RMS WHITE PAPER

2013–2014 WINTER STORMS IN EUROPE

An Insurance and Catastrophe Modeling Perspective

SUMMARY

This paper discusses the 2013 to 2014 European windstorm season from a meteorological, modeling, and insurance loss perspective.

Although specific characteristics of the Northern Hemisphere jet stream over the winter of 2013 and 2014 caused frequent storms to hit Europe, the same jet stream characteristics also meant that the majority of systems were mature and wet. Therefore, these storms, while associated with steep pressure gradients, brought only moderate peak gust wind speeds over land, but were accompanied by both significant inland flooding and unusually high waves and storm surge.

Individual events of particular note included Windstorm Christian, the most severe wind event of the season, which hit parts of Scandinavia with locally damaging wind gusts, and Windstorm Xaver, which was reminiscent of large, historic storm surge events of 1953 in the U.K. and 1962 in Germany. While in both countries the coastal defenses withstood the storm, the event was a reminder of the potential threat from storm surges in the U.K. and the German Bight. Other events, while not individually extreme, collectively brought climatologically extreme rainfall accumulations to parts of the U.K., which contributed to inland flooding.

The character and persistence of the wet, windy weather events that impacted Europe over such a long period provide particular challenges to the insurance and catastrophe modeling communities. The basic issues that arise include questions of data interpretation—for example, how to define an individual event and how to understand and interpret accumulating multi-peril claims data—as well as the longer-term implications of this unusual season for the future wind and flood risk in Europe.

At RMS we are well placed to help our clients to meet these challenges. Building on the existing set of cross-peril wind, storm surge, and inland flood modeling capabilities for the U.K., and the only commercially available hailstorm modeling solution for the region, RMS is developing a number of upcoming peril modeling initiatives to provide insights into the ongoing risk from climatic hazards in Europe. These initiatives include the release of a pan-European high-definition flood model—which includes both a fully integrated, region-wide, stochastic precipitation event set, and ground-up simulation capabilities—as well as updates to the existing windstorm modeling suite.

In addition, the release of the RMS(one) platform will provide the flexibility and resolution required for high-definition flood modeling in a new, resilient risk management framework, including a simulation approach that provides the ability to model timelines and clustering effectively.

INTRODUCTION

The 2013–2014 winter windstorm season in Europe was particularly active from early December 2013 onward. A regular stream of low-pressure systems flowed in from the North Atlantic, impacting northern Europe, particularly the U.K., Ireland and France, with a combination of strong gusts along the coasts, heavy precipitation, large waves, and coastal inundation.

Insured losses from wind damage, inland flooding, and coastal flooding accumulated steadily over the season. However, RMS estimates that losses are not likely to reach the levels of events such as Windstorms Anatol, Lothar, and Martin in 1999 (which reached US$13.9 billion); Kyrill in 2007 ($6.8 billion); Xynthia in 2010 ($2.9 billion); nor recent flood events in the U.K. such as the 2007 ($6 billion in 2007) flood, although it may be similar to the floods of 2012 ($1.8 billion market loss). Nevertheless, the aggregate losses across the season are notable, particularly in the U.K., due to the cumulative damage across three related perils: wind, storm surge, and (especially toward the end of the season) inland flood.

The following report summarizes the impact of the main flooding events in U.K., Ireland, Scandinavia, Germany, and northern France from a meteorological, insurance, and catastrophe modeling perspective.

Full references for works cited in this document can be found in the References section.

METEOROLOGICAL ENVIRONMENT

The background climate to the 2013–2014 winter season provided the perfect breeding ground for low-pressure systems to develop and be propelled into northern Europe. This section highlights the specific characteristics of the regional and global climate that influenced this unique sequence of winter weather.

Favorable Synoptic Environment

The position and intensity of the Northern Hemisphere jet stream strongly influenced the 2013–2014 winter season events. Very cold polar air over Canada, combined with warmer sea-surface temperatures in the sub-tropical West Atlantic and Caribbean Sea caused a stronger than usual jet stream off the U.S. Eastern Seaboard.

According to the U.K. Met Office (February 2014), the severe weather systems observed in the U.K. were strongly associated with an unusual combination of North America and North Pacific jet stream perturbations, including a northerly deflection of the North Pacific jet, and a southerly extension of a secondary branch into the tropical Pacific. As a result, the jet carried cold air into Canada and the northern U.S., establishing an unusually strong temperature gradient that strengthened the North Atlantic jet stream up to 30 percent greater than normal for the time of year. Such conditions are ideal for generating and propelling deep low-pressure systems across the Atlantic.

An unusually strong westerly phase of the Quasi-Biennial Oscillation (QBO) may also have contributed to the strength of the North Atlantic jet stream. The QBO is a mode of internal variability of equatorial stratospheric winds. Research has shown that the QBO has a small but significant impact on the European winter climate, whereby the west phase of the QBO contains a signal of stronger westerly winds over northern Europe.

Under these conditions, low-pressure systems developed rapidly over the western Atlantic, and approached Europe as fully formed, mature systems that consequently brought less damaging winds. In contrast, storms that hit Europe with the most damaging winds tend to occur when the storms are still in their development phase under a strong jet stream, as occurred in 1990 (e.g. Daria, Vivian, and Wiebke).

This unusually persistent and stable, strong jet stream also led to the cluster of storms that occurred over the winter season.

Weather Systems of the 2013–2014 Winter Season

The 2013–2014 winter windstorm season in Europe was particularly active from early December 2013 onward. The unusually strong jet stream propelled a regular stream of low-pressure systems in off the North Atlantic impacting northern Europe.

Figure 1 shows the timeline of events, and denotes individual damaging systems by name and date.

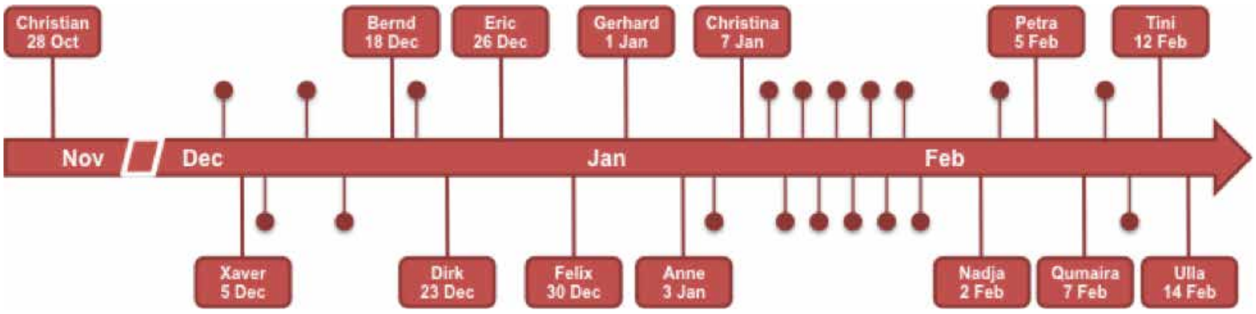

Figure 1: Timeline of low-pressure systems over Northern Europe from October 2013–February 2014, denoting names and dates of damaging systems

The season started early with Windstorm Christian in October. After a quiet November, Windstorm Xaver followed in December, marking the start of over two months of disruptive weather, including Windstorms Bernd, Dirk, Erich, Felix, Gerhard, Anne, and Christina.

January 2014 is classified as the wettest calendar month ever recorded in parts of the U.K., where the frequent passage of low-pressure systems was accompanied by heavy and prolonged precipitation. In February, Windstorms Nadja, Petra, Qumaira, Tini, and Ulla brought yet more rainfall, increasing the severity of flooding along the Thames.

Persistent Wet and Windy Weather

Due to the unusually deep and frequent low-pressure systems close to the U.K. and Ireland, and the persistently strong North Atlantic jet stream off the U.S. East Coast, storms formed farther west than usual, and travelled thousands of miles east across the Atlantic, approaching the U.K. as deep and mature storms. However, as the jet stream tapered off toward the easternmost Atlantic, these storms tended to weaken in intensity when they came to the end of their tracks (about -10° longitude).

In the 2013–2014 winter season, the majority of storms hit the U.K. after their most intense phase (Figure 2). Most of the storms reached their nadir pressure points before reaching Ireland (about -10° longitude), and were losing intensity by the time they hit land. Christian and Xaver were exceptions; they matured after crossing the British Isles into the North Sea, bringing strong winds and storm surge to some European countries.

