2009 PICES Summer School on "*Satellite Oceanography for the Earth Environment*"

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Satellite remote sensing techniques have long been developed to understand the diverse oceanographic and atmospheric processes that are responsible for the current environmental changes on the earth as well as future climate change. The ocean is one of the largest reservoirs of heat on the earth, and it affects our lives by influencing the atmosphere and the earth's environment through multiple air–sea interactions and feedback mechanisms. To understand and predict the changes in the ocean environment, high-quality earth/ocean observational data and *in-situ* measurements are required. Numerous satellites and sensors have provided us with a large number of measurements of the ocean and earth. Such a tremendous satellite database has enabled us to investigate the spatial structures of oceanic phenomena and their temporal changes over decades. Satellite oceanography requires researchers to possess diverse skills and abilities in the areas of computer programming, high-level mathematics and physics, in addition to in-depth knowledge of the specific subjects involved.

The third PICES international summer school entitled "*Satellite Oceanography for the Earth Environment*" was held from August 25–28, 2009, at Seoul National University, Seoul, Korea. The summer school was sponsored by PICES, the Scientific Committee on Oceanic Research (SCOR), Research Institute of Oceanography (RIO) at Seoul National University (SNU), East Asian Sea Time-series (EAST-1) project of the Ministry of Land, Transport and Maritime Affairs (MLTM), "Brain Korea 21" Program (BK21), Korea Ocean Research and Development Institute (KORDI), Pukyung National University (PNU), Sea Space Corporation, OTRONIX Corporation, and the Special Monitoring and Coastal Environmental Assessment Regional Activity Center of the Northwest Pacific Action Plan (CEARAC/NOWPAP). The conveners for the summer school were Kyung-Ae Park (Korea), Joji Ishizaka (Japan), Kyung-Ryul Kim (Korea), and Yu-Hwan Ahn (Korea), who comprised the international Organizing Committee, and Sei-Ichi Saitoh (Japan), Sinjae Yoo (Korea), and Junwu Tang (China), who comprised the international Advisory Committee. All summer school materials are posted on the PICES (www.pices.int/meetings/summer_schools/2009_summer_schools/2009-Seoul-ss/2009-Seoul-main-ss.aspx) and SNU (seoul.snu.ac.kr/pices2009/) websites.

The objective of the summer school was to help and motivate postgraduate students, early-career scientists, and other professionals, including those who are new to satellite oceanography, by providing a basic concept and knowledge of remote sensing for advanced applications. The four-day school covered satellites and sensors, and the principles

Students and professors at the third PICES summer school on satellite oceanography at Seoul National University, August 25–28, 2009.

of deriving oceanic parameters from satellite data in three major areas (optical, infra-red, and microwave) of satellite oceanography. The courses involved lectures and hands-on training in satellite data processing techniques, including data calibration, image processing, and examples of case studies on applications. In particular, a part of this summer school was devoted to introducing the first Korean geostationary satellite, "COMS" (Communication Ocean Meteorological Satellite), which was supposed to be launched in the middle of 2009, but its status for further action is still "alert".

A total of 35 students and early career scientists from 7 countries attended the summer school: 10 from China, 1 from India, 3 from Indonesia, 1 from Italy, 2 from Japan, 2 from Russia, and 16 from Korea. Among the participants, 24 were postgraduate students (16 Ph.D. students and 12 M.Sc. students), 3 were early-career scientists, 3 were undergraduate students, and 1 belonged to a company. Most of the participants majored in physical oceanography, biological oceanography, or earth science. Genki Terauchi and Hidemasa Yamamoto (CERAC/NOWPAP) participated as observers. Genki Terauchi made a great effort to familiarize the students with each lecturer's career at the beginning of each course. As other observers, 3 students majoring in atmospheric science at Seoul National University were part-time participants in some lectures that interested them, particularly all of Prof. Huang's lectures.

The summer school consisted of 16 lectures and practical exercises. During the first two days, optical ocean remote sensing was covered, organized by Joji Ishizaka (Nagasaki University, Japan) and Sinjae Yoo (KORDI). During the last two days, the concepts of infrared and microwave remote sensing were covered, organized by Kyung-Ae Park (SNU).

