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Marine Science Review – 232

Climate and climate change

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In this review:

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B. Recent articles with abstracts

A. Recent articles – no abstract available

Pilewskie, P. **Aerosols heat up.** *Nature* 448(7153): 541-542, 2007.

Thuiller, W. **Climate change and the ecologist.** *Nature* 448(7153): 550-552, 2007.

Trenberth, K. **Climate change - Warmer oceans, stronger hurricanes.** *Scientific American* 297(1): 44-51, 2007.

Kerr, R.A. **Humans and nature duel over the next decade's climate.** *Science* 317(5839): 746-747, 2007.

Loáiciga, H.A. **Reply to comment by K. Caldeira *et al.* on "Modern-age buildup of CO2 and its effects on seawater acidity and salinity".** *Geophysical Research Letters* 34(18): art. L18603, 2007.

B. Recent articles with abstracts

Spicer, J.I., Raffo, A., and Widdicombe, S. **Influence of CO_2-related seawater acidification on extracellular acid-base balance in the velvet swimming crab *Necora puber*.** *Marine Biology* 151(3): 1117-1125, 2007.

Notes: We investigated the effect of different levels of hypercapnia-induced acidification (pH = 7.96, 7.31, 6.74 and 6.05) on the extracellular acid base balance of a shallow-water crustacean, the velvet swimming crab *Necora puber* over a period of 16 days. Any extracellular acidosis incurred was completely compensated by an increase in bicarbonate. Bicarbonate was partly, but not wholly, supplied by dissolution of the exoskeleton. This compensation was sustained for 16 days under all experimental treatments with two exceptions. First there was some evidence of extracellular acidosis in crabs after 16 days at pH = 6.74. Second at the lowest environmental pH (6.05) there was a marked uncompensated acidosis after 24 h. *Necora puber* appears less sensitive to low pH than many other species examined acutely. However, local acidification as a result of ocean CO_2 dispersal or leakage from geological sequestration is likely to compromise even this species.

Donnelly, J.P. and Woodruff, J.D. **Intense hurricane activity over the past 5,000 years controlled by El Nino and the West African monsoon.** *Nature* 447(7143): 465-468, 2007.

Notes: The processes that control the formation, intensity and track of hurricanes are poorly understood. It has been proposed that an increase in sea surface temperatures caused by anthropogenic climate change has led to an increase in the frequency of intense tropical cyclones, but this proposal has been challenged on the basis that the instrumental record is too short and unreliable to reveal trends in intense tropical cyclone activity. Storm-induced deposits preserved in the sediments of coastal lagoons offer the opportunity to study the links between climatic conditions and hurricane activity on longer timescales, because they provide centennial- to millennial-scale records of past hurricane landfalls. Here we present a record of intense hurricane activity in the western North Atlantic Ocean over the past 5,000 years based on sediment cores from a

Caribbean lagoon that contain coarse-grained deposits associated with intense hurricane landfalls. The record indicates that the frequency of intense hurricane landfalls has varied on centennial to millennial scales over this interval. Comparison of the sediment record with palaeo-climate records indicates that this variability was probably modulated by atmospheric dynamics associated with variations in the El Nino/Southern Oscillation and the strength of the West African monsoon, and suggests that sea surface temperatures as high as at present are not necessary to support intervals of frequent intense hurricanes. To accurately predict changes in intense hurricane activity, it is therefore important to understand how the El Nino/Southern Oscillation and the West African monsoon will respond to future climate change.

Zickfeld, K., Levermann, A., Morgan, M.G., Kuhlbrodt, T., Rahmstorf, S., and Keith, D.W. **Expert judgements on the response of the Atlantic meridional overturning circulation to climate change.** *Climatic Change* 82(3-4): 235-265, 2007.

Notes: We present results from detailed interviews with 12 leading climate scientists about the possible effects of global climate change on the Atlantic Meridional Overturning Circulation (AMOC). The elicitation sought to examine the range of opinions within the climatic research community about the physical processes that determine the current strength of the AMOC, its future evolution in a changing climate and the consequences of potential AMOC changes. Experts assign different relative importance to physical processes which determine the present-day strength of the AMOC as well as to forcing factors which determine its future evolution under climate change. Many processes and factors deemed important are assessed as poorly known and insufficiently represented in state-of-the-art climate models. All experts anticipate a weakening of the AMOC under scenarios of increase of greenhouse gas concentrations. Two experts expect a permanent collapse of the AMOC as the most likely response under a $4xCO_2$ scenario. Assuming a global mean temperature increase in the year 2100 of 4 K, eight experts assess the probability of triggering an AMOC collapse as significantly different from zero, three of them as larger than 40%. Elicited consequences of AMOC reduction include strong changes in temperature, precipitation distribution and sea level in the North Atlantic area. It is expected that an appropriately designed research program, with emphasis on long-term observations and coupled climate modeling, would contribute to substantially reduce uncertainty about the future evolution of the AMOC.

