Met Office European Windstorm Event Response Services

Presenting Author: **Bernd Becker**

Bernd Becker [1] bernd.becker@metoffice.gov.uk
Paul Maisey [1] paul.maisey@metoffice.gov.uk
Claire Scannell [1] claire.scannell@metoffice.gov.uk
Lorna Mitchell [1] lorna.mitchell@metoffice.gov.uk
Emilie Vanvyve [1] emilie.vanvyve@metoffice.gov.uk
Hamish Steptoe [1] hamish.steptoe@metoffice.gov.uk

1. Met Office, United Kingdom

European windstorms are capable of producing devastating socioeconomic impacts. Specifically, they are capable of causing power outages to millions of people, closing transport networks, uprooting trees, causing walls, buildings and other structures to collapse, which in the worst cases can result in dozens of fatalities. In Europe windstorm presents the greatest natural hazard risk for primary insurers. Although average claims are much smaller for wind peril than for flood, the high volume of claims results in the greatest aggregate loss. In the low loss winter of 2013/2014 alone storms Christian, Xaver, Dirk and Tini cost the insurance industry an estimated EUR 2500m. The Met Office provides leading meteorological hazard insight to reinsurers, insurers, traders and brokers. Services include Windstorm hazard maps for underwriting and portfolio management, historical windstorm footprints and an event set for risk modelling and capital reserving, alerts and impact analysis of incoming storm events for operations and loss forecasting and forecast scenarios with probabilities for trading weather sensitive stocks. Additionally the Met Office can undertake climate and weather impact investigations tailored to specific financial contexts, as well as detailed modelling and analysis following a major event. In this short presentation we will exemplify our product portfolio in the light of the events during the 2014/2015 winter season.

Some of the products that have resulted from windstorm research include a suite of forecasts around a storm event starting with an alert derived from the Met Office ensemble prediction system, MOGREPS. It describes the exceedance of a probability for wind gust thresholds that triggers the production of additional forecasts as early as seven days in advance of a potentially life threatening situation. Subsequent forecasts include a deterministic high resolution forecast of the maximum wind gust footprint over a 3 day period over the European domain at 3–5 day lead times. The rapid response real time analysis over the past 3 days provides a succinct description of the actual storm foot print.

Pattern matching of current or forecast storms against historical windstorms can enable a rapid prediction of likely loss and aid insurers to plan to allow timely deployment of staff and funds at the right level. Contextualizing the storm footprint with respect to hazard maps describing distinct return periods provides an immediate visual interpretation of the severity of the event.

A 4km resolution historical wind storm catalogue describing hourly data of over 6100 storms and a dynamically consistent low resolution event set with over 80000 storms provide comprehensive datasets to further study European wind storm risk in partnership.

Return times, Dispersion and Memory in Extremes of Midlatitude Vorticity

Presenting Author: **Richard Blender**

Richard Blender [1] richard.blender@uni-hamburg.de
Christoph Raible [2] raible@climate.unibe.ch
Frank Lunkeit [1] frank.lunkeit@uni-hamburg.de

1. Meteorological Institute, University of Hamburg
2. Oeschger Centre for Climate Change Research, University of Bern

Mid-latitude cyclones show deviations from a Poisson process at the storm track exits measured by a dispersion index (Mailier et al., 2006). Non-Poisson behaviour is assessed by deviations of the variance-mean ratio (also coefficient of variation or Fano factor) from unity. Therefore, return times are not exponentially distributed, and an essential assumption in extreme event return time statistics is violated. These deviations are explained by serial correlations. An adequate model is the fractional Poisson process (FPP, Laskin, 2003) where the waiting distribution is given by the Mittag-Leffler (ML) function which describes deviations from the exponential function.

We determine the return time distribution of extreme 850 hPa relative vorticity of the ERA interim reanalysis during boreal winter (DJF) and summer (JJA) seasons (Blender, Raible and Lunkeit, 2015). We approximate the ML-function for the waiting distribution in the FPPs by a Weibull distribution which describes deviations from exponential return times by the shape parameter. The shape parameter is related to the dispersion index. In a linear approximation this agrees with results obtained for Lagrangian cyclones. Note that the FPPs yield time-scale dependent means and variances. In the analysis monthly data are compared. Cyclogenesis in the genesis regions is uncorrelated (a Poisson Process) whereas the lysis at the storm track exits is correlated (an FPP).

The shape parameter depends on the memory in the vorticity time series. The memory is determined independently by detrended fluctuation analysis. The correspondence is based on the assumption of a self-similar memory in terms of a power-law in the spectrum where the exponent is related to the shape parameter. The predictability of extreme cyclones is determined by the correlation function with a power-law decay related to the spectrum. The analysis exhibits a concise framework for correlated extremes in terms of FPPs. Deviations from Poisson statistics are fully described by a single parameter, the shape parameter of the non-exponential return time distribution. This parameter yields the dispersion index and the exponent in the correlation function.

The outcome of the present study is based on weak linear deviations from the exponential return time distribution. Note that the single ingredient of the FPPs in this analysis is the waiting time distribution and there is no reference to the fractional arrival equation defining FPPs. The time-scale dependent means and variances of the FPPs allow possible useful interpretations in terms of Taylor’s law (L. R. Taylor, 1961) obtained for population statistics when variances are proportional to powers of the means. Therefore, the results of the available studies could be reconsidered for different time scales.

Extreme Winter Cyclones in the North Atlantic in a CESM1.0.1 Last Millennium Climate Simulation

Presenting Author: **Sandro Blumer**

Sandro R. Blumer [1, 2] blumer@climate.unibe.ch
Christoph C. Raible [1, 2] raible@climate.unibe.ch
Flavio Lehner [1, 2] lehner@climate.unibe.ch
Thomas Stocker [1, 2] stocker@climate.unibe.ch

1. Climate and Environmental Physics, University of Bern, Bern, Switzerland
2. Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland

Extreme cyclones and their associated impacts are a major threat to mankind, as they often result in heavy precipitation events and severe winds. The last millennium is closest to the Anthropocene and has the best coverage of paleoclimatic information. Therefore, it could serve as a test bed for estimating natural forcing variations beyond the recent observational period and could deliver insights into the frequency and intensity of extreme events, including strong cyclones and their dependency on internal variability and external forcing.

The aim of this study is to investigate how the frequency and intensity of extreme cyclones in the North Atlantic have changed in the last millennium, in particular during prolonged cold and warm periods and which changes might be expected for the 21st century.

We use a comprehensive fully-coupled transient climate simulation of the last millennium (AD 1000-2100) with a relatively high spatial (0.9x1.25 degrees) resolution and define six climatic periods according to prolonged cold or warm phases: Medieval Climate Anomaly (MCA), AD 1150-1200, Little Ice Age (LIA), AD 1450-1500, Maunder Minimum (MMI), AD 1645-1720, Historical (HIS), AD 1850-2005, Modern (MOD), 1960-2010 and Projection (PRO), AD 2006-2099. Cyclones are then detected and tracked in 12-hourly output using an algorithm that is based on the geopotential height field on 1000 hPa. Additionally, two intensity criteria for extreme cyclones are defined: the 90 percentile of the mean gradient in geopotential and the 90 percentile of the precipitation within a radius of 500 km around the cyclone centre at every time step during the lifetime of a cyclone. These criteria consider two aspects of cyclone's intensity: extremes in wind and precipitation.

The results show that extremes of North Atlantic winter cyclone intensity are significantly stronger with respect to the geopotential height gradient during prolonged cold periods and weaker during prolonged warm periods. Especially, the projection for the 21st century shows a significant weakening as the mean of the 90 percentile of the geopotential height gradient decreases by 4.1 % from MOD to PRO. This intensification of extreme cyclones during relatively cold periods compared to relatively warm periods can be explained by an increased meridional temperature gradient accompanied by an increased baroclinicity. In contrast, the extremes of winter cyclones with respect to precipitation are weaker in the prolonged cold periods and stronger during warm periods, such that an increase of 4.4 % in the mean of the 90 percentile of total precipitation is estimated from MOD to PRO. This intensification is expected on the basis of the Clausius-Clapeyron relationship.

The downstream impact of extratropical transition of Hurricane Katia (2011)

Presenting Author: **Sandro Blumer**

Sandro Blumer [1, 2] blumer@climate.unibe.ch
Christian Grams [3] christian.grams@env.ethz.ch

1. Climate and Environmental Physics, University of Bern, Bern, Switzerland
2. Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland
3. Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland

Tropical cyclones (TCs) undergoing extratropical transition (ET) can cause high impact weather (HIW) in the vicinity of the ET system and in remote regions. When North Atlantic Hurricane Katia underwent ET in September 2011, severe thunderstorms occurred in Central Europe, several thousands kilometers downstream. This study quantifies the role of Katia in triggering the European HIW, using numerical sensitivity experiments. Results show that Katia was crucial for the evolution of a narrow downstream trough. Large-scale forcing for ascent ahead of this trough acted as a trigger for deep convection. In the absence of ET, no trough was present over Europe and no HIW occurred, although the airmass was similarly warm and humid. This study is one of the first documenting European HIW caused by the downstream impact of North Atlantic ET. It corroborates the crucial role of ET in altering intensity, region, and timing of HIW in downstream regions.

Impact of Arctic Sea Ice on Circulation Patterns, Planetary and Baroclinic Waves

Presenting Author: **Berit Crasemann**

Berit Crasemann [1] berit.crasemann@awi.de
Dörthe Handorf [1] doerthe.handorf@awi.de
Klaus Dethloff [1] klaus.dethloff@awi.de1
Ralf Jaiser [1] ralf.jaiser@awi.de
Hiroshi Tanaka [2] tanaka@ccs.tsukuba.ac.jp
Tetsu Nakamura [3, 4] nakamura.tetsu@ees.hokudai.ac.jp
Jinro Ukita [5] jukita@env.sc.niigata-u.ac.jp

1. Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research, Research Unit Potsdam, Germany
2. Center for Computational Sciences, University of Tsukuba, Japan
3. National Institute of Polar Research, Tachikawa, Japan
4. Hokkaido University, Sapporo, Japan
5. Niigata University, Niigata, Japan

Arctic amplification and recent Arctic sea ice decline affect the meridional temperature gradient between Equator and North Pole and consequently the mid-latitude circulation patterns. Many studies have used re-analysis data sets such as ERA-Interim and NCEP in order to investigate and quantify the influence of decreasing sea ice on the atmospheric circulation.

In this study, we have additionally made use of AGCM for Earth Simulator (AFES4.1) sensitivity experiments with different sea ice conditions in the Arctic. One sensitivity experiment uses the monthly averaged SST/ICE for a five year period from 1979-1983 (high ice, “CNTL”), the second experiment uses the SST/ICE conditions for 2005-2009 (low ice, “NICE”). The model has a resolution of T79L56 (model top at 60km), uses fixed greenhouse gases, O3, aerosols and solar incident. Each model simulation is a perpetual run over 60 years.

First of all, we have analysed the impact of Arctic sea ice and zonal wind on the instability rates and amplitude of planetary and baroclinic waves using a spectral primitive equation model derived by a orthonormal basis of vertical structure functions and Hough functions. Generally, the most unstable modes exist in the synoptic domain at wave numbers 6-8. These modes appear in the middle troposphere with a wave amplitude maximum at 40-50°N and are related to synoptic scale cyclones. In periods with enhanced zonal winds, we observe higher growth rates on the planetary scale and lower growth rates on the synoptic scale. Further, the amplitude maxima on the synoptic and planetary scales increase and their meridional extension gets smaller. The energy of vertical and meridional modes as a function of zonal wave numbers also differs among phases with low and high ice conditions.

In order to focus on the synoptic scale processes, we have applied a cluster analysis for the simulated daily SLP data fields for low and high ice phases. The cluster analyses have been performed in a reduced state space spanned by the leading EOFs (empirical orthogonal functions). We will present the detected changes in the structure and frequency of occurrence of preferred circulation patterns and subsequent changes of storm tracks.

What factors govern the magnitude and variability of moisture transport to Antarctica?

Presenting Author: **Helen Dacre**

Helen Dacre [1] h.f.dacre@reading.ac.uk
Victoria Sinclair [2] Victoria.Sinclair@helsinki.fi

1. University of Reading, UK
2. University of Helsinki, Finland

The variability in Antarctic ice mass is strongly linked to increasing or decreasing precipitation accumulation over the continent. Since a large fraction of the precipitation in Antarctica is associated with extratropical cyclones, variations in Antarctic precipitation may be due to variability in the number of cyclones reaching Antarctica, variability in the meridional transport of moisture by individual cyclones or to a combination of the two. Whilst changes in the number of cyclones over Antarctica due to shifts in the position of the SH storm track have been the subject of several studies, few have investigated variability in the meridional transport of moisture by individual cyclones. In this presentation we investigate the factors controlling the magnitude of moisture transported by southern hemisphere cyclones and their impact on moisture transport to Antarctica.

Modelling dependency in extremal windstorm footprints

Presenting Author: **Laura Dawkins**

Laura Dawkins [1] lcd206@exeter.ac.uk
David Stephenson [1] D.B.Stephenson@exeter.ac.uk
Ken Mylne [2] ken.mylne@metoffice.gov.uk

1. University of Exeter, UK
2. Met Office, UK

Windstorms are one of the most destructive natural hazards in Europe. Each windstorm has an associated footprint, defined as the maximum 3 second wind-gust to occur at each location in the domain in the 72 hour period covering the passage of the storm. The most damaging historical windstorms have had footprints with differing characteristics, some have a large area of low wind-gust speeds while others have a smaller area of higher wind-gust speeds.

