It might be helpful to understand this idea of satellites becoming more accurate through the use of ground-based observations by drawing an analogy to what happens when news reporters cover a breaking news story. The news anchor sits in the studio and observes a breaking news story in much the same way a satellite observes the Earth—from a distance or *remotely*. The anchor can determine a certain amount about what is happening *on-the-scene* by observing the situation from a distance, but must rely on field reporters to fill in details about what is taking place. Similarly, ground-based instruments can be thought of as *field reporters for Earth observations*; they provide details that a satellite alone could not "see" and help the satellite give more accurate "reports" on the conditions on the surface and in the lower atmosphere. Continuing this analogy, a news anchorperson often talks to several different field reporters when reporting on a breaking news story. Each additional reporter provides additional details and perspective on the situation and adds to the news anchor's ability to give a full and accurate account of what's taking place *on-the-scene*. Likewise, a network of ground-based instruments can provide additional details and perspective for an Earth observing satellite, over and beyond what a single ground-based instrument can provide.

Comprehensive Climate Analysis & Radiation Modeling

To fully understand the many physical, optical, and radiative processes that are at work in the Earth-atmosphere system, satellites and ground-based observations alone aren't sufficient. Scientists need a *bridge* between the infrequent global coverage of satellites and the continuous coverage of a single point or a small area that ground-based instruments provide. It turns out that they find this bridge in the form of *comprehensive climate analysis and radiation modeling*—complex computer simulations that attempt to characterize the physical processes that regulate Earth's climate and radiation balance.

Models allow scientists to take measurements made by ground-based observations at several locations and draw conclusions about what is happening in a larger area, and vice versa. Models are also important tools that help scientists connect information gathered by Earth-observing satellites and ground observations to practical applications for society. The data collected become input for models and help the models become increasingly accurate and realistic representations of the actual physical processes represented in the models.

Mobile Laboratories for Field Campaigns

When NASA decides to participate in field campaigns, they need a quick and cost-efficient means of deploying a wide variety of ground-based instruments to the field, often in remote locations. The Surface-sensing Measurements for Atmospheric Radiative Transfer (SMART) and Chemical, Optical, and Microphysical Measurements of In-situ Troposphere (COMMIT) facilities, based at the Laboratory for Atmospheres, Goddard Space Flight Center (GSFC), respond to this need. Both SMART and COMMIT are independent mobile measurement facilities. They are integrated into two 20-foot long, weather-sealed trailers that can easily be shipped to locations of interest around the world and deployed once they arrive on location. Each trailer is climate controlled so that the instruments that are installed can be used under a wide range of atmospheric conditions.

SMART is equipped with a variety of ground-based remote sensing instruments for measuring solar and terrestrial radiation, some of which are commercially available while others have been specially developed at GSFC. COMMIT extends and complements the capabilities of SMART, and focuses more on making *in situ* measurements—*in situ* means that the observations are taken directly in the place where they originate. These measurements help scientists better characterize the immediate environment around them and improve their understanding of what is occurring in the planetary boundary layer, which is an important step in improving the accuracy of satellite observations. COMMIT is equipped to measure the concentrations of trace gases like carbon monoxide, sulfur dioxide, ozone, and oxides of nitrogen, as well as aerosols of various sizes, shapes, compositions, and scattering and absorption characteristics.

SMART-COMMIT's mission is designed to pursue the following goals:

• Earth Observing System (EOS) validation: By relating ground-based observations of the atmosphere to satellite observations acquired over SMART-COMMIT's location, scientists can form a more thorough understanding of what both sets of measurements are telling them about the composition of the atmosphere and about atmospheric physical processes.

• Innovative investigations: SMART-COMMIT's wide range of instruments allows scientists to develop new approaches and techniques to explore and better understand the workings of the Earth-atmosphere system.

• Long-term atmospheric monitoring: When it is not deployed in the field, the SMART-COMMIT facility is based at GSFC in Greenbelt, Maryland, and provides a unique set of well-calibrated measurements for use in giving scientists a more comprehensive picture of the local environment.