Bengtsson, L., Hodges, K.I., Esch, M., Keenlyside, N., Kornblueh, L., Luo, J.-J., and Yamagata, T. **How may tropical cyclones change in a warmer climate?** *Tellus A* 59(4): 539-561, 2007.

Notes: Tropical cyclones (TC) under different climate conditions in the Northern Hemisphere have been investigated with the Max Planck Institute (MPI) coupled (ECHAM5/MPI-OM) and atmosphere (ECHAM5) climate models. The intensity and size of the TC depend crucially on resolution with higher wind speed and smaller scales at the higher resolutions. The typical size of the TC is reduced by a factor of 2.3 from T63 to T319 using the distance of the maximum wind speed from the centre of the storm as a measure. The full three-dimensional structure of the storms becomes increasingly more realistic as the resolution is increased. For the T63 resolution, three ensemble runs are explored for the period 1860 until 2100 using the IPCC SRES scenario A1B and evaluated for three 30 yr periods at the end of the 19th, 20th and 21st century, respectively. While there is no significant change between the 19th and the 20th century, there is a considerable reduction in the number of the TC by some 20% in the 21st century, but no change in the number of the more intense storms. Reduction in the number of storms occurs in all regions. A single additional experiment at T213 resolution was run for the two latter 30-yr periods. The T213 is an atmospheric only experiment using the transient sea surface temperatures (SST) of the T63 resolution experiment. Also in this case, there is a reduction by some 10% in the number of simulated TC in the 21st century compared to the 20th century but a marked increase in the number of intense storms. The number of storms with maximum wind speeds greater than 50 m s^{-1} increases by a third. Most of the intensification takes place in the Eastern Pacific and in the Atlantic where also the number of storms more or less stays the same. We identify two competing processes effecting TC in a warmer climate. First, the increase in the static stability and the reduced vertical circulation is suggested to contribute to the reduction in the number of storms. Second, the increase in temperature and water vapour provide more energy for the storms so that when favourable conditions occur, the higher SST and higher specific humidity will contribute to more intense storms. As the maximum intensity depends crucially on resolution, this will require higher resolution to have its full effect. The distribution of storms between different regions does not, at first approximation, depend on the temperature itself but on the distribution of the SST anomalies and their influence on the atmospheric circulation. Two additional transient experiments at T319 resolution where run for 20 yr at the end of the 20th and 21st century, respectively, using the same conditions as in the T213 experiments. The results are consistent with the T213 study. The total number of TC were similar to the T213 experiment but

were generally more intense. The change from the 20th to the 21st century was also similar with fewer TC in total but with more intense cyclones.

Tyrrell, T., Shepherd, J.G., and Castle, S. **The long-term legacy of fossil fuels.** *Tellus B* 59(4): 664-672, 2007.

Notes: Fossil fuels will have large impacts on ocean chemistry and climate during the period while they are being burnt (and carbon dioxide emitted) in large amounts. It is frequently assumed that these impacts will fade away soon thereafter. Recent model results, by contrast, suggest that significant impacts will persist for hundreds of thousands of years after emissions cease. We present a new analysis that supports these model findings by elucidating the cause of this 'fossil fuel hangover' phenomenon. We explain why the carbonate compensation feedback is atypical, compared to other feedbacks, in the sense that convergence is back towards a new steady-state that is distinct from the starting state. We also calculate in greater detail the predicted implications for the future ocean and atmosphere. The post-fossil fuel long-term equilibrium state could differ from the pre-anthropogenic state by as much as 50% for total dissolved inorganic carbon and alkalinity and 100% for atmospheric *p*CO2, depending on the total amount of future emissions.

Durant, J.M., Hjermann, D.O., Ottersen, G., and Stenseth, N.C. **Climate and the match or mismatch between predator requirements and resource availability.** *Climate Research* 33(3): 271-283, 2007.

