

**Integration of space technologies for snow monitoring**

**– GNSS, EO and SatCom**

# **First results of ESA IAP SnowSense Demo Project**

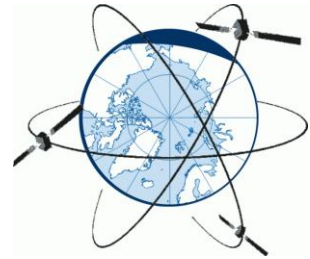
**Florian Appel**

Philipp Klug, Heike Bach

**VISTA Remote Sensing in Geosciences GmbH - Munich / Germany**

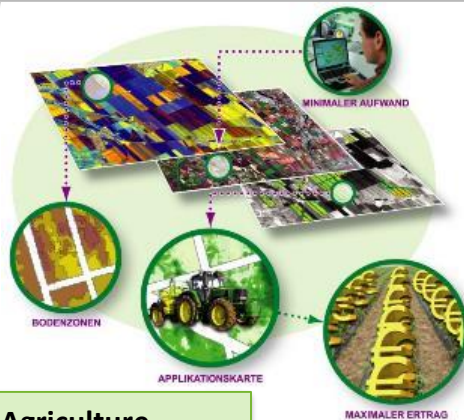
Patrick Henkel, Markus Lamm – ANAVS GmbH

Franziska Koch, Monika Prasch, Wolfram Mauser – LMU Munich

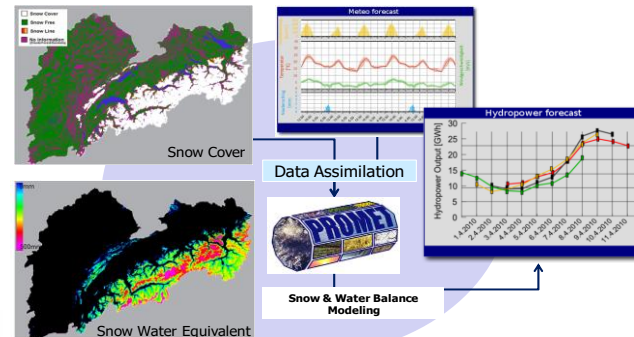


# VISTA Remote Sensing in Geosciences GmbH

www.vista-geo.de



- Agriculture**
- Yield Forecast
  - Precision Farming
  - Organic Certification



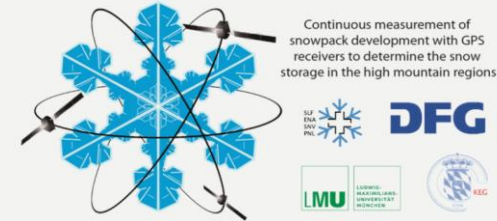
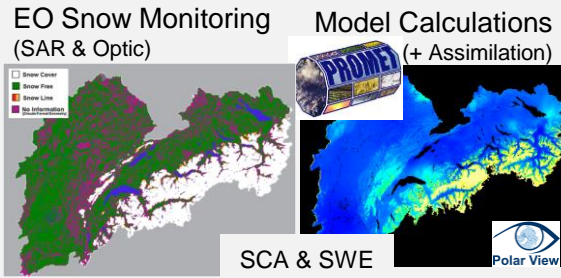
- Hydrology**
- Snow monitoring
  - Soil Moisture monitoring
  - Run-off & Hydropower forecast



# SnowSense Background

VISTA activities in  
**ESA GSE Polar View**  
(2005 – 2013)  
[www.polarview.org](http://www.polarview.org)

