# Short-term Variations of Sea Surface Currents Estimated From Geostationary Satellite Sea Surface Temperature Images

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## Abstract

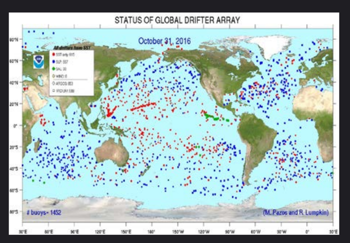
**This study assesses the accuracy of the surface currents from subsequent Himawari-8 SST images, as a proxy for GEO-KOMPSAT-2A (Geostationary - Korea Multi-Purpose Satellite-2A) SST, by comparing the quality-controlled currents obtained by the Himawari-8 satellite with the estimated currents obtained 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 0.15 m/s (-0.05 m/s) and 6.1° (1.8°), respectively. The estimated current field illustrates a rotating feature around a mesoscale anticyclonic eddy, as well as the characteristic meandering pattern of the Kuroshio Current. In addition, we present short-term hourly variations of the surface current and their potential causes, and address the importance of the role of high-resolution geostationary satellite SST measurements in understanding short-term surface current variations.**

## Introduction

**Surface geostrophic currents have long been estimated with reliable accuracy from sea surface height anomalies observed by satellite radar altimeters. However, altimeter-based oceanic current fields contain inherent errors related to the spatial distance and temporal discrepancy of measurements between altimeter tracks. Surface currents based on sequential sea surface temperature (SST) images of near-polar orbiting satellites also 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.**

## Data

- ❖ **Himawari-8/AHI L1B and L2 Data from KMA**
  - **- Ch13 (10.4 μm) Brightness Temperature**
  - **- Resolution : Temporal → 10 min**
  - **: Spatial → 2 km**
  - **- Period : 2016. 04.**
- ❖ **- Cloud mask (from NOAA) and Land/Sea Mask**
- ❖ **Surface Drifter Data**
- ❖ **MADT(Maps of Absolute Dynamic Topography) Data from AVISO**
  - **- Resolution : Temporal → 1 day**
  - **: Spatial → 25 km**



## SSC Retrieval Algorithm

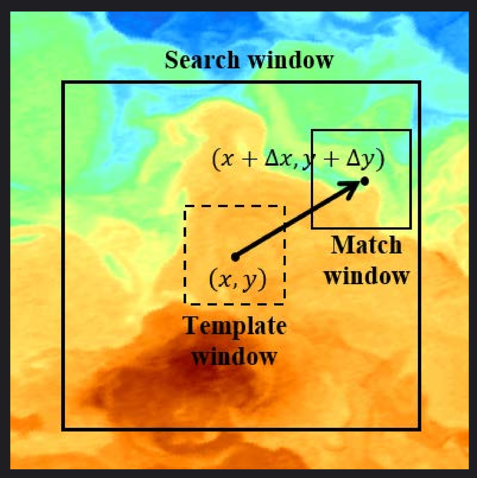
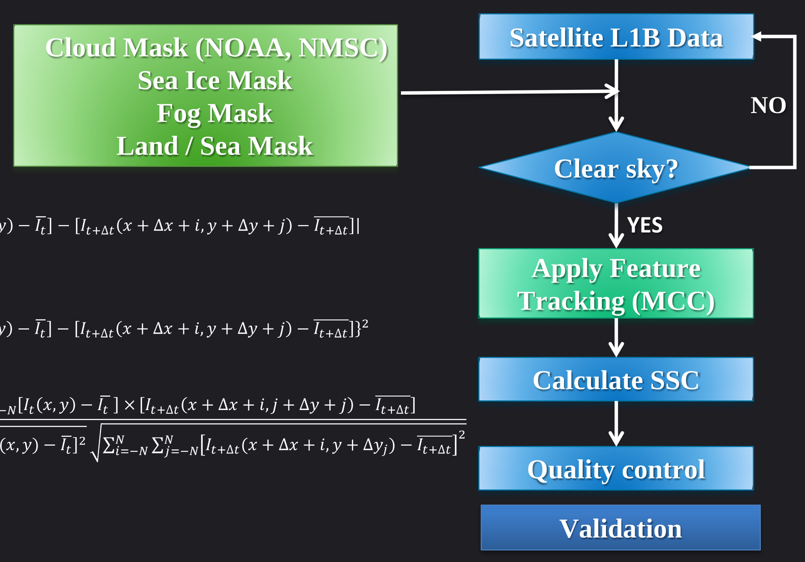



