# The AXA Windstorm Event Set

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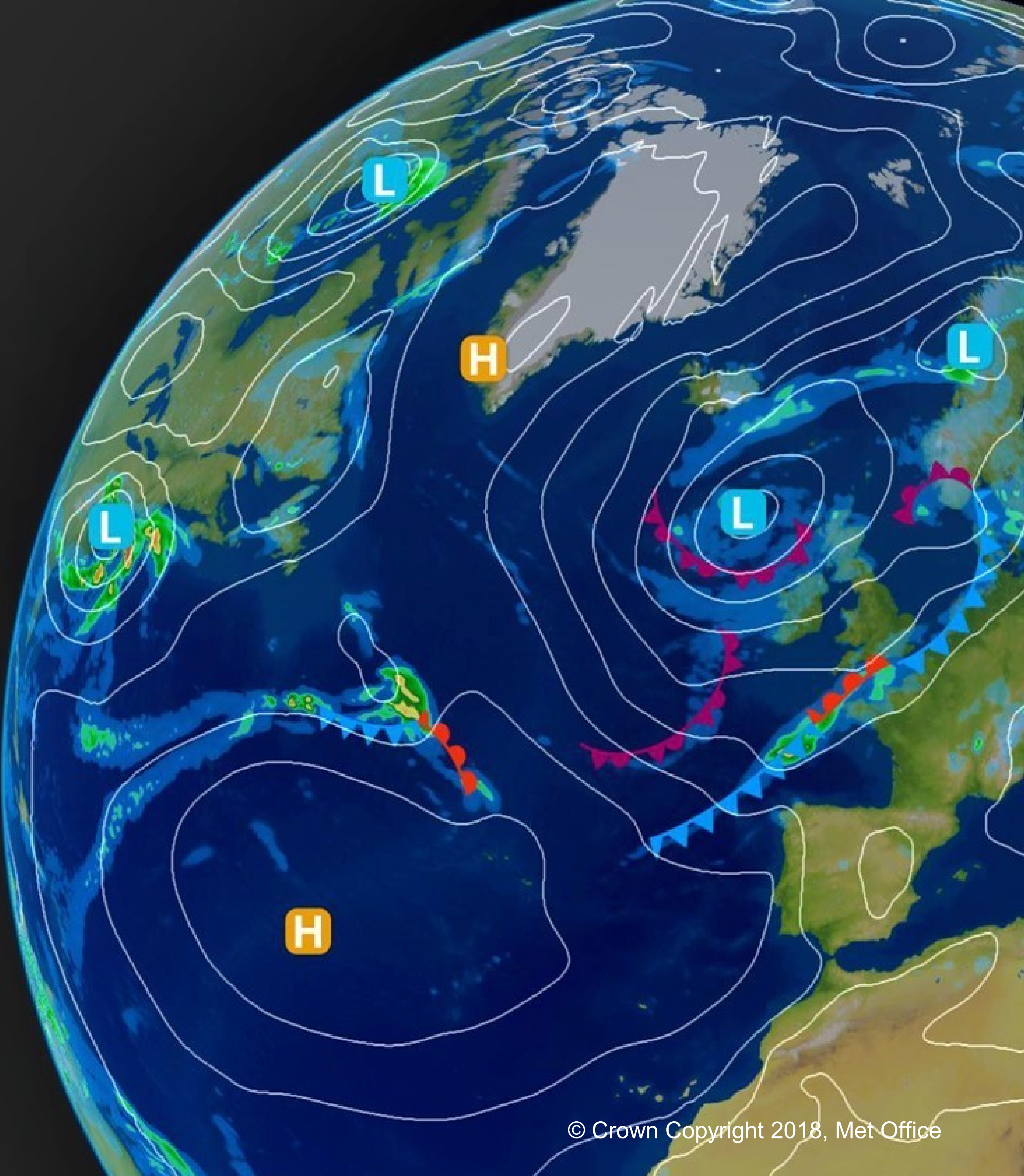


# Introduction

| AXA Joint Research Initiative Title | “Generation of stochastic winter windstorm events in Europe based on the last generation of dynamical and statistical methods” |
| --- | --- |

- The AXA Research Fund
- The story so far:
  - XWS: Extreme Windstorm catalogue
  - WInd StOrm Monitor comprising the early warning system, footprint (forecast, analysis, recalibration), storm matching and return periods (WISdOM)
  - Windstorm information Service WISC (Copernicus Climate Change Service)
- Metaxa: Met Office - AXA research collaboration
  - WP1: Footprint extraction from ensemble atmospheric model
  - WP2: Statistical post-processing and generation of stochastic events
  - WP3: Postprocessing Laura Dawkins

# The AXA Research Fund in Numbers

4 Areas of research:


600+ Research projects supported across the world

archers from

3 nationalities

38 countries


250 M€ committed since the creation of the fund in 2008

Met Office

# Natural Hazards Matter for AXA

100 millions of customers

10 trillion $ of property insured

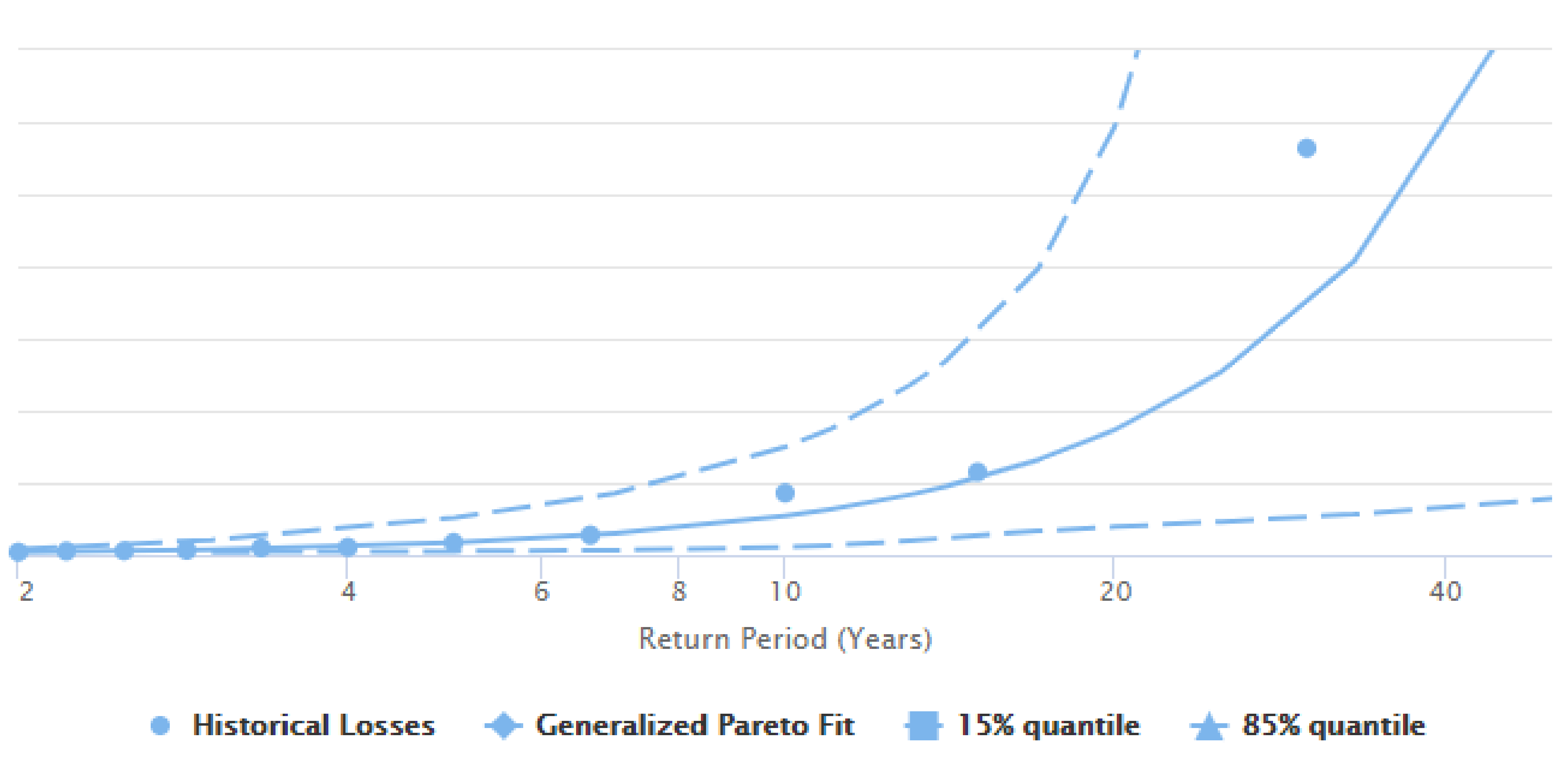
- **Solvency** issue : how much do we need to be able to pay to our clients in case of a catastrophic event ?
- **Claims handling** issue : how to respond to events causing tens or hundreds of thousands of claims ?
- **Profitability** issue : are we pricing catastrophe risks correctly ?
- **Corporate responsibility** issue : how can we contribute to the global risk modeling community ?

