Abrupt Climate Change Studies

Symposium Participants & Abstracts

21-23 May 2013

Climate Change: Recent Discoveries and Future Challenges

DAY 1 - TUESDAY

Session 1	**Ocean Change**
	Conveners: Robert Anderson, Arnold Gordon, & William Smethie

Syd Levitus
National Oceanic and Atmospheric Administration

Ocean Heat Content

We review estimates of near-global ocean heat content for the 1955-2012 period.

Jerry Mitrovica
Harvard University

Leaving Eustasy Behind: Implications for Marine Ice Sheet Stability and Inferences of Ancient Ice Volumes

Over a century of research has shown that melting of ice sheets and glaciers leads to highly variable geographic patterns of sea-level change. Perhaps the most dramatic example of this – and certainly the most counterintuitive and underappreciated – is that sea level will fall in the vicinity of a rapidly melting ice complex. Yet, despite this longstanding research, the assumption that post-glacial sea-level change is uniform (i.e., eustatic), or that sites exist in which departures from eustasy are intrinsically minor, is pervasive in analyses of critical events in the Earth's ice age climate. In this talk, I will review the basic physics of post-glacial sea-level change and highlight two recent case studies that illustrate the insight that can been gained by incorporating this physics. First, I revisit the iconic coral record of relative sea-level change at Barbados (Fairbanks, Nature, 1989) that is commonly interpreted as an uncontaminated measure of ice volume since the Last Glacial Maximum. An analysis that incorporates complex mantle structure beneath this region associated with plate subduction demonstrates that the departure from eustasy can be of order 10 m, or more, and that previous inferences of LGM ice volumes based on the coral record have been biased too low. Second, I present results from a new generation of 3-D marine ice sheet models that are coupled to gravitationally self-consistent models of sea-level change at the grounding line. These models highlight a previously unrecognized self-stabilization that can significantly alter the space-time evolution of marine ice sheet retreat in a warming world.

Lynne Talley
University of California, San Diego Scripps Institution of Oceanography

Closure Of The Global Overturning Circulation Through The Indian, Pacific And Southern Oceans

The overturning pathways for the surface-ventilated North Atlantic Deep Water (NADW) and Antarctic Bottom Water (AABW) and the diffusively formed Indian Deep Water and Pacific Deep Water (IDW and PDW) are intertwined. The global overturning circulation (GOC) includes *both* large wind-driven upwelling in the Southern Ocean *and* important internal diapycnal transformation in the deep Indian and Pacific Oceans. All three northern-source Deep Waters (NADW, IDW, PDW) move southward and upwell in the Southern Ocean. AABW is produced from the denser, salty NADW and a portion of the lighter, low oxygen IDW/PDW, which upwells above and north of NADW. The remaining IDW/PDW stays at the surface, moving into the subtropical thermoclines, and ultimately sources about 1/3 of the NADW. Another third of the NADW comes from AABW in the Atlantic. The remaining third comes from AABW upwelling to the thermocline in the Indian-Pacific. The upwelled IDW/PDW, with their enhanced nutrient content, are thus hypothesized to be the dominant source of the upper ocean waters that leave the Southern Ocean and are essential to the biological productivity of much of the world ocean's thermocline.

Martin Visbeck
GEOMAR Helmholtz Centre for Ocean Research Kiel

Two Aspects Of Global Ocean Dynamics: AMOC Observations At The Exit Of The Labrador Sea And Southern Ocean Eddies

The mean and time variable ocean circulation plays an essential role in the regional redistribution of heat, fresh water, carbon, oxygen and nutrients. On the largest scale, arguably the global overturning circulations regulate many aspects of the global climate. New long-term observations in the North Atlantic Subpolar Subtropical gyre demonstrate the inherent variability of the Atlantic Meridional Overturning Circulation (AMOC) and the challenge to fully observe and understand its dynamics. In the southern hemisphere the cross Antarctic Circumpolar Current flows are thought to play a substantial role in the ocean's uptake of heat and carbon. Recent observations and model studies suggest that local eddy dynamics need to be taken into account to estimate meridional fluxes. Both cases demonstrate that the rich spectrum of ocean dynamics need to be considered when estimating changes in regional ocean heat uptake, CO2 budgets and possibly even more so for estimates of future ocean acidification, freshwater budgets and associate changes in the subpolar stratification. The complexity of the challenge demands large-scale coordination of ocean observations, research activities and efforts to inform the public on sustainability issues in the marine realm.

