The 8th Asian/17th Korea-Japan Workshop on

Ocean Color 2020

Program & Abstracts

: 21-23 December 2020
21 December: Google Earth Engine Lecture
22~23 December: workshop sessions

: Online via zoom
Registration: https://bit.ly/AKJWOC2020

JAMSTEC

NAGOYA UNIVERSITY ISEE INSTITUTE FOR SPACE-EARTH ENVIRONMENTAL RESEARCH

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KOSC KOREA OCEAN SATELLITE CENTER

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LECTURE & WORKSHOP INSTRUCTIONS

Zoom ID and Passcode

Both lecture and workshop have the same Zoom link, ID, and passcode as follows:

- Zoom link: https://us02web.zoom.us/j/82885693242
- Zoom ID: **828 8569 3242**
- Passcode: mailed on **14 December 2020**

Session Structure

- **1 minute before the session**: The session chair will introduce and start the session
- Presenter has **15 minutes** for presentation followed by **5-minute** Q&A (total 20 minutes)

Zoom General Tips

During the sessions

- The host will mute all participant microphones during the sessions
- Participants can unmute themselves for asking questions during the Q&A
- To ask a question, click “Participants” button and click “Raise Hand” button

Breakout rooms

- There will be several breakout rooms allowing participants to have an intense discussion, a relaxed chat with a smaller number of participants
- Participants can join freely available breakout rooms
- Participants can request the host to create breakout rooms with the desired room names
- Breakout rooms will be available during lunch/break times and upon request before/after the sessions

Zoom version and setting

- To be able to use the zoom self-select breakout room feature, participants have to use Zoom Application version 5.3.0 or higher. Do not join the meeting from a web browser
- Download the latest version (5.4.6) from https://zoom.us/download
- The zoom will be set up to hide participant profile pictures. Therefore, when participants turn off the video mode, only participant names will be displayed on the video screen

GOOGLE EARTH ENGINE (GEE) LECTURE

DAY-1, 21 December 2020

Japan Standard Time	PROGRAM
10:55~11:00	**OPENING REMARKS**
Introductory Overview to the Google Earth Engine	
11:00~11:05	Guidance & Training Structure
11:05~11:15	Earth Engine (EE) Platform
11:15~11:45	EE Code Editor
11:45~12:15	EE JavaScript
12:15~12:40	Temporal and Spatial Reducers
12:40~14:00	**LUNCH**
Time Series Analysis Hands-on	
14:00~14:10	Temporal and Spatial Reducers (Recap)
14:10~14:40	Time Series Analysis (By Point or Region)
14:40~15:10	Time Series Analysis (Interactive), User Interface
15:10~15:30	Wrap Up
15:30~15:50	Q&A
	CLOSING

WORKSHOP PROGRAM

DAY-2, 22 December 2020

Japan Standard Time	Program/Session/Title *Presenter/Chairperson*	Page
10:55~11:00	**OPENING REMARKS**	
	Session 1 : Spatiotemporal variability of phytoplankton biomass in the Indonesia Seas *Chair: Sam Wouthuyzen*	
11:00~11:20	Thermal front variability in the East Nusa Tenggara waters *Afif Prabowo Jatiandana*	1
11:20~11:40	Spatio temporal variability of oceanographic features and relationship with VMS footprint in southern Java-Bali waters *Atika Kumala Dewi*	2
11:40~12:00	Study of internal solitary waves patterns on the GCOM-C/SGLI ocean color products in the Lombok Strait areas *Chonnaniyah*	3
12:00~12:20	Distribution of sea surface temperature (SST) and chlorophyll-a in Bone Gulf, Indonesia obtained by using Aqua Modis Satellite Imagery *La Ode Muhammad Yasir Haya*	4
12:20~12:40	Seasonal and interannual variations of surface chlorophyll-a variations in the Karimata Strait *Iskhaq Iskandar*	5
12:40~14:00	**LUNCH**	
	Session 2 : ENSO and IOD impacts on phytoplankton biomass *Chair: Iskhaq Iskandar*	
14:00~14:20	Influence of El Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) on coastal upwelling in south coast of Java Sea *Herlambang Aulia Rachman*	6
14:20~14:40	Enhanced surface wind stress over the Sangihe-Talaud Islands waters during the extreme climate events of 2015 and 2019 *Riza Yuliratno Setiawan*	7
14:40~15:00	The strong downwelling (upwelling) impact on chlorophyll-a during the 2016 (2019) negative (positive) Indian Ocean Dipole events in the Palabuhan Ratu Bay, Indonesia *Jonson Lumban-Gaol*	8
15:00~15:20	Influence of 2019 Indian Ocean Dipole on the MODIS Aqua chlorophyll *a* at northern Malacca Straits and eastern Bay of Bengal *Chun Knee Tan*	9
15:20~15:40	Inter-annual variability of surface circulation of southwestern Indian Ocean and its influence on biological productivity *Benny Peter*	10
15:40~16:00	**BREAK**	

	Session 3 : Ocean color algorithm developments *Chair: Jonson Lumban-Gaol*	
16:00~16:20	Estimation of Indonesian sea surface salinity (SSS) using ocean color of Aqua-MODIS data *Sam Wouthuyzen*	11
16:20~16:40	An algorithm for estimating the suspended sediment concentrations using a multispectral sensor *Jong-Seok Lee*	12
16:40~17:00	A new algorithm to estimate chlorophyll-a concentrations in turbid Yellow Sea water using a multispectral sensor in a low-altitude remote sensing *Ji-Yeon Baek*	13
17:00~17:20	Application of machine learning for ocean colour mapping in the coast of Johor Straits on Landsat 8 and Sentinel 2 imageries *Mohd Nadzri Md Reba*	14
17:20~17:40	Development of green *Noctiluca* discriminating algorithm in the upper Gulf of Thailand based on the *in-situ* bio-optical datasets (2017 – 2019) *Jutarak Luang-on*	15
17:40~18:00	A case study on the remote red tide quantification using multispectral camera on UAV *Wonkook Kim*	16
18:00~18:10	**ANNOUNCEMENT & ADJOURN**	

DAY-3, 23 December 2020

Japan Standard Time	Program/Session/Title *Presenter/Chairperson*	Page
	Session 4 : Marine ecosystem and primary production *Chair: Salem Ibrahim Salem*	
11:00~11:20	The improvement of depth-integrated marine net primary production estimation based on phytoplankton absorption model (AbPM) *Jinghui Wu*	17
11:20~11:40	Estimation of primary production in coastal waters of southern centre of Vietnam using remote sensing data *Phan Minh-Thu*	18
11:40~12:00	Delineation of marine ecosystem zones based on surface chlorophyll-a in the Gulf of Thailand *Dudsadee Leenawarat*	19
12:00~12:20	How much the aerosol affects on chlorophyll bloom *Young-Heon Jo*	20
12:20~12:40	Monitoring coastal fisheries using satellite radar imagery and Google Earth Engine *Fumihiro Takahashi*	21
12:40~14:00	**LUNCH**	

Thermal front variability in the East Nusa Tenggara waters

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Thermal front variability in East Nusa Tenggara waters (NTT) are influenced by seasonal and inter-annual variations. This study aims to examine the relationship between duration and intensity of the thermal front which is influenced by El Niño-Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), and seasonal variations. Thermal front variability analysis was carried out in all NTT waters. The average intensity of the thermal front in NTT waters in 2007-2017 was 1.3°C with an average duration of thermal front for 3 months. The highest average thermal front intensity occurs in Transition Season I of 1.4°C and the combined conditions between La-Nina and Positive IOD of 1.5°C. The strongest thermal front intensity in NTT waters is found in the Sape Strait every season and every year, except in the combination of La-Nina and Negative IOD conditions in the Ombai Strait. There was a strong intensity of the thermal front in the Sape Strait of 3°C in April 2014 (Normal) with the longest duration of the appearance of the thermal front in 2016 (La-Nina and Negative IOD) for 9 months.

