HICO Data User's Proposal

Using HICO data for the preparation of the incoming Italian satellite hyperspectral mission PRISMA

Principal Investigator
Dr. Maria Adamo
Institute of Intelligent Systems for Automation (ISSIA)
Italian National Research Council (CNR)
Via G. Amendola, 122/D-I - 70126 Bari
Phone +39 080 5929437
FAX +39 080 5929460
e-mail adamo@ba.issia.cnr.it

Co Investigators:

- Luigi Alberotanza, Institute for Marine Science - Italian National Research Council (ISMAR–CNR), alberotanza@ve.ismar.cnr.it
- Federica Braga, ISMAR–CNR, braga@ve.ismar.cnr.it
- Mariano Bresciani, Institute for Electromagnetic Sensing of the Environment - Italian National Research Council (IREA–CNR), bresciani.m@irea.cnr.it
- Giacomo De Carolis, IREA–CNR, decarolis.g@irea.cnr.it
- Claudia Giardino, IREA–CNR, giardino.c@irea.cnr.it
- Erica Matta, IREA–CNR, matta.e@irea.cnr.it
- Guido Pasquariello, Institute of Intelligent Systems for Automation - Italian National Research Council (ISSIA–CNR), pasquariello@ba.issia.cnr.it

Using HICO data for the preparation of the incoming Italian satellite hyperspectral mission PRISMA

Abstract

The Italian Space Agency (ASI) is funding the design, development and deployment of the spaceborne PRISMA (Precursor Hyperspectral of the Applicative Mission) mission.
The chief objective of PRISMA mission is to develop innovative applications aimed at monitoring the Earth surface environment based on high resolution hyper-spectral imagery. Indeed, the PRISMA image sensor is designed to cover the em spectrum from 400 nm to 2500 nm with an average spectral resolution of 10 nm and to image the Earth surface over a swath width of 30 km with a spatial resolution of 30 m × 30 m (5 m for the panchromatic band) (Galeazzi et al., 2009).
Among the application fields, it is expected that PRISMA will have prominent capability to monitor the quality of inland and coastal zones with particular concern to the Mediterranean Sea. To accomplish the task, ASI is also funding the research project "Clam-Phym: Coasts and Lake Assessment and Monitoring by PRISMA HYperspectral Mission" with the objective to assess the best imaging performances and develop specific techniques that exploit hyperspectral data for coastal waters and lakes monitoring.
The present proposal is intended to exploit HICO hyperspectral imagery to test and develop algorithms for the retrieval of water quality indicators. The HICO images will be collected during the oceanographic campaign to be carried out with the oceanographic vessel Urania of the Italian National Research Council (CNR).

