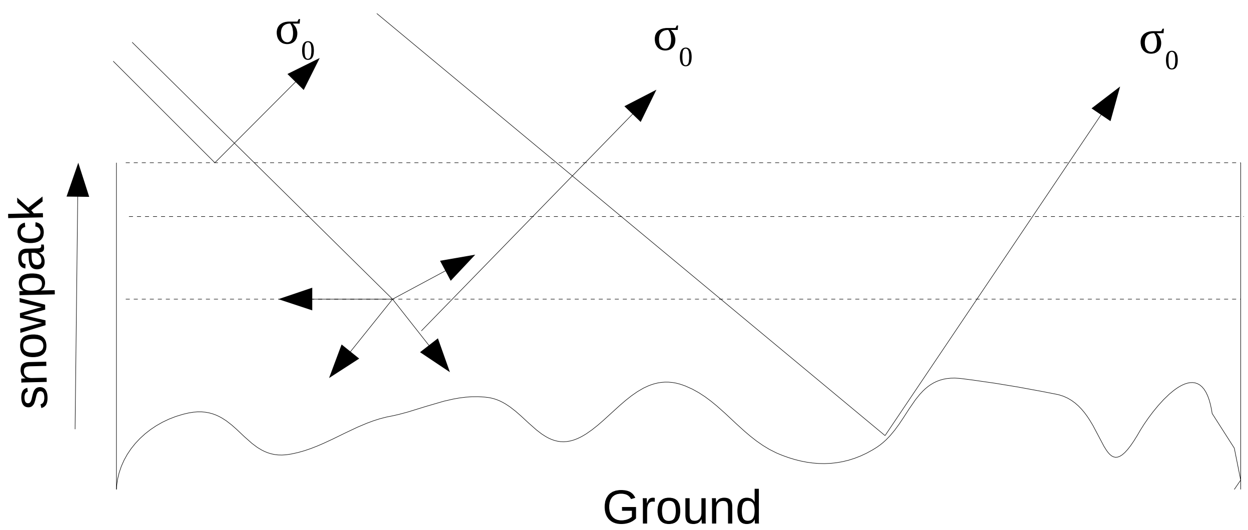
CNRM UMR 3589

Evaluation of sub-kilometric numerical simulations of C-band radar backscatter over the french Alps against Sentinel-1 observations

Gaëlle Veyssière, Fatima Karbou, Samuel Morin, Matthieu Lafaysse
Monterey, July 20th 2017

Introduction

- **Microwave remote sensing of snow :**
  - → Not affected by weather nor day/night periods
  - → Some frequency bands especially relevant for snow study
  - → Microwave signal varies with snow properties
- **Frequently used in the past :**
  - → Mapping of snow extent, seasonal snow
  - → Differentiation between dry and wet snow



Examples of contributions from the snowpack and the ground to the backscatter signal

Introduction

- L-Band (1-2 GHz)
- C-Band (4-8 GHz)
- X-Band (8-12 GHz)
- Ku-Band (12-18 GHz)
- Ka-Band (26,5-40 GHz)

→ **The penetration depth decrease with increasing frequency and the snow moisture**

- **With C-band : small effect of dry snow, very sensitive to wet snow**

Rott and Mätzler, 1987 ;Fily et al., 1995 ;Shi and Dozier, 1997 ;Bagdadi et al., 1997 ;Koskinen et al., 1999 ;Shi and Dozier, 2000 ;Bagdadi et al., 2000; Magagi and Bernier, 2003 ;Sun et al., 2004; Longépé et al., 2008 ; Pivot, 2012 ; Dedieu et al. 2015

