

# Marine Science Review – 169

## 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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Dowdeswell, J.A. **The Greenland Ice Sheet and global sea-level rise.** *Science* 311(5763): 963-964, 2006.

Webster, P.J., Curry, J.A., Liu, J., and Holland, G.J. **Response to comment on "Changes in tropical cyclone number, duration, and intensity in a warming environment".** *Science* 311(5768): U3-U4, 2006.

Joughin, I. **Greenland rumbles louder as glaciers accelerate.** *Science* 311(5768): 1719-1720, 2006.

Bindschadler, R. **Hitting the ice sheets where it hurts.** *Science* 311(5768): 1720-1721, 2006.

Kerr, R.A. **A worrying trend of less ice, higher seas.** *Science* 311(5768): 1698, 2006.

Kintisch, E. **Along the road from Kyoto - Global greenhouse gas emissions keep rising.** *Science* 311(5768): 1702-1703, 2006.

Goodell, J. **Cooking the climate with coal** (Reprinted from *Big Coal: The dirty secret behind America's Energy Future*). *Natural History* 115(4): 36-41, 2006.

## B. Recent publications available online

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Glick, P. and Clough, J. 2006. **An Unfavorable Tide: Global Warming, Coastal Habitats and Sportfishing in Florida.** National Wildlife Federation, Washington, DC. 56pp.

**Available at:** [http://www.nwf.org/nwfwebadmin/binaryVault/An\\_Unfavorable\\_Tide\\_Report.pdf](http://www.nwf.org/nwfwebadmin/binaryVault/An_Unfavorable_Tide_Report.pdf)

**Notes:** This report looks at the potential impacts of sea-level rise on the environment and fishing in nine key coastal zones in Florida and predicts dramatic changes by the end of this century if nothing were done to stop or slow current trends. South Florida's beaches could be smaller, bays deeper, marshes saltier and there could be major disruptions to a food chain that supports about 70 percent of coastal marine life, which could put at risk at least 10 species prized by anglers, including snook, pompano and tarpon.

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German Advisory Council on Global Change (WBGU). 2006. **The Future Oceans – Warming Up, Rising High, Turning Sour.** WBGU, Berlin. 110pp.

**Available at:** [http://www.wbgu.de/wbgu\\_sn2006\\_en.pdf](http://www.wbgu.de/wbgu_sn2006_en.pdf)

**Notes:** This report concentrates on key linkages between climate change and the oceans that are the topic of new scientific insights. These insights include new findings on warming, ocean currents, sea-level rise, carbon uptake and acidification, and on the impacts of these factors upon marine ecosystems. The report also discusses in detail the development of tropical cyclones, the issues surrounding carbon storage in the ocean or under the seabed, and the risks associated with methane hydrate deposits in the sea floor. Many of these issues are closely interlinked – coral reefs, for instance, are affected simultaneously by warming, sea-level rise, storms and acidification. Each theme is explored systematically, starting with the physical and chemical fundamentals, proceeding to the ecological impacts, moving on to the consequences for human society, and finally deriving policy and research recommendations on that basis. WBGU embeds its analysis within a normative framework that it has developed for the sustainable management of the oceans.

## C. Recent articles with abstracts

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Nunez, M., Davidson, A.T., and Michael, K. **Modelled effects of ambient UV radiation on a natural Antarctic marine microbial community.** *Aquatic Microbial Ecology* 42(1): 75-90, 2006.

**Notes:** Ozone depletion over Antarctica has enhanced ultraviolet-B radiation (UVBR, 280 to 320 nm wavelength). We measured the effect of ambient solar UV radiation on the biomass and species composition of phytoplankton, protozoa, bacteria and dissolved organic carbon (DOC) in natural microbial assemblages from Antarctic coastal waters. Results were modelled to determine the features of the irradiance responsible for changes in the biomass of these microbial components and responses of individual phytoplankton taxa. Model results showed that changes in phytoplankton biomass were primarily due to dose rate, indicating that their UV-induced mortality resulted from the equilibrium between damage and repair. However, there was considerable variability between individual species in their response to dose and dose rate. Changes in protozoan biomass were mainly due to dose and were likely due to community-level, trophodynamic interactions. UV radiation did not measurably affect bacterial biomass, but resulted in increasing concentrations of DOC. We found a threshold of erythemal irradiance of 28 mW m<sup>-2</sup>, approximating peak noon-time irradiance at 3.6 m depth near the summer solstice in Antarctic coastal waters, below which no change in the community structure was observed, but above which phytoplankton mortality and protozoan biomass increased. Our results indicate that enhanced UVB radiation in Antarctic waters increases phytoplankton mortality and causes changes in the structure, function and composition of the microbial community that are likely to return more photoassimilated carbon to the atmosphere.

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Huntington, T.G. **Evidence for intensification of the global water cycle: Review and synthesis.** *Journal of Hydrology* 319(1-4): 83-95, 2006.

