

# Marine Science Review - 247

## Climate and climate change

### In this review:

- A. Recent articles – no abstract available
- 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

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Arrow, K.J. 2007. **Global climate change: a challenge to policy.** *The Economists' Voice* 4(3) art. 2. Available at: <http://www.bepress.com/ev/vol4/iss3/art2> O/A

Schiermeier, Q. **Ocean circulation noisy, not stalling.** *Nature* 448(7156): 844-845, 2007.

Wookey, P.A. **Climate change and biodiversity in the Arctic-Nordic perspectives.** *Polar Research* 26(2): 96-103, 2007. O/A

Fischhoff, B. **Nonpersuasive communication about matters of greatest urgency: Climate change.** *Environmental Science and Technology* 41(21): 7204-7208, 2007. O/A

Kerr, R.A. **Global warming: How urgent is climate change?** *Science* 318(5854): 1230-1231, 2007.

## B. Recent publications available online

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Ruth, M., Coelho, D. and Karetnikov, D. 2007. **The US Economic Impacts of Climate Change and the Costs of Inaction.** Center for Integrative Environmental Research, University of Maryland, College Park, Maryland. 48pp.

Available at: <http://www.cier.umd.edu/climateadaptation/>

**Notes:** This report presents a review of economic studies for the United States and relates them to predicted impacts of climate change. The summary findings are organized by region and identify the key sectors likely affected by climate change, the main impacts to be expected, as well as estimates of costs. The report builds on the 2000 Global Change Research Program National Assessment, using additional regional and local studies, as well as new calculations derived from federal, state and industry data sources. From this review and quantification, five key lessons emerge: 1. Economic impacts of climate change will occur throughout the country. 2. Economic impacts will be unevenly distributed across regions and within the economy and society. 3. Negative climate impacts will outweigh benefits for most sectors that provide essential goods and services to society. 4. Climate change impacts will place immense strains on public sector budgets. 5. Secondary effects of climate impacts can include higher prices, reduced income and job losses.

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Twilley, R.R. 2007. **Gulf coast wetland sustainability in a changing climate** in *Regional Impacts of Climate Change: Four Case Studies in the United States*, pp. 42-56. Prepared for the Pew Center on Global Climate Change, Arlington, VA.

Available at: <http://www.pewclimate.org/docUploads/Regional-Impacts-Gulf.pdf>

**Notes:** The coastline of the Gulf of Mexico offers a prototypical example of how human development patterns and climate change can interact to create high risks to human and natural systems. The combination of intense development in low-lying coastal areas, building levees along major rivers such as the Mississippi, high pollution levels, and extreme weather events, have degraded economically and culturally valuable coastal wetlands and made many human settlements in the Gulf region more vulnerable to rising seas and coastal storms. Accelerated sea-level rise and more intense hurricanes resulting from climate change would increase these risks. Therefore, plans to restore Gulf Coast wetlands and make them resilient to human activities and climate variability require careful consideration of how future climate change and human activities will degrade or enhance the natural processes that build and maintain coastal wetlands.

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Boesch, D.F., Coles, V.J., Kimmel, D.G. and Miller, W.D. 2007. **Ramifications of Climate Change for Chesapeake Bay Hypoxia** in *Regional Impacts of Climate Change: Four Case Studies in the United States*, pp. 57-70. Prepared for the Pew Center on Global Climate Change, Arlington, VA.

Available at: <http://www.pewclimate.org/docUploads/Regional-Impacts-Chesapeake.pdf>

**Notes:** Hypoxia (inadequate levels of oxygen that can lead to dead zones) in the Chesapeake Bay is another example of a natural phenomenon made substantially worse by human development and that could also be exacerbated by climate change. Hypoxia occurs when nutrient runoff from land stimulates biological oxygen demand, reducing oxygen levels in the Chesapeake Bay. This condition adversely affects the bay ecosystem, including its fisheries, and recreational opportunities in the bay. Development within the Chesapeake Bay watershed has resulted in runoff of nutrients from farms and settlements, increasing the incidence and intensity of hypoxia in the bay. Increased regional rainfall, which washes nutrients into the bay, and higher summer temperatures, which accelerate oxygen depletion, are likely to increase the incidence and intensity of hypoxia in the Chesapeake Bay. These changes could alter the current assessment of nutrient reductions needed to meet water quality objectives.

## C. Recent articles with abstracts

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Boykoff, M.T. **From convergence to contention: United States mass media representations of anthropogenic climate change science.** *Transactions of the Institute of British Geographers* 32(4): 477-489, 2007.

**Notes:** This article focuses on connected factors that contribute to United States (US) media reporting on anthropogenic climate change science. It analyses US newspapers and television news from 1995 to 2006 as well as semi-structured interviews with climate scientists and environmental journalists. Through analyses of power and scale, the paper brings together issues of framing in journalism to questions of certainty/uncertainty in climate science. The paper examines how and why US media have represented conflict and contentions, despite an emergent consensus view regarding anthropogenic climate science.

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Freitas, V., Campos, J., Fonds, M., and Van der Veer, H.W. **Potential impact of temperature change on epibenthic predator-bivalve prey interactions in temperate estuaries.** *Journal of Thermal Biology* 32(6): 328-340, 2007.

