Towards the use of SAR observations from Sentinel-1 to study snowpack properties in Alpine regions

Gaëlle Veyssière , Fatima Karbou , Samuel Morin et Vincent Vionnet

CNRM-GAME /Centre d'Etude de la Neige (CEN)

Introduction

Snow: **Key role** in global energy and mass budgets ➔ of prime importance for climate studies

The wish list: Snow Water Equivalent (SWE), snow extent, grain size, albedo everywhere as often as necessary.

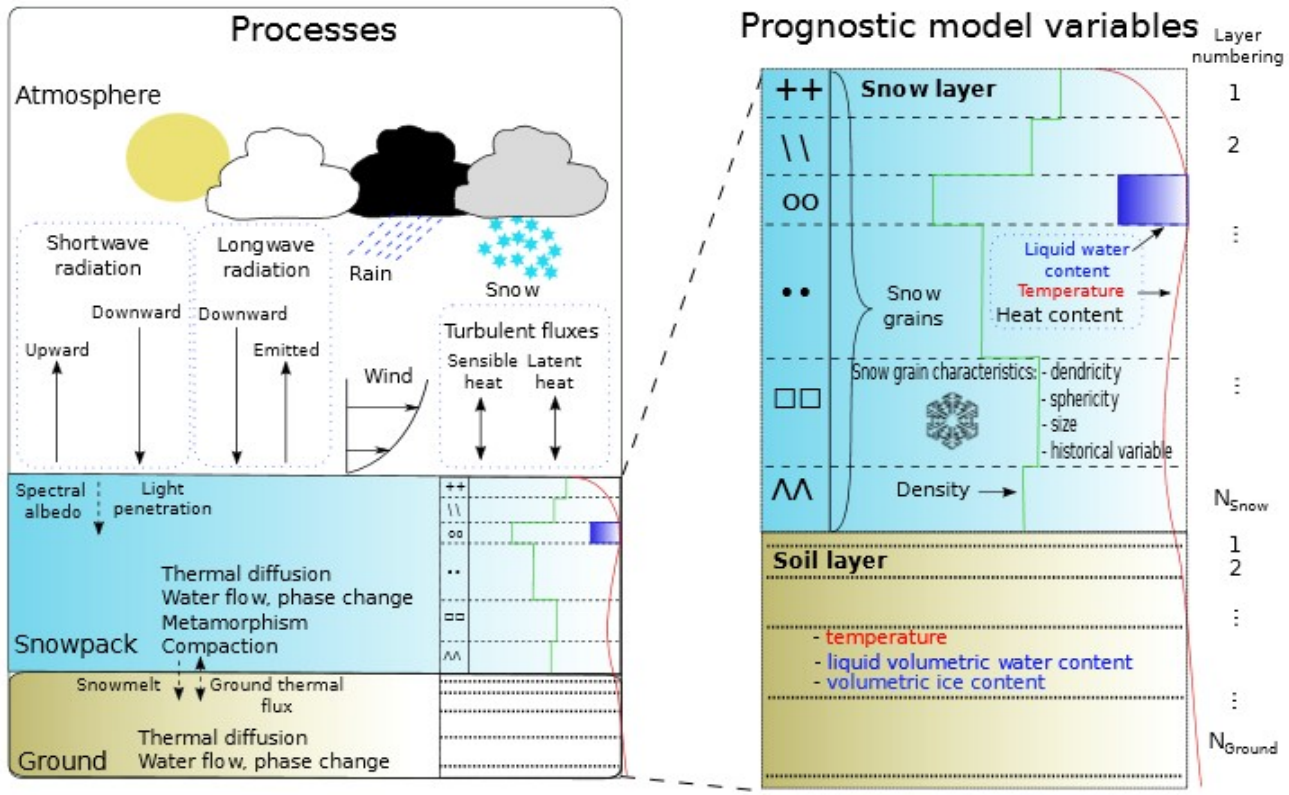
Challenges: Snowpack is a **heterogeneous media**, relatively **few observations** :

- Remote sensing at microwave frequencies: very useful but still a challenging issue!
- Over snow covered areas: microwave signal varies according to the snowpack properties (SWE, grain size, …)

Introduction

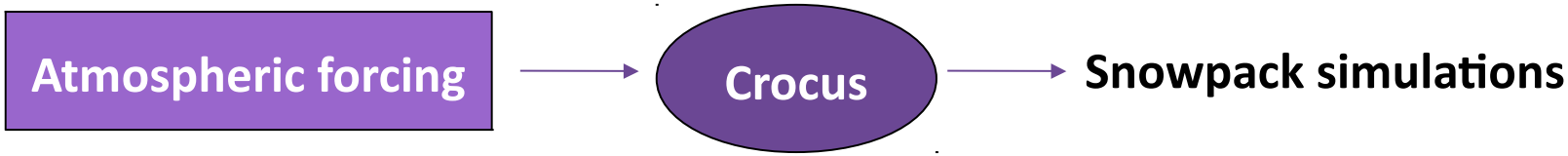
- Numerical model
- Unidimensionnal
- Describes snow physical properties like density, Liquid water content, snow grains, … for each layer
- Vertical stratification
- Up to 50 layers

