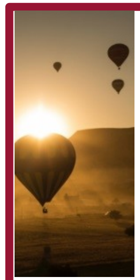
opernicus Climate Change
rvice Operational
indstorm Service -
odate and Way Forward

ropean Windstorm Workshop,
iversity of Birmingham

an Whitelaw, CGI
October 2019

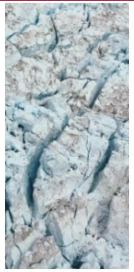
Climate Change

Copernicus Climate Change Service (C3S)



Observations

Observations are key to understanding the climate system. C3S users can access a vast variety of instrumental data records, ranging from historic weather observations to the latest measurements from space.

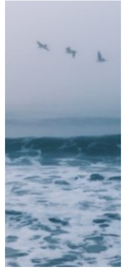


Climate reanalyses

Climate reanalyses combine past observations with models to generate consistent time series for a large set of climate variables. Reanalyses are among the most-used datasets in the geophysical sciences.

Seasonal forecasts

C3S seasonal forecasts combine outputs from several state-of-the-art seasonal prediction systems from providers in Europe and elsewhere. The latest data and products are published monthly on the Climate Data Store.



Climate projections

Projections of future climate change are available for different scenarios for concentrations of greenhouse gases and aerosols, based on outputs from multiple global and regional climate models.

Climate Data Store

Toolbox

Sectoral Information Services

Users / Stakeholders

Evaluation and Quality Control

- ***An authoritative source of climate information for Europe***
- ***Build upon massive European investments in science and technology***
- ***Enable the market for climate services***

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Operational Service Production and Access

ERA5 input data

July 2017: 2010-2016
Mar 2018: 2008-2009
Oct 2019: 1979-2018
(2020: 1950-1978)

Monthly updates provided with a delay of 2-3 months behind real time from Dec 2017 onwards

Storm tracking

Storm footprinting

Risk and loss indicator updates

Updates

Climate Data Store / portal

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User support

Data uptake and application

Outreach

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Evolution of the Operational Service

- **A Copernicus Climate Change Service (C3S) Sectoral Information Service (SIS) for Insurance**
  - **Proof of Concept** – 'WISC' – December 2015 to April 2018 CGI Lead
  - **Operational Service** – October 2018 to December 2019 KNMI Lead

- **Operational Service**
  - **Storm tracks and footprints from ERA5**:
    - New storm tracks and footprints to add to and complement those produced in WISC
    - Produced backwards in time as ERA5 is released to 1979, eventually to 1950
    - Produced forward in time for new storms as these are included in ERA5 updates
    - Tracking as used in the WISC Proof of Concept (Hodges 1995 method)
    - Statistical downscaling of storm footprints (compared to dynamic downscaling in WISC)
  - **Additional 'Tier 3' indicators** – new loss estimates
    - Updating with new storms and additional historical storms as provided in ERA5
  - **Integration of the WISC portal and data into the Climate Data Store (CDS)**
    - CDS now the main access point for WISC and Operational Storm and related Tier 3 data
    - Ease of access and integration with CDS analysis tools
  - **User engagement and on-going technical support**
  - **Consideration of expansion options for the insurance portfolio** (ie to hazards other than wind)

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Operational Approach – Tracks & Footprints

- **Storm tracks**
  - Uses same tracking method as WISC, ie Hodges (1994,1995)
  - Applied to ERA5 back to 1979 - ultimately to 1950 + new
  - Higher track threshold than WISC to give reasonable number of storms to downscale
    - 25m/s for 10m winds over land; some changes as a result:
    - Eg Kyrill falls just below at ~23m/s. Partly Land Sea Mask difference ERA-Int : ERA5
- **Storm Footprints**
  - 1979 to present storms downscaled from ERA5 using ERA5 storm tracks.
  - WISC storm tracks also footprinted to ensure all WISC storms covered in ERA5
  - Statistical downscaling used rather than dynamic downscaling for WISC (UKMO UM)
  - ERA5 native resolution is 31km with native 1 hour source
    - Data provided hourly on a 1km grid
    - Emphasis on minimizing bias and errors rather than increasing the horizontal resolution
    - ERA-20C / Interim (for WISC, downscaled to 4.4km with 3 hours interpolated from 6 hours)
  - Method runs quickly so ERA5 data can be processed on release and updated as new storms are added to the ERA5 catalogue
    - Potentially can be embedded in the CDS toolbox, but not within current project

Approach to statistical downscaling

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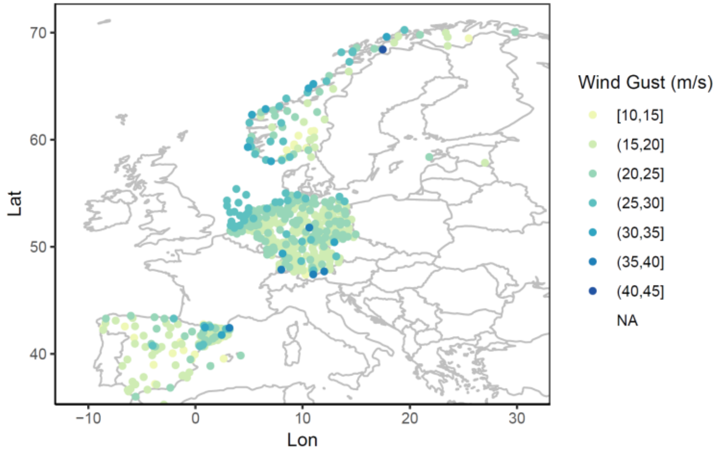
- Use of **Multiple Linear Regression (MLR)** on 17 storms
- Candidate **predictor variables:**
  - **Wind gust forecast from ERA5 (ERA5)**
    - Forecast variable
    - Shortest lead-time forecasts used
  - **Gust estimate from windshear (WgSLh)**
    - Based on turbulence theory
    - Based on difference between hourly mean wind speeds at 10m and 100m and log of ratio of heights
  - **Gust estimate based on station elevation (ELEV)**
    - Elevation is from 1km resolution DEM cell nearest to the observation station
  - Station data from ECA&D – see opposite
  - Select combination of these inputs that is most skilful predictor of the 3s gust speed at 10m, based on comparisons with station observations.
- **Potential combinations of ERA5 + WgSLh + ELEV**:
  - Output horizontal resolution is 1km, but the scales effectively resolved are larger
  - Results shown in next slides.

