EARTH OBSERVATION IN AGRICULTURE WITH LINEAR REGRESSION

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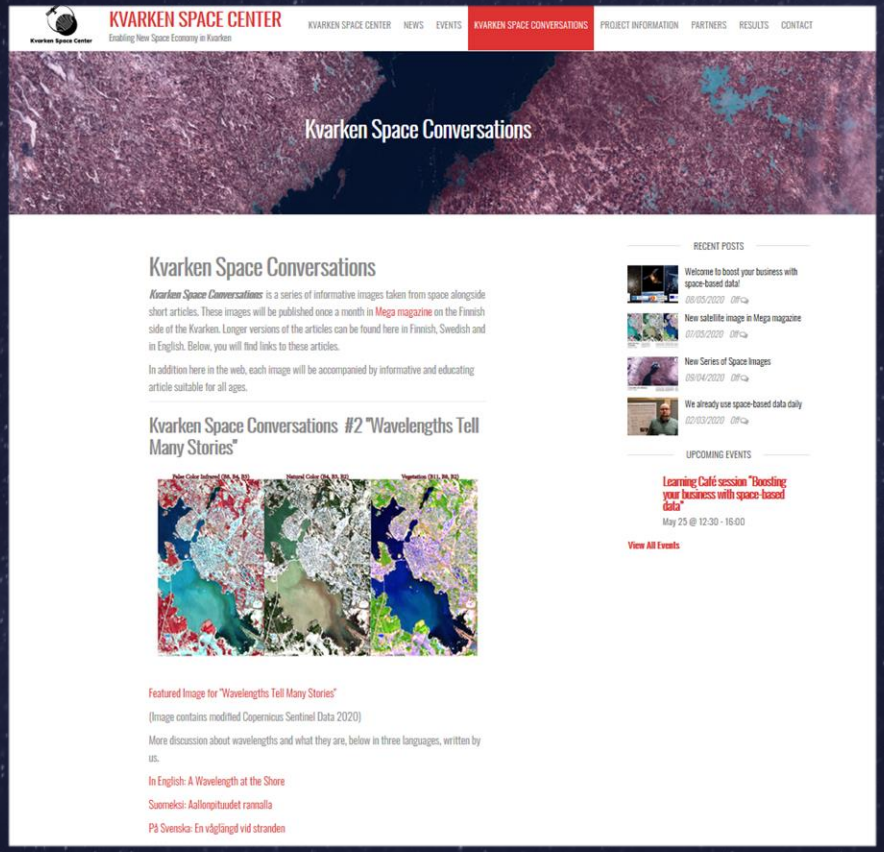
KVARKEN SPACE CENTER

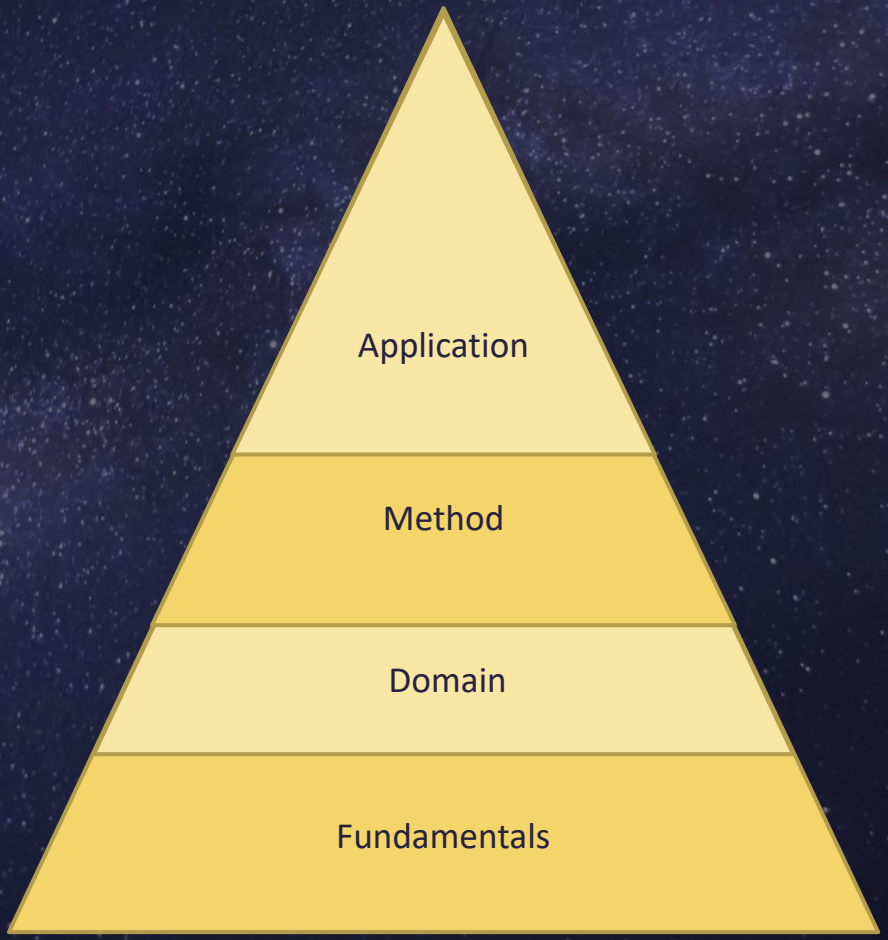
http://www.kvarkenspacecenter.org

KVARKEN SPACE CONVERSATIONS

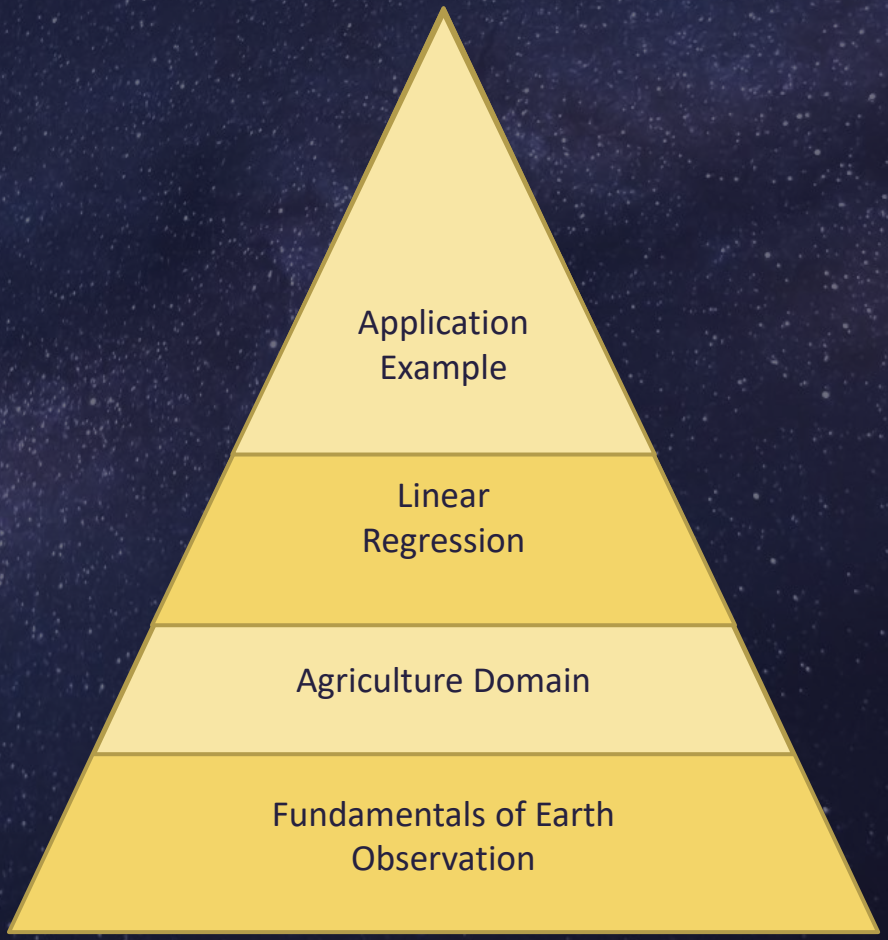


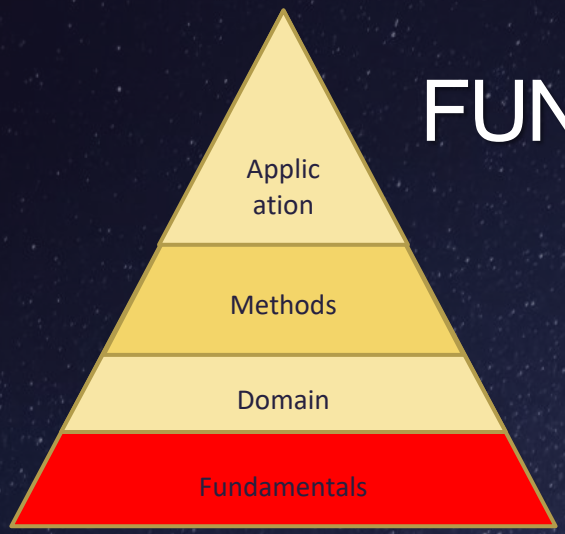
- Steadily growing collection fundamental information in easily understandable form in three languages (English, Finnish, Swedish)
- Related links to each monthly image
- Tutorials on how to recreate the monthly images incoming

CONTENTS



CONTENTS

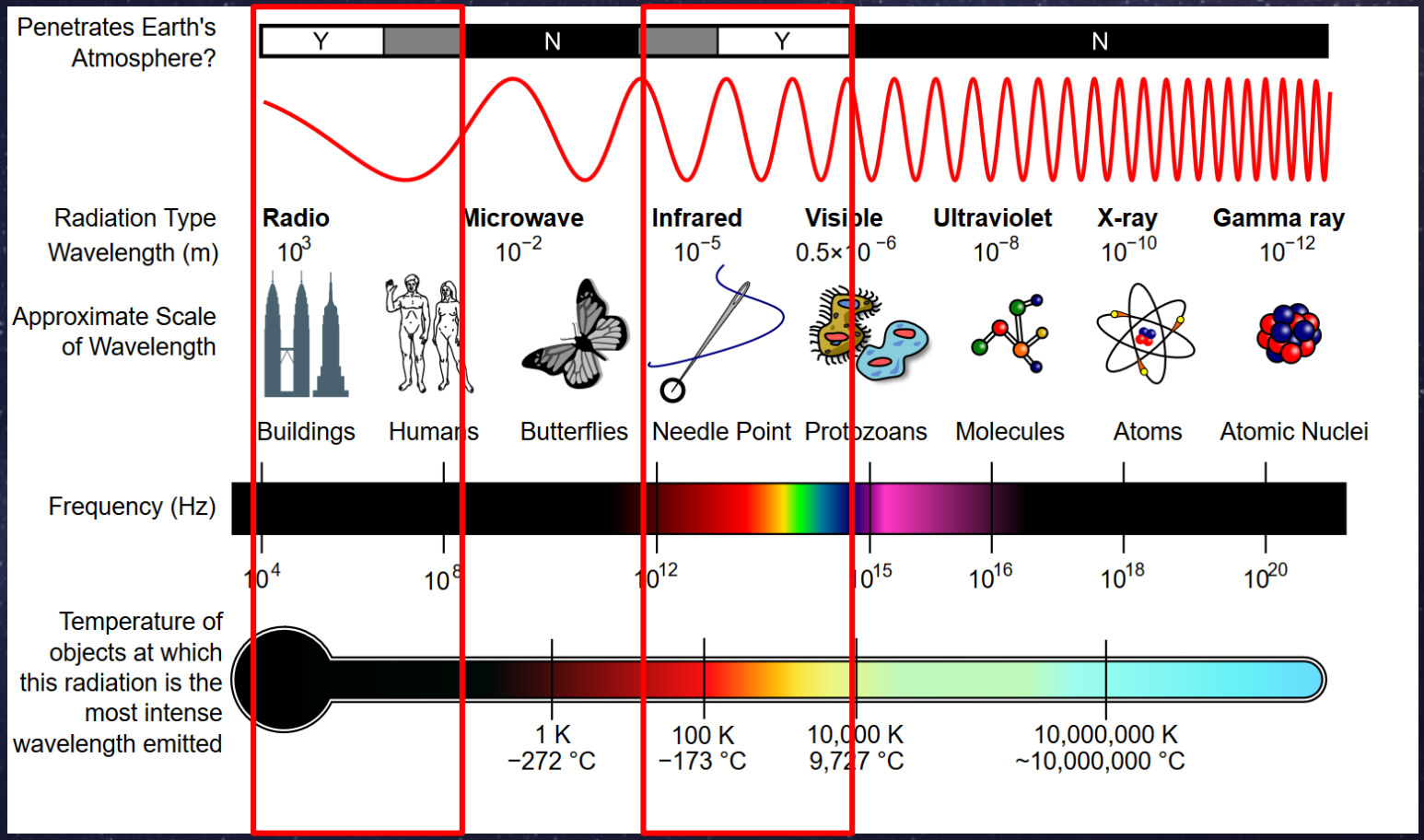

Application Example
Linear Regression
Agriculture Domain
Fundamentals of Earth Observation



FUNDAMENTALS OF EARTH OBSERVATION

- Electromagnetic Spectrum
- EM measurements from space
  - Observation quality
- Available optical satellite data sources
- Sentinel-2 MSI Instrument specifications

ELECTROMAGNETIC SPECTRUM



Original Image Credits: CC 3.0 Indictiveload, NASA / Wikipedia. Based on original image by NASA. Modified.