SURFEX/ISBA-Crocus



Vionnet et al, 2012

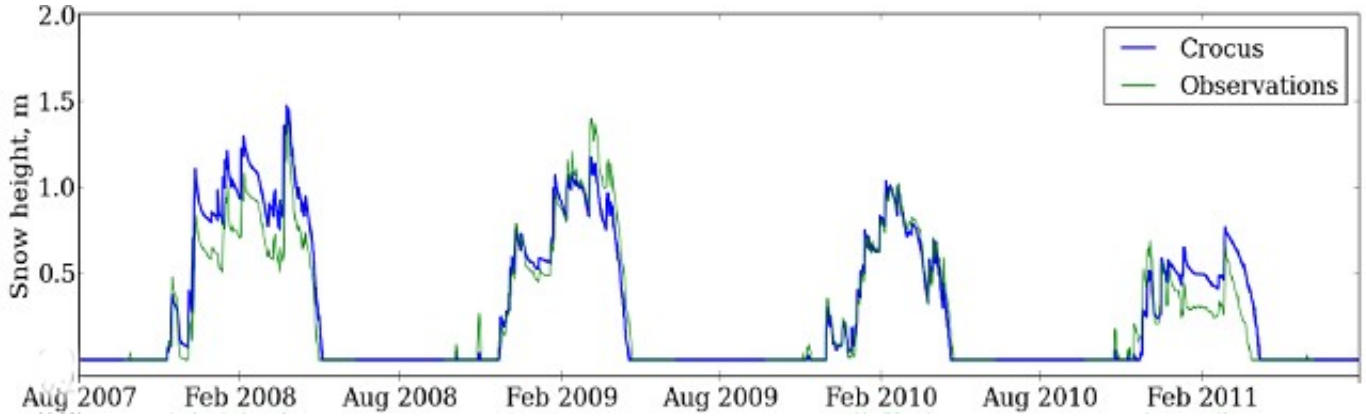
Introduction



To date, no observations are assimilated in Crocus

-> error **accumulation** during the season

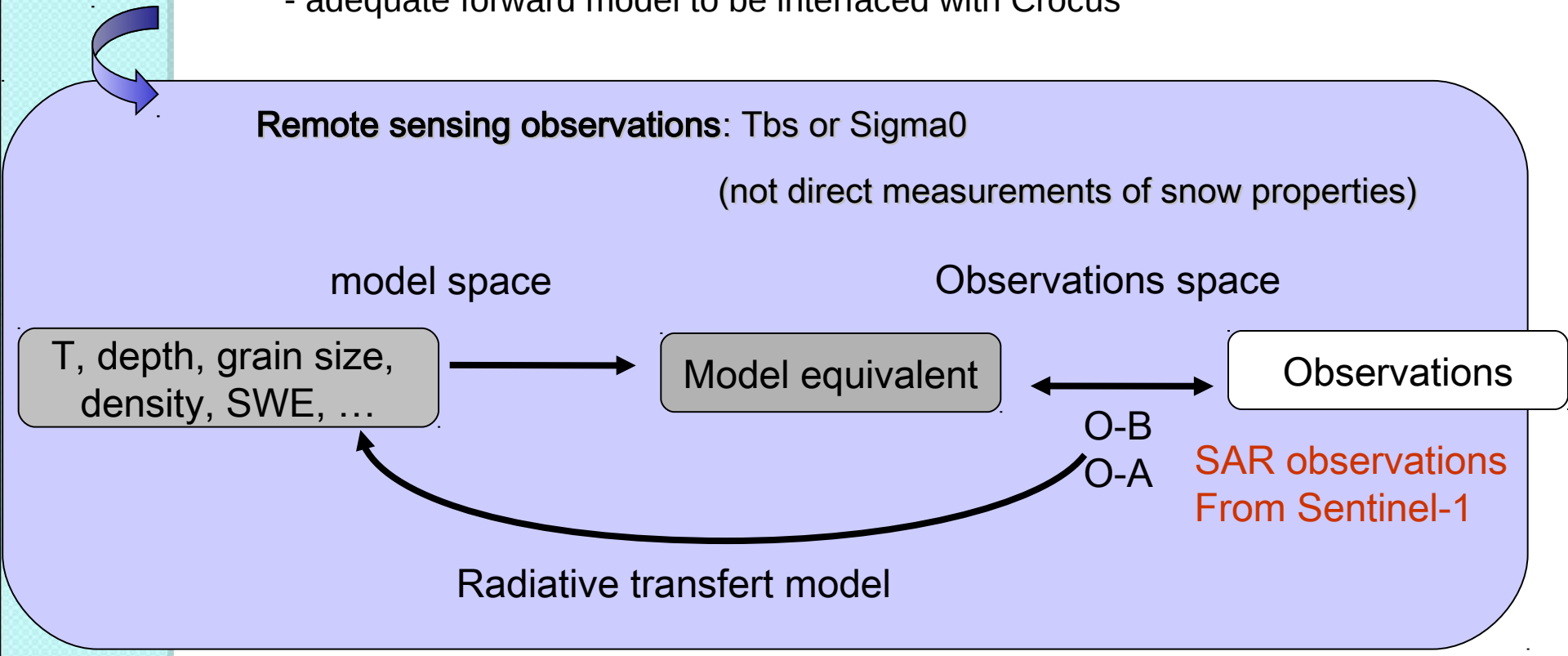
Example at col de Porte (in-situ forcing)



Introduction

Our objective: to assimilate relevant remote sensing microwave observations (active/passive) in the snow model Crocus

- sensitivity studies and synergy between active/passive data
- derive relevant information about snowpack properties
- adequate forward model to be interfaced with Crocus