Janet Sprintall
Scripps Institution of Oceanography UCSD

The Role Of Tropical Interocean Exchange Of The Indonesian Throughflow In Climate Variability

The Indonesian seas play a unique role in providing the only open gateway at tropical latitudes allowing inter-ocean exchange between the Pacific and Indian Ocean basins. As such, the Indonesian Throughflow (ITF) is a significant component of the global thermohaline circulation and plays an important role in the heat and freshwater budget of both the Pacific and the Indian Oceans and in regional climate variability. The ITF heat transport removes the incoming surface heat flux from the tropical Pacific, and represents a net transport of freshwater out of the Pacific into the Indian Ocean, where evaporation increase its salinity. The ITF profile also exerts significant control over the global climate, in particular through its impact on tropical sea surface temperature variability (SST). As a result, SST changes cause changes in the convection, atmospheric pressure and wind patterns in the tropics that impact the tropical monsoon system and regional rainfall, and further impact mid-latitude climate through atmospheric teleconnections. This talk will review recent studies of ITF variability. We will conjecture the role this ITF variability may have on the climate system, and vice-versa.

Arnold Gordon
Lamont Doherty Earth Observatory of Columbia University

The Ocean Has Floods And Droughts Too, You Know

Regional patterns of sea surface temperature (SST) are associated with shifts in the wind field that alter the spread of water vapor, inducing flood and droughts on land. However, the ocean, 97.5% of the free water and covering 70% of the earth surface, also experiences floods and droughts. The ocean floods and droughts are recorded by changes in sea surface salinity (SSS). In order to gain a complete view of the global hydrological cycle, the marine component needs to be included. A convenient way to do this is to use dSSS/dt, the ocean 'rain gauge'. There are regional swings, e.g. subtropical, subpolar, of SSS at interannual and decadal scales, but to turn these into information on the marine hydrological cycle we also need to understand the ocean processes that compensate the air-sea E-P, maintaining a quasi-stationary state. These processes may be on ocean circulation scale: why is the Atlantic so salty? The AMOC and interocean exchange, how do these change? Or as we are becoming more aware, because of improved observational methods (Argo profilers, gliders, and now satellites that can measure SSS from space) of the ocean condition, the role of eddies, the ocean's weather, in producing freshwater divergence/convergence. Changes in SSS and SST, which may not share the same patterns, cause changes in SS-density, which affect the 3-D circulation of the ocean. The marine hydrological cycle is complicated.

Session 2	**Hydroclimate Variability**
	Conveners: Edward Cook, Yochanan Kushnir, & Richard Seager

Richard Seager
Lamont Doherty Earth Observatory of Columbia University

Mechanisms Of Hydroclimate Change Under Global Warming

Climate change is not just about temperature change. Both the mean and variability of precipitation are expected to change, as a consequence of GHG-driven climate change, which, in combination with rises of temperature, will create important changes in hydroclimate. The dynamical and thermodynamical mechanisms of these changes will be examined. To a considerable extent the changes in the mean distribution of P-E - wet regions getting wetter and dry regions getting drier - can be understood as a consequence of amplification of water vapor transports in a warmer, moister, atmosphere. Changes in the strength of the mean circulation are also important, with weakening of the tropical circulation offsetting to some extent the impacts of rising humidity, but with Hadley Cell expansion causing subtropical dry zones to expand poleward. Changes in the transient eddy moisture transports also contribute to the more extreme mean hydroclimate distribution while poleward shifts of storm tracks, where and when they occur, can contribute to subtropical expansion. This essentially zonally symmetric picture can be interrupted by changes in forced stationary waves, which appears responsible for a southward shift of the storm track and jet over western North America. It will also be shown that variability of precipitation increases on all timescales from daily to interannual which, once more, is partly a consequence of rising humidity but also involves changes in circulation variability that are quite poorly understood. The controls on changes in variability, beyond the simple effect of rising humidity, will be briefly examined.

