Trends and Variability of Storminess in the NE Atlantic-European Region During 1874-2007

and Their Relationship to the North Atlantic Oscillation

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Two studies: 1. Wang, X.L. , F.W. Zwiers, V.R. Swail, and Y. Feng, 2008:
Trends and variability of storminess in the Northeast Atlantic region, 1874-2007.
Clim. Dyn., 2008: DOI 10.1007/s00382-008-0504-5
2. Wang, X.L., H. Wan, V.R. Swail, F.W. Zwiers, G.P. Compo, R.J. Allan, R.S. Vose:
Trends and variability of storminess over Western Europe, 1890-2007. (in preparation)

Storminess conditions are inferred from <u>extreme</u> geostrophic wind speeds

(95th, 99th percentiles)   (geo-wind)

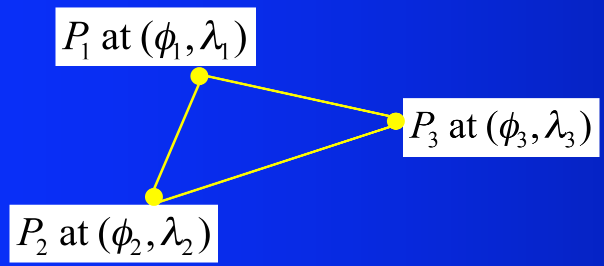
Pressure triangle analysis:

$$
\begin{cases}
P_1 = aR\lambda_1 \cos\phi_1 + bR\phi_1 + c \\
P_2 = aR\lambda_2 \cos\phi_2 + bR\phi_2 + c \\
P_3 = aR\lambda_3 \cos\phi_3 + bR\phi_3 + c
\end{cases}
\xrightarrow{\;a,\;b\;}
$$

Instantaneous SLP for the same hour observed at the 3 sites that form a triangle:

Long.

Lat.



Geostrophic wind speed (geo-wind):

$$W_g = \sqrt{u_g^2 + v_g^2} \quad \text{with}$$

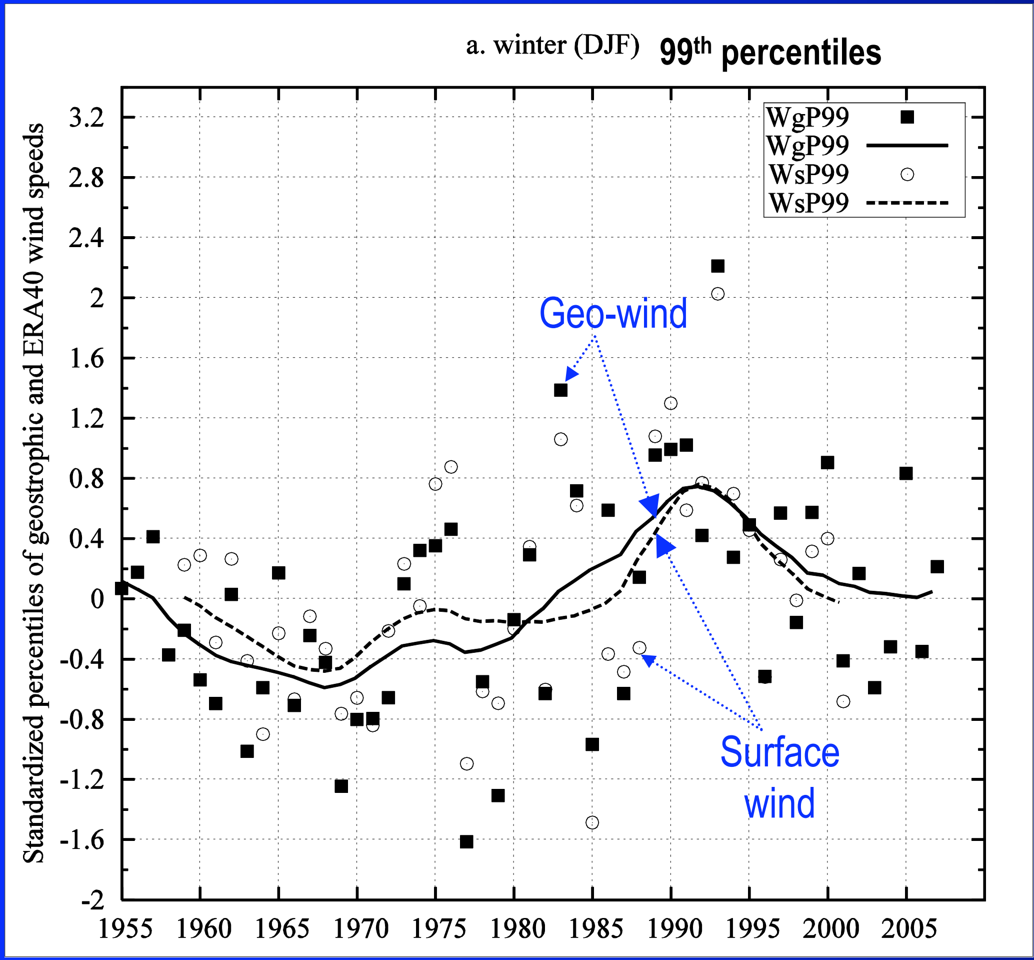
$$u_g = -\frac{1}{\rho f}\frac{\partial P}{\partial Y} = -\frac{b}{\rho f},$$

$$v_g = \frac{1}{\rho f}\frac{\partial P}{\partial Y} = \frac{a}{\rho f}$$

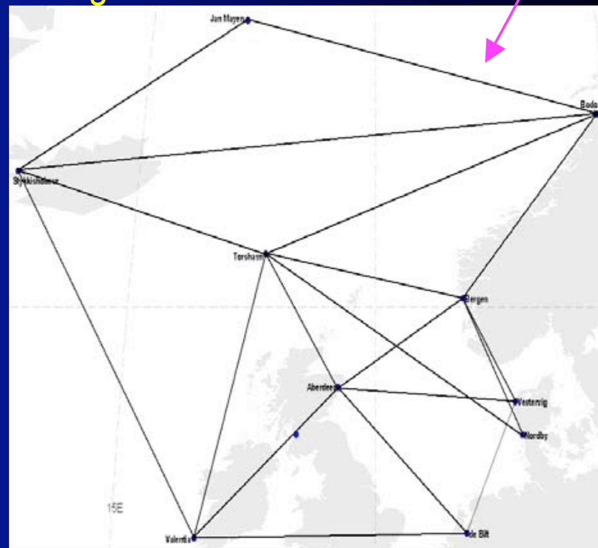
ρ - Air density (ρ = 1.25 kg/m^3)
f - Coriolis parameter ($f = 2\pi\Omega \sin\phi$)
R - Earth radius (R = 6378100 m)
Ω – Earth rotation rate

One can make such inference because …

Geo-wind extremes (WgP99) well approximate ERA40 surface wind extremes (WsP99)



Area average taken over 10 gridpoints, each of which is near one of the 10 sites with SLP used to calculate geo-winds



Background - Pioneer studies:

Alexandersson et al. 1998 (Global Atmos Ocean Syst, 6, 97-120)

Alexandersson et al. 2000 (Clim Res, 14, 71-73)

Historical sub-daily pressure observations at these sites
→ Extreme geo-wind speeds

