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Marine Science Review – 223

Climate and climate change

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In this review:

A. Recent articles – no abstract available

Schiermeier, Q. **Artefacts in ocean data hide rising temperatures.** *Nature* 447(7140): 8-9, 2007.

Rahmstorf, S., Cazenave, A., Church, J.A., Hansen, J.E., Keeling, R.F., Parker, D.E., and Somerville, R.C.J. **Recent climate observations compared to projections.** *Science* 316(5825): 709, 2007.

Tibbetts, J. **Driven to extremes: Health effects of climate change.** *Environmental Health Perspectives* 115(4): A196-A203, 2007.

Morton, O. **Is this what it takes to save the world?** *Nature* 447(7141): 132-136, 2007.

Høye, T.T., Post, E., Meltofte, H., Schmidt, N.M., and Forchhammer, M.C. **Rapid advancement of spring in the High Arctic.** *Current Biology* 17(12): R449-R451, 2007.

Kerr, R.A. **Pushing the scary side of global warming.** *Science* 316(5830): 1412, 2007.

B. Recent publications available online

Anadón, R., Danovaro, R., Dippner, J.W., Drinkwater, K.F., Hawkins, S.J., O'Sullivan, G., Oguz, T., Reid, P.C. 2007. ***Impacts of Climate Change on the European Marine and Coastal Environment***. Marine Board Position Paper 9. European Science Foundation, Strasbourg, France. 83 pp.

Available at: http://www.esf.org/fileadmin/be_user/publications/MB_Climate_Change_Web.pdf

Notes: This report summarises the current state of knowledge with regard to general and regional-specific impacts of climate change on European marine and coastal environments, including the Arctic, Northeast Atlantic, Barents Sea, Nordic Seas, North Sea, Baltic Sea, Celtic-Biscay Shelf, Iberian upwelling margin, Mediterranean Sea, and Black Sea. Results from earlier long-term studies of European seas are used to examine past changes, to put recent rapid changes into context, and to forecast likely future ecosystem responses to climate change. General and regional indicators of climate change are identified, and associated challenges for future research and monitoring are highlighted.

C. Recent articles with abstracts

Leitch, D.R., Carrie, J., Lean, D., Macdonald, R.W., Stern, G.A., and Wang, F.Y. **The delivery of mercury to the Beaufort Sea of the Arctic Ocean by the Mackenzie River.** *The Science of the Total Environment* 373(1): 178-195, 2007.

Notes: Very high levels of mercury (Hg) have recently been reported in marine mammals and other higher trophic-level biota in the Mackenzie Delta and Beaufort Sea of the western Arctic Ocean. To quantify the input of Hg (particulate, dissolved and methylated) by the Mackenzie River as a potential source for Hg in the ecosystem, surface water and sediment samples were taken from 79 sites in the lower Mackenzie Basin during three consecutive summers (2003-2005) and analyzed for Hg and methylmercury (MeHg). Intensive studies were also carried out in the Mackenzie Delta during the freshets of 2004 and 2005. Large seasonal and annual variations were found in Hg concentrations in the river, coincident with the variations in water discharge. Increased discharges during spring freshet and during the summers of 2003 and 2005 compared to 2004 were mirrored by higher Hg concentrations. The correlation between Hg concentration and riverflow suggests additional Hg sources during periods of high water, potentially from increased surface inundation and increased bank erosion. The increase in the Hg concentration with increasing water discharge amplifies the annual Hg and MeHg fluxes during high water level years. For the period 2003-2005, the Hg and MeHg fluxes from the Mackenzie River to the Beaufort Sea averaged 2.2 tonnes/yr and 15 kg/yr, respectively, the largest known Hg source to the Beaufort Sea. More than half of the mercury flux occurs during the short spring freshet season which coincides with the period of rapid growth of marine biota. Consequently, the Mackenzie River input potentially provides the major mercury source to marine mammals of the Beaufort Sea. The Hg and MeHg fluxes from the Mackenzie River are expected to further increase with the projected climate warming in the Mackenzie Basin.

Botkin, D.B., Saxe, H., Araujo, M.B., Betts, R., Bradshaw, R.H.W., Cedhagen, T., Chesson, P., Dawson, T.P., Etterson, J.R., Faith, D.P., Ferrier, S., Guisan, A., Hansen, A.S., Hilbert, D.W., Loehle, C., Margules, C., New, M., Sobel, M.J., and Stockwell, D.R.B. **Forecasting the effects of global warming on biodiversity.** *BioScience* 57(3): 227-236, 2007.

Notes: The demand for accurate forecasting of the effects of global warming on biodiversity is growing, but current methods for forecasting have limitations. In this article, we compare and discuss the different uses of four forecasting methods: (1) models that consider species individually, (2) niche-theory models that group species by habitat (more specifically, by environmental conditions under which a species can persist or does persist), (3) general circulation models and coupled ocean-atmosphere-biosphere models, and (4) species-area curve models that consider all species or large aggregates of species. After outlining the different uses and limitations of these methods, we make eight primary suggestions for improving forecasts. We find that greater use of the fossil record and of modern genetic studies would improve forecasting methods. We note a Quaternary conundrum: While current empirical and theoretical ecological results suggest that many species could be at risk from global warming, during the recent ice ages surprisingly few species became extinct. The potential resolution of this conundrum gives insights into the requirements for more accurate and reliable forecasting. Our eight suggestions also point to constructive synergies in the solution to the different problems.