**Figure.** A schematic diagram of feature tracking method

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

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

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




## Retrieval of sea surface currents

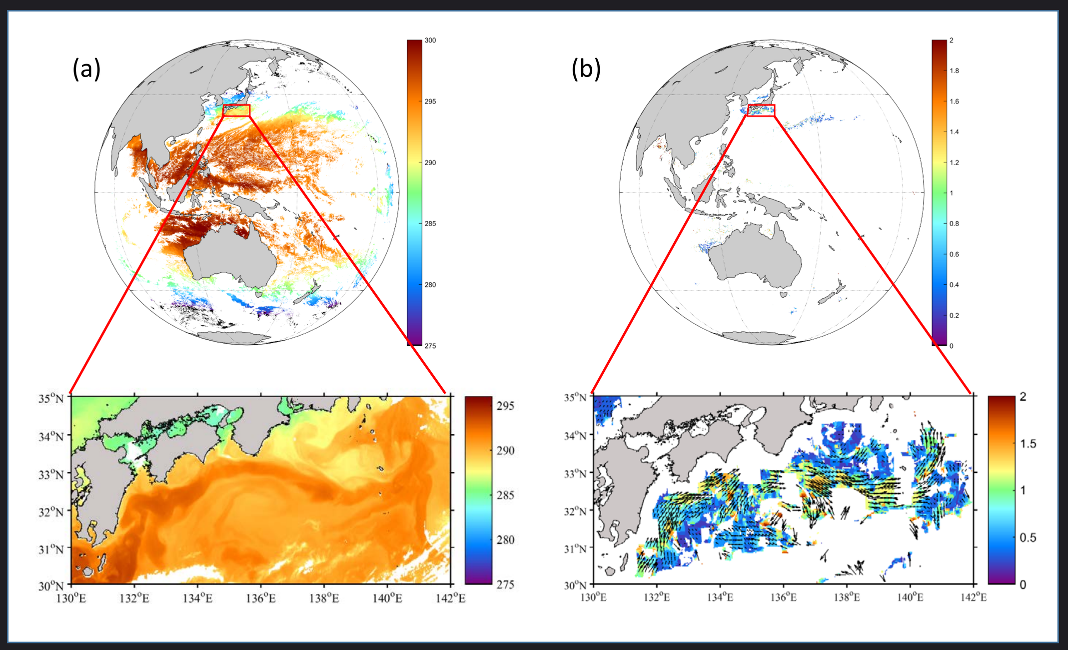
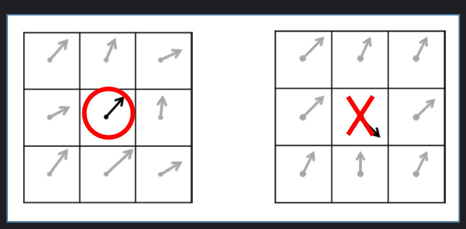


**Figure.** An example of (a) the Himawari8/AHI brightness temperature images on April 19, 2016, 10:40 UTC and (b) the results of the estimated sea surface current vectors using MCC method in the full disk region. The figure below shows the results in the Kuroshio region.

