EARSeL 8th Workshop
REMOTE SENSING OF LAND ICE AND SNOW
Bern, 07 - 09 February 2017

An alternative concept for remote sensing of snow mass

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Motivation

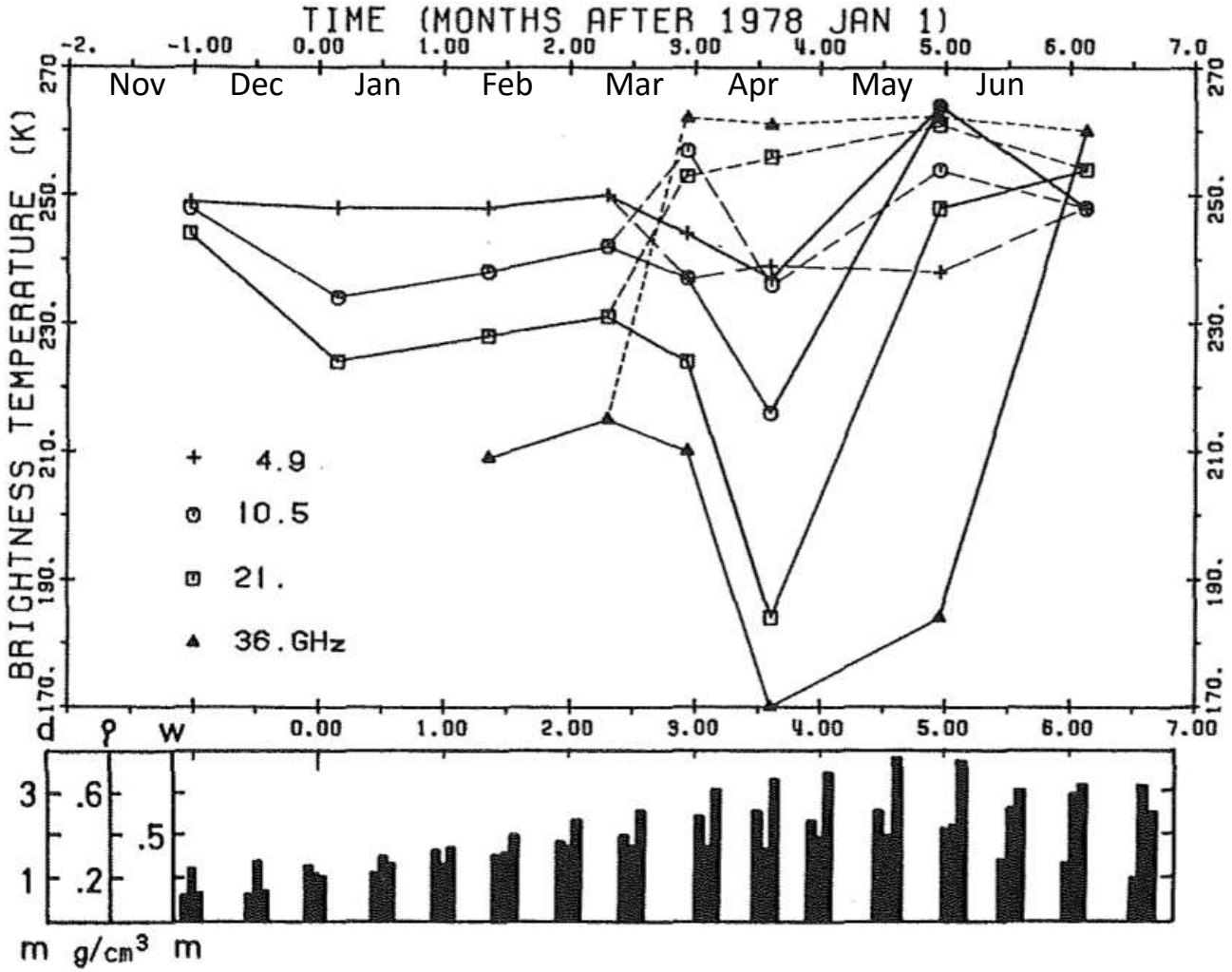
1 So far the penetration capability of microwaves into dry snow has been motivation for extracting snow-mass information by remote sensing. Limiting factor: high variability of scattering for different snow types due to variability of grain size

Signature studies with the Passive & Active Microwave & IR Radiometer (PAMIR), here at Weissfluhjoch alt. 2550 m (1977 – 1986)



Seasonal development, 1977 – 1978 (Hofer & Mätzler, 1980)

20° off nadir
mean (V & H)



Motivation

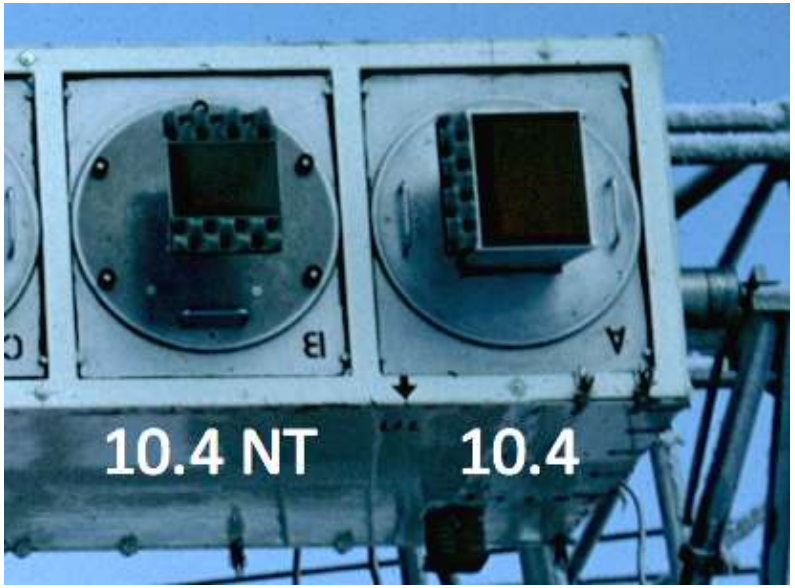
1. So far the penetration capability of microwaves into dry snow has been motivation for extracting snow-mass information by remote sensing. Limiting factor: high variability of scattering for different snow types due to variability of grain size
2. Alternative signatures without this disadvantage apply for backscattering from snowpacks containing wet snow γ_{ws}: Backscattering is much smaller than from snow-free ground γ_{g}

$$\gamma_{\mathrm{ws}} << \gamma_{\mathrm{g}} \Rightarrow \gamma \cong (1 - f_{\mathrm{s}})\gamma_{\mathrm{g}}$$

