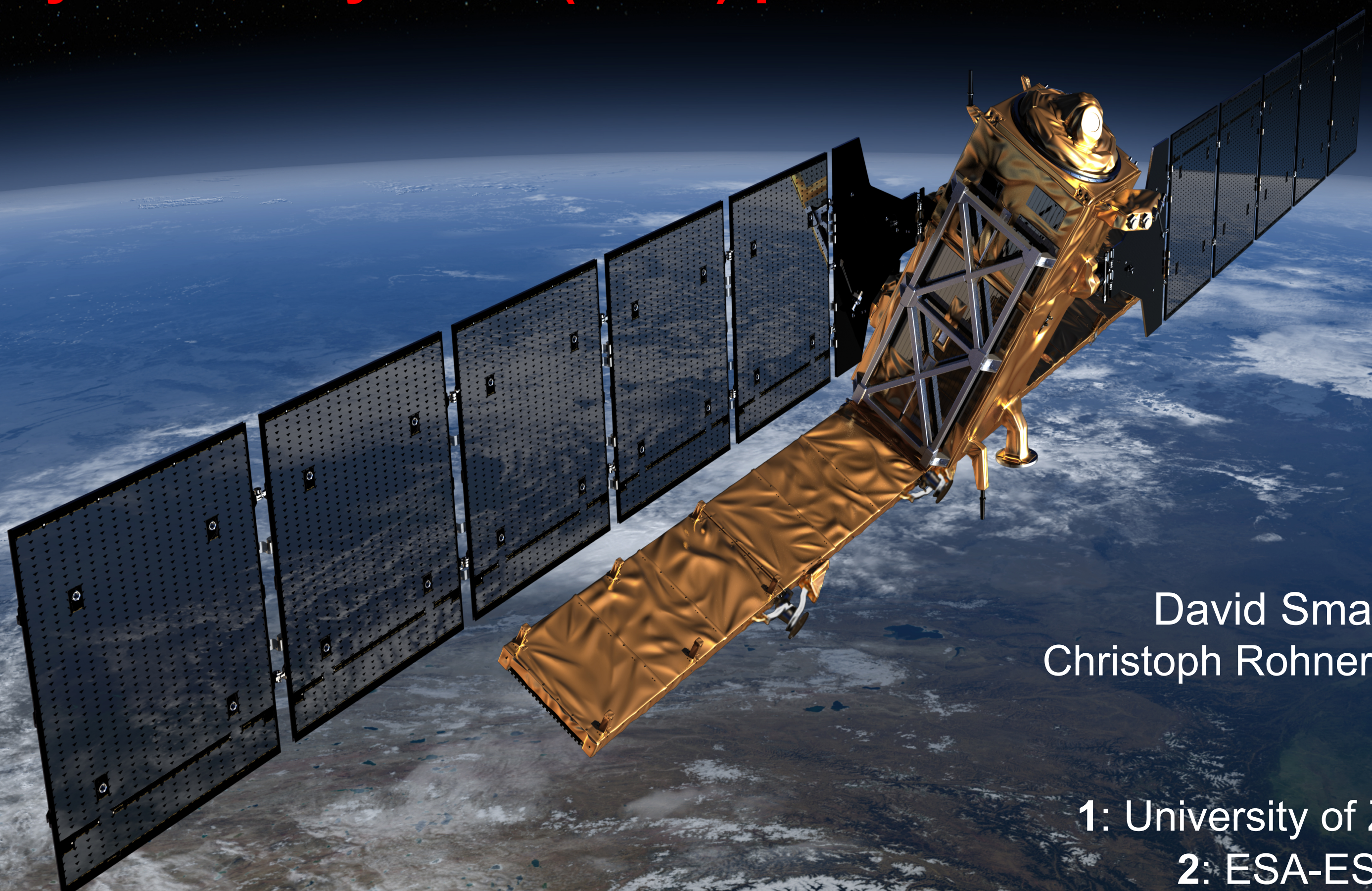
Wide-area radar backscatter composites as a calibrated Analysis-Ready-Data (ARD) product



David Small[1], Nuno Miranda[2],
Christoph Rohner[1], Adrian Schubert[1]

1: University of Zürich, Switzerland
2: ESA-ESRIN, Frascati, Italy

Radar terrain corrections

- 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*
    - *Lowers barrier to entry for analysis*

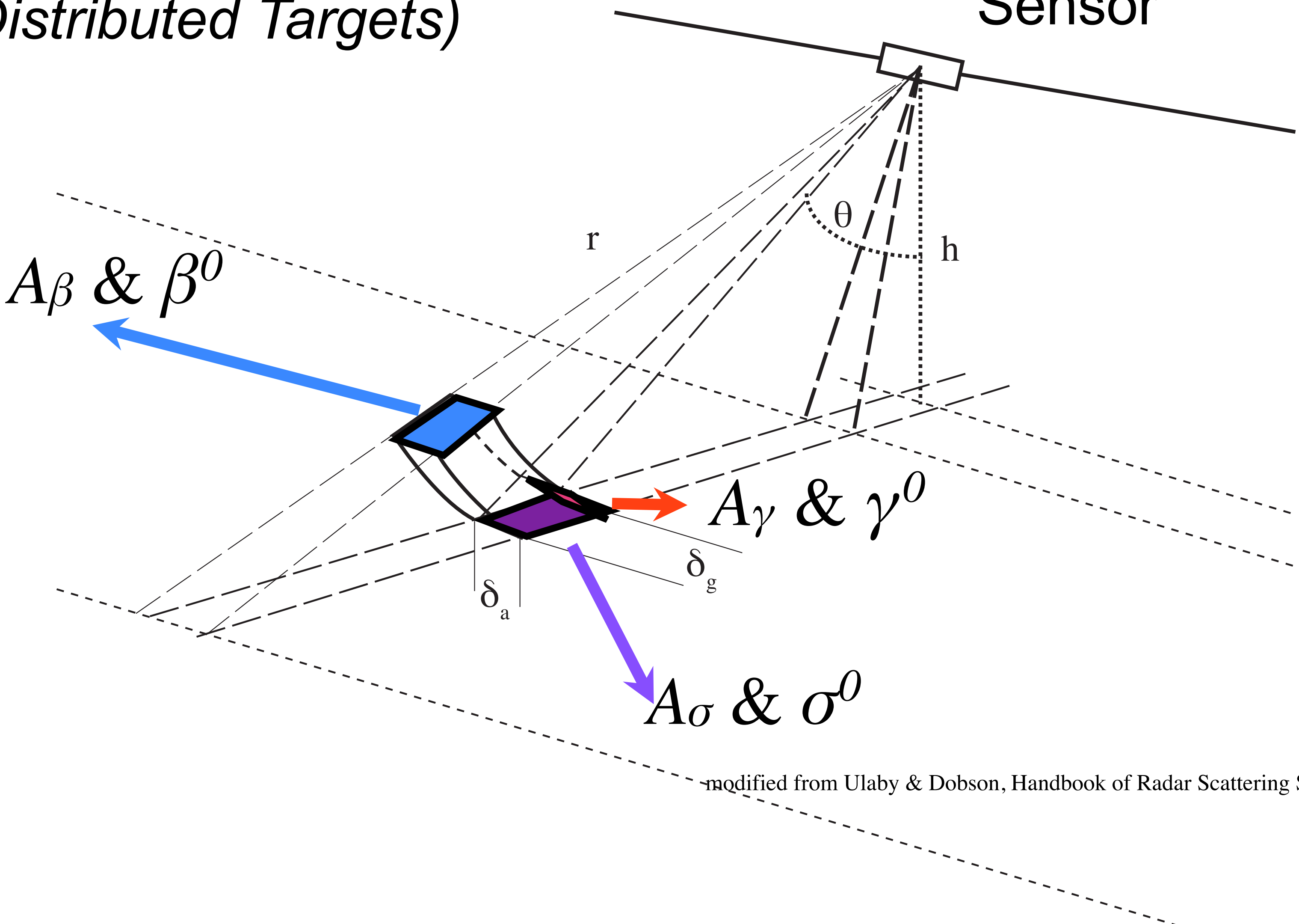
- **CEOS CARD4L** Analysis Ready Data for Land Processes
  - Define standards for ARD backscatter products
    - RTC (L1): Terrain-flattening
    - LRW (L3): Wide-area **Analysis Ready Data**

Radar products in map geometry

Correction(s) Applied	GTC	RTC	LRW (ARD)
Geometry (position)	✔	✔	✔
Radiometry (contributing area)		✔	✔
Resolution homogeneity			✔

Standard Areas for Normalisation

(Distributed Targets)



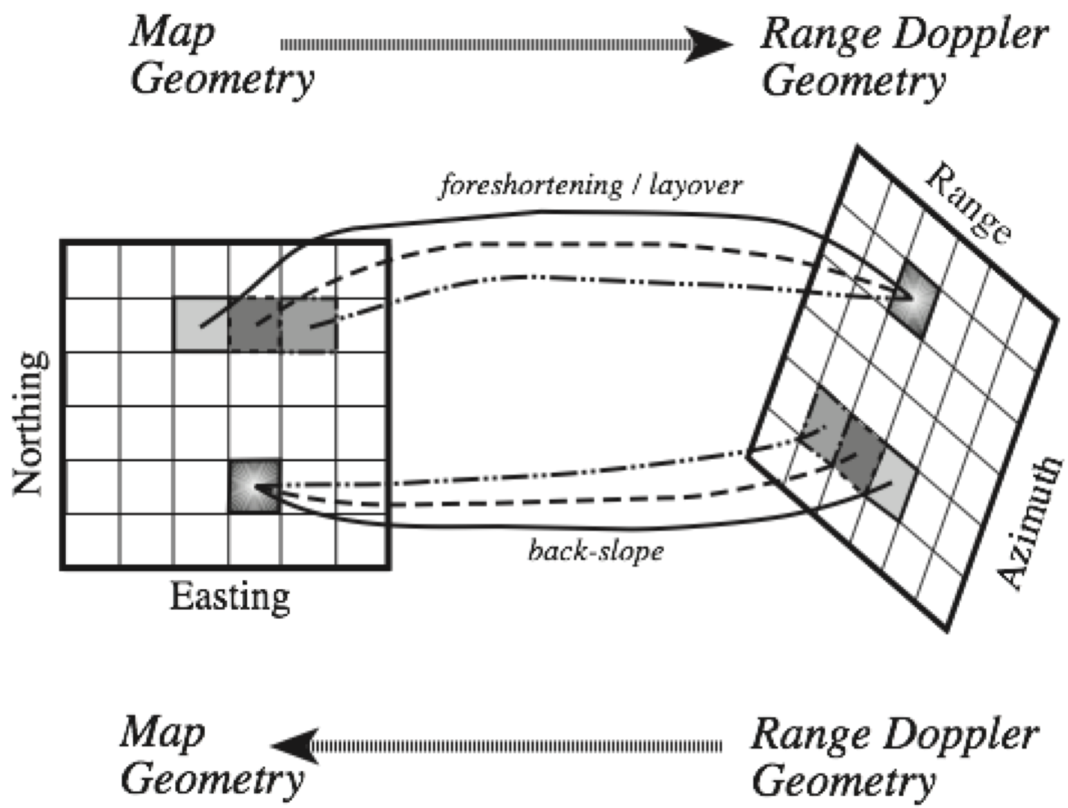
modified from Ulaby & Dobson, Handbook of Radar Scattering Statistics for Terrain, 1989

