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CSA ASC

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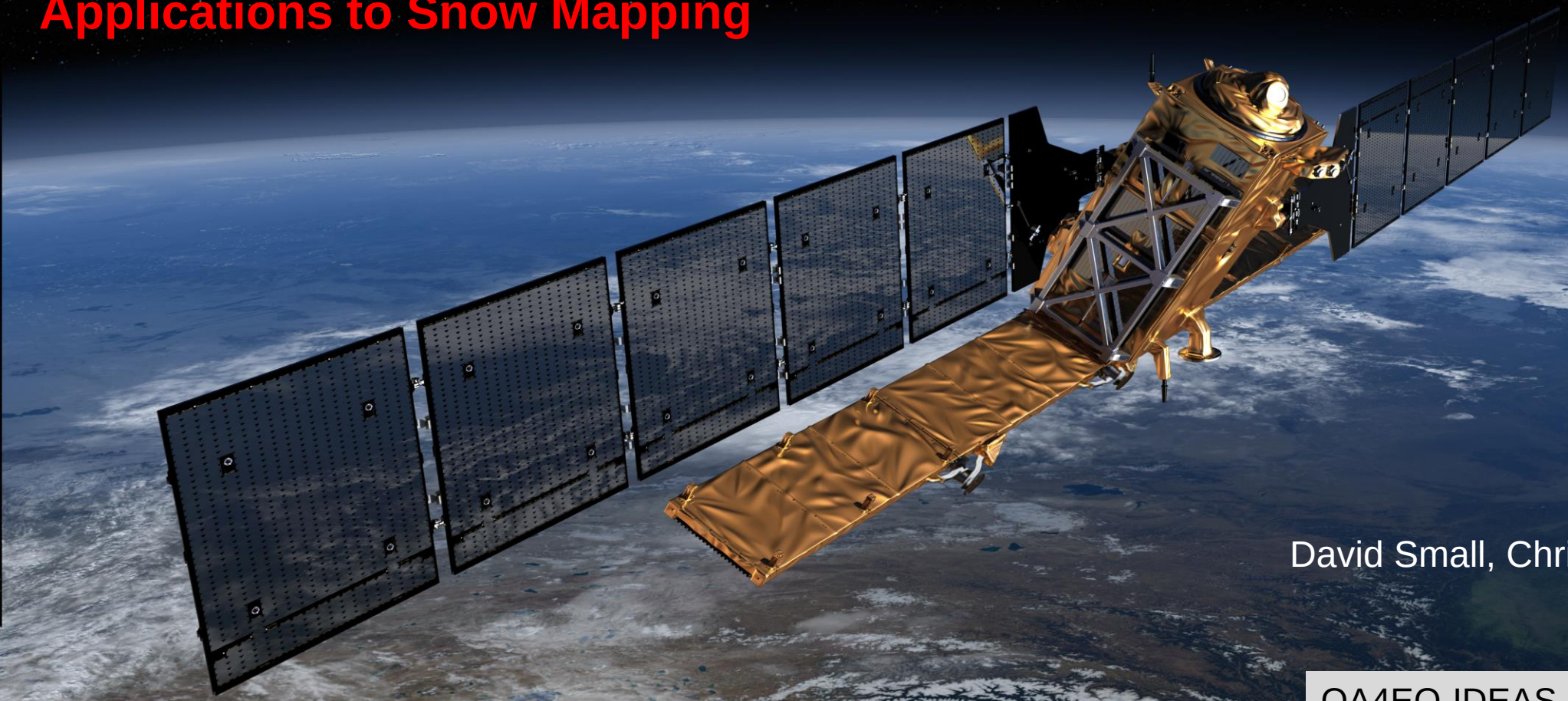
Towards the Concept of Analysis Ready Data for SAR: Applications to Snow Mapping



David Small, Christoph Rohner (UZH)

QA4EO-IDEAS Cal/Val Workshop #1
Rome, Italy, Feb. 20, 2020

SAR Constellations

- Sentinel-1A and Sentinel-1B acquiring >12TB per day
- Radarsat-2 a commercial enterprise
- Radarsat Constellation Mission (RCM) recently finished commissioning

- Sentinel-1 and RCM satellites have same central frequency
  - But they are in differing orbits: systematic *InSAR combinations unviable*
- Combining the backscatter amplitudes will still be possible, assuming acquisitions modes are selected to ensure *common polarisations*

- **Multisource Composite Backscatter maps**
  - Optical constellation composite products are the norm, e.g. for MODIS cloud clearing
  - Systematic composites from radar constellations not yet established

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

Radar terrain corrections

Document Status

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

- Geometric Terrain Correction (**GTC**)
- Radiometric Terrain Correction (**RTC**)
- Wide area backscatter *composites* from Local Resolution Weighting (**LRW**)
- LRW backscatter *composite* time series are ***Analysis Ready Data*** **(ARD)**
  - *2D image time-series: Applicable over wide area, while lowering barrier to entry for analysis*

- **CEOS CARD4L** Analysis Ready Data for Land Processes
  - Define standards for ARD backscatter products
    - RTC (L1): Terrain-flattening: **Normalised Radar Backscatter** (CARD4L **NRB**)
    - LRW (L3): Wide-area **Analysis Ready Data**
  - *NRB Document being finalised*
    - *After internal reviews, being submitted this month for consideration at CEOS Land Surface Imaging – Virtual Constellations (LSI-VC) meeting at end of Mar. 2020*

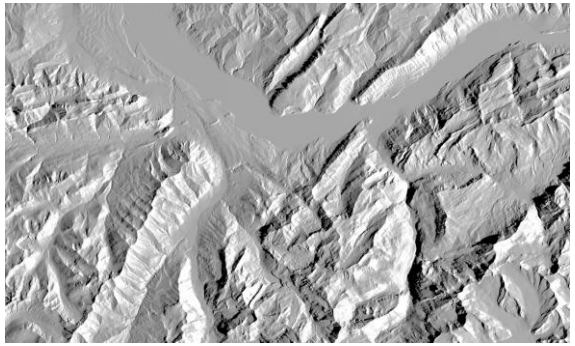
Terrain-flattened Gamma Nought

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

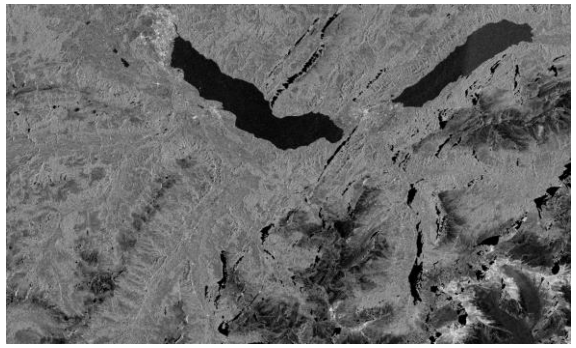


A_γ / A_β

-26dB -1dB

$=$

g_T^0



RTC

$$g_T^0 = b^0 \times \frac{A_b}{A_g}$$

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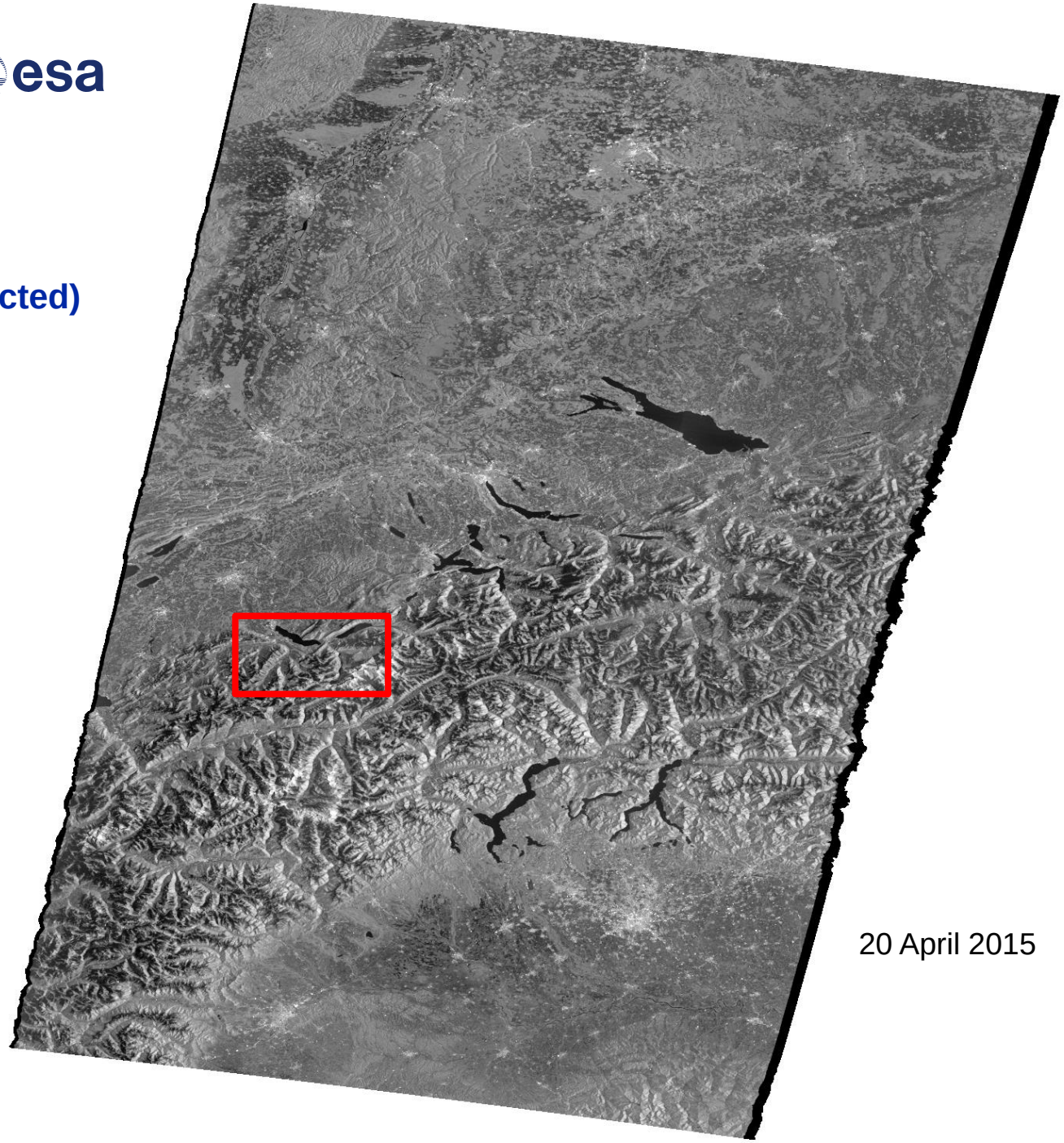
Sentinel-1A: GTC

