Status of Algorithm Development for Sea Surface Current Retrieval of Geo-KOMPSAT-2A/Advanced Meteorological Imager

Kyung-Ae Park[1], Hee-Young Kim[2], Ji-Eun Park[1], Sung-Rae Chung[3], Seong-Hoon Cheong[3],

[1]*Dep. of Earth Science Education / Research Institute of Oceanography, Seoul National University, Seoul, KOREA, Email: kapark@snu.ac.kr*

[2]*Dep. of Science Education, Seoul National University, Seoul, KOREA*

[3]*National Meteorological Satellite Center, KMA, Chungbuk, KOREA*

Abstract

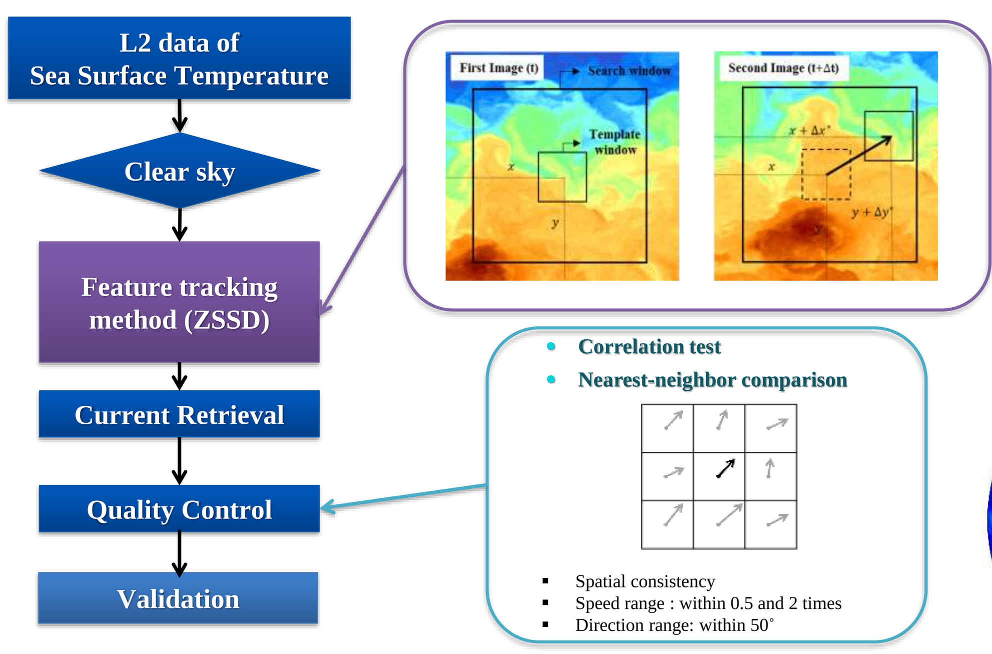
Geo-KOMPSAT-2A (Geostationary-Korea Multi-Purpose Satellite-2A, GK-2A) was successfully launched on 5 December 2018 and Advanced Meteorological Imager (AMI), as a mission-critical payload of GK-2A will offer more spectral bands, higher spatial resolution, and faster imaging than the Meteorological Imager (MI) of Communication, Ocean and Meteorological Satellite (COMS), Korea's first geostationary ocean-weather satellite. In this study, a complete description of the operational GK-2A/AMI Sea Surface Current (SSC) algorithm development is introduced. The SSC products are retrieved from subsequent Himawari-8 SST images, as a proxy for GK-2A SST, by applying the SST quality flag mask data on the satellite images to minimize error value. The estimated currents are subjected to a quality control process to remove the error included in the result. The accuracy of the retrieved surface currents are assessed by comparing the quality-controlled currents with the estimated currents obtained from surface drifters in the full-disk region of GK-2A. Analysis results reveal that the estimated current speeds and directions show good agreement with the drifter-based calculated values. The estimated current field illustrates a rotating feature around a mesoscale anti-cyclonic eddy, as well as the characteristic meandering pattern of the Kuroshio Current.