Spatio temporal variability of oceanographic features and relationship with VMS footprint in southern Java-Bali waters

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Current knowledge of tuna habitat preference is essential for the implementation of an ecosystem approach to fisheries management in the future. Lately, oceanographic parameters approach used for providing habitat preference. In this paper, monthly global ocean satellite observation of chlorophyll-a and monthly global forecasting data of environment parameters such as sea surface temperature (SST), and sea surface height (SSH), and salinity for 2013 to 2017, have been combine as a dataset to observe the spatial patterns of oceanographic features over Southern java and bali waters. The relationships of oceanographic features and habitat preference were explored with a statistical method and GIS-based analysis. Vessel Monitoring System (VMS) of longliner used to determine information about spatial and temporal of fishing activity. Therefore in this study certainly showed the characteristic of chlorophyll-a, SST, SSH, and salinity in tuna habitat preference.

Study of internal solitary waves patterns on the GCOM-C/SGLI ocean color products in the Lombok Strait areas

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Internal solitary waves (ISWs) are the most easily recognized oceanographic phenomena in the remote sensing imagery observation. This study investigates images from ocean color sensors in the Lombok Strait areas when there was a near-coincident pass over the Sentinel-1 Synthetic Aperture Radar (SAR). Ocean color sensors provide another opportunity to observe ISW from the variation of the ocean color products. ISW activity below the sea surface causes variations in the surface currents which modulate the sea surface roughness. Optical imagery can detect ISW as alternating bright and dark stripes. Increased brightness occurs in the ISW-induced surface current convergence zone and the decreased brightness in the current divergence zone. Enhanced band profiles of chlorophyll-a concentration (CHLA), normalized water leaving radiance (NWLR) and sea surface temperature (SST) from the GCOM-C/SGLI sensors in the Lombok Strait areas has been revealed in this study. We used two images of SGLI (TOA Radiance, CHLA, NWLR, and SST) at different dates to compare the TOA Radiance variation when the ISW patterns were detected or not in the SGLI ocean color products. The brightness intensity (TOA Radiance) of optical images can affect the ocean color products ISW detection patterns if the difference between crest and trough is greater than 5 $W.m^{-2}.\mu m^{-1}.sr^{-1}$. The darker line patterns with smaller CHLA values detected in the CHLA data is caused by the converging zone generated by the rough surface due to the ISW crest.

Distribution of sea surface temperature (SST) and chlorophyll-a in Bone Gulf, Indonesia obtained by using Aqua Modis Satellite Imagery

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Sea surface temperature (SST) and chlorophyll-a are two essential parameters needed by organisms in the oceans, including in the Gulf of Bone. This study aims to assess the spatial and temporal distribution of sea surface temperature and chlorophyll-a and analyze its relationship to surface ocean currents' patterns. We use monthly sea surface temperature data from April 2018 to March 2019 obtained from Aqua MODIS level-3 image data, and current data were sourced from the Copernicus Marine Environment Service (CMES) model data. Our analysis results showed that the surface currents in Bone Gulf were strongly influenced by the Flores Sea's surface currents patterns. The average current velocity was 0.5 m/s, with the most significant velocity in the southern part of Bone Gulf. The current speed decreased in the northern part of the Bone Gulf and gradually increased to the gulf's central part, and then there was a high increase in the southern part of the gulf. Spatially, the sea surface temperature appeared to be higher in the northern part of the Bone Gulf (from 27 to 29^{0}C) than in the bay's southern part (from 29 to 32^{0}C). This condition was caused by optimal solar heating in shallow waters (northern part of the Bone Gulf), while the gulf's southern part was influenced by changes in monsoon winds. Spatially, chlorophyll-a concentrations fluctuated every month but tended to be higher in the near land area ranged between 1.6 and 2.2 mg/m^3, while in the central part of the gulf the concentrations were low (from 0.10 to 0.50 mg/m^3). This condition was influenced by the unstable change of the sea surface currents due to the monsoon winds and the Flores Sea's surface currents.

Seasonal and interannual variations of surface chlorophyll-a variations in the Karimata Strait

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Water mass transport from the South China Sea (SCS) via the Karimata Strait (KS) plays an important role in regulating the Indonesian Throughflow (ITF). On seasonal timescale, it was suggested that the KS transport could reduce the Makassar Strait throughflow during boreal winter. On interannual timescale, the increase of SCS throughflow during El Niño years reduced the ITF via the Makassar Strait. The situation reverses for the La Niña years, where very weak SCS throughflow provide favorable condition for the ITF via the Makassar Strait. Considering the important role of the KS transport on the ITF variability as well as the surface chl-a variability within the Indonesian seas, this study is designed to evaluate the dynamics underlying seasonal and interannual surface chl-a variability in the KS. The analysis shows that high chl-a concentration (~0.4 mg m^{-3}) was observed in the KS during December – February (northwest monsoon season). This high chl-a concentration extends northwestward along the eastern coast of Peninsular Malaysia and northeastward along the northern coast of Borneo Island. Interestingly, the observed high chl-a concentration in the KS during the northwest monsoon shows opposite situation with that observed along the western coast of Sumatra and along the southern coast of Java, which shows a low chl-a concentration during this season. Further analysis indicates that strong upwelling signal was observed in the central-eastern part of the South China Sea (i.e. positive wind stress curl) and along the northern coast of Java and eastern coast of Sumatera (i.e. negative wind stress curl) from December to February. In the southeastern part of the KS and northern part of Java Sea off south coast Kalimantan, positive wind stress curl forced downwelling. However, the high chl-a concentration in the KS during the northwest monsoon season could not be explained solely by the wind dynamics. It is suggested that the increase of surface chl-a concentration in the KS during the northwest monsoon season was associated with an increase of allochthonous nutrient from discharges caused by an increased precipitation over the land. On interannual timescale, high chl-a concentration was observed in the KS during the JAS season when the La Niña event took place in the tropical Pacific. The warm SST associated with downwelling favorable winds covered the entire KS during the La Niña events. Therefore, it is suggested that anomalous chl-a bloom during the La Niña event was associated with anomalously high precipitation over the land.

