The 21st century decline in damaging European windstorms

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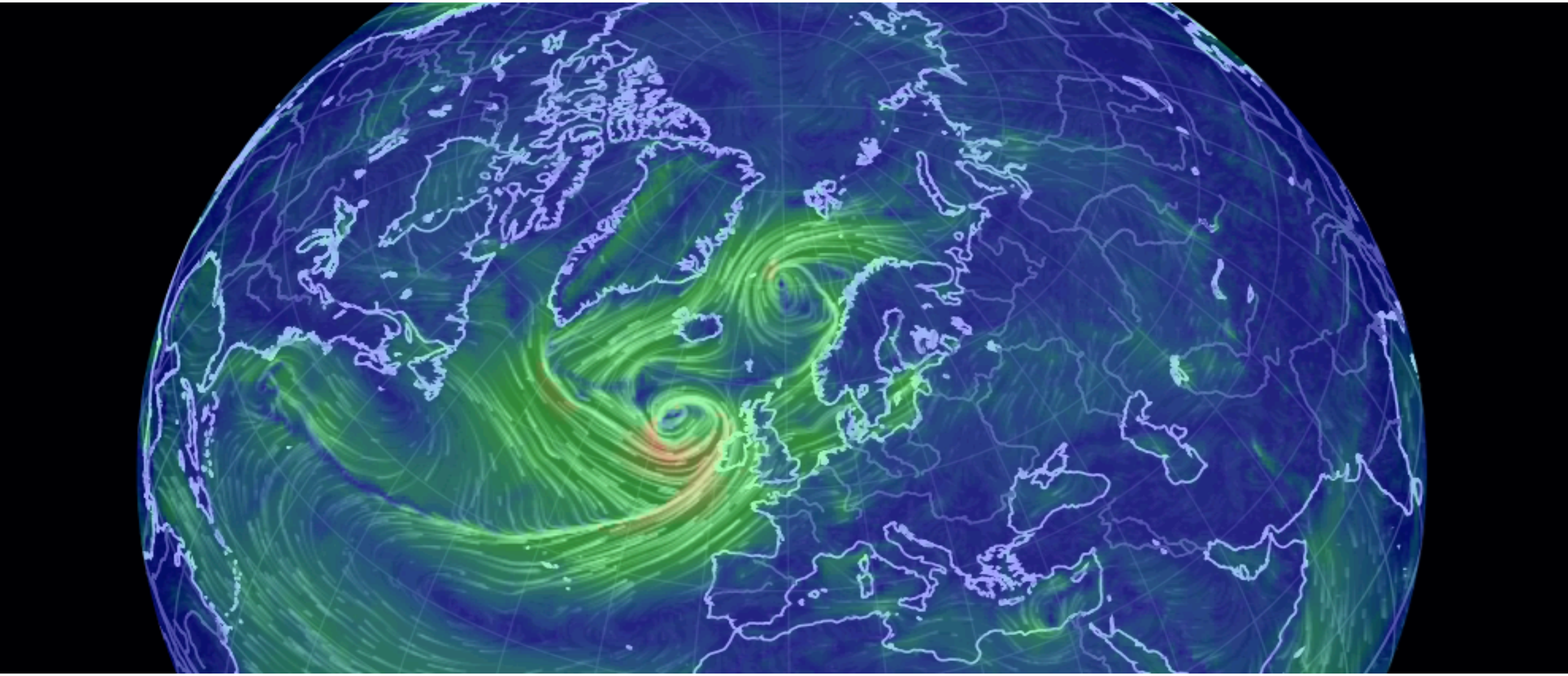
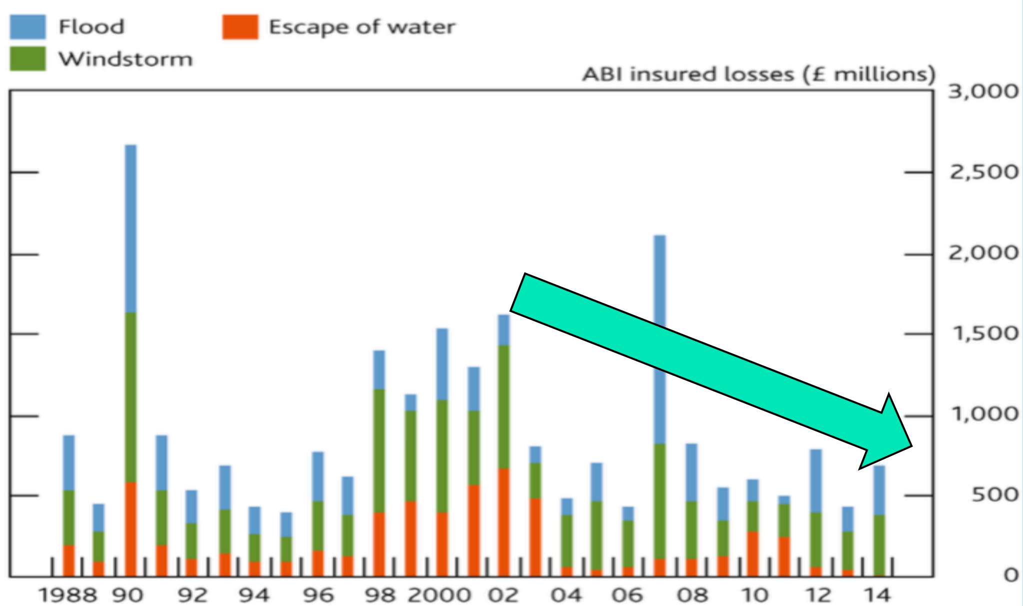
Exeter Climate Systems

Acknowledgements: Julia Lockwood, Paul Maisey



Why have windstorm losses declined since 2000?

Figure 5.5. Insured UK losses from windstorms and other drivers according to the ABI (1988 – 2014)



Source: Prudential Regulation Authority (2015) based on data from Association of British Insurers available at https://www.abi.org.uk/Insurance-and-savings/Industry-data/Industry-data-downloads.
Notes: Spikes in losses correspond to wind storms in 1990 and flooding in 2007.

