Where to Tan and Buy Beach Property: An Overview on Global Warming

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We are at the dawn of the upcoming Paris Conference of Parties (COP21) meeting where the world comes together and debates and tries and craft solutions to imminent climate change. http://www.cop21paris.org/

Climate Change

- Science and Society
- Temperature and Climate Forcings
  - Past, Recent and Trends,
- Trends in Bio-indicators
- Future Projections
  - Role of Climate Change on Ecosystem Disturbance
    - Hurricanes
    - Sea-Level Rise

COP 21- Paris

- In 2015 **COP21, also known as the 2015 Paris Climate Conference,** will, for the first time in over 20 years of UN negotiations, aim to achieve a legally binding and universal agreement on climate, with the aim of keeping global warming below 2°C.

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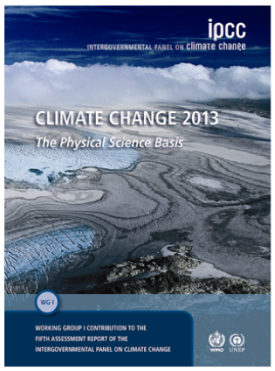
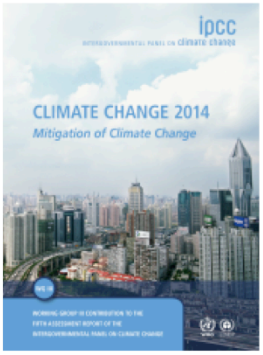
The international political response to climate change began at the Rio Earth Summit in 1992, where the 'Rio Convention' included the adoption of the UN Framework on Climate Change (UNFCCC). This convention set out a framework for action aimed at stabilising atmospheric concentrations of greenhouse gases (GHGs) to avoid "dangerous anthropogenic interference with the climate system." The UNFCCC which entered into force on 21 March 1994, now has a near-universal membership of 195 parties.

The main objective of the annual Conference of Parties (COP) is to review the Convention's implementation. The first COP took place in Berlin in 1995 and significant meetings since then have included COP3 where the Kyoto Protocol was adopted, COP11 where the Montreal Action Plan was produced, COP15 in Copenhagen where an agreement to success Kyoto Protocol was unfortunately not realised and COP17 in Durban where the Green Climate Fund was created.

Newest IPCC Reports Released





http://www.ipcc.ch/report/ar5/

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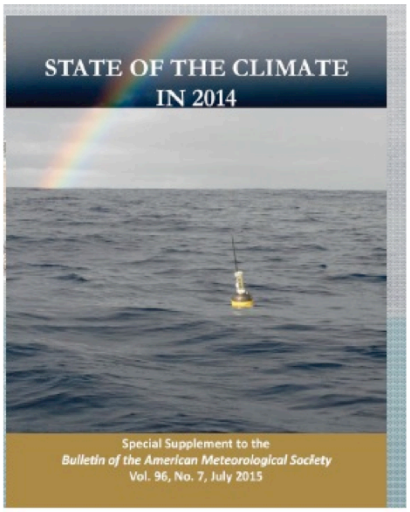
2014 launched the most recent, 5th Assessment Report (AR5) from the Intergovernmental Panel on Climate Change, AR5. These reports are available on line. They have been written by hundreds of scientists from across the globe and have garnered thousands of comments during the review process.

Most Recent Assessment of Climate and Trends



https://www2.ametsoc.org/ams/index.cfm/publications/bulletin-of-the-american-meteorological-society-bams/state-of-the-climate/

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If you want to keep up on the trends on climate, each year the American Meteorological Society has been publishing a special supplement to the Bulletin of the American Meteorological Society. One of the best, most comprehensive and thorough updates by the world's experts on this topic.

Do you Believe in Global Warming?

Global Warming is not an Ecclesiastical issue of Belief
(To the Contrary, one may chose to believe in Santa Claus, the Easter Bunny or God)

How one Decides whether Climate Change is Occurring, and is Possible, is based
the Scientific Method, and the Laws of Physics, Chemistry and Biology that have been derived.

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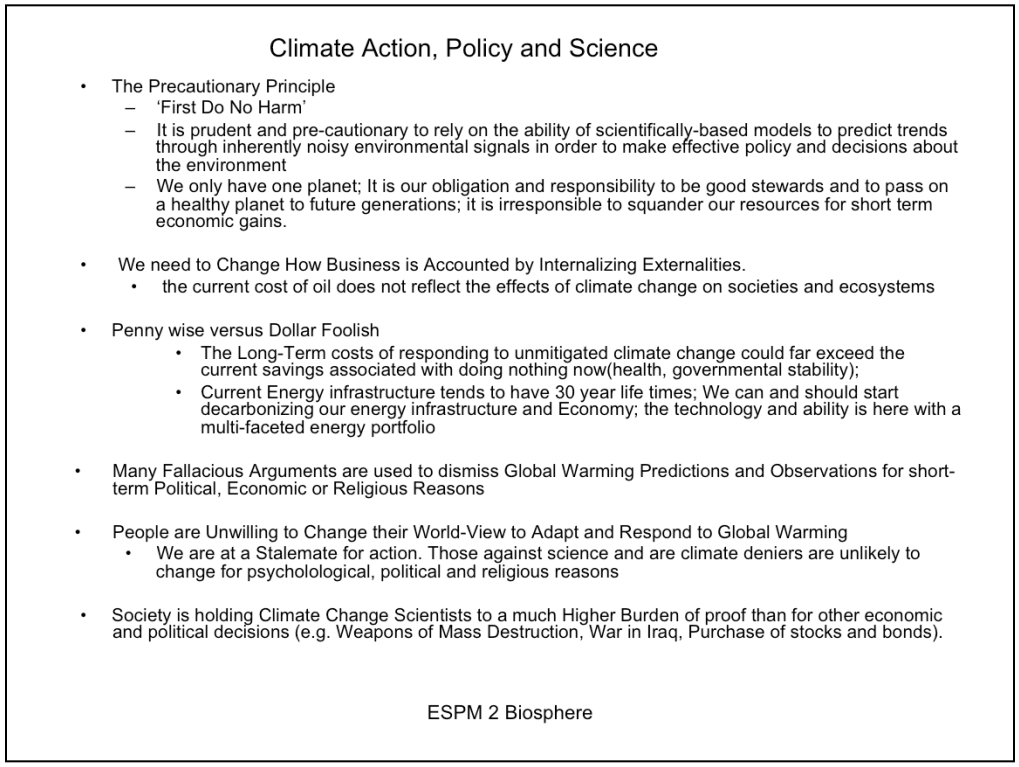
Too often the conversation starts with 'do you believe in global warming? Global Warming and climate change is not a religious issue. Our knowledge of Climate change is based on the scientific method, which uses experimentation, theory and the testing and falsification of hypotheses to advance our knowledge.

Science is Not Democratic. Hypotheses are Rejected and Accepted based on observation and test and falsification theoretical principles, not votes

Hence, constructive criticism and reasonable skepticism is already integrated into the scientific process.

But it is transparent, anyone has access to do science.

It is true that models we use are not perfect and they depend upon the knowledge and assumptions we have. But we have falsified the null hypothesis



The issue of climate change has been over politicized. As a result the world has been too slow to respond and change to the slow and chronic warming of the planet, with the emissions of greenhouse gases from fossil fuel combustion. If we keep business as usual we will soon approach a tipping point. In the medical field. Doctors adopt the precautionary principle, 'do no harm'. Unfortunately, we have been unable to convince society to do the same. Problem is complicated by a society that remains willfully scientifically illiterate and is bombarded with mis information from vested interests of the status quo and the fossil fuel industry.

While scientists feel inclined to be unbiased brokers of information to minimize and remove bias and conflict of interest, we also must face and consider our roles as citizens and the need for better outreach of information

Watch for and Avoid Fallacious Logic

- *Ad hominem* attack
  - Scientists and their Peer Review system are Corrupt; Skeptics claim scientists have invented global warming for the Big Bucks$$
- **Appeal to Authority**
  - Climate Skeptic claim authority because they have PhDs in Physics.
- **Appeal to Motive**
  - 'climate change is a hoax', the oil lobby and organizations funded by the Koch Bros Climate
- **An unrepresentative sample** (e.g. anecdotal evidence)
  - Claims there has been No Global Warming Trends in the past 10-15 years, which are among the Warmest on Record; its been cooler in the Midwest over the past decade (we are talking about global warming)
- **Correlation does not prove Causation**
  - Ice Age Temperature Record, Leads CO2 Changes; new data (Shakun et al Nature 2012) refutes this prior claim; CO2 leads warming during last deglaciation
- **Appeal to False Attribution**
  - Warming is a Hoax because Stolen emails referred to a 'trick' in a few emails by Climate Researchers; it was cold this winter along the East coast so global warming is not happening
- **Begging the Question**
  - CO2 concentrations are so low, 400 ppm, and such a small fraction of the atmosphere's gas burden, how can they have an impact on climate?

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It is my opinion that the climate deniers are masters at using Fallacious Logic to bolster their arguments of climate change. It is important that we apply stronger logic to this topic, and others. Hence it is worth being familiar with some of the fallacious arguments that are often used to promote indefensible theories and ideas.

http://www.unc.edu/depts/wcweb/handouts/fallacies.htm

Climate Deniers Dominate the Media Coverage with MisInformation and Fallacious Arguments

ClimateGate 'Scandal'..Example of Fallacious Logic

'You are Entitled to you own Opinion,
but not you are not entitled to your own Facts'

Senator Daniel Patrick Moynihan

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Years ago I almost dropped this lecture from this class. Al Gore and the IPCC had won the Nobel Peace Prize and Gore had just released his movie on climate change, so I felt a larger portion of the population was getting exposed to the data and message. I did not expect the political backlash that resulted. The tempo and assaults by the climate deniers increase. Hence, I retain this lecture as a preamble to the ecosystem ecology lectures on how ecosystems will respond to global change in general.

Facts, Physics and Observations

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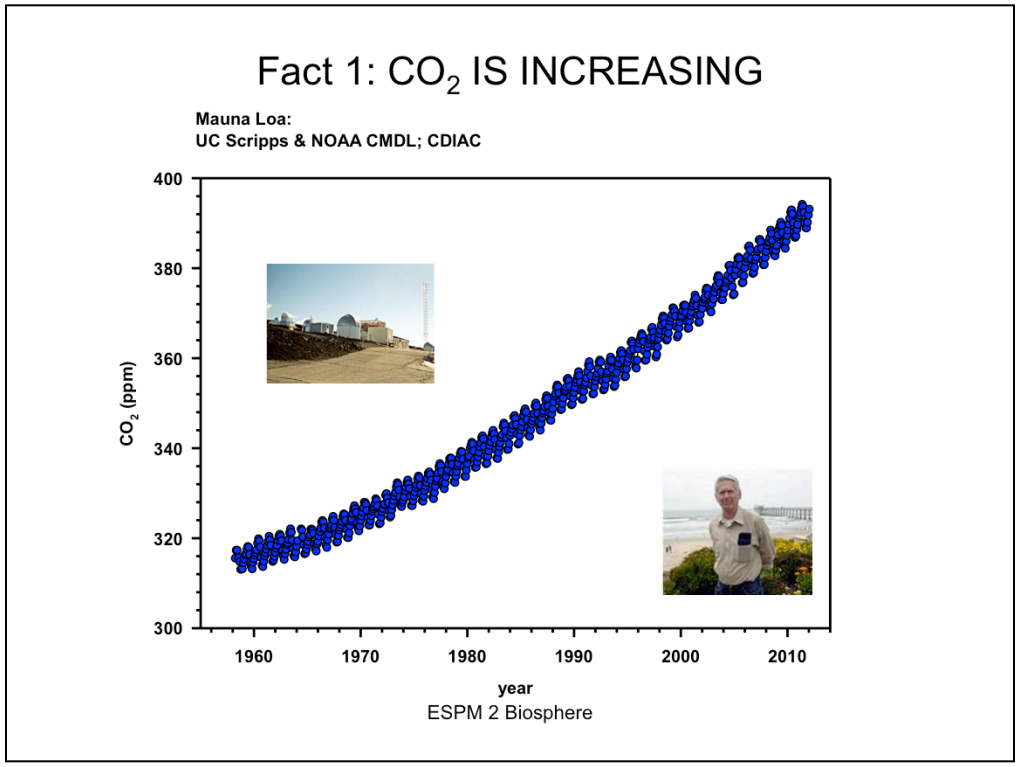
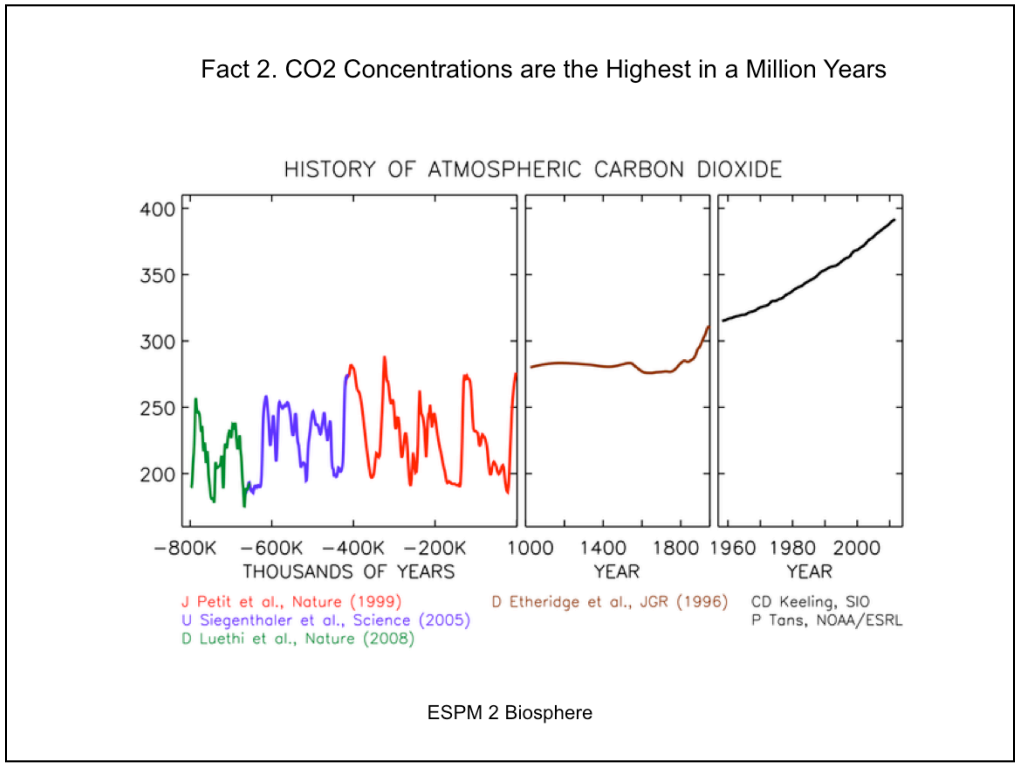
Lets step back and simply and coldly look at the evidence.



