Closure of the Panama Seaway During the Pliocene -

Implications for Climate and Northern and Southern Hemisphere Glaciation

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(1) INTRODUCTION

The "Panama Hypothesis" states the final closure of the Panama Seaway (~ 3.0 to 2.5 MyrBP), and the onset of major Northern Hemisphere glaciations (~3MyrBP) are not contemporaneous by chance, but that the formation of the Panama Isthmus resulted in changes in oceanic circulation, leading to an increase in moisture transport to northern hemisphere high latitudes, leading in turn to the build-up of snow cover, and ultimately continental-scale glaciations.

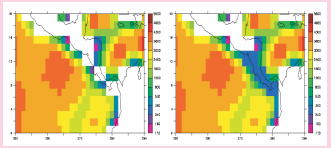
Here, we provide a test of this hypothesis, by running the UK Met Office atmopshere-ocean GCM, HadCM3, with both closed and open Panama Seaways, under Pliocene boundary conditions. We then use the simulated climates to force a dynamic ice-sheet model, GLIMMER, over Greenland and North America.

Finally, we test a further hypothesis, that the closure of the Panama Seaway also had an effect on Antarctic glaciation.

(2) BOUNDARY CONDITIONS

We use the PRISM boundary conditions for the Pliocene simulations, including reduced Greenland and Antarctic ice sheets relative to modern, and modified vegetation and orography. We set atmospheric CO_2 to 400 ppmv.

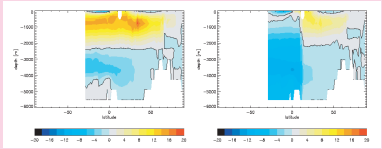
For the Open Seaway simulation, we set the bathymetry in the gateway to 360m below sea level. The bathymetry around Central America in the two simulations is shown below:



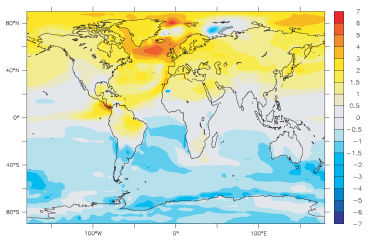
Bathymetry in the Pliocene Closed Seaway (left) and Open Seaway (right) GCM simulations

(3) GCM RESULTS

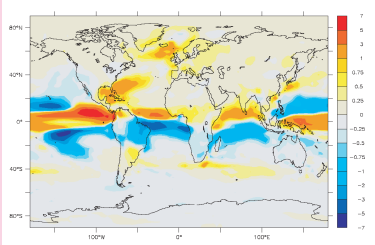
We run the two simulations, Closed Seaway and Open Seaway, for about 250 years. The plots below show the annual mean anomalies for the last 30 years of the simulations, for Atlantic meridional circulation, surface temperature, and precipitation.



Atlantic meridional overturning [Sv], for the Closed Seaway (left) and Open Seaway (right) simulations



Temperature anomaly [celsius], Closed Seaway minus Open Seaway

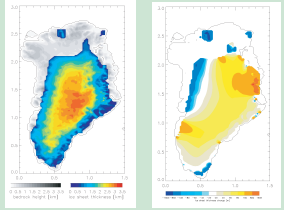


Precipitation anomaly [mm per day], Closed Seaway minus Open Seaway

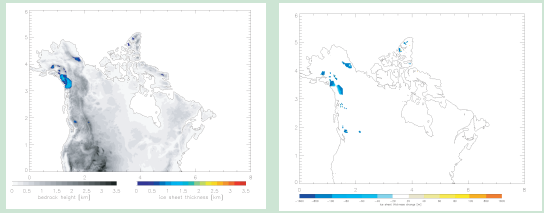
It is clear that the model produces the expected weak THC in the Open Seaway configuration. The closure of the Seaway results in a hemispheric temperature signal, of warming in the Northern hemisphere and cooling in the Southern Hemisphere. This in turn leads to a increase in evaporation in the North Atlantic, and a increase in precipitation over Greenland and North America. This is consistent with the "Panama Hypothesis" outlined in the

(4) ICE SHEET MODEL RESULTS (NORTHERN HEMISPHERE)

We use the temperature and precipitation fields from the two Pliocene GCM simulations, Open Seaway and Closed Seaway, to force (offline) the GLIMMER dynamic ice-sheet model over Greenland and North America. The results are shown below for the Closed Seaway, along with the difference, Closed Seaway minus Open Seaway.



Ice sheet thickness over Greenland, Closed Seaway (left), and anomaly, Closed Seaway minus Open Seaway (right)

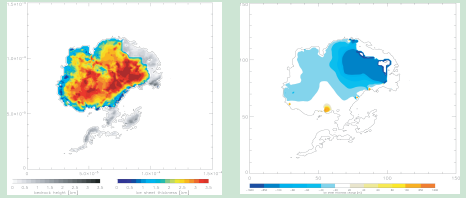


Ice sheet thickness over North America, Closed Seaway (left), and anomaly, Closed Seaway minus Open Seaway (right)

The Pliocene Greenland icesheet is slightly reduced compared to the modern (not shown). The 'Closed Seaway' Pliocene Greenland icesheet is slightly thicker than the 'Open Seaway' icesheet, which does support the original hypothesis. However, the difference is not particularly large.(20 cm of equivalent sea level). In contrast, over North America, the original hypothesis is not supported, because the 'Closed Seaway' icesheet is slightly thinner than the 'Open Seaway', icesheet (14 cm of equivalent sea level).

(5) ICE SHEET MODEL RESULTS (SOUTHERN HEMISPHERE)

Finally, we test a new hypothesis, that the closure of the Panama Seaway was in fact more important for Southern Hemisphere glaciation than Northern Hemisphere glaciation. We use the BASISM ice sheet model over East Antarctica. The volume of the East Antarctic ice sheet is smaller in the Closed Seaway case than in the Open Seaway. The ice volume difference Closed Seaway minus Open Seaway is 2.5 m of sea level equivalent, much greater than in the Northern Hemisphere (6 cm).



Ice sheet thickness over East Antarctica, Closed Seaway (left), and anomaly, Closed Seaway minus Open Seaway (right)

(5) CONCLUSIONS (see submitted paper for more information)

Our GCM simulations are consistent with the standard hypothesis of Panama Seaway-icesheet interactions, in that we obtain an increased moisture transport to northern hemisphere high latitudes, in particular an increase in precipitation over Greenland, when we close the Panama Seaway. We have also found that this increase in precipitation is more important than the increase in temperature in terms of Greenland ice-sheet growth, and results in a increased Greenland ice-sheet, again in agreement with the standard hypothesis. However, this increase is patially offset by a decrease in North American glaciation, leading to just a 6 cm increase in sea level upon closure of the seaway. However, in the Southern Hemisphere , the sign of the signal is opposite - the closure leads to a decrease in ice volume. In addition, the decrease of 2.5 m is much larger than the Northern Hemisphere increase.

We intend to carry out more sensitivity studies on the simulated climates, by varying the Greenland icesheet prescribed in the GCM, by varying the prescribed CO_2, and in particular by varying the orbital parameters between glacial and interglacial values.