Soil Moisture data use for environmental monitoring in Romania

Anişoara IRIMESCU
National Meteorological Administration
Remote Sensing & GIS Laboratory

Framework Partnership Agreement for Copernicus User Uptake

Outline

Introduction

Meteo Romania's contribution the Copernicus Program

Soil Moisture data use for environmental monitoring in Romania

Future work

Introduction

- Romanian Meteorological Service: 1884 – 2020/ **136** years of existence.
- The Romanian National Meteorological Administration (**Meteo Romania**) is a legal entity of national, public interest whose main aim is to ensure the meteorological protection of life and property.
- Romania is a **founding member** of the International Meteorological Organization (IMO), and a signer in 1948 of the Convention for the settlement of the World Meteorological Organization (**WMO**).
- Co-operating state of the European Centre for Medium-Range Weather Forecasts (**ECMWF**).
- Member of the Consortium for Small-scale Modeling (**COSMO**) and of the Regional Cooperation for Limited Area modeling in Central Europe (**RC LACE/ALADIN**) Consortium.
- Since 2011, Meteo Romania represents Romania to the **Copernicus User Forum Committee.**
- **EUMETSAT full member** (2010).
- Actively participates in the implementation of the National Strategy for Sustainable Development

The main activities

Operational activity

- Weather forecasting
  - Nowcasting
  - Short-range forecasting
  - Medium-range forecasting
  - Long-range forecasting
- Observation system
  - Surface observation (SYNOP, agro, climate etc.)
  - Upper-air sounding
  - Doppler radar network
  - Lightning detection network
  - Satellite data
- Telecommunication
- Remote Sensing and GIS

Research activity

- Numerical modelling
  - ALADIN, HRM, LM and MM5
  - RegCM – climatological model
- Climate variability and climate change
  - Regional climatic scenarios
  - Trends in the climatic pattern in Romania over 1961-2015 period
  - Climatic predictability
- Physics of the atmosphere and air pollution
- Remote Sensing and GIS

Meteo Romania is supplying a wide range of operational meteorological services for the public and various users in agriculture, maritime and air navigation, defence, transport, energetics, tourism and environment.

The Remote Sensing & GIS Laboratory (since 1975)

- **Operational and Research Activity**
- Applications in monitoring of meteorological and hydrological hazard phenomena
- Applications in the environmental impacts studies
- Satellite-based products validation using in-situ measurements
- Satellite data integration in crops growth models etc.

- **Research Directions**
- Floods
- Droughts:
  - Vegetation monitoring
  - Soil moisture
- Snow cover and ice extend
- Land cover / land use changes etc.

Meteo Romania’s contribution the Copernicus Program

Copernicus Program

- Since 2011, Meteo Romania represents Romania at European Commission in the **Copernicus User Forum Committee**.
- Meteo Romania plays an important role to deliver information which corresponds to user needs within the "**Copernicus service component**".
- In the framework of the **Copernicus Programs**, Meteo Romania is engaged in the development of all the Copernicus core services, which are also supported by R&D projects financed by the National Programs, in cooperation with the Romanian Space Agency and other research institutes.
- Projects developed, within the Meteo Romania, according to COPERNICUS program:
  - **EC, Copernicus User Uptake Project** 275/G/GRO/COPE/17/10042;
  - **EEA SnowBall project:** the aim was to develop a prototype snow monitoring system that combines daily satellite data from Sentinel-1 and Sentinel-3 with in-situ weather station observations and state-of-the-art snowpack and climate modelling;
  - **National GEODIM project:** the main goal was to create a national Copernicus downstream emergency response service based on satellite data and GIS technology;

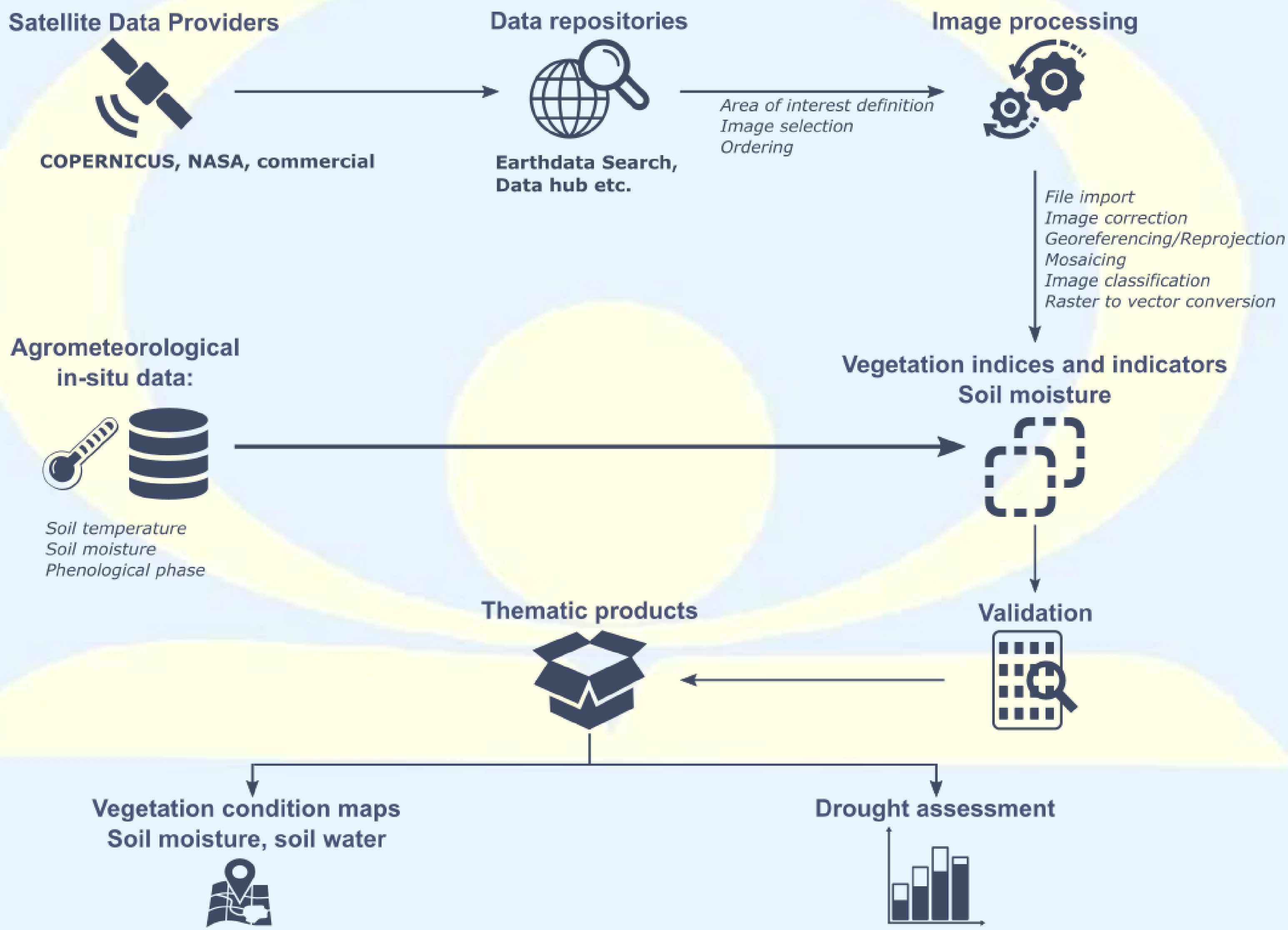
Soil Moisture data use
for environmental monitoring in Romania

Data

- **Satellite:**
  - SAR:
    - ✓ Sentinel-1, spatial resolution: 1 km, temporal coverage: 2015-present
    - ✓ MetOp/Ascat, spatial resolution: 12.5 km, temporal coverage: 2007-present

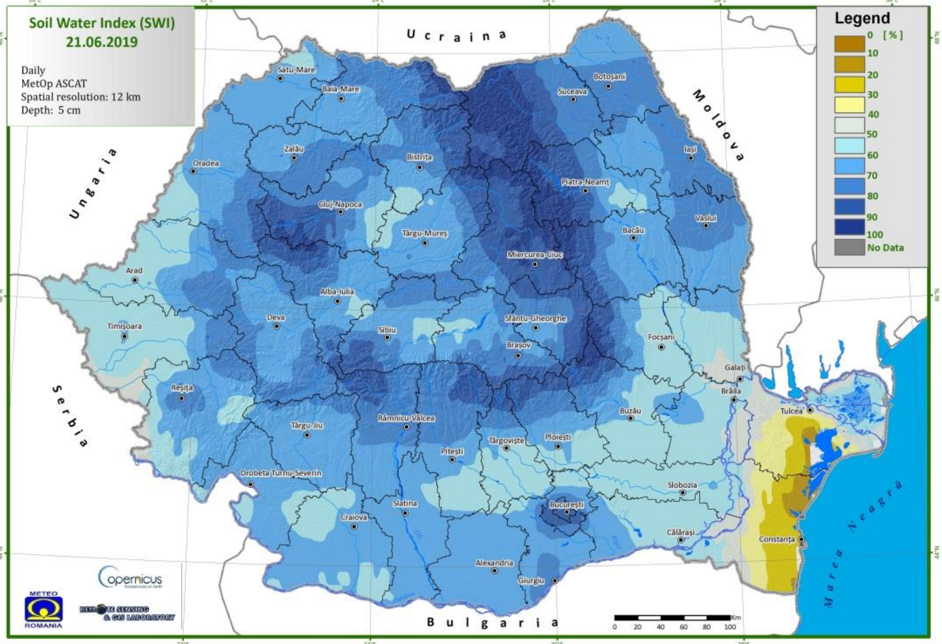
- **Ancillary data:**
  - In-situ measurements (air temperature, precipitations etc.)
  - Agricultural areas based on 2018 Corine Land Cover dataset

