



## Global Warming Science Update September 2007

**Daniel A. Lashof, Ph.D.**  
**Science Director, Climate Center**  
[dlashof@nrdc.org](mailto:dlashof@nrdc.org)

### **The science keeps coming**

The 2007 Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) represents the work of thousands of researchers and includes the strongest scientific consensus to-date that heat-trapping pollution is causing global warming. The official cut-off for including research in the report was the end of 2005, allowing a year for the panel to sort through articles and vast amounts of data. As a result, some important results reported in 2007 and in late 2006 were absent from the IPCC reports released between February and May of this year.

### **The real world outpaces the models**

*Models have underestimated sea level rise*

IPCC sea level rise estimates are conservative, according to Stefan Rahmstorf of Potsdam University and other researchers (see **Figure 1** below). Sea-level rise predictions from climate and ice sheet models are lower than real world rates, which since 1990 have matched the uppermost limit of the IPCC Third Assessment Report range, which assumes a high emissions scenario, high climate sensitivity, and an extra amount of sea-level rise that could result from “ice sheet uncertainty.” Sea-level rise so far has also been significantly faster than predicted in the 2007 IPCC reports.

The rate of sea level rise for the last 20 years was 25% faster than in any other recent 20 year period, with ocean thermal expansion and melting from non-polar glaciers the main culprits. There was a close relationship between temperature and sea level rise throughout the 20<sup>th</sup> century, as sea levels rose at a rate of about 2 mm/year per °F. Applying this relationship to future warming scenarios implies that sea level will rise between 50-140 cm (20-55 inches) by 2100. This estimate is much higher than the IPCC Third Assessment estimates of 21-70 cm by 2100 and Fourth Assessment estimates of 18-59 cm by 2100. The bottom-line is that if the current relationship between warming and sea level rise continues, the IPCC estimates are unrealistic, and sea level rise of more than 1m (more than 3 feet) by 2100 is a real possibility.

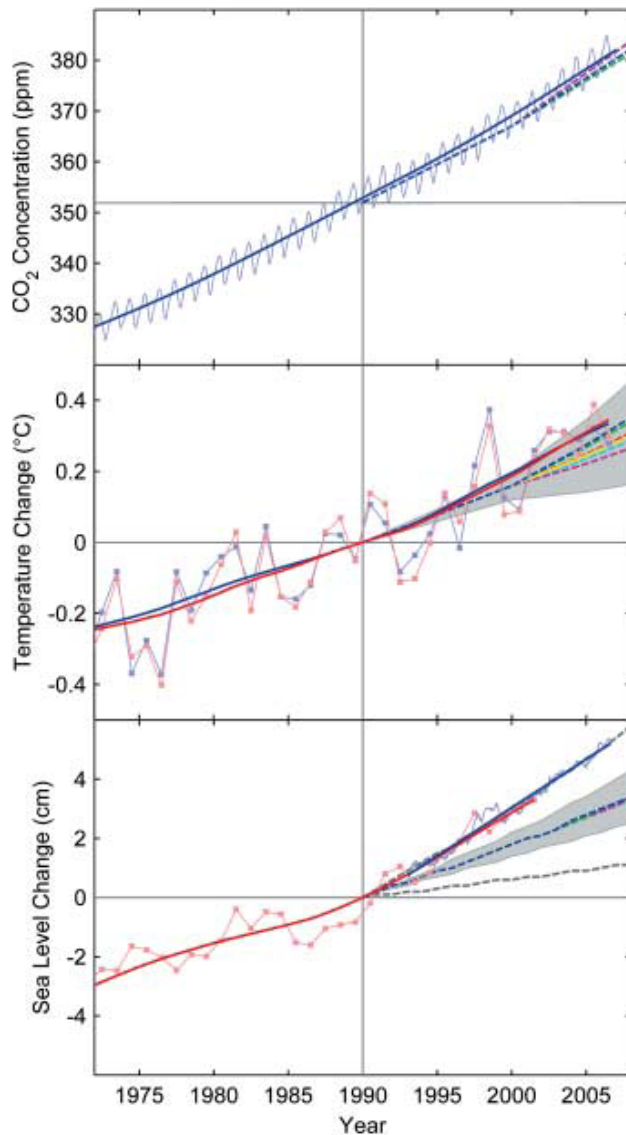
A recent report on disintegrating glaciers by Mark Meier of the University of Colorado and colleagues bolsters this conclusion. They found that the discharge of glacial ice into the ocean is accelerating rapidly due, in large part, to the dynamic instability of glaciers that terminate in the ocean below sea level. Once these glaciers begin to melt, their ice flows into the ocean at an accelerating rate, rather than just melting at the surface. If the current rate of acceleration continues glaciers and ice caps alone (excluding Greenland and Antarctica) would contribute 11-

37 cm to sea-level rise by 2100, consistent with Rahmstorf's projection for total sea-level rise, but not with the lower estimates from the IPCC.

