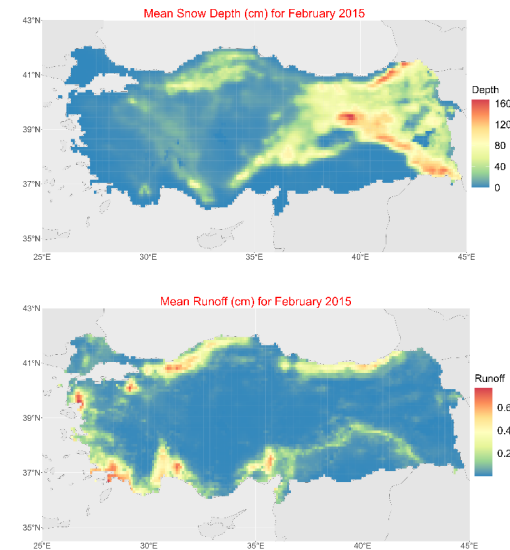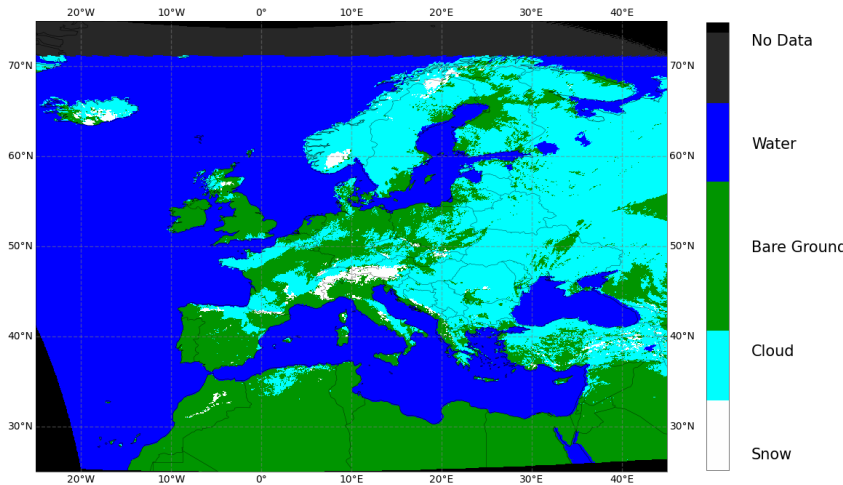# Investigating the Snow Dynamics over Mountainous Terrains from
EUMETSAT HSAF Snow Cover Product-H10

Zuhal Akyurek[1,3] , Semih Kuter[2] , Çağrı Karaman[3] , Berkay Akpinar[1] , Ali Arda Sorman[4]

zakyurek@metu.edu.tr

[1] METU, Department of Civil Engineering, Water Resources Lab, Ankara, TURKEY
[2] Cankiri Karatekin University, Department of Forest Engineering, Cankiri, TURKEY
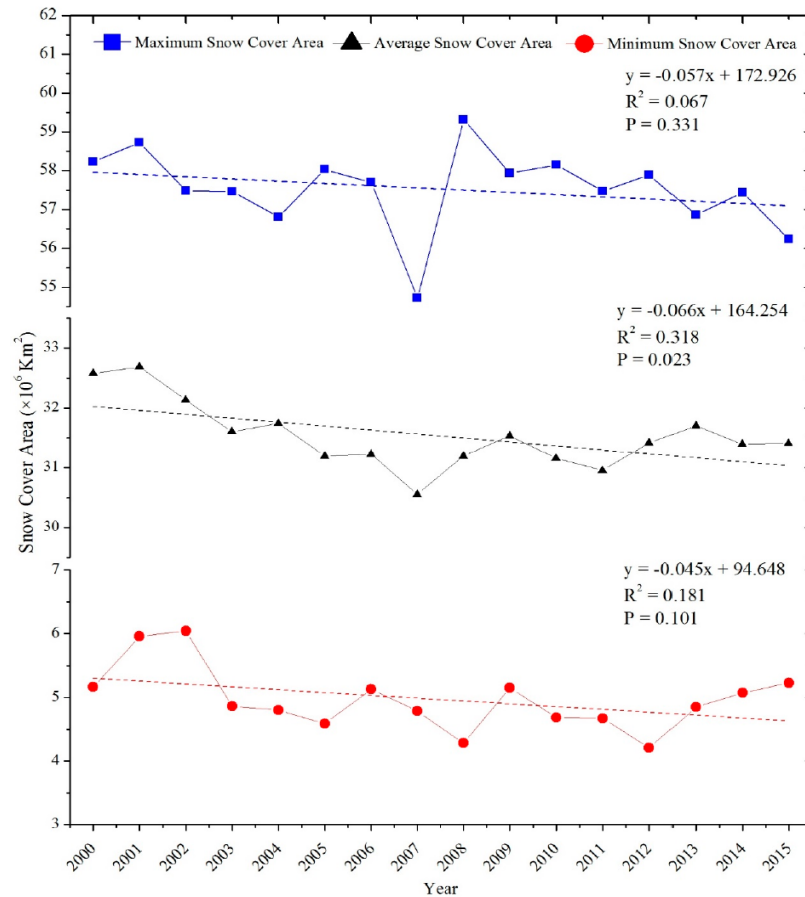[3] Middle East Technical University (METU), Geodetic and Geographic Information Technologies, Ankara, TURKEY
[4] Eskişehir Technical University (ESTU), Civil Eng. Dept., Eskişehir, TURKEY
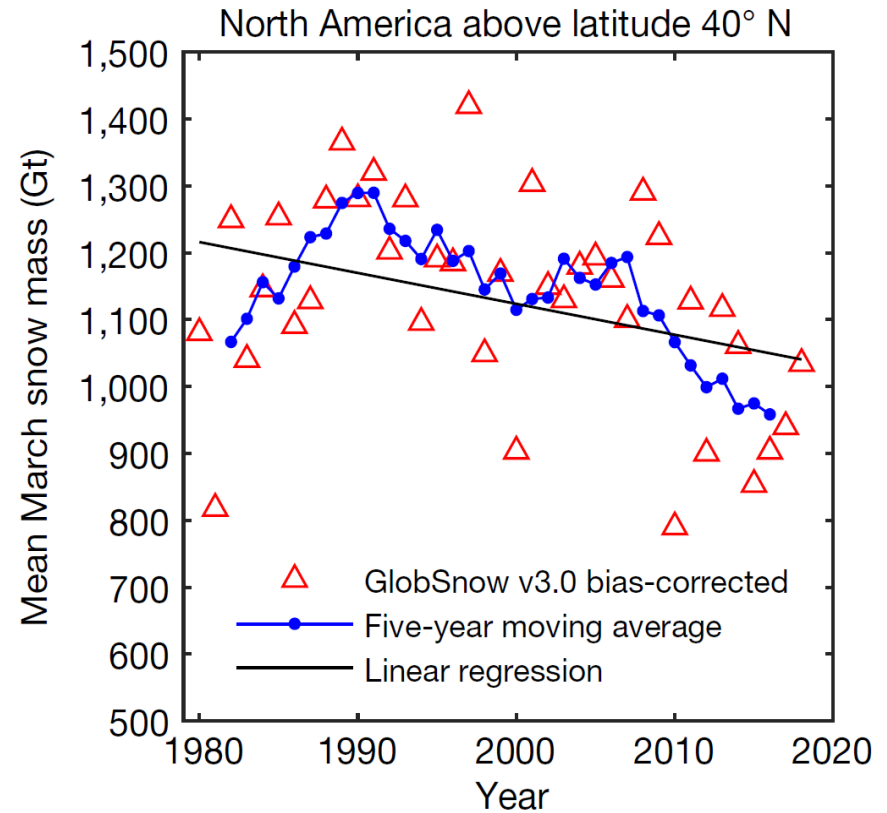
10th EARSeL Workshop on Remote Sensing of Land Ice & Snow | 6-8 Feb 2023

Snow Cover Area in the north hemisphere shows a decreasing trend.

Wang et al. (2018)

North America above latitude 40° N
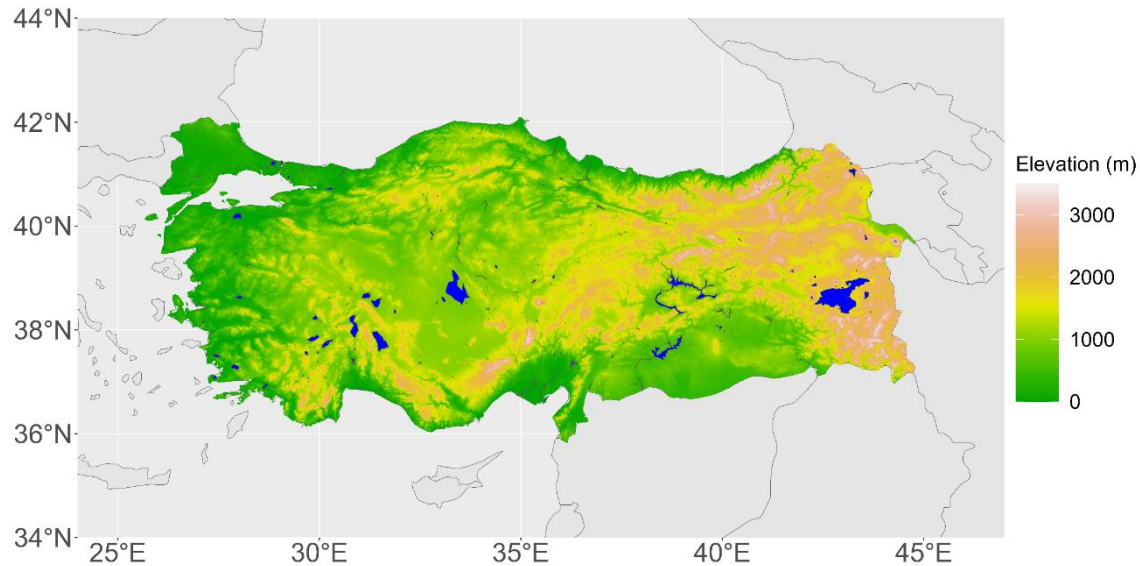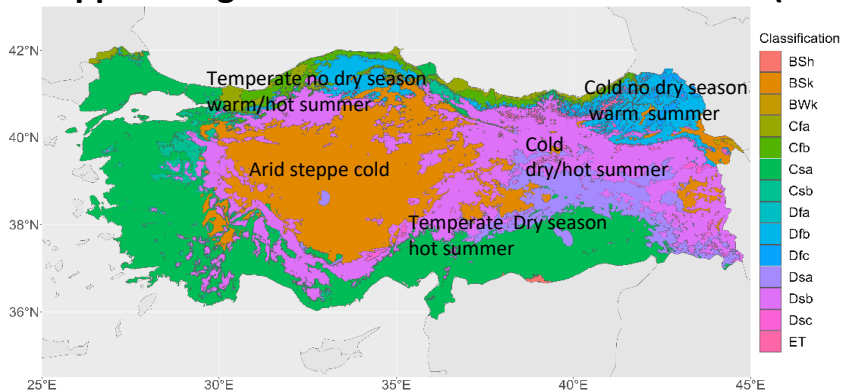