Notes: Climate influences a population through a variety of processes, including reproduction, growth, migration patterns and phenology. Climate may operate either directly through metabolic and reproductive processes or indirectly through prey, predators, and competitors. One mechanism that may be particularly important, and which is the focus of this review, is the role of climate in affecting the reproductive success of a predator through its effect on the relative timing of food requirement and food availability during early life stages. This principle - the match or mismatch of predators' requirement with resource availability - originated in the marine literature, where it initially referred to how growth and survival of fish larvae (predator) depends on this production being synchronous with that of their main food items, i.e. early stage zooplankton (prey). Here we review how the match/mismatch hypothesis (MMH) is used to describe climate effects on ecological patterns and processes in both marine and terrestrial systems. In addition to studying match/mismatch *sensu stricto*, we expand on it to include effects of overall production level and the spatial aspect. Possible impacts of climate change on match/mismatch are examined in the context of one of the most apparent effects of global warming: an advancement of spring phenology. As a consequence of different species reacting dissimilarly, even minor changes in climate may invoke non-linear responses unbalancing established patterns of synchrony. All components of a food chain cannot be expected to shift their phenology at the same rate, and thus are unlikely to remain synchronous.

Mieszkowska, N., Hawkins, S.J., Burrows, M.T., and Kendall, M.A. **Long-term changes in the geographic distribution and population structures of *Osilinus lineatus* (Gastropoda: Trochidae) in Britain and Ireland.** *Journal of the Marine Biological Association of the United Kingdom* 87(2): 537-545, 2007.

Notes: Since the rate of global climate change began to accelerate in the 1980s, the coastal seas of Britain have warmed by tip to 1ºC. Locations close to the northern range edges of a southern trochid gastropod *Osilinus lineatus* in Britain previously surveyed in the 1950s and 1980s were resurveyed during 2002-2004 to determine whether changes in the success of near-limit populations had occurred during the period of climate warming. Between the 1980s and the 2000s, the range limits had extended by up to 55 km. Populations sampled over a latitudinal extent of 4º from northern limits towards the centre of the range showed synchronous increases in abundance throughout the years sampled, suggesting a large-scale factor such as climate was driving the observed changes. These increases in abundance and changes in range limits are likely to have occurred via increased recruitment success in recent years.

Füssel, H.M. **Vulnerability: A generally applicable conceptual framework for climate change research.** *Global Environmental Change* 17(2): 155-167, 2007.

Notes: The term 'vulnerability' is used in many different ways by various scholarly communities. The resulting disagreement about the appropriate definition of vulnerability is a frequent cause for misunderstanding in interdisciplinary research on climate change and a challenge for attempts to develop formal models of vulnerability. Earlier attempts at reconciling the various conceptualizations of vulnerability were, at best, partly successful. This paper presents a generally applicable conceptual framework of vulnerability that combines a nomenclature of vulnerable situations and a terminology of vulnerability concepts based on the distinction of four fundamental groups of vulnerability factors. This conceptual framework is applied to characterize the vulnerability concepts employed by the main schools of vulnerability research and to review earlier attempts at classifying vulnerability concepts. None of these one-dimensional classification schemes reflects the diversity of vulnerability concepts identified in this review. The wide range of policy responses available to address the risks from global climate change suggests that climate impact, vulnerability, and adaptation assessments will continue to apply a variety of vulnerability concepts. The framework presented here provides the much-needed conceptual clarity and facilitates bridging the various approaches to researching vulnerability to climate change.

Collins, W., Colman, R., Haywood, J., Manning, M.R., and Mote, P. **The physical science behind climate change.** *Scientific American* 297(2): 64-73, 2007.

Notes: Scientists are confident that humans have interfered with the climate and that further human-induced climate change is on the way. The principal driver of recent climate change is greenhouse gas emissions from human activities, primarily the burning of fossil fuels. Although further changes in the world's climate are now inevitable, the future, particularly in the longer term, remains largely in our hands - the magnitude of expected change depends on what humans choose to do about greenhouse gas emissions.

Landsea, C.W. **Counting Atlantic tropical cyclones back to 1900.** *Eos Transactions* 88(18): 197-208, 2007.

Notes: Climate variability and any resulting change in the characteristics of tropical cyclones (tropical storms, subtropical storms, and hurricanes) have become topics of great interest and research within the past 2 years [*International Workshop on Tropical Cyclones*, 2006]. An emerging focus is how the frequency of tropical cyclones has changed over time and whether any changes could be linked to anthropogenic global warming. The Atlantic is the one tropical cyclone basin that has quantitative records back to the mid-nineteenth century for the whole basin (i.e., North Atlantic Ocean, Caribbean Sea, and Gulf of Mexico) [*Jarvinen et al.*, 1984; *Landsea et al.*, 2004]. *Mann and Emanuel* [2006] used this data set to find a positive correlation between sea surface temperatures and Atlantic basin tropical cyclone frequency for the period of 1871-2005. Likewise, *Holland and Webster* [2007] analyzed Atlantic tropical cyclone frequency back to 1855 and found a doubling of the number of tropical cyclones over the past 100 years. Both papers linked these changes directly to anthropogenic greenhouse warming. However, both analyses, with no indication of uncertainty or error bars, presumed that tropical cyclone counts are complete or nearly complete for the entire basin going back in time for at least a century. This article will show that this presumption is not reasonable and that improved monitoring in recent years is responsible for most, if not all, of the observed trend in increasing frequency of tropical cyclones.

