Středoškolská technika 2022

Setkání a prezentace prací středoškolských studentů na ČVUT

Earth Observers 202x

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Cíl

Ověření technologií pro dálkový průzkum Země (monitorování environmentálního stavu krajiny) s využitím multispektrálního VIS a NIR senzoru na palubě reálného statelitu na LEO (ISS). Tyto technologie budou následně využity pro konstrukci funkčního modelu environmentálního pikosatu (CanSat) a multispektrálního remote sensing modulu autonomního dronu pro monitorování enviromentálních změn krajiny a zdravotního stavu vegetace (lesů) ve východních Čechách.

Postup

Jako platformu jsme zvolili RaspberryPi + Picameru + Python, k této volbě nás vedli: Jednoduchost, dostupnost, široká mezinárodní komunita, odpovídající HW parametry použitého procesoru a kamery

Náš program vyfotí snímek pomocí Picamery bez IR filtru, vypočítá indexy NDVI (index vegetace) a NDWI (index vodních ploch) a zkomprimované obrázky uloží jako .png.

Vyvinuli jsme pozemní testovací zařízení v naší laboratoři (RasPi 3 a PiCam V2), letové testovací zařízení na dronu (upravený FPV modul) a kód běžící na Mezinárodní kosmické stanici v rámci soutěže AstroPi. Data jsme analyzovali aplikací NDVI + NDWI indexu a srovnali s open-source daty ze sondy Sentinel 2.

Závěr

Úspěšně jsme otestovali možnost DPZ průzkumu pomocí Raspberry Pi na LEO a vyvinuli jsme algoritmus pro zlepšení kvality NDVI indexu získaného touto metodou. Vyvinuli a otestovali jsme modul pro **CanSat** a **enviDron** na bázi Raspberry Pi Zero.

Příloha: Report z dílčí části našeho projektu v roce 2020.

Mission Space Lab - EARTH_OBSERVERS 2020

Team Name: **UTesla Space program**
Chosen theme: **Life on Earth**
Team members' names: **David Theodor Nimrichtr, Vojtěch Dvořák**
Organisation name: **Technecium - Talentcenter of Industry 4.0**
Country: **Czech Republic**

Introduction

We got inspired by the opportunities of present-day DIY Science. In particular PublicLab projects using multispectral camera https://publiclab.org/wiki/near-infrared-camera We plan to develop low cost multispectral sensor based vegetation monitoring devices for education, DIY and citizens science.
We are currently testing PiCamera sensor based a) dual-camera setup (NDVI) and b) single-camera setup (BNDVI) - the same as on ISS.

our laboratory setup *b) BNDVI* *c) NDVI*

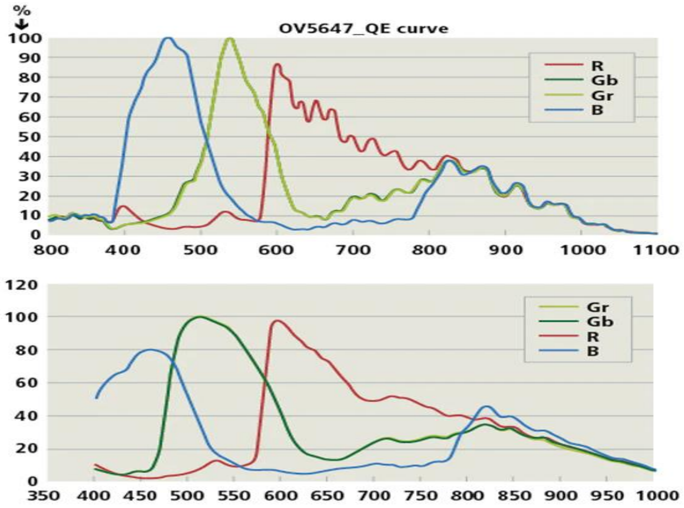
In the summer we plan to start testing AS7256x smart spectral sensor family, (VIS-NIR) sensor and LWIR - bolometer array MLX90640 board to target spectral indices of plant stress (respectively soil moisture).

