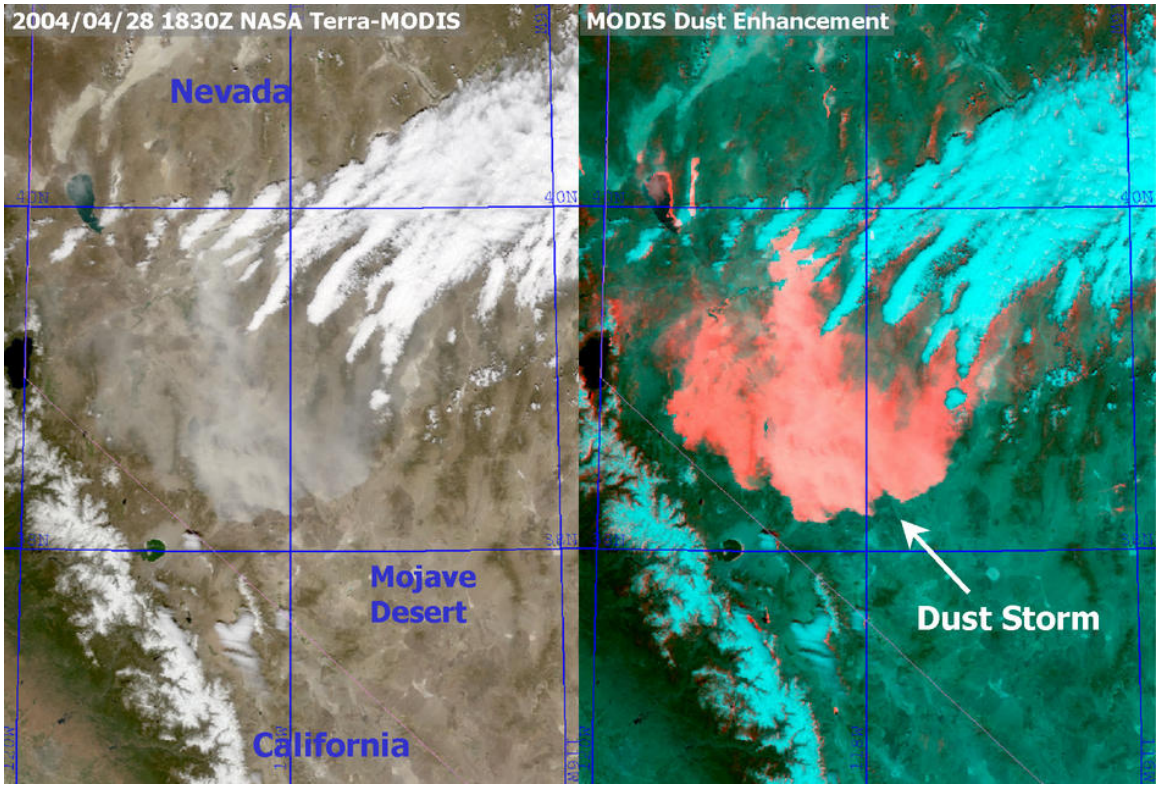
Satellite Product Tutorials:

Desert Dust Storms



Above: A large cloud of dust drifts southward through the Mojave Desert. The dust enhancement (right) depicts large amounts of suspended dust as pink, land as dark green, and clouds/snow as aquamarine. This product is enabled by the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments aboard NASA's Terra and Aqua satellites, as part of NASA's Earth Observing System (EOS) project.

Why We're Interested…

Dust in the atmosphere has numerous impacts to civilian (reduces air quality and travel), military (reduces visibility and impacts the performance of equipment). We are particularly interested in dust from the perspective of its potential role in determining the climate (altering the heating and cooling of the atmosphere, which determines weather patterns). Dust can also

impact the climate indirectly through its interaction with clouds and precipitation. The magnitudes of these effects are poorly understood.

