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The role of tectonics in the estimation of mid-Pliocene eustatic sea level history

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The availability of accurate records of sea-level history is important to the understanding of past climate conditions as eustatic sea level is strongly related to the extent of continental ice cover. Therefore, the possible contamination of proxy based local records of relative sea-level height by tectonic processes that have been active subsequent to the formation of the sea level indicator presents a significant challenge to the inference of eustatic level (eg. Rowley et al, 2013). The uncertainty introduced by tectonic processes has become a significant obstacle to the success of the PlioMIP program, which is an ongoing international collaboration devoted to understand the climate of the most recent period ($\sim$3 Mya – mid-Pliocene) when trace gas concentrations where essentially equal to modern. At this time it has nevertheless been suggested that eustatic sea level was significantly higher than present implying that slow feedbacks in the climate system, given sufficient time to operate, must have led to a significant diminution of polar land ice. The ongoing PlioMip program is devoted to understanding the climate of this era and the quantity of the constraints that can be brought to bear upon eustatic sea level are clearly important to the success of this program.

The Orangeburg Scarp along the U.S. east coast is a palaeo-shoreline that is dated to have formed during the mid-Pliocene. Therefore it continues to be a significant source for the mid-Pliocene eustatic sea-level record. An initial estimate of local relative sea level was provided by Dowsett and Cronin (1990) who suggested on the basis of their analysis that sea-level was 35m higher than present at that time and this estimate has continued to play an important role in the ongoing "Pliocene Debate".

Here we employ a nonlinear 3D mantle convection model (Shahnas and Peltier, 2010, 2011) to investigate the time-dependent change in the dynamic surface topography forced by mantle convection over the past 3Myr at the location of the Orangeburg Scarp. The goal is to provide further estimate of the extent to which this observation could be contaminated by local tectonic influence beyond that recently produced by Rowley et al (2013). Our model is initialized with a three-dimensional heterogeneous temperature field that has been inferred from seismic tomography. Our analysis suggests that the entire scarp has undergone significant and continuing uplift since its formation. After correcting field observations of the present scarp height for dynamic uplift, we find that the sea-level during mid-Pliocene time was no higher than 12-14m above the present level. This estimate is within the error bounds of Miller et al (2012) and implies the complete absence of the Greenland ice-sheet (known not to exist at that time), as well as the West Antarctic ice-sheet, which is understood to be very unstable. Furthermore our results imply no significant mass loss for the East Antarctic ice-sheet during the mid-Pliocene. Our analysis differs significantly from that of Rowley, in that the magnitude of the correction required for the degree of present day glacial isostatic disequilibrium is entirely insignificant.

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Miller et al (2012), Geology, 40, 407-410
Rowley et al (2013), Science, 340, 1560-1563
Shahnas and Peltier (2010), J. Geophys. Res., 115, B11
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