A statistical model for the windstorm footprint has been developed to investigate which of these characteristics is most important for determining the loss a windstorm will cause. The initial step was to develop a bivariate model, which must have the potential to be extended to model the entire footprint, and must be able to represent realistic joint losses.

The bivariate distribution of damaging wind-guts at two locations can be represented by the marginal distributions of wind-gusts and their mutual dependence, explained by a copula. Extreme value theory is used to fit the marginal distributions and an appropriate copula model is selected after investigating the extremal dependence between wind-gusts at pairs of locations. Comparing the empirical joint probability of loss with those calculated using the model validates the ability for the model to represent realistic joint losses.

The left-truncated Generalised Extreme Value distribution is used for the margins and the Gaussian copula explains the dependence in the model, which is found to successfully represent realistic joint losses, and is relatively simple to extend using Geostatistics.

High resolution weather models for storm simulations: uncertainty of results and impact on loss simulations

Presenting Author: **Silke Dierer**

Silke Dierer [1, 2]
Peter Stucki [3, 4]
Stefan Brönnimann [3, 4]

1. Meteotest, Bern, Switzerland
2. Axis, Zurich, Switzerland
3. Oeschger Centre for Climate Change Research, Univ. Bern, Bern, Switzerland
4. Institute of Geography, Univ. Bern, Bern, Switzerland

High resolution weather models are used for storm forecasting, simulating regional wind climatologies, delivering atmospheric input for impact studies or calculating hazard maps in vendor catastrophe models. Today's weather models allow simulations at grid sizes of 1-3 km and, thus, achieve a reasonable representation of the surface wind field. But even moderate errors of the simulated wind field can be amplified when performing loss simulations. The current study aims at estimating the difference of losses calculated based on wind field simulations using different initial and boundary data and model setups that are equally suitable.

Surface winds are strongly influenced by synoptic conditions, mesoscale processes and local characteristics of the environment. The model setup, e.g. grid size and parameterizations, needs to be adapted to the study region and the focus of your study. Additionally, different initial and boundary data might be available for the simulation. There is usually a range of possible set ups for model simulations that show equally good results when compared to observations. Still, the simulated wind fields might differ significantly and the errors of simulated losses are often amplified.

The impact of the model setup on loss simulations is studied based on sensitivity studies for storm Lothar and other storm events. The storm is simulated using the weather model WRF with a grid size of 3 km for Switzerland. The simulations are driven by the 20CR ensemble mean as initial and boundary conditions. Sensitivity studies are performed using 20CR ensemble members, GFS forecasts and NCAR reanalysis as initial and boundary data. Additionally, the model setup is changed, e.g. PBL scheme, resolution and start time before the event. Furthermore, different gust parameterizations are applied. The storm footprint is calculated for every simulation. They are used as input for idealized loss simulations that are performedfor an idealized exposure distribution in Switzerland using a schematic vulnerability curve. Simulated losses and their spatial distribution are compared and it is discussed how changes of initial and boundary conditions or model setup affect the loss simulations.

How extreme can storms get in space and time?

Presenting Author: **Theodoros Economou**

Theodoros Economou [1] t.economou@exeter.ac.uk
David Stephenson [1] d.b.stephenson@exeter.ac.uk
Christopher Ferro [1] c.a.t.ferro@exeter.ac.uk

1. University of Exeter

Extreme North Atlantic extra-tropical cyclones are a major source of risk for society. These natural hazards cause much damage and insurance loss in Europe due to extreme wind speeds and flooding. An important scientific question therefore is: how extreme can these cyclones become? Unlike hurricanes, there are no simple thermodynamic arguments for the minimum pressure achievable by extratropical cyclones. In the absence of reliable physical arguments, we use a statistical model to provide an answer to this question. The challenges in implementing such a model include: 1) Extremal storm properties vary spatio-temporally, 2) events occur irregularly in space and 3) events are rare in many regions.

A Bayesian extreme value model is used to characterise storm sea-level pressure subceedances below the local 0.1 quantile, using tracks of extra-tropical cyclones over the Atlantic and Europe. The storm tracks were objectively identified using an appropriate tracking algorithm from 6-hourly NCEP re-analyses data in 1979–2009. The statistical model allows for spatial variability in the extreme storm pressures but also for the possible effect of the North Atlantic Oscillation (NAO) on the extremal parameters. The NAO is found to have a significant effect on intensifying extremal storm behaviour, especially over Northern Europe and the Iberian peninsula. Estimates of lower bounds on minimum sea-level pressure are typically 10–50 hPa below the minimum values observed for historical storms with largest differences occurring when the NAO index is positive.

An example of extratropically transitioning storms – Hurricane Gonzalo

Presenting Author: **Frauke Feser**

Frauke Feser [1] frauke.feser@hzg.de
Monika Barcikowska [2]
Susanne Haeseler [3]
Christiana Lefebvre [3]
Martina Schubert-Frisius [1]
Martin Stendel [4]
Hans von Storch [1]
Matthias Zahn [1]

1. Institute for Coastal Research, Helmholtz-Zentrum Geesthacht, Geesthacht, Germany
2. Princeton Environmental Institute, Princeton University, NJ, USA
3. German Meteorological Service, Hamburg, Germany
4. Danish Climate Centre, Danish Meteorological Institute, Copenhagen, Denmark

A new atmospheric global climate model simulation which was spectrally nudged towards Reanalysis data is used to analyze extratropically transitioning storms. The strong hurricane 'Gonzalo' which occurred in October 2014 is used as a case study. It was a category 4 hurricane that formed east of the Leeward Islands, passed Bermuda and then transitioned to an extratropical cyclone next to Newfoundland. It then crossed the North Atlantic and headed for Europe where it caused several fatalities, storm surges, large damages and power outages. The storm showed a track length which is among the highest 10% for such storms during the last decades. Also Gonzalo's intensity was very high for large parts of his existence. Extratropical transition increased only marginally during the last decades, both in our climate model simulation and in other studies, but large year-to-year variability can be seen. Even though some small changes over time were found, the storm is still within the expectations of an undisturbed climate and cannot be attributed to climate change.

Representation of storm clustering in the Impact Forecasting European windstorm model

Presenting Author: **Alexandros Georgiadis**

Alexandros Georgiadis [1] alexandros.georgiadis@aonbenfield.com
Radovan Drinka [2] radovan.drinka@aonbenfield.com
Aidan Brocklehurst [1] aidan.brocklehurst@aonbenfield.com
Adam Podlaha [1] adam.podlaha@aonbenfield.com
Melanie K. Karremann [3] mkarre@meteo.uni-koeln.de
Joaquim G. Pinto [3, 4] j.g.pinto@reading.ac.uk

1. Aon Benfield Impact Forecasting, UK
2. Aon Benfield Impact Forecasting, Czech Rebublic
3. Institute for Geophysics and Meteorology, University of Cologne, Germany
4. Department of Meteorology, University of Reading, UK

Intense windstorms are the primary natural hazard affecting Western and Central Europe. Aon Benfield Impact Forecasting has recently developed a novel European windstorm model in close collaboration with academic partners. The hazard component of the windstorm model includes a combination of historical storm events and synthetic events based on a large-ensemble of present-climate GCM simulations (~ 4,700 years). A Storm Severity Index is used to identify high activity days and rank them based on their intensity. The top 12,000 events (~ 2.5 per year) are implemented in the model as a stochastic event set. Overall, the distribution of number of events per year in the stochastic event set compares well with the observed storm distribution from ERA-interim reanalysis data.

Identified stochastic event set biases regarding the storm intensities and storm frequencies are calibrated against the historical NCEP reanalysis record. In this calibration, the extracted events retain their original position in the simulated seasons as generated by the GCM, i.e., they are not pooled and resampled into stochastic seasons. The overarching aim is to preserve the spatial and temporal structure of both clustering and the intensity ranking as represented in the GCM in the final stochastic event set. The adjusted annual frequencies of the stochastic years are calibrated with help of a weather typing approach.

The impact of this novel approach on the modeled losses is discussed with a focus on exceedance probability curves of the annual aggregate loss. The difference between the annual exceedance probability (AEP) and the occurrence exceedance probability (OEP) indicates the relative contribution of single large events to the annual aggregate loss at different return periods. The difference between the AEP and OEP curves peaks between five and ten years return periods, and then slowly decreases for longer return periods. A comparison of the position of the modelled AEP against a synthetic AEP where the storms are pooled and sampled using a Poisson distribution is performed. Differences peak between five and ten years return period with values in a range between 5 and 8% of the GCM clustered AEP.

A simple benchmark model for European Windstorm Losses

Presenting Author: **Leoncini Giovanni**

Giovanni Leoncini [1] giovanni.leoncini@aspen-re.com

1. Aspen Re

This work describes the development and usage of a simple benchmark model to estimate market losses due to European windstorm damage. First, events were identified using a modified version of the tracking methodology of Leckebush et al 2008 applied to the ERA Interim gusts. Then, a loss index was obtained following Klawa and Ulbrich 2003: simply multiplying population within a ERA-I grid cell times a Storm Severity Index. This loss index was then calibrated using loss estimates from the XWS project for specific storms. Different version of the index were tested to assess the sensitivity of the index to loss indexation and different formulations of the SSI. Because of the large uncertainties different realistic versions of the loss index were used to provide a range of possible losses. Finally, the index was used to evaluate vendor catastrophe models.

A novel metric to assess the “extremeness” of cyclones

Presenting Author: **Christian M. Grams**

Christian M. Grams [1] christian.grams@env.ethz.ch
Stephan Pfahl [1] stephan.pfahl@env.ethz.ch
Heini Wernli [1] heini.wernli@env.ethz.ch

1. Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland

Mid-latitude high impact weather (HIW) is often caused by extratropical cyclones. Despite the overall progress in the representation of the general large-scale mid-latitude flow, the correct prediction of individual cyclones, their track, structure and intensity, and their associated HIW is still a challenge for general circulation models.

In this project we explore a novel metric to assess the extremeness of cyclones. In a feature-based approach, extremeness of an individual cyclone is defined as the accumulated area along the track affected by extreme 2m temperature, precipitation, or 10m windgust. Grid-point based thresholds are used to determine the local extremeness of these surface variables. Moreover, general cyclone properties are traced along the cyclone tracks. The diagnostic is applied to all objectively identified cyclones in the ERA-Interim reanalyses (1979-2013).

Globally the most extreme cyclones are predominantly tropical cyclones undergoing extratropical transition. Focusing on Europe, extreme cyclones tend to be more intense, have a stronger deepening rate, form further equatorward, and track more in meridional direction than non-extreme cyclones. It is further demonstrated that a combination of cyclone properties derived from sea level pressure alone is a useful predictor for accumulated extremeness.

This novel feature-based diagnostic and database enables further investigations of the role of cyclones in triggering HIW in different world regions, e.g. stratified by cyclone properties, type of extremes, or cyclone categories.

Pfahl, S., and Wernli, H., 2012. Quantifying the relevance of cyclones for precipitation extremes, J. Climate, 25, 6770–6780, doi:10.1175/JCLI-D-11-00705.1. 429, 430

Wernli, H., Schwierz, C., 2006: Surface cyclones in the ERA40 data set (1958-2001). Part I: novel identification method and global climatology. *J. Atmos. Sci.*, 52, 2486-2507

The impact of tropical cyclones undergoing extratropical transition on the midlatitude flow: a refined view unifying the composite and case study approach

Presenting Author: **Christian M. Grams**

Christian M. Grams [1] christian.grams@env.ethz.ch
Heather M. Archambault [2]

1. Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland
2. NOAA Climate Program Office, Silver Spring, MD, USA

Tropical cyclones (TCs) undergoing extratropical transition (ET) may cause high-impact weather in the vicinity of the transforming TC and in regions far downstream. The remote impact of ET is governed by downstream Rossby wave dispersion. In this study we explore the general characteristics of ET and its role in modifying the midlatitude flow. Composites of the twelve strongest western North Pacific ET cases in September are constructed based on an objective TC–extratropical flow interaction metric, and used as initial data for a control simulation and a simulation representing the environmental background flow. These simulations are investigated in the potential vorticity (PV) perspective with combined Eulerian and Lagrangian diagnostics.

The midlatitude flow modification occurs in three stages, resulting in a highly amplified Rossby wave train: (1) Preconditioning, (2) TC–extratropical flow interaction, and (3) downstream flow amplification. In each stage diabatic outflows are involved. Although these diabatic outflows are associated with the ascent in different weather systems (i.e., a Predecessor Rain Event, the TC/ET itself, and a warm conveyor belt; WCB), they originate from the same basic physical process and have a similar impact on the upper-level flow. In each case, latent heating in ascending warm, moist air results in diabatically enhanced transport of lower-tropospheric low-PV air to the tropopause. When impinging on the upper-level midlatitude tropopause-level waveguide, a jet streak forms and a ridge builds. Air parcels ascending in the TC/ET reach 150 hPa and experience a latent heating of 49 K. On the other hand, WCB outflow only reaches 255 hPa after a latent heating of 33 K. The results of this study corroborate the crucial role of diabatic processes in modifying the upper-level midlatitude flow.

Archambault, H. M., L. F. Bosart, D. Keyser, and J. M. Cordeira, 2013: A Climatological Analysis of the Extratropical Flow Response to Recurving Western North Pacific Tropical Cyclones. *Monthly Weather Review*, **141**, 2325–2346, doi:10.1175/MWR-D-12-00257.1.

