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NEWS

Satellite Imagery Maps Hurricane Katrina Induced Flooding and Oil Slicks

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In the early morning of 29 August 2005, Hurricane Katrina made landfall near Buras, Louisiana, as a Category 4 hurricane. With wind speeds of about 233 kilometers per hour, a storm surge of 8.5 meters, and heavy rains, Katrina pounded the U.S. Gulf Coast states of Alabama, Louisiana, and Mississippi with life-threatening flooding and destruction. Katrina's high winds and storm surge breached the levees protecting New Orleans, a city located below sea level, and flooded approximately 80% of the city.

Katrina also caused major damage to the region's oil and natural gas production and refining capabilities. On 2 September 2005, the Associated Press reported that Katrina had damaged 58 oil platforms, 30 of which were reported lost; one damaged platform had been blown nearly 100 km from its original location.

Synthetic Aperture Radar (SAR) obtained by the Radarsat sensor and the Landsat Enhanced Thematic Mapper (ETM+) sensor are complementary in nature. The SAR data contains information relating to vegetation or surface structure, while the Landsat ETM+ contains spectral information relating to vegetation health. Combining the SAR and Landsat ETM+ imagery allows for the accurate depiction of flooding and the identification of possible oil slicks and debris flows on calm water.

Accurate maps depicting the aerial extent of flooding, oil slicks, and floating debris provide vital information necessary for local and national emergency management personnel to allocate resources to areas of greatest need and to aid urban and environmental planners in preparing for restoration.

To map the flooding in New Orleans and its vicinity, a multi-database approach was used that was created by incorporating SAR images acquired during the flood with a pre-flood Landsat ETM+ image mosaic. The ability of the SAR sensor to penetrate clouds and vegetation cover makes it useful for flood mapping. In addition, it provides information complementary to the spectral information from optical satellites such as the Landsat ETM+ sensor.

The SAR backscatter signal represents the amount of energy reflected back to the sensor from the surface. The signal is controlled by environmental factors such as terrain slope, surface roughness, and moisture content of surface materials. During calm weather, water acts as a specular reflector (or forward scatterer) of the SAR signal, resulting in very low backscatter values for flooded areas.

However, if flooding occurs in areas with tall vegetation or buildings, a phenomenon known as a "double bounce" interaction may occur. With a "double bounce" interaction, the SAR signal is reflected away from the sensor by the water surface, toward a tree or building, and is then reflected directly back to the sensor. The "double bounce" interaction results in a very high backscatter return and is important for identifying flooding in forests and in urban areas.

Discrimination between the two types of SAR interactions requires information relating to pre-flood land cover conditions, which can be derived from the Landsat ETM+ data.

Using C-band SAR images acquired by Radarsat on 2 and 5 September, preliminary inundation maps (Figures 1a and 1b) were derived showing the extent of flooding caused by Hurricane Katrina. By combining the flood extent derived from the Radarsat scenes with pre-flood digital elevation data derived from lidar, flood volumes for New Orleans and its immediate vicinity were calculated to be approximately 528,000,000 m^3 on 2 September and 517,000,000 m^3 on 5 September. In addition, floating debris and the influx of contaminated water (sewage and other household chemicals) into Lake Pontchartrain are identified in the 5 September image (Figure 1b).

The tendency of oil slicks on water to dampen the roughness of the water also allows for the discrimination of oil slicks in open water with moderate to light wind conditions. Therefore, the Radarsat images were utilized to identify possible oil slicks off the Louisiana coast (Figures 1a and 1b).

The high contrast and change in texture observed between the oil slick and the surrounding waters indicate the wind speed was light, while the shapes of oil slicks indicate that the wind was out of the east on 2 September. While the weather reporting station in New Orleans was inoperable on 2 September, weather stations in Baton Rouge and Lafayette, Louisiana, support this finding, as both stations reported light winds out of the northeast and east northeast directions, respectively.

The points of origin for some oil slicks appear to be related to offshore oil platforms; however, other slicks without obvious originating sources may indicate damages to pipelines running along the floor of the Gulf.

Another possible source for the oil slicks are spills from large onshore oil refineries and storage facilities. One suspected oil spill in Chalmette, a town a few miles southeast of New Orleans, was only recently detected, and an oil storage tank there may have spilled some 10,000 barrels (as reported on MSNBC (http://msnbc.msn.com/id/9175553/), 7 September 2005).

