2002 PCC Summer Institute, summary

Background/Purpose: The Program on Climate Change has the bold mandate of unifying climate research and education at UW and forming a renowned center of activity in climate research. An important step toward these goals is identifying present and future problems that the University of Washington is poised to pursue. At our 2002 summer institute we addressed these issues, and strove to promote new collaborations among scientists interested in climate research, to identify areas of climate change research that require coordinated efforts of investigation, and to formalize the roadmap or strategic plan for the future of climate research at the University of Washington.

Schedule/Agenda

Sunday (June 23)

6:30 Dinner

8:00 Introductions by participants: What is PCC? What is its scope? Summary of year to date. Expectations of PCC. Reflections on the past year.

Retrospective Discussion of Science Themes
What were the major breakthroughs in key areas related to PCC over the past 25 years? What role has UW played in those breakthroughs?

Monday (June 24)

7:30 Breakfast

8:30 What are outstanding questions for the future in the keys research areas?

12:00 Lunch

6:30 Dinner

8:00 Which questions should receive a major UW effort? Participants divided into 3 groups, each to determine the three top questions.

Tuesday (June 25)

7:30 Breakfast

8:30 IGERT proposal. Summary of group results from Monday p.m., 4 research priorities and goals of research in each of the areas. Strengths and weaknesses and needs of UW in each of the areas were then discussed.

12:00 Lunch

6:30 Dinner

8:00 Continued discussion of the research priorities. Long range plans: Institute for advanced studies.

Wednesday (June 26)

7:30 Breakfast

8:30 PCC’s current academic program and vision for the future.

Summary Report:

The summer institute held at Sleeping Lady in Leavenworth, WA on June 23-26 was a great success, bringing together 35 scientists from 10 different departments and units for an interdisciplinary discussion of the strengths and weaknesses of climate related research at the University of Washington, and areas where the University and the Program on Climate Change can contribute to climate research. Remarkably, consensus was achieved in the identification of four research priorities that integrate across ~10 science themes. The role of the PCC as a home for an Institute in Advanced Studies in Climate Change Science in the Earth Institute was discussed. PCC's role in undergraduate and graduate education was also discussed. The schedule was set up with afternoons free and this led to many opportunities for people to build relationships with others in the program. Highlights are presented here.

Science Themes: (Jim revised table 3, but its in pdf)

Carbon Cycle
Atmospheric Chemistry
Paleoclimate
Greenhouse Warming
- Impacts
- Adaptation
- Mitigation

High Latitude and Tropical Processes
Modes of Climate Variability and Change
Ocean and Atmospheric Circulation

Research Priorities for the Program on Climate Change

Four research priorities emerged from extensive discussion of recent advances and outstanding questions in the approximately ten science themes related to climate change research. Institute participants were asked to arrive at themes or questions which would (1) bring people together (2) be sound and exciting science (3) be palatable to a variety of interested parties (UW scientists, graduate students, deans and donors) and (4) be questions UW is suited to address. The relationship of these research priorities to existing UW strengths is shown in Table 4. The way these priorities span discipline and time domains is shown in Table 5.

1. Fate of Greenhouse Gases (H2O, CO2, O3, CO, VOC, NOx, CH4, N2O, SF6, CFC's, and halons)What are the fates of the greenhouse gases? What are the feedbacks between the biosphere, climate, and greenhouse gases?

> **Goal:** Improve accuracy of predictions.
> **UW Strengths**: Observations in ocean carbon and CO2.
> **UW Scientific Needs**:
> 1. Synthesis model for global carbon cycling and testing of the model. Model should have a global perspective and include the atmosphere, ocean and terrestrial systems and their linkages.

2. Strong observations of greenhouse gases other than CO_2.

UW Resource Needs:

1. New faculty in the areas of terrestrial carbon cycling and synthesis of global carbon cycle modeling.
2. UW ship time on annual basis
3. Technical support of computation needs.

