Climate Change Impacts

Projected Changes to Sea Ice

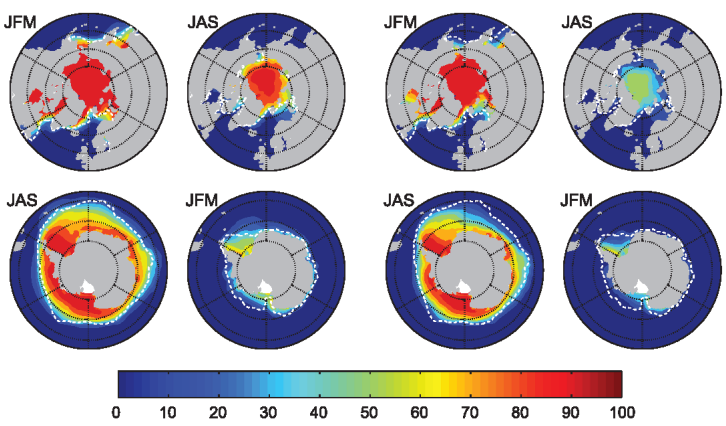
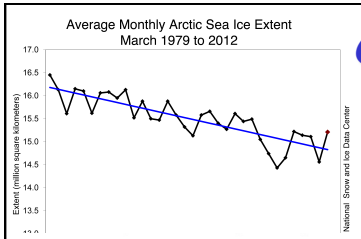
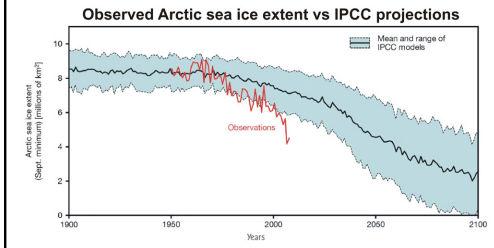


Figure 10.14. *Multi-model mean sea ice concentration (%) for January to March (JFM) and June to September (JAS), in the Arctic (top) and Antarctic (bottom) for the periods (a) 1980 to 2000 and b) 2080 to 2100 for the SRES A1B scenario. The dashed white line indicates the present-day 15% average sea ice concentration limit. Modified from Flato et al. (2004).*

Changes in Sea Ice

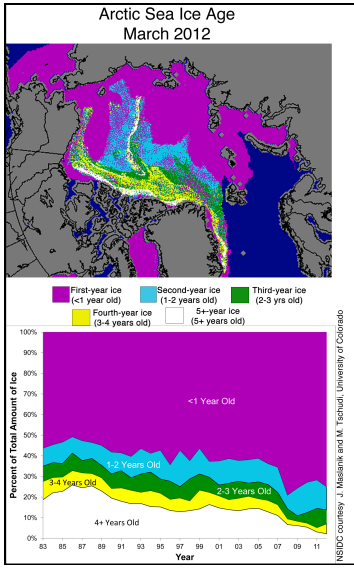




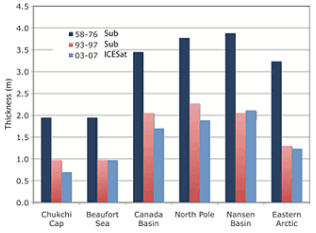
- Winter maximum has decreased by ~ 10%
- Summer Minimum has decreased by ~ 40%
- Decrease is much faster than predicted

Copenhagen Diagnosis 2009 http://sks.to/model

Rapidly Thinning Ice



- Multiyear ice is disappearing very rapidly
- About 80% of Arctic sea ice is now less than 1 year old



Planetary Waves and Poleward Energy Transport

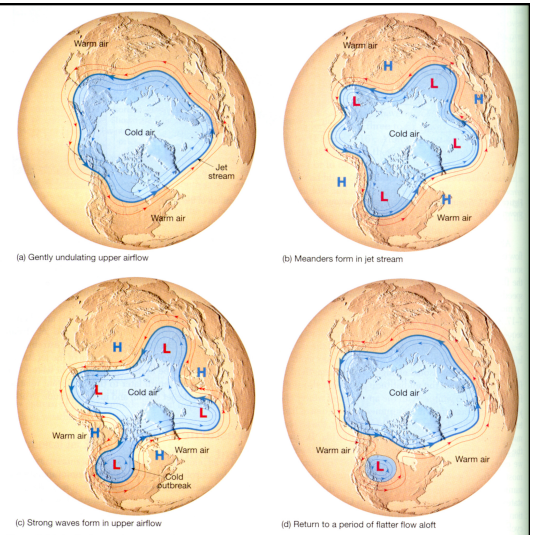
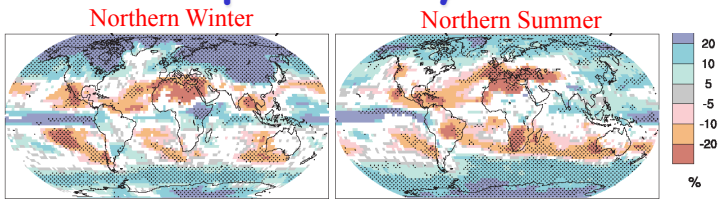


Figure 7–18 Cyclic changes that occur in the upper-level airflow of the westerlies. The flow, which has the jet stream as its axis, starts out nearly straight and then develops meanders and cyclonic activity that dominates the weather.

