

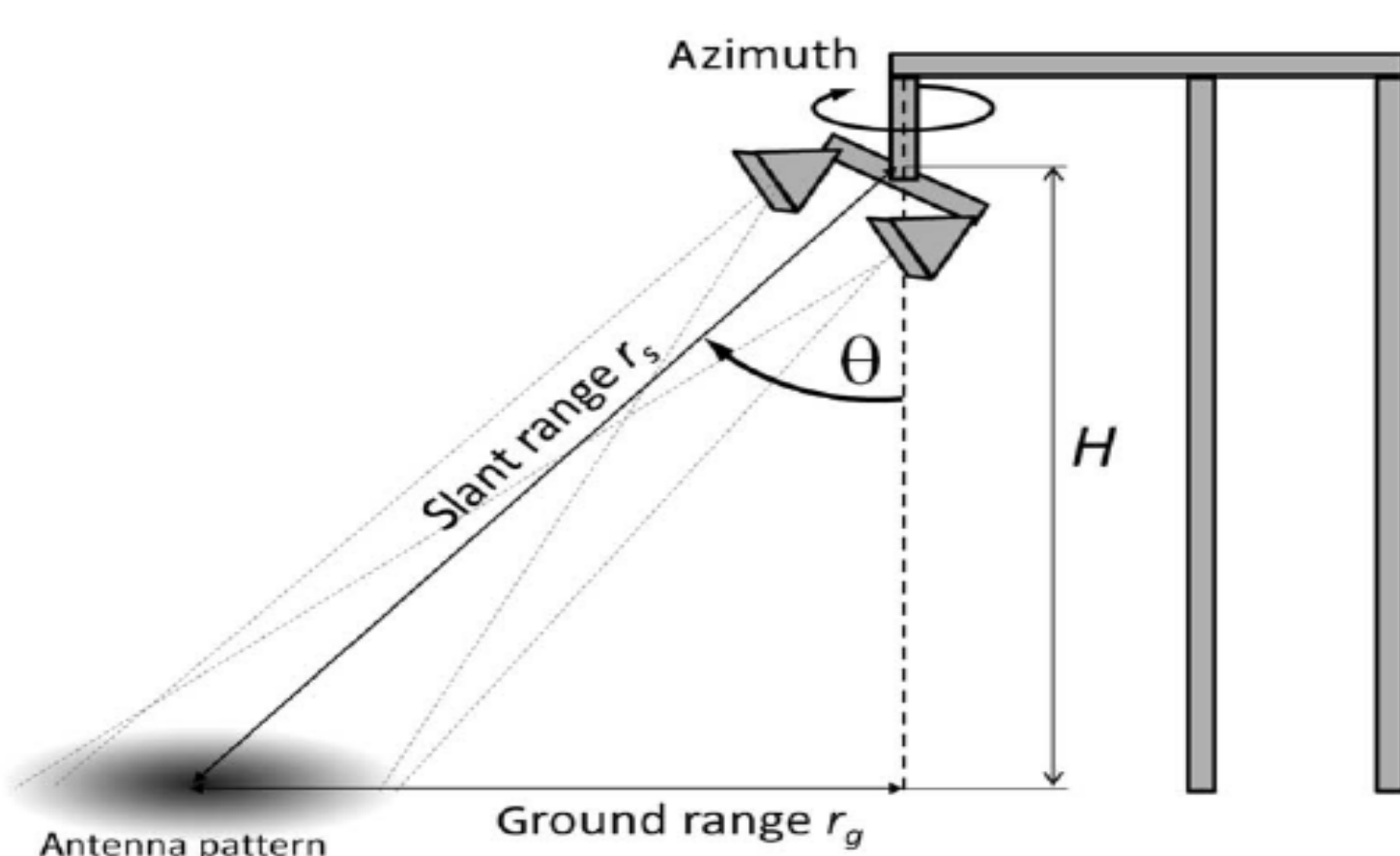
## MOTIVATION

This study concerns the computation of the Snow Water Equivalent (SWE), which is currently obtained by punctual measurements such as snow pit and Gamma Water Instrument (GWI). **Can radar satellite data be used to calculate SWE over a large area?**

From an autoregressive model (ARX) initialized during the first period of winter and the computation of differential interferometric phase, we show that the SWE can be obtained during the period of snow accumulation.