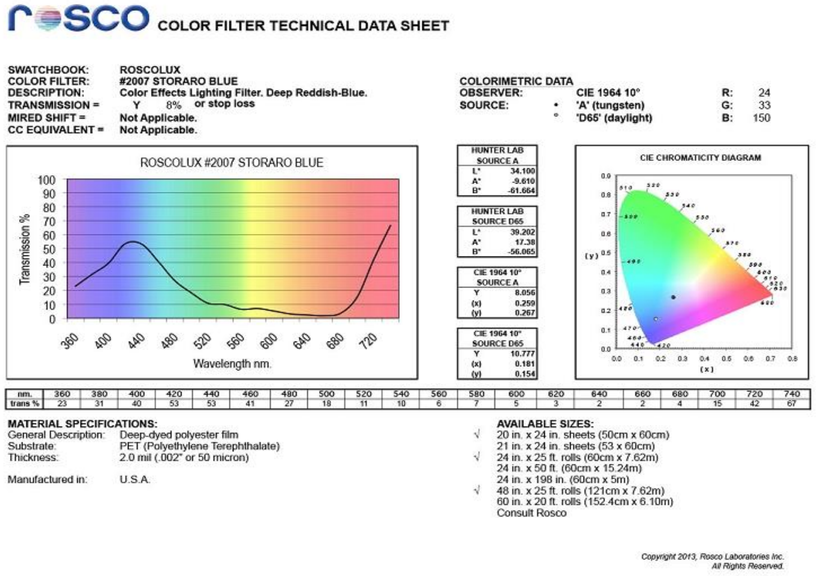
Our initial testing at close ranges and in the lab indicates that blue light can be used to make relatively meaningful (B)NDVI images in-situ but NDVI i.e. double camera setup gives better results.

We decided to test the b) setup on ISS and compare it to Sentinel-2 based NDVI for use in land vegetation. The aim of the comparison is to estimate the effect of the (spectral) resolution, atmospheric corrections as well as of the blue light scatter on (B)NDVI images taken from satellite on analytical value of the indices and develop postprocessing to improve the quality of PiCamera BNDVI imagery.

Method

We used 5MP NoIr Picamera with red filter mounted on Astro Pi Izzy with the following spectral characteristics of the camera (left) and filter (right).

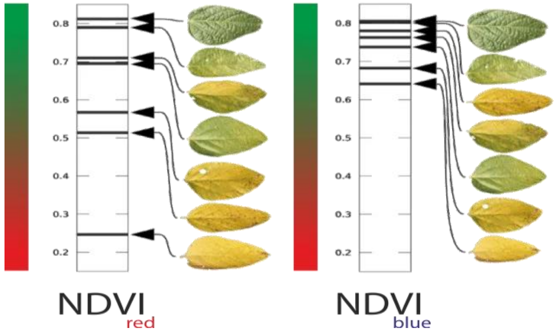




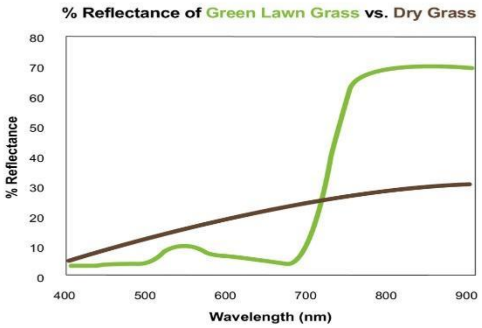
We planned to collect images with fps=1/21.5 (with aim to create a continuous strip where every center of a picture would lie on the edge of the previous).

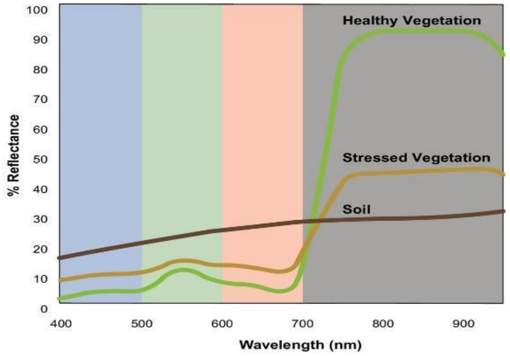
Using opencv and numpy python modules we calculated:

1. Blue normalised difference vegetation index BNDVI = [(NIR-BLUE)/(NIR+BLUE)]
   https://www.indexdatabase.de/db/i-single.php?id=135
2. Normalised difference water index NDWI = [(GREEN-NIR)/(GREEN+NIR)]
   https://custom-scripts.sentinel-hub.com/custom-scripts/sentinel-2/ndwi/



Comparison of NDVI and BNDVI (from analystgroup.com)





Spectral reflectance of vegetation (from www.mapir.camera)

We also saved the original NGB image and performed png-compression (lossless) of NGB, BNDVI and NDWI images to overcome storage limitations.