The aerial coverage of the interpreted oil slicks has a degree of uncertainty, as other natural phenomena such as rain cells, internal waves, low wind, and wind-sheltering effects can also produce low backscatter returns similar to those produced by an oil slick.

Further quantitative analysis, including the

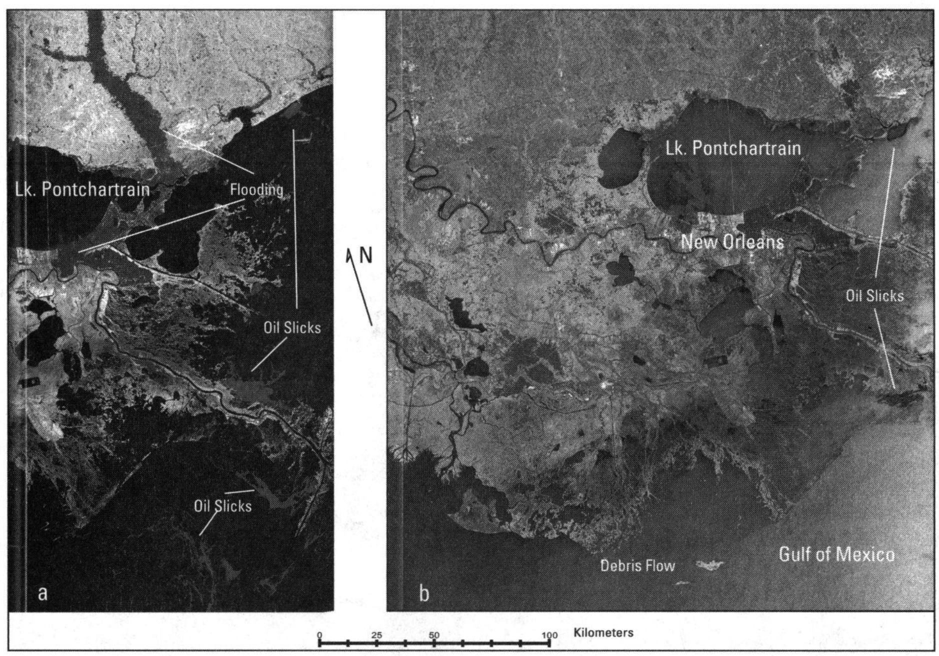

Fig. 1. The extent of flooding (blue) for (a) 2 September 2005 and (b) 5 September 2005 was mapped by combining the Radarsat SAR imagery with a pre-flood Landsat ETM+ image mosaic. Several possible oil slicks (red) are identified in the 2 September image. However, since oil slicks have a signature similar to other natural phenomena, these sites should be treated as a preliminary estimate. Several items of interest can be identified in the 5 September Radarsat image. Two oil slicks (red) are visible in the eastern part of the image, while the large plume in Lake Pontchartrain (magenta) is likely due to the pumping of contaminated New Orleans floodwaters into the lake. The slightly higher backscatter values found in the southern portion of the image are indicative of a debris flow (yellow). Original color image appears at the back of this volume.

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.

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Count-a-Thon of Airplane Contrails

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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.

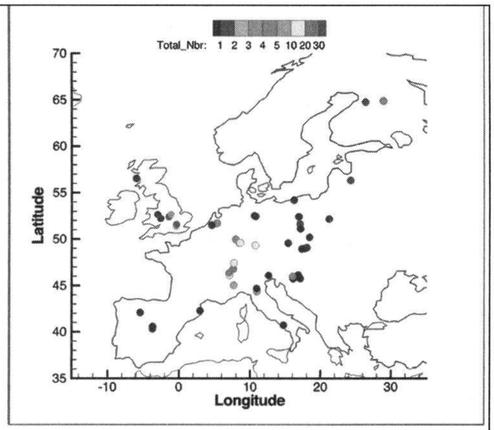
The GLOBE program (www.globe.gov) is an international science program started in 1995 as a U.S. interagency effort. A primary goal of the program is to develop detailed protocols that enable students to make scientifically valuable measurements of environmental parameters. GLOBE includes large numbers 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