Radar signatures

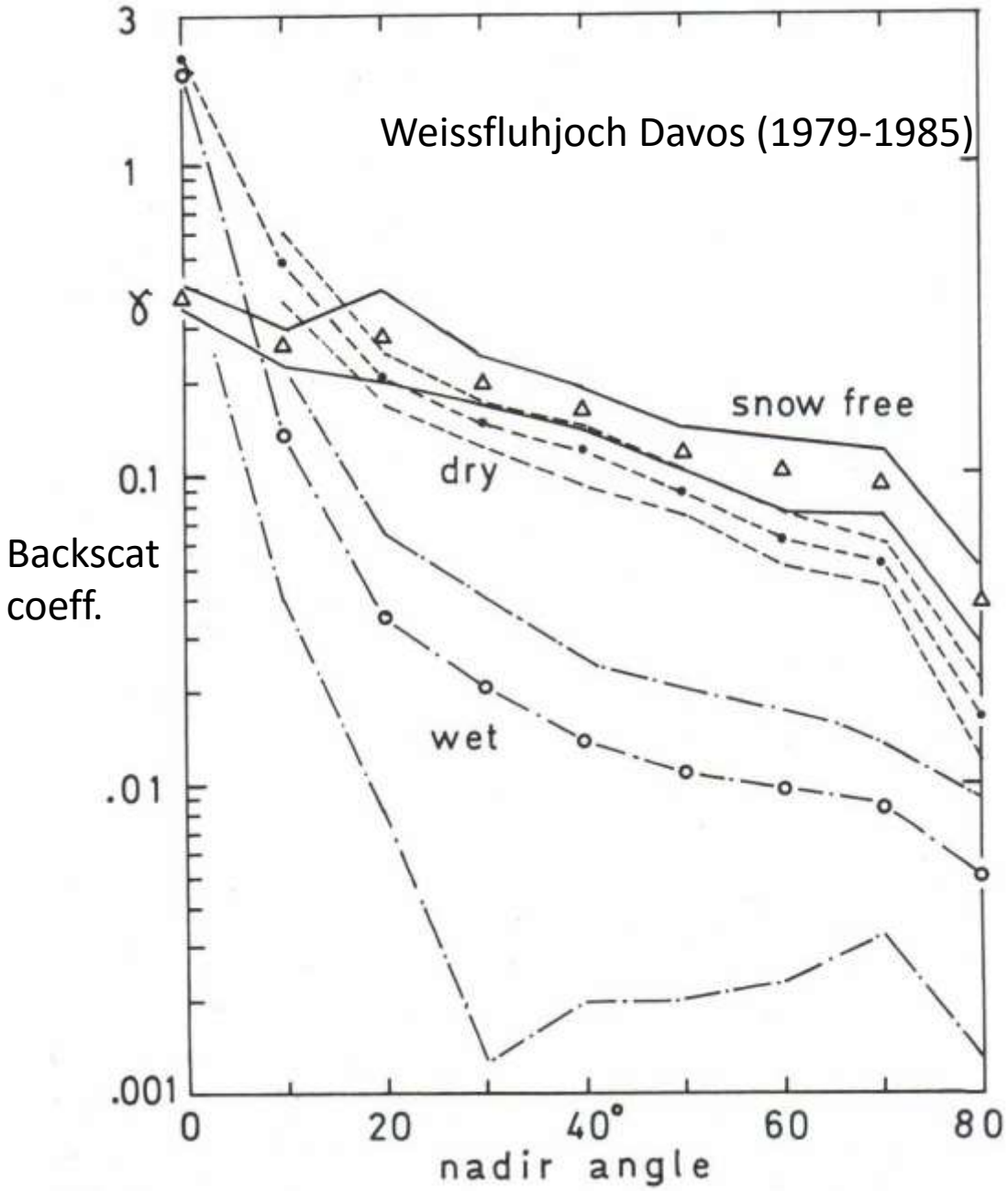
PAMIR Noise Scatterometer
Freq = 10.4 GHz

Weissfluhjoch 1979 – 1985



Like pol (hh & vv averaged)
Mean ± Std vs nadir angle
10.4 GHz

(Mätzler, 1987)

