Ozone and the Oceans:
Tiny reactions have a big effect

On board the research vessel *Ronald H. Brown,* off the coast of Texas in the Gulf of Mexico, a team of scientists measures tiny amounts of ozone moving between the air and the surface of the water. The scientists hope to learn more about *ozone fluxes* (interchanges) between the atmosphere and the world's oceans. The oceans absorb ozone from the air through chemical reactions. The amount of ozone moving between the air and water is very tiny at any one spot, so it has been impossible to measure until very recently. But those tiny effects can add up to a lot, because oceans cover 71% of the earth's surface. The scientists on the *Ron Brown* want to find out more about the chemical processes that change ozone into other substances.

NOAA research vessel *Ronald H. Brown* at sea. Scientists mount instruments onto the bow tower to measure ozone fluxes over the oceans.

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First, they have to measure the amount of ozone moving from the air into the water. The scientists had to invent their own instrument. After a lot of work, they created an ozone analyzer sensitive enough to measure ozone fluxes over the water.

The ozone analyzer works by measuring a reaction between the ozone just above the ocean's surface and nitric oxide in the instrument. The reaction produces a photon of light for each molecule of ozone present. A single photon is too faint to see, however, so they convert it into an electron, which is then multiplied many times. That produces an electric current in waves big enough to measure. On the instrument display the waves look a bit like a fuzzy train. Each "train car" equals one molecule of ozone.

The bundle of instruments, from the top down: an anemometer/thermometer to measure wind speed and air temperature; in the cylinder below it a motion sensor that tracks how the ship is moving; a probe to sense mean air temperature and humidity; a e sensor of carbon dioxide and water; and a hygrometer to record the amount of water vapor in the air.

As well as measuring the ozone moving between air and water, the team wants to know how local conditions affect ozone fluxes. To find out, they mount the ozone analyzer in a bundle of instruments that measure wind speed, humidity, air temperature, and the motion of the ship. They also sample the amount of plankton in the water.

The scientists are taking the instrument bundle on sea voyages all over the world. They hope to see how different conditions at different latitudes change the amount of ozone moving between air and sea.

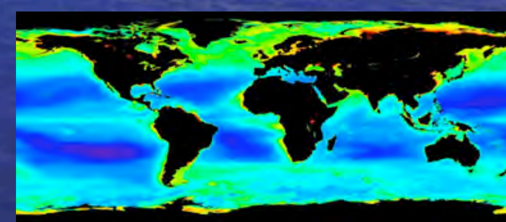
The scientists think that the amount of plankton present is especially important. Ozone reacts with decomposing plankton in a process that absorbs some ozone from the air.

Plankton is concentrated in colder waters near the poles, so more ozone is absorbed near the poles than the equator.

If the connection between the amount of plankton in the water and amount of ozone absorbed is strong enough, then the scientists will have a good way to see ozone fluxes over the world's oceans—because plankton can be seen from space.

Plankton are tiny animals and plants that drift near the surface of the ocean. When plankton decompose, the reaction absorbs ozone.

Plankton are so tiny that it takes a microscope to see them. But there are so many of them that satellite photographs show the chlorophyll they produce. Just like plants on land, planktonic plants use chlorophyll to convert sunlight into food. Satellite photos can pick up the green color of the chlorophyll in the water.



A satellite map of the world, showing chlorophyll (the green color) concentrated near the poles.

If the scientists find out how much ozone is being absorbed into the ocean in each region they visit, and then correlate those amounts with satellite photos, they will have a way to estimate how much ozone is being absorbed into the oceans over the entire world.

Travel along with the team on the project web site, http://instaar.colorado.edu/outreach/ozone-oceans/

What is ozone, anyway?

Ozone is a trace gas in the earth's atmosphere. The atmosphere is made of many different gases, mostly nitrogen (78%), oxygen (21%), and a little argon (almost 1%). Trace gases like ozone and carbon dioxide make up the remaining tiny bit of atmosphere. These trace gases are measured in parts per million or even parts per billion—they are very small amounts! Despite their rarity, they cause some very important chemical reactions.