EM OBSERVATION FROM SPACE

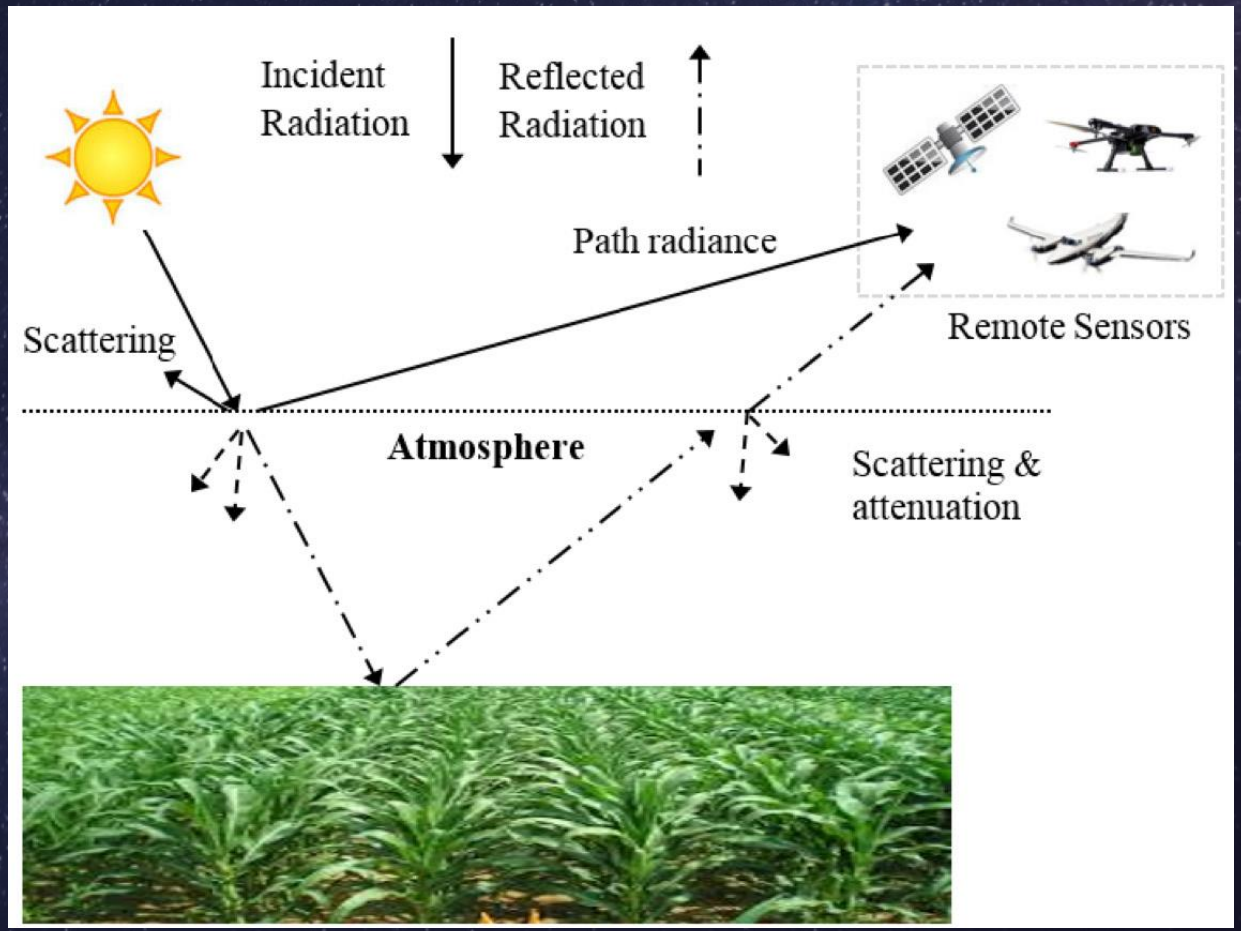


Image credits: Khanal, Fulton, Hawkins, Port & Klopfenstein: ”Remote Sensing in Precision Agriculture”, 2017

EO OBSERVATION QUALITY

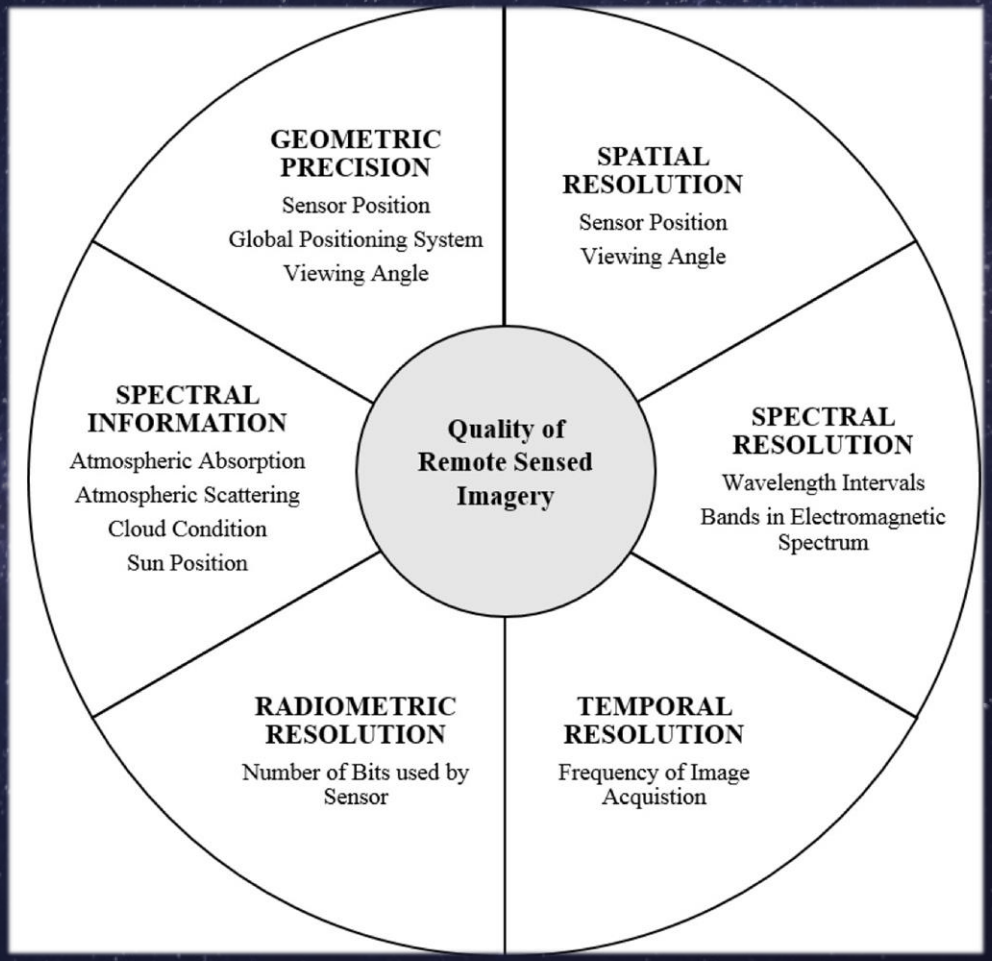


Image credits: Khanal, Fulton, Hawkins, Port & Klopfenstein: ”Remote Sensing in Precision Agriculture”, 2017

AVAILABLE OPTICAL SATELLITE SOURCES

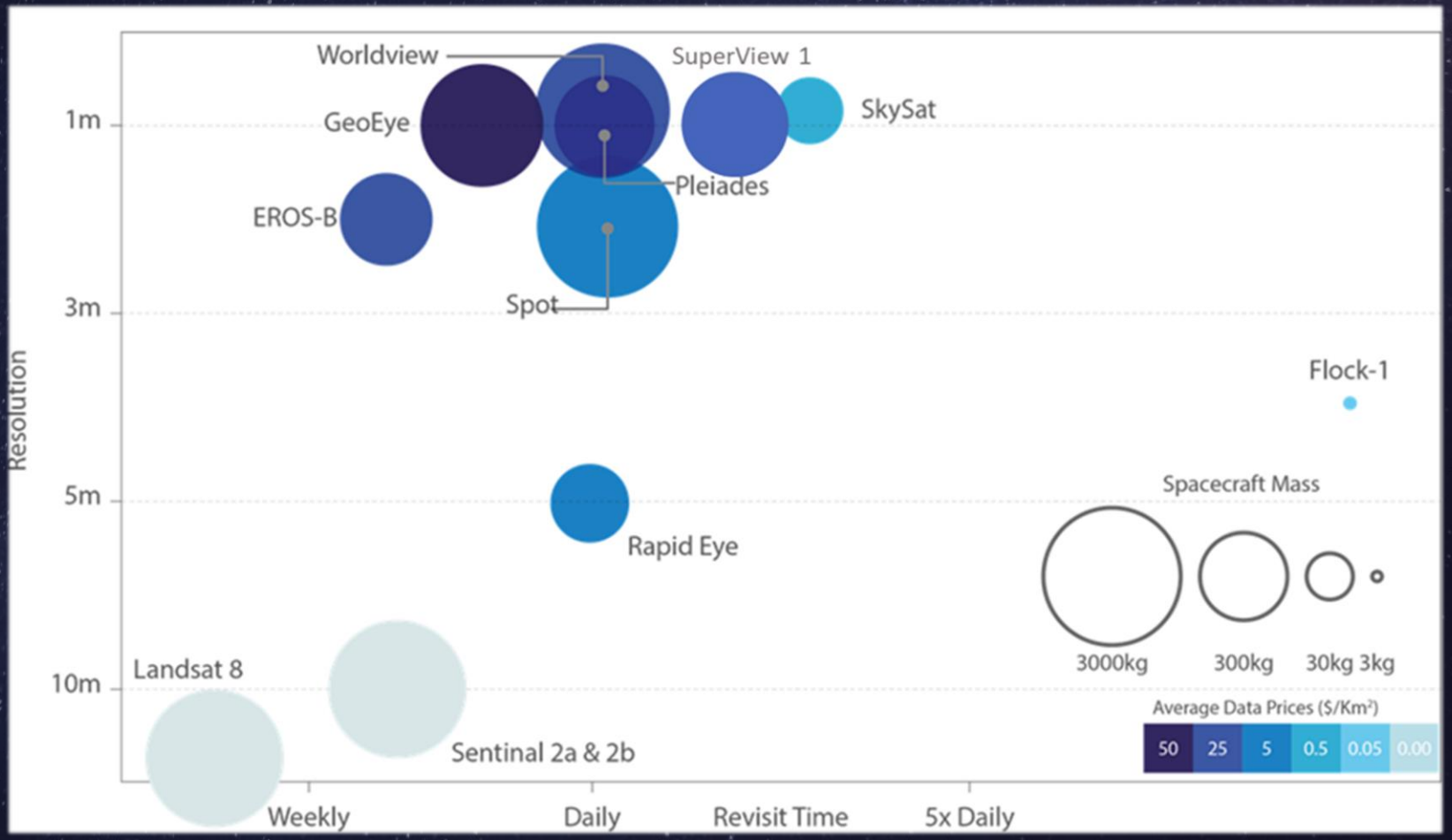


Image source: Satellite Applications Catapult 2017, adapted from EO21 Project

SENTINEL-2 MSI OBSERVED BANDS

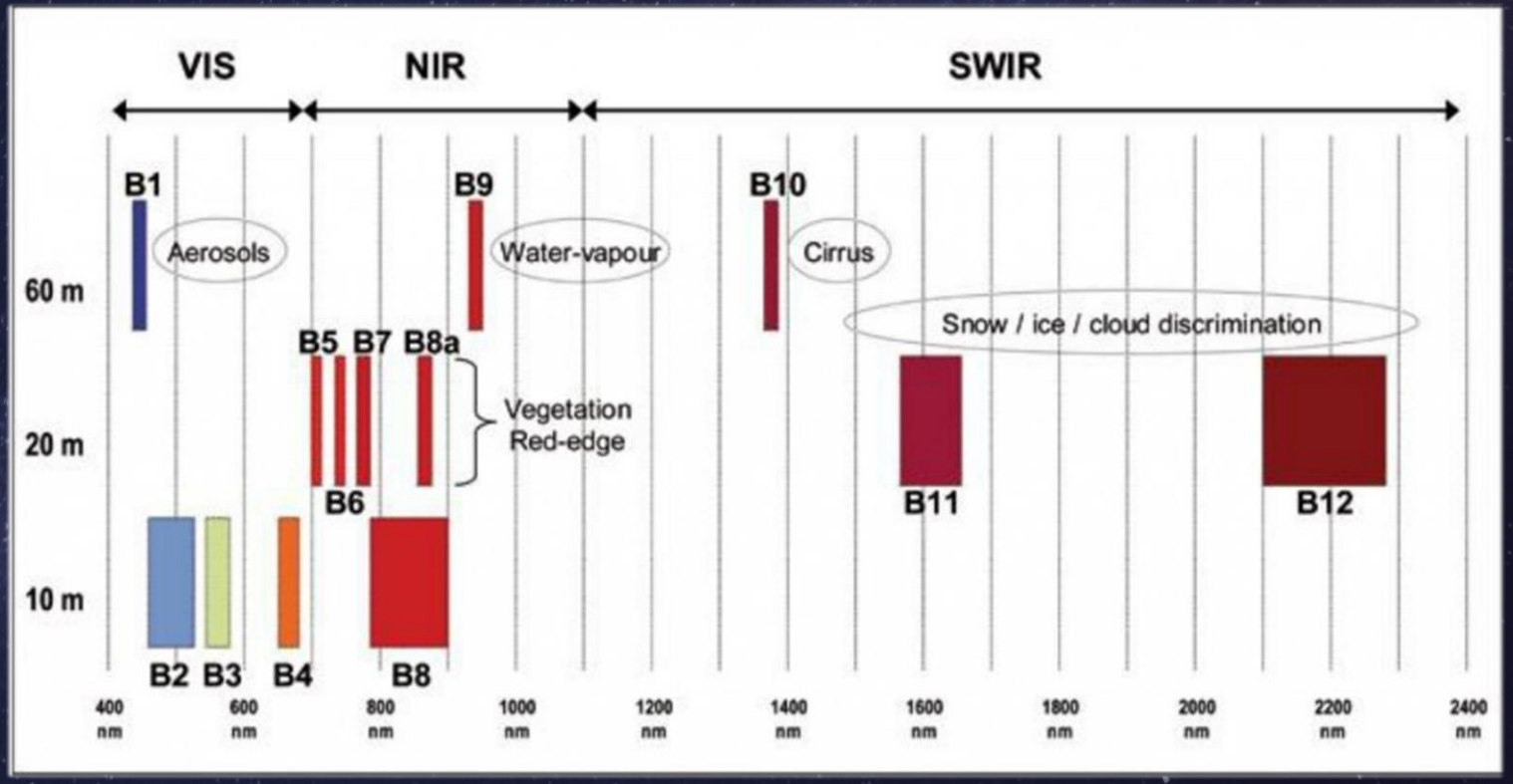
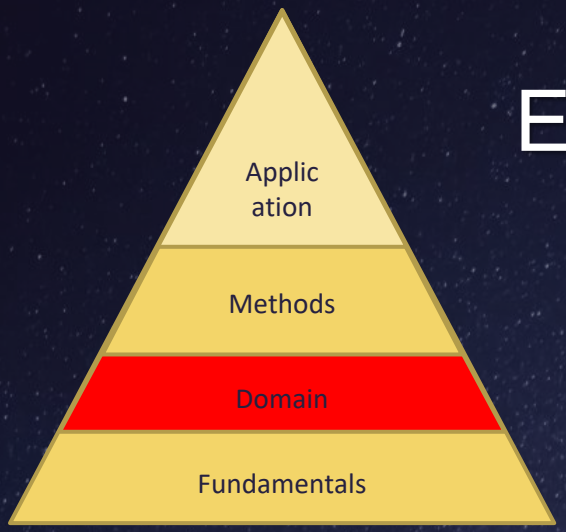