Introduction

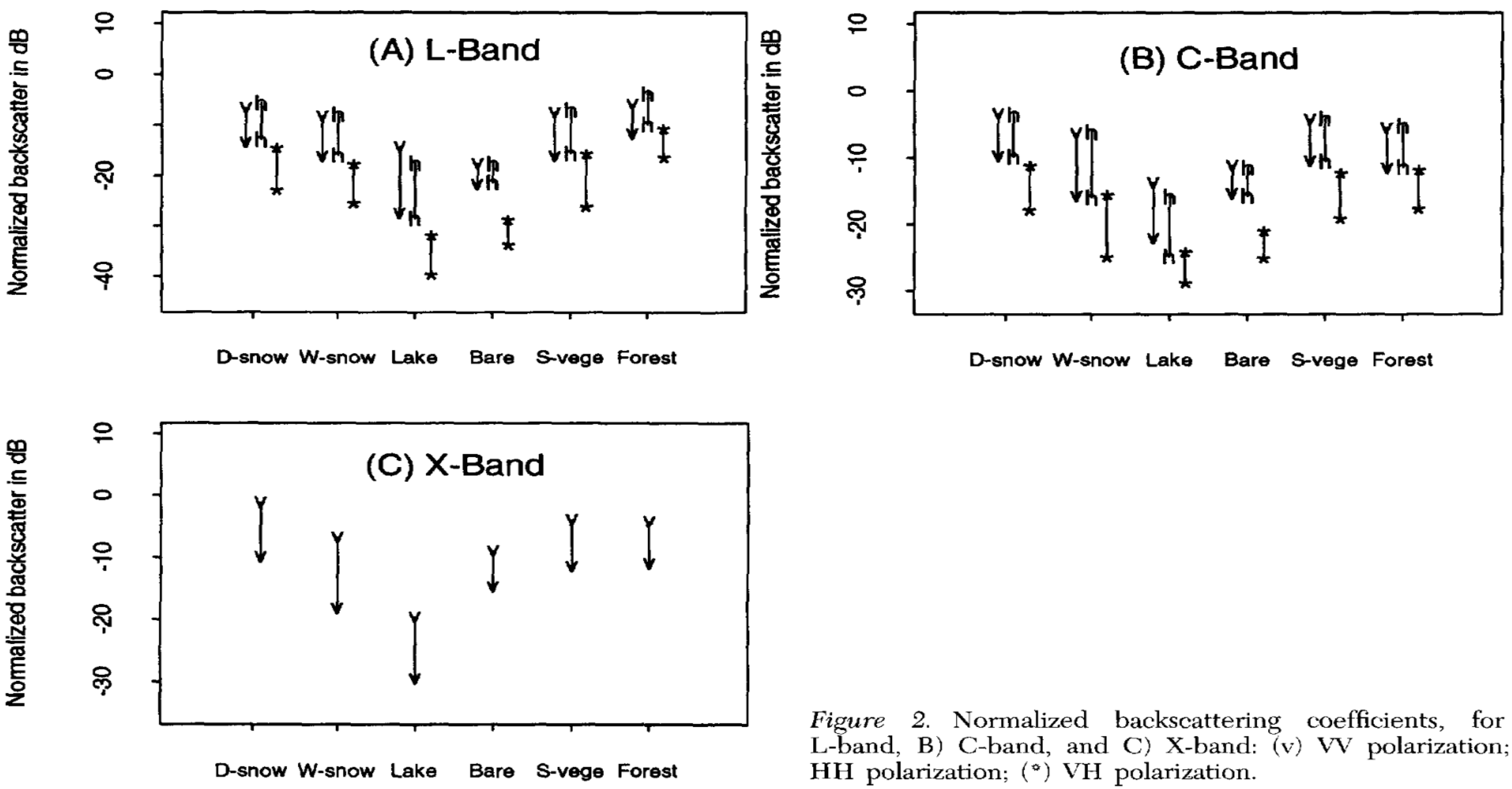
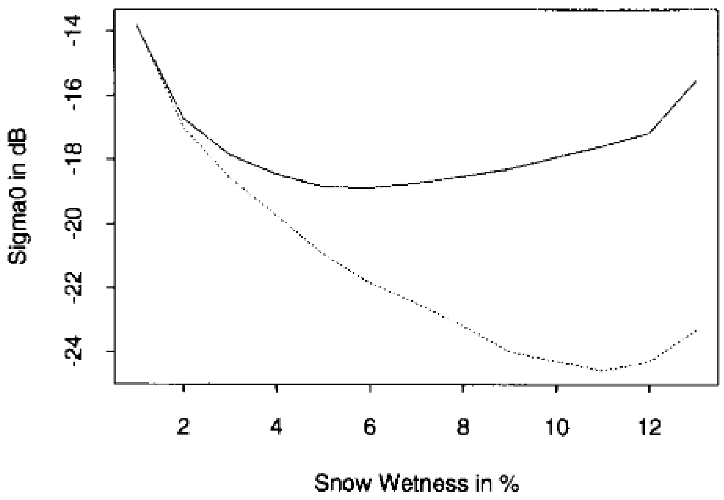


Figure 2. Normalized backscattering coefficients, for A) L-band, B) C-band, and C) X-band: (v) VV polarization; (h) HH polarization; (*) VH polarization.

Shi and Dozier, 1997

Introduction

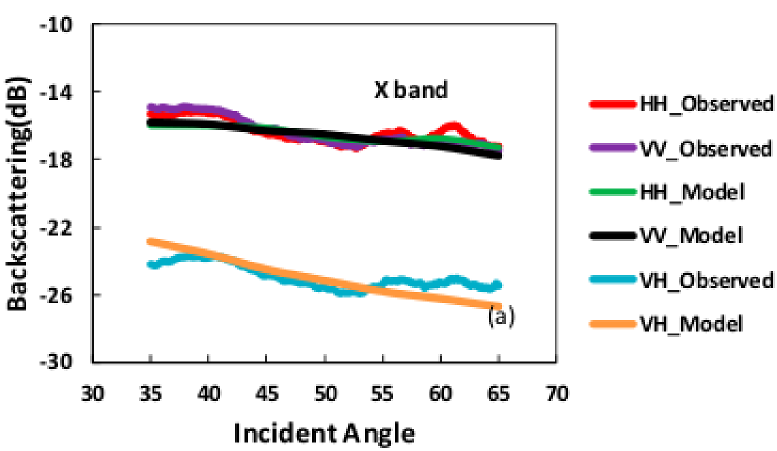
Shi and Dozier, 1995

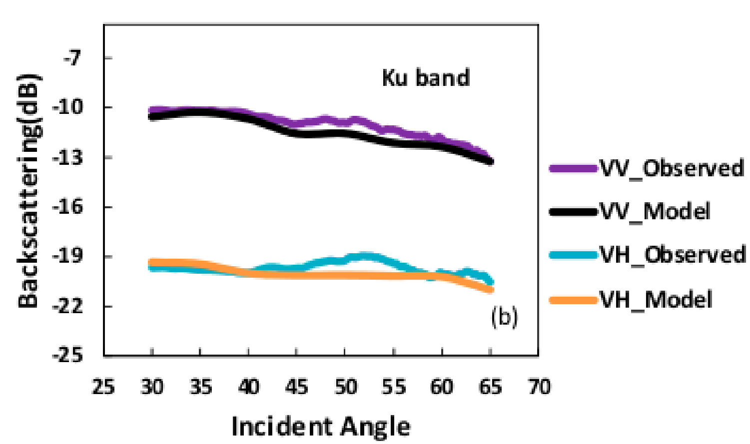


Relation between simulated C-band backscatter signal at polarization VV and snow wetness and snow/air interface roughness

Influence of the incidence angle on the backscattering coefficient : X and Ku-bands