Mobile Laboratories for Field Campaigns

PARAMETERS

SMART Parameters

- Broadband: 0.3 - 3, 0.4 - 3, 0.7 - 3, 4 - 50 μm (global, diffuse and direct component)
- Narrowband: 302, 308, 315, 336, 377 nm (global); 414, 498, 614, 672, 866, 939 nm (global & diffuse); 340, 380, 440, 500, 670, 870, 870 horizontally polarized, 870 vertically polarized, 940, 1020, 1240, 1440, 2130 nm (direct)
- Laser frequency: 532 nm
- Ultraviolet spectra: 0.28 - 0.45 μm
- Shortwave spectra: 0.35 - 2.5 μm
- Longwave spectra: 3 - 20 μm
- Microwave: 23, 36, 90 GHz
- Sky image: Red-Green-Blue
- Meteorological parameters: P, T, RH, wind direction and speed, rain rate

SMART Data Products

- Global, diffuse and direct solar irradiance, with various bands of energy partitioning
- Global sky thermal irradiance
- Transmitted and sky solar spectral radiance and various narrowband radiance at atmospheric window regions
- Emitted downwelling infrared spectral radiance
- Microwave downwelling sky radiance
- Normalized backscatter intensity
- Total sky imagery
- Surface meteorological conditions

COMMIT Parameters

- Aerosol particle mass concentration with size cut at 10 μm PM, 2.5 μm PM, and 1 μm PM
- Aerosol aerodynamic size distribution: 0.01 - 1.0 μm
- Aerosol aerodynamic size distribution: 0.5 - 15 μm
- Aerosol scattering coefficient at 450, 550, and 700 nm
- Aerosol scattering coefficient at 550 nm, for dry sample air, aerosol at the ambient and at high relative humidity
- Aerosol absorption coefficient at 370, 430, 470, 520, 590, 700, and 880 nm
- Gas concentration: NO/NO_x, SO_2, CO, CO_2, O_3
- Meteorological parameters: rain rate, profiles of P, T, RH, wind direction and speed

COMMIT Data Products

- Aerosol particle mass concentration and bulk chemistry
- Aerosol particle size distribution
- Aerosol light scattering coefficient
- Aerosol light absorption coefficient
- Trace gas concentration
- Meteorological conditions in the boundary layer (0 - 1.5 km)

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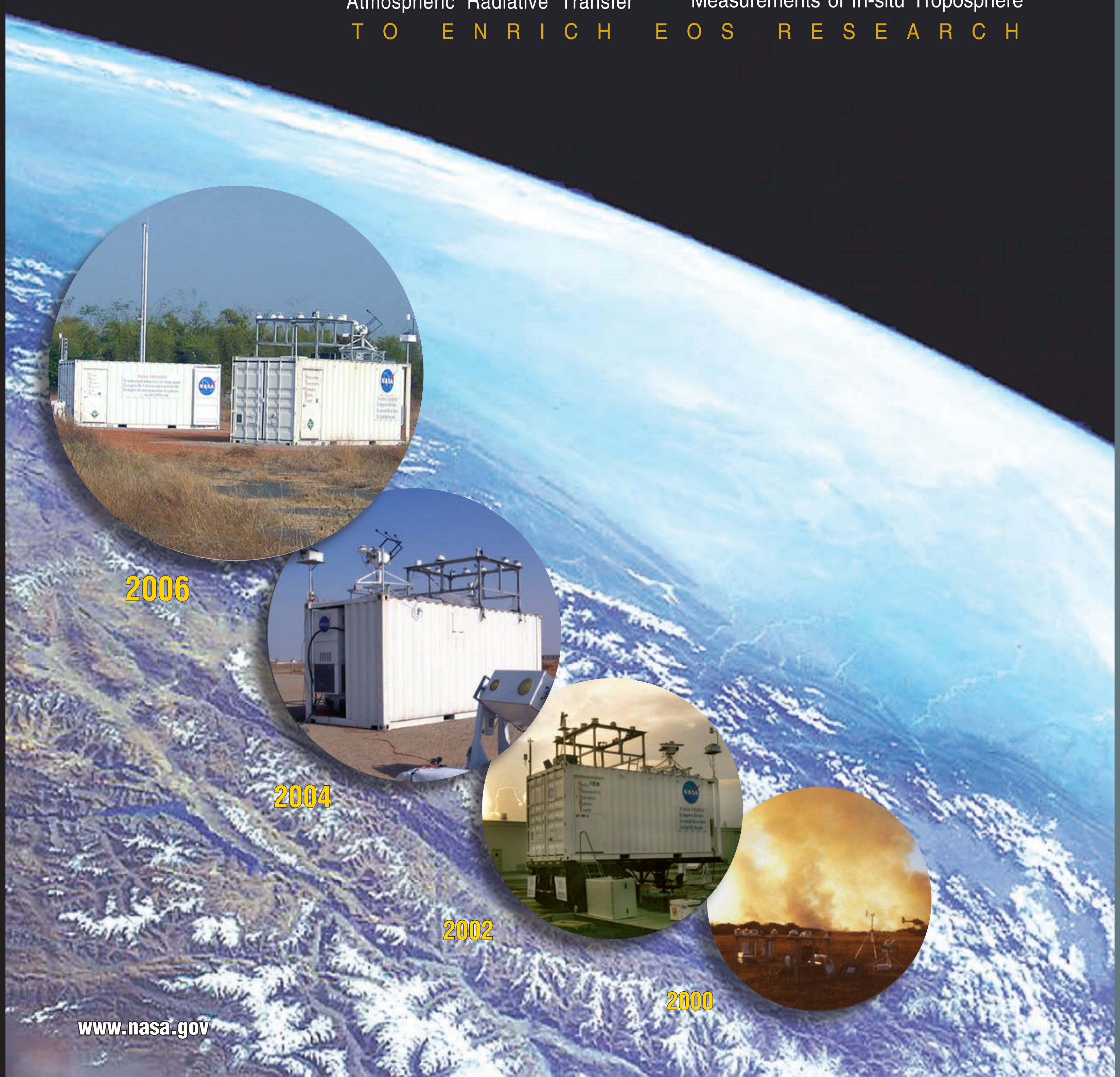
SMART–COMMIT

