What Have We Done:
North America's Mountain Pine Beetle Pandemic

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Scientists have been saying, for literally decades now, that insect infestations and disease will increase as our climate warms. The mountain pine beetle killed twenty million acres of trees in British

Columbia between the mid 1990s and 2006. This outbreak is four or five times larger than the largest outbreak ever recorded – anywhere. In 2006, the forest professionals said that in the next ten years, another 20 million acres of forest would likely succumb to the effects of the beetle in British Columbia alone. In just three years, by the end of 2009, sixteen million additional acres of British Columbia's forest had been killed. (1)

Colorado and southern Wyoming saw the bark beetle infestation grow from 3.6 million to 4 million acres in 2010 with pockets of ponderosa pine impacts increasing dramatically along the front range. The Black Hills of South Dakota saw their epidemic double in a new hot spot that appears to be approaching the infestation levels of other gigantic infestations across the Rockies. (2)

From New Mexico to British Columbia, forest stress from a changing climate has created the conditions for ecoregime change never experienced by the human species.

Campgrounds are being clearcut because of falling tree hazards. Trails are being closed. In three national forests in Northern Colorado 40% of all roads, over 3,400 miles, have been impacted by beetle kill. All of these roads will need the dead trees within falling distance of the road cut down. The swaths are usually clearcut because so many trees are dead, the remaining live ones have little protection from wind and topple easily.

The National Forest Service says that it will cost $100 million to clear the roads and campgrounds in Northern Colorado and Southern Wyoming.

Powerline right of ways are being cleared under emergency orders. In just 2009, in southern Wyoming and northern Colorado, over 600 miles of line were cleared totaling about 20,000 acres. Wildfire risk are extreme as the dead trees' needles dry, but more alarming will be the threat of ground sterilizing fire once the trees have fallen. These conditions, over such large areas, are entirely unprecedented. (3)

The pine beetle is out of control. Sixty-four million acres of forest have been impacted from New Mexico to British Columbia. The beetles are attacking the high altitude forests of the Rockies because the trees there are under the greatest stress from climate change. Warming at higher altitudes is more than twice the planet's average. (4)

This outbreak is far larger than anything that has ever occurred before, and it is happening because of warming. Only cold can kill the pine beetle. The forest professionals and climate scientists say that they see no reasons why the pandemic will not spread entirely across the great boreal forest of the north to the Atlantic seaboard, and then down through the great white pine forests of the northeast all the way to the southern pine forest in the southeastern U.S. (5)

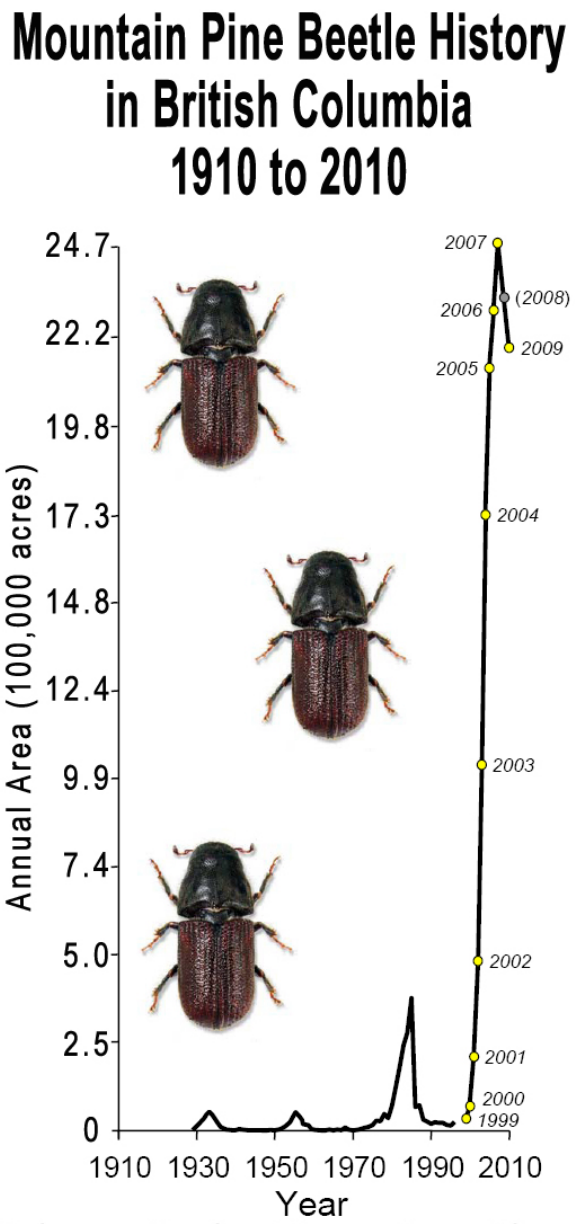
The challenge of our society today us to recognize this ecoregime change for what it is. Although there is a lot of scientific banter about that natural cycles are involved, or forest fire suppression of the twentieth century is responsible, there is a vast and rapidly growing body of scientific evidence that tells us that what we are seeing across this subcontinental region is far more than that. Large scale ecosystems can be irreversibly modified by climate change. It has happened in the past and it is quite likely happening across the Rocky Mountains of North America, now. (6, 7)

The largest outbreak previously recorded was in Montana, Idaho and North Dakota in the late 1970s and early 1980s. This infestation ultimately impacted four million acres. (8)

The other great beetle kill often cited as one of the reasons why this ongoing pandemic is just another natural cycle was reported between 1911 and 1935 in Idaho and Montana. This infestation resulted in a loss of 15 billion board feet of lumber. By standards today this could have been anywhere between one and five million acres. This great outbreak though must be tempered with the knowledge that the

annual national forest production in 1929 was 14 billion board feet. Annual wood products production for the U.S. in 2005 was 51 billion board feet. (9)

Massive regional-scale outbreaks are happening across the Rockies of North America, simultaneously and on an unprecedented scale. Three distinct outbreak centers are evident: one in Southwest Canada, another in the Greater Yellowstone Ecosystem in Wyoming, Montana and Idaho and an the third in southern Wyoming and northern Colorado. Another three million acre attack of pinyon beetle occurred on the Four Corners region of the southwest U.S. from 2003 to 2006 and yet another three million acres of spruce beetle were killed on the Kenai Peninsula in the late 1990s. All of the current attacks are happening at the same time, making the unprecedented nature of these events even more profound. (10)



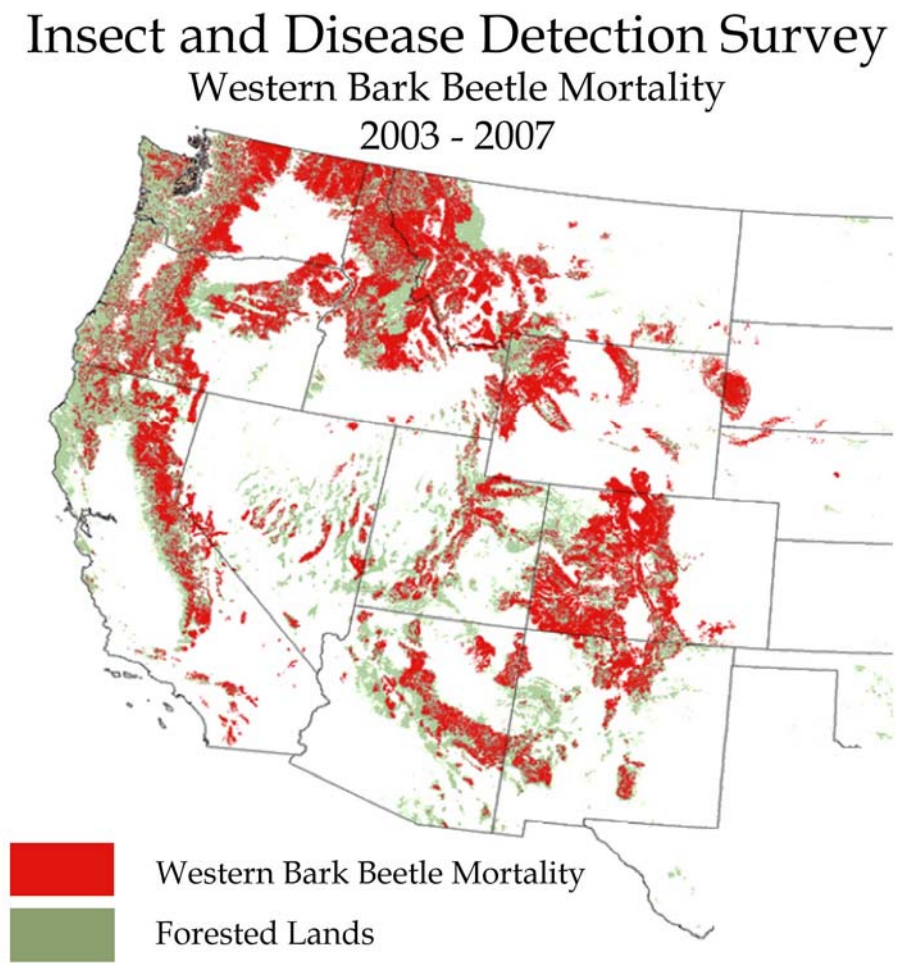
Reference: Allan Carrol, Lessons Learned from the mountain pine beetle outbreak in North America, University of British Columbia, 2010.

Very large outbreaks of spruce beetle, fir beetle, pinyon beetle, western pine beetle, spruce and fir bud worm, fungus, rust, cankers, sudden aspen decline, and many more afflictions are also happening in New Mexico, Arizona, Colorado, Utah, Wyoming, Nevada, Idaho, Montana, California, Oregon, Washington and South Dakota. Many of these outbreaks are happening in areas that have never before seen any such infestations or disease, let alone record breaking attacks. Native insects or diseases are causing almost all of these problems. Stress from continued drought caused by a warming climate has made the forests more susceptible to attack.

The U.S. Forest Service Incident Commander for the pine beetle infestation, Carl Wettstein, says that 17.5 million acres of the U.S. Rockies are under attack. The British Columbia Ministry of Forests says over 40 million acres are dead or dieing in British Columbia, Canada and the Alberta, Canada government pine beetle website says 14 million acres are at risk there. Evaluation of the Alberta maps shows that over half of the 14 million acres area in Alberta is under attack.

Far south, in central Mexico, just north of Mexico City, 7,500 fir trees infested with bark beetles have been cut in Mexico's Monarch Butterfly Biosphere Reserve, after the worst drought in 70 years (11).

All together, over 64 million acres are infested by one type of insect – the mountain pine beetle. This is an area nearly the size of New England and Pennsylvania combined. Up to 10,000 of these beetles, each as big as a grain of rice, can attack just one tree. Trillions of beetles are involved in what can only be described as a pandemic.



Source: Western Bark Beetle Assessment 2009, Western Forestry Leadership Coalition http://www.wflccenter.org/news_pdf/325_pdf.pdf

Each acre of forest includes over 100 trees. Most of the infested areas have serious infestations, and if they are not serious now, it is unlikely that they will not be serious in a few years. Most of the infested trees die. This means that literally, billions of trees are dead or dieing. Billions of trees ... And this infestation is ongoing with no sign of easing beyond a decrease in some areas because there are not enough living trees remaining for the beetle's infestation to be sustainable.

These outbreaks are so critical that the whitebark pine has been petitioned as a candidate for endangered species listing. Eighty-two percent of the whitebark pine (both a foundation species *and* a keystone species) is dead or dieing in the 20 million acre Greater Yellowstone Ecosystem. This totals about 2 million acres of trees.

A foundations species means that the whitebark pine is one of the most numerous trees in the forest. A keystone species means that this tree has some fundamental relationship with other creatures in the forest whereby if the whitebark disappears; a chain reaction will occur with other species dependant on that tree and they too will disappear or be seriously impacted.

The former head of bark beetle research for the U.S. Forest Service, Jesse Logan, referring to the whitebark pine attack in the Greater Yellowstone Ecosystem, says "Ecologically that's an astounding event. … That system was really pretty much in equilibrium for thousands of years. It has undergone absolute, dramatic change in just six years."

Whitebark pines are found today at very high altitudes and they can live for 1,000 years. The high altitudes mean harsh conditions and extreme winters. But warming, and greater warming at altitude has virtually done away with the extreme winter temperatures that the whitebark pine evolved with. Because it has historically been so cold, and because the pine beetle is killed by extreme cold, the whitebark's defenses against the beetle are not as robust as those of lower elevation trees.

Logan and colleagues Macfalane and Powell have prepared the most extensive aerial survey of the Greater Yellowstone Ecosystem ever done and from this survey we have now seen renewed efforts by US Fish and Wildlife to continue with the evaluation for listing the whitebark pine as endangered. Logan says "It's a really different ecological situation in whitebark."

This trouble lies with high altitude forests. Universally, because of the extremeness of the weather at altitude, all plants are slow growing. When alpine plants are covered with snow and ice for eight or nine months of the years, little growth occurs. This makes these ecosystems even more sensitive than they would otherwise be because it just takes so long for regrowth to occur. More and more we are hearing from the climate scientists and forest professionals that the high elevation forests may not grow back. (12)

> "Bark beetle outbreaks driven by climate change may also result in trajectories beyond the historical resilience boundaries of some forest ecosystems, causing irreversible ecosystem regime shifts."

This quote is from a paper in the journal Bioscience in September 2010. What this quote refers to is the ecoregime change that I spoke of earlier. What happens in an ecoregime change is that an ecosystem, a forest in this instance, is replaced by a different ecosystem because the old one can no longer survive in the changed climate. The desertification of the Sahara in northern Africa because of climate change 5,000 years ago is a good example. A sea of shifting sand replaced what once were the Saharan grasslands, because of natural climate change. (13)

There may be scattered places where some whitebark are left, but functionally, the forest will no longer exist and a new forest, capable of surviving in a different environment will take its place, maybe.

But the weather will still be tremendously cold at high elevations, even though climate change has warmed it significantly, so regrowth will be slow. Typically, a lower elevation forest will regrow to maturity in 100 years. Higher elevation forest take much longer.

Another quote from Bentz and team; "Bark beetles are inextricably linked to their host trees, and will undoubtedly influence the formation of new western North American coniferous forests as predicted broad-scale tree migrations occur this century." This is a new world we have created where trees migrate. This is all great and fine and dandy, forests do move – they change over time. The definition of the time factor is important. Time to a tree, especially at high altitudes, is not like time to you and me. It will be 40 to 50 generations before any type of normalcy returns to the highest elevation forests. (14)

Beetle Life

Pine bark beetles are a natural part of our forests. They normally attack weak, diseased, or otherwise "stressed" trees. They help to naturally manage a forest by getting rid of undesirable trees.

The little beetles make their living by burrowing through the bark of a tree and eating the cambium layer. This is that special part of a tree, just beneath the bark, that moves nutrients and water up and down the tree from the roots to the leaves. There are over 200 different kinds of bark beetles in North America, of which a number of different species are wreaking havoc on forest across the West.

Once every thirty or fifty or more years, these beetles will arise and create their mass forest destruction across thousands of acres of forest. They help to cleanse a forest and open up areas to sunlight so new trees can grow.

Once an adult beetle has bored through the bark it lays its eggs in what are called galleries. When the eggs hatch, little beetle larvae eat out the cambium as they grow. When conditions are right, when there is enough stress in the forest, beetle numbers rise. This is what we are seeing today. Stress from drought and warming has allowed beetle numbers to increase so much that they have run out of sick and diseased trees to prey upon and are now attacking all but the most vigorously growing trees.

A tree's natural defense against bark beetles is to drown them in sap, or to "pitch" them out of their burrows in a flood of sticky goo. The beetle's counter is to attack the tree en-masse. Trees move sap around in their cambium layer. If there are enough beetles to severe the trees conductive tissues, it loses this defense mechanism and the beetles bore their galleries unmolested by the sticky goo.

The pitch tube is one of the harbingers of the beetle. It looks like a little tree sap volcano where the hole in the volcano is really the beetle's route through which it dumps the sawdust from its boring operations. Not all tree species have enough or the right kind of sap that for these sap tubes to be created though. The lodegople is one of the sappier trees involved, so they tend to have the largest number of pitch tubes.

Different trees have different beetles. Spruce trees are attacked by spruce beetles, fir by fir beetles, pinyon by pinyon beetles and so on. When conditions are really bad though, the beetles start attacking different trees.

One beetle in particular is wreaking the most havoc. This is the mountain pine beetle and it is the one responsible for 64 million acres of destruction in a little more than the last decade. This is the beetle, whose methods are so ferocious that 10,000 of them can attack a single tree.

They have been known to prey on two-dozen different kinds of pine, from Limberman to lodgepole, but before this current outbreak, only one type of tree was ever involved in any one attack. Six or seven years ago, when this current beetle outbreak increased beyond anything ever known, forest professionals were saying that it was unlikely that they would jump species. Back then this was a phenomenon of the lodgepole pine and the beetles were behaving similarly to previous outbreaks. The beetles had never changed host species in mid attack before, so it was assumed that this would not happen during the current outbreak.

The beetles involved in any one given outbreak had also never crossed the continental divide. It is just too cold up there for them to get a foothold in the high elevation forests. The continental divide is so high and creates such a formidable barrier to the little beetles that they had never before been able to cross while attacking.

Both of these things have changed though. The mountain pine beetle is now attacking lodgepole, limberman, ponderosa, whitebark, and bristlecone pines and there have even been reports of this pine beetle attacking spruce trees.

The beetles swarm individual trees in a coordinated mass attack. They release pheromones (natural beetle attractants) to bring in even more beetles. When the tree is full they release a different pheromone to tell the rest of the beetles to pick another tree. In historic infestations, entire

mountainsides would be killed. Today, entire forests and entire mountain ranges are being attacked and killed.

Healthy trees can repel the attack by pushing the boring beetles from their holes with sap. Mature trees are the main targets of the bark beetles because the younger trees rapid growth allows efficient production of sap.

It difficult to tell which trees have been attacked until the year after their death because the needles stay on the tree and stay green for quite some time - like a fresh cut Christmas tree. The year after the tree is killed it turns the characteristic bright red color. Then within another year or two, all of the needles fall off of the tree and it turns a desolate gray. Their skeletal remains fade back into the forests like the ghosts that they have become.

Under normal conditions, cold is virtually the only enemy of the pine beetle. To kill a mountain pine beetle specifically, temperatures must fall to minus 20 degrees Fahrenheit early in the season, or minus 40 in mid winter. Not only does it have to be so extremely cold, but these temperatures must remain this low for up to two weeks in a row to have any effect on the little bug. (15)

These temps were once common in winter in most of the higher regions of the North American Rockies, but not any longer. Even if we had a really cold winter there are so many beetles now that too few would be killed. It would then be just the matter of a few years until conditions ripe for the beetle population to explode again. But we just are not seeing this happen. The beetle population continues to expand rapidly. The public may perceive that it has been colder over the past several years, and indeed, in a few places it has been, and in many places it is certainly snowing a lot again, but extreme cold in the Rockies has vanished. (16)

The continued drought since the 1990s and steadily warming temperatures are mostly blamed for this outbreak. Like the disappearance of extreme cold, this is climate change in action. Scientists have been warning us about the increased occurrence of insect infestations on a warmer planet just as they have been warming us about the increased occurrence of drought. Forest professionals tell us that forest fire suppression has created a perfect nursery for the beetles because many of our forests are older and weaker now because we have kept them from burning.

Smoky Bear

Forest fires once raged across the land unimpeded. Fire fighting changed all of this. The creation of Smoky Bear by the U.S. Forest Service was the 20th century icon of manifest destiny in the American West. Forest fire suppression, for all the good it did, was directly responsible for the increased age of our forest, the increased density of trees in the forest and the increased amount of underbrush and small trees in addition to creating more stress because of older trees and crowding. All of these things tend to create a less healthy forest and one that is less capable of fending off the impacts of drought.

Pine beetle outbreaks have historically been linked to forest fire suppression for generations so naturally the thought process continues. But those thoughts all occurred on a planet with an unchanged climate. Because past experience are valid does not mean that that validity is as certain today.

Most forests are adapted to regular fires. Trees limbs are high and these regular fires sweep through the understory cleaning out dead logs and small competing trees. This limits competition and creates a healthy forest. It also reduces the chance that small trees will allow a ground fire to jump to the canopy completely destroying the forest. In a forest managed naturally by fire (or managed through man's efforts by fire), there are not too many trees, so crowding is not a problem. There is more moisture to go around in drought, more sunlight and more air circulation. When a forest is open and uncrowded it can stay healthier with less effort. Fire fighting changed all of this.

Even if fire suppression practices were entirely to blame for the recent unprecedented beetle outbreaks that have coincided with the greatest warming of our changed climate though, it does not necessarily mean that in the future, or tomorrow, that it will still be the same. We understand that ecosystem changes like these are not really unprecedented in prehistory. In geologic time frames they happen frequently and naturally. This kind of thinking however, has really never been a part of contemporary forest management. The great fires in the Yellowstone area in 1988 helped us to realize that fire suppression was maybe not such a good thing in all forests. Yellowstone burned in a large part because of crowding and increased amounts of smaller vegetation that allowed fires to jump to the canopy and run out of control. New knowledge, because of catastrophe, made us more aware.

We simply cannot afford to use old forest management wisdom as a guide for current behavior. Even though there is certainly wisdom in the analogy, our warmed and warming climate tells our greatest thinkers that we have transitioned out of our old stable world climate. The warming that has caused the great extent of this insectastrophe will grow to twice what we have seen, even if we were to cease emitting all green house gasses tomorrow morning.

