ANCIENT (AND NOT-SO-ANCIENT) EARTH ENVIRONMENTS: SPANNING THE SPECTRAL POSSIBILITIES. L. E. Sohl[1,2], M. A. Chandler[1,2], and J. A. Jonas[1,2], [1]Center for Climate Systems Research at Columbia University, 2880 Broadway, New York, NY 10025, [2]NASA Goddard Institute for Space Studies, New York, NY.

Introduction: Early (i.e., pre-oxygenic) Earth conditions are an obvious target for producing "exoplanet" spectra, as existing spectroscopic instruments other environments sampled across Earth history also offer a broad range of possibilities for generating integrated spectra via 3-D climate modeling. Distinct atmospheric compositions through time are attractive, an array of planetary features – such as the global distribution of features such as snow and ice, land vs. ocean, and cloud cover – can also contribute to the characterization of an exoplanet, even at low resolution, via contributions to planetary albedo. [1-2]

The great advantage to simulating specific time intervals/environments in Earth history, especially more recent time, lies in the fact that we are trying to reproduce a known habitable (and inhabited) setting, in which at least rudimentary relationships between biology and environment are known, based on the geologic and fossil records. To the extent that we are able to generate paleoclimate simulations that reproduce well known past surface conditions, we can have greater confidence in the resulting spectra produced from model output.

We discuss here some preliminary 3-D modeling results that we feel help highlight the need to take as broad an approach as possible in utilizing past Earth environments for exoplanet characterization.

Experimental Design: We use the Goddard Institute for Space Studies (GISS) GCM, which has been used for past [3-4] as well as current and future Earth climates. [5] To sample Earth in an extreme cold phase, we ran simulations for two "snowball Earths": the Neoproterozoic snowball event ca. 715 Mya (a.k.a. the Sturtian glaciation), and the Paleoproterozoic snowball event ca. 2.1 Gya (a.k.a. the Huronian glaciation). The same paleogeographic distribution of land and CO_2-poor atmospheric composition (selected to foster extreme glacial conditions) were used for both glacial events, with solar luminosity adjusted for appropriate respective levels of -6% and -16% modern. [6] To represent Earth in a warmer than modern phase, we also examined the Pliocene warm interval ca. 3 Mya, and the Cretaceous period ca. 100 Mya, each with appropriate paleogeography, vegetation and CO_2 levels based on geological proxy data.

Results: The colder the global average temperature, the greater the total cloud cover. In the case of the two snowball Earth simulations, the contribution of cloud cover to high planetary albedo values (>45% in the visual, >27% in near-IR) appears to be considerably outweighed by the great extent of ocean ice cover (~49% of the planet's surface for the Sturtian glaciation, and 100% for the Huronian glaciation). This may be related to the extreme aridity of the glacial atmospheres compared to modern (17% and 1% of modern for the Sturtian and Huronian, respectively), so that cloud cover is widespread but optically thin. In the warm climate simulations cloud cover is optically much thicker and thus brighter, though the increasing limited amount of cover is insufficient to boost planetary albedo values above modern (<35% in the visual, <22% in near-IR).

Future Research: With ongoing development at GISS of the Resolving Orbital and Climate Keys of Earth and Extraterrestrial Environments with Dynamics (ROCKE3D) GCM, a generalized version of the GISS GCM, we look forward to additional simulations that explore additional "exoplanet" variability in Earth through time via modifications to atmospheric and planetary parameters.

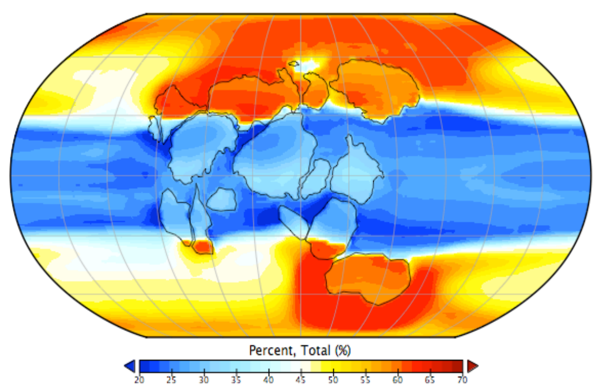

Fig. 1. Total planetary albedo values for the Sturtian snowball Earth simulation. Albedo values >50% correspond closely with the maximum extent of snow and ice cover.

References: [1] Fujii et al. (2010), *ApJ 715, 866-880*. [2] *Fujii et al. (2011), ApJ 738, 184*. [3] Chandler M. A. et al. (2013) *Geosci. Model. Dev., 6, 517-531*. [4] Sohl L. E. et al. (2014) *Habitable Worlds Across Space and Time, STScI Spring Symposium*. [5] Schmidt G. A. et al. (2014) *JAMES, 6, 141-184*. [6] Gough, D. O. (1981) *Solar Phys. 74, 21-34*.