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Marine Science Review – 252

Climate and climate change

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In this review:

O/A denotes an open access article or journal

A. Recent articles – no abstract available

Arrigo, K.R. ***Carbon cycle* - Marine manipulations.** *Nature* 450(7169): 491-492, 2007.

Toggweiler, J.R. and Russell, J. **Ocean circulation in a warming climate.** *Nature* 451(7176): 286-288, 2008. O/A

Heimann, M. and Reichstein, M. **Terrestrial ecosystem carbon dynamics and climate feedbacks.** *Nature* 451(7176): 289-292, 2008. O/A

Gruber, N. and Galloway, J.N. **An Earth-system perspective of the global nitrogen cycle.** *Nature* 451(7176): 293-296, 2008. O/A

Friedlingstein, P. **A steep road to climate stabilization.** *Nature* 451(7176): 297-298, 2008. O/A

Baker, M.B. and Peter, T. **Small-scale cloud processes and climate.** *Nature* 451(7176): 299-300, 2008. O/A

C. Recent articles with abstracts

Boykoff, M.T. **Flogging a dead norm? Newspaper coverage of anthropogenic climate change in the United States and United Kingdom from 2003 to 2006.** *Area* 39(4): 470-481, 2007.

Notes: The journalistic norm of 'balanced' reporting (giving roughly equal coverage to both sides in any significant dispute) is recognised as both useful and problematic in communicating emerging scientific consensus on human attribution for global climate change. Analysis of the practice of this norm in United States (US) and United Kingdom (UK) newspaper coverage of climate science between 2003 and 2006 shows a significant divergence from scientific consensus in the US in 2003-4, followed by a decline in 2005-6, but no major divergence in UK reporting. These findings inform ongoing considerations about the spatially-differentiated media terms and conditions through which current and future climate policy is negotiated and implemented.

Bibby, R., Cleall-Harding, P., Rundle, S., Widdicombe, S., and Spicer, J. **Ocean acidification disrupts induced defences in the intertidal gastropod *Littorina littorea*.** *Biology Letters* 3(6): 699-701, 2007.

Notes: Carbon dioxide-induced ocean acidification is predicted to have major implications for marine life, but the research focus to date has been on direct effects. We demonstrate that acidified seawater can have indirect biological effects by

disrupting the capability of organisms to express induced defences, hence, increasing their vulnerability to predation. The intertidal gastropod *Littorina littorea* produced thicker shells in the presence of predation (crab) cues but this response was disrupted at low seawater pH. This response was accompanied by a marked depression in metabolic rate (hypometabolism) under the joint stress of high predation risk and reduced pH. However, snails in this treatment apparently compensated for a lack of morphological defence, by increasing their avoidance behaviour, which, in turn, could affect their interactions with other organisms. Together, these findings suggest that biological effects from ocean acidification may be complex and extend beyond simple direct effects.

Anestis, A., Lazou, A., Pörtner, H.O., and Michaelidis, B. **Behavioral, metabolic, and molecular stress responses of marine bivalve *Mytilus galloprovincialis* during long-term acclimation at increasing ambient temperature.** *American Journal of Physiology - Regulatory, Integrative and Comparative Physiology* 293(2): R911-R921, 2007.

Notes: The present study aimed to determine the thermal response of the Mediterranean mussel *Mytilus galloprovincialis* by integrating information from various levels of biological organization including behavior, metabolic adjustments, heat shock protein expression, and protein kinase activity. Behavioral responses were determined by examining the effect of warming on valve closure and opening. Metabolic impacts were assessed by examining the activity of the key glycolytic enzyme pyruvate kinase (PK). Molecular responses were addressed through the expression of Hsp70 and Hsp90 and the phosphorylation of stress-activated protein kinases, p38 mitogen-activated protein kinase (p38 MAPK) and cJun-N-terminal kinases (JNKs). Mussels increased the duration of valve closure by about sixfold when acclimated to 24°C rather than to 17°C. As indicated by the activity of PK, such behavior caused metabolic depression and probably a shift from aerobic to anaerobic metabolism. Acclimation to temperatures higher than 24°C caused an increase in mortality and induced the expression of Hsp72. Increased phosphorylation of p38 MAPK and JNKs indicated activation of MAPK signaling cascades. The potential involvement of MAPKs in the induction of Hsp genes in the tissues of *M. galloprovincialis* is discussed. In conclusion, it seems that *M. galloprovincialis* lives close to its acclimation limits and incipient lethal temperature and that a small degree of warming will elicit stress responses at whole organism and molecular levels.

Williams, J.W. and Jackson, S.T. **Novel climates, no-analog communities, and ecological surprises.** *Frontiers in Ecology and Environment* 5(9): 475-482, 2007.

