Oil spill remote sensing in the marine environment: MODIS potentialities

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Introduction

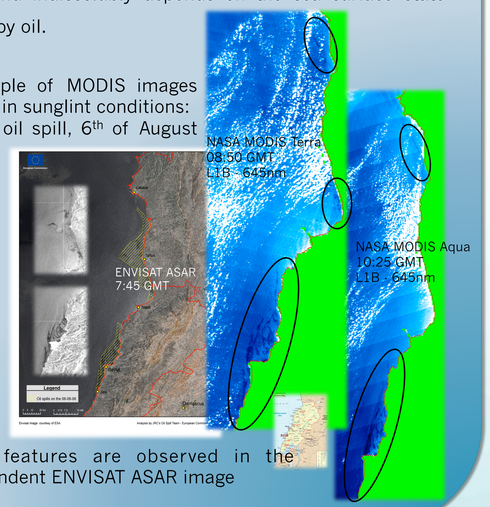
With its higher resolution bands, its two daily acquisitions, and the possibility to obtain near real-time data free of charge, the NASA MODIS multispectral optical sensor shows interesting potential as a cost-effective additional tool for oil spill monitoring in the marine environment. Several MODIS images of both operational (as detected by the EMSA CleanSeaNet service) and accidental oil spills were analyzed to study under which conditions MODIS is able to detect oil features in the sea and which kind of information might be retrieved. The analyzed sample included MODIS images of the accidental oil spill occurred during the Lebanon crisis (summer 2006) and of that generated from the Deepwater Horizon platform in the Gulf of Mexico (April 2010); and MODIS images acquired in coincidence with validated operational oil spills discharged in European waters from 2007 to 2009 (EMSA 2009). Specific attention was focused to define MODIS oil spill detection constraints and which kind of information might be retrieved under the different observed conditions. The whole analysis was carried out making use of the SeaDAS image analysis package (http://oceancolor.gsfc.nasa.gov/seadas/).

Acquisition in sunglint

Images acquired in sunglint may allow, as with SAR, only oil spill localization, without any meaningful possibility to extrapolate other additional spectral information.

The sunlight reflected by the surface is so much greater than the sunlight reflected from below the surface, that the retrieval of information about in-water constituents is severely compromised. In addition, the observed contrast strictly and indissolubly depends on the sea surface state induced by oil.

An example of MODIS images acquired in sunglint conditions: Lebanon oil spill, 6th of August 2006.



Similar features are observed in the correspondent ENVISAT ASAR image

Acquisition in absence of sunglint contamination

Oil detection in absence of sunglint contamination is more difficult. The contrast between an oil feature and its surrounding region may be too weak to be detectable by high resolution low sensitive bands, and/or the oil spill may have an extension not large enough to be detected by low resolution high sensitive bands. The latter consideration holds particularly true for operational oil spills.

On the other side, detection in absence of sunglint might give the possibility to retrieve feature optical information: for observation and illumination zenith angles lower than 60° the contrast at the surface between clean and oil-polluted waters depends on their different optical properties rather than on the different surface state induced.

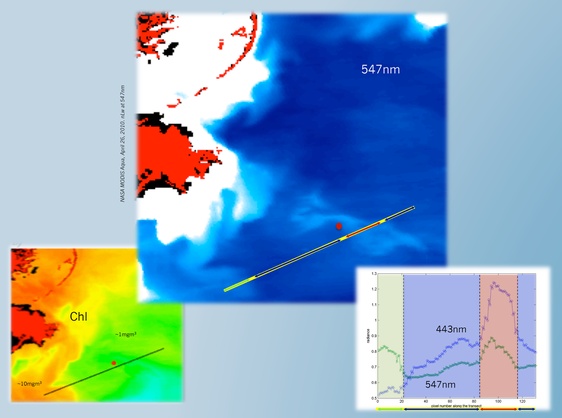
Careful atmospheric corrections must be performed: applying the SeaDAS atmospheric correction scheme in its default version (i.e. inferring aerosol properties on a pixel by pixel basis from the NIR bands), may lead to misinterpret sea surface features as atmospheric ones.

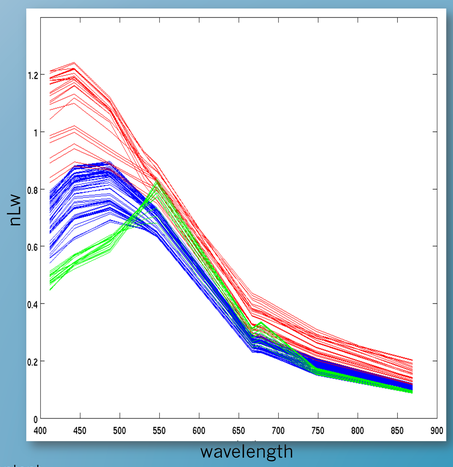
Test case study:

For the NASA MODIS Aqua image of the Deepwater Horizon oil spill (Gulf of Mexico) acquired on the 26th of April 2010 at 19:35 GMT in absence of sunglint (glint coefficient ~10^{-9}) : retrieved normalized water leaving radiance (nLw) spectra along a transect intercepting likely clean and likely oil-polluted seawaters.

Atmospheric properties (i.e., τ_a) in the region of the potential oil spill have been extrapolated from the area around.

Higher nLw spectra in the potentially oil-polluted region are compatible with the optical behavior of emulsified oil (Otremba&Piskozub 2003).





Clean water with high phytoplankton content
Likely clean water with moderate phytoplankton content
Most likely oil-polluted water

Conclusions

MODIS sensor was not conceived to monitor oil spill, nonetheless it shows cost-effective potentialities. Clearly, MODIS can detect oil features under the conditions that the region of the feature is not contaminated by clouds and that the oil feature extension is compatible with the sensor actual resolution. The first constraint may be particularly limiting for specific areas. The second constraint implies that too slanted observations must be generally discarded (the limit depending on the size of the oil spill and on the atmospheric turbidity) and that operational oil spills visibility is somehow limited. The mechanism behind MODIS surface features detection, as well as the type of information that can be retrieved, strictly depends on the illumination conditions. In presence of sunglint contamination MODIS can locate the oil spill on the same backscattering principle of radar observations and no additional spectral information can be retrieved. MODIS detection in absence of sunglint contamination however might allow extraction of oil feature spectral characteristics, which in turn may help in oil discrimination and classification. Careful atmospheric correction must be applied.

References: Bulgarelli and Djavidnia, “On the use of MODIS data to detect oil spills: the Lebanon case”, in *proc. of Oceans from Space” Venice 2010”*, EUR 24324 EN, (2010)
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