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The 21st century decline in damaging European windstorms

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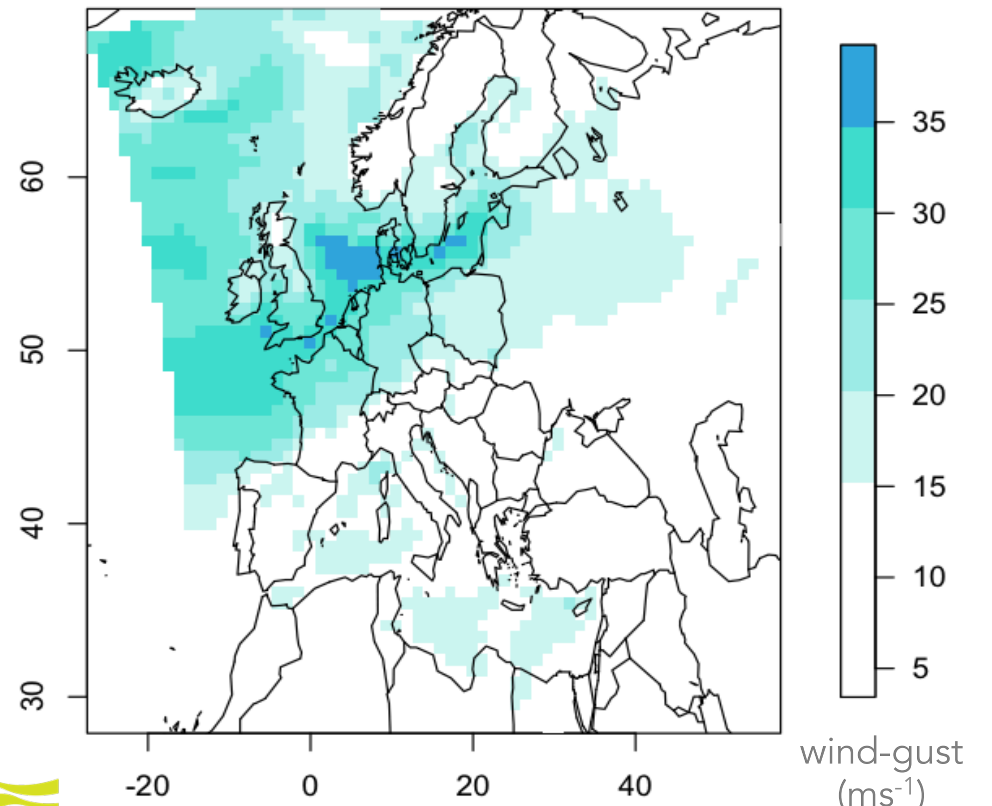
Footprint database: 1979/80-2013/14

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)

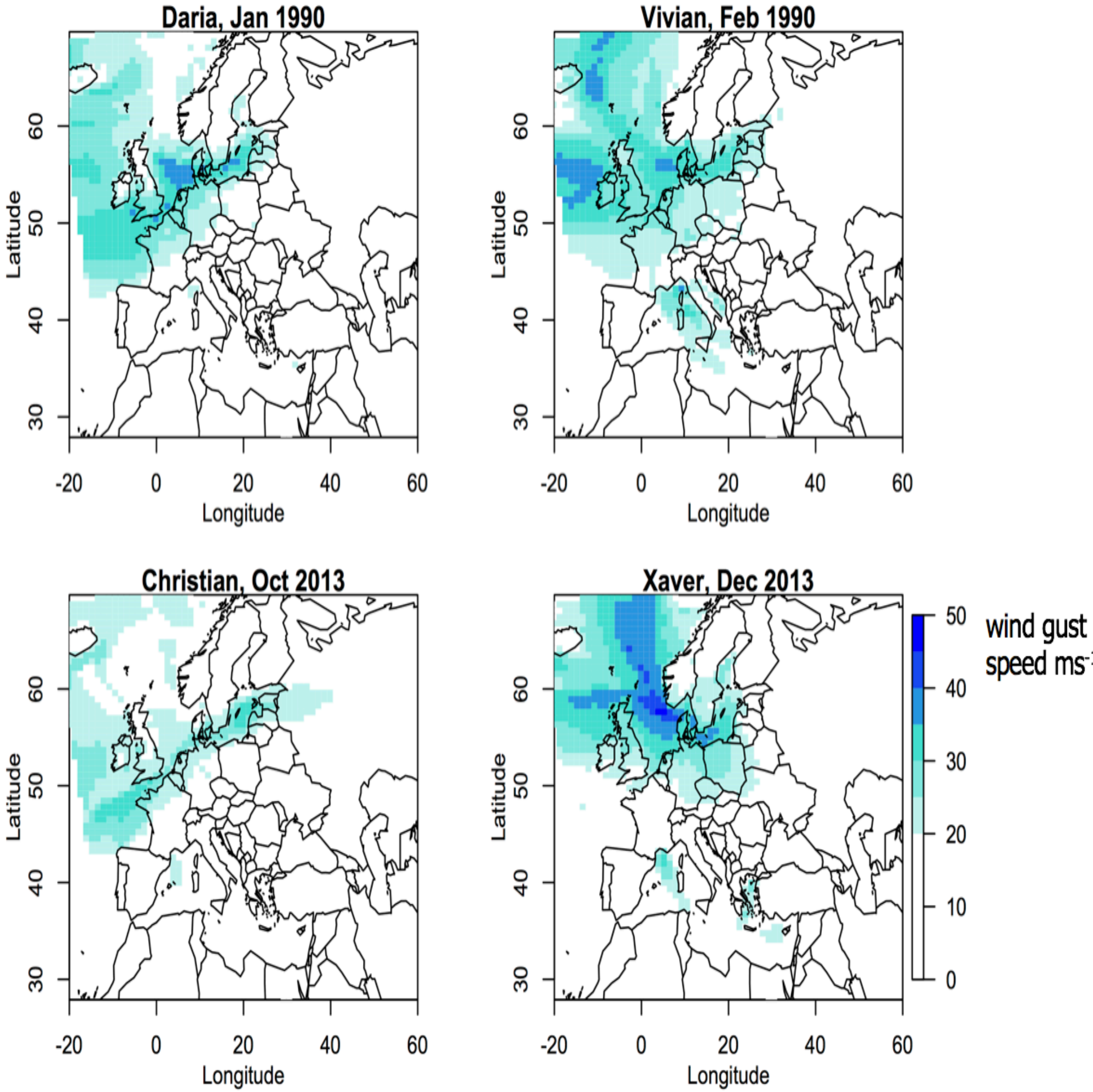


6301 storms identified in extended winters (October-March) using objective tracking algorithm (Hodges, 1995)

