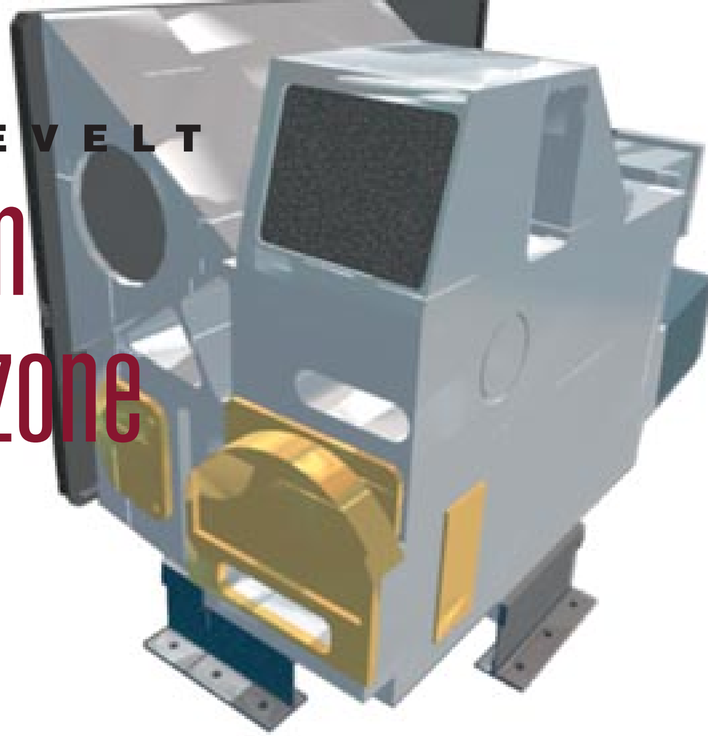
PIETERNEL LEVELT

Shining Light on Atmospheric Ozone



"I have always been fascinated with the explanations for how complex systems work."

A scientist, an athlete, a parent, a manager, a problem-solver—Pieternel Levelt of the Netherlands is all of these things. Yet when she tells people where she works, the Royal Dutch Meteorological Institute, many assume she is a weather forecaster. And that is one thing, she quickly points out, she is not!

But there is a connection between her important work and the weather—global weather, that is. Pieternel is interested in how our planet's atmospheric ozone, the fragile layer so critical to shielding us from damaging ultraviolet radiation and so important to changes in the Earth's climate, is affected by our own human activities.

At NASA, she heads an international team of scientists and engineers; NASA calls her a PI, or Principal Investigator). ***Her group's task is to ensure the construction of an instrument for collecting a variety of atmospheric data, calibrate the instrument, develop its algorithms, and have it ready for its ride aboard the EOS Aura satellite scheduled for an early 2004 launch.*** Pressure? Just this: Everything has to work right the first time!

It's easy for Pieternel to trace her interest in science. Her grandfather was a chemist, her grandmother, a physicist, and that's only the beginning! As a child, she went to her father, a professor of geophysics, with her questions about science, and to her mother, a law professor, with questions about math. In all, 9 of her 18 closest family members have strong science backgrounds. Her husband is a physicist. You could say that science is the family business.

Pieternel speaks of an aunt, an award-winning physicist, and her mother as outstanding role models. Their many accomplishments left her with no doubt that women as well as men can have distinguished careers. But she emphasizes that the strong encouragement of her father was important to her every step of the way.

In high school, she liked problem solving—the harder the problem, the better she liked it. She remembers her chemistry teacher, who encouraged her to solve problems her own way, not always by the book. But there were teachers who doubted science was the right choice for a girl. One teacher even laughed when she announced she wanted to be an astrophysicist. There's a popular expression: "Excellence is the best revenge!" Pieternel went on to earn a degree in chemistry and a Ph.D. in physics. And today, she manages the activities of 15 to 20 other scientists.

