GOCI-II, current status, validation and applications

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National Ocean Satellite Center, KHOA
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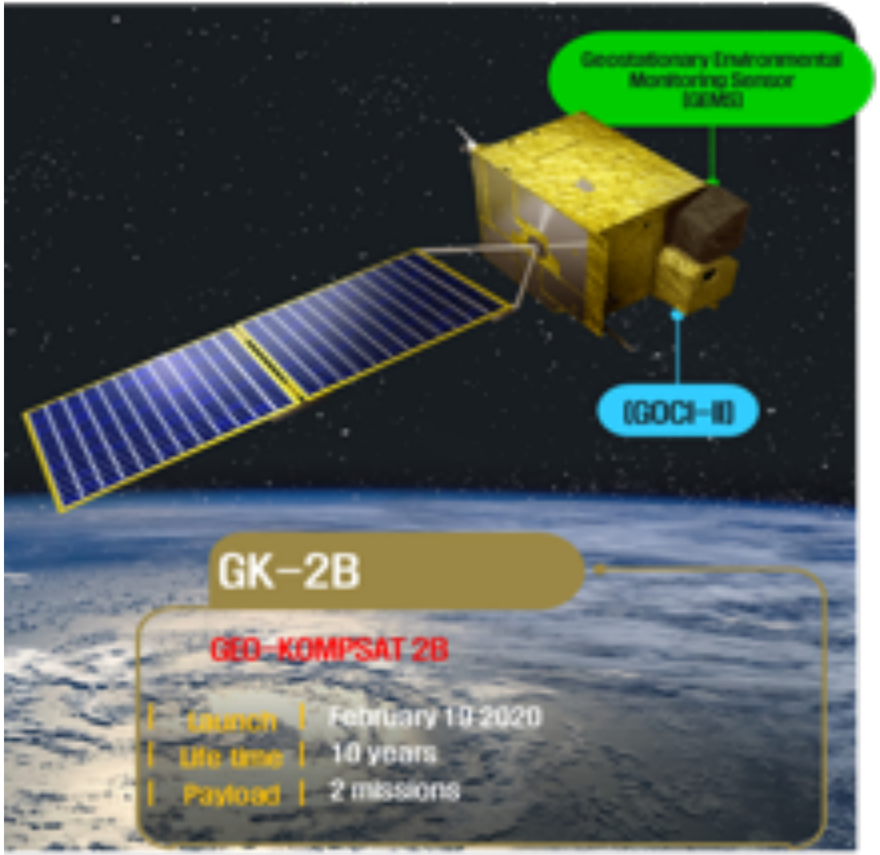
KOSC
Korea Hydrographic and Oceanographic Agency

I. Overview

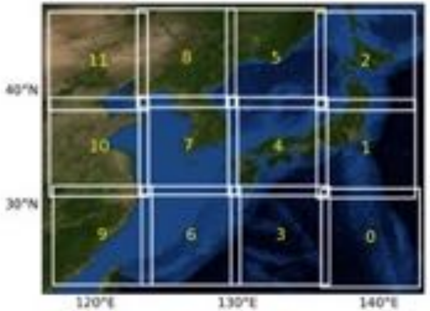
Overview of GOCI-II



380
412
443
490
510
555
620
660
680
709
745
865

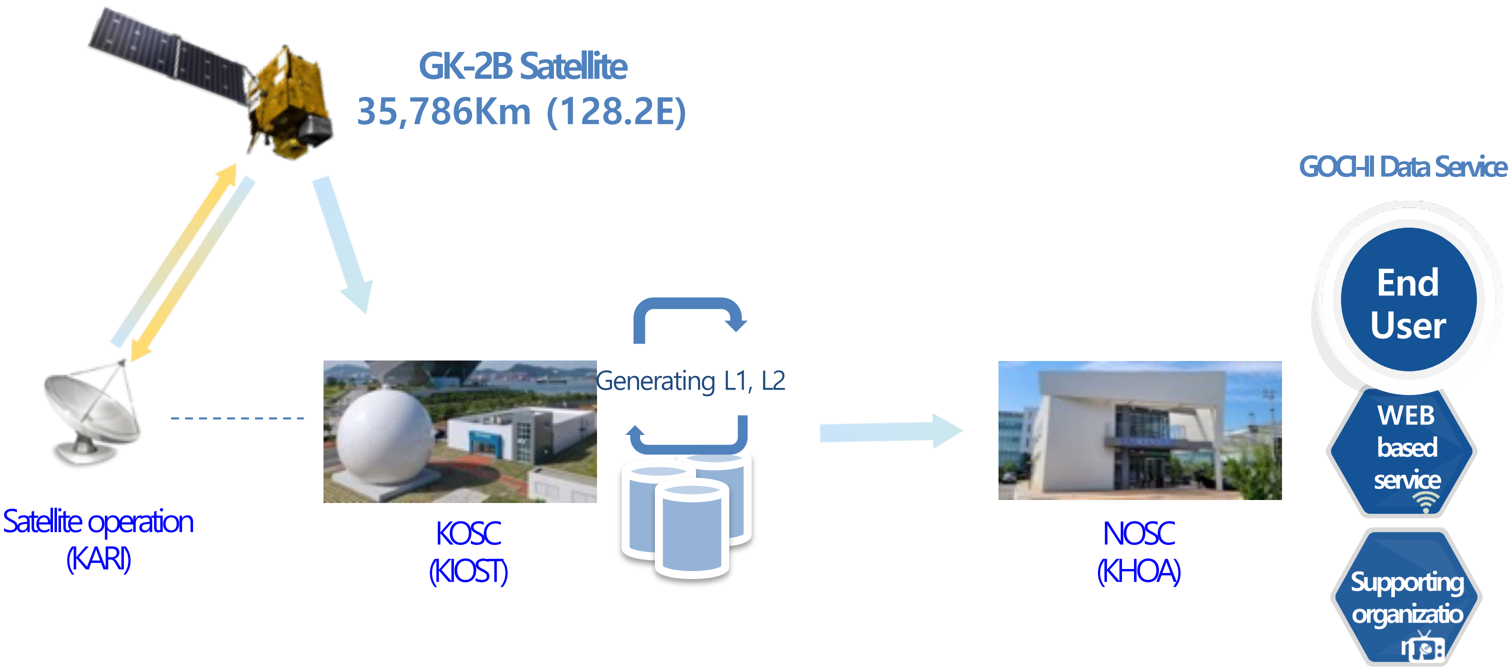
Observation Mode

Local Area (LA)



Full Disk (FD)

Public Service for GOCI-II



** National Ocean Satellite Center (NOSC) in Korea Hydrographic and Oceanographic Agency (KH*

Public Service for GOCI-II by NOSC

- **Established new website *(www.nosc.go.kr)* and started public service from 2021**

  GK2B(GOCI-II) Web Downloads **7-fold increase** : ('21) 1.2million → ('24) 8.5million

Project on GOCI-II accuracy enhancement

Rrs, CHL, TSM, CDOM (basic ocean color products) have been generated and publicly provided without securing accuracies

GOCI-II Launch (2020.02)

GOCI-II mission life time ('20~'29, 10 years)

	'15	'16	'17	'18	'19	'20	'21	'22	'23	'24	'25	'26	'27	'28	'29	'30
GOCI-II	algorithms for 26 GOCI-II products were developed using simulation data (initial algorithm not validated)							'Accuracy enhancement of GOCI-II'					Currently preparing the next project			

Establishing Cal/Val standardization and improving accuracy at international level

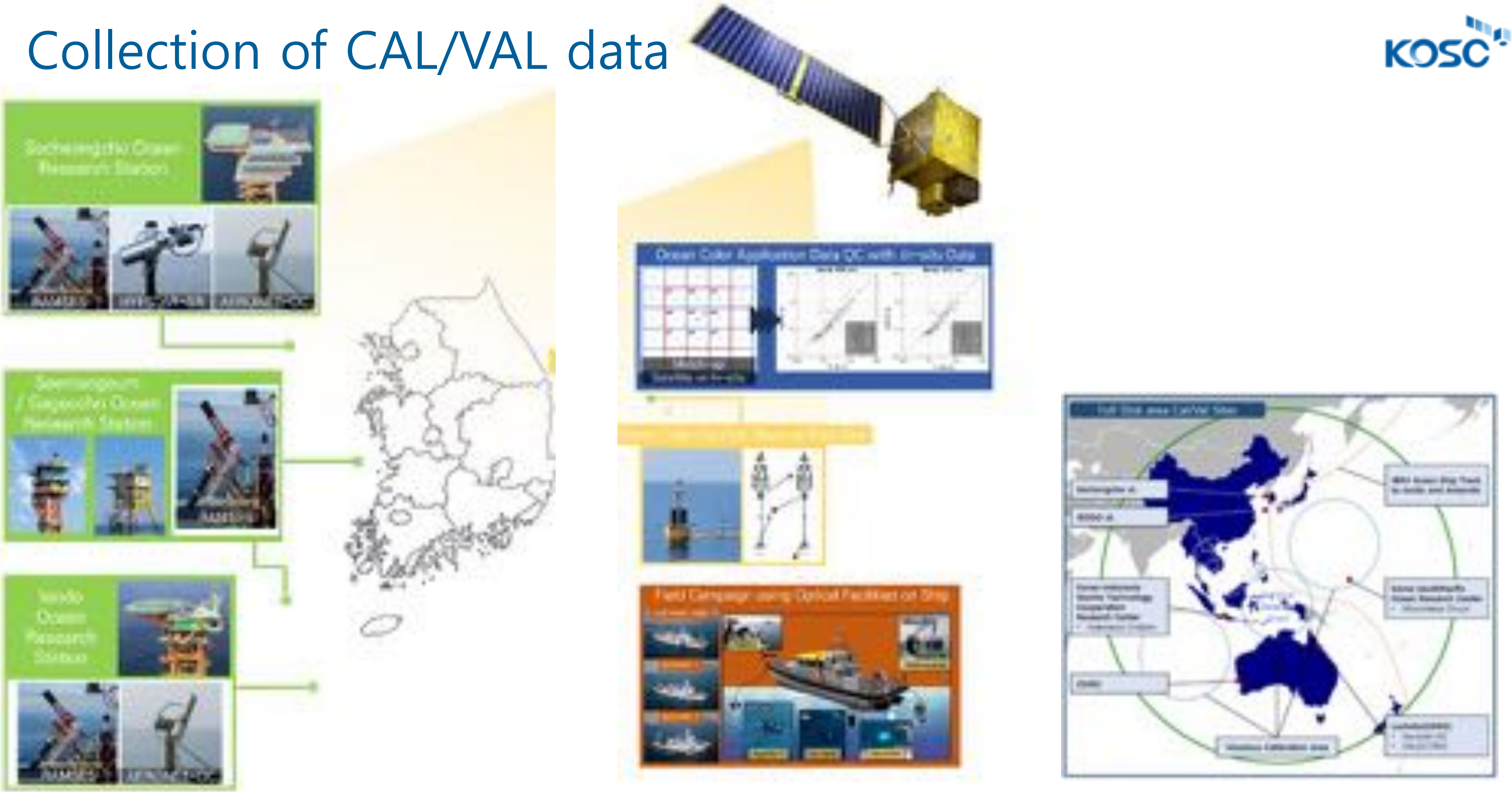
Development of technology for cal/val of GOCI-II products

