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Internal waves in Atmosphere and Oceans seen with Satellite Images and GIMP Retinex Filter

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In Sparavigna, “Internal waves and vortices in satellite images”, arXiv, 2012, <https://arxiv.org/abs/1202.5770>, and in 2014, “Studying the Oceanic Internal Waves using Google Earth”, <https://www.ijsciences.com/pub/article/570> we proposed a discussion and some satellite images of internal waves in atmosphere and oceans. Here we use the GIMP Retonec filter to enhance the presence of these waves in the satellite imagery.

Off Australia

<https://visibleearth.nasa.gov/images/69463/atmospheric-gravity-waves-and-internal-waves-off-australia/694661> We can find “Atmospheric gravity waves and internal waves off Australia”, by Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC, Published December 5, 2003. The image shows a part of the Indian Ocean in a true-color Moderate Resolution Imaging Spectroradiometer (MODIS) image (Terra satellite, November 11, 2003). In the image we can find the “atmospheric gravity waves”, which “reveal themselves in double, overlapping arcs of clouds”. “In the eastern part of the scene, a mixture of wave patterns caused by atmospheric gravity waves and internal ocean waves fans out from the coast”. Atmospheric gravity waves, or atmospheric internal waves, “occur when a uniform layer of air blows over a large obstacle, like a mountain or island”.

“Internal waves happen much in the same way that atmospheric gravity waves do; the main difference being that the waves occur between layers of water with different densities instead of layers of the atmosphere. When the bottom layer of dense water encounters an obstacle, a wave pattern forms at the point where the bottom layer of water and the next, lighter layer meet. These waves don't actually ripple the surface of the water, but they become visible because of the way light reflects off of them.” We can use the courtesy image and enhance with GIMP Retinex filter a part of it to evidence the internal waves.

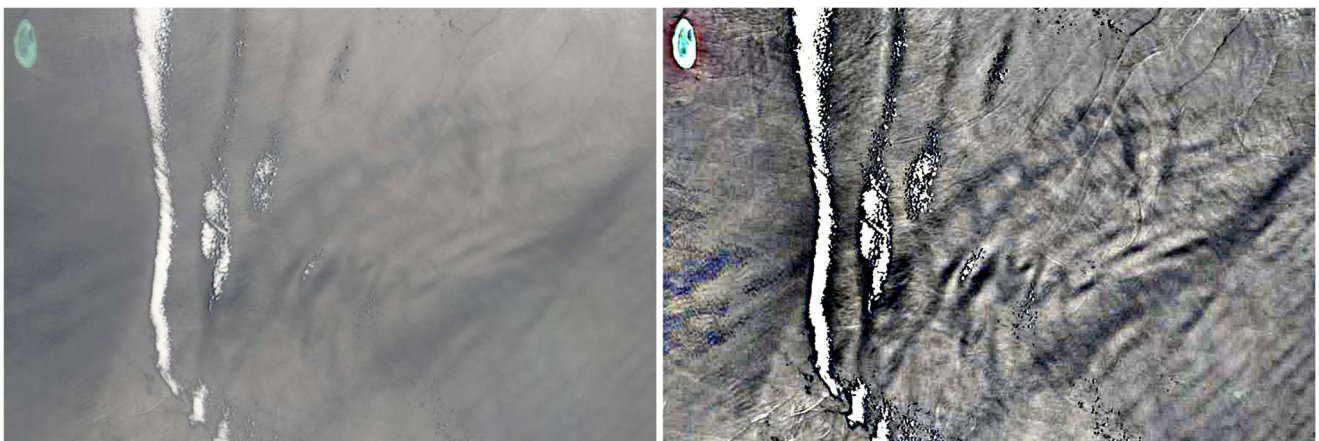


Fig.1

<https://earthobservatory.nasa.gov/images/87519/waves-above-and-below-the-water>

<https://web.archive.org/web/20250416120607/https://earthobservatory.nasa.gov/images/87519/waves-above-and-below-the-water>

“Waves Above and Below the Water”, where we can see NASA image by Jeff Schmaltz, LANCE/EOSDIS Rapid Response. Caption by Mike Carlowicz and Holli Riebeek. February 10, 2016. We can use the courtesy image and enhance with GIMP Retinex filter a part of it to evidence the internal waves.