Notes: No-analog communities (communities that are compositionally unlike any found today) occurred frequently in the past and will develop in the greenhouse world of the future. The well documented no-analog plant communities of late-glacial North America are closely linked to "novel" climates also lacking modem analogs, characterized by high seasonality of temperature. In climate simulations for the Intergovernmental Panel on Climate Change A2 and 131 emission scenarios, novel climates arise by 2100 AD, primarily in tropical and subtropical regions. These future novel climates are warmer than any present climates globally, with spatially variable shifts in precipitation, and increase the risk of species reshuffling into future no-analog communities and other ecological surprises. Most ecological models are at least partially parameterized from modem observations and so may fail to accurately predict ecological responses to these novel climates. There is an urgent need to test the robustness of ecological models to climate conditions outside modem experience.

Straile, D. and Stenseth, N.C. **The North Atlantic Oscillation and ecology: links between historical time-series, and lessons regarding future climate warming.** *Climate Research* 34(3): 259-262, 2007.

Notes: Indices of the North Atlantic Oscillation (NAO) have been very useful for explaining interannual variability in many ecological time series. We suggest that this is based on a combination of 3 factors: (1) the strong relationship between NAO and meteorological conditions in winter; (2) qualitative changes in environmental conditions in response to winter conditions, especially temperatures; and (3) the central importance of those conditions for the distribution and population dynamics of species in temperate and boreal regions. The increase in winter temperatures associated with a shift of NAO towards its positive phase in recent years has resulted in a relief from winter stress for many species and populations. This has reduced mortality rates during winter, thereby influencing local population dynamics and allowing, for example, the northward expansion of many species. In contrast to winter warming, the recent increase in summer temperature has had fewer ecological consequences, as it has not been large enough to cause an increase in heat stress to critical levels during summer. The

difference in the ecological consequences of winter and summer warming also explains why reductions in the ranges of species have been observed less often than expansions during the past few decades. However, with further warming, summer heat stress might become an increasingly important determinant of the response of species to climate warming. This suggests that studies analysing the effects of the winter NAO on species dynamics and distributions will give us only a limited perspective on the further consequences of climate warming.

Lauer, A., Eyring, V., Hendricks, J., Jöckel, P, and Lohmann, U. **Global model simulations of the impact of ocean-going ships on aerosols, clouds, and the radiation budget.** *Atmospheric Chemistry and Physics* 7(19): 5061-5079, 2007. **O/A**

Notes: International shipping contributes significantly to the fuel consumption of all transport related activities. Specific emissions of pollutants such as sulfur dioxide (SO_2) per kg of fuel emitted are higher than for road transport or aviation. Besides gaseous pollutants, ships also emit various types of particulate matter. The aerosol impacts the Earth's radiation budget directly by scattering and absorbing the solar and thermal radiation and indirectly by changing cloud properties. Here we use ECHAM5/MESSy1-MADE, a global climate model with detailed aerosol and cloud microphysics to study the climate impacts of international shipping. The simulations show that emissions from ships significantly increase the cloud droplet number concentration of low marine water clouds by up to 5% to 30% depending on the ship emission inventory and the geographic region. Whereas the cloud liquid water content remains nearly unchanged in these simulations, effective radii of cloud droplets decrease, leading to cloud optical thickness increase of up to 5-10%. The sensitivity of the results is estimated by using three different emission inventories for present-day conditions. The sensitivity analysis reveals that shipping contributes to 2.3% to 3.6% of the total sulfate burden and 0.4% to 1.4% to the total black carbon burden in the year 2000 on the global mean. In addition to changes in aerosol chemical composition, shipping increases the aerosol number concentration, e.g. up to 25% in the size range of the accumulation mode (typically >0.1μm) over the Atlantic. The total aerosol optical thickness over the Indian Ocean, the Gulf of Mexico and the Northeastern Pacific increases by up to 8-10% depending on the emission inventory. Changes in aerosol optical thickness caused by shipping induced modification of aerosol particle number concentration and chemical composition lead to a change in the shortwave radiation budget at the top of the atmosphere (ToA) under clear-sky condition of about -0.014 W/m² to -0.038 W/m² for a global annual average. The corresponding all-sky direct aerosol forcing ranges between -0.011 W/m² and -0.013 W/m². The indirect aerosol effect of ships on climate is found to be far larger than previously estimated. An indirect radiative effect of -0.19 W/m² to -0.60 W/m² (a change in the atmospheric shortwave radiative flux at ToA) is calculated here, contributing 17% to 39% of the total indirect effect of anthropogenic aerosols. This contribution is high because ship emissions are released in regions with frequent low marine clouds in an otherwise clean environment. In addition, the potential impact of particulate matter on the radiation budget is larger over the dark ocean surface than over polluted regions over land.

Doney, S.C. and Schimel, D.S. **Carbon and climate system coupling on timescales from the Precambrian to the anthropocene.** *Annual Review of Environment and Resources* 32: 31-66, 2007.