**Notes:** One of the more important questions in hydrology is: if the climate warms in the future, will there be an intensification of the water cycle and, if so, the nature of that intensification? There is considerable interest in this question because an intensification of the water cycle may lead to changes in water-resource availability, an increase in the frequency and intensity of tropical storms, floods, and droughts, and an amplification of warming through the water vapor feedback. Empirical evidence for ongoing intensification of the water cycle would provide additional support for the theoretical framework that links intensification with warming. This paper briefly reviews the current state of science regarding historical trends in hydrologic variables, including precipitation, runoff, tropospheric water vapor, soil moisture, glacier mass balance, evaporation, evapotranspiration, and growing season length. Data are often incomplete in spatial and temporal domains and regional analyses are variable and sometimes contradictory; however, the weight of evidence indicates an ongoing intensification of the water cycle. In contrast to these trends, the empirical evidence to date does not consistently support an increase in the frequency or intensity of tropical storms and floods.

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Thistle, D., Sedlacek, L., Carman, K.R., Fleeger, J.W., Brewer, P.G., and Barry, J.P. **Simulated sequestration of industrial carbon dioxide at a deep-sea site: Effects on species of harpacticoid copepods.** *Journal of Experimental Marine Biology and*

**Notes:** One proposal for alleviating global warming is to sequester large amounts of industrial carbon dioxide on the deep-sea floor, but the environmental consequences of sequestration for the animals living in the sediment are poorly known. In an earlier publication, we reported that, during an experimental sequestration off central California (36.378°N, 122.676°W 3262 m depth), most individuals of our target taxon (the harpacticoid copepods) were killed, but ~ 20% survived. Because knowledge of which species survived and how they did so could clarify the effects of sequestration on the fauna, we have now identified the individuals from that experiment to species. Although most were adversely affected, species differed significantly in the degree of their susceptibility. Unexpectedly, six species showed no effect and may be resistant. The hypothesis that harpacticoids could escape the effects of carbon dioxide-rich seawater by moving deeper into the seabed was not supported. Exposure to carbon dioxide-rich seawater created partially defaunated areas, but we found no evidence that disturbance-exploiting harpacticoid species invaded during the recovery of the affected area. Because the environmental effects of the carbon dioxide (e.g. unusually acidic pore water) were still present, however, the opportunity for invasion might not yet have occurred. Differences among species in susceptibility increase the complexity of the effects of carbon dioxide sequestration on the deep-sea fauna.

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Mikaloff-Fletcher, S.E., Gruber, N., Jacobson, A.R., Doney, S.C., Dutkiewicz, S., Gerber, M., Follows, M., Joos, F., Lindsay, K., Menemenlis, D., Mouchet, A., Müller, S.A., and Sarmiento, J.L. **Inverse estimates of anthropogenic CO<sub>2</sub> uptake, transport, and storage by the ocean.** *Global Biogeochemical Cycles* 20(2): art. GB2002, 2006.

**Notes:** Regional air-sea fluxes of anthropogenic CO<sub>2</sub> are estimated using a Green's function inversion method that combines data-based estimates of anthropogenic CO<sub>2</sub> in the ocean with information about ocean transport and mixing from a suite of Ocean General Circulation Models (OGCMs). In order to quantify the uncertainty associated with the estimated fluxes owing to modeled transport and errors in the data, we employ 10 OGCMs and three scenarios representing biases in the data-based anthropogenic CO<sub>2</sub> estimates. On the basis of the prescribed anthropogenic CO<sub>2</sub> storage, we find a global uptake of  $2.2 \pm 0.25$  Pg C yr<sup>-1</sup>, scaled to 1995. This error estimate represents the standard deviation of the models weighted by a CFC-based model skill score, which reduces the error range and emphasizes those models that have been shown to reproduce observed tracer concentrations most accurately. The greatest anthropogenic CO<sub>2</sub> uptake occurs in the Southern Ocean and in the tropics. The flux estimates imply vigorous northward transport in the Southern Hemisphere, northward cross-equatorial transport, and equatorward transport at high northern latitudes. Compared with forward simulations, we find substantially more uptake in the Southern Ocean, less uptake in the Pacific Ocean, and less global uptake. The large-scale spatial pattern of the estimated flux is generally insensitive to possible biases in the data and the models employed. However, the global uptake scales approximately linearly with changes in the global anthropogenic CO<sub>2</sub> inventory. Considerable uncertainties remain in some regions, particularly the Southern Ocean.

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Vaughan, D.G. **Recent trends in melting conditions on the Antarctic Peninsula and their implications for ice-sheet mass balance and sea level.** *Arctic, Antarctic and Alpine Research* 38(1): 147-152, 2006.

**Notes:** Long-term records from meteorological stations on the Antarctic Peninsula show strong rising trends in the annual duration of melting conditions. In each case, the trend is statistically significant and represents a major increase in the potential for melting; for example, between 1950 and 2000 the record from Faraday/Vernadsky Station showed a 74% increase in the number of positive degree-days (PDDs). A simple parameterization of the likely effects of the warming of the rate of snow melt suggests all increase across the Antarctic Peninsula ice sheet from  $28 \pm 12$  Gt a<sup>-1</sup> in 1950, to  $54 \pm 26$  Gt a<sup>-1</sup> by 2000. Given a similar rate of warming over the next 50 years this may reach  $100 \pm 46$  Gt a<sup>-1</sup>. The majority of this increased meltwater does not drain into the sea but is refrozen in the ice sheet, and it is difficult to predict the fraction of ablation that will become runoff, however, a calculation based on an established criterion for runoff indicates that the contribution from the Antarctic Peninsula, as a direct and immediate response to climate warming is significant, equivalent to (0.008-0.055) mm a<sup>-1</sup> of global sea level rise. Given future warming this could easily treble in the coming 50 years. This contribution due to increased runoff could be augmented by any dynamic imbalance in the glaciers draining the ice sheet. This finding appears to contradict the conclusions of previous assessments, including the Intergovernmental Panel on Climate Change, which considered the contribution of runoff from Antarctica to sea level rise would be insignificant.