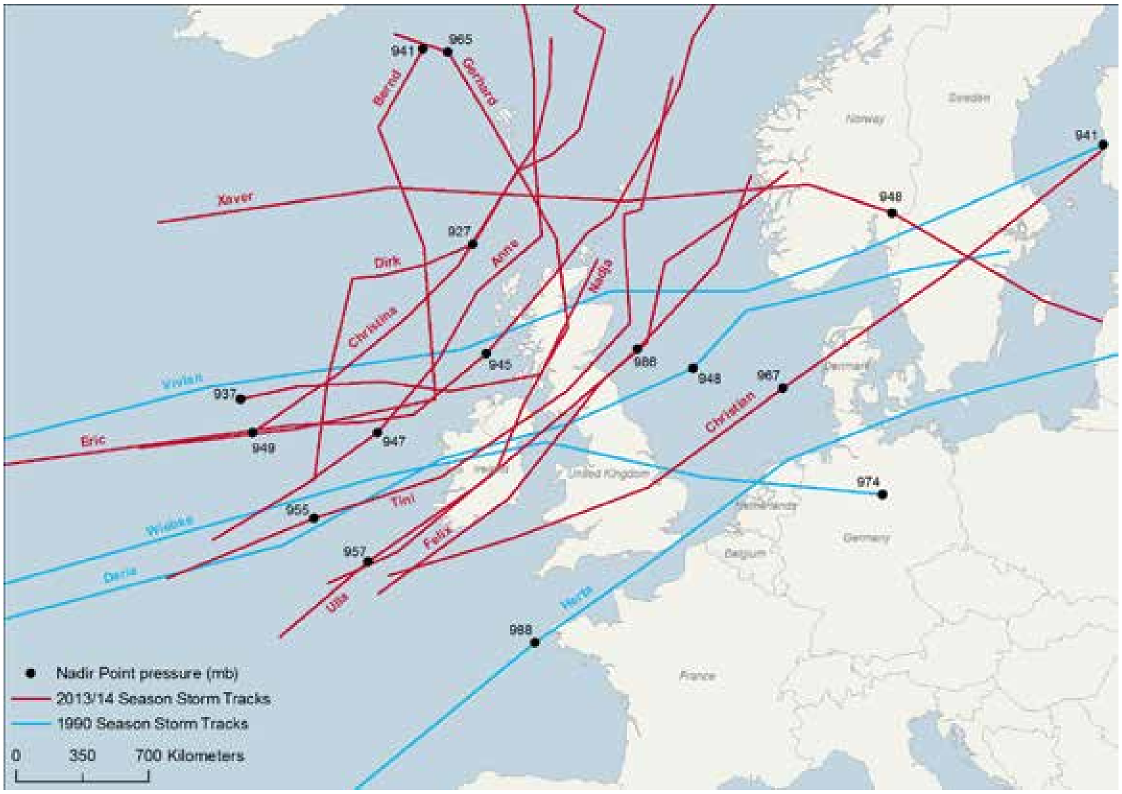

Figure 2: Winter 2013–2014 storm tracks (red) compared with 1990 storm tracks (blue), with nadir point pressures in black.

In contrast, the damaging windstorms of early 1990 were immature systems at landfall, with much potential to cause damage on land (Figure 2). Their tracks were generally farther south and the storms were still intensifying when they hit land (reaching their nadir points well to the east of landfall).

In 2013–2014, unseasonably mild weather in the sub-tropical Atlantic favored storm intensification. In addition, sub-tropical Atlantic sea surface temperatures were warmer than the 30-year climatological average, and the resulting warmer air was able to carry more moisture than cooler air, potentially increasing the amount of precipitation.

The winter 2013–2014 low-pressure systems produced the following impacts on land:

- **Moderate wind gusts:** The weaker jet stream to the east meant that over-land wind gusts were mostly moderate compared to the more intense winds over the Atlantic, where the jet stream was stronger.
- **Unusually strong storm surges and waves:** The longer the distance over which storm winds act, and the longer their duration over water, the greater the magnitude of waves and storm surges. In 2013–2014, the formation of low-pressure systems far to the west, and their intensification as they crossed the Atlantic, caused many systems to develop significant storm surges and strong waves.
- **Significant precipitation:** Many parts of the U.K. experienced record-breaking rainfall, driven by the unusually high frequency of consistently moisture-laden systems. In December the position of the jet stream propelled storms from the north, resulting in record rainfall levels in Scotland. From January, its position was farther south, bringing numerous storms and heavy rainfall predominantly to southern England and Wales.

HAZARD AND DAMAGE OBSERVATIONS

Unusual and occasionally record-breaking hazard observations were recorded in the 2013–2014 winter season, particularly due to storm surge and precipitation. This section highlights specific wind and coastal surge and inland flood observations, including the results of RMS field reconnaissance surveys.

Wind Impacts

In general the events of winter 2013–2014 did not generate particularly damaging peak gust wind speeds over land. Although peak gust wind speeds in exposed areas occasionally exceeded 90 mph, in developed areas they tended not to exceed 60 mph.

Windstorm Tini (February 12, 2014)

Figure 3 shows the RMS reconstructed wind fields for Windstorm Tini, which struck the U.K. on February 12, 2014.

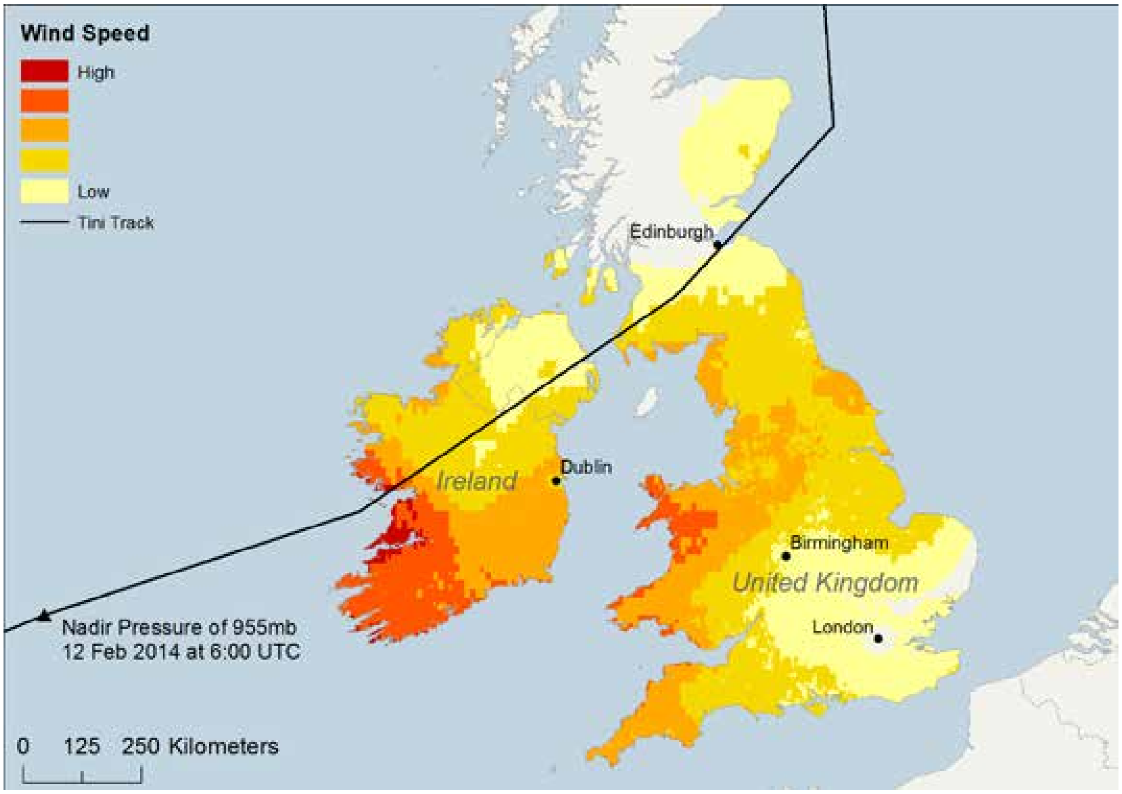

Figure 3: Windstorm Tini track and wind field

Reconstructed wind fields used in catastrophe modeling are smoother than "raw" observationally measured wind fields, as they typically exclude exposed stations, which are not located near property, and smooth the interpolated wind speeds between stations.

While widespread peak gusts during Windstorm Tini ranged from 45–95 mph (75–152 km/h), reaching 65–95 mph (100–152 km/h) across north Wales and northwest England, damage from this event was relatively minor, consisting of low-level roof tile damage. The highest peak wind gust recorded in the U.K. during the storm on February 12 storm was a destructive 112 mph (180 km), but this occurred at an exposed anemometer in Great Dun Fell, in the Peak district, and was not representative of the peak gust wind speeds in regions of property exposure.

Windstorm Christian (October 28, 2013)

Of all the 2013–2014 winter storms, Windstorm Christian caused the most significant wind damage. RMS conducted a field survey to examine the extent of damage following Christian, and reconstructed the storm footprint based on available wind data, this reconnaissance and media reports (Figure 4). The highest winds, and majority of the damage, occurred in Denmark and northern Germany, although reports indicated that losses also occurred in Sweden, the Netherlands, and the U.K.