Station data from European Climate Assessment and Dataset (ECA&D)
Locations and gust maxima shown below

Country	Number of stations
Estonia	2
Netherlands	62
Norway	94
Spain	149
Germany	236



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Model training and cross validation

- **Training / Cross-validation** part of the data set used for the statistical model (training), while an independent part is used for validating predictions from the statistical model
- Compare model skill using cross-validation in time and space.
- **Time**:
  - Use "18-fold cross-validation" over time.
  - From complete data set (18 years of data x 6-months per year), leave out one 'test' year (e.g. 2018), and train the model on the remaining 17 years (e.g. 2000-2017).
  - Make predictions for the independent year that has not been used to train the model (e.g. 2018).
  - Do this 18 times, so each year is left out of training sample and used as independent test data once.
- **Space**:
  - Within the 18-fold cross-validation, leave out 30 random subsets of stations.
  - Each random subset comprises 10% of the total number of stations – called 'test stations'.
  - Independent test data comprises predictions for the 'test stations' in each of the 18 'test years'.
  - 30 independent test data sets (one for each random subset of stations).
  - Method allows verification of skill of statistical model using independent data (years and stations).
- Calculate **RMSE and bias** for each of the above for each of the combinations to be assessed.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(p_i - o_i)^2} \qquad Bias = \frac{1}{n}\sum_{i=1}^{n}(p_i - o_i)$$

p – predicted by statistical model *o – observed at station*

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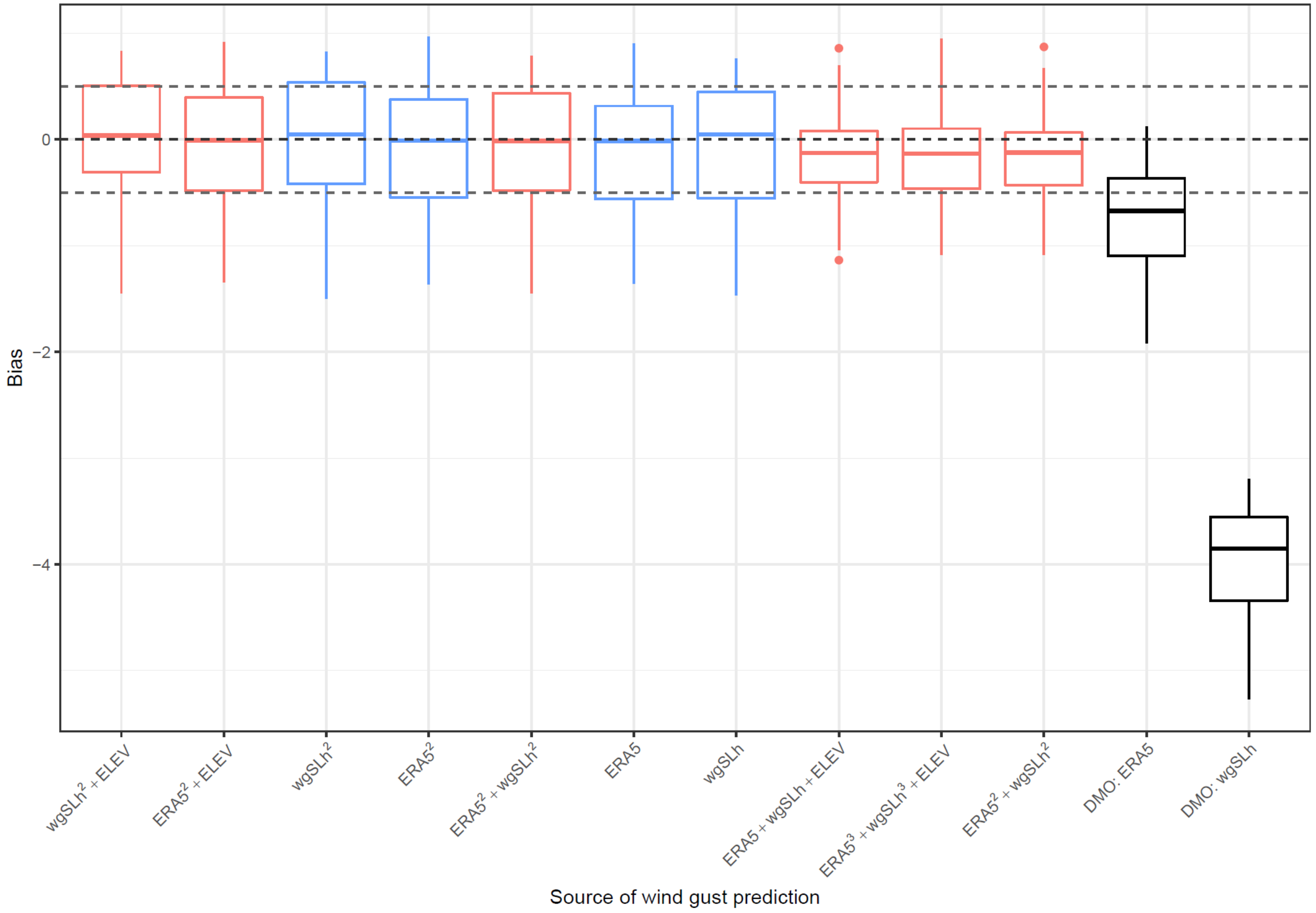
Bias assessment



Bias (m/s) of direct (black) and regression based (colours) wind gust estimates, calculated over all ‘test years’.

Ordered left to right from highest to lowest bias, over all ‘test stations’

Box plots show median value (horizontal line), the 25th and 75th quantiles (the bottom and top of the box) and 1.5 times the interquartile range (whiskers) in the bias over 30 independent test data sets

Colours indicate the type of wind gust estimate:

- black = direct model output (DMO)
- blue = linear regression
- Red = multiple linear regression.

