Simulating the snowpack in Lebanon from dynamical downscaling and fSCA data assimilation

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Introduction

Seasonal snowpacks in the mountains constitute a natural water storage system, which provides key water resources during spring and summer for agriculture, hydropower generation and ecosystems. Despite the relatively mild temperature of the Mediterranean climates, mountains there often exhibit deep and long-lasting snowpacks. As most of the annual precipitations of the Mediterranean regions falls during the winter season, the mountain snowpack strongly reshapes the hydrographs to sustain high flows until the end of the spring. The high variability of the Mediterranean snowpacks and the generalized lack of in-situ informations, difficults its study and monitoring.

Remote sensing is key to monitor different properties of the snowpack from the local to the regional scales. However, SWE estimates from spaceborne or close-range sensors remain elusive especially over complex topography. In the other hand, snowpack models have uncertainities associated to forcing and parameterizations. Therefore, the key is to integrate both observations and models, i.e. by an optimal combination of the data (given their uncertainties) and simulations.

Study Area

Lebanon climatology is typically Mediterranean, influenced mainly by its proximity to the sea and complex topography. There are two main mountain ranges that run in parallel to the Mediterranean coast from north to south. The Lebanese mountains are highly karstified, encouraging the infiltration of rainfall and snowmelt. .

The particular spatial distribution of its mountain ranges constitutes an effective topographical barrier to humidity, enhancing the winter precipitation result in yearly seasonal snowpack over a large part of the country.

The water resource provided by the snowpack is crucial for the Lebanese society. The main water supply of Beirut proced from the Jeita spring, which it is constituted by a 40% of snowmelt water. The need of snowpack freshwater resources is becoming more acute during the recent drought in the eastern Mediterranean, with an increasing water stress due to increase domestic water demand, agriculture and Syrian refugee crisis.

