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Marine Science Review – 261

Climate and climate change

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In this review:

A. Recent articles – no abstract
B. Recent publications available online
C. Recent articles with abstracts

O/A denotes an open access article or journal

A. Recent articles – no abstract available

Law, R.M., Matear, R.J., and Francey, R.J. **Comment on "Saturation of the Southern Ocean CO_2 sink due to recent climate change".** *Science* 319(5863): 570a, 2008.

Zickfeld, K., Fyfe, J.C., Eby, M., and Weaver, A.J. **Comment on "Saturation of the southern ocean CO_2 sink due to recent climate change".** *Science* 319(5863): 570b, 2008.

Le Quere, C., Rodenbeck, C., Buitenhuis, E.T., Conway, T.J., Langenfelds, R., Gomez, A., Labuschagne, C., Ramonet, M., Nakazawa, T., Metzl, N., Gillett, N.P., and Heimann, M. **Response to comments on "Saturation of the Southern Ocean CO_2 sink due to recent climate change".** *Science* 319(5863): 570c, 2008.

B. Recent publications available online

Climate Change Science Program. 2008. ***Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands.*** A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [T.R. Karl, G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray (eds.)]. Department of Commerce, NOAA's National Climatic Data Center, Washington, D.C. 164 pp.

Available at: http://www.climatescience.gov/Library/sap/sap3-3/final-report/default.htm

Notes: Changes in extreme weather and climate events have significant impacts and are among the most serious challenges to society in coping with a changing climate. Many extremes and their associated impacts are now changing. For example, in recent decades most of North America has been experiencing more unusually hot days and nights, fewer unusually cold days and nights, and fewer frost days. Heavy downpours have become more frequent and intense. Droughts are becoming more severe in some regions, though there are no clear trends for North America as a whole. The power and frequency of Atlantic hurricanes have increased substantially in recent decades, though North American mainland land-falling hurricanes do not appear to have increased over the past century. Outside the tropics, storm tracks are shifting northward and the strongest storms are becoming even stronger. It is well established through formal attribution studies that the global warming of the past 50 years is due primarily to human-induced increases in heat-trapping gases. Such studies have only recently been used to determine the causes of some changes in extremes at the scale of a continent. Certain aspects of observed increases in temperature extremes have been linked to human influences. The increase in heavy precipitation events is associated with an increase in water vapor, and the latter has been attributed to human-induced warming. No formal attribution studies for changes in drought severity in North America have been attempted. There is evidence suggesting a human contribution to

recent changes in hurricane activity as well as in storms outside the tropics, though a confident assessment will require further study. In the future, with continued global warming, heat waves and heavy downpours are very likely to further increase in frequency and intensity. Substantial areas of North America are likely to have more frequent droughts of greater severity. Hurricane wind speeds, rainfall intensity, and storm surge levels are likely to increase. The strongest cold season storms are likely to become more frequent, with stronger winds and more extreme wave heights. Current and future impacts resulting from these changes depend not only on the changes in extremes, but also on responses by human and natural systems.

C. Recent articles with abstracts

Menge, B.A., Chan, F., and Lubchenco, J. **Response of a rocky intertidal ecosystem engineer and community dominant to climate change.** *Ecology Letters* 11(2): 151-162, 2008.

Notes: To evaluate how climate change might impact a competitively dominant ecological engineer, we analysed the growth response of the mussel *Mytilus californianus* to climate patterns [El Nino-Southern Oscillation, Pacific Decadal Oscillation (PDO)]. Mussels grew faster during warmer climatic events. Growth was initially faster on a more productive cape compared to a less productive cape. Growth rates at the two capes merged in 2002, coincidentally with a several year-long shift from warm to cool PDO conditions. To determine the mechanism underlying this response, we examined growth responses to intertidal sea and air temperatures, phytoplankton, sea level and tide height. Together, water temperature (32%) and food (12.5%) explained 44.5% of the variance in mussel growth; contributions of other factors were not significant. In turn, water temperature and food respond to climate-driven variation in upwelling and other, unknown factors. Understanding responses of ecosystem engineers to climate change will require knowing direct thermal effects and indirect effects of factors altered by temperature change.

Boeing, W.J. and Duffy-Anderson, J.T. **Ichthyoplankton dynamics and biodiversity in the Gulf of Alaska: Responses to environmental change.** *Ecological Indicators* 8(3): 292-302, 2008.