Fact 1. CO2 is increasing and is approaching 400 ppm



Fact 2. Current CO2 concentrations are the highest over the past million years. The rise started at the dawn of the Industrial Revolution

Other Arguments

If water is such a strong greenhouse gas and is so Abundant (parts per thousand), why should we worry about tiny changes in CO_2 (parts per million) CH_4 and N_2O (parts per billion)?

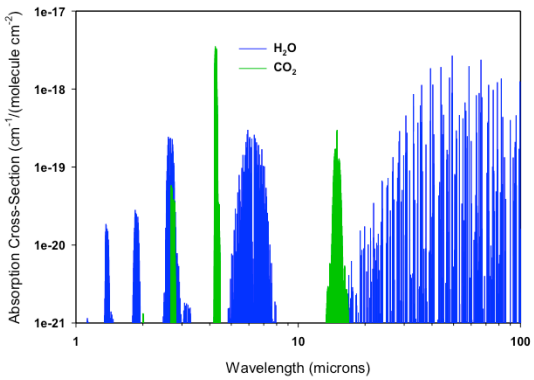
Without Greenhouse effect, Earth would be frozen and water effect would be tiny..

Water Vapor Saturates its IR Absorption Wavebands, while other Greenhouse Gases fill open Niches in infrared Spectrum

How: CO_2 Absorbs Infrared Radiation in Open IR Windows

$$I(\lambda) = I_0(\lambda)\exp(-\rho_c k(\lambda)x)$$

Infrared Absorption and Emission



Peak CO_2 Absorption Bands

4.25 μm (2349 cm^{-1})
7.2 μm (1388 cm^{-1})
14.99 μm (667 cm^{-1})

HITRAN Database

http://cfa-www.harvard.edu/HITRAN/

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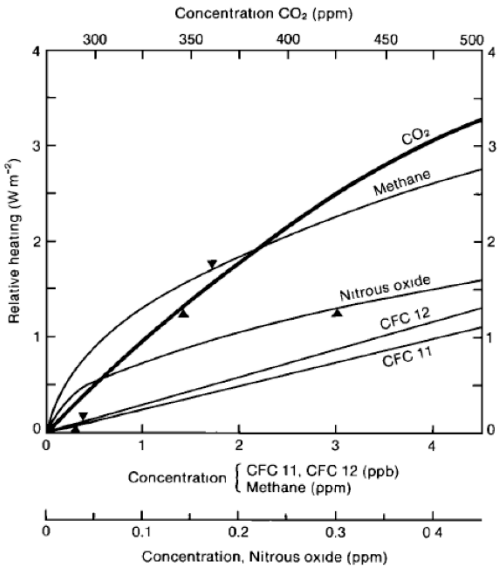
CO2 may be low in concentration, but it is a highly effective greenhouse gas. The atmosphere has an atmospheric window where long wave energy is lost to space. But the absorption spectra of CO2 corresponds with this window, so Increasing CO2 makes this window more opaque.

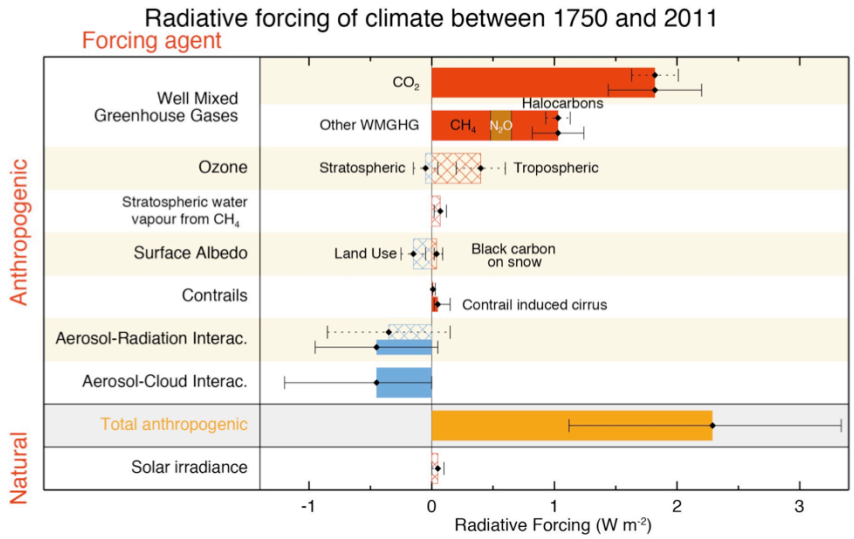
Also recognize how we measure CO2 in the atmosphere. We use infrared absorption spectroscopy. In other words, we pass infrared energy of a known, absorbing wavelength, through a tube of known length filled with gas and the amount of energy absorbed is proportional to the CO2 concentration. This is another application of Beer's Law

PolyAtomic Molecules Absorb Infrared Radiation



Mitchell, 1989 Rev Geophysics ESPM 2 Biosphere

The radiative heating of the surface as a function of CO2 and other greenhouse gases. Since the industrial age the CO2 forcing has increased from near zero W m-2 to about 2 W m-2



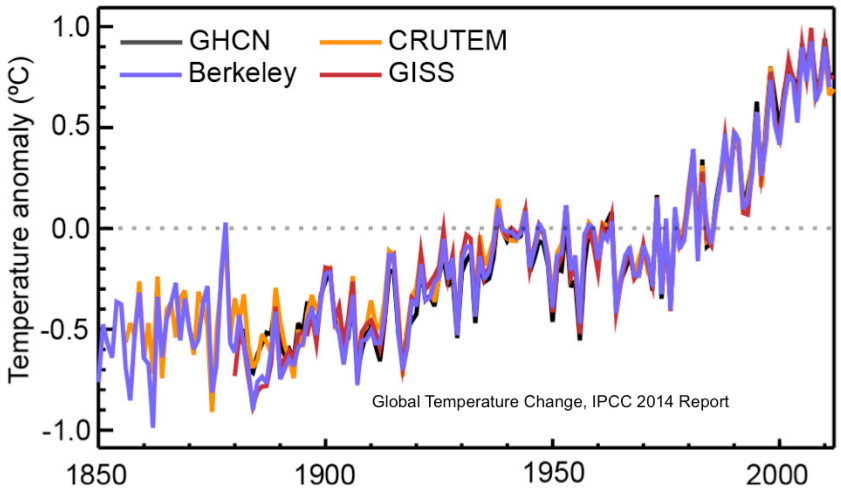
IPCC, 2013

ESPM 2 Biosphere

Radiative forcing on the climate system. Note that not all changes are Positive. Aerosols and land use change, though albedo, can be offsetting. But bottom line is that total radiative forcing is exceeding 2 W m-2

http://www.climatechange2013.org/images/figures/WGI_AR5_Fig8-15.jpg

Fact 3. Various Independent Data Sets show Global Temperature are Rising



http://www.climatechange2013.org/images/figures/WGI_AR5_Fig2-14.jpg

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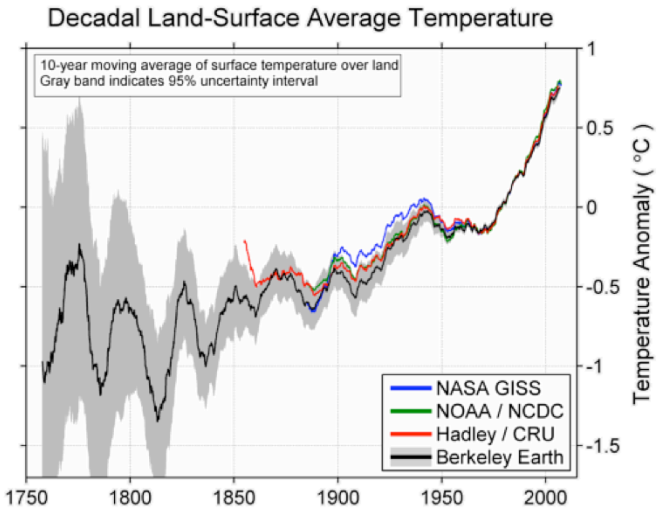
Numerous independent efforts to assess global temperatures have yielded the same results. A few years ago a group of Berkeley skeptics, with funding from the Koch Brothers, also attempted to produce an independent temperature record. What did they learn? That all the scientists were doing an excellent job with the data in hand. There was NO fudging of the records or answers to meet some preconceived expectations!



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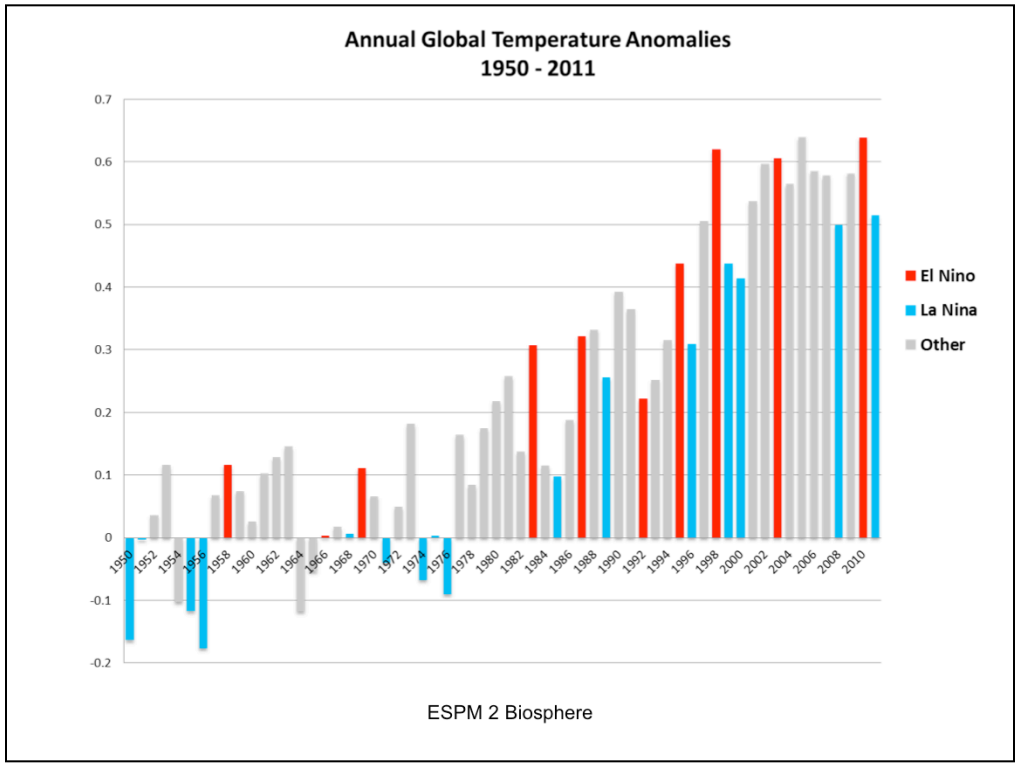
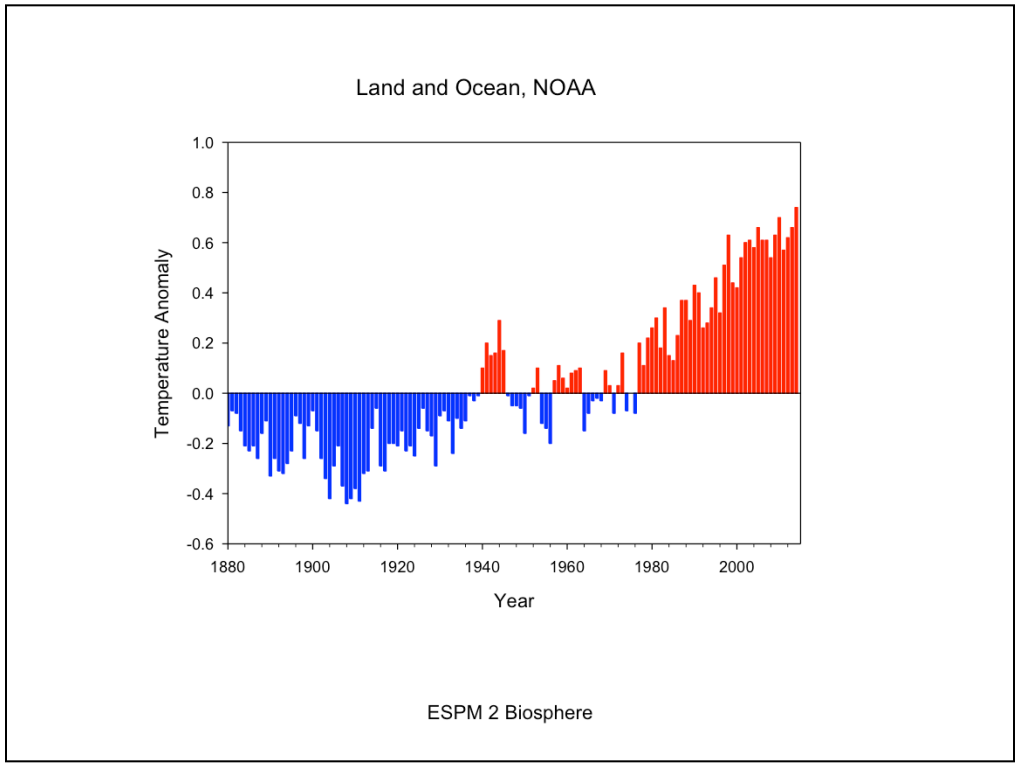
Temperature records become more uncertain as we try and reconstruct historical records before the 1850s when thermometers were commonly used across cities of the world. But the message remains the same. Over 250 years, current temperatures are the warmest