1. Statement of work/project description

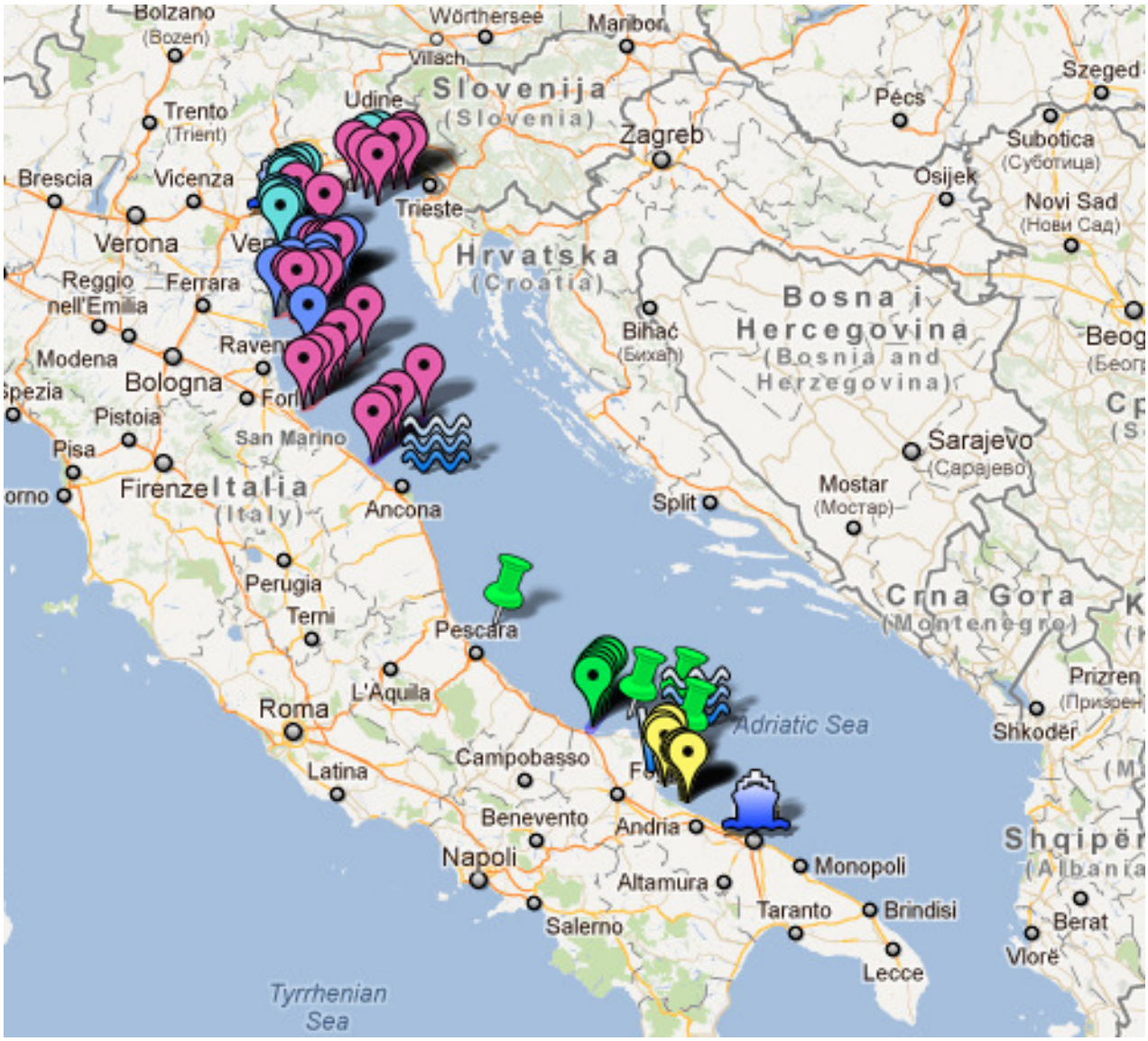
PRISMA is the Italian hyperspectral spaceborne sensor scheduled for launch in 2013. It will be placed in a sun synchronous orbit with a repeat cycle of 29 days. PRISMA will acquire in the 400 – 2500 nm spectral range of the em. spectrum at an average spectral interval of 10 nm (>200) (Galeazzi et al., 2009). Images will cover areas 30 km × 30 km wide at a spatial resolution of 30 m. PRISMA will be also able to acquire with a panchromatic band at 5 m of spatial resolution.
The main objective of this study is to investigate the use of satellite hyperspectral sensors for the retrieval of water quality parameters in coastal areas.
Water quality is an important indicator of the health of an environmental system. Remote sensing offers the capability to provide the spatial distribution of water constituents over large spatial area at temporal rates and relatively low costs. Spatial distributions provide deeper insight into many of the hydrologic and biological processes that are directly affected by the concentrations of water constituents. In contrast, water quality affects the spectral features of the water leaving radiance.
Since 1978 several spaceborne sensors have been launched with the aim to measure water quality (CZCS, SeaWIFS, MODIS, MERIS) (Moore et al., 1999). Many algorithms (empirical and analytical approaches) have been developed and used for the remote estimation of water quality for clear (case I) waters (Morel, 1988) where phytoplankton has been recognized as the optically dominant substance.
Lakes and coastal areas are often characterized by turbid (case 2) waters whose optical properties may be almost independent of the phytoplankton concentration but heavily dependent on other optically active substances such as the suspended inorganic matter and the colored dissolved organic matter (CDOM). Moreover, blooms of cyanobacteria may often occur.
Due to the complexity of case 2 waters composition, it is a challenging task to distinguish among the several different optical signatures and separate them from the remotely detected signal. In addition, removal of atmospheric contributions to the detected signal is somewhat a more difficult task for case 2 than case 1 water imaging (Odermatt et al, 2012). Experimental results show that for