William Boos
Yale University

Thermodynamic Scaling Of The Hydrological Cycle Of The Last Glacial Maximum

In climate models subject to greenhouse gas–induced warming, vertically integrated water vapor increases at nearly the same rate as its saturation value. Previous studies showed that this increase dominates circulation changes in climate models, so that precipitation minus evaporation (P - E) decreases in the subtropics and increases in the tropics and high latitudes at a rate consistent with a Clausius–Clapeyron scaling. This study examines whether the same thermodynamic scaling describes differences in the hydrological cycle between modern times and the last glacial maximum (LGM), as simulated by a suite of coupled ocean–atmosphere models. In these models, changes in water vapor between modern and LGM climates do scale with temperature according to Clausius–Clapeyron, but this thermodynamic scaling provides a poorer description of the changes in P - E. While the scaling is qualitatively consistent with simulations in the zonal mean, predicting higher P - E in the subtropics and lower P - E in the tropics and high latitudes, it fails to account for high-amplitude zonal asymmetries. Large horizontal gradients of temperature change, which are often neglected when applying the scaling to next-century warming, are shown to be important in large parts of the extratropics. However, even with this correction the thermodynamic scaling provides a poor quantitative fit to the simulations. This suggests that circulation changes play a dominant role in regional hydrological change between modern and LGM climates. Changes in transient eddy moisture transports are shown to be particularly important, even in the deep tropics. Implications for the selection and interpretation of climate proxies are discussed.

David Battisti
University of Washington

Precessional Forcing, Monsoons, and Isotopic Composition of Precipitation

On millennial and longer time scales, the stable oxygen-18 isotope composition of calcite (δ^{18}Oc) in stalagmites across China is highly correlated to one another and they feature remarkably large temporal oscillations that are tightly choreographed by precessional forcing. These isotopic excursions reflect changes in the precipitation weighted isotopic composition of precipitation, δ^{18}Op, and are larger than the changes in δ^{18}Oc associated with the last glacial cycles. The δ^{18}Oc in stalagmites in Israel, Oman and Tibet also feature large excursions that are coincident with times of extrema in summer insolation in the subtropics of the Northern Hemisphere. Here, we present results from experiments using an atmospheric general circulation model (ECHAM4.6) coupled to a slab ocean model and with an embedded module of the stable water isotope tracers. We explore the relative impact of precessional forcing and glacial-to-interglacial forcing on the temperature, precipitation and isotopic composition of precipitation. Extrema in precessional forcing can account for 7 per mil changes in the δ^{18}Op over eastern Tibet, and 4 to 5 per mil changes over the Arabian Peninsula and the Horn of Africa that are accompanied by large changes in precipitation over these land areas. In short, the Indian and Asian Monsoon dynamics are fundamentally different when summer insolation in the northern hemisphere is low (like today) and high (like the early Holocene). By comparison, the amplitude of the δ^{18}Op changes due to differences in interglacial and glacial (LGM) forcings are only 1 to 2 per mil and are not accompanied by large changes in the spatial distribution of precipitation. The relative importance of local (amount effect/seasonality of precipitation) and non-local (isotopic composition of incoming vapor) effects for the changes in δ^{18}Op will be discussed.

John Chiang
University of California Berkeley

Extratropical Cooling, Interhemispheric Thermal Gradients, And Tropical Climate Change

Paleoclimate evidence and modeling studies suggest the existence of a global atmospheric teleconnection of extratropical cooling to the tropical rainfall climate, mediated through the development of a thermal contrast between the hemispheres—an interhemispheric thermal gradient. This teleconnection has been largely motivated by studies that show a global synchronization of rapid climate change during abrupt climate changes of the last glacial period. In this talk, I will review the motivations and recent developments of this teleconnection hypothesis, in particular the atmospheric dynamics of the underlying mechanisms and applications of this hypothesis toward understanding past, present and future tropical rainfall change.

Aaron Putnam
Lamont-Doherty Earth Observatory

Hydroclimate Of The Tarim Basin, Western China, Over The Past Millennium: Clues From The Deep Desert

The response of Asian water resources to climate change is uncertain, posing a major challenge to 21st century policy and planning. Here, I present geomorphological and palaeo-ecological evidence, underpinned by radiocarbon and tree-ring chronologies, showing that the Tarim Basin of western China was much wetter than present during much of the past millennium. These data contrast with evidence from Southeast Asia for drier-than-present conditions at the same time, suggesting an anti-phase relationship between the hydroclimates of Asian mid-latitude deserts and monsoonal regions. These observations can be explained by a southward displacement of the jet stream over Eurasia during the 'Little Ice Age' cold interval. In view of these results, I will discuss mechanisms for Late Holocene Asian hydroclimate, cultural links, and implications for the future of Asian water resources in a warming world.