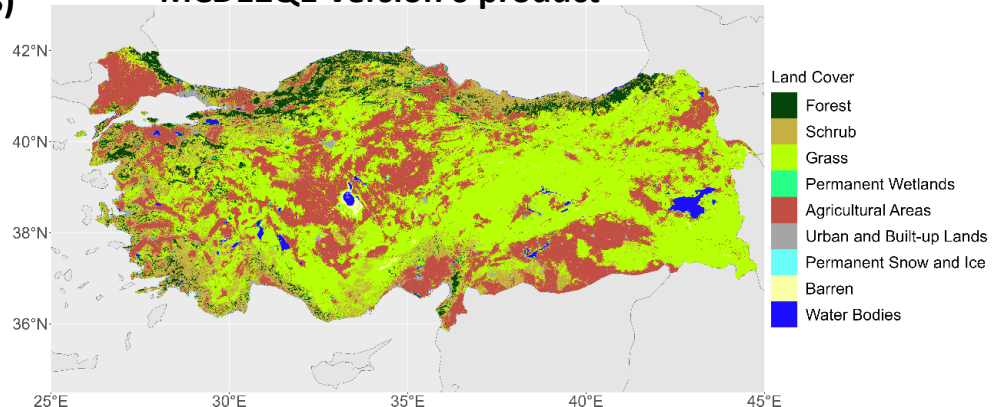
Pulliainen et al. (2020)

Motivation

- In the hydrological year 2021-2022 northern Italy has experienced a very dry period, in terms of both liquid and solid precipitation, and also 2021 was a moderately dry years.
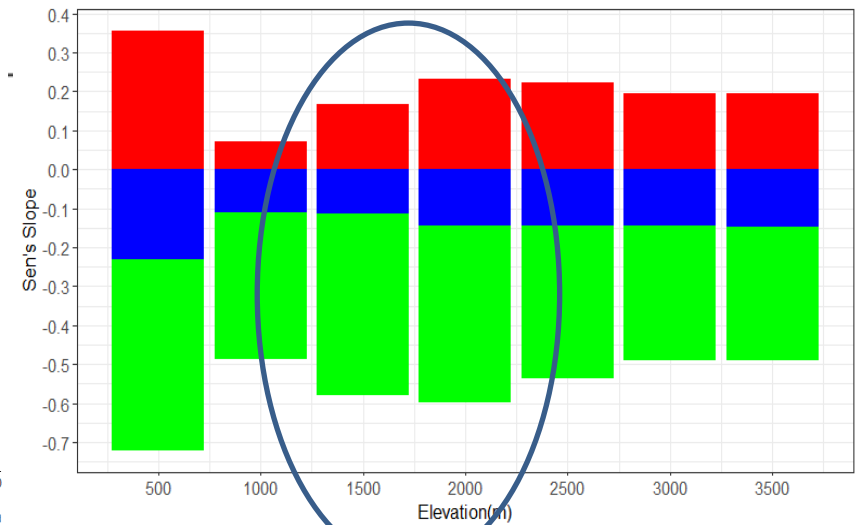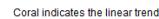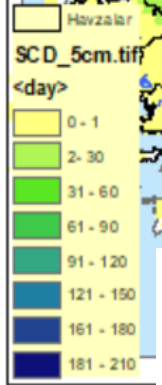- 2022 was a snow rich year in Turkey.

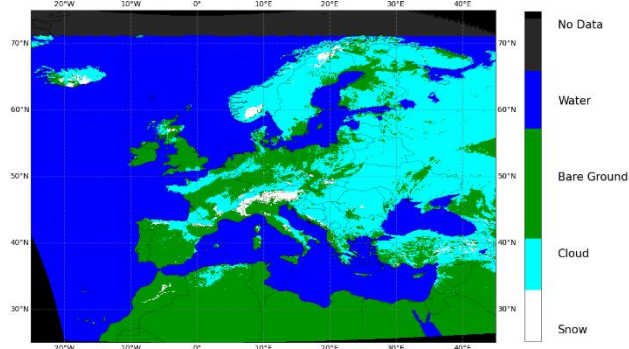**Köppen-Geiger climate classification Beck et al. (2018)**
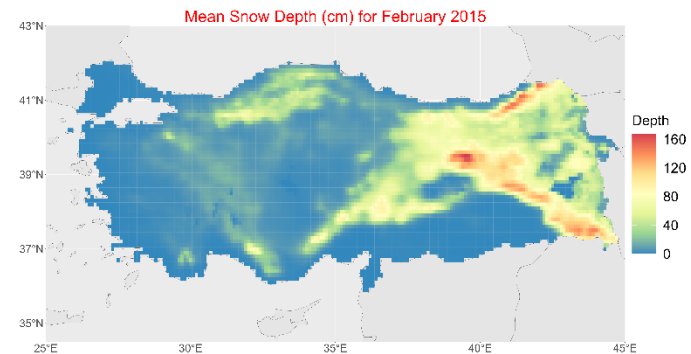
MCD12Q1 Version 6 product

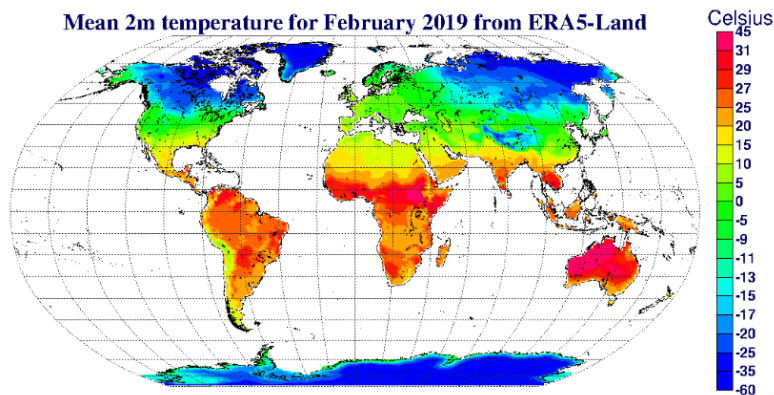# Motivation

Snow Covered Days from ERA5 Land for 1970-2022

Coral indicates the linear trend

Data

- HSAF H10 Snow Mask product

- ERA5 Land Snow Depth (>5cm) product

Mean Snow Depth (cm) for February 2015

- ERA5 Land Temperature product (2011-2022)

Mean 2m temperature for February 2019 from ERA5-Land

- ERA5 Land Runoff product (2011-2022)

Mean Runoff (cm) for February 2015
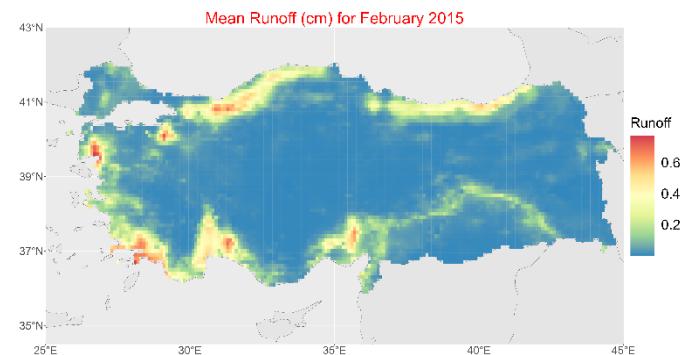
- Hourly Data
- 1950 - Today
- Projection: EPSG / WGS 84
- Spatial Res.: 0.1° x 0.1° (~ 9 km)
- Format: NetCDF

Muñoz-Sabater, J., Dutra, E., Agustí-Panareda, A., Albergel, C., Arduini, G., Balsamo, G., Boussetta, S., Choulga, M., Harrigan, S., Hersbach, H., Martens, B., Miralles, D. G., Piles, M., Rodríguez-Fernández, N. J., Zsoter, E., Buontempo, C., & Thépaut, J. N. (2021). ERA5-Land: A state-of-the-art global reanalysis dataset for land applications. *Earth System Science Data*, 13(9), 4349-4383.

EUMETSAT H10 Snow Product

H10 Snow detection (snow mask) by VIS/IR radiometry 20230129
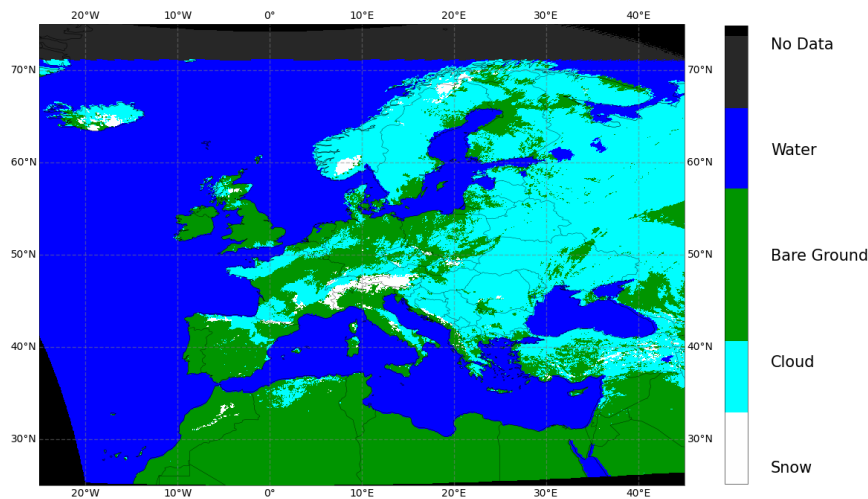
H34 Snow detection (snow mask) by VIS/IR radiometry 20230129
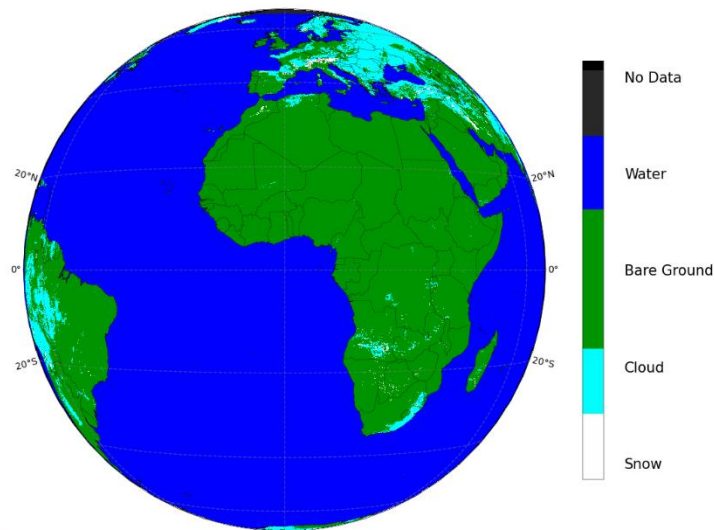
- Cycle: Daily
- Coverage: Europe, Northern Africa, Middle East Grid/Projection: Part of Meteosat/SEVIRI 0° fulldisk, GEOS projection
- Resolution: Variable from 3 km to 10 km, depending on distance from sub-satellite point
- Available since December 2008
- Validation with ground observations and Sentinel data continues
- It will be superseded by H34
- Formats: HDF5, PNG quicklook
- Operational status: **H10 Operational, H34 Pre-operational**