case 2 waters a finer spectral resolution such as that of a hyperspectral sensor could be useful to describe case 2 waters which are characterized by a high degree of variability of the optical components (Gitelson et al., 2011, Santini et al., 2010).
Morel and Gordon (1980) distinguished among empirical (purely statistical), semi-empirical and analytical approaches for the analysis of remote sensing data regarding the estimation of water constituents. Hyperspectral data allow the exploitation of semi-empirical methods based on the knowledge of the specific absorption characteristics of water constituents in connection with regression approaches (Gitelson et al., 2011, Gitelson, 1992); in addition, analytical approaches, which include radiative transfer calculations based on backscattering and absorption characteristics of the constituents, can be adopted (Santini et al., 2010). The latter requires detailed knowledge of the inherent optical properties of the water body to be implemented into the model.
HICO hyperspectral data offer the unique opportunity to test such algorithms, also considering similar specifications in PRISMA and HICO spectral capabilities.
Results will be validated with a comparison with an historical dataset of in situ measurements in the Adriatric Sea and a future dataset which will be collected during the oceanographic campaign to be carried out on board the CNR vessel "Urania" scheduled from 3rd to 17th May 2012 in coastal zone of the Adriatic Sea. During the field campaign the following water parameters will be collected:

1) Chl-a concentration, SPM, SPIM, SPOM, yellow substance, phytoplankton, TSM;
2) Secchi Disk and bathymetry;
3) In vivo phycocyanin fluorescence measurements for monitoring of cyanobacteria;
4) Attenuation coefficient Kd for different wavelengths and depths;
5) Particulate backscattering coefficient;
6) Radiometric measurements (up-welling radiance and down-welling irradiance in the water column and at sea level).

A number of coastal test sites have been selected on the base of the expected water quality state, different typology (presence of river plumes, phytoplankton plumes, cyanobacteria blooms), availability of archive dataset, accessibility of the site. In Figure 1, a sketch of the measurements stations scheduled for the campaign is shown, belonging to two main areas of interest:

1) <u>Adriatic – North</u>
   Latitude: [43.50° N – 45.75° N]
   Longitude: [12.00° E – 14.00° E]
2) <u>Adriatic – South</u>
   Latitude: [41.25° N – 42.25° N]
   Longitude: [15.00° E – 16.50° E]



2. Biographical sketch and available facilities

a. Biographical sketch

Maria Adamo has a PhD in Physics. Her research activity is focused on satellite oceanography. In particular she has been working on: 1) the combined use of Synthetic Aperture Radar and VIS/NIR imagery under sun glint condition for the detection, tracking and characterization of a marine oil spill, 2) the wind field retrieval from SAR images over open ocean and coastal areas.

M. Bresciani is a naturalistic scientist specialized in the study of water quality and aquatic vegetation environments with traditional methodologies and remote sensing techniques. He has a long experience in field campaigns for chemical, biological and radiometric data acquisition. Currently, his research activity is focused on ecological characterization of cyanobacteria in inland waters. He is also collaborating with local authorities for the management of reed habitats and for supporting the monitoring of inland water bodies.

Federica Braga (CNR-ISMAR) is carrying out researches on processing and analysis of multi-hyperspectral data, in order to understand coastal processes and monitor water quality of coastal areas, also for supporting environmental emergencies. She has participated to field campaigns, using optical instrumentations, for the characterization of terrestrial environment, for the identification of bottom substrate and submerged vegetation, for the assessment of apparent and inherent optical parameters of water column in lake, coastal and transitional areas.

