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High-resolution arctic sea ice image acquisition and mosaicking using helicopter-borne sensors

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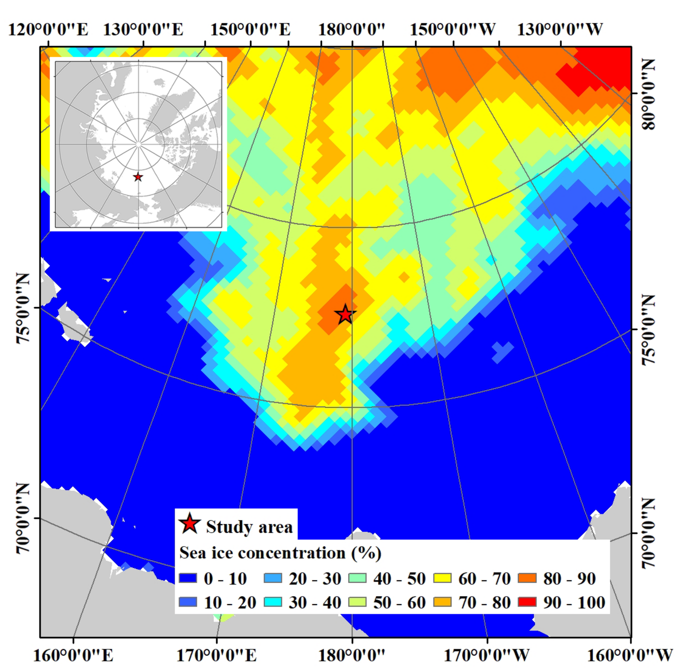
Abstract

Observing state of arctic sea ice using remote sensing techniques plays key role in understanding present state and providing information for predicting future changes. Satellite remote sensing has been applied to investigate various properties of sea ice, e.g., distribution, concentration, surface composition, topography, etc., from the capability of data acquisition over wide areas with short time intervals. To validate or calibrate the satellite remote sensing datasets or products higher resolution ground truth data acquired during field investigation is necessary. Helicopters carried onboard icebreaker for multiple purposes, not only scientific research activities but also carrying people and cargos, can be an efficient remote sensing platform for obtaining the higher resolution ground truth data of sea ice. However, continuously drifting sea ice hampers precise image mosaicking and comparing with other remote sensing datasets or products due to increased ambiguity in geolocation accuracy. This study demonstrates a practical acquisition of high-resolution helicopter-borne images over arctic sea ice using a helicopter carried onboard Korean icebreaking research vessel Araon and proposes a protocol to compensate the effect from sea ice drift to the opportunistically obtained images using a drift trajectory of sea ice. The suggested approach can be applied to the helicopters carried on board other icebreakers. The method for compensation of sea ice drift also can be used to mosaic high resolution sea ice images from unmanned aerial vehicle or other aerial photography.

Materials and Methods

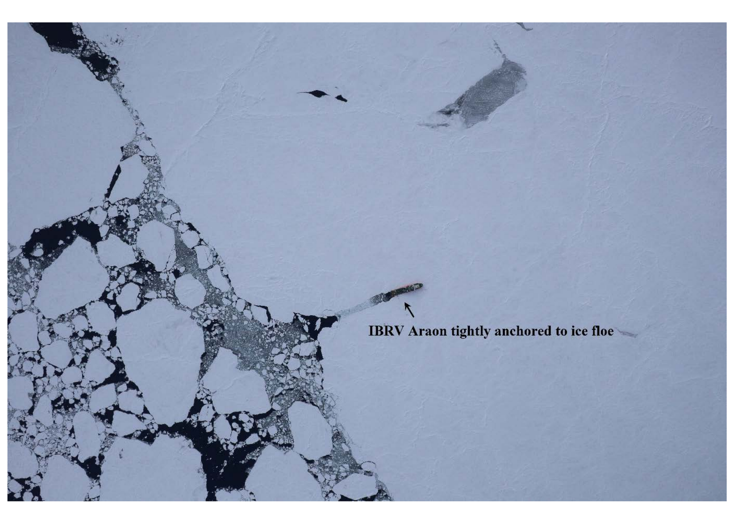
- Description of Study Area
  - The sea ice field investigation was conducted around 77°36'N/179°12'E in the East Siberian Sea, Arctic Ocean with a support of IBRV Araon, during August 13-15, 2017.
  - Sea ice conditions during the field investigation period around the study area were estimated in the range of 80–90% sea ice concentration from the National Snow and Ice Data Centre (NSIDC).



