Patterns of GreenHouse Gas induced climate change for the French Meuse basin during the 21st century : A state of the art

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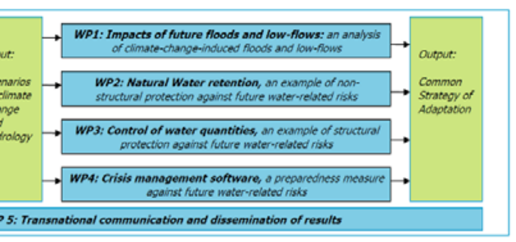
This study has been conducted in the framework of the European INTERREG IVB AMICE (Adaptation of the Meuse to the Impacts of Climate Evolution) project. The main objective of this study is to show the patterns of GHG-induced climate change according to the methods used to downscale the outputs of a Limited-Area climate Model. To achieve this goal, two methods of climate scenario generation (a statistico-dynamical one and the delta change approach) have been applied to the transient simulations of the ARPEGE climate model forced with 3 IPCC emission scenarios (B1, A2 and A1B) on the 1950-2100 time slice.

1.Context and objectives of the study

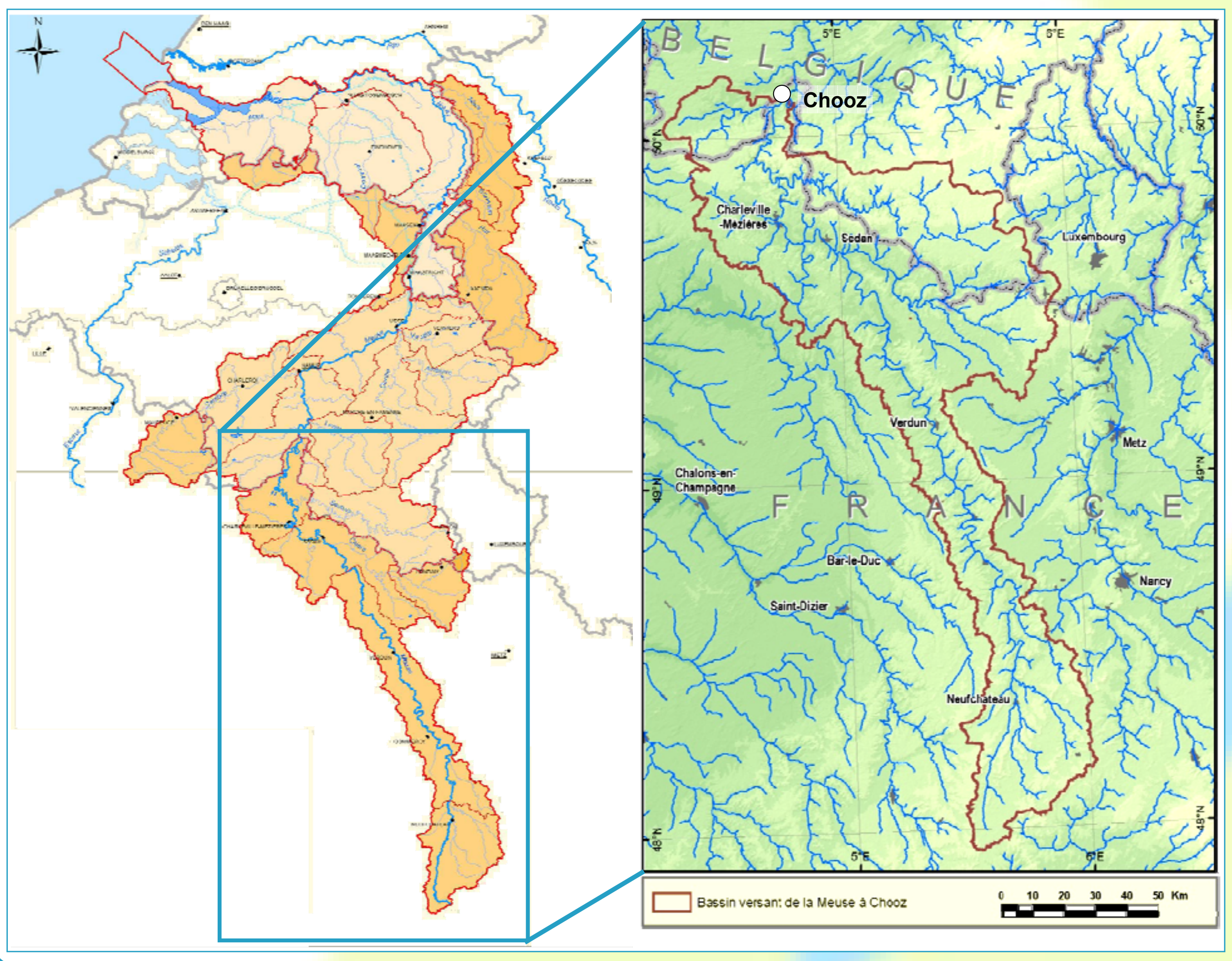
The AMICE Project
AMICE is an Interreg IVB NWE Project involving 17 partners spread across the transnational Meuse basin (France - Walloon - Flanders - Germany – Netherlands)



