Submission
No 27

INQUIRY INTO A SUSTAINABLE WATER SUPPLY FOR SYDNEY

Name: Mr Matt Mushalik

Telephone:

Date Received: 13/02/2006

Subject:

Summary

Matt Mushalik (MIEAust)

3/2/2006

To
Legislative Council
Parliament House
Sydney 2000

Dear Madam, Sir

Re: Inquiry into a Sustainable Water Supply for Sydney

(1) Sustainability must be properly defined

There are many misleading definitions of sustainability but the following is based on the crux of the matter: energy and nature's equilibrium. Therefore a general definition of sustainability has to be:

A system is sustainable if it is running on genuinely renewable energies and/or genuinely renewable fuels without disturbing nature's equilibriums.

Applied to Sydney's water supply:

(a) Sydney, whatever the population size, cannot withdraw more water from its catchment than is regularly replenished by rains
(b) Any desalination plant must be fully powered by renewable energy systems and costed on this basis
(c) Sewer must be treated mechanically, chemically and biologically (3 stage sewer treatment) before any part of it is released into coastal waters

According to these definitions, Sydney's present water supply system is not sustainable. Neither would the proposed (and now shelved, possibly just postponed) desalination plant with electricity from coal-fired power plants be a contribution towards sustainability. See the attached paper: "What 10 years business as usual will do to our climate"

(2) Sydney's population growth from net migration must be curbed

From 1 (a) above it follows that Sydney's population must be limited by the available water divided by a certain per capita consumption. There are many examples in history where cities disappeared from the map because resource constraints were not taken into consideration. There are following options:

(a) Decentralize net migration from Sydney to areas along the coast with sufficient water supplies. The NSW Government is too focused on city planning in Sydney while – as a State body – they are responsible for the whole of New South Wales
(b) Stop or reduce the Federal Government's immigration programme. Sydney attracts 40% of immigrants

(c) Lower per capita consumption of water by demand management and explain to the public that their saving allows population to increase. See whether they like it.
(d) Provide desalination powered by renewables and include cost in new release areas in the West which takes up the net migration. Calculate whether anyone can afford this. If not, stop new suburbs in the West

The current option is: continue business as usual including a perpetual population growth of another 1.2 million; the historically old, but suddenly newly discovered groundwater is – according to the latest insight of Environment Minister Debus – an insurance; hit the 30% dam level mark and build a desalination plant powered by electricity from coal; contribute to more CO_2 emissions causing a warmer and drier climate.

(3) Coming oil crisis (=global peaking of oil production) will limit Sydney's growth anyway

Due to the lack of alternative fuels to fill an emerging oil supply gap around 2008-2010 of initially 2% pa (later more) and in-adequate public transport, Sydney (and other capital cities) may not be as attractive as in the past to live in. Motorists will soon notice after peak oil that every newcomer to Sydney will reduce the available fuel at the nearest filling station. See Appendices 1,2,34

(4) Water from desal plant expensive like bottled water

Peak oil will trigger a global energy crisis. Though initially a liquids problem in the transport sector, peak oil means that the world will try desperately to fill the oil supply gap with whatever other form of primary energy it can find. Skyrocketing electricity prices will make water from for any desal plant expensive like bottled water. If power is from coal, the cost of geo-sequestration must be included. The geo-sequestration must be physically in place before the desal plant is built.

(5) Demand management not taken seriously

Despite endless public debate Sydney Water still has no price structure in place which will motivate users to economise on water consumption. As a monopolist, Sydney Water likes to sit on revenues based on a high percentage of fixed charges. Let's look at my last quarterly water bill (2 adults, 2 children):

Item	Price		Comment
Water service	\$ 18.94	12.4 %	
Sewerage service	\$ 93.53	61.6 %	I HATE this one; I am forced to pay to pollute our ocean; this amount should vary with the consumption of water
Stormwater drainage	\$ 8.20	5.4 %	This money could be used to give me a cheap loan to build a rainwater tank in my garden
26 kilo liters of water	\$ 31.20	20.6 %	
Total	\$ 151.85	100.0 %	
Total cost (18.94+93.53+31.20)/26 = \$ 5.5 per kilo liter			

Though I could hardly consume less than the above, but if I did e.g. reduce by 10% I would not save much $$ and the cost per kilo liter would actually GO UP by 10%! E.g. 23 kilo liter would cost (18.94+93.53+27.60)/23=$ 6.09 per kilo liter.

Here is the cost structure in Frankfurt/Germany:

Item	Price in EUR		Comment
Water service	5.80	4.2 %	Meter rent only
Sewerage service 26 KL x 2.25 EUR (sewer volume=water consumption volume)	58.50	42.0 %	This includes 3 level treatment of sewer (mechanical, chemical, biological) and discharge of treated water into river Main
Stormwater drainage 96 m2 x 0.8 EUR pa x 25% for quarter	19.20	13.8 %	The more concrete surface you have in your yard, the higher this part of the bill
26 KL of water x 2.14 EUR	55.65	40.0 %	This includes water from river bank filtration, underground storage in mountains and long distance pipeline transport
Total	139.15	100 %	
Total cost (5.80+58.50+55.65)/26= 4.6 EUR per kilo liter (= AU$ 7.42)			

Frankfurt's water is more expensive but proper treatment of sewer and recycling of river water is included. With this cost structure, where 82% is variable depending on water consumption, there is more motivation to save.

(6) Storm Water Harvesting

6.1 By Councils
There are many local solutions but in nearby Hornsby, for example, the disused old quarry, now a million dollar burden for the Council due to unreasonable valuations by the Valuer General and windfall profit taking from CSR, could be used as storage for storm water from areas within its catchment. Revenue from using this stormwater could be used to pay off the quarry loan.

6.2 By Private Households
It is an irony that the proposed desal plant would feed water mainly into areas which are still blessed with many coastal showers. There should be an extended scheme to encourage households to build water tanks. For new developments, these should be compulsory (include in BASIX). It is a waste of resources that many new home owners build double and triple garages (when soon there will not be enough petrol to run 2 or 3 cars) but have no water tanks (and solar water heaters).

(7) Industrial water

The use of recycled water for industrial uses should be the first step

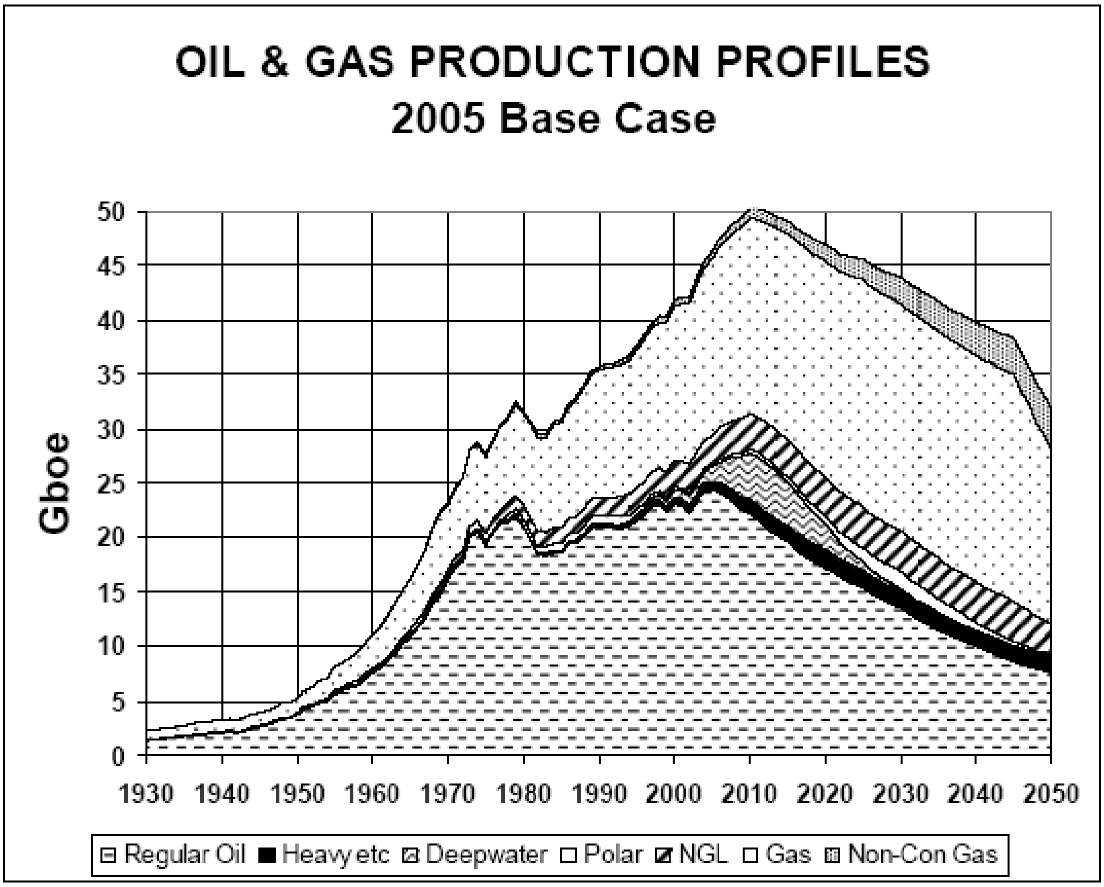
As with peak oil and global warming, time is running out and rainwater collection must start immediately.

Matt Mushalik (MIEAust)
Civil Engineer
Town & Regional Planner
Peak Oil Adviser

Attachments: Appendix 1,2,34 and
"What 10 years business as usual will do to our climate"

Member of:
www.ecotransit.org www.Sydneypeakoil.com www.aspo-australia.org.au

Fact sheet on oil & gas depletion



Gas has a different production profile from oil. It can stay flat for several decades to come. But the combined peak of oil and gas is not much later than the oil peak itself. Source: www.peakoil.ie (Oil geologist Colin Campbell, Ireland). Read the monthly reports on this site for regular updates.