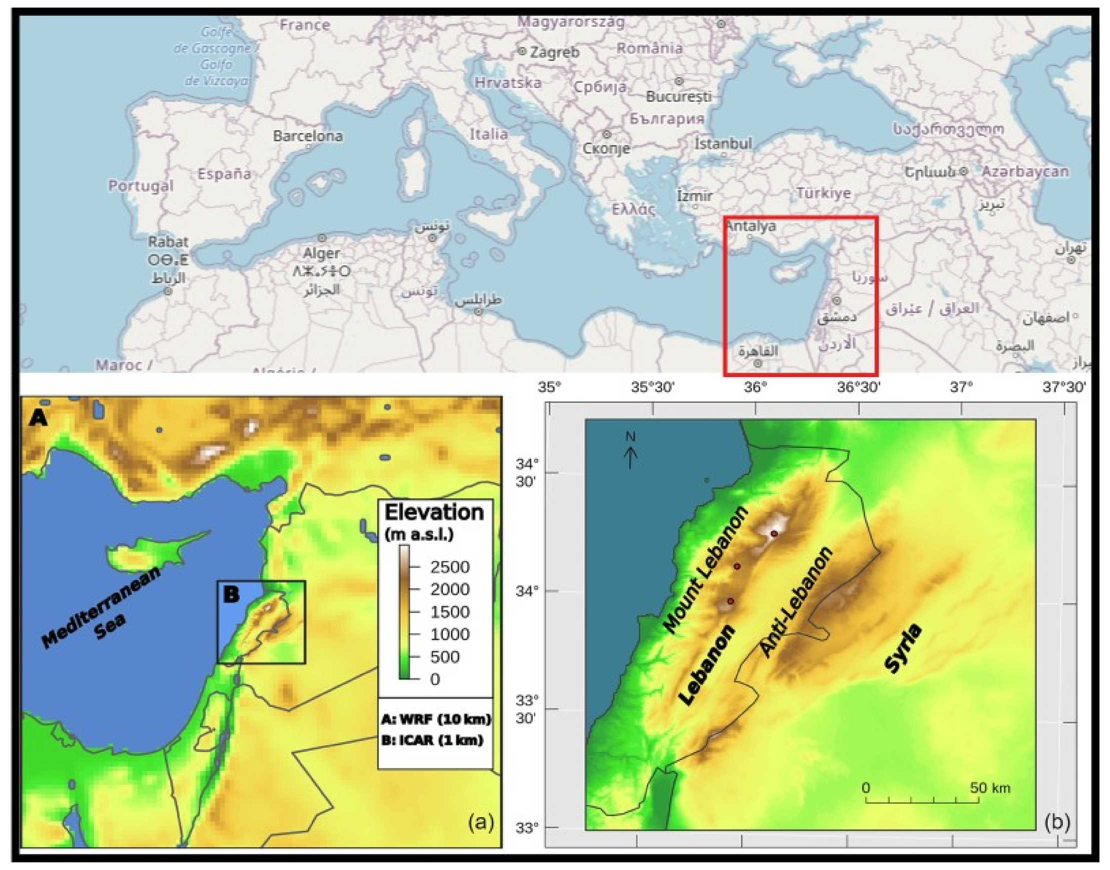

Fig. 1.: Lebanese mountains localization map

Objectives

Explore the potential of a methodology to develop a snowpack reanalysis over data-scarce regions

Describe the main snowpack dynamics over the Lebanese mountains.

Methodology

We have simulated the snowpack of the Lebanese mountains, as an alternative to snowpack observations. We have generated a 1 km resolution snowpack reanalysis, using an ensemble-based assimilation of fractional snow-covered area (fSCA) obtained from the MODIS satellite sensor.

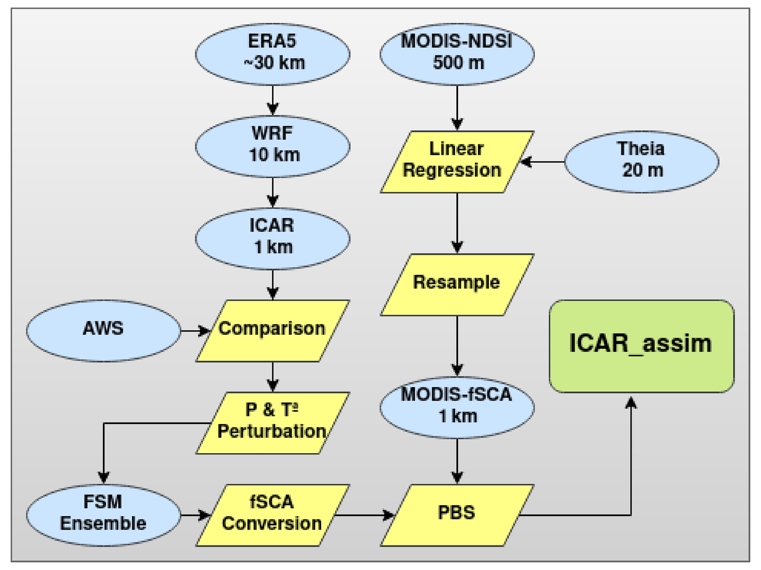

Fig. 2: Snow reanalisis generation workflow

A 10 km resolution atmospheric simulation, using the Weather Research and Forecast model forced by ERA5, was performed covering the period between 2010 and 2017. Then, a finer 1 km simulation, using the Intermediate Complexity Atmospheric Research model (ICAR; Gutmann et al., 2016), was nested inside the previous WRF simulation covering the same time period. To improve the ICAR snowpack outputs, the simulated meteorological data were used to force an energy and mass balance snowpack model, the Flexible Snow Model (FSM2; Essery, 2015), while perturbing the meteorological fields to generate an ensemble of snowpack simulations. Then, the particle batch smoother (PBS; Margulis et al., 2015), a Bayesian data assimilation scheme, was applied to assimilate daily remotely sensed fSCA information.

Results and Discussion

The improvement of the ICAR simulations thanks to the assimilation of fSCA was proved by the comparison with remotelly sensed information and in situ observations. The simulations better captured the spatial and temporal variability affter the PBS implementation (ICAR_assim) at a regional scales.