Ed Cook
Lamont-Doherty Earth Observatory

The Role Of Paleo-Drought Atlases In Climate Change Research

Hydroclimatic variability is a complex spatiotemporal process that requires the generation of long detailed climate field reconstructions to capture its full range of variability over the Common Era. While it is possible to generate these 'paleo-drought atlases' from complex multi-proxy arrays of paleoclimate indicators, the greatest success to date has come from using dense networks of exactly dated, moisture-sensitive, annual tree-ring chronologies for reconstruction. The 'North American Drought Atlas' (NADA) serves as an archetype in this regard. It has been used to identify the occurrence of unprecedented megadroughts over the past millennium in North America and map them out in a form that is useful for climate model experiments. Thus, the NADA has been used with great success in tests of forced and unforced causes of hydroclimatic variability over North America, especially those related to changing sea surface temperatures (SSTs). The NADA archetype has been successfully extended to Asia in the form of the 'Monsoon Asia Drought Atlas' (MADA). Similar to the NADA, the MADA has revealed the occurrence of past megadroughts in areas affected by the Asian monsoon, including ones in the 14th and 15th centuries that are associated with the demise of the Khmer civilization at Angkor located in present day Cambodia. Indo-Pacific SST variability is suggested as a contributor to these and more recent severe droughts in Monsoon Asia. A new 'Old World Drought Atlas' (OWDA) over Europe, North Africa, and Asia Minor is now nearing completion and preliminary results from it will be presented. When completed later this year, the OWDA will allow for joint spatiotemporal comparisons to be made between the NADA, MADA, and OWDA over the Common Era and serve as the basis for climate modeling experiments over hemispheric spatial scales.

Wallace Broecker
Lamont-Doherty Earth Observatory

Keynote address: *What Drives Glaciation?*

In this talk, I will argue that the link between orbital cycles and ice extent is not summer insolation. Rather, it is reorganizations of ocean circulation, which led to changes in CO_2 content. The evidence in support of this idea comes largely from snowline records.

DAY 2 - WEDNESDAY

Session 3 **Cryosphere Change**
Conveners: Robin Bell, Douglas Martinson, & Joerg Schaefer

Garry Clarke
University of British Columbia

The 21st Century Warming And The Deglaciation Of Western Canada

Our study is concerned with the fate of glaciers in the mountainous parts of British Columbia and Alberta in western Canada. The number (>17,000), area (26,700 km2) and estimated volume (2660 km3) of these glaciers greatly exceed values for the European Alps but they are faring badly in a warming climate. We apply a regional glaciation model to simulate the flow and mass wastage of these glaciers in order to project the rate and magnitude of deglaciation to 2100. As inputs, we require a digital elevation model of the deglacierized surface topography and temporally evolving temperature and precipitation fields, downscaled to the 200 m resolution of the regional glaciation model. For the time span 1979–2008, we derive our downscaled climate from the North American Regional Reanalysis (NARR). The downscaled temperature assumes a time- and space-varying thermal lapse rate, which is calculated from the NARR. The downscaled precipitation uses the linear theory of orographic precipitation together with NARR wind velocity and moisture content fields. Where necessary we apply bias adjustments to the precipitation field based on comparison with station data and a global constraint on glacier mass balance, which we have derived. For the pre-NARR interval, 1902–1978, we base our climate forcing on the Climate Research Unit TS2.1 dataset and for future projections (2009–2100), we use GCM output for the A2, A1B, and B1emissions scenarios. An assessment of GCM performance for northwestern North America has led us to favor six GCMs among all GCMs from the IPCCAR4. With three emissions scenarios and six GCMs, we obtain 18 representations of the climate of the 21st century. (By the time of the symposium, we hope to have completed runs for theRCP4.5 and RCP8.5 scenarios as well.) There are differences in the individual glacier response to the various forcings as well as systematic regional differences but for all regions and projected forcings there is substantial ice loss and for some regions, such as the Canadian Rockies, we predict the near-total loss of glacier ice by 2100.

Beata Csatho
University at Buffalo

The Stability of the Greenland Ice Sheet

Despite its significant contribution to sea level rise in response to climate change, the future behavior of the Greenland Ice Sheet remains largely uncertain. This uncertainty stems from our incomplete knowledge of the pattern and timescales of the ice sheet's response to climate change. Dynamic processes, including ice flow adjustments to past climate variations and responses to contemporary atmospheric and oceanic forcings, have been responsible for as much as half of Greenland's accelerating mass loss since the 1990s. However, the detailed spatio-temporal evolution of dynamic mass changes remains poorly understood. Surface Mass Balance histories, estimated by regional climate models, are increasingly used to separate mass losses derived from remote sensing observations into climate induced and ice dynamics related components. At the same time, there has been a concerted effort from the ice sheet modeling community to incorporate improved physical understanding into numerical models and for developing better prognostic whole ice sheet models. This talk will review recent advances in observations and modeling of Greenland Ice Sheet changes, in particular as they pertain to a better understanding of ice dynamical processes.