### Quality Control of estimated currents

- ❖ **Correlation coefficient threshold : 0.8**
- ❖ **Nearest-neighbor comparison**
  - **- Spatial uniformity check**
  - **- Speed threshold : within 0.5 and 2 times**
  - **- Direction threshold : within 50°**



### Quality Controlled Currents

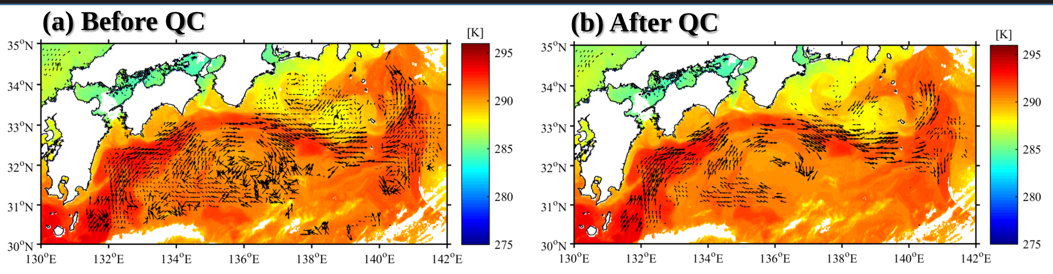



Figure. Estimated surface current vectors (a) without Quality Control, and (b) with Quality Control applied in the Kuroshio current region(south of Japan) on April 19, 2016

- The estimated current field illustrates the characteristic meandering pattern of the Kuroshio Current, which also appears in the SST image.

## Mesoscale Anticyclonic Eddy

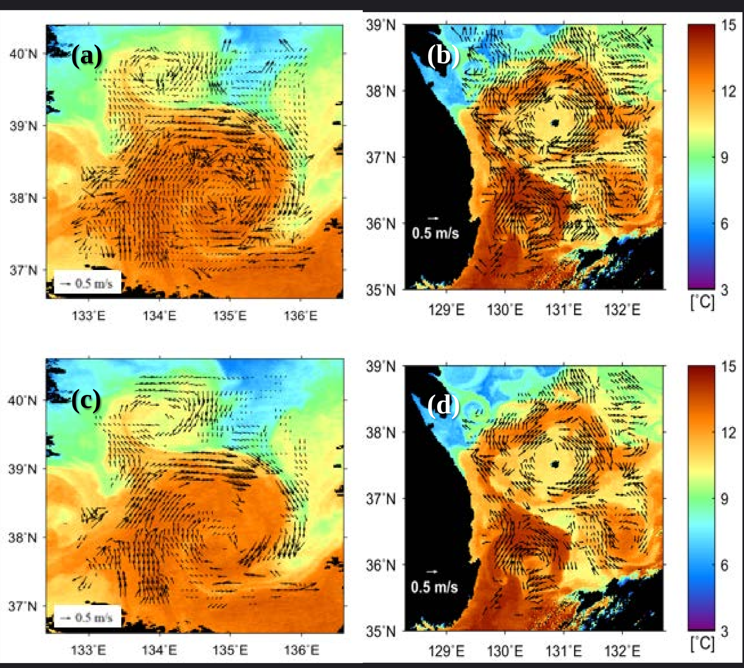


**Figure.** An example of (a), (b) the current vectors retrieved without QC from the NOAA SST images on April 10, 2015 at 20:56(UTC) and 07:46(UTC) of April 11 (c), (d) the results of the estimated sea surface current vectors with QC applied.