Notes: Over a range of geological and historical timescales, warmer climate conditions are associated with higher atmospheric levels of CO_2, an important climate-modulating greenhouse gas. Coupled carbon-climate interactions have the potential to introduce both stabilizing and destabilizing feedback loops into Earth's system. Here we bring together evidence on the dominant climate, biogeochemical and geological processes organized by timescale, spanning interannual to centennial climate variability, Holocene millennial variations and Pleistocene glacial-interglacial cycles, and million-year and longer variations over the Precambrian and Phanerozoic. Our focus is on characterizing, and where possible quantifying, internal coupled carbon-climate system dynamics and responses to external forcing from tectonics, orbital dynamics, catastrophic events, and anthropogenic fossil-fuel emissions. One emergent property is clear across timescales: atmospheric CO_2 can increase quickly, but the return to lower levels through natural processes is much slower. The consequences of human carbon cycle perturbations will far outlive the emissions that caused them.

Field, C.B., Lobell, D.B., Peters, H.A., and Chiariello, N.R. **Feedbacks of terrestrial ecosystems to climate change.** *Annual Review of Environment and Resources* 32: 1-29, 2007.

Notes: Most modeling studies on terrestrial feedbacks to warming over the twenty-first century imply that the net feedbacks are negative-that changes in ecosystems, on the whole, resistwarming, largely through ecosystem carbon storage. Although it is clear that potentially important mechanisms can lead to carbon storage, a number of less well-understood mechanisms, several of which are rarely or incompletely modeled, tend to diminish the negative feedbacks or lead to positive feedbacks. At high latitudes, negative feedbacks from forest expansion are likely to be largely or completely compensated by positive feedbacks from decreased albedo, increased carbon emissions from thawed permafrost, and increased wildfire. At low latitudes, negative feedbacks to warming will be decreased or eliminated, largely through direct human impacts. With modest warming, net feedbacks of terrestrial ecosystems to warming are likely to be negative in the tropics and positive at high latitudes. Larger amounts of warming will generally push the feedbacks toward the positive

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Andreae, M.O. **Atmospheric aerosols versus greenhouse gases in the twenty-first century.** *Philosophical Transactions of the Royal Society of London [A]* 365(1856): 1915-1923, 2007.

Notes: Looked at in a simplistic way, aerosols have counteracted the warming effects of greenhouse gases (GHG) over the past century. This has not only provided some 'climate protection', but also prevented the true magnitude of the problem from becoming evident. In particular, it may have resulted in an underestimation of the sensitivity of the climate system to the effect of GHG. Over the present century, the role of aerosols in opposing global warming will wane, as there are powerful policy reasons to reduce their emissions and their atmospheric lifetimes are short in contrast to those of the GHG. On the other hand, aerosols will continue to play a role in regional climate change, especially with regard to the water cycle. The end of significant climate protection by atmospheric aerosols, combined with the potentially very high sensitivity of the climate system, makes sharp and prompt reductions in greenhouse gas emissions, especially CO_2, very urgent.

Hansen, J., Sato, M., Kharecha, P., Russell, G., Lea, D.W., and Siddall, M. **Climate change and trace gases.** *Philosophical Transactions of the Royal Society of London [A]* 365(1856): 1925-1954, 2007. **O/A**

Notes: Palaeoclimate data show that the Earth's climate is remarkably sensitive to global forcings. Positive feedbacks predominate. This allows the entire planet to be whipsawed between climate states. One feedback, the 'albedo flip' property of ice/water, provides a powerful trigger mechanism. A climate forcing that 'flips' the albedo of a sufficient portion of an ice sheet can spark a cataclysm. Inertia of ice sheet and ocean provides only moderate delay to ice sheet disintegration and a burst of added global warming. Recent greenhouse gas (GHG) emissions place the Earth perilously close to dramatic climate change that could run out of our control, with great dangers for humans and other creatures. Carbon dioxide (CO_2) is the largest human-made climate forcing, but other trace constituents are also important. Only intense simultaneous efforts to slow CO_2 emissions and reduce non-CO_2 forcings can keep climate within or near the range of the past million years. The most important of the non-CO_2 forcings is methane (CH_4), as it causes the second largest human-made GHG climate forcing and is the principal cause of increased tropospheric ozone (O_3), which is the third largest GHG forcing. Nitrous oxide (N_2O) should also be a focus of climate mitigation efforts. Black carbon ('black soot') has a high global warming potential (approx. 2000, 500 and 200 for 20, 100 and 500 years, respectively) and deserves greater attention. Some forcings are especially effective at high latitudes, so concerted efforts to reduce their emissions could preserve Arctic ice, while also having major benefits for human health, agricultural productivity and the global environment.

Desantis, L.R.G., Bhotika, S., Williams, K., and Putz, F.E. **Sea-level rise and drought interactions accelerate forest decline on the Gulf Coast of Florida, USA.** *Global Change Biology* 13(11): 2349-2360, 2007.