Appendix 1

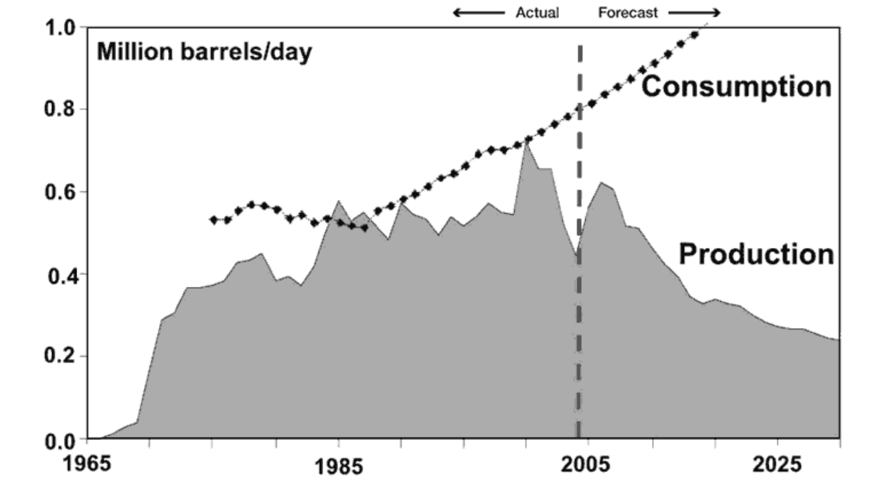
Australia's declining oil production

Australia's liquid fuel **production** decline began in 2000.

Year	Production Kb/day	Decline rate
2000	722	
2001	657	-9%
2002	626	-4.7%
2003	512	-18.2%
2004	455	-11.2%

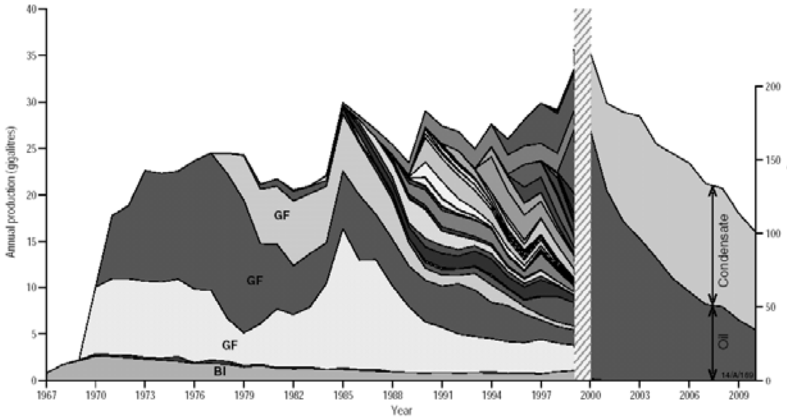
Source: Table 1.1b
http://www.eia.doe.gov/ipm

Kb/d=1,000 barrels per day
Current oil **consumption** is 846 kb/d or 309 mill. barrels per year.



Source of graph: Bruce Robinson's slide show at the ASPO International Workshop on oil depletion in Lisbon, May 2005
http://www.cge.uevora.pt/aspo2005/abscom/ASPO2005_Robinson.ppt

J.Akehurst (former CEO Woodside Petroleum Ltd): Challenges for Australia
www.woodside.com.au/NR/Woodside/investorpack/SG3682_3_ABARE.pdf

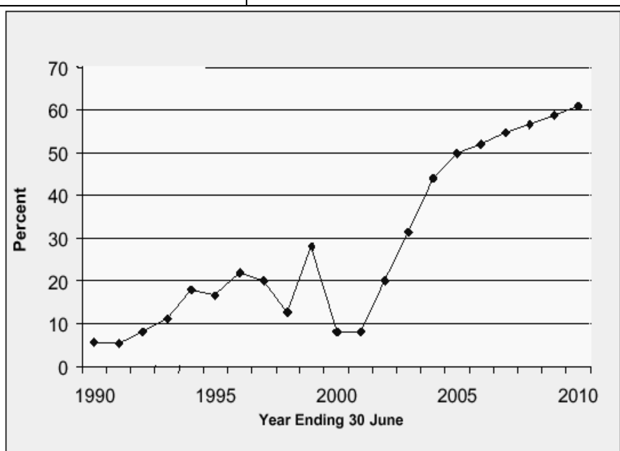


Condensate from gas fields cannot fully compensate declining oil production

The graph (left) illustrates the dramatic changes occurring in Australian oilfields. The large Gippsland fields are declining and being replaced by many smaller fields with shorter production periods and increased costs (risky exploration; more wells needed to maintain production)

A trade surplus of $ 1250 mill. in 2000/2001 from the net balance of oil imports/exports will turn into following deficits pa by 2010.
Calculated at different oil prices and exchange rates:
US$ 20/barrel and AU$ 1= US$ 0.55
AU$ 7.6 billion
US$50/barrel and AU$=US$0.70
AU$ 14.9 billion

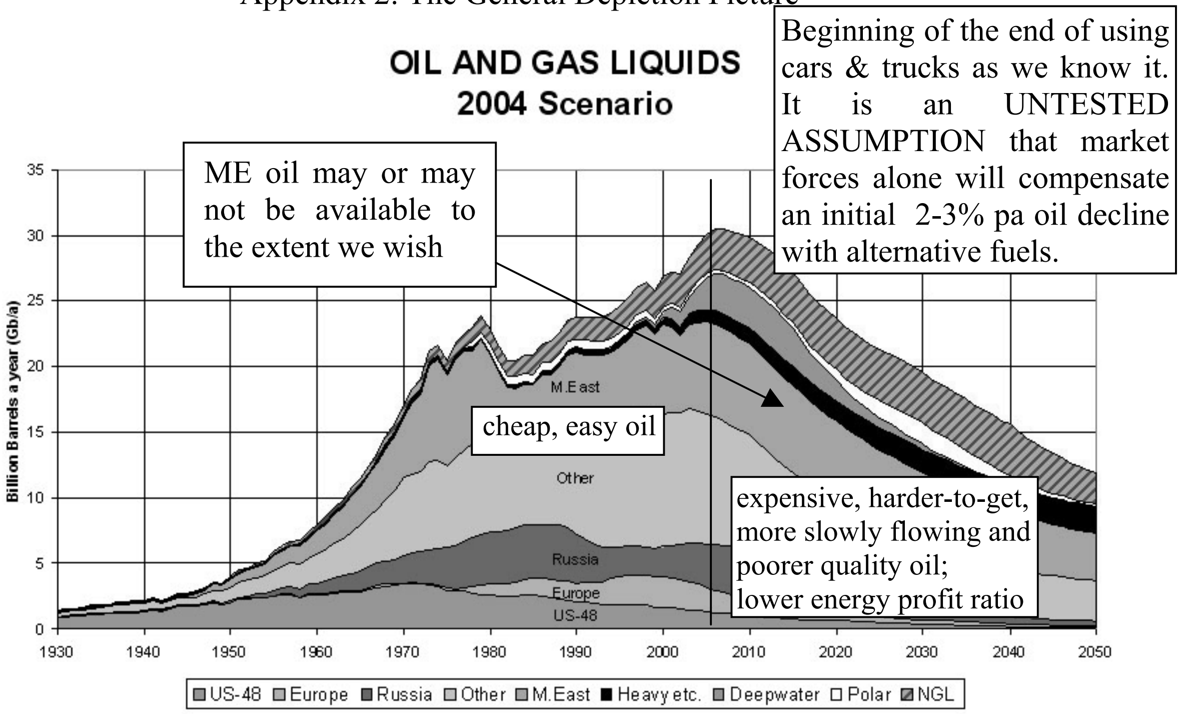
Australia's oil import dependence is rising from a low 10% in 2000 to 60% in 2010.



Source: ABARE Energy Projections, Oct 2001, GeoScience Australia

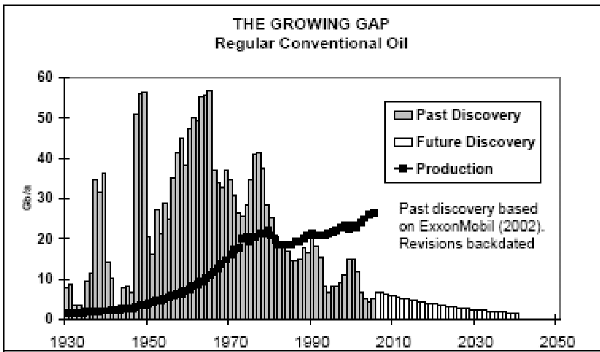
Last Update: 25/11/2005

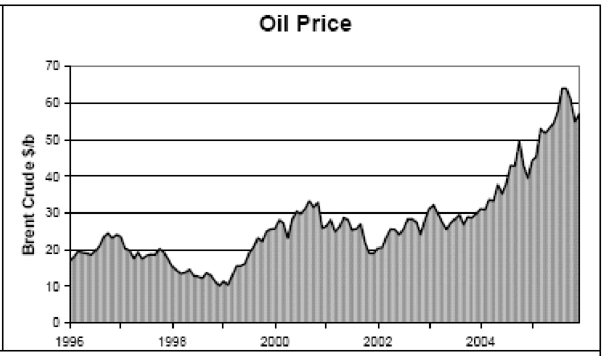
Appendix 2: The General Depletion Picture



ASPO's annual oil production simulated on the basis of technical reserve and production data. Half of the regular oil is already consumed. Though higher oil prices will result in exploration and production from new fields (+123 Gb) future production is limited by oil geology. Peak oil will trigger a general energy crisis as the world will seek to fill the gap. Our economy and transport systems will have to adapt. Prudent governance requires that we change our current energy & transport policies NOW before the crisis manifests itself.

ESTIMATED PRODUCTION TO 2100										End 2005	
Amount		Gb		Annual Rate - Regular Oil						Gb	Peak
Regular Oil				Mb/d	2005	2010	2015	2020	2050	Total	Date
Past	Future		Total	US-48	3.6	2.8	2.2	1.7	0.4	200	1971
	Known Fields	New		Europe	5.2	3.6	2.5	1.7	0.2	75	2000
968	759	123	1850	Russia	9.2	8.4	6.8	5.5	1.5	220	1987
	882			ME Gulf	20	20	20	20	11	680	1974
All Liquids				Other	29	26	22	18	7	675	2005
1074	1326		2400	**World**	**67**	**61**	**54**	**47**	**21**	**1850**	2005
2004 Base Scenario				Annual Rate - Other							
M.East producing at capacity				Heavy etc.	2.3	3	4	4	4	151	2021
(anomalous reporting corrected)				Deepwater	3.6	12	11	6	4	69	2011
Regular Oil excludes oil from				Polar	0.9	1	1	2	0	52	2030
coal, shale, bitumen, heavy,				Gas Liquid	6.9	9	9	10	8	276	2035
deepwater, polar & gasfield NGL				Rounding					-2	2	
Revised 25/12/2005				**ALL**	**80**	**86**	**80**	**70**	**35**	**2400**	2010





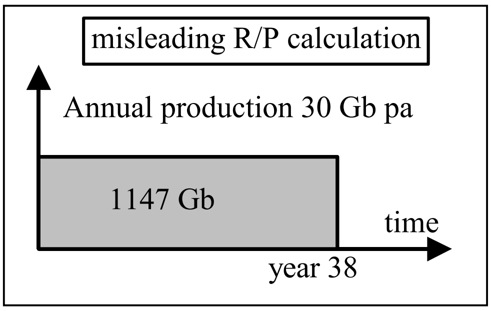
Peak production of regular oil must follow peak discovery, which happened in the mid 1960s, with a time lag (left). Prices react to peak oil but do not reflect yet that oil is a finite resource (right). After peak oil (there may be several peaks or a plateau), prices will increase until demand is physically forced down to declining production levels.