——, D. Keyser, L. F. Bosart, C. A. Davis, and J. M. Cordeira, 2015: A Composite Perspective of the Extratropical Flow Response to Recurving Western North Pacific Tropical Cyclones. *Monthly Weather Review*, **143**, 1122–1141. doi:10.1175/MWR-D-14-00270.1.

Grams, C. M., and Coauthors, 2011: The key role of diabatic processes in modifying the upper-tropospheric wave guide: a North Atlantic case-study. Q.J.R. Meteorol. Soc., 137, 2174–2193, doi:10.1002/qj.891.

——, S. C. Jones, and C. A. Davis, P. A. Harr, and M. Weissmann, 2013: The impact of Typhoon Jangmi (2008) on the midlatitude flow. Part I: Upper-level ridgebuilding and modification of the jet. Q.J.R. Meteorol. Soc., 139, 2148–2164, doi:10.1002/qj.2091.

Predictability and variability of sting jets in extreme windstorms.

Presenting Author: **Suzanne Gray**

Neil Hart [1] n.c.hart@rdg.ac.uk
Suzanne Gray [1] s.l.gray@rdg.ac.uk
Peter Clark [1] p.clark@rdg.ac.uk

1. Department of Meteorology, University of Reading

Sting jets are mesoscale transient jets that descend from the tip of the cloud head towards the boundary layer top in some extreme windstorms. They can lead to strong surface winds and gusts either directly, or
indirectly though enhancement of an underlying cold conveyor belt jet. Detailed published case studies of several sting jet storms affecting the UK and northern Europe, including the Great storm of October 1987,
windstorm Jeanette (2002), windstorm Gudrun (2005) and windstorm Friedhelm (2011), have revealed much about the characteristics of these storms and their associated sting jets. However, the predictability of this mesoscale feature in convection-parameterizing forecasts and the associated potential variability in sting jet characteristics given the synoptic-scale environment are unknown. Hence the reliability of the
sting jet risk predicted by global forecasts at lead times of a several days is poorly understood.

Here we evaluate the variability of sting jet characteristics in ensemble forecasts of three recent sting jet storms from the winter of 2011-12 (windstorms Robert, Friedhelm and Ulli). Despite similar cyclone evolutions there are large spreads in the timing, strength and even existence of sting jets within each ensemble. The three storms also generate sting jets with different characteristics. Characteristics of descent into the strongest wind regions are quantified and the relationships with convective and inertial instabilities are assessed.

Clustering and stalling of extratropical cyclones: their influence on extreme precipitation in the UK.

Presenting Author: **Suzanne Gray**

Ruari Rhodes [1] r.rhodes@pgr.rdg.ac.uk
Len Shaffrey [1] l.c.shaffrey@rdg.ac.uk
Suzanne Gray [1] s.l.gray@rdg.ac.uk

1. Department of Meteorology, University of Reading

Extreme precipitation can be described as that leading to flooding. The timescale of extreme precipitation will thus depend on the size of a river catchment and so can range from days to a month or more. Here we determine the effect of the clustering and stalling of extratropical cyclones on extreme precipitation in the UK. Previous studies have demonstrated that extratropical cyclones and their associated fronts are the dominant source of extreme precipitation in the midlatitudes. Other studies have shown that clustering of these cyclones occurs at the end of storm tracks.

Here we quantify the role of clustering and stalling on extreme UK precipitation. When analysing the relationship of regional precipitation to its parent cyclone it is insufficient to simply consider the cyclone's region of influence as a fixed radius from its centre due to the asymmetric nature of the associated fronts and rainbands. A new method is presented that uses objective feature tracking and the spatial extent of precipitation in gridded datasets to associate extreme rainfall observations to cyclones in model output. This method is applied using ERA-Interim reanalysis data and total precipitation accumulations over England and Wales. Cyclone counts and residence times are used to assess the degree of clustering and stalling of cyclones respectively for a range of accumulation periods. Extreme precipitation is found to be
preferentially associated with stalling on shorter (several days) timescales and clustering on longer (weeks) timescales. Clustering is also found to be preferentially associated with strong upper-level jets extending into Europe.

Winter windstorms during the last millennium and their relationship to NAO and AMV

Presenting Author: **Jens Grieger**

Jens Grieger [1] jens.grieger@met.fu-berlin.de
Mareike Schuster [1] mareike.schuster@met.fu-berlin.de
Ines Höschel [1] ines.hoeschel@met.fu-berlin.de
Uwe Ulbrich [1] ulbrich@met.fu-berlin.de

1. Institute of Meteorology, Freie Universität Berlin, Berlin, Germany

In the present study we analyze the variability of winter windstorms of the northern hemisphere in different model simulations, using an objective identification and tracking methodology, and their relation to different phases of the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Variability (AMV). Therefore, we investigate one millennium simulation with the MPI-ESM and two simulations of ECHAM6 that have been forced with positive (warm) and negative (cold) phases of the AMV.

In this investigation, the NAO is calculated by means of a principle component analysis of both, sea-level pressure (psl) and geopotential height in 500hPa (zg500). Analyzing 50 year sub-periods over the last millennium, the pattern of the NAO shows variability, especially regarding the location of the southern center of action, which is related to the high pressure system. This variability and also the response of winter windstorms is analyzed systematically for all three model simulations, i.e. with and without AMV forcing. Further, the windstorms are being matched to cyclones and the characteristics of windstorm producing cyclones, e.g. genesis, are assessed in all the simulations.

Exploring nearly on-in-a-millennium scenarios of extreme rainfall through dynamically downscaling palaeoclimatic simulations

Presenting Author: **Juan Jose Gómez-Navarro**

Juan José Gómez-Navarro [1, 2] gomez@climate.unibe.ch
Christoph Raible [1, 2] raible@climate.unibe.ch
Sandro Blumer [1, 2] blumer@climate.unibe.ch
Martina Messmer [1, 2] messmer@climate.unibe.ch
Olivia Martius [1, 3] olivia.martius@giub.unibe.ch

1. Oeschger Centre for Climate Change Research
2. Climate and Environmental Physics, Physics Institute, University of Bern
3. Department of Geography, University of Bern

Extreme precipitation is a natural phenomenon that can lead to severe flooding and is a threat to human activities, especially in areas densely populated such as Switzerland. On the one hand, the climatic characterization, i.e. severity, frequency and spatial distribution of such events, is important to design public policies that protect public assets and private property and allow reinsurance companies to accurately estimate the risks, being prepared to cover such unlikely eventualities. On the other hand, the study of such events can lead to process understanding, which is eventually needed to develop reliable projections about the behaviour of such situations under ongoing climate change.

Still, the study of extreme situations is hampered by the fact that they are, by definition, very rare. A proper characterization of such events, like one-in-a-century storms, is limited by the relatively short instrumental period, which limits the available datasets and forces the extrapolation of data. This study proposes a new approach that allows studying storms based on a synthetic, but physically consistent database of whether situations obtained from a very long climate simulation. This is, an 800-year simulation carried out with a comprehensive Earth System Model (ESM) is used as a surrogate of the real climate.

We use the CESM1 model run with a spatial resolution of 1 degree. However, this resolution is not fine enough to reproduce realistically the spatial structure and severity of extreme precipitation events in the Alpine area, so this dataset is dynamically downscaled with the Weather Research and Forecasting model (WRF) to a final resolution of 2 km. However, simulating the 800 years generated by the ESM at such high resolution is infeasible nowadays. Hence, a number of case studies are previously selected. This selection is carried out examining the precipitation averaged in an area encompassing Switzerland in the ESM. Precipitation is accumulated in several temporal windows: 1 day, 2 days, 3 days, 5 days and 10 days. The 4 most extreme events in each category and season are selected. This leads to a total of 336 days to be simulated. Hence, the worst case simulated corresponds to a one-in-eight-centuries scenario, and so on.

Clearly, this database of extreme rainfalls cannot be used as is, since the framework of the ESM simulation followed by dynamic downscaling has to be corrected in terms of systematic biases prior applying the results back in the real world. Hence, a 20-year climatic simulation with the same configuration in both models is carried out. The comparison of the climate reproduced by this simulation and that derived from an independent simulation driven by ERA Interim is used to estimate the biases of the model chain. Finally, quantile mapping is applied, which allows removing systematic biases in the case studies and make the simulated rainfall comparable to reality.

To Warn or not to Warn: That is the risky question! Perspectives on uncertainty in weather warnings.

Presenting Author: **Martin Göber**

Martin Göber [1, 4] Martin.Goeber@dwd.de
Thomas Kox [2, 4] Thomas.Kox@fu-berlin.de
Tobias Pardowitz [3, 4] Tobias.Pardowitz@fu-berlin.de

1. DWD
2. Hans-Ertel-Centre for Weather Research (HErZ)
3. Forschungsforum Öffentliche Sicherheit, FU-Berlin
4. Inst. f. Meteorologie, FU-Berlin

Numerical and statistical models and the forecasters experience provide the meteorological signal for the prediction of severe weather events. The signal is often weak, yet it must be decided, whether to issue a warning in order to trigger protective actions to mitigate the damage from severe weather. We present results from the transdisciplinary project WEXICOM on meteorological and linguistic aspects of uncertainty from the verification of operational wind warnings and about dealing with this uncertainty from surveys with emergency services and the public.

Subjective and statistical forecasts of the probability of the occurrence of severe weather events for the city of Berlin were verified. Human estimates of the probability for the occurrence of thunderstorms and wind gusts in Berlin were found to be reliable and possess significant skill in comparison to the statistical reference forecast. Additionally, the verbal description of warning uncertainty in an operational textual warning report was classified and objectively verified. Results indicate that forecasters actually are aware of the inherent uncertainty, yet express this by means of a multitude of verbal terms. In order to improve the communication and reduce confusions arising from linguistic uncertainty inherent to severe weather information, forecasts should thus contain few and well defined verbal phrases expressing forecast uncertainty.

Different dimensions of risk perception on people’s decision to take protective measures against natural hazards were investigated in a representative online survey within the Berlin population. It revealed that affective variables such as fear of severe weather and confidence in weather forecasts showed a significant effect on people’s decision to take protective action. Contrary, high experience of natural hazards did not necessarily lead to action.

In a survey with emergency services it was investigated, how weather warnings are communicated to professional end-users in the emergency community and how the warnings are converted into mitigation measures. Results show that the emergency service personnel who participated in this survey generally have a good appreciation of the uncertainty of weather forecasts. Although no single probability threshold could be identified for organisations to start with preparatory mitigation measures, it became clear that emergency services tend to avoid forecast based on low probabilities as basis for their decisions. Results suggests that when trying to enhance weather communication by reducing the uncertainty in forecasts, the focus should not only be on improving computer models and observation tools, but also on the communication aspects.

Recent changes in Northern Hemisphere cyclone activity in ERA-Interim data and ECHAM6 simulations and their associations with Arctic sea-ice changes

Presenting Author: **Dörthe Handorf**

Benjamin Segger [1] benjamin.segger@posteo.de
Fabian Kremser [1] kremser@uni-potsdam.de
Dörthe Handorf [1] doerthe.handorf@awi.de
Christoph C. Raible [2] raible@climate.unibe.ch
Richard Blender [3] richard.blender@uni-hamburg.de
Jin-Song von Storch [4] jin-song.von.storch@mpimet.mpg.de
Klaus Dethloff [1] klaus.dethloff@awi.de
Ralf Jaiser [1] ralf.jaiser@awi.de

1. Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, D-14473 Potsdam, Telegrafenberg A43, Germany
2. Climate and Environmental Physics, Physics Institute, University of Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland
3. Universität Hamburg, Center for Earth System Research and Sustainability (CEN), Meteorological Institute, Grindelberg 5, D-20144 Hamburg, Germany
4. Max Planck Institute for Meteorology, Bundesstr. 53,D-20146 Hamburg, Germany

Recent changes in the large scale Northern Hemisphere (NH) autumn and winter circulation have been related to declining Arctic sea ice in late summer and continental snow-cover changes in autumn. Here we study the changes in NH cyclone activity in recent years and their associations to Arctic sea-ice retreat.

To analyse the cyclone activity (characterized by cyclone center and track density) an adapted version of the cyclone tracking tool by Blender et al. (1997) and Raible et al. (2008) has been applied to ERA-Interim data from 1979-2008. Furthermore, the ability of the atmospheric general circulation model ECHAM6 for reproducing the climatology and variability of cyclone activity have been proven by analysing an AMIP-style run of ECHAM6 with high resolution of T255. This run has been carried out in the framework of the STORM project. Whereas ECHAM6 is able to reproduce the large-scale structure and the annual cycle of the main storm tracks, the number of detected cyclones and the spatial variability is larger as for the ERA-Interim data.

In order to investigate the association of changes in NH cyclone activity with Arctic sea-ice changes the differences of cyclone characteristics between periods with high and low sea-ice concentration have been studied. For ERA-interim data, during the summer months of the low sea-ice period less cyclones pass the Arctic Ocean accompanied by increased cyclone activity over Siberia. In the following winter a southward shift and changes in the strength of the storm tracks have been estimated for the low-ice period. For ECHAM6, these changes in cyclone activity between periods with high and low sea-ice concentration have not been simulated. To get insight into the physical reasons for this mismatch between reanalysis and model simulation, differences in surface heat fluxes, vertical static stability, and meridional temperature gradients have been analysed in more detail.

Blender, R., K. Fraedrich, and F. Lunkeit, 1997: Identification of cyclone-track regimes in the North Atlantic. Quart. J. Roy. Meteor. Soc., 123, 727–741.

