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

Towards strategic acquisition planning for the mapping of wet snow using spaceborne SAR sensors

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Environment Canada

Environnement Canada



Polar Space Task Group

- Polar Space Task Group (PSTG) is succeeding the IPY as the coordinating body of international space agencies Space Task Group (STG)
- WMO Polar Space Task Group - SAR Coordination Working Group (PSTG-CWG)

- Dr. Kari Luojus (FMI)

- Draft white paper (v0.5) circulated on Coordinated SAR Acquisition Planning for Terrestrial Snow Monitoring

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Science Requirements

Science Requirements for wide area monitoring

- *Spatial* resolution: ***100m*** ✔

Variable	Extent	Spatial resolution	Temporal resolution	Sensor	Auxiliary Data
Snowmelt area	Regional	100m	1 to 5 days	Sentinel-1	Land cover, DEM
Snowmelt liquid water content	Regional	100m	1 to 5 days	Sentinel-1 dual polarisation	Land cover, DEM

[Malenovský, Z. et al. *Sentinels for science: Potential of Sentinel-1, -2, and -3 missions for scientific observations of ocean, cryosphere, and land*. Remote Sens. Environ. 120, 91–101 (2012)]

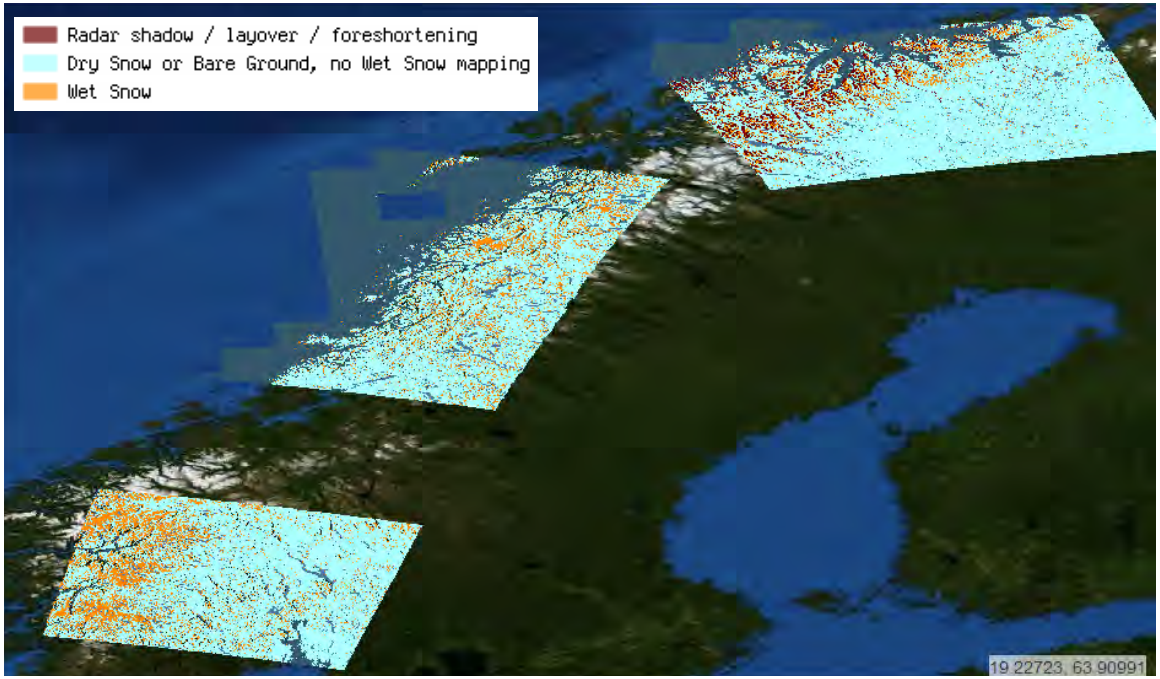
- *Temporal* resolution (target): ***1 day*** ✘
- "Observation of the ***daily*** *geographic extent of snow cover* is essential because it enables inference of several first order effects of snow on many Earth systems." [IGOS Cryosphere Theme Report, 2007]

CryoLand results

Norut results:

- Based on RS2 **SCNA** mode
- Produced NRT at KSAT
- Working continuously since January 2013
- 50 m spatial resolution
- Processed when data is available (5-10 scenes per week on average)

