

Steven Wojtal - Office: Carnegie 416
Office hours: Mon 3:00-4:30 p.m. & Thurs 9:00-11:00 a.m.

Scheduled Meetings - Lectures: Mon - Wed - Fri 11:00 – 11:50 a.m.

Course Aim: To introduce you to the scientific study of Earth's climate system and the history of climate change on Earth.

Glaciers are neither static nor stable features. The ice in glaciers flows in response to gravitational forces. Moreover, glaciers respond to changes in climate. Geologic data indicate that there were times when glacial ice covered more of Earth's surface than it does at present and other times when glacial ice were nearly absent. It is not just changes in ice volume that record changes in climate. Glacial ice itself holds important information on climate variability in the past, and it may provide humans with the keys to decipher the implications of changes in the concentrations of greenhouse gases in the atmosphere, changes in vegetation patterns on land, and changes in temperature and circulation patterns in the oceans. Glaciers are, then, a natural point of departure for anyone who is interested in understanding Earth's climate system and who endeavors to analyze critically the prospects for human-induced climate change.

I intend to use glaciers as a window to understanding Earth's climate. We will begin by examining the morphology, kinematics, and dynamics of glacier systems. We will then consider how glaciers sculpt the land surface and deposit rock debris. Next, we will analyze the patterns and distribution of glacial erosional and depositional features to determine the extent of glaciers at different times in the past. Then we will examine what factors led to alternating cold climates (Ice Ages) and warm climate (interglacial periods). We will end the semester by examining what studies of climate history suggest regarding the prospect for rapid climate change in the near future.

Readings: Alley, Richard B. 2002. *The two-mile time machine; Ice cores, abrupt climate change and our future*. Princeton University Press (required).
I have and will also post to the BlackBoard site for this course (1) PDFs (or links to sites where you can download PDFs) of book chapters and journal articles, (2) PDFs of my lecture notes (i.e. the PowerPoint presentations I show in class), and (3) PDFs of other 'handouts' I have written.

Field Trip: I intend to run a half-day field trip to examine local glacial features on one afternoon in the second half of the semester. Given the size of the class, I will probably run the same trip twice, either once during the week and once on a weekend day or on two weekend days. I have entered a tentative date for the field trip on the schedule of topics below, but I will set the precise date of the trip depending on weather and other factors that arise as the scheduled date approaches.

Grading: Your grade will be based upon short essays written in-class at intervals throughout the semester, an in-class, hour-long exam, and an exam given at the regularly scheduled 'final exam' time of Thursday, May 18 at 7:00 p.m. There will be an optional exercise associated with the field trip, and I will give you an opportunity to include that in calculating your grade.

Quantitative Proficiency: If you wish to earn a **Quantitative Proficiency – Half** certification for this course, you will need to complete and hand in 6 short problem sets according to the schedule posted on BlackBoard. I will distribute/post each problem set on Mondays, with the completed assignment due the following Monday. Additional information on the problem sets, including the name of a student assistant, is available on BlackBoard in a section entitled *Problem Sets*.

