Tropical salt marsh evidence for rapid sea-level changes associated with Heinrich Events

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During the last glacial period the climate of the Earth changed **repeatedly** and **abruptly** within decades.

**Dansgaard-Oeschger oscillations (D-O)**
- Abrupt warming of Greenland (5-10°C) and gradual cooling
- Almost regularly ~1500 yr

**Heinrich Events (H1, H2,…H6)**
- Deposits of ice-rafted debris related to the discharge of ice armadas
- Coldest phase of consecutive stadials
Modeling and paleoclimatic records suggest an intimate coupling between abrupt climatic changes at high and low latitudes.

High latitudes
changes in temperature

Low latitudes
changes in precipitation

ITCZ
Monsoon System

Sea level?
Millennial sea-level variability during MIS 3 (60-30 kyr)

- Coral data are sparse
- Chronologies less precise

**Oxygen isotope records from deep-sea cores (Red Sea)**

Four cycles of sea-level change (15-30 m) have been recorded

but…

**…timing under debate !!!**

Antarctica vs. Northern Hemisphere
Millennial sea-level variability during MIS 3 (60-30 kyr)

1) Central Red Sea: 
Planktic foraminifera (Siddall et al. 2003; Rohling et al. 2004)

**Antarctic rhythm:** Sea level rise during **warm** episodes in Antarctica

2) Northern Red Sea: 
Benthic foraminifera (Arz et al. 2007)

**Greenland rhythm:** Sea level rise during **warm** episodes in Greenland
Independent evidence of sea-level changes is highly needed.

Sensitive intertidal ecosystems can offer a means to study sea-level changes.
Questions

1. Are tropical intertidal plant communities sensitive to abrupt climatic changes during MIS 3?

2. Which mechanisms are responsible for these changes?

3. If they are sensitive to sea-level changes, which model do they support?
Cariaco Basin

- The largest anoxic marine basin (laminated sediments)
- High sedimentation rates (ca. 40 cm/kyr)
- Seasonal migration of the ITCZ
- Very detailed chronology
Boreal summer
(June-August)

- ITCZ over Cariaco
- High rainfall and fluvial input
- Dark laminae (high Ti content)

Boreal winter
(December-February)

- ITCZ south
- Dry conditions
- Light laminae (diatoms, nanofossils)
Results
Heinrich Events

ITCZ

River transport

Lowland moisture

Marine influence & drought

Reflectance L*

Pollen concentration

Lowland forest

Salt marshes

Age (ka)

30
34
38
42
46
50
54
58
62
66
70

Heinrich Events

H3
H4
H5
H5a
H6

(Grains/cm³) x 1000

0 4 8 12

0 40 80 %
Sea level change

Chenopodiaceae

Poaceae

Cyperaceae

Salinity gradient

Reflectance L*

Salt marshes

Age (ka)

Reflectance L* Salt marshes

H3

H4

H5

H5a

H6

Sea level change
Chenopodiaceae

- Pioneers (able to adapt to changing environments)
- Low marshes
- Tolerant to hypersaline soils

Poaceae (small pollen grains)

- Tolerant to hypersaline soils
- Need more stable conditions
- Highly competitive

Cyperaceae

- Do not tolerate hypersaline soils
- High marsh area
- Need more stable conditions
1. Are tropical intertidal plant communities sensitive to abrupt climatic changes during MIS 3?

Yes! **Five** intervals of expanded salt marsh vegetation correspond to HE’s

2. Which mechanisms are responsible for these changes?

   - **Atmospheric**: ITCZ, Greenland variability
   - **Sea level**: HE’s

3. If they are sensitive to sea-level changes, which model do they support?
   - Antarctica
   - Sea level changes might have been a potential trigger of HE’s

**Conclusions**
Thanks for your attention!

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Assuming an increment of 30 m in sea-level, at a rate of 3 cm/yr

- The shore retreated ~1.2-6 km inland
- The surface area inundated every year was ~2.3 km² (~350 soccer fields)

General Bathymetric Chart of the Oceans (GEBCO) 1-minute grid (http://www.gebco.net)
Millennial-scale Sea level change

- Corals U-Th
  Precision of U-Th dates (1.5-3 ka)

- $\delta^{18}O$ in marine sediments (foraminifera)
  Salinity dependent, reservoir ages

- Submerged speleothems
  Rare

- Geomorphologic indicators
  Resolution (few data points)

- ...
Chenopodiaceae

Best candidates

*Salicornia fructicosa*: Falcón and Araya districts

*Atriplex pentandra* (syn. *A. cristata*, *Axyris pentandra*, *Spinacia littoralis*): in beaches in the Cumaná district

*Atriplex pestophora*: Falcón
Poaceae

Best candidates

*Sporobolus pyramidatus*: Araya district

*Distichlis spicata*

*Spartina patens*
Lower sea lever

Cariaco Basin

Intertidal zone

Continent

Higher sea lever

Cariaco Basin

Intertidal zone

Continent
Differences
- Different calibrations
- Different chronologies
- Antarctica vrs. Greenland

Similarities
- Amplitudes 15-30 m
- Four major sea level symmetric cycles

Siddall et al. 2008, PAGES
Roe & van de Plassche, 2005
Palynology in marine sediments

- Direct *land-sea* correlations
- *Stratigraphy and chronology* are determined independently
- Integrate vegetation information over *large areas*
- Large shifts in vegetation over *long* and *continuous* periods
- Information on *transport mechanisms* and *preservation*
Chronology for core MD03-2622. (Stuiver and Grootes, 2000; Rasmussen et al., 2006; Hughen et al., 2006); δ¹⁸O of Hulu Cave stalagmites (Wang et al. 2001). Numbered interstadials are indicated on top of the GISP2 record and gray bars denote Heinrich events.
Hughen et al. 2004

![Graph showing FA δ13C vs. FA C_{24}-C_{28} Average Chain Length with data points for African C_{4} Grassland, northern S. American C_{4} Grassland, and northern S. American C_{3} Wet Forest.](image)

**Table 4**

Results of the multiple linear regression and mass balance mixing models

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<tr>
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<th>Linear regression</th>
<th>Mass balance</th>
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<td></td>
<td>Rainy</td>
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<td>Local rivers</td>
<td>64–76</td>
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<td>Mafic (fluvial or elian)</td>
<td>11–32</td>
<td>8–29</td>
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<td>Saharan dust</td>
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Upper crust from (Taylor and McLennan, 1985), average basalt from (Li, 2000), and summer storm Saharan aerosol from (Glaccum, 1978).

Martinez et al., 2007
Pollen vs. biomarkers $\delta^{13}C_{32}$ in the Cariaco Basin

(González et al., 2008; Drenzek 2007)
Individual pollen percentages

--- Semi-deciduous forest ---/--- Evergreen forest ---/---

**Color reflectance (L°)**

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<th>Sebastiana</th>
<th>Phylobaccaeae</th>
<th>Bussera sinarborza</th>
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**Legend:**
- H3
- H4
- H5
- H5a
- H6

**Subspecies:**
- S

**Institutions:**
- marum
- EuroProx
- Universität Bremen