Surface-sensing Measurements for Atmospheric Radiative Transfer

Chemical, Optical, and Microphysical Measurements of In-situ Troposphere

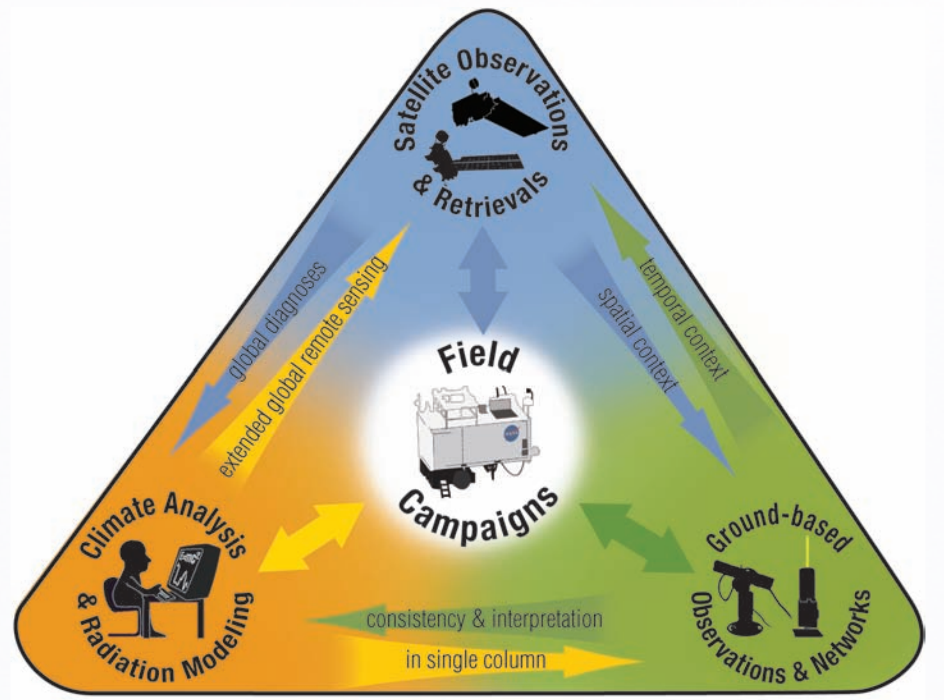
TO ENRICH EOS RESEARCH



SMART–COMMIT

NASA Field Campaigns: Bringing Together EOS Research Activities

Periodically, NASA scientists participate in *field campaigns* where researchers select a region of interest for study and conduct extensive observations in that area. The scientists set up ground-based instruments at one or more locations in this region. They also often arrange for aircraft observations of the region that can view a larger area than the ground-based observations, though not as large as satellites. Ground-based and aircraft observations are carefully planned to correspond with times when Earth observing satellites are passing over the region so that measurements from all sources can be intercompared, as well as interrelated, using models. As depicted in the diagram, field campaigns simultaneously bring together all three components of Earth Observing System (EOS) research—satellite observations and retrievals, ground-based observations and networks, and comprehensive climate analysis and radiation modeling. Each component of the diagram is briefly described below.