Introduction

Sea surface current (SSC) is a major variable not only in the ocean circulation but also in the marine ecosystem and atmospheric environment. Generating accurate and regular data on the speed and direction of the sea surface currents can help in many applications such as rescue operations, predicting target areas for oil spills and contaminated water, forecasting fishery areas in phytoplankton-rich waters, or finding the most economical route of navigation. In that sense, retrieval of sea surface current using consecutive satellite image data is the most efficient way to get the synoptic observations of the sea surface current fields. In recent decades, studies have long been conducted to retrieve information on SSC using satellite data such as sea surface height anomalies observed by satellite radar altimeters, the sequential sea surface temperature (SST) images and ocean color data. Surface currents based on successive SST images of near-polar orbiting satellites have disadvantages arising from the small number of data samplings due to frequent cloud cover or other atmospheric and oceanic conditions over relatively long time intervals. Such sparse samplings can be overcome, in part, by high-resolution and frequently observed geostationary satellite SST images.

The most representative method is a feature tracking method that estimates the flow of seawater by tracking the movement of oceanic_phenomena appearing in satellite image data. We applied the Sum of Squared Distances (ZSSD) algorithm proposed by Marchello (2007). This algorithm has relatively simple computation procedure and fast processing speed.

SSC Retrieval Algorithm



Method : Zero-mean Sum of Squared Distances (ZSSD)

$$ZSSD(x+\Delta x, y+\Delta y) = \sum_{i=-N}^{N}\sum_{j=-N}^{N}\{[I_t(x,y)-\overline{I_t}] - [I_{t+\Delta t}(x+\Delta x+i, y+\Delta y+j) - \overline{I_{t+\Delta t}}]\}^2$$

Assumption :

- The morphologic shape of traced target does not change during observational time.
- The variations of the two images over relatively short time intervals are due only to surface advection.

- Window size : template window (11 x 11) / search window (25 x 25)
- Time Difference : Various time intervals between images are given to account for the regional characteristics of sea surface currents.

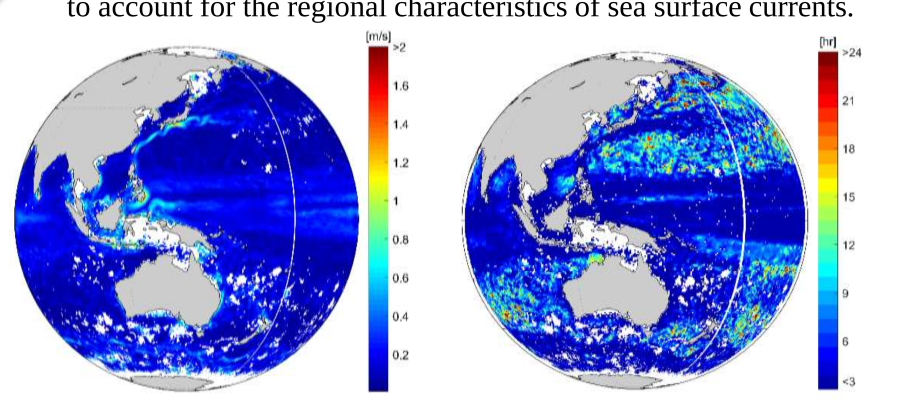


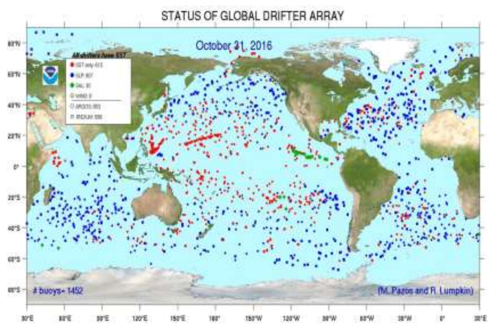
Fig. Mean current speed for global region

