HICO Data User's Proposal

Using HICO data for Ionian coastal waters (Southern Italy) investigation from space: CAL/VAL and model assessment activities

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1. Project summary

Basilicata Region (Southern Italy) has recently co-funded, in the framework of its ERDF (European Regional Development Fund) Operational Program 2007-2013, a project for European Transnational Cooperation named IOSMOS (IOnian Sea water quality MOnitoring by Satellite data). IOSMOS main objective is the development of advanced satellite products and techniques for the study and monitoring of Ionian sea water quality along Basilicata coasts. In particular, IOSMOS intends to investigate water bio-optical properties, such as chlorophyll-A (Chl.a) and Coloured Dissolved Organic Material (CDOM) concentration, as well as those parameters affecting water turbidity (e.g. suspended sediment material - SSM), by using MODIS, SeaWifs, VIIRS and MERIS time series. This also in view of the advent of the Ocean and Land Colour Instrument – OLCI, an heritage of MERIS, on board of the upcoming ESA Sentinel 3 mission that has the capability to acquire data at medium spectral and spatial resolution (300m).
HICO data, thanks to their high spectral/spatial resolution and their high dynamic range, will provide more accurate information about the above mentioned products. HICO measurements, integrated with standard and original satellite products, as well as with in situ/airborne observations (ground-based sampling will be undertaken concurrently with HICO imagery acquisition), will help in increasing knowledge about phenomena and dynamics acting in the investigated areas, as well as in better calibrating satellite outputs at local scale. In addition, HICO data will be used as input within a model (already developed by the group for lagoon turbid waters) to map water quality characteristics in optically complex waters such as the investigated one, hardly affected by the presence of severe torrential river plumes.
Finally, HICO data will be also applied to:

- evaluate the potential of the future hyperspectral spaceborne missions that should be available on 2015/2016 (e.g., EnMap, HYSUI, PRISMA etc);
- analyse the impact of the high spatial resolution data from Sentinel-2 for monitoring the Ionian Sea coastlines with respect to surveys based on hyperspectral imagery;
- locate, in combination with the high temporal sampling of the MODIS images, areas showing a high degradation level and/or with a high potential risk;
- analyse the spatial and spectral variability of the Basilicata coastal waters.

1.1 Statement of work/project description

The main aim of IOSMOS project is the development of advanced satellite products and techniques for the study and monitoring of the Ionian Sea water quality in terms of optical properties along Basilicata coast. The investigated area is located in the western side of the Gulf of Taranto in the south of Italy. The investigated area plays a crucial role for the Basilicata region, being an important touristic destination well recognized both at national and international level. The rate of tourist's presence is increased of about 57% from 2002 to 2007, with about 1,2 million of tourists per year. The area, which is really relevant also from an environmental point of view, is exposed to environmental degradation, both for natural (typical of transitional zones) and anthropogenic causes. This is why it is crucial developing and implementing a monitoring system able to guarantee a consistent control of the coastal-marine habitat and to timely identify any signs of deterioration.
IOSMOS project would like to support managing authorities of such an area both at the regional and the local level in monitoring the sea water quality thus providing to them low-cost but advanced and reliable satellite products/tools.
Specific goals of the project are: i) identification, tuning and assessment of advanced satellite products useful for the estimation of parameters relevant for the optical characterization of the coastal waters quality and for the study of sediment transport mechanisms into the sea; ii) analysis of long-term signal trends (up to 15 years) to identify the most exposed areas, those at highest degradation and/or greatest potential risk. For this purpose airborne and in situ calibration campaigns will be carried out. In detail, within the project the optical parameters taken into consideration will be the chlorophyll-A (Chl-a) concentration, the Coloured Dissolved Organic

Material (CDOM) concentration and parameters useful for assessing the degree of turbidity of the water, i.e. the Sediment Suspended Material (SSM) or the attenuation coefficient widespread (Kd).

