HICO data User's Proposal

Identification of diatoms in coastal waters using HICO imagery within southern part of Hokkaido, Japan

Principal Investigator
Name: Dr. Sei-Ichi Saitoh (Professor)
Address: Laboratory of Marine Bioresource and Environment Sensing
Faculty of Fisheries Sciences, Hokkaido University
3-1-1 Minato-Cho, Hakodade, Hokkaido, Japan
Phone: +81-138-40-8843
Fax: +81-138-40-8844
E-mail: ssaitoh@salmon.fish.hokudai.ac.jp

Co Investigator 1
Name: Dr. Toru Hirawake (Associate Professor)
Address: Laboratory of Marine Bioresource and Environment Sensing
Faculty of Fisheries Sciences, Hokkaido University
3-1-1 Minato-Cho, Hakodade, Hokkaido, Japan
Phone: +81-138-40-8844
Fax: +81-138-40-8844
E-mail: hirawake@salmon.fish.hokudai.ac.jp

Co Investigator 2
Name: Dr. Tomonori Isada (Postdoctoral Fellow)
Address: Laboratory of Marine Bioresource and Environment Sensing
Faculty of Fisheries Sciences, Hokkaido University
3-1-1 Minato-Cho, Hakodade, Hokkaido, Japan
Phone: +81-138-40-5650
Fax: +81-138-40-8844
E-mail: t-isada@salmon.fish.hokudai.ac.jp

Abstract/project summary
The main objective of this study using HICO data is to establish a method for identifying diatoms or other phytoplankton groups in coastal waters because it is important to quantify the contribution of each phytoplankton functional group to marine biogeochemical cycles. Funka bay, located in southwest Hokkaido Island, Japan, is one of the most important aquaculture regions for scallop and kelps in Japan. It is well known that diatoms as well as harmful algae like dinoflagellate influence the cultured aquatic organisms in Funka bay, subsequently leading to fisheries marketing and human health concerns. One of the objectives in our ongoing project is to monitor and assess coastal waters in Funka bay for conservation and sustainable use of natural resources in aquatic biota and aquaculture. Therefore, ocean color remote sensing having a much greater spatial and spectral resolution, that is HICO, is a powerful tool for monitoring the spatio-temporal variability of optically complex coastal waters in aquatic ecosystems. Within this ongoing project, we would like to apply our method for identifying diatoms using light absorption coefficient of phytoplankton derived from hyperspectral remote sensing reflectance through the inversion method of quasi-analytical-algorithm to HICO data. The data from HICO will be of great benefit for a wide range of assessment of environmental impacts in Funka bay. Our objective in this study will be achieved only when used in combination with the HICO product.

1. Statement of work/project description

Funka Bay, which is located in southwest Hokkaido Island, Japan, and opened to Pacific ocean (Fig.1), is one of the most important coastal regions for aquaculture in Japan, especially scallops and kelps. In coastal ecosystem, since phytoplankton plays a major role in not only aquatic carbon cycle but also aquaculture, it is essential to quantify the contribution of each phytoplankton functional group to marine biogeochemical cycles and their spatial and temporal variability. Recently, the hyperspectral approach is becoming more powerful tool for detecting specific phytoplankton species (Craig *et al*., 2006; Lubac *et al*., 2008; Mao *et al*., 2010) or bio-optical province (Taylor *et al*., 2011) and estimating phytoplankton pigments (Torrecilla *et al*., 2011). Our main objective in this study is to establish a method for identifying diatoms with hyperspectral approach in coastal waters. In order to achieve our goal, we have conducted *in situ* measurement and sampling for light absorption of particle, detritus, phytoplankton, and colored dissolved organic carbon (CDOM), phytoplankton pigments with HPLC, and hyperspectral remote sensing reflectance, $R_{rs}(\lambda)$, in Funka bay (Fig. 1) from 2010 April to 2012 January. Based on the *in situ* data set, the algorithm for identifying diatoms using light absorption coefficient of phytoplankton derived from hyperspectral remote sensing reflectance through the inversion method of quasi-analytical-algorithm (Lee *et al*., 2004:2009) was developed. However, since the spectral resolution of MODIS is limited, our method was not applied to MODIS data. By contrast, HICO is the first spaceborne hyperspectral spectrometer designed to specifically sample the coastal ocean and has 88 spectral channels ranging from 400 to 900 nm with a ground sample distance of 90 m (Lucke *et al*., 2011). Therefore, HICO is only suitable tool for investigating coastal waters, which considerably changing the intensity and quality of light field. Through the use of HICO data, we would like to apply our method to the HICO hyperspectral product in coastal region of southern Hokkaido, Japan. Our objective in this study will be achieved only when used in combination with the HICO product.