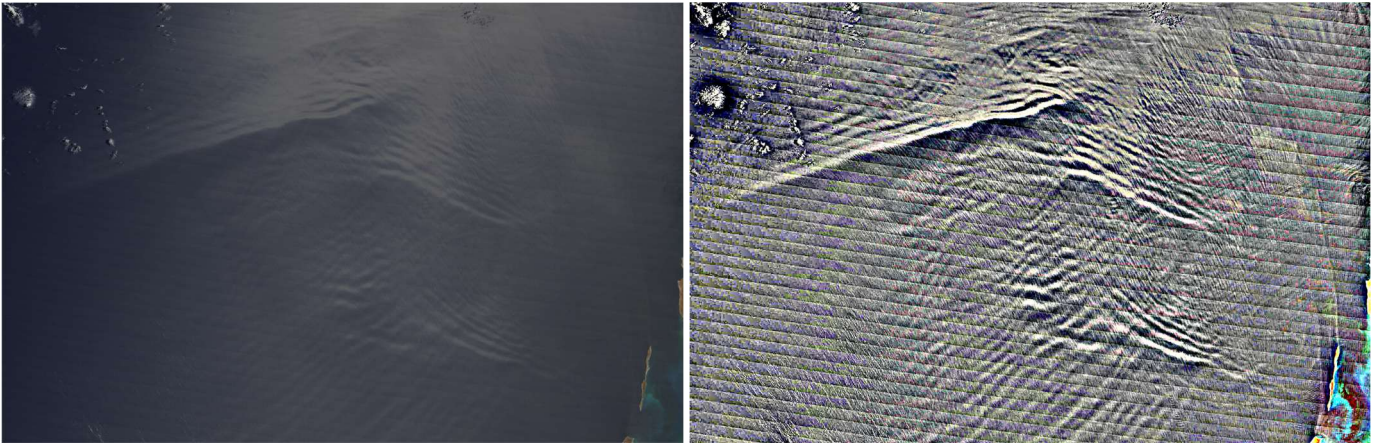


Fig. 2

Sulu Sea

<https://visibleearth.nasa.gov/images/66899/internal-waves-in-the-sulu-sea/669021>

<https://web.archive.org/web/20250416112923/https://visibleearth.nasa.gov/images/66899/internal-waves-in-the-sulu-sea/669021>

“Internal waves in the Sulu Sea”, 2003, are shown by Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC, April, 8, 2003. “In the Sulu Sea between the Philippines and Malaysia, sunglint highlights delicate curving lines of internal waves moving to the northeast toward Palawan Island. ... The Sulu Sea, like all major bodies of water, is composed of layers of water with differing densities. The topmost layer is the least dense, with each successively deeper layer being denser. Internal waves move along underwater at the boundary between layers of different densities.” . We can use the courtesy image and enhance with GIMP Retinex filter a part of it to evidence the internal waves.

