Extreme events: flooding

GG22A: GEOSPHERE & HYDROSPHERE
Hydrology

Types of flood risk

- Main types of climatically influenced flooding:
  1. Flash (rapid-onset)
  2. Lowland (slow-rise)
  3. Coastal
     - (not covered here)
- But! Causal factors are not just climatic…

What is flash flooding?

- Rapid localised flooding of low lying areas
  - Usually along streams but not always
  - Caused by the sudden accumulation of water, usually from intense rainfall (often from thunderstorm events)
    - Can also from sudden release of water from, for example, a breaking dam.

Flash flooding

- Intense rainfall from convective thunderstorms may only last a few hours...
  - but can result in serious flooding in catchments that are small, steep or highly urbanised

Flash flood characteristics

- Occur suddenly – little time for warning
- Fast-moving and generally violent – threat to life and severe damage to infrastructure
- Generally small in scale regarding area of impact
- Frequently associated with other events – riverine floods and mudslides
- They are rare (?)

Causes of flash flooding

- Non-climatic
  - Geomorphology:
    - steepness of slope
    - upstream contributing area
    - relief – is area confined or a wide floodplain? Narrow valleys more likely to experience serious flash flooding.

Causes of flash flooding

- Non-climatic
  - Permeability of land surface
    - If water cannot be absorbed into the ground, it will quickly be moved downslope
  - Caused by:
    - Geology & soil type: e.g. arid hard pan soils
    - Saturation of ground from previous rainfall
    - Land cover – e.g. concrete. Urban areas are susceptible to flash flooding
    - Urbanisation: urban drainage

Causes of flash flooding

- Non-climatic
  - Reduced or insufficient drainage system efficiency
  - Volume of water may be too much for the drainage network to carry, causing flooding
    - Capacity of network may not be sufficient: e.g. British Victorian sewer systems
    - Capacity of network may be reduced: e.g. blockages cause by debris.

Causes of flash flooding

- Climatic
  - Intensive rainfall, often from one or multiple thunderstorms in the same place
    - Can happen when multiple storms move along a stationary front

Flash flooding in Boscastle, UK

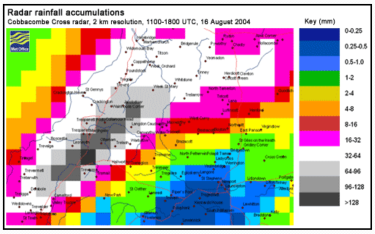
Flash flooding in Boscastle, UK

- River Jordan flows into R. Valency in center of Boscastle.
- Small catchment : 7.7 square miles
- But Steeply sloping – rises over 300 meters in 6km.
- Thin soils
- Impermeable Bedrock: high amounts of runoff.
- High sediment supply: reduces channel capacity
- Human Impact
  - Arched bridges over river collect debris
  - Sewer pipe reduces channel capacity

Boscastle: A History of Flooding

- 28th October 1827 "the whole street was filled with a body of water rolling down & carrying all materials with -devastation & ruin were its concomitants"
- 6th September 1950: Whole trees uprooted, block river and cause flood
- 3rd June 1958: River Valency rose 4.5m in 20 minutes. 1 fatality.
- 6th Feb 1963. Flood caused by melting snow.
- 24th August 2004: worst floods in recent history.
  - 6 buildings washed away (many more reported unsafe)
  - 100 cars washed away
  - 75 people rescued by helicopter
  - Infrastructure (roads, bridges & sewers damaged
- Video: Boscastle flooding, August 2004

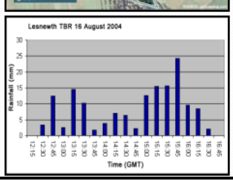
Boscastle: August 2004 Flood



- "Train" of slow moving thunderstorms.
- 181mm of rain in Trevalec, and 200mm in Otterham.
- An estimated 440 million gallons of water flowed through Boscastle

2004 Flood Timeline

- 1.00pm: Flows in Valency and tributaries begin to increase.
- 3.30pm: Valency begins to spill over north bank between the two bridges.
- 3.45pm: Lesnewth rain gauge records 15mm - half an inch - in five minutes.
- 3.45pm: Cars in car park start to float; water on B3263 a few inches deep
- 4.00pm: Witnesses see 3m (10ft) wall of floodwater sweep across car park into Visitor Centre; deep, fast-flowing water makes B3263 impassable.
- 4.10pm: Water levels on car park rise and cars start to be carried through village by floodwater.
- 5.00pm: Floods at their peak; cars washed down from car park. About 84 wrecked cars were later recovered from Boscastle's harbour, streets and gardens, but another 32 were washed out to sea.
- 6.00pm: Floods started to recede
- 8.00pm: Water levels back within river banks



Flood risk in Boscastle

- Risk to People: Short return period, deep, fast flowing and rapidly rising
- Risk to Property: Structural damage, and deposition of silt
- Risk of Blight: Tourists stay away
- Risk to the Environment: Damage to Conservation area and historic buildings.

	1 in 50 (2%) chance	1 in 75 (1.33%) chance	1 in 100 (1%) chance	1 in 400 (0.25%) chance
Commercial	21 properties	24 properties	26 properties	28 properties
Residential	14 properties	15 properties	17 properties	19 properties
Total	*35 properties*	*39 properties*	*43 properties*	*47 properties*
Additional residences with no access	22			20
Infrastructure	Key coastal link road (B3263)			

Hazard Prevention?

