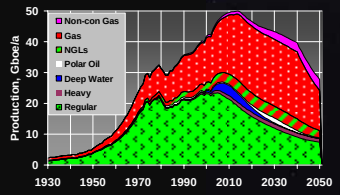
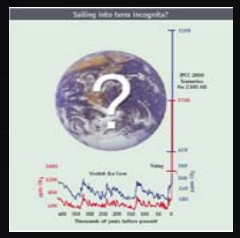
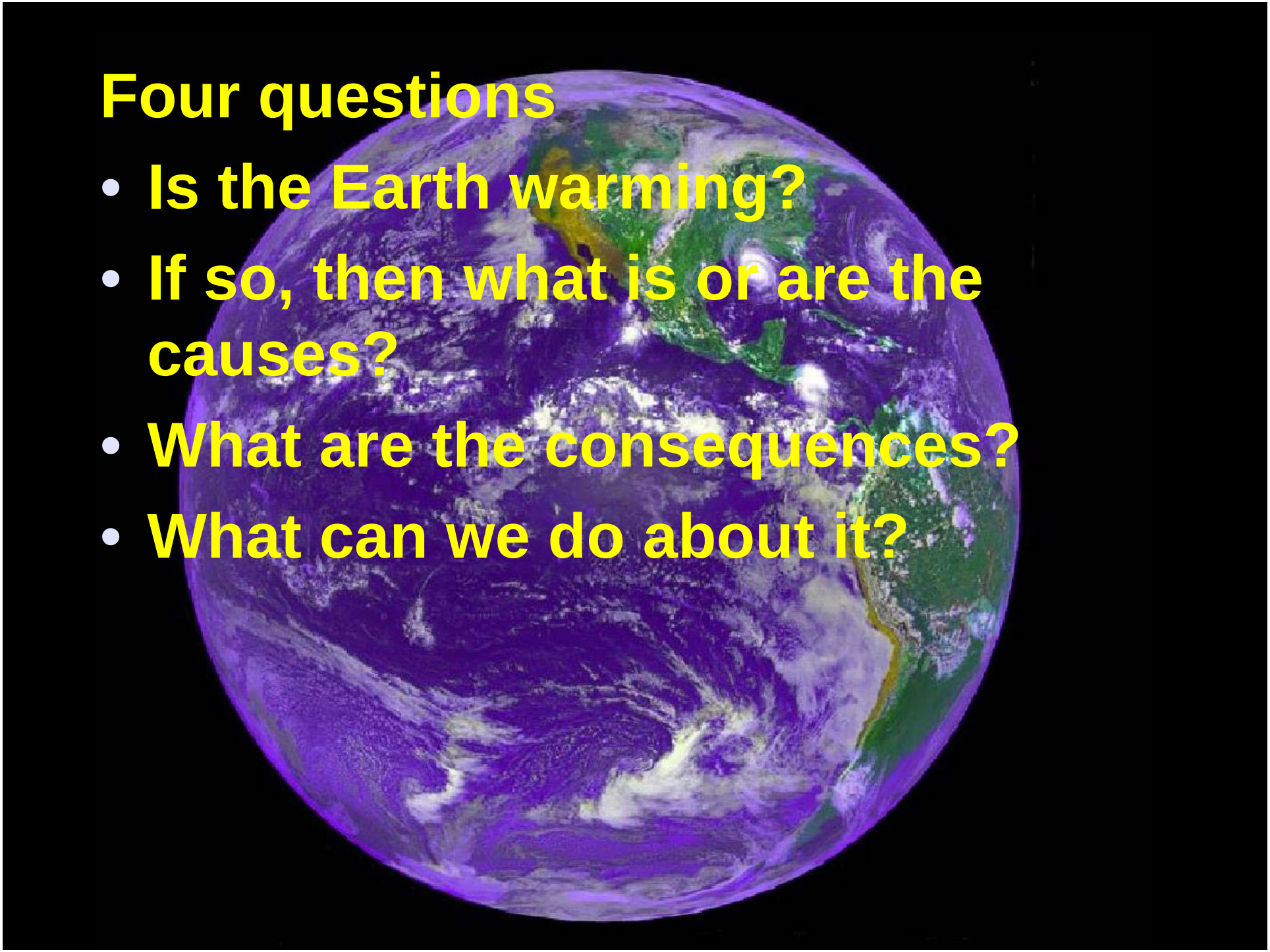



# Anthropogenic Global Warming

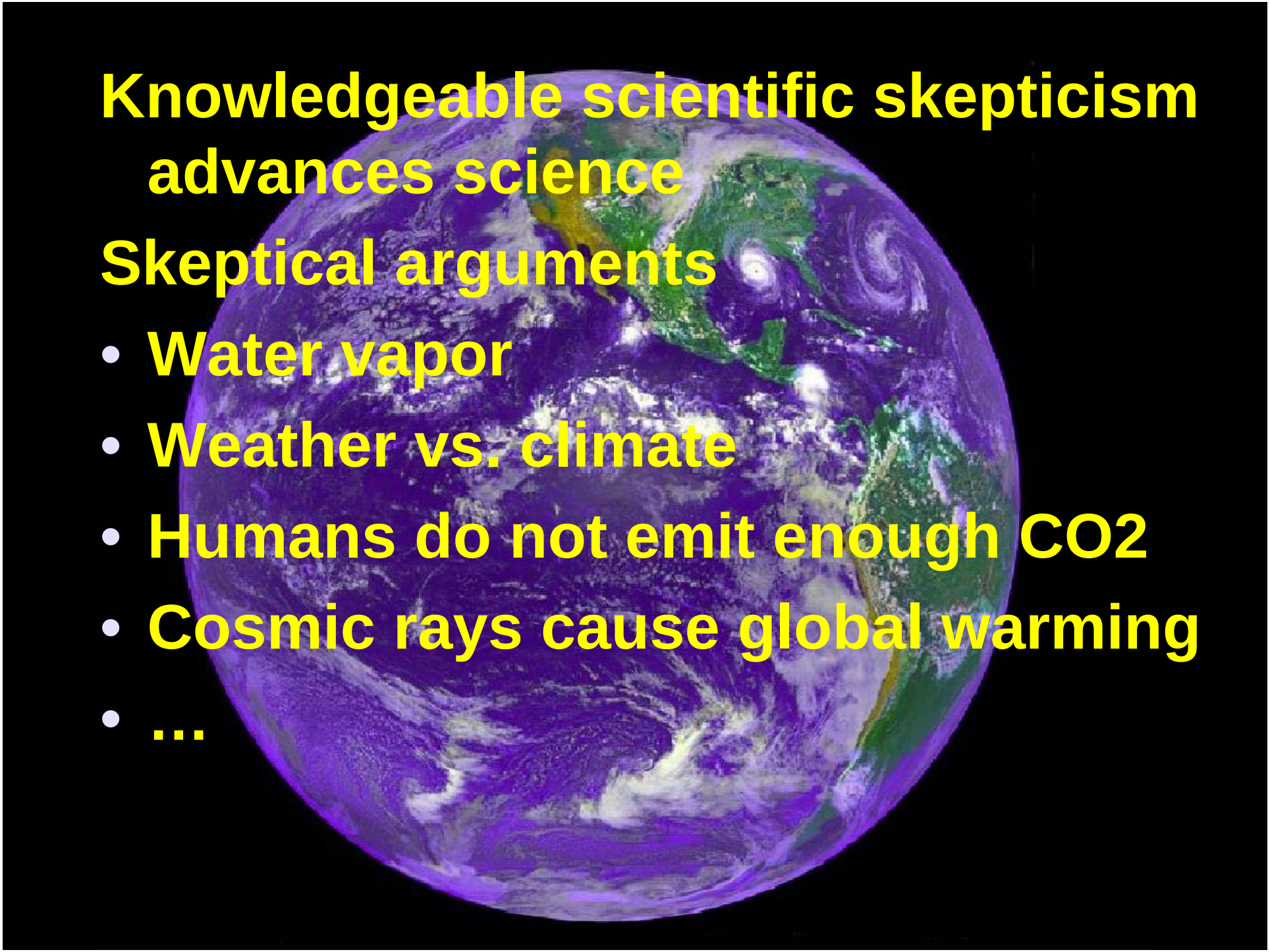
January, 2008





## Four questions

- Is the Earth warming?
- If so, then what is or are the causes?
- What are the consequences?
- What can we do about it?



Knowledgeable scientific skepticism advances science

Skeptical arguments

- Water vapor
- Weather vs. climate
- Humans do not emit enough $CO_2$
- Cosmic rays cause global warming
- …

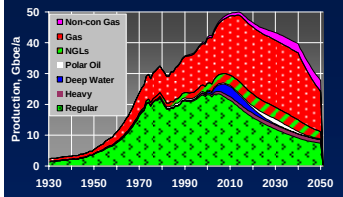
## Four questions

- **Is the Earth warming?**
- **If so, then what is or are the causes?**
- **What are the consequences?**
- **What can we do about it?**

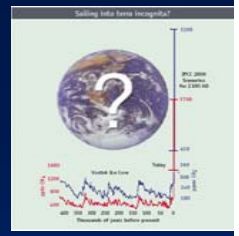
# Is the Earth Warming?