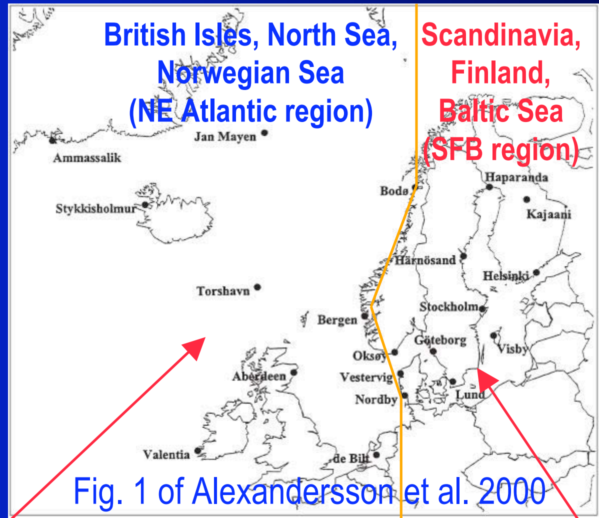


Fig. 1 of Alexandersson et al. 2000

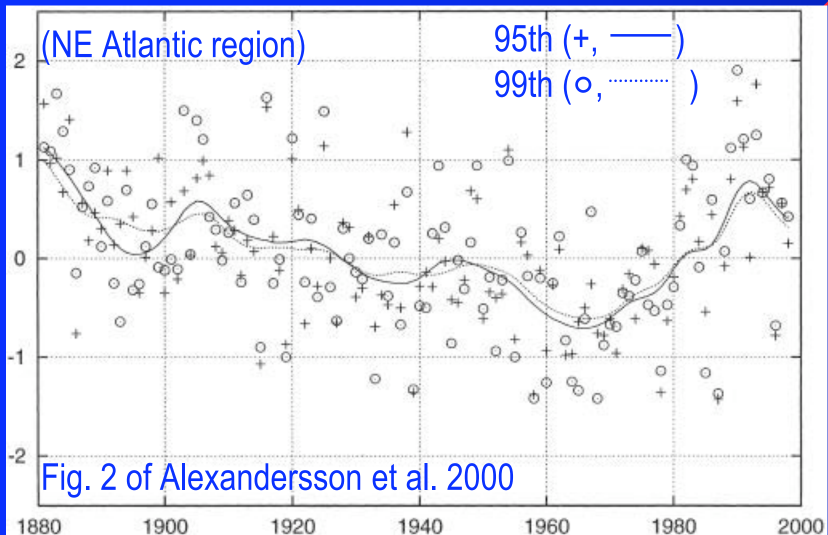


Fig. 2 of Alexandersson et al. 2000

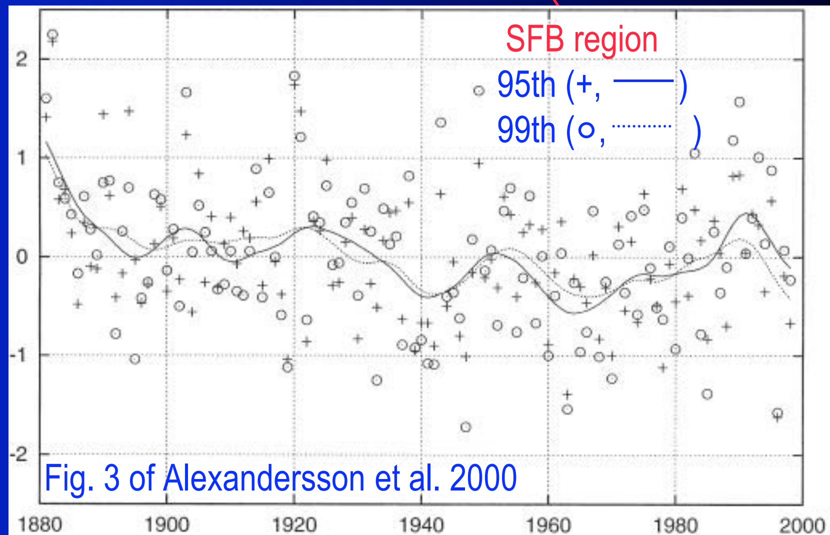


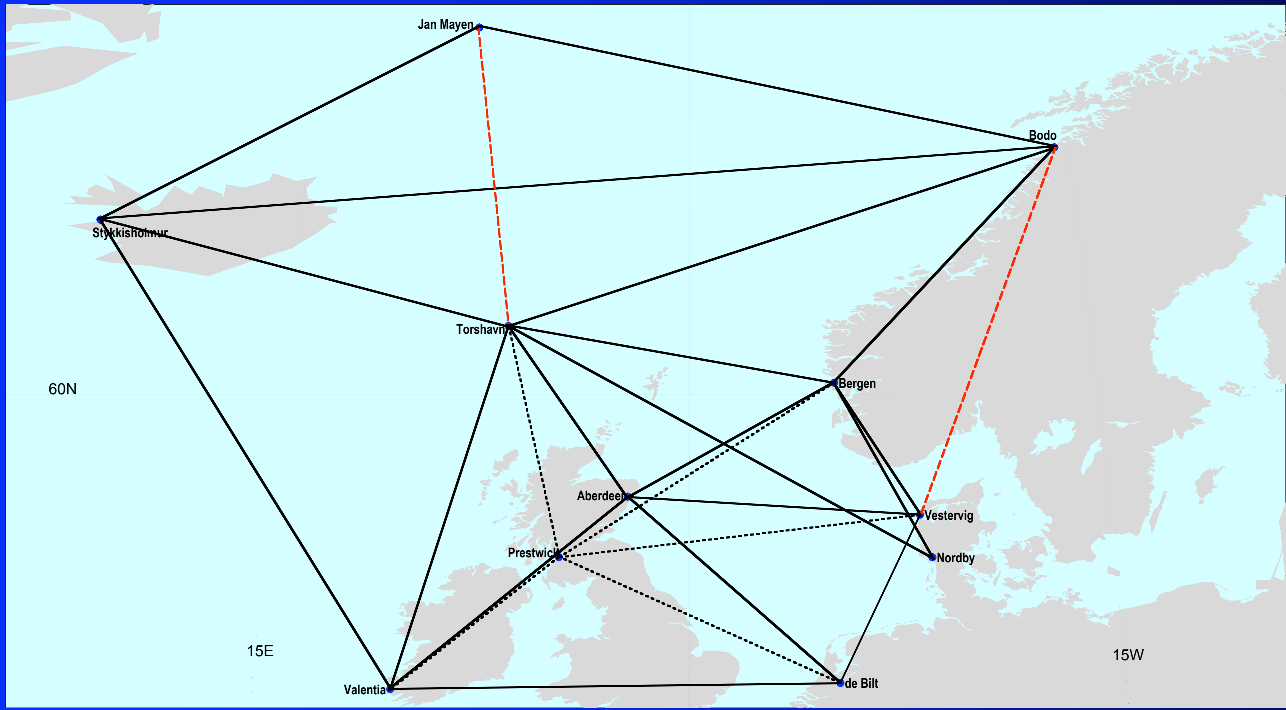
Fig. 3 of Alexandersson et al. 2000

Period of analysis: **1881-1998**

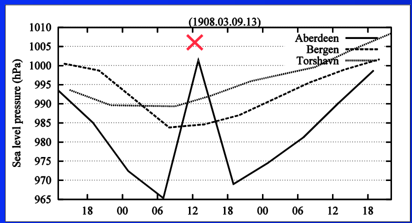
(1) Wang et al. (2008): update the NE Atlantic study to 1874 - 2007; explore seasonality and regional differences

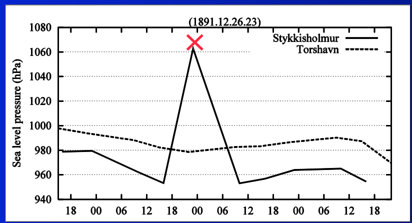
Procedure differences between Alexandersson et al. (2000) and Wang et al. (2008):

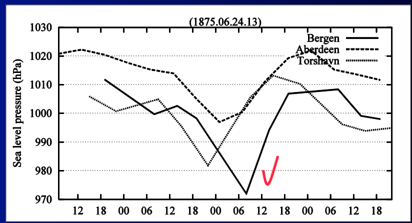
- modify the triangle configuration:



- use data from Prestwick to fill in data gap at Aberdeen (1948-1956) → 5 combined triangles
- Screen out random errors (set to missing, or corrected if possible) – compare data from nearby stns:



