Project: **1024**
Project title: **Impact of the horizontal resolution of regional climate models on storm dynamics in Northwest Scotland**
Project lead: **Oliver Gutjahr (MPI-M)**

Explosive cyclones in the Northern Hemisphere are rapidly intensifying low pressure systems with a drop in mean sea level pressure exceeding 24 hPa in 24 h relative to 60°N, leading to strong winds, extreme precipitation, and high waves (Sanders and Gyakum, 1980). These severe storms threaten primarily coastal and marine livelihood and infrastructure causing severe damage and fatalities (Seiler and Zwiers, 2016). They strongly influence the weather and climate of mid- and northern Europe and any future changes may have large impacts on the local scale (McDonald, 2011), in particularly Northwest Scotland is prone to Atlantic storms (Coll et al., 2013). Such storms are not only of danger because of wind speed, they also cause heavy rainfall and storm surges in Scotland and the UK (Hickey, 2002). However, it is unclear how adequate RCMs represent the mesoscale storm dynamics and thus large uncertainties are associated with climate change issues. Recently, it was found that increasing the horizontal resolution in RCMs increases also the near-surface (extreme) wind speed, e.g. in mid-Europe (Knote et al., 2010) or in the Arctic (e.g. Moore et al., 2015; McInnes et al., 2011), and the intensity of (extreme) precipitation (Gutjahr et al., 2016; Ban et al., 2014), which in turn implies that global models but also current state-of-the-art RCMs underestimate the intensity of both processes (Prein et al., 2015). Therefore, it is proposed that RCM simulations at the 1 km scale are required in order to adequately represent the storm dynamics, as they resolve more of the kinetic energy spectrum (Zentek et al., 2016), and the resulting hazards (Huntingford et al., 2014; Kendon et al., 2012; Chan et al., 2013; Lewis et al., 2015), in particular in areas of complex topography such as in Scotland.

However, recent research focused almost entirely on the representation of deep-convection and convective rainfall in so called convection-resolving climate models at horizontal scales below 4 km (Prein et al., 2015). Although of the analysis of wind speed is of similar importance, it was not addressed sufficiently yet. Further, there is no common agreement on the configuration of convection-resolving climate models, so that the results are afflicted with large uncertainty. Although this study does not aim to perform a full sensitivity analysis to this issue, it will target the dependence of the representation of storms with respect to a handful parameters such as the turbulent length scale for vertical mixing, which was identified to strongly influence the deep-convection dynamics in convection-resolving models (Baldauf et al., 2011).