Lack of Homomorphism

No one-to-one correspondence between slant range and map geometries on **fore-** and **back**-slopes

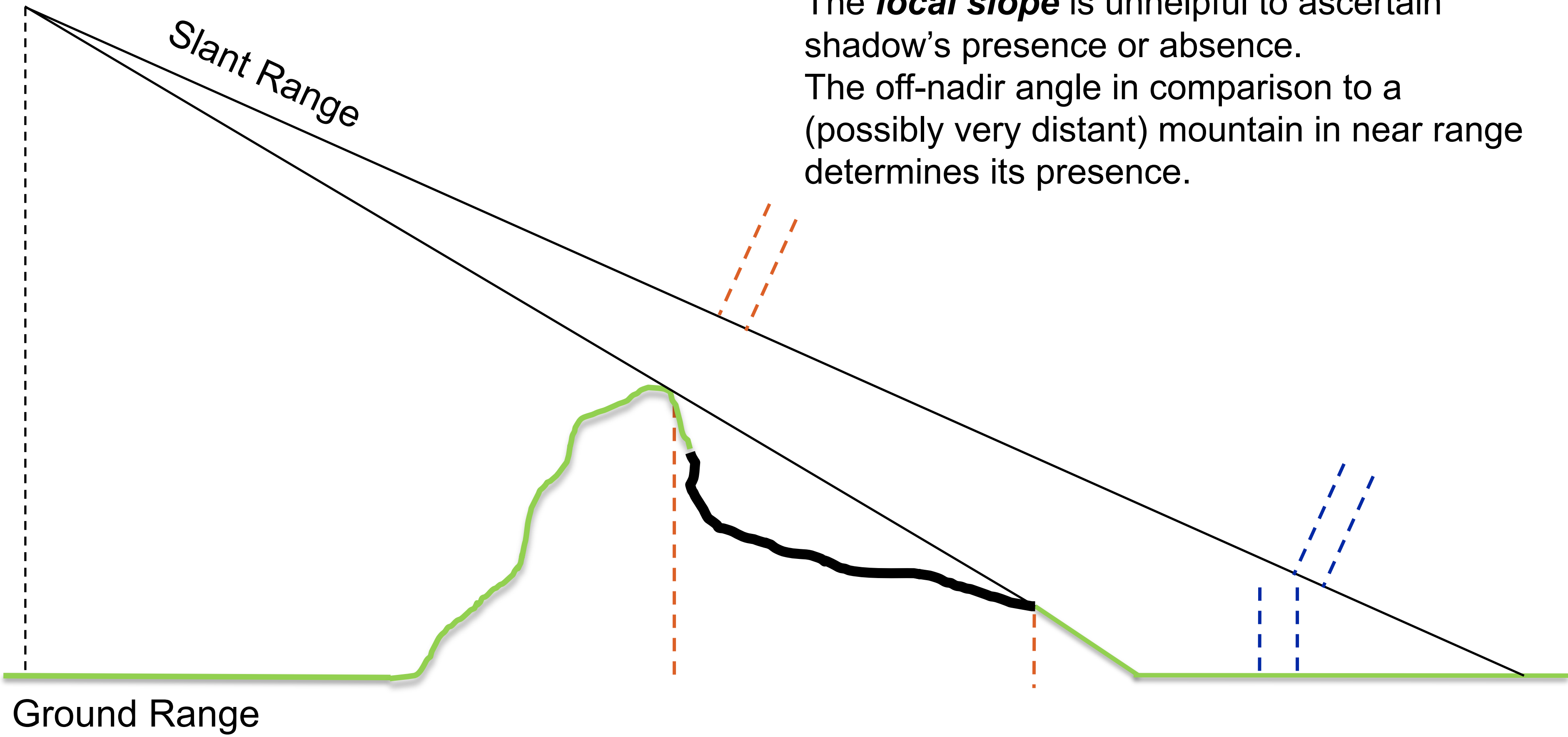
Non-local DEM corrections required for:

- *Layover*
- ***Foreshortening***
- *Shadow*



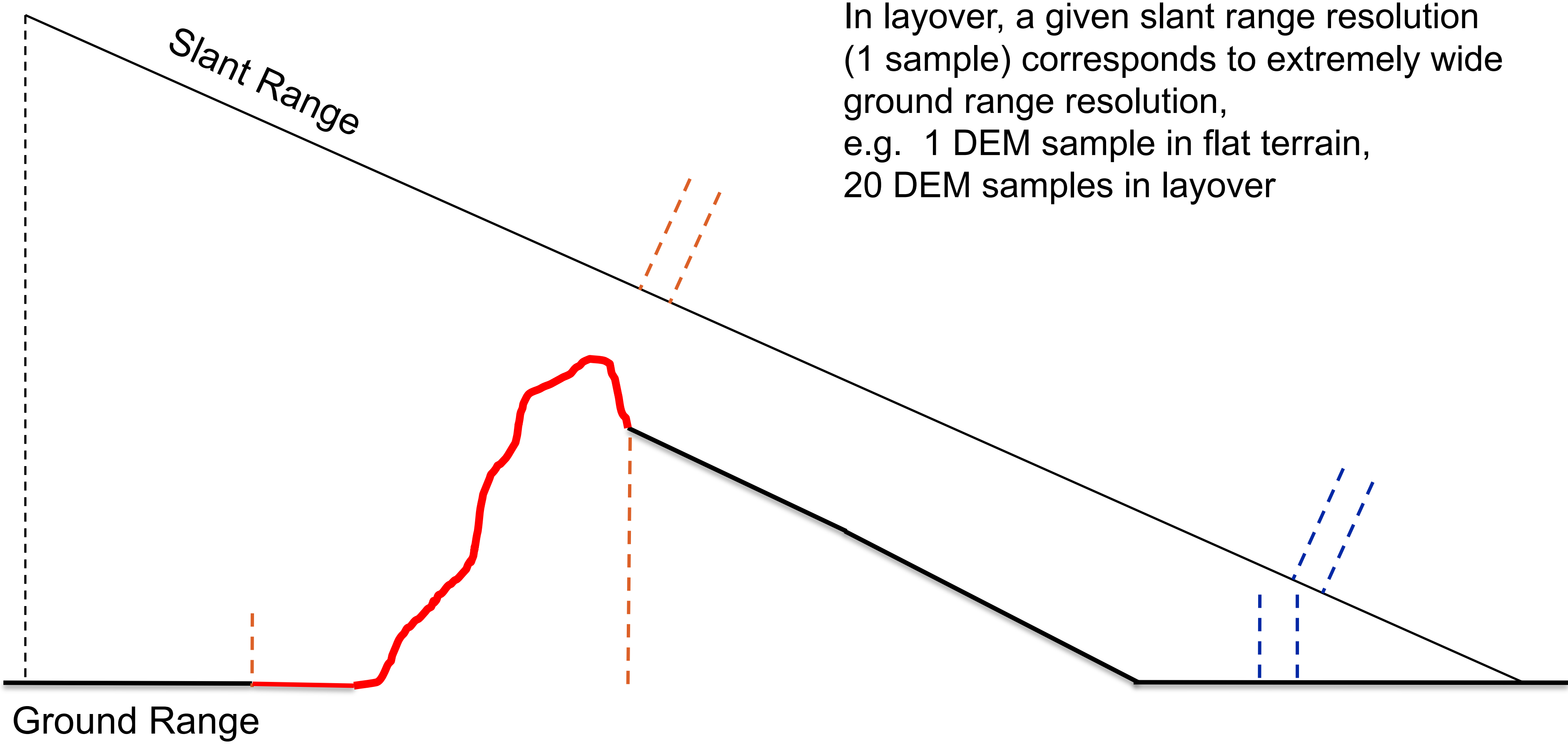
Shadow a non-local phenomenon

The ***local slope*** is unhelpful to ascertain shadow's presence or absence.
The off-nadir angle in comparison to a (possibly very distant) mountain in near range determines its presence.