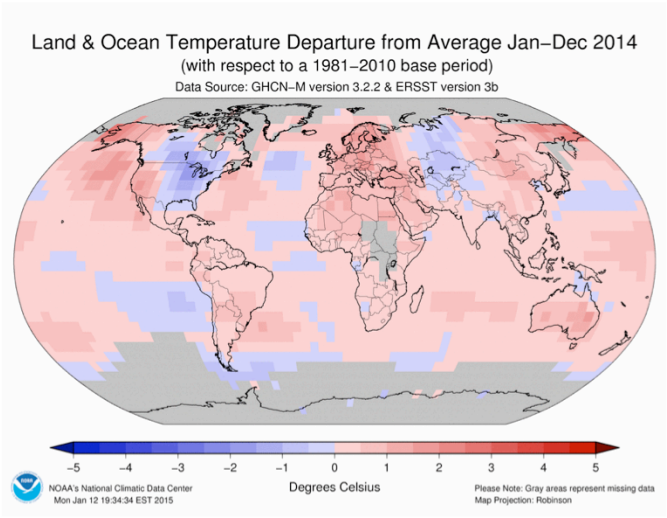


Climate deniers argue that the climate has not warmed lately. Yes there is a plateau, probably due to oceanic effects, but the most recent years remain the warmest. We also need to remember 1998 was extremely warm due to the El Nino.



Data circa 2015 from the NOAA NCDC web site. This dataset goes back to 1880. Warming has been steady since the 1980s

https://www.ncdc.noaa.gov/sotc/global/201510, through 2014!



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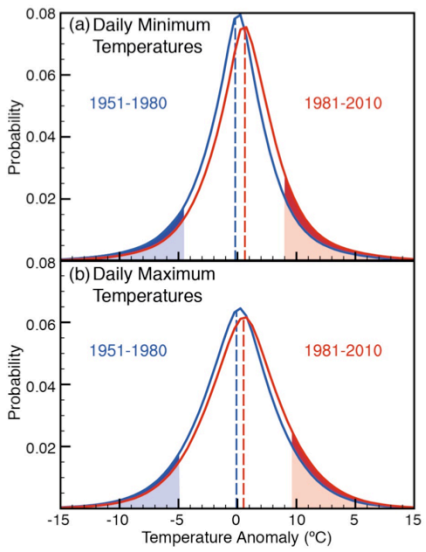
https://www.ncdc.noaa.gov/sotc/service/global/map-blended-mntp/201401-201412.gif

While 2014 was one of the warmest years on record, remember there will be warmer and cooler regions. We see pools of cool air in the eastern North American. But this in part was associated with the unprecedented heat and drought in the west. The warm blob that prevented storms from hitting the west also caused the jet stream to bring colder air down from the Arctic to the east. We also see cooler air off the coast of Greenland. Some say this may be evidence of glacial meltwater. Other cool areas are central Asia, east of the Urals. But also notice the extreme warmth of the tundra in Alaska and Siberia. This is predicted due to the ice-sea albedo feedback and is of grave concern if the permafrost begins to warm and melt.

Fact 5: Both Daily Minimum and Maximum Temperatures are Increasing



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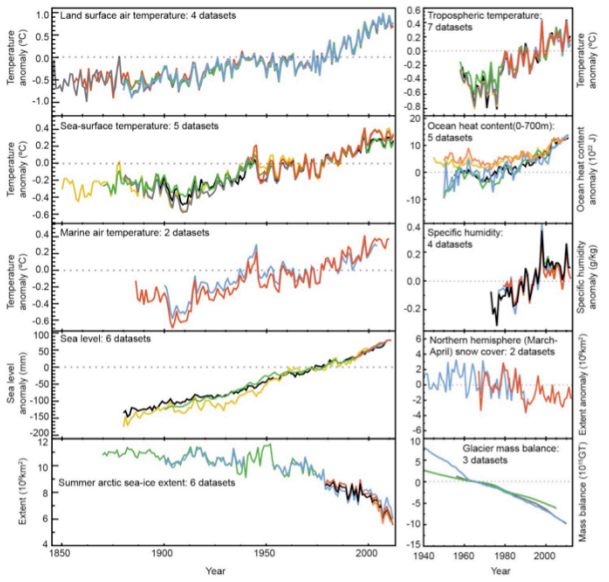
http://www.climatechange2013.org/images/figures/WGI_AR5_FigFAQ2.2-1.jpg

Fact 4. the rise in Temperature is consistent with other Climate Related Trends



Warmer Seas

Increasing Sea Level

Decreasing Polar Ice

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http://www.climatechange2013.org/images/figures/WGI_AR5_FigFAQ2.1-2.jpg

Hartmann, D.L., A.M.G. Klein Tank, M. Rusticucci, L.V. Alexander, S. Brönnimann, Y. Charabi, F.J. Dentener, E.J. Dlugokencky, D.R. Easterling, A. Kaplan, B.J. Soden, P.W. Thorne, M. Wild and P.M. Zhai, 2013: Observations: Atmosphere and Surface. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*[Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Net Shortwave Energy Into Planet Still Equals Longwave Energy Out

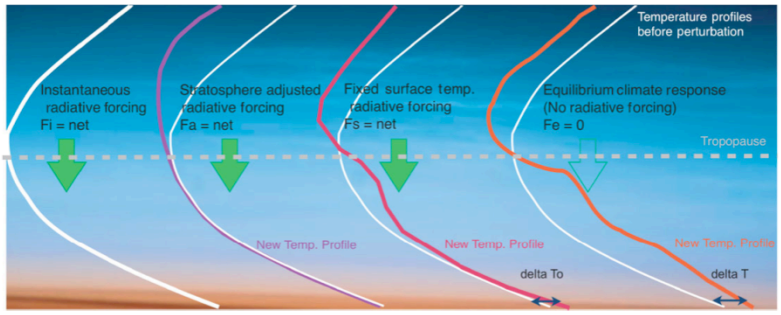


FIGURE 5 | Schematic of atmospheric temperature adjustments to radiative forcings. The conceptual framework of climate forcings and temperature profiles before (white) and after the perturbation was applied for different versions of atmosphere–ocean/land adjustments (colored lines) is shown in Figure 5. The gray dashed line illustrates the tropopause level where the various forcings are symbolized as arrows. For further information see text and also Ref 31.

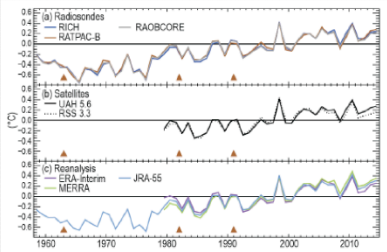
Re-Radiation of Longwave energy by Greenhouse Gases
Warms Troposphere and Cools Stratosphere

Liepert, 2010 Climate Reviews ESPM 2 Biosphere

The radiative forcing of greenhouse gases warms the surface temperature due to re radiation. The whole atmosphere does not warm because energy is conserved. Instead energy is redistributed in the vertical column of the atmosphere. So there ends up being stratospheric cooling, too.

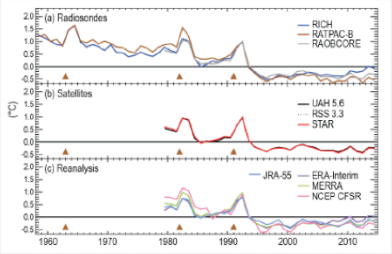
Upper Atmosphere Temperatures Followed Long-Term Trends

Lower Troposphere:
Up to ~6 miles above Earth's surface



3rd to 8th warmest in 36-year period of record, depending on dataset

Lower Stratosphere:
Layer ~7-16 miles above Earth's surface



2014 was slightly cooler than 2013. All estimates indicate below-average annual temperature

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Karl et al AMS State of Climate 2014

Area of Arctic and Greenland Ice Sheets is Decreasing

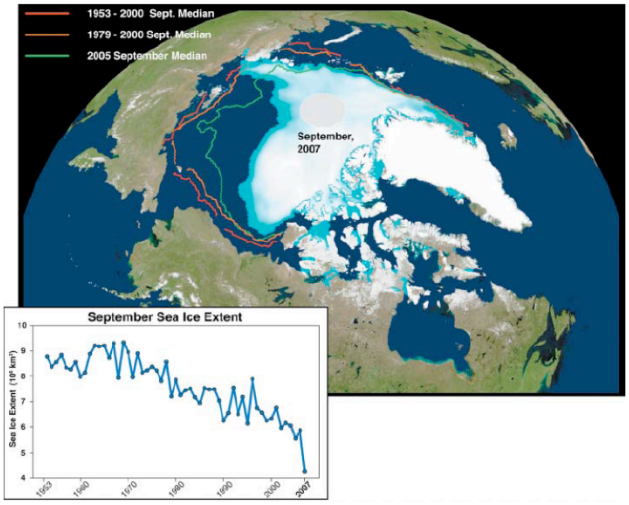

Fig. 1. Sea ice concentration for September 2007, along with Arctic Ocean median extent from 1953 to 2000 (red curve), from 1979 to 2000 (orange curve), and for September 2005 (green curve). September ice extent time series from 1953 to 2007 is shown at the bottom.

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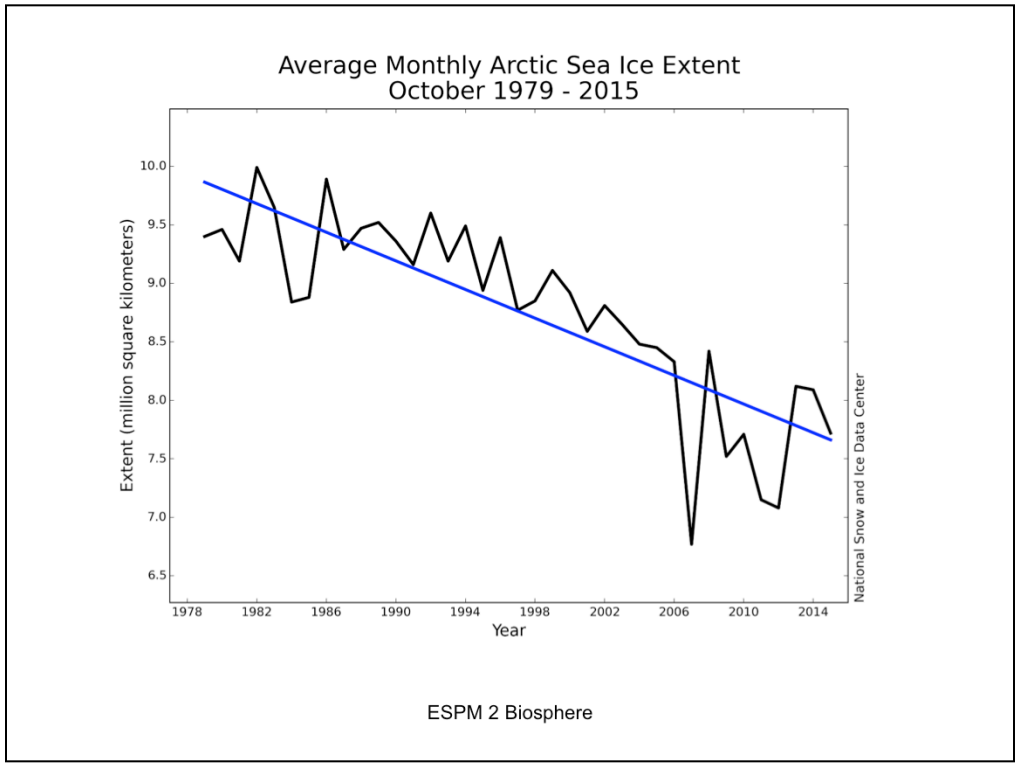
Stroeve et al 2008 EOS

Canary in the Mine are things like Sea ice. While we many not measure temperature perfectly everywhere, all the time, how do we explain the steep drop in sea ice in the Arctic.



NCDC NOAA, State of Climate 2014 AMS BAMS report

Conditional Trends in Arctic Ice

Melt Onset is Earlier

Freeze up is Later

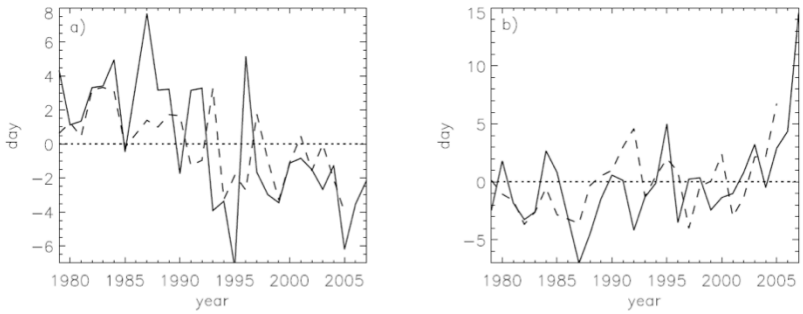


Figure 5. Anomalies of (a) melt onset and (b) freezeup from the PMW data (solid lines) and POLES data (dashed lines) for the entire Arctic.