Fig. Time required to escape one pixel on the GK-2A grid (up to 78 hours, over 3 days)

Data

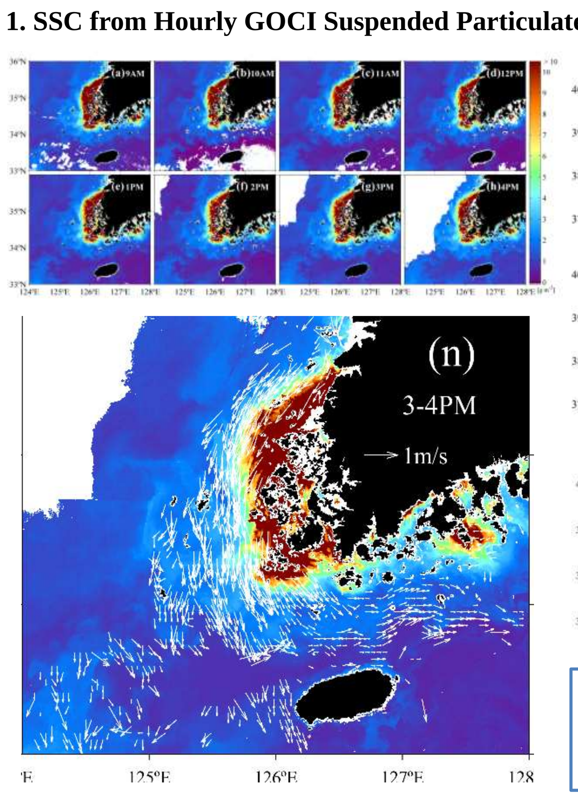
❖ List of Input Data (proxy data : SST retrieved from Himawari-8/AHI data)

Data		Spatial Resolution	Temporal Resolution
AMI L2 Data	Quality-controlled Sea Surface Temperature	2 km	10 min
Ancillary Data	Latitude / Longitude	2 km	
	Viewing Zenith Angle	2 km	
	Land / Sea Mask	2 km	
In-situ data	GTS_Drifter	-	-



Surface Currents from Multi-Sensor Satellite Images

1. SSC from Hourly GOCI Suspended Particulate



- GOGI 500 x500 m
- Hourly variations of spatial distribution of SPM
- SSC estimated using the MCC methods
- Strong tidal currents

2. SSC from Satellite Altimeter SSH, Chl-a, Drifter

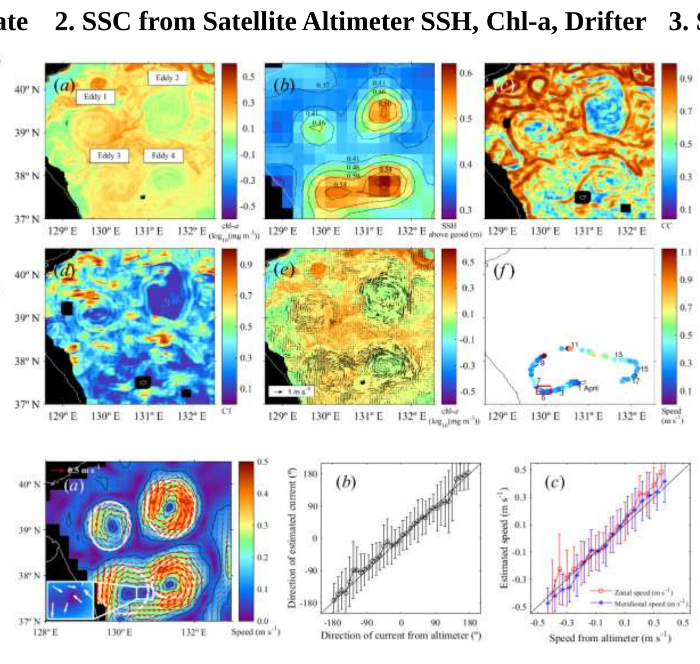
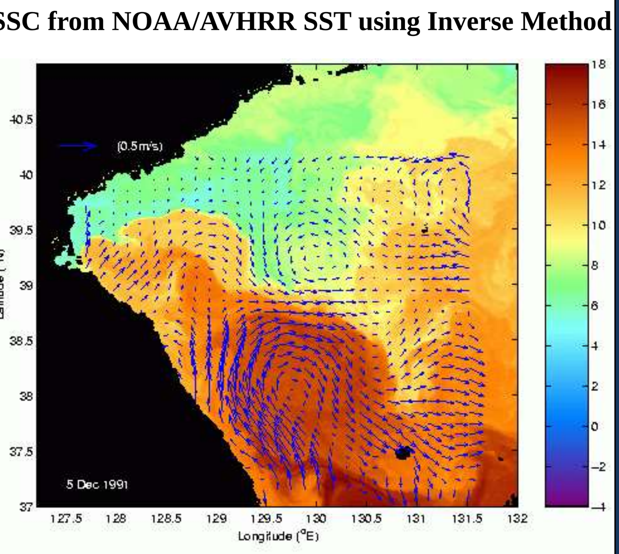


