Snow cover evolution during the last fifty years in the Hautes Fagnes (Belgium) using the regional climate MAR model

Coraline WYARD, Xavier FETTWEIS, Michel ERPICUM
Laboratory of Climatology, ULg, Liège, Belgium
Contact : coraline.wyard@ulg.ac.be





PICO presentation in Session CR4.3
Abstract EGU2015 - 11270
Presented at EGU General Assembly 2015, Vienna

SUMMARY

Validation over the period 2008-2013 : Belgium

Data (temperature, surface pressure and precipitation) from 20 stations
vs
MAR outputs

→ MAR successfully recreates daily mean temperature and surface pressure

→ Improvements in MAR are needed in order to validate daily precipitation amount

Validation over the period 2008-2013 : Hautes Fagnes

Snow height observations from snowcam images and laser snow depth sensor
vs
Snow height simulated by MAR

→ MAR successfully recreates daily snow height evolution

Trends over the period 1958-2013

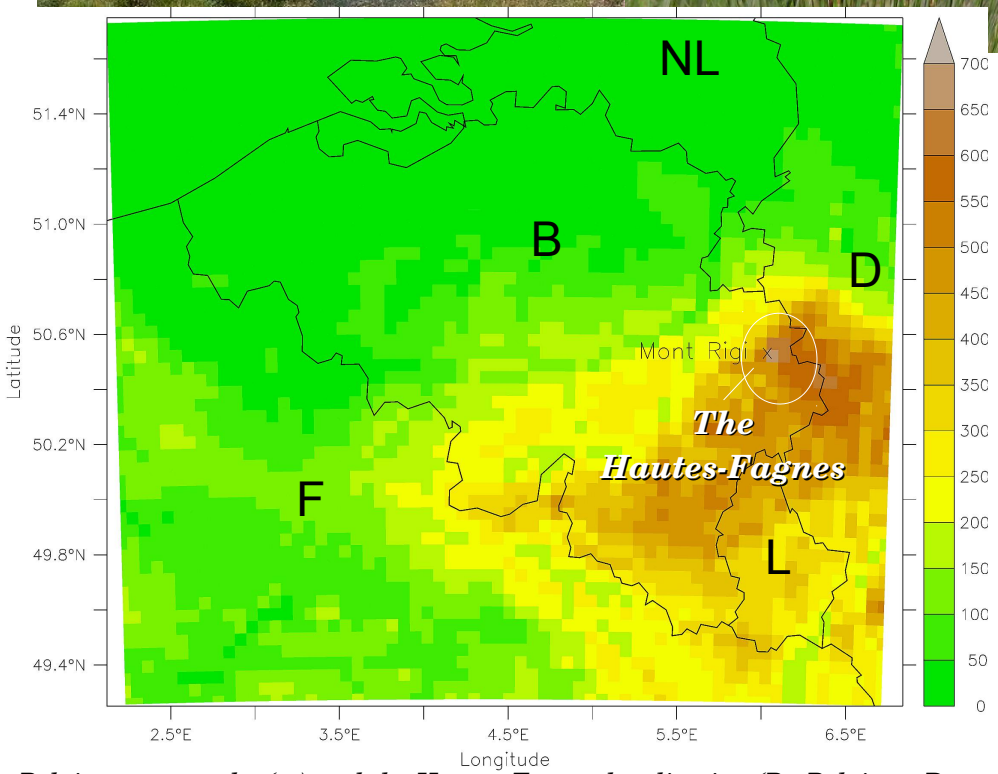
Trends analysis of mean snow height, maximum snow height, number of snow days, mean temperature and mean surface pressure in winter on the basis of MAR outputs

→ No significant trends over the 1958-2013 period because of hypothetical changes in European winter circulation

→ Longer time series must be considered in order to confirm trends

→ It is necessary to conduct further analysis of circulation changes in Europe in orderto confirm our assumptions and refine our analysis.

A 10,000 years ecosystem with unique flora and fauna at this latitude and altitude



Belgian topography (m) and the Hautes-Fagnes localisation (B : Belgium, D : Germany, F : France, L : Luxembourg, NL : the Netherlands)

Why study the Hautes Fagnes (High Fens) ?