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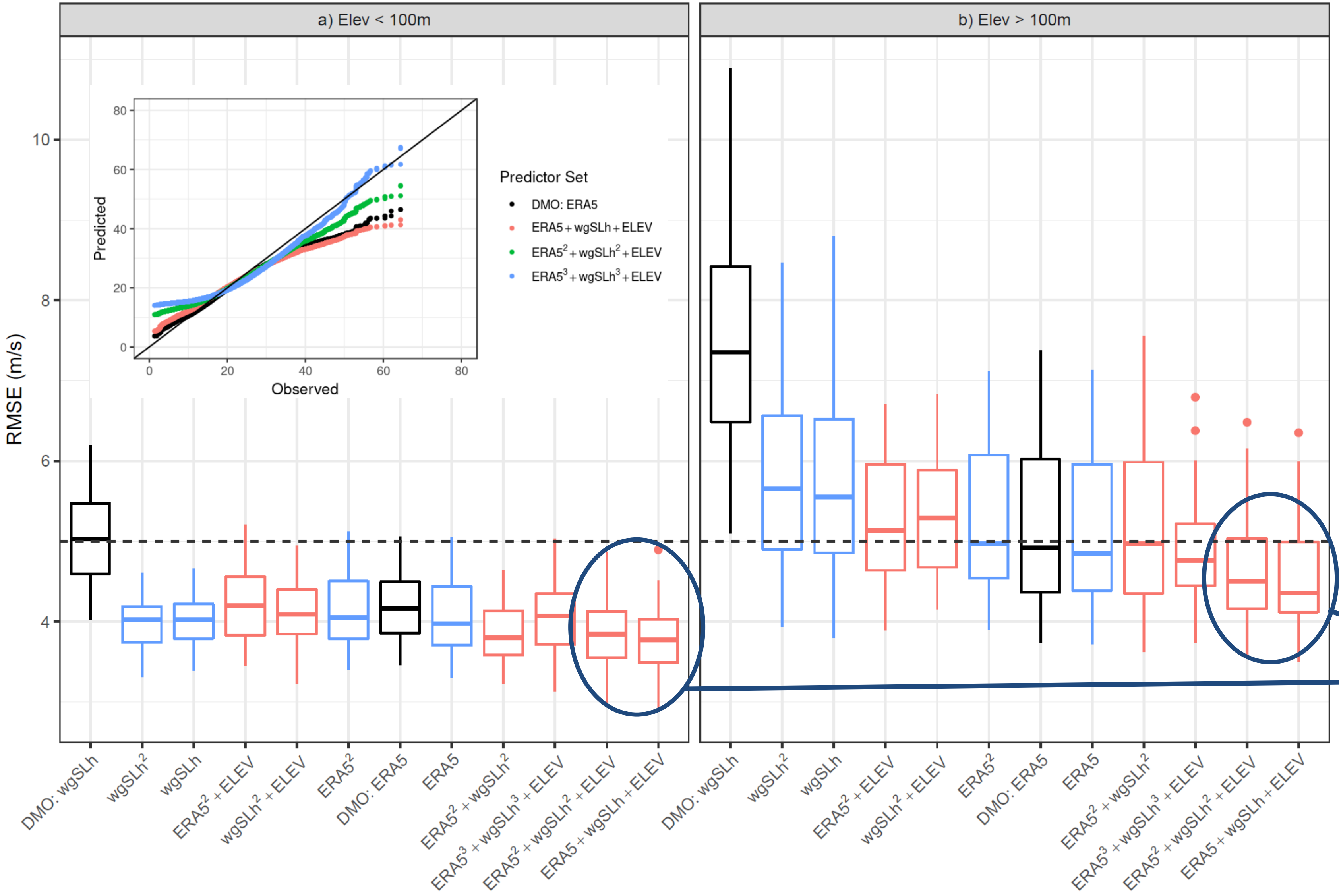
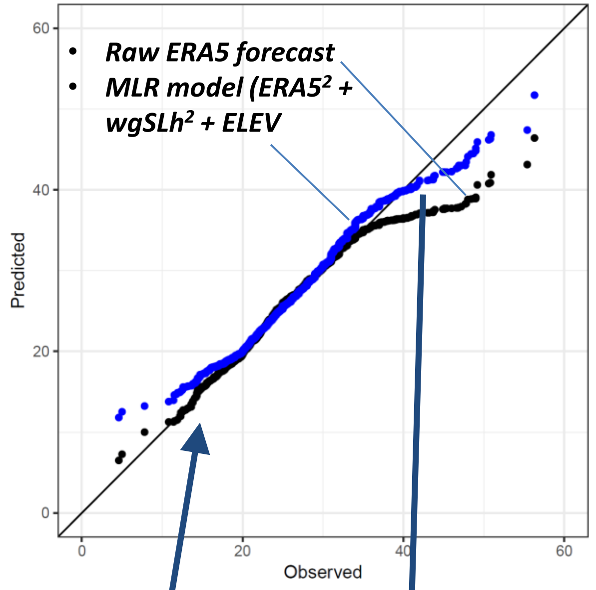
Gust representation combinations