- Acquisition of Dataset
  - The VHR images were acquired during sea ice field investigation using helicopter-borne COTS imaging sensor.
  - A commercial digital camera was attached on the bottom of helicopter and set to nadir viewing geometry. Imaging time interval was set to every single second.
  - To record flight path of the helicopter, a commercial potable GPS logger with a capability of 20 Hz recording frequency was carried during flight for image acquisition.
  - In a post-processing procedure, the GPS logs of the time difference less than 0.02 second between GPS log and timing of image acquisition were selected and designated as the image acquisition positions of corresponding images.

Imaging Setup	Specifications
Digital camera	Canon EOS M6
Imaging interval	1 s
Imaging mode	Aperture priority mode
Sensor	24 mega-pixel APS-C
Focal length	22 mm
Aperture	F11
Shutter speed	Varies between 1/1000 and 1/3200
ISO	400

- Image Processing and Error Estimation
  - To decrease temporal and spatial ambiguity of the VHR images, linear time interpolation approach was adopted.
  - The IBRV Araon was tightly anchored in the sea ice floe where field investigation was conducted during the VHR image acquisition and the position of the IBRV Araon synchronized with drift of ice floe field was recorded in 1 Hz frequency by interior system.



  - The position of the IBRV Araon at the starting time of the VHR images selected for analysis was assigned as a reference position, and then other positions of the IBRV Araon were linearly interpolated to 0.05 second interval to match with the VHR images.
  - From the time interpolated drift records, differences in locations between the reference position and linearly time interpolated positions corresponding to each VHR image acquisition position were calculated.
  - As a final step, the VHR image acquisition positions except for the image at the reference position were adjusted using the differences of locations to compensate temporal and spatial ambiguity from the sea ice drifts
  - After the compensation of the effects from sea ice drifts in the VHR images acquisition positions, structure-from-motion (SfM) technique was applied to mosaic the pre-processed VHR images.
  - To assess improvement of errors of camera locations after pre-processing, photogrammetric inference and accuracy assessment of camera locations were conducted during image mosaicking procedure.

$$\text{X error} = \sqrt{\textstyle\sum_{i=1}^{n}\left(X_{i_{est}} - X_{i_{n}}\right)^2},\ \text{Y error} = \sqrt{\textstyle\sum_{i=1}^{n}\left(Y_{i_{est}} - Y_{i_{n}}\right)^2},\ \text{Z error} = \sqrt{\textstyle\sum_{i=1}^{n}\left(Z_{i_{est}} - Z_{i_{n}}\right)^2},$$

$$\text{XY error} = \sqrt{\textstyle\sum_{i=1}^{n}\left(X_{i_{est}} - X_{i_{n}}\right)^2 + \left(Y_{i_{est}} - Y_{i_{n}}\right)^2},$$

$$\text{Total error} = \sqrt{\textstyle\sum_{i=1}^{n}\left(X_{i_{est}} - X_{i_{n}}\right)^2 + \left(Y_{i_{est}} - Y_{i_{n}}\right)^2 + \left(Z_{i_{est}} - Z_{i_{n}}\right)^2}$$