Our study has been funded by 'Hakodate Marine Bio Cluster Project' in the Ministry of Education, Culture, Sports, Science and Technology program for fostering regional innovation, Japan from 2009 to 2013 (http://www.hakodate-marine-bio.com/en/gaiyou.html). One of the project concepts is measurement and prediction for the improvement of the balance between an advanced use and sustainable use of biota and aquatic environments in coastal areas using marine spatial information. Our project focuses on monitoring and assessing coastal waters around Funka bay, leading to the key to support fisheries resources and to evaluate carrying capacity. Therefore, the use of HICO data is very important beneficial to the ongoing project in various ways. For example, currently, the most suitable sites-selection model based on satellite remote sensing (SeaWiFS and MODIS) and geographic information system (GIS) for cultures of Japanese scallop and kelp in Funka bay were developed in our project (Radiarta and Saitoh, 2009; Radiarta *et al*., 2011). The HICO data will enhance the refinement of the models.

The region of specific interest for this study is bound by the following coordinates:
Northern Boundary –43 ºN
Southern Boundary –40.5 ºN
Western Boundary –139 ºE
Eastern Boundary –143 ºE

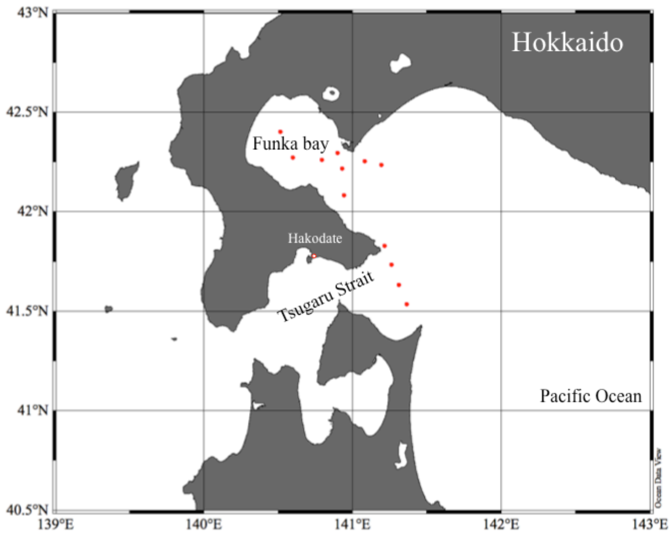

Figure 1: Map of sampling in this study. Red circles represent sampling sites.

We would like to request the level 1 data and the standard level 2 HICO products including chlorophyll, inherent optical properties, and hyperspectral image of ocean remote sensing after atmospheric correction by HICO team. Data from HICO will be used to calculate the following aims;

- To estimate light absorption coefficient of phytoplankton with such as quasi-analytical-algorithm (QAA, Lee *et al*., 2004; 2009)
- Derivative analysis of the R_{rs}-derived $a_{ph}(\lambda)$ for calculating similarity index (Mille *et al*., 1997).

