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

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Abstract

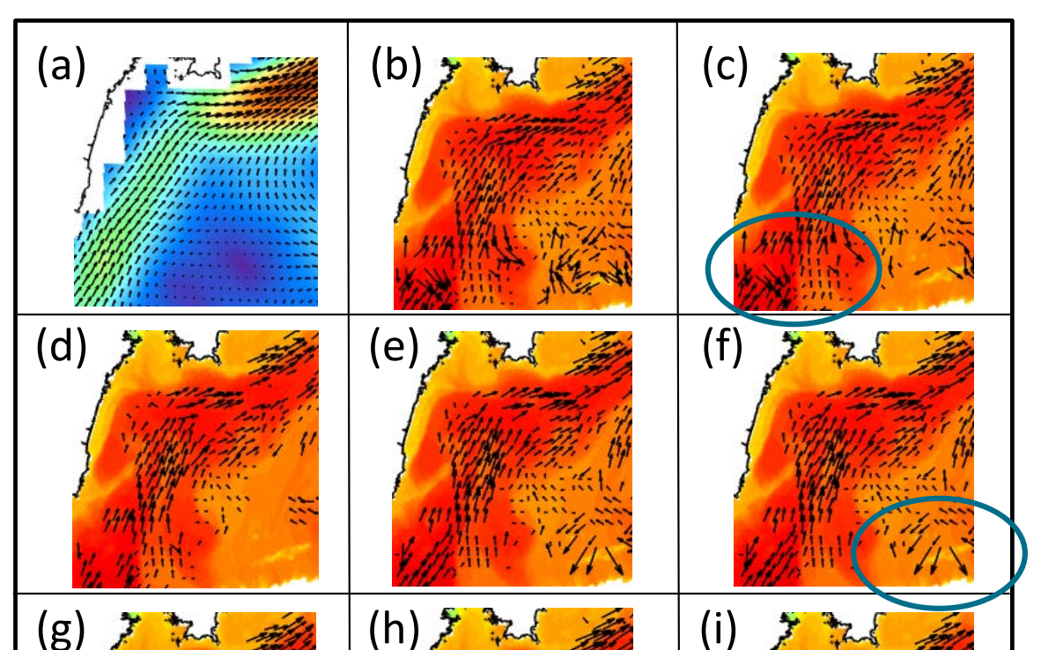
The AMI, as an essential payload of Geo-KOMPSAT-2A (Geostationary-Korea Multi-Purpose Satellite-2A, GK-2A) scheduled for launch in 2018, will offer more spectral bands (to allow new and improved products), higher spatial resolution (for better observing small-scale features), and faster imaging (to improve temporal sampling and to scan additional regions) than the MI of 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 at the current level is introduced. The SSC products are retrieved from subsequent Himawari-8 SST images, as a proxy for GK-2A SST, by applying the cloud detection and land/ocean mask data on the satellite images. 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 Himawari-8. Analysis results reveal that the estimated current speeds and directions show good agreement with the drifter-based calculated values, with root-mean-square (bias) errors of 0.23 m/s (0.05 m/s) and 10.06° (1.8°), respectively. 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

Ocean current is one of the most important aspects of the marine environment. In particular, sea surface current (SSC) is a major variable not only in the ocean circulation but also in the marine ecosystem and atmospheric environment. It provides energy to generate meteorological phenomena through direct interaction with the atmosphere and is closely related to global climate change. Therefore, producing accurate and regular information regarding sea surface currents is crucial task for understanding the global oceanic environment. 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. The SSC retrieval method, which applies the Maximum Cross Correlation (MCC) algorithm proposed by Leese (1971) to the feature tracking method has been proposed. The MCC algorithm is still the most commonly used method. However, as the MCC algorithm takes a long time to obtain the final output, it is not suitable to make real-time predictions for the purpose of weather forecasts. As an alternative to the MCC algorithm, the Sum of Absolute Differences (SAD) and Sum of Squared Distances (SSD) have been suggested by Marchello (2007). Both of these algorithms are based on the feature tracking method as well as the MCC algorithm, but differ in the method for calculating the statistical correlation between two consecutive satellite images used for the SSC retrieval. The SAD and SSD algorithms have relatively simple computation procedure and fast processing speed.

Quality Control Process



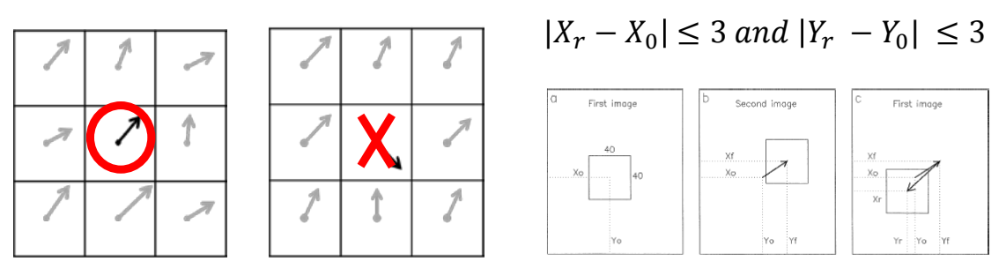
- (a) Altimeter SSHA current
- (b) Without quality control
- (c) Correlation coefficient 0.7
- (d) Correlation coefficient 0.9
- (e) Nearest neighbor comparison
- (f) Reciprocal filtering
- (g) CC 0.7 + Nearest comparison
- (h) CC 0.7 + Reciprocal
- (i) CC 0.7 + Nearest + Reciprocal

