IMAGES - The hydrological cycle and ocean temperatures: A paleo-perspective

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During the last decade a large number of globally distributed paleoclimatic studies have been performed by the IMAGES (International Marine Past Global Changes Study) community on Late Quaternary sediments retrieved by long and large-diameter piston corers, the CALYPSO and CASQ systems installed on the French research vessel Marion Dufresne (www.images-pages.org/references.php). These studies provided overwhelming evidence for rapid changes in ocean thermohaline circulation and surface ocean temperatures at regional and global scales over the past 200-300 kyr BP. Coupled ocean-atmosphere climate modeling suggests that such sudden climate changes could occur in coming decades and centuries in response to natural or anthropogenic forcing.

Much less evidence exists for rapid changes in surface ocean salinity and river runoff. Such records would provide information on past changes in the hydrological cycle, in which surface ocean temperature and circulation changes are strongly tied with fluctuations in precipitation over the continents. PAGES has identified land-ocean climatic linkages as a major objective for the coming years. As water vapor exerts a strong effect on Earth's climate, improved future scenarios of climate change need to take into account changes in the hydrological cycle more than before. The principle processes of past linkages between ocean circulation changes, ocean-atmosphere water exchange, and shifts in the hydrological regimes over the continents are well understood. However, not much is known about the magnitudes of change, such as variations in the evaporation-precipitation balance between the ocean and adjacent continents or between different ocean basins. Quantitative estimates of this kind could be very helpful in testing the performance of Earth system models with a hydrological cycle and therefore, essential for more accurate climate change predictions.

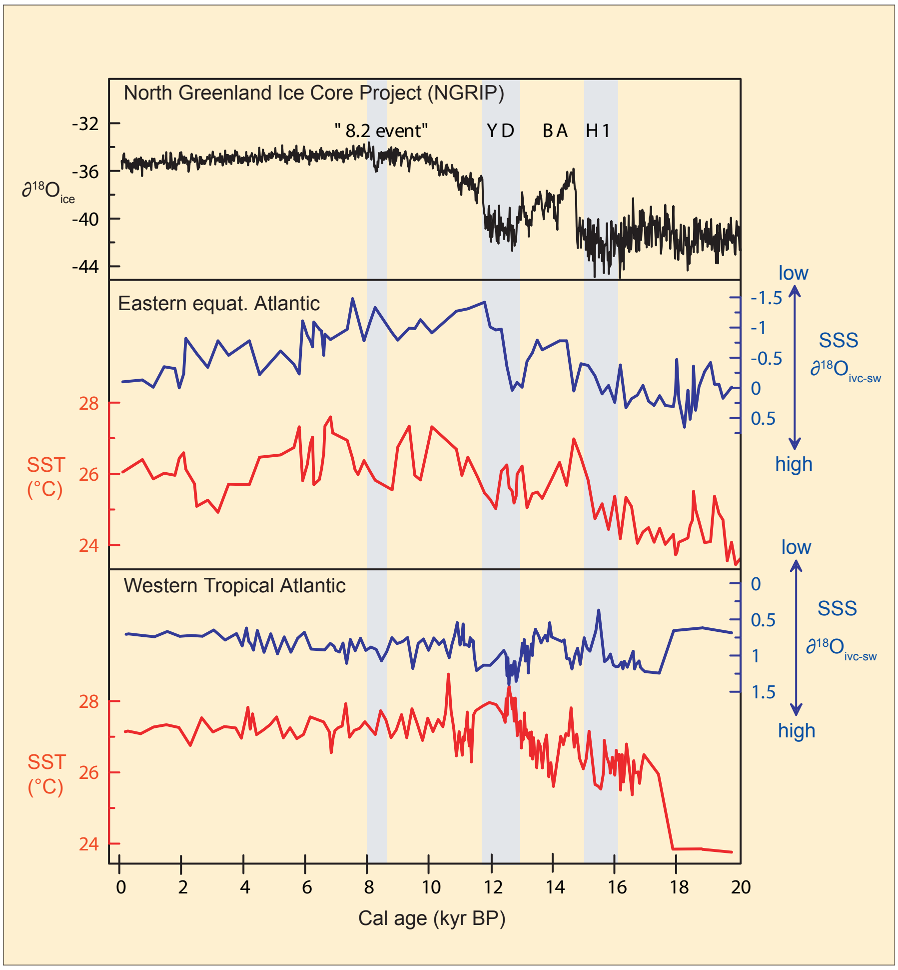

*Figure 1: Comparison of fluctuations in Sea Surface Salinity (SSS) (**blue line**; expressed as $\delta^{18}O_{ivc-sw}$, the planktonic foraminifera $\delta^{18}O$ corrected for changes in continental ice volume and temperature) and Sea Surface Temperature (SST) (**red line**; derived from Mg/Ca of foraminifera shells) between the western and eastern equatorial Atlantic (Courtesy of Syee Weldeab, for more information see Weldeab et al., 2006). YD = Younger Dryas, BA = Bølling-Allerød, H1 = Heinrich event 1.*

The study of past changes in surface ocean temperatures and salinity is one of IMAGES major challenges. Examples from the equatorial Atlantic using paired Mg/Ca and $\delta^{18}O$ measurements on planktonic foraminiferal shells, show that the western and eastern basins have historically experienced very different sea surface temperature and salinity variations, particularly during the Younger Dryas Period and the Holocene (Fig. 1). This can be explained by differences in the response to remote and local forcing. The western equatorial Atlantic is strongly influenced by the thermohaline circulation via the Brazil Current, whereas the eastern Atlantic is intimately coupled to the West African monsoon moisture transport and continental runoff and thus depends on changes in tropical ocean surface temperatures as well as on shifts of the Intertropical Convergence Zone (ITCZ).