- The Hautes Fagnes (summit of Belgium) : a region covered by snow 1 to 2 months/yr
- Unique ecosystem in the Hautes Fagnes
- Importance of snow cover melting in wintry floods when associated with rainfalls events

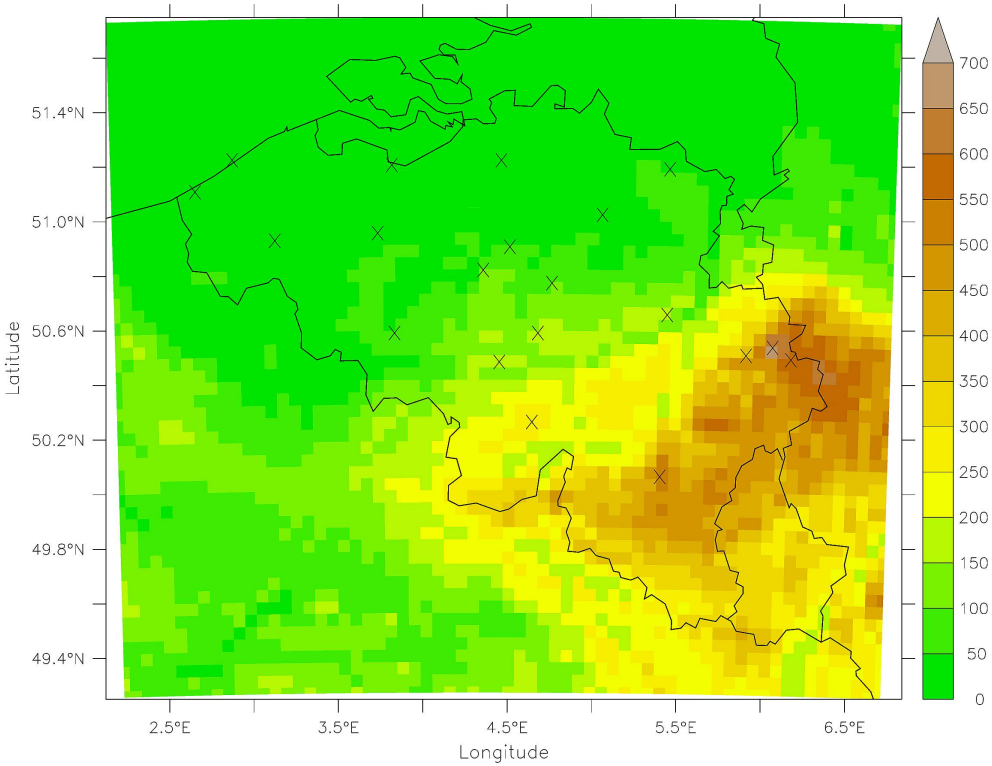
→ <u>Objective</u> : reconstruction of snow cover using the regional climate MAR model running at 5km of resolution

Snow covers the Hautes Fagnes 1 to 2 months/yr and is involved in floods in neighboring regions

The first step consists in validating our model (the MAR model) over Belgium by comparing MAR results with observations

- Validation period : 2008-2013
- Data :
  - Hourly observations from 20 synoptical stations converted into daily observations
  - Daily MAR outputs
- Statistical analysis between daily observations and daily MAR outputs

→ Validation of daily mean temperature and daily surface pressure over Belgium
→ Improvements in the MAR model are needed for daily precipitation amount validation



Belgian topography (m) and synoptical stations localisation

2008-2013	R	R^2	RMSE	Mean biases	σ	Validation
Daily mean temperature (°C/day)	0.99	0.98	1.34	0.32	6.50	V
Daily mean surface pressure (hPa/day)	0.99	0.98	2.05	1.06	9.27	V
Daily precipitation amount (mm/day)	0.55	0.31	3.96 (84.6%)	-0.11 (-4.8 %)	4.68	X

Statistical analysis between daily mean temperature (°C/day), daily mean surface pressure (hPa/day) and daily precipitations amount (mm/day) observed in 20 belgian synoptical stations and simulated with the MAR model over the period 2008-2013: correlation coefficient (R), determination coefficient (R^2), root mean squared error (RMSE), mean biases and standard deviation (σ)