EUMETSAT H10 Snow Product

Continuous Validation
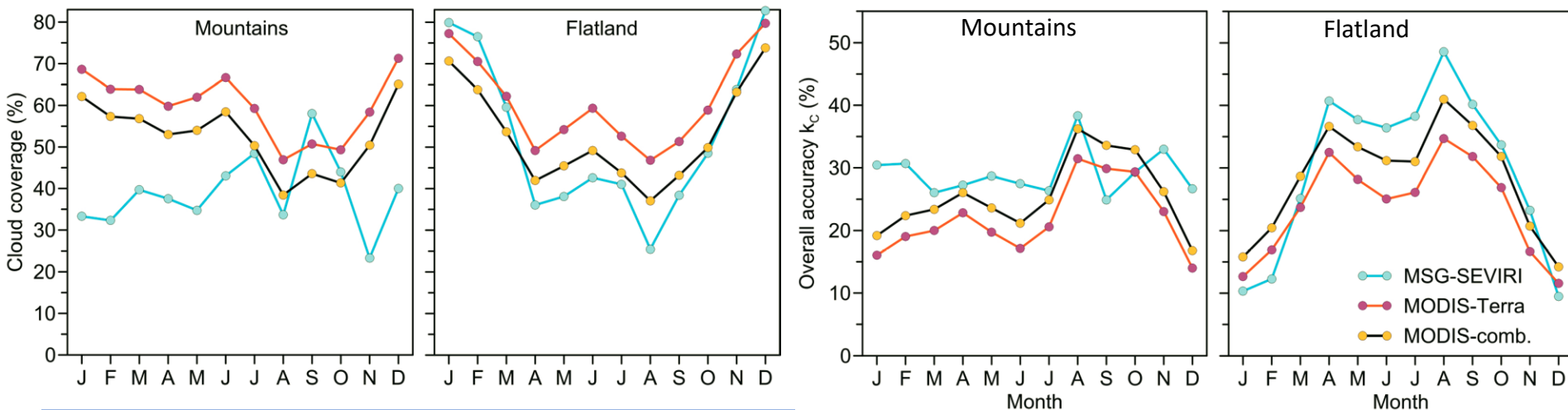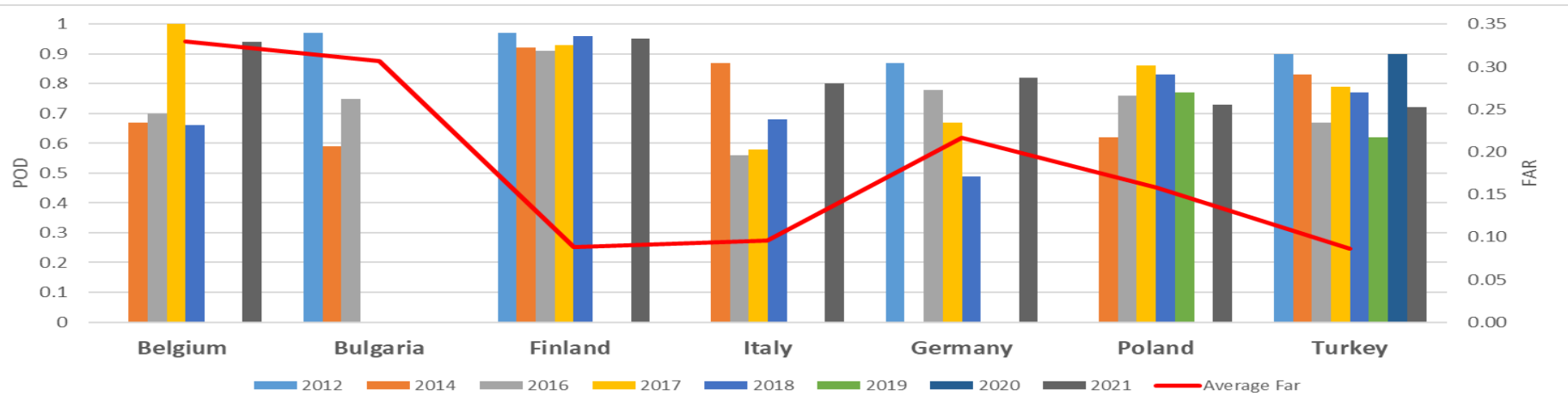
Sürer, S., J. Parajka, and Z. Akyurek, "Validation of the operational MSG-SEVIRI snow cover product over Austria", Hydrol. Earth Syst. Sci. 18, 763–774, 2014

Methodology

- Cloud Filtering
- Anomaly Calculation
  - In Snow cover days (2022 January, February, March, 2011-2022 long term))
  - In Temperature
  - In Runoff and Discharge

$$\text{\textbf{\textit{Anomaly=}}} \frac{SCD_{\text{day/month\_2022}} - \overline{SCD}_{\text{day/month\_longterm}}}{std\_SCD_{\text{day/month\_longterm}}}$$

- Statistical Metrics

Confusion matrix for remote sensing image vs. in situ observations.

Sum of station-pixels	Image: snow	Image: no snow	Image: cloud
Ground: snow	a	b	e
Ground: no Snow	c	d	f

$$IU = \frac{b}{a+b+c+d}$$

$$IO = \frac{c}{a+b+c+d}$$

$$O_a = \frac{a+d}{a+b+c+d+e+f}$$

$$S_a = \frac{a}{a+b+e}$$

Image Underestimation: Image misclassification of snow as land
Image Overestimation: Image misclassification of land as snow
Overall Accuracy & Snow Accuracy under all-sky conditions

Cloud Filtering

Cloud Cover Days (%) (mean monthly values for 2012-2021)

Limited illumination above certain latitudes

Temporal moving window is applied.

Weiss, D. J., Atkinson, P. M., Bhatt, S., Mappin, B., Hay, S. I., & Gething, P. W. (2014). An effective approach for gap-filling continental scale remotely sensed time-series. *ISPRS Journal of Photogrammetry and Remote Sensing*, 98, 106-118.
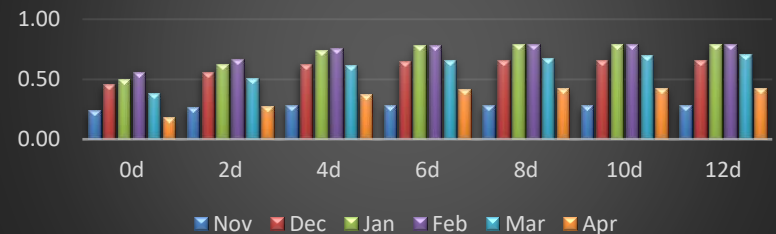
Cloud Filtering

Cloud Filtering

6 days moving window is applied.
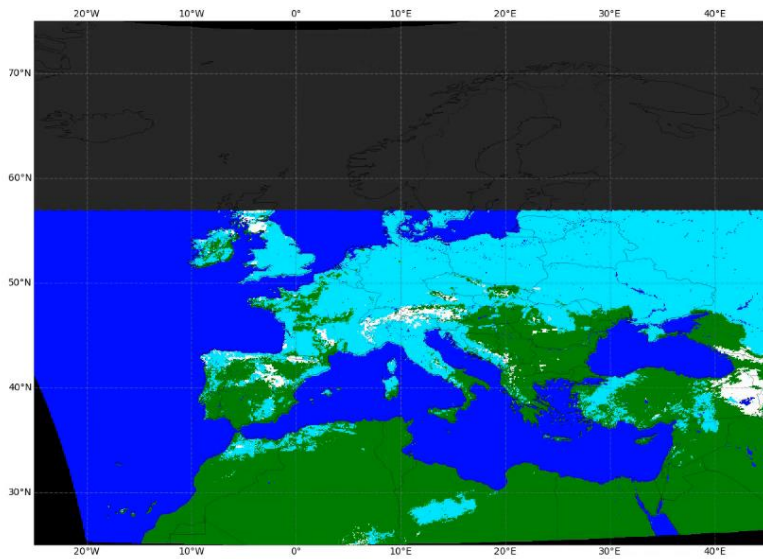
Anomaly Calculation
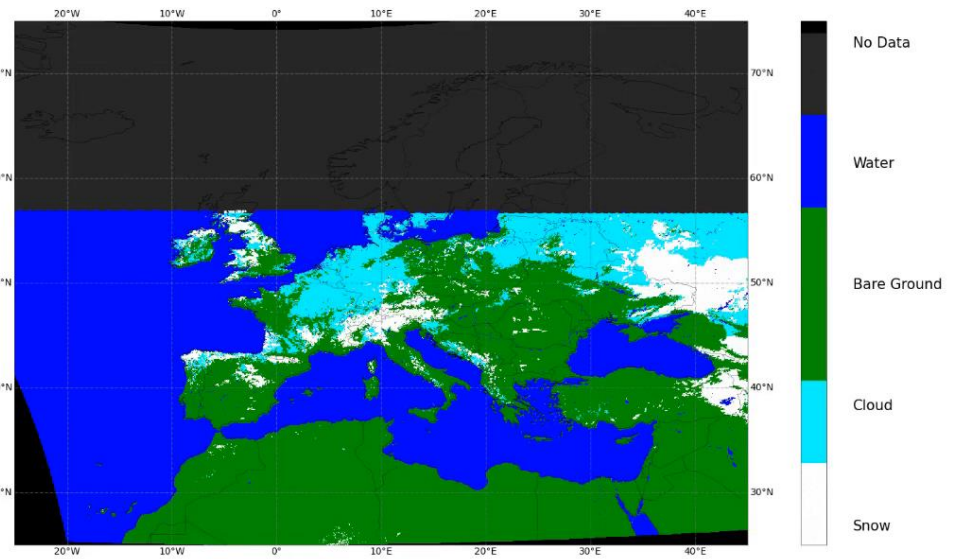
$$\frac{SC_{day} - \overline{SC_{day}}}{SC_{day,std}}$$

Snow Cover Anomaly - January 2022

Near Surface Air Temperature Anomaly - January 2022
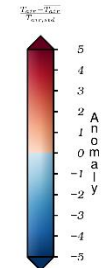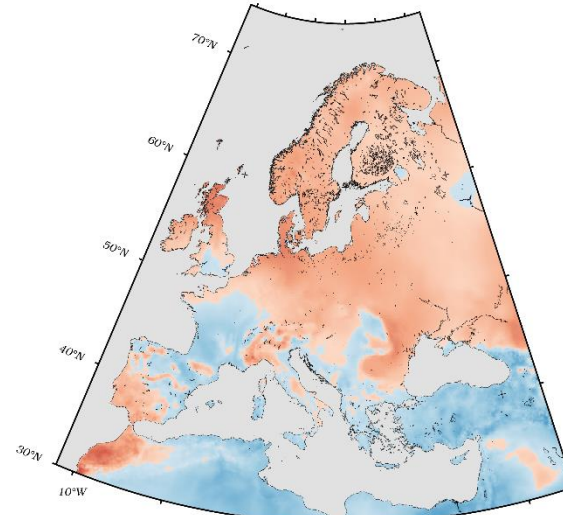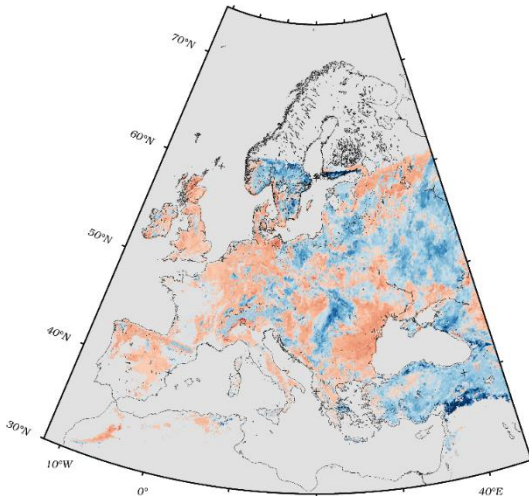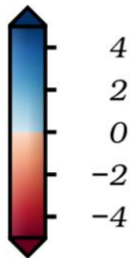
Snow Cover Anomaly - February 2022

