contrast between an area and its surrounding waters, the variability of the pixels within the area, the shape of the area, and the historical occurrence of oil slicks in the area, can be used to further differentiate the oil slicks from other natural phenomena.

Acknowledgments

Radarsat images are copyright 2005 Canadian Space Agency and were provided by MacDonald, Dettwiler and Associates Ltd. This work was funded by the U.S. Federal Emergency Management Agency (FEMA) under contract to the U.S. Geological Survey contract O3CRCN0001, the USGS Land Remote Sensing Program, and the USGS Director's Venture Capital Fund. We thank J. Smith for help with calculating the flood volumes.

—RUSSELL P. RYKHUS, USGS Center for Earth Resources Observation and Science, Sioux Falls, S.D.

Count-a-Thon of Airplane Contrails

PAGE 382

The third Contrail Count-a-Thon of the GLOBE (Global Learning and Observations to Benefit the Environment) project is being held during Earth Science Week 2005 in October. Reports of sky observations—including those of contrail-free skies—taken between 11:00 A.M. and 1:00 P.M. local time on 13 October 2005 are welcome from any interested observers (including *Eos* readers), whether or not they are associated with local schools, clubs, parks, or other groups. The Web site with instructions and the report form is available at http://www.globe.gov/earthsciweek2005.

Clouds remain one of the main sources of uncertainty in efforts to understand and predict the Earth's global climate [*Cess et al.*, 1990]. Although satellite instruments and techniques to study clouds continue to improve, contrails are a cloud type of significant interest that remains a challenge to study.

These human-caused clouds form in the wake of jet aircraft at cruise altitude when the atmosphere is sufficiently cool and moist. Contrails, like cirrus clouds, have a warming effect on the planet.

Contrails are difficult to study using satellite data. The best resolution imager currently available for global studies of the Earth's atmosphere, NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) [*Platnick et al.*, 2003], has a maximum pixel resolution of 250 m (visible) and 1 km (infrared). Thus, it is not able to detect thinner contrails.

In contrast, contrails are easily detectable from the ground, except in cases of lower cloud cover. Even very short-lived contrails that form a small tail behind an aircraft can easily be seen by observers on the ground.

Of course, an observer on the ground can view only a small portion of the sky. Thus, to obtain useful information on contrail distribution from ground observers, one needs a lot of observers.

Research Uses of Observations

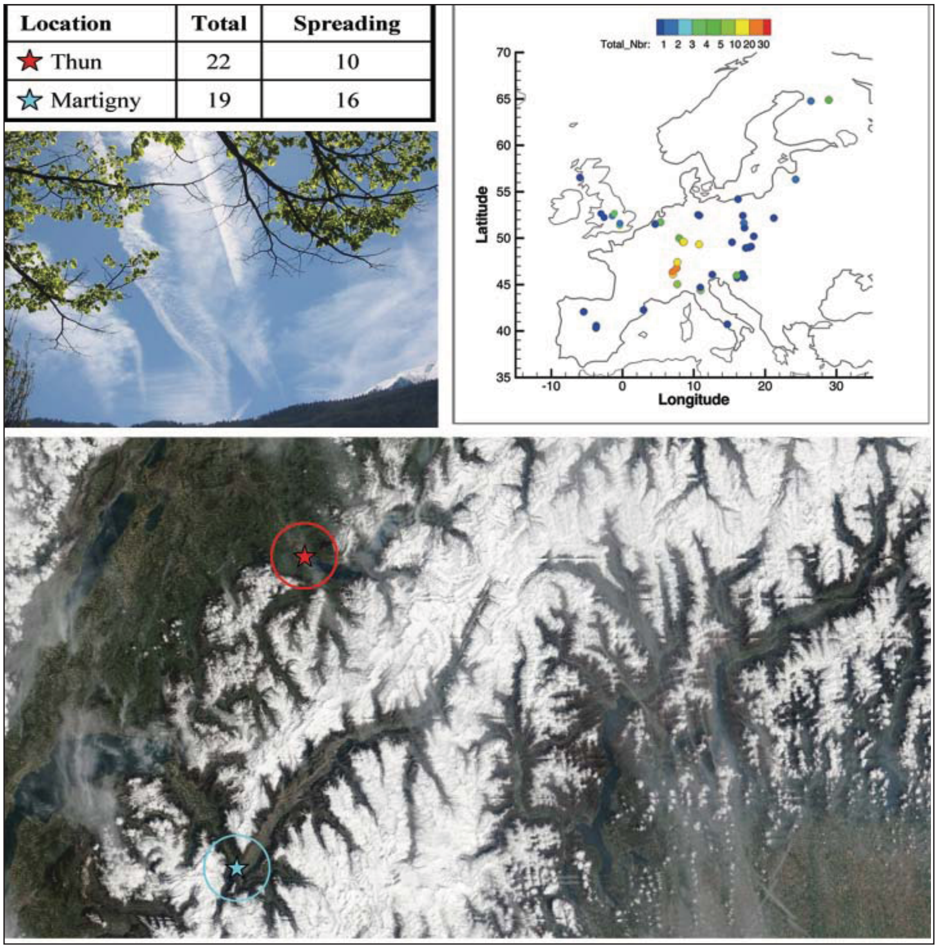
A database of surface-based contrail observations is useful in the study of contrail formation. Although the atmospheric conditions necessary for contrail formation are well known, the limited accuracy of upper tropospheric humidity data used in current numerical weather prediction models makes it difficult to predict contrail formation accurately. By comparing contrail observations with numerical weather prediction model output, improved contrail prediction techniques can be developed and could be applied, for example, to contrail mitigation efforts via flight altitude or course adjustments.

