Managing Risk in an Age of Extremes

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EPSRC-funded UK Network "Maths Foresees"

The Science of Floods: May 8^{th} 2016, Hebden Bridge

Introduction

Who am I?

Is it going to rain more in the future?

Extreme precipitation and flooding events?

Can we predict heavy precipitation & floods?

Can we mitigate flooding?

Conceptual flood demo model?

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2 Who am I?

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1. Introduction

Flood Demo

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I will consider the following questions:

- Who am I? – My background as applied mathematician.
- Is it going to rain more in the future?
- Can we define extreme precipitation & flooding events?
- How (well) can we predict heavy precipitation & floods?
- How (well) can we mitigate and control flooding?
- How can we elucidate the above in an interactive, conceptual table-top demonstration?

2. Who am I?

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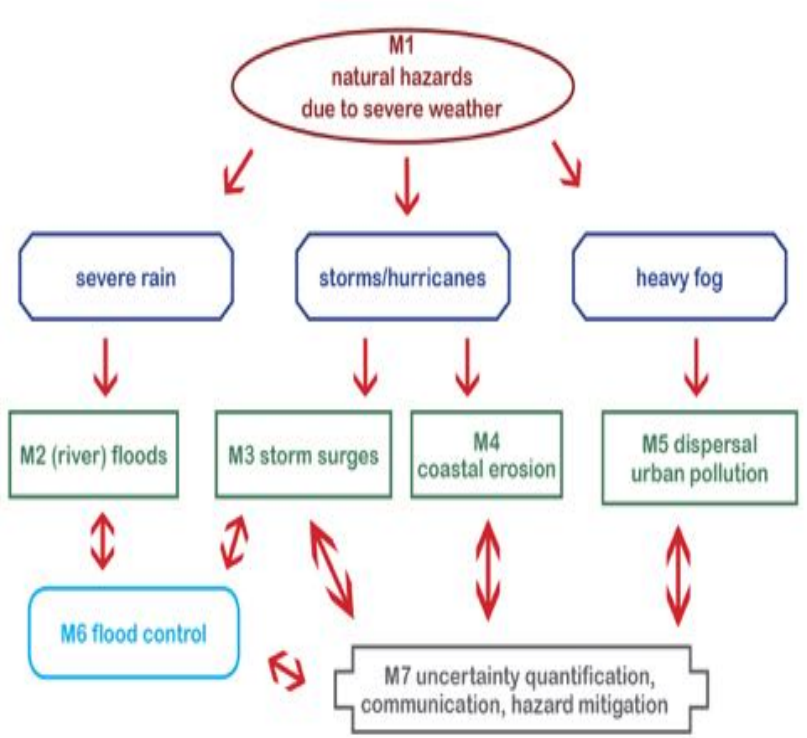
Expert in Geophysical & Environmental Fluid Dynamics, School of Mathematics, University of Leeds:

- Leading UK EPSRC Network "*Maths Foresees*: mitigating severe environmental events":



- Investigating models for numerical weather prediction and data assimilation of rainfall –with the Met Office.

