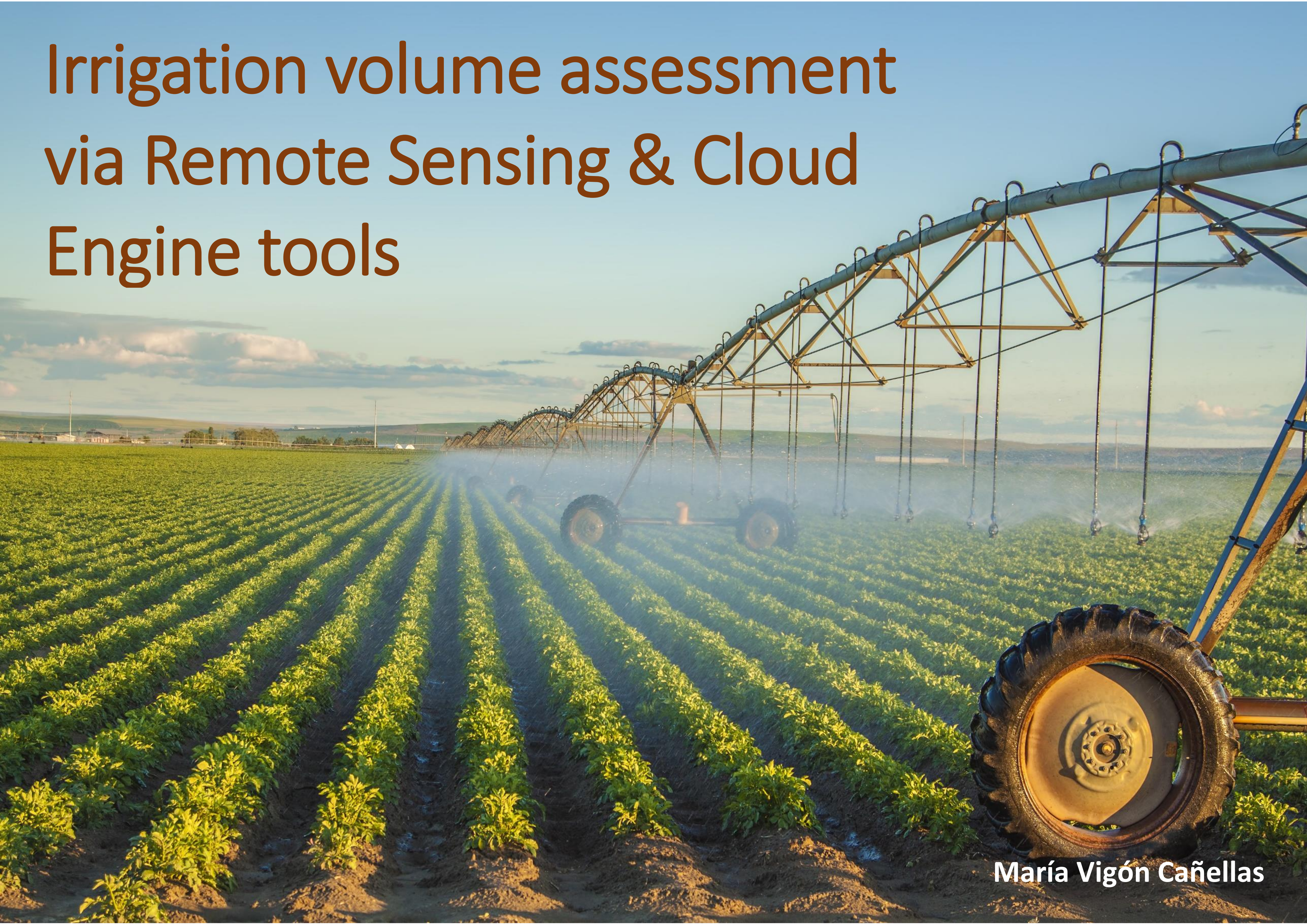
Irrigation volume assessment via Remote Sensing & Cloud Engine tools



María Vigón Cañellas

Contact:

Pierluigi Claps

Professor Polito di Torino

(DATA)

Maria Vigón Cañellas

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Chapter 1:

Technical resources and background studies

The project is being developed on the framework of the available resources in the remote sensing sector, seeking for a global scope. Its main objective it to clarify and improve the existing distribution and assets of water intended for irrigation.

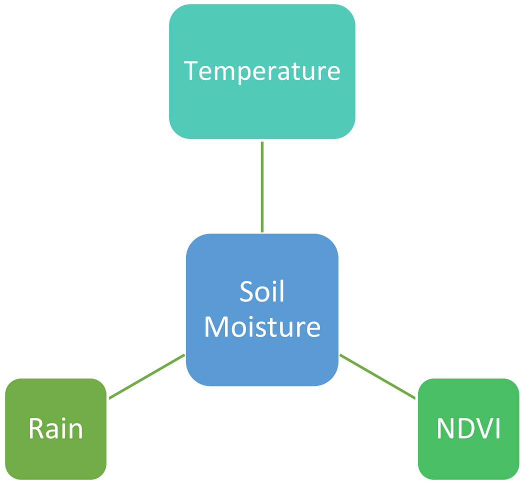
Introduction

The agricultural sector has a lead role on most developing countries being its main source of national income. In Europe, grassland and cropland make up 39% of European land cover (EEA, 2017), playing an important role in land use patterns. In addition to providing food and raw material, agriculture also provides employment opportunities to very large percentage of the population. Furthermore, this sector is highly related with the environment being one of the biggest users of natural resources, for example through irrigation, where agriculture consumes more than 50% of the water used in Europe.

On the one hand, agriculture is experiencing a demand increment due to the population growth, which implies a bigger need of resources. On the other hand, because of climate change rainfall is getting irregular causing droughts and lack of water.

Due to all these issues it is essential to find a way to optimize and control the water use for irrigation. Under this framework several systems and tools have been evaluated to help face the problem. Remote sensing seems to be the solution due to its capacity of global analysis, among other benefits.

The aim of this project is to create a product able to measure the soil moisture of a region with agriculture fields to provide a better control over the irrigation process. These measurements will be obtained through remote sensing. Furthermore, knowing these measurements will give valuable information of the state of the soil crops, because it is interdepending with soil temperature, that can help assessing how much rain has fed the soil and reflects the vegetation health through the NDVI (Normalized Differential Vegetation Index.)



Soil moisture measurements needed for this project will be attained through remote sensing. Due to the progress this sector has gone through, it is possible nowadays to fully develop an application working with the necessary data on a Cloud Engine environment, without having to download the data on a personal computer. In addition, it has become possible to automatize this application on several platforms, in order to have a product that can be globally used. In addition, it is possible to combine data coming from different satellites in order to obtain a product with a better spatial resolution, this has marked an inflection point for the usefulness remote sensing data can have while designing products.

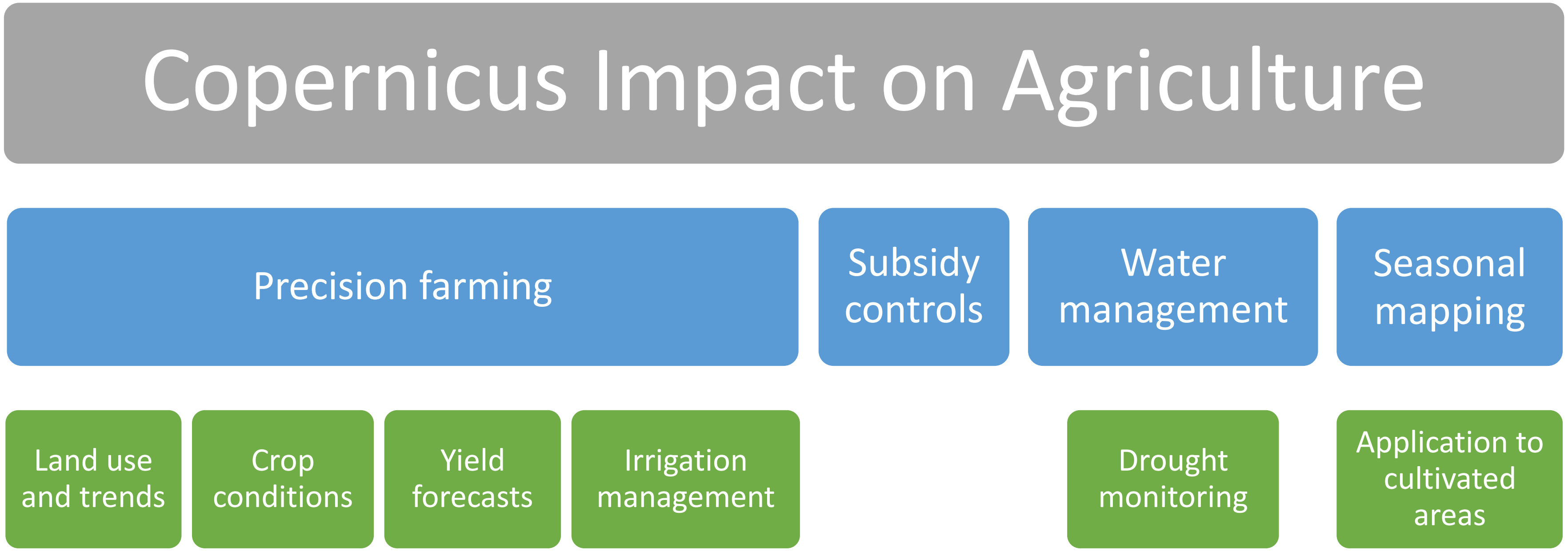
On the framework of this project, these improvements have come by the hand of the Copernicus Program. It will be further explained in following chapters, but in general lines it is a program created and coordinated by the European Commission in partnership with the European Agency.