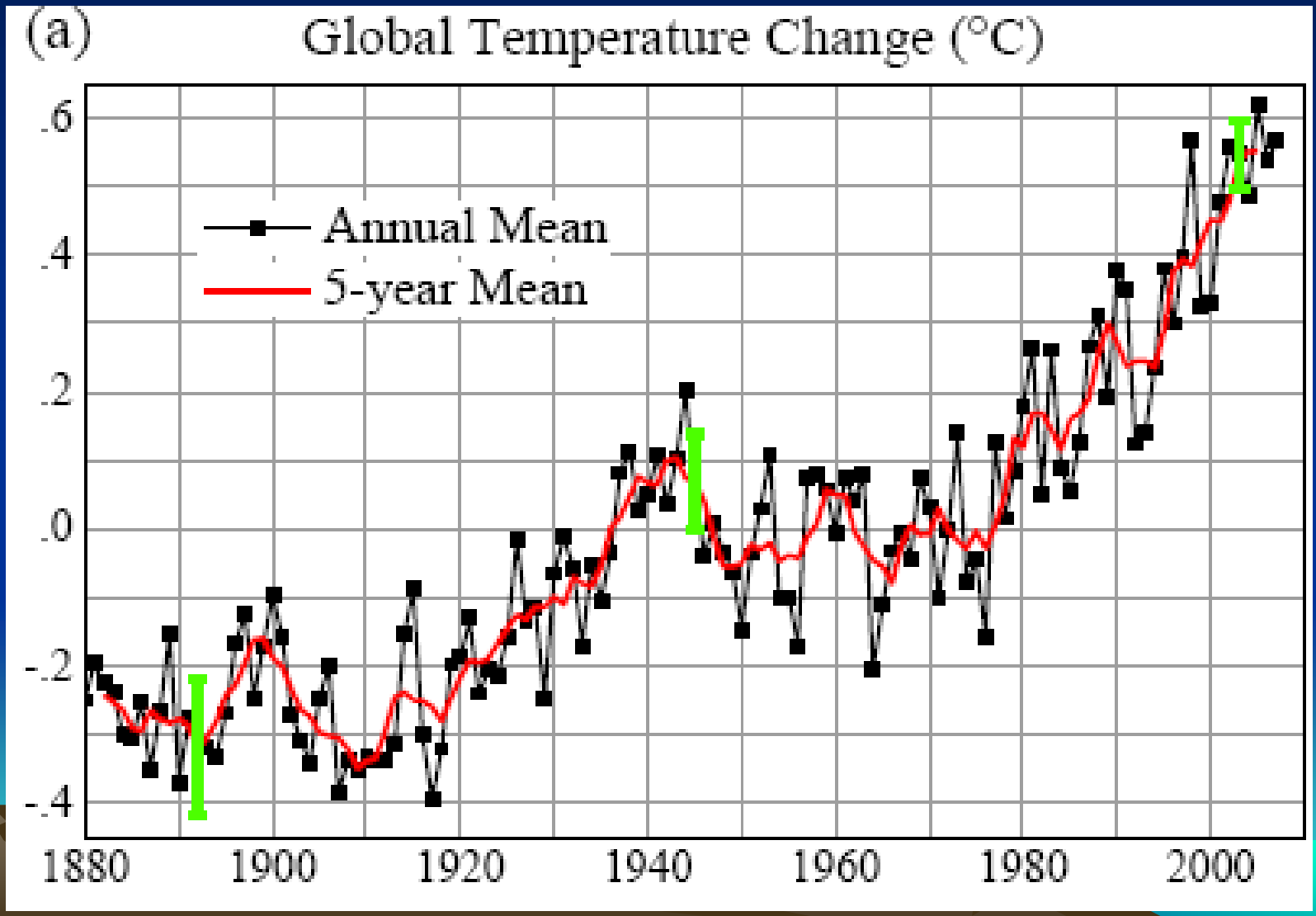
Two ways to answer this question

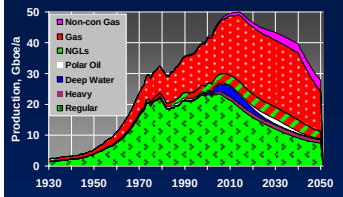
- By direct measurement of the Earth's temperature
- By observation and measurement of anticipated phenomena



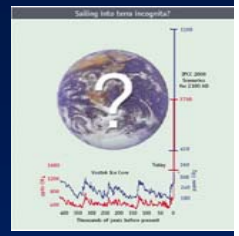

# Direct measurement



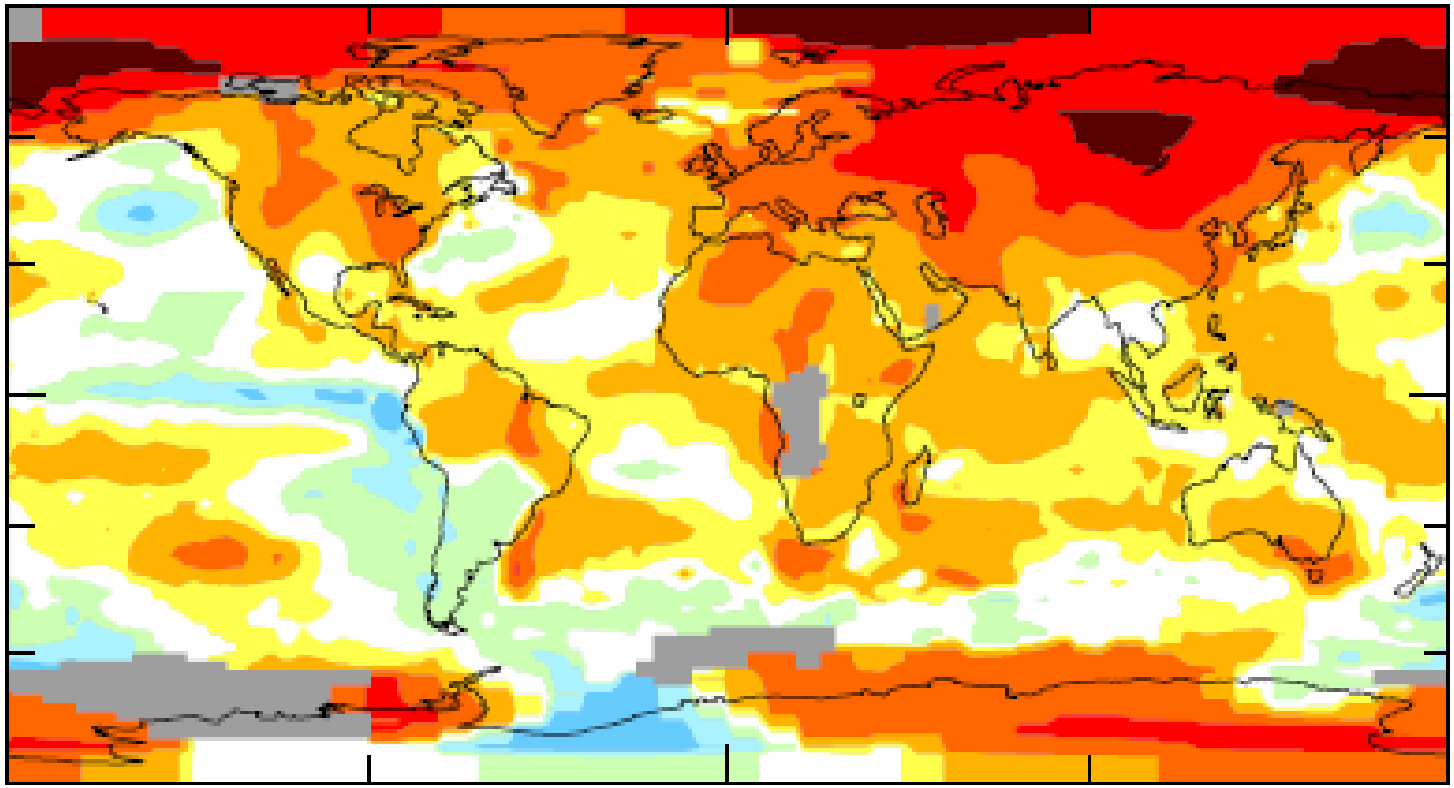




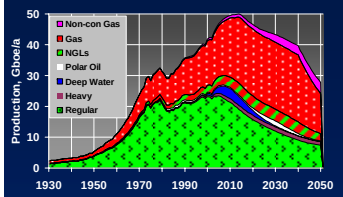

# Temperature anomaly



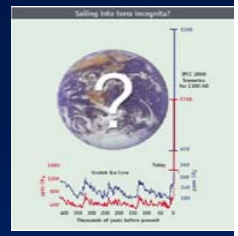
(b) 2007 Surface Temperature Anomaly (°C)



-3.5 -3 -2 -1 -.5 -.2 .2 .5 1 2 3 4




# Proxy Data



Average solar radiation = 198 W/m2 at the Earth's surface

**+/- 0.16 W/m2 direct solar forcing every 1500 years (Shindell, 2006)**

**Cumulative radiative forcing 1.7 W/m2 (2005)**

Degree C anomaly from 1961-90 norm

a

Northern Hemisphere

**Medieval warm period**

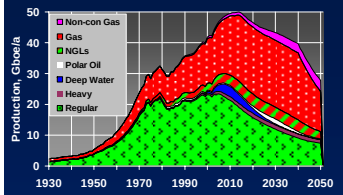
**Little Ice Age Maunder Minimum**

0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
AD 200
400
600
800
1000
1200
1400
1600
1800
2000

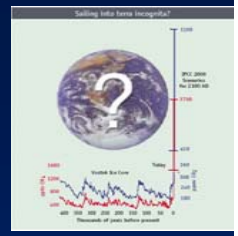
**Temperatures AD 200-2000**, from proxy temperature indicators and direct measurement (red), showing rise from from long-term cooling trend. Mann & Jones, Geophys. Research Letters, 2003.