The lectures given on Day 1 included: *Introduction to satellites and sensors for oceanography and principles of ocean optics* by Yu-Hwan Ahn (KORDI), *Methods of ocean color remote sensing* by Junwu Tang (National Ocean Technology Center, China) and *SeaDAS optical data processing I* by Young Baek Son (Nagoya University, Japan). Six SNU students – Kang-Sun Seo, Minseon Lee, Hwa-Jung Chae, Tsi-Sung Kim, Eun-Young Lee, and Bayrasaikhan Uudus – assisted lecturers and students by addressing some hardware and software problems associated with the SeaDAS software and IMAPP (International MODIS/AIRS Processing Package) software during practical exercises. The lectures held on Day 2 were: *Estimation of primary production from space* by Sinjae Yoo, *Monitoring the earth biosphere using ocean color* by Joji Ishizaka, and *Social applications in fisheries and aquaculture using satellite remote sensing and marine-GIS* by Sei-Ichi Saitoh (Hokkaido University, Japan). After a training course on Day 1, a lecture on *SeaDAS optical/IR data processing II* was held by Young Baek Son over the entire afternoon on Day 2. The lectures on Day 3 included: *Sea surface temperature retrievals from multi-satellites and merging methodology* by Kohtaro Hosoda (Tohoku University, Japan), *Sea surface temperature errors and role of satellite scatterometer winds on understanding the earth/ocean environment* by Kyung-Ae Park, and *Multiple and hyper-spectral infrared sensing of SSTs: Theory and laboratory exercises* and *IMAPP software overview and processing* by Allen Huang (Space Science and Engineering Center, University of Wisconsin-Madison, U.S.A.). The lectures on Day 4 were: *NOAA's satellite remote sensing activities* by Kenneth Casey (National Oceanographic Data Center, U.S.A.), *Overview of infrared radiative transfer theory and modeling* by Allen Huang, *Introduction to COMS MI (Meteorological Imager) sensors and meteorological parameter retrievals* by Mi-Lim Oh (Korea Meteorological Administration), and *Land–ocean interaction study by using remotely-sensed data* by Joo-Hyung Ryu (KORDI).

Before the beginning of the courses, a brief history of satellites and sensors, from visible to microwave, was presented by Yu-Hwan Ahn, who is the Principle Investigator of GOCI (Geostationary Ocean Color Imager) sensor development. This lecture covered the details on how the sensors have been operating and what kinds of products have been generated from multi-satellites and multi-sensors. He started the optical remote sensing session with the principles of ocean optics, which deal with the characteristics of in-water light rays and atmospheric correction. He and his team have wide experience in the development of the first geostationary ocean color sensor, and this seems to have been favorable for helping students to develop a deep understanding of the fundamental ocean optical sensors and related optical theory. Ahn's lecture was believed to endow students with a challenge of new-generation sensor evolution. In the next lecture, Junwu Tang presented methods of ocean color remote sensing for each data product, and methods for calibrating the ocean color data and determining ocean color variables (*e.g.*, chlorophyll-*a* concentration of phytoplankton). It is believed that when students were given a shortened version of the comprehensive summary of data processing, they gained the most fundamental knowledge on how satellite data could be used for biological oceanography. Subsequently, Young Baek Son covered SeaDAS software and processing of SeaWiFS satellite optical data in advance for the first two days, so that all trainees had a first-hand opportunity to process the SeaWiFS ocean color data. This training course introduced all the aspects and applications of SeaDAS software.

On the following day, optical remote sensing was covered without interruption, with the aim of increasing the students' interest in primary production estimation from space. Its principles, algorithm development, and related data processing were presented by Sinjae Yoo. With the help of Joji Ishizaka, students were able to gain knowledge on ocean colors that is obtained by navigating through the earth's biosphere,

Students' whole-hearted participation in lectures given by Dr. Sinjae Yoo (top left) and Dr. Joji Ishizaka (top right); Dr. Joji Ishizaka and students at the Welcome Reception (middle left); Dr. Yu-Hwan Ahn awards a graduation certificate to Mr. Robinson Mugo from Hokkaido University (middle right); a quiz contest during the Farewell Dinner Party (bottom left); and Ms. Susi from Indonesia expressing her joy over receiving a prize as the winner of one of the quizzes (bottom right).

including insights into local and global changes. By obtaining fundamental understanding of data processing and algorithms for the estimation of ocean color variables, students could engage in research on a wide variety of applications such as fisheries and aquaculture using satellite remote sensing methods and a marine GIS (Geographic Information System) technique; their activities were guided by Sei-Ichi Saitoh. Practical exercises conducted by Young Baek Son were followed, covering another utilization of SeaDAS software, this time for infrared data processing.