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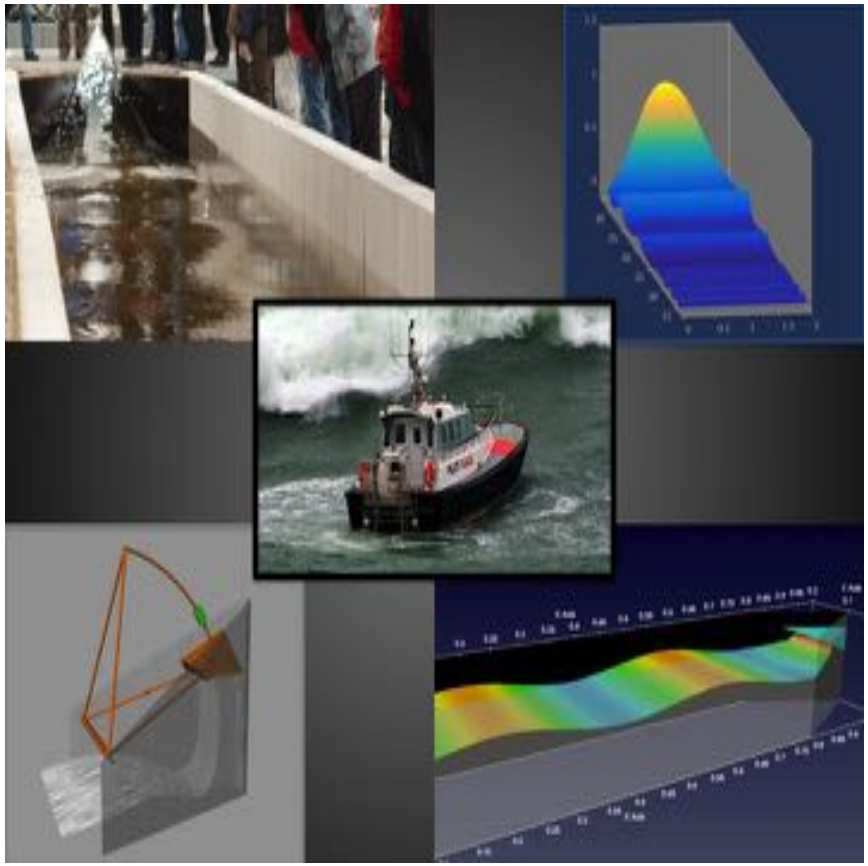
- Modelling extreme waves, ships in waves, *wave-energy*:



3. Is it going to rain more in the future?

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Definitions:

- *Return period*: if 100 years of *daily rainfall* data were available, an event with a 1 in 20 year return period would be expected to occur 5 times in that data set.
- In any year such an event has a probability of 1 in 20, i.e. has a 5% chance.
- *Extreme events*: events with a (longer) return period of 1 in 5, 1 in 10, 1 in 20, 1 in 30, 1 in 50 or 1 in 100 years.

Is it going to rain more in the future?

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IPCC report 2013 (Intergovernmental Panel on Climate Change), measurements:

- No, there is low to medium confidence in increased average annual rainfall.
- But, for extreme precipitation Europe: "High confidence: likely increases in more regions than decreases but regional and seasonal variation"
- "...median reduction in 5-to 20-year return periods of 21% with an increase in moderate extremes".

Is it going to rain more in the future?

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Similarly, Michael Sanderson's UKCP09 report Met Office 2010 (data 1960–2006), for UK:

- No, annual mean daily rainfall has not increased significantly since 1766.
- But proportion of winter rainfall in heavy rainfall events has increased across UK in last 45 years.

- In summer rainfall has decreased except in NE England and Northern Scotland.
- "Although summer rainfall may decrease, it could be concentrated into a number of intense downpours from storms".