Markus et al 2009 JGR Ocean

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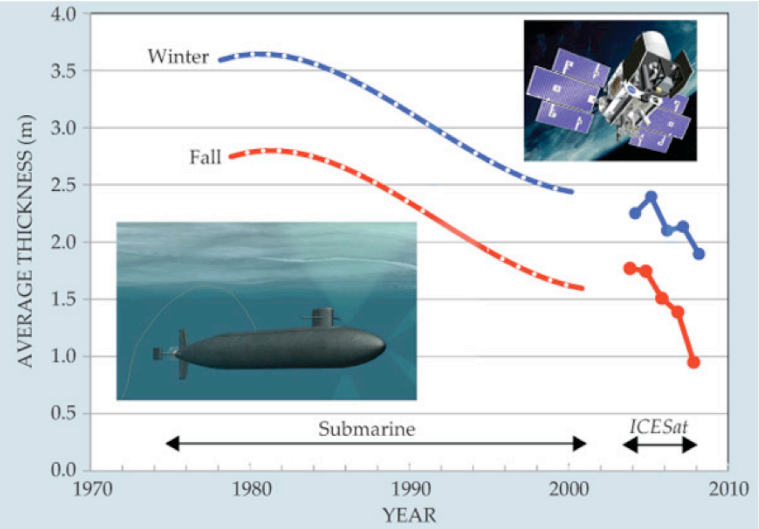
More Arctic Sea Ice Data



Kwok and Untersteiner 2011 Physics Today

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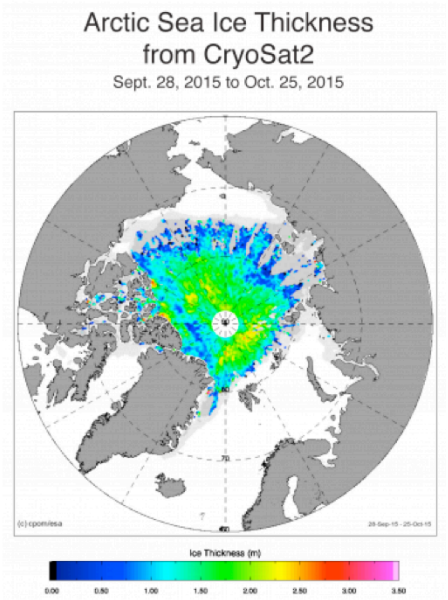

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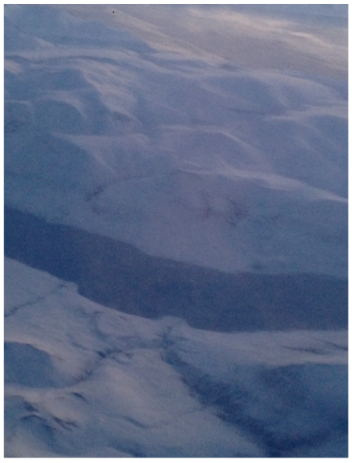
http://nsidc.org/arcticseaicenews/files/2015/11/Figure4a_-350x472.png

Rivers of Melt Water on Glaciers on Greenland, Nov 2013



Look at the Ice-Water Albedo Feedbacks

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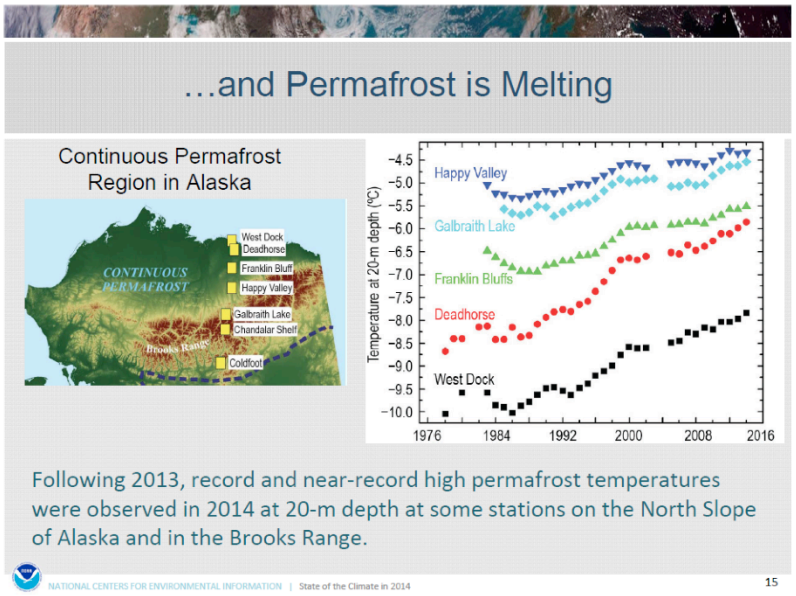
Picture took flying over Greenland this past Nov. I was astounded to see Rivers of melt water on the Glaciers. First this is a cold time of year, so there should not be liquid water and this water was surrounded by more glaciers, indicating to me a warm area.

Think about the feedback effects on ice-water albedo. Snow is white and highly reflective. Water is dark and absorbs energy, leading to a positive feedback

Greenland is Melting

http://www.nytimes.com/interactive/2015/10/27/world/greenland-is-melting-away.html



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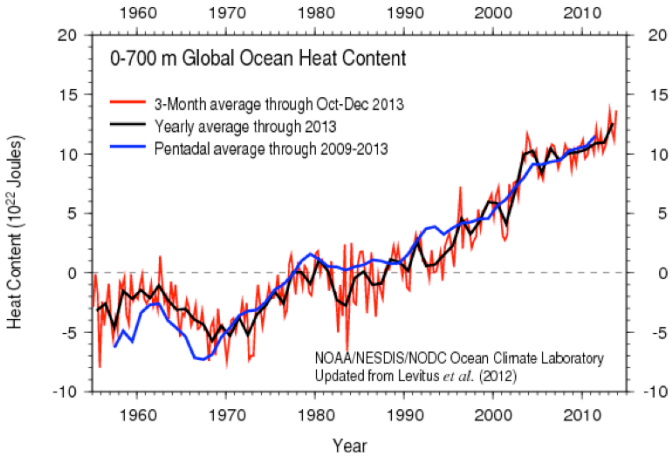
Karl et al presentation State of Climate AMS 2014

Heat Content in the Oceans is Increasing



http://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/

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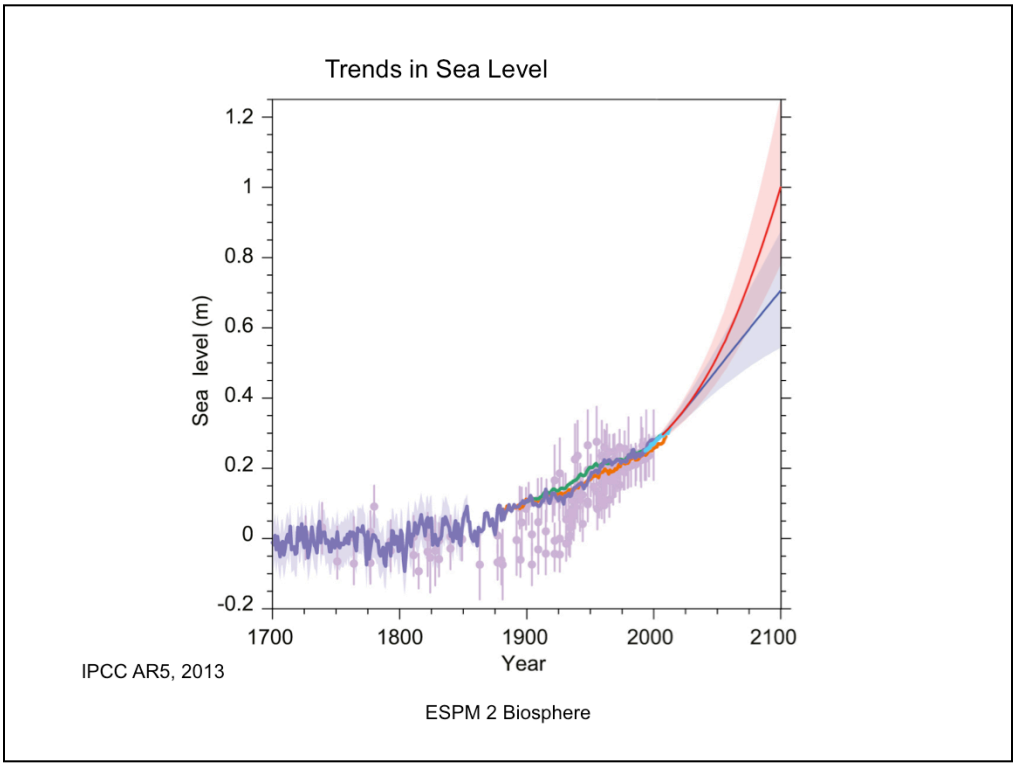
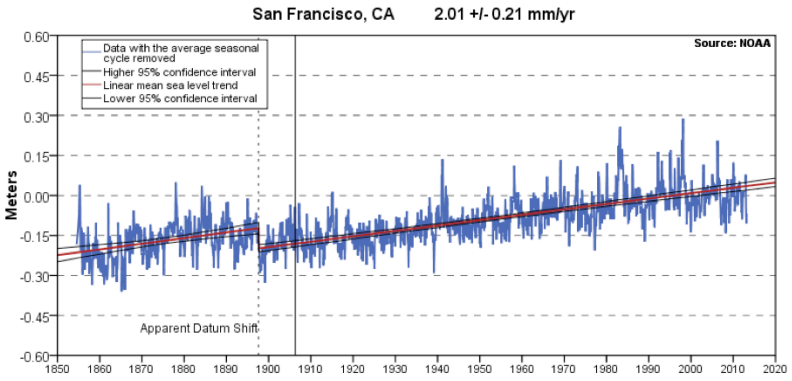
Heat capacity of the ocean is increasing, too. But it has thermal inertial
http://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/



http://www.climatechange2013.org/images/figures/WGI_AR5_Fig13-27.jpg

What's Happening Locally?:
Sea Level at Ft Point, through 2011

+ 25 cm or 10 inch since 1900



http://tidesandcurrents.noaa.gov/data_menu.shtml

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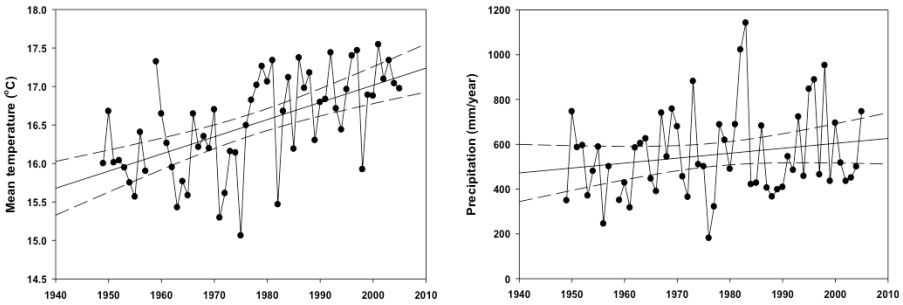
One prediction of global warming is thermal expansion of the oceans and melting ice caps, which together will cause sea level rise. Here is what is happening near home.