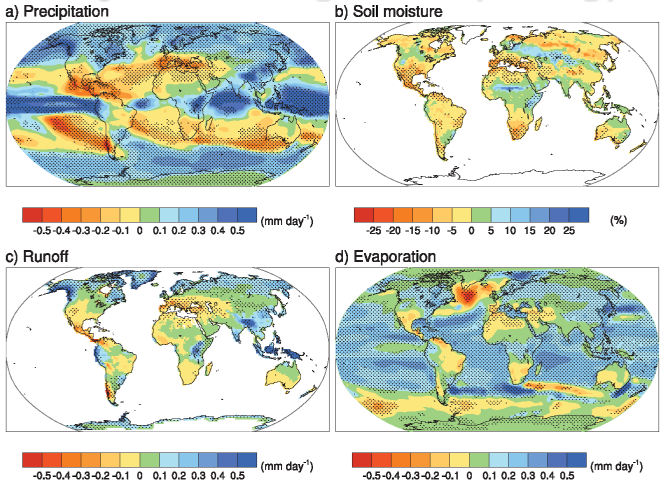
Drought and Water Stress

Projected Changes in Precipitation by 2100



- More rainfall overall because warm air evaporates more water from oceans
- Wet places get wetter, dry places get drier (compare deep tropics to subtropical deserts)
- Severe drying in Mediterranean and SW USA
- Colorado is near the "zero change line"

Projected Changes to Hydrology



Impacts on Water Supply

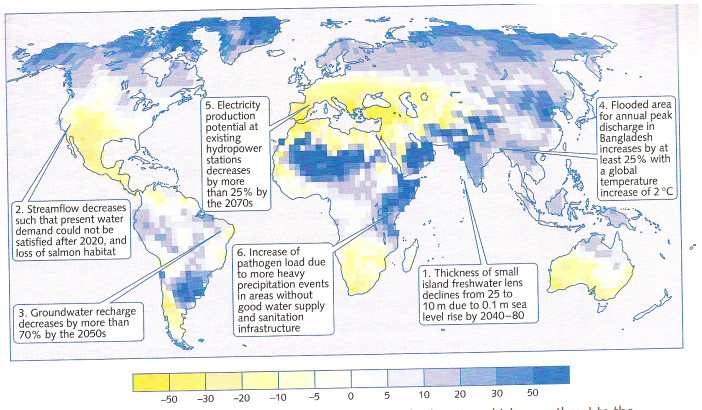
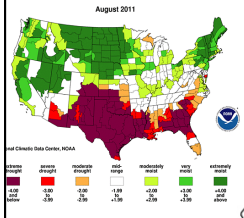
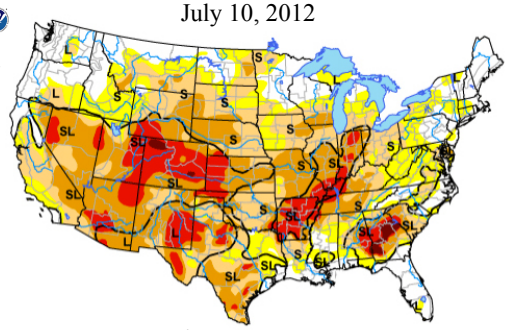


Figure 7.8 Illustrative map of future climate change impacts on fresh water which are a threat to the sustainable development of the affected regions. The background map is of the ensemble mean change in annual run-off in per cent between (1981–2000) and (2081– 2100) for the SRES A1B emissions scenario.