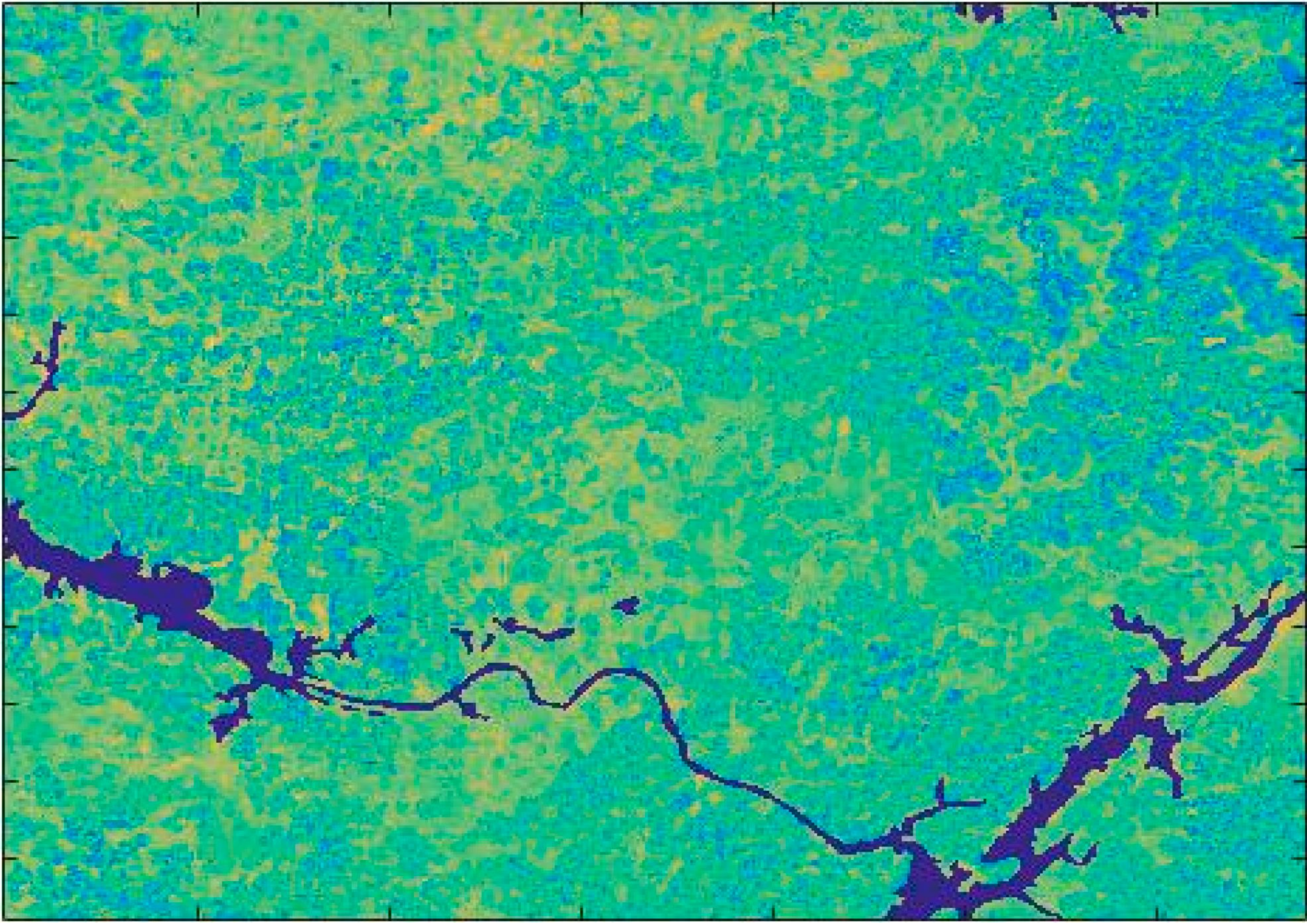
Its aim is to achieve a global, continuous, autonomous, high quality, wide range Earth observation capacity. Providing accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change, and ensure civil security. It is important to underline that agriculture is probably the most promising market in terms of the impact of Copernicus, which is one of the main reasons of development of this project.

One of the benefits of the Copernicus program is that the data and information produced in its framework are made available on a free-of-charge basis to all its users.

Copernicus information has already been implemented in different projects within different application areas, centering on the agricultural sector, two study cases can be highlighted:

1. Carlo De Michele, S. F. (2018). Earth observation data to detect irrigated areas. An application in Southern Italy. ARIESPACE S.r.l., Italy.
2. Papoutsa, C. K. (2018). The challenge of irrigation management in Cyprus using Copernicus. Research Centre, Cypr





Chapter 2:

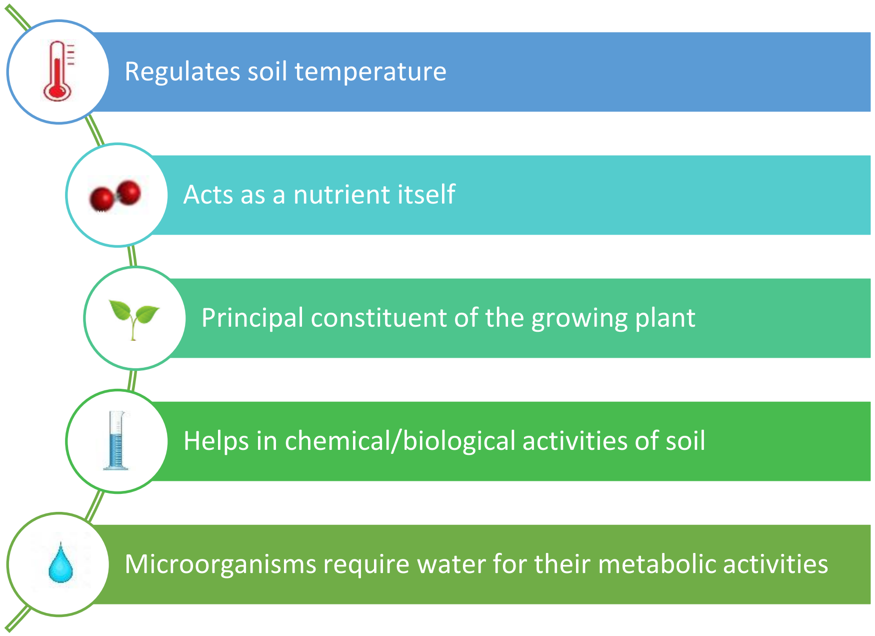
Soil Moisture and Remote Sensing

In the realm of agriculture, a correct measuring of soil moisture is a critical task, due to the amount of information this variable has in relation with the soil crop. Bringing remote sensing to this task make it possible to obtain accurate and global data.

Soil Moisture

Soil Moisture (SM) can generally be described as the water that is held in the spaces between soil particles. Surface soil moisture is the water that is in the upper 10 cm of soil, whereas root zone soil moisture is the water that is available for plants, which is generally considered to be in the upper 200 cm of soil.

Soil moisture volume is small while compared to other components from the hydrological cycle, nevertheless, it is a key variable in the climate cycle, as well as, in many hydrological, biological and biogeochemical processes. Furthermore, it has been proven to be an essential variable for the monitoring and improvement of the agricultural sector:

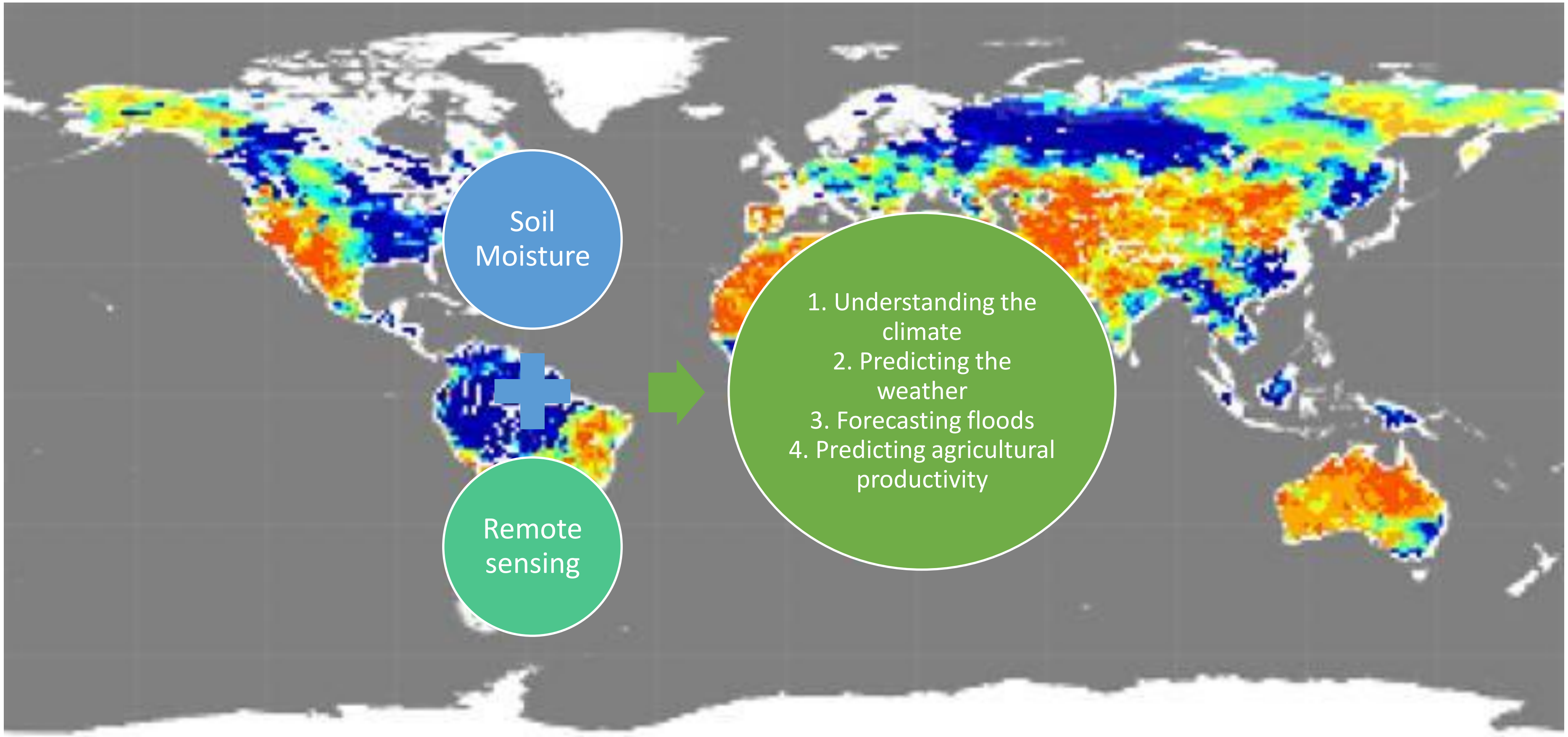


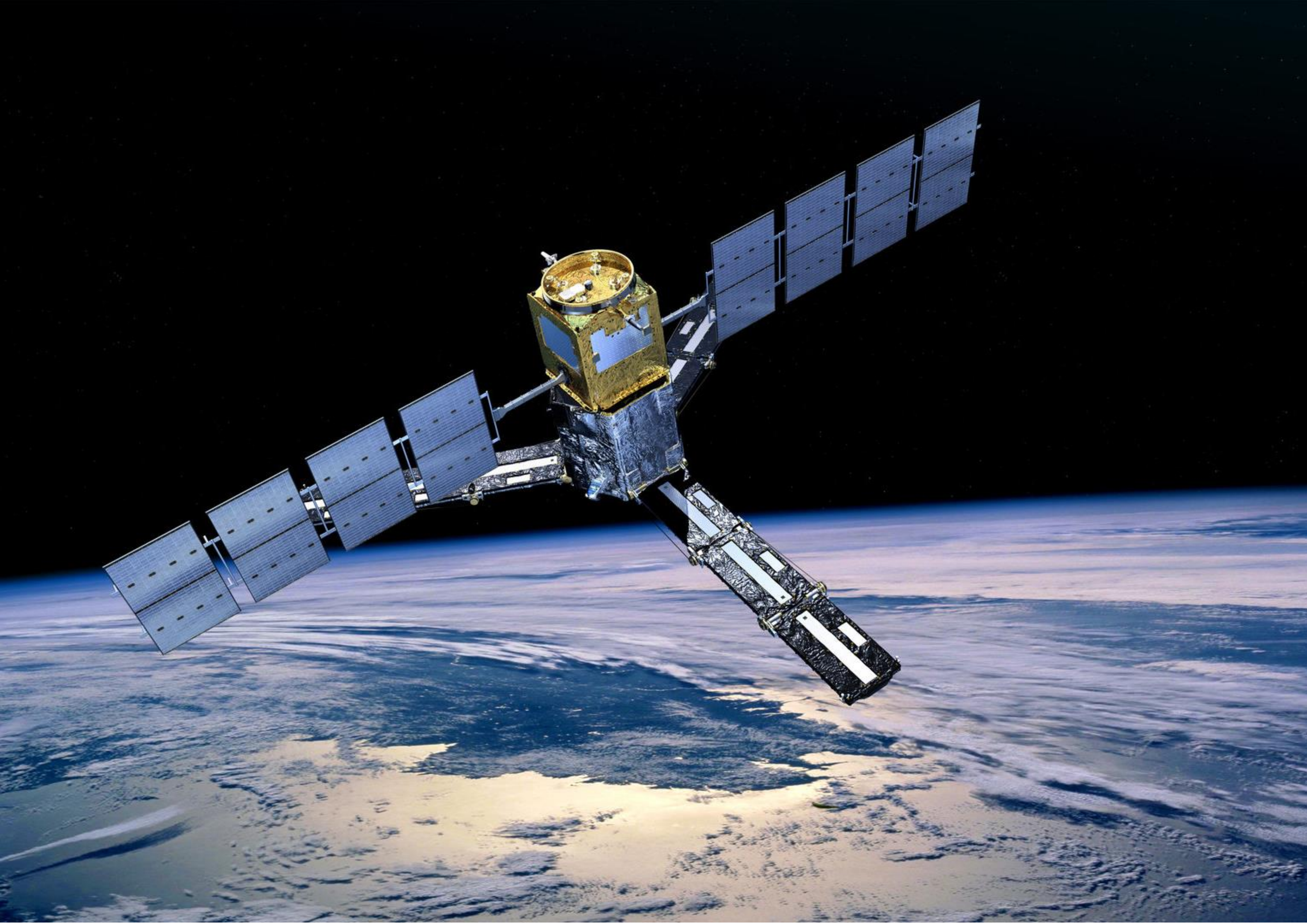
Due to its importance, accurate soil moisture's measurements have become a critical task. Soil moisture can be obtained by extracting soil cores, drying, and weighing them, but this way of measuring is not suitable for long-term monitoring, besides it is destructive. Automated in site measurements can be achieved using different types of devices, such as: tensiometers, various types of electrical resistance sensors or Time-Domain Reflectometry (TDR). These tools are usually used for irrigation management purposes. The huge disadvantage all these techniques have in common is the small volume of soil at few particular locations (close vicinity of the probe itself) that can be measured, which will lead to a poor description of the spatial distribution of the soil moisture in a large agriculture field.

Remote sensing

In order to solve this problem, soil moisture started being measured through remote sensing. This technology is based on several physical aspects, such as: radiation, reflectivity, backscattering. Therefore, various working principles have been developed.

One the one hand, observing large areas became possible. On the order hand, a new problem appeared: low spatial resolution. Spatial resolution depends on various parameters of the satellite sensor. Higher spatial resolution requires a larger diameter antenna which implies a bigger requirement of fuel to maintain the satellite in space. Due to this issue, most sensors have spatial resolutions in 10s of kilometers that are too coarse for catchment hydrology applications. To fulfill the accuracy requirements of the soil moisture applications, some algorithms have been developed.


Soil Moisture
Remote sensing
1. Understanding the climate
2. Predicting the weather
3. Forecasting floods
4. Predicting agricultural productivity



Chapter 3:

How to measure soil moisture: Satellites, Sensors, Products and Cloud Engines

Having analyzed the principal aspects of both soil moisture and remote sensing, to develop a concrete process to obtain the desired measures priorities on the available methods need to be established. To do this, it should be started by studying the technologies resources and at the end, selecting the one that fulfil better the requirements of the project.

On this chapter, the technologies needed to develop the project will be analyzed, as well as a comparison between all the methods, in order to choose the best option to fulfill the objectives of the project proposed.

Soil Moisture Active Passive Satellite

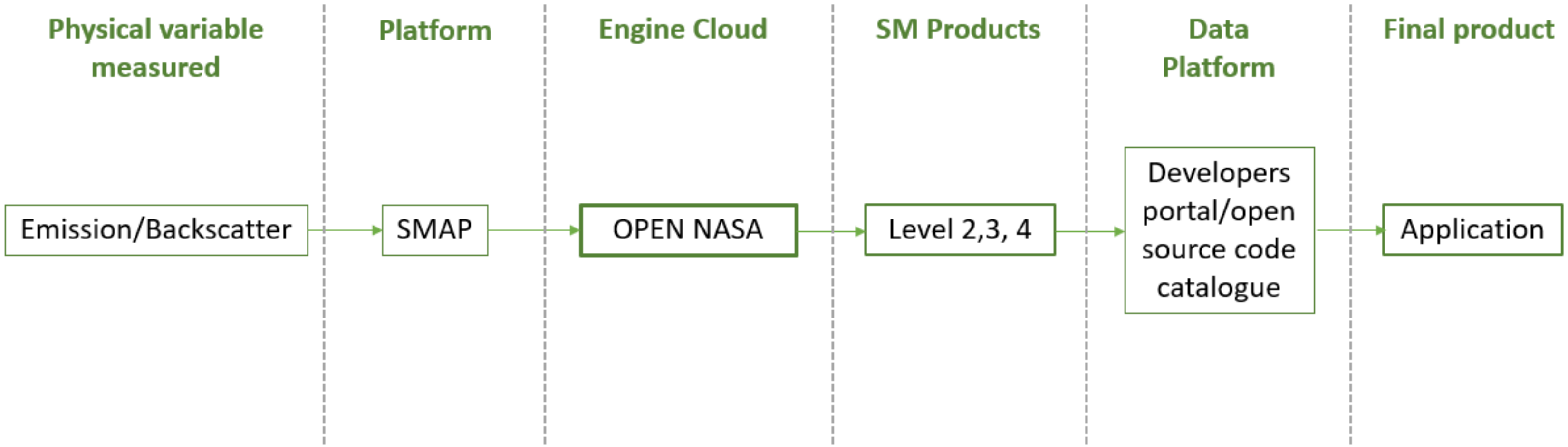
This specific soil moisture satellite was launched by the NASA in January 2015. The Soil Measurement Active and Passive (SMAP) Satellite mission is to map global soil moisture and detect whether soils are frozen or thawed.

The SMAP instrumentation consists on a radiometer (passive) instrument and a radar (active) instrument operating with multiple polarizations in the L-band range. Combining active and passive measurements allows to take advantage of the spatial resolution of the radar and the sensing accuracy of the radiometer. Unluckily, the radar got broken in July 2015, which deteriorates the resolution of the images.