The central theme on the third day was sea surface temperature (SST), which is one of the most fundamental oceanic parameters to discover and explain oceanic phenomena such as mesoscale eddies, fronts, and distribution of currents. SST, along with other satellite data products like ocean color, sea surface height, and sea surface wind, have provided a key to understanding physical and biogeochemical oceanic processes in space and time. In addition, SST has played an important role in air–sea interaction and heat flux change as an indicator of abrupt global/local climate change, and has also been utilized as essential input data in air–sea numerical models. The SST session started with Kohtaro Hosota's lecture on how to retrieve SST and merging methodology using near-polar orbit satellite data from the NOAA geostationary satellite of MTSAT-1R and microwave satellite sensor of AQUA/AMSR-E. Since infrared SST products have had serious limitations in terms of temporal coverage and cloud contamination problems, microwave sensor data have been obtained by multi-satellite, multi-sensor merging techniques. However, SST products themselves have had a variety of errors. The characteristics and causes of the errors were described in depth by Kyung-Ae Park. Her lecture started with an introduction to all the procedures for determining SST from the satellite data and covered cloud removal techniques. It also covered the differences between *in-situ* temperature measurements and satellite-observed SSTs, and addressed

the importance of the existence of different kinds of SST measurements, from satellite to bulk temperature observations. Allen Huang guided the trainees through the use of the IMAPP software, developed by his team at Wisconsin University, by presenting all possible methods for handling IMAPP image processing. He also gave a lecture on multiple sensors and hyper-spectral infrared sensing of SST; the lectures involved theory followed by laboratory exercises. Huang also conducted another lecture on the last day, in which he provided an overview of theory and modeling based on infrared radiative transfer theory.

The fourth day began with a lecture by Kenneth Casey who presented an extensive summary of the history of satellites, sensors, and applications developed thus far. Students used this opportunity to learn about NOAA's past, present, and future activities across all satellite oceanographic applications, from visible to microwave wavelengths. Since COMS has two representative sensors, GOCI for the ocean and MI for the atmosphere, Mi-Lim Oh provided students with a summary of information on the COMS MI sensor and 16 products, including the Korean Meteorological Agency's plan of data distribution. The importance of land-ocean interaction was presented by Joo-Hyung Ryu in the form of many case studies, from basic to applied studies, including studies on tidal flats along the western coast of Korea. After the formal courses were completed, one of the participants, La Regina Veronica from Italy, briefly introduced the Cosmo-Skymed system and its applications. A questionnaire was then distributed to all participants for collecting suggestions on improving future summer schools. Overall, the students' responses indicated that the summer school was well organized and successful. Most of them believed that they had good opportunities to be exposed to the latest knowledge and skills, and learned about new concepts to keep up with the fast progress in satellite data processing methods.

After all the courses and training were completed, a graduation ceremony and a farewell dinner party were held. Certificates signed by the Executive Secretary of PICES (Alexander Bychkov) and three of the conveners (Kyung-Ryul Kim, Yu-Whan Ahn and Kyung-Ae Park) were given to all students at the end of the school. The students' knowledge and understanding of the lecture content were tested in a quiz contest for which all the lecturers willingly submitted "problems". Small prizes were given to the winner of each question.

Satellite oceanography is one of the most advanced and rapidly progressing fields in the investigation of ocean phenomena. Many countries have formulated a variety of plans on earth monitoring from space and, as a result, progress in satellite oceanography might be even more accelerated. This suggests that more advanced summer schools should be conducted continuously in order to provide a labor force that is skilled in the increasing number of space-related tasks. The summer school on "*Satellite Oceanography for the Earth Environment*" is believed to be timely and is an important step toward helping the next generation of scientists to comprehend the current status of the earth's environment or ocean environments and predict their future.

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