June 4, 2013

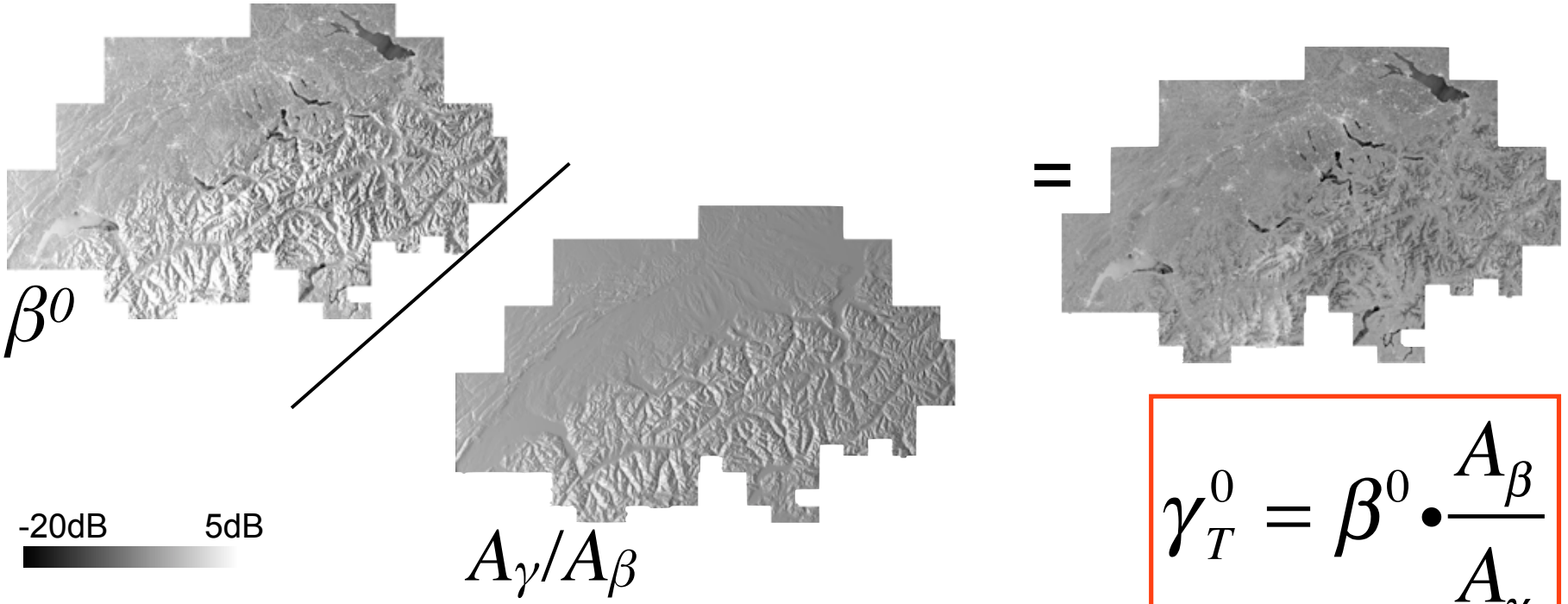


Simulated SAR Image A_γ

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

ASAR WS: April 12, 2010 (Map Geometry)

