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Modelling serial clustering of European winter windstorms

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Contents

Contents

Serial Clustering of annual windstorm counts

- Key component in understanding inter-annual variability of windstorms

  → *Year to year variability*

- Common statistical definition:

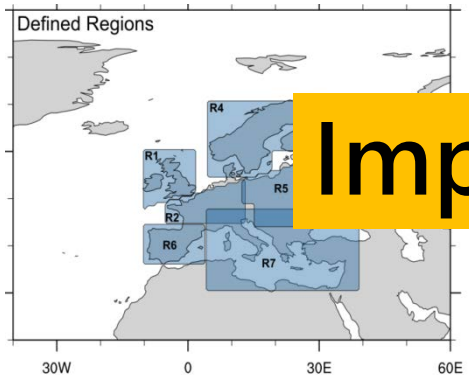
  → *Deviation of windstorm count time series from a Poisson distribution*

- How well is a statistical model able to reproduce serial clustering?

  → *Application in the actuarial industry*

Motivation

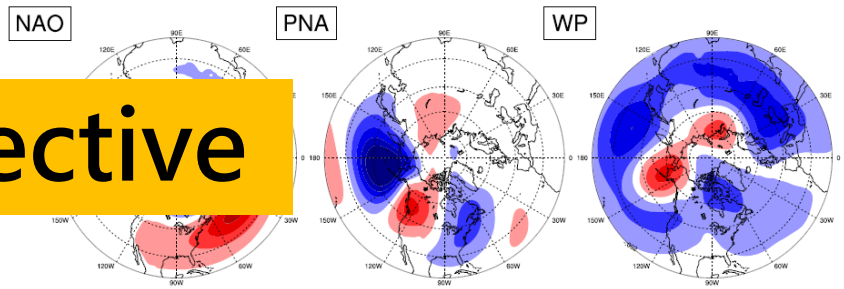
- Trying to answer <u>two questions</u>:



For a particular ***region***, what are the essential

Impact perspective

Statistical model



+ SSTs, QBO…

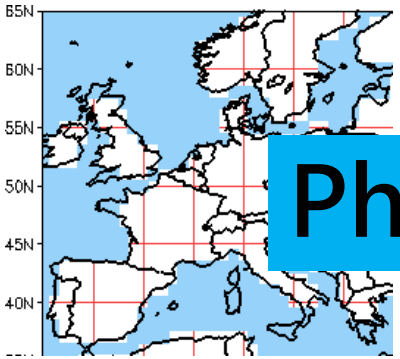
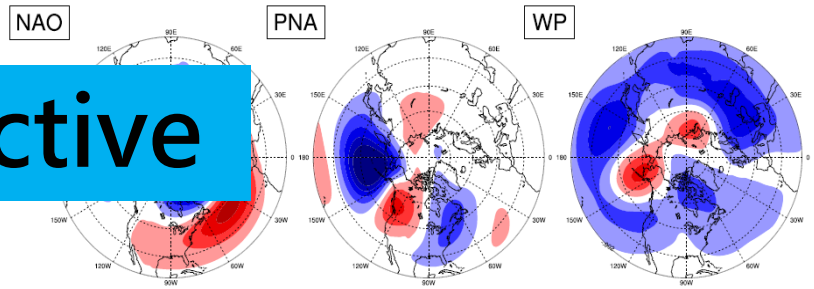