Location	Total	Spreading
★ Thun	22	10
☆ Martigny	19	16



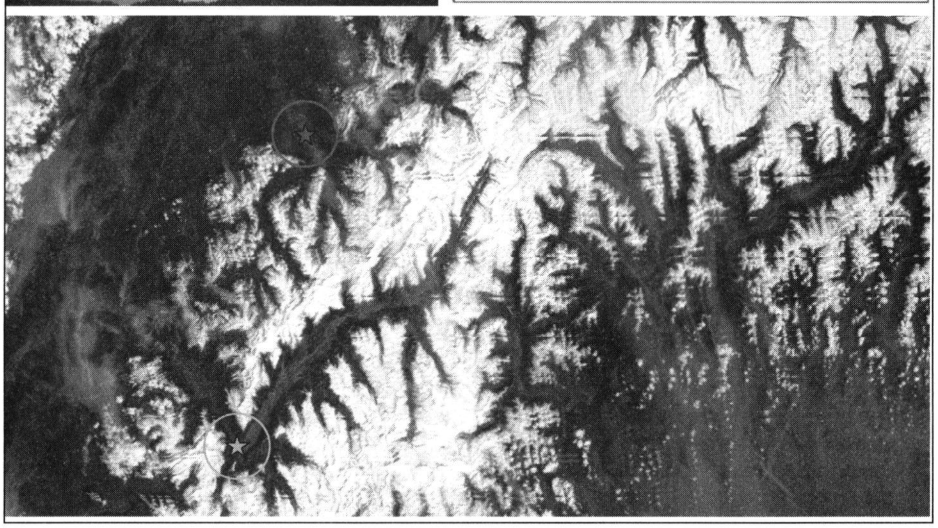


Fig. 1. Example of results from a contrail count-a-thon event. (upper left) Reports from two schools in Switzerland. (middle left) Photo from ground observers in Martigny, Switzerland at 0930 UTC. (bottom) Terra MODIS visible image (250 m), 1050 UTC on 22 April 2004, with the approximate location of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

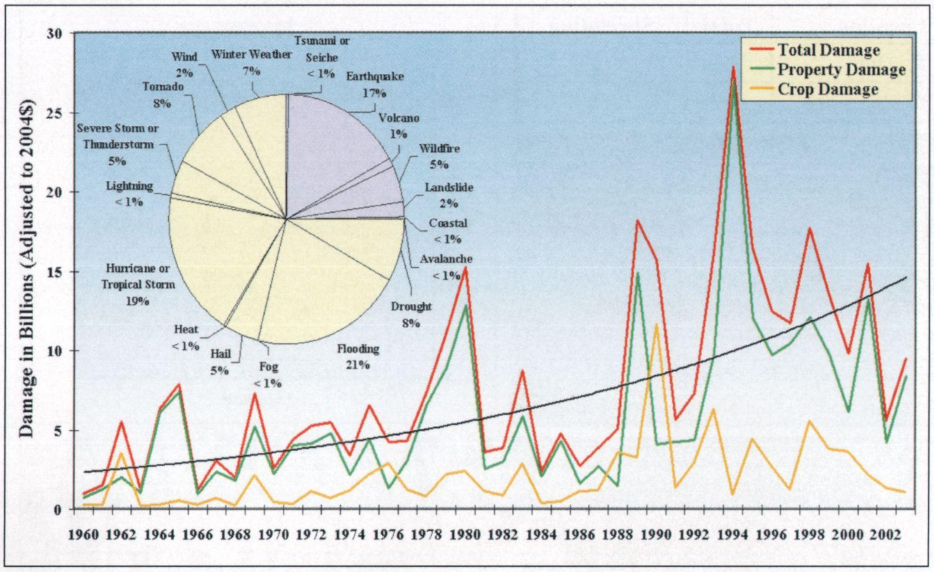
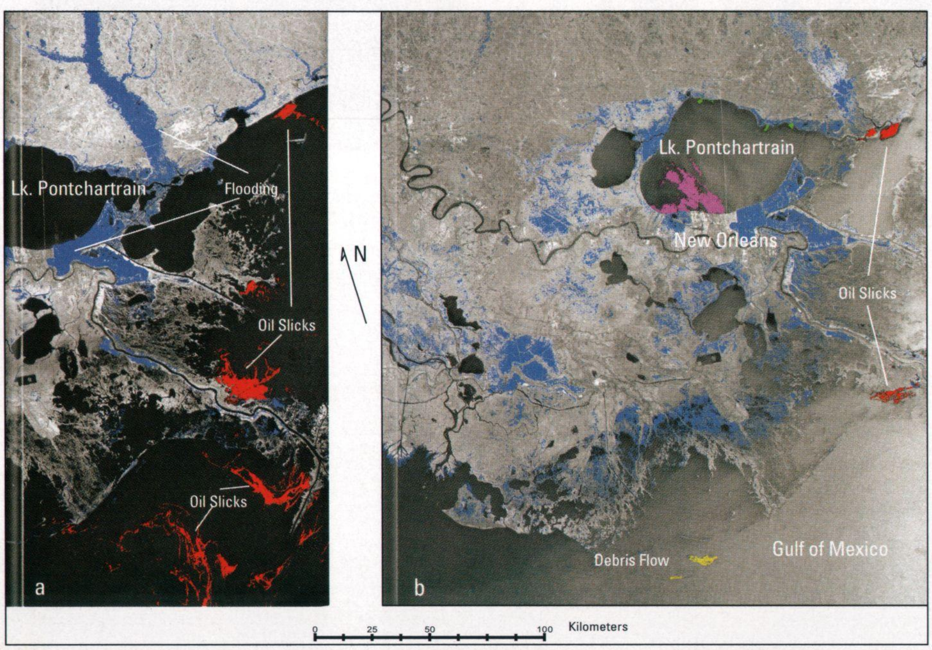