Reusch, T.B.H. and Wood, T.E. **Molecular ecology of global change.** *Molecular Ecology* 16(19): 3973-3992, 2007.

Notes: Global environmental change is altering the selection regime for all biota. The key selective factors are altered mean, variance and seasonality of climatic variables and increase in CO_2 concentration itself. We review recent studies that document rapid evolution to global climate change at the phenotypic and genetic level, as a response to shifts in these factors. Among the traits that have changed are photoperiod responses, stress tolerance and traits associated with enhanced dispersal. The genetic basis of two traits with a critical role under climate change, stress tolerance and photoperiod behaviour, is beginning to be understood for model organisms, providing a starting point for candidate gene approaches in targeted nonmodel species. Most studies that have documented evolutionary change are correlative, while selection experiments that manipulate relevant variables are rare. The latter are particularly valuable for prediction because they provide insight into heritable change to simulated future conditions. An important gap is that experimental selection regimes have mostly been testing one variable at a time, while synergistic interactions are likely under global change. The expanding toolbox available to molecular ecologists holds great promise for identifying the genetic basis of many more traits relevant to fitness under global change. Such

knowledge, in turn, will significantly advance predictions on global change effects because presence and polymorphism of critical genes can be directly assessed. Moreover, knowledge of the genetic architecture of trait correlations will provide the necessary framework for understanding limits to phenotypic evolution; in particular as lack of critical gene polymorphism or entire pathways, metabolic costs of tolerance and linkage or pleiotropy causing negative trait correlations. Synergism among stressor impacts on organismal function may be causally related to conflict among transcriptomic syndromes specific to stressor types. Because adaptation to changing environment is always contingent upon the spatial distribution of genetic variation, high-resolution estimates of gene flow and hybridization should be used to inform predictions of evolutionary rates.

Piao, S., Friedlingstein, P., Ciais, P., de Noblet-Ducoudre, N., Labat, D., and Zaehle, S. **Changes in climate and land use have a larger direct impact than rising CO_2 on global river runoff trends.** *Proceedings of the National Academy of Sciences [USA]* 104(39): 15242-15247, 2007.

Notes: The significant worldwide increase in observed river runoff has been tentatively attributed to the stomatal "antitranspirant" response of plants to rising atmospheric CO_2 [Gedney N, Cox PM, Betts RA, Boucher O, Huntingford C, Stott PA (2006) *Nature* 439: 835-838]. However, CO_2 also is a plant fertilizer. When allowing for the increase in foliage area that results from increasing atmospheric CO_2 levels in a global vegetation model, we find a decrease in global runoff from 1901 to 1999. This finding highlights the importance of vegetation structure feedback on the water balance of the land surface. Therefore, the elevated atmospheric CO_2 concentration does not explain the estimated increase in global runoff over the last century. In contrast, we find that changes in mean climate, as well as its variability, do contribute to the global runoff increase. Using historic land-use data, we show that land-use change plays an additional important role in controlling regional runoff values, particularly in the tropics. Land-use change has been strongest in tropical regions, and its contribution is substantially larger than that of climate change. On average, land-use change has increased global runoff by 0.08 mm/year^2 and accounts for ~50% of the reconstructed global runoff trend over the last century. Therefore, we emphasize the importance of land-cover change in forecasting future freshwater availability and climate.

Michael, J.A. **Episodic flooding and the cost of sea-level rise.** *Ecological Economics* 63(1): 149-159, 2007.

Notes: Previous studies of the cost of sea-level rise focus on the economic loss to inundated property rather than increased damage from episodic flood events to non-inundated property above sea level. This study uses a unique GIS database of three geographically diverse Chesapeake Bay communities that includes 1-ft elevation contours from remote sensing data, local tax assessment records, and aerial photographs of property location. Hedonic property value models estimate the loss from complete inundation, closely following the methodology of previous studies. Increased damage from episodic flooding is estimated using elevation-rated, actuarially fair flood insurance rates. Using a 3-ft sea-level rise over 100 years scenario, damage from episodic flooding averages 9 times the estimated loss from complete inundation, and is an average of 28 times greater under a 2-ft sea-level rise scenario. Although the study areas are not representative of all coastal areas, the results suggest that current studies may substantially underestimate the cost of sea-level rise.

