Atmos. Chem. Phys. Discuss., 15, C6270–C6281, 2015
www.atmos-chem-phys-discuss.net/15/C6270/2015/

Atmospheric Chemistry and Physics
Discussions
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Interactive comment on "Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 °C global warming is highly dangerous" *by* J. Hansen et al.

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Received and published: 26 August 2015

Speculations on superstorms – Interactive comment on "Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 °C global warming is highly dangerous" by J. Hansen et al.

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This comment on the discussion paper “Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 °C global warming is highly dangerous” by Hansen et al. (2015) is jointly composed by Max Engel, Pascal Kindler, and Fabienne Godefroid. Given our thematic and regional research backgrounds, we solely comment on section 2.2 where geologic findings are presented in support of the hypothesis of a late Eemian increase in temperature gradients and extreme storm magnitudes unprecedented in our days. Hansen et al. (2015) compile field evidence from the Bahamas and Bermuda and related conclusions from a range of previous publications by co-author P.J. Hearty, all of which promote the idea of late Eemian superstorms (Hearty, 1997, 1998; Hearty and Neumann, 2001; Hearty and Olson, 2011; Hearty et al., 1998). Field evidence supposedly reflecting hydrodynamic conditions during these superstorms includes large singular boulders, v-shaped, ridge-like coastal landforms, which they call “chevrons”, as well as so-called “runup” deposits, which seem to correspond to some type of washover features.

In general, our comment is motivated by the unbalanced discussion of the origin of these geologic features, as a whole body of literature coming to diverging conclusions is ignored. According to Hansen et al. (2015), the v-shaped ridges, present all across the Bahamas, up to 25 m high, and mainly consisting of well-sorted oolitic sand, were formed by the run-up of “long-period waves” within a short time period. The authors draw on the presence of keystone vugs (fenestrae) and scour features, as well as sedimentary structures interpreted as low-angle, foreshore cross-bedding within the ooid-dominated facies as evidence for intertidal formation (Hansen et al., 2015). No alternative depositional processes are discussed, even though the ridges exhibit striking evidence of eolian sedimentation (Kindler and Strasser, 2000, 2002). Eolian control of both chevrons and runup deposits was demonstrated by the pervasive occurrence of subcritically climbing translatent strata (Hunter, 1977), also known as pin-stripe lamination (Fryberger and Schenk, 1988), excellent sorting, fine grain size, and the lack of larger skeletal debris (Kindler and Strasser, 2000, 2002; Mylroie, 2008). As for the fenestrae, a rainfall origin has been proposed because of the associated presence of terrestrial gastropods, fossil vegetation, and rhizoliths (Bain and Kindler, 1994; Kindler and Strasser, 2000). Fenestrae are further not exclusive to the late MIS 5e chevrons and runup deposits, but have also been observed in subaerial eolianite ridges of middle Pleistocene, early substage 5e (Kindler and Strasser, 2000), and Holocene age (Kindler and Godefroid, unpublished data; Fig. 1). Thus, as already stated by Kindler and Strasser (2000), we interpret the chevron ridges and most runup deposits as eolian bedforms, namely elongate parabolic and climbing dunes, respectively. The v-shaped ridges represent the typical case of a parabolic coastal dune with a downwind elevated apex and two trailing, moderately vegetated ridges with a deflation zone in between, as defined, for instance, in Pye (1982). The parallelism of the dune axes with trade-wind vectors cannot be coincidental (Kindler and Strasser, 2000).

