The MicroVegSnow Project

at Davos-Laret Remote Sensing Test-Site as Part of the "Swiss Alp-SnowLab for Climate-Research and Remote Observations" (SASCRO)


Mike Schwank[1,2]


Urs Wegmüller[1]


Andreas Wiesmann[1]


Reza Naderpour[2]


Christian Mätzler[1]


Martin Schneebeli[2]


Konrad Steffen[2]


Francois Jonard[3]


Lutz Weihermüller[3]


Harry Vereecken[3]

1: GAMMA REMOTE SENSING 2: WSL 3: JÜLICH FORSCHUNGSZENTRUM

1) MicroVegSnow Overview
2) Main Objectives Research Questions and Hypothesis
3) Theory L-band emission model for snow-covered grounds; inversion
4) Experimental Approach
5) Setup of the Experiment *(time-line since August 2016; modifications)*
6) Work under Progress and Future Plans
   treatment of disturbance; radiance of "gridded" area; first retrievals; next steps
7) Summary / Conclusions

Content of this Presentation

Overview of the Lead-Agency Project:

Active/Passive Microwave Remote Sensing in Application to "Vegetation & Soil" and "Snow & Soil"

MicroVegSnow

Snow & Soil

Vegetation & Soil



Mike Schw

Projec
Lead o
"Snow & Soil"
RT modeling

Reza Nadeepour

Exposite Davos
PhD student at WSL-Birmensdorf
started at May 1st 2016

Director of WSL



Franc Jono

Projec
Lead o
"Vegetation & Soil" RT modeling

Thomas Meyer

Soil/Veg. char.
Exp. site Jülich
Inversion
PhD student at FZJ (Jülich)
started at April 4th 2016

Ph.D. adviser
Director of FZJ Agrosphere Institute

1) MicroVegSnow Overview

MicroVegSnow's "overall"

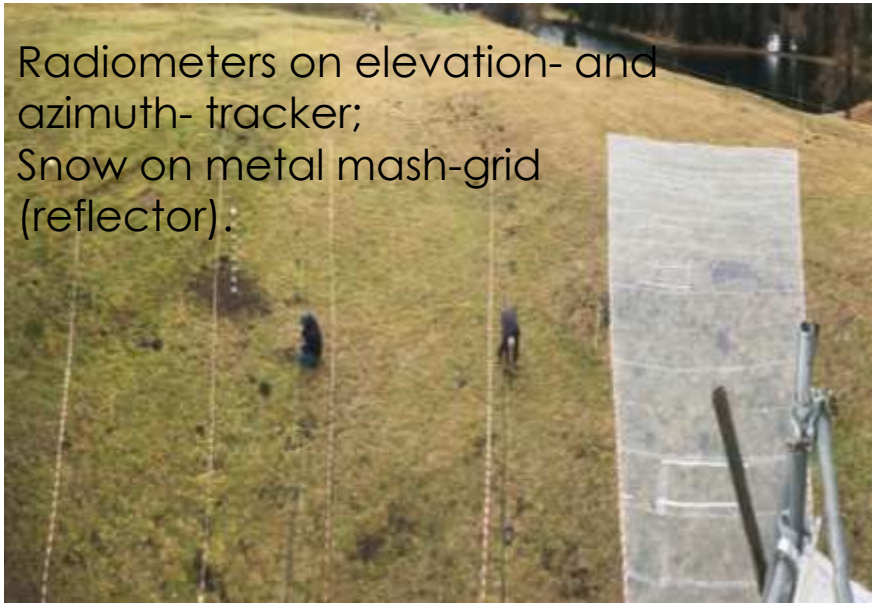
Vegetation & **S**oil ↔ **Research Center Jülich (FZJ)**
+ **S**now & **S**oil ↔ **Swiss Federal Institute WSL (SLF)**

- Similar modelling- and experimental concepts; similar microwave- and in-situ sensors.

Vegetation & Soil part:



Snow & Soil part:

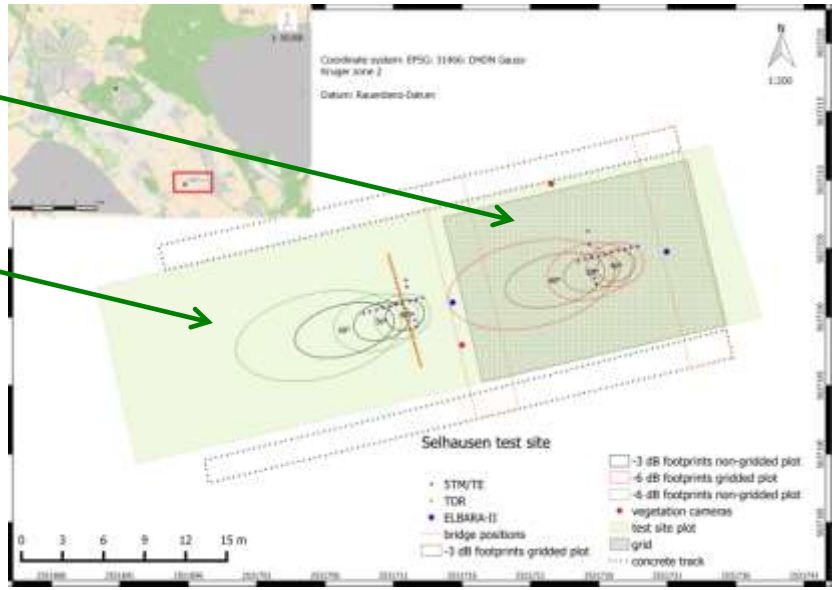


MicroVegSnow's "Vegetation-Part"

