

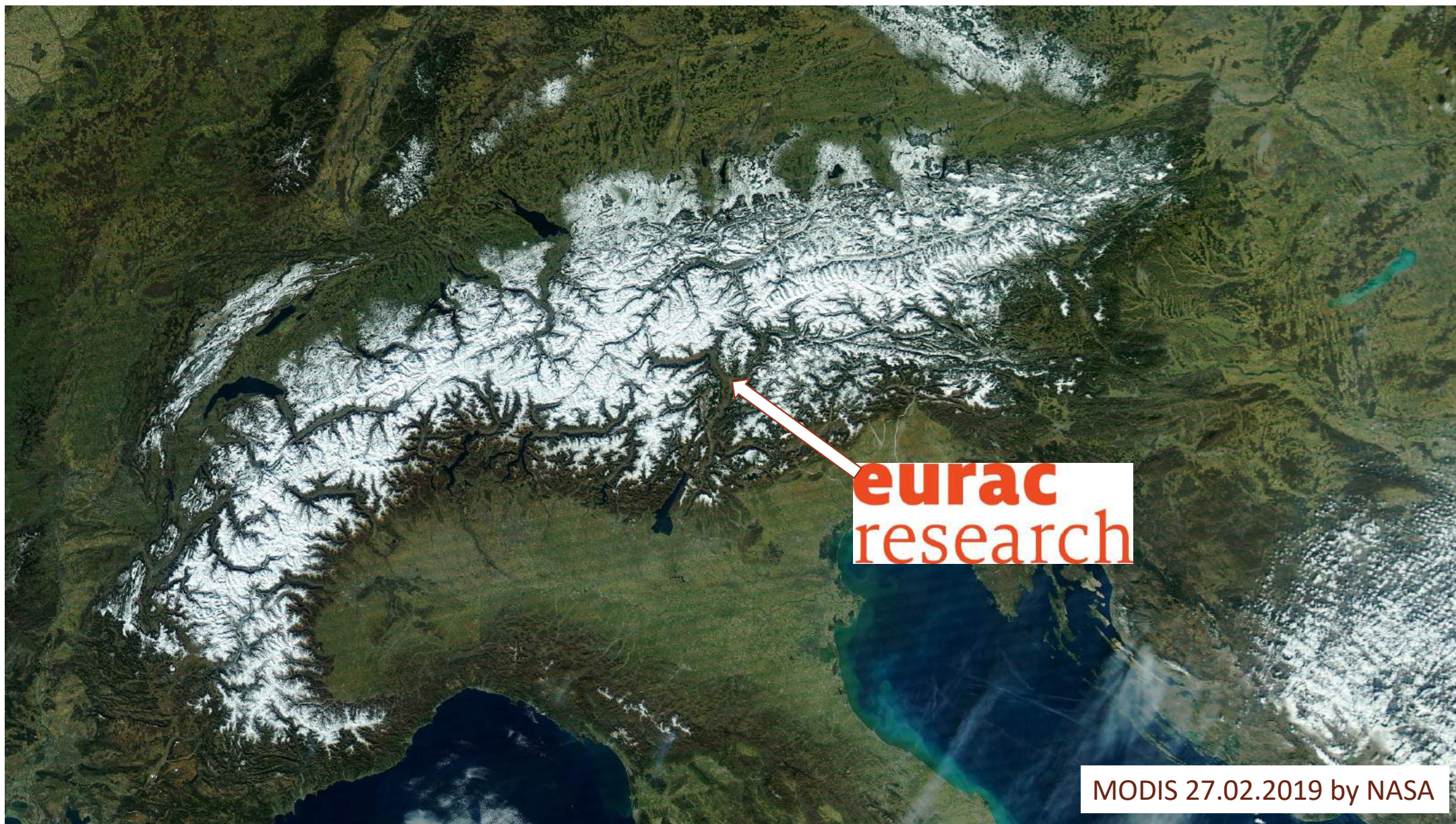
# Earth Observation of cryosphere and mountain hydrology

**Marc Zebisch – presenter**

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Eurac Research - Institute for Earth Observation, Bolzano/Bozen, Italy





MODIS 27.02.2019 by NASA




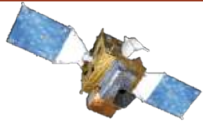



# Copernicus Sentinels – a new Era of EO



NASA Landsat  
1974-today

NASA MODIS  
1999-today

	Name	Main payload for SAO	Spatial Resolution	Temporal Resolution	Description	
	Sentinel 1	C-Band SAR	20 m	6 days	<ul style="list-style-type: none"> <li>Monitoring of cryosphere, Soil Moisture, monitoring c. terrain deformation</li> </ul>	Since 2014
	Sentinel 2	Multispectral 13 (VIS – SWIR)	10/20 m	5 days	<ul style="list-style-type: none"> <li>Monitoring of Cryosphere and Vegetation, information for emergency services</li> </ul>	Since 2015
	Sentinel 3	Multispectral 21 bands (VIS – SWIR)	300 m	1 day	<ul style="list-style-type: none"> <li>monitoring cryosphere, vegetation condition and health</li> </ul>	Since 2016
	Sentinel 4	Meteosat third generation	8 km	Hour	<ul style="list-style-type: none"> <li>monitor key air quality trace gases and aerosols over Europe at high spatial resolution with a fast (hourly) revisit time</li> </ul>	
	Sentinel 5	Hyper-spectral soundings	<8 Km for $\lambda > 300\text{nm}$ ; <50 Km for $\lambda < 300\text{nm}$	1 day	<ul style="list-style-type: none"> <li>monitoring of trace gas concentrations for atmospheric chemistry and climate applications</li> </ul>	

eurac research | Sentinel Alpine Observatory

# Sentinel-2 tiles

UTM Zone 31 UTM Zone 32 UTM Zone 33





2019-02-23



SENTINEL Hub



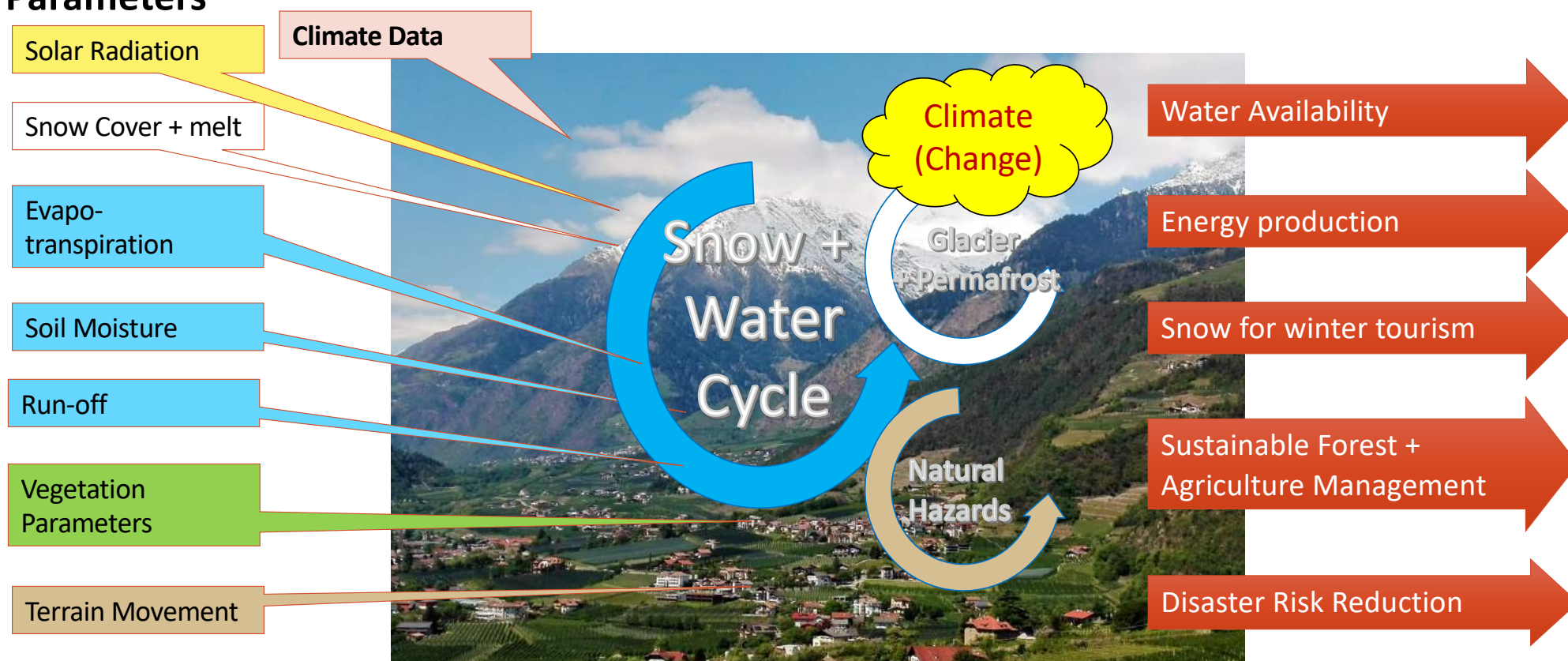


# Mountain hydrology

## EO + in-situ: Essential Environmental Parameters

## Key environmental processes

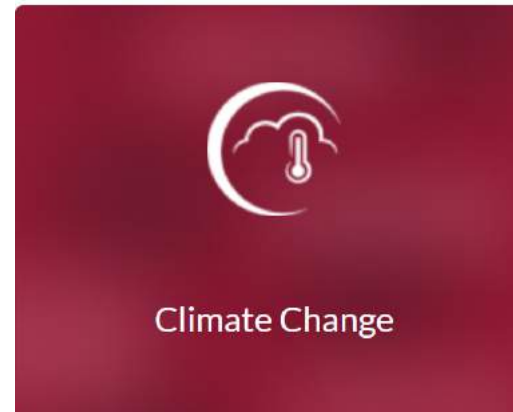
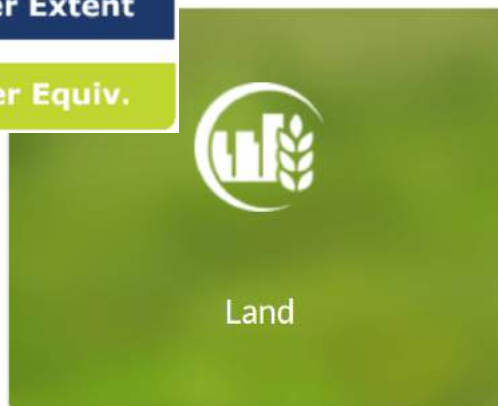
## Societal functions + Challenges