Source of graphs: Association for the Study of Peak Oil & Gas, www.peakoil.ie (ASPO Ireland)
Compiled by C.J.Campbell, Staball Hill, Ballydehob, Co. Cork, Ireland Last Update: 12/1/2006

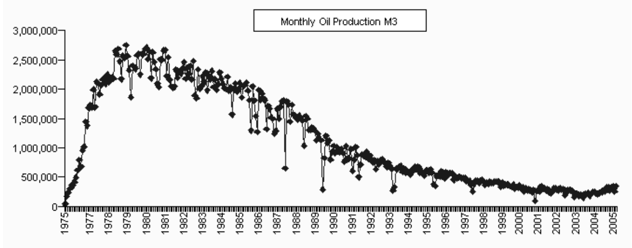
Appendix 34: Peak Oil When?
What is wrong with the common belief that oil will "last" for 40 years?

(1) <u>BP proved oil reserves:</u> These contain political data (unverified reports from Governments), not industry data. The International Energy Agency (IEA), Paris, (**<u>www.iea.org</u>**) found in its WEO 2004 (page 92) that 230 Gb of OPEC reserves are overstated. If this is the case, OPEC's oil depletion clock has to be advanced by 20 years! A summary of this problem is contained in submission 75 on energy efficiency to the Productivity Commission available on line at **<u>www.pc.gov.au/inquiry/energy/subs/sub075attachment2.pdf</u>**. The BP reserves should therefore not be used as a basis for multi billion dollar decisions.

(2) <u>Reserve to production Ratio (R/P)</u>: It is common practice to use this ratio to calculate "how long oil will last", e.g. 40 years as indicated in the energy white paper "Securing Australia's Energy Future", page 119. However, this simplifying calculation is oil-geologically irrelevant. While the R/P ratio is a good indicator for the **<u>size</u>** of the reserves in terms of current annual production, it says nothing about the timeframe during which these reserves can actually be produced.



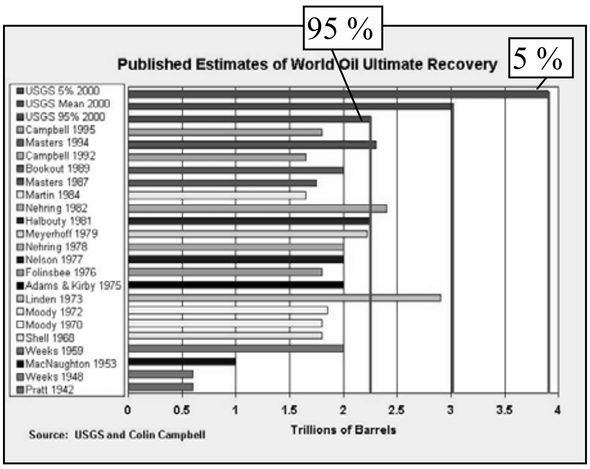
Peak oil in giant oil field Forties, UK, North Sea

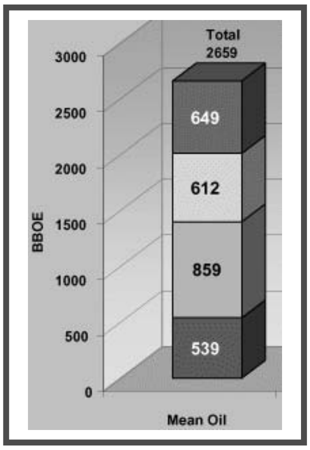


Source: **<u>www.og.dti.gov.uk</u>**

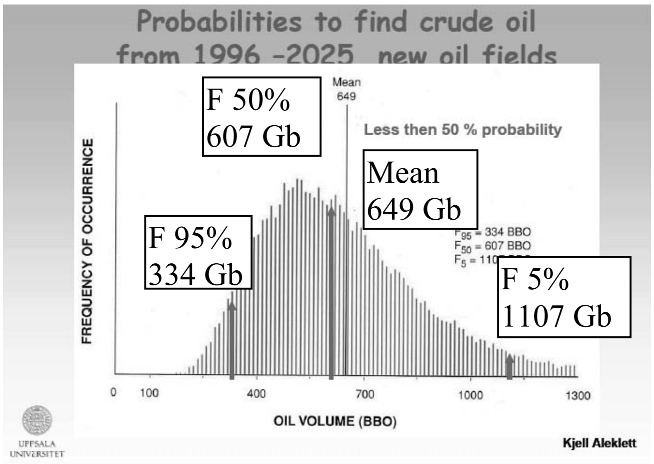
The production profile of oil over time is non-linear due to reservoir rock physics and usually follows a growing path up to a peak and then a declining curve after the peak. Therefore, current reserves may take 70-80 years to be produced, when production **<u>peters out</u>.** The critical event in oil history is the peaking, not the ultimate running out of oil. The global production curve is the superimposition of many peaking curves from fields all over the world at various stages of growth or decline.

(3) <u>Which ultimate recovery to use?</u> Apart from reserves, there are yet-to-be-discovered resources and oil from reserve growth resulting from technological advances. The total including past production (appr. 1000 Gb) is called ultimate recovery. We must understand that all estimated ultimate recoveries (EUR) have a probability attached to them. The larger the EUR, the less probable it is. For example, the longest bar in the chart of EURs (<u>www.eia.doe.gov</u> , left) has only a probability of 5%. For the purpose of deciding on additional oil dependent infrastructure, an estimate with the highest possible probability should be used. Thus, it is not safe to conveniently pick the highest EUR from a pool of estimates in the hope that we will be alright. Investors like super annuation funds need certainty that their investments get safe returns when funding oil dependent infrastructure.





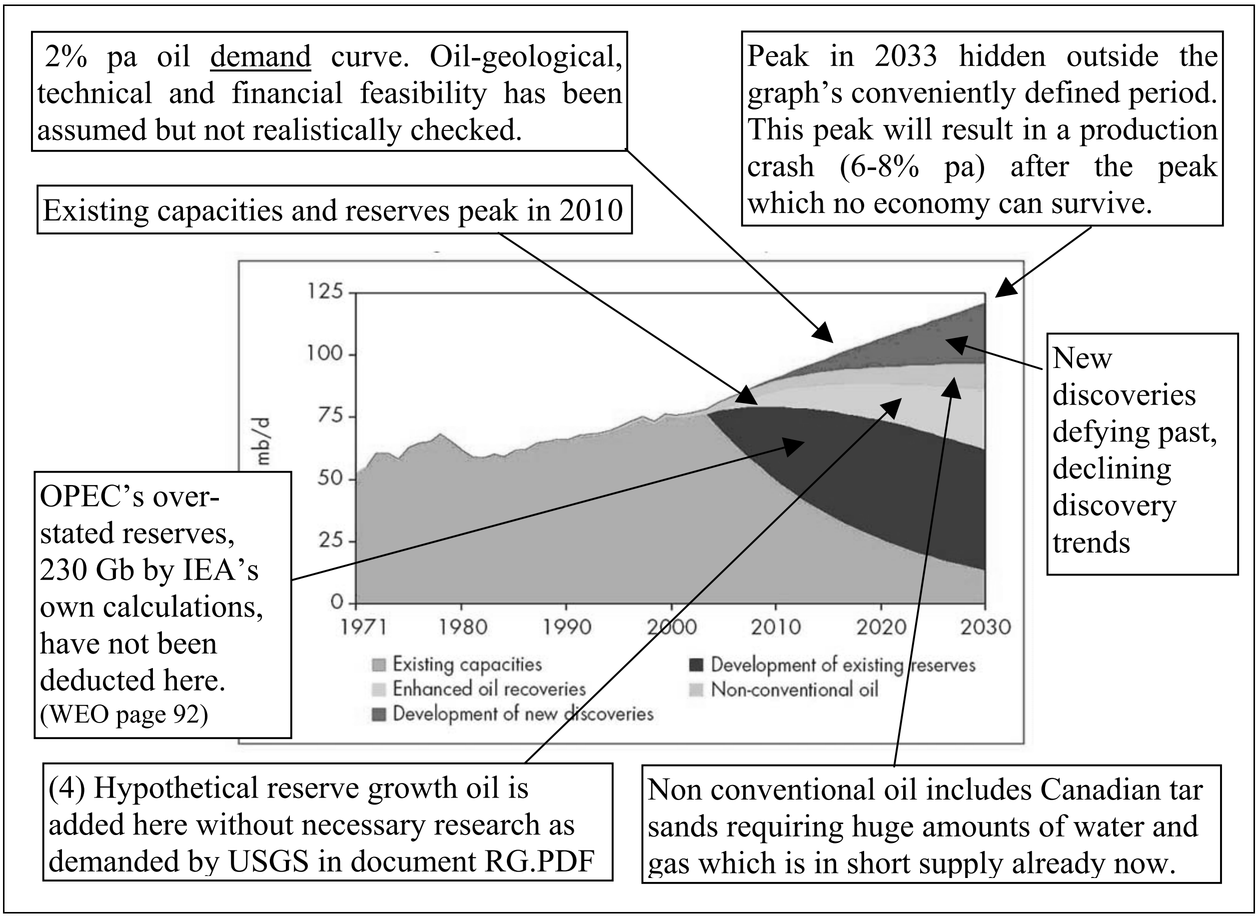
The latest, most extensive oil geological assessment was done by the US Geological Survey (**<u>www.usgs.gov</u>**). However, the USGS 2000 mean estimate (right) contains 612 Gb hypothetical reserve growth oil and 649 Gb of undiscovered oil defying discovery trends in the first 10 years of its study period. Moreover, a mean estimate is not necessarily the most likely estimate. The graph below (http://www.aspo-australia.org.au//PPT/Aleklett.pdf) shows the interdependency between the probability and the size of the USGS undiscovered oil estimates. The 649 Gb has only a probability of less than 50%. Who would invest on such a low chance of success? Yet this is what governments (and banks) are relying on when they base their policy on these types of estimates. They should rather use the USGS 95% probability estimate of 2,248 Gb (as of end 1995) which is fairly close to many other estimates.