Research on algorithm improvement for GOCI-II products

Development of atmospheric correction technique based on the integration of GeoKompsat-2A/2B

II. Works we are doing

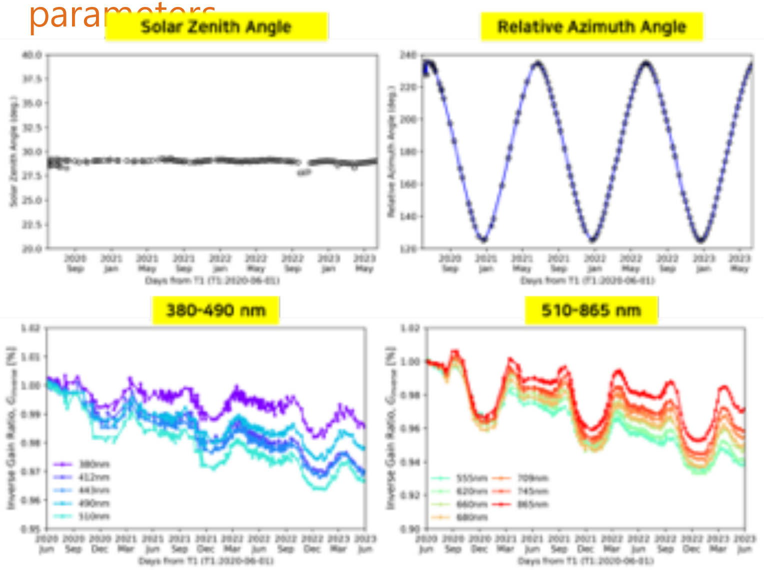
Collection of CAL/VAL data



GOCI-II Radiative Calibration

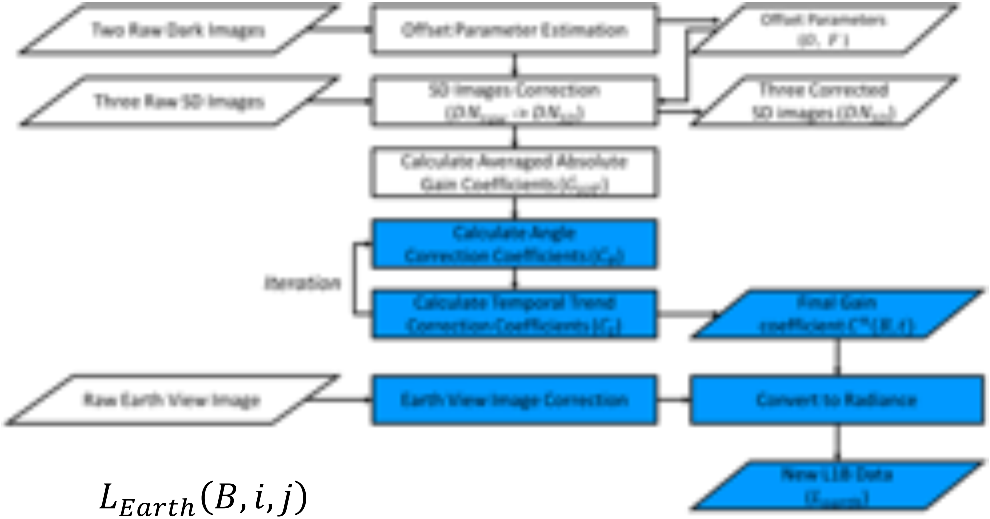
$$G_{inverse}(B,t) = \frac{\bar{G}(B,t_0)}{\bar{G}(B,t)}$$

Time series of Solar Diffuser (SD) Observational Angle and Gain parameters



- $G_{inverse}$ has seasonality
- $G_{inverse}$ has decreasing trend

Flow chart of Improved GOCI-II RC algorithm



$$L_{Earth}(B,i,j) = G_{IOT}(B) \times C^n(B,t) \times [a_0(B,i,j) \times dc_{Earth}(B,i,j) + a_1(B) \times dc_{Earth}^2(B,i,j) + a_2(B) \times dc_{Earth}^4(B,i,j)]$$

$G_{IOT}(B)$: absolute gain coefficient,
$C^n(B,t)$: GOCI-II correction coefficient,
dc: corrected digital number after dark image correction
a_0, a_1, a_2: coefficient of GOCI-II RC algorithm

Improvement of GOCI-II RC algorithm

GOCI-II Radiometric Correction Algorithm

❑ Final GOCI-II RC equation

$$
\begin{aligned}
&\mathrm{L_{TOA}}(\mathrm{B,i,j}) \\
&= \mathrm{G_{IOT}}(\mathrm{B}) \times C_{\theta}^{n}(B,\theta) \times C_{t}^{n}(B,t) \times G_{inverse}(B,t) \\
&\times [\mathrm{a_0}(\mathrm{B,i,j})\mathrm{dc}(\mathrm{B,i,j}) + \mathrm{a_1}\mathrm{dc}^2(\mathrm{B,i,j}) \\
&+ \mathrm{a_2}\mathrm{dc}^4(\mathrm{B,i,j})]
\end{aligned}
$$

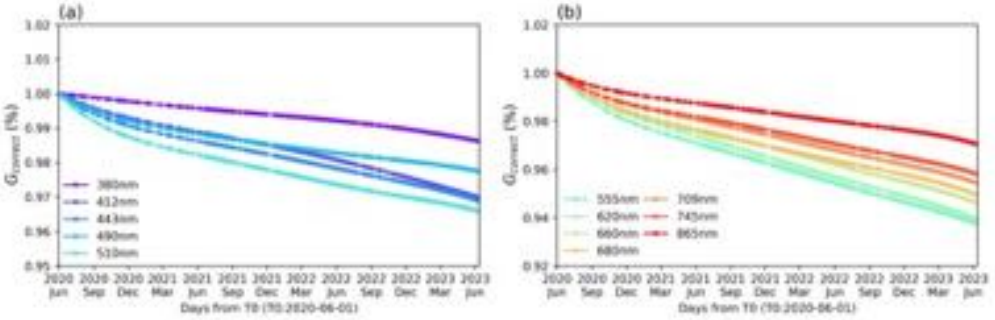
❑ Angle correction model

$$C_{\theta}(B,\theta_{RAA}) = b_0 + \sum_{i}^{5} b_i(B) \times \sin(\theta_{RAA})^i$$

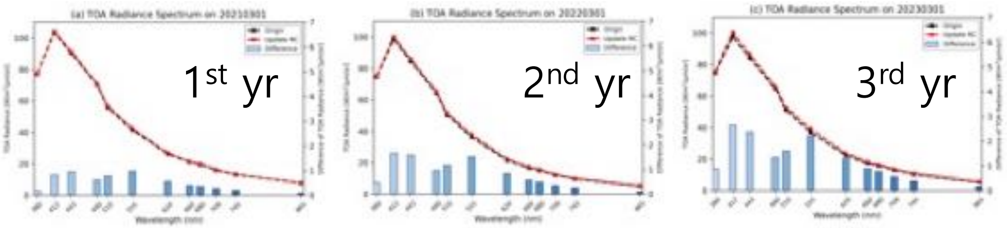
❑ Temporal trend correction model

$$C_t(B,t) = c_0 + \sum_{j}^{5} c_j(B) \times t^j$$

Timeseries of GOCI-II Corrected Gain Trend



Effect of RC: TOA radiance



Improvement of GOCI-II RC algorithm

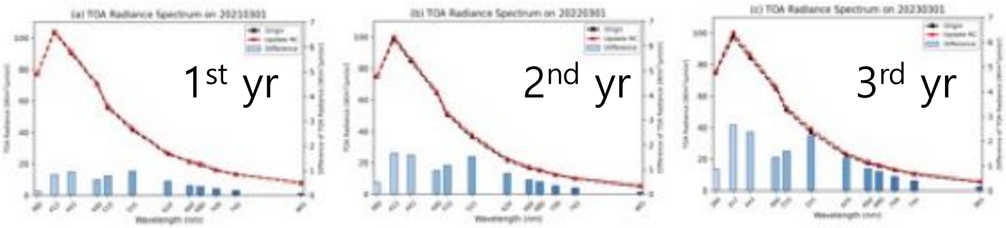
GOCI-II Radiometric Correction Algorithm

Timeseries of GOCI-II Corrected Gain Trend

Poster #: 39
Date: Monday
Session #: 1
Title: Onboard Radiometric Calibration of GOCI-II Using Solar Diffuser and Long-Term Monitoring of Diffuser Stability