*Warming pushes the upper bound*

The 2007 IPCC report is the first to give a best estimate — 5.4°F — of “climate sensitivity,” the global mean temperature rise that is likely to result from a doubling of carbon dioxide levels. It implies that temperatures will increase in this century by between 2 to 11.5°F, depending on how high greenhouse gas concentrations rise. However, IPCC projected temperature increases may be too low. In the last 16 years, the global mean surface temperature increase was 0.6°F according to NASA and the UK Met Office. This falls in the very upper part of the range projected by the IPCC in 2001, and suggests that warming may be more rapid than predicted. The average annual temperature for the contiguous U.S. in 2006 was the 2nd warmest on record and within 0.1°F of the record set in 1998. The past nine years have all been among the 25 warmest years on record in the U.S., a streak which is unprecedented in the historical record.

It is difficult to establish exactly why the world is warming so quickly, but there are a few possibilities. The first is variability within the climate system, which is complex and goes through unpredictable ups and downs. The second possibility is aerosols. There may have been less cooling from aerosol emissions than expected, potentially resulting in faster warming. A third candidate is an underestimate of how sensitive the climate is to carbon dioxide levels. The models have been right on target about carbon dioxide concentrations, with IPCC projections matching data from Mauna Loa, Hawaii, but they may be too conservative when it comes to the relationship between carbon dioxide concentrations and global warming.



**Figure 1:** Changes in key global climate parameters since 1973, compared to the scenarios of the 2001 IPCC (a) Monthly carbon dioxide concentration and its trend line at Mauna Loa, Hawaii up to January 2007, from Scripps in collaboration with NOAA. (b) Annual global-mean land and ocean combined surface temperature from GISS (red) and the Hadley Centre / Climatic Research Unit (blue) up to 2006, with their trends. (c) Sea-level data based primarily on tide gauges (annual, red) and from satellite altimeter (3-month data spacing, blue, up to mid-2006) and their trends.

IPCC Fourth Assessment Report (AR4), 2007 (<http://www.ipcc.ch/>)

Rahmstorf, S. et al. *Science*. May 4, 2007.

Rahmstorf, S. *Science*. Jan 19, 2007.

<http://www.pik-potsdam.de/~stefan/>

Meier, M., et al *Science* **317**:1064. Aug 24, 2007.

2006 Annual Climate Review Summary, Updated June 21, 2007, NOAA, National Climatic Data Center.

<http://www.ncdc.noaa.gov/oa/climate/research/2006/perspectives.html>

**Ice sheet melt concerns and confounds scientists**

The hardest part of predicting sea-level rise is figuring out how fast land-based ice sheets will melt. So far, ice sheets have not contributed very much to sea-level rise, but Greenland and West Antarctic ice sheets are now melting at an accelerated rate. Recent studies show that a large

portion of the melting occurs through dynamic processes, such as rapid melt at the base of ice sheet under pressure from above, with melting at the ice surface playing a smaller role. Yet dynamic melting is not taken into account in the IPCC projections because it is too poorly understood to be modeled. This is a major omission. Even though modeling of dynamic melt is in its infancy, observations of what is occurring on the ground can be incorporated into projections, yielding more realistic estimates and giving us a better sense of what's in store.

Greenland, which holds 10% by weight of global ice, is losing ice at an ever-increasing rate, according to data from the GRACE gravity-measuring satellite. Throughout the 1990's, the Greenland ice sheet remained stable, but has increasingly declined in recent years. A study performed by Luthcke et al found that from 2003 to 2005 the ice sheet lost over 100 billion tons per year, which contributes an estimated 0.3 mm per year to global sea level rise. Chen et al used time-variable gravity measurements from GRACE to measure the weight of the ice sheet from 2002 to 2005. Consistent with Luthcke's results, the team measured a net loss of 239 km<sup>3</sup> per year, most of which occurred in Eastern Greenland. This translates to 0.54 mm/year of global sea level rise, which is slightly higher than the other team's estimate.

