Marine Science Review – 189

Climate and climate change

SeaWeb
Leading Voices for a Healthy Ocean

In this review:

A. Recent articles – no abstract available

Oerlemans, J., Dahl-Jensen, D., and Masson-Delmotte, V. **Ice sheets and sea level.** *Science* 313(5790): 1043-1044, 2006.

Overpeck, J.T., Otto-Bliesner, B.L., Miller, G.H., Alley, R.B., Muhs, D.R., and Marshall, S.J. **Ice sheets and sea level - Response.** *Science* 313(5790): 1044-1045, 2006.

Maney, J. **Carbon dioxide emissions, climate change, and the Clean Air Act: An analysis of whether carbon dioxide should be listed as a criteria pollutant.** *New York University Environmental Law Journal* 13(1): 298-378, 2006.

B. Recent publications available online

Stern, N. (ed.) 2006. **The Economics of Climate Change: The Stern Review.**

Available at: www.sternreview.org.uk

Notes: This Review has assessed a wide range of evidence on the impacts of climate change and on the economic costs, and has used a number of different techniques to assess costs and risks. From all of these perspectives, the evidence gathered by the Review leads to a simple conclusion: the benefits of strong and early action far outweigh the economic costs of not acting. Climate change will affect the basic elements of life for people around the world –access to water, food production, health, and the environment. Hundreds of millions of people could suffer hunger, water shortages and coastal flooding as the world warms. Using the results from formal economic models, the Review estimates that if we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more. In contrast, the costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of global GDP each year. The investment that takes place in the next 10-20 years will have a profound effect on the climate in the second half of this century and in the next. Our actions now and over the coming decades could create risks of major disruption to economic and social activity, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes.

UNEP/CMS. 2006. **Migratory Species and Climate Change: Impacts of a Changing Environment on Wild Animals.** UNEP/CMS Secretariat, Bonn, Germany. 68pp.

Available at: http://www.cms.int/publications/pdf/CMS_CimateChange.pdf

Notes: This report explores the current state of knowledge concerning migratory wildlife and climate change and notes that, as a group, migratory wildlife appear to be particularly vulnerable because they use multiple habitats and sites and a wide range of resources at different points of their migratory cycle.

C. Recent articles with abstracts

Larsen, C.E. and Clark, I. **A search for scale in sea-level studies.** *Journal of Coastal Research* 22(4): 788-800, 2006.

Notes: Many researchers assume a proportional relationship among the atmospheric CO_2 concentration, temperature, and sea level. Thus, the rate of sea-level rise should increase in concert with the documented exponential increase in CO_2. Although sea surface temperature has increased in places over the past century and short-term sea level rose abruptly during the 1990s, it is difficult to demonstrate a proportional relationship using existing geologic or historic records. Tide gauge records in the United States cover too short a time interval to verify acceleration in the rate of sea-level rise, although multicentury tide gauge and staff records from the Netherlands and Sweden suggest a mid-19th-century acceleration in sea-level rise. Reconstructions of sea-level changes for the past 1000 years derived using benthic foraminifer data from salt marshes along the East Coast of the United States suggest an increased rate of relative sea-level rise beginning in the 1600s. Geologic records of relative sea-level rise for the past 6000 years are available for several sites along the US East Coast from C-14-dated basal peat below salt marshes and estuarine sediments. When these three scales of sea-level variation are integrated, adjusted for postglacial isostatic movement, and replotted, the range of variation in sea level suggested by basal peat ages is within +/- 1 meter of the long-term trend. The reconstruction from Long Island Sound data shows a linear rise in sea level beginning in the mid-1600s at a rate consistent with the historic record of mean high water. Long-term tide gauge records from Europe and North America show similar trends since the mid-19th century. There is no clear proportional exponential increase in the rate of sea-level rise. If proportionality exists among sea level, atmospheric CO_2 and temperature, there may be a significant time lag before an anthropogenic increase in the rate of sea-level rise occurs.

Crozier, L. and Zabel, R.W. **Climate impacts at multiple scales: evidence for differential population responses in juvenile Chinook salmon.** *Journal of Animal Ecology* 75(5): 1100-1109, 2006.

Notes: 1. We explored differential population responses to climate in 18 populations of threatened spring-summer Chinook salmon *Onchorynchus tshawytscha* in the Salmon River basin, Idaho. 2. Using data from a long-term mark-release-recapture study of juvenile survival, we found that fall stream flow is the best predictor of average survival across all populations. 3. To determine whether all populations responded similarly to climate, we used a cluster analysis to group populations that had similar annual fluctuations in survival. The populations grouped into four clusters, and different environmental factors were important for different clusters. 4. Survival in two of the clusters was negatively correlated with summer temperature, and survival in the other two clusters was positively correlated with minimum fall stream flow, which in turn depends on snow pack from the previous winter. 5. Using classification and regression tree analysis, we identified stream width and stream temperature as key habitat factors that shape the responses of individual populations to climate. 6. Climate change will likely have different impacts on different populations within this metapopulation, and recognizing this diversity is important for accurately assessing risks.