Notes: Sea-level rise threatens low-lying coastal ecosystems globally. In Florida, USA, salinity stress due to increased tidal flooding contributes to the dramatic and well documented decline of species-rich coastal forest areas along the Gulf of Mexico. Here, we present the results of a study of coastal forest stand dynamics in thirteen 400 m^2 plots representing an elevation gradient of 0.58-1.1 m affected by tidal flooding and rising sea levels. We extended previously published data from 1992-2000 to 2005 to quantify the full magnitude of the 1998-2002 La Nina-associated drought. Populations of the dominant tree species, *Sabal palmetto* (cabbage palm), declined more rapidly during 2000-2005 than predicted from linear regressions based on the 1992-2000 data. Dramatic increases in *Juniperus virginiana* (Southern red cedar) and *S. palmetto* mortality during 2000-2005 as compared with 1995-2000 are apparently due to the combined effects of a major drought and ongoing sea-level

rise. Additionally, coastal forest stands continued to decline in species richness with increased tidal flooding frequency and decreasing elevation. Stable isotope (H,O) analyses demonstrate that *J. virginiana* accesses fresher water sources more than *S. palmetto*. Carbon isotopes reveal increasing $\delta^{13}C$ enrichment of *S. palmetto* and *J. virginiana* with increased tidal flooding and decreased elevation, demonstrating increasing water stress in both species. Coastal forests with frequent tidal flooding are unable to support species-rich forests or support regeneration of the most salt-tolerant tree species over time. Given that rates of sea-level rise are predicted to increase and periodic droughts are expected to intensify in the future due to global climate change, coastal forest communities are in jeopardy if their inland retreat is restricted.

Lima, F.P., Ribeiro, P.A., Queiroz, N., Hawkins, S.J., and Santos, A.M. **Do distributional shifts of northern and southern species of algae match the warming pattern?** *Global Change Biology* 13(12): 2592-2604, 2007.

Notes: Well-documented changes in species abundances and distributions coinciding with global warming have been increasing during recent years. A trend of raising sea-surface temperature has also been observed along the Portuguese coast which could affect intertidal species' ranges. The present study aimed at evaluating the direction and intensity of distribution changes of macroalgae in the area. The last 50-year trend of coastal air and sea temperature was reassessed, providing an accurate estimate of the warming process. Information on species' range shifts was obtained by comparing data from recent resurveys with historical records of algal distributions collected during the 1950s and 1960s. Although a prevalence of northward migrations was anticipated, this work showed a marked difference in the average direction of changes between cold- and warm-water species. Cold-water species, when considered together, showed no particular shifting trend, because the number of species that shifted north or south was the same. Contrarily, all shifting warm-water species expanded their range northwards. Therefore, generalizations about poleward range shifts due to increasing temperature should be made with caution.

Riebesell, U., Schulz, K.G., Bellerby, R.G.J., Botros, M., Fritsche, P., Meyerhofer, M., Neill, C., Nondal, G., Oschlies, A., Wohlers, J., and Zollner, E. **Enhanced biological carbon consumption in a high CO_2 ocean.** *Nature* 450(7169): 545-548, 2007.

Notes: The oceans have absorbed nearly half of the fossil-fuel carbon dioxide (CO_2) emitted into the atmosphere since pre-industrial times, causing a measurable reduction in seawater pH and carbonate saturation. If CO_2 emissions continue to rise at current rates, upper-ocean pH will decrease to levels lower than have existed for tens of millions of years and, critically, at a rate of change 100 times greater than at any time over this period. Recent studies have shown effects of ocean acidification on a variety of marine life forms, in particular calcifying organisms. Consequences at the community to ecosystem level, in contrast, are largely unknown. Here we show that dissolved inorganic carbon consumption of a natural plankton community maintained in mesocosm enclosures at initial CO_2 partial pressures of 350, 700 and 1,050 μatm increases with rising CO_2. The community consumed up to 39% more dissolved inorganic carbon at increased CO_2 partial pressures compared to present levels, whereas nutrient uptake remained the same. The stoichiometry of carbon to nitrogen drawdown increased from 6.0 at low CO_2 to 8.0 at high CO_2, thus exceeding the Redfield carbon:nitrogen ratio of 6.6 in today's ocean. This excess carbon consumption was associated with higher loss of organic carbon from the upper layer of the stratified mesocosms. If applicable to the natural environment, the observed responses have implications for a variety of marine biological and biogeochemical processes, and underscore the importance of biologically driven feedbacks in the ocean to global change

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Vecchi, G.A. and Soden, B.J. **Effect of remote sea surface temperature change on tropical cyclone potential intensity.** *Nature* 450(7172): 1066-1069, 2007.

Notes: The response of tropical cyclone activity to global warming is widely debated. It is often assumed that warmer sea surface temperatures provide a more favourable environment for the development and intensification of tropical cyclones, but cyclone genesis and intensity are also affected by the vertical thermodynamic properties of the atmosphere. Here we use climate models and observational reconstructions to explore the relationship between changes in sea surface temperature and tropical cyclone 'potential intensity' - a measure that provides an upper bound on cyclone intensity and can also reflect the likelihood of cyclone development. We find that changes in local sea surface temperature are inadequate for characterizing even the sign of changes in potential intensity, but that long-term changes in potential intensity are closely related to the

regional structure of warming; regions that warm more than the tropical average are characterized by increased potential intensity, and vice versa. We use this relationship to reconstruct changes in potential intensity over the twentieth century from observational reconstructions of sea surface temperature. We find that, even though tropical Atlantic sea surface temperatures are currently at a historical high, Atlantic potential intensity probably peaked in the 1930s and 1950s, and recent values are near the historical average. Our results indicate that - per unit local sea surface temperature change - the response of tropical cyclone activity to natural climate variations, which tend to involve localized changes in sea surface temperature, may be larger than the response to the more uniform patterns of greenhouse-gas-induced warming.