**User Needs for Snow Monitoring  
in Remote Areas**



**GNSS In-Situ Snow Sensor  
successfully applied in the Alps**

Experience in Service  
Development within  
**IAP TalkingFields**



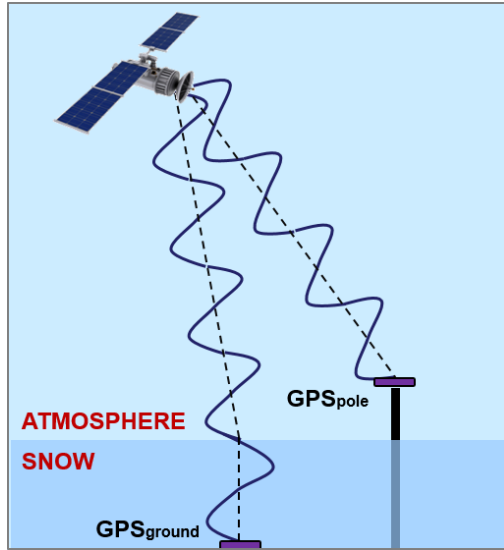
ESA IntegSpace Award 2013

ESA IAP Fast Track  
Feasibility Study

ESA IAP DEMO  
PROJECT

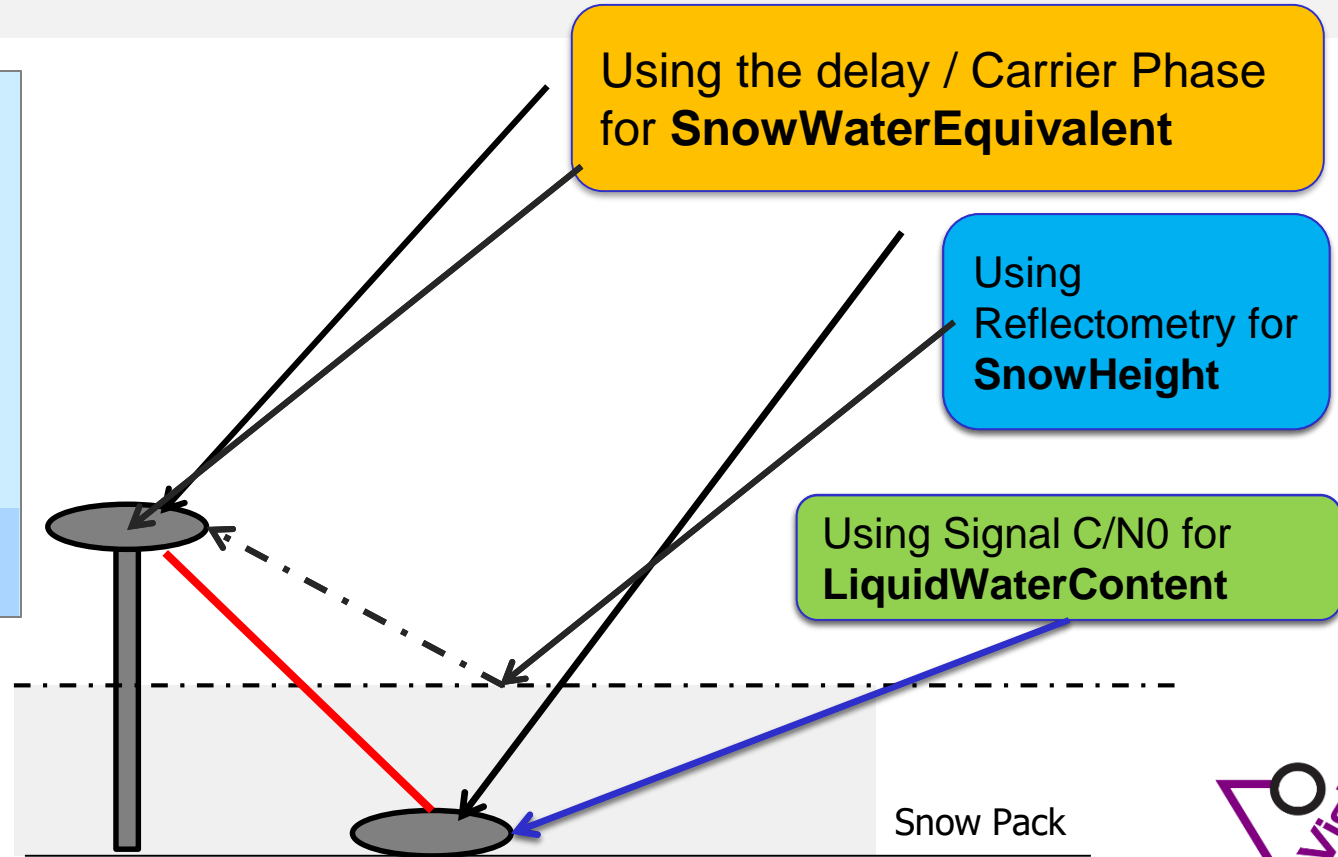
# GNSS for Snow Monitoring

# Snow Parameter Retrieval Methodes



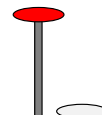
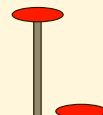
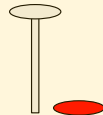
GPS: L1-Band / L2-Band  
1.575 GHz / 1.227 GHz  
32 Sats / 20.200 km Orbits  
23h56m repetition

**SnowSense**  
Demo Project  
EARSeL BERN 2017



# Snow Parameter Retrieval Methods

Method:	Signal Attenuation	Signal Delay	Multipath / Reflectometry
<i>GNSS Data</i>	$C/N_0$	Carrier Phase Differences	Signal separation or $C/N_0$
<i>Snow Parameters</i>	<b>Liquid Water Content</b>	<b>Snow Water Equivalent Snow Depth</b>	<b>Snow Depth / Snow Water Equivalent</b>
<i>GNSS antennas</i>	1	2	1
<i>Sensor Constellation</i>	One antenna below snow cover	<b>One antenna below and one above the snow cover</b>	One antenna above snow cover
<i>References</i>	Koch et al. (2014) Schmid & Koch et al. 2015	<b>New Algorithm and Software Development LMU / ANAVS / VISTA</b>	e.g. Larson et al., 2014, Jacobson et al., 2010, Ozeki & Heki, 2012 <a href="http://www.kristinelarson.net/publications/">http://www.kristinelarson.net/publications/</a>