**Notes:** Temperate estuaries are indispensable as refuelling areas for long-distance shorebirds, where they depend on intertidal benthic fauna, such as bivalves, as food source. Bivalve recruitment is thought to be, at least partly, top-down regulated by epibenthic predators (the shrimp *Crangon crangon* and the crab *Carcinus maenas*) but this interaction is part of a complex predator-prey system since various fish species prey upon the crustaceans. The impact of climate change in temperate estuarine food webs will be determined by how the various size-selective interactions are affected by temperature. This will depend on the temperature sensitivity of each species' growth and on how food conditions allow them to fill in this growth

potential. In this paper, the focus is on the first aspect: temperature sensitivity of the epibenthic predators compared with that of the bivalve prey and among the various predator species. Our results show that crustaceans have higher temperature sensitivity and tolerance range compared with their potential predators and with their bivalve prey. It is hypothesized that a temperature increase can potentially lead to an overall higher predation pressure in these systems with negative impacts in bivalve recruitment and hence, in the functioning of temperate estuaries as fuelling stations. However, prevailing food conditions for bivalves and predators will determine to what extent the potential impacts of an increase in temperature will be realized.

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Widdicombe, S. and Needham, H.R. **Impact of CO<sub>2</sub>-induced seawater acidification on the burrowing activity of *Nereis virens* and sediment nutrient flux.** *Marine Ecology Progress Series* 341: 111-122, 2007.

**Notes:** A mesocosm experiment was conducted to quantify the effects of medium term (5 wk) exposure to acidified seawater on the structure of *Nereis virens* (Polychaeta) burrows and sediment nutrient fluxes. Worms were exposed to seawater acidified to a pH of 3.3, 6.5 or 5.6 using carbon dioxide (CO<sub>2</sub>) gas. These treatments mimicked the effects of either ocean acidification (pH 7.3) or leakage from a sub-seabed CO<sub>2</sub> storage site (pH 6.5 and 5.6). Results from these treatments were compared to those from worms maintained in natural seawater with a pH ~ 7.9. The experiment showed that the presence and structure of *N. virens* burrows significantly increased the sediment uptake of nitrate and the release of ammonium, nitrite and silicate. Phosphate flux was unaffected by the presence of burrows. Nutrient flux rates were also significantly affected by changes in seawater acidity. A reduction in seawater pH caused an increase in nitrate uptake and increase in ammonium release, a decrease in nitrite release and a decrease in phosphate uptake. The flux of silicate was unaffected by changes in seawater pH. As changes in acidity had no impact on the size and structure of worm burrows, it was concluded that the impact of seawater pH on nutrient flux was probably due to changes in the microbial communities responsible for nutrient transformations. Whilst this paper demonstrates that leakage from sub-seabed storage would have significant and immediate effects on nutrient cycling, impacts of ocean acidification through atmospheric absorption are less obvious. This paper concludes that ocean acidification could have a significant impact on sediment nutrient flux in coastal and shelf seas as a result of potential changes in the structure and function of bioturbating communities.

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Archer, D. **Methane hydrate stability and anthropogenic climate change.** *Biogeosciences* 4(4): 521-544, 2007. **O/A**

**Notes:** Methane frozen into hydrate makes up a large reservoir of potentially volatile carbon below the sea floor and associated with permafrost soils. This reservoir intuitively seems precarious, because hydrate ice floats in water, and melts at Earth surface conditions. The hydrate reservoir is so large that if 10% of the methane were released to the atmosphere within a few years, it would have an impact on the Earth's radiation budget equivalent to a factor of 10 increase in atmospheric CO<sub>2</sub>. Hydrates are releasing methane to the atmosphere today in response to anthropogenic warming, for example along the Arctic coastline of Siberia. However most of the hydrates are located at depths in soils and ocean sediments where anthropogenic warming and any possible methane release will take place over time scales of millennia. Individual catastrophic releases like landslides and pockmark explosions are too small to reach a sizable fraction of the hydrates. The carbon isotopic excursion at the end of the Paleocene has been interpreted as the release of thousands of Gton C, possibly from hydrates, but the time scale of the release appears to have been thousands of years, chronic rather than catastrophic. The potential climate impact in the coming century from hydrate methane release is speculative but could be comparable to climate feedbacks from the terrestrial biosphere and from peat, significant but not catastrophic. On geologic timescales, it is conceivable that hydrates could release as much carbon to the atmosphere/ocean system as we do by fossil fuel combustion.

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Brandt, A.R. and Farrell, A.E. **Scraping the bottom of the barrel: greenhouse gas emission consequences of a transition to low-quality and synthetic petroleum resources.** *Climatic Change* 84(3-4): 241-263, 2007.

**Notes:** We investigate uncertainties about conventional petroleum resources and substitutes for conventional petroleum, focusing on the impact of these uncertainties on future greenhouse gas (GHG) emissions. We use examples from the IPCC Special Report on Emissions Scenarios as a baseline for comparison. The studied uncertainties include, (1) uncertainty in emissions factors for petroleum substitutes, (2) uncertainties resulting from poor knowledge of the amount of remaining conventional petroleum, and (3) uncertainties about the amount of production of petroleum substitutes from natural gas and

coal feedstocks. We find that the potential effects of a transition to petroleum substitutes on GHG emissions are significant. A transition to low-quality and synthetic petroleum resources such as tar sands or coal-to-liquids synfuels could raise upstream GHG emissions by several gigatonnes of carbon (GtC) per year by mid-century unless mitigation steps are taken.