Satellite Observations & Retrievals

The Earth Science Division of NASA's Science Mission Directorate is dedicated to understanding the Earth-atmosphere system and the effects of natural and human-induced changes to the global environment. To help them pursue this goal, during the last decade, more than 20 orbital satellites have been launched and most of these continue to operate through today. Satellites offer a unique global perspective that ground-based and aircraft measurements cannot match.

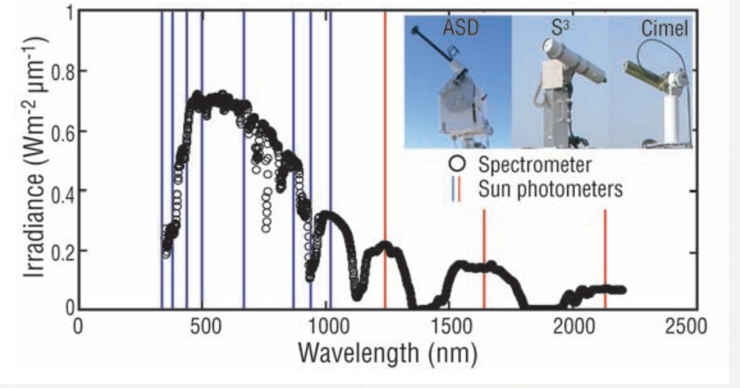
Earth observing satellites beam a tremendous amount of information back to Earth each day, but the images are much more than pretty pictures. Scientists utilize the information collected in space to help them study the Earth's climate and weather, how they have changed in the past, and how they may change in the future. Their goal is to link Earth science observations and measurements to practical applications in society so that information flows smoothly from satellites to society. Polar orbiting satellite observations offer a global perspective that permits continuous observations of an area during both day and night, but they can only observe a particular location on the surface at most two times a day. Satellite observations also usually don't do a very good job at accurately simulating what's going on in the *planetary boundary layer*—the name given to the layer of Earth's atmosphere very near the surface.

Ground-based Observations & Networks

NASA also relies on a wide variety of ground-based observations. The advantage of ground-based observations is that they can give a more continuous observation at a single location. Sometimes scientists set up a *network* of instruments—identical ground-based instruments at a number of different locations. Some networks are global and instruments are deployed all over the world. Others are focused more locally and try to give more extensive coverage over a smaller area. The data collected can later be used to help satellites improve their ability to get a more accurate picture of the surface they are observing.

