

Climate change – weather

The changes in weather over recent decades have been subtle. Have you noticed gradual changes in weather patterns over previous decades? Quite recently, experts studying global ocean currents learned of an impending and momentous shift in the world's ocean circulation. Not from a computer model or theory, but from continuing ocean measurements. In critically important papers published in 2002 and December, 2003 in *Nature*, oceanographers studying the North Atlantic rim concluded that it has been freshening dramatically—continuously for the past 40 years but especially in the past decade.¹

Since the mid-1960s, the subpolar seas feeding the North Atlantic have steadily and noticeably become less salty to depths of 1,000 to 4,000 meters.

This is the largest and most dramatic oceanic change ever measured in the era of modern instruments. This has resulted in a freshening of the deep ocean in the North Atlantic, which in the past disrupted the Ocean Conveyor and caused abrupt climate changes.”²

This increasing accumulation of fresh water in the North Atlantic Ocean is expected by oceanographers to switch the climate of vast areas of our planet toward ice age conditions. Should the current climate changing forces and pressures continue to build as seems inevitable based on current global energy choices, perhaps as soon as a few decades from now, abrupt climate change will rapidly bring ice-age-like changes – beginning especially with Northeast North America and Northern Europe. (More about the “Ocean Conveyor” later.)

Twentieth Century Fox has announced a film, “The Day After Tomorrow^a”, purportedly based on this coming abrupt climate change. This is not a recommendation for “Hollywood science” – simply a caution that the crosscurrent where our environment and energy sources intersect desperately needs wider and deeper understanding and communication. Our weather or climate has already been affected by rising CO₂ and other forced changes.

Yet, detailing the precise mechanisms linking slowly rising CO₂ and methane and other forced changes with record numbers or patterns of hurricanes, tornadoes, drought or precipitation, for example, cannot be exactly proven given the patchy, discontinuous and variable quality of the instrumented meteorological and oceanographic record.

Experts cannot conclusively demonstrate exactly how they are linked. There is certainly a linkage because all such events impact weather, as James Gleick – “Chaos: Making a New

^a <http://www.thedayaftertomorrow.com/> (due for release Memorial Day weekend 2004)

Science” – (and others) have shown. The increase in number of reported tornadoes in the US over time, for example, would be one result of increasing population and better weather forecasting and reporting using improving radar technology.

With more people looking in more places with better instruments, more tornadoes will be seen. Even if atmospheric levels of CO₂ were stable, the improving technology used by more weather stations in recent decades would have shown increasing numbers of tornadoes over the poor technology they had installed fifty years ago. But atmospheric levels of CO₂ have not been stable.

The introduction of better radar, especially Doppler radar, by growing numbers of television weather forecasts greatly improved our ability to “see” these storms and warn people of their approach. This saved many lives. It also made more difficult the task of measuring and correlating the number of tornadoes striking the US annually with increasing CO₂, methane and other forced changes.

Due to these continuing improvements in the technology of weather reporting,³ tracing the connection to climate change has been made extremely difficult. The insurance industry, for example, in a major study released February 2001⁴, listed among the barriers restraining their involvement in the climate change issue:

- Scientific uncertainties regarding the science of climate change and unfounded claims (on both sides of the issue), often amplified by the media.
- The absence of in-house climate expertise to disentangle human-induced climate change from natural climate cycles compounded by demographic trends, disaster mitigation efforts, etc.
- Peer pressure from major energy industries participating in organizations such as the Global Climate Coalition (e.g. William O’Keefe, Chairman, is an executive with the American Petroleum Institute)

Clarifying the issue and growing impact of climate change is essential. Many industries, jobs and prices are being impacted by the environment and energy issues of climate change, although we will not soon untangle or completely understand all the mystery and endless complexities climatologists are confronted with. Some of those industries, notably the energy providers, are naturally defensive toward ill-conceived proposals that would unplug their current coal, oil, or gas-based businesses.

As doctors know, it is more important to save the patient than to perform research on him or her. Preventing injury and damage from tornadoes, for example, is more important than maintaining consistent weather reporting (using outmoded technologies). Finding the best response to this energy/environment challenge is the foundation of a no-regrets solution. Let’s examine the growing evidence close to home first.

In the first 10 days of May, 2003, the US saw the worst outbreak of tornadoes since systematic record keeping began in 1950, as 412 twisters ripped across the Midwest. Tornadoes and related wind, lightning and floods killed 45.⁵ More than 300 homes and 35

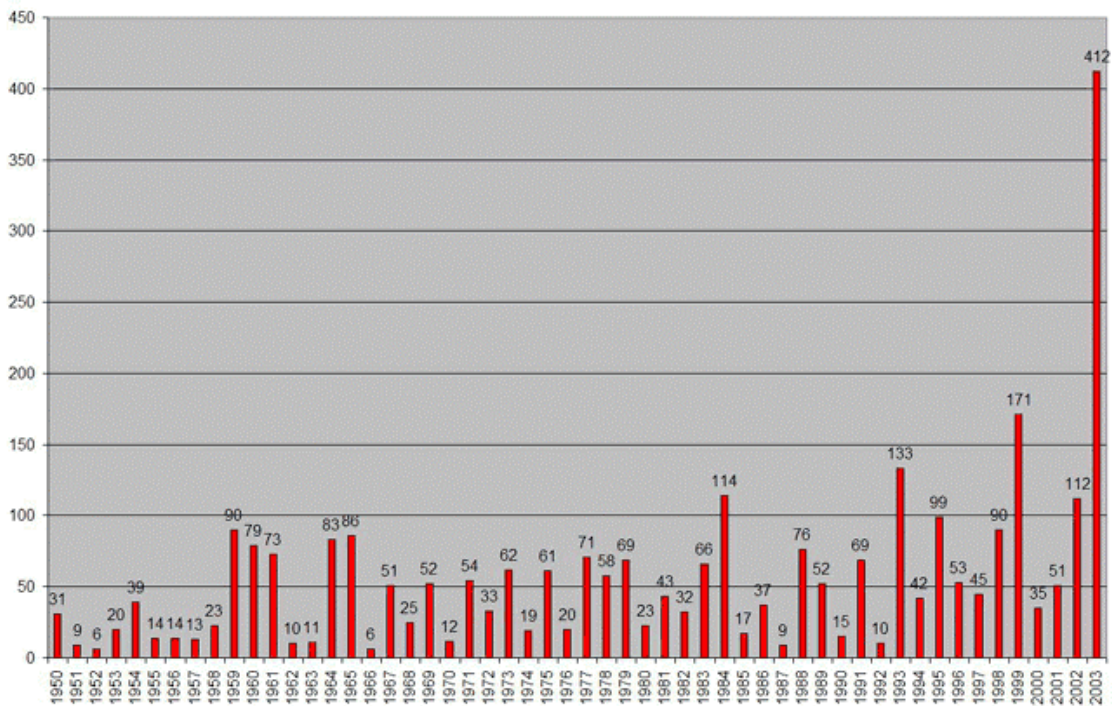
businesses were destroyed in Oklahoma alone. Utility crews strung new power lines in an effort to restore electrical service to more than 18,000 homes and businesses.⁶

The previous record for any 10-day period was also in May, just four years earlier, 1999, when 171 tornadoes struck the nation from May 1 through May 10.⁷ (Historically, more tornadoes occur in May than any other month.) During the “Super Outbreak” of April 3-4, 1974, 147 tornadoes were reported in 13 states. Improving forecasts and warnings since 1974 saved many lives: For example, 307 people were killed by the 147 tornadoes of the Super Outbreak, but “only” 45 were killed by the 412 tornadoes of May, 2003.

We would ask those who argue that the increase in tornadoes was just a result of better observation - did our ability to observe and report tornadoes between 1999 and 2003 increase by 240% as the number of reported tornadoes did? Clearly not. Records such as this *when taken together with large numbers of other new records* are drawing sharply increased attention from world meteorological, oceanographic and geophysical assemblies.



Tornadoes May 1-10
2003 are preliminary numbers



Source: National Climatic Data Center, <http://www.ncdc.noaa.gov/img/climate/research/2003/may/spc-tornadotally-pg.gif>

Hurricanes watchers have also seen much increased activity. The last nine hurricane seasons (1995-2003) have been easily the most active nine consecutive hurricane seasons on records going back to 1886. In 2003, 16 named storms developed, counting December storms Odette and Peter - both formed after the traditional end of the hurricane season. This, again, is much

above the 1944-1996 average of 9.8, and consistent with the strong increase in the annual number of tropical systems since the mid 1990s (The 1995-2003 average is 13.6).⁸

1887 was the only other year on record in which two named storms formed in December. Tropical Storm Ana, the first Atlantic storm on record in the month of April, formed approximately six weeks before the beginning of the season - April 21st. 2003 has become the longest tropical cyclone season since 1952 when the first tropical storm formed on February 2nd and the last one dissipated on October 28th.

And as with tornadoes, experts such as Professor William Gray's Tropical Storm forecasting unit at Colorado State University⁹ do not yet see a way to precisely or directly correlate increased man-made greenhouse gases such as CO₂ and this increase in Atlantic hurricane activity. This is not surprising, given the difficulty in linking the source of favorable hurricane conditions such as warm sea surface temperatures and low wind shear¹⁰ with increasing hurricane activity. This also does not mean that we, - the U.S., and other technologically developed nations - should ignore these issues or sanction unproductive projects and directions.

Floods, droughts, hurricanes and typhoons, diseases and pests extending their range, methane hydrates, and the great impending change in ocean circulation – subtle changes in these to date are like things that go “bump” in the night, things that may cause us to assume, “Oh, it's just the refrigerator or the heating vent creaking; a squirrel in the attic or the house settling. And it usually is. Sometimes, however, we are surprised - like the lady in Newfoundland who first realized her new problems when her dog jumped off the bed one morning and she heard a splash!

We have all been surprised by events which ignored our preconceived assumptions and expectations. “Magicians” employ our habit of convenience to create illusion. I took my children to see a favorite illusionist, David Copperfield. Before the show I pointed out to them a very thin black string five feet over their heads – well out of reach and nearly invisible. I explained to them that David would probably use that thread, and others, in his show - perhaps to pull some things over our head.

Later during the show “ghostly” spirits? (handkerchiefs) zoomed from the stage over their heads drawn by those same threads. David had courteously allowed a few tiny threads of his excellent production to be visible near enough for sharp-eyed folks to “heroically” point them out to our friends and families. This chapter will examine some climate, weather and other threads of data that God has generously provided for us to discover, which provide some clues to “surprising changes” in our weather that we will witness in the years to come.