Characteristics	Radar*	Radiometer
Frequency	1.2GHz	1.41GHz
Polarizations	VV, HH, HV	V, H, U
Resolution	1-3km	40km
Incident angle	40º	
Orbit	Polar, Sun-synchronous	
Temporal coverage	Jan 2015-July 2015	2015-to present
Temporal resolution	2-3 days	

*Radar not working since July 2015.

SMAP provides measurements of the surface emission and backscatter, being able to measure the first 5 cm of soil when there is a moderate vegetation cover.



The previous schema shows the working cycle of the satellite information, from its detection and capture to its final processing. The measured values go through some transformations to become soil moisture data at the first stage. These data can be downloaded from three web sites: WorldView, Earthdata and NSIDC.

The level of the products depends on the grade of transformation the data has gone through. Level 2 products are geophysical retrievals of soil moisture on a fixed Earth grid based on Level 1 products and ancillary information. Level 3 products are daily composites of Level 2 surface soil moisture and freeze/thaw state data. Level 4 products are model-derived value-added data products of surface and root zone soil moisture and carbon net ecosystem exchange that support key SMAP applications and more directly address the driving science questions.

- Understanding processes that link terrestrial water, energy, and carbon cycles.
- Estimating global water and energy fluxes at land surface.
- Quantifying net carbon flux in boreal landscapes.
- Enhancing weather and climate forecast skill.
- Developing improved flood prediction and drought monitoring capability.

Product	Resolution	Latency
Level 2	3, 9, 36km	24 hours
Level 3	3, 9, 36km	50 hours
Level 4	9km	7 days

SMAP applications areas can be directly (graphic below), or indirectly (graphic on the left) addressed coupling the data with hydrologic models in order to obtain soil moisture measurements in the root zone.

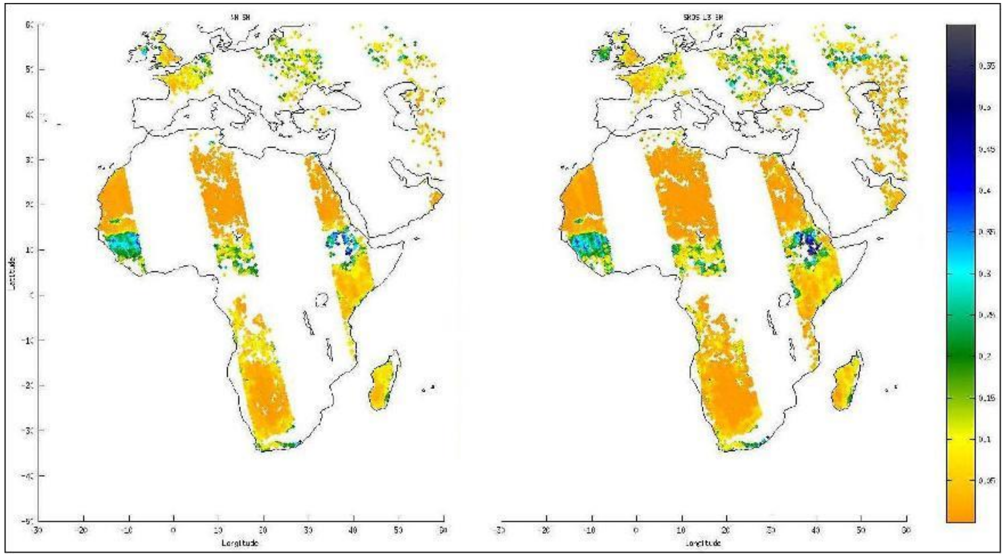
Weather/Climate Forecasting	• Enhacing prediction skills of numerical models.
Droughts	• Enhacing model predictions through space-based observations.
Floods	• Creating hydrologic forecast systems.
Agricultural Productivity	• Information of water availability and estimation of plant productivity.
Human Wealt	• Enhancing risk models: diseases and hunger.
National Security	• Ground trafficability and mobility.

Soil Moisture and Ocean Salinity Mission

The European Space Agency (ESA) launched the Soil Moisture and Ocean Salinity (SMOS) mission on November 2009. Its main objective is to demonstrate observations of Sea Surface Salinity (SSS) over oceans and Soil Moisture (SM) over land to advance climatologic, meteorologic, hydrologic, and oceanographical applications. It is known as the ESA “Water” mission because it looks to improve our knowledge on the water cycle.

SMOS satellite was built with the MIRAS (Microwave Imaging Radiometer using Aperture Synthesis) sensor. The sensor assembly is a dual polarized 2-D interferometer operating at L-band. Its aim is to provide records of pixel brightness temperatures over different incidence angles across a 900 km swath, with a spatial resolution in the range of 30-50 km. From these profiles and auxiliary information, like surface physical temperature, roughness and ionospheric total electron content among others, soil moisture and sea surface salinity will be retrieved.

Characteristics	MIRAS
Frequency	1.41GHz
Polarizations	H & V (polarimetric mode optional)
Resolution	30-50km
Incident angle	0º-55º
Orbit	Sun-synchronous, dawn/dusk
Temporal coverage	Nov 2009-to present
Temporal resolution	3 days revisit at Equator

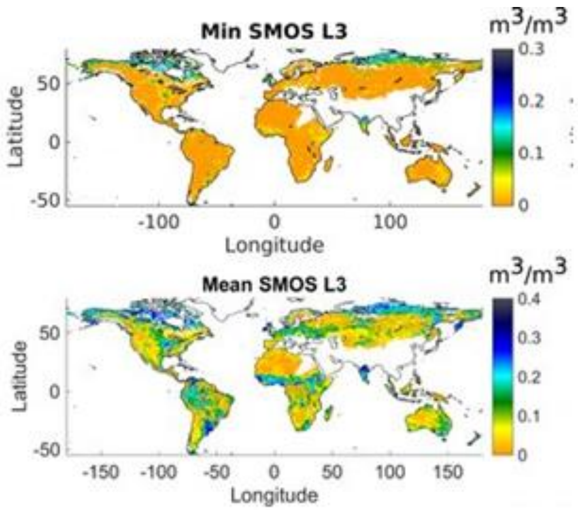


The map at the left of the image was produced from SMOS brightness temperature measurements that are available within three hours of measuring and processed in less than a second using a new ‘neural network'. The map on the right was processed in the usual way, taking several hours. The quality of both datasets is the same. However, the spatial coverage of the fast neural-network product is slightly lower because fewer SMOS measurements are used at the edges of the swath.

SMOS products can be divided in four levels, depending or their processing grade, and the final information they give. In this study, only the soil moisture products have been analyzed.

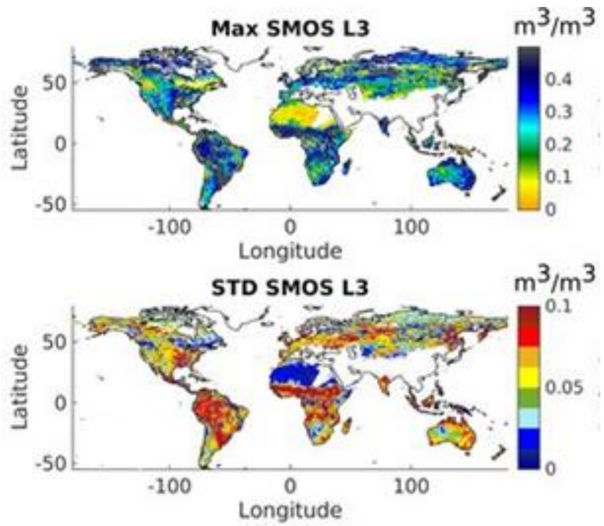
Product	Resolution	Latency
Level 2	15km	8-12 hours
Level 3	25km	1, 3, 10 days, monthly
Level 4	25 km	1 day

Level 2 products consists on global soil moisture maps and are provided by the ESA. Meanwhile, both level 3 and 4 are provided by CATDS. Level 3 products consist on global map of soil moisture, vegetation optical depth, surface roughness and dielectric constant, while, Level 4 provides root zone, agriculture drought index, surface roughness and synergy soil moisture.



SMOS data is applied to a huge range of sectors due to its versatility.

Detection models	• Specfically for fire and ocean.
Weather/Climate Forecasting	• Air temperature and humidity forecasts near the surface.
Agriculture porduction	• Agriculture drought index and root zone data.
Landscape	• Surface roughness, vegetation index.
Cryosphere	• Ice thickness.



