Mission Space Lab Phase 4 Report

Team Name: Jupiter

Chosen theme: Life on Earth

Organisation name: Institut d'Altafulla

Country: Spain

Introduction

Climate change and human activity has led to the shrinking of lakes around the world. This phenomenon is specially alarming for closed hydrological system lakes in drier regions like lakes Chad and Aral.

Decreasing water levels lead to quicker warming of water which in turn increases evaporation that causes rising salinity levels, increased instances of algal bloom and decreasing of fish stocks, just to name a few of the consequences.

Now our team intends to find variations in the surface area of water bodies by comparing pictures taken by Astro Pi Izzy's near-infrared camera to archive images. We will then try to establish the rate of variation by means of NDVI and pixel counting techniques.

NDVI (Normalized Difference Vegetation Index) takes advantage of the fact that vegetation mostly absorbs blue and red light and reflects green and infrared. A camera that doesn't block IR, fitted with a blue filter that gets rid of green light, let us examine the ratio between blue and IR amounts, thus sorting areas according to photosynthetic activity. In that regard, water bodies should stand out against their surroundings.

Method

Our code had the near-infrared camera (V1) taking pictures with the blue filter on about every 10 seconds and logging corresponding coordinates into a csv file as well as into picture's EXIF data. Pictures were taken at maximum resolution (2592x1944) and saved in jpeg format.

In order to save storage space and skip night pictures the code tested for day or night before shooting. This was achieved by using the PyEphem astronomy library to measure the height of the Sun above horizon for the location ISS was passing over.

Once we got the data we run reverse_geocoder.py on csv file to get locations from coordinates so as to start looking for suitable areas.

Reverse_geocoder library results are somewhat inaccurate because areas over sea are assigned to land administrative regions therefore we used a piece of code to plot the ISS path during our experiment (Fig-1).

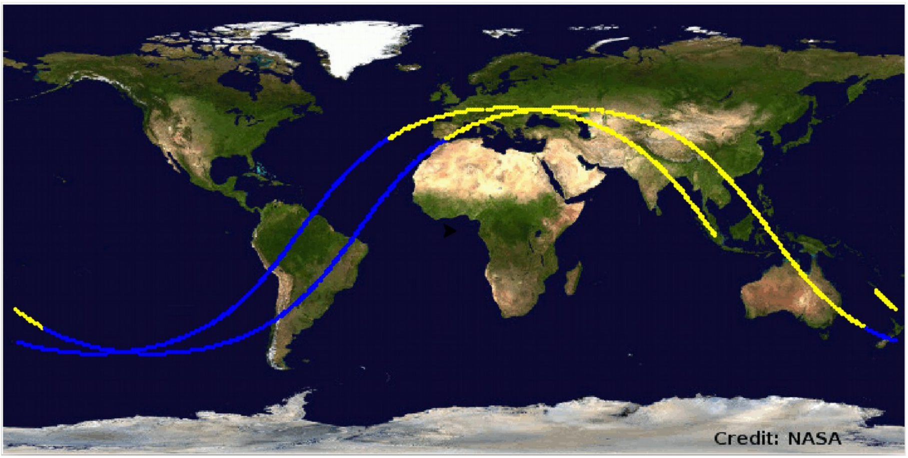


Fig-1: Fig-1: ISS path for team Jupiter on April 24th (yellow dots are for day and blue for night)

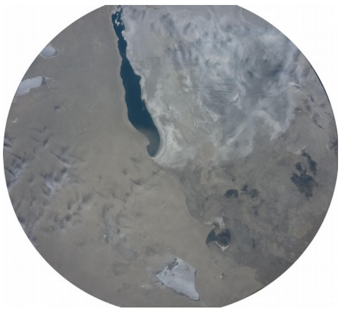
Next, we searched AstroPi pictures for lakes and water bodies in areas within ISS path. Then, in order to highlight water surfaces, we performed NDVI analysis on the selected images.

After that, we estimated the water surface area in pixels with image processing software, for which we had to work out the area covered by a single pixel.

Eventually, we translated pixels into Km² so as to find water surface area values and compare them to those of previous years from archive images of NASA World View on-line tool.

Results

Fortunately, we had ISS passing over **Lake Aral** on April 24th (Fig-2) and got shots from the western basin. On those images we used the on-line tool INFRAGRAM by Public Lab, which performs NDVI calculation on every pixel and returns an 800x600 false color image (Fig-3).