❑ **Temporal trend correction model**

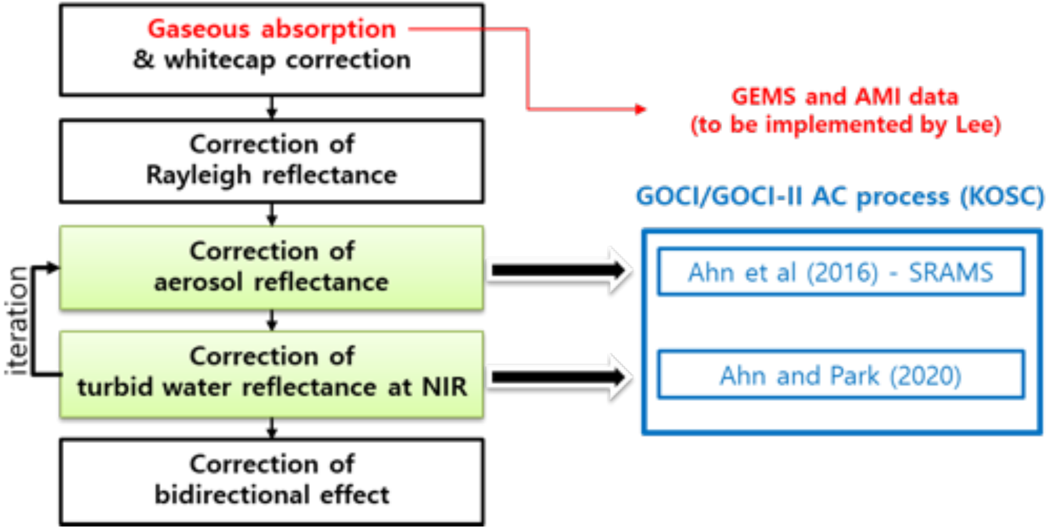
$$C_t(B,t) = c_0 + \sum_{j}^{5} c_j(B) \times t^j$$



Atmospheric correction and it's Cal/Val

GOCI-II AC and VC methods are theoretically based on the SeaWiFS algorithm

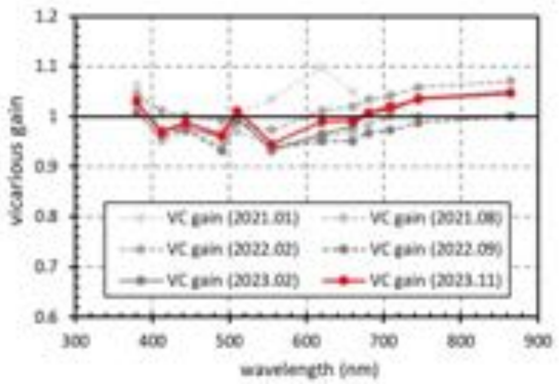
[Atmospheric Correction Process]



Overall flowchart of GOCI-II AC

[Vicarious Calibration Process]

- Current GOCI-II's vicarious calibration relies on the R_{rs} data derived from VIIRS in case-I waters
- Machine learning with simulation dataset for case-I water is used for spectral conversion of VIIRS R_{rs} into GOCI-II's R_{rs}



GOCI-II VC gain update history

GK-2A/B Fusion for GOCI-II gas absorption correction

Improvements of GOCI-II gas absorption correction through via fusion with GK-2A/B data

GK-2B/GOCI-II

TCO: Total column ozone, TPW: Total precipitable water
TNO_2: Total column nitrogen dioxide

- **AMI & GEMS: same geostationary orbit as GOCI-II**
  - valuable input sources of for gas absorption correction
  - provide real-time trace gases data with higher spatial resolution (~8 km) and accuracy than NCEP data (0.25°)

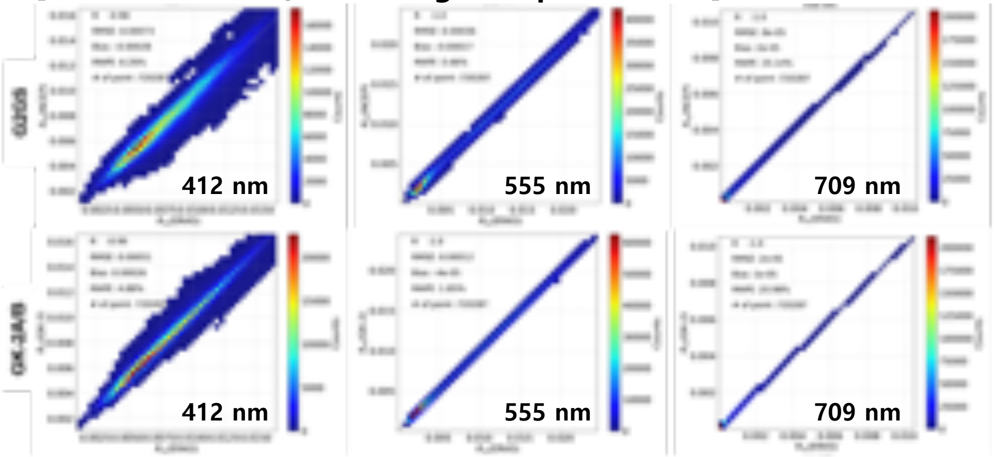
* G2GS Dataset: NCEP[H_2O, O_3] , OMI [NO_2]
** GK-2 Dataset : AMI [H_2O, O_3] , GEMS [NO_2]

Absorbing gas	Validation metrics	G2GS dataset* (used in G2GS)	GK-2 dataset**	Reference
Water vapor	RMSD (mm)	10.2	3.65	RAOB data
	MAPD (%)	35.13	13.01	
	R	0.82	0.98	
Ozone	RMSD (DU)	18.01	9.54	ERA-5 reanalysis
	MAPD (%)	4.34	2.46	
	R	0.82	0.95	
Nitrogen dioxide	RMSE (DU)	0.436	0.311	Pandonia global network data
	MAPD (%)	71.3	56.56	
	R	0.0	0.7	

GK-2A/B Fusion for GOCI-II gas absorption correction

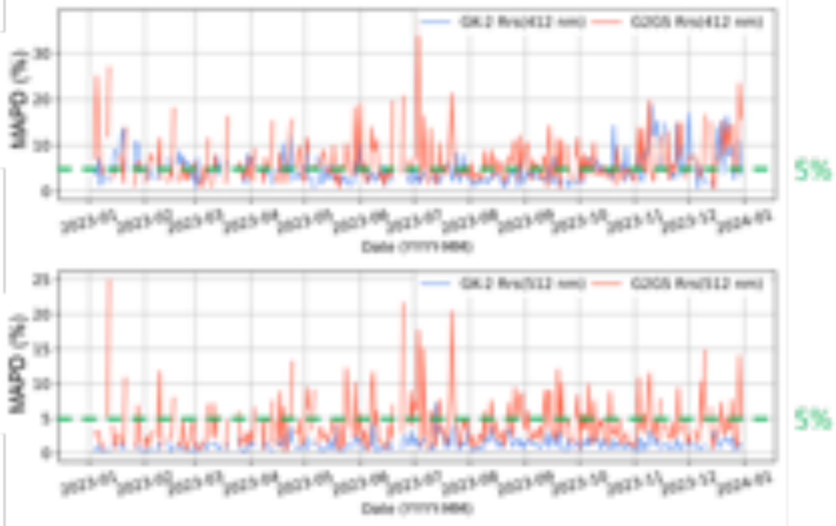
Comparison with an ERA5-based reference to assess the impact of input data on R_{rs}

[Difference in R_{rs} according to input dataset]



wavelength (nm)	412	443	490	512	555	620
G2GS	6.26	5.65	4.67	3.71	5.66	13.5
GK-2A	4.88 (-1.38)	3.25 (-2.4)	1.82 (-2.85)	1.17 (-2.54)	1.85 (-3.81)	4.65 (-8.85)

[Daily mean MAPD of R_{rs}]

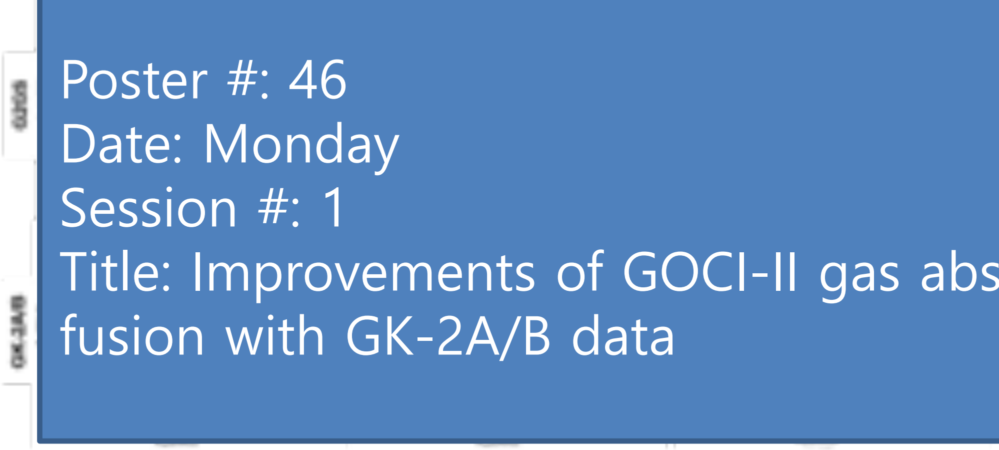


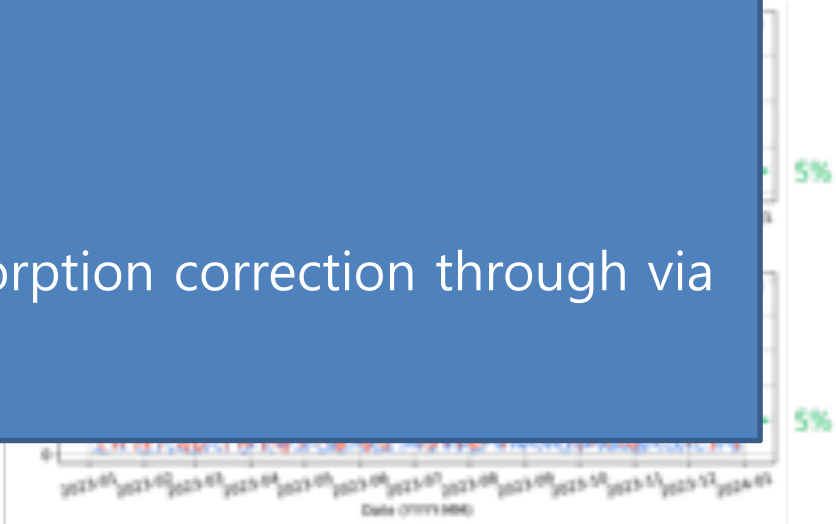
- **GK-2A/B Fusion: Improve accuracy and strengthens the temporal stability of error in R_{rs}**