Thus, our method can be used with SAR satellites data over a large area with an 11-day revisit.

## DATA USED, TEST SITE AND COMPUTATION



### SnowScat Instrument (SSI) radar system (10.2 GHz)

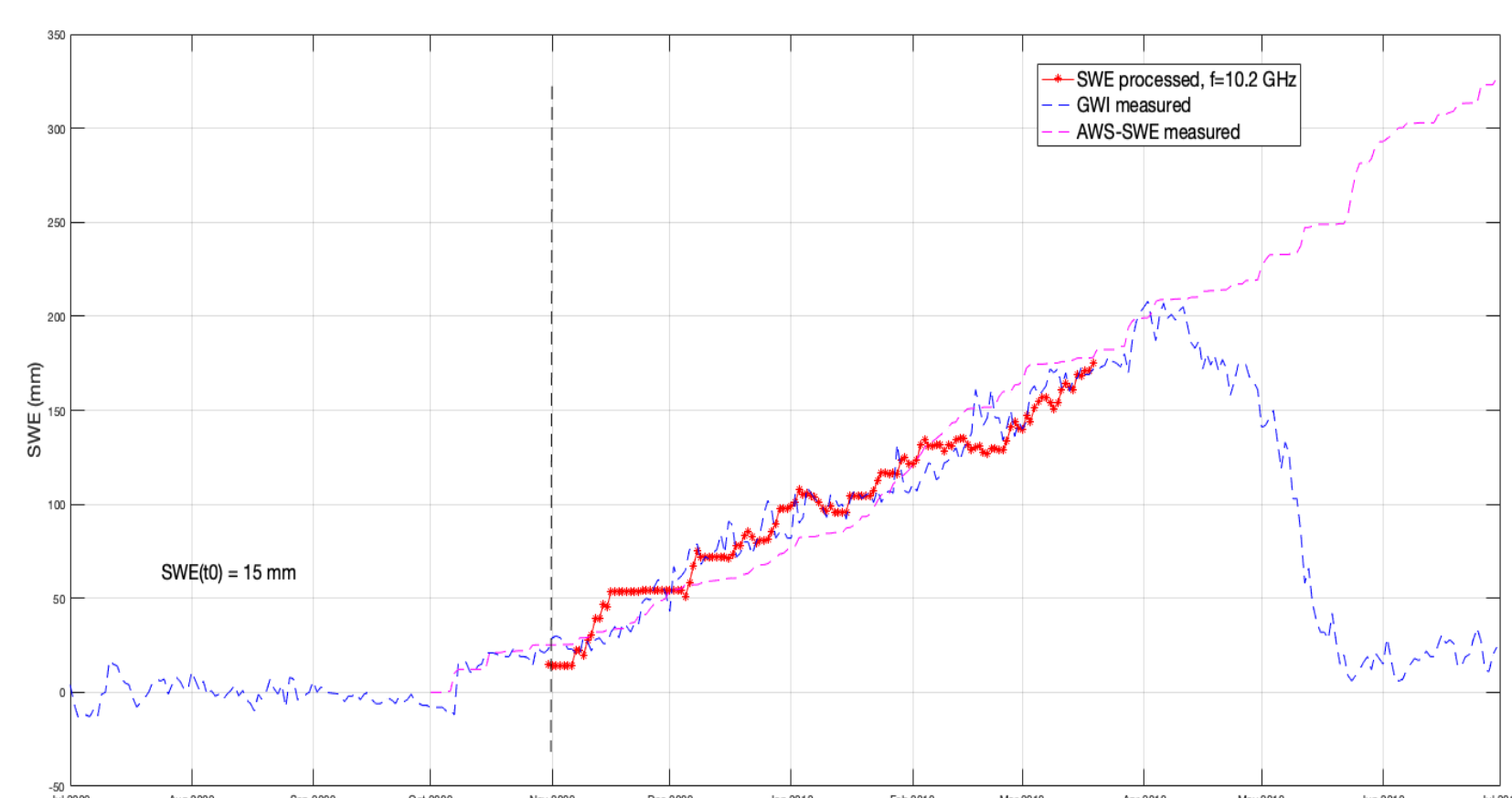
- Campaign: NoSREx (2009-2010),
- Sodankyla, Finland