Linkages to other research priorities:

1. Coordinated data acquisition on repeat ocean sections linked to the Pacific Northwest to yield a biogeochemical/ecosystem understanding.
2. Technical support for modeling and analytical infrastructure.

2. Modes or States of Climate (Steady State Systems): What are the mechanisms that maintain a climate system, and what are those that cause large fluctuations in climate (in the distant past, glacial/interglacial, and Eocene)? The Eocene (54 to 38 mya) received special discussion because this was the last time atmospheric CO_2 was at the level we expect to see in the next 100 years.

Goal: To understand what caused such things as glacial/interglacial changes in CO_2 and ice volume, elevated CO_2 in Eocene, hypothesized snowball earth and rapid climate change.

Strengths of UW:

1. Terrestrial record (dust, pollen, moisture) of climate change on these time scales.
2. Glaciology: Shape, dynamics of ice sheets.
3. Climate dynamics
4. Boundary conditions for models.

UW Needs:

1. New faculty in areas of Paleooceanographic and Paleolimnologic data.
2. Technical support for modeling efforts.
3. Modeling capability for synthesis of data.

Linkages:

1. Integrates across ocean, atmosphere and terrestrial components.
2. Model of present could be used for the past.
3. Further engagement of ESS.

3. Sensitivity and Reducing Uncertainty (Departures from Steady State): Reducing the uncertainty of future climate projections: includes a better understanding of forced changes in snow cover/sea ice; precipitation/clouds; land use/cover; temperature.

Goal: Understand feedback processes and sensitivity of climate system, especially to global and regional anthropogenic forcing. Understanding feedback processes on global and regional scales.

UW Strengths:

1. Study of dynamical processes
2. Cloud and radiation studies
3. Leader in sea ice studies
4. Collaboration exists with NCAR and UW is involved in repeat observational programs (decadal scale ocean observations).

UW Needs:

1. New faculty who make observations of atmospheric chemistry.
2. Global model framework
3. Modeling infrastructure
4. Regional climate

Linkages:

1. Non-CO2 Greenhouse Gas observations
2. Modeling workshops
3. Paleooceanography/chemistry

4. Natural Variability and Impacts (seasonal to millennial scales)

Goals: Projection of anthropogenically-induced change on natural variability. Improve short term climate predictions (seasonal to interannual, better understanding of decadal to millennial time scales). Understand connections between anthropogenically-induced changes to regional climate change.

UW Strengths:

1. Climate Impacts Group
2. PRISM: for observations, model development
3. APL: coastal ocean efforts
4. PNCERS: UW, OSU coastal ecosystem (atm, ocean physics, bio stocks, societal interactions)
5. US Forest Service links

Needs:

1. Space for JISAO/CIG closer to Ocean/Atmos/ESS
2. Open channels to forest resources
3. Study of terrestrial components
4. Studies of Environmental Economics
5. Study of Mitigation
6. The science of sequestration, especially ocean CO2 injection and iron fertilization.

Institute for Advanced Studies in Climate Change: A vision of the future of climate research at the UW includes a strong motion to move towards the creation of a center or institute for advanced studies. The current funding level for the PCC supports our present efforts to unify existing programs and step toward becoming a strong research center in climate change. The longer term goals are to obtain additional funding through IGERT and other NSF programs, as well as generous donors, to support the creation of an institute that draws large numbers of graduate students, postdoctoral research fellows, and visiting faculty. An outreach component is also included in the vision, part of which would be commissioning textbooks. This institute would run hand-in-hand with the future Program on Climate Change which would focus its resources on unification across departments, then expansion of education at the graduate and undergraduate levels.

