"Climate Sensitivity Extremes: Assessing the Risk" – meeting agenda

Monday, April 26, 2010

8:30-8:45	Opening remarks (Michael Previdi, Beate Liepert, Dorothy Peteet)
8:45-9:30	James Hansen – *Climate Sensitivity*[1]
9:30-10:15	V. Ramaswamy – *Understanding the Sensitivity of the Climate System to the Anthropogenic Greenhouse Gas and Aerosol Forcings*[2]
10:15-10:45	Coffee break
10:45-11:30	Daniel Murphy – *The Global Energy Balance and Climate Sensitivity*[3]
11:30-12:15	Sydney Levitus – *Ocean Heat Content, 1955-2009*[4]
12:15-1:15	Lunch
1:15-1:45	Michael Previdi and Beate Liepert – *Climate Sensitivity and the Global Water Cycle*[5]
1:45-2:15	Dorothy Peteet – *Clues and Questions from Paleoclimate – Implications for Climate Sensitivity*[6]
2:15-3:00	Anthony Broccoli – *Climate Sensitivity and Orbital Forcing*[7]
3:00-3:30	Coffee break
3:30-4:15	David Beerling – *Elevated Concentrations of Trace Greenhouse Gases and Climate Sensitivity during Ancient 'Greenhouse' Climates*[8]
4:15-5:00	Corinne Le Quéré – *Climate Change and the Ocean's Carbon Cycle*[9]

Tuesday, April 27, 2010

9:00-9:45	Martin Heimann – *Terrestrial Carbon Cycle-Climate Feedbacks in a Warming World*[10]
9:45-10:30	Steve Frolking – *Peatlands in the Earth's 21st Century Coupled Climate-Carbon System*[11]
10:30-11:00	Coffee break
11:00-11:45	James Galloway – *Nitrogen: A Story of Food, Fuel and Carbon*[12]
11:45-12:30	Discussion/closing remarks

Adjourn

1. James Hansen, NASA Goddard Institute for Space Studies (GISS), New York, NY

   Climate Sensitivity

   Climate sensitivity to a climate forcing depends upon time scale and the mean climate state at the time the forcing is applied. The Earth's history, preserved in paleoclimate data, provides a remarkably rich record that allows climate sensitivity to be deduced empirically with a greater accuracy than is possible with climate models. Climate sensitivity turns out to be remarkably high, as a consequence of the dominance of positive (amplifying) feedbacks on most time scales. Observations of ongoing changes on Earth are consistent with the quantitative inferences about climate sensitivity.

2. V. Ramaswamy, NOAA/Geophysical Fluid Dynamics Laboratory (GFDL) and Princeton University, Princeton, NJ

   Understanding the Sensitivity of the Climate System to the Anthropogenic Greenhouse Gas and Aerosol Forcings

   The NOAA/ Geophysical Fluid Dynamics Laboratory's climate model is employed to compare the effects of the anthropogenic aerosols with that of the long-lived greenhouse gases over the 20th century on the global-mean to continental-mean spatial scales. While aerosols have in general provided an "offset" to the warming tendency due to increases in the greenhouse gases in the past century, there are separate effects exerted with regards to surface temperature and precipitation changes. Limitations arise in the accurate quantification of the role of the aerosols. Of central importance are: the contributions of black carbon and aerosol microphysics, and the nature of the aerosol-cloud interactions. These uncertainties, in turn, affect the inferences about the relationship between anthropogenic radiative forcing and climate response over the course of the 20th century.

3. Daniel Murphy, NOAA Earth System Research Laboratory (ESRL), Boulder, CO

   The Global Energy Balance and Climate Sensitivity

   This talk will review the work on energy balance with an emphasis on climate sensitivity. I will also examine the assumptions behind linear energy balance models. The Earth's energy balance since 1950 can be examined using measurements and radiative transfer calculations, thus identifying results that can be obtained without using global climate models. We explicitly consider the emission of energy by a warming Earth by using correlations between surface temperature and satellite radiant flux data to define this term and show that is already quite significant. The energy balance is consistent with IPCC best estimates of the aerosol direct and indirect effects. Like other methods, energy balance is better at constraining the lower limit to climate sensitivity than the upper limit. There are many assumptions in a linear global energy balance equation, especially the use of a global mean surface temperature. These assumptions need to be considered when attempting to derive climate sensitivities.