Thomas, H. *et al.* **Rapid decline of the CO_2 buffering capacity in the North Sea and implications for the North Atlantic Ocean.** *Global Biogeochemical Cycles* 21(4): art. GB4001, 2007.

Notes: New observations from the North Sea, a NW European shelf sea, show that between 2001 and 2005 the CO_2 partial pressure (pCO_2) in surface waters rose by 22 μatm, thus faster than atmospheric pCO_2, which in the same period rose approximately 11 μatm. The surprisingly rapid decline in air-sea partial pressure difference (ΔpCO_2) is primarily a response to an elevated water column inventory of dissolved inorganic carbon (DIC), which, in turn, reflects mostly anthropogenic CO_2 input rather than natural interannual variability. The resulting decline in the buffering capacity of the inorganic carbonate system (increasing Revelle factor) sets up a theoretically predicted feedback loop whereby the invasion of anthropogenic CO_2 reduces the ocean's ability to uptake additional CO_2. Model simulations for the North Atlantic Ocean and thermodynamic principles reveal that this feedback should be stronger, at present, in colder midlatitude and subpolar waters because of the lower present-day buffer capacity and elevated DIC levels driven either by northward advected surface water and/or excess local air-sea CO_2 uptake. This buffer capacity feedback mechanism helps to explain at least part of the observed trend of decreasing air-sea ΔpCO_2 over time as reported in several other recent North Atlantic studies.

Thistle, D., Sedlacek, L., Carman, K.R., Fleeger, J.W., Brewer, P.G., and Barry, J.P. **Exposure to carbon dioxide-rich seawater is stressful for some deep-sea species: an in situ, behavioral study.** *Marine Ecology Progress Series* 340: 9-16, 2007.

Notes: Since the beginning of the industrial revolution, the concentration of the greenhouse gas carbon dioxide in the atmosphere has increased from 275 to 370 ppm; the increase is thought to have caused much of the rise in global temperature that has occurred during the same period. A means of mitigating its effects is to collect industrial carbon dioxide and sequester it in the deep ocean. Knowledge of effects of such sequestration on deep-sea organisms is crucial to evaluation of the wisdom of deep-ocean sequestration. We therefore tested deep-sea animals for indications that exposure to carbon dioxide-rich seawater is stressful. Our study site was at 3087 m depth off the coast of central California (36°41.91'N, 123°0.14' W). We deployed liquid carbon dioxide in open-topped containers on the sea floor. The carbon dioxide reacted with the carbonate system in the overlying seawater, and carbon dioxide-rich seawater flowed out onto the sediment. We placed inverted funnel traps near the containers and ~ 75 m away from them. Measurements of pH confirmed that the area near the containers was exposed to carbon dioxide-rich seawater. As a test taxon, we chose harpacticoid copepods. The traps near the source of the carbon dioxide-rich seawater caught significantly more harpacticoids than those far from it. The harpacticoids apparently attempted to escape from the advancing front of carbon dioxide-rich seawater and therefore presumably found exposure to it to be stressful.

Le Quere, C., Rodenbeck, C., Buitenhuis, E.T., Conway, T.J., Langenfelds, R., Gomez, A., Labuschagne, C., Ramonet, M., Nakazawa, T., Metzl, N., Gillett, N., and Heimann, M. **Saturation of the Southern Ocean CO_2 sink due to recent climate change.** *Science* 316(5832): 1735-1738, 2007.

Notes: Based on observed atmospheric carbon dioxide (CO_2) concentration and an inverse method, we estimate that the Southern Ocean sink of CO_2 has weakened between 1981 and 2004 by 0.08 petagrams of carbon per year per decade relative to the trend expected from the large increase in atmospheric CO_2. We attribute this weakening to the observed increase in Southern Ocean winds resulting from human activities, which is projected to continue in the future. Consequences include a reduction of the efficiency of the Southern Ocean sink of CO_2 in the short term (~ 25 years) and possibly a higher level of stabilization of atmospheric CO_2 on a multicentury time scale.

Smith, D.M., Cusack, S., Colman, A.W., Folland, C.K., Harris, G.R., and Murphy, J.M. **Improved surface temperature prediction for the coming decade from a global climate model.** *Science* 317(5839): 796-799, 2007.

Notes: Previous climate model projections of climate change accounted for external forcing from natural and anthropogenic sources but did not attempt to predict internally generated natural variability. We present a new modeling system that predicts both internal variability and externally forced changes and hence forecasts surface temperature with substantially improved skill throughout a decade, both globally and in many regions. Our system predicts that internal variability will partially offset the anthropogenic global warming signal for the next few years. However, climate will continue to warm, with at least half of the years after 2009 predicted to exceed the warmest year currently on record.