Normalise β^0: divide by simulated image

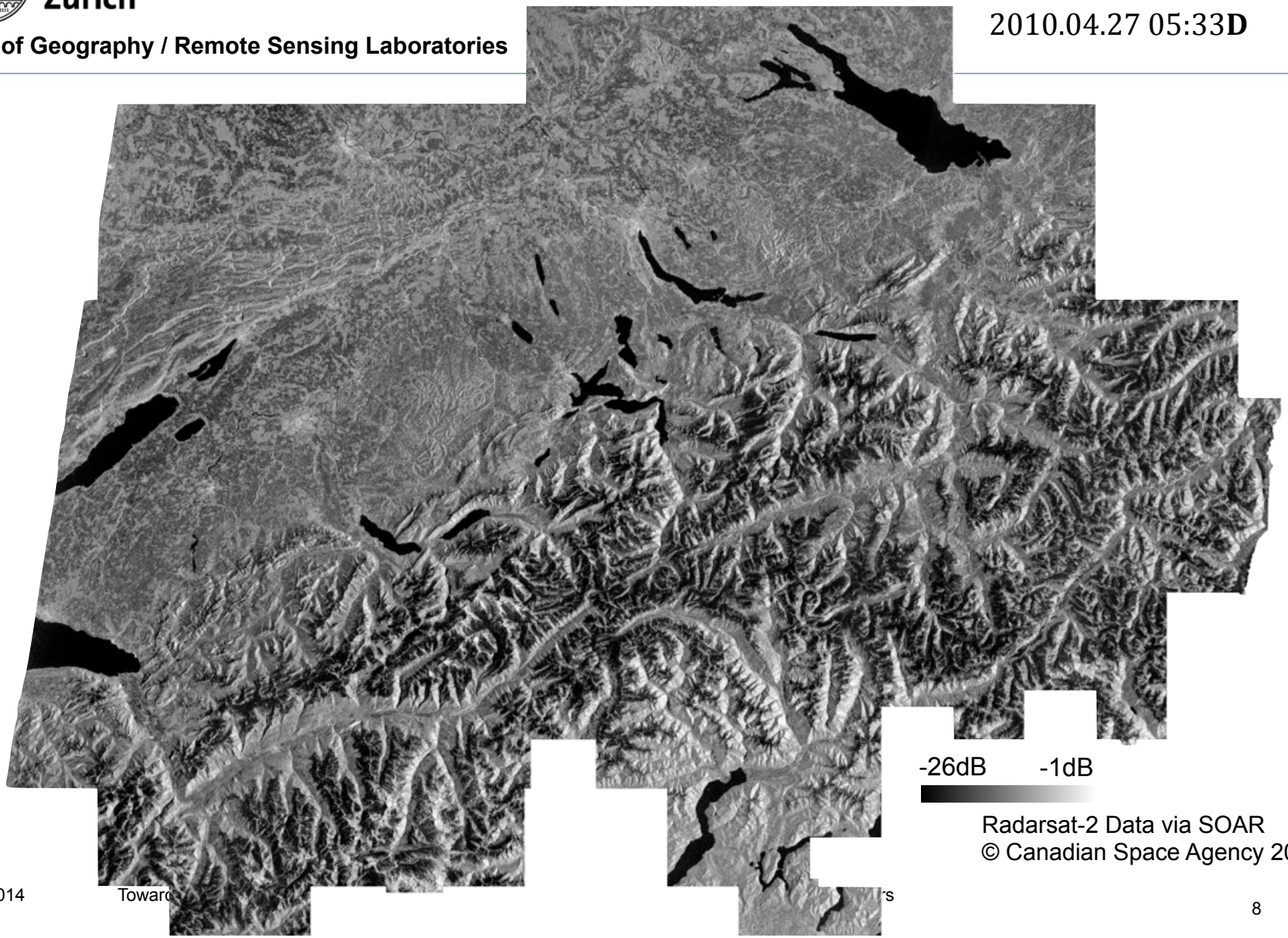


$$\gamma_T^0 = \beta^0 \bullet \frac{A_\beta}{A_\gamma}$$

2010.04.27 05:33**D**

VH GTC

γ_E^0

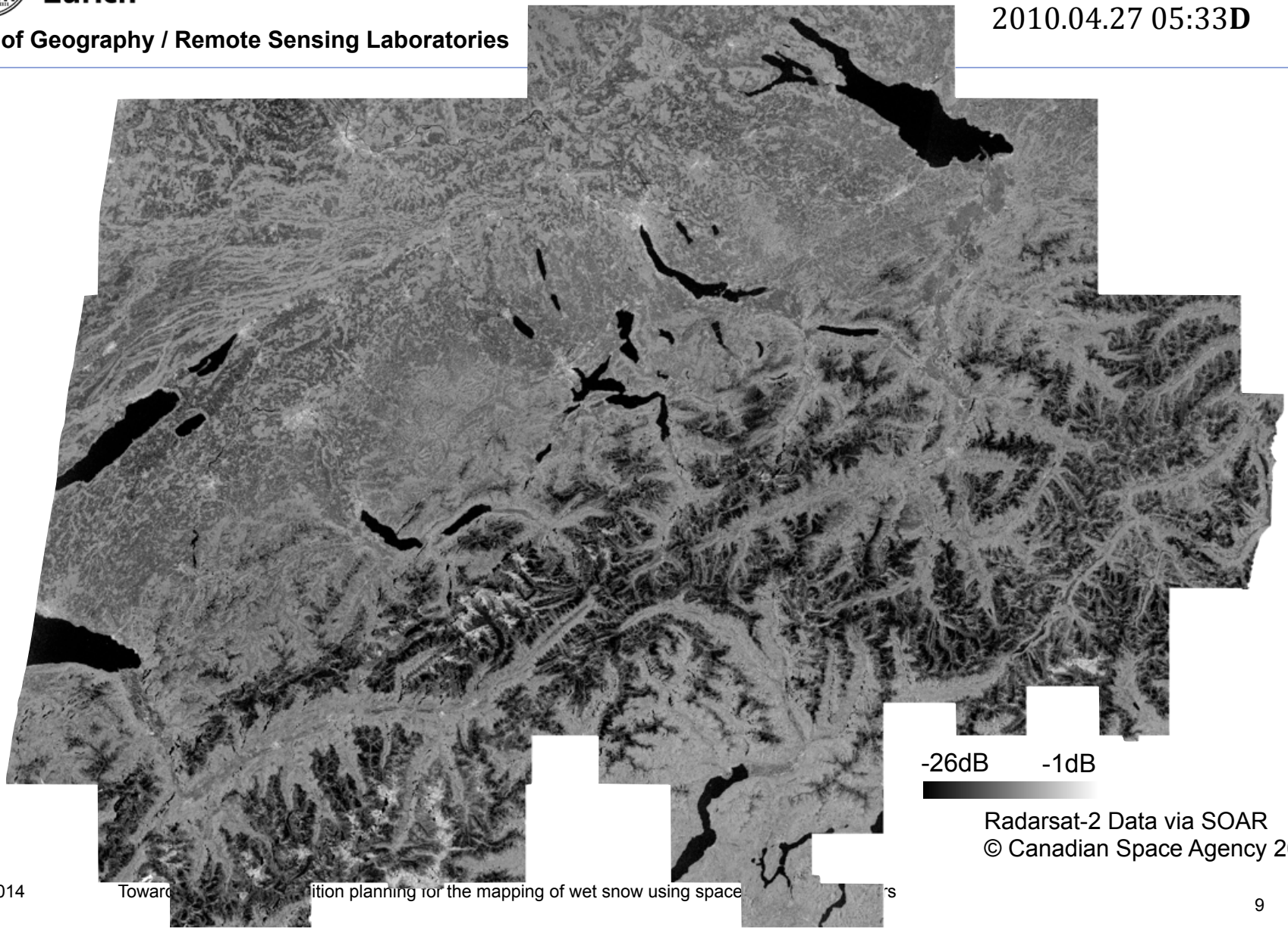


Radarsat-2 Data via SOAR
© Canadian Space Agency 2010

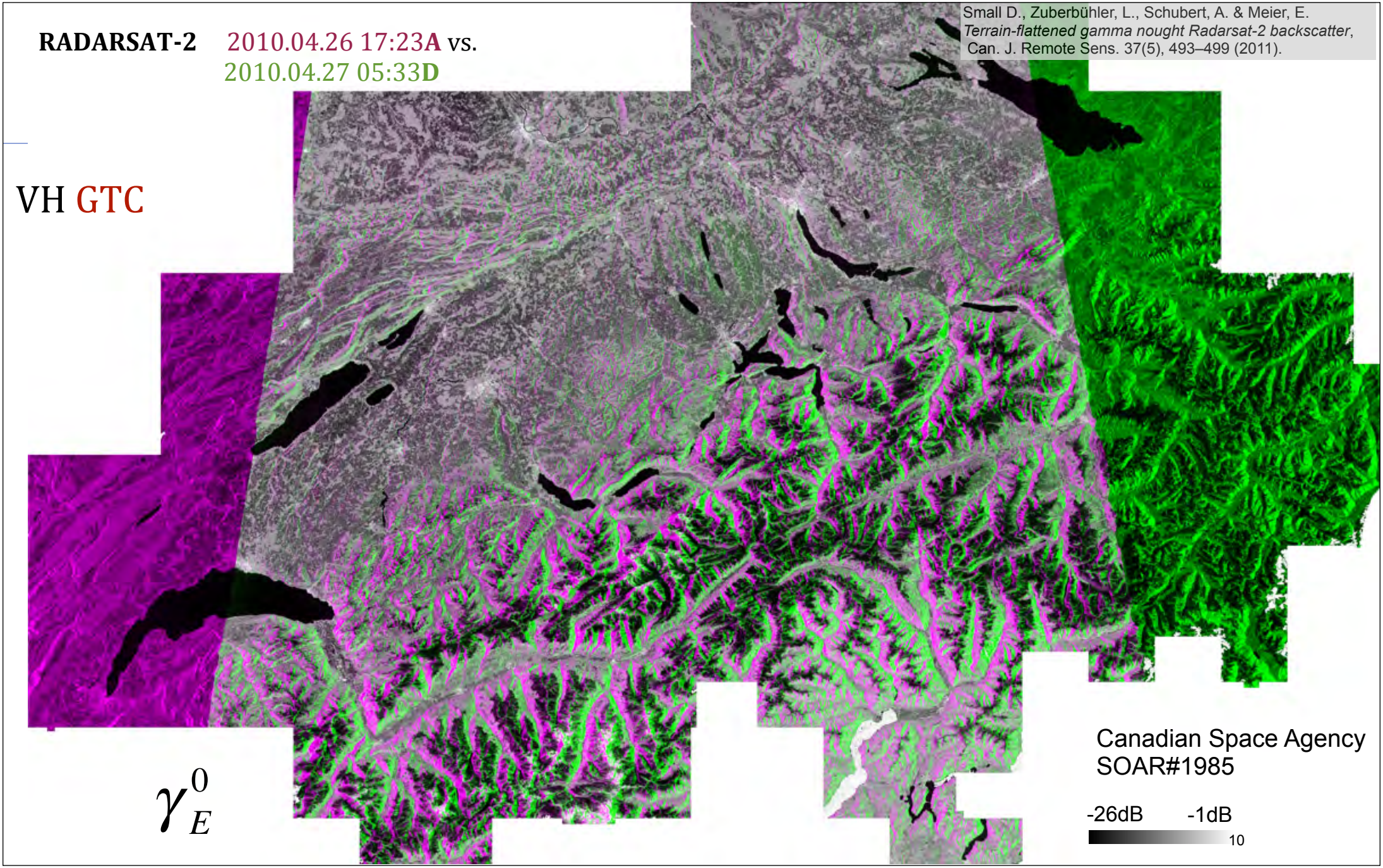
2010.04.27 05:33**D**