Lenton, T.M., Held, H., Kriegler, E., Hall, J.W., Lucht, W., Rahmstorf, S., and Schellnhuber, H.J. **Tipping elements in the Earth's climate system.** *Proceedings of the National Academy of Sciences [USA]* 105(6): 1786-1793, 2008. **O/A**

Notes: The term "tipping point" commonly refers to a critical threshold at which a tiny perturbation can qualitatively alter the state or development of a system. Here we introduce the term "tipping element" to describe large-scale components of the Earth system that may pass a tipping point. We critically evaluate potential policy-relevant tipping elements in the climate system under anthropogenic forcing, drawing on the pertinent literature and a recent international workshop to compile a short list, and we assess where their tipping points lie. An expert elicitation is used to help rank their sensitivity to global warming and the uncertainty about the underlying physical mechanisms. Then we explain how, in principle, early warning systems could be established to detect the proximity of some tipping points.

Milinski, M., Sommerfeld, R.D., Krambeck, H.-J., Reed, F.A., and Marotzke, J. **The collective-risk social dilemma and the prevention of simulated dangerous climate change.** *Proceedings of the National Academy of Sciences [USA]* 105(7): 2291-2294, 2008. **O/A**

Notes: Will a group of people reach a collective target through individual contributions when everyone suffers individually if the target is missed? This "collective-risk social dilemma" exists in various social scenarios, the globally most challenging one being the prevention of dangerous climate change. Reaching the collective target requires individual sacrifice, with benefits to all but no guarantee that others will also contribute. It even seems tempting to contribute less and save money to induce others to contribute more, hence the dilemma and the risk of failure. Here, we introduce the collective-risk social dilemma and simulate it in a controlled experiment: Will a group of people reach a fixed target sum through successive monetary contributions, when they know they will lose all their remaining money with a certain probability if they fail to reach the target sum? We find that, under high risk of simulated dangerous climate change, half of the groups succeed in reaching the target sum, whereas the others only marginally fail. When the risk of loss is only as high as the necessary average investment or even lower, the groups generally fail to reach the target sum. We conclude that one possible strategy to relieve the collective-risk dilemma in high-risk situations is to convince people that failure to invest enough is very likely to cause grave financial loss to the individual. Our analysis describes the social window humankind has to prevent dangerous climate change.

Murphy, E.J., Trathan, P.N., Watkins, J.L., Reid, K., Meredith, M.P., Forcada, J., Thorpe, S.E., Johnston, N.M., and Rothery, P. **Climatically driven fluctuations in Southern Ocean ecosystems.** *Proceedings of the Royal Society of London [B]* 274(1629): 3057-3067, 2007. **O/A**

Notes: Determining how climate fluctuations affect ocean ecosystems requires an understanding of how biological and physical processes interact across a wide range of scales. Here we examine the role of physical and biological processes in generating fluctuations in the ecosystem around South Georgia in the South Atlantic sector of the Southern Ocean. Anomalies in sea surface temperature (SST) in the South Pacific sector of the Southern Ocean have previously been shown to be generated through atmospheric teleconnections with El Niño Southern Oscillation (ENSO)-related processes. These SST anomalies are propagated via the Antarctic Circumpolar Current into the South Atlantic (on time scales of more than 1 year), where ENSO and Southern Annular Mode-related atmospheric processes have a direct influence on short (less than six months) time scales. We find that across the South Atlantic sector, these changes in SST, and related fluctuations in winter sea ice extent, affect the recruitment and dispersal of Antarctic krill. This oceanographically driven variation in krill population dynamics and abundance in turn affects the breeding success of seabird and marine mammal predators that depend on krill as food. Such propagating anomalies, mediated through physical and trophic interactions, are likely to be an important

component of variation in ocean ecosystems and affect responses to longer term change. Population models derived on the basis of these oceanic fluctuations indicate that plausible rates of regional warming of 1ºC over the next 100 years could lead to more than a 95% reduction in the biomass and abundance of krill across the Scotia Sea by the end of the century.

Mayhew, P.J., Jenkins, G.B., and Benton, T.G. **A long-term association between global temperature and biodiversity, origination and extinction in the fossil record.** *Proceedings of the Royal Society of London [B]* 275(1630): 47-53, 2008.