Image source: ESA

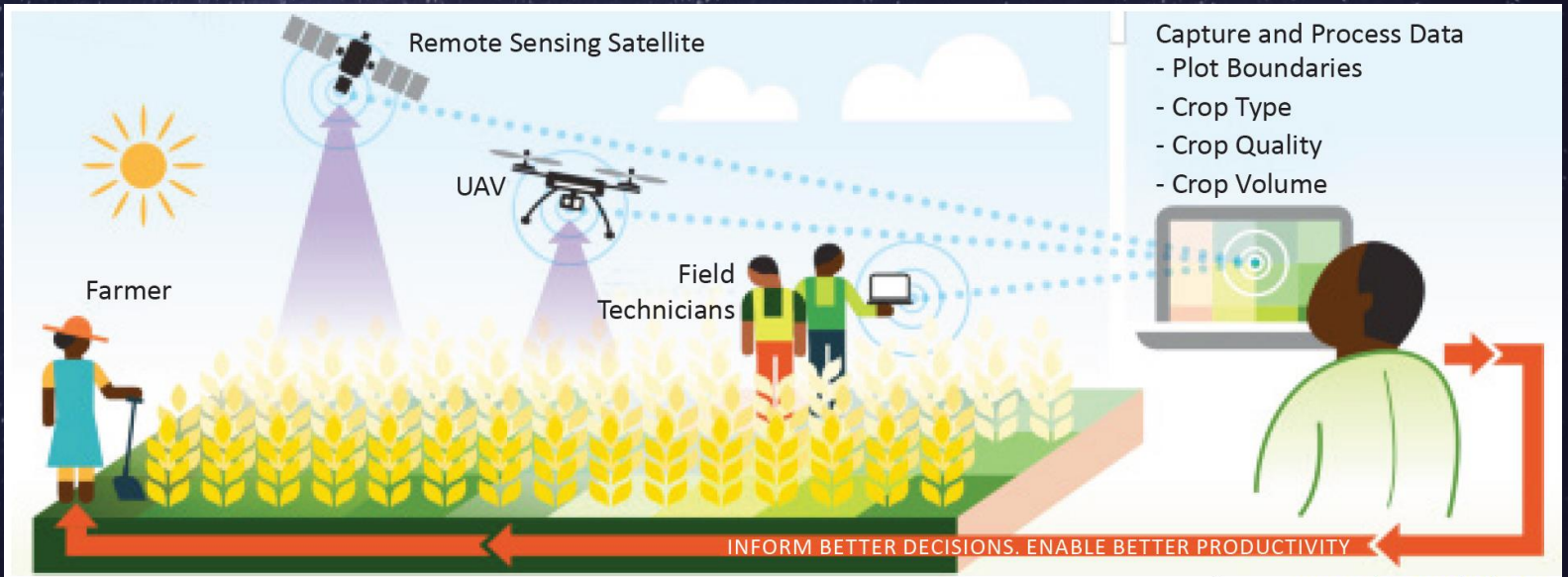


EO AND AGRICULTURE

- EO and Agriculture
  - Reflectance base
- EO Agriculture use cases
  - Vegetation radiation response
  - EO Agriculture use cases
- Crop type classification example
- Mapping of soil characteristics example

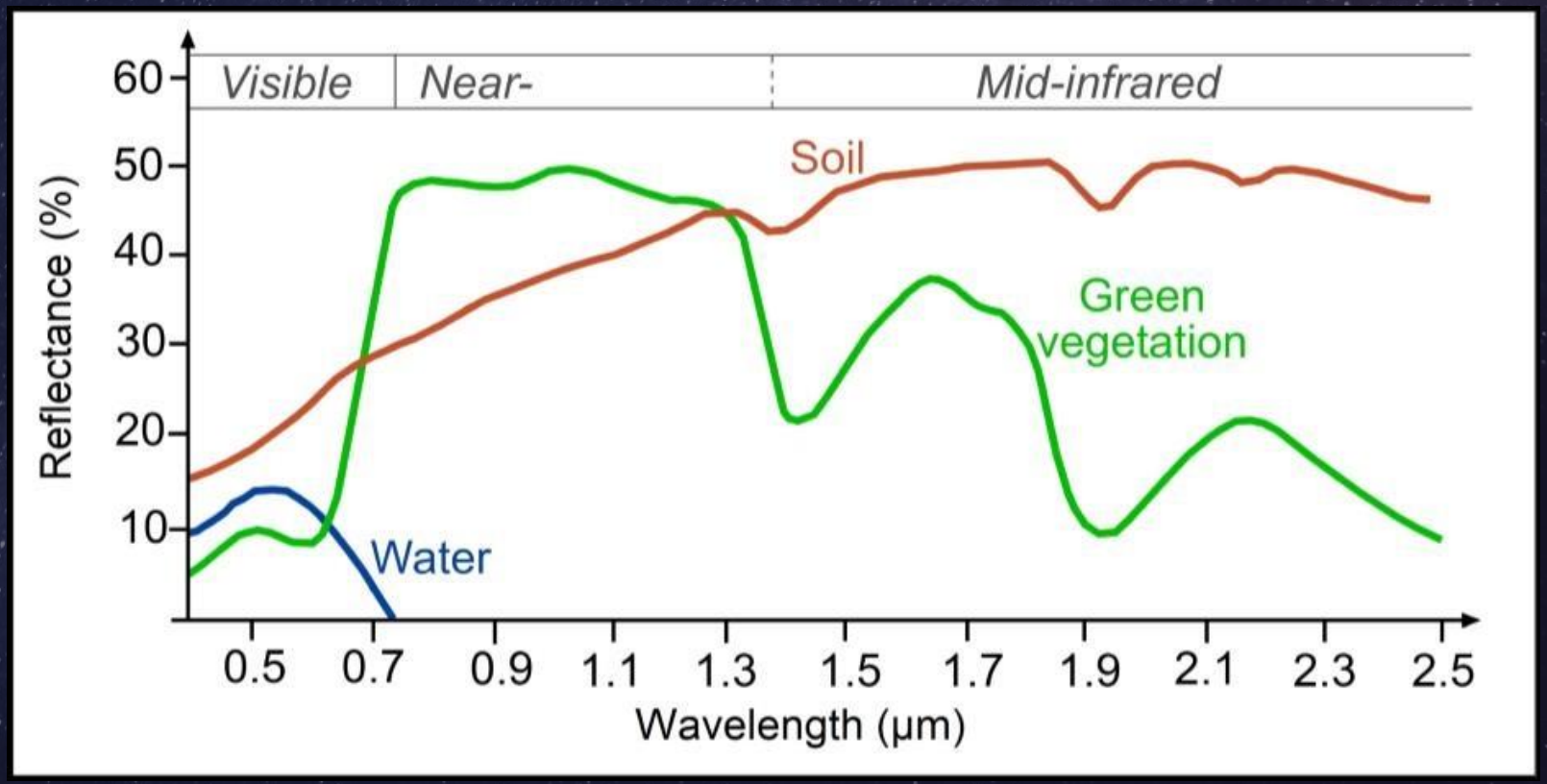
EO AND AGRICULTURE

- 2050 Food and Agriculture Organization (FAO) of the UN estimates the world population will reach 9.1 billion, 34% increase to todays numbers
  - Climate change change available arable land area and crop types
- Precision farming increases productivity, but also increases needs for information quantitity and the update speed of the information



Source: www.stars-project.org

REFLECTANCE BASE



Source: Grind GIS 2017

VEGETATION RADIATION RESPONSE

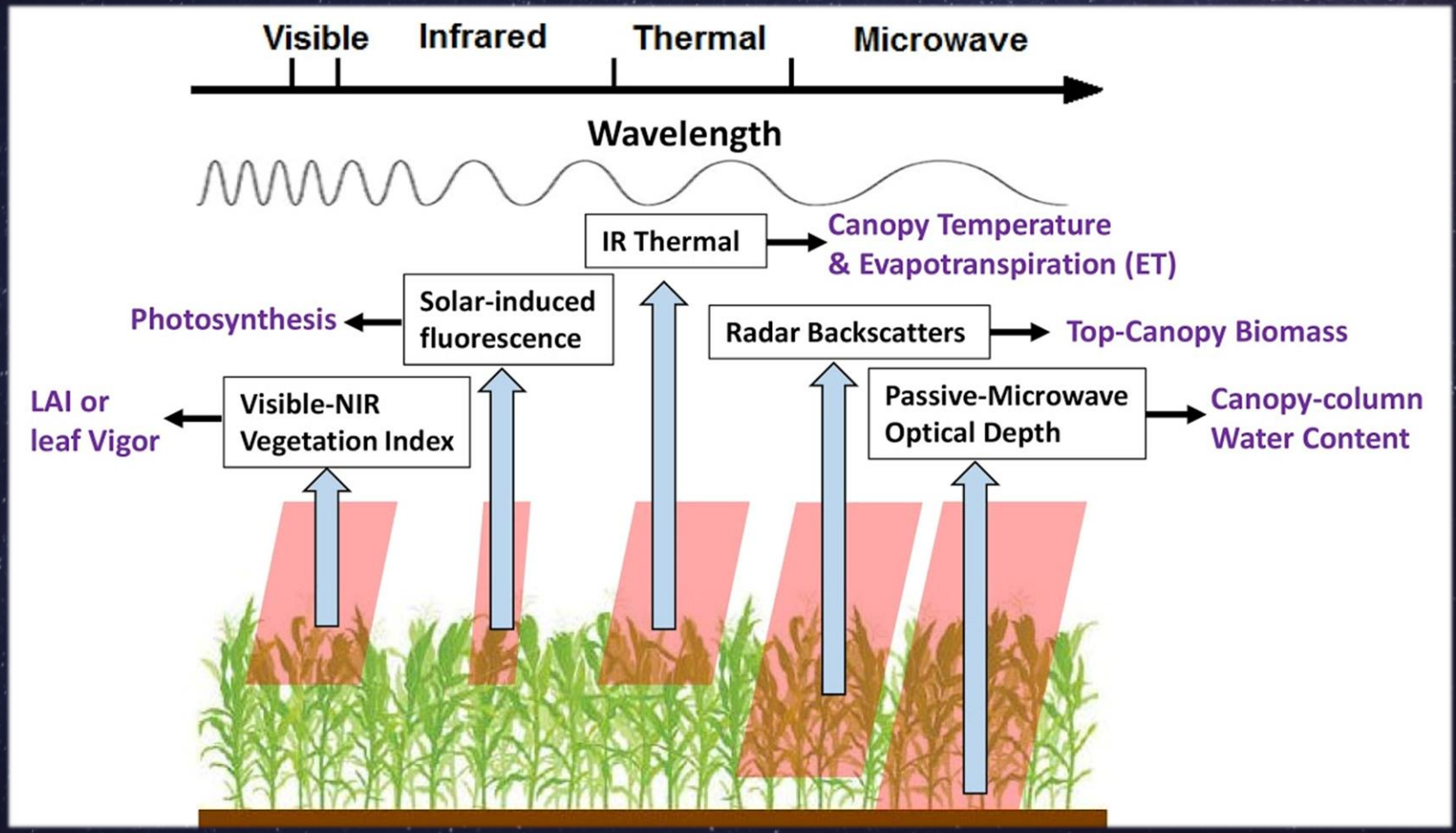
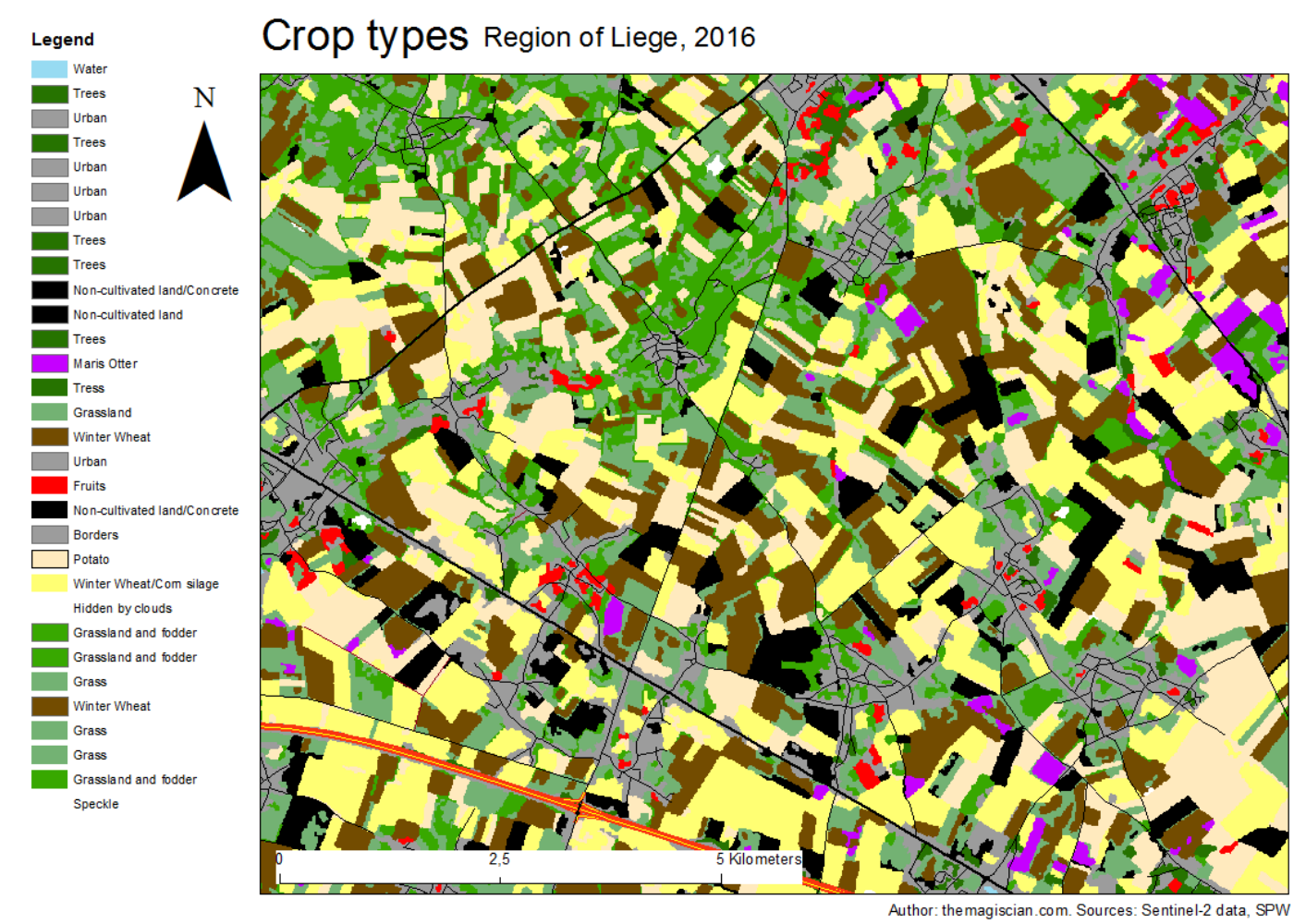