In chapter one we saw, for example, that some crops will increase in production, even while most decline in nutrition and digestibility, such as wheat and rice. These changes are being “forced” in our fields and forests by the increasing CO₂ in our atmosphere. We can now identify some other “forced” climate changes taking place in our weather and some of the escalating climate effects for the near future, most especially “abrupt climate change”.

Abrupt climate change occurs when the climate system is forced across some threshold, triggering new regional climates, or new average annual weather patterns. These changes will be and are being noticed as new records in heat or cold, rain, snow or drought, and cyclone numbers, intensity and destructiveness.

Globally, the 1990s was the warmest decade and 1998 the warmest year in the instrumented record - since 1861 - even though a major volcanic eruption, Mount Pinatubo, cooled the globe by about 1 °F (0.5 °C) from June 1991 through 1993. It injected nearly 20 million tons of bright sulfur dioxide clouds into the stratosphere, reflecting sunlight, and cooling the Earth below.^a The ten warmest years on record have all occurred since 1990. The record warming continues, with 2002 being the new second warmest year.

This climate change is not uniform. In fact, it can be misleading to say our planet is experiencing “global warming”; because the effects we are experiencing and expect to experience are uneven and diverse. The northern hemisphere has warmed more than the southern. Has the northern hemisphere warmed more because most fossil fuel burning occurs in the industrial northern hemisphere? Or because the Southern Ocean mixes with other oceans more effectively than the Northern Ocean, or Arctic, does?

The Northern Ocean, by comparison, is almost encircled by land masses - Asia, Europe, North America, Iceland and Greenland. Since 1958, temperatures over North America have experienced the highest regional warming, increasing by 1.06 degrees C per decade.^{11 12} The vast elevation of central Greenland, however, – away from the coast – has *cooled*¹³ just slightly, by 0.09 degree C per decade, so a better term is climate change. This is not due to volcanoes. Satellite measurements of volcanic heat output show that in 2001, the amount of heat energy produced by volcanoes was 1000 times less than the energy consumed by the United States.¹⁴

Many climate experts are striving to regionalize and integrate their models using new data sources such as the World Ocean Circulation Experiment, the most massive and ambitious oceanographic experiment ever undertaken. In WOCE nearly thirty nations combined global satellite observations with conventional in-situ physical and chemical observations throughout the world’s oceans. While this approach may neglect phytoplankton, zooplankton, and copepods^b, notably, it does permit scientists to improve our understanding of ocean dynamics, which has long been the weaker half of the intertwined ocean and atmosphere components of Earth’s climate system.

^a On June 15, 1991, Pinatubo’s cataclysmic eruption ejected more than 1 cubic mile (5 cubic kilometers) of ash. The 20th century’s second-largest volcanic eruption produced many high-speed avalanches of hot ash and gas, giant mudflows, and a cloud of volcanic ash hundreds of miles across and 22 miles (35 kilometers) high. A coincidentally occurring typhoon blew ash in all directions, fascinating weather watchers. Volcanic ash and pumice lapilli (frothy pebbles) blanketed the Philippine countryside, covering even elevated houses. Fine ash fell as far away as the Indian Ocean, as the ash cloud encircled the Earth.

^b “The copepods are the largest and most diversified group of crustaceans. Including over 14,000 species, 2,300 genera and 210 families, a surely underestimated number. inhabiting sea and continental waters, or living in symbiotic relationships with other organisms. They are considered the most plentiful multicellular group on the Earth, outnumbering even the insects, which include more species, but fewer individuals! Copepods are the dominant forms of marine plankton. <http://copepods.interfree.it/intro.htm>

In the several studies we reviewed in the last chapter, an important technique called FACE enabled many researchers to better understand the effect of doubled CO₂ on plants raised in test plots and on animals grazing on those plants. Directly comparing plants grown in ambient or doubled CO₂ provided researchers sharp insight into the world we are moving toward with higher CO₂ levels in the atmosphere. That powerful technique can, unfortunately for our understanding, hardly be applied to the oceans.

Land dwellers often forget that 71% of Earth's surface is ocean. By far the largest amount of Earth's heat is carried in her immense ocean currents. They capture and carry eleven hundred times the warmth of Earth's atmosphere. A simple illustration might be that the heat in the atmosphere compares to the heat in the ocean currents like a flea on a dog. The flea is like the weather we feel, but where the flea (atmosphere) goes is really determined by the dog (ocean currents). If you wish to know this week's weather look at the atmosphere (or the flea). If you wish to understand next year's weather look at the ocean currents (the dog).

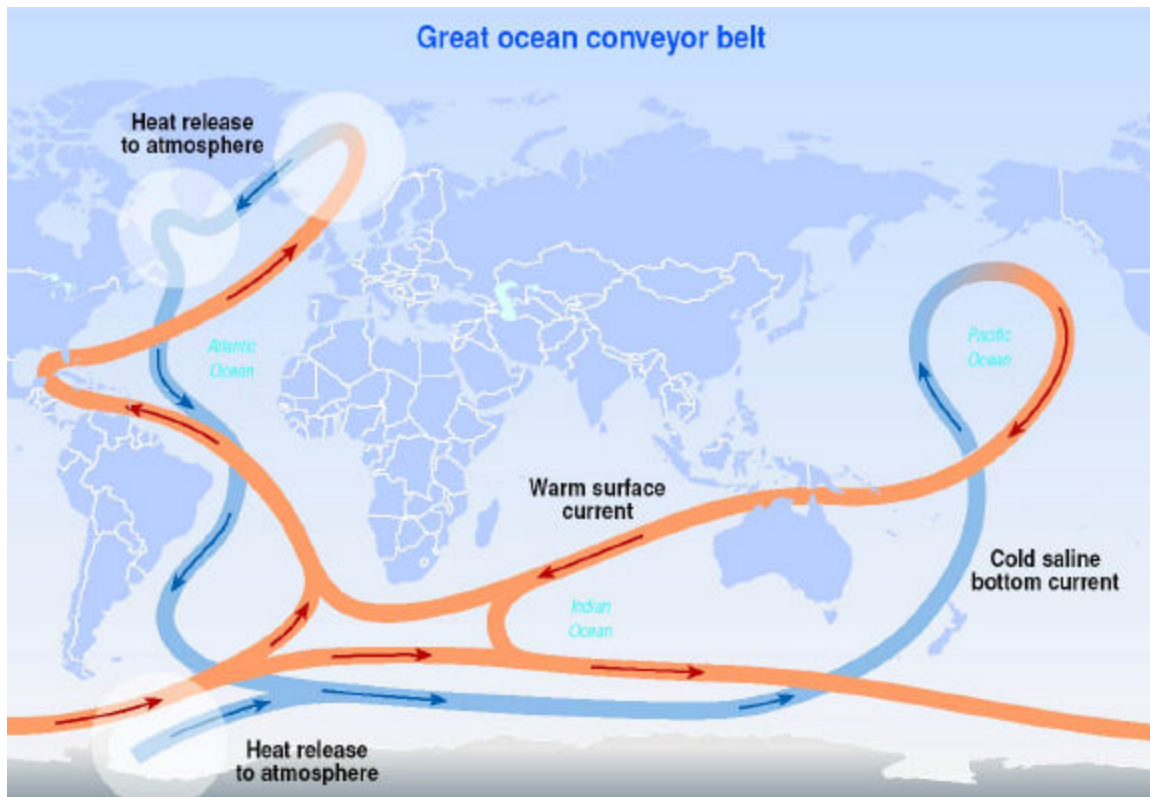
Equatorial areas of the Earth, such as central Africa or the vast Pacific, receive disproportionately more of the sun's heat than temperate areas, since they face the sun directly, instead of at an angle. This, of course, is why polar areas are so cold. The oceans store and circulate all the energy they receive from the sun in great currents, moderating the Earth's weather. London, for example, has warmer winters and cooler summers than New York even though it is 746 miles (1200 km) farther north.

London's warmth is due to the influence of the ocean current we know as the Gulf Stream, which is a local piece of the larger "Great Ocean Conveyor" (GOC) system of global ocean currents. The ocean's currents are like a giant heating and air conditioning system slowly moving vast quantities of water around the globe, mitigating and tempering our weather. The ocean's influence and interaction with the atmosphere drives our global climate and weather. We will begin our story with the vast Pacific Ocean and that additional heat.

You have heard weather forecasters discuss the influence of El Niño (EN) ("the little Boy") – which is a warming of the surface water layers in the eastern and central equatorial Pacific Ocean and a weakening of the trade winds. Peruvian fishermen, who first noticed this phenomenon, named it for the Christ child because it typically appeared on Christmas day.

El Niño events occur irregularly about once every 3-5 years and last 12-18 months. During El Niño, unusually high atmospheric sea level pressures develop in the western tropical Pacific and Indian Ocean regions, and unusually low sea level pressures develop in the southeastern tropical Pacific. By contrast, a period when the equatorial Pacific is abnormally cold is called La Niña ("the little Girl"). This vast alternately cycling planetary "heat pump" we term the Southern Oscillation (SO) - or more often, ENSO.¹⁵

During El Niño the eastward displacement of the atmospheric heat source overlaying the warmest water results in huge changes in the global atmospheric circulation, which in turn force changes in weather in regions far removed from the tropical Pacific. This is the best known and most studied example of how ocean currents impact atmospheric circulation. The illustration below,¹⁶ is a simplified drawing of the world's ocean circulation.



Source: (Broecker, 1995) in "Abrupt Climate Change: Inevitable Surprises", National Research Council. A good source of continuing news about abrupt climate change is http://www.whoi.edu/institutes/occi/currenttopics/ct_abruptclimate.htm

The GOC is really "propelled" by the sinking of cold, salty (and therefore denser) waters in the North Atlantic Ocean. North Atlantic waters are saltier than other parts of the world ocean. Salty water is denser than fresh. Cold water is denser than warm. When the warm, salty waters of the North Atlantic give up their heat to the atmosphere, they become colder and denser and sink. This temperature/salinity forcing is called "thermohaline circulation".

The great majority of this sinking happens above Iceland, where the warm salty current (red line) sinks - becoming a cold deep current (blue line). The GOC gives up its heat to the atmosphere above the North Atlantic Ocean. Prevailing winds carry the heat eastward warming Europe. Thus, the North Atlantic is the source of the deep limb of the Ocean Conveyor. The plunge of this great mass of cold, salty water propels the GOC and helps draw warm, salty tropical surface waters north to replace the sinking waters.