Drought processing flowchart

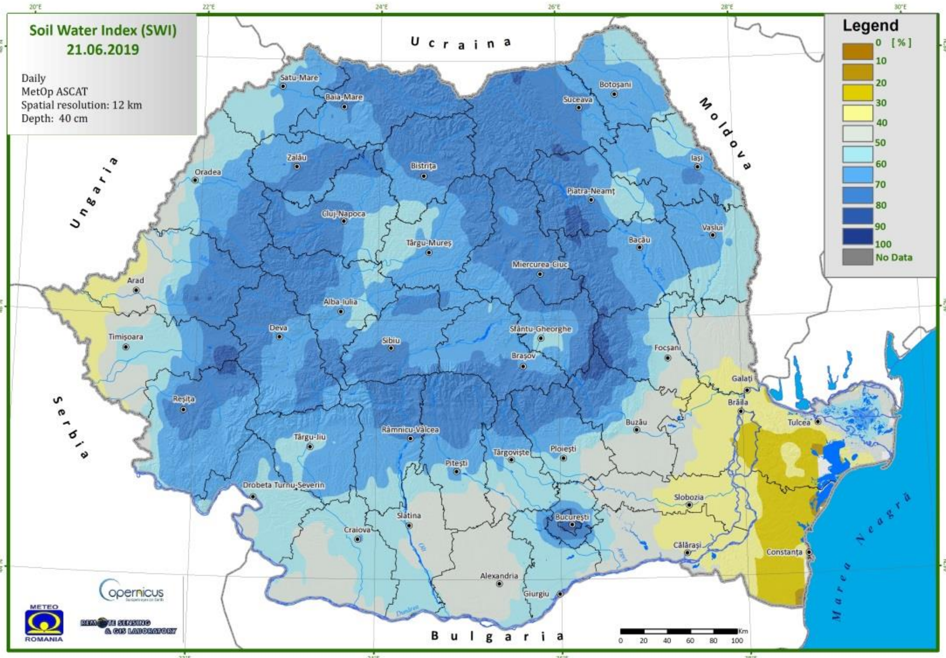


Soil Water Index (SWI) with 12.5 km resolution

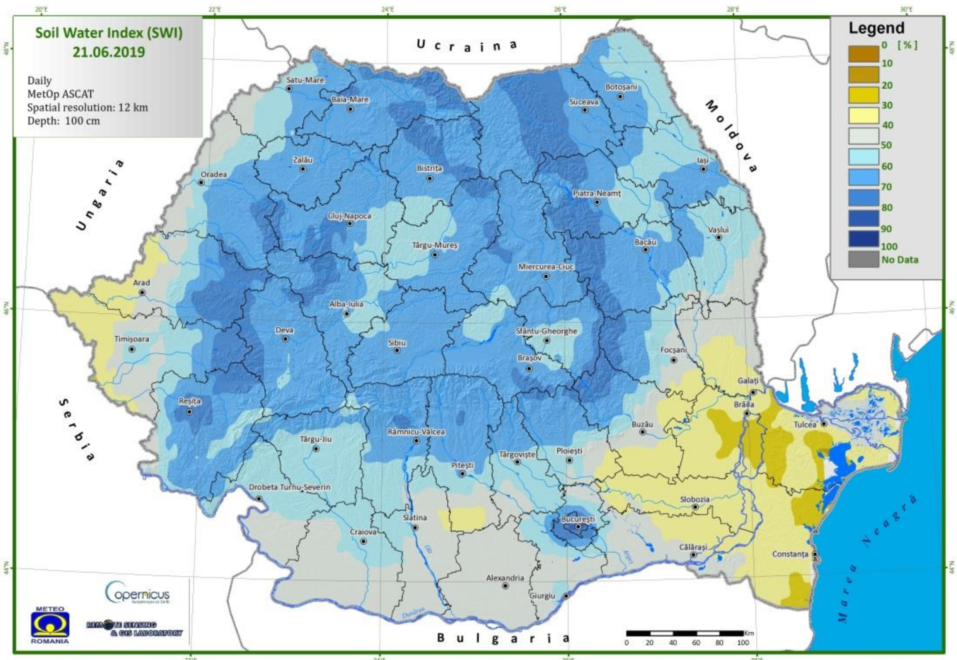
Depth:	20 cm
5 cm	40 cm
10 cm	60 cm
15 cm	100 cm



Soil Water Index from 21.06.2019, depth 0-5 cm



Soil Water Index from 21.06.2019, depth 0-40 cm



Soil Water Index from 21.06.2019, depth 0-100 cm

Soil Water Index Anomaly

- 12.5 km resolution, 10 days synthesis, based on SSM observations from MetOp-ASCAT (temporal coverage: 2007-present);

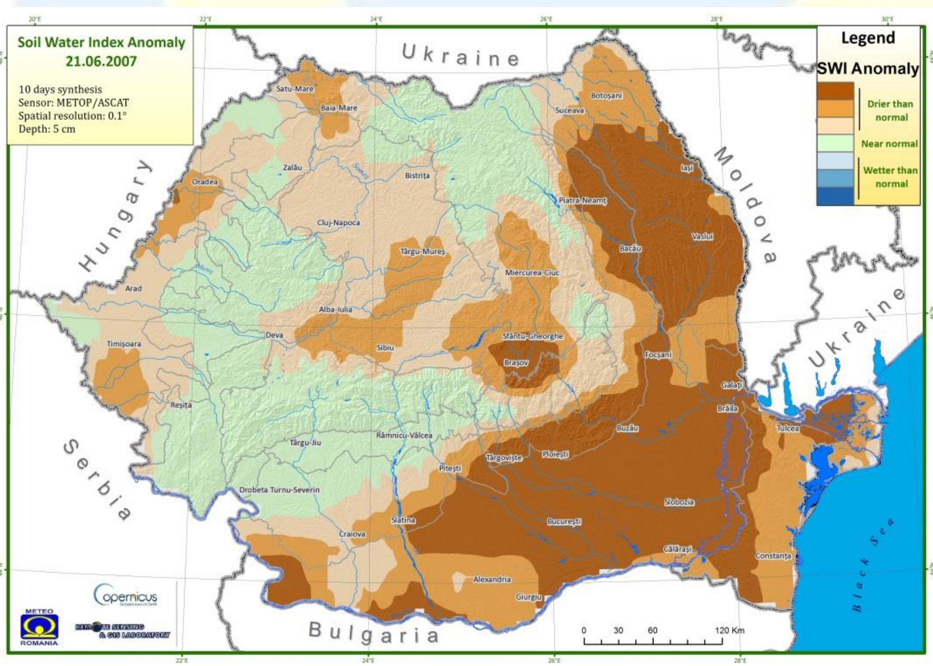
$$\text{SWI Anomaly} = \frac{SWI - \overline{SWI}}{\sigma_{SWI}}$$

Where:

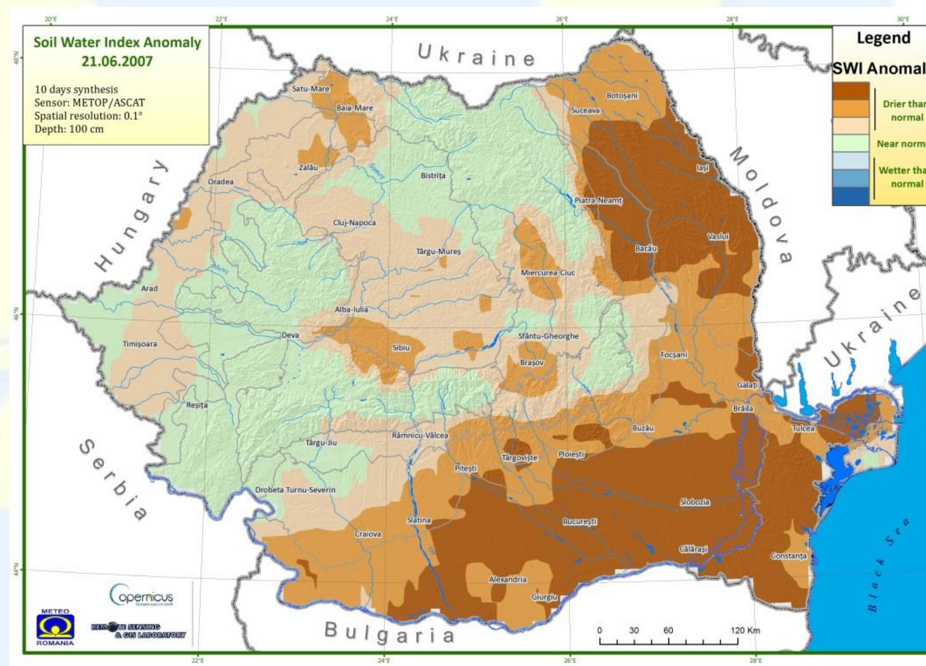
- SWI is the value of Soil Water Index for the decade t of the current year
- $\overline{SWI}$ is the multiannual mean of Soil Water Index (2007-2019)
- σ_{SWI} is the standard deviation of Soil Water Index (2007-2019)

Soil Water Index Anomaly classification

Drier that normal		≤ -2 -2 − -1.5 -1.5 − -1
Near normal condition		-1 − +1
Wetter than normal		1 − 1.5 1.5 − 2 ≥ 2
No data		