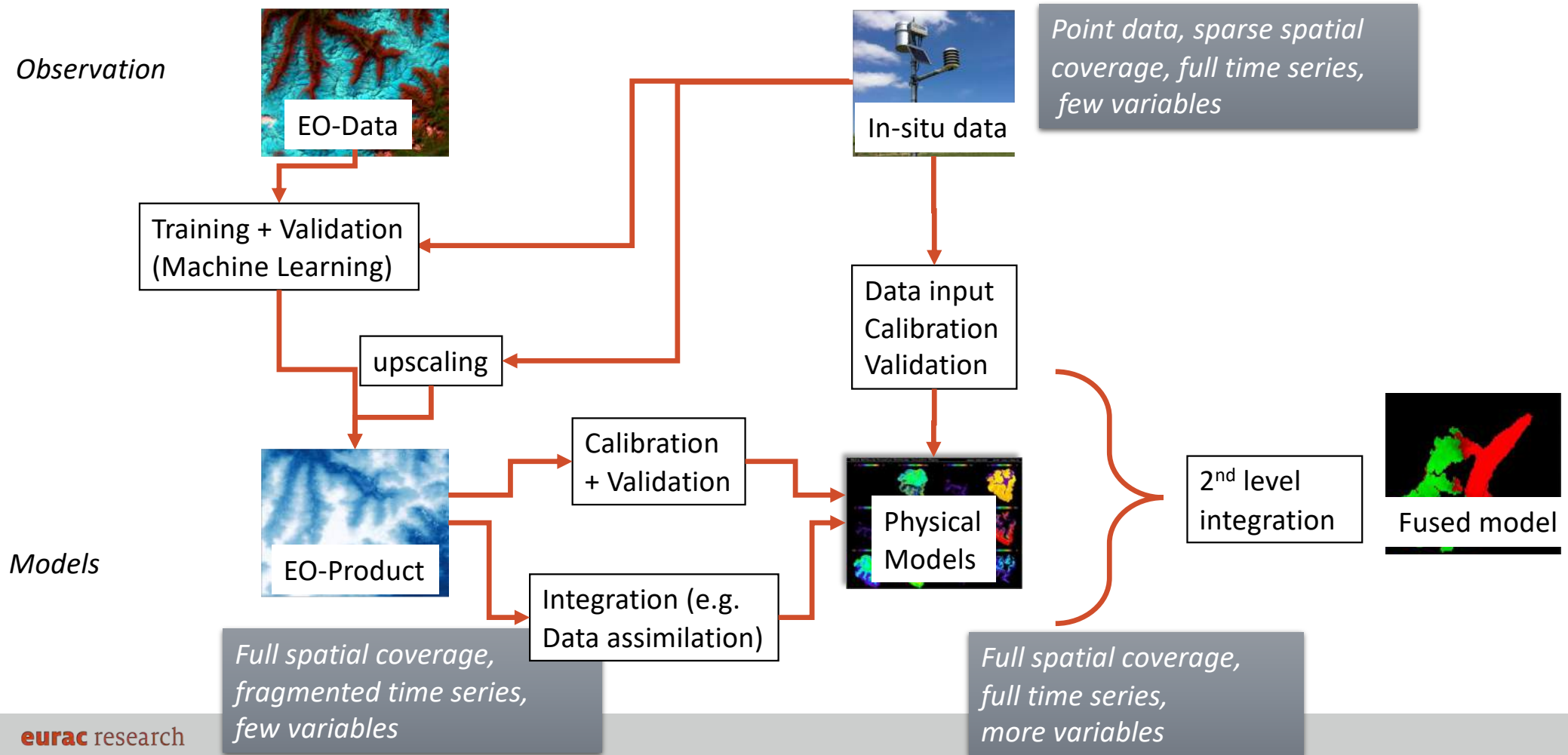
# Global data from ESA CCI and COPERNICUS



+ Geo-Gnome  
the mountain initiative of



# Integration EO, in-situ and models





# **Example 1:**

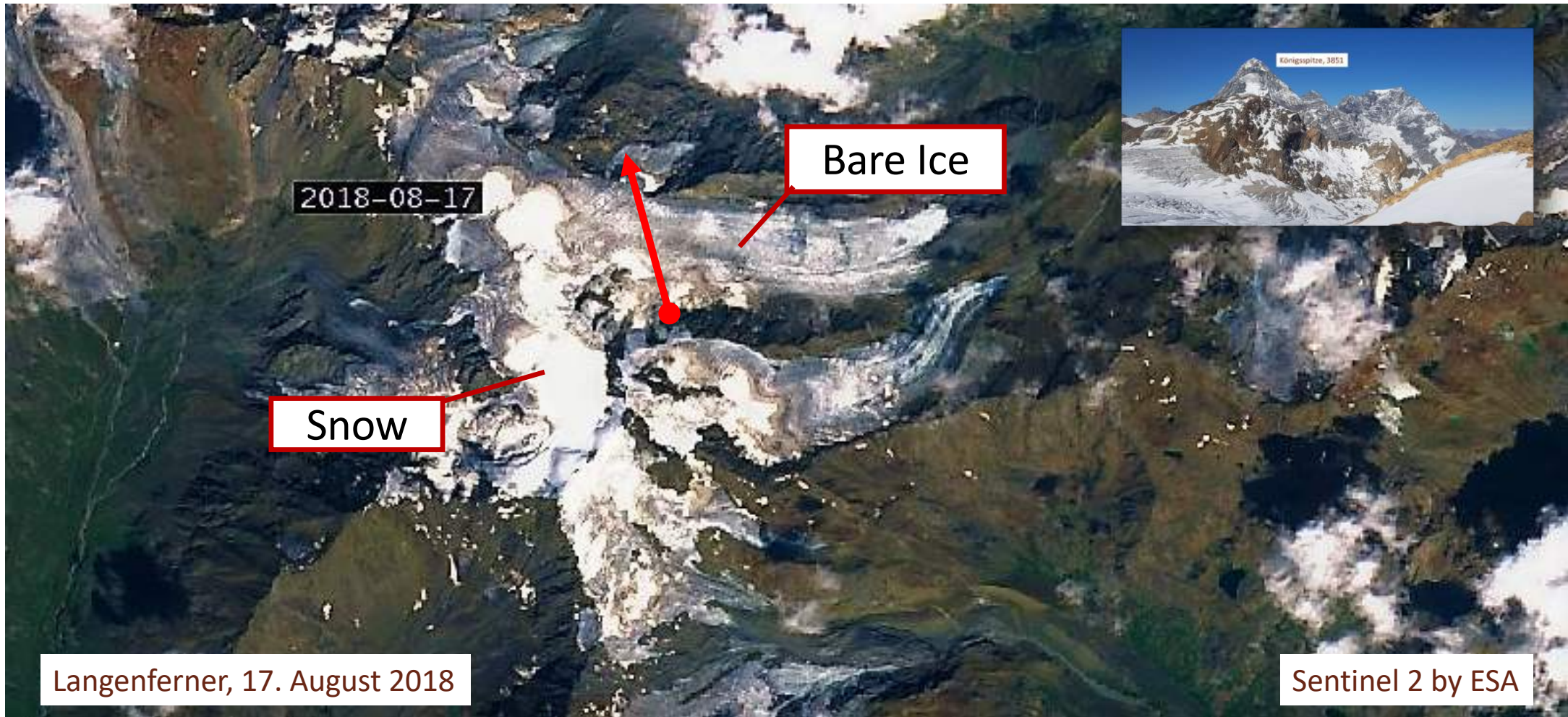
## **Monitoring Glacier outline and mass balance**

# Glaciers without snow cover are melting fast

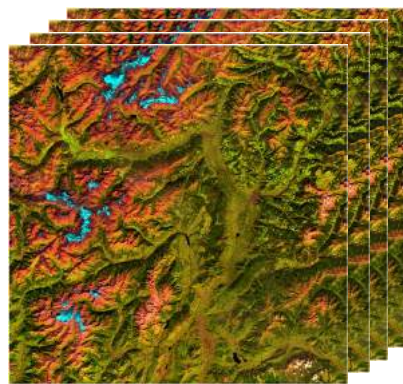




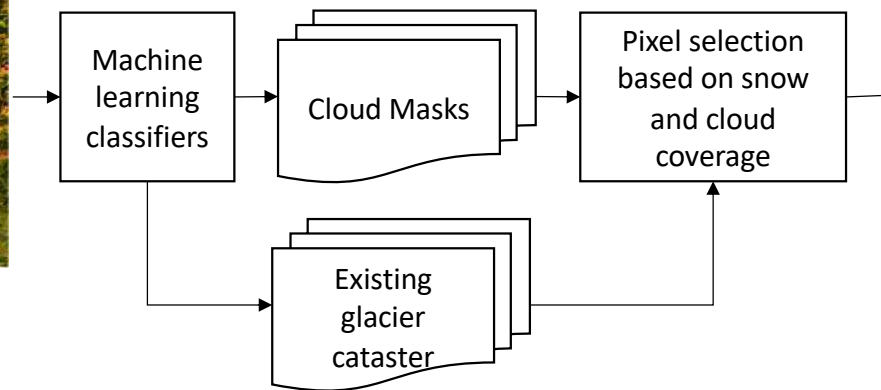
# Glaciers without snow cover are melting fast



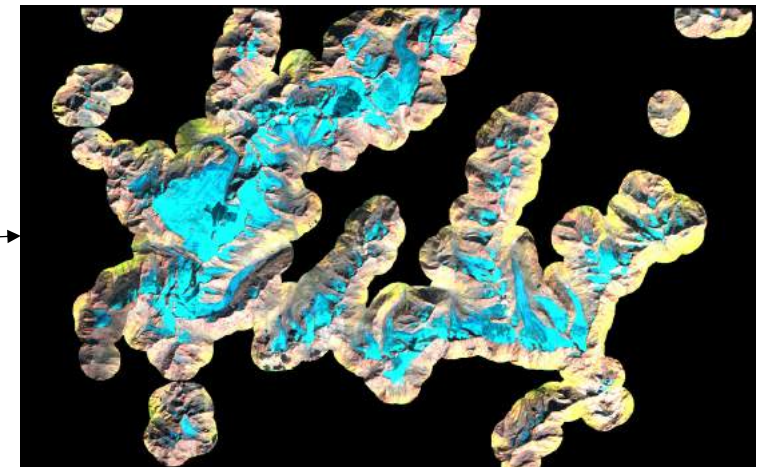
# Automatic mapping of glacier outlines



Stacked Sentinel-2A + 2B  
(Rivisit time  $\leq 5$  days)