Notes: Climate variation can cause major changes in the marine food web. We analyzed over 24 years of ichthyoplankton data from the Gulf of Alaska to evaluate lower trophic level responses to environmental change and judge their usefulness as ecological indicators. We standardized abundance data for each of 77 ichthyoplankton taxa, and used the Bray-Curtis distance measure and Flexible Beta linkage method, which grouped them into 22 discrete clusters. Variance Partitioning Analysis stressed the importance of geographical and seasonal processes for ichthyoplankton dynamics, and helped us identify the specific region(s) and month(s) for each response variable (cluster abundance, diversity) in which annual variation was maximized. Response variables were linked to environmental explanatory variables (atmospheric pressure, temperature, salinity and circulation indices) by Canonical Correspondence Analysis. The North Pacific Index (atmospheric pressure) and meso-scale climate variables like the El Nino Index (temperature), wind, and freshwater input (circulation) had the strongest impacts on ichthyoplankton species clusters. Specifically, the El Nino Index was negatively correlated with several ichthyoplankton clusters that were dominated by cold water species. Circulation was predominantly positively related to diversity and ichthyoplankton clusters, with the exception of clusters that mainly consisted of offshore taxa. The immediate response of ichthyoplankton to environmental forcing might make them suitable ecological indicators of environmental change although additional work is needed to assess affects on survival and recruitment.

Bala, G., Duffy, P.B., and Taylor, K.E. **Impact of geoengineering schemes on the global hydrological cycle.** *Proceedings of the National Academy of Sciences [USA]* 105(22): 7664-7669, 2008.

Notes: The rapidly rising CO_2 level in the atmosphere has led to proposals of climate stabilization by "geoengineering" schemes that would mitigate climate change by intentionally reducing solar radiation incident on Earth's surface. In this article we address the impact of these climate stabilization schemes on the global hydrological cycle. By using equilibrium climate simulations, we show that insolation reductions sufficient to offset global-scale temperature increases lead to a decrease in global mean precipitation. This occurs because solar forcing is more effective in driving changes in global mean evaporation than is CO_2 forcing of a similar magnitude. In the model used here, the hydrological sensitivity, defined as the percentage

change in global mean precipitation per degree warming, is 2.4% K^{-1} for solar forcing, but only 1.5% K^{-1} for CO_2 forcing. Although other models and the climate system itself may differ quantitatively from this result, the conclusion can be understood based on simple considerations of the surface energy budget and thus is likely to be robust. For the same surface temperature change, insolation changes result in relatively larger changes in net radiative fluxes at the surface; these are compensated by larger changes in the sum of latent and sensible heat fluxes. Hence, the hydrological cycle is more sensitive to temperature adjustment by changes in insolation than by changes in greenhouse gases. This implies that an alteration in solar forcing might offset temperature changes or hydrological changes from greenhouse warming, but could not cancel both at once.

Pielke, R.A., Gratz, J., Landsea, C.W., Collins, D., Saunders, M.A., and Musulin, R. **Normalized hurricane damage in the United States: 1900–2005.** *Natural Hazards Review* 9(1): 29-42, 2008.

Notes: After more than two decades of relatively little Atlantic hurricane activity, the past decade saw heightened hurricane activity and more than $150 billion in damage in 2004 and 2005. This paper normalizes mainland U.S. hurricane damage from 1900-2005 to 2005 values using two methodologies. A normalization provides an estimate of the damage that would occur if storms from the past made landfall under another year's societal conditions. Our methods use changes in inflation and wealth at the national level and changes in population and housing units at the coastal county level. Across both normalization methods, there is no remaining trend of increasing absolute damage in the data set, which follows the lack of trends in landfall frequency or intensity observed over the twentieth century. The 1970s and 1980s were notable because of the extremely low amounts of damage compared to other decades. The decade 1996-2005 has the second most damage among the past 11 decades, with only the decade 1926-1935 surpassing its costs. Over the 106 years of record, the average annual normalized damage in the continental United States is about $10 billion under both methods. The most damaging single storm is the 1926 Great Miami storm, with $140-157 billion of normalized damage: the most damaging years are 1926 and 2005. Of the total damage, about 85% is accounted for by the intense hurricanes Saffir-Simpson Categories 3, 4, and 5, yet these have comprised only 24% of the U.S. landfalling tropical cyclones. Unless action is taken to address the growing concentration of people and properties in coastal areas where hurricanes strike, damage will increase, and by a great deal, as more and wealthier people increasingly inhabit these coastal locations.

Mayor, D.J., Matthews, C., Cook, K., Zuur, A.F., and Hay, S. **CO_2-induced acidification affects hatching success in *Calanus finmarchicus*.** *Marine Ecology Progress Series* 350: 91-97, 2007.

