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Review

Salt-marsh reconstructions of relative sea-level change in the North Atlantic during the last 2000 years

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ABSTRACT

Sea-level changes record changes in the mass balance of ice sheets and mountain glaciers, as well as dynamic ocean–atmosphere processes. Unravelling the contribution of each of these mechanisms on Late Holocene timescales ideally requires observations from a number of sites on several coasts within one or more oceans. We present the first 2000 year-long continuous salt marsh-based reconstructions of relative sea-level (RSL) change from the eastern North Atlantic and uniquely from a slowly uplifting coastline. We develop three RSL histories from two sites in north west Scotland to test for regional changes in sea-level tendency (a positive tendency indicating an increase in the proximity of marine conditions and a negative tendency the reverse), whilst at the same time highlighting methodological issues, including the problems of dataset noise when applying transfer functions to fossil salt-marsh sequences. The records show that RSL has been stable (±0.4 m) during the last two millennia, and that the regional sea-level tendency has been negative throughout most of the record lengths. A recent switch in the biostratigraphy of all three records, indicating a regional positive tendency, means we cannot reject the hypothesis of a 20th century sea-level acceleration occurring in north west Scotland that must have exceeded the rate of background RSL fall (-0.4 mm yr^{-1}), but this signal appears muted and later than recorded from the western North Atlantic.

1. Introduction

The challenge of understanding how sea level has varied in the last few thousand years is important for several reasons. Firstly, sea-level variability records the net effect of changes in the mass balance of polar ice sheets and mountain glaciers as well as dynamic ocean–atmospheric processes. Sea-level observations have the potential to unravel these mass contributions which manifest themselves in spatially unique patterns, or 'sea-level fingerprints' (Mitrovica et al., 2011). Secondly, long-term trends in sea level provide insights into climate variability during periods of warmer and cooler periods in the past, such as the Medieval Climate Anomaly or the Little Ice Age (Cronin, 2012). Thirdly, past sea-level records are useful to test and develop models of ice-sheet response to past climate change and models of glacial isostatic adjustment (GIA).

Despite their importance, there are surprisingly few precisely dated, continuous records of sea-level change covering last 2000 years; indeed many existing records are discontinuous or have large vertical or temporal gaps (as summarised in databases such as Shennan and Horton, 2002; Engelhart and Horton, 2012). Continuous records of sea-level change are arguably best developed from low energy salt-marsh deposits that fringe mid latitude coastlines. Although the number of such studies is increasing (see Long et al., 2014) there are only a few near-continuous 2000-year long salt-marsh records: three from the western North Atlantic (Maine, North Carolina and New Jersey, USA; Gehrels, 1999; Kemp et al., 2011, 2013 respectively) and one from Iceland (Gehrels et al., 2006a) (Fig. 1). One of the most complete records from the European margin is a discontinuous series of basal and intercalated

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index points from Ho Bugt, Denmark (Gehrels et al., 2006b; Szkornik et al., 2008). The salt-marsh records presented in Fig. 1 differ in their timing, direction and magnitude of RSL change, suggesting local to regional-scale patterns. Better understanding of the ways that sea level responds to different forcing factors requires additional records from elsewhere in the North Atlantic and beyond, before their significance can be firmly established.

Here we present the first continuous 2000 year-long records of relative sea-level (RSL) change from the eastern North Atlantic, from two salt marshes located in north west Scotland, UK (Fig. 2). These sites record long term RSL fall caused by glacio-isostatic uplift. This contrasts with the existing Late Holocene RSL records that are from subsiding sites where sea-level accelerations are potentially harder to define (e.g. Gehrels et al., 2004; Donnelly, 2006; Szkornik et al., 2006; Kemp et al., 2011, 2013; Long et al., 2014). In this paper we test the hypothesis that the salt marshes in north west Scotland do not record a change in the sign of sea level from negative to positive during the last 2000 years.