Power law closer to extremes: $ERA5^2+wgSLh^2+ELEV$

Most skilful & <5m/s for all elevations

Fitting to all available data for final estimates

$$Wind\ Gust = 10.3 + 0.0112 * ERA5^2 + 0.0148 * wgSLh^2 + 0.00355 * ELEV$$

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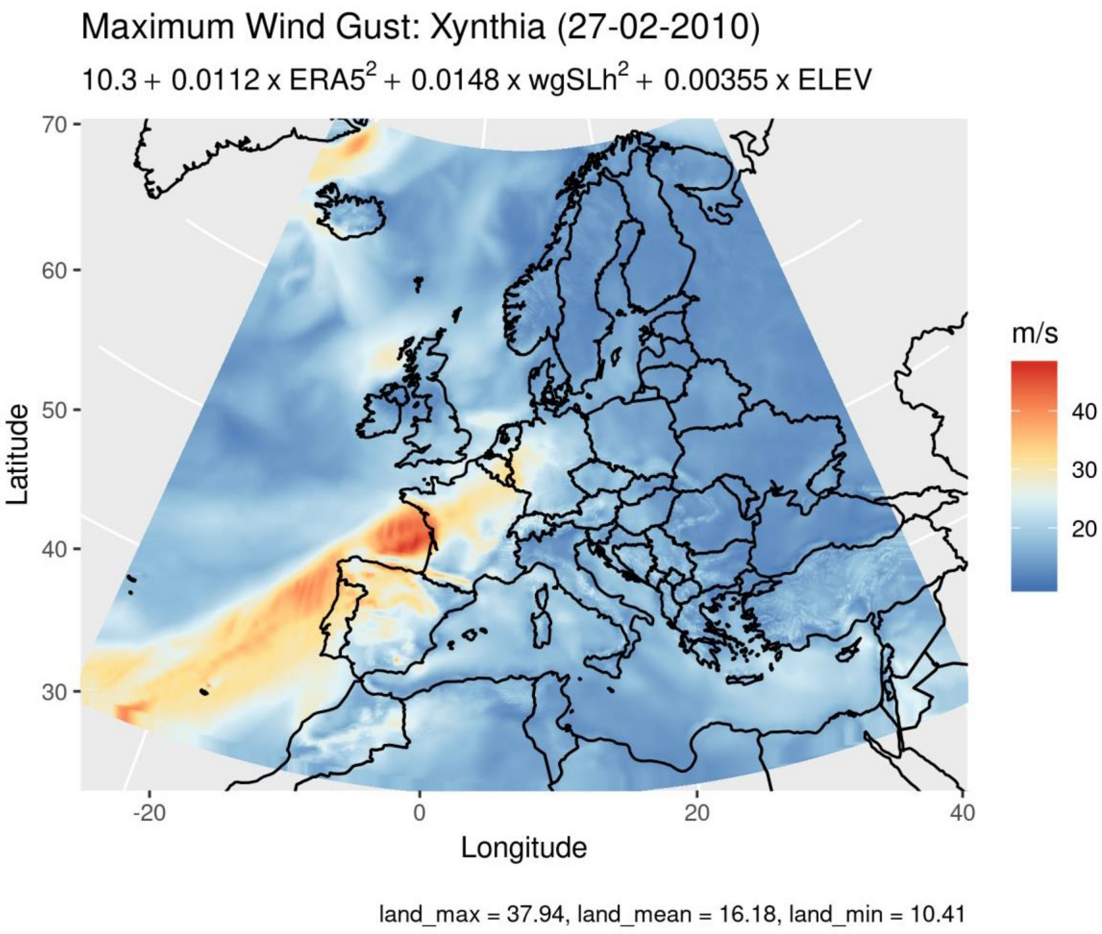
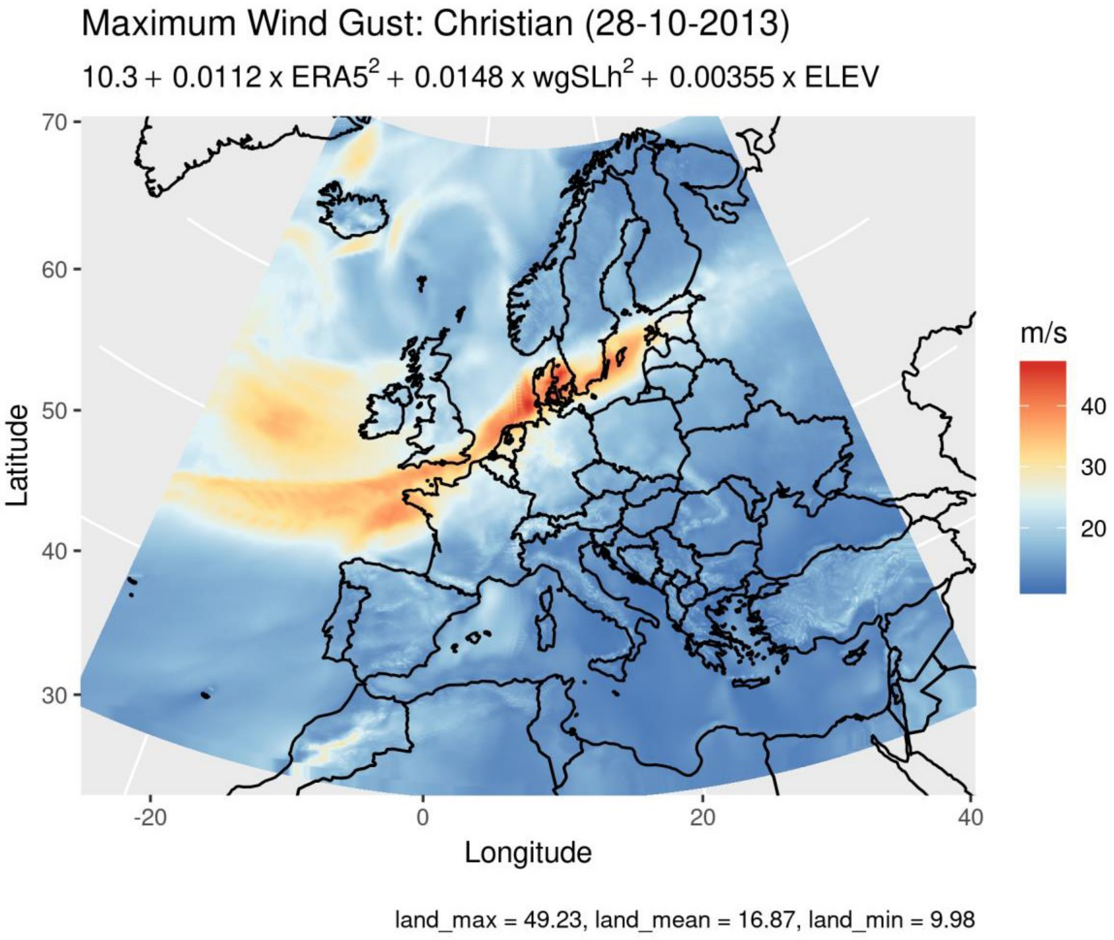
Example footprints (Xynthia / Christian)

Using relationship established on previous slide, footprints generated for key storms (same storms as dynamically downscaled in WISC). Examples shown below.





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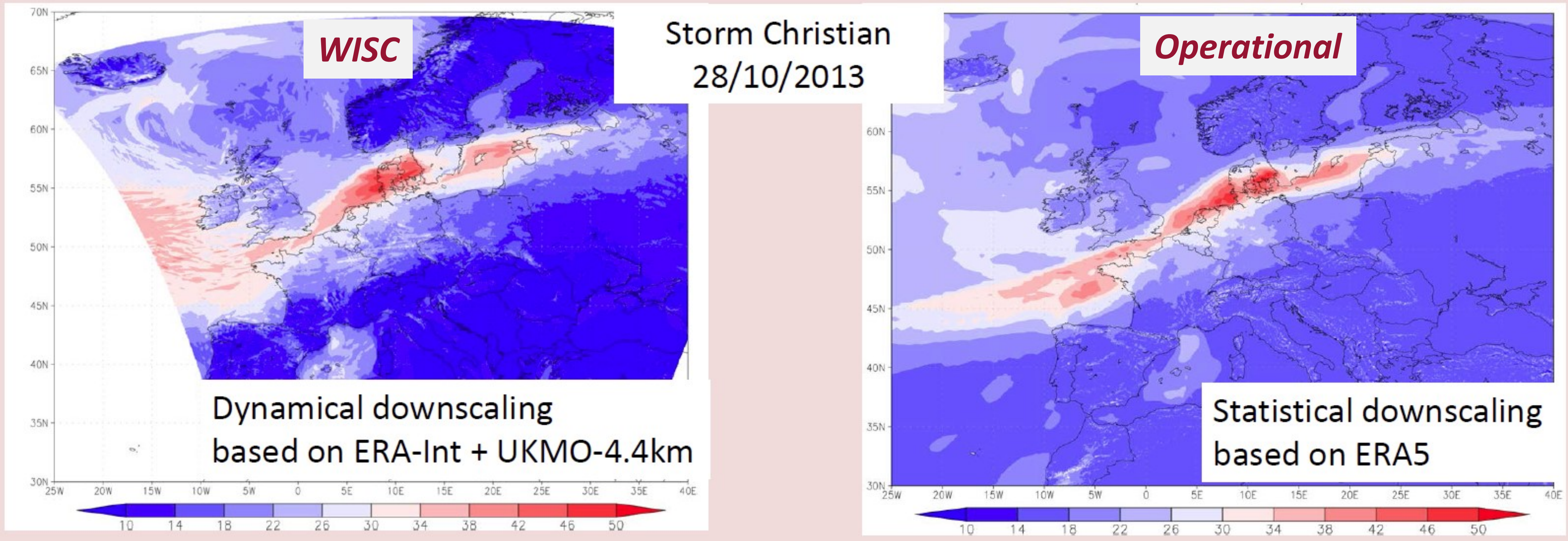
Footprint comparison for Storm Christian

Outcomes for Operational statistical approach vs WISC Dynamically Downscaled from ERA-Interim:

- Approach yields stronger gusts in the area of interest, closer to dynamic extremes with orographic effects more pronounced cf Norway.
- Approach better represents extreme gusts and hence better input for damage calculations, but possibly at the expense of worse overall statistics.



