

# Marine Science Review – 164

## Climate and climate change



### In this review:

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

## A. Recent articles – no abstract available

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Keith, D.W., Giardina, J.A., Morgan, M.G., and Wilson, E.J. **Regulating the underground injection of CO<sub>2</sub>.** *Environmental Science and Technology* 39(24): 499A-505A, 2005.

Schiermeier, Q. **The costs of global warming.** *Nature* 439(7075): 374-375, 2006.

Doney, S.C. **The dangers of ocean acidification.** *Scientific American* : 58-65, 2006.

## B. Recent publications available online

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Levin, K. and Pershing, J. 2006. **Climate Science 2005: Major New Discoveries.** WRI Issue Brief, March. World Resources Institute, Washington, DC. 16pp.

**Available at:** [http://pdf.wri.org/climatescience\\_2005.pdf](http://pdf.wri.org/climatescience_2005.pdf)

**Notes:** A wide body of scientific and technical literature was reviewed in the preparation of this issue brief, including key general science journals (*Nature* and *Science*), several technical journals (*Geophysical Research Letters*, *Annals of the Missouri Botanical Gardens*, *Ecology Letters*, *Ecology*, *Environment International*, and *Journal of Climate*) and material from key web sites and international organizations (RealScience.org, the UN's Food and Agriculture Organization, the U.S. Department of Energy, and others). Each scientific paper is briefly described, along with the full citation to the original paper, and a short comment regarding the implications of each discovery is offered.

## C. Recent articles with abstracts

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Donner, S.D., Skirving, W.J., Little, C.M., Oppenheimer, M., and Hoegh-Guldberg, O. **Global assessment of coral bleaching and required rates of adaptation under climate change.** *Global Change Biology* 11(12): 2251-2265, 2005.

**Notes:** Elevated ocean temperatures can cause coral bleaching, the loss of colour from reef-building corals because of a breakdown of the symbiosis with the dinoflagellate *Symbiodinium*. Recent studies have warned that global climate change could increase the frequency of coral bleaching and threaten the long-term viability of coral reefs. These assertions are based on projecting the coarse output from atmosphere-ocean general circulation models (GCMs) to the local conditions around representative coral reefs. Here, we conduct the first comprehensive global assessment of coral bleaching under climate change by adapting the NOAA Coral Reef Watch bleaching prediction method to the output of a low- and high-climate sensitivity GCM. First, we develop and test algorithms for predicting mass coral bleaching with GCM-resolution sea surface temperatures for thousands of coral reefs, using a global coral reef map and 1985-2002 bleaching prediction data. We then use

the algorithms to determine the frequency of coral bleaching and required thermal adaptation by corals and their endosymbionts under two different emissions scenarios. The results indicate that bleaching could become an annual or biannual event for the vast majority of the world's coral reefs in the next 30-50 years without an increase in thermal tolerance of 0.2- 1.0° C per decade. The geographic variability in required thermal adaptation found in each model and emissions scenario suggests that coral reefs in some regions, like Micronesia and western Polynesia, may be particularly vulnerable to climate change. Advances in modelling and monitoring will refine the forecast for individual reefs, but this assessment concludes that the global prognosis is unlikely to change without an accelerated effort to stabilize atmospheric greenhouse gas concentrations.

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Parks, B.C. and Roberts, J.T. **Globalization, vulnerability to climate change, and perceived injustice.** *Society and Natural Resources* 19(4): 337-355, 2006.

**Notes:** As the earth's climate begins to shift into a hotter and less predictable period, there is a basic injustice in who will suffer worst and first. Nations facing rising oceans and drought are those least responsible for the problem, and they have the least resources to cope with them. To evaluate claims of environmental injustice, we examine three cases where the first signs of climate change are being felt worst and first: murderous flooding from Hurricane Mitch in Honduras, rising sea levels swamping entire Pacific Island atoll nations, and devastation from flooding among squatter settlements in Mozambique. In each case these nations are suffering not only because of bad geography or management. Rather, because of their colonial past and current positions in the world economy, they are brutally vulnerable to forces outside their control. We conclude by offering an explanation for generalized mistrust among Southern nations vis-à-vis Northern nations and the Kyoto treaty.

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Harley, C.D.G., Hughes, A.R., Hultgren, K.M., Miner, B.G., Sorte, C.J.B., Thornber, C.S., Rodriguez, L.F., Tomanek, L., and Williams, S.L. **The impacts of climate change in coastal marine systems.** *Ecology Letters* 9(2): 228-241, 2006.