Current US Drought

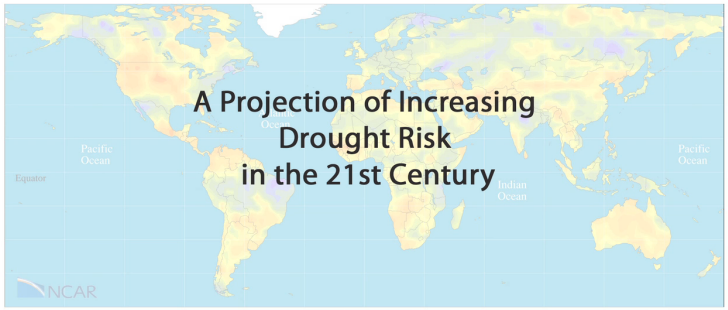


July 10, 2012



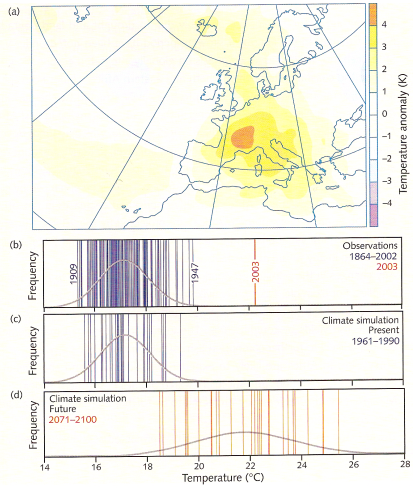
This kind of event is more and more likely under a warming climate

Animation of Palmer Drought Severity Index Using Climate Model Projections of Precipitation and Evaporation

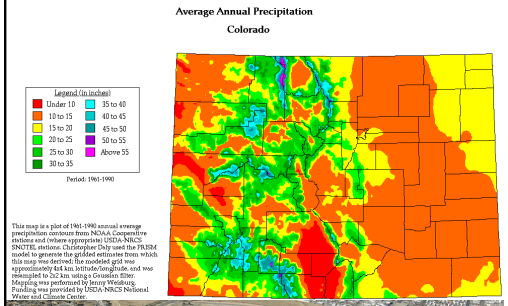


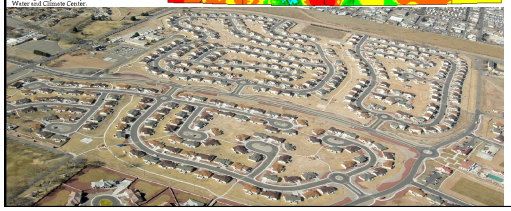
Heat Wave Statistics

Figure 7.19 Characteristics of the summer 2003 heatwave in Europe. (a) June, July, August (JJA) temperature anomaly with respect to 1961–90; (b) to (d) JJA temperatures for Switzerland; (b) observed during 1864–2003; (c) simulated with a regional model for the period 1961–90; (d) simulated for 2071–2100 under the SRES A2 scenario. The vertical bars in (b) to (d) represent mean summer surface temperature for each year of the time period considered; the fitted Gaussian distribution is indicated in black.



A Region On the Edge





Much of the region already receives only marginal precipitation

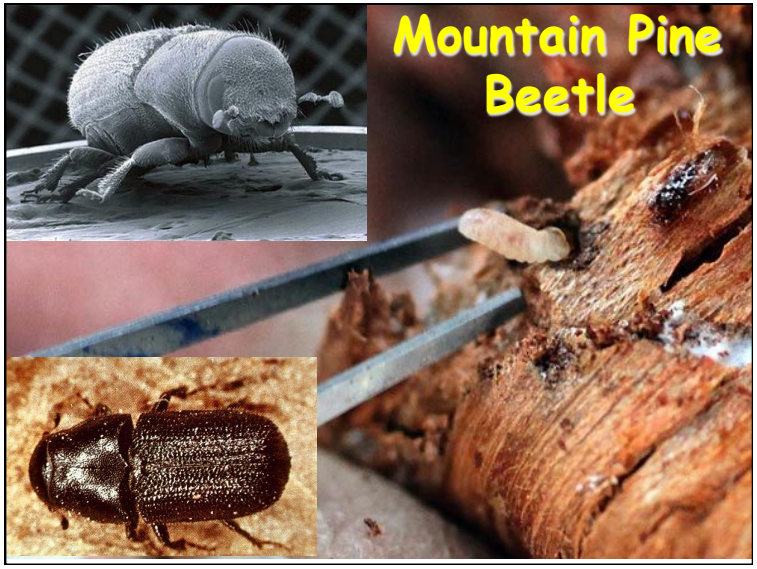
Just enough snow to support forests and reservoirs