# One Illustration: the Lothar & Martin Storms

- **2 storms occurring in 3 days: 26-28th December 1999**
- **140 deaths**
- **20 bn$ economical losses, 14 bn$ insurer payouts**
- **Millions of people impacted**

- **AXA is now global and exposed to a large variety of natural hazards: hurricanes, wildfires, earthquakes, floods…**

# Catastrophe Risks Cannot Simply be Extrapolated from Historical Losses



# We Need Physical Models to Understand Catastrophe Risks

### 1. Exposure module

Location and features of insured policies and sites

### 2. Hazard module

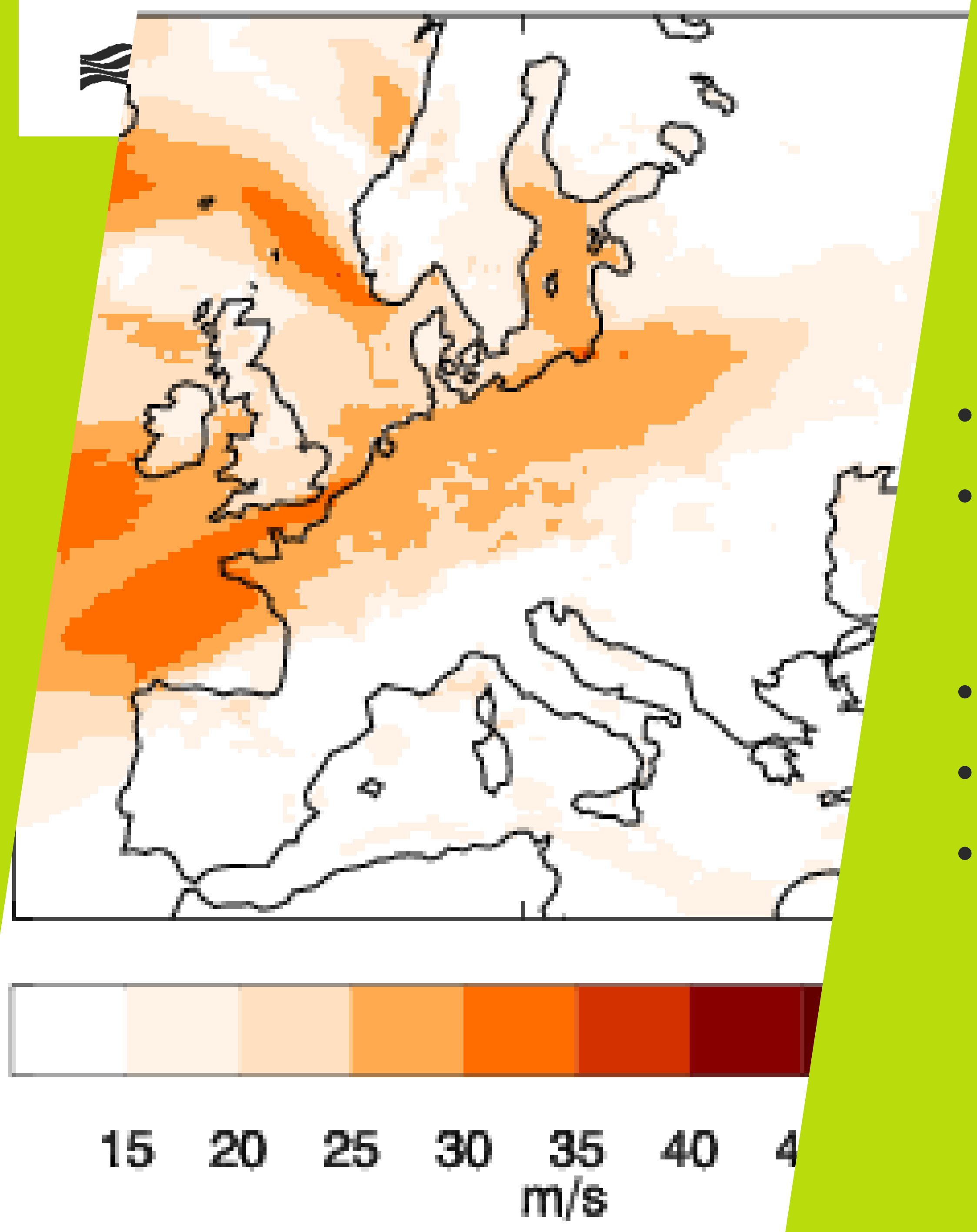
Physical description of past and possible future events

