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Marine Science Review – 215

Climate and climate change

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In this review:

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B. Recent articles with abstracts

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Vaughan, D.G. and Arthern, R. **Why is it hard to predict the future of ice sheets?** *Science* 315(5818): 1503-1504, 2007.

Truffer, M. and Fahnestock, M. **Rethinking ice sheet time scales.** *Science* 315(5818): 1508-1510, 2007.

Chameides, W. and Oppenheimer, M. **Carbon trading over taxes.** *Science* 315(5819): 1670, 2007.

Stokstad, E. **Boom and bust in a polar hot zone.** *Science* 315(5818): 1522-1523, 2007.

Edwards, R. **Sea levels: change and variability during warm intervals.** *Progress in Physical Geography* 30(6): 785-796, 2006.

Anderson, J.B. **Ice sheet stability and sea-level rise.** *Science* 315(5820): 1803-1804, 2007.

Shine, K.P. and Sturges, W.T. **CO_2 is not the only gas.** *Science* 315(5820): 1804-1805, 2007.

Curry, J.A., Webster, P.J., and Holland, G.J. **Mixing politics and science in testing the hypothesis that greenhouse warming is causing a global increase in hurricane intensity.** *Bulletin of the American Meteorological Society* 87(8): 1025-1037, 2006.

B. Recent articles with abstracts

Colgan, C.S. and Adkins, J. **Hurricane damage to the ocean economy in the U.S. gulf region in 2005.** *Monthly Labor Review* August: 76-78, 2006.

Notes: Counties and parishes of the gulf coast ocean economy affected by Hurricanes Katrina and Rita saw the greatest insured dollar losses in 1 year from suchlike catastrophes in U.S. history; the region has yet to recover fully a year after the maelstrom.

Meynecke, J.O., Lee, S.Y., Duke, N.C., and Warnken, J. **Effect of rainfall as a component of climate change on estuarine fish production in Queensland, Australia.** *Estuarine, Coastal and Shelf Science* 69(3-4): 491-504, 2006.

Notes: The speculation that climate change may impact on sustainable fish production suggests a need to understand how these effects influence fish catch on a broad scale. With a gross annual value of A$ 2.2 billion, the fishing industry is a significant primary industry in Australia. Many commercially important fish species use estuarine habitats such as mangroves, tidal flats and seagrass beds as nurseries or breeding grounds and have lifecycles correlated to rainfall and temperature patterns. Correlation of catches of mullet (e.g. *Mugil cephalus*) and barramundi (*Lates calcarifer*) with rainfall suggests that fisheries

may be sensitive to effects of climate change. This work reviews key commercial fish and crustacean species and their link to estuaries and climate parameters. A conceptual model demonstrates ecological and biophysical links of estuarine habitats that influences capture fisheries production. The difficulty involved in explaining the effect of climate change on fisheries arising from the lack of ecological knowledge may be overcome by relating climate parameters with long-term fish catch data. Catch per unit effort (CPUE), rainfall, the Southern Oscillation Index (SOI) and catch time series for specific combinations of climate seasons and regions have been explored and surplus production models applied to Queensland's commercial fish catch data with the program CLIMPROD. Results indicate that up to 30% of Queensland's total fish catch and up to 80% of the barramundi catch variation for specific regions can be explained by rainfall often with a lagged response to rainfall events. Our approach allows an evaluation of the economic consequences of climate parameters on estuarine fisheries, thus highlighting the need to develop forecast models and manage estuaries for future climate change impact by adjusting the quota for climate change sensitive species. Different modelling approaches are discussed with respect to their forecast ability.

Selin, H. and VanDeveer, S.D. **Political science and prediction: What's next for U.S. climate change policy?** *Review of Policy Research* 24(1): 1-27, 2007.

Notes: This article analyzes how U.S. climate change politics and policy making are changing in the public, private and civil society sectors, and how such changes are likely to influence U.S. federal policies. It outlines the current status of U.S. climate change action and explores four overlapping pathways of policy change: (1) the strategic demonstration of the feasibility of climate change action; (2) the creation and expansion of markets; (3) policy diffusion and learning; and (4) the creation and promulgation of norms about the need for more aggressive climate change action. These four pathways seek to fruitfully draw from rationalist and constructivist approaches to policy analysis, without collapsing or confusing the different logics. Building on this analysis, it predicts that future federal U.S. climate policy will include six major components: (1) A national cap on GHG emissions; (2) A national market based cap-and-trade GHG emissions trading scheme; (3) Mandatory renewable energy portfolio standards; (4) Increased national product standards for energy efficiency; (5) Increased vehicle fleet energy efficiency standards; and (6) Increased federal incentives for research and development on energy efficiency issues and renewable energy development. In addition, expanding federal climate policy may bring about significant changes in U.S. foreign policy as U.S. international re-engagement on climate change is likely to occur only after the development of more significant federal policy.