**Notes:** Anthropogenically induced global climate change has profound implications for marine ecosystems and the economic and social systems that depend upon them. The relationship between temperature and individual performance is reasonably well understood, and much climate-related research has focused on potential shifts in distribution and abundance driven directly by temperature. However, recent work has revealed that both abiotic changes and biological responses in the ocean will be substantially more complex. For example, changes in ocean chemistry may be more important than changes in temperature for the performance and survival of many organisms. Ocean circulation, which drives larval transport, will also change, with important consequences for population dynamics. Furthermore, climatic impacts on one or a few 'leverage species' may result in sweeping community-level changes. Finally, synergistic effects between climate and other anthropogenic variables, particularly fishing pressure, will likely exacerbate climate-induced changes. Efforts to manage and conserve living marine systems in the face of climate change will require improvements to the existing predictive framework. Key directions for future research include identifying key demographic transitions that influence population dynamics, predicting changes in the community-level impacts of ecologically dominant species, incorporating populations' ability to evolve (adapt), and understanding the scales over which climate will change and living systems will respond.

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Peterson, S. **Uncertainty and economic analysis of climate change: A survey of approaches and findings.** *Environmental Modeling and Assessment* 11(1): 1-17, 2006.

**Notes:** The analysis of climate change is confronted with large uncertainties that need to be taken into account to arrive at meaningful policy recommendations. The main contribution of economics to this interdisciplinary task is to provide formal frameworks and techniques for analyzing climate policy in the context of uncertainty. This paper will give an overview of existing approaches and findings to provide a broad picture of what economics can contribute to the debate.

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Thomas, D.S.G. and Twyman, C. **Equity and justice in climate change: Adaptation amongst natural resource dependant societies.** *Global Environmental Change* 15(2): 115-124, 2005.

**Notes:** Issues of equity and justice are high on international agendas dealing with the impacts of global climate change. But what are the implications of climate change for equity and justice amongst vulnerable groups at local and sub-national levels? We ask this question for three reasons: (a) there is a considerable literature suggesting that the poorest and most vulnerable groups will disproportionately experience the negative effects of 21st century climate change; (b) such changes are likely to impact significantly on developing world countries, where natural-resource dependency is high; and (c) international conventions increasingly recognise the need to centrally engage resource stakeholders in agendas in order to achieve their desired aims, as part of more holistic approaches to sustainable development. These issues however have implications for distributive and procedural justice, particularly when considered within the efforts of the UNFCCC. The issues are examined through an evaluation of key criteria relating to climate change scenarios and vulnerability in the developing world, and second through two southern African case studies that explore the ways in which livelihoods are differentially impacted by (i) inequitable natural-resource use policies, (ii) community-based natural-resource management programmes. Finally, we consider the placement of climate change amongst the package of factors affecting equity in natural-resource use, and whether this placement creates a case for considering climate change as 'special' amongst livelihood disturbing factors in the developing world.

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Lincoln, S.F. **Fossil fuels in the 21st century.** *Ambio* 34(8): 621-627, 2005.

**Notes:** An overview of the importance of fossil fuels in supplying the energy requirements of the 21st century, their future supply, and the impact of their use on global climate is presented. Current and potential alternative energy sources are considered. It is concluded that even with substantial increases in energy derived from other sources, fossil fuels will remain a major energy source for much of the 21st century and the sequestration of CO<sub>2</sub> will be an increasingly important requirement.

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Palfreman, J. **A tale of two fears: Exploring media depictions of nuclear power and global warming.** *Review of Policy Research* 23(1): 23-43, 2006.

**Notes:** Advanced technologies like nuclear power and looming environmental threats such as global climate change present major policy challenge for modern cultures. Public policy about such crucial and complex issues depends on public attitudes, which, in turn, tend to be strongly affected by mass media coverage. How "well" has the mass media portrayed these two evolving risk stories? Employing perspectives from both journalism and social science, this article will first review the history of mass media coverage of each topic, then analyze their differences.

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van Aalst, M.K. **The impacts of climate change on the risk of natural disasters.** *Disasters* 30(1): 5-18, 2006.

**Notes:** Human emissions of greenhouse gases are already changing our climate. This paper provides an overview of the relation between climate change and weather extremes, and examines three specific cases where recent acute events have stimulated debate on the potential role of climate change: the European heatwave of 2003; the risk of inland flooding, such as recently in Central Europe and Great Britain; and the harsh Atlantic hurricane seasons of 2004 and 2005. Furthermore, it briefly assesses the relation between climate change and El Niño, and the potential of abrupt climate change. Several trends in weather extremes are sufficiently clear to inform risk reduction efforts. In many instances, however, the potential increases in extreme events due to climate change come on top of alarming rises in vulnerability. Hence, the additional risks due to climate change should not be analysed or treated in isolation, but instead integrated into broader efforts to reduce the risk of natural disasters.

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Voigt, C. **From climate change to sustainability: An essay on sustainable development, legal and ethical choices.** *World Views: Environment, Culture, Religion* 9(1): 112-137, 2005.