(4) __Timing and Probability of Global Peaking:__ The USGS did not forecast oil production. The public relations wing of the Department of Energy, the Energy Information Administration (EIA) published scenarios (not forecasts) in which reserves and resources are freely distributed under 2% demand growth curves, an oil-geologically questionable and highly unrealistic procedure which leads to late, theoretical peaks after 2030. In order to observe the EUR, these late peaks are necessarily followed by production crashes of between 6% and 8% pa. which no economy can survive. They are non-desirable doomsday scenarios.

Even the high USGS 2000 mean estimate will produce a **__2016 peak__** if one assumes a more modest 2% decline after the peak (see front cover). The much safer and more conservative USGS 2000 95% probable estimate will therefore peak years **__before 2016__**. An evaluation of these scenarios can be found as submission 75 on energy efficiency to the PC available online at: **__www.pc.gov.au/inquiry/energy/subs/sub075attachment1.pdf__**

On the basis of the USGS 2000 mean estimate, the IEA prepared a projection of future production contained in its WEO 2004 (embellished Fig. 3.20 below, page 103) which,



however, is inconsistent with other findings in the same report. It also assumes that huge investments are made and that these are successful which is by no means guaranteed.

In a smaller table (3.4, page 102) the WEO 2004 also reveals its 90% probable case which **peaks between 2013 and 2017**. These are the hidden warnings by report writers which are too often overlooked.

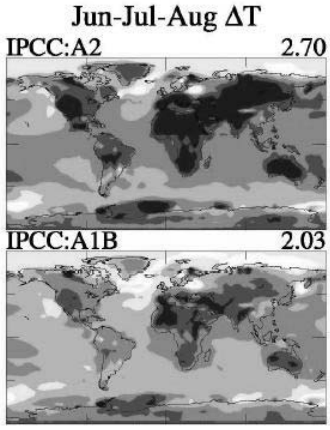
Other peak oil years		
Matthew Simmons Investment banker, Advisor to Cheney's 2001 energy task force Book "Twilight in the desert" ISBN 0-471-73876-X	**Worried about oil production from the world's giant oilfields, in particular in Saudi Arabia: "….that peaking of oil will never be accurately predicted until after the fact. But the event will occur, and my analysis is leaning me more by the month, the worry that peaking is at hand; not years away…." http://www.simmonsco-intl.com**	**Peak oil at hand (if production in Saudi Arabia were sustainable)**
K.S. Deffeyes Princeton Uni Paperback ISBN 0-691-11625-3; page 157	**"The mathematical peak falls at the year 2004.7; call it 2005…. and there is a fair amount of jitter in the year to year production…. There is nothing plausible that could postpone the peak until 2009. Get used to it."**	**Peak oil 2005-2009**
C.J. Campbell Oil geologist from Ireland, founder of ASPO (Association for the Study of Peak Oil & Gas) www.peakoil.net	**"When writing, it is easy to describe the situation in terms of 'an imminent peak' without putting a specific date to it.... The real point is not so much the exact date of peak but the statement that the First Half of the Oil Age, which was characterised by growing production, is about to be followed by the Second Half when oil production is set to decline along with all that depends upon it. On that at least we can stand firm."**	**Regular oil peaked 2004 All liquids peak 2010**
S.Bakhtiari Senior expert, corporate planning division, National Iranian Oil Co.	**"The latest World oil production capacity model simulation predicts that worldwide crude oil production (inclusive of all other hydrocarbon liquids, such as NGLs etc) will peak during 2006-2007" www.stcwa.org.au/BO2/Bakhtiari-O&GJ-April%202004.doc**	**Peak oil 2006-2007**
Chris Skrebowski Editor of Petroleum Review	**Chris balances supplies from new oil fields with decline from existing fields in the slide show *Production Reality* (slide 43): "Whatever approach we use the answer seems to be peak by 2008; before that, if all goes to plan, the world can, possibly, meet likely demand; after that demand can only be met by massive demand destruction". http://www.energyinst.org.uk/content/files/chrisskrebowski.pdf**	**Peak oil 2008**
PFC Energy Strategic advisors in global energy, Washington	**"OPEC production capacity and reserves will suffer from the additional strain and some models suggest that even OPEC will struggle to fill the differential between Non-OPEC supply and global demand beyond 2015-2020". Source: www.csis.org**	**2014 (high demand) 2020 (low demand)**

(5) Conclusion:. In the absence of alternative fuels in the required quantities to fill the emerging oil supply gap and considering the huge technological inertia in our existing oil consuming machinery it is no longer economic to invest in further oil dependent infrastructure and/or facilities. Fuel efficiency improvements may help but cannot overcome the problem of a permanently declining oil production at 2%, later 5% pa. Though peak oil is initially a liquids problem it will trigger a global primary energy crisis as the world will try to replace oil by whatever other source of energy it can find. Due to the denial mode of both State and Federal Governments for 10 years now the alternatives gas and nuclear energy are not ready and may take decades to develop. Coal to liquids without geo-sequestration will mean the heat death of earth. Read J. Hansen's paper "Is there still time to avoid dangerous anthropogenic interference with global climate?" at http://www.columbia.edu/~jeh1/keeling_talk_and_slides.pdf

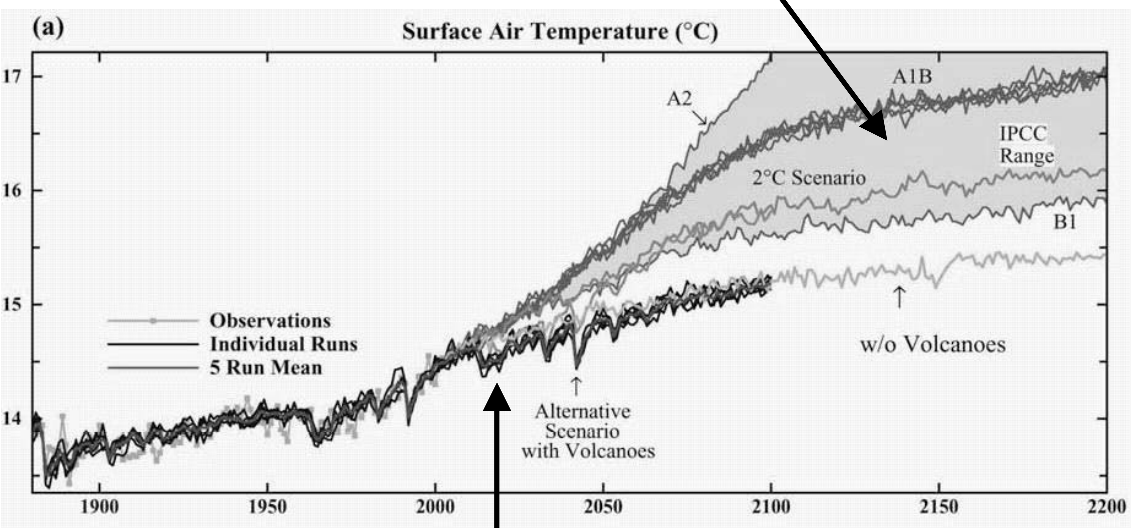
What 10 Years Business as Usual Will do to our Climate

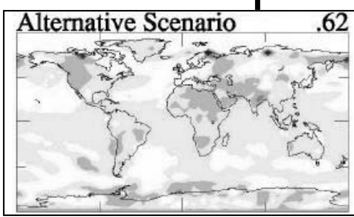
Dangerous human-made interference with climate

Summarized extracts from a study by J. Hansen, director of
NASA Goddard Institute of Space Studies 22/12/2005



Business as usual:
a hot planet Earth outside
our experience



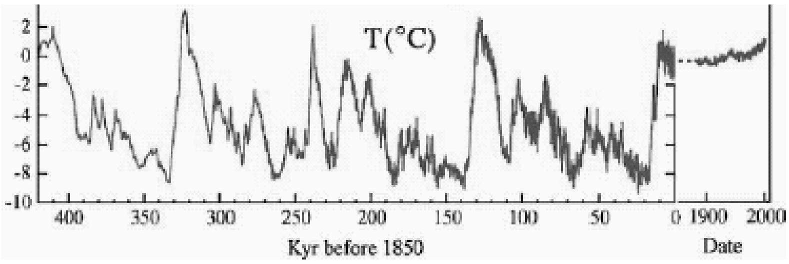


Alternative scenario with $\Delta T < 1\ ^{o}C$: green house gas reduction by 60 – 80 % necessary

Prepared by Matt Mushalik Jan 2006

Summary: Is there still time to rescue our climate?

1. An alternative scenario in which green house gas emissions are being reduced can stabilize the Earth's climate, but this strategy is currently not being pursued in the required quantities and at the required speed of change
2. **<u>Another 10 years of business as usual</u>** (more fossil burning infrastructure) and an alternative scenario at a later stage will no longer be able to control a run-away climate change in future with i.a. large scale flooding of coastal strips.
3. Action is therefore needed NOW, not later. Green house gas reductions must be 60 to 80 % to ensure that temperature increases do not exceed 1 ^{o}C in this century
4. The public must understand these facts and put as much pressure on politicians as is needed to overcome shortsighted, vested interests of the fossil fuel industry



Ice ages and inter-glacial periods differ by just 5 ^{o}C. Increase in temperature by 2-3 ^{o}C would lead us into a hot, unknown world and sea levels 25 ± 10 m higher than today

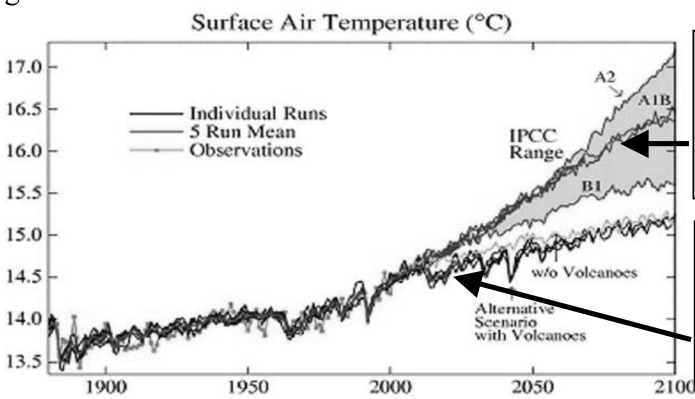
Facts:

(a) We are now in the Holocene, an interglacial period, which lasted for about 10,000 years with a comparatively stable climate and sea level. The preceding ice age, at its peak 20,000 years ago, was around 5 ^{o}C cooler than now. Sea levels were 110 m lower. The previous interglacial period was 1 ^{o}C warmer than today and sea levels 5-6 metre higher than at present.