Objectives of the AMICE Project :
- Producing common climate scenarios based on GHG emission scenarios for performing hydrological simulations
- Studying hydrological impacts of the climate change on the Meuse discharge along the river (low and high flows)
- Improving the resilience of existing hydraulic developments
- Guiding policy planning

Objectives of the study
The objective of this study is to underline impacts of climate change induced by 3 emission scenarios (B1, A1B & A2) on the French Meuse basin in terms of precipitation amounts and air temperatures by :
- Comparing results obtained through 2 downscaling methods: the Boe08 statistico-dynamical method (SD) and the delta change approach (ΔC) for 2071-2100
- Representing the spatial distribution of the climate change for the 2071-2100 period
- Analyzing the evolution of rainfall indices in winter and summer for 2021-2050 and 2071-2100 time spans.

2. Case study



The Meuse river basin
The transnational Meuse basin (France, Belgium, Luxembourg, Germany, Netherlands) can be divided into three geological sub-basins (De Wit et al., 2007) :
- The Lorraine sub-basin, upstream Charleville-Mézières with Mesozoic limestone
- The Ardennes sub-basin, between Charleville-Mézières and Liège with Paleozoic massif
- The third sub-basin downstream Liège with not consolidated Cenozoic sediments

The river rises on the Plateau de Langres 384m above the sea level. The mouth of the river is located 950km downstream in the North Sea near Rotterdam city.
In this study we consider only the French part from the source to the hydrometric station of Chooz just a few kilometers from the Belgian border corresponding to the first geological sub-basin.

The French Part of the Meuse river basin
In this area, the land use is predominantly agricultural in the South and forested in the North. There are few medium-sized cities like Verdun (20.000 inhabitants), Sedan (20.000 inhabitants), and Charleville-Mézières (100.000 inhabitants). The climate of the French sub-basin is semi-oceanic: rainfalls are fairly regular throughout the year (approximately 80mm/month).
The hydrological regime is unimodal (only one low flows period and one high flows period in winter). The French part of the Meuse river basin covers approximately one third of the whole Meuse basin in terms of surface, length, and mean annual flow. Flows of the French part of Meuse are mainly conditioned by the amounts of precipitation and potential evapotranspiration (PET) witch underlines the interest in studies of climate change.

Characteristics	Transnational Meuse basin	The Meuse at Chooz
Basin surface	33 000 km²	10 120 km²
Length	950 km	355 km
Mean annual discharge	350 m³/s	148 m³/s

3. Climate scenarios : data and methods

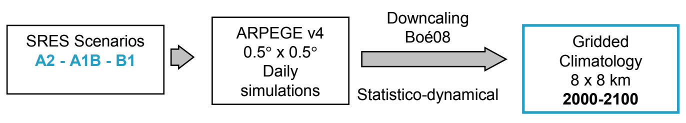
Climate database

E-OBS
The daily climatological database used for this study is the E-OBS 2.0 climatology provided by the European Climate Assessment & Dataset project. This database contains daily precipitation and air temperatures from 1950 to 2008 for Europe (Haylock et al. 2008). Data from meteorological stations are collected and distributed on two grid resolutions (0.5° and 0.25°).