Cropp, R. and Norbury, J. **Investigations into a plankton population model: Mortality and its importance in climate change scenarios.** *Ecological Modelling* 201(2): 97-117, 2007.

Notes: The potential for marine plankton ecosystems to influence climate by the production of dimethylsulphide (DMS) has been an important topic of recent research into climate change. Several General Circulation Models, used to predict climate change, have or are being modified to include interactions of ecosystems with climate. Climate change necessitates that parameters within ecosystem models must change during long-term simulations, especially mortality parameters that increase as organisms are pushed toward the boundaries of their thermal tolerance. Changing mortality parameters can have profound influences on ecosystem model dynamics. There is therefore a pressing need to understand the influence of varying mortality parameters on the long-term behaviour of ecosystem models. This work examines the sensitivity of a model of DMS production by marine ecosystems to variations in three linear mortality coefficients. Significant differences in behaviour are observed, and we note the importance of these results in formulating ecosystem models for application in simulations of climate change.

Lucas, P.L., Van Vuuren, D.P., Olivier, J.G.J., and den Elzen, M.G.J. **Long-term reduction potential of non-CO_2 greenhouse gases.** *Environmental Science and Policy* 10(2): 85-103, 2007.

Notes: A methodology is presented here to assess the potential long-term contribution of non-CO_2 greenhouse gases in mitigation scenarios. The analysis shows the future development of the mitigation potential of non-CO_2 gases (as a function of changes in technology and implementation barriers) to represent a crucial parameter for the overall costs of mitigation scenarios. The recently developed marginal abatement cost curves for 2010 in the EMF-21 project are taken as the starting point. First-order estimates were made of the future maximum attainable reduction potentials and costs on the basis of available literature. The set of MAC curves developed was used in a multi-gas analysis for stabilising greenhouse gas

concentrations at 550 ppm CO_2-equivalent. Including future development for the non-CO_2 mitigation options not only increases their mitigation potential but also lowers the overall costs compared to situations where no development is assumed (3-21% lower in 2050 and 4-26% lower in 2100 in our analysis). Along with the fluorinated gases, energy-related methane emissions make up the largest share in total non-CO_2 abatement potential as they represent a large emission source and have a large potential for reduction (towards 90% compared to baseline in 2100). Most methane and nitrous oxide emissions from landuse-related sources are less simple to abate, with an estimated abatement potential in 2100 of around 60% and 40%, respectively.

Nicholls, N. and Alexander, L. **Has the climate become more variable or extreme?** Progress 1992–2006. *Progress in Physical Geography* 31(1): 77-87, 2007.

Notes: In 1990 and 1992 the Intergovernmental Panel on Climate Change (IPCC), in its first assessment of climate change and its supplement, did not consider whether extreme weather events had increased in frequency and/or intensity globally, because data were too sparse to make this a worthwhile exercise. In 1995 the IPCC, in its second assessment, did examine this question, but concluded that data and analyses of changes in extreme events were 'not comprehensive' and thus the question could not be answered with any confidence. Since then, concerted multinational efforts have been undertaken to collate, quality control, and analyse data on weather and climate extremes. A comprehensive examination of the question of whether extreme events have changed in frequency or intensity is now more feasible than it was 15 years ago. The processes that have led to this position are described, along with current understanding of possible changes in some extreme weather and climate events.

Michaelidis, B., Spring, A., and Portner, H.O. **Effects of long-term acclimation to environmental hypercapnia on extracellular acid-base status and metabolic capacity in Mediterranean fish *Sparus aurata*.** *Marine Biology* 150(6): 1417-1429, 2007.

Notes: In the context of future scenarios of anthropogenic CO_2 accumulation in marine surface waters, the present study addresses the effects of long-term hypercapnia on a Mediterranean fish, *Sparus aurata*. By equilibration with elevated CO_2 levels seawater pH was lowered to a value of 7.3, close to the maximum pH drop expected in marine surface waters from atmospheric CO_2 accumulation. Intra- and extracellular acid-base parameters as well as changes in enzyme profiles were studied in red and white muscles and the heart under both normocapnia and hypercapnia. The activities of pyruvate kinase (PK), lactate dehydrogenase (L-LDH), citrate synthase (CS), malate dehydrogenase and and 3-hydroxyacyl CoA dehydrogenase (HOAD) reflect the pathways and capacity of oxidative processes in metabolism. Long-term hypercapnia caused a transient reduction in blood plasma pH (pH_e) as well as in intracellular pH (pH_i). Compensation of the acidosis occurred through increased plasma and cellular bicarbonate levels. Changes in enzymatic activities, especially the increase in the activity of L-LDH, paralleled by a drop in CS activity in white and red muscles reflect a shift from aerobic to anaerobic pathways of substrate oxidation during long-term acclimation under hypercapnia. The present results suggest that moderate environmental hypercapnia changes the metabolic profile in tissues of *S. aurata*. Consequences for slow processes like growth and reproduction potential as well as potential harm at population, species and ecosystem levels require further investigation.