- Weekly measurements over "gridded" and "natural" area.
- L-band observation @ θ = 40°, 50°, 60°; extensive in-situ obs.
- Wide-band scatterometer (nadir)

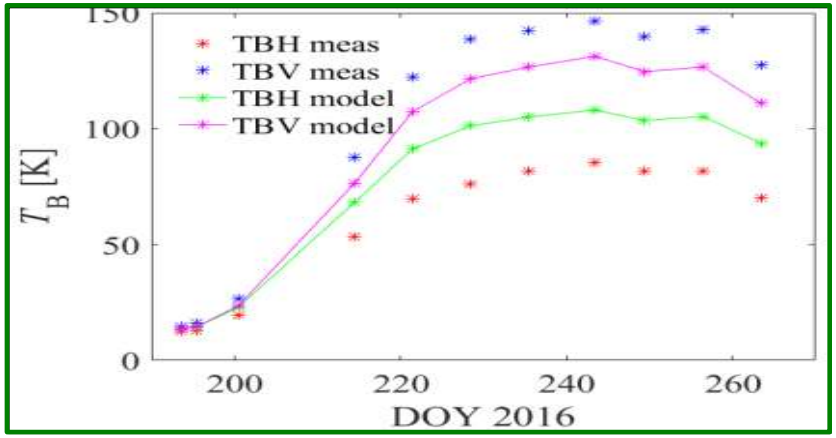






Objectives:

- Microwave emission of grounds covered with developing vegetation (mustard).
- Retrieval scheme to estimate parameters of vegetation (τ, ω, *VWC*) and ground (*SM, roughness*).
- Assessment of retrieval quality.
- Potential of synergistic use of passive and active microwave data.



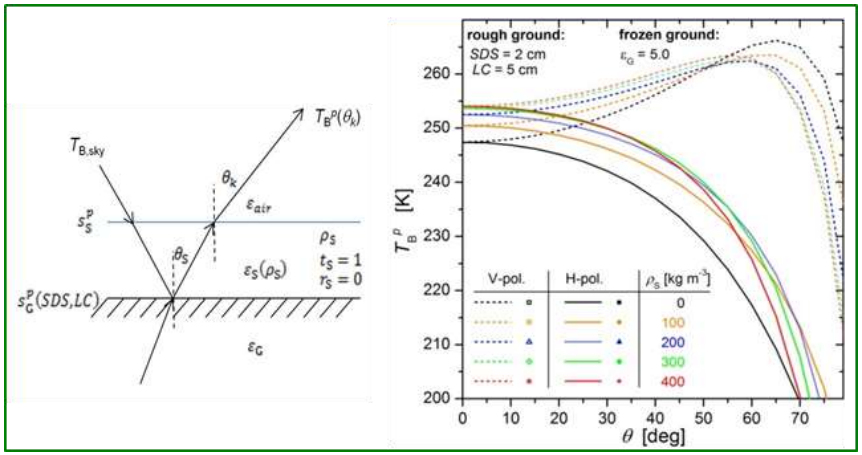
Temporal evolution of T_B^p (θ = 40°) measured over the "gridded" area for advancing vegetation development.

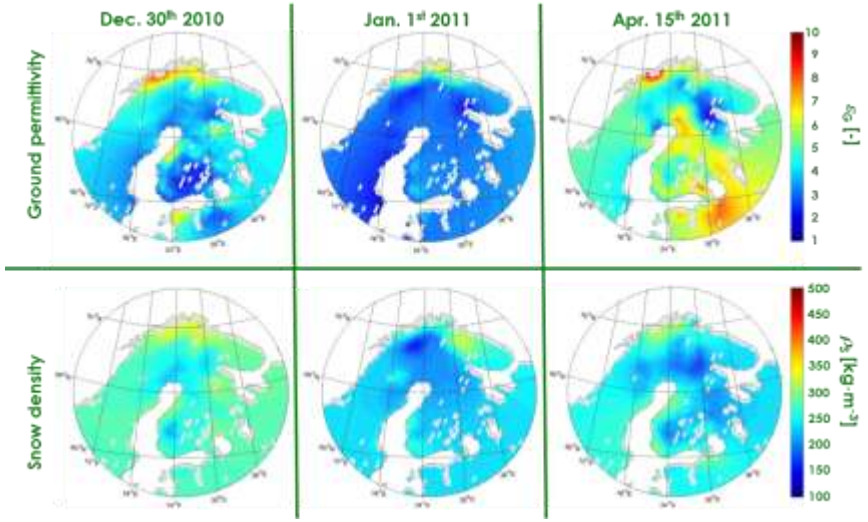
2) Main Objectives

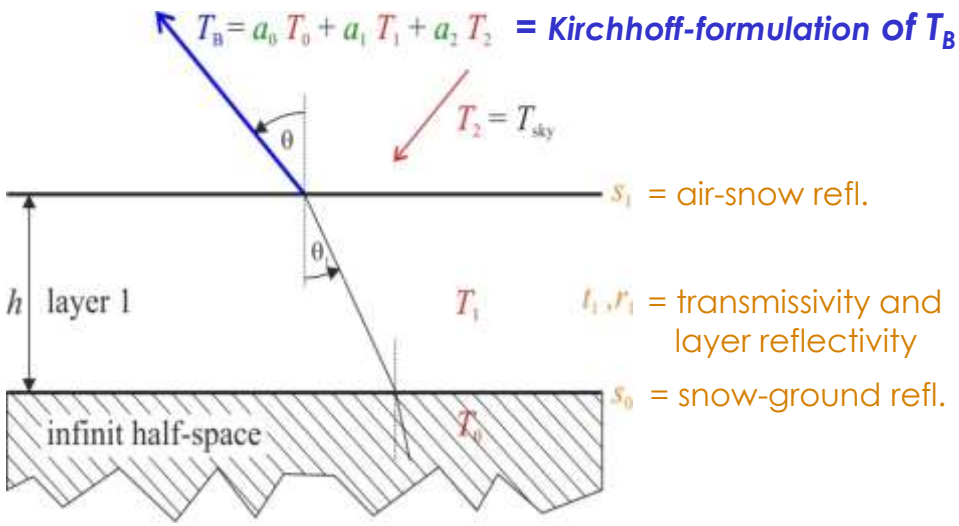
MicroVegSnow's "Snow-Part"