Abrupt regional cooling and widespread global warming can unfold simultaneously. As a 2002 report by the US National Academy of Sciences (NAS) summarized our understanding, "available evidence suggests that abrupt climate changes are not only possible but likely in the future, potentially with large impacts on ecosystems and societies."¹⁷ The most recent GOC data shows, in fact, that greenhouse warming is a destabilizing factor that makes abrupt climate change more likely - indeed as inevitable as current global climate forcings continue to be inevitable. Can those forcings be changed?

Actually the situation is probably worse, as the world appears to be acclimating and planning for “global warming” climate patterns, as we have been experiencing in recent decades, but that are opposite to what will actually occur, especially for those of us living around the edge of the North Atlantic. Accurately gauging these dynamics is beyond the predictive capability of current models and available data, and yet the consequences of ignoring this are likely to be massive.

The Earth’s climate has different climate modes or patterns of ocean - atmosphere interaction. Fossil evidence clearly shows that Earth’s climate can shift modes within a decade, establishing new and different patterns that can persist for many years. We have learned that Earth’s climate system has sensitive thresholds. Pushed past a threshold, it can quickly switch from one stable operating mode to a completely different one—“just as the slowly increasing pressure of a finger eventually flips a switch and turns on a light,” the NAS report said.

Scientists have so far identified just one viable mechanism to induce large, global, abrupt climate changes: a swift reorganization of the ocean currents circulating around the Earth. If too much fresh water enters the North Atlantic too rapidly, and data shows this fresh water increasing, the waters of the GOC could stop sinking. The GOC would slow or cease. Heat-bearing Gulf Stream waters would no longer flow into the North Atlantic, and European and North American winters would become more severe.

Important and recent papers¹⁸ indicate that the North Atlantic region would cool to Celsius if Conveyor circulation were totally disrupted. It would produce winters twice as cold as the worst winters on record in the eastern United States in the past century.

Water evaporating from the oceans is also the source of most of the world’s rain or snow. Changes in ocean circulation or water properties can disrupt this hydrological cycle on a global scale, causing flooding and long-term droughts in various regions. Previous Conveyor shutdowns have been linked with widespread droughts throughout the globe. The El Niño phenomenon most weather watchers know is but a small piece of the oceanic changes which dramatically impact our weather.

In a December, 2003 paper, Curry, Dickson, and Yashayaev reported on five decades of salinity measurements collected from the tip of Greenland to the tip of South America. Much of the ocean water column in the high latitudes of the North and South Atlantic, closer to Earth’s poles, became fresher¹⁹. Surface waters in the tropical and subtropical Atlantic became dramatically saltier. They estimated that these radical effects were due to net evaporation rates over the tropical Atlantic increasing by five percent to ten percent during the last four decades.

Increased evaporation rates would also increase cloud cover. Records from studies around the globe show that over the past 50 years the average amount of sunlight reaching the ground has decreased by almost 3% a decade. There have been reports that sunshine in Ireland was declining; that both the Arctic and the Antarctic were getting darker; that light in Japan was

falling, and levels of solar radiation in the former Soviet Union had gone down almost 20% between 1960 and 1987. These studies have acquired the nickname "global dimming".^{20,21}

"This is consistent with global warming hypotheses that suggest ocean evaporation will increase as Earth's temperature does. These issues are particularly important as pressure on freshwater resources has become critical in many areas around the world," said Elise Ralph, associate director of the National Science Foundation's (NSF) physical oceanography program, which funded Curry, Dickson, and Yashayev's research.

That trend has clearly accelerated since 1990. The decade of the 1990's was the warmest on record to date. And the warming continues – the ten years from January, 1994 to 2004 are the latest warmest ten year period since record keeping began in 1861. Fresh water is being lost from the low latitudes (near the equator) and added at high latitudes at a pace exceeding the GOC's ability to compensate. Other recent studies show parallel salinity changes in the Mediterranean, Pacific, and Indian Oceans.

The global water cycle has accelerated and is intensifying, altering the fundamental planetary system regulating evaporation and precipitation. Ultimately these affect global precipitation patterns which govern the distribution, severity and frequency of droughts, floods and storms. Adding more water vapor—a strong, heat-trapping greenhouse gas—to the atmosphere would also further increase global warming, further freshening North Atlantic Ocean waters eventually disrupting GOC and trigger further climate changes.

Experts stress two points: 1) If thermohaline GOC shuts down and induces abrupt climate change, severe winters in the North Atlantic region would likely persist for decades to centuries — until conditions reached another threshold at which thermohaline circulation might resume. 2) Abrupt regional cooling may occur even as the Earth, on average, continues to warm.

Shutdown or slowing of the GOC would clearly impact the two Atlantic atmospheric phenomena that most strongly affect global climate patterns: the North Atlantic Oscillation (NAO)^{a 22} and the tropical Atlantic ocean-atmosphere system.

1. Cullen and DeMenocal²³ have established a physical link between known, possibly predictable, modes of climate variability originating in the North Atlantic with the observed interannual-interdecadal variability in Middle Eastern climate and Tigris-Euphrates streamflow. The clear possibility exists that GOC shutdown would adversely impact rainfall in Turkey, which is the source for much of the water in the Middle East, such as the Tigris – Euphrates Rivers.

With regional population increasing by 3.2% each year and water storage/irrigation practices consuming at least 80% of available water supply, water is a critical variable

^a The NAO is a meridional oscillation of air mass between the Azores and Iceland. It is the dominant mode of interannual-decadal climate variability in the maritime Atlantic sector. It has been directly linked to large-scale, coherent anomalies in northern hemisphere precipitation and temperature.

affecting agriculture, industry, health and political stability in the Middle East. These factors compound to make the Middle East extremely vulnerable to any (natural or anthropogenic) reductions in available surface water.

2. The correlation pattern on the North Atlantic has been related to a multidecadal variability of Atlantic hurricane activity.²⁴
3. The severe drought of 1998-2001 in Central and Southwest Asia, in combination with socio-political disruption, led to widespread famine affecting over 60 million people. In parts of Iran, Afghanistan, Pakistan and Tajikistan, the drought was the worst to hit the region over the past 50-100 years. Experts have documented both a regional and a large-scale mode of climate variability that, suggest a possible forcing mechanism for the drought. It appears that the combination of unusually warm waters in the western Pacific with cold La Niña waters in the central Pacific can result in rainfall increases over the Indian ocean, changes in the Asia jet stream, and precipitation deficits over Central and Southwest Asia.²⁵

At present the influx of fresher water has been distributed throughout the water column. But at some point, fresh water may concentrate near the surface of the North Atlantic. When that occurs, the Conveyor could slow down or cease operating. Signs of a possible impending slowdown were reported in 2001 in *Nature*, indicating that the flow of cold, dense water from the Norwegian and Greenland Seas into the North Atlantic has diminished by at least 20 percent since 1950.²⁶

A large sustained influx of fresh water into the North Atlantic's surface could create a lid of more buoyant fresh water, lying atop denser, saltier water. This fresh water would effectively cap the surface of the North Atlantic, curtailing the ocean's heat transfer to the atmosphere and diluting the North Atlantic's salinity. At a critical but unknown threshold, when North Atlantic waters are no longer sufficiently salty and dense, they may stop sinking. When will this occur?

No one knows. We only know that large-scale collapse of thermohaline circulation (THC) will result and the GOC will switch when the rates of greenhouse gas forcing are sufficiently large or if warming oceans continue to increase the fresh water accumulating on the North Atlantic's surface.^{27 28}

Oceanographers now rely on a global network of meteorological stations to monitor ocean *atmospheric* conditions, but *have no system for monitoring slower, more critical, ocean circulation changes*. The demise of the Ocean Weather Stations— a network of ships stationed in the ocean after World War II — and the end of the Cold War left oceanographers with access to *far less* data in recent years.

Satellite technology “replaced” these weather ships, but satellites only measure the ocean *surface*. Deep ocean currents – temperature, salinity, direction, etc., – cannot be measured by satellite. Measuring *deep* ocean currents is critical for observing the GOC, but it is difficult.

The recently launched (and poorly funded) Argo program is an international program designed to seed the global ocean with an armada of 3,000 free-floating buoys that measure *upper* ocean temperature and salinity. Efforts have just begun to measure these deep ocean water properties and currents at a few strategic locations with long-term moored buoy arrays, but vast areas of ocean remain unmonitored.

These dramatic changes that *we know are* happening to global ocean currents, beginning but not ending with salinity and temperature, are not neutral to the ocean's food production. Researchers from Scripps Institution of Oceanography studying zooplankton off the coast of southern California noticed an 80% drop in zooplankton biomass, or population, in the upper 200 meters of ocean from 1951 to 1993. Zooplankton are the tiny marine animals we might call fish food. They cruised a 130,000 sq km area during 222 cruises in the Pacific Ocean off Southern California.²⁹ Zooplankton feed on phytoplankton - tiny marine plants.

They ascribed this trend to ocean temperatures rising by 1.5 degrees C, which they logged during this time frame. How does this "regional phenomenon" reflect global trends? What part does this huge change play in our planet's changing climate? Again our understanding of these intricate biological interdependencies is even poorer than our understanding of the physical and chemical changes we are forcing in the oceans.

Changes in the supply of fish food will eventually impact the supply of large fish, which depend on small fish that eat zooplankton. And indeed, experts see such a decline. A recent comprehensive study of global fisheries reported:

"From giant blue marlin to mighty bluefin tuna, and from tropical groupers to Antarctic cod, industrial fishing has scoured the global ocean. There is no blue frontier left," says lead author Ransom Myers, a world-leading fisheries biologist based at Dalhousie University in Canada. "Since 1950, with the onset of industrialized fisheries, we have rapidly reduced the resource base to less than 10% - - not just in some areas, not just for some stocks, but for entire communities of these large fish species from the tropics to the poles."

"The impact we have had on ocean ecosystems has been vastly underestimated," says co-author Boris Worm of Dalhousie University and the University of Kiel, Germany. "These are the megafauna, the big predators of the sea, and the species we most value. Their depletion not only threatens the future of these fish and the fishers that depend on them, it could also bring about a complete re-organization of ocean ecosystems, with unknown global consequences."

Norm Bartoo, who conducts stock assessments on tunas and billfish for the National Marine Fisheries Service expressed doubt that fishing rates, areas and gear remained constant throughout the survey period, as the results seemed to imply.