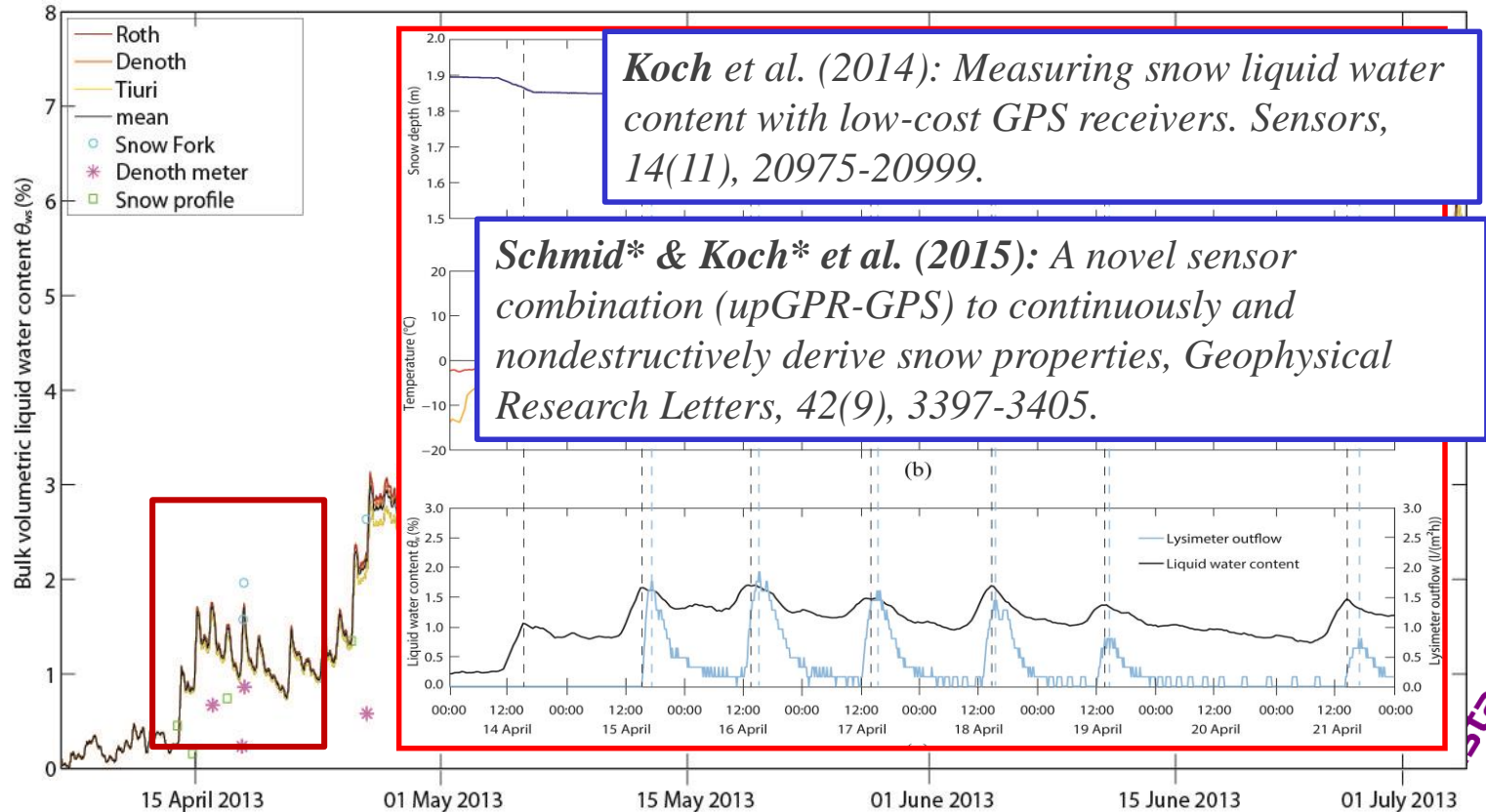
# Fundamental Results on GPS and LWC

LWC derived  
at the  
Weissfluhjoch

Melting Period  
2013



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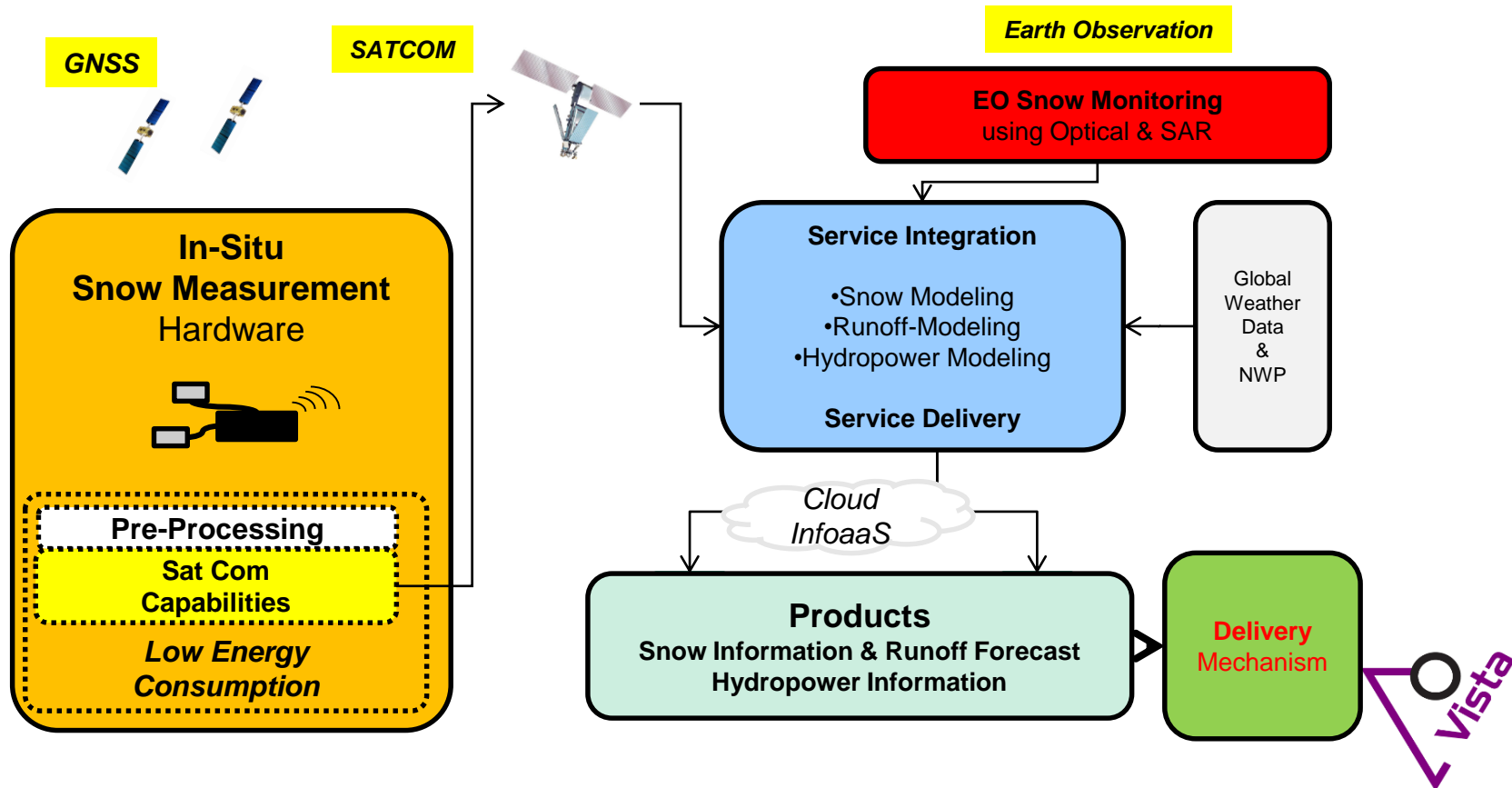