Cui et al., 2016





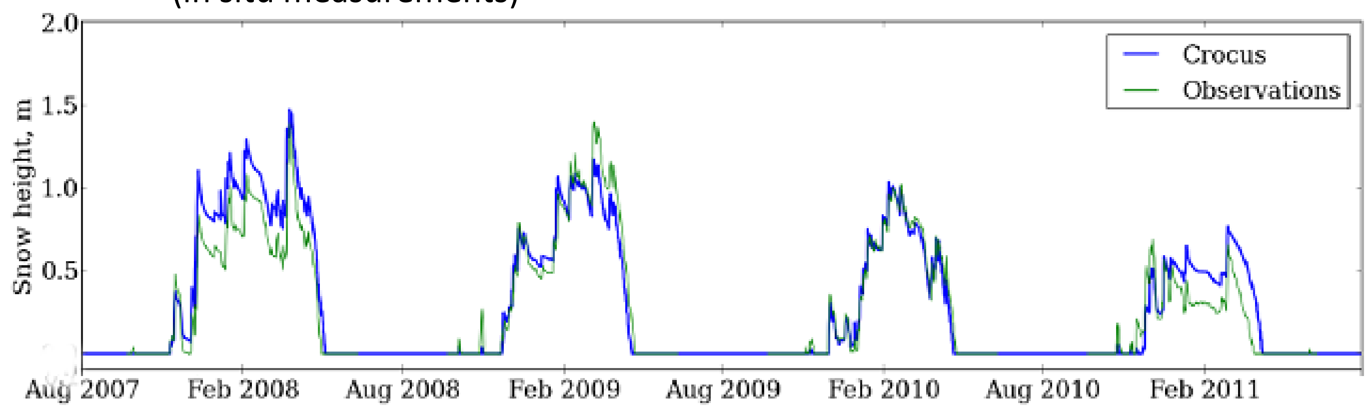
Introduction

Meteorological forcing → SURFEX/Isba-Crocus → Snowpack physical properties simulated

- Currently, Crocus does not assimilate any observations all along the snow season

  → Accumulation of errors inside the snowpack model

Example for the instrumental site of Météo-France at col de Porte
(in situ measurements)



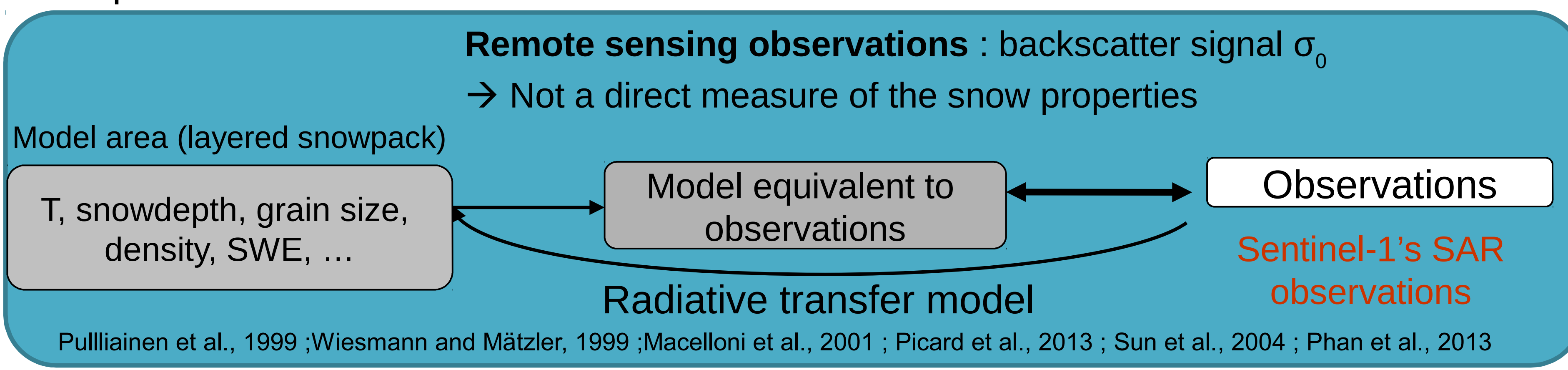
Introduction

PhD objective : Assimilation of Sentinel-1 SAR data over the french mountainous areas into the snowpack model Crocus

- Sentinel-1's C-band :
  - Relevant to study the wet snow evolution
  - Snow liquid water content : significant for the avalanche forecast
  - Continuity of Sentinel-1 observations ⇒ opportunity to consider operational assimilation

- To understand and to simulate the impact of snow properties on the microwave signal