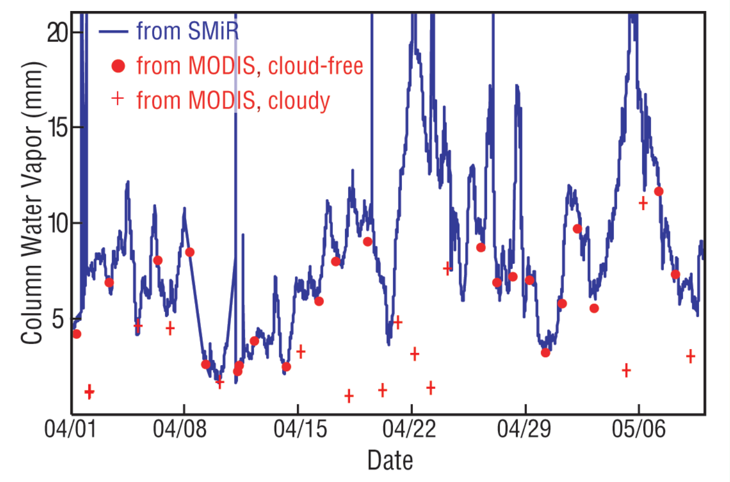
SMART

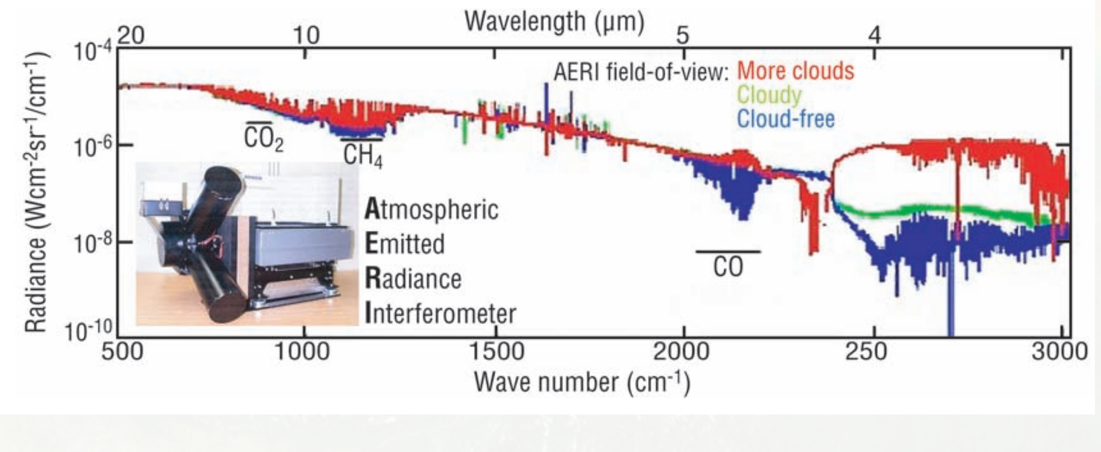
SMART began in 1998 with only a few instruments and has evolved over time into a comprehensive mobile ground-based laboratory. SMART is equipped with a collection of different instruments capable of a wide variety of radiation and other types of measurements leading to numerous data products—a list of parameters and data products for both SMART and COMMIT appears on the back panel.



Some of the instruments on SMART are classified as *narrowband* instruments because they take measurements over a certain narrow portion of the electromagnetic spectrum (EMS). A Cimel sun photometer (left) tracks the sun and takes measurements of the solar spectrum at several different wavelengths, and an Analytical Systems Devices (ASD) spectrometer (left) can either track the sun like the Cimel or focus on the ground to study surface reflection. Measurements from the Cimel and ASD can be used to retrieve column water vapor and cloud and aerosol properties in the atmosphere. The graph (left) depicts the solar spectrum measured using the ASD. Blue lines show the specific wavelengths the Cimel measures. Red lines indicate extra measurements taken by a newer version of the Cimel and also by an instrument called an S^3 which was custom designed to make measurements of the sun, the sky, and the surface.

The Scanning Microwave Radiometer (SMiR) (left) takes measurements at three different microwave frequencies: 23.0, 23.8, and 36.5 gigahertz (GHz). Scientists use the difference between signals at these frequencies to determine the amount of water vapor present in the atmosphere. The blue curve on the graph (right) shows water vapor amounts retrieved during ACE-Asia. The red dots show corresponding satellite retrievals using near-infrared measurements from MODIS. On cloud-free days, the ground-based and satellite measurements match well, but when it is cloudy the satellite measurements are lower than ground-based measurements. This is because the near-infrared satellite measurements cannot "see" through clouds and only measure water vapor that is above the clouds, whereas the SMiR measurements "see" through the clouds and capture all of the water vapor that is present.