Raible, C. C., P. M. Della-Marta, C. Schwierz, H. Wernli, and R. Blender, 2008: Northern Hemisphere extra-tropical cyclones: A comparison of detection and tracking methods and different reanalyses. Mon. Wea. Rev., 136, 880–897.

Cyclonic Windstorms – Morphology, Model Representation and Predictability

Presenting Author: **Tim Hewson**

Tim Hewson [1] tdh878@aol.com

1. ECMWF, UK

Under the auspices of the IMILAST project (Intercomparison of MId-LAtitude STorm diagnostics) 29 damaging European cyclonic windstorms have been examined in detail, using observational evidence as the main tool. Indeed this focussed study has been the culmination of work performed over a period of about 15 years.

From the above a detailed yet malleable conceptual model of windstorm evolution has been constructed. This model usefully has its roots in the evolution one sees on standard synoptic charts, and highlights that three types of damage footprint can be associated at the surface. Building on previous work these are referred to (in chronological order) as the warm jet, the sting jet and the cold jet footprints. The jet phenomena themselves each relate to the proximity of fronts on the synoptic charts, and accordingly occur in airmasses with different stability characteristics. These characteristics seem to play a large role in determining the magnitude of surface gusts, and how those gusts vary between coastal and inland sites. These aspects will be discussed with examples, showing that one cannot simply characterise or rank cyclones using wind strength on a lower tropospheric level such as 850hPa. A key finding that sets the sting jet apart, and that makes it a particularly dangerous phenomena, is that gust magnitude is relatively unaffected by passage inland, and this seems to relate to the atmosphere in its environment being destabilised from above. For sting jets wind strength may be greatest below 850hPa. Evaporation can play a role in some cases in enhancing sting jet gusts at the surface, though does not appear to be a *necessary* feature.

Unfortunately neither current generation global re-analyses, nor global climate models seem to be able to simulate sting jets. This is for various reasons, though their low resolution is key. This limitation has been recognised previously, and the standard way to address this has been to use a re-calibration technique. The potential pitfalls of this approach will be highlighted using the aforementioned windstorm set to illustrate. Based again on case studies it will be shown that spatial resolution in a numerical model needs to be of order 10-20km to capture most major windstorms. However even then some of the smaller systems, which can be equally damaging, will be missed.

Using two past case examples the presentation will also show how an understanding of the new conceptual model, and of the underlying physical processes, can genuinely help to improve real-time forecasts.

The downstream impact of extratropical transition from an eddy kinetic energy perspective

Presenting Author: **Julia H. Keller**

Julia H. Keller [1] julia.keller@dwd.de

1. Deutscher Wetterdienst (DWD), Offenbach, Germany

The extratropical transition (ET) of a tropical cyclone (TC) may strongly impact the midlatitude flow by amplifying or triggering a Rossby wave train. Thus, such an event also has the potential of facilitating cyclogenesis and associated high impact weather events in regions lying far downstream of the transitioning TC.

The processes involved in the transition of the TC and its interaction with the midlatitude flow are often not well represented in numerical weather prediction (NWP) systems. This frequently leads to a reduction in predictability for downstream regions, which at the same time may be affected by extreme weather events. A better understanding of the important processes and their representation in NWP systems will help to overcome those issues in predictability.

This talk will introduce the impact of ET events on the midlatitude flow and its predictability, and will present some recent research highlights. In particular, a study will be introduced that aims on identifying the impact of a transitioning TC, acting as an additional source of kinetic energy, on the modification of the midlatitude flow and the associated forecast uncertainty. We employ ECMWF ensemble forecasts to obtain multiple solutions for the interaction of two transitioning TCs with the midlatitude flow. By determining the sensitivity of the amplifying downstream wave train to the eddy kinetic energy (Ke) budget within the ensemble, the role of the ET in modifying the midlatitude flow configuration can be identified. Specific features of the Ke budget associated with the transitioning cyclone are found to have a significant impact on the amplification of the downstream wave train, while the Ke budget of the upstream midlatitude flow seems to be of secondary importance. We further seek to also link the identified dependencies to predictability in downstream regions.

The pivotal nature of merger and splitting in the cyclone life cycle

Presenting Author: **Sarah Kew**

Sarah Kew [1] sarah.kew@wur.nl
Rodrigo Caballero [2]
John Hanley [3]
Masaru Inatsu [4]

1. Wageningen University, The Netherlands
2. Stockholm University, Sweden
3. Munich Re, Germany
4. Hokkaido University, Japan

The merger and splitting of cyclones are potentially pivotal events in the cylone life cycle. They can be of critical importance in rapidly consolidating or isolating a vortex and may therefore be implicated in the rapid intensification of a storm. A merger or splitting event may also literally serve as a pivot with regard to the direction of motion or changes to the properties of a cyclone. Recent work by Hanley and Caballero suggests a frequent association of both merger and splitting with intense, mature storms. They also claim that multi-centre cyclones occur more frequently as storm intensity increases, with an associated increase in the probability of spurious splittings by single-centre tracking algorithms.

Of the cyclone tracking algorithms contributing to the IMILAST (Intercomparison of mid-latitude storm diagnostics) project, three explicitly handle cyclone merger and splitting. We explore what each approach has to offer and if merger or splitting indeed has an impact on intensity in the cyclone life cycle. We also investigate whether cyclone tracks and diagnostics generated by different cyclone tracking algorithms (including those that do not explicitly handle merger or splitting or multi-centre cyclones) show sensitivity related to the pivotal nature of merger and splitting events.

Sensitivity analysis of Serial Clustering of Extra tropical Cyclones and Wind Storms in Europe

Presenting Author: **Nicolas Kirchner-Bossi**

Nicolas Kirchner-Bossi [1] n.o.kirchnerbossi@bham.ac.uk
Daniel J. Befort [1] D.J.Befort@bham.ac.uk
Gregor C. Leckebusch [1] G.C.Leckebusch@bham.ac.uk

1. School of Geography, Earth and Environmental Sciences, University of Birmingham, United Kingdom

Economic losses over Europe are mostly associated with strong extra-tropical cyclones and their related surface near wind fields. Thus, the year-to-year variability of the aggregated frequency of these events is of special importance, especially for re-insurance industries.

Former studies analysed serial clustering of cyclones from a monthly to seasonal perspective using reanalysis data as well as global climate simulations. These findings indicate that stronger cyclones are more clustered than weaker cyclones. However, damages are not directly related to the location and pathway of the core pressure of the cyclone but to the occurrence of maxima in the accompanying wind field.

In this study, serial clustering of wind storms is compared to clustering of cyclones over the Northern Hemisphere during the extended winter season (October to March). In contrast to cyclones, which are identified e.g., based on the Laplacian of mean sea level pressure, wind storms are identified by large-scale wind fields exceeding the local 98th percentile of surface near (10m) wind speed. We investigate the sensitivity of derived clustering information in dependency of the applied identification algorithm.

Following the approach firstly published by Mailier et al. (2006), we find an over-dispersion over Iceland and the Iberian-Peninsular for both, wind storms and all cyclones. However, only the over-dispersion over Iceland is found for the 5% strongest cyclone events. The wind-based clustering analysis reveals in comparison to other studies additional areas over e.g., Western Europe, which could be subject to clustering of extreme damage related events. This documents the value of additionally investigating the clustering of wind field derived tracks in addition to the clustering of cyclone tracks.

A millennium simulation-based NAO+ loss scenario incorporated in an insurance loss model

Presenting Author: **Ivan Kuhnel**

Ivan Kuhnel [1] ikuhnel@corelogic.com

1. CoreLogic EQECAT, France

One of the most important parameters for the determination of an insurance premium is the Annual Average Loss (AAL). Its value is a function of the severity, frequency and location of the respective peril. Moreover, frequencies of storms tend to be a function of the period over which they are evaluated. In the case of extra-tropical storms in the European region, the length of this period does not exceed more than fifty years. To obtain an alternative view on the activity of the most severe storms and their frequencies, in their latest version of the Eurowind model CoreLogic EQECAT have drawn additional information from a Millennium simulation of the historical (800-2000) climate using an Earth System Model.

While very long, millennium-scale, time series tend to give more robustness to the evaluation of the characteristics of storm activity, there may also be sufficiently long and persistent periods within this system in which the characteristics of the storm activity changes. This, in turn, has an impact on the return periods of the respective storms and the AAL estimates for these particular periods. It is the storm characteristics of these sub-decadal periods CoreLogic EQECAT investigated in more detail in order to see whether it may add any value to the area of loss estimation.

One of the higher-mode climatic oscillations in the millennium system is the North Atlantic Oscillation (NAO), which is known to have a substantial influence on the storm activity in the North Atlantic-European sector. The hundred and more NAO cycles observed in the millennium simulation have been combined to a mean winter NAO+ composite and the respective data subset evaluated with regard to changes in storm severity, frequency and location. From that an experimental mean winter NAO+ scenario has been build, incorporated into a loss insurance model and evaluated with regard to its impact on losses. The procedure underlying this experimental NAO+ scenario and its impact on losses will be discussed.

Spatial improvement of a wind gust scheme for extreme winter storms

Presenting Author: **Charles-Antoine Kuszli**

Charles-Antoine Kuszli [1] charles-antoine.kuszli@unige.ch
Stéphane Goyette [1] stephane.goyette@unige.ch
Ana Gago-Silva [1] ana.gagodasilva@unige.ch

1. Institute for Environmental Sciences, University of Geneva, Switzerland

Wind gusts associated to severe winter storms are simulated at a high resolution over Switzerland with a spatially optimized gust diagnostics scheme implemented within the Canadian Regional Climate Model (CRCM). The most severe winter storms in the 1990-2010 period are dynamically downscaled from NCEP-NCAR reanalysis data to a 2 km grid spacing at which a novel approach for the parameterization of gustiness is performed. The developed gust diagnostic schemes are optimally calibrated with respect to the observations provided by the SwissMetNet network of MeteoSwiss. The novel methods aim at improving over the gust diagnostics operationally in use in Switzerland within the COSMO-2 model, by relaxing a previously constant parameter (α) in the horizontal and computing locally its optimal value regarding the recorded patterns for gustiness. Optimization methods are developed for estimating the spatial distribution of α during stormy conditions, in particular the cokriging interpolation with respect to terrain-related explanatory variables. The corresponding maps for α are integrated into new online gust diagnostic schemes at high resolution, that are evaluated against the state-of-the-art gust schemes. The application of this methods to three specific storms show the ability of the approach to improve the dynamical models for wind gusts by adjusting the variability range of gustiness accordingly to the observed velocities during severe storms. As expected, the spatialization of the parameter α improves in most cases the gust diagnostics performance at the hourly or daily scales as compared with the orginal scheme. Some of the novel methods also compete with the more sophisticated scheme, while at a lower computational cost. Cokriging methods based on explanatory variables are shown to perform worse than simple kriging for the studied storms. Also, optimization methods based on 3-days gusts maxima perform better than hourly-optimized methods that tend to create excessive variability.

Predictability of Extra-tropical Cyclones and Windstorms on Seasonal Timescales

Presenting Author: **Gregor Leckebusch**

Gregor C. Leckebusch [1] g.c.leckebusch@bham.ac.uk
Daniel Befort [1]
Simon Wild [1]
Antje Weisheimer [2]
Julia Roberts [3]
Hazel Thornton [3]
Jeff Knight [3]
Leon Hermanson [3]
Philip Bett [3]

1. University of Birmingham, UK
2. ECMWF
3. Met Office, UK

Severe damages and large insured losses over Europe related to natural phenomena are mostly caused by extra-tropical cyclones and their related windstorm fields. Thus, an adequate representation of these events in seasonal prediction systems and reliable forecasts up to a season in advance would be of high value for society and economy. In this study, state-of-the-art seasonal forecast prediction systems are analysed (ECMWF, Met Office) regarding the general climatological representation and the seasonal prediction of extra-tropical cyclones and windstorms during the core winter season (DJF) with a lead time of up to four months.

Cyclones are identified using six hourly mean sea level pressure data, whereas wind storms are tracked based on 6 hourly 10m wind speed (ECMWF) and 12 hourly wind speeds in 925hPa (ECMWF & Met Office). Thus, these analyses gain a deeper insight into the representation of extra-tropical cyclones and their related wind storm fields in state-of-the-art seasonal forecasting suites. Spatial distributions of both wind storm and cyclone events show the well known centres of activity observed in ERA40 & ERA-Interim reanalyses data. However, large biases are found for some areas.

The skill of the different forecast systems is assessed using deterministic as well as probabilistic measures (e.g., Ranked Probability Skill Score (RPSS), Brier Skill Score (BSS), and Anomalous Correlation Coefficient (ACC)). Statistics are carried out for a hemispheric perspective as focussed on several sub-regions (e.g. Northern Europe).

Results reveal small, but positive skill for the North-Atlantic / European region as well as for the North-Pacific region depending on the model suite and variable investigated. Principle reasons for positive skill (predictability) for extreme wind storm frequency are discussed.