**Notes:** This paper discusses some fundamental impediments to implementing the complex concept of sustainable development within the international legal framework in general, and the climate change regime in particular. It argues that sustainable development should primarily be seen as a normative concept, closely linked to an idea of environmental justice

that incorporates the interests not only of present humans but also of future generations and the non-human environment. The paper explores the relationship between sustainability as a moral idea and sustainability as located in a legal context. It argues for the evolution of a coherent system of ethics and law of sustainability, with particular relevance to decreasing greenhouse gas emissions on a global scale. The importance of multidisciplinary and interdisciplinary research is emphasised. It is suggested that the fundamental challenges posed by a globally changing climate might function as an important impulse to "cross-faculty" research and innovative thinking. The results of such thinking might in turn inform international action in tackling climate change. Although the investigation cannot be exhaustive, this paper aims to serve as an impetus for multidisciplinary research and further discourse on the reconciliation of society and the environment, law and ethics.

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Andersson, A.J., Mackenzie, F.T., and Lerman, A. **Coastal ocean CO<sub>2</sub>–carbonic acid–carbonate sediment system of the Anthropocene.** *Global Biogeochemical Cycles* 20(1): art. GB1S92, 2006.

**Notes:** There is little doubt that human activities such as burning of fossil fuels and land use practices have changed and will continue to change the cycling of carbon in the global coastal ocean. In the present study, two biogeochemical box models were used to investigate the consequences of increasing atmospheric CO<sub>2</sub> and subsequent ocean acidification and increasing riverine transport of organic matter and nutrients arising from human activities on land on the global coastal ocean between the years 1700 and 2300. Numerical simulations show that the net flux of CO<sub>2</sub> between coastal ocean surface water and the atmosphere is likely to change during this time from net evasion to net invasion owing to increasing atmospheric CO<sub>2</sub>, increasing net ecosystem production arising from increasing nutrient loading to this region, and decreasing net ecosystem calcification due to lower carbonate ion concentration and subsequent lower surface water saturation state with respect to carbonate minerals. Model calculations show that surface water saturation state with respect to calcite will decrease 73% by the year 2300 under a business-as-usual scenario, which in concert with increasing temperature will cause overall biogenic calcification rate to decrease by 90%. Dissolution of carbonate minerals increased by 267% throughout the model simulation. This increase was in part due to increased invasion of atmospheric CO<sub>2</sub>, but mainly due to greater deposition and remineralization of land-derived and in situ produced organic matter in the sediments, producing CO<sub>2</sub> that caused pore water pH and carbonate saturation state to decrease. This decrease, in turn, drove selective dissolution of metastable carbonate minerals. As a consequence, the relative carbonate composition of the sediments changed in favor of carbonate phases with lower solubility than that of an average 15 mol% magnesian calcite phase. Model projected changes in surface water carbonate saturation state agree well with observations from the Hawaiian Ocean Time series and the calculated air-sea CO<sub>2</sub> exchange agrees well with a recent independent estimate of this flux derived from measurements from diverse coastal ecosystems scaled up to the global coastal ocean area.

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Wang, M., Overland, J.E., Percival, D.B., and Mofjeld, H.O. **Change in the Arctic influence on Bering Sea climate during the twentieth century.** *International Journal of Climatology* 26(4): 531-539, 2006.

**Notes:** Surface air temperatures (SAT) from three Alaskan weather stations in a north-south section (Barrow, Nome, and St. Paul) show that on a decadal scale, the correlation among the stations changed during the past century. Before the 1960s, Barrow and Nome were dominated by Arctic air masses and St. Paul was dominated by North Pacific maritime air masses. After the 1960s, the SAT correlation in winter between Barrow and St. Paul increased from 0.2 to 0.7 and between Nome and St. Paul from 0.4 to 0.8, implying greater north-south penetration of both air masses. The correlation change in the winter of the Barrow-St. Paul pair is significant at a 95% confidence level. The Nome-St. Paul pair in spring also shows some of this characteristic change in correlation. Relatively stable, high correlations are found among the stations in the fall; correlations are low in the summer. Our study shows a change in the climatological structure of the Bering Sea in the late twentieth century, at present of unknown origin and occurring earlier than the well-known 1976/1977 shift. These climatological results further support the concept that the southeast Bering Sea ecosystem may have been dominated by Arctic species for most of the century, with a gradual replacement by sub-Arctic species in the last 30 years.

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McMichael, A.J., Woodruff, R.E., and Hales, S. **Climate change and human health: present and future risks.** *The Lancet* 367(9513): 859-869, 2006.

**Notes:** There is near unanimous scientific consensus that greenhouse gas emissions generated by human activity will change Earth's climate. The recent (globally averaged) warming by 0.5°C is partly attributable to such anthropogenic emissions. Climate change will affect human health in many ways—mostly adversely. Here, we summarise the epidemiological evidence of how climate variations and trends affect various health outcomes. We assess the little evidence there is that recent global warming has already affected some health outcomes. We review the published estimates of future health effects of climate change over coming decades. Research so far has mostly focused on thermal stress, extreme weather events, and infectious diseases, with some attention to estimates of future regional food yields and hunger prevalence. An emerging broader approach addresses a wider spectrum of health risks due to the social, demographic, and economic disruptions of climate change. Evidence and anticipation of adverse health effects will strengthen the case for pre-emptive policies, and will also guide priorities for planned adaptive strategies.