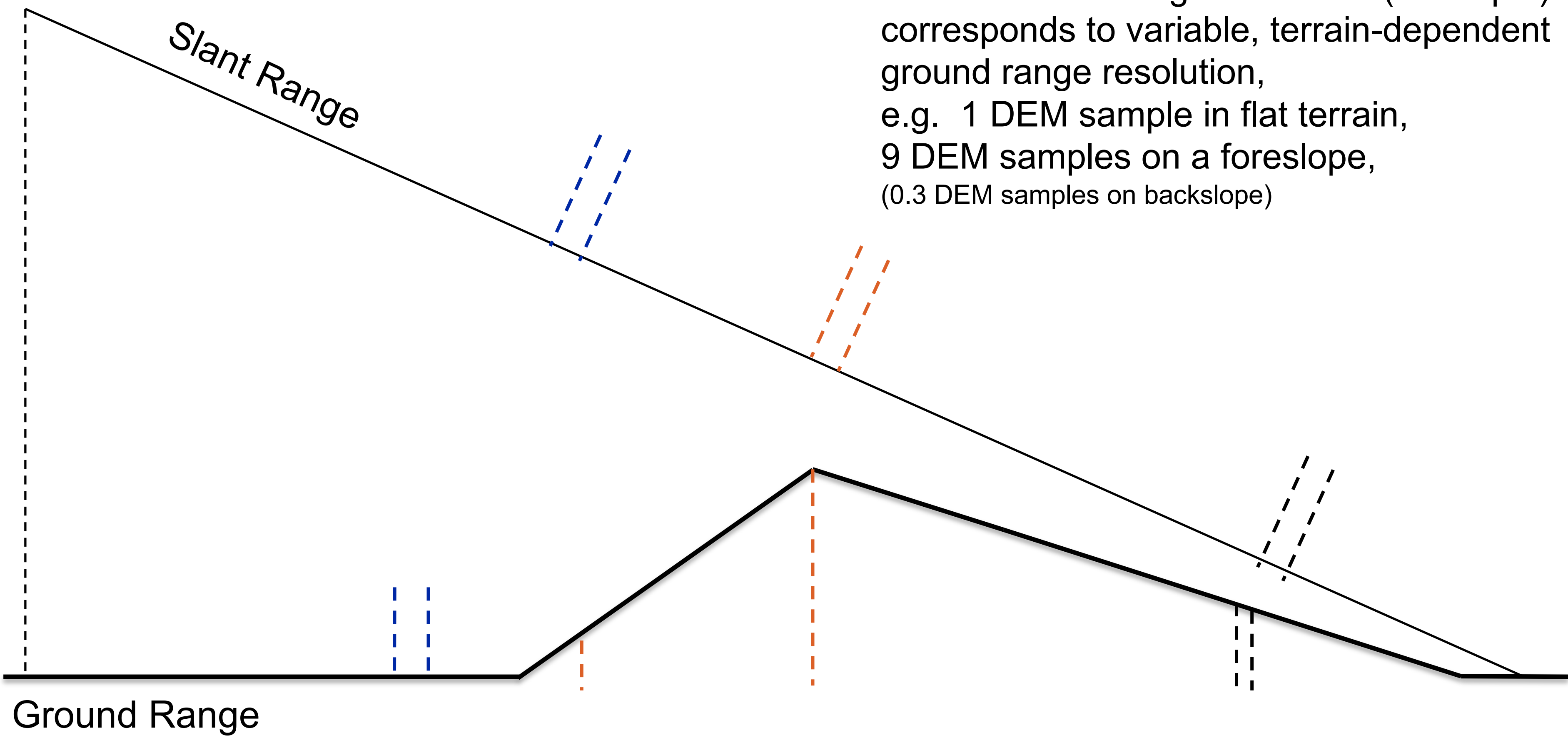
Layover a non-local phenomenon

In layover, a given slant range resolution (1 sample) corresponds to extremely wide ground range resolution,
e.g. 1 DEM sample in flat terrain,
20 DEM samples in layover



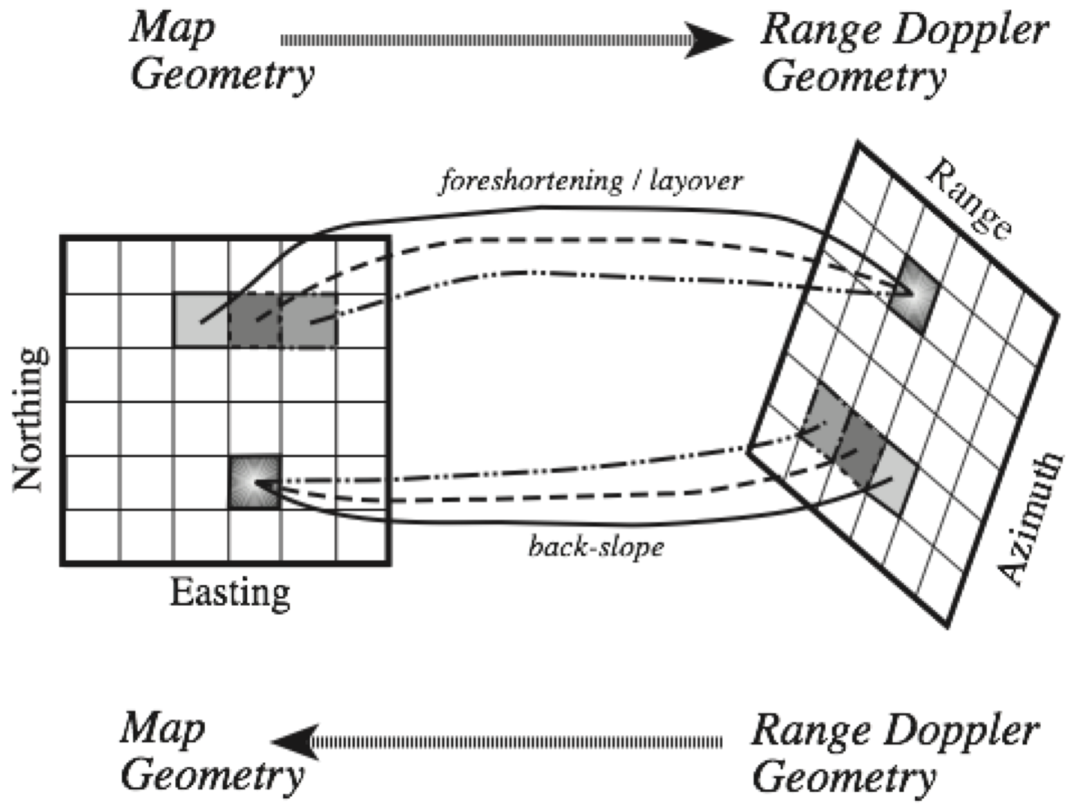
Foreshortening a non-local phenomenon

Constant slant range resolution (1 sample) corresponds to variable, terrain-dependent ground range resolution,
e.g. 1 DEM sample in flat terrain,
9 DEM samples on a foreslope,
(0.3 DEM samples on backslope)



Corrections using only immediate DEM-neighbours *are doomed to failure*

- Shadow
- Layover
- **Foreshortening**



University of Zurich[UZH]

Dept. of Geography / Remote

Projected Ground Illuminated Area

Terrain-flattened Gamma Nought

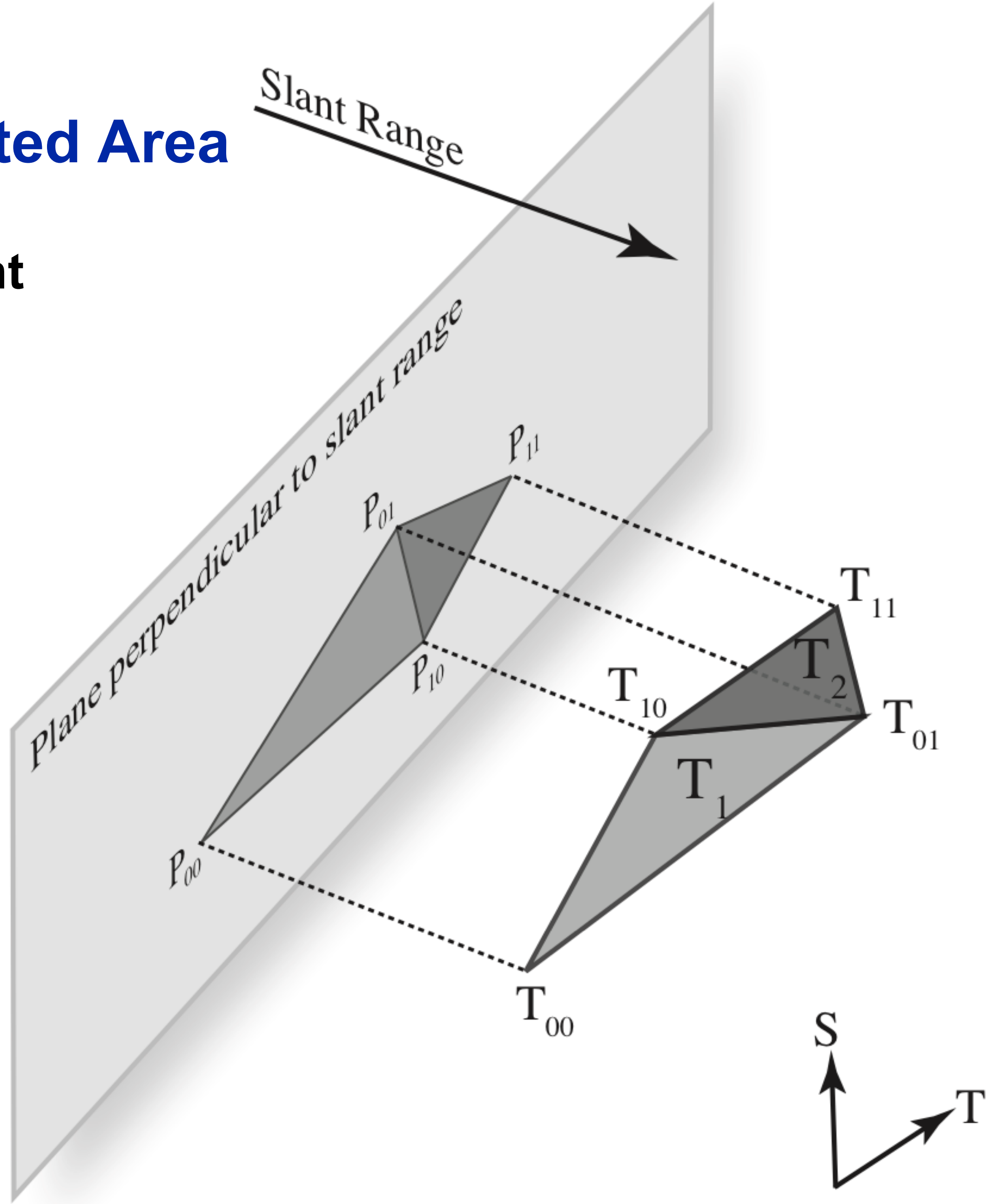
- Normalisation area projected into plane perpendicular to slant range direction
- Conventional gamma nought:

$$\gamma_E^0 = \beta^0 \bullet \tan\theta_E$$

- Terrain-flattened gamma nought:

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

where A_γ sums up all locally contributing DEM facet areas



Radiometric Normalisation Conventions

Convention	1	2	3	4	5
	β^0	σ_E^0	γ_E^0	σ_T^0	γ_T^0
Earth Model	*None*	*Ellipsoid*		*Terrain*	
Reference Area	A_β	$\underline{A}_\sigma$	$\underline{A}_\gamma$	$\hat{A}_\sigma$	A_γ
Area Derivation	$\delta_r \cdot \delta_a$	$\underline{\delta}_g \cdot \delta_a$	$\underline{\delta}_p \cdot \delta_a$	$\delta_g \cdot \delta_a$	$\int_{DHM} \delta_p \cdot \delta_a$
Normalisation	$\beta^0 = \frac{\sigma}{A_\beta}$	$\beta^0 \cdot \frac{A_\beta}{\underline{A}_\sigma} = \beta^0 \cdot \sin\theta_E$	$\beta^0 \cdot \frac{A_\beta}{\underline{A}_\gamma} = \beta^0 \cdot \tan\theta_E$	$\sigma_E^0 \cdot \frac{\hat{A}_\sigma}{A_\beta} = \sigma_E^0 \cdot \frac{\sin\theta_{LIM}}{\sin\theta_E}$	$\frac{\beta^0 \cdot A_\beta}{A_\gamma}$
Product	*GTC*			*NORLIM*	*RTC*