Often, it's her role as a manager that crowds her schedule and leaves so little time for her

COURTESY OF KMNI

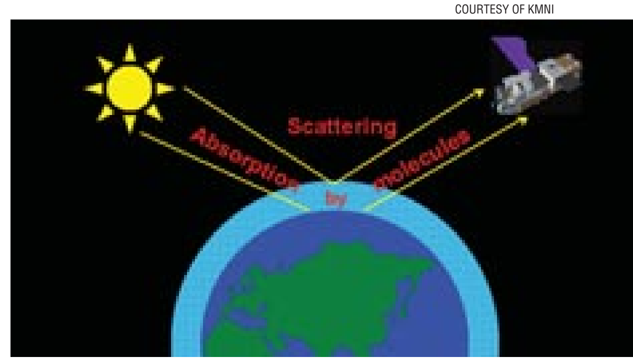


Figure 1. OMI measures UV light that is either reflected from the surface or scattered back from the atmosphere.

many interests—both personal and professional. Her two children, a four-year-old and a two-year-old, and her deep interest in science are top priorities during this countdown to launch date. But Pieternel looks forward to returning to her favorite competitive sports.

When she was very young, it was tennis, gymnastics, and judo. Then, in high school, she started competitive swimming and water polo. She loved both sprints and distance running, doing her first half-marathon in her early 20s. Shortly after that, she found a way to combine her sports by training for triathlons—distance events combining a 1.5-km swim, a 40-km bicycle ride, and a 10-km run. Her personal best triathlon is 2 hours and 12 minutes, and several times, she was rated 12th best in the Netherlands.

COURTESY OF PIETERNEL LEVELT

Triathlon events are among Pieternel Levelt's favorite competitive sports.

Team science

Sports and training with her triathlon club members may re-enter her life at some point. Right now, it's team *science* that occupies her time. Pieternel coaches her team of scientists through the tough challenges involved in building the Ozone Measuring Instrument (OMI), a simple name for a highly technical instrument designed to read both the ultraviolet (UV) and visible light patterns of the solar light reflected from the Earth and the atmosphere. The data will yield daily high-resolution global maps and profiles of ozone—information that scientists have never had on such an ongoing basis. And that's not all. OMI will also measure notorious pollutants in the atmosphere—nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and other "trace gases"—at spatial resolutions higher than ever before. While earlier NASA-launched instruments could collect regional data, OMI will pinpoint data coming from areas the size of a city.

OMI uses UV light to map ozone and pollutants.

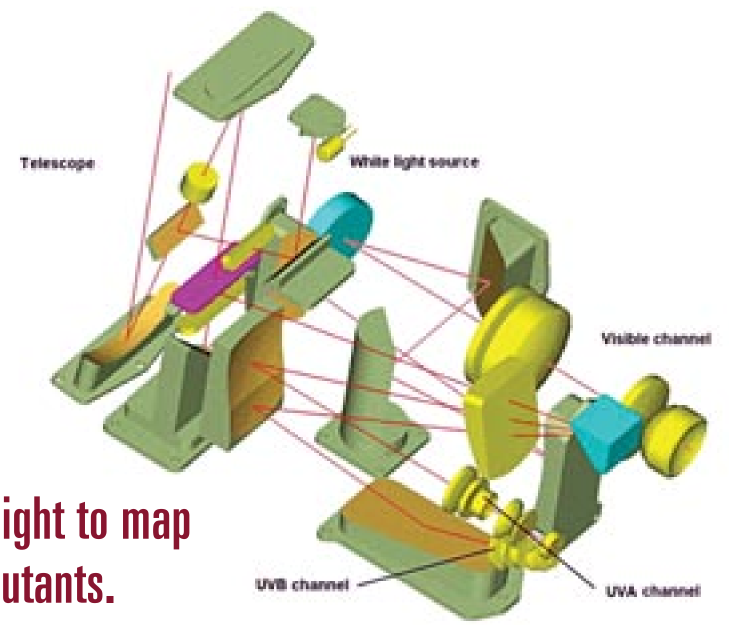
OMI will measure both the amount of ozone in the atmosphere and its vertical distribution by measuring the way ozone molecules absorb certain UV wavelengths. OMI measures both incoming and outgoing radiation using the Backscatter-UV or BUV technique—a method developed for NASA's Total Ozone Mapping Spectrometer, which was launched to monitor global ozone in 1978. The name describes how the technique works. ***UV light emitted by the sun enters the atmosphere. This entering light is called the irradiance.*** That name makes sense, because this is the light that irradiates the Earth.

Some of this light is either reflected from the surface of the Earth or scattered back from the atmosphere. This is called the *radiance*. That name also makes sense, because this is the light that is radiated back from the Earth or atmosphere (see Figure 1).