Visions of the Academic and Outreach Components:

A summary of the current status of our academic program, works in progress, and future ways to contribute to the academic environment of the UW campus were discussed. Five new graduate students, from ESS, OCN and ATMS, will join the UW with fellowships to participate in the Program on Climate Change. Additional graduate student participation is anticipated in the form of enrollment in the PCC core courses, and creation of cross-disciplinary, PCC advised, graduate committees. Core classes are well emplaced and listed below. Discussion on how to achieve a critical mass of 15 students was discussed, although some thought it would not be difficult to get this many students. PCC members are also working toward the submission of an IGERT proposal to support additional graduate students

PCC classes:
Autumn 2002: Climate Dynamics (3 credits, ATMS, OCN, ESS 587) will be taught by Dennis Hartmann (ATM S) and LuAnne Thompson (OCN). PCC supported TA: Camille Li.

Winter 2003: The Global Carbon Cycle and Greenhouse Gases (3 credits, OCN, ATMS, ESS 588) will be taught by Steven Emerson (OCN), Lyatt Jaegle (ATMS) and Virginia Armburst (OCN).

Spring 2003: Paleoclimatology: Data, Modeling and Theory (3 credits, ESS, ATMS,OCN 589) will be taught by Eric Steig (ESS) and David Battisti (ATM S).

The PCC will contribute to courses in the Program on the Environment, although specifics were not discussed (note that Craig Zumbrunnen was present at the discussion). Possible creation of an undergraduate climate change course and/or an undergraduate degree or honors option was also discussed, and it became clear that discussions with Forestry, ATM S, and POE are needed to minimize friction and create a unified front.

Natural Variability and Impacts (research priority #4) was proposed as the research focus for the 2002/2003 academic year. Seminars, the summer retreat and public lecture would revolve around this theme. The possibility of collaborating with David Battisti's proposed 3-week course at Friday Harbor was also discussed.

Outreach efforts could include the distribution of information on environmental and climate change options on campus (with coordination of outreach efforts across campus), creating posters for elementary schools on climate change problems, production of a brochure that describes the PCC. The web site could also be amended to include a newsletter that highlights internal (PCC faculty and student profiles, PCC events and seminars) and external goings on (climate change issues in the news, faculty research in the news).

Science Themes

Carbon Cycle

Three major breakthroughs in carbon cycle science in the last 20 years are: (1) discovery of the rise in atmospheric CO2 (2) correlation between temperature and CO2 changes during glacial/interglacial cycles and (3) a general understanding that anthropogenic CO2 is partitioned between the ocean, atmosphere and land.

Several key, unanswered questions related to carbon cycling were also identified: (1) What is the fate of anthropogenic CO2? We know something about the partitioning, but we need to know more about the processes determining ocean and land uptake of CO2. (2) What are the impacts of climate on the carbon cycle, and how will that change?

Atmospheric Chemistry

Major breakthroughs in atmospheric chemistry that pertain to climate change include: (1) global 3-D models of O3 photochemistry, and an understanding of the contributors to the ozone holes appearances and disappearances. (2) Role of aerosols in climate forcing. (3) Observational networks and/or intensive field experiments constrain the distributions of CH4, O3, N20 and properties of aerosols. (4) Understanding the extent to which pollution is global, that photochemical reactions and the transport of pollutants is more rapid than previously thought; the effects of acid rain on the environment; and the establishment of the clean air act.

Several outstanding future questions in atmospheric chemistry are: (1) What factors control the seasonal/interannual/regional variability of non-CO2 greenhouse gases and aerosols? How do changes in aerosol composition influence climate change? (2) What is the role of stratospheric composition on climate change? We need a better understanding of the dynamics of statosphere-troposphere interactions and cloud formation. (3) How can we use in-situ observations, satellite observations, and global models to reduce uncertainties associated with the forcings of non-CO2 greenhouse gases and aerosols?

