The Oceans and Climate:
A Global View
This pale blue dot is planet Earth taken from Saturn by NASA’s Cassini spacecraft looking back toward the Earth on Sept. 27, 2006. Saturn is about 800 million miles from the Earth.
The Earth from 86 million miles
So let’s dive in
Why are the oceans Important?

Because, that is where most of the excess heat goes

Data from Levitus et al, *Science*, 2001
Why are the oceans Important?

- Oceans contain 97% of Earth’s water, hence they are fundamental in the global hydrological cycle.
- Oceans experience 86% of evaporation, hence they are central to energy exchange on planetary scales.
- Oceans receive 78% of planetary precipitation; for example, a 1% increase in Atlantic precipitation equals the annual Mississippi runoff.
- *The oceans control the timing and magnitude of changes in the global climate system.*
Warming of the World’s Oceans
(An Analysis of the past 40 Years)

HadCM3 (Hadley CM3 Model)

North Atlantic

North Indian

North Pacific

No Anthropogenic Forcing Blue

With Anthropogenic Forcing Green

Observational Data Red Dots

Efficiency of Natural Sinks

Canadell et al. 2007, PNAS
Oceanic absorption of CO$_2$

- The oceans absorb CO$_2$ at a rate of $>20$ million tonnes per day (approx 25% of anthropogenic emissions)
- Since the industrial revolution ocean acidity (defined as hydrogen ion concentration) has increased by 30%
The ocean pH change will persist for thousands of years. Because the fossil fuel CO$_2$ rise is faster than natural CO$_2$ increases in the past, the ocean will be acidified to a much greater extent than has occurred naturally in at least the past 800,000 years [Caldeira and Wicket, 2003].

**Corals**

**Calcareaous plankton**

Photo: Missouri Botanical Gardens

http://www.biol.tsukuba.ac.jp/~inouye
Scanning electron microscopy of calcifying phytoplankton for:

Current Levels of CO₂
- Current CO₂ of 280 to 380 ppm
- Projections of CO₂ of 580 to 720 ppm

Projected Levels of CO₂

Calciscus Leptoporus
The Arctic Ocean
A case study in changing climate
Surface air temperature change: 1954 - 2003
annual - °C

Source: Bulletin of the American Meteorological Society
Temperature-albedo feedback

- Higher temperatures
- More melting
- More solar energy into the ocean
- More open water, less albedo

European Environment Agency
But: Clouds also reflect incoming solar radiation, and may therefore give a cooling effect.
Source: University of Illinois – *The Cryosphere Today*
Greenland’s Annual Temperatures are Projected to Increase

Projected to be in the range of +3°C to 6°C

Climate models indicate that the local warming over Greenland is likely to be up to three times the global average.
Over the past two decades, the melt area on the Greenland ice sheet has increased on average by about 0.7%/year (or about 22% from 1979 to date).
Greenland Ice Sheet Melt Rates

Recent GRACE satellite measurements indicate that Greenland is losing between 150 and 250 cubic kilometers (36 to 60 cubic miles) of ice per year. That is enough melting ice to account for 20% of the observed increase in global sea level.
A Tipping Point?

Compared to past changes in a physical, bio-ecological and/or human system, a “tipping point” is when:

• The change is abrupt and
• The ability of the system to return to its original state is not very likely, that is: Hence, the system is now in a new state.
The Arctic’s changing climate
Some global implications
Indicative estimates of regional and global exposure to a 1 m rise in sea level (MER – market exchange rates)

<table>
<thead>
<tr>
<th>Region</th>
<th>Land area (km²)</th>
<th>Population (millions)</th>
<th>GDP MER (US$ billions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>118</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Asia</td>
<td>875</td>
<td>108</td>
<td>453</td>
</tr>
<tr>
<td>Australia</td>
<td>135</td>
<td>2</td>
<td>38</td>
</tr>
<tr>
<td>Europe</td>
<td>139</td>
<td>14</td>
<td>305</td>
</tr>
<tr>
<td>Latin America</td>
<td>317</td>
<td>10</td>
<td>39</td>
</tr>
<tr>
<td>North America</td>
<td>640</td>
<td>4</td>
<td>103</td>
</tr>
<tr>
<td>Global (Total)</td>
<td>2223</td>
<td>145</td>
<td>944</td>
</tr>
</tbody>
</table>

Source: Anthoff and others 2006
Note: Areas in “Red” are vulnerable to one meter of sea level rise!

+ 1 meter

North America

Weiss and Overpeck
The University of Arizona
Impact on weather?
Impacts on ocean circulation?
Could it change this
Into This?

- Strong cooling in North Atlantic
- Warming everywhere else
The Global Ocean Observing System

A joint initiative of:

IOC / UNESCO
WMO
UNEP
ICSU
A Global ‘system of systems’ linking together existing and planned observing systems around the world
Total *in situ* networks 60%

- 57% Surface measurements from volunteer ships (VOSlim)
  - 200 ships in pilot project
- 100% Global drifting surface buoy array
  - 5° resolution array: 1290 floats
- 40% Tide gauge network (GCOS subset of GLOSS core network)
  - 170 real-time reporting gauges
- 82% XBT sea-surface temperature section network
  - 51 lines occupied
- 100% Profiling float network (Argo)
  - 3° resolution array: 3000 floats
- 43% Repeat hydrography and carbon inventory
  - Full ocean survey in 10 years

Continuous satellite measurements of sea surface temperature, height, winds, and colour.
Operational Systems