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Mieszkowska, N., Kendall, M.A., Hawkins, S.J., Leaper, R., Williamson, P., Hardman-Mountford, N. J., and Southward, A. J. **Changes in the range of some common rocky shore species in Britain - a response to climate change?** *Hydrobiologia* 555: 241-251, 2006.

**Notes:** Since the 1990s there has been a period of rapid climate warming in Europe. Long-term broad scale datasets coupled with time series at specific locations for rocky intertidal species dating back to the 1950s have been collected in Britain and Ireland. Resurveys of the original locations in 2001-2003 have been undertaken to identify changes in the biogeographical range and abundance of these species. The results show that some 'southern' species including *Osilinus lineatus* da Costa and *Gibbula umbilicalis* da Costa have undergone north and north-eastern range extensions. Populations have increased in abundance and adult size has decreased since the previous surveys were conducted. These changes have been synchronous throughout Britain, strongly suggesting that climate is responsible. The use of intertidal species as indicators of climate change is proposed.

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Winton, M. **Amplified Arctic climate change: What does surface albedo feedback have to do with it?** *Geophysical Research Letters* 33(3): art. L03701, 2006.

**Notes:** A group of twelve IPCC fourth assessment report (AR4) climate models have Arctic (60N-90N) warmings that are, on average, 1.9 times greater than their global warmings at the time of CO<sub>2</sub> doubling in 1%/year CO<sub>2</sub> increase experiments. Forcings and feedbacks that impact the warming response are estimated for both Arctic and global regions based on standard model diagnostics. Fitting a zero-dimensional energy balance model to each region, an expression is derived that gives the Arctic amplification as a function of these forcings and feedbacks. Contributing to Arctic amplification are the Arctic-global differences in surface albedo feedback (SAF), longwave feedback and the net top-of-atmosphere flux forcing (the sum of the surface flux and the atmospheric heat transport convergence). The doubled CO<sub>2</sub> forcing and non-SAF shortwave feedback oppose Arctic amplification. SAF is shown to be a contributing, but not a dominating, factor in the simulated Arctic amplification and its intermodel variation.

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Edmunds, P.J., Gates, R.D., Leggat, W., Hoegh-Guldberg, O., and Allen-Requa, L. **The effect of temperature on the size and population density of dinoflagellates in larvae of the reef coral *Porites astreoides*.** *Invertebrate Biology* 124(3): 185-193, 2005.

**Notes:** Pre-settlement events play an important role in determining larval success in marine invertebrates with benthic-pelagic life histories, yet the consequences of these events typically are not well understood. The purpose of this study was to examine the pre-settlement impacts of different seawater temperatures on the size and population density of dinoflagellate symbionts in brooded larvae of the Caribbean coral *Porites astreoides*. Larvae were collected from *P. astreoides* at 14-20m depth on Conch Reef (Florida) in June 2002, and incubated for 24h at 15 temperatures spanning the range 25.1° - 30.0°C in mean increments of 0.4±0.1°C (±SD). The most striking feature of the larval responses was the magnitude of change in both parameters across this 5°C temperature range within 24h. In general, larvae were largest and had the highest population densities of *Symbiodinium* sp. between 26.4°C - 27.7°C, and were smallest and had the lowest population densities at 25.8°C and 28.8°C. Larval size and symbiont population density were elevated slightly (relative to the minimal values) at the temperature extremes of 25.1°C and 30°C. These data demonstrate that coral larvae are highly sensitive to seawater temperature during their pelagic phase, and respond through changes in size and the population densities of *Symbiodinium* sp. to ecologically relevant temperature signals within 24h. The extent to which these changes are biologically meaningful will depend on the duration and frequency of exposure of coral larvae to spatio-temporal variability in seawater temperature, and whether the responses have cascading effects on larval success and their entry to the post-settlement and recruitment phase.

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Johns, D.G., Edwards, M., Greve, W., and SJohn, A.W.G. **Increasing prevalence of the marine cladoceran *Penilia avirostris* (Dana, 1852) in the North Sea.** *Helgoland Marine Research* 59(3): 214-218, 2005.

**Notes:** Rising sea surface temperatures in the North Sea have had consequential effects on not only indigenous plankton species, but also on the possibility of successful colonisation of the area by invasive plankton species. Previous studies have

noted the introduction and integration into the plankton community of various phytoplankton species, but establishment of zooplankton organisms in the North Sea is less well-documented. Examining continuous plankton recorder (CPR) survey data and zooplankton results from the Helgoland Roads study, the autumn of 1999 witnessed the occurrence of the marine cladoceran *Penilia avirostris* in large numbers in the North Sea. The rapid appearance of the species corresponded with exceptionally warm sea surface temperatures (SSTs). Since 1999, the species has become a regular feature of the autumnal zooplankton community of the North Sea. In 2002 and 2003, the species occurred in greater abundance than recorded before. It is suggested that increased autumn SSTs have proved favourable to *P. avirostris*, with warmer conditions contributing to the success of the species' resting eggs and aiding colonisation.