1.2 Background

The NASA provides daily global standard ocean colour products generated from MODIS (Moderate Resolution Imaging Spectroradiometer) and VIIRS (Visible Infrared Imaging Radiometer Suite) acquisitions. In addition, the entire historic archive is available for both these two sensors as well as for SeaWifs (Sea-viewing Wide Field-of-view Sensor), operating till the end of 2010. Those outputs are distributed at spatial resolutions up to 1 km, and they provide a good level of reliability at the global scale, but they may not furnish an adequate sensitivity at the local scale, especially for case 2 waters. These waters are optically complex and more difficult to analyze despite oceanic or fresh waters ("Case 1" waters). In fact, while in Case 1 water all the optical properties can be modelled as a function of the Chl-a concentration using single-variable models, in Case 2 waters such an approach is no more satisfactory as there are other relevant constituents that may vary independently to each other and to phytoplankton, such as CDOM and inorganic particles in suspension (IOCCG 2000, Sathyendranath and Morel, 1983; Morel & Louis Prieur 1977). In addition, the performance of retrieval algorithms are strongly influenced by atmospheric corrections (IOCCG 2000, Ruddick et al., 2000), and case 2 waters could be affected by atmospheric 'over-corrections' in the visible part of the spectrum. Finally, in coastal region the water depth is often less than 3 m, so that in these circumstances the algorithms have to take into account for bottom effects. It is generally recognised that a single remote-sensing algorithm may not be applicable to all Case 2 waters, but they are typically applicable at the local or the regional scale, tailored for a specific area with its specific peculiarity as demonstrated in different works providing information about Chl-a, CDOM as well as suspended sediment material using multispectral satellite measurements in the VNIR spectral range (Jamet et al., 2011; Komick et al., 2009; Volpe et al., 2011; Kuchinke et al., 2009a,b). Coastal areas have strong spatial and spectral variability so the use of hyperspectral satellite data with high spatial and spectral resolution such as HICO can considerably improve the investigation of their 'characteristics'. In Davis et al. (2007) experiments have been conducted with data from Hyperion and airborne hyperspectral imagers to evaluate these potentials. Works about the use of hyperspectral data to develop local models were conducted on several test sites to estimate optical parameters on optically complex water bodies (Craig et al. (2012), Santini et al. (2010) and Brando et al. (2009)). Gitelson et al. (2011) presents the results of Chl-a concentration estimation using the Red and NIR spectral bands of HICO in productive turbid waters of the Azov Sea, Russia.

1.3 Proposed use of HICO data

HICO provides high spectral and spatial resolutions data, which may well complement the coarse resolution datasets (i.e. MODIS, MERIS, VIIRS, SeaWifs) which have been using within the IOSMOS project,. In addition, HICO may guarantee data with high SNR and high dynamic range, useful to appreciate both small variations and high values of the signal. Thanks to these characteristics, HICO sensor could significantly help in better understanding phenomena occurring in this coastal environment. Outcomes expected from the use of such added values records, will be also useful to assess the impact of the next Sentinel-2 high spatial resolution data for monitoring the Ionian Sea coastlines with respect to the surveys based on hyperspectral imagery.

In the framework of the project we would like to use HICO data to tune, at the local scale, the standard NASA algorithms so to calibrate/validate multispectral products on the area of interest. Finally HICO data will be used within a physically based model for the study of the optical properties of the coastal turbid waters of the investigated areas (Santini et al., 2010). Such a model has been already applied to map water quality characteristics in optically complex waters such as lagoon turbid waters. The method includes a non linear analytical relationship between water optical properties and Rrs (Remote sensing reflectance). An inversion method, based on a two step optimization procedure, was also developed to get water quality parameters starting from remotely sensed hyperspectral data.

Likewise we would like to contribute to calibration/validation of HICO products on the investigated area. For these purposes, we are going to carry out field campaigns using airborne/in situ spectral measurements, and traditional sampling for the investigated parameters, in conjunction with the HICO acquisition, where possible.