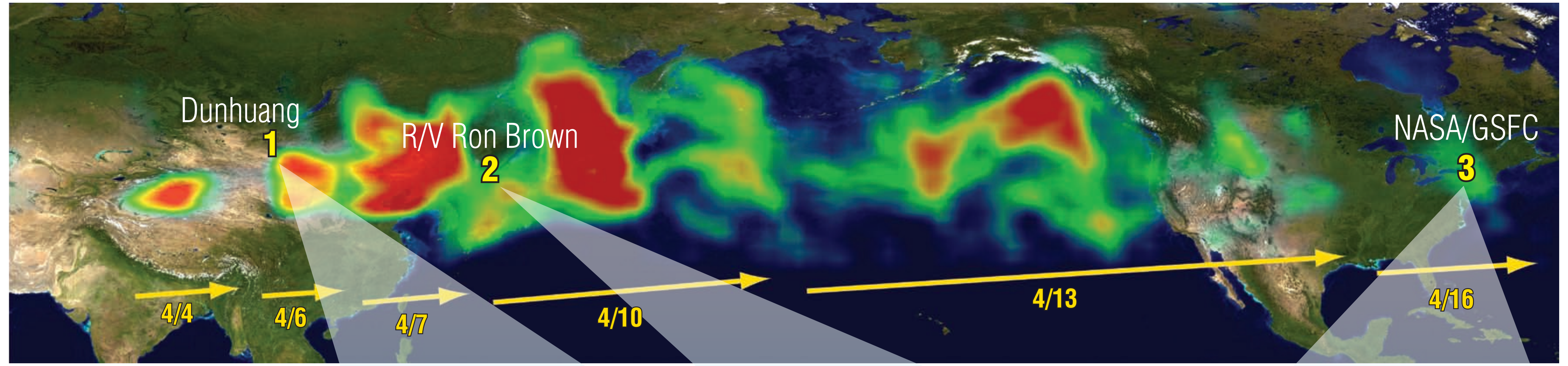




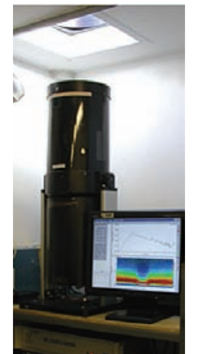
An Atmospheric Emitted Radiance Interferometer (AERI) (left) focuses primarily on the infrared portion of the EMS. Scientists use AERI to study the infrared spectra and determine the amount of trace gases such as carbon monoxide (CO), carbon dioxide (CO_2), and methane (CH_4) present under a cloud-free sky. Also, the infrared spectral measurements can be used to deduce the size of ice crystals in cirrus clouds, along with other useful information such as how much water the cloud holds.

SMART's *broadband* instruments (right) focus on a much broader range of the EMS than the narrowband instruments discussed above. Some broadband instruments measure how much solar or *shortwave* energy the Earth receives, while others measure how much thermal or *longwave* energy the Earth emits back to space, as a result of being heated by the Sun. Scientists monitor the *energy balance* between received solar energy and emitted thermal energy so that they can calculate the rate of warming and/or cooling of the surface and atmosphere, which ultimately drives Earth's weather and climate system. Direct broadband instruments track the solar disk and measure the amount of energy that comes directly from the Sun only. Diffuse broadband measurements block out the solar disk and measure the diffuse energy coming from the sky only. Total or global broadband radiometers measure energy from both the Sun and the sky.

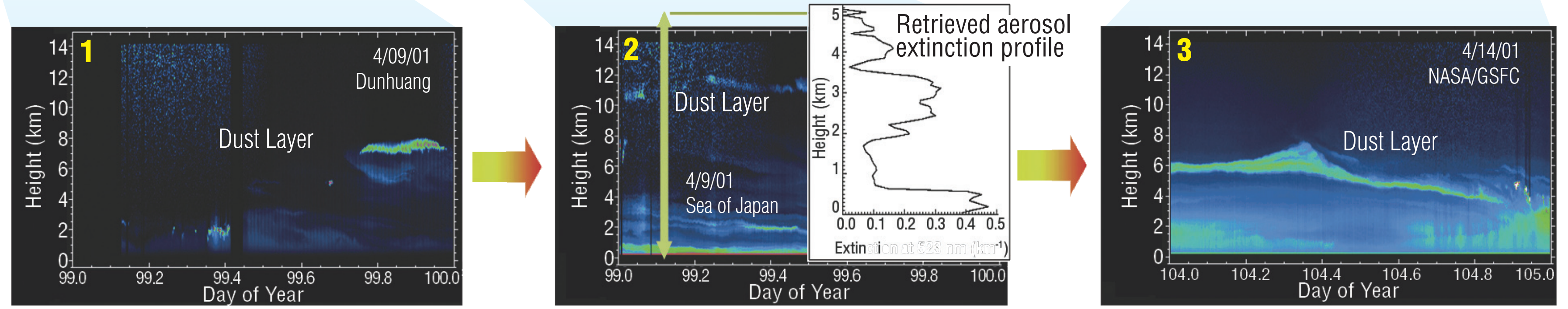
In the Spring of 2001, NASA participated in the Aerosol Characterization Experiment in Asia (ACE-Asia) field campaign. One reason scientists chose to conduct an intensive study in this region is because China's Gobi and Taklimakan deserts are one of the largest aerosol source regions on Earth. These deserts produce huge amounts of tiny dust particles that get swept high into the atmosphere by the prevailing winds, and travel all the way across the Pacific Ocean to North America and beyond. Earth observing satellites can monitor the transport of the dust from space. The image shown below is a composite of data from the Total Ozone Monitoring Spectrometer (TOMS) on the Earth Probe satellite that shows a map of the aerosol index—a measure of the amount of aerosol present—overlaid on a map produced using data from the Moderate Resolution Imaging Spectroradiometer (MODIS). Areas in red correspond to the densest part of the dust cloud, while yellow and green indicate areas where the cloud is not as dense. The arrows indicate the movement of the cloud over time and the size and location of the dust cloud observed on each date specified.