**What would you expect to observe in a warmer world**

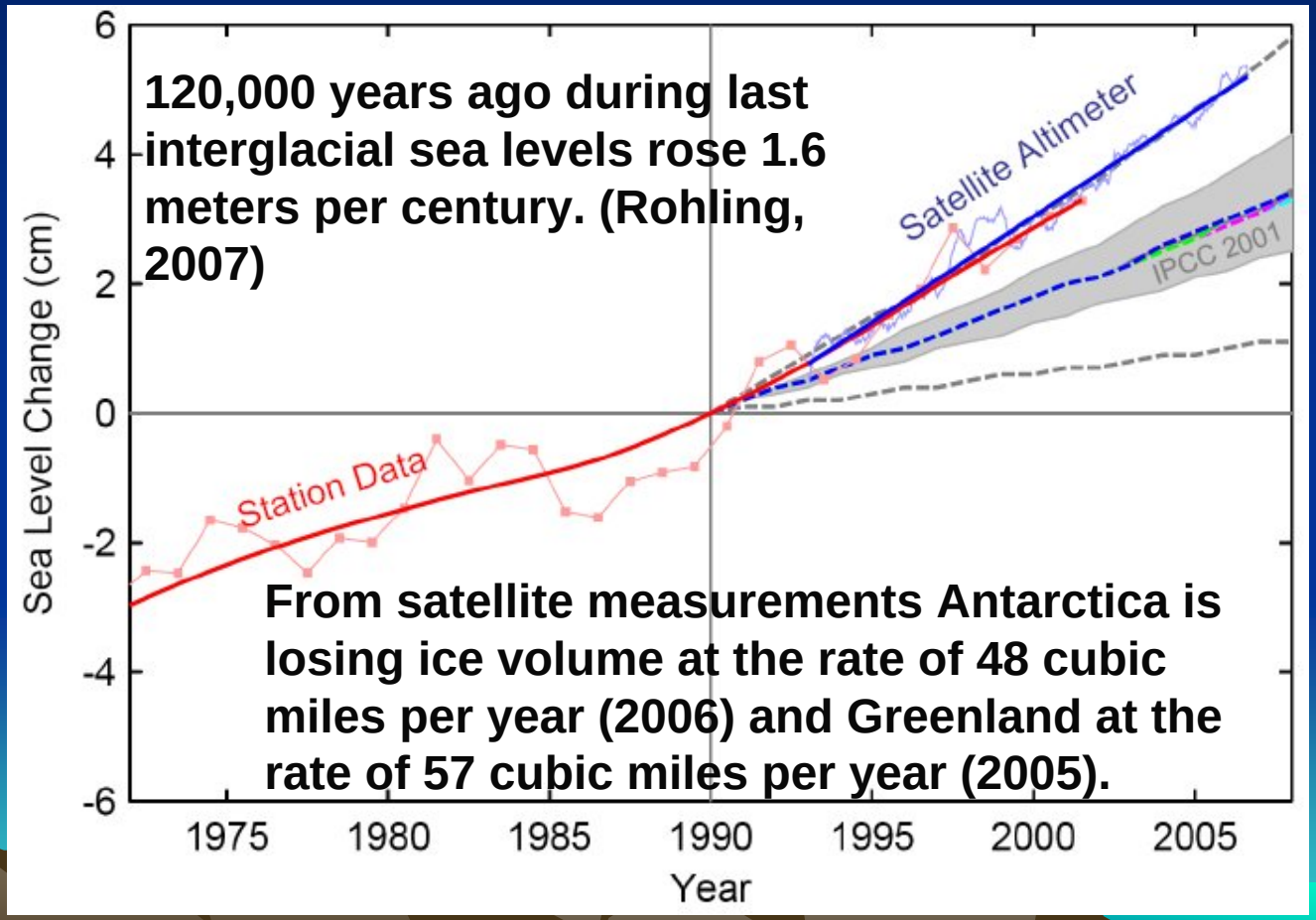
- **Melting tropical glaciers?**
- **Melting ice sheets in Greenland and Antarctica?**
- **Thawing permafrost?**
- **Earlier springs?**
- **Species extinction?**
- **More forest fires?**
- **More intense storms?**
- **More drought?**
- **Will they have to move the Iditarod?**



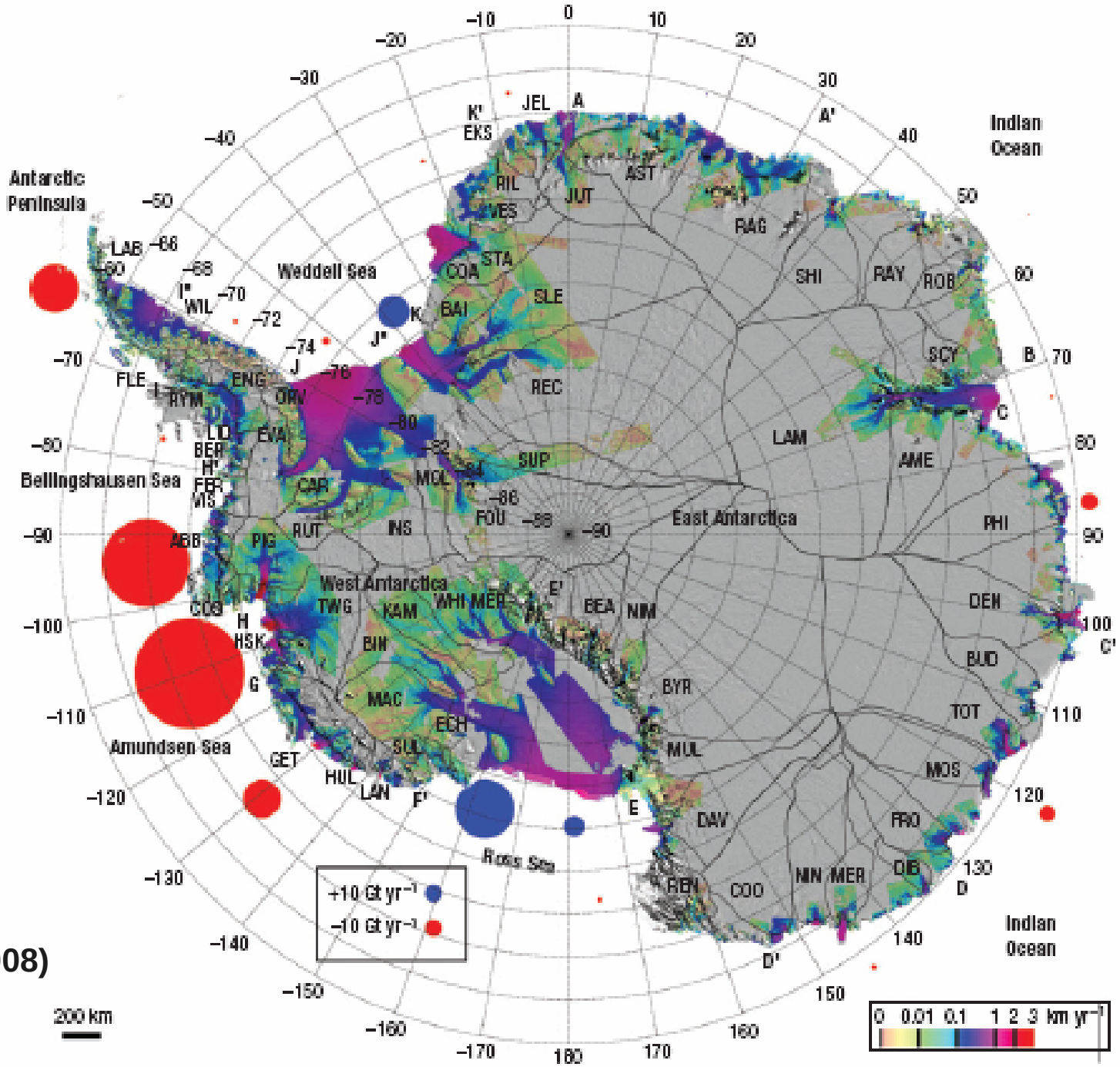

# Sea level rise



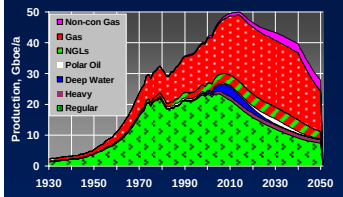
**We know the Earth is warming by direct phenomenological observation**



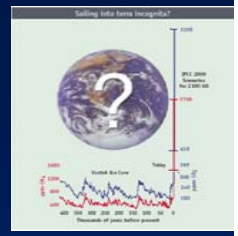

Jet Propulsion Laboratory, 2006; Chen, Wilson and Tapley, Science, 2007


Antarctic Peninsula
Weddell Sea
Bellingshausen Sea
Amundsen Sea
Ross Sea
West Antarctica
East Antarctica
Indian Ocean
Indian Ocean
+10 Gt yr⁻¹
−10 Gt yr⁻¹
200 km
0 0.01 0.1 1 2 3 km yr⁻¹

(Rignot, 2008)




# Arctic Sea Ice



## Ice shrink

The summer sea ice melt in the Arctic shattered previous records as it shrunk 1 million square miles more than the average over the past 25 years.