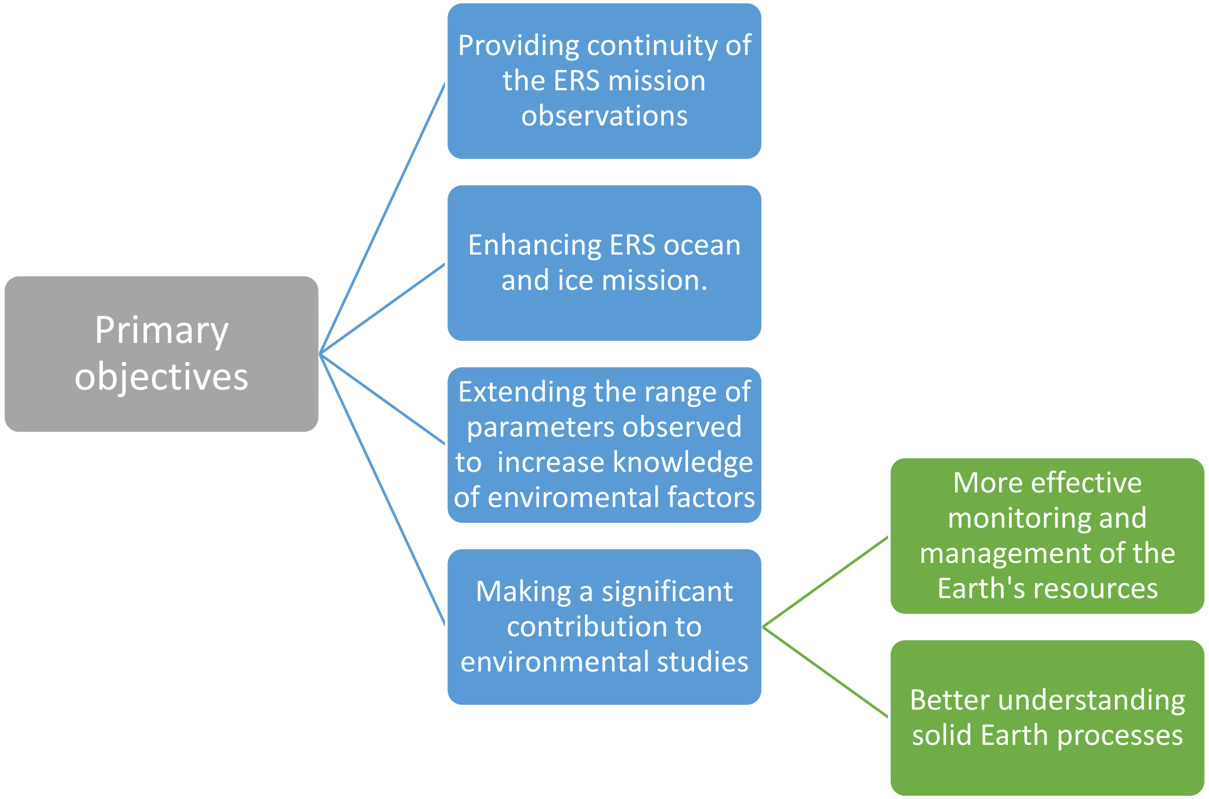
Envisat Mission

Envisat Earth Observation satellite was launched by the ESA on Feb 2002. Envisat mission deeply contributed to expanding our knowledge in the Earth sciences and to develop operational applications related to environmental monitoring. On April 2012 there was a failure on the satellite which lead to the end of its mission.

Envisat was composed of 10 sensors which provided different types of information:

On-board sensors	Complete name	Working principle	Temporal resolution
AATSR	Advanced Along-Track Scanning Radiometer	Optical/IR Radiometer	1km x 1km
ASAR	Advanced Synthetic Aperture Radar	C-Band SAR	Global Monitoring mode: approx1000m x 1000m.
DORIS	Doppler Orbitography and Radio-positioning Integrated by Satellite	Radio Frequency Orbitography	5 cm in altitude
GOMOS	Global Ozone Monitoring by Occultation of Stars	Ultra-Violet and Optical Spectrometer	-
LRR	Laser Retro Reflector	Passive Optical Reflector	-
MERIS	Medium-Resolution Visible and Near-IR Spectrometer	Imaging Spectrometer	Ocean: 1040m x 1200 m, Land & coast: 260m x 300m
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding	Limb-Viewing Infrared Interferometer	3km x 30km
MWR	Microwave Radiometer	Two-Channel Nadir View Radiometer	20km
RA-2	Radar Altimeter 2	Pulsed Radar	20km
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Cartography	Multi-Channel Nadir + Limb View UV/VIS/IR Spectrometers	32 x 215km

This mission was considered an essential element due to its capacity of providing long term data sets that were crucial for addressing environmental and climatological issues. Furthermore, the mission intends to continue and improve upon measurements initiated by ERS-1 and ERS-2, and to take into account the requirements related to the global study and monitoring of the environment



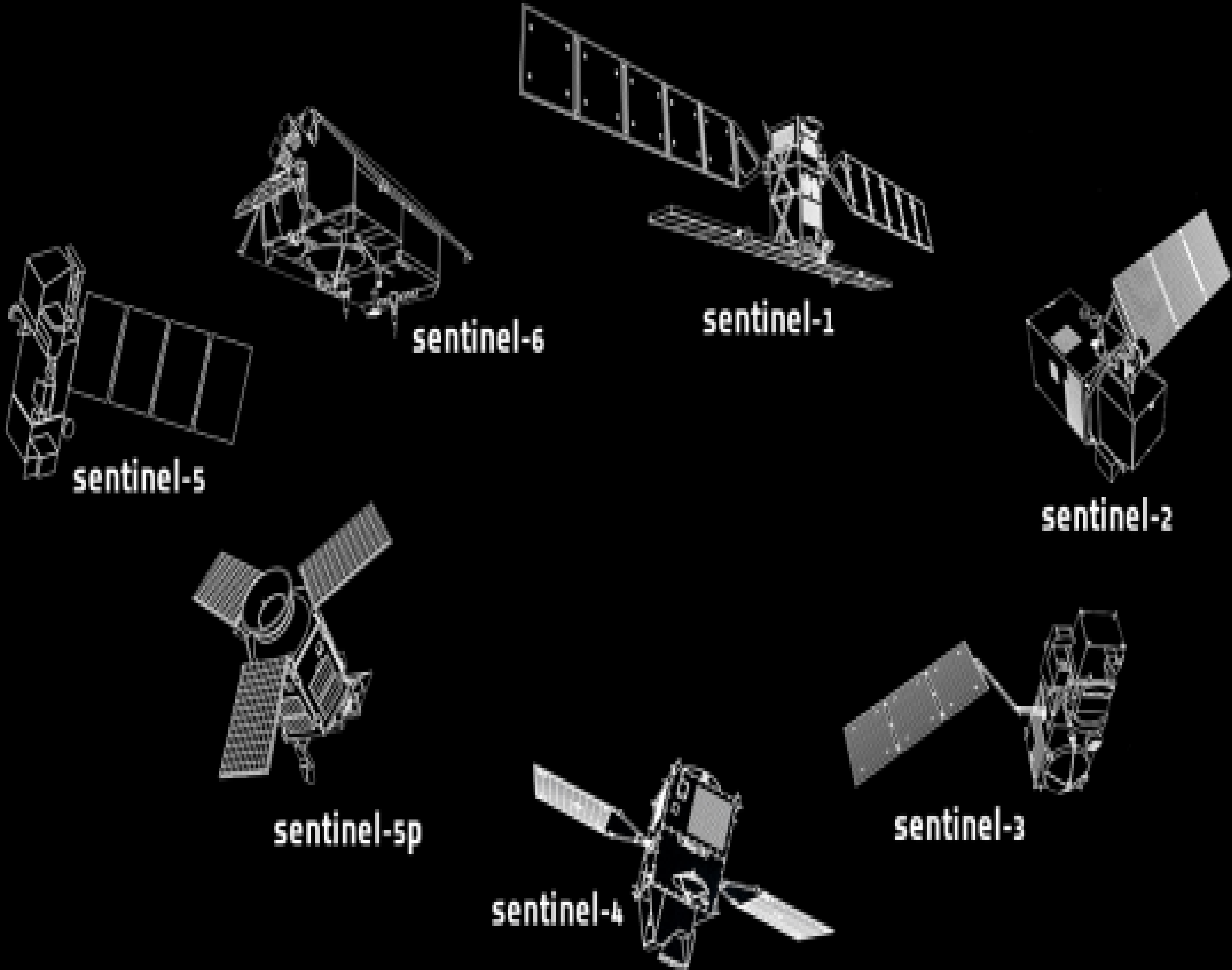
Due to its large number of sensors, the applications of Envisat were many and very different between each other, the main sectors were: ice, ocean, atmosphere and land. It is important to highlight, that obtaining measurements of soil moisture was not one of its applications, but the variable was achieved applying different and complex algorithms and treatment to captured data.

Sentinel Group

Sentinel is a multi-satellite project. It is being developed by the ESA thanks to the Copernicus program.

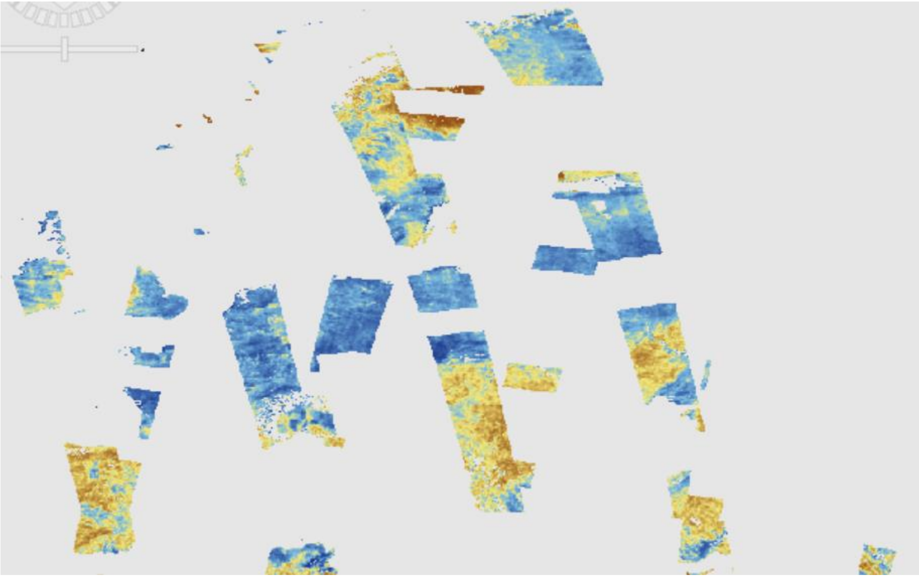
The goal of the Sentinel program is to replace the current older Earth observation missions which have reached retirement, such as the ERS mission, or are currently approaching the end of their operational life span. This will ensure a continuity of data so that there are no gaps in ongoing studies. The objectives of this mission are:

Satellite	**Objective**	**Launch**	**Sensor**	**Spatial resolution**
Sentinel 1	To provide enhanced revisit frequency, coverage, timeliness and reliability for operational services and applications requiring long time series.	Sentinel 1A: April 2014 Sentinel 1B: April 2016	SAR, four acquisition modes: 1. Stripmap (SM) 2. Interferometric Wide swath (IW) 3. Extra-Wide swath (EW) 4. Wave mode (WV)	5m x 5m 5m x 20m 20m x 40m 20km x 20km
Sentinel 2	To monitor variability in land surface conditions.	Sentinel 2A: June 2015 Sentinel 2B: March 2017	MultiSpectral Instrument (MSI).	10, 20, 60m
Sentinel 3	Jointly operated by ESA and EUMETSAT to deliver operational ocean and land observation services.	Sentinel 3A: January 2016 Sentinel 3B: April 2018	Instrument (OLCI) 2. Sea and Land surface Temperature Radiometer (SLSTR) 3. SAR Radar Altimeter (SRAL) Intrument 4. Microwave Radiometer (MWR)	300m-500m
Sentinel 4	To monitor key air quality trace gases and aerosols over Europe	Predicted in 2019 and 2027	Passive imaging spectrometer	8km x 8km
Sentinel 5	Globally monitoring key air quality trace gases and aerosols in support of the Copernicus Atmosphere Monitoring Service (CAMS).	Predicted in 2021	Passive grating imaging spectrometer	50km x 50km
Sentinel 5P	To perform atmospheric measurements with high resolution to be used for air quality, ozone & UV radiation, and climate monitoring & forecasting.	October 2017	TROPOspheric Monitoring Instrument (TROPOMI)	7km x 7km


sentinel-1
sentinel-2
sentinel-3
sentinel-4
sentinel-5p
sentinel-5
sentinel-6

Due to the large number of satellites, the Sentinel group has many different products covering many areas. Focusing on soil moisture, there are not any direct products that give the value of this variable. In order to obtain it, various algorithms can be applied (like change detection methods). The data used is the one coming from Sentinel 1 and 2. To achieve better resolution, Sentinel 3 data can be applied as well.

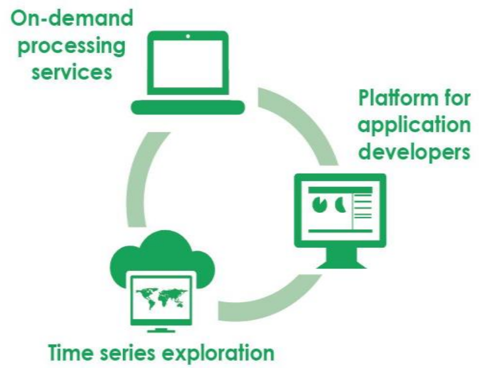
An application has been developed in order to work with the data of these satellites in an easy way. The application is SNAP (Sentinel Application), and it allows to process all the images obtained by the satellites and to apply all kind of algorithms, methods and tools to obtain the desire data.



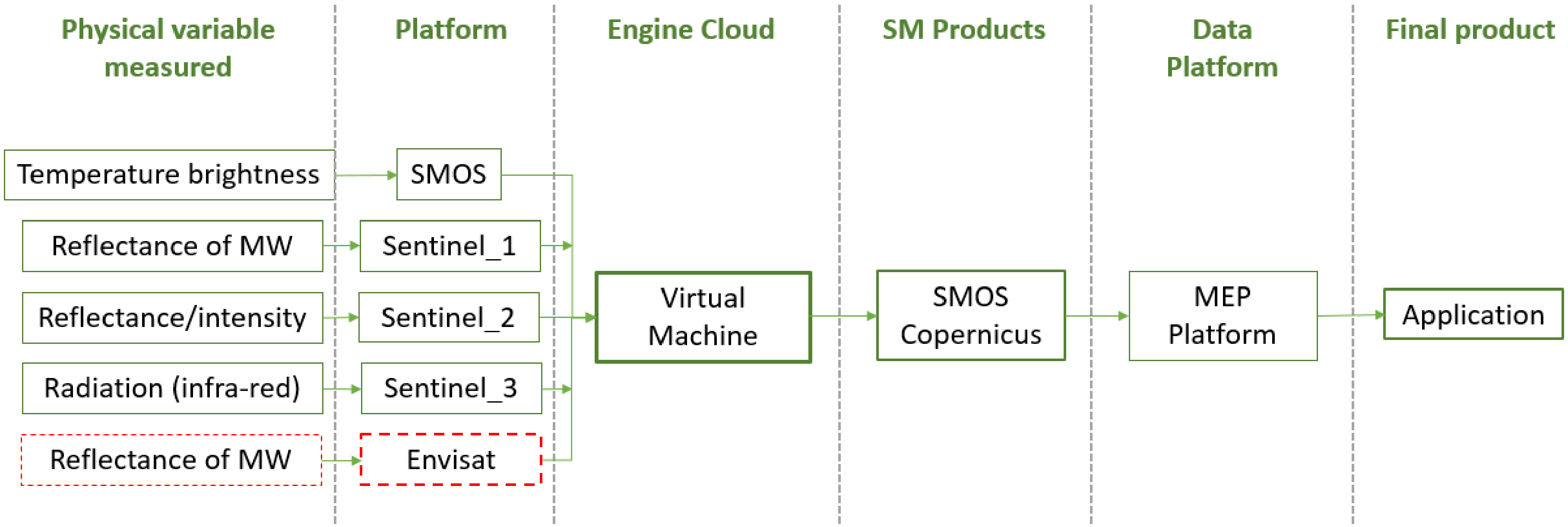
Through the huge number of possible products that can be obtained Sentinel mission has an incredible amount of applications extended in diverse areas. All the information captured by these satellites is manage by the Copernicus program. As it was previously introduced, Copernicus program is a project created between de ESA and the UE, which is growing rapidly, due to its versatility. Because of its importance on the remote sensing sector in general and on this study in particular, this theme will be completely developed on the following chapter.

Finally, a schema of the information flux of the ESA in relation with soil moisture products can be seen.

The ESA has its own Engine Cloud, that is a Virtual Machine, were all the toolboxes necessaries to process the images of their satellites are already installed. Also, all the images can be used directly on this Virtual Machine without having to download them on the computer. Furthermore, once a code for an application has been developed it can be upload to their MEP Platform, after having it validated, in order to create a real application.



The great advantage of this platform, comparing it with the one from the NASA, is its capability to mix data from different satellites. Due to this characteristic the resolution of the products obtained can be higher, and therefore they will be more useful for applications that need this requirement, like in our case, for agriculture fields and irrigation.



Physical variable measured
Platform
Engine Cloud
SM Products
Data Platform
Final product
Temperature brightness
Reflectance of MW
Reflectance/intensity
Radiation (infra-red)
Reflectance of MW
SMOS
Sentinel_1
Sentinel_2
Sentinel_3
Envisat
Virtual Machine
SMOS Copernicus
MEP Platform
Application

Copernicus

Europe’s eyes on Earth

Chapter 4:

Copernicus Program and Copernicus Climate Change Services (C3S)

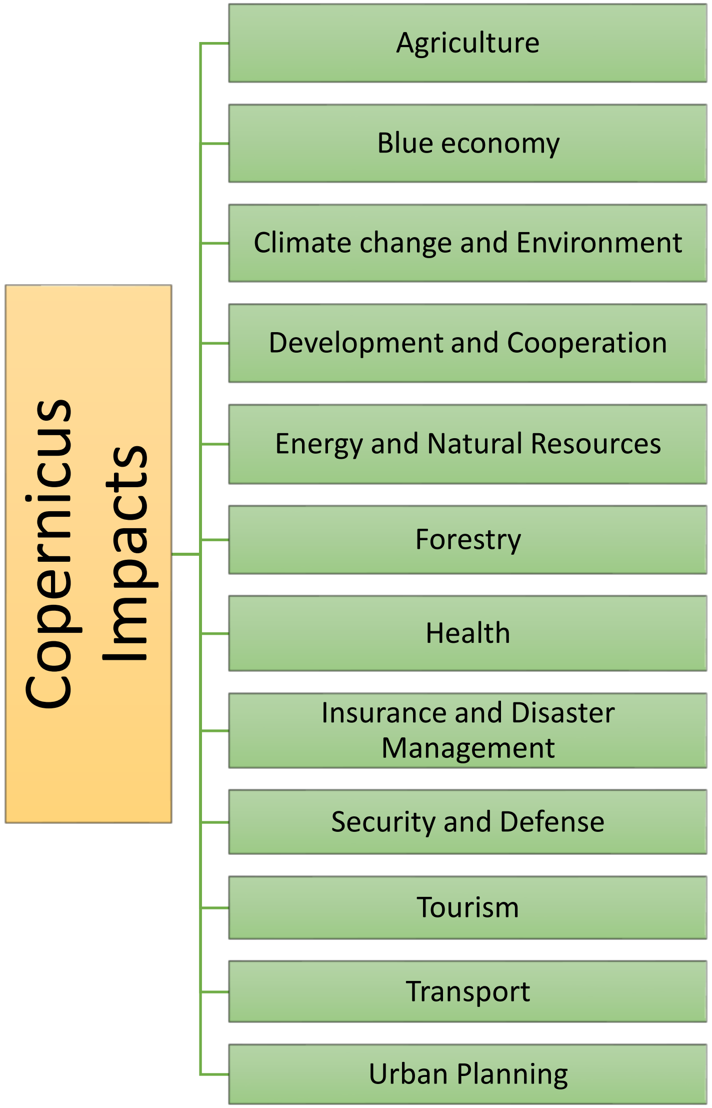
Having studied the satellites used to measure soil moisture, as well as the Cloud Engines of the main space agencies, to develop the application a search of specific tool boxes and already existing products that fulfil the requirements of space resolution need to be carried out.