Van Vuuren, D.P., den Elzen, M.G.J., Lucas, P.L., Eickhout, B., Strengers, B.J., van Ruijven, B., Wonink, S., and van Houdt, R. **Stabilizing greenhouse gas concentrations at low levels: an assessment of reduction strategies and costs.** *Climatic Change* 81(2): 119-159, 2007.

Notes: On the basis of the IPCC B2, A1b and B1 baseline scenarios, mitigation scenarios were developed that stabilize greenhouse gas concentrations at 650, 550 and 450 and - subject to specific assumptions - 400 ppm CO_2-eq. The analysis takes into account a large number of reduction options, such as reductions of non-CO_2 gases, carbon plantations and measures in the energy system. The study shows stabilization as low as 450 ppm CO_2-eq. to be technically feasible, even given relatively high baseline scenarios. To achieve these lower concentration levels, global emissions need to peak within the first two decades. The net present value of abatement costs for the B2 baseline scenario (a medium scenario) increases from 0.2% of cumulative GDP to 1.1% as the shift is made from 650 to 450 ppm. On the other hand, the probability of meeting a two-degree target increases from 0%-10% to 20%-70%. The mitigation scenarios lead to lower emissions of regional air pollutants

but also to increased land use. The uncertainty in the cost estimates is at least in the order of 50%, with the most important uncertainties including land-use emissions, the potential for bio-energy and the contribution of energy efficiency. Furthermore, creating the right socio-economic and political conditions for mitigation is more important than any of the technical constraints.

Royer, D.L., Berner, R.A., and Park, J. **Climate sensitivity constrained by CO_2 concentrations over the past 420 million years.** *Nature* 446(7135): 530-532, 2007.

Notes: A firm understanding of the relationship between atmospheric carbon dioxide concentration and temperature is critical for interpreting past climate change and for predicting future climate change. A recent synthesis suggests that the increase in global-mean surface temperature in response to a doubling of the atmospheric carbon dioxide concentration, termed 'climate sensitivity', is between 1.5 and 6.2ºC (5-95% likelihood range), but some evidence is inconsistent with this range. Moreover, most estimates of climate sensitivity are based on records of climate change over the past few decades to thousands of years, when carbon dioxide concentrations and global temperatures were similar to or lower than today, so such calculations tend to underestimate the magnitude of large climate-change events and may not be applicable to climate change under warmer conditions in the future. Here we estimate long-term equilibrium climate sensitivity by modelling carbon dioxide concentrations over the past 420 million years and comparing our calculations with a proxy record. Our estimates are broadly consistent with estimates based on short-term climate records, and indicate that a weak radiative forcing by carbon dioxide is highly unlikely on multi-million-year timescales. We conclude that a climate sensitivity greater than 1.5ºC has probably been a robust feature of the Earth's climate system over the past 420 million years, regardless of temporal scaling.

Fedorov, A., Barreiro, M., Boccaletti, G., Pacanowski, R., and Philander, S.G. **The freshening of surface waters in high latitudes: Effects on the thermohaline and wind-driven circulations.** *Journal of Physical Oceanography* 37(4): 896-907, 2007.

Notes: The impacts of a freshening of surface waters in high latitudes on the deep, slow, thermohaline circulation have received enormous attention, especially the possibility of a shutdown in the meridional overturning that involves sinking of surface waters in the northern Atlantic Ocean. A recent study by Fedorov *et al.* has drawn attention to the effects of a freshening on the other main component of the oceanic circulation -- the swift, shallow, wind-driven circulation that varies on decadal time scales and is closely associated with the ventilated thermocline. That circulation too involves meridional overturning, but its variations and critical transitions affect mainly the Tropics. A surface freshening in mid- to high latitudes can deepen the equatorial thermocline to such a degree that temperatures along the equator become as warm in the eastern part of the basin as they are in the west, the tropical zonal sea surface temperature gradient virtually disappears, and permanently warm conditions prevail in the Tropics. In a model that has both the wind-driven and thermohaline components of the circulation, which factors determine the relative effects of a freshening on the two components and its impact on climate? Studies with an idealized ocean general circulation model find that vertical diffusivity is one of the critical parameters that affect the relative strength of the two circulation components and hence their response to a freshening. The spatial structure of the freshening and imposed meridional temperature gradients are other important factors.