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Alexander, L.V. and et al. **Global observed changes in daily climate extremes of temperature and precipitation.** *Journal of Geophysical Research* 111(5): art. D05109, 2006.

**Notes:** A suite of climate change indices derived from daily temperature and precipitation data, with a primary focus on extreme events, were computed and analyzed. By setting an exact formula for each index and using specially designed software, analyses done in different countries have been combined seamlessly. This has enabled the presentation of the most up-to-date and comprehensive global picture of trends in extreme temperature and precipitation indices using results from a number of workshops held in data-sparse regions and high-quality station data supplied by numerous scientists world wide. Seasonal and annual indices for the period 1951-2003 were gridded. Trends in the gridded fields were computed and tested for statistical significance. Results showed widespread significant changes in temperature extremes associated with warming, especially for those indices derived from daily minimum temperature. Over 70% of the global land area sampled showed a significant decrease in the annual occurrence of cold nights and a significant increase in the annual occurrence of warm nights. Some regions experienced a more than doubling of these indices. This implies a positive shift in the distribution of daily minimum temperature throughout the globe. Daily maximum temperature indices showed similar changes but with smaller magnitudes. Precipitation changes showed a widespread and significant increase, but the changes are much less spatially coherent compared with temperature change. Probability distributions of indices derived from approximately 200 temperature and 600 precipitation stations, with near-complete data for 1901-2003 and covering a very large region of the Northern Hemisphere midlatitudes (and parts of Australia for precipitation) were analyzed for the periods 1901-1950, 1951-1978 and 1979-2003. Results indicate a significant warming throughout the 20th century. Differences in temperature indices distributions are particularly pronounced between the most recent two periods and for those indices related to minimum temperature. An analysis of those indices for which seasonal time series are available shows that these changes occur for all seasons although they are generally least pronounced for September to November. Precipitation indices show a tendency toward wetter conditions throughout the 20th century.

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Gagnon, A.S. and Gough, W.A. **Trends in the dates of ice freeze-up and breakup over Hudson Bay, Canada.** *Arctic* 58(4): 370-382, 2005.

**Notes:** Hudson Bay experiences a complete cryogenic cycle each year. Sea ice begins to form in late October, and the Bay is usually ice-free in early August. This seasonally varying ice cover plays an important role in the regional climate. To identify secular trends in the cryogenic cycle, we examined variability in the timing of sea-ice formation and retreat during the period 1971-2003. The dates of ice freeze-up and breakup at 36 locations across Hudson Bay were catalogued for each year from weekly ice charts provided by the Canadian Ice Service. We used the nonparametric Mann-Kendall test to determine the statistical significance of the trends and the Theil-Sen approach to estimate their magnitude. Our results indicate statistically significant trends toward earlier breakup in James Bay, along the southern shore of Hudson Bay, and in the western half of Hudson Bay, and toward later freeze-up in the northern and northeastern regions of Hudson Bay. These trends in the annual ice cycle of Hudson Bay coincide with both the regional temperature record and the projections from general circulation models. If this trend toward a longer ice-free season continues, Hudson Bay will soon face important environmental challenges.

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Watanabe, Y., Yamaguchi, A., Ishidai, H., Harimoto, T., Suzuki, S., Sekido, Y., Ikeda, T., Shirayama, Y., MacTakashi, M., Ohsumi, T., and Ishizaka, J. **Lethality of increasing CO<sub>2</sub> levels on deep-sea copepods in the western North Pacific.** *Journal of Oceanography* 62(2): 185-196, 2006.

**Notes:** The first CO<sub>2</sub> exposure experiments on several species of pelagic copepods inhabiting surface and deep layers in the western North Pacific were conducted. Living organisms were collected from two layers between the surface and 1,500 m between latitudes of 11 and 44°N, and they were exposed aboard ship to various pCO<sub>2</sub> up to about 98,000 matm. Mortality of copepods from both shallow and deep layers in subarctic to subtropical regions increased with increasing pCO<sub>2</sub> and exposure time. Deep-living copepods showed higher tolerance to pCO<sub>2</sub> than shallow-living copepods. Furthermore, deep-living copepods from subarctic and transitional regions had higher tolerances than the subtropical copepods. The higher tolerances of the deep-living copepods from subarctic and transitional regions may be due to the adaptation to the natural pCO<sub>2</sub> conditions in the subarctic ocean.

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Zwally, H.J., Giovinetto, M.B., Li, J., Cornejo, H.G., Beckley, M.A., Brenner, A.C., Saba, J.L., and Yi, D. **Mass changes of the Greenland and Antarctic ice sheets and shelves and contributions to sea-level rise: 1992–2002.** *Journal of Glaciology* 51(175): 509-527, 2005.

