hurdles need to be overcome. Workshop presentations demonstrated the utility of digital acquisition tools ranging from computer-aided mapping to the coupled laser scanning/digital imaging of outcrops and structures for research as well as for education. A presentation of three-dimensional outcrops and structures captured over a wide range of scales further highlighted the need for inexpensive geovisualization tools for the Earth science community.

The move toward the digital environment within the United States is growing as community awareness of technological capabilities increases. Presentations of international participants documented that similar trends are prevalent in Europe, Canada, and China. Although many of the components are in hand and are being applied to a wide range of specific problems, an integrated system for acquisition, analysis, and visualization does not exist. Without an integrated system, there is limited community incentive to move from reliable and easy-to-use analog technology to digital acquisition.

The incorporation of digital acquisition and visualization technology into the Earth sciences presents a significant challenge in establishing standards for data reporting and exchange to ensure access to and interoperability of digital data resources. The new technology also increases the burden on community time and resources, through expansion of the educational infrastructure required for effective use of digital acquisition tools and through the increased maintenance and calibration requirements of high-end acquisition technology.

Thus, the greatest educational burden lies not with students now entering the Earth sciences, but rather with existing researchers and educators. This realization focused attention on the need to provide training and support for the use of digital acquisition tools and to expand research and development into the effective use and application of the tools typically designed for use in activities outside of the Earth sciences.

Digital acquisition technology is rapidly evolving, and best practices for data processing and software are not well established for Earth science applications. Given the broad range of anticipated uses, it is clear that significant effort will be required to bench mark techniques and to provide straightforward user interfaces for acquisition tools. Digital acquisition typically uses commercial software that in many applications provides the most cost effective use of resources, but improved efficiency requires revision and development of research and instructional work flows and will require open-source software tailored for specific user groups.

The necessary equipment and facilities are expensive and difficult to capitalize for many research and educational institutions. This financial reality, coupled with the rapid evolution of hardware and software, poses a vexing problem for the transformation of the Earth science community over the next several years. Given the expense, rate of equipment evolution, and lack of processing and analysis infrastructure now in existence, workshop participants advocated that the only practical means of addressing this problem was through the formation of national facilities as the optimal means of propelling geoscience field observation into the digital world. These facilities would supply equipment and develop infrastructural resources required by the research and educational communities. A primary mission for such facilities would be to acquire new equipment and software, work on best practices for use of equipment and software, and serve as clearinghouses to make equipment and software resources available to the community at large.

As a first step, the U.S. participants at the workshop advocated development of a national facility in the United States to supply infrastructural needs of the U.S. community and to serve as a key element in coordinating digital acquisition efforts with other groups around the world.

The Workshop to Identify Ground-Based Digital Acquisiton, Analysis, and Visualization Needs of the Geological Science Community was held on 6–8 April 2006 on the campus of the University of California, San Diego.

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FORUM

How Long Will Our Interglacial Be?

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In a recent *Eos* article (*87*(3), 27, 2006), Broecker and Stocker criticize *Ruddiman*'s [2003] hypothesis of an anthropogenic origin to the Holocene carbon dioxide (CO_2) rise.

Broecker and Stocker note the analogy between the Earth's orbital configuration 400,000 years ago and the current configuration by aligning the *EPICA Community Members* [2004] ice core record for the deglaciation that occurred 430,000–420,000 years ago, with the last deglaciation (20,000–10,000 years ago). Considering that the two situations are analogous, it appears that no glacial inception, marking the end of the Holocene, should have occurred by now.

Several remarks need to be formulated. First, the similarity between the orbital configurations 400,000 years ago and today has long been pointed out and analyzed [*Berger and Loutre,* 1996, 2003; *Droxler et al.,* 2003] on the basis of *Berger*'s [1978] astronomical calculations.