# SnowSense as a ESA IAP Demo Project





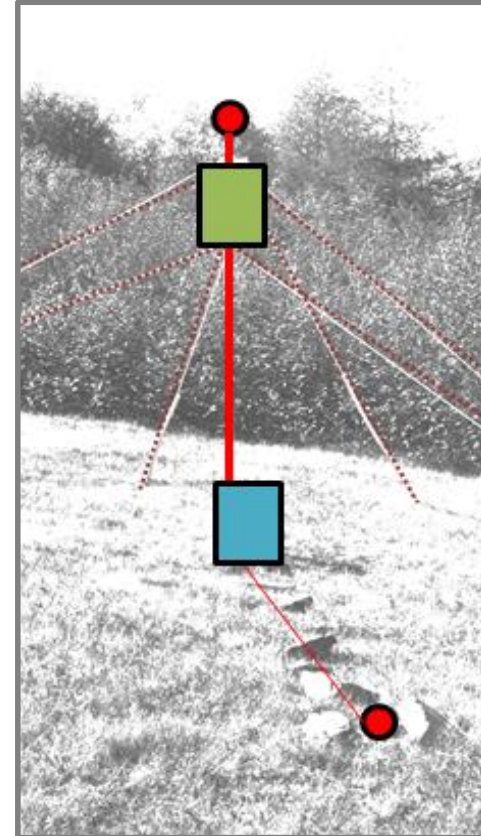
# SnowSense Overall Concept



# SnowSense in-situ hardware – design for remote areas

## Requirements

- Weather independent operation
  - Maintenance free during operations
  - Non-Destructive Snow Parameter Retrieval
- Independent Power Supply - during winter
  - Intelligent Power & Operation Management
- On-Board Recording & Processing Capability
  - SatCom / Terrestrial Communication Cap.
- Light weight system for transportation
  - Easy installation (1-2 persons)
  - Low-Cost Hardware & Low Cost operation



Portable Mast  
System

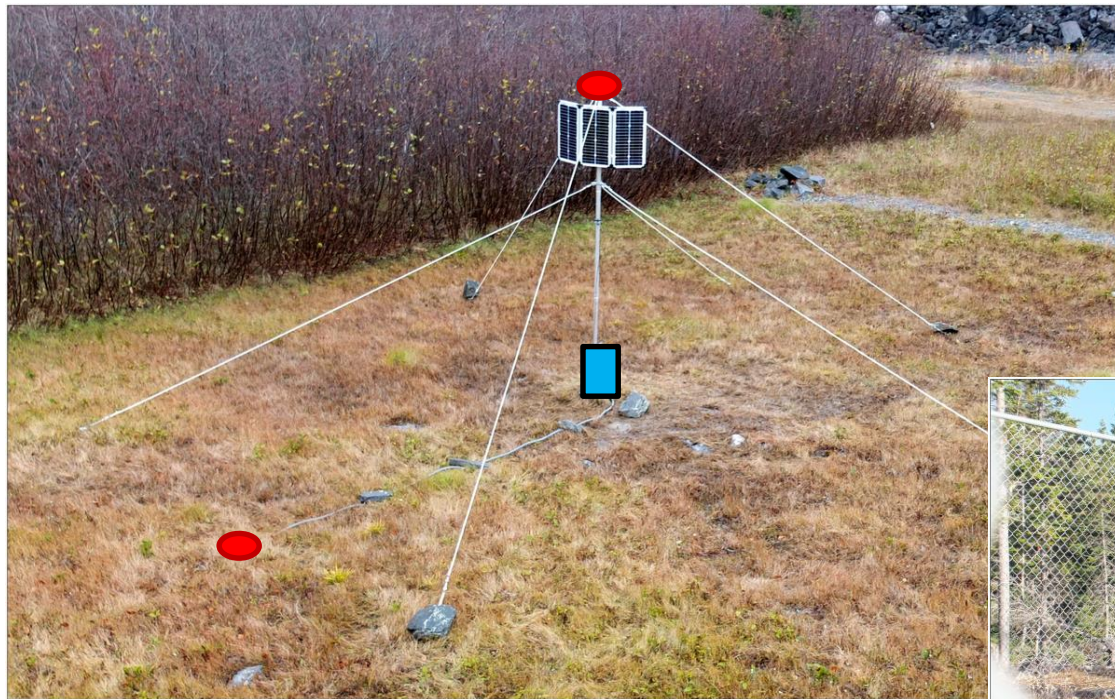
2 GNSS  
antennas

Solar panel  
array

Electronic Box  
including  
SnowSense  
GNSS receivers,  
power  
management,  
processing and  
communication  
boards, battery  
pack