Soil Water Index Anomaly from 12-21.06.2007, depth 0-5 cm

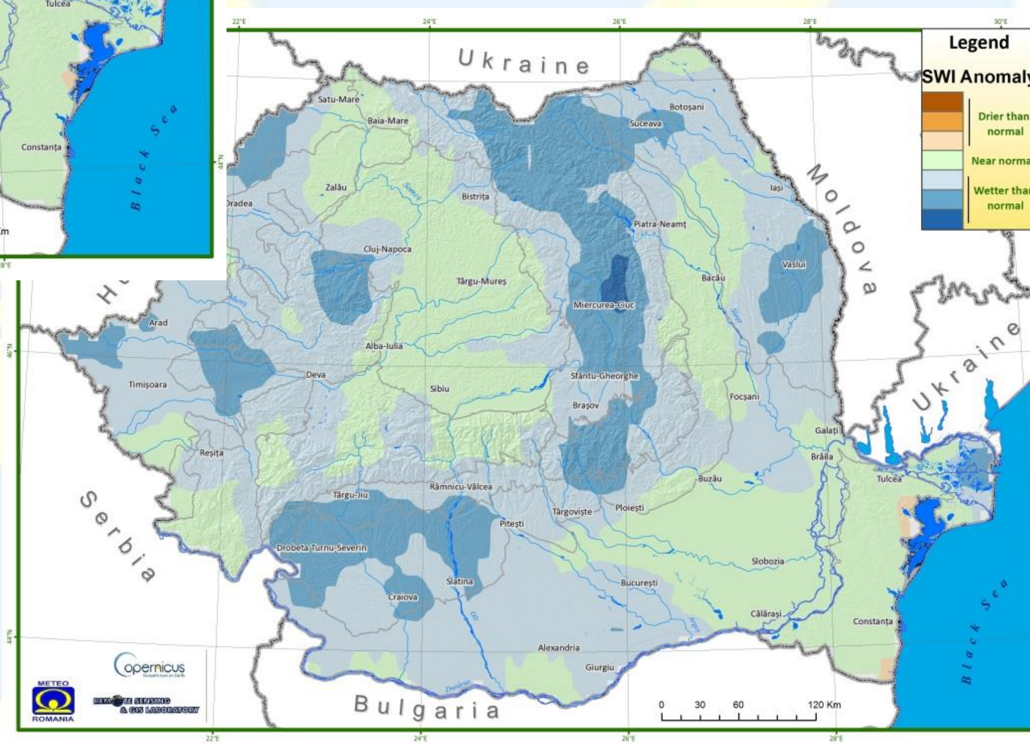


Soil Water Index Anomaly from 12-21.06.2007, depth 0-100 cm

SWI Anomaly analysis June 2012 and 2019 (0-5 cm depth)

Soil Water Index Anomaly, 12-21.06.2012, depth 0-5 cm

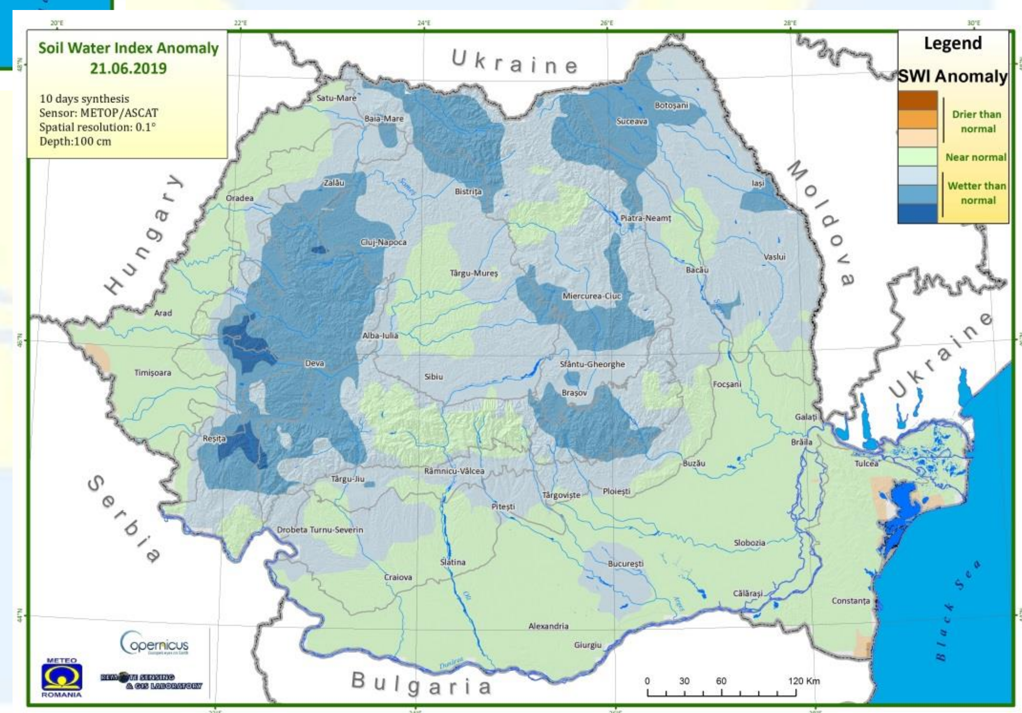
Soil Water Index Anomaly, 12-21.06.2019, depth 0-5 cm



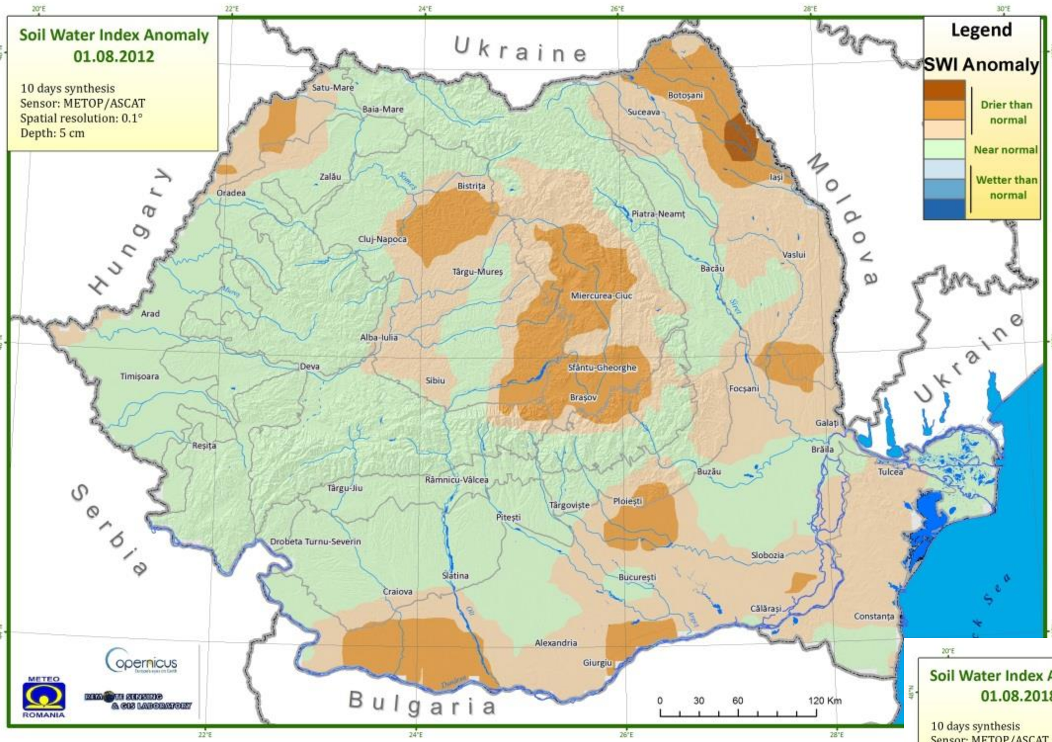
SWI Anomaly analysis June 2012 and 2019 (0-100 cm depth)

Soil Water Index Anomaly, 2-21.06.2012, depth 0-100 cm

Soil Water Index Anomaly, 12-21.06.2019, depth 0-100 cm

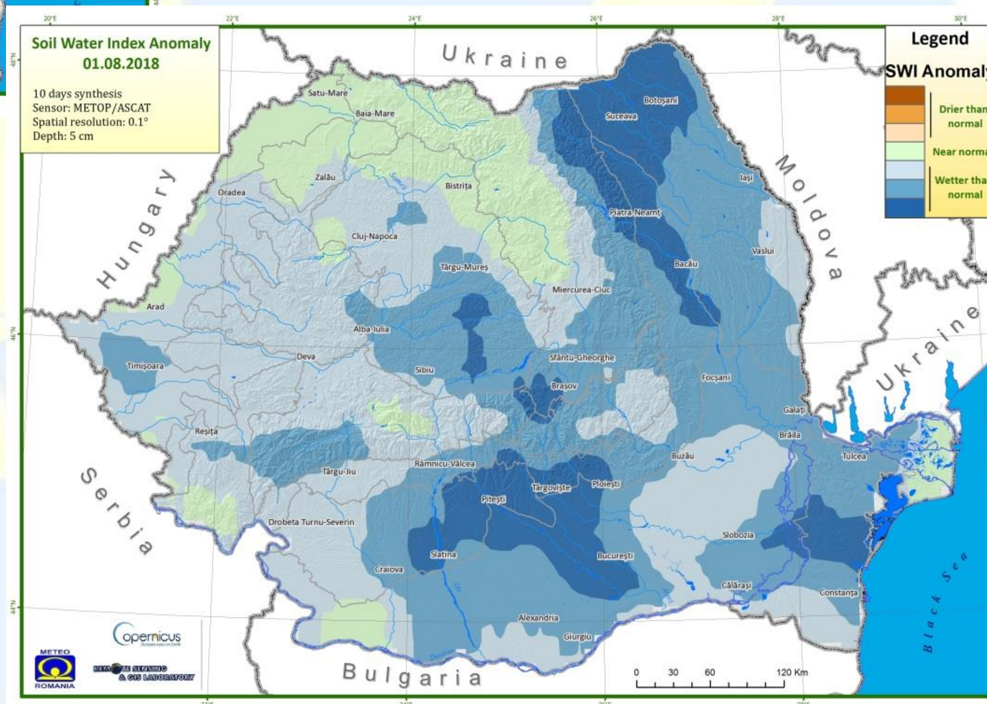


SWI Anomaly analysis July 2012 and 2018 (0-5 cm depth)