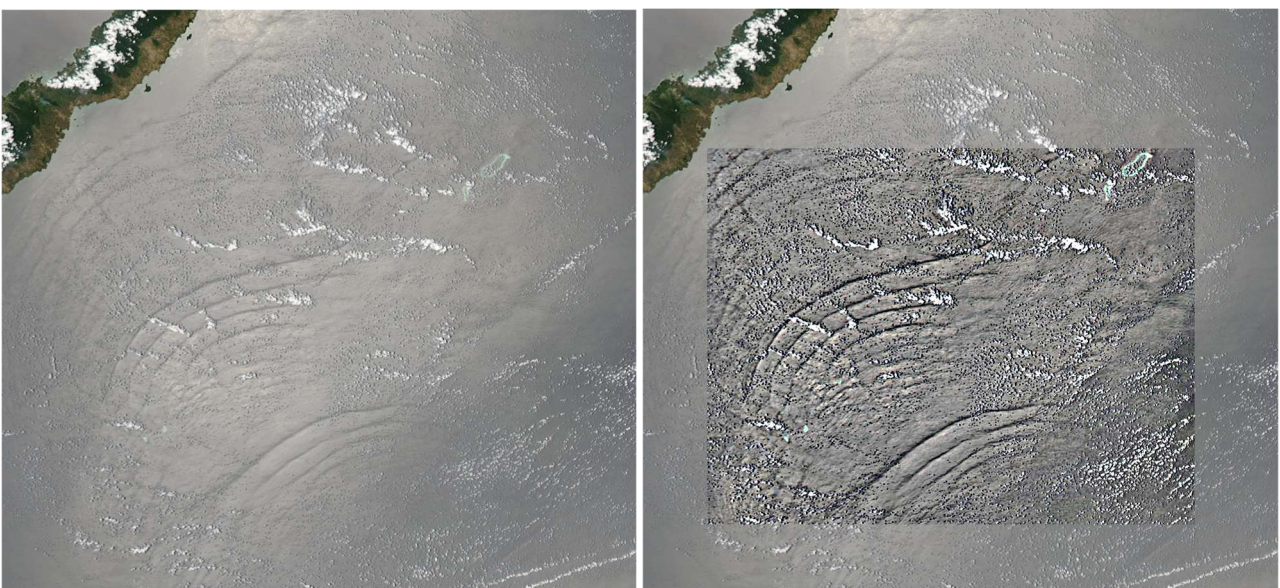


Fig.3

Indian Ocean south of Java, Indonesia.

<https://www.visibleearth.nasa.gov/images/72184/atmospheric-gravity-waves-and-internal-waves-south-of-java/721871>

<https://web.archive.org/web/20250416130646/https://www.visibleearth.nasa.gov/images/72184/atmospheric-gravity-waves-and-internal-waves-south-of-java/721871>

This web page is giving us the “Atmospheric gravity waves and internal waves south of Java”, courtesy Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC. “In this image, dark and light streaks on the ocean show where the waves have roughened the surface water. This image was acquired on October 13, 2004 by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Terra satellite.” We can use the courtesy image and enhance with GIMP Retinex filter a part of it to evidence the waves.

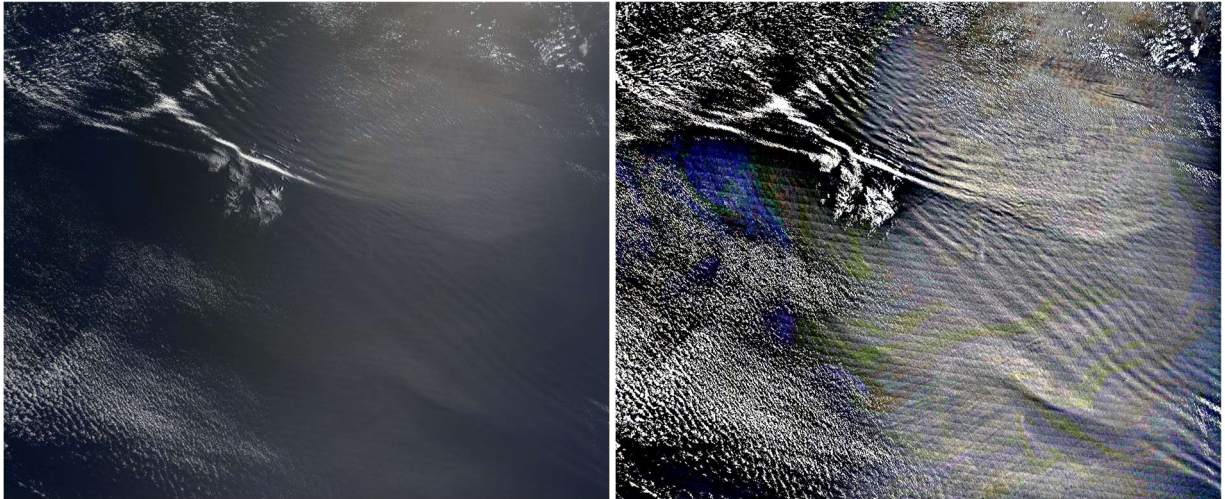


Fig.4

Internal Solitary Waves at the Lombok Strait

<https://www.nasa.gov/image-article/oceanic-nonlinear-internal-solitary-waves-from-lombok-strait/>