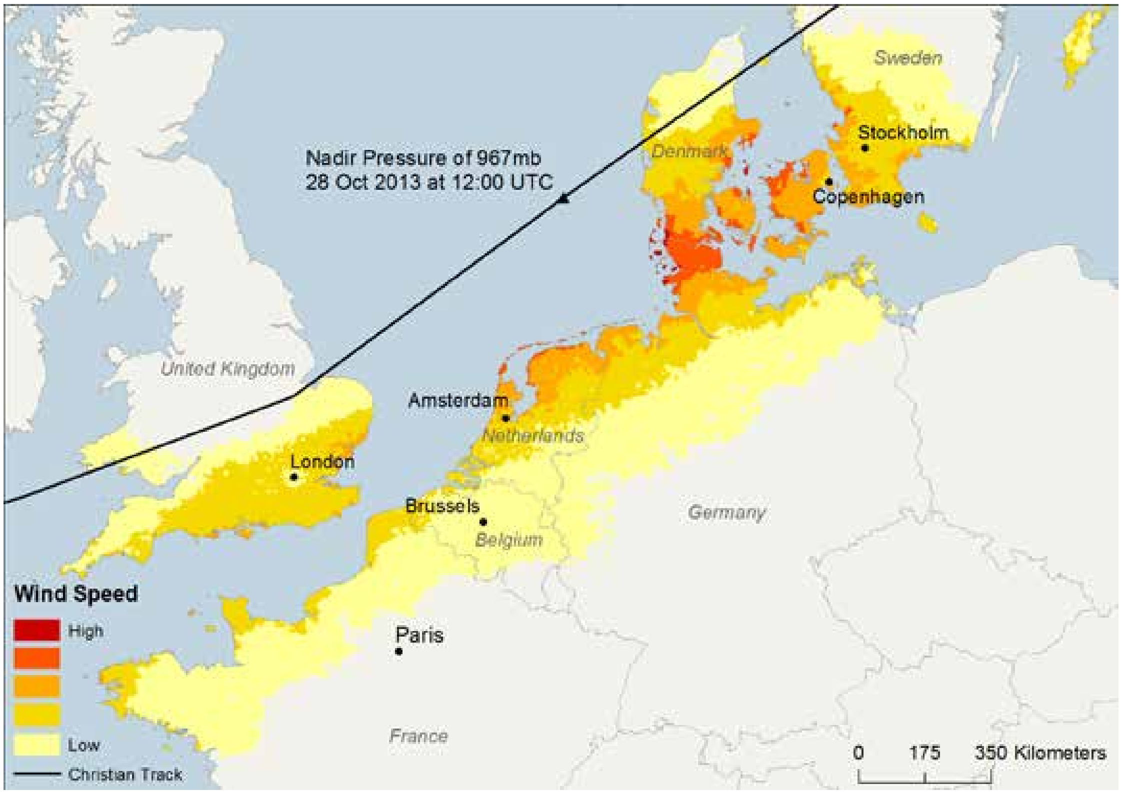

Figure 4: Windstorm Christian track and wind field

RMS conducted field reconnaissance from Hamburg, Germany to Toftlund, Denmark in the Jutland peninsula; and from Kalundborg and Copenhagen, on Denmark's Sjælland island, to Malmö and Landskrona in the Skåne province of Sweden (Figure 5). RMS engineers observed that the majority of building damage consisted of roof cover damage, dominated by tile uplift along the edges of the buildings (where the highest suction levels are developed as wind blows over the building).

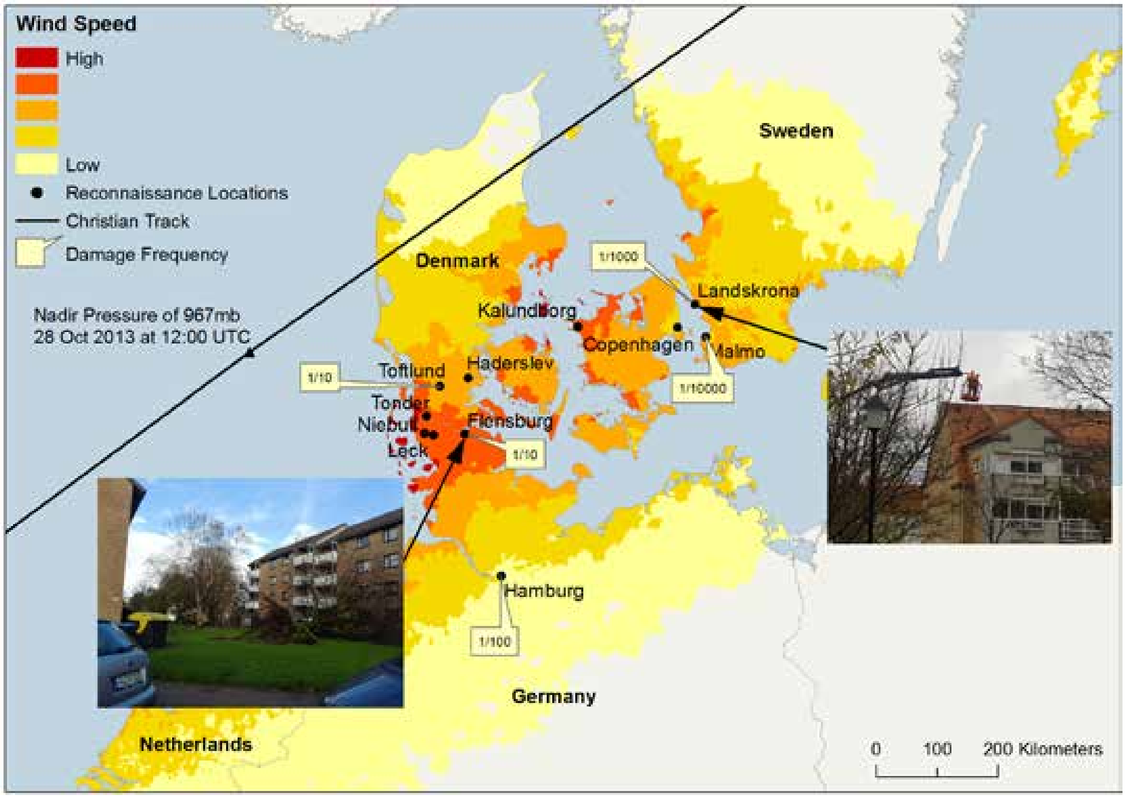

Figure 5: Windstorm Christian field reconnaissance locations in Germany, Denmark, and Sweden

There was also evidence of tree fall, but damage only occurred where the trees were in close proximity to buildings; in most cases, there was sufficient clearance to prevent this from occurring. The higher level of tree fall observations could be attributed to the storm occurring in late October when trees still have leaves, and thus a larger effective cross-section area for wind loading than in the mid-winter.

While there were widespread media reports of tree fall in the U.K., the frequency of tree fall in the visited locations in Scandinavia was low. Most of the damage was as a result of wind loads on roofs, confined to single-family dwelling (SFD) and multi-family dwelling buildings (MFD), which had similar roof covers.

Although the severity of direct wind damage was similar everywhere, the frequency of roof tile uplift damage varied by location. Figure 5 illustrates the damage frequencies deduced from the damage survey, which ranged from 1:1,000 to 1:10,000 in Skåne, Sweden, to between 1:10 and 1:100 from Hamburg to the Jutland peninsula of Denmark. RMS deduces that, given the similar wind speeds, the damage frequency from Copenhagen to Kalundborg in Denmark would have been similar to that of Skåne in Sweden.

Other Damaging Wind Events

Other damaging windstorms of the 2013–2014 winter season include Windstorm Ulla, which brought 80 mph (129 km/h) gusts to the south coast of England, with 50–70 mph (80–113 km/h) winds experienced widely through England and Wales. In addition, the U.K. Meteorological Office reports that Windstorm Xaver produced gusts of 60–80 mph (95–130 km/h) over Scotland and northern England. However, these gusts were reported in remote locations, and Xaver was most noteworthy for the storm surge that it generated, which is discussed later in this report.

Storm Surge (Coastal) Flood Impacts

Storm surge was a significant hazard for the U.K. in the 2013–2014 winter season, as several of the windstorms that impacted the U.K. coincided with some of the largest tides of the year. Coastal water levels were very high on the east coast of U.K. for storm Xaver in early December, and for storm Anne in late December / early January on the west coast (see Figure 2).

The U.K. is subject to some of the largest tides in the world. With tidal ranges of up to approximately 15 meters on the Bristol Channel, the water levels reached during a windstorm depend on the time at which the storm strikes relative to the time and magnitude of the highest tide. During a storm surge event, the actual peak high-water level usually occurs slightly before the predicted high tide.

A strong storm on a neap tide can produce a very large storm surge without producing dangerous high water levels. Conversely, a medium storm on a spring tide may produce a smaller storm surge, but the high water level can lead to extensive flooding.

In addition, the configuration of the coastal geometry, topography, and bathymetry can have a significant impact on the damage caused and the extent of any coastal flooding.