4 Can we define extreme precipitation & flooding events?

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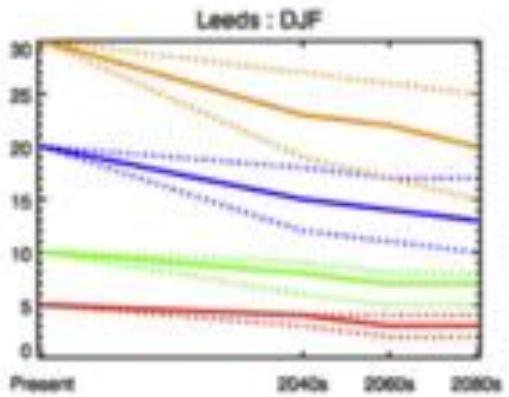
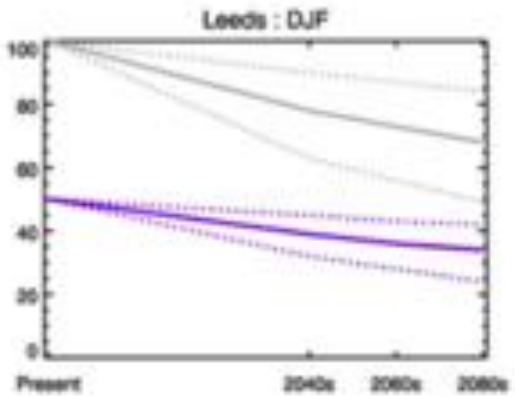
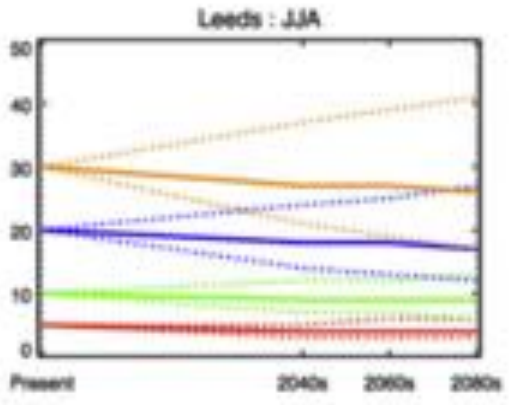
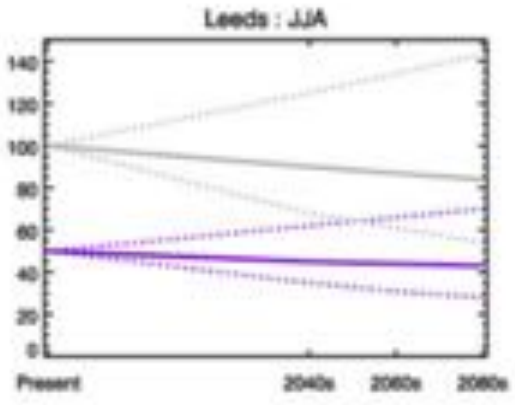
Caution:

- The uncertainty in the return period for a 1 in 100 year event will be larger than in a 1 in 20 year event.
- Uncertainty will be smaller for larger data sets.









Extreme precipitation and flooding events?

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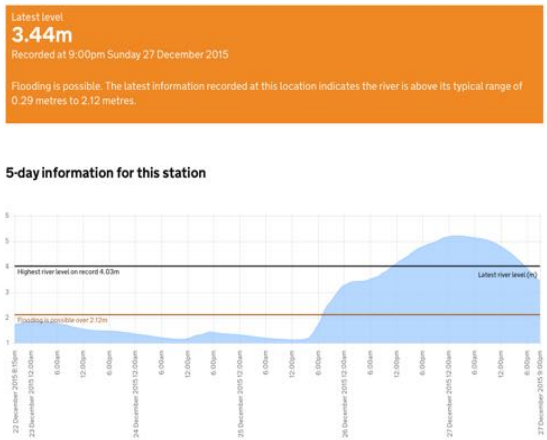
Challenges and basic problem (Coles, 2001):

- There are very few observations "in the tail of the distribution", i.e. for extremes with long return periods.
- Estimates required beyond largest observed data values.
- E.g., Aire River gauge at Armley/Leeds had highest record of 4.03m prior to 26-12-2015; how to estimate return period for the Boxing Day flood with 5.21m at this gauge?



- Standard statistical techniques work well when there are a lot of data, but don't work well for extremes.

5. How (well) can we predict heavy precipitation and (overland) floods?

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Distinguish between downpours and sustained rainfall:

- Downpours (short ca. 1 hour) and flash floods, e.g., *Hebden Bridge July 2012*
  `http://www.bbc.co.uk/news/uk-18778840`

Hebden Bridge hit by flash floods

- Aquaduct as 2012 flood control point:
  `https://www.youtube.com/watch?v=k4OPhlCYn4A`
  (Sara Dee)

How (well) can we predict heavy precipitation and (overland) floods?