### Meteorological data (precipitation, temperature) and GWI

### Computation of SWE (S. Leinss et al.)

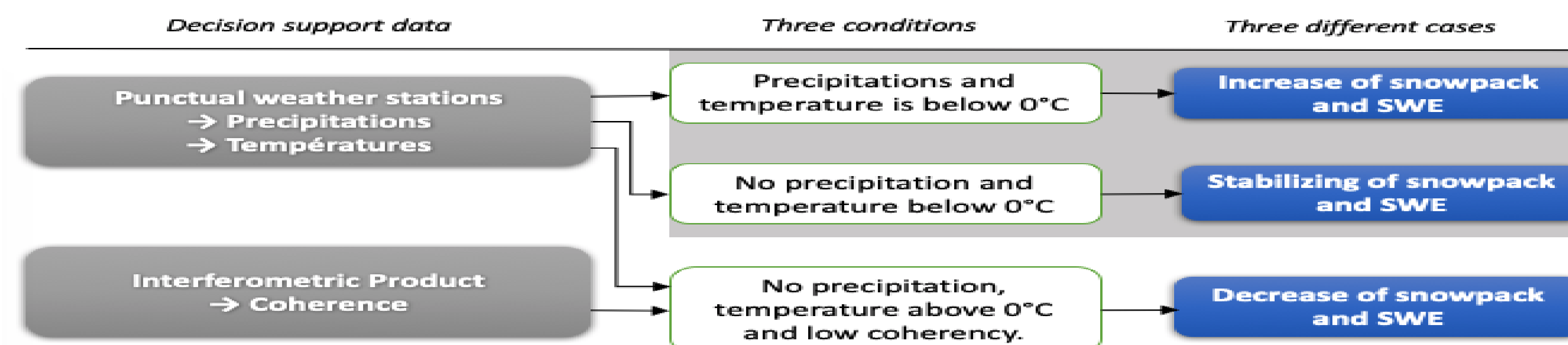
According calculating  $\Delta\Phi_s$ , by phase integration, the total phase difference was converted into  $\Delta SWE$  according to:

$$\Delta SWE(t, t_0) = \frac{\Delta\Phi_s(t, t_0)}{\alpha \cdot k_i (1.59 + \theta^{5/2})} \quad (1)$$



## SNOWPACK EVOLUTION

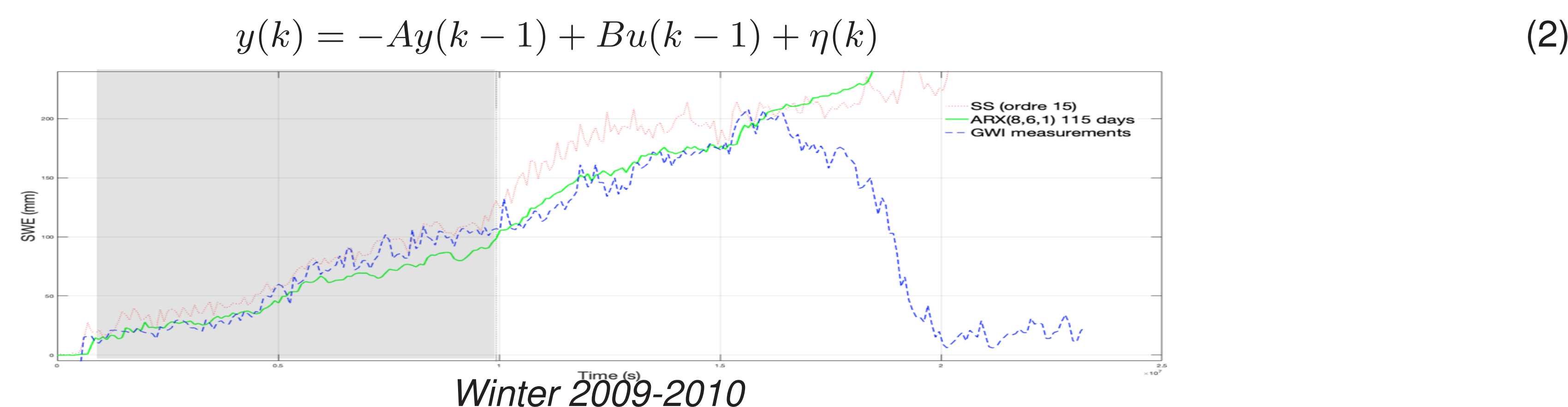
Three cases can be distinguished for the temporal evolution of snowpack (SWE).



