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Article

Pack ice observations by UAV and Sentinel-2 Satellite

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Abstract

Pack ice observations using Unmanned Aerial Vehicles System (UAVs) and Sentinel-2 Satellite were conducted. The possibilities of detecting pack ice conditions were examined using RGB and Normalized Moisture index (NDMI). A low-cost fixed wing UAV for conducting the pack ice observation carrying a visible camera was developed. To establish Beyond Visual Line of Sight (BVLOS) flight, telecommunication system based on Low Power Wide Area Network (LPWA) and the method to correlate UAV data with satellite acquired data for sea surface acquisitions are proposed.

Key words: Pack ice, NDMI, UAV, Sentinel-2

1. Introduction

The advantage of using Unmanned Aerial Vehicle (UAV) is that imagery can be obtained according to the required data necessities. The cost-effective Sentinel-2 Satellite images of 12 days repeat cycle are widely used and can be complimented by UAV. An appropriate use of these two monitoring methods is very useful for completing analysis and interpretation. The authors proposed of developing a hand-made low-cost fixed wing UAV. A fixed wing UAV consumes less energy and can cover much wider area over 100ha in a single flight. Sentinel-2 Satellite image acquisition system with easy-to-use Graphical User Interface (GUI) for satellite image applications was modified and applied for pack ice observation. The ground sampling distance (GSD) or resolution of Sentinel-2 Satellite system is 10 meters meanwhile UAV aerial photos is at 0.15 meter. The authors conducted the experiments at Mombetsu and Yubetsu along Sea of Okhotsk in February,2021 (Fig. 1).

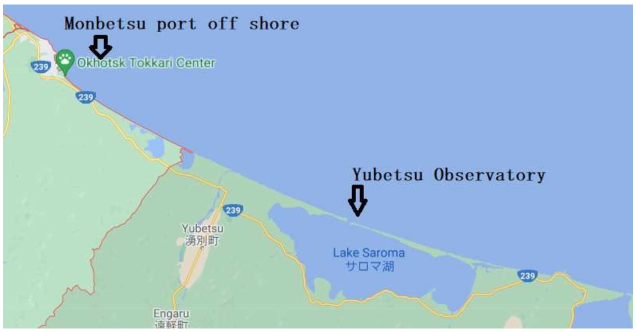

Fig 1. Port and Observatory locations on GoogleMap

A research team comprised of foreign graduate students from Hokkaido University accompanied by the author conducted series of pack ice observations from Feb 11th to 15th at Yubetsu. The wind direction recorded was from west to east which caused the pack ice moved away from the coast. No pack ice was detected during the observation period.

2. UAV data acquisition

World first commercialized fixed wing UAV is "Parrot Disco" and its modified version with multispectral camera is "Parrot Disco AG". It can cover 80ha coverage at 120 meters altitude for maximum 30-minute flight and communication range of 2km (2021, Parrot AG). One of the authors is experienced using Parrot Disco for Agricultural fields. However, in this experiment the small size and short wing span Parrot Disco is vulnerable to high winds as roll, yaw and pitch affecting the scene of aerial photo. He has experience in development of a self-made fixed wing UAV and conducted surveys over oil palm plantations and forest in Malaysia. He proposed a data collection using a self-made fixed wing UAVs to cover much larger area. The advantage of a self-made UAV is its cost effectiveness compared to commercial ones which spare parts such as flight battery are sometimes difficult to replace it with generic on the market ones. The airframe and components of the self-made UAV are also easily applicable to accommodate different sensors type and flight mission requirements. We obtained insurance policy for the self-made UAV as regulations requisite for the flight experiments.

In this experiment we chose FX-61 fixed wing UAV airframe powered by electric motor propulsion system sourced to hobby-grade parts. The flight mission was controlled using open-source autopilot system and open-source mission planning software (Mission Planner, 2019). A quick comparison of Parrot Disco and FX-61 UAV as in Table 1 below.

Table 1. Parrot Disco and FX-61 UAV comparison specifications

	Wingspan (mm)	Take-off Weight (g)	Coverage (ha)	Flight time (min)
Parrot Disco	1,150	940	80	30
FX-61	1,550	1,300	100	40

Prior to the planned flight, we conducted a manual test flight to ensure all the system of working properly as in Fig. 2.