(Geometrically Terrain Corrected)

$$g_E^0$$

-26dB -1dB



Generated automatically from 3 IW GRDH products using SRTM3

20 April 2015

Copernicus Sentinel data (2015)

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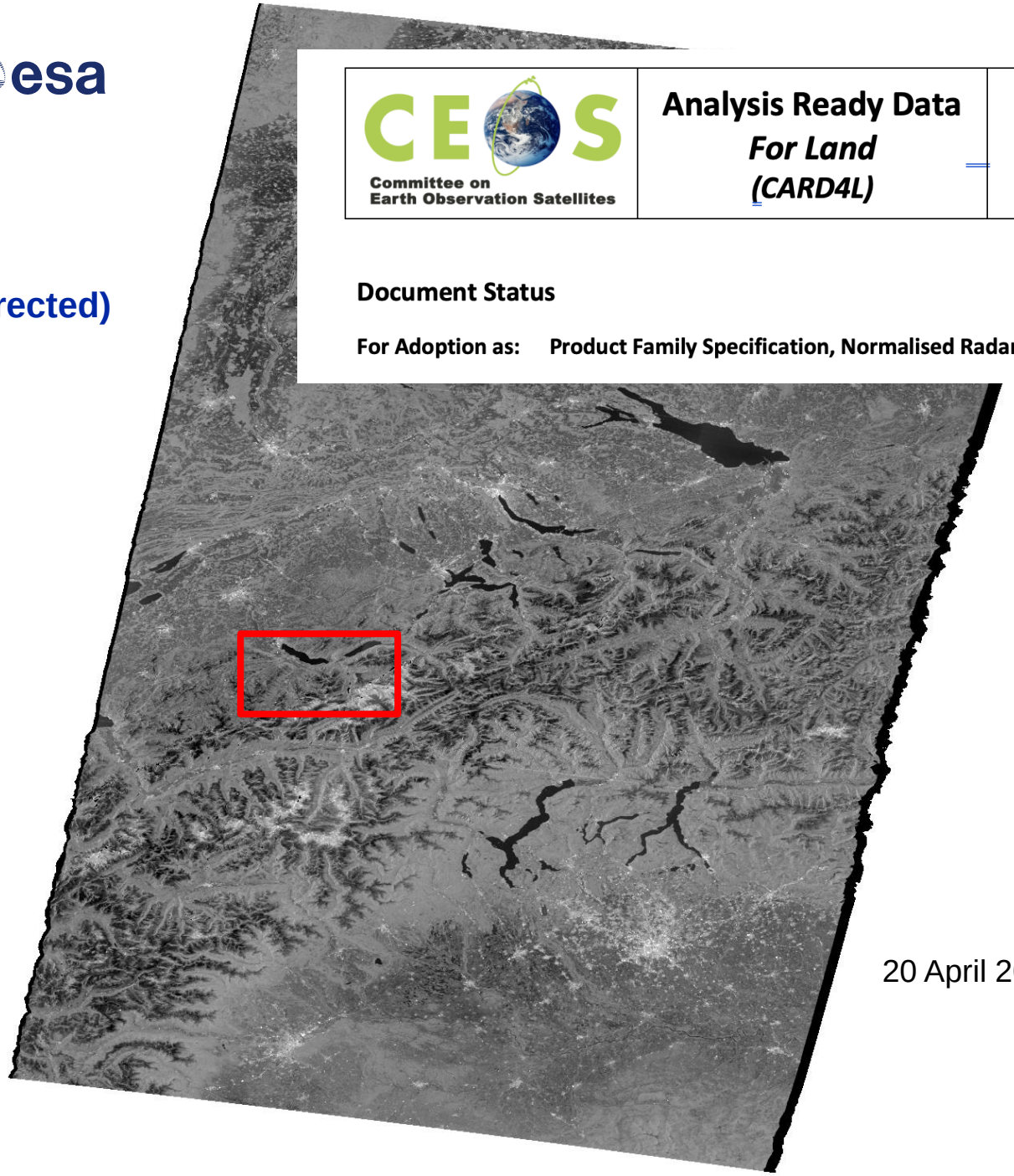
Sentinel-1A: RTC
(Radiometrically Terrain Corrected)

$$g_T^0$$

-26dB -1dB

Generated automatically from 3 IW GRDH products using SRTM3

Contains modified Copernicus Sentinel data (2015)



CEOS Committee on Earth Observation Satellites

Analysis Ready Data *For Land (CARD4L)*

Product Family Specification: Normalised Radar Backscatter

Document Status

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

20 April 2015

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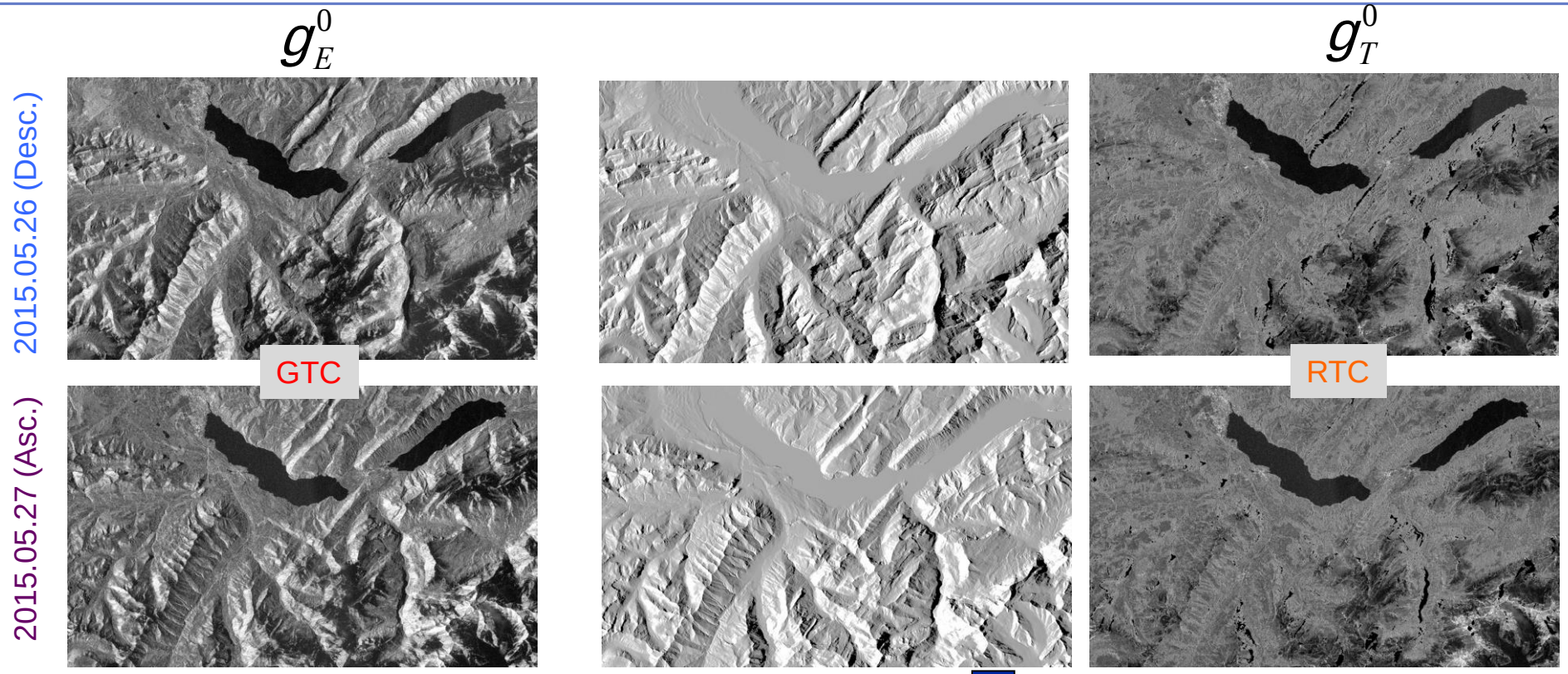
Backscatter Composites