Notes: Bottle incubations were conducted to examine how exposure to seawater containing 8000 ppm carbon dioxide (CO_2; pH 6.95) influenced the growth and reproduction of the keystone copepod *Calanus finmarchicus*. The chosen concentration of CO_2 is expected to occur over 100s of cubic kilometres of seawater as a result of marine CO_2 storage/disposal, and is also representative of the predicted 'worst-case' atmospheric CO_2 scenario in the year 2300. Growth (egg production and biomass loss) in adult female copepods was not affected by the simulated ocean acidification. In contrast, a maximum of only 4% of the eggs successfully yielded nauplii after 72 h in the experimental treatment. Our results demonstrate that environmental risk assessments for marine CO_2 storage/disposal must look beyond adult mortality as an endpoint. Furthermore, if CO_2 is to be disposed of in the deep sea, the location and timing of such activities must take into consideration the overwintering populations of *C. finmarchicus*.

Hobson, V.J., McMahon, C.R., Richardson, A., and Hays, G.C. **Ocean surface warming: The North Atlantic remains within the envelope of previous recorded conditions.** *Deep Sea Research Part I: Oceanographic Research Papers* 55(2): 155-162, 2008.

Notes: Anomalously warm air temperatures in various parts of the world have been widely noted in recent decades. In marine systems, biological indicators such as the range of plankton and fish have been used to indicate impacts of ocean warming, although for many regions recent ocean warming does not exceed short-term warming events over the last two centuries. Here we use International Comprehensive Ocean-Atmosphere Data Set (ICOADS) sea-surface temperature data to update analysis in the North Atlantic to show that present warm conditions are currently no more persistent than those encountered in the last 150 years. We show that the position of various isotherms, which play a central role in influencing the distribution of

marine taxa ranging from plankton to fish and turtles, are more regularly found further north in recent years than at any time since the 1850s.

Minobe, S., Kuwano-Yoshida, A., Komori, N., Xie, S.P., and Small, R.J. **Influence of the Gulf Stream on the troposphere.** *Nature* 452(7184): 206-210, 2008.

Notes: The Gulf Stream transports large amounts of heat from the tropics to middle and high latitudes, and thereby affects weather phenomena such as cyclogenesis and low cloud formation. But its climatic influence, on monthly and longer timescales, remains poorly understood. In particular, it is unclear how the warm current affects the free atmosphere above the marine atmospheric boundary layer. Here we consider the Gulf Stream's influence on the troposphere, using a combination of operational weather analyses, satellite observations and an atmospheric general circulation model. Our results reveal that the Gulf Stream affects the entire troposphere. In the marine boundary layer, atmospheric pressure adjustments to sharp sea surface temperature gradients lead to surface wind convergence, which anchors a narrow band of precipitation along the Gulf Stream. In this rain band, upward motion and cloud formation extend into the upper troposphere, as corroborated by the frequent occurrence of very low cloud-top temperatures. These mechanisms provide a pathway by which the Gulf Stream can affect the atmosphere locally, and possibly also in remote regions by forcing planetary waves. The identification of this pathway may have implications for our understanding of the processes involved in climate change, because the Gulf Stream is the upper limb of the Atlantic meridional overturning circulation, which has varied in strength in the past and is predicted to weaken in response to human- induced global warming in the future.

Knutson, T.R., Sirutis, J.J., Garner, S.T., Vecchi, G.A., and Held, I.M. **Simulated reduction in Atlantic hurricane frequency under twenty-first-century warming conditions.** *Nature Geoscience* 1(6): 359-364, 2008.

Notes: Increasing sea surface temperatures in the tropical Atlantic Ocean and measures of Atlantic hurricane activity have been reported to be strongly correlated since at least 1950, raising concerns that future greenhouse-gas-induced warming could lead to pronounced increases in hurricane activity. Models that explicitly simulate hurricanes are needed to study the influence of warming ocean temperatures on Atlantic hurricane activity, complementing empirical approaches. Our regional climate model of the Atlantic basin reproduces the observed rise in hurricane counts between 1980 and 2006, along with much of the interannual variability, when forced with observed sea surface temperatures and atmospheric conditions. Here we assess, in our model system, the changes in large-scale climate that are projected to occur by the end of the twenty-first century by an ensemble of global climate models, and find that Atlantic hurricane and tropical storm frequencies are reduced. At the same time, near-storm rainfall rates increase substantially. Our results do not support the notion of large increasing trends in either tropical storm or hurricane frequency driven by increases in atmospheric greenhouse-gas concentrations.

Lane, P.V.Z., Llinas, L., Smith, S.L., and Pilz, D. **Zooplankton distribution in the western Arctic during summer 2002: Hydrographic habitats and implications for food chain dynamics.** *Journal of Marine Systems* 70(1-2): 97-133, 2008.