Notes: The past relationship between global temperature and levels of biological diversity is of increasing concern due to anthropogenic climate warming. However, no consistent link between these variables has yet been demonstrated. We analysed the fossil record for the last 520Myr against estimates of low latitude sea surface temperature for the same period. We found that global biodiversity (the richness of families and genera) is related to temperature and has been relatively low during warm 'greenhouse' phases, while during the same phases extinction and origination rates of taxonomic lineages have been relatively high. These findings are consistent for terrestrial and marine environments and are robust to a number of alternative assumptions and potential biases. Our results provide the first clear evidence that global climate may explain substantial variation in the fossil record in a simple and consistent manner. Our findings may have implications for extinction and biodiversity change under future climate warming.

Visser, M.E. **Keeping up with a warming world; assessing the rate of adaptation to climate change.** *Proceedings of the Royal Society of London [B]* 275(1635): 649-659, 2008.

Notes: The pivotal question in the debate on the ecological effects of climate change is whether species will be able to adapt fast enough to keep up with their changing environment. If we establish the maximal rate of adaptation, this will set an upper limit to the rate at which temperatures can increase without loss of biodiversity. The rate of adaptation will primarily be set by the rate of microevolution since (i) phenotypic plasticity alone is not sufficient as reaction norms will no longer be adaptive and hence microevolution on the reaction norm is needed, (ii) learning will be favourable to the individual but cannot be passed on to the next generations, (iii) maternal effects may play a role but, as with other forms of phenotypic plasticity, the response of offspring to the maternal cues will no longer be adaptive in a changing environment, and (iv) adaptation via immigration of individuals with genotypes adapted to warmer environments also involves microevolution as these genotypes are better adapted in terms of temperature, but not in terms of, for instance, photoperiod. Long-term studies on wild populations with individually known animals play an essential role in detecting and understanding the temporal trends in life-history traits, and to estimate the heritability of, and selection pressures on, life-history traits. However, additional measurements on other trophic levels and on the mechanisms underlying phenotypic plasticity are needed to predict the rate of microevolution, especially under changing conditions. Using this knowledge on heritability of, and selection on, life-history traits, in combination with climate scenarios, we will be able to predict the rate of adaptation for different climate scenarios. The final step is to use ecoevolutionary dynamical models to make the link to population viability and from there to biodiversity loss for those scenarios where the rate of adaptation is insufficient.

Changnon, S.A. **Catastrophic winter storms: An escalating problem.** *Climatic Change* 84(2): 131-139, 2007.

Notes: Winter storms are a major weather problem in the USA and their losses have been rapidly increasing. A total of 202 catastrophic winter storms, each causing more than $1 million in damages, occurred during 1949-2003, and their losses totaled $35.2 billion (2003 dollars). Catastrophic winter storms occurred in most parts of the contiguous USA, but were concentrated in the eastern half of the nation where 88% of all storm losses occurred. They were most frequent in the Northeast climate district (95 storms), and were least frequent in the West district (14 catastrophic storms). The annual average number of storms is 3.7 with a 1-year high of 9 storms, and 1 year had no storms. Temporal distributions of storms and their losses exhibited considerable spatial variability across the nation. For example, when storms were very frequent in the Northeast, they were infrequent elsewhere, a result of spatial differences in storm-producing synoptic weather conditions over time. The time distribution of the nation's 202 storms during 1949-2003 had a sizable downward trend, whereas the nation's storm losses had a major upward trend for the 55-year period. This increase over time in losses, given the decrease in storm incidences, was a result of significant temporal increases in storm sizes and storm intensities. Increases in storm intensities were small in the

northern sections of the nation, but doubled across the southern two-thirds of the nation, reflecting a climatic shift in conditions producing intense winter storms.

Boykoff, M.T. **Lost in translation? United States television news coverage of anthropogenic climate change, 1995-2004.** *Climatic Change* 86(1-2): 1-11, 2008.

Notes: Eminent climate scientists have come to consensus that human influences are significant contributors to modern global climate change. This study examines coverage of anthropogenic climate change in United States (U.S.) network television news - ABC World News Tonight, CBS Evening News and NBC Nightly News - and focuses on the application of the journalistic norm of 'balance' in coverage from 1995 through 2004. This study also examines CNN WorldView, CNN Wolf Blitzer Reports and CNN NewsNight as illustrations of cable news coverage. Through quantitative content analysis, results show that 70% of U.S. television news segments have provided 'balanced' coverage regarding anthropogenic contributions to climate change vis-à-vis natural radiative forcing, and there has been a significant difference between this television coverage and scientific consensus regarding anthropogenic climate change from 1996 through 2004. Thus, by way of the institutionalized journalistic norm of balanced reporting, United States television news coverage has perpetrated an informational bias by significantly diverging from the consensus view in climate science that humans contribute to climate change. Troubles in translating this consensus in climate science have led to the appearance of amplified uncertainty and debate, also then permeating public and policy discourse.

Peters, G.P. and Hertwich, E.G. **Post-Kyoto greenhouse gas inventories: production versus consumption.** *Climatic Change* 86(1-2): 51-66, 2008.