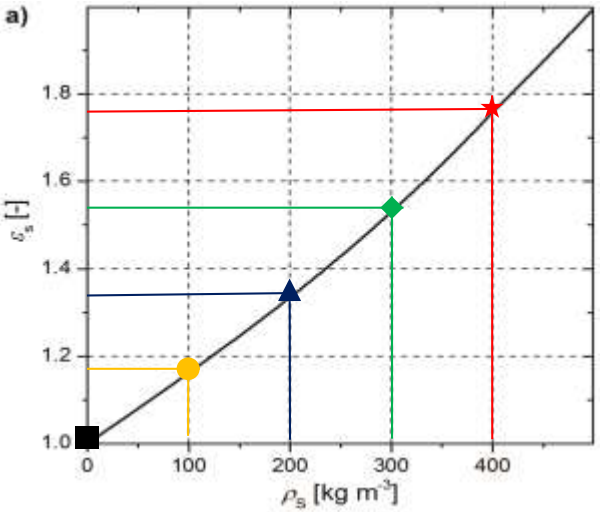


- Microwave emission of snow-covered grounds.
- Bottom-layer snow-density & ground permittivity (ρ_S, ε_G) from L-band $T_B^{p,\theta}$.
- Assessment of (ρ_S, ε_G)-retrievals.
- Application of the (ρ_S, ε_G)-retrieval scheme to SMOS and SMAP.
- (ρ_S, ε_G)-retrieval is a novel SMOS product
  $\Rightarrow$ improved estimates of SWE and soil freeze/thaw.
- Potential of synergistic use of passive and active microwaves.









Snow permittivity model (same as used in MEMLS).

Dry uniform snow layer:

⇒ *transparent* ($t_1 = 1$)

⇒ *no vol. scatt.* ($r_1 = 0$)

$$a_0 = \frac{(1-s_0)(1-s_1)}{1-s_0 s_1}$$

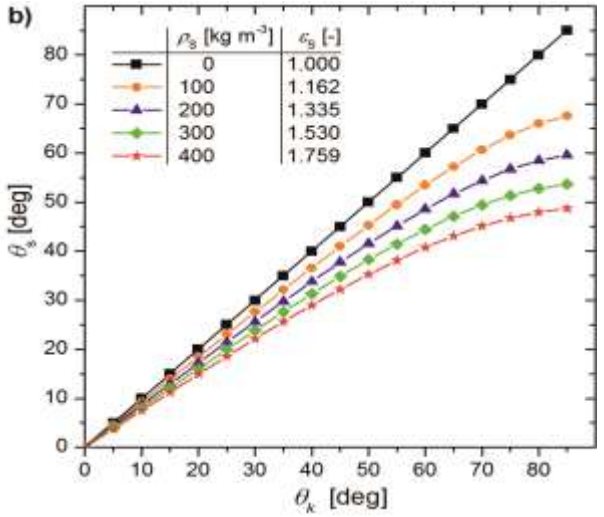
$$a_1 = 0$$

$$a_2 = 1 - a_0$$

⇒ **Although dry-snow is transparent and not scattering at L-band it affects T_B^p**

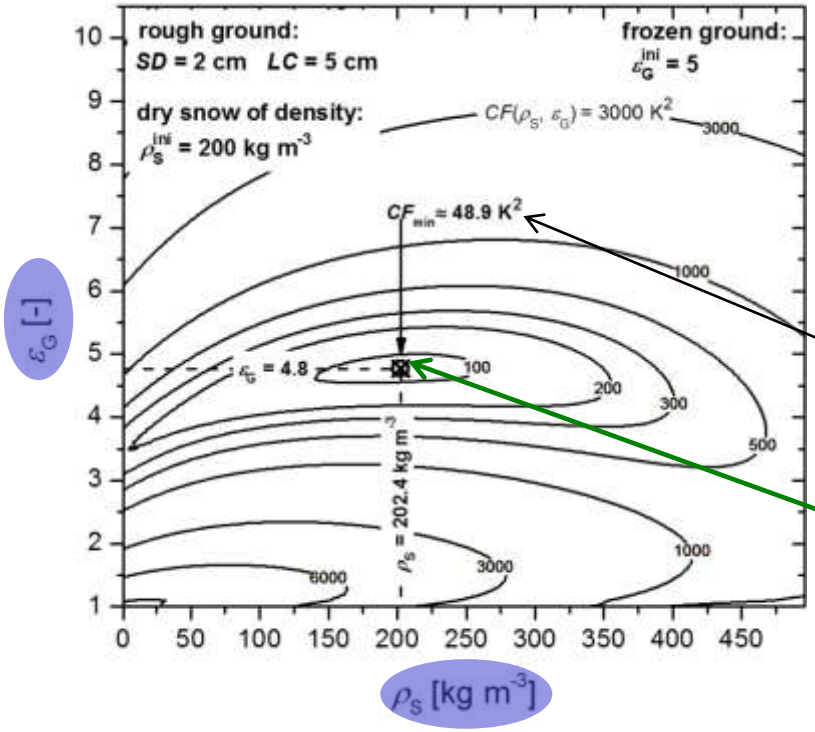
! Dry-snow is clearly 'visible' at L-Band !