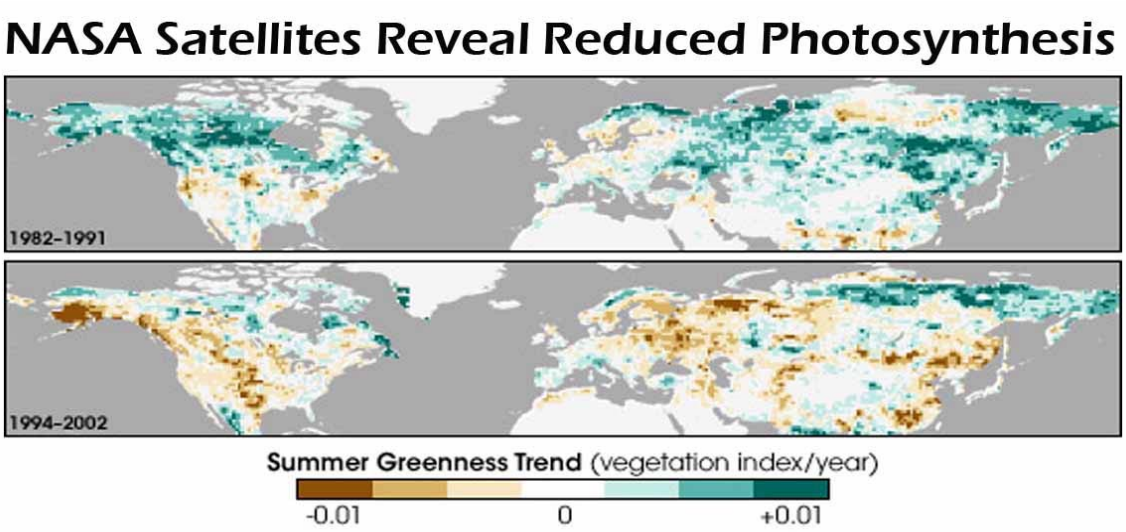
This beetle behavior is not like anything we know. The beetles are attacking all sorts of trees and crossing the continental divide. New thinking will be fundamental to our new world. We cannot fall into the trap of old world thinking. Too much is at risk.

NASA's Global Browning

Our new climate is becoming all too evident. A mega report by the U.S. Geological Survey, National Oceanic and Atmospheric Administration, National Science Foundation, U.S. Department of Agriculture, U.S. Forest Service, U.S. Department of Energy and the U.S. Environmental Protection Agency, tells us that it takes just a few degrees of temperature change to significantly impact and change ecosystems. (17)

The American West is warming at twice the rate of the average temperature across the globe. Warming so far has been about 2.5 degrees Fahrenheit. At high altitudes in the Rockies, the temperature is warming at faster than twice the average. This is a direct result of warmer temperatures melting more snow sooner each season. Impacts because of just this few degrees of change are becoming all too evident. (18)

The decline of Northern Hemisphere forest health has been observed on the ground, from satellites and in carbon sinks. Warming is blamed. NASA's Earth Observatory tells us that visible browning of our forests is an indicator of this health decline. As trees become less healthy, their leaves naturally brown and fall. As the canopy becomes less dense, we can see more branches and more of the forest floor beneath. This is all being shown in the satellite photos. At the same time, scientists looking at the sequestration ability of our forests have seen a marked decline in recent years at high elevations and high latitudes because the trees are not growing as quickly. (19)



Greeness Trend is photosynthetic activity. Trend is in percent per year, so -0.01 is equal to 10% per decade. Remember also that much of the high latitudes still showing increased photosynthetic activity are Arctic tundra, where no trees grow.
Source: NASA Earth Observatory, Satellites Reveal A Browning Forest
http://earthobservatory.nasa.gov/Features/BorealThreshold/boreal_threshold2.php

In addition, trees in forests across the American West are dieing twice as fast as they were 20 to 25 years ago. This finding from the U.S. Geological Service and the U.S. Forest Service shows that the most obvious beetle infestations, record outbreaks of forest disease, logging, land development practices, increasing population in the West and even forest preservation techniques are absolutely not to blame in this increasing rate of tree mortality. The paper, published in Geophysical Research Letters, says:

> "The rapid and pervasive increases in tree mortality rates in old forests of the western United States are notable for several reasons. First, increasing mortality rates could presage substantial changes in forest structure, composition, and function, and in some cases could be symptomatic of forests that are stressed and vulnerable to abrupt dieback".

The paper also found that, in contrast to tropical forests where warming and possible CO2 enrichment of the atmosphere have encouraged more reforestation that includes larger numbers of young trees and faster growth, northern forests are seeing fewer numbers of young trees, slower growth and smaller average diameter of trees in addition to the increased rate of mortality. (20)

Climate Changed, More to Come - Faster

The fundamental driver that has made these unprecedented events possible is warming. It is not just fleas and ticks and malaria infested mosquitoes that will be more numerous on a warmer planet. We humans as a species are increasing the carbon dioxide concentration of our atmosphere 14,000 times faster than the long-term average over the last 610 million years. The last time a similar change took place was 65 million years ago when a giant asteroid struck the Yucatan Peninsula and the dinosaurs went extinct. (21, 22)

We know that global warming has increased temperatures to as warm as or nearly as warm as any time in the last 1.35 million years and in some places the temperature has increased more than others. (23)

The Chair of the IPCC (Intergovernmental Panel on Climate Change), Rejandra Pachauri, in his report to the United Nations after the release of the 2007 IPCC Fourth Assessment Report, had this to say:

"… Much stronger trends in climate change [have occurred since we stopped taking papers for the 2007 report] … That means [we] better start with intervention much earlier." He said "If there's no action before 2012, that's too late. What we do in the next two to three years will determine our future. This is the defining moment." (24)

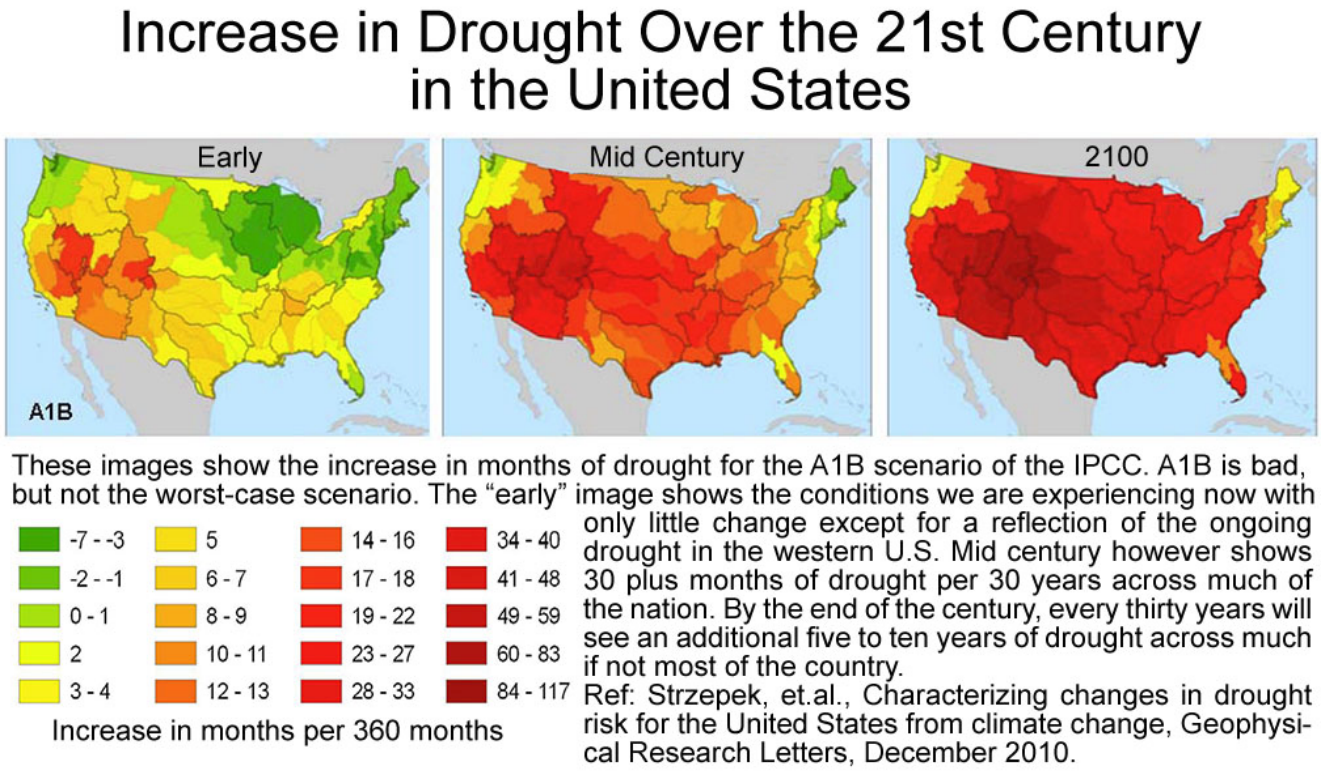
It is the changes in the Rockies that matter to the beetle however. The Rocky Mountain Climate Organization, a group of 17 government agencies, 17 business representatives, and 11 non-profit organizations, sponsored the mega report *Hotter and Drier – The West's Changed Climate*, compiling climate change science from the Rocky Mountain area of North America.

This report is a broad look at subcontinental scale climate changes already evident across the American West. It shows that since 1970, the average temperature in the West has increased 2.5 degrees Fahrenheit, far greater than the Earth's average and second in the U. S. only to Alaska. These are some of the findings of this mega-study:

- Snow pack has been less than average 60% to 90% of the time since 1950,
- Rain is falling 75% more of the time instead of snow,
- Since 1948 peak snowmelt has been arriving 30 days earlier in many cases,
- Since 1950 stream flow in the west has been decreasing by 2% per decade (this adds up to about a 10% total reduction) and,
- The most recent drought in the west that peaked in 2005 affected nearly 90% of the west and was one of the longest droughts in 105 years.

> *The study found that "measured increases in temperatures, decreases in snow pack, and earlier peak stream flows from 1950 to 1999 are more than 99 percent likely to be outside what could be expected through natural climate variations." (25)*

A new analysis of future drought in the United States was published in Geophysical Research Letters in December 2010. The models are getting more and more accurate as time runs on into the 21st century. What this model does is to calculate an increase in the number of months that the U.S. will see drought conditions.

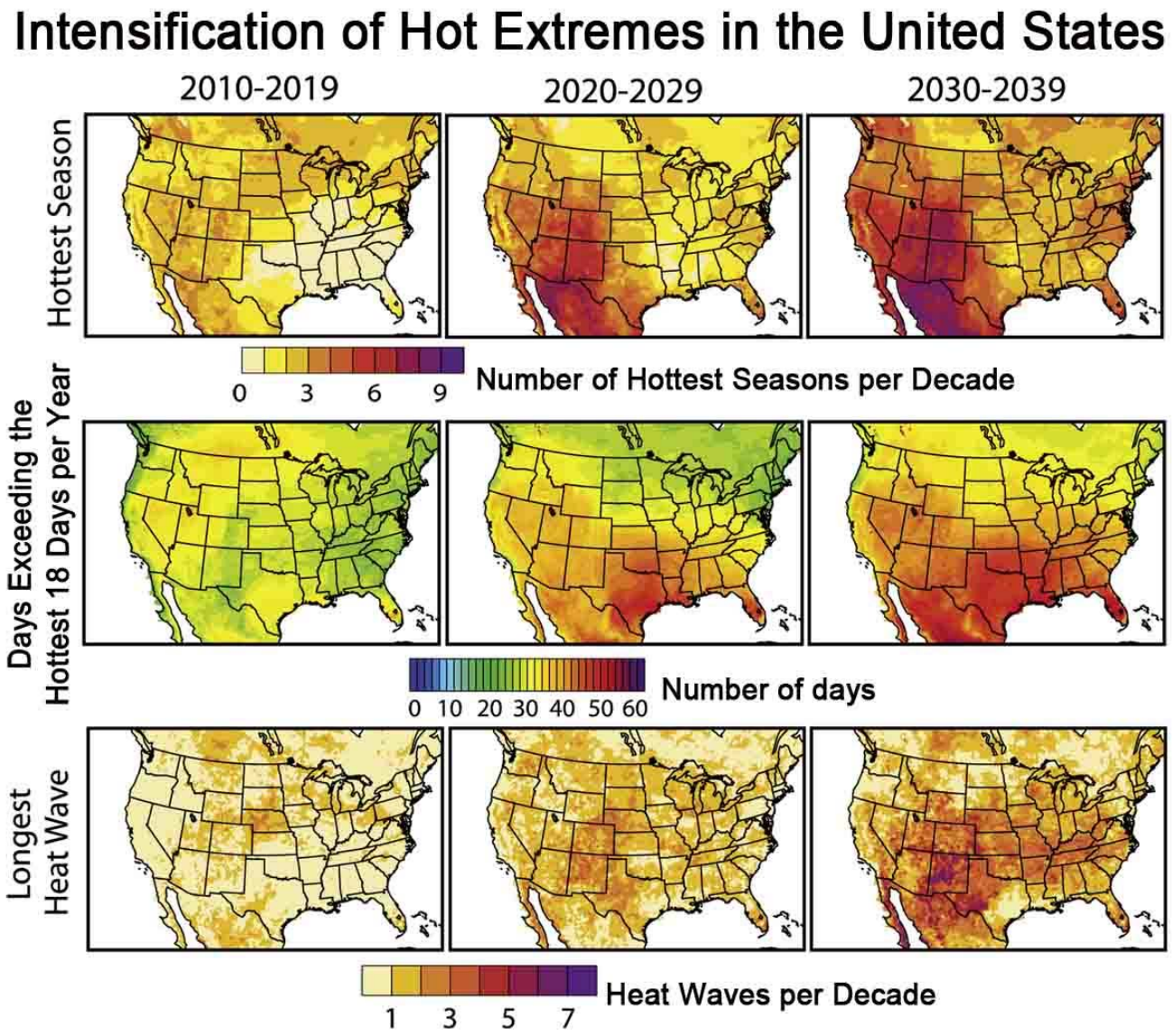


These images show the increase in months of drought for the A1B scenario of the IPCC. A1B is bad, but not the worst-case scenario. The "early" image shows the conditions we are experiencing now with only little change except for a reflection of the ongoing drought in the western U.S. Mid century however shows 30 plus months of drought per 30 years across much of the nation. By the end of the century, every thirty years will see an additional five to ten years of drought across much if not most of the country.
Ref: Strzepek, et.al., Characterizing changes in drought risk for the United States from climate change, Geophysical Research Letters, December 2010.

The authors say that by mid century, drought conditions (encountered during major droughts) will dramatically increase across the American West and large parts of the Midwest and South. For reference, over the last 100 years, Wyoming has spent about a third of its time in a major drought. By mid century that will increase by three or four years and by the end of the century nearly double. So when the minor droughts are taken into consideration, Wyoming will see very little time with normal rain and snow. Drought will be nearly continuous. (26, 27)

Future heat will be simply mind-boggling. The latest high-resolution climate supercomputer models show in searing detail just how hot it will become. What the science workers did, in *Intensification of hot extremes in the United States*, published in Geophysical Research Letters in July 2010, was identify the longest heat wave, the hottest summer season and the average number of extremely hot days per year over the last half of the 20th century. This period includes the drought of the 1950s (which in meteorological extent and severity was as extreme as the Dust Bowl) and it includes the

Super El Nino years of 1997 and 1998. They then ran two dozen climate models with their new extremely fine resolution programming off into the future. What they found is sobering. (28)



Source: Diffenbaugh and Ashfaq, Intensification of hot extremes in the United States, Geophysical Research Letters, 2010.

These two Stanford and Purdue researchers found a dramatic increase in extreme seasonal temperatures during the current decade, that is between 2010 and 2019. They say that temperatures equaling the hottest season on record for the last half of the 20th century could occur three to four times on average over large areas of the nation *before 2020* (just in the next ten years.)

Their results intensify over the 2020–2029 period, with hot extremes equaling the last half of the twentieth centuries hottest period eight times over the western U.S. and up to four times over much of the eastern United States, and 2030-2039, five to seven times.

What this likely means is that perpetual drought, due to extreme heat, will settle in much sooner than has been anticipated. But this diagnosis has to be taken with skepticism. Remember, this team used the AIB scenario in their models, a scenario that is worse than the middle of the road, but not as bad as the worst-case scenario. Climate scientists call the A1B scenario "moderate." Actual emissions today are increasing faster than the worst-case scenario. (29)

Based on their work, Diffenbaugh and Ashfaq tell us that dangerous global warming could occur before the commonly accepted 2 degrees C (3.6 degrees F) threshold is met. Their paper ends "...the response to a given GHG stabilization target is likely to be greater than to the equivalent concentrations within the [modeling] tested here. Although accurate decadal-scale climate prediction represents a significant challenge, the intensification of hot extremes reported here suggests that constraining global warming to 2 °C above pre-industrial conditions may not be sufficient to avoid dangerous climate change."

Feedback in the Rockies

The warming in the Rockies is greater at high elevations in exactly the same way that the Arctic is warming so much faster than the rest of our planet. This effect is called the albedo feedback. Albedo is Latin for whiteness and the "albedo feedback" works like this:

Snow and ice reflect up to 90 percent of the suns light harmless back into space. Vegetation, rock and water absorb up to 90 percent of sunlight and change it into infrared energy that warms non-snow covered surfaces and can then be mostly trapped in our atmosphere by the greenhouse effect. This difference in the amount of sunlight because of snow and ice covered surfaces results in up to nine times more heat being trapped by the greenhouse effect when snow and ice melts.

The albedo effect demonstrated about a mile inland on the Greenland Ice Sheet. These small holes are about as big around as a quarter and three to four inches deep. They were formed in an area where dust had accumulated in shallow depressions on the ice. The dust absorbs more sunlight than ice, warms more and melts more ice.

A little warming then, melts a little snow. A little more heat is captured because there is less snow and this creates more melt, which captures more heat in a feedback loop that continues until all of the snow and ice are gone.

Climate surprises like this bark beetle pandemic should rightly be scaring the public silly. The alarm is warranted. These changes happen fast, before the models predict, sometimes by as much as 100 years. One climate surprise has been the speed at which sea ice is melting in the Artic Ocean. Arctic sea ice is melting 40 to 70 years ahead of the worst-case scenario. (30)

More examples: Greenland's ice loss has trippled to quadrupled in the last 20 years. Antarctica was not supposed to be losing ice until at least 2100 according to the 2001 IPCC report. Today, Antarctica has not only started losing ice, but the loss down there has even caught up with Greenland. (31)

Werner Kurz and a team of scientists at the Canadian Forest Service have looked at another feedback involving trees and their ability to store CO2. These land based carbon sinks as they are known, are responsible for around half of the CO2 absorbed out of the atmosphere every year. The oceans soak up the other half. As a tree grows, it takes in CO2, changes it into wood through photosynthesis, and stores that CO2 beyond the reach of the greenhouse effect. When a tree dies that carbon is released back to the atmosphere as the wood decays.

These Canadian Forest Service researchers say that devastating beetle attack in British Columbian alone, ten times larger than anything recorded, has changed the forests there from carbon sinks to carbon sources. These forests will *emit* CO2, not absorb it as forests are supposed to do. In the worst year of emissions, these trees will emit nearly as much CO2 as is emitted annually from all of Canada's forest fires combined, or about a quarter of BC's annual fossil fuel emissions in 2007. (32)

A new study by the British Columbia Ministry of Forests paints a darker picture. The difference between the two studies is vitally important. The new study looked at the big picture whereas Kurz 2008 looked at forest recovery based on traditional forest regeneration dynamics. What this means is that Kurz' modeling was based on our climate in the 20th century. Dymond's work looked at our climate in the 21st century.

Kurz' model did not take into consideration continued warming that reduces future forest regrowth because of a hostile (overly warm) environment and increased forest fire's under warmer, drier conditions. The latest work looks at twelve different modeling scenarios and the average carbon emissions were eight times higher than Kurz had projected, or twice as much carbon emitted as from all of British Columbia's fossil fuel emissions in 2007. The new study showed that these emissions would continue every year for 70 years and at the end of 70 years, conditions had basically not improved over the preceding fifty years. (33)

What are the implications for the planet? The beetle has crossed the boreal forest boundary in Alberta. This means the jump to the largest forest ecosystem on Earth has begun. The global boreal forest stretches in a massive band around the top of the world. Its biosystem holds more than five times the carbon of temperature forests and nearly twice as much carbon as all tropical forests. The reason is that soils in the north are thick and full of carbon. The cold climate helps preserve the carbon that drops to the forest floor or as peat or in frozen storage as permafrost.

When a forest in the north dies, the carbon at risk is not just from the decaying wood. More carbon is actually in the northern soils, peat and permafrost. When the forest dies, two things happen. The first is that the forest rain machine decreases. This dries forest soils (another feedback loop.) Drier soils emit more of their stored carbon (from organic material decay) back into the air. The lack of a forest canopy then allows the forest floor to warm. Warming also causes more of soil carbon to be released, but the drier conditions also lowers the water table. Much of Canada's soil carbon is in "wet" peat below the water table. Once this wet peat dries, it too increases its carbon emissions.

Melted permafrost, Fairbanks, Alaska. When permafrost melts, what is often left behind is a shallow lake full of dead trees. The lake usually drains off leaving a dry depression with thousands of years of dry, partially decomposed organic material emitting CO2 to the atmosphere.

Then there is permafrost. Somewhere around half of the boreal forests of the world are underlain by permafrost that can be hundreds and even thousands of feet thick. Losing the forest cover warms the soil and melts the permafrost, releasing more carbon back into the environment. Permafrost stores an immense amount of carbon that has been stable in its frozen state for tens of thousands and possibly

even hundreds of thousands of years considering deep permafrost. Once the melting starts, on a warmer planet it is an irreversible process.