- Could the 2004 flood have been prevented? **No:** To much rainfall in too short a time.
- Environmental consultants H.R. Wallingford concluded that land use changes had little impact on the severity of flooding
- However, despite the immense difficulty of preventing a similar flood in the future extensive flood defences have been outlined.
- Most likely to protect against 50 year return period floods.
  - Proposals include:
  - Widening Channel
  - Lowering the river bed
  - Flood defence wall
  - Raising the car park
  - Removing sewer
  - Creating braided channel section

Video: Boscastle flooding, 21 June 2007

Climate and flash flooding

- Many factors causing flash flooding are not climate driven
- Main climate factor in the cause of flash flooding is *intensive rainfall*
  - Intense rainfall on its own doesn't cause flash flooding – other causal factors are necessary
  - An increase in frequency of intense rainfall events would increase likelihood of flash flooding

Climate change and flash flooding

- UKCIP02 study:
  - Summer rainfall will decrease (Hulme et al. 2002)
  - But thunderstorms are likely to become more frequent and produce heavier and more intense rainfall (Dale 2005)
- General trend to drier summer conditions in Europe
  - But episodes of severe flooding may become more frequent due to short (1-5 days) episodes of heavy precipitation.

2. Lowland river flooding

- Lowland river flooding
  - How is this different?
  - Climatic factors
- Assessing flood risk
  - General overview

Lowland river flooding

- What is it?
  - Inundation of areas of low lying land from a river that has burst its banks
- Caused by excessive precipitation, which may have fallen hundreds of kilometres upstream.

Lowland river flooding

- How is it different?
  - Larger and less dynamic event than flash flooding, and usually further downstream
- May be connected to other types of flooding (multiple flash floods leading to lowland flooding)

Lowland river flooding

- Usually caused by:
  - long-duration rain from one or more frontal systems
  - springtime snowmelt
- Can be many other causal factors or a combination

Tewkesbury flooding video, July 2007

Climate and river flooding

- Warmer climate → more atmospheric water
  - possibly both intensifies low-pressure systems and makes more water available for precipitation

(see Frei et al. 1998)

- Climate model integrations:
  - increases in both the frequency and intensity of heavy rainfall in high latitudes of the northern hemisphere

(see Palmer and Räisänen 2002, Ekström et al. 2005)

Climate and river flooding

- Increases in *average amount* and *variability* of precipitation predicted for N European regions
  - higher flood risks

(see Arnell et al. 2000)

Climate and river flooding

- Incidence of "great floods" (floods that exceed 100-year levels in basins larger than 200,000km²) increased in the 20th century.
  - Statistically significant positive trend, consistent with results from climate models.

(see Milly et al. 2002)

Climate and river flooding

- UKCIP02 predicts that UK winter rainfall will increase

(see Hulme et al. 2002)

  - *probability of the total winter precipitation exceeding two standard deviations above normal levels will increase by a factor of five over the next 100 years*.

(see Palmer and Räisänen 2002)

Climate and river flooding

- Research by Lehner et al. (2006):
  - global integrated water model (WaterGAP)
  - driven by climate change projections (temperature and precipitation) from GCMs
  - set of scenario assumptions for changes in human water use.
    - "Business as usual approach" for economic growth and activity
    - Imply an average annual increase of CO_2 emissions of 1% per year.

Climate and river flooding

- As early as 2020, across large parts of the northern Europe, the north of the UK and the Iberian peninsular:
  - Floods with a return period of 100-years today can be expected to occur every 40-years,
  - The 100-year event will be around 10% more severe.

Lehner et al. (2006)

Climate and river flooding

- Research by Hall et al. (2005):
  - Assessment of current/ future flood risk in England and Wales:
    - current expected annual economic flood damage to residential and commercial property to be US$550M (uncertainty range: US$330M – $1.15Bn).
    - *high emission* and relatively *loose regulation* scenarios, this may be expected to rise to ~US$8Bn by 2050 and US$11.3Bn by 2080.
    - *global sustainability scenario*, annual economic damage is predicted at US$2.7Bn by 2080.

Climate and river flooding

- Many extreme floods are caused by intense precipitation in mountainous areas, or a combination of precipitation and snowmelt
  - Research by Kim, 2005:
    - Western US:
      - Increased winter precipitation
      - Increase in the rainfall-portion of precipitation (at the expense of snowfall) =

        ⟶ large increases in high-runoff events in river basins already prone to winter flooding
    - Higher average temperatures = higher freezing levels = change in the normal type of precipitation from snow to rainfall, and an increase in winter snowmelt

Climate and river flooding

- Many extreme floods are caused by intense precipitation in mountainous areas, or a combination of precipitation and snowmelt
  - Research by Kaczmarek, 2003:
    - Study for Poland, found that the risk of snowmelt induced flooding is linked to the North Atlantic Oscillation (NAO):
      - Increasing NAO leads to an increase in surface air temperature and a temporal redistribution of winter and spring runoff.

        → Winter runoff increases, increasing in flood risk

        → Spring snowmelt decreases, reducing flood risk.

Flood risk: defining probability

- What is the probability of a flood or other natural hazard occurring?
- Often defined using past observations
  - Are the occurrence of past events a good indicator of future probability under climate change?
- Change in probability may be cyclical in line with natural climate variability – e.g. ENSO

Consequences of climate change

- As well as changing *averages*, climate change is likely to affect *extremes* of distributions: but quantifying extremes is very difficult.
- Possible effect of climate change on events:
  - Increased *frequency* and *magnitude* (return periods decreasing)
  - Therefore, increased *probability* and *consequences*
- Changes the *risk* and may increase *vulnerability* (risk management strategy no longer sufficient).