2. Background

Along the northeast coast of the USA, two salt marsh sea-level records identify Late Holocene phases of sea level rise and fall. Kemp et al.'s (2011) North Carolina salt-marsh reconstruction

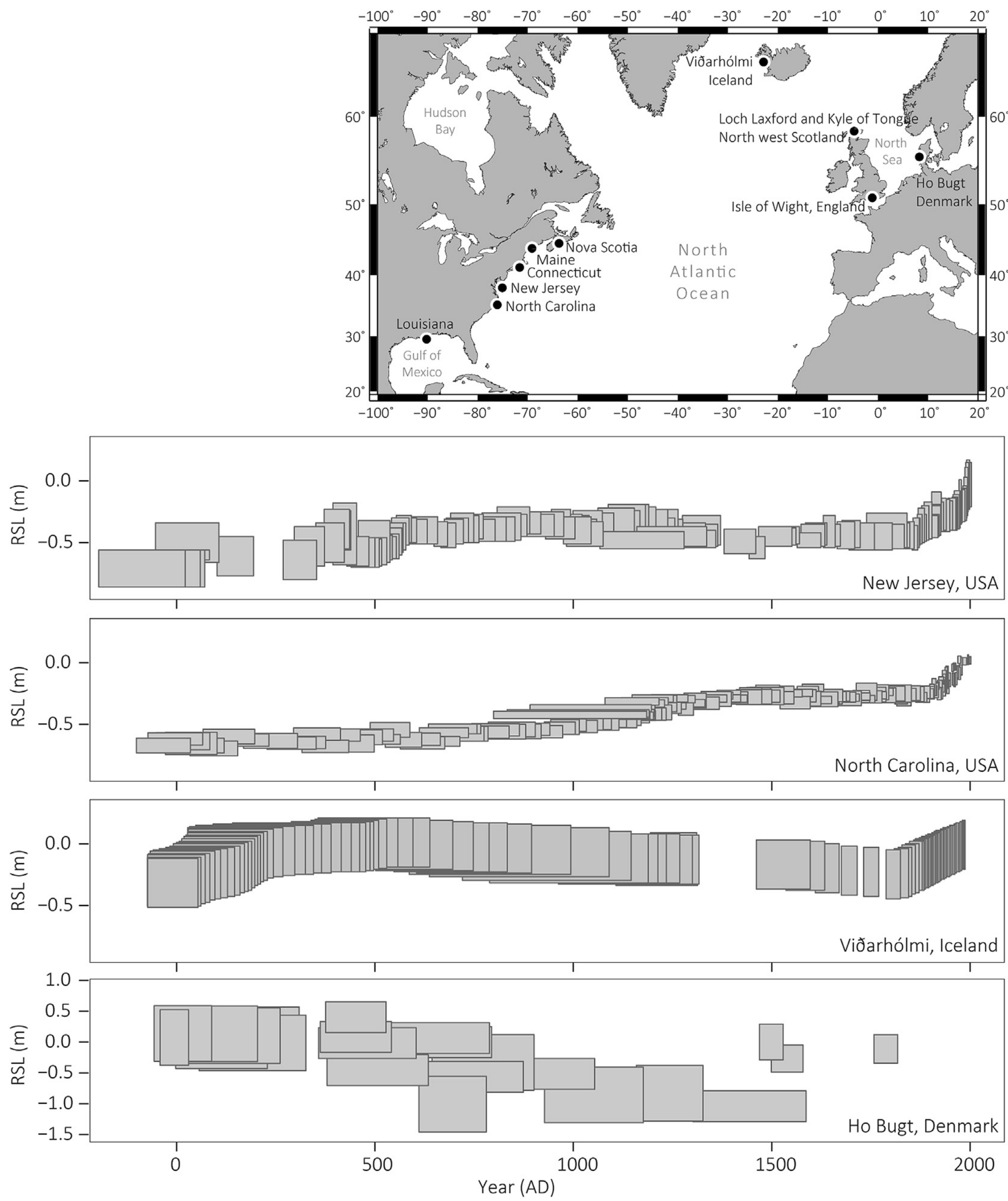

Fig. 1. Map of North Atlantic and key locations mentioned in the text. Graphs show 2000 year salt marsh based relative sea-level reconstructions from New Jersey and North Carolina, USA and Iceland; plus a basal/intercalated sea-level record from the eastern North Atlantic (Ho Bugt, western Denmark). All records have been detrended for background long-term RSL using values stated in the original papers: Iceland 0.65 mm yr^{-1} (Gehrels et al., 2006a); New Jersey 1.4 mm yr^{-1} (Kemp et al., 2013); North Carolina 0.9 or 1.0 m yr^{-1} (Kemp et al., 2011). For Ho Bugt (Gehrels et al., 2006b; Szkornik et al., 2008) we assume a linear rate through the last 2000 years and detrend the record by 0.7 mm yr^{-1} (detailed in Supplementary information). In all instances we only plot the samples which cover AD 0 to present, with 2σ age and 1σ attitude errors reported by the original authors. Note the different *y*-axis for the Ho Bugt record.