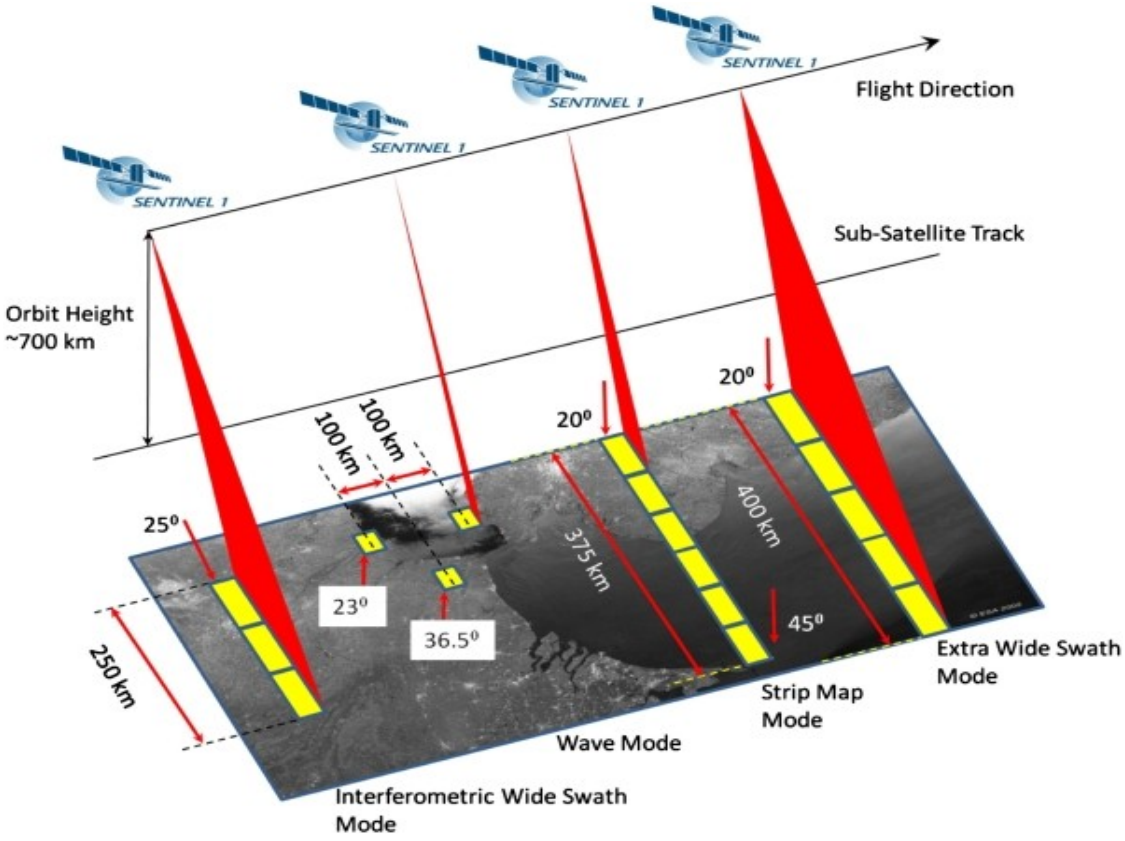
Sentinel-1

- ESA mission
- Two satellites orbiting 180° apart
- First part, Sentinel-1A was launched on April,3rd, 2014
- Polar orbit, at an altitude of 693 km
- Revisit time of 12 days -> 6 days with second part Sentinel -1B
- **Radar instrument onboard**

The instrument

- **S**ynthetic **A**perture **R**adar (**SAR**)
- Band frequencies : **C-band**
- Central frequency of **5.405 GHz**
- 2 polarisations : VV and VH
- **250 km swath, resolution of 20m**
- Various operational modes

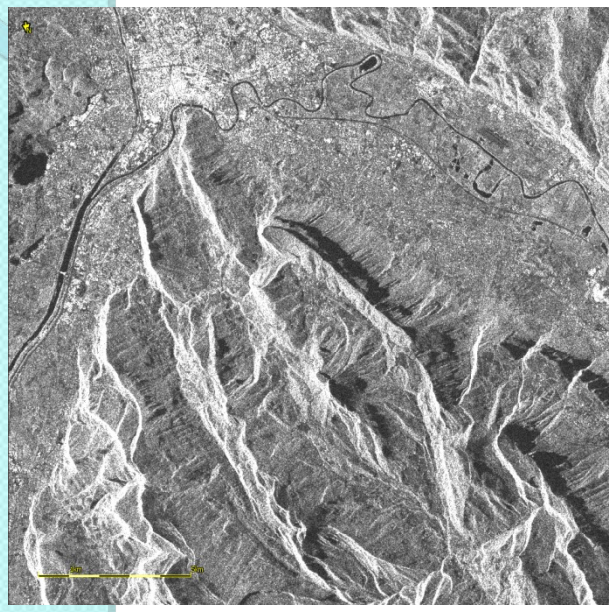
SAR observations



- A **S**ynthetic **A**perture **R**adar (**SAR**), or SAR, is a radar system which uses the flight path of the satellite to simulate a very large antenna or aperture electronically, and that generates high-resolution remote sensing imagery
- The radar in the active mode send a wave and measures the wave that it's backscatter into its direction or **the backscatter coefficient**