This similarity, as recalled by Broecker and Stocker, is related to low values of eccentricity (orbit close to a circle), which indeed occur every 400,000 years: 366,000 years ago it was 0.004, and within 27,000 years it will be 0.003. In such scenarios, it must be kept in mind that the decision by scientists to align one time period to another is partly arbitrary: It is not possible to match exactly the phases of all three orbital parameters (eccentricity, precession, and obliquity) from two different time periods. *Berger and Loutre* [1996] align the present (year 0) with 400,000 years ago on the basis of summer insolation at 65°N over the interval [-5,+60 kiloyears] correlating well ($r = 0.87$) with that over [-405,-360 kiloyears] (Figure 1). This choice is physically justified by the idea that glacial inception is to a good extent correlated with the amount of insolation received in summer at northern high latitudes. If one considers obliquity as the reference for the alignment, the present will be aligned with -407,000 years (Figure 2). The latter might be somehow justified because obliquity determines annual mean insolation for a given latitude, which in turn partly controls sea surface temperatures [*Lee and Poulsen,* 2005].

However, *Broecker and Stocker* [2006] instead align the deglaciation events that precede those two intervals. In that case, the present is aligned with 410,000 years ago. This alignment is more difficult to justify for two reasons: (1) The evolution of insolation at the time of the deglaciation that led to stage 11 largely differs from that before the last deglaciation (compare insolation during 430,000–420,000 years before present (B.P.) with 20,000–10,000 years B.P. in Figure 1); and (2) the precession parameter was near a local maximum 410,000 years ago, while it is near a local minimum today. Broecker and Stocker recognize precession as crucial in determining the evolution of the system, but this actually suggests the first alignment (400,000 years versus present, as in Figure 1) as being the most appropriate.

Given that there is no perfect alignment, climate modeling is needed to provide further insights into this question. *Ruddiman* [2003, 2005] claims that CO_2 and methane (CH_4) concentrations would have drawn down to 240 parts per million by volume and 450 parts per billion by volume, respectively, in the absence of anthropogenic perturbation. Would glacial inception occur under these circumstances?

Coupled climate and ice sheet models of ‘intermediate complexity’ (that is, simplified with respect to state-of-the-art general circulation models) can calculate the transient response of Holocene ice sheet volume to Ruddiman’s ‘natural’ scenario for CO_2 concentration (but ignoring CH_4) [*Claussen et al.,* 2005; *Crucifix et al.,* 2005]. These simulations suggest that glacial inception would have been close, but not reached.

More extreme tests, with CO_2 kept constant and lower than 230 parts per million by volume [*Loutre and Berger,* 2000] or decreasing at a much faster rate than during marine isotopic stage 7, (234,000 years ago) [*Berger and Loutre,* 2006], yield a glacial inception. On the other hand, general circulation models can predict the present-day snow mass balance for different greenhouse gas concentrations. One of these models [*Vettoretti and Peltier,* 2004] indicates that glacial inception would be very close to occurring today with a CO_2 concentration of 260 parts per million by volume. Another model [*Ruddiman et al.,* 2005] indicates that glacial inception would occur below a combination of CO_2 concentration of 240 parts per million by volume and methane concentration of 450 parts per billion by volume.

The CO_2 concentration threshold for a present glacial inception is thus somewhere around 240–250 parts per million by volume, which does not allow us to exclude Ruddiman’s hypothesis. Of course, glacial inception has not occurred, and given the present greenhouse gas concentrations, it is not expected before at least 40,000 years [*Berger and Loutre,* 2002; *Loutre,* 2003].

The final issue involves whether this ‘natural greenhouse gases scenario’ is realistic. Broecker and Stocker demonstrate that massive anthropogenic emissions prior to the industrial era are not plausible. If Ruddiman is correct, that is, if glacial inception was indeed avoided by humans, it must be understood that the ocean exerted a positive feedback on the anthropogenic perturbation. This implies that humans changed the system’s trajectory at the time it was about to enter glacial inception, thereby triggering a chain of feedbacks that sent the system into a long interglacial. We leave open that question, which has potentially large implications on our understanding of climate system dynamics and its response to orbital forcing.