Near Surface Air Temperature Anomaly - February 2022
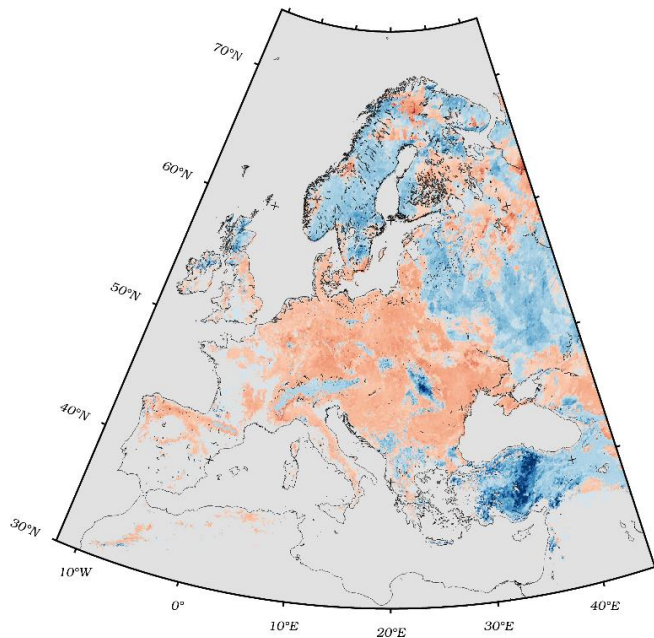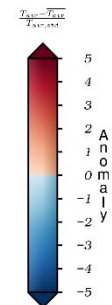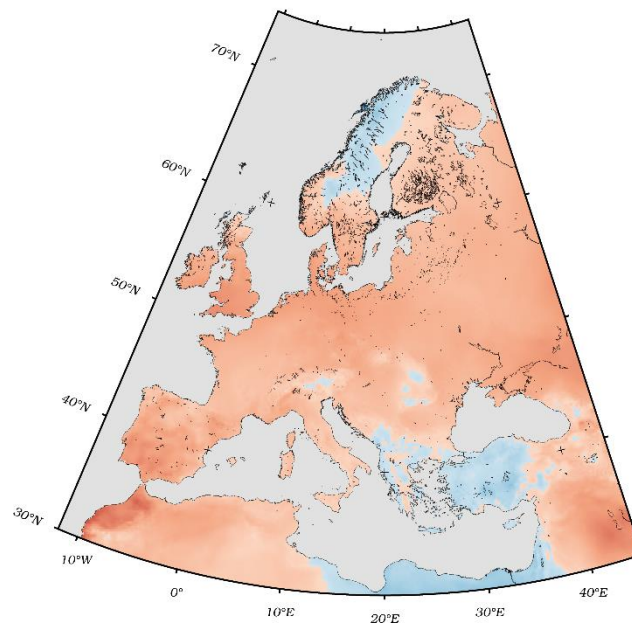
Anomaly Calculation

$$\cdot\frac{SC_{day} - \overline{SC_{day}}}{SC_{day,std}}$$
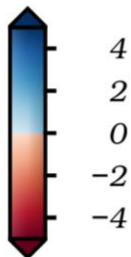
Snow Cover Anomaly - March 2022
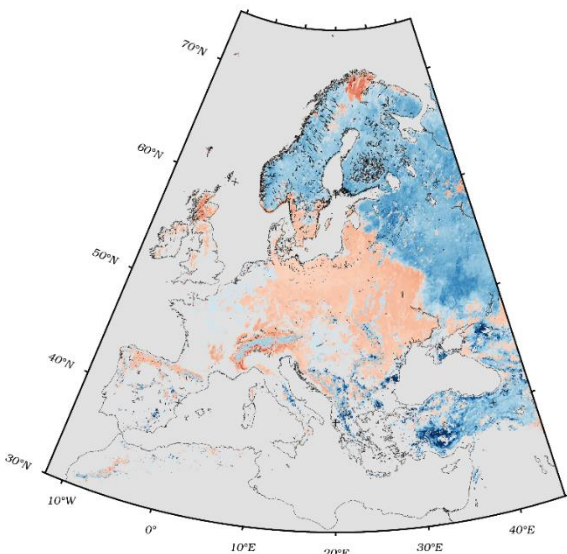
Near Surface Air Temperature Anomaly - March 2022
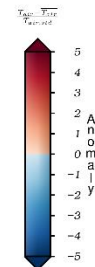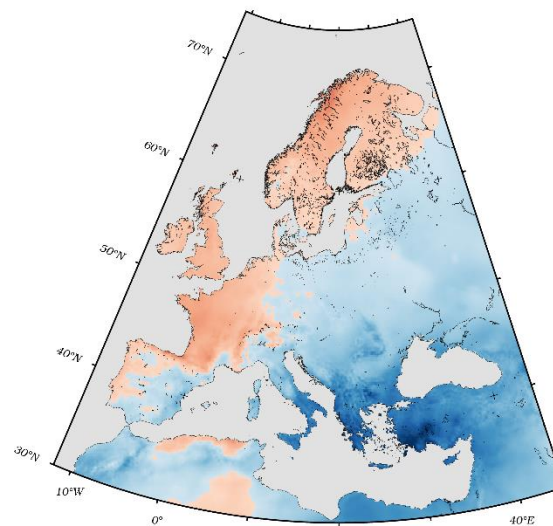
Snow Cover Anomaly - April 2022
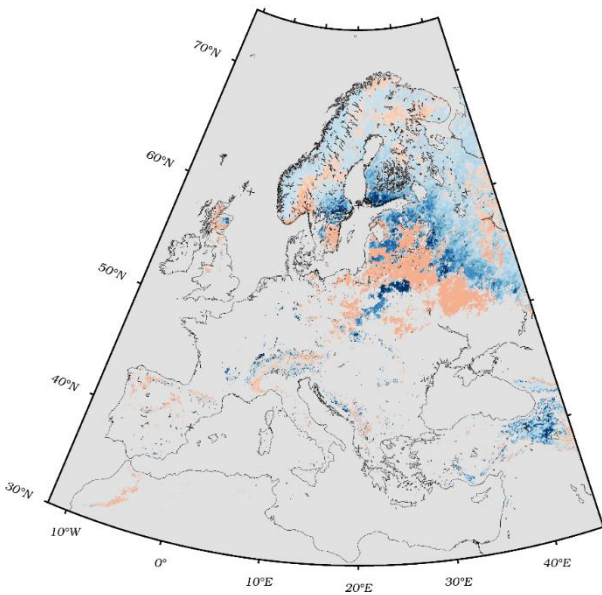
Near Surface Air Temperature Anomaly - April 2022
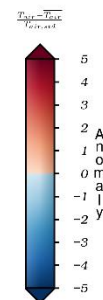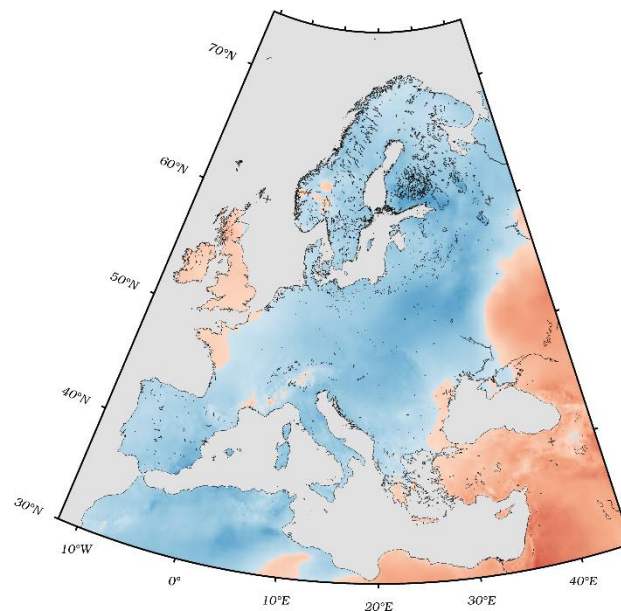
Snow Covered Day and Runoff Anomaly