Dr Giacomo De Carolis (b. 1963) is a senior researcher at IREA-CNR, Milan. He has held posts in the Physics Department of the University of Bari, and at the CNR laboratories in Bari and Matera, before moving to Milan. His research has focused on the retrieval of geophysical parameters detected by spaceborne sensors operating in the microwave (SAR) and optical region of the electromagnetic spectrum with special concern for the marine and polar environment. In particular, the following topics have been investigated to develop image inversion techniques and procedures:
- SAR radiometric and polarimetric calibration;
- SAR image spectra inversion techniques for two-dimensional ocean wave spectra retrieval;
- SAR wind field estimation over open ocean and enclosed basins;
- Estimation of frazil and pancake sea ice thickness from SAR imagery, especially the modeling of surface wave attenuation and dispersion in sea ice;
- Integration of SAR and visible-near infrared imaging for marine oil spill detection.

C. Giardino has a PhD in Remote Sensing (Polytechnic of Milano). She is specialized on quantitative aspects of remote sensing, including radiative transfer model and biophysical parameters assessment. Her main interests include: retrieval of water quality parameters from remote sensing, Case-2 water systems, harmful algal blooms, submerged vegetation recognition, medium/low resolution satellite data and hyperspectral signal processing. Visiting Scientist at CSIRO Land and Water (Caneberra, Australia) in the years 2004 and 2006. Member of the working group on “Inland and Near-Coastal Water Quality” of GEO and of the working group on “Harmful Algal Blooms and Ocean Colour” of IOCCG.

Guido Pasquariello received the Laurea degree (cum laude) in physics from the University of Bari, Italy, in 1975. In 1976 he joined the CSATA, where he worked in the field of statistical data analysis. From 1977 to 1978 he was scientific fellow of the Commission of European Communities at the Central Bureau for Nuclear Measurements (CBNM), Geel, Belgium. From 1978 to 1980 he joined the National Laboratory of Frascati, Rome, of Italian Institute of Nuclear Physics (INFN). From 1980 to 1985 he joined the TECNOPOLIS Science Park of Bari, where he was project leader of projects related to the classification of satellite remote sensing images. Since 1985 he has worked as Senior Scientist at the Institute for Signal and Image Processing of the Italian National Research Council (CNR)). His research interests include application of statistical to digital image processing in the field of computer vision, remote sensing and medical data.

List of selected publications

1) Bresciani M., Bolpagni R., Braga F., Oggioni A., Giardino C., 2012, Retrospective assessment of macrophytic communities in southern Lake Garda (Italy) from in situ and MIVIS (Multispectral Infrared and Visible Imaging Spectrometer) data, Journal of Limnology, vol. 71(1), 180-190.
2) Giardino C., Candiani G., Bresciani M., Lee Z., Gagliano S., Pepe M., 2011, BOMBER:A tool for estimatine water quality and bottom properties from remote sensing images. Computers & Geosciences (2011), doi:10.1016/j.cageo.2011.11.022, in press.

