LESSON 15

GLOBAL WARMING AND THE OCEAN
Human Impact on a Greenhouse Planet

Fig. 15.01. Our planet is a good place to live, because of the greenhouse effect.

Our planet has life because of greenhouse gases in the air. They keep Earth warm, so that water can flow and clouds can form to bring rain.

Without these gases, most of the planet would be covered with thick masses of ice and the air would be dry. The two most important greenhouse gases are water vapor and carbon dioxide. Molecules of these gases intercept heat radiation that attempts to leave the planet. As a result, the planet's radiation balance is achieved several kilometers up in the atmosphere, and the ground and lower atmosphere, where we live, are pleasantly warm and suitable for growing things (Fig. 15.01).

Within the last several decades, where we live has been getting warmer. Greenhouse gases have considerably increased since the industrial revolution. Each year, the burning of fossil fuels produces additional carbon dioxide – roughly one percent of what is in the air already. The ocean takes up a large portion of it, but nevertheless the atmospheric content of this gas has been increasing by just under 0.5% annually. Methane, another greenhouse gas, also has been increasing substantially. In response to these changes, Earth is warming. Countervailing effects – heat uptake by the ocean, shading by effects from air pollution – are slowing the process somewhat, but warming continues.(1)

The physical interactions between the various elements of the climate system are very complex, and there are natural variations producing warming and cooling in the climate on the scale of decades and centuries. Thus, it is not possible to state precisely just how much of the observed warming owes to the man-made increase in greenhouse gases. Also, as the climate warms and the atmosphere changes composition (including an increase of particulate pollution), the rules are changing, especially concerning the formation of clouds and their role in the heat budget as heat traps and reflective umbrellas. Thus, projections of future warming effects are subject to considerable uncertainty – things could change more, or they could change less than the best guesses offered by experts indicate. The uncertainties (but not the fact that man-made greenhouse gases produce warming) are the subject of much research and discussion among active geophysicists. Others, with little or no research background in the relevant sciences, also participate in the discussion, motivated by various political or economic concerns. (Since global warming has political and economic impacts this is a perfectly reasonable development.)

What is of interest to ocean scientists is how the ocean will respond to warming. Since the ongoing warming is greater in high northern latitudes than in low latitudes, temperature gradients in the northern hemisphere will decrease, zonal winds will decrease correspondingly, and mixing and upwelling will decrease as a result. Productivity will drop. What will happen in the south is less clear: enormous ice masses on Antarctica are resistant to removal, which stabilizes the existing situation. Anticipated changes will affect the uptake of heat and carbon dioxide by the global ocean, and its patterns of productivity. In any case, sealevel will continue to rise globally, and the rise might well accelerate to rates considerably higher than those of the 20^{th} century. On the whole, the weather will become less predictable. In addition, with continued warming from burning coal and petroleum, the risk from unanticipated and troublesome events will keep increasing (Fig. 15.02). (2)

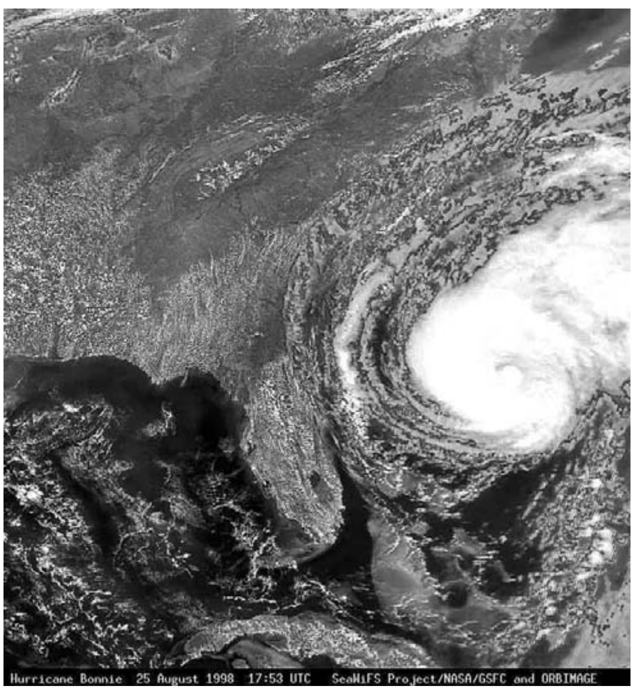


Fig. 15.02. Tropical storms are powered by the heat of surface waters of the sea. Thus, warming increases risks concerning occurrence and power of such storms. (Shown: NASA image of Hurricane Bonnie east of South Carolina, August 1998.)