(b) Green house gas emissions from burning fossil fuels since the industrial revolution are now heating up an already warm planet Earth. An increase in temperatures of 0.75 ^{o}C since 1880 has already been measured. Due to the time lag inherent in our climate system, a further 0.6 ^{o}C is unavoidably in the pipeline. A further warming of 2-3 ^{o}C resulting from business as usual would mean a different planet Earth outside our present and past experience where today's extreme weather events become average.

Conclusion:

The processes controlling the Earth's temperature, green house gas concentrations, ice melting and sea level changes are highly complex and non-linear. We do not fully understand the consequences of burning fossil fuels. This life-experiment with our planet must stop before it gets out of control



These BAU scenarios with CO_2 emissions growing around 2% pa will mean a different planet Earth and a climate outside our experience

This alternative scenario with a reduction of green house gases by 60 to 80 % must be pursued NOW, not when it is too late

Read J. Hansen's articles (http://pubs.giss.nasa.gov NASA Goddard Institute for Space Studies)

Introduction

In 2005, Tim Flannery published “The Weather Makers” (ISBN 1-920885-84-6) in which he describes the destructive impact of global warming on flora and fauna. His book and many other studies around the world warn us that we cannot continue the way we have lived in the past decades.

In December 2005, the community discussion forum on peak oil, “The Oil Drum” posted a topic entitled

"Greenland or why you might care about ice physics"
http://www.theoildrum.com/story/2005/12/9/31522/5910

and alerted us of a worrisome acceleration of ice melting in Greenland, including links to research done by James Hansen, director of the NASA Goddard Institute for Space Studies (http://www.giss.nasa.gov/staff/jhansen.html) and researcher at the Columbia University Earth Institute both of which participate in the work being done by the Intergovernmental Panel on Climate Change (IPCC, http://www.grida.no)

The IPCC considered in its 2001 report a global warming of 2-3 degrees ^{o}C likely to be dangerous. Climatologists around the world are preparing now for the next IPCC report due out in 2007.

J. Hansen, in December 2005, has published results from his climate simulation models in a paper entitled

"Is there still time to avoid dangerous anthropogenic interference with global climate?"
(http://www.columbia.edu/~jeh1/keeling_talk_and_slides.pdf)

and found that the **dangerous level of global warming is closer to just 1 degree ^{o}C.** Hansen’s focus is on sea level changes from melting ice sheets which are of particular interest to Australia as most of its population is concentrated along the coast. This paper is a summary of Hansen’s recent study and also includes information from some of his earlier publications:

“Defusing the Global Warming Time Bomb”
Article in the ***Scientific American***, March 2004, pages 70-77
http://pubs.giss.nasa.gov/docs/2004/2004_Hansen1.pdf

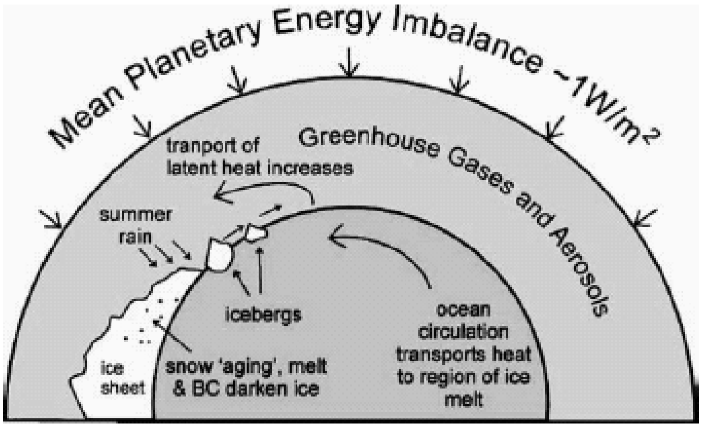
“A slippery slope: How much global Warming constitutes ‘Dangerous Anthropogenic Interference’?”
Article in ***Climatic Change*** (2005) pages 269-279
http://pubs.giss.nasa.gov/docs/2005/2005_Hansen1.pdf

“Earth’s Energy Imbalance: Confirmation and Implications”
Research article in ***Science***, Vol 308, June 2005
http://pubs.giss.nasa.gov/docs/2005/2005_Hansen_etal_1.pdf

Readers interested in future updates of Hansen’s research can subscribe to his mailing list by sending a request to jhansen@giss.nasa.gov

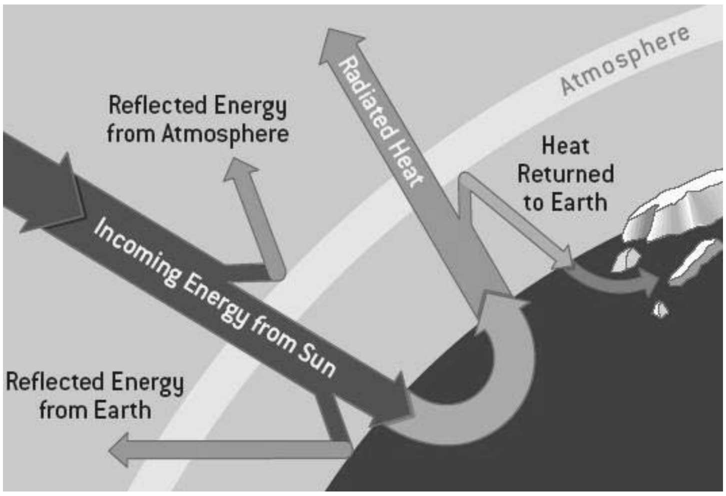
Closer to dangerous man-made climate interference than we think

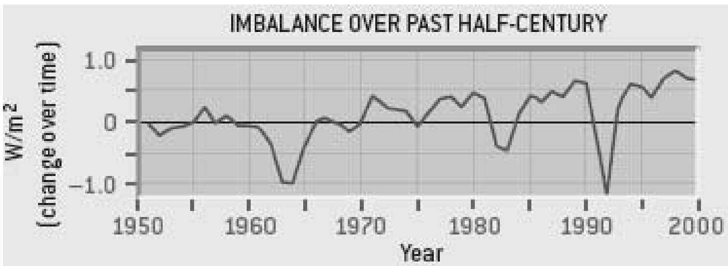
The mechanics of global warming:
The earth is out of energy balance with space



http://pubs.giss.nasa.gov/docs/2005/2005_Hansen1.pdf

"This large planetary energy imbalance has no known precedent, greatly exceeding the global mean energy imbalance associated with changes of the Earth's orbital elements that paced the natural building and decay of ice sheets."





An imbalance of 1 W/m2 translates to an increase of global temperatures of ¾ ^{o} C.
http://pubs.giss.nasa.gov/docs/2004/2004_Hansen1.pdf

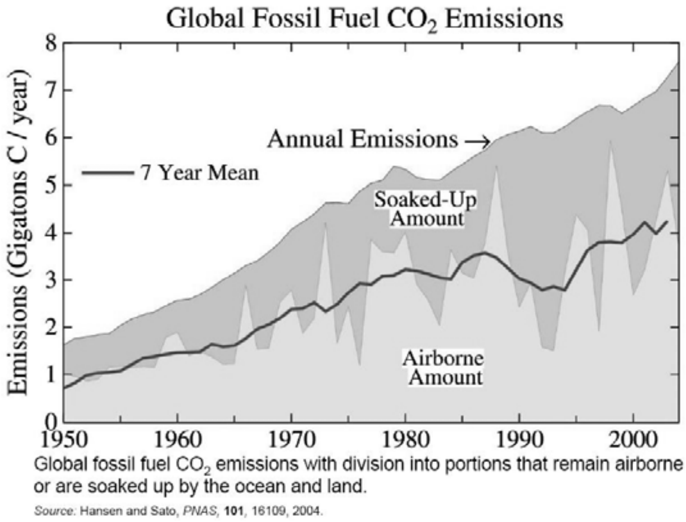
Green house gases like water vapour, carbon dioxide, methane and nitrous oxide trap the infrared radiation released by the Earth's surface. This is our resulting energy balance:

Energy in Watt/m^2	
Incoming solar	340
Reflected natural	-100
Reflected human	-1
Radiated natural	-240
Radiated human	2
Net balance	+1

The net balance is a small difference compared to the total incoming and outgoing energy. This means that our climate is very sensitive to changes in reflected and radiated energy.
The human-made planetary energy imbalance has increased from 0.2 W/m2 in 1950 and is now an **incessant 1 W/m2** which goes mainly into:
(1) warming the ocean (90-95%)
(2) melting ice (5-10%)

The fraction of the energy imbalance that goes into ice melting will increase as the atmosphere becomes moister and transports energy more efficiently to the ice, and especially as ice streams accelerate and more ice is rafted to warmer regions.

Black carbon (BC) from pollution accelerates melting.

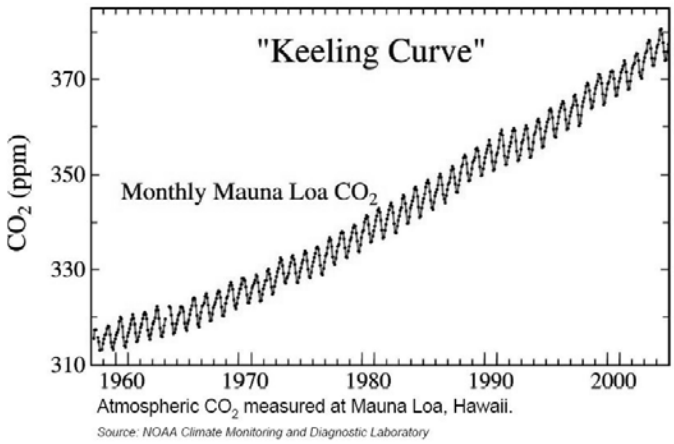


Carbon dioxide emissions increase 2% pa

What happens to our CO2 emissions?