Meier, M.F., Dyurgerov, M.B., Rick, U.K., ONeel, S., Pfeffer, W.T., Anderson, R.S., Anderson, S.P., and Glazovsky, A.F. **Glaciers dominate eustatic sea-level rise in the 21st century.** *Science* 317(5841): 1064-1067, 2007.

Notes: Ice loss to the sea currently accounts for virtually all of the sea-level rise that is not attributable to ocean warming; about 60% of the ice loss is from glaciers and ice caps rather than from the two ice sheets. The contribution of these smaller glaciers has accelerated over the past decade, in part due to marked thinning and retreat of marine-terminating glaciers associated with a dynamic instability that is generally not considered in mass-balance and climate modeling. This acceleration of glacier melt may cause 0.1 to 0.25 meter of additional sea-level rise by 2100.

Marsland, S.J., Church, J.A., Bindoff, N.L., and Williams, G.D. **Antarctic coastal polynya response to climate change.** *Journal of Geophysical Research* 112(7): art. C07009, 2007.

Notes: Sensitivity of sea ice formation and dense shelf water production to perturbations of air temperature, precipitation, and wind stress in an important Antarctic coastal polynya system is investigated. Shelf water formation in the Mertz Glacier Polynya is a major source of Adélie Land Bottom Water. Coupled ocean and sea ice model simulations for 1996-1999 span a transitional period of the system: The 1996-1997 strong polynya state is characterized by high sea ice growth and export, ocean to atmosphere heat flux, shelf water density, and rate of dense water export; in the 1998-1999 weak polynya state all these quantities are greatly reduced. The 1990s interannual variability in air temperature and precipitation is of similar magnitude to future increases as projected for the Southern Ocean by the IPCC assessment. We model the polynya with perturbed climate change forcing and find that the system shows a reduction in shelf water export in both the strong/weak modes. Overall, the dense water export is reduced by 40% for a 2°C surface warming, and by 33% for a 20 cm a^{-1} precipitation increase. In the weak polynya state that is more likely in future climate, shelf water export is reduced by 81% for the warming and by 65% for the freshening. The reduction in dense shelf water export implies a corresponding reduction in Antarctic Bottom Water formation.

Chen, W.-T., Liao, H., and Seinfeld, J.H. **Future climate impacts of direct radiative forcing of anthropogenic aerosols, tropospheric ozone, and long-lived greenhouse gases.** *Journal of Geophysical Research* 112(14): art. D14209, 2007.

Notes: Long-lived greenhouse gases (GHGs) are the most important driver of climate change over the next century. Aerosols and tropospheric ozone (O_3) are expected to induce significant perturbations to the GHG-forced climate. To distinguish the equilibrium climate responses to changes in direct radiative forcing of anthropogenic aerosols, tropospheric ozone, and GHG between present day and year 2100, four 80-year equilibrium climates are simulated using a unified tropospheric chemistry-aerosol model within the Goddard Institute for Space Studies (GISS) general circulation model (GCM) II'. Concentrations of sulfate, nitrate, primary organic (POA) carbon, secondary organic (SOA) carbon, black carbon (BC) aerosols, and tropospheric ozone for present day and year 2100 are obtained a priori by coupled chemistry-aerosol GCM simulations, with emissions of aerosols, ozone, and precursors based on the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenario (SRES) A2. Changing anthropogenic aerosols, tropospheric ozone, and GHG from present day to year 2100 is predicted to perturb the global annual mean radiative forcing by +0.18 (considering aerosol direct effects only), +0.65, and +6.54 W m^{-2} at the tropopause, and to induce an equilibrium global annual mean surface temperature change of +0.14, +0.32, and +5.31 K, respectively, with the largest temperature response occurring at northern high latitudes. Anthropogenic aerosols, through their direct effect, are predicted to alter the Hadley circulation owing to an increasing interhemispheric temperature gradient, leading to changes in tropical precipitation. When changes in both aerosols and tropospheric ozone are considered, the predicted patterns of change in global circulation and the hydrological cycle are similar to those induced by aerosols alone. GHG-induced climate changes, such as amplified warming over high latitudes, weakened Hadley circulation, and increasing precipitation over the Tropics and high latitudes, are consistent with predictions of a number of previous GCM studies. Finally, direct radiative forcing of anthropogenic aerosols is predicted to induce strong regional cooling over East and South Asia. Wintertime rainfall over southeastern China and the Indian subcontinent is predicted to decrease because of the increased atmospheric stability and decreased surface evaporation, while the geographic distribution of precipitation is also predicted to be altered as a result of aerosol-induced changes in wind flow.