- QC Procedure Test for 9 Cases
- Correlation cutoff (0.7) with many of irregular current directions as (c)
- Poor functioning of Reciprocity filtering as (f)
- Nearest-neighbor combined with R(0.7) : better
- The QC method of (g) adopted

❖ Nearest-neighbor comparisons

❖ Reciprocity

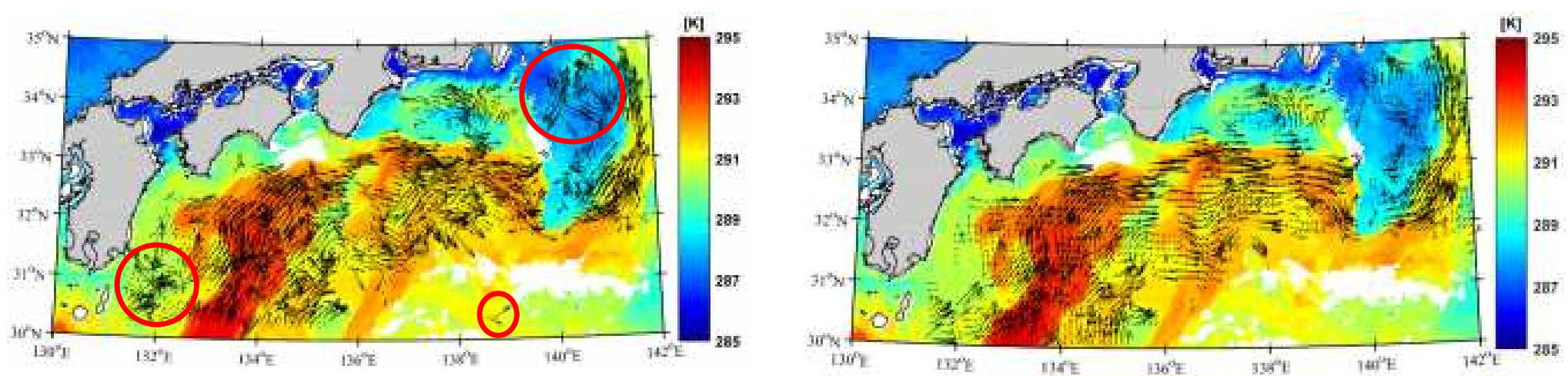
$|X_r - X_0| \leq 3$ and $|Y_r - Y_0| \leq 3$



- Spatial consistency
- Speed range : within 0.5 and 2 times of center vector (3x3windows)
- Direction range : within 50° of center vector (3x3windows)

❖ **Tested the performance of adopted QC processes**

- Considering the number of good quality vectors
- Completion of QC program code by applying test results



