SAHRA Collection permit application #302

Dr. Paul J. Hearty

A. Supplementary information: Description of Research Proposal

1100074: FESD Preliminary Proposal, Type I -- PLIOcene MAXimum sea level (PLIOMAX): Dynamic ice sheet-Earth response in a warmer world

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Knowing the maximum eustatic sea level rise that occurred during the mid-Pliocene warm period (~3 Ma ago) is critical to understanding the dynamic equilibrium response of Greenland and Antarctic ice sheets to a modest global warming. Achieving this objective will require advances in modeling ice sheet dynamics, mantle processes, and the interactive coupling of solid Earth, ocean, atmosphere, and cryosphere components of the climate system. A critical missing element in such studies is a comprehensive data base of globally distributed and dated Pliocene shoreline elevations, capable of providing the data constraints needed to test and guide the development of ice sheet and crustal deformation models required to predict the magnitude and distribution of sea-level rise in a warmer world.

Climate simulations of the mid Pliocene, made with a state-of-the-art ice model and using 400 ppm atmCO_2 as suggested by proxy data, fail to produce air temperatures capable of causing significant surface melt in East Antarctica. These results are at odds with the +25 m sea level rise typically cited for the mid-Pliocene (e.g., PRISM) and imply: a) Pliocene CO_2 levels may be underestimated; b) climate model sensitivity to CO_2 may be far too low; c) the current generation of ice sheet models do not adequately represent important ice sheet physics; d) most sea level estimates for this time period are too high; e) some combination of the above, or f) some alternative major influence on climate that has yet to be identified. It is critical that we collaboratively and *systematically* work to reduce these uncertainties.

We submit that our expertise in four distinct disciplines, focused on the three objectives described below, will ultimately result in one internally consistent solution to a long-standing question, namely that of Antarctic ice sheet stability in a slightly warmer world. **Our proposed five-year plan will deliver:**

1) **A dramatically improved database of Pliocene shoreline elevations from around the world, in this case, those of Western and Northern Cape Provinces of South Africa.**
2) **A series of experiments (and mapped results) that predict the global isostatic response and expected modern elevations of Pliocene shorelines under different ice sheet, mantle, and dynamic topography scenarios.**
3) **A coupled high-resolution atmosphere-ocean-ice sheet/shelf-Earth model, the first of its kind.**

M. Raymo, a geologist with expertise in geochronology and paleoclimatology, and P. Hearty, an expert in field geology of near-shore environments, will lead the data collection effort. J. Mitrovica, an expert on mantle-crustal dynamics with a specific focus on glacial isostasy, will lead the mantle-crust modeling effort. R. DeConto, a climatologist and Earth System modeler, will work with D. Pollard, a leading numerical ice sheet modeler, on climate-ice model construction efforts including coupling, for the first time, to a dynamic Earth model accounting for mantle and gravitational processes (with Mitrovica).

Intellectual Merit: Evidence for ongoing warming of the climate system is unequivocal [*IPCC 2007*] and sea level rise due to melting glaciers is accelerating [*Rignot et al*., 2011]. Conservative estimates suggest a further 1-2 ˚C of global temperature rise, even if massive reductions in GHG emissions were to occur. Building a fully-coupled ice-ocean-atmosphere-mantle/crust model capable of predicting future climate and sea level response of a dynamic Earth system, and providing the data that can help modelers evaluate the fidelity of their ice sheet/climate simulations under different forcing scenarios, are the primary intellectual goals of this proposal. Improving predictive model capability is an essential need in the face of ongoing warming and no greater uncertainty (or potential catastrophe) exists than that of sea level rise.

Broader Impacts: The need for a global array of Pliocene sea level estimates lends itself to a broad, multi-investigator approach and we are committed to engaging as many scientists as possible in this endeavor. This will be accomplished through outreach and collaboration as well as with a wiki site that will serve as a repository for information relevant to undertaking field studies including customizable access modeling results of predicted global eustatic, dynamic topography, and isostatic effects. An NSF-funded companion project, *Sea Change*, is already providing outreach material for a general audience and these efforts will continue in this project. In addition to involving two early career scientists as project collaborators, the PIs (who collectively have a strong record of teaching and mentoring) will train and mentor post-doctoral, graduate student, and undergraduate researchers as part of this project.