Eyring, V. and et al. **Multimodel projections of stratospheric ozone in the 21st century.** *Journal of Geophysical Research* 112(D16): art. D16303, 2007.

Notes: Simulations from eleven coupled chemistry-climate models (CCMs) employing nearly identical forcings have been used to project the evolution of stratospheric ozone throughout the 21st century. The model-to-model agreement in projected temperature trends is good, and all CCMs predict continued, global mean cooling of the stratosphere over the next 5 decades, increasing from around 0.25 K/decade at 50 hPa to around 1 K/decade at 1 hPa under the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) A1B scenario. In general, the simulated ozone evolution is mainly determined by decreases in halogen concentrations and continued cooling of the global stratosphere due to increases in greenhouse gases (GHGs). Column ozone is projected to increase as stratospheric halogen concentrations return to 1980s levels. Because of ozone increases in the middle and upper stratosphere due to GHG-induced cooling, total ozone

averaged over midlatitudes, outside the polar regions, and globally, is projected to increase to 1980 values between 2035 and 2050 and before lower-stratospheric halogen amounts decrease to 1980 values. In the polar regions the CCMs simulate small temperature trends in the first and second half of the 21st century in midwinter. Differences in stratospheric inorganic chlorine (Cly) among the CCMs are key to diagnosing the intermodel differences in simulated ozone recovery, in particular in the Antarctic. It is found that there are substantial quantitative differences in the simulated Cly, with the October mean Antarctic Cly peak value varying from less than 2 ppb to over 3.5 ppb in the CCMs, and the date at which the Cly returns to 1980 values varying from before 2030 to after 2050. There is a similar variation in the timing of recovery of Antarctic springtime column ozone back to 1980 values. As most models underestimate peak Cly near 2000, ozone recovery in the Antarctic could occur even later, between 2060 and 2070. In the Arctic the column ozone increase in spring does not follow halogen decreases as closely as in the Antarctic, reaching 1980 values before Arctic halogen amounts decrease to 1980 values and before the Antarctic. None of the CCMs predict future large decreases in the Arctic column ozone. By 2100, total column ozone is projected to be substantially above 1980 values in all regions except in the tropics.

Vecchi, G.A. and Soden, B.J. **Increased tropical Atlantic wind shear in model projections of global warming.** *Geophysical Research Letters* 34(8): art. L08702, 2007.

Notes: To help understand possible impacts of anthropogenic greenhouse warming on hurricane activity, we assess model-projected changes in large-scale environmental factors tied to variations in hurricane statistics. This study focuses on vertical wind shear (Vs) over the tropical Atlantic during hurricane season, the increase of which has been historically associated with diminished hurricane activity and intensity. A suite of state-of-the-art global climate model experiments is used to project changes in Vs over the 21st century. Substantial increases in tropical Atlantic and East Pacific shear are robust features of these experiments, and are shown to be connected to the model-projected decrease in the Pacific Walker circulation. The relative changes in shear are found to be comparable to those of other large-scale environmental parameters associated with Atlantic hurricane activity. The influence of these Vs changes should be incorporated into projections of long-term hurricane activity.

Chang, E.K.M. and Guo, Y. **Is the number of North Atlantic tropical cyclones significantly underestimated prior to the availability of satellite observations?** *Geophysical Research Letters* 34(14): art. L14801, 2007.

Notes: The number of North Atlantic tropical cyclones that may have been undetected before satellite observations are available is estimated by passing the cyclone tracks taken from 1976 to 2005 through ship observations from 1900 to 1965. The probability of detection is equated to the probability that the ships would have made wind observations of 18 m/s or higher had the tropical cyclones been present during the earlier years, based on the probability computed from actual wind observations around tropical cyclones during the satellite era. It is estimated that the number of tropical cyclones not making landfall over any continent or the Caribbeans may have been underestimated by up to 2.1 per year during 1904-1913, with this number decreasing to 1.0 per year or less during the 1920s and later decades. Our results suggest that the characteristics of North Atlantic tropical cyclone track statistics might have changed during the 20th century.

Jenkins, A. and Holland, D. **Melting of floating ice and sea level rise.** *Geophysical Research Letters* 34(16): art. L16609, 2007.

Notes: Contrary to popular belief, the melting of floating ice (in the form of ice shelves, icebergs and sea ice) may have a non-zero impact on sea level. This is because the melting process cools and dilutes the oceans on average, and unless these opposing effects exactly balance each other there will be a net change in the ocean density. We discuss how these subtle effects can be quantified and put bounds on the potential sea level rise associated with melting of the ice masses that are currently afloat in the world's oceans.