Figure 6 shows the astronomical tidal range and windstorm activity from December 2013 to February 2014 at two locations in the U.K.: Aberystwyth in the St Georges Channel, on the west coast of Wales, and Avonmouth in the Bristol Channel. Several large storms occurred during extreme high tides. Windstorm Anne occurred on January 3, when the astronomical tide was over 5.5 m in Aberystwyth and over 14 m in Avonmouth. Windstorm Anne brought a surge of up to 1.5 m at Avonmouth compared to the tidal ranges in the range of 5.5 to 14 m. If this storm had occurred seven days later, the astronomical tide would have been reduced by 4 m at Avonmouth, significantly reducing the high-water level. The size of the storm-induced surge was much smaller than the tidal range, reinforcing the importance of understanding the tides when assessing surge hazard.

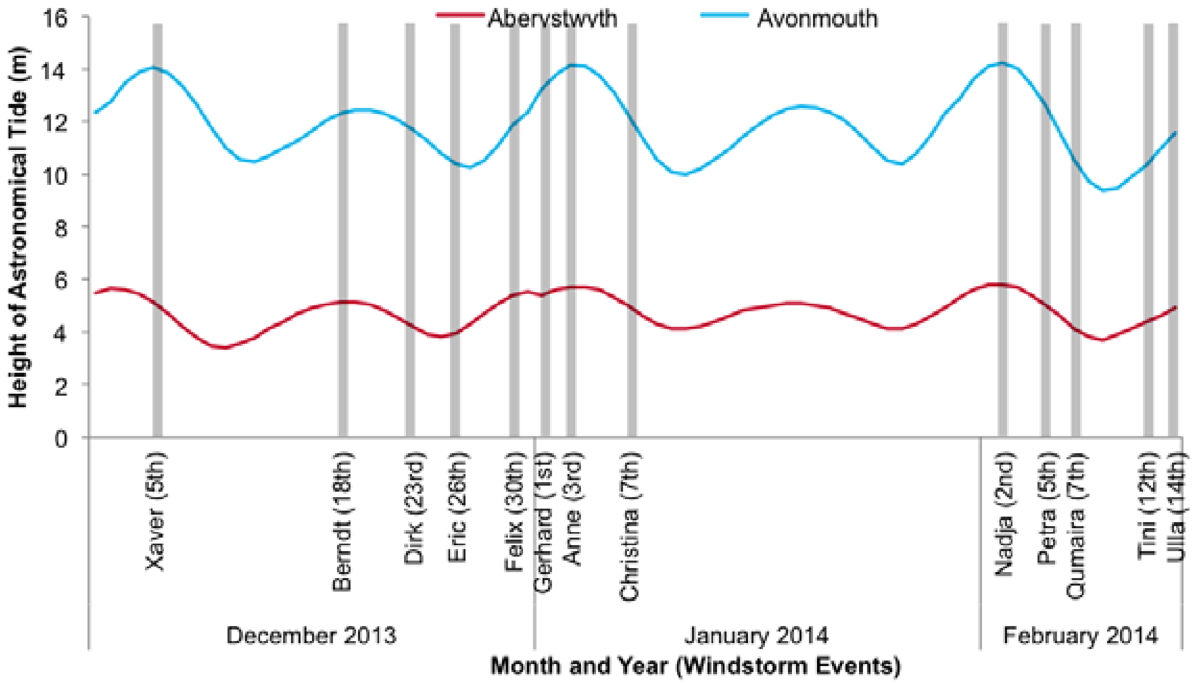

Figure 6: Astronomical tidal range over the Months of December 2013 to February 2014 at Aberystwyth (West Wales) and Avonmouth (Southwest England)

Storms like Windstorm Anne are not particularly unusual for the northeast Atlantic, but the storm's path followed a relatively low-latitude track, pushing the bulk of the wave energy toward the southwest of Ireland and England. Peak wave periods were exceptionally long (even compared with storms of similar wave height occurring in December), and enhanced the impact of the waves at the coastline. The combination of significant wave height and peak period is likely to mark the storm as a 1 in 5–10 year event in the southwest of the U.K., based on wave conditions experienced over the last 30 years.

The U.K. has seen significant improvements in flood defenses, particularly along the east coast of the U.K., since the devastating 1953 floods. The coastal flood damage from this year's events has been small in historical comparison thanks to these improvements in coastal flood defenses, even though the water levels experienced were some of the most severe in decades.

Figure 7 shows the water level at different locations in Europe during storm Xaver.

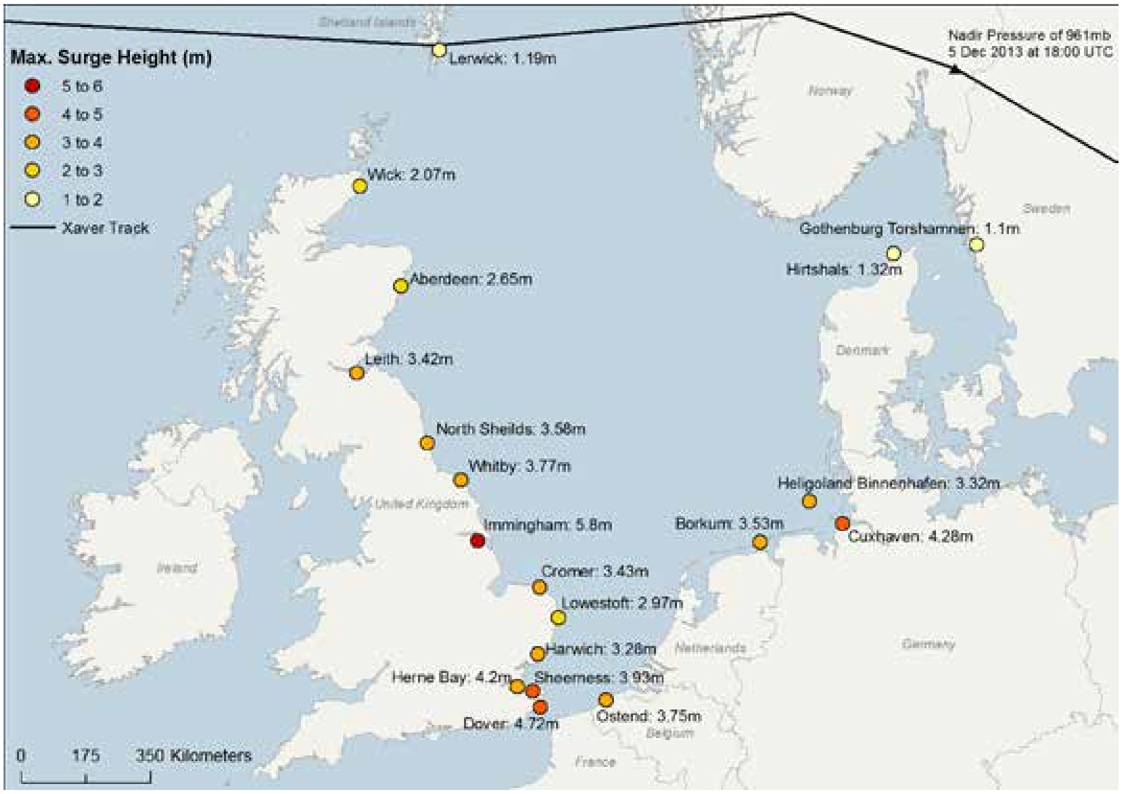

Figure 7: Coastal water levels (above mean sea level) in Europe during Windstorm Xaver (source: UNESCO Intergovernmental Oceanographic Commission sea-level station monitoring facility)

Windstorm Xaver impacted Northern Ireland, Scotland, and northern England, producing strong wind gusts up to 60–80 mph (95–130 km/h) over Scotland and northern England on Thursday, December 5, uprooting trees, downing power lines and toppling lorries. Coastal flooding also occurred as a result of Xaver's storm surge, with the Environment Agency (EA) reporting 1,400 flooded properties across England and Wales.

The surge from Xaver combined with high tides to bring record sea levels. In fact, water levels in places exceeded those seen during the devastating U.K. floods of January 1953, which inundated an area of 1,000 km2, seriously damaged 24,000 properties, and killed over 300 people. In contrast, Xaver caused no flood-related deaths, inundated 6,800 hectares of land, and flooded only 1,400 properties, thanks to the warning, response, and flood defenses put in place by the Environment Agency since 1953.

The storm also brought strong winds and coastal surge to mainland Europe. In Germany, wind damage appears to have been minimal but the port city of Hamburg was hit by a surge height of 6.09 m (20 ft) above mean sea level. This event equaled the surge height that caused devastation and significant loss of life in 1962 but the city was spared from severe flooding due to improved defenses. Flooding was also reported by the German authorities on the low-lying North Sea islands of Langeness and Hooge, near Denmark. Additional limited wind damage and flooding were also observed, notably in Belgium, the Netherlands, Sweden, and Denmark.

Historically, the most severe storm surges in Europe result from events like Xaver, which are of long duration and blow directly from the north, funneling water into the North Sea, and pushing it up onto the exposed coastlines. Xaver induced high sea levels along the U.K. east coast that lasted for about 40 hours as the storm approached and passed. Three tidal maxima fell into this time span, with the EA issuing flood warnings for large parts of the U.K. east coast.