Melting the entire Greenland ice cap would raise sea level 6.5 m (over 20 feet). The World Bank estimates that a much smaller 1 m increase in sea level would displace at least 56 million people living in coastal regions, and a 5 m rise would displace over 240 million people. The stakes are high, and ice sheet modelers are working hard to try to better understand how these ice sheets accumulate and lose ice.

Cazenave, A. *Science*. Nov 24, 2006.

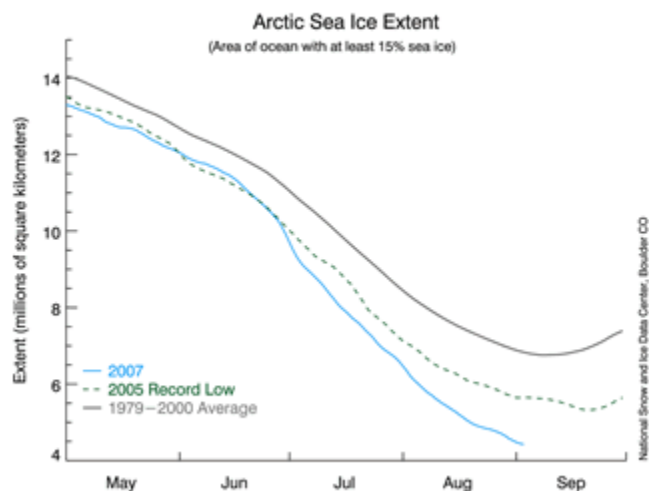
*World Bank Policy Research Working Paper S4136*, February 2007. The impact of sea level rise on developing countries: a comparative analysis.

Luthcke, S., et al. *Science*. Nov 24, 2006.

Chen, J., et al. *Science*. Sept 29, 2006.

### Sea ice is reaching a breaking point

Multiple climate models predict that Arctic sea ice will disappear as the earth warms and the most recent observations provide alarming evidence that these predictions are being realized. As of September 4, 2007 Arctic sea ice extent reached a record low of 4.42 million square kilometers (1.70 million square miles), almost 20 percent lower than the previous record low of 5.32 million square kilometers (2.05 million square miles) set on September 20-21 2005, and is still falling. The monthly average Arctic sea ice extent for August 2007 is 31% below the average for all Augusts since 1979 and is the lowest monthly



average ever recorded by satellite for *any* month. September typically has the lowest monthly average sea ice extent and we can expect a new record low to be set when these data come in.

Holland et al predict abrupt and widespread sea ice melting early in the 21<sup>st</sup> century, beginning as soon as 2015. Loss of ice spurs further melting, because sea ice is better at reflecting back the sun's rays than is open water, which absorbs more solar heat. As sea ice disappears, increasing amounts of open water will lead to even warmer waters and more melting. This is compounded by predictions of rapid ocean heat transport to the poles. Abrupt summer ice melting is expected to arise as the ice pack over the Arctic and in other areas thins and disappears during summer months.

Researchers analyzed multiple climate scenarios for the IPCC Fourth Assessment Report and found that abrupt summer reductions in sea ice cover occurred in over 50% of the models. Examined as a group, their results suggest we may have ice-free Arctic Septembers in 30-50 years, and as early as 15 years from now. Reducing emissions could play a major role in mitigating this possibility. Under high-emissions scenarios, the likelihood of ice-free conditions increases sharply, while reductions in greenhouse gas emissions reduce the likelihood.

[http://nsidc.org/news/press/2007\\_seaiceminimum/20070810\\_index.html](http://nsidc.org/news/press/2007_seaiceminimum/20070810_index.html)

Holland, Marika et al. *Geophysical Research Letters*. Dec 12, 2006.

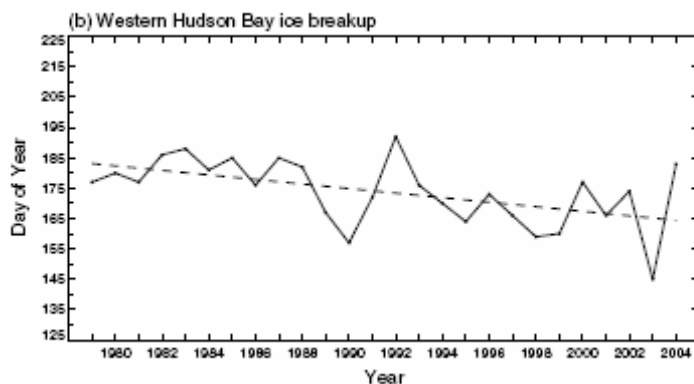
Winton, M. *Geophysical Research Letters*., Dec 13, 2006.