Just enough irrigation water to support farming

Just enough water to support 5.1 million people

Ski Industry

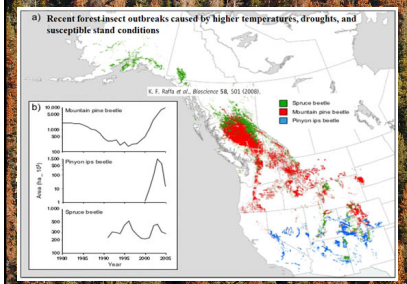
Mountain Pine Beetle



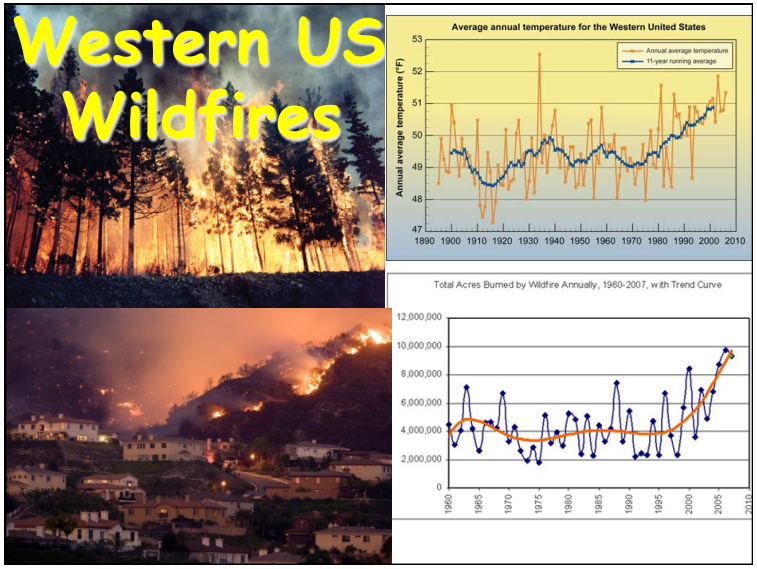
Insect Pests

Extent of Infestation

- Colorado is only the southernmost outbreak of a continental problem
- Estimated CO2 emissions ~ 10% of fossil fuel for 1 year



Western US Wildfires



Irrigated Agriculture

Sea Level & Coastal Flooding

Changes in Stored Energy

Energy Content in the Climate System

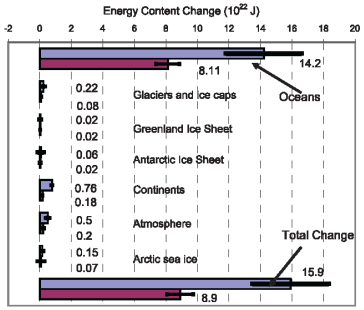


Figure TS.15. *Energy content changes in different components of the Earth system for two periods (1961–2003 and 1993–2003). Blue bars are for 1961 to 2003; burgundy bars are for 1993 to 2003. Positive energy content change means an increase in stored energy (i.e., heat content in oceans, latent heat from reduced ice or sea ice volumes, heat content in the continents excluding latent heat from permafrost changes, and latent and sensible heat and potential and kinetic energy in the atmosphere).*

Global Ocean Heat Content (0 - 700 m)

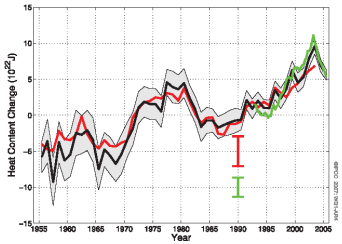


Figure TS.16. *Time series of global ocean heat content (10^{22} J) for the 0 to 700 m layer. The three coloured lines are independent analyses of the oceanographic data. The black and red curves denote the deviation from their 1961 to 1990 average and the shorter green curve denotes the deviation from the average of the black curve for the period 1993 to 2003. The 90% uncertainty range for the black curve is indicated by the grey shading and for the other two curves by the error bars. (Figure 5.1)*

Historical Sealevel Changes

Global Mean Sea Level

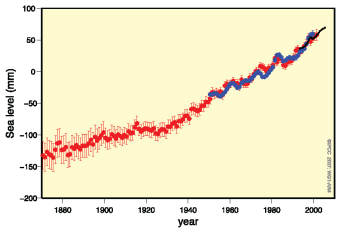


Figure TS.18. *Annual averages of the global mean sea level based on reconstructed sea level fields since 1870 (red), tide gauge measurements since 1950 (blue) and satellite altimetry since 1992 (black). Units are in mm relative to the average for 1961 to 1990. Error bars are 90% confidence intervals. (Figure 5.13)*

Sea Level Rise (mm yr⁻¹)	1961–2003		1993–2003	
Sources of Sea Level Rise	Observed	Modelled	Observed	Modelled
Thermal expansion	0.42 ± 0.12	0.5 ± 0.2	1.6 ± 0.5	1.5 ± 0.7
Glaciers and ice caps	0.50 ± 0.18	0.5 ± 0.2	0.77 ± 0.22	0.7 ± 0.3
Greenland Ice Sheet	0.05 ± 0.12[a]		0.21 ± 0.07[a]	
Antarctic Ice Sheet	0.14 ± 0.41[a]		0.21 ± 0.35[a]	
Sum of individual climate contributions to sea level rise	1.1 ± 0.5	1.2 ± 0.5	2.8 ± 0.7	2.6 ± 0.8
Observed total sea level rise	1.8 ± 0.5 (tide gauges)		3.1 ± 0.7 (satellite altimeter)	
Difference (Observed total minus the sum of observed climate contributions)	0.7 ± 0.7		0.3 ± 1.0	

