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Earth's Climate - Past, Present, and Implications for Finding Life Elsewhere

Session Moderator: Erika Harnett, Earth & Space Sciences
026 JHN
1:15 PM to 2:45 PM

* Note: Titles in order of presentation.

The Snowball Earth Hypothesis and Its Implications on the Habitable Zone

David Youngjun (David) Yun, Junior, Mathematics, Astronomy, Physics: Comprehensive Physics
Mentor: Cecilia Bitz, Atmospheric Science

Prior to about 650 million years ago, the Earth's surface is believed to have completely frozen and thawed multiple times, each frozen period lasting for millions of years. The term "Snowball Earth" describes the runaway effect of ice expanding equatorward, with its brightly reflecting surface causing reduced absorption of sunlight, increased cooling, and further ice expansion. We used Global Climates Models to better understand the conditions necessary for other planets to be trapped in a Snowball state. We modeled planets that are Earth-like but with ocean-only surfaces. Our object is to investigate and further define the inner edge of the habitable zone - the theoretical region around a star where liquid water can exist on the surface. Our research has big implications for habitability, as liquid water is required for life to exist as we know it. The obliquity of a planet is also very important, as it controls the relative proportion of sunlight received at each latitude. Even within our own solar system there is a wide range. The Earth is tilted 23 degrees, Uranus 97, and Venus 177. We present results for an ensemble of planets with differing obliquities to demonstrate its effects. Furthermore, we also present results for planets around G-type stars, like our Sun, and M-type stars, also known as red dwarfs. Red dwarfs are by far the most common type of star in the Milky Way Galaxy. It is easier to detect orbiting extrasolar planets around M-stars. M-stars tend to have a relatively high abundance of Earth-sized and smaller planets, which are more likely to be rocky - a necessary condition for habitability. The effect of an M star's solar spectrum on a planet's energy balance is significantly different than a G star's, which changes the location of the habitable zone. Our model study provides exciting new insights into the differing dynamics.

Are Glacier Records a Good Climate Proxy?

Joel David Simon, Senior, Earth & Space Sciences (Physics)
Mentor: Gerard Roe, ess

In seeking to put future climate change in context, researchers have used past glacier fluctuations as a proxy for temperature. While an undeniable correlation exists between a warming climate and shrinking glaciers over long time-scales, it has also been shown that the interannual climate variability that occurs in a constant climate can drive large-scale glacier fluctuations. In other words, there is a classic statistical problem of identifying a signal-to-noise ratio. This study seeks to establish how large a change in glacier length needs to be in order to be considered statistically significant. Physically, this study asks how far a glacier must recede, and how quickly, before one can say with confidence that a trend exists. Two glacier models, one linear and one dynamic, based on the geometry and weather patterns of Mt. Baker glaciers in Washington State, USA, are randomly forced in a constant climate and the resulting time series are used for statistical analysis. The statistical significance of a trend depends in large part on constraining the effective degrees of freedom contained in a glacier record. A glacier is a large block of ice and thus has more inertial resistance to change than the weather that forces it. Glacial flow is therefore an integration of multiple years of previous climate forcings. This memory of previous years means the change in glacier length one year does not represent independent information about the current climate; a glacier can lengthen even if the temperature warms for a period. We present several methods for correcting for this effect, and evaluate the power of two standard trend tests for detecting whether a given glacier trend should be attributed to climate change.

Petrology of the Basalt of Summit Creek: A [Slab] Window into Pacific Northwest Magmatism During the Eocene

Lisa Kant, Senior, Geology, University of Puget Sound
Mentor: Jeffrey Tepper, Geology Department, University of Puget Sound
Mentor: Bruce Nelson, Earth And Space Sciences

