Classification: Public

# Understanding the Risk from Correlated Windstorms and Floods in the UK











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# A Thought Experiment

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#### Great Storm of 1987



£2bn<sup>(1)</sup> (£5.526bn today)

#### Floods of winter 2013/14



£1.3bn<sup>(2)</sup>

References

1. The Great Storm of 1987, RMS Special Report.

2. U.K. Environment Agency

Could extreme wind and flood events occur in tandem?

Are the two physically linked?

What are the implications for the insurance industry?

# Talk Outline

- 1. Knowledge Transfer Partnerships (KTP)
- 2. What is our KTP?
- 3. Methodology
- 4. Spatial patterns in correlations between windstorm and high river flow
- 5. Case studies of some extreme compound events
- 6. The frequency of compound events
- 7. Summary

# Knowledge Transfer Partnerships (KTP)

Innovate UK

- "UK-wide programme that has been helping businesses for the past 40 years to improve their competitiveness and productivity through the better use of knowledge"
- An extended research problem usually for **12 to 36 months**
- Shared funding between government (innovate UK) and a business
- Academic partners who take part in a KTP produce on average more than **3 new research projects** and **2 research papers** for each project.



# Our Project

- Collaborative 2-year project venture between Reading University and insurers at Lloyds Banking Group
- Will use a combination of observations/reanalysis/climate simulations to understand the risk in correlated flood and windstorms in order to prepare for an extreme compound event
- Small (but growing!) area of research
- Big problem for the Insurance industry, who currently do not know what to do. Any correlation will effect capital requirements.







National Centre for Atmospheric Science

# Correlations in River Flow and Wind: Method

Data:

- ERA5 10m wind speed
- NRFA river gauge data
- 1979-2015

Method:

- 1. Choose a sample of locations
- 2. Filter river peak over threshold (POT)
- 3. Choose max wind and max flow during POT.
- 4. Extra filters (e.g. event proximity)



Figure: Scatter plot of NFRA maximum POT flow and ERA5 **maximum 10m wind speed** for London (Kingston), 1979-2015. Dashed lines show 99<sup>th</sup> percentile. Spearman correlation coefficient is printed in the top left.

#### Correlations in River Flow and Wind



# London extreme: Winter 13/14

References

1. Environment Agency

2. UK Met Office



# Carlisle Extreme: Storm Desmond

References

1. PricewaterhouseCoopers (2015)

2. McCarthy et al. (2016)

- Winter 15-16
- 5,200 homes flooded, 43,000 without power
- Estimated £500m in damages<sup>(1)</sup>
  <u>Meterology</u>
- Highest 24-hour total rainfall (341.4 mm)<sup>(2)</sup>
- Extra-tropical cyclone
- Atmospheric river advection of mild moist air from Atlantic
- Damaging winds and extreme flood a compound event! (albeit, flood dominated)



#### Winter 13/14 vs Desmond





2 different regimes, both led to compound events.

How frequent are compound events?

# London History



Black lines = exceeding 99% in both wind and river

Events: 88 - Floods in Maidstone, London. 90 – Storm Daria

Red lines = exceeding 99% in wind and 99.9% in River

Events: Winter 13/14

# The Likelihood of Extreme Compound Events



- More lines than expected! (~10,000 data points, would expect 1 compound point to exceed 99<sup>th</sup> percentile in both data if uncorrelated).
- Some locations have >10 times as many lines
- Nearly all locations have a very extreme event (red lines).

# Wide-ranging Extreme Compound Events



- Winter 13/14 appears in 6 locations
- Daria (1990) appears in 8 locations
- Kyrill (2007), Lothar and Martin (1999)...
- Big events can affect large areas of the country
- Winter 13/14 floods estimated return period >100yrs (CEH)
- Daria estimated return period ~25-39yrs (Della-Marta 2009).

# Frequency of extreme compound events

no. of points that exceed a given percentile in each data set

ER = \_\_\_\_

expected no. of points which exceed the percentile by pure chance

•	Define an	exceedance	ratio (ER)	
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- Quick calculation to estimate the number of compound events in the historical set compared to the number we'd expect by pure chance
- Over 1 in all locations more than chance.

Location	10 day ER <sub>90</sub>
Carlisle	2.7
Edinburgh	2.1
Newcastle	1.6
Manchester	1.8
Leeds	2.1
York	2.1
Cardiff	4.0
Birmingham	3.7
Norwich	1.2
Exeter	1.8
Brighton	3.3
London	2.1

# Drivers of compound events



Left – winter 13/14

- Blue = all storms
- Red = compound events
- We found no evidence for certain antecedent conditions that lead to compound events

Right – Storm vs compound events in each season

 When it's stormy, there are more compound events!



No. of compound UK events per winter (DJF)

### Summary

- 1. We have undertaken a research project with insurers at Lloyds Banking Group to asses the **risk of compound windstorm and flood**.
- 2. We have investigated **correlations in wind and stationed river flow** and found modest correlations in the South and West UK.
- 3. We have linked some **extreme compound events** to **named storms**. A number of these events affect multiple areas across the UK.
- 4. Compound event have occurred at a surprising frequency. In some locations, we find **more extreme compound events** than expected if windstorm and floods were uncorrelated.
- 5. We found no evidence for specific drivers of compound events. Instead, invents are prevalent when a storm passes though after a wet period.