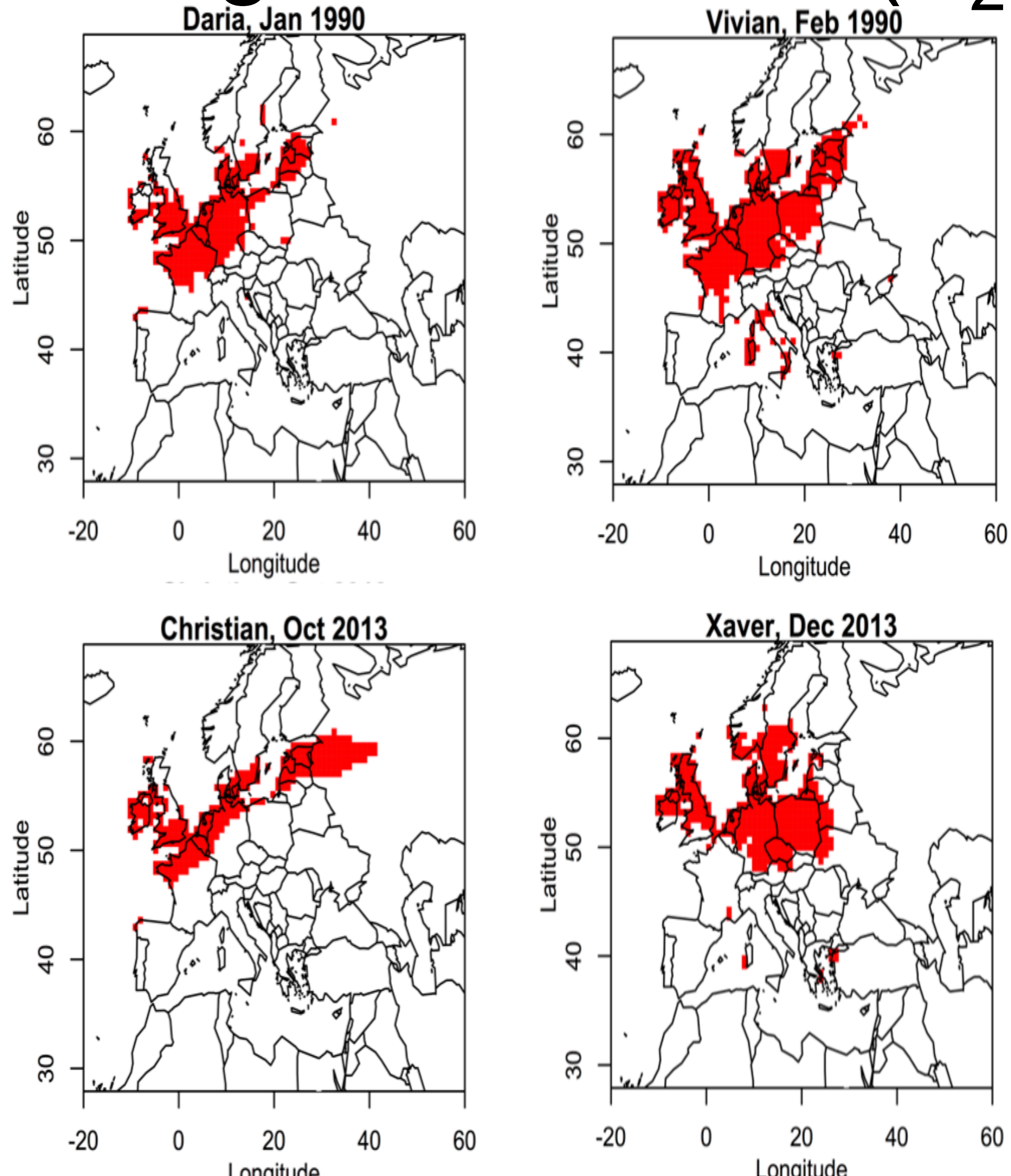
Then footprints created for each storm by dynamically downscaling ERA-Interim using the Met Office 25km resolution North Atlantic-European operational NWP model.

Met Office

Damaging windstorm examples: 1990 & 2013

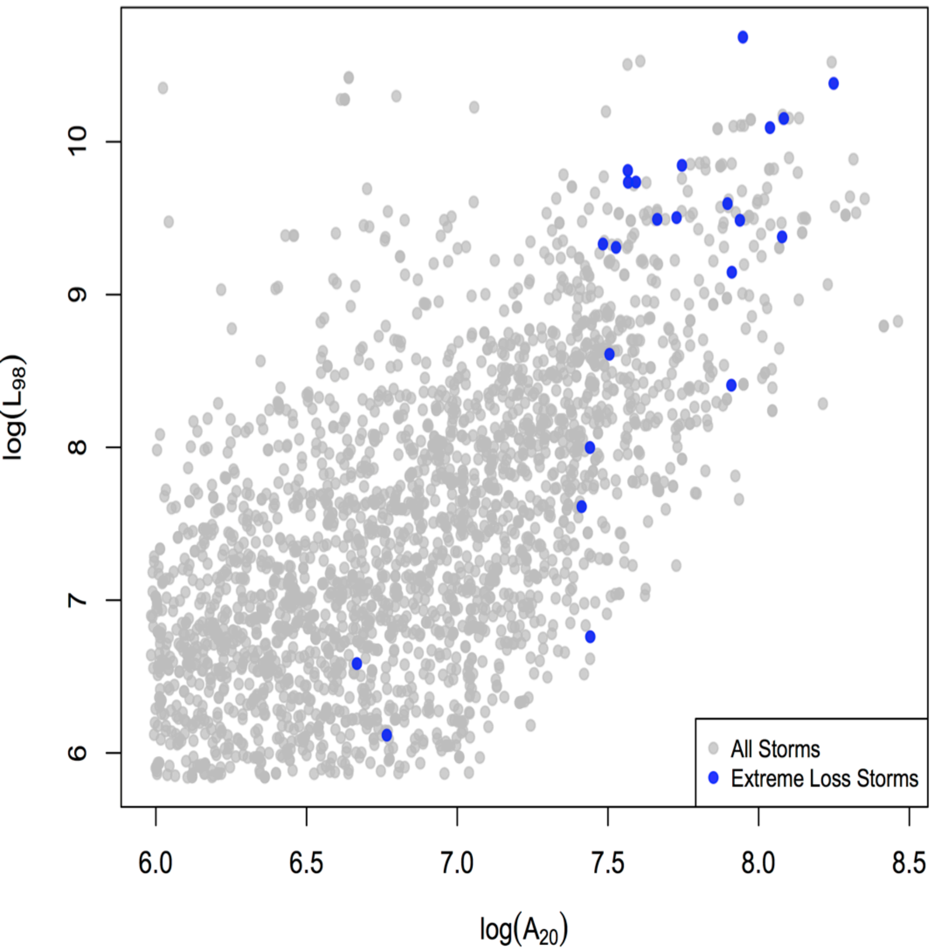


Area with gusts > 20m/s (A_{20} index)



$$A_{20_i} = \sum_{j=1}^{J} I(v_i(s_j) > 20)$$

Area A_{20} is a good predictor of severity



Klawa, M. and Ulbrich, U.: A model for the estimation of storm losses and the identification of severe winter storms in Germany, Nat. Hazards Earth Syst. Sci., 3, 725-732, 2003.