Robin Bell
Lamont-Doherty Earth Observatory

Water Beneath Ice Sheets: Changing Paleoclimate Records Changing Ice Flow

In Greenland, water flows through subglacial water networks feed by both surface melt falling through moulins and melting of base of the ice sheet. Much work is ongoing on how this water can lubricate the ice sheet base and increase the ice sheet velocity. Some of this water does refreeze to the base of the ice sheet. Sequences of gas- refrozen free ice outcrop along the margins of Greenland but little is known about how water is captured from the basal water networks and what impact this new ice has on ice sheet structure and dynamics. We demonstrate that freezing from these water networks produces distinct glacier sized bodies of ice that change the ice sheet's structure and key processes. In the interior, basal freezing and the associated large-scale deformation modulates surface accumulation, localizes the onset of fast flow and focuses melt at the grounding line. Basal freeze-on can trigger mobile stick-slip spots in the ice sheet that modulate ice flux at intervals similar to Heinrich events. The evidence for the widespread freezing from subglacial water networks in Greenland from the interior to the margins, reveal that through freeze-on subglacial hydrology influences ice sheet processes from top to bottom.

Eric Steig
University of Washington

The Role Of The Tropical Pacific In Climate Change And Ice Dynamics In Antarctica On Decadal To Millennial Timescales

The West Antarctic Ice Sheet is the most dynamic part of the Antarctic ice sheet. The WAIS may have collapsed entirely during the last interglacial period, and certainly collapsed during some earlier interglacials. The outlet glaciers than drain the WAIS into the Southern Ocean are thinning rapidly today due to wind-driven inflow of warm ocean water onto the Antarctic continental shelf. Contemporaneously, sea ice in the West Antarctic sector has declined, and air temperatures over the WAIS have risen as fast as anywhere else on the planet. All of these observations are linked to changes in atmospheric circulation forced primarily by changes in the tropical Pacific -- essentially, the anomalous character of ENSO events in recent decades (Steig et al., 2009; 2012; 2013; Ding et al., 2011; Ding and Steig, 2012).

Is the link between tropical forcing and climate and ice sheet response in West Antarctica as important on millennial timescales as has been observed on decadal timescales? This question is of interest in the light of currently popular idea that changes in the “thermal equator” (the position of the ITCZ) have a profound role to play in the worldwide expression of climate anomalies associated with Dansgaard-Oeschger events. Results from the new WAIS Divide ice core -- the first high resolution, annually layer counted long ice core record from Antarctica -- suggest that the answer is yes.

The oxygen isotope record from WAIS Divide shows the expected out-of-phase “seesaw” relationship between Greenland and Antarctica already seen in other records. However, the deuterium excess record, from WAIS Divide, shows a clear in-phase relationship with the D-O events, with rapid rises in deuterium excess accompanying rapid rises in global methane concentrations. Methane variations are in turn already well known to be in phase with Greenland climate. Rapid increases in methane during D-O events are almost certainly of tropical origin, and are linked to rainfall changes associated with the ITCZ. In model experiments, rapid changes in deuterium excess in West Antarctica also occur in response to changes in tropical rainfall -- due to the characteristic poleward propagating Rossby wave response to changes in tropical convection. The WAIS Divide record thus provides evidence for changes in atmospheric circulation over West Antarctica, similar to those occurring today, during D-O warming events. One can speculate that Meltwater Pulse 1A, which occurred in phase with the Bølling rapid warming event, had its origin in wind-driven ocean circulation changes that delivered additional heat to the margin of the West Antarctic ice sheet.

Doug Martinson
Lamont-Doherty Earth Observatory

Changes In Antarctic Marine Glaciers, Sea Ice, And The Underlying Ocean

Antarctic marine glaciers, predominantly in west Antarctica, are melting rapidly contributing to global sea level rise. The melt is primarily driven by melting of the underside of the ice via warm ocean waters. These warm waters, specifically Upper Circumpolar Deep Water (UCDW), are delivered to the continental margins by the Antarctic Circumpolar Current. The UCDW controls the upper ocean stratification that dictates how much sea ice can grow, and is the water responsible for melting the underside of the marine glaciers. That UCDW has undergone tremendous warming in the last 50 years, reflecting the warming that the global oceans have undergone.

