HICO Data User's Proposal

Assessment and application of HICO data for the study and monitoring of lakes

Principal Investigator: Evangelos K. Spyrakos
University of Stirling
School of Natural Sciences
Biological and Environmental Sciences
Stirling FK9 4LA UK
TEL.: +44 (0)1786 467757
FAX: +44 (0)1786 467843
E-mail: evangelos.spyrakos@stir.ac.uk

Co-Investigator: Andrew N. Tyler
University of Stirling
School of Natural Sciences
Biological and Environmental Sciences
Stirling FK9 4LA UK
TEL.: +44 (0)1786 467838
FAX: +44 (0)1786 467843
E-mail: a.n.tyler@stir.ac.uk

Co-Investigator: Peter D. Hunter
University of Stirling
School of Natural Sciences
Biological and Environmental Sciences
Stirling FK9 4LA UK
TEL.: +44 (0)1786 466538
FAX: +44 (0)1786 467843
E-mail: p.d.hunter@stir.ac.uk

Co-Investigator: Mátyás Présing
Balaton Limnological Research Institute of the
Hungarian Academy of Sciences
H-8237 Tihany, 35
TEL.: +36 87 448244
FAX: +36 87 448006
E-mail: presing.matyas@okologia.mta.hu

Project summary

The use of satellite observations for monitoring change in the status of lakes has progressed significantly in recent years but the complexity in the optical properties of these water bodies and the continentality of the overlying atmosphere still presents notable challenges for the accurate retrieval of in-water biogeochemical constituents. In addition, strong land adjacency effects also diminish the accuracy of satellite observations over lakes. Consequently, algorithms for chlorophyll a (Chla) retrieval developed for ocean and coastal waters have limited applicability to turbid lakes. The recently-funded €3.5M GloboLakes project (www.globolakes.ac.uk), involving a consortium of six UK universities and research institutes including the University of Stirling (USTIR), Plymouth Marine Laboratory (PML), and the Centre for Ecology & Hydrology (CEH), is developing an operational satellite-based observatory for more than 1000 lakes globally. The GloboLakes project provides a unique opportunity to assess HICO as a potential tool for the study and monitoring of lakes. In addition, we propose to validate a range of atmospheric and in-water biogeochemical algorithms using HICO data products. The principal objectives of this proposal are thus:

- To exploit HICO data products over lakes around the world using in-situ matchups from field campaigns, routine monitoring programmes and instrumented moorings
- To develop and validate water constituent retrieval algorithms from HICO data specifically for lakes and explore the algorithm requirements for future remote sensing water colour missions

1. Statement of work/project description

The development of operational geophysical and biogeochemical satellite products for lakes is challenging for a number of reasons including: (i) complexity and variability in the mass-specific inherent optical properties (SIOPs) of lake water constituents; (ii) greater atmospheric turbidity and variability in aerosol properties than over the oceans; and (iii) land adjacency effects on water-leaving reflectances that can extend over a large proportion of the lake surface. Consequently, standard algorithms for ocean and coastal waters (e.g. OC4v4, MERIS Algal_1 and Algal_2) often fail or perform poorly when applied to lakes (Alikas & Reinart, 2008; Binding et al., 2011). Recently, new algorithms for the correction of atmospheric (Guanter et al., 2010) and land adjacency effects (Knaeps et al., 2010) and biogeochemical parameter retrieval have been developed specifically for highly turbid Case 2 waters and recent validation studies have reported very promising results using MERIS (Giardino et al., 2010; Hunter et al., 2010; Matthews et al., 2010; Odermatt et al., 2010; Kutser et al., 2009). However, with the loss of MERIS contact in 2012 there is a gap in the availability of operational satellite products for the monitoring of inland water bodies until the ESA Copernicus Sentinel-3a satellite is launched in mid-2014.

The prototype HICO (Hyperspectral Imager for the Coastal Ocean) instrument provides thus a unique opportunity to enable the development and validation of algorithms and products for inland waters. HICO is a hyperspectral sensor with 87 spectral bands; this improved spectral resolution is potentially of significant benefit for the observation of water bodies with optically complex properties such as lakes. The continuous spectral coverage should allow for more accurate quantification of phytoplankton characteristics while its fine spatial resolution enables the study of relatively small inland water bodies. Gitelson et al. (2011) have shown the potential of HICO for the quantification of Chla as well as other accessory pigments (e.g. phycocyanin).