Cotte, C. and Guinet, C. **Historical whaling records reveal major regional retreat of Antarctic sea ice.** *Deep Sea Research Part I: Oceanographic Research Papers* 54(2): 243-252, 2007.

Notes: Several studies have provided evidence of a reduction of the Antarctic sea ice extent. However, these studies were conducted either at a global scale or at a regional scale, and possible inter-regional differences were not analysed. Using the long-term whaling database we investigated circum-Antarctic changes in summer sea ice extent from 1931 to 1987. Accounting for bias inherent in the whaling method, this analysis provides new insight into the historical ice edge reconstruction and inter-regional differences. We highlight a reduction of the sea ice extent occurring in the 1960s, mainly in the Weddell sector where the change ranged from 3° to 7.9° latitude through summer. Although the whaling method may not be appropriate for detecting fine-scale change, these results provide evidence for a heterogeneous circumpolar change of the sea ice extent. The shift is temporally and spatially consistent with other environmental changes detected in the Weddell sector and also with a shift in the Southern Hemisphere annular mode. The large reduction of the sea ice extent has probably influenced the ecosystem of the Weddell Sea, particularly the krill biomass.

Bancroft, B.A., Baker, N.J., and Blaustein, A.R. **Effects of UVB radiation on marine and freshwater organisms: a synthesis through meta-analysis.** *Ecology Letters* 10(4): 332-345, 2007.

Notes: Ultraviolet-B (UVB) radiation is a global stressor with potentially far-reaching ecological impacts. In the first quantitative analysis of the effects of UVB on aquatic organisms, we used meta-analytic techniques to explore the effects of UVB on survival and growth in freshwater and marine systems. Based on the large body of literature on the effects of UVB in aquatic systems, we predicted that UVB would have different effects in different habitats, experimental venues, trophic groups and life history stages. Contrary to our predictions, we found an overall negative effect of UVB on both survival and growth that crossed life histories, trophic groups, habitats and experimental venues. UVB had larger negative effects on growth in embryos compared with later life history stages. Despite the overall negative effect of UVB, effect sizes varied widely. In the survival analyses, no relationship between mean effect size and taxonomic groups or levels of exposure to UVB was detected. In the growth analyses, a larger negative effect on protozoans was observed. Our analyses suggest that the effects of UVB in aquatic systems are large and negative but highly variable between organisms. Variation in susceptibility may have important implications for population and community structure.

Khalil, M.A.K., Butenhoff, C.L., and Rasmussen, R.A. **Atmospheric methane: Trends and cycles of sources and sinks.** *Environmental Science and Technology* 41(7): 2131-2137, 2007.

Notes: For more than 20 years the global emissions and the lifetime of methane have probably been constant, so the buildup of methane in the atmosphere has been slowing down for as long. During this time, there have been periodic events occurring every seven to eight years, when global methane concentrations increased by some 10 ppb and later fell back, in some cases due to temporary increases of emissions from the northern tropics that spread to the global scale. These conclusions are derived from the accumulated global observations that now span 23 years and define the role of human activities in the recent cycle of atmospheric methane.

Hansen, J.E. **Scientific reticence and sea level rise.** *Environmental Research Letters* 2(2): art. 024002, 2007.

Notes: I suggest that a 'scientific reticence' is inhibiting the communication of a threat of a potentially large sea level rise. Delay is dangerous because of system inertias that could create a situation with future sea level changes out of our control. I argue for calling together a panel of scientific leaders to hear evidence and issue a prompt plain-written report on current understanding of the sea level change issue.

Comrie, A. **Climate change and human health.** *Geography Compass* 1(3): 325-339, 2007.

Notes: What kinds of climate-mediated diseases exist, and how are projected climate changes expected to alter their spread and timing? Disease is produced in a complex way, through coupled interactions between natural and human systems. Climate is a major factor controlling ecosystem variability and therefore the potential for outbreaks of certain diseases. Yet, the concept of vulnerability shows how overall disease risk depends not only on the environmental exposure, but also on the sensitivity and adaptive capacity of the group and place experiencing it. These interactions between environment and society are highlighted through a set of climate-related diseases, ranging from direct to complex relationships, including extreme heat, air pollution, aeroallergens, fungi, water- and food-borne diseases, influenza, rodent-borne diseases, and insect-borne diseases.

Bosello, F., Roson, R., and Tol, R.S.J. **Economy-wide estimates of the implications of climate change: Sea level rise.** *Environmental and Resource Economics* 37(3): 549-571, 2007.

Notes: The economy-wide implications of sea level rise in 2050 are estimated using a static computable general equilibrium model. This allows for a better estimate of the welfare effects of sea level rise than the common direct cost estimates; and for an estimate of the impact of sea level rise on greenhouse gas emissions. Overall, general equilibrium effects increase the welfare costs of sea level rise, but not necessarily in every sector or region. In the absence of coastal protection, economies that rely most on agriculture are hit hardest. Although energy is substituted for land, overall energy consumption falls with the shrinking economy, hurting energy exporters. With full coastal protection, GDP increases, particularly in regions with substantial dike building, but utility falls, least in regions that protect their coasts and export energy. Energy prices rise and energy consumption falls. The costs of full protection exceed the costs of losing land. The results also show direct costs - the usual method for estimating welfare changes due to sea level rise - are a bad approximation of the general equilibrium welfare effects; previous estimates of the economic impact of sea level rise are therefore biased.