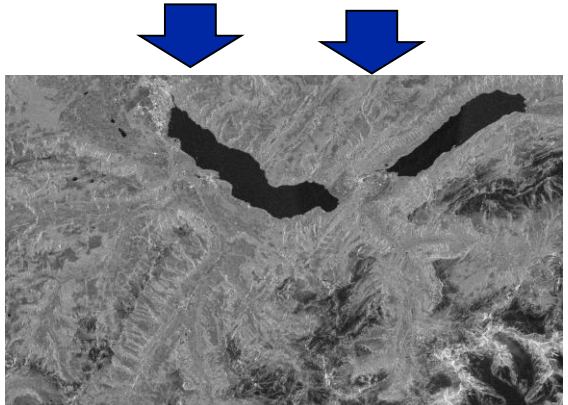
-26dB -1dB

Dept. of Geography / Remote Sensing Laboratories



- Combine asc. & desc. observations to generate **composite** with improved local resolution
- Less shadow than single RTC, lower noise

Interlaken, Switzerland



Composite

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Composites in Time Series Movie

-26dB -1dB

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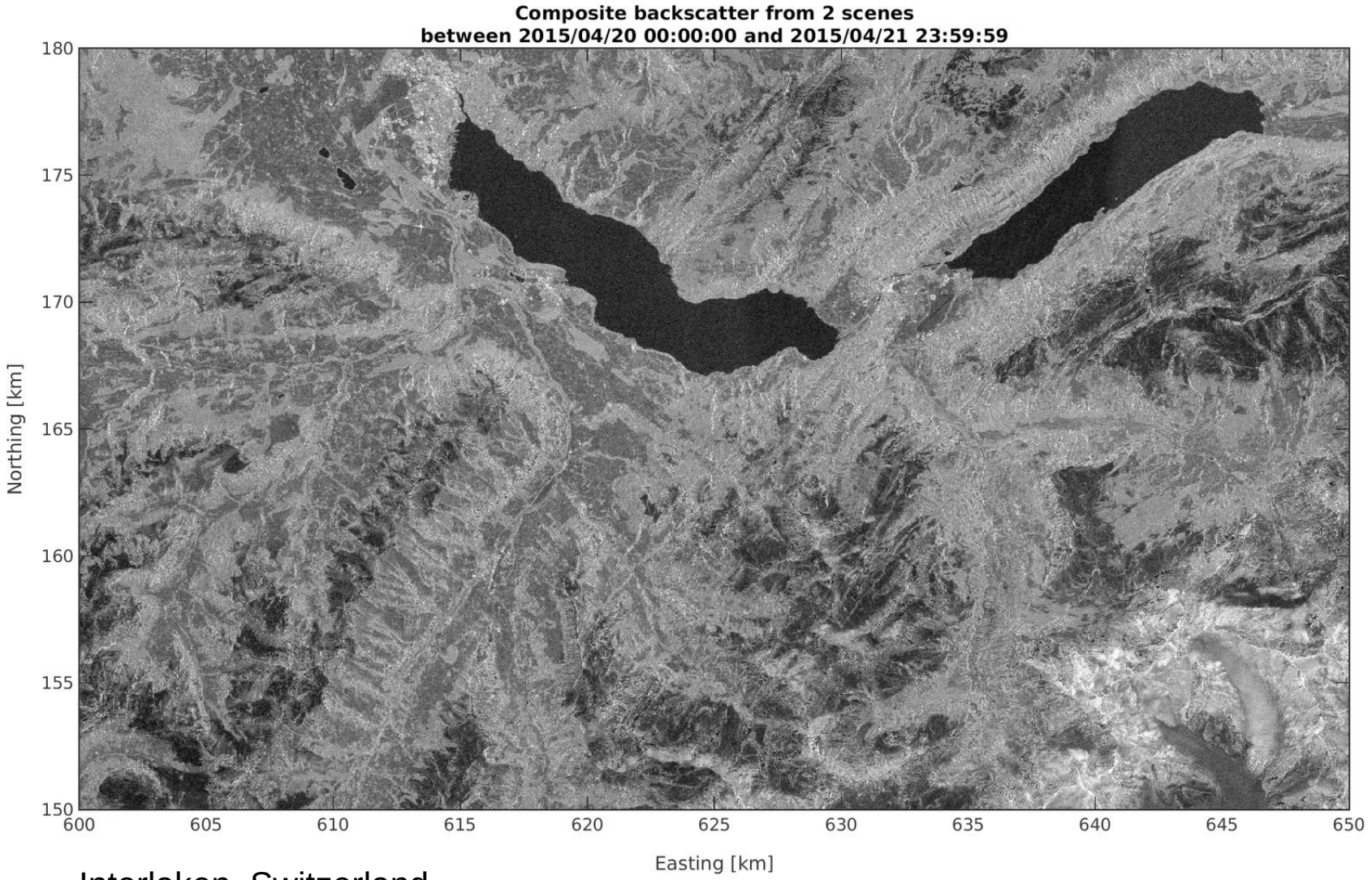
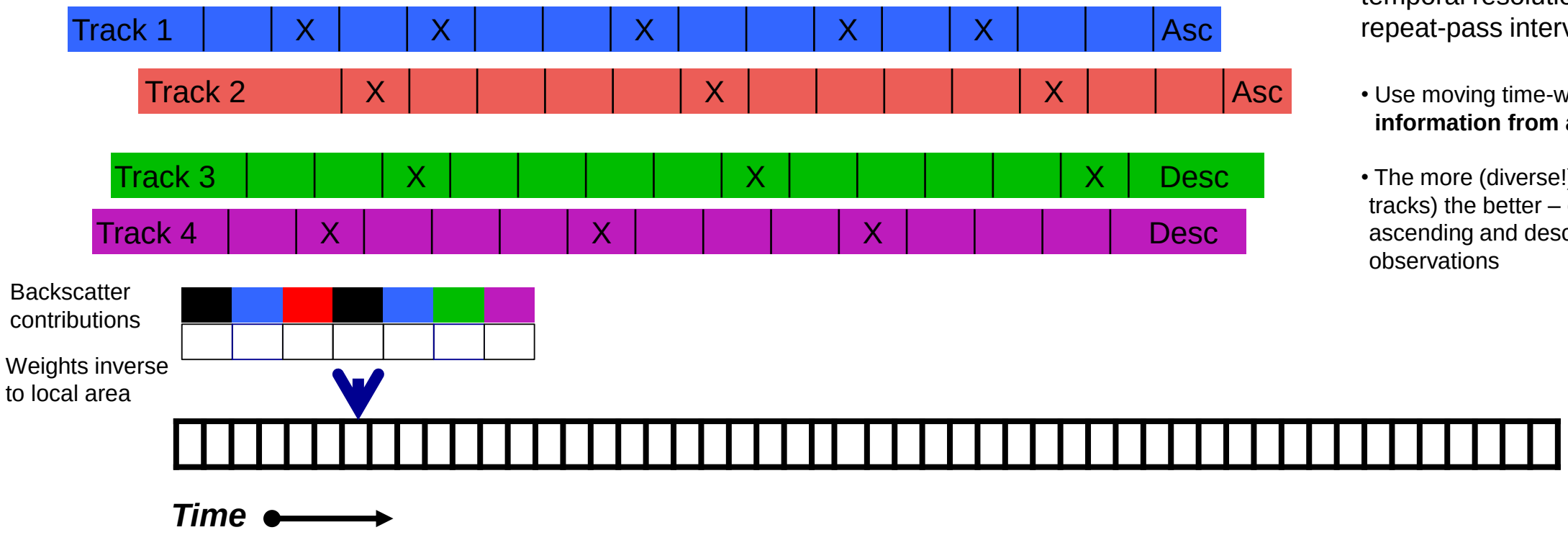
Jan – May 2015



Contains modified Copernicus Sentinel data (2015)

Interlaken, Switzerland

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 et al., Submitted Sept. 2019.