⇒ **Potential to retrieve snow density from passive L-band observations**



Incidence θ_S at ground versus observation angle θ_k (Snell's law).

Retrievals (ρ_S, ε_G) based on synthetic $T_B^{\theta,p}$ with error ΔT_B^p = 2K



Cost-Function

$$CF(\rho_S, \varepsilon_G) \equiv \sum_{\theta;\, p} \left(T_{B,m}^p(\theta) - T_B^p(\theta) \right)^2 \Big/ \Delta T_B^p(\theta)^2$$

computed for "synthetic measurements" $T_{B,m}^p(\theta_k)$ synthesized for the scenario:

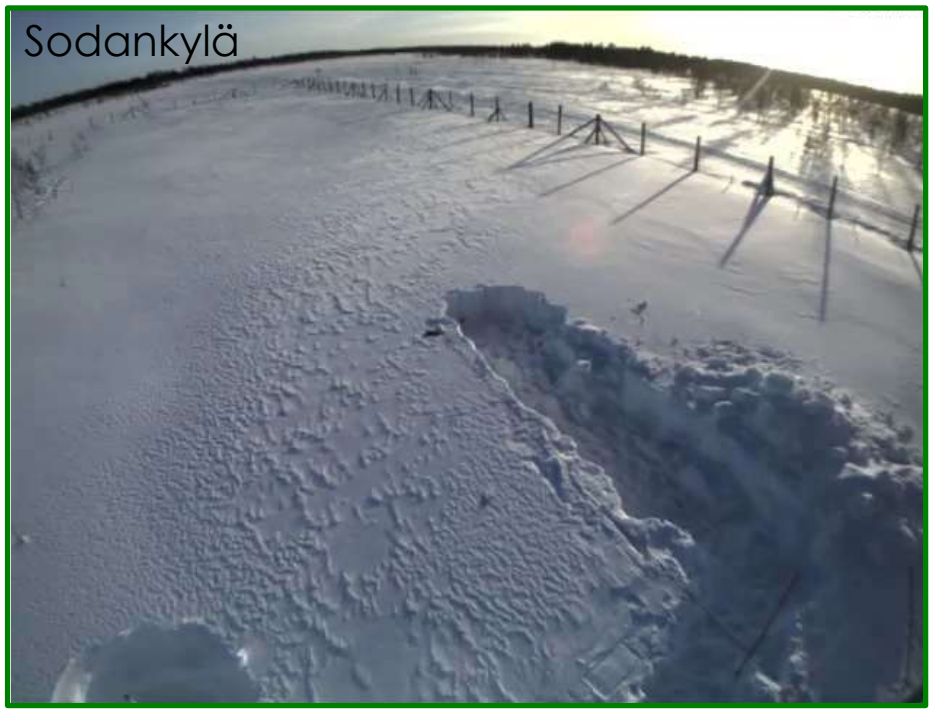
$(\rho_S^{ini}, \varepsilon_G^{ini})$ = (200 kg m^{-3}, 5)
(*SDS*, *LC*) = (2 cm, 5 cm)
T_G = 268.15 K.

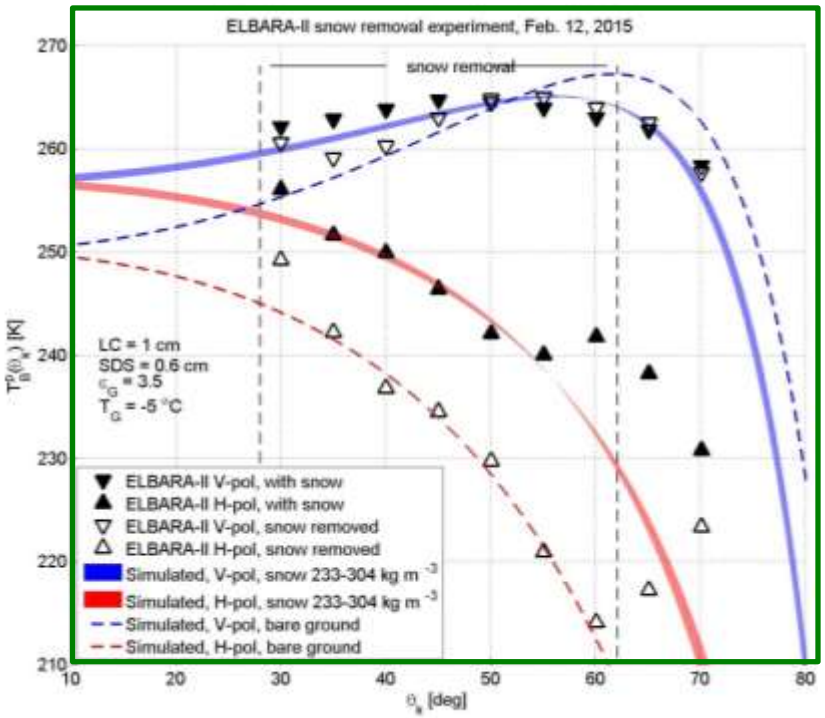
The minimum $CF_{min} \approx$ 48.9 K^2 of $CF(\rho_S, \varepsilon_G)$ at **$P = (\rho_S, \varepsilon_G) \approx$ (202.4 kg m^{-3}, 4.8)** correspond to the values retrieved (close to initial values $(\rho_S^{ini}, \varepsilon_G^{ini})$).