Joerg Schaefer/ Summer Rupper
Lamont-Doherty Earth Observatory

Climate And Mountain Glacier Change Through The Holocene To Present Day

Mountain glaciers are shrinking around the globe, creating dramatic problems for societies by natural hazard (Glacial Lake Outburst Floods) and by changing the downstream hydrology with immediate impacts on energy and agricultural production. Sustainable development in such regions critically depends on a robust evaluation of ongoing and future climate and glacier change. Here we present new results from Central Asia and beyond that afford for a better understanding of the past, present and future glacier-climate coupling. We apply paleo-data to calibrate glacier models, and discuss future glacier change scenarios and their down-stream impacts together with first mitigation and adaption strategies in a region where hundreds of millions depend directly or indirectly on glacier melt water discharge.

Session 4	**Climate Forcing**
	Conveners: Gisela Winckler, Mike Previdi, & Jason Smerdon

Andreas Schmittner
Oregon State University

Climate Sensitivity Estimated From Paleoclimate Data

Climate sensitivity, defined as global average surface temperature change due to a doubling of atmospheric CO_2, remains uncertain. Many previous studies using observations from the instrumental period of the last ~100 years have indicated a small but significant probability for very high climate sensitivities up to 10 K and more. Here I summarize recent attempts to use paleoclimate temperature reconstructions to estimate climate sensitivity focusing on the Last Glacial Maximum (LGM, ~20,000 years ago).

The LGM is a particularly interesting period not only because of the large amount of data available but also because of the forcing is relatively well known. Simple back-on-the-envelope calculations as well as detailed Bayesian inversions indicate that high climate sensitivities (> 5 K) are inconsistent with the paleodata and should have zero probability. Methodological issues will be briefly discussed as well as how the new PMIP3 LGM simulations fit into the picture.

David Archer
University of Chicago

CO2 vs Methane

I'll compare and contrast the potential climatic impacts of CO2, an accumulating, massively released but relatively weak greenhouse gas, with shorter-lifetime greenhouse forcing agents such as methane and black carbon. Developments in extraction technology, such as fracking, have resulted in ~10% increases in the estimates of total fossil fuel available globally, but there have been claims that there is less coal than previously thought, which would decrease this potential CO2 source by ~ 2/3, good news if true. Permafrost peats stand poised to potentially significantly amplify the fossil fuel carbon release, and the mysterious process responsible for the glacial / interglacial cycle in atmospheric CO2 could also possibly act as a carbon source in a warming world, although probably only on a time frame of a millennium or longer. For methane, there is abundant potential source from degradation of the permafrost peats, although the slow melting time scale for permafrost will probably make this a small perturbation to atmospheric methane concentration, which is dominated by low-latitude wetland sources. Ocean hydrates contain vast stores of methane but these too will take a long time to thaw, and most of the methane released will probably degrade to CO2 within the sediments or ocean rather than reaching the atmosphere as methane gas. I'll conclude with a comparison of the climate impacts of slugs of greenhouse gases, CO2 vs. methane, to show why CO2 is the greenhouse gas most to be feared.

Lorenzo Polvani
Columbia University

Stratospheric Ozone and Southern Hemisphere Climate Change

The effects of stratospheric ozone depletion on the entire Southern Hemisphere climate system, as well as the projected impacts of ozone recovery, will be reviewed and contrasted with those due to increasing greenhouse gases.

Gavin Schmidt
NASA Goddard Institute for Space Studies

Last Millennium Forcings And Responses

The important natural climate drivers over the last thousand years include orbital forcing, volcanoes and solar variability. Estimates of their changes over that time are uncertain, and I will describe the wider protocol for assessing the response to these forcings in the 'past1000' PMIP3/CMIP5 experiments. I will present some preliminary results from a suite of model runs sampling structural uncertainty in both model configuration and forcing estimates and compare them to recently updates in proxy-based climate reconstructions.

Gisela Winckler
Lamont-Doherty Earth Observatory

Aerosol Forcing or Aerosol Feedback?

It is well established that anthropogenic aerosols act as short lived forcing in the climate system, in contrast to natural aerosols, which are considered feedbacks. Anthropogenic aerosols however, are also governed by feedback processes that change aerosol properties with changing climate. In Earth system studies the question of what perturbation constitutes a forcing and what constitutes a feedback will become more challenging with increasing complexity of Earth system models. In this presentation, I will discuss feedback loops of natural and anthropogenic aerosols to address this issue in more detail.

