The 21st century decline in damaging European windstorms

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Why have windstorm losses declined since 2000?
Windstorm footprint:
Maximum 3-second wind-gust speed at each location in a 72 hour period covering the passage of the storm, centred on the time at which the maximum wind speed over land occurs.

Example:
Footprint for windstorm Daria (24th - 26th January 1990)

6301 storms identified in extended winters (October-March) using objective tracking algorithm (Hodges, 1995)

Then footprints created for each storm by dynamically downscaling ERA-Interim using the Met Office 25km resolution North Atlantic-European operational NWP model.
Damaging windstorm examples: 1990 & 2013
Area with gusts > 20m/s ($A_{20}$ index)

\[
A_{20i} = \sum_{j=1}^{J} I(v_i(s_j) > 20)
\]
Area $A_{20}$ is a good predictor of severity


Indices defined as

\[
L_{98} = \sum_{v_j > v_{98j}} d_j \left( \frac{v_j}{v_{98j}} - 1 \right)^3
\]

\[
A_{20} = \sum_{v_j > 20} 1
\]

where for grid point $j$, $v_j$ is gust speed, $v_{98j}$ is 98th percentile of gust speeds, and $d_j$ is population density.

→ Area A20 strongly related to L98 and a better classifier for largest loss storms

Recent trends: 1979/80-2013/14

The number of European storms in Oct-Mar has become more volatile and has shown an increasing trend. No explanation yet for this recent 2% change which is not consistent with long term decrease expected from climate change projections. Early period is less volatile than chance i.e. Poisson standard deviation of $\sqrt{175}=13$.

\[
\text{Number of storms} = \text{average area} \times \text{number of storms}
\]

→ 12% drop in average area which has led to a 10% drop in total area
Frequency of exceeding 20m/s

\[ F_1(s_j) = \frac{1}{n_1} \sum_{i \in 20^{th\ century}} I(v_i(s_j) > 20) \]

\[ F_2(s_j) = \frac{1}{n_2} \sum_{i \in 21^{st\ century}} I(v_i(s_j) > 20) \]

\[ n_1 = 3654 \quad n_2 = 2554 \]

→ statistically significant decreases in frequencies over most of Europe.
→ increase in 21\textsuperscript{st} century over Iberian peninsula.
Change in gust speed distribution

Figure 5. Quantile-quantile plot of footprint wind gust speeds in the grid cell closest to Paris for events in the two comparative periods: winters in the 20th century (1979/1980–1999/2000) and winters in the 21st century (2000/2001–2013/2014). The thick solid black line shows where $y = x$, the dashed black lines show the 20 ms$^{-1}$ damage threshold and the thin solid black lines show the 95% confidence interval, based on the asymptotic sampling distribution of the order statistics.

→ 10% reduction in scale of wind gust speeds close to Paris
Are the changes related to climate mode variability?

North Atlantic Oscillation (NAO) index for Oct-Mar winters 1900-2017
(Hurrell PC index)

→ NAO is known to modulate extreme storms (e.g. Economou et al. 2014)
→ NAO has been more positive during 1979-1999 than from 2000-2014

So can NAO changes account for the changes noted in footprint area?
Relationship between $A_{20}$ and Sea Level Pressure

Correlation between winter $A_{20}$ and mean SLP
Oct-Mar 1979-2014

→ Correlation of $A_{20}$ with SLP shows NAO-like pattern (shifted eastwards slightly)
→ Strong significant correlation (0.72) between $A_{20}$ and NAO indices

However, note than NAO doesn’t explain everything e.g. 89/90 and 13/14 differences!
NAO as a loss driver on longer time scales


Fig. 2 Histogram of values representing the sum of storm loss index each year, and the corresponding running 10-year mean (blue line) for historical wind storms in the Netherlands.

Additional confirmation of NAO being a potential driver of EUWS loss trends
Future climate change in NAO

Figure 14.16: Summary of multi-model ensemble simulations of wintertime (Dec-Feb) mean NAO, NAM and SAM sea-level pressure indices for historical and RCP4.5 scenarios produced by 39 climate models participating in CMIP5. Panels a-c) show time series of the ensemble mean (black line) and inter-quartile range (grey shading) of the mean index for each model.

- **NAO/NAM is likely to become slightly more positive (on average)**
- **SAM positive trend is likely to weaken as ozone depletion recovers**

- **Medium confidence** that projected changes in NAO and SAM are sensitive to boundary processes (stratosphere-troposphere interaction, ozone chemistry, response to Arctic sea ice loss), which are not yet well represented in many climate models.
Summary

• Area of wind gusts >20m/s is a good storm severity index for classifying high loss storms;

• Total area of wind gusts >20m/s has decreased by 10% in winters from 2000-2013 compared to winters 1979-1999;

• The decrease in total area is due to a significant reduction in wind speeds over much of Europe (apart from Iberian peninsula). Storm numbers have not shown any decrease;

• This wind speed change can be accounted for by a decrease in the North Atlantic Oscillation. Total area of wind gusts is highly correlated with winter mean NAO;

• The decrease in NAO is contrary to what one expects due to global warming so change is most likely natural variability. Indication that we are now heading back into a more positive phase of NAO.
Additional slides for questions etc. ...
Future directions: use of big data

Windstorm footprint estimation typically only uses standard meteorological observations which can have poor spatial coverage (e.g. at urban postcode scales);

There are many other less conventional data sources that may be useful for inferring high gust speeds e.g.

- Amateur observer network (WOW);
- Newspaper reports;
- Social media feeds e.g. twitter;
- Webcams and CCTV imagery.

Can this data be mined to improve footprint estimation? The stochastic model is a way of integrating these diverse data sources.

NERC Highlight Proposal BIGFOOT (£1.5 million funding – 4 postdocs – 3 years).

Let me know if you have any ideas about this or would like to be involved!
Projected CMIP5 ensemble mean changes RCP4.5 scenario
Difference in time means over 2070-99 and 1976-2005

Winter (DJF)               Summer (JJA)

Track density (no. of storms/month)

Wind speed intensity (m/s)

Precipitation intensity (mm/hour)