McKenzie, R.L., Aucamp, P.J., Bais, A.F., Björn, L.O., and Ilyas, M. **Changes in biologically-active ultraviolet radiation reaching the Earth's surface.** *Photochemical and Photobiological Sciences* 6(3): 218-231, 2007.

Notes: The Montreal Protocol is working. Concentrations of major ozone-depleting substances in the atmosphere are now decreasing, and the decline in total column amounts seen in the 1980s and 1990s at mid-latitudes has not continued. In polar regions, there is much greater natural variability. Each spring, large ozone holes continue to occur in Antarctica and less severe regions of depleted ozone continue to occur in the Arctic. There is evidence that some of these changes are driven by changes in atmospheric circulation rather than being solely attributable to reductions in ozone-depleting substances, which may indicate a linkage to climate change. Global ozone is still lower than in the 1970s and a return to that state is not expected for several decades. As changes in ozone impinge directly on UV radiation, elevated UV radiation due to reduced ozone is expected to continue over that period. Long-term changes in UV-B due to ozone depletion are difficult to verify through direct measurement, but there is strong evidence that UV-B irradiance increased over the period of ozone depletion. At unpolluted sites in the southern hemisphere, there is some evidence that UV-B irradiance has diminished since the late 1990s.

The availability and temporal extent of UV data have improved, and we are now able to evaluate the changes in recent times compared with those estimated since the late 1920s, when ozone measurements first became available. The increases in UV-B irradiance over the latter part of the 20th century have been larger than the natural variability. There is increased evidence that aerosols have a larger effect on surface UV-B radiation than previously thought. At some sites in the Northern Hemisphere, UV-B irradiance may continue to increase because of continuing reductions in aerosol extinctions since the 1990s. Interactions between ozone depletion and climate change are complex and can be mediated through changes in chemistry, radiation, and atmospheric circulation patterns. The changes can be in both directions: ozone changes can affect climate, and climate change can affect ozone. The observational evidence suggests that stratospheric ozone (and therefore UV-B) has responded relatively quickly to changes in ozone-depleting substances, implying that climate interactions have not delayed this process. Model calculations predict that at mid-latitudes a return of ozone to pre-1980 levels is expected by the mid 21st century. However, it may take a decade or two longer in polar regions. Climate change can also affect UV radiation through changes in cloudiness and albedo, without involving ozone and since temperature changes over the 21st century are likely to be about 5 times greater than in the past century. This is likely to have significant effects on future cloud, aerosol and surface reflectivity. Consequently, unless strong mitigation measures are undertaken with respect to climate change, profound effects on the biosphere and on the solar UV radiation received at the Earth's surface can be anticipated. The future remains uncertain. Ozone is expected to increase slowly over the decades ahead, but it is not known whether ozone will return to higher levels, or lower levels, than those present prior to the onset of ozone depletion in the 1970s. There is even greater uncertainty about future UV radiation, since it will be additionally influenced by changes in aerosols and clouds.

Häder, D.-P., Kumar, H.D., Smith, R.C., and Worrest, R.C. **Effects of solar UV radiation on aquatic ecosystems and interactions with climate change.** *Photochemical and Photobiological Sciences* 6(3): 267-285, 2007.

Notes: Recent results continue to show the general consensus that ozone-related increases in UV-B radiation can negatively influence many aquatic species and aquatic ecosystems (*e.g.*, lakes, rivers, marshes, oceans). Solar UV radiation penetrates to ecological significant depths in aquatic systems and can affect both marine and freshwater systems from major biomass producers (phytoplankton) to consumers (*e.g.*, zooplankton, fish, *etc.*) higher in the food web. Many factors influence the depth of penetration of radiation into natural waters including dissolved organic compounds whose concentration and chemical composition are likely to be influenced by future climate and UV radiation variability. There is also considerable evidence that aquatic species utilize many mechanisms for photoprotection against excessive radiation. Often, these protective mechanisms pose conflicting selection pressures on species making UV radiation an additional stressor on the organism. It is at the ecosystem level where assessments of anthropogenic climate change and UV-related effects are interrelated and where much recent research has been directed. Several studies suggest that the influence of UV-B at the ecosystem level may be more pronounced on community and trophic level structure, and hence on subsequent biogeochemical cycles, than on biomass levels *per se*.