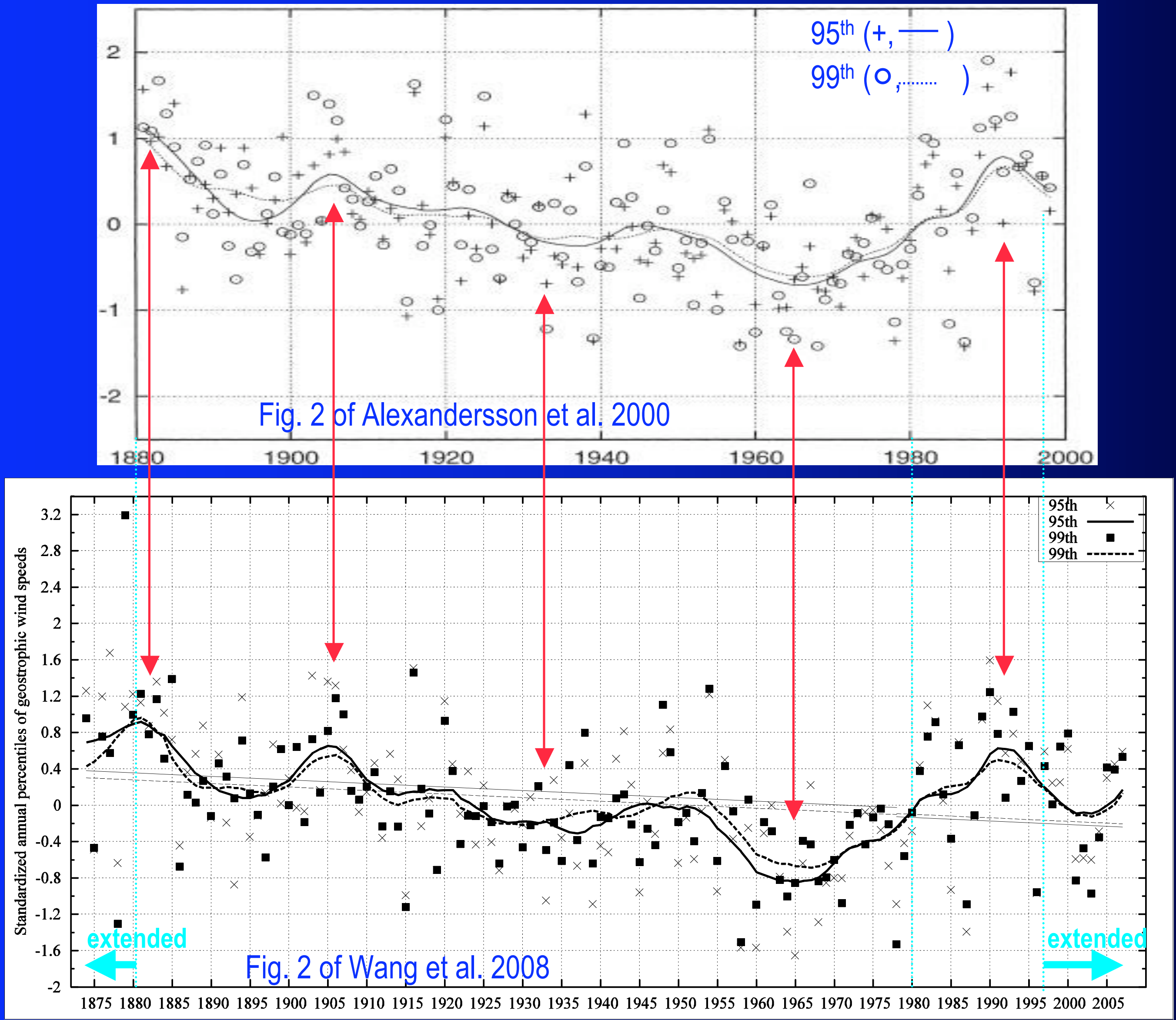




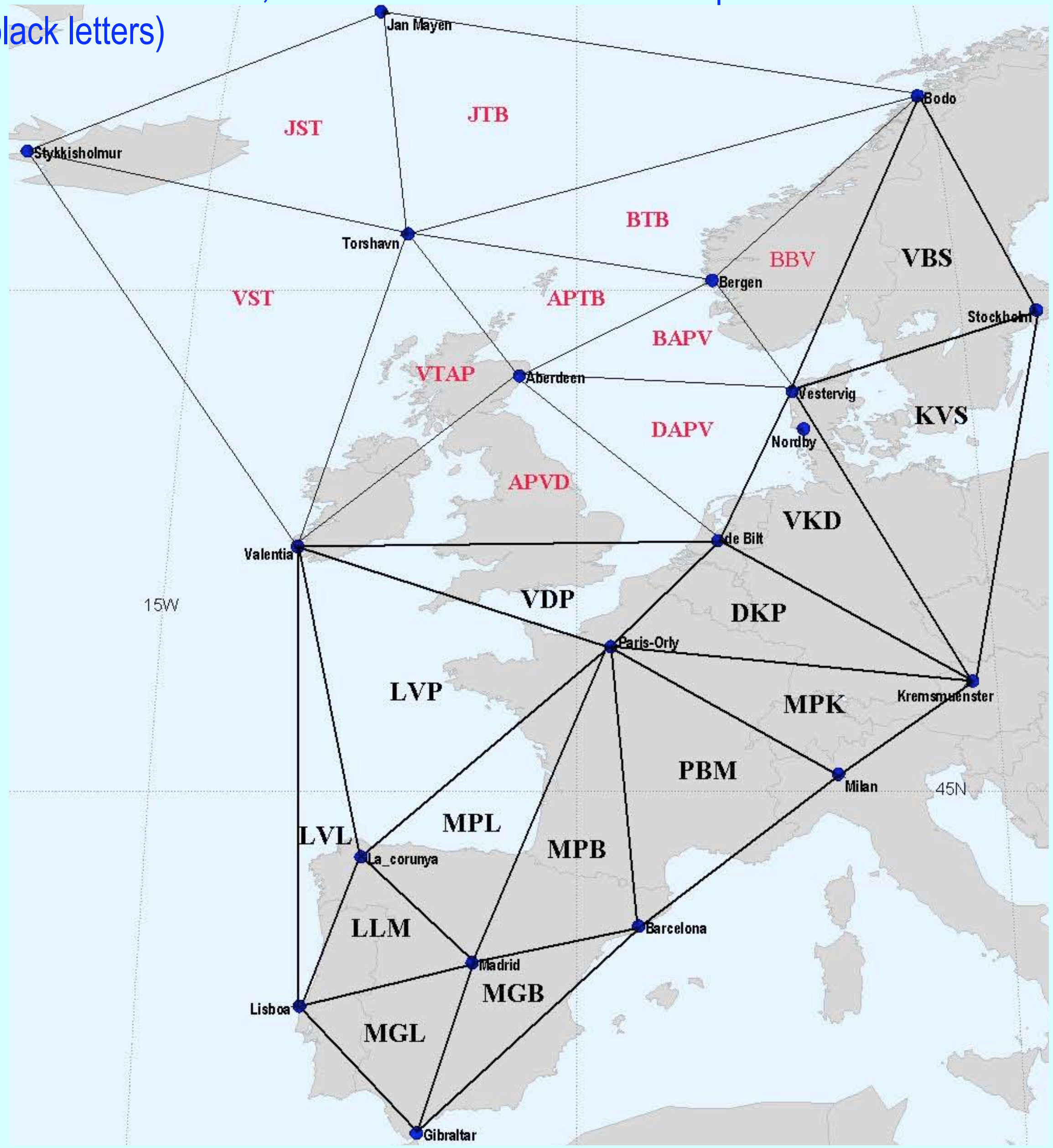
- homogeneity tests on monthly mean geo-wind series
- interpolate the sub-daily pressure data series to form 3-hourly series → more homogeneous sampling rate

→ similar results, as shown next:

NE Atlantic average of standardized **annual** 95th and 99th percentiles of geo-winds and corresponding Gaussian smoothed series:



(2) Extend the region southward to Iberian Peninsula, and eastward to Northern Europe
(add in 14 triangles, shown in black letters)



Storminess trends and low-frequency variations

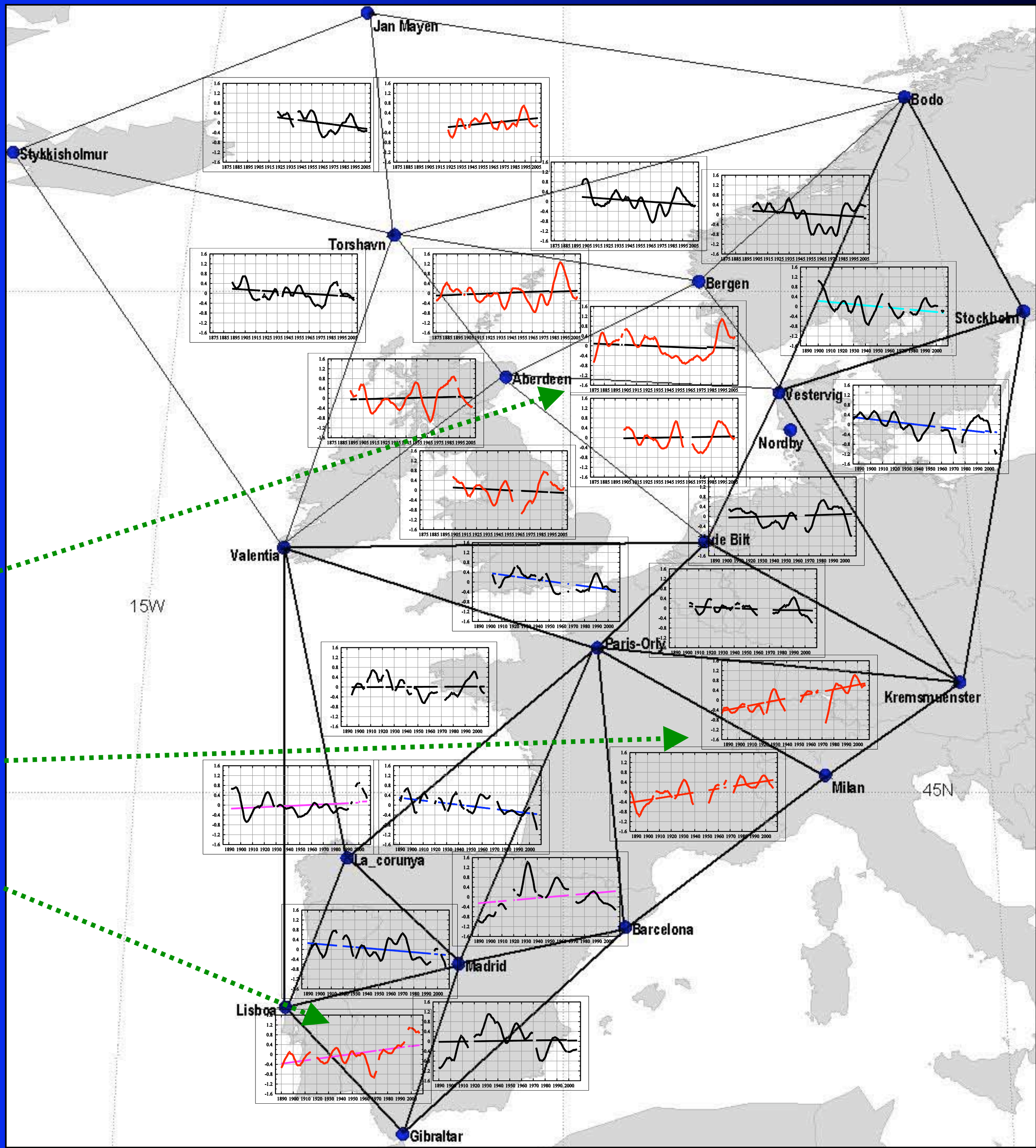
show

significant seasonality and regional differences

Winter (DJF)
99th percentiles:
(linear trends and
11-point Gaussian
smoothed series)

- Unprecedented peak in the early 1990s in the North Sea area

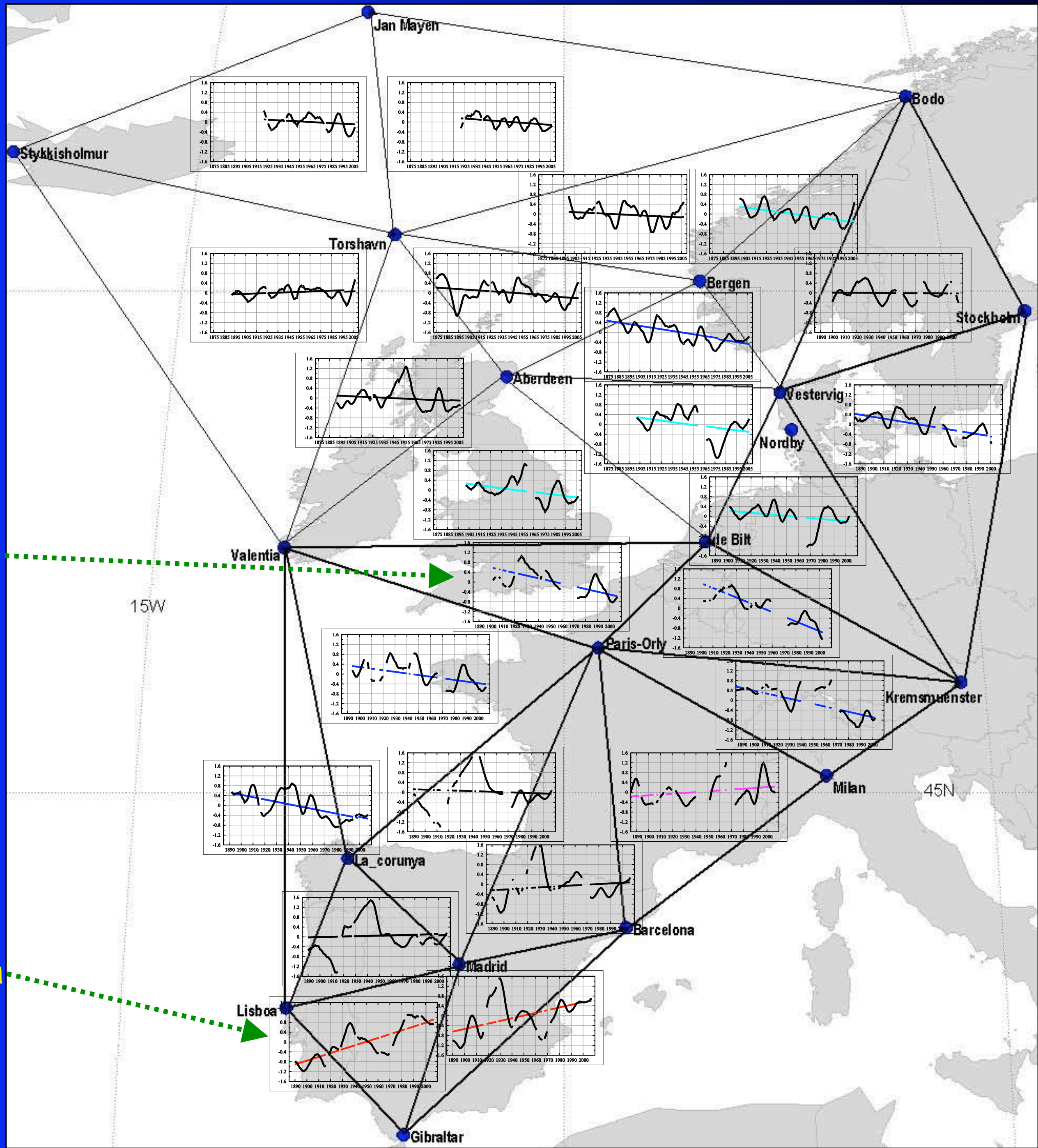
- Steady increasing trend in Western Alps and SW Iberia