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Sentinel-1 Alpine Springtime Backscatter Time-Series

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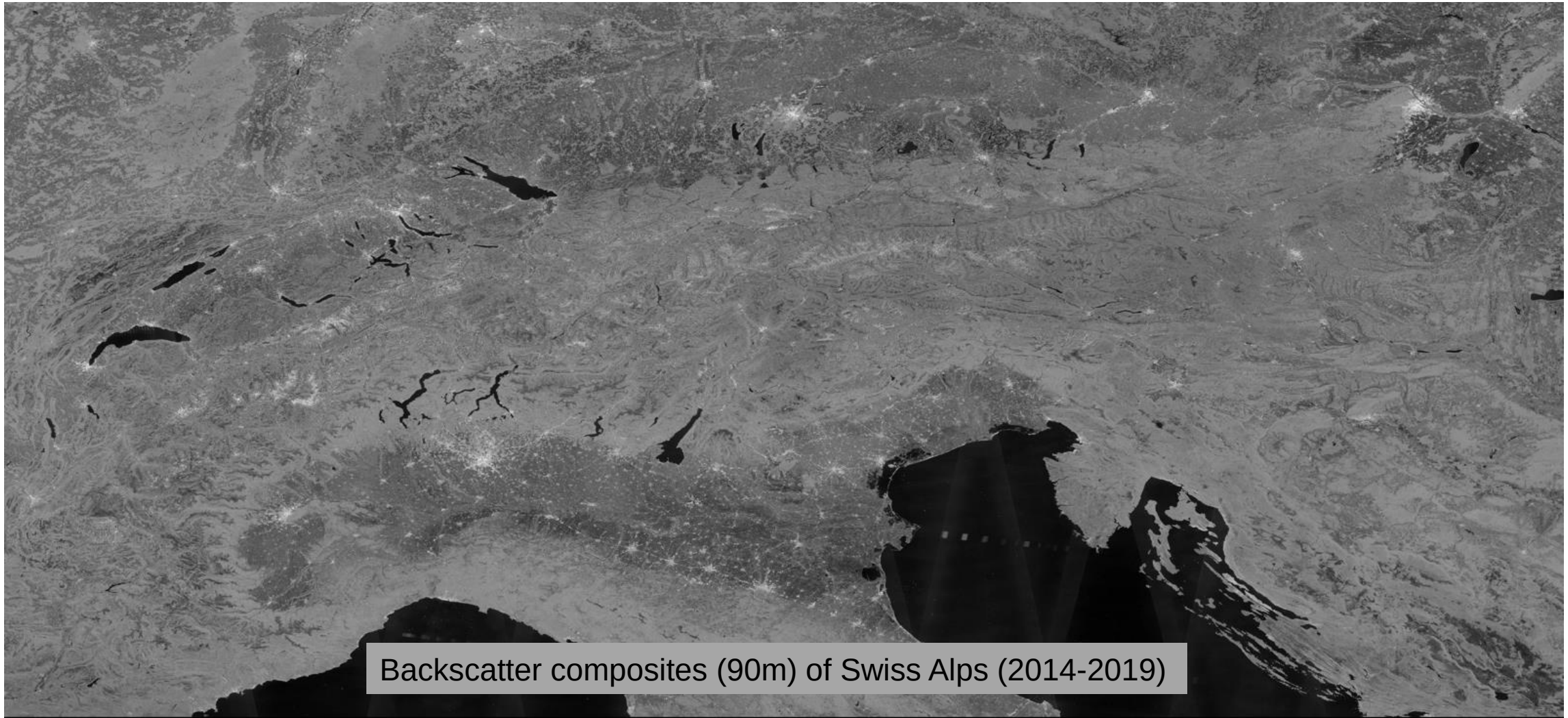
S-1A + S-1B IW VH-pol. **Feb. - June 2019**: 12 day windows

Contains modified Copernicus Sentinel data (2019)



Backscatter composites (90m) of Swiss Alps (2014-2019)

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Contains modified Copernicus Sentinel data (2018)

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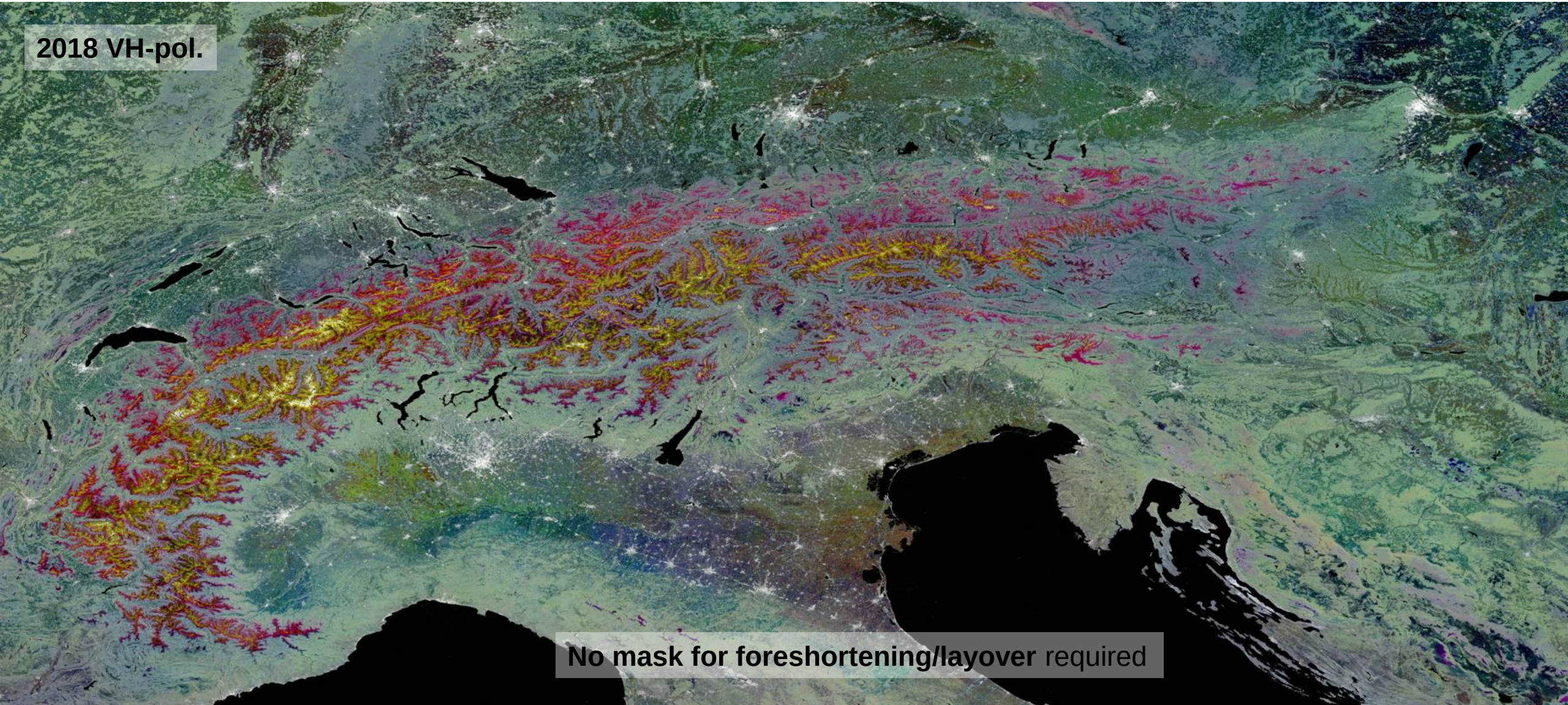
Sentinel-1 IW Backscatter Composites 2018 VH: Feb 24-Mar 7, April 1-12, May 1-12; -23dB (black) to -6dB (white)



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Contains modified Copernicus Sentinel data (2019)