All total, more than twice the carbon emitted by man over the last 200 years is at risk in the boreal forest and its soils. The processes that release this carbon: beetle kill, warming, soil drying, increased fires and permafrost melt have already begun. (34)

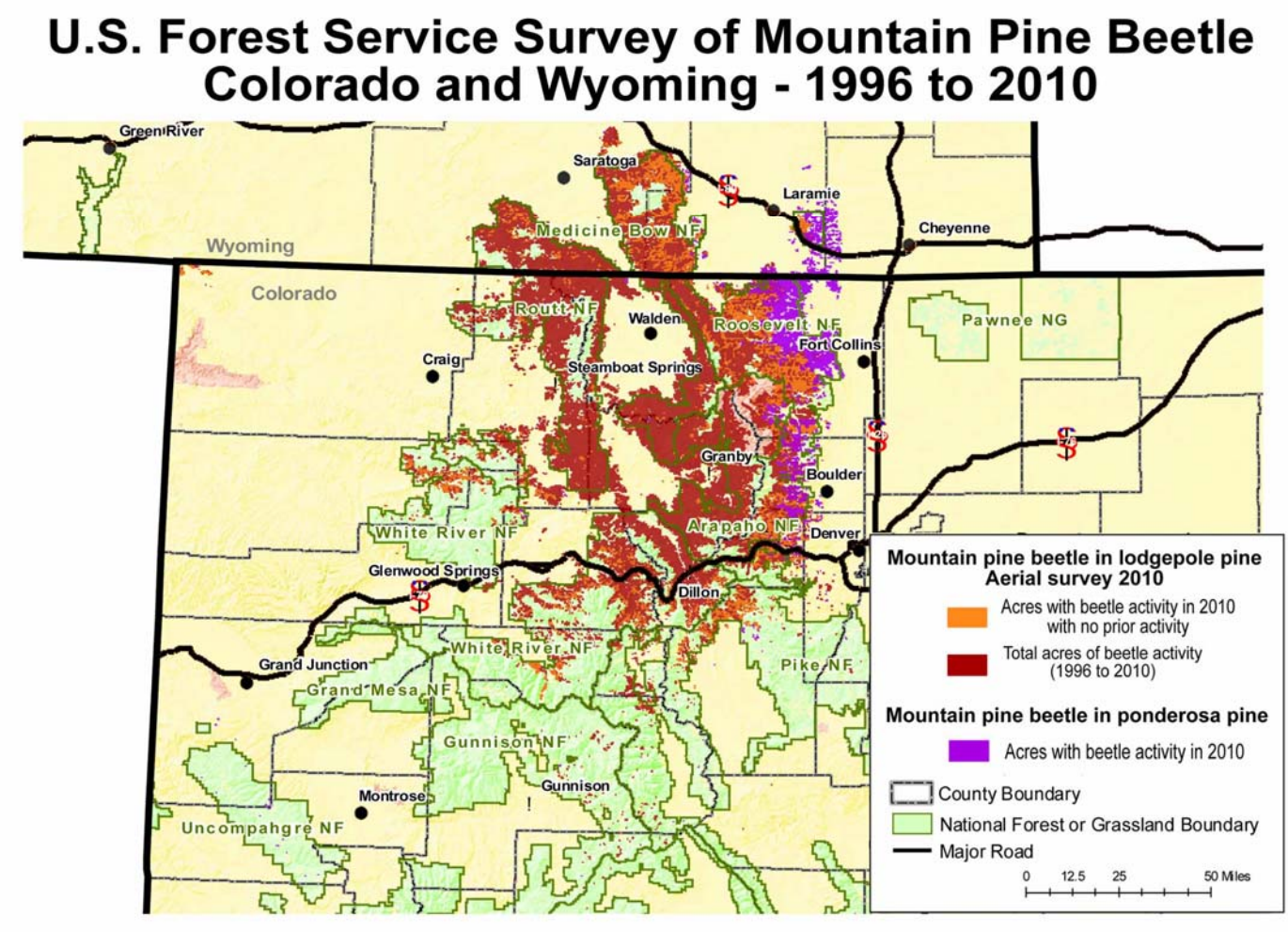
All the Trees are Red

In three to five years, by the year 2013, The National Forest Service says that all of the mature lodgepole pine forests in the American Rockies will be dead. This includes about 11% of the forest of the U.S. Rockies. Bark beetle outbreaks of this size have never happened before – at least not during normal climactic periods. We are now entering a period of change that the scientists have been talking about since the 1980s. Long term drought and warmer winter temperatures have created an environment where the beetles can reproduce explosively.

The above photos were taken in Rocky Mountain national park, of the same camspite in Timber Ridge Campground. It once took two years at the highest elevations, for beetles to reproduce. In some places today we are seeing two broods of beetles per year – a four times increase in beetle reproduction. The Canadian Forest Service calls it the largest known beetle infestation in North American history.

In Colorado and Wyoming the toll is staggering. Four million acres have been heavily attacked and mortality is high. The Forest Service says "The bark beetle continues to spread rapidly along the Front Range and into ponderosa pine trees." There were very few who thought that the bark beetles would even cross the Continental Divide, yet alone attack entire forests, but this has now occurred. In just two years much of the forest north of Denver and east of the front range is now red. (35)

The visual spectacle is startling. Entire ranges of mountains are red with dead trees. This is nothing like the last major outbreak in the 1970s where single mountainsides were infested. The vast majority of the forested areas in northern Colorado have been attacked, or will be in just a few years. Most of the trees in these areas are lodgepole pines. At the least, the forests will be changed for generations.



This graphic shows the tremendous extent of beetle kill in Colorado and Wyoming. The most important thing to understand in this area is that almost all of the forests here are contained within national forest boundaries. The areas in yellow are almost exclusively not forested and are made of plains or drylands covered with sparse grass and scrubby plants (sagebrush.)

In Grand Lake at the west entrance to Rocky Mountain National Park (right), the scene is worse than that presented by the fires in Yellowstone in 1988. Almost all of the trees are dead. Timber Creek Campground has been completely clearcut because of falling tree hazards. What the forest professionals call "red kill" extends all the way up to treeline.

On the east side of the park, what was completely green in 2008 now looks like a war zone covered with bloody trees. Glacier Basin Campground has been 80 to 90 percent clearcut. The third major campground here, Moraine Park, is now under attack.

Park service employees have been spraying the trees in campgrounds and other critical areas since 2007, but they say that "the scale of the epidemic is enormous" and it is not possible to protect all of the trees. Even with the spraying, the clearcutting of campgrounds continues.

In Colorado the beetle has heavily impacted Vail, Winter Park, Georgetown, Silverthorne, Hayden, Grand Lake, Breckenridge, Walcott, Walden, Frasier and into Wyoming in the Snowy Range and as far west as Steamboat Springs, Craig and Hamilton.

In the Pipeline

The momentum of our Earth's systems are truly planetary in size. Even if we were to cease the emissions of all manmade greenhouse gases this instant, we would continue to warm because of our past greenhouse gas emissions. This warming would actually double the current warming we have already seen. (36)

The Alaska Pipeline

Climate momentum comes from many different places and things like the albedo feedback that feeds upon itself until all of the ice is gone. But the greatest momentum comes from the heat capacity of our oceans. The top ten feet of our oceans can hold the same amount of heat as can our entire atmosphere. (37)

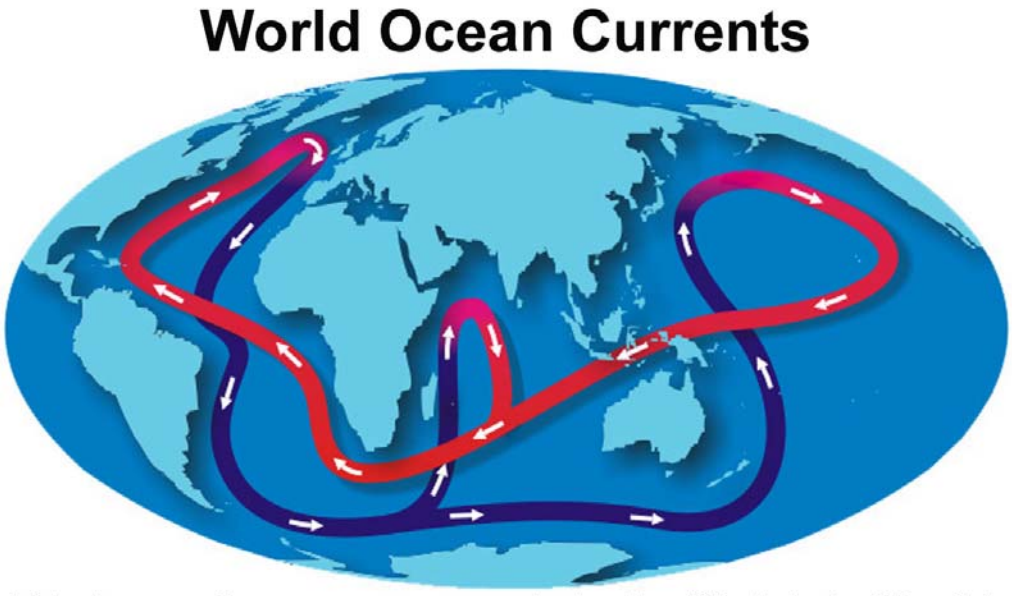
What this means is that our oceans act like a giant refrigerator, cooling the planet as it warms. Anyone ever visiting the beach or the lake during on a hot summer day knows the cooling influence of such large amounts of water. Once the beach is in sight, or once you can smell the salt water, the temperature begins to fall. It can often be ten degrees cooler on the beach than inland. It is all because water can absorb so much more heat than air.

Ocean currents also control the amount of heat stored by the oceans. Cold at the poles makes a lot of ocean water really cold at the surface. This cold water is much heavier than warm water and it sinks. This sinking water pulls in warmer water from warmer areas away from the poles, which along with

the wind, creates ocean currents. The cold polar waters sink to the bottom of the sea which moves other ocean waters across the planet.

These ocean currents are global in extent. They are all connected to some extent and all behave similarly. The great momentum of the ocean refrigerator comes from this cold polar water sinking to the bottom of the sea. The currents it creates drive the inertia of the ocean heat engine. It takes 1,000 years (plus or minus a few centuries) for the waters of our ocean to turn over, or circulate once around the tank.

This momentum creates what is known as our climate lag. This "lag" is the time it takes our climate to come into equilibrium, or for the heat to mix thoroughly with the oceans. Think of heat as red Kool-Aid as it is being mixed into a tall pitcher of water. It takes time for the Kool-Aid to mix with the water depending on how fast the water is being stirred. Dump the Koolaid in to the water before stirring and it's easy to see how mixing affects heat content. Slow mixing means slow heat uptake. The standard climate "lag" is viewed as about 30 years for more than half of warming to be realized. In other words, the cooling effect of the oceans hides warming caused by increases in greenhouse gases. (38)



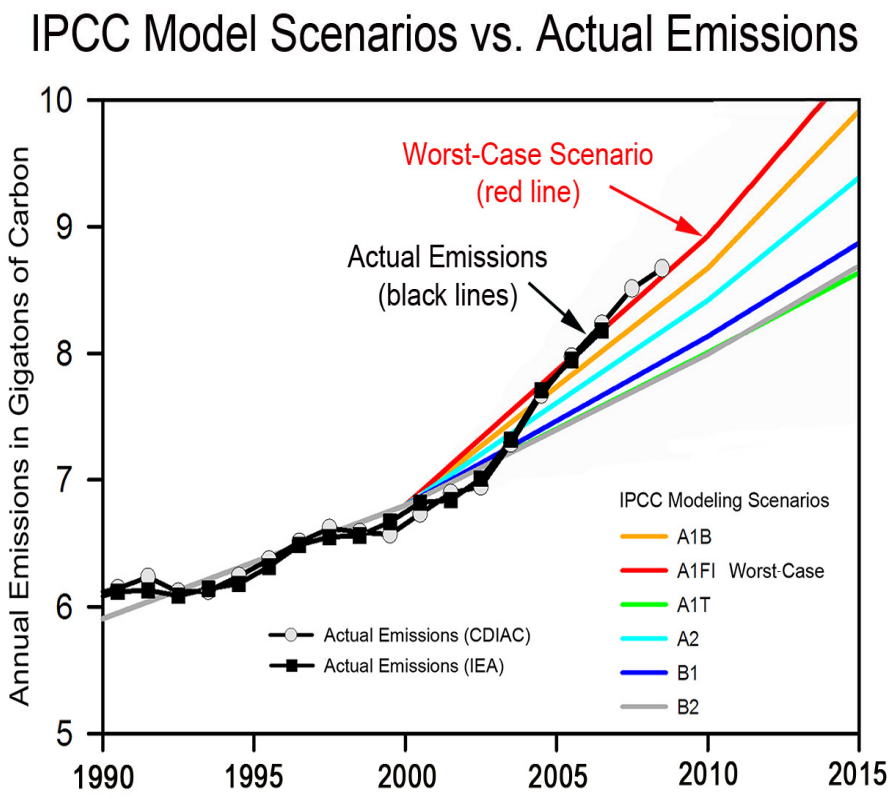
This image of our oceans currents is simplified, but still valid. Cold sinking polar waters (blue) drive the warm surface currents (red). It can take 1,000 years to complete the loop. Source: NOAA

So we have a lot of CO2 emissions happening right now because of man. Emissions are so great that we are increasing the CO2 concentration of our atmosphere 14,000 times faster than the "natural cycles" for any time in the last 610 million years. This 610 million year ago milestone is an extremely important piece of information to comprehend when understanding the shape and size of this climate experiment that we are performing on our planet.

What happened 610 million years ago was that plants became firmly colonized on land. Before this time land was not green, there was only dirt and rocks on land. There were no plants except in the oceans (or wet places…). Before this time the concentration of oxygen in our atmosphere was only about two percent instead of eighteen percent as we have today.

Earth was a dirt ball with very little oxygen, kinda-like Mars or Venus only with more water. Then plants colonized land and everything was different. Today, mankind is changing the atmospheric concentration of carbon dioxide on this planet faster than anytime since plants colonized land. (39)

But what happens when we are adding greenhouse gases to our atmosphere faster than the worst-case scenario. We don't know yet, because nobody has modeled a worse than worst-case scenario yet. We do know that we are emitting CO2 faster than the worst-case scenario. (40)



Observed global fossil-fuel and industrial CO2 emissions compared with averages of 6 scenario groups from the IPCC Special Report on Emissions Scenarios (colored lines). The Carbon Dioxide Information and Analysis Center (CDIAC) and the International Energy Agency provided the current observations of CO2 emissions. The latest update was obtained from www.globalcarbonproject.org.

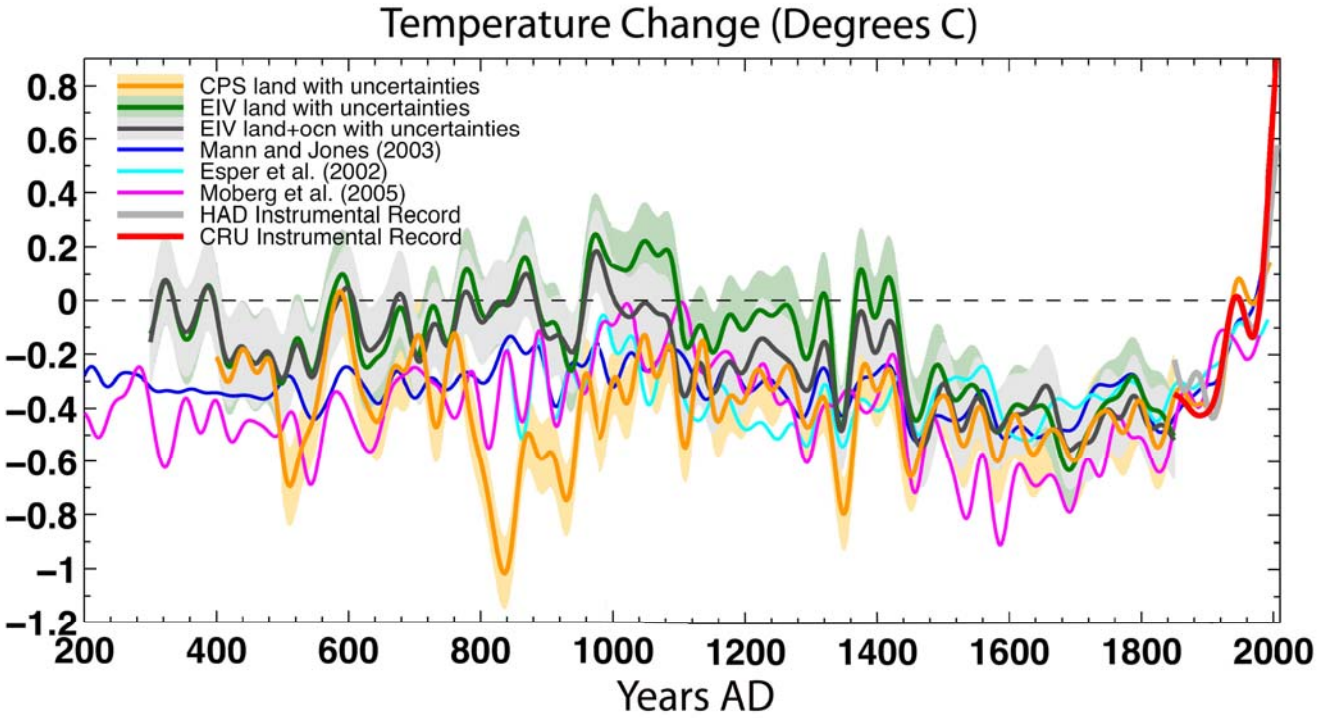
Source: Synthesis Report, Climate Change, Global Risks, Challenges and Decisions, Climate Change Congress, International Alliance of Research Universities, University of Copenhagen, March 2009. Raupach and Canadell, Carbon and the Anthropocene, Current Opinion in Environmental Sustainability, August 2010

We also know what would happen if we were to become successful with ambitious emissions reductions. An article appearing in the Proceedings of the National Academy of Sciences of the United States of America, produced by an international team and edited by a climate scientist from Stanford, has modeled what would happen to our climate under fifteen different mitigation scenarios and 19 different modeling simulations. What they found was that in the best case, global average temperature increased by five degrees by the end of the century. So a doubling of warming in the pipeline may be too conservative. (41)

What we have to consider in understanding the validity of the assumption of the continued existence of forests in the Rockies, that are similar to the forest that have been present throughout the evolution of mankind's complicated society follows:

- The global average temperature will increase about four times greater than the warming we have seen that has caused the increased insect infestation and disease,
- Warming is greater in high altitude mountains, and
- We are currently emitting greenhouse gases faster than the worst-case scenario.

What is beginning to become commonplace in the academic world of climate science is the realization that we could likely have already passed the threshold of dangerous climate change. This is not to say that we could not return from beyond the threshold, only that there is a growing body of science that understands that business as usual has already committed us to great danger in the coming decades, as the climate lag catches up with greenhouse gas concentrations already emitted.



Mann, et. al, Proxy based reconstructions of hemispheric and global surface temperature variations over the past two millenia, Proceedings of the National Academy of Science of the United States of America, September 2008.

In the 1990s, the dangerous threshold level of CO2 was understood to be about 550 parts per million (ppm) or about 0.05 percent. Our concentration today is 389 ppm. After the release of the IPCC Third Assessment Report in 2001, the consensus position was reduced to 450 ppm where it remained through the 2007 IPCC Fourth Assessment Report. But a lot of science has happened in the 21st century.

The IPCC stopped taking papers for their 2007 report in 2005. Since 2005, the growing consensus is that a maximum atmospheric concentration of 350 parts per million CO2 is as high as we dare let it go in order to prevent dangerous climate change. Yes this is lower than today's current CO2 concentration. But this new 350 number is well based in the journals.

The most recent writing on the subject though, continues the trend. The latest paper comes from the University of California, Santa Barbara. This paper soundly supports the 350 target for CO2 with copious references of the decline of the "safe" carbon dioxide limits in our atmosphere over the last two decades. Only, like all research these days, this research goes a little further. Science does not sit still. The U.C. Santa Barbara scientists looked at all greenhouse gases, not just carbon dioxide.

So it should come as no surprise to understand that the current "safe" limit of CO2 in our sky is lower than 350 parts per million. The new number is 350 ppm CO2e. The small case "e" is the difference. What this means is CO2 equivalent. There are more greenhouse gases in our skies than just carbon dioxide. Methane, nitrous oxide and ozone are a few of the more common ones. These gases all trap heat. Until now, the lower target of 350 ppm was a target for CO2. The small case "e" in this research from U.C. Santa Barbara means that if all of the other greenhouse gases were converted to CO2, we could measure one simple thing and be done with it. When the math is done, 350 ppm CO2e is about the same as between 300 and 315 ppm CO2. (42)

Unknown Unknowns

Back in the day, way back in the day, we were a migratory species. If our forest died back then, we moved. Then we discovered, and some say that the discovery was prompted by climate change, our ability to cultivate food crops and domesticate animals. We immediately kicked back and ceased that strenuous nomadic lifestyle. Ever since, our climate has been stable and our forests have not changed.

Humans as a species have experienced plenty of beetle kills and catastrophic fires, but no ecosystem replacements caused by abrupt climate change in time frames that matter. In our past – the one that matters - the recent past where we are dependent on our forests as they are today, we have never experienced this sort of thing. We literally do not know what to expect.

Grand Tetons and Cottonwood Creek

We understand that abrupt climate changes in the past have completely wiped out subcontinental regions of forest and replaced them with some entirely different ecosystems. We know that they life forms that existed in those areas were replaced with other life forms. In other words, we know that deciduous forests replaced pine forests and grasslands replaced deciduous forests and that deserts replaced grasslands. We know that these replacements happened where temperatures changed as little as is being predicted by climate models for the next several decades to generations. But we do not know this information in context with our well-developed human society.

Water availability is dramatically cut in the Rocky Mountains on a warmer planet. We know that river flows will drop far below anything that we have experienced in the most extreme drought o0f the 20th century, and we know that our current civilization has evolved with the current amount of water availability in the American West. But we do not know how we will adapt to a drastically reduced water supply.

Our sphere of understanding, as a society, not as scientists, does not contain knowledge necessary to give us guidance on how we should make decisions based on our knowledge of past ecosystem changes. But more importantly: our knowledge as a society by and far, does not include an understanding of how ecosystems behave under changed climatic conditions. It is this unknown knowledge, the knowledge that society (not scientists) does not have about ecosystem and climate that could get us into trouble.