### 3. Vulnerability module

Computation of ground up losses based on hazard values and site information

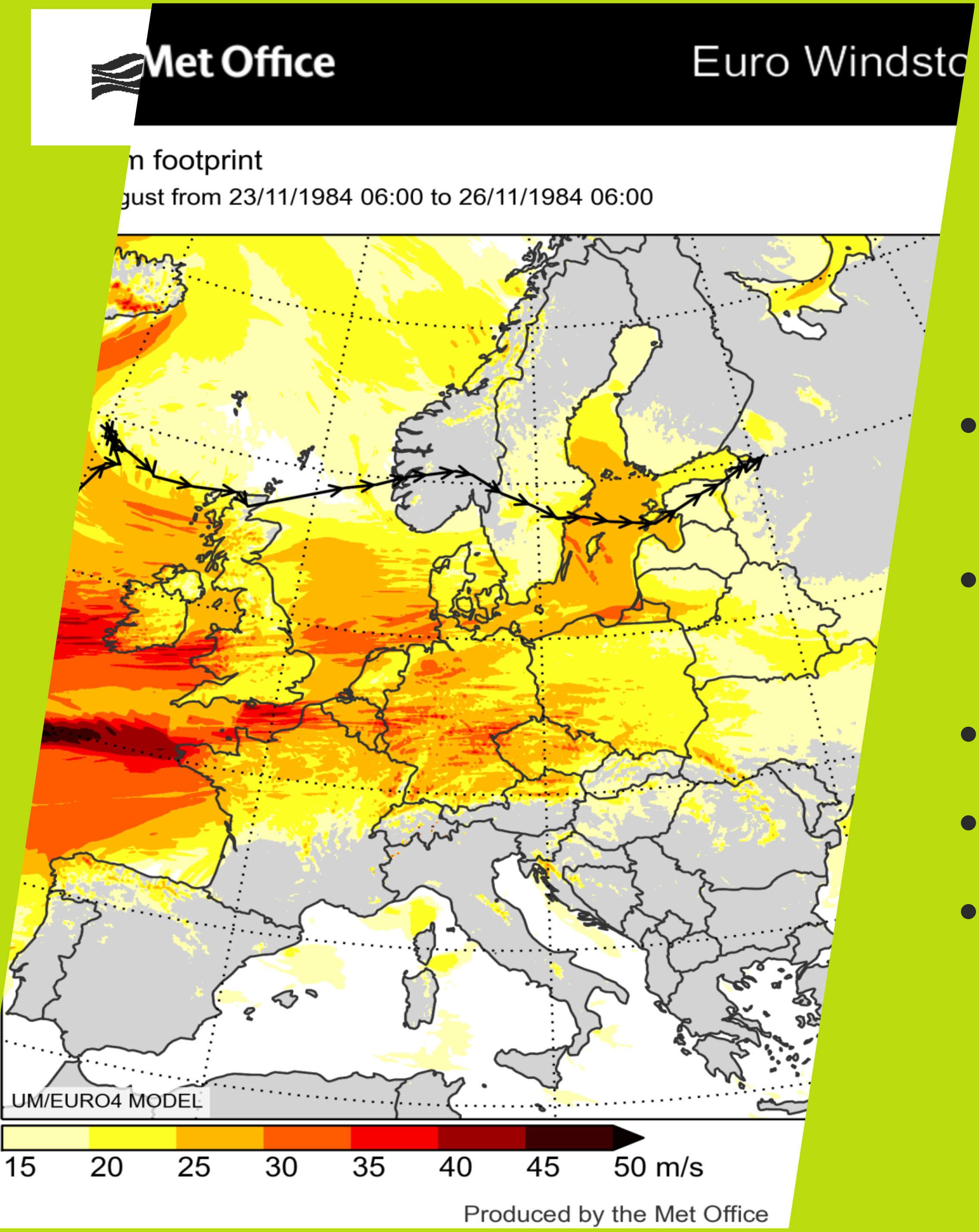
### 4. Financial module

Application of policy conditions (deductible, limit, …) to compute an insured loss




# Humble beginnings: XWS

- Extreme windstorm catalogue
- Reading University downscaled Era-40 to 25 km, ca. 50 extreme wind storms.
- http://www.europeanwindstorms.org/
- Storm foot print from 1984
- Maximum wind gust over a 3-day period



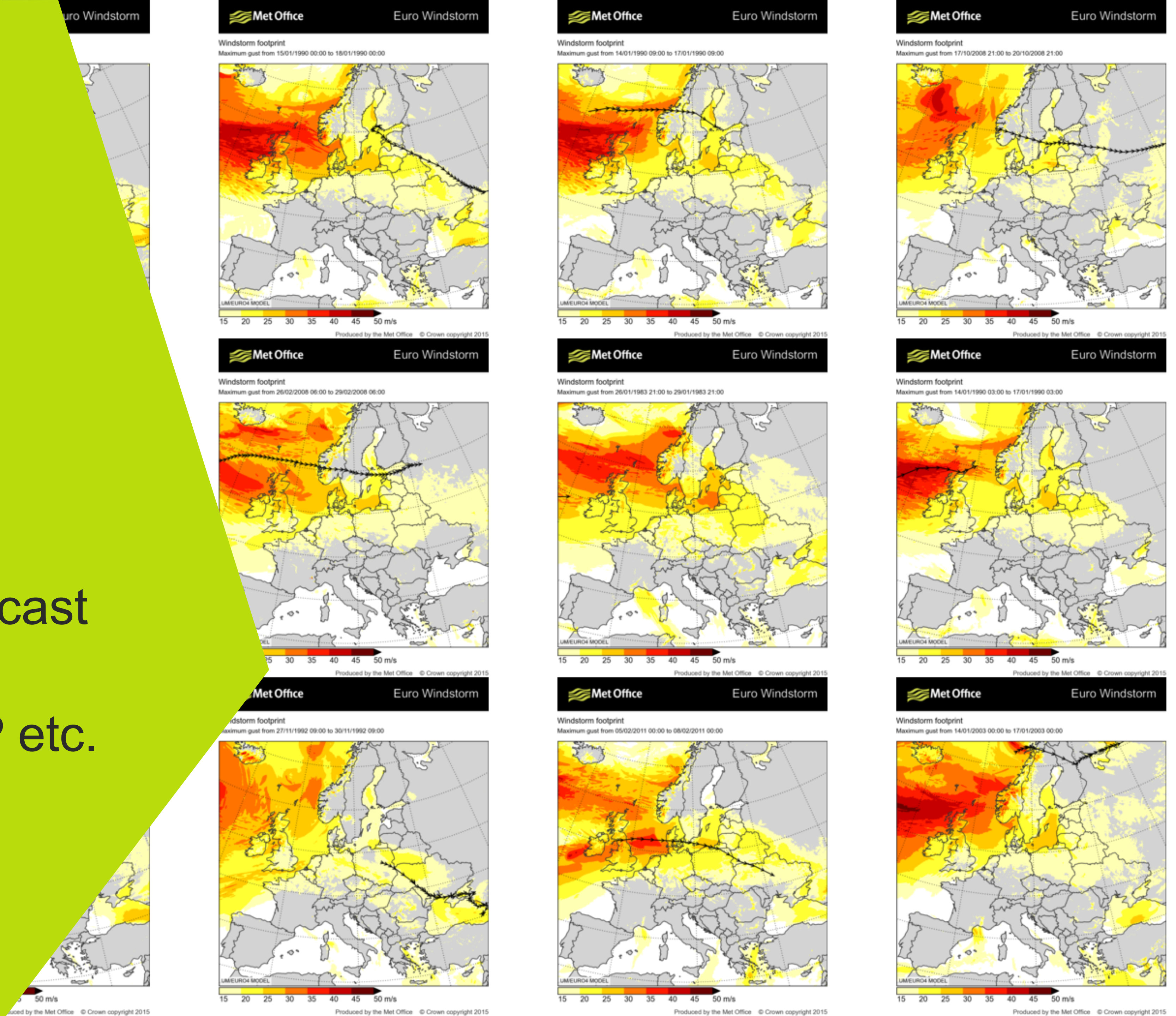

# First steps: Historical Windstorm Catalogue

- downscaled Era-interim to 4.4 km, ca. 6110 storms.
- https://metnet2.metoffice.gov.uk/content/historic-windstorm-catalogue
- Storm from 1984
- Higher resolution
- More storm foot prints (SFP)