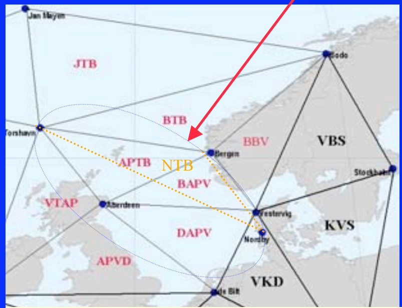
Summer (JJA)
99th percentiles:
(linear trends and
11-point Gaussian
smoothed series)

- Decreasing trend over North Sea to Central Europe

- Significant increasing trend in Southern Iberia



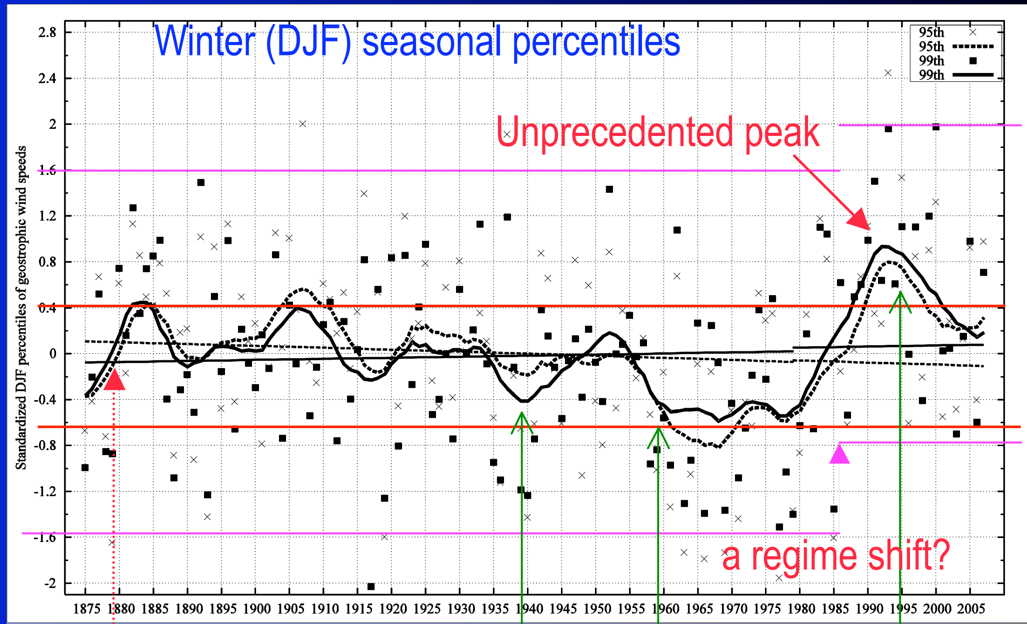
Area averages - four triangles over the North Sea – winter & summer

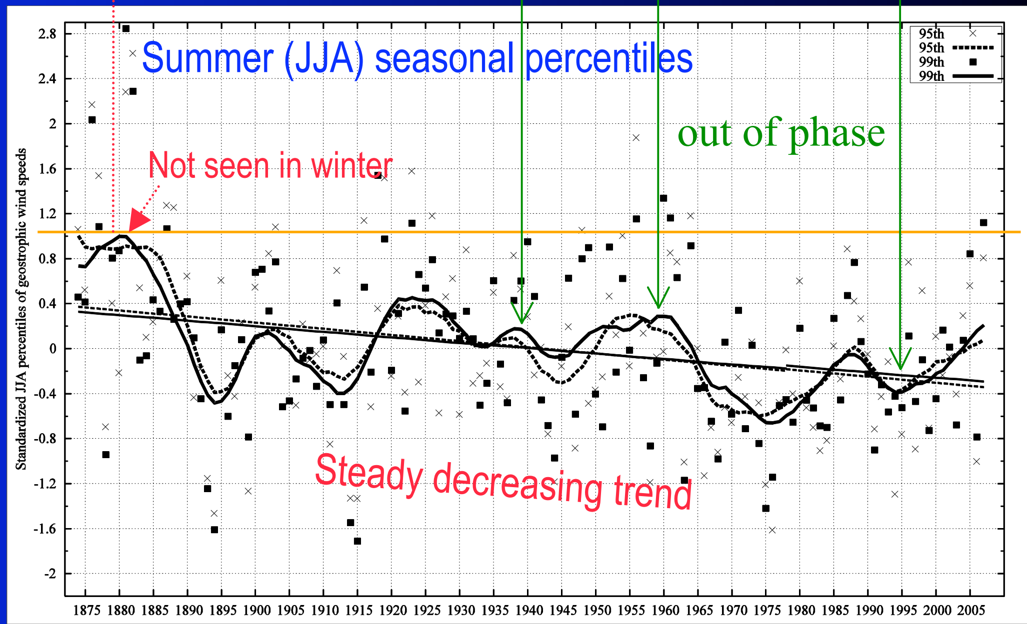


- at the decadal or longer time scales, winter storminess conditions often fluctuate out of phase with summer storminess conditions

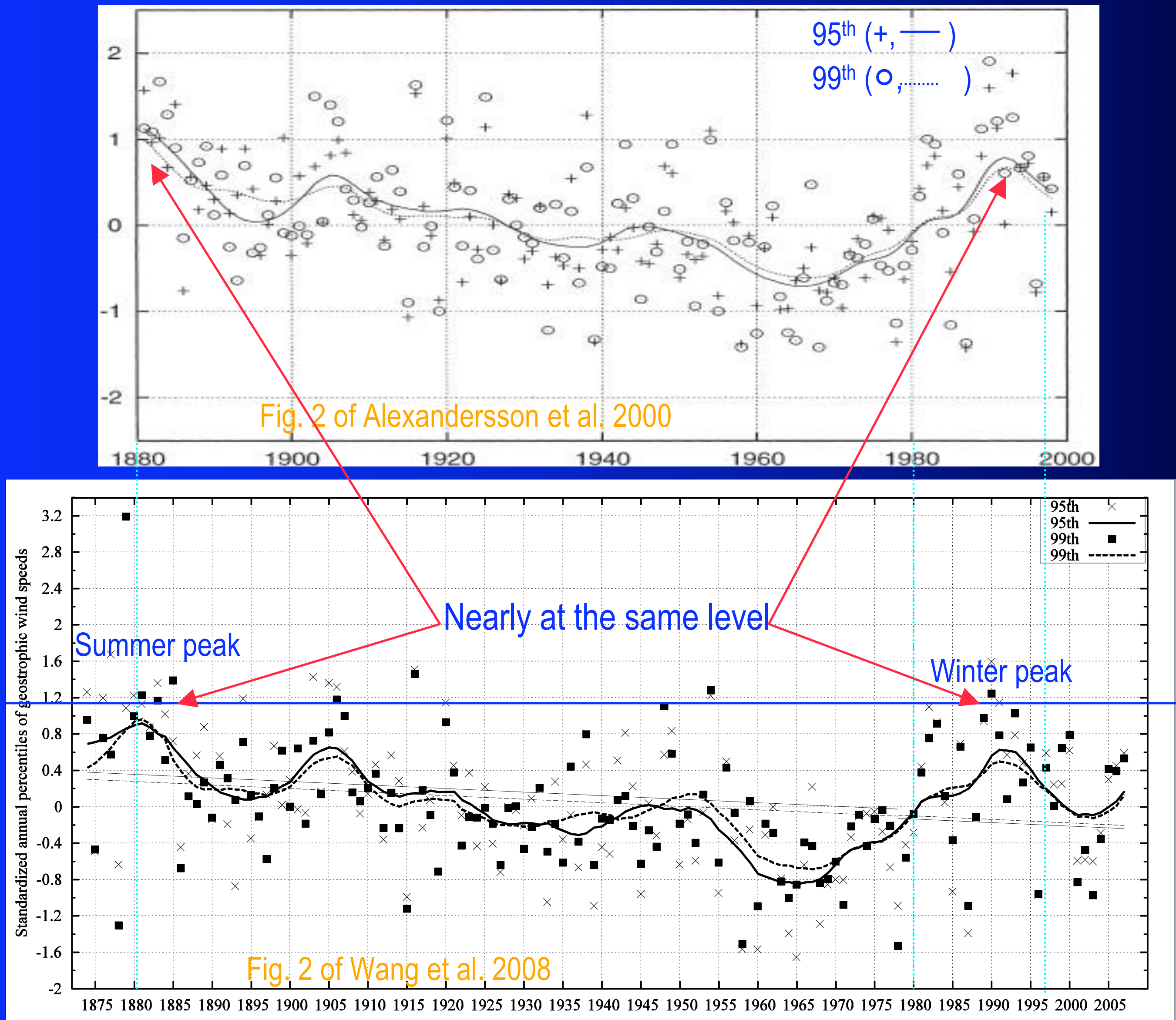
The use of annual metrics and the NE Atlantic regional average has masked the seasonality and regional differences.