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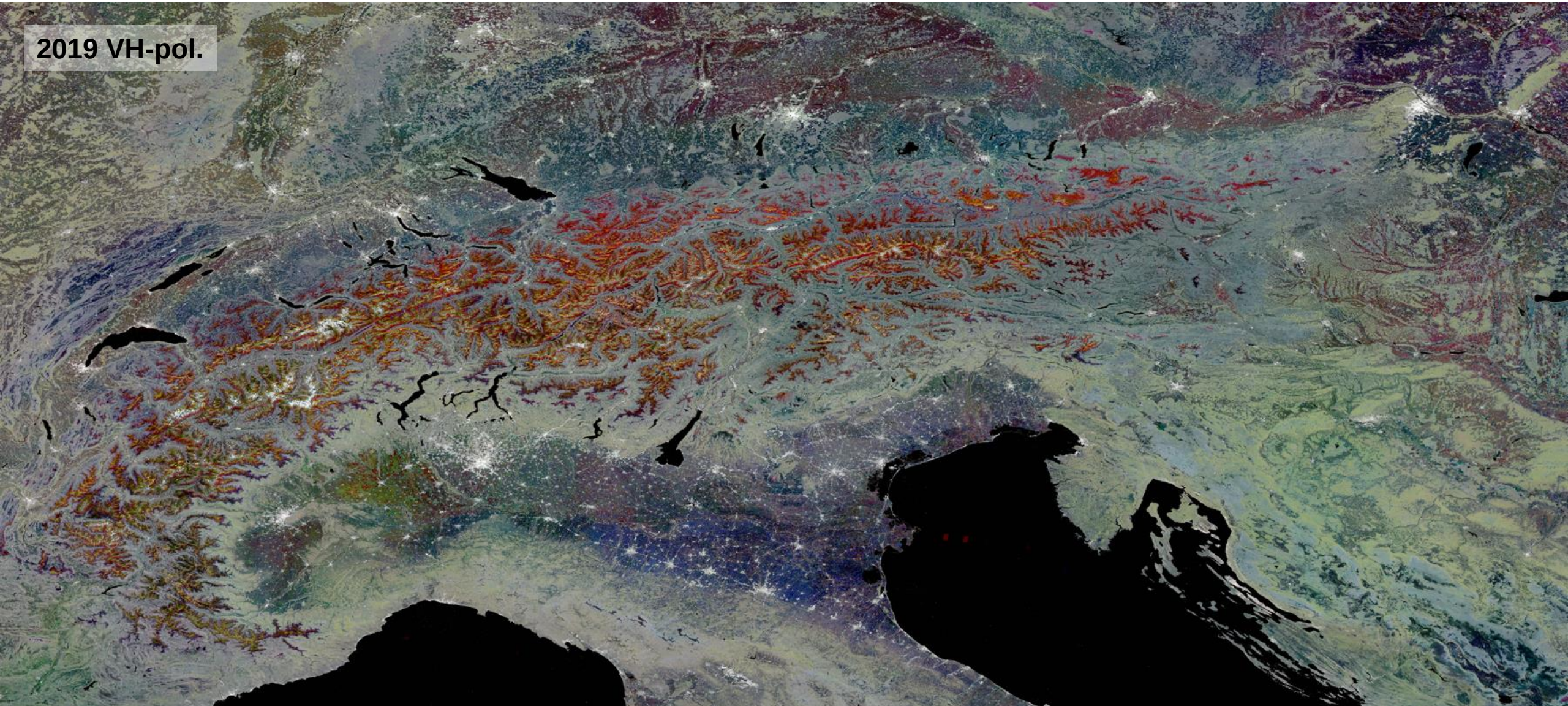
Sentinel-1 IW Backscatter Composites 2019 **VH**: Feb 6-17, April 1-12, May 1-12; -23dB (black) to -6dB (white)



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Contains modified Copernicus Sentinel data (2019)

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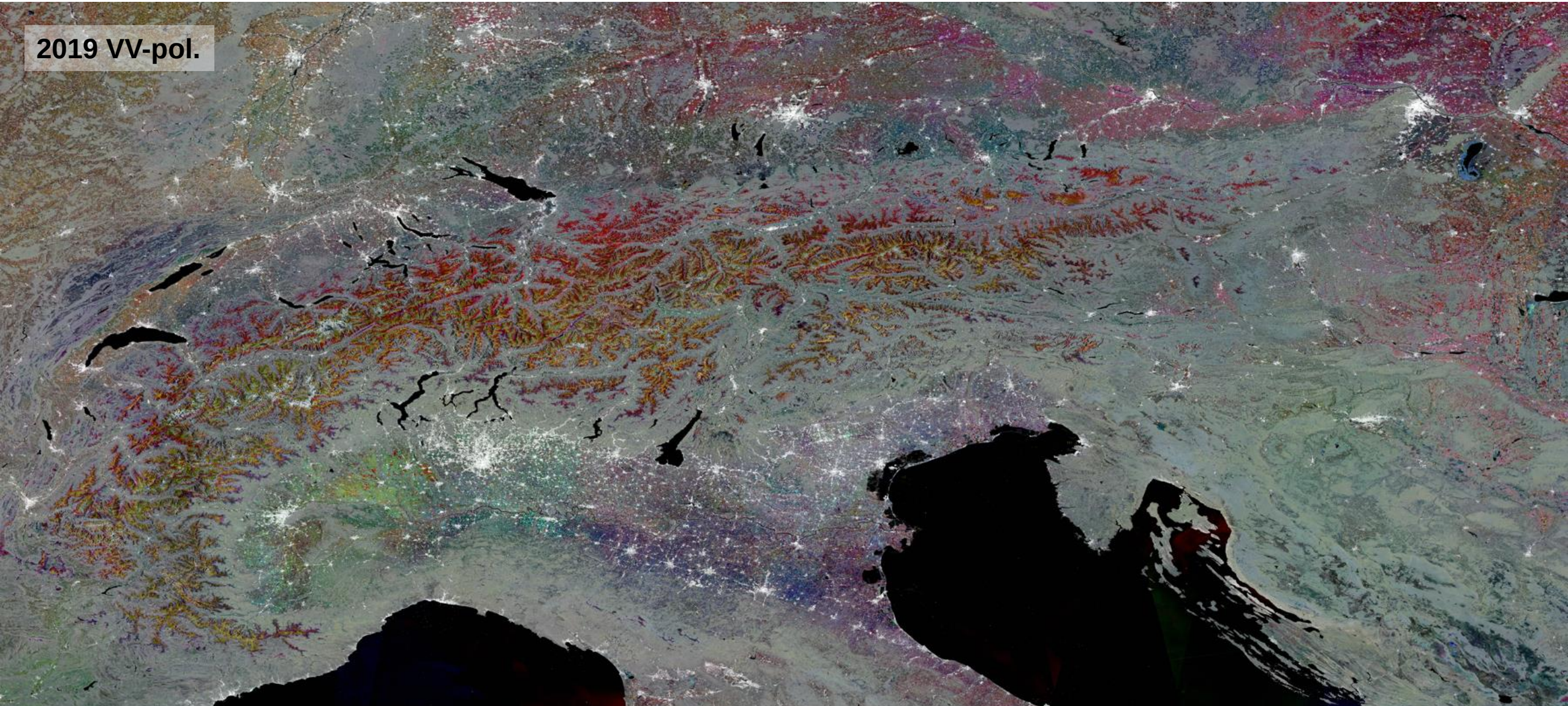
Sentinel-1 IW Backscatter Composites 2019 **VV**: Feb 6-17, April 1-12, May 1-12



Radar products in map geometry

Correction(s) Applied	L1 GTC	L1 RTC	L3 LRW
Geometry (position)	✔	✔	✔
Radiometry (contributing area)		✔	✔
Spatial Resolution homogeneity			✔
Seamless wide-area coverage			✔
Time series from multi-sensor inputs			✔
Temporal resolution can be < repeat			✔

Ellesmere Island, Nunavut, Canada

Severe topography in the Arctic

Image Kyle Odonoghue, 2013.

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Ellesmere Island Backscatter Composites