Influence of El Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) on coastal upwelling in south coast of Java Sea

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The South Coast of Java is areas with an intensity of coastal upwelling caused by the Monsoon Winds (Trade Winds). Coastal Upwelling phenomenon will affect oceanographic conditions, especially in areas near Coastal. Also, this region is affected by several regional climate anomalies such as El Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD). This study will analyze how the strength of these two phenomena on the intensity of coastal upwelling. Coastal Upwelling is calculated based on Cross Shore Ekman Transport, Upwelling Index (UI) and Coastal-Offshore SST gradient in South Coast of Java. Based on Partial Correlation Analysis is showing the impact of each of these phenomena on coastal upwelling and oceanographic parameters in both the adjacent coastal and offshore regions. The result show of the analysis using partial correlation shows that the effect of IOD is more significant than ENSO on the intensity of Upwelling and Variability of Oceanographic Parameters in South Coast of Java. The anomaly of UIsst, UIwind, and Chlorophyll-a show that during IOD years is higher impact on coastal upwelling than during ENSO event.

Enhanced surface wind stress over the Sangihe-Talaud Islands waters during the extreme climate events of 2015 and 2019

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The ocean region off the Sangihe-Talaud Islands (STI) is pivotal as it provides a pathway for the Indonesian Throughflow and situated in the epicenter of global marine biodiversity. However, until today sea surface variability of the region is poorly studied due to lacked long-term in situ measurements. The present research aims to elucidate the seasonal and interannual variability of surface winds and the effect of 2015 El Niño-Southern Oscillation (ENSO) and 2019 Indian Ocean Dipole (IOD) on the wind by analyzing long-term datasets (2007-2019) of satellite-derived sea surface wind, sea surface temperature (SST), and surface chlorophyll-a concentration. Results show that the prevailing northeasterly and southerly winds over the STI waters induce SST cooling and phytoplankton bloom. Furthermore, our correlation analysis revealed that the ENSO plays a dominant role in affecting sea surface condition off the STI than the IOD, presumably due to its proximity to the Pacific Ocean. This inference is also supported by anomaly analysis that shows robust effect during the climate extreme events of 2015 compared to 2019. Collectively, results of this research highlight the importance of extreme climate events in shaping ocean condition.

The strong downwelling (upwelling) impact on chlorophyll-a during the 2016 (2019) negative (positive) Indian Ocean Dipole events in the Palabuhan Ratu Bay, Indonesia

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The Indian Ocean Dipole (IOD) is well-known as a anomalously low sea surface temperatures (SST) associated with strong upwelling in the eastern Indian Ocean and high SST in the western Indian Ocean, it is known as the IOD positive phase (pIOD). Featuring opposite anomalies over a similar region is the IOD negative phase (nIOD). In this study, we analyzed the influence of negative (positive) of IOD on a chlorophyll a (Chl-a) concentration as an indicator of phytoplankton biomass in the eastern Indian Ocean (EIO) off Java. We also conducted field surveys in the EIO off Palabuhanratu Bay at the peak (October) and the end (December) of the 2019 positive IOD phase. Our findings show that the Chl-a concentration had a strong and robust association with the 2016 (2019) negative (positive) IOD phases. The negative (positive) anomalous Chl-a concentration in the Palabuhan Ratu Bay associated with the negative (positive) IOD phase induced strong downwelling (upwelling), leading to the preponderant decrease (increasing) of small pelagic fish production in the Palabuhanratu.

Influence of 2019 Indian Ocean Dipole on the MODIS Aqua chlorophyll *a* at northern Malacca Straits and eastern Bay of Bengal

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The Positive Indian Ocean Dipole (IOD) in 2019 is one of the strongest IOD events after the 1997 IOD. The influence of the 2019 IOD on the Chlorophyll *a* (chl *a*) at northern Malacca Straits (NMS) and eastern Bay of Bengal (BOB) is investigated using the MODIS Aqua satellite imageries (July 2002- April 2020). During the Northeast Monsoon (November – February), large phytoplankton bloom occurs at NMS and northern tip of Sumatra Island due to the upwelling event. A 1^{o} x 1^{o} box area at the NMS (98^{o} - 99^{o}E, 5^{o} - 6^{o}N) between the Malay Peninsular and Sumatra Island has been selected to study the variation of the chl *a* as well as the intensity of the monsoon driven phytoplankton bloom event. Results show that chl *a* at NMS recorded highest value of 2.1 mg m^{-3} in January 2020. High chl *a* water extended from the Malay Peninsular reached the Sumatra Island in December 2019 and January 2020. At the same time, strong upwelling observed at the northern tip of Sumatra Island where there is intense cooling on the sea surface temperature. It triggered a large bloom of high chl *a* water from the upwelling region of northern Sumatra Island extended across the Bay of Bengal and reached Sri Lanka. This cross basin chl *a* bloom event occurred from December 2019 till February 2020, and start decaying in March 2020. Analysis of the chl *a* variation at 90^{o} - 93^{o}E, 5^{o} - 8^{o}N found highest chl *a* value of 0.405 mg m^{-3} recorded during January 2020. The bloom that spanning across the Bay of Bengal is distinctly different from the upwelling induced large bloom at Southwestern Sumatra Island which occurred earlier during September – November 2019. This high chl *a* bloom coincides with the propagation of low Sea Surface Height Anomaly from the east to west of southern Bay of Bengal. A similar event has been observed during 1997 IOD. In brief, the 2019 IOD caused the surge of high chl *a* at the NMS upwelling region and the eastern BOB during Northeast Monsoon. Detailed investigation on the effect of upwelling coastal Kelvin Wave that originated from the Java & Sumatra during strong IOD on the upwelling events in the study area is needed.

Inter-annual variability of surface circulation of southwestern Indian Ocean and its influence on biological productivity

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South western Indian Ocean receives much attention as it is a region of intense mesoscale activity and associated biophysical processes. The present study analysed the near surface circulation and its influence on surface Chlorophyll distribution using remote sensing observations. High resolution Eulerian mean velocity field had been derived by combining the available satellite tracked surface drifter data with satellite altimetry and ocean surface winds. The drifter data used in this study includes Argos and surface drifter data from Global Drifter Program. Maps of Sea Level Anomaly (MSLA) weekly files with a resolution of 1/3° in both Latitude and Longitude for the period 1993-2012 had been used. The weekly ocean surface mean wind fields derived from the scatterometers onboard ERS 1 / 2, Quikscat and ASCAT have been employed to estimate the wind driven component. The inter-annual variations of surface currents and associated changes in productivity were determined for the southwestern Indian Ocean region between 2 ºS to 40 ºS and East African Coast to 60 ºE. The estimated mean velocity field exhibits the conspicuous South Equatorial Current and the southward flowing East Madagascar Current with speed up to 1 m/s. The Mozambique Current is evident in the mean field, but strong anomaly is found in the Mozambique Channel. Largest velocity anomalies of about 0.5 m/s are present near the equator. The currents and the Chlorophyll distribution shows significant changes during Dipole events. Mesoscale features like; eddies and meanders are modifying the Chlorophyll distribution especially, in the Mozambique Channel and south of Madagascar. The local Chlorophyll maxima and minima is closely associated with the mesoscale features of the surface circulation.