Before QC

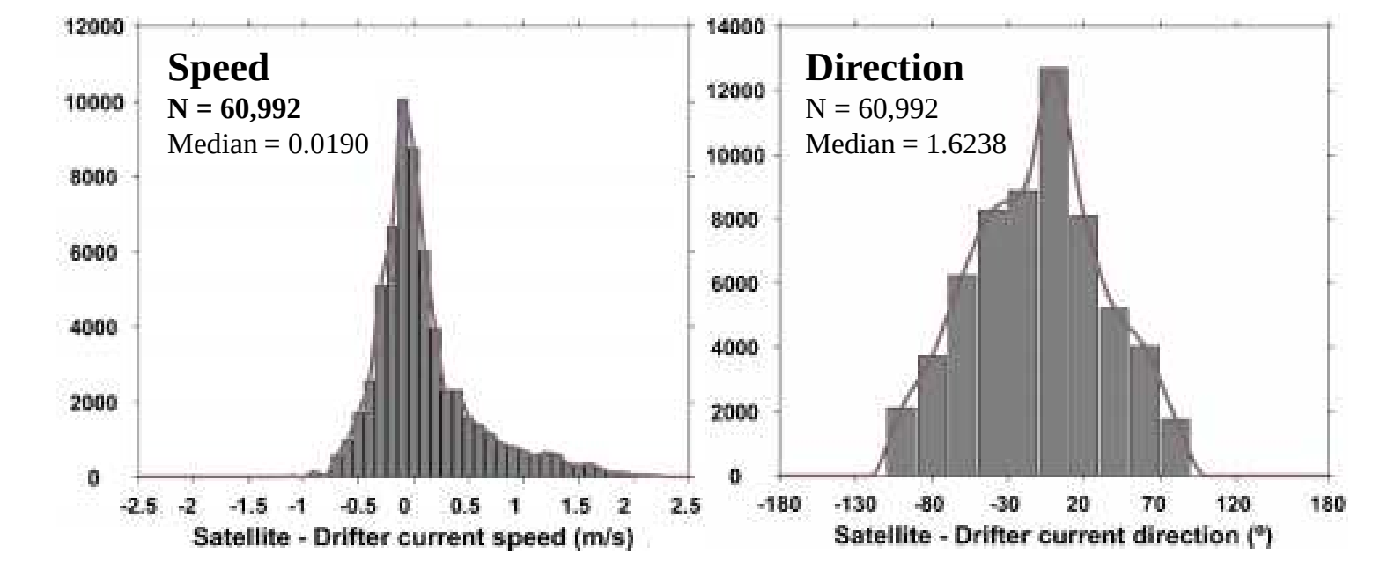
After QC

Accuracy of the Estimated Currents

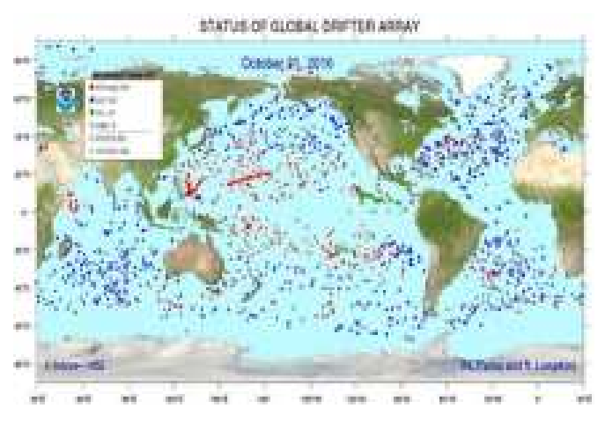
❖ **Validation Period : 2017.07.24 - 2017.08.07 (15 days)**

❖ **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°

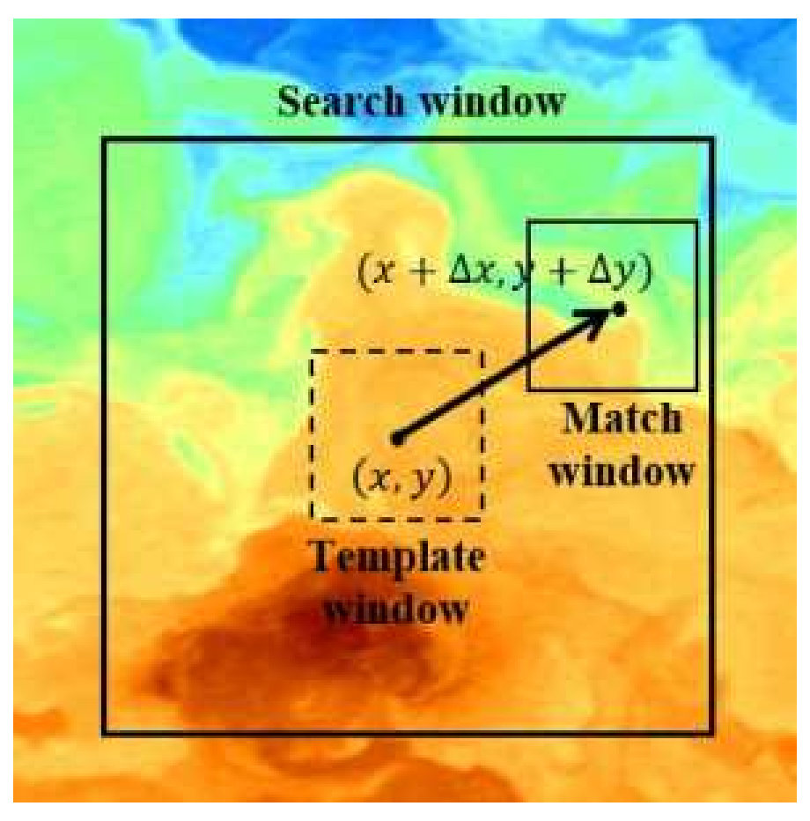


Data



- ❖ Himawari-8/AHI L1B and L2 data from KMA
  - CH7(3.9 µm), CH13(10.4 µm), CH14(11.2 µm), CH15(12.3 µm) Brightness Temperature
  - Resolution : Temporal → 10 min
    : Spatial → 2 km
  - Cloud mask and Land/Sea mask
  - Period : 2017.04
- ❖ Surface Drifter Data
- ❖ MADT(Maps of Absolute Dynamic Topography) Data from AVISO
  - Resolution : Temporal → 1 day
    : Spatial → 25 km