3) Bresciani M., Giardino C., Boschetti L., 2011, Multi-temporal assessment of bio-physical parameters in lakes Garda and Trasimeno from MODIS and MERIS. Italian Journal of Remote Sensing, 43(3): 49-62.
4) Bresciani M., Giardino C., Bartoli M., Tavernini S., Bolpagni R., Nizzoli D., 2011, Recognising harmful algal bloom based on remote sensing reflectance band ratio, Journal of Applied Remote Sensing, 053556-1 Vol. 5, 2011.
5) Bresciani M., Stroppiana D., Odermatt D., Morabito G., Giardino C., 2011, Assessing remotely sensed chlorophyll-a for the implementation of the Water Framework Directive in European perialpine lakes, Science of the Total Environment, 409, 3083-3091.
6) Giardino C., Bresciani M., Pilkaityte R., Bartoli M., Razinkovas A., 2010, In situ measurements and satellite remote sensing of case 2 waters: first results from the Curonian Lagoon, Oceanologia, Vol. 52, N. 2, pp. 197-210.
7) Giardino C., Bresciani M., Villa P., Martinelli A., 2010, Application of remote sensing in water resource management: the case study of Lake Trasimeno, Italy. Water Resource Management, Vol. 24, N. 14, pp. 3885-3899, DOI: 10.1007/s11269-010-9639-3.
8) Giardino C., Oggioni A., Bresciani M., Yan H., 2010, Remote sensing of suspended particulate matter in Himalayan lakes: a case-study of alpine lakes in the Mount Everest region. Mountain Research and Development, Vol. 30; N. 2, pp. 157-168.
9) Odermatt D., Giardino C, Heege T., 2010, Chlorophyll retrieval with MERIS Case-2-Regional in perialpine lakes, Remote Sensing of Environment, Vol. 114, N. 3, 607-617.
10) Guanter L., Ruiz-Verdù A., Odermatt D., Giardino C., Simis S., Estellès V., Heege T., Domìnguez-Gòmez J. A., Moreno J., 2010, Atmospheric correction of ENVISAT/MERIS data over inland waters: Validation for European lakes, Remote Sensing of Environment, Vol. 114, N. 3, 467-480.
11) Bresciani M., Stroppiana D., Montagna M., Fila G., Giardino C., 2009, Monitoring reed vegetation in environmentally sensitive areas in Italy, Italian Journal of Remote Sensing (Rivista Italiana di Telerilevamento), 41(2), pp. 125-137.
12) Bresciani M., Giardino C., Longhi D., Pinardi M., Bartoli M., Vascellari M., 2009, Imaging spectrometry of productive inland waters. Application to the lakes of Mantua, Italian Journal of Remote Sensing (Rivista Italiana di Telerilevamento), 41(2), pp. 147-156.
13) Giardino C., Brando V. E., Dekker A. G., Strömbeck N., Candiani G., 2007, Assessment of water quality in Lake Garda (Italy) using Hyperion, Remote Sensing of Environment, Vol. 109, N. 2, 183-195.
14) Giardino C., Bartoli M., Candiani G., Bresciani M., Pellegrini L., 2007, Recent changes in macrophyte colonisation patterns: an imaging spectrometry-based evaluation of southern Lake Garda (northern Italy), Journal of Applied Remote Sensing (SPIE), Vol. 1, 011509.
15) F. Braga, L. Alberotanza, A. Cucco, M. Ferla, A. Rusconi, M. Sclavo, G. Umgiesser, L. Zaggia e A. Zuliani, 2005, Morphology of the Veneto coast, Northern Adriatic Sea, Italy. Geo-Eco-Marina 9/10, pp.77-81.
16) S. Salviato, J. Barbaro, F. Braga, L. Alberotanza, 2005. Analisi spettrale delle fanerogame marine in laguna di Venezia, Rivista Italiana di Telerilevamento, n.33/34, p.91-107.
17) L. Alberotanza, F. Braga, R.M. Cavalli, S. Pignatti and F. Santini. Hyperspectral tecniques for water quality monitoring: Application to the “Sacca di Goro” — Italy. Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS), 2010, 2nd Workshop on Digital Object Identifier: 10.1109/WHISPERS.2010.5594927 Pp. 1 - 4
18) F. Santini, L. Alberotanza, F. Braga, R.M. Cavalli, S. Pignatti Hyperspectral applications for the improvement of water quality assessment and monitoring in coastal areas. Proceedings of Hyperspectral Workshop 2010, ESA-ESRIN, Frascati, Italy, 17- 19 March 2010, SP-683 May 2010.