Zepp, R.G., Erickson, D.J., Paul, N.D., and Sulzberger, B. **Interactive effects of solar UV radiation and climate change on biogeochemical cycling.** *Photochemical and Photobiological Sciences* 6(3): 286-300, 2007.

Notes: This report assesses research on the interactions of UV radiation (280-400 nm) and global climate change with global biogeochemical cycles at the Earth's surface. The effects of UV-B (280-315 nm), which are dependent on the stratospheric ozone layer, on biogeochemical cycles are often linked to concurrent exposure to UV-A radiation (315-400 nm), which is influenced by global climate change. These interactions involving UV radiation (the combination of UV-B and UV-A) are central to the prediction and evaluation of future Earth environmental conditions. There is increasing evidence that elevated UV-B radiation has significant effects on the terrestrial biosphere with implications for the cycling of carbon, nitrogen and other elements. The cycling of carbon and inorganic nutrients such as nitrogen can be affected by UV-B-mediated changes in communities of soil organisms, probably due to the effects of UV-B radiation on plant root exudation and/or the chemistry of dead plant material falling to the soil. In arid environments direct photodegradation can play a major role in the decay of plant litter, and UV-B radiation is responsible for a significant part of this photodegradation. UV-B radiation strongly influences aquatic carbon, nitrogen, sulfur and metals cycling that affect a wide range of life processes. UV-B radiation changes the biological availability of dissolved organic matter to microorganisms, and accelerates its transformation into dissolved inorganic carbon and nitrogen, including carbon dioxide and ammonium. The coloured part of dissolved organic matter (CDOM) controls the penetration of UV radiation into water bodies, but CDOM is also photodegraded by solar UV radiation. Changes in CDOM influence the penetration of UV radiation into water bodies with major consequences for aquatic

biogeochemical processes. Changes in aquatic primary productivity and decomposition due to climate-related changes in circulation and nutrient supply occur concurrently with exposure to increased UV-B radiation, and have synergistic effects on the penetration of light into aquatic ecosystems. Future changes in climate will enhance stratification of lakes and the ocean, which will intensify photodegradation of CDOM by UV radiation. The resultant increase in the transparency of water bodies may increase UV-B effects on aquatic biogeochemistry in the surface layer. Changing solar UV radiation and climate also interact to influence exchanges of trace gases, such as halocarbons (*e.g.*, methyl bromide) which influence ozone depletion, and sulfur gases (*e.g.*, dimethylsulfide) that oxidize to produce sulfate aerosols that cool the marine atmosphere. UV radiation affects the biological availability of iron, copper and other trace metals in aquatic environments thus potentially affecting metal toxicity and the growth of phytoplankton and other microorganisms that are involved in carbon and nitrogen cycling. Future changes in ecosystem distribution due to alterations in the physical and chemical climate interact with ozone-modulated changes in UV-B radiation. These interactions between the effects of climate change and UV-B radiation on biogeochemical cycles in terrestrial and aquatic systems may partially offset the beneficial effects of an ozone recovery.

Mann, M.E. **Climate over the past two millennia.** *Annual Review of Earth and Planetary Sciences* 35(111): 136, 2007.

Notes: To assess the significance of modern climate change, it is essential to place recent observed changes in a longer-term context. This review assesses the evidence from both "proxy" climate data and theoretical climate model simulations with regard to the nature and causes of climate variability over a time interval spanning roughly the past two millennia. Evidence is reviewed for changes in temperature, drought, and atmospheric circulation over this timescale. Methods for reconstructing past climate from proxy data are reviewed and comparisons with the results of climate modeling studies are provided. The assessment provided affirms the role of natural (solar and volcanic) radiative forcing in past changes in large-scale mean temperature changes and in dynamical modes of climate variability such as the North Atlantic Oscillation (NAO) and El Niño/Southern Oscillation (ENSO) influencing large-scale climate. At hemispheric scales, late twentieth century warmth appears unprecedented in the context of at least the past 2000 years. This anomalous warmth can only be explained by modern anthropogenic forcing.

Alley, R.B. **Wally was right: Predictive ability of the North Atlantic "conveyor belt" hypothesis for abrupt climate change.** *Annual Review of Earth and Planetary Sciences* 35: 241-272, 2007.

Notes: Linked, abrupt changes of North Atlantic deep water formation, North Atlantic sea ice extent, and widespread climate occurred repeatedly during the last ice age cycle and beyond in response to changing freshwater fluxes and perhaps other causes. This paradigm, developed and championed especially by W.S. Broecker, has repeatedly proven to be successfully predictive as well as explanatory with high confidence. Much work remains to fully understand what happened and to assess possible implications for the future, but the foundations for this work are remarkably solid.