Notes: Global warming is presently a widely accepted phenomenon with a broad range of anticipated impacts on marine ecosystems. Alterations in temperature, circulation and ice cover in Arctic seas may result in changes in food chain dynamics, beginning with planktonic processes. As part of the Shelf-Basin Interactions (SBI) program, we conducted zooplankton surveys during summer 2002 to assess the biomass, distribution and abundance of copepods and other pelagic zooplankton over the Chukchi and Beaufort shelves, slope regions and the adjacent Canada Basin. The motivation for our fieldwork was the question, "Will global change, particularly warming, result in more large-sized zooplankton which support a pelagic food web of fish, birds, and certain mammals over the Chukchi and Beaufort shelves or in more smaller-sized zooplankton which will diminish the fish, birds and mammals and favor sedentary benthic organisms?" The objectives of the present study were 1) to census the regional zooplankton community and establish a baseline for comparisons with historical and future studies and 2) to determine whether large-bodied copepods associated with deep waters of the Bering Sea or the Canada Basin were transported to the shelves in sufficient numbers to modify the food web in a region where smaller copepods often dominate the zooplankton numerically. Spatial distributions of zooplankton communities were clearly associated with hydrographic habitats determined by the chemical, physical and biological characteristics of the upper water layer. Smaller taxa dominated the shelf communities while offshore zooplankton assemblages were characterized by large-bodied copepods. The

mesozooplankton community was numerically dominated by copepod nauplii and small-bodied juveniles, including *Pseudocalanus* spp. and *Oithona similis*. We observed very few large-bodied copepods from the Bering Sea. However, much of the shelf region surveyed included relatively numerous *Calanus glacialis* juveniles and adults, suggesting that these copepods were advected onto the shelf and possibly reproducing there. Juvenile stages of the large-bodied copepod *Calanus hyperboreus* were found in relative abundance on the Chukchi shelf in the vicinity of Hanna Canyon. These observations suggest that large-bodied, deep-water species from the basin are advected onto the Chukchi Shelf where they may impact the fate of shelf-derived primary production and alter the food webs of the shelves. Regional comparisons of abundances of selected taxa enumerated in the present study with sample data from the early 1950s suggested that some taxa were more abundant in the SBI region in 2002 than ca. 50 years ago. Long-term changes in planktonic populations are expected to have significant implications for shelf-basin exchange of biogenic material in the Chukchi and Beaufort Seas and the adjacent Arctic Basin.

Timlin, M.S. and Walsh, J.E. **Historical and projected distributions of daily temperature and pressure in the Arctic.** *Arctic* 60(4): 389-400, 2007.

Notes: Changes in extreme temperatures and pressures in the Arctic have received little attention in the context of climate change. Here we examine the distributions and extremes of surface air temperature and pressure in the Arctic for the late 20th century, using Alaskan weather station data, an atmospheric reanalysis, and general circulation models (GCMs). There is good agreement among these sources for the late 20th century, with broader distributions for both temperature and pressure in winter as compared to summer, and over land as compared to over ocean. We used the output from 21st-century greenhouse simulations by the GCMs to address the occurrence of extremes in the coming decades. The model projections of the 21st-century extremes largely agree with changes in the mean state, with record low temperatures decreasing in frequency and record high temperatures increasing in frequency. The changes in 21st-century extremes are more pronounced over the ocean, where the present-day distributions are narrower. The projected decreases of mean pressure result in more frequent occurrences of extreme low pressure, especially over the Arctic Ocean, although the extremes of pressure are less affected by changes of the means than are the extremes of temperature. Lastly, we find that the transition from sea ice to open water, and associated changes in the salinity of the surface water, can cause changes in the temperature distribution that are more complex than simple shifts in the distribution, leading to unexpected changes in the occurrence of extreme temperatures.

Mustin, K., Sutherland, W.J., and Gill, J.A. **The complexity of predicting climate-induced ecological impacts.** *Climate Research* 35(1-2): 165-175, 2007.

Notes: The anticipated future increases in global surface temperatures are likely to have major impacts on the distribution of species. Predicting future species' distributions is a key area of importance in research, which is largely being addressed through the use of climate envelope models. While climate envelope models may indicate the broad direction of likely changes in distribution, they fail to incorporate the non-climatic factors that are important determinants of species' distributions within their current range, which may mean that the observed response will differ greatly from these predictions. When considering specific species, these ecological details are likely to be extremely important, but their inclusion in predictive models is difficult. We illustrate the complexities of unravelling climate impacts on species distribution and population size using migratory shorebirds as an example.