### Species stressed from Global Warming

Many plants and animals are stressed due to habitat destruction and fragmentation and other human-induced pressures. Global warming presents another threat, and warming is occurring at a rate that may prove too fast for species to adapt. Already, species that can are migrating to cooler habitats. A study of 1,700 species found pole-ward migration of 6 km/decade and vertical migration in alpine regions of 6 m/decade since 1950.

#### *The Polar Bear faces danger*

Global warming presents a particularly stressful change for arctic species that cannot migrate further northward. Some populations of polar bears are already beginning to decline in numbers. Polar bears depend on Arctic sea ice to hunt, but global warming is causing reduced ice cover and thickness, with the ice breaking up about three weeks earlier than it did 30 years ago. Stirling et al performed a study in the Canadian Arctic and found that in some areas polar bear populations have declined 22% between 1989 and 2004. If the earth continues to warm, all five of the populations they studied are endangered.



**Figure 2:** Western Hudson Bay- the Julian dates by which the percent ice coverage decreased to 50% or less, following the winter maximum for the years 1979-2004.

g fossil fuel  
bed by the  
changing

### *Tropical forest sink*

Conventional wisdom about land sinks has recently been challenged. Stephens et al. measured the vertical atmospheric carbon dioxide distribution at 12 sites around the globe and compared the measurements to model predictions. Their results suggest that the Northern Hemisphere plays a smaller role in carbon dioxide uptake than previously thought and that the tropics may be strong carbon sinks as opposed to a net carbon source, even with continuing, high rates of deforestation. This implies that tropical forests are even more critical than previously assumed. Tropical deforestation released ~1.5 billion metric tons of carbon (GtC) to the atmosphere annually throughout the 1990s, accounting for almost 20% of anthropogenic greenhouse gas emissions. Without effective policies to slow deforestation, the clearing of tropical forests will likely release an additional 87 to 130 GtC by 2100, equivalent to more than a decade of global fossil fuel combustion at current rates. As the temperature rises, drought-induced tree mortality, logging, and fire may double these emissions, and loss of land-sink capacity as forest area decreases may further increase atmospheric carbon dioxide levels.

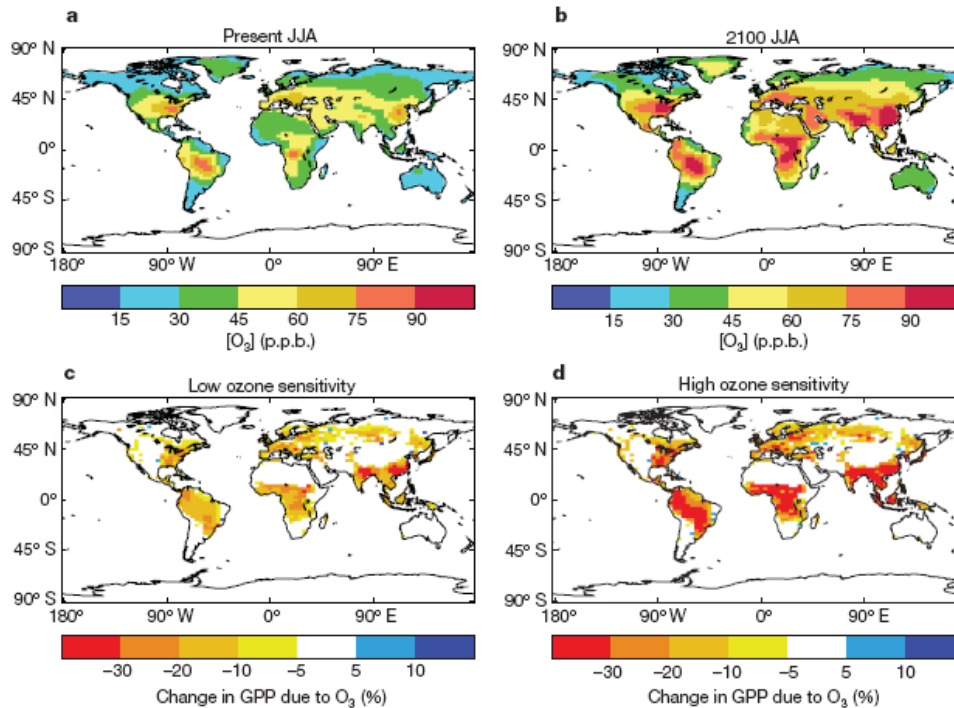
Raymond E. Gullison, et. al. *Science*. Vol 316:18. May, 2007.