Dybas, C.L. **On a collision course: Ocean plankton and climate change.** *BioScience* 56(8): 642-646, 2006.

Notes: Plankton are showing the effects of a warming climate as marine populations worldwide experience a regime shift caused by climate change. In northern oceans, biogeographical boundaries are shifting northward as warm-water species displace cold-water species, causing trophic cascades. Ocean acidification is accelerating and threatening the long-term survival of many marine species.

Costello, J.H., Sullivan, B.K., Gifford, D.J., Van Keuren, D., and Sullivan, L.J. **Seasonal refugia, shoreward thermal amplification, and metapopulation dynamics of the ctenophore *Mnemiopsis leidyi* in Narragansett Bay, Rhode Island.** *Limnology and Oceanography* 51(4): 1819-1831, 2006.

Notes: The lobate ctenophore *Mnemiopsis leidyi* occurs throughout Narragansett Bay, Rhode Island, during warm summer months but is often undetectable in the central portion of the bay during winter months. During 2 yr of weekly sampling, we found that *M. leidyi* populations in a shallow embayment, Greenwich Cove, either overwintered or were only briefly absent during winter. The Greenwich Cove population reproduced weeks earlier and reached higher average and peak population concentrations than open-bay populations. Shallow embayment populations such as that in Greenwich Cove probably serve as source populations that inoculate the main region of the bay by advective transport in the spring months. We propose that earlier occurrences of *M. leidyi* during recent years are due to amplification of pulsed spring warming events that permit early reproduction in the shallow embayments that serve as source regions for *M. leidyi* in Narragansett Bay. We further suggest that the source-sink perspective we describe is relevant not only to Narragansett Bay but other temperate regions of the world persistently occupied by *M. leidyi*.

Fleeger, J.W., Carman, K.R., Weisenhorn, P.B., Sofranko, H., Marshall, T., Thistle, D., and Barry, J.P. **Simulated sequestration of anthropogenic carbon dioxide at a deep-sea site: Effects on nematode abundance and biovolume.** *Deep Sea Research Part I, Oceanographic Research* 53(7): 1135-1147, 2006.

Notes: One proposal for ameliorating global warming is to sequester large amounts of carbon dioxide in the deep ocean, but the environmental consequences of sequestration for sediment-dwelling animals are poorly known. In a previous publication, we reported that ~ 80% of benthic copepods were killed in an experimental release of CO_2 off northern California at 3262 m. The effects of this release on nematodes are reported here. We examined samples of nematodes taken inside two 'corrals' into which CO_2 was directly injected (providing an extreme endpoint for CO_2 exposure) and taken near to and far from this CO_2 source. After 30 days, pore-water pH was unchanged (~ 7.8) at the sediment-water interface far (~ 40 m) from corrals, but pH profiles were reduced by ~ 0.75 near (~ 2 m) corrals. Corral pH was highly acidic (5.4 in a measurement from a subsequent experiment). Fifty randomly selected nematodes from each of four vertical layers from the 14 cores were photographed. They were assigned to a tail group (based on morphology), and individual biovolume was estimated from measurements of body length and width. Although nematode abundance (expressed as total nematodes and by tail group) was not affected, length, width, and individual biovolume significantly differed between near and far samples. Median nematode biovolume examined across tail group and core layer increased by ~ 48% inside and near corrals. Differences between near and corral samples were always less than differences between near and far samples. However, nematode length:width ratio did not differ between near and far, and the shapes of length, width, and biovolume frequency distributions were similar in all samples. We postulate that the nematode community throughout the upper 3 cm suffered a high rate of mortality after exposure to CO_2, and that nematodes were larger because postmortem expansions in body length and width occurred. Decomposition rates were probably low and corpses did not disintegrate in 30 days. The observable effects of a reduction in pH to about 7.0 after 30 days were as great as an extreme pH reduction (5.4), suggesting that 'moderate' CO_2 exposure, compared to the range of exposures possible following CO_2 release, causes high mortality rates in the two most abundant sediment-dwelling metazoans (nematodes and copepods).

Velicogna, I. and Wahr, J. **Acceleration of Greenland ice mass loss in spring 2004.** *Nature* 443(7109): 329-331, 2006.

Notes: In 2001 the Intergovernmental Panel on Climate Change projected the contribution to sea level rise from the Greenland ice sheet to be between -0.02 and +0.09m from 1990 to 2100. However, recent work has suggested that the ice sheet responds more quickly to climate perturbations than previously thought, particularly near the coast. Here we use a satellite gravity survey by the Gravity Recovery and Climate Experiment (GRACE) conducted from April 2002 to April 2006 to provide an independent estimate of the contribution of Greenland icemass loss to sea level change. We detect an ice mass loss of 248 +/- 36 $km^3\ yr^{-1}$, equivalent to a global sea level rise of 0.5 +/- 0.1 mm yr^{-1}. The rate of ice loss increased by 250 per cent between the periods April 2002 to April 2004 and May 2004 to April 2006, almost entirely due to accelerated rates of ice loss in southern Greenland; the rate of mass loss in north Greenland was almost constant. Continued monitoring will be needed to identify any future changes in the rate of ice loss in Greenland.