Mike Previdi
Lamont-Doherty Earth Observatory

How Will Atmospheric Moisture Transport From Ocean To Land Change With Anthropogenic Climate Change?

Ocean evaporation and subsequent moisture transport by the atmospheric circulation is the primary mechanism supplying moisture for precipitation over land. The atmospheric moisture flux convergence over land and its changes through time are therefore of great interest to society, significantly impacting land hydrology and availability of water resources. In this talk, I will use coupled atmosphere-ocean general circulation model simulations from the Coupled Model Intercomparison Project 5 (CMIP5) to examine changes in the atmospheric moisture transport from ocean to land associated with anthropogenic climate change. CMIP5 "single forcing" experiments will be employed in order to separate the moisture transport effects of anthropogenic greenhouse gases and aerosols. Initial results indicate a strong sensitivity to aerosols, thus providing additional evidence that future changes in aerosol emissions in response to air quality concerns, as well as possible geoengineering solutions to address global warming, could significantly impact the hydrological cycle.

Peter Molnar
University of Colorado

Keynote address: *Orographic Controls On Climate And Paleoclimate Of Asia: Thermal And Mechanical Roles For The Tibetan Plateau*

For decades, heating of Tibetan Plateau has been seen as a crucial part of the South Asian monsoon. Over the past two decades, geologic evidence has accumulated to suggest both (a) a change in how Tibet has grown into a higher wider plateau some time since 10-15 million years ago and (b) a roughly concurrent change in regional climates of eastern Asia. The temptation to link them has been hard to ignore, but with peril for those of us who have been tempted, for somewhat different views of the monsoon and Tibet's influence on it are emerging; Tibet's role in the monsoon may be more modest than previously assumed. (1) Perhaps heating over it is important for onsets and withdrawals of the Indian monsoon, but not obviously during the main part. (2) The growth of eastern Tibet since 10 million years ago maybe have led to a drying of northern Pakistan, rather than an enhancement of monsoon rainfall. (3) For eastern Asia (the "East Asian Monsoon"), heating over Tibet may also play a minor role, compared with the mechanical effect of inserting a barrier in the westerly winds. (4) Over northern China, the marked increase in loess deposition since ~10 million years ago may be blind to the growth of Tibet, though perhaps not to increased topography farther north. The Asian monsoon system remains a challenge for those interested in both modern and paleo-climate.

DAY 3 - THURSDAY

Session 5	**Human Perspectives**
	Conveners: Mark Cane, Peter DeMenocal, & Yochanan Kushnir

Arlene Fiore
Lamont-Doherty Earth Observatory

Influence Of Changes In Emissions And Climate On Baseline And Extreme Levels Of Air Pollution

Air pollutants and their precursors force the climate system by altering radiation budgets, and their distributions are in turn highly dependent upon regional climate. We focus here on methane and tropospheric ozone, the second and third most important anthropogenic greenhouse gases, respectively. Since methane is a key precursor to tropospheric ozone, reducing methane emissions decreases climate forcing and lessens the global public health burden by decreasing ozone levels in surface air. Accurate projections of future air quality require a thorough understanding of not only changes in precursor emissions but also the meteorological conditions that modulate the accumulation versus ventilation of pollutants in surface air. Here we analyze changes in the distribution of ozone smog in surface air over the eastern United States, as observed over the past few decades, and as projected by a chemistry-climate model under 21st century air pollutant emission and climate scenarios, with a particular focus on extreme pollution events. Additional model sensitivity simulations enable us to attribute projected changes of both baseline pollution levels and extreme events, to controls on regional non-methane precursor emissions, global methane, and climate-induced meteorological changes. We highlight the potential for rising global methane and meteorological changes, such as shifts in the jet stream location in a warmer climate, to offset some of the air quality improvements otherwise attainable via traditional pollution control efforts.

Cynthia Rosenzweig
NASA Goddard Institute for Space Studies

Science for Hurricane Sandy Recovery

Hurricane Sandy caused significant impacts to the built and natural environment in New York City. Many impacts were identified many years in advance due to the City's long history of recognizing climate risks. In the wake of this trans formative storm, the rebuilding process should be informed by the potential for a changing climate. This process requires collaboration and coordination across a range of administrative scales and systems.