INFRAGRAM PRESETS:

- Upload image
- Select "NDVI for BLUE filters / Colorized"
- Select "Grey"
- Enter NDVI formula[1]: (R-B)/(0.5*(R+B))
- Select "RGB"
- Hit "Run" and "Download"

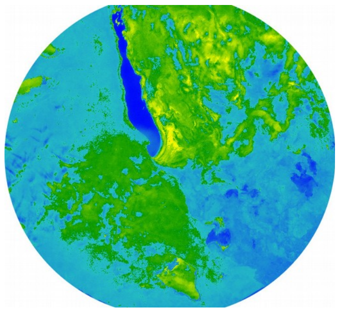
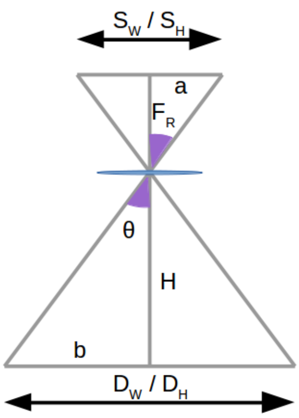


Fig-2: Lake Aral (jupiter_400.jpg)

Fig-3: Infragram presets and false color NDVI image

Next, we estimated the area covered by a single pixel based on the ground sampling distance method (Fig-4).

1 Although the simplest NDVI equation is (R-B)/(R+B), we made minor modifications so as to enhance results.



S_W (sensor width) =3,76mm
F_R (Focal length) = 3,6mm
H (ISS height) ~ 419833m
D_W(distance covered in width direction)

Equally:
S_H (sensor height) =2,74mm
F_R(Focal length) = 3,6mm
D_H(distance covered in height direction)

I_W (image width) = 2592 px
I_H (image height) = 1944 px

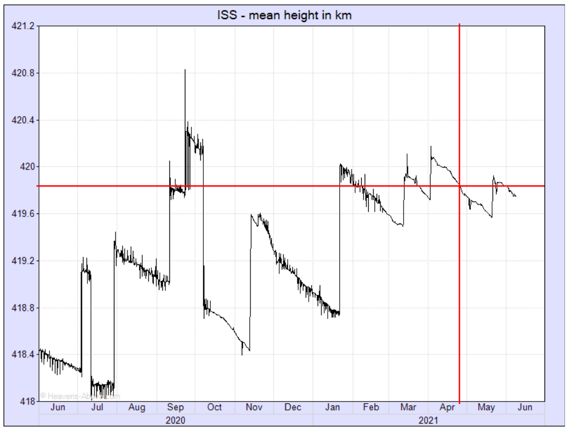


Fig-4: Ground sampling distance drawing with corresponding data and ISS height according to heavens-above.com

$$\tan(\theta) = \frac{a}{F_R} = \frac{b}{H} \rightarrow \frac{2 \cdot a}{F_R} = \frac{2 \cdot b}{H} \rightarrow \frac{S_W}{F_R} = \frac{D_W}{H} \rightarrow \rightarrow \rightarrow D_W = \frac{H \cdot S_W}{F_R}$$

$$D_W = \frac{H \cdot S_W}{F_R} \rightarrow \frac{419833\ m \cdot 3{,}76\ mmm}{3{,}6\ mm} = 438492\ m \qquad \frac{D_W}{I_W} \rightarrow \frac{438492\ m}{2592\ px} = 169{,}17\ \frac{m}{px}$$

$$D_H = \frac{H \cdot S_H}{F_R} \rightarrow \frac{419833\ m \cdot 2{,}74\ mmm}{3{,}6\ mm} = 319540\ m \qquad \frac{D_H}{I_H} \rightarrow \frac{319540\ m}{1944\ px} = 164{,}37\ \frac{m}{px}$$

which results in 169,17 x 164,37 = **27807m² per pixel**. Finally, we used ImageJ image processing software from NIH to find the aggregate area in pixels which turned out to be 7661-86 = 7575 pixels (Fig-5).