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Aronson, R.B., Thatje, S., Clarke, A., Peck, L.S., Blake, D.B., Wilga, C.D., and Seibel, B.A. **Climate change and invasibility of the Antarctic benthos.** *Annual Review of Ecology, Evolution, and Systematics* 38: 129-154, 2007.

**Notes:** Benthic communities living in shallow-shelf habitats in Antarctica (<100-m depth) are archaic in their structure and function. Modern predators, including fast-moving, durophagous (skeleton-crushing) bony fish, sharks, and crabs, are rare or absent; slow-moving invertebrates are the top predators; and epifaunal suspension feeders dominate many soft substratum communities. Cooling temperatures beginning in the late Eocene excluded durophagous predators, ultimately resulting in the endemic living fauna and its unique food-web structure. Although the Southern Ocean is oceanographically isolated, the barriers to biological invasion are primarily physiological rather than geographic. Cold temperatures impose limits to performance that exclude modern predators. Global warming is now removing those physiological barriers, and crabs are reinvading Antarctica. As sea temperatures continue to rise, the invasion of durophagous predators will modernize the shelf benthos and erode the indigenous character of marine life in Antarctica.

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Trathan, P.N., Forcada, J., and Murphy, E.J. **Environmental forcing and Southern Ocean marine predator populations: effects of climate change and variability.** *Philosophical Transactions of the Royal Society of London [B]* 362(1488): 2351-2365, 2007.

**Notes:** The Southern Ocean is a major component within the global ocean and climate system and potentially the location where the most rapid climate change is most likely to happen, particularly in the high-latitude polar regions. In these regions, even small temperature changes can potentially lead to major environmental perturbations. Climate change is likely to be regional and may be expressed in various ways, including alterations to climate and weather patterns across a variety of time-scales that include changes to the long interdecadal background signals such as the development of the El Niño-Southern Oscillation (ENSO). Oscillating climate signals such as ENSO potentially provide a unique opportunity to explore how biological communities respond to change. This approach is based on the premise that biological responses to shorter-term sub-decadal climate variability signals are potentially the best predictor of biological responses over longer time-scales. Around the Southern Ocean, marine predator populations show periodicity in breeding performance and productivity, with relationships with the environment driven by physical forcing from the ENSO region in the Pacific. Wherever examined, these relationships are congruent with mid-trophic-level processes that are also correlated with environmental variability. The short-term changes to ecosystem structure and function observed during ENSO events herald potential long-term changes that may ensue following regional climate change. For example, in the South Atlantic, failure of Antarctic krill recruitment will inevitably foreshadow recruitment failures in a range of higher trophic-level marine predators. Where predator species are not able to accommodate by switching to other prey species, population-level changes will follow. The Southern Ocean, though oceanographically interconnected, is not a single ecosystem and different areas are dominated by different food webs. Where species occupy different positions in different regional food webs, there is the potential to make predictions about future change scenarios.

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Roe, G.H. and Baker, M.B. **Why is climate sensitivity so unpredictable?** *Science* 318(5850): 629-632, 2007.

**Notes:** Uncertainties in projections of future climate change have not lessened substantially in past decades. Both models and observations yield broad probability distributions for long-term increases in global mean temperature expected from the doubling of atmospheric carbon dioxide, with small but finite probabilities of very large increases. We show that the shape of these probability distributions is an inevitable and general consequence of the nature of the climate system, and we derive a simple analytic form for the shape that fits recent published distributions very well. We show that the breadth of the distribution and, in particular, the probability of large temperature increases are relatively insensitive to decreases in uncertainties associated with the underlying climate processes.

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Schuster, U. and Watson, A.J. **A variable and decreasing sink for atmospheric CO<sub>2</sub> in the North Atlantic.** *Journal of Geophysical Research* 112(11): art. C11006, 2007.

**Notes:** A time series of observations from merchant ships between the U.K. and the Caribbean is used to establish the variability of sea surface  $p\text{CO}_2$  and air-to-sea flux from the mid-1990s to early 2000s. We show that the sink for atmospheric CO<sub>2</sub> exhibits important interannual variability, which is in phase across large regions from year to year. Additionally, there has been an interdecadal decline, evident throughout the study region but especially significant in the northeast of the area covered, with the sink reducing >50% from the mid-1990s to the period 2002-2005. A review of available observations suggests a large region of decrease covering much of the North Atlantic but excluding the western subtropical areas. We estimate that the uptake of the region between 20°N and 65°N declined by ~0.24 Pg C a<sup>-1</sup> from 1994/1995 to 2002-2005. Declining rates of wintertime mixing and ventilation between surface and subsurface waters due to increasing stratification, linked to variation in the North Atlantic Oscillation, are suggested as the main cause of the change. These are exacerbated by a contribution from the changing buffer capacity of the ocean water, as the carbon content of surface waters increases.

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Kloster, S., Six, K.D., Feichter, J., Maier-Reimer, E., Roeckner, E., Wetzel, P., Stier, P., and Esch, M. **Response of dimethylsulfide (DMS) in the ocean and atmosphere to global warming.** *Journal of Geophysical Research - Biogeosciences* 112(G3): art. G03005, 2007.

