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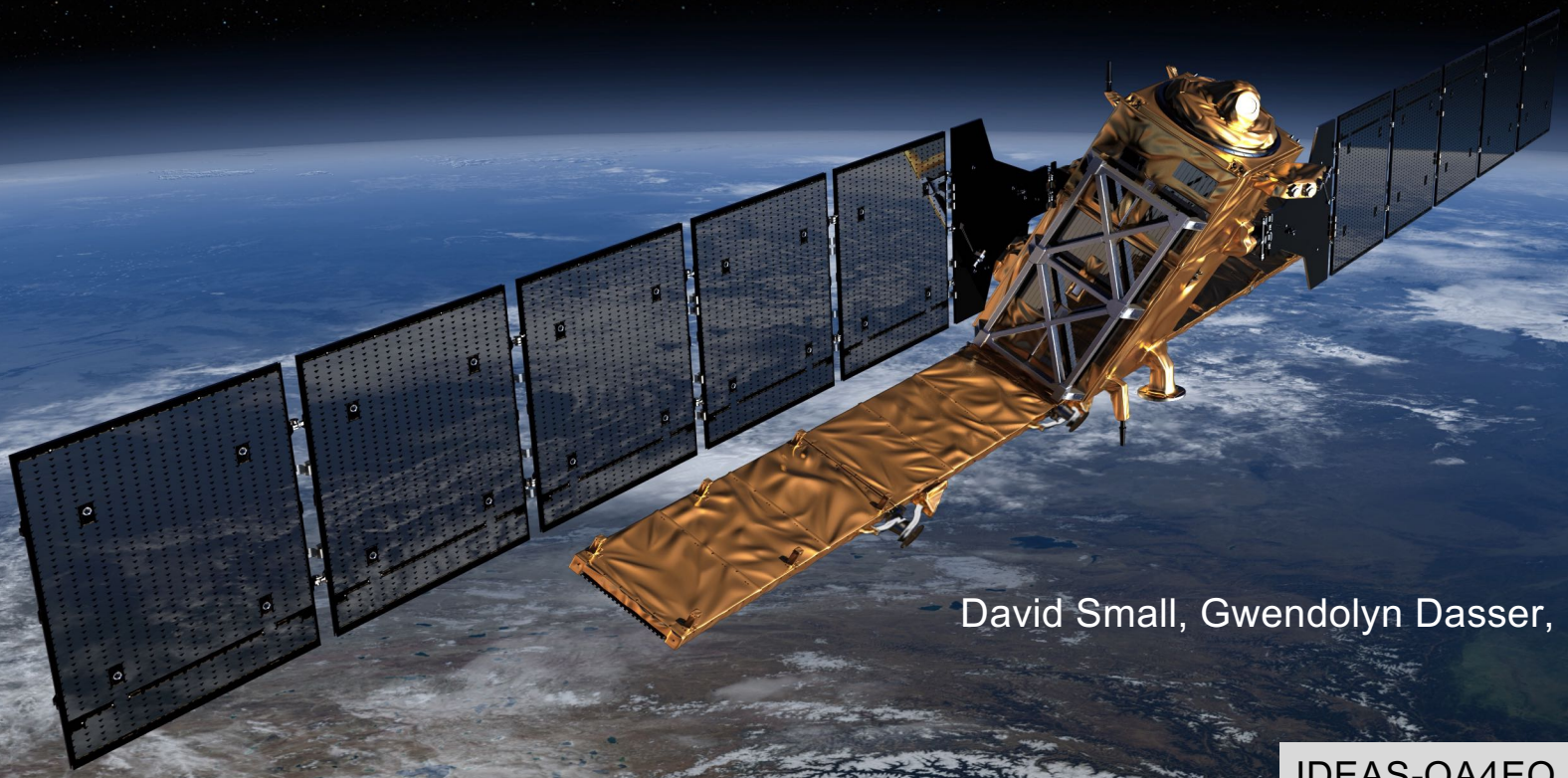
esa

CSA ASC

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Use of Satellite-based SAR data for Snow Monitoring



David Small, Gwendolyn Dasser, Hendrick Wulf (UZH)

IDEAS-QA4EO Cal/Val Workshop #3
Apr. 1, 2022

SAR terrain corrections

- Geometric Terrain Correction (**GTC**)
  - Range-Doppler *Orthorectified Backscatter*

- Radiometric Terrain Correction (**RTC**)
  - *Terrain Flattened Backscatter* – Small, "Flattening Gamma: Radiometric Terrain Correction for SAR Imagery", TGRS, Aug. 2011. doi: 10.1109/TGRS.2011.2120616

- Wide area backscatter *composites* from Local Resolution Weighting (**LRW**)
  - Small, Rohner, Miranda, Rüetschi, Schaepman, "Wide-area Analysis Ready Radar Backscatter Composites", TGRS, 2022. doi: 10.1109/TGRS.2021.3055562

CEOS CARD4L Goals

Dense time-series analyses at national-global scales

Broaden user community

– Provide data products that do not require expert knowledge

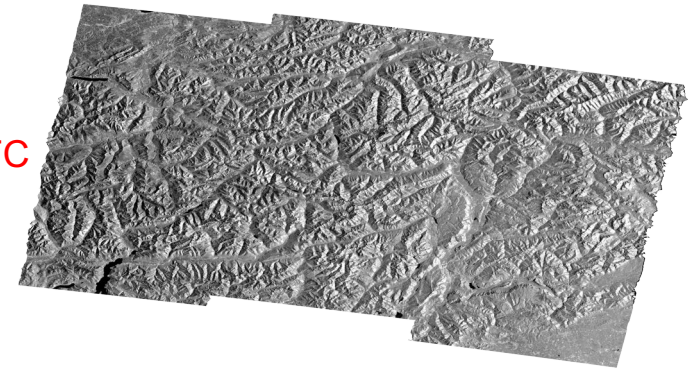
– Move from radar geometry (slant & ground range) to map coordinates

Radiometric Terrain Correction

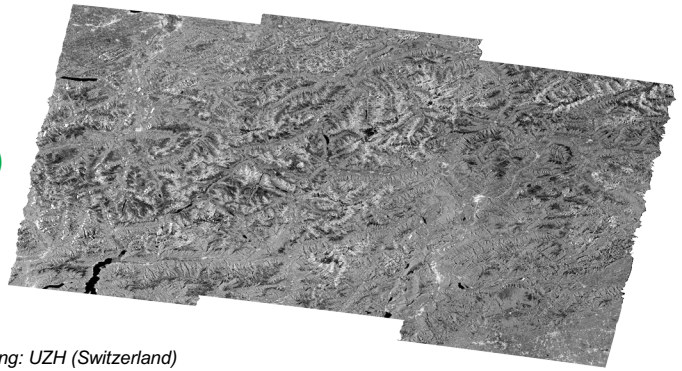
– A level playing field for multi-sensor data integration: planned to be built in to all SAR CARD4L products

– Backscatter normalised using ***local scattering area***, not incident angle

GTC



RTC (NRB)



Swiss/Austrian Alps – Processing: UZH (Switzerland)

Contains modified Copernicus Sentinel data (2016)

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Terrain-flattened Gamma Nought

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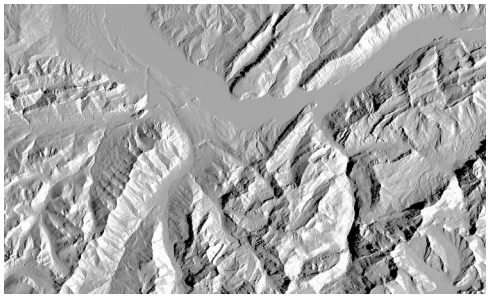
Interlaken, Switzerland
Sentinel-1A IW GRDH VH-pol.
May 26, 2015

Terrain-flattening: Small D. *Flattening Gamma: Radiometric Terrain Correction for SAR Imagery*, IEEE Trans. on Geoscience & Remote Sensing, 49(8), Aug. 2011, pp. 3081-3093.