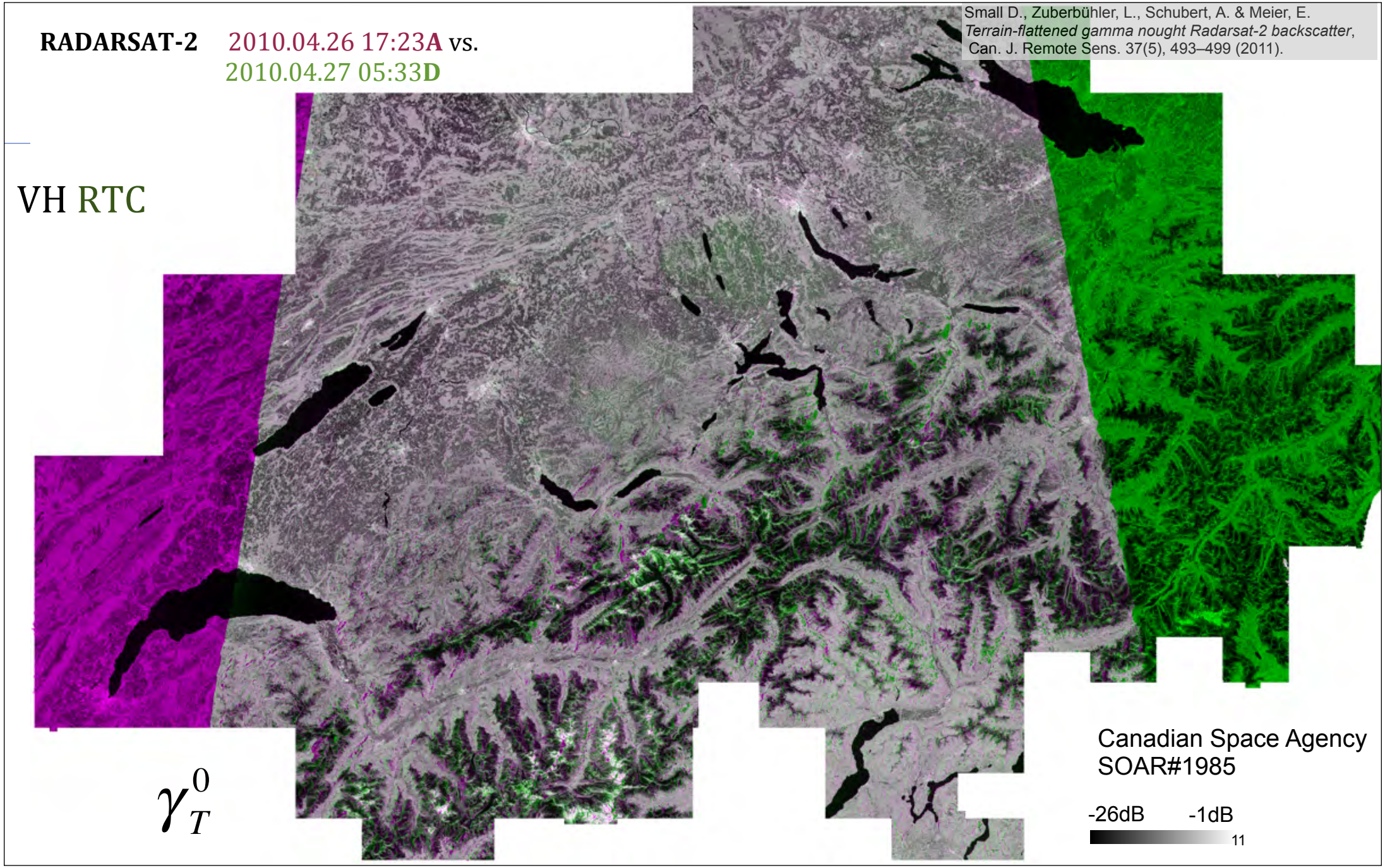
VH RTC

γ_T^0



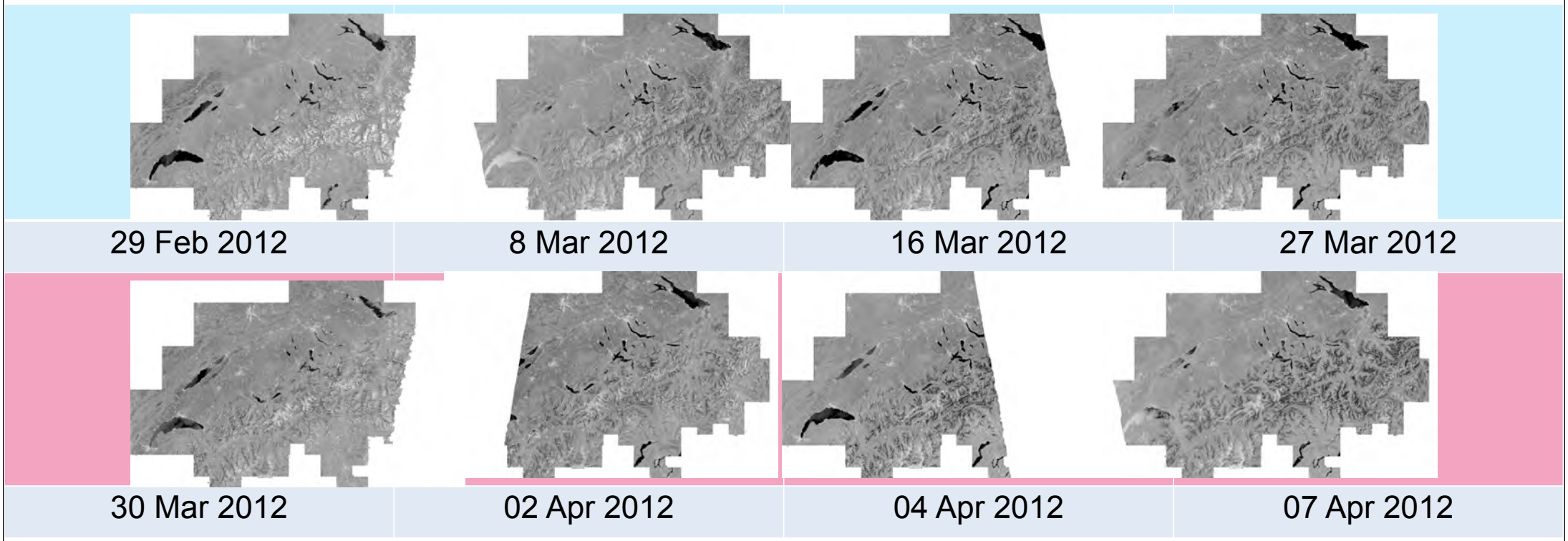
Radarsat-2 Data via SOAR
© Canadian Space Agency 2010


RADARSAT-2 2010.04.26 17:23A vs.
2010.04.27 05:33D
Small D., Zuberbühler, L., Schubert, A. & Meier, E.
Terrain-flattened gamma nought Radarsat-2 backscatter,