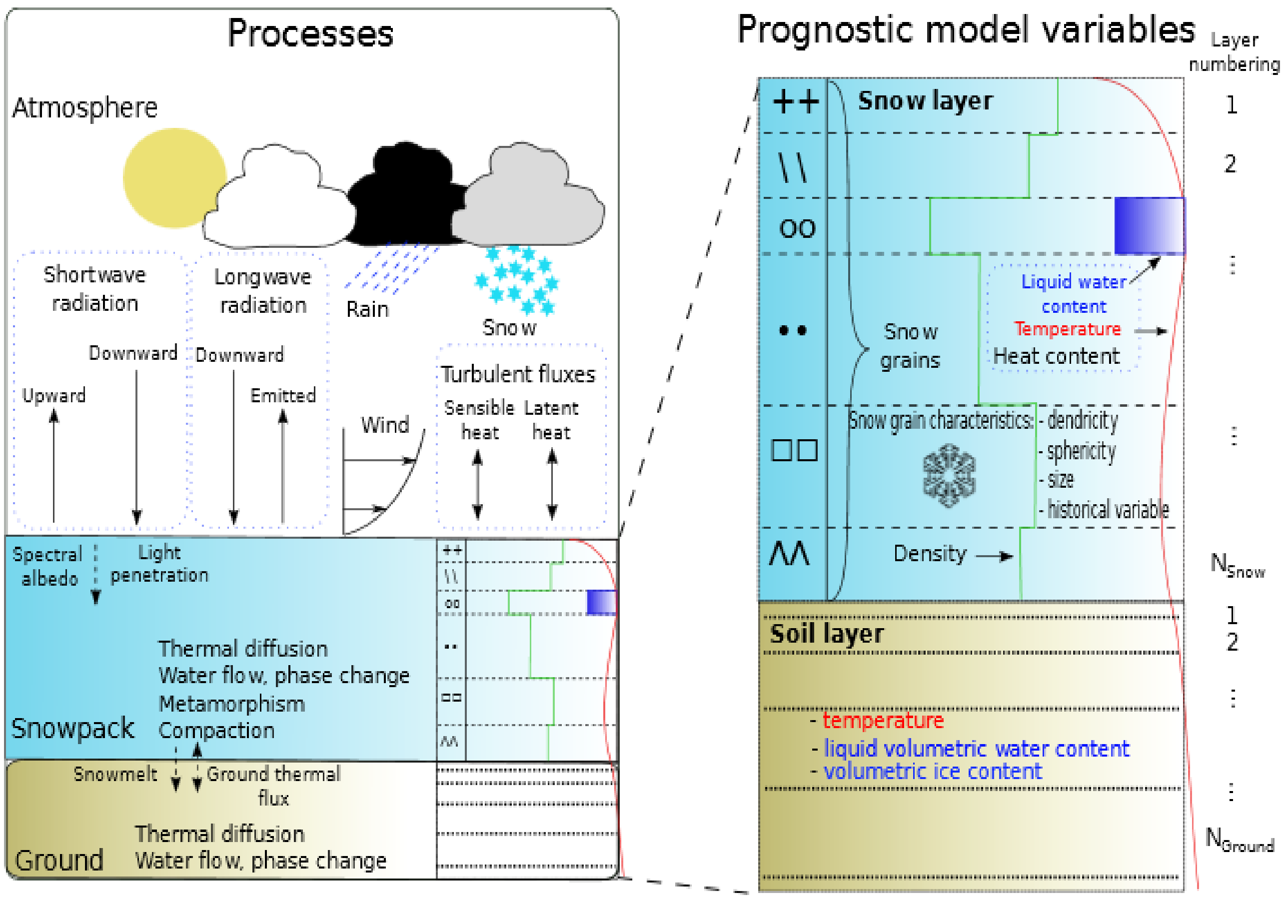
- Evaluation of the association of various micro-wave bands to caracterize snow properties : L-band(Alos-2), C-band(Sentinel-1), X-band(TerraSAR-X)
- To develop an relevant data assimilation method to assimilate Sentinel-1 data



Models and data

Crocus

- Numerical snowpack model
- One dimension and vertically layered snowpack simulations
- Coupled to ISBA ground model
- Provide a description of the snowpack properties
- Choice of the number of layers : 50 layers available



Vionnet et al., 2012

Models and data

- **MEMLS : Microwave Emission Model of Layered Snowpacks**
(Wiesmann, A and Mätzler, C, 1999; Proksch et al., 2015)

- Radiative transfer model for snowpacks based on a 6 flux theory → takes into account the various absorptions, reflexions and scattering between each layer of the snowpack
- **Inputs** : → simulations of snowpack state variables from Crocus (temperature, density, correlation length, layers thickness, liquid water content)

  → soil properties

  → instrument characteristics (incidence angle, frequency of acquisition)
- **Outputs** : backscatter coefficients displayed for the wanted polarization (active mode)

Models and data

Sentinel-1's observations

→ ESA Mission

→ Two satellites orbiting 180° apart

→ Revisit time of 6 days since October 2016 with Sentinel 1-B

→ Polar orbit, at an altitude of ~700 km

→ **Radar instrument onboard**

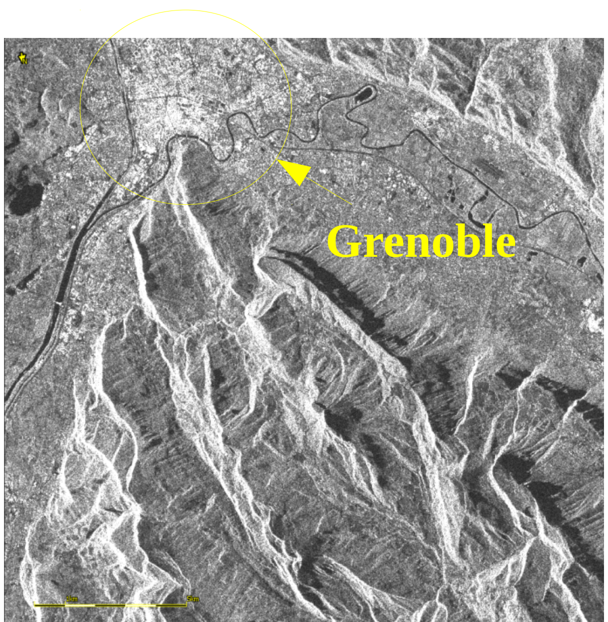
Synthetic Aperture Radar (SAR)

- C-band, central frequency : **5,405 GHz**
- Single polarizations (VV ou HH) or double (VV+VH, HH+HV)
- Swath : **250 km**, resolution : **20m**
- Various operational modes : selection of the Interferometric Wide Swath
- Type of product : GRD (Ground Range Detection)