Stephens, B.B. et al. *Science*. June 22, 2007.

### *More bad news about smog*

Climate-carbon cycle models suggest that global warming will lead to less land-carbon sequestration, but they don't include the indirect impacts of increases in smog (tropospheric ozone). A recent Nature paper estimated the impact on the land-carbon sink and found significant reduction in the sink due to indirect effects on plants. Emissions from fossil fuel and biomass burning have doubled the global smog concentration, which has a damaging effect on plants. Ozone enters a plant's respiration pores (stomata) and hinders photosynthesis, resulting in weakened and smaller plants that absorb less carbon dioxide. Through this impact on plants, smog causes more carbon dioxide to build up in the atmosphere and accelerates global warming.

The study examined two scenarios for the period 1901 to 2100. One was based on plants with a high sensitivity to ozone and the other on vegetation with low sensitivity. In the high sensitivity model, ozone decreased land carbon capture by 23% over two centuries. In the other, land carbon capture declined 14%. Lead researcher Stephen Sitch of the Hadley Center warned that most climate change studies have not taken ozone's effect on carbon sinks into account, which could indirectly add 0.9°F to 2.3°F to global warming.



**Figure 4: Changes in modeled ozone concentrations and gross primary productivity.** **a, b** Modelled diurnal mean surface ozone in ppb averaged over June, July, and August for the present day (a) and the year 2100 (b). Simulated percentage change in gross primary productivity (GPP) between 1901 and 2100 due to ozone effects at fixed pre-industrial atmospheric carbon dioxide for ‘low’ (c) and ‘high’ (d) ozone plant sensitivity.

Sitch, S., et al. *Nature*. Published online 25 July 25, 2007. doi:10.1038/nature06059.

### *Old growth forests continue to accumulate carbon*

As atmospheric conditions change, soils in old-growth forests may keep soaking up carbon long after they reach maturity, according to recent measurements from China. Traditionally, old-growth forests have been considered negligible carbon sinks (although they hold large carbon stocks), because carbon uptake and respiration rates are thought to be roughly balanced. However, a study of a forest reserve in Guangdong, southern China, showed that soil carbon increased by 68% in 25 years. The top soil layer accumulated atmospheric carbon at an unexpectedly high rate from 1979 to 2003. The study suggests that belowground carbon cycle processes are changing in response to climate changes, and challenges the belief that old-growth forests are in equilibrium. Nonetheless, forests alone can’t be relied on to offset carbon dioxide emissions from fossil fuel combustion. A long-term Duke University study applied higher-than-normal levels of carbon dioxide to a North Carolina loblolly pine forest. As expected, extra carbon dioxide, which stimulates plant growth, allowed the trees to grow more, but only those pines receiving the highest levels of water and nutrients were able to store significant additional carbon, scientists told a meeting of the Ecological Society of America (ESA) in August.

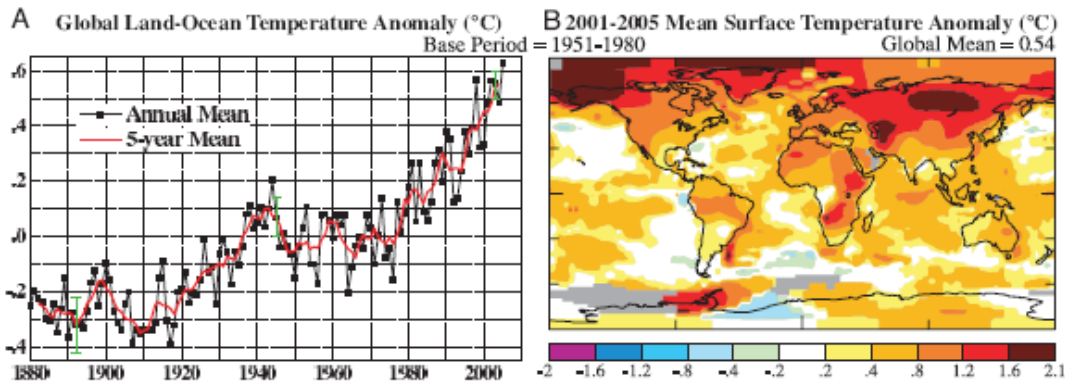
G. Zhou *et al. Science* 314, 1417; 2006

*ScienceDaily* article summarizing Ecological Society of America presentation. August 7, 2007.

