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OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

Summertime hailstorms over Switzerland in 2012 -2015 in convection-permitting WRF simulations: assessment of modeling performance

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Motivation

- 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, CMIP5/RCP8.5)
- Climate change can potentially make summer hailstorms more harmful by enhancing their intensity, frequency, footprints. It is essential to be able to estimate possible changes for planning adaptation measures.

Bilder: 20 minuten, Leser-Reporter

General framework

- Summer hailstorms over Switzerland are simulated by the WRF model.

The simulations are run in a free-domain environment, no nudging / data assimilation is used: we want to let the model to freely react to the climate change.

- The hailstorms in current climate conditions are simulated (unbiased run) and assessed against available observations - *this talk.*

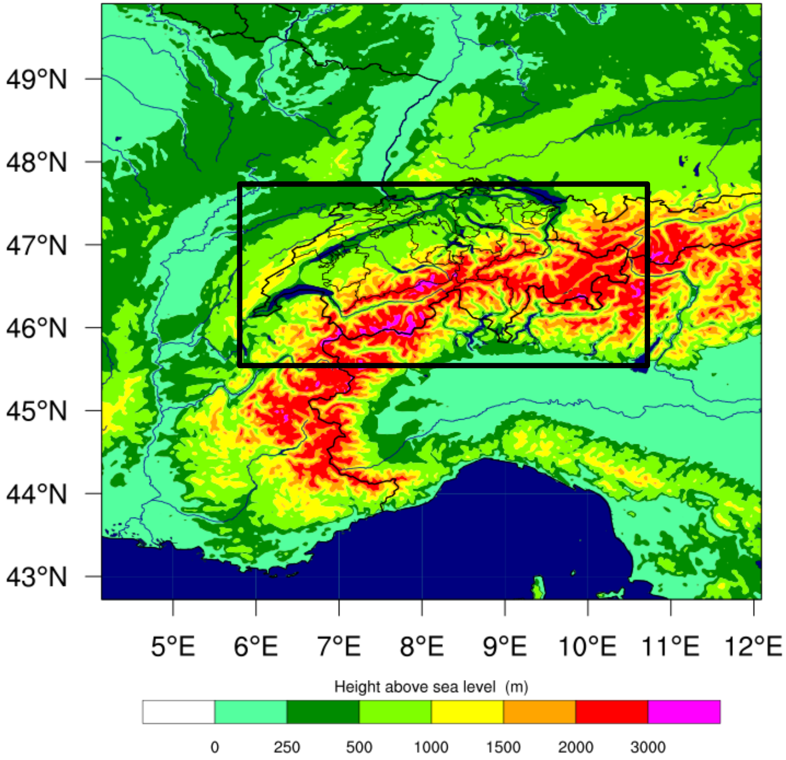
Principal research questions: How close in time/space are the simulated hailstorms to the observed ones in the most vulnerable regions of Switzerland? How can we estimate this?

- Then, the Surrogate Climate Change (CC) approach (*Schär et al. 1996*) is applied to these simulations.

First results - see our poster.

WRF simulation settings

- WRF 3.6.1 model. Simulation periods: 25.05 – 31.08 of each year



- Domain settings:
  - 2.14 km horizontal resolution,
  - 414 x 375 latlon grid,
  - 35 vertical levels, upper boundary: 50 hPa
- Forcing data: ECMWF analysis, 1/8º, 6-hourly.
- No cumulus parameterization (CPM)
- Microphysics: Morrison double-moment scheme
- AFWA diagnostics package for WRF, HAILCAST-1D hail model.
- Hail-related variables: - MaxEcho, microphysics-dependent;
  - MaxEcho, microphysics-independent (AFWA);
  - Hail size (from HAILCAST 1D).