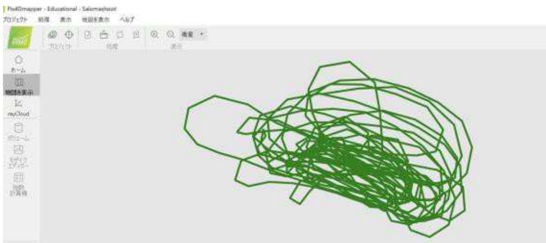

Fig 2. Flight pass on Pix4D mapper

Flight plan was set in Mission Planner software prior to the data collection flights. The UAV conducted auto pilot flight according to a pre-defined flight plan (Fig. 3). An action camera, GoPro5 with built-in Global Navigation Sentinel-2 Satellite System (GNSS) was programmed to shoot aerial photos at every 2 seconds.

Fig 3. (a) Checking Center of Gravity (CoG), (b) Takeoff and (c) Flight plan in Mission Planner.

The fixed wing UAV was capable of tracing a pre-planned flight path as shown in Fig. 3c. The aerial photos were processed using Pix4D mapper Structure from Motion (SfM) software (Fig. 4a) and an Orthomosaic rectified aerial photo was produced (Fig. 4b).

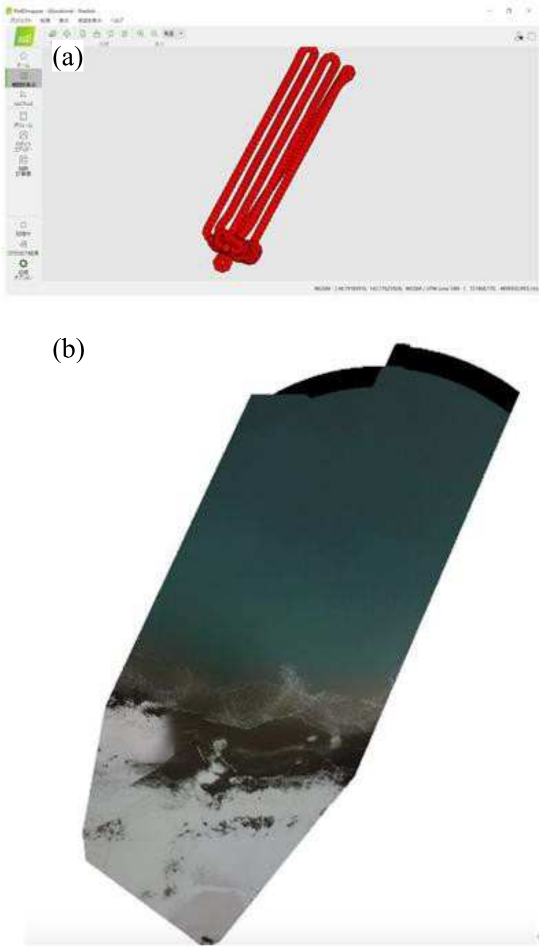

Fig 4. (a) Flight path of each aerial photo on Pix4D mapper software and (b) Orthomosaic rectified image.

Unfortunately, during the experiment in Yubetsu no pack ice was detected. Only the UAV operational capability for precise monitoring of pack ice was checked and confirmed.

3. Satellite and UAV data processing

The 10m resolution bi-weekly Sentinel-2 generated Normalized Difference Vegetation Index (NDVI), Normalized Difference Moisture Index (NDMI) and visible RGB data was provided by collaboration with AgriForetell company. The Sentinel-2 is a wide-swath Multispectral, high-resolution imaging mission, supporting the Copernicus Land Monitoring studies including the monitoring of vegetation, soil and water cover (Restec, 2020). The author has supported the farmers to visualize the condition of farmland and also providing UAV obtained image during summer using UAV and data provided by AgriForetell company. The area along the sea of Okhotsk is suffered from long and severe winter. To achieve an effective utilization of equipment, it is an urgent matter to establish observation system which can run both summer and winter time. The possibilities of applying data provided by "AgriForetell" for pack ice observations were examined. NDVI is calculated from the visible and near-infrared light reflected by vegetation (2020, NASA) meanwhile NDMI is used to measure the water stress level in vegetation. The formula for NDVI and NDMI are as follows.