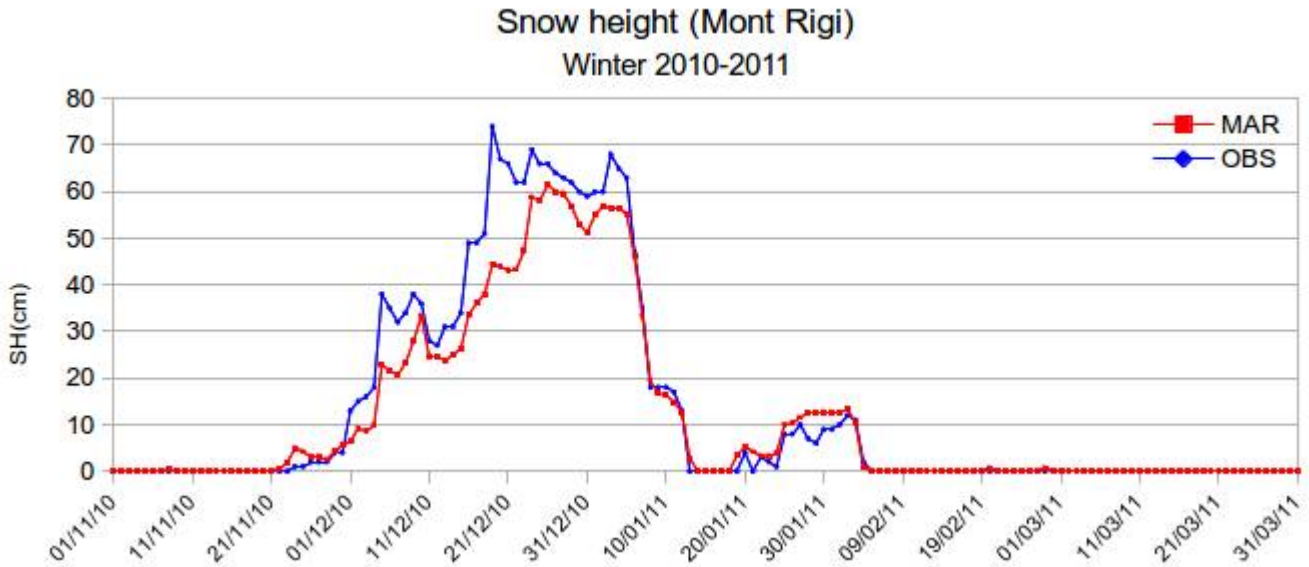
The next step consists in validating the snow height simulated by the MAR model in the Hautes Fagnes (Mont Rigi station).

- Validation period : 2008-2013
- Data :
  - Daily snow height observations at Mont Rigi station based on snowcam images and laser snow depth sensor
  - Daily snow height simulations with the MAR model
- Statiscal analysis between observed and simulated snow height for each winter of the validation period

→ Validation of the daily snow height in Mont Rigi

Snow Height (cm/day)	R	R^2	RMSE	Mean biases	Mean snow height	σ
2008-2009	0.61	0.37	10.75	-6.72	8.93	10.20
2009-2010	0.89	0.79	10.50	-5.14	10.85	15.70
2010-2011	0.98	0.96	5.80	-2.00	13.34	22.13
2011-2012	0.93	0.86	1.96	-0.10	1.72	5.22
2012-2013	0.82	0.67	6.27	-2.80	7.52	9.85
2008-2013	0.85	0.73	7.06	-3.35	8.47	12.62