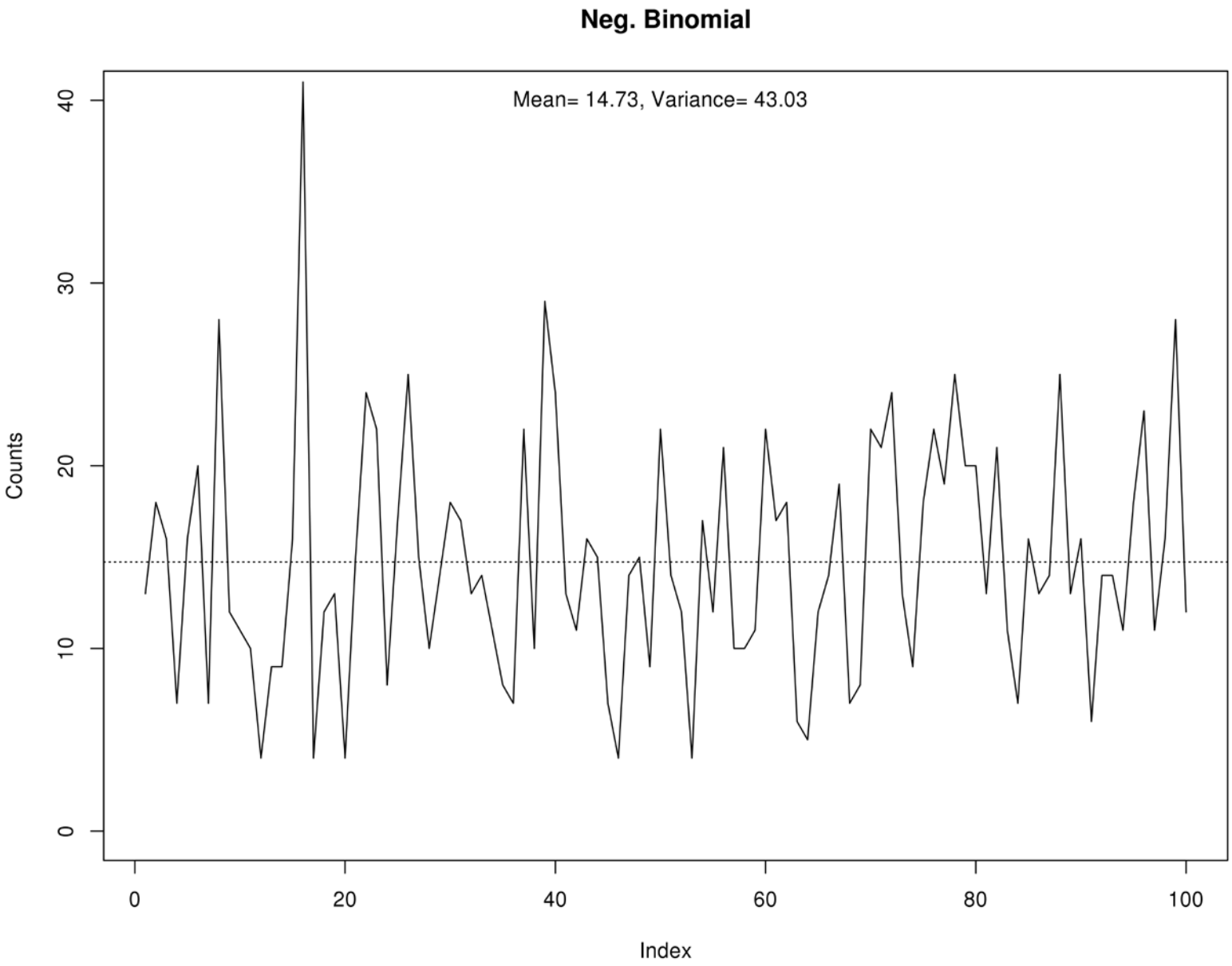
Image: Courtesy of NOAA

Where is the ***main area of action*** for the leading large scale drivers with regard to

Physical perspective

level? → ***Map of drivers***




Neg. Binomial
Mean= 14.73, Variance= 43.03
Counts
Index
0
10
20
30
40
0
20
40
60
80
100