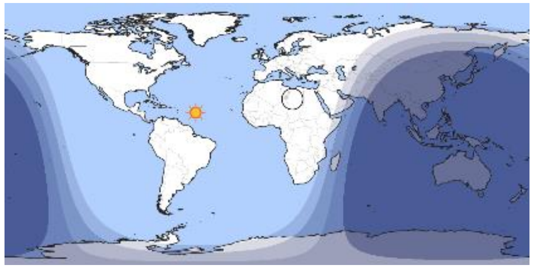
We have collected exact time and location data of each photo using python module ephem and datetime and saved them to a .csv file. Selected imagery was analyzed with Q-GIS (in contrast to PublicLabs Infragram) the same program that we use in our collaboration with remote sensing researchers from the Faculty of the Natural Science of the Charles University. Sentinel-2 MSI sensor data were sourced from Sentinel EO Browser. Collection of magnetometer data was skipped (for next year) in order to streamline the code.

Sentinel-2 MSI spectral bands

Sentinel-2 Bands	Central Wavelength (µm)	Resolution (m)
Band 1 - Coastal aerosol	0.443	60
Band 2 - Blue	0.490	10
Band 3 - Green	0.560	10
Band 4 - Red	0.665	10
Band 5 - Vegetation Red Edge	0.705	20
Band 6 - Vegetation Red Edge	0.740	20
Band 7 - Vegetation Red Edge	0.783	20
Band 8 - NIR	0.842	10
Band 8A - Vegetation Red Edge	0.865	20
Band 9 - Water vapour	0.945	60
Band 10 - SWIR - Cirrus	1.375	60
Band 11 - SWIR	1.610	20
Band 12 - SWIR	2.190	20

Results

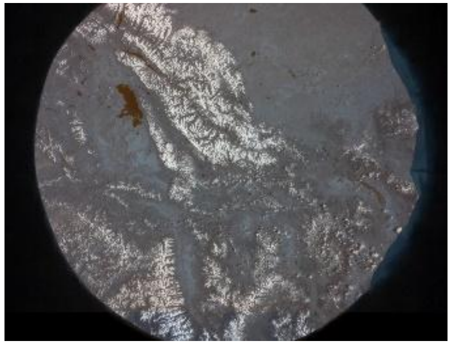
Our SW ran without major issues, however, as the AstroPi Izzy was cca 7x slower than the RaspberryPi 3 used for ground testing, so we have taken only 84 images.

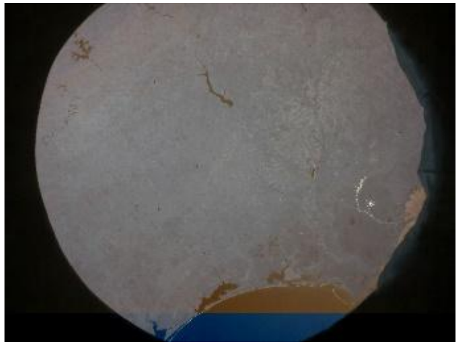


Geolocation of our images

Sunlighting of Earth at the start of the experiment (GMT 15:15)

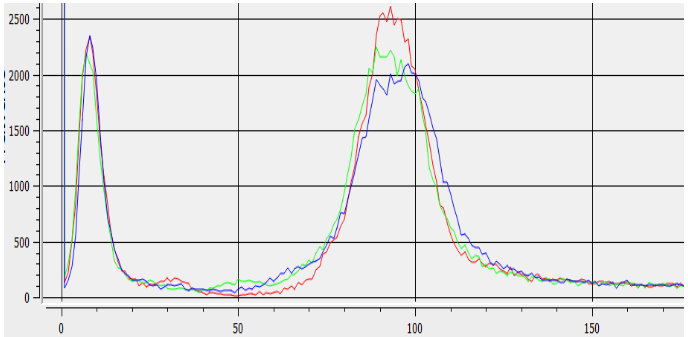
Due to the more than 2 min delay in image file processing and compression, the recorded positions had to be corrected.
We decided to focus our report on vegetation analysis and comparison of BNDVI and NDVI resp. NDWI from our experiment and Sentinel-2 as the algae bloom detection is too time consuming to be performed in the given time frame and will be performed later.
For this we have selected images on the lit side of Earth and with zero cloud coverage from Montana and Louisiana as they represent very different environments in terms of vegetation cover etc.

