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CLIMATE CHANGE RESEARCH

Potential der Fernerkundung für hydrologische Anwendungen und limnologische Untersuchungen

Stefan Wunderle
Institute of Geography and
Oeschger Centre for Climate Change Research
University of Bern

Active vs passive remote sensing

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- Active remote sensing: system has its own device to transmit EM-waves, which are received by a sensor on the same platform.
  - Synthetic Aperture RADAR (SAR) on satellites
  - Light Detection And Ranging (LiDAR) on satellites and airborne platforms (helicopter, airplanes, drones)
- Passive remote sensing: system using only reflected sunlight or emitted longwave radiation.
  - Many satellites are in orbit (different temporal and spatial resolution)
  - Aerial images for topographic mapping
  - Drones (high spatial but limited spectral resolution)

Focus of all retrieval techniques: extract information

Variables in hydrology and limnology

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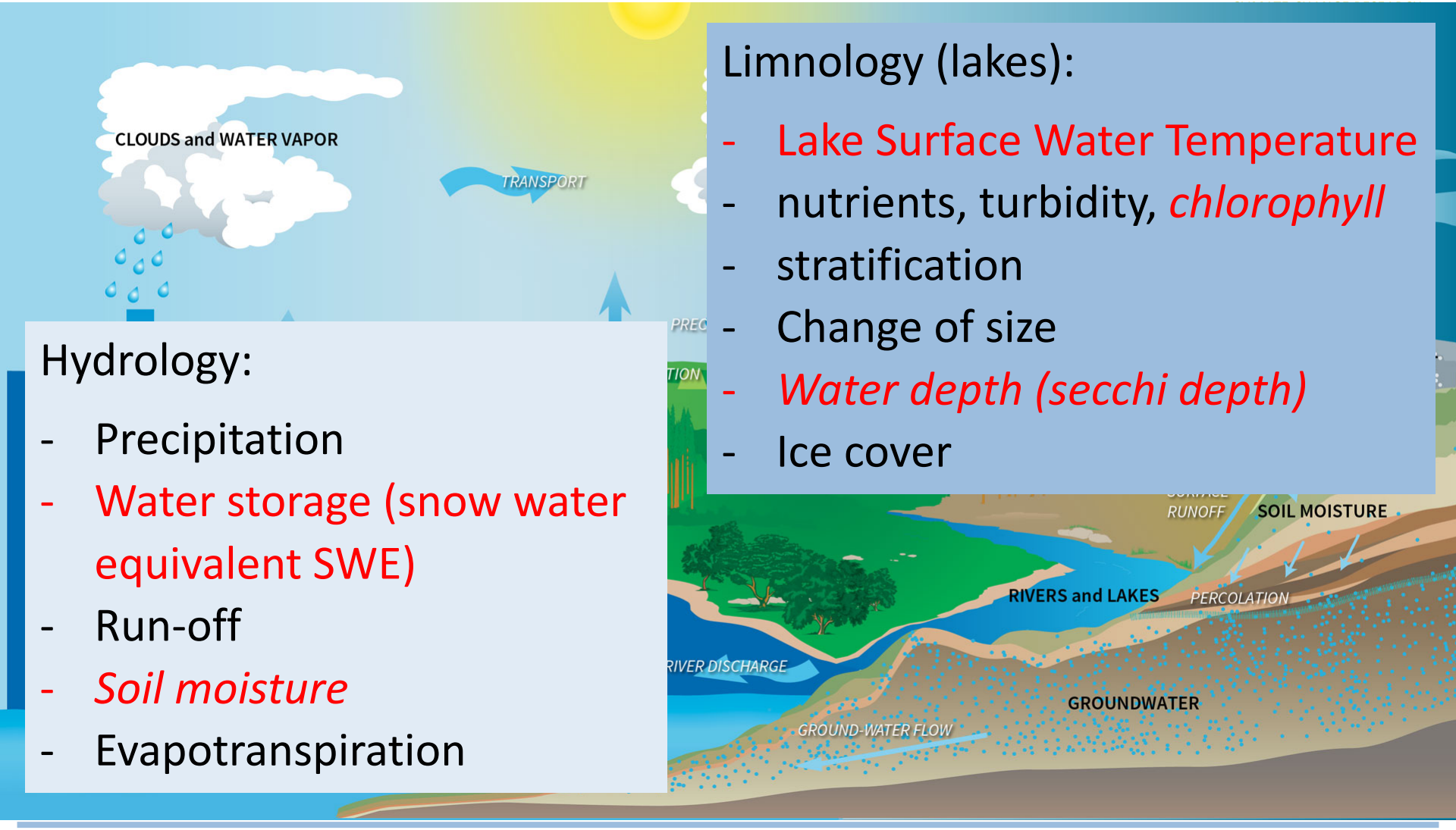

Limnology (lakes):

- Lake Surface Water Temperature
- nutrients, turbidity, *chlorophyll*
- stratification
- Change of size
- *Water depth (secchi depth)*
- Ice cover

Hydrology:

- Precipitation
- Water storage (snow water equivalent SWE)
- Run-off
- *Soil moisture*
- Evapotranspiration

Tools to gather information about snow

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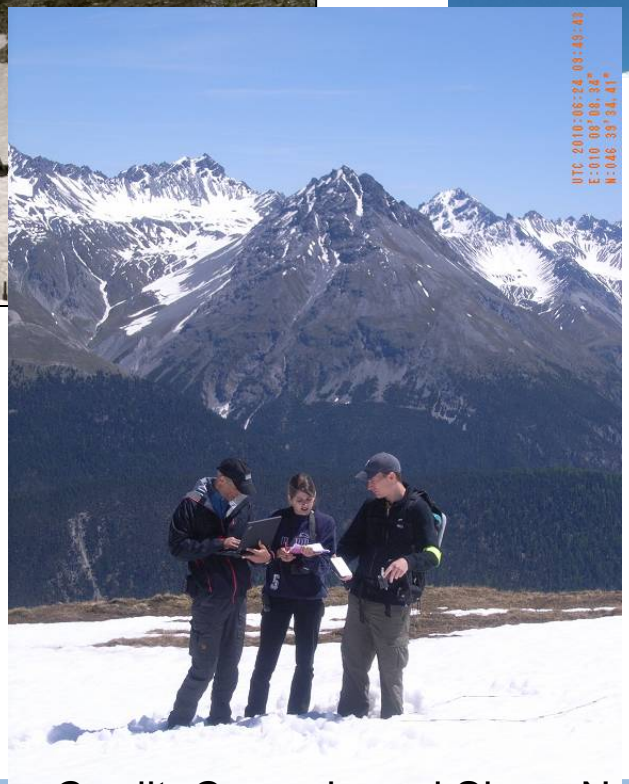

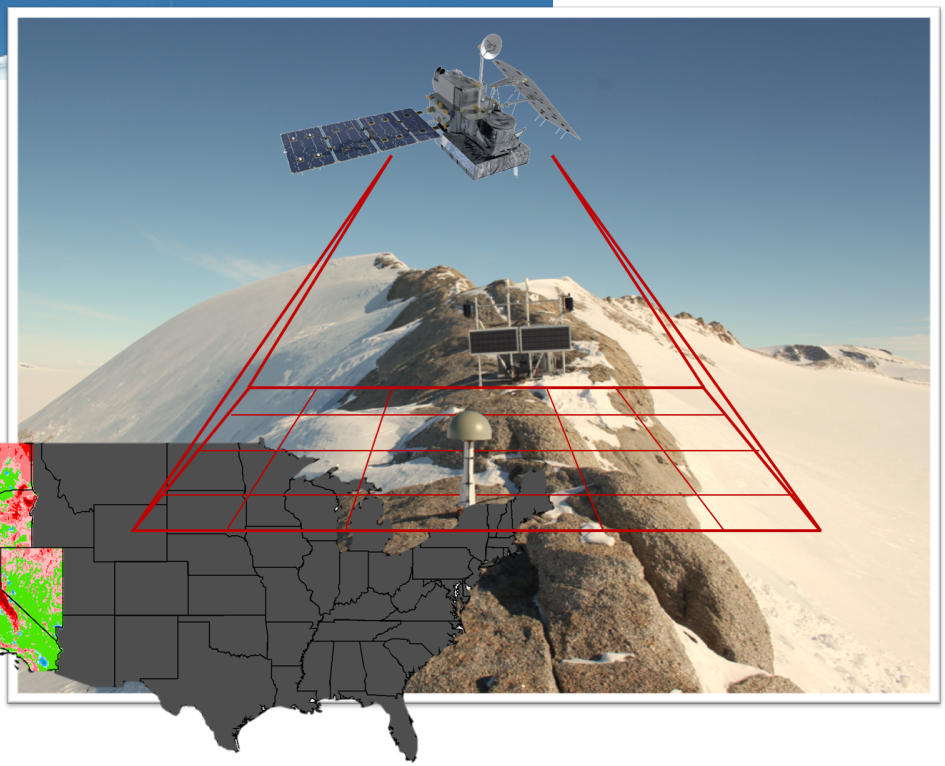

Image Credit: Cascade and Sierra Nevada Mountains Water Resources Team
https://blogs.nasa.gov/earthexpeditions/category/uncategorized/