Mann, M.E. and Emanuel, K.A. **Atlantic hurricane trends linked to climate change.** *Eos Transactions* 87(24): 233, 238-241, 2006.

Notes: Increases in key measures of Atlantic hurricane activity over recent decades are believed to reflect, in large part, contemporaneous increases in tropical Atlantic warmth. Some recent studies have attributed these increases to a natural climate cycle termed the Atlantic Multidecadal Oscillation (AMO), while other studies suggest that climate change may instead be playing the dominant role. Using a formal statistical analysis to separate the estimated influences of anthropogenic climate change from possible natural cyclical influences, this article presents results indicating that anthropogenic factors are likely responsible for long-term trends in tropical Atlantic warmth and tropical cyclone activity. In addition, this analysis indicates that late twentieth century tropospheric aerosol cooling has offset a substantial fraction of anthropogenic warming in the region and has thus likely suppressed even greater potential increases in tropical cyclone activity.

Eyring, V. and et al. **Multi-model simulations of the impact of international shipping on atmospheric chemistry and climate in 2000 and 2030.** *Atmospheric Chemistry and Physics Discussions* 6: 8553-8604, 2006.

Notes: The global impact of shipping on atmospheric chemistry and radiative forcing, as well as the associated uncertainties, have been quantified using an ensemble of ten state-of-the-art atmospheric chemistry models and a pre-defined set of emission data. The analysis is performed for present-day conditions (year 2000) and for two future ship emission scenarios. In one scenario emissions stabilize at 2000 levels; in the other emissions increase with a constant annual growth rate of 2.2% up to 2030 (termed the "Constant Growth Scenario"). The first key question addressed by this study is how NOx and SO_2 emissions from international shipping might influence atmospheric chemistry in the next three decades if these emissions increase unabated. The models show future increases in NOx and ozone burden which scale almost linearly with increases in NOx emission totals. For the same ship emission totals but higher emissions from other sources a slightly smaller response is found. The most pronounced changes in annual mean tropospheric NO_2 and sulphate columns are simulated over the Baltic and North Seas; other significant changes occur over the North Atlantic, the Gulf of Mexico and along the main shipping lane from Europe to Asia, across the Red and Arabian Seas. Maximum contributions from shipping to annual mean near-surface ozone are found over the Atlantic (5-6 ppbv in 2000 reaching up to 8 ppbv in the 2030 Constant Growth Scenario). Large increases in tropospheric ozone column are found over the Atlantic and even stronger over the Indian Ocean (1DU in 2000 and up to 1.8DU in 2030). Tropospheric ozone forcings due to shipping are $9.8\pm2.0 mW/m^2$ in 2000 and $13.6\pm2.3 mW/m^2$ in 2030. Whilst increasing ozone, ship NOx simultaneously enhances OH, reducing the CH4 lifetime by 0.13 yr in 2000, and by up to 0.17 yr in 2030, introducing a negative radiative forcing. Over Europe, the increase in ship emissions under the "Constant Growth Scenario" will enhance the positive trend in NO_2 over land up to 2030. In addition, efforts to lower European sulphate levels through reductions in SO_2 emissions from anthropogenic sources on land will be partly counteracted by the rise in ship emissions. Globally, shipping contributes with 3% to increases in ozone burden until 2030 and with 4.5% to increases in sulphate. The results discussed above are calculated under the assumption that all other emissions follow the IPCC SRES A2 scenario. However, if future ground based emissions follow a more stringent scenario, the relative importance of ship emissions becomes larger. The second key issue of this work is to examine the range of results given by the individual models compared to the ensemble mean. Uncertainties in the different model approaches in the simulated ozone contributions from ships are found to be significantly smaller than estimated uncertainties stemming from the ship emission inventory, mainly the ship emission totals, the neglect of ship plume dispersion, and the distribution of the emissions over the globe.

Peterson, B.J., McClelland, J., Curry, R., Holmes, R.M., Walsh, J.E., and Aagaard, K. **Trajectory shifts in the Arctic and subarctic freshwater cycle.** *Science* 313(5790): 1061-1066, 2006.

Notes: Manifold changes in the freshwater cycle of high-latitude lands and oceans have been reported in the past few years. A synthesis of these changes in freshwater sources and in ocean freshwater storage illustrates the complementary and synoptic temporal pattern and magnitude of these changes over the past 50 years. Increasing river discharge anomalies and excess net precipitation on the ocean contributed ~ 20,000 cubic kilometers of fresh water to the Arctic and high-latitude North Atlantic oceans from lows in the 1960s to highs in the 1990s. Sea ice attrition provided another ~ 15,000 cubic kilometers, and glacial melt added ~ 2000 cubic kilometers. The sum of anomalous inputs from these freshwater sources matched the amount and rate at which fresh water accumulated in the North Atlantic during much of the period from 1965 through 1995. The changes

in freshwater inputs and ocean storage occurred in conjunction with the amplifying North Atlantic Oscillation and rising air temperatures. Fresh water may now be accumulating in the Arctic Ocean and will likely be exported southward if and when the North Atlantic Oscillation enters into a new high phase.