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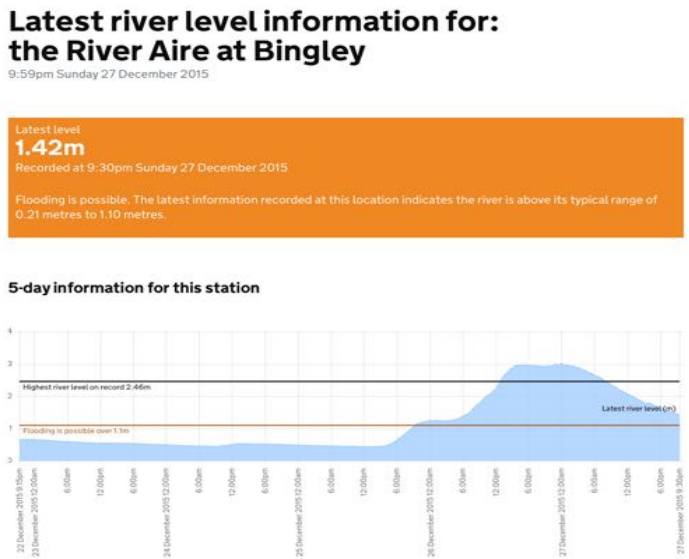
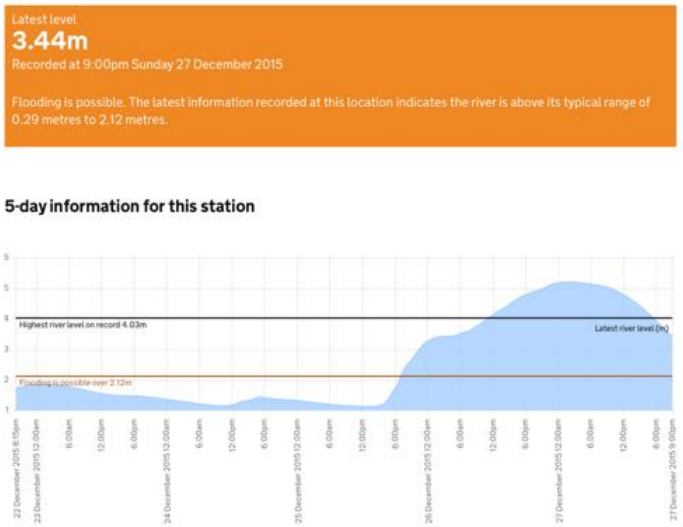
- Sustained rainfall and flooding, e.g.
  Boxing Day rainfall and floods 26-12-2015
  Bradford: 69mm/48hrs; Bingley: 94mm/48hrs
- *Aire River Flood* & *Aire River Kirkstall The Forge*





How (well) can we predict heavy precipitation and (overland) floods?

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- Downpours, their location and the amount of rain, are very difficult to predict.
- Numerical Weather Prediction (NWP is computer modelling from e.g. the Met Office) cannot handle those cases (well), due to lack of computer power and lack of insights in the physics of precipitation.
- Also, NWP uses/assimilates lots of data to bring the computer model back to reality.
- Sustained rainfall and river flooding is by and large well-predicted: the Met Office and Environment Agency do a reasonably good job e.g. Aire River floods.
- Prediction of localized surface water/brooke flooding is more uncertain/less good, due to a lack of data.

6. How (well) can we mitigate flooding?

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- Create multiple storage and buffers upstream.
  - Lowers peak values but broadens the flood peaks.
  - May work less well for large water volumes, including consecutive heavy rainfall events.
- Create more permeable surfaces, green soft-surface gardens and absorbing roofs in urban areas, wadi's.
- Use bypass canals as overflow channels to lessen peaks. Does require maintenance and alteration to canal system.

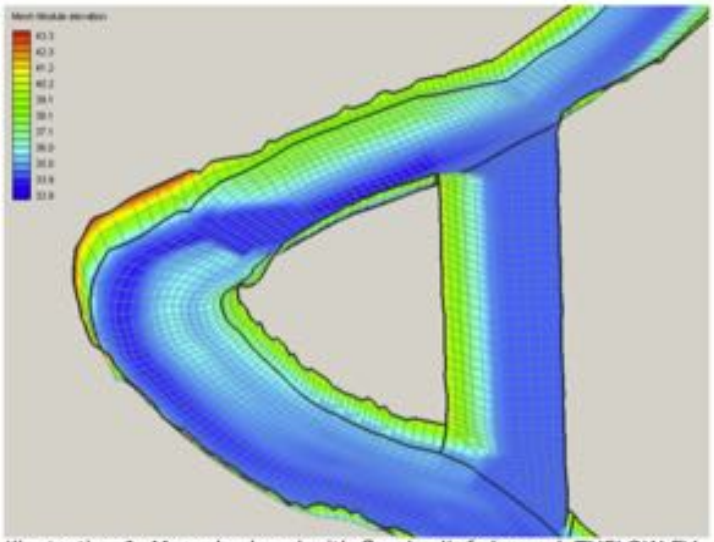

Illustration 1: Meander bend with flood relief channel, TUFLOW FV mesh

How (well) can we mitigate flooding?