Snow Anomaly
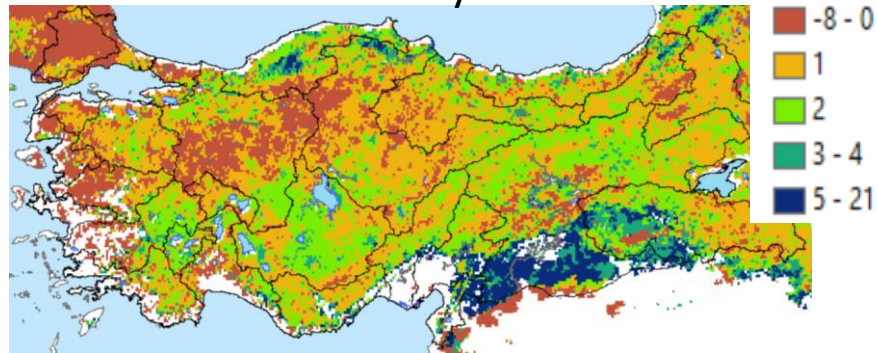
Runoff Anomaly
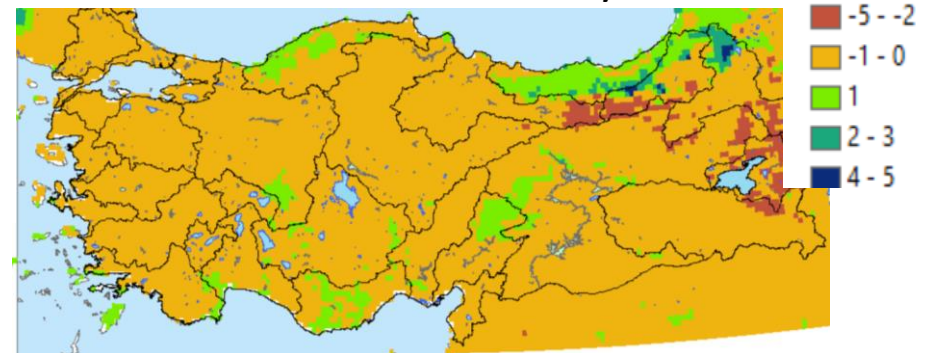
January 2022
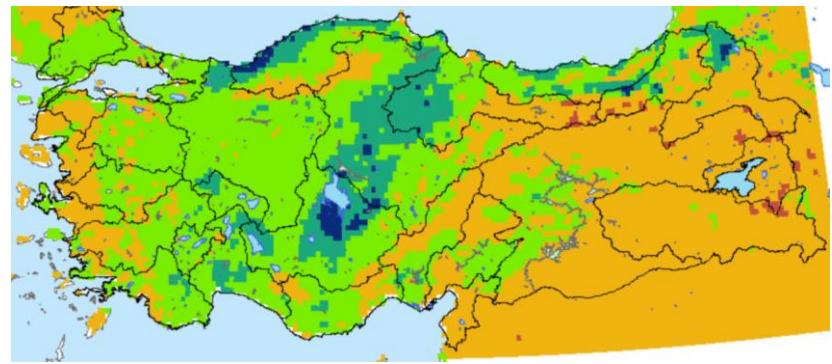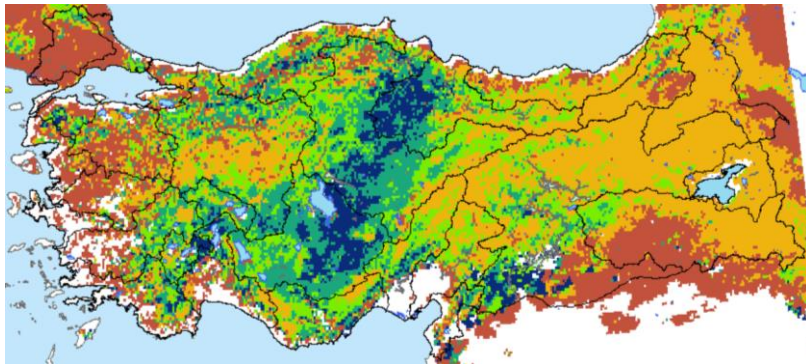
February 2022
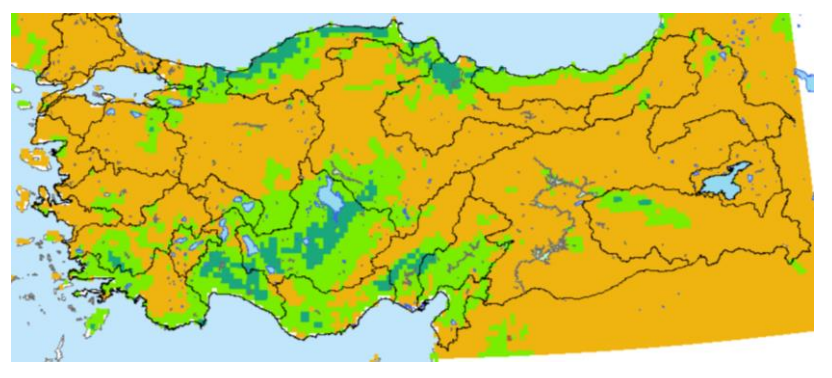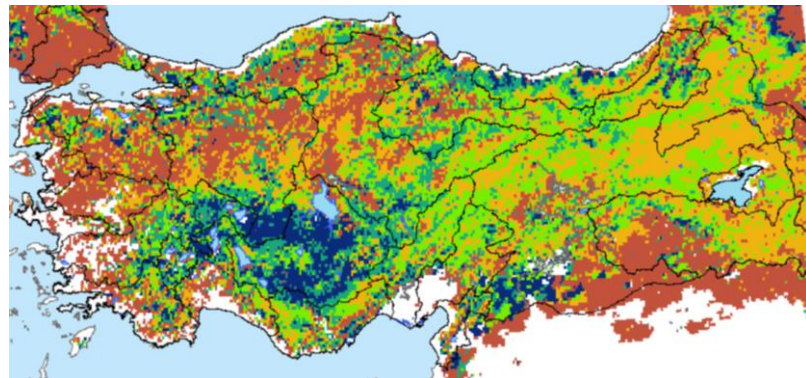
March 2022

Runoff Anomaly
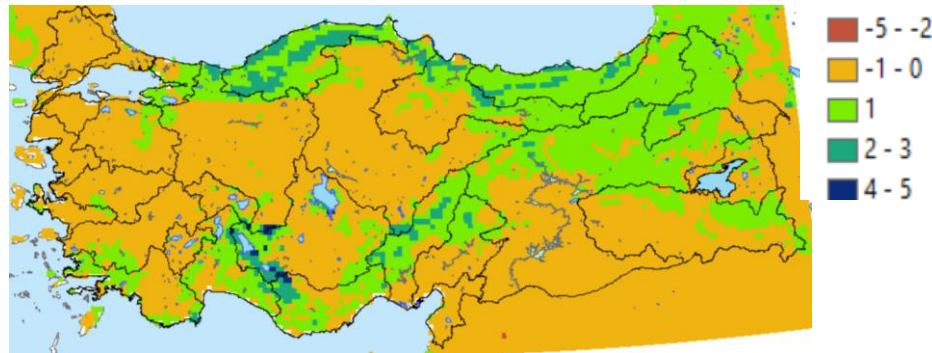
April 2022

May 2022

Legend:
- -5 – -2
- -1 – 0
- 1
- 2 – 3
- 4 – 5
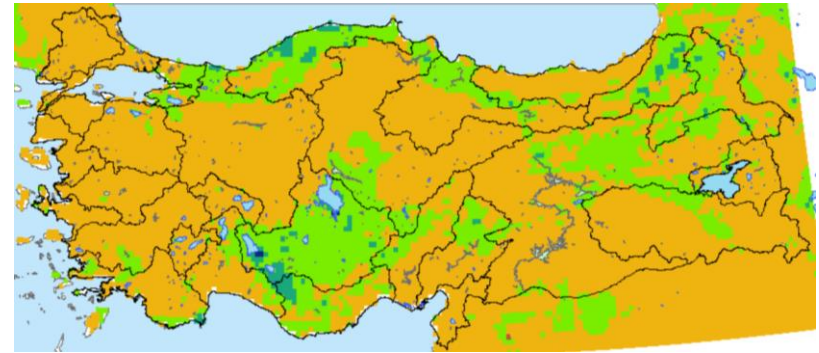
- Runoff values from ERA5 Land product is the summation of sub-surface and surface runoff in cm.
- Subsurface water fluxes are determined by Darcy's law. The surface runoff is obtained by the Hortonian runoff formulation.

Discharge Anomalies at basin scale

E11A002
361 km2

E13A019
786 km2

D14A177
11 806 km2

E21A019
10 356 km2

E11A008
790 km2

E15A017
8 592 km2
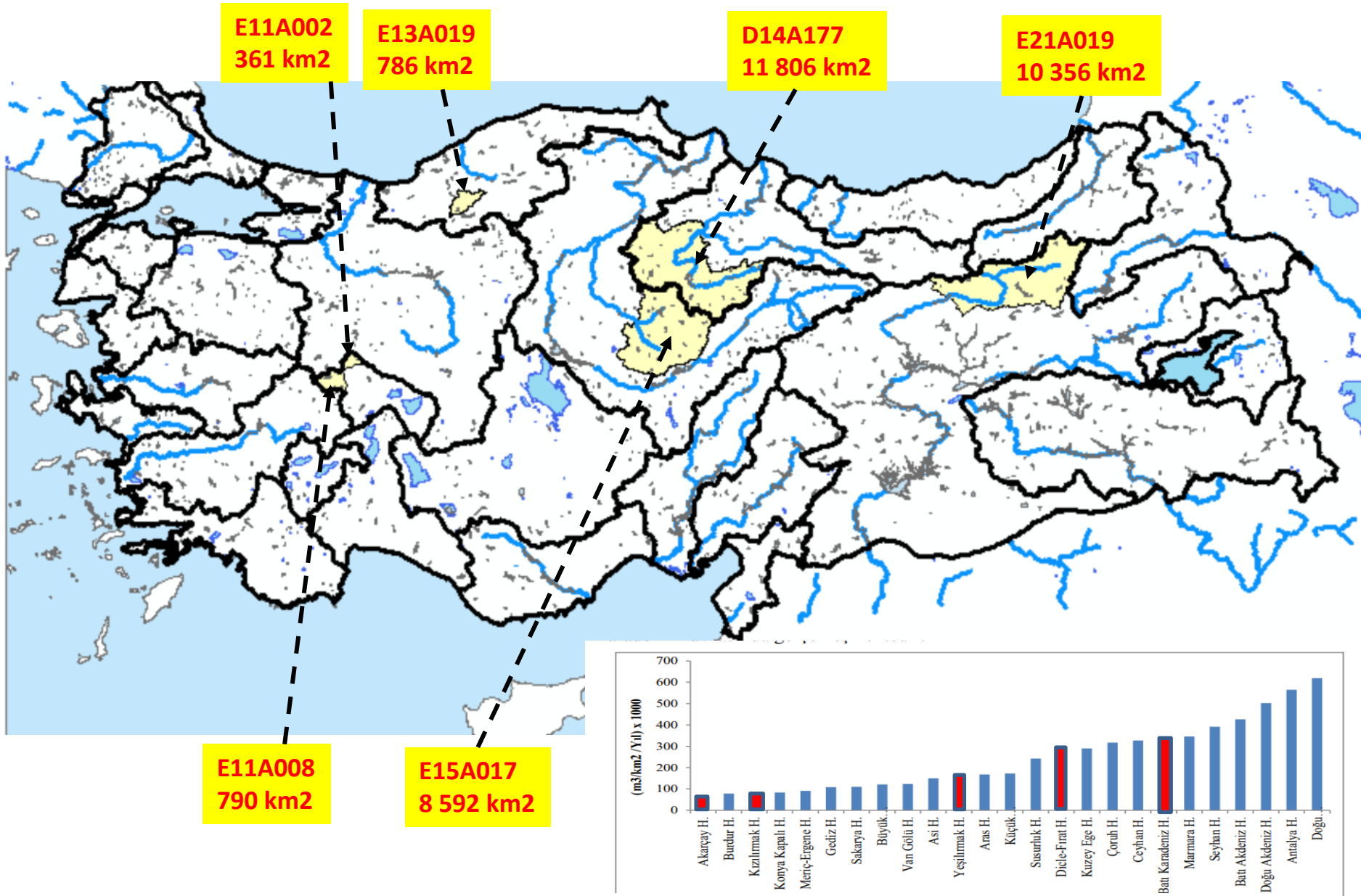
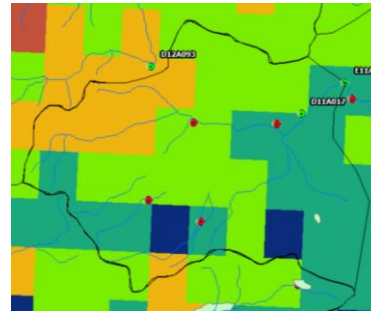Catchment Yields (m3/km2)x 1000

Discharge Anomalies at basin scale

Snow Cover Area (H10) Anomalies

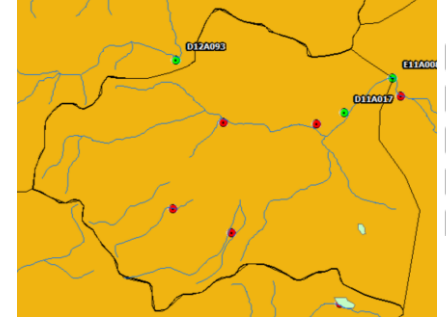Jan 2022   Feb 2022   March 2022   April 2022