OMI will measure a broad range of wavelengths, including some wavelengths that are strongly absorbed by ozone and others that are weakly absorbed. Scientists study these measurements to find the telltale spectral signature made by light-absorbing ozone. They look at the amount of the incoming solar irradiance and then they look at the wavelength pattern of strong and weak absorbing wavelengths in the backscattered radiation. By comparing the incoming and outgoing radiation, scientists can derive how much ozone there is in any given locale of the atmosphere.

How is ozone distributed vertically? To answer that question, scientists rely on ozone's, appetite for absorbing light at the shorter UV wavelengths. As they measure at lower and lower altitudes, they would expect to find less and less shorter-wavelength UV—*if* ozone is around to do its job. Measuring the amount of this shorter-wavelength UV light being scattered about by other molecules at a given altitude is the key to determining how much ozone is in the neighborhood.

Besides advising on the construction of OMI, Pieternel's team works with the instrument builders to calibrate the instrument to be sure it sends back reliable, meaningful, and accurate data from its satellite platform 705 km (438 mi) above the surface of the Earth. For this exacting assignment, Pieternel relies on all of the experience that her team of specialists and industrial partners brings to the task.



GRAPHIC COURTESY OF NASA/EOS AURA

Managing the problem solvers

Accustomed to taking on personal challenges, Pieternel admits she is still learning to manage this group of problem solvers. Sometimes her management skills are tested by the diverse cultural and personal work styles of her international team. Early in the project, she learned that the best strategy is to look for common ground—always starting with "on what do we agree?"

If Pieternel could pursue her dream science project, what would it be? It's actually pretty close to the one she is doing now—minus the demanding deadlines as launch day approaches. She wants to return to the problem that first captured her scientific interest—"How does ozone affect the future of life on Earth?" This time, not only will she have good, reliable data on which to draw, but she'll also have the satisfaction of knowing that her team played an important role in making OMI a state-of-the-art instrument for reading the chemistry of the sky.

Teacher's guide: SEPTEMBER 2002

Special NASA EOS Aura Issue

A supplement to *ChemMatters* magazine

INTRODUCTION

The NASA EOS Aura mission represents a significant undertaking that promises to produce significant contributions to both our general understanding of Earth's atmosphere and some specific environmental issues such as global warming and the status of the fragile ozone layer that protects us from excessive ultraviolet radiation. These environmental problems are complex, both scientifically and politically. Gathering the kinds of data needed to form scientifically sound courses of action requires enormously complex state-of-the-art technology.

A coordinated effort of literally thousands of scientists, engineers, mathematicians, managers, and technicians located in several countries makes a mission like Aura a challenge that boggles the mind. Its success depends on the talents, knowledge, skills, enthusiasm and dedication of all these individuals.

Committed to the Educational Outreach of the Aura mission, NASA formed a partnership with *ChemMatters* magazine to publish four special issues. The first of these issues, the September, 2001 edition, centered around three significant environmental problems, global warming, ozone depletion, and atmospheric pollution. In addition, it explained how scientists can detect and measure molecules in the atmosphere without actually collecting them by remote-sensing spectroscopy. If you do not have a copy of this issue, you can still access it at the *ChemMatters* Web site, along with the Teacher's Guide material that accompanied the articles. Just go to:

http://www.chemistry.org/education/chemmatters.html

and click on the appropriate magazine cover or link.

In the September 2002 edition, we try to answer another question: ***How Does the Science Get Done?***

Of course the science gets done by *people*. A few of these amazing individuals, their fellow team members, and the some of the technicians and other "supporting cast" are the focus of this 2002 issue.

The individuals featured in the main articles were extensively interviewed. They explained the nature of their work—not only the technical aspects, but also the human and management aspects, so critical in a complex project like EOS Aura. Despite their busy schedules and the crush of enormous responsibilities and pressures, each managed to devote many hours, often over a period of weeks, to assist us in preparing this issue. They patiently and sometimes repeatedly explained the science and technology related to their roles. They provided photographs and other supporting materials and graphics. And they were even willing, often as a result of a little coaxing, to talk about *themselves*—their younger years, how they became interested in science or engineering, their hobbies, and their interests.

As science teachers, we often battle the "scientists as nerds" image projected in popular media. We hope this issue of *ChemMatters* will adjust this image, or at least put it in a more proper perspective.

