CLIMATE SCIENCE FORUM

Autumn 2012: #17

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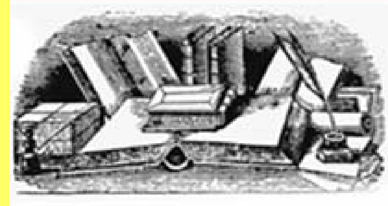

West Coast Waters Will be too Acidic for Some Marine Organisms with Shells

A Result of Rising Levels of CO_2

Scientists have long expected that recent high atmospheric CO_2 levels will make ocean water more acidic, but the impact was expected to be minor. Now a Swiss team suggests that by 2050, more than half of the surface waters in the California current off the US west coast will become too acidic for shell-building marine life to thrive, at certain times of the year. When that happens, essentially all of the water near the bottom layer will be unable to support oysters and other shell-building organisms.

When CO_2 is dissolved in water, it creates a weak acid with some hydrogen ions. Acidity measures how many hydrogen ions are present; and when more are present, an organism must expend more work to build a shell. Many marine organisms, including oysters, crabs, lobsters, periwinkles, and corals, use calcium carbonate ($CaCo_3$) to build shells, which are essential for their life. Above a certain level of acidity, it is no longer possible to build shells, and shells can dissolve.

The atmospheric level of CO_2 has risen over the last century. The impact on the oceans is still small, but in certain areas where deep water rises up to the surface, CO_2 is already naturally high. In these areas, the CO_2 level in the water is closer to the "saturation point" of carbonate.

In west-coast currents around the world, deep cold water rises to the surface. The water is rich in nutrients from organic matter that decomposed near the bottom. Decomposition releases CO_2, which makes water more acidic and closer to being undersaturated. There have been incidents of "corrosive" undersaturated water on the Oregon coast that led to failures of oyster hatcheries (see one report here[1]). To date, excess atmospheric CO_2 has reduced the pH in the ocean by about 0.1 unit, and the saturation state of carbonate by 0.4 units for the whole ocean. When this saturation state reaches a value below 1, it may not be possible to build shells.

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Climate News

A team from ETH in Zurich, Switzerland, explored where and when acidification might result from elevated CO_2 levels. They simulated the ocean chemistry of the California current to the year 2050, in a model based on two common scenarios of CO_2 emissions from economic activities. Their model was able to depict details of the current and the nearshore waters, unlike global ocean models which are too coarse to depict such fine details.

The Swiss team reported[2] that large areas (about one-half) of California surface waters are expected to become undersaturated by 2050, and thus "acidic" in the summer. If this happens, sensitive organisms would be forced to live in less than half of their current habitat area. Water naturally becomes more acidic the deeper one goes: in twenty to thirty years from now, "essentially all the waters just above the shelf sediments will be undersaturated" and water on the sea floor would be undersaturated all year long.

The impact of acidification depends very much on the atmospheric level of CO_2. When this level reaches 400 parts per million (or ppm) *(today's level is 390 ppm)*, "substantial parts of the twilight zone . . .and habitats along the sea floor on the shelf become undersaturated." Many scientists expected that the Arctic Ocean would be the first ocean to experience profound acidification, but the California waters will become acidic before the Arctic Ocean will. When the atmospheric CO_2 reaches 500 ppm, surface waters in

(*Continued on page 2*)

Ocean Surface actually fell because of La Niña in 2011

Sea level has been rising slowly for at least 130 years, but last year the sea level actually fell. Looking at all possible influences, a team led by Carmen Boening at the Jet Propulsion Laboratory in Pasadena, CA, concluded that the very strong La Niña of 2010–2012 caused the drop.[1] In general, either cooling of the ocean or a loss of water would cause sea level to drop. The team insists that loss of water was responsible. The atmosphere transported enough water from the sea to the continents that sea level actually fell by one-half centimeter (5 mm) worldwide.

The El Niño-Southern Oscillation (ENSO) is the largest year-to-year climate signal on Earth, according to Dr. Michael McPhaden[2] of the NOAA Pacific Marine Laboratory in Seattle. El Niño is the warm phase of this oscillation, and has been shown to cause temporary rises in sea level. The cold phase, popularly known as La Niña, may similarly cause sea level to fall for a while.

As you may see on the figure to the right, sea level began to fall in the middle of 2010 after a long and fairly steady rise. In that year, the most recent El Niño (a strong one) morphed into a strong La Niña that continued into 2012. Boening's team was able to separate the effect of ocean temperature on sea level from the effect of a gain or loss of water, by combining measurements of ocean temperature taken by buoys, and satellite observations of ocean mass and rainfall. The satellites observed increasing amounts of water stored on land in Australia, Southeast Asia, and northern South America by the end of 2010. These regions were coming out of a drought and were receiving more precipitation than in earlier years. The team concluded that ocean temperatures were affecting sea level very little in this case, but that enough water was transferred from the sea to these three land areas that sea level dropped globally by one-half centimeter.