The validation of HICO data products will be achieved using matchup data collected during dedicated field campaigns. These measurements will be supplemented by data available to the project

from existing long-term monitoring programmes and instrumented buoys for lakes around the world. The project will follow established protocols for satellite validation to ensure transparency and traceability. The field campaigns and associated data processing will be funded entirely by GloboLakes. Highly experienced scientists from USTIR and PML will lead the field campaigns and image processing. CEH will contribute in-situ validation data from existing long-term lake monitoring programmes and instrumented buoy networks.

The lakes for the assessment of HICO data products have been selected on the basis that: (i) they encompass a range of optical water types; (ii) they have existing long-term lake monitoring programmes and many have instrumented buoys to provide in-situ data for validation; and (iii) they are accessible for sampling by the our team to maximise the generation of satellite matchups. In order to test the performance of HICO over lakes we will be using in-situ match-up (historical, current and future) data obtained from:

i. ***dedicated field campaigns:***

In-situ data will be collected as part of the field campaigns to be undertaken as part of the following projects: (1) UK Natural Environment Research Council (NERC) GloboLakes; (2) EU FP7 Space INFORM (Improved monitoring and forecasting of ecological status of European INland waters by combining Future earth ObseRvation data and Models); and (3) Hungarian Academy of Science KTAMOP (Ecological status and monitoring of Lake Balaton).

Geographic coordinates (lat/long)

- Lake Balaton, Hungary (N46°49.8'; E17°44.0'). Lake Balaton is the largest shallow lake in central Europe and is comprised of 4 basins of varying trophic state. The lake is also characterised by very high concentrations of mineral particles and localised inputs of CDOM-rich water from river tributaries.
- Field campaigns may be undertaken on other lakes if further external funding is secured.

ii. ***LIMNADES*** (Lake Bio-optical Measurements and Matchup Data for Remote Sensing database).

LIMNADES is an initiative to establish a centralised database of ground bio-optical measurements of worldwide lakes and has been developed in the framework of GloboLakes. It is hosted at the University of Stirling.

The lake targets are:

- Lake Taihu, China (N31° 10'; E120°09')
- Lake Bogoria, Kenya (N0°15'; E36°06')
- Skaneateles Lake, USA (N42°51'; W76°22')

iii. ***long-term lake monitoring programmes (e.g. WISER);***

This includes data contributed to the WISER database, held by CEH, which encompasses some 800 lakes across Europe of which approximately 50% have frequent data for summer months.

iv. ***instrumented semi-autonomous buoys (e.g. GLEON).***

This data will also be used to increase the potential number of in-situ match-ups with HICO overpasses.

The geographic locations for which further validation data is available will be provided once the data have been compiled by the GloboLakes project.

2. Biographical sketch and available facilities

Evangelos Spyrakos has a PhD in Applied Physics (University of Vigo, Spain), funded under EU "Marie Curie Action". His research has focused on the retrieval of biogeochemical constituents in optically complex waters from satellite data and quantitative aspects of remote sensing. In 2012 he joined University of Stirling as a post-doctoral researcher, where he is carrying out researches on validation and development of retrieval algorithms for lakes at regional and global scale, bio-optical characterisation of inland water bodies and establishment of a centralised database of Lake Bio-optical Measurements and Matchup Data for Remote Sensing.

Peter D. Hunter is a Lecturer in Earth Observation at the University of Stirling. His main research interests lie in the use of remote sensing for studying ecosystem responses to environmental change at multiple spatial and temporal scales. He uses data acquired from near ground sensors as well as those mounted on unmanned aerial vehicles, aircraft and satellites to deliver new insights into ecological processes and function in a range of environments including wetlands, estuaries and lakes. He works with high spatial resolution hyperspectral imagery through to global observations from polar-orbiting satellites and is looking at ways to integrate these data into numerical and process-based ecosystem models. Hunter leads the work package on algorithm development and validation on GloboLakes; is the PI on the INFORM and KTAMOP projects and also leads a Sentinel-3 validation team.

Andrew Tyler is a Professor in Environmental Science and Head of Biological & Environmental Sciences at the University of Stirling. His research interests specialise in the spatial characterisation of contaminants in the environment and the impacts they have, focusing in the area of the Environment and Human Health. His research has pioneered the development of satellite and airborne remote sensing in quantifying the fate and impact of pollutants on the environment – especially aquatic systems. He is the lead PI on the €3.5M Million NERC funded consortium Global Observatory of Lake Response to Environmental Change (GloboLakes).

Mátyás Présing is a senior research fellow at the Balaton Limnological Research Institute of the Hungarian Academy of Sciences. He has a PhD in Hydrobiology/hydrochemistry. He leads several projects on water quality and N-cycling of Lake Balaton and he is contributor of over 70 publications in scientific journals. His current investigations include ammonium regeneration in the water column and sediment and influences on the processes controlling the internal nitrogen supply of the lake and remote sensing applications.