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- Sustainable flood plain management: designated flood plains (pay owners), houses on stilts, houses on mounts with surrounding canals/wadi's.
- Legislation & "Waterschappen" (Water Governance).
- Create "Ruimte voor Water" (Space-for-Water), cf. The Netherlands & Germany 1995 & 1997 floods.

How (well) can we mitigate flooding?

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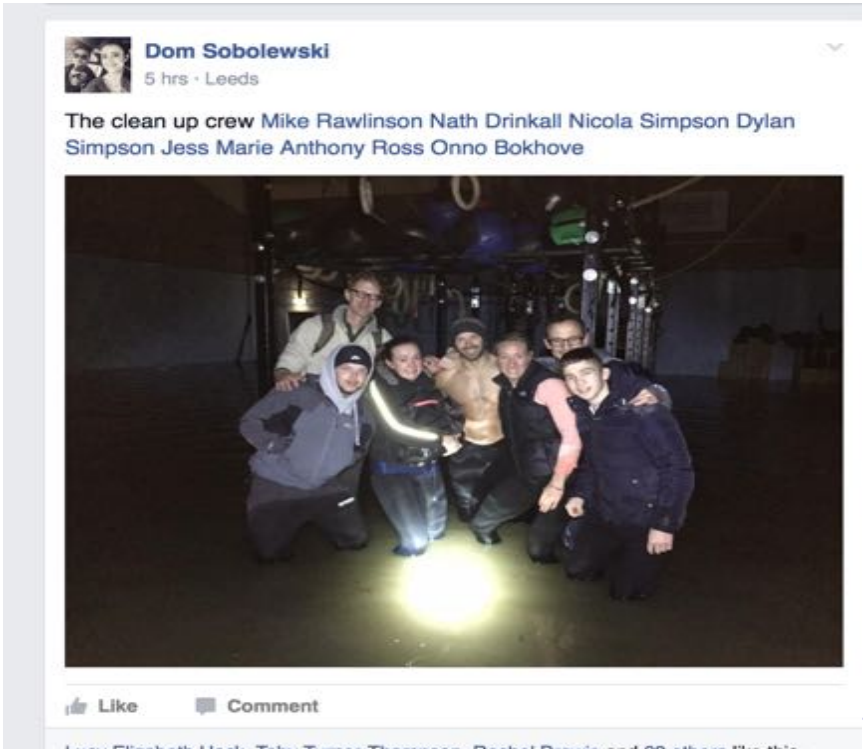
- Active (mathematical) control of weirs, sluice gates, and buffer areas.
- Teach people how to make a local flood evacuation plan (goods/people), based on online river-level gauges, previous floods (CCTV/mobile phone data), and rainfall predictions, themselves.



7. How can we elucidate the above in an interactive, conceptual table-top demo?

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A conceptual demo to highlight the concepts of flooding, complementary to the experiments shown this afternoon:

- Use *vertical Hele-Shaw cell* as conceptual valleys:
  - spungy material=moor
  - hard surface=urban asphalt,
  - adjustable weirs for storage in reservoirs, etc.

How can we elucidate the above in an interactive, conceptual table-top experiment?