**Notes:** Changes in ice mass are estimated from elevation changes derived from 10.5 years (Greenland) and 9 years (Antarctica) of satellite radar altimetry data from the European Remote-sensing Satellites ERS-1 and -2. For the first time, the  $dH/dt$  values are adjusted for changes in surface elevation resulting from temperature-driven variations in the rate of firn compaction. The Greenland ice sheet is thinning at the margins ( $-42 \pm 2$  Gt a<sup>-1</sup> below the equilibrium-line altitude (ELA)) and growing inland ( $+53 \pm 2$  Gt a<sup>-1</sup> above the ELA) with a small overall mass gain ( $+11 \pm 3$  Gt a<sup>-1</sup>;  $-0.03$  mm a<sup>-1</sup> SLE (sea-level equivalent)). The ice sheet in West Antarctica (WA) is losing mass ( $-47 \pm 4$  Gt a<sup>-1</sup>) and the ice sheet in East Antarctica (EA) shows a small mass gain ( $+16 \pm 11$  Gt a<sup>-1</sup>) for a combined net change of  $-31 \pm 12$  Gt a<sup>-1</sup> ( $+0.08$  mm a<sup>-1</sup> SLE). The contribution of the three ice sheets to sea level is  $+0.05 \pm 0.03$  mm a<sup>-1</sup>. The Antarctic ice shelves show corresponding mass changes of  $-95 \pm 11$  Gt a<sup>-1</sup> in WA and  $+142 \pm 10$  Gt a<sup>-1</sup> in EA. Thinning at the margins of the Greenland ice sheet and growth at higher elevations is an expected response to increasing temperatures and precipitation in a warming climate. The marked thinnings in the Pine Island and Thwaites Glacier basins of WA and the Totten Glacier basin in EA are probably ice-dynamic responses to long-term climate change and perhaps past removal of their adjacent ice shelves. The ice growth in the southern Antarctic Peninsula and parts of EA may be due to increasing precipitation during the last century.

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Fox, A.J. and Vaughan, D.G. **The retreat of Jones Ice Shelf, Antarctic Peninsula.** *Journal of Glaciology* 51(175): 555-560, 2005.

**Notes:** In recent decades, several ice shelves along the Antarctic Peninsula have diminished in size as a result of climate warming. Using aerial photographic, satellite and survey data we document a similar retreat of Jones Ice Shelf, which was another small ice shelf on the west coast of the Antarctic Peninsula. This ice shelf was roughly stable between 1947 and 1969, but in the early 1970s it began to retreat and had completely disappeared by early 2003. Jones Ice Shelf has two ice fronts only a few kilometres apart and its retreat provides a unique opportunity to examine how different ice fronts retreat when subjected to similar climate forcing. We mapped the retreat of both the east and west ice fronts of Jones Ice Shelf and found that, although individual episodes of retreat may be related to particularly warm summers, the overall progress of retreat of the two ice fronts has been rather different. This suggests that in this case the course of retreat is controlled by the geometry of the embayment and location of pinning points as well as climatic events.

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Field, D.B., Baumgartner, T.R., Charles, C.D., Ferreira-Bartrina, V., and Ohman, M.D. **Planktonic foraminifera of the California Current reflect 20th-century warming.** *Science* 311(5757): 63-66, 2006.

**Notes:** It is currently unclear whether observed pelagic ecosystem responses to ocean warming, such as a mid-1970s change in the eastern North Pacific, depart from typical ocean variability. We report variations in planktonic foraminifera from varved sediments off southern California spanning the past 1400 years. Increasing abundances of tropical/subtropical species throughout the 20th century reflect a warming trend superimposed on decadal-scale fluctuations. Decreasing abundances of

temperate/subpolar species in the late 20th century indicate a deep, penetrative warming not observed in previous centuries. These results imply that 20th-century warming, apparently anthropogenic, has already affected lower trophic levels of the California Current.

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Ragauskas, A.J., Williams, C.K., Davison, B.H., Britovsek, G., Cairney, J., Eckert, C.A., Frederick, W.J., Hallett, J.P., Leak, D.J., Liotta, C.L., Mielenz, J.R., Murphy, R., Templer, R., and Tschaplinski, T. **The path forward for biofuels and biomaterials.** *Science* 311(5760): 484-489, 2006.

**Notes:** Biomass represents an abundant carbon-neutral renewable resource for the production of bioenergy and biomaterials, and its enhanced use would address several societal needs. Advances in genetics, biotechnology, process chemistry, and engineering are leading to a new manufacturing concept for converting renewable biomass to valuable fuels and products, generally referred to as the biorefinery. The integration of agroenergy crops and biorefinery manufacturing technologies offers the potential for the development of sustainable biopower and biomaterials that will lead to a new manufacturing paradigm.