Passage of Eocene slab windows beneath the Pacific Northwest is documented by plate motion reconstructions as well as the on-land geologic record. The earliest known record of this process is the 55-44 Ma Basalt of Summit Creek (BSC), a steeply dipping 1600 m section of subaerial lavas exposed southeast of Mount Rainier. These tholeiitic basalts erupted in an arc setting (as evidenced by underlying tuffs) but display a mix of MORB and OIB traits and have isotopic signatures of a depleted mantle source. In chemical and isotopic composition BSC lavas overlap with the voluminous Crescent Formation basalts on the Olympic Peninsula, which are of similar age but located ˜100 km farther west. A few BSC samples display arc traits (e.g., HFSE depletions); we suggest these may record interaction between ascending asthenospheric mantle / melts and a mantle wedge previously modified by subduction processes. Compositional diversity among BSC lavas appears to reflect both fractional crystallization and source heterogeneity. Modeling with MELTS (Ghiroso and Sack, 1995) indicates that differentiation dominated by removal of clinopyroxene and plagioclase took place at mid crustal depths (P = 5 kbar) and that the parent magma had <0.2 wt. % water. However, this process cannot account for all incompatible element data, which appear to require multiple parent magmas. The Eocene was a critical juncture in Pacific Northwest tectonics. Subduction, slab window magmatisim, terrane accretion and mantle plume activity were all ongoing at this time. Increased understanding of the petrology BSC will contribute to our overall knowledge of the evolution of the western margin of North America.

Vegetation Reconstruction of the Middle Miocene in Southwest Montana using Phytolith and Stable Isotope Analyses

Kimberly Johanna (Kim) Smith, Senior, Earth and Space Sciences: Geology
Mary Gates Scholar
Mentor: Caroline Stromberg, Biology

The warmest climatic event of the last 34 million years occurred during the middle Miocene, culminating in the Middle Miocene Climatic Optimum, (MMCO; 17-15 Ma) which was a period of substantial warming. The climate change likely affected plant community composition as grasses spread across North America, but because plant macrofossils from the MMCO in North America are rare, the response of vegetation to this warm interval is poorly understood. We combine analysis of plant silica (phytolith) assemblages and study of stable carbon isotopes from the same paleosols to document vegetation changes during the MMCO in southwestern Montana. Phytolith assemblage analysis provides information about vegetation structure, as well as the composition of grass communities, whereas isotopic data allows determination of the proportion C3 and C4 plants. The site near Drummond, Montana, has previously produced Barstovian-aged mammals and is productive for phytoliths. Our results show that grass silica short cells, diagnostic of grasses, in particular C3 pooid grasses, dominate assemblages (up to 75%). The remainder of the assemblages is made up of phytoliths typical of forest indicators, including palms, woody and herbaceous dicotyledons, and conifers. This suggests a fairly open habitat, with grass communities dominated by C3 grasses. Preliminary stable carbon isotope data are consistent with the phytolith results, indicating dominantly C3 plants (90% or above) in the samples. Lateral and vertical sampling from the site shows very little variation in phytolith composition, indicating low spatial and temporal variability.

Linking People, Highlands, and Climate: Climate Change on High-Elevation Socio-Ecological Systems in the Tropical Andes

Paulette A Costanza, Senior, Environmental Studies (Bothell)
Mary Gates Scholar
Mentor: Santiago Lopez, Interdisciplinary Arts and Sciences Program

Due to its global position, the Cotopaxi Nation Park (CNP) area in the Ecuadorian Tropical Andes is expected to experience a large temperature increase of 4 - 7 C during this century due to global warming, affecting approximately 200,000 people, especially regarding water scarcity and environmental degradation. Land use and land cover changes in relationship to climate change are being analyzed using four remote sensing images of the area from 1987, 1999, 2007, and 2009 using a geographic information system (GIS) framework. We are analyzing the recession of glaciers in Mount Cotopaxi, an active volcano with an elevation of 5897 meters above sea level, and changes in highland grasslands (i.e. the paramo ecosystem), which are the two primary water sources for the region. Our analysis will allow us to determine rates of change and estimate future scenarios to help local officials plan for more efficient land and water use. In addition, we are performing statistical analyses on weather data obtained from two weather stations in the area located at different elevations to determine changes in temperature, soil moisture, rainfall, and relative humidity. These data, in conjunction with information gained from the remote sensing images and GIS, will help us answer our research question regarding the effects of climate change on water resources, land use, and land cover in CNP.