Indices defined as

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

$$A_{20} = \sum_{v_j > 20}^{J} 1$$

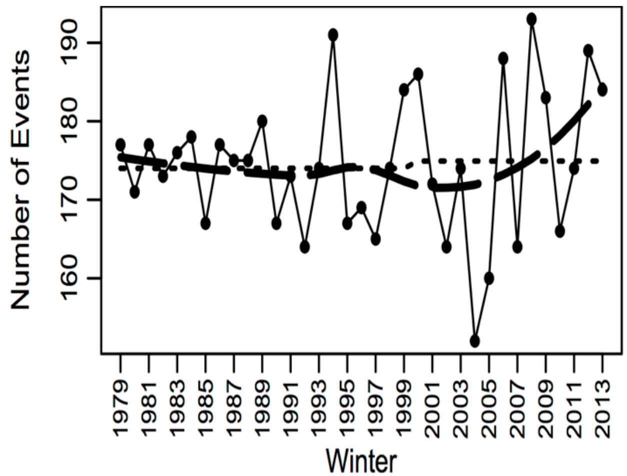
where for grid point j, v_j is gust speed, v_{98j} is 98th percentile of gust speeds, and d_j is population density.

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

Roberts, J et al. (2014): *The XWS open access catalogue of extreme European windstorms from 1979-2012, Natural Hazards and Earth System Sciences Discussions 2 (3), 2011-2048.*

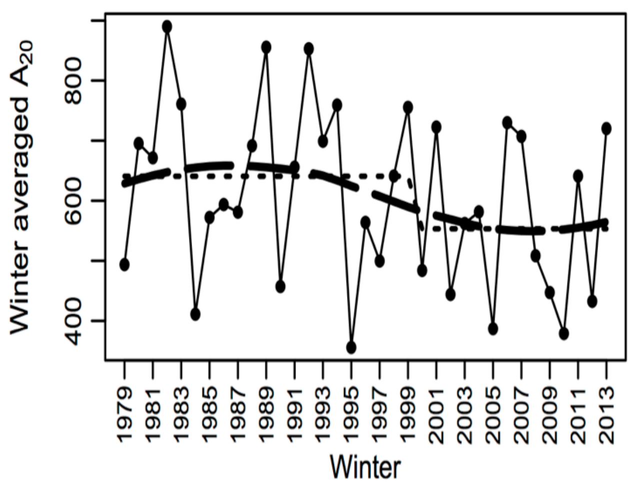
Recent trends: 1979/80-2013/14

Number of storms

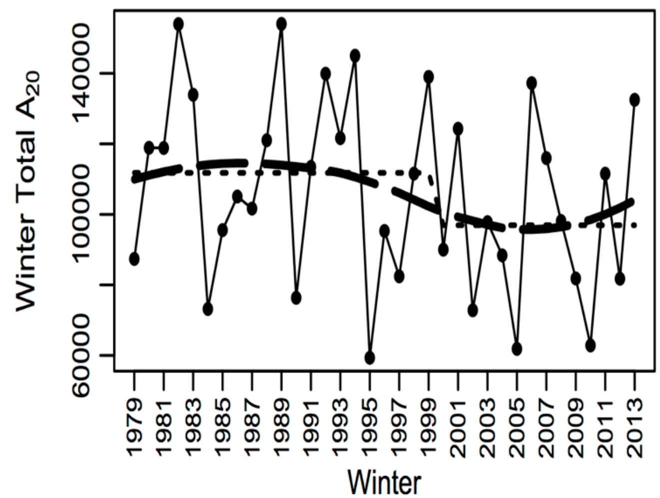


← The number of European storms in Oct-Mar has become more volatile and has shown an increasing trend. No explanation yet for this recent 2% change which is not consistent with long term decrease expected from climate change projections. Early period is less volatile than chance i.e. Poisson standard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

Average A_{20} area



Total A_{20} area
= average area X number of storms



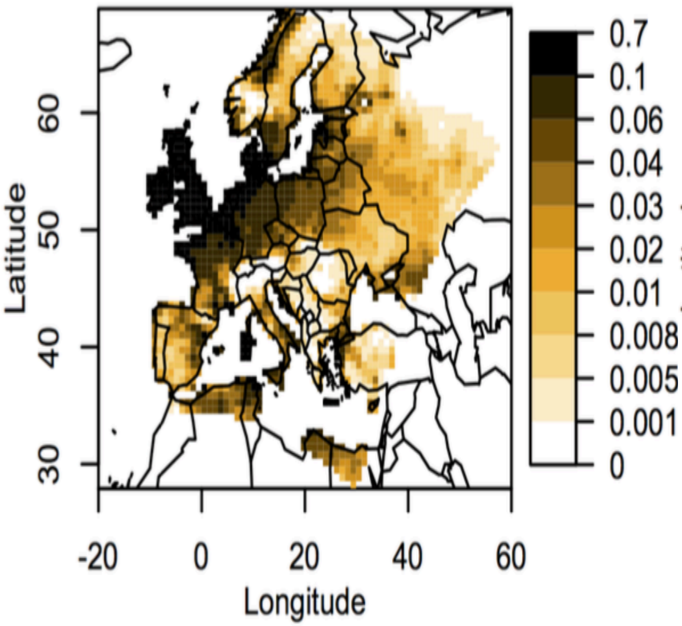
→ 12% drop in average area which has led to a 10% drop in total area

Frequency of exceeding 20m/s

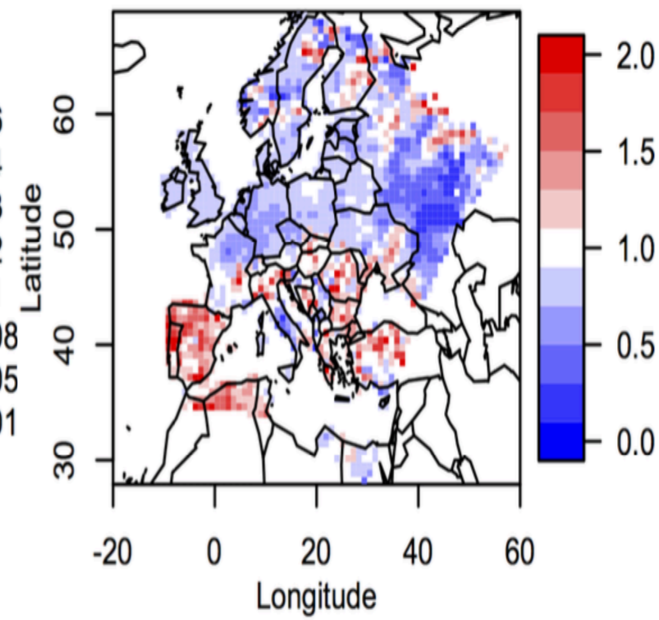
$$F_1(s_j) = \frac{1}{n_1} \sum_{i \in 20^{th}\text{century}} I(v_i(s_j) > 20) \qquad F_2(s_j) = \frac{1}{n_2} \sum_{i \in 21^{st}\text{century}} I(v_i(s_j) > 20)$$