<https://web.archive.org/web/20250228033643/https://www.nasa.gov/image-article/oceanic-nonlinear-internal-solitary-waves-from-lombok-strait/>

Jeff Schmaltz, MODIS Land Rapid Response Team, NASA GSFC, is providing the image. We can use the courtesy image and enhance with GIMP Retinex filter a part of it to evidence the waves.

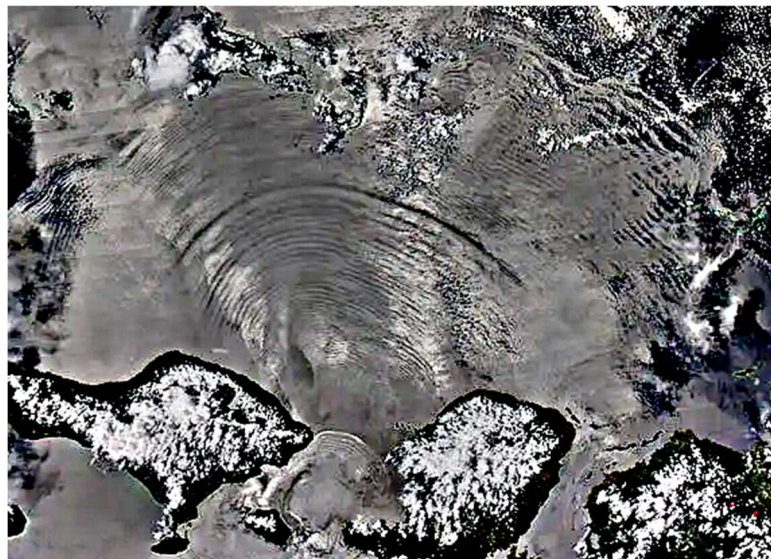


Fig.5

Indian Ocean

<https://earthobservatory.nasa.gov/images/44567/internal-waves-in-the-indian-ocean>

<https://web.archive.org/web/20250416133900/https://earthobservatory.nasa.gov/images/44567/internal-waves-in-the-indian-ocean>

The web page is providing an image which is showing “both internal waves and surface waves on the Indian Ocean near the Andaman Islands. The active Barren Island Volcano, part of the Andaman Islands, is shown emitting puffs of steam on the left side of the image. The Advanced Land Imager (ALI) on the Earth Observing 1 satellite acquired the image on March 6, 2007. Sunlight reflecting off the water’s surface gives it a pale, silvery blue color. The tiny wrinkles running roughly horizontally across the ocean are surface waves. Internal waves paint long diagonal lines across the ocean on the right side of the image.” (NASA Earth Observatory image created by Jesse Allen and Robert Simmon, using EO-1 ALI data provided courtesy of the NASA EO-1 team. Caption by Holli Riebeek”. . We can use the courtesy image and enhance with GIMP Retinex filter a part of it to evidence the surface waves too.