Current climate: observation data

- Observation data available from MeteoSwiss:

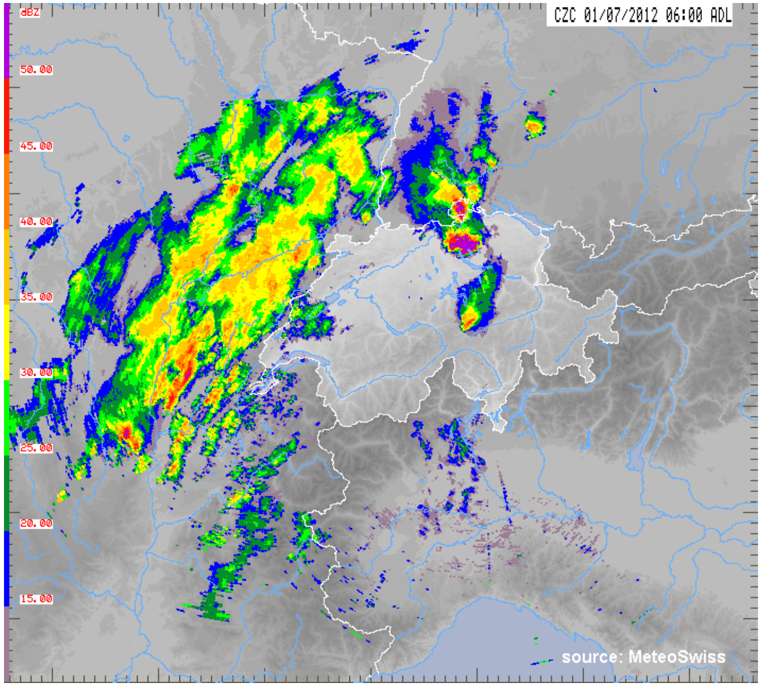
- MaxEcho, dBZ;

- MESHS, mm (valid if greater than 20 mm)
  Treloar, 1998

- POH (Probability of hail), %
Waldvogel et al. 1979, Foote et al. 2005

Radar data for June 2012: not used
(maintenance works on one of radars)

- ESWD “large hail” data over Switzerland.

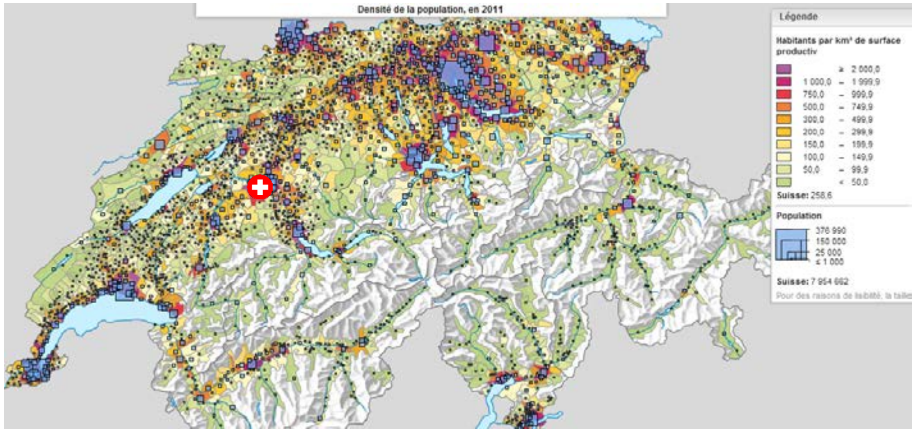


source: MeteoSwiss

Maximum radar reflectivity (Max Echo), example:
A hailstorm over Zurich, 01.07.2012