Overland, J.E. and Wang, M. **Future regional Arctic sea ice declines.** *Geophysical Research Letters* 34(17): art. L17705, 2007.

Notes: Because animals and humans respond to seasonally and regionally varying climates, it is instructive to assess how much confidence we can have in regional projections of sea ice from the 20 models provided through the International Panel on Climate Change Fourth Assessment Report (AR4) process (IPCC 2007). Based on the selection of a subset models that closely simulate observed regional ice concentrations for 1979-1999, we find considerable evidence for loss of sea ice area of greater than 40% by 2050 in summer for the marginal seas of the Arctic basin. This conclusion is supported by consistency in the selection of the same models across different regions, and the importance of thinning ice and increased open water at mid-century to the rate of ice loss. With less confidence, we find that the Bering, Okhotsk and Barents Seas have a similar 40% loss of sea ice area by 2050 in winter. Baffin Bay/Labrador shows little change compared to current conditions. These seasonal ice zones have large interannual/decadal variability in addition to trends. Large model-to-model differences were seen for the Kara/Laptev Seas and East Greenland. With a careful evaluation process, AR4 sea ice projections have some utility for use in assessing potential impacts over large Arctic subregions for a 2020-2050 time horizon.

Caldeira, K. *et al.* **Comment on "Modern-age buildup of CO_2 and its effects on seawater acidity and salinity" by Hugo A. Loáiciga.** *Geophysical Research Letters* 34(18): art. L18608, 2007.

Notes: A doubling of present atmospheric CO_2 concentrations (to 760 ppm) may occur by the end of this century in the absence of efforts to diminish CO_2 emissions from fossil-fuel combustion [Intergovernmental Panel on Climate Change (IPCC), 2001]. Based on inappropriate assumptions and erroneous thermodynamic calculations, Loaiciga [2006] mistakenly reports that atmospheric CO_2 concentrations of 760 ppm will lower the pH of the surface ocean by 0.28 relative to the natural "mid 18th century" conditions. He implies that a drop of this magnitude will have minimal biological impact, neglecting numerous recent experiments and observations showing that this decrease in pH would substantially affect the physiology and health of marine organisms. Here, we focus on two fundamental flaws in the published analysis that invalidate his conclusions: (1) he assumes instantaneous chemical equilibration of the ocean with carbonate minerals although this process is known to take five to ten thousand years and (2) contrary to what is implied by Loaiciga, many marine organisms are sensitive to a pH decrease of 0.2 units.

Weaver, A.J., Zickfeld, K., Montenegro, A., and Eby, M. **Long term climate implications of 2050 emission reduction targets.** *Geophysical Research Letters* 34(19): art. L19703, 2007.

Notes: A coupled atmosphere-ocean-carbon cycle model is used to examine the long term climate implications of various 2050 greenhouse gas emission reduction targets. All emission targets considered with less than 60% global reduction by 2050 break the 2.0°C threshold warming this century, a number that some have argued represents an upper bound on manageable climate warming. Even when emissions are stabilized at 90% below present levels at 2050, this 2.0°C threshold is eventually broken. Our results suggest that if a 2.0°C warming is to be avoided, direct CO_2 capture from the air, together with subsequent sequestration, would eventually have to be introduced in addition to sustained 90% global carbon emissions reductions by 2050.

Nghiem, S.V., Rigor, I.G., Perovich, D.K., Clemente-Colón, P., Weatherly, J.W., and Neumann, G. **Rapid reduction of Arctic perennial sea ice.** *Geophysical Research Letters* 34(19): art. L19504, 2007.

Notes: The extent of Arctic perennial sea ice, the year-round ice cover, was significantly reduced between March 2005 and March 2007 by 1.08×106 km^2, a 23% loss from 4.69×106 km^2 to 3.61×106 km^2, as observed by the QuikSCAT/SeaWinds satellite scatterometer (QSCAT). Moreover, the buoy-based Drift-Age Model (DM) provided long-term trends in Arctic sea-ice age since the 1950s. Perennial-ice extent loss in March within the DM domain was noticeable after the 1960s, and the loss became more rapid in the 2000s when QSCAT observations were available to verify the model results. QSCAT data also revealed mechanisms contributing to the perennial-ice extent loss: ice compression toward the western Arctic, ice loading into the Transpolar Drift (TD) together with an acceleration of the TD carrying excessive ice out of Fram Strait, and ice export to Baffin Bay. Dynamic and thermodynamic effects appear to be combining to expedite the loss of perennial sea ice.