Marine biologist Lorne Clayton, executive director of the Tuna Fishermen's Association Canadian Highly Migratory Species Foundation, thought the authors should have taken into account natural population fluctuations driven by changes in environment and temperature,

such as those triggered by the water-warming El Niño phenomenon that carries global weather consequences.³⁰

The Johannesburg World Summit on Sustainable Development called for a restoration of world fisheries stocks to levels that can provide maximum sustainable yield by 2015. Recovery requires reducing quotas, reducing overall effort, cutting subsidies, reducing bycatch and creating networks of marine reserves. Myers argues, "A minimum reduction of 50% of fishing mortality may be necessary to avoid further declines of particularly sensitive species."^{31 32}

It is not surprising that fisheries experts naturally tend to view the solution to their problems primarily in terms of extending fisheries' study and control of fishing fleets. Sometimes that perspective is inadequate. Scripp's earlier study, showing an 80% drop in ocean zooplankton biomass (fish food) in the Pacific's vast California Current, was not mentioned by these fisheries experts, yet it may be a crucial piece of the problem. It is exceedingly difficult to trace the full impact and cost of climate change; or our impact on the oceans in the larger context.

Shifts in ocean currents also impact ocean food production. As we learned above, the GOC sinks as it flows around Iceland. When the GOC sinks though, somewhere else it must rise or "upwell". The great majority of upwelling happens in the Southern Ocean and northwest Pacific Ocean. This upwelling brings important nutrients from the deep ocean to feed the ocean's bounty. Recent studies are racing to trace those GOC pathways as it returns nutrients from deep waters and flows on through the Southern Hemisphere and North Atlantic.³³

Yet GOC upwelling is assumed to largely depend on GOC sinking - if the GOC sinking slows or stops, what will happen to this critical nutrient upwelling? This large looming question is another that experts are uncomfortable with and unable to answer without vastly better data than is on the oceanographic horizon.

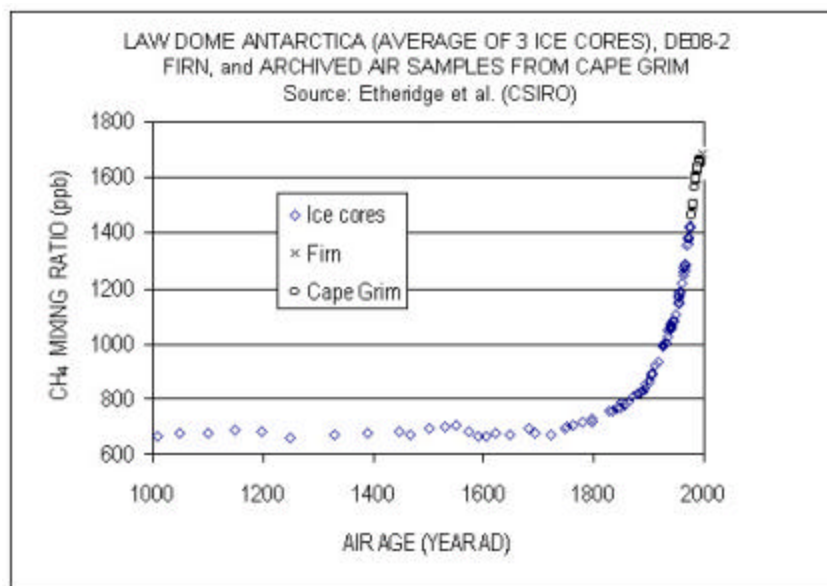
Recently geologists discovered the existence of vast beds of methane, or natural gas, hydrates - natural gas is principally methane - covering millions of square miles of ocean bottom. Methane hydrate is an incredible ice-like material that has been formed of methane gas locked in an icy matrix - a cage formed by water pressure and cold temperatures. Methane, or natural gas, is both an important fuel and a powerful greenhouse gas.



A thin layer of methane hydrate. Source: USGS

Methane hydrates have been found in sedimentary layers up to four meters thick by expeditions to the permafrost covered tundra of polar regions and deep-water continental shelves all over the globe. Where water depths exceed 300 m and bottom water temperatures approach 0° C, hydrate is found at the seafloor to depths of about 1,100 m.

New studies show that this vast, dynamic, and previously unnoticed methane reservoir is in constant flux, absorbing and releasing methane in response to ongoing changes in the environment. While the lifetime of methane in the atmosphere is thought to currently average about twelve years, atmospheric methane levels have increased about 140% since 1800³⁴.



The magnitude of this previously unknown global methane storehouse is fantastic, with current estimates converging around 10,000 gigatons of methane carbon. The U.S. Geological Survey estimates that methane hydrate contains more carbon than all other known conventional hydrocarbon (coal, oil, and non-hydrate natural gas) sources combined. The USGS and other government and private energy research organizations have combined to investigate whether it may be economically feasible to tap these methane hydrate deposits as a source of energy.³⁵

However, if a rapid slowdown in GOC occurs, a downward shift of the thermocline (the boundary between warm surface waters and cold deep (heavier) waters) could bring a temperature increase at depth – enough to greatly increase hydrate melting. Other researchers have recently documented how the release of these immense methane reservoirs appear to have played an important role in the deglaciation from Earth's most severe glaciations³⁶ (or ice ages). Siberian peat bogs, once thought to be a stable sink, or storage place, for carbon for millennia are now believed to have formed rapidly between 8 and 11.5 thousand years ago around the end of the last ice age, apparently contributing to the great methane spike³⁷.

Due to the high pH of ocean water (about 8), CO₂ dissolves readily in Earth's oceans. Since pre-industrial times, the pH of ocean surface water has decreased nearly 0.1 pH-units due to the increase in dissolved atmospheric CO₂.³⁸ Because CO₂ dissolves so readily into seawater, the ocean absorbs about 2 billion tonnes of carbon per year³⁹, yet the ocean's ability to remove CO₂, has not kept pace with our CO₂ production from fossil fuel burning. We are producing CO₂ much faster than plants on land and even the sea can remove and recycle it.⁴⁰

Some suggested that if the ocean were "fertilized", the ocean could be used to help remove the excess dissolved atmospheric CO₂. In the vast Southern Ocean, the low level of dissolved iron in the water was recently found to be the limiting factor to the ocean's phytoplankton (plant) growth. That is, the ocean water is iron-poor, so if more soluble iron were available to the phytoplankton, they would grow better. A suggestion was made to seed the Southern Ocean with iron to artificially increase the ocean's CO₂ removal rate.

Plankton take up carbon in surface waters during photosynthesis, creating a bloom that other animals feed upon. Carbon - in the plankton - is eaten and expelled from zooplankton, krill and other animals, and settles to the seafloor. Iron added to the ocean surface increases the plankton production, so in theory fertilizing the ocean with iron would mean more carbon would be removed from surface waters, where it is exchanged with the atmosphere, and carried to the deep sea. Would ocean fertilization actually work?

In three open-ocean experiments iron was used to fertilize large sections of the cold, productive, nutrient-rich Southern Ocean surrounding Antarctica, most recently the month-long US-led Southern Ocean Iron Experiment (SOFeX). All produced significant increases in planktonic biomass and decreases in dissolved inorganic carbon. However, researchers concluded that sequestration of just 30% of the carbon released annually as a result of human activities would require fertilizing a region more than ten times the entire area of the vast globe encircling the Southern Ocean.

Iron fertilization would clearly be a prohibitively expensive and marginally significant carbon dioxide sequestration or reduction scheme, according to the low impact levels shown in studies to date.⁴¹ Adding iron to the Southern ocean is also likely to alter all the ocean (and its food production) in unknown ways, Buesseler noted, and says its impact on the ocean should be thoroughly studied.

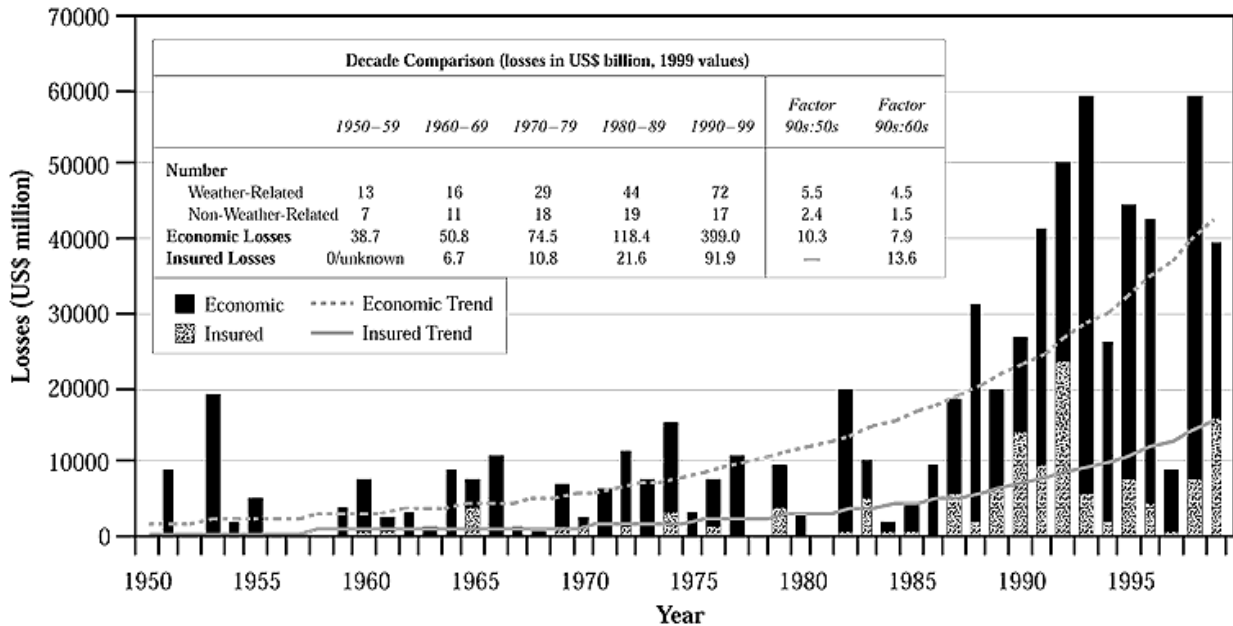
It is usually less costly to prevent a problem than to clean it up later, if it can be "cleaned up". Preventing the generation of excessive CO₂, and other industrial excesses is far easier and cheaper than cleaning them up later. It is essential to do this with profound sensitivity to our shared environment using the most environmentally sensitive new power systems available, as we will discuss in later chapters.

We have all been surprised by events which ignored our convenient assumptions and expectations – like brutal gangs of inescapable facts. The impact of climate change has been and will be measured in many ways, from changing crops to drought, famine and flood, to new businesses adapting to massive change, increasing property losses and undoubtedly ways we can not yet imagine. Insurance companies - which insure against many of these disasters

as well as the mortgages held by banks – are among the prognosticators we turn to if we wonder “What have and will these climate changes cost?”