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Purcell, J.E. **Climate effects on formation of jellyfish and ctenophore blooms: a review.** *Journal of the Marine Biological Association of the United Kingdom* 85(3): 461-476, 2005.

**Notes:** Much speculation and some evidence suggest that jellyfish and ctenophore populations have increased in recent decades. Unfortunately, few past records exist with which to compare current populations, and our knowledge of how environmental factors affect jellyfish population size is meagre. Human enterprise has wrought many changes in the ocean that are hypothesized to favour jellyfish, including eutrophication, reduction of fish stocks, and global warming. In addition to anthropogenic changes, natural climate cycles may affect jellyfish populations. Records of jellyfish and ctenophore abundance that appear to be related to indices of climate variations (temperature, salinity, North Atlantic Oscillation, North Pacific Decadal Oscillation, El Nino Southern Oscillation) are reviewed. In eleven species studied from subtropical, temperate and subarctic environments, warm temperatures were related to large population sizes; three scyphozoan species in the North Sea, and one mesopelagic hydromedusan were exceptions to that trend. One tropical scyphomedusan species was decimated by unusually warm, salty El Nino conditions in Palau. Because climate changes have complex ecosystem-level effects, the proximate causes of jellyfish increases are difficult to deduce. Therefore, the effects of temperature, salinity and prey on asexual production of new medusae from the benthic polyps of scyphomedusae and hydromedusae also are reviewed. Experiments on temperate species show greater and more rapid production of medusae at warmer temperatures. Salinity also had significant effects, and was especially important for estuarine species. Temperature and salinity affect asexual reproduction rates directly through metabolism, and indirectly through prey capture. Ocean warming may shift the distributions, expand the seasonal occurrence, and increase the abundances of temperate-boreal species. Populations living near their thermal maximum may suffer negative consequences of warming.

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Guinotte, J.M., Orr, J., Cairns, S., Freiwald, A., Morgan, L., and George, R. **Will human-induced changes in seawater chemistry alter the distribution of deep-sea scleractinian corals?** *Frontiers in Ecology and Environment* 4(3): 141-146, 2006.

**Notes:** The answer to the title question is uncertain, as very few manipulative experiments have been conducted to test how deep-sea scleractinians (stony corals) react to changes in seawater chemistry. Ocean pH and calcium carbonate saturation are decreasing due to an influx of anthropogenic CO<sub>2</sub> to the atmosphere. Experimental evidence has shown that declining carbonate saturation inhibits the ability of marine organisms to build calcium carbonate skeletons, shells, and tests. Here we put forward a hypothesis suggesting that the global distribution of deep-sea scleractinian corals could be limited in part by the depth of the aragonite saturation horizon (ASH) in the world's oceans. Aragonite is the metastable form of calcium carbonate used by scleractinian corals to build their skeletons and the ASH is the limit between saturated and undersaturated water. The hypothesis is tested by reviewing the distribution of deep-sea, bioherm-forming scleractinian corals with respect to the depth of the ASH. Results indicate that > 95% of 410 coral locations occurred in saturated waters during pre-industrial times. Projections indicate that about 70% of these locations will be in undersaturated waters by 2099. Lab experimentation, in situ experimentation, and monitoring efforts are needed to quantify the effects of changing seawater chemistry on deep-sea coral ecosystems.

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Paavola, J. and Adger, W.N. **Fair adaptation to climate change.** *Ecological Economics* 56(4): 594-609, 2006.

**Notes:** This article identifies social justice dilemmas associated with the necessity to adapt to climate change, examines how they are currently addressed by the climate change regime, and proposes solutions to overcome prevailing gaps and ambiguities. We argue that the key justice dilemmas of adaptation include responsibility for climate change impacts, the level

and burden sharing of assistance to vulnerable countries for adaptation, distribution of assistance between recipient countries and adaptation measures, and fair participation in planning and making decisions on adaptation. We demonstrate how the climate change regime largely omits responsibility but makes a general commitment to assistance. However, the regime has so far failed to operationalise assistance and has made only minor progress towards eliminating obstacles for fair participation. We propose the adoption of four principles for fair adaptation in the climate change regime. These include avoiding dangerous climate change, forward-looking responsibility, putting the most vulnerable first and equal participation of all. We argue that a safe maximum standard of 400-500 ppm of CO<sub>2</sub> concentrations in the atmosphere and a carbon tax of \$20-50 per carbon equivalent ton could provide the initial instruments for operationalising the principles.

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Woth, K., Weisse, R., and von Storch, H. **Climate change and North Sea storm surge extremes: an ensemble study of storm surge extremes expected in a changed climate projected by four different regional climate models.** *Ocean Dynamics* 56(1): 3-15, 2006.