SSC Retrieval Algorithm

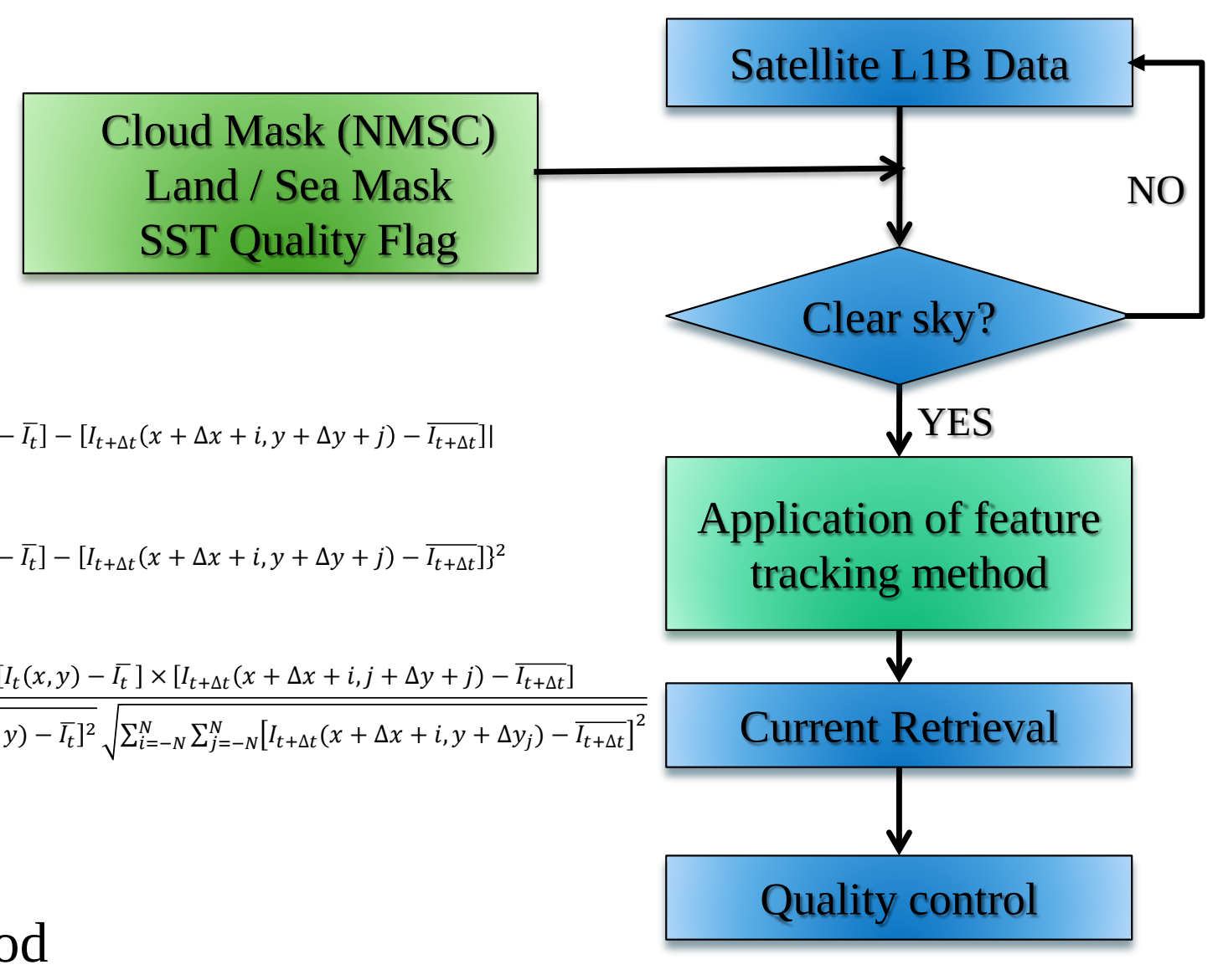


$$ZSAD(x+\Delta x, y+\Delta y) = \sum_{i=-N}^{N}\sum_{j=-N}^{N} |[I_t(x,y) - \overline{I_t}] - [I_{t+\Delta t}(x+\Delta x+i, y+\Delta y+j) - \overline{I_{t+\Delta t}}]|$$

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

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

Figure. A schematic diagram of feature tracking method



Satellite L1B Data

Cloud Mask (NMSC)
Land / Sea Mask
SST Quality Flag

Clear sky?