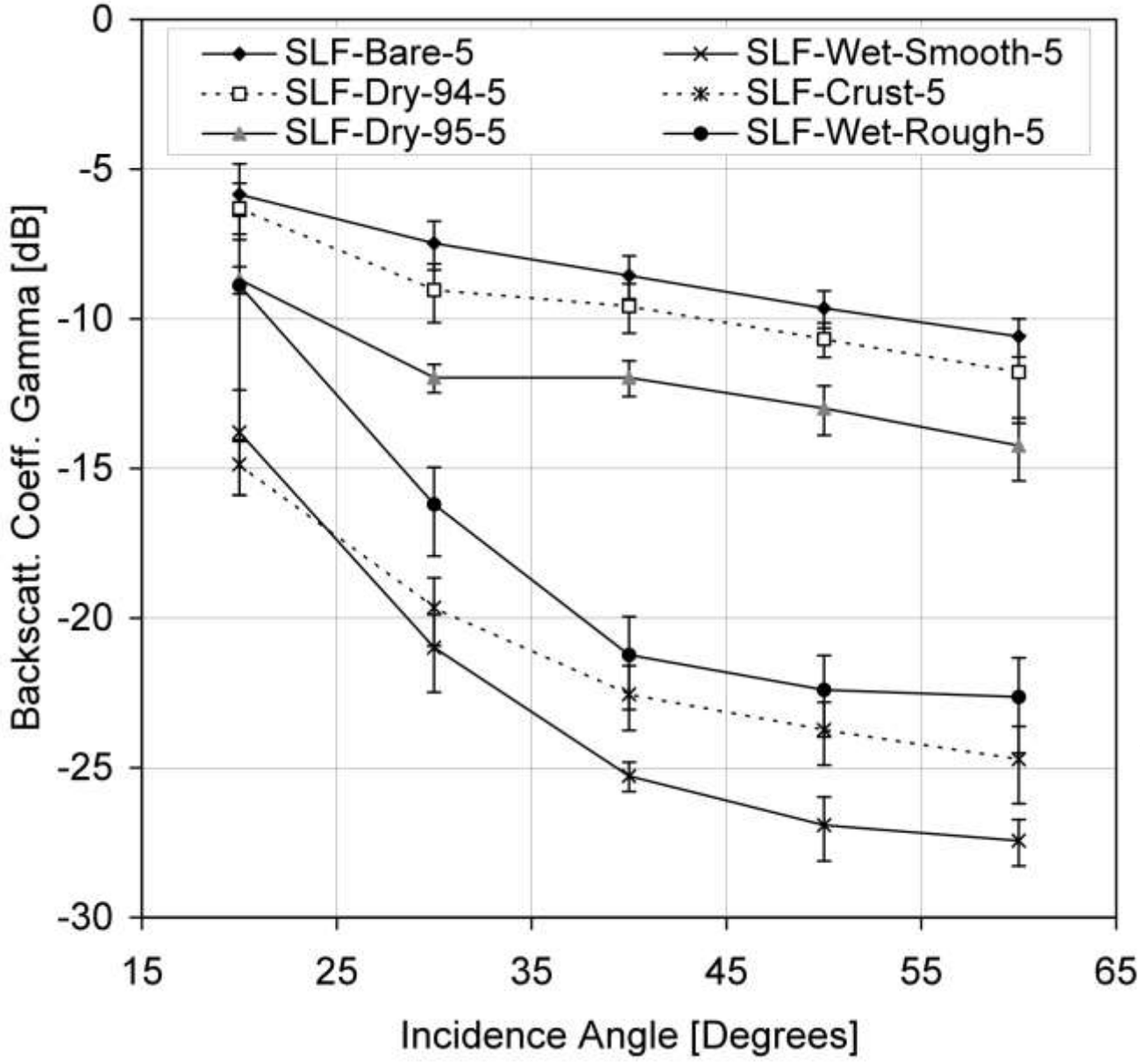




NA Scatterometer 5.3 GHz
1993 - 1996

Backscatter
at 5.3 GHz
vv pol

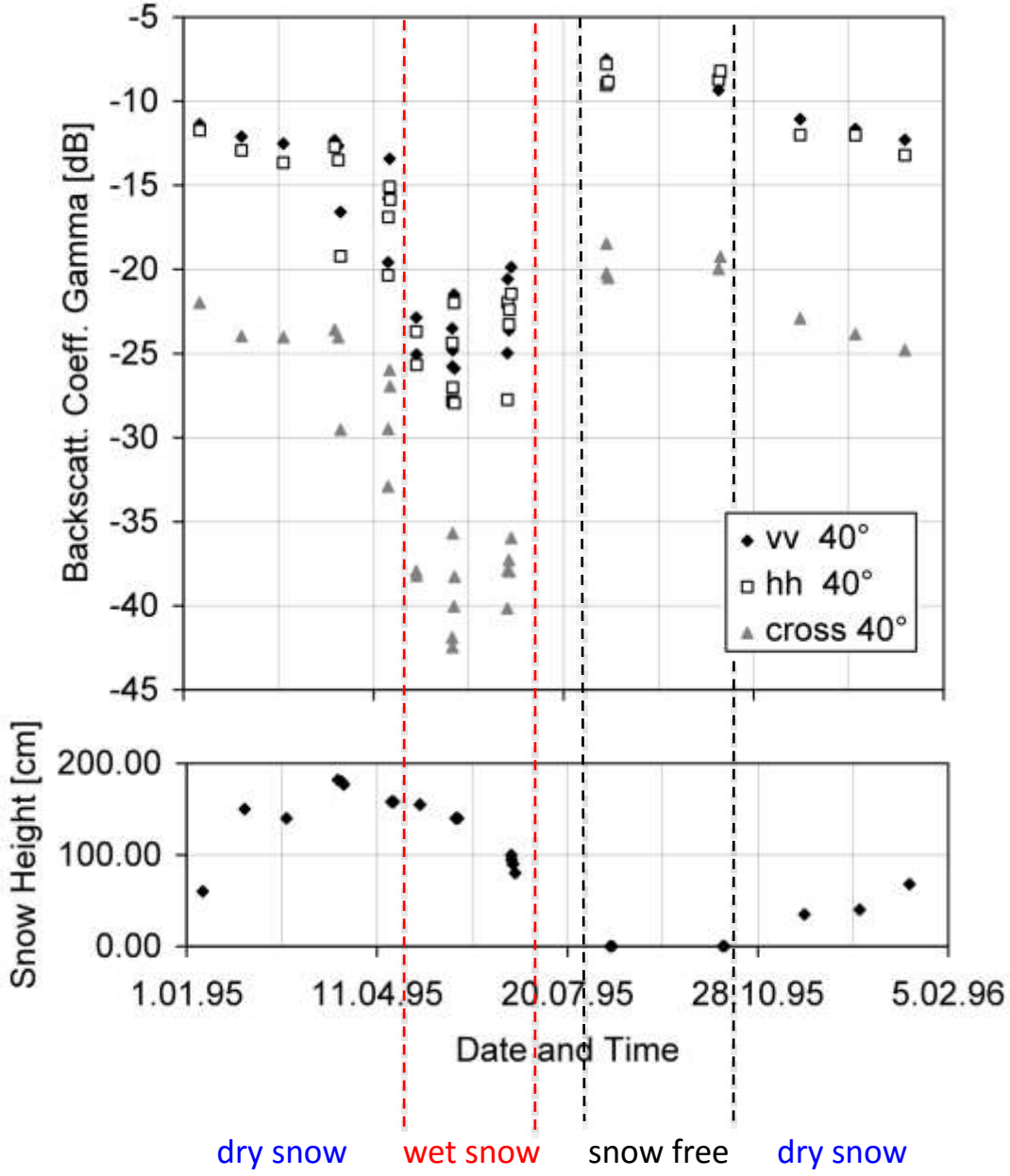
Strozzi & 1998

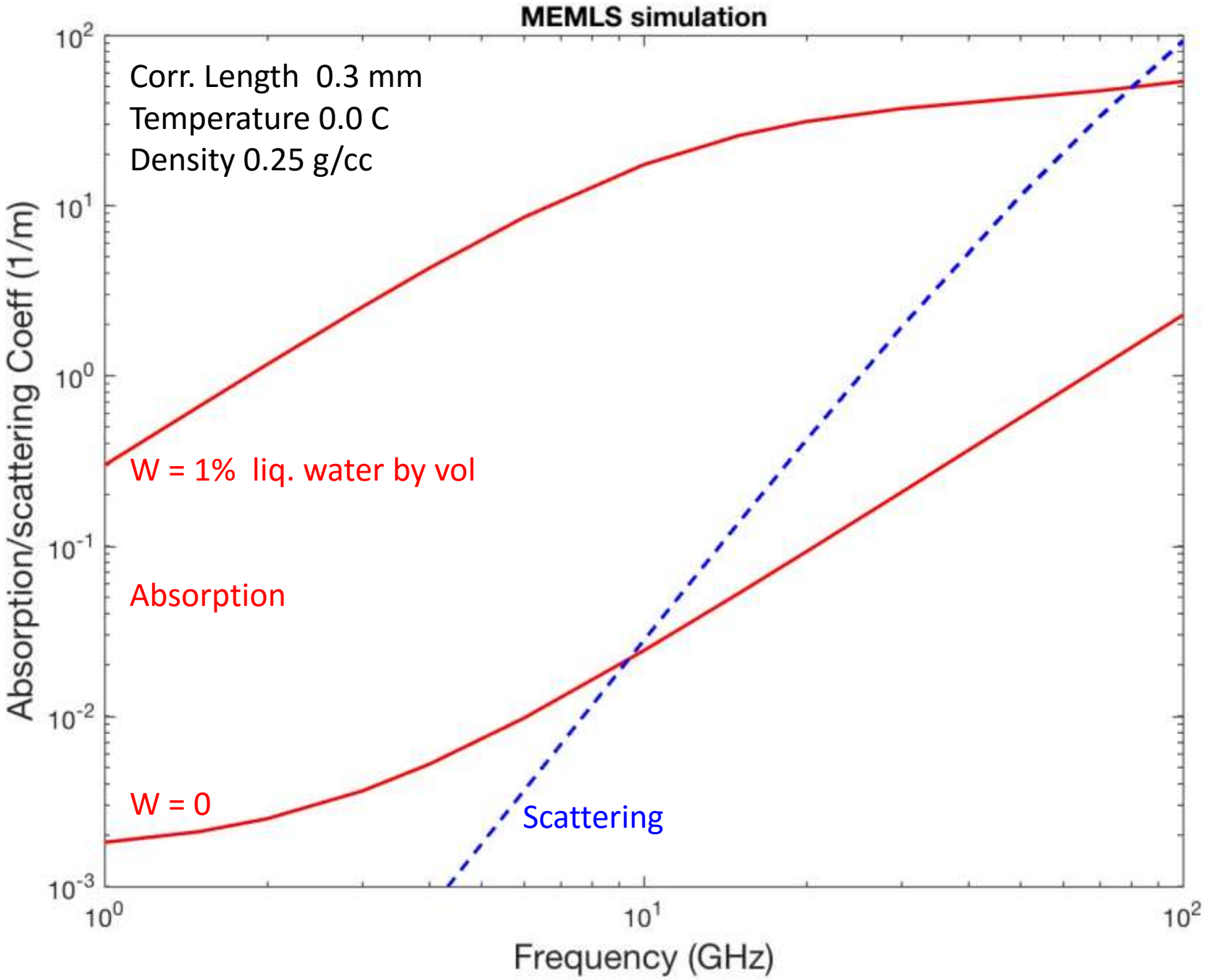


snow free
dry
snow

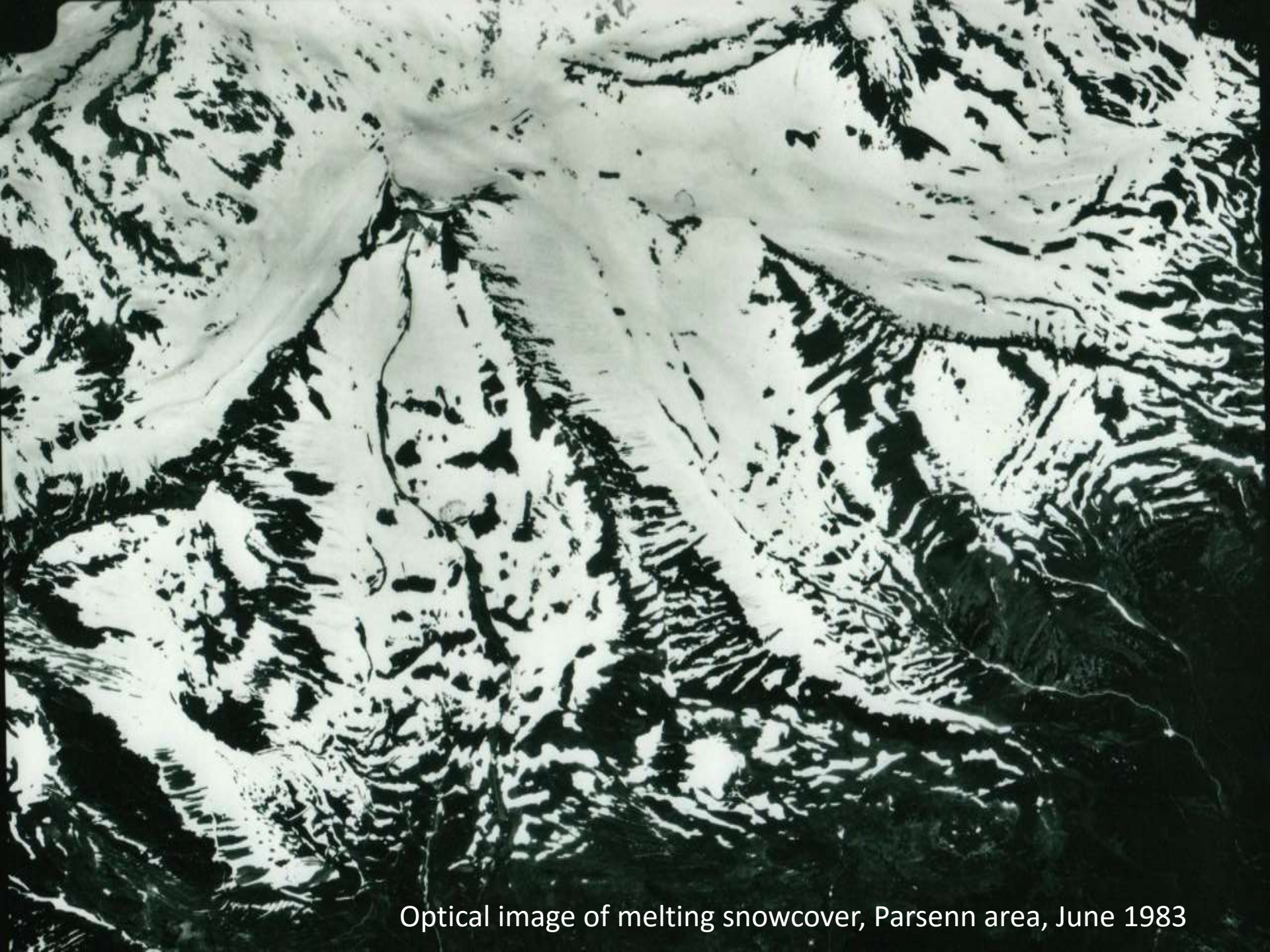
wet
snow

Temporal variation 1995 - 1996

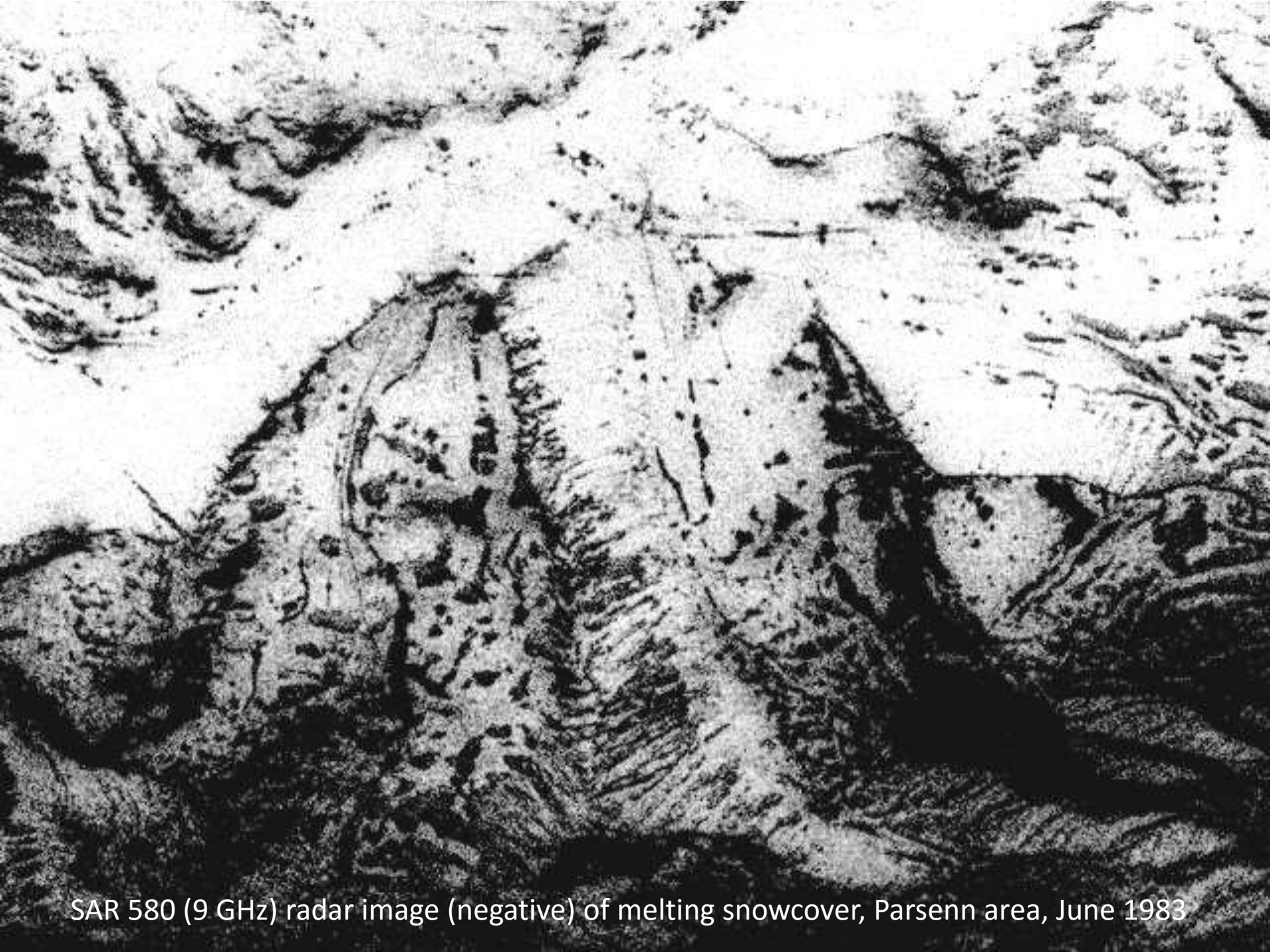