GK-2A/B Fusion for GOCI-II gas absorption correction

Comparison with an ERA5-based reference to assess the impact of input data on R_{rs}

> Poster #: 46
> Date: Monday
> Session #: 1
> Title: Improvements of GOCI-II gas absorption correction through via fusion with GK-2A/B data





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- **GK-2A/B Fusion: Improve accuracy and strengthens the temporal stability of error in R_{rs}**

Comparison of AMI and GEMS TCO for GOCI-II Atmospheric Correction

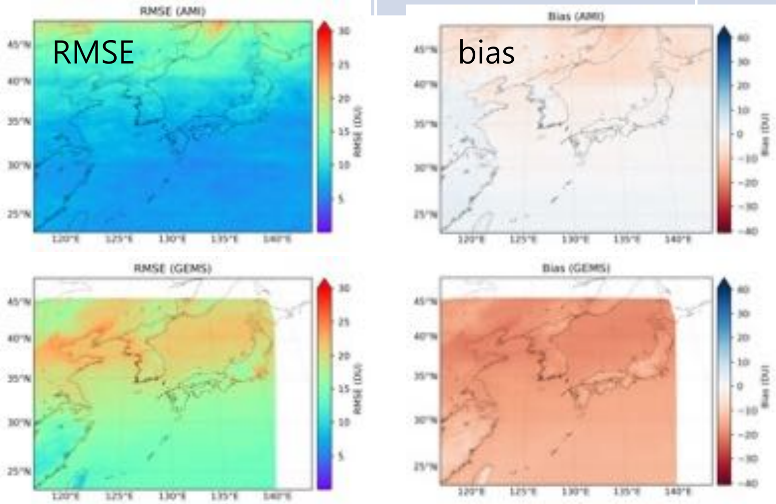
Sensor Characteristics and TCO Accuracy Assessment over the GOCI-II Local Area

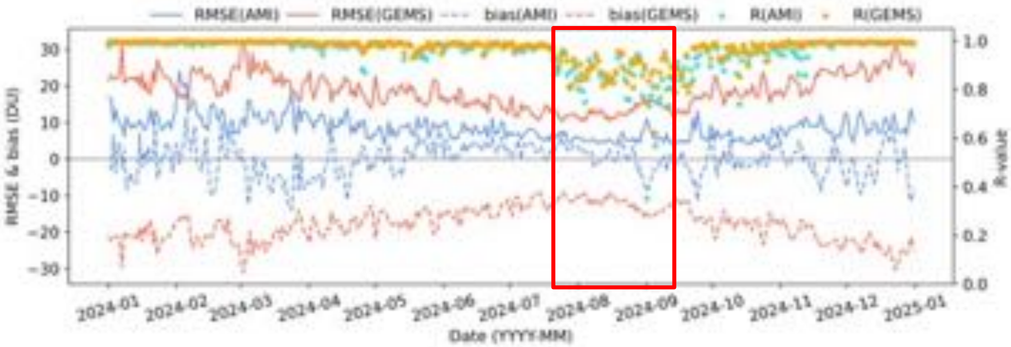
*TCO: Total Column Ozone

Satellite/Sensor	Temporal resolution	Spatial resolution	Number of channel	Spectral range
GK-2B/GOCI-II	1-hour (LA mode)	0.5~2 km	13	375~900 nm
GK-2B/GEMS	1-hour	7×8 km	1000	300~500 nm
GK-2A/AMI	10-min (FD)	0.25 km	16	470~13,310 nm

AMI

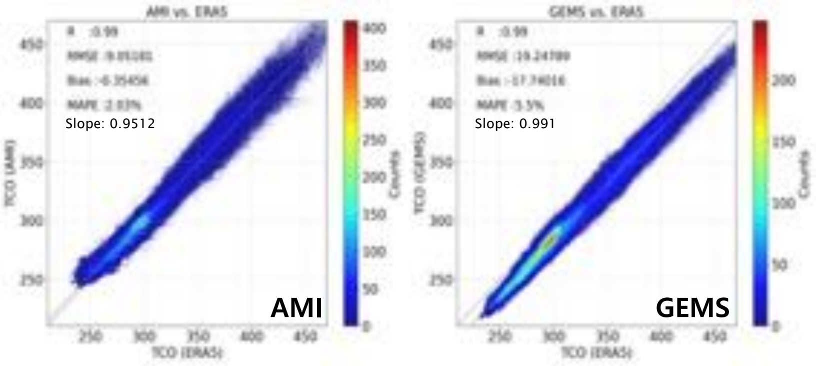
GEMS





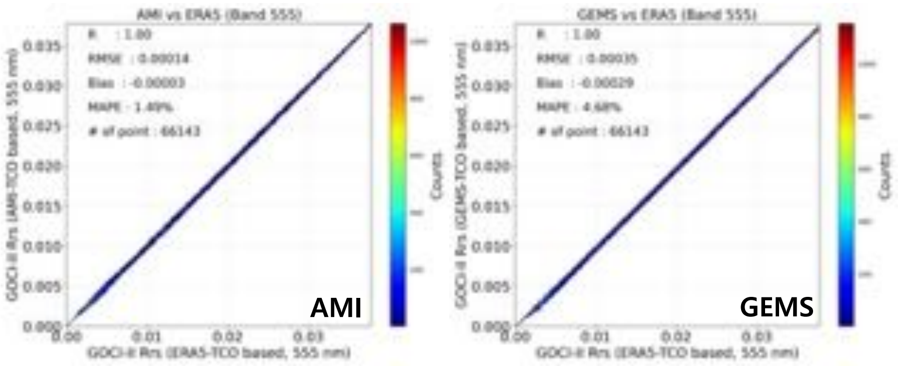
Comparison of AMI and GEMS TCO for GOCI-II Atmospheric Correction

Evaluation of AMI/GEMS TCO



	AMI	GEMS
R	0.99	0.99
RMSE	9.05181	19.24789
Bias	-0.35456	-17.74016
MAPE	2.03 %	5.5 %

Impact of AMI/GEMS TCO on **GOCI-II Rrs** Retrieval



	AMI	GEMS
R	1.00	1.00
RMSE	0.00014	0.00035
Bias	-0.00003	-0.00029
MAPE	1.49 %	4.68 %

→ The AMI data is considered to be relatively more suitable as input for GOCI-II atmospheric correction.

Comparison of AMI and GEMS TCO for GOCI-II Atmospheric Correction

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Evaluation of AMI/GEMS TCO

Impact of AMI/GEMS TCO on GOCI-II Rrs Retrieval

Poster #: 47
Date: Monday
Session #: 1
Title: Evaluation of Total Column Ozone from AMI and GEMS for Atmospheric Correction of GOCI-II

RMSE	9.05181	19.24789
Bias	-0.35456	-17.74016
MAPE	2.03 %	5.5 %

RMSE	0.00014	0.00035
Bias	-0.00003	-0.00029
MAPE	1.49 %	4.68 %

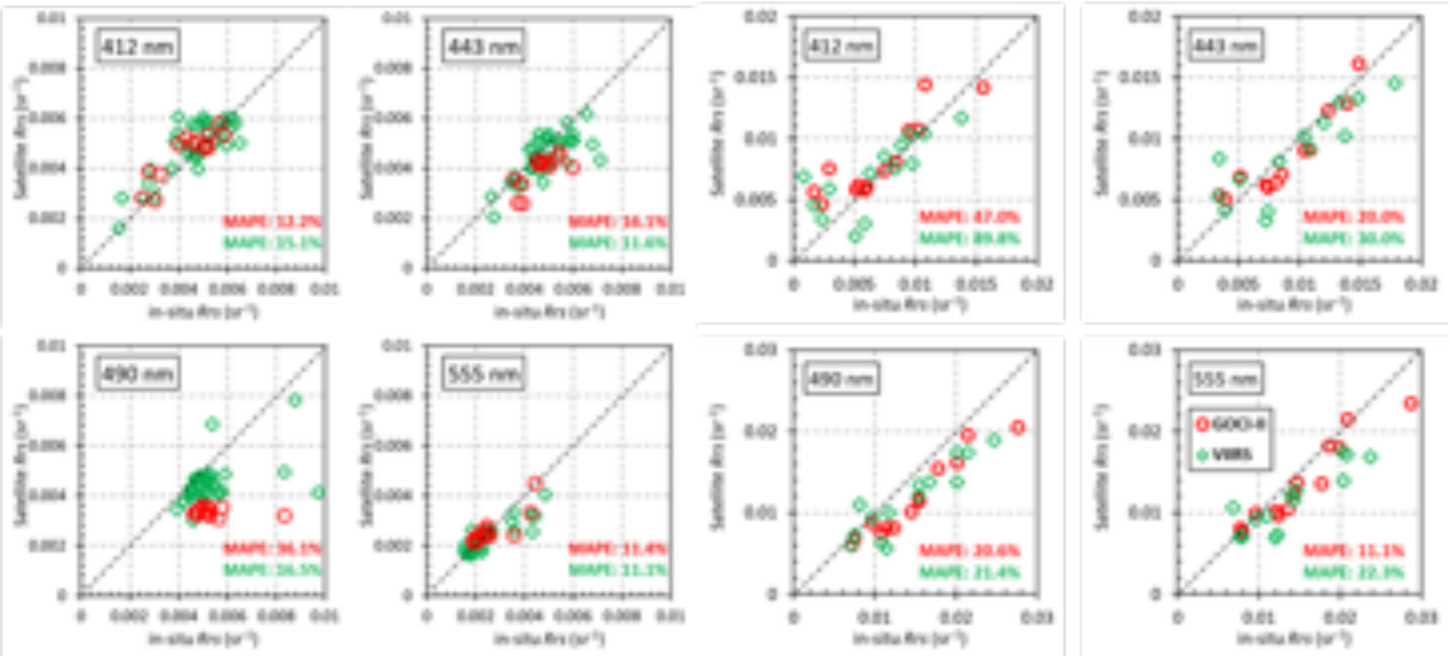
→ The AMI data is considered to be relatively more suitable as AC input material.