Paleoclimate

The major breakthroughs in paleoclimate research include: (1) Acknowledgement that the recent warming of the global earth is exceptional. This comes in part from the reconstruction of natural patterns of variability on interannual-to-centennial time scales, including the 1000 year record of northern hemisphere surface temperature (Mann et al.). (2) Large scale climate change can occur abruptly (work at UW and R. Alley). UW borehole thermometry has provided data on the magnitude of past climate changes. (3) CO2 from ice cores, and the close coupling between CO2/greenhouse gases and climate. (4) Changes in the overturning of the oceans during glacial times (from 13C, Ca/Cd etc. e.g. Charles and Fairbanks.).

The key unanswered questions in paleoclimate are: (1) What are the basic mechanisms or feedbacks that explain glacial/interglacial cycles? Part of this question is obtaining a better understanding of the relationship between Milankovitch forcing, the atmospheric carbon dioxide concentration and the global climate, understanding carbon chemistry during glacial times, and understanding paleovegetation-albedo-climate feedbacks. (2) How has SST varied in the tropics? Can we get a better understanding of how and why climate changes in the tropics? (3) What are the patterns in climate variability? Over the last 100 years, and the entire Holocene from more highly resolved ice core and other records; on centennial to millenial scales and on decadal to centennial scales. (4) Can we examine specific processes and patterns using GCM's? specifically, implement tracers in GCMs to investigate the relationship between the archives of ocean and ice cores and the actual climate or ocean conditions they record; utilize ocean observations (T,S, and chemistry) and predicted changes from ocean GCM's to investigate how seawater preserves decadal to centennial-scale climate change.

Greenhouse Warming

General:
Over the last 20 years, we have (1) measured a warming signal in the ocean (2) have attributed a measured warming of the earth to man (detection and attribution) (3) seen the role of volcanic forcing and (4) created the IPCC process.

Outstanding questions include (1) What are the global warming trends patterns in variables other than temperature? e.g. hydrology and precipitation, floods, droughts; also extreme events (extreme cold, heat, windstorms, etc.) (2) To what extent is regional climate change predictable? What is the role of topography? What are the links between coastal oceanography and climate? (3) How sensitive is climate to specific variables? e.g. clouds and cloud formation, ice, ocean warming, terrestrial processes, aerosols, and lapse rate. Can we better understand feedbacks in the climate system? In addressing these questions, can we reduce the uncertainty in climate predictions? for temperature rise, changes in the hydrological cycle and ecological/regional zones? (4) What are the effects of climate change on organized physical elements of the climate system? e.g. monsoons, ENSO, PDO, annular modes.

Impacts of Greenhouse Warming
The most important contributions over the last 20 years, has been the acceptance that impacts of global warming are occurring, and that global warming is linked to ENSO, PDO and to regional climate patterns.

The fundamental question for the future, is (1) what are the impacts that result form climate change? Where will these impacts be felt? Consider the physical elements (e.g. ENSO), and the impacts of sea level rise on coastal erosion and related hazards. (2) How will the ocean ecosystem structure and dynamics be impacted by global warming? (3) How will changes in freshwater and land use impact estuarine systems? (4) What will be the effects on human health and agriculture? (5) How can institutions change to respond and deal with changes such as drought?

Adaptation and Mitigation
How can we adapt to Greenhouse Warming? What will be the impacts of CO2 injection, both natural and enhanced? What will be the impacts of iron fertilization? What are the policy consequences of different adaptation pathways? How should land use management change? e.g. fires and fire management, forests, soils, urbanization, grasslands, croplands. What are the possible solutions to atmospheric/oceanic/land pollution?

Can we mitigate greenhouse warming using emission controls and sequestration techniques (physical chemical, ecological, genetic)?

High Latitude Processes

Most recent advances in our understanding of high latitude processes include (1) Recognition that a complex suite of significant, interrelated, atmospheric, oceanic and terrestrial changes have occurred in the Arctic in recent decades. This event is affecting every part of the Arctic environment and is having societal repercussions. (2) This complex suite of changes may be related to a change in the atmospheric circulation of the Northern Hemisphere. Many of the changes can arguably be related to the rising trend in the Arctic Oscillation (AO) to Northern Hemisphere Annular Mode (NAM), a mode of atmospheric variability that is potentially active over a broad range of time scales, including climatic time scales. Because there is theoretical evidence that the positive trend observed in the AO index might be indicative of greenhouse warming, the complex suite of changes may also be related to greenhouse warming.