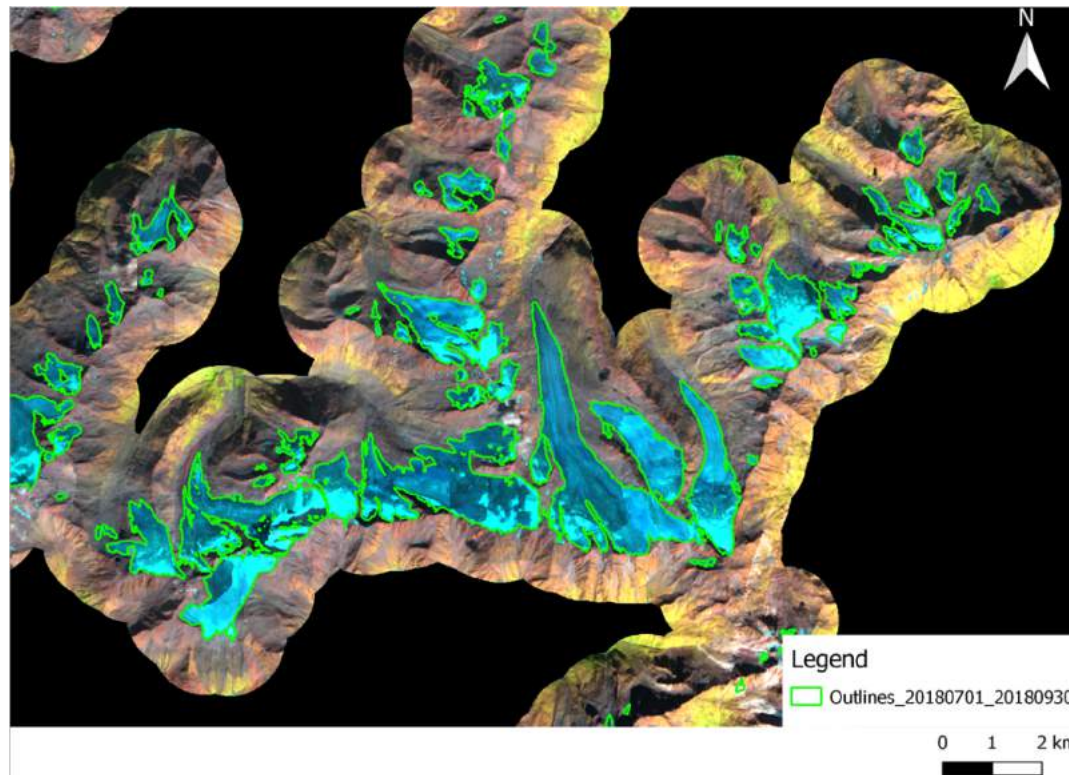
Automatic pre-processing,  
snow and ice classification



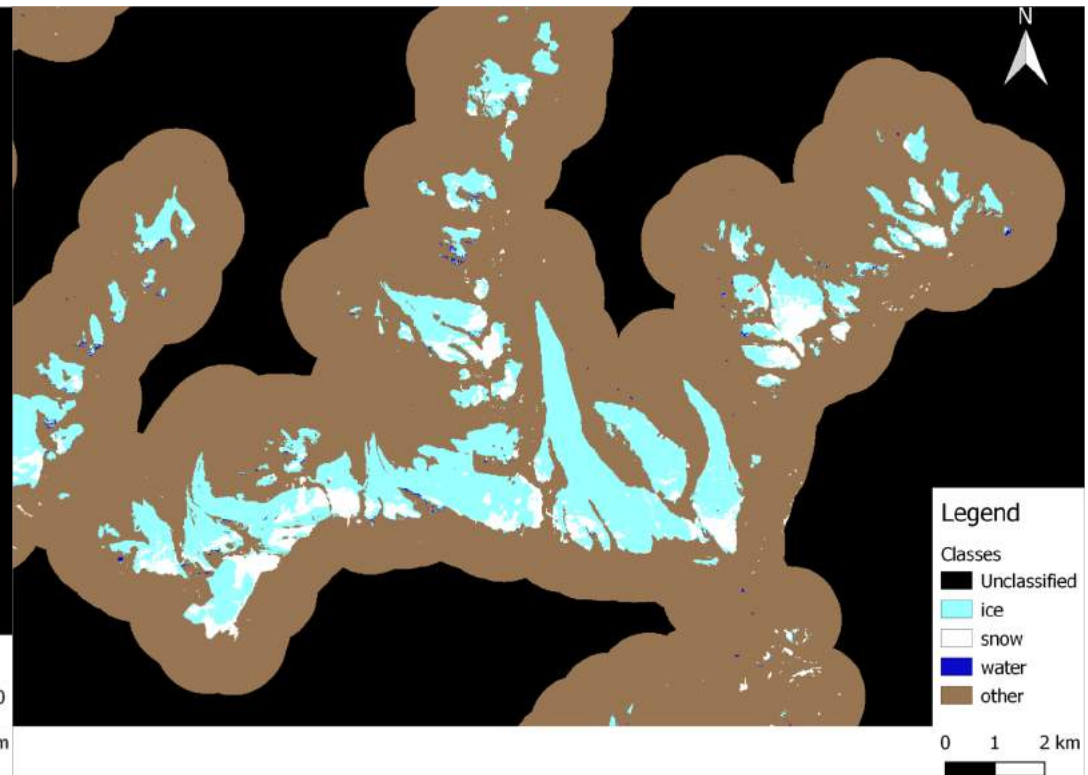
Multitemporal Mosaic of high  
summer snow classification