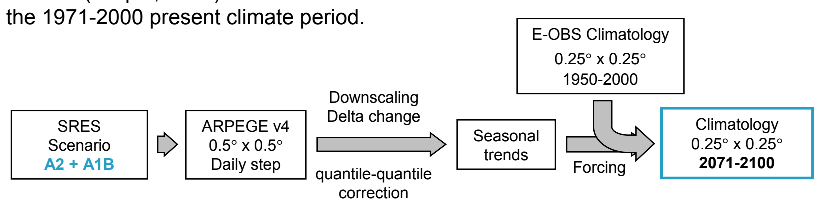
About 60 grid points included in the study area were extracted from the E-OBS database in order to estimate daily areal precipitation s and air temperature s through a Thiessen polygon tessellation.

Downscaling methods

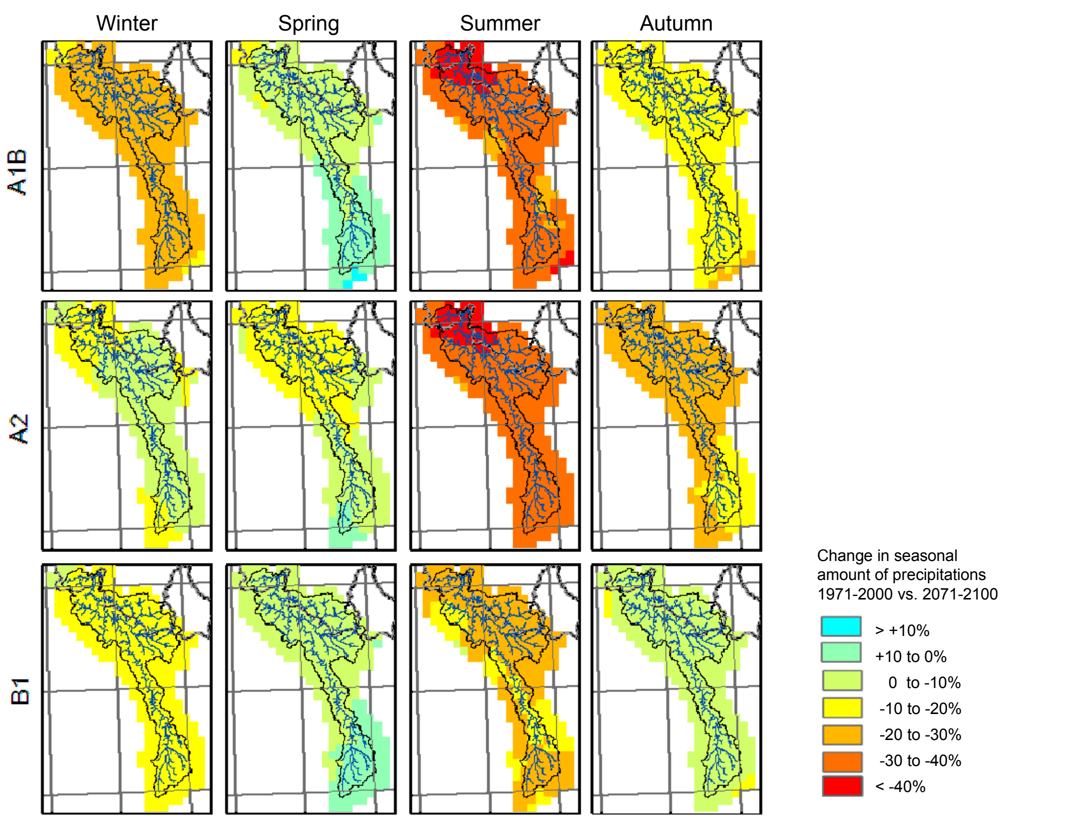
Statistico-dynamical method - Boé08 (SD)
Climate simulations have been provided by Météo France using ARPEGE v.4 (Variable resolution climate model developed by the CNRM). To refine the resolution and allow the use of data across the French Meuse basin these data were downscaled by the CERFACS with the Boé08 method (Boé 2007) which is based on a weather types approach. Precipitation and air temperature values are available on a Lambert II regular grid of 8x8km resolution (Pagé et al., 2008).