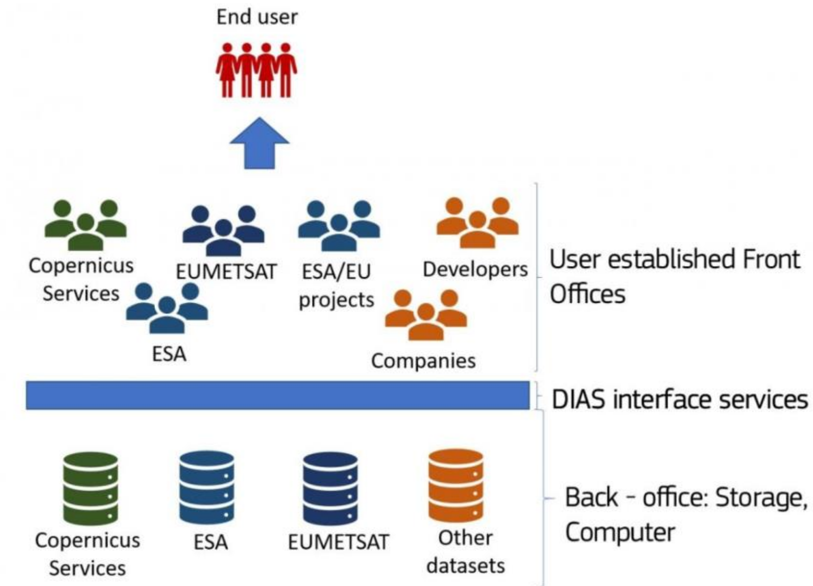
Copernicus Program

Copernicus program has been already introduced on the first chapter because is the key element of this project, for both the data that captures and its contribution to the remote sensing sector.

Firstly, the general services of Copernicus will be exposed. Secondly, its main impacts will be listed. In addition, a brief abstract of its value chain will be shown. Finally, its main tool to treat and manage the data will be analyzed.

Copernicus Services			
Atmosphere (CAMS)	**Marine Environment** (CMEMS)	**Emergency Management** (EMS)	**Security**
Land (CLMS)	Systematically produces a series of qualified bio-geophysical products on the status and evolution of the land surface, at global scale and at mid to low spatial resolution, complemented by the constitution of long-term time series. The products are used to monitor the vegetation, the water cycle, the energy budget and the terrestrial cryosphere.		
Climate Change (C3S)	Provides reliable access to high-quality climate data, through the Climate Data Store (CDS). Furthermore, it offers tools that makes it possible to transform the data into more visual products, such as maps and charts.		





This schema shows the chain value of Copernicus program. It can be seen that the initial data goes through two different blocks before arriving to the end user. The second one is a compound of organizations that create the products. Meanwhile, the first one is the DIAS companies; five platforms based on the cloud that provide centralized access to the data and information, as well as to the processing tools.

The DIAS companies are: ONDA, MUNDI, CREODIAS, WEKEO and SOBLOO.

Copernicus Climate Change Services

Having introduced the six services of Copernicus program, this project is centered in two of them: Global Land Monitoring Service (GLMS) and Climate Change Service (C3S).

From the GLM, soil moisture global maps can be obtained. Meanwhile, C3S make it possible to work with all the data by using python programing in order to fit the data to the needs of the project.

The schema of the next page shows the information flow of the information processed by the C3S. Comparing it with the ones of the NASA and the ESA of the previous chapter, the main and most notable difference is the number of satellites used to capture the data. This system does not only utilize satellites from one space agency or enterprise, but it takes the information from all of the useful ones. This way of attaining data is used as well by Google Cloud Engine, that will be explain on the following chapter.

The satellites marked in red are the ones that are no longer working, but its data was used to achieve past products.

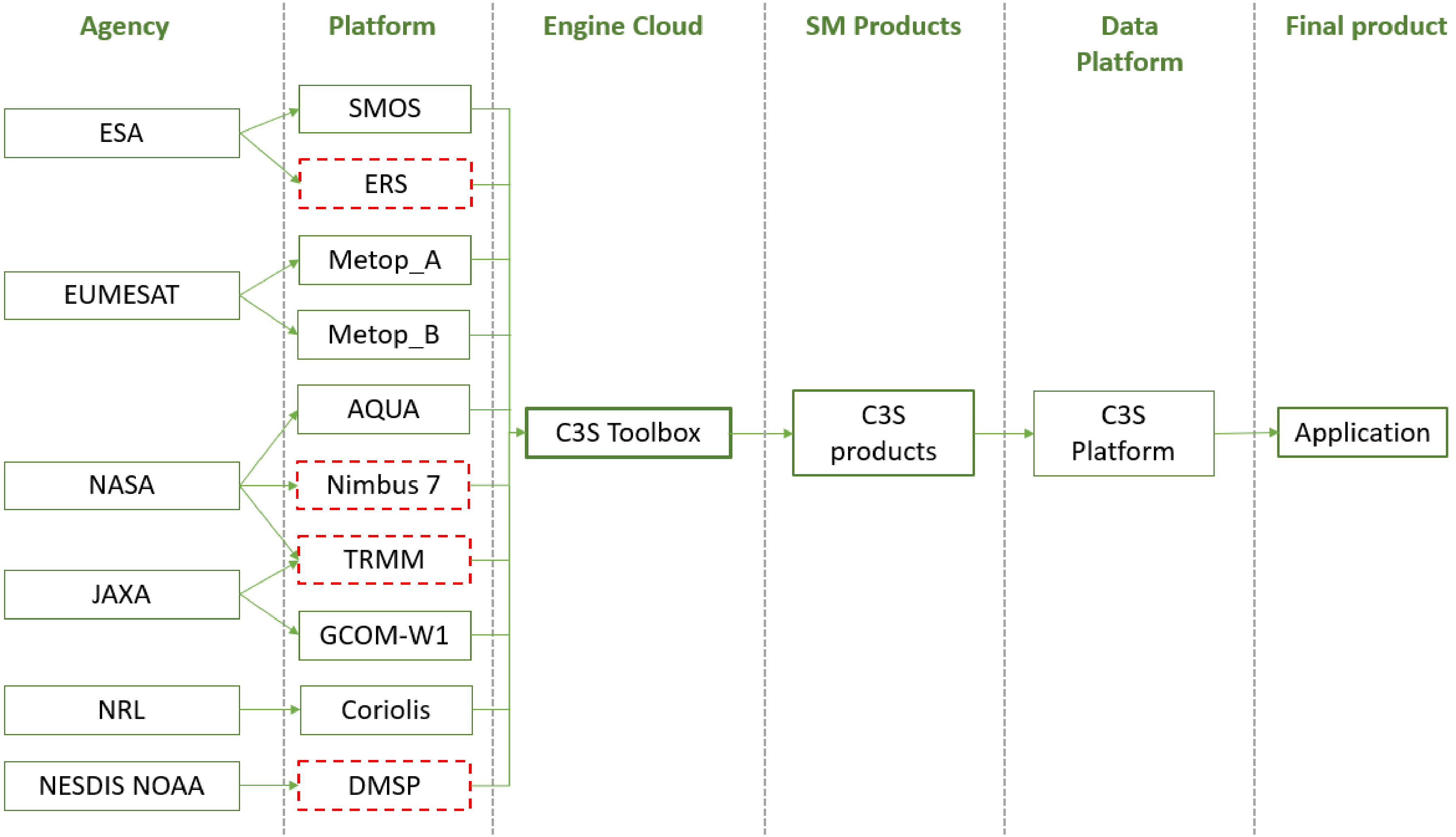
The products obtained with this system which contain data of soil moisture measurements are six. All of them, as well as their main characteristics, can be seen on the following pages.

This service has been used by companies, such as, GECOsistema (Geographic Environmental Consulting) to develop several climate tools, principally for forecasting.

Another advantage of this system is its capacity to work online. The images and data can be obtained online and automatized without actually having to enter on a download portal. The C3S toolbox can be programmed to obtain the needed information (region, time and data format).

October 2019						
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
29	30	1	2	3	**4**	**5**
6	7	8	9	**10**	**11**	12
13	14	15	**16**	**17**	18	19
20	21	**22**	**23**	24	25	26
27	**28**	**29**	30	31	1	2

This table represents the acquisition dates of Sentinel 1 satellite for the month of October on the area on the city of Rome. It is used to highlight the temporal resolution limitations these group of satellites have. Due to this issue, achieve global measured daily data is not possible. In order to develop an everyday product some mathematical methods, such as interpolation or extrapolation, must be apply, to have regular data to work with. Therefore, another motive to use a programming online platform to work with the satellites images has been found.



Copernicus Cilmate Change Services Data flow (red squares mean that satellite mission is finished).