MEMLS simulation
Corr. Length 0.3 mm
Temperature 0.0 C
Density 0.25 g/cc
W = 1% liq. water by vol
Absorption
W = 0
Scattering
Absorption/scattering Coeff (1/m)
Frequency (GHz)
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^0
10^1
10^2

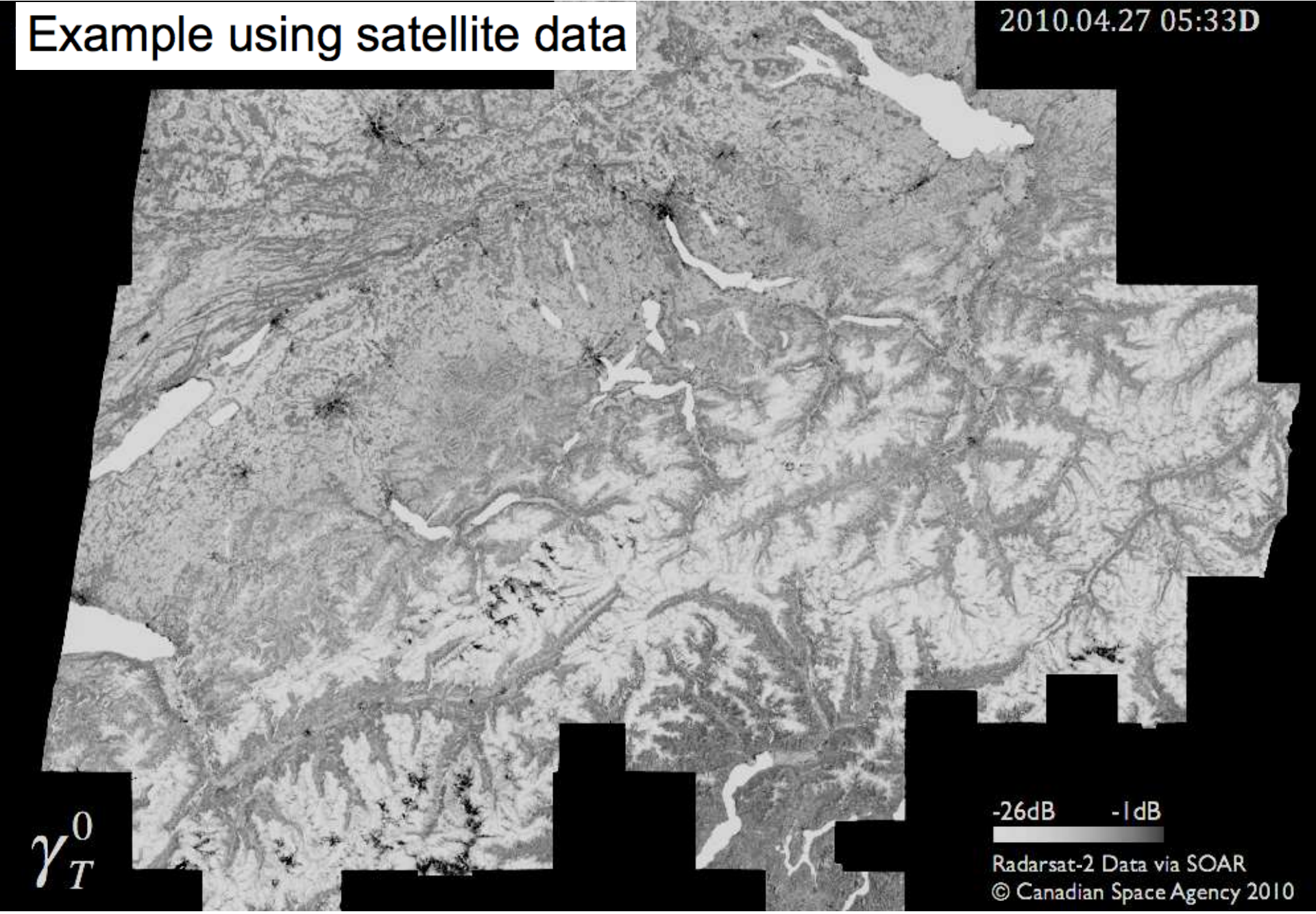
Airborne SAR-580 Campaign Davos, June 1983