$$n_1 = 3654 \qquad n_2 = 2554$$

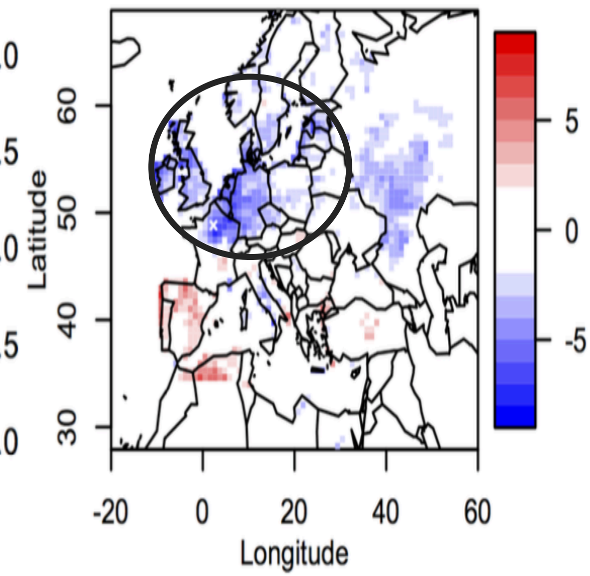
Frequency in 20th century



Ratio of frequencies in 21st and 20th centuries



Statistical significance t-statistic



→ statistically significant decreases in frequencies over most of Europe.
→ increase in 21st century over Iberian peninsula.

Change in gust speed distribution

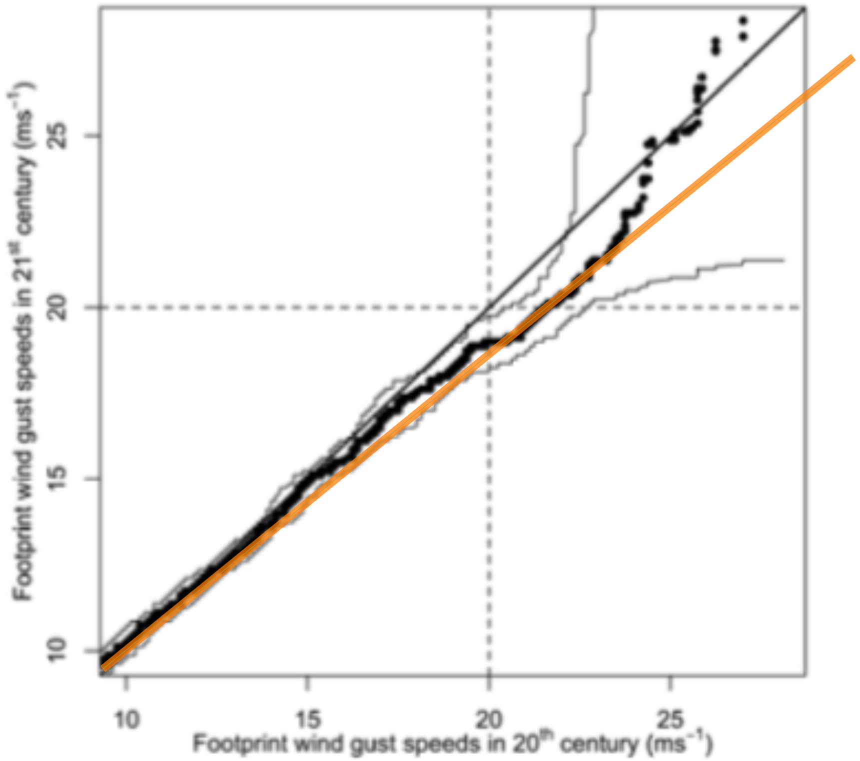
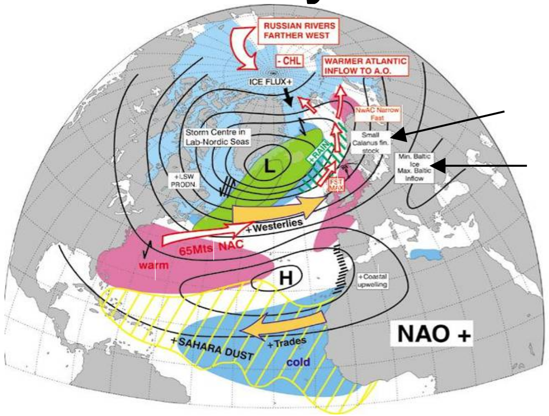


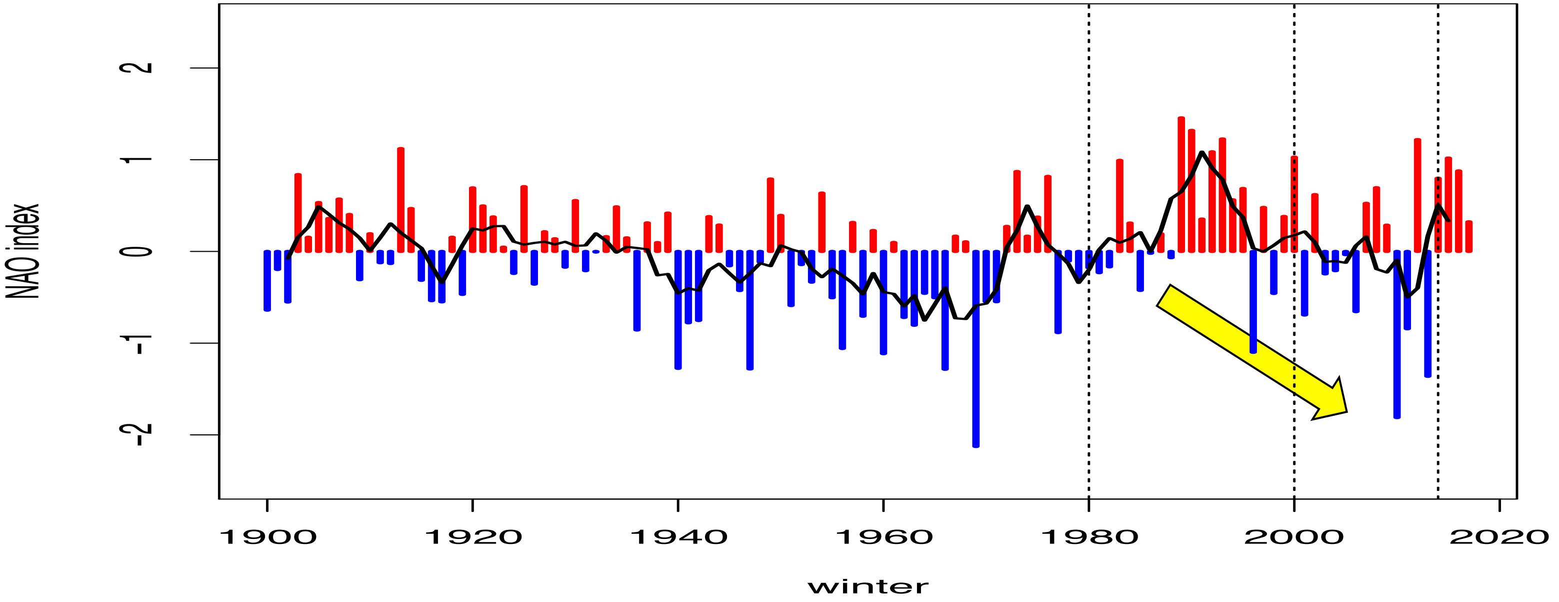
Figure 5. Quantile-quantile plot of footprint wind gust speeds in the grid cell closest to Paris for events in the two comparative periods: winters in the 20th century (1979/1980–1999/2000) and winters in the 21st century (2000/2001–2013/2014). The thick solid black line shows where $y = x$, the dashed 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)