Sea Level Change Patterns

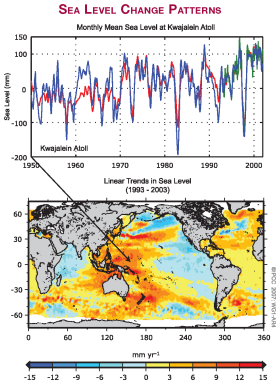


Figure TS.19. *(Top) Monthly mean sea level (mm) curve for 1950 to 2000 at Kwajalein (8°44'N, 167°44'E). The observed sea level (from tide gauge measurements) is in blue, the reconstructed sea level in red and the satellite altimetry record in green. Annual and semiannual signals have been removed from each time series and the tide gauge data have been smoothed. (Bottom) Geographic distribution of short-term linear trends in mean sea level for 1993 to 2003 (mm yr⁻¹) based on TOPEX/Poseidon satellite altimetry. (Figures 5.15 and 5.18)*

Sealevels and Emission Scenarios

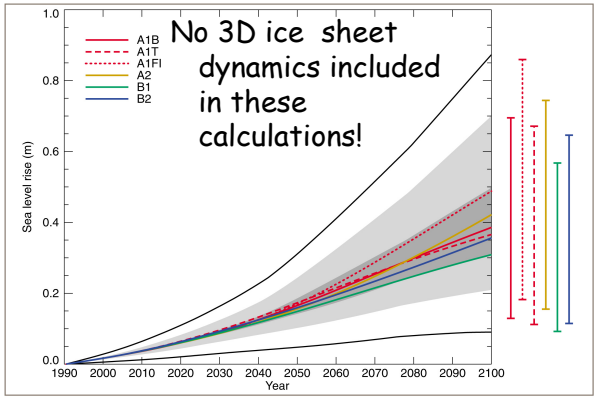
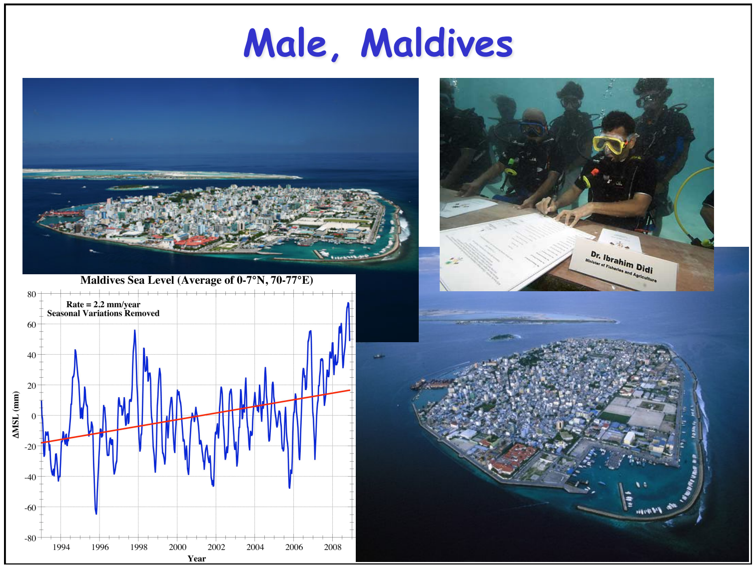
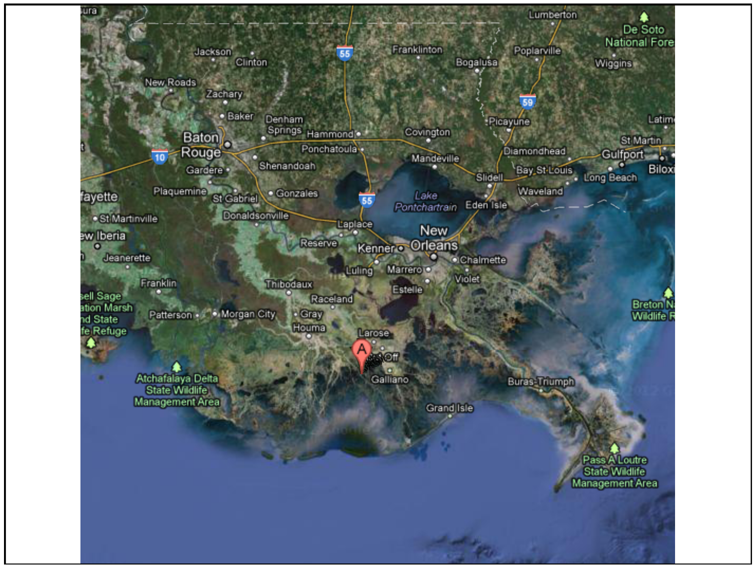
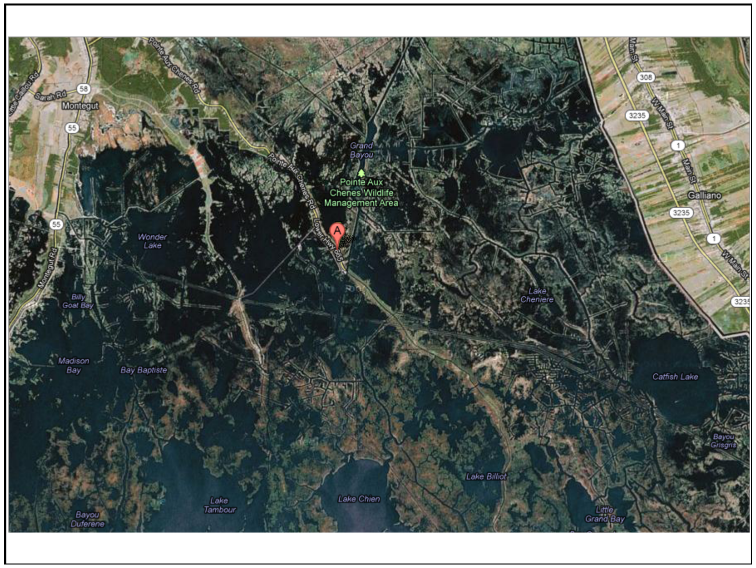
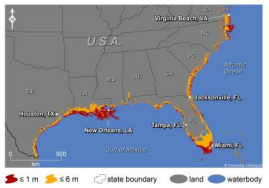