On the figure, notice that sea level was recovering in 2011 after the sharp drop in 2010, even though La Niña continued through 2011. Because the excess water was running off the land into streams and rivers, such a drop is only temporary. The century-long rise of global sea level is back on track.

CITATIONS

1. The 2011 La Niña: So strong, the oceans fell" by Carmen Boening and four others (2012). *Geophysical Research Letters*, vol. 39, L19602, doi:10.1029/2012GL053055; 4 October 2012.

2. "ENSO as an integrating concept in Earth science" by Michael J. McPhaden, S. E. Zebiak, and M. H. Glantz (2006). *Science*, vol. 314, p. 1740–1745, doi:10.1126/science.1132588.

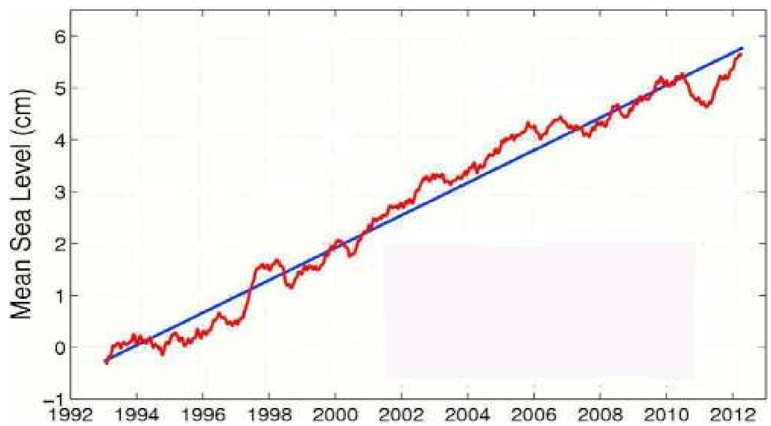

Figure above: Change in sea level (cm) since 1994 over the last twenty years. Sea level is arbitrarily set to zero in 1994. Sea level has been rising one centimeter every 3 years, but it fell in 2010–11.

(Acid West Coast Waters: Continues from page 1)

the sunlit zone would be acidic for long periods.

The Swiss cautioned that organisms differ greatly in their tolerance of acidity: for some, undersaturated water is not a problem. And some species have evolved to tolerate acidic water for certain periods of time.

The team concludes that the California current is rapidly moving toward conditions "well outside the natural range" with frequently undersaturated water. The impact of this can be magnified if further warming or low oxygen levels ("dead zones") accompany the acidic water; both have been observed off California.

Jane Lubchenco, administrator of the US National Oceanic and Atmospheric Administration (NOAA), remarked to the Associated Press that the speed by which the oceans have become more acid caught scientists off-guard, and the problem is now considered to be the "equally evil twin" of climate change in the atmosphere.

CITATIONS

1. "Rising acidity brings an ocean of trouble," news focus, *Science,* vol. 337, 146-148, 13 July 2012.

2. "Rapid progression of ocean acidification in the California Current system" by N. Gruber, C. Hauri, Z. Lachkar, D. Loher, T. Frolicher, G-K. Plattner, *Science,* vol. 337, 220-223, 13 July 2012.

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CLIMATE SCIENCE FORUM

http://climate-science.org

Editor-in-Chief: Michael A. Fortune, Ph.D.

Email: editor (@) climate-science. org

Portland, Oregon, USA; Tel: (503) 922-0003

Outlook for Winter 2012/13

Unremarkable, but Uncertain

After a remarkable year in which North Americans coped with widespread damage from Hurricane Sandy, terrific windstorms in June and October, and a record-setting drought in most of the nation, the winter of 2012–2013 (December, January, and February) will present few surprises. The U.S. Climate Prediction Center released a new three-month climate outlook recently.

Most of the nation west of the Mississippi River is expected to be warmer than usual in the upcoming cold season, except in California and along the Pacific Coast (map above). This is in line with a warming trend lasting over twenty years in the West. Very often when the West has been unseasonably warm, it has also been drier than usual. That may not be true this year, but the Pacific Northwest from San Francisco to British Columbia, which is typically dripping wet in the cool season, is now expected to be

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drier than normal, as far east as Yellowstone Park. Another region centered on Minnesota is expected to be dry (see the rainfall outlook in the map below). Florida and Hawaii are the only states expected to be cooler than normal in winter.