Figure Spatial distribution of
(a) GOCI chlorophyll-*a* concentration, (b) AVISO MADT height field, (c) correlation coefficients for the estimation of surface currents, and (d) critical thresholds around the four eddies (Eddy 1 to Eddy 4) on 5 April 2011. (e) Daily-averaged (9:30–16:30) surface current vectors derived from the MCC method. (f) SSC form Surface Drifter

- Comparison of SPM SSC with altimeter SSHA current
- Good agreement between SSHA Current and Surface drifter current

3. SSC from NOAA/AVHRR SST using Inverse Method

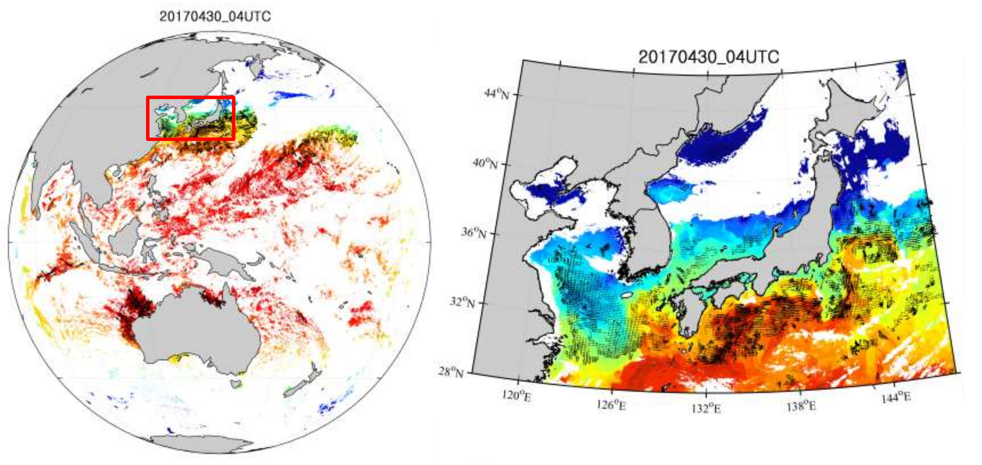


$$\sum_{ij}\left|\frac{\partial T}{\partial t} + \mathbf{u}\cdot\nabla T - S\right|^2_{ij} + \alpha^2\sum_{ij}|\nabla\cdot u|^2_{ij} + \beta^2\sum_{ij}|\mathbf{u}|^2_{ij} + \gamma^2\sum_{ij}|\nabla\times u|^2_{ij}$$