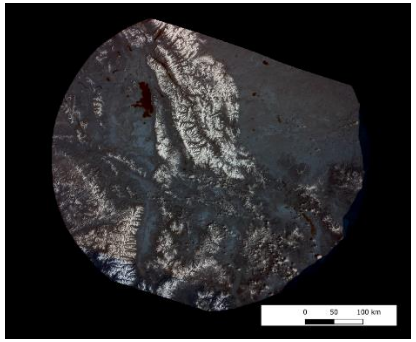




The selected raw images of Montana(left) and Louisiana (right)

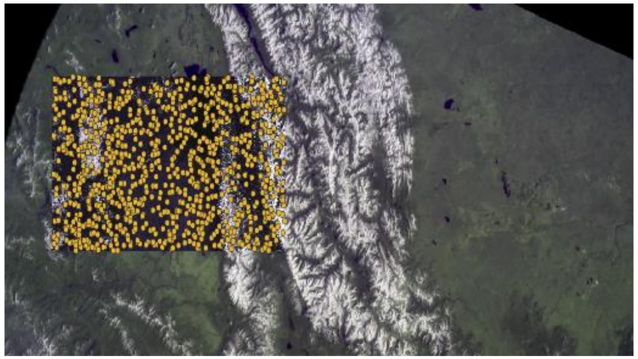
Because of limited space we will focus first on Montana imagery, covering Luisiana in supplementary materials on our site www.technecium.org.
For our post processing we are using QGIS and Microsoft Excel. We linearly edited the histogram for all 3 spectral bands to introduce basic atmospheric correction using the dark subtraction method (cutting out all values less than 40).

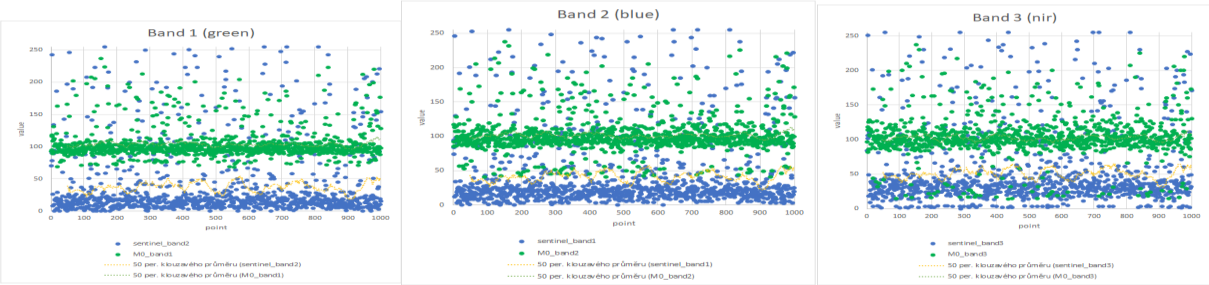




Histogram of blue, green and NIR band *Image after atm. correction*

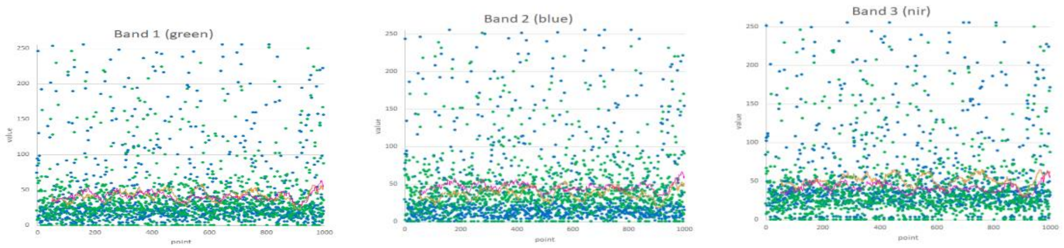
We georeferenced the image and overlapped with Sentinel-2 data from the same day and location. We transformed both PiCam and Sentinel-2 MSI imagery into **green-blue-nir** (3-2-5) false color images. In the NIR region we have chosen the band 5 (~705 nm) of the Sentinel-2 MSI as it is best matched with the maximum of the red filter Picam v1 NoIR NIR sensitivity.
For the sake of direct comparison between the two sensors we have selected diverse area approx. 135x95km in the center of the image where we randomly generated 1000 points, see pic on the left, and (using QGIS) compared the radiometric values at each of the across all 3 bands, see bellow.