**Notes:** A global coupled ocean-atmosphere modeling system is applied in a transient climate simulation to study the response to global warming of dimethylsulfide (DMS) in the ocean, the DMS flux to the atmosphere, and the resulting DMS concentrations in the atmosphere. The DMS production and consumption processes in the ocean are linked to plankton dynamics simulated in the marine biogeochemistry model HAMOCC5.1, embedded in an ocean general circulation model (MPI-OM). The atmospheric model ECHAM5 is extended by the microphysical aerosol model HAM, treating the sulfur chemistry in the atmosphere and the evolution of microphysically interacting internally and externally mixed aerosol populations. For future conditions (2000-2100) we assume greenhouse gas concentrations, aerosol and aerosol precursor emissions according to the SRES A1B scenario. We analyzed the results in terms of simulated changes between the period 1861-1890 and 2061-2090. For the global annual mean DMS sea surface concentration and the DMS flux we found a reduction by 10%. The DMS burden in the atmosphere is reduced by only 3%, owing to a longer lifetime of DMS in the atmosphere in a warmer climate (+7%). Regionally the response and the underlying mechanisms are quite inhomogeneous. The largest reduction in the DMS sea surface concentration is simulated in the Southern Ocean (-40%) caused by an increase in the summer mixed layer depth, leading to less favorable light conditions for phytoplankton growth. In the mid and low latitudes DMS sea surface concentrations are predominantly reduced due to nutrient limitation of the phytoplankton growth through higher ocean stratification and less transport of nutrients into the surface layers.

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Holland, M.M., Finnis, J., Barrett, A.P., and Serreze, M.C. **Projected changes in Arctic Ocean freshwater budgets.** *Journal of Geophysical Research - Biogeosciences* 112(G4): art. G04S55, 2007.

**Notes:** Arctic Ocean freshwater budgets are examined from 10 models participating in the Intergovernmental Panel on Climate Change Fourth Assessment Report. This includes an analysis of sea ice transport and storage, ocean transport and storage, and net surface flux exchange. Simulated budgets for the late 20th century are compared to available observations, followed by an analysis of simulated changes from 1950 to 2050. The consistent theme over this period is an acceleration of the Arctic hydrological cycle, which is expressed as an increase in the flux of water passing through the hydrologic elements. Increased freshwater inputs to the ocean from net precipitation, river runoff, and net ice melt result. While generally attended by a larger export of liquid freshwater to lower latitudes, primarily through Fram Strait, liquid freshwater storage in the Arctic Ocean increases. In contrast, the export and storage of freshwater in the form of sea ice decreases. The qualitative agreement between models for which the only common forcing is rising greenhouse gas concentrations implicates this greenhouse gas loading as the cause of the change. Although the models perform quite well in their simulations of net precipitation over the Arctic Ocean and terrestrial drainage, they differ significantly regarding the magnitude of the trends and their representation of contemporary mean ocean and sea ice budget terms. To reduce uncertainty in future projections of the Arctic freshwater cycle, the climate models as a group require considerable improvement in these aspects of their simulations.

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Whitney, F.A., Freeland, H.J., and Robert, M. **Persistently declining oxygen levels in the interior waters of the eastern subarctic Pacific.** *Progress in Oceanography* 75(2): 179-199, 2007.

**Notes:** Fifty years of measurements at Ocean Station Papa (OSP, 50°N, 145°W) show trends in the interior waters of the subarctic Pacific that are both impacted by short term (few years to bi-decadal) atmospheric or ocean circulation oscillations and by persistent climate trends. Between 1956 and 2006, waters below the ocean mixed layer to a depth of at least 1000 m have been warming and losing oxygen. On density surfaces found in the depth range 100-400 m ( $\sigma_\theta = 26.3-27.0$ ), the ocean is warming at 0.005-0.012°C y<sup>-1</sup>, whereas oxygen is declining at 0.39-0.70  $\mu\text{mol kg}^{-1} \text{ y}^{-1}$  or at an integrated rate of 123 mmol m<sup>-2</sup> y<sup>-1</sup> (decrease of 22% over 50 years). During this time, the hypoxic boundary (defined as 60  $\mu\text{mol O}_2 \text{ kg}^{-1}$ ) has shoaled from ~400 to 300 m. In the Alaska Gyre, the 26.2 isopycnal occasionally ventilates, whereas at OSP 26.0 $\sigma_\theta$  has not been seen at the ocean surface since 1971 as the upper ocean continues to stratify. To interpret the 50 year record at OSP, the isopycnal transport of oxygenated waters within the interior of the subarctic Pacific is assessed by using a slightly modified "NO" parameter [Broecker, W., 1974. "NO" a conservative water-mass tracer. *Earth and Planetary Science Letters* 23, 100-107]. The highest nitrate-oxygen signature in interior waters of the North Pacific is found in the Bering Sea Gyre, Western Subarctic Gyre and East Kamchatka Current region as a consequence of winter mixing to the ~26.6 isopycnal. By mixing with low NO waters found in the subtropics and Okhotsk Sea, this signature is diluted as waters flow eastward across the Pacific. Evidence of low NO waters flowing north from California is seen along the coasts of British Columbia and SE Alaska. Oxygen in the subsurface waters of the Alaskan Gyre was supplied ~60% by subarctic and 40% by subtropical waters during WOCE surveys, whereas such estimates are shown to periodically vary by 20% at OSP. Other features discernable in the OSP data include periods of increased ventilation of deeper isopycnals on an ~18 year cycle and strong, short term (few month) variability caused by passing mesoscale eddies. The potential impacts of declining oxygen on coastal ecosystems are discussed.