# Automatic mapping of glacier outlines



Glacier outlines

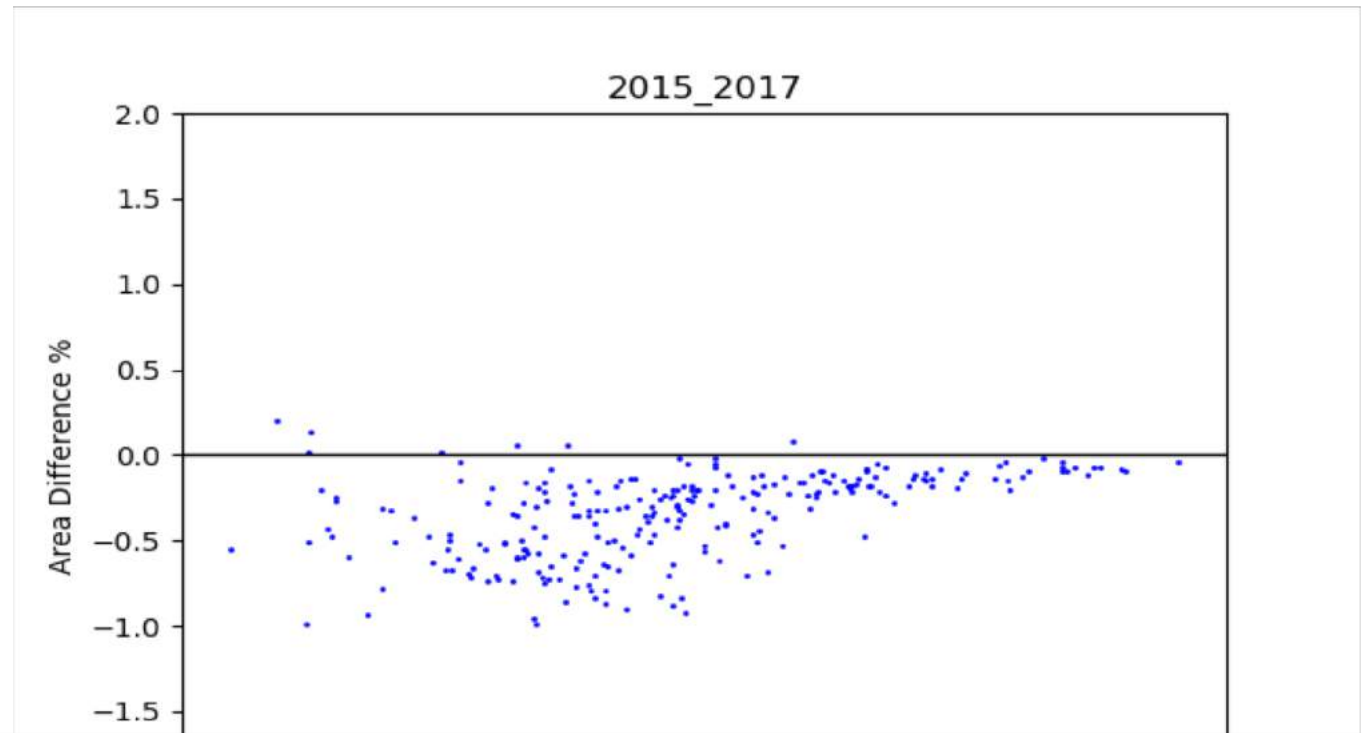


Snow – ice classification for glacier mass balance

# Automatic mapping of glacier outlines



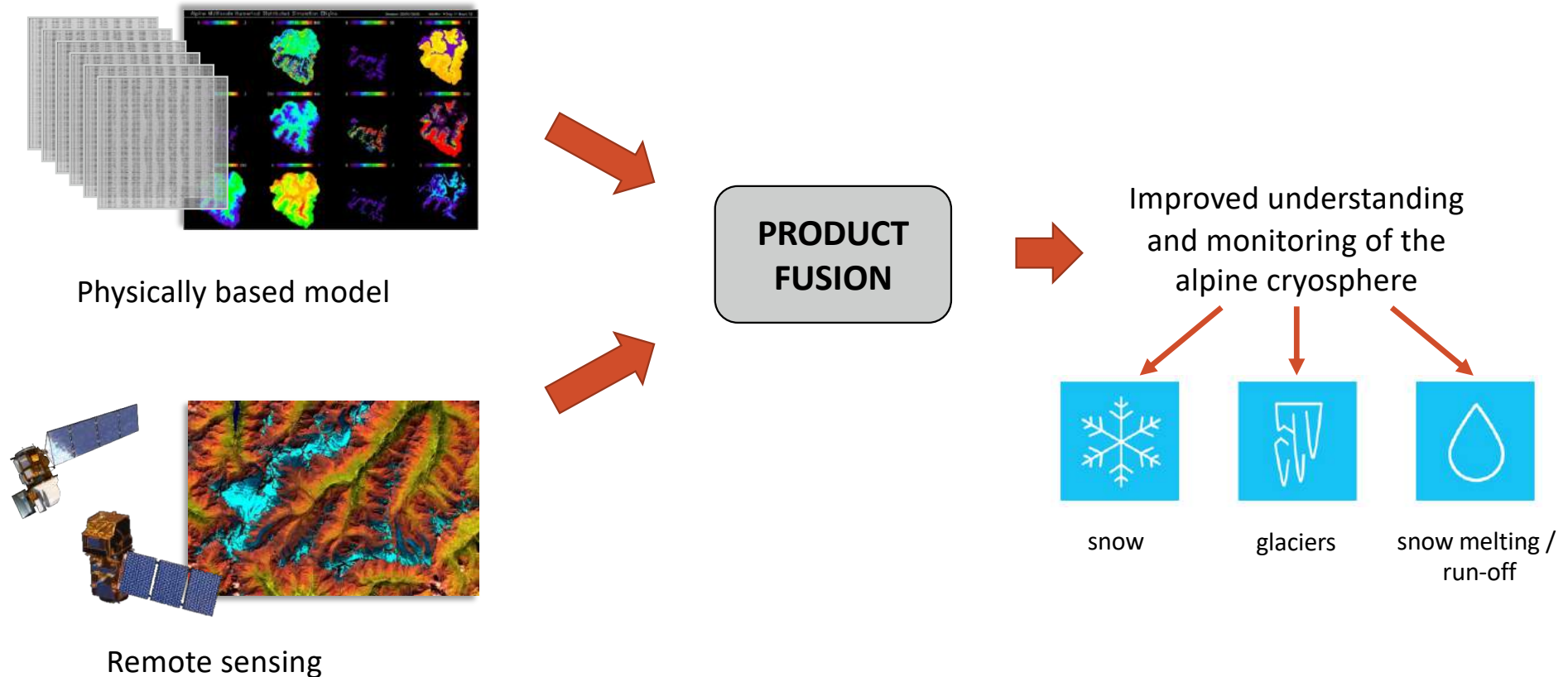
Glacier area change over T32TPS tile



- EO classification and in-situ integration with machine learning
- Product produced for and with Hydrological Service



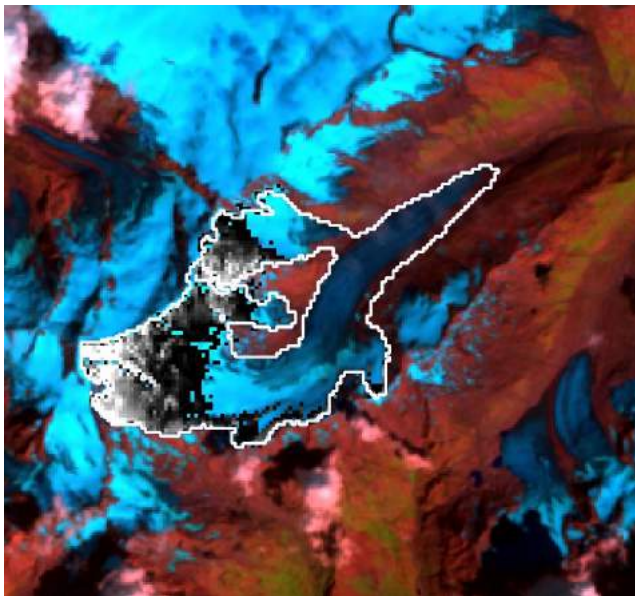
# Fusion of hydrological model and EO for glacier mass balance estimation



# Fusion of hydrological model and EO for glacier mass balance estimation

## MODEL

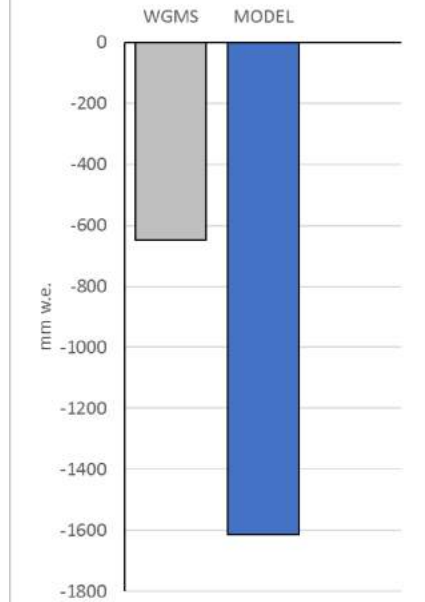
Snow water equivalent



Mass balance



Annual mass balance 2002

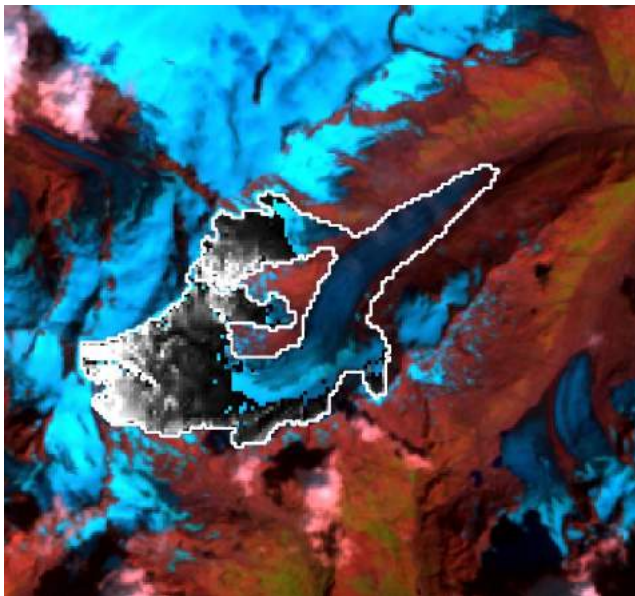




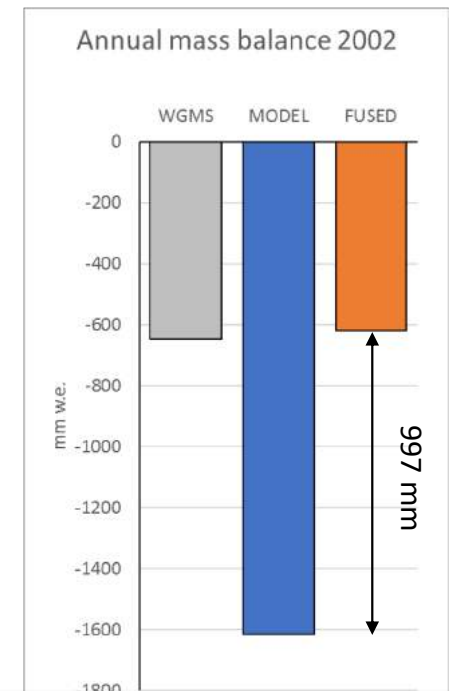
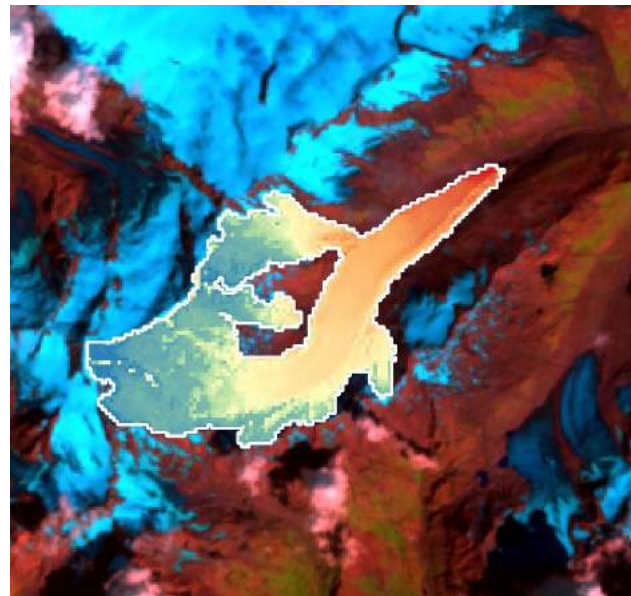
# Fusion of hydrological model and EO for glacier mass balance estimation

## FUSED PRODUCT

Snow water equivalent



Mass balance



- 2<sup>nd</sup> level fused model (EO + hydro)
- Fully scientific product, potential for application

## **Example 2:**

### **Snow cover variability with optical and radar data**



# Snow Monitoring: Snow Cover Area

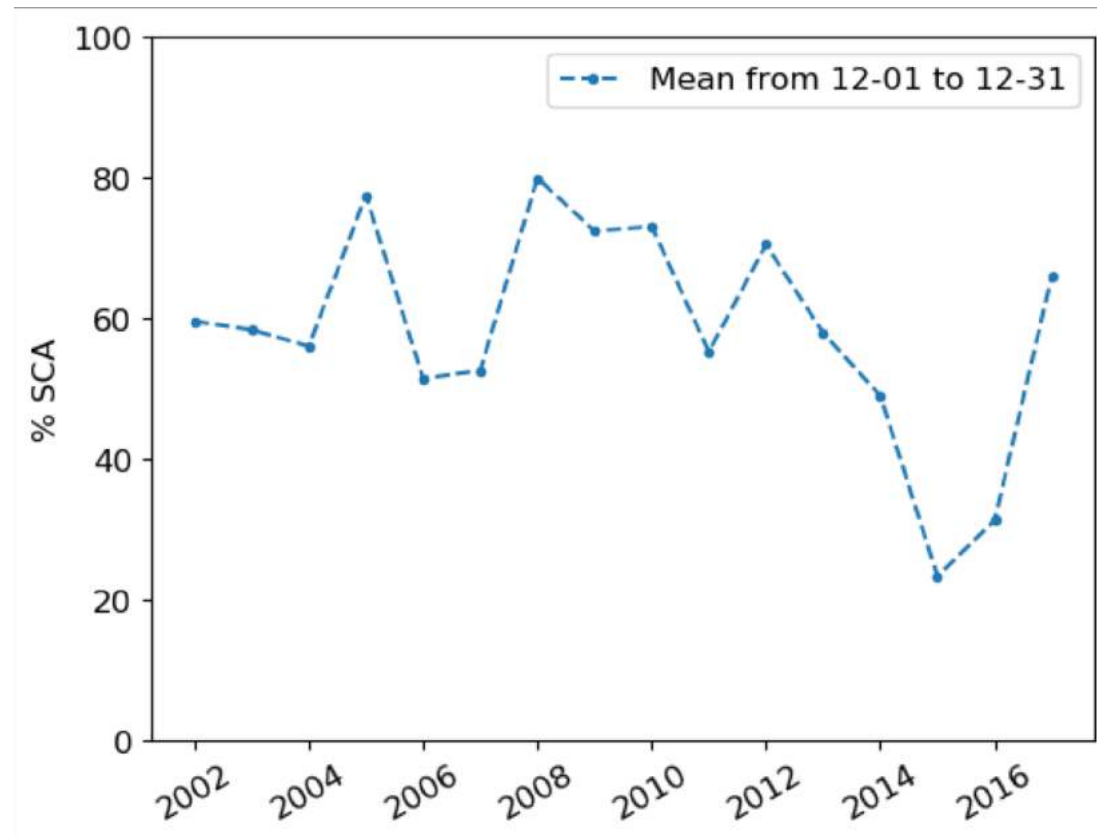
An aerial photograph of a mountainous landscape, likely in the Alps, showing a mix of green forested slopes and white snow-covered peaks and valleys. The snow cover is patchy, following the topography. The image serves as a background for the text.