Available facilities and instrumentation

In situ bio-optics and radiometry (available instrumentation):

- Spectral attenuation, absorption and scattering (Wetlabs AC-9, AC-S; HobiLabs a-Sphere);
- Spectral backscattering (2 x Wetlabs ECOBB3, Hobi Labs Hydroscat);
- Subsurface irradiance reflectance and above water-leaving reflectances (Satlantic HyperOCRs and HyperSAS);
- Chlorophyll fluorescence (Wetlabs WetStar);
- Temperature, depth and salinity (SeaBird CTD);
- Attenuation coefficient for photosynthetically active radiation (K_d(PAR); Licor Quantum Sensor)
- Atmospheric aerosol optical thickness (AOT) and water vapour content (Microtops sun photometer; Cimel tracking sun photometer)
- Boat adapted for bio-optical studies in lakes

Laboratory measurements & computing facilities:

- Absorption coefficients for total particulate (a_p), phytoplankton (a_{ph}), non-algal particles (a_{NAP}) and CDOM (a_{CDOM}) (Cary 100 dual beam spectrophotometers with an integrating-sphere attachment)
- Spectrophotometric chlorophyll
- HPLC chlorophyll and accessory pigments (2 HPLC systems)
- Total (TSM), inorganic (PIM) and organic (POM) particulate matter
- Phytoplankton cell counts (microscopy and flow cytometry)
- Computer workstations for image processing and computer clusters

3. Output and deliverables

The "*Assessment and application of HICO data for the study and monitoring of lakes*" will support efforts to establish the full applicability range and uncertainties associated with the HICO data products across the continuum of water optical types. In particular, by extending the validation of HICO data to lakes, we will be able to better identify in which water types retrieval algorithms fail and why. We will also provide recommendations to alternative HICO-compatible algorithms for turbid Case 2. Our results will be available through:

- peer-reviewed papers and technical documents produced within GloboLakes frameworks
- HICO meetings and workshops and other national and international conferences (e.g. Ocean Optics, EARSel, AGU, EGU, ASLO, SIL) and workshops (IOCCG).

References

Alikas K., and A. Reinart, "Validation of the MERIS products on large European lakes: Peipsi, Vänern and Vättern," Hydrobiologia, 599 (1): 161–168 (2008).

Binding, C. E., T. A. Greenberg, J. H. Jerome, R. P. Bukata, and C. Letourneau, "An assessment of MERIS algal products during an intense bloom in lake of the woods," Journal of Plankton Research, 33(5): 793–806 (2011).

Giardino, C., M. Bresciani, R. Pilkaityte, M. Bartoli, and A. Razinkovas, "In situ measurements and satellite remote sensing of case 2 waters: First results from the Curonian Lagoon," Oceanologia, 52(2): 197–210 (2010).

Gitelson, A. A., B. Gao, R. Li, S. Berdnikov, V. and Saprygin, "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: 1-6 (2011).

Guanter, L., A. Ruiz-Verdu, D. Odermatt, C. Giardino, S. Simis, V. Estelles, T. Heege, J. A. Dominguez-Gomez, and J. Moreno, "Atmospheric correction of Envisat/MERIS data over inland waters: validation for European lakes," Remote Sensing of Environment, 114(3): 467–480 (2010).

Hunter, P. D., A. N. Tyler, L. Carvalho, G. A. Codd, S. C. Maberly, "Hyperspectral remote sensing of cyanobacterial pigments as indicators for cell populations and toxins in eutrophic lakes," Remote Sensing of Environment, 114 (11): 2705-2718 (2010).

Knaeps, E., S. Sterckx, and D. Raymaekers, "A Seasonally Robust Empirical Algorithm to Retrieve Suspended Sediment Concentrations in the Scheldt River," Remote Sensing(2): 2040-2059 (2010).

Kutser, T., B. Paavel, L. Metsamaa, and E. Vahtmäe, "Mapping coloured dissolved organic matter concentration in coastal waters," International Journal of Remote Sensing, 30(22): 5843–5849 (2009).

Matthews, M. W., S. Bernard, and K. Winter, "Remote sensing of cyanobacteriadominant algal blooms and water quality parameters in Zeekoevlei, a small hypertrophic lake, using MERIS," Remote Sensing of Environment, 114(9): 2070–2087 (2010).

Odermatt, D., C. Giardino, and T. Heege, "Chlorophyll retrieval with MERIS Case-2-Regional in perialpine lakes," Remote Sensing of Environment, 114(3): 607–617 (2010).