Notes: For the long-term stabilization of greenhouse gas (GHG) concentrations it is important that post-Kyoto policy has broad participation to ensure environmental integrity. Many post-Kyoto frameworks have been debated, but surprisingly approaches that focus on consumption have received little attention in the climate change literature despite broader interest in other areas. In this article we extend the argument for constructing GHG inventories using a country's consumption rather than production. First, we argue that constructing GHG inventories using a country's economic activity instead of geographic territory solves allocation issues for international activities such as international transportation and carbon capture and storage. Second, we argue that consumption-based GHG inventories have many advantages over production-based inventories. The main advantages are to address carbon leakage, reduce the importance of emission commitments for developing countries, increase options for mitigation, encourage environmental comparative advantage, address competitiveness concerns, and naturally encourage technology diffusion.

White, D., Hinzman, L., Alessa, L., Cassano, J., Chambers, M., Falkner, K., Francis, J., Gutowski, W.J., Holland, M., Holmes, R.M., Huntington, H., Kane, D., Kliskey, A., Lee, C., McClelland, J., Peterson, B., Rupp, T.S., Straneo, F., Steele, M., Woodgate, R., Yang, D., Yoshikawa, K., and Zhang, T. **The arctic freshwater system: Changes and impacts.** *Journal of Geophysical Research - Biogeosciences* 112(G4): art. G04S54, 2007.

Notes: Dramatic changes have been observed in the Arctic over the last century. Many of these involve the storage and cycling of fresh water. On land, precipitation and river discharge, lake abundance and size, glacier area and volume, soil moisture, and a variety of permafrost characteristics have changed. In the ocean, sea ice thickness and areal coverage have decreased and water mass circulation patterns have shifted, changing freshwater pathways and sea ice cover dynamics. Precipitation onto the ocean surface has also changed. Such changes are expected to continue, and perhaps accelerate, in the coming century, enhanced by complex feedbacks between the oceanic, atmospheric, and terrestrial freshwater systems. Change to the arctic freshwater system heralds changes for our global physical and ecological environment as well as human activities in the Arctic. In this paper we review observed changes in the arctic freshwater system over the last century in terrestrial, atmospheric, and oceanic systems.

Koenigk, T., Mikolajewicz, U., Haak, H., and Jungclaus, J. **Arctic freshwater export in the 20th and 21st centuries.** *Journal of Geophysical Research - Biogeosciences* 112(G4): art. G04S41, 2007.

Notes: Climate simulations suggest that the emissions of carbon dioxide and other greenhouse gases will lead to strong climate changes in the 21st century. Here the resulting effects of the freshwater balance of the Arctic Ocean in the 21st century are analyzed using coupled Intergovernmental Panel on Climate Change simulations with the Max Planck Institute for Meteorology climate model. For the Arctic region, particularly strong warming and an almost complete removal of sea ice during summer time are predicted. Arctic river runoff and net atmospheric freshwater input (P-E) are strongly enhanced. Most of this additional freshwater input is stored in the Arctic Ocean. While the total freshwater export out of the Arctic remains almost constant, significant changes occur in its distribution. The dominance of sea ice for the Fram Strait export disappears, while the liquid freshwater export is enhanced. The mean export shows therefore almost no changes, but its interannual variability is slightly reduced. In contrast, both the export through the Canadian Archipelago and its variability are increased in the 21st century. Therefore the importance of the Canadian Archipelago for the total Arctic export grows. Enhanced freshwater input into the Labrador Sea leads to a strong decrease in deep convection. Greenland Sea convection is reduced as well but mainly because of strong warming of the upper ocean layers. The meridional overturning circulation responds with a decline of about 6 sverdrups.

Rennermalm, A.K., Wood, E.F., Weaver, A.J., Eby, M., and Dery, S.J. **Relative sensitivity of the Atlantic meridional overturning circulation to river discharge into Hudson Bay and the Arctic Ocean.** *Journal of Geophysical Research - Biogeosciences* 112(G4): art. G04S48, 2007.

Notes: Increases in high-latitude river discharge over the 20th century and projected continued increases during the 21st century may have an impact on the Atlantic meridional overturning circulation (AMOC), which could feed back to regional and global climate. Although the general trend in high-latitude river discharge is positive, there is important geographical spread in the trends. While Eurasian rivers draining into the Arctic Ocean show positive trends over the 20th century, rivers draining into Hudson Bay show negative trends since 1964. Here the sensitivity of AMOC to changes in river discharge into Hudson Bay and the Arctic Ocean is studied with an intermediate-complexity Earth system model. It is found that ocean freshening originating from Arctic rivers is more effective in slowing down the AMOC than freshening originating from Hudson Bay rivers, given the same magnitude of freshening in both regions. The lesser impact of Hudson Bay river discharge on AMOC is the result of a buildup of freshwater anomalies in the Labrador Sea affecting the northward flow of the Gulf Stream. This work highlights that not only the freshening magnitude but the region where this freshening takes place is crucial for the AMOC response to altered river discharge climatology.

Francis, J. and Hunter, E. **Drivers of declining sea ice in the Arctic winter: A tale of two seas.** *Geophysical Research Letters* 34(17): art. L17503, 2007.