EURAC-MODIS Snow cover maps (250 m - daily)  
Oct-2015 - Jun-2016



# Snow Cover in South Tyrol 2002 - 2017

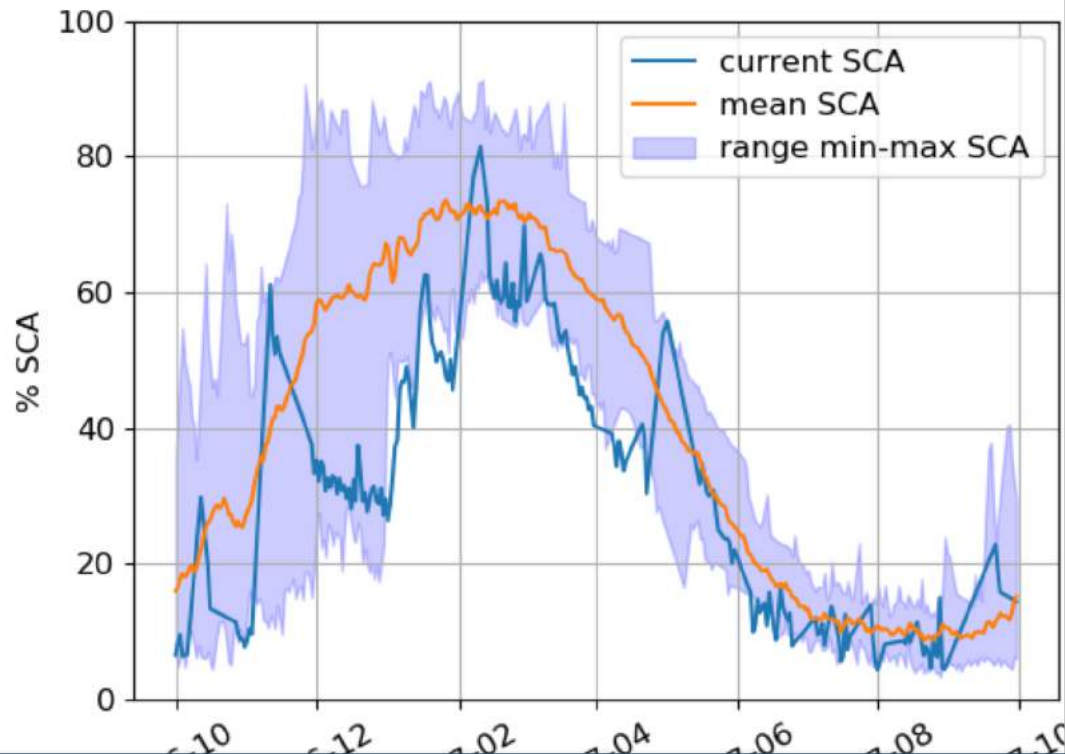
December



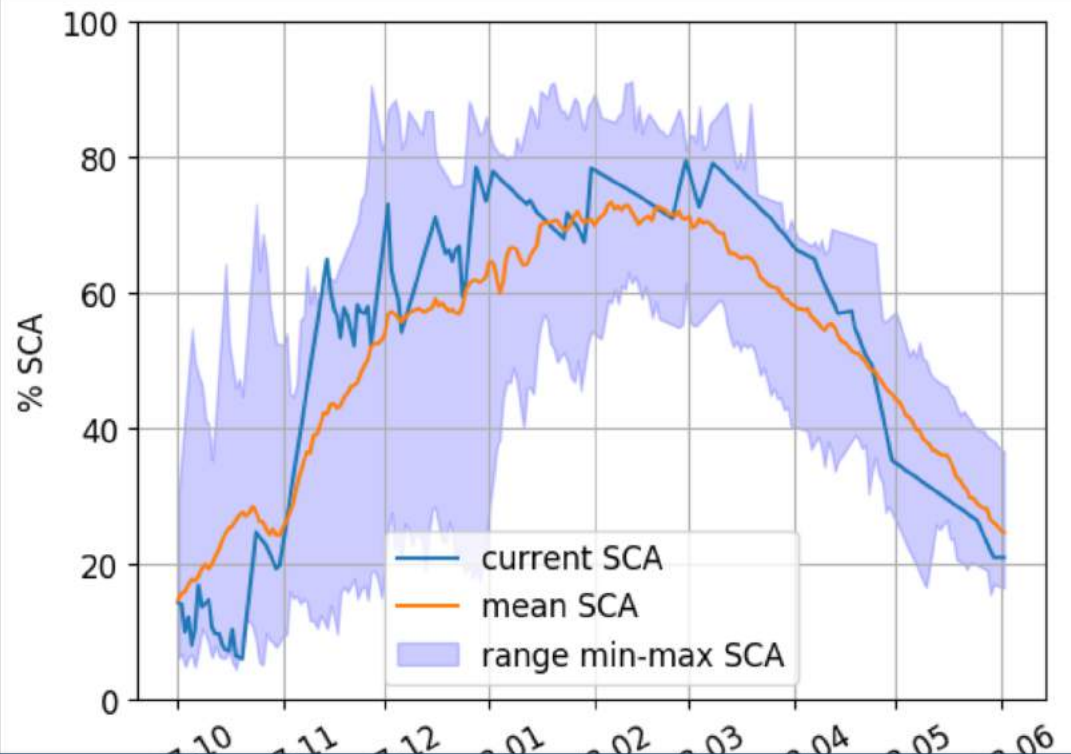


# Snow Cover dynamics in South Tyrol

2016-17



2017-18









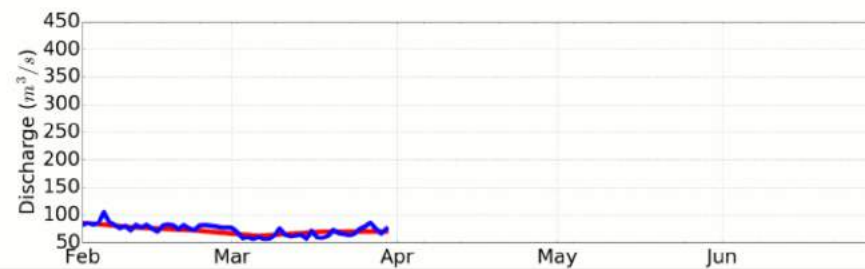
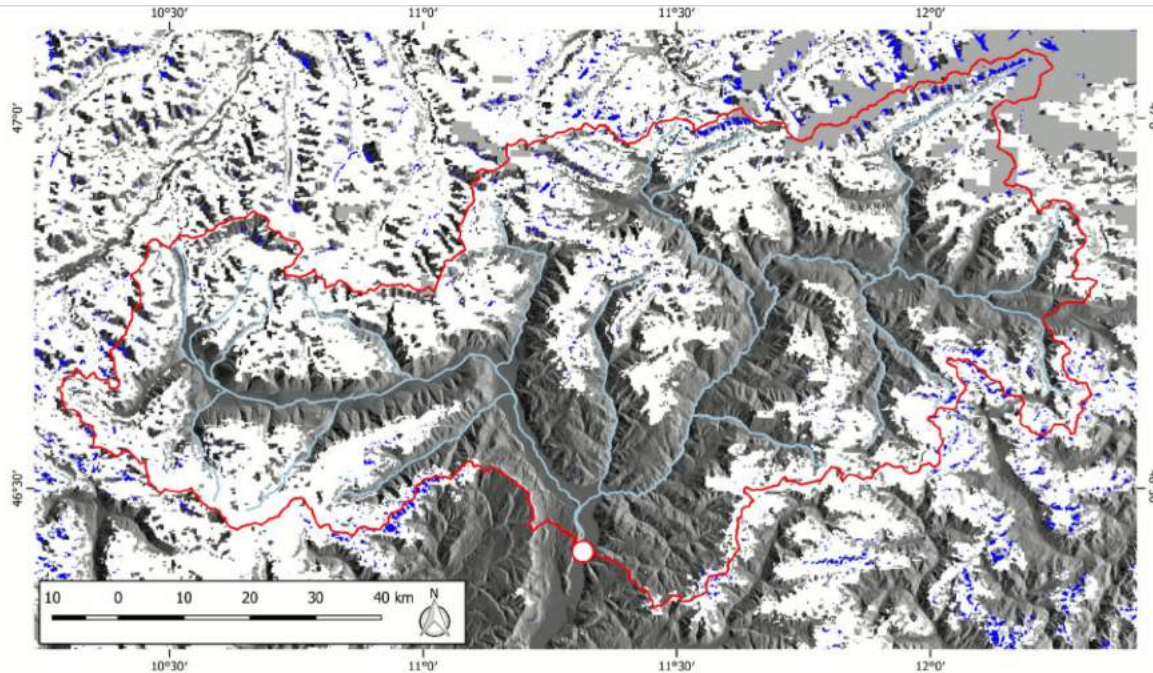
→ Time Series + Anomaly Detection as Basis for Monitoring  
→ Snow Bulletin request by Province of Bolzano



# Wet Snow with Sentinel 1

30-Mar-2015

Map legend:

-  snow (MODIS)
-  cloud (MODIS)
-  wet snow (S1)
-  watershed limit (Adige at Bronzolo)
-  gauging station (Bronzolo)
-  main rivers



-  Daily mean discharge
-  Mean discharge of the 12 days after the S1 acquisition



## **Example 3:**

### **Snow cover and run-off forecast**



In South Tyrol...