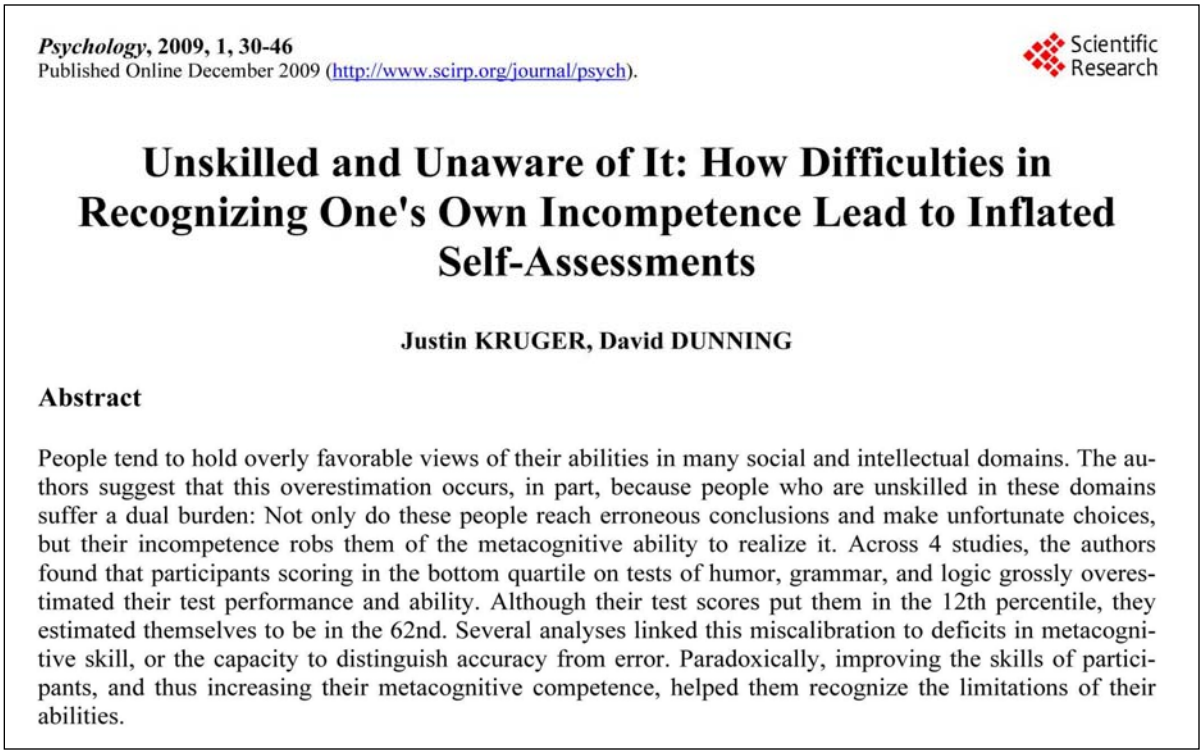
Forest professionals have a very complete understanding of the way forests react to fires, beetle kill, and to droughts of the 20th century. But foresters are not climate scientists. The foresters say that the forests will recover from the beetle kill in a hundred years. Sometimes they say that this recovery is dependent on future climate changes, but that is as far as they go. The say nothing about what happened to these forests in the prehistoric past when temperature changes as large as today are predicted to happen. Their knowledge is incomplete as is ours as a society.

Our ability to make decisions is based on our shared knowledge. If we are not successfully sharing this knowledge, our ability to make decisions is impaired. We as a society are not smart enough to consider that a completely different outcome could come from this current pandemic because we (not scientists) as a society generally know little about prehistoric ecosystems.

So we continue to prognosticate by looking backwards into the near past. This is generally a prudent thing to do, paying attention to history has never been a bad idea. But in this case, maybe we should be looking quite a bit further back. Just because our forests have always grown back in the past, after any and all cataclysms even after being blown off the earth by a volcanic eruption, does not mean that in our current future, the one with a changed climate, those forests will grow back.

What we are dealing with are unknown unknowns. We do not know enough about climate change (we as a society, not we as scientists) to understand that our knowledge is imperfect. We are blissfully and innocently ignorant.

This psychological trait is described all too painfully by what is known as the Kruger-Dunning Effect, after the two behavioral scientists who popularized the phenomena in a paper in 1999 titled "Unskilled and Unaware of it: How Difficulties in Recognizing One's Own Incompetence Lead to Inflated Self-Assessments." (43)



Psychology, 2009, 1, 30-46
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Scientific Research

Unskilled and Unaware of It: How Difficulties in Recognizing One's Own Incompetence Lead to Inflated Self-Assessments

Justin KRUGER, David DUNNING

Abstract

People tend to hold overly favorable views of their abilities in many social and intellectual domains. The authors suggest that this overestimation occurs, in part, because people who are unskilled in these domains suffer a dual burden: Not only do these people reach erroneous conclusions and make unfortunate choices, but their incompetence robs them of the metacognitive ability to realize it. Across 4 studies, the authors found that participants scoring in the bottom quartile on tests of humor, grammar, and logic grossly overestimated their test performance and ability. Although their test scores put them in the 12th percentile, they estimated themselves to be in the 62nd. Several analyses linked this miscalibration to deficits in metacognitive skill, or the capacity to distinguish accuracy from error. Paradoxically, improving the skills of participants, and thus increasing their metacognitive competence, helped them recognize the limitations of their abilities.

Kruger and Dunning make obvious the simple fact that, without accurate knowledge, the decisions we make can be entirely wrong.

The U.S. Forest Service Incident Commander for the Rocky Mountain Region Pine Beetle Outbreak is Cal Wettsein. In an interview with the Billings Gazette in Montana, Wettstien said "This is a funny way to end my Forest Service career, dealing with millions of acres of dead trees," Wettstein holds true to 20th century forestry knowledge when he says that, in the long term, the forests will return. He said. "Our forests will look different, sure, but there will be trees. Forests are resilient and always come back." (44)

The Forest Service continues to say - in a hundred years the forest will again be mature. There position could be correct, but the die-off we are seeing today that is so frighteningly large, has been caused by only a relatively small portion of the warming that would come even if we were to completely stop emitting all greenhouse gases this instant. As the U.C. Santa Barbara researchers have told us, the best-case scenario is now somewhere around five degrees of warming if we immediately begin to aggressively reduce carbon emissions.

This "aggressive action" however, is fairly certain not to begin immediately. If the track record over the last two decades (since Kyoto in 1991) is any sign of future progress, it will be some time yet before we even begin to stabilize our greenhouse gas emissions, much less aggressively begin to reduce them.

It is now all too apparent that just a few degrees of change are all it takes to push an ecosystem over the edge. We have no record of any kind showing an outbreak of this severity has ever taken place before, but we can infer from ecosystem shifts in the prehistoric past that abrupt climate changes have caused this kind of ecosystem destruction before on a much larger scale.

Beetles are Rewriting the Textbooks

"Some research has found virtually no regeneration of the boreal forests in eastern Canada following wildfires over the past 900 years, with a commensurate decline in forest cover. These findings are contrary to the "widespread belief of northward expansion of forests due to recent warming." This quote comes from a paper published in the Philosophical Transactions of the Royal Society by a team from the University of Quebec.

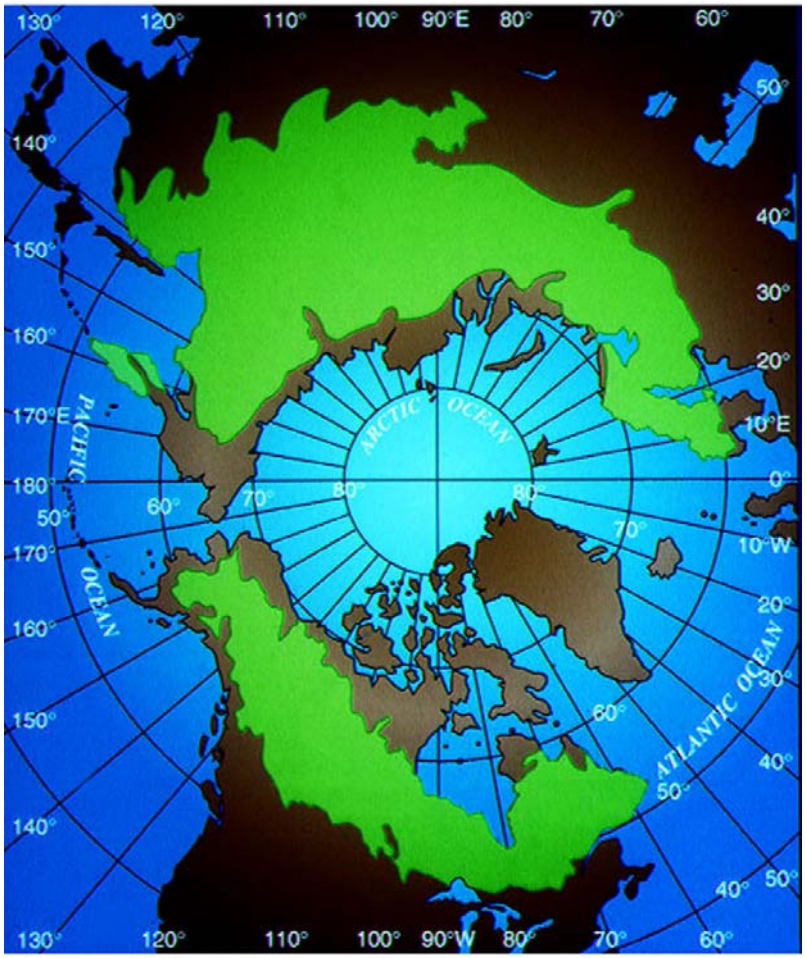
Steamboat Lake, Colorado

These research workers looked at boreal forest regeneration after fire over the last 2,000 years. What they found was that between 1,000 and 2,000 years ago, forests in the north regenerated according to accepted forest beliefs about fire and regrowth. But starting about 1,000 years ago, climate conditions changed so that little regeneration has occurred after fire since.

"Contrary to widespread belief of northward boreal forest expansion due to recent warming, lack of post-fire recovery during the last centuries, in comparison with active tree regeneration more than 1,000 years ago, indicates that the current climate does not favor such expansion." In other words, climate change has created a hostile environment a where the boreal forest cannot survive. This hostile environment is counterintuitive to the traditional understanding of hostile though, and this is what these researchers are trying to point out. (45)

Even if the ecosystem climate warms, it can be hostile to life forms that have evolved in the cold. They do not have the traits necessary to survive in the warm conditions. The pine beetle pandemic is an excellent example. Pine beetles are controlled by extreme cold. Remove the extreme cold and the beetle numbers increase to where entire forests can be killed. The influence of warming is so great that the beetle begins to attack trees in areas that it has never before been seen, in the highest altitude or most northern latitude forests where it has always been too cold for the beetle.

In 2006, updraft winds in a thunderstorm picked up billions of beetles from the massive attack in British Columbia and blew them over the Continental Divide to the East into Northern Alberta. The beetle has never before been seen in this far northern forest. Residents in northern Alberta said that the beetle fell like rain. This is just another example of the beetle going where it has never gone before, but this example is doubly concerning because of the forest here.



Boreal Forest (from the Boreas Project)

Northern Alberta is a transition area from the Rocky Mountain forests and northern temperate forests region to the vast boreal forest of the north. The boreal woods are dominated by jack pine in North America. This tree is particularly susceptible to the pine beetle because it has not developed the pitching defense where the beetle is drowned or forced out of its bore by excessive sap production. (46)

In many ways the high altitude forests of the Rockies are similar to the boreal forest. They share traits of relatively few species, a tendency towards monoculture where one tree species dominates a forest, and a short growing season. Climate change impacts are also similar in that warming is compounded by the "albedo effect" where snow and ice melt and create more warmth in a

continuing feedback loop. Warming in the high Rockies is similar to the boreal forest in that it is double or more the global average.

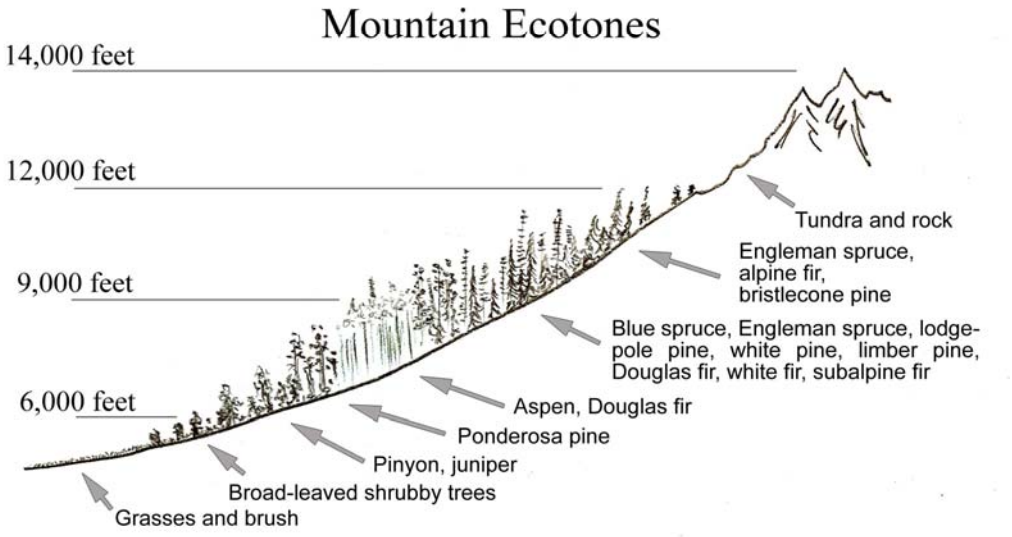
These things could certainly allow the forests of the Rockies to behave similarly to those of the far north. This fact that is spelled out in discussions of the application for endangerment for the white bark pine. It takes a thousand years for these slow growing trees to regrow after a cataclysm, ten times greater than the traditional 100-year time span for regrowth of a forest.

The textbook rewrite continues: Young trees are being attacked and even spruce trees are falling victim. The Mountain pine beetle is a pine bark beetle. Pine bark beetles just don't eat spruce trees. But now, there are so many bugs that their favorite food - the older, less healthy pines - are no longer enough. It remains to be seen whether or not the beetles will continue to prey on these traditionally non-targeted trees. There are also so many beetles now that they are attacking young and healthy trees successfully. Even these healthy trees cannot produce enough sap to push all of the beetles out of their boreholes: there are just too many beetles.

Beetle infestations are occurring further north and at higher elevations than have ever been seen before. Northern British Columbia has seen its first outbreak ever of mountain pine beetle in the last few years. Longer growing seasons, because of a warming climate, are allowing beetles to complete their life cycle in one year instead of two or more as is common in areas of the northern Rockies. This has caused a proportional increase in the number of beetles involved in the current outbreak.

Beetles have now been found in Canada on the western side of the Rockies. Because of the high altitude and low temperatures high in the Rockies, mountain pine beetles have been unknown west of the Rockies until recent warming has allowed the beetles to survive winters at high altitude and naturally spread to the east.

There is another thing that impacts a forest's ability to survive that is compounded by mountainous terrain. As one climbs in altitude, temperature decreases. It does not take too many trips driving over a mountain pass to know that when you get to the top and get out to look around, it is a lot



colder than down below. This is called the adiabatic rate and it is equal to about three degrees for every thousand vertical feet. So if one travels 4,000 feet up a mountain in Colorado, from about 7,000 feet where the trees begin to 11,000 feet at treeline, the temperature, on average, will fall 12 degrees.

This changing local climate can easily be seen by looking at the different forests that grow alongside the road as we drive up to the top of a theoretical pass in the mountains. Coming up out of the valley, at 7,000 feet, there are few or no trees except along water courses (it is too hot and dry) but just a minute more up the road and suddenly we are in a pinyon and juniper forest of scrubby trees mixed with grasses and brush.

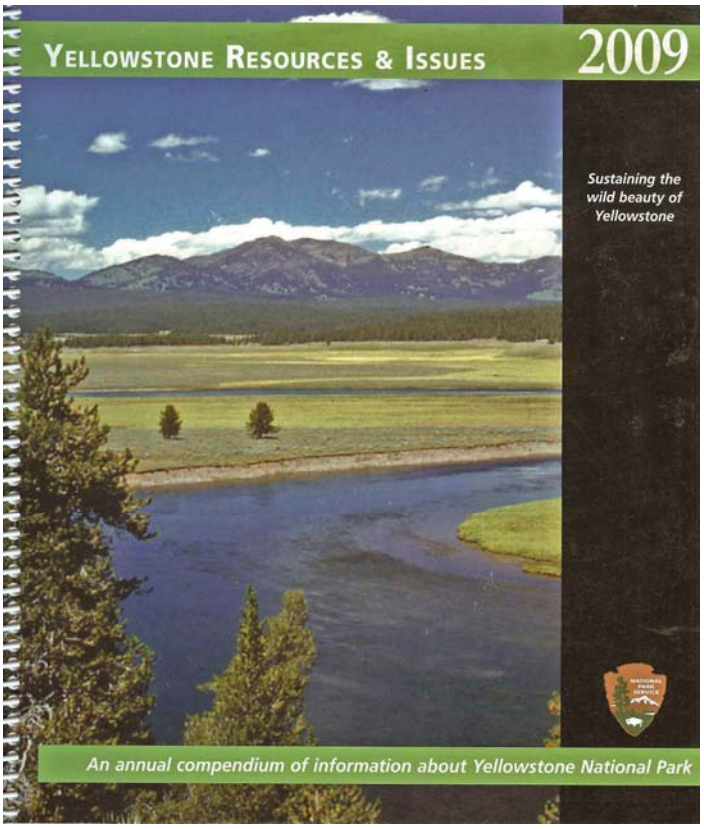
These mountains in the southern Sawatch Range of central and south central Colorado have not been hit by the beetle yet, but the battle front is only about fifty miles north. What this photo shows is two treelines. One close to the top of these 14,000 foot peaks, where wind and cold are too extreme for trees, and the lower treeline, below which it is too dry for trees.

After two more minutes driving up the mountain we begin to see ponderosa pine. The ponderosa often forms a continuous belt of trees – the first tall trees we encounter.

Another three or four minutes up the road and we are at 9,000 feet and deep within the aspen and fir forest. At 10,000 feet we see blue spruce and lodgepole pine. At 11,000 feet it is Englemann spruce and alpine fir. Then, as we near the pass, the forest abruptly ends at treeline. The climate above here is too hostile for any trees because of cold temperatures, hurricane force winds and rocks, rocks, rocks.

It is clear that different forests prefer different climates, or different altitudes where different temperatures and moisture levels exist. The demarcation of each forest zone is not in reality as clear as I have described. sometimes there are more types of trees than I have listed. For example, on the dry southern side of a mountain at 9,000 feet a ponderosa forest may exist but on the cool, wet northern

side, sheltered from the sun's drying effects, blue spruce, aspen and lodgepole pine may flourish at the same elevation.



What climate change does is it shifts these different forest zones up the mountain as climate warms. The local climate where a forest exists today becomes hostile to that forest if the local climate changes by more than a few degrees. This is what has happened with the browning of the boreal forest in Canada. Since the turn of the 20th century the average temperature has been warming. It has warmed just a few degrees, but this is enough, in the eyes of NASA, to cause the forest to brown.

The Yellowstone Ranger's Reference Manual "Yellowstone Resources and Issues" says that climate change in the Rockies could be as much as 13 degrees F and more at higher altitudes. What this will do to the forests of the Rockies is shift their habitable niche up the mountain to follow that ideal temperature and moisture zone that the trees evolved with. The warmer local climate will be hostile to the trees that once grew there and the existing forests will not be able to regenerate. The lower elevation forests will have to climb – migrate as the foresters call it - to higher elevations to find suitable place to live.

Now, let's go back to the adiabatic rate: 13 degrees of warming is about 4,000 feet of elevation. This means that the pinyon and juniper forest at 7,000 feet will need to shift up to 11,000 feet to enjoy the same local climate as where they originally evolved. What then will happen to the forests and those forest zones at higher elevations? At first, regeneration may begin to take place for some trees at higher elevations. But saying that trees migrate slowly is an overstatement. This is why, in the prehistoric past, we have seen ecosystems disappear. Abrupt climate jumps move suitable environments away from existing populations of life forms faster than they can migrate.

Fraser Experimental Forest, Fraser, Colorado. The average annual temperature here is 33 degrees Fahrenheit.

To make it crystal clear just how significant 13 degrees of temperature change will be to an existing forest, the average temperature at headquarters in Big Bend National Park, in the middle of the Chihuahuan desert is about 49 degrees. The average temperature in the Fraser Experimental Forest in Colorado is 33 degrees. When we take into consideration that all of the experts agree that warming will be higher at higher altitudes, the implications become sobering. (47)

Chihuahuan Desert and Chisos Mountains, Big Bend National Park. The Average annual temperature here is 49 degrees.

The forest zones, or ecotones as they are called, will shift dramatically, pushing the plants and animals that evolved in those ecotones further and further up the mountain. Some will be able to move fast enough, but some will not. For some life forms, like trees, it takes centuries for this kind of forest migration to happen.

A recent paper from Switzerland, published in *Global Change Biology*, has carried out the greatest modeling effort yet on this topic. The authors looked at most of the mountains in Europe in a very fine scale, high-resolution computer model that can predict the survival and regeneration of forest life.

What they found was that the worst case IPCC scenario saw, on average, 50 percent to 80 percent of forest life forms losing suitable habitat. Some plants and animals will be just fine with this kind of fragmentation in their homes, but others will not. They will die-off and disappear.

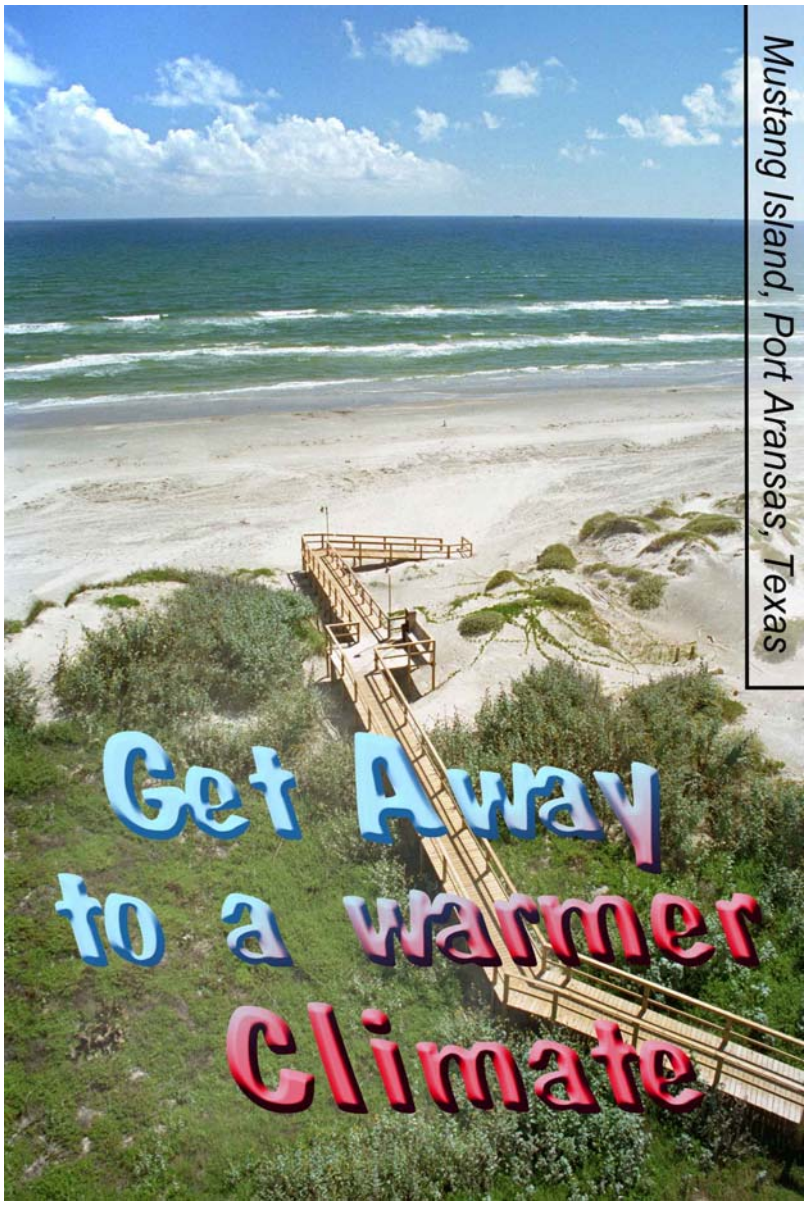
A convergence of climates - Great Sand Dunes National Park, Colorado.