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Osborn, T. and Briffa, K.R. **The spatial extent of 20th-century warmth in the context of the past 1200 years.** *Science* 311(5762): 841-844, 2006.

**Notes:** Periods of widespread warmth or cold are identified by positive or negative deviations that are synchronous across a number of temperature-sensitive proxy records drawn from the Northern Hemisphere. The most significant and longest duration feature during the last 1200 years is the geographical extent of warmth in the middle to late 20th century. Positive anomalies during 890 to 1170 and negative anomalies during 1580 to 1850 are consistent with the concepts of a Medieval Warm Period and a Little Ice Age, but comparison with instrumental temperatures shows the spatial extent of recent warmth to be of greater significance than that during the medieval period.

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Nordhaus, W.D. **Geography and macroeconomics: New data and new findings.** *Proceedings of the National Academy of Sciences [USA]* 103(10): 3510-3517, 2006.

**Notes:** The linkage between economic activity and geography is obvious: Populations cluster mainly on coasts and rarely on ice sheets. Past studies of the relationships between economic activity and geography have been hampered by limited spatial data on economic activity. The present study introduces data on global economic activity, the G-Econ database, which measures economic activity for all large countries, measured at a 1° latitude by 1° longitude scale. The methodologies for the study are described. Three applications of the data are investigated. First, the puzzling "climate output reversal" is detected, whereby the relationship between temperature and output is negative when measured on a per capita basis and strongly positive on a per area basis. Second, the database allows better resolution of the impact of geographic attributes on African poverty, finding geography is an important source of income differences relative to high-income regions. Finally, we use the G-Econ data to provide estimates of the economic impact of greenhouse warming, with larger estimates of warming damages than past studies.

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West, J.J., Fiore, A.M., Horowitz, L.W., and Mauzerall, D.L. **Global health benefits of mitigating ozone pollution with methane emission controls.** *Proceedings of the National Academy of Sciences [USA]* 103(11): 3988-3993, 2006.

**Notes:** Methane (CH<sub>4</sub>) contributes to the growing global background concentration of tropospheric ozone (O<sub>3</sub>), an air pollutant associated with premature mortality. Methane and ozone are also important greenhouse gases. Reducing methane emissions therefore decreases surface ozone everywhere while slowing climate warming, but although methane mitigation has been considered to address climate change, it has not for air quality. Here we show that global decreases in surface ozone concentrations, due to methane mitigation, result in substantial and widespread decreases in premature human mortality. Reducing global anthropogenic methane emissions by 20% beginning in 2010 would decrease the average daily maximum 8-h surface ozone by 1 part per billion by volume globally. By using epidemiologic ozone-mortality relationships, this ozone reduction is estimated to prevent ~30,000 premature all-cause mortalities globally in 2030, and 370,000 between 2010 and

2030. If only cardiovascular and respiratory mortalities are considered, ~17,000 global mortalities can be avoided in 2030. The marginal cost-effectiveness of this 20% methane reduction is estimated to be ~\$420,000 per avoided mortality. If avoided mortalities are valued at \$1 million each, the benefit is ~\$240 per tonne of CH<sub>4</sub> (~\$12 per tonne of CO<sub>2</sub> equivalent), which exceeds the marginal cost of the methane reduction. These estimated air pollution ancillary benefits of climate-motivated methane emission reductions are comparable with those estimated previously for CO<sub>2</sub>. Methane mitigation offers a unique opportunity to improve air quality globally and can be a cost-effective component of international ozone management, bringing multiple benefits for air quality, public health, agriculture, climate, and energy.

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Unger, N., Shindell, D.T., Koch, D.M., and Streets, D.G. **Cross influences of ozone and sulfate precursor emissions changes on air quality and climate.** *Proceedings of the National Academy of Sciences [USA]* 103(12): 4377-4380, 2006.

**Notes:** Tropospheric O<sub>3</sub> and sulfate both contribute to air pollution and climate forcing. There is a growing realization that air quality and climate change issues are strongly connected. To date, the importance of the coupling between O<sub>3</sub> and sulfate has not been fully appreciated, and thus regulations treat each pollutant separately. We show that emissions of O<sub>3</sub> precursors can dramatically affect regional sulfate air quality and climate forcing. At 2030 in an A1B future, increased O<sub>3</sub> precursor emissions enhance surface sulfate over India and China by up to 20% because of increased levels of OH and gas-phase SO<sub>2</sub> oxidation rates and add up to 20% to the direct sulfate forcing for that region relative to the present day. Hence, O<sub>3</sub> precursors impose an indirect forcing via sulfate, which is more than twice the direct O<sub>3</sub> forcing itself (compare -0.61 vs. +0.35 W/m<sup>2</sup>). Regulatory policy should consider both air quality and climate and should address O<sub>3</sub> and sulfate simultaneously because of the strong interaction between these species.