NO

YES

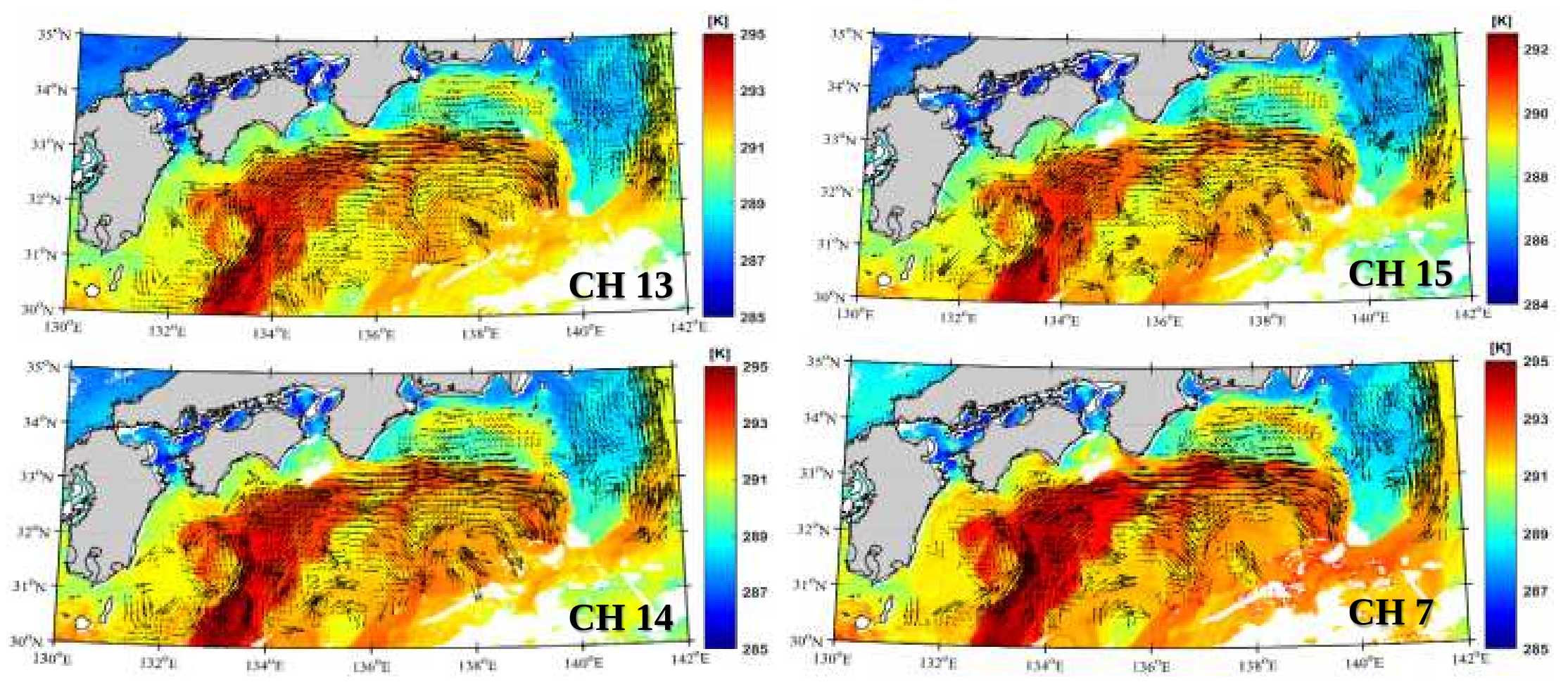
Application of feature tracking method

Current Retrieval

Quality control

Development of optimal algorithm for SSC retrieval

❖ **Which channel is the most appropriate for SSC estimation?**



CH 13 (10.4 μm)	Speed	Direction
RMSE	0.23 m/s	10.06°
Bias	0.04 m/s	0.87°
Number of retrieved vectors	32154	

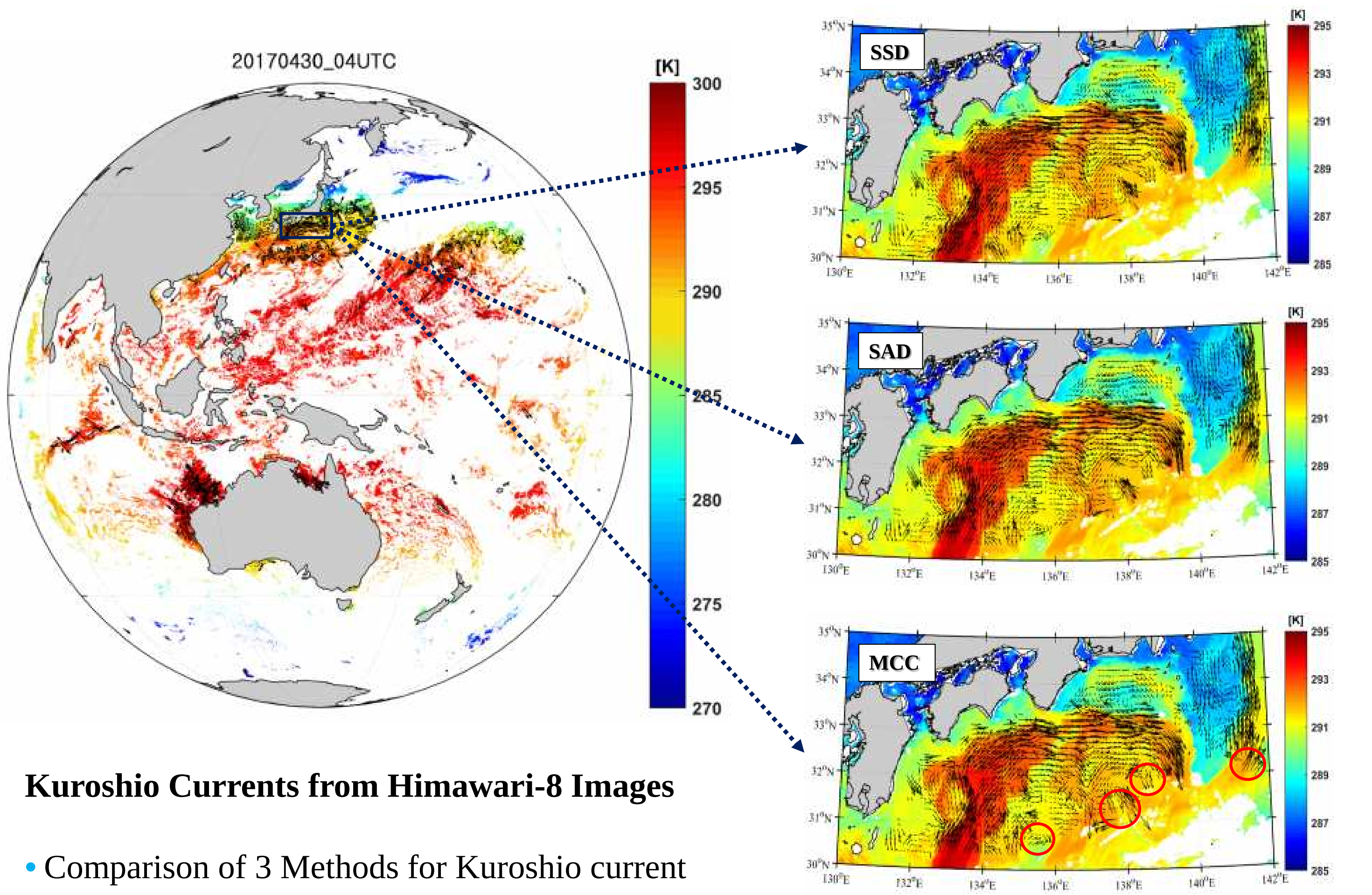
CH 15 (12.3 μm)	Speed	Direction
RMSE	0.26 m/s	25.2°
Bias	0.06 m/s	-7.51°
Number of retrieved vectors	23966	

CH 14 (11.2 μm)	Speed	Direction
RMSE	0.25 m/s	10.3°
Bias	-0.05 m/s	0.93°
Number of retrieved vectors	30942	

CH 7 (3.9 μm)	Speed	Direction
RMSE	0.25 m/s	11.2°
Bias	0.08 m/s	1.04°
Number of retrieved vectors	22819	

- Comparison of SSC accuracy with drifter current vectors
- Again, 10.4 ***µ*m (13th)** smaller errors than other thermal bands
- Relatively large number of current vectors of 10.4 ***µ*m** channel after QC