Chen, J.L., Wilson, C.R., and Tapley, B.D. **Satellite gravity measurements confirm accelerated melting of Greenland ice sheet.** *Science* 313(5795): 1958-1960, 2006.

Notes: Using time-variable gravity measurements from the Gravity Recovery and Climate Experiment (GRACE) satellite mission, we estimate ice mass changes over Greenland during the period April 2002 to November 2005. After correcting for the effects of spatial filtering and limited resolution of GRACE data, the estimated total ice melting rate over Greenland is -239 +/- 23 cubic kilometers per year, mostly from East Greenland. This estimate agrees remarkably well with a recent assessment of -224 +/- 41 cubic kilometers per year, based on satellite radar interferometry data. GRACE estimates in southeast Greenland suggest accelerated melting since the summer of 2004, consistent with the latest remote sensing measurements.

Santer, B.D., Wigley, T.M.L., Gleckler, P.J., Bonfils, C., Wehner, M.F., Achuta-Rao, K., Barnett, T.P., Boyle, J.S., Brüggemann, W., Fiorino, M., Gillett, N., Hansen, J.E., Jones, P.D., Klein, S.A., Meehl, G.A., Raper, S.C.B., Reynolds, R.W., Taylor, K.E., and Washington, W.M. **Forced and unforced ocean temperature changes in Atlantic and Pacific tropical cyclogenesis regions.** *Proceedings of the National Academy of Sciences [USA]* 103(38): 13905-13910, 2006.

Notes: Previous research has identified links between changes in sea surface temperature (SST) and hurricane intensity. We use climate models to study the possible causes of SST changes in Atlantic and Pacific tropical cyclogenesis regions. The observed SST increases in these regions range from 0.32°C to 0.67°C over the 20th century. The 22 climate models examined here suggest that century-timescale SST changes of this magnitude cannot be explained solely by unforced variability of the climate system. We employ model simulations of natural internal variability to make probabilistic estimates of the contribution of external forcing to observed SST changes. For the period 1906-2005, we find an 84% chance that external forcing explains at least 67% of observed SST increases in the two tropical cyclogenesis regions. Model "20th-century" simulations, with external forcing by combined anthropogenic and natural factors, are generally capable of replicating observed SST increases. In experiments in which forcing factors are varied individually rather than jointly, human-caused changes in greenhouse gases are the main driver of the 20th-century SST increases in both tropical cyclogenesis regions.

Hansen, J., Sato, M., Ruedy, R., Lo, K., Lea, D.W., and Medina-Elizade, M. **Global temperature change.** *Proceedings of the National Academy of Sciences [USA]* 103(39): 14288-14293, 2006.

Notes: Global surface temperature has increased ~0.2°C per decade in the past 30 years, similar to the warming rate predicted in the 1980s in initial global climate model simulations with transient greenhouse gas changes. Warming is larger in the Western Equatorial Pacific than in the Eastern Equatorial Pacific over the past century, and we suggest that the increased West-East temperature gradient may have increased the likelihood of strong El Niños, such as those of 1983 and 1998. Comparison of measured sea surface temperatures in the Western Pacific with paleoclimate data suggests that this critical ocean region, and probably the planet as a whole, is approximately as warm now as at the Holocene maximum and within ~1°C of the maximum temperature of the past million years. We conclude that global warming of more than ~1°C, relative to 2000, will constitute "dangerous" climate change as judged from likely effects on sea level and extermination of species.

Steffen, W. **The Arctic in an earth system context: From brake to accelerator of change.** *Ambio* 35(4): 153-159, 2006.

Notes: Human activities over the past few centuries have profoundly changed the functioning of the earth system as a whole. These changes are particularly evident in the high latitudes of the Northern Hemisphere, where environmental change has been pronounced and rapid. Such changes have implications beyond the region, as they can lead to two important feedback processes: the ice-albedo feedback and the terrestrial carbon cycle-climate feedback. These processes play an exceptionally

important role in earth system functioning, particularly because they may switch this century from damping the effects of anthropogenic climate change to accelerating them. Rapid environmental change in the high latitudes also has consequences for issues of direct importance to humans, particularly water resources.

Payet, R. and Agricole, W. **Climate change in the Seychelles: Implications for water and coral reefs.** *Ambio* 35(4): 182-189, 2006.