Climate Trends:
Pardee, CA



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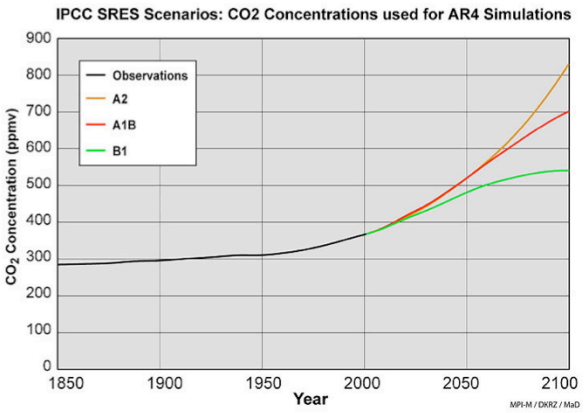
Future Conditions



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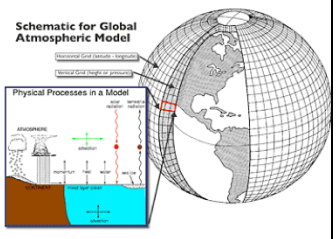
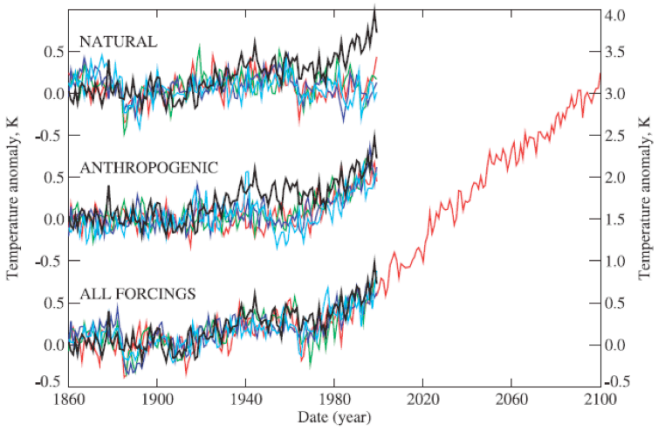
Climate Model Refinements

- Sulfate aerosols
- Transient Changes in Trace Gases
- Suite of Radiative trace gases, CO_2, H_2O, CFC, N_2O
- Coupled ocean and atmosphere
- Cloud/water vapor feedbacks
- Finer Resolution, 19 layers, 250 km grid
- Improved Land Surface schemes



Climate Models Reproduce Data Record Best when they consider Natural and Anthropogenic Forcings Together



Stott et al., 2000 Science

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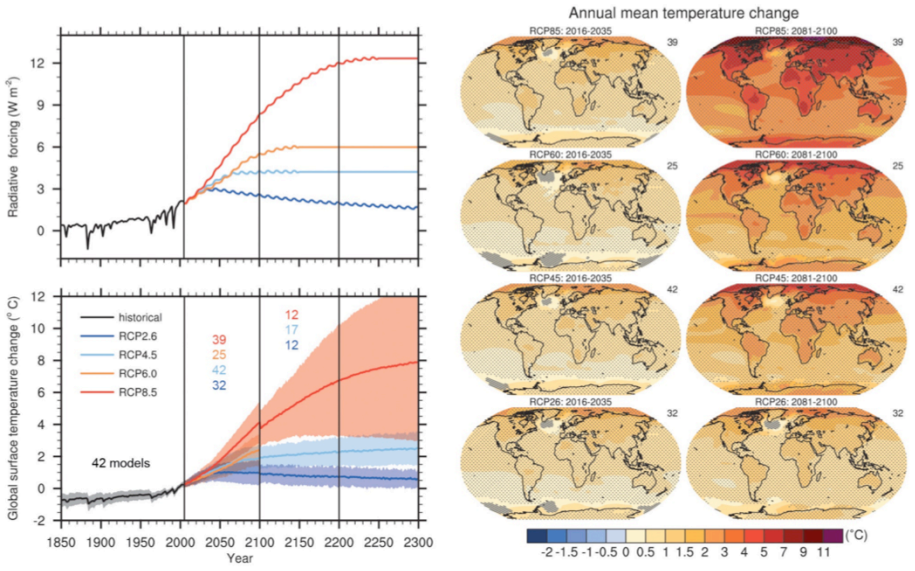
There remain lots of questions about the accuracy and representativeness of the climate models. They do a good job predicting climate, long term, global averages. They are shown to predict past and natural climate variations well and only predict future condition if they include all forcings, positive and negative



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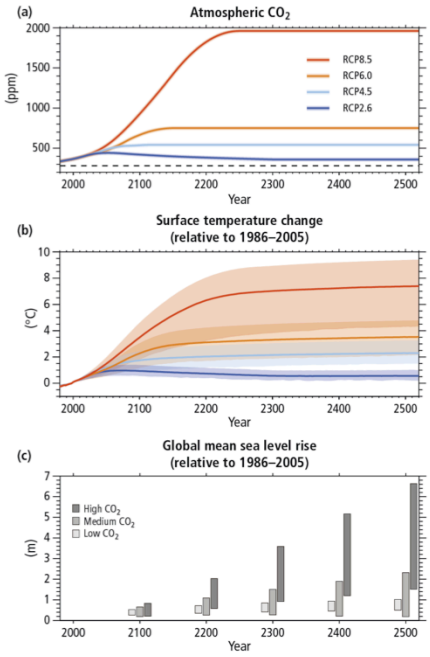
http://www.ipcc.ch/report/graphics/images/Assessment%20Reports/AR5%20-%20WG1/Technical%20Summary/FigTS-15.jpg



IPCC 2013

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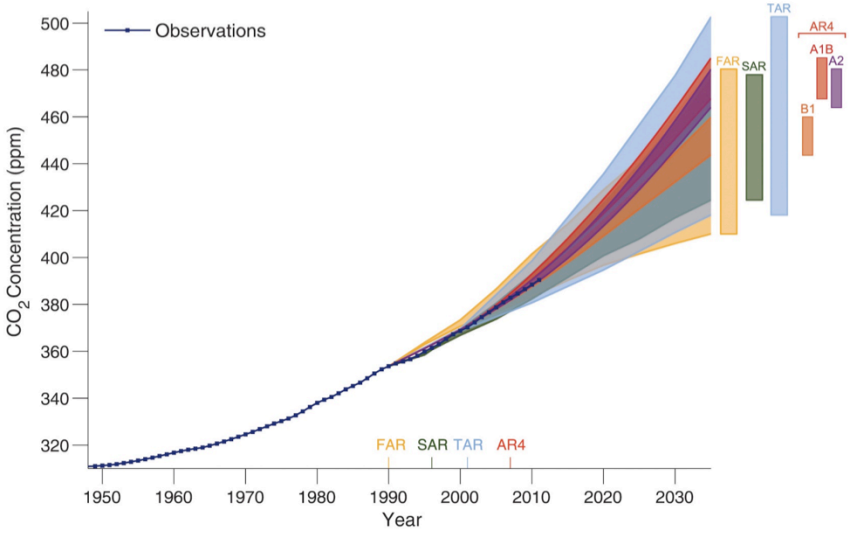
http://www.ipcc.ch/report/graphics/images/Assessment%20Reports/AR5%20-%20Synthesis%20Report/Topic%202/Fig%202.8-01.png



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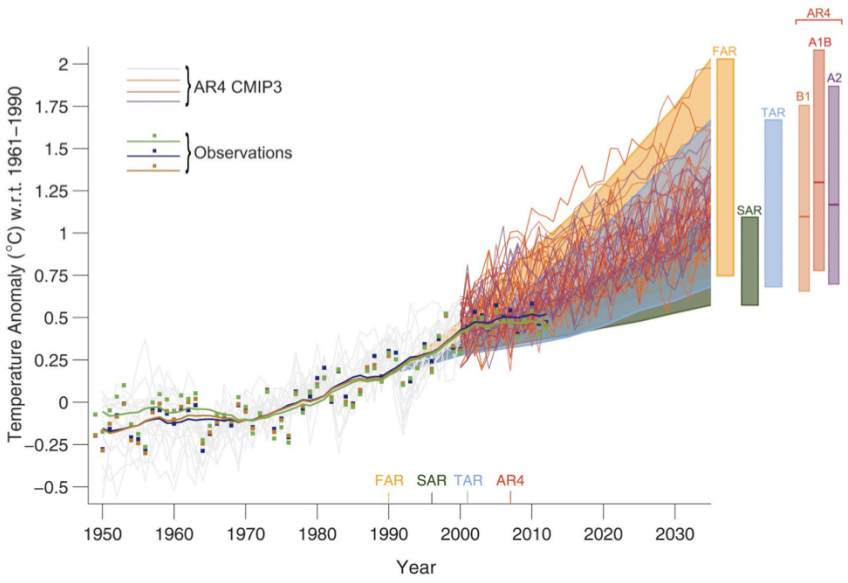
http://www.ipcc.ch/report/graphics/images/Assessment%20Reports/AR5%20-%20WG1/Chapter%2001/Fig1-05.jpg



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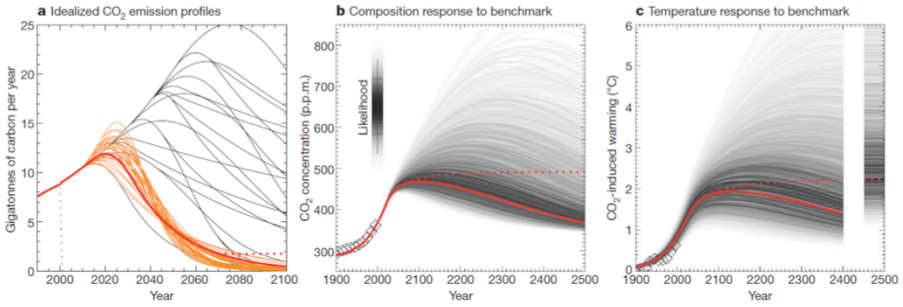
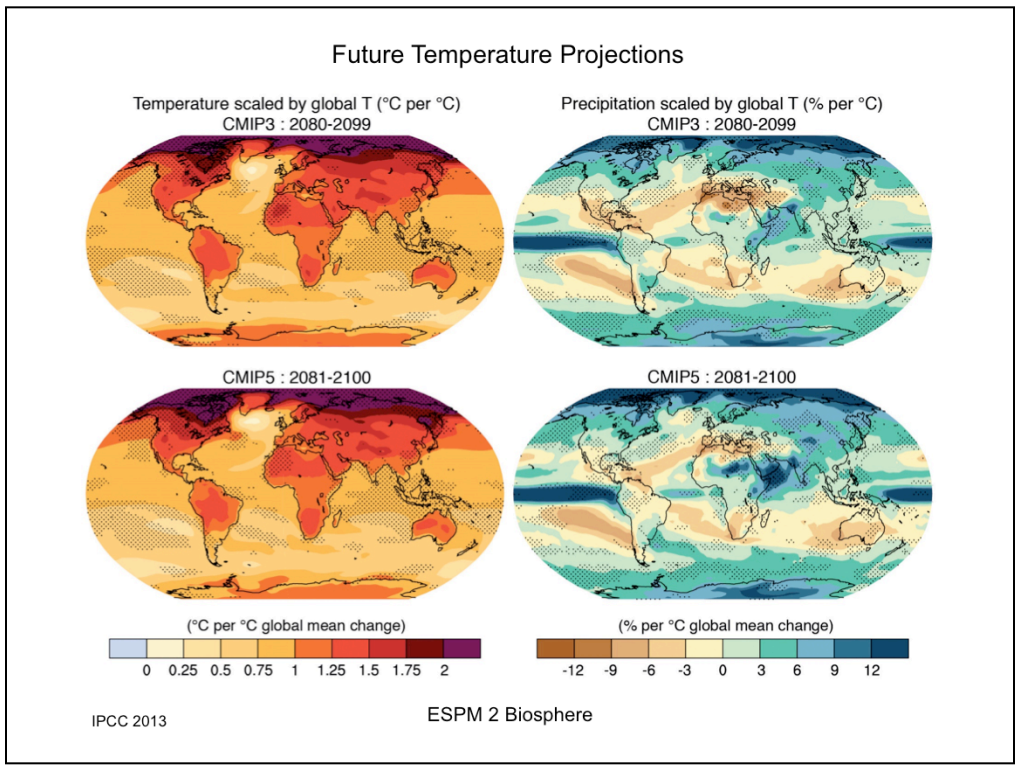
http://www.ipcc.ch/report/graphics/images/Assessment%20Reports/AR5%20-%20WG1/Chapter%2001/Fig1-04.jpg

Future climate depends upon cumulative Carbon emission, not pathway



Allen et al 2009 Nature



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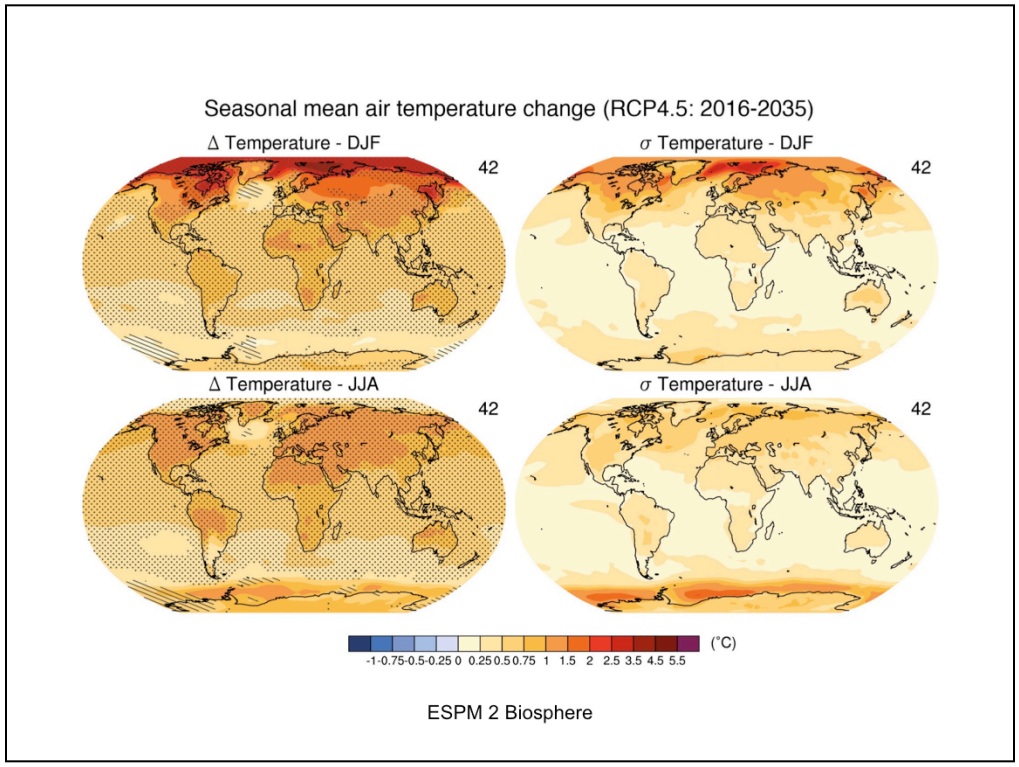
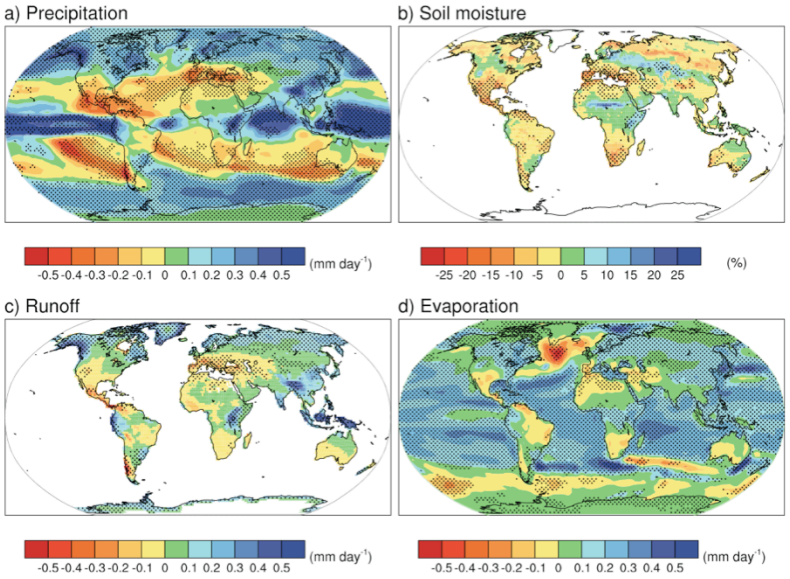


http://www.ipcc.ch/report/graphics/images/Assessment%20Reports/AR5%20-%20WG1/Chapter%2011/Fig11-10.jpg