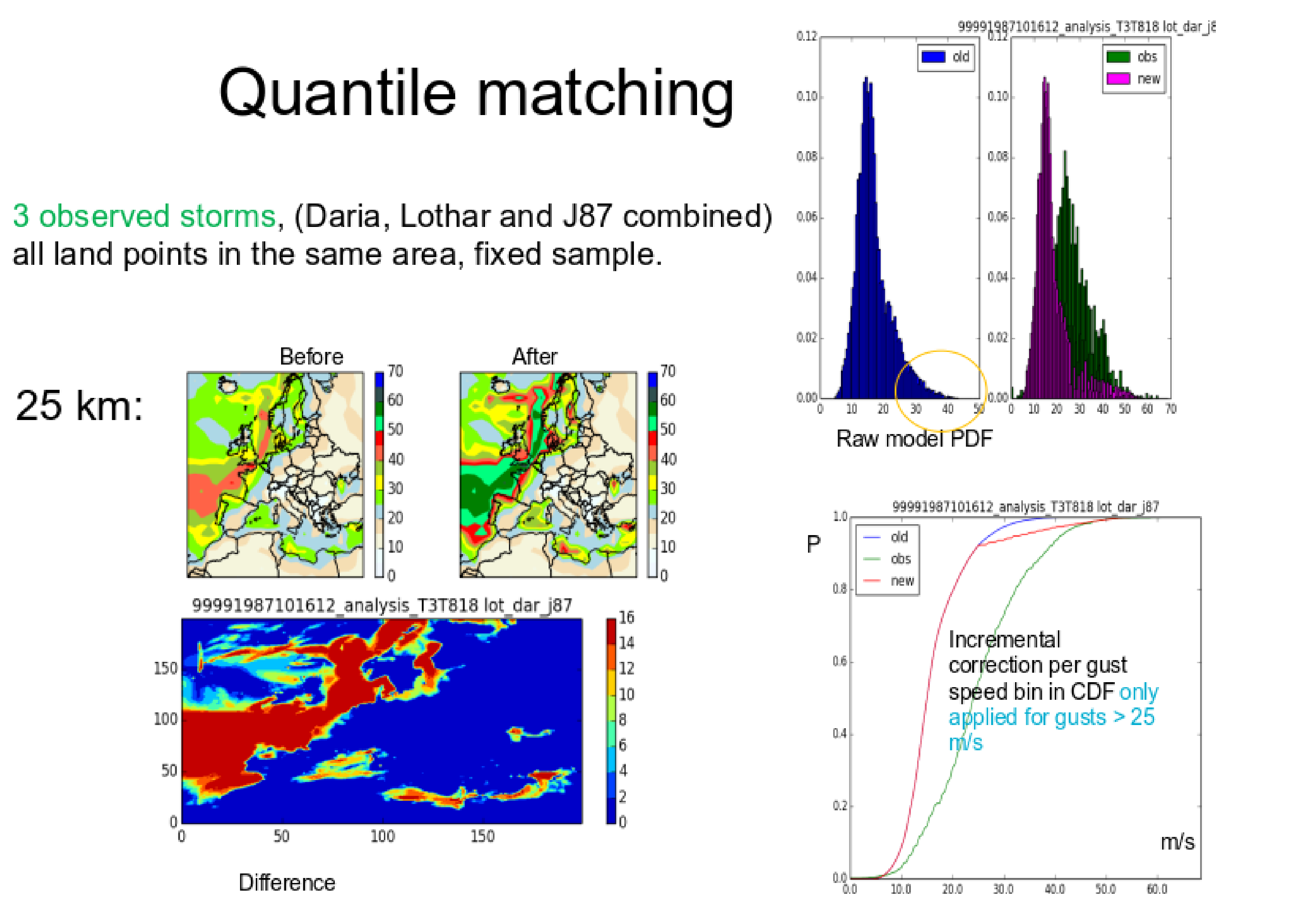
# Walking the line: WISdOM

- Insurance and Capital markets Windstorm monitoring system

- EURO4 real time forecast model at 4.4 km
- Pattern matching SFP etc.



# Learning to fly: WISC




- WISC Windstorm Information System
- https://climate.copernicus.eu/windstorm-information-service

Catalogue extended backwards to 1940 at 4.4 km resolution

Event set:

current Climate Simulation (Upscale)

- Interpolated to 4.4 km
- QQ-matched with 4.4km SFP

Kidding ourselves!

Despite value range similar to as observed, SFP still shows no fine scales of gusts but the exact same broad pattern as resolved by the coarse 25 km model.

# The METAXA event set: 3 basic data sources and 3 new ingredients

## Data sources:

Upscale current climate simulations (25km) 7500
EURO4 historical windstorm catalogue (4.4km) 6110
Station observations (point scale) 220

## The aim: to build a large set of realistic SFPs

## The procedural ingredients:

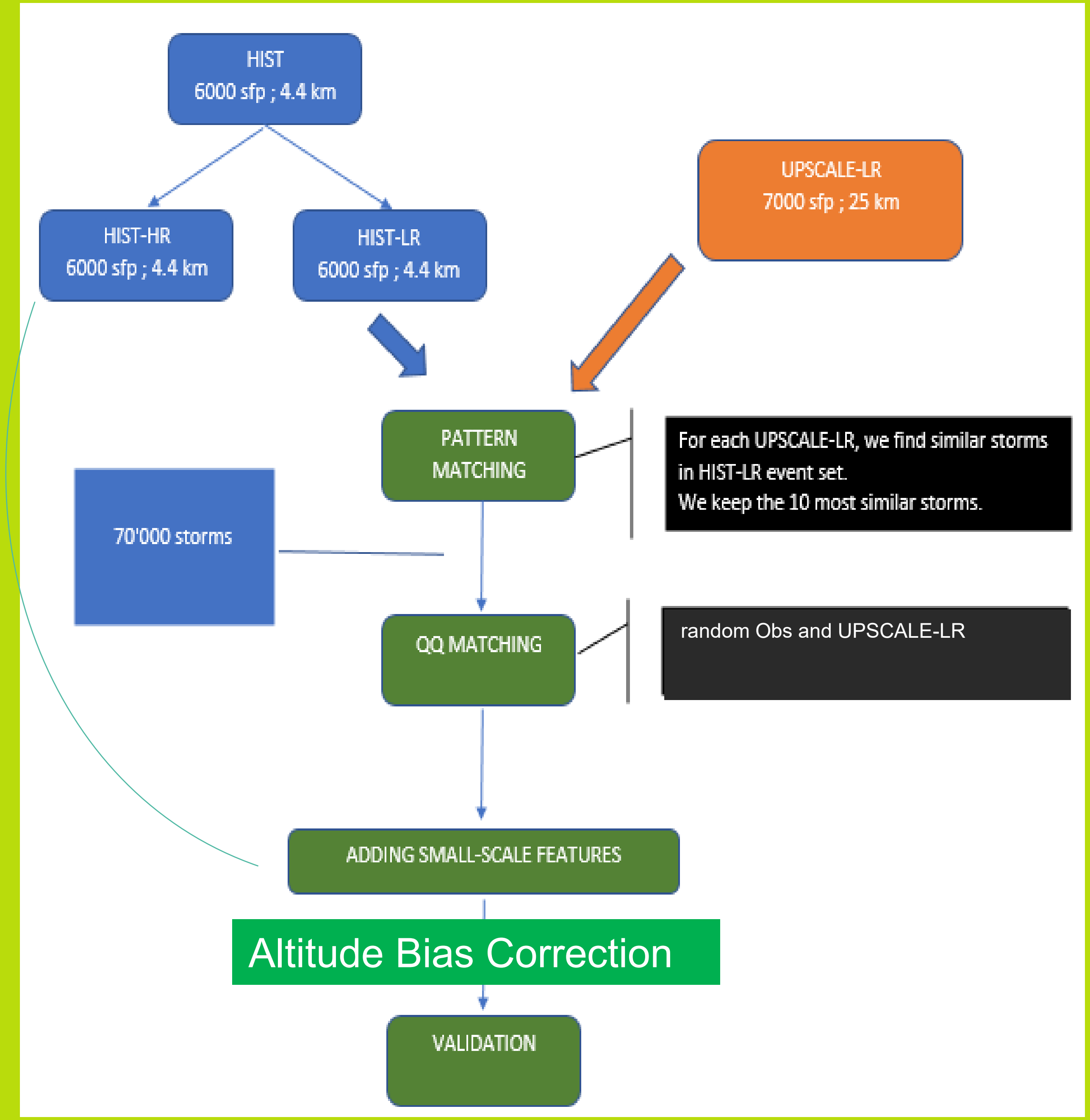
scale separation,
pattern matching,
altitude calibration.

The Upscale events provide dynamically consistent and plausible storm events resolving the large scale. The historical catalogue provides detail missing in the Upscale set of the wind gusts  up to 4.4 km resolution. The observed footprints provide the detail of real storm as much as point measurements can and crucially, the station observations help correcting the altitude bias due to un-resolved orographic detail.