Notes: The Seychelles is a small island state in the western Indian Ocean that is vulnerable to the effects of climate change. This vulnerability led the Intergovernmental Panel on Climate Change (IPCC) in 2001 to express concern over the potential economic and social consequences that may be faced by small island states. Small island states should be prepared to adapt to such changes, especially in view of their dependence on natural resources, such as water and coral reefs, to meet basic human welfare needs. Analysis of long-term data for precipitation, air temperature, and sea-surface temperature indicated that changes are already observable in the Seychelles. The increase in dry spells that resulted in drought conditions in 1999 and the 1998 mass coral bleaching are indicative of the events that are likely to occur under future climate change. Pre-IPCC Third Assessment Report scenarios and the new SRES scenarios are compared for changes in precipitation and air surface temperature for the Seychelles. These intercomparisons indicate that the IS92 scenarios project a much warmer and wetter climate for the Seychelles than do the SRES scenarios. However, a wetter climate does not imply readily available water, but rather longer dry spells with more intense precipitation events. These observations will likely place enormous pressures on water-resources management in the Seychelles. Similarly, sea-surface temperature increases predicted by the HADCM3 model will likely trigger repeated coral-bleaching episodes, with possible coral extinctions within the Seychelles region by 2040. The cover of many coral reefs around the Seychelles have already changed, and the protection of coral-resilient areas is a critical adaptive option.

Serreze, M.C. and Francis, J.A. **The arctic amplification debate.** *Climatic Change* 76(3-4): 241-264, 2006.

Notes: Rises in surface air temperature (SAT) in response to increasing concentrations of greenhouse gases (GHGs) are expected to be amplified in northern high latitudes, with warming most pronounced over the Arctic Ocean owing to the loss of sea ice. Observations document recent warming, but an enhanced Arctic Ocean signal is not readily evident. This disparity, combined with varying model projections of SAT change, and large variability in observed SAT over the 20th century, may lead one to question the concept of Arctic amplification. Disparity is greatly reduced, however, if one compares observed trajectories to near-future simulations (2010-2029), rather than to the doubled-CO_2 or late 21st century conditions that are typically cited. These near-future simulations document a preconditioning phase of Arctic amplification, characterized by the initial retreat and thinning of sea ice, with imprints of low-frequency variability. Observations show these same basic features, but with SATs over the Arctic Ocean still largely constrained by the insulating effects of the ice cover and thermal inertia of the upper ocean. Given the general consistency with model projections, we are likely near the threshold when absorption of solar radiation during summer limits ice growth the following autumn and winter, initiating a feedback leading to a substantial increase in Arctic Ocean SATs.

Arvai, J., Bridge, G., Dolsak, N., Franzese, R., Koontz, T., Luginbuhl, A., Robbins, P., Richards, K., Korfmacher, K.S., Sohngen, B., Tansey, J., and Thompson, A. **Adaptive management of the global climate problem: Bridging the gap between climate research and climate policy.** *Climatic Change* 78(1): 217-225, 2006.

Notes: To date the Intergovernmental Panel on Climate Change (IPCC) has concerned itself with gathering a state of the art review of the science of climate change. While significant progress has been made in enhancing our integrated understanding of the climate system and the dynamics of the social systems that produce an array of potential greenhouse gases, it is also clear from the panel's reports how far the science community is from being able to present a dynamic and synoptic view of the climate system as a whole. Clear evidence of these complexities and uncertainties inherent in the climate system is evident in efforts aimed at designing robust policy interventions. In this paper, we argue that the adaptive management framework in ecosystem management may be a useful model for guiding how the IPCC can continue to be relevant both as a scientific establishment and as a policy-relevant scientific endeavor.

Overpeck, J.T. and Cole, J.E. **Abrupt change in Earth's climate system.** *Annual Review of Environment and Resources* 31: 1-31, 2006.

Notes: Many aspects of Earth's climate system have changed abruptly in the past and are likely to change abruptly in the future. Although abrupt shifts in temperature are most dramatic in glacial climates, abrupt changes, resulting in an altered probability of drought, large floods, tropical storm landfall, and monsoon rainfall, are all important concerns even in the absence of significant anthropogenic climate forcing. Continued climate change will likely increase the probability of these types of abrupt change and also make abrupt changes in ocean circulation and sea level more likely. Although global warming may have already triggered abrupt change, current understanding and modeling capability is not sufficient to specify details of future abrupt climate change. Improved adaptation strategies are warranted, as well as efforts to avoid crossing climate change thresholds beyond which large abrupt changes in sea level, ocean circulation, and methane-clathrate release could greatly amplify the impacts of climate change.

Parkinson, C.L. **Earth's cryosphere: Current state and recent changes.** *Annual Review of Environment and Resources* 31: 33-60, 2006.

Notes: Earth continues to have a third of the ice that it had at the peak of the last ice age, although that ice continues to decrease, as it has, overall, for the past 18,000 years. Over the last 100 years, the retreat signal has been especially strong in ice shelves of the Arctic and along the Antarctic Peninsula, with a more mixed signal elsewhere. For instance, since the early 1990s, the massive Greenland and Antarctic ice sheets have thinned along the coasts but thickened in the interior, and since the late 1970s, sea ice has decreased in the Arctic but increased (slightly) in the Antarctic. Major difficulties in the interpretations of the climate record come from the high interannual variability of most cryosphere components and the lack of consistent long-term global data records; the latter problem is now being slowly remedied, in part, through satellite technology.