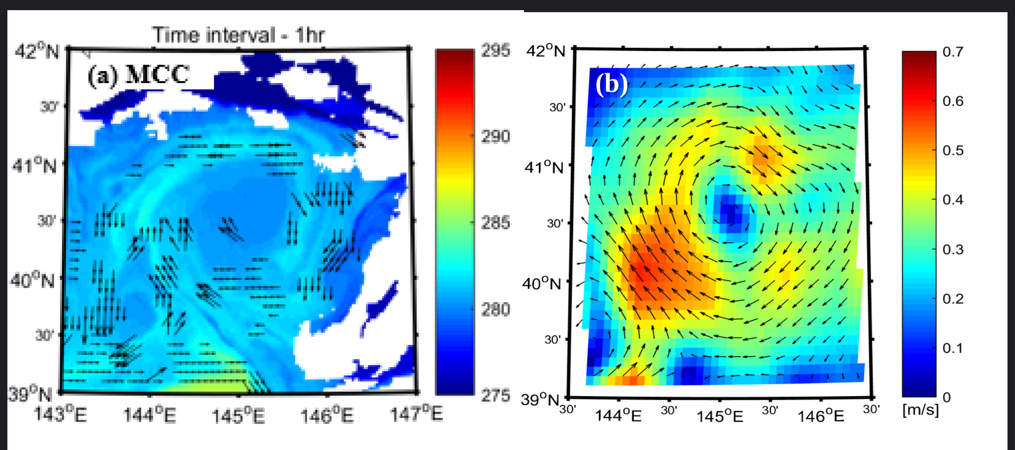
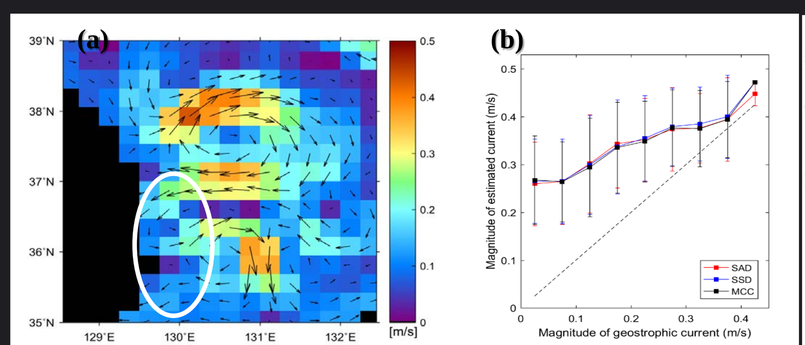
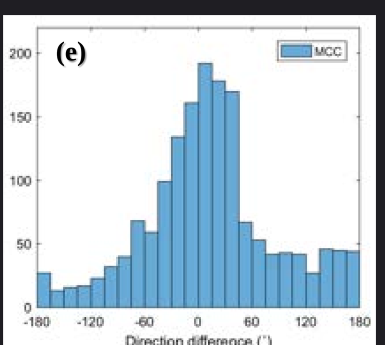



Figure. (a) Sea surface currents field estimated from Himawari8/AHI SST images on May 08, 2016 using MCC Method (b) Gridded geostrophic current from AVISO

### Accuracy & Error Characteristics

| | Magnitude (m/s) | | Direction (degree) | | Total number |
|---|---|---|---|---|---|
| | RMSE | BIAS | RMSE | BIAS | |
| MCC | 0.1416 | -0.0179 | 12.5802 | -0.8915 | 67 |





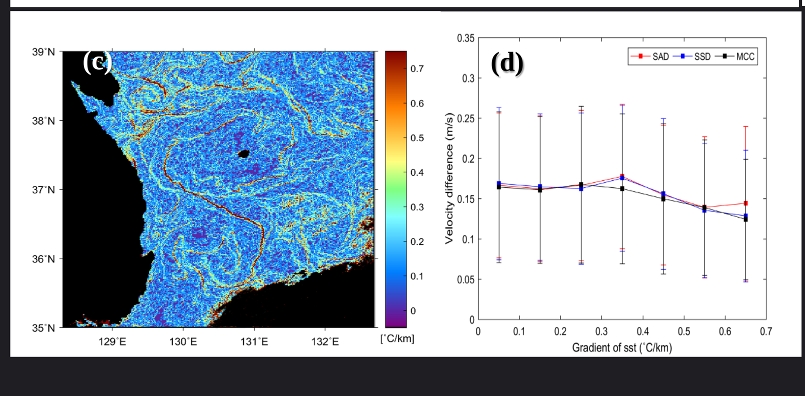


Figure. (a) Spatial distribution of altimeter current vectors, where the background image shows the magnitude of vectors (b) Speed differences and (c) direction differences between ZSSD currents and geostrophic currents as a function of brightness temperature gradient. (e) histogram of direction difference of circled area in (a)