The GLOBE program (www.globe.gov) is an international science program started in 1995 as a U.S. interagency effort. A primary goal of the program is to develop detailed protocols that enable students to make scientifically valuable measurements of environmental parameters. GLOBE includes large numbers of ground observers, involving students from kindergarten through high school in more than 100 countries.

A contrail observation protocol was added to the GLOBE cloud type and cover protocols in spring 2003. Since then, more than 200,000 contrail reports from more than 1250 locations have been reported to GLOBE. These observation reports are being used to help evaluate numerical weather models for contrail prediction [*Duda et al.*, 2004].

To obtain large numbers of contrail observations at specific times, GLOBE and its contrail science team have held two special events: the GLOBE Earth Day 2004 Contrail Count-a-Thon and the Earth Science Week 2004 Contrail Count-a-Thon (see http://asd-www.larc.nasa.gov/GLOBE/count-a-thon.html for details). These events were open to interested observers around the world, who submitted contrail reports through a simplified Web form on the appointed day.

Both events in 2004 garnered about 200 daily observation reports from widely distributed participants in all inhabited parts of the world



Location	Total	Spreading
★ Thun	22	10
☆ Martigny	19	16

Fig. 1. Example of results from a contrail count-a-thon event. (upper left) Reports from two schools in Switzerland. (middle left) Photo from ground observers in Martigny, Switzerland at 0930 UTC. (bottom) Terra MODIS visible image (250 m), 1050 UTC on 22 April 2004, with the approximate location of ground observing sites in Switzerland. (upper right) Ground observer reports from around Europe. Dark blue dots indicate locations where no contrails were reported.

except Africa. Sufficient reports of thicker, persistent contrails were received from North America and Europe to enable useful comparisons with satellite imagery and numerical prediction techniques (Figure 1).

The goal for the 2005 event is to obtain many more reports so that information is available to help pinpoint the conditions under which contrails do and do not form in different meteorological and flight regimes around the world.

Acknowledgments

This material is based upon work supported by the U.S. National Science Foundation under grant 0222623, with additional support from NASA.

References

Cess, R. D., et al. (1990), Intercomparison and interpretation of climate feedback processes in 19 atmospheric general circulation models, J. Geophys. Res., 95, 16,601–16,615.

Duda, D. P., R. Palikonda, and P. Minnis (2004), Relating satellite-based contrail detection to NWA output, paper presented at the 11th Conference on Aviation, Range, and Aerospace, Am. Meteorol. Soc., Hyannis, Mass., 4–8 October [CD-ROM].

Platnick, S., M. D. King, S. A. Ackerman, W. P. Menzel, B. A. Baum, J. C. Riedi, and R. A. Frey (2003), The MODIS cloud products: Algorithms and examples from Terra, IEEE Trans. Geosci. Remote Sens., 41, 459–473.

—L. H. CHAMBERS, NASA Langley Research Center, Hampton Va.; and D. P. DUDA, National Institute of Aerospace, Hampton, Va.

MEETINGS

Monitoring Carbon From Space

PAGE 384–385

Over the past two centuries, there have been great changes in the atmospheric concentrations of greenhouse gases including carbon dioxide, methane, and carbon monoxide (CO_2, CH_4, and CO). The natural cycles of these gases have been strongly affected by human actions such as fossil fuel burning, land use change, and fire management.

While there will always be uncertainty in understanding a system as complex as the world's climate, there is strong evidence that global warming is occurring and is being caused by increases in greenhouse gases in the atmosphere. The effects of such warming are already significant, and they are certain to accelerate in future decades as the magnitudes and feedback effects of the causative human actions increase.

