PolarMonitoring study: WP3 CRISTAL performance analysis over snow surfaces

Outcomes

Outcomes summary

CLS

Outcomes in the CRISTAL context

Summary of the study

- **SMRT & AltiDop were combined to simulate altimetry measurement in multiple configurations:**
  - Accounting for the interaction between radar wave & snow **(=> SMRT)**
  - Accounting for surface topography at scale > 1 meter. Possibility to include realistic ice sheet topography (REMA).
  - Simulation possible in LRM & SAR, power waveforms [$I^2 + Q^2$]
  - Simulation possible in Ku & Ka bands. Ka band modelling could be improved by integrating 2nd order scattering (see Ghislain's presentation)

- **AltiDop was also converted from script code to object-oriented code,** making it more "modular" and facilitating the coupling with SMRT (both python codes)

- **By slightly tuning snow parameters in realistic range of values, it was possible to fairly reproduce the acquisitions of real altimeters** (Sentinel-3A, CryoSat-2 & AltiKa configurations - lake Vostok conditions)

- **A first sensitivity study was conducted over ice sheet surface *(see following slides)***

- **But sea-ice surface not yet addressed *(see perspectives)***

WP3 summary

Screenshot of the main python program running AltiDop & SMRT: modularity !!!

```python


################################################################################
##################### Starting AltiDop 2020 ####################################
################################################################################


# 1 - Reading simulation parameters
run_p    = read_param.configAD('./parameter_files/global_parameters_lrm.ini')

# 2 - Reading sensor parameters
sensor_p         = radar_sensor_def.cristal_ku_cb()
sensor_p.ngate   = 128                   # Number of simulated range gates


# 3 - Calling SMRT
# "smrt_call" is a function designed to be in interface between AltiDop & SMRT
volume_signal         = smrt.smrt_call(sensor_p, run_p,temperature=220, radius=0.000225, density=320, mss=0.03)


# 4 - Scene generation
scene_o, orbite_o = scene_modules.build(run_p, sensor_p)

# 5 - Radar equation computation
radargram_o         = waveform_modules.Radargram(orbite_o, run_p, sensor_p, volume_wf_smrt=volume_signal) # initialisation
radar_equation_modules.computation(run_p, sensor_p, scene_o, orbite_o, ind_orbite)

# 6 - Waveforms / Radargram generation
radargram_o.main_waveform_generation(run_p, sensor_p, scene_o, orbite_o, ind_orbite)


# ---------------------- SAR mode operations -------------------------

# Range migration correction
radargram_o.range_migrations_sar(orbite_o, run_p, sensor_p, ind_orbite)

# SAR multilooking
radargram_o.multilooking()

# PTR convolution  + waveform subsampling
radargram_o.ptr_convolution(sensor_p, run_p, flg_lrm_f = 0 )

# Waveform subsampling
radargram_o.wf_range_subsampling(run_p, sensor_p, flg_lrm_f = 0)
```

CRISTAL sensitivity to snow parameters over ice sheets

- CRISTAL simulated measurements are sensitive to **snow grain size, snow density and surface roughness**.

- **These three parameters act differently on the waveform shape**, depending on the mode (LRM/SAR) and the frequency band (Ku/Ka). For instance SAR Ka band waveform shape is mostly sensitive to snow grain size. *=> Results to be confirmed & refined*