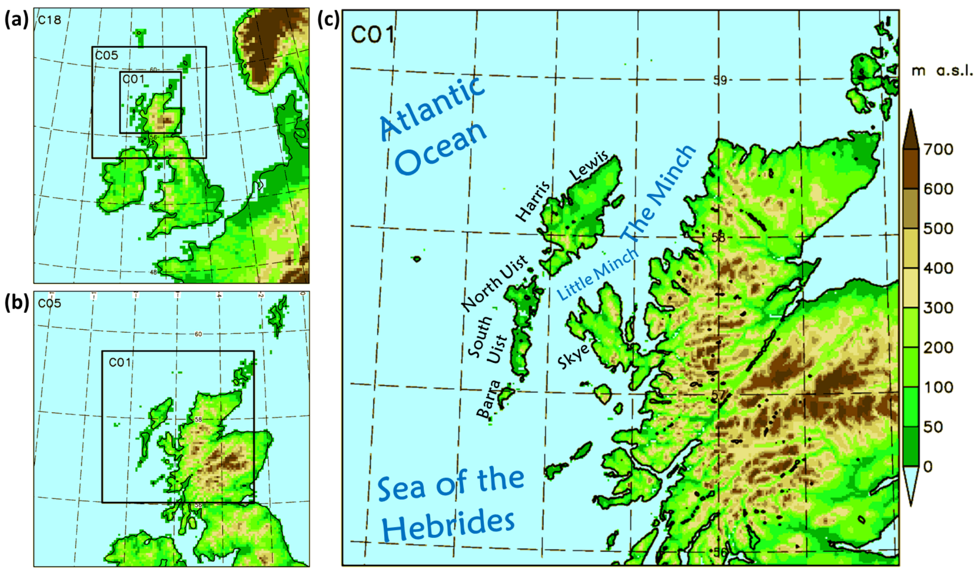

Figure 1: Model domains of COSMO-CLM at horizontal resolutions of (a) 18 km (C18), (b) 5 km (C05), and (c) 1.3 km (C01) with the height of the orography (shaded colours). The black boxes mark the inner domains of the better resolved models, respectively.

The Northwest of Scotland is a research area where both processes act together and produce severe weather hazards that put the physical and cultural environment at risk (Hickey, 2002). In particular the Hebrides and the Hebridean Sea are prone to easterly tracking Atlantic storms (Coll et al., 2013) causing extreme winds and bringing heavy rainfall (Mattison and Phillips, 2016), storm surges (Woolf et al., 2002, 2003) and fluvial and pluvial flooding (Huntingford et al., 2014; Sibley et al., 2015). Thus this domain is ideal for addressing the question what impact the horizontal model resolution has on such storm events and extreme statistics for risk assessment. This study focuses on the winter 2013/14, which produced an unusual storm sequence in terms of frequency and intensity of Atlantic Lows hitting Scotland and the UK (Kendon, 2015; Huntingford et al., 2014; Matthews et al., 2014; Sibley et al., 2015). In the period from December 2013 to February 2014 at least 12 major storms with heavy rainfall battered the country (Lewis et al., 2015), which constitutes the stormiest period for at least 20 years (Kendon and McCarthy, 2015). Based on cyclone frequency and intensity (Matthews et al., 2014) extend this estimate to 143 years. These storms were caused in association with a powerful Atlantic jet stream and they rapidly deepened on their way to Scotland/UK and later southern Norway (Kendon and McCarthy, 2015) causing also the wettest winter in Britain in almost 250 years (Lewis et al., 2015).

For answering the raised question on the impact of the horizontal resolution on the simulation of these winter storms, a three-step dynamical downscaling will be applied to the ERA-Interim (Dee et al., 2011) data set. The ERA-Interim data is subsequently downscaled by using the regional climate model COSMO-CLM (CCLM, Rockel et al., 2008) from about 80 km to 18 km (C18) to 5 km (C05) and finally 1.3 km (C01) (Fig. 1). As the configuration of all CCLM models is identical, except the horizontal resolution and physical parameterizations changing for C01, this allows to determine the effect of the impact of the horizontal resolution in a consistent way. To validate the C18 and C05 on a climatological scale, these two simulations will be performed for the whole ERA-Interim period (1979–2015) and compared to reanalysis and observational data, such as ERA-Interim, the gridded global cross-calibrated multi-platform ocean surface wind vector analysis version 2.0 (CCMP, Wentz et al., 2015; Atlas et al., 2011) product over ocean, and with the gridded observational product UKCP09 of the UK Met Office (Perry and Hollis, 2005; Perry et al., 2009). In order to use computational resources efficiently, the sensitivity experiments will then focus on the C01 simulation only for the case study in winter 2013/2014 (Nov to Feb) to explore impacts of the horizontal resolution and physical parameterizations on near-surface wind speeds and precipitation. Therefore, the C01 simulations will be repeated with changes to the tuning and parameterizations that might affect the (extremes) wind speed and the formation of heavy precipitation.

These simulation results might help to depict and reduce the uncertainty of convection-resolving models by identifying crucial parameters of physical parameterizations that affect the simulation significantly. Improved knowledge of and confidence in convection-resolving climate simulations are of crucial importance for reliable projections of the future climate.

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