4. Sydney Levitus, NOAA National Oceanographic Data Center (NODC), Silver Spring, MD

   Ocean Heat Content, 1955-2009

   We present updated estimates of the change in global ocean heat content (OHC) for the 1955-2009 period. The global integral is characterized by a positive trend that is consistent with the amount of warming expected due to the observed increase in greenhouse gases in earth's atmosphere.

5. Michael Previdi, Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY
   Beate Liepert, Northwest Research Associates, Bellevue, WA

   Climate Sensitivity and the Global Water Cycle

   The radiative feedbacks that determine Earth's climate sensitivity are typically defined at the top-of-atmosphere (TOA) or tropopause, yet climate sensitivity itself refers to a change in temperature at the surface. In this presentation, we describe how TOA radiative perturbations translate into surface temperature changes. It is shown using first principles that radiation changes at the TOA can be equated with the change in energy stored by the oceans and land surface. This ocean and land heat uptake in turn involves an adjustment of the surface radiative and non-radiative energy fluxes, with the latter being comprised of the turbulent exchange of latent and sensible heat between the surface and atmosphere. We employ the radiative kernel technique to decompose TOA radiative feedbacks in the IPCC Fourth Assessment Report models into components associated with changes in radiative heating of the atmosphere and of the surface. It is shown that the two strongest feedbacks, the temperature and water vapor feedbacks, affect primarily the turbulent energy exchange at the surface rather than the radiative energy exchange. Since changes to this turbulent energy exchange are dominated in the global mean sense by changes in surface evaporation, this result serves to highlight the fundamental importance of the global water cycle to Earth's climate sensitivity.

6. Dorothy Peteet, NASA Goddard Institute for Space Studies (GISS), New York, NY, and Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY

   Clues and Questions from Paleoclimate – Implications for Climate Sensitivity

   Through an examination of an integrated suite of paleoclimate records documenting shifts in the atmosphere, oceans, and terrestrial records we can make inferences concerning past climate sensitivity and its application to our future climate. Useful examples include records of the last glacial maximum and modeling experiments attempting to reconstruct the glacial climate. Controversy over the timing of the Laurentide retreat is one example of the importance of understanding the paleorecord. Detailed scrutiny of the last deglaciations gives us information about the relationship of orbital forcing, trace gas rises, and ocean circulation shifts compared to terrestrial records. We can also examine the relative timing of shifts in trace gases and their role in the gradual and abrupt coolings at the regional scale. Understanding the last interglacial 125,000 years ago provides a useful analogue for a warmer climate. Examining the entry into the last ice age are useful, as are modeling experiments to gauge the strengths of various feedbacks. Outlining the questions in paleoclimate that remain difficult to answer help constrain our knowledge of what we do not understand.

7. Anthony Broccoli, Rutgers University, New Brunswick, NJ

   Climate Sensitivity and Orbital Forcing

   The concept of climate sensitivity has proven useful in understanding the response of the climate models to a variety of radiative forcing agents, both natural and anthropogenic.

Extending the concept to Pleistocene paleoclimate can be more problematic if changes in atmospheric composition and ice sheet extent are regarded as feedbacks rather than exogenous forcings. The ultimate driver of glacial-interglacial cycles is the seasonal and spatial redistribution of insolation resulting from variations in Earth's orbital parameters, which produce only small global mean radiative forcing. Thus radiative feedbacks are crucial in understanding how the climate responds to orbital forcing. We present some results from coupled atmosphere-ocean model simulations of the effects of orbital forcing on climate and examine some of the feedback mechanisms that contribute to the simulated temperature changes.

