</td>
<td>Drought (Famine)</td>
<td>14*</td>
<td>17</td>
<td>?</td>
</tr>
<tr>
<td>2 (3)</td>
<td>Floods</td>
<td>6.9</td>
<td>207</td>
<td>123</td>
</tr>
<tr>
<td>3 (4)</td>
<td>Earthquakes</td>
<td>1.8</td>
<td>249</td>
<td>9</td>
</tr>
<tr>
<td>4 (2)</td>
<td>Tropical cyclones</td>
<td>1.1</td>
<td>80</td>
<td>34</td>
</tr>
<tr>
<td>5 (5)</td>
<td>Volcanoes</td>
<td>0.1</td>
<td>?</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Based on Bryant Table 1.3 (from WHO, 2002) / Table 1.4 / Table 1.2
Statistics are for the 20th century.
*NB assumes all famine deaths are due to drought (oversimplification)

Weather Hazard risks

- Drought, Floods, and Tropical Cyclones rank in the top 4 deadliest natural hazards, based on the 20th century
- The time period considered can be crucial, especially for infrequent, severe events. Extreme example here is asteroid impacts…
- Hurricane Katrina (2005) cost ~$80bn – i.e. a single event is equivalent to the entire 20th century estimate for tropical cyclones!
- Treat all statistics with due caution!
- Underlying poverty level, and interaction with other factors, such as war and ease of relief administration, have crucial impact on e.g., number of deaths, economic losses
Analysis by Munich Re, 1950-2008

- Great Natural Catastrophes (GNC)
  
  UN definition:
  ‘…if the affected region’s ability to help itself is clearly overstretched and supra-regional or international assistance is required
  - Number of fatalities exceeds 2,000 and/or
  - number of homeless exceeds 200,000 and/or
  - overall losses exceed 5% of that country’s per capita GDP and/or the country is dependent on international aid
How much of the increase from increasing vulnerability (i.e. building in dangerous places) and increasing population? How much (if any) due to climate change?
Tropical Cyclones

Hurricane Katrina August 2005

Image Courtesy: CIMSS/SSEC
What is a tropical cyclone?

- Synoptic scale (100’s km) – typically 500km
- Low surface pressure system – convergence of air at surface, ascent and cloud formation
- Associated thunderstorm activity
- High wind (>74 mph), heavy rain, storm surge
- **Hurricanes** in North/Central America (~5/yr / ~9/yr)
- **Typhoons** in Western N. Pacific (~16/yr)
- **Cyclones** in Australia/Indian Ocean
Regions of Formation

Q. Why do they form only these regions of the tropics and during these periods?

Tracks and Intensity of All Tropical Storms

Hurricane Catarina, March 2004
1st Hurricane in S. Atlantic

Saffir-Simpson Hurricane Intensity Scale
Conditions for Tropical Cyclone Formation

- They form only over oceanic regions with sea-surface temperatures (SSTs) are greater than 26.5°C
- They do not form within 5° of the equator due to the negligible Coriolis force there
- They form in regions where vertical wind shear between the surface and upper troposphere is low (less than ~23 mph or 10 m/s)

Evaporation and temperature

- Evaporation increases rapidly as temperature increases
- Evaporation = energy in the form of latent heat that fuels the cyclone
Regions and seasons T>26.5°C

Orange/yellow regions - tropics between June and December

Reasons why cyclones do not form in certain tropical regions

- Cold currents
- Without the Coriolis force, surface winds cannot gain sufficient rotation to converge and the low pressure of the disturbance cannot be maintained
- Large values of vertical wind shear disrupt the formation of a tropical cyclone by interfering with the organization of deep convection around the cyclone centre
Tropical cyclone dissipation

- Typical lifetime is less than 1 week
- Record: hurricane John (1994) 31 days
- Weaken rapidly when they lose their heat source:
  - Reach more northerly locations and cooler waters
  - Travel over land: a) energy source removed b) friction at land-surface decreases surface winds causing central pressure to rise
- Encounter large vertical shear e.g. in mid-latitude jet-stream
Prediction is still very difficult

The 8-day ensemble forecast shows large uncertainties in the path of Hurricane Ivan. Ultimate path in black. Operational path in red. Note tendency for clustering of tracks. 5 members to east, 4 members to west, 1 ensemble member in the middle.

Hurricane forecasting

- The “Cone of uncertainty”-also known colloquially as the “Cone of death”
- It represents the forecasted track of the centre of a hurricane and the likely error in the forecast track based on predictive skill of past years as well as details about the storm
“Cone of Death”

- Based on forecasts over the previous 5 years, the entire track of the tropical cyclone can be expected to remain within the cone roughly 60-70% of the time
- It only conveys the uncertainty in the track forecast
- Usefulness to decision makers?
- Many believe that it depicts the potential swath of destruction of the storm while in reality, it only represents the potential area the center (“the eye”) of the storm may travel in
- New weather-based experimental probability graphics

Wind speed probabilities provide the chances of wind speeds equal to or exceeding familiar thresholds (for example, tropical storm force and hurricane force) at individual locations on the map.
Tropical Cyclones: Summary

- Size: ~500 km
- Lifetime: ~1 week
- To form: SST > 26.5°C, >5°N/S, low vertical wind shear
- Dissipate over land/cool ocean/mid-latitudes
- Flooding from storm surge greatest hazard
- Probabilistic forecasting a few days ahead
- Will TCs increase with climate change?
  - Question for upcoming lectures