McGuire, A.D., Chapin, F.S., Walsh, J.E., and Wirth, C. **Integrated regional changes in Arctic climate feedbacks: Implications for the global climate system.** *Annual Review of Environment and Resources* 31: 61-91, 2006.

Notes: The Arctic is a key part of the global climate system because the net positive energy input to the tropics must ultimately be resolved through substantial energy losses in high-latitude regions. The Arctic influences the global climate system through both positive and negative feedbacks that involve physical, ecological, and human systems of the Arctic. The balance of evidence suggests that positive feedbacks to global warming will likely dominate in the Arctic during the next 50 to 100 years. However, the negative feedbacks associated with changing the freshwater balance of the Arctic Ocean might abruptly launch the planet into another glacial period on longer timescales. In light of uncertainties and the vulnerabilities of the climate system to responses in the Arctic, it is important that we improve our understanding of how integrated regional changes in the Arctic will likely influence the evolution of the global climate system.

Austin, J. and Wilson, R.J. **Ensemble simulations of the decline and recovery of stratospheric ozone.** *Journal of Geophysical Research* 111(16): art. D16314, 2006.

Notes: An ensemble of simulations of a coupled chemistry-climate model is completed for 1960-2100. The simulations are divided into two periods, 1960-2005 and 1990-2100. The modeled total ozone amount decrease throughout the atmosphere from the 1960s until about 2000-2005, depending on latitude. The Antarctic ozone hole develops rapidly in the model from about the late 1970s, in agreement with observations, but it does not disappear until about 2065, about 15 years later than previous estimates. Spring averaged ozone takes even longer to recover to 1980 values. Ozone amounts in the Antarctic are determined largely by halogen amounts. In contrast, in the Arctic, ozone recovers to 1980 values about 25-35 years earlier, depending on the recovery criterion adopted. By the end of the 21st century, the climate change associated with greenhouse gas changes gives rise to a significant superrecovery of ozone in the Arctic but a less marked recovery in the Antarctic. For both polar regions, ensemble and interannual variability is greater in the future than in the past, and hence the timing of the

full recovery of polar ozone is very sensitive to the definition of recovery. It is suggested that the range of recovery rates between the hemispheres simulated in the model is related to the overall increase in the strength of the Brewer-Dobson circulation, driven by increases in greenhouse gas concentrations.

Auad, G., Miller, A., and Di Lorenzo, E. **Long-term forecast of oceanic conditions off California and their biological implications.** *Journal of Geophysical Research* 111(9): art. C09008, 2006.

Notes: The impact of global warming due to an increased content of atmospheric CO_2 is studied by forcing a numerical eddy-resolving ocean model with wind stresses, heat fluxes, and open boundary conditions obtained from a state-of-the-art coupled model. Specifically, we have compared the 1986-1996 and 2040-2050 decades to describe and analyze the changes attained by several oceanographic variables in the California Current System. A richer atmosphere in CO_2 leads to increased sea surface and near-surface temperatures in the model domain and to an increased stratification along the coast that, however, is not strong enough to overcome the effect of increased upwelling favorable winds. A mild oceanic cooling is forecast below the 70-m depth, in agreement with recent studies of global warming trends. Near-surface vertical velocities increase by about 30% in April, but our simulations also forecast anomalous offshore transports in most of the coastal areas. The eddy kinetic energy decreases, on an annual mean, along the California Current main path with maximum negative anomalies in winter. The upward displacement of the 26.5 isopycnal surface, especially in the northern half of our study area, leads to an increase in the concentration of nutrients in the subsurface. The agreement between some results of this forecasting study and recent published findings would suggest that the current global warming trend would persist in the study area with similar changes to those observed over the last half century.

Jevrejeva, S., Grinsted, A., Moore, J.C., and Holgate, S. **Nonlinear trends and multiyear cycles in sea level records.** *Journal of Geophysical Research* 111(9): art. C09012, 2006.

Notes: We analyze the Permanent Service for Mean Sea Level (PSMSL) database of sea level time series using a method based on Monte Carlo Singular Spectrum Analysis (MC-SSA). We remove 2-30 year quasi-periodic oscillations and determine the nonlinear long-term trends for 12 large ocean regions. Our global sea level trend estimate of 2.4 ± 1.0 mm/yr for the period from 1993 to 2000 is comparable with the 2.6 ± 0.7 mm/yr sea level rise calculated from TOPEX/Poseidon altimeter measurements. However, we show that over the last 100 years the rate of 2.5 ± 1.0 mm/yr occurred between 1920 and 1945, is likely to be as large as the 1990s, and resulted in a mean sea level rise of 48 mm. We evaluate errors in sea level using two independent approaches, the robust bi-weight mean and variance, and a novel "virtual station" approach that utilizes geographic locations of stations. Results suggest that a region cannot be adequately represented by a simple mean curve with standard error, assuming all stations are independent, as multiyear cycles within regions are very significant. Additionally, much of the between-region mismatch errors are due to multiyear cycles in the global sea level that limit the ability of simple means to capture sea level accurately. We demonstrate that variability in sea level records over periods 2-30 years has increased during the past 50 years in most ocean basins.

