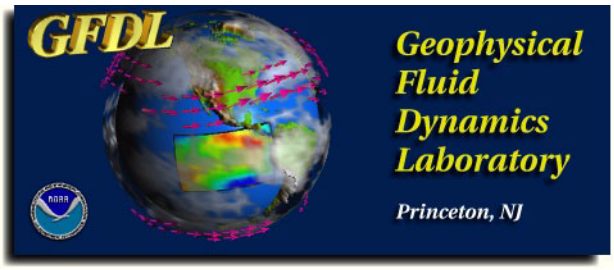
Warming of World Ocean Linked To Human-induced Greenhouse Gases



The ocean has become warmer over the past 50 years, and the warming is likely due to human-induced causes such as increases in atmospheric greenhouse gases, according to NOAA scientists at the Geophysical Fluid Dynamics Laboratory (GFDL), National Ocean Data Center (NODC) and Air Resources Laboratory (ARL).

NOAA scientists compared temperature data gathered by instruments and satellites with results from an atmosphere-ocean general circulation model developed at GFDL. The researchers considered various factors in several model simulations. These factors include the radiative effects of the observed variations in greenhouse gases (GHGs), sulfate aerosols, solar irradiance, and volcanic aerosols - all of which can affect temperatures within the Earth's climate system. They found that the computer model-simulated increase in the ocean heat content was comparable to the observed change only when increasing GHGs were added to the model atmosphere (see figure). That the GFDL computer model produced ocean heat content changes comparable to that seen in late 20th century observations can lead one to have increased confidence in the model's projections of future climate change.

TAKE HOME POINTS

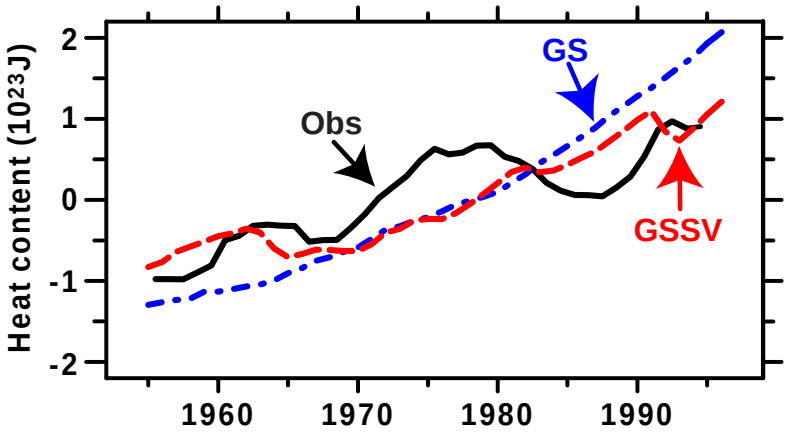
- ☛ **Observations show that over the last 50 years, the increase in global ocean heat content is at least 10 times larger than that associated with any other climate system component (atmosphere, ice or snow).**
- ☛ **Ocean heat content changes simulated by the GFDL computer model agree with observations when the effects of greenhouse gases and other forcings are included.**
- ☛ **The computer model results suggest that much of the observed increase in ocean heat content may be due to the human-induced increase of atmospheric greenhouse gases.**

The observation that at least ten times more heat has been gained by the ocean in the past half-century than has been gained by any other part of the climate system shows the value of analyzing multi-decadal ocean heat content trends. The long term increase in the ocean's heat content requires a sustained warming, such as would be expected from increasing atmospheric GHG levels.

The model results also suggest that random fluctuations of the Earth's climate system are very unlikely to produce an increase in global ocean heat content as large as that observed from the 1950s to the 1990s. This appraisal depends on how well the model simulates the climate system's internal variability (changes not related to GHG increases) on time scales of 40 to 50 years.

These findings appeared in the April 13, 2001 issue of the journal *Science*, in a paper by lead author Syd Levitus (NODC) along with GFDL scientists Thomas Delworth, Keith Dixon and Anthony Broccoli (now at Rutgers Univ.). The other authors are John Antonov (NODC) and Julian Wang (ARL).

REFERENCE: Levitus, S., J.I. Antonov, J. Wang, T.L. Delworth, K.W. Dixon, and A.J. Broccoli, 2001: "Anthropogenic warming of Earth's climate system", *Science*, vol. 292, p. 267-270.



Time variations of the global ocean heat content calculated over depths from 0 to 3000 meters (9800 feet). Observations are shown in black. The red dashed curve (GSSV) shows the ensemble average global ocean heat content from a set of three simulations produced by the GFDL coupled ocean-atmosphere model. The GSSV experiments include the effects of past changes in GHGs, sulfate aerosols, solar irradiance and volcanic aerosols. The blue dot-dashed curve (GS) denotes the same for a set of three simulations in which the radiative effects of changes in solar irradiance and volcanic aerosols are omitted. To facilitate comparisons, the respective time averages for 1955-1996 were removed from the curves before plotting. For perspective, the energy needed to warm the global ocean's upper 3000m by the observed amount (0.06°C, 0.1°F) is equal to about 15,000 years of US electricity use at current rates. Note that 1.5×10^{22} Joules = 1 watt-year m^{-2} averaged over the entire Earth's surface.

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