8. David J. Beerling, University of Sheffield, Sheffield, UK
   Paul J. Valdes, University of Bristol, Bristol, UK

   Elevated Concentrations of Trace Greenhouse Gases and Climate Sensitivity during Ancient 'Greenhouse' Climates

   Trace greenhouse gases (GHGs) are a fast-responding fundamentally important component of Earth's global climate system known to be sensitive to global change. However, their concentration in the ancient pre-Quaternary atmosphere during warm 'super-greenhouse' climates is highly uncertain because of the lack of geochemical or biological proxies. In consequence, this long-standing issue hinders assessment of their contribution to past global warmth and the equilibrium climate sensitivity of the Earth system (E_{ss}) to a doubling of the atmospheric CO_2 concentration. This contribution will report new three-dimensional Earth system modelling simulations showing that the 'super-greenhouse' worlds of the early Eocene (55 million years ago) and late Cretaceous (90 million years ago) maintained high concentrations of methane, surface ozone and nitrous oxide. Methane concentrations exceeded by 400-500 % the pre-industrial (PI) value typically adopted in modelling investigations of these intervals over the past two decades, even after accounting for CO_2-supression of isoprene emissions from vegetation. Higher concentrations of all trace GHGs exerted marked planetary heating (>2K), amplified in the high latitudes (>6K) by lower surface albedo feedbacks. In the Eocene, trace GHGs increased E_{ss} (2× to 4× PI CO_2) by 1K, indicating the requirement for including fast-responding feedback processes in model E_{ss} estimates for comparison with empirical palaeoclimate assessments. However, biological aerosol-cloud feedbacks remain to be assessed.

9. Corinne Le Quéré, University of East Anglia, Norwich, UK

   Climate Change and the Ocean's Carbon Cycle

   The oceans absorb ~25% of the CO2 emitted to the atmosphere by human activities every year, thus slowing down the rate of global warming. This CO2 'sink' occurs on top of a very active natural carbon cycle, involving chemical, physical, and biological processes. All the processes that regulate the natural carbon cycle are controlled by climate. Hence changes in climate are expected to affect the natural carbon cycle, with consequences for the oceanic sink of CO2 and the long-term stabilisation of CO2 in the atmosphere. The Southern Ocean exerts an important control on atmospheric CO2. During glacial conditions, circulation changes in the Southern Ocean have caused a decrease of atmospheric CO2 ~100 parts per million (ppm), as large as the recent atmospheric CO2 increase caused by human activities. During the past few decades, observations have shown that the CO2 sinks of the Southern Ocean and North Atlantic have not increased at the rate expected from the buildup of CO2 in the atmosphere, at least since the early 1980s. The exact processes driving the observed changes are under debate, but they have been associated with the intensification of the winds in the Southern Ocean and with surface warming, with important non-linear effects. This presentation will discuss the recent trends in the context of past and future climate change.

10. Martin Heimann, Max-Planck-Institute for Biogeochemistry, Jena, Germany

Terrestrial Carbon Cycle-Climate Feedbacks in a Warming World

Carbon as CO2 is taken up by the terrestrial biosphere through photosynthesis, cycled through vegetation and soils and released back into the atmosphere by a multitude of processes on various time scales. All transfer processes between the different carbon reservoirs depend on environmental conditions, are thus susceptible to climate change and may therefore contribute to the global terrestrial carbon cycle - climate feedback. Assessment of the sign and magnitude of this feedback for different ecosystems needs to be done separately for the relevant time scales. Observations exist to bracket the possible response on the interannual time scale from atmospheric observations, and also on time scales beyond several centuries using biogeographical approaches. Unfortunately, the decadal-centennial time scale, relevant for the current anthropogenic climate perturbation, is poorly constrained from existing observations. Current comprehensive global models of terrestrial ecosystems show a wide range of responses even though they represent only the most fundamental processes, a.o. photosynthesis and respiration in highly simplified forms. Heretofore poorly represented processes with significant climate feedback "potential" include fire frequency and the degradation of the large organic carbon stores in deeper soils, in particular in wetlands and permafrost. In the latter case the potential release as methane depending on the hydrological conditions introduces a further degree of complexity. Overall, based on existing analyses and modeling studies, it is believed that the global terrestrial carbon cycle - climate feedback is positive but, on a 50-100 year time scale, definitely not larger than 30% and possibly much smaller. In any case, in the context of current climate change, the terrestrial carbon cycle - climate feedback will be overshadowed by the direct anthropogenic impacts on terrestrial ecosystems through changes in land use and management. This necessitates the establishment of a range of future land use and management projections in order to assess and bracket possible futures of the Earth system.