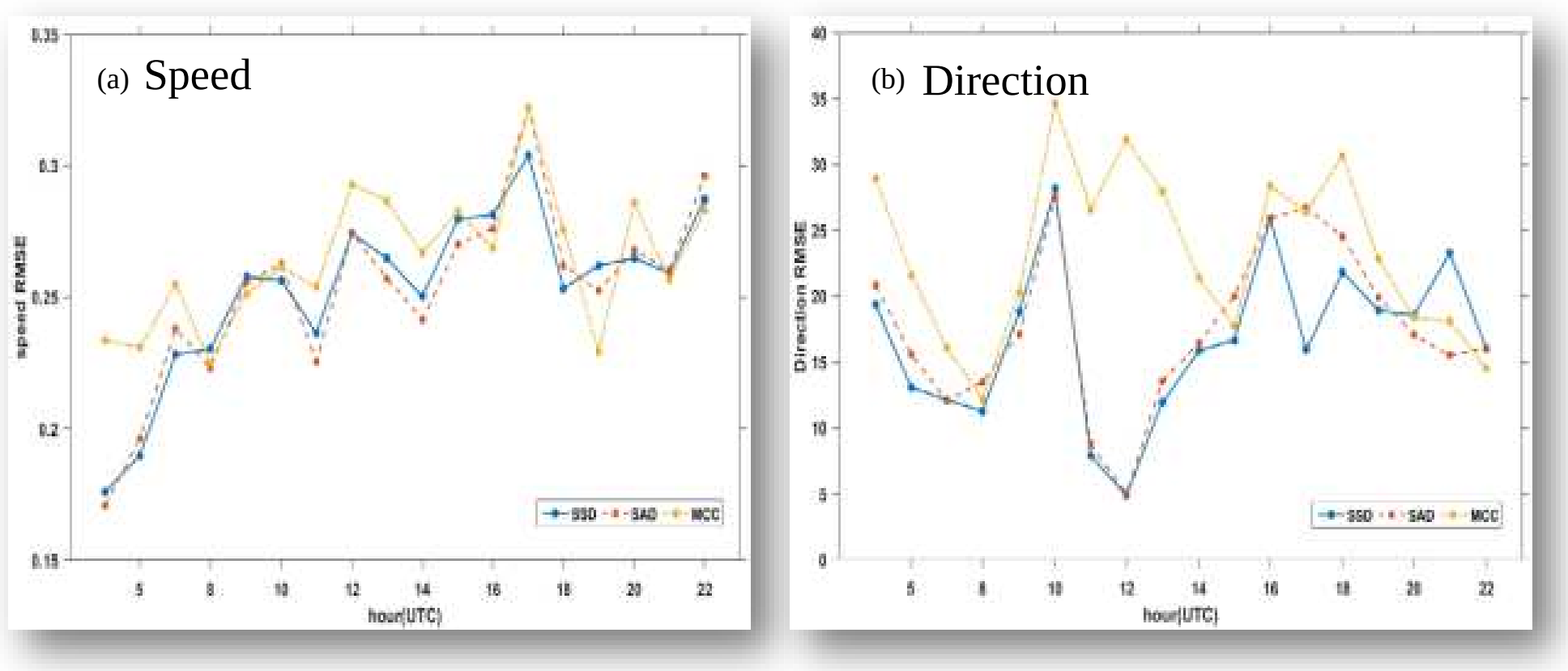
❖ **Which algorithm is the most appropriate for GK-2A AMI?**



Kuroshio Currents from Himawari-8 Images

- Comparison of 3 Methods for Kuroshio current
- The results of SSD and SAD are quite a similar
- MCC-based currents show erroneous outlier vectors relatively frequently

❖Hourly variations of RMSE of estimated current vectors by each algorithm



- Largest errors from MCC (yellow) method for both speed and direction
- The results of SSD and SAD are quite a similar
- Relative small errors at 16-20h: SSD seems better in night

❖Computation Time and the Error Ratios (%) to the Total Number of current vectors

		SAD	SSD	MCC
Computation time		0.90	0.87	1
Error / Total	Kuroshio	9.06 %	8.86 %	9.83 %
	Global	10.4 %	10.31 %	11.23 %

- **Computation time**
  MCC > SAD > SSD
- **Ratio of error vectors**
  Nrejected / Nestimated (%)
  MCC > SAD > SSD

SSD
- **Efficient Time /A few erroneous vectors**

Validation

❖ **Satellite-tracked surface drifter data**
- **Collocation : within 3x3 pixels, ±3 hrs**