SAR observations

- Level-1 products
- Pre-treatment with **ESA S1-Toolbox**

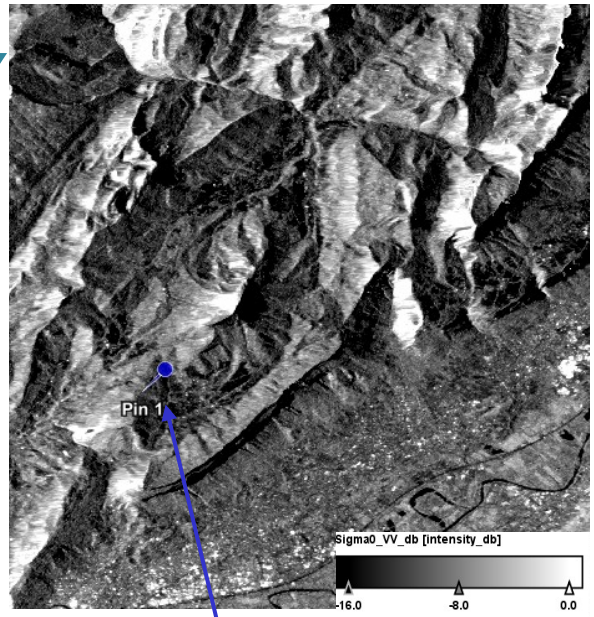


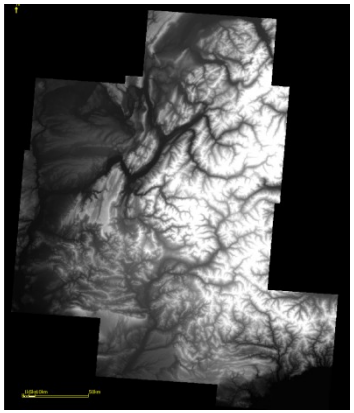
SAR Sentinel-1, 22/02/2014, 20m

Radiometric calibration : from intensity to basckscatter coefficient

Speckle filtering : reduce speckle noise

Terrain correction with IGN's 2008 DEM





Digital **E**levation **M**odel from **IGN**
Resolution : **25 m**

Météo-France experimental site « Col de Porte »

Modelling of the backscatter coefficient

Outputs from CROCUS

- Temperature
- Depth
- Density
- Liquid Volumetric Water Content
- Snow Water Equivalent (SWE)
- Specific Surface Area (SSA)

…

Microwave Emission Model of Layered Snowpacks (MEMLS)

- MEMLS is based on a six-flux theory to describe radiative transfert into the snowpack
- Produce simulation of the backscatter coefficient (active) and of the brightness temperature (passive) of the snowpack at VV and VH polarisation

Wiesmann, A. and Mätzler, C.: Microwave emission model of layered snowpacks, 1999

MEMLS inputs :

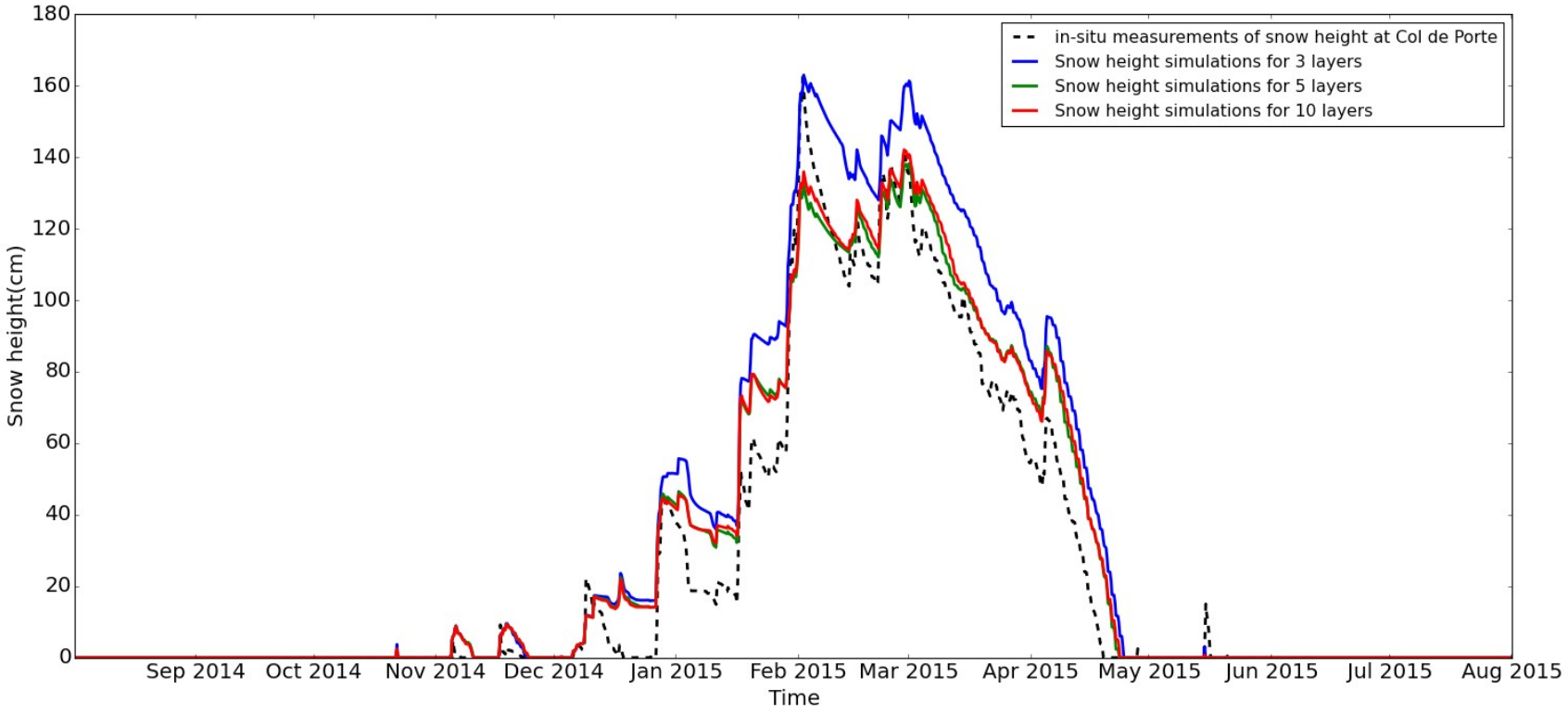
- **outputs from Crocus -> properties of the snowpack**
- **incidence angle**
- **snow ground reflectivity and its specular part**
- **ground temperature**
- **cross polarisation fraction**