Figure 24: Global average sea level rise 1990 to 2100 for the SRES scenarios. Thermal expansion and land ice changes were calculated using a simple climate model calibrated separately for each of seven AOGCMs, and contributions from changes in permafrost, the effect of sediment deposition and the long-term adjustment of the ice sheets to past climate change were added. Each of the six lines appearing in the key is the average of AOGCMs for one of the six illustrative scenarios. The region in dark shading shows the range of the average of AOGCMs for all thirty five SRES scenarios. The region in light shading shows the range of all AOGCMs for all thirty five scenarios. The region delimited by the outermost lines shows the range of all AOGCMs and scenarios including uncertainty in land-ice changes, permafrost changes and sediment deposition. Note that this range does not allow for uncertainty relating to ice-dynamic changes in the West Antarctic ice sheet. [Based on Figure 11.12]


Male, Maldives
Dr. Ibrahim Didi
Maldives Sea Level (Average of 0-7°N, 70-77°E)
Rate = 2.2 mm/year
Seasonal Variations Removed
ΔMSL (mm)
Year

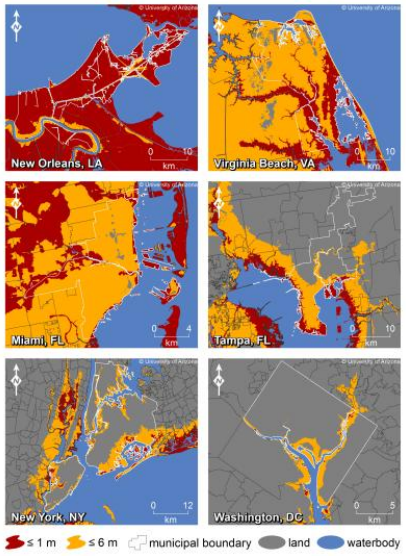

Lumberton
De Soto National Fore
Jackson
Clinton
Franklinton
Bogalusa
Poplarville
Wiggins
New Roads
Zachary
Baker
Denham Springs
Hammond
Covington
Picayune
Baton Rouge
Gardere
Shenandoah
Ponchatoula
Mandeville
Diamondhead
St Martin
Gulfport
Biloxi
Plaquemine
St Gabriel
Gonzales
Slidell
Bay St Louis
Long Beach
Waveland
Donaldsonville
Lake Pontchartrain
Eden Isle
St Martinville
New Iberia
Jeanerette
Laplace
Reserve
Kenner
New Orleans
Chalmette
Luling
Marrero
Violet
Franklin
Thibodaux
Estelle
Raceland
Patterson
Morgan City
Gray
Houma
Larose
Galliano
Breton N Wildlife R
Atchafalaya Delta State Wildlife Management Area
Buras-Triumph
Grand Isle
Pass A Loutre State Wildlife Management Area