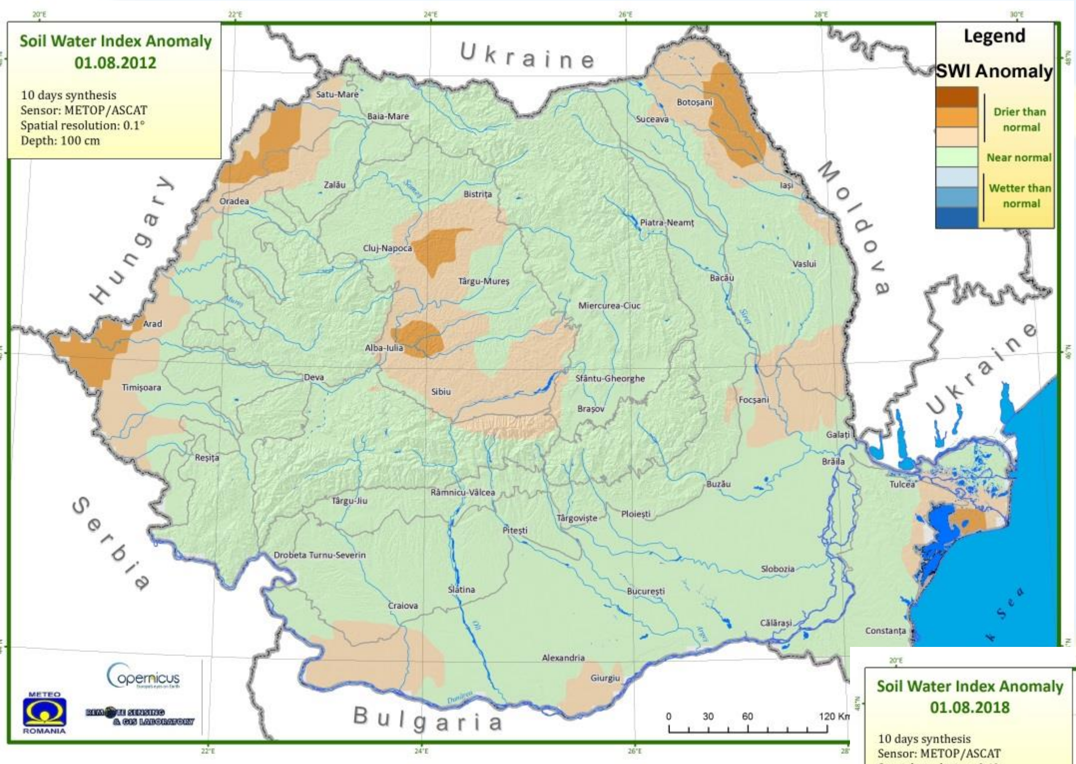


Soil Water Index Anomaly, 22.07-01.08.2012, depth 0-5 cm

Soil Water Index Anomaly, 22.07-01.08.2018, depth 0-5 cm

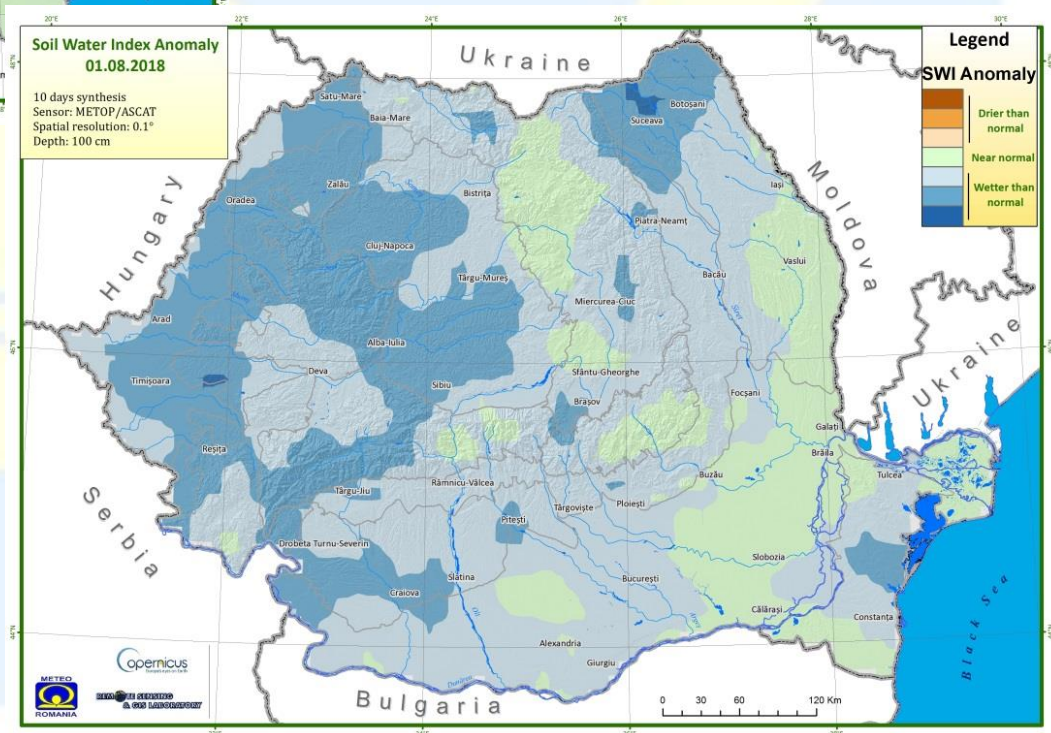


SWI Anomaly analysis July 2012 and 2018 (0-100 cm depth)

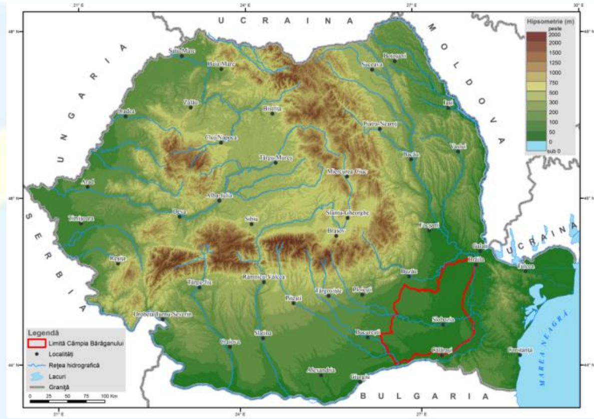


Soil Water Index Anomaly, 22.07- 01.08.2012, depth 0-100 cm

Soil Water Index Anomaly, 22.07- 01.08.2018, depth 0-100 cm



Case study: Agriculture area in Baragan Plain SWI (0-5 cm)



Mann-Kendall test and the magnitude of the trend with the Sen's method in Baragan Plain (depth 5 cm)

Soil Water Index (SWI) from MetOp/Ascat, depth 0-5 cm, Baragan Plain (2007-2019)

5 cm	Synthesis (10 days)	Year												
		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
March	22.03-01.04	**16.0**	31.2	15.7	38.3	12.6	15.5	47.3	19.4	60.1	31.6	34.2	45.1	14.8
April	02.04-11.04	**8.2**	29.4	10.6	25.7	30.9	21.0	36.1	38.0	39.1	34.5	31.6	26.5	9.2
	12.04-21.04	**6.1**	22.8	8.2	25.0	18.6	18.9	16.6	38.8	26.9	39.2	47.3	**19.8**	31.3
	22.04-01.05	**10.3**	**29.7**	**10.5**	**11.8**	**20.7**	**12.6**	**12.1**	**28.3**	**21.5**	**47.6**	**28.1**	17.0	17.2
May	02.05-11.05	6.6	20.2	9.5	27.4	33.2	25.1	21.9	39.9	17.3	50.8	26.8	30.1	19.5
	12.05-21.05	18.8	28.4	18.7	41.0	24.4	50.5	45.0	47.5	27.7	52.9	38.3	38.1	26.2
	22.05-01.06	19.6	32.1	30.1	47.5	38.4	50.1	53.2	63.6	40.1	59.5	53.1	45.0	28.5
June	02.06-11.06	15.2	32.9	23.8	43.3	54.4	43.2	55.3	62.0	44.4	60.9	66.8	40.4	49.8
	12.06-21.06	7.5	31.2	27.3	55.8	53.7	44.5	46.6	61.0	52.0	50.0	66.2	42.0	56.9
	22.06-01.07	**4.7**	24.7	38.9	58.1	59.5	41.6	54.5	56.4	44.3	39.9	57.8	57.7	54.1
July	02.07-11.07	**5.6**	24.2	44.3	61.4	46.2	38.1	49.0	49.2	41.4	35.2	48.8	57.5	40.0
	12.07-21.07	**3.3**	23.1	31.7	54.2	49.3	31.7	44.9	48.8	37.2	35.8	50.9	56.6	42.1
	22.07-01.08	**21.0**	17.4	28.5	47.6	42.5	24.4	43.0	44.9	37.0	34.9	51.2	54.6	39.7
August	02.08-11.08	**24.2**	9.0	16.1	39.6	48.7	31.7	29.6	37.3	35.2	39.0	41.5	39.8	40.8
	12.08-21.08	**16.3**	3.3	8.7	27.2	33.5	16.2	25.5	34.2	51.2	38.4	34.9	31.1	25.4
	22.08-01.09	**31.5**	1.1	25.0	28.6	21.1	10.5	32.3	26.7	22.9	27.9	28.3	24.4	15.1
Septemb er	02.09-11.09	**26.9**	17.8	28.7	20.5	15.7	7.2	41.2	18.3	36.1	18.8	20.7	23.1	10.1
	12.09-21.09	**17.5**	22.7	13.0	20.4	12.6	37.6	26.9	30.7	36.5	46.0	22.0	22.2	7.0
	22.09-01.10	**14.4**	18.8	25.5	32.2	14.8	21.8	37.8	34.5	48.2	35.0	25.0	17.1	11.2

***	if trend at $\alpha = 0.001$ level of significance;
**	if trend at $\alpha = 0.01$ level of significance;
*	if trend at $\alpha = 0.05$ level of significance;
+	if trend at $\alpha = 0.1$ level of significance

Case study: Agriculture area in Baragan Plain, SWI (0-100 cm)

Mann-Kendall test and the magnitude of the trend with the Sen's method in Baragan Plain (depth 100 cm)

Soil Water Index (SWI) from MetOp/Ascat, depth 0-100 cm, in Baragan Plain (2007-2019)