Hansen, J. and et al. **Dangerous human-made interference with climate: a GISS modelE study.** *Atmospheric Chemistry and Physics* 7: 2287-2312, 2007.

Notes: We investigate the issue of "dangerous humanmade interference with climate" using simulations with GISS modelE driven by measured or estimated forcings for 1880-2003 and extended to 2100 for IPCC greenhouse gas scenarios as well as the "alternative" scenario of Hansen and Sato (2004). Identification of "dangerous" effects is partly subjective, but we find evidence that added global warming of more than 1°C above the level in 2000 has effects that may be highly disruptive. The alternative scenario, with peak added forcing ~1.5 W/m² in 2100, keeps further global warming under 1°C if climate sensitivity is ~3°C or less for doubled CO_2. The alternative scenario keeps mean regional seasonal warming within 2° (standard deviations) of 20th century variability, but other scenarios yield regional changes of 5-10°, i.e. mean conditions outside the range of local experience. We conclude that a CO_2 level exceeding about 450 ppm is "dangerous", but reduction of non-CO_2 forcings can provide modest relief on the CO_2 constraint. We discuss three specific sub-global topics: Arctic climate change, tropical storm intensification, and ice sheet stability. We suggest that Arctic climate change has been driven as much by pollutants (O_3, its precursor CH_4, and soot) as by CO_2, offering hope that dual efforts to reduce pollutants and slow CO_2 growth could minimize Arctic change. Simulated recent ocean warming in the region of Atlantic hurricane formation is comparable to observations, suggesting that greenhouse gases (GHGs) may have contributed to a trend toward greater hurricane intensities. Increasing GHGs cause significant warming in our model in submarine regions of ice shelves and shallow methane hydrates, raising concern about the potential for accelerating sea level rise and future positive feedback from methane release. Growth of non-CO_2 forcings has slowed in recent years, but CO_2 emissions are now surging well above the alternative scenario. Prompt actions to slow CO_2 emissions and decrease non-CO_2 forcings are required to achieve the low forcing of the alternative scenario.

Bamber, J.L., Alley, R.B., and Joughin, I. **Rapid response of modern day ice sheets to external forcing.** *Earth and Planetary Science Letters* 257(1-2): 1-13, 2007.

Notes: The great ice sheets covering Antarctica and Greenland were, traditionally, believed to take thousands of years to respond to external forcing. Recent observations suggest, however, that major changes in the dynamics of parts of the ice sheets are taking place over timescales of years. These changes were not predicted by numerical models, and the underlying cause(s) remains uncertain. It has been suggested that regional oceanic and/or atmospheric warming are responsible but separating the influence and importance of these two forcings has not been possible. In most cases, the role of atmospheric versus oceanic control remains uncertain. Here, we review the observations of rapid change and discuss the possible mechanisms, in the light of advances in numerical modelling and our understanding of the processes that may be responsible.

Walczowski, W. and Piechura, J. **Pathways of the Greenland Sea warming.** *Geophysical Research Letters* 34(10): art. L10608, 2007.

Notes: Progressive warming of the West Spitsbergen Current (WSC) has been observed since 2004. During summer 2006 temperature and salinity of the core of Atlantic Water (AW) reached the highest ever observed by the Institute of Oceanology Polish Academy of Sciences (IOPAS) values. The structure of the WSC, the heat content and the extent of AW in the Fram Strait (FS) region has also changed. Temperature changes resulted from the upstream warming of the Norwegian-Atlantic

Current (NwAC); the structure of the WSC and its heat content were modified by the northward advection of large mesoscale eddies observed within the western branch of the WSC in summer 2005. These changes may have large impacts on the Arctic Ocean (AO) climate and ecosystem.

Zhuang, Q., Melillo, J.M., McGuire, A.D., Kicklighter, D.W., Prinn, R.G., Steudler, P.A., Felzer, B.S., and Hu, S. **Net emissions of CH_4 and CO_2 in Alaska: Implications for the region's greenhouse gas budget.** *Ecological Applications* 17(1): 203-212, 2007.

Notes: We used a biogeochemistry model, the Terrestrial Ecosystem Model (TEM), to study the net methane (CH_4) fluxes between Alaskan ecosystems and the atmosphere. We estimated that the current net emissions of CH_4 (emissions minus consumption) from Alaskan soils are ~ 3 Tg CH_4/yr. Wet tundra ecosystems are responsible for 75% of the region's net emissions, while dry tundra and upland boreal forests are responsible for 50% and 45% of total consumption over the region, respectively. In response to climate change over the 21st century, our simulations indicated that CH_4 emissions from wet soils would be enhanced more than consumption by dry soils of tundra and boreal forests. As a consequence, we projected that net CH_4 emissions will almost double by the end of the century in response to high-latitude warming and associated climate changes. When we placed these CH_4 emissions in the context of the projected carbon budget (carbon dioxide [CO_2] and CH_4) for Alaska at the end of the 21st century, we estimated that Alaska will be a net source of greenhouse gases to the atmosphere of 69 Tg CO_2 equivalents/yr, that is, a balance between net methane emissions of 131 Tg CO_2 equivalents/yr and carbon sequestration of 17 Tg C/yr (62 Tg CO_2 equivalents/yr).

