HICO Data User's Proposal

Study and monitoring of water quality and oil pollution of coastal areas through HICO images.

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Abstract/project summary
The aim of this study is to exploit the HICO sensor in water quality studies in particularly environmental sensitive marine and coastal areas, such as the Adriatic and Tyrrhenian sea, which host many of the most relevant commercial harbours and industrial districts of Italy and are at the same time characterized by worldwide famous naturalistic marine sites and wildlife reserves (Sanctuary of the Cetaceans). Major sources of water pollution mainly correspond to industrial and municipal discharges, runoff from agricultural land, mining operations, urban land and construction; moreover, since the the Mediterranean Sea is one of the most important routes for oil transportation between eastern and western Europe, oil slicks caused by oil tanker accidents represent a major source of pollution, together with the deliberate discharge of oil and residues and illegal activities. Through the use of the high signal-to-noise and high spectral resolution HICO data, combined with in-situ sampling and laboratory chemical analysis, we will provide for empirical and semi-empirical algorithms which will be used to elaborate raster maps of coastal and marine areas pollution distribution and change detection models, exploiting satellite sensor's ability to provide study area coverage repeated at regular intervals. The complete procedure for characterization and mapping of pollutants or water quality will be available for sea safeguarding and remediation purposes.

1. Statement of work/project description

The aim of this project is to develop and test a new procedure for rapid and cost-effective detection and assessment of water pollution and mapping of contaminated coastal waters. This goal appears particularly crucial for environmental control in those marine areas or shores having a particular naturalistic and touristic value, or being exposed to risk of accidental or even intentional contamination due to their vicinity to industrial or densely populated settlements, or crossed by a heavy ship traffic.

The study area corresponds the Tyrrhenian and the Adriatic seas, along whose shores are located many of the most relevant commercial harbour areas of Italy (e.g.: Venice, Ancona, Bari, Brindisi, Genoa, Leghorn, Civitavecchia, Naples), as well as many petroleum ports (e.g.: Sarroch-Cagliari, Olbia and Porto Torres in Sardinia) and densely inhabited areas and industrial districts (e.g.: Bagnoli in the Pozzuoli bay, Naples). At the same time, these marine basins are characterized by worldwide famous naturalistic sites, such as national and regional protected marine areas (e.g.: Venice Lagoon, Gulf of Portofino and Cinque Terre, the Tuscan Archipelago, the Maddalena Archipelago, Capri Island and Amalfi coast, Eolian Archipelago, ect.) and wildlife reserves (e.g.: Sanctuary of the Cetaceans, in the area comprised among northern Sardinia, Liguria and Tuscany coasts).

In this study, the HICO suitable data should be comprised between latitude = 4041570 m N and 5058686 m N and longitude = 532360 m E and 590696 m E (UTM).

In general the Mediterranean Sea One is one of the most important routes for oil transportation between East and West. Oil slicks caused by tanker accidents, deliberate discharge of oil and oily residues, associated with routine tanker operations (bilges residues, tank oil sediments) or with illegal activities represent a major source of hydrocarbon pollution. Several remote sensing techniques have been tested (Fingas and Brown, 1997) for oil spill detection, including passive (multispectral visible and infrared) radar (Synthetic Aperture Radar, SAR) methodologies (Brekke & Solberg, 2005), as well as ultraviolet (UV) and microwave sensors (MWR) (Fruhwirth et al., 1994; Balick et al., 1997). However, problems associated with each of these systems preclude their exclusive use during oil spills (McFarland et al., 1993).

A number of studies on oil spill observability by optical sensors in different areas of the world have been carried out (Voloshina & Sochnev, 1992; Grimaldi et al., 2008; Casciello et al., 2007). Anyway, only in recent times, the Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's TERRA and AQUA platforms (Hu et al. 2003) and Medium Resolution Imaging Spectrometer (MERIS) on board European Space Agency (ESA)'s ENVISAT platform gave proof of being very useful in the detection of medium and small oil spills, thanks to the improved spatial

resolution (250 m and 300 m respectively), thus overcoming the limitations of old generation sensors, characterized by a coarse spatial resolution (~ 1 km). Landsat TM/ETM+ was extensively used for retrieving several water quality variables, such ad chlorophyll, transparency, total phosphorous, turbidity and temperature (Akbar et al., 2010; Nelson et al., 2003; Vignolo et al., 2006). Significant results were also obtained by Wong et al. (2008) by using Terra/MODIS images in water quality modeling.