- **The cost-function $CF(\rho_S, \varepsilon_G)$ reveals a unique minimum over the ρ_S-ε_G parameter-space.**
- **The minimum $CF_{min} \approx$ 48.9 K^2 of $CF(\rho_S, \varepsilon_G)$ at $P = (\rho_S, \varepsilon_G) \approx$ (202.4 kg m^{-3}, 4.8) correspond to the values retrieved** (close to initial values $(\rho_S^{ini}, \varepsilon_G^{ini})$).

Snow Removal Experiment: Feb. 12th 2015; Sodankylä

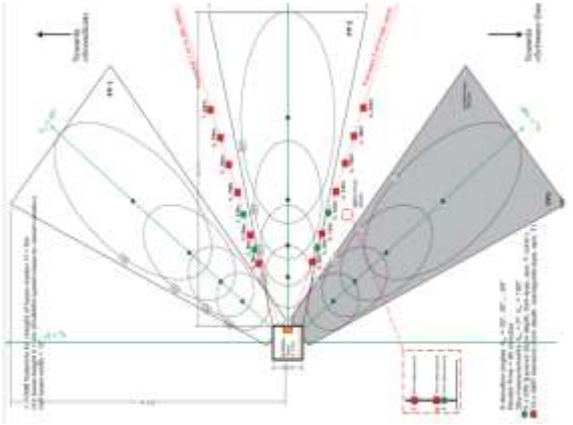
- Experimental proof of sensitivity of $T_B^p(\theta)$ with respect to dry-snow.
- $T_B^p(\theta)$ measured before (▼▲) and after (▽△) snow-removal.
- Reasonable agreement between measured (▬) and simulated (▼▲▽△) $T_B^p(\theta)$.





3) Theory: L-band emission of grounds covered with dry snow

- Key remote sensing instruments mounted on the 4.5m-tower:
  - L-band radiometer ELBARA II (since November 2016)
  - X-band radiometer MIRA (since November 2016)
  - Wide-band Scatterometer (winter 2017/18)



- Alternately elevation scans on "natural" and "gridded" footprints (FP).
  "natural" ↔ snow-covered ground
  "gridded" ↔ ground emission shielded with a metal mash-grid



- $T_B^{p,\theta}$ over "gridded" FPs mainly carry information on snow.
  $T_B^{p,\theta}$ over "natural" FPs carry information on snow **and** ground.
  ↔ experimental setup suited for disentangling (moist) snow and ground radiance

Time-Line since August 2016






August September October November







5) Setup of the Experiment

Modification:

10th January 2017:
Installation of a heating-system for the elevation-tracker gear-box to reduce increased friction at very low ambient temperatures.

→ **Heating cable wrapped around the gear-box and thermal insulation.**

→ **Tracker works properly even at very low temperatures**







Maintenance Tasks

10th January 2017 and 30th January 2017:
Large amounts of snow accumulated on the ELBARA-II antenna had to be removed to avoid overload of the elevation tracker.

→ **Successful remote recommissioning of the system**

Modification:

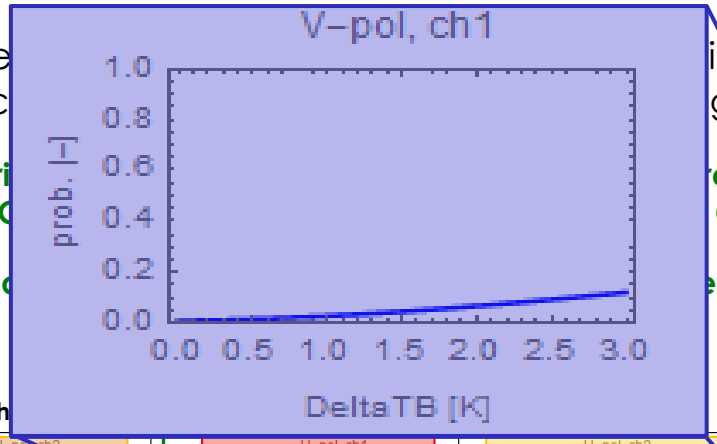
19th December 2016:

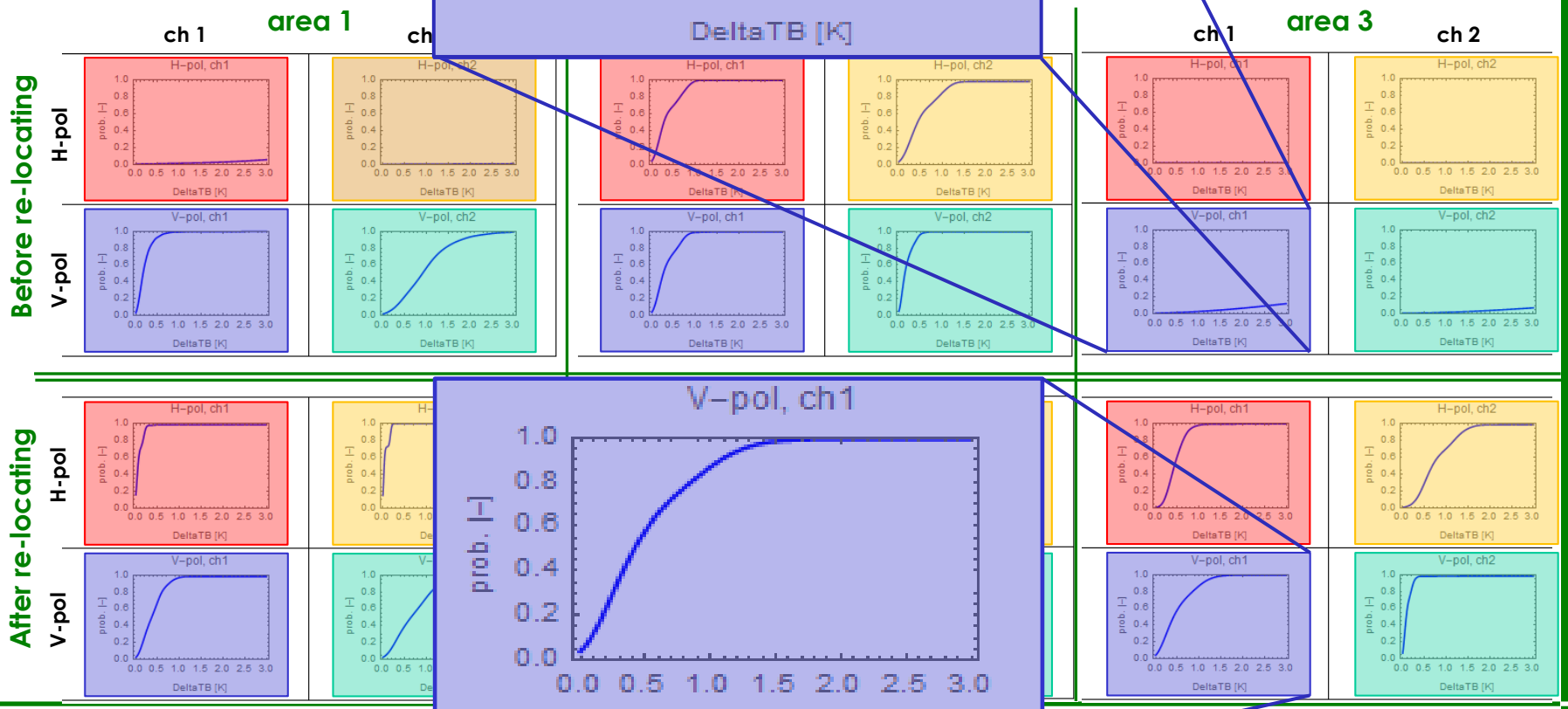
Moving ELBARA-II to the e…ing the height (≈ 80 cm) to reduc…gles.

→ **"disturbance" is characteri…ed voltage samples U_i" and "mean of …G_{RM}**

→ **Number of undisturbed mea…eased significantly!**







5) Setup of the Experiment

Mitigation / Quantification of Disturbances (RFI):

Impact of measurement errors $\Delta T_B^{p,\theta}$ caused by non-thermal emission received by the radiometer.

The approach:

"Intensities" of radiance measured for a thermal noise source has a Gaussian PDF.

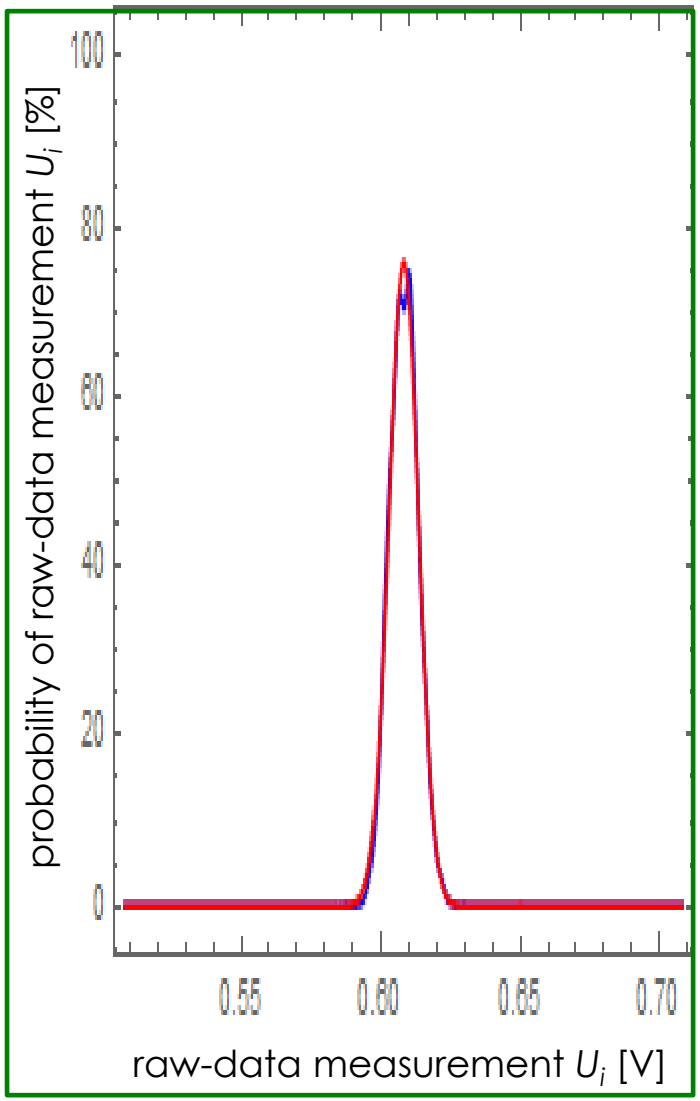
1) Compute the mean $\langle U_i \rangle$ of the (2400) voltage samples U_i measured (@ 800Hz) by ELBARA-II L-band radiometer.

2) Compute the $PDF_{measured}$ of the measured raw-data U_i (blue).