- 20-35% soaked up by oceans, making them acidic
- 5-20% taken up by vegetation and soil
- 58% accumulates in the atmosphere

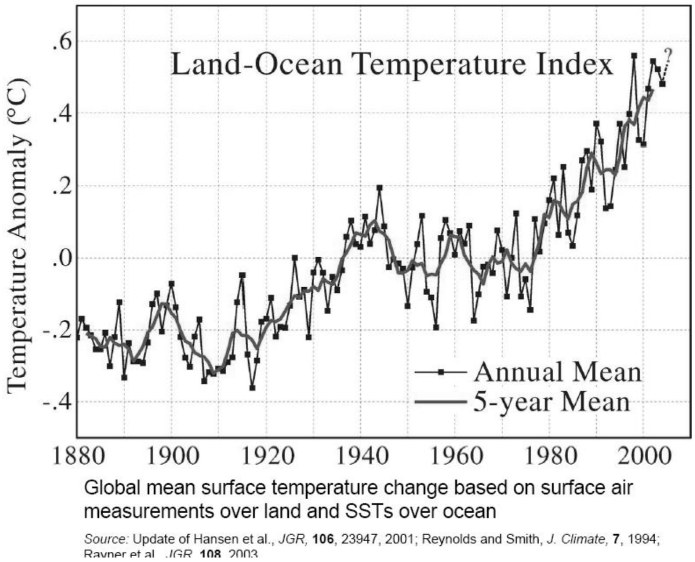
The increasing annual emissions result in higher CO2 concentrations (down, left), year after year. This cannot continue for very much longer without serious consequences.



CO2 concentrations: A curve with increasing slope becomes visible.

Keeling found that atmospheric CO2 decreases in the daytime as plants assimilate CO2 and increases at night. While plants take one breath a day, the Earth takes one breath a year.

Stabilization of atmospheric CO2 levels in the next few years would require a reduction of annual fossil fuel emissions by 60% - 80%



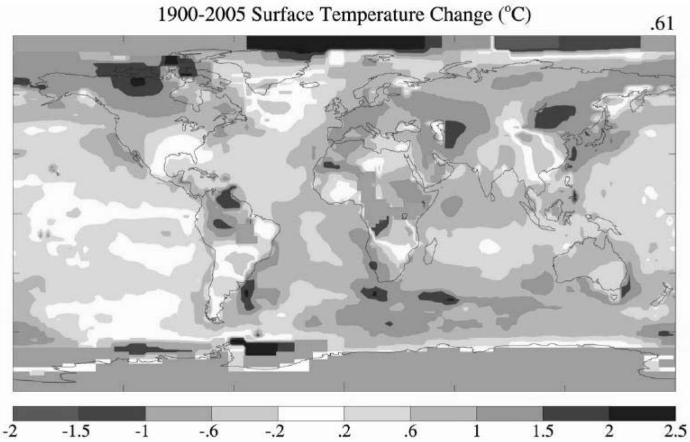
Temperatures increased by more than half degree in the last 30 years.

There can be no doubt the Earth is becoming warmer.

In 1998, temperature had jumped 2 standard deviations from the previous trend line, caused by the strongest El Nino of the century.

Green house gases absorb the Earth's infrared radiation and reduce heat emissions to space. This creates a temporary planetary energy imbalance.

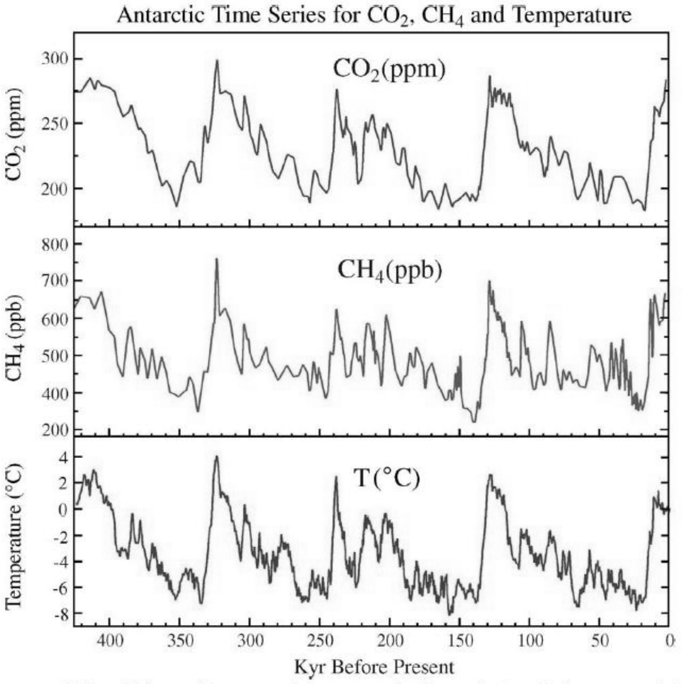
The Earth will warm up until it restores its energy balance.



Change of surface temperature index based on local linear trends using surface air temperature over land and SST over ocean.

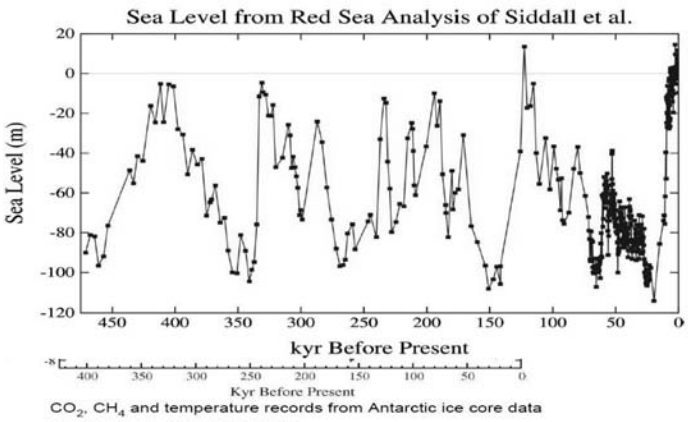
Sources: Hansen et al., *JGR*, **106**, 23947, 2001; Reynolds and Smith, *J. Climate*, **7**, 1994; Rayner et al., *JGR*, **108**, 2003.

The increase of temperature is not equally distributed over the whole world. In some areas, temperatures have soared more than average while in others there even was a decrease. Measurements come from weather stations, ships and satellites. Urban heat as a cause for systematic errors in temperature readings were eliminated. The largest areas of warming are over the oceans



CO_2, CH_4 and temperature records from Antarctic ice core data

Source: Petit et al., Nature, 399, 429, 1999



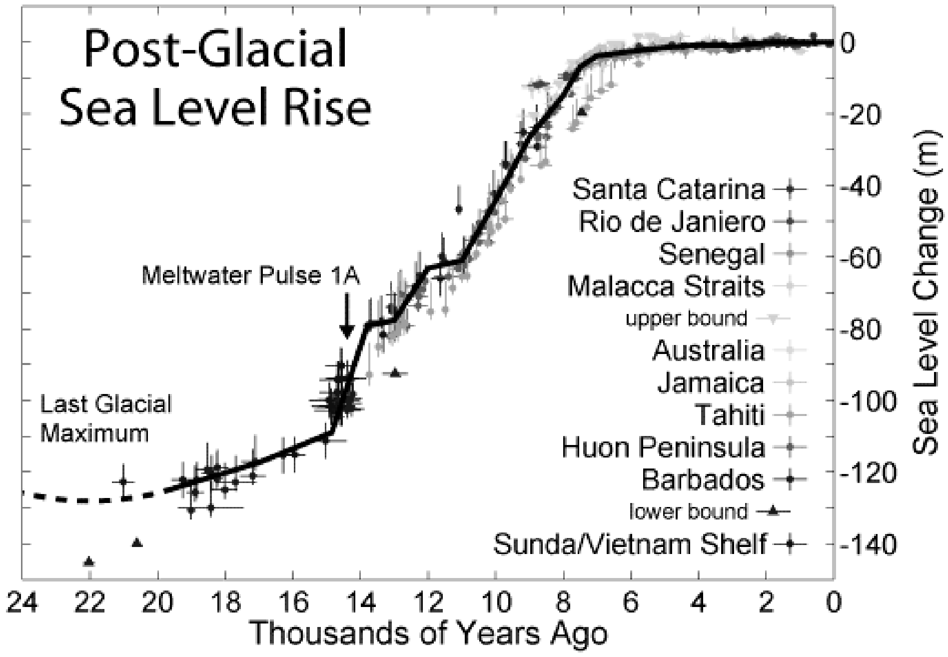
CO_2, CH_4 and temperature records from Antarctic ice core data

Source: Petit et al., Nature, 399, 429, 1999

This graph shows the close interrelationship between the greenhouse gases carbon dioxide and methane and temperatures over the past 400,000 years. Natural climate swings between ice ages and interglacial periods were caused by slow variations of the earth's orbit induced by changing gravitational forces mainly from the positions of Jupiter, Saturn and Venus. They alter the geographical and seasonal distribution of incoming solar energy by as much as 20%, resulting in small planetary energy imbalances which affect, over long periods of time, the building and melting of ice sheets.

The temperature change observed between the last ice age 20,000 years ago and today was 10 ^{o}C in Antarctica and 3 ^{o}C in the equatorial Pacific, an average of 5 ^{o}C ± 1 ^{o}C.

During that time period (recorded Egyptian history goes back 5,000 years!) water levels rose by 110 m. But during Meltwater Pulse 1A, sea levels rose by 1 m each 20 years!!



Source : http://en.wikipedia.org/wiki/Image:Post-Glacial_Sea_Level.png

Sea levels and temperatures were comparatively constant for the last 8,000 years, one of the factors allowing civilisation to take hold. When ice is disintegrating, sea level rises can be fast, as happened during the so-called Meltwater Pulse 1A event when sea levels rose by 20 m in 400 years or 1 m per 20 years (www.mala.bc.ca/%7Eearles/mwp1a-mar02.htm)

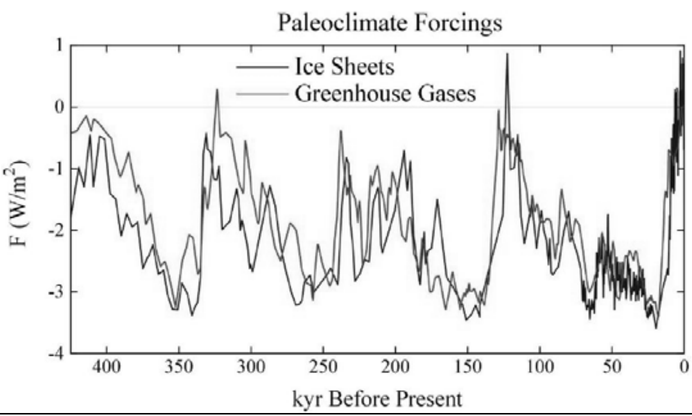
Paleoclimate Forcings

Total ice age climate forcings	
Ice sheets and vegetation	3.5 ± 1 Watt/m^2
$CO_2 + CH4 + N_2O$	2.6 ± 0.5 Watt/ m^2
Aerosols	0.5 ± 1 Watt/ m^2
Total	6.6 ± 1.5 Watt/ m^2

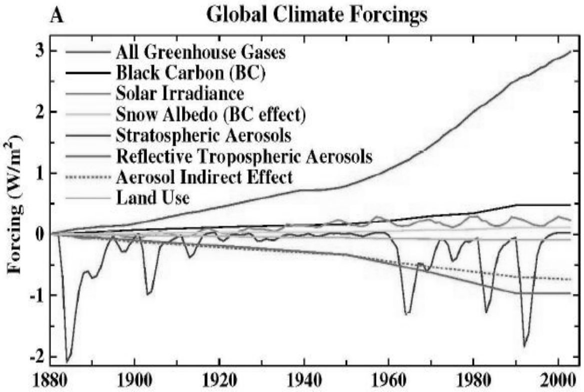
The climate sensitivity is measured in degree temperature change per Watt/ m^2 climate forcing. With a total temperature change between ice ages and interglacial periods of 5 ^{o}C we get:

$$5\ ^oC / 6.6 \text{ Watt/ } m^2 = 0.75 \pm 0.25\ ^oC \text{ per Watt/ } m^2$$

Climate forcing is measured in Watt per m^2 of the Earth's surface. 1 Watt/m2 acting for 1000 years could melt enough ice to raise sea levels by 100 m. Under natural, paleoclimate forcings, the Earth is in radiation balance within a fraction of 1 Watt/m2.