Räisänen, J. **How reliable are climate models?** *Tellus A* 59(1): 2-29, 2007.

Notes: How much can we trust model-based projections of future anthropogenic climate change? This review attempts to give an overview of this important but difficult topic by using three main lines of evidence: the skill of models in simulating present-day climate, intermodel agreement on future climate changes, and the ability of models to simulate climate changes that have already occurred. A comparison of simulated and observed present-day climates shows good agreement for many basic variables, particularly at large horizontal scales, and a tendency for biases to vary in sign between different models, but there is a risk that these features might be partly a result of tuning. Overall, the connection between model skill in simulating present-day climate and the skill in simulating future climate changes is poorly known. An intercomparison of future climate changes between models shows a better agreement for changes in temperature than that for precipitation and sea level pressure, but some aspects of change in the latter two variables are also quite consistent between models. A comparison of simulations with observed climate changes is, in principle, a good test for the models, but there are several complications. Nonetheless, models have skillfully simulated many large-scale aspects of observed climate changes, including but not limited to the evolution of the global mean surface air temperature in the 20th century. Furthermore, although there is no detailed agreement between the simulated and observed geographical patterns of change, the grid box scale temperature, precipitation and pressure changes observed during the past half-century generally fall within the range of model results. Considering the difficulties associated with other sources of information, the variation of climate changes between different models is probably the most meaningful measure of uncertainty that is presently available. In general, however, this measure is more likely to underestimate than overestimate the actual uncertainty.

Jansen, J.M., Pronker, A.E., Bonga, S.W., and Hummel, H. ***Macoma balthica* in Spain, a few decades back in climate history.** *Journal of Experimental Marine Biology and Ecology* 344(2): 161-169, 2007.

Notes: The marine bivalve *Macoma balthica* has disappeared from the Spanish part of the Bay of Biscay during the past four decades. Investigating the possible role of climate change in forcing this species up north, we translocated it down south, back into two Spanish estuaries, and followed the thermal acclimatization of the metabolic rate during spring, summer and autumn. Our results reveal that in natural populations the respiratory response to temperature becomes down-regulated during summer and autumn. The respiration rate in the southward translocated populations became down-regulated to a safe level at very high temperatures (31ºC), but remained high at average temperatures instead. These translocated populations showed a gradual reduction of the condition-index, down to the level of starvation at the end of summer. Combined with an increased metabolic rate this indicates that the translocated specimens suffered from elevated maintenance rates. We conclude that short-term but

frequent exposure to >30ºC in the Spanish estuaries, induces elevated maintenance rates in *M. balthica*, and ultimately starvation. *M. balthica* indeed disappeared from the northern Spanish coast due to increasing summer maxima during the last decades. We prospect that the southern distribution limit of *M. balthica* will shift further north, and that the clam will eventually disappear from the entire Bay of Biscay with future increases in summer temperatures.

Tamerius, J.D., Wise, E.K., Uejio, C.K., McCoy, A.L., and Comrie, A.C. **Climate and human health: synthesizing environmental complexity and uncertainty.** *Stochastic Environmental Research and Risk Assessment* 21(5): 601-613, 2007.

Notes: Broad relationships between weather and human health have long been recognized, and there is currently a large body of research examining the impacts of climate change on human health. Much of the literature in this area examines climate-health relationships at global or regional levels, incorporating mostly generalized responses of pathogens and vectors to broad changes in climate. Far less research has been done to understand the direct and indirect climate-mediated processes involved at finer scales. Thus, some studies simplify the role of climate and may over- or under-estimate the potential response, while others have begun to highlight the subtle and complex role for climate that is contingent on other relevant processes occurring in natural and social environments. These fundamental processes need to be understood to determine the effects of past, current and future climate variation and change on human health. We summarize the principal climate variables and climate-dependent processes that are believed to impact human health across a representative set of diseases, along with key uncertainties in these relationships.

Barcelos e Ramos, J., Biswas, H., Schulz, K.G., LaRoche, J., and Riebesell, U. **Effect of rising atmospheric carbon dioxide on the marine nitrogen fixer *Trichodesmium*.** *Global Biogeochemical Cycles* 21(20): art. GB2028, 2007.

Notes: Diazotrophic (N_2-fixing) cyanobacteria provide the biological source of new nitrogen for large parts of the ocean. However, little is known about their sensitivity to global change. Here we show that the single most important nitrogen fixer in today's ocean, *Trichodesmium*, is strongly affected by changes in CO_2 concentrations. Cell division rate doubled with rising CO_2 (glacial to projected year 2100 levels) prompting lower carbon, nitrogen and phosphorus cellular contents, and reduced cell dimensions. N_2 fixation rates per unit of phosphorus utilization as well as C:P and N:P ratios more than doubled at high CO_2, with no change in C:N ratios. This could enhance the productivity of N-limited oligotrophic oceans, drive some of these areas into P limitation, and increase biological carbon sequestration in the ocean. The observed CO_2 sensitivity of *Trichodesmium* could thereby provide a strong negative feedback to atmospheric CO_2 increase.