❖ **AVISO geostrophic current**

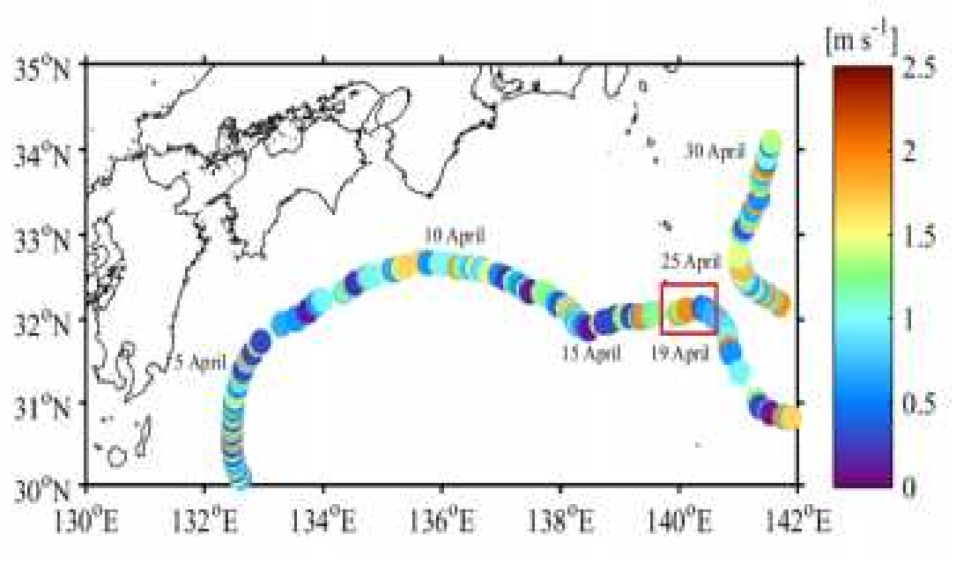


Figure. Trajectory of surface drifters in the study area on April 2016 where the colors represent the speed of surface drifter currents.

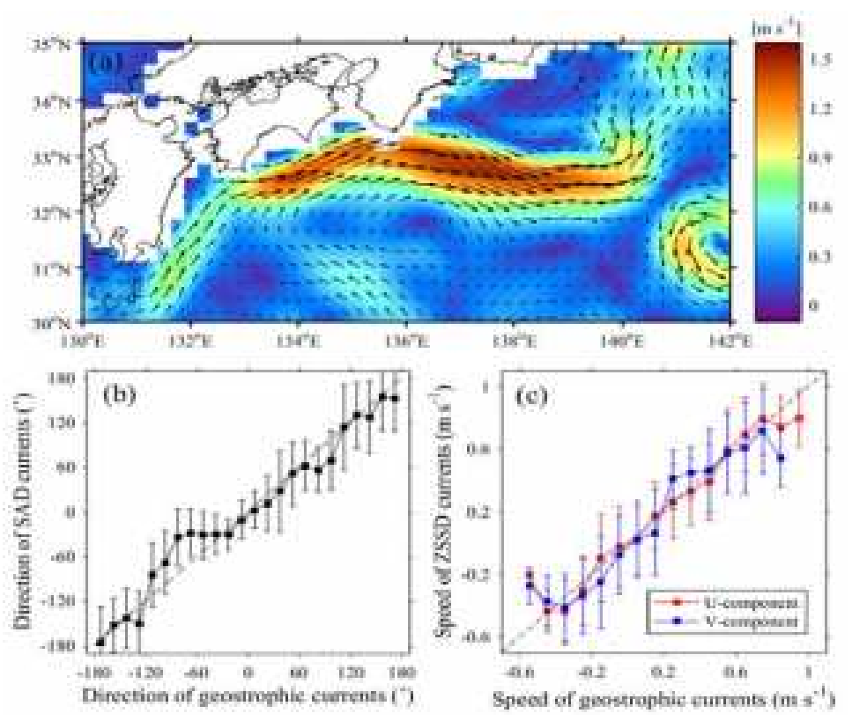


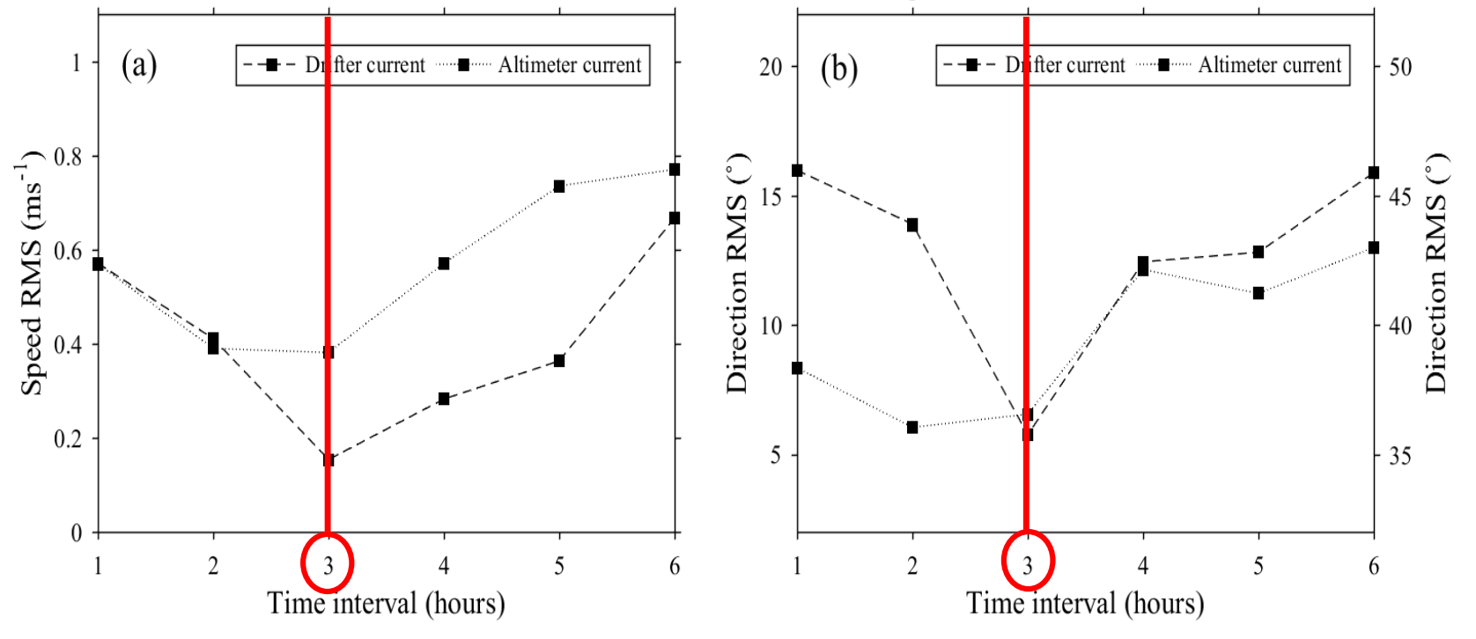
Figure. (a) Spatial distribution of AVISO geostrophic current vectors, where the background image shows the speed. Comparisons of MCC current vectors and geostrophic current vectors with respect to (b) direction, (c) u-component (red) and v-component (blue)

