Summertime hailstorms over Switzerland in surrogate climate change simulations

Andrey Martynov (1), Luca Nisi (1,2), and Olivia Martius (1)

(1) Institute of Geography and Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland (2) Federal Office of Meteorology and Climatology MeteoSwiss, Locarno-Monti, Switzerland

UNIVERSITÄT BERN

OESCHGER CENTRE CLIMATE CHANGE RESEARCH

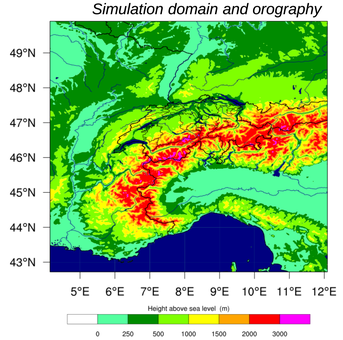
Motivation and objectives

- Summer hailstorms over Switzerland cause considerable damage to the property, crops, real estate, etc.
- Future climate changes over Switzerland can be considerable (up to 5 °C surface warming towards 2100, RCP8.5)
- Climate change can potentially make summer hailstorms more harmful by enhancing their intensity, frequency, footprints. It is essential to be able to foresee possible changes for planning adaptation measures.
- Summer hailstorms over Switzerland can be simulated by using a mesoscale model at high resolution, e.g. WRF.
- Surrogated climate change approach - a convenient and simple method of imitating the climate change can be applied to these simulations. While oversimplified, it can help to reveal trends in hailstorm characteristics.
- To imitate the expected warming, we apply an uniform 5 °C warm bias in atmosphere and land/sea surface.
- Two air humidity levels were simulated.
- We perform unbiased and biased WRF simulations of JJA2012 and compare features of simulated hailstorms: frequency, hailstone size on ground, spatial distribution, diurnal cycle, etc.

Simulation settings

- WRF 3.6.1 model. Simulation period: 25.05.2012 – 31.08.2012
- Domain settings:
  - 2 km horizontal resolution,
  - 414 x 375 latlon grid,
  - 35 vertical levels, upper boundary: 50 hPa
- Forcing data: ECMWF analysis, 1/8°, 6-hourly.
- No cumulus parameterization.
- Noah land-surface model.
- Microphysics: Morrison double-moment scheme (with explicit hail)
- AFWA diagnostics package for WRF (Creighton et al. 2014)
- HAILCAST-1D hail model

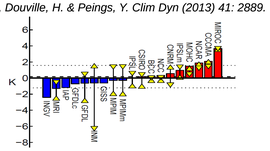
Simulation domain and orography



Surrogate climate change simulations

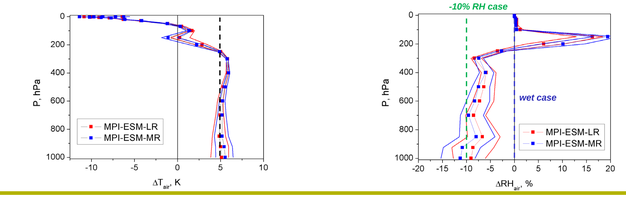
- Surrogate climate change (Schär et al. 1996): adding artificial biases to air temperature and humidity forcing for simulating changed climate conditions.

CMIP5 model biases averaged over continental Europe for summer. *Cattiaux, J., Douville, H. & Peings, Y. Clim Dyn (2013) 41: 2889.*



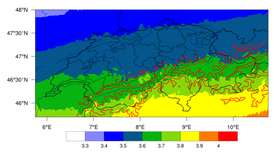
- CMIP5, RCP8.5 scenario. Bias: "2070-2100" – "1970-1999", JJA. MPI-ESM-LR, MPI-ESM-MR: among the least biased models.
  - Strong warming in lower troposphere, stratospheric cooling.
  - Mean RH decrease in lower troposphere up to 10-15% (last-saturation-temperature constraint, *Sherwood et al. 2010*)
- Simulations: Unbiased control run + 2 surrogate climate change cases with homogenous +5 °C temperature bias: "wet case": unchanged air RH (following Clausius-Clapeyron), "-10%RH case": 10% decrease of the RH.

Climate change - related biases of air temperature and RH in **MPI-ESM-LR**, **MPI-ESM-MR**. Simplified biases, used in this work.