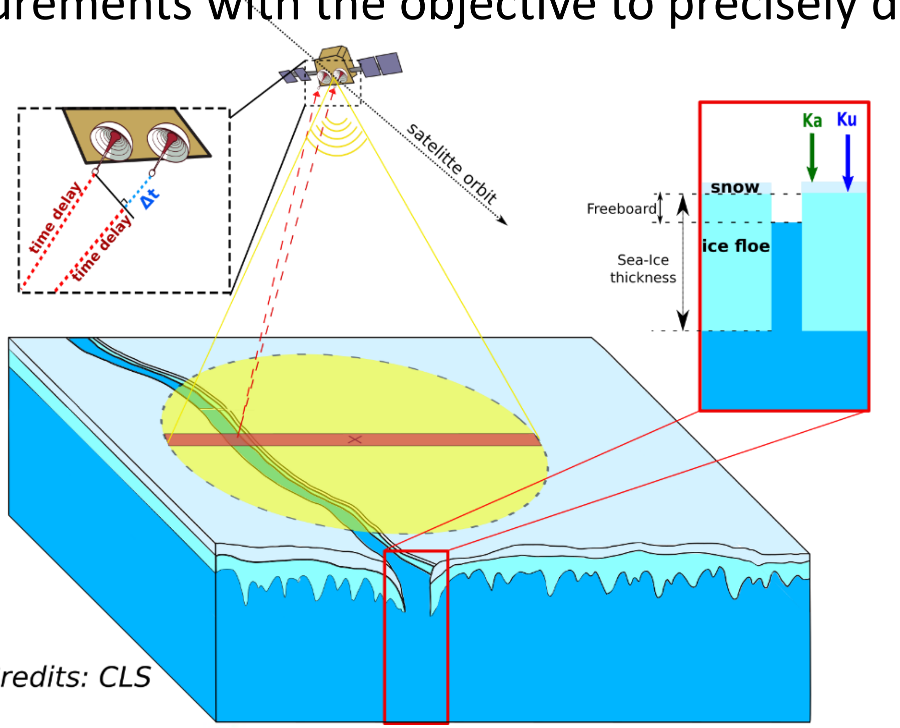
- A **dual band altimeter such as CRISTAL will be highly valuable to discriminate the different snow parameters** that modify the waveform shape over the snow surface.

- **The additional effect of the surface topography, at different scales, even more complicates the problematic over ice sheets,** by also modifying radar waveform shape. But that could be tackled with the new high resolution DEMs for large scale effects. Metric & sub-metric effects still to be clearly understood.

- **Due to the narrow antenna aperture (0.46° at -3dB), Ka band will be more sensitive to surface slope than Ku band**, and waveform leading edge will be disrupted from 0.5% of surface slope (LRM). Over complex, irregular topographies, Ku & Ka measurements might not be co-located (to be studied).

Perspectives: Sea-Ice surface

- Sea-ice was weakly addressed in this study (lack of in-situ measurement to define snowpack parameters)
- But, based on the tools that have been developed, a relevant study addressing sea ice surfaces could be envisaged.
- Snow depth over sea ice and freeboard estimations (which estimation is closely linked to snow depth) are among the main objectives of the CRISTAL mission. Many questions have still to be addressed to efficiently exploit CRISTAL Ku/Ka measurements with the objective to precisely derive these parameters.

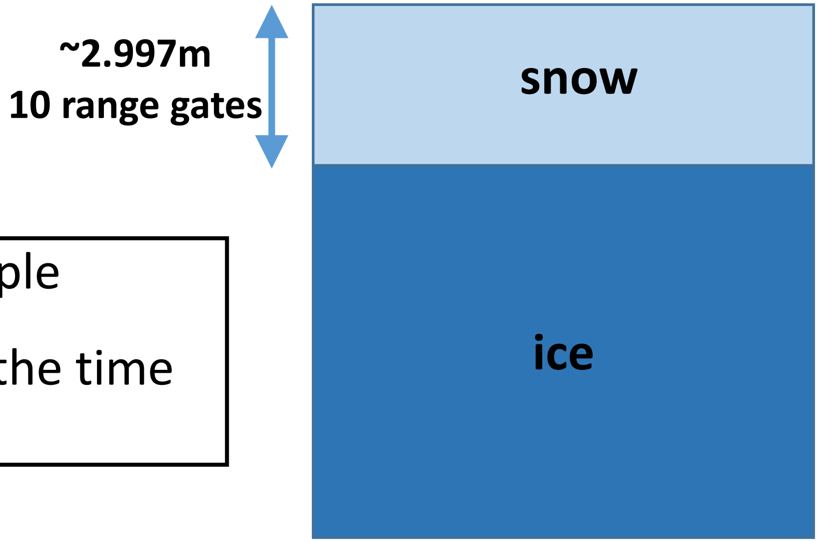


Credits: CLS

First analyses of Sea-Ice surfaces

First basic simulations over sea-ice, using a large snow depth to discriminate air/snow & snow/ice interfaces