The authors found that the higher elevations are more sensitive and that 85 to 90 percent of species will lose suitable habitat at these higher elevations. Further findings show that the losses will be greater in some areas than others. Their modeling shows that areas expected to experience more drying were

worse off. Almost all of the Rockies in North America are expected to experience significant drying in the future, beyond what has already happened. (47)

There will likely be refuges in nooks and crannies in the mountains where the forest will survive. This has long been a well understood way that plants can continue to exist through abrupt climate change in a hostile world. These nooks and cranny's filled with forest from different climate zones are called relic forest and they exist today throughout the world in sheltered places that retain small habitat areas left over from the ice ages. For example: two high altitude canyons in the arid mountains of the Chihuahuan Desert in Big Bend National Park in West Texas have a vastly different landscape than the surrounding desert. At the highest altitudes, juniper and pinyon trees appear. In the highest canyons, ponderosa pine and fir abound, with birds and other life forms more common hundreds of miles north. There is even one place in Big Bend National Park where there is a single stand of aspen. Everywhere else however, there are no trees, little grass and only cactus and the most hardy plants evolved to live in one of the harshest environments on the planet.

Does this mean that we will be ok then, because these climate refuges will still contain small patches of the forest that once was? The answer to this question embodies unknown unknowns.



Misinformation Critically Affects the Public

There is a great disconnection between climate science and the public (including our leaders.) It is not just in the understanding of the meaning of this pine beetle outbreak. Climate scientists everywhere are confounded at the poor success they have had with outreach. It was not this difficult when the ozone layer was threatened. But that was a different problem – much smaller and encapsulated by a single issue. The story was easier to tell. It was a quick read. There were only a few questions.

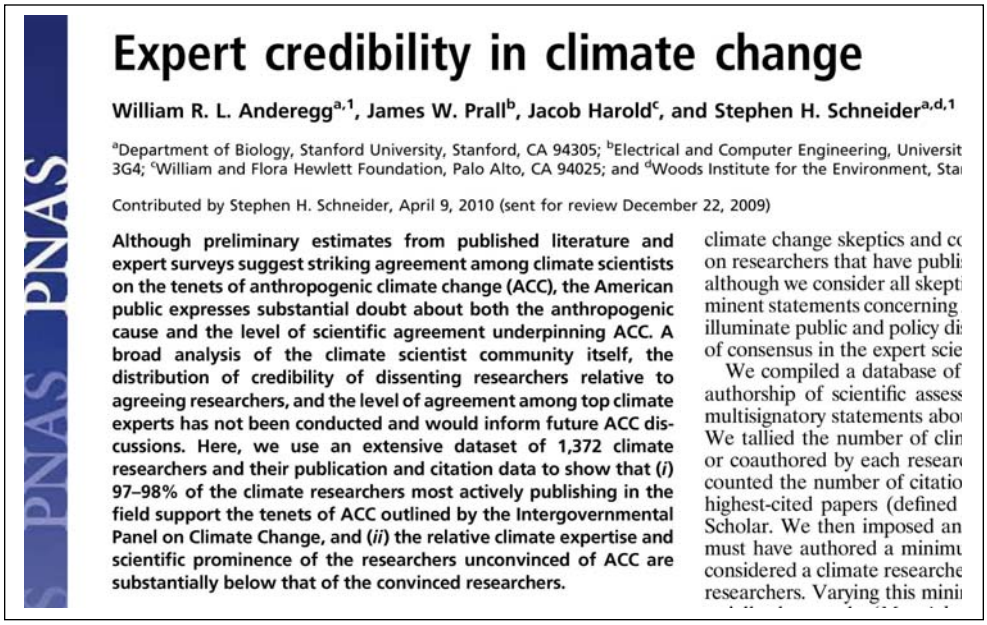
The climate change story is anything but easy. The questions are found layer upon layer in great piles. Few new what ozone was, or its function in our atmosphere. We humans are intimately familiar with climate. It is woven into

our lives like the skin on our bodies. This is probably the main reason why climate change is so difficult to understand.

The climate changes that we are all familiar with – that we encounter every day of our lives – are ten to a hundred times larger and happen hundreds and even thousand of times faster than the climate changes that climate scientists have been warning us about. But how can something that we have already conquered be harmful to us? We conquered climate generations ago. How big of a deal can a few degrees of warming be? These thought processes consciously and subconsciously guide our understanding of climate, our reporting of climate and our leadership dealing with climate change. (48)

One thing in particular compounds our understanding climate change. This is the knowledge level of our media professionals who report on climate science. Journalists are supposed to be, not smarter, but more persistent in getting their information than the rest of us. In a world where belief systems, moral standards, religion, philosophy, ideological issues and human nature are concerned, traditional journalism is an appropriate medium for communicating information. Journalists *fairly* present both sides of the issue.

Climate science however is not grounded in belief systems. Science has no politics or morals. Facts associated with science are more stringent than those associated with a murder trial. A murder suspect can be convicted and put to death based on circumstantial evidence. Few academic papers are published based on circumstantial evidence.



PNAS

Expert credibility in climate change

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Contributed by Stephen H. Schneider, April 9, 2010 (sent for review December 22, 2009)

Although preliminary estimates from published literature and expert surveys suggest striking agreement among climate scientists on the tenets of anthropogenic climate change (ACC), the American public expresses substantial doubt about both the anthropogenic cause and the level of scientific agreement underpinning ACC. A broad analysis of the climate scientist community itself, the distribution of credibility of dissenting researchers relative to agreeing researchers, and the level of agreement among top climate experts has not been conducted and would inform future ACC discussions. Here, we use an extensive dataset of 1,372 climate researchers and their publication and citation data to show that (*i*) 97–98% of the climate researchers most actively publishing in the field support the tenets of ACC outlined by the Intergovernmental Panel on Climate Change, and (*ii*) the relative climate expertise and scientific prominence of the researchers unconvinced of ACC are substantially below that of the convinced researchers.

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Tirelessly, journalists seek opposing views on issues. They then ethically report these opposing views in an unbiased manner giving equal time to both sides of the issues … this is where popular science journalism breaks down. The challenge with reporting on science is to be able to tell if an opposing view is valid and worthy of discussion. This is the way normal science works – findings are questioned when new information arises. Issue based debate however is different. If a journalist reporting on abortion interviewed someone who believed that any mother considering abortion should be executed, that interviewee would likely not get much time in the journalists article because it is obvious that the interviewee is nuts.

Journalists interviewing opposing viewpoints concerning climate change however, cannot tell who is nuts. They do not have enough knowledge to sort out the nuts from the facts. The do not know that they do not know…Unknown unknowns plague their ability to accurately report. (49)

Among climate scientists, 97 to 98 percent support the tenets of the IPCC concerning the validity, risks and urgency of the climate change issue. Of the two to three percent that do not support the IPCC, 80 percent have published less than 20 papers on climate science. Of the 97 to 98 percent group who support man-caused climate change science, only 10 percent have published fewer than 20 papers on climate science. The original sample group was 1382 active climate scientists. This is a huge statement. Not only do the vast, vast majority of climate science specialists support human induced warming science, but the very small group who do not support it have very few credentials to stand on. (50)

Yet, a paradox exists. Fewer and fewer Americans see solid evidence of global warming. Since 2006 the portion of Americans who think that there is not solid evidence for global warming has doubled. One third of Americans believe that there is no evidence for man-caused warming. In 2006, seventy-nine percent believed that there was evidence that showed Earth was warming. Only 59 percent believed there was evidence that Earth was warming in 2010. Only a third believe it is a serious problem, this is down 35 percent from 2006. Forty-four percent, nearly half, believe that scientists do not agree that Earth is warming because of human activity. Nearly two-thirds of Republicans believe that climate science is exaggerated in while only 17 percent of Democrats hold the same view. (51)

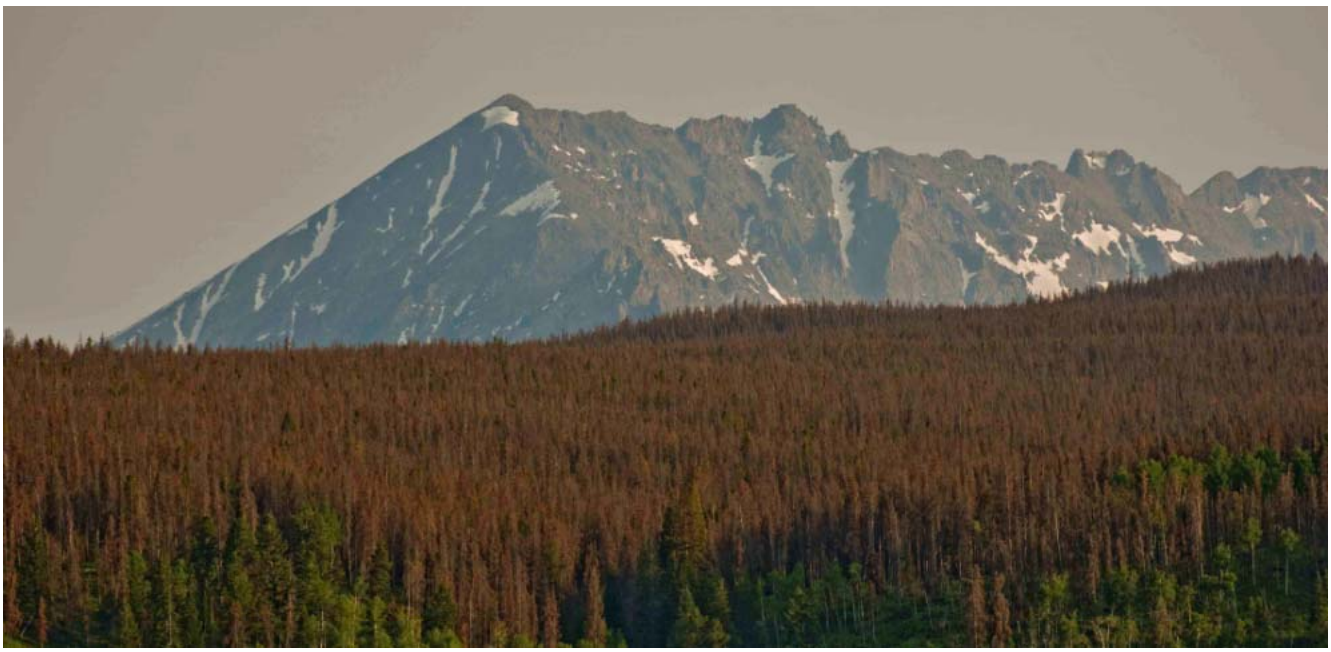
The reasons that these folks understand things to be this way, when 97 to 98 percent of climate scientists understand that this discussion is over, are extensive and omni-present in our society. They range from vested interests' propaganda and war chest funding of negative information and disinformation to religion and include just about everything in-between. One of the biggest things that contribute to the public's disconnection with the science is corporate money. The same people and institutions are involved that were involved in scamming the nation about tobacco smoke and for the same reasons – money. Everything from The Creation to our beloved weatherman and weathergirl plays a significant role in the misunderstanding of the validity of climate science. (52, 53)

Specifically, how poor communications, or propaganda, denial, ideological differences or a lack of fundamental knowledge of climate science relates to the pine beetle is clear: Forest professionals continue to insist (although some of the steam has gone out of their proclamations over the last four or five years) that this unprecedented outbreak is natural and that natural cycles will continue and everything will be the same in a hundred years when the forests regrow. The U.S. Forest Service and

the National Park Service (two of the largest institutions that, for the longest time kept to the natural cycles concept) have now started publishing papers that lay the majority of the blame squarely on warming and continued stress from warming. But you could not tell that by the National Forest Service's public interface on the Internet concerning the beetle. Their Bark Beetle Website continues to view forest regeneration based on historic knowledge. (54, 55)

The Forest Service does make a statement that the forest composition may change to one with more diversity. They say though that this is not based on a warmer climate being more suitable to a higher diversity, but the presence / absence of aspens and other high elevation forest species of the 20th century. Many Western forests today are old monocultures, or dense stands of single tree species. Ecosystems trend towards this state – called a climax ecosystem – over century times scales. Often, when forests burn or blow down, what regrows starts out as a more mixed species forest. The first plants to grow are called colonizing or pioneer plants. These life forms have shorter life spans than the climax species, so over hundreds of years, the shorter life span trees eventually die out leaving only the longest living species in the forest: A climax ecosystem with relatively few species.

They Forest Service also tells us on their website that large areas will grow back in a monoculture. This pattern of course is one that has reoccurred repeatedly over the past one hundred centuries. The philosophy of their thought (or at least their printed statements on the website) includes the consideration of local climate only, which is controlled significantly by exposure to the sun and hence different amounts of drying that create different micro climates.



This behavior by the Forest Service, that perpetuates the business as usual philosophy of climate as we understood it for most of the 20th century, creates an alarming false authority position. Whether through innocence or ignorance, the Forest Service is making a false impression. This "impression" then gives you and me the ability to make bad decisions.

The U.S. Forest Service is a very large and economically, historically and socially important institution in the United States. We look to the Forest Service as an authority figure and have become accustomed to taking what they say at face value. Many of us would trust our children to the Forest Service in other words. The Forest Service (and the National Park Service) – on this topic - are doing us and the planet a grave injustice. The media regularly picks up anything the Forest Service says and passes it along without thought to its validity. This gives you and me the false impression that all is well in our nation's forests.

Inappropriate reporting of the "natural nature" of insect infestations across the West is playing a crucial role in the public perception of the impacts of climate change. The size of these outbreaks and the shear volume of evidence showing extended drought, warmer temperatures, continued drought induced by a longer warm season, and the resulting continued forest stress are ample evidence to prove the close association with climate change

The Intergovernmental Panel on Climate Change (IPCC) warned in their 2007 fourth Assessment report that it is "virtually certain" that global warming will increase insect outbreaks in forests. (56)

The findings of the Rocky Mountain Climate Organization, that the current outbreak has been significantly affected by climate, take into consideration 50 scientific studies and data from 125 other scientific sources. The study finds that when compared to the twentieth century average, the West has warmed 70 percent *more* than the world as a whole.

Innocent (or ignorant) misinformation is a real threat to efforts to convince the public of the seriousness of this outbreak and of climate change in general. Normal outbreaks do not continue on until nearly all of the trees are dead in areas as large as British Columbia and northern Colorado. Scientists have been warning us of massive insect infestations because of climate change for decades.

The perpetration of the assumption that this outbreak is natural, leads the people to believe that this is normal, that we could expect this to happen even if we had not significantly changed our atmosphere by releasing unfathomable amounts of stored fossil carbon energy over the last 150 years.

This pandemic is rapidly approaching continental scale. The effects from this widespread regional forest destruction are large enough to impact our earth's climate by themselves through greenhouse gas emissions instead of the sequestration function that forests are supposed to provide. As this pandemic grows, the effects to our climate will grow too and increase the effects of warming in a feedback loop that works like an avalanche. The forests will no longer be able to absorb carbon dioxide. This excess carbon dioxide stays in our atmosphere and warms the planet more. More warming makes forest conditions even more hostile and more trees die. Up until just a few years ago, the greenhouse gas feedback loop from beetle infestation was not even in the climate models.

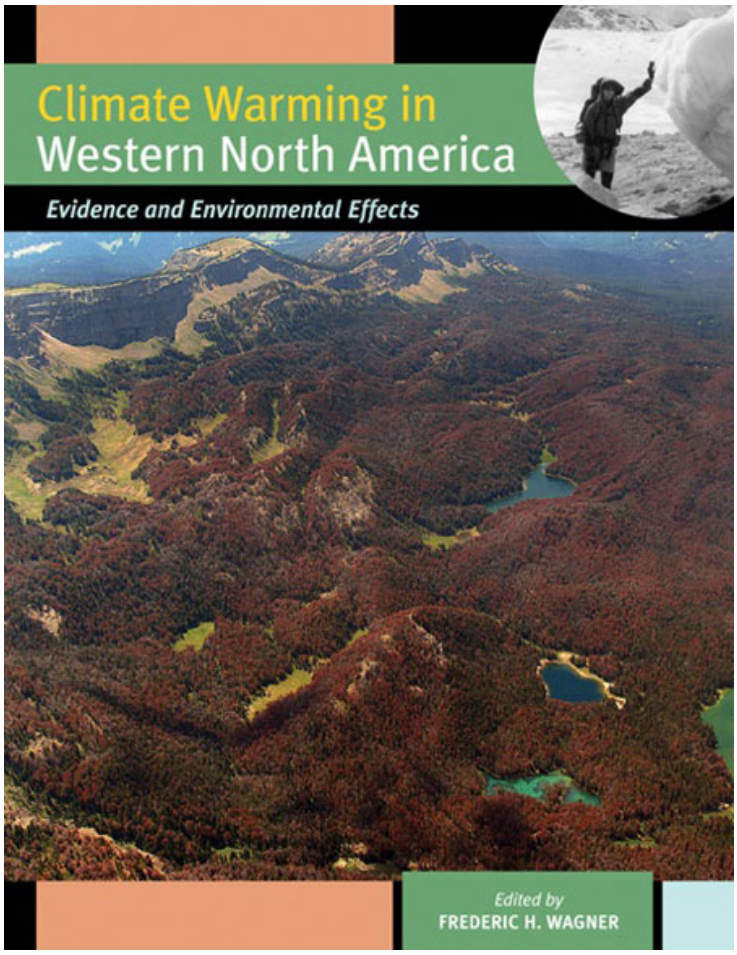
The Future

"Trees are the cloud machines you see, when they are gone, few will stay." (from *The Momentum of Ignorance* by the band *Climate Change*.) Future, and ongoing, impacts of precipitation due to the loss of so much tree cover in the Rockies will undoubtedly impact the cloud machine.

Spruce beetle attack in southern Colorado

One hundred thousand trees are falling each day in northern Colorado and southern Wyoming alone, and the dead trees are just beginning to fall. Our complicated human society has evolved with these forests – alive and healthy - and although humans as a species have experienced abrupt climate change and its associated ecoregime replacement, we have *not* experienced anything of the sort since we were nomadic hunter-gatherers with the ability to migrate to a more favorable climate. (57)

These next three passages embody much of the thought processes of current academic literature that are now beginning to see something different in the 21st century that has not been expected by traditional climate science thinking. This paradigm shift of thought has been ongoing for some time but has had little momentum because the U.S. Forest and National Park Services have been maligning the discussion, again, whether through ignorance or innocence, through their "natural cycles" philosophy. The new thinking, about the meaning of this pine beetle invasion and what we can expect in the future, has started being published in earnest in the journals in the last three to five years. The language in these reports is becoming more and more alarming. Scientists do not normally use extremely explicative adjectives in their findings, but when a "eureka" moment is finally acknowledged, adjectives help to give the discoveries the recognition they deserve. Also note that I have chosen quotes mostly from U.S. Forest Service academic publications. This highlights the extreme disconnection, not between the public and climate science knowledge, but the inter-Forest Service disconnection between forest scientists working for the Forest Service, and policy makers and public information employees.



These quotes come from a paper published by the U.S. Forest Service, Rocky Mountain Research Station titled "Ecological Consequences of Climate Change Altered Forest Insect Disturbance Regimes" and from Wagner 2010, "Climate Warming in the Western United States":

"Unprecedented outbreaks of native bark beetles are occurring in forests throughout the mountains of western North America. Any one of these events would be unusual; their simultaneous occurrence is nothing short of remarkable. Significant biogeographical events are occurring at a continental scale, and a warming climate is the one commonality across all of these spectacular outbreak events."

"… The situation with mountain pine beetle is only one of several current unprecedented outbreaks involving a variety of bark beetles. The commonality across time and space for all these events is increasing temperatures that began sometime in the late 1980s or early 1990s, and continues to the present. Perhaps the time has past for simply being aware of the potential disruptive influence of a warming climate, and it is now time to begin formulation of responses. Insights from [prehistoric] ecology may be helpful in formulating these responses, however, other aspects of global change complicate the current situation."