Status of GOCI-II atmospheric correction and Cal/Val

Match-ups from Indonesian Sea (Cirebon and Makassar)

Makassar

Cirebon



Status of GOCI-II atmospheric correction and Cal/Val

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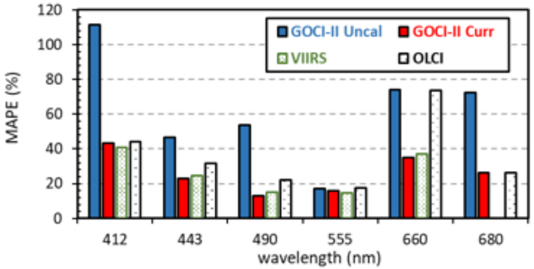
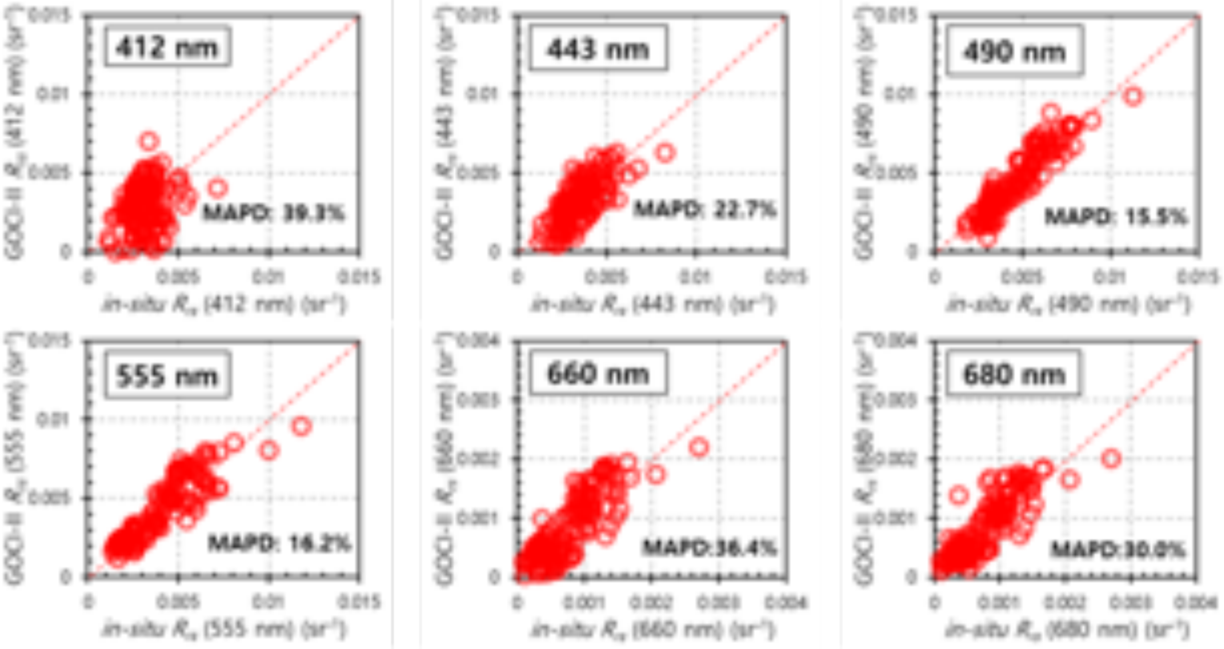
Match-ups from Socheong Station (AERONET-OC)

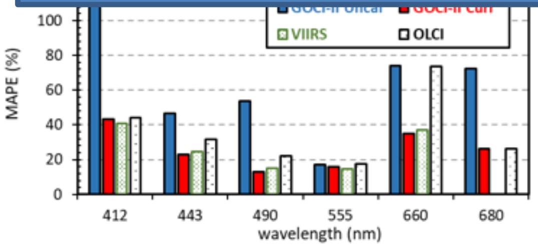


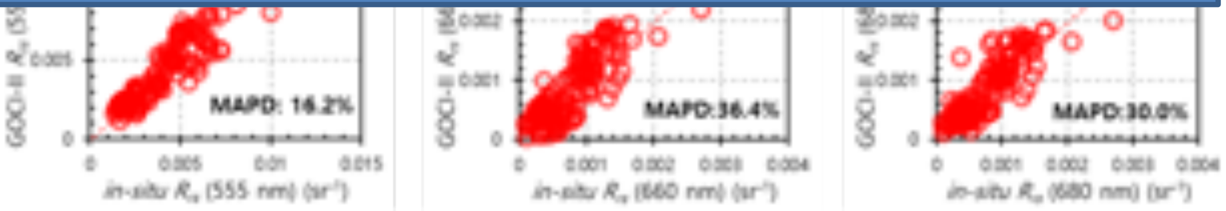


Status of GOCI-II atmospheric correction and Cal/Val

Match-ups from Socheong Station (AERONET-OC)

Poster #: 1
Date: Monday
Session #: 1
Title: Current Status of the GOCI-II Atmospheric Correction and Its System Vicarious Calibration



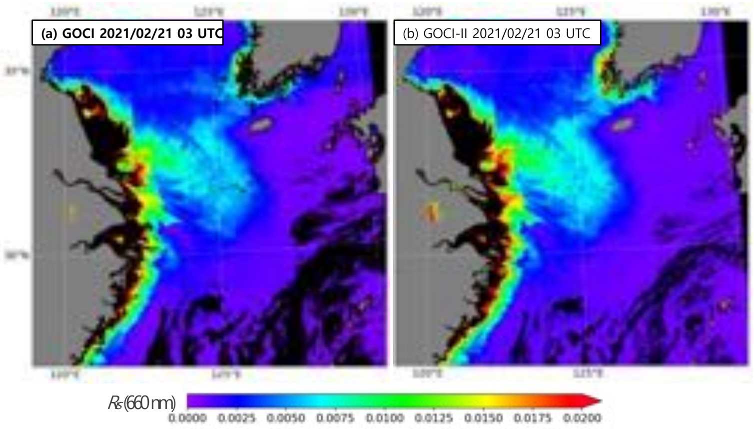


Comparison Rrs b/w GOCI & GOCI-II : East China Sea

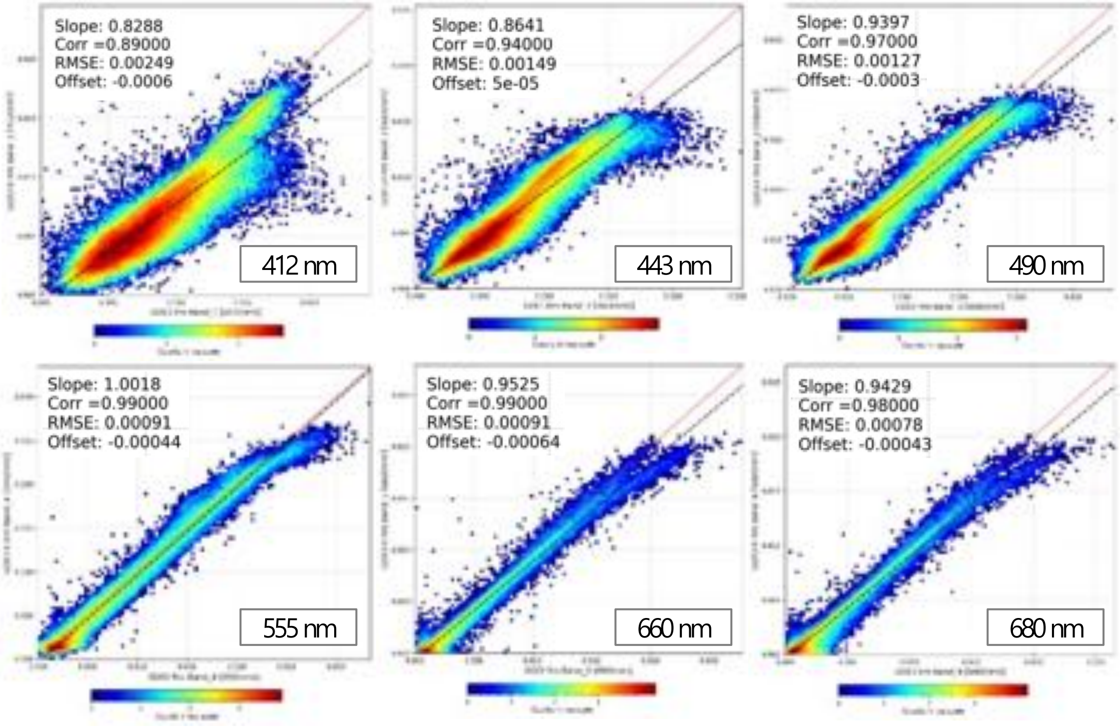
GOCI, GOCI-II (September 2020, February 2021)

Results of GOCI and GOCI-II by Spectral Band over the East China Sea (ECS)

	412 nm	443 nm	490 nm	555 nm	660 nm	680 nm
Corr.	0.89	0.94	0.97	0.99	0.99	0.98
RMSE	0.00249	0.00149	0.00127	0.00091	0.00091	0.00078



Rrs 660 nm images from GOCI(a), GOCI-II (b): (a, b) 21 February 2021. GOCI and GOCI-II 03 UTC images.