al
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ries

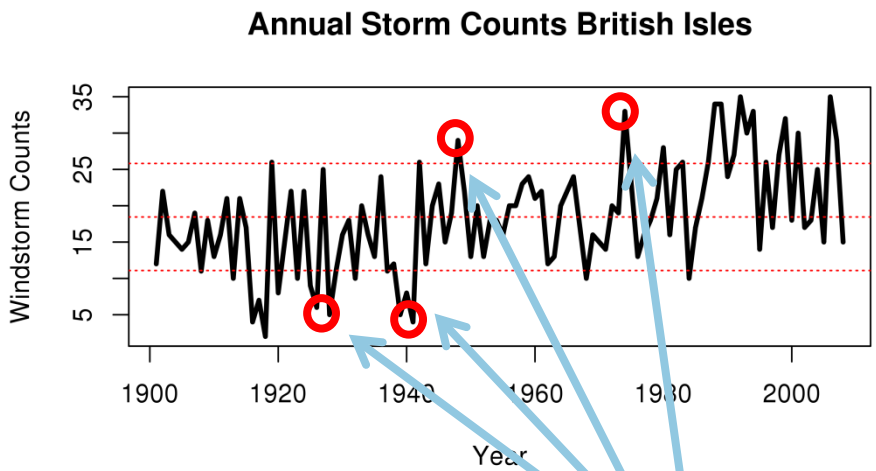
Contents

Windstorms and large scale drivers

- Objective windstorm tracking algorithm (Kruschke, 2015 and Leckebusch et al. 2008)
- Based on exceedance of 98th percentile
- Tracked in ECMWF ERA 20C (1901-2008)
- Counts per DJF per region
- All drivers were computed using ERA 20C except for QBO (Broennimann et al. 2007)

Modelling serial clustering

Inter-annual variability for a region



1.Serial Clustering statistic D

2.Active/Inactive season (AS/IAS)

$\mu_r \pm \sigma_r$

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Regions and drivers: Clustering model

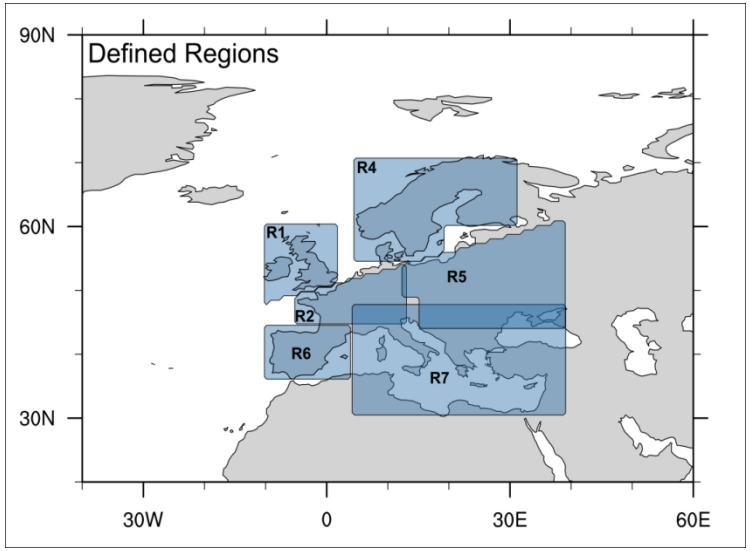

Figure: Regions for the 7 different models
Walz et al., 2017 submitted to IJOC

Index Name	Long name
QBO30	Quasi-Biennial Oscillation (30 hPa)
QBO70	Quasi-Biennial Oscillation (70 hPa)
AMO	Atlantic Meridional Oscillation
HIS	Horse-Shoe-Index
SSTS	Southern Box of HSI
Tdif.Nam	Temperature difference North America – West Atlantic
W.Atl T	West Atlantic SST
NINO3.4	Nino 3.4 index
NAO.Is.Li	Station Based NAO index
PDO	Pacific Decadal Oscillation
West Pac	West Pacific Pattern (EOF)
PNA	Pacific-North American pattern (EOF)
EOF10	West Pacific pattern II (EOF)
EA.WR	East Atlantic/West Russia pattern (EOF)
EA	East Atlantic pattern (EOF)
SCA	Scandinavian Pattern (EOF)
TNH	Tropical Northern hemisphere (EOF)
EP.NP	East Pacific/North Pacific pattern (EOF)
POL	Polar index (POL)
Sea Ice	Northern Hemispheric sea ice cover

- 7 Regions based on *insurance related regions*
- Potential pool of 20 large-scale drivers

Poisson GLM: European regions

- *Stepwise AIC approach* for driver selection for every region
- χ^2 *–test* to test for significance of drivers
- Poisson GLM:

Annual storm counts

$$y(t) \sim Poisson\big(\lambda(t)\big)$$

$$\log\big(\lambda(t)\big) = \beta_0 + \beta_1 x_1(t) + \sum_{i=2}^{N} \beta_i x_i(t)$$