Water storage of snow in January  
> 3 x water storage of all artificial reservoirs

~40% of run-off is  
snow-melt driven



# Mountains as water towers - too less

## Siccità in Italia: la situazione è grave in Pianura Padana e sulle Alpi Orientali

La conferma arriva dal ministro dell'Ambiente Gian Luca Galletti



28 aprile 2017 - ore 12:00 | Redatto da [Meteo.it](#)

Heavy drought  
in the Alps  
and Po-Valley in 2017





# Alps, 06. January 2017



MODIS 06.01.2017 by NASA



# Alps, 29. January 2018



MODIS 28.01.2018 by NASA

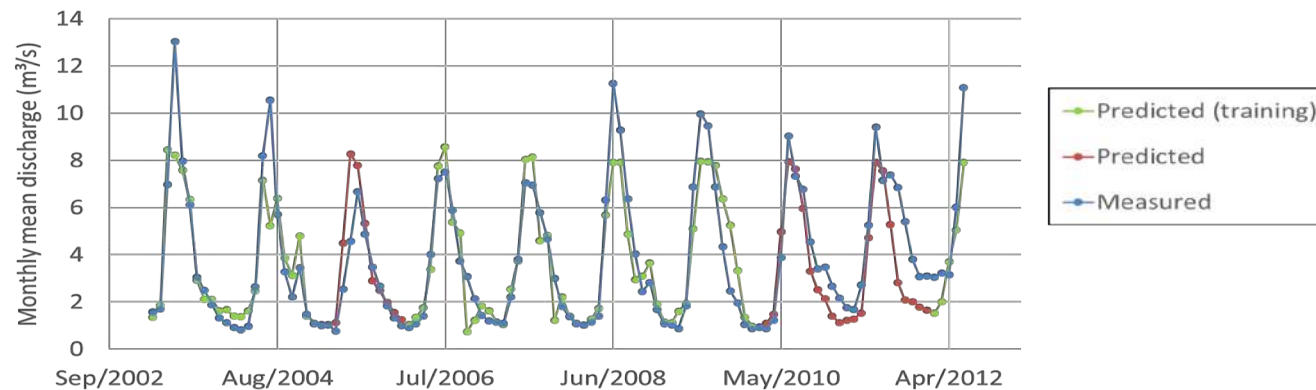


# Integrated Run-off Forecast



Model (Machine Learning)

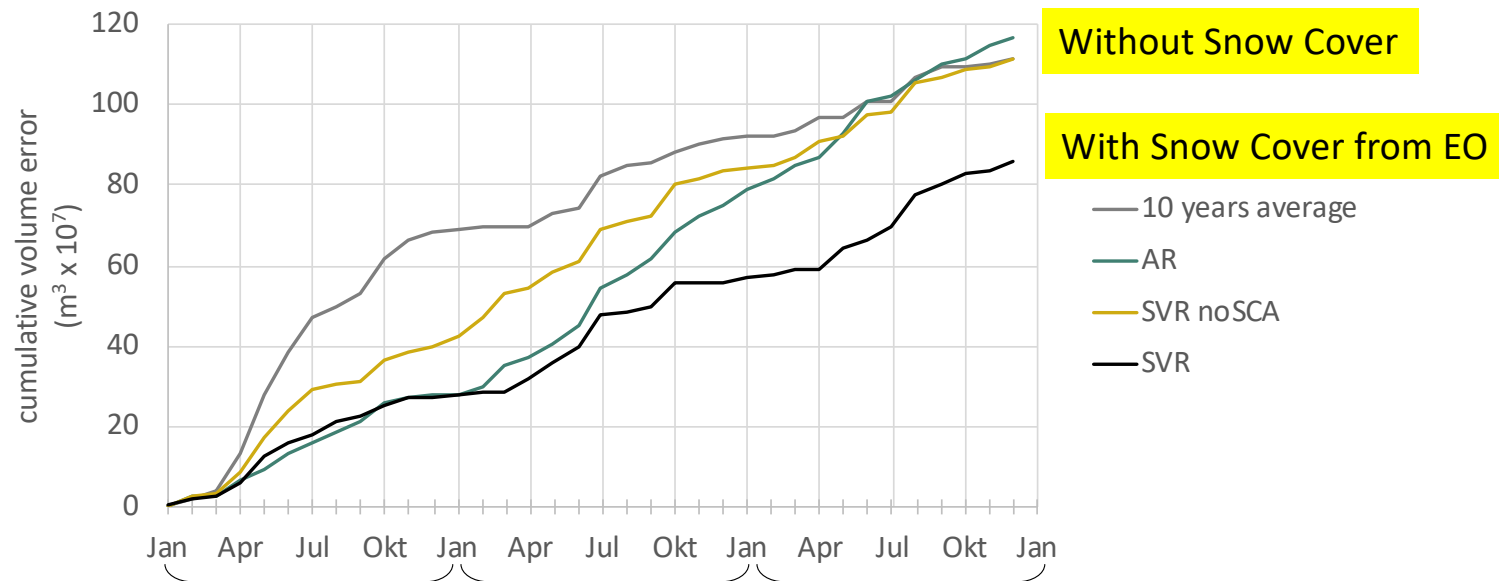
Run-off  
forecast





# Integrated Run-off Forecast

watershed 7, mean annual water volume =  $160 \times 10^7 \text{ m}^3$   
prediction lag = 1 month



- Integration of different data sources – modelling and AI
- Run-off forecast for Hydropower provider

## **Example 4:**

### **Surface soil moisture with Sentinel-1**



# Surface soil moisture with Sentinel-1

Sentinel-1

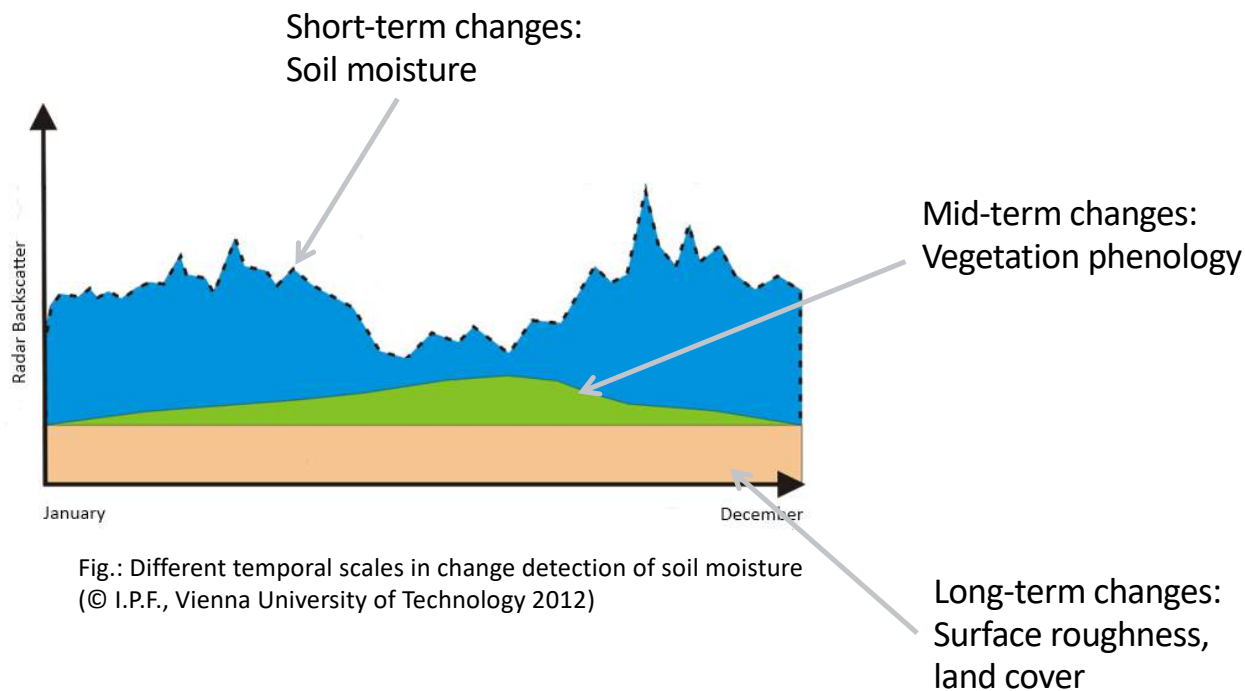
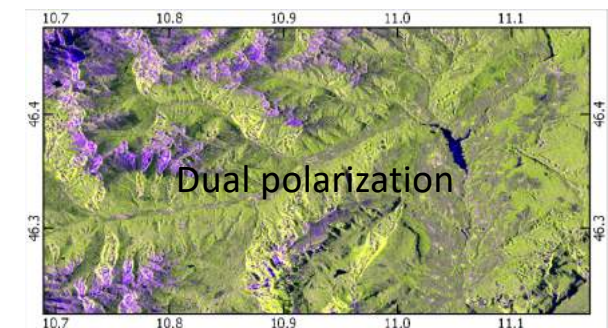
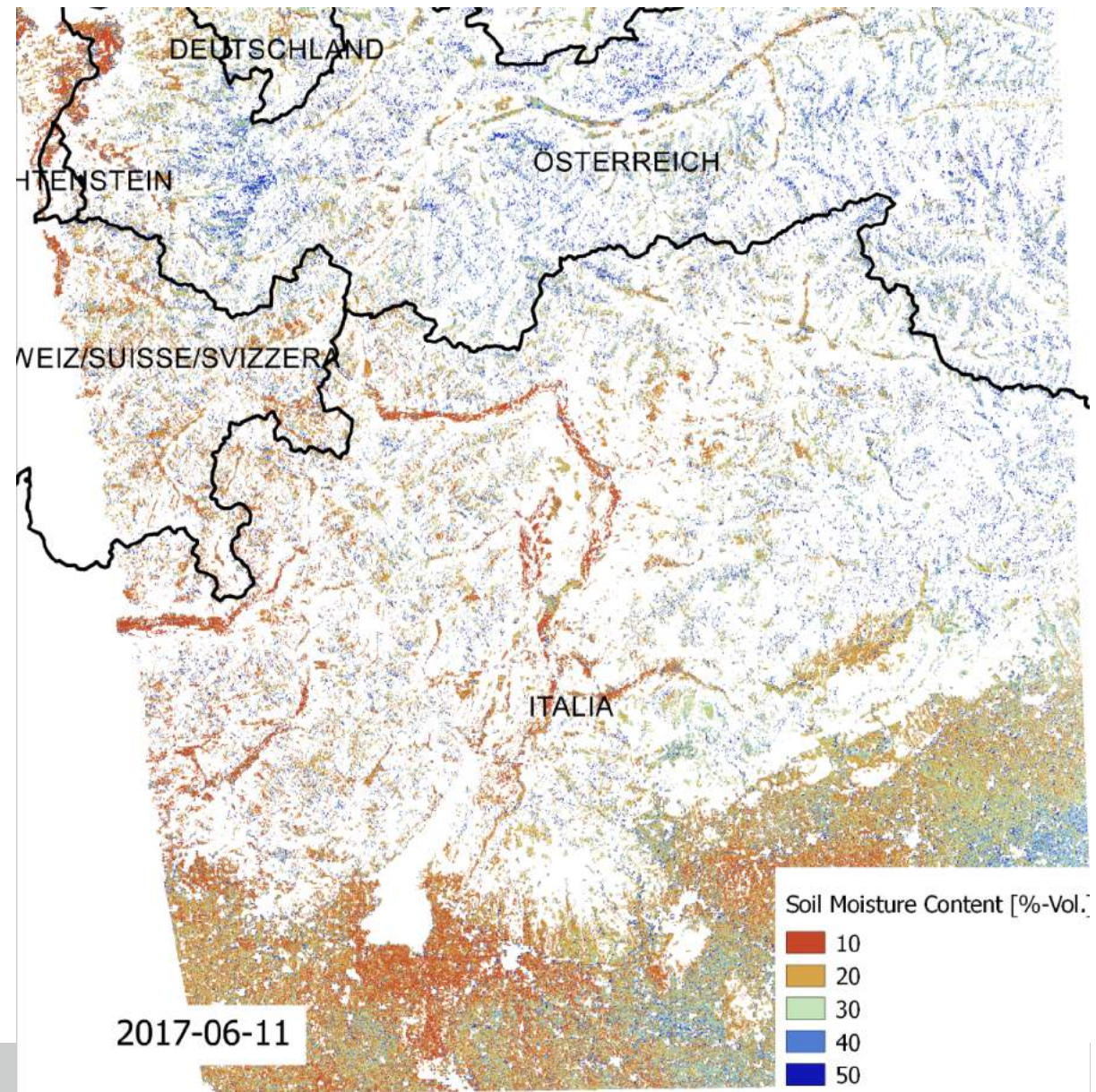