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Mackas, D.L., Batten, S., and Trudel, M. **Effects on zooplankton of a warmer ocean: Recent evidence from the Northeast Pacific.** *Progress in Oceanography* 75(2): 223-252, 2007.

**Notes:** The consequences for pelagic communities of warming trends in mid and high latitude ocean regions could be substantial, but their magnitude and trajectory are not yet known. Environmental changes predicted by climate models (and beginning to be confirmed by observations) include warming and freshening of the upper ocean and reduction in the extent and duration of ice cover. One way to evaluate response scenarios is by comparing how "similar" zooplankton communities have differed among years and/or locations with differing temperature. The subarctic Pacific is a strong candidate for such comparisons, because the same mix of zooplankton species dominates over a wide range of temperature climatologies, and observations have spanned substantial temperature variability at interannual-to-decadal time scales. In this paper, we review and extend copepod abundance and phenology time series from net tow and Continuous Plankton Recorder surveys in the subarctic Northeast Pacific. The two strongest responses we have observed are latitudinal shifts in centers of abundance of many species (poleward under warm conditions), and changes in the life cycle timing of *Neocalanus plumchrus* in both oceanic and coastal regions (earlier by several weeks in warm years and at warmer locations). These zooplankton data, plus indices of higher trophic level responses such as reproduction, growth and survival of pelagic fish and seabirds, are all moderately-to-strongly intercorrelated ( $|r| = 0.25-0.8$ ) with indices of local and basin-scale temperature anomalies. A principal components analysis of the normalized anomaly time series from 1979 to 2004 shows that a single "warm-and-low-productivity" vs. "cool-and-high-productivity" component axis accounts for over half of the variance/covariance. Prior to 1990, the scores for this component were negative ("cool" and "productive") or near zero except positive in the El Niño years 1983 and 1987. The scores were strongly and increasingly positive ("warm" and "low productivity") from 1992 to 1998; negative from 1999 to 2002; and again increasingly positive from 2003-present. We suggest that, in strongly seasonal environments, anomalously high temperature may provide misleading environmental cues that contribute to timing mismatch between life history events and the more-nearly-fixed seasonality of insolation, stratification, and food supply.

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Vallina, S.M., Simó, R., and Manizza, M. **Weak response of oceanic dimethylsulfide to upper mixing shoaling induced by global warming.** *Proceedings of the National Academy of Sciences [USA]* 104(41): 16004-16009, 2007.

**Notes:** The solar radiation dose in the oceanic upper mixed layer (SRD) has recently been identified as the main climatic force driving global dimethylsulfide (DMS) dynamics and seasonality. Because DMS is suggested to exert a cooling effect on the earth radiative budget through its involvement in the formation and optical properties of tropospheric clouds over the ocean, a

positive relationship between DMS and the SRD supports the occurrence of a negative feedback between the oceanic biosphere and climate, as postulated 20 years ago. Such a natural feedback might partly counteract anthropogenic global warming through a shoaling of the mixed layer depth (MLD) and a consequent increase of the SRD and DMS concentrations and emission. By applying two globally derived DMS diagnostic models to global fields of MLD and chlorophyll simulated with an Ocean General Circulation Model coupled to a biogeochemistry model for a 50% increase of atmospheric CO<sub>2</sub> and an unperturbed control run, we have estimated the response of the DMS-producing pelagic ocean to global warming. Our results show a net global increase in surface DMS concentrations, especially in summer. This increase, however, is so weak (globally 1.2%) that it can hardly be relevant as compared with the radiative forcing of the increase of greenhouse gases. This contrasts with the seasonal variability of DMS (1000-2000% summer-to-winter ratio). We suggest that the "plankton-DMS-clouds-earth albedo feedback" hypothesis is less strong a long-term thermostatic system than a seasonal mechanism that contributes to regulate the solar radiation doses reaching the earth's biosphere.

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Canadell, J.G., Le Quéré, C., Raupach, M.R., Field, C.B., Buitenhuis, E.T., Ciais, P., Conway, T.J., Gillett, N.P., Houghton, R.A., and Marland, G. **Contributions to accelerating atmospheric CO<sub>2</sub> growth from economic activity, carbon intensity, and efficiency of natural sinks.** *Proceedings of the National Academy of Sciences [USA]* 104(47): 18866-18870, 2007.  
O/A