**Notes:** The coastal zones are facing the prospect of changing storm surge statistics due to anthropogenic climate change. In the present study, we examine these prospects for the North Sea based on numerical modelling. The main tool is the barotropic tide-surge model TRIMGEO (Tidal Residual and Intertidal Mudflat Model) to derive storm surge climate and extremes from atmospheric conditions. The analysis is carried out by using an ensemble of four 30-year atmospheric regional simulations under present-day and possible future-enhanced greenhouse gas conditions. The atmospheric regional simulations were prepared within the EU project PRUDENCE (Prediction of Regional scenarios and Uncertainties for Defining European Climate change risks and Effects). The research strategy of PRUDENCE is to compare simulations of different regional models driven by the same global control and climate change simulations. These global conditions, representative for 1961-1990 and 2071-2100 were prepared by the Hadley Center based on the IPCC A2 SRES scenario. The results suggest that under future climatic conditions, storm surge extremes may increase along the North Sea coast towards the end of this century. Based on a comparison between the results of the different ensemble members as well as on the variability estimated from a high-resolution storm surge reconstruction of the recent decades it is found that this increase is significantly different from zero at the 95% confidence level for most of the North Sea coast. An exception represents the East coast of the UK which is not affected by this increase of storm surge extremes.

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Baker, J.D., Littnan, C.L., and Johnston, D.W. **Potential effects of sea level rise on the terrestrial habitats of endangered and endemic megafauna in the Northwestern Hawaiian Islands.** *Endangered Species Research* art. 4: 1-10, 2006.

**Notes:** Climate models predict that global average sea level may rise considerably this century, potentially affecting species that rely on coastal habitat. The Northwestern Hawaiian Islands (NWHI) have high conservation value due to their concentration of endemic, endangered and threatened species, and large numbers of nesting seabirds. Most of these islands are low-lying and therefore potentially vulnerable to increases in global average sea level. We explored the potential for habitat loss in the NWHI by creating topographic models of several islands and evaluating the potential effects of sea level rise by 2100 under a range of basic passive flooding scenarios. Projected terrestrial habitat loss varied greatly among the islands examined: 3 to 65% under a median scenario (48 cm rise), and 5 to 75% under the maximum scenario (88 cm rise). Spring tides would probably periodically inundate all land below 89 cm (median scenario) and 129 cm (maximum scenario) in elevation. Sea level is expected to continue increasing after 2100, which would have greater impact on atolls such as French Frigate Shoals and Pearl and Hermes Reef, where virtually all land is less than 2 m above sea level. Higher elevation islands such as Lisianski, Laysan, Necker, and Nihoa may provide longer-term refuges for species. The effects of habitat loss on NWHI biota are difficult to predict, but may be greatest for endangered Hawaiian monk seals, threatened Hawaiian green sea turtles, and the endangered Laysan finch at Pearl and Hermes Reef. This study marks the first effort to detail the topography and evaluate sea level rise effects on NWHI species.

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Shein, K.A. (ed.) **State of the climate in 2005.** *Bulletin of the American Meteorological Society* 86(6): S1-S102, 2006.

**Notes:** The State of the Climate 2005 report summarizes global and regional climate conditions and places them, where possible, into the context of historical records. Descriptions and analyses of notable climatic anomalies, both global and regional, also are presented. According to the Smith and Reynolds global land and ocean surface temperature dataset in use at

the NOAA National Climatic Data Center (NCDC), the globally averaged annual mean surface temperature in 2005 was the warmest since the inception of consistent temperature observations in 1880. Unlike the previous record positive anomaly of 1998 (+0.50°C), the 2005 global anomaly of 0.53°C above the 1961-90 mean occurred in the absence of a strong El Niño signal. The record ranking of 2005 was corroborated by a dataset maintained at NASA, while United Kingdom archives placed 2005 second behind 1998. However, statistically, the 2005 global temperature anomaly could not be differentiated from either 1998 or any of the past four years. The majority of the top 10 warmest years on record have occurred in the past decade, and 2005 continues a marked upward trend in globally averaged temperature since the mid-1970s. Lower-tropospheric temperature was the second warmest on record, with northern polar regions the warmest at 1.3°C above the 1979-98 mean. Unlike air temperatures, globally averaged precipitation was near normal relative to the 1961-90 period mean value. The global 2005 anomaly was just -0.87 mm. Over the past 25 years, only 7 years have had above-normal precipitation. Additionally, in 2005, only September-November experienced a positive anomaly. Northern Hemisphere snow cover extent was 0.9 million km<sup>2</sup> below the 36-year average (fifth lowest) and Arctic sea ice extent was record lowest in all months of 2005 except May, resulting in a record lowest annual average Arctic sea ice extent for the year and continuing a roughly 8% yr<sup>-1</sup> decline in ice extent. Carbon dioxide (CO<sub>2</sub>) concentrations rose to a global average of 378.9 parts per million (ppm); about 2 ppm over the value from 2004. This record CO<sub>2</sub> concentration in 2005 continues a trend toward increased atmospheric CO<sub>2</sub> since the preindustrial era values of around 280 ppm. The globally averaged methane (CH<sub>4</sub>) concentration in 2005 was 1774.8 parts per billion (ppb), or 2.8 ppb less than in 2004. Stratospheric ozone over Antarctica reached a minimum of 110 Dobson units (DU) on 29 September. This represented the 10th lowest minimum level in the 20 years of measurement of stratospheric ozone. In the global ocean, sea level was above the 1993-2001 base period mean and rose at a rate of 2.9 ±0.4 mm yr<sup>-1</sup>. The largest positive anomalies were in the Tropics and Southern Hemisphere. Globally averaged sea surface temperature (SST) also was above normal in 2005 (relative to the 1971-2002 mean), reflecting the general warming trend in SST observed since 1971. In the Tropics, only a weak warm phase of El Niño materialized, but dissipated by March. A relatively active Madden-Julian oscillation (MJO) resulted in the disruption of normal convective patterns in the tropical Pacific and generated several Kelvin waves in the oceanic mixed layer. In the Atlantic Ocean basin, there was record tropical storm activity, with 27\* named storms (15 hurricanes). Three became category 5 storms on the Saffir-Simpson scale, and Hurricane Wilma set a new record for the lowest pressure (882 hPa) recorded in the basin. Both Hurricanes Stan and Katrina had exceptional death tolls, and Katrina became the costliest storm on record. Below-normal tropical storm activity in several other basins resulted in nearnormal conditions globally in 2005. Regionally, annual and monthly averaged temperatures were above normal across most of the world. Australia experienced its warmest year on record, as well as its hottest April. For both Russia and Mexico 2005 was the second warmest year on record. Intermittent and delayed monsoons in Africa and East Asia resulted in below-normal precipitation in many areas. Drought continued in much of the Greater Horn of Africa and developed in the central United States. Record severe drought occurred over both the Iberian Peninsula and western Amazonia in 2005. In the Amazon, river levels dropped by as much as 11 m between May and September. Conversely, heavy snows early in 2005 combined with a warm boreal spring to generate widespread flooding in areas of southwest Asia. Canada experienced its wettest year on record in 2005, with flooding in Alberta, Manitoba, and Ontario. In July, the South Asian monsoon delivered a record 944.2 mm of precipitation over 24 h to areas around Mumbai, India.