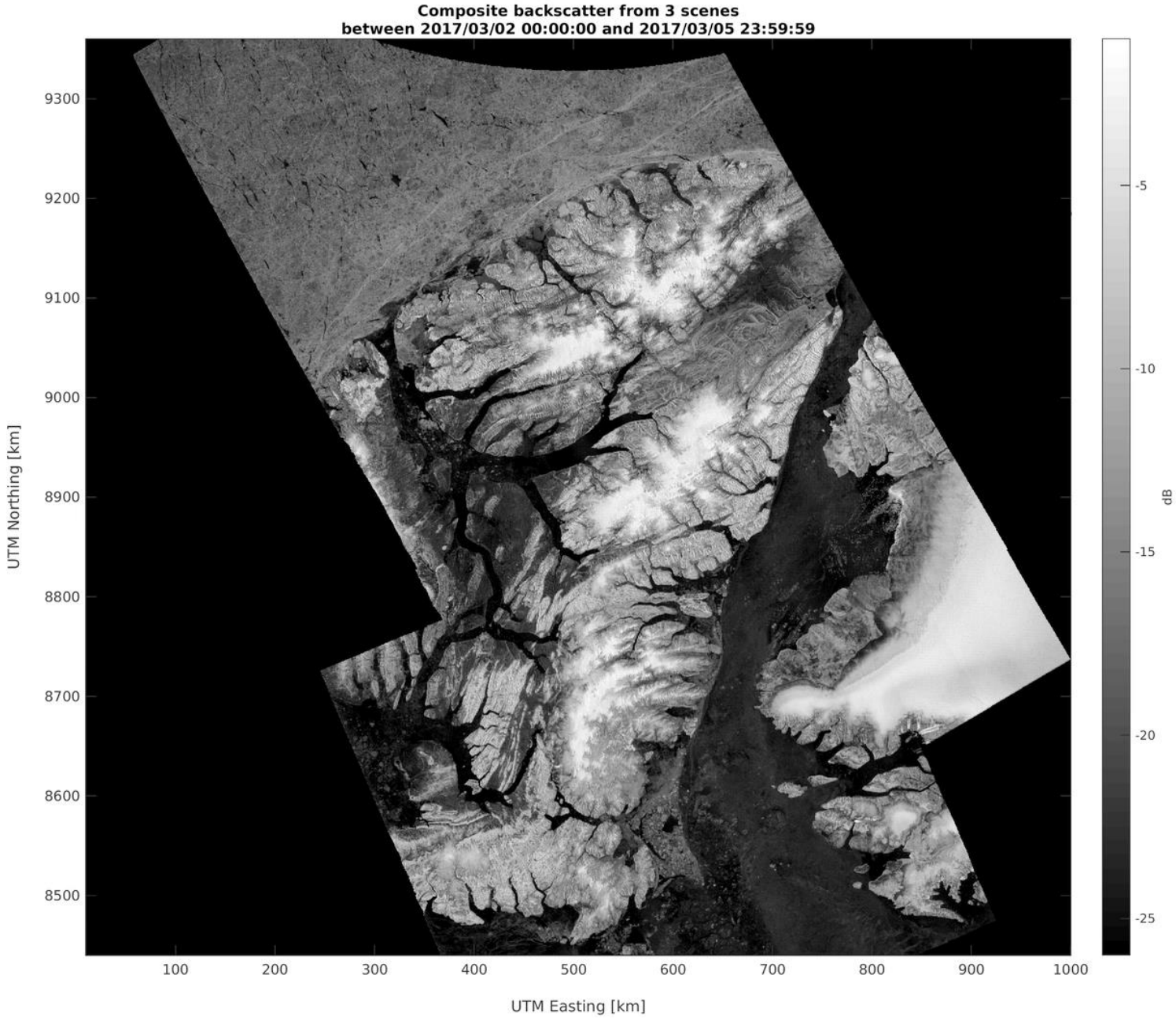
RS2 SCWA HV

2 day delta

4 day window

N.B. CDEM

Mar – Aug. 2017



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Ellesmere Island Backscatter Composites

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

1 day delta

2 day window

N.B. CDEM

Apr. – Aug. 2017

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Ellesmere Island Backscatter Composites

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

+RS2 SCWA

1 day delta
1 day window

N.B. CDEM

Apr. – Aug. 2017

- **Comparisons with Passive Microwave & ASCAT:**
- **Sea ice melt onset detection** (Howell, Small, et al., Rem. Sens. Env., 2019)

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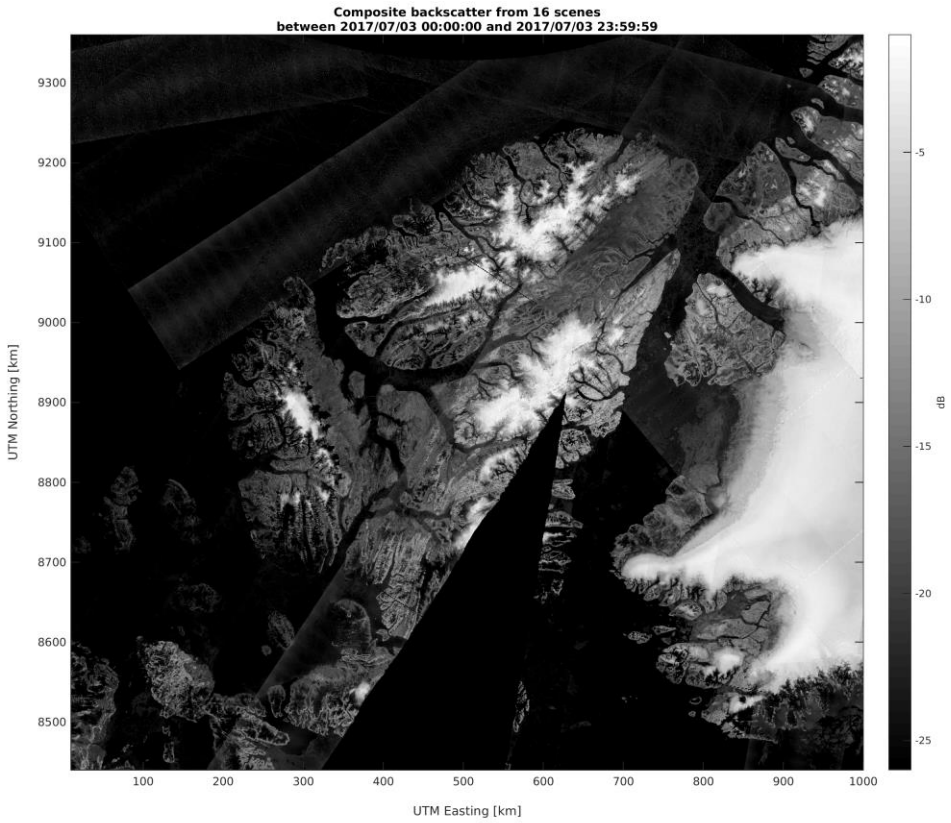
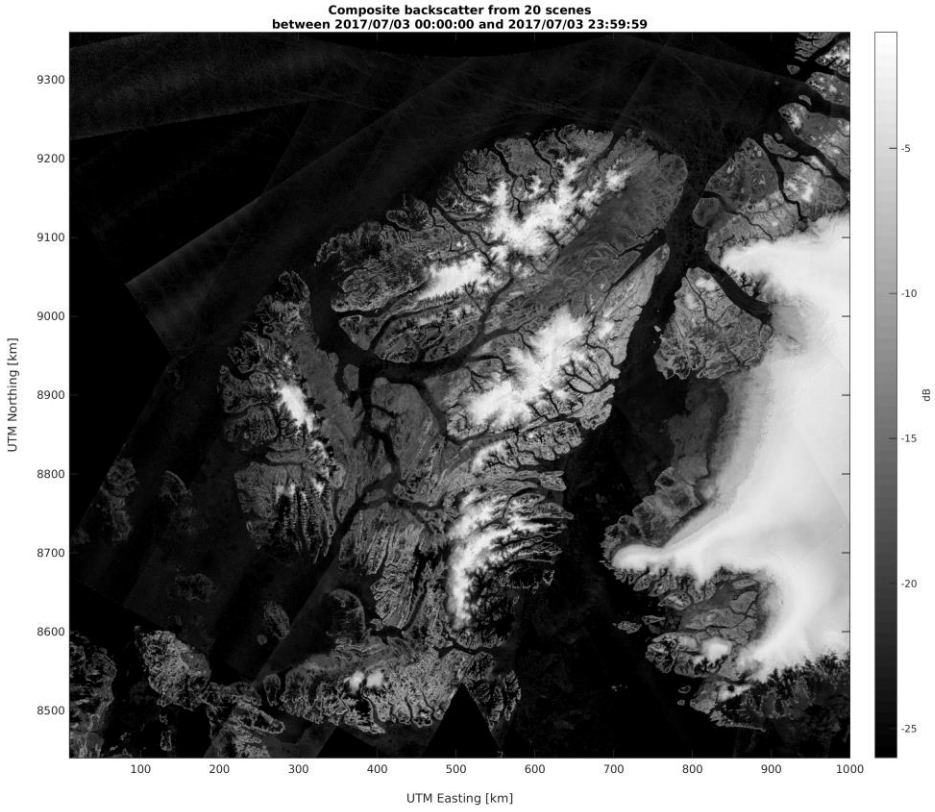
Ellesmere Island Backscatter HV-pol. Composites – July 3, 2017