AVHRR reception, coverage and data

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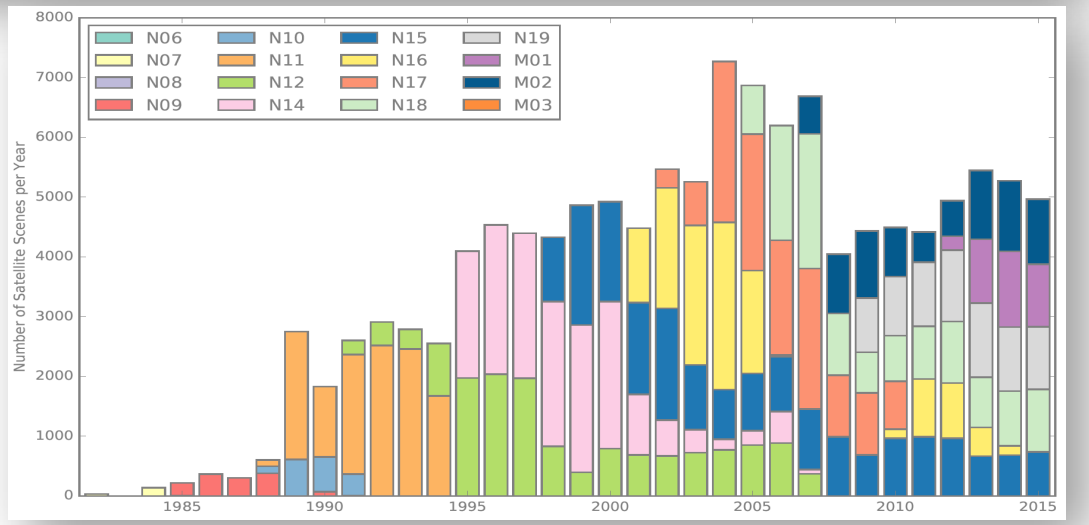

AVHRR data archived at UniBe from 01/1983 – ongoing

Hydrology: example I
Snow Water Equivalent (SWE)

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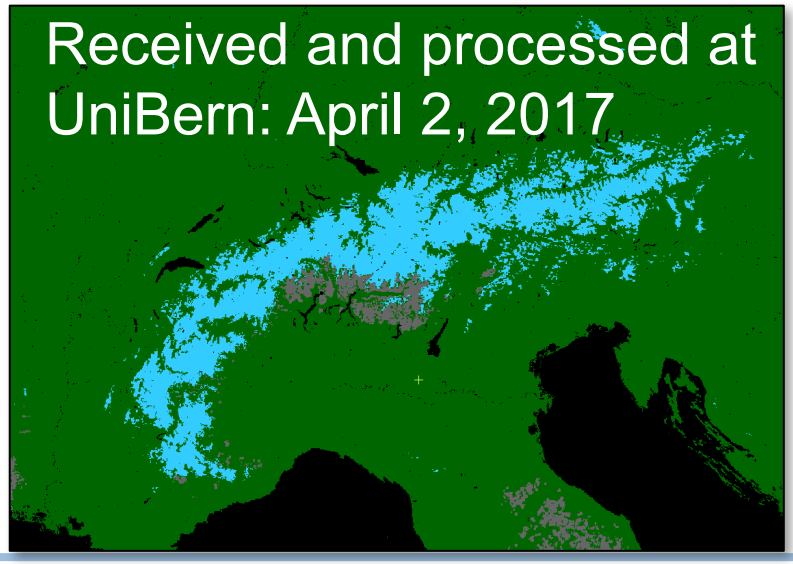
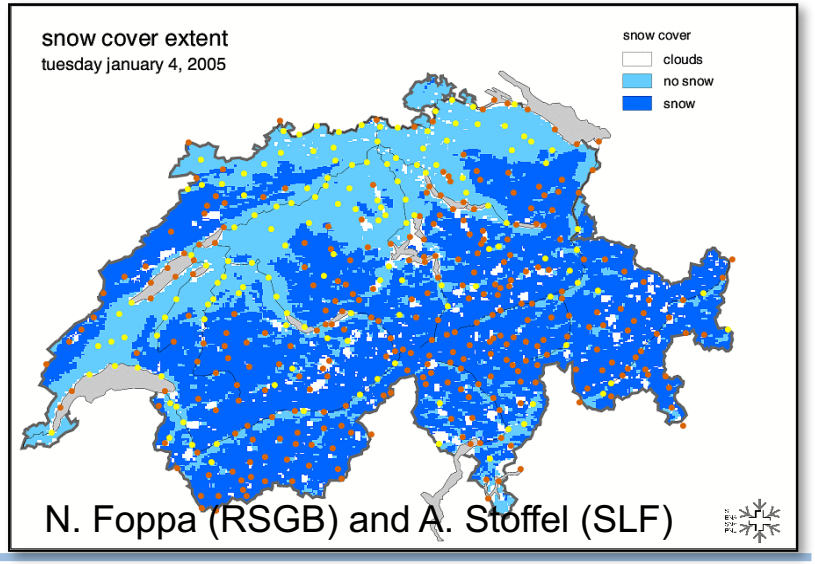
- Water stored in snow (SWE)
  - Retrieval based on passive microwave data has some limitations:
    - spatial resolution of 25km not usable for mountainous applications.
    - Saturation of retrieval technique for SWE > 150mm
  - Combine snow monitoring (snow extent) with ground measurements.





EUMETSAT – Hydrology Satellite Application Facility (H-SAF)

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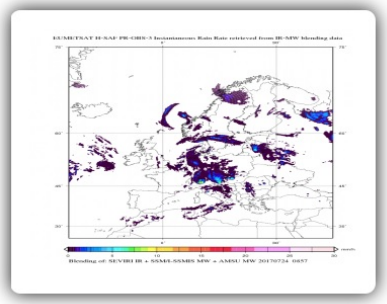
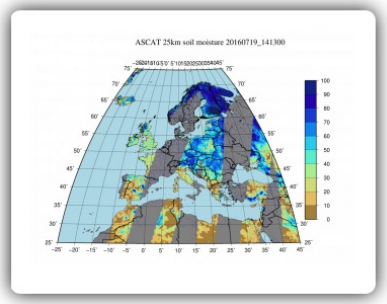


PRECIPITATION

Images | Descriptions | Quality Monitoring | User Documents | Visiting Scientist | References

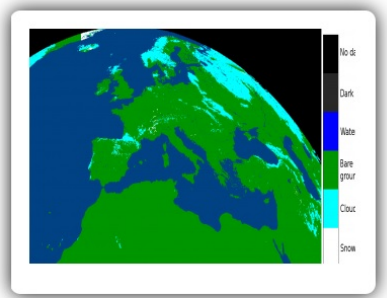
PR OBS 1 - H01	PR OBS 2 - H02	H02B-H03B-H05B-H15B-H17-H18-H23	PR OBS 3 - H03	PR OBS 4 - H04	PR OBS 5 - H05	PI
Precipitation rate at ground by MW conical scanners (with indication of phase)	Precipitation rate at ground by MW cross-track scanners (with indication of phase)	H-SAF Full Disk Precipitation Products	Precipitation rate at ground by GEO/IR supported by LEO/MW	Precipitation rate at ground by LEO/MW supported by GEO/IR (with flag for phase)	Accumulated precipitation at ground by blended MW and IR	Blen area
operational	operational	demonstrational	operational	operational as off-line product	operational	



SOIL MOISTURE

Images | Descriptions | Quality Monitoring | User Documents | Visiting Scientist | References

SM OBS 2 - H08	SM DAS 2 - H14	H25-H108-H109-H110	SM DAS 3 - H27	H101-H102-H16-H103
Small scale surface soil moisture by radar scatterometer	Profile Index in the roots region by scatterometer data assimilation	Surface Soil Moisture ASCAT Data Record Time Series	Soil Wetness Index in the roots region by ERS/SCAT and Metop ASCAT-A Scatterometer assimilation in a Land Data Assimilation System	Surface Soil Moisture ASCAT A/B NRT Orbit
pre-operational	operational	released	released	operational



SNOW

Images | Descriptions | Quality Monitoring | User Documents | Visiting Scientist | References

SN OBS 1 - H10	SN OBS 2 - H11	SN OBS 3 - H12	SN OBS 4 - H13
Snow detection (snow mask) by VIS/IR radiometry	Snow status (dry/wet) by MW radiometry	Effective snow cover by VIS/IR radiometry	Snow water equivalent by MW radiometry
operational	pre-operational	pre-operational	operational

http://hsaf.meteoam.it/

Snow Water Equivalent (SWE) Change in 2050 based on RCP 8.5

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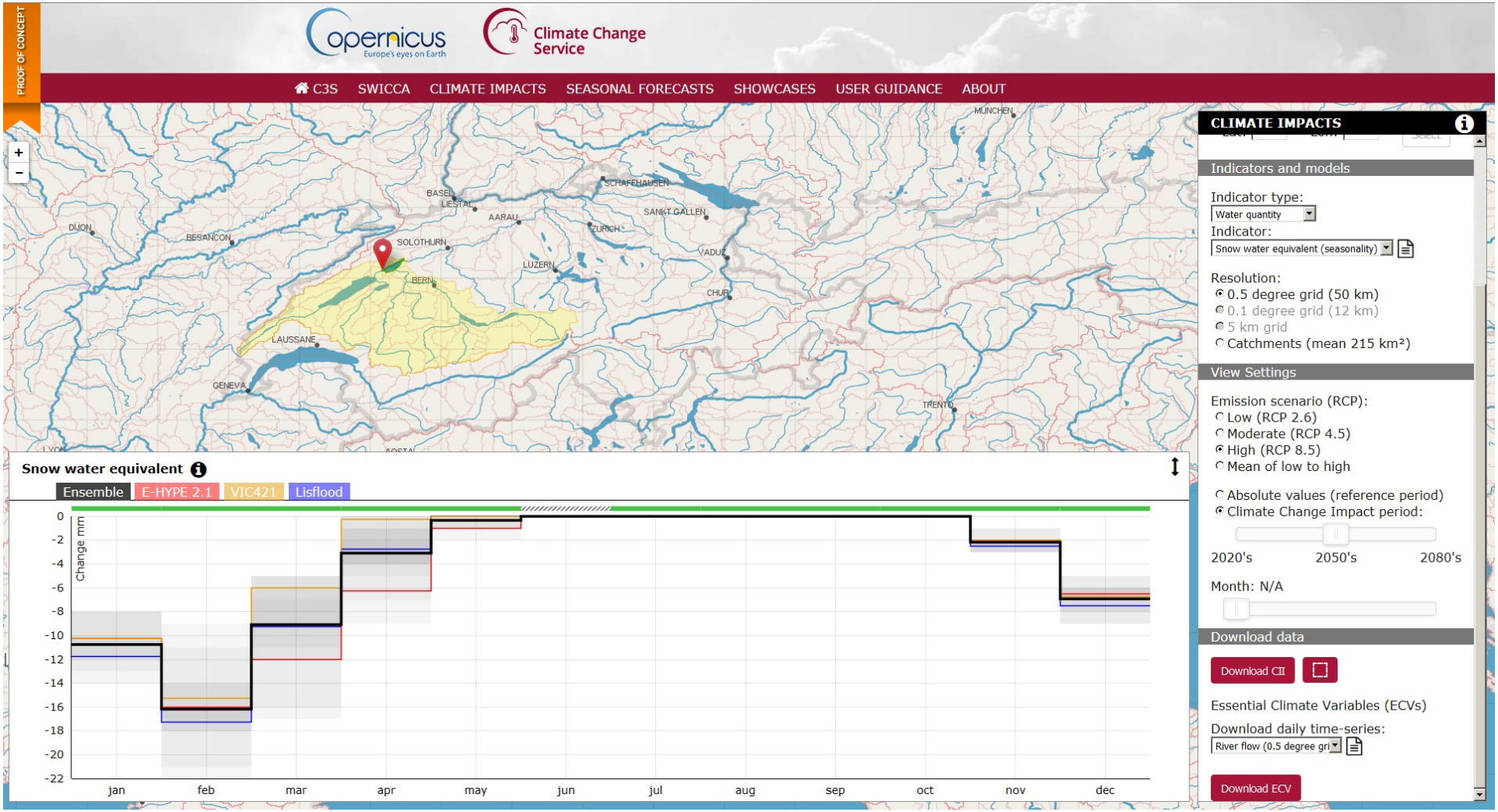

http://swicca.climate.copernicus.eu/indicator-interface/graphs-and-download/

Summary: snow

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- **Snow depth** measurements in Switzerland; good distribution, excellent quality;
- **Snow extent**: daily products are available (H-SAF, UniBern) but with medium spatial resolution (1km). Products with better spatial resolution are under development using Sentinel-1 (SAR) and Sentinel-2 (VIS-NIR) and will be available via Copernicus access points.
- **Snow Water Equivalent** (SWE): products for Northern Hemisphere are available but with coarse spatial resolution (25km). This resolution prevents a retrieval in mountainous areas. It is recommended to use snow extent products based on satellite data and combine it with ground measurements or snow models.

Soil moisture – contribution from satellite remote sensing

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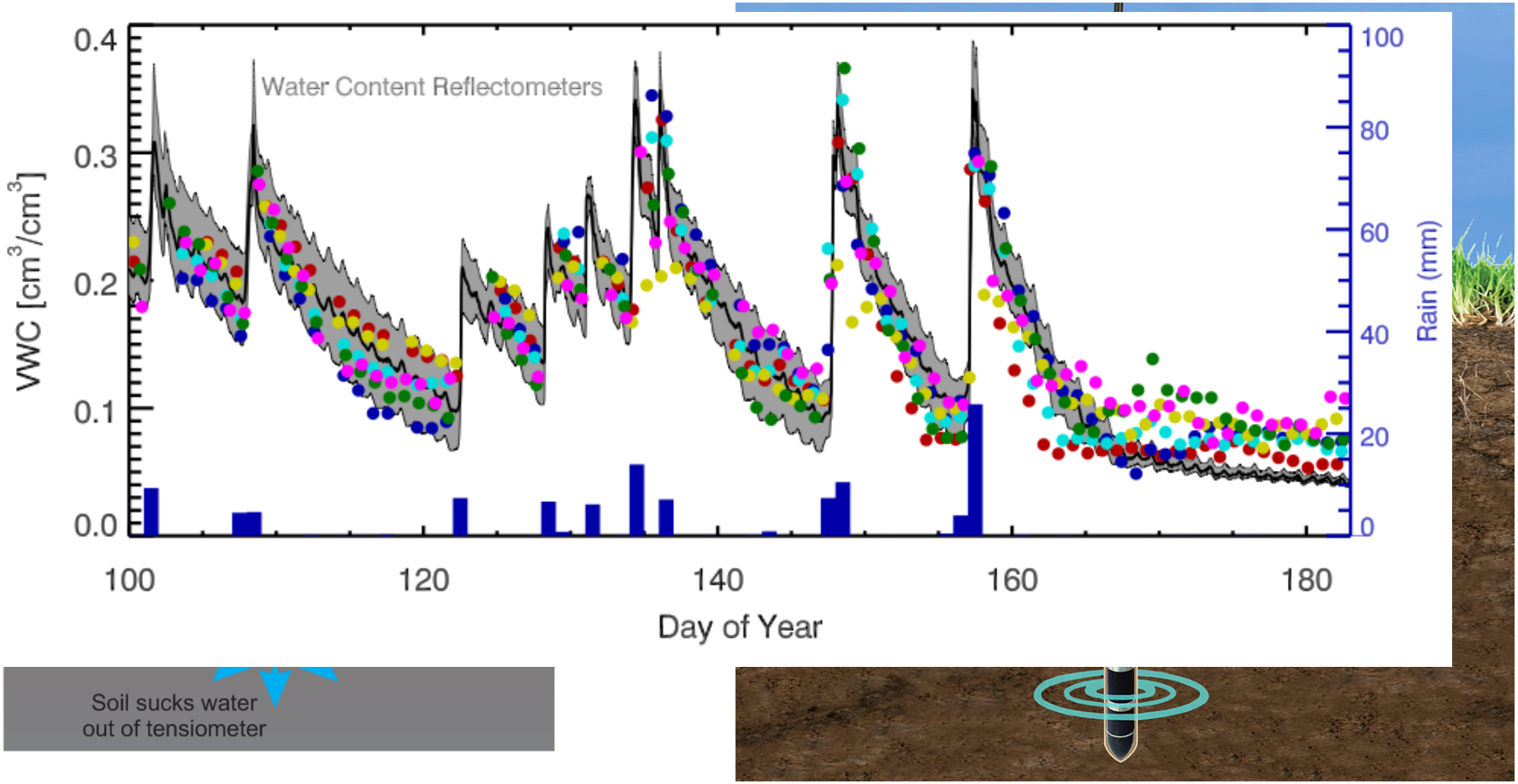

Soil moisture

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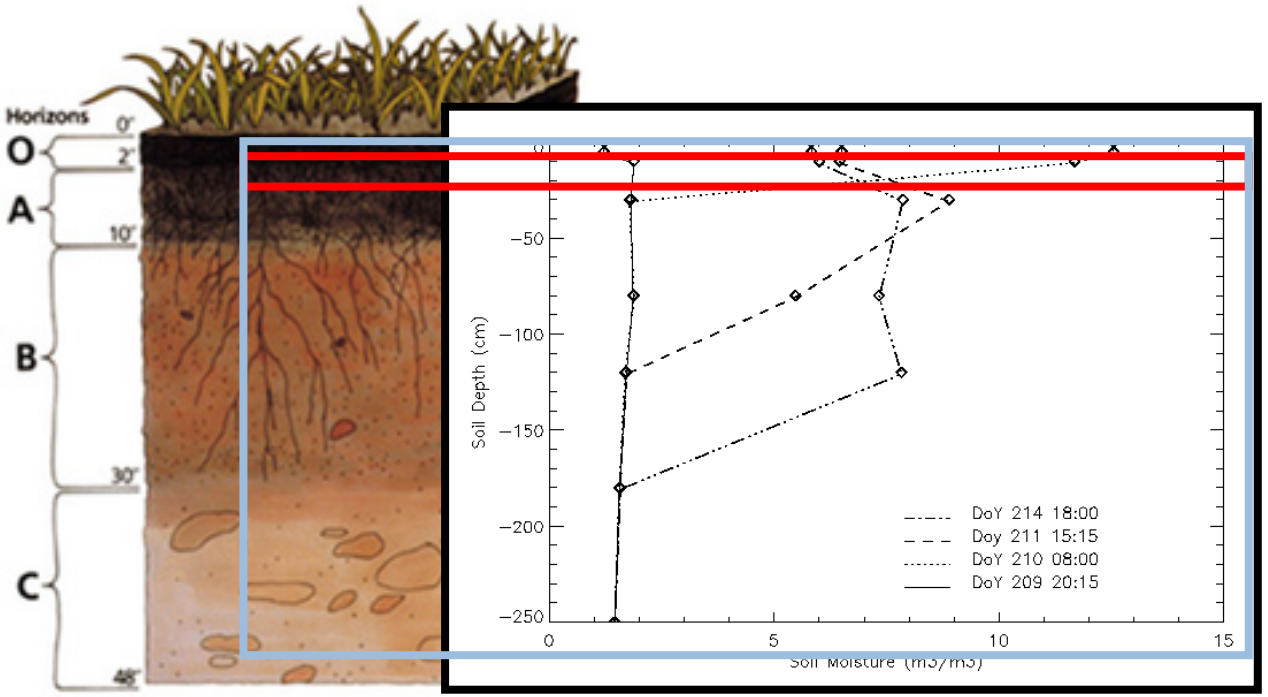
> **Satellite data → Surface information**

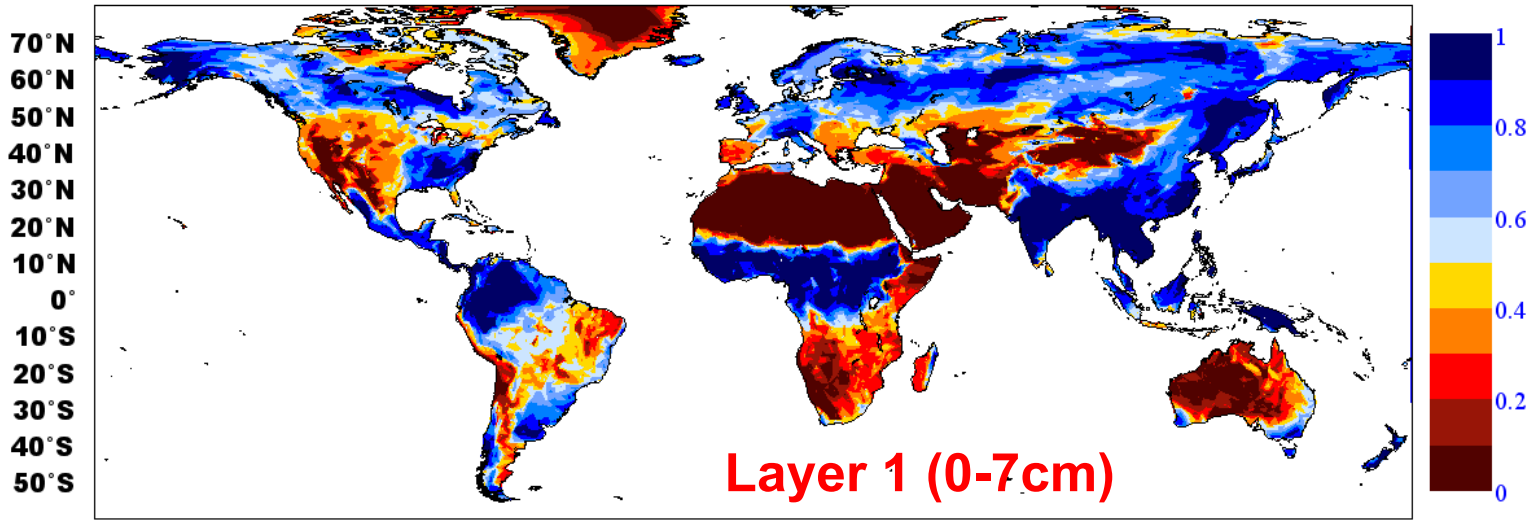
Top soil moisture sampling depth: 0-2cm ASCAT, 0-5cm SMOS

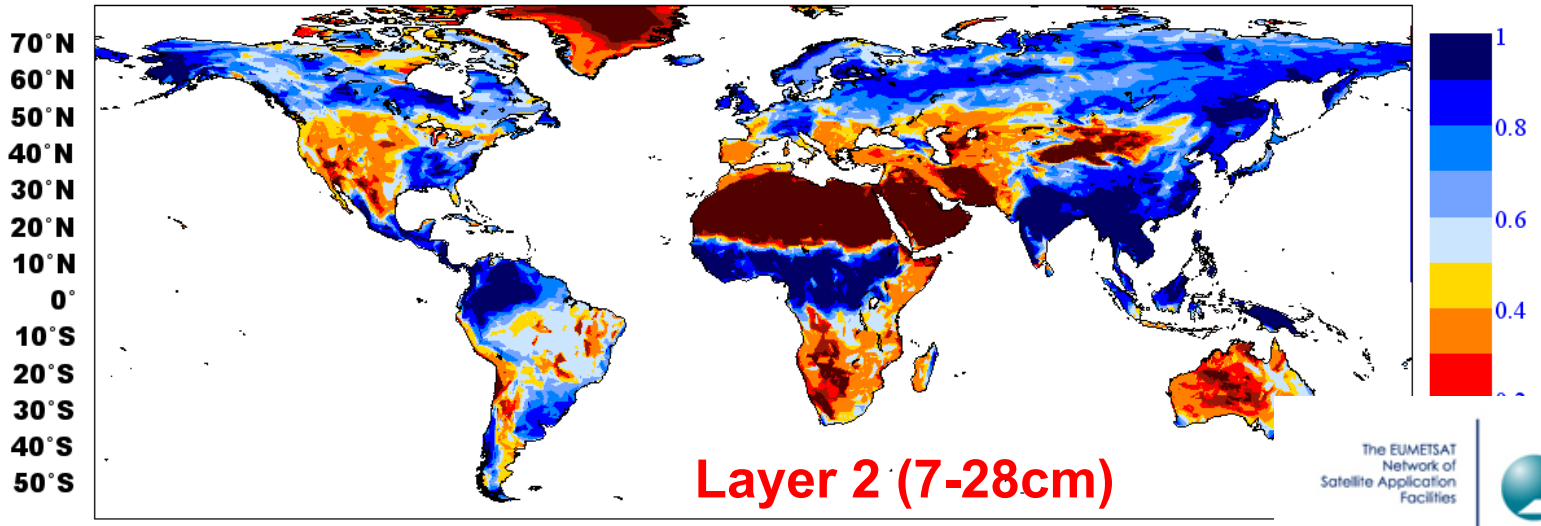


→ Retrieval of root zone soil moisture using satellite data requires data assimilation approaches

Figure from Patricia de Rosnay, ECMWF

ASCAT root zone retrieval based on data assimilation





Assimilated ASCAT soil moisture index (0-1); 04.08.2012 00UTC

Slide from Patricia de Rosnay, ECMWF

European Center for Medium Weather Forecast (ECMWF) – example: soil moisture

Soil moisture from ASCAT (Time-averaged geographical mean

Monitoring of the observing system

Satellite Data

Filters

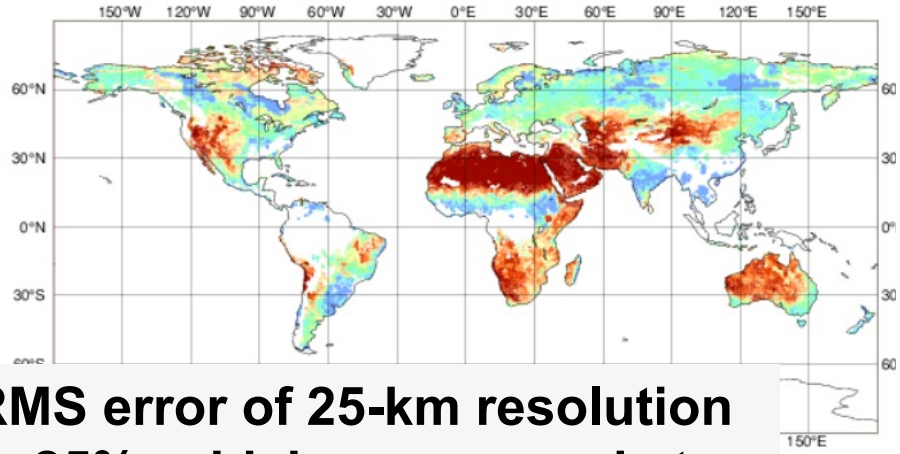
Show All

Parameter

- 2m Relative humidity (0/2)
- 2m temperature (0/2)
- All sky radiances (0/51)
- Bending angles (0/6)
- GPS Path delay (0/3)
- Ozone (0/19)
- Potential Temperature (0/6)
- Radar precipitation (0/2)
- Radiances (0/91)
- Surface pressure (0/3)

STATISTICS FOR SOIL MOISTURE FROM METOP-A/ASCAT
MEAN OBSERVATION [M3/M3] (ALL)
DATA PERIOD = 2017-06-20 21 - 2017-07-21 21
EXP = 0001, CHANNEL = 1
Min: 0.000 Max: 0.765 Mean: 0.227
GRID: 0.50x 0.50

25km footprint



Expected average RMS error of 25-km resolution soil moisture index ~25%, which corresponds to about 0.03 - 0.07 m^3 water per m^3 soil, depending on soil type

https://www.ecmwf.int/en/forecasts/charts/obstat/slmoist_metop__geo_0001_plot_o_geo_slmoist_metop

Summary soil moisture

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- ASCAT backscatter strength is influenced by 0-2cm depth
- SMOS brightness temperature is influenced by 0-5cm depth
- ASCAT: ensured operational continuity on MetOp
- SMOS: ? But new NASA-mission SMAP (soil moisture active passive) launched in March 2015
- NRT products available from HSAF or ESA-SMOS (high quality) via EUMETCAST
- Spatial resolution: 40km
- Daily availability (00:00 UTC)
- HSAF-ASCAT product includes DA to model soil moisture in four layers (0-7, 7-28, 28-100, 100-235 cm)
- Soil moisture index (0-1) directly related to soil moisture (m^3m^{-3})

Variables in hydrology and limnology

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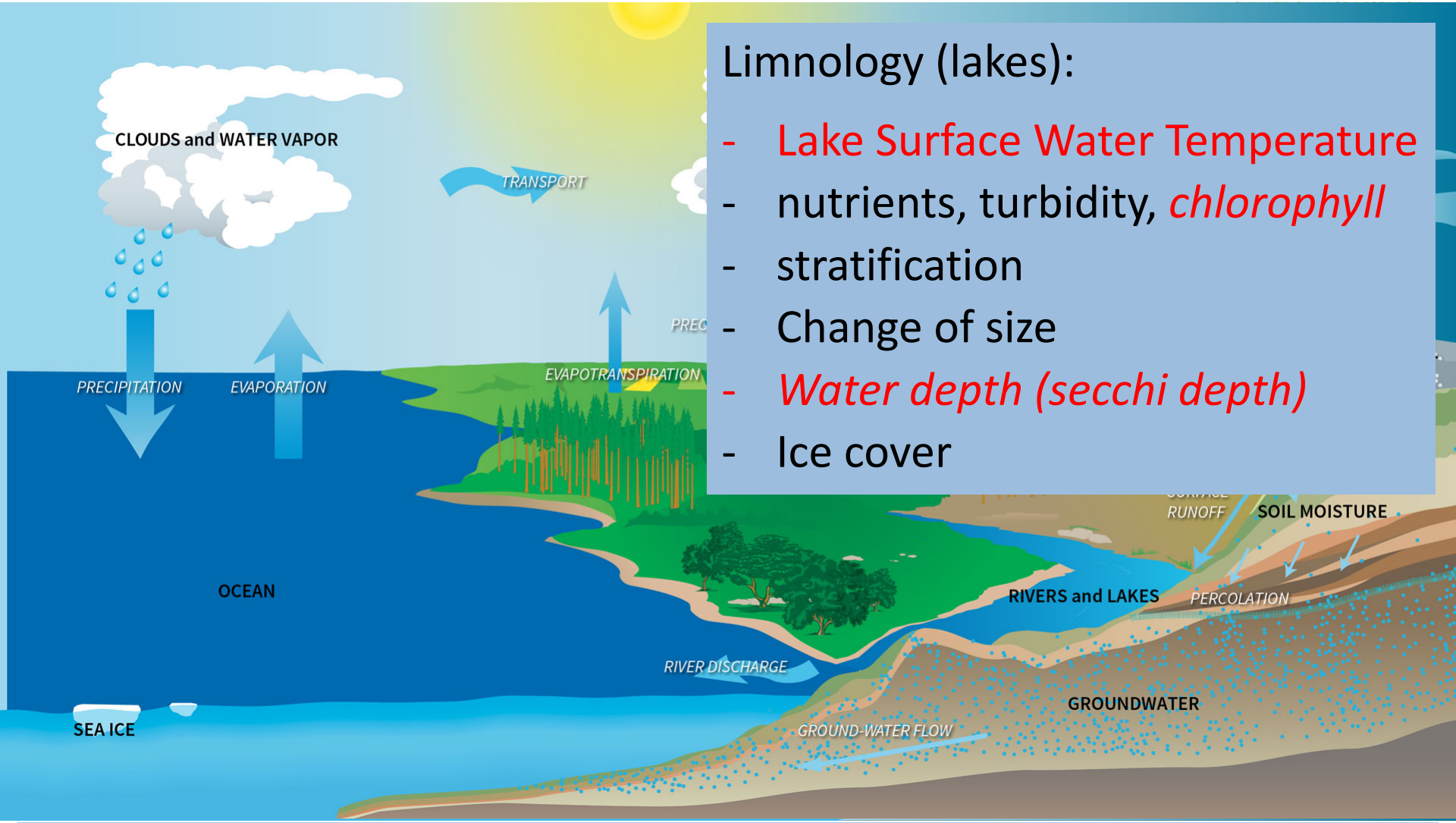

Limnology (lakes):

- Lake Surface Water Temperature
- nutrients, turbidity, *chlorophyll*
- stratification
- Change of size
- *Water depth (secchi depth)*
- Ice cover

New-NASA-Estimates-of-Liquid-Assets

Copernicus - Permanent Water Bodies

http://land.copernicus.eu/pan-european/high-resolution-layers/permanent-water-bodies/view

Absorption coefficient of water determines spectral bands to be used for product retrieval

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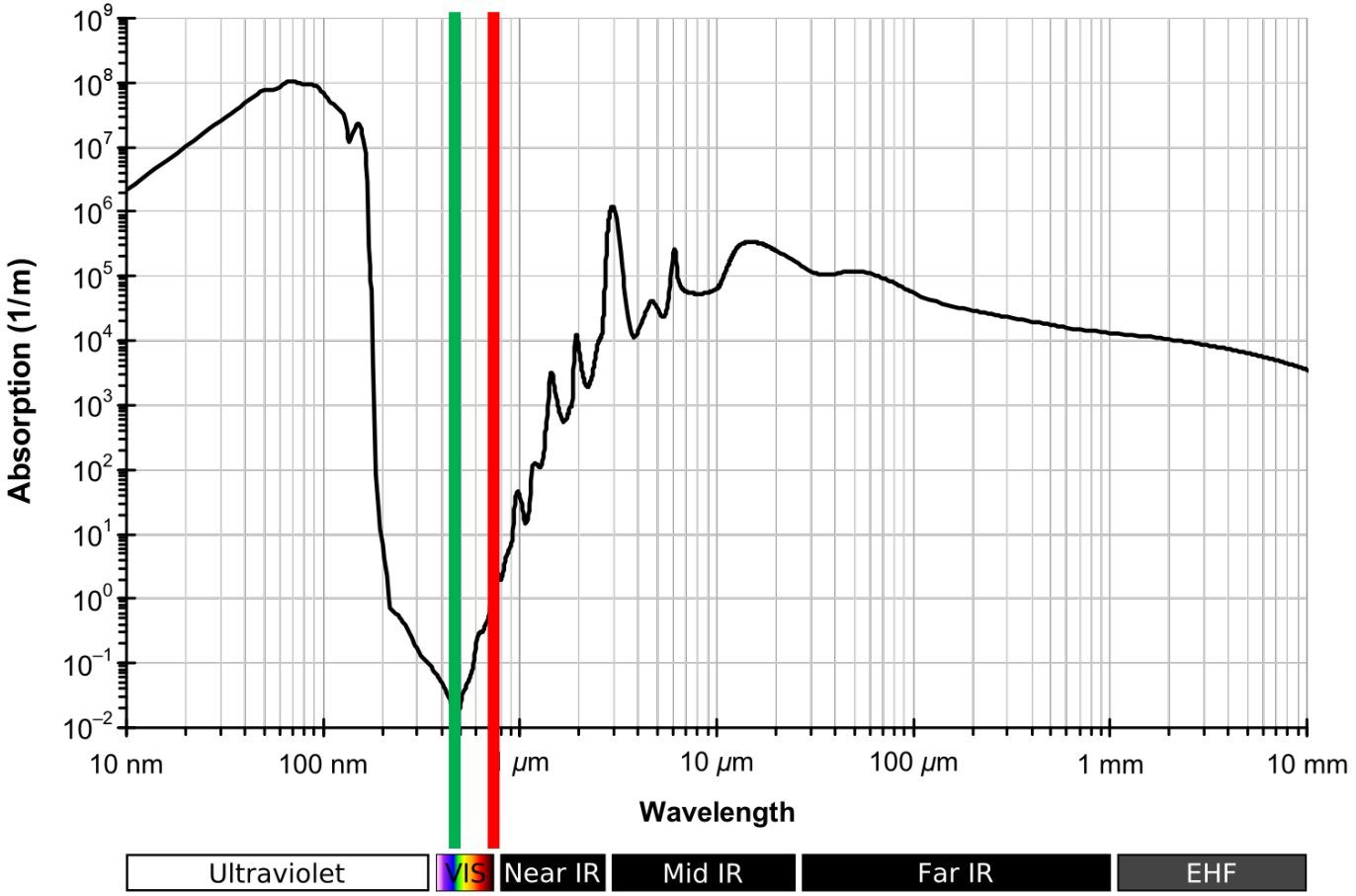

https://upload.wikimedia.org/wikipedia/commons/1/18/Absorption_spectrum_of_liquid_water.png

Active remote sensing bathymetry and floodplain mapping

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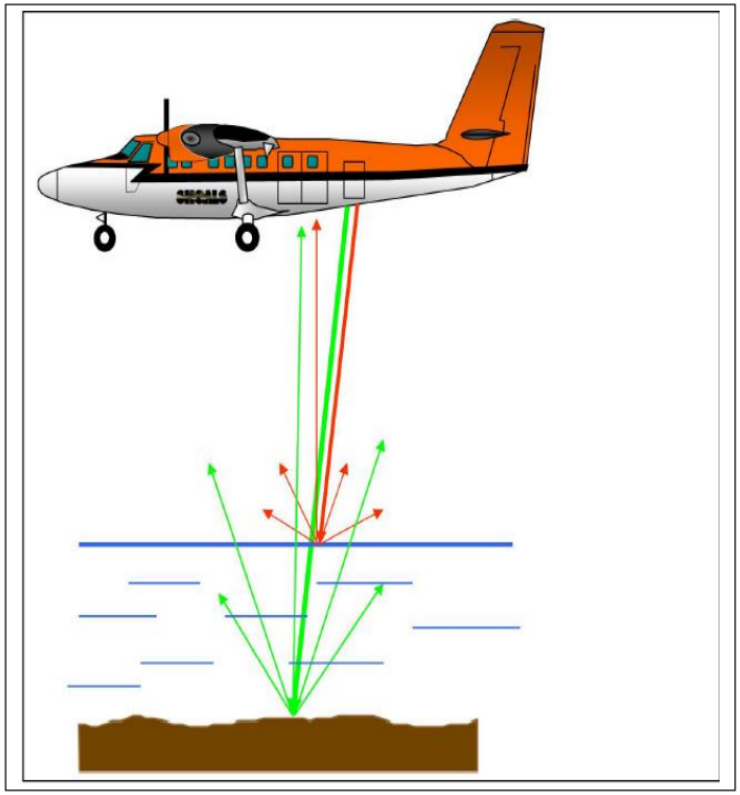

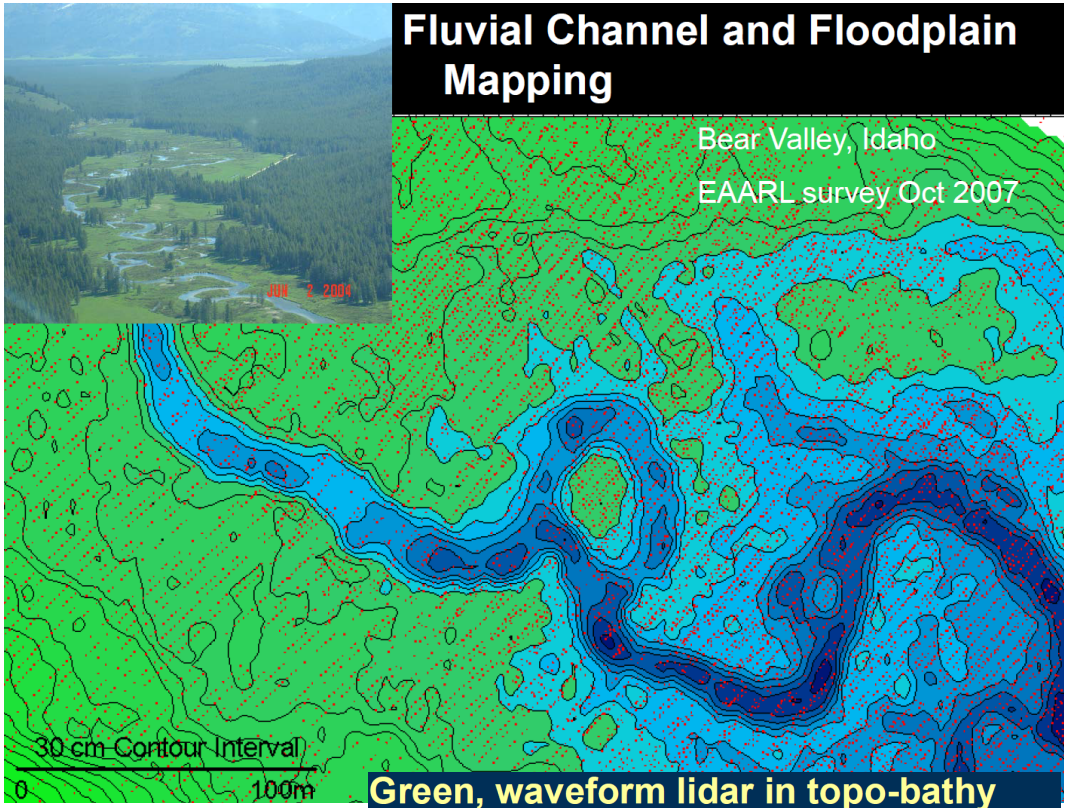

Green, waveform lidar in topo-bathy mapping – Principles and Applications

Amar Nayegandhi

Jacobs Technology contracted to
US Geological Survey, St. Petersburg Coastal and Marine Science Center, St. Petersburg, FL 33701.
anayegandhi@usgs.gov

Colored Dissolved Organic Matter (Chlorophyll)

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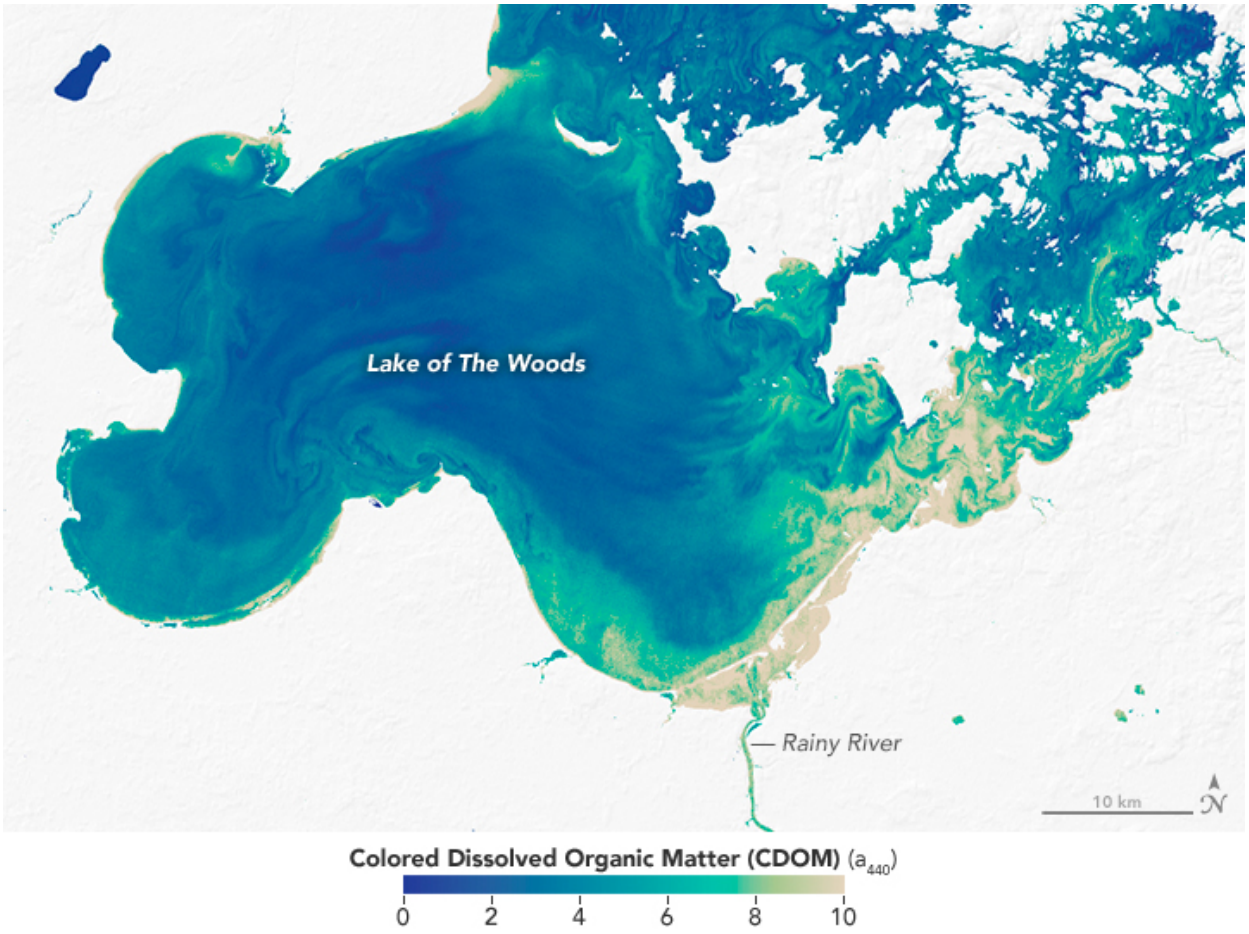

Retrieval based on data of Landsat-8 OLI sensor considering absorption of different spectral bands

https://earthobservatory.nasa.gov/IOTD/view.php?id=88971

Copernicus: water quality in lakes and reservoirs based on Sentinel-2 and -3 data

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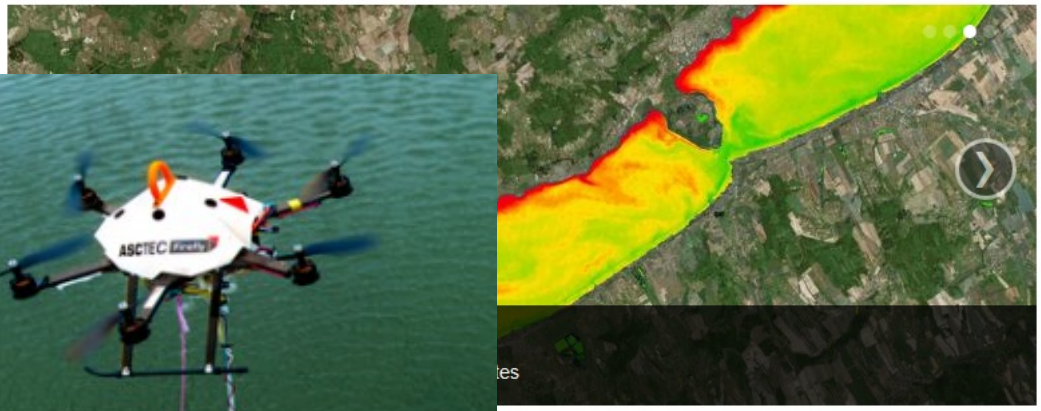
GLaSS

Copernicus

Home | News & Events | Project | Consortium | Downloads | Contact | GLaSS-S3VT team | Training material

Global Lakes Sentinel Services

GLaSS developed innovative tools to prepare for using the new Sentinel-2 and Sentinel-3 satellites to monitor water quality in lakes and reservoirs.



ithms and applications for the use of data of Sentinel-2 (S2) and ervoirs. The results are demonstrated with global lake use material.

an Union under the 7th Framework Programme (project number:313256).

Latest News

Our fourth newsletter with the latest results is out!

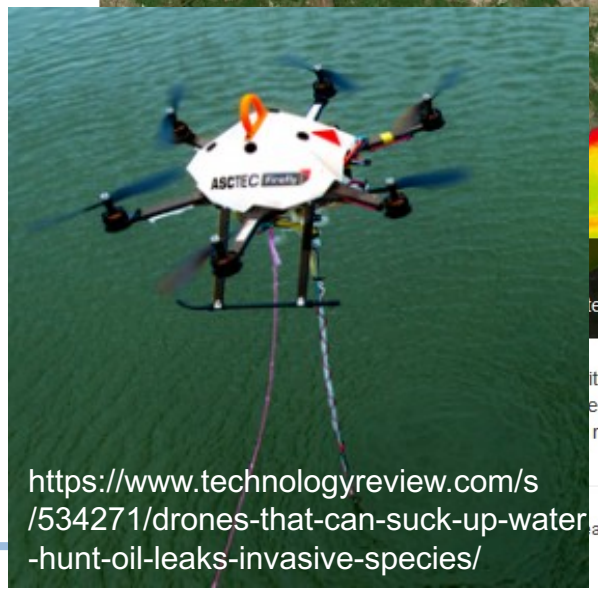
GLaSS Global lake use cases
First results from our global lake use cases, check the newest GLaSS Newsletter

Optical in situ protocol document for inland waters now available
Ocean Optics for inland waters

More news

Tweets by @GLaSS_Project

http://www.glass-project.eu/



https://www.technologyreview.com/s/534271/drones-that-can-suck-up-water-hunt-oil-leaks-invasive-species/

Monthly mean lake surface temperature Metop-A (May 2007 – Dec. 2012)

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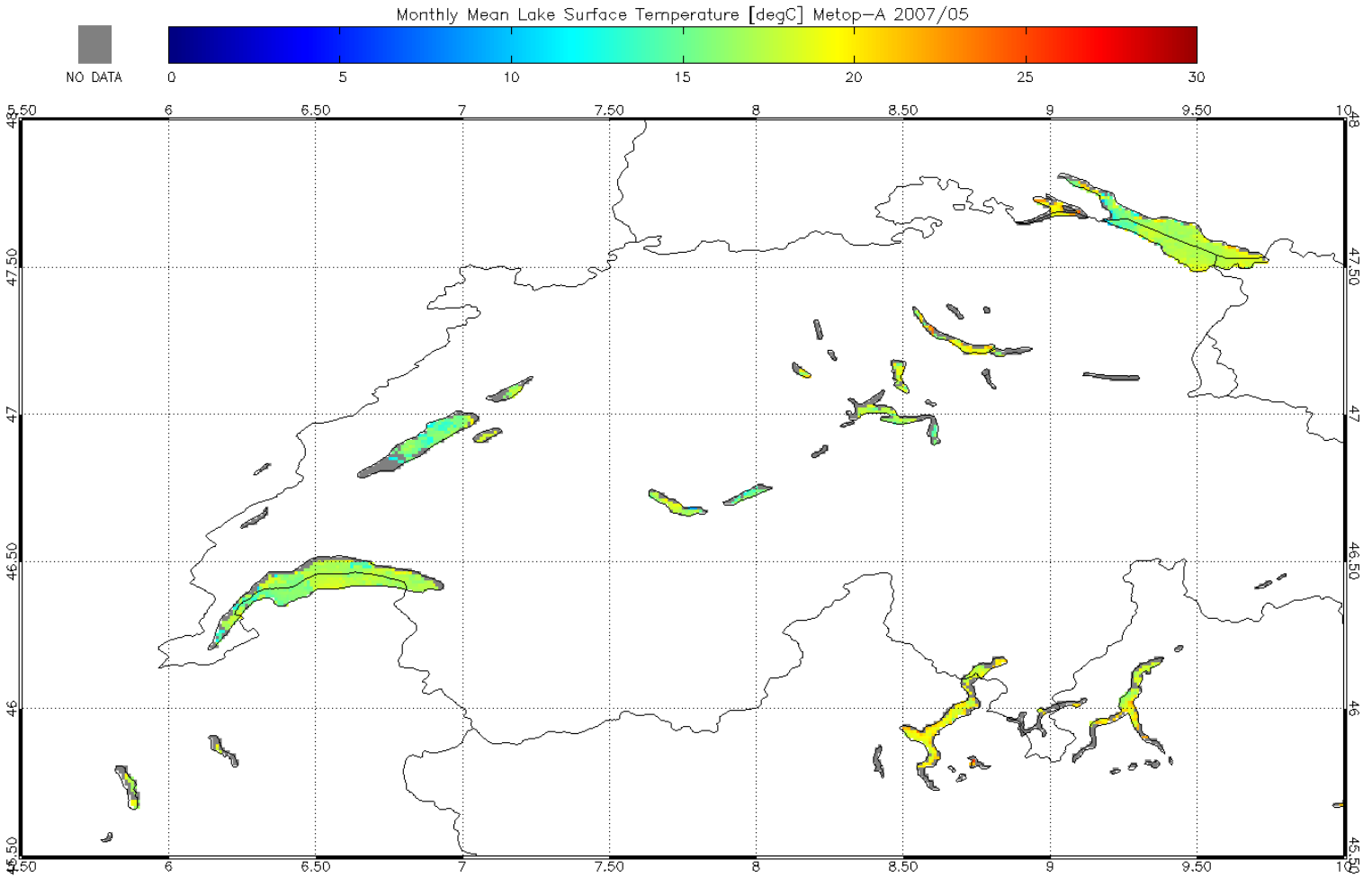
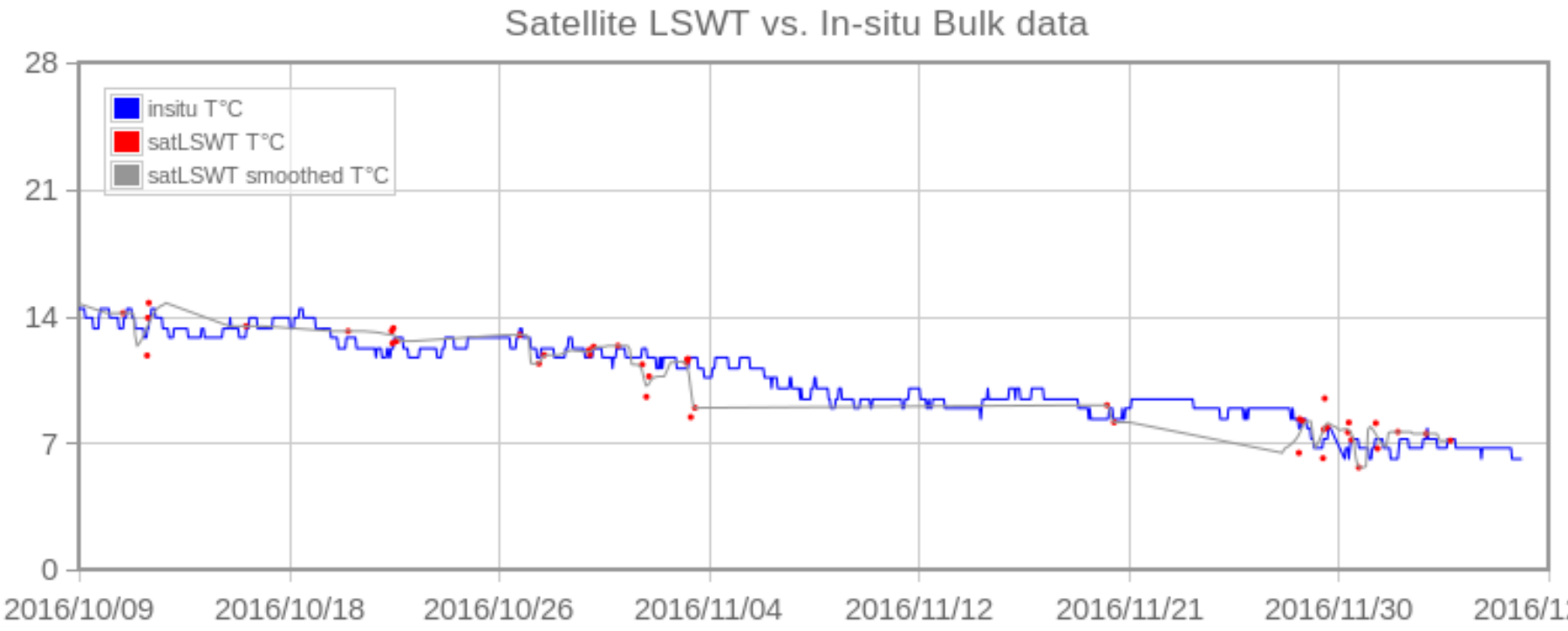


NRT application (example: Lake Constance)
blue: in-situ; red: Satellite LSWT

Bodensee



NRT: Spatial comparison with hydrodynamic lake model (Lake Geneva)

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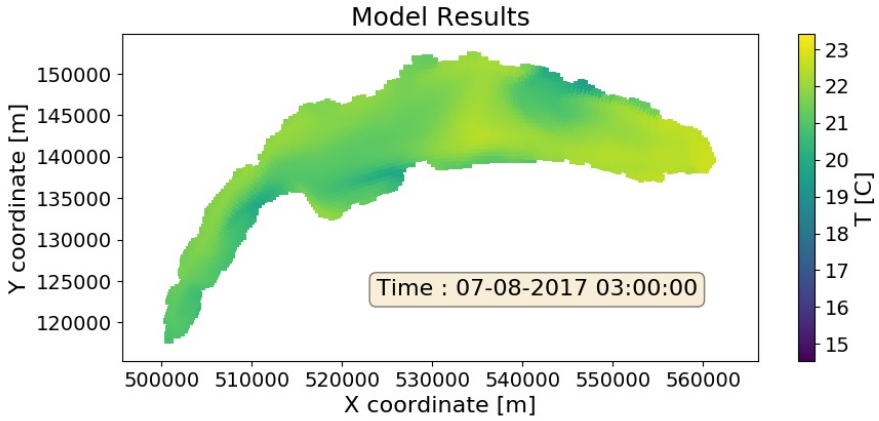

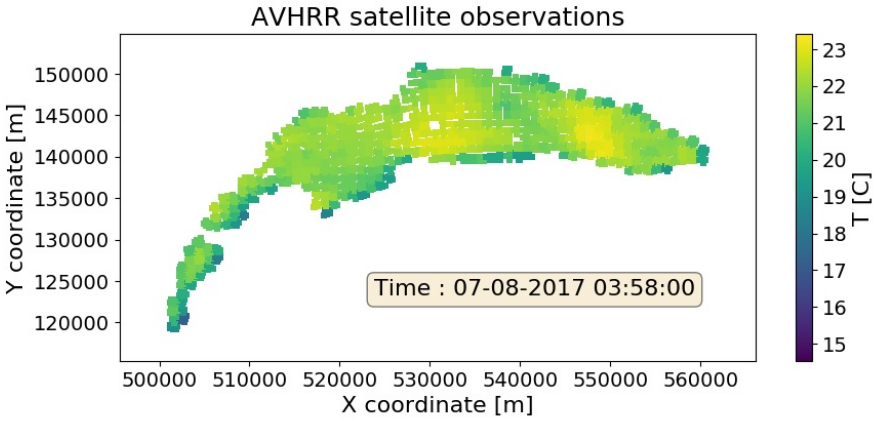

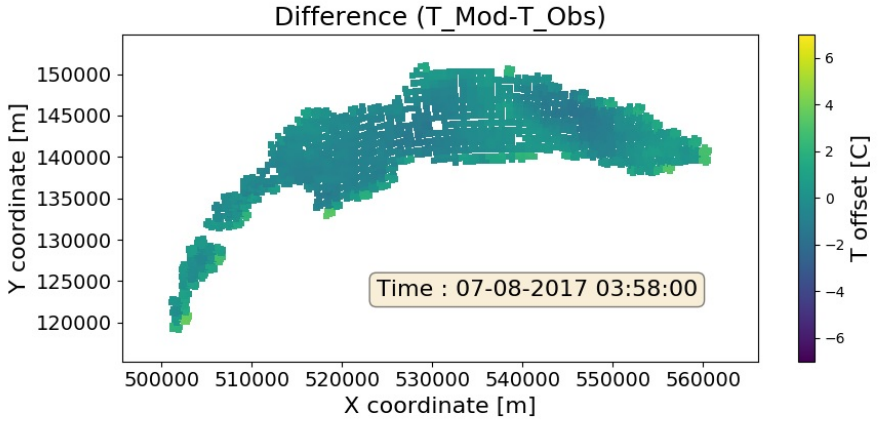

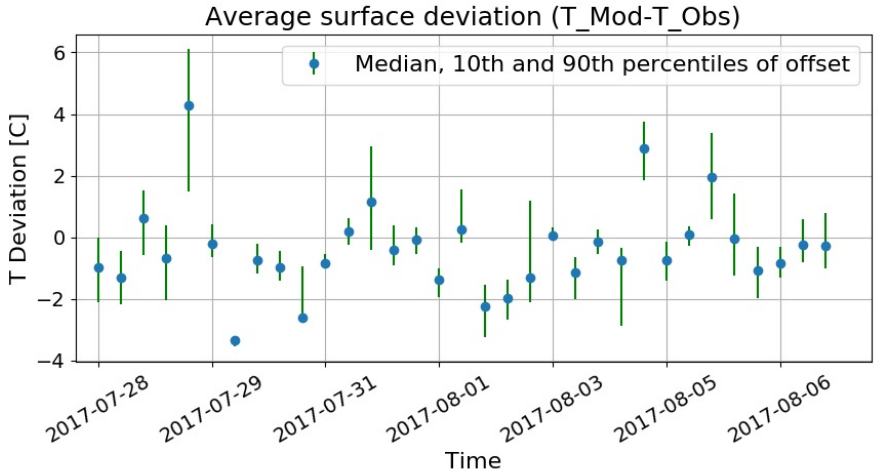

http://meteolakes.ch/validation/
theo.barachini@epfl.ch
gian.lieberherr@giub.unibe.ch

Summary: retrieval of water temperature

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- Methods and satellite data are available to retrieve water temperature in near-real-time.
  - Only skin-temperature can be measured. Skin-to-bulk needs additional effort.
  - Spatial resolution (375m – 1.000m); depending on sensor
  - During cloud cover: no retrieval of ground information if based on thermal remote sensing (passive microwave measures brightness temperature but with a spatial resolution of 25km)
  - RSGB – UniBern receives and processes satellite data to generate lake surface water temperature (1km) 8-10 times/day.

Summary: boundary conditions and product availability

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- **Spatial resolution**:
  - UAV, drones: 5 – 20 cm
  - LiDAR: points / m^2
  - Aerial cameras: 20 cm – 50 cm
  - Satellite data: 50 cm – 500 m (25 km)
- **Temporal resolution**:
  - UAV, drones: depending on field work
  - Aerial cameras: matter of costs; daily – two times per year
  - Satellites: fixed orbit; 15min – 16days.
- **Products**:
  - Near real time: → COPERNICUS and EUMETSAT Satellite Application Facilities (SAF)
  - Time series: ESA climate change initiative (CCI)

Final conclusions

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- Remote Sensing is a powerful tool to retrieve many variables for hydrological and limnological applications.
- For highest product quality it is recommended to combine remote sensing, insitu measurements and models.
- Spatial product generation is an advantage but pixel size limits sometimes usability in mountainous terrain or for small catchments (e.g. snow water equivalent)
- The retrieval of many variables relies on spectral bands in the visible, near and thermal infrared. Hence, no product generation during cloudy conditions.
- During the next 2-3 years many products will be generated based on the Sentinel-Satellites of the European Space Agency under the frame of EU-Copernicus program. Products will public available and free of charge.

Availability of data and products

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- http://hsaf.meteoam.it/
- http://land.copernicus.eu/pan-european/high-resolution-layers/permanent-water-bodies/view
- http://swicca.climate.copernicus.eu/indicator-interface/maps/
- http://cci.esa.int/
- https://wci.earth2observe.eu/
- http://rs.geo.tuwien.ac.at/cci_dataviewer/
- http://www.cyanolakes-project.com/
- http://www.glass-project.eu/