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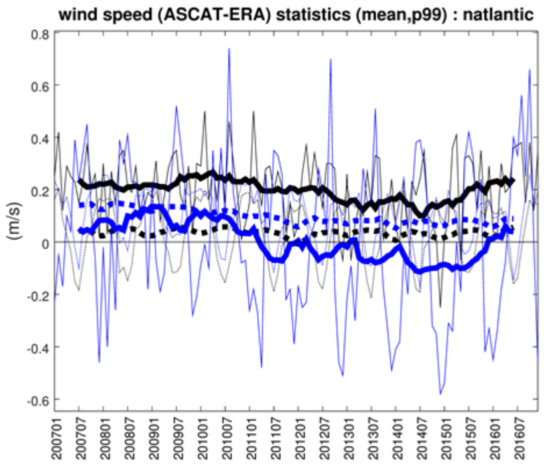
Validation of ERA5 winds with Scatterometer

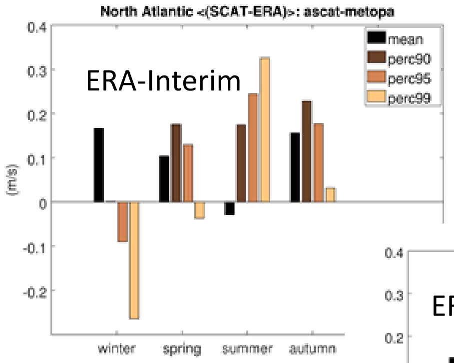
Assessment

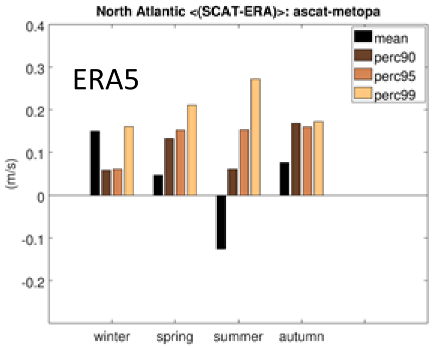
- ERA5 10-m winds over ocean more realistic than ERA-Interim
  - ERA-Interim 10-m winds appear too strong especially for the strongest winds
  - ERA5 simulated winds generally very close to ASCAT observations
    - Positive bias (observations > model) of about 0.15 m/s over the North Atlantic for mean winds and the strongest 1% winds in the winter period
    - Positive bias expected given higher resolution of ASCAT coastal product (12.5 km) compared to simulated winds and limited spatial extent of wind maxima
- Other assessments
  - Belmonte et al. (2018) extended comparisons of ERA-Interim, ERA5 and ASCAT suggests an explanation in seasonal variability in the extremes of ERA-Interim and the overestimation of winter storm maxima
  - Although errors are reduced for ERA5 and the operational ECMWF model, they are still expected to affect downscaling of winds in limited areas
  - Mean monthly winter biases ~ 0.15 m/s of the highest percentile (99%)

Conclusions

- ERA5 10-m winds found in better agreement with scatterometer winds, which confirms their use in statistical downscaling method to generate storm footprints (van den Brink and Whan, 2018) for the C3S windstorm service
- Noted that ASCAT is assimilated in ERA5, but not in ERA-Interim







Mean 10-year statistics of observation-minus-model for 10-m winds observed by ASCAT vs ERA-Interim and ERA5 - Northern Atlantic region only and discriminated between the seasons

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Operational Vulnerability and Loss Data

Operational ERA5 based storm footprints

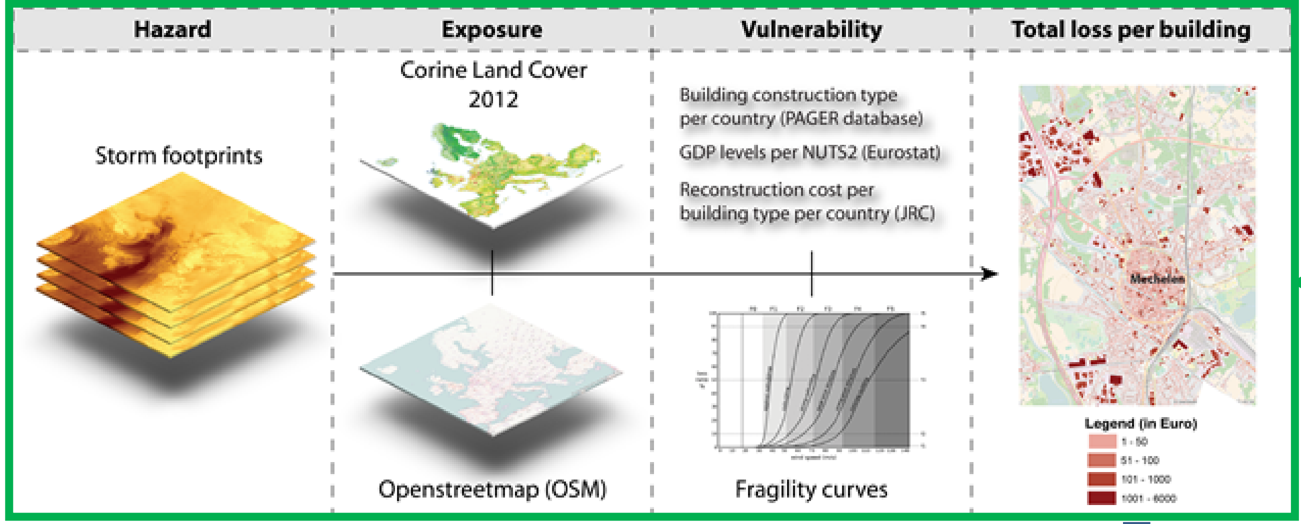
Approach as for WISC but updated and maintained with new ERA5 storm footprints