S-1A+S-1B



S-1A+S-1B+ RS2



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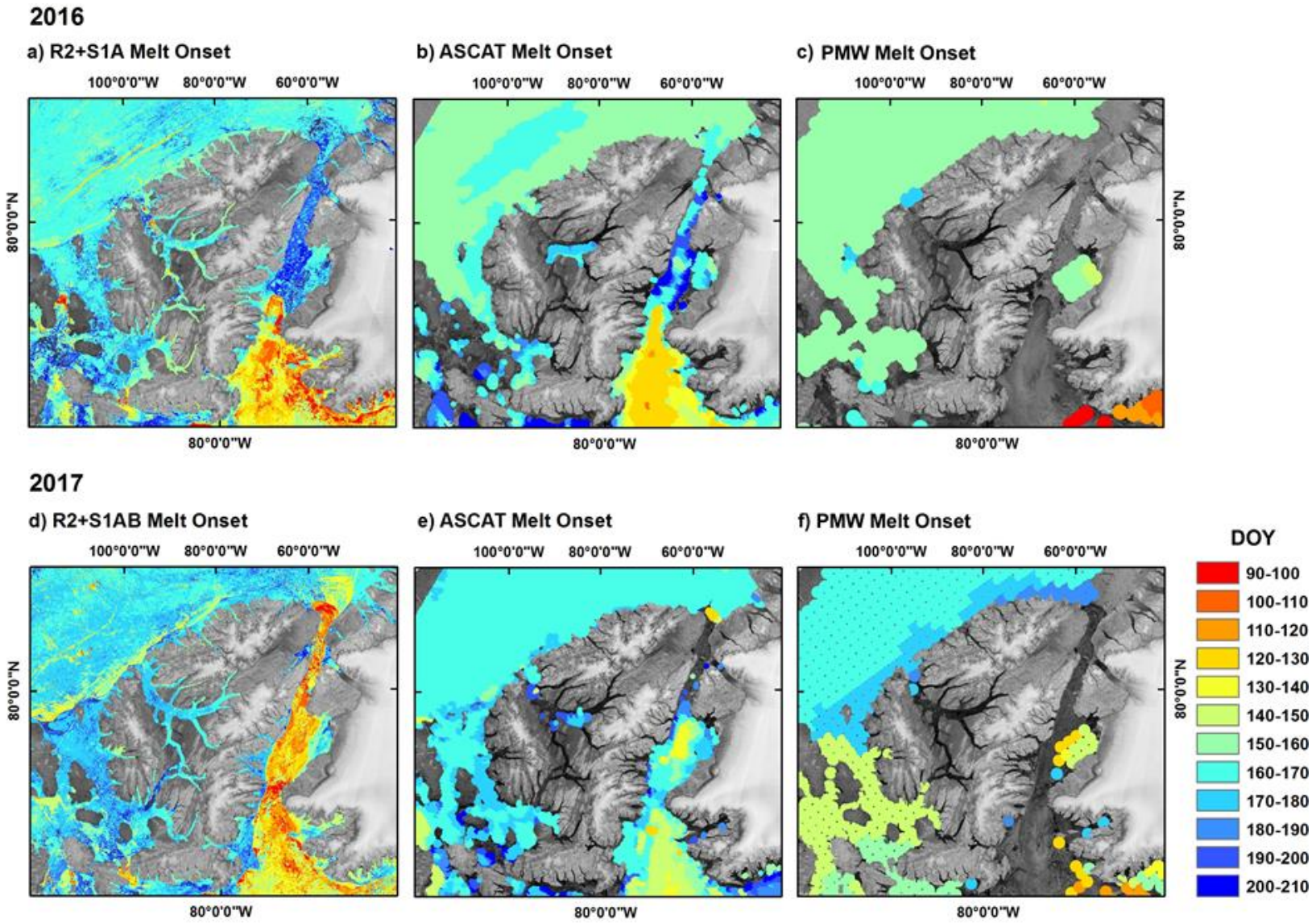

Ellesmere Island

- **R2+S-1**
- **ASCAT**
- **Passive microwave**

SAR *greatly improves spatial resolution* compared to conventional sensors, *now at competitive temporal resolution*

Contains modified Copernicus Sentinel data (2016-2017)

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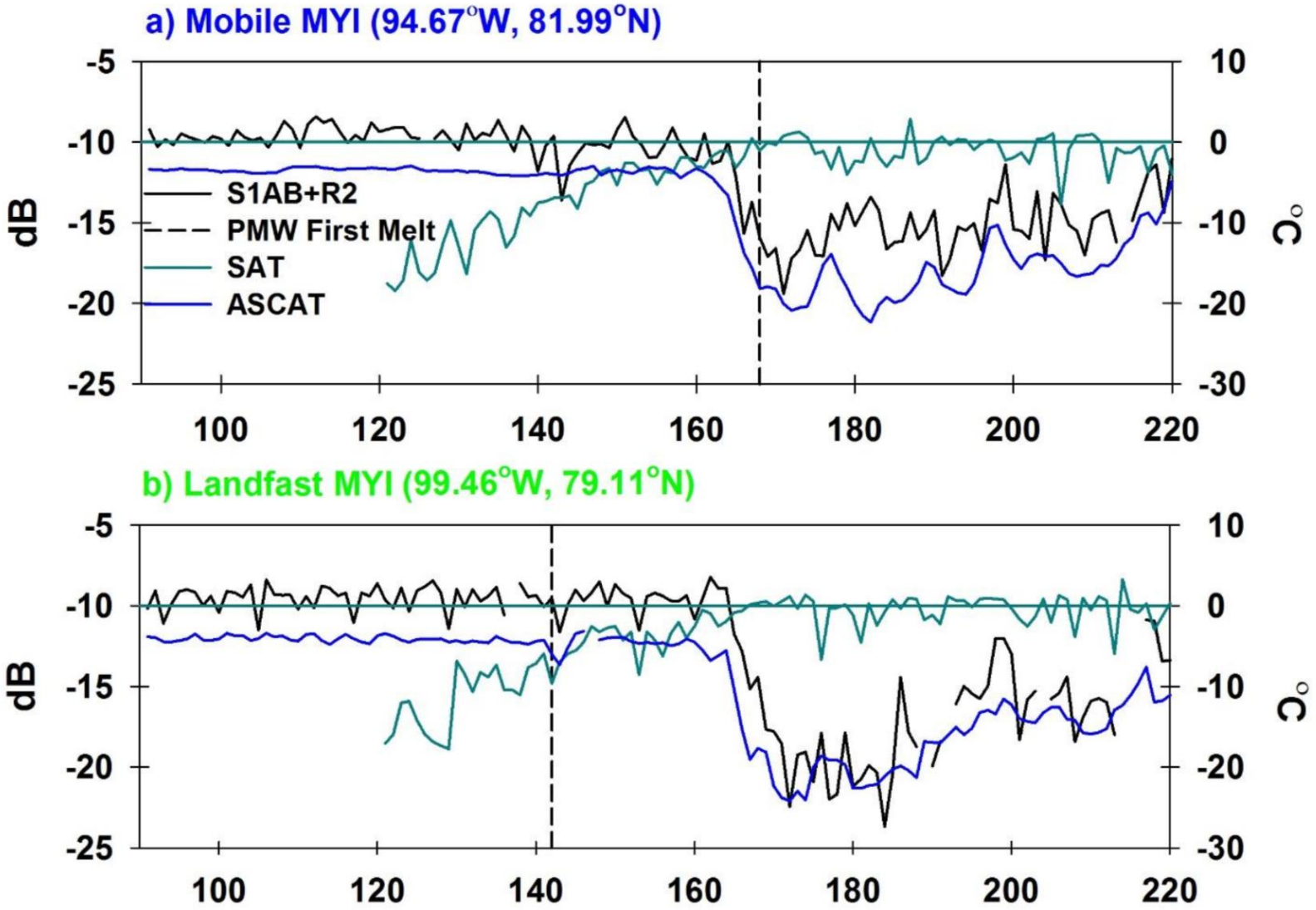
Howell S., D. Small, C. Rohner et al.,
Estimating melt onset over Arctic sea ice from time series multi- sensor Sentinel-1 and RADARSAT-2 backscatter, RSE, 2019.



Ellesmere Island

- **R2+S-1**
- **ASCAT**
- **Passive microwave**

PM misjudges melt onset due to mixed pixel contaminations

- *ASCAT & SAR more consistent*

Contains modified Copernicus Sentinel data (2017)

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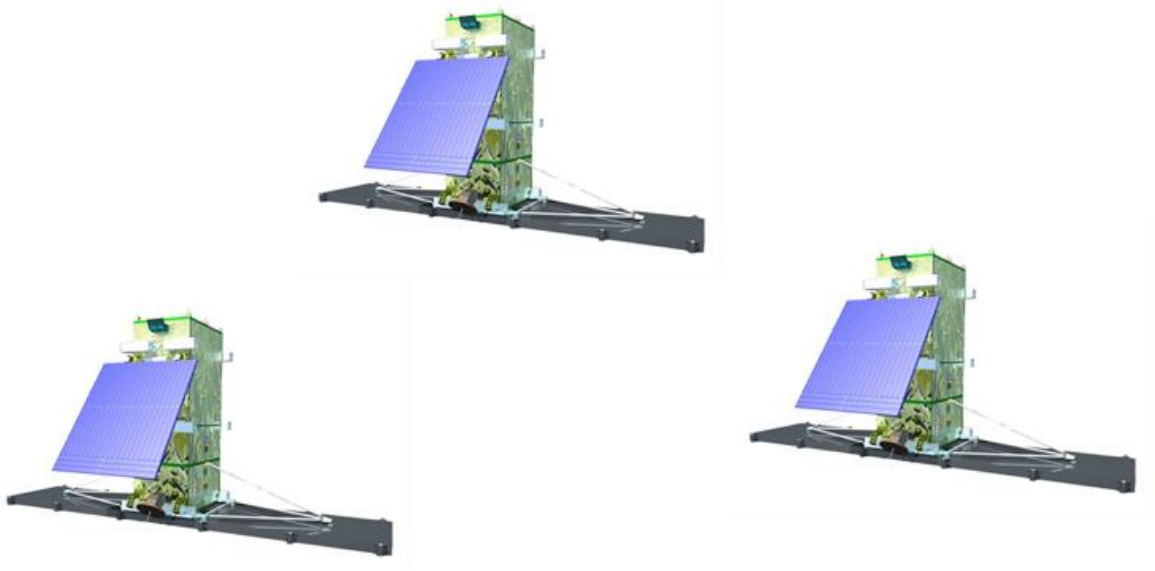
Howell S., D. Small, C. Rohner et al.,
Estimating melt onset over Arctic sea ice from time series multi- sensor Sentinel-1 and RADARSAT-2 backscatter, RSE, 2019.