RMS carried out extensive post-Xaver reconnaissance on December 17 and 18, to accurately investigate dike integrity and damages. Dike breaches are difficult to model. An apparently uniform dike may be breached due to non-uniform water pressure, or a structural weakness of the dike. The example of the Boston dike breach (Figure 8) illustrates the complexity in modeling dike breaches.

Figure 8: Repair work underway at the breached Boston Dike

Prior to the flooding, a system of two dikes protected the region around Boston. The flood water destroyed the first, weaker structure, which then allowed floodwater to flow between two mounds of buried refuse, thus inundating a recycling plant. Unfortunately, developers had cut through the secondary dike to build an access road to the recycling plant. Therefore, the flood water came farther inland, partially destroying crops and flooding the warehouses of an industrial estate and hundreds of houses.

In general, RMS reconnaissance confirmed that defenses performed well. However, the incidences of defense overtopping suggest that defense heights are not designed to withstand a possible future larger event, like a 1-in-1000 year storm surge.

The inundation lasted approximately two hours. Shop owners, especially those uninsured, reacted quickly to get their business running again as quickly as possible. The short duration of the flooding appears to have reduced the resultant losses considerably, compared to inland flood where the duration of inundation can be longer. Table 1 summarizes some key differences between the impacts of inland versus coastal flooding on property.

Table 1: Storm Surge and River Flood Differences

Storm Surge (Coastal Flooding)	River Flood (Inland Flooding)
Duration: 2–3 hours	Duration: Hours, days, or weeks
Contamination: Salty and sandy water but not muddy, less contaminated	Contamination: Very muddy and dirty. After event a thick layer of mud left in buildings. Visible in thrown-out contents, sewage, and back up

Inland Flood Impacts

The inland flood risk in Europe arises from both river (fluvial) and surface water (pluvial) sources. Both types of inland flooding pose the highest risk in the winter, when storms are more frequent, although flooding is possible in all seasons (RMS, 2013).

Surface water or “pluvial” flooding can result from intense precipitation in areas with saturated soil, high groundwater levels, and inadequate drainage. The risk that pluvial flooding poses to property is the most difficult to model and defend against—rather than using measurements such as river or tide gauge data to extrapolate river discharge conditions during extreme events, understanding this type of risk requires models that simulate both precipitation and antecedent conditions; for example, in soil moisture and groundwater levels.

Surface water can pool or create temporary streams in dips and hollows in topography regardless of location relative to the river network. Local surface cover and sewer design also impact the overall level of risk. For example, in 2007 the sewer systems of Kingston upon Hull became overwhelmed, resulting in the flooding of 6,500 buildings (RMS, 2007).

River flooding occurs when precipitation runoff drains into an existing river network, creating an anomalously high river discharge with the potential to overtop riverbanks or to breach defenses. A flood wave can take several days to travel the length of a river, causing long-lasting, geographically widespread flood extents.

The sequence of systems passing over northern Europe in 2013 and 2014 produced an unusually prolonged spell of wet weather. Individual storms were not uniquely severe, but the impact was cumulative. Provisionally, December was the wettest month in the U.K. since records began in 1910 (U.K. Meteorological Office, 2014). Regionally, the Meteorological Office reports new monthly-mean rainfall records in Scotland (296.1 mm) and southern England (165.4 mm). The Meteorological Office estimates that the combined impact of these meteorological conditions is a 1-in-248 year accumulated rainfall event, producing 372.2 mm of two-month (December–January) cumulated precipitation in southeast and central southern England.

Figure 9 illustrates monthly precipitation anomalies in England, as a percentage of the climatic average, by month from 2007 to 2014 inclusive (data from U.K. Meteorological Office). Positive anomalies, shown in red, show the extent to which precipitation in that month exceeded the monthly average. The figure indicates the main precipitation anomalies in this time period using square brackets, and the mean magnitude of the anomalies are shown in each case. For example, the mid-2007 positive anomaly had an average difference from the climatic average of 109.6 percent, and lasted for three months. Dry periods are illustrated by negative anomalies and show up as blue columns in the figure.

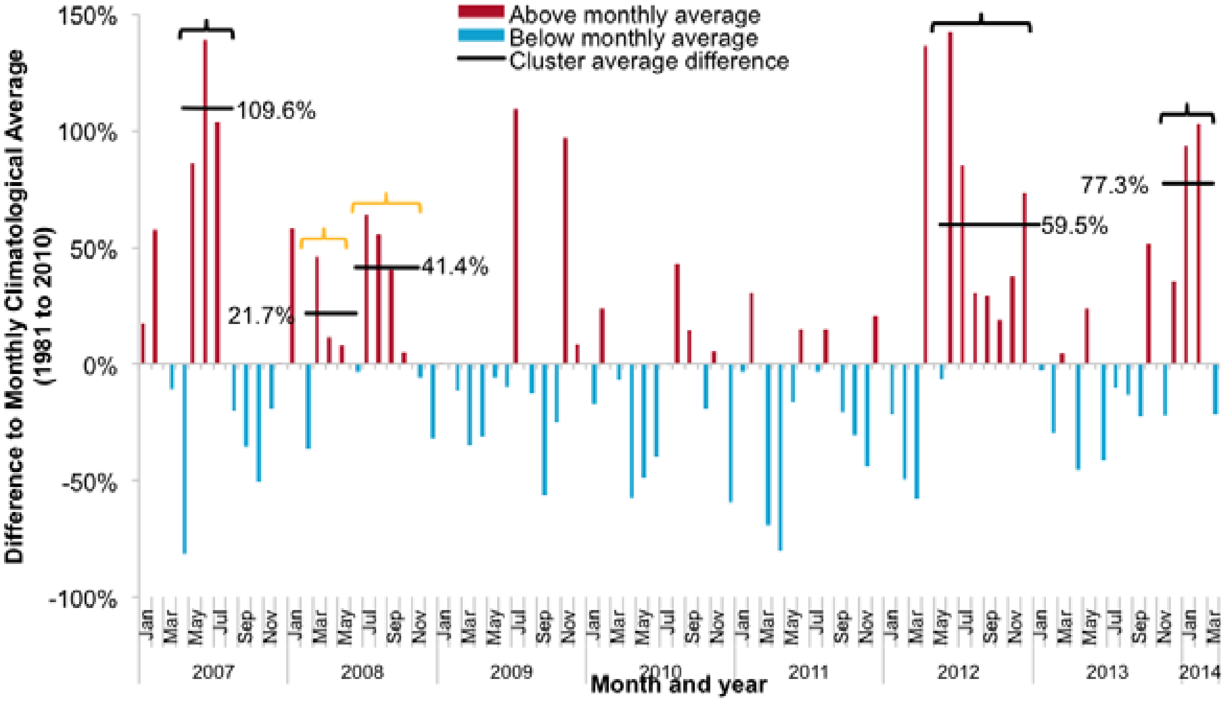

Figure 9: Precipitation anomalies in England (as a percentage of the climatic average from 1981 to 2010) by month, from 2007 to 2014

Figure 9 shows that, from January 2007 to March 2014, five main precipitation clusters (indicated by black horizontal lines on the graph), were recorded in England, three of which produced significant flooding (in 2007, 2012, and 2013–2014, as indicated by black brackets on the graph). The two positive anomaly clusters recorded in 2008 (indicated by orange brackets) differ from the flood-causing ones by being significantly lower in mean cumulative amount and thus not providing the amount of water needed to trigger large scale flooding.

When comparing the monthly precipitation amount with regional monthly climatological statistics for the period 1981–2010, it is evident that similar multi-month periods of above-average precipitation are a typical cause of flooding in the U.K.

Table 2 shows the dates and precipitation anomalies associated with seven significant clusters of large-scale persistent monthly precipitation patterns that caused flooding between January 1981 and March 2014. The percentages in the table are monthly precipitation anomalies, expressed as a fraction of the climatological monthly mean over the period 1981–2010. The gray highlight indicates months when flooding occurred as consequence of precipitation clusters.

Table 2: Precipitation Anomalies for Clusters of Large Scale Persistent Monthly Precipitation Patterns, between January 1981 and March 2014 (data from U.K. Meteorological Office)

Index	Month	England	Scotland	Wales	Length of precipitation cluster (months)	Flooded region
1	Dec-89	42%	-41%	24%	3	Wales
	Jan-90	38%	36%	62%		
	Feb-90	115%	117%	105%		
2	Mar-98	32%	-12%	59%	2	England
	Apr-98	102%	26%	80%		
3	Sep-98	25%	-32%	20%	2	Wales
	Oct-98	59%	34%	63%		
4	Sep-00	67%	12%	45%	4	England
	Oct-00	82%	32%	68%		
	Nov-00	82%	6%	79%		
	Dec-00	39%	16%	52%		
5	May-07	86%	63%	55%	3	England
	Jun-07	139%	31%	103%		
	Jul-07	104%	43%	126%		
6	Jun-12	142%	51%	165%	7	England, Scotland, and Wales
	Jul-12	85%	34%	48%		
	Aug-12	31%	20%	51%		
	Sep-12	29%	13%	17%		
	Oct-12	19%	-11%	-10%		
	Nov-12	37%	0%	13%		
	Dec-12	73%	36%	65%		
7	Dec-13	36%	88%	39%	3	England and Wales
	Jan-14	94%	17%	77%		
	Feb-14	103%	65%	127%		

Table 2 shows that since 1981 two or more consecutive months of above-average precipitation caused seven separate instances (shown as blocks of gray in the table) of significant flooding in the U.K. This aggregated monthly statistic excludes the effect of small spatial- and temporal-scale events, which can cause localized flash floods, especially where the ground is already saturated by prior events.