Solomon Hsiang
Princeton University

The Causal Effect of Environmental Catastrophe on Long Run Economic Growth

Do natural disasters have a causal effect on economic development? Reconstructing every country's physical exposure to the universe of tropical cyclones during 1950-2008, we exploit year-to-year variation in cyclone strikes to identify the effect of disasters on long-run growth. The data reject long-standing hypotheses that disasters stimulate growth via "creative destruction" or that short-run losses disappear following migrations or transfers of wealth. Instead, we find robust evidence that national incomes decline, relative to their pre-disaster trend, and do not recover within twenty years. This result is globally valid holding for countries of all types, and is supported by non-income variables as well as global patterns of climate-based adaptation. National income loss arises from a small but persistent suppression of annual growth rates spread across the fifteen years following disaster, generating large and significant cumulative effects: a 90th percentile event reduces per capita incomes by 7.4% two decades later, effectively undoing 3.7 years of average development. The gradual nature of these losses render them inconspicuous to a casual observer, however simulations indicate that they have dramatic influence over the long-run development of countries that are endowed with regular or continuous exposure to disaster. Linking these results to projections of future cyclone activity, we estimate that under conservative discounting assumptions the present discounted cost of "business as usual" climate change is roughly $9.7 trillion larger than previously thought.

Kris Karnauskas
Woods Hole Oceanographic Institution

The Hadley Circulation: Dynamics, Asymmetry, and CMIP5 Projections

The Hadley circulation (HC) represents the Earth’s major atmospheric overturning and is responsible for the majority of heat exchange between the tropics and higher latitudes. Questions as to the dynamics governing its mean state, variability, and trends remain. Investigations of trends in the strength of the HC over recent decades have yielded mixed results. The future behavior of the HC bears obvious societal importance as the descending branch of the HC is associated with the world’s desert regions in the subtropics, and tentative links have been made to regional precipitation changes, including extreme events. Projections from CMIP3 models indicate a robust poleward expansion of the zonal mean HC along with a poleward shift of the midlatitude storm tracks due to an increase in subtropical static stability moving the zone where the HC becomes baroclinically unstable towards higher latitudes. Here we show that the Earth’s HC is sufficiently asymmetric that it is well described by three regionally distinct cells along the eastern edges of the three major ocean basins with opposing circulations elsewhere. Moreover, comparable summertime hemisphere cells emerge in each region. The dynamics of the HC are shown to be fundamentally geostrophic, driven by zonal pressure gradients supported by land surface heating and large-scale ocean-atmosphere interaction. CMIP5 model projections of the HC are analyzed with close attention given to the aforementioned dynamics, associated expressions of regional heterogeneity, and uncertainty.

Connie Woodhouse
University of Arizona

A Paleoclimatic Perspective on Water Resource Vulnerability in the Western US

Ongoing droughts in major watersheds in the western US, particularly in the Colorado and Rio Grande basins, have prompted concerns about water resource vulnerability to climate change. To date, these droughts have not exceeded the severity and persistence of drought documented by tree rings over the past 2000 years. Reconstructions of streamflow and seasonal precipitation allow an assessment of the range of hydroclimatic variability that has occurred in the past, and which should be expected in the future, even without the impacts of climate change. These records, and the droughts they document, have obvious implications for water resource management. Extended records of hydroclimatic variability are increasingly being considered, along with projections of climate change, in planning for future drought. Current applications of this information include testing water system response to persistent drought, and building scenarios for the future to help anticipate extreme drought and plan adaptive responses.

Kim Knowlton
Natural Resources Defense Council

Climate Change & Health: Connecting The Dots

Climate change threatens human health in the US and globally, with impacts already underway. Estimated health costs of US climate change-related events totaled in the tens of billions from 2000-2009, yet many Americans are unaware of these climate-health connections. Health threats are amplified most acutely for vulnerable communities and people. Preparedness can limit some of these health effects, but society's ability to adapt to increasing threats may be limited in future. Combatting climate change in the near term can protect health, while also providing benefits to transportation, energy and agriculture. Creating healthier, more climate-secure communities will take the combined creative power of science, people and policymakers, as abrupt climate changes bear down on us globally.

Lisa Goddard
The International Research Institute for Climate and Society

Beyond Climate Predictions

Climate information is needed across timescales, from days to decades, to better inform decisions and to build resilience. This information may inform early warning systems to facilitate early action, or it may inform year-to-year management or longer term planning. Such climate information may be based on predictions of the future, but just as important is how information is conveyed about past and current observations. In this talk, I will overview examples of climate information that has been motivated by real world context. Issues related to the production of quality forecast, as well as their presentation, will be discussed. A critical element in this discussion is the contribution of observations to decision support systems, particularly in situations where forecast skill is weak. Consideration of the full range of climate information, with attention to its presentation, can help build resilience to current and future climate.