This quote (from the U.S. Forest Service - same reference), about implications of this attack on the North American continent, from the Rockies all the way across the sub Arctic to Nova Scotia, the Gulf of St. Lawrence and the Atlantic Ocean, down the Eastern Seaboard of the United States, through the great white pine forests of the northeastern North American continent and in the upper Midwest, and then down the eastern seaboard to the great pine forests of the Southeast U.S., is just, to me anyway, beyond alarming:

" …There is a continuous connection of pine distributions all the way from the western Rocky Mountains to the south east United States. During historical times, the Great Plains has served as an insurmountable barrier to mountain pine beetle eastward migration. Once this barrier is breached to the north, as it has been in the Peace River Valley of British Columbia, the previously inaccessible habitat of boreal and eastern pines become vulnerable. The ecological impact of mountain pine beetle in these new habitats can only be surmised. However, there is reason to expect the impact of a native invasive species will be no less than an exotic invasive species. The potential economic impact is even less ambiguous." (58)

A report coming out of the Saskatchewan Research Council, Canadian Forest Service and British Columbia Ministry of Forests is giving deep thought to the future:

"Impacts on forests will vary regionally across Canada, with continental interior locations likely to experience greater extremes in temperature and precipitation… Trees that are adapted to the climate at the time of establishment may be considerably maladapted to the climate at harvest time, displaying reduced productivity and increased frequency of pest attack. Although our ability to pro-actively mitigate possible short-term impacts to current climate change is limited, we have the opportunity to assist species and populations with migration to climatically-suitable habitats. This is a management activity called "assisted migration", and represents an important forest management activity to mitigate the negative consequences of climate change." (59) The big challenge with Johnson's work however is:

> *Will the future climate, where assisted forest migration has been implemented, be suitable for forest growth, not only at the time of harvest, but for the entire life period of the tree?*

But what about all the snowstorms for the last four or five years? What if we keep getting this kind of weather? How will this impact the beetle and other unprecedented forest maladies caused by a warming climate? The winter temperature across the U.S. in 2009 ranked 18th coldest out of 115 years, but for the entire year the U.S., ranked 34th warmest out of 115 years of records. The year 2008 ranked 38th warmest of 114 and 2010 ranked 23rd warmest. Northern Canada however had its second warmest winter ever recorded in 2009 and the combined global average temperature was the fifth warmest ever recorded. In 2010 Canada had its warmest ever winter, spring and annual average temperature. Globally, 2010) tied 2005 as the warmest year ever recorded. (60)

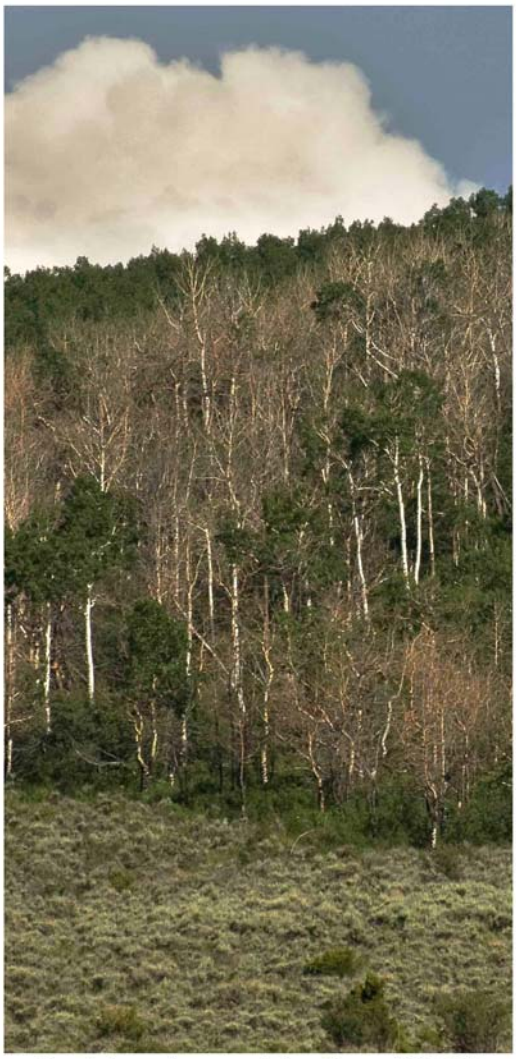
Pentagon City, Arlington Virginia, February 2010

Just because it was one of the coldest (more accurately – one of the most extreme) winters in decades in some parts of the U.S. for the last few years does not mean it was very cold. It means that it has been warmer (or less extreme) than normal for decades. This natural climate variation will continue to increase as more energy from Arctic warming is recognized in Earth's environmental system. A warming Arctic has already intensified the Beaufort High, a semi-stable pressure system in the Arctic Ocean north of Alaska and Canada. This increased energy enhances the jet stream and pushes Arctic weather systems further south. Even though Arctic temperatures are significantly warmer, these air masses reaching further south are still quite cold creating a paradox of increased winter weather extremes on a warming planet. (61)

Beginning in the late 1970s, our climate really started to warm. The warming has only been a little more than a degree, but most of the warming comes in the winter. So we have been lulled into complacency by decades of warmer than usual temperatures, and even warmer winters. I remember in the 1960s and 70s when I was a kid, I was fascinated when arctic air invaded the northern tier of the United States and temperatures plummeted to 40 below and just hung there for weeks. That just does not happen anymore

The mountain pine beetle is the biggest threat to our planet's forests today. It has already changed the sequestration capacity of a large continental region from a carbon sink to a carbon source. But these 64 million acres impacted so far are just from the mountain pine beetle. The California pine beetle outbreak has killed nearly a million acres. The New Mexico and Four Corners Region outbreak of the pinyon bark beetle has killed four and a half million acres of the high altitude "desert forests" in the southwest. The Alaskan spruce beetle outbreak has killed another three million acres on the Kenai Peninsula. All of these outbreaks are at unprecedented levels.

Aspens are at risk too. A new phenomena is killing hundreds of thousands of acres of this beloved white-trunked mountain icon. This phenomena is called Sudden Aspen Decline or SAD. It killed 500,000 acres of aspen in Colorado between 2000 and 2009. There is no one individual cause of death of these forests. The killing is caused by a soup of warming induced maladies that have simply overwhelmed the ability of aspens to exist. These maladies include bark beetles, fungus, blight, cancer, rust and leaf miners. Individually, these things usually do not kill, but the combined stresses of climate warming have allowed multiple infestations and diseases to attack aspen simultaneously. This is SAD.



Sudden Aspen Decline (SAD)

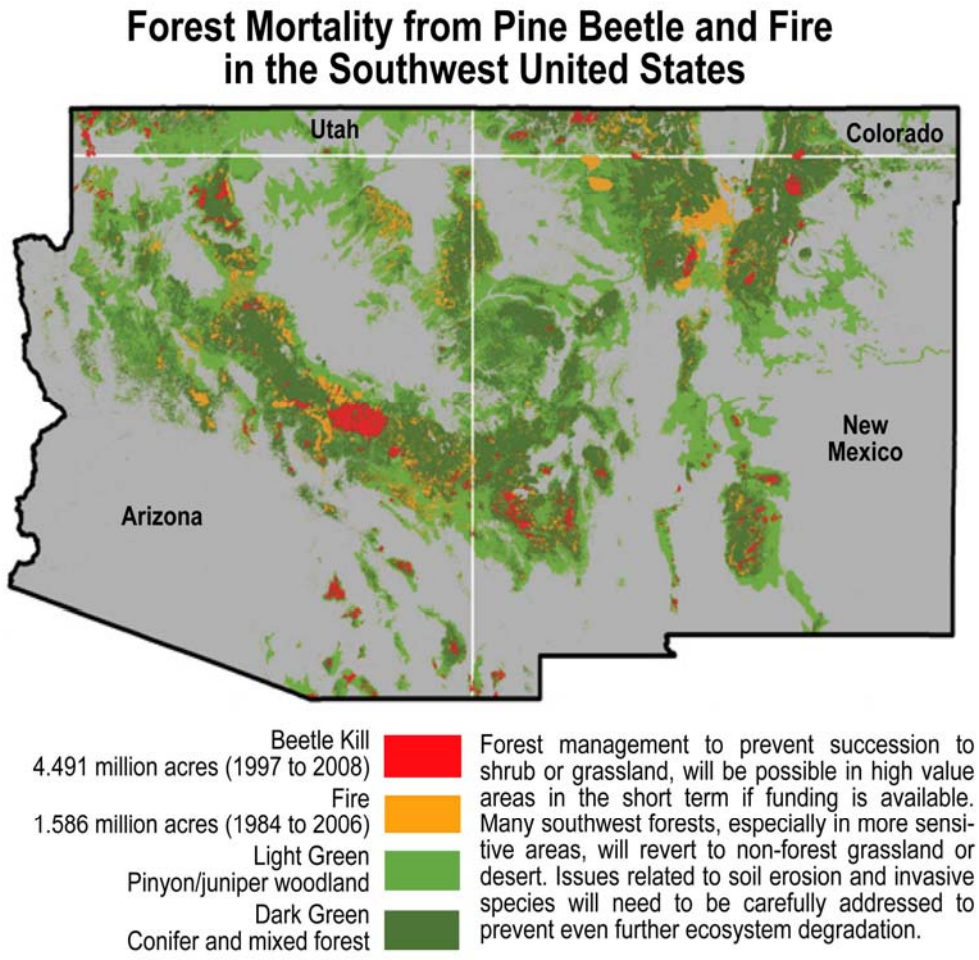
SAD is not always easy to see because of the prominence of aspen's white trunk. The healthy aspen with the dark green leaves are easy to spot in this photo.

Another big problem with aspen is the leaf miner. This little fly larva eats the meat out of a leaf in an action similar to someone eating the cream out of an Oreo cookie. What remains is the semi-transparent leaf surface, but nothing to perform photosynthesis and provide the tree with nutrients. Typically, this pest does not kill, but these are not normal times and, like the pine beetle, warming conditions have increased stress so that the numbers of pests have overwhelmed the aspen. After several years of repeated infestations, death results from starvation.

The Alaskan outbreak that was isolated to the Kenai Peninsula in the 1990s is spreading to the interior of the state. Far to the south, the southern pine beetle has been a long time problem with pine monocultures from Texas to South Carolina. The beetle is resurging in numbers today because of extreme drought in some areas and there are concerns of its northward migration following the northward extension of its range because of general warming. And to my surprise, while watching the Tour-de-France last fall, I saw thousands of acres of red pine in the Bordeaux region. A researcher in Switzerland later confirmed to me that pine beetle was responsible.

Other important players that are considered real threats to forest stability not yet mentioned include the Jeffrey pine beetle, fir engraver, Douglas fir beetle, western balsam beetle, western spruce bud worm, red turpentine beetle, sub-alpine fir decline, and Douglas fir tussock moth.

A special feature in the Proceedings of the National Academy of the United States of America in December 2010 looked at the dry forests of the southwestern U.S., the 4.5 million acre pinyon beetle outbreak there between 2003 and 2006 and the sensitive nature of this high altitude arid forest region.



Reference: Williams, et. al., Forest responses to increasing aridity and warmth in the southwestern United States, Proceedings of the National Academy of Science, December 2010.

This report discusses forest management to prevent succession to shrub or grassland, will be possible in high value areas in the short term if funding is available. The study says many southwest forests, especially in more sensitive areas, will revert to non-forest grassland or desert. Issues related to soil erosion and invasive species will need to be carefully addressed to prevent even further ecosystem degradation.

The U. S. Forest Service report "Climate and Forest Diseases of Western North America: A Literature Review" includes evaluation of over 230 different sources:

- "The effects of climate change on hosts, pathogens, and their interaction will have numerous, mostly adverse, consequences to forest ecosystems. Most of these consequences are not currently accounted for in climate change models.

- Relatively rapid changes in climate may result in host resistance to pathogens being overcome more rapidly, owing to accelerated pathogen evolution, a result of the shorter regeneration time of fungal pathogens relative to trees. This decrease in host resistance may also result in greater than expected ecosystem damage.

- Some studies suggest that with regional warming and drying, subalpine forests will be a net source of carbon.

- Climate change may cause a crossing of an environmental threshold, resulting in irreversible changes to ecosystems…" (62)

This phenomenon is not limited to North America and France. Around the world trees are dieing because of stress from warming caused by climate change. This is not just a "natural cycle", at least as it has been defined in the 20th century. It is however a natural cycle when looking at ancient ecosystem changes. Forest die-off is common in the greater prehistory of Earth where abrupt climate changes into and out of ice ages, as well as abrupt changes during ice ages, of temperature changes less than what is projected because of man's pollution of our atmosphere, have demonstrated the low sensitivity of forest ecosystems to change in temperature.

A researcher named Dr. Henry Adams at Stanford, and a team from around the U.S. and the world have shown us that, not only has forest mortality increased because of warming, but it will continue to increase as we experience more warming. Adams' team's, paper published in the EOS, Transactions of the American Geophysical Union in April 2010, gives us these insights:

"Reports of tree mortality associated with heat and drought from around the world have increased in the past decade, and although each cannot be conclusively linked to climate change, they collectively illustrate the vulnerability of many forested ecosystems to rapid increases in tree mortality due to warmer temperatures and more severe drought."

Forests contain more than half of all of the carbon in land ecosystems and northern forests contain two and a half times as much carbon as tropical ecosystems because of the large carbon content of northern soils in the north. Forests also absorb a third of all carbon emissions, or at least they did during the 20th century according to our traditional understanding of the way our unwarmed planet worked.

Understanding the future of our world forest carbon sink is vital to understanding the needs of our society on a warmer planet. The work done on carbon sequestration in the beetle-killed forests of British Columbia shows us that the modest carbon sink that we take for granted in our woodlands can rapidly change to a large carbon source and remain that way for decades. A related paper by Adams, published in the Proceedings of the National Academy of Sciences of the United States of America in April 2009 concludes:

> "Most importantly, because increased temperature is among the most widespread and least uncertain climate projections, our results portend widespread increases in the extent and frequency of vegetation die-off." (64)

Globally the situation is little better than in North America. In a paper in Forest Ecology Management, an international team of 20, led by a researcher from the USGS, lists the major forest problems associated with drought and heat stress across the world. This is the first such work ever created and it reveals "a potential for amplified tree mortality due to drought and heat in forests worldwide."

The team reveals that, (at least) "… some of the world's forested ecosystems already may be responding to climate change and raise concern that forests may become increasingly vulnerable to higher background tree mortality rates and die-off in response to future warming and drought, even in environments that are not normally considered water-limited." They also identify that "computer models lack functionally realistic mortality mechanisms", and what they do have are based on 20th century knowledge of Earth's ecosystems that does not consider climate warming.

This paper identified 88 well-documented heat and drought related forest die-offs across the world spanning all forest types and climate zones.

Africa has shown increased forest die-off due to drought and heat in Uganda, Zimbabwe, South Arfrica's Kruger National Park, Namibia, the Sahel, Senagal and across North Africa from Morroco to Algeria.

Asia's forest woes include Borneo, India, South Korea, Saudi Arabia, Turkey, 12 million acres in east central China and extensive areas in southwest China. The Russian Federal Forest agency has mapped areas that show 188 million acres at "high risk". The report also cautions that climate science and forestry reporting in some parts of the world are not as advanced as in other parts of the world.

Australia and New Zealand have reported repeated tree mortality events associated with drought in northeastern and southern Australia and mainland New Zealand. In Europe, Spain, France, Switzerland, Italy, Greece, Poland and northwest Russia have all shown significant tree die-offs since 2000.

In North America, beyond the pine beetle pandemic, red oaks from Missouri to South Carolina have been hard hit. In Quebec there has been a significant die-off of maple. Forest die-offs are also happening in South and Central America, Costa Rica, Panama, Northwest and Southeast Brazil, and Patagonia.

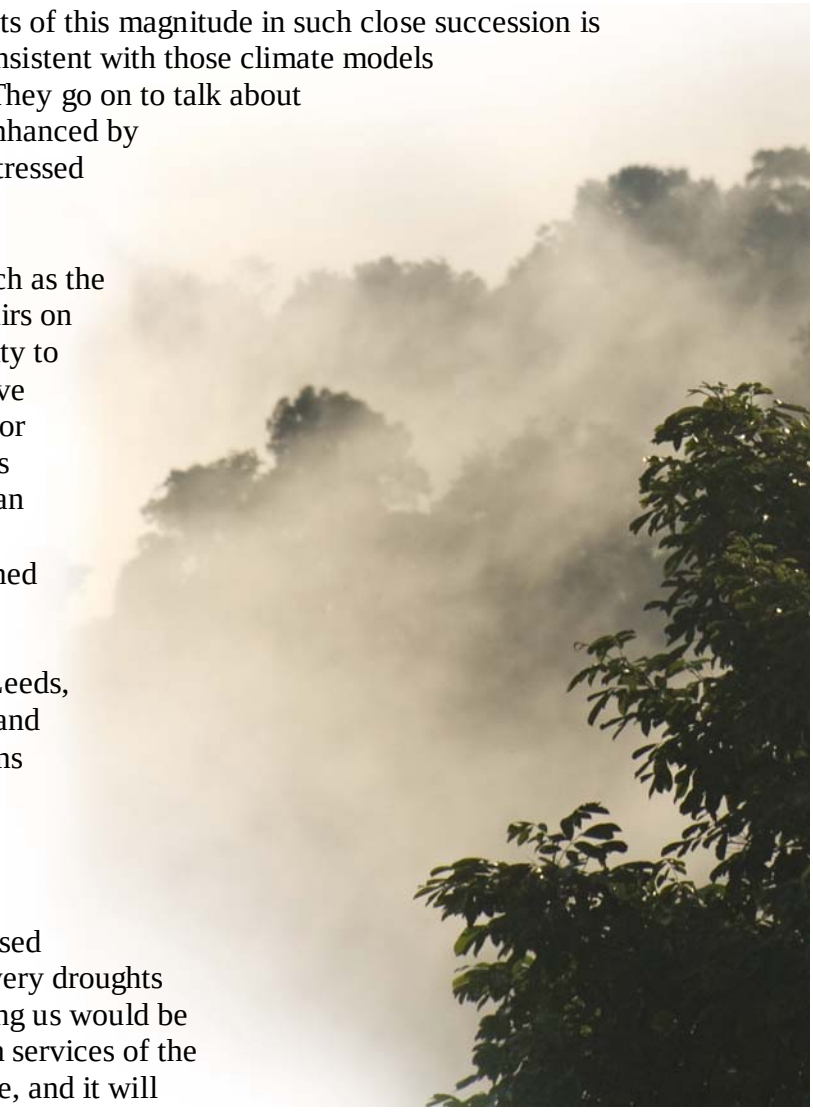
One of the most salient observations from this paper is that, not only will these climate-induced forest mortalities emit extremely large plugs of carbon back into the atmosphere, but they will hinder the ability of Earth's forest to act as a carbon capture safety net "in the coming centuries" … (65)

The biggest news however may eclipse the beetle pandemic in North America. In 2005, the Amazon had a one hundred year drought. In 2010, they had another. One of these droughts alone is supposed to be a once in a hundred-year occurrence, more accurately, Only one should occur on average every one-hundred years or, an event like this has a one percent chance of occurring in any one given year. So the probability that the Amazon would have a second 100-year drought, five years after the 2005 event, is quite low: except during an abrupt climate change. Not only has it happened, but also the 2010 drought was likely more than half again as extreme as the 2005 drought.

What has been projected in the models is happening now. Drought is rapidly increasing in the Amazon. The rain forest is dieing off. A hundred year drought is not an easy thing to live through if you are a tree. The 2005 event was devastating to the Amazon forest. But the death of trees is just the beginning.

What does this mean for the critical climate control system that is the Amazon rain forest? You know, the one that captures so much CO2 that it is indispensable?

A tropical earth systems climate scientist named Lewis at the University of Leeds in the United Kingdom captured the essence of this Amazonian event in a recent article in the Journal Science. Dr. Lewis and his team say: "Having two events of this magnitude in such close succession is extremely unusual, but is unfortunately consistent with those climate models that project a grim future for Amazonia." They go on to talk about the likelihood that the 2010 tree kill was enhanced by the 2005 drought because trees were still stressed and may have succumbed more easily.



What happens in a tree-killing drought, such as the 2005 event, is that dry soils kill the root hairs on tree roots first. This destroys the trees ability to soak up water and if the damage is extensive enough the tree dies. It can take a decade for trees to regrow their root hairs. During this recovery time, the least amount of stress can push them over the threshold and they die, years afterward, because of damage sustained during the original drought.

These researchers from the University of Leeds, in the UK, estimate that the 2010 drought and tree kill will be responsible for 8 billion tons of additional CO2 emissions. The Amazon biosystem normally sequesters 1.5 billion tons of CO2 per year. This significant ecosystem service, that forests normally provide our planet, is gone. It has been erased by drought. It has been eliminated by the very droughts that the climate scientists have been warning us would be greater on a warmer planet. The ecosystem services of the greatest tropical forest on the planet is gone, and it will remain gone for a decade or more as the trees decay and the forests attempts to recover. It is gone exactly like the computer simulations said it would be gone, and it is happening alone path of the worst-case scenario.

The 2005 and 2010 droughts combined now make the Amazon forest responsible 13 billion tones of CO2 emissions per year, for the next decade or more as the trees decay. Thirteen billion tons of CO2 is almost a decade's worth of normal carbon sequestration from the Amazon - one of the largest single carbon sinks in the world. Thirteen billion tons is also more than two years worth of CO2 emissions from all sources in the United States (2009 emissions from the U.S. were 5.4 billion tons.) It is also 42 percent of mankind's annual global CO2 emissions. The likeyhood of another drought of this size

happening in the next decade is higher than it was in the 20th century, and getting even higher every year.

The authors also tell us that their analysis does not consider forest fires caused by the drought conditions. That's extra. Of course, if fire burns the trees already killed by drought, that carbon is not counted in the "extra", but many other trees (as in hundreds of millions or more) burn when forests catch fire.

In an article in the U.K. Guardian, Lewis is quoted as saying the number of trees that died in the 2010 drought alone "in the low billions of trees." The Amazon has changed from a carbon sink to a carbon source because of two droughts in rapid succession and the death of a couple billion trees. This is not something that is going to happen, it just happened. From Lewis's paper in Science: "If drought events continue, the era of intact Amazon forests buffering the increase in atmospheric carbon dioxide may have passed." (66)

This is the danger of climate change feedbacks. The Amazon may be one of the largest single carbon sinks on the planet, but there are many more where that came from. And it is not the largest sink on land. That honor goes to the boreal forest.

Black spruce in the boreal forest of central Alaska that have been killed by spruce beetle.

We have already been warned about the boreal forest and how the pine beetle attack has already begun in the mixed pine forests of northern Alberta Canada. There are 4.2 billion acres of boreal forests at risk to the pine and spruce beetles and other impacts from warming. (67)

The world's boreal forests are about as large as the world's tropical forests, but their size is deceiving. Because of the cold climate, additional carbon is stored in soils of the north. Nearly twice as much carbon exists in the boreal forests as exists in tropical forests.

Warming causes this carbon to be released. When trees die, more sun can hit the forest floor and further increase warming. When permafrost melts (nearly half of the boreal forest is underlain by permafrost) even more carbon is released. (68)

The implications arising from a significant tree kill in these forests from this continuing outbreak are quite literally unimaginable. To illustrate the great risk, the beetle-killed trees in British Columbia today represent only about one percent of the trees in the boreal forests.

Craig Allen at the USGS has this to say about the speed that forest can radically change because of a shifting climate and about the current "consensus" knowledge of forests in climate science. "The potential for broad-scale climate-induced tree mortality can be considered a nonlinear 'tipping element' in the Earth's climate system,. Because forest die-offs from drought can emerge abruptly at a regional scale when climate exceeds species-specific physiological thresholds the potential for climate change to trigger widespread forest die-off may be underrepresented in important assessments to date, notably including the latest major IPCC report." (69)

What Do We Do?

Continued warming is a well-established part of climate change. There is a high level of confidence that warming has significantly enhanced this infestation. Warming yet to come will be triple what we have already seen (at the least) – triple the warming already that has so greatly enhanced this beetle infestation and all of the various other forest diseases changing our forests right now.