# SnowSense In-Situ Hardware



- ✓ Installation as independent Mast System
- ✓ Installation at existing infrastructure or stations (but with own power and communication)



# Technical Design Issue: Recording and Communication

- On-Board Processing Capability
- SatCom / Terrestrial Communication

## Data Recoding:

~ 8 MB per hour as raw data  
~ 200 MB per day

## On-Board Processing

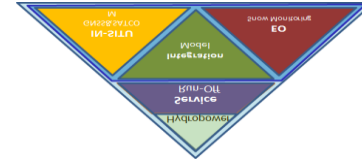
low-power ARM processor

- ✓ Pre SWE algorithm
- ✓ Fast LWC algorithm
- Integr. SWE + LWC algorithm (in prep.)

## Data Transfer via Iridium SBD service:

- ✓ 1-5 messages a day: ~ 200 bytes a day
- ✓ Monthly data rate: < 10 kB

Final SWE Processing at VISTA facilities



## SWE Products & Maps

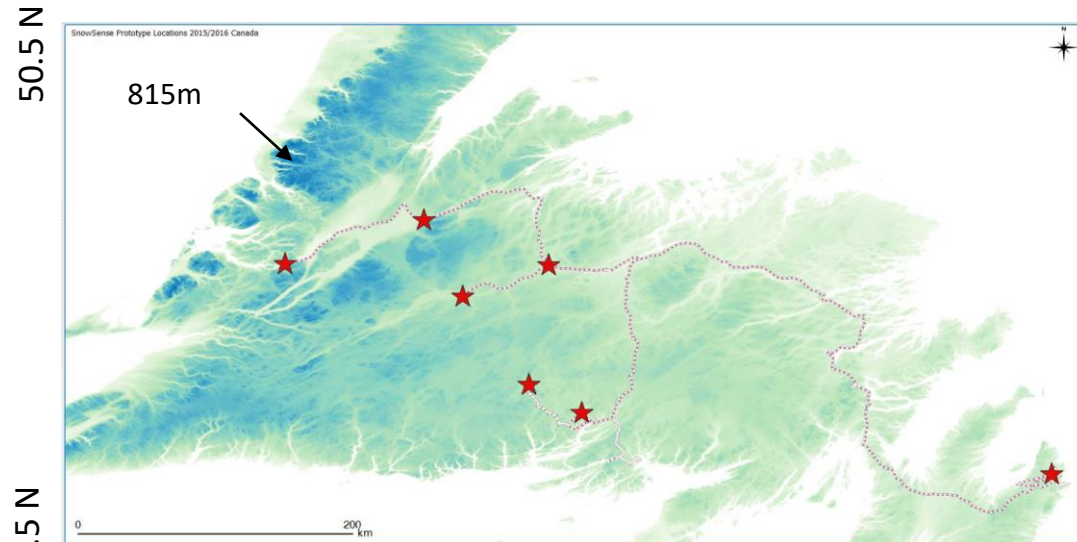
Daily SWE information  
Requirement: Weekly

Runoff and Hydropower Products  
from model integration





# Prototype Hardware Installation Newfoundland / Canada



- Island of Newfoundland: 110.000 km<sup>2</sup>
- Existing SWE stations: 2 public + 2 private
  - + seasonal snow survey using helicopters and snow mobiles
- Hydropower and Flood Forecast as stakeholders

- ✓ **Successful installation of 7 SnowSense stations in October 2015**
  - autonomous operation and offline recording without failure
- ✓ **Hardware and Software update in November 2016 (6 Stations)**
  - Improved Recording Plan
  - **On-Board Pre-Processing (all)**
  - **Iridium SatCom (2 locations)**



# Experimental and Demo Stations in Europe

- Switzerland: Weissfluhjoch (2540 m)
- Austria: Großarl (1000 m)
- Germany: Hunsrück (600 m)

+ Munich (520 m): on roof top and for soil moisture retrieval



# SnowSense Snow Results

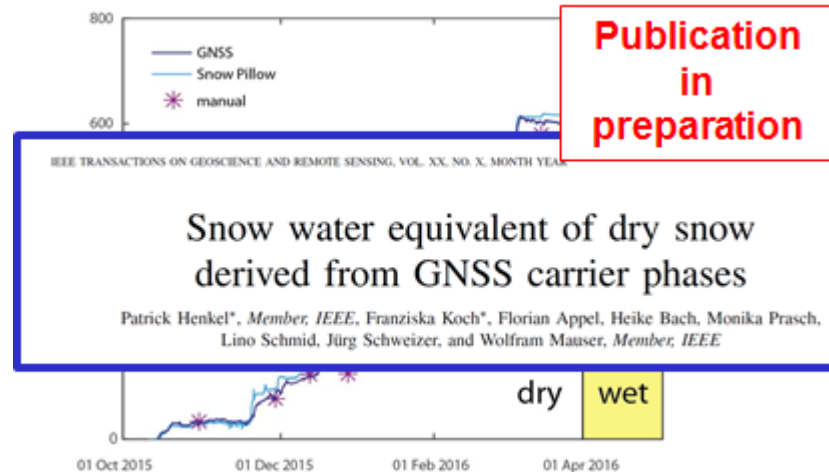


# Results SWE from GNSS – Alpine Testsite

Best conditions

## SWE derived at the Weissfluhjoch 2015/2016

- Continuous recording data
- Processing using the original dry snow 3h algorithm
- Dry snow precisely from derived from GNSS
- Wet Snow algorithm under implementation