11. Steve Frolking, University of New Hampshire, Durham, NH
(Contributions from: Nigel Roulet, Dave Lawrence, Miriam Jones, many others)

Peatlands in the Earth's 21st Century Coupled Climate-Carbon System

Peatlands cover ~4 million km^2 and have accumulated ~300-600 Pg C over the past ~10-20 thousand years, almost entirely as peat (organic soil). For comparison, the ~40 million km^2 of global forests have ~200 Pg C aboveground woody biomass, mostly accumulated within the past few hundred years. The majority of peatland area and peatland carbon is north of 45°N, where warming is projected to be greater than the global mean. About one-third of northern peatlands are associated with permafrost. Peatlands influence the global carbon-climate system primarily through the net exchange of two greenhouse gases – CO_2 (peatlands are typically a sink) and CH_4 (peatlands are typically a source). The net climate impact of a peatland depends primarily on its hydrological setting, vegetation composition, and the time horizon chosen for impact assessment – in the short term CH_4 is important, while over centuries to millennia the CO_2 balance dominates. The impact of warming on peatland carbon balance will be the net tradeoff between increased decomposition of the large but generally recalcitrant peat carbon pool, and increased productivity of peatland vegetation. Changes in peatland hydrology will likely be a more important feedback, and more difficult to predict. Drying is likely to lead to a net decrease in CH_4 flux; a net increase in CO_2 emissions is not likely to be substantial in the short term (unless fires or erosion increase significantly), because most of the peat is well-decomposed, recalcitrant material, and water tables will drop slowly. But drying could cause a persistent net source for a long time, frustrating mitigation efforts to reduce atmospheric CO_2 concentrations. Wetting is likely to lead to increases in CH_4 emissions that could be important in the short term because of methane's characteristics as a greenhouse gas. Two key questions are (1) what fraction of peatlands (including those with thawing permafrost) will get wetter and have enhanced CH_4 emissions?, and (2) how long will enhanced CH_4 emissions persist? Additional climate impacts may arise from anthropogenic peatland disturbance, which includes draining for agriculture and forestry, peat harvest for fuel and horticulture, and linear disturbances (e.g., roads and seismic lines). These disturbances affect the net peatland greenhouse gas budget, and, particularly for tropical peatlands, generally increase their susceptibility to catastrophic disturbance (e.g., fire). Peatlands share many general carbon, water, and energy cycle functions with upland, mineral-soil ecosystems – productivity, decomposition, water infiltration, evapotranspiration, runoff, latent, sensible and ground heat fluxes. However, peatlands have several unique characteristics – deep organic soils, a significant fraction of non-vascular vegetation, shallow water tables, high spatial heterogeneity on a range of scales, anaerobic biogeochemistry, and potentially unique disturbance regimes – that need to be addressed before coupled climate-carbon system models can estimate the magnitude and strength of any feedbacks associated with the dynamics of the large peatland carbon pool.

12. James Galloway, University of Virginia, Charlottesville, VA

Nitrogen: A Story of Food, Fuel and Carbon

Humans obtain metabolic energy by eating food. Nitrogen is required to grow food, but natural supplies of nitrogen to grow food have been inadequate since the beginning of the twentieth century. The Haber-Bosch process, invented in the early 20th century, now provides a virtually inexhaustible supply of nitrogen fertilizer. This one invention is responsible for the existence of about half of the world's population. That's the good news. The other news is that most of this nitrogen (and additional amounts from fossil fuel combustion) is lost to the environment where it contributes to smog, greenhouse effect, ecosystem eutrophication, acid rain and loss of stratospheric ozone in a sequential manner—the Nitrogen Cascade. This lecture will 1) illustrate how nitrogen is lost to the environment during food and energy production, 2) describe the resulting impacts on human and ecosystem health due to the loss, 3) describe the opportunities for an integrated nitrogen management plan at the local and national level and 4) show where N and C cycles overlap with respect to global change.