Legend: -8 - 0, 1, 2, 3 - 4, 5 - 21

Legend: -5 - -2, -1 - 0, 1, 2 - 3, 4 - 5
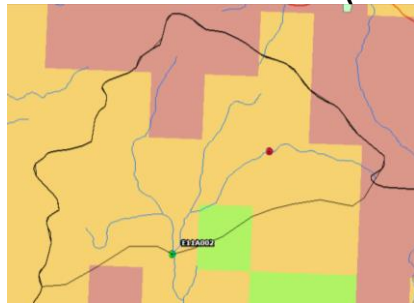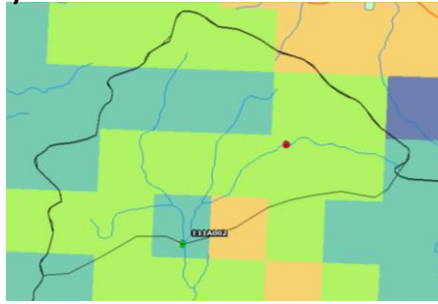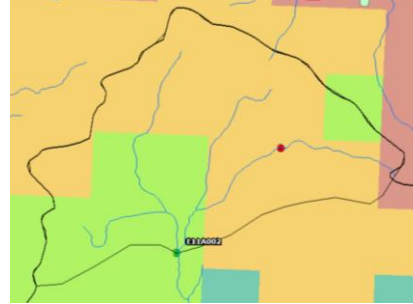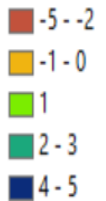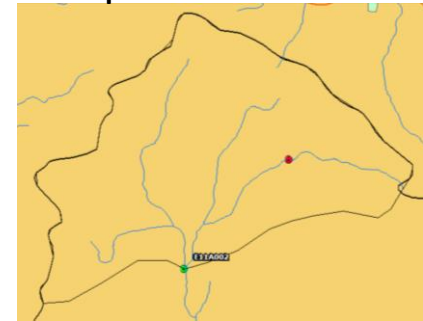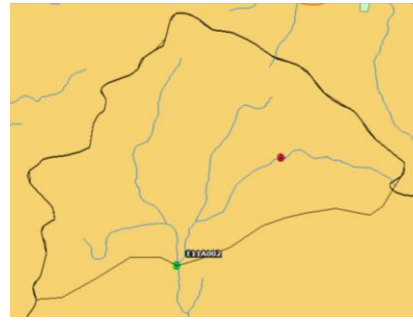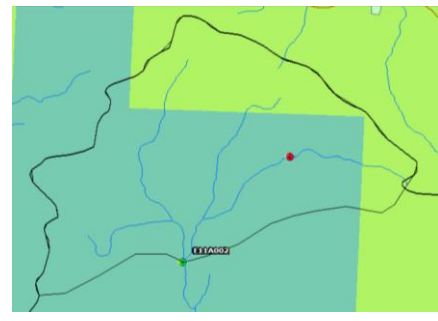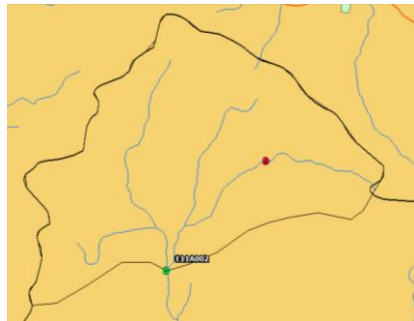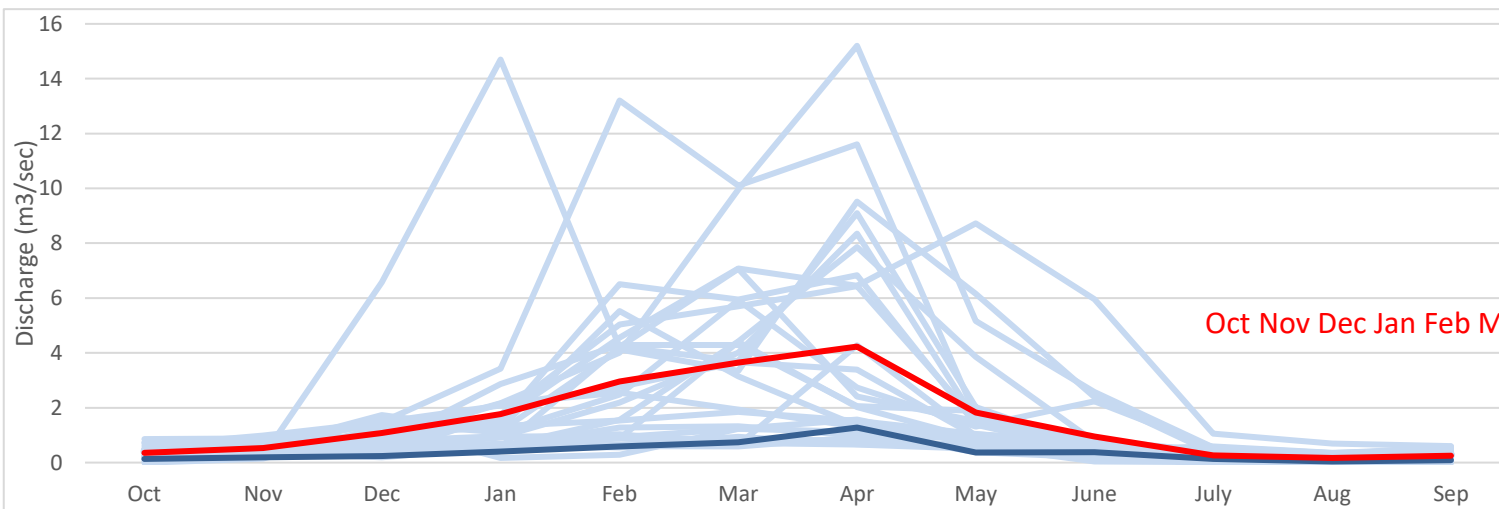
ERA5 Land Runoff Anomalies
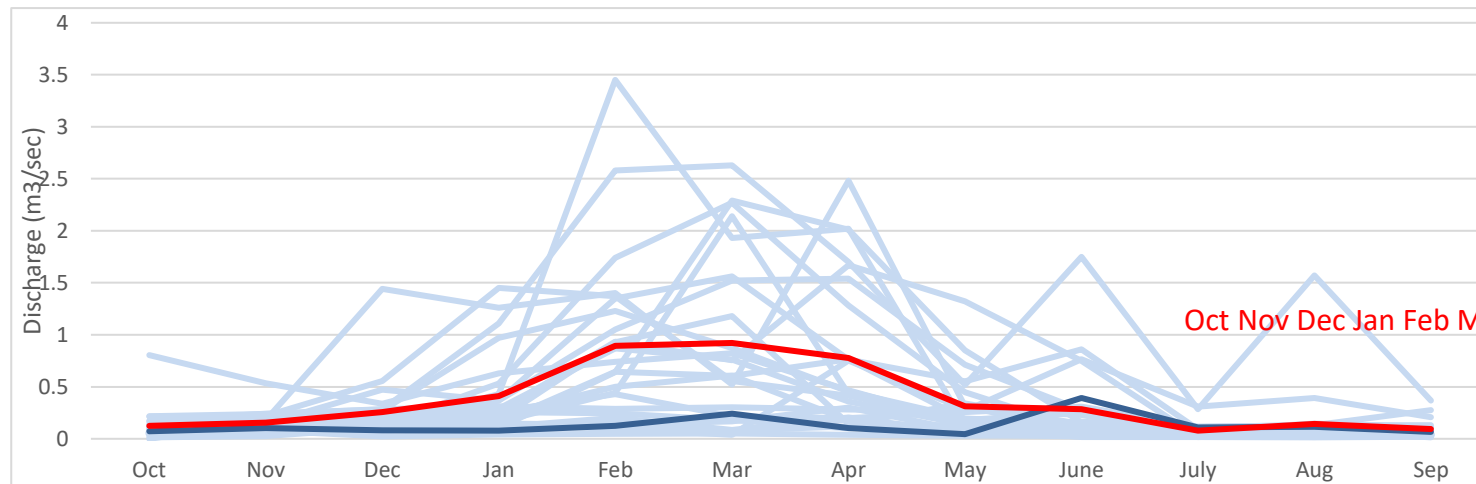
E11A002 Basin A= 360.8 km2
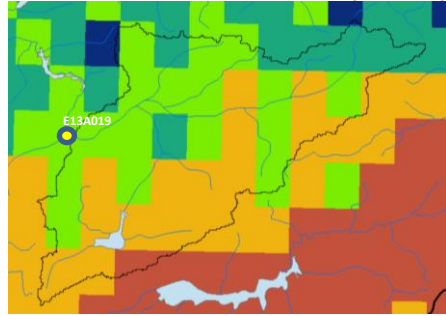Altitude= 1049 m

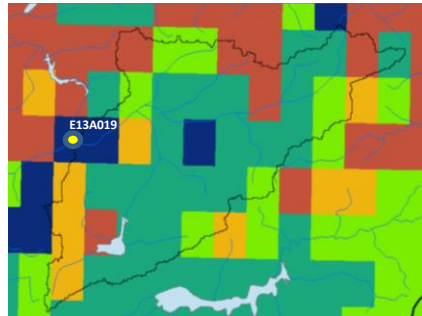1996-2021
2022
Long term Average

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

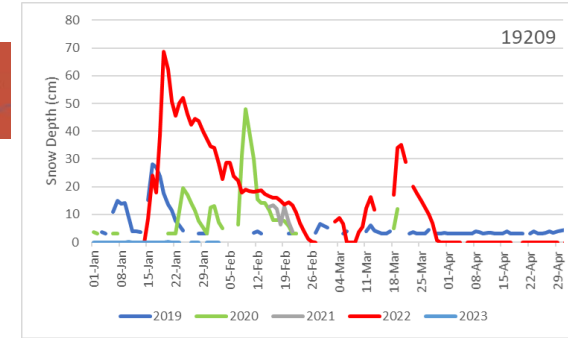# Discharge Anomalies at basin scale

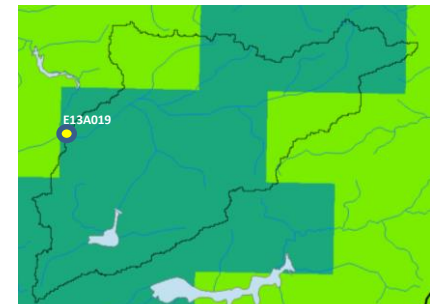## Snow Cover Area (H10) Anomalies

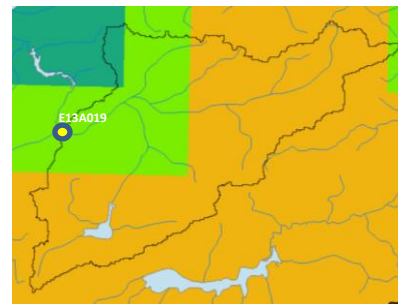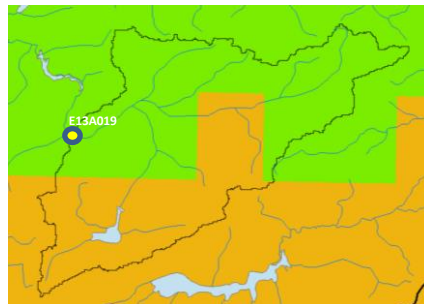Jan 2022 Feb 2022 March 2022 April 2022