Normalise β^0: divide by simulated image

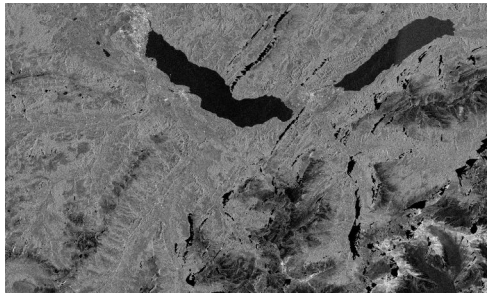
β^0 GTC



-26dB -1dB

A_γ / A_β

γ_T^0 =



RTC

$$\gamma_T^0 = \beta^0 \cdot \frac{A_\beta}{A_\gamma}$$

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Committee on Earth Observation Satellites	Analysis Ready Data *For Land (CARD4L)*	Product Family Specification: Normalised Radar Backscatter

CEOS CARD4L

Document Status

For Adoption as: **Product Family Specification, Normalised Radar Backscatter**

- Analysis Ready Data for Land Processes
  - See: **ceos.org/ard**
  - Define standards for ARD backscatter products
    - RTC (L1): Terrain-flattening: **Normalised Radar Backscatter** (CARD4L ***NRB***)
      - *NRB Product Family Specification revised in multiple iterations*
      - *Late-night collaborations with participants from Japan, USA, Canada, Australia, …*
      - *v5.5 approved by CEOS Land Surface Imaging - Virtual Constellations (LSI-VC) virtual meeting in 2021*
      - *POL "Polarimetric Radar" v3.5 Product Family Specification now also approved by LSI-VC*
    - Further products: **interferometric, geocoded SLC**: reviews ongoing
      - All further products to date include NRB terrain flattening
    - LRW (L3): Wide-area **Analysis Ready Data**
      - *Multi-Source Backscatter (**MSB**)*
      - *Initial MSB Product Family Specification to be drafted*

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Local Resolution Weighting

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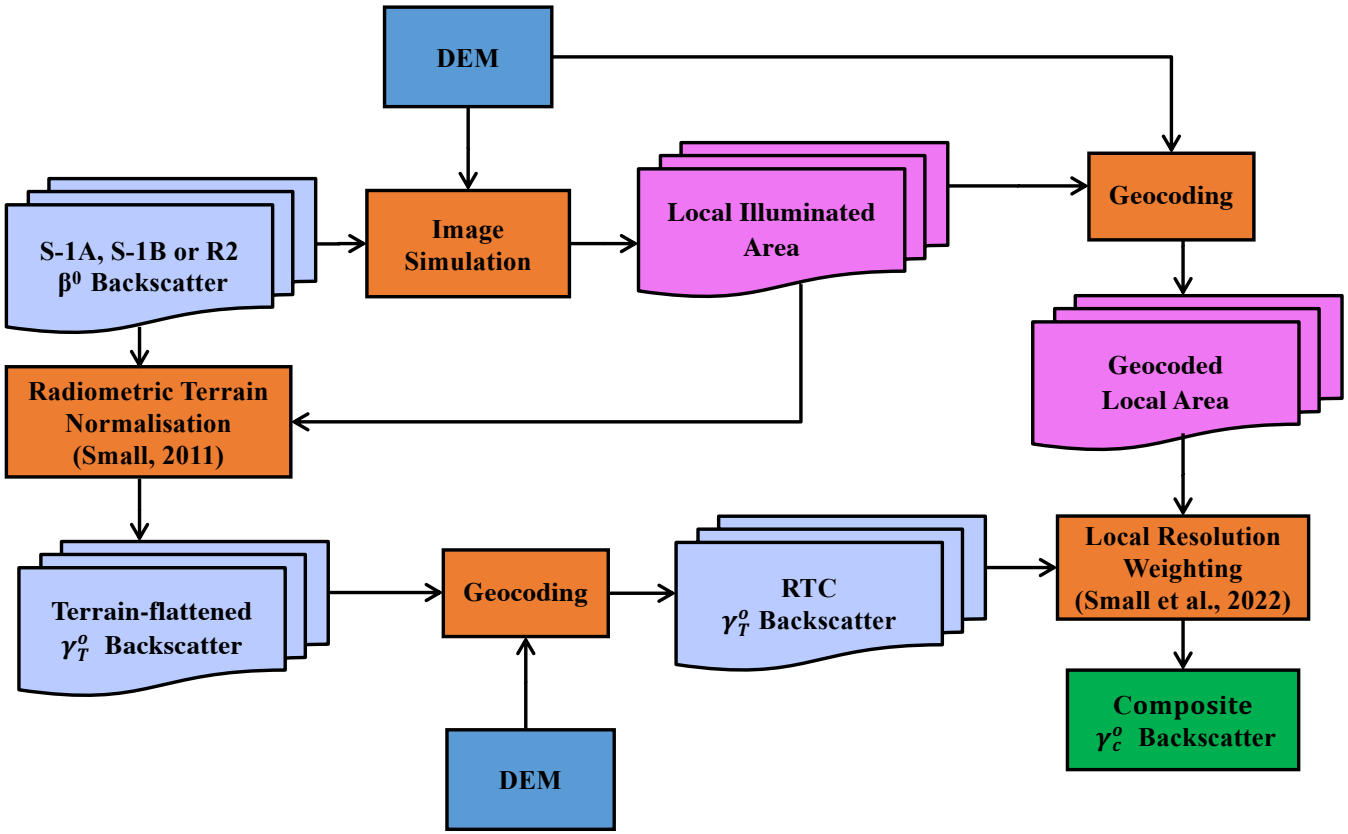
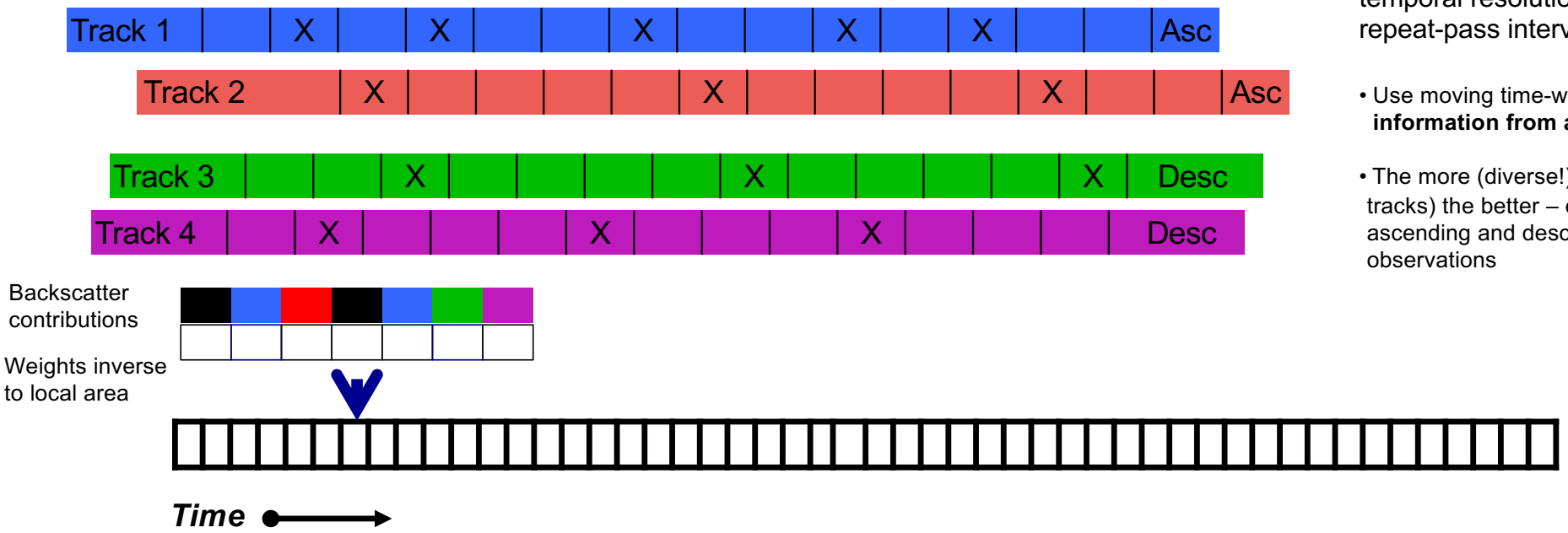


