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

> 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

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

Limnology (lakes):
- Lake Surface Water Temperature
- nutrients, turbidity, chlorophyll
- stratification
- Change of size
- Water depth (secchi depth)
- Ice cover
Tools to gather information about snow

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

AVHRR data archived at UniBe from 01/1983 – ongoing
Hydrology: example I
Snow Water Equivalent (SWE)

- 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.

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N. Foppa (RSGB) and A. Stoffel (SLF)
EUMETSAT – Hydrology Satellite Application Facility (H-SAF)

### PRECIPITATION

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### SOIL MOISTURE

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### SNOW

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[http://hsaf.meteoam.it/](http://hsaf.meteoam.it/)
Snow Water Equivalent (SWE)
Change in 2050 based on RCP 8.5

Summary: snow

- **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

Water Content Reflectometers

Soil sucks water out of tensiometer
Soil moisture

- 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

Layer 1 (0-7cm)

Layer 2 (7-28cm)

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

Slide from Patricia de Rosnay, ECMWF
Soil moisture from ASCAT (Time-averaged geographical mean)

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

> 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 (m³m⁻³)
Variables in hydrology and limnology

Limnology (lakes):
- Lake Surface Water Temperature
- nutrients, turbidity, *chlorophyll*
- stratification
- Change of size
- *Water depth (secchi depth)*
- Ice cover
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.
Active remote sensing bathymetry and floodplain mapping

http://aucillaresearchinstitute.org/?page_id=134
Colored Dissolved Organic Matter (Chlorophyll)

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

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

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

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

NRT application (example: Lake Constance)
blue: in-situ; red: Satellite LSWT
NRT: Spatial comparison with hydrodynamic lake model (Lake Geneva)

http://meteolakes.ch/validation/
theo.barachini@epfl.ch
gian.lieberherr@giub.unibe.ch
Summary: retrieval of water temperature

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

- **Spatial resolution:**
  - UAV, drones: 5 – 20 cm
  - LiDAR: points / m²
  - 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

- 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

- http://hsaf.meteoam.it/
- http://cci.esa.int/
- https://wci.earth2observe.eu/
- http://rs.geo.tuwien.ac.at/ci_dataviewer/
- http://www.cyanolakes-project.com/
- http://www.glass-project.eu/