Legend:
- -8 – 0
- 1
- 2
- 3 – 4
- 5 – 21

Legend:
- -5 – -2
- -1 – 0
- 1
- 2 – 3
- 4 – 5
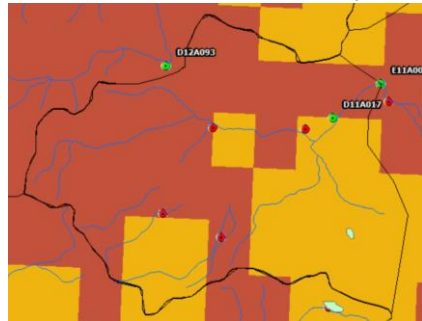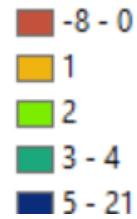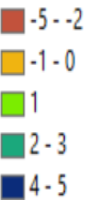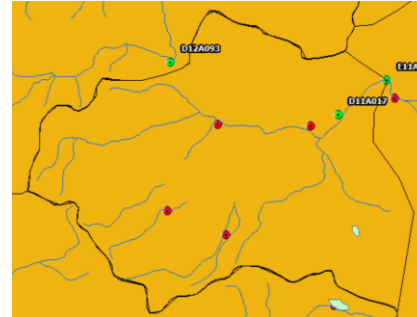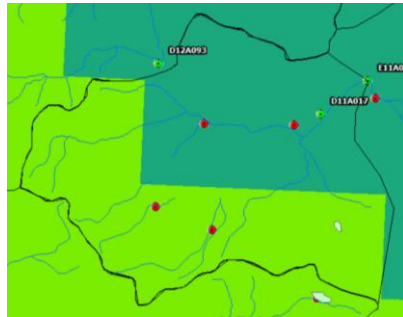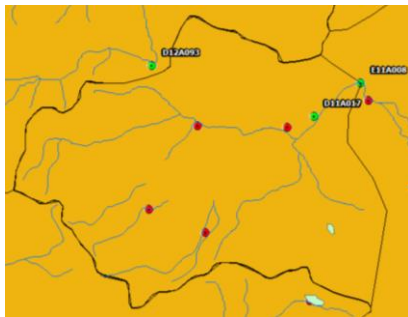
ERA5 Land Runoff Anomalies

E11A008 Basin A= 789.5 km2
Altitude= 1028 m

1996-2021
2022
Long term Average

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

Discharge Anomalies at basin scale

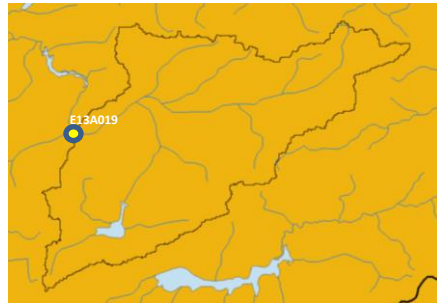## Snow Cover Area (H10) Anomalies
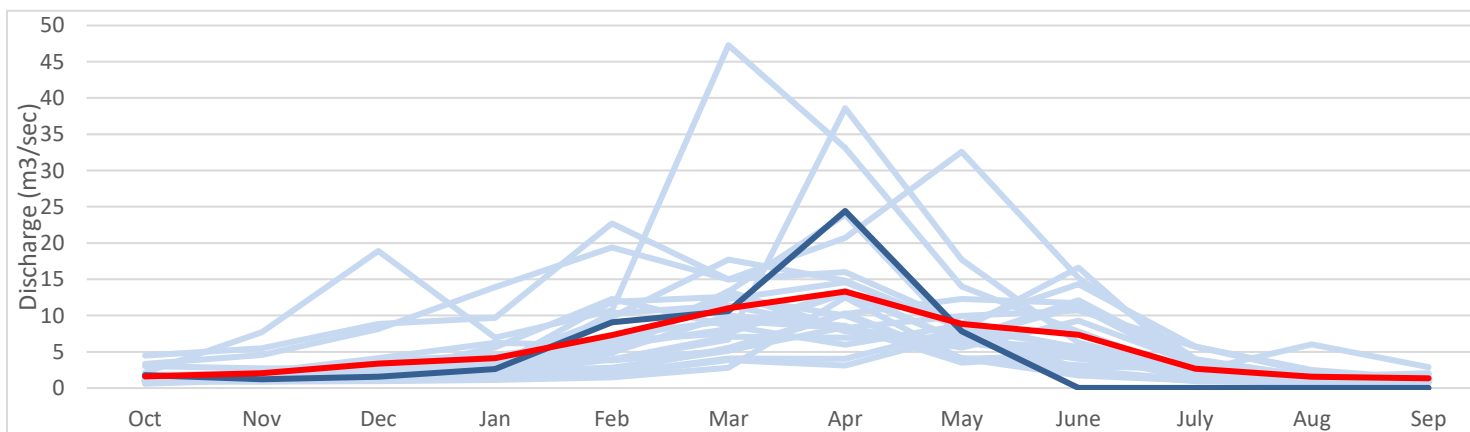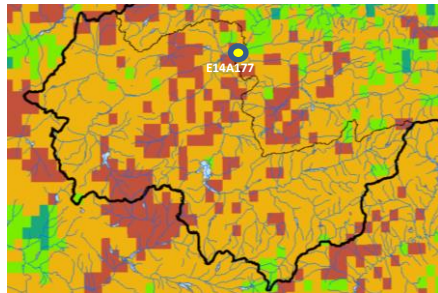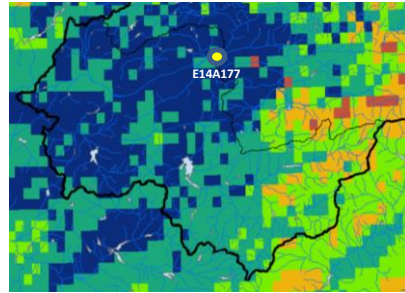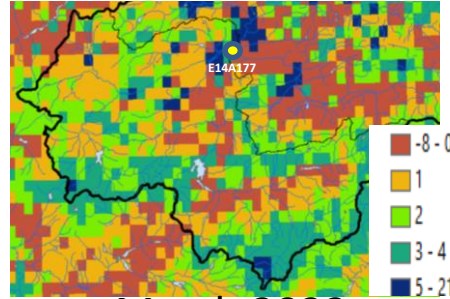

Jan 2022 Feb 2022 March 2022 April 2022

ERA5 Land Runoff Anomalies

E13A019 Basin A= 786 km2
Altitude= 507 m

1996-2021
2022
Long term Average

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

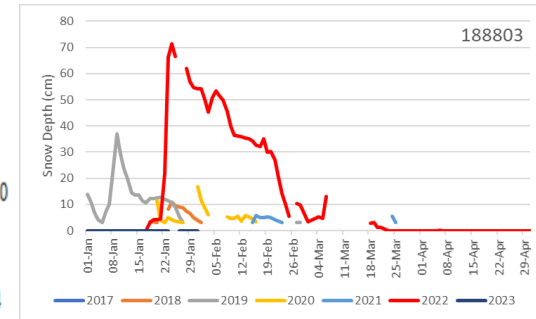# Discharge Anomalies at basin scale

Snow Cover Area (H10) Anomalies

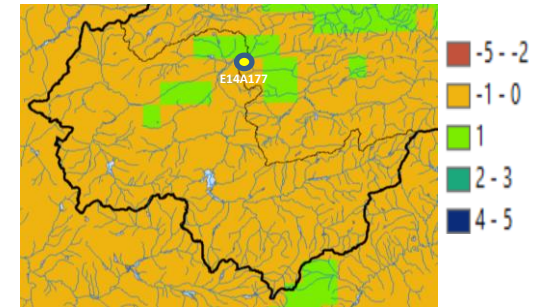Jan 2022   Feb 2022   March 2022   April 2022