Houghton, R.A. **Balancing the global carbon budget.** *Annual Review of Earth and Planetary Sciences* 35: 313-347, 2007.

Notes: The global carbon budget is, of course, balanced. The conservation of carbon and the first law of thermodynamics are intact. "Balancing the carbon budget" refers to the state of the science in evaluating the terms of the global carbon equation. The annual increases in the amount of carbon in the atmosphere, oceans, and land should balance the emissions of carbon from fossil fuels and deforestation. Balancing the carbon budget is not the real issue, however. The real issue is understanding the processes responsible for net sources and sinks of carbon. Such understanding should lead to more accurate predictions of future concentrations of CO_2 and more accurate predictions of the rate and extent of climatic change. The recent past may be insufficient for prediction, however. Oceanic and terrestrial sinks that have lessened the rate of growth in atmospheric CO_2 until now may diminish as feedbacks between the carbon cycle and climate become more prominent.

Howat, I.M., Joughin, I., and Scambos, T. A. **Rapid changes in ice discharge from Greenland outlet glaciers.** *Science* 315(5818): 1559-1561, 2007.

Notes: Using satellite-derived surface elevation and velocity data, we found major short-term variations in recent ice discharge and mass loss at two of Greenland's largest outlet glaciers. Their combined rate of mass loss doubled in less than a year in 2004 and then decreased in 2006 to near the previous rates, likely as a result of fast re-equilibration of calving-front geometry after retreat. Total mass loss is a fraction of concurrent gravity-derived estimates, pointing to an alternative source of loss and the need for high-resolution observations of outlet dynamics and glacier geometry for sea-level rise predictions.

Shepherd, A. and Wingham, D. **Recent sea-level contributions of the Antarctic and Greenland ice sheets.** *Science* 315(5818): 1529-1532, 2007.

Notes: After a century of polar exploration, the past decade of satellite measurements has painted an altogether new picture of how Earth's ice sheets are changing. As global temperatures have risen, so have rates of snowfall, ice melting, and glacier flow. Although the balance between these opposing processes has varied considerably on a regional scale, data show that Antarctica and Greenland are each losing mass overall. Our best estimate of their combined imbalance is about 125 gigatons per year of ice, enough to raise sea level by 0.35 millimeters per year. This is only a modest contribution to the present rate of sea-level rise of 3.0 millimeters per year. However, much of the loss from Antarctica and Greenland is the result of the flow of ice to the ocean from ice streams and glaciers, which has accelerated over the past decade. In both continents, there are suspected triggers for the accelerated ice discharge -- surface and ocean warming, respectively -- and, over the course of the 21st century, these processes could rapidly counteract the snowfall gains predicted by present coupled climate models.

Serreze, M.C., Holland, M.M., and Stroeve, J. **Perspectives on the Arctic's shrinking sea-ice cover.** *Science* 315(5818): 1533-1536, 2007.

Notes: Linear trends in arctic sea-ice extent over the period 1979 to 2006 are negative in every month. This ice loss is best viewed as a combination of strong natural variability in the coupled ice-ocean-atmosphere system and a growing radiative forcing associated with rising concentrations of atmospheric greenhouse gases, the latter supported by evidence of qualitative consistency between observed trends and those simulated by climate models over the same period. Although the large scatter between individual model simulations leads to much uncertainty as to when a seasonally ice-free Arctic Ocean might be realized, this transition to a new arctic state may be rapid once the ice thins to a more vulnerable state. Loss of the ice cover is expected to affect the Arctic's freshwater system and surface energy budget and could be manifested in middle latitudes as altered patterns of atmospheric circulation and precipitation.

Alley, R.B., Anandakrishnan, S., Dupont, T.K., Parizek, B.R., and Pollard, D. **Effect of sedimentation on ice-sheet grounding-line stability.** *Science* 315(5820): 1838-1841, 2007.

Notes: Sedimentation filling space beneath ice shelves helps to stabilize ice sheets against grounding-line retreat in response to a rise in relative sea level of at least several meters. Recent Antarctic changes thus cannot be attributed to sea-level rise, strengthening earlier interpretations that warming has driven ice-sheet mass loss. Large sea-level rise, such as the approximate to 100-meter rise at the end of the last ice age, may overwhelm the stabilizing feedback from sedimentation, but smaller sea-level changes are unlikely to have synchronized the behavior of ice sheets in the past.