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Cai, W. **Antarctic ozone depletion causes an intensification of the Southern Ocean super-gyre circulation.** *Geophysical Research Letters* 33(3): art. L03712, 2006.

**Notes:** Recent climate trends over the Southern Hemisphere (SH) summer feature a strengthening of the circumpolar westerly and a weakening of the midlatitude westerly extending from the stratosphere to Earth's surface. Much of the change is attributable to Antarctic ozone depletion. However, the consequential ocean circulation changes are unknown. Here I demonstrate that the observed surface wind changes have forced a southward shift and spin-up of the super gyre, which links the subtropical South Pacific, Indian and Atlantic Ocean circulation, advecting more warm water southward. The circulation change includes a strengthening of the East Australian Current (EAC) flow passing through the Tasman Sea. The southward shift may be responsible for the observed unusually large warming in the SH midlatitude ocean and may contribute to the reported range extension to the south of many marine species in the South West Pacific.

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Virmani, J.I. and Weisberg, R.H. **The 2005 hurricane season: An echo of the past or a harbinger of the future?** *Geophysical Research Letters* 33(5): art. L05707, 2006.

**Notes:** Recent Atlantic hurricane activity raises several questions. For example, why was the 2005 season so early and active and are there similarities with the past? We show that parallels exist between 2005 and previously active years. Tropical Atlantic sea surface temperature (SST) anomalies beginning in winter aided the formation of early storms. On longer timescales SST, sea level pressure and zonal winds exhibit multidecadal variability; weaker easterlies during the positive phase of the Atlantic Multidecadal Oscillation (AMO) result (via ocean-atmosphere interactions) in warmer water and increased hurricane activity. However, individual active years appear independent of the AMO phase.

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Scafetta, N. and West, B.J. **Phenomenological solar contribution to the 1900-2000 global surface warming.** *Geophysical Research Letters* 33(5): art. L05708, 2006.

**Notes:** We study the role of solar forcing on global surface temperature during four periods of the industrial era (1900-2000, 1900-1950, 1950-2000 and 1980-2000) by using a sun-climate coupling model based on four scale-dependent empirical climate sensitive parameters to solar variations. We use two alternative total solar irradiance satellite composites, ACRIM and PMOD,

and a total solar irradiance proxy reconstruction. We estimate that the sun contributed as much as 45-50% of the 1900-2000 global warming, and 25-35% of the 1980-2000 global warming. These results, while confirming that anthropogenic-added climate forcing might have progressively played a dominant role in climate change during the last century, also suggest that the solar impact on climate change during the same period is significantly stronger than what some theoretical models have predicted.

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Nunes, F. and Norris, R.D. **Abrupt reversal in ocean overturning during the Palaeocene/Eocene warm period.** *Nature* 439(7072): 60-63, 2006.

**Notes:** An exceptional analogue for the study of the causes and consequences of global warming occurs at the Palaeocene/Eocene Thermal Maximum, 55 million years ago. A rapid rise of global temperatures during this event accompanied turnovers in both marine and terrestrial biota, as well as significant changes in ocean chemistry and circulation. Here we present evidence for an abrupt shift in deep-ocean circulation using carbon isotope records from fourteen sites. These records indicate that deep-ocean circulation patterns changed from Southern Hemisphere overturning to Northern Hemisphere overturning at the start of the Palaeocene/Eocene Thermal Maximum. This shift in the location of deep-water formation persisted for at least 40,000 years, but eventually recovered to original circulation patterns. These results corroborate climate model inferences that a shift in deep-ocean circulation would deliver relatively warmer waters to the deep sea, thus producing further warming. Greenhouse conditions can thus initiate abrupt deep-ocean circulation changes in less than a few thousand years, but may have lasting effects; in this case taking 100,000 years to revert to background conditions.

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Raper, S.C.B. and Braithwaite, R.J. **Low sea level rise projections from mountain glaciers and icecaps under global warming.** *Nature* 439(7074): 311-313, 2006.

**Notes:** The mean sea level has been projected to rise in the 21st century as a result of global warming. Such projections of sea level change depend on estimated future greenhouse emissions and on differing models, but model-average results from a mid-range scenario (A1B) suggests a 0.387 m rise by 2100. The largest contributions to sea level rise are estimated to come from thermal expansion (0.288 m) and the melting of mountain glaciers and icecaps (0.106 m), with smaller inputs from Greenland (0.024 m) and Antarctica (20.074 m). Here we apply a melt model and a geometric volume model to our lower estimate of ice volume and assess the contribution of glaciers to sea level rise, excluding those in Greenland and Antarctica. We provide the first separate assessment of melt contributions from mountain glaciers and icecaps, as well as an improved treatment of volume shrinkage. We find that icecaps melt more slowly than mountain glaciers, whose area declines rapidly in the 21st century, making glaciers a limiting source for ice melt. Using two climate models, we project sea level rise due to melting of mountain glaciers and icecaps to be 0.046 and 0.051 m by 2100, about half that of previous projections.

