

SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	Investigation of large scale precursor conditions for extreme cyclone development in the extra-tropics
Computer Project Account:	SPGBLECK
Start Year - End Year :	2012- 2014
Principal Investigator(s)	Dr GC Leckebusch
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Other Researchers (Name/Affiliation):	DJ Befort, S Wild School of Geography, Earth and Environmental Sciences University of Birmingham Edgbaston Birmingham B15 2TT United Kingdom

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

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This project aims at the investigation and diagnosis of severe storm events in different geographical regions of the earth. Several kinds of dynamical systems are highly affecting social and technical infrastructures and the estimation of wind storm related risks for e.g. Europe or other wind storm affected regions is of crucial interest. Thus, this project addresses mainly extreme, severe mid-latitude winter storms. Basically, studies on (historical) wind storms suffer from a lag of knowledge about meteorological conditions responsible for the storm development and in consequence for the reasons of variability in frequency and intensity and eventually for related impacts. In this project key circulation patterns will be identified and related to their physical origins with respect to different characteristics of extra-tropical storm events.
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Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

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No problems encountered
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Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

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Very Positive
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Summary of results

The project originally commenced in summer 2012. As some postponement of arriving staff members had occurred during the project duration (later starts of new projects), the originally intended use of ECMWF facilities took place only in a much reduced amount, with **no use of the allocated computer resources**. Nevertheless, an overview of activities making use of **general** ECMWF facilities in the context of this project is given here. In the current special project (2015-16), we intend to make use of the allocated storage and compute serve resources.

In SPGBLECK project multiple datasets have been used: 1) ERA-Interim, 2) ECMWF Seasonal Forecasts (system3 & 4) and 3) ERA-20C. All datasets have been obtained via the MARS archive.

Our studies including e.g., the ERA Interim data were multiple with respect to spatial and temporal scale but mainly focussed on the investigation of extra-tropical cyclones in the European / North Atlantic region. Two algorithms to detect cyclones as well as wind-storm events have been used for identification in reanalysis data. For cyclone systems in terms of core pressure the algorithm developed by Murray and Simmonds (1991) and for surface wind storm identification the algorithm developed by Leckebusch et al. (2008). These wind and cyclone tracks are further used for an in depth analysis of the synoptic scale precursor parameters (e.g. baroclinicity, latent heat release, upper-tropospheric divergence).

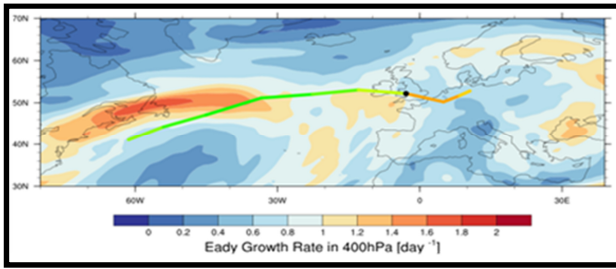


Figure 1: Track of wind storm “Vivian” from 24th to 27th Feb. 1990 and mean of Eady Growth Rate between 500 and 300hPa of previous 3 days before storm reached British Isles

In detail, we investigated the role of available baroclinicity for the transformation of a cyclone from a normal ETC to a severe storm system. Baroclinicity is one of the core components to the growths of baroclinic waves, which are directly related to growth of surface cyclones and storms. Our results show enhanced baroclinic instability over the North Atlantic previously to the occurrence of wind storms in the extended winter season from October to March (see Fig. 1 for the example of wind storm *Vivian*, Fe. 1990). Further on, our findings suggest that wind storms over Northern Europe are mainly preceded by a SW-NE elongated anomaly pattern while wind storms in Central Europe are preceded by a more zonal oriented anomaly in baroclinicity.

The second example of October 2013 shows that also previously of storm *Christian* (25th-29th Oct 2013) the *Eady-Growth-Rate* in 400hPa was enhanced (Figure 2). However, it can also be seen that enhanced baroclinicity is not always related the occurrence of an extreme wind storm further downstream. We diagnose a high storm-to-storm variability and the aforementioned quantification of the importance of precursor conditions is necessary to estimate when and why an extra-tropical cyclone will be transformed into a severe storm. Research is ongoing to evaluate in a more systematic way the responsibility of one forcing factor (e.g. baroclinicity) against other known influence factors (latent heat, upper-tropospheric divergence). The results of these analyses will be published in a peer-reviewed journal (Wild et al., 2016a).