Image credit: University of Illinois at Urbana-Champaign

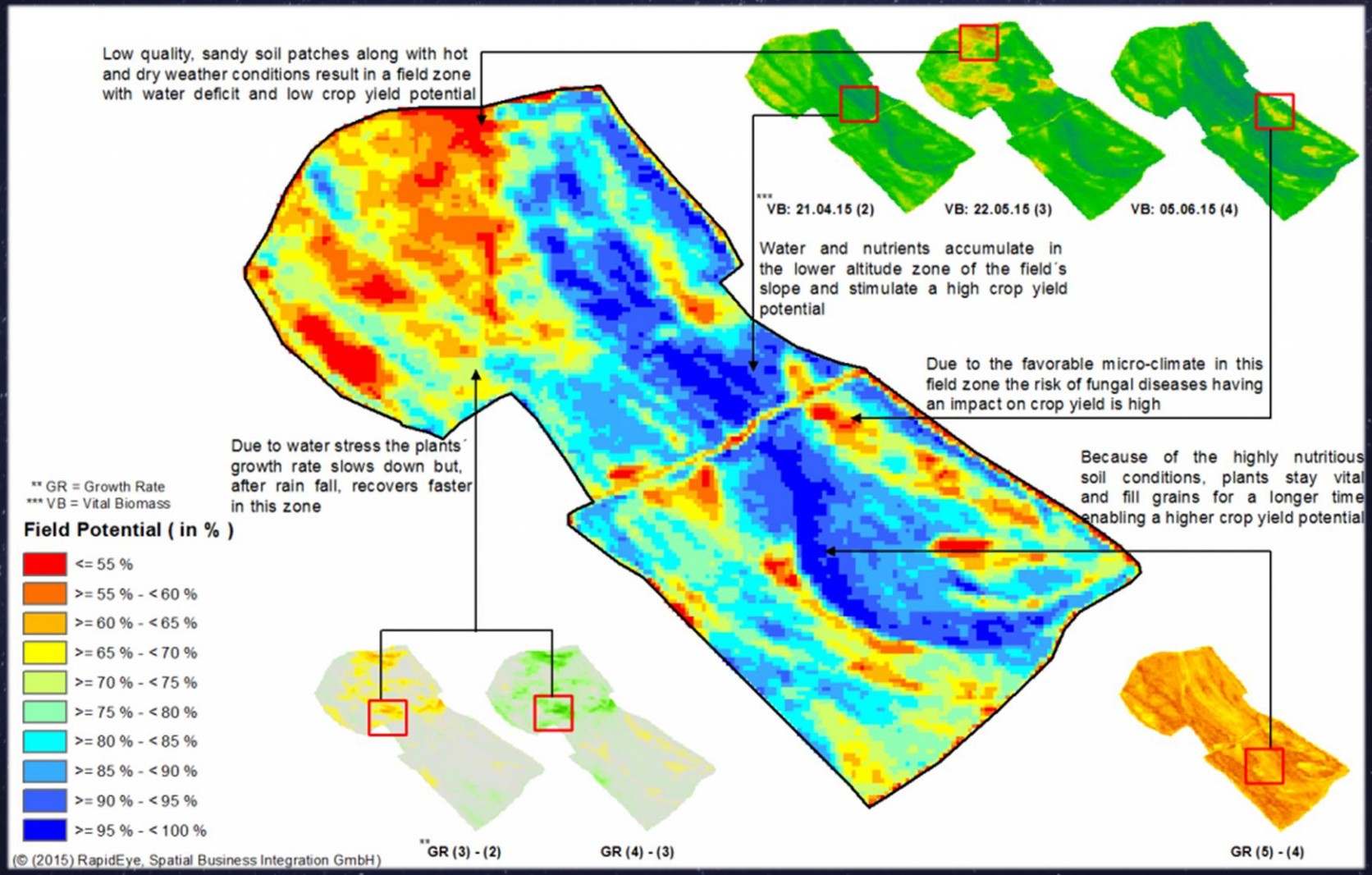
EO AGRICULTURE USE CASES

- Crop type classification
- Crop yield estimation
- Mapping of soil characteristics
- Mapping of soil management practices
- Compliance monitoring
- Crop Condition assessment

CROP TYPE CLASSIFICATION EXAMPLE



MAPPING OF SOIL CHARACTERISTICS EXAMPLE



LEAF AREA INDEX (1/2)

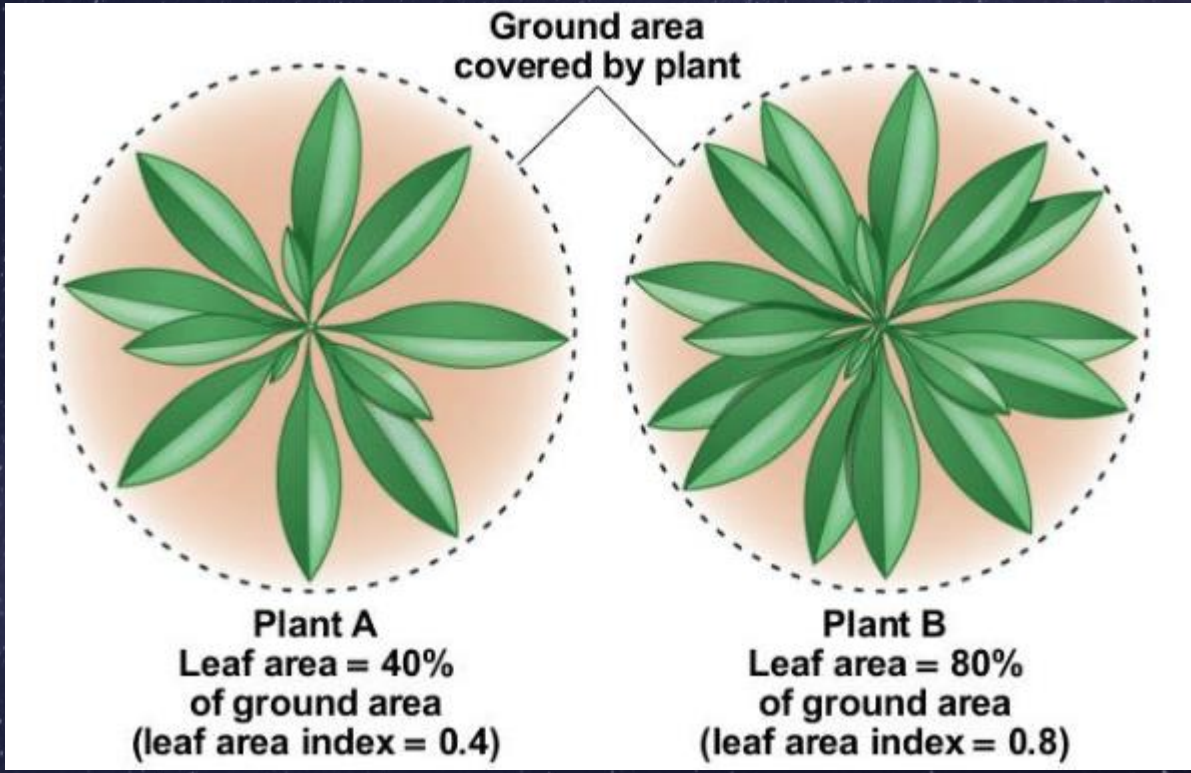


Image Source: **Leaf Area Index estimation. Source: http://www.slideshare.net/hayabranko/36-lecture-presentation-16973941 (Pearson Education, Inc., 2013)**

LEAF AREA INDEX (2/2)

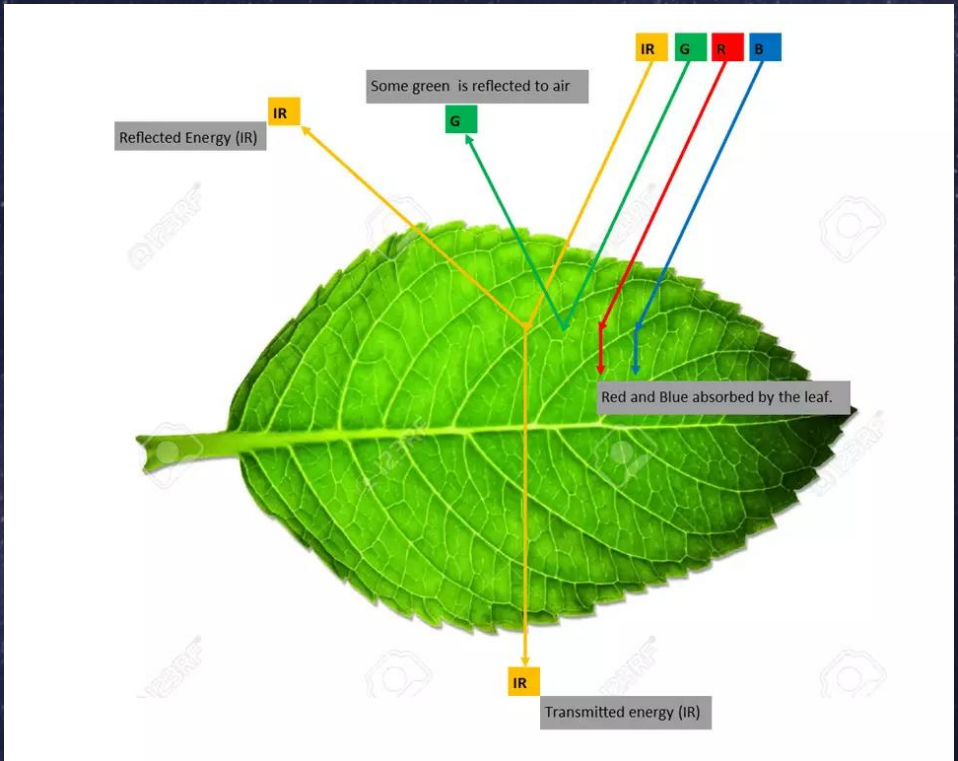
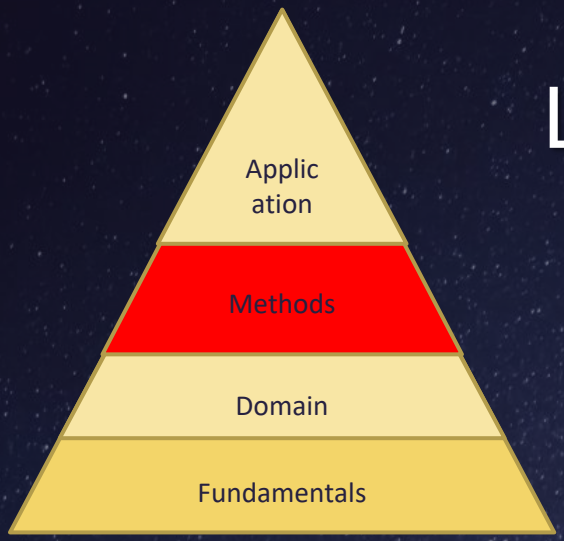