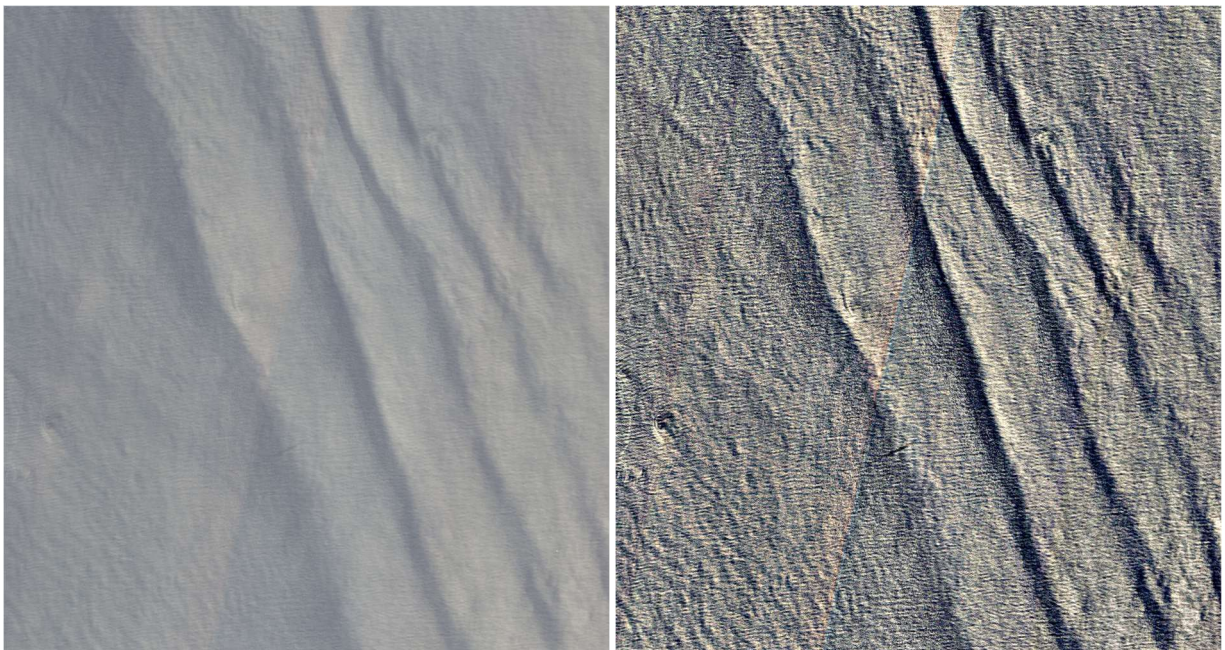


Fig.6

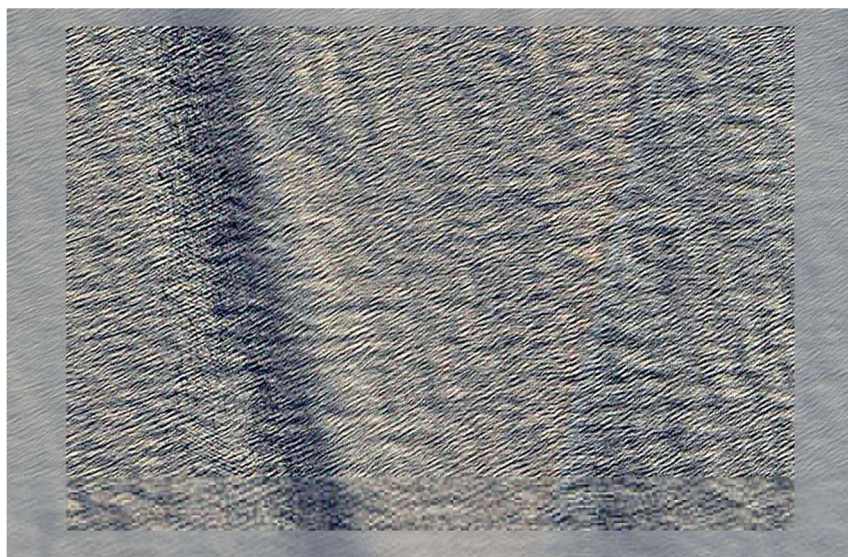


Fig.7

Arabian Sea

<https://earthobservatory.nasa.gov/images/5528/atmospheric-gravity-waves-over-arabian-sea>

“On May 23, 2005, the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Terra satellite captured this image of a large-scale, overlapping wave pattern in the sunglint region of an image of the Arabian Sea. The wave pattern seen in the image is not from large ocean waves, however. The pattern is the “impression” of atmospheric gravity waves on the surface of the ocean.” (Jeff Schmaltz MODIS Rapid Response Team, NASA-GSFC).