University of Zurich[UZH]

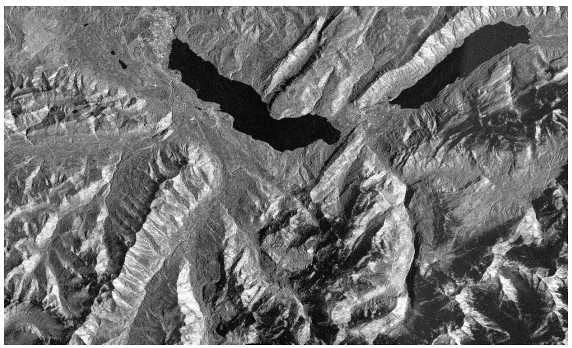
Terrain-flattened Gamma Nought

Dept. of Geography / Remote Sensing Laboratories

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

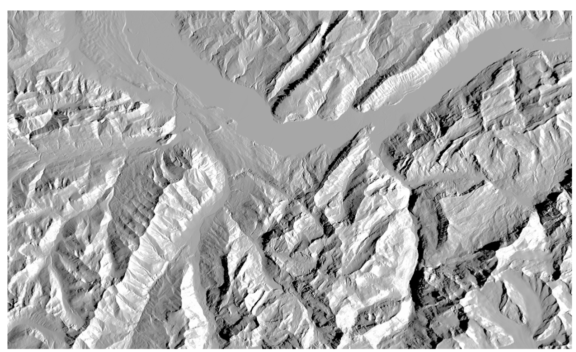
Terrain-flattening: Small D. *Flattening Gamma: Radiometric Terrain Correction for SAR Imagery*, IEEE Trans. on Geoscience & Remote Sensing, 49(8), Aug. 2011, pp. 3081-3093.

Normalise β^0**:** divide by simulated image



β^0 GTC

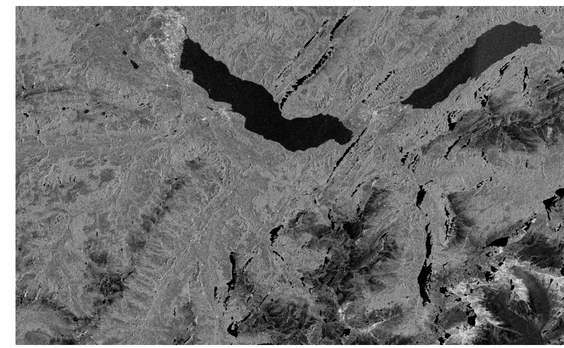
/



$A\gamma / A\beta$

=

γ_T^0



RTC

-26dB -1dB

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

Dept. of Geography / R

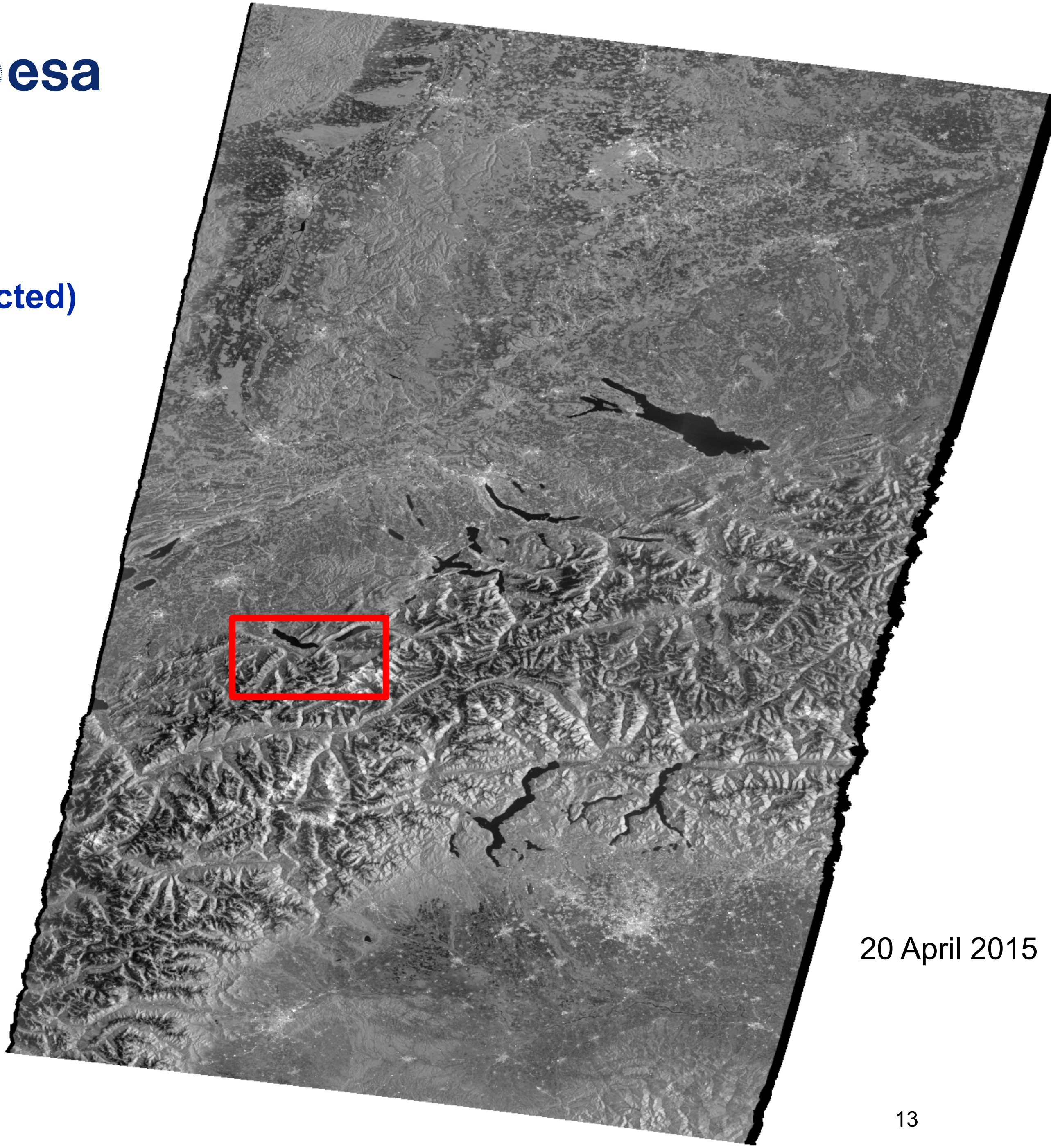
Sentinel-1A: GTC
(Geometrically Terrain Corrected)

$$\gamma_E^0$$

-26dB -1dB

Generated automatically from 3 IW GRDH products using SRTM3

Copernicus Sentinel data (2015)



20 April 2015

University of Zurich[UZH]

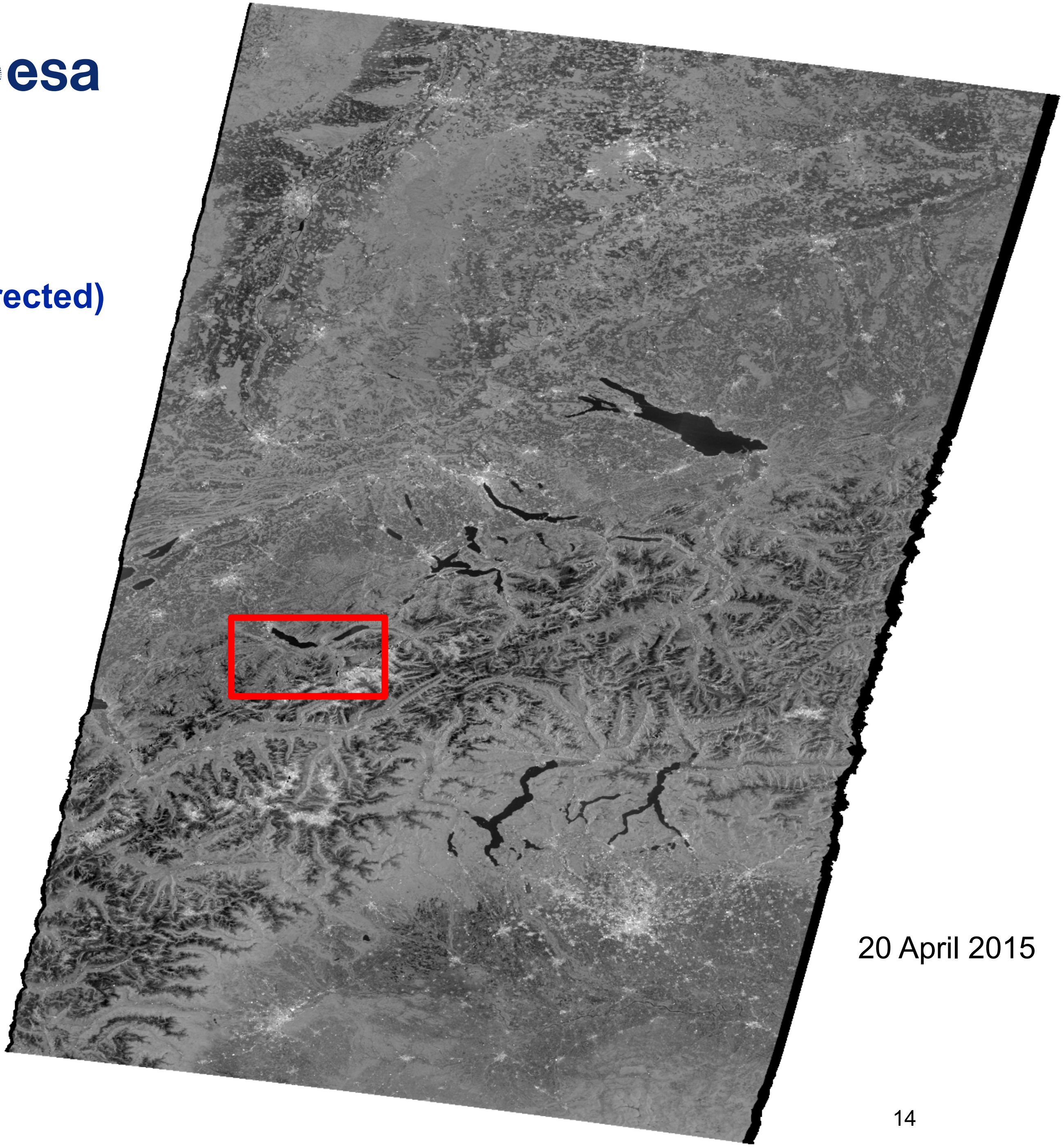
esa

Dept. of Geography / R

Sentinel-1A: RTC
(Radiometrically Terrain Corrected)