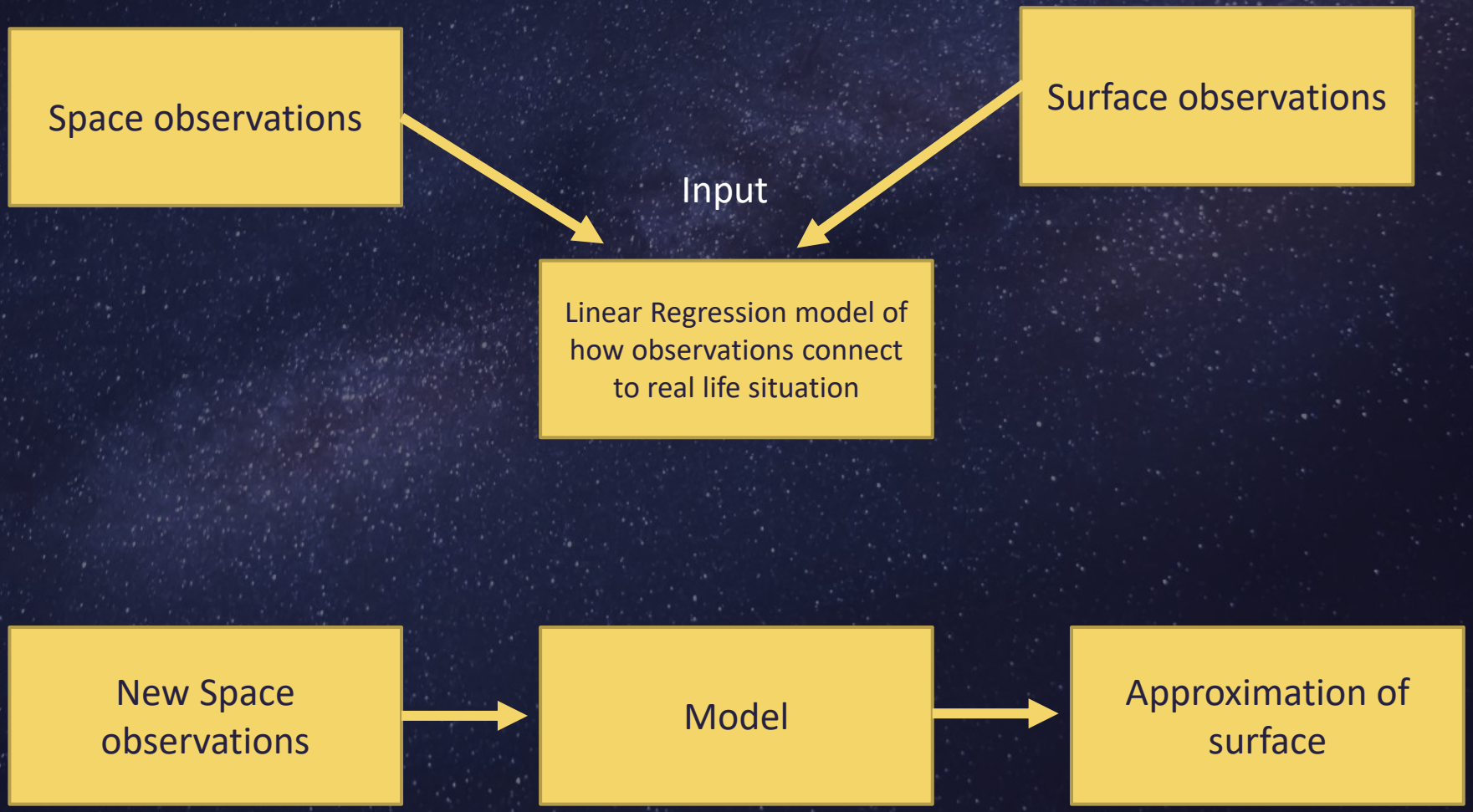
Image Source: Grind GIS



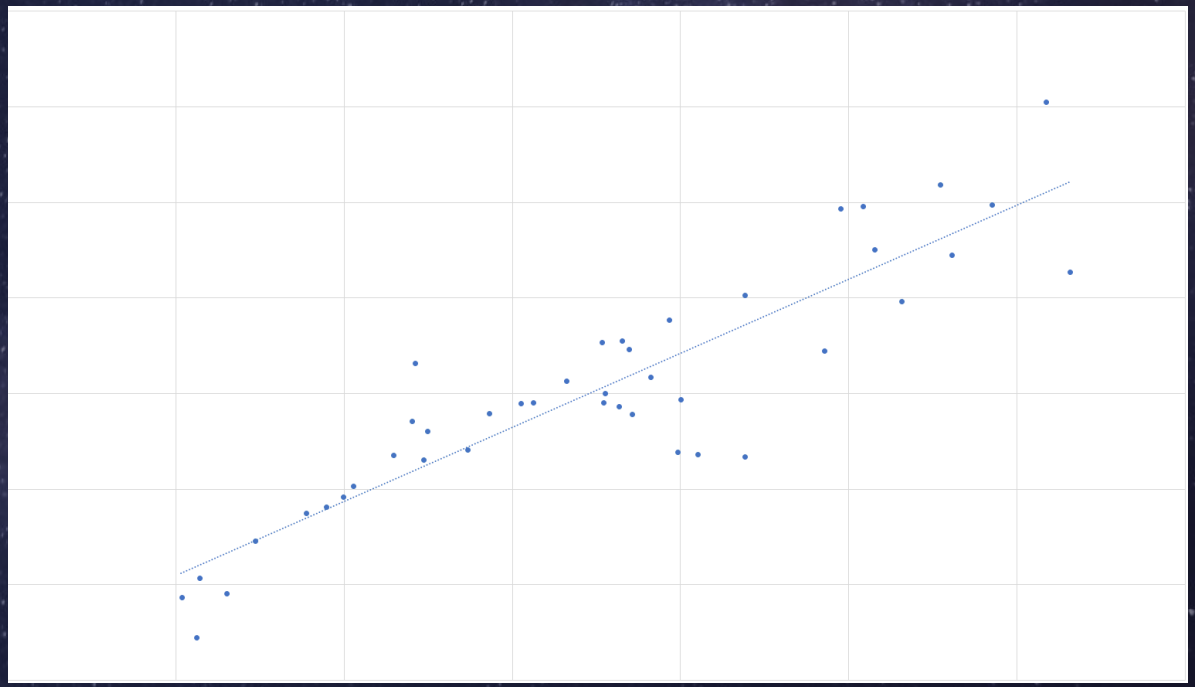
LINEAR REGRESSION

- Outline
- Modelling

OUTLINE


Space observations
Surface observations
Input
Linear Regression model of how observations connect to real life situation
New Space observations
Model
Approximation of surface

LINEAR REGRESSION



SIMPLE REGRESSION EQUATION

$$Y' = A + B * X$$

- **X**: predictor (present in data)
- **B**: coefficient (estimated by regression)
- **A**: intercept (estimated by regression)
- **Y'**: predicted value (calculated from A, B and X)

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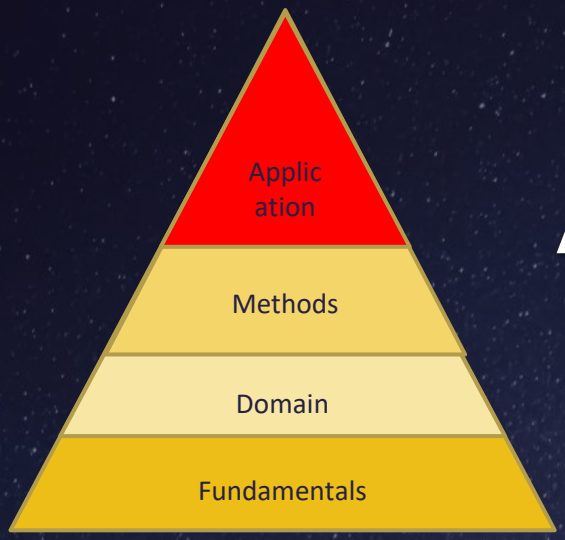
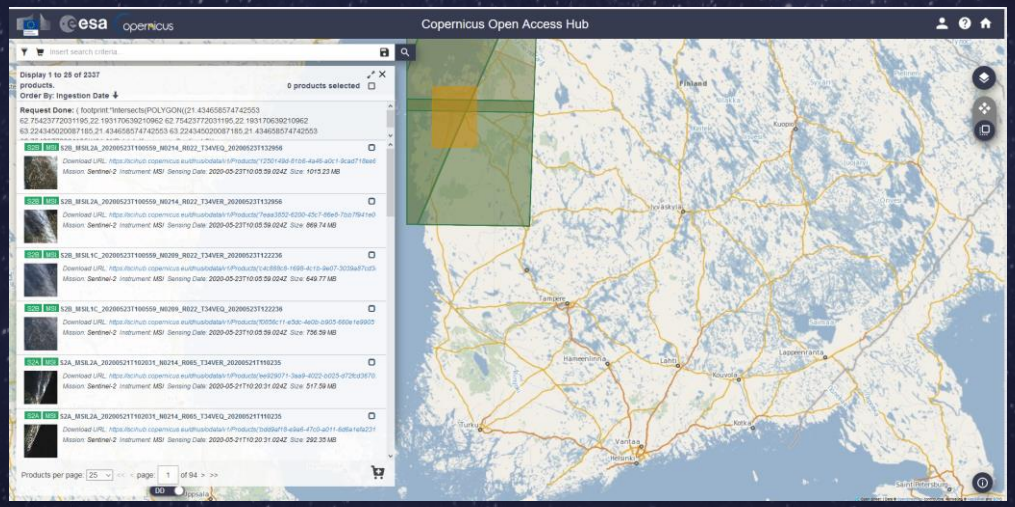


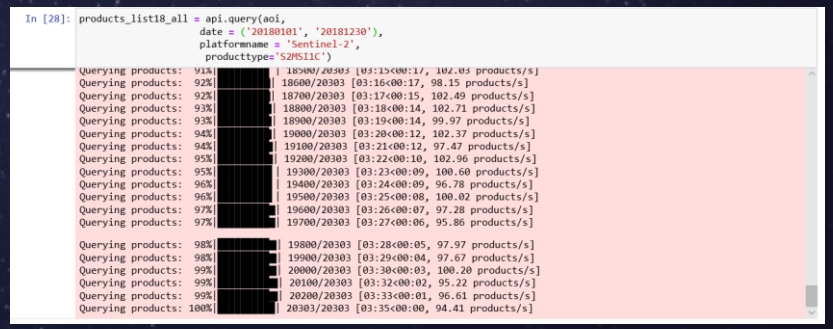
LINEAR REGRESSION IN AGRICULTURE EXAMPLE

- Data acquisition
- SNAP Toolset
- SNAP processing
- Results

DATA ACQUISITION

- Open Sentinel-2 data has many sources
  - Copernicus Scihub
    - DIAS
  - Finnish Satellite Data Centre

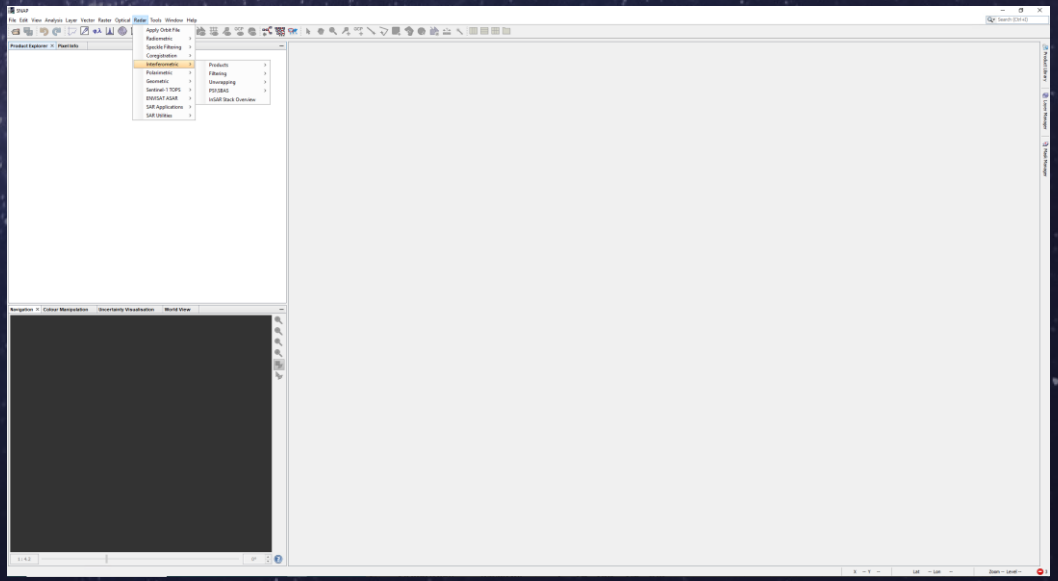




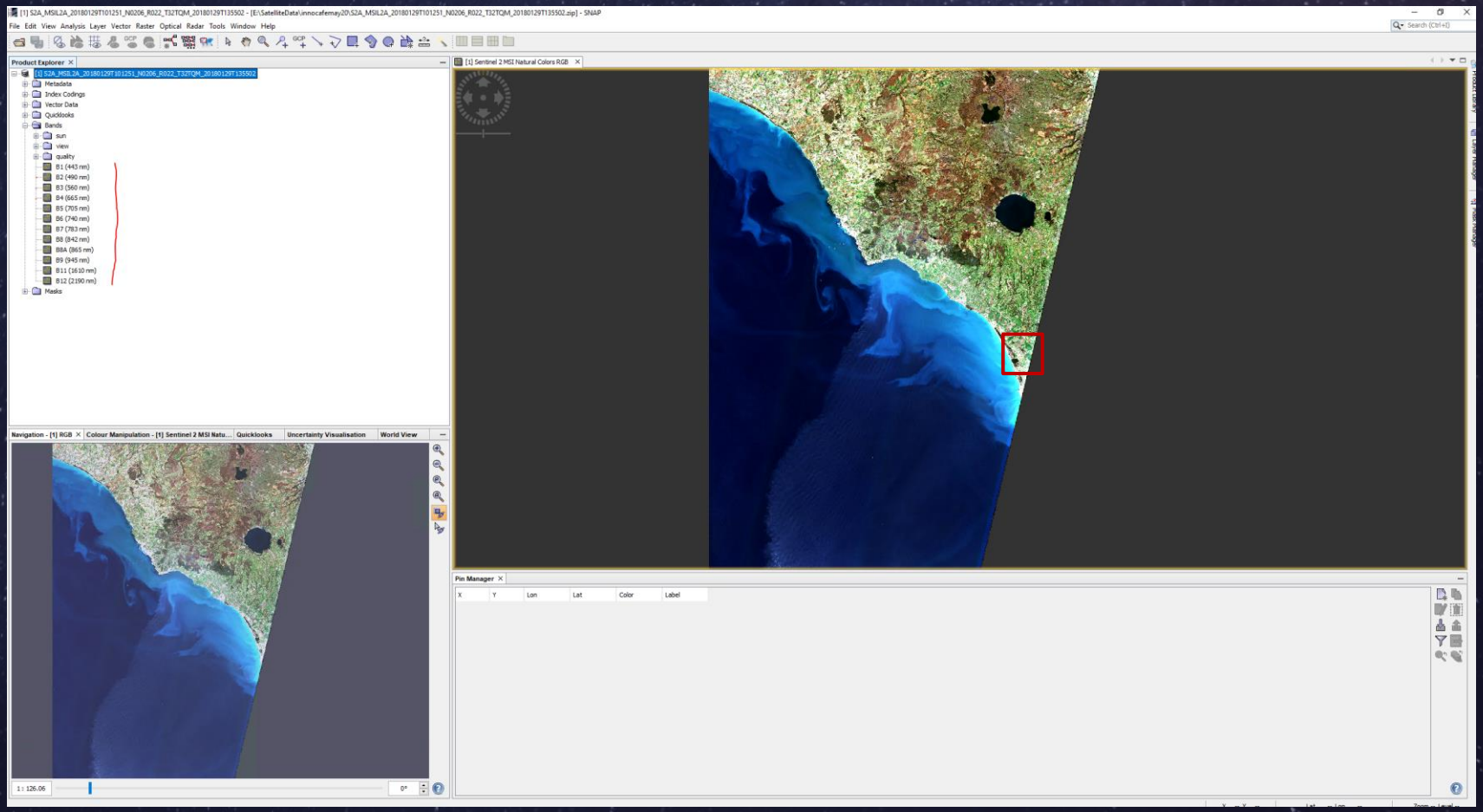

```
C:\Users\ham>curl  -u antti.kinnuner[redacted]:[redacted] -H "Content-Type:application/json" -X POST "https://catalog
ue.onda-dias.eu/dias-catalogue/Products(c08d7002-4510-46e1-8d79-59597edb1667)/Ens.Order"
{"@odata.context":"$metadata#Ens.Order","Id":"c08d7002-4510-46e1-8d79-59597edb1667","Status":"RUNNING","StatusMessage":"
The order is in progress","EstimatedTime":"2020-05-23T11:43:50.525Z"}
```