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Elsner, J.B., Tsonis, A.A., and Jagger, T.H. **High-frequency variability in hurricane power dissipation and its relationship to global temperature.** *Bulletin of the American Meteorological Society* 87(6): 763-768, 2006.

**Notes:** The power dissipation of Atlantic tropical cyclones has risen dramatically during the last decades and the increase is correlated with an increase in the underlying sea surface temperature (SST) at low (decadal) frequencies. Because of the large positive correlation between global mean surface air temperature (GT) and Atlantic SST it has been speculated that increases in the power dissipation might, in part, be related to human activity. Here we investigate the question of the relationship between GT and hurricane power dissipation directly using statistical analysis and show that after removing the effect of SST, the correlation between GT and hurricane power dissipation is negative. This suggests that the positive influence of global temperature on Atlantic hurricanes appears to be limited to an indirect connection with tropical Atlantic SST. We also show that the relationship between hurricane power dissipation and Atlantic SST is significant at the high-frequency time scales. El Niño-Southern Oscillation (ENSO) plays an important role in statistically explaining the variations in hurricane power at these higher frequencies.

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Garrett, T.J. and Zhao, C.F. **Increased Arctic cloud longwave emissivity associated with pollution from mid-latitudes.** *Nature* 440(7085): 787-789, 2006.

**Notes:** There is consensus among climate models that Arctic climate is particularly sensitive to anthropogenic greenhouse gases and that, over the next century, Arctic surface temperatures are projected to rise at a rate about twice the global mean. The response of Arctic surface temperatures to greenhouse gas thermal emission is modified by Northern Hemisphere synoptic meteorology and local radiative processes. Aerosols may play a contributing factor through changes to cloud radiative properties. Here we evaluate a previously suggested contribution of anthropogenic aerosols to cloud emission and surface temperatures in the Arctic. Using four years of ground-based aerosol and radiation measurements obtained near Barrow, Alaska, we show that, where thin water clouds and pollution are coincident, there is an increase in cloud longwave emissivity resulting from elevated haze levels. This results in an estimated surface warming under cloudy skies of between 3.3 and 5.2 W m<sup>-2</sup> or 1 and 1.6°C. Arctic climate is closely tied to cloud longwave emission, but feedback mechanisms in the system are complex and the actual climate response to the described sensitivity remains to be evaluated.

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Hegerl, G.C., Crowley, T.J., Hyde, W.T., and Frame, D.J. **Climate sensitivity constrained by temperature reconstructions over the past seven centuries.** *Nature* 440(7087): 1029-1032, 2006.

**Notes:** The magnitude and impact of future global warming depends on the sensitivity of the climate system to changes in greenhouse gas concentrations. The commonly accepted range for the equilibrium global mean temperature change in response to a doubling of the atmospheric carbon dioxide concentration, termed climate sensitivity, is 1.5-4.5 K. A number of observational studies, however, find a substantial probability of significantly higher sensitivities, yielding upper limits on climate sensitivity of 7.7 K to above 9 K. Here we demonstrate that such observational estimates of climate sensitivity can be tightened if reconstructions of Northern Hemisphere temperature over the past several centuries are considered. We use large-ensemble energy balance modelling and simulate the temperature response to past solar, volcanic and greenhouse gas forcing to determine which climate sensitivities yield simulations that are in agreement with proxy reconstructions. After accounting for the uncertainty in reconstructions and estimates of past external forcing, we find an independent estimate of climate sensitivity that is very similar to those from instrumental data. If the latter are combined with the result from all proxy reconstructions, then the 5-95 per cent range shrinks to 1.5-6.2 K, thus substantially reducing the probability of very high climate sensitivity.