Notes: While the summer perennial Arctic sea ice has declined markedly in recent decades, the maximum extent of the winter ice cover had decreased only slightly, until the past few years when it also receded dramatically. This investigation reveals that the timing of maximum extent varies greatly, and the drivers of ice-edge location differ strikingly between two of the areas where it varies most: the Bering and Barents Seas. Between 1979 and 2005 in the Bering Sea, the ice edge is influenced mainly by anomalies in easterly winds associated with the Aleutian Low, which was particularly strong during the 1980s. The Barents Sea ice edge, in contrast, is driven primarily by two factors: anomalies in sea-surface temperature, particularly close in time to the maximum extent, and by southerly wind (from the south) anomalies integrated back to mid- and early winter. The hemispheric-mean decline in winter ice extent is due in large part to increasing sea-surface temperatures in the Barents Sea and adjoining waters, which are consistent with increased concentrations of greenhouse gases.

Miller, J.R., Chen, Y., Russell, G.L., and Francis, J.A. **Future regime shift in feedbacks during Arctic winter.** *Geophysical Research Letters* 34(23): art. L23707, 2007.

Notes: The Arctic is among the regions where climate is changing most rapidly today. Climate change is amplified by a variety of positive feedbacks, many of which are linked with changes in water vapor, cloud cover, and other cloud properties. We use

a global climate model to examine several of these feedbacks, with a particular emphasis on determining whether there are significant temporal changes in these feedbacks that would make them stronger or weaker during the 21st century. The model results indicate that one of the significant positive feedbacks on Arctic surface air temperature in winter weakens substantially toward the end of the 21st century. The feedback loop begins with a temperature increase that produces increases in water vapor, cloud cover, and cloud optical depth which increase the downward longwave flux by 30 Wm^{-2} by 2060 which then increases the surface air temperature.

Kinnard, C., Zdanowicz, C.M., Koerner, R.M., and Fisher, D.A. **A changing Arctic seasonal ice zone: Observations from 1870-2003 and possible oceanographic consequences.** *Geophysical Research Letters* 35(2): art. L02507, 2008.

Notes: Changes in the extent of seasonal ice were investigated using historical and satellite observations for the period 1870-2003. The seasonal ice zone (SIZ) has been gradually expanding since 1870, with a marked acceleration over the past three decades, and has migrated north to encompass all peripheral Arctic seas. The expansion of the SIZ may be increasing the salinity of the upper Arctic Ocean, consistent with recent observations. The migration of the SIZ over continental shelves may also be enhancing the formation rate and salinity of Arctic deep waters, which are subsequently advected to the convective region of the Greenland-Iceland-Norwegian Sea, thereby influencing the formation of North Atlantic deep waters and related global thermohaline circulation.

Steele, M., Ermold, W., and Zhang, J. **Arctic Ocean surface warming trends over the past 100 years.** *Geophysical Research Letters* 35(2): art. L02614, 2008.

Notes: Ocean temperature profiles and satellite data have been analyzed for summertime sea surface temperature (SST) and upper ocean heat content variations over the past century, with a focus on the Arctic Ocean peripheral seas. We find that many areas cooled up to ~0.5°C per decade during 1930-1965 as the Arctic Oscillation (AO) index generally fell, while these areas warmed during 1965-1995 as the AO index generally rose. Warming is particularly pronounced since 1995, and especially since 2000. Summer 2007 SST anomalies are up to 5°C. The increase in upper ocean summertime warming since 1965 is sufficient to reduce the following winter's ice growth by as much as 0.75 m. Alternatively, this heat may return to the atmosphere before any ice forms, representing a fall freeze-up delay of two weeks to two months. This returned heat might be carried by winds over terrestrial tundra ecosystems, contributing to the local heat budget.

Polovina, J.J., Howell, E.A., and Abecassis, M. **Ocean's least productive waters are expanding.** *Geophysical Research Letters* 35(3), 2008.

Notes: A 9-year time series of SeaWiFS remotely-sensed ocean color data is used to examine temporal trends in the ocean's most oligotrophic waters, those with surface chlorophyll not exceeding 0.07 mg chl/m^3. In the North and South Pacific, North and South Atlantic, outside the equatorial zone, the areas of low surface chlorophyll waters have expanded at average annual rates from 0.8 to 4.3%/yr and replaced about 0.8 million km^2/yr of higher surface chlorophyll habitat with low surface chlorophyll water. It is estimated that the low surface chlorophyll areas in these oceans combined have expanded by 6.6 million km^2 or by about 15.0% from 1998 through 2006. In both hemispheres, evidence shows a more rapid expansion of the low surface chlorophyll waters during the winter. The North Atlantic, which has the smallest oligotrophic gyre is expanding most rapidly, both annually at 4.3%/yr and seasonally, in the first quarter at 8.5%/yr. Mean sea surface temperature in each of these 4 subtropical gyres also increased over the 9-year period. The expansion of the low chlorophyll waters is consistent with global warming scenarios based on increased vertical stratification in the mid-latitudes, but the rates of expansion we observe already greatly exceed recent model predictions.