- Sea surface currents calculated from NOAA SST data and Himawari8 SST data are both illustrating well the mesoscale anticyclonic eddy located in the East Sea.
- Compared to AVISO geostrophic current, it shows relatively good accuracy.
- The current retrieved from the SST image is advantageous for understanding the detailed structure of the currents rather than the altimeter current due to its high resolution

## Validation

### Accuracy of the Estimated Currents

- ❖ **Satellite-tracked surface drifter data from KMA**
  - **- Collocation : 2km, 24hr**
- ❖ **AVISO geostrophic current**

Table. RMS and bias errors of estimated surface currents to observed currents from satellite-tracking drifter

| | Speed ($ms^{-1}$) | | Direction (˚) | | Total |
|---|---|---|---|---|---|
| | RMS | Bias | RMS | Bias | number |
| MCC | 0.154 | -0.047 | 6.121 | 1.813 | 75 |

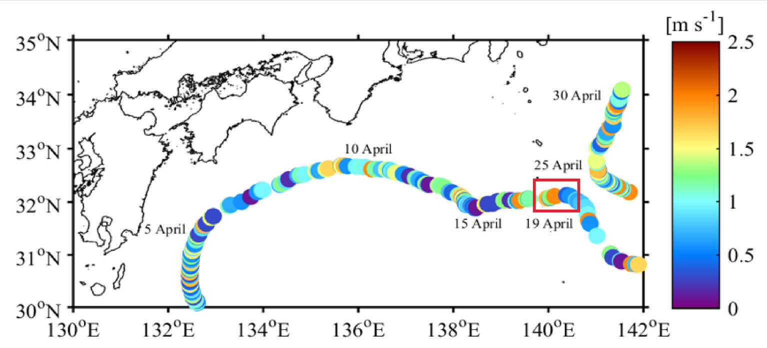


Figure. Trajectory of surface drifters in the study area on April 2016 where the colors represent the speed of surface drifter currents.

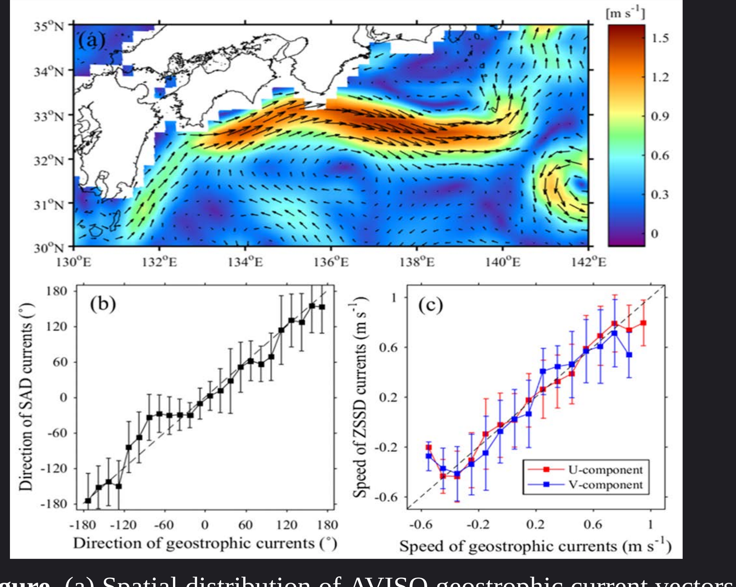


**Figure.** (a) Spatial distribution of AVISO geostrophic current vectors, where the background image shows the speed. Comparisons of MCC current vectors and geostrophic current vectors with respect to (b) direction, (c) u-component (red) and v-component (blue)