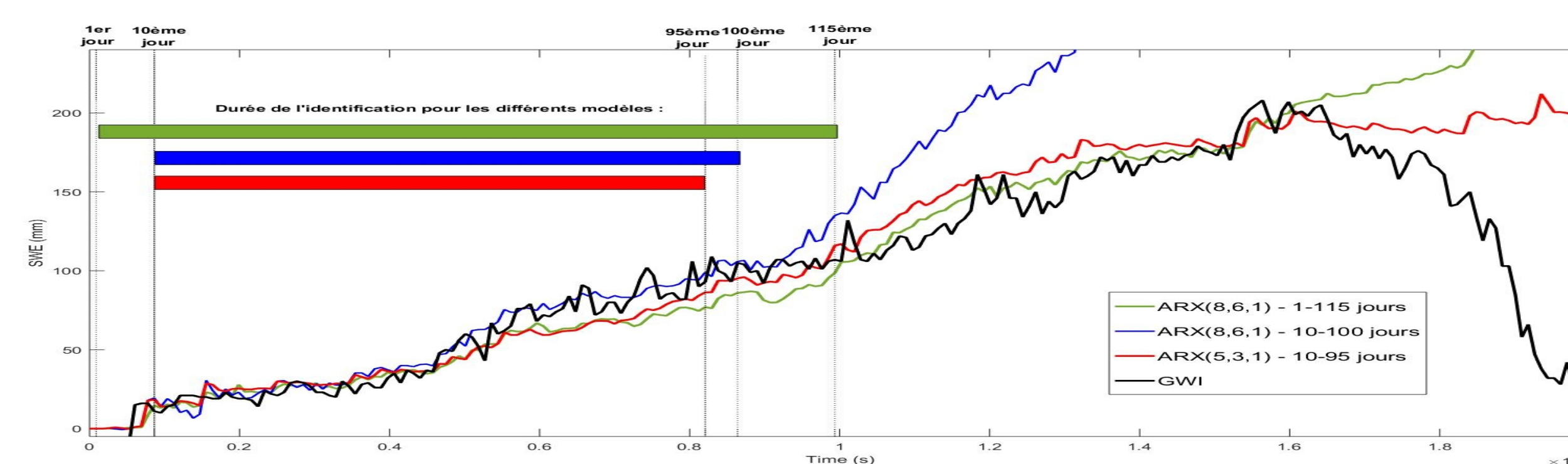
Our work focuses on increasing and stabilizing snowpack.

## MODEL IDENTIFICATION

The Auto Regressive model (eq. 2) with parameters 8,6,1 (ARX(8,6,1)) was performed at the beginning of winter (grey in the figure). The inputs  $u(k-1)$  are precipitation and temperature and the output  $y(k)$  is GWI. We use the model to calculate the SWE during the rest of this season. The SWE modelling and the measurements (GWI) are in agreement, except for the melting period.