2. Biographical sketch and available facilities

Sei-Ichi Saitoh (PI) is a professor of the Faculty of Fisheries Sciences and Center of Sustainability Science at Hokkaido University and also executive adviser at Green & Life Innovation, Inc. which is a venture company on fisheries information service. His research interests involve the detection of large-scale biological events (i.e. phytoplankton blooms and squid migration). Recently, he developed and implemented the TOREDAS system (Traceable and Operational Resource and Environment Data Acquisition System). This system provides fishermen with fishing ground forecasts for Japanese common squid, Pacific saury, Skipjack tuna, and Albacore tuna. This service aims to promote sustainable fisheries operation and management in the offshore around Japan. He specializes in operational fisheries oceanography and satellite oceanography. He was PI of OCTS/ADEOS-I (JAXA) and GLI/ADEOS-II (JAXA) and is now PI of SGLI/GCOM-C (JAXA) which will be launched in 2014. He has been contributed to Cal/Val activities of several ocean color sensors. He is also an international PI of

GOCI (KOSC/KORDI). He was a co-chair for MONITOR Technical Committee of PICES and is still a member of MONITOR T/C. He is a member of Science Council of Japan and participates to domestic committees on SCOR and IASC for contributing on international coordination.

List of selected recent publications

Iida, T., and **S.-I. Saitoh**, "Temporal and spatial variability of chlorophyll concentrations in the Bering Sea using empirical orthogonal function (EOF) analysis of remote sensing data," Deep-Sea Res. Part II 54(23-26): 2657-2671 (2007).

Matsuoka, A., Y. Huot, K. Shimada, and **S.-I**. **Saitoh**, "Bio-optical characteristics of the western Arctic Ocean: Implications for ocean color algorithms," Canadian J Remote Sens. 33(6): 503-518 (2007).

Muzzneena A. M., and **S.-I. Saitoh**, "Observations of sea ice interannual variations and spring bloom occurrences at the Japanese scallop farming area in the Okhotsk Sea using satellite imageries," Estuar. Coast. Shelf Sci. 77: 577-588, (2008)

Lihan, T., **S.-I. Saitoh**, T. Iida, T. Hirawake, and K. Iida, "Satellite-measured temporal and spatial variability of the Tokachi River plume," Estuar. Coast. Shelf Sci. 78: 237-249 (2008).

Zainuddin, M., K. Saitoh, and **S.-I. Saitoh**, "Albacore (*Thunnus alalunga*) fishing ground in relation to oceanographic conditions in the western North Pacific Ocean using remotely sensed satellite data," Fish. Oceanogr. 17(2): 61-73 (2008).

Mizobata, K., **S.-I. Saitoh,** and J. Wang, "Summer biochemical enhancement in relation to the mesoscale eddy at the shelf break in the vicinity of the Pribilof Islands," Deep-Sea Res. Part II 55: 1717-1728 (2008).

Radiarta, I. N., and **S.-I. Saitoh**, "Satellite-derived measurements of spatial and temporal chlorophyll-*a* variability in Funka Bay, southwestern Hokkaido, Japan," Estuar. Coast. Shelf Sci. 79: 400-408 (2008).

Radiarta, I. N., **S.-I. Saitoh**, and A. Miyazono, "GIS-based multicriteria evaluation models for identifying suitability sites for Japanese scallop (*Mizuhopecten yessoensis*) aquaculture in Funka Bay, southwestern Hokkaido, Japan," Aquaculture 284: 127-135 (2008).

Radiarta, I. N., and **S.-I. Saitoh**, "Biophysical models for Japanese scallop, *Mizuhopecten yessoensis*, aquaculture site selection in Funka Bay, Hokkaido, Japan using remotely sensed data and geographic information system," Aquacult. Int. 17: 403-419 (2009).

Wang, J., H. Hu, K. Mizobata, and **S.-I. Saitoh**, "Seasonal variations of sea ice and ocean circulation in the Bering Sea: A model-data fusion study," *J. Geophys. Res.* 114: C08019, doi:10.1029/2008JC004727 (2009).