Simulations

- In this study the simulations are made at Col de Porte
- Two seasons 2014/2015 and the beginning of 2015/2016
- Simulations of the backscatter coefficient for the central frequency of the C-band (as Sentinel-1 SAR band frequencies)
- Simulations assuming several snowpack layers: from 3 to 10 layers
- Comparisons with SAR observations from Sentinel-1
- But also simulations of different properties of the snowpack to compare with

Simulations

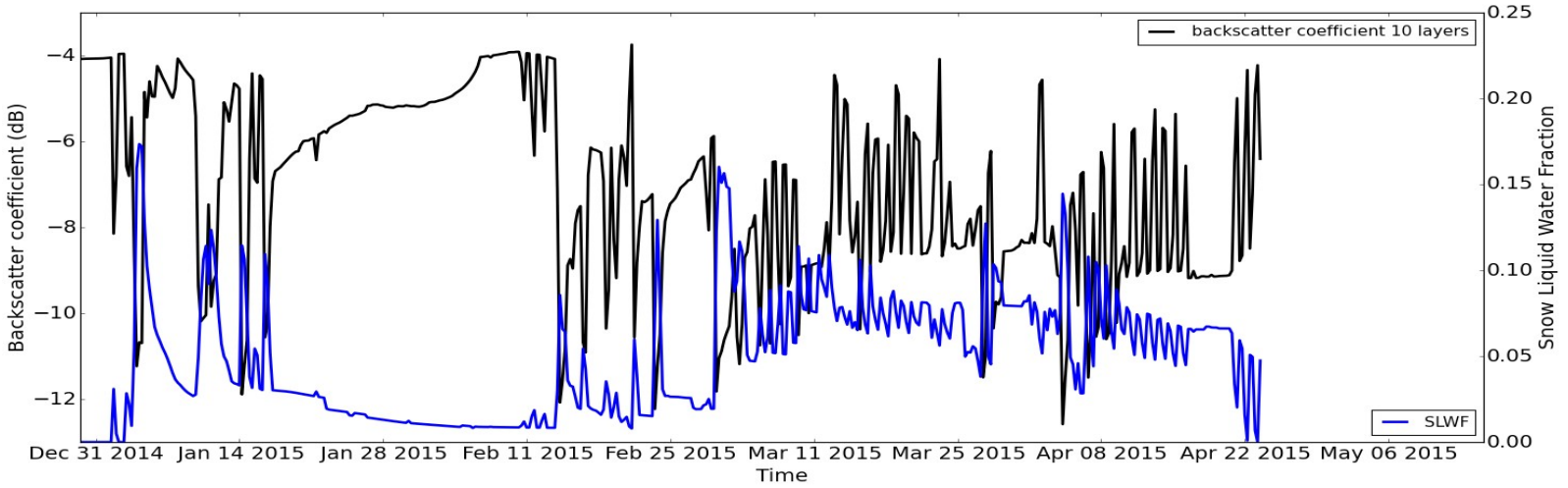
- Comparison between in-situ measurements of snow height at Col de Porte and the simulations (3, 5 and 10 layers) for the 2014/2015 season



Simulations

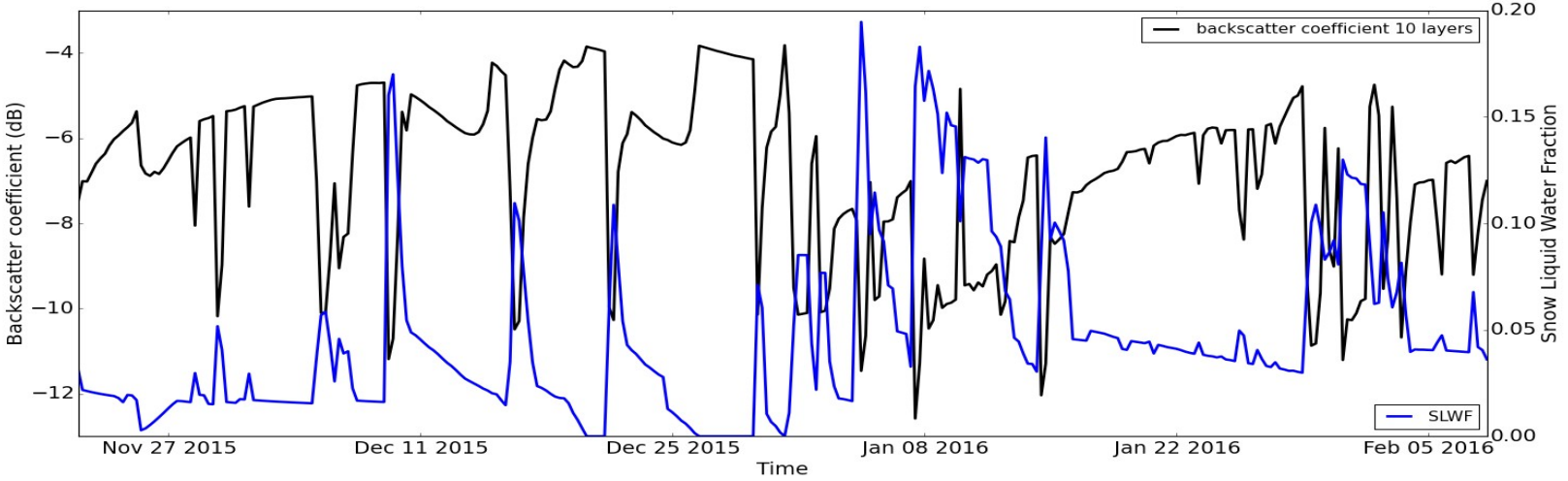
- Comparison between the simulated backscatter coefficient and the snow liquid water fraction of the snowpack (2014/2015 season)