Fig. 1. Natural hazards losses from 1960–2003 based on the Spatial Hazard Events and Losses Database for the United States (SHELDUS).



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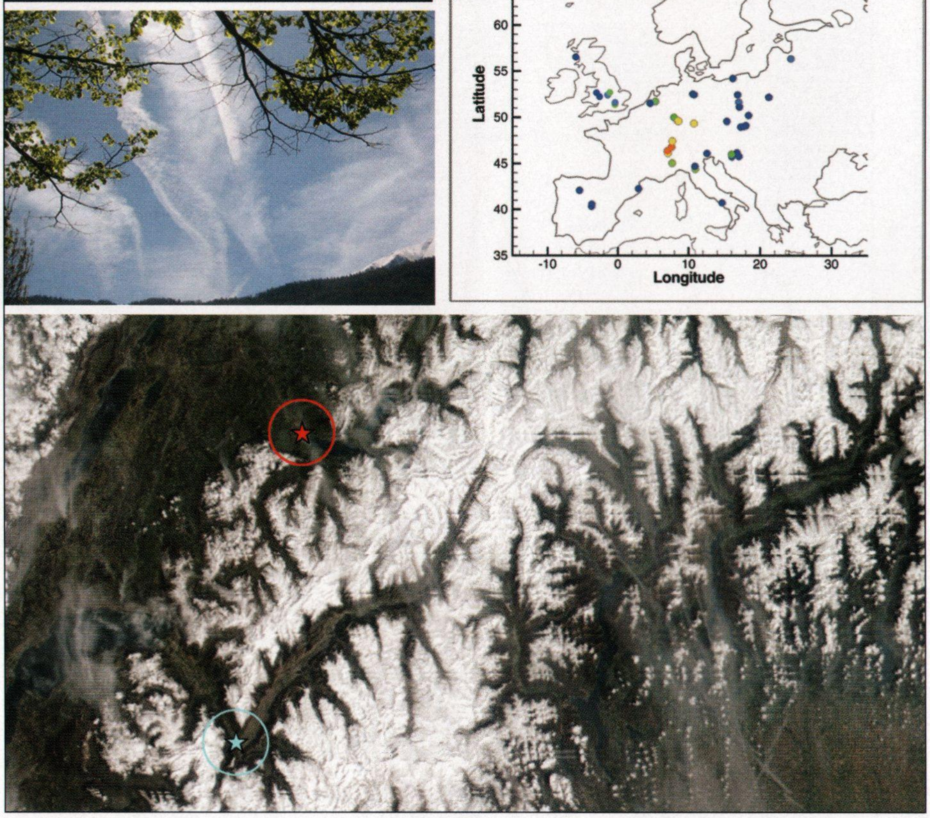

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