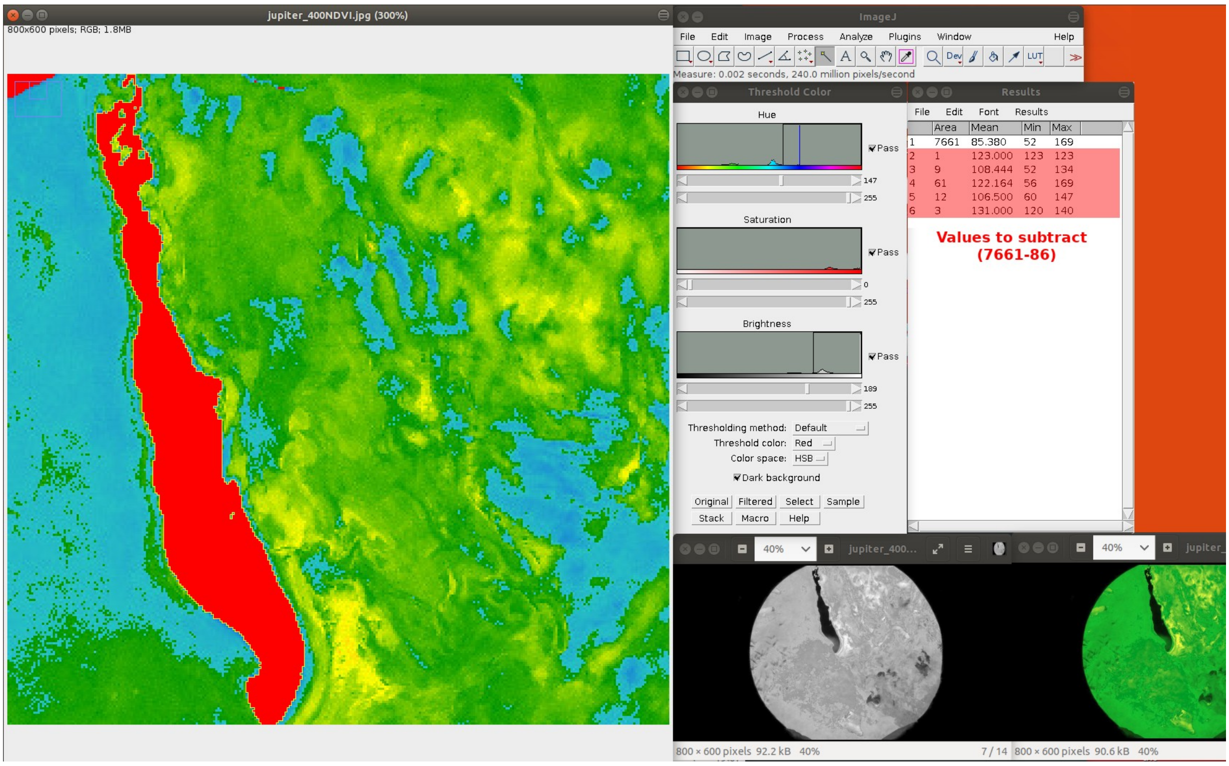


Fig-5: Pixel counting with ImageJ software

Before we can use the combined number of pixels we have to compensate for the shrinking Infragram did to our image: 2592/800 = 1944/600 = 3,24 so the amount of pixels have to be factored by 3,24² that is 7575 x 3,24² = 79519px at 27807m² per pixel which makes an area of 2211,2 Km².

With the area measurement tool from NASA World View we found out the evolution of water surface area for the western basin for each year since 2000 (Fig-6).

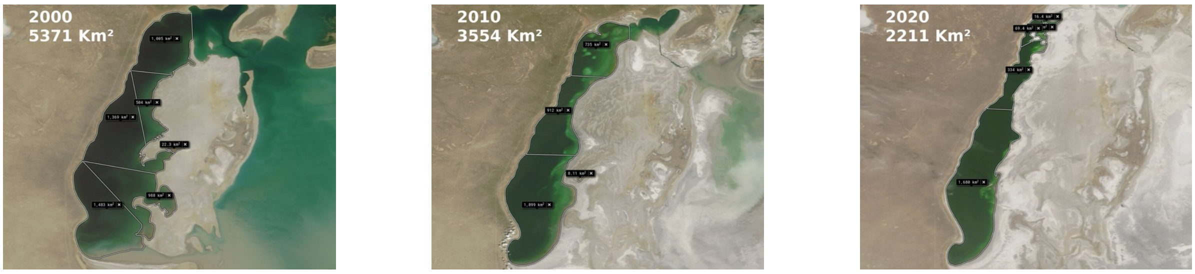


Fig-6: The shrinking evolution from Worldview: MODIS/Terra corrected reflectance imagery (True Color)

Subsequently, measured areas were entered in a spreadsheet and assessed to calculate a yearly surface loss average which happened to be 4,1%. This average was eventually fed into the *Compound Interest Formula* as a negative rate in order to compute how long it would take for the water surface to drop below 100 Km² given the aforementioned rate remained constant. As shown in the results, in just under 75 years Lake Aral could be on the brink of disappearance, in the best case scenario.