19) M. Adamo, G. De Carolis, V. De Pasquale, G. Pasquariello, “Detection and tracking of oil slicks on sun-glittered visible and near infrared satellite imagery”, International Journal of Remote Sensing, 30(24), pp. 6403 – 6427, 2009. DOI: 10.1080/01431160902865772.
20) M. Adamo, G. De Carolis, S. Morelli, F. Parmigiani, “Synergic use of SAR imagery and high-resolution atmospheric model to estimate marine wind fields: an application in presence of an atmospheric gravity wave episode”, Italian Journal of Remote Sensing, 2006, 35: 147-160.
21) M. Adamo, G. De Carolis, G. Pasquariello, “Assessing wind fields by means of remote sensing techniques on coastal zones”, Proc. of the 2nd Int. Conf. on the Application of Physical modelling to Port and Coastlab Protection, Coastlab08, Bari, 2-5 July 2008, ISBN: 978-90-78046-07-3, 2009.
22) R. Matarrese, V. De Pasquale, L. Guerriero, A. Morea, G. Pasquariello, G. Umgiesser, I. Scroccaro, G. Alabiso "Comparison between remote-sensed data and in situ measurements in coastal waters: the Taranto sea case", Chemistry and Ecology, vol. 20, No. 3, pp. 225 - 237, June 2004.
23) M. Veil, G. Ceriola, P. Manunta,V. De Pasquale, R. Matarrese, G. Pasquariello,” Marcoast Adriatic Service MERIS Products Validation”, Proceedings of the Envisat Symposium 2007 Montreux, Switzerland (ESA SP-636, July 2007), 463658, ISBN 92-9291-200

b. Available facilities

In the laboratories of the three CNR institutes involved in this proposal there are computer workstations for image processing (with IDL/ENVI, ERDAS, ARC/GIS software) supply. Moreover a series of instruments for water quality parameters and radiometric measurements are available:

- Hydroscat-6, Hobi Labs Inc (CNR-ISMAR)
- AC-9, WET Labs (CNR-ISMAR)
- Ramses, Trios (CNR-ISMAR)
- LISST-100X, SEQUOIA (CNR-ISMAR)
- Water Insight SPectrometer (WISP-3) (CNR-IREA)
- Fluorimeter Cyclops 6, Turner Design (CNR-IREA)
- LI-COR LI-192SA Underwater Quantum Sensor (CNR-IREA)
- Sunphotometer EKO MS-120 (CNR-IREA)
- Profiler SATLANTIC (CNR-ISSIA) for multi - parametric measurements.

3. Output and deliverables

The main output of this proposal will be the comparison between HICO and PRISMA data processing for the water quality parameters retrieval. Methods and algorithms will be developed using HICO imagery and successively optimized for PRISMA. Moreover a yearly attending to HICO data team meeting will be assured.

References

C. Galeazzi, R. Carpentiero, V. De Cosmo, L .Garramone, F. Longo, E. Lopinto, G. Varacalli, “The PRISMA System an Pan/Hyp Instrument,” Proceedings of the 6th EARSeL Imaging Spectroscopy SIG (Special Interest Group) Workshop, March 16-18, 2009, Tel Aviv, Israel

Moore, J.K., Abbott, M.R., Richman, J.G., Smith, W.O., Cowles. T.J., Coale, K.H., Gardner, W.D., and Barber, R.T., SeaWiFS satellite ocean color data from the Southern Ocean. Geophysical Research Letters, vol. 26, no. 10, pp. 1465-1468, 1999.

Morel, A., Optical modeling of the upper ocean in relation to its biogeneous matter content (Case 1 waters). Journal Geophysical Research., vol. 93(C9), pp. 10749- 10768, 1988.

Odermatt D., Gitelson A., Brando V. E. and M. Schaepman, Review of constituent retrieval in optically deep and complex waters from satellite imagery, Remote Sensing of Environment 118 (2012) 116–126.

Gitelson A., Gao B.-C., Li R.-R., Berdnikov S., Saprygin V., Estimation of chlorophyll-a concentration in productive turbid waters using a Hyperspectral Imager for the Coastal Ocean: The Azov Sea case study, Environmental Research Letters, 6/024023 (2011), p. 6

Gitelson, A. (1992). The peak near 700 nm on radiance spectra of algae and water: relationships of its magnitude and position with chlorophyll concentration, International Journal of Remote Sensing, 13, 3367– 3373.

Santini, F., Alberotanza, L., Cavalli, R. M., & Pignatti, S. (2010). A two-step optimization procedure for assessing water constituent concentrations by hyperspectral remote sensing techniques: An application to the highly turbid Venice lagoon waters. Remote Sensing of Environment, 114(4), 887–898.