Climate Forcings in the industrial period



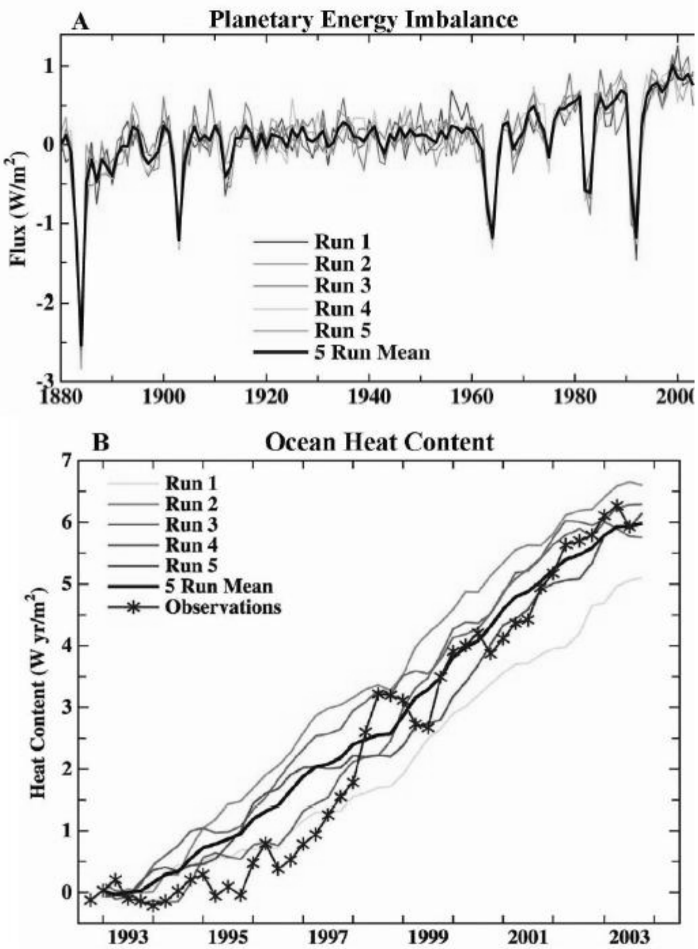
(A) Forcings used to drive climate simulations.

The burning of fossil fuels has introduced many new climate forcings. Including natural forcings (changes in sun radiation and volcanic activities) they amount to a total of 1.85 W/m2

	Watt/m^2
CO_2	**1.5 ± 0.2**
CH_4,CFCs	**1.2 ± 0.3**
O_3	**0.4 ± 0.2**
Black carbon	**0.6 ± 0.3**
Reflective aerosols	**-1.0 ± 0.5**
Forced cloud changes	**-1.0 ± 0.6**
Land cover change	**-0.15 ± 0.2**
Sun	**0.3 ± 0.2**
Total	**1.85**

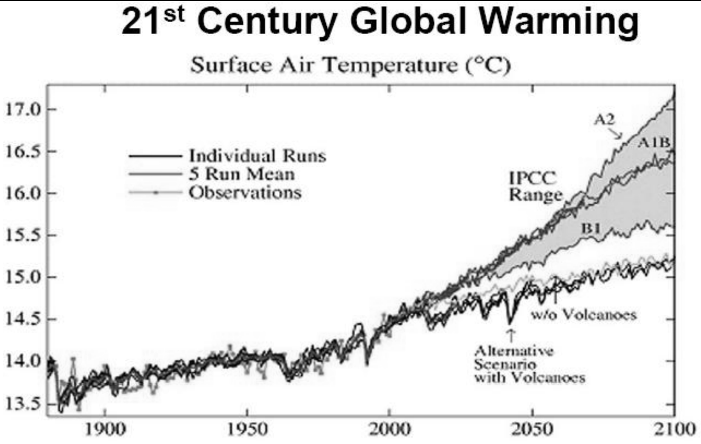
1880 – 2003 climate forcing 1.85 W/m2
Observed 0.75 ^oC increase corresponds to 0.75 ^oC/climate sensitivity = 1 W/m2
Difference from time lag between forcing and temperature increase = 0.85 W/m2

More warming in the pipeline: 0.85 * 0.75 = 0.6 ^oC



The above industrial climate forcings have been put into a climate simulation model. The graph shows the resulting net radiation at the top of atmosphere resulting from different assumptions (variance in climate forcings according to the above table). The spikes are caused by aerosols and other particle emissions from volcanic eruptions.

Where does the heat go? Primarily into the top 750 m of the world oceans where the heat accumulates.
This does not only lead to the destruction of coral reefs but also to an expansion of the ocean water, resulting in rising sea levels.
Heat also goes into melting of ice caps which causes another sea level rise.



Climate Simulations for IPCC 2007 Report

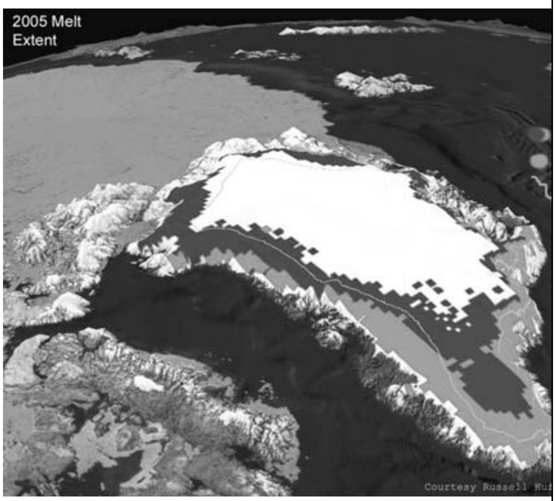
Climatologists around the world are busy preparing for the 2007 report of the Intergovernmental Panel of Climate Change (IPCC). The business as usual scenarios will result in temperature increases of 2 ^{o}C and a still increasing trend at the end of the century.

The model used for the above simulation of past temperatures is now being applied to forecast temperatures of the future up to 2100. The IPCC defined certain sets of scenarios assuming different levels of CO2 emissions. Scenarios A1B and A2 have a CO2 growth rate of 2% pa over 50 years.
The alternative scenario assumes slowly declining CO2 emissions in such a way that climate forcings are about 1 W/m2 in 50 years and 1.5 W/m2 in 100 years, resulting in a temperature increase of less than 1 ^{o}C.

Sea level investigations have to answer 2 questions:

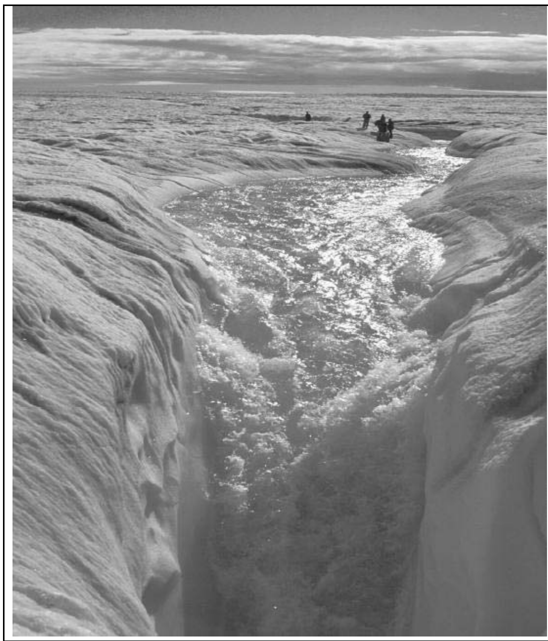
(1) What is the equilibrium change for a given magnitude of global warming?
During the last 400,000 years there were 2 interglacial periods when temperatures were about 1 ^{o}C higher than today. Corresponding sea levels were 5-6 m higher. To find a planet 2-3 ^{o}C warmer than now (business as usual scenario) one must go back 3 million years, when sea levels were 25 ± 10 m higher.

(2) How long do ice sheets take to respond to global warming?
There are ice sheet models around which put response times to warming at millennia but they fail paleoclimate and satellite tests. It is more reliable to look at what happened in the past, the real world. There were cases when sea levels rose rapidly, several metres in a century (see Meltwater Pulse 1A above). In a business as usual CO2 growth scenario, thermal expansion of ocean water and melting of alpine glaciers would cause a half meter rise in sea levels. Non-linear melting of Antarctic and Greenland ice sheets might bring about several metres sea level rise this century and several more next century.