Moore, P., Hawkins, S.J., and Thompson, R.C. **Role of biological habitat amelioration in altering the relative responses of congeneric species to climate change.** *Marine Ecology Progress Series* 334: 11-19, 2007.

Notes: The distribution of most species is expected to alter in response to climate change. Predictions for the extent of these range shifts are frequently based on 'climate envelope' approaches, which often oversimplify species responses because many do not consider interactions between physical and biological factors. The local persistence of some species, however, is likely to be strongly modulated by microhabitat-forming organisms. Using congeneric patellid gastropods with northern/boreal and southern/lusitanian distributions, we have demonstrated how the loss of habitat-forming macroalgal species could modify species responses to climate change. The northern limpet *Patella vulgata* preferentially aggregates beneath *Fucus* spp. When *Fucus vesiculosus* was experimentally removed, to simulate a decline in macroalgal abundance in response to climatic warming, *P. vulgata* suffered increased mortality or relocated home scars, often to nearby *Fucus* spp. patches. In contrast, the southern limpet *P. depressa* did not aggregate beneath *Fucus* spp. and showed no response in terms of movement or mortality to the loss of *F. vesiculosus*. Based on these results, we predict that the loss of *Fucus* spp. will influence the relative abundance of these 2 limpet species, particularly at the distributional limit of *Fucus* spp. In addition, differences in the aggregative behaviour of these limpet species will result in changes in the spatial distribution of grazing in the intertidal, with likely consequences for community dynamics. These outcomes could not be anticipated from predictions based on direct responses to temperature alone, highlighting the need for biotic and abiotic factors to be incorporated into predictions of species responses to climate change.

Sriver, R.L. and Huber, M. **Observational evidence for an ocean heat pump induced by tropical cyclones.** *Nature* 447(7144): 577-580, 2007.

Notes: Ocean mixing affects global climate and the marine biosphere because it is linked to the ocean's ability to store and transport heat and nutrients. Observations have constrained the magnitude of upper ocean mixing associated with certain processes, but mixing rates measured directly are significantly lower than those inferred from budget analyses, suggesting that other processes may play an important role. The winds associated with tropical cyclones are known to lead to localized mixing of the upper ocean, but the hypothesis that tropical cyclones are important mixing agents at the global scale has not been tested. Here we calculate the effect of tropical cyclones on surface ocean temperatures by comparing surface temperatures before and after storm passage, and use these results to calculate the vertical mixing induced by tropical cyclone activity. Our results indicate that tropical cyclones are responsible for significant cooling and vertical mixing of the surface ocean in tropical regions. Assuming that all the heat that is mixed downwards is balanced by heat transport towards the poles, we calculate that approximately 15 per cent of peak ocean heat transport may be associated with the vertical mixing induced by tropical cyclones. Furthermore, our analyses show that the magnitude of this mixing is strongly related to sea surface temperature, indicating that future changes in tropical sea surface temperatures may have significant effects on ocean circulation and ocean heat transport that are not currently accounted for in climate models.

Nyberg, J., Malmgren, B.A., Winter, A., Jury, M.R., Kilbourne, K.H., and Quinn, T.M. **Low Atlantic hurricane activity in the 1970s and 1980s compared to the past 270 years.** *Nature* 447(7145): 698-701, 2007.

Notes: Hurricane activity in the North Atlantic Ocean has increased significantly since 1995. This trend has been attributed to both anthropogenically induced climate change and natural variability, but the primary cause remains uncertain. Changes in the frequency and intensity of hurricanes in the past can provide insights into the factors that influence hurricane activity, but reliable observations of hurricane activity in the North Atlantic only cover the past few decades. Here we construct a record of the frequency of major Atlantic hurricanes over the past 270 years using proxy records of vertical wind shear and sea surface temperature (the main controls on the formation of major hurricanes kin this region) from corals and a marine sediment core. The record indicates that the average frequency of major hurricanes decreased gradually from the 1760s until the early 1990s, reaching anomalously low values during the 1970s and 1980s. Furthermore, the phase of enhanced hurricane activity since 1995 is not unusual compared to other periods of high hurricane activity in the record and thus appears to represent a recovery to normal hurricane activity, rather than a direct response to increasing sea surface temperature. Comparison of the record with a reconstruction of vertical wind shear indicates that variability in this parameter primarily controlled the frequency of major hurricanes in the Atlantic over the past 270 years, suggesting that changes in the magnitude of vertical wind shear will have a significant influence on future hurricane activity.

Pertoldi, C. and Bach, L.A. **Evolutionary aspects of climate-induced changes and the need for multidisciplinarity.** *Journal of Thermal Biology* 32(3): 118-124, 2007.

Notes: An integrated view on the possible effects of global climate change is provided while taking into account that not only the rising average temperature is likely to impact natural populations but also that increased variation around the mean and higher frequency of extreme events will be important. We propose that complex genetic effects in concert with demographic patterns may affect how focal populations react to the environmental challenge in an adaptive way (if they can). In order to aim for an inclusive picture of the ongoing environmental change we argue for a synthesis of knowledge from a range of 'classical' disciplines such as quantitative genetics, conservation genetics and population ecology. A hereto little exposed concern is the importance of the increase in amplitude of environmental fluctuations and how the corresponding evolutionary and ecological reactions are expected to occur. Due to the complex interactions between the ecological and genetic mechanisms in the response to climate-induced impacts interdisciplinary approaches are the most promising path in seeking knowledge about the present and future changes in the biosphere.