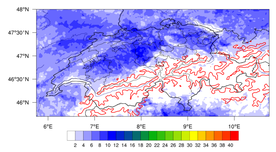
Changes in the atmospheric conditions

Mean freezing level (unbiased case), km

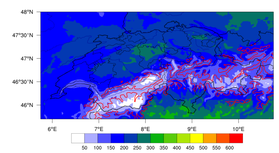


Red line: 2000 MASL

Number of days with Liftind Index < -4 (unbiased case)

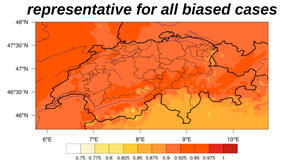


Mean daily maximum MU CAPE 0-180 mb (unbiased case), J/kg



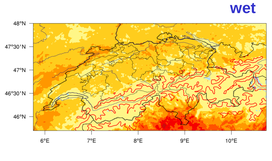
Mean freezing level increase, km

representative for all biased cases

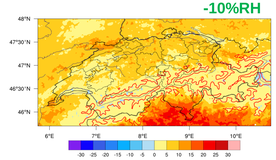


Change of number of days with LI < 4 in biased cases

wet

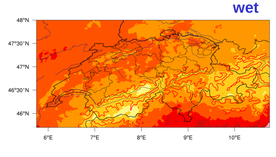


-10%RH

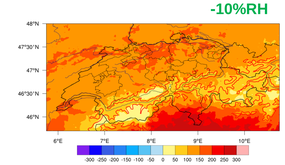


Changes in mean daily maximum MU CAPE 0-180 mb, J/kg

wet

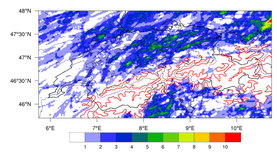


-10%RH

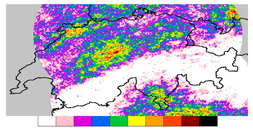


Changes of hailstorm characteristics

Hail days (hailstone size on ground > 5mm), unbiased case

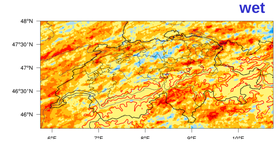


For reference (from Nisi et al. 2014):
Radar-derived hail climatology (hail size > 20 mm), April-September 2004-2014

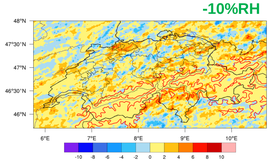


Change in hail days (hailstone size on ground > 5 mm), biased cases

wet

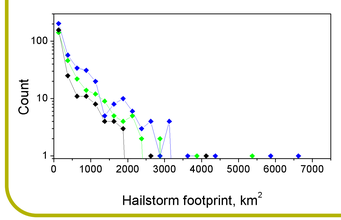


-10%RH



Simulated hailstorms are much more frequent in the surrogate CC conditions.

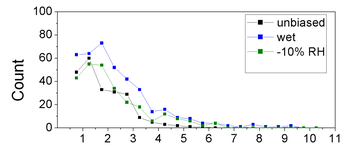
Main spatial patterns remain unchanged ("holes" = internal variability).



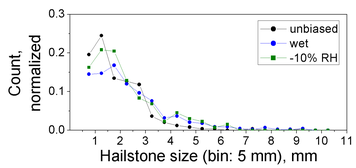
Hailstorm footprint (total size of spots with HS > 0.5 mm) - strongly enhanced in the CC simulations. Footprints up to 7 000 km² are simulated in the wet case (Area of Switzerland: 41 285 km²).

Hourly hail size (HS) distribution (> 5 mm)

Absolute

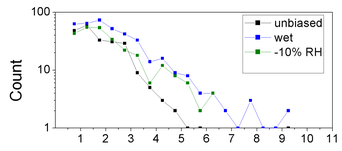


Normalized

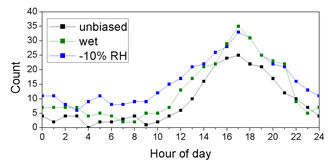


Unbiased case:
hail is present in 11% of all hours (245 out of 2208)
-10% RH case: 14% (314 events)
Wet case: 20% (434 events)

"Unbiased" and CC distributions are close for medium-sized hailstones.



Large hailstones: strongly enhanced in both CC simulations!
Unbiased run: Storms with HS> 40 mm: 9
-10%RH: storms with HS> 40 mm: 32
Wet case: storms with HS> 40 mm: 51



The biased diurnal cycles remains predominantly convective.
In both CC cases additional surface warming and moisture seem to enhance both the mesoscale forcing (nighttime formation of hailstorms) and the convective forcing (afternoon maximum).

Summary

- Simple uniform air temperature and relative humidity biases were used to roughly simulate the future climate conditions.
- More frequent hailstorms, covering larger surfaces and producing larger hailstones were simulated in CC conditions (relative to an unbiased JJA2012 run).
- Future work: more realistic climate-change biases. Pseudo-Global Warming?