SNAP TOOLSET

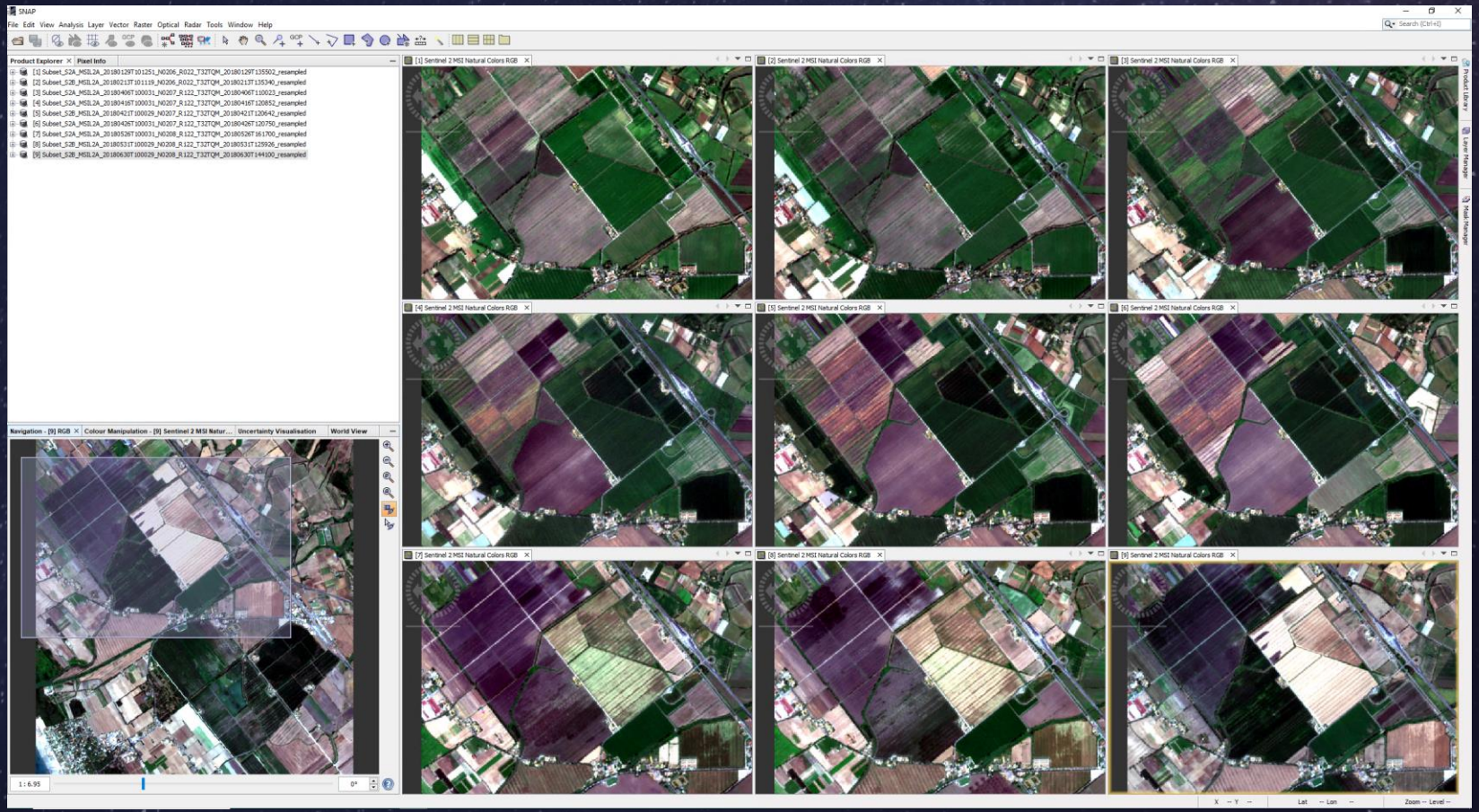
- Free extendable and flexible base for Sentinel Toolboxes (and more!)
  - https://step.esa.int/main/toolboxes/snap/
  - Developed by Brockmann Consult, SkyWatch and C-S
    - Processing graphs
      - Plugins
    - Extendable with Java