By consulting the principles of uniformitarism, not a single v-shaped, sandy ridge is known to have formed where strong tropical cyclones made landfall in the recent past. The hypothesis of long-period waves from superstorms generating the chevrons seems entirely off the point when compared to coastal landforms generated by recent highest-magnitude tropical cyclones. Depending on coastal topography, foreshore bathymetry, and sediment composition and availability, the most common isolated landforms created by single storm surges and waves include steep, elongated ridges of coarse debris (e.g. Maragos et al., 1973; Reyes et al., 2015) or landward-fining washover terraces, sheets or fans behind barriers or barrier-shaped islands in sand-dominated environments (Sedgwick and Davies, 2003; Wang and Horwitz, 2007). On the Bahamas, similar to other reef-accompanied islands in the Caribbean (e.g. Scheffers and Scheffers, 2006; Atwater et al., 2014), storm deposits mainly consist of long conglomeratic berms and small-scaled, unstratified washover deposits. Larger lobate washover fans, in particular when they are formed through multiple overwash, may share similarities with inland-pointing parabolic dunes as they often have a wide central channel with proximal scour features and two broad shoulders (May et al., 2015a). However, supratidal washover structures lack the characteristic apical mound as well as any particular anomalous porosity (fenestrae), and exhibit a range of bedforms, such as landward-dipping strata with a basal lag of coarser material (shells, coral fragments) or normally (channel throat, proximal and mid-fan) and reversely (proximal fan) graded layers (Sedgwick and Davies, 2003), which are not reported from the Bahamian chevrons. Further evidence against subaqueous formation of the chevron ridges is related to cross-bedding within the chevrons indicating bedload-dominated transport. In order to create the up to 25 m-high bedforms, constant minimum flow depth of twice their elevation is required. Bourgeois and Weiss (2009) showed that these -merely unrealistic-flow conditions would result in pure suspended-load transport.

The large block-like rock pieces resting on top of a 20 m-high sea cliff on Eleuthera Island, first described by Hearty (1997), and used by Hansen et al. (2015) as evidence for superstorms at the end of the last interglacial period, are indeed boulders. In addition to their overall morphology, the dip of the bedding observed in the boulders (up to 85°; Viret, 2008), which far exceeds the angle of repose of wind-deposited sands, the occurrence of rotated geopetal structures (Kindler, unpublished data), and their high grade of diagenetic alteration compared to their substrate, all indicate that these “topographic projections” (Mylroie, 2008) are truly limestone blocks. Hearty (1997) suggested that the boulders were brought up onto the island by large waves, and speculated these waves could have been triggered by a tsunami of distant origin, by local bank-margin collapse, or by giant storms in the Atlantic Ocean. He and other authors later considered extreme storms and attendant waves as the most probable agents of block transport, and situated the boulder emplacement during an interval of catastrophic climate near the end of MIS 5e (Hearty et al., 1998). Nevertheless, distinguishing between tsunami- and storm-emplaced boulder fields is a challenging task (e.g. Goto et al., 2009; Engel and May, 2012). A major characteristic of tsunami boulder fields in carbonate settings with steep offshore bathymetries is a more random distribution of clasts as a single layer and rather abrupt landward boundaries compared to boulder fields created during tropical cyclones, which tend to show exponential landward fining (Goto et al., 2009; Watt et al., 2012). However, recent observations made after Supertyphoon Haiyan, where dislocation of extremely large clasts (a-axis up to 9 m) was attributed to long-period infragravity waves, showed that storms may create boulder patterns similar to tsunamis and that sheer size is not a valid criterion to separate between tsunamis and storms (May et al., 2015b). As further indicative factors such as pre-transport setting and relation to sea level, transport distance, and post-depositional modification of the boulders and their setting are not entirely certain, each attempt of inferring a particular transport process based on the currently published spectrum of evidence must be associated with a high degree of speculation. In view of the extraordinary transport capacities of infragravity waves observed during Supertyphoon Haiyan (Roeber and Bricker, 2015) or the potential of numerically modelled, locally generated landslide tsunamis (Hasler et al., 2010), further supported by the convex-bankward shape of the bank margin in this area (Mullins and Hine, 1989; Fig. 2), neither storm waves generated in a present day-like climate nor a near-field tsunami, respectively, can be excluded to have dislocated the blocks near Glass Window on Eleuthera. Given this range of possibilities, the principle – we take the liberty of adapting a presentation title of Bahlburg et al. (2010) here – in dubio pro superstorm deposits simply is not viable. Absence of evidence for tsunamis on the US east coast, as part of Hansen et al.'s (2015) line of argument, legitimately refutes the relevance of far-field sources, such as flank collapse of Canary Islands' volcano edifices, which has been demystified by Hunt et al. (2013) anyway. But it is no argument against a low-frequency, high-magnitude local tsunami related to submarine mass failure (Fig. 2) typically inducing only local effects (Bardet et al., 2003).