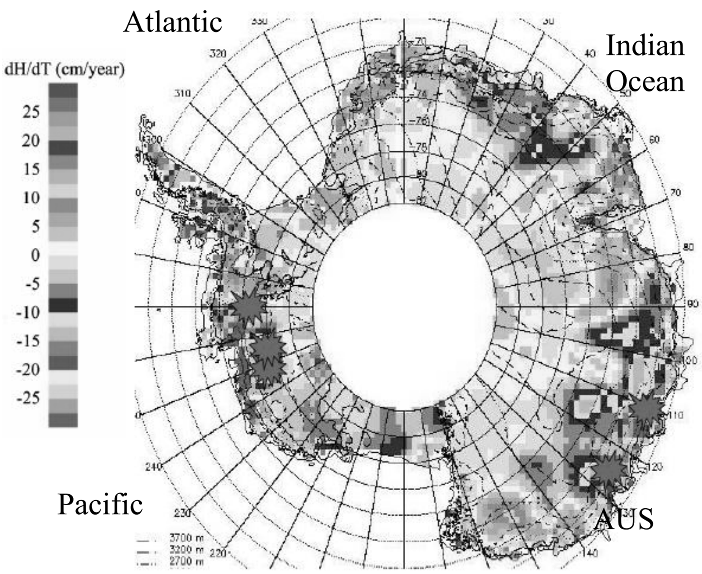


Greenland ice melting

- Record melt area in 2005
- Melting occurs up to an elevation of 2000m (highest altitude of ice 3000 m)
- 16% increase of melt area from 1979 to 2002
- 70 m thinning at one outlet glacier in last 5 years
- parts of the interior are thickening by 2-10 cm pa due to increased snow falls (global warming brings about a higher humidity) but this is only temporary as summer melt areas are creeping upwards
  http://news.nationalgeographic.com



Greenland meltwater disappears in a crack in the ice called a moulin (left), running down to its base and lubricating the ice's flow to the ocean. Jakobshaven ice stream (right) has almost doubled in recent years.



Acceleration of outlet glaciers in Antartica (red explosions on map). The ice exits in submarine valleys.

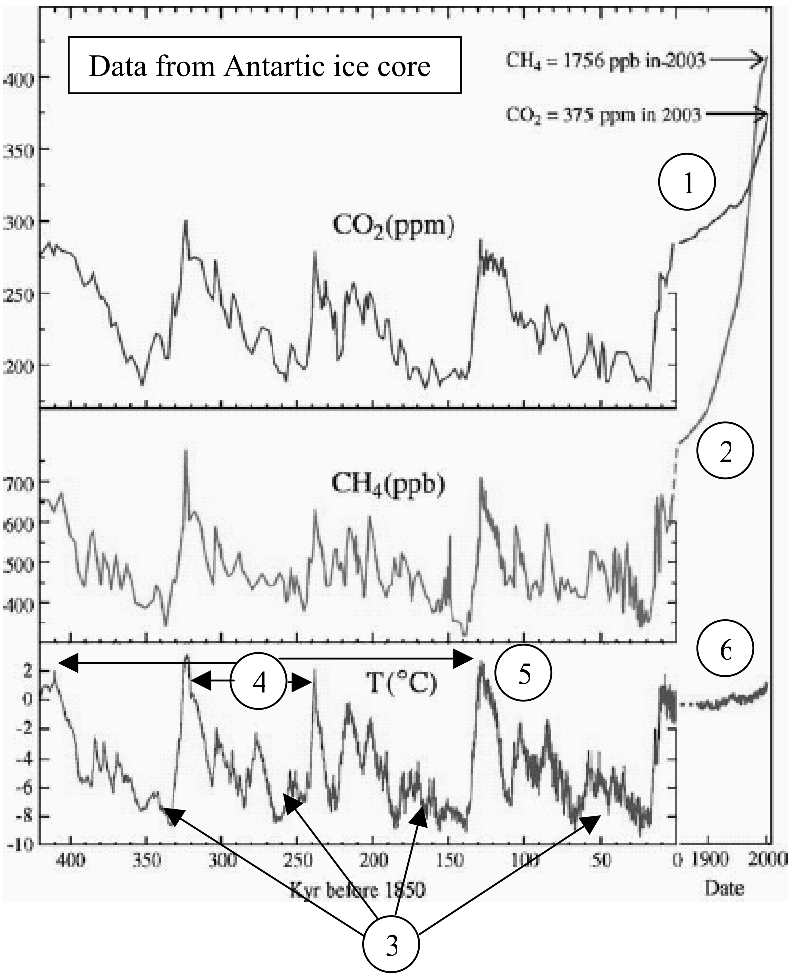
As in Greenland, there are areas of increasing ice thickness but there are multiple positive feedback loops which will give melting the upper hand.

So at present sea level changes are slow at first but will later accelerate when interior ice sheet growth can no longer offset melting at the margins.

"The IPCC calculates only a slight change in the ice sheets in 100 years; however, these calculations include only the gradual effects of changes in snowfall, evaporation and melting. In the real world, ice-sheet disintegration is driven by highly nonlinear processes and feedbacks…. Given the present unusual global warming rate on an already warm planet, we can anticipate that areas with summer melt and rain will expand over larger areas of Greenland and fringes of Antarctica. Rising sea level itself tends to lift marine ice shelves that buttress land ice, unhinging them from anchor points. As ice shelves break up, this accelerates movement of land ice to the ocean. Although building of glaciers is slow, once an ice sheet begins to collapse, its demise can be spectacularly rapid."

J.Hansen, source: http://pubs.giss.nasa.gov/docs/2004/2004_Hansen1.pdf

Human made climate forcings out of natural range



(The time scale for the last 150 years has been enlarged to show more detail)

Accumulating carbon dioxide (1) and methane (2) in the atmosphere from burning fossil fuels have now exceeded all historic records and constitute a human made climate forcing which is much greater than the natural forcing causing climate swings. Another ice age cannot occur unless humans become extinct.

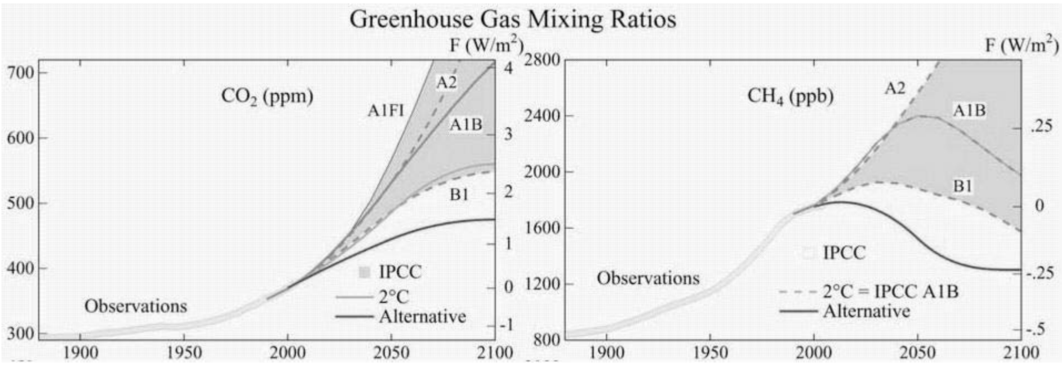
Ice ages (3) were around 5-6 degrees cooler than interglacial periods (4).
In the previous interglacial period (5) temperatures were 1 degree higher than today **with sea levels 5-6 m above current levels**.

Green house gases are heating up (6) our already warm planet earth which is now at the end of an interglacial period called Holocene.

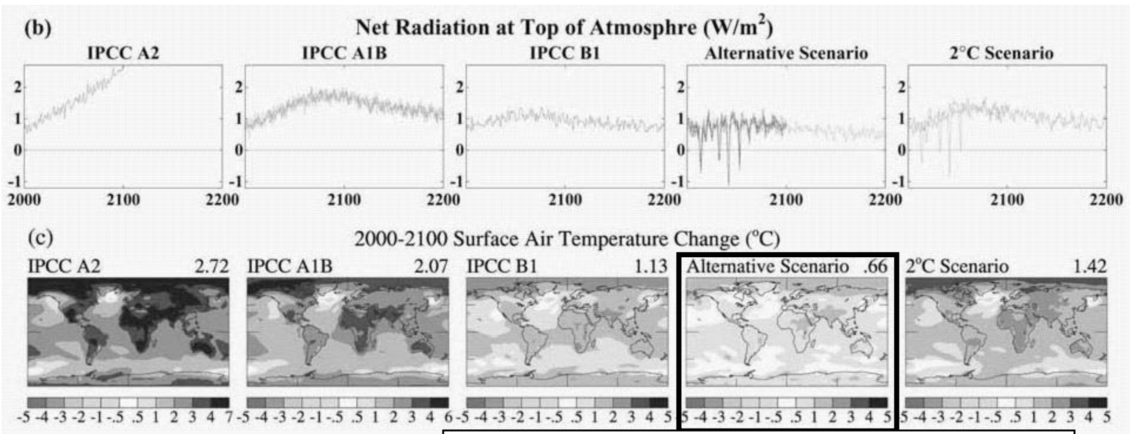
J. Hansen summarizes: "The Earth's temperature, with rapid global warming over the past 30 years, is now passing through the peak level of the Holocene, a period of relatively stable climate that has existed for more than 10,000 years. Further warming of more than 1ºC will make the Earth warmer than it has been in a million years. “Business-as-usual” scenarios, with fossil fuel CO2 emissions continuing to increase ~2%/year as in the past decade, yield additional warming of 2 or 3°C this century and **imply changes that constitute practically a different planet.**"

"The grim ‘business-as usual’ climate change is avoided in an alternative scenario in which growth of greenhouse gas emissions is slowed in the first quarter of this century, primarily via concerted improvements in energy efficiency and a parallel reduction of non-CO2 climate forcings, and then reduced via advanced energy technologies that yield a cleaner atmosphere as well as a stable climate. The required actions make practical sense and have other benefits, but they will not happen without strong policy leadership and international cooperation. **Action must be prompt, otherwise CO2-producing infrastructure that may be built within a decade will make it impractical to keep further global warming under 1°C**."

The business-as-usual scenarios A2, A1B and A1FI with increasing CO2 and CH4 levels in the atmosphere (down) will mean a warming of around 3 degrees ^{o}C far outside the range which has existed on earth in millions of years. Hansen: "***If anthropogenic climate change is several degrees Celsius, with equilibrium sea level rise 25 ± 10 m, a response time of centuries would provide little consolation to coastal dwellers, because they would be faced with intermittent incursions associated with storms and with continually rebuilding above a transient sea level.***"



"The alternative scenario target to keep added CO2 to ~ 80 ppm between 2000 and 2050, may already be beyond reach due to the 2%/year growth of CO2 emissions in the past decade. Continued rapid growth of CO2 emissions for another decade, along with the infrastructure producing the emissions, would make achievement of the alternative scenario impractical if not impossible."



This alternative scenario with reduced green house gas emissions over the next decades is still within reach but **prompt action is needed now, not later.**

"Given that wide-scale commercial use of technologies such as power plants with CO2 sequestration is at least a decade or more away, this implies that strong near-term emphasis on energy efficiency and renewable energy is essential to achieve a flattening of CO2 emissions. Potential energy savings from improved efficiency, even in developed countries, are sufficient to cover increased energy demand for the 1-2 decades needed to commercialize improving energy technologies"

Source: http://pubs.giss.nasa.gov/docs/notyet/submitted_Hansen_etal_1.pdf