The world endured nearly one trillion dollars in economic losses and 560,000 fatalities due to 8,800 natural disasters from 1986 to 2001. Three-quarters of the loss costs were weather-related. A fifth were insured. Over the past 50 years, the number of weather-related natural disasters - and insured and uninsured losses - has been steadily rising. Nearly 60% of these losses were by U.S.-based companies. *Between 1970 and 1999 inflation-adjusted losses grew nine-times faster than population.*⁴² The insured fraction of total losses has increased steadily, as has the size of those losses in relation to premium income.

Of the 24 largest weather related catastrophes in history, 21 happened in the 1990s. Hurricane Andrew, for example, cost the insurance industry over \$17 billion and bankrupted eight companies. "Climate change poses a real threat to our business." said Franklin Nutter, president of the Reinsurance Assn. In a full-page ad, Swiss Reinsurance Co. argued that reducing the risk of calamities from global warming was a better policy than merely raising rates or refusing to insure some risks. Of the 40 worst insured losses between 1970 and 1999, twenty-eight were related to windstorm and only six were not weather related. Nineteen of the weather-related catastrophes hit the United States.



Source: Munich Re

“The costs of catastrophic weather events have exhibited a rapid upward trend in recent decades. Yearly economic losses from large events increased 10.3-fold from US \$4 billion in the 1950s to US \$40 billion per year in the 1990s (inflation adjusted to 1999 US\$).⁴³ ...”

In contrast, of the 40 worst events in terms of fatalities, only 16 were weather related, of which 13 occurred in Asia. A list of 30 natural disasters causing billion-dollar losses drawn up by Munich Re revealed that 15 affected the United States and seven affected Europe. Eighteen were related to windstorm. With the exception of earthquakes, all were weather related.

Nearly everyone has been impacted by the effects of increasing weather extremes and will be more so in the future as the frequency and intensity of weather-related events increases. The continued insurability of such risks is a central question being considered within the industry, as experts project increases in extreme weather events going forward.

The world's second-largest reinsurer, Swiss Re, reports that the costs of natural disasters, aggravated by global warming, threaten to spiral out of control, “forcing the human race into a catastrophe of its own making”. The economic costs of such disasters threaten to double to \$150 billion a year in 10 years, hitting insurers with \$30-40 billion in claims, or the equivalent of one World Trade Centre attack annually.⁴⁴

"There is a danger that human intervention will accelerate and intensify natural climate changes to such a point that it will become impossible to adapt our socio-economic systems in time. The human race can lead itself into this climatic catastrophe -- or it can avert it."

Business and individual policy holders, of course, ultimately bear these rising costs. The report comes as a growing number of policy experts warn that the environment is emerging as the security threat of the 21st century, eclipsing terrorism.

Imagine you are taking a trip in your SUV and the brakes suddenly fail driving down Monteagle Mountain. (Monteagle, Tennessee, is the highest pass on any Interstate in the eastern US.) Under good conditions, it is a scenic trip. Interstate 24 crosses Monteagle Mountain at an elevation of 1,915 feet – low by western US standards. But in bad weather or with failing brakes or steering, such a mountain road can be treacherous. Very much like the situation we are rapidly approaching with our energy and environment.

On the eastern side of the mountain there are several runaway truck ramps. The western side of Monteagle has none. Why? Probably because there is nothing but tall air on the downhill curb side of the western slope. Like a runaway truck, our climate, including earth's hydrologic cycle, driven by increasing CO₂ and other forces is accelerating ever faster – to what climate? Looks like Murphy's Law^a is doing the driving. And there are no road, map, or brakes available on this mountain.

Unlike most trucks rolling down foggy mountain roads, we need the ability to ameliorate or prevent many of the unusual environmental and energy shocks lurking ahead on our foggy mountain road. We can build clean baseload energy alternatives and cut CO₂ production to manageable levels. Baseload power is power that runs 24x7 - all the time - when we need it. It runs through the night or when clouds blot out the sun - when photovoltaic panels mounted on some buildings and homes refuse to give power.

Baseload power should run when the wind doesn't blow at all or it blows at high speeds – either of which shut down windmills' power generation. It must run through hot summer droughts with rivers scarcely flowing – which can shut down nuclear, coal, and gas power plants that depend on vast quantities of fresh water to make steam to turn their turbines.

^a Murphy's Law states that, “If anything can go wrong, it will - at the worst possible time.”

We have the technology to build clean baseload power systems that don't harm the environment, yet provide power when and where we need it.

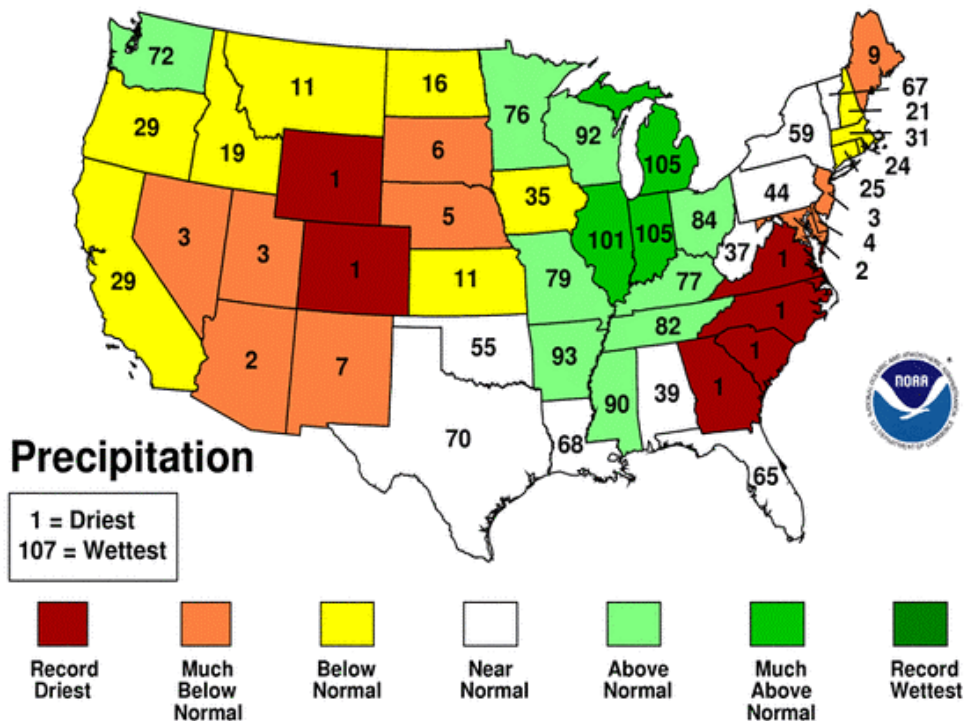
We shall close this chapter by listing a year of world weather record events. Many people are not familiar with what our world weather is doing outside their region. It is fun, useful and interesting to contrast a year of global weather records with our own experience in the hope that we can gain a small appreciation of our neighbors' changing weather.

August 2002

» Six new state-wide drought records for July-August, 2002 were set in the US. “On a statewide basis, the Carolinas were the epicenter of the 2002 drought in the Southeast. States from Virginia to Georgia had their driest August-July on record. This extreme dryness, coupled with the persistent dryness over of the last four years, resulted in a near-record dry statewide Palmer Drought Index for both North and South Carolina.”⁴⁵ Communities around Charlotte, North Carolina in the Catawba River basin, were warned by Duke Power that supplies in the 11 lakes it manages could drop sharply by next summer if significant winter rain doesn't fall. The four-year drought is the worst in the region's 123-year record, and rainfall in the basin has dropped for three years in a row.⁴⁶

Aug 2001-July 2002 Statewide Ranks

National Climatic Data Center/NESDIS/NOAA



Source: http://lwf.ncdc.noaa.gov/img/climate/research/2002/ann/08-07Statewideprank_pg.gif

- » Combined with the extreme dryness of the previous wet season, the seventh driest February – August period, Oregon saw the largest wildfire in the state's history, burning over 500,000 acres.⁴⁷ The Great Salt Lake in Utah was at its lowest level since 1980.
- » In China, water levels on the Yangtze river reached their highest levels in 14 years. The Xiangjiang river was more than 6.5 feet above its flood- warning levels for the first time on record and was still rising. Southern China suffered its worst flooding since 1998, when the flooding was the worst in decades. ... Researchers found that “the effect of increased amounts of soot over southern China created a "clear tendency" for flooding in southern China and increasing drought over northern China that has persisted for several years.” Research is currently being done on a similar pattern over India.⁴⁸
- » India saw its worst drought in 14 years. Manipur state in India, however, suffered their worst flooding in three decades. Bangladesh suffered their worst flooding in 4 years.
- » Many parts of Europe suffered some of the worst flooding since records were first kept in 1896.⁴⁹ The rebuilding job is expected to cost about \$20 billion, according to the first estimates. Relentless storms in early August pushed rivers over their banks and caused chaos from Bavaria to the Black Sea. Record floodwaters blocked major and secondary motorways, wiped out bridges, disrupted train service and knocked out powerplants and water and wastewater treatment systems. Towns and villages were isolated and thousands of people were forced from their homes. More than 100 people died. Flooding throughout Germany was the worst in their history.
- » In Prague, the Vltava River reached 30 times its normal volume. The city stationed a backhoe and crane on the 14th Century Charles Bridge to remove trees and other flotsam smashing into piers. Prague, the Czech capital, suffered their biggest flood in more than 175 years, with more than a week of unprecedented flooding in Austria. Rainfall, which in some areas was the highest since records began, had by yesterday morning swollen to bursting point in two big river systems in central Europe, the Danube and the Elbe.
- » "In parts of upper and lower Austria and Salzburg we had rainfall the like of which we have never measured before since records began, over 100 years ago," said Elisabeth Koch of the Austrian centre for meteorology and geophysics. Her words were echoed at Germany's weather service, which reported that 317 litres per square metre (84 gallons) of rain had fallen in the hills near the Czech border - the highest readings since it began records in 1870. The River Danube - swollen to record levels - burst its banks in the capital Vienna on Tuesday. The city of Salzburg was declared a disaster zone. The city was cut in half a day earlier with 1,000 buildings partially or totally submerged.⁵⁰

The German weather service said: "We are seeing the first indications of climate change. In the last 10 years, the summers have been both very much warmer and very much wetter, which is the origin of the high humidity in the atmosphere."