## Error Characteristics

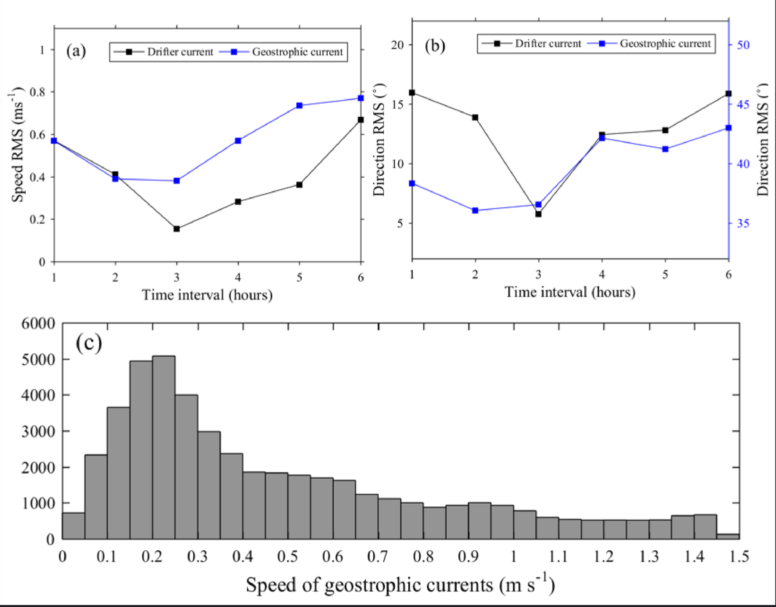


**Figure.** (a) Speed and (b) direction RMS errors of ZSSD currents to surface drifter currents (black) and AVISO geostrophic currents (blue) by time interval between satellite image sequences. (c) Distribution of speed of geostrophic current on April 19, 2016

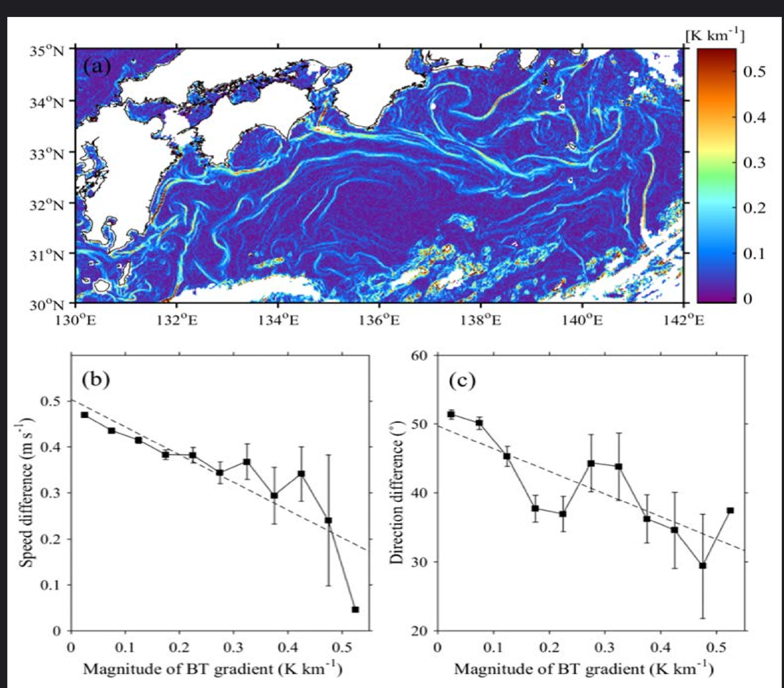


**Figure.** (a) Spatial distribution of magnitude of brightness temperature gradients on April 19, 2016, 10:40 UTC. (b) Speed differences and (c) direction differences between ZSSD currents and geostrophic currents as a function of brightness temperature gradient.