Linear time trend

Selected driver time series

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Map of large-scale drivers

- 5 predominant drivers identified by AIC are examined on grid cell level
- Poisson model for 1x1 degree grid cell
- Identifying the driver that explains most variability per grid cell
- → *Spatial distribution of most important drivers of inter-annual variability*

Contents

Identified large scale drivers

Table: Identified large scale drivers per region and observed and modelled Dispersion score

	BI **Region 1**	**C.Eur** **Region 2**	**BI/C.Eur** **Region 3**	**Scand** **Region 4**
Selected large scale drivers	NAO stat SCA Tdif.Nam ---------- EA POL	SCA Tdif.Nam QBO30 ---------- EA EA.WR	SCA NAO stat Tdif.Nam EOF 10 ---------- /	SCA W.Atl.T West Pac ---------- PNA POL
Dispersion score D model	1.14	0.12	0.60	1.54
Dispersion score D observed	1.94	0.85	1.35	2.67

- *SCA*, *NAO* and *EA* appear as key drivers
- *Tdif.Nam (Wild et al., 2016) and W.Atl.T* also explain variance
- Modelled *Dispersion* score generally *too small*

Qualitative performance of statistical model

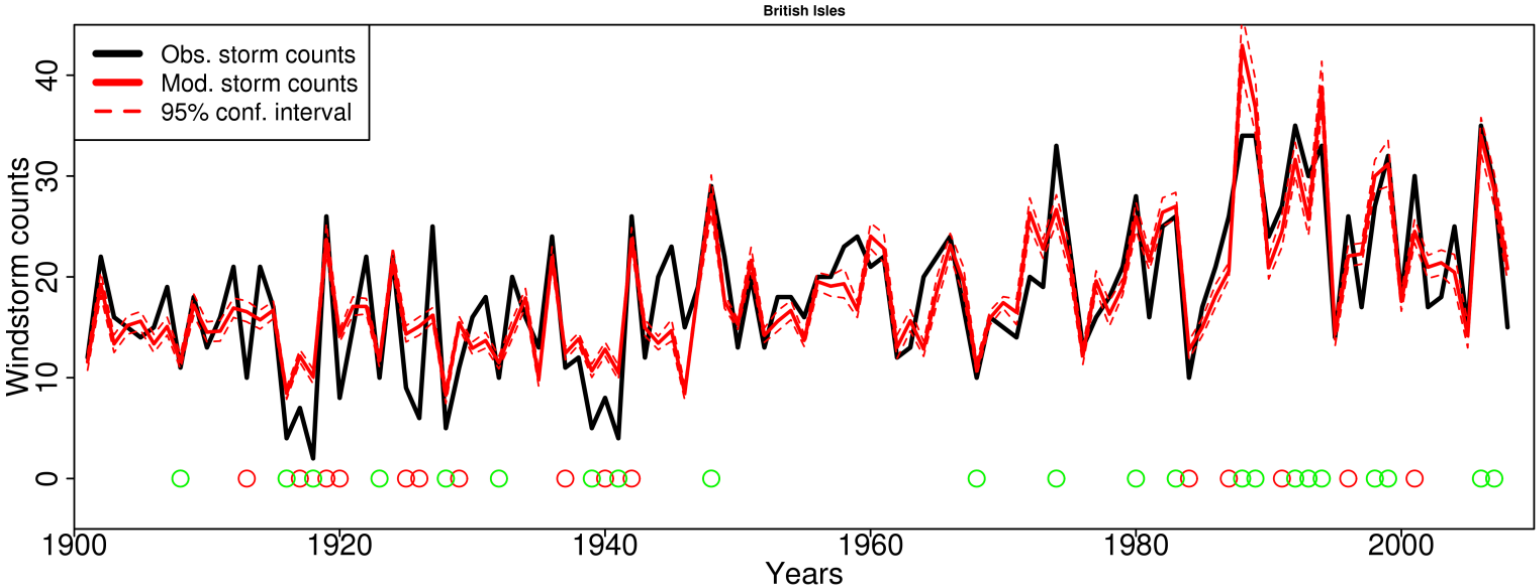

Figure: Windstorm frequency per year for the British Isles from 1901-2008. Circles indicate active/inactive seasons.
Walz et al., 2017 submitted to IJOC