3) Fit a Gaussian-model PDF_{Gauss} to $PDF_{measured}$.
⇒ The mean $\langle PDF_{Gauss} \rangle$ is one of the fit-parameters.

4) The difference $\langle U_i \rangle$ - $\langle PDF_{Gauss} \rangle$ is a measure of the contribution of non-thermal radiance.
With the radiometer gain G_{RM} = 0.322 mV/K the impact of non-thermal radiance (disturbance, RFI) can be quantified as:

$$\Delta T_B^{p,\theta} = (\langle U_i \rangle - \langle PDF_{Gauss} \rangle) \cdot G_{RM}$$

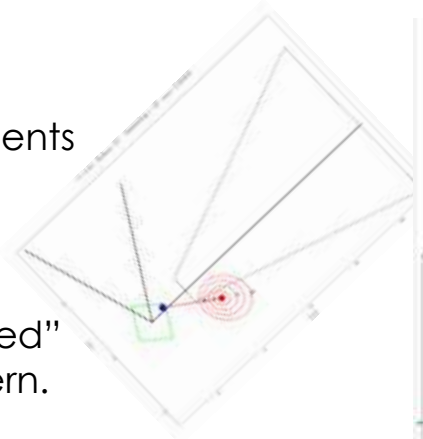


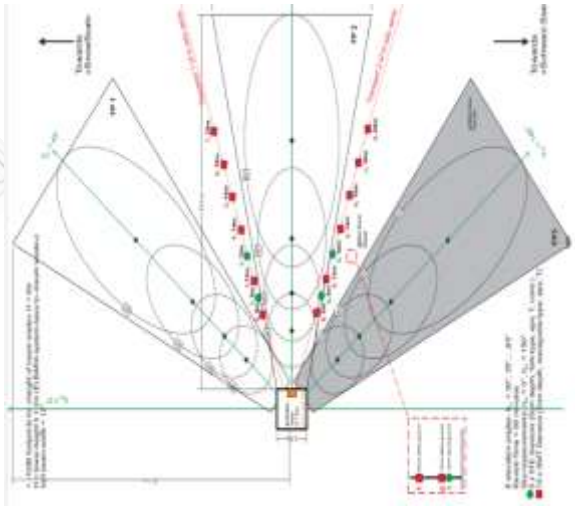
Weighting factor of radiance "gridded" area

Crucial for the interpretation of measurements $T_{B3}^{p,\theta}$ performed over the area 3.

Two approaches are investigated:

1) Theoretical: Convolution of the "gridded" area with the antenna sensitivity pattern.





2) Experimental: $T_{B3}^{p,\theta}$ measured over area 3 is:

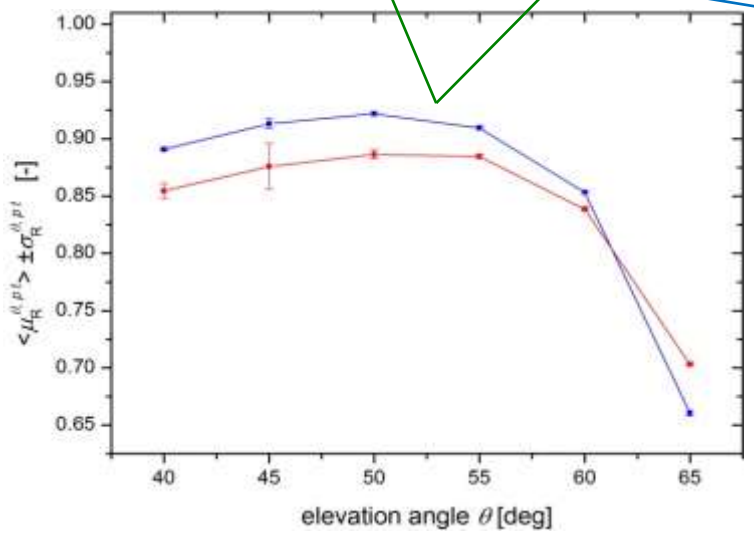
$T_{B3}^{p,\theta} = T_{BR}^{p,\theta} \cdot \mu_R + T_{BN}^{p,\theta} \cdot (1 - \mu_R)$

$T_{BR}^{p,\theta} = T_{sky}^{\theta} \cdot r_R$ with $r_R \approx 1$ (grid reflectivity)