Summary

- **The sea surface currents were estimated from the Geostationary satellite SST images and validated with drifter data and AVISO geostationary current data.**
- **The accuracy was affected by the magnitude of brightness temperature gradients and the time interval between satellite image data.**

Error Characteristics

❖**Time interval between two images**



- Comparison with the currents from drifters and altimeter SSHA data
- Minimum errors of current speed and direction at 3 hour-interval
- The larger SST fronts, the smaller the SSC errors
- SST fronts may contribute to the accuracy of SST retrievals

❖**Magnitude of BT spatial gradient**

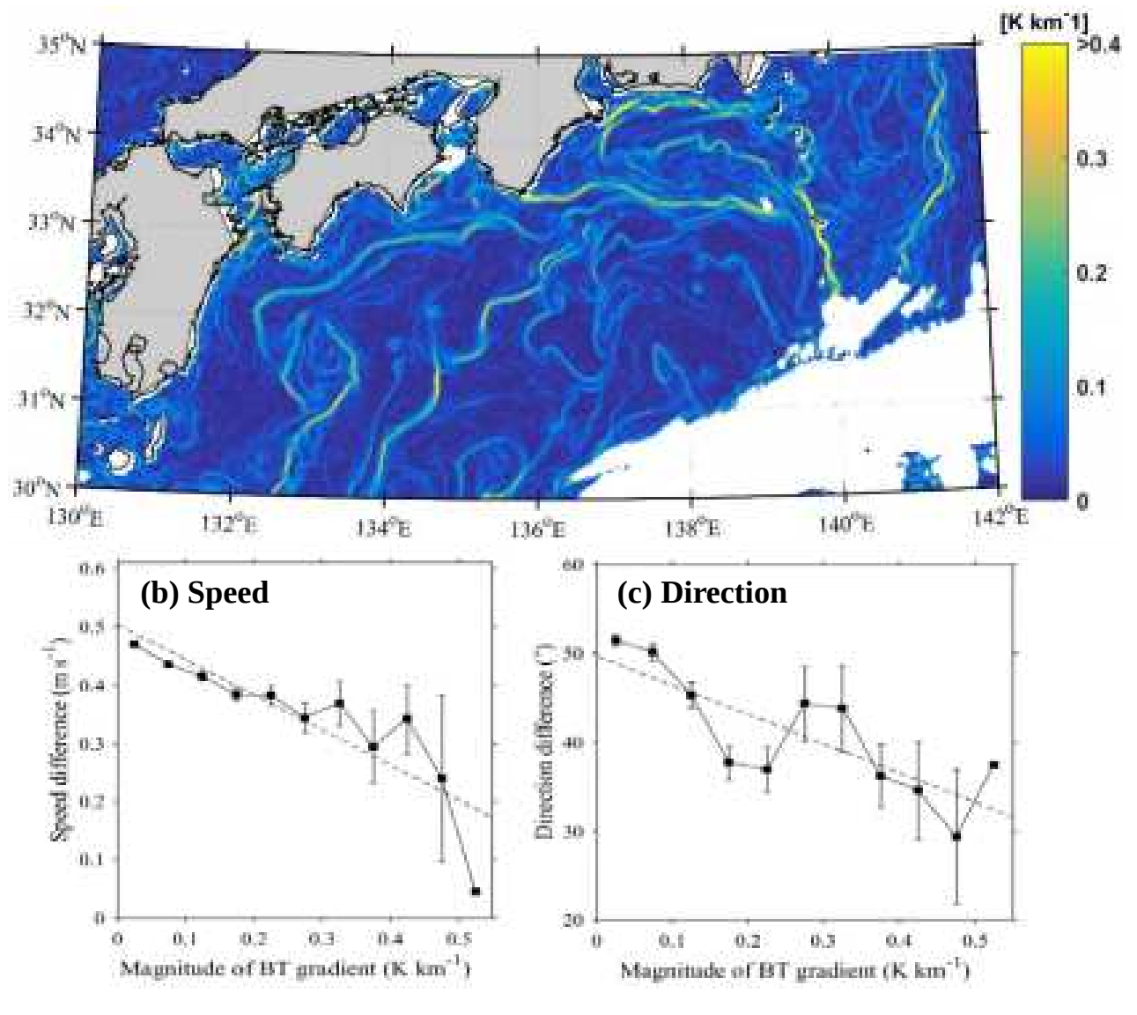


Fig. (a) Spatial distribution of the magnitude of brightness temperature gradients on April 30, 2017, 12:00(UTC). Difference in (b) speed and (c) direction between estimated surface currents as a function of the magnitude of brightness temperature gradients

Acknowledgment

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