The applicability of the hyperspectral techniques in oil spill detection have been recently investigated (Sanchez et al., 2003; Salem et al., 2005, Wettle et al., 2009; Freeman 2003) and they generally proved to be more reliable in minimizing the limitations of conventional remote sensing techniques in detecting oil spills. Some recent studies exploited both airborne and spaceborne hyperspectral sensors also in the assessment of water quality, showing their significant potential: CASI (Shafique et al., 2003), CHRIS/Proba (Mannhaeim et al., 2004), CZCS, AVHRR (Huang et al., 2010) and Hyperion (Brando and Dekker, 2003) were used to map chlorophyll, suspended solids, total nitrogen, total phosphorus, Secchi disk transparency, light conditions, temperature and other physicochemical parameters. A review of the hyperspectral applications in water quality estimation is given in Govender et al. (2006). Possible outcomes of this promising methodology include the identification and mapping of environmentally sensitive sites (contaminated soil wetlands, shallow water, lagoons, sand beaches and shorelines), with high spatial and spectral resolution.

Given this state of the art, this research intends to exploit HICO high signal-to-noise data, in combination with other well-known and widely used multispectral/hyperspectral sensors in order to develop a new, reliable approach for rapid assessment and mapping of coastal water contamination. Peculiar attention will be paid to data fusion/cross validation of results and maps, aiming at increasing their reliability, and to resolving the still open issues of this research field, such as:

1) obtaining more reliable results thanks to the use of imaging spectrometry and signature matching technique, combined with conventional remote sensing techniques;
2) in oil spill monitoring: distinguishing between oil types (light/crude), determining the thickness of the slick, detecting minute concentrations of hydrocarbon (crude oil), predicting the evolution of the spill phenomenon by integrating change detection analysis with mathematical models; guaranteeing a near global coverage and change-detection products at regular intervals thanks to the employment of satellite data;
3) retrieval of suitable models and empirical/semi-empirical inversion algorithms for water quality monitoring in coastal areas through HICO, using principal components analysis (PCA) and regression techniques to examine the relationship between water quality parameters and spectral reflectance. The quantitative relationship between remotely sensed variables and water quality indicators can be potentially used to extrapolate point-based water quality measurements to large spatial extents for an improved water quality assessment;
4) development of raster maps of water physicochemical parameters;
5) validation and accuracy assessment of produced models and maps.

2. Biographical sketch and available facilities

Francesca Garfagnoli (PI) graduated with honours at the University of Firenze in 2002. In 2008 she obtained her PhD in structural geology from the University of Firenze. During this phase of her studies, she attended dedicated courses in some Universities of Northern Italy, such as Turin and Milan. She has been member of the editorial board of Ofioliti, an International Journal on Ophiolites and Modern Oceanic Lithosphere (http://www.edizioniets.com/ofioliti/), since 2007. Since 2008 she has been attending many courses on image processing and data treatment techniques and also personally organized a short course of imaging spectroscopy, open to students and

workers, held in Florence by Laurie Chisholm (University of Wollongong, Australia). Working as post-doc research assistant, she was involved in several national or international projects focusing on the application of hyperspectral and multispectral imagery for solving problems related to environmental risk, land management and hazard prevention, pollution, natural resources and conservation of cultural heritage, in collaboration with the UE, the Italian National Research Council, the Ministry of University and Research and the Regional Government of Tuscany, the most important of which are SKY-EYE and DIGISOIL. The SKY-EYE project aims at investigating the possibility of obtaining distribution maps of minerals harmful for human health and minerals that may indirectly indicate the evolution of geological systems, using hyperspectral sensors. In the past three years she participated to the EU FP7 project DIGISOIL, whose goal was to integrate and improve in situ and proximal measurement technologies to assess soil properties and soil degradation indicators and their exploitation in digital soil mapping. Within the University of Florence, the PI contributed to the project by employing HyperSIM-GA sensor from Selex Galileo, to realize detailed-scale digital maps of soil properties and elaborated an innovative procedure for quantitative cartography of clay mineral distribution from hyperspectral images. In 2011, she was also involved in a project of cooperation with the Sahrawi Arab Democratic Republic (SADR), which yielded very satisfying results in employing multispectral images for the identification of new unexploited mineral resources in Western Sahara, with the final aim of contributing to Saharawi people emancipation. Since 2009, she has been assistant lecturer of geology, geomorphology, physical geography and engineering geomorphology at the University of Florence, Department of Earth Sciences.