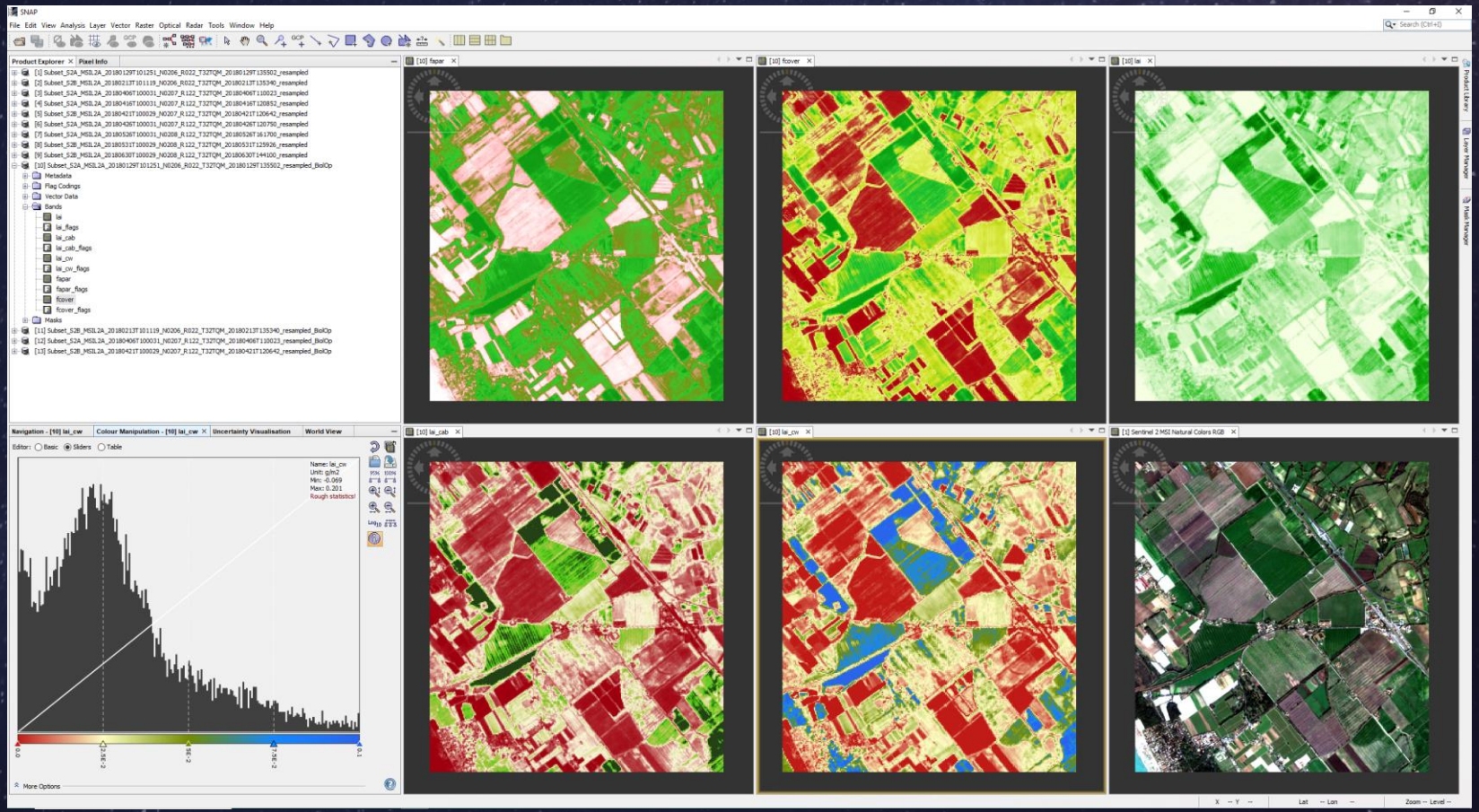
SNAP PROCESSING (1/9) - AOI



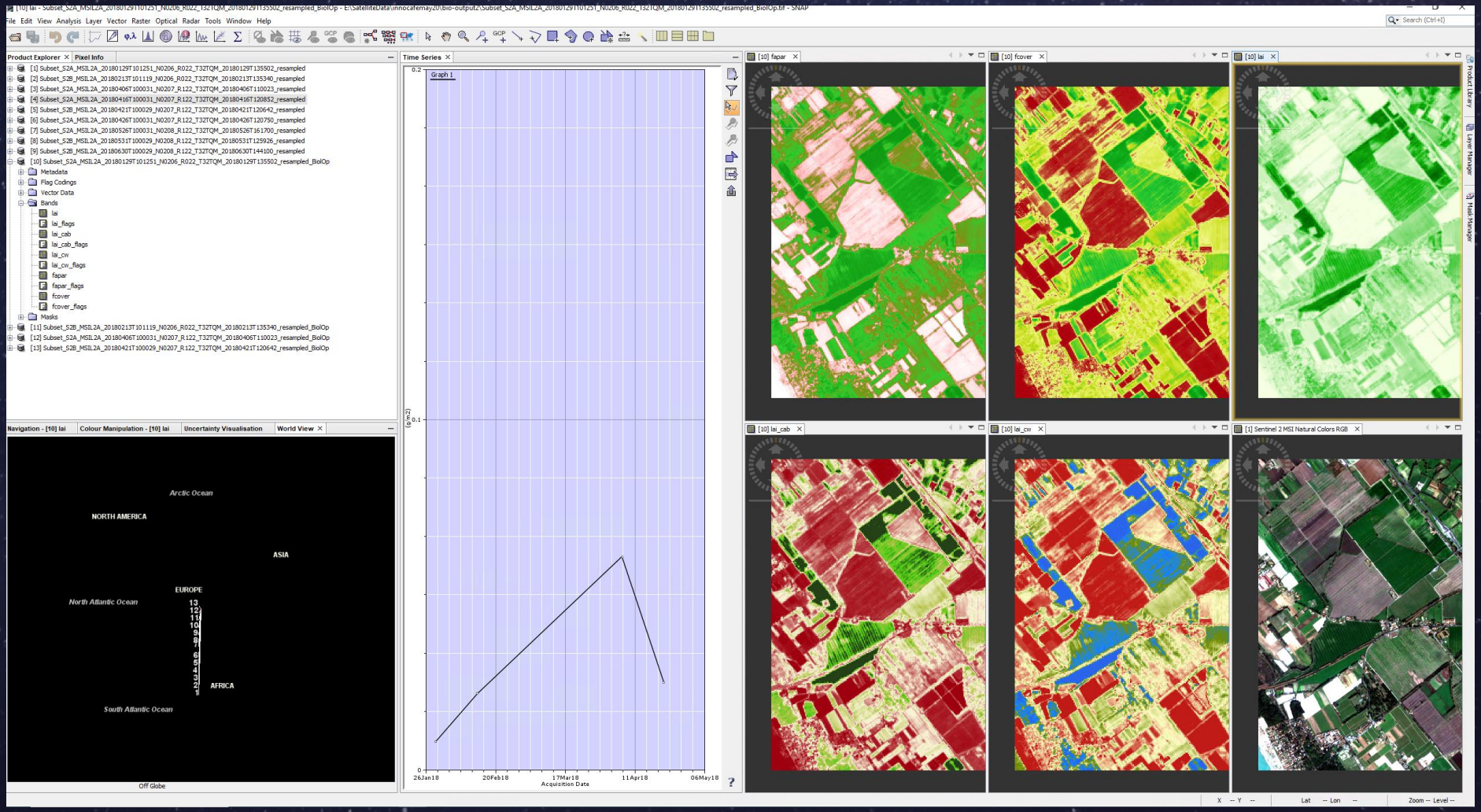
SNAP PROCESSING (2/9) - IMAGE SERIES



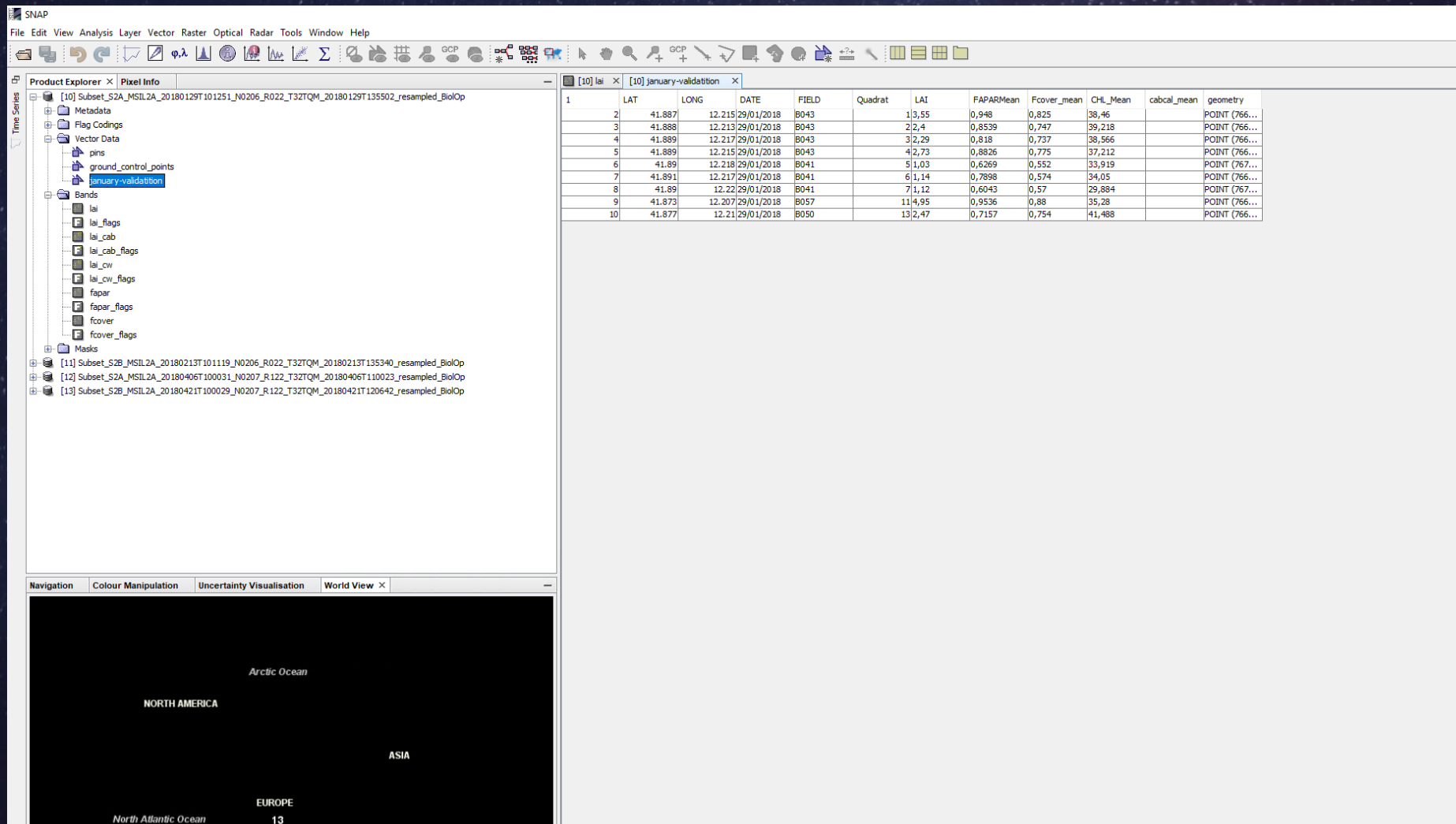
SNAP PROCESSING (3/9) - PRETRAINED ARTIFICIAL NEURAL NETWORKS PROCESSING



SNAP PROCESSING (4/9) - TIME SERIES

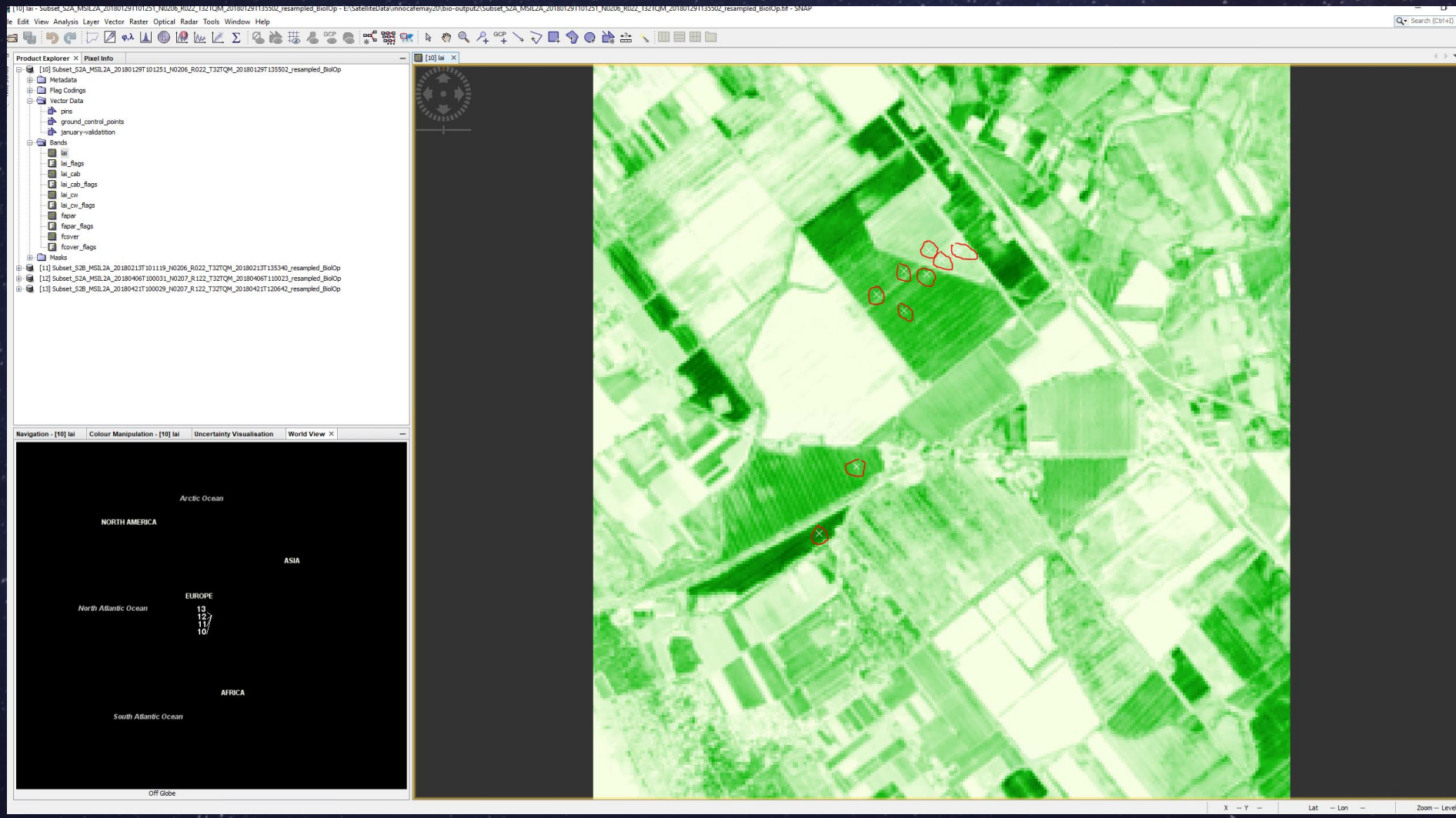


SNAP PROCESSING (5/9) - IMPORT VALIDATION DATA

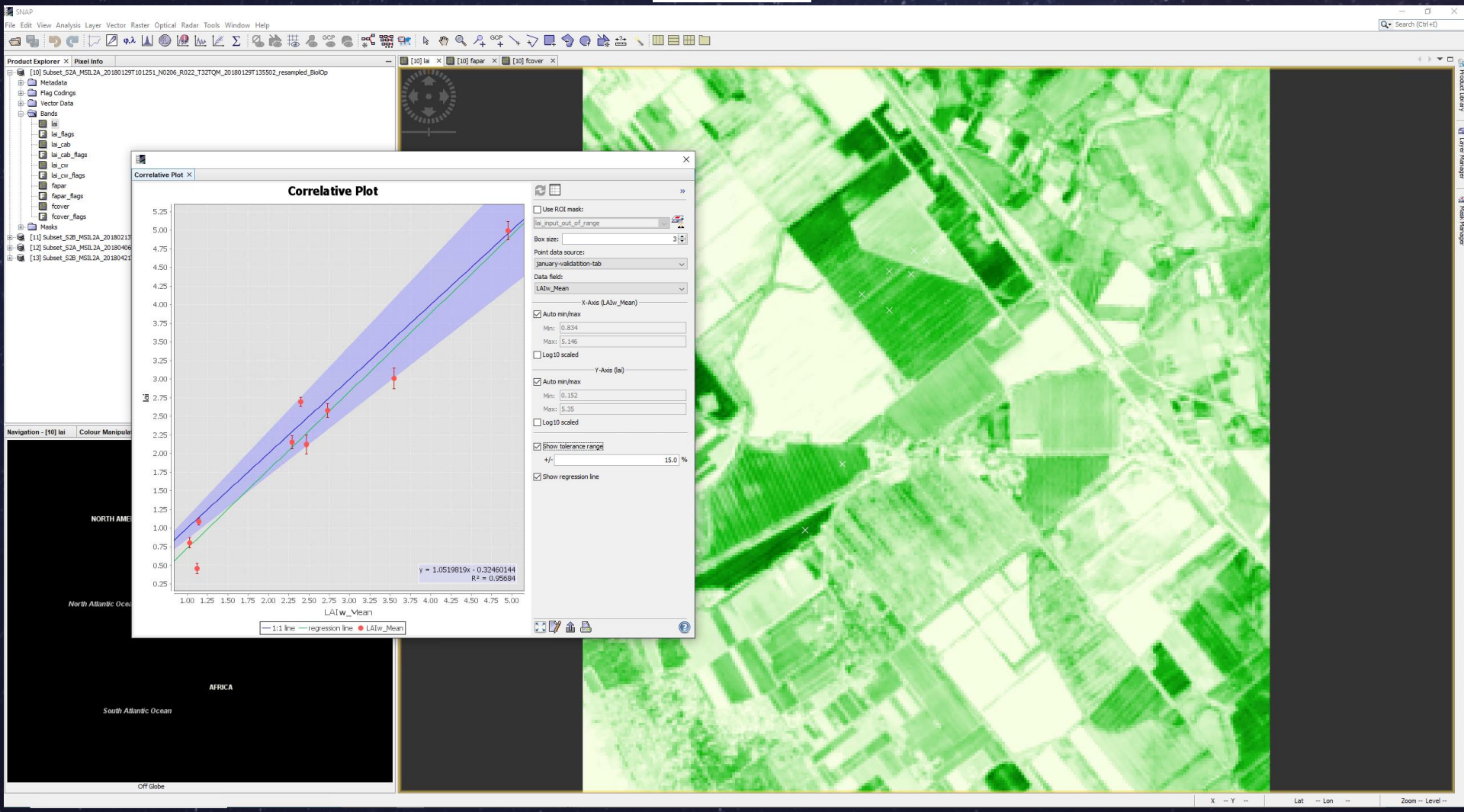


1	LAT	LONG	DATE	FIELD	Quadrat	LAI	FAPARMean	Fcover_mean	CHL_Mean	cabcal_mean	geometry
2	41.887	12.215	29/01/2018	B043	1	3,55	0,948	0,825	38,46		POINT (766…
3	41.888	12.213	29/01/2018	B043	2	2,4	0,8539	0,747	39,218		POINT (766…
4	41.889	12.217	29/01/2018	B043	3	2,29	0,818	0,737	38,566		POINT (766…
5	41.889	12.215	29/01/2018	B043	4	2,73	0,8826	0,775	37,212		POINT (766…
6	41.89	12.218	29/01/2018	B041	5	1,03	0,6269	0,552	33,919		POINT (767…
7	41.891	12.217	29/01/2018	B041	6	1,14	0,7898	0,574	34,05		POINT (766…
8	41.89	12.22	29/01/2018	B041	7	1,12	0,6043	0,57	29,884		POINT (767…
9	41.873	12.207	29/01/2018	B057	11	4,95	0,9536	0,88	35,28		POINT (766…
10	41.877	12.21	29/01/2018	B050	13	2,47	0,7157	0,754	41,488		POINT (766…