- **CRISTAL LRM configuration**
- Without surface topography (**flat surface**)
- **MSS = 2e-5** (relatively arbitrary, used to match simulations with MYI acquisitions)
- **Snow over first year ice**: density = 200kg.m-3 / grain radius size = 100µm
- **Snow over multi year ice**: density = 350kg.m-3 / grain radius size = 300µm
- **Snow depth ~ 3 meters**



Air/snow interface is positioned at the 44th waveform sample

Snow/ice interface is positioned at the 54th waveform sample + the time delay due to the slower speed of radar wave in snow*

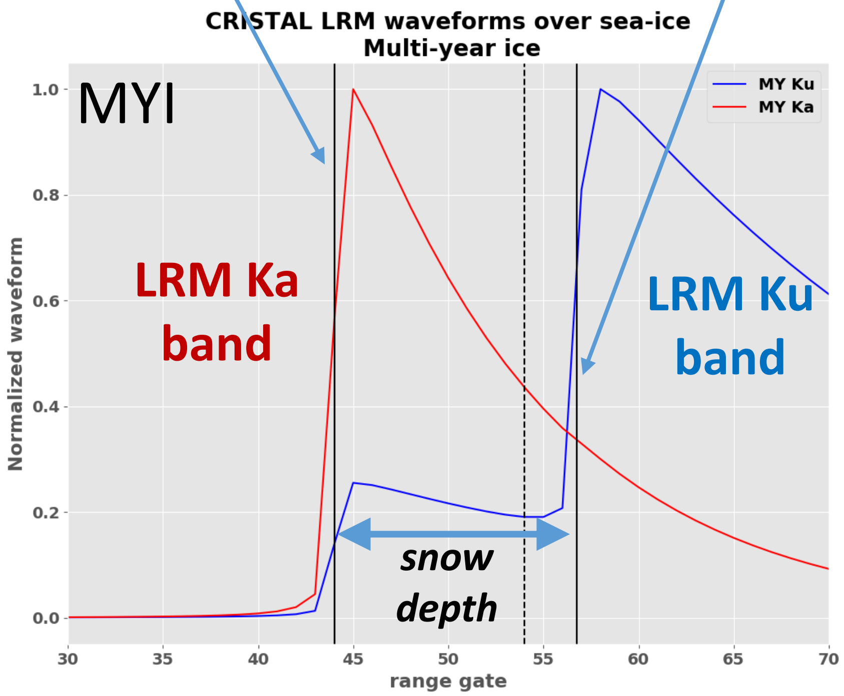
* *At a density of 300kg.m-3, propagation speed is ~0.81 times the speed of light. Varying the density by 100 kg.m-3 changes the speed of propagation by ~5% [Kwok et al., 2011]*

