

Editorial

Storms and their significance in coastal morpho-sedimentary dynamics

The issue of storms as extreme events in coastal evolution and their variation over the late Holocene is the theme of this special issue. There has been no coherent attempt to address the theme of storms with respect to their effect on coastal margins around the North Atlantic Ocean as a whole. Although a number of authors have approached the issue of hurricanes and tropical storms on the American seaboard (e.g. [Simpson and Riehl, 1981](#)), the effect of the westerly depressions leading to mid-latitude storms along the western coast of Europe has not been described in a coherent thematic way from storm inception to land-fall. Apart from [Lamb's \(1991\)](#) seminal work on storm reconstruction and impact, there is no real exposition of historical variations in storms, storminess and associated coastal evolution in the face of such extreme events.

This issue is based around papers originally presented at the spring meeting of the American Geophysical Union in Boston (June 2001) which centred on the issue of storms primarily in the Atlantic and Gulf of Mexico region, and, to a lesser extent, the Pacific. Four special sessions were run and an initial culling of papers took place in preparation for this thematic issue. We jointly organized and convened the sessions. There were two themes identified and most papers overlapped in this respect. The first theme was to consider the impact of storms and storminess on the geomorphological response of the shoreline to such events, and where appropriate, the post-storm adjustment of coastal systems. This set of contributions is based on storms that occur along the east, Gulf and, to a lesser extent, the west coast of the United States coast, and the Atlantic coast of Canada. This effort concentrates on tropical and extratropical cyclones.

The emphasis is to understand the synoptic dynamics of such extreme events and the resulting morpho-sedimentary responses to variation in the structure and nature of such extreme episodes. High-resolution data sets including bathymetric/topographic survey comparisons, hydrodynamic and sediment transport measurements during and after high-energy events are commonly used in these papers to provide a unique set of contributions. Time series spanning millennia to hours are used to understand the instantaneous response to storms and the cumulative effect of variable storminess frequencies. Stratigraphic interpretation of event layers is presented for all three coastlines and new approaches to couple event stratigraphy to hydrodynamic numerical modelling are also presented.

The second theme centres around a series of contributions from European authors (connected via a major European Union research contract: Coastal sensitivity and severe Atlantic storms, EU Environment and Climate Programme, Contract No. ENV4-CT97-0488) who considered the development of storm magnitude, frequency, and impact of such storminess over the last 2000 years. Their results highlight the variation in geomorphological, historical and instrumental lines of evidence required to substantiate past storminess and its effects along the European coastlines. Inevitably this 2000 year time-scale has necessitated an interdisciplinary approach, combining techniques from geology, geomorphology, biogeography, history and meteorology as well as employing a range of statistical and computational techniques. The methodology of the project has been to construct a record of storms over the chosen time period and to determine their impact at selected locations, using these different lines of evidence, as

well as determining storminess trends and developing models of storm behaviour that influence the shoreline through surge generation. There is imbalance in the detail of the record given the imprecision and coarse resolution of most stratigraphical specification of storminess during the penultimate millennium. However, to balance these shortcomings is the wealth of evidence that is now emerging from the Atlantic coastal margins of Europe regarding storminess and its effects during the last few centuries that identifies a number of issues that will be of concern in analysis of future Atlantic storminess.

The papers hold together as they are following the sequence of extreme events, their position, occurrence and generation through to the effects of such events on depositional coasts. A flavour of a range of analytical approaches is identified. Storms and storminess is a thematic issue that impinges on a number of disciplines and is attractive to an equal range. It is our belief that the specification of storms through accessing this range of disciplines allows us to consider storms in a more coherent and pertinent way than hitherto identified. Thus, a few papers deal with climatological elements of storminess on both sides of the Atlantic basin. The essential physical consequence of coastal storms is to be experienced in the coastal geomorphology of the ocean's margins. To understand these margins, one needs to understand storms in all their variety. Thus, we have attempted to produce an integrated thematic piece that is oceanic based and geologically resolvable—we believe this is a major impetus to the interdisciplinary understanding of coastal storminess.