The El Niño / La Niña oscillation, also known as "*ENSO*," is often the main influence that shapes the climate forecasts for future seasons up to one year in advance. This time, ENSO is in a neutral phase, which did not make it easy for forecasters to settle on an outlook for this winter. ENSO is neither in El Niño nor La Niña, and while some expect a weak El Niño to develop at year's end, it has not happened. However, the expectation that it will happen led the forecaster to expect a wetter Gulf Coast this winter.

The Climate Prediction Center cautioned that this forecast is particularly uncertain. The maps shown here are based largely on relatively new dynamical climate models developed in the past few years, rather than a more traditional analysis of well-known climate cycles like ENSO and the Pacific Decadal Oscillation.

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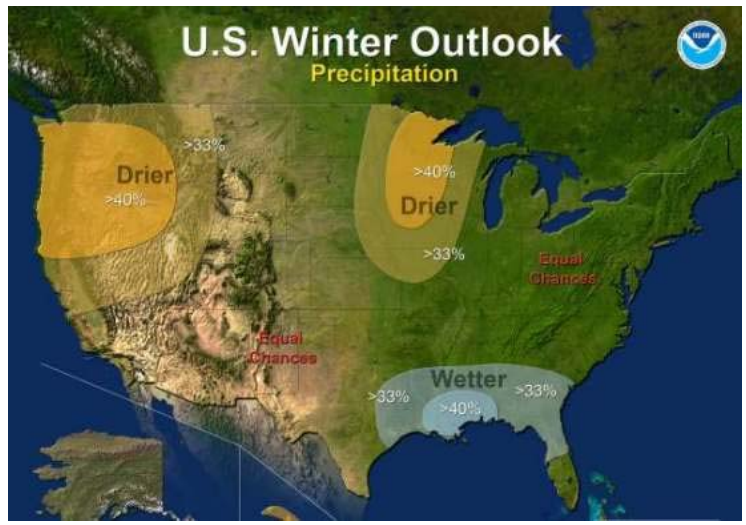

Year-round Arctic Ice Set to Disappear in your Lifetime

In 2007 the world of science was astounded when a record amount of ice had melted on the Arctic Ocean by September. But even more ice melted away this year: by September 16, only 1.4 million square miles of ice cover remained on the Arctic Ocean. That is 49% less than the long-term average for the month of September in the years 1979–2000 (the first twenty years of satellite observation).

The coastlines of Siberia and Russia, Scandinavia, Alaska, and most of Canada became ice-free by the end of last summer (top figure, next page). Compare this summer's ice cover (white) with the average location of the ice edge from 1979 to 2000 (purple curve), to appreciate the magnitude of the change. Monitoring of ice cover[1] in the Arctic and Antarctic is done by the National Snow and Ice Data Center.

The volume of Arctic ice has declined faster than its area has, as thick, multi-year ice melts. On the bottom figure, the amount of ice is depicted by age class from 1 to 5+ years. The older and thicker ice enables part of the ice pack to survive the summertime melting season. The ice that is 5 or more years old has now largely disappeared. Compared to 1983, there is practically no "old ice" left. When spring arrives, more of the Arctic ice pack is thinner than before and is more prone to melt in the summer.

The University of Washington estimates that the volume of sea ice has reached an all-time low. Even after

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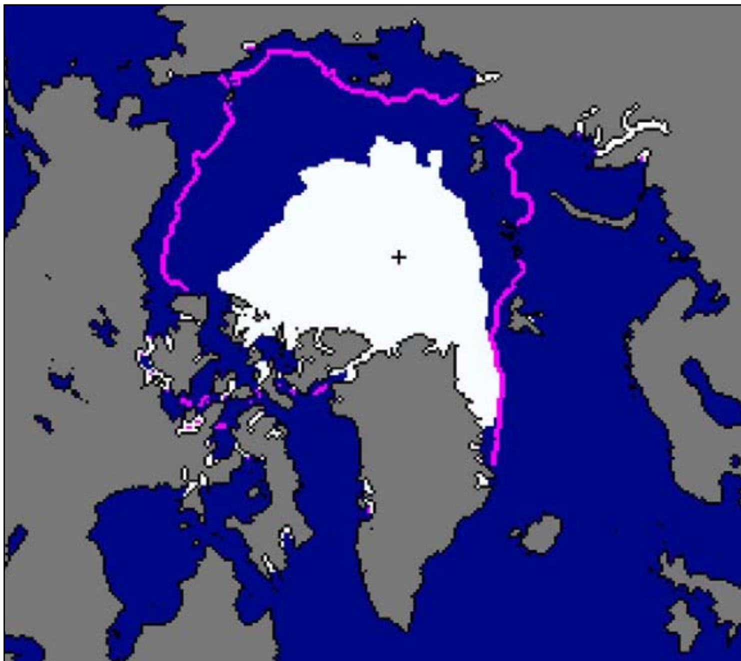

Map: Record-low extent of sea ice (white) on Arctic waters in September 2012. Purple line: average extent for this month, 1979–2000. Black cross marks the North Pole. *(Return to the Story)*
Credit: National Snow and Ice Data Center

(Arctic Ice Cover, continues from page 3)

more new ice is added this winter, they estimate that in 2013 there will only be 20% of the amount of five-year-old ice that had been present in 1983.