Soil moisture gridded data from 1978 to present	**Horizontal coverage**	Global
	Horizontal resolution	0.25°x0.25°
	Temporal coverage	1978 to present
	Temporal resolution	Day, 10-day and month
	Update frequency	Depends on the product: 10-day for the ICDR and 6 months for the CDR.
	File format	NetCDF
	Data type	Grid
River discharge and related historical data from the European Flood Awareness System	**Horizontal coverage**	Europe - The domain spans from northern Africa beyond the northern tip of Scandinavia. In the west it ranges far into the Atlantic Ocean and in the east as far as to the Caspian Sea.
	Horizontal resolution	5km x 5km
	Temporal coverage	1991-01-01 to near real time (30-day delay) for the most recent version.
	Temporal resolution	Daily data.
	Update frequency	A new historical simulation will be published with every major update of the EFAS system. The latest version will always be the version used in operations. For more information on the model versions, we refer to the documentation.
	File format	GRIB and NetCDF
	Data type	Grid

River discharge and related forecasted data by the European Flood Awareness System	**Horizontal coverage**	Europe - The domain spans from northern Africa beyond the northern tip of Scandinavia. In the west it ranges far into the Atlantic Ocean and in the east as far as to the Caspian Sea.
	Horizontal resolution	5km x 5km
	Temporal coverage	2018-10-10 to near real-time
	Temporal resolution	Forecasts are issued daily at 00 and 12 UTC.
	Update frequency	The EFAs forecasts are published on CDS at regular intervals with a minimum of 1-month lag with respect to the actual date.
	File format	GRIB and NetCDF
	Data type	GRID - The geographical projection is the INSPIRE compliant ETRS89 Lambert Azimuthal Equal Area Coordinate Reference System (ETRS-LAEA).
Essential climate variables for assessment of climate variability from 1979 to present	**Horizontal coverage**	Global
	Horizontal resolution	0.25°x0.25°
	Temporal coverage	1979 to present.
	Temporal resolution	Monthly
	Update frequency	Monthly
	File format	GRIB
	Data type	Grid

UERRA regional reanalysis for Europe on soil levels from 1961 to present	**Horizontal coverage**	Europe: The domain spans from northern Africa beyond the northern tip of Scandinavia. In the west it ranges far into the Atlantic Ocean and in the east, it reaches to the Ural.
	Horizontal resolution	11km x 11km for the UERRA-HARMONIE system. 5.5km x 5.5km for the MESCAN-SURFEX system.
	Temporal coverage	January 1961 to present.
	Temporal resolution	Analysis are available each day at 00, 06, 12 and 18 UTC.
	Update frequency	Month with a delay of about four months relatively to actual date.
	File format	GRIB2.
	Data type	GRID: Lambert conformal conic grid with 565 x 565 grid points for the UERRA-HARMONIE system. Lambert conformal conic grid with 1069 x 1069 grid points for the MESCAN-SURFEX system.
CMIP5 monthly data on single levels	**Horizontal coverage**	Global
	Horizontal resolution	From 0.125°x0.125° to 5°x5° depending on the model
	Temporal coverage	1850-2300 (shorter for some experiments)
	Temporal resolution	Month
	Update frequency	-
	File format	NetCDF
	Data type	Grid

Era5 Land hourly data from 2001 to present	**Horizontal coverage**	Global
	Horizontal resolution	0.1ºx0.1º
	Temporal coverage	January 2001 to present
	Temporal resolution	Hourly
	Update frequency	Monthly with a delay of a few months relatively to actual date.
	File format	GRIB
	Data type	Grid
Era5 Land monthly data from 2001 to present	**Horizontal coverage**	Global
	Horizontal resolution	0.1ºx0.1º
	Temporal coverage	January 2001 to present
	Temporal resolution	Monthly
	Update frequency	Monthly with a delay of a few months relatively to actual date.
	File format	GRIB
	Data type	Grid

Chapter 5:

Google Earth Engine

Having analyzed the Copernicus Program online tool box platform and its already existing products, to develop an accurate process to create the desire application, another online platform is studied in order to select the one that fulfil better the requirements of the project.

Google Earth Engine

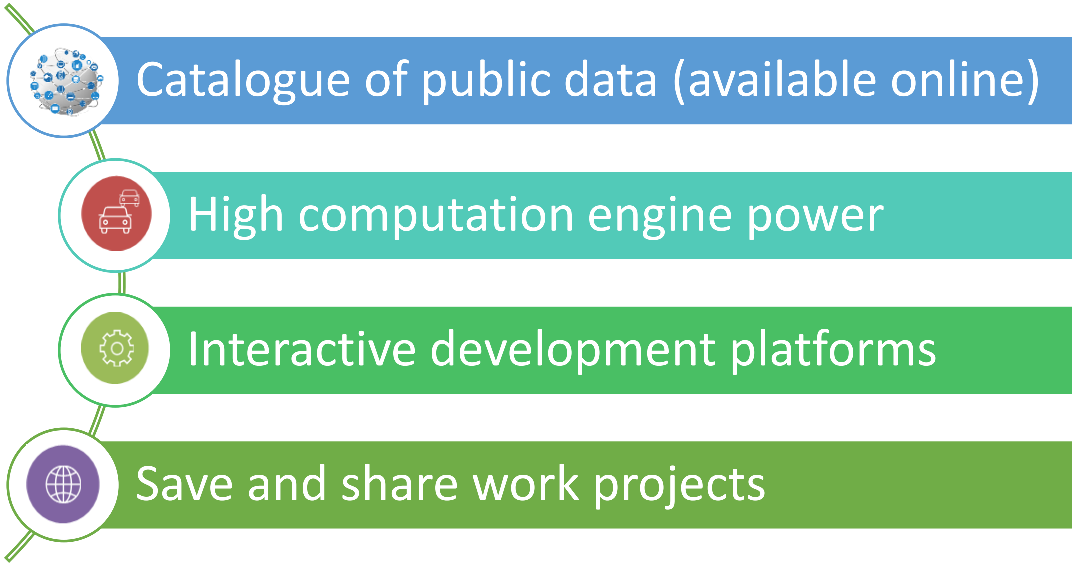
Google Earth Engine (GEE) is a platform for scientific analysis and visualization of geospatial datasets. It hosts satellite imagery and stores it in a public data archive that includes historical earth images going back more than forty years. The images, ingested on a daily basis, are then made available for global-scale data mining. Furthermore, it provides APIs and other tools to enable the analysis of large datasets.

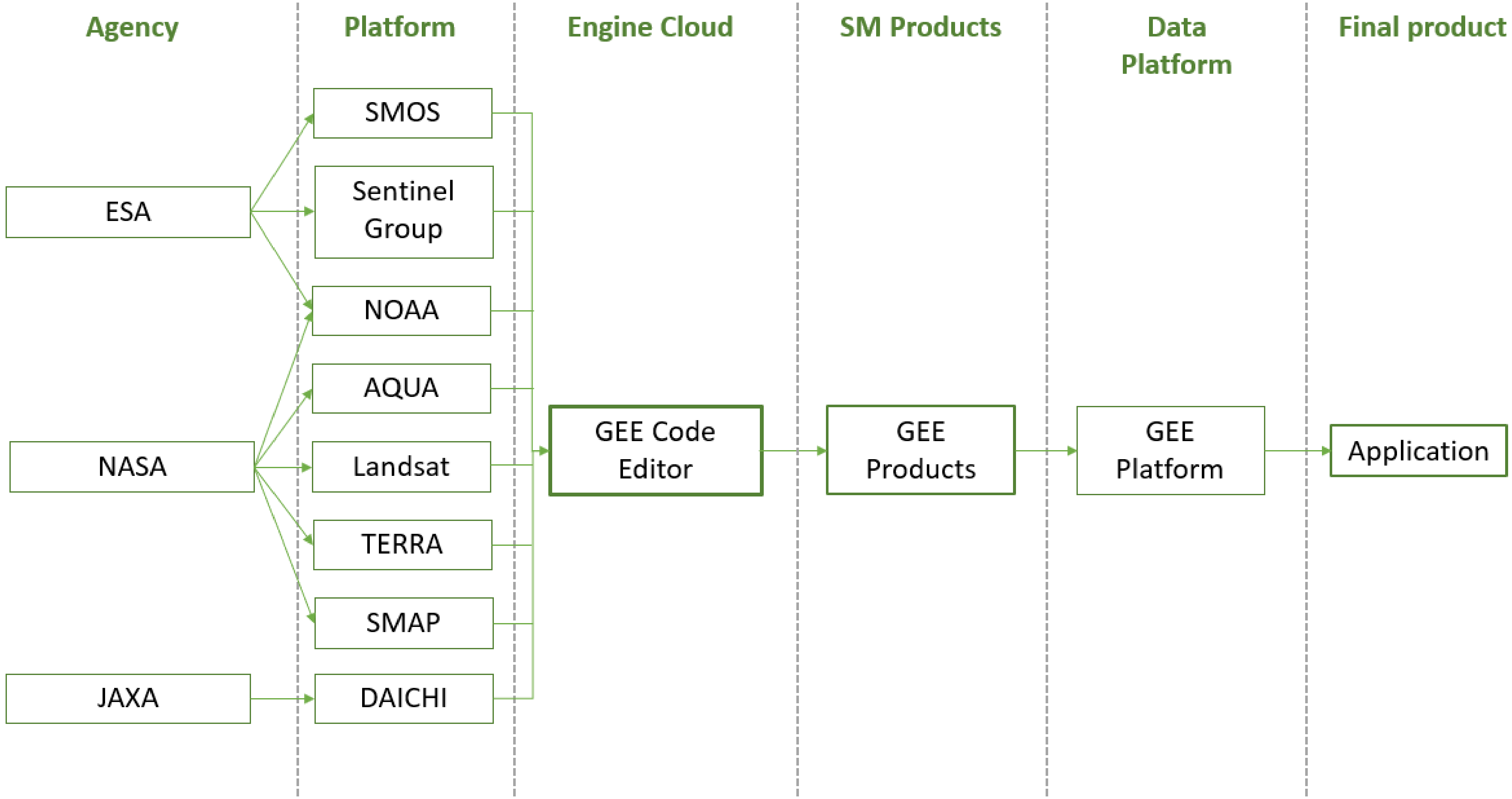
It is very useful to work with raw data when C3S products do not have the desire resolution. Online work of the data can be done, as well as the creation of applications, through its code editor, explorer and client libraries.

In addition, the programming language of GEE code editor platform is Java, while the one used on C3S is particular of the platform. Therefore, working with GEE is easier and more intuitive.

On the one hand, Google Earth Engine allows to work with row data of the satellites available on their catalogue, which leads to a huge range of possibilities in the framework of developing remote sensing products and applications on different areas. On the other hand, the number of ready to use products and applications is limited in comparation with Copernicus Climate Change Services.

The following graphic shows the main characteristics of the software tool:





GEE Data Flow (only the main satellites have been taken into account). Soil Moisture products with a reasonable spatial resolution do not exist. They have to be computed by the user utilizing the code editor and the other available tools.