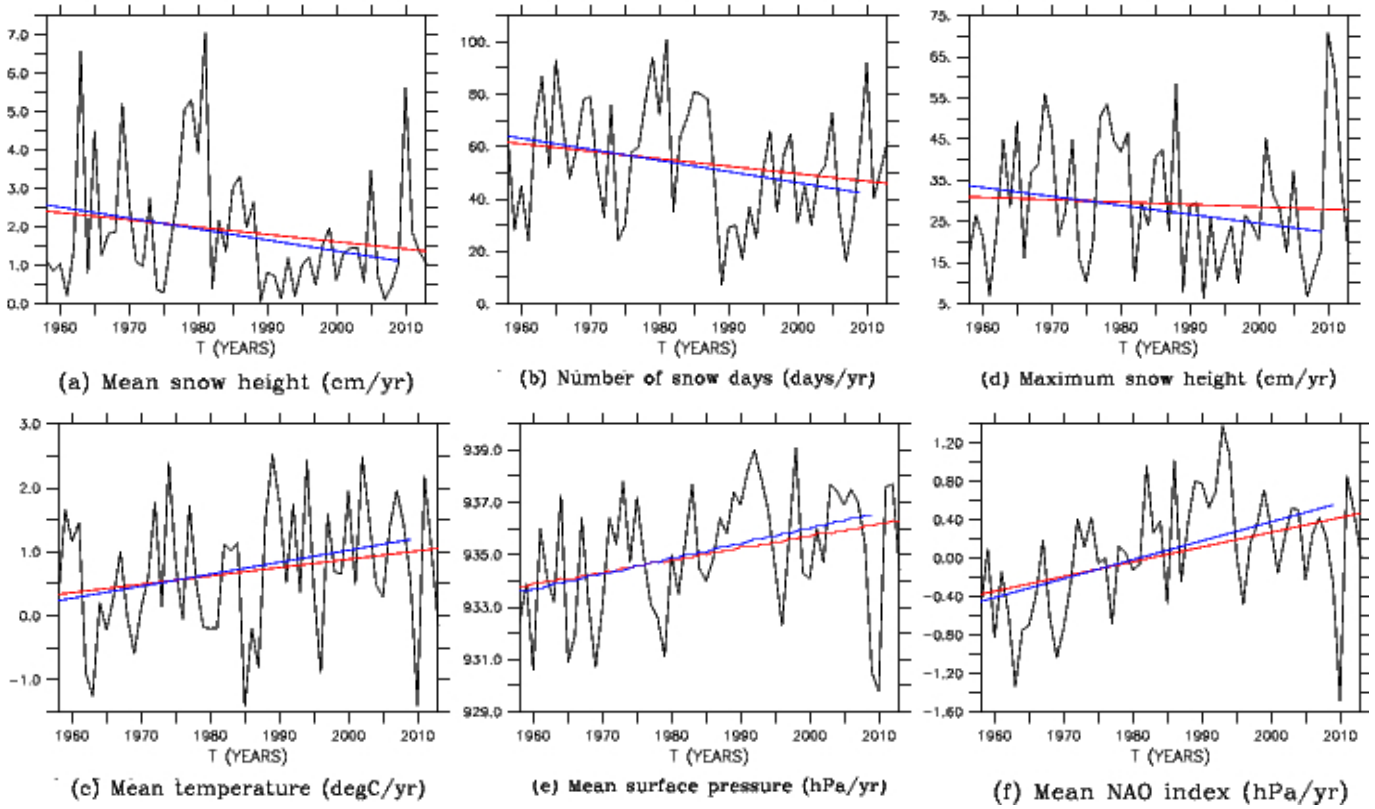
Statistic analysis between daily snow height observations and simulations in Mont Rigi (Hautes-Fagnes, Belgium) for each winter of the period 2008-2013 : correlation coefficient (R), determination coefficient (R^2), root mean squared error (RMSE), mean biases, mean snow height and standard deviation (σ).



Evolution of the observed (blue) and the simulated (red) snow height in Mont Rigi during the winter 2010-2011.