Notes and references

1. None of the statements in this paragraph are in doubt, and they were recognized as true 25 years ago. (E.g., see W.A. Nierenberg and members of the Carbon Dioxide Assessment Committee, 1983. *Changing Climate.* National Academy of Sciences, Washington DC, 496pp.)
2. None of the statements in this paragraph are in any manner controversial, although the fact that zonal winds must decrease when the temperature gradient weakens in northern latitudes has received surprisingly little attention. Controversy centers mainly on the last sentence, with regard to risk assessment, as it has economic implications.

Images

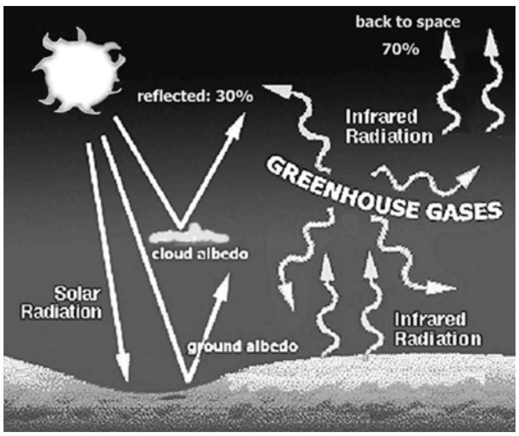


Fig. 15.03. Radiation balance, light and heat radiation. Schematic.

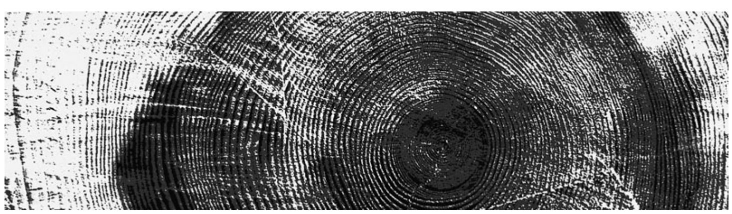


Fig. 15.04. Trees, where growing seasonally, retain information in their growth rings about spring and summer conditions (precipitation and temperature) for many years. Such information is useful in reconstructing climate history well beyond instrumental measurements.

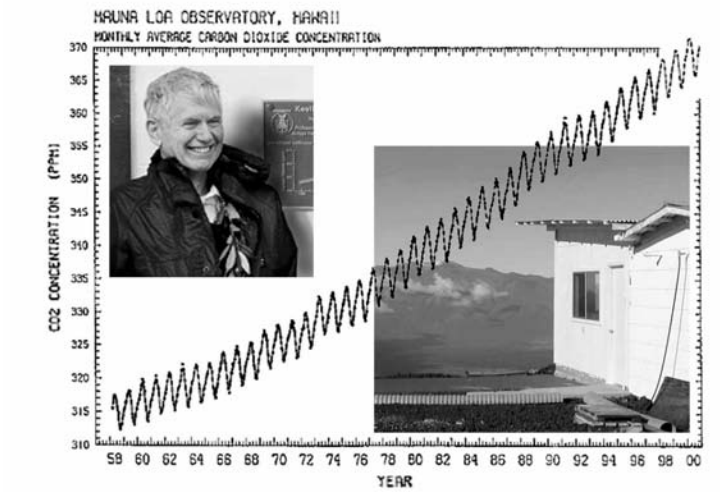
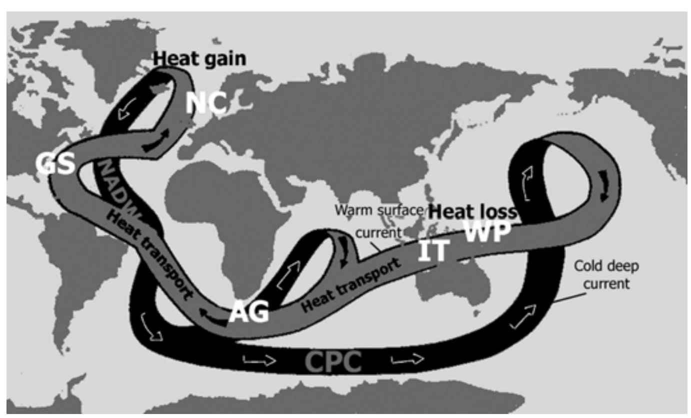