SURFACE LOSS EVOLUTION (NASA WORLD VIEW AND ASTROPI) AND YEARLY AVERAGE LOSS RATE

Date	Block1	Block2	Block3	Block4	Block5	Block6	Block7	Km²	yearly surface loss Km²	yearly surface loss %
20000420	1005,0	504,0	1369,0	22,3	988,0	1483,0		5371,3		
20010425	983,0	1787,0	897,0	1435,0	11,4	3,8		5117,2	254,1	4,7
20020416	958,0	1712,0	811,0	1435,0				4916,0	201,2	3,9
20030419	958,0	1676,0	2062,0					4696,0	220,0	4,5
20040428	958,0	1676,0	1998,0					4632,0	64,0	1,4
20050426	958,0	1609,0	1925,0					4492,0	140,0	3,0
20060425	958,0	1609,0	1870,0					4437,0	55,0	1,2
20070421	815,0	926,0	1357,0	1000,0				4098,0	339,0	7,6
20080425	700,0	484,0	2633,0					3817,0	281,0	6,9
20090428	757,0	939,0	1941,0	6,1				3643,1	173,9	4,6
20100427	735,0	912,0	1899,0	8,1				3554,1	89,0	2,4
20110416	735,0	912,0	1945,0	5,4				3597,4	-43,3	-1,2
20120418	722,0	912,0	1869,0	8,9				3511,9	85,5	2,4
20130421	82,7	779,0	193,0	848,0	1354,0			3256,7	255,2	7,3
20140417	76,1	510,0	524,0	1943,0				3053,1	203,6	6,3
20150416	54,5	40,6	135,0	180,0	262,0	2114,0		2786,1	267,0	8,7
20160422	45,2	66,4	149,0	187,0	443,0	1807,0		2697,6	88,5	3,2
20170423	36,4	77,6	106,0	116,0	240,0	435,0	1591,0	2602,0	95,6	3,5
20180415	31,3	42,1	37,9	88,6	125,0	210,0	1885,0	2419,9	182,1	7,0
20190422	26,4	33,9	46,2	168,0	443,0	1677,0		2394,5	25,4	1,0
20200415	14,1	58,0	64,8	305,0	1373,0	452,0		2266,9	127,6	5,3
20210424					**Area from AstroPi picture**			**2211,2**	55,7	2,5
20210416	16,4	33,3	69,4	334	1680			2133,1	**3160,1**	**4,1**

Yearly surface loss average (%)
Surface lost since 2000 (Km²)
AstroPI image results
Area from World View pictures for 2021

SURFACE LOSS GUESS FOR THE NEXT FUTURE

Rearranging the compound interest formula into

$$FV = IV \cdot (1 - r\ (\%))^n \rightarrow n = \frac{\log\left(\frac{FV}{IV}\right)}{\log\left(1 - r\ (\%)\right)}$$

where FV is Future Value
IV is Initial Value
r is yearly variation rate in %
n is period in years

we get an estimation for how long it will take for the surface area to reach target value
To reach 100 km² it will take

$$n = \frac{\log\left(\frac{100}{2211}\right)}{\log\left(1 - 0{,}041\right)} \rightarrow n = 74\ years$$

IV	FV	r(%)	n(years)
2211	100	4,1	73,95

Conclusion

When we noticed the pictures of Lake Aral we knew it would end up being our research object because it makes for such an explanatory example of the awful consequences that climate change and water misuse can have.

Regarding area measurements, the method used to work out pixel dimensions makes some assumptions such as Earth's surface is flat, camera is vertically facing surface, and that there are no significant differences in relief. And also that water depth is the same anywhere in the lake. But, despite all previous factors being potential source of error, the area we calculated for 2021 only differs 3,6% from that of World View.

Now, as much as we would like our results to be more accurate, the fact that such an extent of water could almost vanish within our lifetime saddens us and makes us take climate change even more seriously.

Nevertheless, we would like to thank ESA and RaspberryPi for giving us such an amazing opportunity, as well as NASA, Public Lab, heavens-above.com and National Institutes of Health (NIH) for making their tools available.

And also many thanks to Josep Palau for his mentoring through this challenge.

Project data, code and further information can be found at:

https://github.com/jpalau-edu/AstroPi2021/tree/main/Jupiter