2014/ 2015

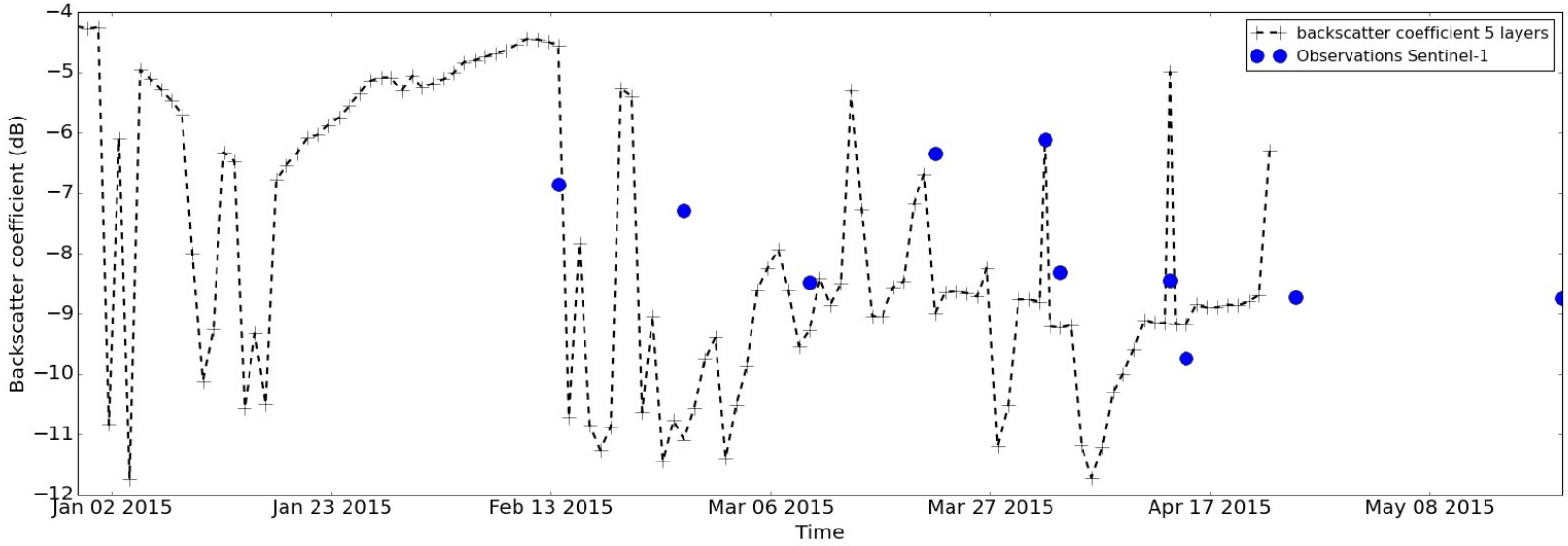


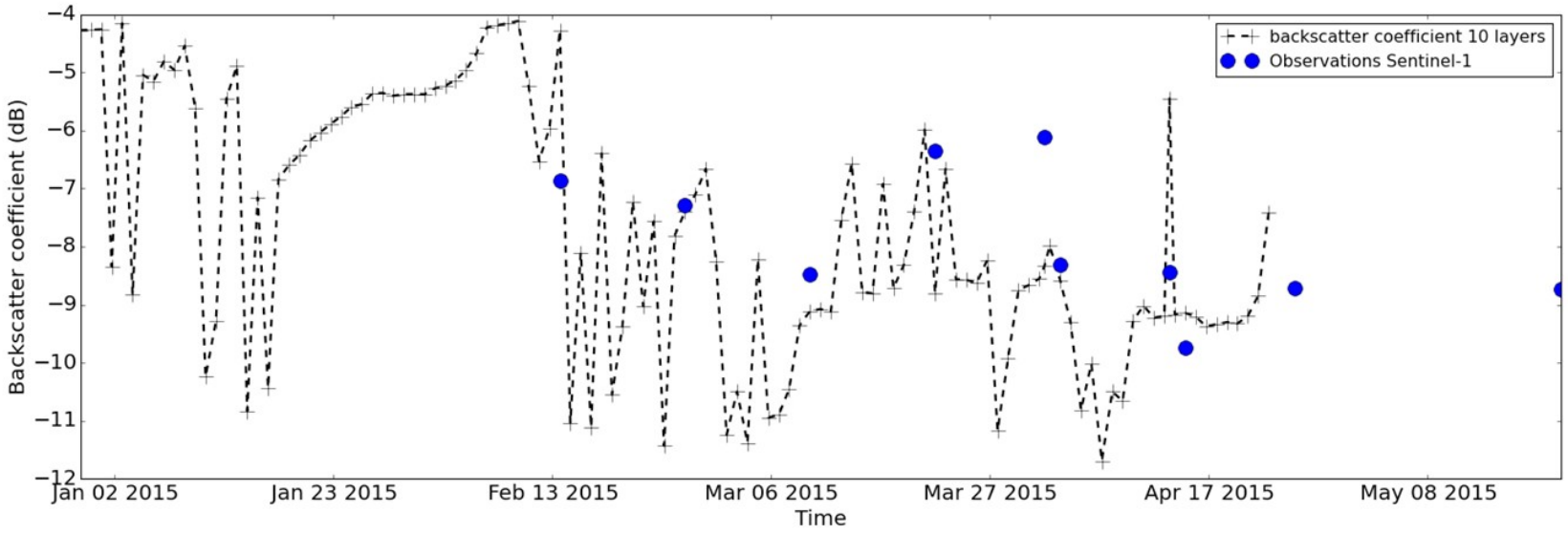
- Comparison between the simulated backscatter coefficient and the snow liquid water fraction of the snowpack (beginning of 2015/2016 season)