McClanahan, T.R., Cinner, J.E., Maina, J., Graham, N.A.J., Daw, T.M., Stead, S.M., Wamukota, A., Brown, K., Ateweberhan, M., Venus, V., and Polunin, N.V.C. **Conservation action in a changing climate.** *Conservation Letters* 1(2): 53-59, 2008.
O/A

Notes: Climate change will pose new challenges to conserving Earth's natural ecosystems, due to incremental changes in temperature and weather patterns, and to increased frequency and intensity of extreme climate events. Addressing these challenges will require pragmatic conservation actions informed by site-specific understanding of susceptibility to climate change and capacity of societies to cope with and adapt to change. Depending on a location's environmental susceptibility and social adaptive capacity, appropriate conservation actions will require some combination of: (1) large-scale protection of ecosystems; (2) actively transforming and adapting social-ecological systems; (3) building the capacity of communities to cope with change; and (4) government assistance focused on de-coupling communities from dependence on natural resources. We

apply a novel analytical framework to examine conservation actions in five western Indian Ocean countries, where climate-mediated disturbance has impacted coral reefs and where adaptive capacity differs markedly. We find that current conservation strategies do not reflect adaptive capacity and are, therefore, ill prepared for climate change. We provide a vision for conservation policies that considers social adaptive capacity that copes with complexities of climate change better than the singular emphasis on government control and the creation of no-take areas.

Monaghan, A.J., Bromwich, D.H., Chapman, W., and Comiso, J.C. **Recent variability and trends of Antarctic near-surface temperature.** *Journal of Geophysical Research* 113(4): art. D04105, 2008.

Notes: A new monthly 1° x 1° Antarctic near-surface temperature reconstruction for 1960-2005 is presented. The use of numerical model fields to establish spatial relationships between fifteen continuous observational temperature records and the voids to which they are interpolated inherently accounts for the effects of the atmospheric circulation and topography on temperature variability. Employing a fixed observation network ensures that the reconstruction uncertainty remains constant in time. Comparison with independent observations indicates that the reconstruction and two other gridded observational temperature records are useful for evaluating regional near-surface temperature variability and trends throughout Antarctica. The reconstruction has especially good skill at reproducing temperature trends during the warmest months when melt contributes to ice sheet mass loss. The spatial variability of monthly near-surface temperature trends is strongly dependent on the season and time period analyzed. Statistically insignificant ($p > 0.05$) positive trends occur over most regions and months during 1960-2005. By contrast, 1970-2005 trends are weakly negative overall, consistent with positive trends in the Southern Hemisphere Annular Mode (SAM) during summer and autumn. Subtle nearsurface temperature increases during winter from 1970 to 2000 are consistent with tropospheric warming from radiosonde records and a lack of winter SAM trends. Widespread but statistically insignificant ($p > 0.05$) warming over Antarctica from 1992 to 2005 coincides with a leveling off of upward SAM trends during summer and autumn since the mid-1990s. Weakly significant annual trends ($p < 0.10$) of about +1 K decade^{-1} are found at three stations in interior and coastal East Antarctica since 1992. The subtle shift toward warming during the past 15 years raises the question of whether the recent trends are linked more closely to anthropogenic influences or multidecadal variability.

Inoue, J., Kikuchi, T., and Perovich, D.K. **Effect of heat transmission through melt ponds and ice on melting during summer in the Arctic Ocean.** *Journal of Geophysical Research* 113(5): art. C05020, 2008.

Notes: To observe sea ice and ocean conditions in the Arctic in summer, a trans-Arctic research cruise of the U.S. Coast Guard Cutter *Healy* was conducted from 5 August to 30 September 2005. The relationship between the ice concentration observed by the on-board ice-watch and the temperature above the freezing point (ΔT) measured by expendable conductivity-temperature-depth (XCTD) sensors had a negative correlation (CT-relationship) before the onset of freezing. This means that as ice concentration decreases, ΔT increases due to the larger absorption of solar radiation. However, ΔT in high ice-covered regions (>90%) remains more than 0.1 K during the melting season, suggesting that sea-ice and melt-pond areas work as heat source areas as well as leads. By separating the effects of heat input from open water, melt ponds, and ice on the heating of mixed layers, we found that the contribution of the transmitted heat through ponds and ice on the ΔT-gain is large in highly ice-covered regions. To examine the effect of such heating on ice melting, a simplified ice-ocean-coupled model was applied. By changing the heat input to obtain the analyzed ΔT-gain for each surface category, the transmittances of ponds and ice were indirectly estimated as 55% and 9%, respectively. After including the effects of transmitted heat through ponds and ice, the modeled results agreed with the observed CT-relationship. Comparisons between the results of turning on and off the effect of transmitted heat through ponds and ice showed that it amplified the open water-albedo feedback mechanism in the highly ice-covered region.