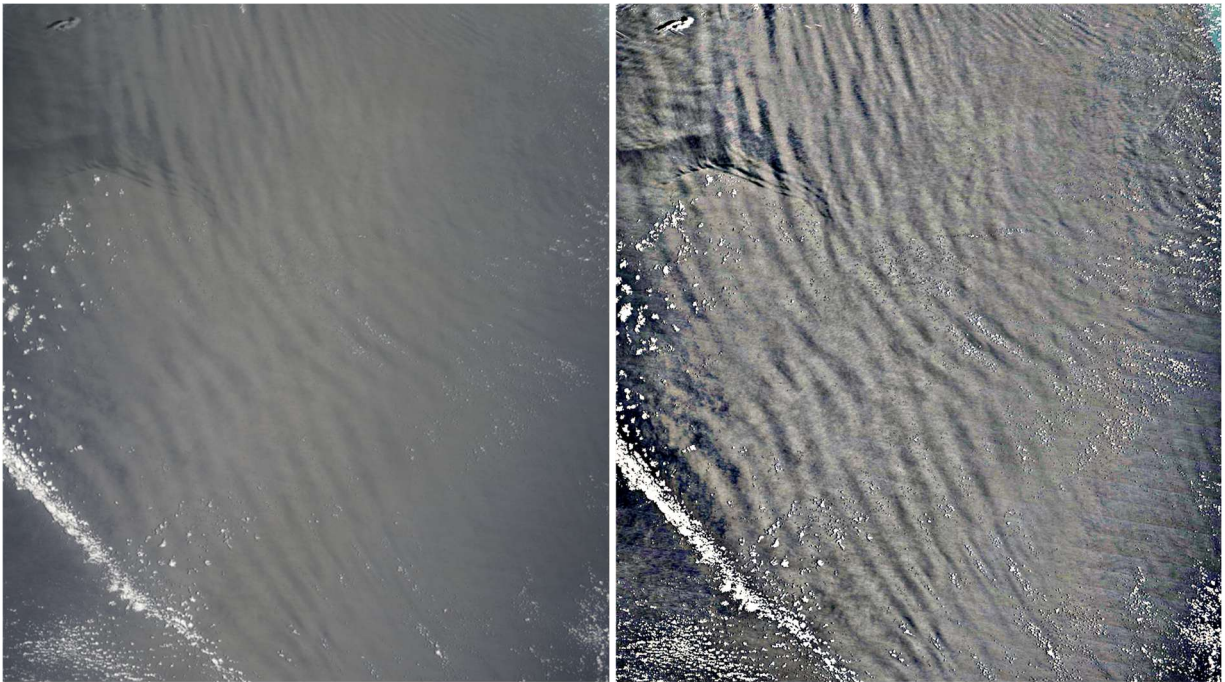


Fig.8

Red Sea

<https://visibleearth.nasa.gov/images/67682/internal-waves-in-the-red-sea/676831>