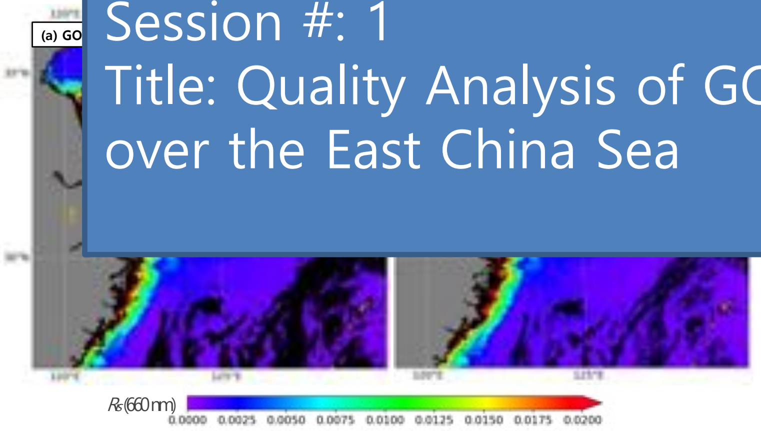


GOCI versus GOCI-II *Rrs* 412-660 nm for East China Sea

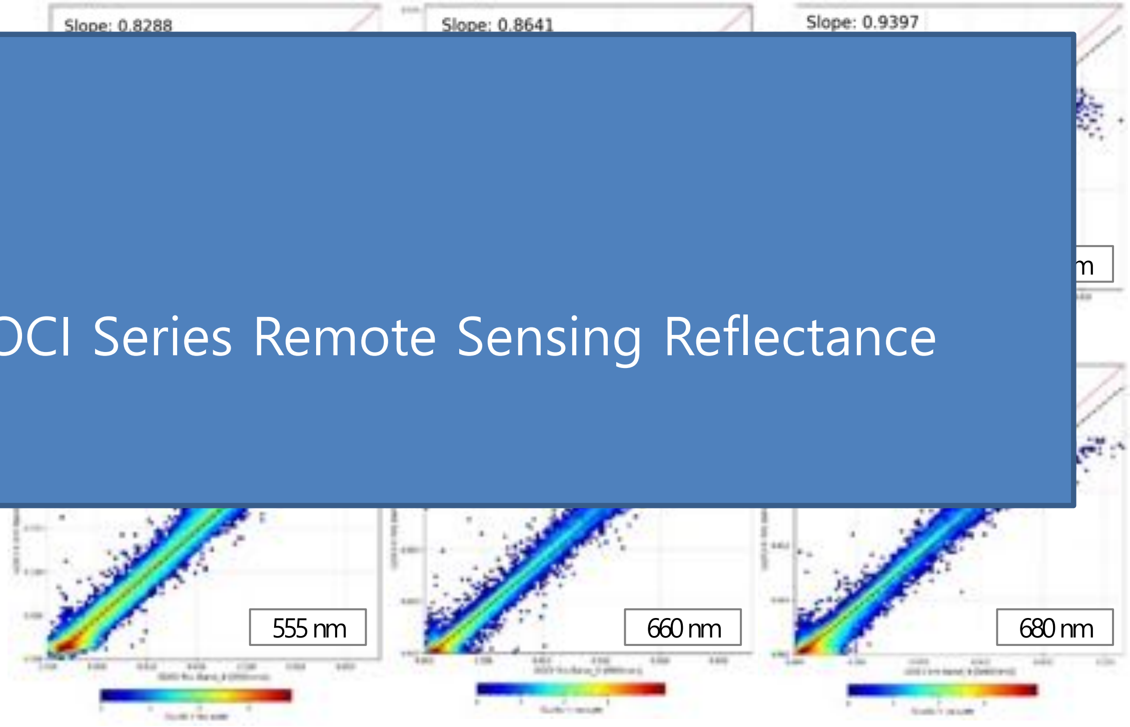
Comparison Rrs b/w GOCI & GOCI-II : East China Sea

GOCI, GOCI-II (September 2020, February 2021)

Poster #: 6
Date: Monday
Session #: 1
Title: Quality Analysis of GOCI Series Remote Sensing Reflectance over the East China Sea



Rrs 660 nm images from GOCI(a), GOCI-II (b): (a, b) 21 February 2021. GOCI and GOCI-II 03 UTC images.



GOCI versus GOCI-II *Rrs* 412-660 nm for East China Sea

Improvement of GOCI-II IOP

Hybrid IOP estimation using QAA and machine learning

Estimated IOP using a radiative transfer simulation dataset (Hydrolight) based on machine learning and QAA

Type	Brown Earth, Red Clay, Yellow Clay	
CDOM	**Chl-a**	**TSM**
0.01 - 1.6654 m^{-1}	0.1 - 17.7438 mg/m^3	0.1 - 100 g/m^3

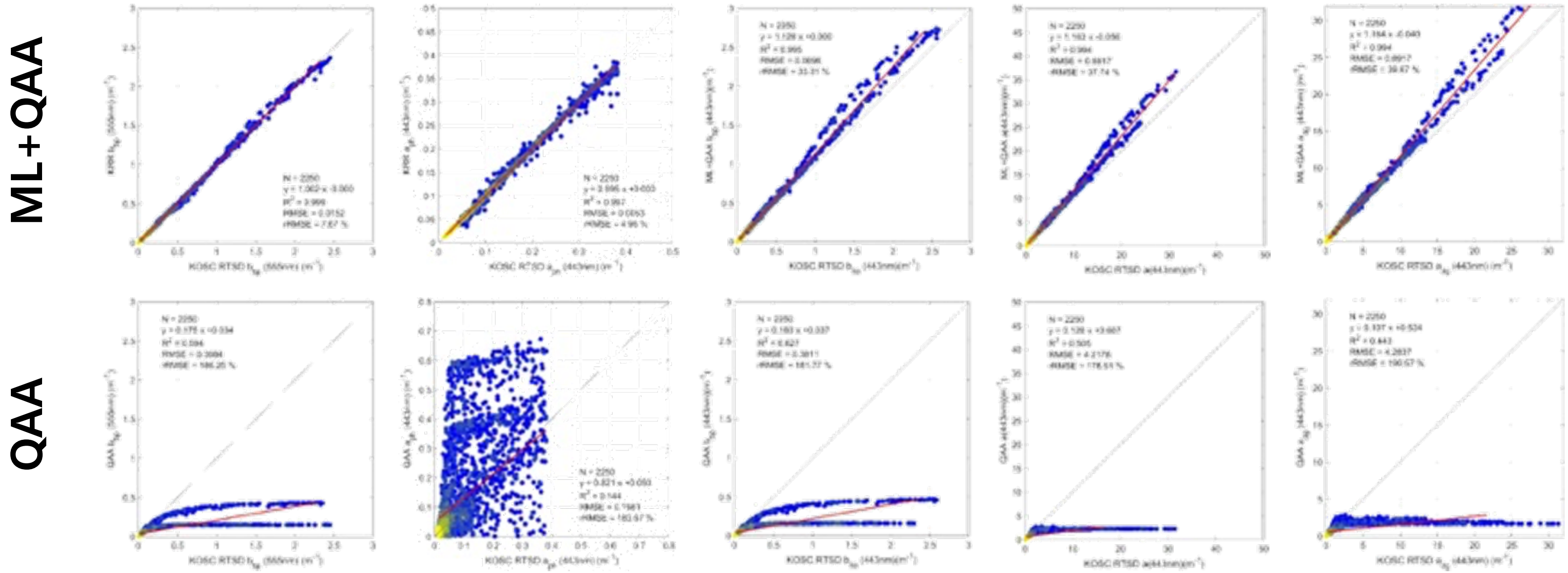
Input (11)	• Simulated U value of GOCI-II 7 bands (412, 443, 490, 510, 555, 620, and 660 nm) • Bands ratio
Target (3)	• Backscatter coefficient of particles **(b_{bp}) slope** • **b_{bp} (555 nm)** • Absorption coefficient of phytoplankton **(a_{ph}) (443 nm)**
Machine learning models	• Artificial Neural Network (ANN) • Kernel Ridge Regression (KRR) • Histogram-based Gradient Boosting Regression (HGBR) • Light Gradient Boosting Machine (LGBM) • Categorical Boosting (CatBoost)

1. Compute u from GOCI-II R_{rs}
2. Estimate b_{bp}(555nm) and b_{bp} slope using the ML model
3. Compute spectral $b_{bp}(\lambda)$ using QAA
4. Compute spectral b_b (λ) using QAA
5. Compute spectral $a(\lambda)$ using QAA
6. Estimate a_{ph}(443 nm) using the ML model
7. Compute a_{dg}(443 nm) using QAA

Improvement of GOCI-II IOP

Hybrid IOP estimation using QAA and machine learhning

Estimated IOP using a radiative transfer simulation dataset (Hydrolight) based on machine learning and QAA

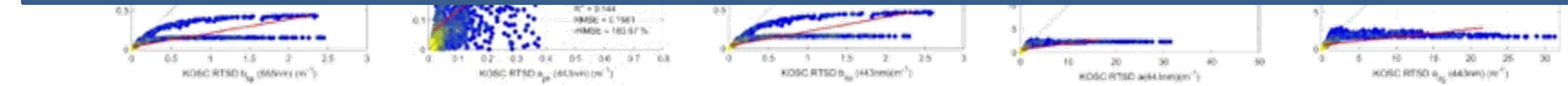


Improvement of GOCI-II IOP

Hybrid IOP estimation using QAA and machine learhning

Estimated IOP using a radiative transfer simulation dataset (Hydrolight) based on machine learning and QAA