Future projections of North Atlantic explosive cyclones simulated by the EC-Earth model

Presenting Author: **Margarida Liberato**

Margarida Liberato [1, 2] mlr@utad.pt
Victoria Gil [2] vealfonso@fc.ul.pt
Isabel Trigo [2, 3] isabel.trigo@ipma.pt
Ricardo Trigo [2] rmtrigo@fc.ul.pt

1. Escola de Ciências e Tecnologia, Universidade de Trás-os-Montes e Alto Douro, UTAD, Vila Real, Portugal
2. Instituto Dom Luiz, Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal
3. Instituto Português do Mar e da Atmosfera, IPMA, Lisboa, Portugal

Extreme windstorms are one of the major natural catastrophes in the extratropics, representing one of the most costly natural hazards in Europe and are often responsible for substantial economic damages, as well as several human fatalities. Cyclones which undergo strong intensification within a short time range are of special interest due to their low predictability and hence difficulty in issuing timely early warning. Cyclones with deepening rates of at least (24*sinϕ/sin60º) hPa in 24 hours are referenced in the literature as explosive cyclogenesis/developments or simply as "bombs".

Over the Euro-Atlantic region mature extratropical cyclones typically undergo the maximum intensification phase over the North Atlantic Ocean, propagate eastward and reach Europe, where they impinge a dominant influence on local weather. Occasionally, these fast moving systems can reach western Europe with outstanding wind strength, causing widespread damage and often human fatalities, such as the recent cases of storms Klaus (2009; Liberato et al. 2011), Xynthia (2010; Liberato et al. 2013) and Gong (Liberato 2014).

The analysis of storm characteristics presented here is based on the objective cyclone detecting and tracking algorithm developed by Trigo (2006). The response of extratropical explosive cyclogenesis in the North Atlantic to climate change is analysed by means of 7 ensemble members of EC-EARTH model from CMIP5. We restrict the analysis to a relatively small subset (7 members) of the total number of ensemble members available in order to take into account only the members present in the three (historical, RCP4.5 and RCP8.5) experiments. The standard procedure is then applied by comparing a common 25-year period: (i) for recent climate conditions from ERA Interim Reanalysis (ECMWF) to historical (control period) simulations (1980-2004); and (ii) for historical and future climate simulations (2074-2098) forced by RCP4.5 and RCP8.5 scenarios. All stormtrack databases are built over the Northern Hemisphere, spanning the winter season from December to March.

Results show that the EC-Earth historical runs compare well in terms of identifying the cyclogenetic regions as well as the minimum pressure patterns, even though they underestimate the values when comparing to ERA Interim Reanalysis data. These results hold for different categories of cyclones including explosive cyclones. Future scenarios obtained with RCP4.5 and RCP8.5 ensemble means suggest that the current pattern will change slightly, with less explosive storms occurring near Iceland.

Acknowledgements: This work was partially supported by FEDER funds through COMPETE programme and by national funds through FCT under project STORMEx FCOMP-01-0124-FEDER-019524 (PTDC/AAC-CLI/121339/2010).

References:

Liberato MLR (2014) Weather and Climate Extremes, doi: 10.1016/j.wace.2014.06.002

Liberato MRL, et al. (2011) Weather 66: 330-334. doi: 10.1002/wea.755

Liberato MLR, et al. (2013) Nat Hazards Earth Syst Sci 13: 2239-2251. doi: 10.5194/nhess-13-2239-2013

Trigo IF (2006) Clim. Dynam., 26: 127-143. doi: 10.1007/s00382-005-0065-9

Probabilistic prediction of extreme storm surges in Venice

Presenting Author: **piero lionello**

riccardo mel [2] riccardo.mel@dicea.unipd.it
piero lionello [1] piero.lionello@unisalento.it

1. DISTEBA (Dipartimento Scienze e Tecnologie Biologiche e Ambientali, University of Salento, Lecce, Italy
2. Department of Ingegneria Idraulica Marittima Ambientale e Geotecnica, University of Padua, Italy

A probabilistic prediction procedure is described and applied to storm surge forecast for Venice, where an accurate and fully informative prediction of sea level (SL) is needed for operating the movable barriers that are presently being built to close the inlets of the lagoon. An operational procedure based on ensemble prediction forecast (EPF) and has been carried out both covering a three month period (from 1st October to 31st December 2010) and selecting a set of 10 high events that occurred in 2010. Storm surge computation is based on the HYPSE model, which is a standard single-layer nonlinear shallow water model, whose equations are derived from the depth averaged momentum equations. The forcing of HYPSE is provided by the 50 ensemble members of the ECMWF meteorological EPS (ensemble prediction system) producing in this way a corresponding EPF of storm surge. These simulations are integrated with a high resolution meteorological forecast (DF), a control run forecast (CRF, which differs from the deterministic forecast for it lower meteorological fields resolution), and a hindcast, where HYPSE is driven by the ECMWF analysed fields. Results are analyzed considering the EPS spread, the rms of the simulations, the Brier Skill Score and are compared to observations at tide gauges distributed along the Croatian and Italian coast of the Adriatic Sea. It is shown that the ensemble spread is indeed a reliable indicator of the uncertainty of the storm surge prediction. Further, results show how uncertainty depends on the predicted value of sea level and how it increases with the forecast time range. The accuracy of the ensemble mean forecast is actually larger than that of the deterministic forecast, though the latter is produced by meteorological forcings at higher resolution.

Analysis of synoptic conditions leading to positive and negative sea level extremes along the coast of the Mediterranean Sea

Presenting Author: **piero lionello**

piero lionello [1, 2] piero.lionello@unisalento.it
dario conte [2] dario.conte@cmcc.it
marco reale [3] mcreal82@hotmail.com

1. DiSTeBA, University of Salento, via per Monteroni, Lecce, Italy
2. CMCC, Centro Euromediterraneo per i Cambiamenti Climatici, Lecce, Italy
3. OGS, Istituto Nazionale di Geofisica e Oceanografia Sperimentale, Trieste , Italy

The obvious association (largely based on the paradigm of the inverse barometric effect) is that a cyclone increases sea level and an anticyclone decreases it. This contribution shows that in the Mediterranean Sea, this concept often does not represent the actual phenomenology. The relation between cyclone and sea level anomalies in the Mediterranean Sea is explored using a 44 year simulation of sea level and considering 9 locations (Toulon, Alicante, Trieste, Dubrovnik, Thessaloniki, Gabes, Tripoli, Iskendur, Alessandria) distributed along the whole coast of Mediterranean Sea. In Toulon, Alicante, Trieste, Dubrovnik observed time series were available for validating model results. It is found that in many stations negative sea level extremes are, in fact, associated to cyclones, because of the redistribution of water inside this semi-enclosed basin when a large SLP gradient is applied at its surface. Further, over shallow water areas an intense high pressure system can determine a surface wind circulation causing negative sea level. For instance, among the considered stations, in Alicante, Toulon and Trieste negative sea level extremes are associated to cyclones over the Ionian Sea, in Dubrovnik, Thessaloniki, Gabes, Tripoli, Iskendur, Alessandria to cyclones over the western Mediterranean Sea. These results explain why both positive and negative sea level extremes have been found to decrease their intensity in future climate scenarios (Conte and Lionello, 2013), when cyclones in the Mediterranean regions are projected to become less frequent than presently.

Conte D., P. Lionello ,2013 Characteristics of large positive and negative surges in the Mediterranean Sea and their attenuation in future climate scenarios , Global and Planetary Change 111:159-173, ISSN 0921-8181, DOI:10.1016/j.gloplacha.2013.09.006

Storminess trends in the Northern Mediterranean Sea from the analysis of one among the longest wave gauge time series in the world

Presenting Author: **piero lionello**

angela pomaro [1] angela.pomaro@ismar.cnr.it
luigi cavaleri [1] luigi.cavaleri@ismar.cnr.it
piero lionello [2, 3] piero.lionello@unisalento.it

1. National Research Council Institute of Marine Sciences CNR-ISMAR, Venice, Italy
2. DiSTeBA, University of Salento, via per Monteroni, Lecce, Italy ,
3. CMCC, Centro Euromediterraneo sui Cambiamenti Climatici, Lecce, Italy

Multi-decadal time-series of observational wave data are relatively rare and potentially very relevant for assessing trends and characteristics of marine storminess. The present study analyses the 36-year long directional wave time-series recorded between 1979 and 2014 at the CNR-ISMAR "Acqua Alta" oceanographic tower, located in the Northern Adriatic Sea, 16 km offshore the Venice lagoon, on 16 m depth. The analysis suggests a positive trend of the significant wave height (SWH) monthly 50th percentile, larger during the cold season (September to March) than in the rest of the year. Positive trends are present also considering the frequency of data exceeding higher SWH values, such as the 90^{th} and 95^{th} percentiles, but are not confirmed if higher SWHthresholds (e.g. 4 meters) are considered. Correlation with the large scale north hemisphere teleconnection patterns has been computed for the North Atlantic Oscillation (NAO), East Atlantic Pattern (EA), East Atlantic/West Russia Pattern (EA/WR) and Scandinavian Pattern (SCA). Results show the important role of NAO, SCA and EA/WR in winter and of EA in summer.

The use of hindcasts to assess European windstorm risk

Presenting Author: **Paul Maisey**

Paul Maisey [1] paul.maisey@metoffice.gov.uk
Bernd Becker [1] bernd.becker@metoffice.gov.uk
Lorna Mitchell [1] lorna.mitchell@metoffice.gov.uk
Hamish Steptoe [1] hamish.steptoe@metoffice.gov.uk
Claire Scannell [1] claire.scannell@metoffice.gov.uk
Emilie Vanvyve [1] emilie.vanvyve@metoffice.gov.uk
Julia Roberts [1] julia.roberts@metoffice.gov.uk

1. Met Office, United Kingdom

Anecdotally it has been suggested that damage from extra-tropical cyclones accounts for 60% of the insured losses caused by weather over Europe in an average year. Whilst this figure could be debated, what is less in doubt is that many stakeholders in the insurance industry have a significant interest in understanding the frequency and likelihood of extreme storm events.

One of the most intuitive ways of assessing the risk from extreme windstorms is to calculate the maximum wind that can be expected at a specific location or over a region for a given return period. This approach could be of benefit to insurers looking to accurately assess and price individual or aggregated risk.

Based on a high-resolution multi-year hindcast covering a limited domain over Europe, Hazard Maps have been created for different return periods. Extreme value analysis (EVA) is applied at all points in the domain using a peaks-over-threshold approach. The implications of adjusting the threshold and the independence of events within the hindcast period are analysed in developing the methodology. The results have been verified against observed data spanning the same period as the hindcast and show a small underestimation of wind speed and gust relative to observations. Techniques for recalibrating the results are discussed.

To assess the potential extremes in future storm risk it is necessary to extend analysis of windstorms beyond the historical record. Event Sets are a method employed by catastrophe modellers to extend the recorded distribution and represent more extreme storms. Met Office ensemble model data has been used to create an Event Set, using all the storms generated by all the ensemble members to represent possible scenarios. The use of a numerical model constrains the events to ensure that they are all dynamically realistic. Work to apply the events to a timeline for use by the insurance industry will be discussed.

Sensitivity of high-impact weather events associated with jet streaks to changes in latent heat and longwave radiation

Presenting Author: **Oscar Martinez-Alvarado**

Oscar Martinez-Alvarado [1, 2] o.martinezalvarado@reading.ac.uk
Tobias Selz [3] tobias.selz@lmu.de
George Craig [3] george.craig@lmu.de
Suzanne Gray [2] s.l.gray@reading.ac.uk

1. National Centre for Atmospheric Science - Atmospheric Physics, United Kingdom
2. Department of Meteorology, University of Reading, United Kingdom
3. Ludwig-Maximilians-Universität Munich

Recent work has shown the importance of diabatic processes and longwave radiation in determining upper-tropospheric features, such as the amplitude of Rossby waves and the sharpness of the tropopause. These upper-level features determine the dynamics of tropopause level structures, such as the intensity and life cycle of jet streaks. In turn, jet streaks are important factors in the generation of high-impact weather near the surface, influencing extratropical cyclones' life cycles and potentially leading to events of enhanced wind and precipitation. Therefore, accurate forecast of these high-impact events heavily rely on the accuracy of numerical models to represent the environmental effects of diabatic processes and longwave radiation.

In this contribution we establish the sensitivity of a high-impact weather event, linked to the presence of a jet streak at upper levels, to latent heat release and longwave radiation. The work focuses on a case study, consisting of a heavy precipitation event that led to flooding over parts of the UK on 24-25 June 2007. In the first part of this study, we investigate the sensitivity of intensity and life cycle of the jet streak to changes in latent heat release and longwave radiation in two numerical models. In the second part of the study we use diabatic tracing analysis to quantify the environmental effects of latent heat release and longwave radiation in terms of circulation and cross-isentropic motion. Finally we use the results from the first two parts to outline a process-based link between changes in latent heat release and longwave radiation, the jet-streak intensity and duration and the downstream effects in terms of precipitation intensity.

Joint occurrence of precipitation and wind extremes

Presenting Author: **Olivia Martius**

Olivia Martius [1] olivia.martius@giub.unibe.ch
Stephan Pfahl [2]
Clément Chevalier [3]

1. University of Bern, Switzerland
2. ETH Zürich, Switzerland
3. University of Zürich, Switzerland

Strong storms can be associated with damaging winds but also with significant amounts of precipitation. This has consequences for the modelling of these two hazards, namely they can not be treated as being independent and the combined effects of strong winds and large amounts of precipitation can exacerbate the associated impacts. Here the combined occurrence of extreme winds and extreme precipitation is analysed for the Euro-Atlantic sector based on the ERA-interim reanalysis data set using a logistic regression approach. The co-occurence of wind and precipitation extremes is statistically significant for almost all areas of Europe but there is substantial spatial variation in the fraction of joint extremes. Joint wind and precipitation extremes are most frequent along the Atlantic coast and in the eastern Mediterranean.