Fig. 15.05. The late Charles David Keeling, the “Keeling Curve” showing the inexorable rise of carbon dioxide, and the shack on Mauna Loa where the measurements were made – arguably the most important geophysical observatory of the 20th century.

Fig. 15.06. In the Rocky Mountains, glaciers are retreating. This tongue of the Columbia Ice Field in the Canadian Rockies filled the entire valley below the ice a few decades ago. (The moraines mark the site of the “ghost glacier.”)

Fig. 15.07. A map of the inner Baltic Sea published by the Swedish geographer Olaus Magnus in 1539, showing conditions during the Little Ice Age.

Fig. 15.08. The global conveyor, a major element in deep circulation linked to North Atlantic Deep Water production. According to W.S. Broecker (Lamont), a shutdown of the conveyor by blocking deep mixing in the far north is a serious climate hazard. It would result in strong cooling in northern Europe. WP, warm pool in the western tropical Pacific; IT, Indonesian throughway; AG, Agulhas Current; GS, Gulf Stream; NC, Norwegian Current; CPC, Circumpolar Current.



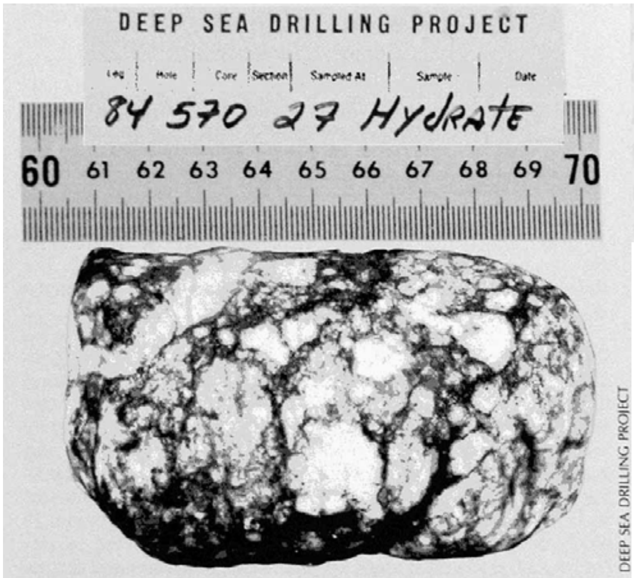


Fig. 15.09. Massive methane hydrate recovered during DSDP Leg 84, Middle America Trench. The methane is contained within a structure of water ice that is stable at high pressure and low temperature.

Figure sources (where based on sources in the literature, on the web or in museum exhibits: figures are considerably modified and adapted for present purposes, using Adobe Photoshop; drawings and photographs by the author are marked “orig.”):
1, orig; 2, SeaWIFS NASA; 3, NOAA; 4, orig; 5, SIO Carbon Dioxide Laboratory, and orig (shack); 6, orig; 7, Olaus Magnus (1490-1557), poster at Fisheries Museum Bergen; 8, W. Broecker 1991; 9, DSDP archives. **References**: U.S. National Aeronautics and Space Administration; National Oceanic and Atmospheric Administration, U.S. Department of Commerce; W.S. Broecker, 1991. Oceanography 4, 71-89; also see W.S. Broecker and G.H. Denton, 1989, *The role of ocean-atmosphere reorganizations in glacial cycles*, *Geochim. Cosmochim. Acta*, *53*, 2465-2501; Deep Sea Drilling Project (SIO/UCSD) and Ocean Drilling Program (Texas A&M).