Can. J. Remote Sens. 37(5), 493–499 (2011).
VH GTC
γ_E^0
Canadian Space Agency
SOAR#1985
-26dB -1dB
10


RADARSAT-2 2010.04.26 17:23A vs.
2010.04.27 05:33D
Small D., Zuberbühler, L., Schubert, A. & Meier, E.
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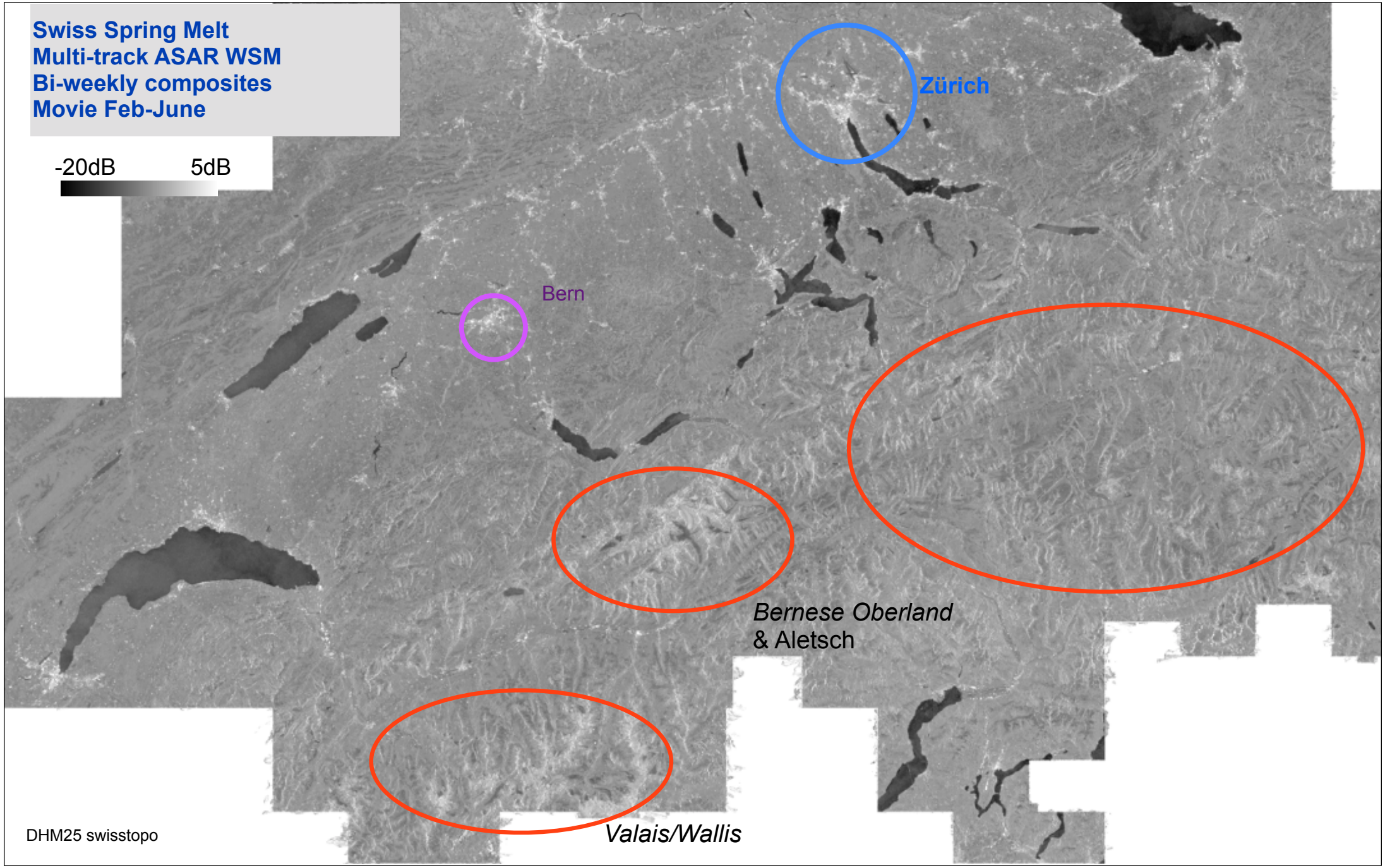
Selections from ASAR WS RTC, 2012 Spring