Snow pillow data and manual SWE measurements by the SLF

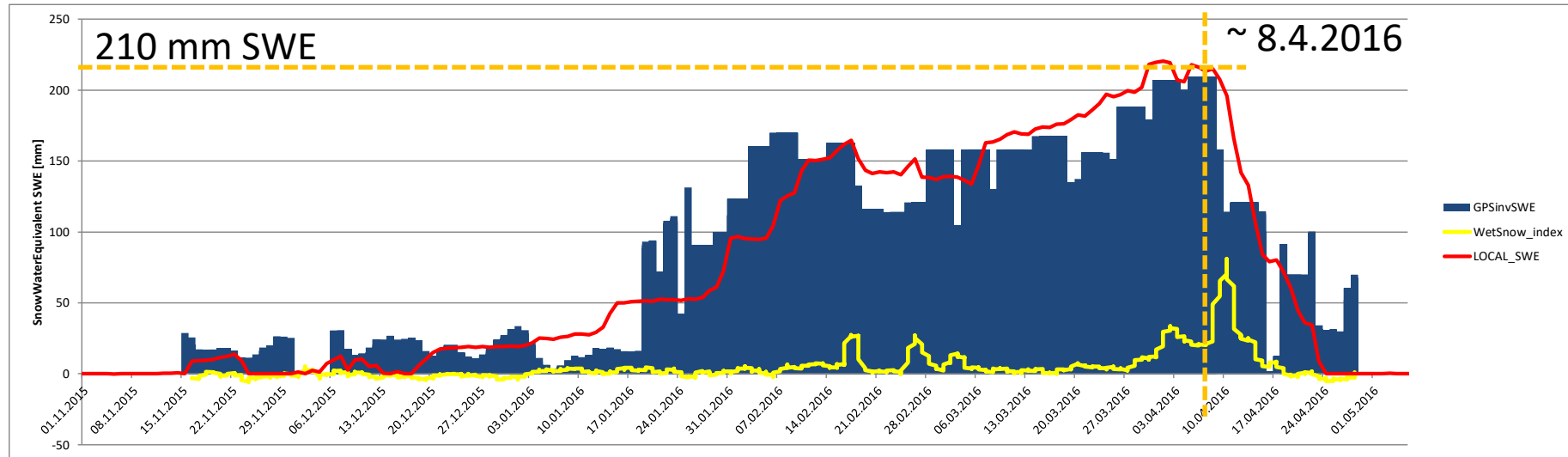




# Results SWE from GNSS – Newfoundland 2015/2016

Non optimal  
data recording  
schema

## SWE derived at WRMD station Sandy Lake (180m)



- 20min data recordings (now improved!)
- post-processing by inversion method

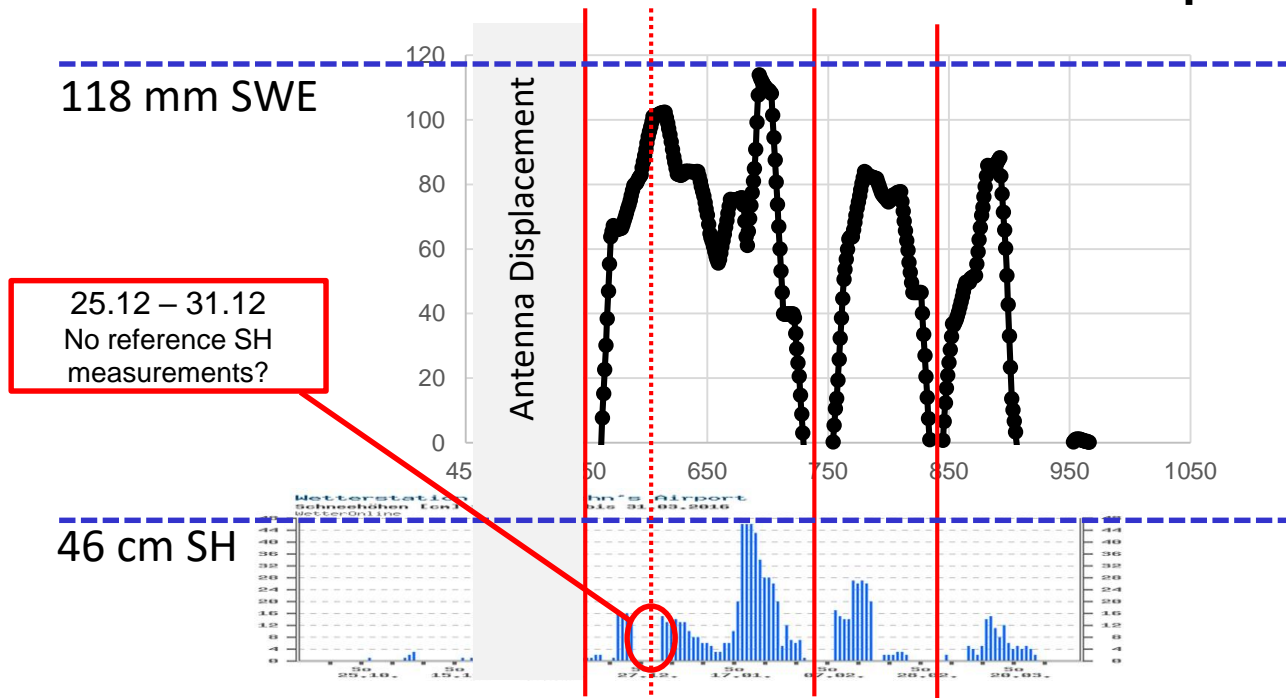
Here: No Wet Snow  
considerations