Williams, J.W., Jackson, S.T., and Kutzbach, J.E. **Projected distributions of novel and disappearing climates by 2100 AD.** *Proceedings of the National Academy of Sciences [USA]* 104(14): 5738-5742, 2007.

Notes: Key risks associated with projected climate trends for the 21st century include the prospects of future climate states with no current analog and the disappearance of some extant climates. Because climate is a primary control on species distributions and ecosystem processes, novel 21st-century climates may promote formation of novel species associations and other ecological surprises, whereas the disappearance of some extant climates increases risk of extinction for species with narrow geographic or climatic distributions and disruption of existing communities. Here we analyze multimodel ensembles for the A2 and B1 emission scenarios produced for the fourth assessment report of the Intergovernmental Panel on Climate

Change, with the goal of identifying regions projected to experience (*i*) high magnitudes of local climate change, (*ii*) development of novel 21st-century climates, and/or (*iii*) the disappearance of extant climates. Novel climates are projected to develop primarily in the tropics and subtropics, whereas disappearing climates are concentrated in tropical montane regions and the poleward portions of continents. Under the high-end A2 scenario, 12-39% and 10-48% of the Earth's terrestrial surface may respectively experience novel and disappearing climates by 2100 AD. Corresponding projections for the low-end B1 scenario are 4-20% and 4-20%. Dispersal limitations increase the risk that species will experience the loss of extant climates or the occurrence of novel climates. There is a close correspondence between regions with globally disappearing climates and previously identified biodiversity hotspots; for these regions, standard conservation solutions (e.g., assisted migration and networked reserves) may be insufficient to preserve biodiversity.

McConnell, J.R., Aristarain, A.J., Banta, J.R., Edwards, P.R., and Simões, J.C. **20th-Century doubling in dust archived in an Antarctic Peninsula ice core parallels climate change and desertification in South America.** *Proceedings of the National Academy of Sciences [USA]* 104(14): 5743-5748, 2007.

Notes: Crustal dust in the atmosphere impacts Earth's radiative forcing directly by modifying the radiation budget and affecting cloud nucleation and optical properties, and indirectly through ocean fertilization, which alters carbon sequestration. Increased dust in the atmosphere has been linked to decreased global air temperature in past ice core studies of glacial to interglacial transitions. We present a continuous ice core record of aluminum deposition during recent centuries in the northern Antarctic Peninsula, the most rapidly warming region of the Southern Hemisphere; such a record has not been reported previously. This record shows that aluminosilicate dust deposition more than doubled during the 20th century, coincident with the ~ 1°C Southern Hemisphere warming: a pattern in parallel with increasing air temperatures, decreasing relative humidity, and widespread desertification in Patagonia and northern Argentina. These results have far-reaching implications for understanding the forces driving dust generation and impacts of changing dust levels on climate both in the recent past and future.

Battin, J., Wiley, M.W., Ruckelshaus, M.H., Palmer, R.N., Korb, E., Bartz, K.K., and Imaki, H. **Projected impacts of climate change on salmon habitat restoration.** *Proceedings of the National Academy of Sciences [USA]* 104(16): 6720-6725, 2007.

Notes: Throughout the world, efforts are under way to restore watersheds, but restoration planning rarely accounts for future climate change. Using a series of linked models of climate, land cover, hydrology, and salmon population dynamics, we investigated the impacts of climate change on the effectiveness of proposed habitat restoration efforts designed to recover depleted Chinook salmon populations in a Pacific Northwest river basin. Model results indicate a large negative impact of climate change on freshwater salmon habitat. Habitat restoration and protection can help to mitigate these effects and may allow populations to increase in the face of climate change. The habitat deterioration associated with climate change will, however, make salmon recovery targets much more difficult to attain. Because the negative impacts of climate change in this basin are projected to be most pronounced in relatively pristine, high-elevation streams where little restoration is possible, climate change and habitat restoration together are likely to cause a spatial shift in salmon abundance. River basins that span the current snow line appear especially vulnerable to climate change, and salmon recovery plans that enhance lower-elevation habitats are likely to be more successful over the next 50 years than those that target the higher-elevation basins likely to experience the greatest snow-rain transition.

Thresher, R.E., Koslow, J.A., Morison, A.K., and Smith, D.C. **Depth-mediated reversal of the effects of climate change on long-term growth rates of exploited marine fish.** *Proceedings of the National Academy of Sciences [USA]* 104(18): 7461-7465, 2007.