-20dB 5dB

Future: **Composite** products with relatively homogenous properties on fore and back-slopes (requires asc./desc. & slight temporal blurring)

DHM25 swisstopo


Swiss Spring Melt
Multi-track ASAR WSM
Bi-weekly composites
Movie Feb-June
-20dB
5dB
Zürich
Bern
Bernese Oberland
& Aletsch
Valais/Wallis
DHM25 swisstopo

Snow mapping with spaceborne SAR sensors

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Relevant operating and future upcoming SAR missions

Sensor	Band	Mission Duration	Space Agency	Left-looking capability	# Satellites	Comments
Radarsat-2	C	2007-ongoing	CSA	Yes	1	Commercial mission: may affect sensor availability.
TSX/TDX	X	2007-ongoing	DLR	Yes	2	Commercial mission: may affect sensor availability.
CSK	X	2007-ongoing	ASI	No	4	Commercial mission: may affect sensor availability.
RISAT-1	C	2012-ongoing	ISRO	Information not available	1	Access to science data unclear.
RISAT-2	X	2009-ongoing	ISRO	Information not available	1	Access to science data unclear.
HJ-1C	S	2012-ongoing	NDRCC / SEPA	Information not available	1	Access to science data unclear.
KOMPSAT-5	X	2013-ongoing	KARI	Information not available	1	Access to science data unclear.
Sentinel-1	C	Launches 2014, 2015	ESA	No	2	Government mission – **science access possible**.
RCM (Radarsat Constellation Mission)	C	Launches 2018+	CSA	No	3	Government mission – science access possible.
ALOS2	L	Launch 2014	JAXA	Yes	1	Commercial mission: may affect sensor availability.
PAZ	X	Launch 2014	INTA	Yes	1 (constellation with TSX/TDX)	Access to science data unclear.
SAOCOM	L	Launches 2014+	CONAE	Information not available	2	Access to science data unclear.

Revisit Interval

- Orbital track **exact repeat** interval
  - time interval between acquisitions with same geometry
  - relevant for SAR interferometry, conventional wet vs. winter dry snow detection

- **Accessibility swath**
  - relevant for revisit to a ***point*** target

- **Swath width**
  - relevant for revisit to an ***area*** being monitored
  - large swath width necessary for monitoring applications covering large regions

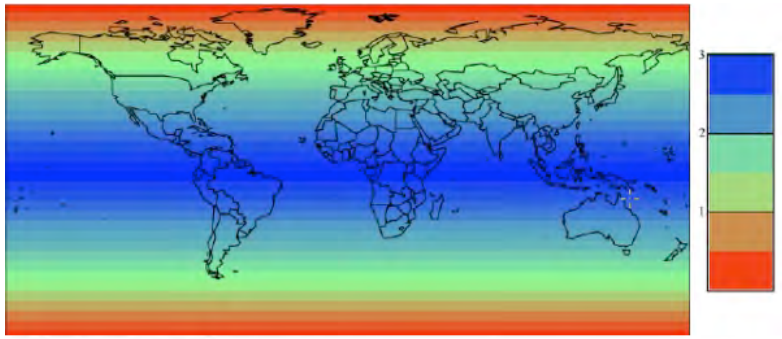
Satellite SAR instruments, modes, and swaths

	Satellite Instrument	Exact Repeat Interval	Mode	Inc. Angle [°]	Swath Width [km]	Available Polarisations
C	ENVISAT ASAR	35d	IM: Image Mode AP: Alternating Polarisation WS: Wide Swath	15 – 45 15 – 45 17 – 44	56-100 56-100 400	Single: HH or VV Dual: HH/HV or VV/VH or HH/VV Single: HH or VV
	Sentinel-1: S1A & S1B	12d	SM: Strip-Map **IW**: Interferometric Wideswath EW: Extra Wideswath	18.3 – 46.7 29.2 – 46 18.2 – 47	up to 100 **250** 400	For all modes: Single-pol.: HH or VV or Dual-pol.: HH/HV or VV/VH
	Radarsat-2	24d	Wide or Wide-Fine SCNA: ScanSAR Narrow A **SCNB**: ScanSAR Narrow B SCWA: ScanSAR Wide A SCWB: ScanSAR Wide B	20 – 45 20 – 39 31 – 47 20 – 49 20 – 46	120-170 300 **300** 500 450	For all these modes: Single-pol.: HH or VV or HV or VH, or Dual-pol.: HH/HV or VV/VH
X	TerraSAR-X: TSX, TDX & PAZ	11d	ScanSAR (SC) Wide ScanSAR (**SC Wide**)	20 – 45 15.6 - 49	100 200	Single: HH or VV Single: HH or VV or (HV or VH) N.B. Cross-pol experimental
	Cosmo-Skymed: CSK1- CSK4	16d	ScanSAR Wide Region ScanSAR **Huge Region**	~20 - ~60 ~20 - ~60	100 200	For all modes: HH or VV or HV or VH