Fig.: Different temporal scales in change detection of soil moisture  
(© I.P.F., Vienna University of Technology 2012)



# Surface soil moisture with Sentinel-1 during summer drought in Italy 2017

Sentinel-1



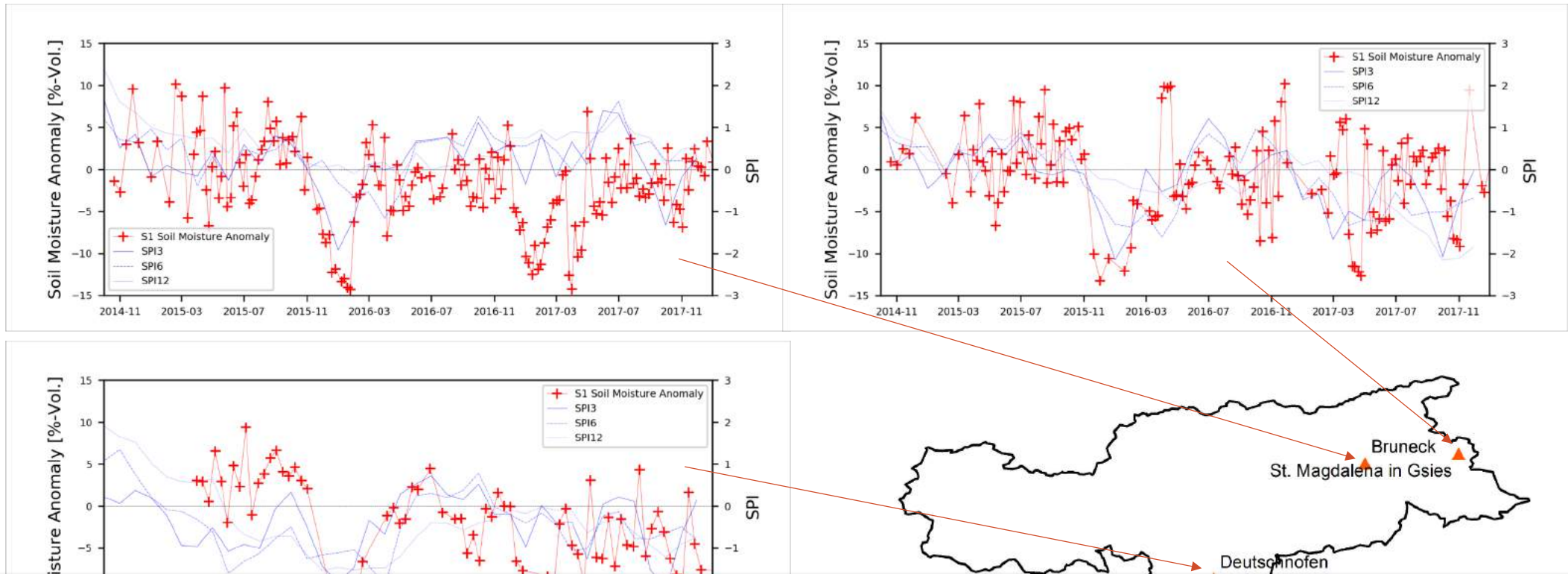


# Surface soil moisture anomalies



Comparison Soil Moisture anomaly vs. SPI

H2020 ECOpotential project



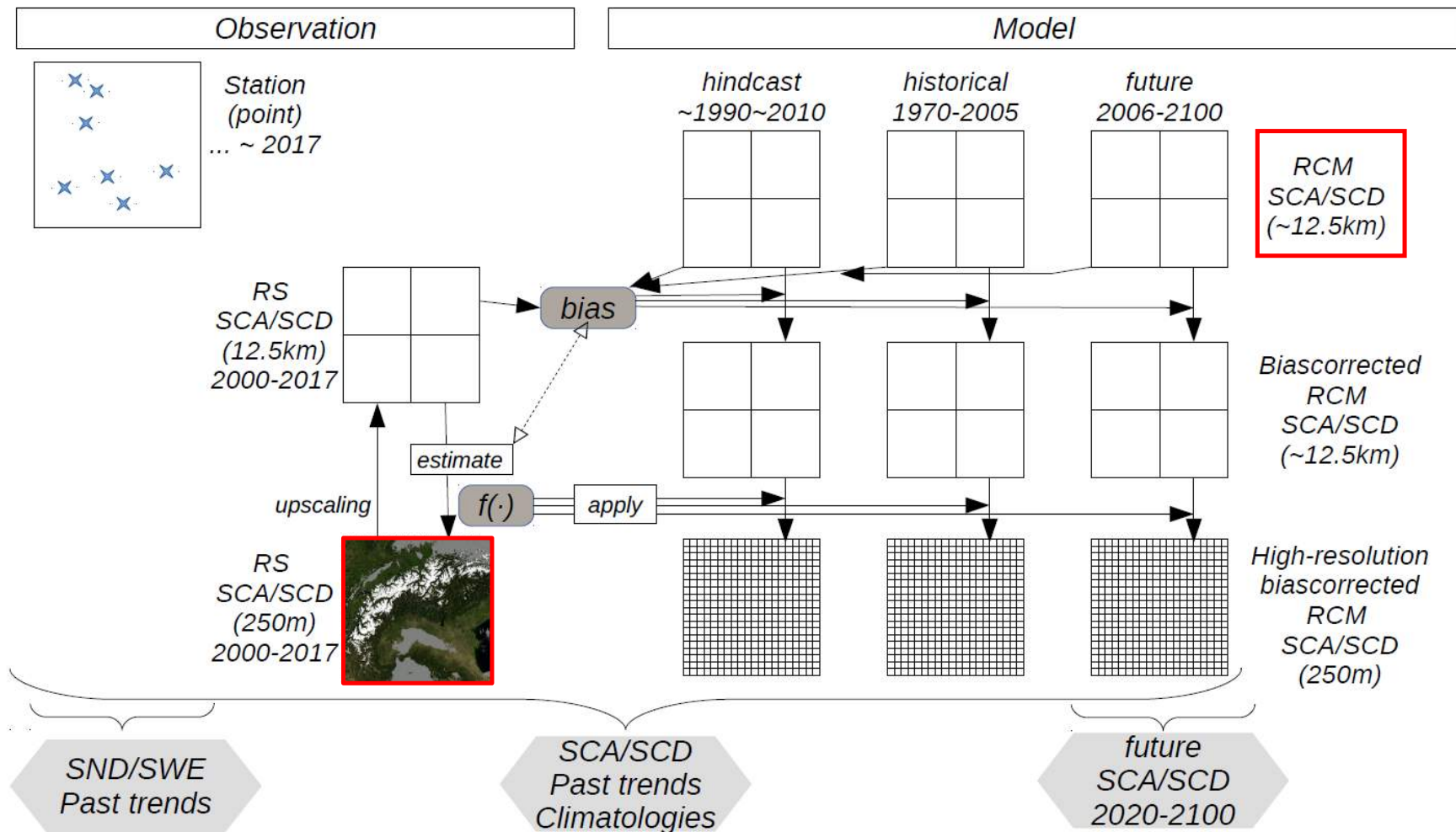
- ➔ Integration of EO and in-situ with machine learning
- ➔ Scientific product; drought early warning