2015/ 2016

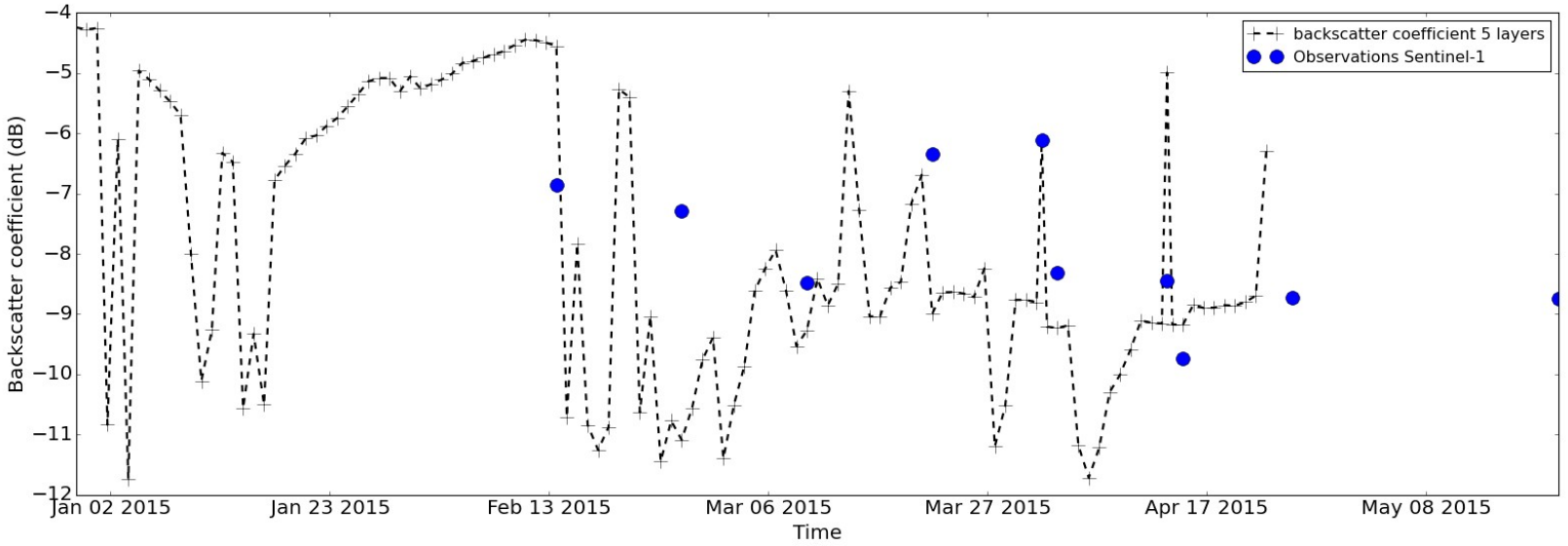


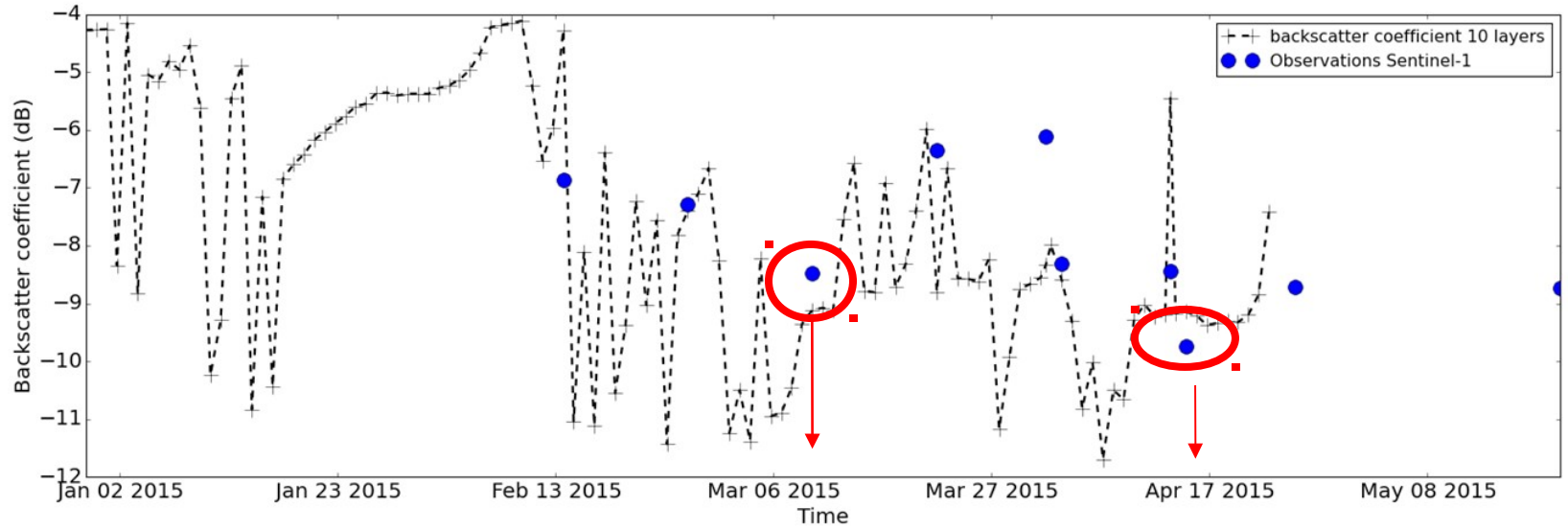
Simulations versus observations





Simulations versus observations





March 09, 2015

April 14, 2015

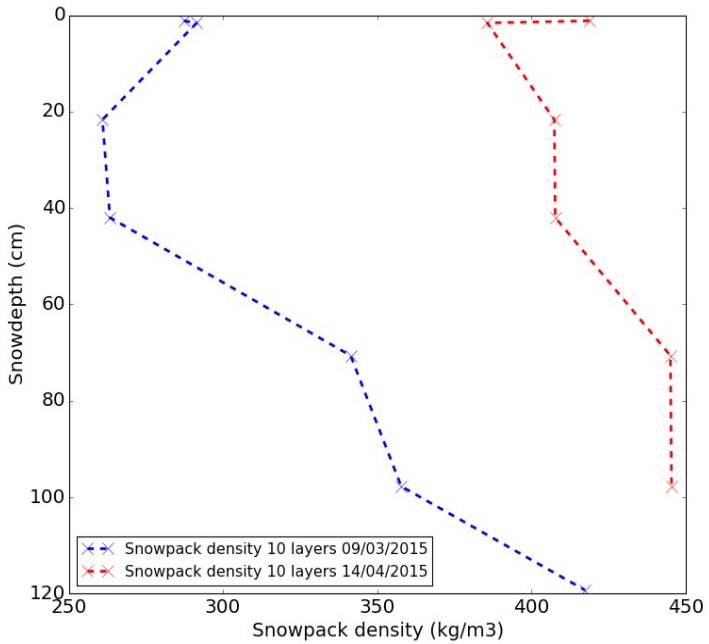
Simulations of snow properties

- Simulations of snow properties for two different times with different backscatter coefficient values

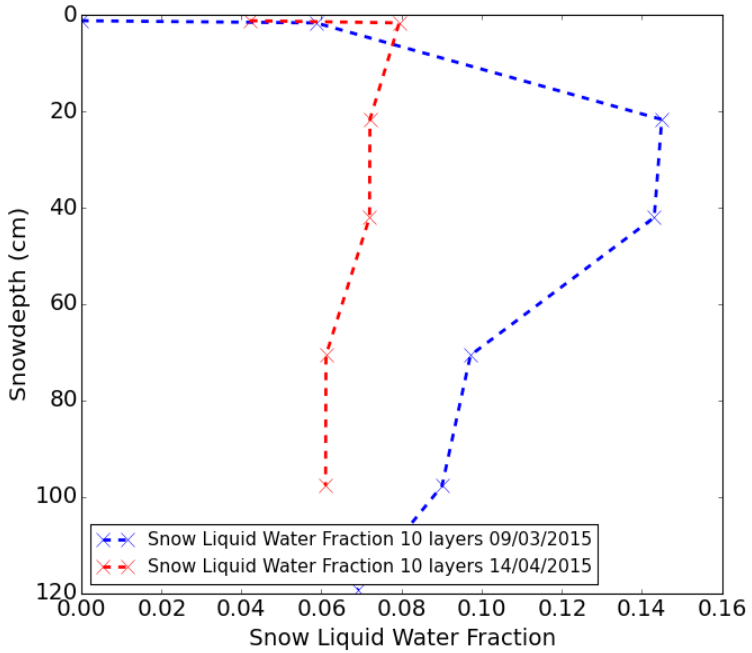
Backscatter coefficient March,09 2015 ~ -6.5 dB

Backscatter coefficient April,14,2015 ~ -10 dB

Density



Snow liquid water fraction



- The density of the snowpack is lower in March,09,2015 than in April,14,2015
- The Snow Liquid Water Fraction of the snowpack is higher in March,09,2015 than in April,14,2015

Summary & Perspectives

- Simulations made **ponctually** in this study but we wish to **extend it to larger alpine regions**

- Use of **Sentinel-1 SAR active observations** for this study → wish to use active/passive observations from **Ka-band (35.75 GHz) Saral/AltiKa altimeter** but also active/passive data from **L-band (1.20 GHz) SMAP radar/radiometer** for example;

- The simulations are **coherent with in situ measurements** from the experimental site of Météo-France at Col de Porte **and also with Sentinel-1 observations**

- Better understand how the backscatter coefficient is linked to different properties of the snowpack like the number of layers, the density or the snow liquid water fraction

Thank you for your attention !