Small, Rohner, Miranda, et al., "**Wide-area Analysis Ready Radar Backscatter Composites**" IEEE-TGRS, 2022 (open access).

Revisit Interval: Breaking the tyranny of exact repeat passes



For *Regular Intervals* with temporal resolution better than repeat-pass interval

- Use moving time-window integrating **information from all tracks**
- The more (diverse!) data (and tracks) the better – esp. combine ascending and descending observations

Detailed Methodology in:
Small, Rohner, Miranda et al., “Wide-area Analysis Ready Radar Backscatter Composites”, IEEE-TGRS, 2022.

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Sentinel-1 Alpine Backscatter Time-Series

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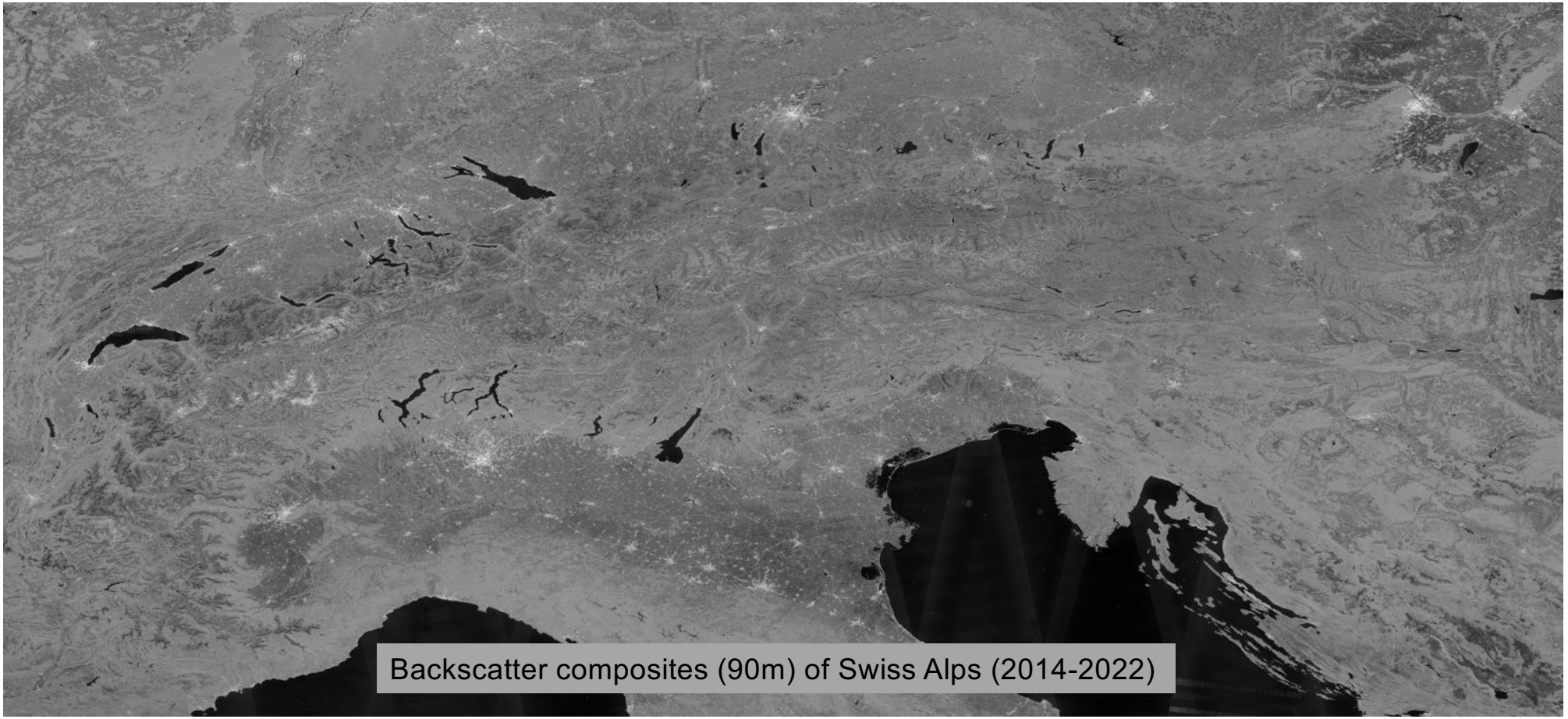
S-1A + S-1B IW VH-pol. **Apr. – Aug. 2020**: 12 day windows



Backscatter composites (90m) of Swiss Alps (2014-2022)