Future questions in high latitude processes include: (1) What feedbacks exist between Arctic changes and the global climate system? Ice albedo and control of global thermohaline convection are the two main candidates that need to be investigated. (2) Why is the salinity of the subpolar ocean decreasing? (3) What environmental/climate changes are anthropogenically forced in the Polar Regions? (4) What changes are occurring in the stability of the Antarctic ice sheets and shelves?

Tropical Processes

Two important advances in our understanding of the tropics are: (1) Characterization of the ENSO cycle, and other time scale ocean variations in the Pacific basin, and their relation to fisheries and North American climate; the role of ENSO in carbon and nutrient cycling of the Pacific, and their role in the interannual variability of CO2 in the atmosphere and (2) Documented changes in SST on glacial/interglacial time scales.

Future questions in tropical processes include: (1) What will be the frequency and intensity of ENSO as global warming continues? To answer this question we must better understand the nature of ENSO variability. (2) Why are tropical glaciers melting? The retreat of tropical glaciers is out of proportion with temperature data, is the melting due to relative humidity changes? (3) What are the connections between upwelling velocity and source waters, ENSO and monsoons, and subtropical/tropical circulation via meridional overturning? (4) How will changes in patterns and emissions of reactive gases impact the topics, the area closest to developing nations that will have the largest increase in emissions?

Modes of Climate Variability and Change (ENSO, including PDO; annular modes, e.g. northern hemisphere annular mode, the NAO)

Recent contributions in this area include: (1) Understanding that there are intrinsic natural modes of variability and what the mechanisms are that give rise to these modes of climate, both dynamical and statistical. These modes cause regional impacts. (2) Climate variability occurs on hemispheric scales. (3) Discovery that Dansgaard-Oeschger events occurred during glaciations only (a series of rapid warm and cold oscillations; associated with these D/O events are SST and convection changes). (3) The existence of an Arctic Oscillation (AO).

Future contributions to understanding modes of climate variability will include answering the following questions: (1) How do modes respond to (and possibly feedback on) changes in climate? Including the development of a dynamic theory of annual modes; (2) What can we learn about processes in the earth system by analyzing the coupled signals of the modes? Including stratosphere-troposphere connections; tropical-subtropical connections; impact of mid-latitude oceans and esp. western boundary currents on modes; trends in modes that are responses to anthropogenic forcing, both annular modes and ENSO.

Ocean Circulation

Recent advances in our understanding of ocean circulation are: (1) There are changes in ocean properties and circulation that reflect climate change. (2) Freshwater dynamics/changes in hydrological cycle permit multiple global states of ocean circulation/ventilation and mixing. (Related advances: global meridional overturning circulation and competing roles of heat and fresh water; 30 year freshening of the subpolar Atlantic, saltier subtropics). (3) Thermocline ventilation and interaction between oceanic gyres and boundary currents; quantification of mixing in the thermocline and evidence for topographic control of mixing.

Unanswered questions in ocean circulation include: (1) How stable will the thermocline be during greenhouse warming? (2) What is the role of western boundary currents in coupled ocean/atmosphere modes of variability? (3) What was glacial ocean circulation like? (4) Can we get a better understanding of upwelling and mesoscale eddy processes and variability?

Atmospheric Circulation

Two contributions to our understanding of atmospheric circulation stand out over the last 20 years. (1) Dynamic links between circulation and stratospheric circulation. (2) Coupling between the ocean and atmosphere in the tropics as seen in ENSO.

An important area of research in atmospheric circulation, not included in previous topics is the deficient low frequency variability in coupled modes.