- Significant trend in observations (cf. Befort et al., 2016)
- Satisfactorily performance of predicting annual storm count

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Quantitative performance of the Poisson model

Table: Cross validated skill scores for the developed statistical model

Region	Hit rate active	Hit rate inactive	D bias Model-Obs	Correlation
British Isles	**78.9%**	61.1%	-0.80	**0.84**
Central Europe	71.1%	50.0%	**-0.73**	0.72
BI+C.Europe	71.1%	65.5%	-0.75	0.81
Scandinavia	75.0%	64.3%	-1.13	0.82

- Underestimation of *D* → underestimation of inter-annual variability by model

Large scale driver on grid cell level – *Map of drivers*

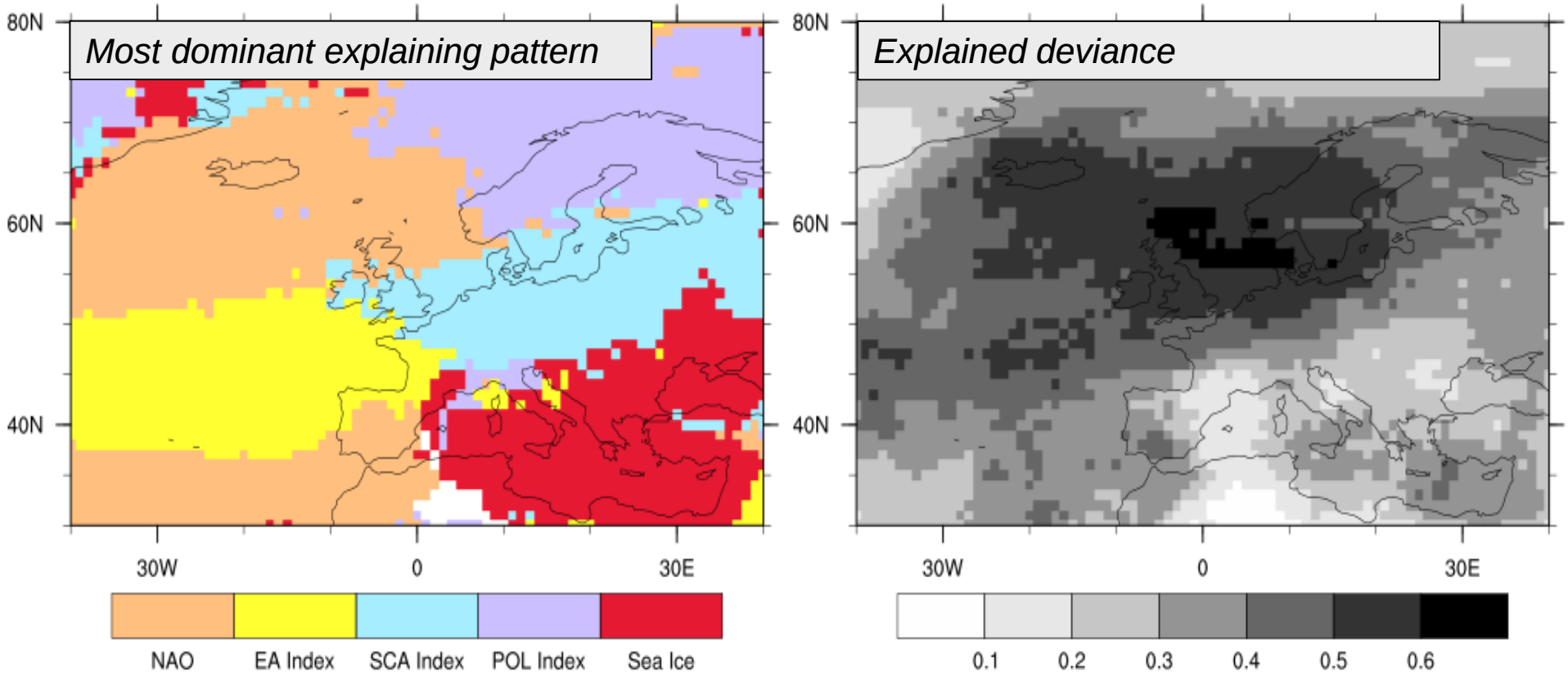

Figure: Left: Most dominant pattern explaining the inter-annual variability of windstorm. Right: Explained deviance of the Poisson regression. Walz et al., 2017 submitted to IJOC