**Notes:** The growth rate of atmospheric carbon dioxide (CO<sub>2</sub>), the largest human contributor to human-induced climate change, is increasing rapidly. Three processes contribute to this rapid increase. Two of these processes concern emissions. Recent growth of the world economy combined with an increase in its carbon intensity have led to rapid growth in fossil fuel CO<sub>2</sub> emissions since 2000: comparing the 1990s with 2000-2006, the emissions growth rate increased from 1.3% to 3.3% yr<sup>-1</sup>. The third process is indicated by increasing evidence ( $P = 0.89$ ) for a long-term (50-year) increase in the airborne fraction (AF) of CO<sub>2</sub> emissions, implying a decline in the efficiency of CO<sub>2</sub> sinks on land and oceans in absorbing anthropogenic emissions. Since 2000, the contributions of these three factors to the increase in the atmospheric CO<sub>2</sub> growth rate have been  $\sim 65 \pm 16\%$  from increasing global economic activity,  $17 \pm 6\%$  from the increasing carbon intensity of the global economy, and  $18 \pm 15\%$  from the increase in AF. An increasing AF is consistent with results of climate-carbon cycle models, but the magnitude of the observed signal appears larger than that estimated by models. All of these changes characterize a carbon cycle that is generating stronger-than-expected and sooner-than-expected climate forcing.

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Vazquez-Dominguez, E., Vaque, D., and Gasol, A.M. **Ocean warming enhances respiration and carbon demand of coastal microbial plankton.** *Global Change Biology* 13(7): 1327-1334, 2007.

**Notes:** The increase of anthropogenic CO<sub>2</sub> during this century is expected to cause warming of large regions of the ocean. Microbes lead the biological role in the CO<sub>2</sub> balance of marine ecosystems, their activity is known to be influenced by temperature, and it is important to constrain and quantify these effects on bacterial carbon use. Furthermore, if warming were to enhance the carbon demand (production + respiration) of planktonic microbes but would maintain their efficiency low (as it generally is), then most carbon consumed would end up respired. We designed a strategy in which we measured bacterial production and respiration throughout a seasonal cycle in a coastal Mediterranean site, and determined experimentally the effects of ca. 2.5°C on these processes. We show that warming will increase nearly 20% the total carbon demand of coastal microbial plankton without any effect on their (commonly low) growth efficiency, which could generate a positive feedback between coastal warming and CO<sub>2</sub> production.

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MacKenzie, B.R. and Schiedek, D. **Daily ocean monitoring since the 1860s shows record warming of northern European seas.** *Global Change Biology* 13(7): 1335-1347, 2007.

**Notes:** Ocean temperatures in most parts of the world are increasing and are expected to continue to rise during the 21st century. A major challenge to ecologists and marine resource managers is to understand and predict how these global changes will affect species and ecosystems at local scales where temperature more directly affects biological responses and species interactions. Here, we investigate historical variability in regional sea surface temperature in two large heavily exploited marine ecosystems and compare these variations with expected rates of temperature change for the 21st century. We use four of the world's longest calibrated daily time series to show that trends in surface temperatures in the North and Baltic Seas now

exceed those at any time since instrumented measurements began in 1861 and 1880. Temperatures in summer since 1985 have increased at nearly triple the global warming rate, which is expected to occur during the 21st century and summer temperatures have risen two to five times faster than those in other seasons. These warm temperatures and rates of change are due partly to an increase in the frequency of extremely warm years. The recent warming event is exceeding the ability of local species to adapt and is consequently leading to major changes in the structure, function and services of these ecosystems.

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Swanson, A.K. and Fox, C.H. **Altered kelp (Laminariales) phlorotannins and growth under elevated carbon dioxide and ultraviolet-B treatments can influence associated intertidal food webs.** *Global Change Biology* 13(8): 1696-1709, 2007.

**Notes:** Due to the importance of brown algae, such as kelp (Laminariales, Phaeophyta), within most cool nearshore environments, any direct responses of kelp to multiple global changes could alter the integrity of future coastal marine systems. Fifty-five-day manipulation of carbon dioxide (CO<sub>2</sub>) and ultraviolet light (UVB) within outdoor sea-tanks, approximating past, present and two predicted future levels, examined the direct influences on *Saccharina latissima* (= *Laminaria saccharina*) and *Nereocystis luetkeana* development and biochemistry, as well as the indirect influences on a marine herbivore (*Tegula funebris*; Gastropoda, Mollusca) and on naturally occurring intertidal detritivores. Kelp species displayed variable directional (negative and positive growth) and scale responses to CO<sub>2</sub> and UVB manipulations, which was influenced by interactions. Kelp phlorotannin (phenolic) production in blade tissues was induced by elevated UVB levels, and especially enhanced (additively) by elevated CO<sub>2</sub>, further suggesting that some actively growing kelp species are carbon limited in typical nearshore environments. Negative indirect effects upon detritivore consumers fed CO<sub>2</sub>-manipulated kelp blade tissues were detected, however, no statistical relationships existed among UVB-treated tissues, and test herbivores did not distinguish between phlorotannin-altered CO<sub>2</sub>:UVB-treated kelp blade tissues. Results suggest that past and future conditions differentially benefit these kelp species, which implies a potential for shifts in species abundance and community composition. Higher CO<sub>2</sub> conditions can indirectly impede marine decay processes delaying access to recycled trace nutrients, which may be disruptive to the seasonal regrowth of algae and/or higher trophic levels of nearshore ecosystems.

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Reid, P.C., Johns, D.G., Edwards, M., Starr, M., Poulin, M., and Snoeijs, P. **A biological consequence of reducing Arctic ice cover: arrival of the Pacific diatom *Neodenticula seminae* in the North Atlantic for the first time in 800,000 years.** *Global Change Biology* 13(9): 1910-1921, 2007.