Of these gases, CO_2 is the major contributor to anthropogenic climate change. CO_2 levels have increased from 280 parts per million (ppm) in 1750 to over 375 ppm currently. This concentration is higher than at any time in the past million years. Only around half of the extra carbon dioxide human activity sends into the atmosphere stays there; unidentified "sinks" on the land or ocean surface absorb the rest. The rate of climate change would be much greater without this absorption. Further, there is great variability in the strength of sinks from year to year, largely as a response to climate anomalies such as the El Niño–Southern Oscillation (ENSO). To make reliable predictions of future CO_2 concentrations, the sink strength variability needs to be understood since it is also subject to climate change.

Quantifying the variations in space and time of the sources of CO_2 requires precise and continuous monitoring at global scale. Space-based remote sensing is ideally placed to contribute to this monitoring.

More than 60 researchers discussed this topic at the European Space Agency's (ESA) European Space Research Institute (ESRIN) in Italy, during the three-day Carbon From Space workshop.

The meeting, jointly organized by ESA, the International Geosphere-Biosphere Programme (IGBP), the Integrated Global Carbon Observations Theme (IGCO) of the Integrated Global Observing Strategy (IGOS), and the Global Carbon Project (GCP), brought together the science community, the space agencies (ESA, NASA, and the Japan Aerospace Exploration Agency (JAXA)), and the observation coordinating bodies (e.g., IGCO) to discuss the state of the science, share knowledge of each other's activities, and coordinate measurements and modeling activities.

Status and Prospects for Improved Space-Based Observations

Currently, four orbiting space-based systems are capable of measuring CO_2, CH_4, and CO concentrations in the atmosphere. Although none of these systems was optimally designed for making such measurements, useful results are nonetheless being derived from the NOAA's High-Resolution Infrared Sounder (HIRS) (CO_2), ESA's Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) (CH_4, CO_2), NASA's Atmospheric Infrared Sounder (AIRS) (CO, CO_2), and NASA's Measurements of Pollution in the Troposphere (MOPITT) sensor (CO).

This situation will change shortly, as four additional instruments capable of measuring greenhouse gases will soon be launched.

The first two, the French Centre National d'Études Spatiales (CNES)/European Meteorological Satellite Organisation (EUMETSAT) Infrared Atmospheric Sounding Interferometer (IASI) and the NASA/NOAA Cross-track Infrared Sounder (CrIS), are similar to currently orbiting instruments. They will primarily benefit weather forecasting but also can measure greenhouse gas concentrations. Their operational nature guarantees continuity, which is important given the spatial and temporal variability in carbon exchange between land, ocean, and atmosphere.

The other two instruments, NASA's Orbiting Carbon Observatory (OCO) and JAXA's Greenhouse Gases Observing Satellite (GOSAT), are the first purpose-built CO_2 measurement satellite instruments. They use different technological approaches to the same measurement, and their performance will help guide future missions.

The ESRIN meeting represented an opportunity for Europeans to hear about progress on these missions and to discuss plans for data analysis. Additionally, agency representatives discussed potential European involvement in the missions, such as providing data downlink services.

Current and planned missions offer a significant increase in the capability to measure atmospheric CO_2, but they still leave gaps. Thermal infrared instruments (e.g., IASI) are sensitive only to the small variation in CO_2 in the upper troposphere. Passive near-IR instruments (e.g., OCO) see the stronger signals in the lower troposphere but are limited to sunlit surfaces. This means Passive near-IR instruments are prone to diurnal biases and leave parts of the Earth invisible for much of the year because there is either no or not enough sunlight for reliable measurement. Active instruments (e.g., lidar), in which the satellite provides its own light source, overcome these limitations.

The current technical feasibility of launching lidars into space is the subject of independent studies funded by NASA and ESA (E. Browell, NASA; G. Ehret, German Space Agency (DLR); and P. Flamant, Laboratoire Meteorologie Dynamique, Palaiseau, France) with future joint activity a real prospect.

Validation of Measurements

Validation of measurements is vital in any satellite program, especially for a measurement as potentially controversial as CO_2 concentration. Meeting attendees heard about the existing networks of discrete and continuous measurements taken at the Earth's surface or from aircraft. A problem is that these measurements are taken at specific altitudes, while satellite measurements will integrate concentration over some depth in the atmosphere. More comparable measurements are coming from surface-based upward-looking Fourier transform spectrometers (FTS) or lidars.

The joint presentation by C. Miller (NASA Jet Propulsion Laboratory) and G. Inoue (National Institute for Environmental Studies, Japan) showcased the coordination of these valida-