1979-2000 median edge of ice

SUMMER SEA ICE EXTENT

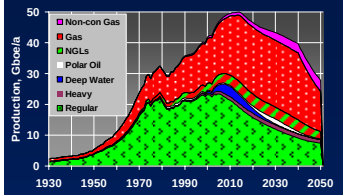
Sept. 16, 2007

Sept. 21, 2005

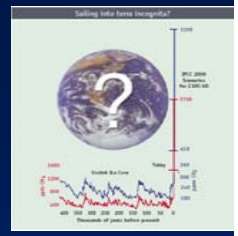
ARCTIC CIRCLE
RUSSIA
Kara Sea
Laptev Sea
Barents Sea
FINLAND
SWEDEN
ARCTIC OCEAN
North Pole
Greenland Sea
NORWAY
Norwegian Sea
Bering Sea
Chukchi Sea
North Sea
GREENLAND
ICELAND
Baffin Bay
ALASKA
Atlantic Ocean
Gulf of Alaska
CANADA

Source: The National Snow and Ice Data Center

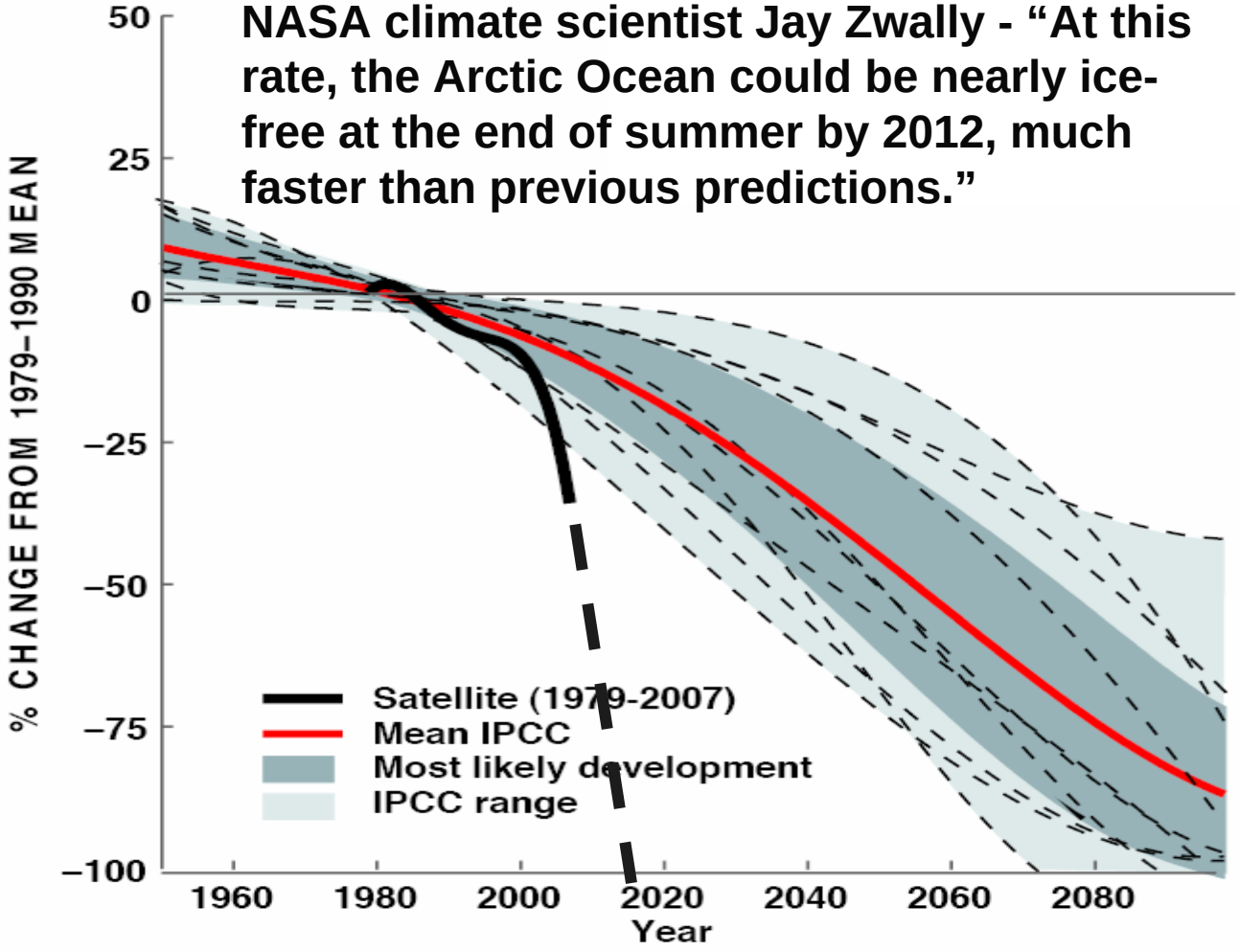
JOHN BLANCHARD / The Chronicle



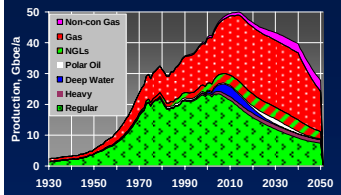

# Arctic Ice Melting



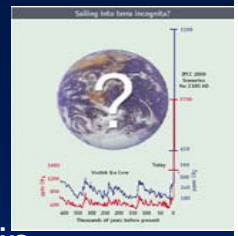
**NASA climate scientist Jay Zwally - "At this rate, the Arctic Ocean could be nearly ice-free at the end of summer by 2012, much faster than previous predictions."**




Lodgepole pine mortality

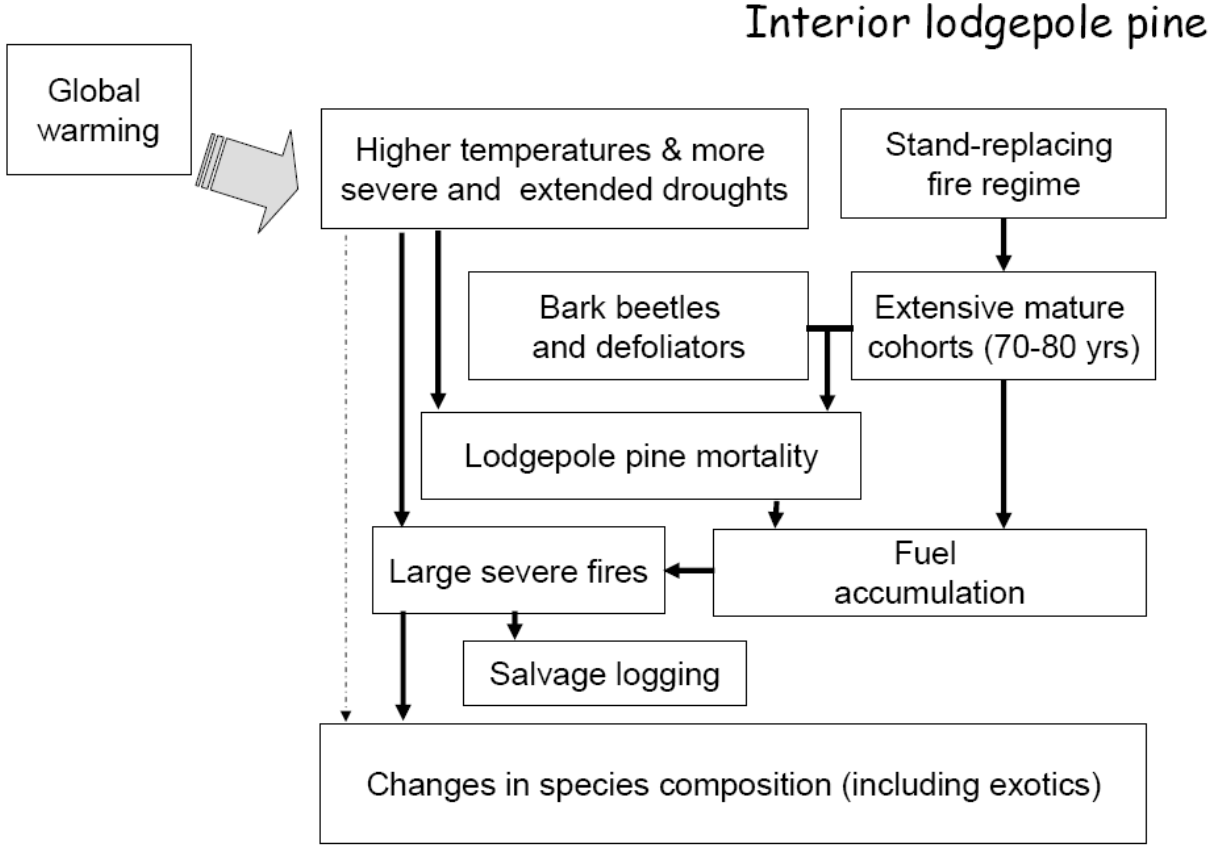



# Deforestation

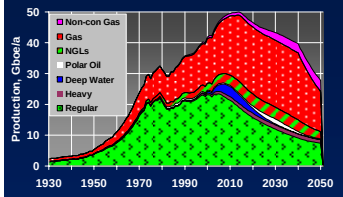


Recent beetle outbreaks have caused extensive mortality across millions of hectares in western North America (Figure 6 – Logan and Powell 2001, 2006), with large mature cohorts (age 70-80 yr) contributing to widespread vulnerability (Carroll 2006). Warmer temperatures facilitate insect outbreaks in two ways: 1) drought stress makes trees more vulnerable to attack, and 2) insect populations respond to increased temperatures by speeding up their reproductive cycles (e.g., to 1-year life cycles – Werner and Holsten 1985, Logan and Bentz 1999, Logan and Powell 2001).