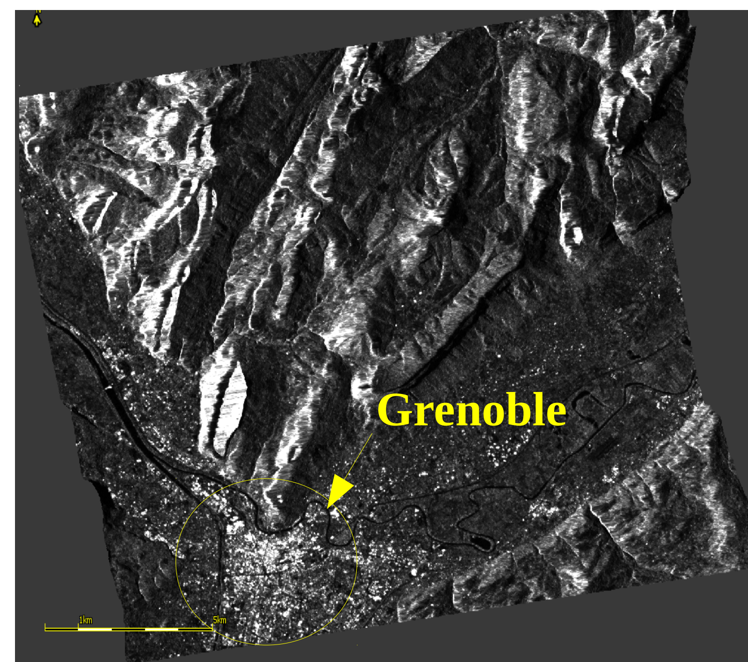
Models and data

- Pre processing for Sentinel-1 SAR data
  - → Level-1 SAR products, available for free
  - → Need to realise the pre processing of S1 SAR data before working with it

Example of pre processing realised on a raw image around Grenoble in the northern french Alps



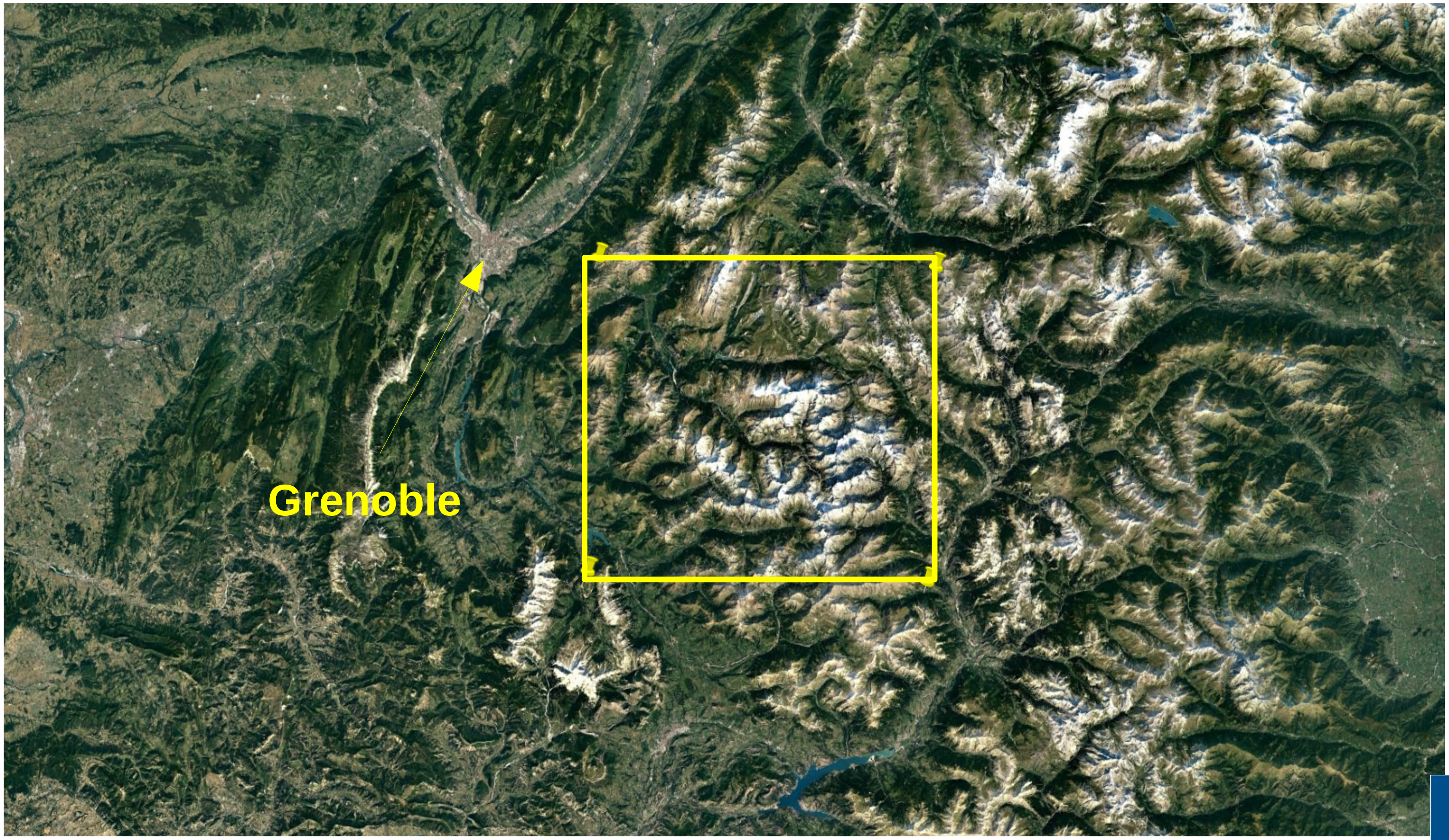
- **Radiometric calibration : from intensity to backscatter coefficient**
- **Speckle filtering : reduce speckle noise**
- **Terrain correction with IGN's 2008 25 m resolution DEM**



