Ben Goldman

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| Word | Definition | Source |
| Last Glacial Maximum | Cold period/ice age caused by reduced greenhouse gas concentrations | Article |
| Individual foraminifera analysis | Use of radioisotope analysis in fossilized plankton to estimate sea temperature | Wikipedia |
| Thermocline | Layer of the ocean where temperature changes rapidly with depth | Wikipedia |
| Planktonic | Relating to plankton | Dictionary.com |
| Monte Carlo Approach | Using random selection to analyze a physical phenomenon | Article, Wikipedia |
| Ekman pumping | Impact of wind velocity on ocean currents | Wikipedia |
| Advection | Horizontal transport of heat from wind | <http://glossary.ametsoc.org/wiki/Advection> |
| Thermal damping |  |  |

Zhu, J., et al. (2017), Reduced ENSO variability at the LGM revealed by an isotope-enabled Earth system model, Geophys. Res. Lett., 44, 6984–6992, doi:10.1002/2017GL073406.

1. How did the LGM ice sheets increase ocean thermal stratification, causing decreased ENSO strength?
2. What effects will increased ENSO strength have on present human society?
3. Do your results agree with alternative measurements of ENSO variability at the LGM?
4. Did you determine the quantitative significance of your results?

Introduction:

Scientists are not sure how ENSO activity will change in the future due to climate change. One way that scientists are answering this question is by analyzing ENSO activity during the Last Glacial Maximum (LGM), a period when decreased CO2 concentrations caused lower global temperatures. However, sea temperature records derived from concentrations of radioisotopes in fossilized plankton (IFA) do not agree about how ENSO variability was different during the LGM, as compared to the preindustrial period. Additionally, computer climate simulations disagree about ENSO activity at the LGM and are not able to simulate the climate’s effect on radioisotope concentrations. This limitation prevents them from being accurately compared to paleoproxy records. This study uses the first isotope-enabled model to evaluate the changes in ENSO at the LGM and the validity of the IFA records.

Model and Experiments:

The researchers used the new iCESM model, the first one able to accurately simulate the climate’s effect on isotope levels. They ran 2 separate experiments, one for the LGM, and one for preindustrial times. For the LGM simulations, they set up the model with known conditions at the LGM, including decreased greenhouse gas levels. They set up the preindustrial simulation with the earth’s climate around the year 1850. They then ran both of these models for 500 years and analyzed the last 200 years. They then calculated both the total standard deviation of the SST and isotope levels, along with the interannual standard deviation. The calculated the interannual standard deviation by calculating monthly departures from the annual cycle, and then detrended the data and calculated the standard deviation.

Weakened ENSO in the Simulations:

First, the researchers compared the LGM simulation with the preindustrial simulation and observed data. They saw that the model exhibited overly large SST variability, when compared with observed data. However, the researchers believe that in the future, this problem can be fixed by using a higher-resolution simulation. The LGM simulation showed a sizeable reduction in ENSO variability, compared to the preindustrial simulation. This result is in agreement with previous experiments. The LGM simulation showed overall cooling, in a Niña-like pattern, with strengthened trade winds and a deeper thermocline. Compared with reconstructions of LGM SST in previous studies, the model results are cooler, but still within the range of standard error.

Comparison with the IFA Records:

They analyzed the variance of the isotope levels in the foraminiferal shells. The researchers observed increased variability in certain core samples and decreased variability in others. There are many possible sources for this disagreement, including vertical foraminifera migration. The researchers then used the model results to fix some of these uncertainties. First, they compared the change in total vs. interannual variance. They observed that while many of the IFA records showed an increase in total variance, they had a decrease in interannual variance, consistent with the model’s result showing a decrease in interannual variance but an increase in overall variance. These results are interpreted as a strengthened annual cycle at the LGM but decreased ENSO strength and the conclusion that overall variance is not an accurate way to measure ENSO variability for sediment cores. The researchers then explored another possible inaccuracy in the IFA cores, vertical migration of foraminifera depending on sea temperature. They found that when calculating isotope levels at a variable depth does not capture either variability in ENSO or in the annual cycle. To address the question of the extent to which depth variability impacts isotope levels, they randomly selected values of the oxygen isotope levels from the model simulations. This test showed a reduction in ENSO strength in the LGM. However, this result does not rule out the effect that vertical migration may have on IFA data and produce a false conclusion.

Mechanisms in the Model and Implications for Global Warming:

To determine the mechanisms responsible for the concluded reduction of ENSO variability at the LGM, the researchers calculated the Bjerknes stability index. The BJ index measures the effect that the interactions between the atmosphere and the ocean have on ENSO growth rate. They found a reduced BJ index, caused by a reduction in the positive feedback loops. This weakening is caused by a reduction in the vertical sea temperature gradient. Reduced greenhouse gas levels caused increased ice sheets, which reduced ocean stratification. They additionally performed an experiment with increased CO2 levels, which resulted in increased ENSO variability.

Conclusions and Discussion:

The researchers concluded that the LGM had reduced ENSO strength and variability. Although some of the IFA records showed an increase in SST variance, the researchers attributed it to an increased annual cycle, rather than increased ENSO variance. Additionally, the model results showed that the IFA records may be inaccurate due to vertical plankton migration. Their results agree with results from previous analysis of foraminifera fossils, but contrast in that they used model results to support their findings and evaluate the usefulness of the IFA approach. Model biases may have impacted their results, but probably did not, as the climate model sed has been shown to reproduce ENSO variability very well. Their results provide evidence supporting an increased ENSO strength in the future caused by global warming. Future studies should use other isotope-enabled models to check the validity of their findings.