Simulations of hailstorms over Switzerland in a warmer climate using a surrogate climate change approach

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OESCHGER CENTRE CLIMATE CHANGE RESEARCH

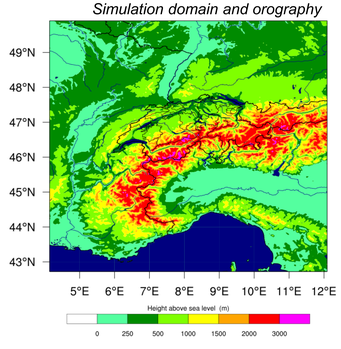
Motivation and objectives

- 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.
- Three air humidity levels were simulated: dry, wet and intermediate.
- We perform unbiased and biased WRF simulations of JJA2012 and compare features of simulated hailstorms: intensity, hailstone size on ground, spatial distribution, diurnal cycle, etc.

Simulation settings

- WRF 3.6.1 model. Simulation periods: 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



Surrogated climate change simulations

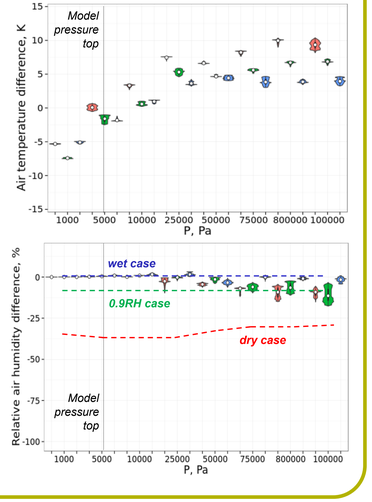
- Surrogated climate change (Schär et al. 1996):

adding artificial biases to air temperature and humidity.

- Which climate change is expected over Switzerland -> 2100?
- CMIP5, worst case (RCP8.5), 3 models were assessed:
  - **CanESM2**, **BCC-CSM1.1**, **CNRM-CM5**
- Changes of daily air temperature and RH over Switzerland:

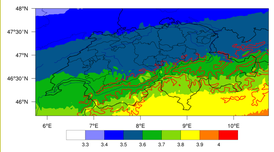
- Changes of air temperature almost constant (**CNRM-CM5**) or decreasing (**CanESM2**, **BCC-CSM1.1**) to ~250 hPa, then transition to cooling in the upper troposphere.
- 0% to 15% mean RH decrease in lower troposphere, (last-saturation-temperature constraint, *Sherwood et al. 2010*). Slight increase or no changes in upper troposphere.

A simplified experiment consists of 3 simulations (+ control run): homogenous +5 °C temperature bias,
"**wet case**": unchanged air RH,
"**0.9RH case**": 10% decrease of the relative humidity,
"**dry case**": unchanged air SH (60-70% decrease in RH).