## Global Warming affects weather extremes

### *Super El Nino*

Hansen et al suggest that the global temperature increase of about 0.4°F per decade over the past 30 years is contributing to extreme El Nino patterns. He attributes the super El Nino episodes in 1983 and 1998 to asymmetrical warming of the Western Equatorial Pacific and the Eastern Equatorial Pacific. Warmer waters, attributed to anthropogenic global warming, will most likely increase the intensity of extreme El Nino occurrences.



**Figures 5 and 6:** Surface Temperature anomalies relative to 195-1980 from surface air measurements at meteorological stations and ship and satellite SST measurements

Hansen, James et al. *Proceedings of the National Academy of Science*. September 26, 2006.

### *Increases in severe hurricanes*

Rising sea-surface temperatures correlate strongly with the observed increase in the number of category four and five Atlantic hurricanes between 1970 and 2004 according to scientists at Georgia Tech. Other factors that affect hurricane formation, such as wind shear and humidity levels, do not appear to have changed over that time period and are not causing the long-term upward trend in hurricane intensity.

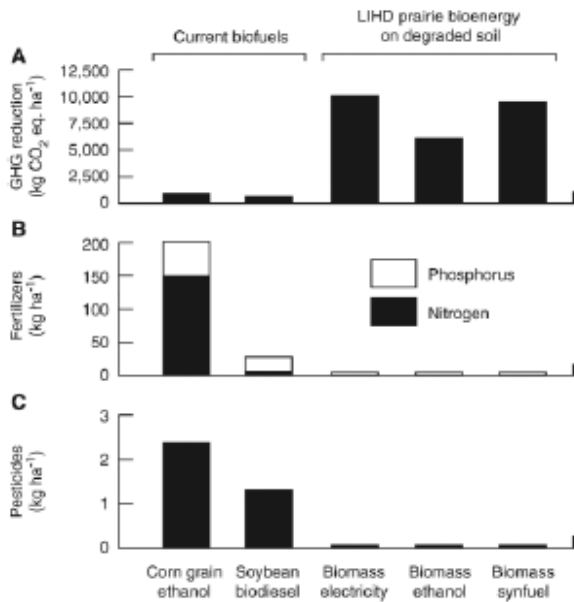
Hoyos, C. D. et al. *Science* 312, 94–97; 2006

## Sustainable biofuels

Low-input, high-diversity (LIHD) mixtures of grassland perennials can “provide more usable energy, greater greenhouse gas reductions, and less agrichemical pollution per hectare than can corn grain ethanol or soybean biodiesel” according to David Tilman and colleagues at the University of Minnesota.

Mixtures of native prairie grasses can be grown on degraded lands so they do not displace agricultural or protected lands, and require few inputs, which make them less environmentally damaging than conventional agriculture. They also have 238% higher bioenergy yields than monocultures after 10 years. Additionally, Tilman found that these mixtures can be used to make biofuels that have negative net lifecycle carbon dioxide emissions because they sequester more carbon dioxide than they release during production and processing. Growing LIHD perennials on the 500 million acres of agriculturally abandoned and degraded land in the world could produce 13% of the global petroleum consumption for transportation and 19% of global

electricity consumption. This could remove 15% of current global carbon dioxide emissions and potentially more if sequestration were factored in.



**Figure 7:** Environmental effects of bioenergy sources. A) GHG reduction for complete life cycles from biofuel production through combustion, representing reduction relative to emissions from combustion, representing reduction relative to emissions from combustion of fossil fuels for which a biofuel substitutes; B) Fertilizer and C) pesticide application rates are US averages for corn and soybeans.

Tilman, David et al. *Science*, **314**, p.1598-1600, doi:10.1126/science.1133306. Dec 8, 2006.