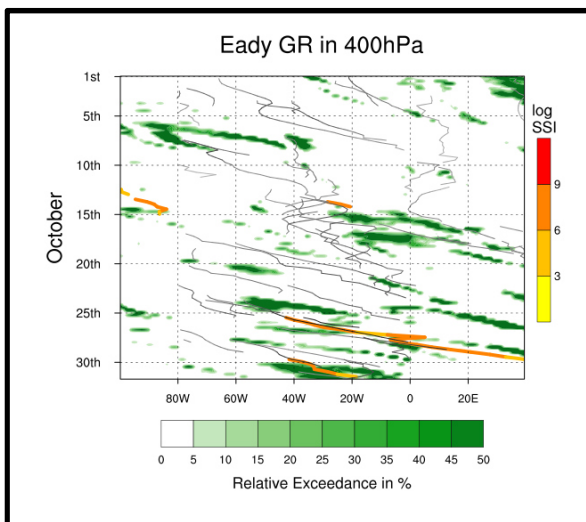


Figure 2: Hovmoeller diagram for October 2013, including “Christian”, 25th-29th Oct. Green: Relative exceedance of 98th percentile of standardized Eady-Growth-Rate (45°-55°N meridional mean) between 500hPa and 300hPa. Lines: Windstorm events with logarithm of Storm Severity Index (SSI, colour, after Leckebusch et al., 2008) between two time steps

Related to the impact of baroclinic instability, we further analyse the relation between mid-tropospheric geopotential waves (from planetary to synoptic scales) and surface wind storms caused by extra-tropical cyclones (Wild et al., 2016b). We use ERA Interim data to 1) identify and track extra-tropical cyclones, 2) identify and track surface wind storms and 3) identify and decompose mid-tropospheric geopotential waves. The aim of this study is to identify distinctive wave lengths, including respective amplitudes and phases, responsible for surface wind storms beyond the existing knowledge about the general influence of short synoptic waves on the generation of surface disturbances. If a (statistical significant) relationship can be firmly established, mid-latitude wave characteristics could be used as a predictor for surface wind storms once a clear triggering mechanism, e.g. via suitable baroclinic instability mechanism, could be diagnosed. This would be

extremely useful for diagnostic studies based on coarse resolution future climate simulations. This work is ongoing and will be continued in the current special project by the PI. A related publication of the results is foreseen in Wild et al. (2016b).

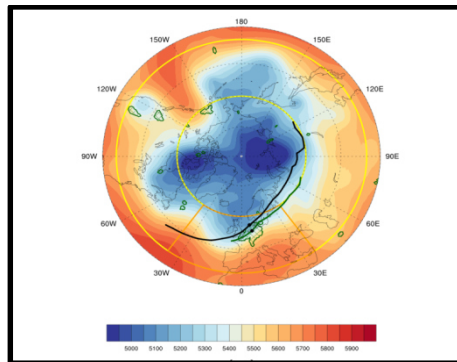


Figure 3: Wind Storm “Christian“ (28th Oct 2013). Shading: geopotential height in 500hPa; green area: exceedances of 98th percentile of 10m wind speed; Green line: wind track (based on 10m wind speed); Black line: cyclone track (based on MSLP)

An excellent test-bed to investigate precursor situations and favourable conditions for extra-tropical storm formation was given in by the extreme winter 2013-14, with an outstanding number of extreme storms hitting the UK. With the wind storm identification and tracking algorithm (cf. Leckebusch et al. (2008) we find an absolute maximum of wind storm occurrence in the eastern North Atlantic including the British Isles in the ERA Interim period from 1979-2014. It has been hypothesized that the extreme number of storms in this particular winter were associated and driven by sea surface temperature anomalies in the tropical West Pacific. Such a mechanism – if existing – would originate in the West Pacific, where anomalously high convective activity would trigger Rossby-Waves in the mid-latitudes. This wave (if locked in the right phase) would cause a reduced number of extra-tropical cyclones in the North East Pacific and cold temperatures over North America. Through cold temperature over the North American continent baroclinicity over the western North Atlantic would increase and eventually cause a higher number of extra-tropical cyclones and wind storms respectively over the eastern North Atlantic and the British Isles.