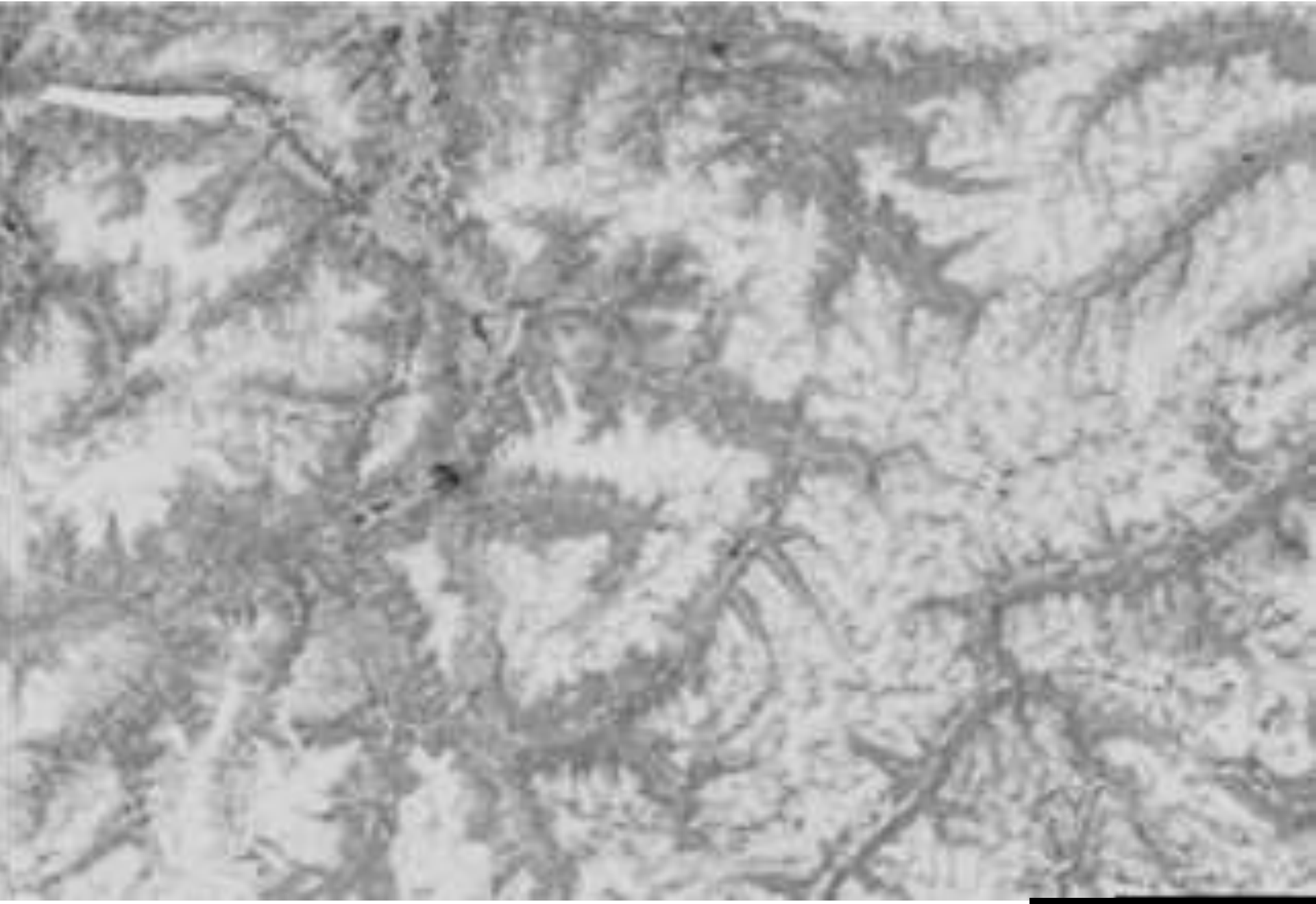
Optical image of melting snowcover, Parsenn area, June 1983



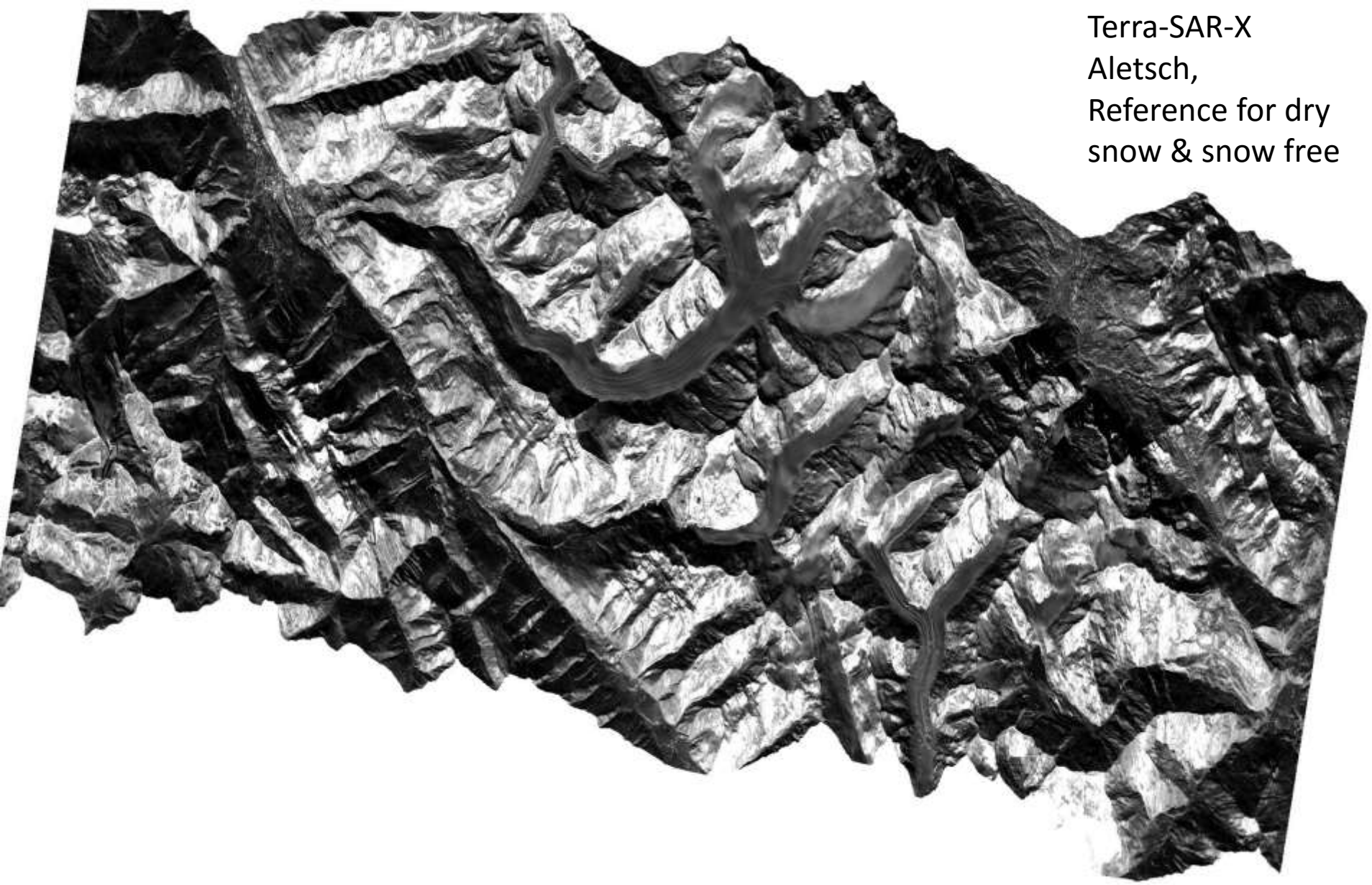
SAR 580 (9 GHz) radar image (negative) of melting snowcover, Parsenn area, June 1983