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Study Area

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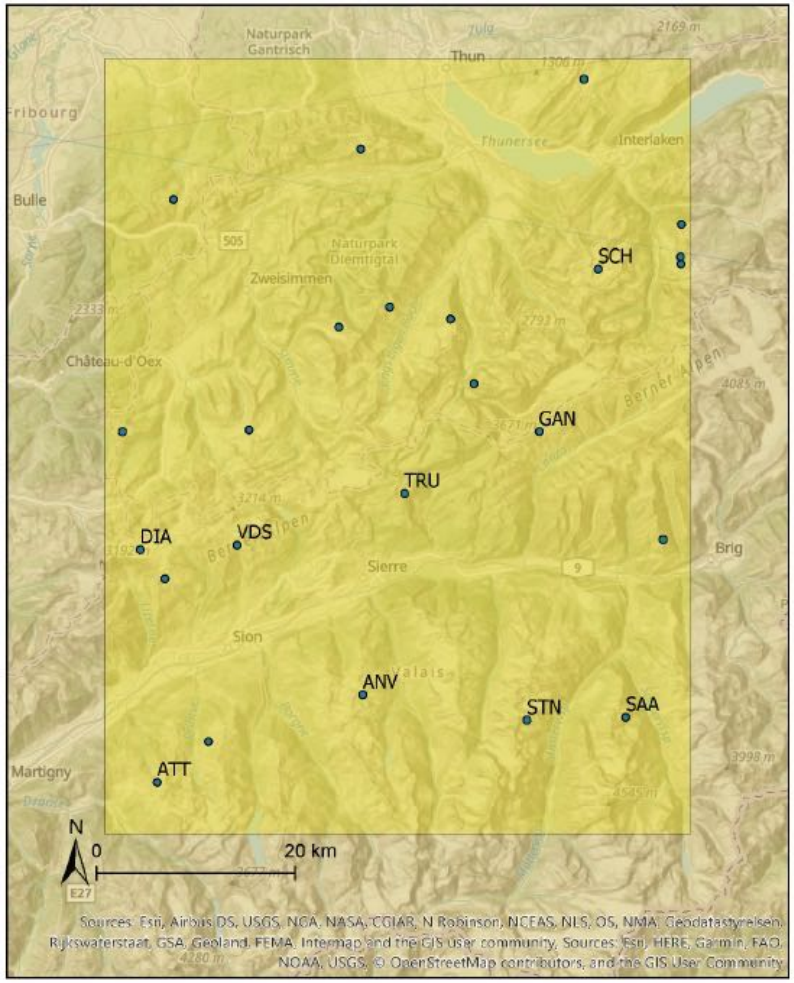

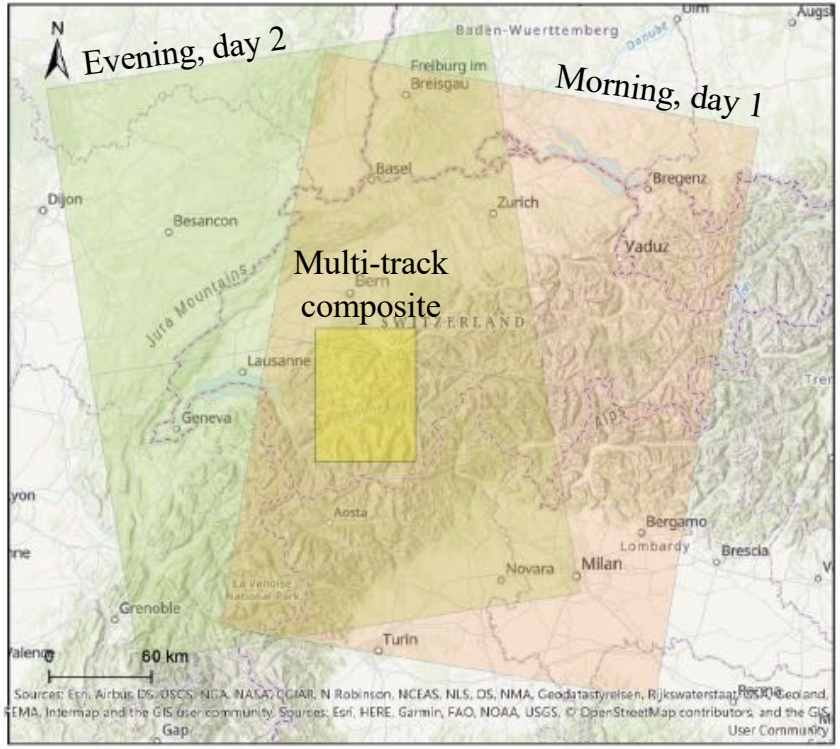

- IMIS measurement stations
- Research site
- Sentinel-1 descending orbit 66
- Sentinel-1 ascending orbit 88

Gwendolyn Dasser,
MSc. UZH, 2021.

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Sentinel-1 Backscatter 36 hour Local Resolution Weighting

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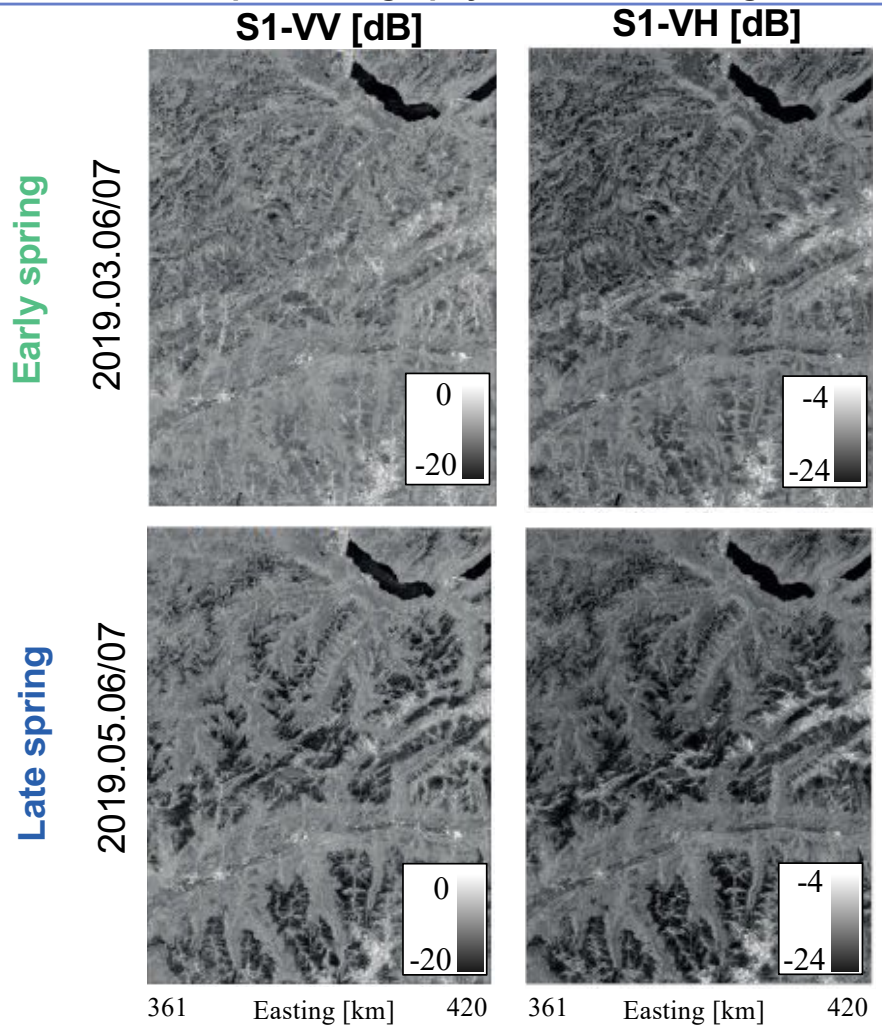

Low backscatter:
Wet Snow
High backscatter at high elevations:
Dry snow

Gwendolyn Dasser,
MSc. UZH, 2021.

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S1 Backscatter vs. Snow cover

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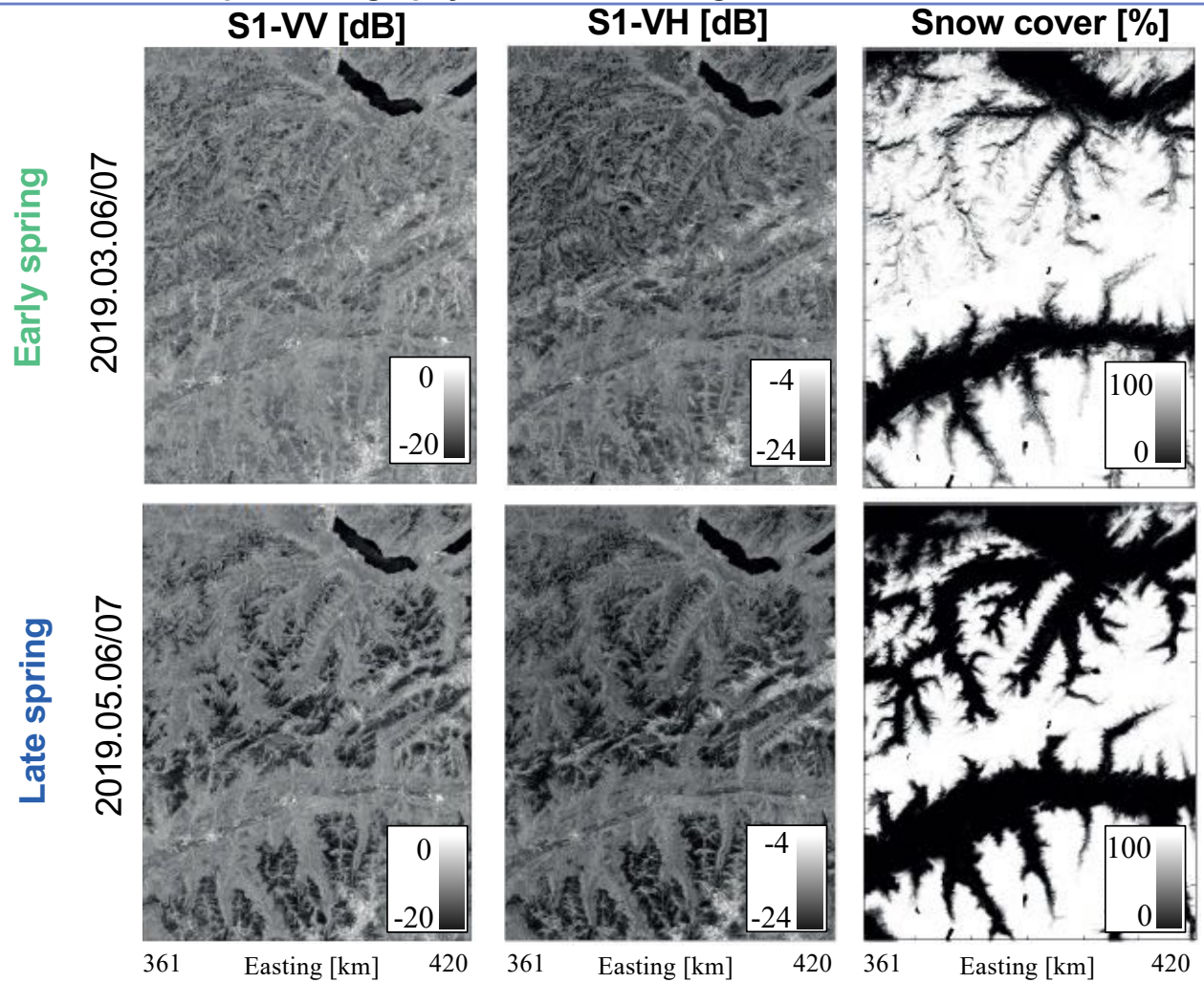

Snow cover from fusion of:
S2, Landsat, MODIS
(processing Hendrick Wulf, UZH)

Gwendolyn Dasser,
MSc. UZH, 2021.

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S1 Backscatter vs. Snow cover and Liquid Water Content / SWE

Gwendolyn Dasser,
MSc. UZH, 2021.

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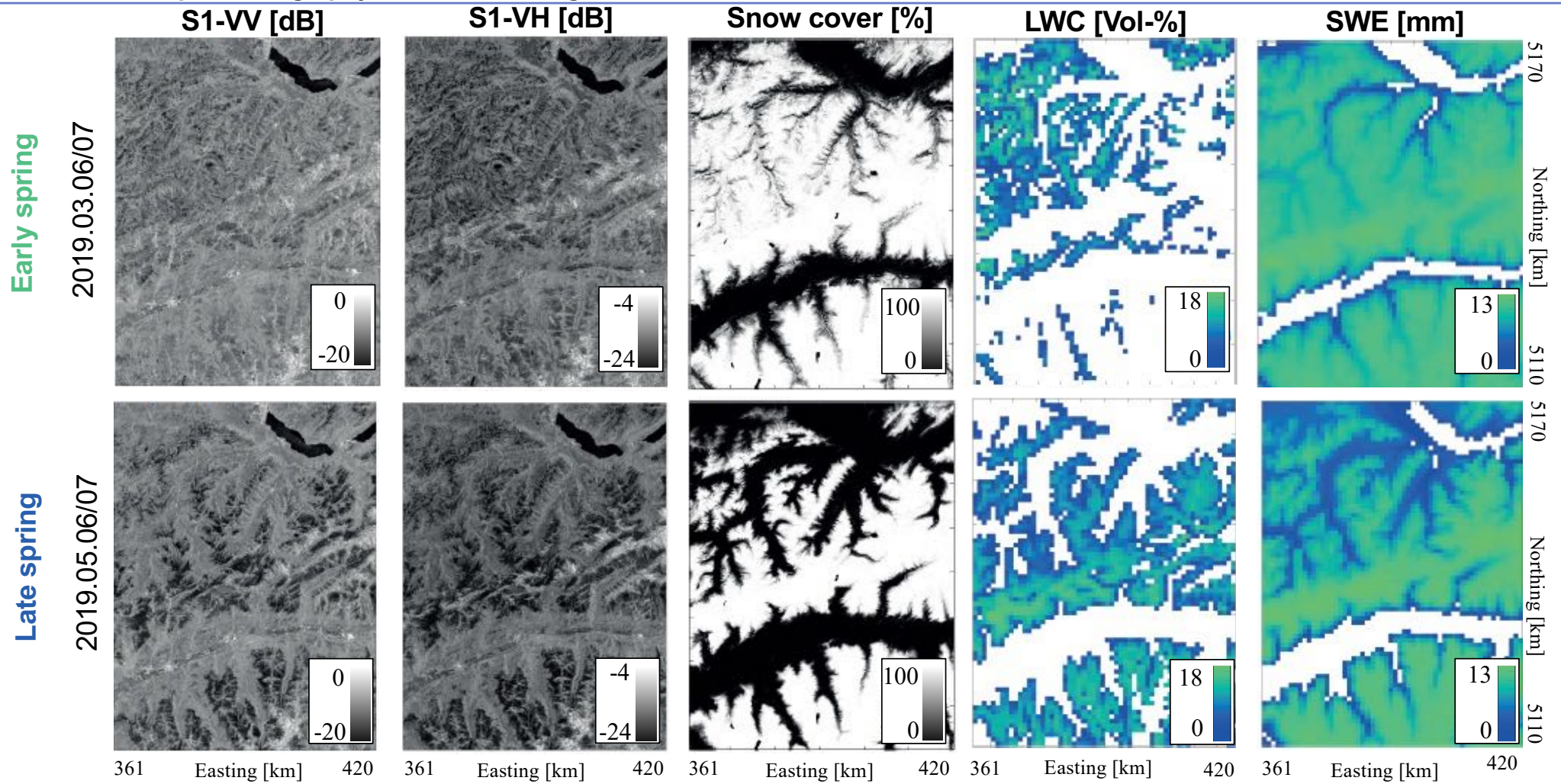

LWC & SWE from Tobias Jonas, SLF

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Snow backscatter time series

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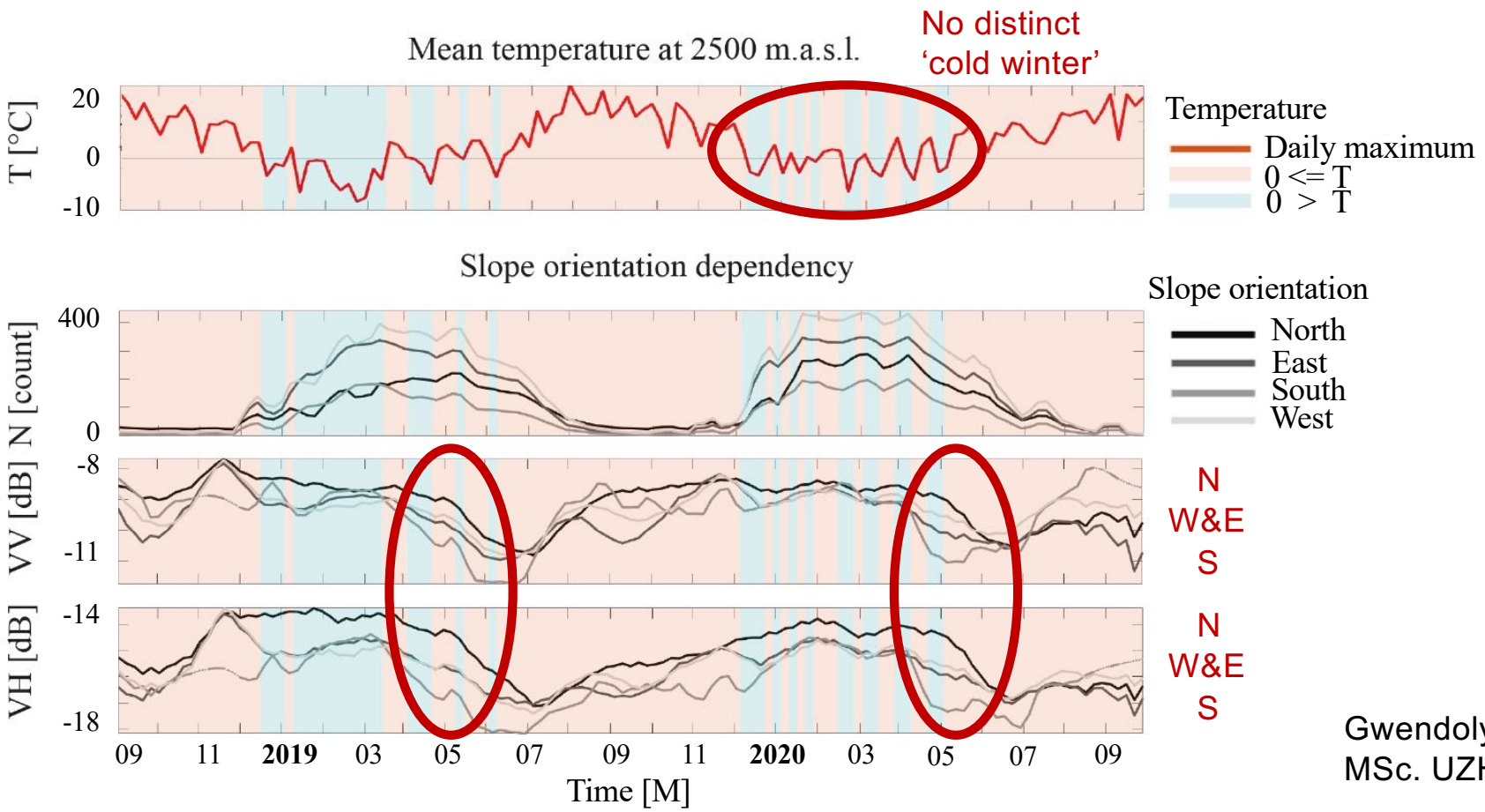

Gwendolyn Dasser,
MSc. UZH, 2021.

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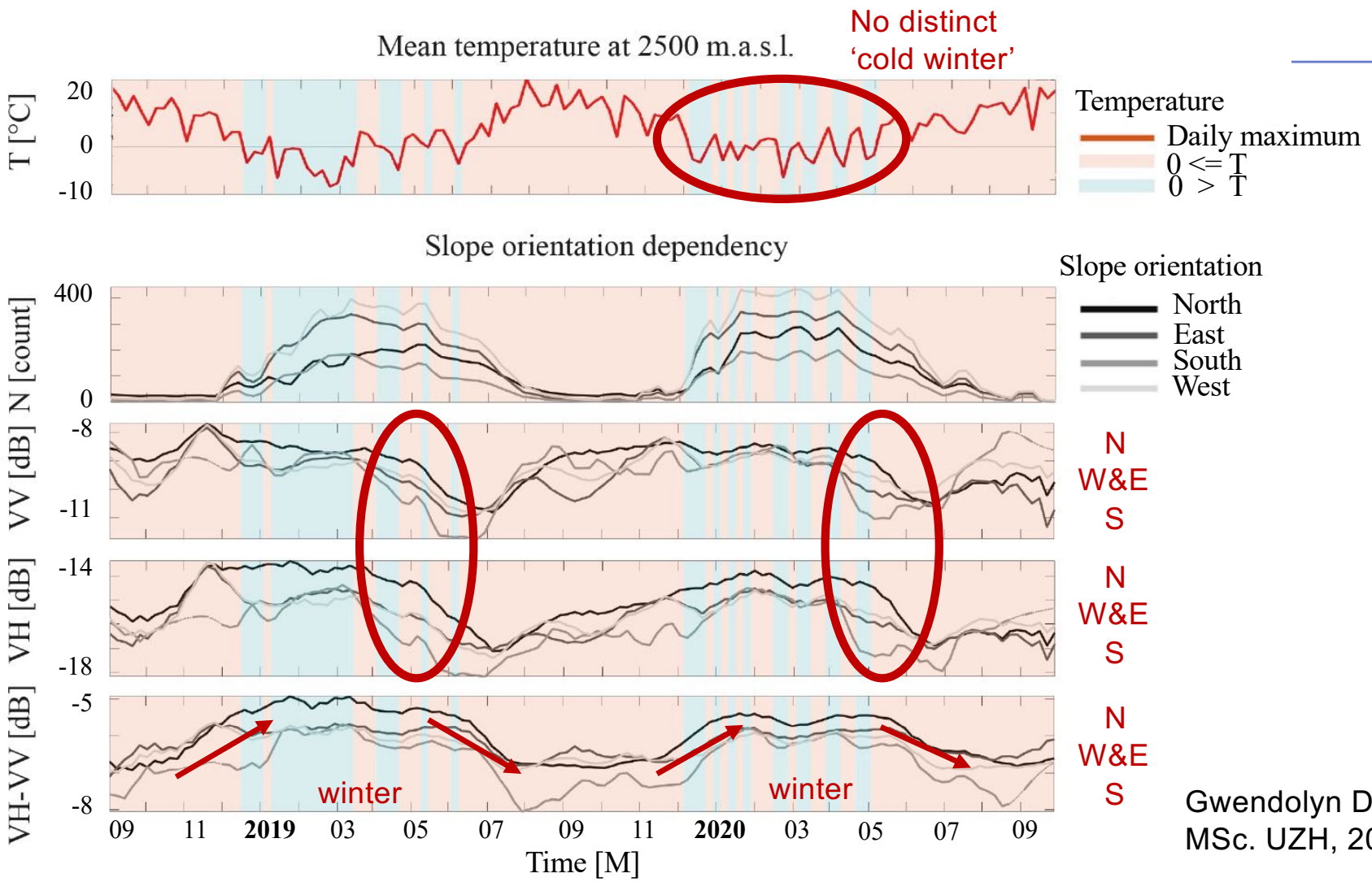
Snow backscatter time series



Gwendolyn Dasser, MSc. UZH, 2021.

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Contains modified Copernicus Sentinel data (2021)

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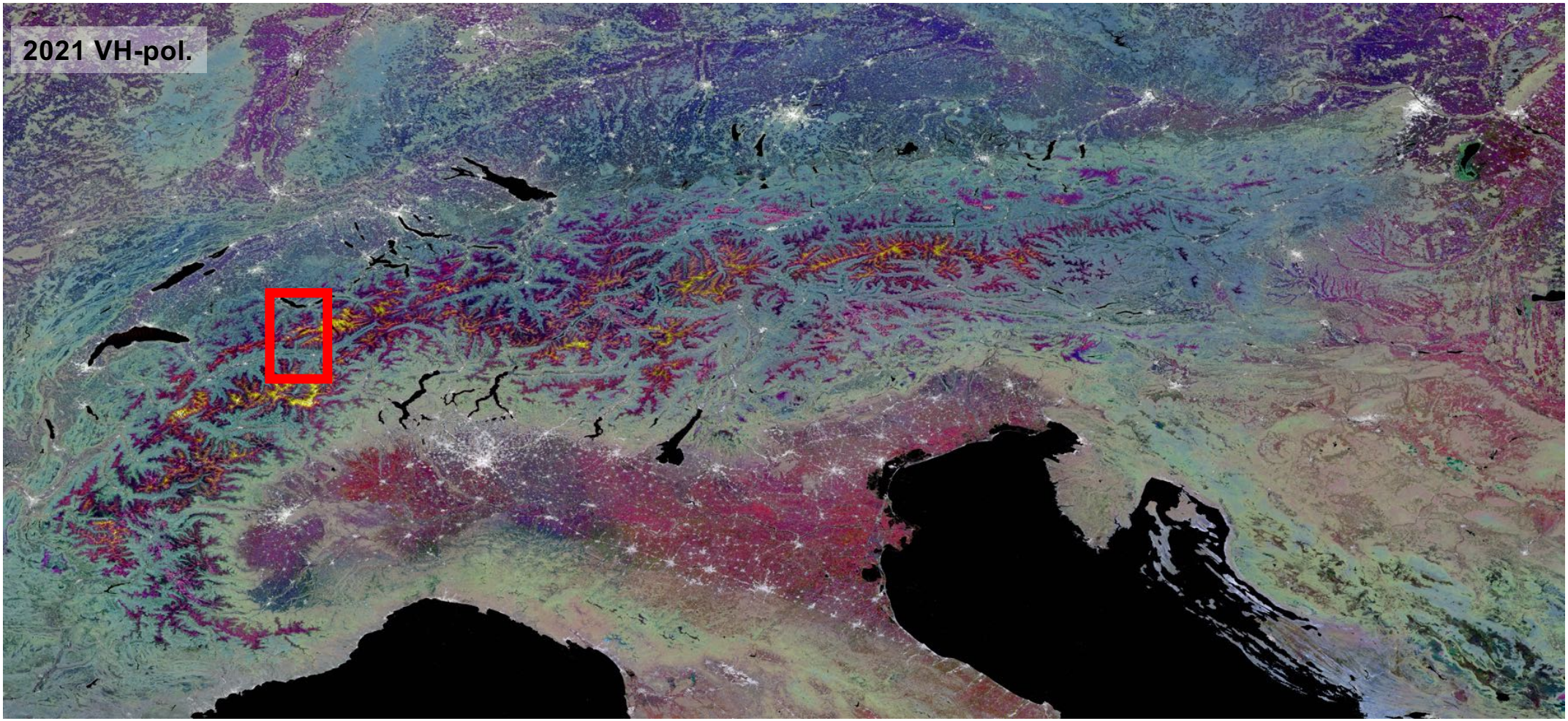
Sentinel-1 IW Backscatter Composites 2021 **VH**: Jan 1-12, Apr 25-May 6, June 24-July 5; -21dB (black) to -6dB (white)



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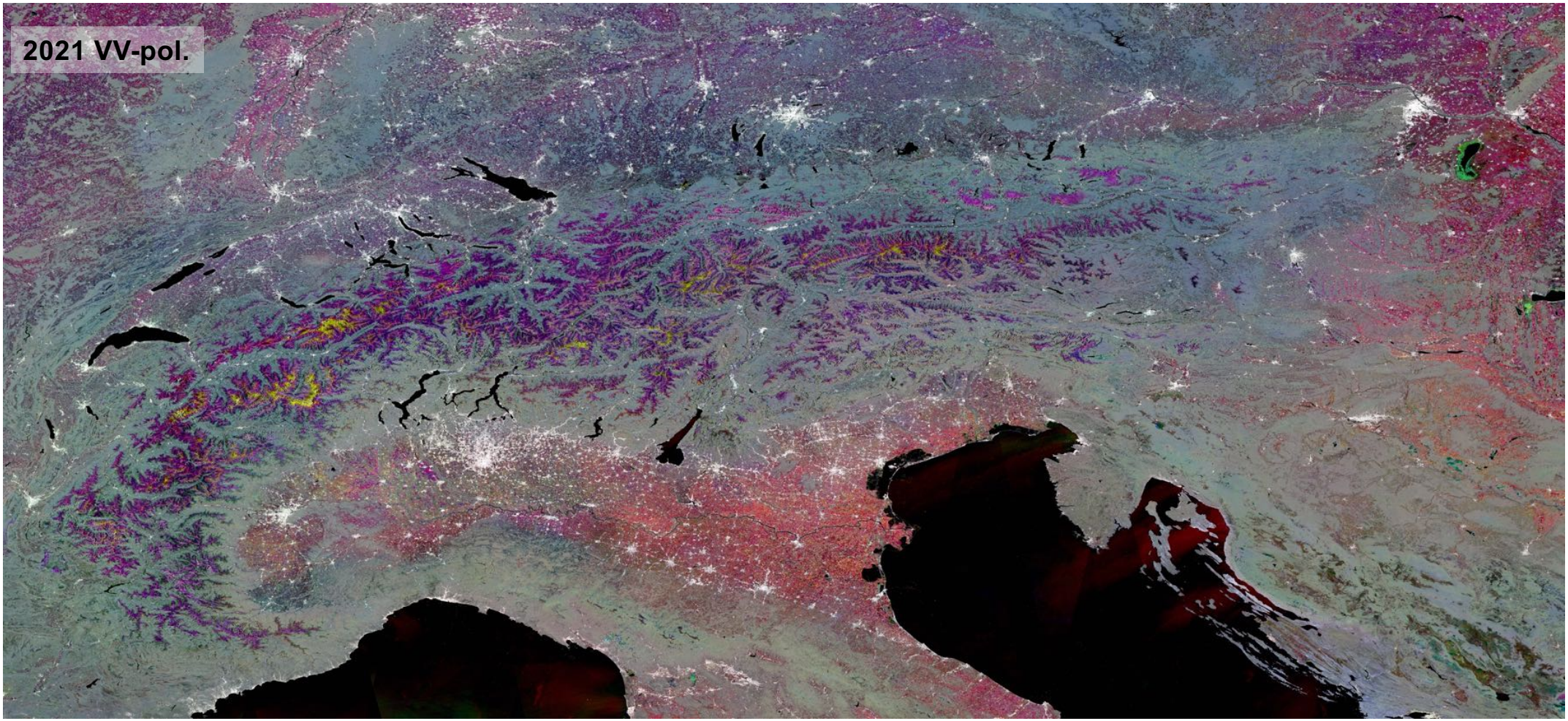
Sentinel-1 IW Backscatter Composites 2021 **VH**: Jan 1-12, Apr 25-May 6, June 24-July 5; -15dB (black) to 0dB (white)



Radar products in map geometry

Correction(s) Applied	GTC	RTC	LRW Backscatter Composite
Geometry (position)	✔	✔	✔
Radiometry (contributing area)		✔	✔
Spatial Resolution homogeneity			✔
Seamless wide-area coverage			✔
Time series from multi-sensor inputs			✔
Temporal resolution can be < repeat			✔

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Ellesmere Island Backscatter Composites

S-1A+S-1B EW+IW HV

+RS2 SCWA

Temporal Resolution:

1 day!

May – Aug. 2019

Contains modified Copernicus Sentinel data (2019)

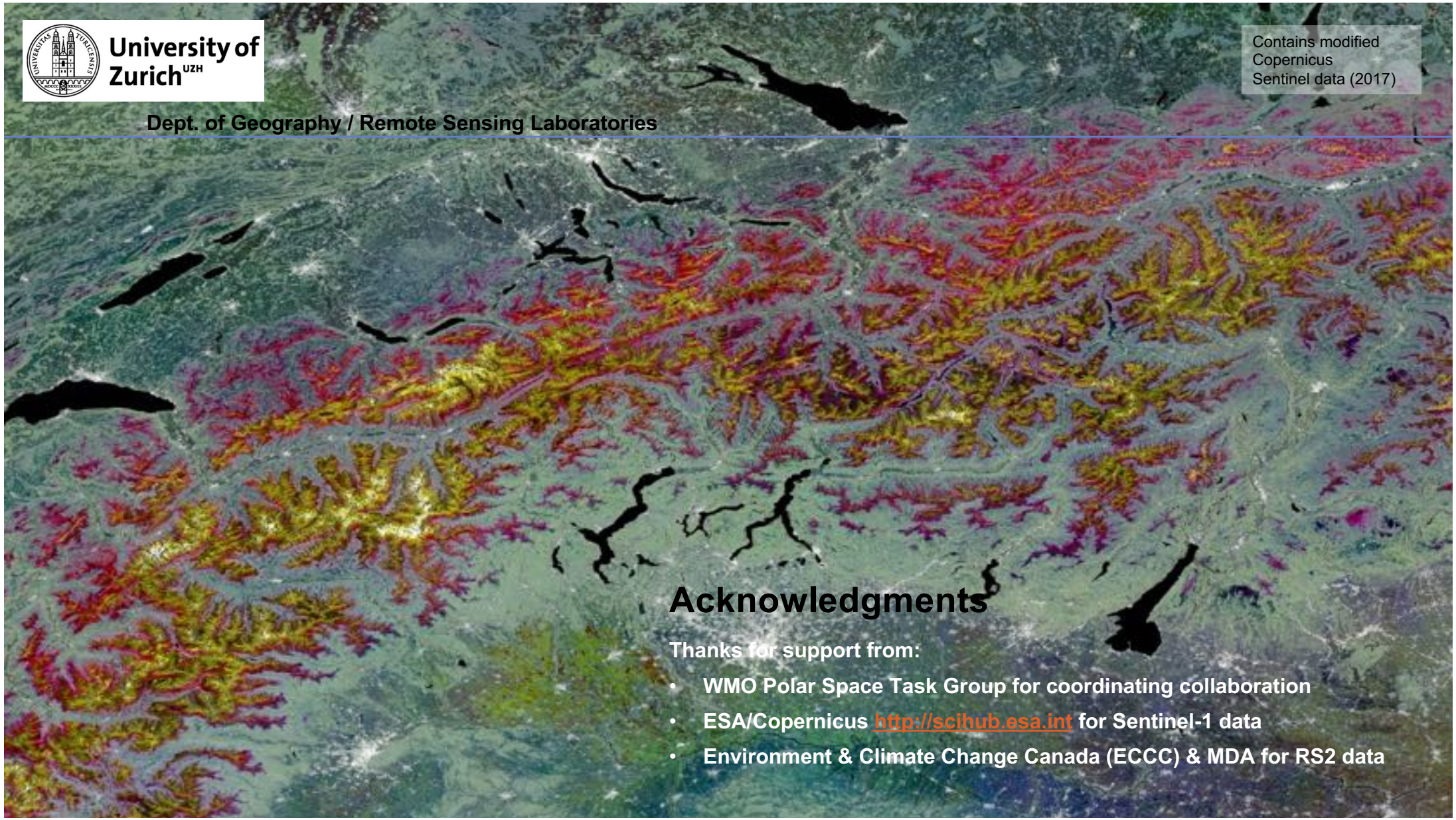
QA4EO

- Paper on backscatter composite methodology (IDEAS+ support acknowledged) in TGRS IEEE-Explorer early access since Feb. 2021
- Expert advice in response to inquiries from CEOS/CARD4L on NRB and POL

Recommended next steps:

- Submit small erratum in single equation of methodology paper
- Prepare draft of CARD4L Multi-Source Backscatter (MSB) specification for expert review following final publication of method

- Test and validate thermal noise removal based on SLC and GRDH S1 products
- Investigate mitigation of Antenna Gain presence in noise patterns.
- Further investigation of wet snow retrieval given diverse set of external liquid-water-content (LWC) scenarios; extension to wider region
- Build and test processing interface with existing small set of RCM data products
  - Possibly adopt new test site for S1/RCM combination to fit with CDN data policy



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Contains modified Copernicus Sentinel data (2017)

Acknowledgments

Thanks for support from:

- WMO Polar Space Task Group for coordinating collaboration
- ESA/Copernicus http://scihub.esa.int for Sentinel-1 data
- Environment & Climate Change Canada (ECCC) & MDA for RS2 data