If being "nerdy" means having a compelling interest in how nature works and in developing the tools to learn how it works, then every featured individual would proudly accept that label. If it means enjoying intellectual effort and valuing achievement, then they all qualify. But if it means being narrowly focused, socially inept, and lacking "people" skills, then you'll have to look elsewhere. These scientists and engineers hardly fit that mold, as is so clearly shown in the articles. They are athletes, hobbyists, scuba divers, and dancers. Their range of interests is vast and varied. They work hard, AND they know how to have fun. They are individuals of high integrity, enjoying life to the fullest. In short, they model the characteristics that we educators value and try to instill in our students.

Organization of this Teacher's Guide

If you have used the Teacher's Guide materials that accompany *ChemMatters* issues in the past, be aware that this guide is different. The relevant NASA and EOS Aura Web sites are informative, complete, and extensive. As a result, the goal of this Teacher's Guide is to enhance your use of the materials. We will try to select specific links that will take you to the most relevant information while providing a synopsis of their content.

A second change in format relates to the nature of this particular issue. Normally the Teacher's Guide contains separate sections devoted to each separate article. But this special *ChemMatters* edition is unique in the sense there is no clear delineation between the content of the separate articles. Consequently, the Teacher's Guide is not keyed to each individual article but rather is designed to provide background material for the entire issue.

Please Note

In some instances material from various NASA and EOS Websites is quoted directly. In order to insure that proper credit is given, these sections have been italicized.

General NASA Website

The National Aeronautics and Space Administration encompasses a great number of scientific enterprises all with related educational and public outreach activities. Much of this material is intended for use by young people. The general Website can be found at:

http://www.nasa.gov/

As expected, there are almost an unlimited number of links to different projects, activities and topics of interest.

NASA's Earth Observing System

There is a Web site for the overall NASA Earth Observing System (EOS). It contains links to many useful sites. There are Education Links, Educational Publications, Desktop Pictures/Wallpaper, Satellite Tracking and others. The URL for NASA's entire Earth Observing System is:

http://eospso.gsfc.nasa.gov/

EOS Terra

EOS Terra, designed to study land areas was launched on December 18, 1999. The Web site is http://terra.nasa.gov/

EOS Aqua

EOSAqua, was launched on May 4, 2002. As the name suggests, it is a satellite mission designed to study Earth's bodies of water and the water cycle. The Web site is

http://aqua.nasa.gov/

Earth Observatory

NASA maintains a wonderful Web site called the "Earth Observatory". The title describes the contents. From the Home Page you can link to data and iImages related to an incredible variety of environmental factors and conditions. Some examples include atmospheric precipitation, total ozone, and cloud fraction. Other examples are sea surface temperature, snow cover and ice depth, and land surface temperature. The "Features" links will take you to articles devoted to environmental issues. A few examples are "Changing our Weather One Smokestack at a Time," "Critical Chemistry," and "Second Guessing Mother Nature: Forecasting the Surprise Snow of January 2000." There are literally hundreds of these kinds of links. You can subscribe (for free) to their newsletter which will bring you the latest images, environmental articles in the news, etc. The URL is:

http://earthobservatory.nasa.gov/

NASA Earth Science Enterprise

A good general site for educational activities, reports, and projects connected to Earth science is the Official Web site for the entire NASA Earth Science Enterprise, of which EOS is a part. It is called "Destination Earth", and like the Earth Observatory Web site, it contains many links. Some of the main ones are "For Kids Only, "Teaching Earth Science," "40 Years of Earth Science," and "Healthy Planet." Other sites have general titles like, "What We Do," "Science," "Technology," "Missions," and "Products." Go to http://earth.nasa.gov/

Global Learning and Observations to Benefit the Environment (GLOBE)

The GLOBE Program is featured on the last pagein both this issue and the 2001 special issue. Students and teachers involved in the GLOBE program are collecting ground data that will be related to satellite collected data . To learn more about this program, and find out how to get your students involved, see http://www.globe.gov/

EOS Program Description

You'll find background information about the EOS program at http://eospso.gsfc.nasa.gov/eos_homepage/description.html

The following is an excerpt:

Since its creation in 1958, NASA has been studying the Earth and its changing environment by observing the atmosphere, oceans, land, ice, and snow, and their influence on climate and weather. We now realize that the key to gaining a better understanding of the global environment is exploring how the Earth's systems of air, land, water, and life interact with each other. This approach--called Earth System Science--blends together fields like meteorology, oceanography, biology, and atmospheric science.