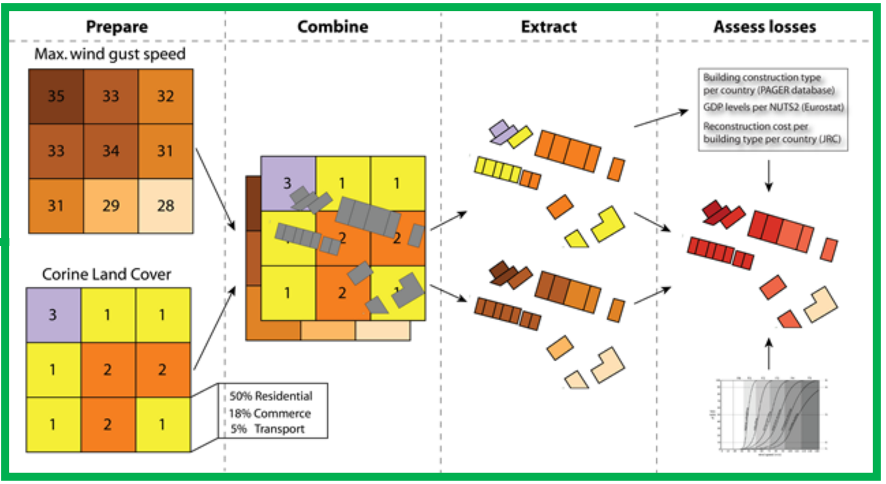
Exposure / Vulnerability

- CORINE – 45 land classes
- PAGER – 106 construction types – aggregated to 6 types
- Fragility curves applied for these 6 types
- Fragility to vulnerability curves via reconstruction costs
- GDP per NUTS3 region applied

Process for Loss Assessment

- Datasets clipped to NUTS3 regions before loss calculations applied
- Loss per hazard (max gust speed) from fragility curves
- Loss ratio multiplied by reconstruction cost per building type
- Losses adjusted by GDP per region
- Validate losses vs actuals





Revised risk and loss estimates

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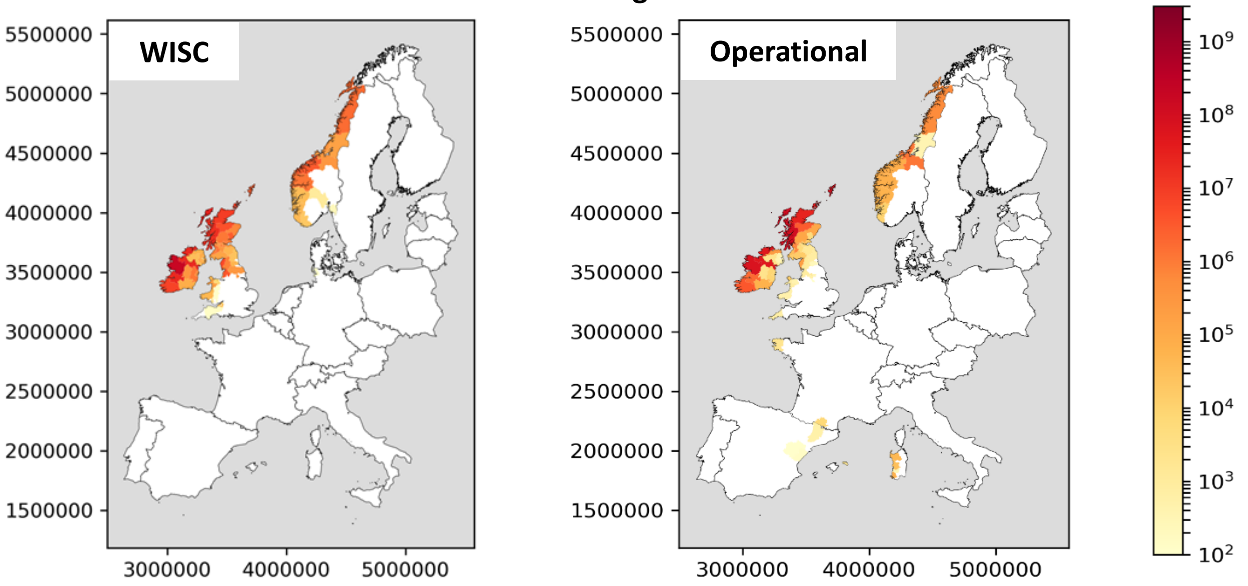
Tier 3 Losses - Sensitivity to footprints

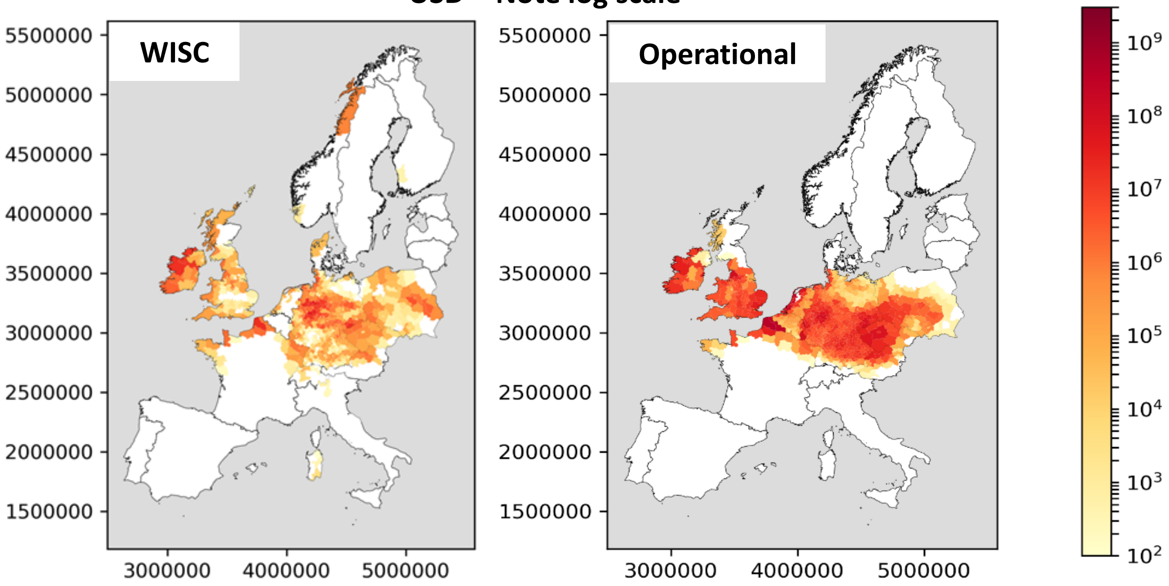
USD – Note log scale



Storm Gero, January 2005

- Over Scotland, up to 57m/s. After Ireland and UK, it crossed Scandinavia, with highest wind speeds on the Norwegian coast
- Small differences in regions affected can be seen in Norway and UK, but overall the spread is similar.
- Different from the WISC footprint, the Operational footprint also led to some damages elsewhere in Europe, but minor, likely as a result of local conditions.
- Overall, the Operational footprints led to slightly higher loss estimates in most regions.