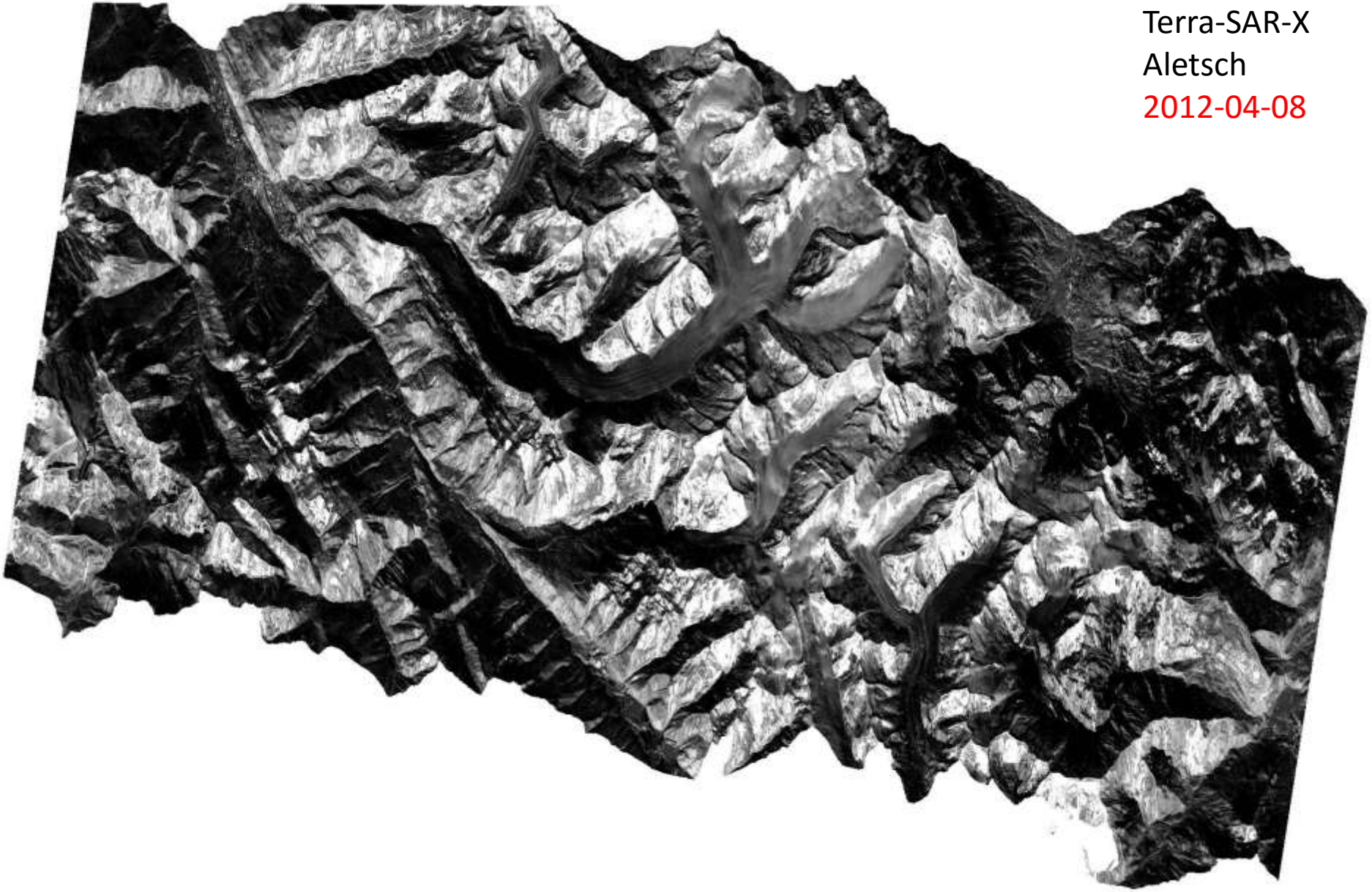
Cross-pol backscat coeff at 5 GHz (terrain adapted) during snowmelt in the Alps, negative of Small (2011)



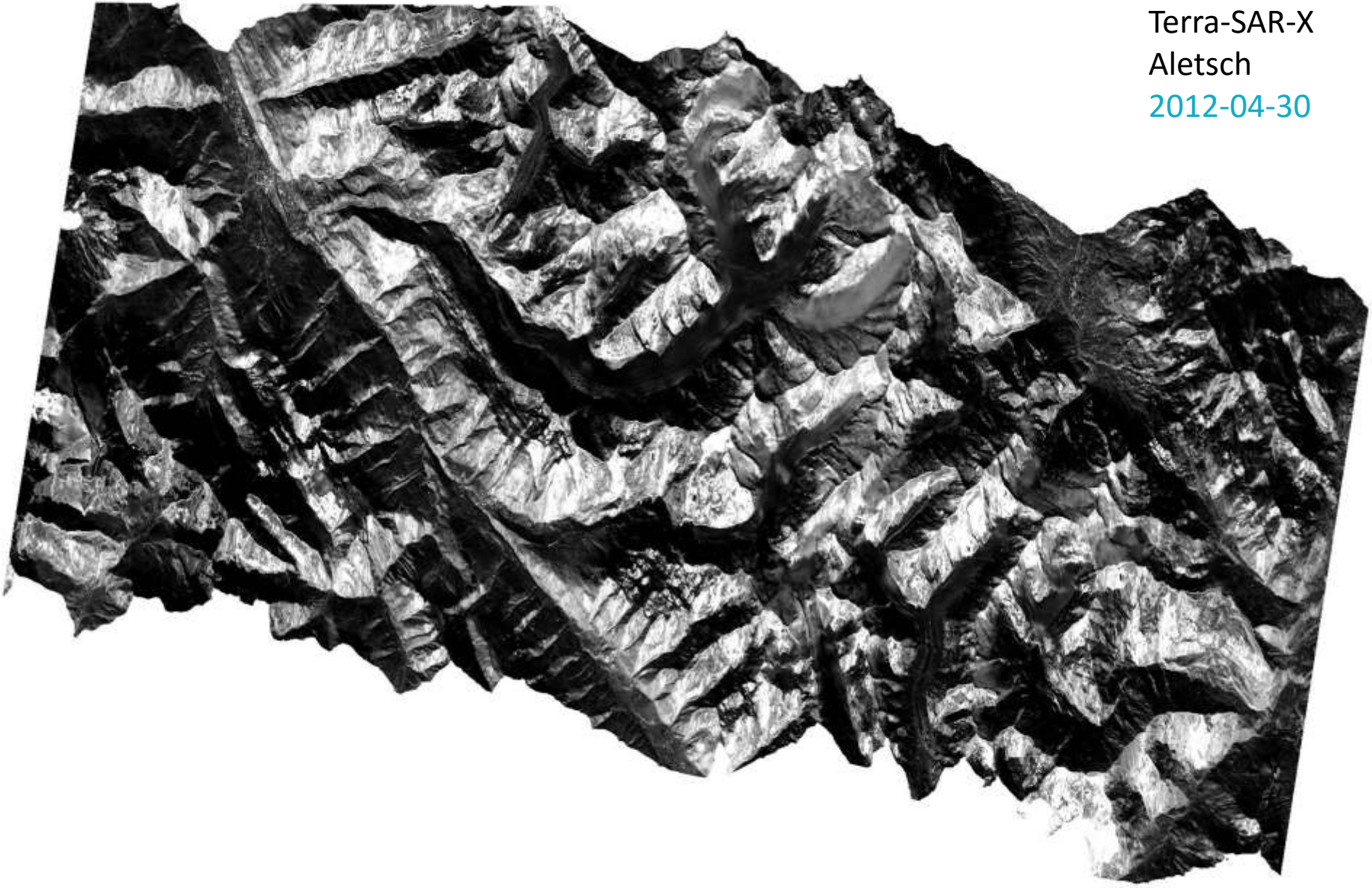
Zoomed section: “Davos + ”