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Sathaye, J., Shukla, P.R., and Ravindranath, N.H. **Climate change, sustainable development and India: Global and national concerns.** *Current Science* 90(3): 314-325, 2006.

**Notes:** Climate change is one of the most important global environmental challenges, with implications for food production, water supply, health, energy, etc. Addressing climate change requires a good scientific understanding as well as coordinated action at national and global level. This paper addresses these challenges. Historically, the responsibility for greenhouse gas emissions' increase lies largely with the industrialized world, though the developing countries are likely to be the source of an increasing proportion of future emissions. The projected climate change under various scenarios is likely to have implications on food production, water supply, coastal settlements, forest ecosystems, health, energy security, etc. The adaptive capacity of communities likely to be impacted by climate change is low in developing countries. The efforts made by the UNFCCC and the Kyoto Protocol provisions are clearly inadequate to address the climate change challenge. The most effective way to address climate change is to adopt a sustainable development pathway by shifting to environmentally sustainable technologies and promotion of energy efficiency, renewable energy, forest conservation, reforestation, water conservation, etc. The issue of highest importance to developing countries is reducing the vulnerability of their natural and socio-economic systems to the projected climate change. India and other developing countries will face the challenge of promoting mitigation and adaptation strategies, bearing the cost of such an effort, and its implications for economic development.

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Unnikrishnan, A.S., Kumar, K.R., Fernandes, S.E., Michael, G.S., and Patwardhan, S.K. **Sea level changes along the Indian coast: Observations and projections.** *Current Science* 90(3): 362-368, 2006.

**Notes:** Sea level changes can be of two types: (i) changes in the mean sea level and (ii) changes in the extreme sea level. The former is a global phenomenon while the latter is a regional phenomenon. Estimates of mean sea level rise made from past tide gauge data at selected stations along the coast of India indicate a rise of slightly less than 1 mm/year; however these estimates need to be corrected by including the rates of vertical land movements, whose measurements are not available at present. Simulation results of a regional climate model, HadRM2, were analysed for the northern Indian Ocean to provide the future scenarios of the occurrence of tropical cyclones in the Bay of Bengal for the period 2041-60. This model simulations consist of a control run with concentration of CO<sub>2</sub> kept constant at 1990 levels and a perturbed run with transient increase in the concentrations of CO<sub>2</sub> (GHG) according to the IS92a scenario for the period 2041-2060. The simulation results show increase in frequencies of tropical cyclones in the Bay, particularly intense events during the post-monsoon period, for the increased GHG run. A storm surge model was used to compute the surges associated with the cyclones generated by the climate model. The storm surge model was forced by the wind field from HadRM2 over the model domain and tides prescribed along the open boundary from a global tidal model. The frequency of high surges is found to be higher in the model run forced by winds from increased GHG run than in the model run forced by winds from the control run.

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Schipper, L. and Pelling, M. **Disaster risk, climate change and international development: scope for, and challenges to, integration.** *Disasters* 30(1): 19-38, 2006.

**Notes:** Reducing losses to weather-related disasters, meeting the Millennium Development Goals and wider human development objectives, and implementing a successful response to climate change are aims that can only be accomplished if they are undertaken in an integrated manner. Currently, policy responses to address each of these independently may be redundant or, at worst, conflicting. We believe that this conflict can be attributed primarily to a lack of interaction and institutional overlap among the three communities of practice. Differences in language, method and political relevance may also contribute to the intellectual divide. Thus, this paper seeks to review the theoretical and policy linkages among disaster risk reduction, climate change and development. It finds that not only does action within one realm affect capacity for action in the others, but also that there is much that can be learnt and shared between realms in order to ensure a move towards a path of integrated and more sustainable development.

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Thomalla, F., Downing, T., Spanger-Siegfried, E., Han, G., and Rockström, J. **Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation.** *Disasters* 30(1): 39-48, 2006.

**Notes:** Over the past few decades, four distinct and largely independent research and policy communities - disaster risk reduction, climate change adaptation, environmental management and poverty reduction - have been actively engaged in reducing socio-economic vulnerability to natural hazards. However, despite the significant efforts of these communities, the vulnerability of many individuals and communities to natural hazards continues to increase considerably. In particular, it is hydro-meteorological hazards that affect an increasing number of people and cause increasingly large economic losses. Arising from the realisation that these four communities have been largely working in isolation and enjoyed only limited success in reducing vulnerability, there is an emerging perceived need to strengthen significantly collaboration and to facilitate learning and information exchange between them. This article examines key communalities and differences between the climate change adaptation and disaster risk reduction communities, and proposes three exercises that would help to structure a multi-community dialogue and learning process.

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Bouwer, L.M. and Aerts, J.C.J.H. **Financing climate change adaptation.** *Disasters* 30(1): 49-63, 2006.