$T_{BN}^{p,\theta}$ measured over "Natural" area 1 or 2

measured

used to estimate (moist) snow emission

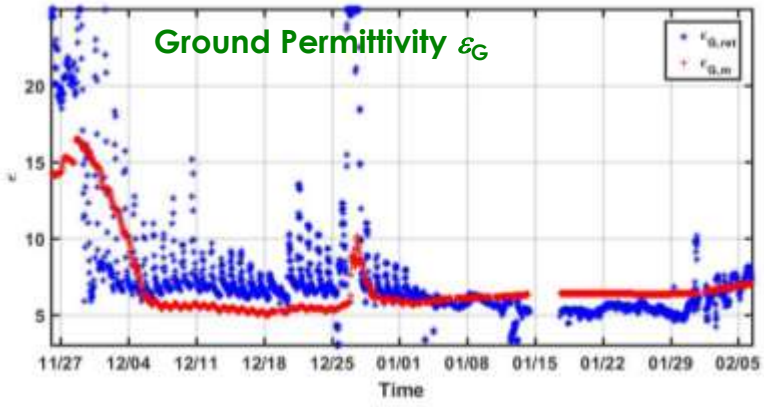


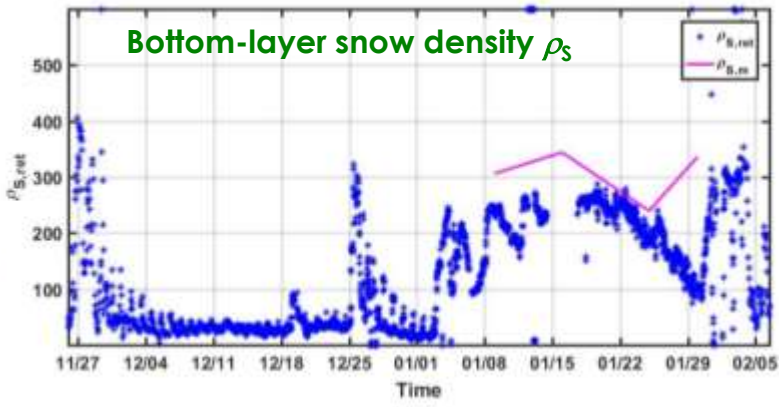
Raw-data processing ($U_i \rightarrow T_B^{p,\theta}$)

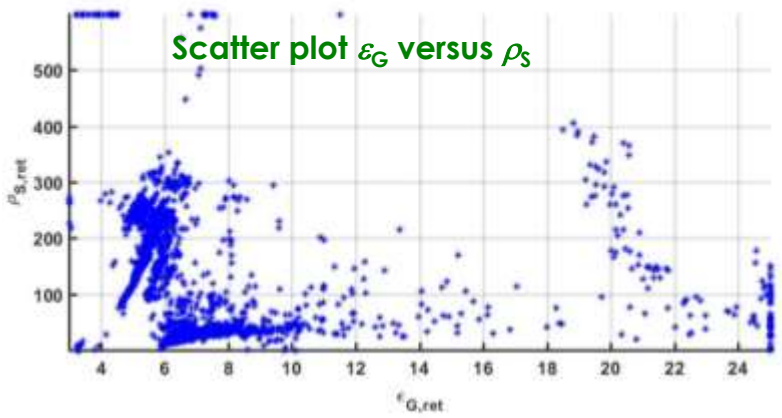
- "optimal" assumption for the Feed-Cable losses to yield most accurate $T_{B,sky}$ for different T_{air}.
- RFI mitigation / flagging / consideration in $CF(\rho_S, \varepsilon_G)$.

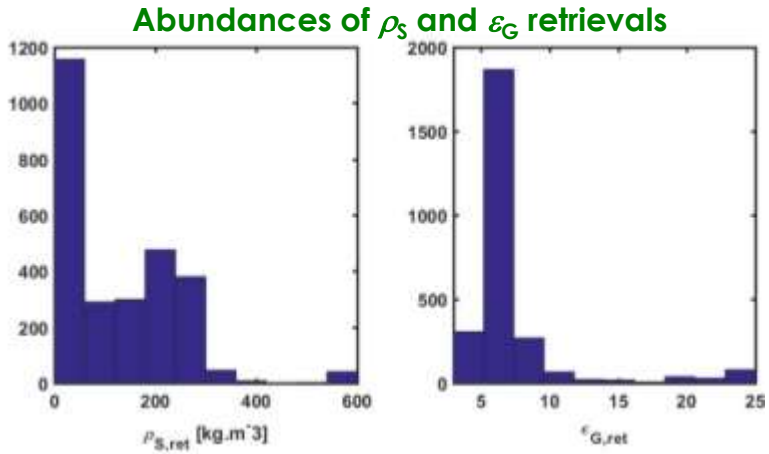
First Retrievals (ρ_S, ε_G)

area 2, h_G = 0.1, θ = 30°, 35°,…,65°, p = H & V









⇒ Pros and cons of using only H or V pol.
⇒ "optimal" ranges of observation angles
⇒ Different versions of cost-function $CF(\rho_S, \varepsilon_G)$
a) regularization function (e.g. angular weighting, "soft constrains")
b) consideration of errors ΔT_B^p of measurements $T_B^{p,\theta}$.
⇒ sequential retrieval: first ε_G using V-pol $T_B^{V,\theta}$. only, than ρ_S using H- and V-pol $T_B^{p,\theta}$.

Next Steps

Measurement campaigns over manipulated areas

Snow-removal experiment

- To demonstrate and quantify the impact of snow on $T_B^{p,\theta}$
- To "reset" the observed area for the "snow-compression experiment"

Snow-compression experiment

- With new snow to achieve maximal contrast of bottom-layer snow mass-density ρ_S
- In-situ measured bottom snow-layer density and snow-depth before and after compression (using "snow compression-table")





Summary / Conclusions

- **MicroVegSnow** is a 3-year project between the WSL (**snow-part**) and FZJ Jülich (**vegetation-part**). Project-parts share common microwave instruments, experimental- and modelling approaches.
- **MicroVegSnow snow-part** and **ESA SnowLab** project are both conducted at the SLF/WSL Davos-Laret test site.
- **MicroVegSnow snow-part** provides almost continuous (first year) L- and X-band brightness temperatures $T_B^{\theta,p}$, as well as in-situ ground temperatures, ground permittivities, snow density-profiles,…
- **MicroVegSnow snow-part** and **ESA SnowLab** are both in support of the development of methods to estimate snow-properties from microwave remote sensing.
  MicroVegSnow snow-part targets on the retrieval of bottom-layer snow-density and ground permittivity based on L-band $T_B^{\theta,p}$ (potential to improve SWE estimates and Freeze/Thaw states).
- The spatio-temoral collocated active- and passive microwave data, available from **ESA SnowLab** and **MicroVegSnow**, are unique. Optimal scientific exploitation of the data requires a common research project.