<i>Tentative Schedule of class topics</i>		
<i>Date</i>	<i>Topic</i>	<i>Assigned Reading*</i>
Feb 6	Introduction: Weather, climate & glaciers	Alley, ch. 1
Feb 8	Ice, water, & water vapor	Hambrey & Alean, ch. 1 & 2
Feb 10	Water & ice in glacial systems	
Feb 13	Glacier ice & glacier systems	
Feb 15	Morphology of glaciers, I	Hambrey & Alean, ch. 3
Feb 17	Morphology of glaciers, II	Lecture notes
Feb 20	Glacier dynamics I – ice deformation & glacier flow	Hambrey & Alean, ch. 5
Feb 22	Glacier dynamics II – mass balance	Hambrey & Alean, ch. 4
Feb 24	Mass balance II	Alley, ch. 4
Feb 27	Glacier erosion I – processes	Sharp, ch. 5
Mar 1	Glacier erosion II - landforms	Sharp, ch. 6
Mar 3	Glacier deposition – processes & landforms	Sharp, ch. 7 & 8, pp. 132-152
Mar 6	Glacial meltwater	Sharp, ch. 8, pp. 152-169
Mar 8	Ancient glacial lakes & large floods	
Mar 10	Methods for inferring glacier advances & retreats	
Mar 13	Isotopic method of inferring mass of glacial ice	Alley, ch. 2 - 8
Mar 15	Pleistocene Ice Age history	Alley, ch. 9 & 10
Mar 17	<i>FIRST EXAM</i> - on lectures and reading through 3/10	
Mar 20	Pleistocene Ice Age history	Alley, ch. 11 & 12
Mar 22	The global heat budget	Alley, ch. 13; IPCC TAR WG1, ch. 1, pp. 87-92
Mar 24	Atmospheric circulation	
<i>SPRING BREAK</i>		
Apr 3	Atmospheric circulation and oceanic circulation	Alley, ch. 14 & 15
Apr 5	Seasonal changes in weather	IPCC TAR WG1, ch. 1, pp. 87-92
Apr 7	Factors that alter the global heat balance - solar irradiance, greenhouse gases and aerosols	IPCC TAR WG1 Technical Summary, pp. 21-46
Apr 8-9	Field trip to Marblehead	
Apr 10	Factors affecting the global heat budget- the carbon cycle	IPCC TAR WG1 ch 3, pp. 187-202
Apr 12	Factors affecting the global heat budget- the carbon cycle	IPCC TAR WG1 ch 3, pp. 202-213;
Apr 14	High-frequency cycles of changing climate	McElroy (1992); IPCC TAR WG1 ch. 2 (esp. pp. 136-142); Broecker (1998)
Apr 17	Low frequency cycles of changing climate	Fischer (1984); Crowley & Berner (2001)
Apr 19	Anthropogenic impact on the global heat budget	IPCC TAR WG 1 ch. 1, pp. 92-98; TAR WG1 Technical Summary pp. 46-79

Apr 21	Anthropogenic impact on the global heat budget	Crowley (2000); Levitus <i>et al.</i> (2001)
Apr 24	Anthropogenic impact on the global heat budget	Stott <i>et al.</i> (2000); IPCC TAR WG1 Technical Summary pp. 55-61
Apr 26	Is the climate system stable or unstable	Alley, ch. 14 - 18
Apr 28	Is the climate system stable or unstable	Broecker (1997)
May 1	Predicting changes in global climate	IPCC TAR WG1 Technical Summary pp. 62-79; IPCC TAR WG 1 ch. 9
May 3	Assessing predictions of global climate change, I	IPCC TAR WG 1 ch. 8
May 5	Assessing predictions of global climate change, II	
May 8	Potential effects of global climate change	IPCC TAR WG 1 ch. 9
May 10	Potential effects of global climate change	IPCC TAR WG 1 ch. 12
May 12	Where do we go from here?	Hoffert: Mintzer
Thursday, May 18, 7:00 p.m. - SECOND EXAM		

* Unless otherwise noted, PDF versions of any readings other than the assigned text will be posted to BlackBoard.

Full citations for readings posted to BlackBoard

Broecker, W. 1997. Will our ride into the greenhouse future be a smooth one? *GSA Today* **7/5**, 1-6.

Broecker, W. 1998. End of the present interglacial: How and when. *Quaternary Science Reviews* **17**, 689-694.

Crowley, T. J. 2000. Causes of climate change over the past 1000 years. *Science* **289**, 270-277.

Crowley, T. J. & Berner, R. A. 2001. CO₂ and climate change. *Science* **292**, 870-872.

Fischer, A. G. 1984. The Two Phanerozoic Supercycles. In: *Catastrophes and Earth History - The New Uniformitarianism* (edited by Berggren, W. A. & Van Couverling, J.E.). Princeton University Press, Princeton, 129-150.