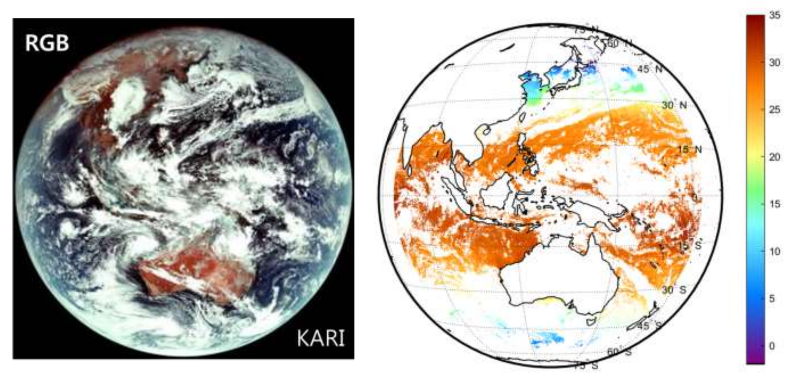
- Inverse method applied to derive SST from Two SST images
- Dynamic constraints applied
- Too long computation time
- Impractical for Real-time SSC estimation
- Importance of time-efficient and accurate methods for real-time SSC estimation

GK-2A/AMI L2 SSC output

❖ **An Example of Retrieved Sea Surface Current**



First image of GK-2A/AMI (26 Jan. 2019 0310 UTC)



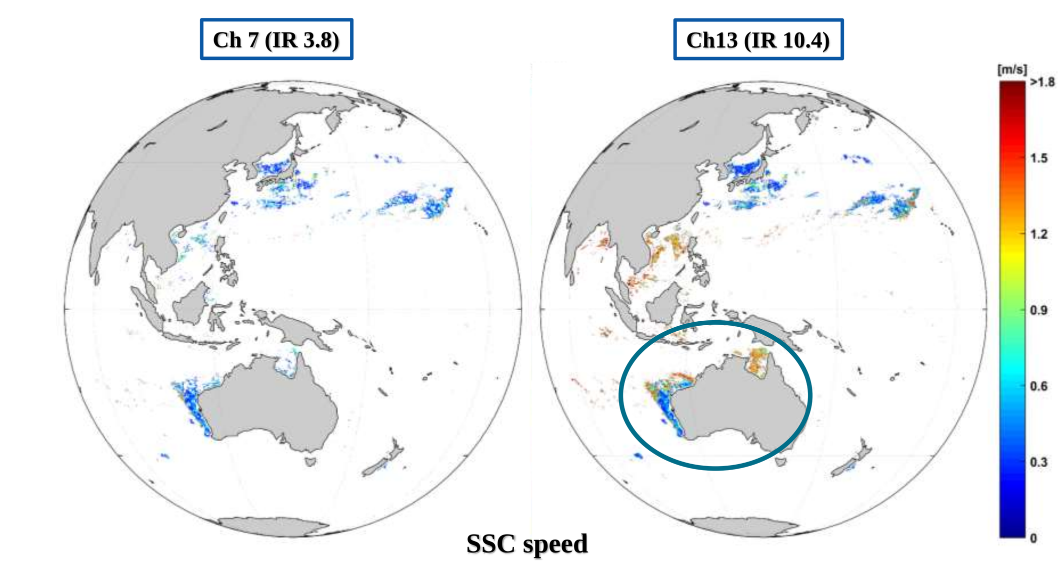
▲ **Figure.** The first RGB image of GK-2A / AMI and an example of spatial distribution of retrieved SST from GK-2A/AMI data at 00:30 UTC on 1 April 2019.