Table 2 also highlights the spatial correlation of large-scale flood-causing precipitation patterns. In most cases, at least two out of the three regions listed (England, Wales, and Scotland) experienced above average precipitation at the same time. The temporal and spatial distribution of precipitation plays a major role in defining flood risk across seasons and geographical and political regions.

Impacted Areas

RMS identified a list of postcode sectors and towns that experienced some level of flooding between December 1, 2013 and February 25, 2014 using local media reports and web reconnaissance, together with publically available satellite imagery. Flooding of properties was most notable in the southeast and southwest of England. The floodplain inundations resulted in noteworthy flooding in some low-lying hamlets in the Somerset Levels, and communities along the River Thames and River Severn. The floods also caused major disruption to transport and agriculture.

Table 3 and Figure 10 report the locations of affected postcodes.

Table 3: Breakdown of Affected Postal Code Sectors by U.K. County

County	Affected Postal Code Sectors
Berkshire	39
Buckinghamshire	7
Cornwall	13
Devon	9
Dorset	2
Gloucestershire	28
Hampshire	32
Isle of Wight	1
Kent	3
Oxfordshire	29
Shropshire	2
Somerset	37
Surrey	73
West Sussex	12
Wiltshire	4
Worcestershire	22
Total	**313**

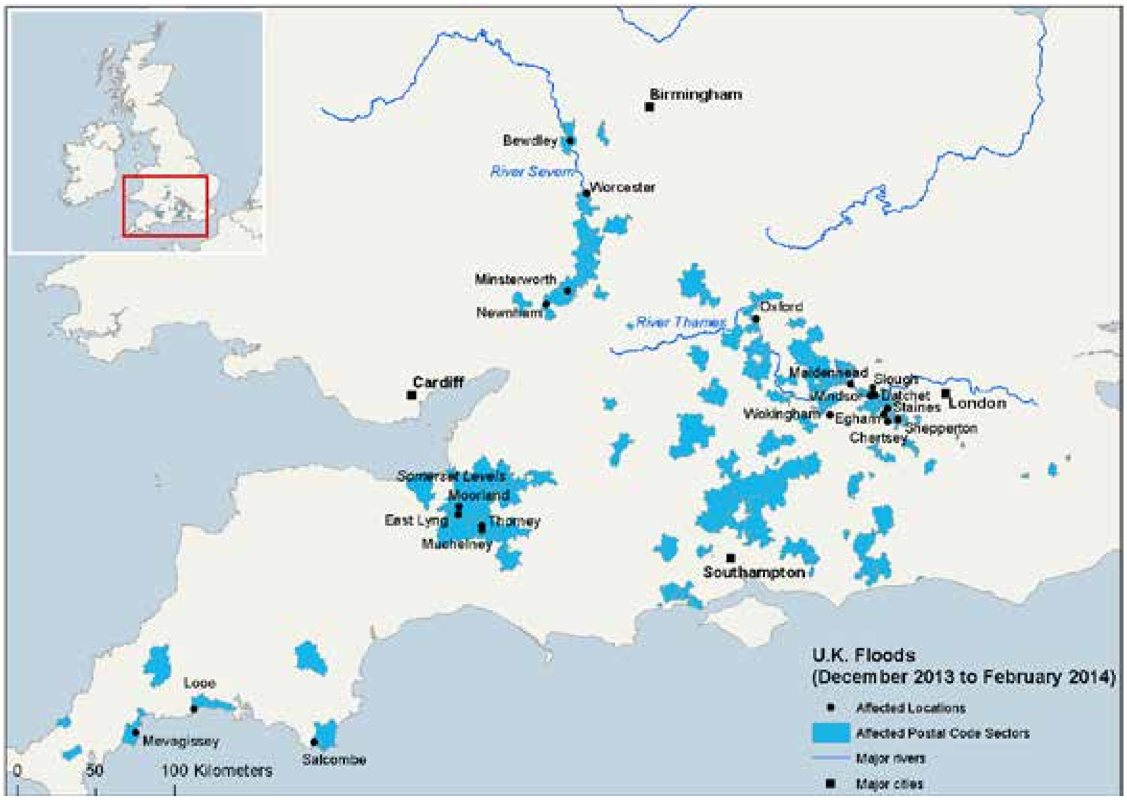

Figure 6: Affected locations in the December 2013 to February 2014 U.K. Floods

River Thames

Flooding along the River Thames began in late December and continued into January and February as river levels continued to rise. As of February 12, reports indicated that over 1,000 properties had been flooded along the River Thames. Homes across Berkshire, Surrey, Buckinghamshire, and Oxfordshire were the worst impacted, including communities in Datchet, Wraysbury, Chertsey, Windsor, Maidenhead, Staines, Egham, and Shepperton.

In January, monthly mean river flows at Kingston on the River Thames were the highest of any month in the naturalized flow since records began in 1883, and the second highest gauged monthly mean flow on record (the highest being March 1947). Furthermore, flow rates on the River Thames in January remained exceptionally high for longer than in any previous flood episode since 1883. During the month of January, the Environment Agency Thames Barrier was raised 13 consecutive times to protect people and property as high fluvial flows and high spring tides coincided.

Somerset Levels

The Somerset Levels in southwest England began to flood in late December as persistent, heavy rainfall caused the Rivers Parrett and Tone to overflow. The flooded area remained inundated for several weeks, as continued heavy rainfall maintained floodwaters.

Overall, reports indicate that approximately 150 properties were flooded in the Somerset Levels. Several villages were inundated and cut-off by the flooding for several weeks, with some of the worst impacted villages including Thorney, Muchelney, Moorland, and East Lyng.

On January 24, 2014, with 17,000 acres (6,900 hectares) of agricultural land having been under water for over a month, Somerset County Council and Sedgemoor District Council declared a “major incident.” On January 27, the National Farmers Union estimated that 28,420 acres (11,500 hectares) of land had been inundated across the Somerset Levels, since the flooding began.

In late January, the armed forces were called in to help villagers that were cut off, while in early February, the EA imported 13 high-capacity pumps from the Netherlands to help reduce levels more quickly.

River Severn

In the lower reaches of the River Severn, several homes were flooded in Gloucestershire in early January after a combination of high tides and the Severn Bore. Towns impacted included Minsterworth and Newnham.

Farther upstream the River Severn, flooding began in February, with the river reaching its highest level (5.67m) on February 13, the highest since records began in Worcester according to the EA. At this time, flooding impacted several communities, including Worcester (where around 60 properties were flooded), Bewdley, Upton-upon-Severn, and Minsterworth.

INSURED LOSSES

The 2013–2014 winter season was more active than many in recent years, continuing a trend in the last decade toward more extreme rainfall in the U.K., though reports of record-breaking wind and rainfall observations do not necessarily translate into record-breaking insurance losses. Nevertheless, as insurance policies in the U.K. continue to offer a unique combination of both wind and flood (including storm surge) coverage as standard, the combination of all three perils experienced in 2013–2014 can trigger reporting thresholds or, on an aggregated basis, even reinsurance recoveries.

Market-Wide Insured Losses in the U.K.

The picture of insured losses in the U.K. took time to evolve. At the end of January, the Association of British Insurers (ABI) reported that policyholders had made 174,000 storm-related claims, totaling £426 million ($710 million[1]) between December 23, 2013 and January 8, 2014, including 5,800 flood claims. A follow-up press release on March 13, 2014 communicated the extension of the period to February 28, and reported an estimated 421,500 storm insurance claims, plus an additional 17,500 flood claims totaling £446 million ($740 million) in value. They estimate the total value of weather-related claims in the U.K. over this the extended period to be £1.1 billion ($1.8 billion).

This figure is comparable to the 486,000 claims, totaling £1.19 billion in loss ($1.97 billion), which the ABI reported for weather events in 2012.

In 2013–2014, of the 17,500 flood claims, 9,000 were from homeowners, with an estimated overall cost of £276 million ($460 billion), implying an average claim value of around £35,000 ($58,000). Around 5,400 of the claims were for flooded vehicles, totaling £22 million ($37 million), and 3,100 claims were from flooded businesses, totaling £149 million ($250 million), with an average claim value of just over £48,000 ($80,000).

The average claim value for non-flood storm losses was around £1,600 ($2,700), only about 5 percent of the average claim value for flood-related losses. For this reason, although the total number of flood claims was lower than the number of non-flood weather-related claims, comprising less than 5 percent of the total, flood losses contributed disproportionately to the overall payout. The ABI estimates that flood losses contributed £446 million ($740 million), or around 37 percent of the total.