Michaels, P.J., Knappenberger, P.C., and Davis, R.E. **Sea-surface temperatures and tropical cyclones in the Atlantic basin.** *Geophysical Research Letters* 33(9): art. L09708, 2006.

Notes: Whereas there is a significant relationship between overall sea-surface temperature (SST) and tropical cyclone intensity, the relationship is much less clear in the upper range of SST normally associated with these storms. There, we find a step-like, rather than a continuous, influence of SST on cyclone strength, suggesting that there exists a SST threshold that must be exceeded before tropical cyclones develop into major hurricanes. Further, we show that the SST influence varies markedly over time, thereby indicating that other aspects of the tropical environment are also critically important for tropical cyclone intensification. These findings highlight the complex nature of hurricane development and weaken the notion of a simple cause-and-effect relationship between rising SST and stronger Atlantic hurricanes.

Sriver, R. and Huber, M. **Low frequency variability in globally integrated tropical cyclone power dissipation.** *Geophysical Research Letters* 33(11): art. L11705, 2006.

Notes: Surface wind and temperature records from the European Centre for Medium-Range Weather Forecasts 40 Year Reanalysis (ERA-40) Project are used to estimate low-frequency variations in globally integrated tropical cyclone (TC) intensity from 1958 to 2001. For the first time, the annually integrated power dissipation (PD) is explicitly calculated on a global scale, and results show an upward trend in PD during much of the ERA-40 project period, although we argue this is at least partially due to limitations in cyclone representation in ERA-40. Comparing our estimated trend in PD with Emanuel's (2005) approximation to PD reveals good agreement after 1978, coinciding with the onset of a major satellite observing-system epoch in ERA-40. The low pass (>60 months) filtered PD time series correlates with mean annual tropical temperature, thus this result is consistent with the hypothesis that tropical temperatures may directly regulate the integrated intensity of TCs.

Schneider, D.P., Steig, E.J., van Ommen, T.D., Dixon, D.A., Mayewski, P.A., Jones, J.M., and Bitz, C.M. **Antarctic temperatures over the past two centuries from ice cores.** *Geophysical Research Letters* 33(16): art. L16707, 2006.

Notes: We present a reconstruction of Antarctic mean surface temperatures over the past two centuries based on water stable isotope records from high-resolution, precisely dated ice cores. Both instrumental and reconstructed temperatures indicate large interannual to decadal scale variability, with the dominant pattern being anti-phase anomalies between the main Antarctic continent and the Antarctic Peninsula region. Comparative analysis of the instrumental Southern Hemisphere (SH) mean temperature record and the reconstruction suggests that at longer timescales, temperatures over the Antarctic continent vary in phase with the SH mean. Our reconstruction suggests that Antarctic temperatures have increased by about 0.2°C since the late nineteenth century. The variability and the long-term trends are strongly modulated by the SH Annular Mode in the atmospheric circulation.

Juillet-Leclerc, A., Thiria, S., Naveau, P., Delcroix, T., Le Bec, N., Blamart, D., and Corrège, T. **SPCZ migration and ENSO events during the 20th century as revealed by climate proxies from a Fiji coral.** *Geophysical Research Letters* 33(17): art. L17710, 2006.

Notes: Instrumental sea surface temperature (SST) and sea surface salinity (SSS) records since 1975 have indicated that migrations of the South Pacific Convergence Zone (SPCZ) are strongly related to El Niño-Southern Oscillation (ENSO) events. To reconstruct independent SSS and SST time series for the past century and document this SPCZ and ENSO relationship prior to 1975, we apply a neural network analysis to seven climate proxies derived from a coral skeleton collected in Fiji. These reconstructions suggest that five SPCZ migrations linked to ENSO occurred between 1908 and 1970 while as many migrations occurred during the last three decades, highlighting the recent enhanced frequency of ENSO occurrence.

Nghiem, S.V., Chao, Y., Neumann, G., Li, P., Perovich, D.K., Street, T., and Clemente-Colón, P. **Depletion of perennial sea ice in the East Arctic Ocean.** *Geophysical Research Letters* 33(17): art. L17501, 2006.