For example





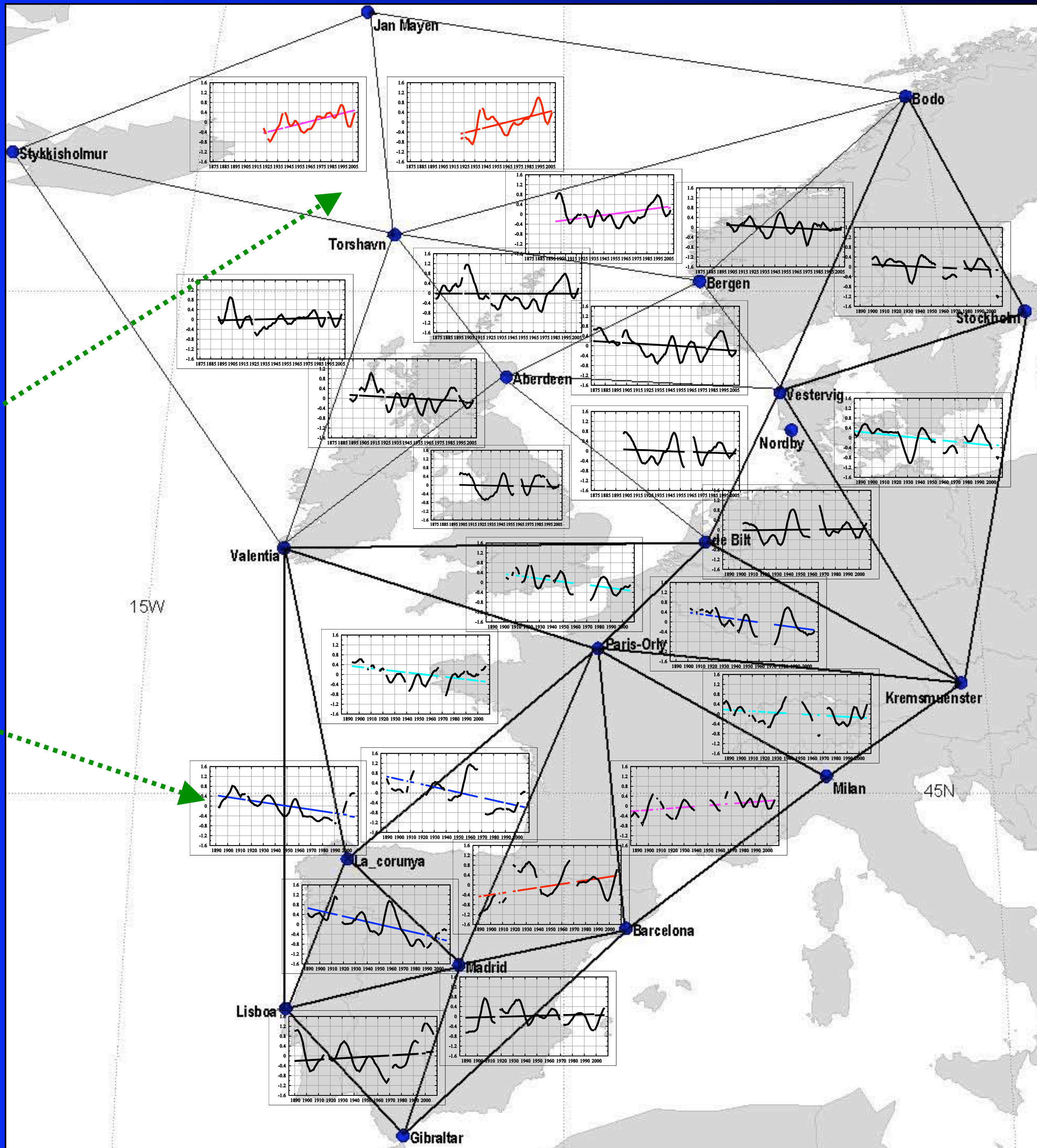
NE Atlantic average of standardized **annual** 95th and 99th percentiles of geo-winds and corresponding smoothed curves:



Spring (MAM)
99th percentiles:
(linear trends and
11-point Gaussian
smoothed series)

- Increasing trend
  in the North

- Decreasing trend
  in the area from
  NW Iberia-Bay of Biscay

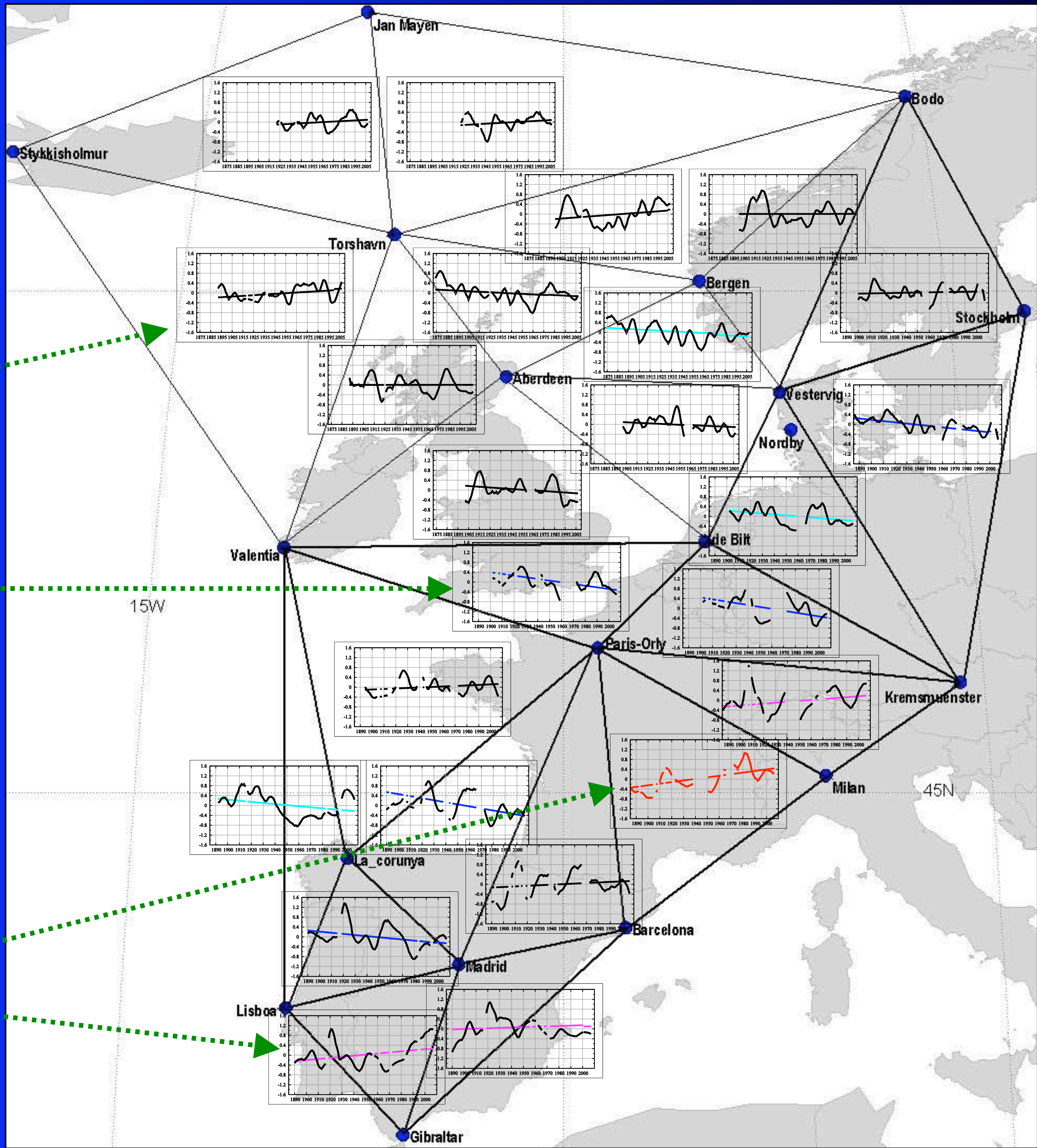


Autumn (SON)
99th percentiles:
(linear trends and
11-point Gaussian
smoothed series)

- No significant trend in the North

- Decreasing trend in the central part?

- Increasing trend in Western Alps and Southern Iberia?