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Lubin, D. and Vogelmann, A.M. **A climatologically significant aerosol longwave indirect effect in the Arctic.** *Nature* 439(7075): 453-456, 2006.

**Notes:** The warming of Arctic climate and decreases in sea ice thickness and extent observed over recent decades are believed to result from increased direct greenhouse gas forcing, changes in atmospheric dynamics having anthropogenic origin, and important positive reinforcements including ice - albedo and cloud - radiation feedbacks. The importance of cloud - radiation interactions is being investigated through advanced instrumentation deployed in the high Arctic since 1997. These studies have established that clouds, via the dominance of longwave radiation, exert a net warming on the Arctic climate system throughout most of the year, except briefly during the summer. The Arctic region also experiences significant periodic influxes of anthropogenic aerosols, which originate from the industrial regions in lower latitudes. Here we use multisensor radiometric data to show that enhanced aerosol concentrations alter the microphysical properties of Arctic clouds, in a process known as the 'first indirect' effect. Under frequently occurring cloud types we find that this leads to an increase of an average 3.4 watts per square metre in the surface longwave fluxes. This is comparable to a warming effect from established greenhouse gases and implies that the observed longwave enhancement is climatologically significant.

Keller, K., Hall, M., Kim, S.R., Bradford, D.F., and Oppenheimer, M. **Avoiding dangerous anthropogenic interference with the climate system.** *Climatic Change* 73(3): 227-238, 2005.

**Notes:** The UN Framework Convention on Climate Change calls for the avoidance of "dangerous anthropogenic interference with the climate system". Among the many plausible choices, dangerous interference with the climate system may be interpreted as anthropogenic radiative forcing causing distinct and widespread climate change impacts such as a widespread demise of coral reefs or a disintegration of the West Antarctic ice sheet. The geological record and numerical models suggest that limiting global warming below critical temperature thresholds significantly reduces the likelihood of these eventualities. Here we analyze economically optimal policies that may ensure this risk-reduction. Reducing the risk of a widespread coral reef demise implies drastic reductions in greenhouse gas emissions within decades. Virtually unchecked greenhouse gas emissions to date (combined with the inertia of the coupled natural and human systems) may have already committed future societies to a widespread demise of coral reefs. Policies to reduce the risk of a West Antarctic ice sheet disintegration allow for a smoother decarbonization of the economy within a century and may well increase consumption in the long run.

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Giorgi, F. **Climate change prediction.** *Climatic Change* 73(3): 239-265, 2005.

**Notes:** The concept of climate change prediction in response to anthropogenic forcings at multidecadal time scales is reviewed. This is identified as a predictability problem with characteristics of both first kind and second kind (due to the slow components of the climate system). It is argued that, because of the non-linear and stochastic aspects of the climate system and of the anthropogenic and natural forcings, climate change contains an intrinsic level of uncertainty. As a result, climate change prediction needs to be approached in a probabilistic way. This requires a characterization and quantification of the uncertainties associated with the sequence of steps involved in a climate change prediction. A review is presented of different approaches recently proposed to produce probabilistic climate change predictions. The additional difficulties found when extending the prediction from the global to the regional scale and the implications that these have on the choice of prediction strategy are finally discussed.

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Smith, S.J., Pitcher, H., and Wigley, T.M.L. **Future sulfur dioxide emissions.** *Climatic Change* 73(3): 267-318, 2005.

**Notes:** The importance of sulfur dioxide emissions for climate change is now established, although substantial uncertainties remain. This paper presents projections for future sulfur dioxide emissions using the MiniCAM integrated assessment model. A new income-based parameterization for future sulfur dioxide emissions controls is developed based on purchasing power parity (PPP) income estimates and historical trends related to the implementation of sulfur emissions limitations. This parameterization is then used to produce sulfur dioxide emissions trajectories for the set of scenarios developed for the Special Report on Emission Scenarios (SRES). We use the SIZES methodology to produce harmonized SIZES scenarios using the latest version of the MiniCAM model. The implications, and requirements, for integrated assessment modeling of sulfur dioxide emissions are discussed. We find that sulfur emissions eventually decline over the next century under a wide set of assumptions. These emission reductions result from a combination of emission controls, the adoption of advanced electric technologies, and a shift away from the direct end use of coal with increasing income levels. Only under a scenario where incomes in developing regions increase slowly do global emission levels remain at close to present levels over the next century. Under a climate policy that limits emissions of carbon dioxide, sulfur dioxide emissions fall in a relatively narrow range. In most cases, the relative climatic effect of sulfur dioxide emissions decreases dramatically to a point where sulfur dioxide is only a minor component of climate forcing by the end of the century. Ecological effects of sulfur dioxide, however, could be significant in some developing regions for many decades to come.

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