Mustapha, M. A., **S.-I. Saitoh**, and T. Lihan, "Satellite-measured seasonal variations in primary production in the scallop-farming region of the Okhotsk Sea," *ICES J. Mar. Sci.* 66: 1557-1569 (2009).

Nihashi, S., K. I. Ohshima, T. Tamura, Y. Fukamachi, and **S.-I. Saitoh**, "Thickness and production of sea ice in the Okhotsk Sea coastal polynya from AMSR-E," *J Geophys. Res*. 114: C08019, doi:10.1029/2008JC005222 (2009).

Okamoto, S., T. Hirawake, and **S.-I. Saitoh**, "Interannual variability in the magnitude and timing of the spring bloom in the Oyashio region," Deep Sea Res. Part II 57: 1608-1617 (2010).

Mizobata, K., K. Shimada, **S.-I. Saitoh**, and J. Wang, "Estimation of heat flux through the eastern Bering Strait," J. Oceanogr. 66: 405 - 424 (2010).

Mugo, R., **S.-I. Saitoh**, A. Nihira, and T. Kuroyama, "Habitat characteristics of skipjack tuna (*Katsuwonus Pelamis*) in the western North Pacific: a remote sensing perspective," Fish. Oceanogr. 19: 382-396 (2010).

Radiarta, I. N., **S.-I. Saitoh**, and H. Yasui, "Aquaculture site selection for Japanese kelp (*Laminaria japonica*) in southern Hokkaido, Japan, using satellite remote sensing and GIS-based models," ICES J. Mar. Science 68(4): 773-780 (2011).

Saitoh, S.-I., R. Mugo, I. N. Radiarta, S. Asaga, F. Takahashi, T. Hirawake, Y. Ishikawa, T. Awaji, T. In, and S. Shima, "An operational use of remote sensing and marine-GIS for sustainable fisheries and aquaculture," ICES J. Mar. Science 68(4): 687-695 (2011).

Lipa, B., D. Barrick, **S.-I. Saitoh**, Y. Ishikawa, T. Awaji, J. Largier, and N. Garfield, "Japan tsunami current flows observed by HF radars on two continents," Remote Sensing 3: 1663-1679 (2011).

Fujiwara, A., T. Hirawake, K. Suzuki, and **S.-I. Saitoh**, "Remote sensing of size structure of phytoplankton communities using optical properties of the Chukchi and Bering Sea shelf region," Biogeosciences 8(12): 3567-3580 (2011).

Iida, T., K. Mizobata, and **S.-I. Saitoh**, "Interannual variability of coccolithophore *Emiliania huxleyi* blooms in response to changes of water column stability in the eastern Bering Sea," Cont. Shelf Res. 34: 7-17 (2012).

Available facilities

In each cures, we has carried out *in situ* measurement for apparent optical properties ($E_s(\lambda)$, $E_d(\lambda)$, and $L_u(\lambda)$) with hyperspectral profiling radiometer (HyperProII, Satlantic, Inc.) and inherent optical properties ($b_b(\lambda)$ and $\beta(\theta, \lambda)$) with spectral backscattering sensor (HydroScat6P, HOBI Labs, Inc.) and volume scattering function meter (VSF3P, WET Labs, Inc.). Additionally, photosynthetically active radiation (PAR) above the sea surface was continuously measured on deck with a PAR sensor (LI-1400, LI-COR, Inc.).

Water samples taken from acid clean niskin bottle or bucket were used to measure light absorption coefficient of non algal particle ($a_{NAP}(\lambda)$), phytoplankton ($a_{ph}(\lambda)$), and colored dissolved organic matter ($a_{CDOM}(\lambda)$), chlorophyll *a*, and phytoplankton pigments. Light absorption properties were measured with spectrophotometer (MPS-2450, Shimadzu). Chlorophyll *a* concentration was determined fluorometrically using Turner fluorometer (Turner Designs 10-AU). Phytoplankton pigments including chlorophyll *a* were analyzed by high performance liquid chromatography (LC-VP, Shimadzu). Note that we used the HPLC in laboratory of Dr. Koji Suzuki who is associated professor in Hokkaido University in Sapporo, Japan. For processing data and imagery of HICO products, we have the latest versions of software as follows: ENVI / IDL (ITT VIS), Matlab (Mathworks) and SeaDAS (NASA).