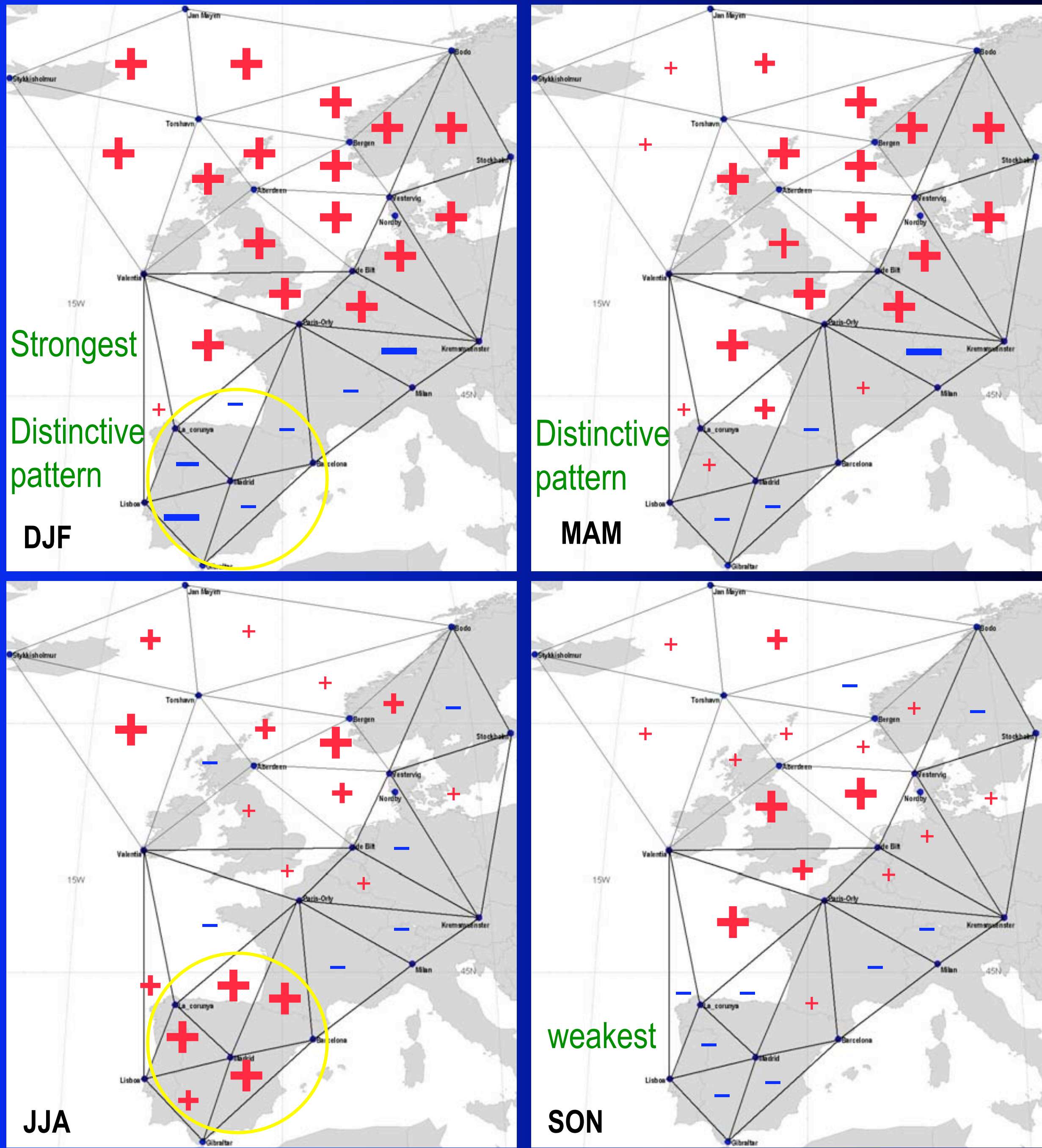
Simultaneous NAO-WgP99 correlation:

Period: 1874 or later - 2007

Confidence level:

+ —	: ≥ 95%
+ –	: 80-95%
+ –	: < 80%

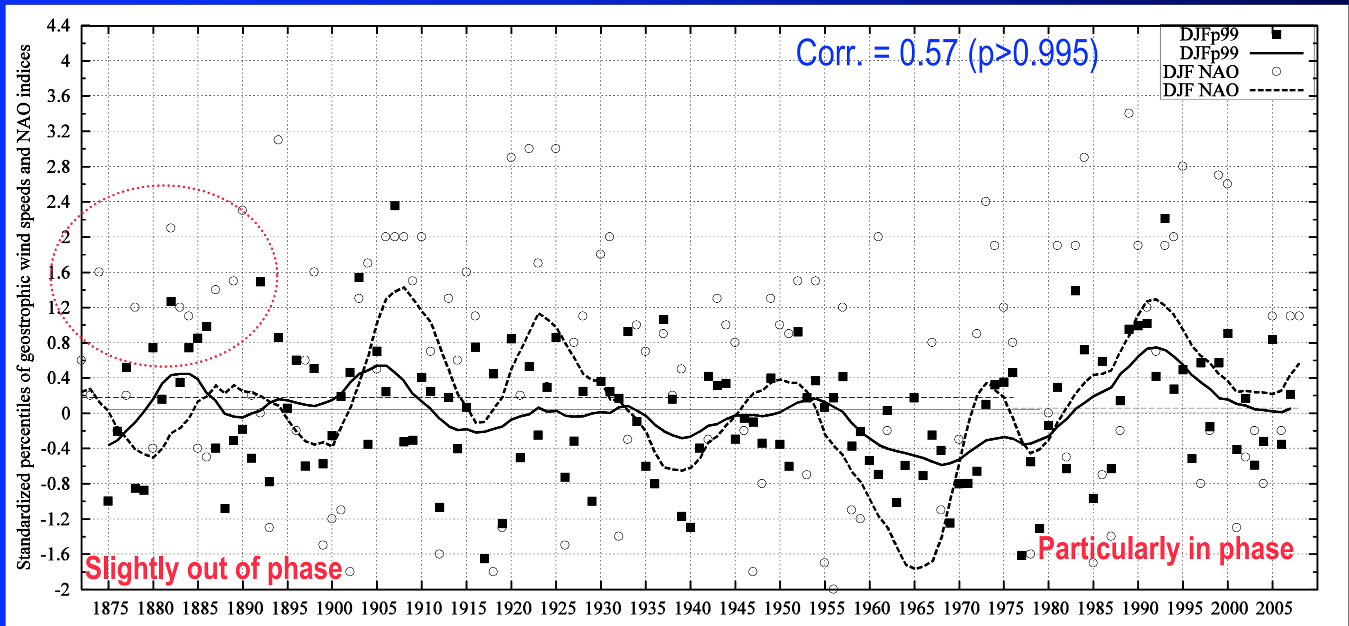
(Hurrell's seasonal NAO index series used; Hurrell 1995)



How did the relationship evolve over time?

Simultaneous: NAO index – NE Atlantic area averages of winter WgP99

The higher the NAO index, the rougher the storminess conditions in winter (& spring)



NE Atlantic region average of standardized winter 99th percentiles of geo-winds, in comparison with the seasonal mean NAO index series (Hurrell 1995) and its 11-point Gaussian smoothed series and Kendall's slope estimate.

Summary

1. Profound decadal or longer time scale variability

2. Notable seasonality and regional differences in trends and variability:

- Winter: unprecedented maximum (early 1990s, North Sea);

  ↑ over Central France-Western Alps, and over SW Iberia;

  ↓ over NW Europe, NW Iberia and Bay of Biscay

- Summer: significant ↓ over British Isles - North Sea - Central Europe → increased risk of drought in summer?

  ↑ over Southern Iberia

North Sea: Low frequency variations of <u>winter and summer</u> storminess were often <u>out of phase</u>

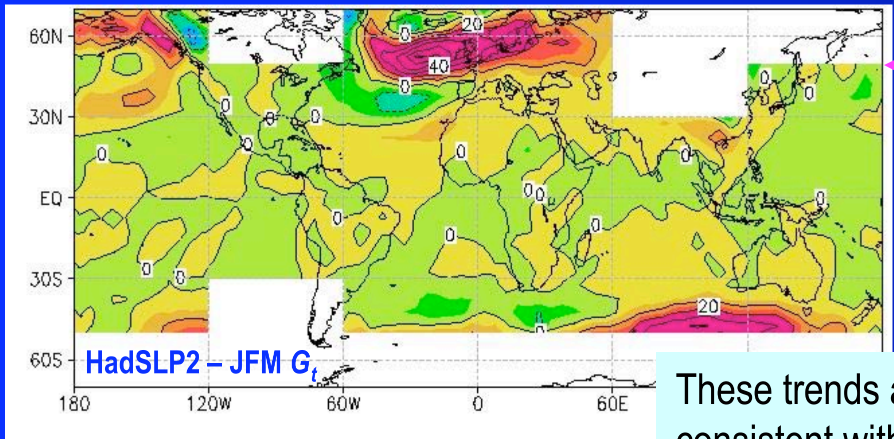
3. Winter & spring storminess over NE Atlantic-NW Europe and summer storminess over Iberia are highly positively correlated with simultaneous NAO

4. Human influence? – still an **open** question

Wang et al. 2008: *Clim. Dyn.*
(used ERA40 & HadSLP2 data, & 20C all forcing simulations from 9 coupled models, 45 runs)

→ Effect of **external** influence on storminess: strongest in winter hemisphere (anthropogenic **+** natural forcing such as volcanic, solar)

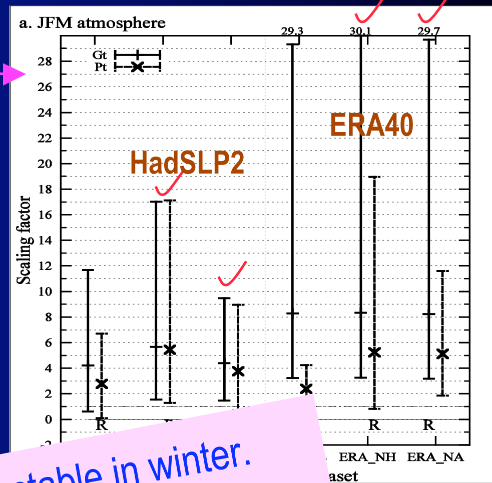
1955-2004 linear trends in squared pressure gradients G_t (geostrophic wind energy index)

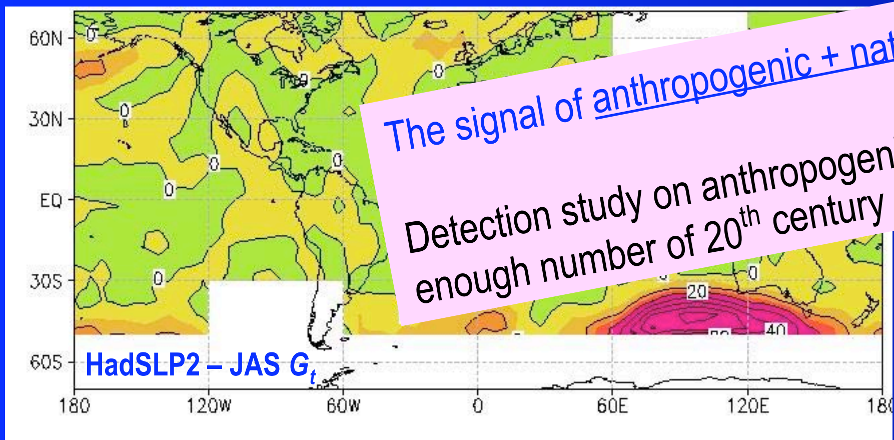


Yellow-Red: increase
Green-Blue: decrease

These trends are consistent with the geo-wind trends

Boreal winter (JFM):
NH trend pattern contains a detectable response to external forcing





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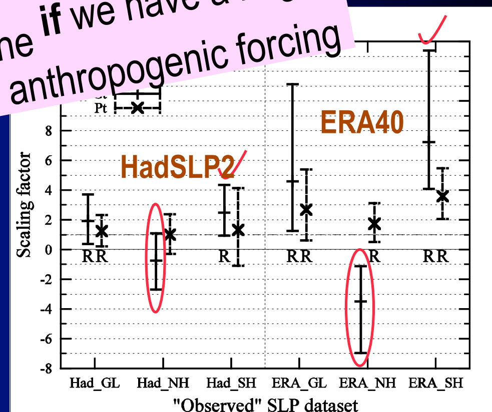


The signal of anthropogenic + natural forcing combined is detectable in winter.