SAR Sentinel-1, 22/02/2015, 20m

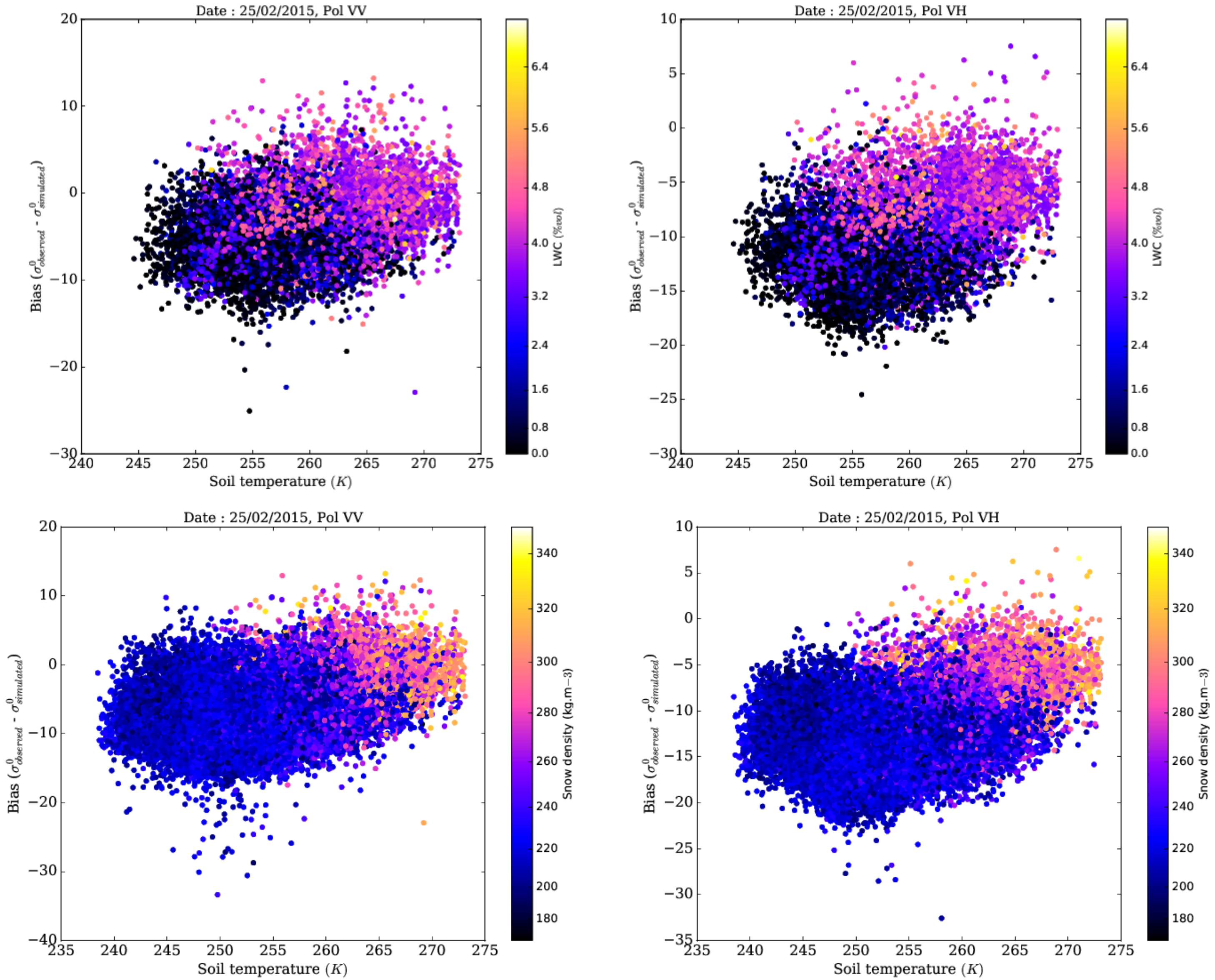
Results

- **Two snow seasons** : 2014-2015 and 2015-2016
- **Crocus configuration :** 20 layers
- **2D simulations** over the yellow area below **in the northern French Alps** → many mountainous areas, spatial variability