$$\gamma_T^0$$

-26dB -1dB



Generated automatically from 3 IW GRDH products using SRTM3

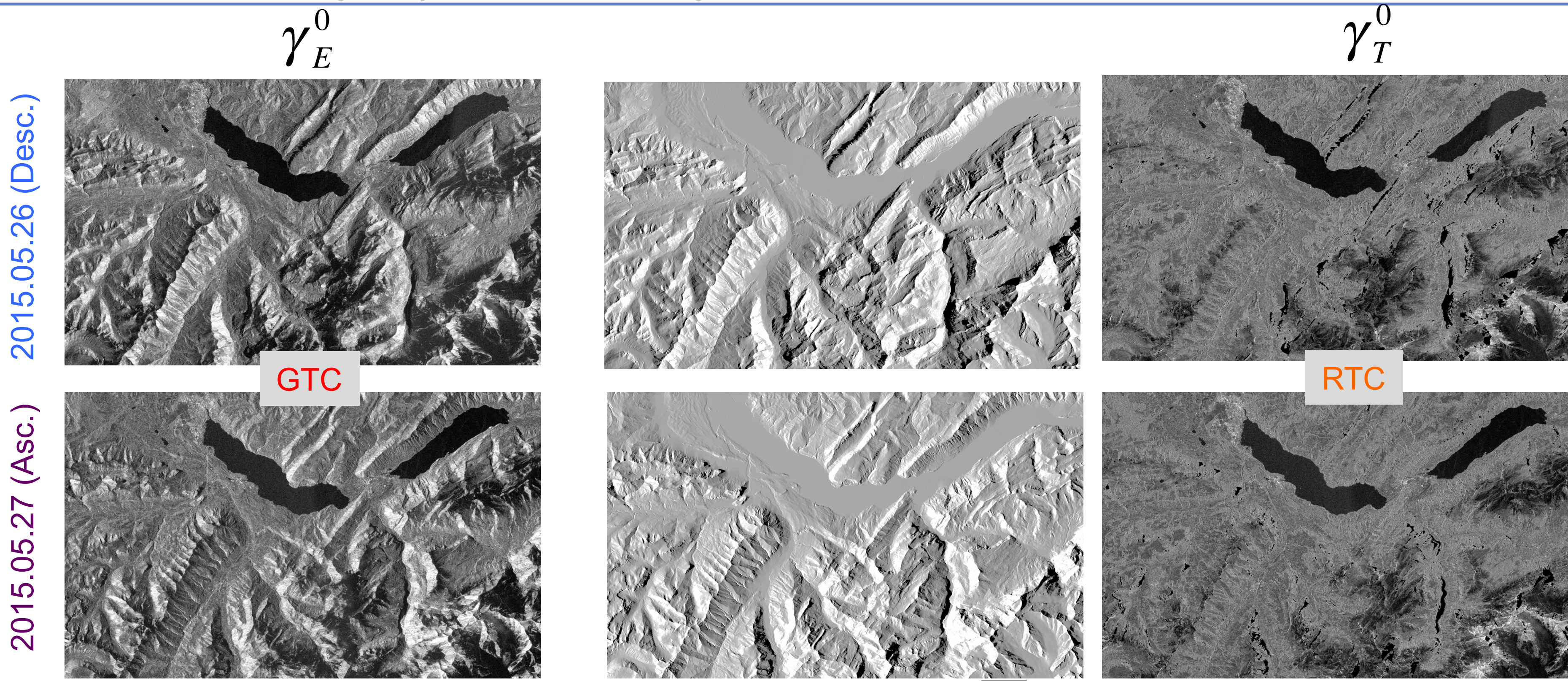
Contains modified Copernicus Sentinel data (2015)

20 April 2015

University of Zurich[UZH]

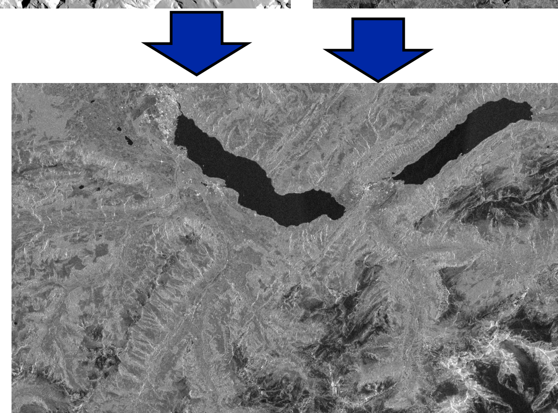
Dept. of Geography / Remote Sensing Laboratories

Backscatter Composites



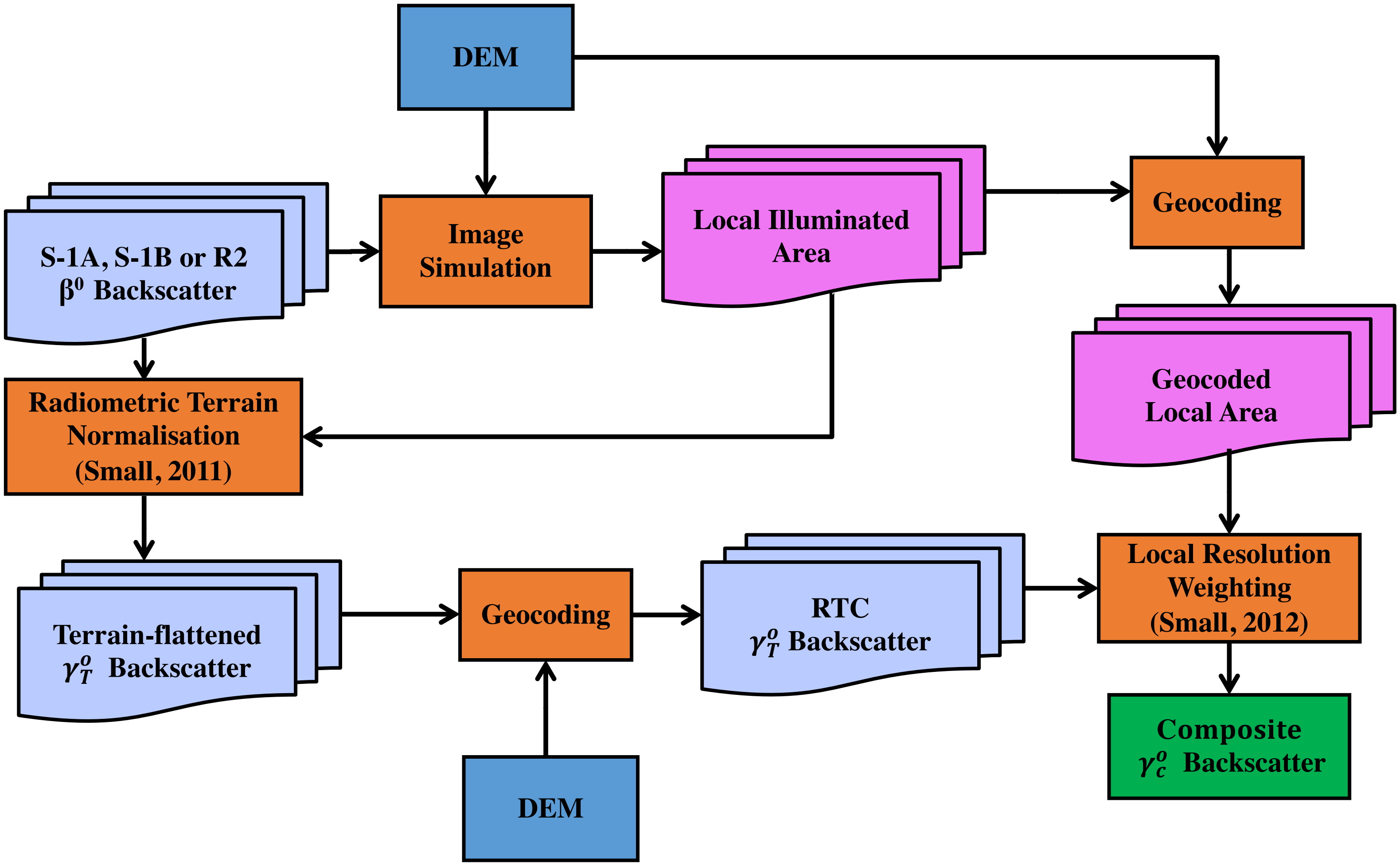
- Combine asc. & desc. observations to generate **composite** with improved local resolution
- Less shadow than single RTC, lower noise