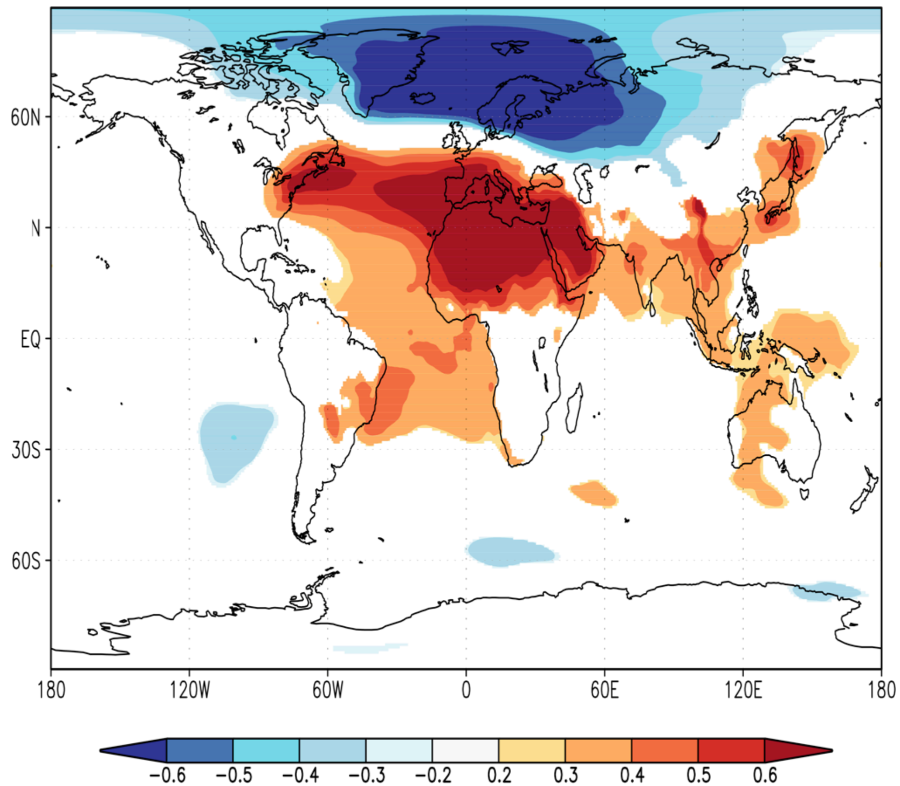


→ NAO is known to modulate extreme storms (e.g. Economou et al. 2014)
→ NAO has been more positive during 1979-1999 than from 2000-2014

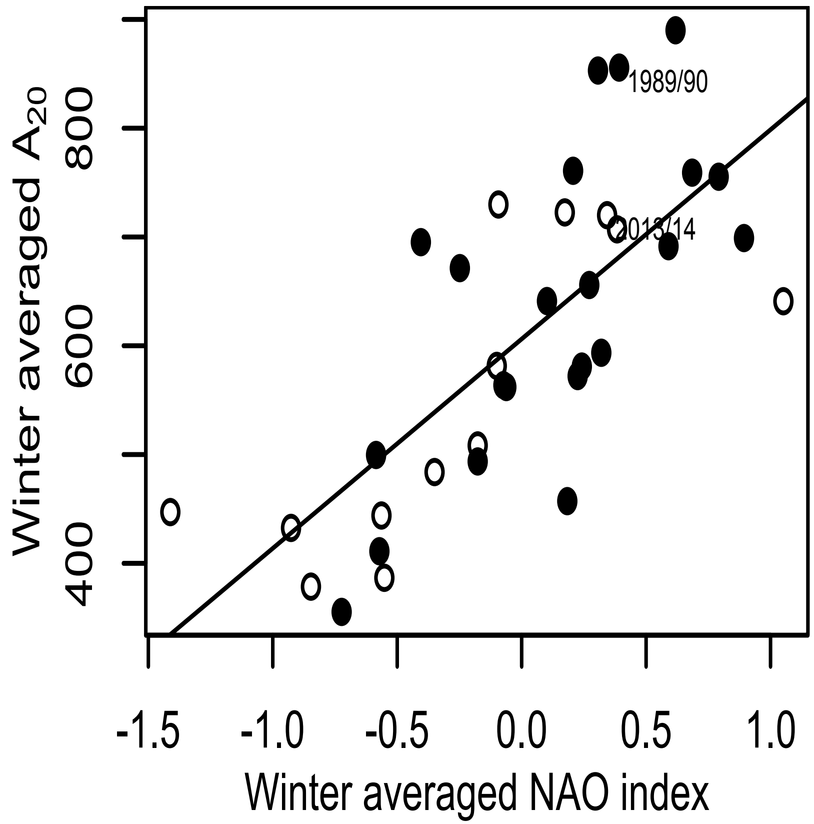
So can NAO changes account for the changes noted in footprint area?