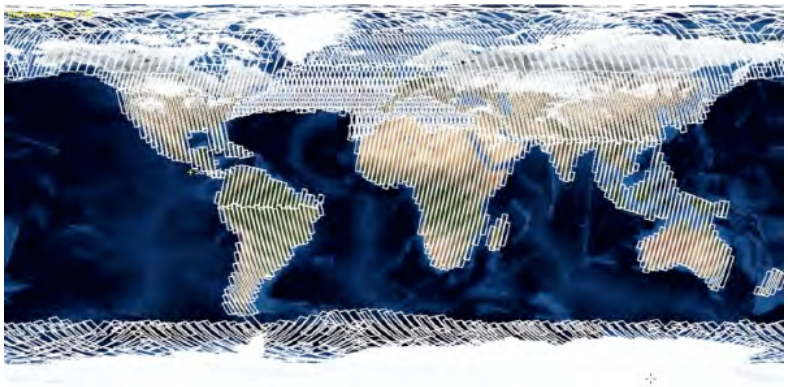
Revisit Interval

- **Latitude**
  - higher latitudes potentially accessible more often
- **Instrument duty cycle**
  - power availability, heat build-up, data rate
- **Topography**
  - shadow, layover, variation in local resolution (contributing area)
  - ascending / descending combinations critical in mountainous regions
  - composite products: slight temporal blurring for improved noise and spatial resolution characteristics
- **Operator priority**
  - decision when to turn SAR on
  - e.g. Sentinel-1A initial operations with land acquisitions over Europe, north Atlantic, Canada

Sentinel-1 Revisit



- ✓ Two satellites in a 12 day orbit
- ✓ Repeat frequency: 6 days (important for coherence)
- ✓ Revisit frequency: (asc/desc & overlap): 3 days at the equator, <1 day at high latitudes (Europe ~ 2 days)



Potential S1A IW revisit after 12 days
- N.B. priority to ocean applications

Potentially revisit in Europe:
~3.5 days with S1A, <2 days with S1A+S1B

...cooperation envisaged between the Sentinel-1 mission and the Radarsat Constellation Mission (RCM) of the Canadian Space Agency. The Sentinel-1 observation scenario is planned at a certain stage to be *coordinated with the RCM one*, for the benefit of respective users, establishing some complementarities in the observations and selected modes of operations, allowing ***increased revisit***, etc.

Potin, P., et al. *Sentinel-1 Mission Operations Concept*. Proc. *IGARSS* 2012, pp. 1745–1748.

Polarisation

- **Scope for harmonisation across missions**
  - possible to harmonise S1A & RS2 as far as possible on VV/VH dual-pol. acquisitions over land for snow applications?
  - this would enable simple combinations between Sentinel-1 and Radarsat-2 datasets

Ramp-up snow mapping capability progressively

- **S1A: half-*weekly***
- **S1A+S1B: *every 2 days***
- Integration of complementary data from RS2 & RCM would further improve temporal resolution
- Research into supplementary retrievals from 200km ScanSAR TSX & Cosmo-Skymed

- Robust promise (incl. combinations from asc./desc.):

1w → 0.5w → 1d

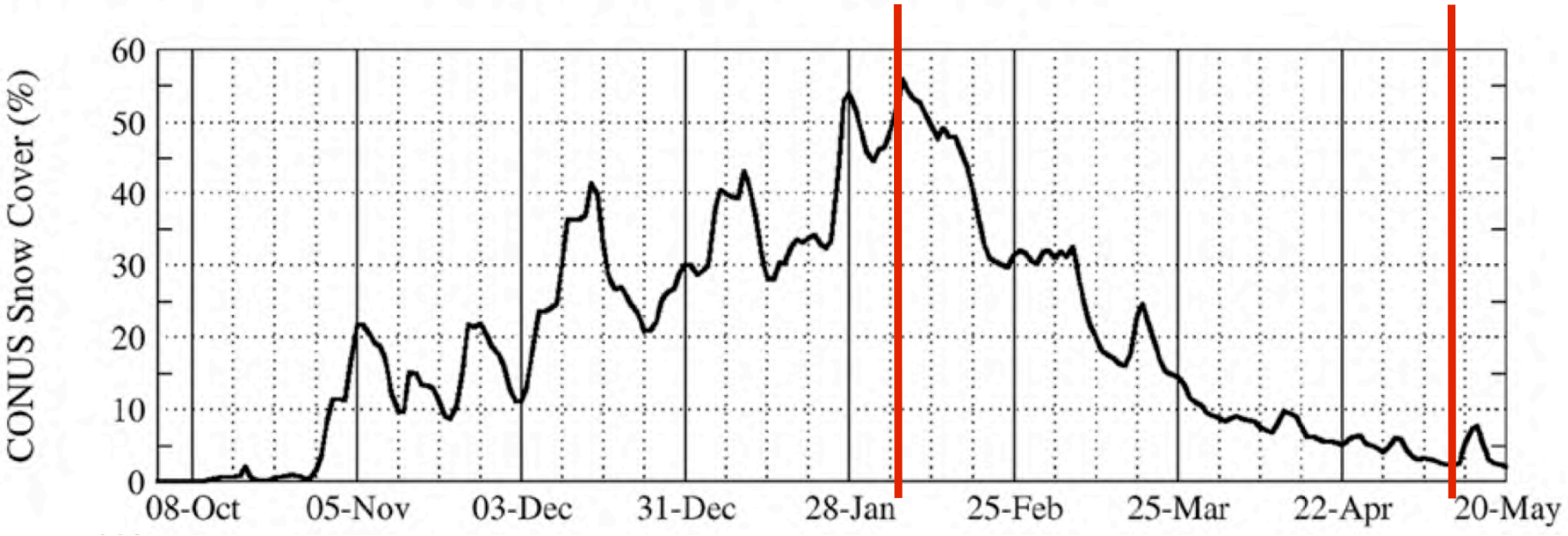
By working together across missions and agencies, we would be able to achieve the goal of ***daily*** coverage set in the IGOS 2007 Cryosphere Theme Report

Seasonal Observation Windows

Evolution of Snow Cover in the US

[IGOS Cryosphere Theme Report, 2007]

Fig. 3.1. Percentage of snow-covered area within the conterminous U.S. during the 2003-2004 season with corresponding unique snow depths and SWE.