In winter 2013-14 we find an anomalously low number of extra-tropical cyclones over the eastern North Pacific, very cold temperatures over central North America and the mentioned extreme number of wind storms over the British Isles (see Figure 4). Despite the concurrent occurrence of these events, a statistical robust relationship from the West Pacific via North America to Europe can not be found in the ERA Interim data set. We therefore conclude that the tropical Pacific sea surface temperatures cannot be the major driver of the observed extreme number of wind storms over the eastern North Atlantic and the British Isles in winter 2013-14. These results were submitted for publication and are currently under review (Wild et al., 2015).

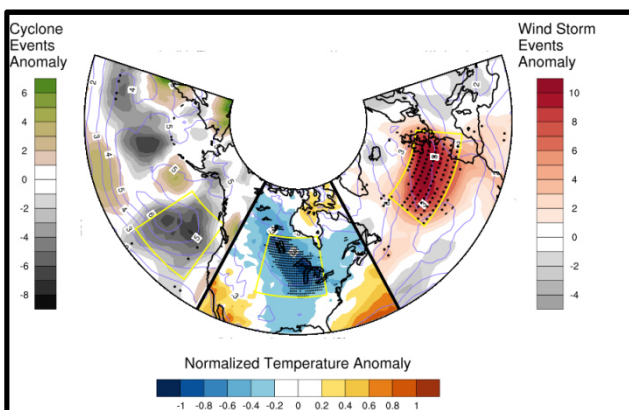


Figure 4: Anomalies for December 2013 - February 2014 compared to long-term climatology (1979-2014) in shadings;

Right: Wind storm events anomaly (in events per season) & interannual standard deviation in contours.

Centre: 2m temperature seasonal normalized anomaly mean.

Left: Cyclone events anomaly (in events per season). Black dots indicate locations where the maximum (minimum) value for wind storm events (2m temperatures, cyclones) appeared in winter 2013-14.

List of publications/reports from the project with complete references

Peer-reviewed Publications:

- Wild, S., D.J. Befort and G.C. Leckebusch, 2015: Was the extreme storm season 2013-14 over the North Atlantic and the United Kingdom triggered by changes in the West-Pacific Warm Pool? [in Explaining Extremes of 2014 from a Climate Perspective]. submitted to Bull. Amer. Meteor. Soc.
- Wild, S., D.J. Befort and G.C. Leckebusch, 2016a: Influence of magnitude and location of tropospheric growth factors for the transformation of cyclones to severe storms over the North Atlantic. in preparation
- Wild, S., I. Simmonds and G.C. Leckebusch, 2016b: Tropospheric mid-latitude geopotential wave characteristics associated with strong wind events in the North Atlantic/European region. in preparation.

Conference contributions:

- Wild, S., D.J. Befort and G.C. Leckebusch, 2015: Structural Variability of Tropospheric Growth Factors Transforming Mid-latitude Cyclones to Severe Storms over the North Atlantic. *EGU2015-11696. EGU General Assembly. Vienna, Austria.*
- Wild, S., I. Simmonds and G.C. Leckebusch, 2015: Tropospheric mid-latitude geopotential wave characteristics associated with strong wind events in the North Atlantic/European region. EGU2015-10537. EGU General Assembly. Vienna, Austria.
- Wild, S., D.J. Befort and G.C. Leckebusch, 2014: Importance of latent heat release for the transformation of cyclones to severe storms over the North Atlantic in dependence of spatial resolution. EMS2014-457. 14th EMS Annual Meeting / 10th ECAC. Prague, Czech Republic.
- Wild, S. and G.C. Leckebusch, 2014: Influence of magnitude and location of tropospheric growth factors for the transformation of cyclones to severe storms over the North Atlantic. EGU2014-11627. EGU General Assembly. Vienna, Austria.
- Wild, S., T. Kruschke and G.C. Leckebusch, 2013: The role of baroclinic instability for the transformation of cyclones to severe storms over the North Atlantic. 3rd European Windstorm Workshop. Exeter, UK.
- Wild, S., T. Kruschke and G.C. Leckebusch, 2013: The role of baroclinic instability for the transformation of cyclones to severe storms over the North Atlantic. EMS2013-583. 13th EMS Annual Meeting / 11th ECAM. Reading, UK.
- Wild, S. and G.C. Leckebusch, 2013: Surface wind storms in relation to mid-tropospheric baroclinicity. EGU2014-853. EGU General Assembly. Vienna, Austria.

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

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Work to this topic will be ongoing in our current special project.
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