ERA5 Land Runoff Anomalies

D14A177 Basin A= 11 806 km2
Altitude= 414 m

2010-2021
2022
Long term Average

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

Discharge Anomalies at basin scale
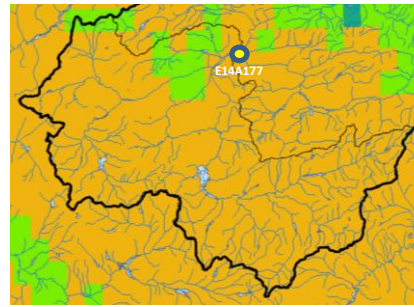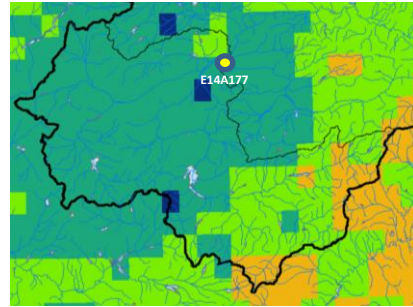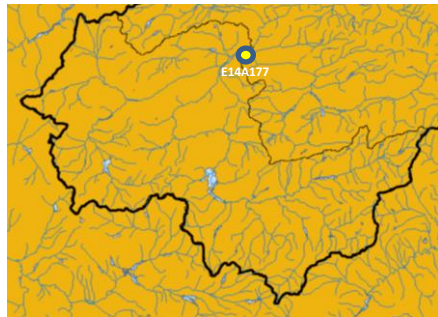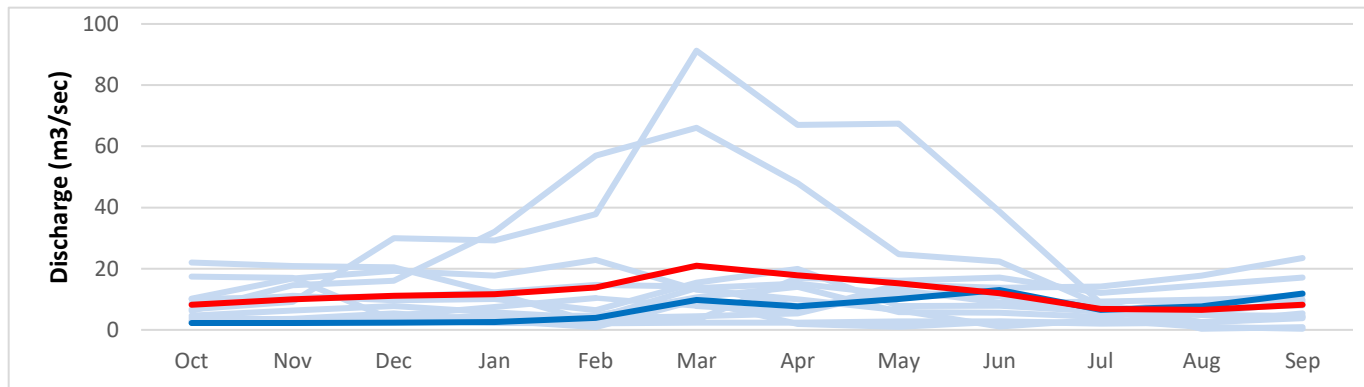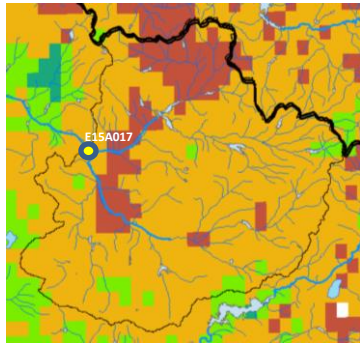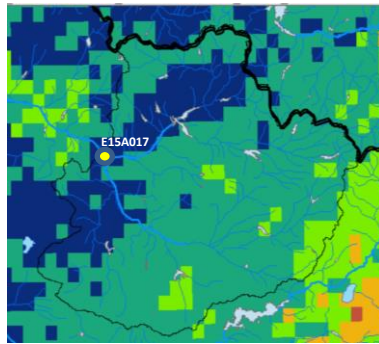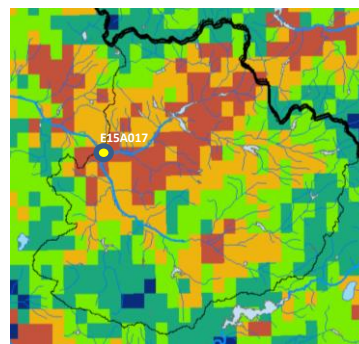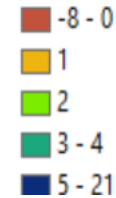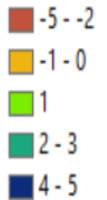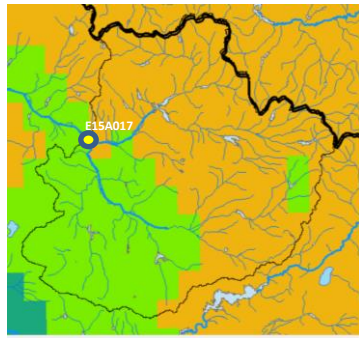
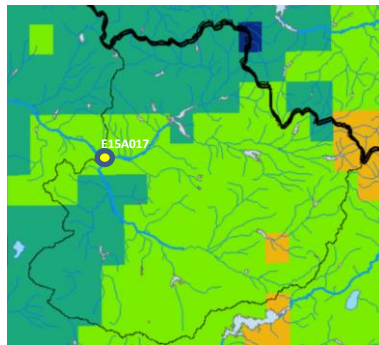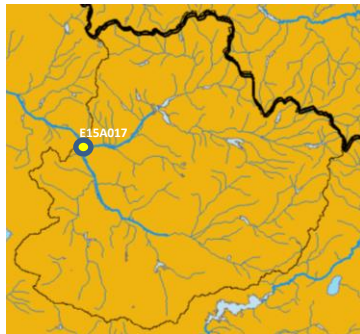Snow Cover Area (H10) Anomalies
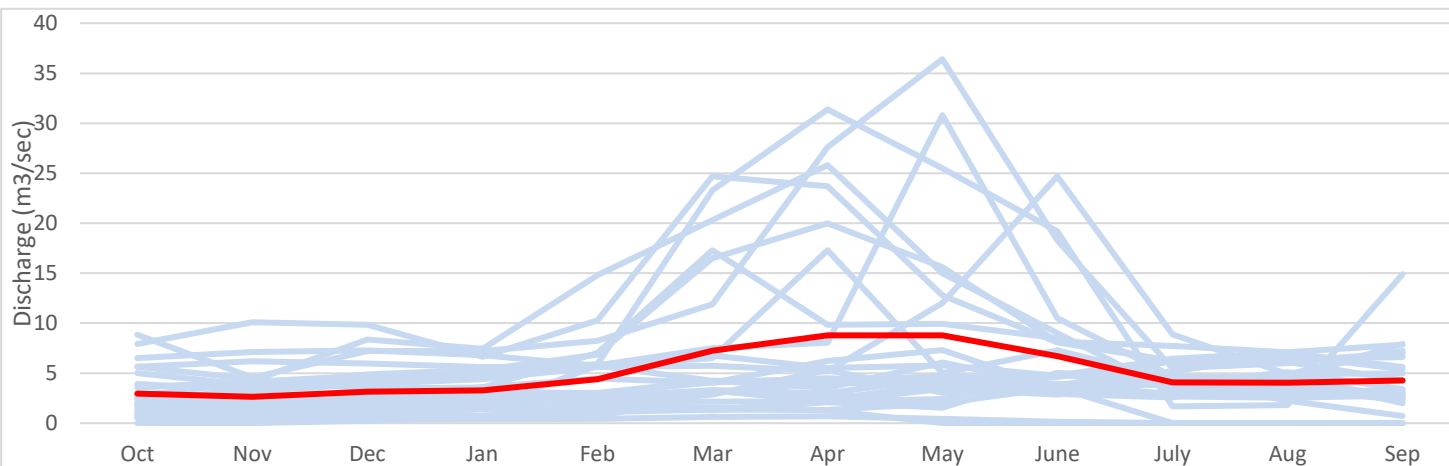

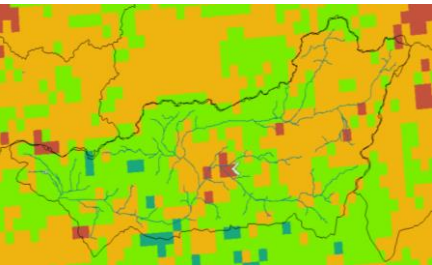Jan 2022 Feb 2022 March 2022 April 2022

ERA5 Land Runoff Anomalies
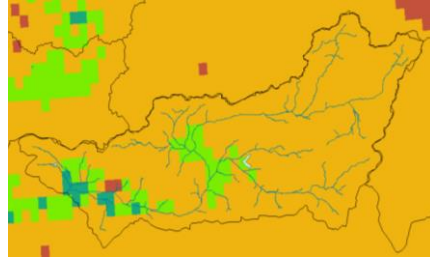

E15A017 Basin A= 8 592.4km2
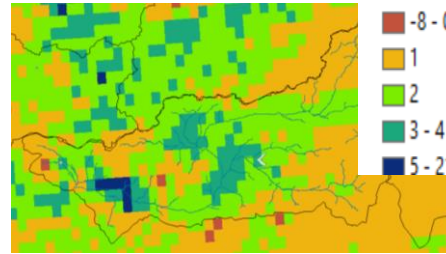Altitude= 895 m

1996-2021
Long term Average

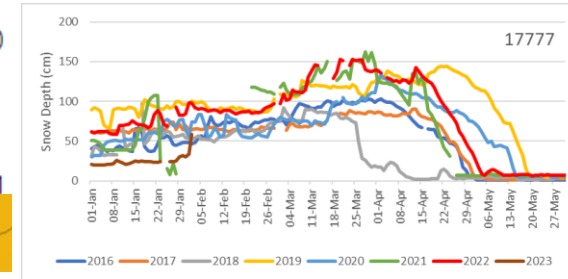# Discharge Anomalies at basin scale

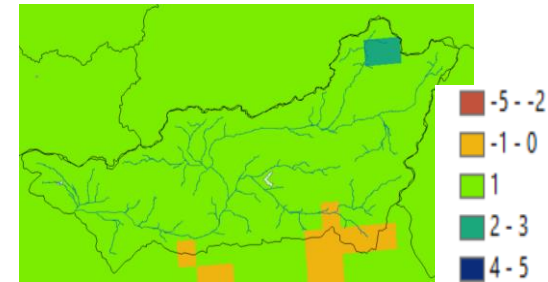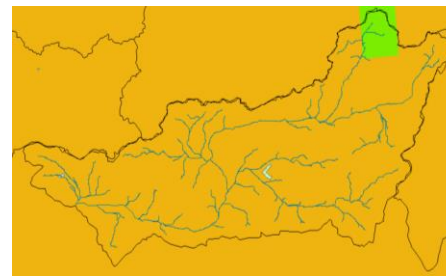## Snow Cover Area (H10) Anomalies

Jan 2022   Feb 2022   March 2022   April 2022
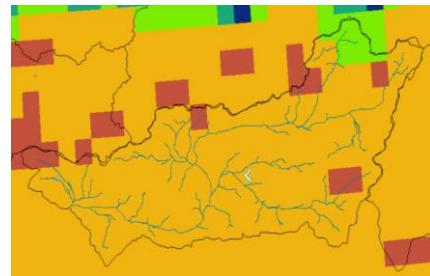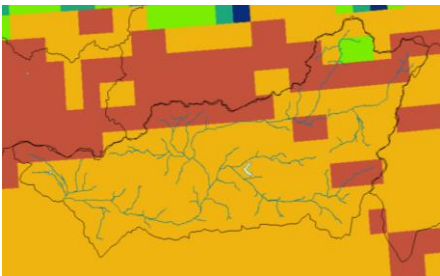
ERA5 Land Runoff Anomalies

E21A019 Basin A= 10 356 km2
Altitude= 1123 m

1996-2021
Long term Average
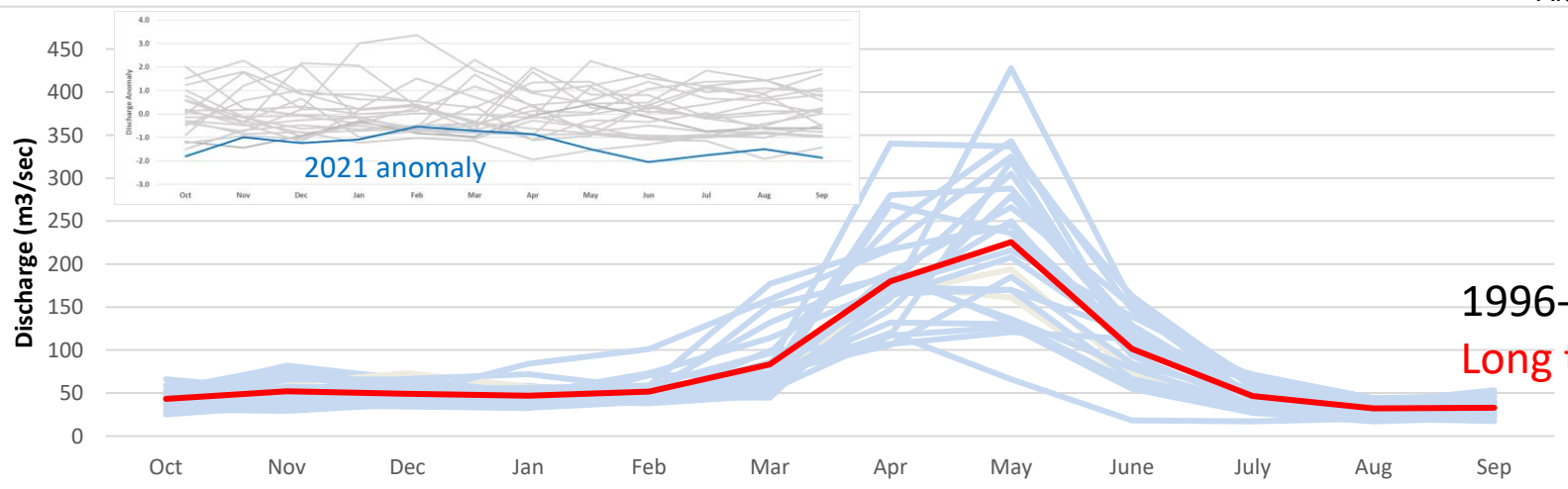
Discussions

- HSAF H10 Snow Mask by VIS/IR radiometry product presents the snow anomalies well.

- 6 days moving window gives the highest overall accuracy for 2019-2021 compared to the ground observations.

- Positive Snow Covered Day anomalies did not cause positive anomaly in discharge in many of the basins.

- The ERA5 Land Runoff anomalies are consistent with the snow covered day anomalies.

- No direct access to river discharges, however LISFLOOD can be utilized for this purpose (Muñoz-Sabater et al, 2021).

- Satellite snow products and Reanalysis products are good to understand the Snow Dynamics over Mountainous Terrains.

Acknowledments

- EUMETSAT HSAF project

- State Water Works DSI