**Notes:** This paper examines the topic of financing adaptation in future climate change policies. A major question is whether adaptation in developing countries should be financed under the 1992 United Nations Framework Convention on Climate Change (UNFCCC), or whether funding should come from other sources. We present an overview of financial resources and propose the employment of a two-track approach: one track that attempts to secure climate change adaptation funding under the UNFCCC; and a second track that improves mainstreaming of climate risk management in development efforts. Developed countries would need to demonstrate much greater commitment to the funding of adaptation measures if the UNFCCC were to cover a substantial part of the costs. The mainstreaming of climate change adaptation could follow a risk

management path, particularly in relation to disaster risk reduction. 'Climate-proofing' of development projects that currently do not consider climate and weather risks could improve their sustainability.

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O'Brien, G., O'Keefe, P., Rose, J., and Wisner, B. **Climate change and disaster management.** *Disasters* 30(1): 64-80, 2006.

**Notes:** Climate change, although a natural phenomenon, is accelerated by human activities. Disaster policy response to climate change is dependent on a number of factors, such as readiness to accept the reality of climate change, institutions and capacity, as well as willingness to embed climate change risk assessment and management in development strategies. These conditions do not yet exist universally. A focus that neglects to enhance capacity-building and resilience as a prerequisite for managing climate change risks will, in all likelihood, do little to reduce vulnerability to those risks. Reducing vulnerability is a key aspect of reducing climate change risk. To do so requires a new approach to climate change risk and a change in institutional structures and relationships. A focus on development that neglects to enhance governance and resilience as a prerequisite for managing climate change risks will, in all likelihood, do little to reduce vulnerability to those risks.

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Rignot, E. and Kanagaratnam, P. **Changes in the velocity structure of the Greenland ice sheet.** *Science* 311(5763): 986-990, 2006.

**Notes:** Using satellite radar interferometry observations of Greenland, we detected widespread glacier acceleration below 66° north between 1996 and 2000, which rapidly expanded to 70° north in 2005. Accelerated ice discharge in the west and particularly in the east doubled the ice sheet mass deficit in the last decade from 90 to 220 cubic kilometers per year. As more glaciers accelerate farther north, the contribution of Greenland to sea-level rise will continue to increase.

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Overpeck, J.T., Otto-Bliesner, B.L., Miller, G.H., Muhs, D.R., Alley, R.B., and Kiehl, J.T. **Paleoclimatic evidence for future ice-sheet instability and rapid sea-level rise.** *Science* 311(5768): 1747-1750, 2006.

**Notes:** Sea-level rise from melting of polar ice sheets is one of the largest potential threats of future climate change. Polar warming by the year 2100 may reach levels similar to those of 130,000 to 127,000 years ago that were associated with sea levels several meters above modern levels; both the Greenland Ice Sheet and portions of the Antarctic Ice Sheet may be vulnerable. The record of past ice-sheet melting indicates that the rate of future melting and related sea-level rise could be faster than widely thought.

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Otto-Bliesner, B.L., Marsha, S.J., Overpeck, J.T., Miller, G.H., and Hu, A.X. **Simulating Arctic climate warmth and icefield retreat in the last interglaciation.** *Science* 311(5768): 1751-1753, 2006.

**Notes:** In the future, Arctic warming and the melting of polar glaciers will be considerable, but the magnitude of both is uncertain. We used a global climate model, a dynamic ice sheet model, and paleoclimatic data to evaluate Northern Hemisphere high-latitude warming and its impact on Arctic icefields during the Last Interglaciation. Our simulated climate matches paleoclimatic observations of past warming, and the combination of physically based climate and ice-sheet modeling with ice-core constraints indicate that the Greenland Ice Sheet and other circum-Arctic ice fields likely contributed 2.2 to 3.4 meters of sea-level rise during the Last Interglaciation.

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Velicogna, I. and Wahr, J. **Measurements of time-variable gravity show mass loss in Antarctica.** *Science* 311(5768): 1754-1756, 2006.

**Notes:** Using measurements of time-variable gravity from the Gravity Recovery and Climate Experiment satellites, we determined mass variations of the Antarctic ice sheet during 2002-2005. We found that the mass of the ice sheet decreased

significantly, at a rate of 152 +/- 80 cubic kilometers of ice per year, which is equivalent to 0.4 +/- 0.2 millimeters of global sea-level rise per year. Most of this mass loss came from the West Antarctic Ice Sheet.

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Ekstrom, G., Nettles, M., and Tsai, V.C. **Seasonality and increasing frequency of Greenland glacial earthquakes.** *Science* 311(5768): 1756-1758, 2006.

**Notes:** Some glaciers and ice streams periodically lurch forward with sufficient force to generate emissions of elastic waves that are recorded on seismometers worldwide. Such glacial earthquakes on Greenland show a strong seasonality as well as a doubling of their rate of occurrence over the past 5 years. These temporal patterns suggest a link to the hydrological cycle and are indicative of a dynamic glacial response to changing climate conditions.

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Chan, J.C.L. **Comment on "Changes in tropical cyclone number, duration, and intensity in a warming environment".** *Science* 311(5768): U1-U2, 2006.

**Notes:** Analyses of tropical cyclone records from the western North Pacific reveal that the recent increase in occurrence of intense typhoons reported by Webster *et al.* (Reports, 16 Sep. 2005, p. 1844) is not a trend. Rather, it is likely a part of the large interdecadal variations in the number of intense typhoons related to similar temporal fluctuations in the atmospheric environment.