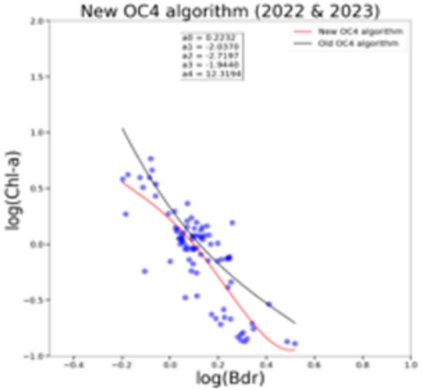
Poster #: 36
Date: Monday
Session #: 1
Title: Enhancing GOCI-II Inherent Optical Properties Algorithms via Machine Learning



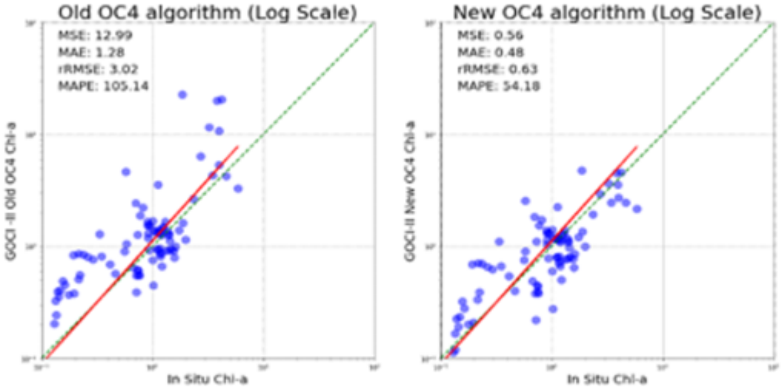
Updating GOCI-II regional Chl-a algorithm

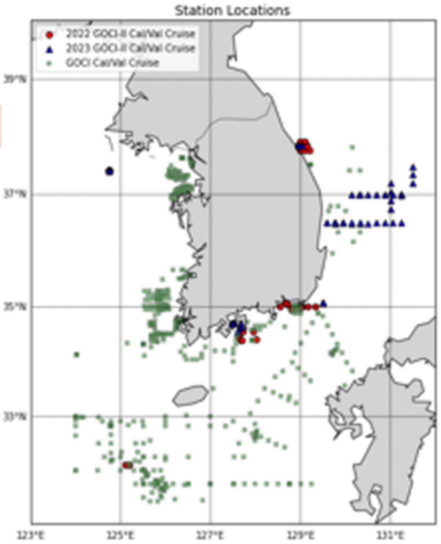
Regional OC4 Algorithm

Deriving a regional algorithm



Validation of Standard OC4 vs. Regional OC4 algorithm



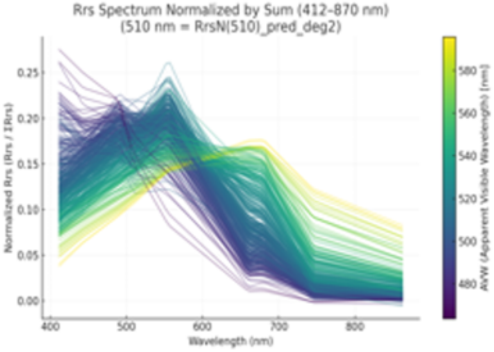


- Development of the OC4 algorithm for the GOCI-II sensor in Korean coastal waters
- Adjustment of OC4 coefficients using the latest in-situ observations
- Validation of the new algorithm (showing improved accuracy)

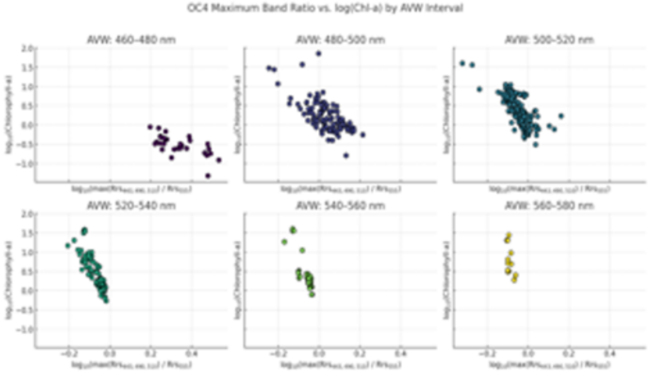
Updating GOCI-II regional Chl-a algorithm

Development OC4 algorithm depending on water quality

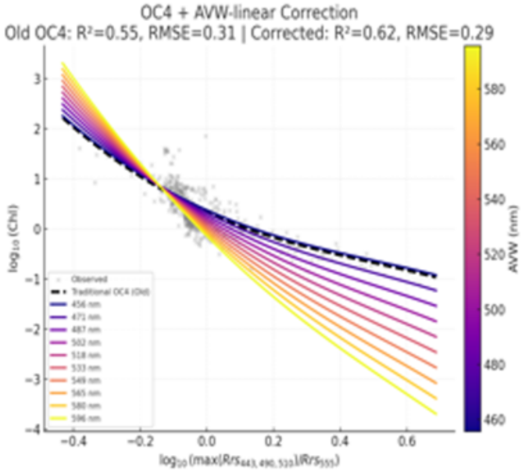
Global distribution of Apparent Visible Wavelength(AVW)



Band ratio – Chl-a relationship depending on water quality



OC4+water quality algorithm



Updating GOCI-II regional Chl-a algorithm

KOSC

Development OC4 algorithm depending on water quality

Poster #: 160
Date: Wednesday
Session #: Poster session 3b
Title: Advancing GOCI-II Chlorophyll a: Through sensor calibration

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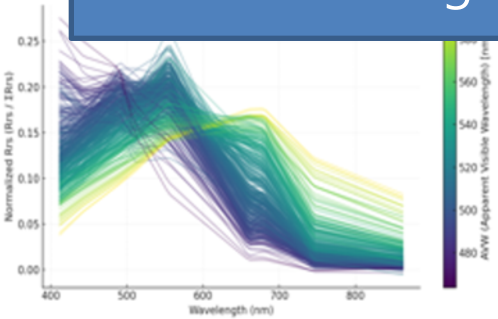
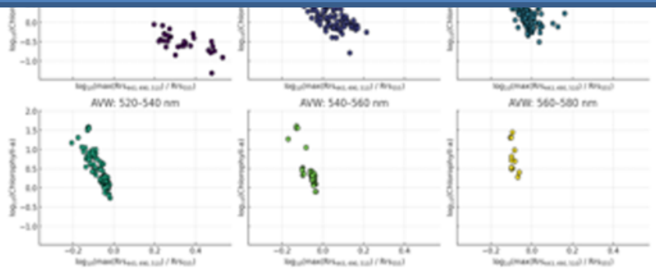
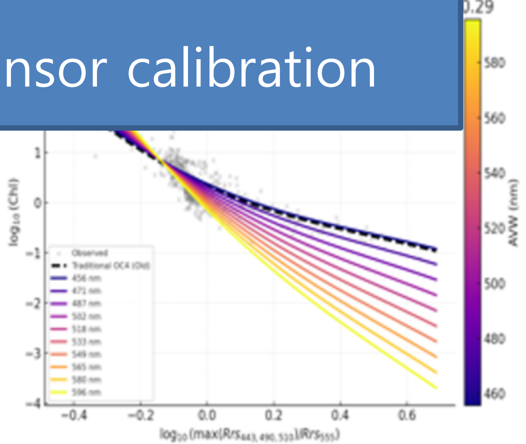


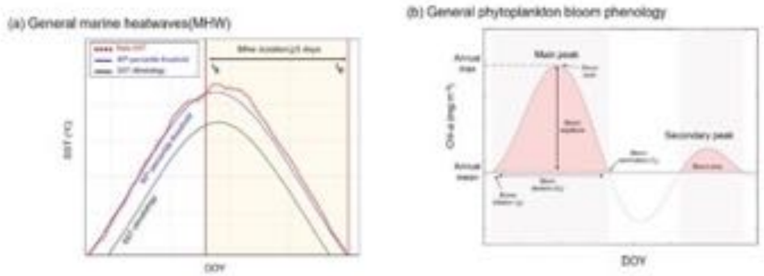


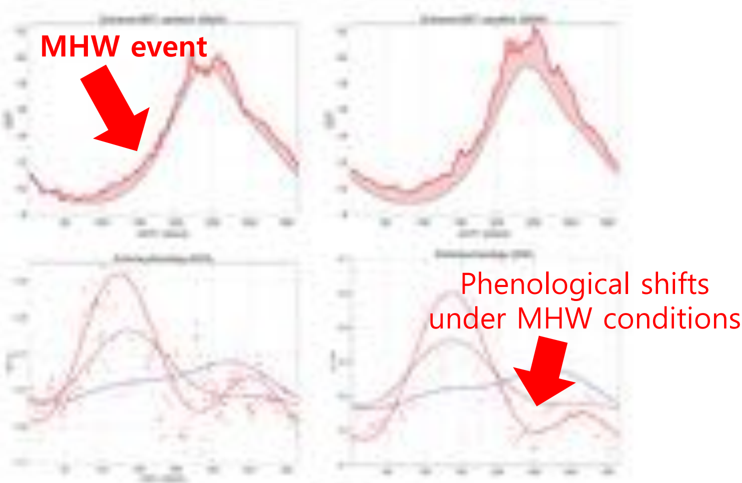


Marine Heatwave reshape phytoplankton phenology

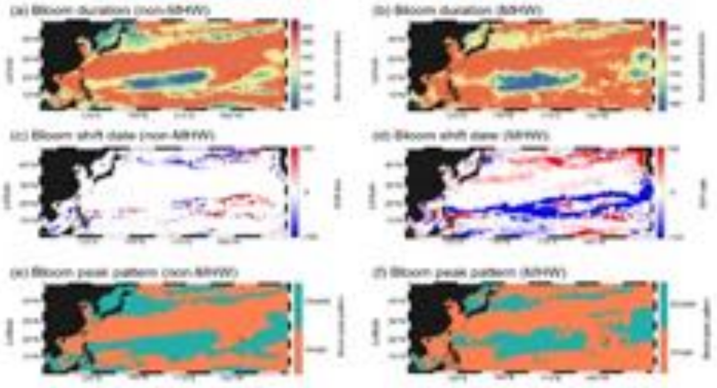
Defined marine heatwave(MHW) and phytoplankton phenology

Please refer to **Poster No.##** for more details!