Delta change approach (ΔC)
The delta change approach is the method selected by the AMICE partners for producing hydrological scenarios. Seasonal trends (% for ΔP and °C for ΔT) have been provided by Météo-France for the 2071-2100 period based on ARPEGE v.4 simulations forced with the A2 and the A1B emission scenarios. Before being used these data have been previously corrected through the quantile-quantile method (Déqué, 2007). The seasonal trends have then been used to force the E-OBS climatology on the 1971-2000 present climate period.



Spatial distribution of change in seasonal amount of precipitations for three IPCC emission scenarios

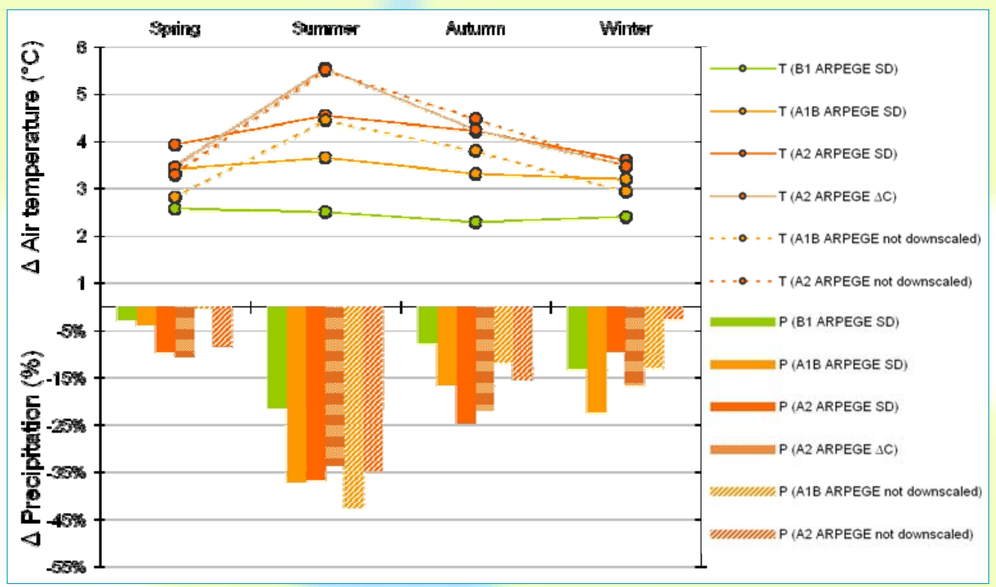


The map above presents the spatial distribution of change in precipitation for 2071-2100 vs.1971-2000 and for the 3 SD simulations (B1, A1B, A2). It shows a significant heterogeneity for this variable mainly in spring and summer where we can observe a spatial North-South gradient. In spring ,rainfalls are increasing in the south and decreasing in the north. In summer we observe a strong decrease of rainfall in the French Ardennes area.
A possible explanation for these results is a change in the intrinsic characteristics of air masses (e.g. drying) witch could be linked to global warming in areas from the air masses are originating.

Concerning the change in air temperature (not shown) for the same period, the spatial distribution of warming is relatively homogeneous with differences inferior to +1°C between grid points.