In 1991, NASA launched a more comprehensive program to study the Earth as an environmental system, now called the Earth Science Enterprise. By using satellites and other tools to intensively study the Earth, we hope to expand our understanding of how natural processes affect us, and how we might be affecting them. Such studies will yield improved weather forecasts, tools for managing agriculture and forests, information for fishermen and local planners, and, eventually, the ability to predict how the climate will change in the future.

The Earth Science Enterprise has three main components: a series of Earth-observing satellites, an advanced data system, and teams of scientists who will study the data. Key areas of study include clouds; water and energy cycles; oceans; chemistry of the atmosphere; land surface; water and ecosystem processes; glaciers and polar ice sheets; and the solid Earth.

Why the Earth Observing System Matters to All of Us

Your students might ask or even confront you with this: Why should so much effort and money be spent on an Earth Observing System? Indeed, one of the individuals featured in this issue reported that one fairly common question asked by students when he/she talks to high school classes runs something like, "Why are we spending so much money on satellites to study the atmosphere when our school is falling apart?" That's a good question, and deserves a serious and thoughtful answer. This Web page

http://earthobservatory.nasa.gov/Study/WhyItMatters

provides some history relating to global climate change and the need to have more comprehensive and accurate data about the state and behavior of Earth's ecosystems.

EOS Aura

The Home Page for EOSAura is http://eos-chem.gsfc.nasa.gov/

The Home Page summarizes the scope of the project and the general content of the Web site:

Earth Observing System (EOS) Aura is a NASA mission to study the Earth's ozone, air quality and climate. This mission is designed exclusively to conduct research on the composition, chemistry and dynamics of the Earth's upper and lower atmosphere employing multiple instruments on a single satellite. EOS Aura is the third in a series of major Earth observing satellites to study the environment and climate change and is part of NASA's Earth Science Enterprise. The first and second missions, Terra and Aqua, are designed to study the land, oceans, and the Earth's radiation budget. Aura's chemistry measurements will also follow up on measurements which began with NASA's Upper Atmosphere Research Satellite and continue the record of satellite ozone data collected from the TOMS missions.

Note: TOMS stands for Total Ozone Mapping Spectrometer. The TOMS Website can be found at http://www.gsfc.nasa.gov/gsfc/earth/sentinel/toms.htm

The EOS Aura satellite, instruments, launch, and science investigations are managed by NASA's Goddard Space Flight Center in Greenbelt, Maryland. The satellite will be launched in January 2004 and operated for five or more years. Scientific investigations will continue throughout the years the spacecraft is in operation and several years afterwards.

This site provides information on the mission's science objectives, spacecraft and instrument technology, mission operations, and data analysis. Aura project management is described with useful information on conducting business with the project. Recent milestones and events of interest are also posted. There are many links relating to atmospheric chemistry research and related spaceflight projects in the United States and the rest of the world.

Links from the EOS-Aura Home Page

The Aura page is organized with the following main headings, each leading to multiple related pages:

What's new?

Science

Mission

Spacecraft

Instruments

Outreach

Links

EOSAura Science Link

A particularly useful link For educators accessing the EOS-Aura Home Page is the Science link. You can go there directly by clicking on:

http://eos-chem.gsfc.nasa.gov/science/index.html

Here, you'll find descriptions of Aura's mission, prior related missions such as UARS and TOMS, new objectives, validation program, and implementation. Each of these contains hyperlinks to other Web sites adding further technical details and in-depth discussion.

For example, the three major science questions that EOS Aura is designed to answer are:

Is the Earth's ozone layer recovering?

Is air quality getting worse?

How is Earth's climate changing?

Clicking on these questions takes you to other pages with relevant information.

EOS Aura Mission Link

Another important link for teachers from the EOS Aura Home Page is the Mission link:

http://eos-chem.gsfc.nasa.gov/mission/index.html

This page is important not so much because of the information presented on the page itself, but because it contains links to other pages of importance. You'll find links for describing the launch vehicle complete with an "exploded" diagram of its components. You'll see a brief description of the orbit into which the satellite will be placed.

You'll learn about "formation flying". EOS Aura is queued up in a line of existing NASA satellites. Included among them are Aqua, Parasol, CloudSat. and Calipso. You'll find a diagram of the formation as well as additional information.

Validation of measurements is an important aspect of all NASA missions. How much confidence can be placed in their accuracy? One way is to measure the same thing using different means. The "Validation" link describes some of these efforts.