Detection study on anthropogenic influence alone can be done **if** we have a large enough number of 20[th] century simulations that include only anthropogenic forcing

Acknowledgements

The authors are thankful to members of the International Surface Pressure Databank (ISPD) Working Group for providing us the pressure data analyzed in this study, and to Sylvie Jourdain (Meteo-France) for helping us locate the early 1900s pressure data for the Paris site, to José Antonio López (Spanish Met Office) for providing us extra data to fill in data gaps at the Spanish stations, and to Manola Brunet-India (Spain) for helping us find the contact for Spanish data.

Thank you very much!

Outline

- Introduction – geostrophic winds vs. surface winds
- Data & procedure
- Trends and low-frequency variability of storminess
- Storminess-NAO relationship
- Summary

Datasets: subdaily in-situ surface pressure observations from 20 sites

- Exclude any 24-h period with < 2 observations

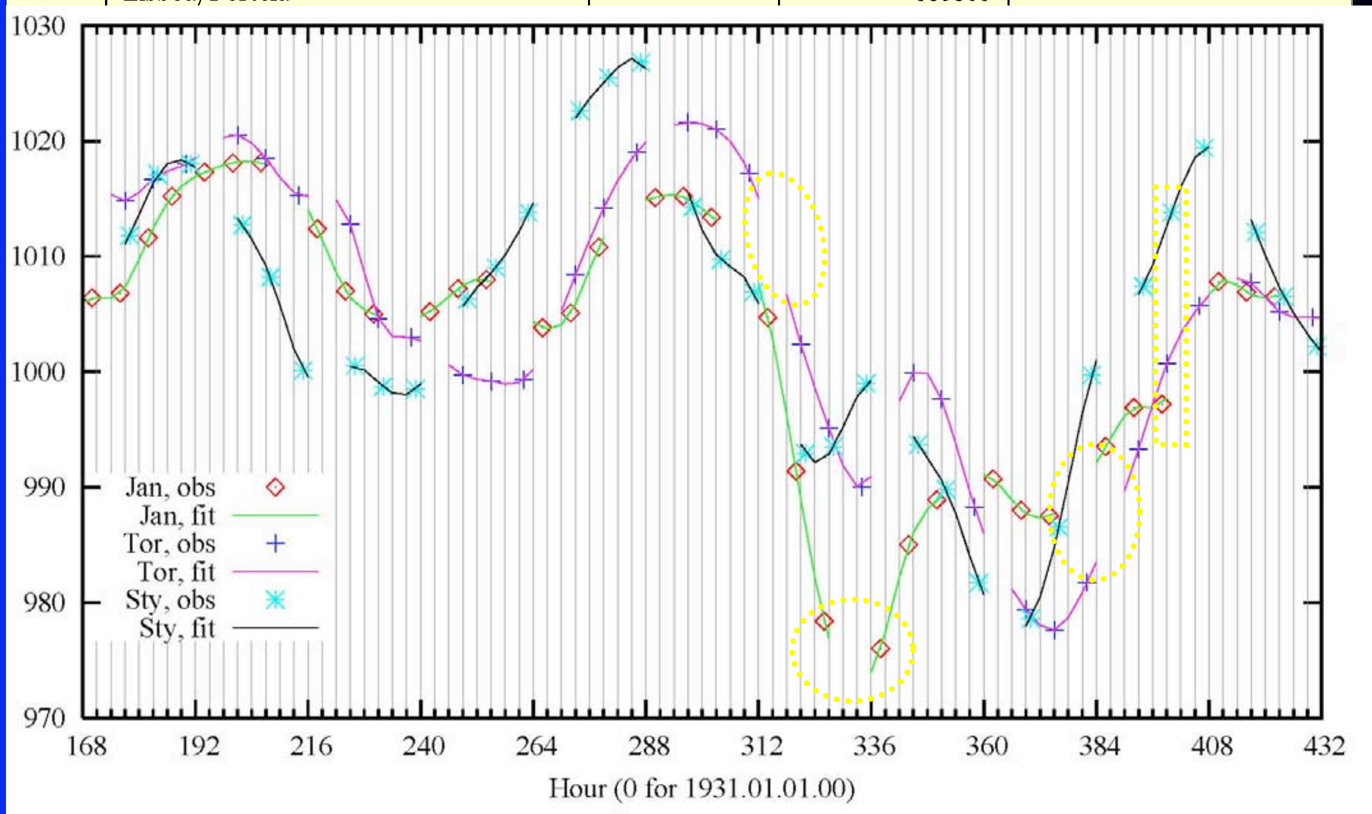
Hours of obs are often different among the 3 sites of a triangle

- Fit a natural spline to the instantaneous SLP series at each site to interpolate the series to form a 3-hly series:

- Interpolate an unobserved 3-hly value only between two observations that are less than 8 hours apart

→ more simultaneous SLP triplets for estimating geo-winds over a triangle, more homogenous sampling rate over time

Site	Name of station(s)	Country	Station IDs	Period of data used (YYYY.MM.DD.HH)
Lis	Lisboa/Geofisico; Cabo Carvoeiro; Lisboa/Portela	Portugal	535; 085300; 085360	1863.12.01.09-2007.12.31.23
Ber	Bergen-Fredriksberg; Bergen Flesland	Norway	01316; 013110	1868.01.01.08-2008.01.03.23
Abe	Aberdeen/Dyce Airport; Aberdeen Obs.	Great Britain	03091; 030910	1871.01.01.07-2008.01.03.23 (no data for 1948-1956)
Pre	Prestwick(Civ/Navy)	Great Britain	031350	1944.01.01.00-2002.07.10.18
Jan	Jan Mayen(Nor-Navy); Jan Mayen	Norway	01001; 010010	1922.01.01.02-2008.01.03.23
Nor	Nordby; Esbjerg	Denmark	25140; 060800	1874.01.01.08-2008.01.03.21



NAO-WgP99 Correlation (NAO leads for 1 season)