# Results SWE from GNSS – Newfoundland 2015/2016

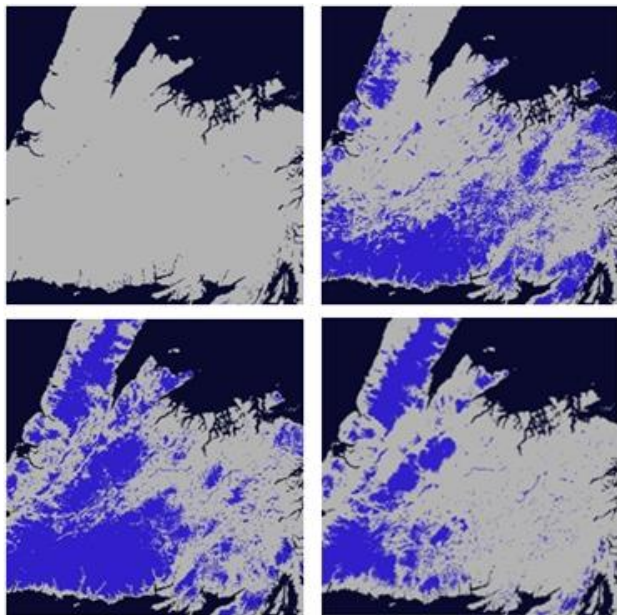
Non optimal  
station location

## SWE derived at St. John's – vs. SH at YYT airport (~ 5km)



# Other Techniques within SnowSense Service Integration

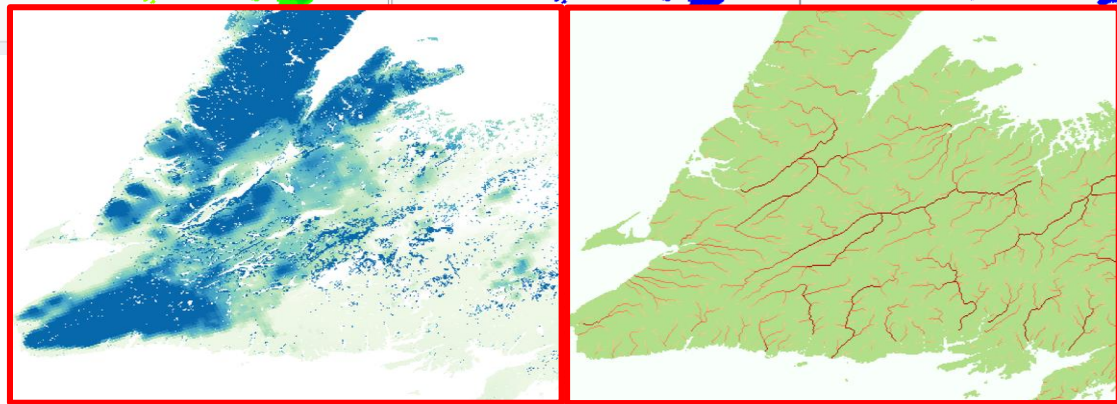
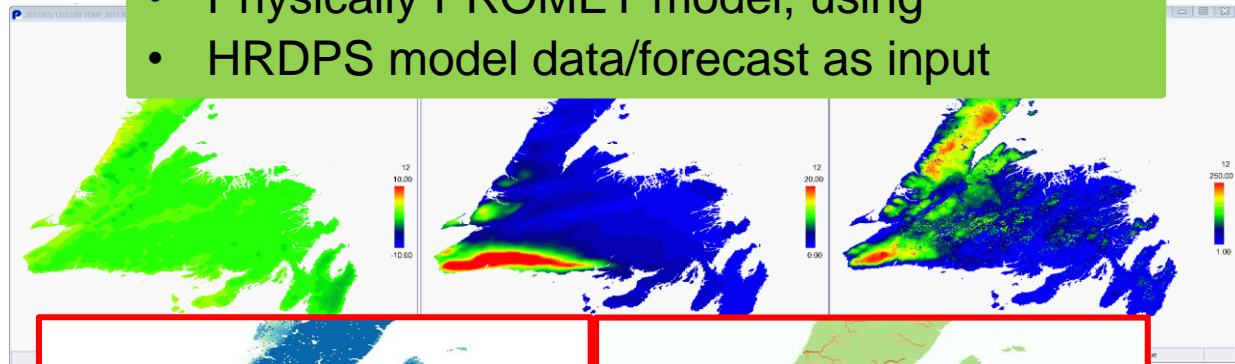
## EO Snow Monitoring: Sentinel-1 WetSnow Mapping



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## Land Surface & Water Balance Modelling