3. Output and deliverables

It will be possible to compared *in situ* hyperspectral remote sensing reflectance using HyperProII with HICO data after atmospheric correction. Algorithm developed in this study and resulting processed imagery will be shared with the HICO project. We will attend the annual HICO team meeting to present and discuss our study results.

4. References

Craig, S. E., S. E. Lohrenz, Z. Lee, K. L. Mahoney, G. J. Kirkpatrick, O. M. Schofield, and R. G. Steward, "Use of hyperspectral remote sensing reflectance for detection and assessment of the harmful alga, *Karenia brevis*," Appl. Opt. 45(21): 5414–5425 (2006).

Lee, Z, and K. L. Garder, "Absorption spectrum of phytoplankton pigments derived from hyperspectral remote-sensing reflectance," Remote Sens. Environ. 89: 361–368 (2004).

Lee, Z, B. Lubac, J. Werdell, and R. Arnone, "An Update of the Quasi-Analytical Algorithm (QAA_v5)," retrieved from http://www.ioccg.org/groups/software.html (2009).

Lubac, B., H. Loisel, N. Guiselin, R. Astoreca, L. F. Artigas, and X. Mériaux, "Hyperspectral and multispectral ocean color inversions to detect *Phaeocystis globosa* blooms in coastal waters," J. Geophys. Res. 113: C06026, doi:10.1029/2007JC004451 (2008).

Lucke, R. L., M. Corson, N. R. McGlothlin, S. D. Butcher, D. L. Wood, D. R. Korwan, R. R. Li, W. A. Snyder, C. O. Davis, and D. T. Chen, "Hyperspectral Imager for the Coastal Ocean: instrument description and first images," Appl. Opt. 50(10): 1501-1516 (2011).

Mao, Z., V. Stuart, D. Pan, J. Chen, F. Gong, H. Huang, and Q. Zhu, "Effects of phytoplankton species composition on absorption spectra and modeled hyperspectral reflectance," Ecological Informatics 5: 359–366 (2010).

Millie, D. F, O. S. Schofield, G. J. Kirkpatrick, G. Johnsen, P.A. Tester, and B. T. Vinyard, "Detection of harmful algal blooms using photopigments and absorption signatures: A case study of the Florida red tide dinoflagellate, *Gymnodinium breve*," Limnol. Oceanogr. 42: 1240-1251 (1997).

Taylor, B. B., E. Torrecilla, A. Bernhardt, M. H. Taylor, I. Peeken, R. Röttgers, J. Piera, and A. Bracher, "Bio-optical provinces in the eastern Atlantic Ocean and their biogeographical relevance," Biogeosciences 8: 3609–3629 (2011).

Torrecilla, E., D. Stramski, R. A. Reynolds, E. Millán-Núñez, and J. Piera, "Cluster analysis of hyperspectral optical data for discriminating phytoplankton pigment assemblages in the open ocean," Remote Sens. Environ. 115: 2578–2593 (2011).

Radiarta, I. N., and S, Saitoh, "Biophysical models for Japanese scallop, Mizuhopecten yessoensis, aquaculture site selection in Funka Bay, Hokkaido, Japan, using remotely sensed data and geographic information system," Aquacult. Int. 17: 403–419 (2009).

Radiarta, I. N., S, Saitoh, and H. Yasui, "Aquaculture site selection for Japanese kelp (Laminaria japonica) in southern Hokkaido, Japan, using satellite remote sensing and GIS-based models," ICES J. Mar. Science 68(4): 773–780 (2011).