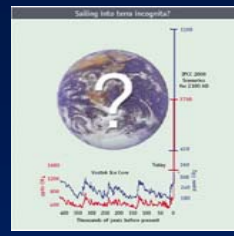
Warming temperatures would be expected to exacerbate these already devastating outbreaks northward and even eastward across the continental divide (Logan and Powell 2006, but see Hicke et al. 2006), but even at current levels of recent mortality lodgepole pine ecosys-tems may be poised for significant changes.




4 million acres of
Dead Kenai Spruce
Ecosystem Destruction

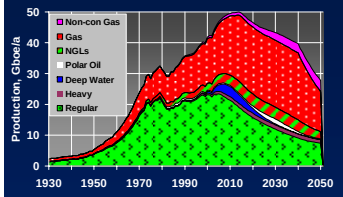



# Ecosystem destruction

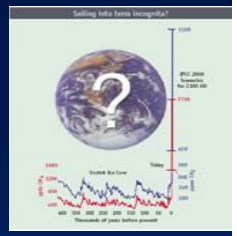


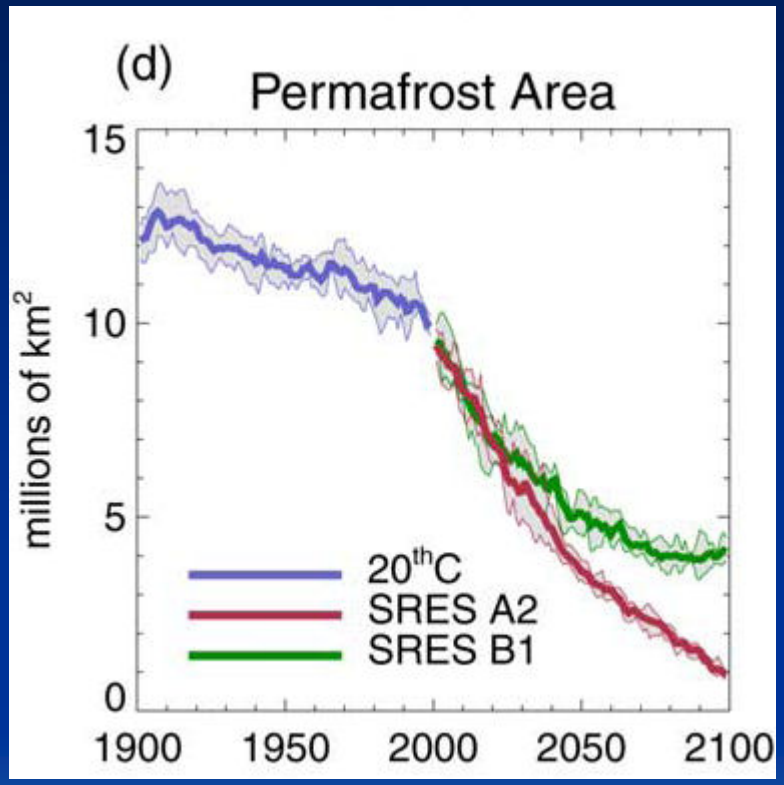
**The state of Alaska has experienced massive fires in the last decade, including the five largest fires in the USA (NIFC 2006). Over 2.5 million ha burned in the interior in 2004. Concurrently (1990s), massive outbreaks of the spruce bark beetle (Dendroctonus rufipennis)**
**occurred on and near the Kenai Peninsula in south-central Alaska (Berg et al. 2006). Although periodic outbreaks have occurred throughout the historical record, both in south-central Alaska and the southwestern Yukon, these most recent outbreaks may be unprecedented in extent and percentage mortality (over 90% in many places – Ross et al. 2001, Berg et al. 2006).**
**Both these phenomena are likely associated with warmer temperatures in recent decades (Duffy et al. 2005, Berg et al. 2006, Werner et al. 2006). Summer temperatures in the Arctic have risen 0.3 – 0.4 deg. C per decade since 1961 (Chapin et al. 2005).**