How This Enhancement is Created…

To isolate and enhance dust in the satellite imagery, we must rely on measurable qualities that distinguish it from other components of the scene. There are many ways to do this, but in practice we have found some of the most reliable ones to be:

1) *Color:* we can distinguish dust from most clouds with our eyes simply through color differences (mineral dust clouds have earthen tones, while clouds appear gray/white). In the same way, a satellite with the right "eyes" (or "channels" on an instrument) can sense color and thereby remove non-dust components of a given scene.
2) *Temperature:* When dust is lifted into the atmosphere, its temperature quickly adjusts to whatever the air temperature of the environment is. Since temperatures in the lower atmosphere generally decrease with height, the dust layer cools as it rises, and soon produces a nice "thermal contrast" against the warmer surface. A satellite instrument sensitive to heat (infrared measurements) can therefore assist in detecting an elevated dust plume based on its temperature contrast.
3) *Transparency:* Due to certain physical properties of mineral dust layers, they will appear "thinner" or "thicker" depending on what part of the infrared spectrum we observe them in. The thick-channel measurements will appear cooler than the thin measurements, since in the former we're seeing a cool temperature of the dust layer and in the latter we're seeing through the dust to the warmer surface background. Taking a difference between two such measurements provides a convenient way to identify dust.

While any one of the above properties alone is not sufficient to fully distinguish elevated dust, we can more often than not arrive at a reasonable isolation of dust from other components of the scene through *combining* of points 1-3. When all three items are satisfied simultaneously (i.e., an intersection) we can say with greater confidence that the scene contains dust. The degree to which the components were satisfied is proportional to the relative brightness of the enhanced dust features.

How to Interpret…

The MODIS dust enhancement is designed to simplify the detection of any significant dust regions present in a potentially complex scene. We do this by gathering together all our "dust information" as outlined above and presenting it in a form that helps it stand out from other constituents of the scene. The end result is something that no longer looks "real," but provides a less ambiguous depiction where dust resides.

What to look for: Regions of pink/orange against dark green backgrounds, sometimes displaying sharp boundaries (most often along the leading edge of a dust front) but more often possessing a diffuse appearance.

What to watch out for: Cloud shadows, coastlines (both ocean and lake), and mountainous terrain (especially during the winter months) occasionally appear "enhanced" as red.

Other Considerations: While major dust outbreaks do occur typically a few times per year over the southwestern deserts of the United States, they are far less prolific than the expansive deserts of Eurasia. A more common variety of dust storm to the United States is associated with the cold-pool outflow of thunderstorm complexes. Called "Haboobs" in the Middle East, these storms form impressive walls of thick dust on scales of several miles (compared to hundreds or even thousands of miles for major dust storms). Oftentimes this variety of dust storm is missed by MODIS due either to time sampling (catching the event in progress from one or two snap-shot observations) or their being obscured by overriding clouds associated with the parent thunderstorm(s).

Note: this dust detection product requires information from sunlight reflection, and thus is only valid for daytime observations.

Looking Toward the NPOESS Era…

The measurements required for enhancing dust storms via the technique shown here will become available operationally during the National Polar-orbiting Operational Environmental Satellite System (NPOESS) era using the

Visible Infrared Imaging Radiometer Suite (VIIRS). With a three-satellite constellation, NPOESS-VIIRS will provide roughly 4-hour refresh over the United States. The high spatial resolution (370 meters, or just under ¼ mile "boxes") will enable detailed depiction of dust flow patterns to supplement the higher time refresh information (but coarser spatial resolution) to be offered from the next-generation geostationary operational environmental satellite series, GOES-R.

Did You Know…?

Dust from Africa, China, and the Middle East can "ride the atmospheric currents" all the way to the United States. Intense dust storms over the Sahara Desert of Northern Africa reach the Eastern United States on a regular basis, while storms originating in the Gobi Desert of China sometimes make for a hazy afternoon on the California coast. Studies have found links between these exotic dust sources and local respiratory health problems, as well as marine ecosystem impacts in the form of coral reef bleaching.

Want to Learn More?

COMET® Program NPOESS Education and Training Series:

A tutorial on Dust Detection

A tutorial on the NPOESS Program

Science Papers:

Ackerman, S. A., 1997: Remote sensing of aerosols using satellite infrared observations, *J. Geophys. Res*, **102**, 17069-17079.

Hillger, D. W., and G. P. Ellrod, 2003: Detection of important atmospheric and surface features by employing principle component image transformation of GOES imagery, *J. Appl. Meteorol.*, **42**, 611-629.

Lee, T. F., Dust tracking using composite visible/IR images: A case study. *Weath. Forecast.*, **4**, 258-262.

Miller, S. D., 2003: A consolidated technique for enhancing desert dust storms with MODIS, Geophys. Res. Lett., 30, 2071—2074.

Prospero, J. M., 1999: Long-term measurements of the transport of African mineral dust to the southeastern United States: implications for regional air quality. *J. Geophys. Res.*, **104**, 15917-15927.

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