Students can even view an "Orbit Movie" to get a better picture of the Aura flight path.

Here, you'll see an animation of the orbit taken by EOS-Aura as it traverses the earth. Viewing requires that you install some special cost-free plug-ins.

EOS Aura Project Link

Illustrating the complexity of this NASA mission, the project page links to all the different working groups. Go down the list of names, and you'll find some of the individuals featured in the articles along with numerous fellow scientists and engineers. Some of the working groups are Aerosol, Algorithm, Data Systems, Education/Outreach, Missions Operations, Science, and Validation. The project page is at

http://eos-chem.gsfc.nasa.gov/project/working_groups/workgroup.html

EOS Aura Spacecraft

The spacecraft should not be confused with what is called the "launch vehicle". The launch vehicle is the rocket that will put the spacecraft into orbit. The spacecraft is referred to as the "bus" that will carry the four instruments for gathering data. It's somewhat analogous to a bus that carries passengers. The site describing the specifications of the EOS Aura spacecraft is at

http://eos-chem.gsfc.nasa.gov/spacecraft/index.html

EOS Aura Instruments

This link is one of the most important because it contains descriptions and diagrams of each of the four instruments to be carried aboard EOS Aura. Here, you'll learn what they will be measuring and how the measurements will be carried out. Some of the descriptions are quite technical, but they all add interesting details to the stories in this edition. Some of your students may want to access this section for more in-depth information about the instruments described in the articles. The four individual Aura instruments are presented as links on this page:

http://aura.gsfc.nasa.gov/instruments/

The four instruments carried aboard EOS-Aura are referred to as HIRDLS (High Resolution Dynamics Limb Sounder), MLS (Microwave Limb Sounder), OMI (Ozone Monitoring Instrument) and TES (Tropospheric Emission Spectrometer).

When you open a page devoted to one specific instrument, it, in turn, will contain links to additional information about the instrument. Each instrument page contains the following topics:

Introduction

Facts

Instrument Science

Data Products

Image Gallery (shows what the instrument actually looks like)

Animations (may require downloading a viewer such as QuickTime Player)

Instrument Team (some of the featured scientists and engineers are mentioned there)

Links

References

Another good link for additional information about the MLS is:

http://mls.jpl.nasa.gov/

EOS Aura Outreach

http://eos-chem.gsfc.nasa.gov/outreach/index.html

Here's where we fit in! This link shows you the Educational and Public Outreach activities for making the public aware of the nature and goals of the EOS Aura mission. Included are *ChemMatters*, the GLOBE program, and the Smithsonian's National Museum of Natural History. There are also additional links to many Web sites containing educational and informational material on atmospheric chemistry.

Spectroscopy Information

All the instruments carried aboard EOS Aura are remote-sensing. That means that they gather data, for example, about the amount and concentration of a particular atmospheric component, without actually collecting samples of that material. The remote sensors aboard Aura include several types of spectroscopy including infrared, microwave, terahertz, visible and ultraviolet.

For more information on the general topic of spectroscopy, there are many helpful Web sites. A Google search on the word "spectroscopy" yielded over 800,000 hits! Needless to say, this is overwhelming! And most of the sites are probably too advanced and technical for high school use.

Here are a few sites with useful basic information about spectroscopy.
http://www.thespectroscopynet.com/

It modestly describes its mission as follows: "To bring emission spectroscopy to the world."

It links to topics such as:

Why spectroscopy?

Atomic vs. Optical

News

For Kids

Books & Articles

Manufacturers

Suppliers

Service Labs

Spectroscopists

Educational

Techniques

Instruments

Emission Theory

Workshop

Support

Related Sites

Other Spectroscopies

Another good spectroscopy site is maintained by the **National Institute of Standards and Technology**.

http://physics.nist.gov/Pubs/AtSpec/index.html

The information available at this site ranges from the very general (frequency, wavenumber, wavelength), to the highly technical.

A Web site that includes almost 2000 spectra of natural and man made materials can be found at:

http://speclib.jpl.nasa.gov/

More useful sites

For an interesting discussion about ozone and the stratosphere, go to

http://earthobservatory.nasa.gov/Library/Ozone/ozone_2.html

In discussions of ozone, the term Dobson Unit (DU) is often encountered. It is a measure of the ozone layer thickness, and is named after G. M. B. Dobson, who was an early investigator of atmospheric ozone.