Interlaken, Switzerland

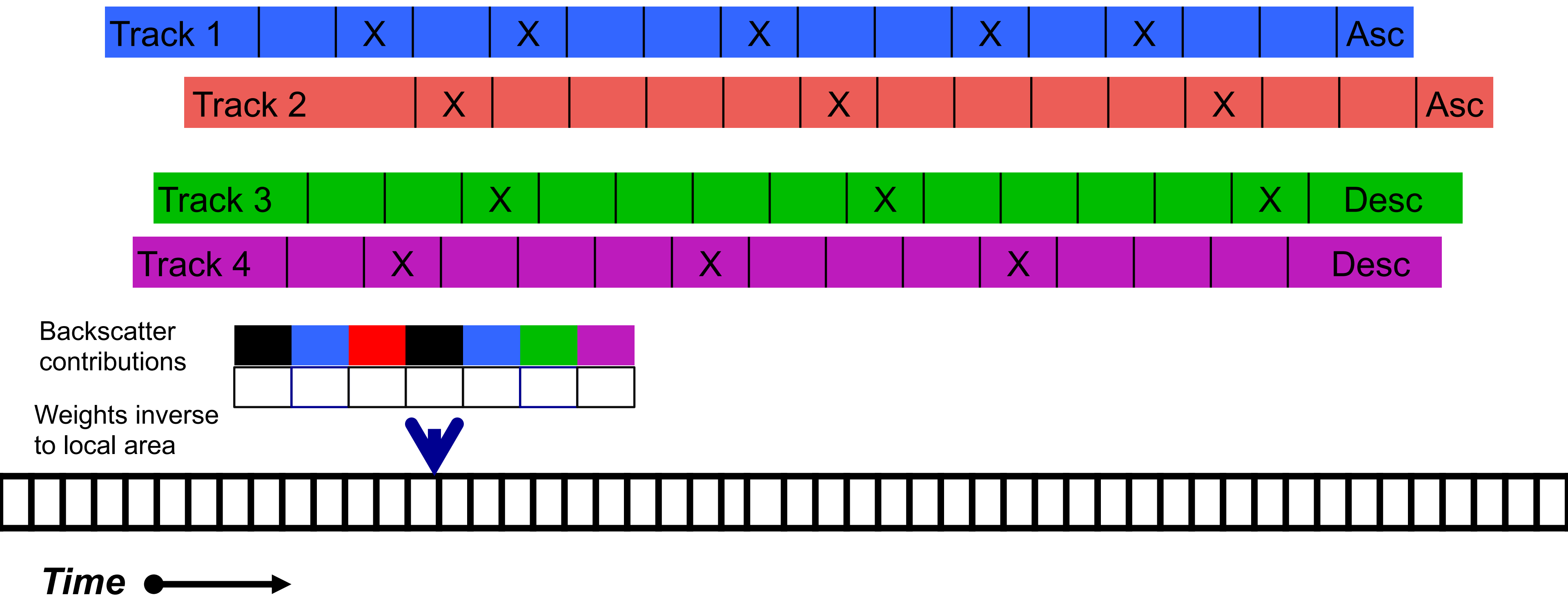


Composite

Composite Backscatter Production



Multitrack Integration: *Escaping the tyranny of exact repeat passes*

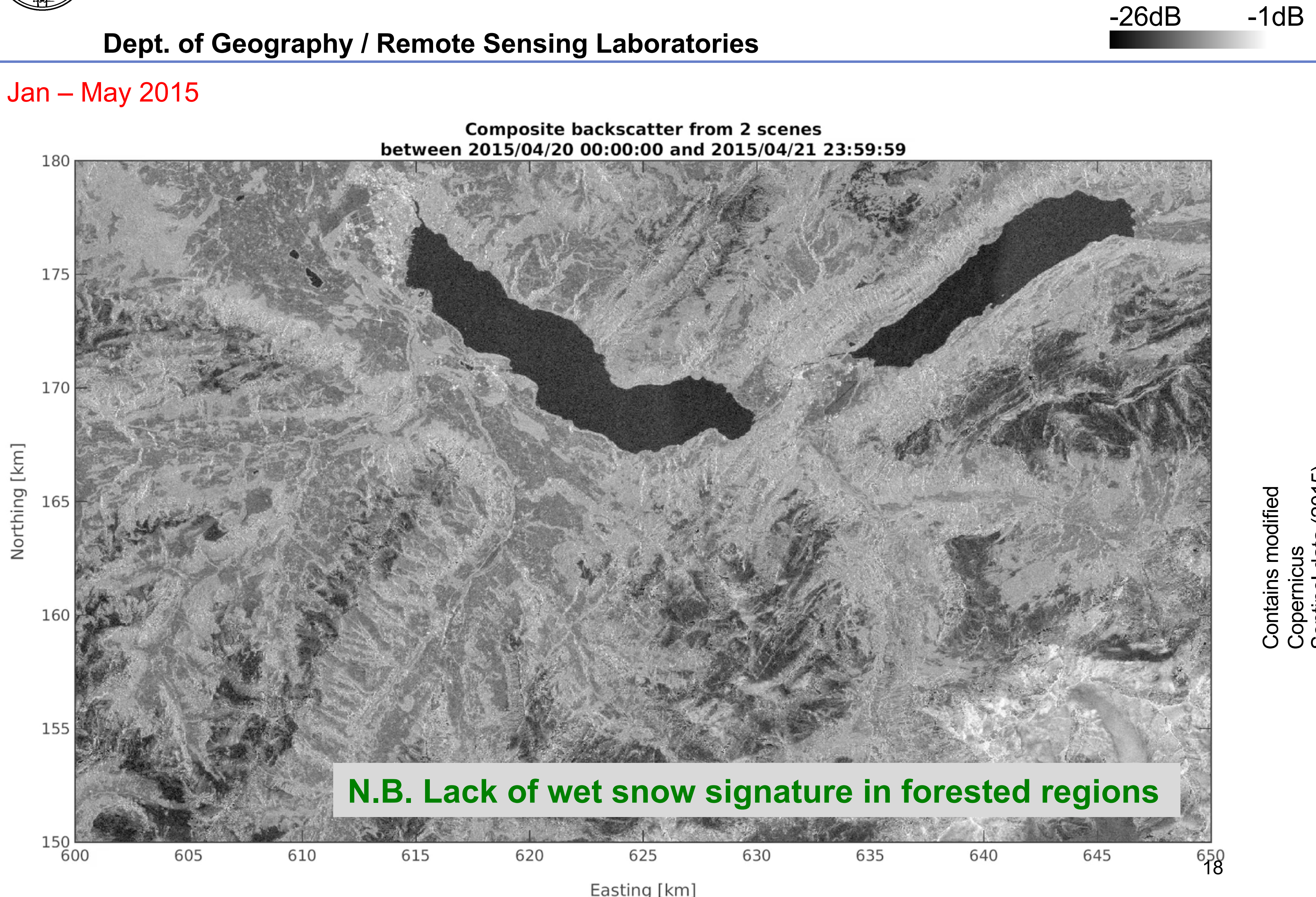


For *Regular Intervals* with temporal resolution better than repeat-pass interval

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

Composites in Time Series Movie

Jan – May 2015



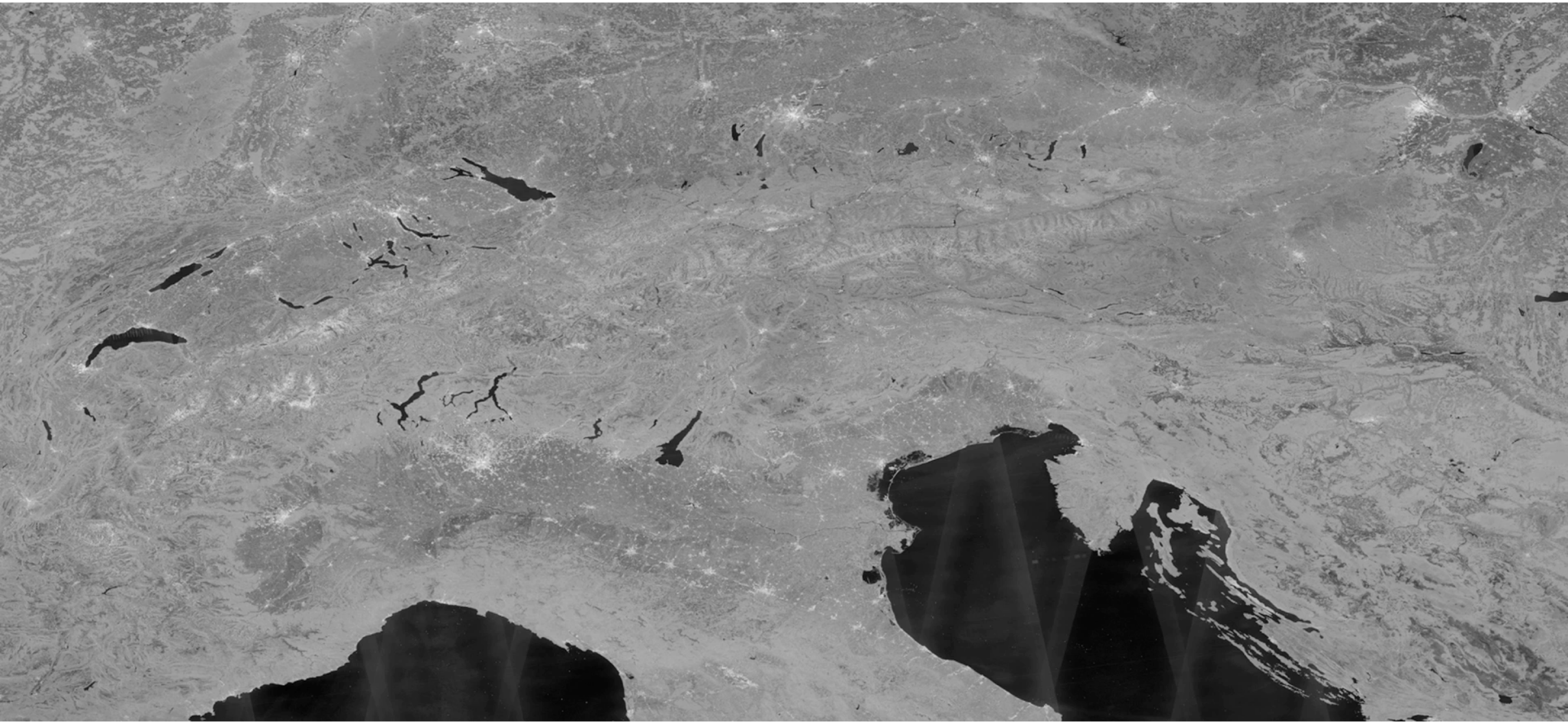
Interlaken, Switzerland

Sentinel-1 Alps-wide Backscatter Movie

University of Zurich[UZH]