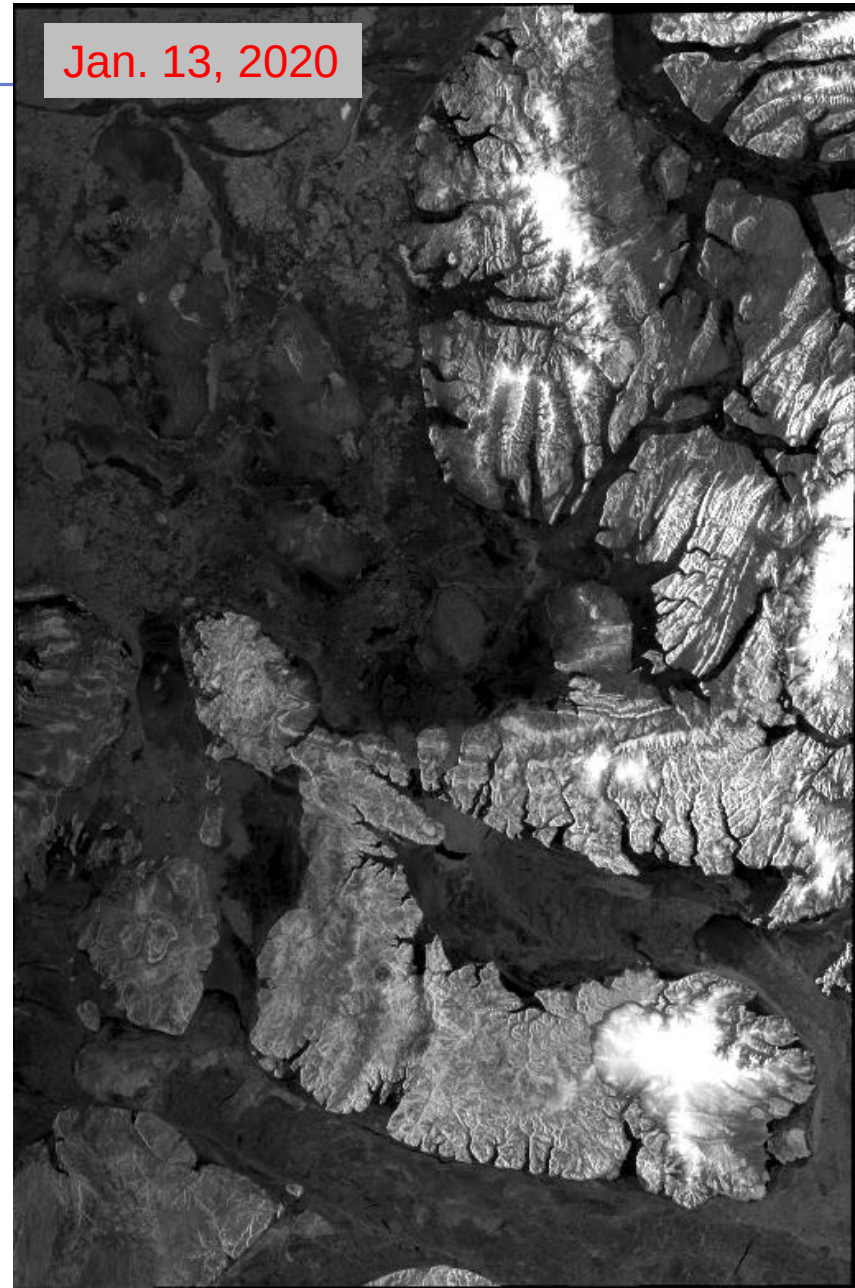
Radarsat Constellation Mission:

3 new C-band Satellites launched in 2019

- Open-data policy
- Six active C-band satellites: S-1A, S-1B, RS2, RCM1-3
- **Integration of RCM into S-1 composite data flow**



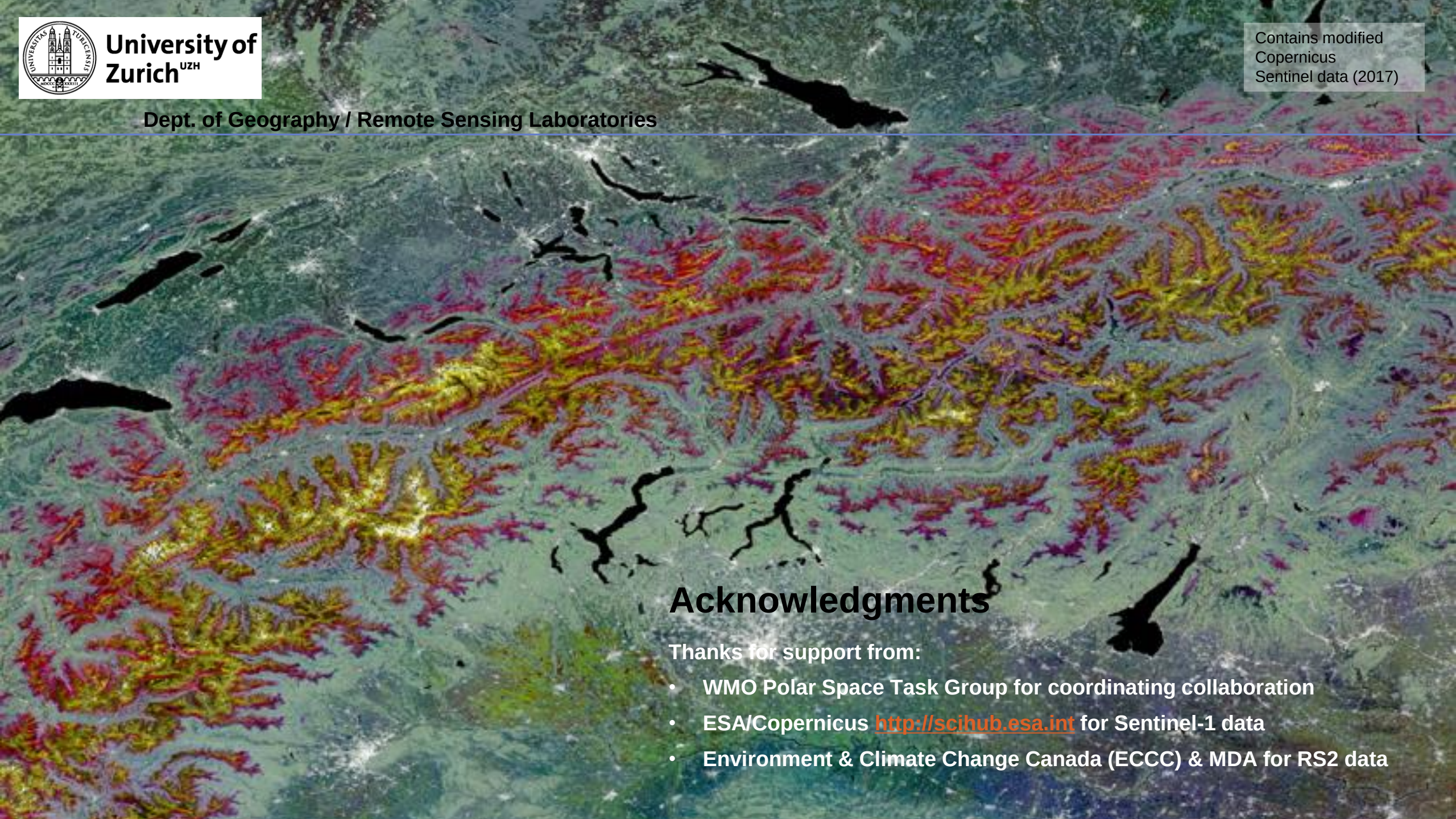
RCM ScanSAR Image of Ellesmere Island



QA4EO-IDEAS Phase 1 Outlook

1. Review and comment on CEOS CARD4L Normalized Backscatter Documentation:
   - In progress: Updated version **NRB** document nearing completion within team and will
   - RTC backscatter selected as basis for all CARD4L backscatter products (**NRB**, **polarimetric**, interferometric, geocoded SLC all in progress)
2. Antenna-pattern boost to Noise:
   - Estimate and optionally subtract local noise values in S-1 products during RTC production
3. Investigate acceleration of L3 composite products

4. Optional further supplementary work not in core package:
   - Radarsat Constellation Mission: Test integration of calibrated product input
     - CEOS SAR Workshop announced today will be Oct. 6-9 hosted by CSA in *Longueuil*, Canada
   - Detailed evaluation of acceleration of L3 composite product generation
   - Demonstrate seasonal extended-area backscatter maps



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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