100 cm	Synthesis (10 days)	Year												
		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
March	22.03-01.04	35.3	32.5	40.7	42.6	44.3	34.9	47.9	42.6	59.5	51.8	51.9	60.3	41.2
April	02.04-11.04	30.3	32.1	37.3	41.7	42.6	33.1	46.8	42.2	57.1	49.8	49.4	56.6	37.4
	12.04-21.04	27.8	30.9	33.8	40.5	40.6	31.8	43.5	42.0	53.8	48.6	49.3	53.0	36.7
	22.04-01.05	25.2	30.8	31.6	37.2	38.5	30.5	40.2	40.3	50.0	48.3	46.8	49.0	34.9
May	02.05-11.05	22.3	29.2	29.2	36.7	38.4	30.3	37.8	40.2	47.0	48.9	44.5	47.1	33.1
	12.05-21.05	21.7	28.9	27.8	37.2	36.8	33.0	38.6	41.1	44.7	49.2	43.5	46.3	32.4
	22.05-01.06	21.5	29.5	28.2	38.9	36.9	35.5	40.4	43.5	44.0	50.4	44.6	46.1	31.9
June	02.06-11.06	20.7	30.0	27.9	39.3	39.0	36.2	42.0	45.1	44.2	51.4	47.1	45.7	33.8
	12.06-21.06	18.8	30.1	27.5	41.0	40.4	37.1	42.4	46.4	45.0	51.4	49.3	45.1	36.4
	22.06-01.07	17.0	29.5	28.8	43.2	42.3	37.9	43.6	47.4	44.9	50.2	50.1	46.5	38.4
July	02.07-11.07	15.7	28.8	30.6	45.4	42.9	37.8	44.4	47.6	44.6	48.7	50.0	47.6	38.9
	12.07-21.07	14.0	28.2	30.7	46.6	43.3	37.2	44.4	47.7	43.7	47.1	49.8	48.3	39.2
	22.07-01.08	14.4	27.0	30.6	46.8	43.4	35.7	44.3	47.5	42.7	46.2	50.3	49.2	39.3
August	02.08-11.08	16.0	25.1	29.0	46.0	43.9	35.5	42.8	46.4	41.4	45.4	49.3	48.3	39.4
	12.08-21.08	15.8	22.6	26.9	43.6	42.9	32.9	41.0	45.0	43.9	44.7	47.7	46.5	38.2
	22.08-01.09	17.4	20.0	26.3	41.7	40.6	30.9	40.8	43.3	40.3	43.1	45.8	44.2	35.7
September	02.09-11.09	18.4	19.3	27.2	39.6	37.9	28.4	40.6	41.6	39.5	40.8	43.1	42.2	32.8
	12.09-21.09	18.3	20.2	25.6	37.1	35.7	29.4	39.8	40.8	38.8	41.4	41.0	40.2	30.4
	22.09-01.10	17.7	19.5	25.5	36.7	33.4	28.7	39.6	40.6	40.4	40.6	39.2	38.0	28.4

***	if trend at $\alpha = 0.001$ level of significance;
**	if trend at $\alpha = 0.01$ level of significance;
*	if trend at $\alpha = 0.05$ level of significance;
+	if trend at $\alpha = 0.1$ level of significance

Case study: Agriculture area in Baragan Plain
SWI Anomaly (0-5 cm)

Soil Water Index Anomaly from MetOp/Ascat, depth 0-5 cm, Baragan Plain (2007-2019)

5 cm	Synthesis (10 days)	Year												
		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
March	22.03-01.04	**-0.9**	0.1	-0.9	0.6	-1.1	-1.0	1.2	-0.7	2.1	0.2	0.3	1.1	-1.0
April	02.04-11.04	**-1.7**	0.3	-1.5	0.0	0.4	-0.5	0.9	1.1	1.2	0.8	0.5	0.0	-1.6
	12.04-21.04	**-1.6**	-0.2	-1.4	0.0	-0.5	-0.5	-0.7	1.2	0.2	1.3	2.0	-0.4	0.6
	22.04-01.05	**-1.0**	0.9	-1.0	-0.9	0.0	-0.8	-0.8	0.8	0.1	2.6	0.7	-0.3	-0.3
May	02.05-11.05	**-1.6**	-0.4	-1.4	0.2	0.7	0.0	-0.3	1.3	-0.7	2.2	0.1	0.4	-0.5
	12.05-21.05	**-1.4**	-0.6	-1.4	0.5	-1.0	1.3	0.9	1.1	-0.7	1.6	0.3	0.3	-0.8
	22.05-01.06	**-1.9**	-0.9	-1.0	0.3	-0.4	0.6	0.8	1.6	-0.2	1.3	0.8	0.1	-1.2
June	02.06-11.06	**-2.1**	-0.9	-1.5	-0.2	0.6	-0.2	0.7	1.1	-0.1	1.1	1.5	-0.4	0.3
	12.06-21.06	**-2.5**	-1.0	-1.2	0.7	0.5	-0.1	0.1	1.0	0.4	0.3	1.3	-0.2	0.7
	22.06-01.07	**-2.6**	-1.3	-0.4	0.8	0.9	-0.3	0.6	0.7	-0.1	-0.4	0.8	0.8	0.5
July	02.07-11.07	**-2.6**	-1.3	0.2	1.4	0.3	-0.3	0.5	0.6	0.0	-0.5	0.5	1.1	-0.1
	12.07-21.07	**-2.5**	-1.1	-0.5	1.1	0.7	-0.5	0.4	0.7	-0.1	-0.2	0.8	1.2	0.2
	22.07-01.08	**-1.5**	-1.8	-0.8	0.9	0.5	-1.2	0.5	0.7	0.0	-0.2	1.2	1.5	0.2
August	02.08-11.08	**-0.9**	-2.3	-1.6	0.6	1.4	-0.1	-0.3	0.4	0.2	0.5	0.8	0.6	0.7
	12.08-21.08	**-0.8**	-1.9	-1.4	0.0	0.6	-0.8	-0.1	0.6	2.0	0.9	0.7	0.4	-0.1
	22.08-01.09	**1.0**	-2.5	0.3	0.7	-0.2	-1.4	1.1	0.5	0.0	0.6	0.7	0.2	-0.9
September	02.09-11.09	**0.6**	-0.5	0.7	-0.2	-0.7	-1.6	2.1	-0.4	1.6	-0.3	-0.1	0.1	-1.3
	12.09-21.09	**-0.6**	-0.1	-1.1	-0.4	-1.1	1.2	0.3	0.6	1.2	2.0	-0.2	-0.2	-1.6
	22.09-01.10	**-1.1**	-0.7	0.0	0.6	-1.0	-0.4	1.1	0.8	2.1	0.9	-0.1	-0.8	-1.4

Soil Water Index Anomaly classification

Drier that normal		≤ -2
		-2 − -1.5
		-1.5 − -1
Near normal condition		-1 − +1
Wetter than normal		1 − 1.5
		1.5 − 2
		≥ 2
No data		

Case study: Agriculture area in Baragan Plain
SWI Anomaly (0-100 cm)

Soil Water Index Anomaly from MetOp/Ascat, depth 0-100 cm, Baragan Plain (2007-2019)

100 cm	Synthesis (10 days)	Year												
		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
March	22.03-01.04	**-1.1**	-1.5	-0.5	-0.3	-0.1	-1.2	0.3	-0.3	1.7	0.8	0.8	1.8	-0.5
April	02.04-11.04	**-1.5**	-1.3	-0.6	-0.1	0.0	-1.1	0.5	-0.1	1.7	0.8	0.8	1.6	-0.6
	12.04-21.04	**-1.6**	-1.2	-0.9	-0.1	0.0	-1.1	0.3	0.1	1.6	0.9	1.0	1.5	-0.5
	22.04-01.05	**-1.7**	-1.0	-0.9	-0.2	0.0	-1.1	0.2	0.2	1.5	1.2	1.0	1.3	-0.5
May	02.05-11.05	**-1.9**	-1.0	-1.0	-0.1	0.1	-0.9	0.1	0.4	1.2	1.5	0.9	1.2	-0.5
	12.05-21.05	**-2.0**	-1.0	-1.2	0.0	0.0	-0.5	0.2	0.5	1.0	1.6	0.8	1.2	-0.6
	22.05-01.06	**-2.1**	-1.0	-1.2	0.1	-0.1	-0.3	0.3	0.7	0.8	1.6	0.9	1.0	-0.7
June	02.06-11.06	**-2.1**	-1.0	-1.3	0.1	0.0	-0.3	0.4	0.8	0.7	1.5	1.0	0.8	-0.6
	12.06-21.06	**-2.3**	-1.0	-1.3	0.2	0.1	-0.2	0.3	0.8	0.6	1.4	1.1	0.6	-0.3
	22.06-01.07	**-2.5**	-1.1	-1.2	0.3	0.2	-0.2	0.4	0.8	0.5	1.1	1.1	0.7	-0.2
July	02.07-11.07	**-2.6**	-1.2	-1.0	0.5	0.3	-0.3	0.4	0.8	0.5	0.9	1.0	0.8	-0.1
	12.07-21.07	**-2.6**	-1.2	-0.9	0.7	0.3	-0.3	0.4	0.8	0.4	0.7	1.0	0.8	-0.1
	22.07-01.08	**-2.5**	-1.3	-0.9	0.7	0.4	-0.4	0.5	0.8	0.3	0.6	1.0	0.9	-0.1
August	02.08-11.08	**-2.4**	-1.5	-1.0	0.7	0.5	-0.4	0.4	0.8	0.2	0.7	1.1	0.9	0.0
	12.08-21.08	**-2.3**	-1.6	-1.1	0.6	0.5	-0.5	0.3	0.7	0.6	0.7	1.0	0.9	0.0
	22.08-01.09	**-2.1**	-1.8	-1.1	0.6	0.5	-0.6	0.5	0.8	0.5	0.8	1.0	0.9	0.0
September	02.09-11.09	**-2.0**	-1.8	-0.9	0.6	0.4	-0.8	0.7	0.8	0.6	0.7	1.0	0.9	-0.2
	12.09-21.09	**-2.0**	-1.7	-1.0	0.4	0.2	-0.6	0.8	0.9	0.6	1.0	0.9	0.8	-0.4
	22.09-01.10	**-1.9**	-1.7	-0.9	0.5	0.1	-0.5	0.8	1.0	0.9	1.0	0.8	0.6	-0.6

Soil Water Index Anomaly classification

Drier that normal		≤ -2
		-2 − -1.5
		-1.5 − -1
Near normal condition		-1 − +1
Wetter than normal		1 − 1.5
		1.5 − 2
		≥ 2
No data		

Needs

transformation from SSM(t) to SSM(a)

