Understanding the Role of Cloud Feedbacks in the Warming of High Latitude Continental Interiors During the Eocene.

Mauricio Santillana[1], Eli Tziperman[2], Dorian S. Abbot[3], and Chris Walker[2].

[1] Harvard University Center for the Environment, [2] Harvard University School of Engineering and Applied Sciences, and [3] Geophysical Sciences, University of Chicago.

ABSTRACT

As our Earth gets into higher CO_2 scenarios, the IPCC Report in 2007 has stressed the need to study the role of ***cloud feedbacks*** in our changing climate***. In this work, we examine the role of cloud feedbacks in the warming of continental interiors over North America during the "high-CO_2" Eocene period (55-35 million years ago).*** To this end, we use a cloud resolving model (the state-of-the-art Weather Research & Forecasting modeling system, WRF) over a patch of the Earth containing North America, and prescribe lateral boundary conditions from a Eocene-like run using the CAM AGCM (NCAR Community Atmospheric Model) in high-CO2 concentration scenarios. Preliminary results in coarse resolution runs using WRF, show disagreement with previous proposed cloud feedback mechanisms over marine regions as well as continental interior regions, and open the possibility for alternative explanations.

INTRODUCTION

Among the surprising and interesting climates of Earth's past is the ***Eocene*** period, which is thought to be ***the warmest interval of global climate*** in the Cenozoic. During this period, Earth's climate was equable, *i.e.*, polar surface temperatures were much closer to equatorial surface temperatures than they are today (low equator to pole temperature difference) and high-latitude winter surface temperatures were much closer to summer surface temperatures than they are today (low seasonality). Furthermore, the presence of alligator and palm tree fossils –two frost intolerant species– in northern North America during this period suggests that continental interior temperatures were above freezing during winter times.

The ***explanation*** for this climatic circumstances ***remains elusive*** within the framework of our current understanding of climate dynamics. In particular, our ability to reproduce warm continental interiors with current Global Circulation Models (GCMs) –run with Eocene-like conditions–, along with a convincing physical explanation is limited, and requires further investigation.

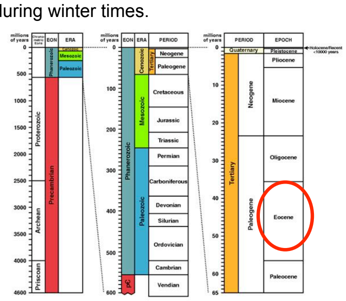

Figure 1. Geological timeline

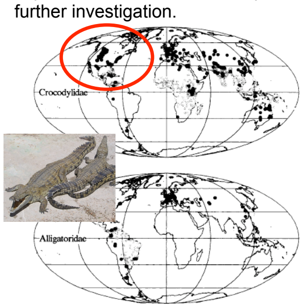

Figure 2. Location of alligator fossils. Evidence of warm winters.

Factors such as changes in continental configuration and in the Sun's output do not appear to play dominant roles in explaining equable climates. Changes in greenhouse levels, however, represent a more flexible avenue of explanation, as the ***CO_2 level*** during equable climates is very uncertain –it may have been as high as ***4000 ppm***– and the concentration of methane and other trace gasses is entirely unknown.

Previous studies have suggested a high-latitude ***cloud feedback*** mechanism as an important factor in the warming of ocean and continental interior regions during the Eocene. The proposed feedback over the ocean, is thought to be triggered by an increase in sea surface temperature due to an increase of atmospheric CO_2.These studies were conducted using the cloud representations available in SCAM (the NCAR single column atmospheric model), and the NCAR community atmospheric model (CAM) AGCM, and thus, their findings rely heavily on the models' cloud parameterizations.

OBJECTIVES

In this work, we intend to gain new insights about the role of clouds in high CO_2 scenarios by running the state-of-the-art cloud resolving model WRF over North America in Eocene-like conditions. WRF encompasses our best understanding of cloud systems up to date, and can be run in horizontal scales not available in GCMs.

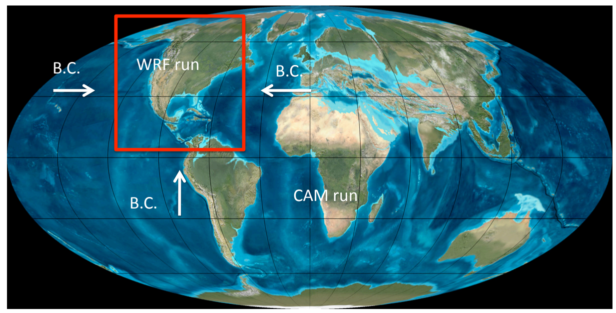

Figure 3. Diagram showing the domain of study with WRF. Lateral boundary conditions (B.C.) are prescribed using the results from a CAM model run with Eocene-like conditions.

METHOD

As shown in Figure 3, we run WRF as a nested domain of CAM. Thus, lateral boundary conditions as well as SSTs are prescribed by the output of a 10-year run of Eocene-like conditions using CAM. We then analyze whether the cloud systems, surface temperatures, and in general the meteorological variables observed using CAM, persist in the WRF runs. So far, we have been able to run WRF for a one-year period with a 50km x 50km resolution. The preliminary results of this run are shown in Figures 4 and 5. In the near future we intend to run WRF with nests with a horizontal resolution up to 2km x 2km.

PRELIMINARY RESULTS

In Figure 4, we see that the January mean surface temperatures obtained by WRF and CAM over North America with a very high concentration of CO_2 are very similar. However, the cloud radiative forcing (CRF) associated to cloud feedbacks appears different in WRF and CAM as shown in Figure 5.

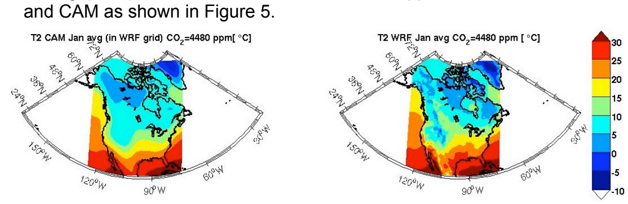

Figure 4. January mean surface temperature (T2) using CAM (left) and WRF (right) in a high-CO_2 (4480 ppm) scenario.

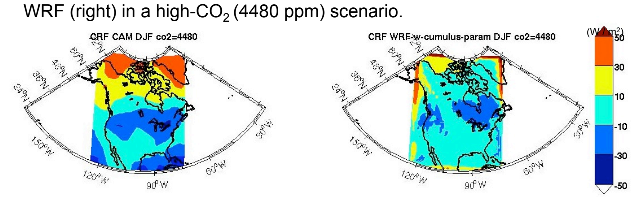

Figure 5. December-January-February (DJF) mean CRF using CAM (left) and WRF (right) in a high-CO_2 (4480 ppm) scenario.

CONCLUSIONS

Our preliminary results show that clouds (and thus, cloud feedbacks) do not seem to play a major role contributing to the warming of the continental interiors in WRF, as they play in CAM runs. This finding motivates further investigation into the role of other factors causing this high temperatures. Also, we need to understand the dependence of cloud systems on cloud parameterizations in WRF.

REFERENCES

Abbot and Tziperman, QJRLM, 2008; Abbot et al, GRL, 2009; Santillana et al. in prep. 2010.