Metzger, R., Sartoris, F.J., Langenbuch, M., and Portner, H.O. **Influence of elevated CO_2 concentrations on thermal tolerance of the edible crab *Cancer pagurus*.** *Journal of Thermal Biology* 32(3): 144-151, 2007.

Notes: Current trends of global climate change affect marine ectothermal animals not only through the increase in ambient temperature. Synergistic effects of carbon dioxide and temperature changes as well as more frequent hypoxia events must also be considered. As a first attempt, the combined effects of warming and elevated CO_2 concentrations were investigated in the edible crab (*Cancer pagurivs*). Arterial oxygen tension (PaO_2) in the haemolymph was recorded on-line during a progressive warming scenario from 10 to 22ºC and cooling back to 10ºC. Hypercapnia (1% CO_2) caused a significant reduction of oxygen partial pressure in the haemolymph as well as a large, 5ºC downward shift of upper thermal limits of aerobic scope. The present findings are the first to show that hypercapnia causes enhanced sensitivity to heat and thus, a narrowing of the thermal tolerance window of a marine ectotherm. Such interactions of ambient temperature and anthropogenic increases in ambient CO_2 concentrations will need to be considered during future investigations of the effects of climate change on ecosystems.

Law, K.S. and Stohl, A. **Arctic air pollution: Origins and impacts.** *Science* 315(5818): 1537-1540, 2007.

Notes: Notable warming trends have been observed in the Arctic. Although increased human-induced emissions of long-lived greenhouse gases are certainly the main driving factor, air pollutants, such as aerosols and ozone, are also important. Air pollutants are transported to the Arctic, primarily from Eurasia, leading to high concentrations in winter and spring (Arctic haze). Local ship emissions and summertime boreal forest fires may also be important pollution sources. Aerosols and ozone could be perturbing the radiative budget of the Arctic through processes specific to the region: Absorption of solar radiation by aerosols is enhanced by highly reflective snow and ice surfaces; deposition of light-absorbing aerosols on snow or ice can decrease surface albedo; and tropospheric ozone forcing may also be contributing to warming in this region. Future increases in pollutant emissions locally or in mid-latitudes could further accelerate global warming in the Arctic.

Buesseler, K.O., Lamborg, C.H., Boyd, P.W., Lam, P.J., Trull, T.W., Bidigare, R.R., Bishop, J.K. B., Casciotti, K.L., Dehairs, F., Elskens, M., Honda, M., Karl, D.M., Siegel, D.A., Silver, M.W., Steinberg, D.K., Valdes, J., Van Mooy, B., and Wilson, S. **Revisiting carbon flux through the ocean's twilight zone.** *Science* 316(5824): 567-570, 2007.

Notes: The oceanic biological pump drives sequestration of carbon dioxide in the deep sea via sinking particles. Rapid biological consumption and remineralization of carbon in the "twilight zone" (depths between the euphotic zone and 1000 meters) reduce the efficiency of sequestration. By using neutrally buoyant sediment traps to sample this chronically understudied realm, we measured a transfer efficiency of sinking particulate organic carbon between 150 and 500 meters of 20 and 50% at two contrasting sites. This large variability in transfer efficiency is poorly represented in biogeochemical models. If applied globally, this is equivalent to a difference in carbon sequestration of more than 3 petagrams of carbon per year.

Pritchard, H.D. and Vaughan, D.G. **Widespread acceleration of tidewater glaciers on the Antarctic Peninsula.** *Journal of Geophysical Research* 112(3): art. F03S29, 2007.

Notes: Over the last half century, the Antarctic Peninsula (AP) has been among the most rapidly warming regions on Earth. This has led to increased summer snowmelt, loss of ice shelves, and retreat of 87% of marine and tidewater glacier fronts. Tidewater-glacier flow is sensitive to changes in basal water supply and to thinning of the terminus, and faster flow leads directly to sea level rise. The flow rates of most AP tidewater glaciers have never been measured, however, and hence their dynamic response to the recent changes is unknown. We present repeated flow rate measurements from over 300 glaciers on the AP west coast through nine summers from 1992 to 2005. We show that the flow rate increased by ~12% on average and that this trend is greater than the seasonal variability in flow rate. We attribute this widespread acceleration trend not to meltwater-enhanced lubrication or increased snowfall but to a dynamic response to frontal thinning. We estimate that as a result, the annual sea level contribution from this region has increased by 0.047 ± 0.011 mm between 1993 and 2003. This contribution, together with previous studies that assessed increased runoff from the area and acceleration of glaciers resulting from the removal of ice shelves, implies a combined AP contribution of 0.16 ± 0.06 mm yr^{-1}. This is comparable to the contribution from Alaskan glaciers, and combined with estimated mass loss from West Antarctica, is probably large enough to outweigh mass gains in East Antarctica and to make the total Antarctic sea level contribution positive.

Murata, A., Kumamoto, Y., Watanabe, S., and Fukasawa, M. **Decadal increases of anthropogenic CO_2 in the South Pacific subtropical ocean along 32°S.** *Journal of Geophysical Research* 112(5): art. C05033, 2007.