Estimation of Indonesian sea surface salinity (SSS) using ocean color of Aqua-MODIS data

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Salinity is an important marine parameter that affects the physical, chemical, and biological characteristics of the sea. However, the sea surface salinity (SSS) measurement from space lags far behind the SST and Chlorophyll-a (Chl-a) for about 3 decades. Salinity does not have a signal that can be detected directly by satellites sensor. However, many studies showed that SSS is strongly correlated with the inverse of the ocean color parameter called CDOM. This study aims to develop an empirical model to estimate the SSS of Indonesian seas using ocean color data obtained from Aqua-MODIS satellite and to evaluate its reliability. The empirical SSS estimation model was developed using SSS data measured by Argo floats between 2003 and 2019, which are scattered across the western and eastern Indonesian seas, under the influence of the Indian and Pacific oceans, respectively. The satellite data used is 8-daily remote sensing reflectance data (Rrs) in the blue band (412, 443, 469, and 488 nm) and absorption coefficient data of non-algal material due to gelbstoff, detrital material, and CDOM (ADG at 443 nm) from Aqua-MODIS satellite with 4 km resolution obtained simultaneously with the SSS measurement dates of the Argo floats. All of these data can be obtained on the NASA Giovanni's website. The results show that the relationship between a total number of 2955 Rrs Aqua-MODIS data sets at blue wavelengths (412, 443, 469, and 488 nm) and SSS data sets measured by Argo float is weak ($R^2 < 0.01$). On the other hand, adg at 443 nm has a strong correlation with SSS (R^2 0.203, low RMS Error 0.11 PSU, and mean absolute bias 0.27 PSU). This empirical model predicts well the SSS of Indonesian clear (case-1) waters with an adg at 443 nm ranging from 0.00220 ~ 0.01895 m^{-1} or with an SSS value ranging from 31.61~35.01 PSU. Multi-temporal validation of this model using CTD cast data acquired from various oceanographic cruises (2006-2019) show that the empirical model predicts SSS in moderate to well level for the clear seas with adg 443 nm in the range of 0.0058 to 0.0190 m^{-1}, but it will introduce worse bias of SSS if adg at 443 nm > 0.0200 $m^{-1}$with unrealistic RMSE of 14 PSU. In conclusion, the use of ocean color parameter of adg at 443 nm seems applicable to estimate the SSS of Indonesian clear (case-1) seas. Even so, more validation is still needed to improve this empirical model.

An algorithm for estimating the suspended sediment concentrations using a multispectral sensor

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In this study, a turbidity concentration algorithm based on a multispectral camera was proposed. The study area is Saemangeum in the west sea of Korea, and the turbidity is high, and the water depth is shallow due to the sediment supplied from the broad river nearby. In addition, due to the construction of the seawall, the sea areas inside and outside the seawall are separated, and seawater exchange occurs periodically due to the opening of the sluice gate. The sensor used in this study is Micasense's RedEdge-MX, which can take spectral images of a total of 5 wavelength bands (475, 560, 668, 717, 842 nm). In addition, RedEdge-MX can acquire downward irradiance and GPS/IMU information whenever spectral image data is captured through a downwelling light sensor (DLS) module. Water sampling for turbidity (SPM: Suspended Particulate Matter) measurement was performed in parallel with multispectral imaging at each station using a ship, and after observation, it was measured by filtration on GF/F filter paper in a laboratory. Multi-linear regression (MLR) was used to compare the reflectance of seawater observed through a multispectral camera and turbidity data observed in the field. R-square and RMSE between the two parameters were 0.8441 and 5.4205 (mg/L), respectively. Finally, we attempted to perform turbidity imaging by altitude (~500m) through a multispectral camera mounted on the LARS (low-altitude remote sensing) system.

A new algorithm to estimate chlorophyll-a concentrations in turbid Yellow Sea water using a multispectral sensor in a low-altitude remote sensing

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In this study, a low-altitude remote sensing (LARS) observation system was employed to observe a rapidly changing coastal environment-owed to the regular opening of the sluice gate of the Saemangeum seawall-off the west coast of South Korea. The LARS system uses an unmanned aerial vehicle (UAV), a multispectral camera, a global navigation satellite system (GNSS), and an inertial measurement unit (IMU) module to acquire geometry information. The UAV system can observe the coastal sea surface in two dimensions with high temporal (1 s^{-1}) and spatial (20 cm) resolutions, which can compensate for the coarse spatial resolution of in-situ measurements and the low temporal resolution of satellite observations. Sky radiance, sea surface radiance, and irradiance were obtained using a multispectral camera attached to the LARS system, and the remote sensing reflectance (R_{rs}) was accordingly calculated. In addition, the hyperspectral radiometer and in-situ chlorophyll-*a* concentration (CHL) measurements were obtained from a research vessel to validate the R_{rs} observed using the multispectral camera. Multi-linear regression (MLR) was then applied to derive the relationship between R_{rs} of each wavelength observed using the multispectral sensor on the UAV and the in-situ CHL. As a result of applying MLR, the correlation and root mean square error (RMSE) between the remotely sensed and in-situ CHLs were 0.94 and ~0.8 μg L^{-1}, respectively; these results show a higher correlation coefficient and lower RMSE than those of other, previous studies. The newly derived algorithm for the CHL estimation enables us to survey 2D CHL images at high temporal and spatial resolutions in extremely turbid coastal oceans.

Application of machine learning for ocean colour mapping in the coast of Johor Straits on Landsat 8 and Sentinel 2 imageries

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Satellite ocean colour has a spectroscopic capability to extract Chlorophyll-a (Chl-a) concentration on the ocean surface. The Chl-a information has been used as a proxy to determine the phytoplankton biomass distribution and becomes an indicator of the trophic status of the water body. Long-term records of Chl-a from 1-km satellite ocean colour images have served worldwide users since 1999 and offered the opportunity for the development of ocean colour algorithms. Most of the ocean color algorithms performed well in a clear water state but if the water contains algae abundance, particularly exist in the near coast and shallow water, the algorithm may result in significant uncertainty when applying on the coarse spatial resolution image. Therefore, this study assesses the capability of the recent Landsat 8 Operational Land Imager (OLI) and Sentinel-2 Multi-Spectral Instrument (MSI) to estimate the high-resolution Chl-a in the coastal area of Johor Straits, Malaysia. To improve the accuracy of Chl-a estimation and assess the impact of complex optical interaction in the coastal water, machine learning modeling in different variants were proposed. Artificial Neural Network (ANN), Support Vector Machine (SVM) and Random Forest (RF) techniques establish the relationship between the normalized water-leaving reflectance and the collocated in-situ measurements and later hypothetically estimate the Chl-a from the OLI and MSI images. This study also presents the results of nutrients (nitrate and phosphate) and sea surface temperature derived from the same machine learning methods. For both MSI and OLI products, the RF and SVM give comparable accuracy of Chl-a (> 6 mgm^{-3}) but the ANN provides slightly better (< 3 mgm^{-3}). The machine learning approach has powerful capability to improve the ocean color algorithm accuracy which is limited by the complex optical interaction in coastal waters, and this study has successfully demonstrated the application during the algae abundance in coastal water of Johor Straits.