4. Main Results

Seasonal trends for 2071-2100 vs 1971-2000

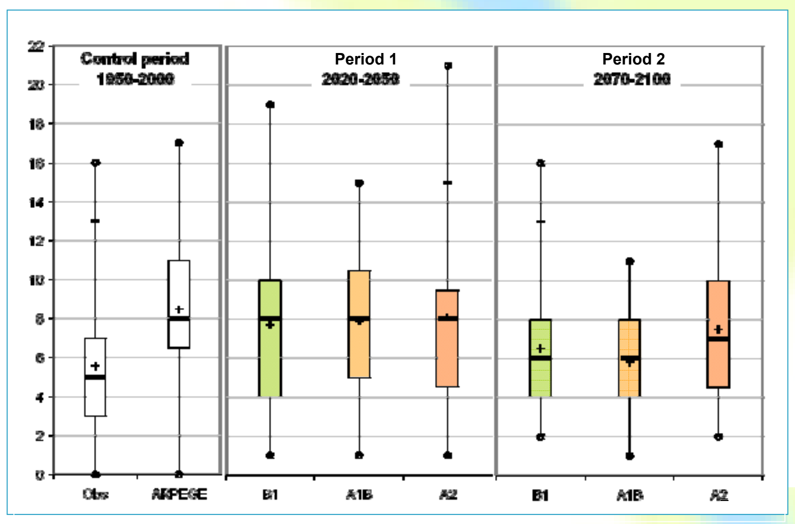


Four couples of *downscaling method/emission scenario* plus raw ARPEGE simulations (i.e. not downscaled) are presented on the graph, including seasonal changes in air temperature (T) and precipitation (P).

Air Temperature (°C)
For all climate scenarios the increase in air temperature is significant and relatively homogenous for winter and spring values (+2.5 to +4°C).
The strongest discrepancies are observed in summer (+2.5 to +5.5°C).
Concerning the SD method, the more the emission scenario is pessimistic the more air temperature increases whatever the season is.
Taking apart the downscaling method, the change values for a same emission scenario are comparable except for summer witch presents higher values with the delta change approach.

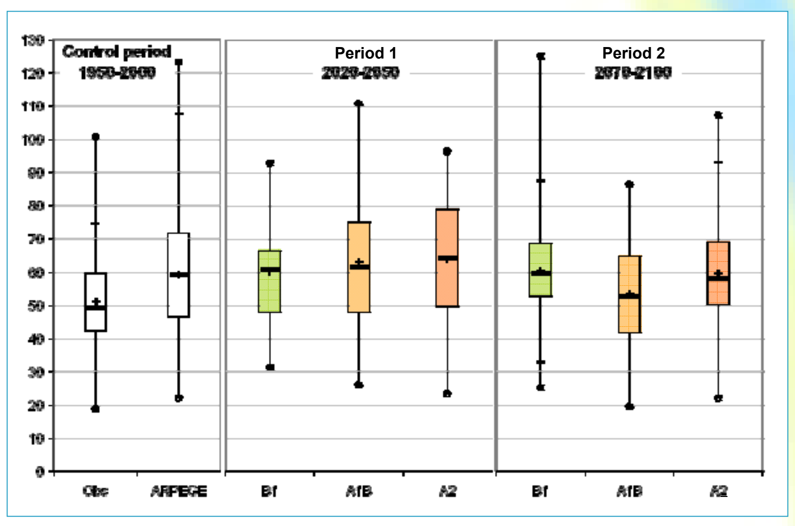
Precipitation (mm)
Excepted spring, mean seasonal precipitation decreases strongly whatever the emission scenario is. Summer is the most impacted season (from -21% to -39%) whereas autumn and winter are less affected by climate change (-8 % to -28 %).
The more pessimistic the emission scenario is the more precipitation decreases whatever the season is. The results obtained with both downscaling methods and for a same emission scenario (A2) are relatively comparable.

Evolution of rainfall indices in winter and summer (SD only)