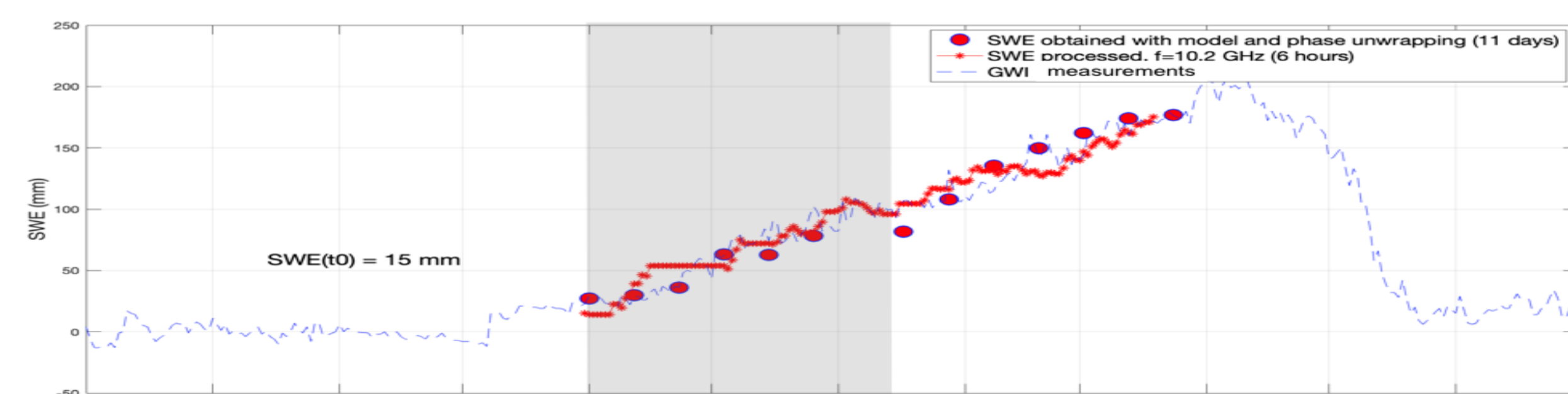
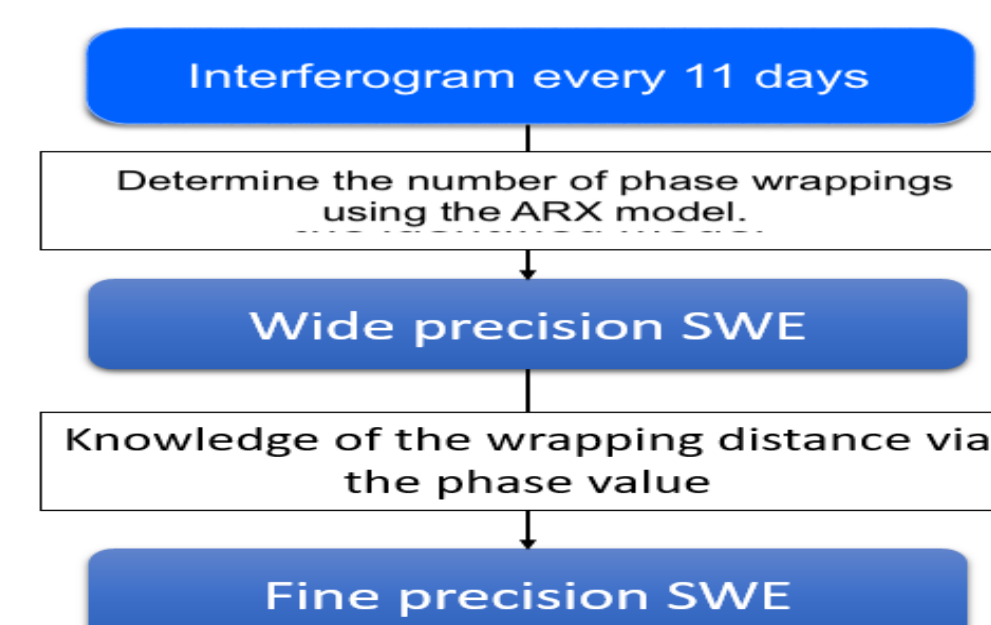


The model ARX(8,6,1) is the more accurate one, and we can use to unwrap the phase.