Comparing raw pixel values from PiCam (green) and sentinel-2 (blue) for all 3 bands

We developed mathematical formula y=(x-85)*1,8 to fit PiCam radiometric data with MSI data, the results for the 3 bands can be seen below.



Comparing pixel values from PiCam (green) and Sentinel-2 (blue) for all 3 bands after fit.

NDVI indexes PiCam (green) and Sentinel-2 (blue) before (left) and after the fit (right).

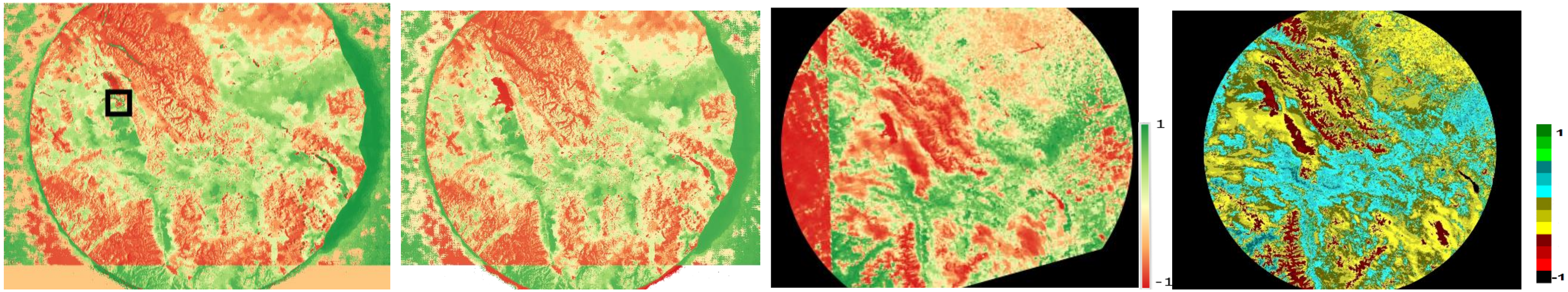
Comparison of the resulting NDVI indexes shows significant improvement by the introduction fit, but the difference is still there and may possibly lie with much better atmospheric correction provided by Sentinel-2 postprocessing while PiCam is still handicaped by the inability to efficienty handle strong atmospheric scatter of the blue light. Utility of the developed fit will be verified using images of Luisiana.

Conclusion

Despite the problem of missing about 80% of the imagery data we planned to collect due to the slow running AstroPi Izzy, our experiment fulfilled its purpose and provided us with valuable data on:
i) the performance of single Picamera setup BNDVI and its limitation in satellite based remote sensing
ii) the (overwhelming) superiority of the Sentinel-2 NDVI imagery in this area was clearly presented. We plan to make use of this in summer 2020 during our monitoring campaign of East Bohemia pine and fir forests hit by bark beetle and drought.
iii) the direction of our future effort in development of multispectral sensor - that clearly points towards using a double camera NDVI setup in environmental monitoring instead of a single camera. (Reserving single camera BNDVI for close in remote sensing e.g. within our greenhouse for astrobiology experiments etc.)
iv) the post-processing NGB from PiCam in Q-GIS to produce BNDVI and in particular the fitting procedure was found to provide much improvement in the results (NDVI) and holds promise for the future (i.e. 2021 mission) especially in conjunction with development of more robust atmospheric correction method for PiCam.
The calcutad NDWI (from both PiCam and MSI) shows us water content and can be used pretty reliably on identifying both water and snow/ice, but in terms of monitoring the environmental disturbances we plan on moving to SWIR-based NDWI, which can reliably detect moisture and is therefore more useful in this regard.