The location of the eastern Atlantic core, in close vicinity to the mouths of the Sanaga and Niger rivers, enabled a clear ocean salinity signal of changing river runoff that corresponds in a systematic manner to central African lake-level fluctuations. Such core locations offer great opportunities to directly combine reconstructions of paleosalinities and ocean temperatures with novel organic biomarkers as proxies for river runoff, humidity, and continental temperature (e.g., Weijers et al., 2007). As marine and terrestrial paleoclimate signal carriers are deposited in the same sediment their quantitative investigations are predestined to provide unprecedented results on land-ocean climate linkages.

However, quantitative multi-proxy studies for land-ocean reconstruction at high temporal resolution, and covering periods preceding the last glacial period or even preceding the penultimate interglacial, are not a trivial task. To be successful, we have to retrieve long, large-volume sediment cores from regions sensitive to changes in the hydrological cycle. Short (i.e. 10 m long) gravity cores are not sufficient to cover in appropriate detail the wide range of rapid climate variability that is documented, for example, for the last 130 kyr BP in Greenland ice cores. Instead, by using sediment cores from IODP (Integrated Ocean Drilling Program) and with CALYPSO and CASQ coring, the IMAGES community has recently delivered important contributions to the PAGES objective of investigating past land-ocean climate interactions at high temporal resolution. These studies addressed changes in paleotemperatures and -salinities in the western Pacific (e.g., Stott et al., 2004; Xu et al., 2006), the water vapor exchange between the equatorial eastern Pacific and western Atlantic (Leduc et al., 2007), and changes in monsoonal precipitation over West Africa (Weldeab et al., 2007). These promising results highlight the importance for IMAGES to continue with its strong efforts to assure financial support for future CALYPSO and CASQ coring expeditions and sediment core investigations in the tropical realm.

To synthesize and discuss the paleorecords now available on past variability of the hydrological cycle and associated land-ocean climate linkages, an IMAGES-PAGES-NSF workshop will take place in Trins, Austria, 30 May to 2 June (www.images-pages.org/news_2006-2007.html#trins2007). Together, with the IMAGES Scientific Committee meeting in Shanghai, China, 8-9 September, prior to the International Conference of Paleoceanography (ICP 9, http://icp9.iodp.cn/), the Trins workshop will be dedicated to the identification of new coring sites and strategies to further investigate past changes in the hydrological cycle and to proceed with this theme relevant to PAGES objectives. In the longer term, the task of unraveling past changes in the hydrological cycle and in ocean-land linkages offer ample opportunities, and raise urgent needs, to converge and integrate marine-based and land-based paleoresearch.

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RESOLuTION - Rapid climatic and environmental shifts during Oxygen Isotope Stages 2 and 3 - linking high-resolution terrestrial, ice core and marine archives

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Understanding the complex paleoenvironmental processes associated with the rapid centennial- to millennial-scale Dansgaard-Oeschger (DO) oscillations and Heinrich (H) events during the last glacial period is a major issue in paleoclimate research. These dramatic changes have been documented in ice-core, marine and terrestrial records, but large dating uncertainties prevent detailed, time-synchronous correlations between land, ocean and ice core archives. These correlations are necessary if the roles played by the different parts of Earth's environmental system are to be understood. The ESF EuroCores Project on EuroClimate RESOLuTION is addressing these issues by linking high-resolution, multi-proxy marine, terrestrial and ice-core records through detailed geochronology and time-synchronous tephra horizons (Fig. 1). Moreover, it explores the impact of abrupt climatic changes on Paleolithic populations in Europe and performs transient simulations with a coupled atmosphere-ocean-vegetation model to simulate realistic DO stadial-interstadial changes. The overall aim of RESOLuTION is to propose a scenario that can explain the different timing and impact of DO climate variability on the Atlantic Ocean and adjacent European regions, thus significantly contributing to the debate on mechanisms underlying sub-orbital climate variability.

RESOLuTION is organized around different work packages, each addressing different parts of the climate system. Terrestrial records comprise lacustrine sequences from northern Finland, eastern Germany and eastern France, and marine sequences stretch from the high-latitude to the mid-latitude North Atlantic. The marine records have the advantage that they contain both terrestrial (pollen, microcharcoal) and marine climatic tracers and thus provide a direct correlation between terrestrial (vegetation, fire) and marine environmental responses in western Europe to DO and H events.

For each of our sites we establish detailed, qualitative and quantitative records of biological and geochemical proxies and combine these with analyses of time-synchronous marker horizons (e.g., crypto-tephra, paleointensity changes) and carefully established chronologies. This concerted approach allows the impact of DO oscillations and H events on the terrestrial paleoenvironment to be deciphered and enables detailed comparisons on leads/lags between ice-core, marine and terrestrial records. It also elucidates to what extent these abrupt changes influenced settlement patterns and subsidence strategies of late Neanderthal and Upper Paleolithic populations.

During the two workshops in Les Eyzies, France (September, 2005) and Svinaberga, Sweden (October, 2006) RESOLuTION group members decided to zoom in with highest possible temporal resolution on the time windows of Greenland Interstadials (GIS) 3-8, 14-16 and H event 4. Key tephra layers during this interval are Z2 and the Fugloyarbanki Tephra, although several more crypto tephras are currently under investigation in the Greenland ice cores and in the marine and terrestrial sequences of our transect. Together with the Laschamp and Mono Lake geomagnetic events, these tephra layers form important correlation tools between terrestrial, marine and ice core records. Precise correlations, however, not only depend on specific marker horizons, but also on the choice of a common chronological approach. RESOLuTION uses for compari-