Past, present and future impact of Vb-cyclones on extreme precipitation over Central Europe

Presenting Author: **Martina Messmer**

Martina Messmer [1, 2] messmer@climate.unibe.ch
Juan José Gómez-Navarro [1, 2] gomez@climate.unibe.ch
Christoph C. Raible [1, 2] raible@climate.unibe.ch

1. Climate and Environmental Physics, Physics Institute, University of Bern, Bern, Switzerland
2. Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland

Cyclones, which develop over the western Mediterranean and move northeastward, are a major source of extreme weather and responsible for heavy precipitation over Central Europe. However, despite their importance, the relevant processes triggering these so-called Vb-events and their impact on extreme precipitation are not yet fully understood. Gaining insight into these processes is crucial to improve the projection of changes in frequency and severity of Vb-driven extreme events under future climate change scenarios.

To identify prominent Vb-situations, this study applies a cyclone detection and tracking tool to the ERA-Interim reanalysis (1979-2013). Results indicate that although Vb-cyclones are rare events (2.3/year), they are present in around 15% of all extreme precipitation days (99 percentile) over the Alpine region during the analysed period. Still, only 23% of all Vb-events are associated with extreme precipitation, indicating high variability in precipitation amounts across these events. Thus, we further explore this variability and show that a major parameter in triggering heavy precipitation in such events is the large-scale dynamics, while the thermodynamic state of the atmosphere seems to be of secondary importance. Thus, precipitation amounts are closely linked to the intensity of the Vb-cyclone, although it is important to note that the impact they produce is rather local and strongly dependent on the interaction between the large-scale circulation and the complex orography around the Alps.

The impact of climate change on Vb-events is also explored in this contribution. It can affect such events mostly through two mechanisms: changes in the thermodynamic state of the atmosphere through global warming, or shifts in the large-scale circulation that leave a footprint in the trajectory and intensity of Vb-cyclones. To obtain a first glance on the changes associated to modifications in the thermodynamic processes during Vb-events under climate change, we perform a number of sensitivity experiments to assess the role of the Sea Surface Temperature (SST) and its contribution to the moisture content in the atmosphere. For this, we use the regional climate model WRF, which allows simulating a physical consistent response of Vb-cyclones to different SSTs, leaving the dynamical component of the problem fix through experiments. The changes in SST are designed to follow the expected temperature changes in a future climate scenario, also considering the uncertainty in such projections. The regional climate model allows simulating explicitly the diabatic processes and the influence of the Alps, which are of major relevance for the Vb-cyclones. Preliminary results indicate that an increase of up to 3 °C is needed to noticeably influence the precipitation amounts delivered over Central Europe during Vb-events. This indicates a non-linear response to the SST warming, and is in broad agreement with the previous finding indicating that thermodynamic state only plays a secondary role in triggering precipitation during Vb-events. Future studies will address the influence of climate change on the large-scale dynamics, and how this modifies the trajectory and depth of Vb-cyclones. For this, we will compute and analyse a number of transient simulations driven by comprehensive Earth System Models run under climate change scenarios.

Maps of windstorm risk in Switzerland

Presenting Author: **Stefan Müller**

Stefan Müller [1] stefan.mueller@meteotest.ch
Silke Dierer [1, 2] sdierer@web.de
Peter Stucki [3] peter.stucki@giub.unibe.ch
Olivia Romppainen-Martius [3] olivia.romppainen@giub.unibe.ch
Stefan Brönnimann [3] stefan.broennimann@giub.unibe.ch

1. Meteotest, Bern, Switzerland
2. Axis, Zürich, Switzerland
3. Institute of Geography and Oeschger Centre for Climate Change Research, University of Bern, Switzerland

Knowledge about wind extremes in the past is important in order to estimate potential loss and damage to buildings, forests or lake ecosystems, or to revise construction standards. The aim of the project was to create gust maps for different return periods for Switzerland.

Creating highly resolved information about winter storm events in the past is a challenging task. One important reason is that wind measurements are usually not available for a sufficiently long time period. The Twentieth Century Reanalysis (20CR, Compo et al. 2011) data set offers new opportunities, as it covers a period of the last 140 years.

Still, the resolution of the 20CR data set is too coarse for estimating storm damages to structures or forests. Thus, downscaling of 20CR reanalysis data is applied to a selection of the strongest 90 winter windstorm events in Switzerland since 1859. The 90 storm events are downscaled to a grid size of 3 km for the region of Switzerland using the numerical weather model WRF. To calculate wind gusts based on the model results, several gust parameterizations were evaluated.

The gust speeds of each of the 90 high-resolution windstorm event simulations were used as a basis to calculate extreme gusts for different return periods by applying extreme value statistics at every model grid point. The final result is a map of gusts for different return periods for Switzerland and an uncertainty estimate for the map. The total uncertainty contains estimations for the selection of the windstorms from the storm catalog, the downscaling of the 20CR with WRF and the extreme value statistics and is aggregated to a total uncertainty for each grid point of the map.

Comparisons with extreme gust calculations at locations of measurement stations show an agreement in the order of 5 m/s in the flatlands and rise to 7 m/s in moderate mountain area and up to 20 m/s for exposed Alpine locations for the 50 year return period. Regional wind patterns are in agreement compared to an existing map of reference dynamic pressure used for building constructions.

Vortex-vortex interaction between Hurricane Nadine (2012) and an Atlantic cutoff dropping the predictability over the Mediterranean

Presenting Author: **Florian Pantillon**

Florian Pantillon [1, 2] florian.pantillon@kit.edu
Jean-Pierre Chaboureau [1] jean-pierre.chaboureau@aero.obs-mip.fr
Evelyne Richard [1] evelyne.richard@aero.obs-mip.fr

1. Laboratoire d\'Aérologie, University of Toulouse and CNRS, France
2. Institute of Meteorology and Climate Research (IMK-TRO), Karlsruhe Institute of Technology (KIT), Germany

Operational ensemble forecasts for the western Mediterranean exhibited high uncertainty while Hurricane Nadine was slowly moving over the eastern North Atlantic in September 2012. The forecasts showed a bifurcation in the track of Nadine – a significant fraction predicting its landfall over the Iberian Peninsula – and a high spread in the synoptic conditions downstream. The forecast uncertainty was a major issue
for planning observations during the first special observation period (SOP1) of the Hydrological cycle in Mediterranean eXperiment (HyMeX). Clustering the ensemble forecast of the European Centre for Medium-Range Weather Forecasts reveals two scenarios for the interaction between Nadine and an Atlantic cutoff, which controls both the track of Nadine and the synoptic conditions downstream. The observed scenario of weak interaction is characterized by Nadine moving westward and the cutoff moving eastward. The cutoff then triggers precipitation over the Cévennes in southeastern France. The contrasting scenario of strong interaction is characterized by Nadine and the cutoff rotating around each other over the Atlantic. Nadine then either merges with the cutoff or makes landfall over the Iberian Peninsula. The interaction between Nadine and the cutoff mimics the vortex-vortex interaction previously observed between two tropical cyclones or two upper-level vortices. It differs from the usual interaction
between a tropical cyclone and a larger trough during extratropical transition. A critical distance of about 1000 km between Nadine and the cutoff distinguishes the cases of weak and strong interaction in the ensemble forecast. Shifting the initial position of Nadine in Meso-NH numerical experiments confirms the critical distance and suggests a bifurcation point in the relative position of Nadine and the cutoff. The high forecast sensitivity to the vortex-vortex interaction resulted in the lowest predictability over the
Mediterranean during the whole HyMeX SOP1.

Return periods of losses associated with European windstorm series in a changing climate

Presenting Author: **Joaquim G. Pinto**

Joaquim G. Pinto [1, 2] j.g.pinto@reading.ac.uk
Melanie K. Karremann [2] mkarre@meteo.uni-koeln.de
Mark Reyers [2] mreyers@meteo.uni-koeln.de
Matthias Klawa [3] matthias.klawa@deutscherueck.de

1. Department of Meteorolgy, University of Reading, UK
2. Institute for Geophysics and Meteorology, University of Cologne, Cologne, Germany
3. DeutscheRück AG, Düsseldorf, Germany

During the last decades, several windstorm series hit Europe leading to large aggregated losses. Such storm series are examples of serial clustering of extreme cyclones, presenting a considerable risk for the insurance industry. Clustering of events and return periods of storm series affecting Europe are quantified based on potential losses using empirical models. Moreover, possible future changes of clustering and return periods of European storm series with high potential losses are quantified. Historical storm series are identified using 40 winters of NCEP reanalysis data (1973/1974 - 2012/2013). Time series of top events (1, 2 or 5 year return levels) are used to assess return periods of storm series both empirically and theoretically. Return periods of historical storm series are estimated based on the Poisson and the negative binomial distributions. Additionally, 800 winters of ECHAM5/MPI-OM1 general circulation model simulations for present (SRES scenario 20C: years 1960– 2000) and future (SRES scenario A1B: years 2060– 2100) climate conditions are investigated. Clustering is identified for most countries in Europe, and estimated return periods are similar for reanalysis and present day simulations. Future changes of return periods are estimated for fixed return levels and fixed loss index thresholds. For the former, shorter return periods are found for Western Europe, but changes are small and spatially heterogeneous. For the latter, which combines the effects of clustering and event ranking shifts, shorter return periods are found everywhere except for Mediterranean countries. These changes are generally not statistically significant between recent and future climate. However, the return periods for the fixed loss index approach are mostly beyond the range of preindustrial natural climate variability. This is not true for fixed return levels. The quantification of losses associated with storm series permits a more adequate windstorm risk assessment in a changing climate.

Robustness of serial clustering of extra-tropical cyclones to the choice of tracking method

Presenting Author: **Joaquim G. Pinto**

Joaquim G. Pinto [1, 2] j.g.pinto@reading.ac.uk
Sven Ulbrich [2] sulbrich@meteo.uni-koeln.de
Melanie K. Karremann [2] mkarre@meteo.uni-koeln.de
David B. Stephenson [3] D.B.Stephenson@exeter.ac.uk
Theodoros Economou [3] t.economou@exeter.ac.uk
Len C. Shaffrey [4] l.c.shaffrey@reading.ac.uk

1. Department of Meteorolgy, University of Reading, UK
2. Institute for Geophysics and Meteorology, University of Cologne, Cologne, Germany
3. College of Engineering, Mathematics and Physical Sciences, University of Exeter, UK
4. NCAS Climate, Department of Meteorolgy, University of Reading, UK

Cyclone families are a frequent synoptic weather feature in the Euro-Atlantic area in winter. Given appropriate large-scale conditions, the occurrence of such series (clusters) of storms may lead to large socio-economic impacts and cumulative losses. Recent studies analyzing Reanalysis data using single cyclone tracking methods have shown that serial clustering of cyclones occurs on both flanks and downstream regions of the North Atlantic storm track. This study explores the sensitivity of serial clustering to the choice of tracking method. With this aim, the IMILAST cyclone track database based on ERA-interim data is analysed. Clustering is estimated by the dispersion (ratio of variance to mean) of winter (DJF) cyclones passages near each grid point over the Euro-Atlantic area. Results indicate that while the general pattern of clustering is identified for all methods, there are considerable differences in detail. This can primarily be attributed to the differences in the variance of cyclone counts between the methods, which range up to one order of magnitude. Nevertheless, clustering over the Eastern North Atlantic and Western Europe can be identified for all methods and can thus be generally considered a robust feature. The statistical links between large-scale patterns like the NAO and clustering are obtained for all methods, though with different magnitudes. We conclude that the occurrence of cyclone clustering over the Eastern North Atlantic and Western Europe is largely independent from the choice of tracking method and hence from the definition of a cyclone.

The importance of Atmospheric Rivers in the development of explosive cyclogenesis in the North Atlantic basin

Presenting Author: **Alexandre M. Ramos**

Alexandre M. Ramos [1] amramos@fc.ul.pt
Jorge Eiras-Barca [2] jorge.eiras@usc.es
Margarida L.R. Liberato [1, 3] mlr@utad.pt
Gonzalo Miguez-Macho [2] gonzalo.miguez@usc.es
Ricardo M. Trigo [1] rmtrigo@fc.ul.pt

1. Instituto Dom Luiz, Faculty of Sciences, University of Lisbon, Portugal
2. Non-Linear Physics Group, Faculty of Physics, Universidade de Santiago de Compostela, Galicia, Spain
3. School of Sciences and Technology, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal

In the North Atlantic Ocean, rapid extratropical cyclone deepening occur frequently. When these deep low pressure systems struck Western Europe the extreme wind and precipitation associated can inflict major socio-economic impacts, such as extensive property damage and life losses. Cyclones with deepening rates of at least (24*sin φ / sin 60º) hPa in 24 hours, where φ represents latitude in degrees of the cyclone centre position, are referenced in the literature as explosive cyclogenesis / developments or simply as “bombs”. An objective cyclone detecting and widely used tracking methodology (Trigo, 2006) is applied to ECMWF ERA-Interim reanalyses to build a dataset of extra-tropical cyclones over the Euro-Atlantic sector spanning from 1979 to 2014. From this dataset, a sub-set of explosive cyclones is selected for further analysis.

To the best of our knowledge no previous work has evaluate the link between ARs occurrence and intense deepening rates associated to explosive cyclogenisis. Zhu and Newell in 1994, identified a few cases when an extratropical cyclone is penetrated by an AR, and where the cyclone centre moves closer to the leading edge of the AR prior to a rapidly deepening phase.