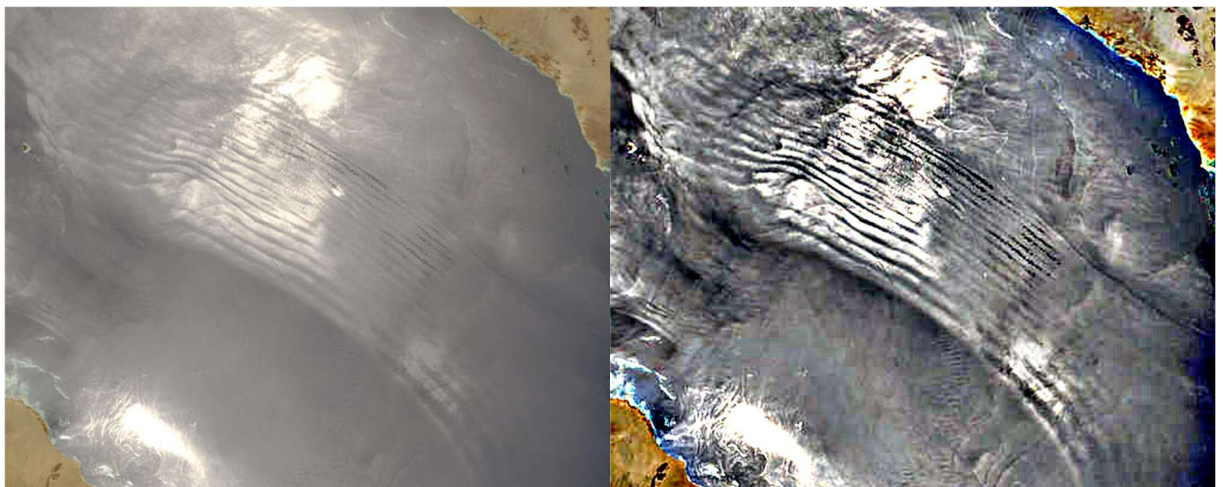


Fig.9

“Internal waves ruffle the waters of the Red Sea between Egypt and Saudi Arabia. These underwater waves travel through the boundary between layers of water of different temperature and density. They usually happen when the tide pulls the bottom layer of dense water across a rough surface. As the bottom layer undulates, it creates waves along the boundary of the surface layer of water” (Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC). The waves have been detected by MODIS, on July 26, 2003

Ocean Color Image Gallery

<https://oceancolor.gsfc.nasa.gov/gallery/671/> The NASA image shows Internal Waves in the Andaman Sea. The web page is mentioning Osborne and Burch, 1980. Figs. 10 and 11 are details enhanced by Retinex filter.



Fig.10

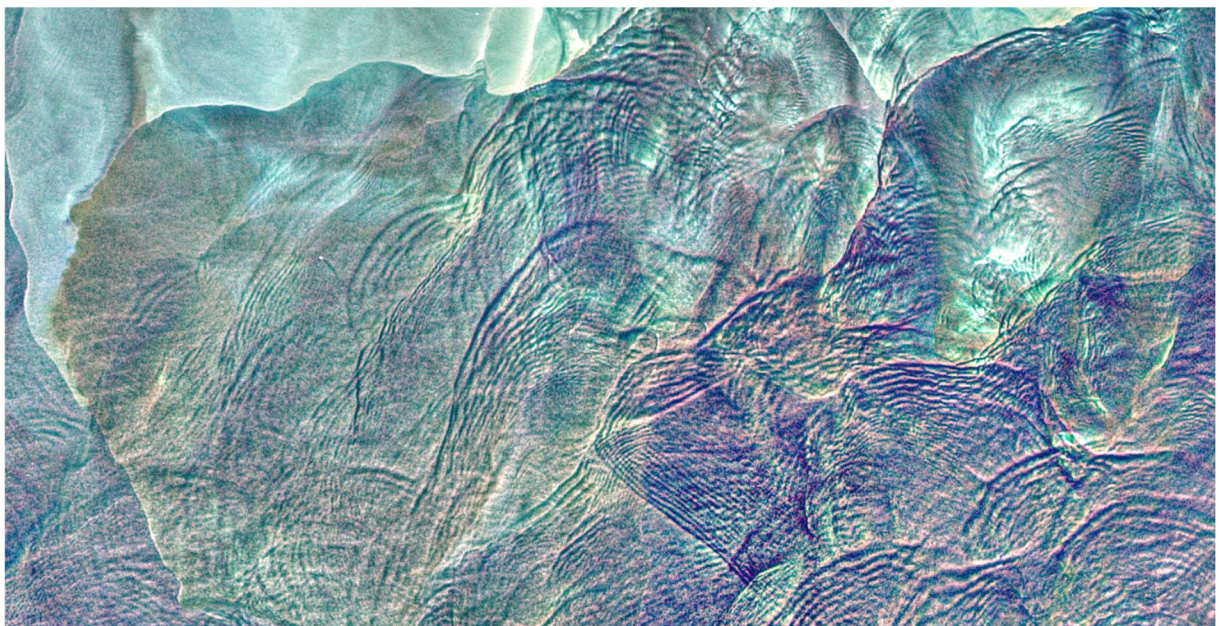


Fig. 11

Sea of Japan

<https://visibleearth.nasa.gov/images/114528/internal-waves-in-the-sea-of-japan/1145301>