There will be Wetter and Drier Regions



IPCC 2007

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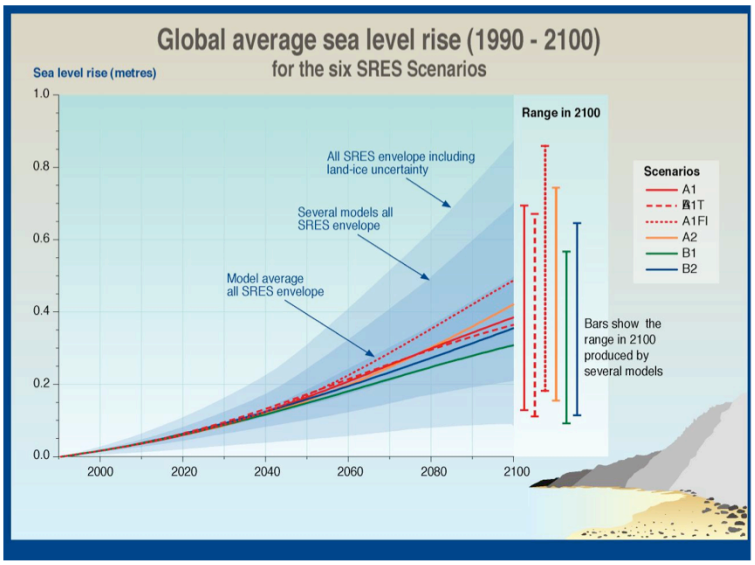
Multi model average A1B scenario


Global average sea level rise (1990 - 2100)
for the six SRES Scenarios
Sea level rise (metres)
1.0
0.8
0.6
0.4
0.2
0.0
2000
2020
2040
2060
2080
2100
All SRES envelope including land-ice uncertainty
Several models all SRES envelope
Model average all SRES envelope
Range in 2100
Scenarios
A1
A1T
A1FI
A2
B1
B2
Bars show the range in 2100 produced by several models

IPCC, 2001

Caveat Emptor

- The ability of climate models to reproduce past is no guarantee of predicting future if new processes come into play, and they are not well parameterized or modeled
  - Physics of Melting ice caps
  - Timing and Extent of melting tundra
    - 1500+ GtC is in the tundra permafrost
    - Methane emissions from wetlands
  - Cloud physics
  - Aerosols and Black Carbon
  - Portending future changes in Land Use
  - Portending future CO2 levels
    - Effects of technology and adapting alternative energy
    - Changes in population and World economy
    - Pandemics, wars, water scarcity

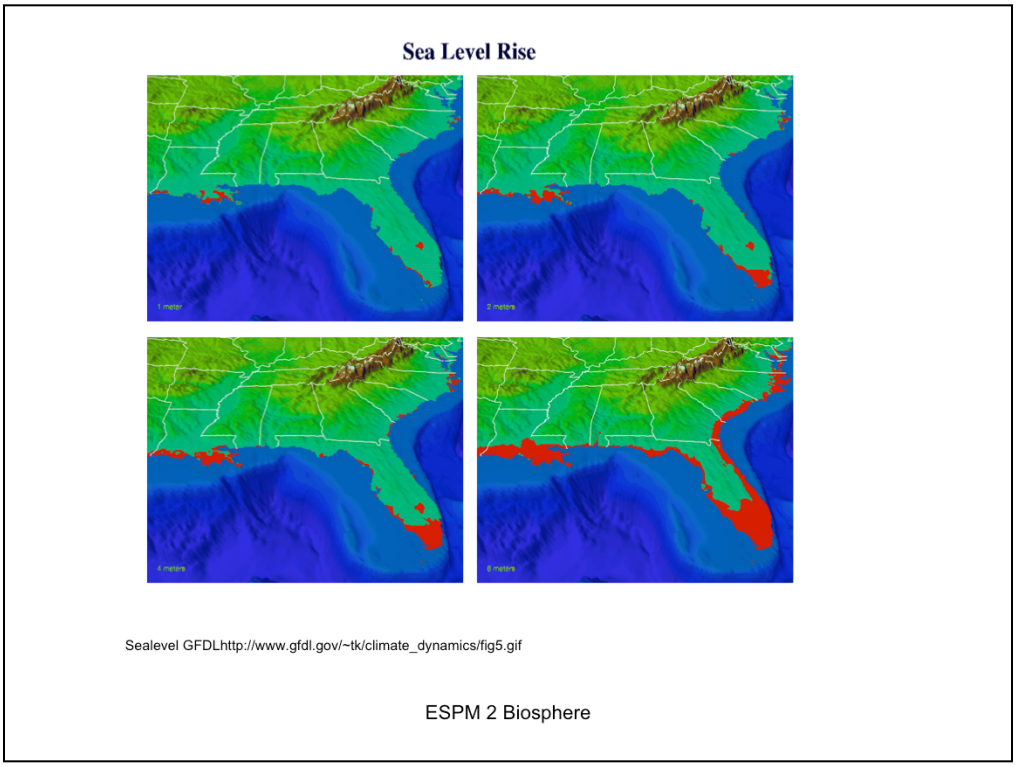
Further Refinements

- Coupling Climate, Biogeochemistry and Ecosystem Dynamic models
  - Climate Change is needed to predict Vegetation Changes
  - Changes in Vegetation affects land/surface interactions and Climate
  - Mass and energy fluxes are constrained by links to Biogeochemistry
  - Assess changes in landcover due to mankind

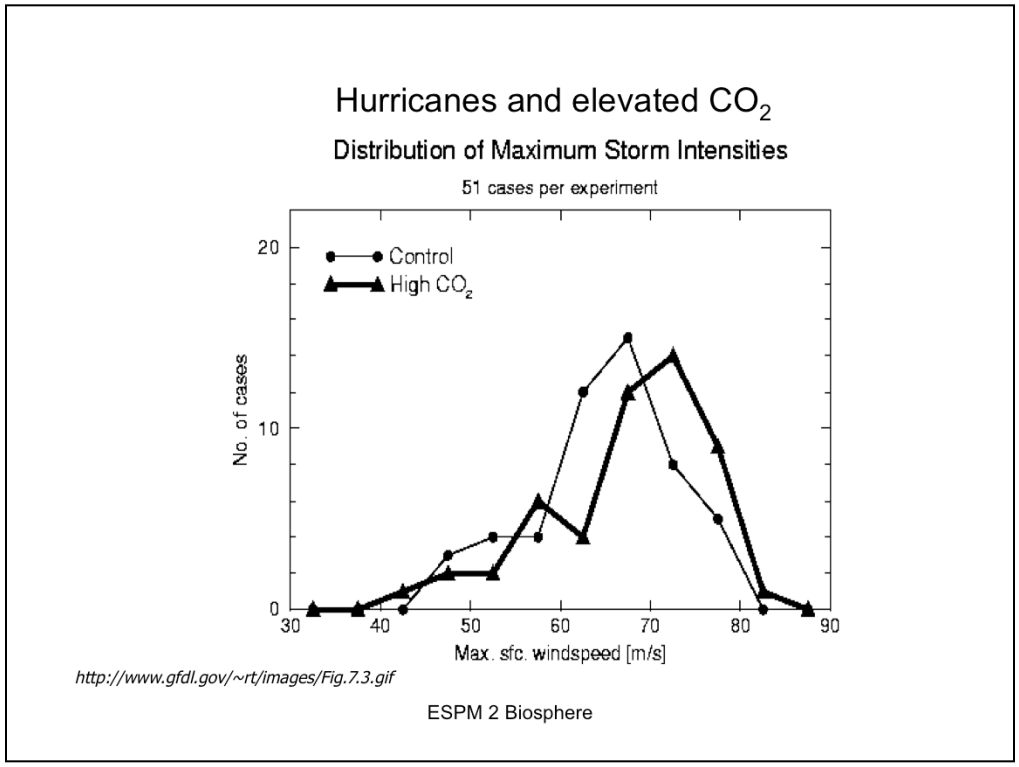
Conclusions, p1

- Climate system is inherently noisy, but Trends are Emerging
  - We view climate system with multiple tools at multiple time and space scales
  - Consistent and Repeatable Patterns are Arising
- Climate Forecasts are based on fundamental principles of Physics, Biology and Chemistry
- Climate Change is Associated with many complex feedbacks
  - Change can be slow at first, but accelerate later as ice-caps melt, albedo decreases and moisture in the atmosphere increases
- Science is Not Democratic
  - Hypotheses are Rejected and Accepted based on observation and theoretical principles, not votes
  - Hence, constructive criticism and reasonable skepticism is already integrated into the scientific process
  - But it is transparent, anyone has access to do science


ESPM 2 Biosphere

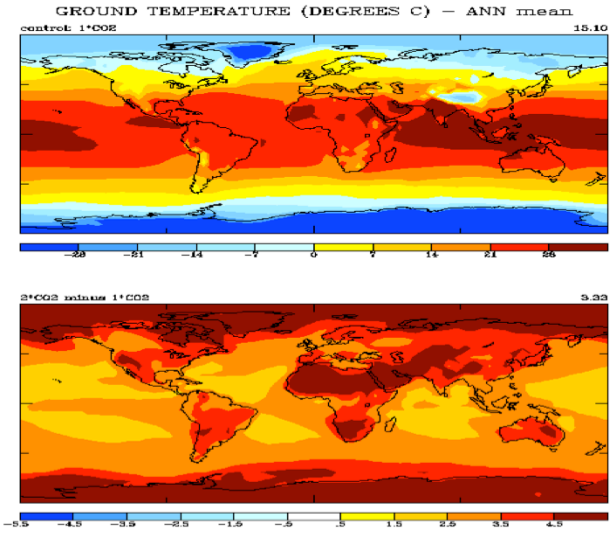


The sea level rise is not anticipated to be uniform over all regions of the globe due to the influence of ocean circulation changes, as well as land movements unrelated to global warming. A more realistic projection of the geographical distribution of sea level rise remains as a problem for future research. However, to crudely illustrate the effect of various hypothetical spatially uniform sea level rise scenarios, the red areas in **Fig. 5** indicate regions of the southeastern United States that would be below sea level for regionally uniform rises of one, two, four, and eight meters, respectively.



According to a new simulation study by a group of scientists at NOAA's Geophysical Fluid Dynamics Laboratory (GFDL), a 5-12% increase in wind speeds for the strongest hurricanes (typhoons) in the northwest tropical Pacific is projected if tropical sea surfaces warm by a little over 2 degrees C (Figure 1). Although such an increase in the upper-limit intensity of hurricanes with global warming was suggested on theoretical grounds a decade ago, this investigation is the first to examine the question using a hurricane prediction model that is being used operationally to simulate realistic hurricane structures.