**Notes:** The Continuous Plankton Recorder survey has monitored plankton in the Northwest Atlantic at monthly intervals since 1962, with an interregnum between 1978 and 1990. In May 1999, large numbers of the Pacific diatom *Neodenticula seminae* were found in Continuous Plankton Recorder (CPR) samples in the Labrador Sea as the first record in the North Atlantic for more than 800 000 years. The event coincided with modifications in Arctic hydrography and circulation, increased flows of Pacific water into the Northwest Atlantic and in the previous year the exceptional occurrence of extensive ice-free water to the North of Canada. These observations indicate that *N. seminae* was carried in a pulse of Pacific water in 1998/early 1999 via the Canadian Arctic Archipelago and/or Fram Strait. The species occurred previously in the North Atlantic during the Pleistocene ~ 1.2 to ~ 0.8 Ma as recorded in deep sea sediment cores. The reappearance of *N. seminae* in the North Atlantic is an indicator of the scale and speed of changes that are taking place in the Arctic and North Atlantic oceans as a consequence of regional climate warming. Because of the unusual nature of the event it appears that a threshold has been passed, marking a change in the circulation between the North Pacific and North Atlantic Oceans via the Arctic. Trans-Arctic migrations from the Pacific into the Atlantic are likely to occur increasingly over the next 100 years as Arctic ice continues to melt affecting Atlantic biodiversity and the biological pump with consequent feedbacks to the carbon cycle.

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Sutherst, R.W., Maywald, G.F., and Bourne, A.S. **Including species interactions in risk assessments for global change.** *Global Change Biology* 13(9): 1843-1859, 2007.

**Notes:** Most ecological risk assessments for global change are restricted to the effects of trends in climate or atmospheric carbon dioxide. In order to move beyond investigation of the effects of climate alone, the CLIMAX (TM) model was extended to investigate the effects of species interactions, in the same or different trophic levels, along environmental gradients on a geographical scale. Specific needs that were revealed during the investigations include: better treatment of the effects of temporal and spatial climatic variation; elucidation of the nature of boundaries of species ranges; data to quantify the role of

species traits in interspecies interactions; integrated observational, experimental, and modelling studies on mechanisms of species interactions along environmental gradients; and high-resolution global environmental datasets. Greater acknowledgement of the shared limitations of simplified models and experimental studies is also needed. Above all, use of the scientific method to understand representative species ranges is essential. This requires the use of mechanistic approaches capable of progressive enhancement.

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Meehl, G.A., Arblaster, J.M., and Tebaldi, C. **Contributions of natural and anthropogenic forcing to changes in temperature extremes over the United States.** *Geophysical Research Letters* 34(19): art. L19709, 2007.

**Notes:** Observations averaged over the U.S. for the second half of the 20th century have shown a decrease of frost days, an increase in growing season length, an increase in the number of warm nights, and an increase in heat wave intensity. For the first three, a nine member multi-model ensemble shows similar changes over the U.S. in 20th century experiments that combine anthropogenic and natural forcings, though the relative contributions of each are unclear. Here we show results from two global coupled climate models run with anthropogenic and natural forcings separately. Averaged over the continental U.S., they show that the observed changes in the four temperature extremes are accounted for with anthropogenic forcings, but not with natural forcings (even though there are some differences in the details of the forcings). This indicates that most of the changes in temperature extremes over the U.S. are likely due to human activity.

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Montenegro, A., Brovkin, V., Eby, M., Archer, D., and Weaver, A.J. **Long term fate of anthropogenic carbon.** *Geophysical Research Letters* 34(19): art. L19707, 2007.

**Notes:** Two earth-system models of intermediate complexity are used to study the long term response to an input of 5000 Pg of carbon into the atmosphere. About 75% of CO<sub>2</sub> emissions have an average perturbation lifetime of 1800 years and 25% have lifetimes much longer than 5000 years. In the simulations, higher levels of atmospheric CO<sub>2</sub> remain in the atmosphere than predicted by previous experiments and the average perturbation lifetime of atmospheric CO<sub>2</sub> for this level of emissions is much longer than the 300-400 years proposed by other studies. At year 6800, CO<sub>2</sub> concentrations between about 960 to 1440 ppmv result in global surface temperature increases between 6 and 8°C. There is also significant surface ocean acidification, with pH decreasing from 8.16 to 7.46 units between years 2000 and 2300.

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Perovich, D.K., Light, B., Eicken, H., Jones, K.F., Runciman, K., and Nghiem, S.V. **Increasing solar heating of the Arctic Ocean and adjacent seas, 1979-2005: Attribution and role in the ice-albedo feedback.** *Geophysical Research Letters* 34(19): art. L19505, 2007.

**Notes:** Over the past few decades the Arctic sea ice cover has decreased in areal extent. This has altered the solar radiation forcing on the Arctic atmosphere-ice-ocean system by decreasing the surface albedo and allowing more solar heating of the upper ocean. This study addresses how the amount of solar energy absorbed in areas of open water in the Arctic Basin has varied spatially and temporally over the past few decades. A synthetic approach was taken, combining satellite-derived ice concentrations, incident irradiances determined from reanalysis products, and field observations of ocean albedo over the Arctic Ocean and the adjacent seas. Results indicate an increase in the solar energy deposited in the upper ocean over the past few decades in 89% of the region studied. The largest increases in total yearly solar heat input, as much as 4% per year, occurred in the Chukchi Sea and adjacent areas.