# UPscale DOWNscaler

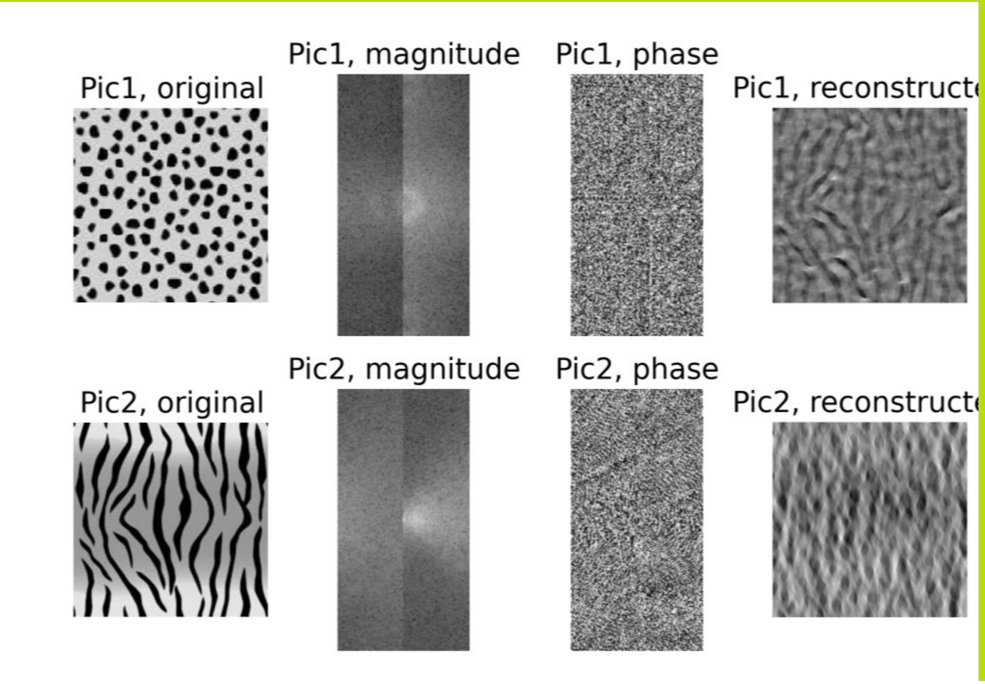
"New" Ingredients:

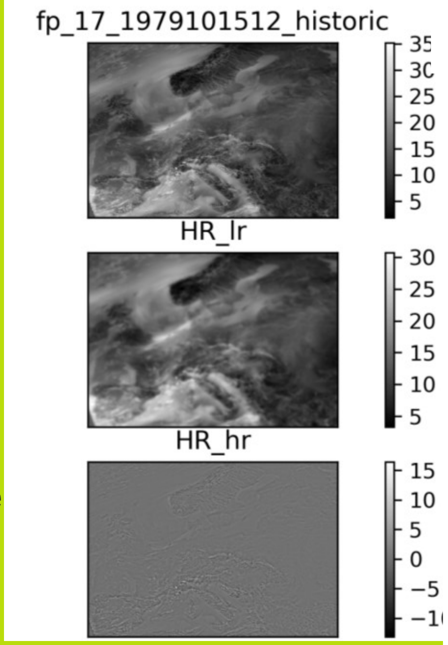
- Scale separation
- Haralick measures for pattern matching
- Altitude bias correction

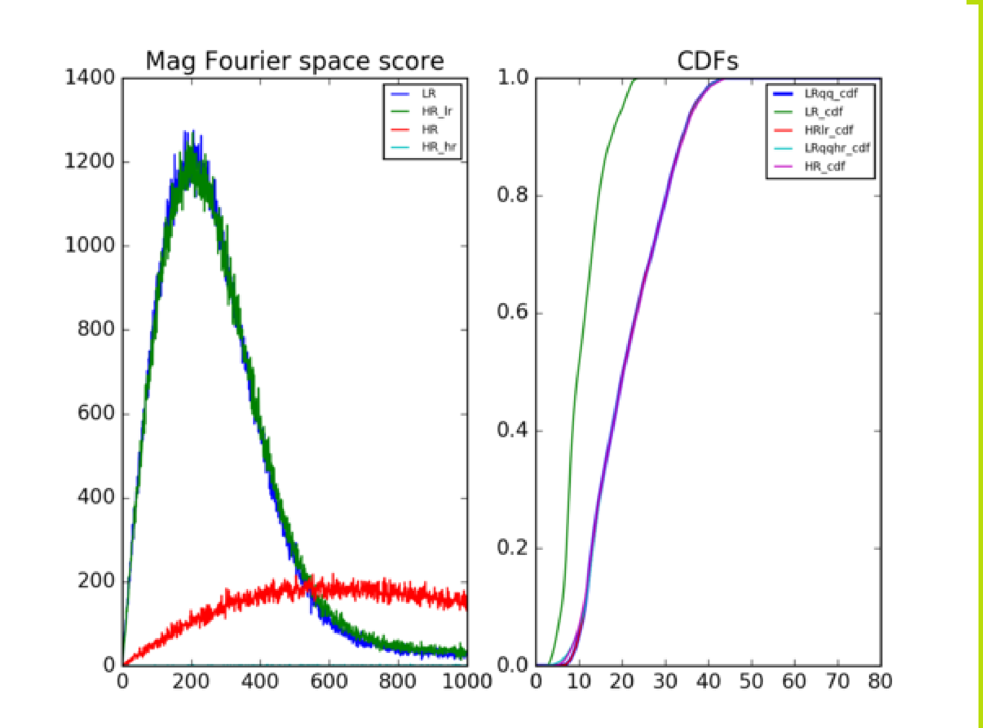


# Scale separation

- Inspired by [https://princeton.learningu.org/download//E241_Computer%20vision%20notes.pdf](https://princeton.learningu.org/download//E241_Computer%20vision%20notes.pdf)
- Fourier analysis of the SFP provides a distinct resolution dependent histogram of the magnitude spectrum. The lower the resolution, the tighter the histogram.
- Separate the scales in the high resolution 4.4 km SFPs by low path filtering: SFP_hr = SFP – SFP_lr with SFP_lr a smoothed version of SFP.
- Tune the separation point by averaging the SFP so that its spectrum matches the histogram of resolved scales of the 25km Upscale SFP.
- Now we have scale separation that makes the low-resolution part of the historical catalogue comparable with the Upscale unseen current climate simulations.
- Yield the high resolution "random" but physical plausible view of unresolved gust detail at 4.4 km scales to be added later.



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# Pattern Matching

Needs enough discrimination that even between very similar images/SFPs remains measurable.

## Evaluation of close matches

In each similarity measure of Storm footprints (SFP) we:

- Note the distance in rank for each measure
- Pick the top N best matches
- Calculate the distance ||F|| between candidate and group members
- Pick a winner

1. Rank proximity measure:
   Count positional distance in rank from perfect match in each category, integrate over all categories and declare the winner with the smallest rank proximity measure



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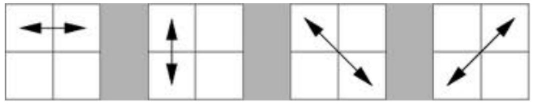
## Haralick texture features:



- Derived from the Gray-Level-Co-occurrence matrix
- Defined over an image, to be the distribution of co-occurring values at a given offset which
- Contains information about how image intensities in pixels with a certain position in relation to each other occur together.
- Mahotas computer image processing library for Python calculates thirteen features for each SFP

H1: Angular Second Moment
H2: Contrast
H3: Correlation
H4: Sum of Squares: Variation
H5: Inverse Difference Moment
H6: Sum Average
H7: Sum Variance
H8: Sum Entropy
H9: Entropy
H10: Difference Variance
H11: Difference Entropy
H12: Information Measure of Correlation 1
H13: Information Measure of Correlation 2

www.metoffice.gov.uk

Robert M Haralick, K Shanmugam, Its'hak Dinstein (1973). "Textural Features for Image Classification". IEEE Transactions on Systems, Man, and Cybernetics. SMC-3 (6): 610–621.