NDVI=(NIR-VIS)/(NIR+VIS)
NDMI= (NIR-SWIR)/(NIR+SWIR)

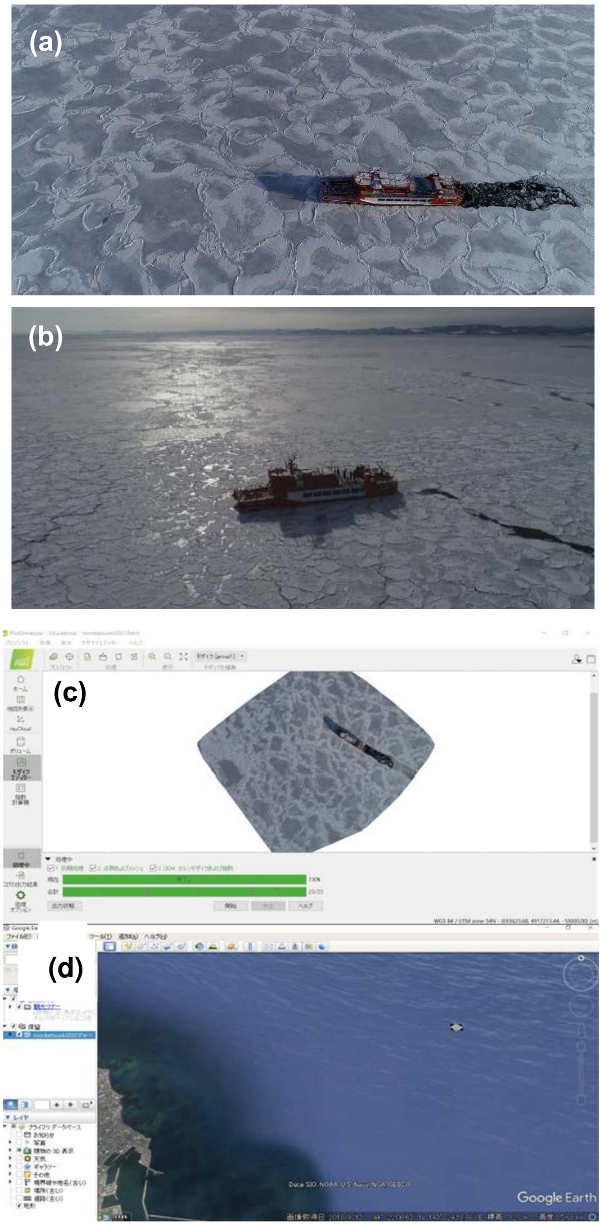

Fig 5. A photo over the ice-breaker (a,b), Orthorectified pictures around the ice-breaker ship (c) and its location relative to Mombetsu (d).

where VIS is Visible light, NIR is Near infrared, 835.1nm (S2A) and 833nm (S2B) and SWIR is Short wave infrared, 1613.7nm (S2A) / 1610.4nm (S2B). Pack ice observation using Multirotor UAVs, DJI Phantom 4 series, was conducted on Feb the 5th 2021 at coast of Mombetsu. The Okhotsk Garinkotower Co. Ltd. provided an ice breaker rental service to Kitami Institute of Technology (KIT) for conducting experiment for students where the author had an opportunity to joined (Fig. 5a, b).

We collected aerial photos at 7 km off coast of Mombetsu port where it is free from aerial traffic regulations (Fig. 5 a, b & c). Series of aerial photos were processed using Structure from Motion (SfM) (Inoue and others, 2014) for producing Digital Elevation Model (DEM) to visualize the Orthomosaic image. Visible Atmospherically Resistant Index (VARI) was applied to the RGB Orthomosaic. The formula for VARI is as follows (2021, Esri Japan).

VARI = (Green – Red) / (Green + Red – Blue)

The "AgriForetell" system provided NDVI, NDMI and Visible images (Fig. 6 a, b & c) on January the 22nd, February the 26th and March the 5th, 2021. In each figure, NDVI (Left), NDMI (Middle) and Visible image (Right).

The RGB images show cloud portion. NDMI was calculated from infrared short wave, and it might be able to detect pack ice portion.