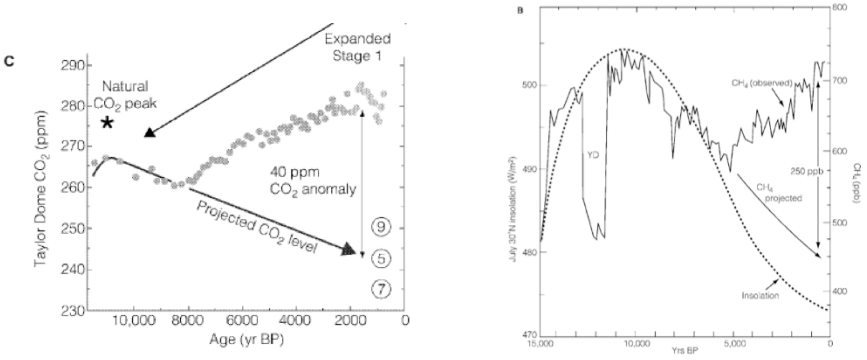
2x CO_2 and ground Temperature



http://www.giss.nasa.gov/cgi-bin/co2hansen.cgi

•Wm Ruddiman Claims Anthropogenic Influences started with the dawn of Agriculture (8000 yr BP) rather at dawn of Industrial Age (200 yr BP) due to Forest Clearing, Wide-Spread Rice Production in Asia and Animal Husbandry

•Contends this may have staved off the next ice age



Ruddiman, Climatic Change, 2003

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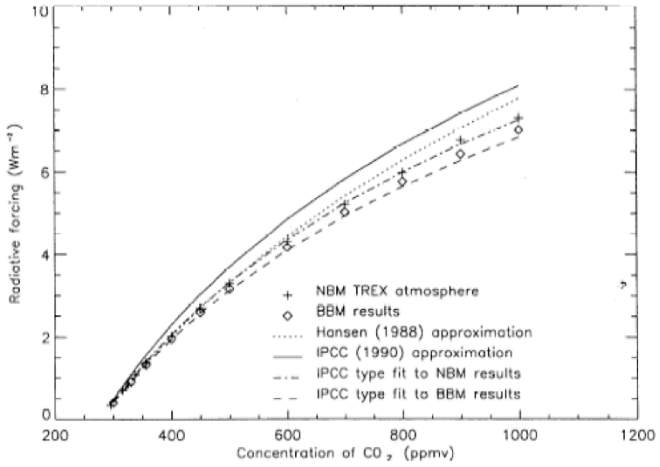
Energetics of Greenhouse Gas Forcing:
Doubling CO_2 provides a 4 Wm^{-2} energy increase (ΔR), Worldwide

$$\Delta T = \Delta R\, Gain / (1 - feedback)$$



Myhre et al 1998 GRL

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Attribution of the present-day total greenhouse effect

Table 1. Effect of Each Absorber on the Percentage Net LW Absorbed by the Circa 1980 Atmosphere for Each Absorber Being Removed (Minimum Effect) and for That Absorber Acting Alone (Maximum Effect)[a]

Absorber	Single Factor Removal (% of Total *G*)	Single Factor Addition (% of Total *G*)	Attribution (Including Overlaps)	
			All Sky	Clear Sky
H_2O (Vapor)	39.0	61.9	50	67
CO_2	14.0	24.6	19	24
Clouds	14.5	36.3	25	
All Others	4.9	9.2	7	9
N_2O	1.0	1.6		
Ozone	2.7	5.7		
CH_4	0.7	1.6		
CFCs	0.1	0.5		
Aerosols	0.3	1.8		
All GHGs	18.8	32.0		
H_2O + Clouds	66.9	80.9		
H_2O + CO_2	57.6	79.1		
H_2O + Clouds + CO_2	90.8	95.1		
All Others + CO_2	19.1	33.1		
All Others + Clouds	20.9	42.4		

[a]"All GHGs" encompasses CO_2, CH_4, N_2O, CFCs, and O_3. "All Others" refers to all absorbers other than H_2O, CO_2, and clouds. The attribution columns account for overlaps for "all-sky" and "clear-sky" conditions. Multiply all percentages by 155 W/m^2 to get the equivalent change in radiative flux units.

Schmidt et al 2010
JGR Atmos

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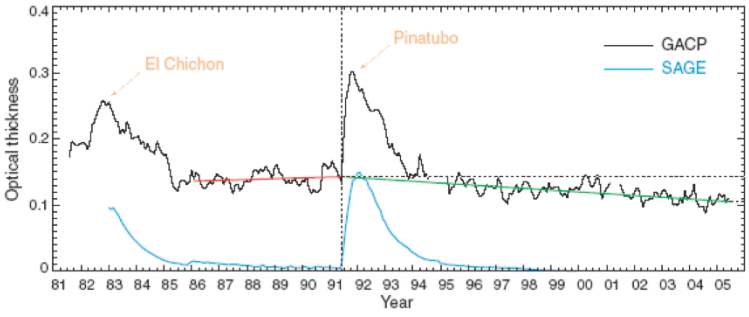
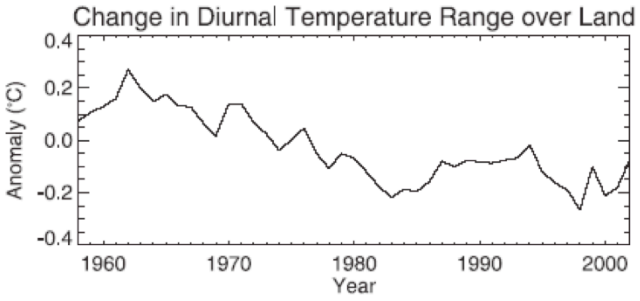
Global Dimming



Mishchenko et al. 2007 Science

Solar Dimming and DTR:

More Particles Reduce Daytime Warming from Sun
More Greenhouse Gases Reduce Nightime Cooling



Wild et al, 2007 GRL

Increase in Hurricane Intensity Trends, rather than Hurricane Frequency

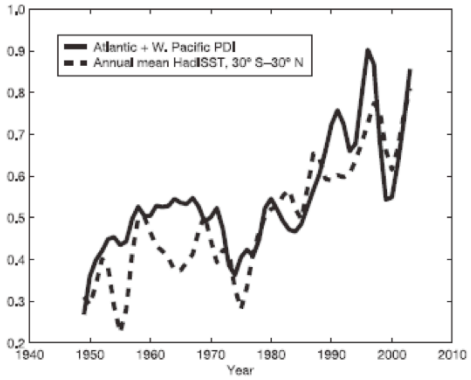


Figure 3 | Annually accumulated PDI for the western North Pacific and North Atlantic, compared to annually averaged SST. The PDI has been

Emanuel, 2005 Nature

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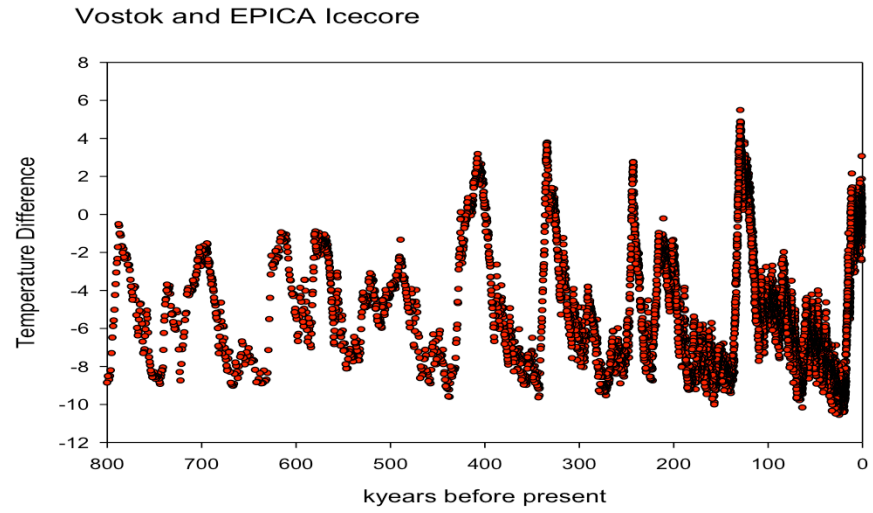
Hurricane storm duration and intensity are scaling with SST

Temperature over the past 800,000 years



Data of Barnola, Raynaud and Lorius

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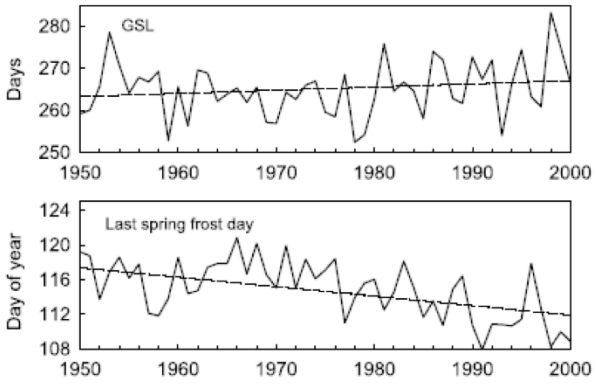
Trends in Growing Season Length and Last Frost Date



United States

Feng and Hu, 2004, J Theor Appl Clim

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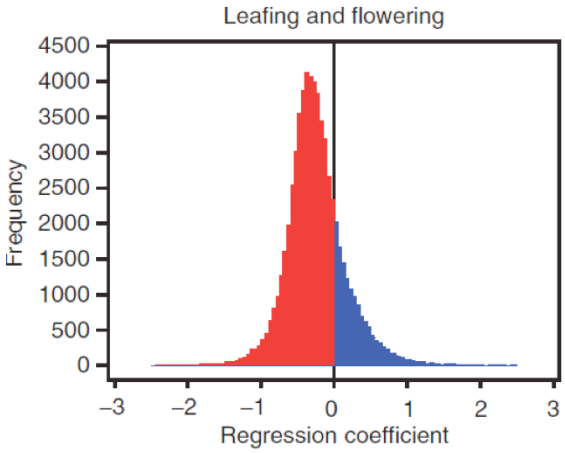
Trends in Phenology across Europe



Change in Days/Year

Menzel et al. 2006 GCB

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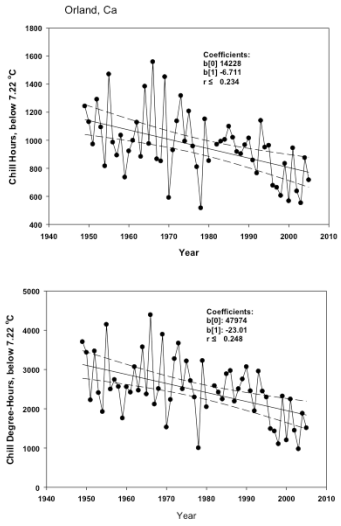
Downward Trend in Chill Hours near Orland, northern Sac Valley



50+ year Record,
Coop Data

Baldocchi and Wong, Climatic Change, 2008

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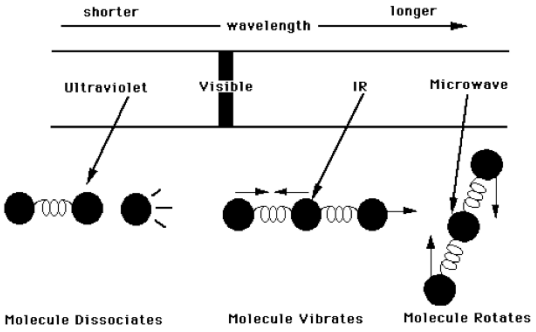
Radiation and Tri-Molecular Compounds



- High Energy (uv) dissassociates/ionizes molecules
- Medium energy (IR) vibrates
- Low Energy (microwave) rotates

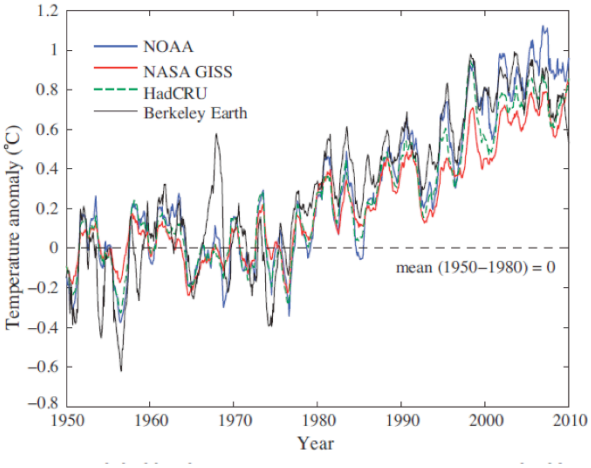
http://www.wag.caltech.edu/home/jang/genchem/infrared.htm

Tipping points and Arctic sea ice???

feedback, but in winter the excess oceanic heat is lost to the atmosphere due to a lack of insulating sea-ice cover. This leads to an anomalously warm atmosphere, which in turn causes increased heat loss by longwave radiation at the top of the atmosphere and decreased heat gain by atmospheric advection from lower latitudes. A lasting impact of the ice–albedo feedback is not possible because the large-scale heat fluxes quickly adapt to release the excess oceanic heat from the Arctic.

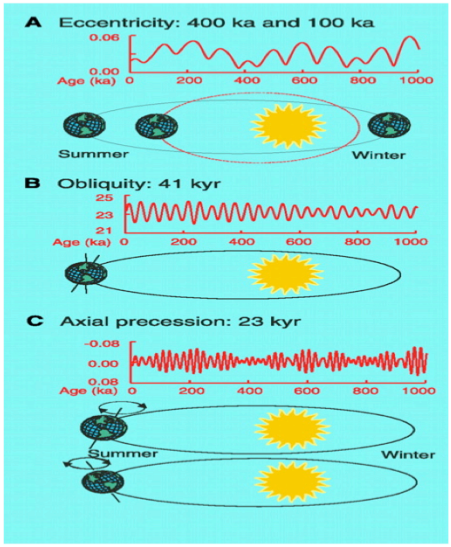
Tietsche et al 2011 GRL

Berkeley Earth Temperature Project Confirms Global Warming



http://berkeleyearth.org/

Natural Solar Forcing of Climate Variability



Zachos et al Science 2002

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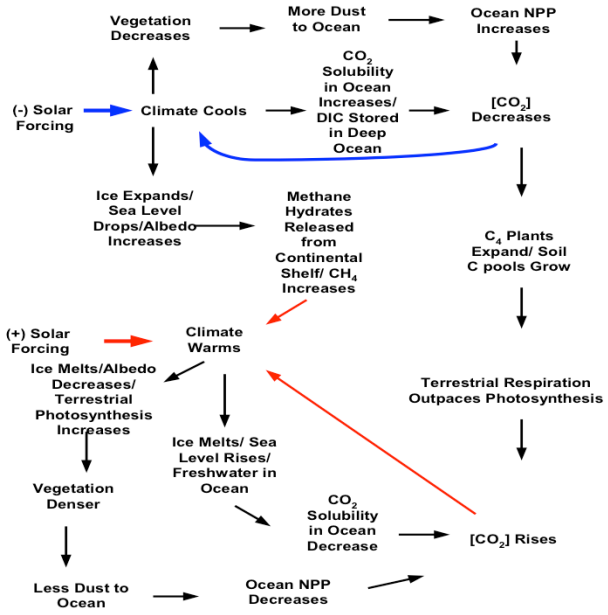
Zachos et al Science 2001