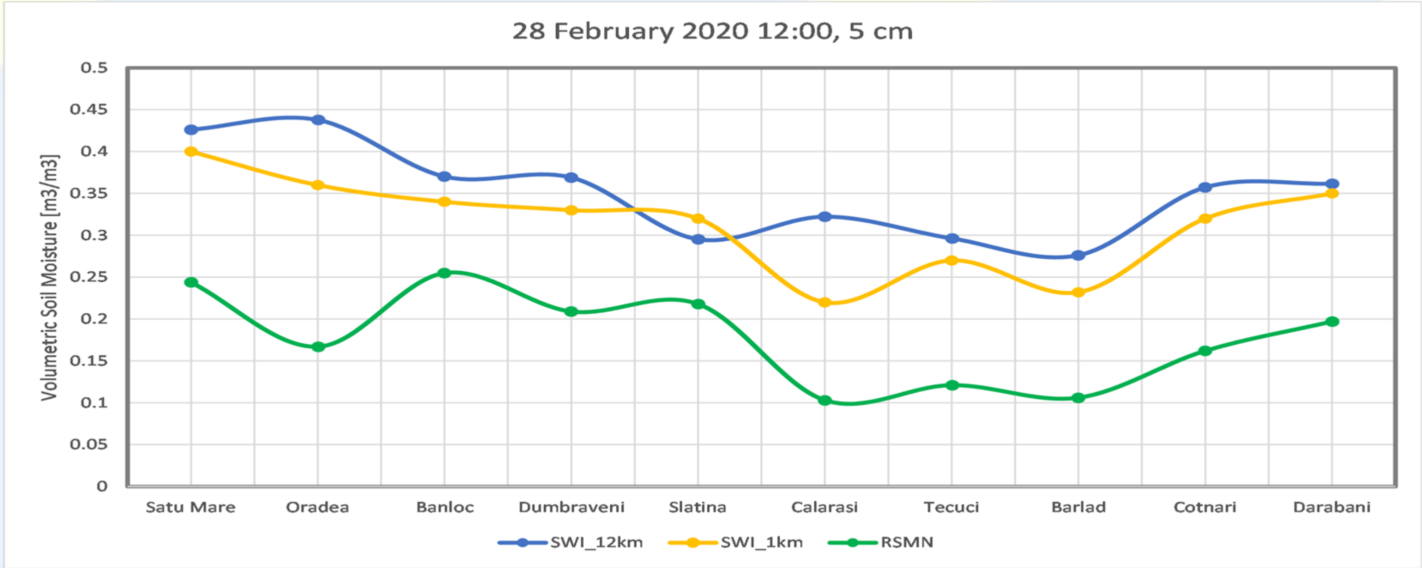
- The relative surface soil moisture *SSM(t)* estimates range between 0% and 100% and are derived by linearly scaling the angle-normalized backscatter between the lowest/highest backscatter values at the individual location.
- These backscatter values correspond to the driest/wettest soil conditions. The difference between those values is called the soil moisture sensitivity.
- These parameters necessary for the production are obtained from the Sentinel-1 backscatter long-term time series of the individual location.
- The soil moisture in the SSM1km represents degree of saturation SSM(t) , but can be translated from relative (%) to absolute volumetric units SSMa (m^3/m^3), using porosity information p (also in m^3/m^3):

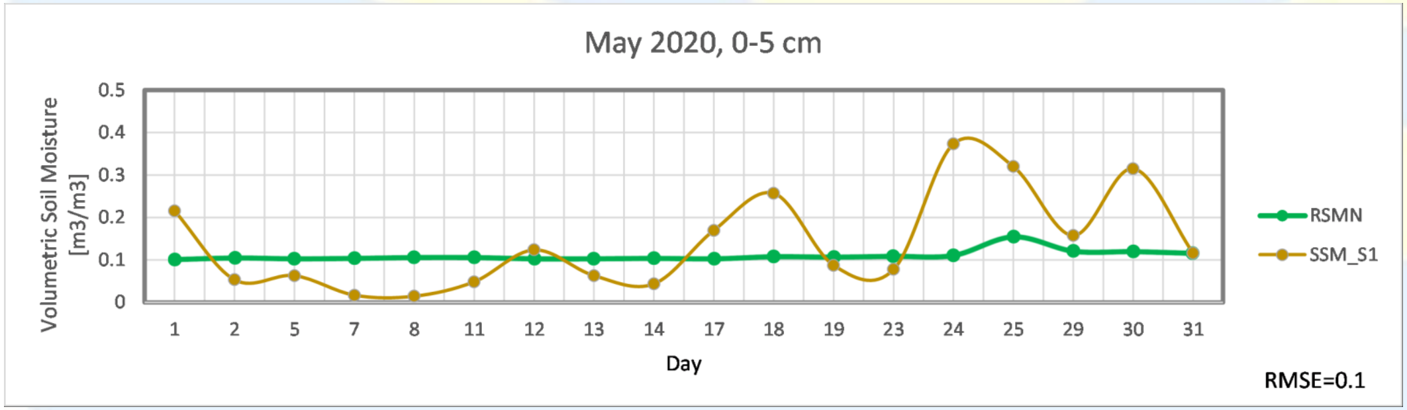
$$SSMa(t)=p*(SSM(t))/100$$

- The SSM1km value range is from 0% to 100% relative soil moisture, which is encoded in the files as datatype “byte” with the integer values 0-200, using the scale factor of 0.5.

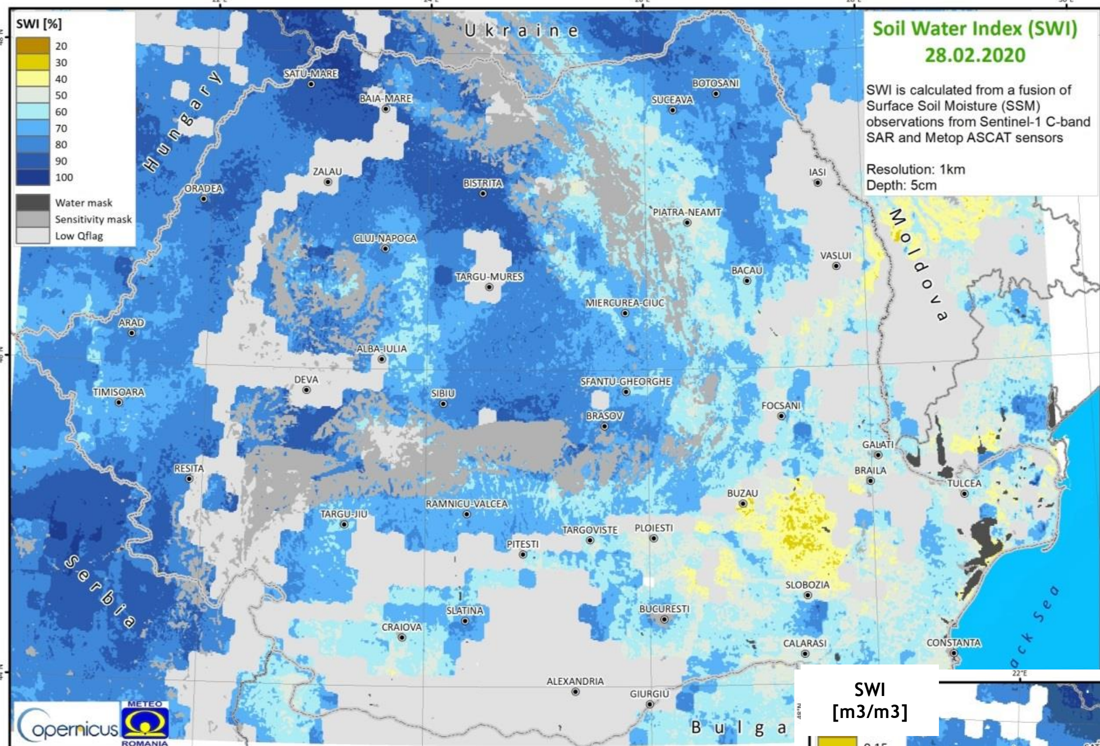
Transformation results

In-situ data (RSMN) from 10 weather station across Romania and SM from SWI 12km and SWI 1km (derived from Metop Ascat and Sentinel-1) for 28.02.2020

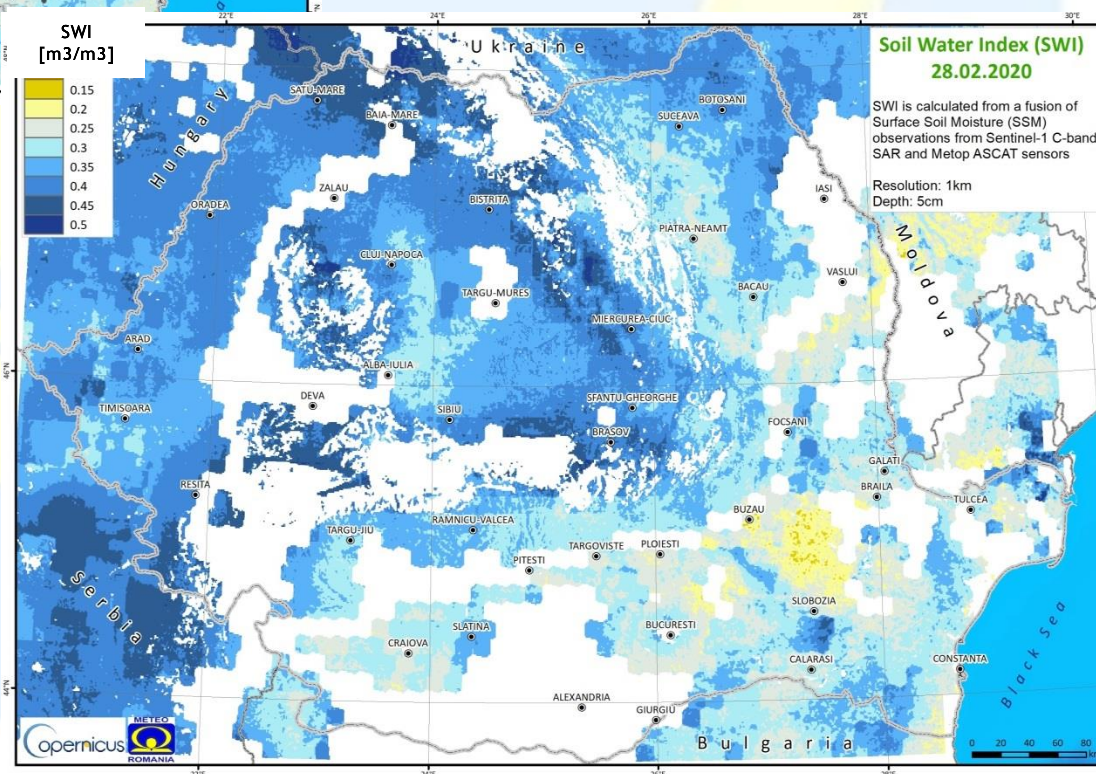




In-situ data (RSMN) from 1 weather station (Oradea) and SSM 1km (from Metop Ascat/Sentinel-1) for May 2020