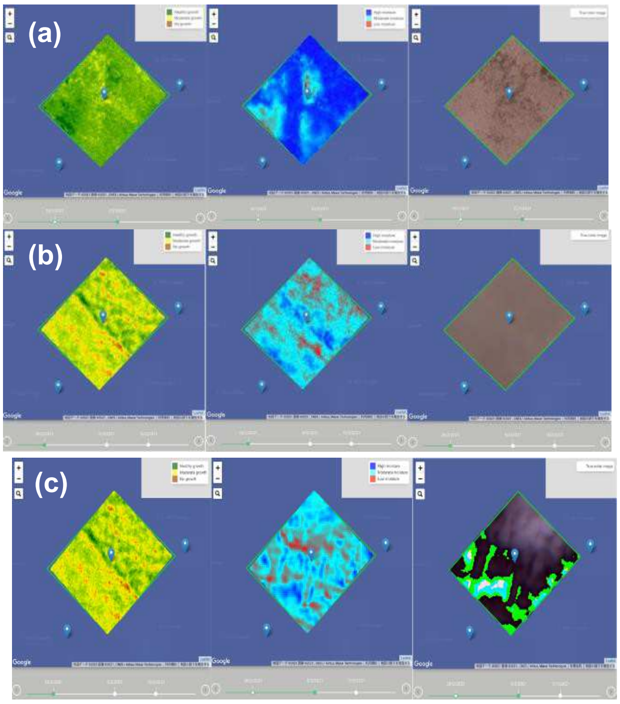

Fig 6. NDVI, NDMI and Visible images on January 22 (a), February 26 (b), and March 5 (c)

Red colored portion shows relatively low humidity portion, and the portion corresponds to the pack ice. Blue colored portion corresponds to water body. Shape file format of NDMI can be downloaded for further analysis.

UAV observed data was obtained on Feb the 5th, 2021. If the UAV and Satellite datasets simultaneously or on the same day at least, boundary values of pack ice can be defined and confirmed (Matsumura and Avtar, 2020). The proposed method workflows of combining Satellite and UAV based pack ice observation is as follows:

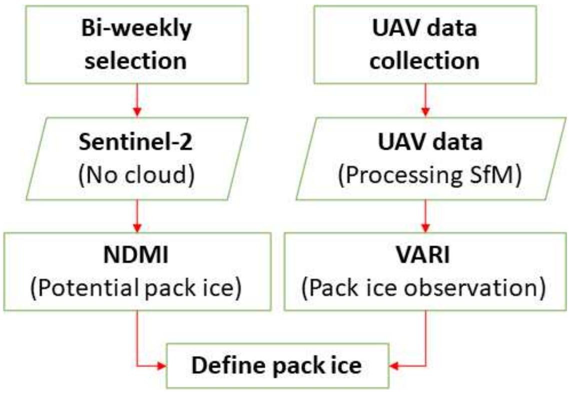

Fig 7. Method workflow to define pack ice.

4. Conclusion and Future Prospects

The validity of the observation system, using both of Sentinel-2 remote-sensing data and a fixed wing UAV for pack ice observation data, was examined. The definite validity proof of this method needs periodical case studies. To deal with invisible UAV flight for operators, the authors adopted and are developing a Low Power Wide-Area-Network (LPWA) based on Long Range Drone Communication System. Through this system the operators can easily control UAVs in various ways. For the flight of insured UAVs, a legislative structure of flight permission regulation will hopefully be changed.

Acknowledgements

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References

AgriForetell,(2021) a brand of Ignisnova Robotics Pvt. Ltd, https://agriforetell.com, accessed September, 2021

Editage,(2021), English editing company, https://www.editage.com/, accessed September, 2021

Esri Japan (2021), Visible AtmosphericallyResistant Index,https://blog.esrij.com/2018/10/12/post-31475/, accessed September, 2021

Jellafin,(2020), SEC Corporation LTD, https://seckaiyo.com/, accessed September, 2020

Matsumura, K. and R.Avtar,(2020), Comparison between UAV and Satellite Data and Applying Deep learning to Classify Satellite Images for Agriculture Practices in The Eastern Hokkaido, *ES Journal of Agriculture and Current Research*, Volume 1 Issue 1.

Mission Planner (2019), http://plane.arudupilot.com/, accessed September 2021

NASA (2000), Normalized Difference Vegetation Index (NDVI), https://earthobservatory.nasa.gov/features /Measuring Vegetati on/measuring_vegetation_2.php, accessed December, 2022

Restec, (2020): Copernicus: Sentinel-2 https://www.restec.or.jp /satellite/sentinel-2-a-2-b

Summary in Japanese

和文要約

UAV と衛星による流氷観測

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オホーツク海に面した紋別と湧別にて UAV と人工衛星を組み合わせた流氷の観測を行った。低コストの自作固定翼機材を製作して、その有効性を確認した。また任意の地域を対象として Sentinel-2 衛星による NDMI,NDVI,RGB を体感的に取得できるシステムを構築し、流氷観測への可能性が示された。

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