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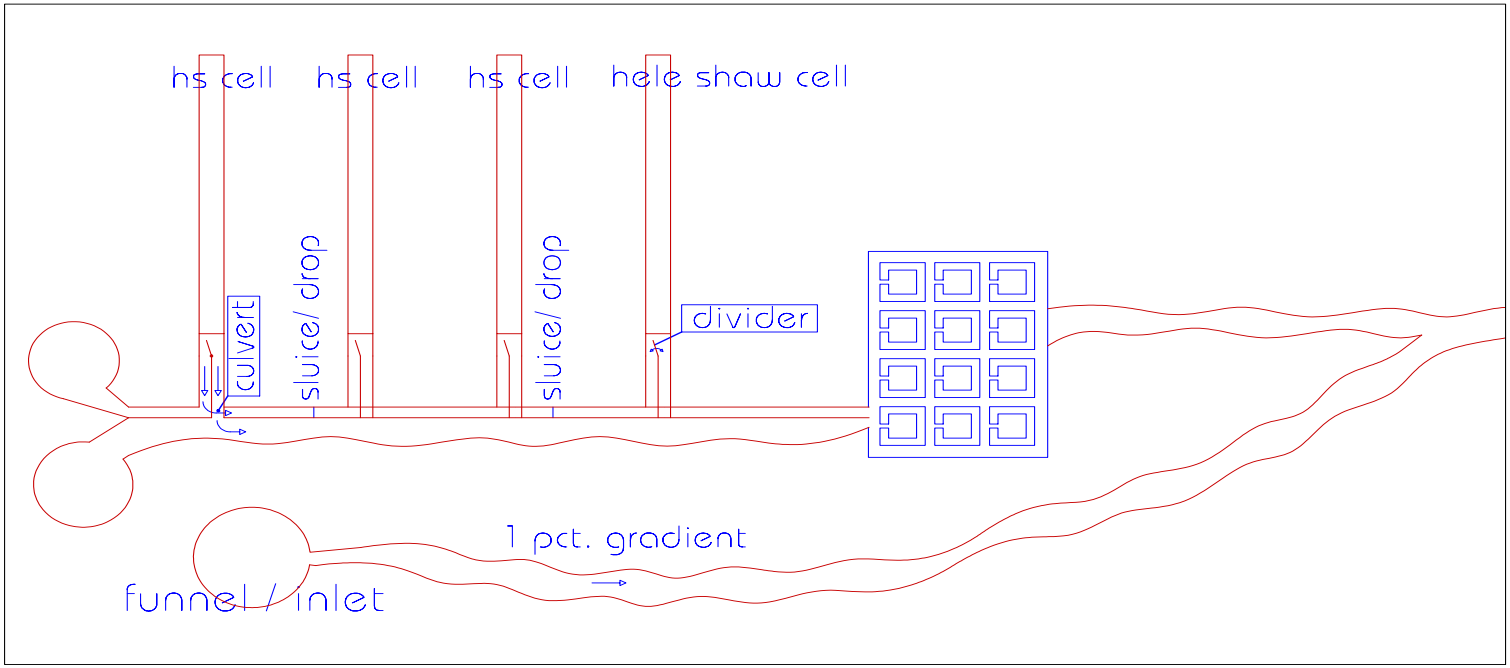
- In progress. Sketch plan-view:



- More demos and movies on fluid dynamics & flooding: `https://www.facebook.com/resurging.flows`

Appendix A: 48hr UK rainfall Boxing Day 2015

48hr UK RAINFALL TOTALS 9am 25 DEC - 9am 27 DEC 2015

SITE	AREA	RAINFALL (MM)	TOTAL
CAPEL CURIG	GWYNEDD	210.6	
STONYHURST	LANCASHIRE	100	
PATELEY BRIDGE, RAVENS NEST	NORTH YORKSHIRE	97	
BINGLEY	WEST YORKSHIRE	93.6	
BAINBRIDGE	NORTH YORKSHIRE	89.8	
BALA	GWYNEDD	89.4	
SHAP	CUMBRIA	86.4	
SPADEADAM	CUMBRIA	79.4	
PRESTON, MOOR PARK	LANCASHIRE	73.2	
MYERSCOUGH	LANCASHIRE	72.4	
BRADFORD	WEST YORKSHIRE	69.4	
ROCHDALE	GREATER MANCHESTER	68.2	
MORECAMBE	LANCASHIRE	65.8	
MONA	ISLE OF ANGLESEY	63.6	
KIELDER CASTLE	NORTHUMBERLAND	61.2	
DISHFORTH AIRFIELD	NORTH YORKSHIRE	60.8	

This wet spell has added to the heavy rainfall through the rest of the month to make December 2015 already the wettest on record in parts of the UK.

Figure 2: http://blog.metoffice.gov.uk Rainfall summary 25-27 December 2015.