Notes: To estimate decadal increases of anthropogenic CO_2 in the ocean, distributions of dissolved inorganic carbon (C_T) corrected by apparent oxygen utilization and salinity (nC_T^{ANT}) were investigated along the World Ocean Circulation Experiment (WOCE Hydrographic Programme (WHP)) P6 section based on data obtained 10 years apart. Significant increases of nC_T^{CAL} were detected down to 1500 m (~/=27.5σ θ) water depth, above which the Sub-Antarctic Mode Water (SAMW) and the Antarctic Intermediate Water (AAIW) are found. The decadal increases of nC_T^{CAL} on the isopycnal surfaces (26.6-26.9σ θ) of SAMW were higher (5-8 μmol kg^{-1}) to the east of 160°W than to the west of it, while the increases in AAIW were almost constant on the isopycnal surfaces (27.0-27.5σ θ). The averaged increases of nC_T^{CAL} in SAMW and AAIW were 10 ± 3.1 and 4.1 ± 2.0 μmol kg^{-1}, respectively. Small but significant increases of nC_T^{CAL} and salinity-normalized C_T (nC_T) were also found (approximately 3.0 and 5.0 μmol kg^{-1}, respectively) in abyssal waters occupying depths greater than 3500 m at longitude 180°-160°W, which correspond to Circumpolar Deep Water. Spatial differences of anthropogenic CO_2 accumulation are discussed in terms of water mass distributions. The water column inventory of increases of anthropogenic CO_2 in the South Pacific subtropical ocean was estimated to be 1.0 ± 0.4 mol m^{-2} yr^{-1}, which is almost the same as that previously reported.

Harvey, L.D.D. **Dangerous anthropogenic interference, dangerous climatic change, and harmful climatic change: non-trivial distinctions with significant policy implications.** *Climatic Change* 82(1-2): 1-25, 2007.

Notes: Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC) calls for stabilization of greenhouse gas (GHG) concentrations at levels that prevent dangerous anthropogenic interference (DAI) in the climate system. However, some of the recent policy literature has focused on dangerous climatic change (DCC) rather than on DAI. DAI is a set of increases in GHGs concentrations that has a non-negligible possibility of provoking changes in climate that in turn have a non-negligible possibility of causing unacceptable harm, including harm to one or more of ecosystems, food production systems, and sustainable socio-economic systems, whereas DCC is a change of climate that has actually occurred or is assumed to occur and that has a non-negligible possibility of causing unacceptable harm. If the goal of climate policy is to prevent DAI, then the determination of allowable GHG concentrations requires three inputs: the probability distribution function (pdf) for climate sensitivity, the pdf for the temperature change at which significant harm occurs, and the allowed probability ("risk") of incurring harm previously deemed to be unacceptable. If the goal of climate policy is to prevent DCC, then one must know what the correct climate sensitivity is (along with the harm pdf and risk tolerance) in order to determine allowable GHG concentrations. DAI from elevated atmospheric CO_2 also arises through its impact on ocean chemistry as the ocean absorbs CO_2. The primary chemical impact is a reduction in the degree of supersaturation of ocean water with respect to calcium carbonate, the structural building material for coral and for calcareous phytoplankton at the base of the marine food chain. Here, the probability of significant harm (in particular, impacts violating the subsidiary conditions in Article 2 of the UNFCCC) is computed as a function of the ratio of total GHG radiative forcing to the radiative forcing for a CO_2 doubling, using two alternative pdfs for climate sensitivity and three alternative pdfs for the harm temperature threshold. The allowable radiative forcing ratio depends on the probability of significant harm that is tolerated, and can be translated into allowable CO_2 concentrations given some assumption concerning the future change in total non-CO_2 GHG radiative forcing. If future non-CO_2 GHG forcing is reduced to half of the present non-CO_2 GHG forcing, then the allowable CO_2 concentration is 290-430 ppmv for a 10% risk tolerance (depending on the chosen pdfs) and 300-500 ppmv for a 25% risk tolerance (assuming a pre-industrial CO_2 concentration of 280 ppmv). For future non-CO_2 GHG forcing frozen at the present value, and for a 10% risk threshold, the allowable CO_2 concentration is 257-384 ppmv. The implications of these results are that (1) emissions of GHGs need to be reduced as quickly as possible, not in order to comply with the UNFCCC, but in order to minimize the extent and duration of non-compliance; (2) we do not have the luxury of trading off reductions in emissions of non-CO_2 GHGs against smaller reductions in CO_2 emissions, and (3) preparations should begin soon for the creation of negative CO_2 emissions through the sequestration of biomass carbon.

Kallbekken, S. and Rive, N. **Why delaying emission reductions is a gamble.** *Climatic Change* 82(1-2): 27-45, 2007.

Notes: In the debate on the timing of greenhouse gas emissions reductions the aspect of political feasibility has often been missing. We introduce this aspect and show that, if we decide to delay emissions reductions, and the environmental effectiveness of global mitigation efforts is to remain the same in terms of temperature change, we must be willing and able to undertake much more substantial emission reductions than with early action. Even under conservative assumptions on initial political feasibility (maximum 0.25% year-on-year reductions), a 20-year delay means that we must reduce emissions at an annual rate that is 5 to 11 times greater than with early climate action. Our capacity for technological progress, political change and the inertia of the socio-economic system gives us reason to be concerned about our ability to achieve such higher rates of emission reductions. If we are not able to achieve such higher rates, delaying action will inevitably result in higher temperatures in 2100. Unless we are willing to accept higher temperatures, choosing to delay climate action is a gamble that political feasibility will increase over time as a result of the delay itself.