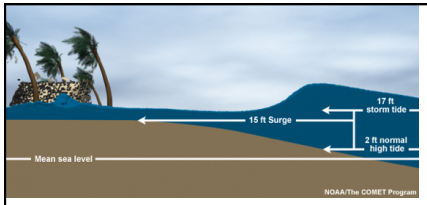

Montegut
Pointe Aux Chenes Wildlife Management Area
Wonder Lake
Galliano
Lake Cheniere
Madison Bay
Bay Baptiste
Catfish Lake
Lake Tambour
Lake Chien
Lake Boeuf



Changes in Mean Sea Level

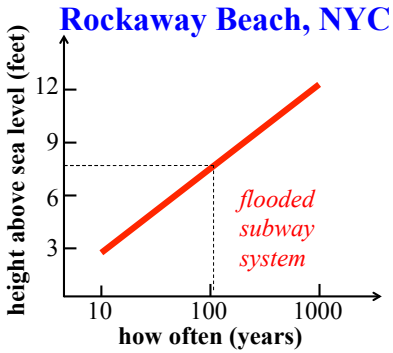
- 1 meter is a high-end estimate for 2100
- 6 m is loss of Greenland





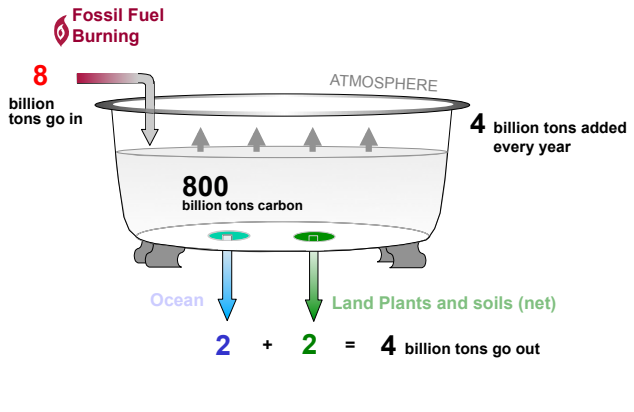
Coastal Flooding

- Small floods are common, big floods are rare
- **Sea level rise shifts the line up**
- **What was a 100-year flood becomes a 10-year flood!**



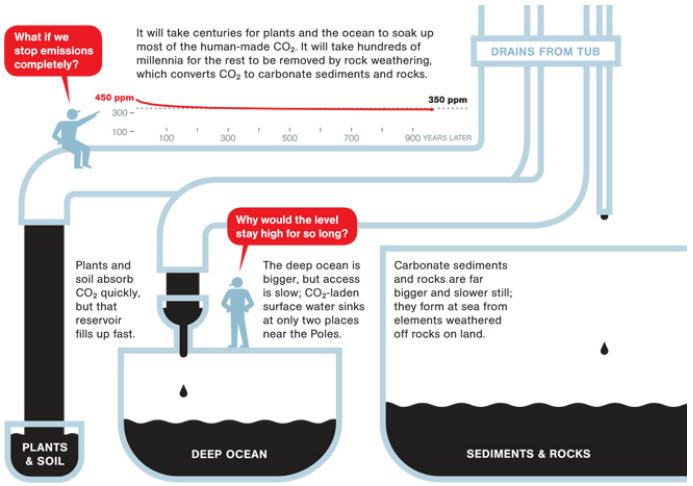
Distant Future

CO_2 "Budget" of the World



Extra heat comes from the water, not the faucet!

Bathtub Drainage



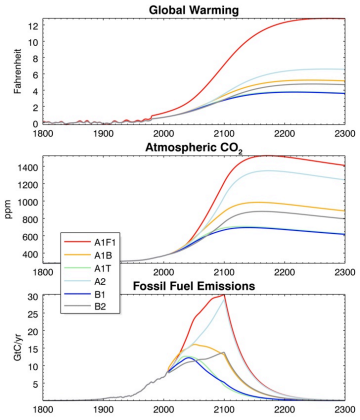
Common Myth #2

- "When we reduce or stop the burning of fossil fuel, the CO_2 will go away and things will go back to normal"

CO_2 from fossil fuel will react with oceans, but only as fast as they "mix"