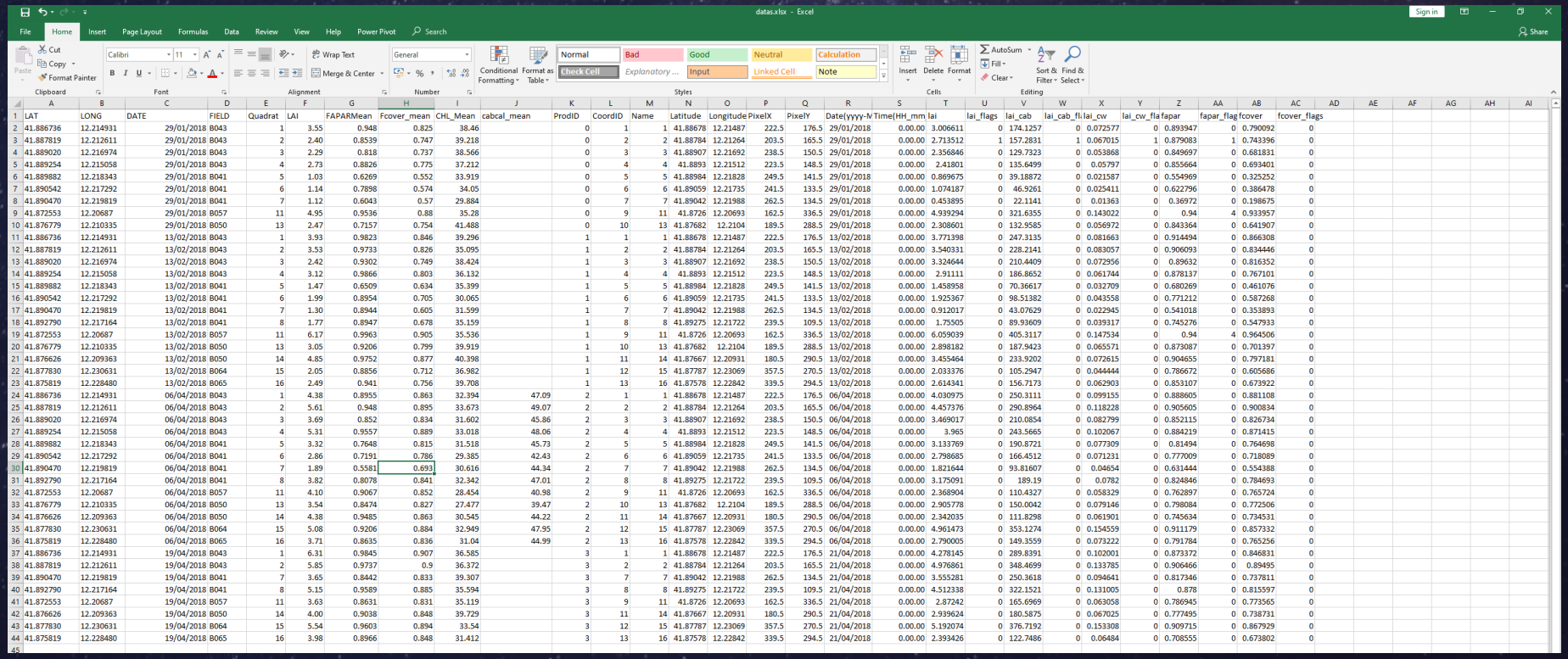
SNAP PROCESSING (6/9) - VALIDATION DATA VISUALIZED



SNAP PROCESSING (7/9) - LAI LINEAR REGRESSION SINGLE IMAGE



SNAP PROCESSING (8/9) - EXPORT DATA FOR ANALYSIS IN OTHER TOOLS



datas.xlsx - Excel

LAT	LONG	DATE	FIELD	Quadrat	LAI	FAPARMean	Fcover_mean	CHL_Mean	cabcal_mean	ProdID	CoordID	Name	Latitude	Longitude	PixelX	PixelY	Date(yyyy-M	Time(HH_mm	lai	lai_flags	lai_cab	lai_cab_fl	lai_cw	lai_cw_fla	fapar	fapar_flag	fcover	fcover_flags
41.886736	12.214931	29/01/2018	B043	1	3.55	0.948	0.825	38.46		0	1	1	41.88678	12.21487	222.5	176.5	29/01/2018	0.00.00	3.006611	0	174.1257	0	0.072577	0	0.893947	0	0.790092	0
41.887819	12.212611	29/01/2018	B043	2	2.40	0.8539	0.747	39.218		0	2	2	41.88784	12.21264	203.5	165.5	29/01/2018	0.00.00	2.713512	1	157.2831	1	0.067015	1	0.879083	1	0.743396	0
41.889020	12.216974	29/01/2018	B043	3	2.29	0.818	0.737	38.566		0	3	3	41.88907	12.21692	238.5	150.5	29/01/2018	0.00.00	2.356846	0	129.7323	0	0.053868	0	0.849697	0	0.681831	0
41.889254	12.215058	29/01/2018	B043	4	2.73	0.8826	0.775	37.212		0	4	4	41.8893	12.21512	223.5	148.5	29/01/2018	0.00.00	2.41801	0	135.6499	0	0.05797	0	0.855664	0	0.693401	0
41.889882	12.218343	29/01/2018	B041	5	1.03	0.6269	0.552	33.919		0	5	5	41.88984	12.21828	249.5	141.5	29/01/2018	0.00.00	0.869675	0	39.18872	0	0.021587	0	0.554969	0	0.325252	0
41.890542	12.217292	29/01/2018	B041	6	1.14	0.7898	0.574	34.05		0	6	6	41.89059	12.21735	241.5	133.5	29/01/2018	0.00.00	1.074187	0	46.9261	0	0.025411	0	0.622796	0	0.386478	0
41.890470	12.219819	29/01/2018	B041	7	1.12	0.6043	0.57	29.884		0	7	7	41.89042	12.21988	262.5	134.5	29/01/2018	0.00.00	0.453895	0	22.1141	0	0.01363	0	0.36972	0	0.198675	0
41.872553	12.20687	29/01/2018	B057	11	4.95	0.9536	0.88	35.28		0	9	11	41.8726	12.20693	162.5	336.5	29/01/2018	0.00.00	4.939294	0	321.6355	0	0.143022	0	0.94	4	0.933957	0
41.876779	12.210335	29/01/2018	B050	13	2.47	0.7157	0.754	41.488		0	10	13	41.87682	12.2104	189.5	288.5	29/01/2018	0.00.00	2.308601	0	132.9585	0	0.056972	0	0.843364	0	0.641907	0
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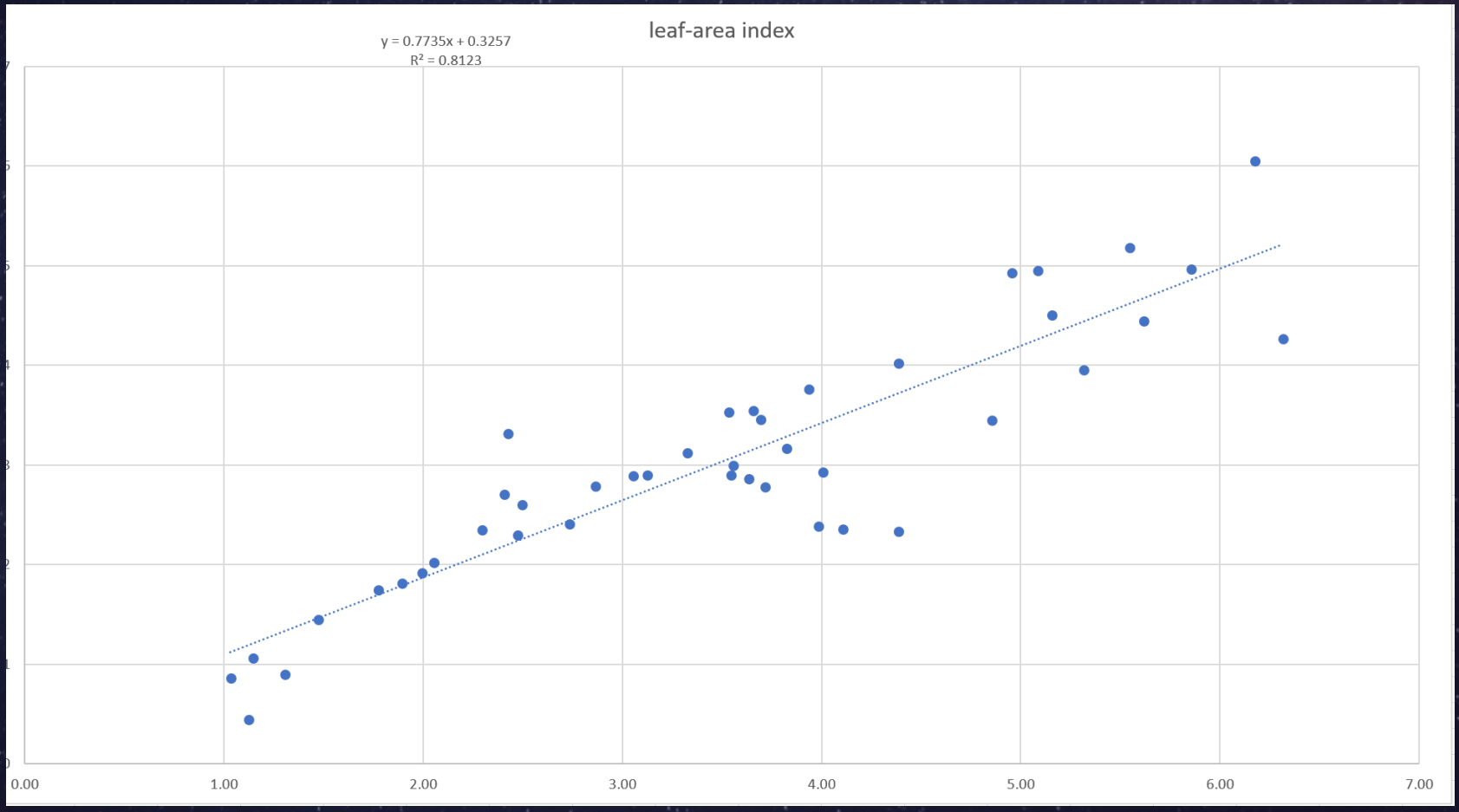
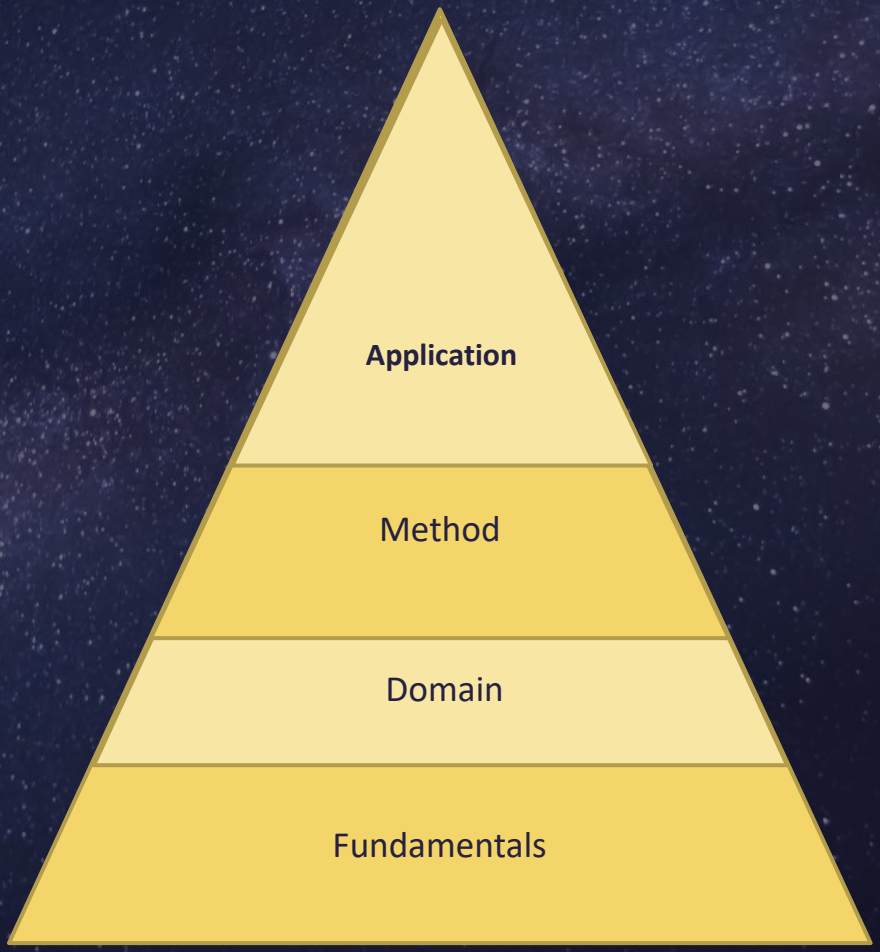
41.889254	12.215058	13/02/2018	B043	4	3.12	0.9866	0.803	36.132		1	4	4	41.8893	12.21512	223.5	148.5	13/02/2018	0.00.00	2.91111	0	186.8652	0	0.061744	0	0.878137	0	0.767101	0
41.889882	12.218343	13/02/2018	B041	5	1.47	0.6509	0.634	35.399		1	5	5	41.88984	12.21828	249.5	141.5	13/02/2018	0.00.00	1.458958	0	70.36617	0	0.032709	0	0.680269	0	0.461076	0
41.890542	12.217292	13/02/2018	B041	6	1.99	0.8954	0.705	30.065		1	6	6	41.89059	12.21735	241.5	133.5	13/02/2018	0.00.00	1.925367	0	98.51382	0	0.043558	0	0.771212	0	0.587268	0
41.890470	12.219819	13/02/2018	B041	7	1.30	0.8944	0.605	31.599		1	7	7	41.89042	12.21988	262.5	134.5	13/02/2018	0.00.00	0.912017	0	43.07629	0	0.022945	0	0.541018	0	0.353893	0
41.892790	12.217164	13/02/2018	B041	8	1.77	0.8947	0.678	35.159		1	8	8	41.89275	12.21722	239.5	109.5	13/02/2018	0.00.00	1.75505	0	89.93609	0	0.039317	0	0.745276	0	0.547933	0
41.872553	12.20687	13/02/2018	B057	11	6.17	0.9963	0.905	35.536		1	9	11	41.8726	12.20693	162.5	336.5	13/02/2018	0.00.00	6.059039	0	405.3117	0	0.147534	0	0.94	4	0.964506	0
41.876779	12.210335	13/02/2018	B050	13	3.05	0.9206	0.799	39.919		1	10	13	41.87682	12.2104	189.5	288.5	13/02/2018	0.00.00	2.898182	0	187.9423	0	0.065571	0	0.873087	0	0.701397	0
41.876626	12.209363	13/02/2018	B050	14	4.85	0.9752	0.877	40.398		1	11	14	41.87667	12.20931	180.5	290.5	13/02/2018	0.00.00	3.455464	0	233.9202	0	0.072615	0	0.904655	0	0.797181	0
41.877830	12.230631	13/02/2018	B064	15	2.05	0.8856	0.712	36.982		1	12	15	41.87787	12.23069	357.5	270.5	13/02/2018	0.00.00	2.033376	0	105.2947	0	0.044444	0	0.786672	0	0.605686	0
41.875819	12.228480	13/02/2018	B065	16	2.49	0.941	0.756	39.708		1	13	16	41.87578	12.22842	339.5	294.5	13/02/2018	0.00.00	2.614341	0	156.7173	0	0.062903	0	0.853107	0	0.673922	0
41.886736	12.214931	06/04/2018	B043	1	4.38	0.8955	0.863	32.394	47.09	2	1	1	41.88678	12.21487	222.5	176.5	06/04/2018	0.00.00	4.030975	0	250.3111	0	0.099155	0	0.888605	0	0.881108	0
41.887819	12.212611	06/04/2018	B043	2	5.61	0.948	0.895	33.673	49.07	2	2	2	41.88784	12.21264	203.5	165.5	06/04/2018	0.00.00	4.457376	0	290.8964	0	0.118228	0	0.905605	0	0.900834	0
41.889020	12.216974	06/04/2018	B043	3	3.69	0.852	0.834	31.602	45.86	2	3	3	41.88907	12.21692	238.5	150.5	06/04/2018	0.00.00	3.469017	0	210.0854	0	0.082799	0	0.852115	0	0.826734	0
41.889254	12.215058	06/04/2018	B043	4	5.31	0.9557	0.889	33.018	48.06	2	4	4	41.8893	12.21512	223.5	148.5	06/04/2018	0.00.00	3.965	0	243.5665	0	0.102067	0	0.884219	0	0.871415	0
41.889882	12.218343	06/04/2018	B041	5	3.32	0.7648	0.815	31.518	45.73	2	5	5	41.88984	12.21828	249.5	141.5	06/04/2018	0.00.00	3.133769	0	190.8721	0	0.077309	0	0.81494	0	0.764698	0
41.890542	12.217292	06/04/2018	B041	6	2.86	0.7191	0.786	29.385	42.43	2	6	6	41.89059	12.21735	241.5	133.5	06/04/2018	0.00.00	2.798685	0	166.4512	0	0.071231	0	0.777009	0	0.718089	0
41.890470	12.219819	06/04/2018	B041	7	1.89	0.5581	0.693	30.616	44.34	2	7	7	41.89042	12.21988	262.5	134.5	06/04/2018	0.00.00	1.821644	0	93.81607	0	0.04654	0	0.631444	0	0.554388	0
41.892790	12.217164	06/04/2018	B041	8	3.82	0.8078	0.841	32.342	47.01	2	8	8	41.89275	12.21722	239.5	109.5	06/04/2018	0.00.00	3.175091	0	189.19	0	0.0782	0	0.824846	0	0.784693	0
41.872553	12.20687	06/04/2018	B057	11	4.10	0.9067	0.852	28.454	40.98	2	9	11	41.8726	12.20693	162.5	336.5	06/04/2018	0.00.00	2.368904	0	110.4327	0	0.058329	0	0.762897	0	0.765724	0
41.876779	12.210335	06/04/2018	B050	13	3.54	0.8474	0.827	27.477	39.47	2	10	13	41.87682	12.2104	189.5	288.5	06/04/2018	0.00.00	2.905778	0	150.0042	0	0.079146	0	0.798084	0	0.772506	0
41.876626	12.209363	06/04/2018	B050	14	4.38	0.9485	0.863	30.545	44.22	2	11	14	41.87667	12.20931	180.5	290.5	06/04/2018	0.00.00	2.342035	0	111.8298	0	0.061901	0	0.745634	0	0.734531	0
41.877830	12.230631	06/04/2018	B064	15	5.08	0.9206	0.884	32.949	47.95	2	12	15	41.87787	12.23069	357.5	270.5	06/04/2018	0.00.00	4.961473	0	353.1274	0	0.154559	0	0.911179	0	0.857332	0
41.875819	12.228480	06/04/2018	B065	16	3.71	0.8635	0.836	31.04	44.99	2	13	16	41.87578	12.22842	339.5	294.5	06/04/2018	0.00.00	2.790005	0	149.3559	0	0.073222	0	0.791784	0	0.765256	0
41.886736	12.214931	19/04/2018	B043	1	6.31	0.9845	0.907	36.585		3	1	1	41.88678	12.21487	222.5	176.5	21/04/2018	0.00.00	4.278145	0	289.8391	0	0.102001	0	0.873372	0	0.846831	0
41.887819	12.212611	19/04/2018	B043	2	5.85	0.9737	0.9	36.372		3	2	2	41.88784	12.21264	203.5	165.5	21/04/2018	0.00.00	4.976861	0	348.4699	0	0.133785	0	0.906466	0	0.89495	0
41.889020	12.219819	19/04/2018	B041	7	3.65	0.8442	0.833	39.307		3	7	7	41.89042	12.21988	262.5	134.5	21/04/2018	0.00.00	3.555281	0	250.3618	0	0.094641	0	0.817346	0	0.737811	0
41.892790	12.217164	19/04/2018	B041	8	5.15	0.9589	0.885	35.594		3	8	8	41.89275	12.21722	239.5	109.5	21/04/2018	0.00.00	4.512338	0	322.1521	0	0.131005	0	0.878	0	0.815597	0
41.872553	12.20687	19/04/2018	B057	11	3.63	0.8631	0.831	35.119		3	9	11	41.8726	12.20693	162.5	336.5	21/04/2018	0.00.00	2.87242	0	165.6969	0	0.063058	0	0.786945	0	0.773565	0
41.876626	12.209363	19/04/2018	B050	14	4.00	0.9038	0.848	39.729		3	11	14	41.87667	12.20931	180.5	290.5	21/04/2018	0.00.00	2.939624	0	180.5875	0	0.067025	0	0.777495	0	0.738731	0
41.877830	12.230631	19/04/2018	B064	15	5.54	0.9603	0.894	33.54		3	12	15	41.87787	12.23069	357.5	270.5	21/04/2018	0.00.00	5.192074	0	376.7192	0	0.153308	0	0.909715	0	0.867929	0
41.875819	12.228480	19/04/2018	B065	16	3.98	0.8966	0.848	31.412		3	13	16	41.87578	12.22842	339.5	294.5	21/04/2018	0.00.00	2.393426	0	122.7486	0	0.06484	0	0.708555	0	0.673802	0

SNAP PROCESSING (9/9) - TIME SERIES LINEAR REGRESSION



IT'S A GENERIC PROCESS!



TAKE AWAY

to get useful results, you need

1. Understanding of the domain, what is useful, what are the relationships
2. Understanding of the radiation properties related to the phenomena
3. Validation data from surface observations
4. High quality satellite data captured with relevant sensors
5. Understanding of the methods
6. Tools (free tools work well):
   - Python
   - SNAP
   - QGIS
   - Google Earth Engine

(Fundamentals, Domain, Methods, Application)

THANK YOU!

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