At the end we will compare historical series available on the selected area to assess how much parameters objective of this study are changed over the time. In addition, this analysis will also allow for the identification of areas with a remarkable criticality.

1.4 Requested HICO products and Study site

On the areas shown below we require HICO Level 1B data products (calibrated radiances with geolocation) and Level 2B standard data products. We ask if you can push the data to the FTP site.
Below the center scenes of the two test areas are indicated.

Test site 1: center point 1 (40.127306° N; 16.816056°E)
Test site 2: center point 2 (40.365868°N; 17.004135° E)

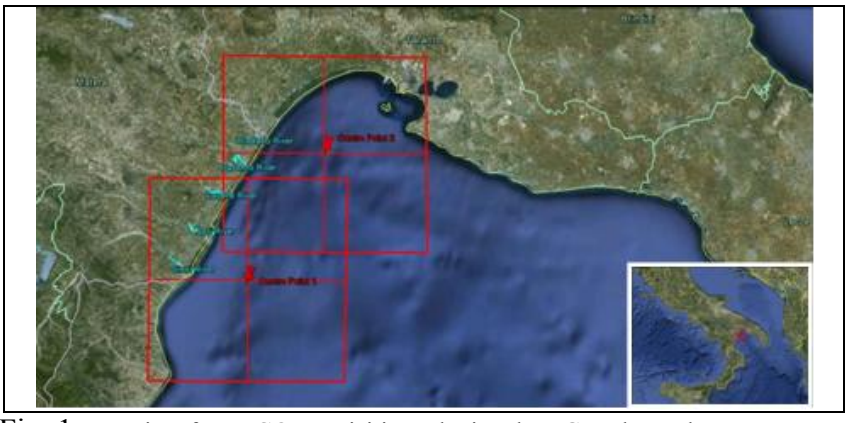

Fig. 1 Test sites for HICO acquisitions depicted on Google earth Map.

2. Biographical sketch

Teodosio Lacava: He graduated in Geological Sciences in 1999 at the University of Basilicata (Potenza - Italy). He received the Ph.D degree in Methods and Technologies for Environmental Monitoring from University of Basilicata in 2004. Since 2005 he is a researcher at the Institute of IMAA CNR (Potenza - Italy). His main interests are in the field of satellite data analysis for environmental research, especially regarding the development and assessment of advanced satellite techniques for natural hazards investigation. In particular his work is based on the analysis of high temporal resolution satellite data, acquired both in the optical and microwave range of electromagnetic spectrum. He has been co-investigator of several EU, ASI and CNR projects. He was PI of the ESA SMOS CAT-1 project "Assessment of EO-based soil wetness variation maps for Geohazards monitoring and mitigation". He is PI of IOSMOS (IOnian Sea Water quality MOnitoring by satellite data) project co-funded by OP ERDF Basilicata 2007-2013. He is author of several peer-reviewed scientific journal articles.

Federico Santini: He received his degree in Physics at the University of Rome "La Sapienza" in May 1998 and his PhD in Environmental Engineering at the University of Basilicata (PZ - Italy) in 2007. He has been working for CNR since 2003. At present he is a researcher at the CNR IMAA (Institute of Methodologies for Environmental Analysis). His present research activity concern the: a) development of physical models for remote sensing applications; b) development of advanced inversion techniques for the retrieve of physical parameters from remotely sensed data; c) implementation and development of algorithms for atmospheric corrections of remotely sensed data; d) algorithms development for imaging spectroscopy in the VNIR and TIR ranges. He published on referred international journals concerning the physical modeling of the radiative transfer on water and atmosphere and other remote sensing environmental applications.