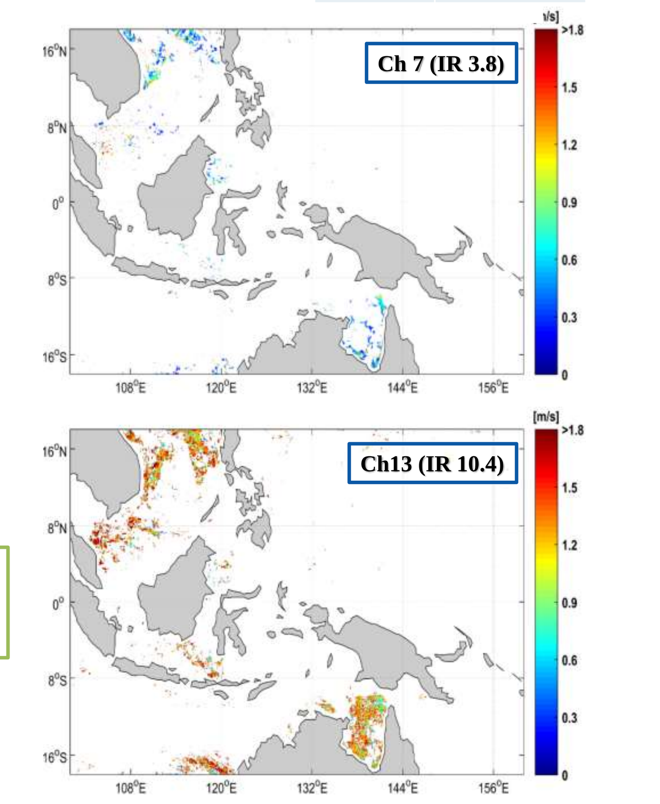
Development of optimal algorithm for SSC retrieval

❖ **Using additional channel 7 data (3.8 μm) ?**

- Channel 7 (3.8) is less affected by water vapor absorption so it is expected to 'see' features better in the Tropical latitudes

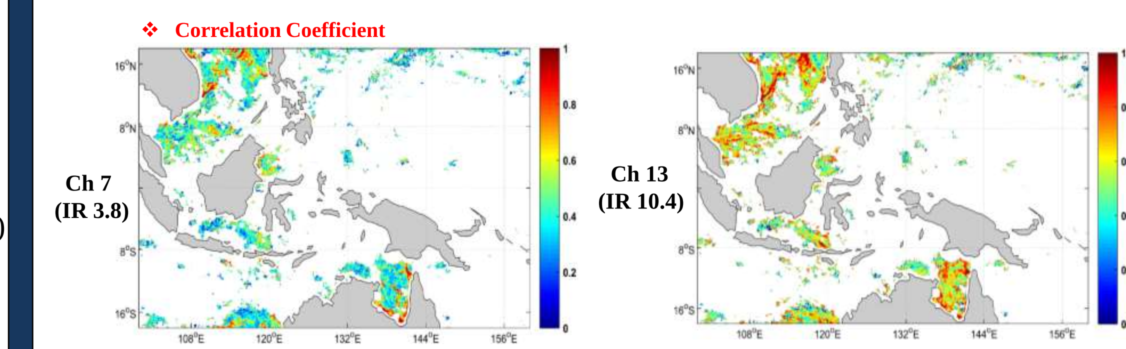
Used channel	Number of retrieved SSC vectors
channel 7	21949
channel 13	50550





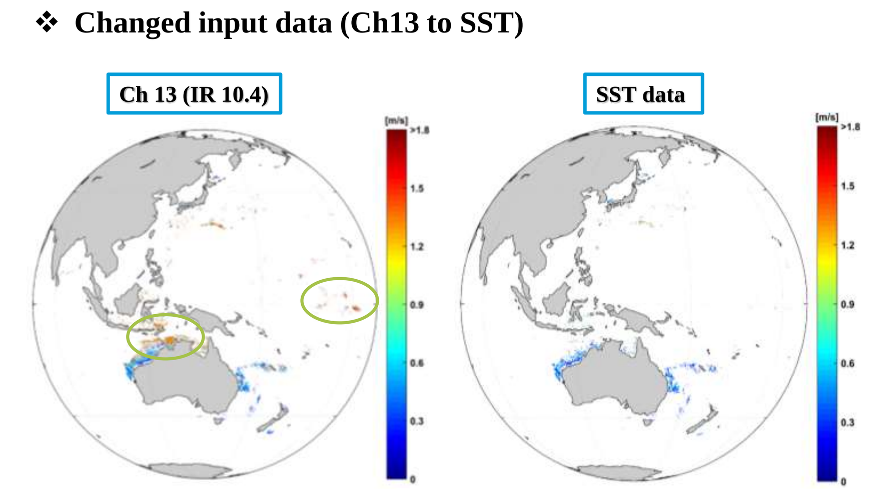
≫ **10.4 μm : More SSC vectors were generated using channel 13 data rather than channel 7 data, but contained overestimation problems.**
≫ **3.8 μm : appropriate range of SSC, but other issues (discontinuity in the Twilight Zone ..)**