Eventually, fossil CO_2 will react with rocks

About 1/3 of today's emissions will stay in the air **permanently!**



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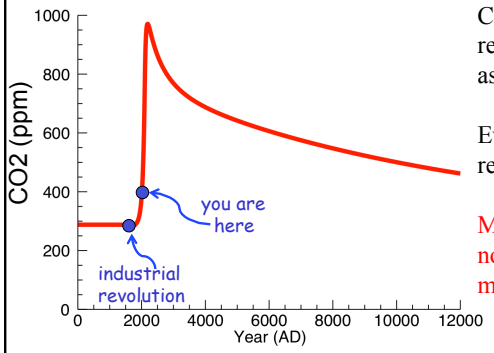
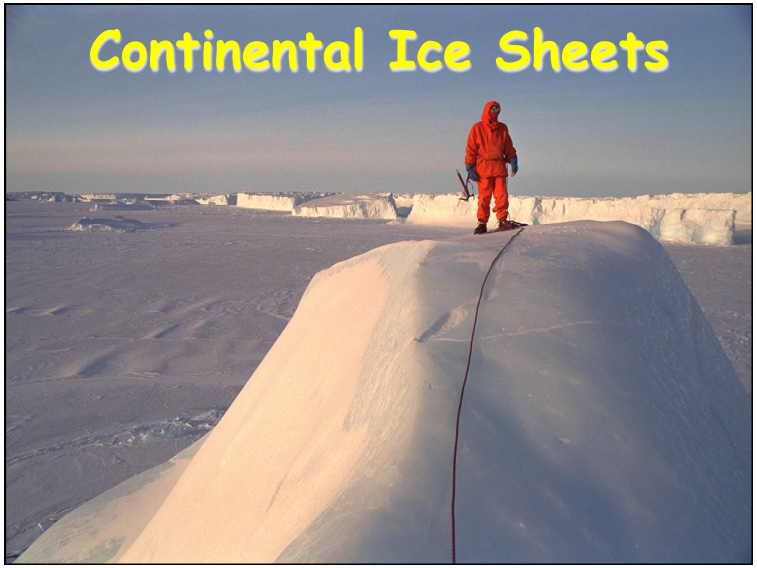


CO_2 from fossil fuel will react with oceans, but only as fast as they "mix"

Eventually, fossil CO_2 will react with rocks

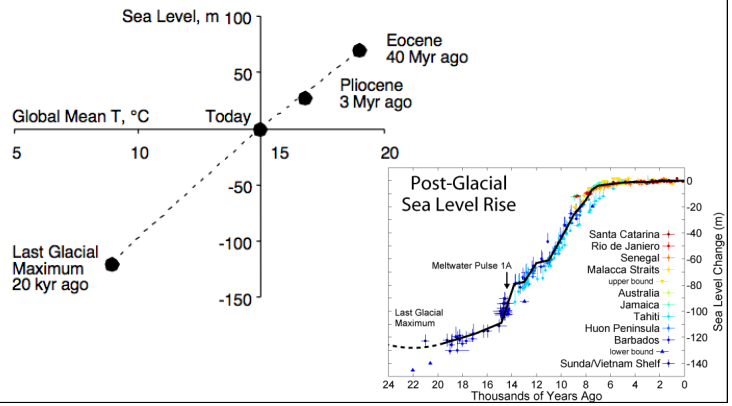
Much of the CO2 we emit now will stay in the air for many thousands of years!

Continental Ice Sheets



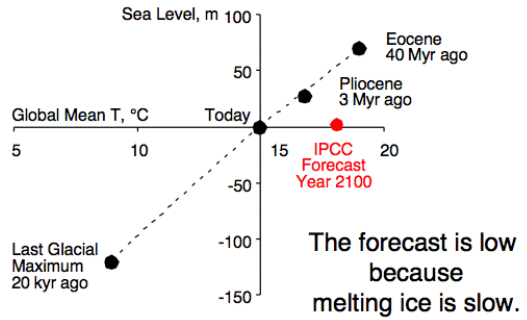
Climate and Sea Levels

Sea Level



Climate and Sea Levels

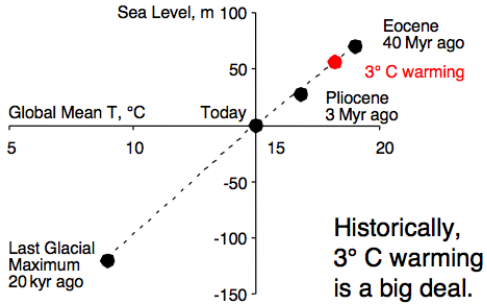
Sea Level



The forecast is low because melting ice is slow.

Climate and Sea Levels

Sea Level



Historically, 3° C warming is a big deal.

What we Know for Sure

- CO_2 molecules absorb & re-emit thermal radiation (Tyndall, 1863)
- Doubling the number of CO_2 molecules would add 4 W m^{-2} to the surface 24/7 (Arrhenius, 1896)
- If China and India industrialize with coal, CO_2 will approach 400% preindustrial by 2100
- Additional CO_2 will continue adding heat to Earth's surface for thousands of years

What We're Not So Sure About

- When and in precisely what ways the climate will change, especially **locally**
- The economic, political, and social **consequences** of these changes
- **What to do** about all of this