Guinotte, J.M. and Fabry, V.J. **Ocean acidification and its potential effects on marine ecosystems.** *Annals of the New York Academy of Sciences* 1134(1): 320-342, 2008. **O/A**

Notes: Ocean acidification is rapidly changing the carbonate system of the world oceans. Past mass extinction events have been linked to ocean acidification, and the current rate of change in seawater chemistry is unprecedented. Evidence suggests that these changes will have significant consequences for marine taxa, particularly those that build skeletons, shells, and tests of

biogenic calcium carbonate. Potential changes in species distributions and abundances could propagate through multiple trophic levels of marine food webs, though research into the long-term ecosystem impacts of ocean acidification is in its infancy. This review attempts to provide a general synthesis of known and/or hypothesized biological and ecosystem responses to increasing ocean acidification. Marine taxa covered in this review include tropical reef-building corals, cold-water corals, crustose coralline algae, *Halimeda*, benthic mollusks, echinoderms, coccolithophores, foraminifera, pteropods, seagrasses, jellyfishes, and fishes. The risk of irreversible ecosystem changes due to ocean acidification should enlighten the ongoing CO_2 emissions debate and make it clear that the human dependence on fossil fuels must end quickly. Political will and significant large-scale investment in clean-energy technologies are essential if we are to avoid the most damaging effects of human-induced climate change, including ocean acidification.

Moline, M.A., Karnovsky, N.J., Brown, Z., Divoky, G.J., Frazer, T.K., Jacoby, C.A., Torres, J.J., and Fraser, W.R. **High latitude changes in ice dynamics and their impact on polar marine ecosystems.** *Annals of the New York Academy of Sciences* 1134(1): 267-319, 2008.

Notes: Polar regions have experienced significant warming in recent decades. Warming has been most pronounced across the Arctic Ocean Basin and along the Antarctic Peninsula, with significant decreases in the extent and seasonal duration of sea ice. Rapid retreat of glaciers and disintegration of ice sheets have also been documented. The rate of warming is increasing and is predicted to continue well into the current century, with continued impacts on ice dynamics. Climate-mediated changes in ice dynamics are a concern as ice serves as primary habitat for marine organisms central to the food webs of these regions. Changes in the timing and extent of sea ice impose temporal asynchronies and spatial separations between energy requirements and food availability for many higher trophic levels. These mismatches lead to decreased reproductive success, lower abundances, and changes in distribution. In addition to these direct impacts of ice loss, climate-induced changes also facilitate indirect effects through changes in hydrography, which include introduction of species from lower latitudes and altered assemblages of primary producers. Here, we review recent changes and trends in ice dynamics and the responses of marine ecosystems. Specifically, we provide examples of ice-dependent organisms and associated species from the Arctic and Antarctic to illustrate the impacts of the temporal and spatial changes in ice dynamics.

Stabeno, P.J., Bond, N.A., and Salo, S.A. **On the recent warming of the southeastern Bering Sea shelf.** *Deep Sea Research Part II: Topical Studies in Oceanography* 54(23-26): 2599-2618, 2007.

Notes: During the last decade, the southeastern Bering Sea shelf has undergone a warming of ~ 3ºC that is closely associated with a marked decrease of sea ice over the area. This shift in the physical environment of the shelf can be attributed to a combination of mechanisms, including the presence over the eastern Bering Sea shelf of a relatively mild air mass during the winter, especially from 2000 to 2005; a shorter ice season caused by a later fall transition and/or an earlier spring transition; increased flow through Unimak Pass during winter, which introduces warm Gulf of Alaska water onto the southeastern shelf, and the feedback mechanism whereby warmer ocean temperatures during the summer delay the southward advection of sea ice during winter. While the relative importance of these four mechanisms is difficult to quantify, it is evident that for sea ice to form, cold arctic winds must cool the water column. Sea ice is then formed in the polynyas during periods of cold north winds, and this ice is advected southward over the eastern shelf. The other three mechanisms can modify ice formation and melt, and hence its extent. In combination, these four mechanisms have served to temporally and spatially limit ice during the 5-year period (2001-2005). Warming of the eastern Bering Sea shelf could have profound influences on the ecosystem of the Bering Sea - from modification of the timing of the spring phytoplankton bloom to the northward advance of subarctic species and the northward retreat of arctic species.

Coyle, K.O., Konar, B., Blanchard, A., Highsmith, R.C., Carroll, J., Carroll, M., Denisenko, S.G., and Sirenko, B.I. **Potential effects of temperature on the benthic infaunal community on the southeastern Bering Sea shelf: Possible impacts of climate change.** *Deep Sea Research Part II: Topical Studies in Oceanography* 54(23-26): 2885-2905, 2007.