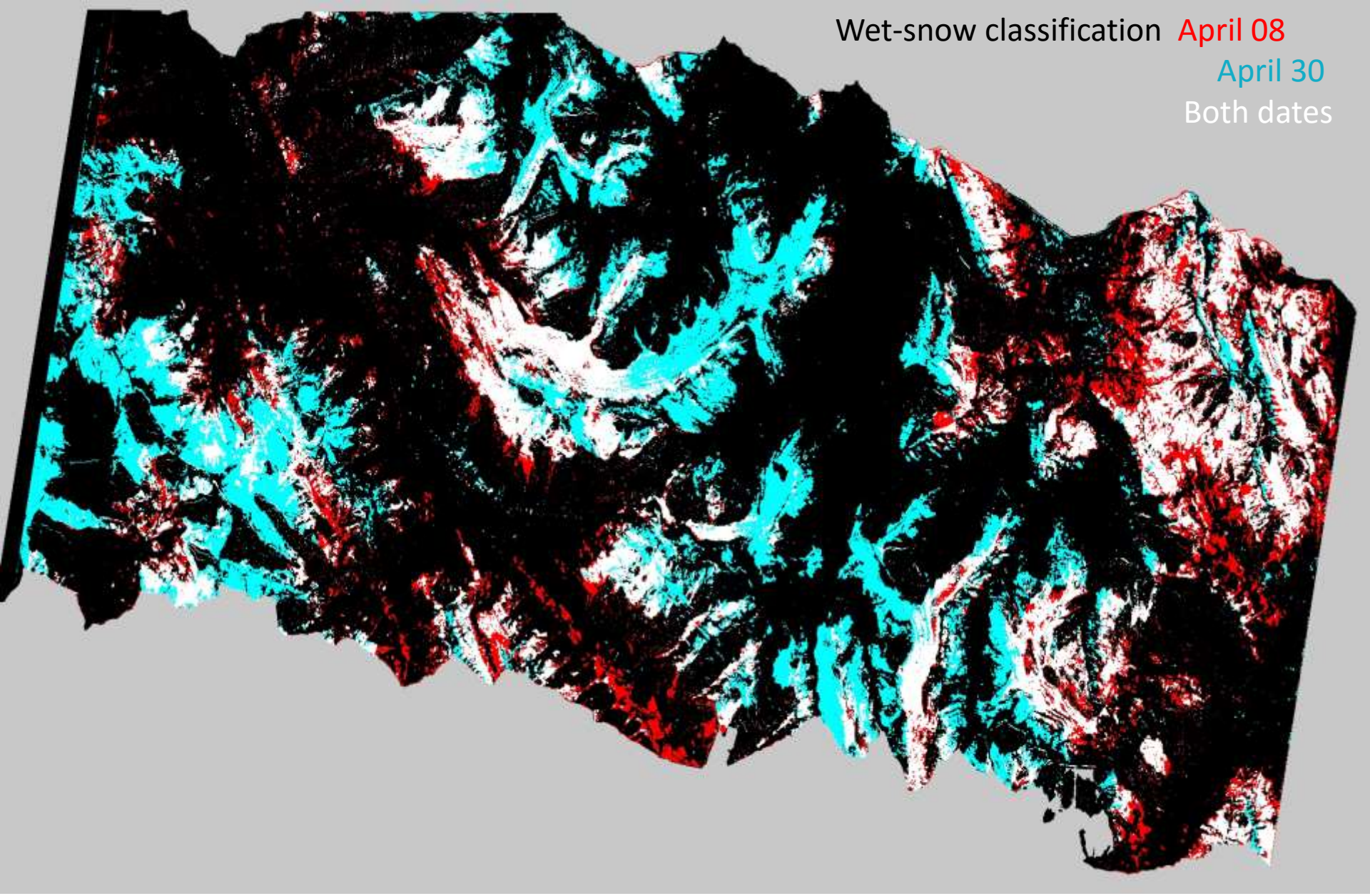
Terra-SAR-X
Aletsch,
Reference for dry
snow & snow free



Terra-SAR-X
Aletsch
2012-04-08



Terra-SAR-X
Aletsch
2012-04-30



Terra-SAR-X data analysis, Gamma Remote Sensing

Motivation

1 So far the penetration capability of microwaves into dry snow has been motivation for extracting snow-mass information by remote sensing. Limiting factor: high variability of scattering for different snow types due to variability of grain size

2 Alternative signatures without this disadvantage apply for backscattering from snowpacks containing wet snow γ_{ws}: Backscattering is much smaller than from snow-free ground γ_g

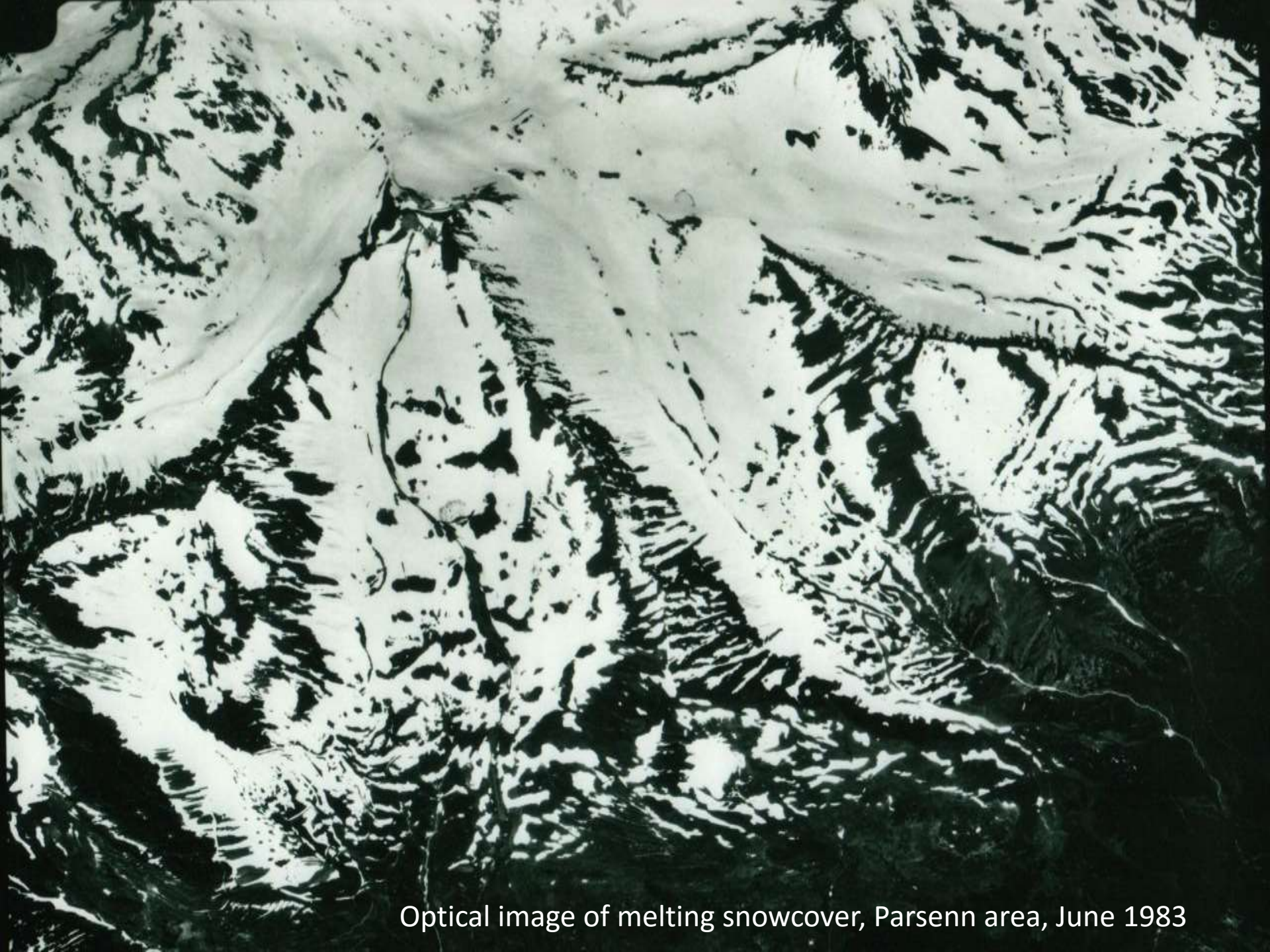
$$\gamma_{ws} << \gamma_g \Rightarrow \gamma \cong (1 - f_s)\gamma_g$$

3 There is an indication that snow-cover fraction f_s and snow volume or SWE are correlated (Molotch & Schneider, 2016*). If we can use this relation and if we know γ_g we may obtain estimates of SWE from radar measurements even if we are unable to resolve the snow patches in detail

* See

73rd Eastern Snow Conference

Development of Universal Relationships between Snow Depth, Snow Covered Area and Terrain Roughness from NASA Airborne Snow Observatory data