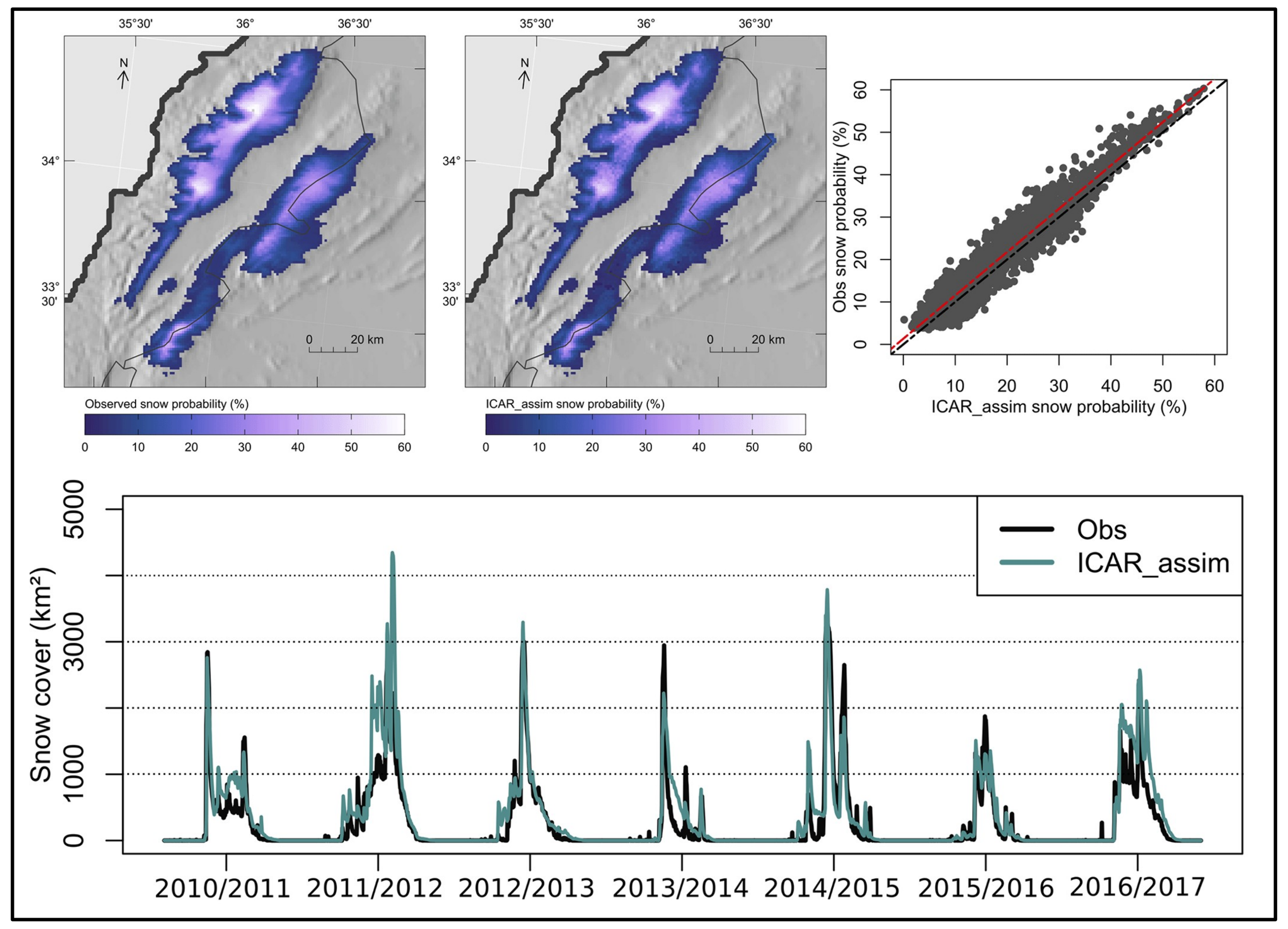

Fig. 3: ICAR_assim performance compared with MODIS remotelly sensed snow cover in both spatial snow probability (upper pannels), and temporal snow cover evolution (lower pannel).

The new products allowed us to developed accurate snow climatologies at a regional scales over the region. The snowpack over Lebanon is characterized by a high temporal variability. Mount Lebanon exhibits thicker, longer and more regular snowpacks compared to the Anti-Lebanon Mountains. Such differences cannot only be explained by the elevation difference but also by the drier conditions on the lee side of the Mount Lebanon range. The hypsometry of Lebanon results in the most important snow freshwater reservoir being in the middle elevations (2200–2500 m a.s.l.). Snowpacks at these elevations close to the 0 ◦C isotherm are highly vulnerable to climate warming. As such, our findings suggest big challenges for the future management of water resources over the Lebanon region.