Notes: In the late 1950s, Soviet researchers collected benthic infaunal samples from the southeastern Bering Sea shelf. Approximately 17 years later, researchers at University of Alaska Fairbanks also sampled the region to assess infaunal biomass and abundance. Here, the two data sets were examined to document patterns and reveal any consistent differences in infaunal

biomass among major feeding groups between the two time periods. No significant differences in the geometric mean biomass of all taxa, pooled were indicated between the two study periods (1958-1959=49.1 g m^{-2}; 1975-1976 = 60.8 g m^{-2}; $P = 0.14$); however, significant differences were observed for specific functional groups, namely carnivores, omnivores and surface detritivores. Of the 64 families identified from both data sets from all functional groups, 21 showed statistically significant ($P \leq 0.05$) differences in mean biomass. Of the 21 families showing significant differences, 19 (91%) of the families had higher mean biomass in the 1975-1976 data set. The above differences suggest a trend toward higher overall infaunal biomass for specific functional groups during mid 1970s compared with the late 1950s. Temperature measurements and literature data indicate that the mid-1970s was an unusually cold period relative to the period before and after, suggesting a mechanistic link between temperature changes and infaunal biomass. Food-web relationships and ecosystem dynamics in the southeastern Bering Sea indicate that during cold periods, infaunal biomass will be elevated relative to warm periods due to elevated carbon flux to the benthos and exclusion of benthic predators on infaunal invertebrates by the cold bottom water on the shelf. As long-term observations of temperature and sea-ice cover indicate a secular warming trend on the Bering Sea shelf, the potential changes in food-web relationships could markedly alter trophic structure and energy flow to apex consumers, potentially impacting the commercial, tourist and subsistence economics.

Stempniewicz, L., Blachowlak-Samolyk, K., and Weslawski, J.M. **Impact of climate change on zooplankton communities, seabird populations and arctic terrestrial ecosystem - A scenario.** *Deep Sea Research Part II: Topical Studies in Oceanography* 54(23-26): 2934-2945, 2007.

Notes: Many arctic terrestrial ecosystems suffer from a permanent deficiency of nutrients. Marine birds that forage at sea and breed on land can transport organic matter from the sea to land, and thus help to initiate and sustain terrestrial ecosystems. This organic matter initiates the emergence of local tundra communities, increasing primary and secondary production and species diversity. Climate change will influence ocean circulation and the hydrologic regime, which will consequently lead to a restructuring of zooplankton communities between cold arctic waters, with a dominance of large zooplankton species, and Atlantic waters in which small species predominate. The dominance of large zooplankton favours plankton-eating seabirds, such as the little auk (*Alle alle*), while the presence of small zooplankton redirects the food chain to plankton-eating fish, up through to fish-eating birds (e.g., guillemots *Uria* sp.). Thus, in regions where the two water masses compete for dominance, such as in the Barents Sea, plankton-eating birds should dominate the avifauna in cold periods and recess in warmer periods, when fish-eaters should prevail. Therefore under future anthropogenic climate scenarios, there could be serious consequences for the structure and functioning of the terrestrial part of arctic ecosystems, due in part to changes in the arctic marine avifauna. Large colonies of plankton-eating little auks are located on mild mountain slopes, usually a few kilometres from the shore, whereas colonies of fish-eating guillemots are situated on rocky cliffs at the coast. The impact of guillemots on the terrestrial ecosystems is therefore much smaller than for little auks because of the rapid washing-out to sea of the guano deposited on the seabird cliffs. These characteristics of seabird nesting sites dramatically limit the range of occurrence of ornithogenic soils, and the accompanying flora and fauna, to locations where talus-breeding species occur. As a result of climate warming favoring the increase of ichthyiofagous cliff-nesting seabirds, we can expect that large areas of ornithogenic tundra around the colonies of plankton-eating seabirds situated far from the sea may disappear, while areas of tundra in the vicinity of cliffs inhabited by fish-eating seabirds, with low total production and supporting few large herbivores, will likely increase, but only imperceptibly. This may lead to habitat fragmentation with negative consequences for populations of tundra-dependent birds and mammals, and the possibility of a substantial decrease in biodiversity of tundra plant and animal communities.

Reagan, M.T. and Moridis, G.J. **Oceanic gas hydrate instability and dissociation under climate change scenarios.** *Geophysical Research Letters* 34(22): art. L22709, 2007.

Notes: Global oceanic deposits of methane gas hydrate (clathrate) have been implicated as the main culprit for a repeated, remarkably rapid sequence of global warming effects that occurred during the late Quaternary period. However, the behavior of contemporary oceanic methane hydrate deposits subjected to rapid temperature changes, like those predicted under future climate change scenarios, is poorly understood, and existing studies focus on deep hydrate deposits under equilibrium conditions. In this study, we simulate the dynamic response of several types of oceanic gas hydrate accumulations to temperature changes at the seafloor and assess the potential for methane release into the ecosystem. The results suggest that while many deep hydrate deposits are indeed stable under the influence of rapid seafloor temperature variations, shallow

deposits, such as those found in arctic regions or in the Gulf of Mexico, can undergo rapid dissociation and produce significant carbon fluxes over a period of decades.

Monaghan, A.J., Bromwich, D.H., and Schneider, D.P. **Twentieth century Antarctic air temperature and snowfall simulations by IPCC climate models.** *Geophysical Research Letters* 35(7): art. L07502, 2008.