ARs are identified as narrow plumes of enhanced moisture transport that are usually present in the core section of the broader warm conveyor belt occurring over the oceans along the warm sector of extra-tropical cyclones. They are usually W-E oriented steered by pre-frontal low level jets along the trailing cold front and subsequently feed the precipitation in the extra-tropical cyclones. The large amount of water vapour that is usually transported in ARs can lead to heavy precipitation and if persistent in time or amplified by near coastal orography can lead to floods when they make landfall.

An automated AR detection algorithm for the North Atlantic Ocean basin, based on ERA-Interim reanalyses from 1979 to 2014, is used to identify the ARs that are present in the region regardless of making landfall over Europe or not.

The main objective of this work is to analyse systematically the importance of the ARs on the development of extratropical cyclones, with special emphasis on the explosive cyclogenesis. The two different databases (explosive cyclogenesis and AR) are analysed simultaneously in order to study the importance of the ARs in the different stages of the explosive cyclogenesis in the North Atlantic basin.

Results confirm the link between these two phenomena on the North Atlantic Ocean, while showing that in some cases the explosive development is not associated with the presence of ARs, particularly for events of explosive cyclogenesis that occurs at higher latitudes.

Trigo I.F. (2006) Climatology and interannual variability of storm-tracks in the Euro-Atlantic sector: a comparison between ERA-40 and NCEP/NCAR reanalyses. doi:10.1007/s00382-005-0065-9

Zhu Y. and Newell R.E. (1994) Atmospheric rivers and bombs. doi: 10.1029/94GL01710

Acknowledgements: This work was partially supported by FEDER funds through COMPETE programme and by national funds through FCT under project STORMEx FCOMP-01-0124-FEDER-019524 (PTDC/AAC-CLI/121339/2010). A. M. Ramos was also supported by a FCT postdoctoral grant (FCT/DFRH/SFRH/BPD/84328/2012).

Climatology of dry air intrusions and their relation to strong surface winds in extratropical cyclones

Presenting Author: **Shira Raveh-Rubin**

Shira Raveh-Rubin [1] shira.raveh@env.ethz.ch
Heini Wernli [1] heini.wernli@env.ethz.ch

1. ETH Zurich, Institute for Atmospheric and Climate Science, Switzerland

Dry air intrusions (DAIs) are large-scale descending airstreams. A DAI is typically referred to as a coherent airstream in the cold sector of an extratropical cyclone. However, there is yet no strict Lagrangian definition of DAIs, and so their climatological frequency, physical characteristics as well as their seasonal and spatial distributions are unknown. Furthermore, it is unclear how many of the DAIs occur together with a cyclone, and the link between DAIs and strong surface winds within cyclonic systems is not fully understood.

Here, we suggest a Lagrangian definition for DAI air parcels, namely a minimum pressure increase along a trajectory of 400 hPa in 48 hours. Based on this criterion, the open questions are addressed from three aspects: (i) a novel global Lagrangian climatology is compiled for the ECMWF ERA-Interim dataset for the years 1979-2014; (ii) a statistical relationship between the occurrences of DAIs and cyclones is presented; and (iii) the mesoscale structure of a DAI and its interaction with surface winds is exemplified in a case study of a high-impact cyclone, using a 7-km resolution regional model simulation.

We find that DAIs occur predominantly in winter, with higher occurrence frequency in the northern hemisphere. Different physical characteristics typify DAIs in the different regions and seasons, and when occurring together with a cyclone. Finally, we show some evidence for the complex interplay between the descent of DAIs to the lowest troposphere and the formation of strong surface winds.

Developing a winter storm model for Europe: Challenges, potential solutions, and open issues

Presenting Author: **Dominik Renggli**

Dominik Renggli [1] Dominik_Renggli@swissre.com
Stefan Reese [1] Stefan_Reese@swissre.com
Peter Zimmerli [1] Peter_Zimmerli@swissre.com
Elisabeth Viktor [1] Elisabeth_Viktor@swissre.com
Marc Wueest [1] Marc_Wueest@swissre.com

1. Swiss Reinsurance Company Ltd

The quantitative assessment of the potential losses of European winter storms is essential for the economic viability of a global reinsurance company. For this purpose, reinsurance companies generally use probabilistic loss assessment models.
This work presents an innovative approach to develop physically meaningful probabilistic events footprint for Swiss Re's new European winter storm loss model. The meteorological hazard component of the new model is based on cyclone and windstorm tracks identified in the 20th Century Reanalysis data. The knowledge of the evolution of winter storms both in time and space allows a physically meaningful perturbation of properties of historical events (e.g. track, intensity). The perturbation includes a random element but also takes the local climatology and the evolution of the historical event into account. The low-resolution wind footprints taken from 20th Century Reanalysis are processed by a statistical-dynamical downscaling to generate high-resolution footprints of the historical and probabilistic winter storm events. Downscaling transfer functions are generated using ENSEMBLES regional climate model data.
The result is a set of reliable probabilistic events representing thousands of years. The event set is then combined with country- and risk-specific vulnerability functions and detailed market- or client-specific exposure information to calculate adequate (re-)insurance risk premiums.
The presentation concludes with some major learnings gathered during the 2-year model development phase and a list of open issues that will need to be addressed in the future.

Added value of very high resolution model simulations for the coasts of Northern Germany using the example of two case studies of extra-tropical cyclones

Presenting Author: **Benjamin Schaaf**

Benjamin Schaaf [1] benjamin.schaaf@hzg.de
Frauke Feser [1] frauke.feser@hzg.de

1. Helmholtz-Zentrum Geesthacht, Germany

This study aims to analyse a range of added values for a very high-resolution climate model simulation (RCM) which permits convection in comparison to a regional model with coarser grid resolution.

Reanalysis data was dynamically downscaled with the RCM COSMO-CLM to a much higher resolution, using in addition to the conventional forcing via the lateral boundaries the spectral nudging technique in the model domain´s interior. This method 'nudges' the large spatial scales of the regional climate model towards the reanalysis, while the smaller spatial scales are left unchanged. It was applied successfully in a number of applications, leading to realistic atmospheric weather descriptions of the past.

The hindcast was calculated for the last 67 years, from 1948 until 2014. The model area is the German Bight, including Northern Germany and parts of the Baltic Sea. This is one of the first model simulations at climate scale with a very high resolution of 2.8 km, so even small-scale effects can be detected.

Two case studies were analysed, storms Xynthia (February/March 2010) and Christian (October 2013) which both moved through the model area. With a filtering and tracking program the course of individual storms was tracked and compared with observations. The high-resolution model simulation shows precipitation areas which are not present in the coarser grid simulation, especially in summer months when the maximum of convective precipitation is reached. This leads to a higher monthly accumulated precipitation, which is more realistic in comparison to observations. Also for wind speed and gusts one can see a more realistic wind field in urban areas, which is caused by a better description of surface topography. In addition return values and percentiles of wind speed and precipitation were examined.

Frontal-wave cyclogenesis in the North Atlantic - A climatological characterisation

Presenting Author: **Sebastian Schemm**

Sebastian Schemm [1] sebastian.schemm@uib.no
Michael Sprenger [2] michael.sprenger@env.ethz.ch

1. Geophysical Institute and Bjerknes Centre for Climate Research, University of Bergen, Norway
2. Institute for Atmospheric and Climate Science, ETH Zürich, Zürich, Switzerland

Frontal-wave cyclones are cyclones which form on trailing cold fronts. These “secondary” cyclones are typically small in scale, shallow and deepen rapidly, and pose a challenge to forecasters and numerical weather prediction models. Frontal- wave development has been studied intensively in the past based on observations (e.g., FASTEX). Based on the combination of two automated detection schemes for fronts and cyclones, a climatology of frontal-wave cyclogenesis is presented and the ambient conditions during cyclogenesis on fronts in the North Atlantic (NA) are characterised climatologically in the ERA-Interim dataset. The findings are also compared with assumptions made in earlier idealized studies of frontal waves.

We highlight the role of along-frontal stretching is determining the onset of frontal-wave cyclogenesis. Previous theoretical studies in the early 1990's suggest the existence of an upper limit of along-frontal stretching above which frontal-wave development is strongly suppressed. The presented multi-decadal analysis confirms its existence in a range between $0.6 – 0.8\times10{-}5s^{-1}$. The threshold appears as usefull information for the forecasting of rapid developing cyclones from fronts.

Understanding the climate change response of the Northern Hemisphere wintertime storm tracks

Presenting Author: **Len Shaffrey**

Ben Harvey [1] b.j.harvey@reading.ac.uk
Tim Woollings [2] t.g.woollings@atm.ox.ac.uk

1. Unviersity of Reading, Reading, UK
2. University of Oxford, Oxford, UK

There are large uncertainties in the circulation response of the atmosphere to climate change. One manifestation of this is the substantial spread in projections for the extratropical storm tracks made by different state-of-the-art climate models. This presentation covers recent work investigating the physical processes causing the large spread in the projections of extratropical storm track in the CMIP5 climate models. The relationship between the climate change responses of the storm tracks and the equator-to-pole temperature differences in the upper- and lower-troposphere is investigated in the CMIP5 models and in a series of climate model sensitivity experiments. The results suggest that, whilst the changes in the upper-tropospheric equator-to-pole temperature difference have an influence on the storm track response to climate change, the large spread of projections for the extratropical storm track present in the northern North Atlantic in particular is more strongly associated with changes in the lower-tropospheric equator-to-pole temperature difference.

On separating the forced response from variability in circulation changes over Europe

Presenting Author: **Ted Shepherd**

Ted Shepherd [1] theodore.shepherd@reading.ac.uk

1. University of Reading, UK

Extratropical storms and other high-impact weather events are strongly controlled by atmospheric circulation. In contrast to global thermodynamic aspects of climate change, projected changes in atmospheric circulation have a small signal-to-noise compared to natural variability, and there has as yet been no identification of any such changes in the observations. There is consequently much interest in trying to remove the effects of atmospheric variability on changes in circulation, to isolate the forced response, as this would constitute a change in risk of extreme events. I will critically discuss some of the approaches proposed so far, with a particular focus on the European sector. I will argue that in some cases, the forced change projects on the modes of variability so removing the component congruent with variability — as has been suggested in the literature — will underestimate the forced response. I will describe how a distinction between dynamic and thermodynamic aspects of climate change can help to characterize uncertainty and changes in risk.

Serial clustering of extra-tropical cyclones in a multi-model ensemble of historical and future simulations

Presenting Author: **David Stephenson**

David Stephenson [1]
Theo Economou [1]
Joaquim Pinto [2]
Len Shaffrey [2]
Giuseppe Zappa [2]

1. Department of Mathematics and Computer Science, University of Exeter, UK
2. Department of Meteorology, University of Reading, UK

This study has investigated serial (temporal) clustering of extra-tropical cyclones simulated by 17 climate models that participated in CMIP5.

Clustering was estimated by calculating the dispersion (ratio of variance to mean) of 120 December-March monthly counts of Atlantic storm tracks passing nearby each grid point. Results from single historical simulations
of 1975-2005 were compared to those from historical ERA40 reanalyses from 1958-2001 ERA40 and single future
model projections of 2069-2099 under the RCP4.5 climate change scenario.

Models were generally able to capture the broad features in reanalyses reported previously: under-dispersion/regularity (i.e. variance less than mean) in the western core of the Atlantic storm track surrounded by over-dispersion/clustering (i.e. variance greater than mean) to the north and south and over western Europe.

Regression of counts onto North Atlantic Oscillation (NAO) indices revealed that much of the over-dispersion
in the historical reanalyses and model simulations can be accounted for by NAO variability.

Future changes in dispersion were generally found to be small and not consistent across models. The over-dispersion statistic, for any 30 year sample, is prone to large amounts of sampling uncertainty that obscures the climate change signal e.g. for storm counts near London in the HadGEM2 model, the projected increase in dispersion is 0.1 compared to a standard deviation of 0.4.

Projected changes in the mean and variance of NAO are insufficient to create changes in over-dispersion that are discernible above natural sampling variations.

Evaluation of dynamical downscaling and wind gust parameterizations for recent and historical windstorms in Switzerland

Presenting Author: **Peter Stucki**

Peter Stucki [1, 2] peter.stucki@giub.unibe.ch
Christoph Welker [1, 2] christoph.welker@giub.unibe.ch
Silke Dierer [3] sdierer@web.de
Juan José Gómez-Navarro [1, 4] gomez@climate.unibe.ch
Christoph Raible [1, 4] raible@climate.unibe.ch
Olivia Martius [1, 2, 5] olivia.romppainen@giub.unibe.ch
Stefan Brönnimann [1, 2] stefan.broennimann@giub.unibe.ch

1. Oeschger Centre for Climate Change Research, University of Bern, Switzerland
2. Institute of Geography, University of Bern, Switzerland
3. Meteotest, Bern, Switzerland
4. Climate and Environmental Physics, Physics Institute, Univ. Bern, Switzerland
5. Mobiliar Lab for Natural Risks, Bern, Switzerland

Statistical assessment of regional windstorm hazard requires spatial information on wind gusts for a large number of storms. One option to obtain such high-resolution data is dynamical downscaling of windstorm events from the Twentieth Century Reanalysis (20CR) using the Weather Research and Forecasting (WRF) model. Here, we test possible configurations for the case of Switzerland. Specifically, we address: (i) the choice of either ensemble member or ensemble mean as driving data, (ii) four wind gust parameterizations (WGP), and (iii) the effect of topographical location. We evaluate initial, intermediate and final products (i.e., reanalysis data, simulated sustained winds, and simulated gusts) from this modeling chain against observations. This is done in detail by means of a set of two recent (>1980) and two historical (early 20th century) windstorms, and statistically based on a set of 14 recent windstorms.