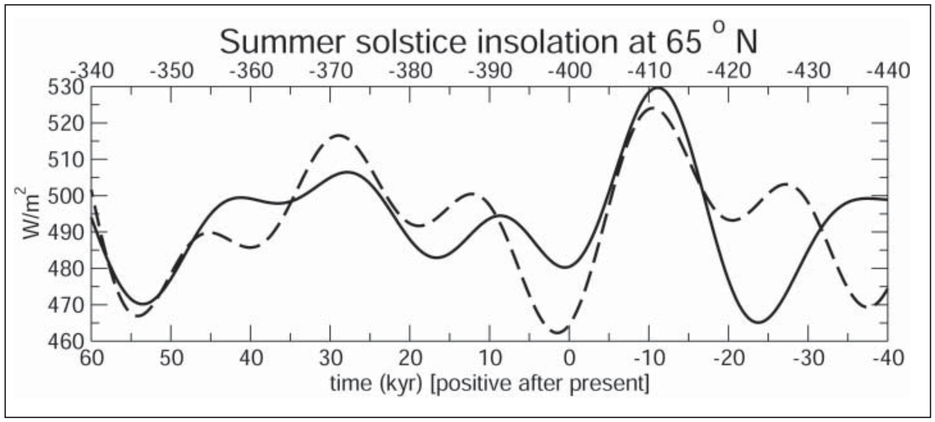

Fig. 1. Evolution of summer solstice insolation at 65°N calculated after Berger *[1978]. The graph is constructed so as to align the present with 400,000 years before present (B.P.). Insolation between 5000 years B.P. and 60,000 years after present (A.P.) (solid curve) correlates well with that between 405,000 and 365,000 years A.P. (dashed curve) [*Berger and Loutre, *1996], even though the correspondence is not perfect. Note, however, the different structures of the evolution around 425,000 years B.P., compared with 15,000 years B.P. Because of this difference, we consider it not appropriate to align the deglaciation events (425,000 and 15,000 years B.P.) as suggested by* EPICA Community Members *[2004] and* Broecker and Stocker *[2006].*

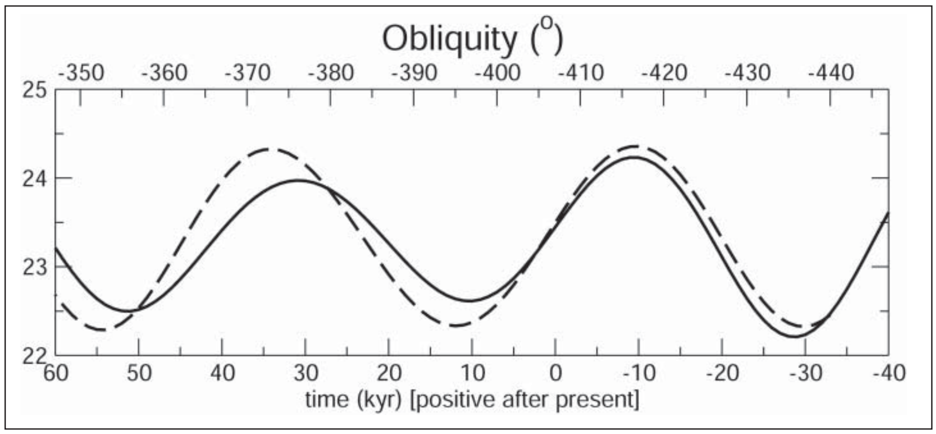

*Fig. 2. Evolution of obliquity [*Berger, *1978]. Obliquity (dashed curve) best correlates with the present times (solid curve) when the present is aligned with 407,000 years B.P. (around marine isotopic stage 11). This is different from the alignment in Figure 1, and shows that no alignment matches the phases of all orbital parameters.*

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