## Example 5:

# Downscaling and bias-correction of snow from RCMs with EO-Data (Time series of MODIS)

[Skip](#) →

# Downscaling of Snow in RCMs with EO?





# Deviation in Snow Cover RCM vs. MODIS over the full Alps

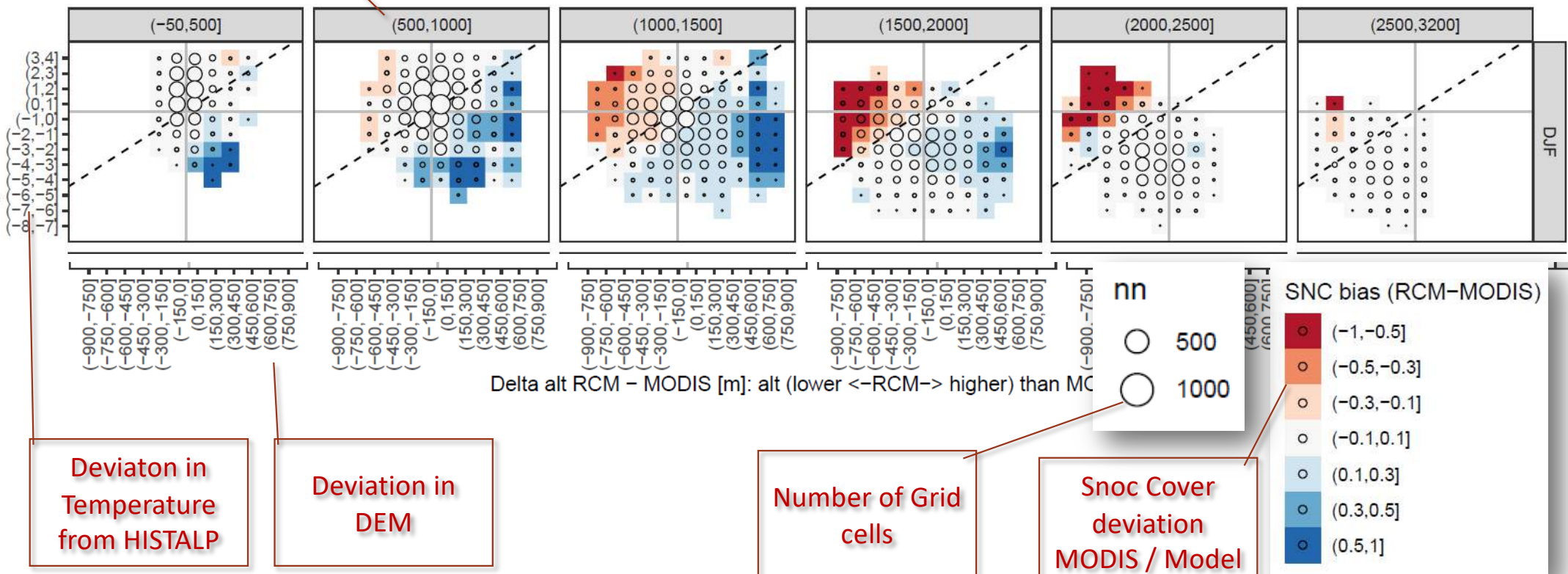
## Analysis of drivers

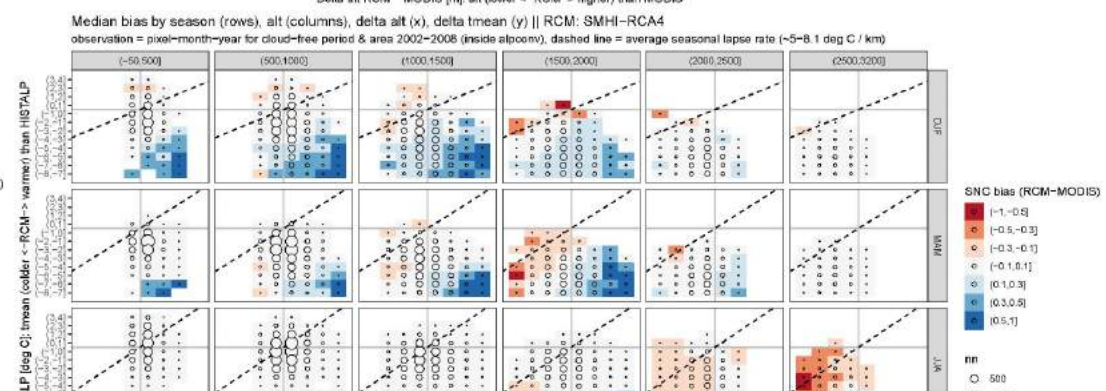
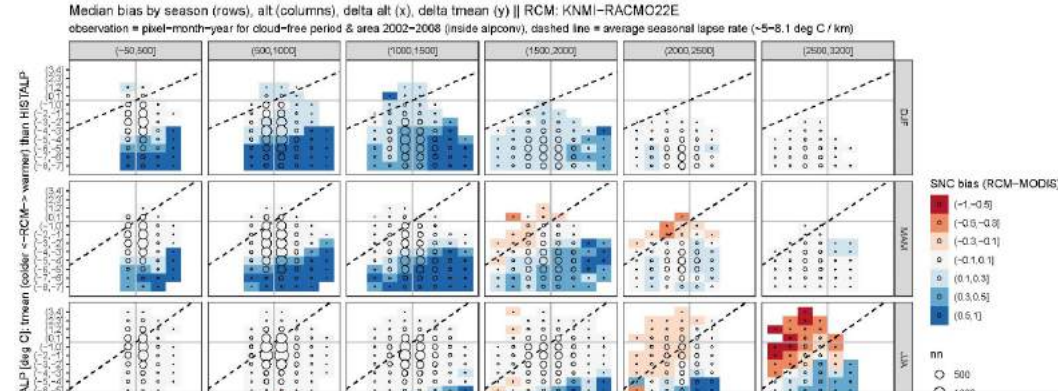
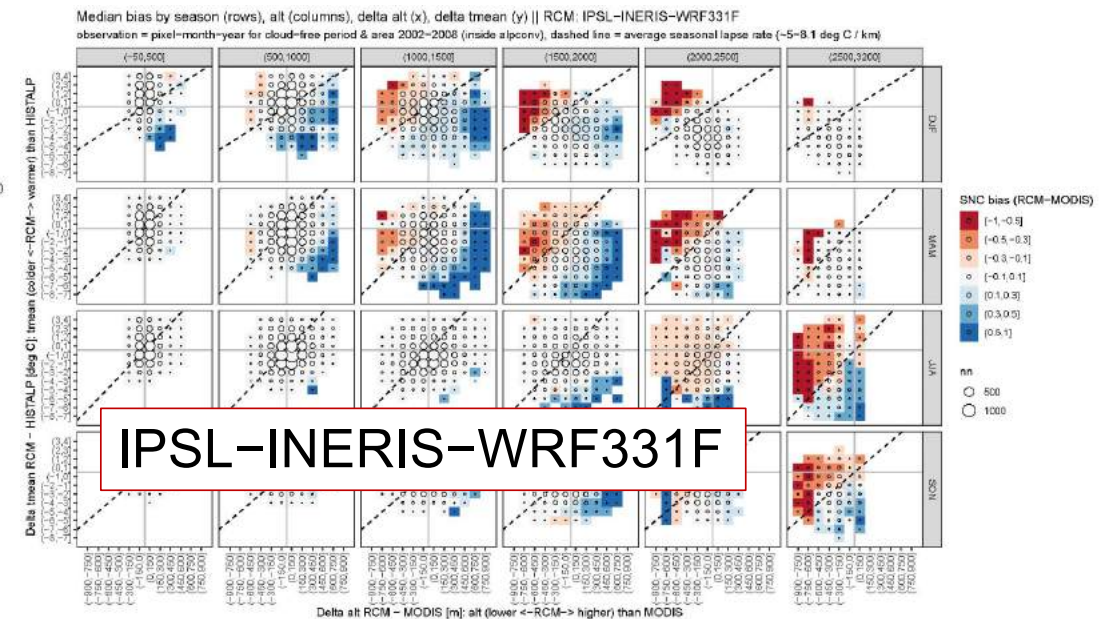
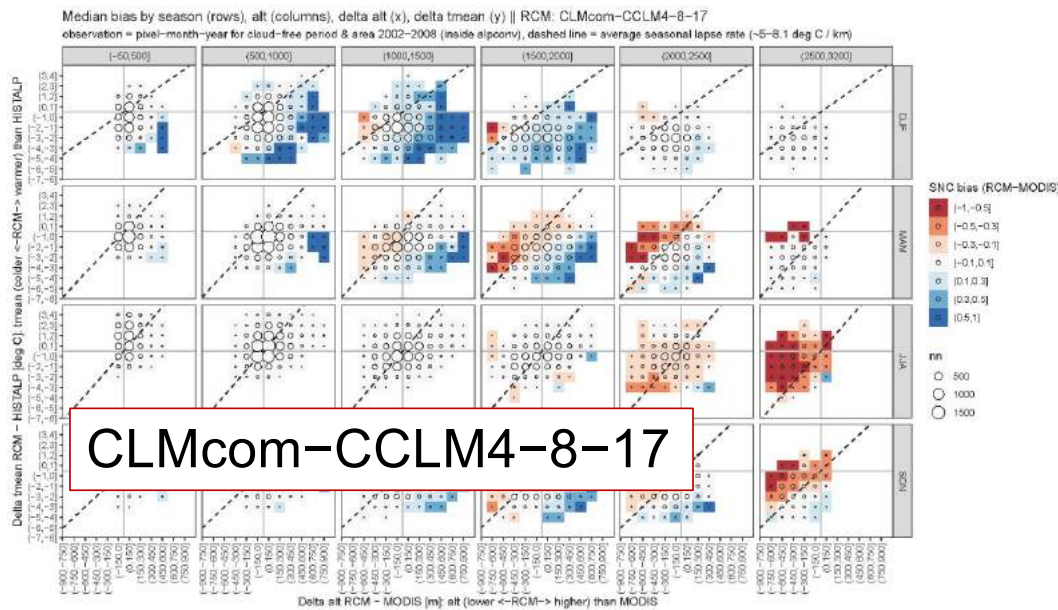
Altitudinal  
slices

Different  
GCM/RCM

Median bias by season (rows), alt (columns), delta alt (x), delta tmean (y) || RCM: IPSL-INERIS-WRF331F

observation = pixel-month-year for cloud-free period & area 2002-2008 (inside alpcnv), dashed line = average seasonal lapse rate (~5-8.1 deg C / km)





→ Integration of EO, in-situ and RCMs with machine learning  
 → Fully scientific product

# Conclusion: how Remote Sensing can contribute

## Potential

- Spatially explicit times series of hydrological relevant data where other observations are rare – high temporal and spatial resolution
- Strong in Energy Balance related approaches of hydrology

## Limitation

- Data gaps and availability in the past (> 20 years)
- Accuracy of indirect parameters (compared to measurements)
- Key parameters not directly observable by remote sensing imagery

## Solution

- Clever integration with other data sources and / through models to reduce data gaps, cloud, and provide the required data