Development of green *Noctiluca* discriminating algorithm in the upper Gulf of Thailand based on the *in-situ* bio-optical datasets (2017 – 2019)

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Green *Noctiluca scintillans*, a single cellular heterotrophic dinoflagellate containing photosynthetic symbiont *Pedinomonas noctilucae*, is one of the most frequent harmful algal bloom in the upper Gulf of Thailand (uGoT). The high density of green Noctiluca cells change the seawater to deep milky green and potentially lead to massive fish mortality due to depleting dissolved oxygen in the water column. Since data continuity limitation, our knowledge of the green Noctiluca and other red-tide species behaviors has not been clarified. This study aims to develop an algorithm to discriminate green *Noctiluca* from the other dominant species on satellite ocean color data. The development was based on chlorophyll-a, phytoplankton composition derived from HPLC-CHEMTAX, and remote sensing reflectance measured by the RAMSES hyperspectral radiometer (320 – 950 nm), which collected in the uGoT during the blooming period between 2017 and 2019. The spectral characteristics of green Noctiluca and other species blooms, discrimination method, and application of the algorithm to satellite data will be presented.

A case study on the remote red tide quantification using multispectral camera on UAV

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Red tide is a harmful algal bloom that causes adverse effects on the coastal ecosystem as well as on the aquacultural industry. This study investigates the potential of a multispectral camera loaded on an unmanned aerial vehicle in terms of quantifying red tide intensity in coastal waters. The red tide quantification algorithm was constructed based on the band ratio of remote sensing reflectance at the blue and the red bands of MicaSense RedEdge-M, using chlorophyll-a concentration measurements obtained from a ship surveying. After the airborne observation with the optimal observation geometry and the radiometric preprocessing steps, red tide patches around Yeosu were successfully identified with the UAV/multispectral system, producing the intensity images in the study area.

The improvement of depth-integrated marine net primary production estimation based on phytoplankton absorption model (AbPM)

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While there has been considerable progress over the past two decades in estimating marine net primary production (NPP, mg C m^{-2} d^{-1}) from space, current satellite NPP products (VGPM, CbPM or CAFE) for the oceans continue to suffer from large uncertainties. To highlight the potential sources of uncertainties in NPP estimates and lay the groundwork for reducing uncertainties and improving satellite estimates of NPP, we provide a phytoplankton absorption coefficient $a_{ph}(\lambda)$-based mechanism model (AbPM). AbPM define NPP as the product of energy absorption (derived from $a_{ph}(\lambda)$ and photosynthetically active radiation (PAR, $\lambda = 400$ to 700 nm, W m^{-2})) within photosynthesis and photosynthetic quantum yield (ϕ, mol C mol $photons^{-1}$) in which absorbed energy is converted into carbon biomass. AbPM is the only method that not only separate the physiology and optical actions, but also use the direct derivatives from ocean-color remote sensing, i.e, $a_{ph}(\lambda)$ spectrum and the surface or vertical profile of wavelength-dependent irradiance. Here, we use the long-term *in-situ* data from HOT (Hawaii Ocean Time series), BATS (Bermuda Atlantic Time series Study) and CARIACO Ocean Time-Series Program for more than 20 years to evaluate the performance of the AbPM in capturing the seasonal dynamic distribution of NPP. We also take two of the most widely used models, the chlorophyll-based VGPM and the carbon-based CbPM, and the newest model CAFE into comparison. The results show that the NPP estimated by the AbPM is obviously more consistent with the *in-situ* NPP and has the highest coefficient of determination and lowest uncertainties. AbPM uses optical properties (a_{ph}) instead of biological properties (Chlorophyll *a*) as a variable, which not only avoids the uncertainty and error caused by the estimation of a^*_{ph} as a constant, but also remove the influence of pigment "packaging effect" and Colored dissolved organic matter (CDOM). Another advantage of AbPM is that it accurately expresses the non-uniform vertical distribution of the underwater light field, effectively avoiding the high uncertainty caused by the complexity of the vertical distribution of chlorophyll *a*. The application of AbPM in the North Atlantic and North Pacific regions also proves that the regionalized AbPM model can match the measured data more accurately, and has a more accurate estimation of the temporal and spatial changes in the North Atlantic and North Pacific. All above indicate that the AbPM has a good potential application prospect.

Estimation of primary production in coastal waters of southern centre of Vietnam using remote sensing data

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Based on the in-situ and remote sensing data, the paper aims to recognize spatial and temporal distribution of phytoplankton photosynthesis in coastal waters and its ecological factors impacting on changes of primary production. These results support to discuss the variation of primary production in coastal waters of Southern Central Regions in Vietnam, such as Van Phong, Nha Phu, Nha Trang and Cam Ranh Bay as well as the coastal waters. The paper also contribute to the discussion how to involve primary production to ecological modelling in coastal waters.

Delineation of marine ecosystem zones based on surface chlorophyll-a in the Gulf of Thailand

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The Gulf of Thailand (GoT) is a semi-enclosed sea, located in the tropical area. This area is under monsoon systems which controlling the variations of phytoplankton. To understand more details about dynamic of phytoplankton in this area, we delineated the zones of phytoplankton variations in the GoT by applying the Empirical Orthogonal Function (EOF). The level-3 Moderate Resolution Imaging Spectroradiometer (MODIS) chl-a from 2002 to 2018 were used in this study. Our results showed the three EOF modes of the spatial-temporal patterns of surface chl-a variability. The three modes accounted for 57% of the total variance. The first mode (39%) revealed high chl-a variation near the cape Ca Mau and southern coast of the GoT. The positive and negative phases occurred during the northeast and southwest monsoons, respectively. The second mode (12%) described the variation near the northern coast, eastern part of Upper GoT, and GoT mouth. The positive phase occurred from June to September and became negative from November to May. The first two modes of EOFs showed a distinctive difference in the spatial and temporal chl-a variations during the northeast and southwest monsoons. The third mode of EOF (6%) described by the chl-a variability along the western coast from Upper GoT to 10 degrees south, and the west of cape Ca Mau near the Rach Gia Bay. The positive phase occurred only from October to December. This mode revealed the impacts of river discharge and northeast monsoonal wind. By combining the results from EOF modes, the marine ecosystem zones in the GoT were separated into three coastal zones and three offshore zones which response in different environmental parameters.

How much the aerosol affects on chlorophyll bloom

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One of the most difficult research is to estimate how much the environmental changes affect on marine ecosystem quantitatively. The deep learning algorithm is one of ways to understand how the complex natural systems are related. In this presentation, we examined the influence of deficient aerosols over the central Yellow Sea resulting from the shutting down plants in China due to COVID-19 from early this year. Specifically we designed Random Forest algorithm with five inputs influencing Chlorophyll blooms there. We found that this year's non-blooming is related with lack of normal aerosol, which is used to provide high nutrients into the sea. Especially, we could determine the ranges of Sea Surface Temperature (SST) and aerosol concentration for the favourable conditions for CHL blooms.