Given the focus of the issue on storms and storminess, we present the papers in a geographically meaningful manner, beginning on the west coast of the United States, commencing eastward into the Gulf of Mexico and then along the Atlantic coast of the eastern seaboard to Canada. Papers comprising the European contributions follow beginning with research findings from Scotland and Ireland, then moving to France and Portugal. The first paper (Keim et al., 2004) helps establish the framework of this issue by assessing the temporal variability of coastal storms and wave climatology of the North Atlantic Basin and the Gulf of Mexico. The authors suggest that tropical storms have shown a decrease in frequency over the past two to three decades perhaps as a consequence of

prolonged El Niño periods. Similarly, extratropical storms have declined in number, although very powerful storms at high latitudes have shown an increase in frequency. The authors link an apparent increase in wave energy to the North Atlantic Oscillation and conclude that such a trend may increase with global warming.

The second paper (Fan et al., 2004) presents data elucidating fluvial and coastal storm deposits on the shelf off northern California. Their work illustrates that sand beds on the central shelf are not necessarily peak storm deposits as has been concluded widely in the literature, but instead appear to be the product of secondary winnowing from fluvially introduced mud during storms. These storm-driven processes are very different than those dominating the northern Gulf of Mexico as reported in the third paper by Pepper and Stone (2004) and who underscore the significance of extratropical storms on bottom boundary layer physics and sediment transport on the inner shelf. The authors present end member types of cold fronts and distinguish respective trends in sediment transport based on results from a 61-day time series obtained using bottom-mounted instrumentation. In addition to the high incidence of tropical cyclone activity, the shelf along the northern Gulf is heavily influenced by the high incidence of winter storms associated with frontal passages—approximately 30 per year. It is precisely this interaction, extratropical and tropical storms that Stone et al. (2004) address in the fourth paper along the same area. Their data show that some barrier islands along the Gulf have the ability to conserve mass during intense (category 3 and above) hurricanes, a phenomenon related to extensive overwash along areas impacted by the storm. Post-storm recovery of these systems is not immediate and extratropical storms play an important role in causing erosion of the marginal lobe of the deposits due to locally generated, high frequency waves in bays/sounds accompanying frontal activity. The fifth paper (Keen et al., 2004) focuses on the location and analyses of event layers in the same general area of the north-central Gulf of Mexico. Two layers representing two powerful historic hurricanes were identified and provided the authors an opportunity to reconstruct oceanographic and sedimentological processes using a suite of hydrodynamic and geological numerical models. The authors conclude that “layer cake” stratigraphic

analysis cannot be used to evaluate the impact of large storms on sedimentology.

Overwash deposits obtained from vibracores along the mid-Atlantic coast were used by [Donnelly et al. \(2004\)](#) to provide a record of past severe storms. In this sixth paper of the issue, the authors reconstruct the storm record as far back as 550 AD along a portion of the New Jersey coast and conclude that prehistoric storms may have been more powerful than during the recent past. A similar approach was taken by [Dougherty et al. \(2004\)](#) in the seventh paper for a barrier located in Maine. Using techniques including ground penetrating radar, seismic and vibracores, the authors use several diagnostics (overwash deposits, beach scarps, coarse-grained sediment and heavy minerals) to identify storm events. These layers were identified in the subsurface barrier deposits and their preservation attributed to the exposure of nearby drumlins resulting in greater availability of iron oxide and ferromagnesian sands. There is some evidence indicating a greater frequency of storms during the transgressive evolution of the study site. A companion paper comprises the eighth contribution and in which [Buynevich et al. \(2004\)](#) document the frequency of severe storms in the subsurface of sandy barriers and bays in south-central and southwest coastal Maine. Using similar approaches to that of [Dougherty et al.](#), the authors reconstruct the storm history of the area for a period extending back to 4.5 ka BP. Evidence exists permitting correlation of one of the overwash deposits to the “Great Colonial Hurricane” that occurred in New England during 1635. The ninth paper focuses on coastal processes along southern Maine in response to winter storms. The authors ([Hill et al., 2004](#)) provide data (beach profile comparisons and hydrodynamic measurements) indicating that sediment is preferentially transported onshore during certain types of storms (originating from the northeast) and offshore during others (frontal passages and those originating from the southwest). The 10th paper focuses on storm effects on barriers located in the Gulf of St. Lawrence, Canada. [Forbes et al. \(2004\)](#) conclude that storm surge and storm wave inundation have increased along these barriers, concomitant with rising relative sea level. Intervals of increased autumn storminess were detected in the 1960s, 1980s and 1990s according to local storm surge and wind data. The authors provide data indicating the importance of

storm clustering on time scales of weeks to years driving shoreline retreat.