Relationship between A_{20} and Sea Level Pressure

Correlation between winter A20 and mean SLP
Oct-Mar 1979-2014



A20 versus mean NAO index
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

Cusack, S. (2013): A 101 year record of windstorms in the Netherlands, Climatic Change (2013) 116:693–704

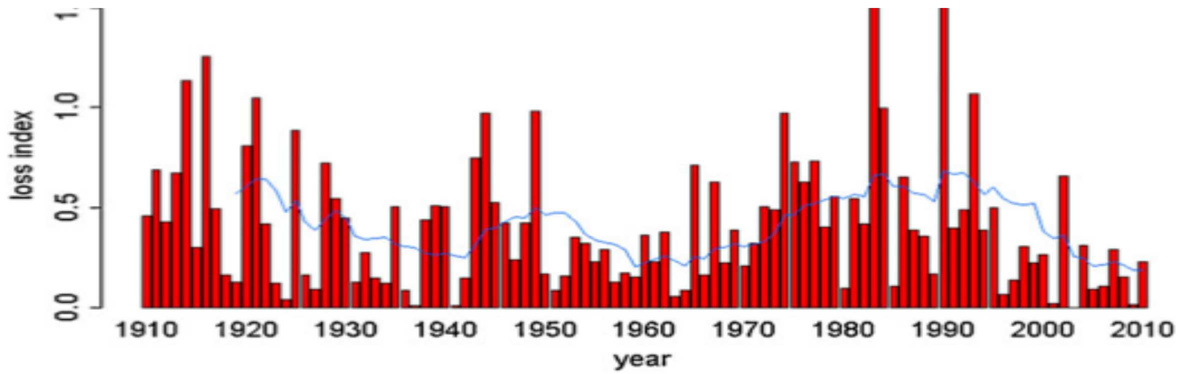
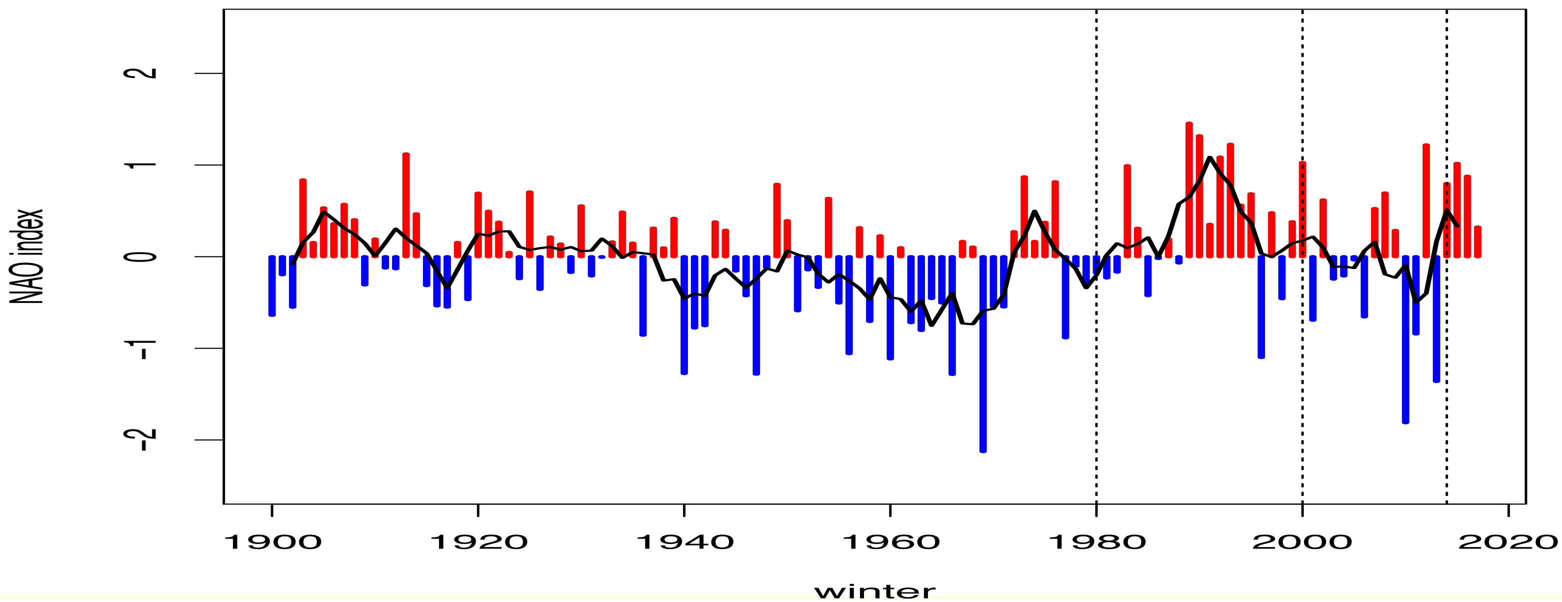


Fig. 2 Histogram of values representing the sum of storm loss index each year, and the corresponding running 10-year mean (*blue line*) for historical wind storms in the Netherlands