But London's meteorological office said: "Computer models [of climate change] suggest extreme rainfall events are most likely in winter. Summers are predicted to become drier over many parts of Europe."⁵¹

Vienna, for example, is thought to have been spared the worst effects of the current havoc because of far-sighted engineering projects which began in the late 1800s. In Austria, blame was directed at mayors who approved forest clearances to make way for lucrative holiday homes and business parks. "The toll was made worse due to the sprawl of homes and industry over areas that ecologically have always been flood plains," says the Regional Environmental Centre for Central and Eastern Europe, "The more trees and plants that an area loses, the faster the run-off and more water that ends up in the river"

"You could deforest the whole area and you have 20 centimetres of rain in a week - you're still going to have massive flooding," says Professor Rowsell, head of the UK's Flood Hazard Research Centre.⁵²

- » The Canadian Wheat Board confirmed Prairie farmers' worst fears with wheat production slashed to 15.4 million tonnes, the smallest since 1974, after one of worst growing seasons since the dust bowl of the 1930s. The crop, excluding durum, will fall 40 percent. Spring wheat is down even further, to 1970 levels. Farmers were plagued with a late planting season, followed by severe drought, soaring temperatures, grasshoppers and then fears of early frosts. Barley, used for beer making and livestock feed, approached 1968 production levels, after an unrelenting drought in central and northern Alberta and Saskatchewan.⁵³
- » Smoke from peat and forest fires caused the thickest smog in 30 years in Moscow, Russia.

September 2002

- » Typhoon Rusa killed 184 and was the worst typhoon to hit south Korea since 1959, when typhoon Sarah killed more than 840. Gangneung, where 128 people were killed or missing was one of the areas hit hardest - 3 feet of rain fell within 30 hours, the highest precipitation since weather officials began compiling records in the 1930s.⁵⁴ Rusa destroyed many sections of railways and roads, wiped out bridges, knocked out electricity and submerged thousands of homes. Property damage was placed at \$750 million. A landslide washed away hundreds of graves. "This is a hell on Earth," said Kim Jung-ok, a 54-year-old housewife in Gangneung, wiping tears from her face as she shoveled mud from her living room. Cars and trucks were completely buried as roads buckled beneath deadly landslides. More than 17,000 houses and buildings in low-lying areas were submerged. Residents took shelter at public buildings and schools.
- » Russia recorded the lowest rainfall in a century and the worst smog from burning peat bogs and forests in 30 years.⁵⁵ Millions of Muscovites were advised to stay indoors as thick smog from 200 forest fires choked the city through one of the hottest summers on record.

October 2002

- » The driest October on record in Vancouver, Canada.
- » New South Wales, Australia recorded the driest October on record
- » Hurricane Kenna was the most powerful storm to hit Mexico's Pacific coast in decades. Kenna appeared to hit land with the strongest Pacific coast winds since hurricane Madeline came ashore near Zihuatanejo in 1976 with 144 mph winds.⁵⁶

- » The ice fields atop Mount Kilimanjaro have retreated to their lowest surface extent in the past 12,000 years and could disappear within the next two decades.
- » Higos was one of the strongest typhoons to ever threaten Tokyo, since the end of World War II. More than 50 people were injured as the typhoon made its way across Japan. Stronger typhoons have struck other parts of Japan, but rarely pass over Tokyo.⁵⁷

November 2002

- » El Nino gave the Yukon record-breaking high November temperatures, the third warmest November on record and tied for the second warmest fall since 1942.⁵⁸ Whitehorse recorded a mean of -1.5 degrees, the highest official mean temperature in Yukon. The airport set two extreme maximum records. Every site in Yukon had temperatures at least 6 degrees above normal with near record minimum snowfall - less than 50% of normal. Recorded the latest date for zero snow on the ground. Combined snowfall and rainfall tied for the 8th driest month on record.
- » A dry winter and wet summer ravaged Italy's grapevines, causing the worst harvest in a half a century.
- » Drought has caused the worst famine in Malawi, southern Africa, in 50 years. The situation is much the same in Ethiopia, Zimbabwe and Zambia.

December 2002

- » 2002 was the driest year in Colorado's 108-year record. "This is our sixth consecutive year of below-average snowpack," said Mike Gillespie, snow-survey supervisor for the U.S. Department of Agriculture's Natural Resources Conservation Service. "In my 20-some years doing this, I haven't seen another period where we've had that many consecutive below-average snowpack years."⁵⁹ Allen Green, the state conservationist for the Natural Resources Conservation Service, described the current drought as more severe than the "Dust Bowl" days of the 1930s. There's only so much you can do," Green said.⁶⁰ It was Colorado's deadliest fire season in eight years: nine firefighters dead, at least 235 homes destroyed, 915,000 acres charred. Cities imposed strict watering restrictions, about \$100 million worth of wheat withered. A study of tree rings suggested 2002 was the driest year on the Front Range since 1725.
- » Such devastating drought hasn't been seen in Canada since the record-setting dust bowl years of the 1930's. Quebec, Canada, experienced its worst forest fires in 10 years. For half the people of Canada, from Windsor to Quebec City, 2002 was the warmest year on record.⁶¹ For the second year in a row the three prairie provinces have been slammed by drought, devastating field crop yields and forcing sales of livestock. "Wheat production has fallen 25 per cent this year, to levels last seen in 1974. Barley production has fallen to late-1960s levels. Canola and specialty crop yields are down as well. Meanwhile, the disappearance of pastures and rising costs of feed have caused livestock farmers to sell live animals at distressed prices."⁶²

- » Ethiopia suffered a record drought. It was responsible for producing food shortages for nearly 11 million people, as the drought cut cereal production by an estimated 20 to 30 percent in 2002 (WFP/FAO).⁶³
- » Oklahoma City had its first white Christmas in more than 25 years. Springfield, MO reported 20.5 inches of snow for the month, for a new December record. Snow spread eastward from parts of the Ohio Valley and into the Northeast on Christmas Day, with some locations experiencing the snowiest Christmas Day ever recorded.⁶⁴ Record snowfall in New England.
- » Loss from tropical ice fields near the world's highest capital, La Paz, Bolivia, has been 10 times greater in the 1990s than in previous decades. The Zongo glacier has retreated by around 10 metres and lost about one metre of depth every year. The nearby Chalcaltaya glacier, known as the world's highest ski-field, has lost over 40% of its thickness and surface area.⁶⁵ "The key factor accelerating mass loss on these glaciers is increasingly frequent El Niño events in this part of the world. It means lower precipitation and higher temperatures," explained Dr Robert Gallaire.
- » Beijing, China's capital city, was blanketed by falling snow for six days in a row -- its longest consecutive snowfall for the last 128 years.⁶⁶
- » The Arctic is warming at an unprecedented trend. It is experiencing the most rapid increase in temperature in recorded history. Surface ice melt on Greenland was the highest in recorded history - and extended to elevations previously untouched by melt. Greenland's unusual summer slush was part of a record-breaking year of northern polar ice loss, reported by Dr Steffen and other scientists this weekend at the American Geophysical Union (AGU) conference in San Francisco.⁶⁷
- » Tokyo, Japan, got its earliest blanket of snow in a decade. It was the heaviest in 15 years. Utsunomiya, north of Tokyo, got seven inches of snow on December 9th, the most there for the month of December since 1912.⁶⁸ It was Yokohama's biggest December snowfall since 1947. Snow affected transit in the metropolitan area, with East Japan Railway Co. (JR East) reporting 743 trains on 24 lines stopped, inconveniencing 740,000 passengers, on the Keihin-Tohoku and Yokosuka Lines.
- » One of the worst winters storms in North Carolina's history. Electric utilities provider Duke Power characterized the ice storm as the worst in the company's history, with 1.2 million customers or nearly half its entire customer base without power on the morning of the 5th. This surpassed electrical outages inflicted by Hurricane Hugo in September 1989.⁶⁹

January 2003

- » Record snowfall levels occurred in Newfoundland, Canada. Again. St. John's resumed its march toward a new annual snowfall record as another blizzard pounded the East Coast. St. John's set monthly and daily records in January. Just under 185 centimetres fell last month, surpassing the old record of 162 centimetres set in 1960. A record 45 centimetres fell during a blizzard on Jan. 24, beating a 37-year old record by 6.5 centimetres. By January 18, 2003, St. John's had received 250.9 centimetres, just one millimetre short of the total to the same date in 2001. That year, a century-old record was smashed with a total of 648 centimetres of snowfall. Record snowfalls also occurred in February 2001⁷⁰.

By the early morning hours of April 7, 2001, St. John's broke the all-time record for total snowfall set back in 1881-82. By early May, 648 cm of snow had fallen, making it the highest recorded snowfall among all major Canadian cities. Last winter also set records for both storm frequency and snow depth. Hurricane Gabrielle dumped record rainfalls onto the Avalon Peninsula, resulting in major flooding problems for the capital city. Numerous homes and basements were flooded and damage was extensive. When one lady's dog jumped off her bed - she was surprised to hear a splash!

- » Record low levels of the Mississippi river.⁷¹ Again. During a 1988 drought, Mississippi River levels were some of the lowest recorded since 1895. During a normal July, the Vicksburg, Miss., river gauge records 272 billion gallons of water flowing by it per day. In June 1988, the Vicksburg river gauge recorded an average flow of 108 billion gallons of water per day - less than half the normal flow. Near Memphis, the river shrank to half its normal width.

“Unlike in 1988 when drought conditions led to blockages of traffic, the recent drought has had little impact on shipping. Norris said that is because of channel improvements that have been put in place in the past several years.

“We have been able to manage the low water very effectively,” Norris said. “The drought of 1999 passed *without most people knowing how low the river stages were* (ed. - italics added) because there were no channel closures as a result of the low water levels. It was a real success story.”

- » Canberra, Australia experienced the worst bushfires ever seen. Australia saw the worst bushfires in over 70 years.⁷² An unprecedented 6,233 bushfires were recorded across New South Wales in the past 6 months. The "fire storm" was beyond the experience of emergency workers, including some who fought the Ash Wednesday fires in the Adelaide Hills in 1983. "This was a freakish conjunction of events and conditions," Prime Minister Howard said, "Eastern Australia is in its worst drought in 100 years." Much of the rest of Australia was hit by the longest drought in history. Queensland state recorded its driest January on record. Melbourne had its second hottest day on record and Victoria sweltered under its hottest weather in 64 years.