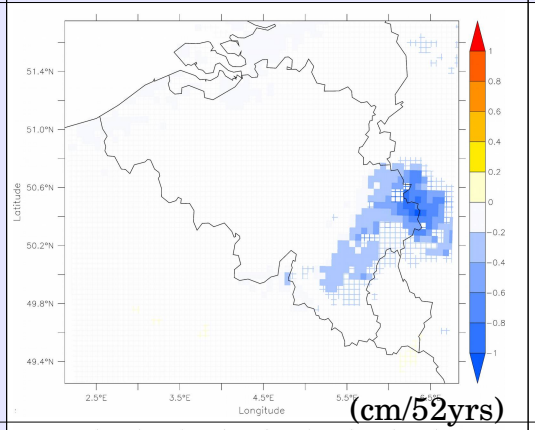
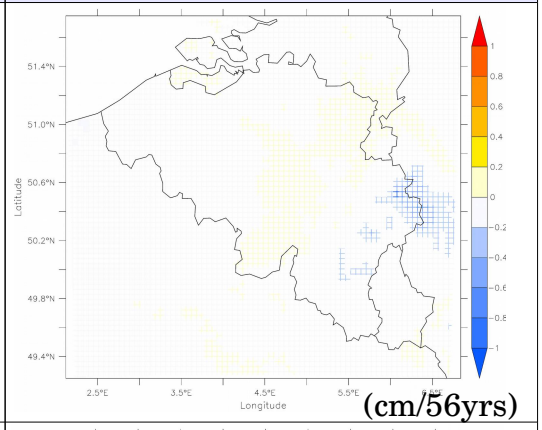
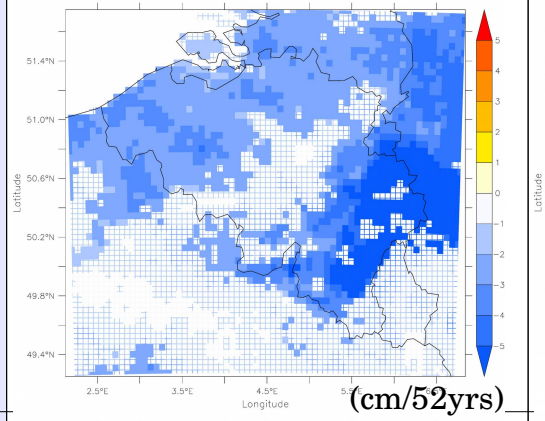
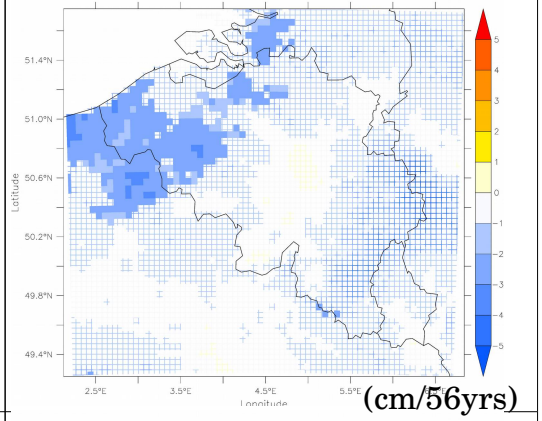
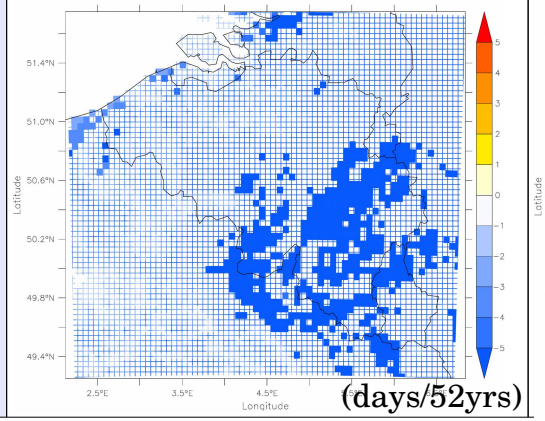
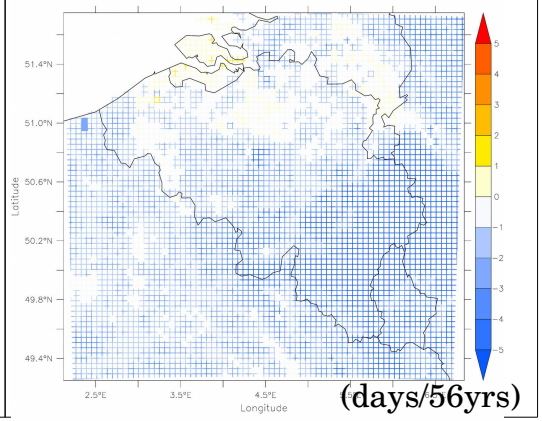
Given the successful validation of the MAR model in Mont Rigi, we analyse snow cover trends simulated by MAR in Mont Rigi for each winter over the periods 1958-2013 and 1958-2009. Then, we determine their significance by using the uncertainty range for the 95% confidence interval of Snedecor.