The amount of change that is coming in the future is even more likely to be beyond the stability limits of ecosystems as we know them. If our climate continues to change as fast as it has been changing, our forests will be in a state of change from one set of life forms to another, for hundreds of years. Only when climate changes slow or cease will our landscapes stabilize.

IPCC 2007: Warming In the Pipeline

Scenario	Description of Scenario	CO2 Concentration	Warming
B1	Aggressive emissions reductions	600 ppm	5.2 F
A2	Modest emissions reductions	850 ppm	7.4 F
A1F1	Worst Case: minimum reduction	950 ppm	11.5 F

Our planet's temperature has changed on average 1.4 degrees F. This small temperature change has created the havoc in our world's forests today that peaks in the great pandemics occurring in the Rockies of North America. Even with aggressive global emission controls, the IPCC says we will warm three or four times as much in the future, and a significant proportion of this warming comes from already emitted greenhouse gases. Since the IPCC 2007 report came out however, it has become apparent that we are progressing along a path that is worse than the worst-case scenario (see the graph at reference 41.) The IPCC does not model this "Worse than the Worst-case Scenario", yet. (70)

When I say that future warming is three or four times what we have already seen, I say this based on an assumption that we will have some trigger in the immediate future that allows our society to

understand the risks of climate change and begin appropriate aggressive action. On the path that we are rapidly descending, the global average increase in temperature will be ten times what we have already seen (*ten times!*) Changes this large are as large or larger than prehistoric abrupt climate changes that resulted in changes to Earth's ecosystems far greater than just an ecoregime change.

There are a few techniques that could be used as a temporary bandages to reduce the rapid progression of forest mortality for a year at a time. Two of the natural beetle pheromones, or beetle behavior chemicals emitted by the beetles, have been shown to be fairly effective at temporarily stopping the beetle. These two pheromones tell beetles that it is time to make more little beetles, or to go away, the babies are brooding in the galleries. They can be effectively used to attract large numbers of beetles to traps, or repel beetles from an area.

Our clever scientists have leaned how to make these chemicals from scratch and they are expensive. But their price would fall dramatically if production were increased to the amount needed to defend North America's forests. They chemicals are distributed through the forest in sachets packets four or five inches across and a quarter of an inch thick. They are stapled to the north side of a tree so the sun doesn't degrade them any faster than necessary.

Pheromone Sachet

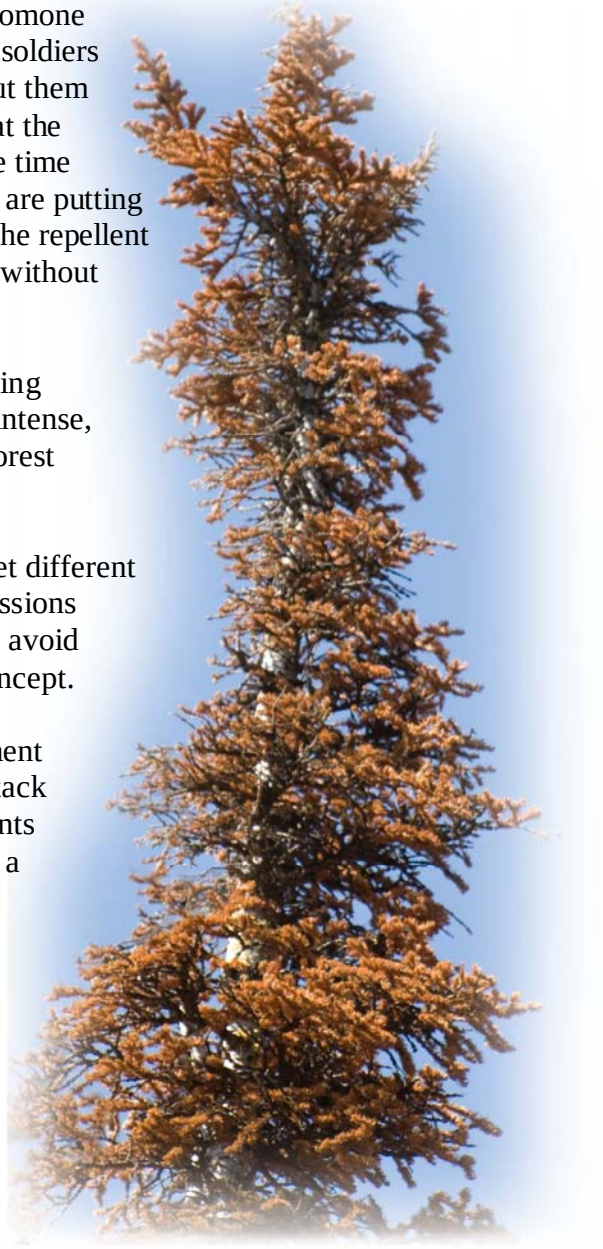
All we would need to do then would be to send out an army of pheromone foot soldiers to staple millions of sachets to trees in our forests. Sounds like a daunting task, but it certainly does not hold a candle to the cost and complexity of the war in Iraq or Afghanistan.

One pheromone foot soldier could install 20 repellent sachets per acre on forty acres per day. In two months, 40,000 workers could treat 100 million acres using 2 billion sachets. The cost of pheromones today is to high to for this to work, but like printed holograms, when the market was proven, costs fell dramatically. Holograms were once prized possessions of the elite, now they come printed on Christmas wrapping paper. $450 million would be needed for labor and overhead and add in ten or twenty million for the pheromones. We spent about $100 billion a year for seven years on the war in Iraq. Protecting our nation's forests, or the world's forests would cost one-half of one percent of the annual cost of the Iraq war. This is with a labor cost of $35 per hour ($18 to $20 per hour wage + $15 to $17 in overhead and benefits.)

The repellent sachets emit their chemicals for one season, telling the pine beetles that this tree is full, move on to the next one. So the work has to be performed every year to make sure the beetle does not have its way. The chemicals are not harmful in the least to species other than beetles, they don't even harm the beetles, they just influence them to go somewhere else.

Beetle trap with pheromone lure.

The other pheromone is called an aggregation chemical. This synthesized beetle stuff is placed in one of those little beetle traps that have a sticky goo in them that "traps" the beetles. We could get the pheromone foot soldiers to put them out at the same time they are putting out the repellent sachets. It is a very simple and effective way of killing beetles without pesticides and it works.



Adaptation is something we will have to do that will help. Having forests that are capable of withstanding the future, with more intense, more frequent droughts would be great. For example, an oak forest is not susceptible to the pine beetle.

Assisted forest migration, where we help forests change to meet different environmental conditions is a common thread in forestry discussions concerning the future. By replanting with other species we can avoid the maladies impacting our forest today. At least, this is the concept.

There are many other things that can be done. Forest management Practices of the past have certainly contributed to the beetle attack and the general poor health of forests today. Nobody really wants to blame Smokey Bear, but if our forests were a little younger, a little thinner, the beetle attack may not be so bad.

We do not know how long these outbreaks will continue. Because we see this happening with so little warming, it is entirely possible that forest mortality will continue to increase and forest migration will happen naturally, like in climate changes past, regardless of what we do to help.

But forests do not grow in time frames that can help us with this challenge. Without a stabile climate, forests will not be

able to grow to maturity. As our climate continues to change, a suitable environment for any given forest will continue to change as well. Pheromones and forest management practices only work for short times periods. "Assisted forest migration" takes generations.

It is the changed climate and the changes yet to come that will prevent forests from reestablishing themselves. We have changed our climate innocently however. It is our fault, but our innocence is still intact. Ignorance is to blame.

Until relatively recently nobody new – it was an unknown unknown. We knew that these changes were possible, they were evident in prehistory. But we really didn't think that it would happen to us. We thought that our current path of emissions reductions was appropriate.

To find solutions to this challenge we must over come both what is now apparent as the rapid momentum of climate change as well as the societal momentum of ignorance. This is our challenge today. We have the knowledge now to tell us that something terribly wrong is happening. Our society will be vastly changed, not only by the ongoing ecoregime changes happening in our forests, but by sea level rise and desertification of food growing areas and who knows what else.

The future path of climate change itself will be affected by the continued decline of our forests. This feedback has already been shown to be happening in British Columbia and the Amazon. Dead forests don't store any carbon.

It is a moral imperative that we must stabilize our climate. The new reports about climate change being worse than anticipated and future changes likely being greater than projected are, likely, still conservative. At least, the trend for this kind of thing is well developed. For twenty years, since Kyoto in 1991, we have been accustomed to the understanding that we were going to do something so that impacts would be limited to the lower end of the scale. We all understand that 2 degrees C of warming, above preindustrial temperatures, would mean dangerous climate change. Our mitigation policies have been crafted so that we do not exceed 2 degrees of warming. We understand implicitly that we must act soon or it will be too late, and our policies, for twenty years have reflected such knowledge.

Reality however, is a different beast. Our policies have had no backbone. Our leaders even less. Globally, our emissions have increased, not decreased, as our policies would have had us believe. The United States was the sole holdout in agreeing to these policies. Everyone – *everyone* else agreed. And now the Copenhagen Accord has evolved into a global anti-policy, even worse than Kyoto. To think that this trend will not continue is not a rational assumption. Things may get better, but that is not the direction we have been moving.

Something else is needed, divine intervention maybe… Without a trigger, response does not seem to be forthcoming. Given the current situation, research published in the United Kingdoms Philosophical Transactions of the Royal Society (the U.K.'s academy of sciences) by scientists from the Universities of Manchester, East Anglia, Oxford, the University of Arizona and the Tyndall Center for Climate Research, tells us that "Most analysts would agree that the current state of [most of the] efforts to reduce greenhouse gases make the chances of keeping below 2 degrees C extremely slim."

All of these scientists however share one commonality. They are all looking at the climate challenge in a way where the challenges can be solved based on what we have done in the past. This is a new world we have created, one that will eat us alive unless we recognize the seriousness of the situation. Once we have accomplished this minor hurdle, (acknowledged that 'yes Buill, we have a problem') we are free to actually do something productive.

The only true solution to this challenge is that we must stabilize and even possibly reverse climate changes happening today. We have a responsibility to ourselves, our children, people of other nations, and to the life forms in the forests themselves.

The costs may be great but, as with other major challenges that our society have faced on this planet in the past, we will likely surprise ourselves at how

well we address the problem. Solutions will likely be easier than expected and have great benefit to society other than their intended purposes. The human species has a long history of overcoming great obstacles with brain power and the efforts of her people.

That does not mean that our path is lined with rose petals. We have already demonstrated, as a society, that our past caries more weight in understanding of the world around us than the present knowledge of our scientists. Our past carries momentum that is difficult to overcome.

As we have faced environmental (and social) challenges in the past, conservative voices have been quick and loud in proclaiming the grave cost to society of the solutions. Economics and freedom are always on the top of the list. We supposedly cannot have whatever environmental (or social) issue de jour without destroying our economy and losing our freedom. They are always wrong.

We can fix climate, but we have to act. We have to act fast and purposefully (an not just say we are going to act like we have been doing for twenty years.) We have to understand the cost of climate change so that we can budget for solutions that minimize this cost. When American's were attacked at Pearl Harbor in 1942, we had no problem doing what was needed to meet the challenge. We understood the risks and the outcome of not winning the war.

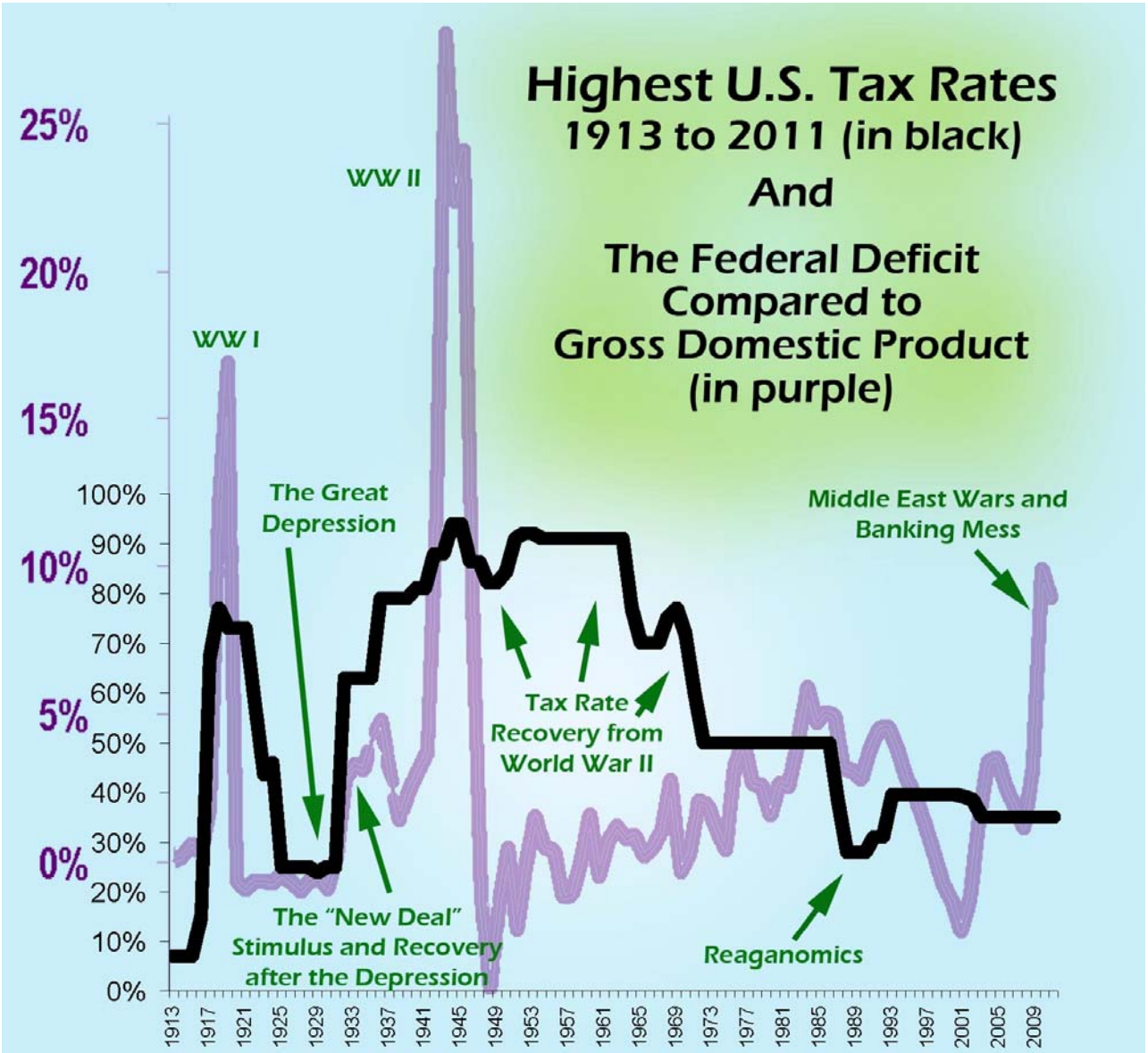
We spent money during WW II like it did not matter, because it did not. The only thing that mattered was preserving freedom. Deficit spending soared far, far beyond anything encountered in the stimulus from this recent little recession.

Tax rates then soared proportionately to pay the deficit spending back. For forty years, tax rates were more than double what they are today and for 25 years they were triple what they are today! It is also very, very important to understand that the U.S. tax code, as stated in the introductory paragraph to the Internal Revenue Service document that this quote was taken from, was "…closely tied to income distribution and, thus, at least theoretically, to ability to pay …"

This IRS documents continues "The modern U.S. income tax was enacted in 1913, following ratification of the Sixteenth Amendment to the Constitution. For about 30 years thereafter, until the advent of World War II, the tax applied only to high-income individuals. Exemptions from the tax were high, and few people had incomes large enough for even the lowest tax rate to apply." The rates for the top income bracket reached 94 percent at one point during WW II. Rates for the highest income earners stayed above 80 percent until 1963 and above 50 percent until 1986. The average person in the U.S. paid more than 50 percent income taxes for nearly 20 years to pay back the spending. (71)

The deficit to GDP rate grew to an enormous 28 percent. This is four times the rate that it is today, even considering two wars a recession and a banking and insurance mess caused by deregulation. If we subtract the major expenditures of War and expenditures for saving institutions that are too big to fail, what we are left with is a very normal deficit to GDP ratio of somewhere around two to three percent of GDP.

I'll not call our climate change challenge a war however, but it is a social and moral challenge even bigger than World War II. It has the capacity to change our way of life that is at least as violent and long lasting as world war, although not quite as loud.



The general public understanding of tax rates today could be no further from reality. Except for a brief period during the Reagan years, tax rates are as low as any time since before the Great Depression.

What this graph shows is that we have a great capacity as a society to spend deficit money when we understand the risk warrants such spending. WWII saw us spend 28% of our Gross Domestic Product in our efforts to keep from being defeated by what we perceived as a great societal risk. After WWII, except for spending because of the Middle East wars and the stimulus because of the recession, our defect to GDP rate is still completely appropriate. Even if we count the current wars and the banking mess, we still have the capacity to spend nearly four times what we have spent in the last several years before we spend as much as we spent fixing World War II.

It is not like we have never had an economic challenge of the magnitude of climate change before. We clearly have in the form of the Great Depression and World War II.

Reference: Personal exemptions and individual income tax rates, 1913-2002 (Rev. 6-02), in Internal Revenue Service, Statistics of Income Bulletin (Publication 1136), Spring 2002, pp. 216-225. http://www.irs.gov/pub/irs-soi/02inpetr.pdf and www.usgovernmentspending.com

Now let me make one more thing crystal clear. There is no need for panic. We do know that it is likely that we are falling off of the edge of the climate cliff. It is however, in climate time frames, a slow motion fall. The latest evaluation of our situation from literally thousands of climate specialists is that we do have ample time to act. (Again, if we really act this time instead of just saying we are going to act. This too must be crystal clear. We have wasted 20 years. We truly are very near the edge of the climate cliff of no return. The Venus Syndrome is real. Runaway greenhouse gas warming could evaporate our oceans and our atmosphere, just like it did on Venus. (72))

This may not mean however, that we can act according to the current public understanding, based on the IPCC, of how we should treat our society's greenhouse gas emissions. The consensus position of the IPCC is now old and dated. More recent research has shown that greater action needs to be taken need I say, sooner.

To prevent dangerous climate change, time frames today are on the order of a decade or two to achieve aggressive greenhouse gas emissions reductions, and even these findings, according to the scientists' maxim of "publish or perish" are likely conservative. I continue: it is not time to panic, but time to act with determination and resolution. It is not just our children and grandchildren any longer. It is you and me.

And most of us are doing our part, well a lot of us are doing our part. Some of us have been brainwashed. So, as we go about our lives, buying locally, reusing more, doing with less, bring wary of greenwashing, recycling constantly, thinking about an EV, combining trips, reinvesting in a high efficiency A/C unit, telecommuting one day a week, writing our Senators, putting to good use those 1,001 great little efficiency ideas, striving for carbon neutrality, or even better, sequestering carbon on our own, we need to do a little more. Business as usual is not happening with climate change, so we have to help.

How? Very simply, tell your friends. Tell them everything. Go to meetings. Join the Sierra Club or a local environmental group. Sign petitions. Join environmental groups on the Internet, you should be signing a petition or two every day. Share some of the links to the academic findings in the references of this book. Tell strangers at the supermarket. Ask your neighbors what they think about climate change or if they have heard about the pine beetle pandemic. Did I say this was going to be easy? No. Tell your parent. Discuss it with your crazy aunt that keeps buying guns. Read, read, read. Read some of the academic references at the end of this work. Many of them are really not all that hard to read, and reading the words straight from the science explorer's mouth brain, is really exciting… Well maybe not *really* exciting, I am just geeky that way, don't tell anyone. But if you made it through to here and understood 75 or 80 percent of what I have written, your are good to go. If you stumble onto an article that is written in science Geek, go on to the next one, there are plenty more. It doesn't matter if you skip a few. I cannot tell you how fascinating this all is. You will just have to find out for yourself.

Start Googling. Goolge "sequestration." The solutions do exist right now. Or at least they appear to in the literature. Study after study shows fabulous new ways to more efficiently and more cheaply remove CO2 from our atmosphere and safely tuck it away where it will do no harm. Paper after paper has

evaluated the technical difficulties, the pros and cons, the cost benefit of one sequestration technique after another.

Just as the solutions to World War II were in existence when the war began (atomic bomb theory), the solutions to the climate challenge are in existence now. It took the Manhattan project to build the bomb, and it will likely take no less to fix climate, but the solutions are already known. The evidence is circulating throughout the scholarly journals just like the evidence that the pine beetle pandemic was caused by climate change is circulating in the scholarly journals right now.

The forests will return if we act now to stabilize our climate, just like our past climate will return to allow our society to continue to prosper. Please help mankind to achieve our climate challenge goals by supporting even more aggressive actions now than popular policy requires. We need to be spending money on Earth's environment like we are spending it on our institutions that are too big to fail because, Earth is too big to fail.

Tell your friends.