The next paper by [Lozano et al. \(2004\)](#) focuses on storminess and vulnerability along the Atlantic coasts of Europe and the relationship between the North Atlantic Oscillation and storms since the 1940s. Data suggest a seasonal shift in the wind climate with regionally more severe winters and calmer summers, a phenomenon linked to a northward displacement in the main North Atlantic cyclone track. The authors conclude that for low lying erodable beaches along the European Atlantic (e.g. Ireland), future increases in rates of coastal erosion are highly probable. In the next paper by [Betts et al. \(2004\)](#), the authors focus on extreme storminess impacting the coast of the southwestern approaches to northern France and southwest England. A Storm Calendar of low frequency, high magnitude surge generation derived from tidal gage records at Brest in France (in the second half of the 20th century) is employed to accomplish their objectives. The authors identify a number of variables critical to the formation of cyclogenesis and surge generation and highlight the problems imposed by differing scale resolution of key forcing variables compared to the resolvable detail of tide gauge data (a somewhat neglected proxy of storminess).

In the 13th paper of this issue, [A. Dawson et al. \(2004\)](#) document historical storminess and climate “see-saws” in the North Atlantic concluding that over the past 150 years, the stormiest winters in Scotland, northwest Ireland and Iceland can be strongly correlated to when temperatures in western Greenland have been significantly below average. In contrast, winters of reduced storminess are linked to higher than average air temperatures in western Greenland. The authors conclude that the reconstruction of winter storminess implies a relationship between chronologies of coastal erosion and the history of North Atlantic climate fluctuations. Despite the high incidence of storms along the coastlines of Western Europe and the British Isles, their precise impact on beaches is not well documented. In paper number 14, [Cooper et al. \(2004\)](#) identify storm impacts on embayed beaches along the high energy, west coast of Ireland. Using a combination of historical data, meteorological records, field observations and numerical modelling, the authors conclude that beaches and dunes along this coast are attuned to high-energy

regimes and thus require extreme storms to undergo any significant morphological impact.

Contribution 15 by [S. Dawson et al. \(2004\)](#) is a lithostratigraphical and biostratigraphical investigation of portions of the Outer Hebrides along the Atlantic coast. Specifically, sand units found in marsh deposits are used as proxies to construct a chronology of storm events. The data indicate that from around 1400 AD, these aeolian deposits suggest a period of increased cyclogenesis in the Atlantic associated with increased sea ice and an increase in the thermal gradient across the North Atlantic region.

The next paper by [Pirazzoli et al. \(2004\)](#) focuses on changes in storminess and surges in western France over the past century. Using meteorological data from 1890 and storm surge levels from the Brest tide gage since 1860, the data indicate that strong winds are increasing in frequency although surges associated with these winds show a slight decreasing trend. The authors conclude that their findings have very important implications for beaches along the Atlantic French coast. Paper 17 by [Regnaud et al. \(2004\)](#) also addresses the influence of storms along this coast. The authors conclude that the French coast is highly varied in its response to storms because of variations in wave amplitude and direction during the events and, to a much lesser extent, storm strength. Bathymetric complexities exercise significant controls on wave refraction patterns during the storms and, according to the authors, result in significant variability in coastal response.

The final paper of this issue, paper 18 by [Andrade et al. \(2004\)](#) concentrates on stratigraphical evidence showing late Holocene barrier breaching due to extreme storms in Ria Formosa, Algarve, Portugal. The authors conclude that throughout the late Holocene evolution of the study site that in all likelihood this was a period of increased storminess and extreme storm frequency.

These papers reflect in their subject matter considerable diversity of approaches, techniques and data sources. All are connected by the theme of variation in storms, whether in their inception, extremity and impact. All have some degree of multi-disciplinarity as their key to understanding coastal storminess. Substance is gained from this crossing of boundaries. One might wonder why we know so little about extreme Holocene coastal forcing; yet we probably

know even less about the last millennium and yet we are trying to calibrate the nature of future climate change based on these fleeting palimpsests. There is still much to do to unlock the nature of past coastal forcing.

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