USD – Note log scale



Storm Kyrill, January 2007

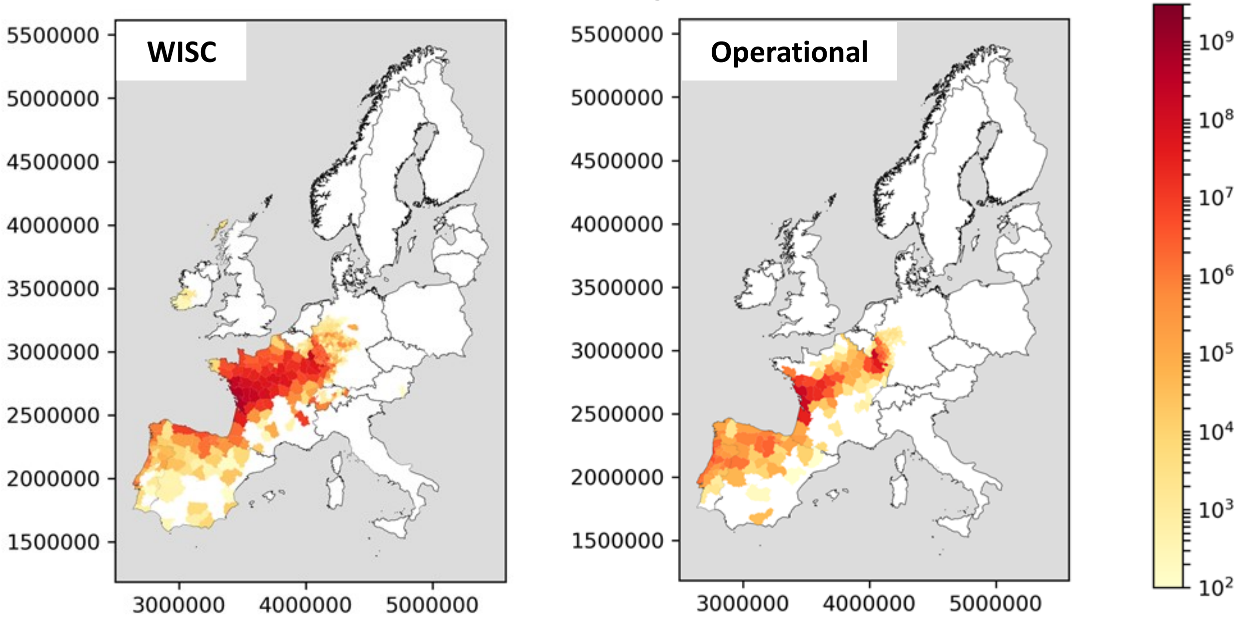
- Kyrill crossed Ireland, UK, Central Europe before moving over eastern Europe towards Russian federation
- Norway, Denmark, Switzerland, and other sustain minor losses with WISC footprints but unaffected when using Operational footprints.
- Regions in Netherlands and Belgium unaffected in WISC footprints are affected in the Operational footprints.
- Ireland, Southern UK, west coast of Netherlands, Germany, and Poland all face higher losses with Operational footprints as a direct result of higher wind gust estimates compared to WISC

Tier 3 Losses - Sensitivity to footprints

Storm Xynthia, February 2010.

- Xynthia developed close to Madeira, and moved towards the coast of Portugal across France towards Germany resulting in 51 dead and 12 missing.
- Portugal, Spain and Southern France show matching patterns
- Main differences are NW coast of France where WISC footprints show losses but Operational footprints do not.
- More regions are affected in Belgium and Germany with WISC than Operational footprints. As with all results, this is directly related to differences in windspeed.
- Especially in France, we see that the WISC footprints result in significant higher losses

USD – Note log scale



General Comparison

Storm	WISC	STATDOWN	XWS
Oratio (2000-10)	1.3	3.4	-
Jan 02 (2002-01)	0.8	1.4	-
Jeanette (2002-10)	1.4	2.5	-
Erwin (Gudrun) (2005-01)	3.1	6.8	2.2
Gero (2005-01)	0.3	0.5	0.6
Kyrill (2007-01-18)	0.5	6.8	6.7
Feb 2008 (2008-02)	0.2	0.0	-
Emma (2008-03)	0.1	0.2	1.4
Klaus (2009-01)	2.5	3.2	3.5
Feb 09 (2009-02)	3.6	0.2	-
Xynthia (2010-02)	2.9	0.7	2.9

Storm	WISC	STATDOWN	XWS
Dec 11 (2011-12)	1.2	2.1	-
Dagmar (2011-12)	0.1	0.4	0.04
Dec 2011 (2011-12)	0.1	0.0	-
Ulli (2012-01)	0.3	0.5	0.2
Christian (2013-10)	2.4	1.3	1.3
Xaver* (2013-12)	1.7	1.3	0.9

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WISC Products – Existing Data Access

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WISC HOME PRODUCTS EXPLORE USER GUIDANCE ACCOUNT HELP C3S

PROOF OF CONCEPT

WISC products

home > Products

The WISC project has generated a range of windstorm products tailored for the insurance sector. This page describes the nature of these products, including methodology, format and provides access. The WISC products include:

- Storm Tracks
- Operational Storm Tracks
- Storm Footprints
- Operational Storm Footprints (1979 to 2016)
- Synthetic Event Set
- Tier 1 Indicators
- Operational Tier 1 Indicators
- Tier 3 Indicators
- Case Studies

New, Operational data

Extreme Windstorms

As with the predecessor project (Extreme Windstorms Catalogue [XWS]), WISC focuses on monitoring windstorms that have hit Europe. Most of the damaging windstorms in Europe are Extra Tropical Cyclones (ETC): synoptic-scale (~1000 km) low pressure systems, which grow from unstable frontal waves (Eady 1949, Shapiro & Keyser 1990). In order for these systems to grow, a strong north-south temperature gradient is needed, and a strongly baroclinic atmosphere. During the months October to March the North Atlantic Ocean satisfies these conditions, allowing extra-tropical cyclones to form (cyclogenesis) which travel eastwards towards Europe.

The path that these storms follow (storm track) tends to curve northwards (Hoskins & Hodges 2002), and so Iceland and northern European countries (e.g. the Faroe Islands, Ireland, the UK, and Scandinavia) are frequently hit. However, occasionally the storms can travel further southwards, for example when the jet stream is in a more southerly position (e.g. Liberato et al., 2013), affecting countries such as France, Germany, Portugal, and Spain.