Swiss Seasonal Hydrology: 1971-2012 Daily SWE plotted by elevation

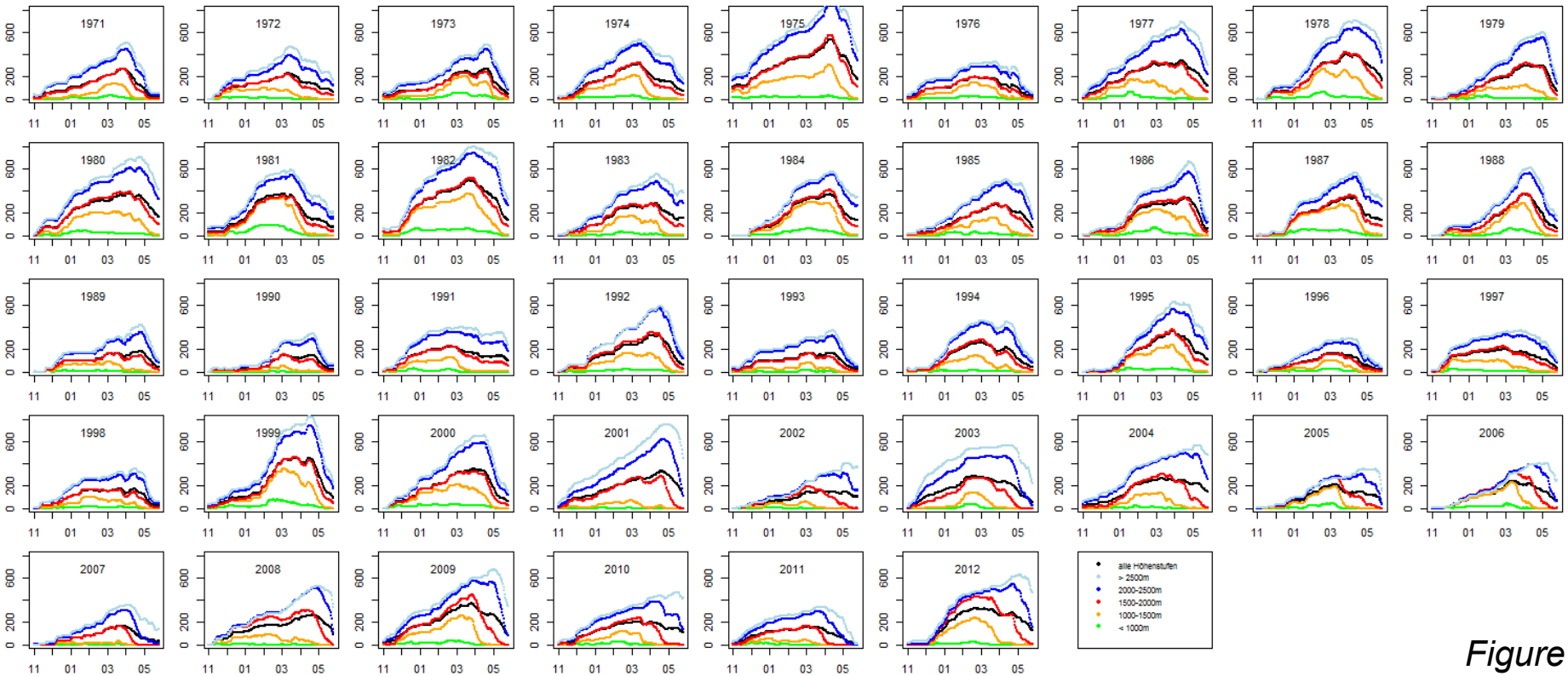


Figure courtesy Tobias Jonas, WSL-SLF

Melting generally captured at significant elevations between Feb. 15 and May 15

Seasonal Observation Windows

- **Optimise available system capacity**
  - snow melting often regularly takes place within *relatively narrow time window* every year
  - devote maximum sensor resources to acquisitions within these highly dynamic periods
  - reduced observation frequency possible outside of peak season - base level = ?

Region	Window Start Date	Window End Date	References	Historical Time Series
European Alps	Feb. 15	May 15		ASAR WS
Canadian Rockies	April 1	July 15		
Finland	April 1	June 30		ASAR WS
Norway	April 1	July 31		ASAR WS RS2 SCNA
Continental US	Feb. 1	May 15	IGOS Cryosphere Report, 2007	
Arctic Canada, ...	June 1	July 15		

Further contributions requested!

Draft White Paper

Feedback on PSTG SARCWG Draft White Paper

- MDA (Canada)
  - further modes with swaths greater than 100km: wide modes (3 **wide** (25m @4looks) or **wide-fine** (8m @1look) beams with swath widths 120,150,170km; 20-45° accessibility; also avail. in dual-pol.)
- ZEMKON (Canada)
  - Elaboration on value of products of harmonised acquisitions, not just for science but for wider user community
  - More on state-of-the-art in retrieving desired information and likely quality / adequacy of results
- EURAC (I)
  - synergy with optical sensors
- CONAE (Argentina)
  - additional information on L-band satellites SAOCOM, launches 2014+

Open Questions

- Comments on general science requirements

- Identify where science acquisitions may be required to meet our science requirements
  - include *locations*, *seasonality*, and *frequency of repeat* here

- Identify how existing archives could help science evaluation
  - Timeline important: Commercial users want (and pay for) NRT. Could such data be re-used after a waiting period?
  - Could a data sharing model be worked out for commercial missions?

- Optimising SAR parameters (wavelength, polarisation, temporal vs. spatial resolution)
- Develop *mission-specific* **recommendations** - e.g. S1 & RSAT2 large area coverage, higher resolutions for small test sites using TSX/TDX/PAZ/CSK

Way forward

- For those interested who have not yet seen the draft white paper (v0.5)
  - Request from colleague known to have a copy, or request via email to david.small@geo.uzh.ch

- Send further feedback on draft white paper document by **Feb. 28th**
  - Email to: david.small@geo.uzh.ch
- Integration & further iteration planned

- Presentation of status at IGARSS in Québec - July, 2014
- Presentation of consolidated white paper at PSTG meeting in late summer 2014

Acknowledgments

- Thanks to:
  - MDA & CSA for Radarsat-2 data
  - ESA for ASAR data
  - Bernd Scheuchl (UC Irvine, California) and Tobias Jonas (SLF) for contributions