As a result of this research period, three main articles in international peer reviewed journals (two as main author), were published. The PI's outcomes in the remote sensing field were exposed in leading international conferences proceedings, several other papers being "submitted" to peer reviewed journals or "in progress" (five of them as main author) or divulgated in national and international congresses, such as the 32 IGC, Geoitalia 2005 and 2007, EGU 2009 and 2011, AGU 2010, the 6th and 7th EARSeL SIG Imaging Spectroscopy Workshops, ESA-ESRIN "Hyperspectral Workshop 2010", 2010 IEEE Gold Remote Sensing Conference, 2011COST Strategic Workshop on Safeguard of Cultural Heritage, 5th International Congress on CULTURAL HERITAGE 2011. In 2010 she was member of the scientific commission of the "4th Global Workshop on Digital Soil Mapping", held in Rome (http://2010.digitalsoilmapping.org/).

This research project will take advantage of the employment of a very high spatial and spectral resolution hyperspectral imager (either HyperSIM-GA by Selex Galileo), with more than 600 spectral bands and a spatial resolution of about 1.5 m, which will provide for an additional hyperspectral dataset for cross validation. The possibility to mount and use this instrument on board of the University of Florence FOLDER ultraligh aircraft (ULM) will guarantee independence in flight programming and research schedule decisions. The department of Earth Science (University of Florence) is also provided with an ADS FieldSpec Pro 3 spectrometer, operating in the 350-2500 nm range, with 2151 bands and a spectral resolution of 3-10 nm, provided with an indoor illuminating setting and contact probe for building of spectral libraries from the collected samples of water and other impacted materials. Outdoor employment contemporary to the airborne sensor flights will be used for ancillary calibration and result validation. Other facilities are represented by a FLIR thermal camera, to be possibly installed on the ULM as well, and by other hyperspectral (Hyperion)/multispectral images of the study area, to be purchased/downloaded for complementary

use or cross-validation. ATCOR software and other common image analysis tools will be also available, as well as a detailed dataset of the study area physicochemical parameters, based on a dedicatedly collected samples archive.

3. Output and deliverables

The proposed research will contribute to the HICO mission by testing the data on a new, environmentally vulnerable and extremely valuable test area. The results of this research will represent progresses in answering to some outstanding environmental concerns. The facilities provided by the Department of Earth Sciences of Florence, such as HyperSIM-GA, ASD FieldSpec and the ultralight aircraft, will guarantee the possibility of freely accessing a complete validation and ancillary dataset in every moment on the study area. Moreover, the HICO program will benefit from our specific approach, based on exploring the effectiveness of a multi-sensor technique and investigating the feasibility of data fusion and cross validation of results and maps.

In particular, the principal investigator and her collaborators will return to the HICO program the following outcomes:

° Spectral libraries of impacted water and other materials (e.g.: sand, etc.).

° General GIS geo-data-base for the test-sites.

° Pre-processing and correction procedures of spectra and images.

° Retrieval of calibration relations for quantitative predictions and spatialization of the inversion procedure. Pollutant change detection elaborations and development of marine simulated mathematical models.

° Validation for the study sites, accuracy/noise assessments for the sensor and evaluation of classification/inversion performance in relation to the specific target of the project.

° Production of classified maps of distribution/concentration of studied compounds and physicochemical parameters, for all the considered scenes within the test-site.

° Integration of hyperspectral and multispectral data and production of second-order thematic maps.

° Written reports explaining the complete methodology.

° Participation to national and international congresses; articles in scientific dedicated journals.

° Annual reporting of applications, outcomes and future perspectives to the HICO team meeting.

4. References

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