MHW changes phytoplankton phenology



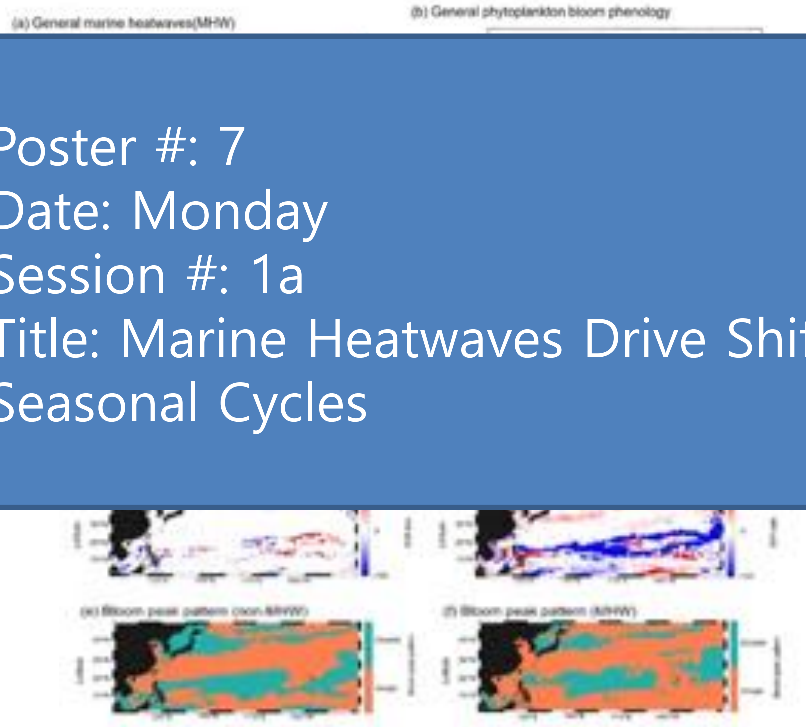
Difference between original and MHW case phenology

Marine Heatwave reshape phytoplankton phenology

KOSC

Defined marine heatwave(MHW) and phytoplankton phenology

Please refer to **Poster No.##** for more details!



Poster #: 7

Date: Monday

Session #: 1a

Title: Marine Heatwaves Drive Shifts in Phytoplankton Phenology and Seasonal Cycles

H/W specifications of GOCI series

- Spectral bands

[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	
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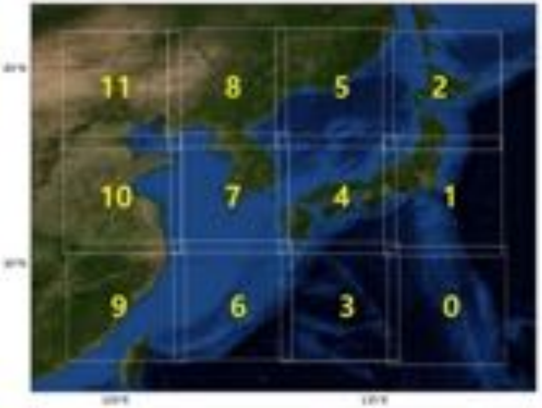
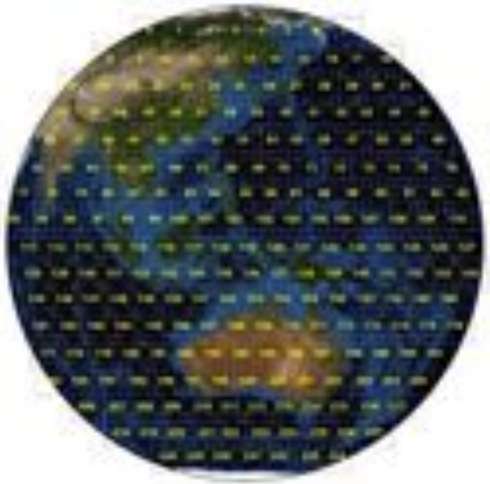
		[illegible]	[illegible]

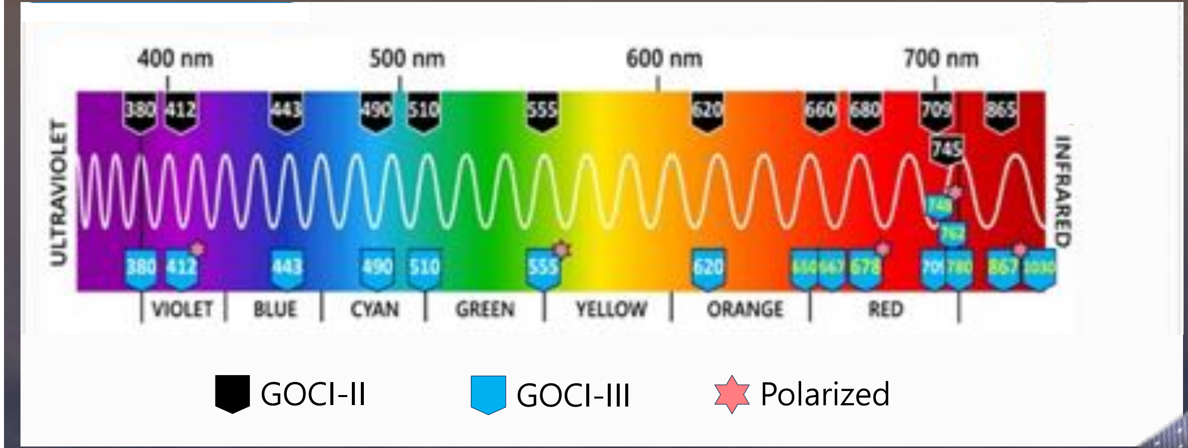
- Spatial resolution
  - GOCI
    - 500 m/pxl at projection center (36˚N) (~400 m/pxl at nadir)
  - GOCI-II & GOCI-III
    - 250 m/pxl at nadir

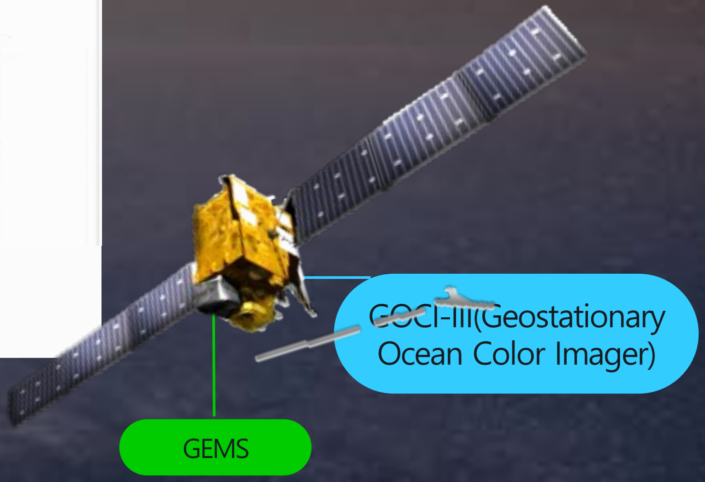
- Observation area





Plan for GEO-KOMPSAT-6





GEO-KOMPSAT-6

Launching expected 2033

Summary

- The project on Cal/Val and algorithm improvement for GOCI-II will finish next year, and we are preparing the next project and trying to secure the budget to carry out the project until the end of GOCI-II mission
- We are developing and improving algorithms for radiometric calibration, atmospheric correction, IOP, Chlorophyll-a concentration, etc. to secure the accuracies of L2 until the end of / after the mission
- Using nearly 20 years of GOCI-series data, we are trying to carry out diverse studies on seeing long term trend relating to climate changes like phenology study
- We are preparing the development of GOCI-III with improved spectral design including polarization, which can be launched about 2023

Remote Sensing of Environment (RSE) Journal Special Issue

- *Geostationary Ocean Color Remote Sensing Data for Improved Understanding of Surface Ocean Biogeochemistry*
- Guest Editors
  - Dr. Jongkuk Choi, Korea Institute of Ocean Science & Technology (KIOST)
  - Dr. Myungsook Park, Korea Institute of Ocean Science & Technology (KIOST)
  - Prof. Joseph Salisbury, (PI of GLIMR), University of New Hampshire
  - Dr. Cara Wilson, (Program Leader of CoastWatch West Coast Node and of PolarWatch), NOAA
  - Dr. Hayley Evers-King, EUMESAT
- Submission deadline : 2026. 7. 31
- Key words : Geostationary Ocean Color, GOCI, GLIMR, GeoXO, SEVIRI
- Opinion from RSE Editors-in-chief
  - papers from many sensors GOCI, GOCI 2, Himawari 8, ABI and perhaps other Ocean GEO Sensors that can get meaningful information from the oceans (E.g. TEMPO).
  - set the target for at least 15 papers, but 20 is better. Also, while the rejection rate is typically 20% for RSE, it is often much higher (perhaps 50%) for special issue papers. So, we should shoot for at least 30 submissions

Remote Sensing of Environment (RSE) Journal Special Issue

- *https://www.sciencedirect.com/special-issue/318780/geostationary-ocean-color-remote-sensing-data-for-improved-understanding-of-surface-ocean-biogeochemistry*

Thank you !!!