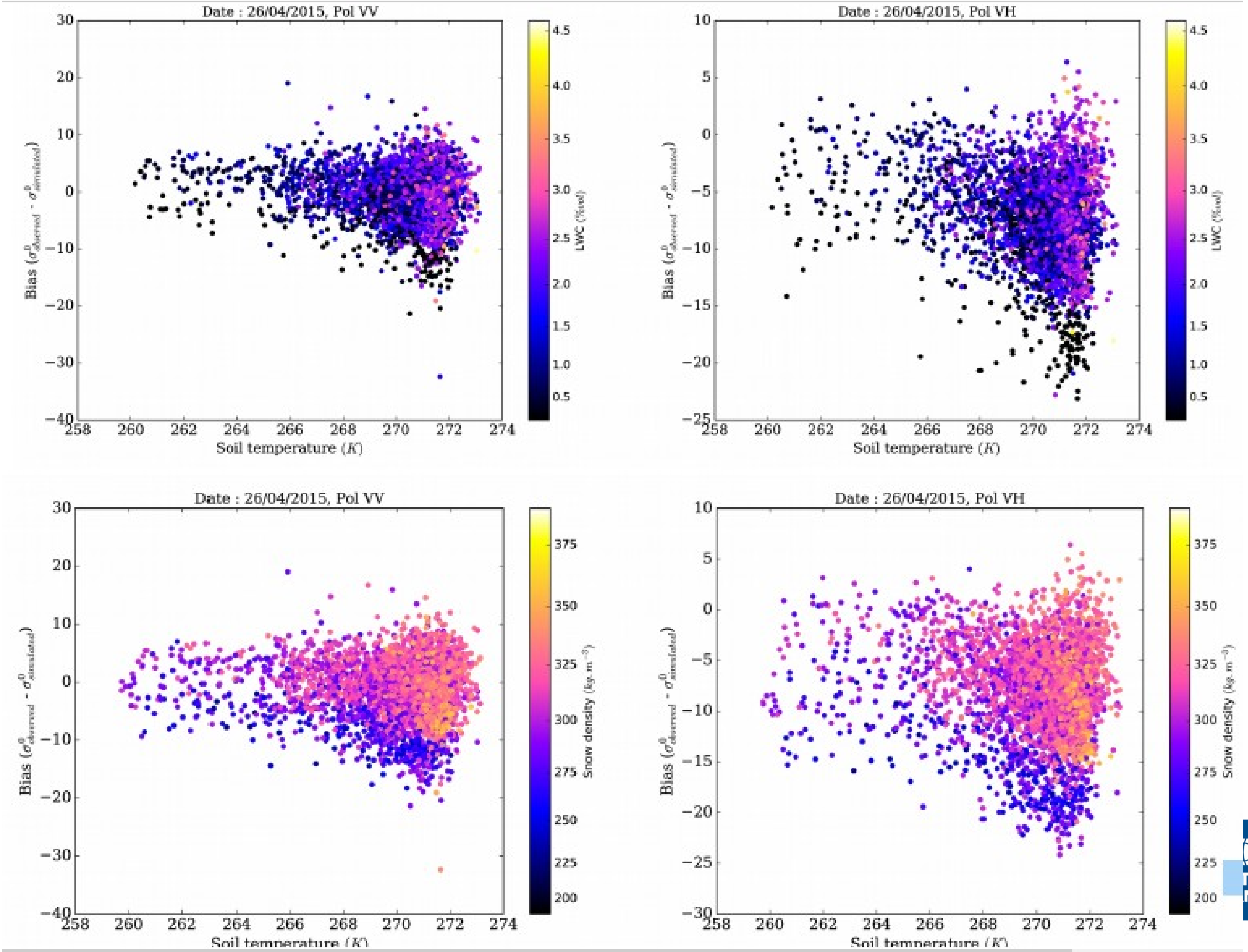
Results

Illustration of the difference between observations and simulations in terms of snow and soil properties for a selected date in winter : 25/02/2015



Results

Illustration of the difference between observations and simulations in terms of snow and soil properties for a selected date during the melting period : 26/04/2015

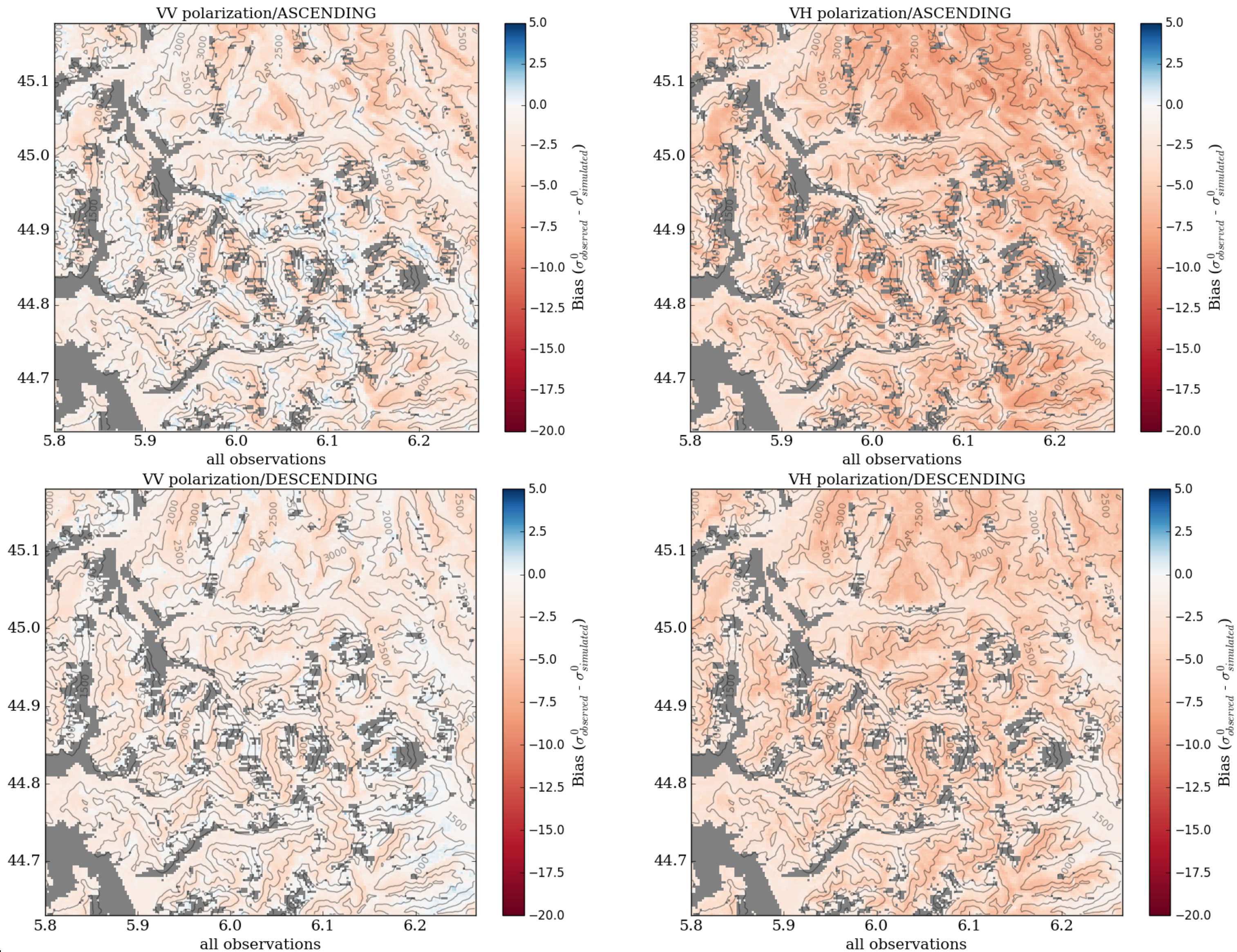


Results

Statistics over two seasons == > bias, RMSE and correlation maps for VV and VH polarization