In a reply to a previous comment by A. Revkin, J. Hansen provided six criteria "that support a rapid late-Eemian sea-level rise and superstorms" (Hansen, 2015: C5616). However, we must state that none of these "geologic data" is seriously capable (i) of challenging an eolian origin of the chevron and runup deposits and (ii) of reliably excluding other processes than superstorm-related, long-period waves for transport of the large boulders on Eleuthera. In view of the inevitable length of the present multidisciplinary synthesis on future climatic changes, it is understandable that the authors try “to avoid an unacceptably long paper”. Nevertheless, it seems more unacceptable to us to omit highly relevant and certainly not “marginally pertinent” (Hansen, 2015: C5616) geologic evidence as presented above - an approach unfortunately paving the way for misleading conclusions.

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Figure captions

Figure 1

A: General view of the exposure where fenestral porosity has been observed in a Holocene eolianite (eastern side of North Point, San Salvador Island, Bahamas, N 24° 07.346', W 74° 27.232'). These features occur in the ooid-rich North Point Member (NPM) that revealed 14C ages of 5700 to 6700 cal a BP (Hearty and Kaufman, 2009). Standing person is 1.58 m tall. White rectangle shows the location of Fig. 1B. B: Closer view of the zone where fenestrae occur. The zone of fenestral porosity overlies and is capped by sediment showing subcritically climbing translatent strata (scts). A similar pattern is observed in the chevrons and runup deposits of last interglacial age (Kindler and Strasser, 2000, 2002). Hammer for scale is 36 cm long. C: Close-up on fenestral porosity. Pencil width is 5 mm.

Figure 2

Satellite view of northern Eleuthera showing scalloped (i.e. convex-bankward) margin (modified from Kindler and Hine, 2009). This peculiar shape of the bank edge (Mullins and Hine, 1989) and the fact that, near Glass Window, the backside of last-interglacial lagoon beaches is exposed on ocean-facing cliffs (Kindler and Hine, 2009), both suggest a collapse of part of the adjacent bank margin. That the blocks were displaced to their current position by a tsunami with massive, locally restricted impacts triggered by this collapse is thus a possibility. Image from: https://zulu.ssc.nasa.gov.

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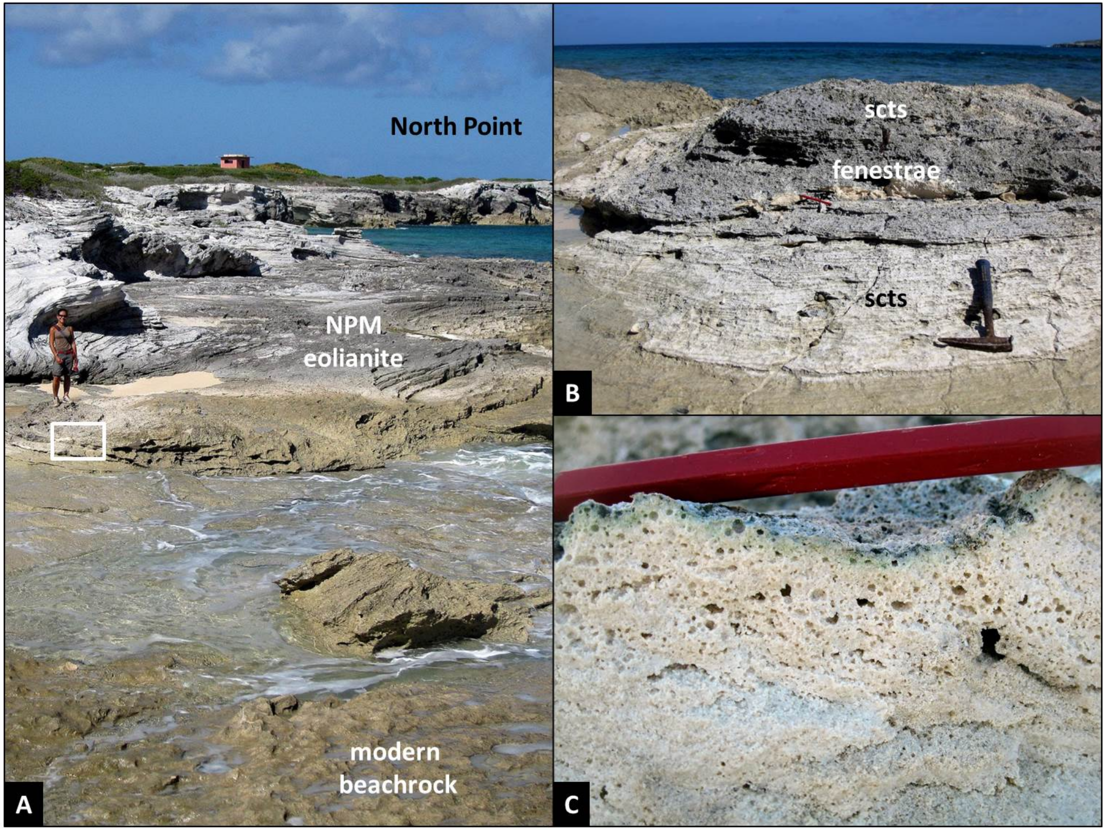
North Point
NPM eolianite
modern beachrock
A
scts
fenestrae
scts
B
C