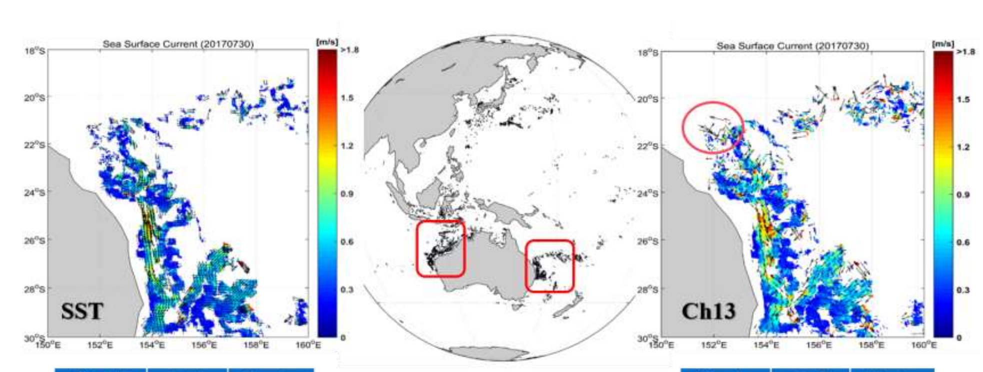
❖ **Correlation Coefficient**



≫ Much smaller correlation coefficients of channel 7
≫ A lot of SSC vectors are eliminated in the QC process
≫ Atmospheric feature rather than oceanic feature in some cases

❖ **Changed input data (Ch13 to SST)**





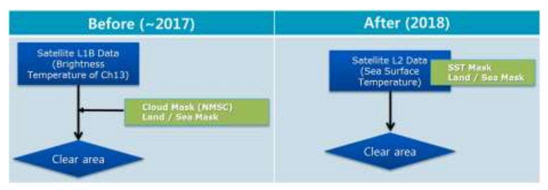
Using SST	Speed	Direction
RMSE	0.42 m/s	32.02°
Bias	0.15 m/s	3.77°

Using ch13	Speed	Direction
RMSE	0.48 m/s	46.39°
Bias	0.13 m/s	7.18°

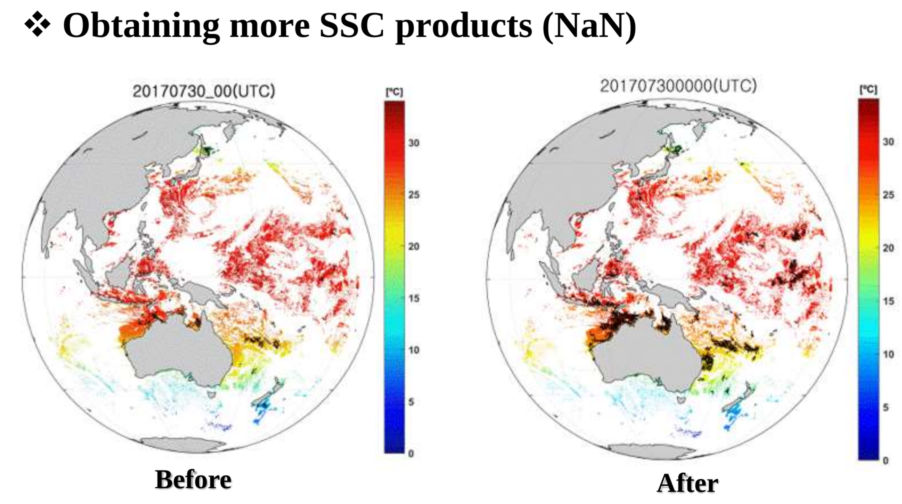
Use of SST:
- The problem of overestimation of the SSC speed in the equatorial region has been resolved.
- Good Correlation Coefficient
- Free of Atmospheric Features because of clear SST mask