ASCENDING ORBIT

DESCENDING ORBIT

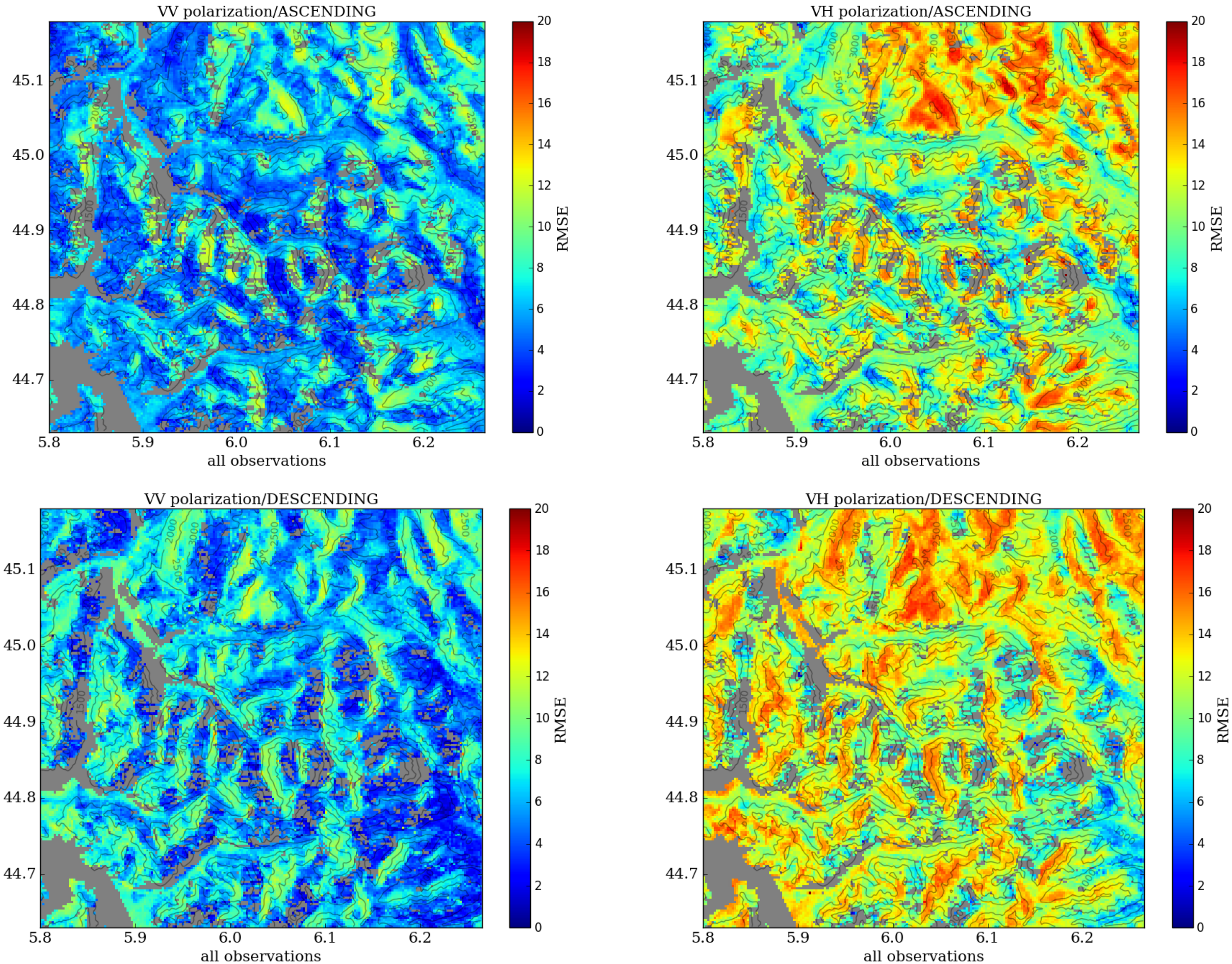


Results

Statistics over two seasons == > bias, RMSE and correlation maps for VV and VH polarization

ASCENDING ORBIT

DESCENDING ORBIT



FRANCE

Conclusions and futur improvements

- Promising results of simulations of the backscatter coefficients compared to Sentinel-1 SAR observations over a 50 km² area in the northern french Alps ==> the model chain Crocus-MEMLS is relevant to simulate C-band Sentinel-1 backscatters (soil and snow)

  ==> More results in Veyssiere et al., Evaluation of sub-kilometric numerical simulations of C-band radar backscatter over the French Alps against Sentinel-1 observations, 2017, in prep

- Study the seasonal variability of the backscatter coefficients (obs, sim) near in-situ station measurements (4 stations inside the area of interest)

- Study the complementarity of other bands to characterise snow properties: X, L bands
- Improve preprocessing of Sentinel-1 data: geometric corrections (TandemX DEM - DLR)
- Use of high resolution products (land cover) to evaluate the model chain over forests areas

- Development of a data assimilation method to assimilate Sentinel-1 SAR backscatters in the snowpack model Crocus (particle filter (Charrois et al. 2016), Ensemble Kalman Filter...)