References:

1) **40 Million Acres** … British Columbia Ministry of Forests Mines and Lands. http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/facts.htm
2) **USDA Forest Service Forest Health Highlights for 2010** … link
3) **Roads, powerlines** … Mountain Pine Beetle (MPB) Epidemic in Colorado and Southeastern Wyoming, USFS Fact Sheet.
4) **The Rockies have seen more than twice the average global warming**… Hotter and Drier: The West's Changed Climate, Rocky Mountain Climate Organization, February, 2008. http://www.rockymountainclimate.org/website pictures/Hotter and Drier.pdf
5) **Spread across the continent**… Risk assessment of the threat of mountain pine beetle to Canada's boreal and eastern pine forests, Canadian Forest Service, 2008. http://dsp-psd.pwgsc.gc.ca/collection_2009/nrcan/Fo143-2-417E.pdf
6) **Ecoregime change** … Gorte, Mountain pine beetles and forest destruction - effects, responses and relationship to climate change, Congressional Research Service Report R40203, February 2009. http://assets.opencrs.com/rpts/R40203_20090206.pdf
7) **Large-scale ecosystems can be irreversibly modified by climate change** … Adams, et. al, Climate induced tree mortality - Earth systems consequences, EOS, April 2010. http://www.cals.arizona.edu/research/breshears/Breshears & authors reprints/Adams et al EOS 2010.pdf
8) **Four million acres in Montana in the 1970s and 1980s** … Montana Department of Natural Resources and Conservation. http://beetles.mt.gov/Documents/FlashPresentations/MTNPineBeetleFinal.swf
9) **15 billion board feet** … Bark and Wood Boring Beetles of the World. http://www.barkbeetles.org/biocontol/mountainpinebeetle.html **37 million board feet in 1929 had dropped to 14 million in 1932.** Cowlin, R.W. 1988. Background Information About the 1930s Inventory, Federal Forest Research in the Pacific Northwest. http://www.fs.fed.us/r6/uma/publications/history/Cowlin2.pdf The Forest Situation in the Untied States, USDA Forest Service, 1932. http://www.fs.fed.us/r6/uma/publications/history/USFS1.pdf **2005 timber production in the U.S. was 51 billion board feet**… Lumber Production and Mill Stocks 2005, U.S. Census Bureau. http://www.census.gov/industry/1/ma321t05.pdf
10) **Massive simultaneous outbreaks**… Jesse A. Logan and James A. Powell, "Ecological Consequences of Climate Change Altered Forest Insect Disturbance Regimes, USDA Rocky Mountain Research Station, 2005. http://www.usu.edu/beetle/documents/Logan-Powell2005.pdf
11) **Mexico's Monarch Butterfly Preserve** … Sara Miller Llana, "Butterflies vs. Beetles", Christian Science Monitor, December 10, 2009. http://www.csmonitor.com/Environment/Wildlife/2009/1210/butterflies-versus-beetles
12) **Whitebark pine endangered species listing**…Macfarlane W.W, J. A. Logan and W.R Kern 2010. Using the Landscape Assessment System (LAS) to Assess Mountain Pine Beetle-Caused Mortality of Whitebark Pine, Greater Yellowstone Ecosystem, 2009: Project Report. Prepared for the Greater Yellowstone Coordinating Committee, Whitebark Pine Subcommittee, Jackson, Wyoming. http://docs.nrdc.org/land/files/lan_10072101a.pdf

Petition: http://www.fws.gov/mountain-prairie/species/plants/whitebarkpine/NRDCPetitionWhitebarkPine12082008.pdf
Press Release http://www.nrdc.org/media/2010/100722a.asp

13) **Saharan Grasslands changed to the Saharan Desert**… Renssen et. al., Holocene climate instability during the termination of the African humid period, Geophysical Research Letters, February 2003. http://www.astr.ucl.ac.be/users/thierry/articles/2003_Renssen_et_al_GRL.pdf
14) **Ghost forests for 40 to 50 generations** … Bentz, et. al., Climate change and bark beetles of the Western United States and Canada - Direct and indirect effects, Bioscience, September 2010.
15) **Beetle Life** … The Mountain Pine Beetle: A Synthesis of Biology, Management and Impacts on Lodgepole Pine, Canadian Forest Service, 2006.
16) **Extreme cold has vanished** … Hotter and Drier: The West's Changed Climate, Rocky Mountain Climate Organization, February, 2008. http://www.rockymountainclimate.org/website pictures/Hotter and Drier.pdf
17) **It takes just a few degrees of climate change to impact and change an ecosystem** … Thresholds of climate change in ecosystems, U.S. Geological Survey, National Oceanic and Atmospheric Administration, National Science Foundation, U.S. Department of Agriculture, U.S. Forest Service, U.S. Department of Energy and the U.S. Environmental Protection Agency, U.S. Climate Change Science Program, January 2009. http://downloads.climatescience.gov/sap/sap4-2/sap4-2-final-report-all.pdf
18) **The American West is warming twice as fast the Earth and the Rockies even faster** … Hotter and Drier: The West's Changed Climate, Rocky Mountain Climate Organization, February, 2008. http://www.rockymountainclimate.org/website pictures/Hotter and Drier.pdf
19) **Decline of world forest health:**
    a. http://earthobservatory.nasa.gov/Study/BorealThreshold/boreal_threshold.html
    b. Goetz, et. al., Satellite-observed photosynthetic trends across boreal North America associated with climate and fire disturbance. PNAS, 2005.
    c. Angert, et. al., Drier summers cancel out the CO2 uptake enhancement induced by warmer springs. PNAS, 2005.
20) **Trees are dieing twice as fast as they were 20 to 25 years ago** … Mantgem, et. al., Widespread increase of tree mortality rates in the western United States, Science, January 2009. http://library.eri.nau.edu/gsdl/collect/erilibra/index/assoc/HASH011d/a4f5ae2b.dir/doc.pdf
21) **CO2 is changing 14,000 times faster than the long-term average for the last 610,000 million years** … Zeebe, Richard E., and Ken Caldeira. Close mass balance of long-term carbon fluxes from ice-core CO2 and ocean chemistry records. Nature Geoscience, Advance Online Publication, April 27, 2008. Press Release: http://www.hawaii.edu/news/article.php?aId=2272
22) **The last CO2 increased this fast was 65 milion years ago when a giant asteroid** … Hansen, Bjerknes Lecture, Presentation to the annual meeting of the American Geophysical Union, December 2008. http://www.columbia.edu/~jeh1/mailings/
23) **Average Earth temperature within 1.25 degrees of being the warmest in 1.35 million years**… Hansen, et. al. Global temperature change, Proceedings of the National Academy of Sciences, September, 2006. http://www.pnas.org/content/103/39/14288.full
24) **This is the defining moment**… Pachauri, New York Times Interview, "U.N. Report Describes Risks of Inaction on Climate Change", U.N. Report Describes Risks of Inaction on

Climate Change, November 17, 2007.
http://www.nytimes.com/2007/11/18/world/europe/18iht-climate.2.8378031.html

25) **The American West is warming twice as fast the Earth and the Rockies even faster** … **Rocky Mountain Climate Organization** … Hotter and Drier: The West's Changed Climate, Rocky Mountain Climate Organization, February, 2008. http://www.rockymountainclimate.org/website pictures/Hotter and Drier.pdf
26) **Major droughts will double** … Characterizing changes in drought risk for the United States from climate change, Geophysical Research Letters, December 2010. http://iopscience.iop.org/1748-9326/5/4/044012/fulltext
27) **Wyoming drought will be nearly continuous** … Wyoming Climate Atlas, http://www.wrds.uwyo.edu/sco/climateatlas/drought.html and Strzepek, et.al.
28) **Mind-boggling heat** … Diffenbaugh and Ashfaq, Intensification of hot extremes in the United States, Geophysical Research Letters, July 2010. http://www.stanford.edu/~omramom/Diffenbaugh_GRL_10.pdf
29) **CO2 emissions are worse than the worst-case scenario developed by the IPCC** … Synthesis Report, Climate Change, Global Risks, Challenges and Decisions, Climate Change Congress, International Alliance of Research Universities, University of Copenhagen, March 2009. http://climatecongress.ku.dk/pdf/synthesisreport, Raupach, et. al., Global and regional drivers of accelerating CO2 emissions, PNAS, April 2007. http://www.pnas.org/content/104/24/10288.full.pdf+html, IPCC Special Report on Emissions Scenarios http://www.ipcc.ch/ipccreports/sres/emission/index.htm
30) **Arctic Sea Ice Crash** …
Haas et. al., Reduced ice thickness in Arctic Transpolar Drift favors rapid ice retreat, Geophysical Research Letters, Sept 2008. http://www.agu.org/pubs/crossref/2008/2008GL034457.shtml
Maslowski, Ebb and Flow Arctic Sea Ice, Challenges, Arctic Regions Supercomputing Center, April 2008. http://www.arsc.edu/challenges/2008/ice_cover.html
Maslowski, Fresh Nor Conference in NUUK, August 2009. http://www.dmi.dk/dmi/handout_freshnor_4.pdf
Stroeve, et. al., Arctic Sea Ice Extent: Decline Faster than Forecast, American Geophysical Letters, 2007. http://www.ualberta.ca/~eec/Stroeve2007.pdf
October 2010, National Snow and Ice Data Center. http://nsidc.org/arcticseaicenews/2010/100410.html
31) **Greenland melt quadrupled, Antarctica not supposed to melt for 100 Years** … Velicogna, Increasing rates of ice mass loss from the Greenland and Antarctic ice sheets revealed by GRACE, Geophysical Research Letters, October 2009. http://www.agu.org/journals/ABS/2009/2009GL040222.shtml , **NASA** http://www.nasa.gov/topics/earth/features/20100108_Is_Antarctica_Melting.html, Rignot, et. al., Change in the Velocity structure of the Greenland Ice Sheet, Science, February 2006. http://www.sciencemag.org/content/311/5763/986.abstract , Velicogna, Increasing rates of ice mass loss from the Greenland and Antarctic ice sheets revealed by GRACE, Geophysical Research Letters, October 2009. http://www.agu.org/journals/ABS/2009/2009GL040222.shtml , Intergovernmental Panel on Climate Change, Third Assessment Report, Working Group I, The Scientific Basis, 2001.

32) **Feedback - Carbon Sink to Carbon Source** … Kurz, et. al., Mountain pine beetle and forest carbon feedback to climate change, Nature, April 2008. http://www.nature.com/nature/journal/v452/n7190/full/nature06777.html
33) **Forest will emit carbon at least three gerneations into the future** … Dymond, et. al., Preliminary assessments of climate change impacts on the carbon balance of British Columbia's forest ecosystems, British Columbia Ministry of Forests, Natural Resources Canada, Annual Report for FSP project F100212, May 2010. http://www.for.gov.bc.ca/hfd/library/FIA/2010/FSP_F100212a.pdf
34) **Boreal Forest Carbon** … Carlson, et. al., The Carbon the World Forgot, Conserving the Capacity of Canada's Boreal Forest Region to Mitigate and Adapt to Climate Change, Canadian Boreal Initiatives, 2009. Website: http://www.borealbirds.org/carbonreport.shtml Full Report http://www.borealbirds.org/resources/carbon/report-full.pdf
35) **Four million acres** … Forest Health Conditions, Rocky Mountain Region, US Forest Service and Colorado Stae Forest Service, January 21, 2010. Link
36) **Double the warming is already in the "pipeline"**…Hansen et. al., Target atmospheric CO2: Where should humanity aim, Open Atmospheric Science Journal, August 2008. http://earth.geology.yale.edu/~mp364/data/2008 Hansen.pdf
37) **The top ten feet of ocean hold as much heat as our entire atmosphere** … Hansen, et. al., Earth's Energy Imbalance: Confirmation and Implications, Science, June 2005. http://pubs.giss.nasa.gov/abstracts/2005/Hansen_etal_1.html
38) **Climate Lag 30 years** to a century – It takes a third of a century for two thirds of the heat from global warming to be absorbed by the oceans. Hansen, et. al., Earth's Energy Imbalance: Confirmation and Implications, Science, June 2005. http://pubs.giss.nasa.gov/abstracts/2005/Hansen_etal_1.html
39) **CO2 is changing 14,000 times faster than the long-term average for the last 610,000 million years** … Zeebe, Richard E., and Ken Caldeira. Close mass balance of long-term carbon fluxes from ice-core CO2 and ocean chemistry records. Nature Geoscience, Advance Online Publication, April 27, 2008. Press Release: http://www.hawaii.edu/news/article.php?aId=2272
40) **CO2 emissions are worse than the worst-case scenario developed by the IPCC**: Synthesis Report, Climate Change, Global Risks, Challenges and Decisions, Climate Change Congress, International Alliance of Research Universities, University of Copenhagen, March 2009. http://climatecongress.ku.dk/pdf/synthesisreport Raupach, et. al., Global and regional drivers of accelerating CO2 emissions, PNAS, April 2007. http://www.pnas.org/content/104/24/10288.full.pdf+html IPCC Special Report on Emissions Scenarios, http://www.ipcc.ch/ipccreports/sres/emission/index.htm
41) **Five degrees of warming even with aggressive emissions controls** … Van Vuuren, et. al., Temperature increases of 21st century mitigation scenarios, PNAS, October 2008. http://www.pnas.org/content/105/40/15258.full
42) **We could likely have already passed the threshold of dangerous climate change** … Morrigan_2010_Target Atmospheric GHG Concentrations Why Humanity Should Aim for 350 ppm CO2e University of Cal Santa Barbara. http://www.global.ucsb.edu/climateproject/papers/pdf/Morrigan_2010_Target%20Atmospheric%20GHG%20Concentrations.pdf

Ramanthan, On avoiding dangerous anthropogenic interference with the climate system: Formidable challenges ahead, Proceedings of the National Academy of Science of the Untied States of America, 2008. http://www.pnas.org/content/105/38/14245.full.pdf+html
Hansen et. al., Target Atmospheric CO2 Where Should Humanity Aim Open Atmospheric Science Journal, NASA, November 2008.
http://pubs.giss.nasa.gov/abstracts/2008/Hansen_etal.html

43) **Dunning – Kruger Effect** … Kruger and Dunning, Unskilled and Unaware of it How difficulties in recognizing ones own, Journal of Personality and Social Psychology, 1999, Psychology 2009. Link
44) **Cal Wettstein, U.S. Forest Service Incident Commander** … FORESTS: How pine bark beetles created an elaborate and deadly mess, Dina Fine Maron, E&E News, October 28, 2010. http://www.eenews.net/public/climatewire/2010/10/28/1 from Forest and Insect Disease Conditions in the United States, 2009, U.S. Forest Service. The Billings Gazette, June 17, 2010. http://billingsgazette.com/news/state-and-regional/wyoming/article_06b2910a-7a41-11df-98ba-001cc4c03286.html
45) **Virtually no regeneration of boreal forests** … Payette, et. al., Spatially Explicit Fire-Climate History of the Boreal Forest-Tundra (Eastern Canada) Over the Last 2000 Years. http://rstb.royalsocietypublishing.org/content/363/1501/2299.full
46) **Northern Alberta is the transition to the boreal forest** … "North America Faces Beetle Plaugue", BBC, June 30, 2009.http://news.bbc.co.uk/2/hi/science/nature/8126663.stm and "Bark Beetles Kill Millions of Acres of Trees in West", New York Times, November 17, 2008. http://www.nytimes.com/2008/11/18/science/18trees.html?pagewanted=all
47) **Mean annual temeparture for Big Bend National Park and Fraser Experimental Forest** … Big Bend Link, Fraser: http://www.fs.fed.us/rmrs/experimental-forests/fraser-experimental-forest/
48) **Higher elevations are more sensitive, 85 to 90 percent of species will lose suitable habitat** … Engler et. al., 21st century climate change threatens mountain flora unequally across Europe, Global Change Biology, January 2011. Link
49) **These thought processes consciously and subconsciously guide our understanding of climate** … Hulme, *Why We Disagree About Climate: Understanding Controversy, Inaction and Opportunity*, Cambridge University Press, 2009.
50) **Journalists do not have enough knowledge** … Anderegg, et. al., Expert Credibility in climate change, PNAS April 2010. http://www.pnas.org/content/107/27/12107.full
51) **Fewer and fewer Americans see solid evidence for global warming** … Wide Partisan Divide on Energy Policies, Pew Center Survey, October 2010.
http://pewresearch.org/pubs/1780/poll-global-warming-scientists-energy-policies-offshore-drilling-tea-party
Dunlap and McCright, A Widening Gap: Republican and Democratic Views on Climate Change, http://www.environmentmagazine.org/Archives/Back Issues/September-October 2008/dunlap-full.html
52) Among climate scientists, 97 to 98 percent support the tenets of the IPCC concerning the validity, risks and urgency of the climate change issue … Anderegg, et. al., Expert Credibility in climate change, PNAS April 2010.
http://www.pnas.org/content/107/27/12107.full
53) **Vested interests propaganda and war chest funding of negative information and disinformation** … Oreskes and Conway, Merchants of Doubt: How a Handful of Scientists

Obscured the Truth on Issues from Tobacco Smoke to Global Warming, Bloomsbury Press, 2010.

54) **Forest Service views, over the last three to five years have started to lay majority of blame squarely on climate change** … Bentz, Western U.S. Bark Beetles and Climate Change, U.S. Department of Agriculture, Forest Service, Climate Change Resource Center, 2008. http://www.fs.fed.us/ccrc/topics/bark-beetles.shtml

55) **U.S. Forest Service says future forest based on past knowledge** … U.S. Forest Service Rocky Mountain Bark Beetle Website, Our Future Forest (Link)

56) **It is "virtually certain" that global warming will increase insect outbreaks in forests** … IPCC, 2007: Climate Change 2007: Synthesis Report, Summary for Policy makers, World Meteorological Organization, Geneva, Switzerland. Cambridge University Press, Cambridge, UK, page 13. http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm

57) **One-hundred thousand trees are falling each day** … FORESTS: How pine bark beetles created an elaborate and deadly mess, Dina Fine Maron, E&E News, October 28, 2010. http://www.eenews.net/public/climatewire/2010/10/28/1 from Forest and Insect Disease Conditions in the United States, 2009, U.S. Forest Service. The Billings Gazette, June 17, 2010. http://billingsgazette.com/news/state-and-regional/wyoming/article_06b2910a-7a41-11df-98ba-001cc4c03286.html

58) **Approaching continental scale** … Jesse A. Logan and James A. Powell, "Ecological Consequences of Climate Change Altered Forest Insect Disturbance Regimes, USDA Rocky Mountain Research Station, 2005. http://www.usu.edu/beetle/documents/Logan-Powell2005.pdf and Wagner, *Climate Warming in Western North America: Evidence and Environmental Effects*, University of Utah Press, 2009. http://content.lib.utah.edu/cdm4/item_viewer.php?CISOROOT=/upcat&CISOPTR=1198&CISOBOX=1&REC=20

59) **Tree migration assistance** … Johnson et. al., Climate change impacts and adaptation strategies for the forest sector in Canada, Saskatchewan Research Council, Canadian Forest Service, May 2009. www.for.gov.bc.ca/hre/forgen/interior/SCV444.pdf

60) **Average temperatures for the U.S. and the world** … National Climatic Data Center. http://www.ncdc.noaa.gov/temp-and-precip/maps.php?ts=3&year=2010&month=2&imgs[]=Nationaltrank&submitted=Submit http://www.ncdc.noaa.gov/sotc/global/

61) **Arctic Amplification: How the Arctic warms so much more rapidly than the rest of the world** … Serreze, et .al., The emergence of surface based Arctic amplification, The Cryosphere Discussion, February 2009. http://www.the-cryosphere.net/3/11/2009/tc-3-11-2009.pdf

The Beaufort High … Li, et. al., Changes to the North Atlantic Subtropical High and Its Role in the Intensification of Summer Rainfall Variability in the Southeastern United States, Journal of Climate, October 2010.

Duke Press Release: http://www.nicholas.duke.edu/news/increasingly-variable-summer-rainfall-in-southeast-linked-to-climate-change

The Winter of 2005-6 recreated by climate models … Petoukhov and Semenov, A link between reduced Barents-Kara sea ice and cold winter extremes over northern continents,

Journal of Geophysical Research, November 2010.
http://www.agu.org/pubs/crossref/2010/2009JD013568.shtml

62) **Most of these consequences are not accounted for in climate change models** … Kliejunas, et. al., Review of Literature on Climate Change and Forest Diseases of Western North America, U.S. Forest Service, PSW-GTE-225, October 2009. Link
63) **Reports of tree mortality from around the world have increased in the past decade** … Adams, et. al, Climate induced tree mortality - Earth systems consequences, EOS, April 2010.
http://ag.arizona.edu/research/breshears/Breshears%20&%20authors%20reprints/Adams%20et%20al%20EOS%202010.pdf
64) **Demonstrated a low sensitivity of our forests to temperature change** … Adams, et. al., Temperature sensitivity of drought-induced tree mortality portends increased regional die-off under global change type drought, PNAS, April 2009.
http://www.pnas.org/content/106/38/E107.full
65) **Globally** … Allen et al., A global overview of drought and heat-induced tree mortality reveals emerging climate change risk for forests, Forest and Ecology Management, September 2010. Link
66) **Two 100-year droughts in a row in the Amazon kill billions of trees** … Lewis et. al., The 2010 Amazon Drought, Science, February, 2011.
http://www.sciencemag.org/content/331/6017/554.abstract.
Press Release: http://www.leeds.ac.uk/news/article/1466/
Guardian Article, February 3, 2011:
http://www.guardian.co.uk/environment/2011/feb/03/tree-deaths-amazon-climate
67) **The Boreal Forest at risk extends for 4.2 billion acres around the top of the globe** …Canada's Boreal Forest, Part of the Global Climate Change Solution, Canadian Boreal Initiative, Natural Resources Defense Council, ForestEthics, Boreal Songbird Initiative, Canadian Parks and Wilderness Society and the International Boreal Conservation Campaign. Link Russia's Boreal Forest, World Wildlife Fund.
http://www.assets.panda.org/downloads/russia_forest_cc_final_13nov07.pdf
68) **Almost twice as much carbon is stored in the forests and soils of the boreal forest as is in the tropical forests of the world** … Carlson, et. al., The Carbon the World Forgot: Conserving the Capacity of Canada's Boreal Forest Region to Mitigate and Adapt to Climate Change. Boreal Songbird Initiative and Canadian Boreal Initiative, Seattle, WA, and Ottawa. 33 pp. http://www.borealbirds.org/resources/carbon/report-full.pdf
69) **Underrepresented in the latest IPCC report** … Allen et al., A global overview of drought and heat-induced tree mortality reveals emerging climate change risk for forests, Forest and Ecology Management, September 2010. Link
70) **Warming in the Pipeline** … IPCC, 2007: Climate Change 2007: Synthesis Report, Summary for Policy makers, World Meteorological Organization, Geneva, Switzerland. Cambridge University Press, Cambridge, UK., page 8. The warming shown considers the worst case for the given scenario because of Raupach (reference 29) and Van Vuurren (reference 41.)
http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm
71) **Extremely slim chance of holding to 2 degrees C** … New et. al., Four degrees and beyond: the potential for a global temperature increase of four degrees and its implications,

Philosophical Transactions of the Royal Society, December, 2010. http://rsta.royalsocietypublishing.org/content/369/1934/6.full

72) **The Venus Syndrome** … James Hansen, Bjerknes Lecture, American Geophysical Union Annual Meeting, San Francisco, December 2008. http://www.columbia.edu/~jeh1/presentations.shtml

73) **Tax rates are the lowest since the Great Depression / Deficit to GDP ratio is nowhere near WWII** … Reference: Personal exemptions and individual income tax rates, 1913-2002 (Rev. 6-02), in Internal Revenue Service, Statistics of Income Bulletin (Publication 1136), Spring 2002, pp. 216-225. http://www.irs.gov/pub/irs-soi/02inpetr.pdf and www.usgovernmentspending.com