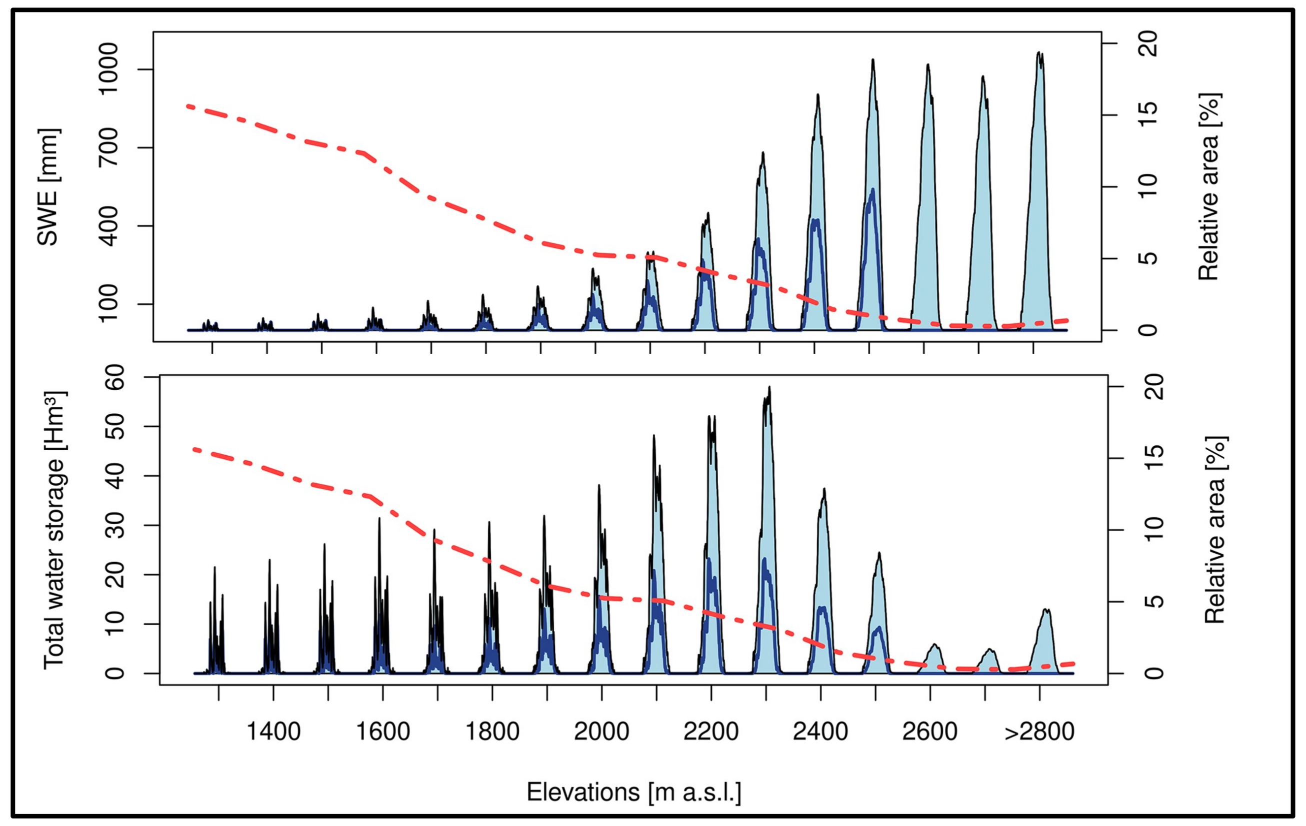

Fig. 3: Averaged SWE and total water storage in the snowpack per elevations.

Future work

A new data assimilation tool is being developed from the routines used in this study. In its current stage, the tool has a number of features that enhance the capabilities of the routines exposed here. This includes the implementation of different data assimilaiton algorithms (PBS, particle filter, ensemble Kalman filter and kalman filters) and parallel support in a user-friendlly way. In a nearlly future stage we will implement support for assimilating multiple remotely sensed retrievals simultaniouslly (Surface temperature, fSCA, snow depth…).

Rigth now it is being used to assimilate high resolution (5m), snow depth maps derived from drone surveis by using different data assimilation algortihm in the Izas catchment (Pyrenees, Spain).

References

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