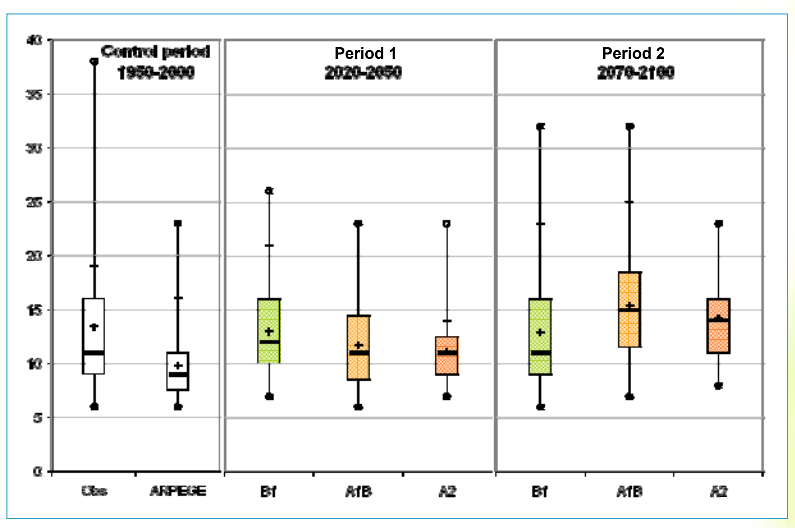
RD10 : numbers of winter days with intense rainfall (> 10mm/d)

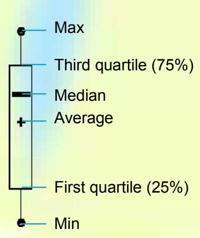
Boxplots show a strong overestimation (+60% on average) of ARPEGE RD10 values for the control period (1950-2000) in comparison to the E-OBS data. Until the end of the century and whatever the emission scenario is, ARPEGE is simulating mean RD10 values of 6 to 8 days. For the first time slice (2021-2050) there is no significant difference between the 3 emission scenarios and the ARPEGE control period. For the second time slice (2071-2100) a slight decrease in RD10 for all emission scenarios is observed.



R5d : maximum accumulated rainfall amount of 5 consecutive winter days (mm)

ARPEGE overestimates this variable too for the control period (+20% on average). During the first time slice, we can observe a slight increase in R5d values with the GHG emissions. For the second period there is any clear link between the scenario and the R5d evolution.





CDD : Cumulative number of dry days (days <1 mm/d)

Concerning this variable ARPEGE slightly underestimates the CDD values for the control period. However, we can observe a increase in CDD for the second period (+2 to +5 days). Even at the end of the century the emission scenario is not really discriminating.

The representation of the climate change through weather types as implemented in the statistico-dynamical downscaling method could explain these results. Indeed, the analysis of frequency of weather types occurrence for the A1B scenario and for the end of 21st century shows a statistically significant change in the distribution (especially in the spring).

Boé, J. (2007). Changement global et cycle hydrologique: Une étude de régionalisation sur la France. Thèse, Université Toulouse III - Paul Sabatier.
De Wit, M. J. M., Van Den Hurk, B. J. J. M., Warmerdam, P. M. M., Torfs, P. J. J. F., Roulin, E., & Van Deursen, W. (2007). Impact of climate change on low-flows in the river meuse. Climatic Change, 82(3), 351–372.
Déqué, M. (2007). Frequency of precipitation and temperature extremes over France in anantrhopogenic scenario: model results and statistical correction according to observed values. Global and Planetary Change, 57, 16-26.
GIEC (2001). Changements climatiques 2001 : Rapport de synthèse. Intergovernmental Panel on Climate Change.
GIEC (2007). Changements climatiques 2007 : Rapport de synthèse. Intergovernmental Panel on Climate Change.
Haylock, M.R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D. Jones, M. New. 2008: A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res (Atmospheres), 113, D20119, doi:10.1029/2008JD10201.
Pagé C., Terray L. & Boé J. (2008). Projections climatiques à échelle fine sur la France pour le 21ème siècle: Les scénarii SCRATCH08. Technical Report TR/CMGC/08/64, CERFACS.
Pagé C., Terray L. & Boé J. (2009). dsclim: A software package to downscale climate scenarios at regional scale using a weather-typing based statistical methodology. Technical Report TR/CMGC/09/21, CERFACS.
Planton S (1999). Incertitudes sur la détermination des changements climatiques. Papier présenté à l'Ecole Thématique du CNRS " Risques et incertitudes : le cas du changement climatique ", Les Houches, 17- 22 novembre 1999.