- Physically PROMET model, using
- HRDPS model data/forecast as input

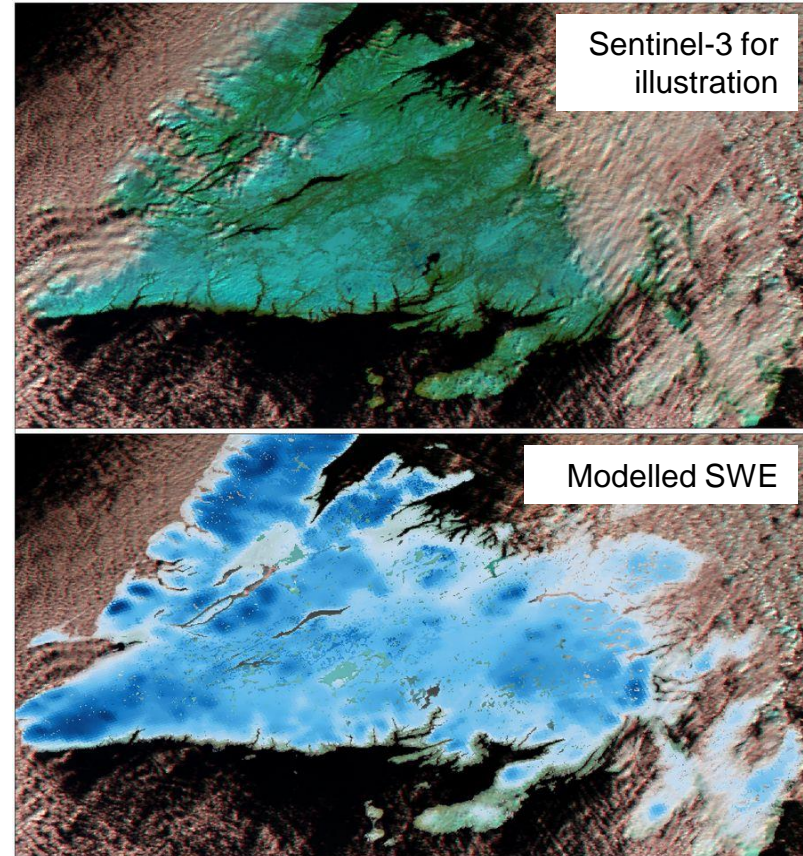
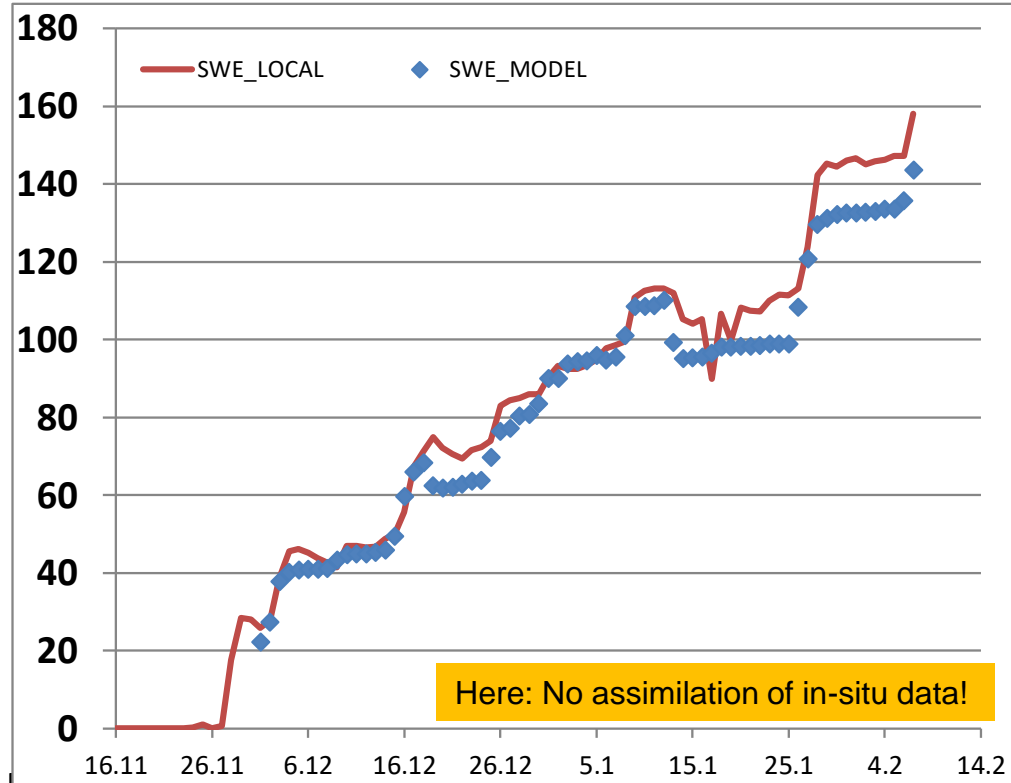


*Hourly calculated SWE*

*Hourly calculated Runoff*

# Results Modelled SnowWaterEquivalent – Newfoundland 2016/2017

## SWE derived for WRMD station Sandy Lake



# SnowSense Summary

- **GNSS 2 antenna technique** is able to **measure relevant snow parameters**
  - Perfect correlation with measured **Snow Water Equivalent for Dry Snow**
  - **Liquid Water Content** is independently obtained from GNSS signal
  - **Wet Snow SWE** algorithm close to implementation
- **SnowSense In-Situ Sensor Hardware** successfully proven in different locations
- **EO Service, Model Integration** and **Service Provision** as prototype applied
- **Full Demo planned for Winter 2017/2018 in Newfoundland** (SWE & Runoff)
- **Further developments, applications and collaborations in preparation**
- **Hardware and Service soon ready for the market**





# SnowSense

Snow Water Equivalent  
Information for Remote Areas



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[www.vista-geo.de/snowsense/](http://www.vista-geo.de/snowsense/)

[www.facebook.com/SnowSenseDemo/](https://www.facebook.com/SnowSenseDemo/)