With respect to the choice of ensemble mean or members, we find that almost all members represent the cyclones associated to the four studied windstorms adequately, yet the downscaled peak (i.e., maximum during a windstorm event) wind gusts differ. Downscaling a set of members does not reliably deliver bounding estimates for peak gusts. Nevertheless, downscaling of selected members may inform about the consistency of the simulated flow.

Peak sustained winds are well reproduced in the set of 14 windstorms, although variability is reduced compared to observations and velocities are overestimated on average. Performance and skill measures are best for locations on the Swiss Plateau, and inferior for Alpine mountain and valley locations.

These limitations are largely reflected in the simulated peak gusts. As a consequence, performance and skill measures differ more strongly with regard to location than to a particular WGP. The four tested WGP largely reproduce the observed flow, but none of the WGP stands out as single best in all cases. Peak gusts are rather underestimated for plateau and the total of 63 evaluated locations, clearly underestimated for mountain and rather overestimated for valley locations. Together with comparisons to an independent WRF simulation based on ERA-Interim data, this points to decelerating effects of the WGP and to the role of model configuration and model resolution.

We infer that the simulation quality is not imperatively dependent on the information from a large number of downscaled 20CR ensemble members, and that the simulation setup should ideally be selected and re-calibrated depending on the specific applications and areas of interest.

Association of cyclone characteristics in the North Atlantic with synoptic variability in surface turbulent fluxes

Presenting Author: **Natalia Tilininia**

Natalia Tilinina [1] tilinina@sail.msk.ru
Sergey Gulev [1, 2] gul@sail.msk.ru
Alexander Gavrikov [1] gavr@sail.msk.ru

1. P.P. Shirshov Institute of Oceanology, Russia
2. Lomonosov Moscow State University, Russia

Surface turbulent heat fluxes are responsible for variability of surface ocean heat budget on synoptic and interannual scales. This variability is driven by variations of near surface atmospheric characteristics controlled in midlatitudes by atmospheric cyclones. We focus on understanding the mechanisms of synoptic variability of surface turbulent fluxes and on the origins of extreme turbulent fluxes and their impact on the atmospheric dynamics. The main questions addressed in this study are (i) what are the large scale atmospheric conditions associated with extreme ocean surface fluxes and are they related to cyclones, (ii) what is the role of extreme surface fluxes in the variability of oceanic heat content, and (iii) which characteristics of atmospheric cyclones are sensitive to the surface ocean flux signals? To answer these questions, we derived characteristics of the extreme surface fluxes from their empirical probability distributions from the NCEP-CFSR reanalysis, 1979-onwards and analyse them together with cyclone characteristics over the midlatitudinal North Atlantic. Cyclone tracking has been performed using state of the art numerical tracking algorithm applied to the reanalysis SLP at 6-hourly resolution. We argue that the presence of the high pressure system following to the rare part of propagating cyclone is a critical condition for the formation of extreme surface ocean fluxes which are associated with the cyclone-anticyclone interaction zone rather than with cyclone per se. We also demonstrate that the fraction of oceanic heat loss due to extremes linked to the atmospheric circulation. Locally this fraction can be as large as 50%. We also show that over the Gulf Stream more than 60% of cyclogenesis were associated with extreme surface fluxes.

A Probabilistic View on Winter Storm Damages

Presenting Author: **Uwe Ulbrich**

Uwe Ulbrich [1] ulbrich@met.fu-berlin.de
Tobias Pardowitz [1, 2] tobias.pardowitz@met.fu-berlin.de
Robert Osinski [3]

1. Freie Universität Berlin, Institut f. Meteorologie, Berlin, Germany
2. Hans-Ertel-Zentrum für Wetterforschung, Berlin, Germany
3. Centre National de Recherches Météorologiques

While extreme weather information usually informs users about forecasted meteorological parameters, the understanding of warnings may be enhanced by first converting the forecasted values into impact based information. Here, we address winter storms and their damaging impact on residential buildings in Germany using ECMWF ensemble forecasts and data provided by the German insurance association. A probabilistic estimate of the occurrence of local damages is computed for different lead times. Significant skill is found for the first forecast days. As expected, the skill of the ensemble mean is higher than that of the individual ensemble members. The spread of the forecast ensemble in terms of predicted local damages is, however, smaller than the observed spread. This can be addressed by applying an ensemble dressing. It turns out that ensemble dressing results in an improvement of the skill, equivalent to a gain of 1-2 forecast days. As expected, this gain is not reflected in the skill of the individual runs' output modified after application of dressing.

20th Century extratropical cyclone climatology and risk assessment

Presenting Author: **Filipa Varino**

Filipa Varino [1] filipa.varino@meteo.fr
Philippe Arbogast [1] philippe.arbogast@meteo.fr
Bruno Joly [1] bruno.joly@meteo.fr
Gwendal Rivière [2] griviere@lmd.ens.fr
Marie-Laure Fandeur [3] mfandeur@scor.com
Henry Bovy [3] hbovy@scor.com

1. Centre National de Recherches Météorologiques (CNRM)-Meteo-France, Toulouse,France
2. Laboratoire de météorologie dynamique (LMD),Paris, France
3. SCOR, Paris, France

The passage of extra-tropical storms over populated regions, especially cities, may cause severe damage. Storms like Lothar and Martin (1999) or Xynthia (2010) are typical storms that crossed continental areas with very strong surface winds producing big losses. In this study we intend to better understand the climatology of storms during the last century and their impacts. In order to do that we use the new-released long-term ERA-20C reanalysis from ECMWF to identify and track winter extratropical cyclones since the beginning of the 20th Century until 2010. The tracking algorithm used was adapted from Ayrault (1998) which detects and tracks relative vorticity maxima at 850hPa.

Secondly we quantifiy the severity of each storm for several european countries with a 0.25 x 0.25 grid and a 3-hour time step. We used two different indexes, the first by Pinto et al. (2012), that takes into account the population density and is based on the ratio of local 10-meters wind speed (V) and the correspondant 98% (V98) percentile. The second, index used is based on the difference between V and V98 at each grid point.

Finally, we associate the storms trajectories and the loss index in order to study the trajectories patterns of the most severe storms for each country.

Franck, Ayrault,1998, Environnement, struvture et évolution des dépression météorologiques: realité climatologique et modèles types, Ph.D. Thesis, Universite Paul Sabatier, France.

Pinto, J. G., M. K. Karremann, K. Born, P. M. Della-Marta, and M. Klawa (2012), Loss potentials associated with European windstorms under future climate conditions, Clim. Res., 54, 1–20.

Analysis of a Sting Jet in Simulations of Windstorm Tini

Presenting Author: **Ambrogio Volonté**

Ambrogio Volonté [1] a.volonte@pgr.reading.ac.uk
Peter Clark [1] p.clark@reading.ac.uk
Suzanne Gray [1] s.l.gray@reading.ac.uk

1. Department of Meteorology, University of Reading, United Kingdom

Some extratropical cyclones are termed windstorms due to their intense surface winds and these storms can have a large social and economic impact. Generally, these strong surface winds are related to low-level jets occurring along warm and cold fronts but, analysing the Great Storm that affected the UK in October 1987, Browning (2004) and Clark (2005) highlighted that an additional region of strong surface winds can exist on the southern side of the cyclone centre, in the frontal fracture area located between the cold front and the bent-back front. These strong winds are related to an airstream, called a ``sting jet", that exits from the tip of the hook-shaped cloud head in the mid-troposphere and descends towards the surface, accelerating and reducing its relative humidity.

This poster describes an investigation of the occurrence of the sting jet in storm Tini, which affected the UK on 12 February 2014. Tini was a strong and rapidly deepening extratropical cyclone that developed a well-defined frontal fracture area. These properties, along with Aberytswyth MST Radar wind observations, are hints of sting-jet presence in the storm. A method to identify this airstream, its typical features and their differences to those of warm and cold conveyor belts are presented. The investigation is carried out through simulations run with the MetUM, which is the operational forecast model of the Met Office, UK; back-trajectories are used to gain further information on the dynamics of the sting jet. Particular attention is devoted to the evolution of atmospheric instabilities (e.g. conditional symmetric instability) in the region where the descending airstream originates. Outlining the behaviour of a sting jet in a real system could lead to the formulation of more insightful questions about its dynamics. These hypotheses will be verified in the future using more general frameworks, e.g. idealised simulations.

Diabatic Rossby waves: from “Lothar” to a global climatology

Presenting Author: **Heini Wernli**

Heini Wernli [1] heini.wernli@env.ethz.ch
Maxi Boettcher [1] maxi.boettcher@env.ethz.ch

1. ETH Zürich, Switzerland

“Lothar” was not only a devastating winter storm in December 1999, it was also poorly predicted and characterised by a puzzling structure that did not resemble the classical models of extratropical cyclones. It turned out that the early phase of “Lothar” can be nicely described as as so-called “diabatic Rossby wave” (DRW) - a phenomenon that has been introduced a few years earlier in theoretical studies. DRWs are low-tropospheric positive potential vorticity (PV) anomalies that are continuously regenerated through moist-diabatic processes, leading to a rapid propagation along an intense baroclinic zone. Idealized and real case numerical simulations have corroborated this particular propagation mechanism, which does not require strong upper-level forcing, and have shown that DRWs can intensify explosively (as did “Lothar”) if they couple at the end of their propagation phase with an upper-level disturbance near the jet-axis.

This presentation will provide a brief overview on DRW-related extreme cyclones and a global climatology of DRWs for the years 2001-2010 based upon operational analysis data from the ECMWF and a specifically designed DRW tracking algorithm. DRWs occur in both hemispheres, but are more frequent and have a stronger seasonal cycle in the Northern Hemisphere. On average, about 120 DRWs exist globally per year with a peak in the warm season. Only 20% of all DRWs intensify explosively (via coupling with an upper-level disturbance) and a few of them make landfall - indicating that events like “Lothar” are rare. However, studies on the predictability of DRWs show that their evolution is highly uncertain in today’s weather forecasts. The coupling of the diabatically produced low-level PV and the stratospheric upper-level anomaly is sensitive to small differences in the relative phasing of the two disturbances, which can lead to strongly differing scenarios in DRW forecasts (either in a particular ensemble model or when comparing deterministic runs started at different initial times). This high forecast uncertainty and the interesting dynamics of DRWs highlight their relevance for high-impact weather prediction in the extra-tropics.

Was the extreme storm season 2013-14 over the North Atlantic and the UK triggered by changes in the West-Pacific Warm Pool?

Presenting Author: **Simon Wild**

Simon Wild [1]
Daniel J. Befort [1]
Gregor C. Leckebusch [1]

1. University of Birmingham, School of Geography, Earth and Environmental Sciences, UK

In winter 2013-2014, the UK experienced exceptional stormy and rainy weather conditions. The period from December 2013 to February 2014 was the stormiest regarding frequency for at least 20 years according to the UK Met Office. While the UK was hit by several high intensity storms, surface temperatures over large parts of central North America fell to near record minimum values. One potential driver for these cold conditions is discussed to be the increasingly warm surface waters of the tropical West Pacific. It has been suggested that these increasing sea surface temperatures could also be the cause for extreme weather over the British Isles.

To test this hypothesis, we investigate potential mechanisms linking SST anomalies the Western Pacific Warm Pool with European wind storm activity. We will mainly focus on two research questions. Firstly: Was a chain of anomaly patterns with origin in the West Pacific present in the winter 2013-14? And secondly: What is the role of this mechanism in explaining interannual variability of wind storms over Europe in the recent past?

Our results, using ERA-Interim Reanalysis from 1979 – 2014 for December to February, show an absolute maximum of wind storm frequency for large parts of the eastern North Atlantic and coastal regions of West Europe in winter 2013-14. Wind storms are identified with a tracking algorithm based on exceedances of the local 98th percentile of surface wind speeds. We also find an absolute minimum for the surface temperature over large regions in central North America and a substantially reduced number of cyclones in the eastern North Pacific in the same season.

The convective activity over the West Pacific Warm Pool and the number of cyclones in the eastern North Pacific are significantly correlated. The location of the highest cyclone density in the North Pacific, respectively the PNA, is in turn strongly related to temperature anomalies over central North America. We further find a significant anti-correlation of interannual variability between surface temperatures in North America and wind storm frequency in the eastern North Atlantic.

Thus, we find indications for teleconnections between the variability of sea surface temperatures in the West Pacific Warm Pool and European cyclone activity, which supports the above suggested hypothesis.

Statistical simulation of extreme European windstorms and other natural hazard events

Presenting Author: **Ben Youngman**

Ben Youngman [1] b.youngman@exeter.ac.uk

1. University of Exeter, UK.

This talk presents a statistical model built for simulating European windstorm events that can be generalised to other types of natural hazard. Reliable simulations of natural hazard events are vital for good catastrophe modelling. At present simulations are produced by various contrasting approaches, which usually fall within dynamical and statistical models. The statistical model for simulating natural hazard events presented here combines methods from extreme value theory with geostatistics; the former gives accurate and theoretically sound representation of an event's extremity, while the latter gives a robust characterisation of spatial dependence.

The model incurs little computational cost; it can quickly simulate thousands of years worth of events at high resolution using just a desktop computer. Realistic simulations of extreme European windstorm events, which can be formally validated against the model's assumptions in terms of their extremal and spatial properties, will be shown based on various measures of severity. This approach to hazard event simulation is intended to offer a new perspective on catastrophe modelling.