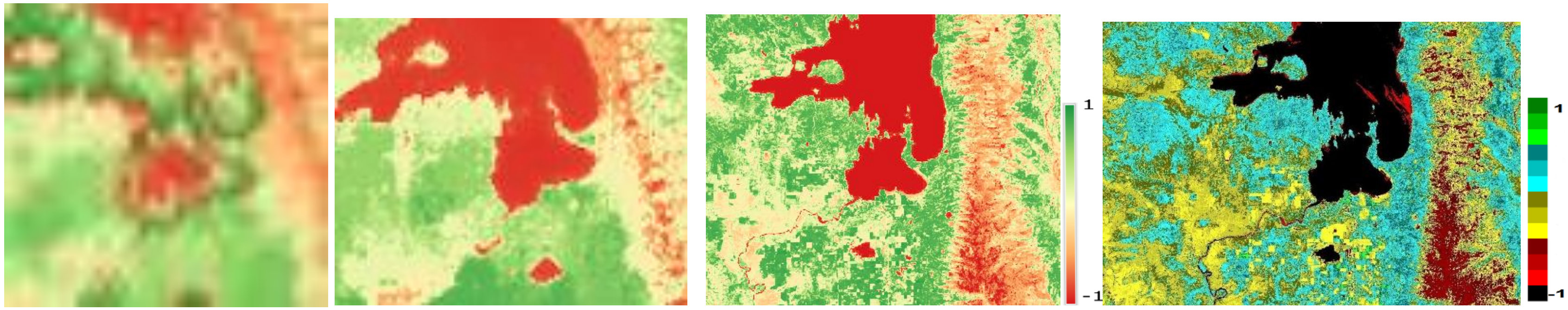
Suplementary material

We calculated 3 sets of BNDVI images: [M1.1] directly by AstroPi Izzy, [M1.2] from PiCam NGB Image in Q-GIS, [M1.3] from Sentinel-2 in sentinel-hub playground and compared them to the more commonly used NDVI set from Sentinel-2.



[M1.1] - Izzy(BNDVI) *[M1.2] - QGis (BNDVI)* *[M1.3] - Sentinel(BNDVI)* *[M2.3] - Sentinel-2 (NDVI)*

Detailed imagery of selected area approx. 20 x 20 km (see below) clearly shows the differences in both spatial and spectral resolution between BNDVI calculated (a) directly from PiCam Imagery by Izzy [M1.1], (b) calculated from PiCam NGB imagery in Q-GIS [1.2] and (c) from Sentinel-2 data [M1.3] as well as better spectral differentiation of vegetation by NDVI [M2.3] compared to BNDVI.



a *b* *c* *d*

The comparison of NDWI calculated from PiCam Imagery [M3.1] by Izzy, [M3.2] by Q-GIS and [M3.3] from Sentinel-2 data can be seen below.

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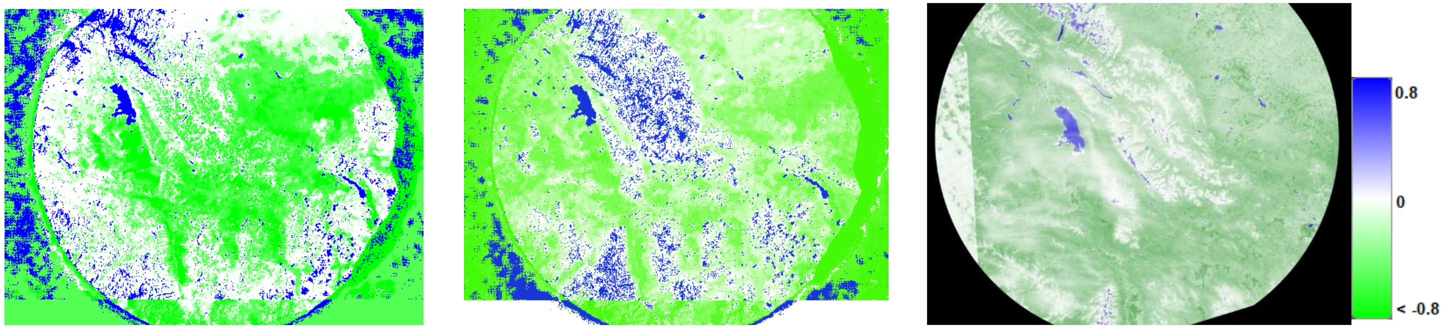

[M3.1] PiCam/Izzy (NDWI) *[M3.2] PiCam/Qgis (NDWI)* *[M3.3] Sentinel-2 (NDWI)*