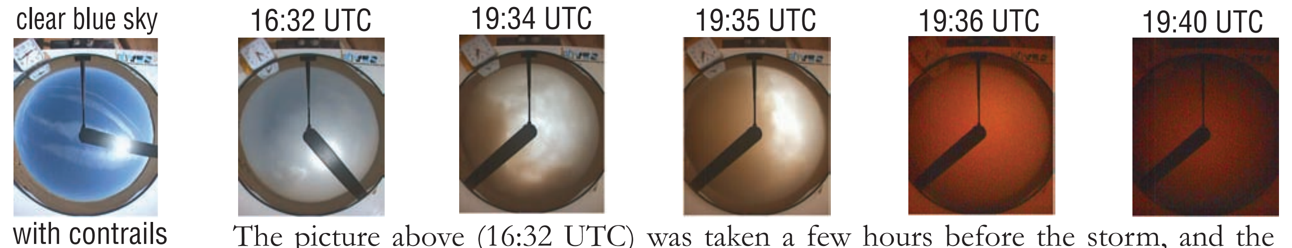
During ACE-Asia, the SMART mobile laboratory was deployed in Dunhuang, China (40° N, 94° E), one of the largest oases between the Taklimakan and the Gobi deserts in China, to obtain ground-based measurements near the source of the aerosols. Additional instruments, deployed at other locations, observed the aerosols during transport across the Pacific and beyond.



A Micropulse Lidar (MPL) (left) is part of SMART and observed the dust plume as it passed over Dunhuang (**1**). Two other MPLs, which are part of a global network of lidar called MPLNET, also observed the dust cloud as it passed over their location—(**2**) and (**3**). Taken together, the series of lidar images give scientists a better sense of how the vertical distribution of dust properties (e.g., the aerosol extinction profile over the Sea of Japan on April 9, 2001) changes during transport.



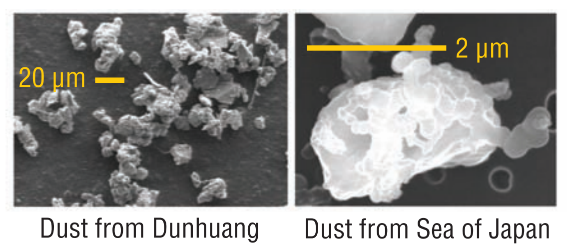
A Total Sky Imager (TSI) (left) captured a series of pictures of the sky during the storm as it passed over Dunhuang.



The picture above (16:32 UTC) was taken a few hours before the storm, and the other four images were taken in short succession as the storm was passing over.

On April 28, 2001, an intense dust storm passed over the Dunhuang site. The picture on the left was taken at 1:30 PM local time and shows the approaching storm, while the picture on the right shows the dense blanket of dust in the air approximately one hour after the storm passed.

Close-up photos of dust from locations (**1**) and (**2**) reveal how dust changes during transport. Dust at (**1**) contains mainly silicates, with some clays, feldspars, and gypsum present. Dust passes over polluted areas and is "dirtier" by the time it reaches (**2**). The far-right aircraft photo shows soot balls attached to a particle of quartz—Image Credit: J. Andersen, Arizona State University.

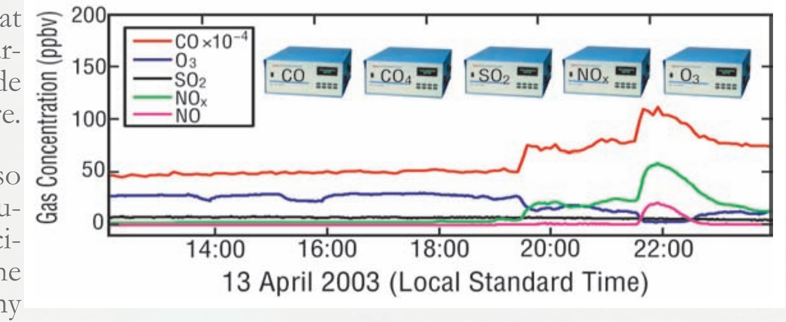


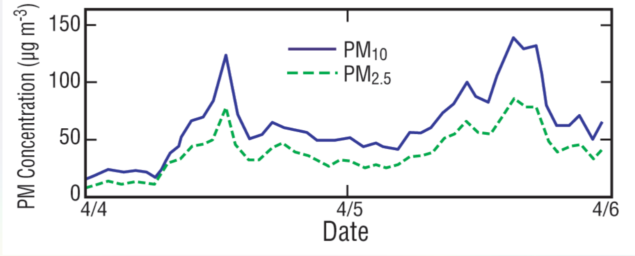
Dust from Dunhuang   Dust from Sea of Japan

COMMIT

COMMIT is a new facility deployed to the field for the first time in 2006. Using the instrumentation on COMMIT, scientists can analyze a sample of air from the planetary boundary layer. The observations will improve scientist's understanding of physical processes going on in the planetary boundary layer that involve chemically and radiatively important aerosols and trace gases.