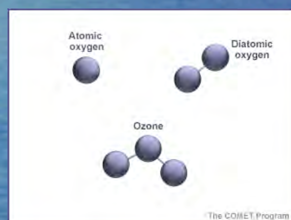


Image from UCAR's Project LEARN.

The oxygen you breathe is made of two oxygen atoms bonded together. Ozone is *three* oxygen atoms bonded together—but the bonds are much weaker. So ozone atoms combine very easily with other chemicals around them. What does ozone combine with? It depends where you are!

Ozone high up

Ozone in the *stratosphere,* an upper layer of the atmosphere that reaches from about 8 to 31 miles above the earth's surface, protects the earth from excess solar radiation. Ultraviolet light from the sun causes sunburns and damages the tissues of people, animals, and plants when it reaches the earth's surface. Ozone works to absorb much of this ultraviolet radiation in the stratosphere, before it gets to the surface. Ultraviolet light breaks the chemical bonds of oxygen atoms, freeing up single oxygen atoms. Those single atoms combine with paired oxygen to form ozone. More radiation breaks the ozone down into oxygen, starting the cycle again.

That's pretty good work for such a rare gas—if all the ozone in the stratosphere were compressed into a single, unmixed layer, it would measure only three millimeters (just over an inch) thick!

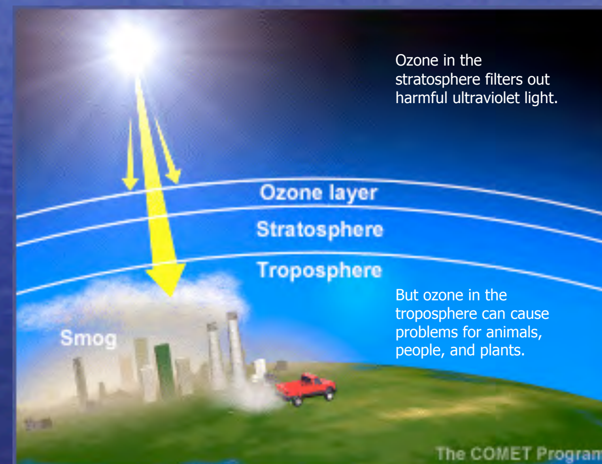


Diagram of ozone in the various layers of the atmosphere, from Project LEARN: Atmospheric Science Explorers web site *Cycles of the Earth and Atmosphere,* www.ucar.edu/learn

Ozone low down

Ozone in the *troposphere,* the lowest layer of the atmosphere, acts differently than ozone in the stratosphere. Ozone near the earth's surface acts as a form of air pollution. It can damage living tissues and break down materials like rubber and nylon. Ozone also acts as a *greenhouse gas* in the troposphere. It traps heat energy from the earth near the surface.

Much of the ozone in the troposphere is formed by the interaction of sunlight with the hydrocarbons and nitrogen oxides found in car exhaust and other fossil fuel emissions. The level of ozone in the troposphere has doubled over the last century.

Meet the scientists

Detlev Helmig
principal investigator
Institute of Arctic and Alpine Research, University of Colorado, Boulder
Detlev is the lead scientist on this project. This picture shows him at the South Pole, where he conducted experiments on ozone fluxes between air and the snow-pack that helped prepare for similar studies at sea.

Chris Fairall
research scientist
Clouds, Radiation, and Surface Processes Division, NOAA, Boulder, Colorado
Chris is shown on a previous voyage on the *Ron Brown.*

Jeff Hare
research scientist
CIRES, University of Colorado, Boulder
Jeff works in a lab on board ship. He will be gathering all the data streams from the instruments used for this project.

Jacques Huber
professional scientist
Institute of Arctic and Alpine Research, University of Colorado, Boulder
Jacques built the first version of the ozone analyzer, working with wire, circuit boards, and canisters of nitric oxide gas.

Lauren Ganzeveld
research scientist
Atmospheric Chemistry Division, Max-Planck Institute for Chemistry, Germany
Laurens will be busy figuring out how the data from this project can lead to better models of atmospheric chemistry for the whole world. He is shown here at Niwot Ridge, Colorado, helping gather data in a blizzard.