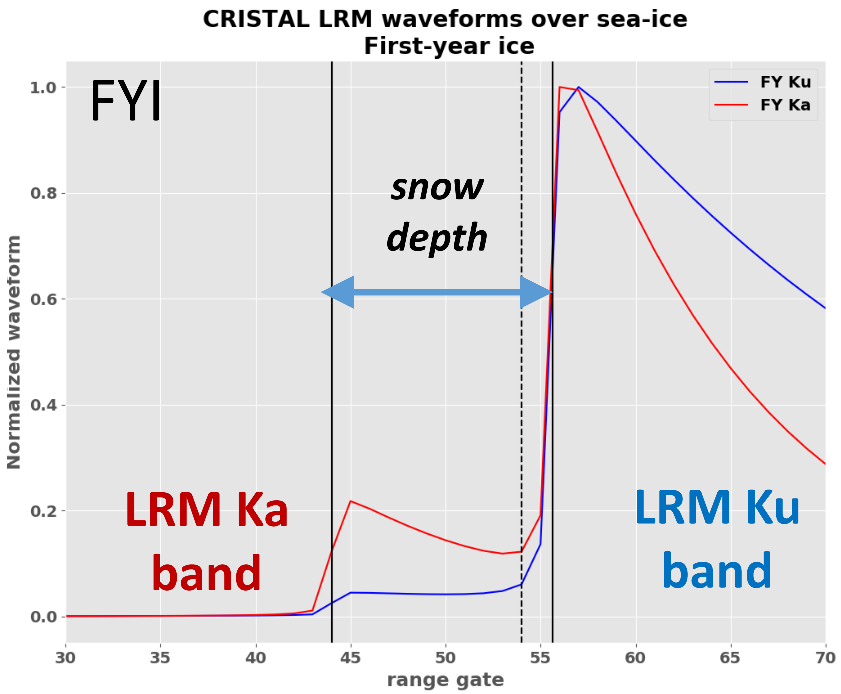
First analyses of Sea-Ice surfaces

First basic simulations over sea-ice, using a large snow depth to discriminate air/snow & snow/ice interfaces