Optical image of melting snowcover, Parsenn area, June 1983

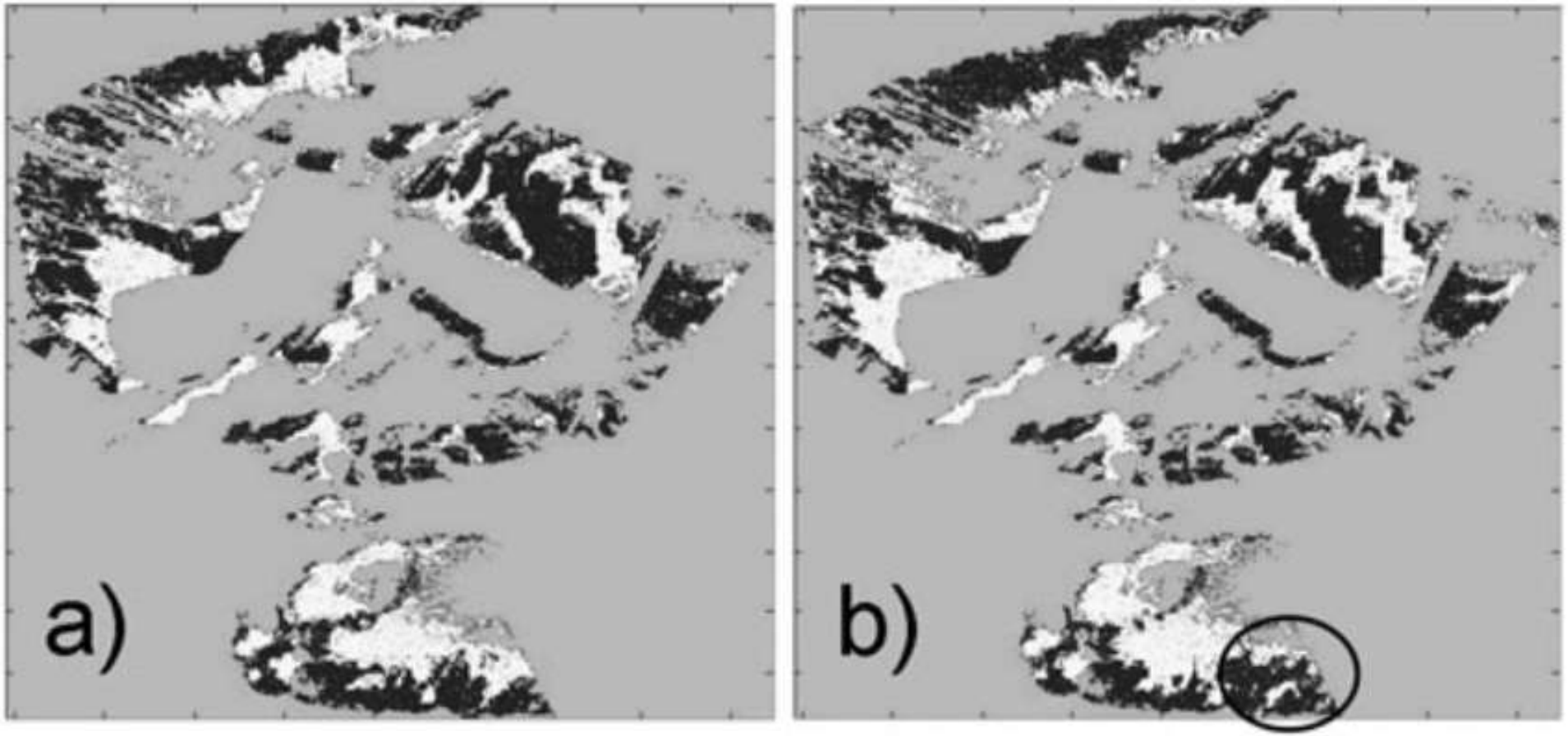

East Greenland, June 2008



West Greenland, June 2014



West Greenland, June 2014



2 June 2008

20 May 2009

Snow-free (black) snow-covered (white) areas of alpine region near Davos, from Egli & 2012

Thoughts on work to be done

1 Determine f_s and SWE for different landscapes & topographies using remote sensing methods (mainly laser scanners), during accumulation and ablation. Explore these relationships.

2 Include effects of trees and other vegetation

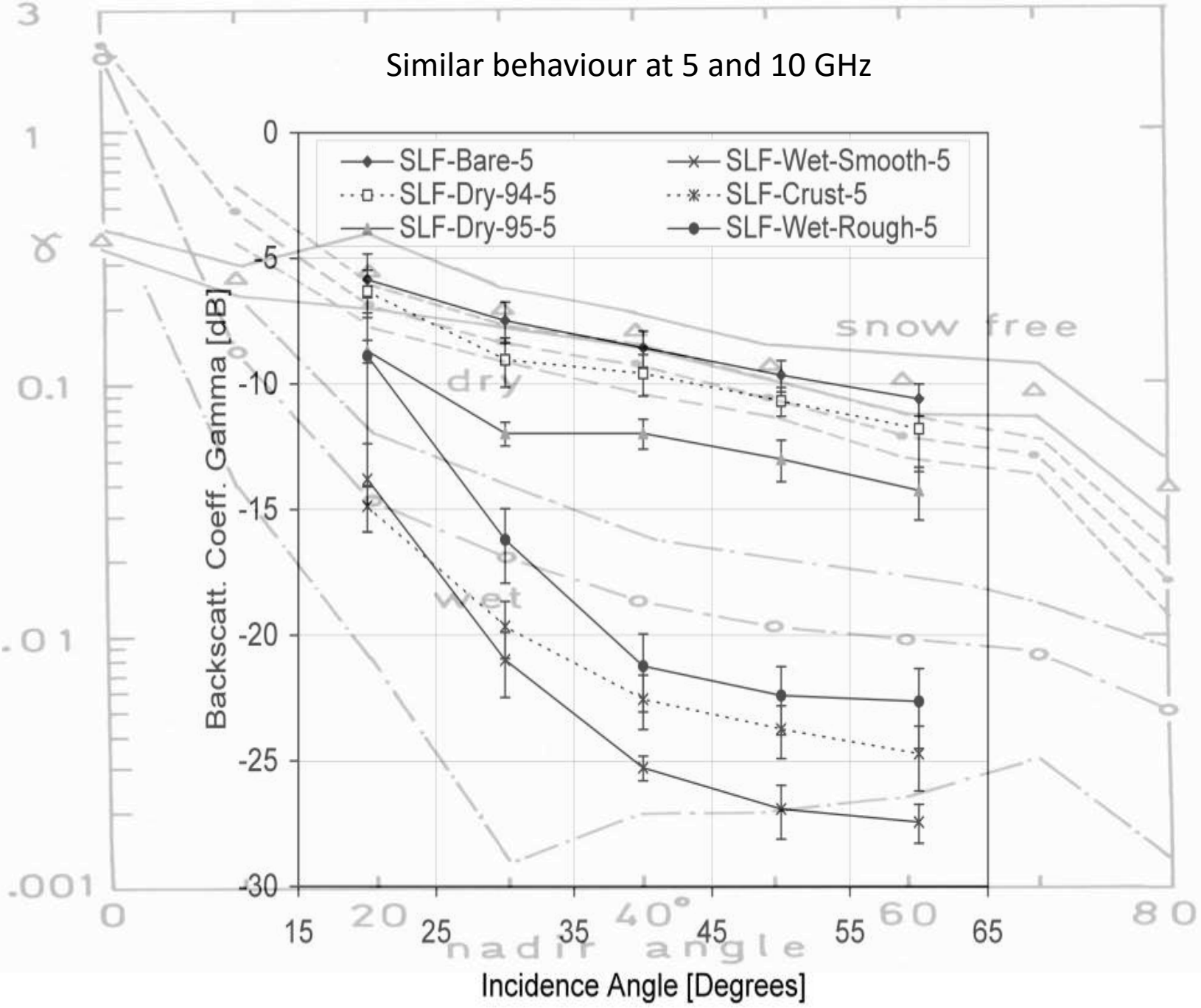
3 Check persistence & variability of snow-free & snow-covered areas using empirical and modelling efforts (Egli et al. 2012 and references)

4 Determine backscatter properties of snow-free & snow-covered areas. Look for ranges of frequency, incidence angle and polarisation with most robust behaviour

5 Generate (snow-free) reference radar datasets for areas of interest

6 ..... Design optimum snow-mass mission

Similar behaviour at 5 and 10 GHz



For discussion: additional figure from Strozzi @ 5.3 GHz