Dept. of Geography / Remote Sensing Laboratories

Sentinel-1 IW VH-pol. **Feb. - June 2018**: 12 day windows



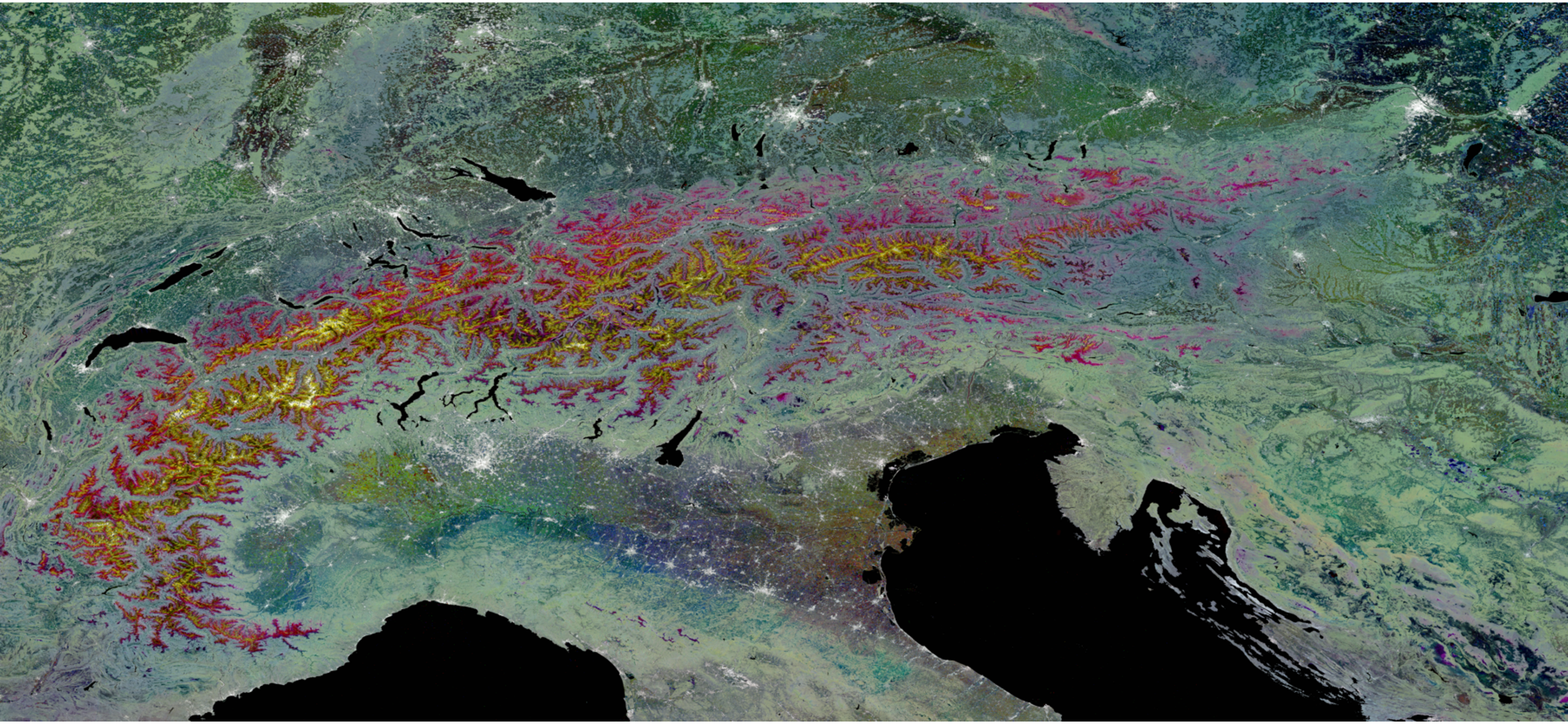
SRTM used for geometric and radiometric corrections

University of Zurich[UZH]

esa

Dept. of Geography / Remote Sensing Laboratories

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



No mask for foreshortening/layover required

Ellesmere Island Backscatter Composites

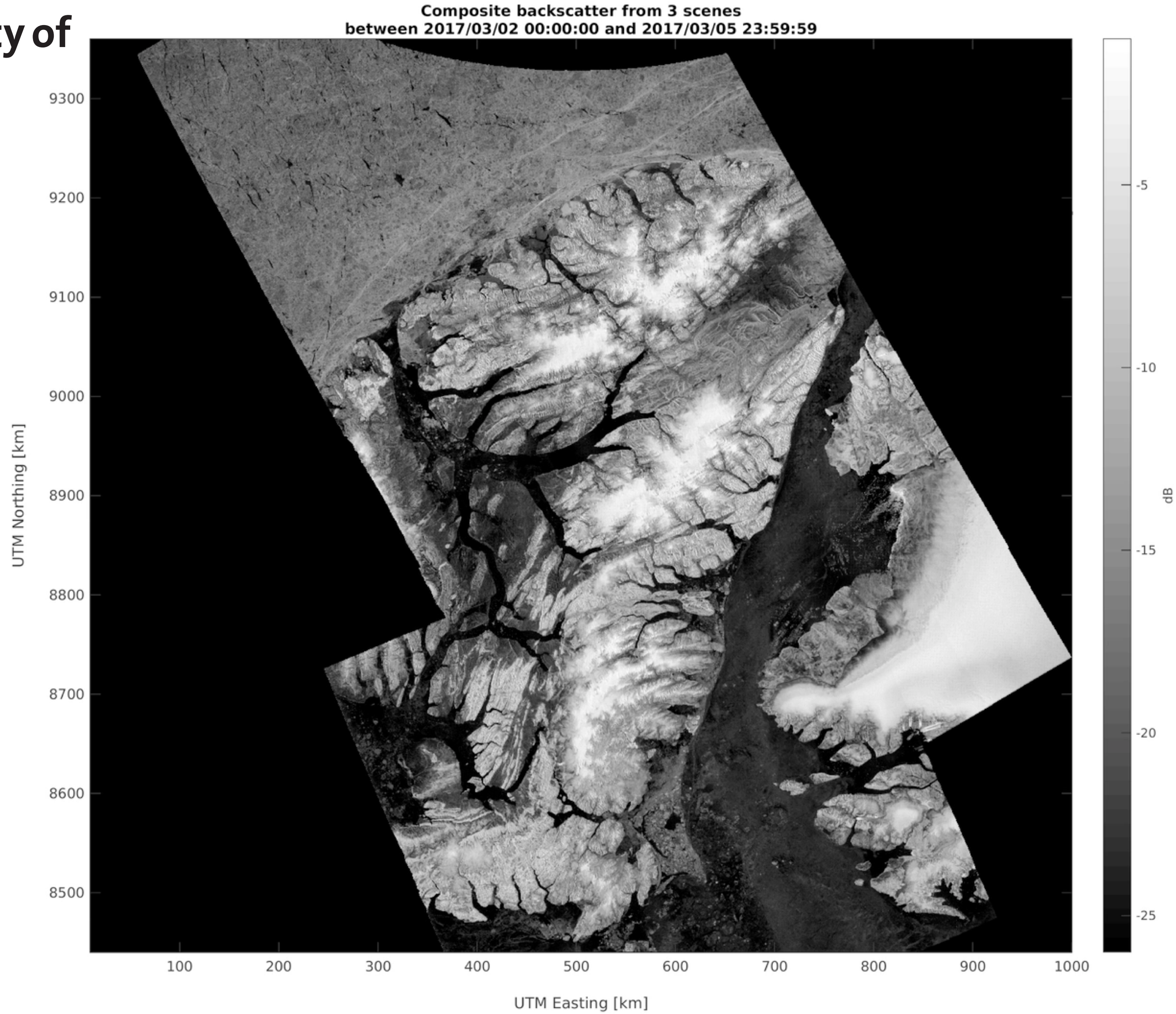
RS2 SCWA HV

2 day delta

4 day window

N.B. CDEM

Mar – Aug. 2017



University of Zurich[UZH]

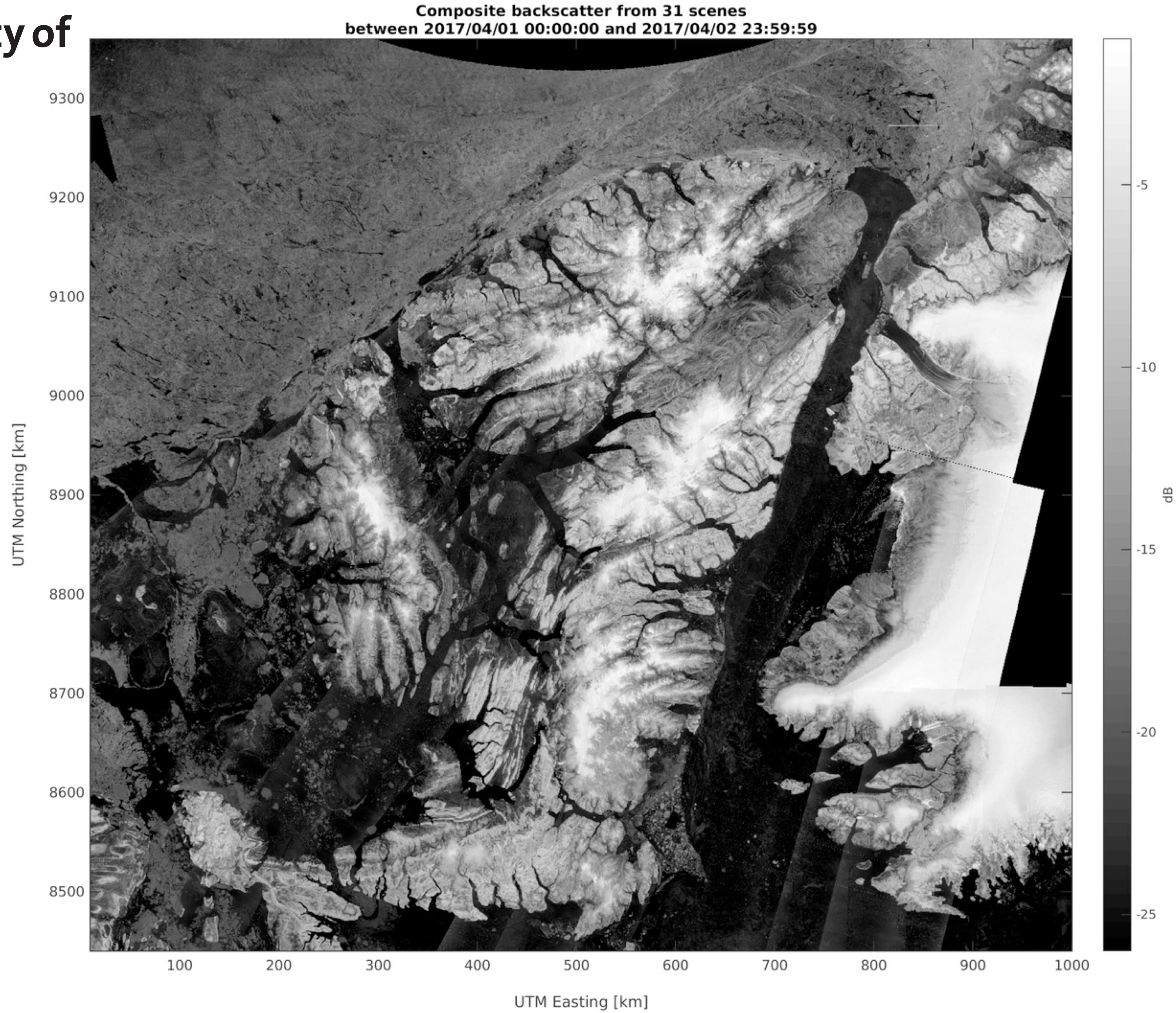
CSA ASC

Environment and Climate Change Canada

Environnement et Changement climatique Canada

University of Zurich[UZH]