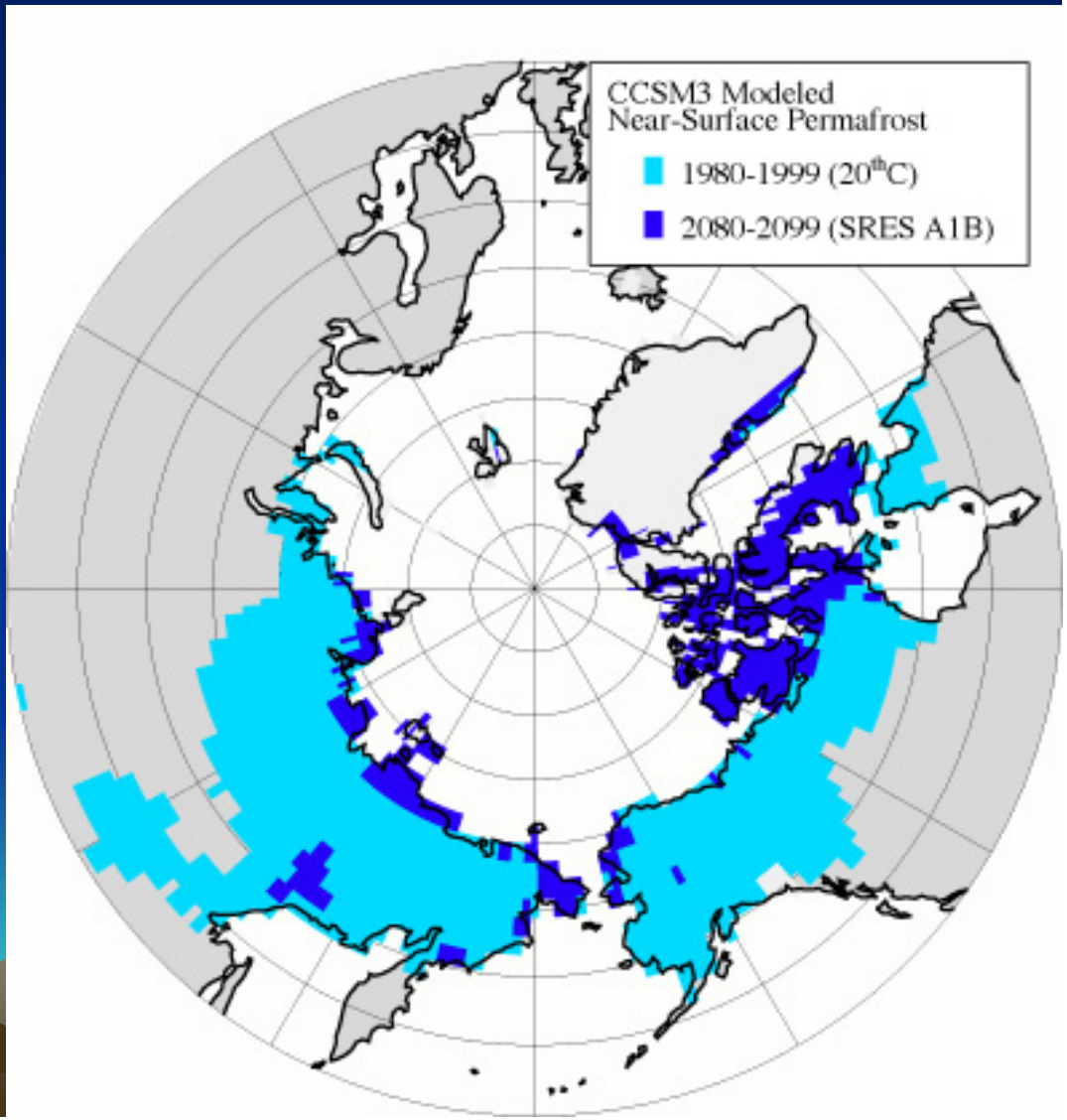

McKenzie, 2007

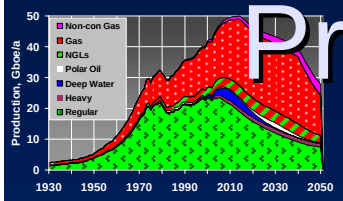



# Permafrost thaw

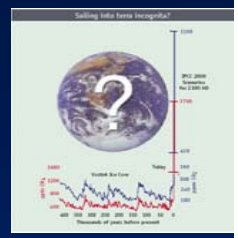




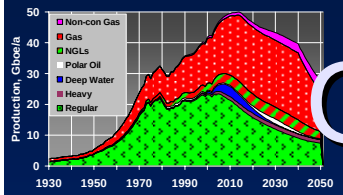





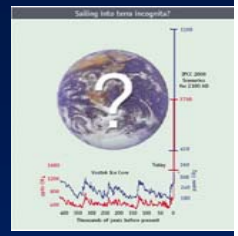

# Predicted effects are occurring faster than predicted



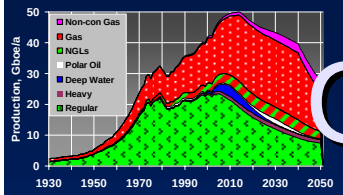
- Ocean saturation
  - Southern Ocean (Le Quere, 2007)
  - North Atlantic (Schuster, 2007)
- Loss of efficiency of all natural sinks
  - Land and sea (Canadell, 2007)
- Permafrost thaw (Delisle, 2007)
- Increase in observed river runoff (Piao, 2007)
- Increase in atmospheric moisture content (Santer, 2007)




# Global warming evidence



- Bleached corals
- Species extinction
- More violent weather
- Glacier melting
- Permafrost thawing
- Drought

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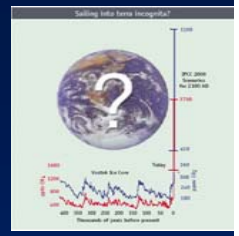

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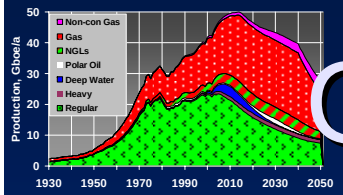


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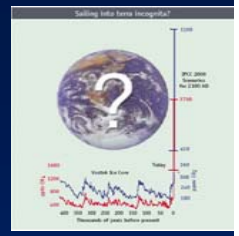

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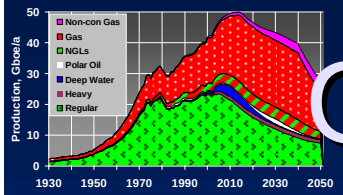


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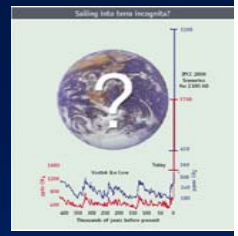

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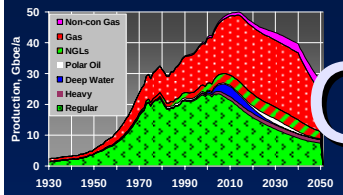


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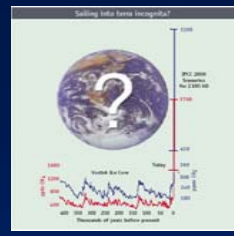

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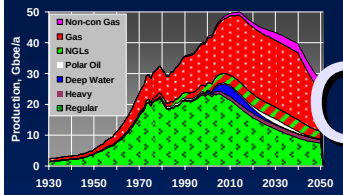


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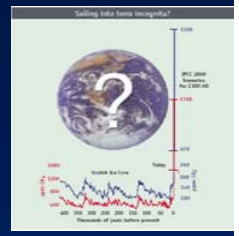

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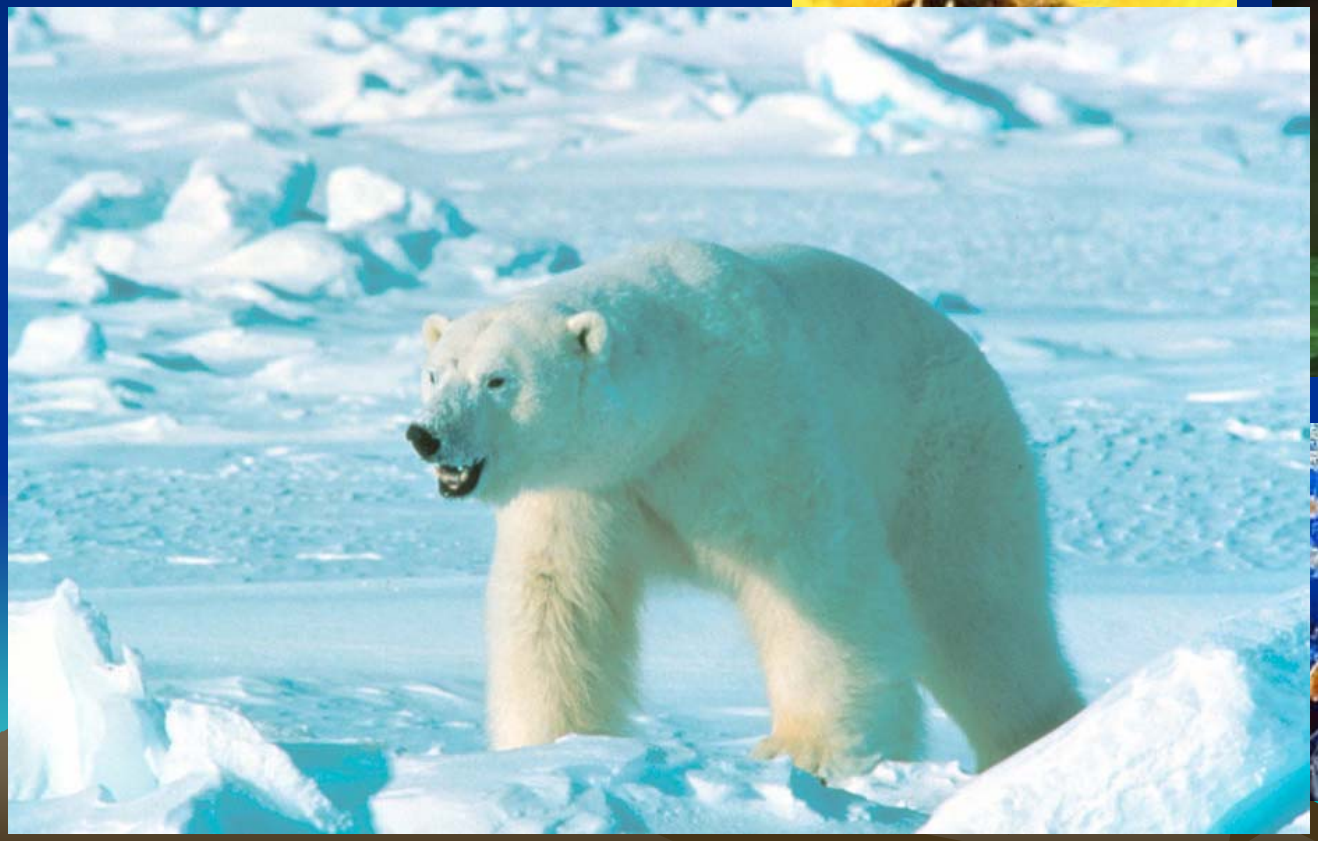

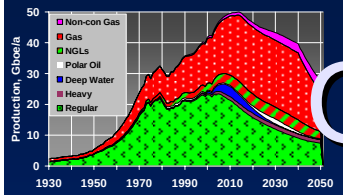


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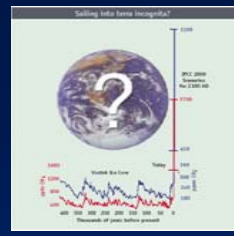

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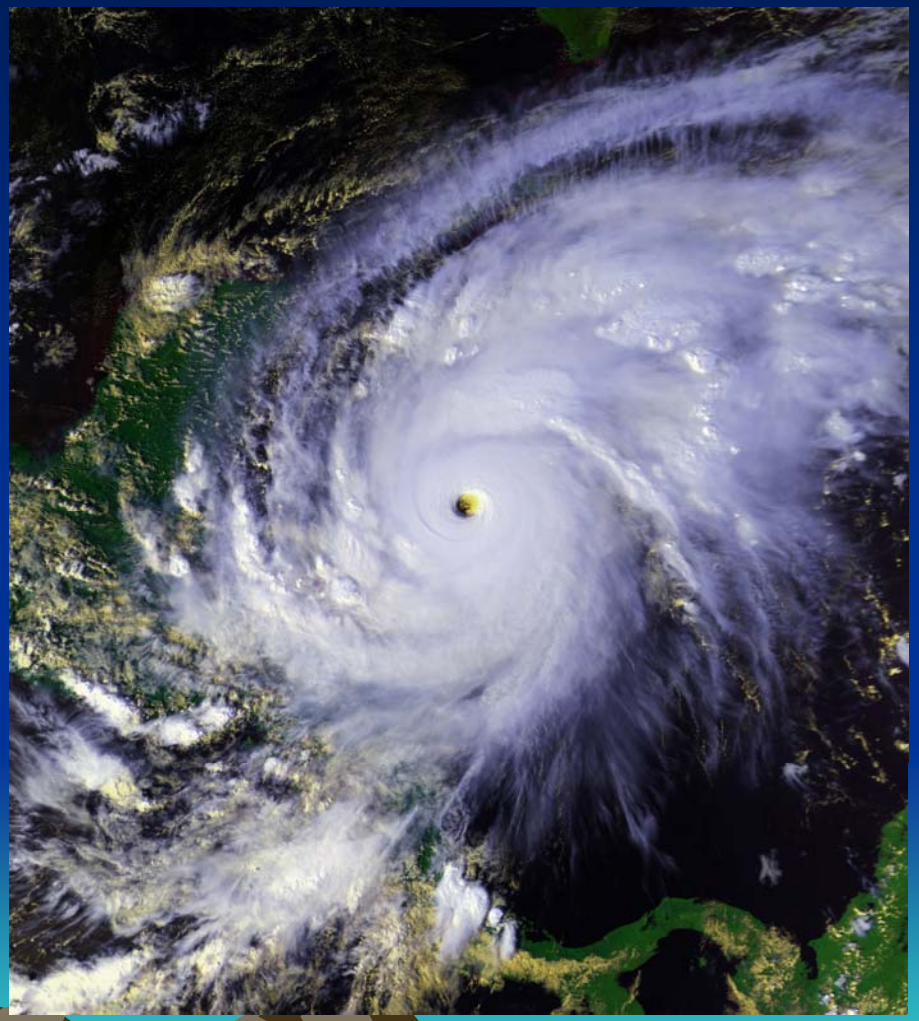