There is a chance during prolonged periods of wet, windy weather that single properties may be affected by more than one event or source of loss. In such cases, a building that is damaged by both wind and flood may be processed in one single claim for this single risk depending on the gap in time between the events. As a result, there is some potential for the number of claims to be under-recorded.

Although meteorologically, these events may be linked to the same underlying atmospheric situation, defining individual events from an insurance industry perspective is less straightforward. The ABI distinguishes between flood and storm, but the storm peril can be anything weather-related. According to the ABI:

> “A storm is not just a period of bad weather, it is a period of violent weather, involving rain, hail, wind, snow, lightning or any combination of these. It can last for a short or a long time, and can affect a large or a small area, but in all cases it refers to a period of violent weather that is likely to cause damage to property.”

Reinsurance treaties can be particularly affected by such long duration or consecutive series of events, as claims aggregate to significant levels and activate or potentially exhaust the coverage. The usual practice is to incorporate an hours clause into reinsurance treaty contracts, which is commonly 72 hours but could be as large as 504 hours, in order to limit the number of claims that the treaty is exposed to for a single event. However, even if an hours clause is defined, questions about the exact start of the event and how to differentiate between wind and flood related claims remains.

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[1] Exchange rates are January-March 2014 averages as follows:
British Pound to United States Dollar: 1.659
Euro to United States Dollar: 1.373

Comparison with Past Storms

When a storm occurs, the media frequently gives a subjective view of the insured risk that confuses the impact of hazard intensity and insured loss. Although the media may describe an event as a severe storm if an exceptional wind speed observation occurs in an exposed coastal location, this observation may be an outlier, and therefore not be representative of winds incurred by regions of insured exposure. For example, in its earlier stage, Christian was often quoted as a new 87J in the media, but this assertion was then significantly downplayed.

This section contextualizes and benchmarks the winter 2013–2014 storms in terms of insurance industry losses from historical single events.

Although not exceptional in terms of insurance loss from any one event, or indeed any one single source of loss, the season was remarkable in terms of the accumulated loss from such a wide variety of contributing, correlated perils.

Storm Surge

Coastal water levels were very high on the east and west coasts of the U.K. during storm Xaver in early December. The storms in late December and early January also produced significant west-coast storm surges.

Nevertheless, storm surge losses in the U.K. from the winter 2013–2014 events were not exceptional. Water levels and wave heights on the west coast, for example, did not surpass those observed on February 26–28, 1990 when a 1.3m surge coincided with high tide and waves up to 4.5m in height.

In 2003, RMS reconstructed the 1953 storm surge event and, at the time, calculated that the same extent of flooding as occurred in 1953 could trigger insured property loss as high as £5.5 billion in 2003 values ($9 billion, assuming 2014 currency conversion rates), with additional business interruption costs as high as £1.5 billion ($2.5 billion). Around 59,000 residential properties lie within the 1953 flood footprint. However, as sea defenses have evolved—in the U.K., specifically to counter a repeat of the 1953 storm—flood extents from modern storm surge events are not comparable with those experienced in 1953 in the U.K., or during the 1962 or 1976 (Capella) events in Germany.

Wind

There were several noteworthy headlines in the mainstream press quoting high wind observations in exposed, isolated coastal locations in the U.K. in winter 2013–2014. Nevertheless, winter 2013–2014 wind losses were not exceptional.

As the systems spinning in from the Atlantic tended to mature well before hitting land, direct losses from wind in the U.K. are unlikely to greatly exceed €200 million ($275 million, assuming 2014 currency conversion rates) for any one individual event of winter 2013–2014. In contrast, wind losses from storm Ulli (Jan 2012), which had much higher peak gust wind speeds in the U.K., cost around €200 million ($275 million) while Windstorm Kyrill (Jan 2007) caused losses close to €500 million ($690 million) in the U.K. Many past storms in the U.K. generated similar or much higher wind-only insured losses.

In the wider geographical region, the most damaging wind-loss event of the season was Windstorm Christian, which affected western and northern Europe from October 27–29, 2013. At the time of going to press, latest loss estimates from PERILS AG amount to just under €1.1 billion ($1.5 billion).

Inland Flooding

Although the mainstream press reported record rainfall through much of England and Wales, with headline-grabbing coverage of flooded properties in the Somerset Levels, Severn Valley and Thames Valley, flood losses from winter 2013–2014 were not exceptional.

About 17,500 properties flooded in England and Wales from early December 2013 to end of first week in January 2014, according to the Environment Agency.

This level of flooding is not exceptional, even in terms of events in the last decade. The 2007 floods resulted in at least

55,000 residential and business claims. Based on an analysis of the events at the time, RMS estimated the insured loss for the two main U.K. flood events of 2007 to be: £1.25–1.75 billion ($2.1–2.9 billion, assuming 2014 currency conversion rates) for the June 25 floods, and £1–1.5 billion ($1.7–2.5 billion) for the July 20 events alone (see RMS, 2007).

More recently, the 2012 U.K. floods led to the second highest annual insured flood losses in the U.K. since records began (see RMS, 2013). The ABI states that 486,000 weather claims were made in 2012, for a total insured damage amount of approximately £1.2 billion ($2 billion). As with the 2013–2014 floods, pluvial flooding was a significant contributor to the 2012 flood losses, especially as the year progressed and groundwater levels rose. The worst flooding, in November 2012, was triggered when exceptional rain fell on catchments that were already saturated by two to three times the average monthly rainfall, culminating in the final weather system stationing itself over the North Sea, causing severe and persistent flooding in northeast England.

Combined Peril Losses

No individual event or peril was exceptional in terms of insured loss this winter, even when compared to recent events over the past five years. For example, combined wind and flood losses in the U.K. in 2012 were comparable to those observed during the winter of 2013–2014.

What was unusual was the accumulation and correlation of claims across three related causes of loss. To a certain extent, the accumulation of claims from wind and flooding in 2013–2014 followed a similar pattern to those of 2012, although there was very little contribution from storm surge losses in 2012. What is certain is that in previous years, accumulations of loss have tended to be dominated by either wind or inland flooding, but not both.

As discussed earlier, the fact that the majority of systems were mature on landfall meant that they tended not to be characterized by particularly extreme, damaging peak gusts, but rather by abundant precipitation. A cyclone producing long return-period inland flood loss is unlikely to produce a long return-period loss for the wind peril, and vice-versa. Severe inland flooding usually follows many hours of precipitation. The sorts of cyclones that cause many hours of precipitation tend to be slow-moving systems, such as to those that were typical in winter 2013–2014. In contrast, the cyclones that produce extreme wind damage are more likely to move very quickly. The precipitation associated with such systems is much shorter duration at any location, which means that there is less chance of widespread flooding.

MODELING CHALLENGES

The unusual meteorological patterns and widespread impacts of the 2013–2014 winter windstorm season highlight the importance of overcoming key challenges associated with modeling European winter storm risk. Examples of these challenges include:

- Understanding correlation and clustering of related perils driven by the same underlying meteorological phenomenon
- Modeling clusters of small inland wind intensity storms that cause significant flooding
- Modeling different types of inland flooding, and antecedent conditions
- Analyzing claims data for reliable vulnerability calibration

Ongoing RMS research produces specific solutions to these challenges. This section describes some of the techniques that RMS models use to allow clients to understand both event-specific behavior, and the clustering of loss-causing events driven by the same underlying meteorological phenomenon.

Analyzing Claims Data

When validating and calibrating vulnerability functions, modelers relate claims data for the various contributing lines of businesses and coverages to the severity of the underlying contributing perils. There are several challenges that complicate this process, which requires access to approximately contemporaneous information about both the contributing peril and the coverage. For example, although loss adjusters differentiate between winter wind and flood damage, if a risk is hit by wind and flood at the same time, the insurer may combine the claims, to reduce the adjusting expenses. Similarly, aggregate claims data may not separate surge inundation claims from inland flood damage claims.

RMS therefore assesses and validates insurance company claims data before using it in model calibration and validation. RMS uses three approaches to assess the relative importance of different sub-perils to the overall claim value:

- Detailed analysis of the event's characteristics, combined with data on the accurate location of the risk, to assess the relative contribution of inland versus storm surge flooding
- Distance to coast measurements can facilitate separating storm-surge flood damage from inland flood damage (possible in the U.K., where most locations are geocoded at street address level)
- Expert post-event reconnaissance

Correlation of Related Perils

The correlation between wind, inland flooding, and surge losses is a key component of the events of winter 2013–2014. Although related to the same underlying atmospheric phenomenon, the impacts of these three contributing loss-drivers are separated in time and space.

To correctly separate the impacts of historical events that generate both storm surge and inland flooding, RMS continues to develop techniques for clearly separating the hazard boundaries. In RiskLink 13.1, RMS released a new version of the China and Hong Kong Typhoon Model, which specifically ensures that footprints are not overlapping or overstating the actual condition. RMS is currently investigating how to integrate peril correlation into the next generation of its catastrophe models.