Degree of saturation expressed in relative units [%]

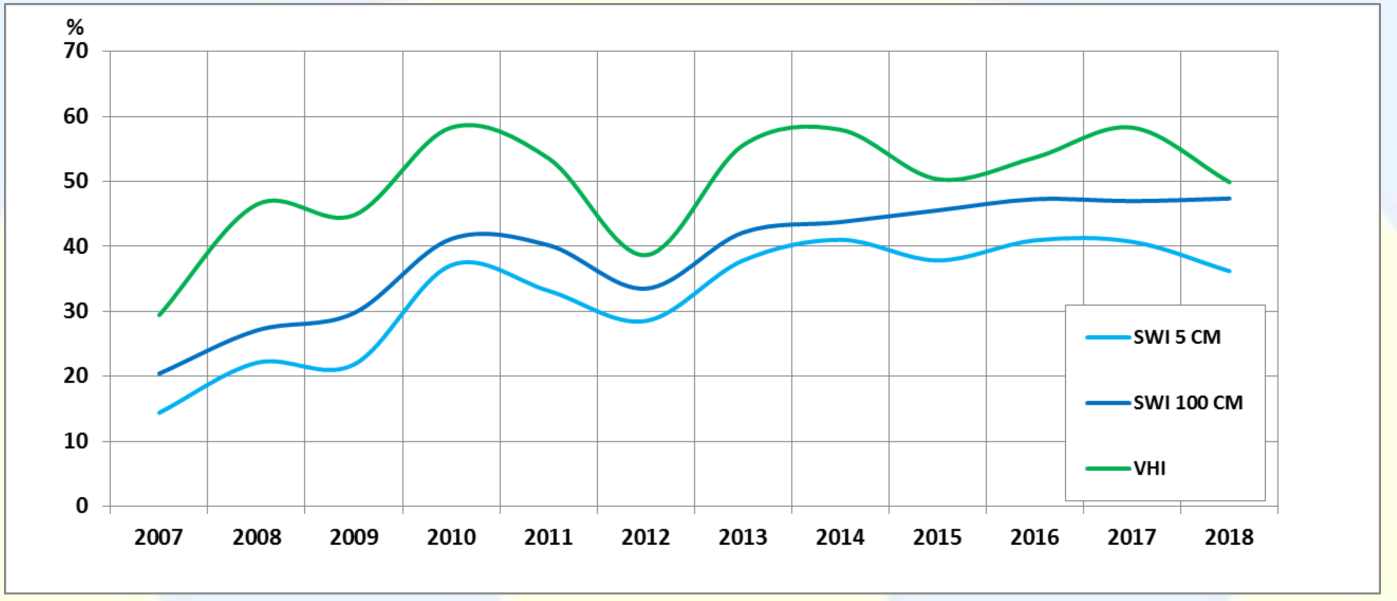


Soil Water Index expressed in volumetric units [m^3/m^3]

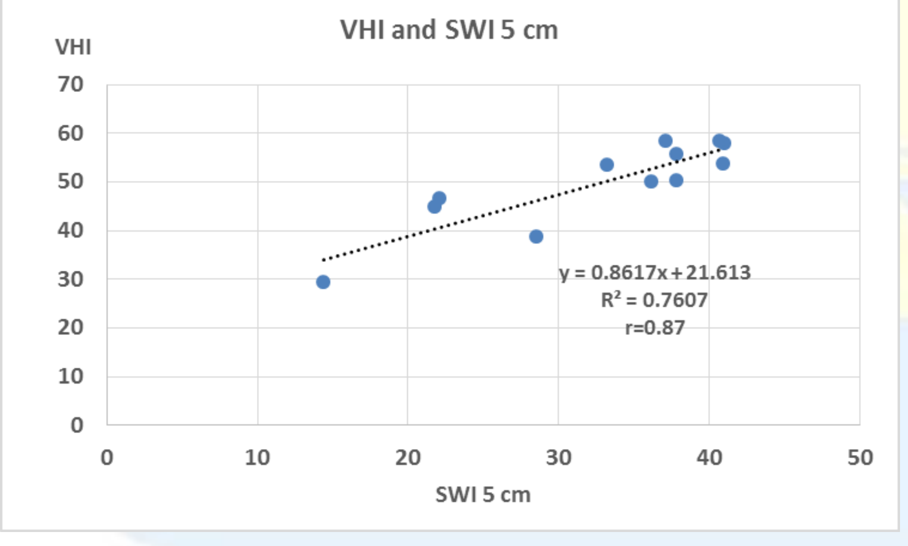
Future work

- Validation of SSM(t) to SSM(a) transformation based on multiple data and in-situ observations at different depths
- Transformation of SSM(t) to SSM(a) based on Cumulative Distribution Function (CDF)
- Correlation with vegetation indices in order to be used for drought monitoring;
- Correlation with precipitation data in order to be used for flood monitoring;
- Copernicus data website for Romania.

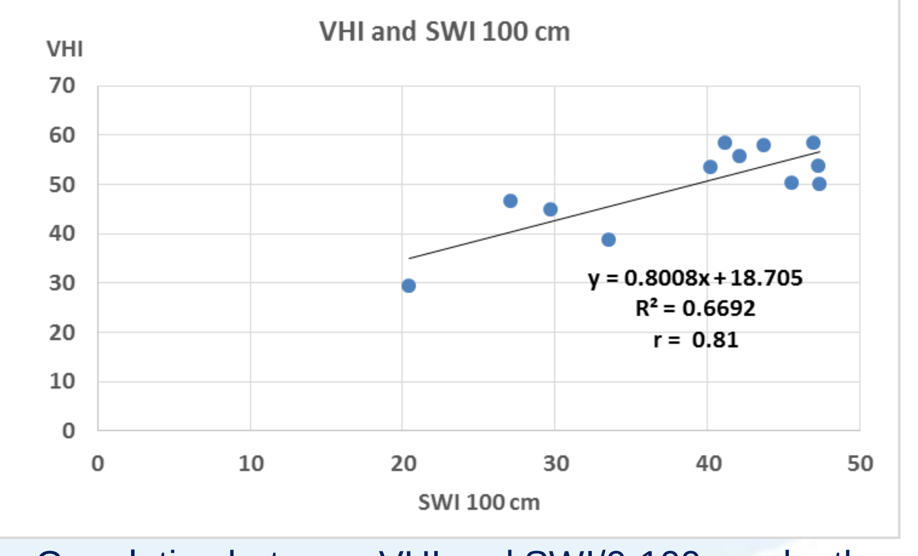
Case study: Agriculture area in Baragan Plain
Correlation between VHI and SWI/0-5 cm and SWI/0-100 cm



Comparative analysis between VHI, SWI-5 and SWI-100



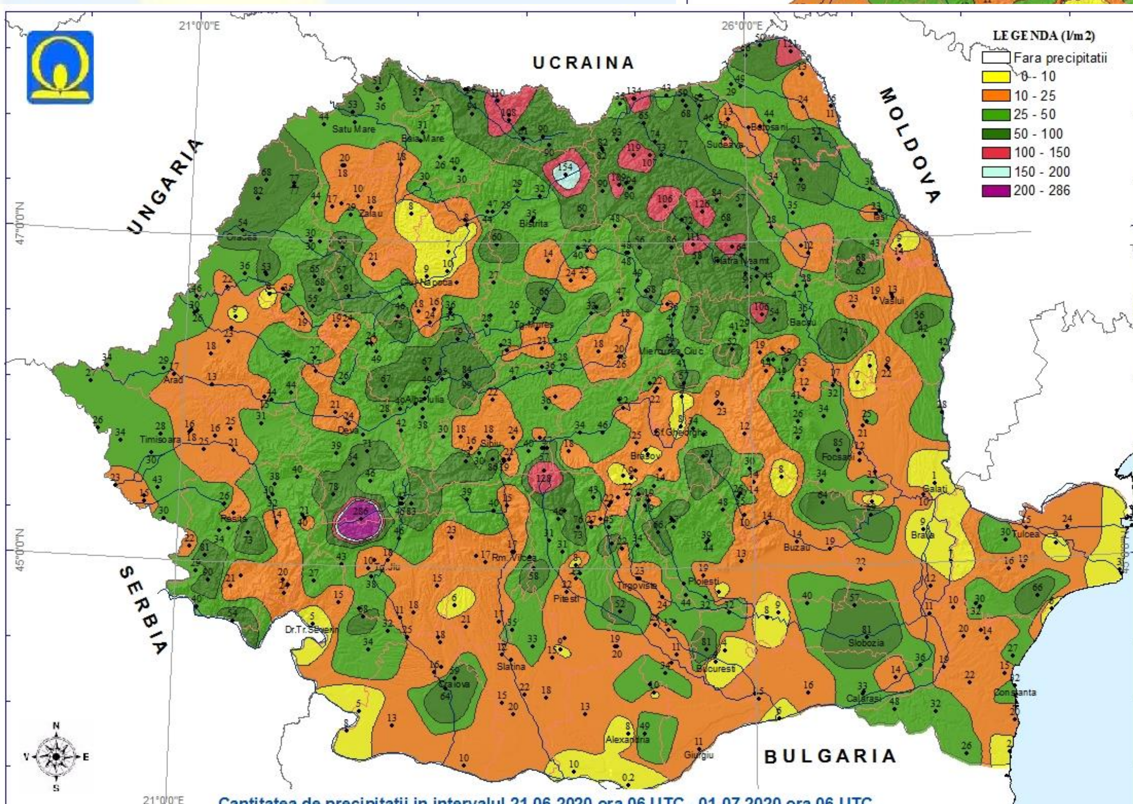
Correlation between VHI and SWI/0-5 cm depth