The pattern matching enables us to select the most similar ca. 20 storms from the historical catalogue for each of the unseen low-resolution storms, providing a physical plausible view of unresolved gust detail at 4.4 km.

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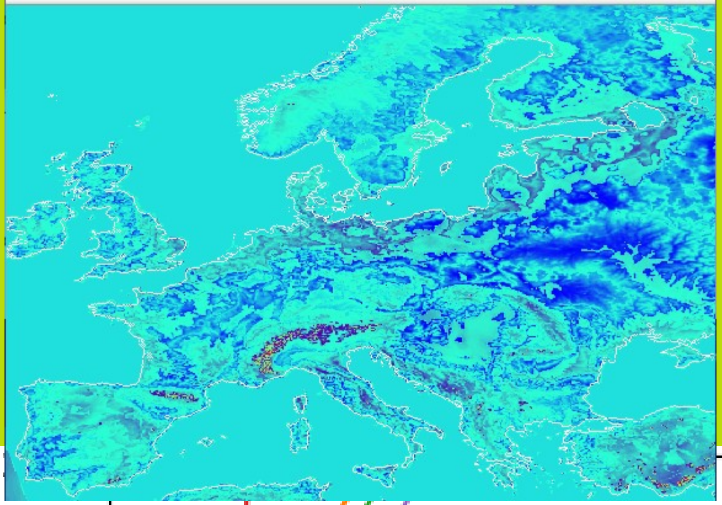
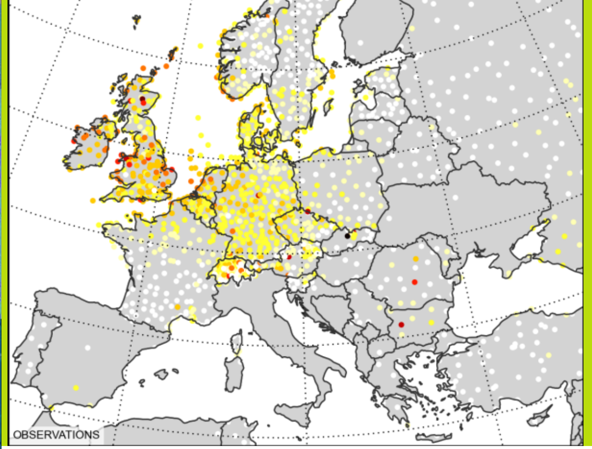
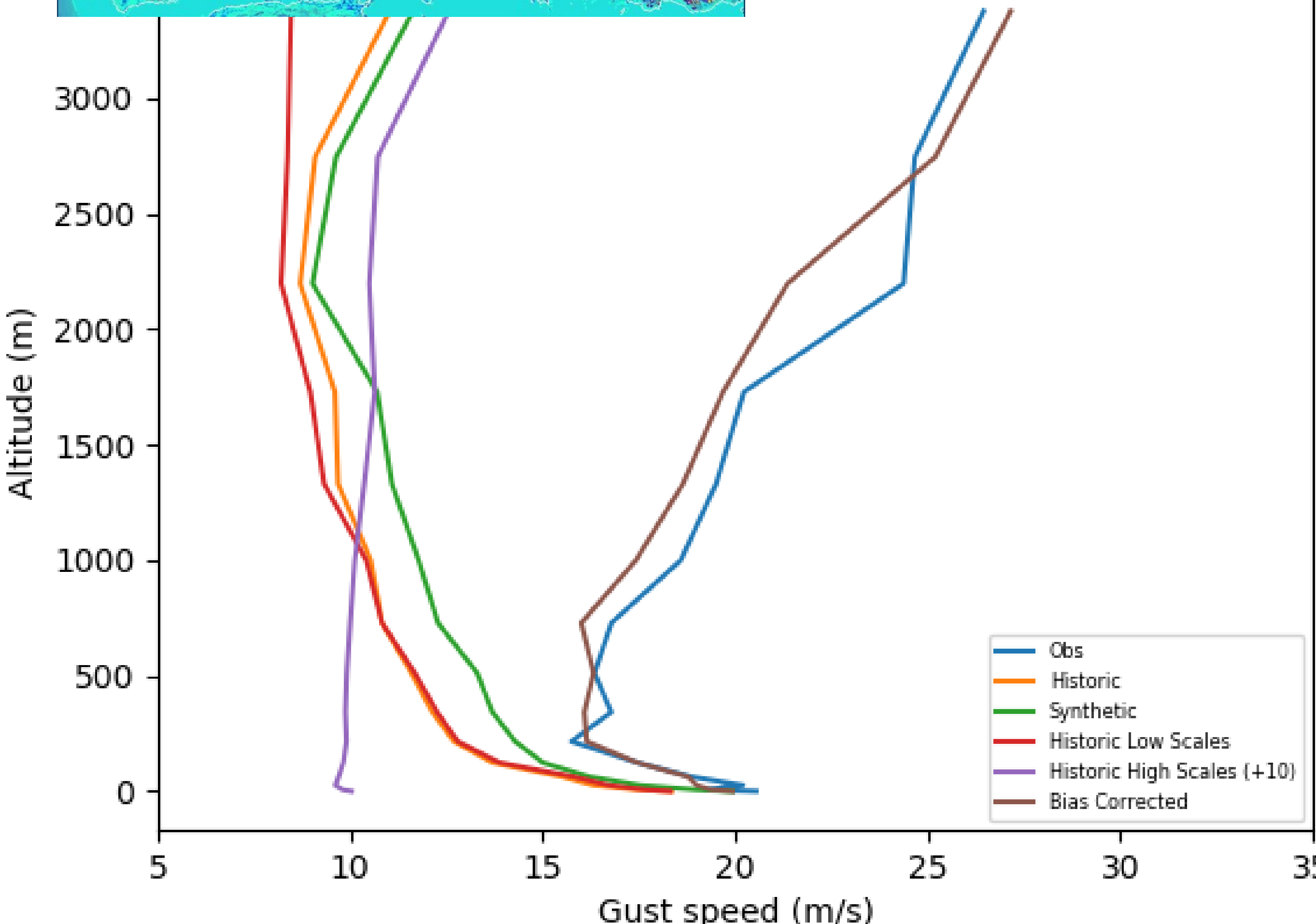
# Altitude bias correction