Stefano Pignatti: He received the Laurea degree in geology at the University of Rome 'La Sapienza' in 1988. He is senior researcher at IMAA-CNR where he leads the airborne geophysical remote sensing research group

that is also managing hyperspectral sensors covering from the VSWIR to the LWIR spectral regions. His main scientific interest is focused on the use of imaging spectroscopy for environmental applications. At present he is Project coordinator of the 4 years research contract "Algorithms and products development for agriculture and land monitoring applications in support of the mission PRISMA Hyperspectral mission" supported by ASI within the scientific activities related to the new hyperspectral Italian mission PRISMA. He has authored more than 50 scientific papers published on international journals.

Nicola Pergola: He graduated in physics in 1993. Presently he is a research scientist at IMAA-CNR, leading the IMAA Satellite Remote Sensing Laboratory – Geohazards Unit. His main research interests are in the field of development of advanced satellite data analysis and original techniques, especially regarding high temporal resolution sensors, like NOAA-AVHRR, EOS-MODIS and MSG-SEVIRI, for environmental research, mainly focused on natural/environmental hazards investigation and on security related applications. He was scientific coordinator of national projects (funded by CNR, ASI, INGV, etc.) and co-investigator in several EU and international (e.g. ESA, NATO, INTAS) Projects. He was recently involved in the EU-FP6 GMOSS and GRIDCC projects. Presently, he is involved in EU-FP7 GMES projects DORIS_Net, G-MOSAIC projects and in PRE-EARTHQUAKES project where he is part of the coordinating team. He was an active member of the "core team" Geohazards within the ESA-UNESCO IGOS initiative. He is adjunct professor at University of Basilicata since 2004. He is author of more than 50 papers on ISI journal and more than 150 publications and proceedings with peer reviewing and international distribution.

Simone Pascucci: He received a degree in Environmental Sciences in 2009 and he is graduating in Master of Science in
Conservation of the marine environment at the University La Tuscia of Viterbo. Remote sensing expert, from 2002 he worked with the CNR, at the CNR-IMAA since 2006, and the research has been focused on different aspects related to hyperspectral remote sensing applications for environmental, agronomic and urban environment. He has participated in several CAL/VAL campaigns conducted by the IMAA, both nationally and internationally. He has published several articles in referred international journals concerning the applications of airborne (MIVIS and CASI) and satellite (Hyperion, CHRIS) imaging spectroscopy. At present he is WP leader in the 4 years research contract "SAP4PRISMA" supported by ASI within the scientific activities related to the Italian PRISMA mission.

Angelo Palombo: received the M.Sc. degree in physics from the University of Rome, "La Sapienza," Rome, Italy, in 2002. He is currently working for the CNR IMAA, Italy. His research interests focus on (a) the development of techniques for noise reduction and the radiometric and geometric correction of hyperspectral images, (b) development of imaging spectroscopy techniques and data processing for environmental analysis, and (c) the validation of imaging spectroscopy data by means of in-field measurements. At present he is task leader in the 4 years research contract "SAP4PRISMA" supported by ASI within the scientific activities related to the Italian PRISMA mission. He published several articles on national and international referred journals.

Maria Girolamo Daraio: She received her degree in Environmental and territorial engineering in November 2005 , and her PhD in Industrial and Innovation Engineering in February 2009, both at the University of Basilicata (Potenza – Italy). From 2007 to 2011, she was a research fellow at the ASI – CGS (Italia Space Agency- Space Geodesy Center). Her research has focused on remote sensing applications to monitor coastal sea water. In detail the activity concerned the identification of discharges into the sea by SAR images (ERS and CosmoSkymed). Areas investigated were the Apulia Adriatic coast and the Ionian coast of Basilicata, in the southern of Italy. This work was presented in international conferences. At present she is a research fellow at the CNR IMAA. Her present research activity concerns the analysis of time series of satellite data for the study and monitoring of environmental parameters of interest and identification of space-time anomalies.