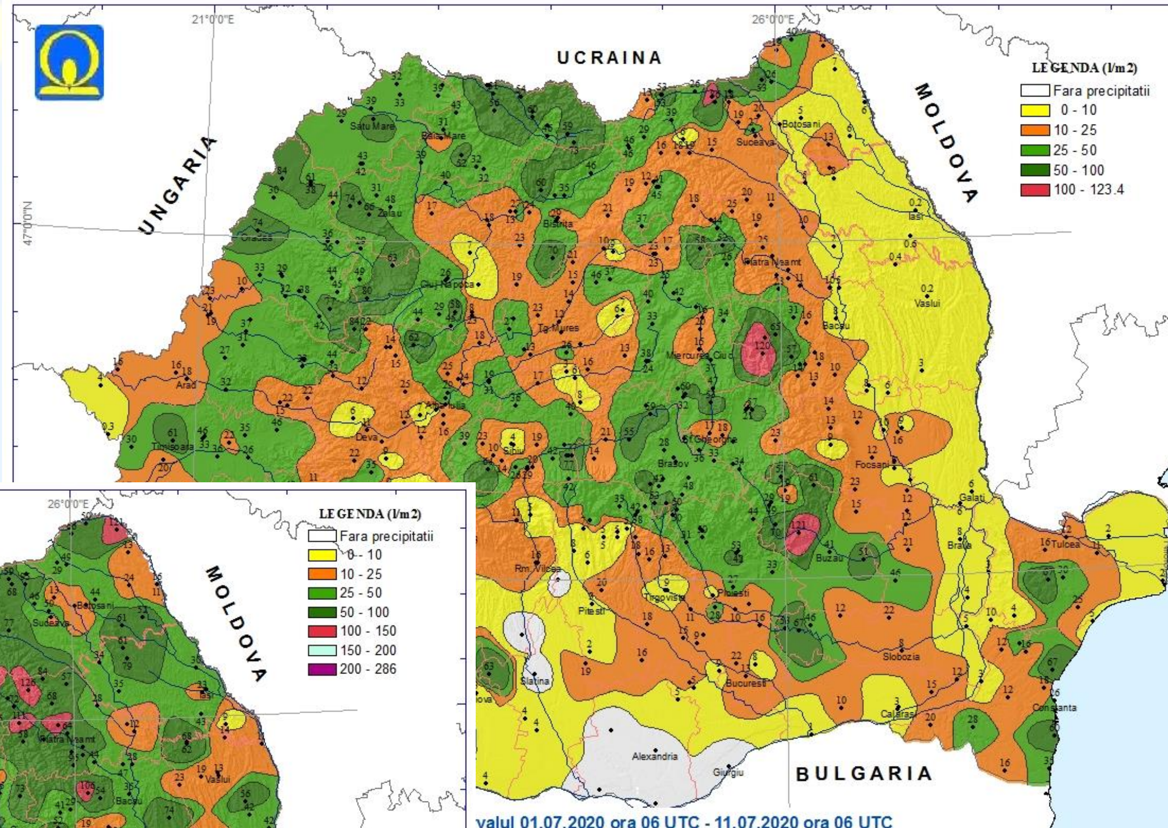


Correlation between VHI and SWI/0-100 cm depth

Current situation - precipitation

21.06-30.06.2020

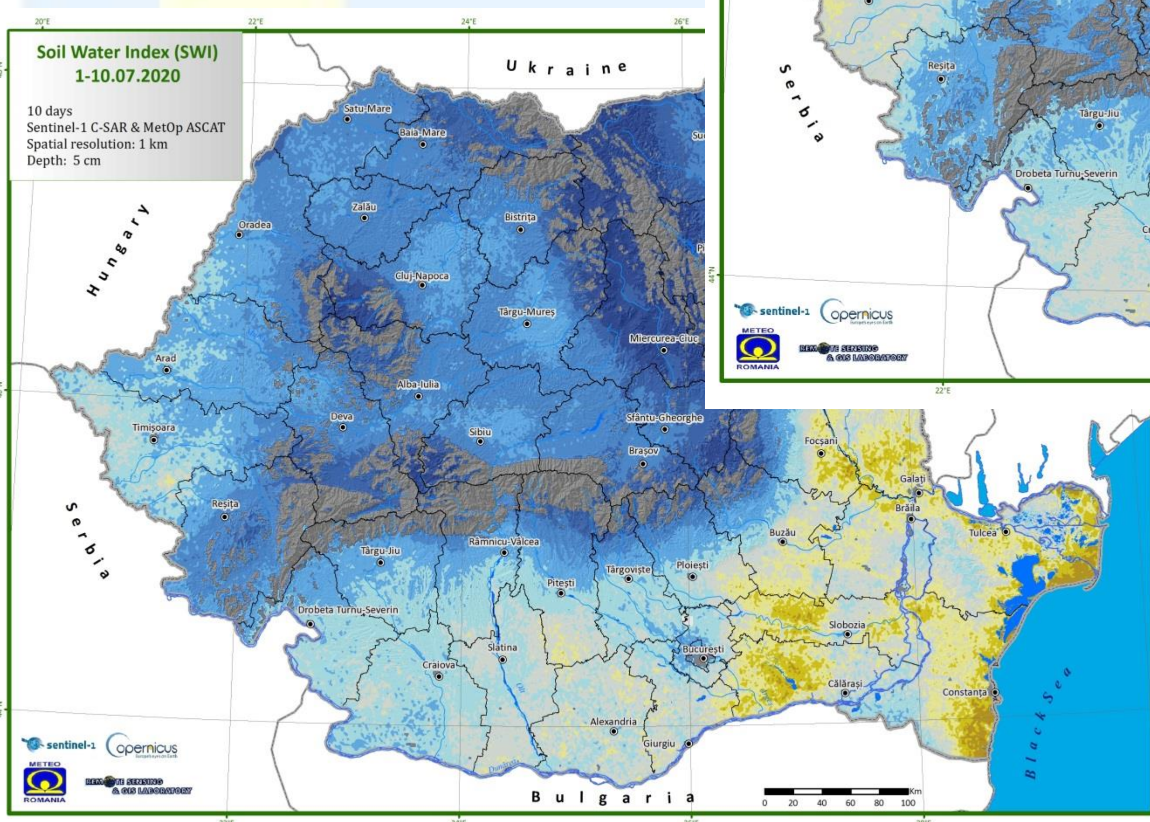


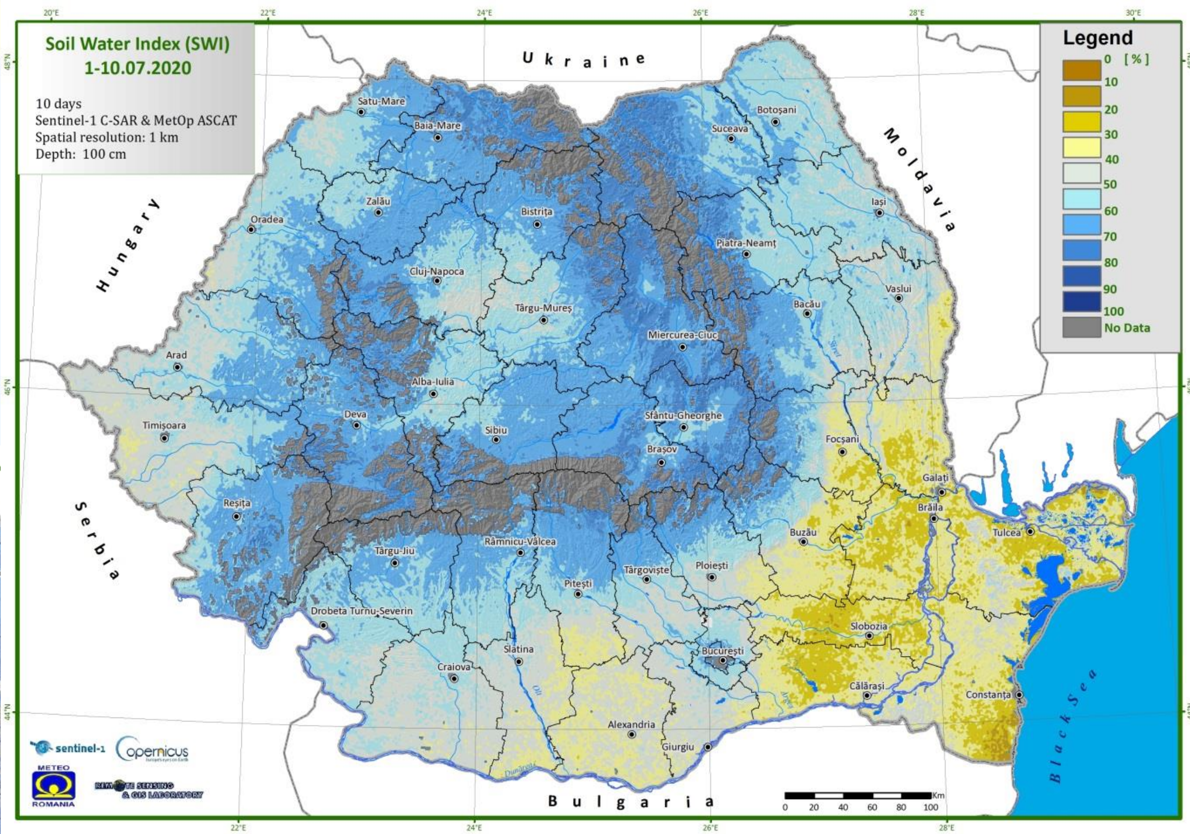


01.07-10.07.2020

Current situation - SWI

0-5 cm





0-100 cm

Thank you for kind attention!

Contact:
Anişoara Irimescu
anisoara.irimescu@meteoromania.ro