- **SST : Low RMS and Bias errors**
- **Comparison revealed Improved accuracy of SSC products**
- **Outlier vectors are reduced (the irregular SSC directions)**

- **The input data was changed from L1B brightness temperature (channel 13 [10.4 μm]) to Level 2 SST data.**
  - ✓ **SST data is used as input data instead of single band data where various conditions of atmosphere affect.**
  - ✓ **Additional quality control process of SST output minimizes error value.**



❖ **Obtaining more SSC products (NaN)**



▶ **Adjustment of rejection conditions applied in the SSC retrieval**

- Before : If there is any NaN value in the calculating window, the calculation is stopped.
- After : SSC products are retrieved when there are more than 95% of data values in the calculating window.
- More SSC vectors were calculated and survived from a series of procedure.

Validation

❖ **Using satellite-tracked surface drifter data**

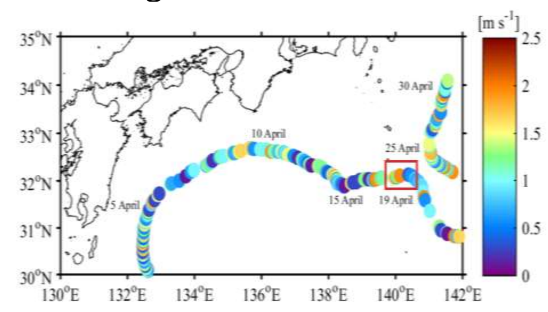


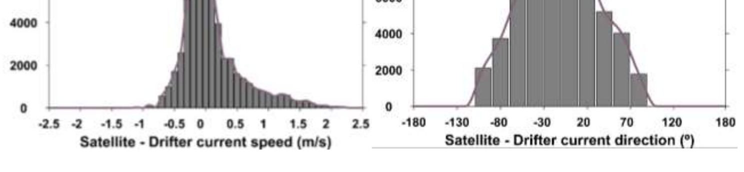
Figure. Trajectory of surface drifters in the study area on April 2016 where the colors represent the speed of surface drifter currents.

- Computed ocean currents using the location and time information of the drifter data
- Application of Quality Control Procedure of Drifter Current
  - Values above 3 m/s and outside the 2σ (standard deviation) range are excluded
- Producing matchup data between drifter current and retrieved SSC
  - Within the range of 3 x 3 pixels, ± 6 hours interval

Accuracy of the Estimated Currents

❖ **Validation Period : 2017.07.24 - 2017.08.07 (15 days)**
❖ **Region: Global**

Product	Accuracy Goal	Accuracy Obtained
SSC	Speed RMSE : 0.5 m/s Speed Bias : ± 0.3 m/s Direction RMSE : 50°	Speed RMSE : 0.47 m/s Speed Bias : ± 0.13 m/s Direction RMSE : 42.9°



- Considering the number of drifter current data in the drifter-satellite matchup database
- Accuracy assessment period was assigned for every 15 days
- Current algorithm satisfied the limit of accuracy goal

Summary

- **The GK-2A/AMI sea surface current retrieval algorithm was developed and has been improved for the better product accuracy. The AMI SSC are currently retrieved by the Zero-mean Sum of Squared Distances (ZSSD) method and the Level 2 SST data are used as input data.**
- **The estimated current speeds and directions show good agreement with the drifter-based calculated values and the estimated current field illustrates a rotating feature around a mesoscale anti-cyclonic eddy, as well as the characteristic meandering pattern of the Kuroshio Current.**

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