Acknowledgement

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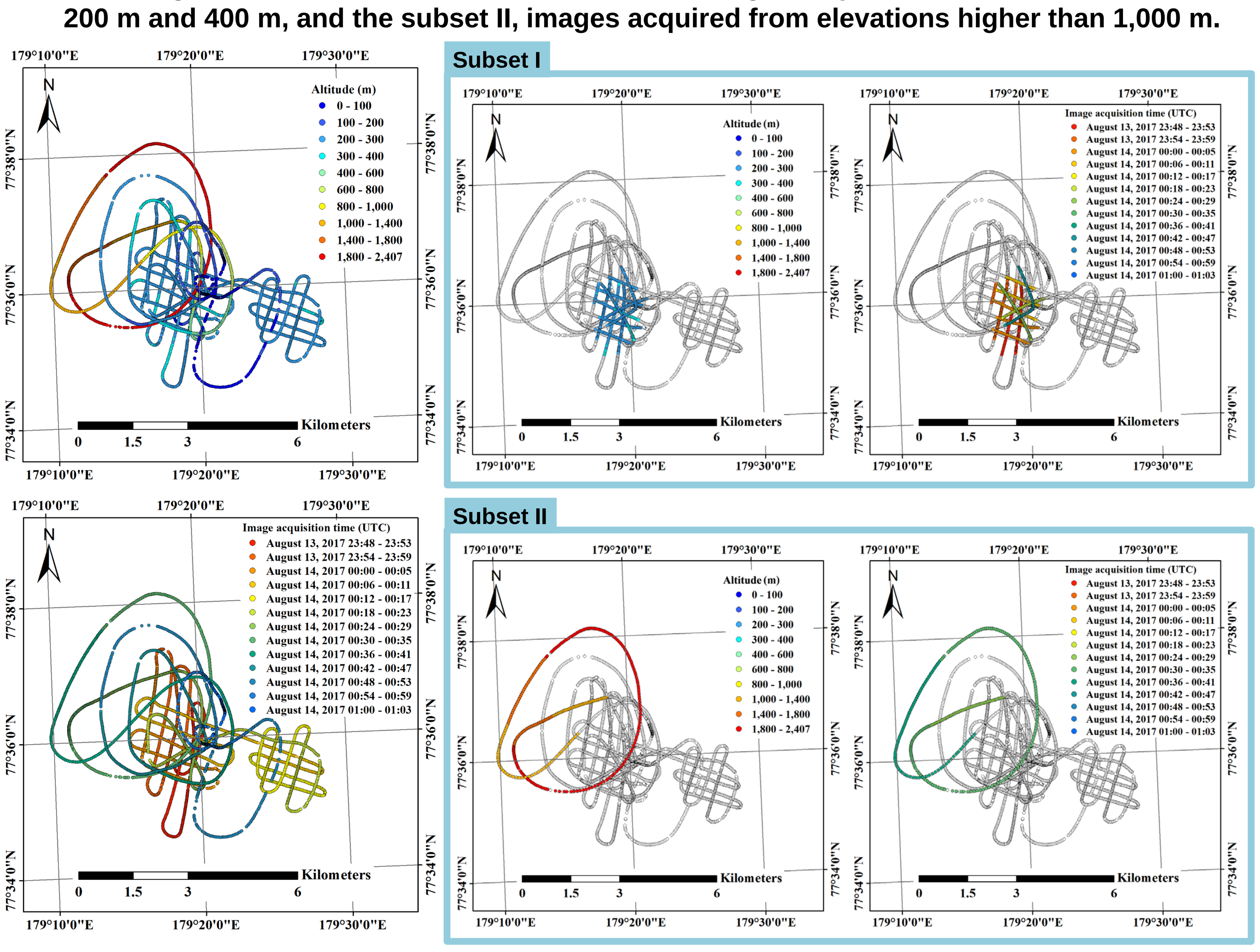
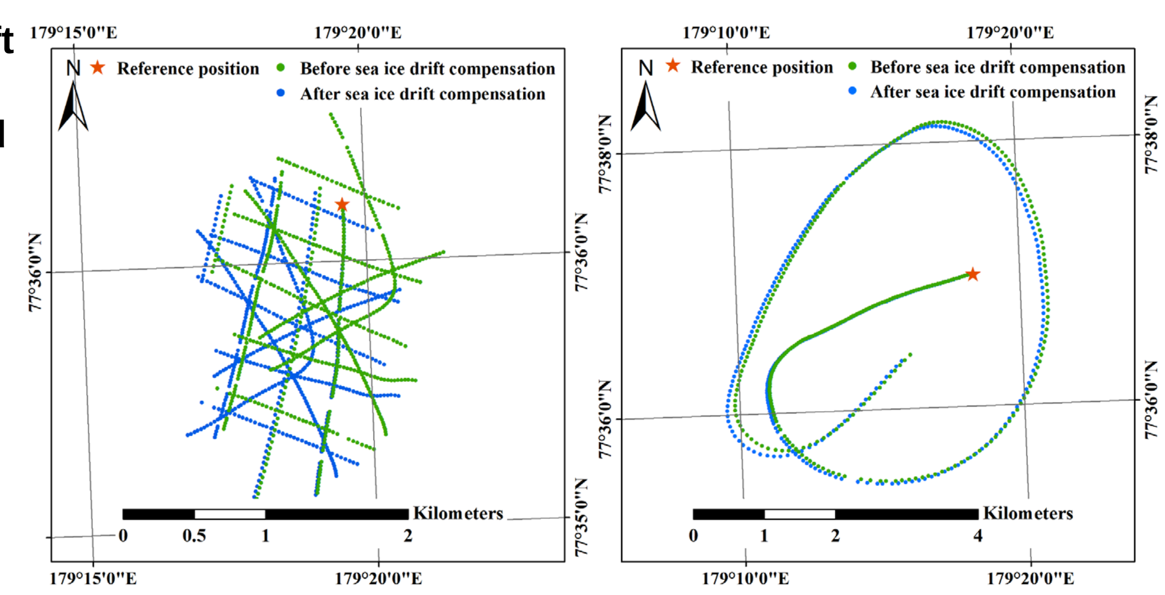
Results

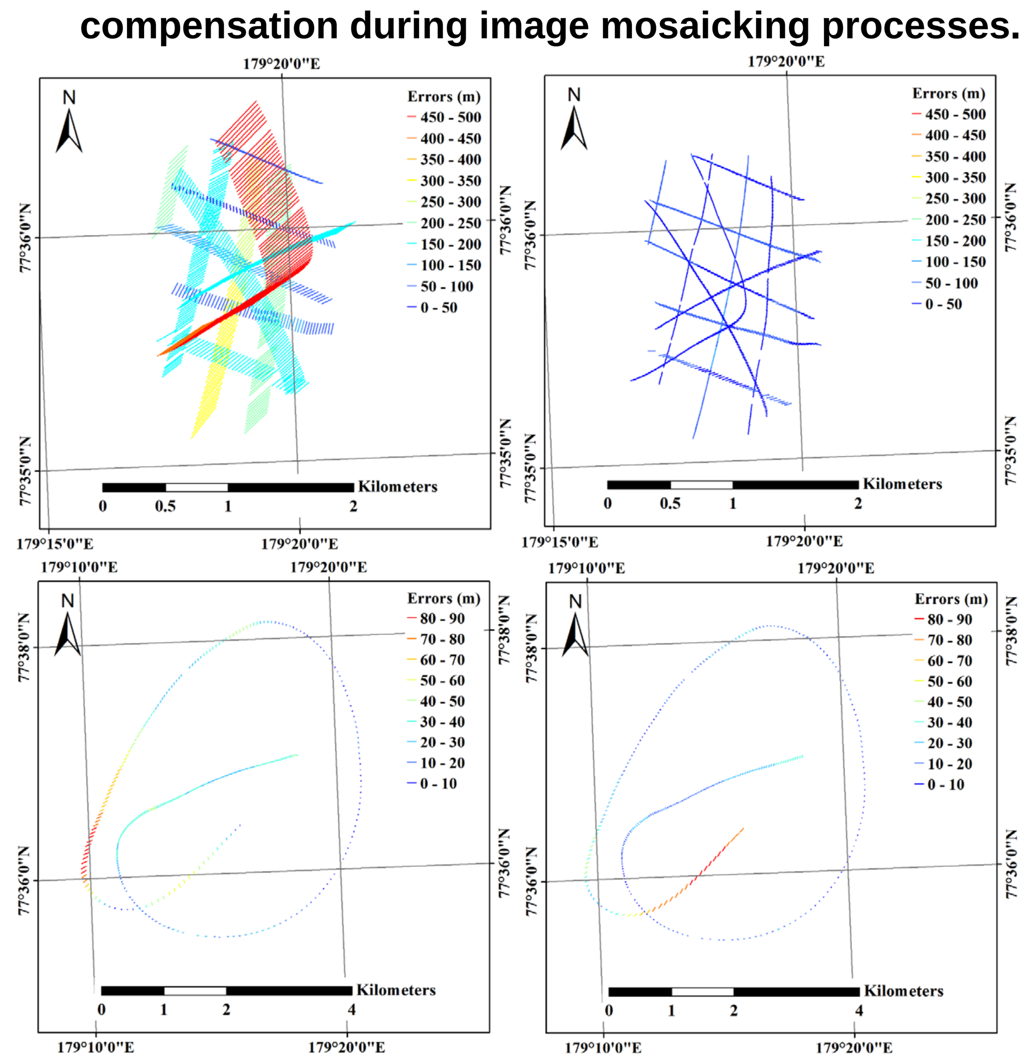
- Results of Image Acquisition
  - Totally, about 4,000 VHR images were acquired during sea ice field investigation in a single flight using helicopter-borne COTS imaging sensor.
  - Two image subsets were defined as the subset I, images acquired from elevations between 200 m and 400 m, and the subset II, images acquired from elevations higher than 1,000 m.



- Compensation of Sea Ice Drift
  - Image acquisition positions of the subsets were mapped after compensation of sea ice drift.



  - Errors were estimated from camera location of the subsets before and after sea ice drift compensation during image mosaicking processes.



Camera location of subset I	X error (m)	Y error (m)	Z error (m)	Total error (m)
Before sea ice drift compensation	188.4	150.7	8.1	241.4
After sea ice drift compensation	33.5	36.5	5.5	49.9

Camera location of subset II	X error (m)	Y error (m)	Z error (m)	Total error (m)
Before sea ice drift compensation	26.5	24.4	13.7	38.5
After sea ice drift compensation	18.9	20.2	9.4	29.2

- Comparison between Helicopter-Borne Mosaicked VHR Image and Satellite SAR Image