The 2002-2003 crop year will be one of the worst on record for Australian grain producers, according to the Australian Bureau of Agricultural and Resource Economics. ABARE's crop report not only cut the final figure for the winter cereal crop, but forecast a significant reduction in summer crops. Winter grain production was down 61 per cent on last year and the lowest since 1982-83. Dr Sheales said because the crop area was significantly larger than in 1983, this year was effectively worse. "The incomes of farmers have been absolutely devastated," Grains Council vice-president Ron Hards said. "Although you have a 62 per cent reduction in wheat yield across Australia, an enormous amount of Australia never had any at all. All the expenses were outlaid and you have no income."⁷³

- » Record cold temperatures hit India. All south Asia has been enveloped by the region's most severe winter in decades. Officials in New Delhi told Reuters news agency the cold has killed perhaps more than 1,500.⁷⁴

- » Central Russia saw its coldest winter in 24 years, with temperatures dropping to a low of minus 33 degrees Celsius. Overnight, the temperature hit minus 27 degrees, leaving three people dead and 29 hospitalized. 300 people died from the cold in Moscow. 205 died last winter.⁷⁵ In eastern Turkey, temperatures dropped to their lowest in 10 years, reaching minus 40 degrees Celsius
- » Naval authorities expect that the Baltic Sea will completely freeze over again. The ice last covered the Baltic in 1948. Some 40 ships were trapped in the icy Gulf of Finland, near St Petersburg and ice-breakers were sent to their rescue. In addition to covering an unusually large area, the ice is also five to 20 centimetres thicker than average.⁷⁶ Helsinki has had a dry cold snap not seen so extreme in four decades.
- » The long drought and cold severely depleted Nordic hydropower reservoirs. Spot prices for electricity on the region's Nord Pool surged to an all-time peak of 831.41 crowns per megawatt hour in early January.⁷⁷ Finland, Helsinki has not had such a dry cold spell in four decades.
- » Dry, warm Santa Ana winds gusted up to 80 mph roaring from the desert interior toward the Southern California coast. They contributed to two deaths and fanned wildfires that threatened hundreds of Malibu homes. Whipped by the Santa Ana winds, over 600 firefighters battled Malibu blazes, said Mike Brown, Los Angeles County Fire Department.
- » Record cold temperatures throughout much of the eastern United States penetrated into Florida, with record temperatures observed in many areas January 24th. (Reuters) New Yorkers shivered in record sub-zero temperatures for 10 days.^{78 79}
- » An estimated 250,000 Southern California Edison customers lost power. Dozens of power poles were knocked over by trees. "It has been a long time since we have had so many power outages related to a weather pattern," said Stephanie Donovan of SDG&E. Public works crews worked through the night, responding to 150 calls of downed trees.

A transit bus driver saw a tree falling ahead and he swerved as it fell. Eight of his 28 riders suffered injuries as the tree broke the driver's window, shattered the passenger side front window and deeply dented the top of the bus. Lifeguards were kept busy with rescues in Cardiff, contending with 8-foot waves and 10-foot faces, compounded by the Santa Ana winds. Lifeguard Karl Tallman said, "We had to pull in five surfers. Another group of surfers barely avoided getting pitched onto the rocks."⁸⁰ In 1993 Santa Ana winds spread fires that charred thousands of acres, killed three and destroyed 1,000 buildings.

- » Cyclone Zoe, the most powerful Pacific cyclone ever recorded, tore through the Solomon Islands with winds "over 225 mph and destructive tidal waves". The Category 5 storm flooded entire villages under 10m (33ft) waves, uprooted trees, destroyed crops and downed radio lines. The island looked like 'Hiroshima, with whole villages inundated by the sea'.

The locals sheltered in mountain caves during Cyclone Zoe. Although the population on Tikopia survived, their homes and crops appear to have been wiped out by the immense waves. Fresh water is now severely limited and apparently only accessible at low tide. Home to around 3700 people, Tikopia is the largest of the affected islands and has been declared a disaster zone by the Solomon Islands government. A French reconnaissance airplane brought back aerial photos showing the once-lush island of Tikopia completely stripped of vegetation. Cyclone Zoe packed the highest cyclonic winds ever recorded. The fate of thousands of people on other hard-hit nearby islands remains a mystery.^{81 8283}

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photos: Associated Press

- » London measured its heaviest snowfall in 12 years.⁸⁴ Belgium, swamped by the worst floods in nearly a decade, put its army on flood alert. Many parts of the country were under almost a metre (three feet) of water.⁸⁵ Odd weather throughout Europe has left parts of the Alps without snow, and Northern Europe with their worst cold snap in decades.
- » Heavy rains in the Democratic Republic of Congo could burst the banks of the River Congo, particularly in the capital Kinshasa, where the river is at its widest. Violent tropical storms regularly hit Kinshasa and the river ran dangerously high. Congo's national weather station said it was the heaviest in ten years.⁸⁶

February 2003

- » The worst blizzard in seven years, “The Blizzard of ‘03” shut down much of the northeastern U.S. and left record snowfalls topping more than 2 feet from Washington to Boston with 30 dead⁸⁷.
- » Record-setting rains fell over southern California February 14. Rainfall amounts broke and in some cases doubled records Wednesday in many locations. Mount Wilson had 7.68 inches of precipitation topping 2001’s record for the date by 4.34 inches. At Tejon Pass north of Los Angeles, a mile-long wall of mud covered all four southbound lanes of Interstate 5 as deep as 4 feet in some areas.⁸⁸
- » Water storage levels have fallen below 60%, to their lowest levels in five years, in Sydney, the Blue Mountains and the Illawarra regions of Australia.

March 2003

- » Many places in Tasmania state, Australia, set new records for rainfall.⁸⁹
- » Denver, Colorado had its biggest blizzard since 1913, with 31.8 inches. Snow destruction was found all over town after the blizzard of March 18.⁹⁰
- » Record-shattering cold temperatures threatened to freeze Lake Superior's surface for the first time in over two decades. Craig Evanego, an ice forecaster with the National Ice Center in Washington said, “Lake Superior last froze completely in 1979, and this year's ice cover is the most since 1996-97.” Ice covered more than 90 percent of Superior. In

some areas, the ice is a scant inch or so, but vast portions of the big lake have 12 to 28 inches of ice. Lakes Huron and Erie are also covered in ice, with much of shallow Lake Erie buried under 28 or more inches of ice, the Ice Center reported. Northern Lake Michigan is frozen, but the mid- to lower section is open, other than coastal areas.⁹¹

- » England, Wales, Scotland and Northern Ireland experienced record-breaking hours of sunshine in March. The first two months of 2003 were also the UK's second sunniest since record-keeping began in 1960.⁹²

April 2003

- » Cherrapunji, in the Khasi Hills of northern India, once recorded more than 1,000 inches (2,540 centimetres) of rain in one year - a global record. One of the world's wettest places now suffers from a chronic shortage of water. Area villagers now have to bring water from other areas. Cherrapunji received less rain in the year 2001 - only 363 inches (922 cm) - than it got in just one month in 1861. They worry they have received less and less rain over the years during monsoon. During winter, the rains almost stop and the springs dry up. Long rows of trucks can be seen carrying drums of water to Cherrapunji.⁹³
- » Ana, the first named storm of the 2003 hurricane season and one of only two storms to form in April on records going back to 1886. Ana presaged the longest tropical cyclone season since 1952 when the first tropical storm formed on February 2nd and the last one dissipated on October 28th.
- » Water temperatures in Smith Sound, Trinity Bay, Newfoundland, were the coldest measured in decades as a massive cod kill occurred there. Fisheries ecologist George Lilly, on the research vessel Teleost, said, "The water reached -1.7 degrees C. That's about as cold as sea water in our area can get." The cod recovered had ice crystals around their organs. The future impact is yet to be felt because the fish were preparing to spawn.⁹⁴

May 2003

- » The record 562 tornadoes which hit the United States in the month of May was hugely higher than the previous monthly peak of 399 in June 1992. It was "the most devastating series of tornadoes we've ever had in the state of Missouri," Gov. Bob Holden said after walking the rubble-strewn streets of Pierce City.⁹⁵
- » Global average land and sea surface temperatures in May 2003 were the second highest since records began in 1880.⁹⁶
- » The heaviest rainfall and worst flooding in Samoa in 20 years affected the islands, causing mudslides that killed 4 people and prompted a state of emergency declaration.⁹⁷
- » At least 40% of the Argentina state of Santa Fe was hit by the worst flooding in five centuries of records. Torrential rains that produced severe flooding at the end of April continued into early May, exacerbating conditions in the provinces of Santiago del Estero, Entre Rios and Santa Fe. At least 23 fatalities were reported and 28,000 houses were damaged or destroyed by the floodwaters. By May 8, 25 percent of the city of Santa Fe was under water. At least 60,000 people were evacuated from their homes. President Duhalde declared a national disaster.⁹⁸

- » Flooding in Sri Lanka killed 280 people and made at least 175,000 others homeless. One day of unusually heavy rainfall at the start of the monsoon season caused landslides and some villages have been submerged under seven feet of water. "It's the worst flooding we've seen since 1947," said Reverend Ebenezer Joseph, National Christian Council of Sri Lanka general secretary.⁹⁹
- » Some of the heaviest rainfall in more than a hundred years swamped parts of the southern U.S. The Tennessee River saw its highest level in four decades after days of torrential rain. Central Alabama set a record for rainfall in a two-hour period Wednesday, with nearly 11 inches falling near Birmingham. Weather service officials said no higher amount is on record dating back 130 years.

Record flooding occurred on the Chickamauga River. Other rivers had moderate flooding. At West Point the Chattahoochee River crested at 23.2 feet; the highest level since February 26, 1961 when the river rose to 24.9 feet. The Chattahoochee crested near 40 feet at Columbus. This is the highest water level since 41.4 feet on March 17, 1990.¹⁰⁰

- » Manitoba, Canada experienced scorching wildfires and one of its most combustible springs ever.

June 2003

- » Switzerland experienced its hottest June in at least 250 years. Since 29 May, daytime temperatures in Geneva did not fall below 25C. Austria experienced its hottest June since 1811. Southern France saw record average temperatures - between 5 and 7 degrees C (9 to 13 degrees F) warmer than the long term average, rising above 40C in places. Record high temperatures in Italy. England and Wales also experienced their hottest month since 1976.¹⁰¹
- » Swarms of Mormon crickets infested Nevada, Utah and Idaho--possibly the worst infestation in decades. Mormon crickets's diet includes sagebrush, alfalfa, wheat, barley, clover, seeds, grasses, vegetables and even weeds. Experts say this year's infestation in Nevada, Utah and Idaho could be the worst in decades. Officials in southwestern Idaho say the infestation there is the worst since World War II. In Utah, agriculture officials estimate 6 million acres, more than double last year's plague, will be infested before the crickets die off by fall.