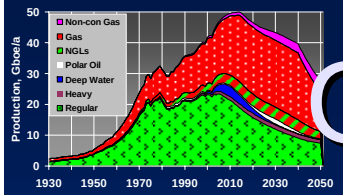


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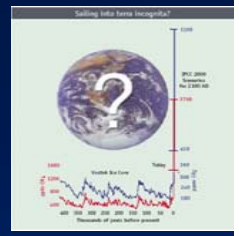

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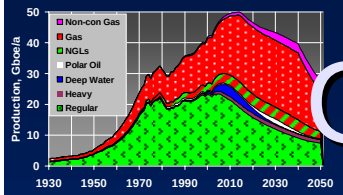


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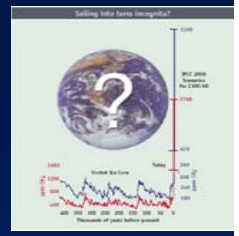

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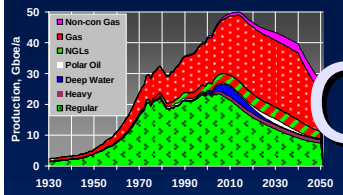


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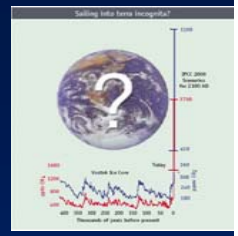

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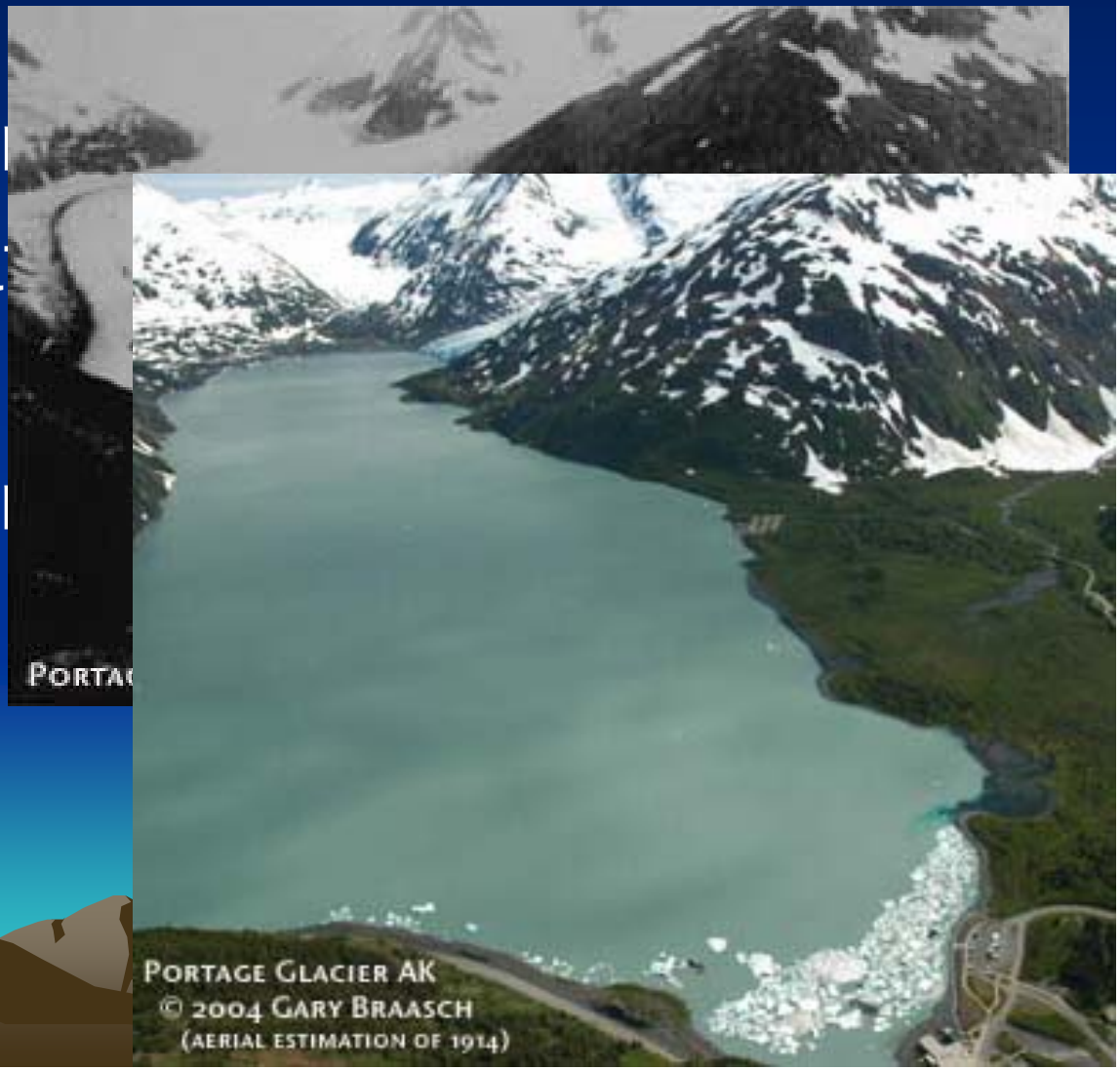

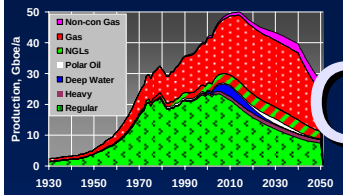


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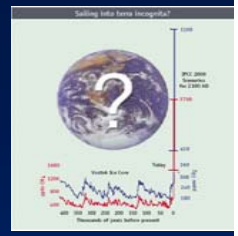

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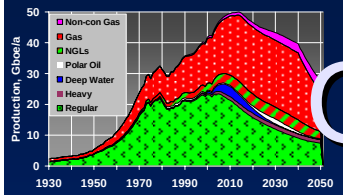


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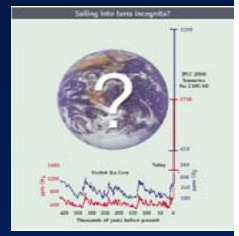

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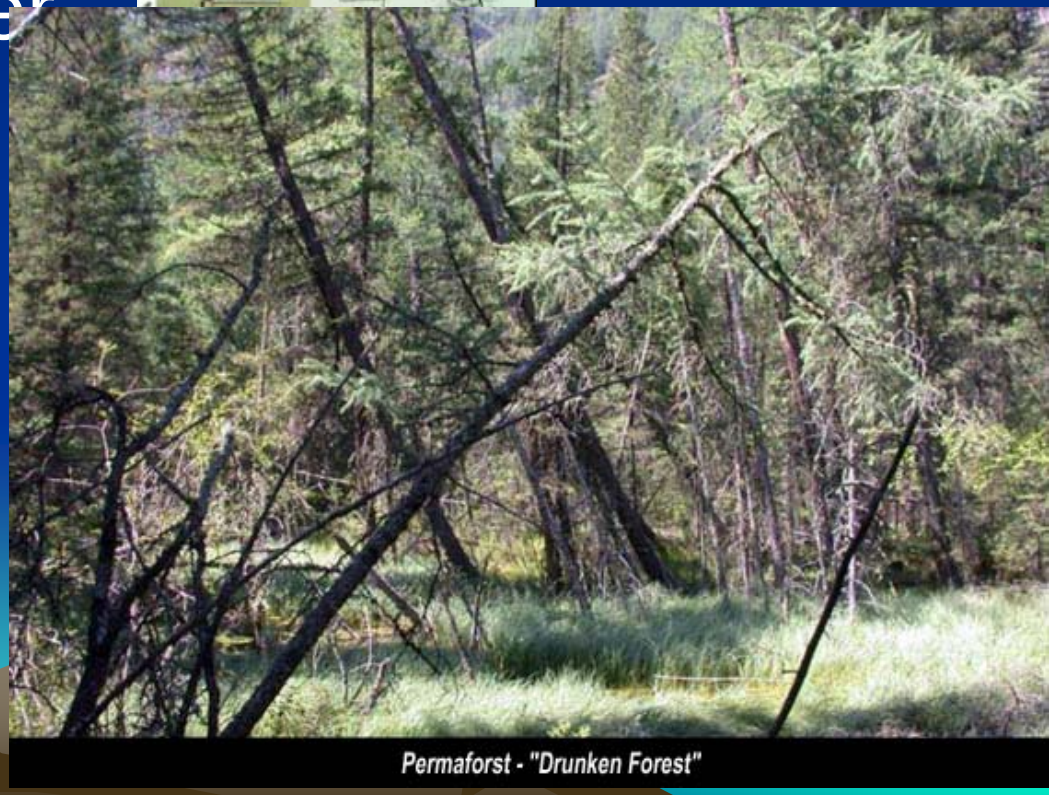
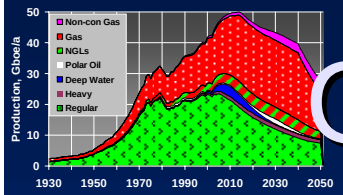