## Diurnal Variation

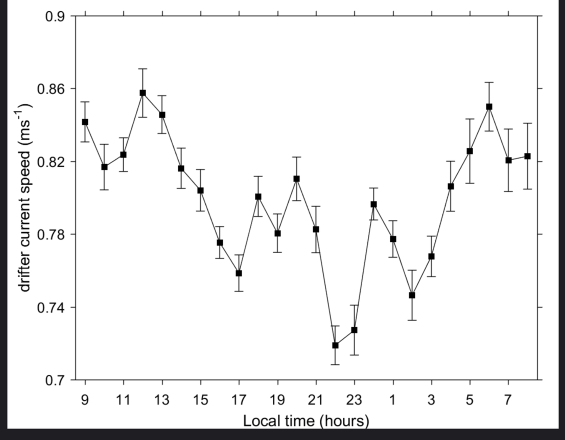


**Figure.** Hourly variation of MCC surface current speed of the Kuroshio, south of Japan, on April 19, 2016

- **Diurnal signal was observed**
- **Current speed showed maximum value at 12:00(LT) and minimum value at 0:00-02:00(LT).**

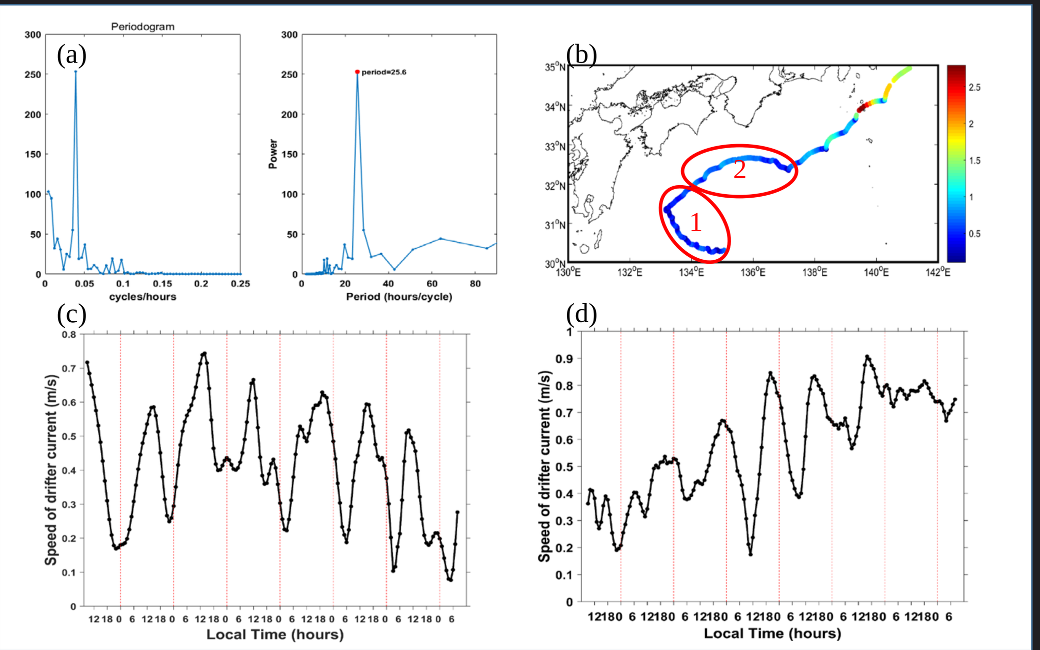


**Figure.** Variation of the drifter current speed with time. (a) the results of Fast Fourier Transform. It shows dominant period at 25.6 hrs. (b) Trajectory of surface drifters in the study area on April 2016 where the colors represent the speed of the surface drifter currents (c) time series of the drifter current speed in area 1 (d) and area2

## Summary and Conclusion

- 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.
- The diurnal changes of the Kuroshio surface currents along the southern coast of Japan were observed at both of the satellite estimated currents and drifter current. It address the importance of the role of high-resolution geostationary satellite SST measurements in understanding short-term surface current variations.

### Acknowledgment

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