Fig. 1.

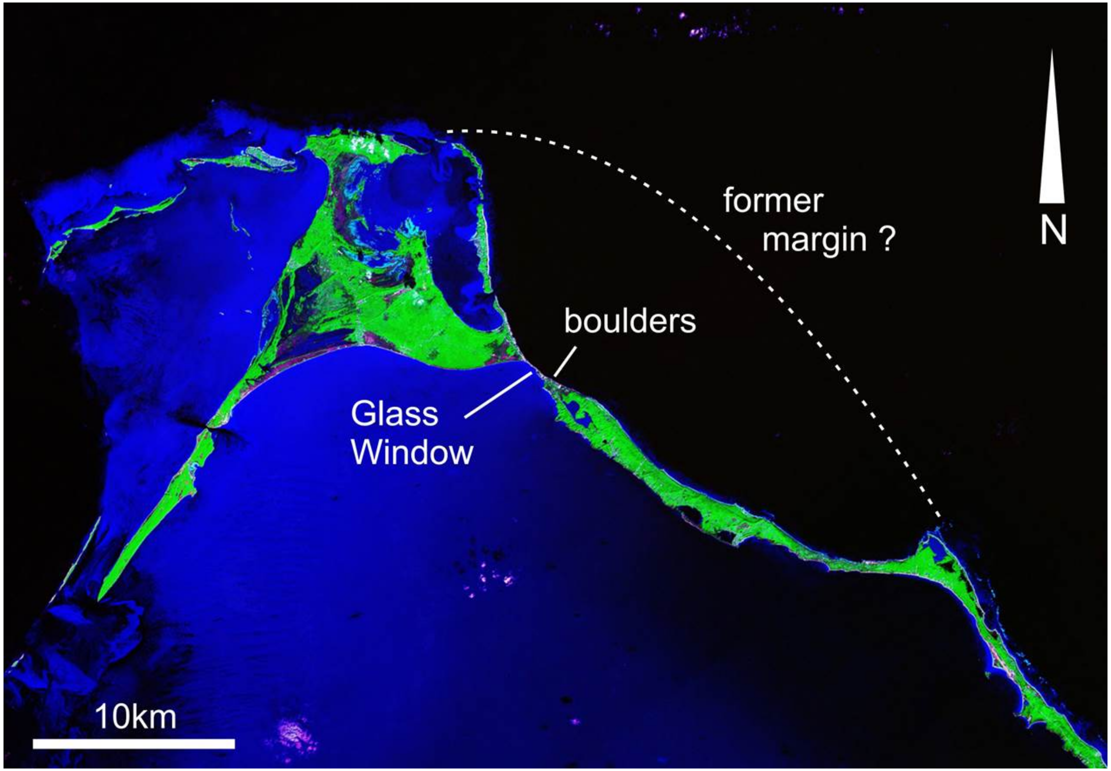

Fig. 2.