- If trend > range → trend is significant :
  → High interannual variability and recent cold and snowy winters (e.g. winter 2010)
  → 1958-2009 trends are significant : decrease in the number of snow days, increase in mean temperature, mean surface pressure and NAO index
  → On a longer period (1958-2013), number of snow days and mean temperature trends become non-significant because of recent cold and snowy winter



	Trend	Range
Mean snow hight (cm/yr)	-0.019 -0.029	0.027 0.030
Number of snow days (days/yr)	-0.29 **-0.42**	0.36 **0.40**
Maximum snow height (cm/yr)	-0.058 -0.22	0.25 0.25
Mean temperature (°C/yr)	0.013 **0.019**	0.016 **0.017**
Mean surface pressure (hPa/yr)	**0.046** **0.058**	**0.037** **0.038**
Mean NAO index (hPa/yr)	**0.015** **0.02**	**0.009** **0.009**

*Evolution over the 1958-2013 period in Mont Rigi of wintry (from November to March) (a) mean snow height (cm/yr), (b) number of snow days (we consider a day is a snow day if snow height simulated by MAR is greater or equal to 1 cm à 00 UTC) (days/yr), (c) maximum snow height (cm/yr), (d) mean temperature (°C/yr), (e) mean surface pressure (hPa/yr) and (f) observed mean NAO index (black curves) and their **trends** and **uncertainty range (representing the interannual variability)** over the 1958-2013 period (red curves and caracters) and over the 1958-2009 period (blue curves and caracters).*

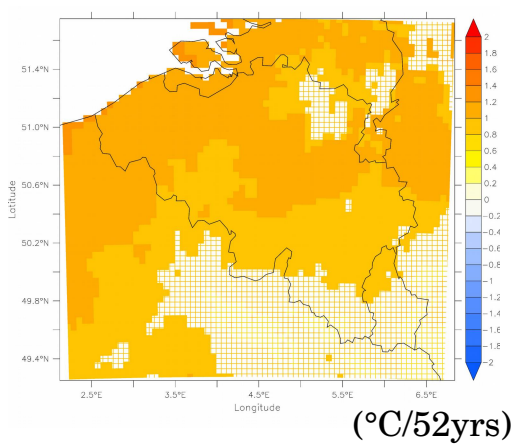
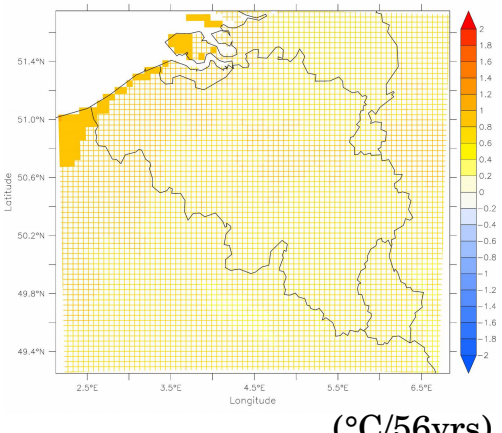
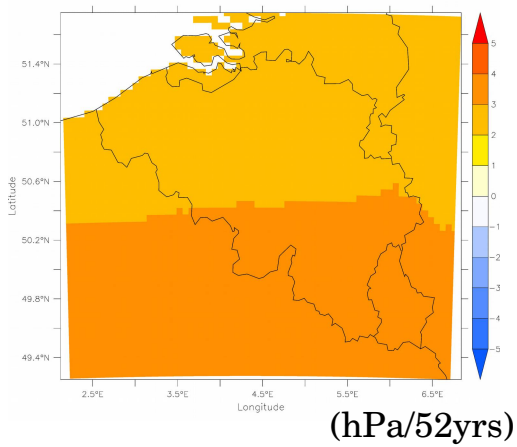
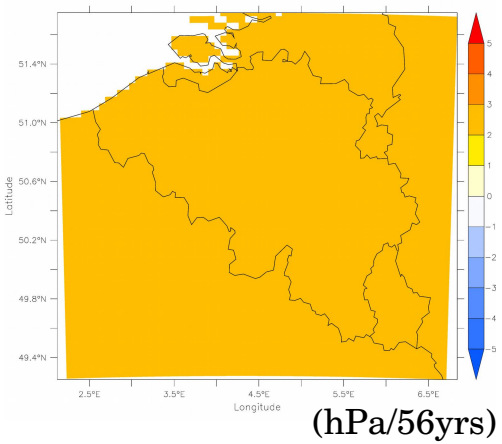
	1958-2009 trends	1958-2013 trends
Mean snow height during winter[1]	 (cm/52yrs)	 (cm/56yrs)
Maximum snow height during winter	 (cm/52yrs)	 (cm/56yrs)
Number of snow day[2] during winter	 (days/52yrs)	 (days/56yrs)

Finally, we extend our snow cover trend analysis to the entire country

→ The 1958-2009 snow cover (mean snow height, maximum snow height, number of snow days) trends are significant over a larger part of Belgium than the 1958-2013 snow cover trends and show a decrease in snow cover.