Hambrey, M. J. & Alean, J. 2004. *Glaciers*. Cambridge University Press

Hoffert, M. I. 1992. Climate sensitivity, climate feedbacks, and policy implications. In: *Confronting climate change: Risks, implications, and responses* (edited by Mintzer, I. M., Kleiner, A. & Leonard, A.). Cambridge, Cambridge University Press, 33-54.

IPCC TAR WG1 = Intergovernmental Panel on Climate Change Third Assessment Report by Working Group 1, *Climate Change 2001 - The Scientific Basis*. The full report (which you can download from 'http://www.ipcc.ch/') includes a *Summary for Policy Makers*, a *Technical Summary*, 14 separate chapters, and *Appendices*.

Levitus, S., Antonov, J. I., Wang, J., Delworth, T. L., Dixon, K. W., & Broccoli, A. J. 2001. Anthropogenic warming of Earth's climate system. *Science* **292**, 267-270.

McElroy, M. B. 1992. Changes in climates of the past: Lessons for the future. In: *Confronting climate change: Risks, implications, and responses* (edited by Mintzer, I. M., Kleiner, A. & Leonard, A.). Cambridge, Cambridge University Press, 65-83.

Mintzer, I. M. 1992. Living in a warming world. In: *Confronting climate change: Risks, implications, and responses* (edited by Mintzer, I. M., Kleiner, A. & Leonard, A.). Cambridge, Cambridge University Press, 1-14.

Sharp, R. 1988. *Living ice: Understanding glaciers and glaciation*. Cambridge University Press.

Stott, P. A., Tett, S. F. B., Jones, G. S., Allen, M. R., Mitchell, J. F. B., & Jenkins, G. J. 2000. External control of 20th century temperature change by natural and anthropogenic forcings. *Science* **290**, 2133-2137.

General References (not posted)

Alverson, K. D., Bradley, R. S. & Pedersen, T. F. (editors). 2003. *Paleoclimate, Global Change, and the Future*. Springer.

Barry, R. G. & Chorley, R. J. 1992. *Atmosphere, weather, and climate, 6th Edition*. Routledge.

Bigg, G. R., 1996. *The Oceans and Climate*. Cambridge University Press.

Bradley, R. S. 1985. *Quaternary Paleoclimatology: Methods of Paleoclimatic Reconstruction*. Allen & Unwin.

Bryant, E. 1997. *Climate Processes & Change*. Cambridge University Press.

Eichenlaub, V. 1979. *Weather and Climate of the Great Lakes Region*. University of Notre Dame Press.

Houghton, J. T. 1997. *Global Warming: The Complete Briefing (2nd Edition)*. Cambridge Press.

Houghton, J. T., Jenkins, J. G. & Ephraums, J. J. 1990. *Climate Change: The IPCC Scientific Assessment*, Cambridge Press.

Houghton, J. T., Meira Filho, L.G. , Callander, B. A., Harris, N., Kattenberg, A., & Maskell, K. (1995) *Climate Change: The Science of Climate Change* (The Second Assessment Report), Cambridge Press.

Jager, J. & Ferguson, H, L. 1991. *Climate Change: Science, Impacts, and Policy*. Cambridge Press.

Lamb, H.H. 1977. *Climate: Past, present, and future*. Methuen, v. I & II.

Moore, P. D., Chaloner, B., & Scott, P. 1996. *Global Environmental Change*. Blackwell Science.

Nesje, A. & Dahl, S. O. 2000. *Glaciers and Environmental Change*. Arnold Press.

Open University Team. 1989. *Ocean Circulation*. Pergamon Press, Oxford.

Paterson, W. S. B. 1994. *Physics of Glaciers, 3rd Edition*. Pergamon Press.

Skinner, B.J. & Porter, S.C. 1987. *Physical Geology*. John Wiley & Sons, New York.