Monitoring coastal fisheries using satellite radar imagery and Google Earth Engine

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In the coastal region, satellite remote sensing data is being used to verify the legality of commercial trap net fisheries and to detect changes in fishing gear that cause a decrease in fishing efficiency at an early stage. High-frequency observation services using small satellite constellations are becoming more familiar, and such efforts are expected to accelerate. In this study, the Sentinel-1 satellite C-band SAR image VV polarization GRD product that observed Hokkaido from May 2019 to October 2019 was analyzed using Google Earth Engine to identify stationary fishing gear laid in water. The possibility was examined. As a result of comparing the fishery display layer of "Umishiru" provided by the Japan Coast Guard with the SAR image, it was concluded that the locations of the underwater fishing gear were the same and could be roughly identified. Based on this result, in order to further improve the accuracy of discrimination using SAR images, we will carry out a basic technical study on the structure and materials that efficiently reflect the radar radio waves of the satellite, and use it for marine work and fixing fishing gear. We have started the trial development of a buoyancy body that is possible and has a large radar cross section. In the future, we plan to utilize the data of Japan's commercial X-band radar satellite "ASNARO-2". Accurate sharing of the distribution of underwater fishing gear using remote sensing data can reduce marine accidents for vessels entering fixed nets zone and reduce the burden of accountability for fishery activities. Through this research and development, we will contribute to the realization of a sustainable fishery. This research and development work was supported by the MIC/SCOPE #192101001. We would like to thank Dr. Yoriko Arai, RESTEC, for handling satellite data. We would like to thank Japan EO Satellite Service, ltd. (JEOSS) for providing sample data.

Vicarious calibration of GCOM-C/SGLI

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Global Change Observation Mission-Climate (GCOM-C) satellite carrying Second-generation Global Imager (SGLI) has been launched on 23 Dec. 2017 and operated global observation since 1 Jan. 2018. SGLI has 19 spectral bands from near-UV to thermal infrared with 250m spatial resolution. The targets of SGLI include observation of global ocean color which need precise calibration better than 2-3 % accuracy of the pre-launch sensor characterization (Hashiguchi et al., Proc. SPIE, 2016). After the launch, the temporal change of SGLI gain has been evaluated by the lamp and solar light through on-board diffusers (Urabe et al., Remote Sensing, 2020) and monthly lunar calibration (Urabe et al., Proc. of IEEE/IGARSS, 2019), the temporal change of the gain has been corrected in the processing of Level-1B data (the top of atmosphere radiance/reflectance product). However, vicarious calibration is still needed to reduce the bias-type error of radiometric gain and improve the consistency with aerosol models used in the ocean-color atmospheric correction. SGLI vicarious calibration is based on in-situ water-leaving radiance (L_{wn}) observation of MOBY (Clark et al., 2003) and BOUSSOLE (Antoine et al., 2006) with BRDF correction by Morel and Maritorena 2001. Look up tables of the Rayleigh reflectance, aerosol reflectance and transmittance are calculated by Pstar4 (Ota et al., 2010) using size distribution of AERONET climatology (Omar et al., 2005) and Shettle and Fenn, 1979. For each in-situ observation (clear sky and out of the sun-glint area), the aerosol reflectance and transmittance are estimated by SGLI observations at VN07 and VN10 as same as the ocean-color atmospheric correction except for using in-situ L_{wn} at VN07 band. The vicarious calibration coefficients k_v are derived as $k_v = L_{observation} / L_{simulated}$. The results are listed in table 1. The different aerosol models caused about 1% difference of k_v. The coefficients are compared with k_v by the same way using L_{wn} from AERONET-OC and MODIS Level-3 global R_{rs}; the difference was less than about 2%.

Table 1 Vicarious calibration coefficients k_v (Corrected radiance = L1B radiance × k_v)

references	Sample number	VN01 380nm	VN02 412nm	VN03 443nm	VN04 490nm	VN05 530nm	VN06 566nm	VN07 672nm	VN08 672nm	VN09 763nm	VN10 867nm	VN11 867nm
MOBY+BOUSSOLE (aerosol models by AERONET)	84	0.983	1.028	1.003	1.019	1.058	1.036	*1.000*	1.005	1.006	*1.000*	0.994
MOBY+BOUSSOLE (aerosol models by Shettle and Fenn, 1979)	84	0.996	1.041	1.015	1.028	1.065	1.042	1.000	1.004	0.995	1.000	0.995
AERONET-OC (aerosol models by AERONET)	1066	0.965	1.010	0.987	1.010	1.055	1.036	*1.000*	1.009	0.990	*1.000*	1.005
Aqua MODIS Rrs (aerosol models by AERONET)	>5E+7	0.982	1.021	1.004	1.009	1.060	1.038	*1.000*	1.010	0.984	*1.000*	0.992

Verification of SGLI data in Ise and Ariake Bays, Japan

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Second Generation Global Imager (SGLI) of Global Change Observation Mission-Climate (GCOM-C) is providing 250 m resolution ocean color data from 2018. Because of the high resolution data, it is expected to use in small bays. We conducted field surveys in Ise and Ariake Bays, Japan, and also set AERONET-OC in Ariake Bay. SGLI images in Ise and Ariake Bays were clear and showed the advantages of the high resolution data. Chlorophyll-a concentrations are also fairly accurate, although the short wavelength remote sensing reflectances were often negative. Improvement of atmospheric correction is desirable.

Validation of inherent optical properties algorithms considering GCOM-C SGLI bands using *in situ* dataset

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Inherent Optical Properties (IOPs) describe the light absorption and scattering properties of substances in water. In ocean color remote sensing, IOPs are estimated from the remote sensing reflectance (R_{rs}) by IOPs algorithms (e.g., Lee et al. (2002); Doerffer et al. (2002); Hoge and Lyon. (1996); Loisel and Stramski. (2000)). These algorithms are validated using global datasets (Lee et al. (2006); Werdell et al. (2013); Brewin et al. (2015)). However, the algorithm contains empirical parameters developed mainly considering case-1 waters (e.g., open oceans). The accuracy of these algorithms over optically complex waters (e.g., coastal waters) needs further investigation. On the other hand, the Global Change Observation Mission-Climate (GCOM-C)/ Second generation Global Imager (SGLI) was launched by the Japan Aerospace Exploration Agency (JAXA) in 2017. The SGLI sensor has excellent abilities in terms of the spatiotemporal resolution of 250 m every 2 to 3 days on global coverage. It is expected not only to monitor water qualities at coastal areas but also to estimate the IOPs as a research product for scientific understanding of biogeochemical processes, such as carbon exchanges, phytoplankton biodiversity shifts, the responses to climate changes, and so on. In this study, several IOPs estimation algorithms were validated using the global in-situ datasets (Valente et al., (2019)) and several coastal datasets cover a wide range of IOPs. The validation was conducted considering SGLI visible and near-infrared bands.