Climate/Biosphere/Cryosphere/Ocean Feedbacks on Ice Ages



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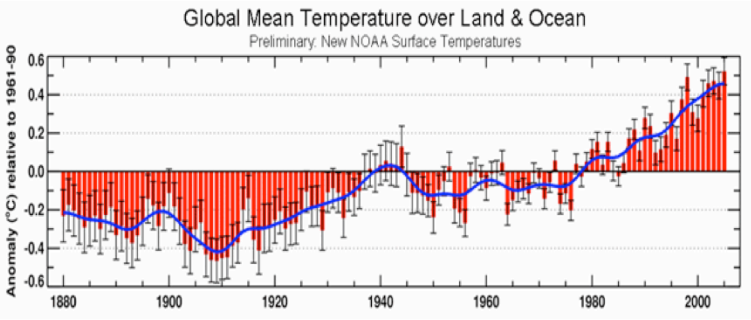
Temperature Anomaly Trends: Instrument Record



The 20 Hottest Years on Record*

Rank	Year
1	2005
1	1998
3	2002
4	2003
5	2004
6	2001
7	1997
8	1990
9	1995
10	1999
11	2000
12	1991
13	1987
14	1988
15	1994
16	1983
17	1996
18	1944
19	1989
20	1993

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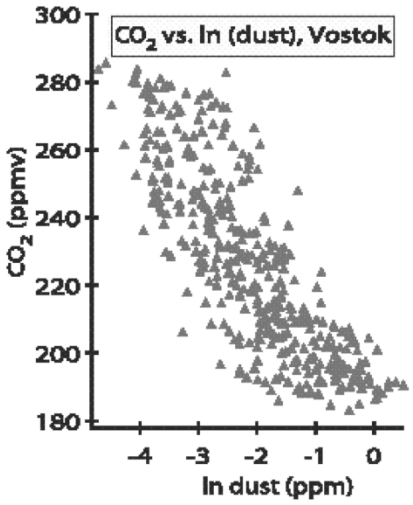
Dust and CO_2 Amplify Feedbacks on Climate



Bender, GBC, 2003

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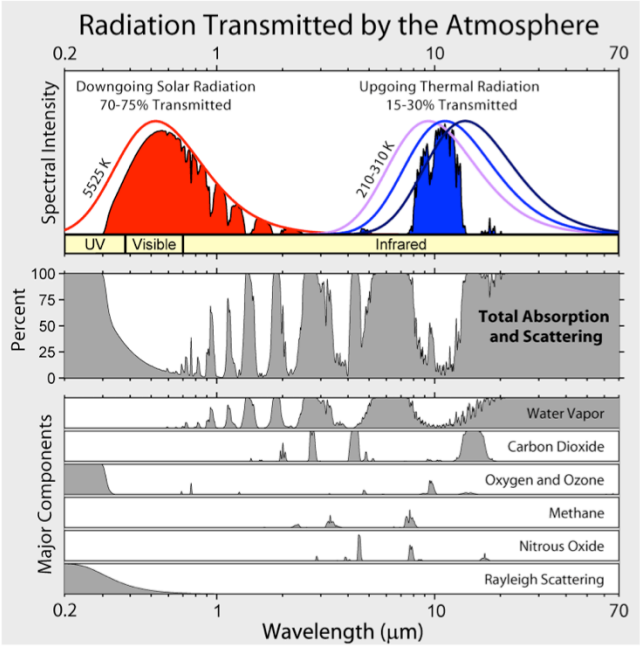

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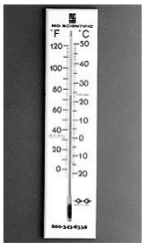
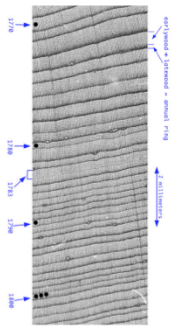
GlobalWarmingArt.org

Evidence of Global Warming :
Direct and Indirect Confirmation by Multiple Methods

- Observations
  - Climate Networks (~1850 to present)
    - Air, Sea and Soil Temperature Networks
  - Phenology Networks
    - Date of flowering (lilac, cherries, fruit trees)
    - Timing of grape harvest
  - Sea Level Rise
  - Tree Rings (~1000 to present)
  - Stable Isotopes
    - Ice Cores (800 kyr BCE to present)
    - Oxygen isotope ratio ($^{18}O/^{16}O$) in calcium carbonate of seashells (forams)
  - Satellite Observations
    - Length of Growing Season (1970s to present)
    - Extent of Sea Ice
- Modeling
  - Global Circulation-Climate Models
    - Diagostic
    - Prognostic





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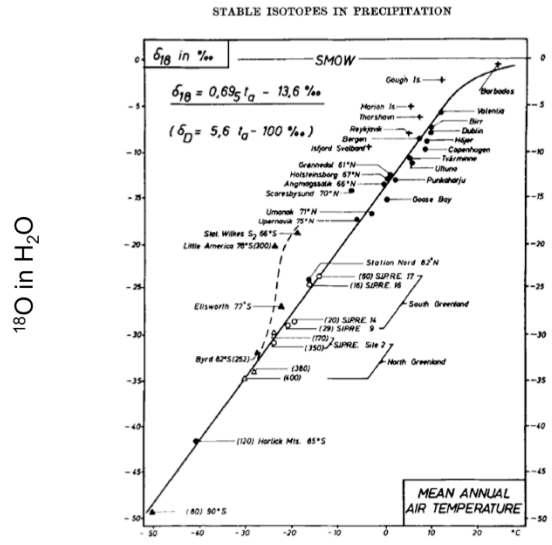
Let's look at other sources of information on global warming. Remember, as scientists we must be self consistent.

Stable Isotopes in Ice, a Proxy for Temperature



^{18}O in H_2O

Dansgaard, 1964 Tellus

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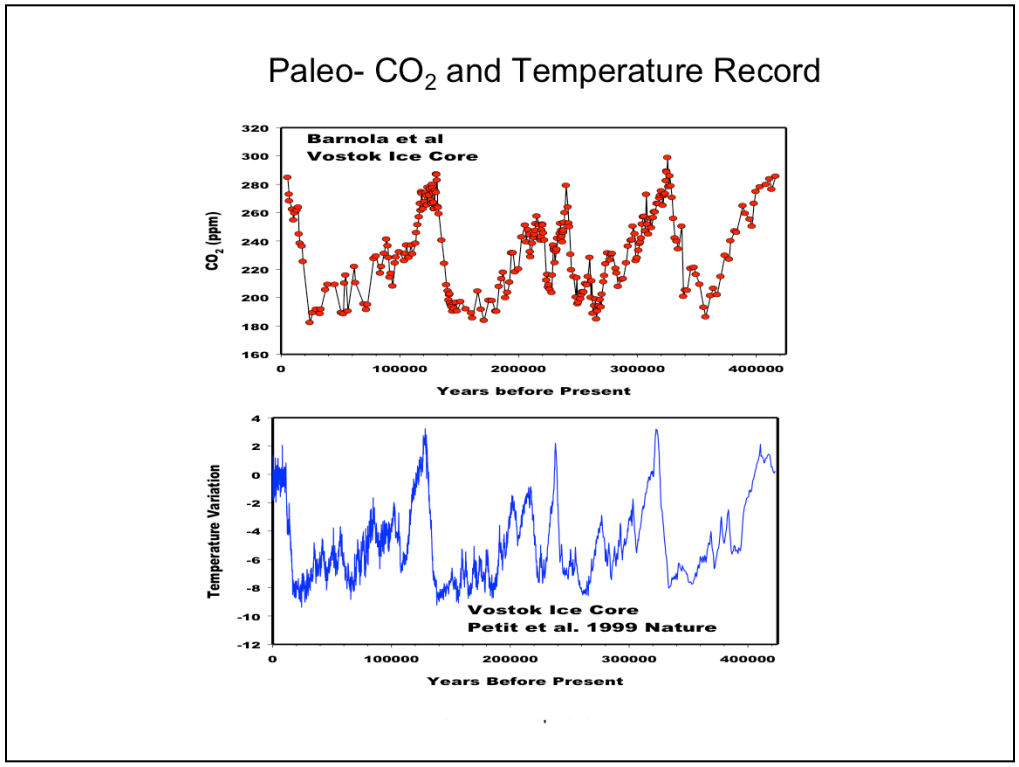
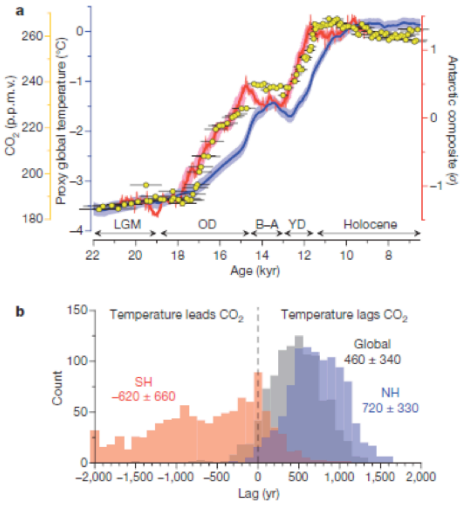
Stable isotopes in ice are great proxies for studying paleo climates



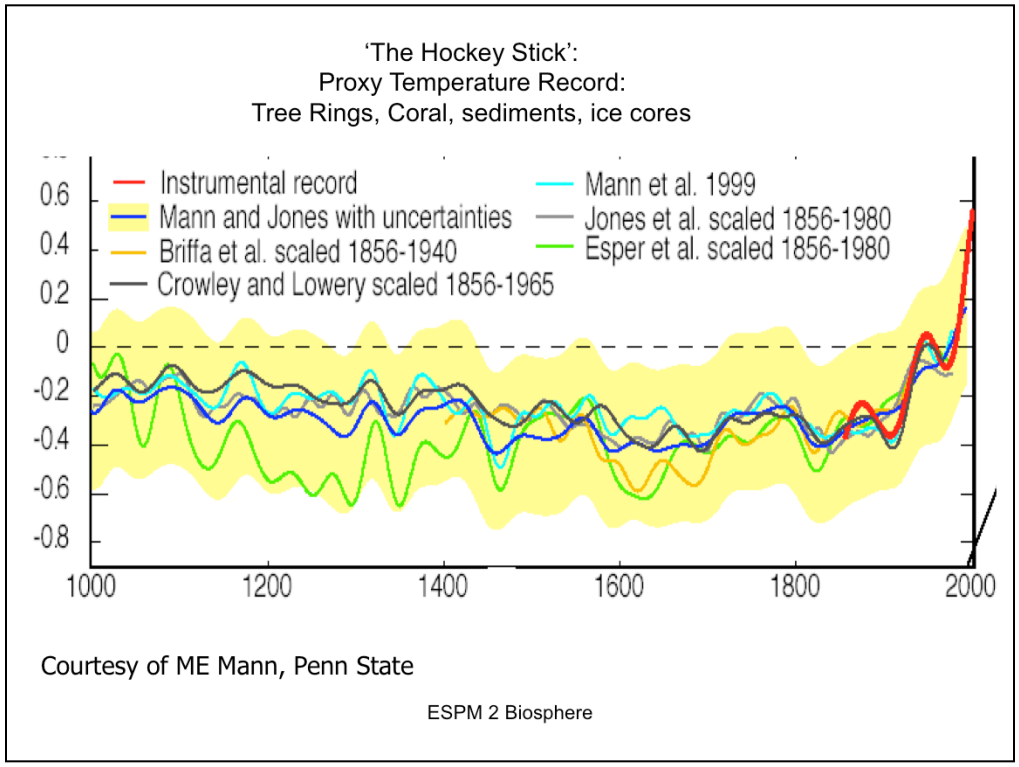
Paleo record of temperature and CO2. Yes, climate has changed in the past and it will again in the future. But this change is slow, over thousands and tens of thousands of years, not over several decades, like today

CO_2 Leads Warming during Last Deglaciation

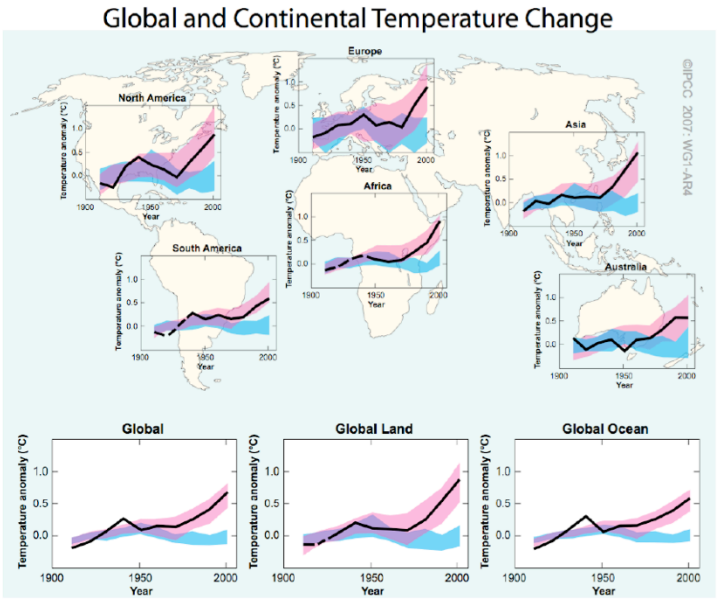


Shakun et al 2012 Nature

ESPM 2 Biosphere



Tree rings have been used as proxies for temperature. Complicated because both rain and temperature affect tree ring growth. But with careful analysis and adjustments for artifacts and confounding effects, time series can be extended back a 1000 years. We see the famous hocky stick curve with the increase in temperature over the past century.



IPCC Summary, 2007

ESPM 2 Biosphere

Blue band, modesl with natural forcing, red models with natural and anthropogenic forcings