Emanuele Ciancia: He was born in Potenza, Italy, in 1984. He graduated in Environmental Engineering in 2011 at the University of Basilicata (Potenza - Italy). Since 2012 he collaborates with the IMAA-CNR (Institute of Methodologies for Environmental Analysis – National research Council) of Tito Scalo (Potenza - Italy) in the framework of IOSMOS (IOnian Sea Water quality MOnitoring by satellite data) Project activities. He is

attending the PhD in Environmental Engineering at the University of Basilicata, working on the development of advanced satellite techniques for coastal marine water quality monitoring, which actually is his main research activity. He is author of few peer-reviewed scientific journal articles.

2.1 Available facilities

- Direct readout receiving, archiving and processing polar satellite system
- Infrastructure to receive, store and process satellite data (such as X&L band, multi-mission antennas, EUMETCAST system, archives made by NAS&SAN technology). They are located in Potenza (Italy), Institute of Methodologies for Environmental Analysis and at University of Basilicata.
- Image processing software us IDL/ENVI e PCI/Geomatics.

A series of instruments for radiometric measurements listed below.

- Portable spectrometers: Ocean Optics USB2000 Fiber Optic Spectrometer (0.3-1.0 μm), ASD FieldSpec Pro (0.4-2.5 μm)
- Hyspex-VNIR-SWIR hyperspectral cameras (wavelength ranges 0.4-1.0 μm and 1.3-2.5 μm)

We are agreeing with several CNR Institutions the organization and planning of in-field measurements and laboratory analysis about the above-mentioned optical parameters. The first field campaign is scheduled for March-April 2013. We also requested airborne acquisitions of the investigated area by DAEDALUS Airborne Thematic Mapper (ATM-2), a sensor with GSD of about 70 cm to a minimum height of 600m and 16 bands in wavelength range 0.43-12.5 μm.

3. Output and deliverables

We would like to use the HICO products to carry a tuning of free products available at a larger scale, about waters optical characteristics on the investigated area. More in detail, we would like to

i) Tune at the local scale the standard NASA algorithms about chlorophyll-a concentration, CDOM and parameters related to the water clarity by SeaWifs, MODIS and VIIRS data;
ii) Produce Chl-a and turbidity periodic maps, based on HICO acquisitions;
iii) Identify critical areas for the above-mentioned products.

Results will be available and presented at the annual HICO team meeting.

4. References

Brando, V.E., J. M. Anstee, M. Wettle, A. G. Dekker, S. R. Phinn, and C. Roelfsema, "A physics based retrieval and quality assessment of bathymetry from suboptimal hyperspectral data", Remote Sensing of Environment 113: 755–770 (2009).

Craig, S. E., C. T. Jones, W. K. W. Li, G. Lazin, E. H. C. Caverhill, and J.J. Cullen, "Deriving optical metrics of coastal phytoplankton biomass from ocean colour", Remote Sensing of Environment 119: 72–83 (2012).

Davis, C. O., M. Kavanaugh, R. Letelier, W. P. Bissett, and D. Kohler, "Spatial and Spectral Resolution Considerations for Imaging Coastal Waters", Proc. of SPIE - Coastal Ocean Remote Sensing 6680 (2007).

Gitelson, A. A., B.-C. Gao, R.-R. Li, S. Berdnikov, and V. Saprygin, "Estimation of chlorophyll-a concentration in productive turbid waters using a Hyperspectral Imager for the Coastal Ocean-the Azov Sea case study". Environ. Res. Lett. 6(024023): 6pp (2011).

IOCCG (2000). Remote Sensing of Ocean Color in Coastal, and Other Optically-Complex, Waters. Sathyendranath, S.(ed.), Reports of the International Ocean-Colour Coordinating Group, No. 3, IOCCG, Dartmouth, Canada.

Morel, A. and L. Prieur, "Analysis of variations in ocean color", Limnology and oceanography 22(4): 709-722 (1977).

Ruddick, K. G., F. Ovidio, and M. Rijkeboer, "Atmospheric correction of SeaWiFS imagery for turbid coastal and inland waters", Appl. Opt. 39(6): 897-912 (2000).