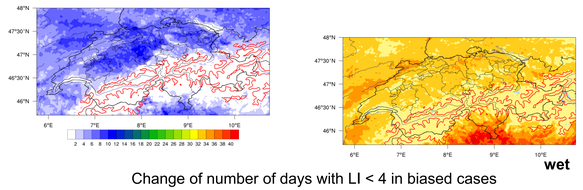


Changes in the atmospheric conditions

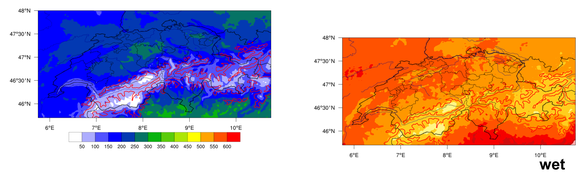
Mean freezing level (unbiased case), km



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

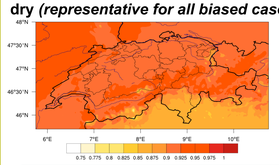


Mean daily maximum MU CAPE 0-180 mb (unbiased case), J/kg



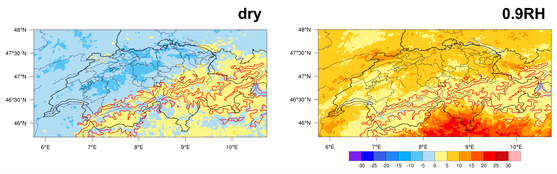
Mean freezing level increase, km

dry *(representative for all biased cases)*

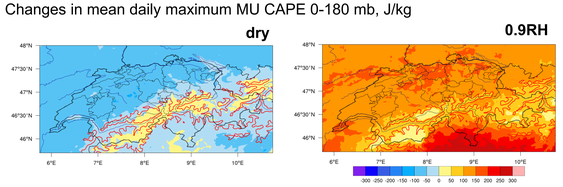


Red line: 2000 MASL

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

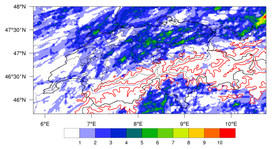


Changes in mean daily maximum MU CAPE 0-180 mb, J/kg

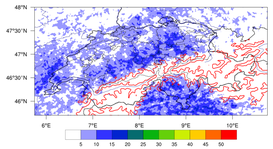


Changes of hailstorm characteristics

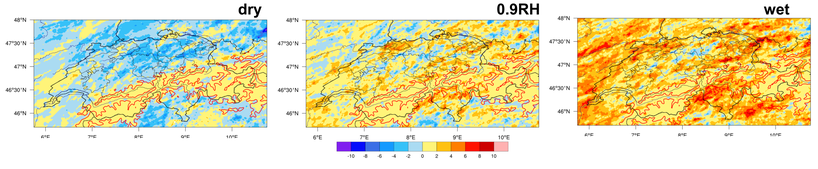
Hail days (hailstone size on ground > 0.5 cm)
unbiased case



*For comparison: **JJA 2012-2015**,*
days with MeteoSwiss radar MaxEcho > 45 dBZ



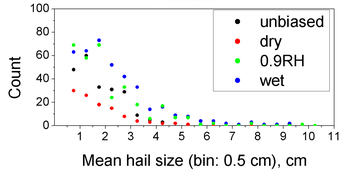
Change in hail days (hailstone size on ground > 0.5 cm), biased cases



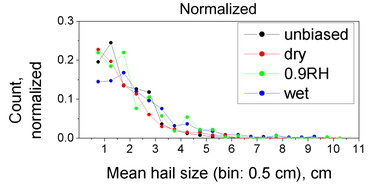
Simulated hailstorms are much frequent in the wet conditions and are less frequent in the "dry" conditions in comparison to the unbiased run. Main spatial patterns remain unchanged.

Hourly hail size distribution (> 0.5 cm)

Absolute

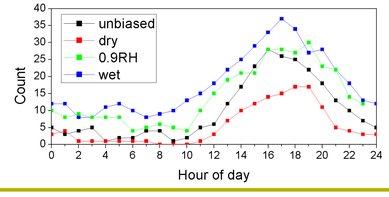


Normalized



Unbiased case:
hail is present in 11% of all hours (245 out of 2208)
Dry case: 6% (132 events),
0.9RH case: 14% (314 events)
Wet case: 20% (434 events)

"Unbiased" and "dry" distributions are close.
Wet and 0.9 RH cases:
fewer small and slightly more large particles.



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

Summary

- The HAILCAST 1D model , coupled with WRF, is used for predicting the properties of ground-reaching hailstones. The simulated spatial patterns are close to observations.
- The +5 C° air temperature bias, combined with enhances water content in the soil and in the atmosphere leads to strong enhancement of hailstorm activity over Switzerland (wet case).
- If the amount of atmospheric and soil water remains unchanged, the 5 C° air warming leads to stabilization of the atmosphere, much fewer hailstorm occurrences are predicted (dry case).
- Two studied cases represent the extreme conditions, with the humidity changes, predicted by CLIM5, lying in between.
- The fraction of hours with hailstorm over Switzerland, increased more than twice (from 11% to 20%) in the wet case. and decreased considerably in the "dry" case (from 11% to 6%).
- The hail size distributions are close in all studied cases; relatively few smaller particles and many larger particles were simulated in two wetter cases.
- The diurnal cycle remains predominantly convective, with a strong afternoon maximum. In the wetter cases the hailstorms are enhanced during the whole daily cycle.

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