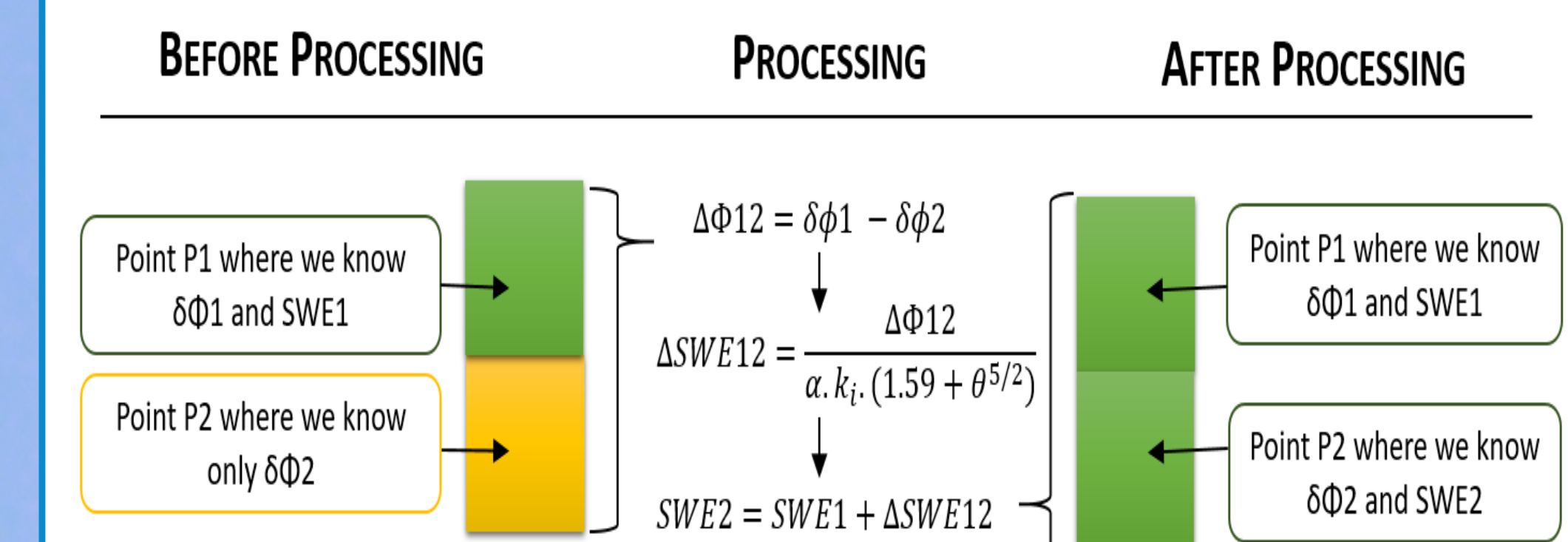
## UNWRAPPING PHASE

Using the model ARX, we determine the number of phase wrappings during 11 days, and we unwrap the phase.



We calculated the  $\Delta\Phi_s$  by unwrapped phase integration and we converted  $\Delta\Phi_s$  to SWE. This figure shows agreement between the SWE calculated and measurements. This result demonstrates the possibility to compute SWE from interferometric satellite data with an 11-day revisit over a large area.

## SPATIALIZATION - ALGORITHM



- Proposal based on unwrapping phase for interferometric images.
- To be used on high coherence and low relief area to limit problems of discontinuity.
- For areas of high relief, complementary information can be used to solve ambiguity of critical area.

## CONCLUSION / Future work

- Reconstitution of SWE during the winter, from meteorological and GWI data at the beginning of this season.
- SWE reconstitution by interferometric phase integration given every 11 days.
- Proposal for spatialization of SWE from punctual points.
- This work is specifically adapted to arctic zones.
- Study the use of C-band
- Process for SWE decreasing case
- Depend spatialization
- Exploit polarization information.

## REFERENCES

- S. Leinss, A. Wiesman, J. Lemmetyinen, and I. Hajsek, IEEE Journal, vol. 8, august 2015.
- J. Lemmetyinen, A. Kontu, J. Pulliainen, A. Wiesmann, C. Werner, T. Nagler, H. Rott, and M. Heiding, Final Report, ESA ESTEC Contract No. 22671/09/NL/JA., 2011.

## ACKNOWLEDGEMENT

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