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Past and future climate change in the context of memorable seasonal extremes

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ABSTRACT

It is thought that direct personal experience of extreme weather events could result in greater public engagement and policy response to climate change. Based on this premise, we present a set of future climate scenarios for Ireland communicated in the context of recent, observed extremes. Specifically, we examine the changing likelihood of extreme seasonal conditions in the long-term observational record, and explore how frequently such extremes might occur in a changed Irish climate according to the latest model projections. Over the period (1900–2014) records suggest a greater than 50-fold increase in the likelihood of the warmest recorded summer (1995), whilst the likelihood of the wettest winter (1994/95) and driest summer (1995) has respectively doubled since 1850. The most severe end-of-century climate model projections suggest that summers as *cool* as 1995 may only occur once every ~7 years, whilst winters as wet as 1994/95 and summers as dry as 1995 may increase by factors of ~8 and ~10 respectively. Contrary to previous research, we find no evidence for increased wintertime storminess as the Irish climate warms, but caution that this conclusion may be an artefact of the metric employed. It is hoped that framing future climate scenarios in the context of extremes from living memory will help communicate the scale of the challenge climate change presents, and in so doing bridge the gap between climate scientists and wider society.

1. Introduction

Despite the considerable body of climate change research produced in recent decades and evidence that decision-makers are actively seeking to improve the uptake of climate risk information, a gap persists between knowledge production and use (NRC, 2009, 2010; Lemos et al., 2012). Among the many challenges is the perception of remote impacts (Moser, 2010), where climate change is regarded as temporally, geographically or socially distant from people's everyday lives (Pidgeon, 2012). This has contributed to a 'psychological distancing' of people from climate change and a consequent lack of public engagement (Spence et al., 2012). It is argued, therefore, that direct personal experience of climate-related weather events may act as a strong 'signal' or 'focusing event' (November et al., 2009; Renn, 2011) around which the otherwise futuristic and abstract

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nature of climate change may become more tangible, and crucially trigger more substantive public engagement and policy response (Capstick et al., 2015). For example, interview respondents in five flood affected areas of the UK who were directly affected by the series of exceptional deluges during winter 2013/14 exhibited heightened concerns about the impacts of climate change when compared with a national sample of un-impacted respondents (Capstick et al., 2015). With such cases in mind, we assert that Irish climate change projections would be more tangible if grounded in analogues of the recent past.

The Irish climate is projected to warm across all seasons, and it is expected this will be accompanied by an amplified precipitation regime, characterised by wetter winters and drier summers respectively (Sweeney et al., 2008; Gleeson et al., 2013). In addition, the British-Irish Isles (BI) region is expected to experience enhanced wintertime cyclone activity ("storminess"; Gleeson et al., 2013; Zappa et al., 2013a). Recent research suggests that such signals in air temperature and precipitation are already emerging in long-term observational records (McElwain and Sweeney, 2003; Noone et al., 2015), whilst Matthews et al. (2014) reported that the winter of 2013/14 was stormiest in at least 143 years – a season that also experienced above average rainfall at more than half of Irish synoptic stations. The annual air temperature during 2014 was well above the long-term average, being only 0.2 °C below the record set in 2007 (Met Eireann, 2014). While dry summers have been more infrequent of late (Sutton and Dong, 2012; McCarthy et al., 2015), notable deficits in summer rainfall have occurred in living memory, including, for example, the warm and dry summers of 1975/76, 1995 and 2006 (Jones and Conway, 1997; Met Eireann, 2006; Wilby et al., 2015).

Extreme seasonal weather has significant societal implications. Wet and stormy conditions during winter 2013/14 resulted in widespread flooding and coastal inundation. Similarly, hot summers have been associated with increased mortality in Ireland (Pascal et al., 2013), whilst rainfall deficits have impacted the agricultural sector (Stead, 2014). The effects of the latter have the potential to propagate internationally through Ireland's agricultural exports (Hunt et al., 2014). Despite the economic and human costs associated with seasonal extremes being embedded in the public consciousness, communicating to stakeholders the exact scale of the challenge posed by climate change still presents significant difficulties.

Clearly, then, it is of interest to situate observed seasonal extremes within the context of Ireland's possible future climate. Despite extensive research into climate change undertaken for the Island of Ireland (IoI) (e.g. Fealy and Sweeney (2007), Sweeney et al. (2008), Mullan et al. (2012), Gleeson et al. (2013) and Foley et al. (2013)), to date, no study has mapped observed extreme conditions onto projected climates to explore changes in their occurrence. Yet, this kind of information can be particularly useful when communicating the potential impacts of climate change and determining adaptation needs (Sexton and Harris, 2015).

Our aim is therefore to update and complement existing IoI climate projections by exploring the changing likelihood of seasonal extremes – both in the period of observations and future climate scenarios. We first identify the wettest, stormiest winters, and the driest, hottest summers in observational datasets, before assessing how unusual these events are in the long-term context. These extremes are of particular interest given the magnitude of social, environmental and economic impacts they have had previously; additionally they provide a reference for stress testing existing management plans under likely future conditions. We then assess how the likelihoods of these extreme seasons may have already changed during the period of observation, before employing output from a suite of climate model experiments to explore projected future change. We pursue this aim on the premise that such analysis may enable communication of the magnitude of projected changes to a wide range of audiences.

2. Materials and methods

To characterise observed precipitation and temperature extremes we use the average of five long-running Irish temperature series 1900–2014 (Met Eireann, n.d.; A. Murphy, *personal communication*), and the Island of Ireland Precipitation (IIP) series 1850–2010 (Noone et al., 2015). The latter ends in 2010, but winter 2013/14 has already been acknowledged as very wet, and thus potentially of interest in our study of seasonal extremes. We therefore extended the winter (DJF) precipitation series by bridging to 2014 using the $0.25 \times 0.25°$ gridded E-OBS dataset (Haylock et al., 2008). The winter E-OBS time-series was produced by averaging over the domain -10.5 to -5.5 °E and 51.5 to 55.5 °N. For the overlapping period (1950–2014) correlation between E-OBS and IIP is strong (Pearson's $r = 0.95$), so we infer winter IIP precipitation for 2011–2014 by regression-adjusting the E-OBS series (Fig. 1).

To construct a time series of storminess we employ the 20CR reanalysis data (Compo et al., 2011) and use the same spatial domain as Matthews et al. (2014, 2015), who reconstructed wintertime BI storminess (1872–2014) using a cyclone identification routine applied to atmospheric reanalysis products. Whilst desirable because of their explicit classification of cyclones, such techniques are logistically challenging to apply to large climate model ensembles such as the Fifth Coupled Model Intercomparison Project (CMIP5). We therefore sought a simpler metric to define storminess, and, consistent with Benestad and Chen (2006) found that mean seasonal sea-level pressure (MSLP) over the BI was strongly correlated with the storminess metric of Matthews et al. (2014; Fig. 1). Hence, we adopt this simpler metric to quantify DJF storminess. Given concern expressed about the integrity of the early 20CR, we restrict our usage here to the period 1900–2014. As in Matthews et al. (2014) the 20CR data were extended from 2011 to 2014 by regression-adjusting NCEP 1 reanalysis (Kalnay et al., 1996) for the last 4 years. The regression was formulated with 20CR and NCEP MSLP as the independent and dependent variables, respectively. Over the common period (1948–2012) the regression equation had a slope and intercept of 1.41 and 146 hPa, respectively, with a correlation coefficient of 0.97. These regression coefficients were used to adjust