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C3S Service Desk

FIND WHAT YOU NEED

WISC Tutorials & Documents

WISC Products Explained

C3S Knowledge Base

READ MORE

More about WISC

Existing WISC portal used at present pending finalisation of a unified cross CDS portal to cover SIS projects

Example for Event Set

Data Access

The full event set is approximately 45GB, which is considered too large for regular download as a single file. It is therefore provided as a collection of smaller files, which can be downloaded from the links below. The summary csv files provide maximum gust, mean gust and storm severity index (SSI) for each footprint. the .zip files contain the individual netCDF footprints for the three sub-datasets as described in the revised Event Set Description Document.

Summary files

Containing maximum gust, mean gust and storm severity index (SSI) for each synthetic event:

- eventset_v1.2_summary.csv
- eventset_v2_summary.csv
- eventset_v3_summary.csv

Original WISC synthetic Event Set

- calibrated_v1_0001_to_1600.zip
- calibrated_v1_1601_to_3200.zip
- calibrated_v1_3201_to_4800.zip
- calibrated_v1_4801_to_6400.zip
- calibrated_v1_6401_to_7660.zip

WISC Synthetic Event Set 2

- calibrated_v2_0001_to_1600.zip
- calibrated_v2_1601_to_3200.zip
- calibrated_v2_3201_to_4800.zip
- calibrated_v2_4801_to_6400.zip
- calibrated_v2_6401_to_7660.zip

WISC Synthetic Event Set 3

- calibrated_v3_0001_to_1600.zip
- calibrated_v3_1601_to_3200.zip
- calibrated_v3_3201_to_4800.zip
- calibrated_v3_4801_to_6400.zip
- calibrated_v3_6401_to_7660.zip

https://wisc.climate.copernicus.eu/wisc/#/help/products

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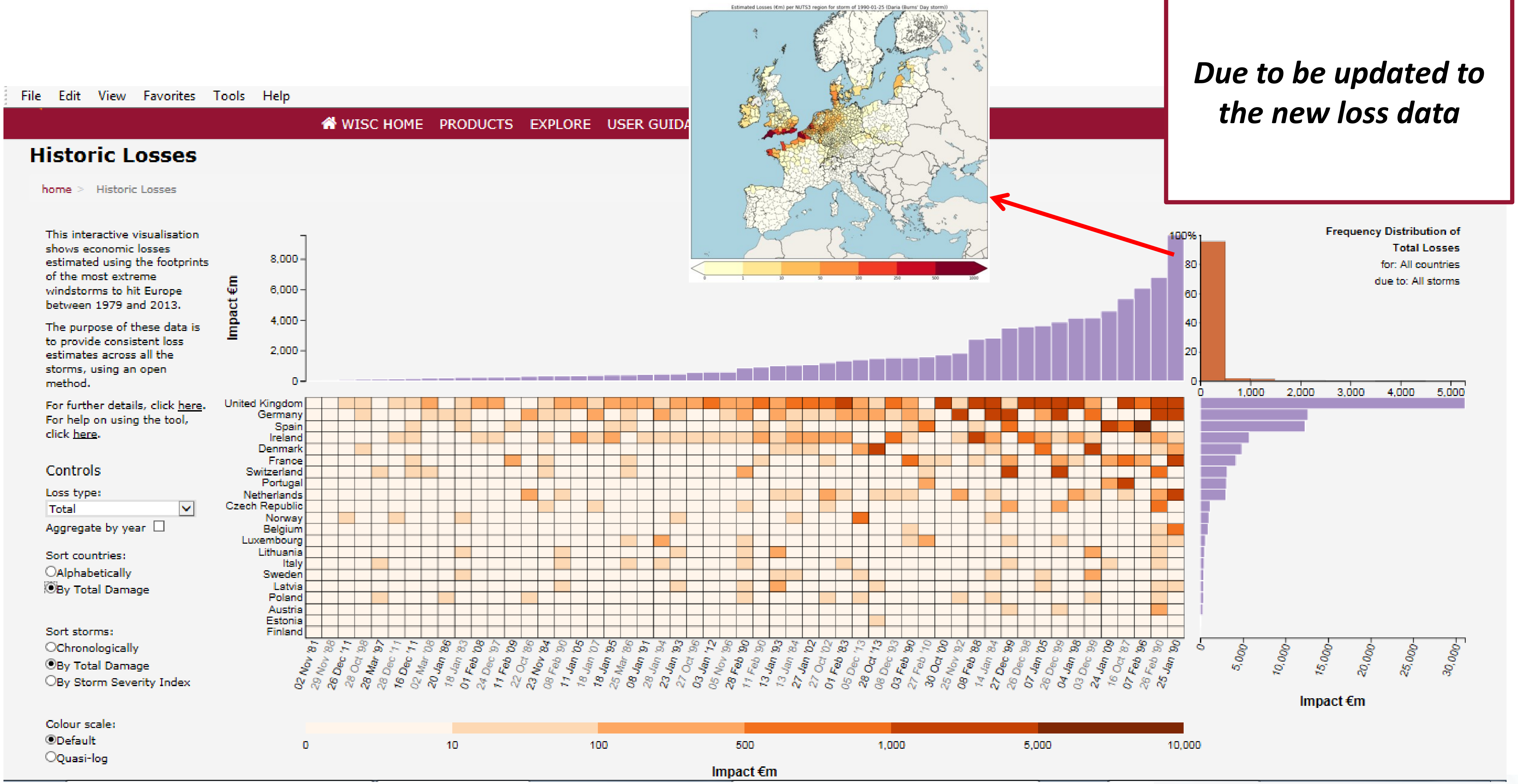
WISC Tier 3 – Risk and Loss overview

Due to be updated to the new loss data



Updated with new ERA5 footprint data; Basic 'building block' data still available

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Way forward

- Potential next steps:
  - Inclusion of the downscaling method in the CDS toolbox
  - Tracking and downscaling of the remainder of the ERA5 storm dataset
    - 1950 to 1979
    - Rapid updates as new storms occur
  - Possible update to the synthetic event set
  - Maintaining loss data based on updated storm footprints
  - Consideration of windstorm effects other than from ETCs, eg convection

For more information, please contact: alan.whitelaw@cgi.com
For documents and data downloads: https://wisc.climate.copernicus.eu

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Workshop – 9th December, Fenchurch St, London

- **Workshop arranged on 9th December**
- Aimed primarily at Insurance and related users
- Aims:
  - Present the C3S Windstorm data in more detail
  - Respond to questions / issues
  - Consider possible next steps / priorities within the C3S programme
  - EQC presentation and CDS demonstration
- Morning, with Lunch and informal follow ups afterwards
- Location: **CGI, 14th Floor, 20 Fenchurch Street, London EC3M 3BY**
- Open invitation - free to attend

To sign up, please contact: alan.whitelaw@cgi.com

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