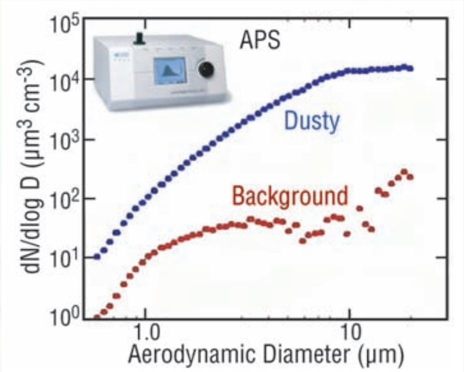
COMMIT is equipped with gas sensors like those shown (right) that measure the amount of trace gases such as carbon monoxide (CO), carbon dioxide (CO_2), ozone (O_3), sulfur dioxide (SO_2), nitrous oxide (NO), and other oxides of nitrogen (NO_x), present in the atmosphere.



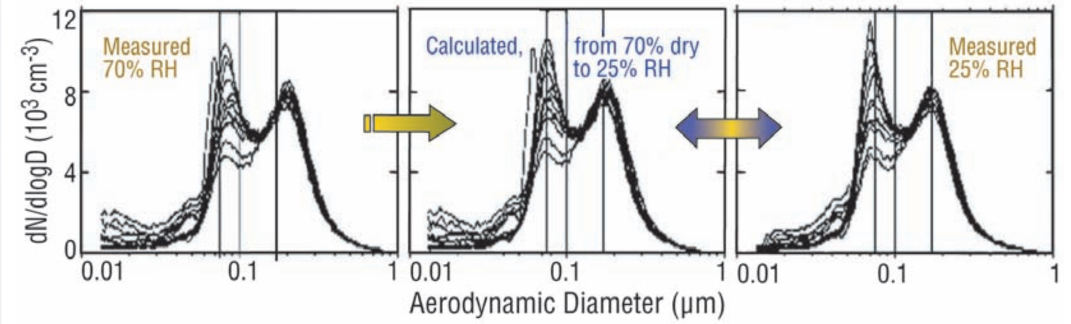


COMMIT is also equipped with instruments that allow scientists to study the properties of tiny atmospheric particles called aerosols or particulate matter (PM). Aerosols with a diameter of 2.5 micrometers ($\mu m = 10^{-6}$ meters) or less (referred to as fine particles or $PM_{2.5}$) are a particular concern because they can penetrate deep into the lungs and possibly cause serious health problems. COMMIT monitors the amount of PM present in the boundary layer using an instrument called a Tapered Element Oscillating Microbalance (TEOM) (right) that measures particle mass and captures the particles on filter paper so that scientists can further analyze the sample. The graph (above) shows the amount of PM_{10} (blue) and $PM_{2.5}$ (green) as it changes with time.

Aerosol particles that are greater than about 1 μm in diameter can be measured optically using an Aerodynamic Particle Sizer (APS) (right). The graph shows the range of aerosol sizes detected using the APS, known as a size distribution. The two size distributions shown are representative cases of dusty (blue) and background (red) conditions observed during the ACE-Asia campaign.



Aerosol particles that are about 1 μm in diameter—sub-micron particles—cannot be seen directly and their size is inferred based on how they move in air, using a Scanning Mobility Particle Sizer (SMPS) (above). The distribution of aerosol size may change as the amount of moisture present in the atmosphere varies. As relative humidity (RH) increases, some aerosols attract water vapor and grow in size while others do not and remain unchanged. As an example, particle size distributions are measured simultaneously by two SMPSs at two specific RH values: 70% (left) and 25% (right). These measurements allow scientists to apply aerosol physical models to predict what the size distributions would be between 70% RH and 25% RH (middle) and to compare them with the actual observations.



Scientists also want to understand how the aerosol in the boundary layer interacts with light. A TSI nephelometer (right) measures light scattering at red, green, and blue wavelengths, which is used to compute Scatter Coefficient and Ångström Exponent. The graph shows how the Scatter Coefficient (green) and the Ångström Exponent (blue) varied over the course of a week during ACE-Asia. As the particle size increases, the Scatter Coefficient increases (Ångström Exponent decreases). The sharp change in the values of both quantities that occurs on April 3 corresponds to the onset of a dusty period over the Dunhuang site (note similar dates on the satellite map in the center), i.e., there was a dramatic shift in particle sizes from what was present in the normal background air.