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Large scale driver on grid cell level

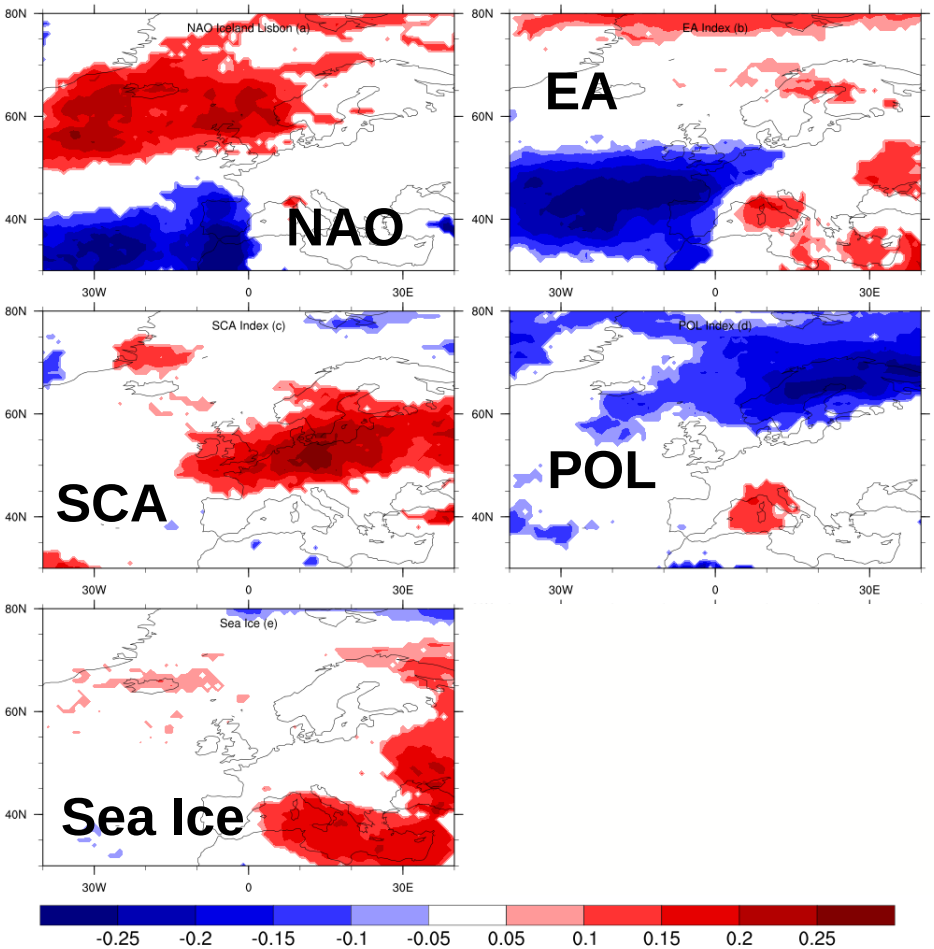

Figure: Significant Poisson GLM regression coefficients for the dominant selected large scale drivers

Walz et al., 2017 submitted to IJOC

- Prominent *NAO* pattern
- *SCA* as main driver for **Central Europe**
- *POL* for Scandinavia

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Contents

Summary/Outlook

- Statistical model to estimate seasonal clustering and also active/inactive seasons
- Identified drivers entail *SCA, NAO,W.Atl.T*
- "*Map of drivers*":
  - **SCA** is dominant driver for windstorms in Central Europe
  - **NAO** for Brit. Isles and NA

- Statistical model with *time lag* → *SON indices*
- *Interactions* between drivers in statistical model

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