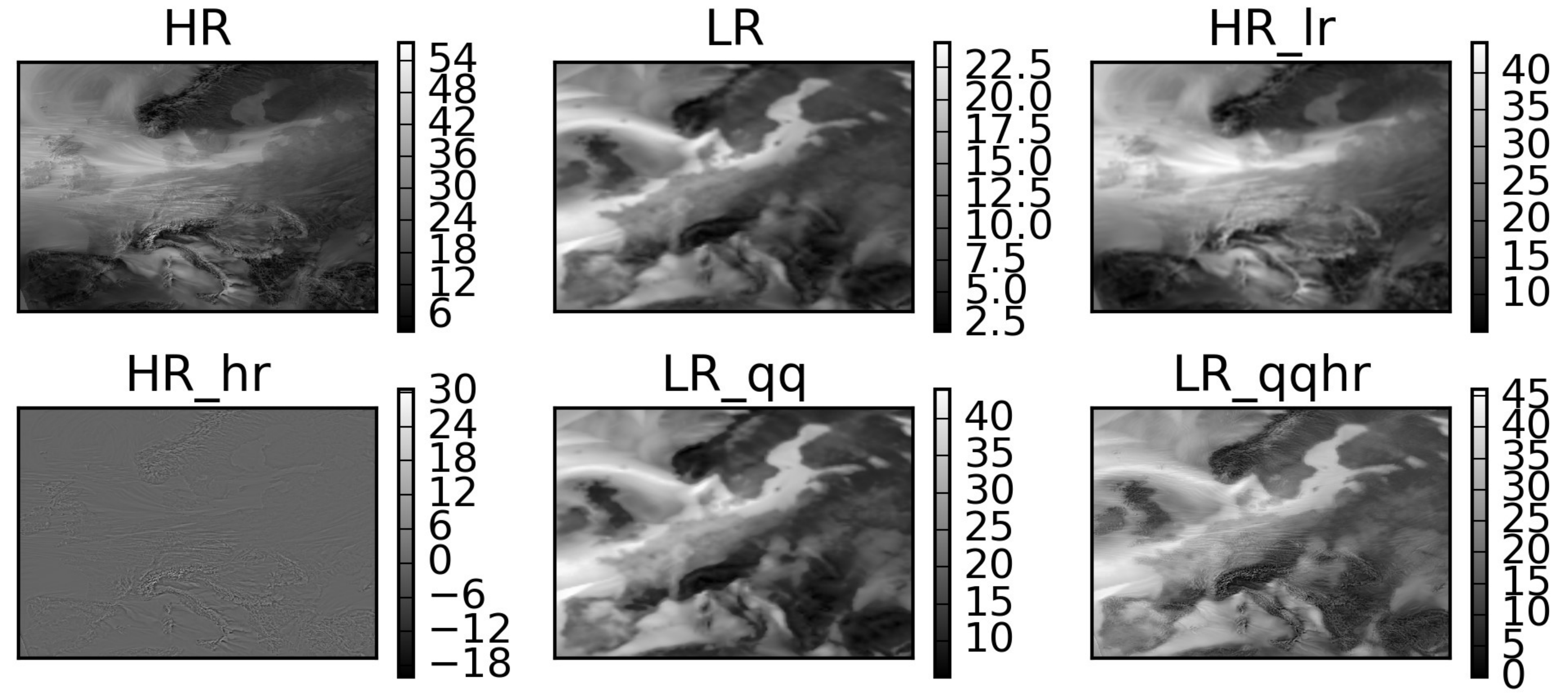




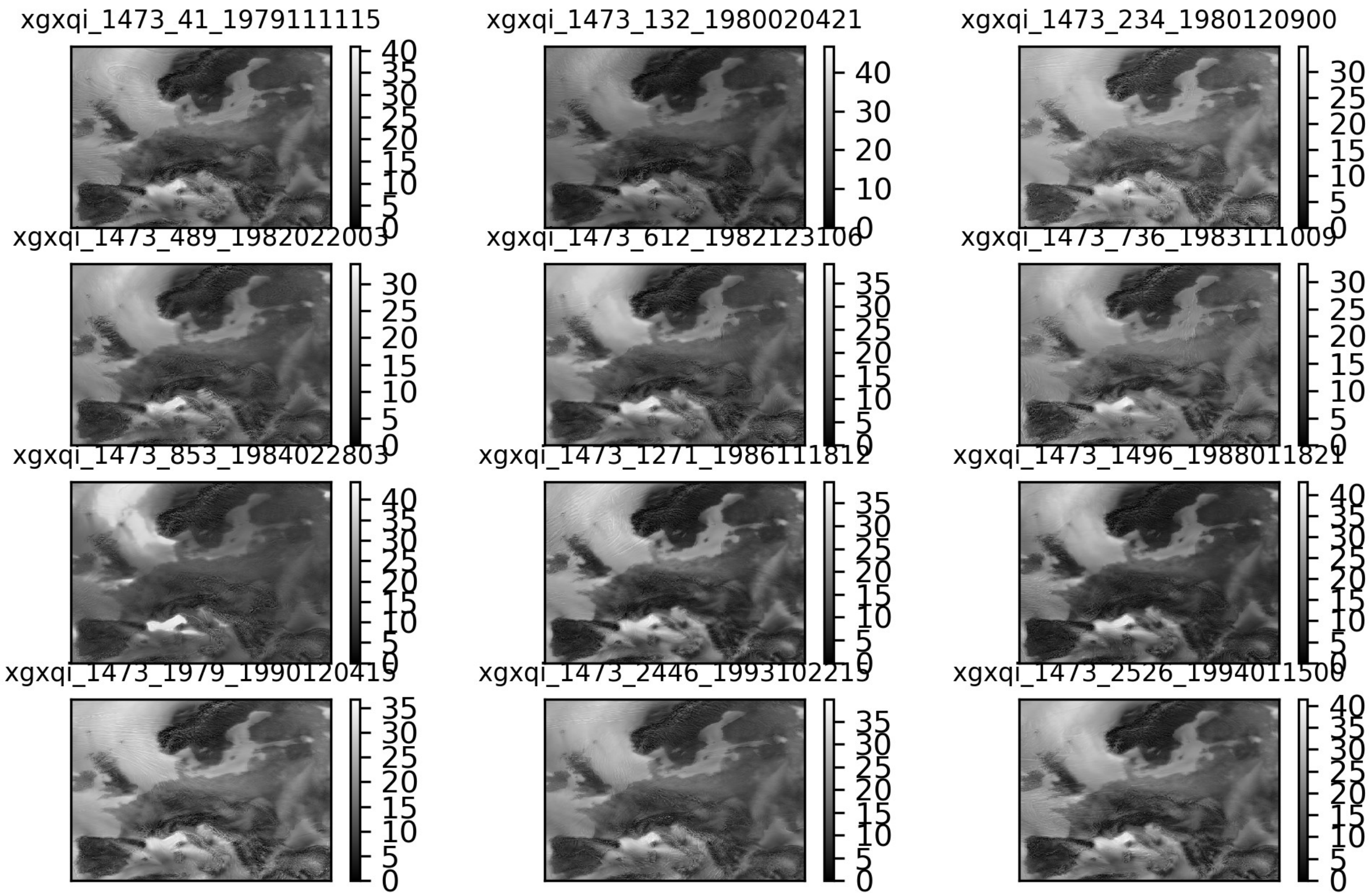

- Standing issue: too low wind gusts over complicated orography.
- UM parameterizes the turbulent form drag exerted on the flow in the boundary layer due to the unresolved sub-grid orography. This is necessary to correctly model the synoptic scale flow but has a detrimental impact on the lower level winds over complex terrain (Howard & Clark, 2007).
- Compare the wind gust profile from observations with synthetic SFPs.
- For each height slab, average all wind gusts in a set of SFPs.
- Define a gust fix factor per slab: uquot = obs_gust_profile / model_gust_profile
- udif = np.diff(uquot)
- Scale the correction factor with height, ranges from 0 at bottom to 1 at  the top.
- slab[h] = (slabtop-orographie[h])/(slabtop-slab_bot)
- hfix[h] = uquot_low+ slab[h] * udif_low
- Final gust = gust * hfix, within each height slab h
- The effect of altitude bias correction is well constrained on the high peaks, Pyrenees, Alps, western Taurus (Turkey)