Notes: The extent of perennial sea ice in the East Arctic Ocean (0-180°E) decreased by nearly one half with an abrupt reduction of 0.95 × 106 km², while the West Arctic Ocean (0-180°W) had a slight gain of 0.23 × 106 km² between 2004 and 2005, as observed by satellite scatterometer data during November-December. The net decrease in the total perennial ice extent is 0.72 × 106 km², about the size of Texas. Perennial ice in the East Arctic Ocean continued to be depleted with an areal reduction of 70% from October 2005 to April 2006. With the East Arctic Ocean dominated by seasonal sea ice, a strong summer melt may open a vast ice-free region with a possible record minimum ice extent largely confined to the West Arctic Ocean. Simultaneous scatterometer measurements of sea ice and winds will be crucial for sea ice monitoring and forecasts.

Comiso, J.C. **Abrupt decline in the Arctic winter sea ice cover.** *Geophysical Research Letters* 33(18): art. L18504, 2006.

Notes: Although the Arctic perennial ice cover has been on a rapid decline, the winter ice cover had been unexpectedly stable. We report and provide insights into a remarkable turn of events, with the observation of record low ice extent and area during the winters of 2005 and 2006. Negative ice anomalies in these years are prevalent in the peripheral seas but are most dominant in the eastern Arctic basin where the perennial ice becomes even more vulnerable to further decline. Overall, the winter ice anomalies correlate well with surface temperature anomalies and wind circulation patterns. Since historical satellite data indicate a positive trend in winter temperatures and a negative trend in the length of seasonal ice growth period, it is likely that the winter ice cover will continue to retreat in the near future. Results suggest that the expected warming impact of greenhouse gases is becoming apparent in the Arctic during the dark winter months.

Slott, J.M., Murray, A.B., Ashton, A.D., and Crowley, T.J. **Coastline responses to changing storm patterns.** *Geophysical Research Letters* 33(18): art. L18404, 2006.

Notes: Researchers and coastal managers are pondering how accelerated sea-level rise and possibly intensified storms will affect shorelines. These issues are most often investigated in a cross-shore profile framework, fostering the implicit assumption that coastline responses will be approximately uniform in the alongshore direction. However, experiments with a recently developed numerical model of coastline change on a large spatial domain suggest that the shoreline responses to climate change could be highly variable. As storm and wave climates change, large-scale coastline shapes are likely to shift - causing areas of greatly accelerated coastal erosion to alternate with areas of considerable shoreline accretion. On complex-shaped coastlines, including cuspate-cape and spit coastlines, the alongshore variation in shoreline retreat rates could be an order of magnitude higher than the baseline retreat rate expected from sea-level rise alone.

Fyfe, J.C. **Southern Ocean warming due to human influence.** *Geophysical Research Letters* 33(19): art. L19701, 2006.

Notes: I show that the latest series of climate models reproduce the observed mid-depth Southern Ocean warming since the 1950s if they include time-varying changes in anthropogenic greenhouse gases, sulphate aerosols and volcanic aerosols in the Earth's atmosphere. The remarkable agreement between observations and state-of-the art climate models suggests significant human influence on Southern Ocean temperatures. I also show that climate models that do not include volcanic aerosols produce mid-depth Southern Ocean warming that is nearly double that produced by climate models that do include volcanic aerosols. This implies that the full effect of human-induced warming of the Southern Ocean may yet to be realized.

Moore, G.W.K. **Reduction in seasonal sea ice concentration surrounding southern Baffin Island 1979-2004.** *Geophysical Research Letters* 33(20): art. L20501, 2006.

Notes: Sea ice plays an important role in the climate and ecology of the Arctic. Numerous studies have identified a reduction in Arctic sea ice cover that has occurred over the past several decades, the period for which we have remotely sensed sea ice concentration data. The regional and seasonal expressions of this reduction have not been as extensively studied. In this paper, we describe the reduction in sea ice concentration that has occurred around southern Baffin Island, one of the Arctic's most biologically active regions. We show that a reduction in sea ice concentration, statistically significant at the 95% level or higher in the presence of temporally correlated noise, in the range of 10-20% per decade has occurred in the region with the largest reduction occurring during the early winter. This reduction is consistent with a recent statistically significant surface warming in the region during the fall and early winter.

Tilmes, S., Müller, R., Engel, A., Rex, M., and Russell, J.M. **Chemical ozone loss in the Arctic and Antarctic stratosphere between 1992 and 2005.** *Geophysical Research Letters* 33(20): art. L20812, 2006.

Notes: The magnitude of chemical loss of polar ozone induced by anthropogenic halogens depends on the extent of chlorine activation, which is controlled by polar stratospheric clouds (PSCs) and thus by temperature. We propose a new quantity, the PSC formation potential (PFP) of the polar vortex, suitable for comparing the amount of ozone depletion in the Arctic and Antarctic regions. PFP represents the fraction of the vortex, over an ozone loss season, exposed to PSC temperatures.

Chemical ozone loss in the Arctic correlates well with PFP, for winters between 1991 and 2005. For Antarctic and cold Arctic winters, PFP has been increasing over the past 30 years. In winter 2005, PFP and ozone loss in the Arctic reached record highs, approaching Antarctic levels. Nevertheless, column ozone in spring in the Arctic is much larger than the Antarctic, because of larger dynamical resupply of ozone to the Arctic.