Spectral-spatial fusion between SGLI and MODIS in the Ariake Sea

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Harmful algal bloom (HAB) is an environmental problem in both freshwater and marine systems. In Japan, HAB always appears in the western part, such as the Ariake Sea. Some toxic species, like raphidophytes, could reduce fishery production and thus cause economic loss. Therefore, it is essential to know the dynamic of the toxic and non-toxic HAB in Japan's coastal area. The discrimination between different phytoplankton is based on the optical properties difference, such as remote sensing reflectance (Rrs), and derived backscattering and absorption in the visible light range. Nevertheless, there are two main restrictions from ocean color satellites in this field; spectral resolution and spatial resolution. Currently, ocean color satellites could only carry a multi-spectral spectroradiometer, which could only get the optical properties in a few specific wavelengths. For example, the MODerate Resolution Imaging Spectroradiometer (MODIS) and the Second generation GLobal Imager (SGLI) measure only ten and six visible ocean bands, respectively. Such spectral resolution makes it hard to get unique optical properties of different phytoplankton. Another restriction from the satellite is spatial resolution. MODIS takes 1 km spatial resolution data, and it may not be satisfactory to catch small HAB patches. Currently, SGLI is the highest spatial resolution (250 m) ocean color satellite in the Japanese coastal region. This research aims to develop a method for the fusion between SGLI and MODIS in the Ariake Sea. The fusion product has high spatial (250 m)-spectral (14 wavelengths) resolution Rrs. First, we will adjust SGLI wavelength to MODIS wavelength to generate a reference image only from SGLI Rrs. Then the same wavelength MODIS Rrs will be used to calibrate the reference image through regression and interpolation. The spatial and optical properties will be investigated as a basis of the fusion process. Further evaluation will be done by in-situ data and the Aerosol Robotic Network-Ocean Color (AERONET-OC) established in the Ariake Sea. This is the first research that increases the spectral resolution of SGLI by image fusion. Moreover, this research could provide more spatial and spectral optical characteristic details of phytoplankton bloom than a single satellite.

A suggestion for SGLI atmospheric correction model by considering absorptive aerosol in Tokyo Bay

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GCOM-C/SGLI launched by JAXA in December 2017 is expected to provide spatially detailed aquatic environment monitoring on coastal areas, as it is capable of 250 m resolution. However, accurate estimation of water quality on highly turbid coastal areas is very difficult due to errors of the atmospheric correction caused by anthropogenic absorptive aerosols such as exhaust fumes. In the SGLI standard atmospheric correction algorithm (Toratani et al., 2020), the aerosol reflectance is estimated by selecting the best aerosol model from a set of predetermined aerosol models based on the ratio of aerosol reflectance at two near-infrared wavelengths (673.5 nm and 868.5 nm). This aerosol model assumes non-absorbing aerosols and does not accurately identify aerosols with strong absorption properties in the visible short wavelengths. As a result, absorptive aerosols cannot be accurately identified and corrected for, and the estimated water leaving reflectance at visible short wavelengths is underestimated. In this study, an atmospheric correction method was developed at Tokyo Bay, which is surrounded by urban and industrial areas and has a high frequency of anthropogenic absorptive aerosols (Fukagawa et al., 2006), using 380 nm of a near-ultraviolet band. The algorithm uses an aerosol model constructed based on aerosol optical properties measured by a radiometer (CE318TV-12 OC) installed in Tokyo Bay. First, if the normalized water leaving radiance at 380 nm ($nL_W(380)$) is a non-physical negative value, we assume that $nL_W(380) = 0$. We then re-estimate the aerosol reflectance from the ratio of the aerosol reflectance at 380 nm and 673.5 nm by the constructed aerosol model in this study. Thereby removing unphysical values of $nL_W(\lambda)$ spectra. From the resulting nL_W of visible wavelengths, the Bio-Optical model, which was based on measured SIOPs in Tokyo Bay, was used to calculate Chl-a (Chlorophyll-a), CDOM (Color dissolved organic matter), NAP (Non algal particles) and re-estimate $nL_W(380)$. The aerosol reflectance calculation is repeated until the $nL_W(380)$ converges sufficiently, by comparing the re-estimated $nL_W(380)$ with the initial value. As a result of verifying of the constructed atmospheric correction method with the synchronous observation data with SGLI, the suggested method became possible to estimate the water leaving reflectance with higher accuracy compared to the current SGLI method.

Development of chlorophyll-a monitoring system using Geostationary Ocean Color Imager (GOCI) and high-frequency radar in Tokyo Bay

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Red tides have occurred frequently in semi-enclosed water areas like Tokyo bay, and they have been recognized as a serious environmental problem. As a way of understanding spatial distributions of phytoplankton, ocean color remote sensing is effective. Geostationary Ocean Color Imager (GOCI) instrument, on Korea's Communications, Oceans, and Meteorological Satellite (COMS), provides images with a spatial resolution of 500 m at hourly intervals, 8 times a day. GOCI satellite data is useful to figure out short-term variations of spatial distributions of Chlorophyll-a due to its characteristics of a high spatial and temporal resolution. In addition, High-Frequency radar (HF radar) is a suitable instrument for observing spatial distributions of surface currents. HF radar installed on the coast of Tokyo Bay can observe surface currents of the entire bay every 15 minutes. In this study, our objective is to develop a system, which is possible to monitor the detailed spatial and temporal behavior of Chlorophyll-a (Chl-a), using GOCI satellite images and HF radar in Tokyo Bay. For the optical satellite image analysis, the process of atmospheric correction is essential for an accurate estimation of water quality. An existing atmospheric correction algorithm for open ocean causes errors when estimating water quality in coastal areas. In this study, we developed an atmospheric correction algorithm of GOCI for coastal areas by improving the existing algorithm. Regarding Chl-a estimation model, OC4 algorithm was calibrated using *in situ* R_{rs} and Chl-a which was acquired at Tokyo Bay. Then, a comparison of estimated Chl-a with *in situ* data was conducted, and the estimation accuracy was verified. By using the developed atmospheric correction algorithm, we showed hourly spatial distributions of Chl-a, and superimposed surface currents observed by HF radar on them. The results indicated the diurnal spatial variation of Chlorophyll-a concentrations in Tokyo Bay and the factor of the variations was analyzed.