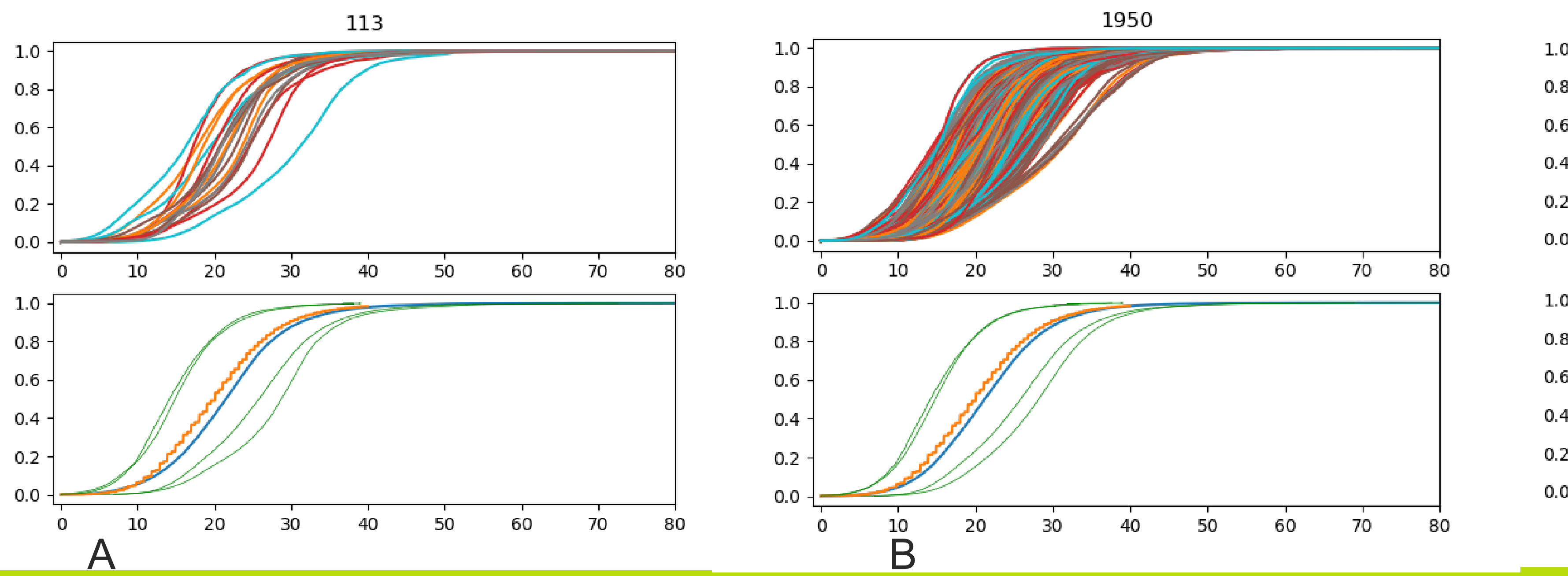
# Putting it together:



# One Upscale SFP, 12 new HR SFPs.



Do the simulated events reflect the observations?




# CDFs of subsets of the Event Set

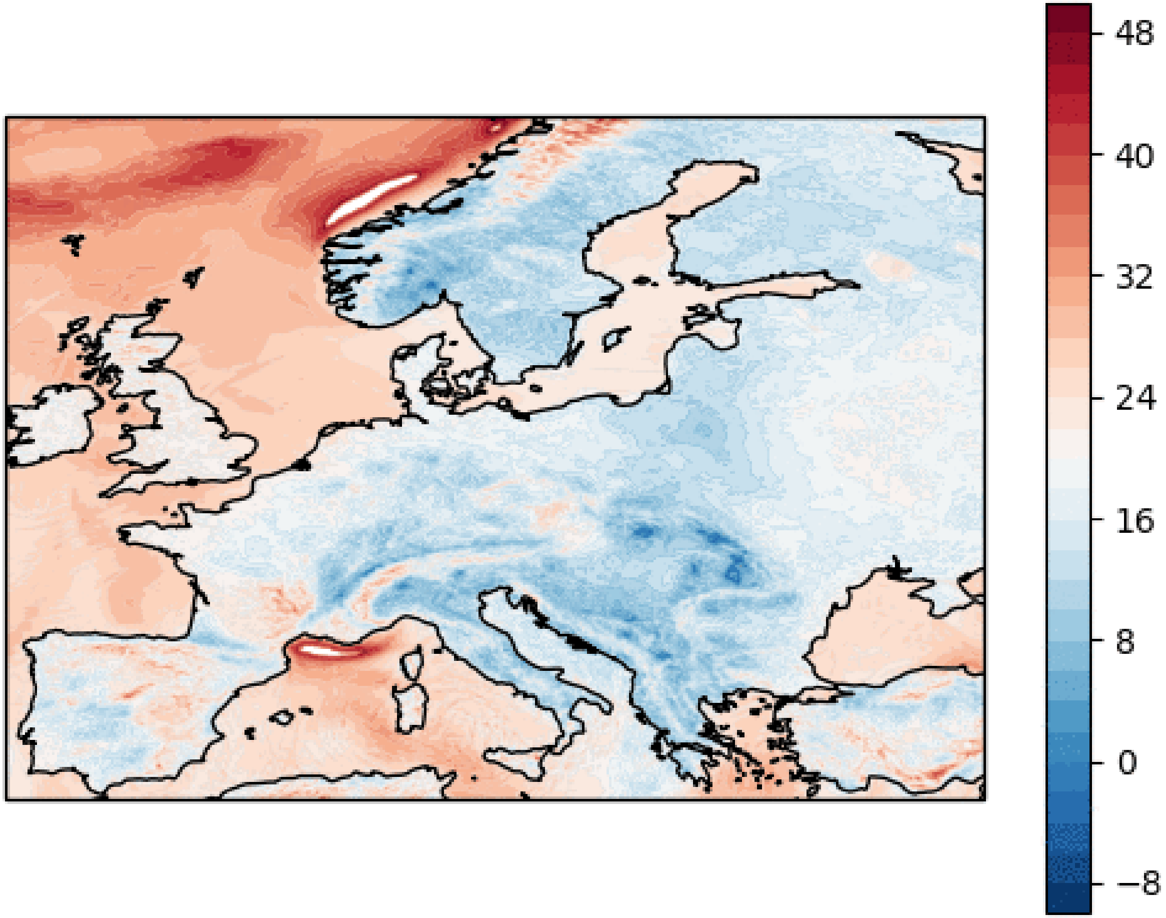
A: Plume of CDFs matching the member 0111 from all 5 upscale streams xgxq[e,f,g,h,i]_0111*.

B: Plume of CDFs matching the historical SFP 3679 from Oct. 26th 2000

C: Plume of CDFs matching observed storm from Dec. 4th 1988

Below: the mean observed CDF (orange) plus/minus 2 sigma (green) and the mean plus/minus 2 sigma of the top SFPs in this set.

# Same CDF, different storms:




148282 SFPs have been provided to AXA

And another
148282 SFPs have been provided to AXA
without height bias correction

Interesting next steps:
Rank the event set per gridpoint to derive damage curves at high spatial resolution.

# Summary: Dynamically consistent statistical downscaling (DCSD)

- Scale separation: to match similar SFPs between the unseen storms and the historical catalog but also to add the unresolved  HR scales onto the unseen dynamically consistent, plausible but low resolution SFPs.

- Pattern matching: a method to find similar storms so that we can argue, the HR scale from the historical catalogue is a plausible match to bring detail to the unseen SFPs.

- Altitude Bias correction: a method to bring the synthetic SFP to the same value range as observed, even at altitude.

Met Office

# Take home messages:

Framing a research interest into an "Event", defining the geographic and time boundaries, really helps comparing different realizations of Events.

CDFs are really useful when comparing large number sets (model fields, time series … ) with a view on risk.

Scale separation allows scale dependant attribution of cause and effect.

Observations and impacts data are vital for the communication of risk.

We will probably apply similar methods to increase resilience in other areas(IKI, Bangladesh).

Potential for more machine learning applications.

Thank you!