Notes: We compare new observationally-based data sets of Antarctic near-surface air temperature and snowfall accumulation with 20th century simulations from global climate models (GCMs) that support the Intergovernmental Panel on Climate Change Fourth Assessment Report. Annual Antarctic snowfall accumulation trends in the GCMs agree with observations during 1960-1999, and the sensitivity of snowfall accumulation to near-surface air temperature fluctuations is approximately the same as observed, about 5% K^{-1}. Thus if Antarctic temperatures rise as projected, snowfall increases may partially offset ice sheet mass loss by mitigating an additional 1 mm y^{-1} of global sea level rise by 2100. However, 20th century (1880-1999) annual Antarctic near-surface air temperature trends in the GCMs are about 2.5-to-5 times larger-than-observed, possibly due to the radiative impact of unrealistic increases in water vapor. Resolving the relative contributions of dynamic and radiative forcing on Antarctic temperature variability in GCMs will lead to more robust 21st century projections.

Gillett, N.P., Stott, P.A., and Santer, B.D. **Attribution of cyclogenesis region sea surface temperature change to anthropogenic influence.** *Geophysical Research Letters* 35(9): art. L09707, 2008.

Notes: Previous research has identified links between tropical cyclone activity and sea surface temperatures in the tropical cyclogenesis regions of the North Atlantic and Western North Pacific. Other work has demonstrated that warming in these regions is inconsistent with simulated internal variability. After evaluating the variability of a suite of climate models on a range of timescales, we use detection and attribution methods and a suite of 20th century simulations including anthropogenic and natural forcing to identify a significant response to external forcing in both regions during the June-November hurricane season over the 20th century. We then use separate simulations of the response to natural and anthropogenic forcing to identify anthropogenic influence independently of natural influence in both the Atlantic and Pacific Cyclogenesis Regions.

Solow, A.R. and Beet, A.R. **On the incompleteness of the historical record of North Atlantic tropical cyclones.** *Geophysical Research Letters* 35(11): art. L11803, 2008.

Notes: There is some question as to whether the historical record of observed North Atlantic tropical cyclones prior to the advent of satellite coverage is complete. This question is central to understanding the historical trend in tropical cyclone activity and the effect of environmental factors on it. To address this question, a statistical model of the relationship between annual cyclone counts between 1870 and 2004 and sea surface temperature and the state of the Southern Oscillation is extended to allow for non-decreasing observation probability prior to 1966. The estimated observation probabilities increase from 0.72 in 1870 to 1 in 1964. Allowing for record incompleteness reduces the estimated effect of sea surface temperature on annual tropical cyclone activity.

Perovich, D.K., Richter-Menge, J.A., Jones, K.F., and Light, B. **Sunlight, water, and ice: extreme Arctic sea ice melt during the summer of 2007.** *Geophysical Research Letters* 35(11): art. L11501, 2008.

Notes: The summer extent of the Arctic sea ice cover, widely recognized as an indicator of climate change, has been declining for the past few decades reaching a record minimum in September 2007. The causes of the dramatic loss have implications for the future trajectory of the Arctic sea ice cover. Ice mass balance observations demonstrate that there was an extraordinarily large amount of melting on the bottom of the ice in the Beaufort Sea in the summer of 2007. Calculations indicate that solar heating of the upper ocean was the primary source of heat for this observed enhanced Beaufort Sea bottom melting. An increase in the open water fraction resulted in a 500% positive anomaly in solar heat input to the upper ocean, triggering an ice-albedo feedback and contributing to the accelerating ice retreat.

Zhang, J., Lindsay, R., Steele, M., and Schweiger, A. **What drove the dramatic retreat of arctic sea ice during summer 2007?** *Geophysical Research Letters* 35(11): art. L11505, 2008.

Notes: A model study has been conducted of the unprecedented retreat of arctic sea ice in the summer of 2007. It is found that preconditioning, anomalous winds, and ice-albedo feedback are mainly responsible for the retreat. Arctic sea ice in 2007 was preconditioned to radical changes after years of shrinking and thinning in a warm climate. During summer 2007 atmospheric changes strengthened the transpolar drift of sea ice, causing more ice to move out of the Pacific sector and the central Arctic Ocean where the reduction in ice thickness due to ice advection is up to 1.5 m more than usual. Some of the ice exited Fram Strait and some piled up in part of the Canada Basin and along the coast of northern Greenland, leaving behind an unusually large area of thin ice and open water. Thin ice and open water allow more surface solar heating because of a much reduced surface albedo, leading to amplified ice melting. The Arctic Ocean lost additional 10% of its total ice mass in which 70% is due directly to the amplified melting and 30% to the unusual ice advection, causing the unprecedented ice retreat. Arctic sea ice has entered a state of being particularly vulnerable to anomalous atmospheric forcing.