### Yellowstone Area Grizzly Bears suffer as Whitebark Pines decline



Whitebark pine seeds are a major food source for grizzly bears in the Greater Yellowstone Area, and considered important for the long-term viability of the population. During years of good whitebark pine cone production, more than 70 percent of Yellowstone-area bears consume whitebark pine cones. Without rich, fatty whitebark pine seeds to help female grizzlies add weight during the fall, both the number of grizzly bear litters and the number of cubs per litter declines dramatically. This causes grizzlies to seek alternate food sources and results in increased human-bear conflicts and grizzly mortalities. Unfortunately, a decline in whitebark pine seed cone production is well underway in the Yellowstone area, and in many ecosystems in the western United States and Canada, as whitebark pine forests have been decimated by mountain pine beetles and by blister rust, an invasive plant disease. Whitebark pine mortality is already as high as 40-100 % in certain areas. As the climate warms, mountain pine beetle outbreaks will spread further north and into higher elevation forests. Virtually all whitebark pine stands in the Yellowstone area, except for portions of the Absaroka Mountains and the Wind River Range, will be severely damaged during the next several decades according to a model

developed by Jesse Logan, a recently retired Forest Service scientist. The beetles can kill entire stands of whitebark pine in just one summer and have immediate impacts on grizzly bears. From 2000-2004, 18,000 acres of whitebark pines in Yellowstone National Park were killed by mountain pine beetle outbreaks. Once whitebark pine forests are damaged, the grizzly bears that depend on this critical food source would face food shortages for many years because it takes 60-80 years for the pines to begin producing large cone crops.

Powell, J. A., and J. A. Logan. 2005. Insect seasonality: circle map analysis of temperature-driven life cycles. *Theor. Popul. Biol.* 67: 161-179

Felicetti, L.A., et al. 2003. *Canadian Journal of Zoology* 81:763-770.

Interagency Grizzly Bear Study Team. 2004. Annual Report. Interagency Grizzly Bear Study Team, USGS Northern Rocky Mountain Science Center, Montana State University, Bozeman, Montana, U.S.A..

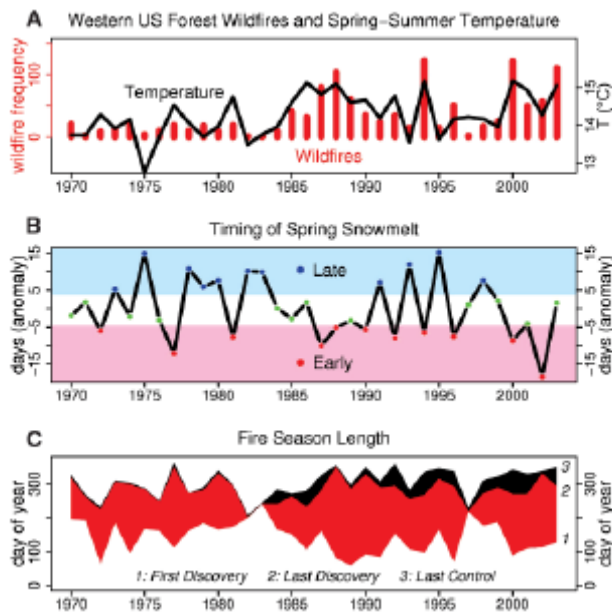
Mattson, D. J., B. M. Blanchard, and R. R. Knight. 1992. *J. Wildl. Manage.* 56: 432-442.

Mattson, D.J. 1998. *Ursus* 10:129-138.

Schwartz, C.C., et al. 2005. *Wildlife Monographs* 161.

### Warming Will Lead to Frequent and More Intense Wildfires in the Western U.S.

Following up on several previous analyses, Westerling et al assembled data on 1,166 large wildfires (over 400 ha) within forested areas in the Western U.S. since 1970. They related this data to meteorological and hydroclimatic records and found that hotter, drier periods experienced worse and more frequent wildfires and longer wildfire seasons.



Earlier snowmelt dates correspond to increased wildfire frequency because it can lead to a longer dry season, making the forests vulnerable to ignition. As a whole, longer summers result in drier vegetation and longer fire seasons. If the warming continues to exacerbate the wildfire seasons, it could be costly. Currently, Western forests sequester a large amount of carbon, and fire-fighting expenditures have consistently totaled upwards of \$1 billion/year.

**Figure 9:** A) annual frequency of large western U.S. forest wildfires and mean March through August temperature for the western U.S. B) Timing of Spring snowmelt, values indicate early, mid and late timing. C) Annual time between first and last large-fire ignition, and last large-fire control.

Westerling, A., et al. *Science*, 313, p.940-943, doi: 10.1126/science.1128834. August 18, 2006.