In the U.K., the RMS approach to stochastic modeling, which generates specific wind, flood, and storm surge footprints, already allows the user to separate and re-combine the impacts of these disparate contributing perils. Future releases, including the planned release of a pan-European flood model, will extend these capabilities to other affected European territories. Finally, RMS(one) includes computationally intensive simulation methodologies, which associate events with timelines, and thus provides a platform capable of assessing the correlation in time and space between these contributing perils for future model releases.

Types of Inland Flooding and Importance of Antecedent Conditions

As seen in the 2013–2014 winter season, the U.K. is at high risk of flooding from multiple sources, including rivers, surface water, and coastal storm surge. These flood types are all driven by stormy weather, but have different causes, impact different geographic locations, and are defended against in different ways. All types of flooding pose the highest risk in the winter. The historical record shows that antecedent conditions, specifically ground saturated by rainfall or snowmelt, play an extremely important role in generating floods in the U.K. Although the 2007 U.K. flood losses, which exceeded those experienced in winter 2013–2014, occurred in the summer, they were preceded by several weeks of unusually wet weather that saturated the ground prior to the rainfall that led to the flooding (see RMS, 2013).

Flood hazard is further complicated by urbanization, floodplain development, and overuse of impervious surface coverings, which have aggravated the flood risk. The Committee on Climate Change's Adaptation Sub-Committee found that "the rate of development in the floodplain between 2011 and 2012 was higher (12 percent) than outside the floodplain (7 percent)" (CCC ASC, 2012).

The RiskLink 13.1 RMS U.K. Inland Flood Model provides a robust modeling solution for understanding the evolving risk from this peril in the U.K. It captures both fluvial and pluvial flood risk. The model physically simulates rainfall events and runoff into over 1 million kilometers (625,000 miles) of river network, including a probabilistic view of flood defense failure and simulated antecedent soil conditions.

The model estimates that only 50 percent of the U.K. average annual loss (AAL) for flood comes from major river flooding, with the remaining 50 percent from small river and stream flooding, flash flooding, pluvial flooding, and localized heavy precipitation. RMS models pluvial flooding dynamically, based on a combined 100,000 simulated years of precipitation in order to capture crucial antecedent soil moisture conditions. This approach facilitates modeling of event clustering and correlation between regions as well as a more realistic estimation of pluvial risk.

RMS is currently building a pan-European probabilistic inland flood model, which builds on the innovations first released for the U.K. Inland Flood Model, and extends them to new territories. It will include 10 new countries and rebuilt models for Belgium, Germany, and the U.K.

The 2015 update takes into consideration lessons learned from recent events and will incorporate RMS' full high-definition (HD) simulation capabilities. HD simulation explicitly represents important hazard features, such as the spatial correlation of hazard from the ground-up coverage level, or the temporal features of flood, which represents developing antecedent conditions and clustering of events. The model also introduces several new features to aid risk assessment and decision making for the insurance industry, including a single European event set and the ability for users to define new financial terms, such as the hours clause. The latter point will represent an innovative capability able to support current and future reinsurance practices.

Climate Change

Jongman et al. (2014) give robust evidence that flood risk in Europe is increasing. The study estimates that, mainly because of socio-economic growth and change in precipitation patterns, European flood risk could more than double by 2050. Large events are forecast to hit multiple countries, with particular evidence in case of unfavorable antecedent conditions as the one leading to the large Central Europe Flood in June 2013 (RMS Blog, 2013), which produced major losses in Germany, Austria, Czech Republic, and Slovakia.

Climate models forecast increased episodes of flooding for the U.K. under climate change conditions (U.K. Meteorological Office, 2011). Some commentators claim that an upward trend in extreme rainfall events over the past years is already apparent in the meteorological record (Harrabin, 2013). Peer-reviewed scientific research, performed by academics in collaboration with RMS scientists, found that climate change increased the likelihood of the floods that impacted England and Wales in the year 2000 (Pall et al., 2011).

With regard to the wind peril, initial climate projections from the Intergovernmental Panel on Climate Change (IPCC) indicated a potentially more active storm track for Europe and a greater penetration of storms into Western Europe (e.g., Bengtsson et al., 2006). However, more recent studies show weaker signals (e.g., Zappa et al., 2013). The current view from the IPCC is that "substantial uncertainty and thus low confidence remains in projecting changes in Northern Hemisphere storm tracks, especially for the North Atlantic Basin."

Although RMS continues to monitor scientific developments in this crucial area of research, RMS considers that understanding the inherent storm variability is more relevant and of greater concern for the insurance industry than climate change. The climate change signal is currently weak, and the impact may spread over several decades, thus leaving time for the industry to adapt to it.

RMS discussed this issue together with external academic experts at a workshop that RMS jointly hosted with the Bermuda based Risk Prediction Initiative (RPI) in October 2013. A key conclusion from this workshop was that a sophisticated catastrophe model should give the user the possibility of exploring different views around storm variability, based on different wind period calibrations (as reported in Marescot & Mark, 2013). RMS is therefore working on solutions that will help clients further explore the uncertainty and variability inherent to this complex peril, by giving access to different view of risks.

Clustering of Events

The meteorological conditions that lead to one event occurring can persist over a matter of days, weeks, or even months, as observed in the winter of 2013–2014. This can lead to a series of similar events occurring in quick succession, a phenomenon known as "clustering." One additional modeling challenge is therefore to correctly capture the clustering of these events over the duration of the winter. The way this challenge is solved depends on which view of clustering is deemed to be most important, i.e., strong storms bringing high wind or weaker storms. There is also a large uncertainty in the way the model should represent the exact level of precipitation generating flood. As the Met Office mentioned in their February 2014 report into the then ongoing persistent wet, windy weather in the U.K.:

> "The persistence of the recent storminess is unusual, and although clustering of storms is quite common, the continued run of deep depressions, through December, January and on into February, is not. It is this continued run of storms that has created the exceptional flooding conditions experienced in the Somerset Levels, for example."

Clustering is a real but very complex phenomenon. There is significant scientific uncertainty surrounding the mechanisms that define it and no real consensus about how best to model it. It is thus very difficult to deliver one view of clustering that would match all different climate assumptions.

For this reason, RMS avoids restricting clients to one view of the clustering phenomenon, and instead provides an optional storm clustered view that reflects well-defined assumptions, i.e., cluster of strong storms like in 1990 and 1999, as an alternative view, to enable clients to explore the uncertainty in hazard variability.

The RMS clustering model is fully transparent and provides the flexibility for clients to implement their own, different view if preferred.

RMS continues to research the modeling of windstorm clustering, and is working with scientific partners to better understand clustering mechanisms and dynamics, in initiatives such as the recent workshop jointly hosted by RMS and the Bermuda based RPI, which took place on October 2–3, 2013. Consequently, RMS may revise its position in the future if sufficient scientific consensus around the clustering is achieved.

The new RMS(one) simulation capabilities will provide all users with the ability to propagate accumulated losses through time in order to quantify losses to stop-loss and other accumulated-loss treaties.

CONCLUSIONS

Winter 2013–2014 in Europe was unusual, both in terms of the jet stream's characteristics and its persistence. In combination, these two factors caused persistent wet, windy weather in the U.K., from December 2013 to February 2014.

Although low-pressure systems appeared unusually deep, with strong pressure gradients on weather charts, the damage from wind alone was not severe because the systems were mature by the time they reached land on the west side of the Atlantic. Nevertheless, the relatively long-duration high winds out at sea led to noteworthy coastal flooding from storm surges, especially in the U.K.

In this regard, the sea defenses along the east coast of the U.K. generally performed well, withstanding sea levels similar to those observed in the historic 1953 event with only minor and short-lived inundation in affected areas.

The degree of rainfall in the U.K. over the winter season was unprecedented, leading to significant inland flooding.

In terms of the insurance loss, the overall costs of individual events did not match some of the past extremes that Europe has experienced. Even in aggregate they did not reach the levels achieved by major severe windstorms, such as those of 1990 or 1999, or more recent flood-dominated loss events, such as the 2007 floods in the U.K.

Nevertheless, this combination of wind, storm surge flooding, and inland flooding presents particular challenges to the catastrophe modeling industry and its clients.

RMS is meeting this challenge, providing market-leading solutions that represent the combined impact of wind and flood in the U.S., as well as for countries in Europe and Asia. We are actively expanding this coverage to other territories, such as the high definition Japan Typhoon Model, which is currently in development and will model all three perils; wind, inland flood, and coastal flood, each of which will be physically correlated.

In addition, the release of the RMS(one) platform will provide the flexibility and resolution required for high-definition flood modeling in a new, resilient risk management framework, including a simulation approach that provides the ability to model timelines and clustering effectively.

ABOUT RMS

RMS models and software help insurers, financial markets, and public agencies evaluate and manage catastrophe risks throughout the world, promoting resilient societies and a sustainable global economy. Our scientific and objective measurement of risk facilitates the efficient flow of capital needed to insure, manage, and mitigate risks to reduce the consequences of disasters.

To learn more, visit www.rms.com or contact us at info@rms.com.

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