One Dobson Unit is defined to be 0.01 mm (0.001 cm) thickness at STP. Thus the ozone layer thickness can be expressed in terms of Dobson Units. For example, an ozone layer thickness of 300 Dobson units would mean that if the ozone over a particular section of the earth were compressed to STP, it would have a thickness of 3 mm.

A good illustration of this can be found at:

http://www.atm.ch.cam.ac.uk/tour/dobson.html

For comparison, prior to the springtime period in Antarctica, when ozone depletion occurs, a typical ozone reading might be around 274 Dobson Units. The minimum reading when depletion is at its maximum might range from 88-98 DU.

CONNECTIONS TO THE NATIONAL SCIENCE EDUCATION STANDARDS

Beginning with the September 2002 issue, the *ChemMatters* Teacher's Guide provideS important information about ways in which the content of individual articles support the National Science Education Content Standards.
We are pleased to offer this service, and we hope that this makes your curriculum planning a little easier.

National Science Education Content Standard Addressed	Peter Siegel	Anne Douglass	John Gille	Pieternel Levelt	Andrea Razzaghi
Science as Inquiry Standard A: As a result of activities in grades 9-12, all students should develop understandings about scientific inquiry.	4	4	4	4	4
Physical Science Standard B: As a result of activities in grades 9-12, all students should develop an understanding of the interactions of energy and matter.	4		4	4	
Earth and Space Science Standard D: As a result of their activities in grades 9-12, all students should develop an understanding of energy in the earth system.			4		
Earth and Space Science Standard D: As a result of activities in grades 9-12, all students should develop an understanding of the origin and evolution of the universe	4				
Science and Technology Standard E: As a result of activities in grades 9-12, all students should develop understandings about science and technology.	4	4	4	4	4
Science in Personal and Social Perspectives Standard F: As a result of activities in grades 9-12, all students should develop an understanding of environmental quality.		4		4	
Science in Personal and Social Perspectives Standard F: As a result of activities in grades 9-12, all students should develop understanding of science and technology in local, national, and global challenges.	4	4	4	4	4
History and Nature of Science Standard G: As a result of activities in grades 9-12, all students should develop understanding of science as a human endeavor and nature of scientific knowledge.	4	4	4	4	4

Graphic Organizers for Effective Reading

Beginning in this September 2002 issue, the *ChemMatters* Teacher's Guide will include reproducible pages with graphic organizers relating to the articles. These pages are designed to support effective student reading in the science content area. Teachers may use these organizers as pre-discussion or pre-writing steps in a complete content reading program.

We include the following organizers for the September 2002 articles:

A pre-reading activity

Andrea Razzaghi
Anne Douglass
John Gille
Pieternel Levelt
Peter SiegelT

About Graphic Organizers

Students can use this strategy to create an organized visual representation of key terms and concepts in each article. Graphic organizers help students learn by encouraging them to look for connections and find relationships as they reorganize the information in the article. For many students, the visual links in graphic organizers aid comprehension and recall of information.

If your students have not used graphic organizers before, you can explain the purpose and benefits of graphic organizers before giving them the suggested graphic organizers for each article in this month's issue. For students familiar with graphic organizers, you may wish to have them create their own after reading each article. As students become more familiar with graphic organizers, they will improve their metacognitive skills and take more responsibility for their own learning.

Suggested pre-reading activity for all articles in this issue

Since each of the articles focuses on the work of a different NASA scientist or engineer, students should brainstorm to predict and list the following (individually or in small groups) prior to reading. They could use a table like the one below.

- What interests would you expect these NASA individuals had in high school?
- What do you think were their college majors?
- In addition to scientific knowledge, what expertise would these individuals have?
- What hobbies do you think they would have as adults?

High school interests	College major	Non-scientific expertise	Hobbies

As students read, they should check each interest, major, expertise, and hobby they guessed correctly. They should also list the ones they missed. For those that students did not find listed in the articles, students could decide whether they should delete them from their lists. If they decide to keep them, students should give reasons why.

NSES addressed:

History and Nature of Science Content Standard G: As a result of activities in grades 9-12, all students should develop understanding of science as a human endeavor.

Pieternel Levelt: Shining Light on Atmospheric Ozone

OMI

Definition:

Measures using:

1.

2.

Purpose:

Chemicals measured:

Energy measured: