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Mosaicking very-high-resolution helicopter-borne images acquired over drifting arctic sea ice using COTS sensors

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Abstract

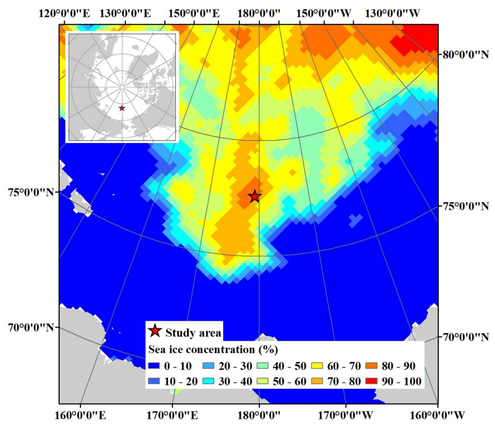
In order to observe and record conditions of the sea ice efficiently and specifically during in-situ investigation with the support of icebreaker research vessel (IBRV), the very-high-resolution (VHR) imaging systems have been used in recent past. The VHR images are generally acquired lower altitude than cloud height, therefore, the images can be acquired even in unfavourable weather conditions for optical satellite image acquisition, and can be applied to comparison with various kinds of remote sensing datasets. However, producing mosaicked image using the VHR images have suffered from drift of sea ice. The sea ice drift interrupts simultaneous geotagging in overall study area as geographic locations of sea ice moves continuously; therefore, the mosaicked image generated from improperly geotagged individual image depicts a scene of ambiguous time. In this study, we present a case study of VHR sea ice image acquisition using a helicopter equipped with commercial off-the-shelf (COTS) geotagging and imaging sensors with a support of IBRV Araon in East Siberian Sea, Arctic Ocean. We also propose an image mosaicking strategy using the improperly geotagged VHR images acquired over drifting sea ice to decrease temporal and spatial ambiguity.

Introduction

- Changes in properties of arctic sea ice, e.g., extent, concentration, thickness and melt pond coverage, reflect climate changes in arctic ocean. To investigate the former and present states and predict future condition of sea ice, low-resolution remote sensing technique with a spatial resolution of 1 km or larger pixel size, generally has been used, e.g., passive microwave satellite remote sensing and optical satellite remote sensing, because the low-resolution satellite remote sensing has capabilities of acquiring dataset over vast polar regions within a short period of time. Therefore, high temporal resolution sea ice products e.g., extent, concentration and thickness, over entire arctic or antarctic regions can be produced.
- In order to observe and record conditions of the sea ice more efficiently and specifically during the period of in-situ investigation with the support of icebreaker research vessel (IBRV), the very-high-resolution (VHR) imaging systems attached on the IBRV have been used in recent past. The shipborne imaging systems have limits on observing range from restricted height of observation position and oblique viewing geometry. More recently, unmanned aerial vehicle (UAV) or helicopter equipped with VHR imaging systems have been used. While the UAV and helicopter imaging systems improved spatial coverage from multiple higher image acquisition positions than the shipborne imaging systems, drifting sea ice still hampers generating precisely mosaicked image.
- In this study, we present a case study of VHR sea ice image acquisition using a helicopter equipped with commercial off-the-shelf (COTS) geotagging and imaging sensors with a support of IBRV Araon of Korea Polar Research Institute in Arctic Ocean. We also propose an image mosaicking strategy using the improperly geotagged VHR images acquired over drifting sea ice to decrease temporal and spatial ambiguity.

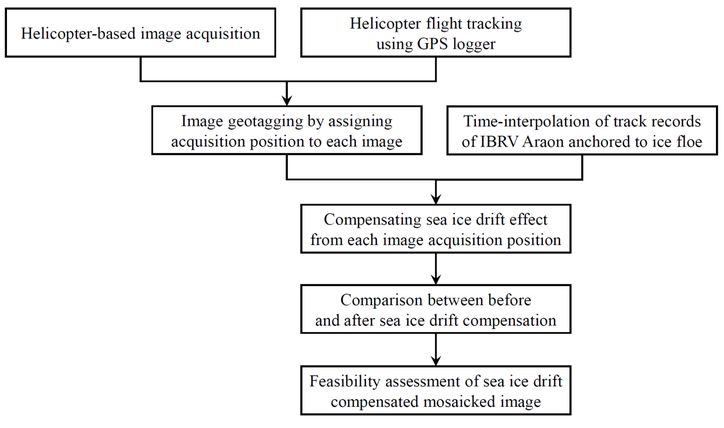
Materials and Methods

- 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).



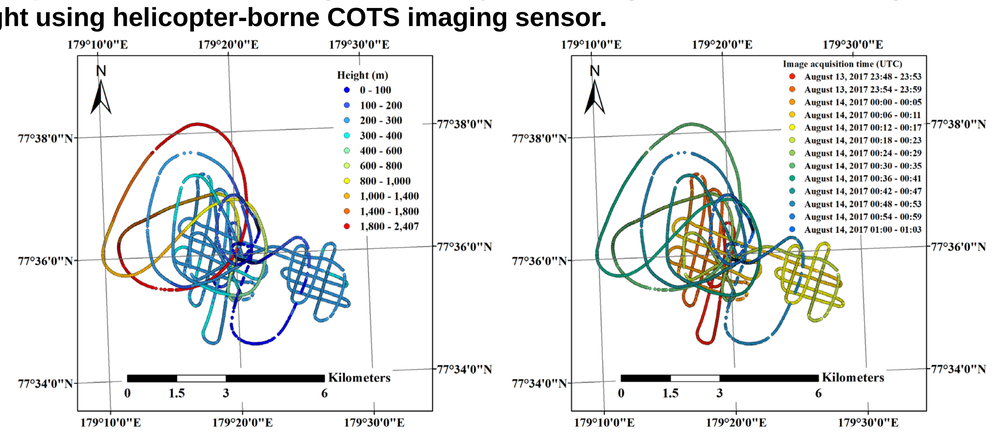
- Acquisition of Dataset
  - The VHR images were acquired during sea ice field investigation using helicopter-borne COTS imaging sensor. A commercial digital camera was attached on the bottom of helicopter and set to nadir viewing geometry. Imaging time interval was set to every single second.
  - To 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.

- 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 anchored firmly 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.

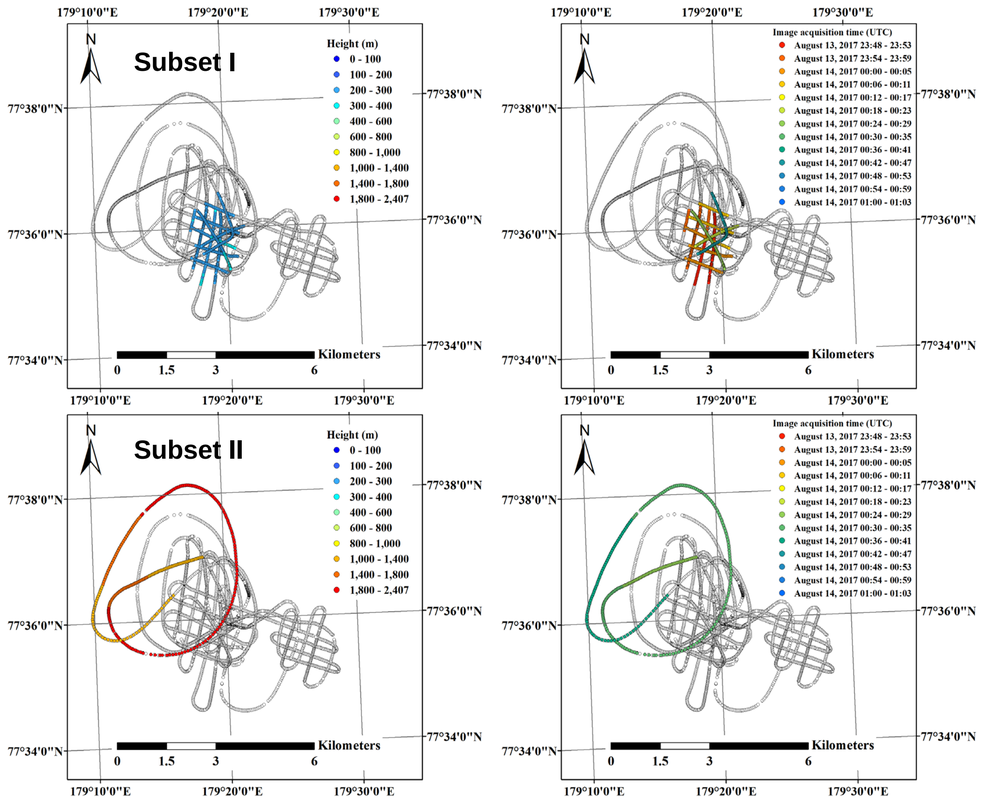


Results

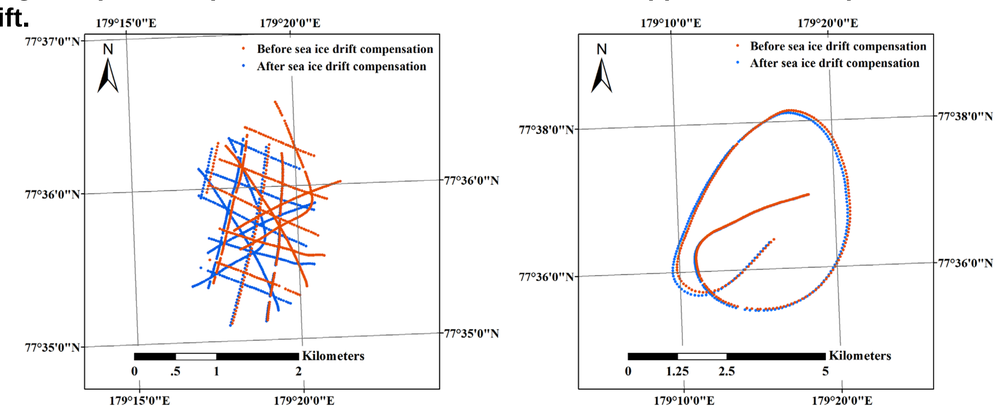
- Specifications of Image Acquisition
  - Totally, about 4,000 VHR images were acquired during sea ice field investigation in a single flight using helicopter-borne COTS imaging sensor.



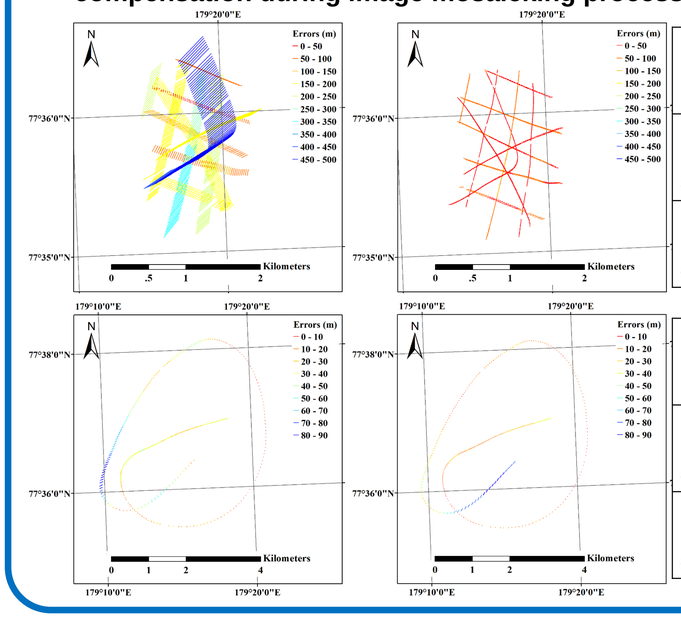
- Predefined Subsets of Acquired Images
  - Two image subsets were defined as the subset I, images acquired from elevations between 200 m and 400 m, and the subset II, images acquired from elevations higher than 1,000 m.



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



  - Error estimation 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 I	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

Acknowledgement

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