Huntington, H.P., Boyle, M., Flowers, G.E., Weatherly, J.W., Hamilton, L.C., Hinzman, L., Gerlach, C., Zulueta, R., Nicolson, C., and Overpeck, J. **The influence of human activity in the Arctic on climate and climate impacts.** *Climatic Change* 82(1-2): 77-92, 2007.

Notes: Human activities in the Arctic are often mentioned as recipients of climate-change impacts. In this paper we consider the more complicated but more likely possibility that human activities themselves can interact with climate or environmental change in ways that either mitigate or exacerbate the human impacts. Although human activities in the Arctic are generally assumed to be modest, our analysis suggests that those activities may have larger influences on the arctic system than previously thought. Moreover, human influences could increase substantially in the near future. First, we illustrate how past human activities in the Arctic have combined with climatic variations to alter biophysical systems upon which fisheries and livestock depend. Second, we describe how current and future human activities could precipitate or affect the timing of major transitions in the arctic system. Past and future analyses both point to ways in which human activities in the Arctic can substantially influence the trajectory of arctic system change.

Matthews, H.D. and Caldeira, K. **Transient climate–carbon simulations of planetary geoengineering.** *Proceedings of the National Academy of Sciences [USA]* 104(24): 9949-9954, 2007.

Notes: Geoengineering (the intentional modification of Earth's climate) has been proposed as a means of reducing CO_2-induced climate warming while greenhouse gas emissions continue. Most proposals involve managing incoming solar radiation such that future greenhouse gas forcing is counteracted by reduced solar forcing. In this study, we assess the transient climate response to geoengineering under a business-as-usual CO_2 emissions scenario by using an intermediate-complexity global climate model that includes an interactive carbon cycle. We find that the climate system responds quickly to artificially reduced insolation; hence, there may be little cost to delaying the deployment of geoengineering strategies until such a time as "dangerous" climate change is imminent. Spatial temperature patterns in the geoengineered simulation are comparable with preindustrial temperatures, although this is not true for precipitation. Carbon sinks in the model increase in response to geoengineering. Because geoengineering acts to mask climate warming, there is a direct CO_2-driven increase in carbon uptake without an offsetting temperature-driven suppression of carbon sinks. However, this strengthening of carbon sinks, combined with the potential for rapid climate adjustment to changes in solar forcing, leads to serious consequences should geoengineering fail or be stopped abruptly. Such a scenario could lead to very rapid climate change, with warming rates up to 20 times greater than present-day rates. This warming rebound would be larger and more sustained should climate sensitivity prove to be higher than expected. Thus, employing geoengineering schemes with continued carbon emissions could lead to severe risks for the global climate system.

Raupach, M.R., Marland, G., Ciais, P., Le Quéré, Canadell, J.G., Klepper, G., and Field, C.B. **Global and regional drivers of accelerating CO_2 emissions.** *Proceedings of the National Academy of Sciences [USA]* 104(24): 10288-10293, 2007.

Notes: CO_2 emissions from fossil-fuel burning and industrial processes have been accelerating at a global scale, with their growth rate increasing from 1.1% y^{-1} for 1990-1999 to >3% y^{-1} for 2000-2004. The emissions growth rate since 2000 was greater than for the most fossil-fuel intensive of the Intergovernmental Panel on Climate Change emissions scenarios developed in the late 1990s. Global emissions growth since 2000 was driven by a cessation or reversal of earlier declining

trends in the energy intensity of gross domestic product (GDP) (energy/GDP) and the carbon intensity of energy (emissions/energy), coupled with continuing increases in population and per-capita GDP. Nearly constant or slightly increasing trends in the carbon intensity of energy have been recently observed in both developed and developing regions. No region is decarbonizing its energy supply. The growth rate in emissions is strongest in rapidly developing economies, particularly China. Together, the developing and least-developed economies (forming 80% of the world's population) accounted for 73% of global emissions growth in 2004 but only 41% of global emissions and only 23% of global cumulative emissions since the mid-18th century. The results have implications for global equity.

AchutaRao, K.M., Ishii, M., Santer, B.D., Gleckler, P.J., Taylor, K.E., Barnett, T.P., Pierce, D.W., Stouffer, R.J., and Wigley, T.M.L. **Simulated and observed variability in ocean temperature and heat content.** *Proceedings of the National Academy of Sciences [USA]* 104(26): 10768-10773, 2007.

Notes: Observations show both a pronounced increase in ocean heat content (OHC) over the second half of the 20th century and substantial OHC variability on interannual-to-decadal time scales. Although climate models are able to simulate overall changes in OHC, they are generally thought to underestimate the amplitude of OHC variability. Using simulations of 20th century climate performed with 13 numerical models, we demonstrate that the apparent discrepancy between modeled and observed variability is largely explained by accounting for changes in observational coverage and instrumentation and by including the effects of volcanic eruptions. Our work does not support the recent claim that the 0- to 700-m layer of the global ocean experienced a substantial OHC decrease over the 2003 to 2005 time period. We show that the 2003-2005 cooling is largely an artifact of a systematic change in the observing system, with the deployment of Argo floats reducing a warm bias in the original observing system.