Permaforst - "Drunken Forest"

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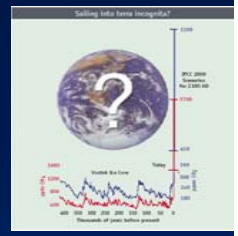

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Houses undermined by melting Permafrost

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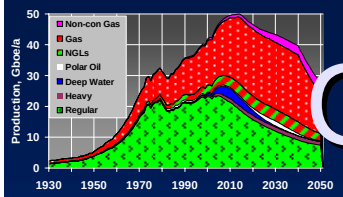


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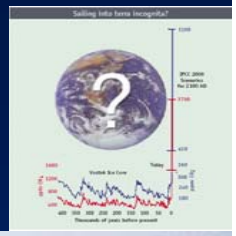

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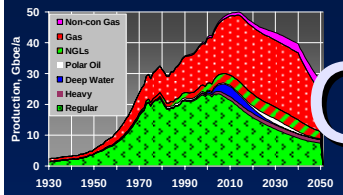


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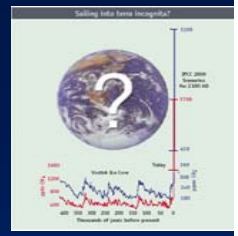

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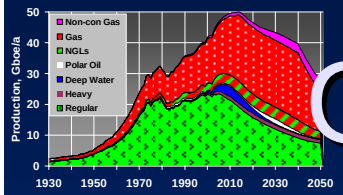


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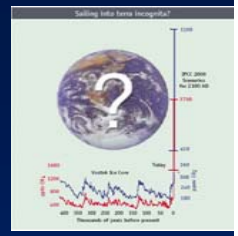

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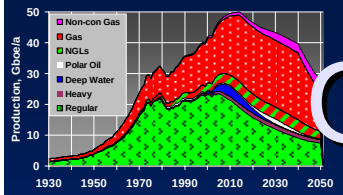
Pakistan

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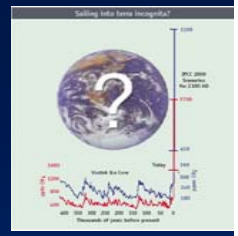

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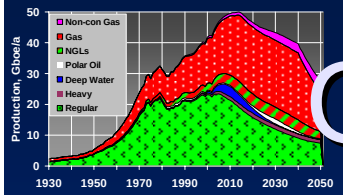


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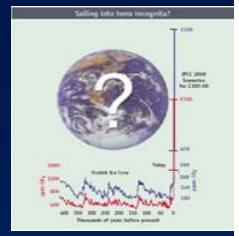

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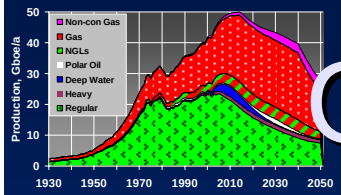


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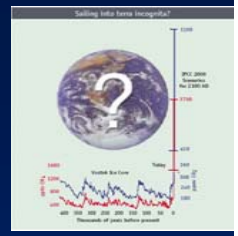

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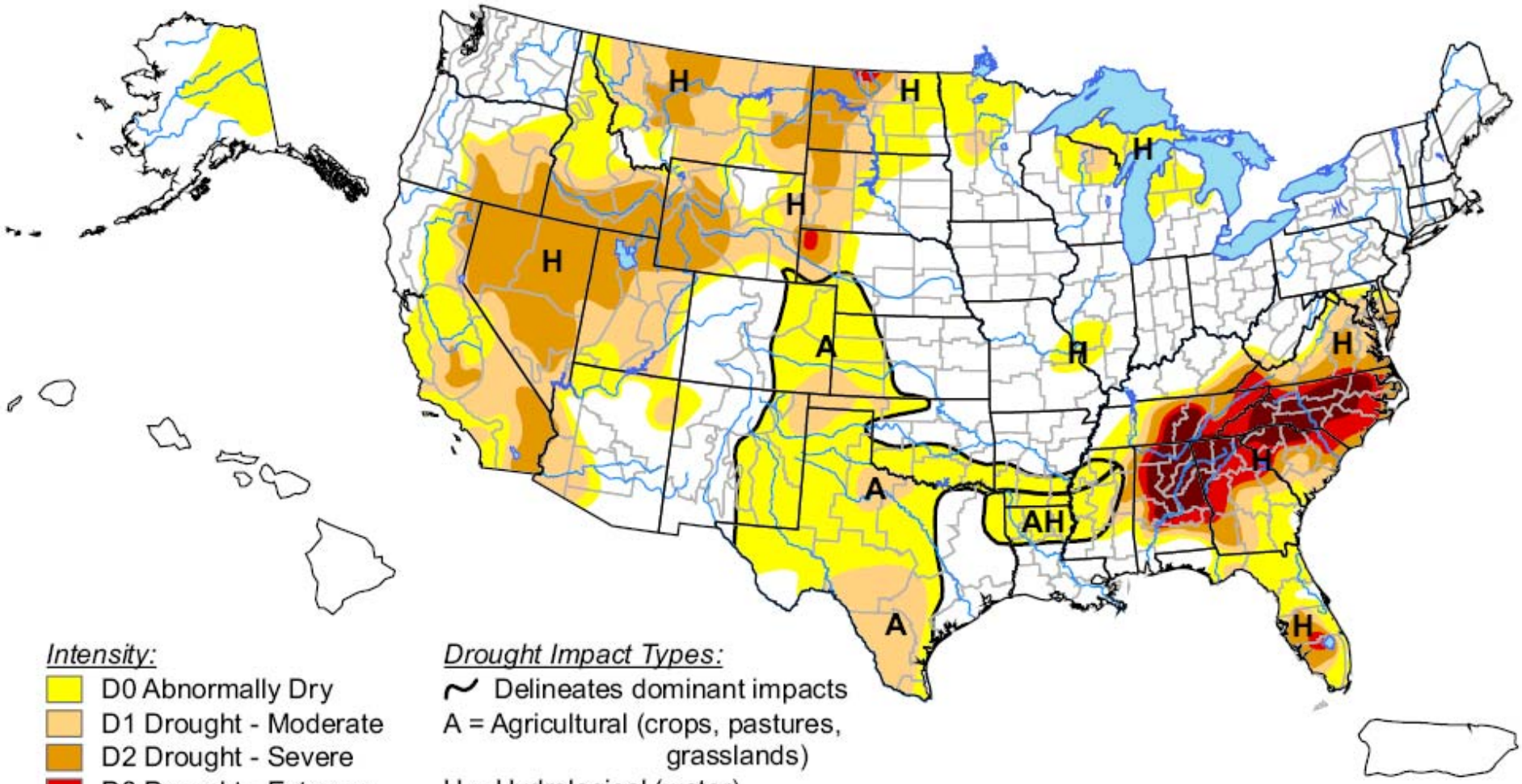
More Kenya Drought

# U.S. Drought Monitor

**January 29, 2008**
Valid 7 a.m. EST




*Intensity:*
- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

*Drought Impact Types:*
- ~ Delineates dominant impacts
- A = Agricultural (crops, pastures, grasslands)
- H = Hydrological (water)

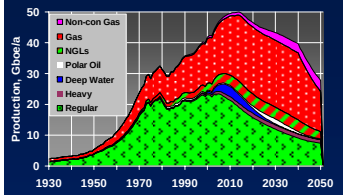
*The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.*

**http://drought.unl.edu/dm**

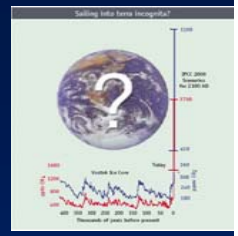
USDA National Drought Mitigation Center

***Released Thursday, January 31, 2008***

***Author: David Miskus, JAWF/CPC/NOAA***




# Conclusion



- The Earth is in fact warming at a current rate greater than 0.2C or .36F per decade
- The observed phenomena are matching or exceeding predictions.