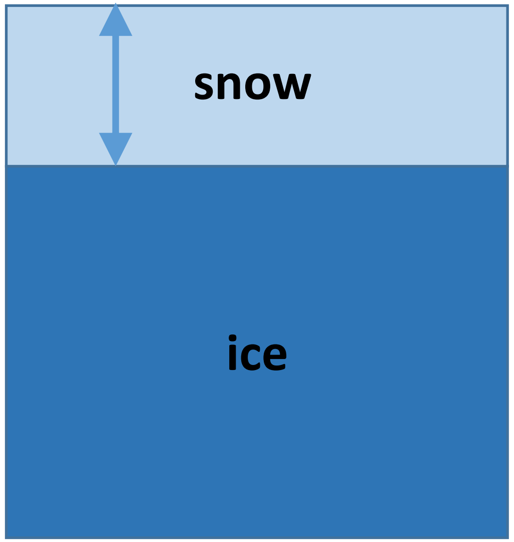
simulated air/snow interface

theoretical snow/ice interface





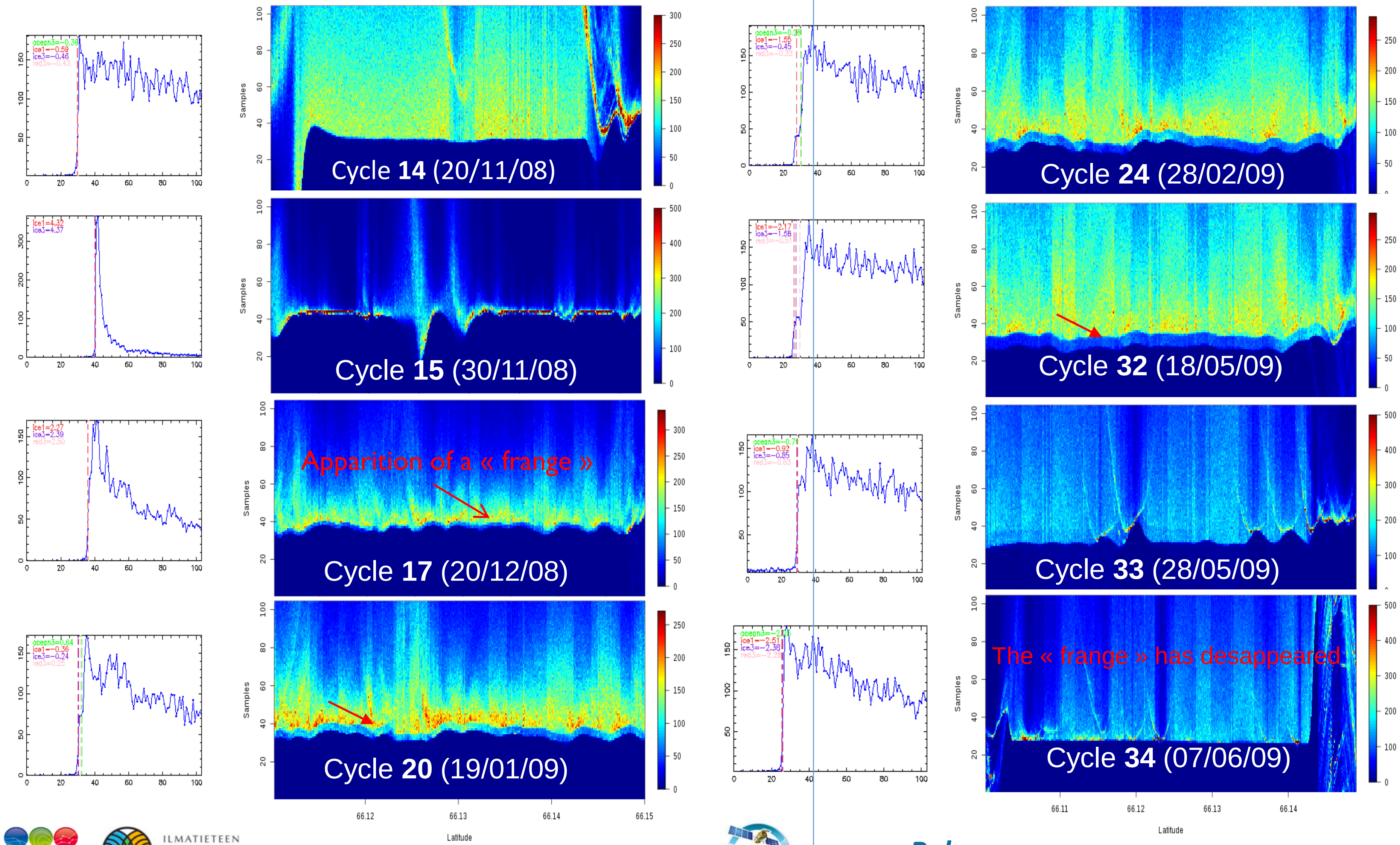
~2.997m snow depth
=
10 range gates
+ time delay due to slower radar wave celerity in snow



Be careful with interpretations as the snowpack parametrisation is relatively arbitrary !