Estimation of hourly sea surface salinity in the East China Sea using Geostationary Ocean Color Imager measurements

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Sea surface salinity (SSS) is an important tracer for monitoring the Changjiang Diluted Water (CDW) extension into Korean coastal regions; however, observing the SSS distribution in near real time is a difficult task. Even though the Korean National Fisheries and Research Development Institute has been conducting ocean observations in the East China Sea (ECS), these surveys are insufficient in specific areas leading to limitations when investigating the SSS distribution. Therefore, this study aims to develop a multilayer perceptron neural network (MPNN) algorithm to estimate the SSS based on Geostationary Ocean Color Imager (GOCI) and sea surface temperature (SST) data. As in previous similar studies, various combinations of input measurements were used to train the MPNN model. A combination with 3 to 6 GOCI remote sensing reflectance (Rrs) bands, SST, and coordinate information (longitude and latitude) was found to work best for estimating the SSS in this study. According to model validations with the Soil Moisture Active Passive (SMAP) and Ieodo Ocean Research Station SSS measurements, the values of the coefficient of determination (R2) were 0.81 and 0.92 and the root mean square errors (RMSEs) were 1.30 psu and 0.30 psu, respectively. Maps of R2 and RMSE between the SMAP and GOCI SSS were examined to understand the spatial differences in the MPNN model performances. In addition, a sensitivity analysis revealed the importance of SST and the red-wavelength spectrum signal for estimating the SSS. Finally, hourly estimated SSS images were used to illustrate the hourly CDW distribution. With the model developed in this study, the near real-time SSS distribution in the ECS can be monitored using GOCI and SST data.

Comparison of cloud-free pixel ratio of chl.a field derived from different satellite ocean color missions over Ise-Mikawa Bay

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The observation frequency of satellite-derived from ocean products is important in utilizing ocean color remote sensing. The purpose of this study is to confirm the observation frequency and the effective pixel rates of chlorophyll a concentration by GCOM-C/SGLI, MODIS/Aqua, COMS/GOCI in Ise-Mikawa Bay. The target period is one year of 2019. After identical remapping, the effective pixel rate was calculated by dividing the number of effective pixels by the total number of pixels in the sea area. Comparison between MODIS/Aqua and GCOM-C/SGLI showed that the number of scenes (including cloud cover) was 340 for MODIS/Aqua versus 228 for SGLI, and the effective pixel rate per scene was 25.3% for MODIS/Aqua versus 38.0% for SGLI. In terms of average effective pixel rate per day throughout the year, it is about 24% for both sensors. The COMS/GOCI geostationary satellite observes every day and eight times per day. The eight data sets were combined to calculate the rate of effective pixels per day. The rate of effective pixels per day throughout the year was 38.8%. One GOCI-type satellite may be said to equivalent to two polar-orbiting SGLI-type satellites. The reason why MODIS/Aqua has fewer effective pixels than SGLI is because of its afternoon orbit: From the time variation of the GOCI data, the effective pixel rate is lower with 9.7-22.5% in the afternoon (12:00 to 14:00) than with 23.4-24.6% in the morning (9:00 to 11:00). Morning observations are better for ocean color remote sensing around Japan. The monthly effective pixel rate for all satellites was high in winter and lowest during the rainy season. In particular, little data is available in June. In the rainy season, it should be supplemented by in-situ observations and oceanic simulations.

Global-scale retrieval of inherent optical properties using machine learning

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Water leaving reflectance recorded by ocean color sensors is governing by the inherent optical properties (i.e., absorption and backscattering) of water and in-water constituents (i.e., phytoplankton, detritus, and colored dissolved organic matter). Through the last few decades, researchers have been proposed many approaches to retrieve the inherent optical properties (IOPs) of water bodies on a global scale. These approaches include bands ratio, semi-analytical algorithms, quasi-analytical algorithm, linear matrix inversion algorithms, and conventional neural network (NN) algorithms. However, the retrieval accuracy has significant uncertainty, particularly over inland lakes and coastal regions, due to the water environment's nonlinear complexity. The recent advantages of deep neural networks (DNN) could provide a promising approach to overcoming conventional NN limitations and water bodies complexities. The current research highlights the performance of DNN models to retrieve the total $a_{tot}(443)$ and coefficients absorption of phytoplankton $a_{ph}(443)$, detritus $a_d(443)$ and colored dissolved organic matter $a_g(443)$ at 443 nm. The DNN models' input is the remote sensing reflectance at six bands (i.e., 412,443, 488, 555, 665, 683), which are common among ocean color satellites. The DNN models were trained using simulated datasets and evaluated using in-situ datasets cover global scale. The retrieval of $a_{tot}(443)$ provided the highest accuracy with the coefficient of determination (R^2) and root mean square error (RMSE) of 0.86 and 0.52 $mg.m^3$, respectively. $a_{dg}(443)$ retrieval shows similar accuracy comparing with $a_{tot}(443)$ with R^2 and RMSE of 0.83 and 0.49 $mg.m^3$, respectively. The results show the ability of DNN to provide high retrieval accuracy over wide ranges of constituent concentrations.

Development of ocean color datasets for an optically complex coastal area

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A radiative transfer simulation is currently developing ocean color datasets to validate and intercomparison the algorithms of ocean color remote sensing (Lee, Z. 2006, Nechad, et al., 2015). As a development method for the datasets, remote sensing reflectance (R_{rs}) has been calculated by using Hydrolight radiative transfer simulation coupled with bio-optical models based on the inherent optical properties (IOPs) of phytoplankton, detritus and colored dissolved organic matters (CDOM) used by only a variable of Chlorophyll-a (Chl-a) concentration. Therefore, the method is not suitable for coastal areas due to river inflow because it only considers internal production using Chl-a as a variable. The CoastColour Round Robin dataset has also been developed by the European Space Agency (Nechad, et al., 2015). In this dataset, R_{rs} spectra were simulated from IOPs of phytoplankton, mineral particles, and CDOM which used by a random number function modeling a log-normal probability density function of each concentration based on field observations in the coastal area. However, the specific IOPs and slope coefficients of each substance are fixed values, so that it is not take into account changes in phytoplankton species, size, and components of the inorganic suspensions and CDOM. The current study developed a new ocean color dataset for an optically complex coastal area, Tokyo Bay, considering the change of phytoplankton species and differences for the components of detritus, mineral particles and CDOM by classifying each IOPs and their components as a subset using hierarchical clustering.

An improvement of σ correction for backscattering coefficient measurement by hydroscat-6P in Tokyo Bay

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The accurate measurement of backscattering properties is significantly difficult in turbid waters. Typically, several backscattering sensors commercially available such as the WET Labs ECO-BB and HOBI Labs Hydroscat instruments. These sensors suffer from attenuation along the path. A correction method is suggested when the pathlength between source, sample volume, and receiver exceeds several cm. For Hydroscat-6p, s correction is used based on the attenuation coefficient ($K_{bb} = a + 0.4b$). In the calculation of K_{bb}, usually, it is measured by an attenuation Meter (AC-S, WET Labs), and then the attenuation effect at the pathlength is corrected. However, in turbid waters, the attenuation coefficient measurements are subject to uncertainties and require a new correction method (de Carvalho et al., 2015). In this study, a new s correction for Hydroscat-6p measurement based on the radiative transfer simulation is proposed by targeting a highly eutrophicated water area, Tokyo Bay. In addition, since backscattering probability (B) can be derived in the process of the new correction method, we theoretically tried to estimate scattering phase function using the derived B.

Google Earth Engine Lecture

21 December 2020

(By Dr. Elígio Maure, Northwest Pacific Region Environmental Cooperation Center)

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