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**\*\*\*** University of



Thanks! Questions?

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#### **Reserve Slides**

## Correlations in Precipitation and Wind

Data:

- ERA5 10m wind speed
- CHESS precipitation

Method:

- 1. Choose a sample of point locations
- 2. Designate time "windows"
- 3. Correlate accumulated rainfall and max wind over time window

	1 dav	3 dav	5 dav	' 10 dav	21 dav
Exeter-	0.3026	0.4083	0.414	0.41	0.3629
Brighton-	0.3766	0.5152	0.5392	0.5746	0.5225
London-	0.2788	0.3909	0.4091	0.3853	0.2345
Norwich-	0.2334	0.3657	0.3964	0.3541	0.2684
Cardiff-	0.3419	0.4497	0.4497	0.4531	0.4091
Birmingham-	0.3123	0.4346	0.4219	0.3828	0.3555
Leeds-	0.2832	0.3778	0.3701	0.3312	0.2502
Manchester-	0.3398	0.4492	0.4544	0.4591	0.3931
York–	0.1875	0.2854	0.2511	0.2162	0.0834
Newcastle-	0.0957	0.1329	0.1269	0.0795	-0.0682
Carlisle-	0.331	0.452	0.4816	0.5275	0.4749
Edinburgh-	0.2503	0.3452	0.3702	0.4063	0.3244

Figure: Spearman correlation coefficients for the **accumulated** CHESS **rainfall** and ERA5 **maximum 10m wind speed**, for various accumulation periods and locations. Data shown is from an extended winter period only (NDJFM) for the time series 1979-2015.

# Spatial Aggregations

	1 dav	3 dav	5 dav	ا 10 dav	1 21 dav
SEEng-	0.3868	0.5038	0.523	0.5397	0.4298
SWEng-	0.4186	0.5291	0.539	0.5455	0.4884
Wales-	0.3201	0.4247	0.4411	0.3931	0.2699
WMids-	0.3219	0.4083	0.4017	0.3523	0.2201
EMids-	0.3879	0.4875	0.4764	0.4428	0.3658
EEng–	0.4942	0.5925	0.6097	0.6161	0.5338
WScot-	0.3597	0.451	0.4397	0.4001	0.308
NWEng-	0.4759	0.5913	0.6069	0.6071	0.4984
Yorks-	0.2276	0.2973	0.3058	0.2859	0.2294
NEEng-	0.4714	0.5815	0.6028	0.5763	0.5186
EScot–	0.387	0.4818	0.4805	0.4646	0.4402
NScot–	0.5351	0.6291	0.6361	0.6075	0.5689

0.5993 I 1 21 day
0.5693
0.5693
0.5862
0.5467
0.5653

Time Period

# 1 – Observations: Exceedance Ratios

Exceedance Ratio = no. of points exceeding a percentile / no. of expected values to exceed that percentile ... i.e. how many extreme we have against how many we would expect randomly

Location	$10 \text{ day } ER_{90}$	$20 day ER_{90}$	$30 \operatorname{day} \mathrm{ER}_{90}$
Carlisle	1.78	2.08	2.22
Edinburgh	2.52	2.37	3.11
Newcastle	0.74	0.89	0.89
Manchester	1.78	1.18	1.33
Leeds	2.22	2.08	2.22
York	1.63	1.17	1.33
Cardiff	2.96	3.86	2.67
Birmingham	2.37	2.97	1.78
Norwich	1.33	0.89	1.33
Exeter	3.65	2.67	2.67
Brighton	3.11	2.97	3.11
London	2.37	1.78	2.67

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Location	$10 \text{ day } ER_{90}$		
Carlisle	2.67		
Edinburgh	2.08		
Newcastle	1.63		
Manchester	1.78		
Leeds	2.08		
York	2.08		
Cardiff	4.00		
Birmingham	3.71		
Norwich	1.19		
Exeter	1.78		
Brighton	3.26		
London	2.08		

Wind Divor

There are generally 2-3 times the number of extreme events than would occur if there were no relationship between wind and flood!

## Example Time window histograms





- 99<sup>th</sup> percentile in each dataset. Note: due to filtering (POT windows) scatter plots show sub set of data. Percentiles calculated from full timeseries.
- 2. Extract compound events from each location (red square)
  - No. of compound points = 228
  - No. of unique compound points = 157
- 3. Find corresponding storm tracks
  - Search files for any tracks which cross UK and have a matching timestep at any time in storm life time.
  - No. of storm tracks = 167 (i.e. some of compound events are happening at the same time as another storm?)

# 1 – Observations: Physical mechanisms



(We did some more science to understand the physics, which we are about to submit for publication in an academic journal)

# Future Work

- 1. Find the physical mechanism that leads to extreme compound events
- Use a very long timeseries (~1000 years) of precipitation from a climate model (HiGEM) to examine the correlation in very extreme events.