Ellesmere Island Backscatter Composites



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

1 day delta

2 day window

N.B. CDEM

Apr. – Aug. 2017

esa

University of Zurich[UZH]

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

esa

Contains modified Copernicus Sentinel data (2017)

CSA ASC

Environment and Climate Change Canada
Environnement et Changement climatique Canada

University of Zurich[UZH]

esa

CSA ASC

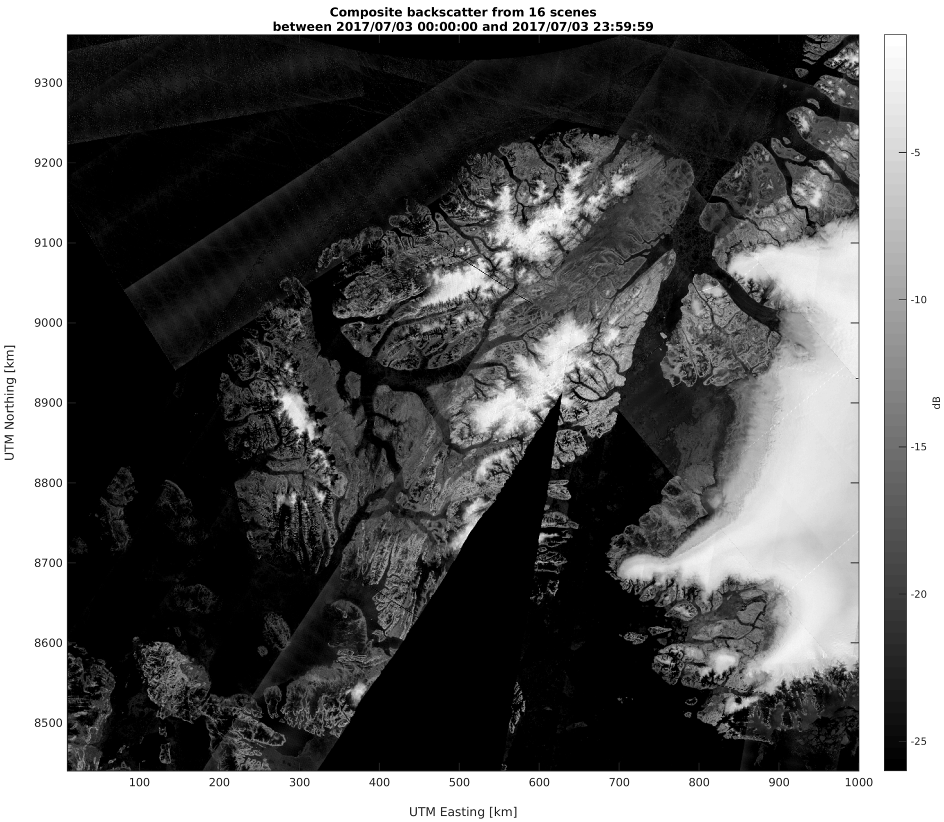
Environment and Climate Change Canada

Environnement et Changement climatique Canada

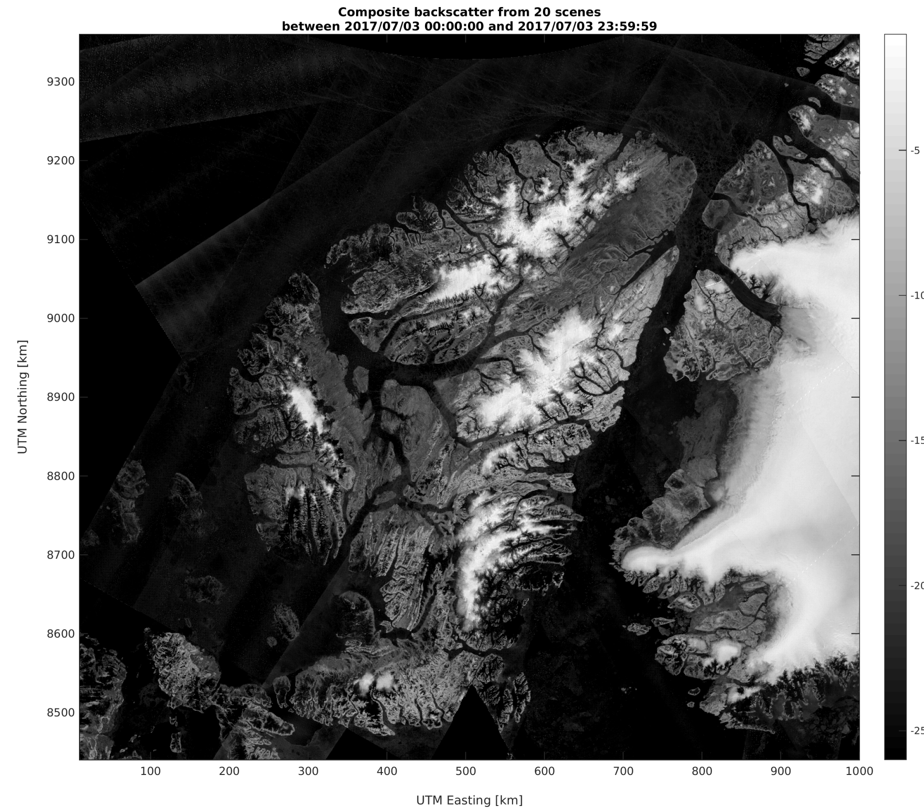
Dept. of Geography / Remote Sensing Laboratories

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

S-1A+S-1B



S-1A+S-1B+ RS2



Conclusions

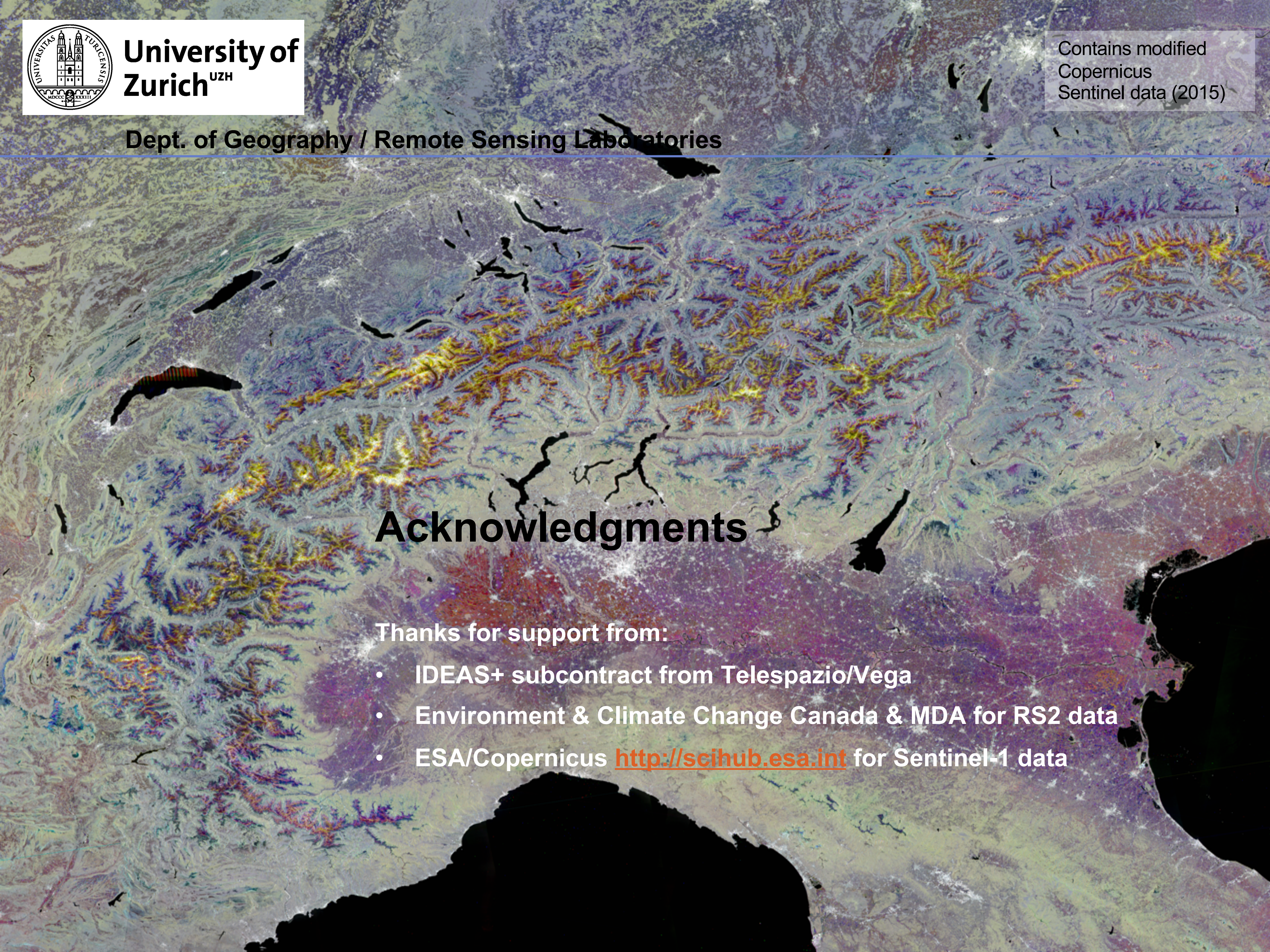
Backscatter composites are ***Analysis Ready***

- Less noise and higher mean resolution than single-scene RTC products
- Applications demonstrated (Small et al., ***BioGeoSAR***, ESA/DLR, Nov. 2018):
  - **Wet snow mapping** (Jäger, M.Sc., UZH, 2015)
  - **Forest-type classification** (Rüetschi et al., Rem. Sens., 2018)
  - **Sea ice melt onset detection** (Howell et al., Submitted, 2018)

Outlook

- Additional C-band satellites on the way:
  - **Sentinel-1C** / **Sentinel-1D** // CSA **RCM**: 3 satellites planned for launch in early 2019
  - ***Daily*** temporal resolution achieved with multi-sensor / multi-agency data integration (S-1 + RS2) – in the future, also at more temperate latitudes?
- Coordination between space agencies to strive for diversity of acquisition patterns ESA (S-1A, S-1B) and CSA (RCM)
- Integration of ARD backscatter in data cube(s)

University of Zurich[UZH]
Dept. of Geography / Remote Sensing Laboratories



Acknowledgments

Thanks for support from:

- IDEAS+ subcontract from Telespazio/Vega
- Environment & Climate Change Canada & MDA for RS2 data
- ESA/Copernicus http://scihub.esa.int for Sentinel-1 data