<https://web.archive.org/web/20250416144739/https://visibleearth.nasa.gov/images/114528/internal-waves-in-the-sea-of-japan/1145301>

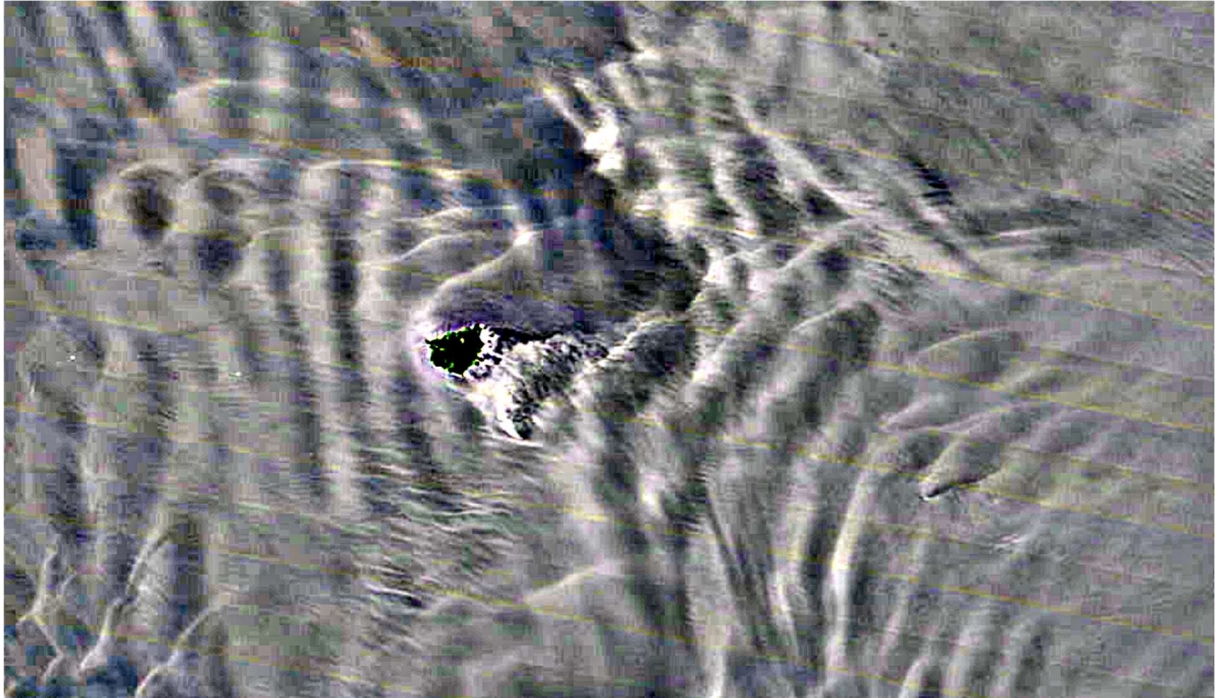


Fig.12

Other cases:

<https://visibleearth.nasa.gov/images/117760/internal-waves-in-the-north-australian-basin-and-the-java-sea>

<https://earthobservatory.nasa.gov/images/3589/ocean-features-from-seasat>

<https://www.visibleearth.nasa.gov/images/113610/internal-waves-in-the-atlantic-ocean-northeast-of-brazil/1136111>

<https://visibleearth.nasa.gov/images/114045/internal-waves-between-sumatra-and-malaysia/1140471>

Off of Somalia

<https://www.visibleearth.nasa.gov/images/68939/internal-waves-off-somalia/689411>

“At the boundary between the Gulf of Oman and the Indian Sea, internal waves abound”. At the web page we can find a “true-color Aqua MODIS image [that] was acquired on August 27, 2003. The large land-mass to the west is the northeastern point of Somalia, while the islands are part of Yemen” (Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC).



Fig.13

In the past, we used Retinex filter for several purposes. It has been applied for fabric fault detection, for the filtering of foggy images, for Underwater and Night Image Enhancement.

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