The formation of the Panama Isthmus during the Pliocene in a fully coupled GCM - implications for northern hemisphere cooling.

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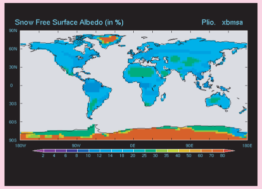
(1) INTRODUCTION

It has been suggested that the final closure of the Panama gateway (~ 3.0 to 2.5 MyrBP), and the onset of major Northern hemisphere glaciations (~3MyrBP) are not coincident 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 an initial test of this hypothesis, by running the UK Met Office atmopshere-ocean GCM, HadCM3, both with and without a Panama Isthmus, under Pliocene boundary conditions. We then use the simulated climates to force a dynamic ice-sheet model, GLIMMER.

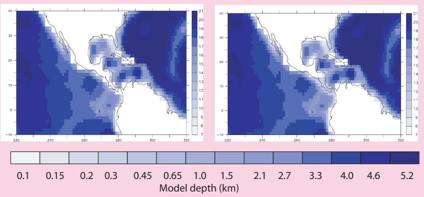
(2) BOUNDARY CONDITIONS

We use the PRISM boundary conditions for the Pliocene simulations; the resulting snow-free surface albedo is shown below. In particular, note the reduced Greenland and Antarctic ice-sheets.



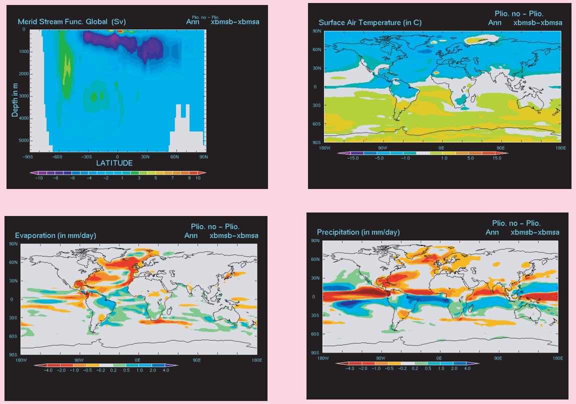
snow-free surface albedo in the Pliocene HadCM3 simulations.

For the no-Panama 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.

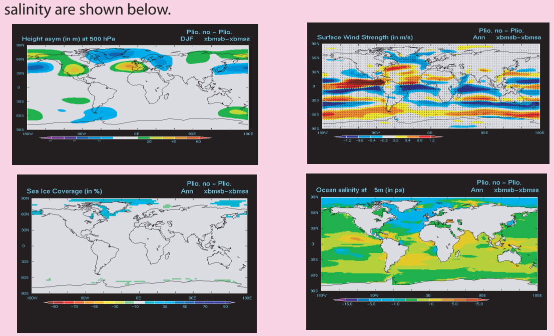


(3) GCM RESULTS

We run the two simulations for 250 years. The plots below show the annual mean anomalies, no-Panama - Panama, for the last 30 years of the simulations, for meridional stream function in the Atlantic, surface temperature, evaporation, and precipitation.

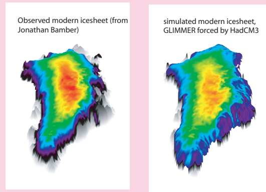


It is clear that the model produces the expected weakening of the THC in the no-Panama configuration. This results in a hemispheric signal, of cooling in the Northern hemisphere and warming in the Southern Hemisphere. This in turn leads to a decrease in evaporation in the North Atlantic, and a decrease in precipitation over Greenland. So far this is consistent with the hypothesis outlined in the introduction. In addition, for information, the anomalies of 500mbar geopotential height, surface winds, seaice, and ocean surface salinity are shown below.

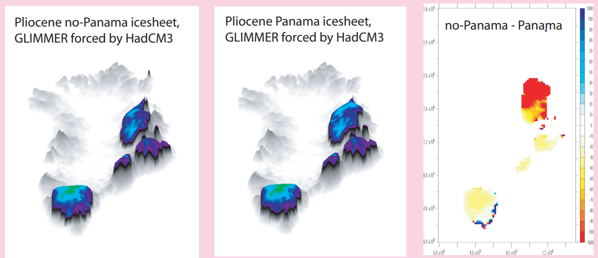


(4) ICESHEET MODEL RESULTS

Initially, we make a brief test by using a pre-industrial model-simulated climate, and using it to force the icesheet model. In an ideal world, one would expect the model to predict a similar icesheet to the observed Greenland icesheet (left); however, the GLIMMER icesheet model predicts an icesheet which is more extensive but lower at the centre (right). It is likely that the cause of this is an oversimulation of precipitation by the GCM, and a mis-representation by the icesheet model of coastal effects such as calving.



We then take the two Pliocene simulations, Panama and no-Panama, and use them to force offline the GLIMMER dynamic ice-sheet model. The results are shown below, along with a difference plot of icesheet thickness. Both Pliocene icesheets are much reduced compared to the modern. The 'no-Panama' icesheet is thinner than the Panama icesheet, which does support the original hypothesis. However, the difference is not particularly large, and the 'no-Panama' simulation has certainly shown signs of glacial incpetion. The large icecap on the southern tip of Greenland is probably due to an oversimulation of precipitation in that region by the GCM.



(5) CONCLUSIONS AND FUTURE WORK

Our GCM simulations are consistent with the standard hypothesis of Panama-icesheet effects, in that we obtain an decreased moisture transport to northern hemisphere high latitudes, in particular an decrease in precipitation over Greenland, when we remove the Panama Isthmus. We have also found that this decrease in precipitation is more important than the decrease in temperature in terms of Greenland ice-sheet growth, and results in a reduced ice-sheet, again in agreement with the standard hypothesis. Although it is not clear that the formation of the Panama Isthmus was the driving force behind the onset of northern hemisphere glaciations, this work implies that it was a factor.

Future work will include: using anomalies to force the icesheet model instead of the direct; starting from different icesheet initial conditions; and tuning the icesheet model parameters using standard observed climatologies.

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

We will also look beyond the Greenland region and run the icesheet model over North America.