→ Additional confirmation of NAO being a potential driver of EUWS loss trends

Future climate change in NAO

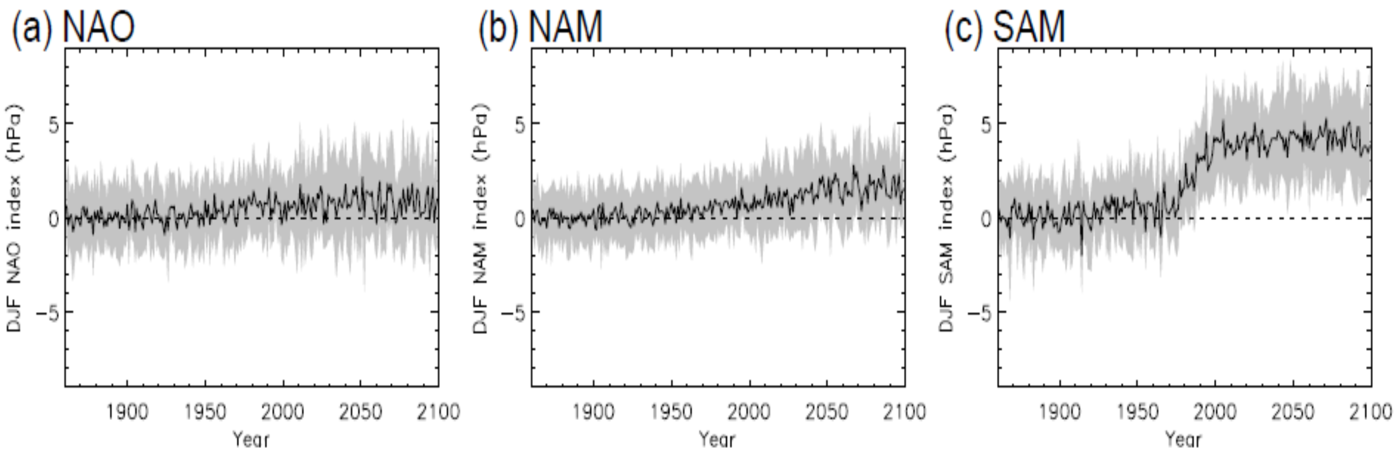
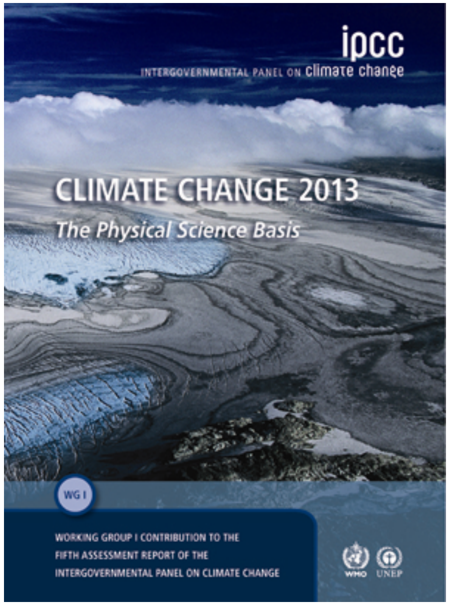
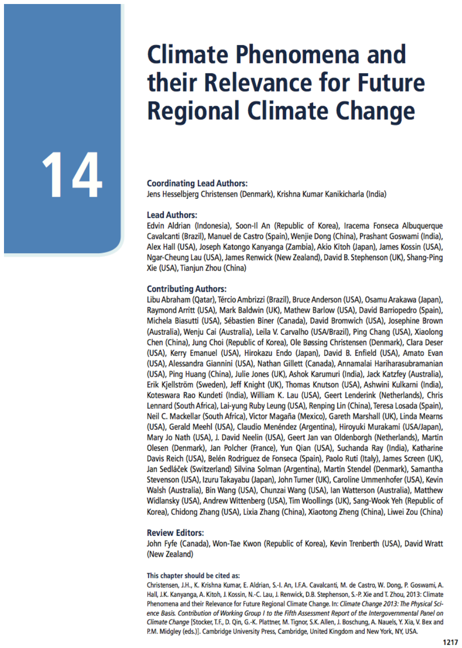


Figure 14.16: Summary of multi-model ensemble simulations of wintertime (Dec-Feb) mean NAO, NAM and SAM sea-level pressure indices for historical and RCP4.5 scenarios produced by 39 climate models participating in CMIP5. Panels a-c) show time series of the ensemble mean (black line) and inter-quartile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



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Climate Phenomena and their Relevance for Future Regional Climate Change

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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);

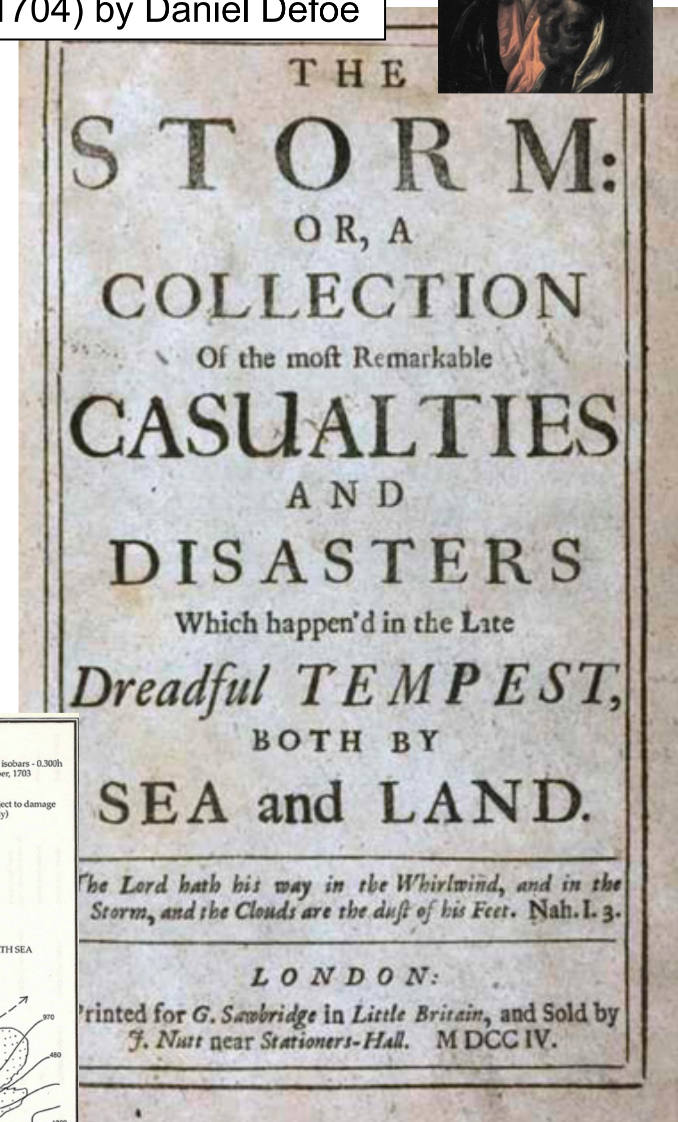
There are many other less conventional data sources that may be useful for inferring high gust speeds e.g.
- Amateur observer network (WOW);
- Newspaper reports;
- Social media feeds e.g. twitter;
- Webcams and CCTV imagery.

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!

The Storm (1704) by Daniel Defoe



THE STORM: OR, A COLLECTION Of the most Remarkable CASUALTIES AND DISASTERS Which happen'd in the Late *Dreadful TEMPEST*, BOTH BY SEA and LAND.

The Lord hath his way in the Whirlwind, and in the Storm, and the Clouds are the dust of his Feet. Nah. I. 3.

LONDON:

Printed for *G. Sawbridge* in *Little Britain*, and Sold by *J. Nutt* near *Stationers-Hall*. MDCCIV.

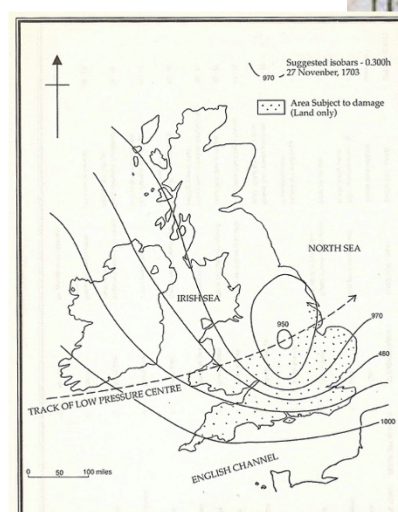


Figure 1: The Passage of the Great Storm

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)