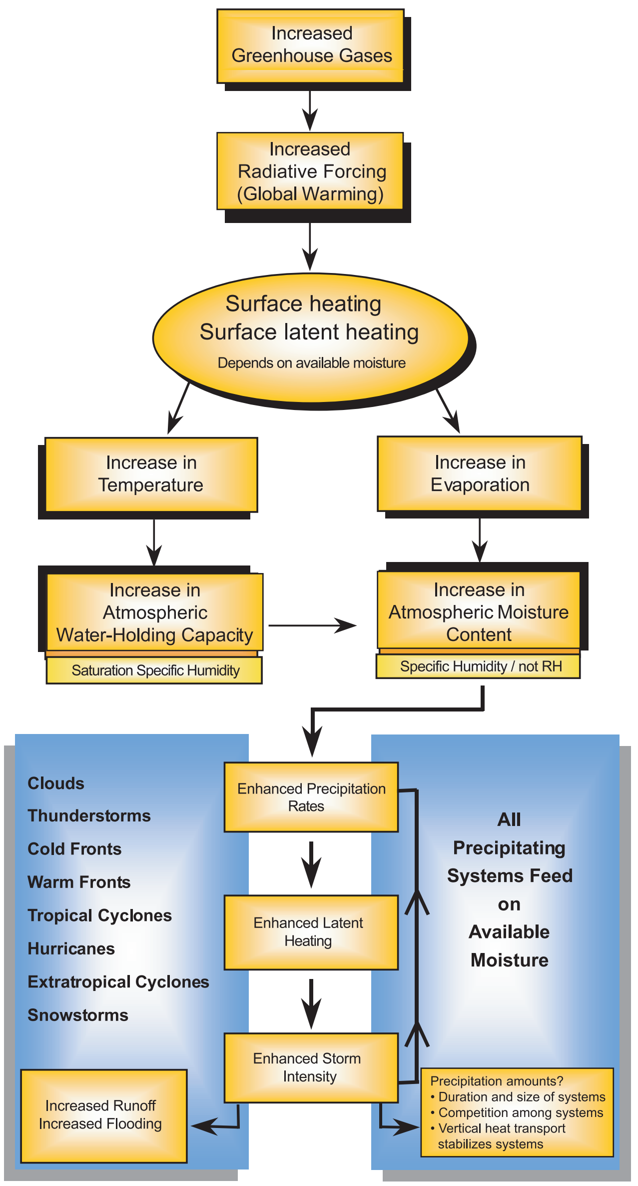

Figure 1: *Schematic outline of the sequence of processes involved in climate change and how they alter moisture content of the atmosphere, evaporation, and precipitation rates. All precipitating systems feed on the available moisture leading to increases in precipitation rates and feedbacks. (Trenberth, 1998)*

events, yet still deal with whole storms rather than individual rain cells, hourly precipitation data are recommended. Such data are also retrievable from climate models.

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Century to Decadal Scale Records of Norwegian Sea Surface Temperature Variations of the past 2 Millennia

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Recent focus on rapid climate change and millennial scale climate variability in paleoceanography has led to a marked improvement in the temporal resolution of paleoceanographic climate records. Recent studies have indicated a possible existence of pervasive cycles of oceanic variability at approximately 1500 years, both in surface waters and in the strength of North Atlantic deep water flows (Bond *et al.*, 1997; Bianchi and McCave, 1999). These cycles appear to continue into the Holocene (postglacial phase – i.e. the last 11,000 years). The last such event may have been the warm-cold alteration normally associated with the Medieval Warm Period (MWP) centred at approximately 1000 AD, and the Little Ice Age (LIA) between 1400 and 1800 AD in Europe. This increased potential for detailed paleoclimatic records from rapidly accumulating sediments, as documented by these and other results, has spurred much interest in the community. The focus has been on obtaining ultra high temporal resolution from sediment cores retrieved from areas where sediment focusing expands the sections and enables detailed sampling. It is also a prerequisite that it is possible to utilise the normal methods of paleoclimatic estimation. This would require open ocean settings and a temporal resolution approaching decadal scale in the best cases. In some very restricted areas annually laminated sediments may be found, which may provide annually resolved paleoclimate records. Outside of these areas, one would need to obtain cores from rapidly deposited sediments in areas of high sediment focusing. Annual resolution is not feasible here.

Using this approach, a pilot study was conducted in high accumulation rate sediments from the Vøring Plateau in the Eastern Norwegian Sea at 67°N (IMAGES core MD95–2011). The study documents SST-variations during the last millennia at hitherto unprecedented resolution (Fig. 1b) from this kind of research. This indicates that careful selection of cores will enable quantitative estimates of ocean proxies approaching decadal scale (see below). The core is dated by ^{210}Pb and AMS-^{14}C (6 dates for the past 2000 years). We estimate the accuracy of the time scale to be about 50 years, which may be somewhat improved in the future by more detailed AMS ^{14}C-chronology. The summer SST is estimated using diatom transfer functions. Parallel work using other SST-estimation techniques are underway.