Notes: The oceanographic consequences of climate change are increasingly well documented, but the biological impacts of this change on marine species much less so, in large part because of few long-term data sets. Using otolith analysis, we reconstructed historical changes in annual growth rates for the juveniles of eight long-lived fish species in the southwest Pacific, from as early as 1861. Six of the eight species show significant changes in growth rates during the last century, with the pattern differing systematically with depth. Increasing temperatures near the ocean surface correlate with increasing growth rates by species found in depths <250 m, whereas growth rates of deep-water (>1,000 m) species have declined substantially

during the last century, which correlates with evidence of long-term cooling at these depths. The observations suggest that global climate change has enhanced some elements of productivity of the shallow-water stocks but also has reduced the productivity, and possibly the resilience, of the already slow-growing deep-water species.

Williams, P.D., Guilyardi, E., Sutton, R., Gregory, J., and Madec, G. **A new feedback on climate change from the hydrological cycle.** *Geophysical Research Letters* 34(8): art. L08706, 2007.

Notes: An intensification of the hydrological cycle is a likely consequence of global warming. But changes in the hydrological cycle could affect sea-surface temperature by modifying diffusive ocean heat transports. We investigate this mechanism by studying a coupled general circulation model sensitivity experiment in which the hydrological cycle is artificially amplified. We find that the amplified hydrological cycle depresses sea-surface temperature by enhancing ocean heat uptake in low latitudes. We estimate that a 10% increase in the hydrological cycle will contribute a basin-scale sea-surface temperature decrease of around 0.1°C away from high latitudes, with larger decreases locally. We conclude that an intensified hydrological cycle is likely to contribute a weak negative feedback to anthropogenic climate change.

Pozdnyakov, D.V., Johannessen, O.M., Korosov, A.A., Pettersson, L.H., Grassl, H., and Miles, M.W. **Satellite evidence of ecosystem changes in the White Sea: A semi-enclosed arctic marginal shelf sea.** *Geophysical Research Letters* 34(8): art. L08604, 2007.

Notes: Recent observations suggest an arctic climate system in broad transformation, yet the regional marine-ecosystem response is poorly known. Here, we develop and analyze a comprehensive biogeophysical dataset of key water constituents - chlorophyll (*chl*), suspended sediments (*sm*) and dissolved organic matter (*doc*) - using satellite ocean-color data from the White Sea in the Russian Arctic, for the period 1998-2004. The revealed changes in *chl*, *sm* and *doc* are more pronounced in the bays (e.g., the southeastern bay trends are -20%, +18% and +11%, respectively) than in the central basin (-5%, +5% and +3%, respectively). The chlorophyll decreases reflect the impact of enhanced runoff on *sm* and *doc*, which make the water more turbid and less favourable for phytoplankton growth, in contrast to other arctic seas where *increased* phytoplankton is expected. This case study supports our hypothesis that the marine ecosystems of semi-enclosed arctic shelf seas respond rapidly to climate change and are thus particularly vulnerable to future global warming.

Matthews, H.D. and Keith, D.W. **Carbon-cycle feedbacks increase the likelihood of a warmer future.** *Geophysical Research Letters* 34(09): art. L09702, 2007.

Notes: Positive carbon-cycle feedbacks have the potential to reduce natural carbon uptake and accelerate future climate change. In this paper, we introduce a novel approach to incorporating carbon-cycle feedbacks into probabilistic assessments of future warming. Using a coupled climate-carbon model, we show that including carbon-cycle feedbacks leads to large increases in extreme warming probabilities. For example, for a scenario of CO_2 stabilization at 550 ppm, the probability of exceeding 2°C warming at 2100 increased by a factor of between 1.7 and 3, while the probability of exceeding 3°C warming increased from a few percent to as much as 22%. CO_2 fertilization was found to exert little influence on the amount of future warming, since increased carbon uptake was partially offset by fertilization-induced surface albedo changes. The effect of positive carbon-cycle feedbacks on the likelihood of extreme future warming must be incorporated into climate policy-related decision making.

Stroeve, J.S., Holland, M.M., Meier, W., Scambos, T., and Serreze, M. **Arctic sea ice decline: Faster than forecast.** *Geophysical Research Letters* 34(09): art. L09501, 2007.

Notes: From 1953 to 2006, Arctic sea ice extent at the end of the melt season in September has declined sharply. All models participating in the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC AR4) show declining Arctic ice cover over this period. However, depending on the time window for analysis, none or very few individual model simulations show trends comparable to observations. If the multi-model ensemble mean time series provides a true

representation of forced change by greenhouse gas (GHG) loading, 33-38% of the observed September trend from 1953-2006 is externally forced, growing to 47-57% from 1979-2006. Given evidence that as a group, the models underestimate the GHG response, the externally forced component may be larger. While both observed and modeled Antarctic winter trends are small, comparisons for summer are confounded by generally poor model performance.