Experts said this year's outbreak isn't the most severe in Nevada history. In Eureka County in 1882, trains were unable to make headway over the main line of the Central Pacific Railroad "due to the rails being so thoroughly greased with crushed crickets," state Archivist Guy Rocha said. In the 1930s, a band of crickets 12 miles long and at times several feet deep was reported in Elko County, Rocha said.¹⁰²

- » Texas had the second-driest spring in a century.¹⁰³ Parts of the East Coast, including Virginia, North Carolina and South Carolina, experienced their wettest spring on record. Texas, however, endured its second-driest spring in the 109-year record.
- » Dan Johnson, a research scientist with Agriculture Canada, says 2003 could be the worst year ever for grasshopper infestation in east central Alberta.

"In 42 years that I've farmed, I've never seen them this bad," said Bob Penner, a grain farmer northeast of Calgary, "It's the very worst I've ever seen." Last year's drought allowed grasshoppers to lay what researchers believe to be an enormous number of eggs. Now they are hatching.¹⁰⁴

- » The southern Indian state of Andhra Pradesh is battling its worst drought in 40 years due to lack of rain last year. The death toll stands at 637 with temperatures of 117.50 F. Last year's heat wave killed over 1,000 people in the state, when temperatures reached 122 degrees. Tin-roofed shanties were like ovens for many poor people.¹⁰⁵

July 2003

- » Australia suffered its worst-recorded environmental disaster when brushfires fueled by a severe drought blackened almost ten percent of the country, a parliamentary inquiry heard. Melbourne, Australia instituted the toughest water-use restrictions in 20 years.¹⁰⁶
- » The "worst sandstorms in living memory" swept more than 12,000 people in Afghanistan.(AFP) Sandstorms began in the region in early June and continued during July. Up to 20 villages had to be evacuated because they were completely covered in sand, and many irrigation canals and waterways were filled.

Croatia's major rivers, including the Sava, Drava, Kupa and Danube, were reported at their lowest levels ever, threatening water and electricity shortages. In neighboring Serbia, ecology minister Adjelka Mihajlov said their major rivers were at their lowest in 100 years. Lack of rain beyond occasional brief thunderstorms have also slashed crops outside the EU, including the Czech Republic, Hungary, Serbia, Croatia and Romania.

The Danube flow was at the lowest level in 160 years.

Imbudo was the strongest typhoon to hit the Philippines in five years, with maximum sustained winds near 240 km/hr (130 knots or 150 mph).^{107 108}

- » In Italy where a heat wave and accompanying drought have lasted weeks, the national grid was overloaded by the use of air conditioners, causing summer blackouts for the first time in over 20 years. "The River Po is at record lows - nearly eight metres (24 feet) below its normal level."¹⁰⁹ A northern Italian power station, at Ostiglia, was shut down due to a lack of water to cool its turbines. In Venice, rainfall in the first six months of the year was 40% lower than average. "Water supplies are guaranteed until the end of the month. But if it doesn't rain we'll have to decide what our priorities are - agriculture or industry," said Italy's civil protection head, Guido Bertolaso.
- » In France wildfire raged in several southern regions, spread at a pace unseen since special fire-fighting services were created after World War II. Southern and eastern France were without significant rainfall for two months.¹¹⁰
- » Russian Emergencies Ministry reports far-eastern Russia is experiencing the worst year on record for forest fires in the region. Since January, fires have burned 20,000 square kilometers of forests—almost 5 million acres.¹¹¹
- » The blizzard that hit New Zealand over the weekend of July 5 is being reported as the worst in 50 years.¹¹² North Island's east coast reported the worst snowfalls in 40 years.

August 2003

» Western and Central Europe experienced its hottest June, July and August in over 500 years.¹¹³ The nations of Portugal, Switzerland, Britain, and Germany set new record high temperatures. And they were the warmest by a very long way. On 10 August Britain registered 38.5°C(101.3°F) at Faversham - the first three-figure Fahrenheit temperature. Germany saw 40.8°C (105.4°F), Switzerland 41.5°C (106.7°F) and Portugal an astonishing 47.3°C (117.1°F). From west of Paris to northern Italy and southern Germany, the average temperature for the summer months was 3.78°C above the long-term norm.¹¹⁴ "It was enormously exceptional."

France recorded its highest temperatures since 1945 as the mercury rose to 40 degrees Celsius (104 Fahrenheit) in early August. Drought-parched countries from Russia to Portugal suffered the greatest heat wave in more than a quarter century. Hungary and Croatia have not had such extreme heat in more than a half century. The French government and the opposition Socialist Party blamed each other for a rapidly mounting death toll from a heat wave that killed between 11,000 and 13,000 people in France alone.¹¹⁵

Scorching temperatures and low water levels in rivers across Europe threatened to cut output at many nuclear and other electric power stations as homes and businesses cranked up air conditioners. Officials in France and Germany approved temporary permits allowing nuclear plants to raise the maximum temperature of the cooling water its plants pump into the country's depleted rivers - risking damage to fish and plants¹¹⁶.

Swiss power officials cut output throughout the summer at their nuclear plants rather than put hotter cooling-off water into their Alpine rivers. Most nuclear reactors are sited along riverbanks to obtain their operating water to make steam. Europe's hot and dry summer depleted its rivers, causing problems for hydro-electric power plants. The Danube, needed for 40 percent of Romania's hydroelectric plants, shrunk to its lowest level in a century.

English engineers slowed trains for fear of buckled tracks as London recorded an unprecedented 99 degrees F. In eastern Serbia, the masts of German warships sunk during World War II emerged above the surface of the Danube last week after the river sank to its lowest level since the end of the 19th century. Serbian wheat production sank to its lowest level in 50 years.

The French government loosened requirements for making Roquefort cheese, allowing farmers to feed their goats food scraps during periods where their animals are not producing milk. Water rationing was imposed in more than half of France's 95 departments, with fines of up to \$1,700 for transgressors.¹¹⁷

» Fierce blazes sweeping across two-thirds of Portugal's mainland regions were the worst in living memory. Quercus believes the final toll of lost woodland will be 250,000 hectares - with each hectare potentially shedding 50 tons of soil. "During the first rainfalls in the fall there will be a huge quantity of soil dragged as sediment into bodies of water," said

Francisco Ferreira, vice-president of Quercus. More than 12.5 million metric tons of topsoil will be eroded next year, they expect.¹¹⁸

- » When 2003 began, parts of coastal British Columbia and the southern interior were in the middle of their worst drought in 100 years after the driest three-year period on record. British Columbia saw 2,500 wildfires that forced 50,000 people to flee their homes over the summer. British Columbia's forests were the driest on record, contributing to the worst fires in 50 years. Streams ran at 10 to 20 per cent of their normal flows and were so "lethally warm" that salmon were suffocating; ground waters were dipping perilously low; and the Fraser River had one of its lowest peaks in 90 years of record-keeping.^{119 120}
- » Mongolian zuds (a long dry summer followed by an extremely cold winter) have never before been so bad and so often. Three years in a row winter temperatures have plunged dramatically low. A third of Mongolia's herds have been lost¹²¹

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An international shipping company placed an ad to hire a radio operator. The next day a dozen people came to apply. Each took a number and sat down in the waiting room outside an office door marked "Private". A new guy walked into the office to join the applicants. The guy at the desk said, "Take a number and sit down." As the intercom crackled, everyone waited. A minute later the new guy jumped up and walked into the closed office. Five minutes later the guy came back out, wearing a big grin. She had the job. Several other applicants who had arrived before her attacked her for going into the office door before them.

They said, "Hey, Slick, I got here before you did."

The new guy answered, "Any one of you could have had that job. I just listened to the Morse code coming in over the intercom. It said, 'We want alert radio operators. If you understand this message, please enter the private office immediately.'"¹²²

We don't want to ignore the signals we are getting. In this chapter we have carefully examined the climate change record and the work of innumerable distinguished research scientists. It is overdue for the politicization of this energy/environment issue to move toward solution, before an ice age or worse climate changes become locked into our future. We should join Professor Phil Jones, director of the Climatic Research Unit, of the University of East Anglia, who in December, 2003, joined a long and steadily growing list of distinguished scientists, including the Council of the American Geophysical Union,¹²³ who stated that month that

"Human activities are increasingly altering the Earth's climate. These effects add to natural influences that have been present over Earth's history. Scientific evidence strongly indicates that natural influences cannot explain the rapid increase in global near-surface temperatures observed during the second half of the 20th century. Research indicates that increased levels of carbon dioxide will remain in the atmosphere for hundreds to thousands of years. It is virtually

certain that increasing atmospheric concentrations of carbon dioxide and other greenhouse gases will cause the global surface climate to be warmer.

“Human impacts on the climate system include increasing concentrations of atmospheric greenhouse gases (e.g., carbon dioxide, chlorofluorocarbons and their substitutes, methane, nitrous oxide, etc.), air pollution, increasing concentrations of airborne particles, and land alteration. A particular concern is that atmospheric levels of carbon dioxide may be rising faster than at any time in Earth's history, except possibly following rare events like impacts from large extraterrestrial objects.

We can generate virtually unlimited clean baseload energy using Space Solar Power. The time has come to stop exacerbating climate change with inappropriate energy policies. The tools and technology are available today.

Until we, as a nation, recognize this opportunity perhaps we should sympathize with farmers from Montana to Texas, who are not so interested in the fine points of climate theory as they are weathering yet another blistering hot drought. We will close this chapter with the tough, dry humor inspired by the heat that irked Gen. Phil Sheridan enough to claim, "If I owned Texas and all hell, I would rent out Texas and live in hell."

It got so hot, they fed the chickens cracked ice to keep them from laying hard-boiled eggs.
It got so dry, the cows gave evaporated milk.
It got so hot, the birds had to use potholders to pull the worms out of the ground.
It got so dry the trees were whistlin' for the dogs.¹²⁴

Nearly 20 years later, Gen. Phil Sheridan explained that he had been asked his opinion of Texas by a reporter just after an exhaustive, dusty trip from San Antonio to Galveston. Sheridan was so mad, he said, and blurted out his well-known statement. "Now I want to assure you," he said later, "that I only meant to convey how disgusted I was with that newspaper man. It did not represent my opinion of Texas."

Texans didn't hold Sheridan's statement against him. In fact, one bloke who heard the general's explanation commented: "I have never understood there was any bitterness towards General Sheridan on account of his having made that remark. The only reason people thought hard of him at all, was on account of his failing to kill that reporter."

U.S. Sen. Ben "Pitchfork" Tillman of South Carolina once said, "Texas has more trees and less timber; more rivers and less water; more resources and less cash; more itinerant preachers and less religion; more cows and less milk, and you can see farther and see less than any damn country in the world."

The best thing to come out of a drought is a dry sense of humor.

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