As can be noticed in the figure, SST during the past 2000 years varied around a mean with amplitude of variations of 1–2 degrees. Compared to the thermal optimum of the Early Holocene (data not shown here) the mean SSTs are a few degrees colder, probably due to the long term influence of declining summer insolation by the orbital factors. Both the MWP and a two-phased LIA are detectable in the data set, as well as rapid cooling and warming intervals, happening over a decade: Note cold-warm-cold phase in the period 1300–1450 AD according to the time scale of the core. Possible century scale cycles may be identified in the data set, but await improved chronological control.

In the figure we have compared this record with the SST record from Bermuda Rise over the same time period recently published (Keigwin, 1996; Keigwin and Pickart, 1999) (Fig. 1A). The lower temporal resolution of the sediment section and possibly a higher degree of bioturbation at this site, has probably worked as a low pass filter on the variability over Bermuda Rise. Hence, only the main multi-centennial scale variations may be compared at this stage. SST changes associated with the MWP and LIA at Bermuda Rise were of the same order of magnitude as in the Norwegian Sea. The timing of the warm and cold phases are not identical. This may be due to the bioturbation filtering, time scale problems, or time scale inaccuracies. Hence, improved temporal resolution and chronologies are required to further compare the spatial SST variability in the North Atlantic. An important path to follow by further investigations is the intriguing proposition of Keigwin and Pickart (1999). They suggest that opposite SST anomalies between the Western North Atlantic and the Labrador Sea region were developed during the LIA in a similar way as the anomaly pattern known from the NAO phases (see Sarachik, this issue).

This work is now underway. Under the auspices of the PAGES marine program, IMAGES, a large community based coring expedition was conducted in the summer of 1999, using the unique large coring system of the French *RV Marion Dufresne*. A large number of sites dedicated for ultra-high resolution studies of this type were cored in the Circum Atlantic and the Nordic Seas. A new era of very high-resolution paleoceanographic reconstructions has been initiated by this cruise, and a wealth of new high quality data can be expected in the next years. This holds good promise for future interaction between the paleoceanogrphy community of PAGES and CLIVAR.

Acknowledgements: We acknowledge support from the EU-Environment and Climate Programme, the Norwegian Research Council and the French CNRS/IFRTP for supporting the IMAGES coring expeditions.

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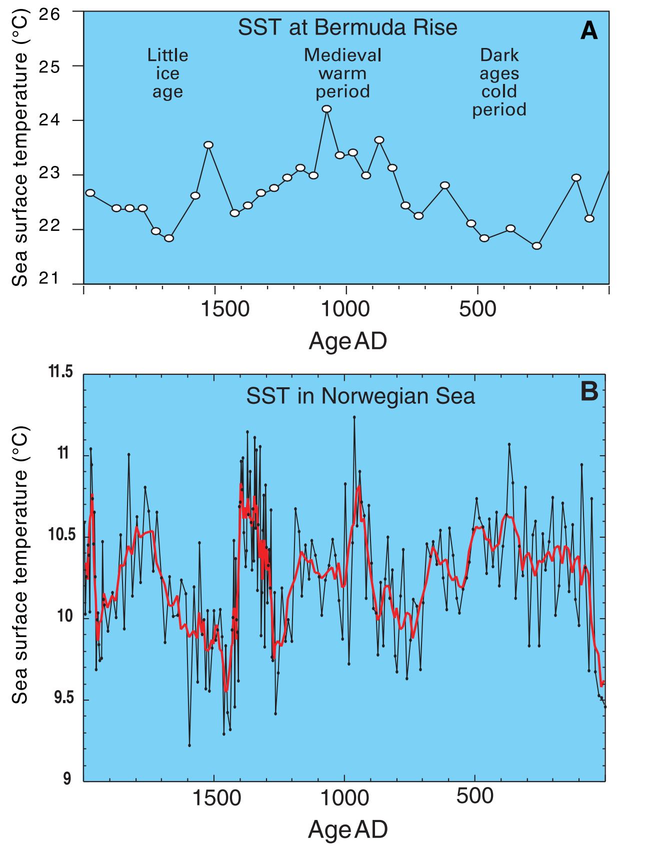

Figure 1: *(A) SST-summer estimates for the last 2000 years at Bermuda Rise. From [Keigwin and Pickart, 1999]. (B) New SST- summer estimates for the last 2000 years at Vøring Plateau, Eastern Norwegian Sea based on diatom transfer functions. The red line is a 5pt running mean.*

Opportunities for CLIVAR/PAGES NAO Studies

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The normal atmospheric situation over the North Atlantic Ocean has surface westerlies blowing across the ocean at about 40°N between the surface expression of the Icelandic low and the Azores high, with the most intense westerlies existing during the winter season. On times scales ranging from monthly to interdecadally, there is an oscillation of the strength of these pressure features which can be conveniently measured by the difference in surface pressure between the Azores (or some nearby station) and Iceland. The state of this North Atlantic Oscillation (NAO) is positive when the Azores high is strong and the Icelandic low is deep and negative when reversed. A time series of this normalized winter index is given in Fig. 1.