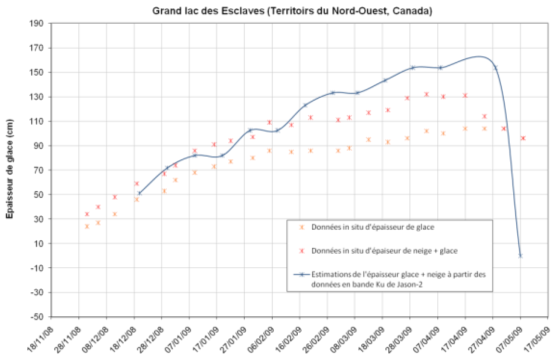
Analogy with Jason-2 data over lakes

Individual echo | 2D radargram | Individuel echo | 2D radargram



CLS study, 2009

Grand lac des esclaves, Canada

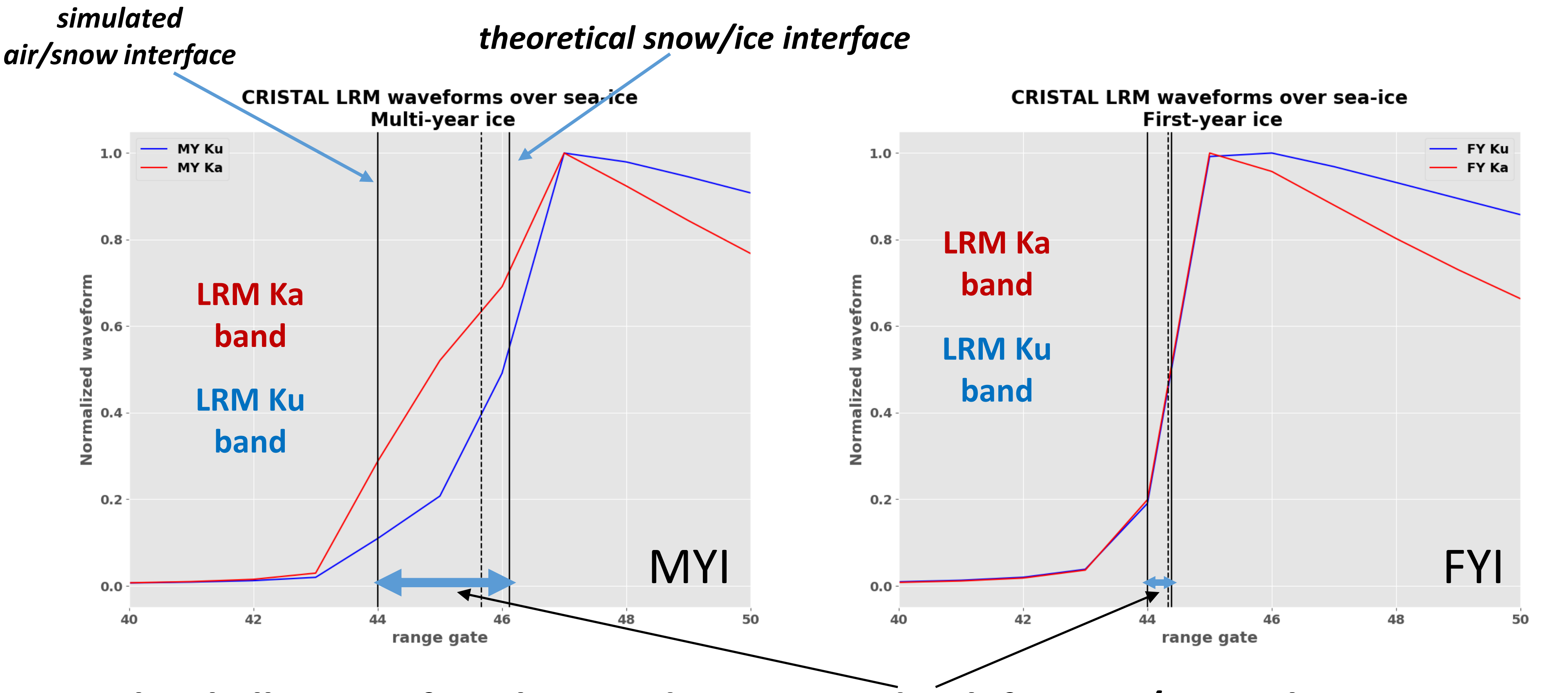


First analyses of Sea-Ice surfaces

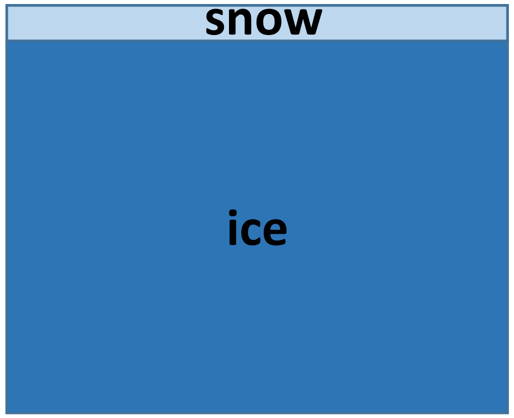
Using realistic snow depth values: 10cm in FYI ; 50cm in MYI

Snow over first year ice*: density = 200kg.m-3 / grain radius size = 100µm*

Snow over multi year ice*: density = 350kg.m-3 / grain radius size = 300µm*



10cm snow depth for FYI
50cm snow depth for MYI



The challenge to face: how to derive <u>snow depth</u> from Ku/Ka, with varying snow properties over space & time ?

Perspectives

=> See dedicated slides