South of the Equator . . .

Only ten days after the record low ice cover was observed in the Arctic, an all-time record large extent of ice was seen in the Southern Ocean. It's winter in the South Polar region when it's summer in the far North. The Southern Ocean pack ice surrounding Antarctica has been expanding for years, not so much because the temperature is changing but because ever-faster winds in the southern hemisphere have caused the pack ice to expand northward. Loss of ozone in the stratosphere over Antarctica (the famous "ozone hole") led to a stronger jet-stream, which ultimately ramped up wind speeds in the lower atmosphere in that region.

Let's compare the changes in ice cover at the two poles. While the Southern ice cover has grown, the increase has been +6200 square miles per year over the last 32 years, an expansion somewhat larger than the state of Connecticut each year. Meanwhile, the Arctic lost 35,500 square miles of ice each year, about the size of the state of Indiana. And the loss has been much faster since the year 2000.

Snow cover has dwindled even faster than sea ice

While disappearing sea ice has been in the headlines since 2007, snow cover has been declining in the spring even more rapidly than the ice has in the summer, in northern latitudes. According to a report[2] by Chris Derksen and Ross Brown, record low snow cover has been observed each spring in the Eurasian Arctic for each year since 2008, and in four of the last five years in Arctic Canada and Alaska. Snow loss in May and June was statistically significant. June snow cover decline since 1979 (at –21.5% per decade) was twice the rate that Arctic sea ice declined in September (–11% per decade). Most climate models have not successfully reproduced nor predicted the accelerating snowmelt in the spring, just as they have not anticipated the rate that Arctic sea ice has melted.

The consequences are not hard to imagine. Wherever and whenever ice or snow covers the surface, it refrigerates the neighborhood, and effectively counteracts global warming by reflecting 80 to 90% of incoming solar energy back to space, so that the energy is unavailable on Earth. With less snow on land in May and June, and less ice covering Arctic waters in late summer, the season when the surface is dark becomes longer. Dark surfaces warm up as they absorb sunlight and they then pass this warmth to the air above. *Voila!* More warming ensues in a previously cold region, for a longer summer season. The warming observed in the Arctic has been greater than what was predicted by a variety of global climate models. The consequences of these polar climatic changes are far-reaching.

CITATIONS

1. "Poles apart: A record-breaking summer and winter" at National Snow and Ice Data Center, Boulder, Colorado: http://nsidc.org/arcticseaicenews/2012/10/poles-apart-a-record-breaking-summer-and-winter/ .

2. "Spring snow cover extent reductions in the 2008-2012 period exceeding climate model projections" by Chris Derksen and Ross Brown (2012), *Geophysical Research Letters*, vol. 39, 19, 10 Oct. 2012, doi:10.1029/2012GL053387.

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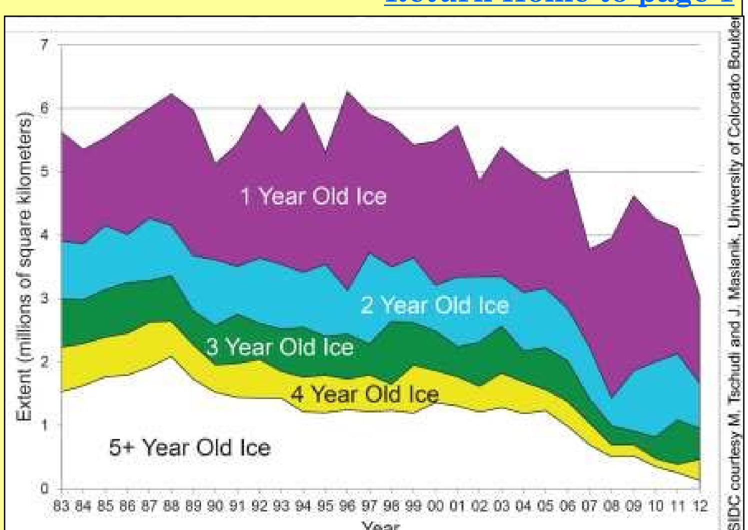

Above: *Trend of area of ice cover on the Arctic Ocean in five age classes from 1-year-old to 5-(or more) years-old, from 1983 to 2012. The oldest ice has virtually vanished.* CREDIT: National Snow and Ice Data Center, Boulder, CO. *(Return to the Story)*