Trends and their significance over the periods 1958-2009 and 1958-2013 of the mean snow height, maximum snow height and number of snow days. Significant trends are represented with solid pixels while non-significant trends are represented with gridded pixels.

(1) We consider winter extends from November to March
(2) We consider a day is a snow day if snow height simulated by MAR is greater or equal to 1 cm à 00 UTC

	1958-2009 trends	1958-2013 trends
Mean winter[(1)] temperature	 (°C/52yrs)	 (°C/56yrs)
Mean surface pressure in winter	 (hPa/52yrs)	 (hPa/56yrs)

Trends and their significance over the periods 1958-2009 and 1958-2013 of the mean winter temperature and mean surface pressure in winter. Significant trends are represented with solid pixels while non-significant trends are represented with gridded pixels.

We complete our trends study with an analysis of mean temperature and mean surface pressure in winter trends.

→ The 1958-2009 mean temperature trend is significant over a larger part of Belgium than the 1958-2013 mean temperature trend. Trends show an increase in mean winter temperature

→ Mean surface pressure trend is significant over both periods and shows an increase in surface pressure over entire Belgium

(1) We consider winter extends from November to March

- MAR succeeds in simulating daily mean temperature, daily mean surface pressure and daily snow height.

  → Improvements are needed in the MAR model to successfully simulate daily precipitation amount.

- Our results show significant trends of decreasing snow cover (number of snow days), increasing mean temperature and mean surface pressure in Belgium over the period 1958-2009. However, over a longer period (1958-2013), trends in snow cover and mean temperature are non-significant.

  → Our results illustrate the importance of considering all the years and longer time series in trends studies.

- The winter NAO index analysis shows a trend of increasing values during winter in aggrement with previous studies. Positive winter NAO index is usually associated with a strenghtening in westerly circulation implying warmer temperatures and more liquid precipitation over our regions (northern Europe).

  → The apparent decreasing trend in snow cover and the increasing trend in mean winter temperature and surface pressure could be due to positive winter NAO index trends.
  → The depreciating trend of snow cover at the end of our time serie could be due to changes in the circulation.

- However, it is difficult to link snow cover, temperature and surface pressure changes over the small Belgium to changes in NAO, and in the circulation over Europe.

  → It is necessary to conduct further investigation of circulation changes in Europe in order to confirm our assumptions and refine our analysis.

Short-term prospects

- Improvement of daily precipitation amount simulation with the MAR model
- Simulation with the MAR model forced by ERA-20C from 1900 in order to obtain longer time series
- Analysis of circulation evolution in winter over Europe

Medium-term prospects

- Future projections with the MAR model

Long term prospects

- Forcing hydrological models with runoff calculated by the MAR model in order to simulate the flow rate of the rivers of Belgium during snow cover melting associated rainfalls events

References

Bardossy, A., & Caspary, H. J. (1990). Detection of climate change in Europe by analyzing European atmospheric circulation patterns from 1881 to 1989. *Theoretical and Applied Climatology*, 42(3), 155-167.

Cassou, C. (2008). Intraseasonal interaction between the Madden–Julian oscillation and the North Atlantic oscillation. *Nature*, 455(7212), 523-527.

Cattiaux, J., Vautard, R., Cassou, C., Yiou, P., Masson-Delmotte, V., & Codron, F. (2010). Winter 2010 in Europe: a cold extreme in a warming climate. *Geophysical Research Letters*, 37(20).

De Ridder, K., & Gallée, H. (1998). Land surface-induced regional climate change in southern Israel. *Journal of applied meteorology*, 37(11), 1470-1485.

Gallée, H., & Schayes, G. (1994). Development of a three-dimensional meso-γ primitive equation model: katabatic winds simulation in the area of Terra Nova Bay, Antarctica. *Monthly Weather Review*, 122(4), 671-685.

Gallée, H. (1995). Simulation of the mesocyclonic activity in the Ross Sea, Antarctica. *Monthly Weather Review*, 123(7), 2051-2069.

Küttel, M., Luterbacher, J., & Wanner, H. (2011). Multidecadal changes in winter circulation-climate relationship in Europe: frequency variations, within-type modifications, and long-term trends. *Climate Dynamics*, 36(5-6), 957-972.