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Rösevall, J.D., Murtagh, D.P., and Urban, J. **Ozone depletion in the 2006/2007 Arctic winter.** *Geophysical Research Letters* 34(21): art. L21809, 2007.

**Notes:** Ozone depletion in the 2006/2007 Arctic winter is studied by assimilating ozone from the Odin/SMR satellite instrument into a 2-D isentropic transport model. Cross-isentropic transport is implemented by letting the vortex descend at a rate estimated from the inert tracer N<sub>2</sub>O. Ozone depletion is estimated by comparing ozone fields, passively transported in the model from 1 January 2007, to model fields continuously updated by assimilation of incoming satellite data. Significant ozone

destruction is inferred in February and March 2007. By 15 March, an average ozone destruction in the range 0.5-1.0 ppmv is estimated north of 65° equivalent latitude at 475 K potential temperature, whilst 0.3-0.8 ppmv and 0.4-0.8 ppmv ozone destruction is estimated at 525 K and 575 K. By comparing the 2007 ozone depletion to losses inferred in 2003 and 2005 we conclude that the 2007 Arctic ozone destruction is the most severe found in the Odin/SMR data set.

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Copland, L., Mueller, D.R., and Weir, L. **Rapid loss of the Ayles Ice Shelf, Ellesmere Island, Canada.** *Geophysical Research Letters* 34(21): art. L21501, 2007.

**Notes:** On August 13, 2005, almost the entire Ayles Ice Shelf (87.1 km<sup>2</sup>) calved off within an hour and created a new 66.4 km<sup>2</sup> ice island in the Arctic Ocean. This loss of one of the six remaining Ellesmere Island ice shelves reduced their overall area by ~7.5%. The ice shelf was likely weakened prior to calving by a long-term negative mass balance related to an increase in mean annual temperatures over the past 50+ years. The weakened ice shelf then calved during the warmest summer on record in a period of high winds, record low sea ice conditions and the loss of a semi-permanent landfast sea ice fringe. Climate reanalysis suggests that a threshold of >200 positive degree days year<sup>-1</sup> is important in determining when ice shelf calving events occur on N. Ellesmere Island.

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Chen, J.L., Wilson, C.R., Tapley, B.D., Blankenship, D.D., and Ivins, E.R. **Patagonia Icefield melting observed by Gravity Recovery and Climate Experiment (GRACE).** *Geophysical Research Letters* 34(22): art. L22501, 2007.

**Notes:** Using recently released reprocessed gravity solutions from the Gravity Recovery and Climate Experiment (GRACE), we estimate the ice loss rate for the Patagonia Icefield (PIF) of South America, for the period April 2002 through December 2006. After postglacial rebound and hydrological effects are corrected, the estimated rate is  $-27.9 \pm 11$  km<sup>3</sup>/year, equivalent to an average loss of  $\sim -1.6$  m/year ice thickness change if evenly distributed over the entire PIF area. The estimated contribution to global sea level rise is  $0.078 \pm 0.031$  mm/year. This is an independent confirmation of relatively large melting rate estimates from earlier studies employing topographic and cartographic data.

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Levine, J.S., Matter, J.M., Goldberg, D., Cook, A., and Lackner, K.S. **Gravitational trapping of carbon dioxide in deep sea sediments: Permeability, buoyancy, and geomechanical analysis.** *Geophysical Research Letters* 34(24): art. L24703, 2007.

**Notes:** Liquid carbon dioxide injected in deep-sea sediments at km depths and near freezing temperatures is denser than surrounding pore water and will be trapped by gravitational forces. Storage capacity for CO<sub>2</sub> in such formations below the ocean floor is shown to vary with seafloor depth, geothermal gradient, porosity, and pore water salinity. The formation permeability, or the successful engineering of such permeability through hydraulic fracturing, will determine the capacity for gravitational trapping in deep-sea geological formations. We conclude that most ocean sediments at appropriate depth will lack the required permeability and that conventional hydraulic fracturing would only be possible in carefully selected sites.

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Maslanik, J.A., Fowler, C., Stroeve, J., Drobot, S., Zwally, J., Yi, D., and Emery, W. **A younger, thinner Arctic ice cover: Increased potential for rapid, extensive sea-ice loss.** *Geophysical Research Letters* 34(24): art. L24501, 2007.

**Notes:** Satellite-derived estimates of sea-ice age and thickness are combined to produce a proxy ice thickness record for 1982 to the present. These data show that in addition to the well-documented loss of perennial ice cover as a whole, the amount of oldest and thickest ice within the remaining multiyear ice pack has declined significantly. The oldest ice types have essentially disappeared, and 58% of the multiyear ice now consists of relatively young 2- and 3-year-old ice compared to 35% in the mid-1980s. Ice coverage in summer 2007 reached a record minimum, with ice extent declining by 42% compared to conditions in the 1980s. The much-reduced extent of the oldest and thickest ice, in combination with other factors such as ice transport that assist the ice-albedo feedback by exposing more open water, help explain this large and abrupt ice loss.