Period: 1874 or later - 2007

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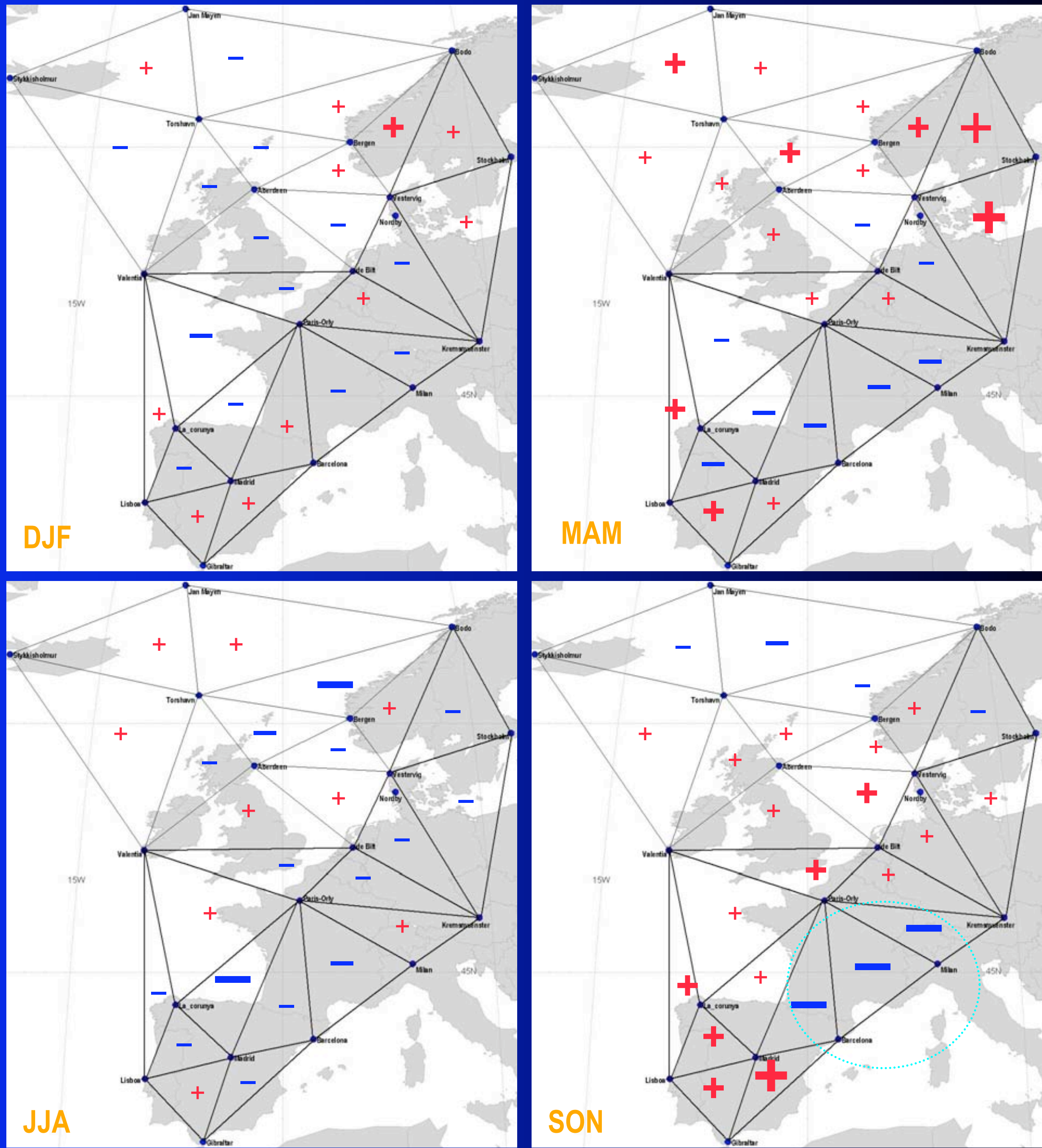
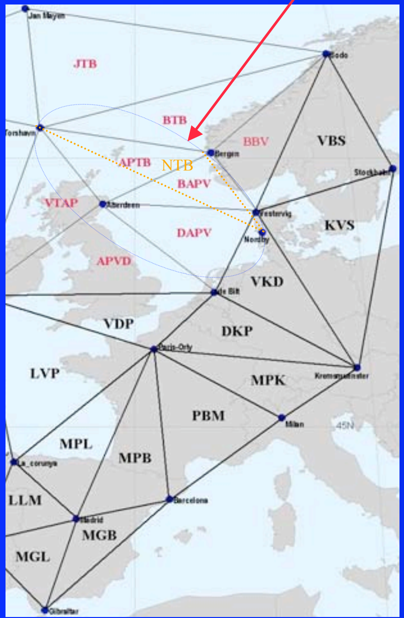
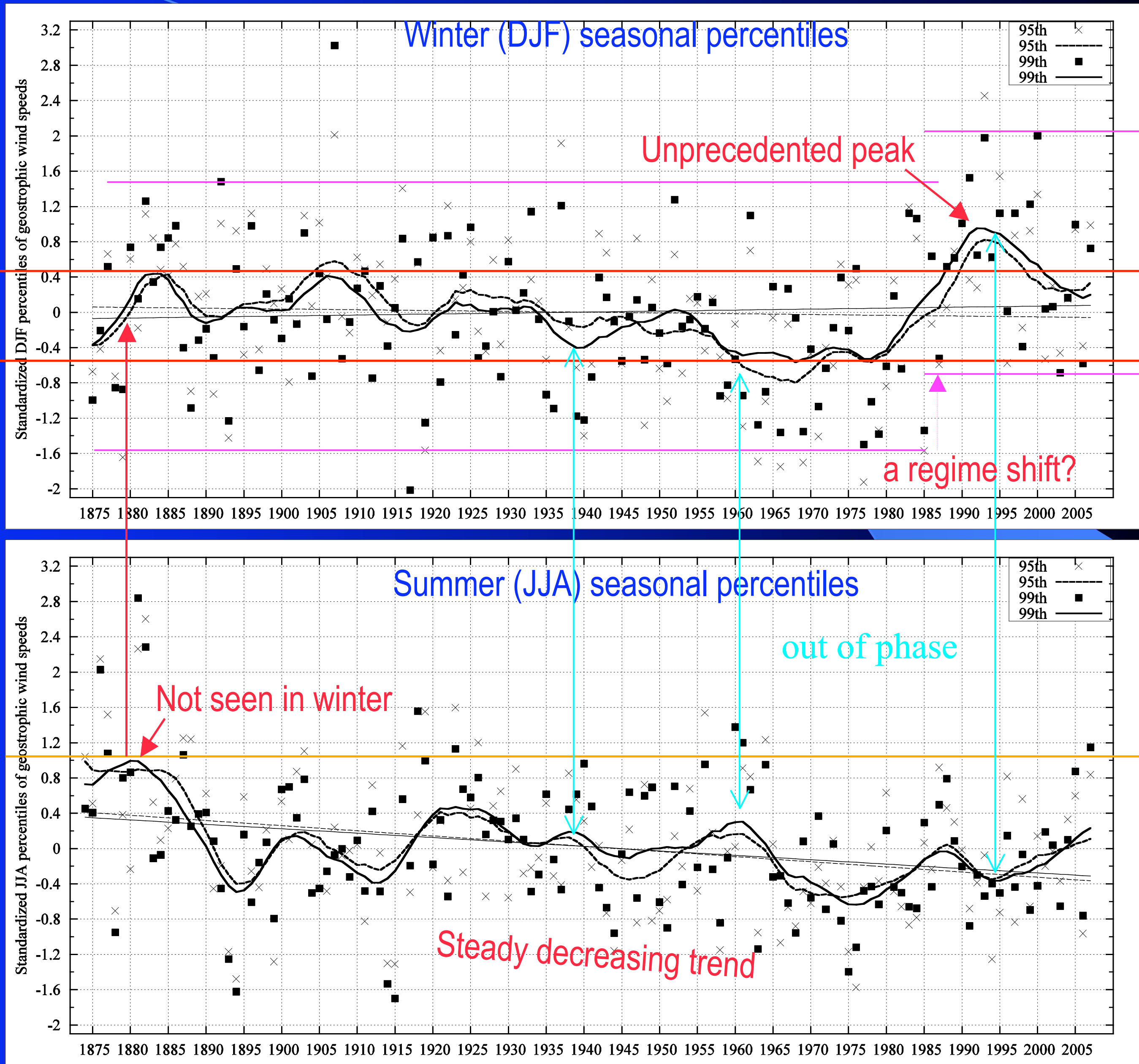
(Hurrell's seasonal NAO index series used; Hurrell 1995)



Area averages - four triangles over the North Sea – winter & summer





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For example

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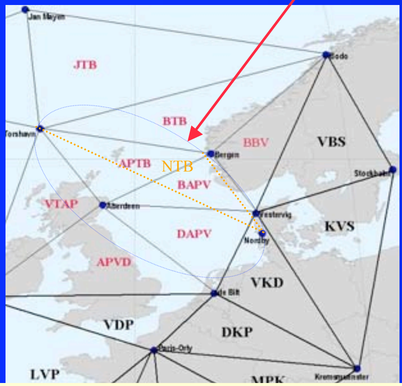
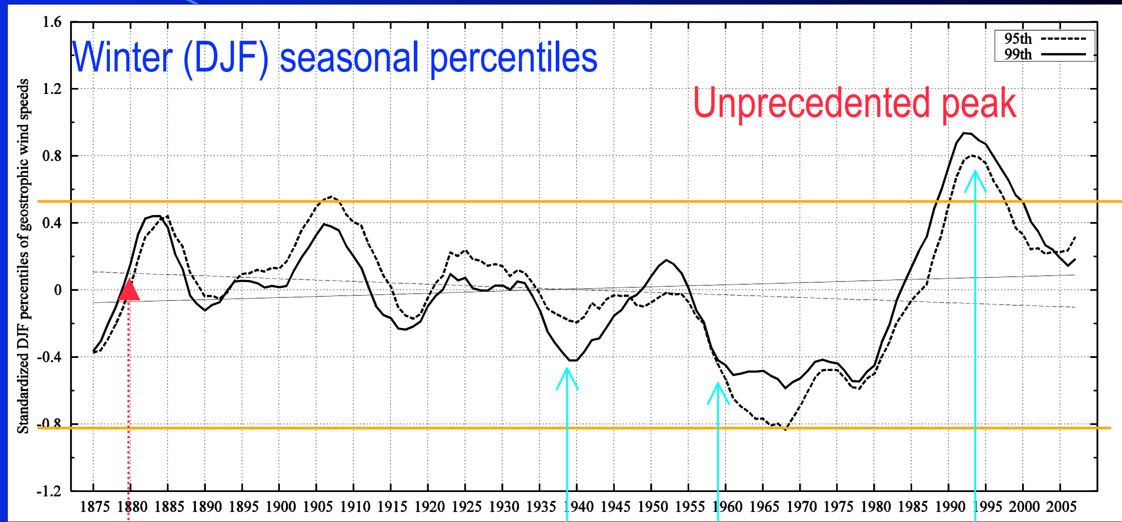
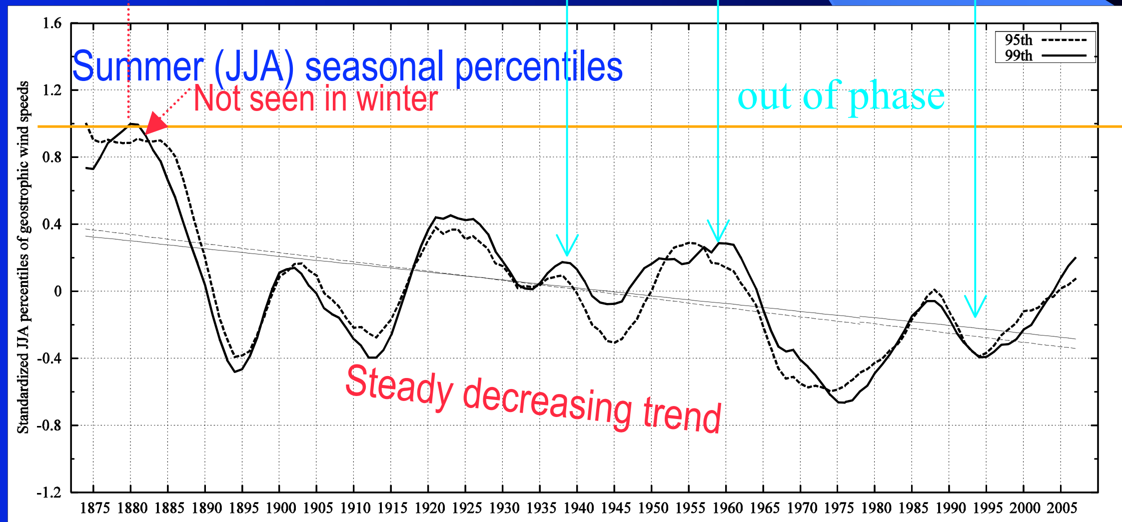


- at the decadal or longer time scales, <u>winter</u> storminess conditions often fluctuate <u>out of phase</u> with <u>summer</u> storminess conditions





The use of <u>annual metrics</u> and <u>the NE Atlantic regional average</u> has masked the <u>seasonality</u> and <u>regional differences.</u>

For example