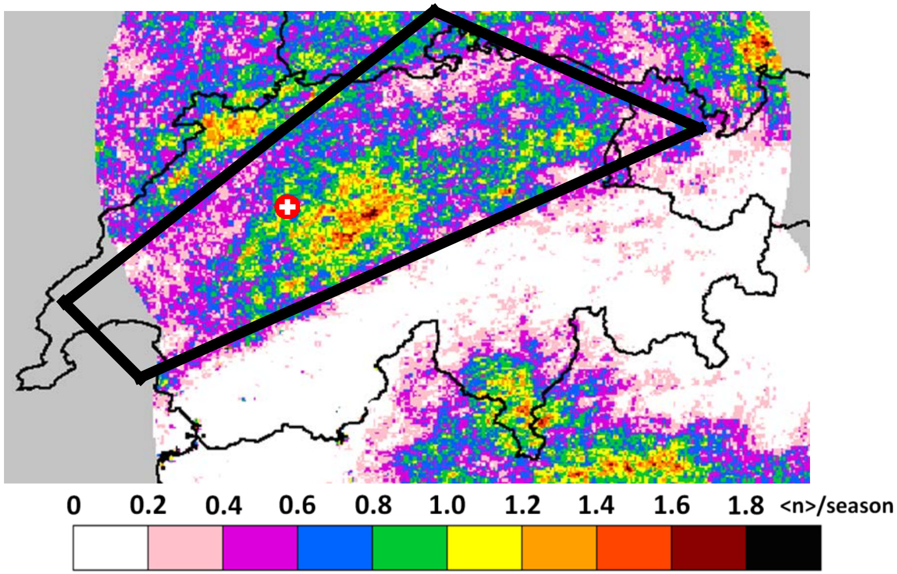
Hail climatology and population density

Population density



Radar-derived hail climatology (> 20 mm),

April-September 2004-2014



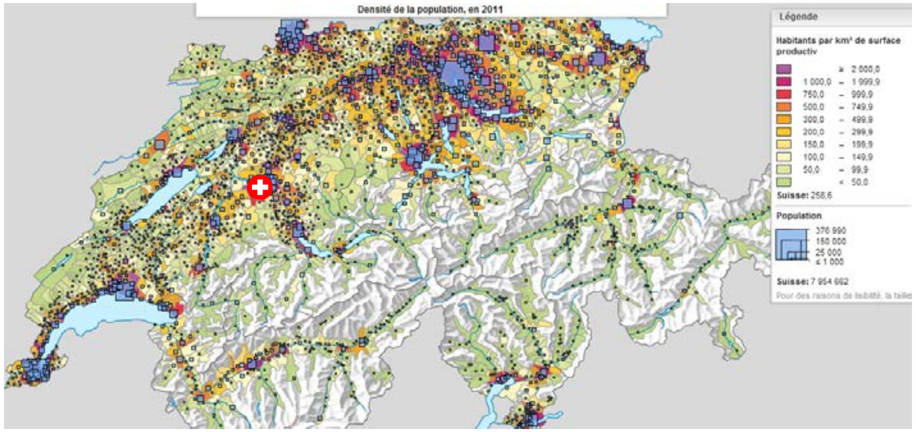
Nisi et al. 2014

The most hail-prone regions are the Swiss Plateau, Jura and Ticino.

In this work we will focus on the most populated and vulnerable Swiss Plateau region (black contour).

Hail climatology and population density

Population density



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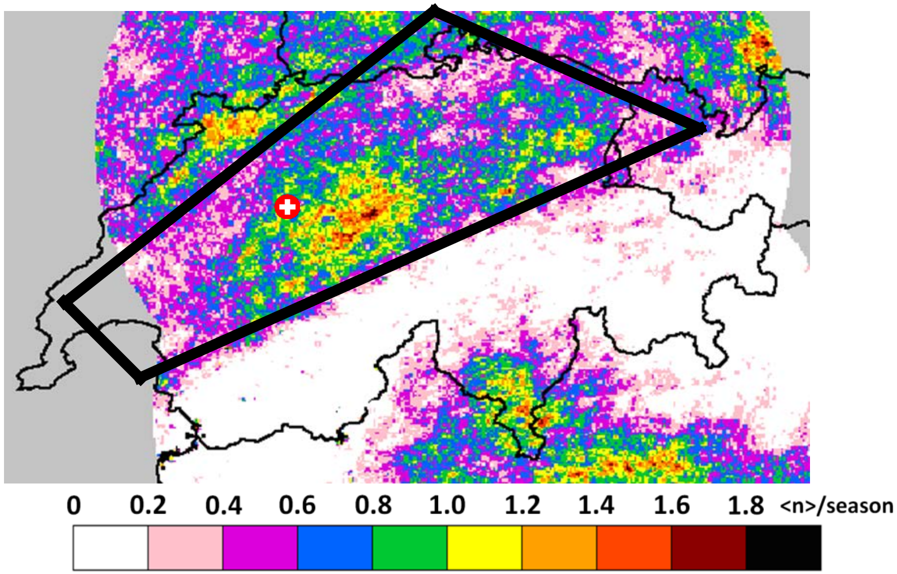

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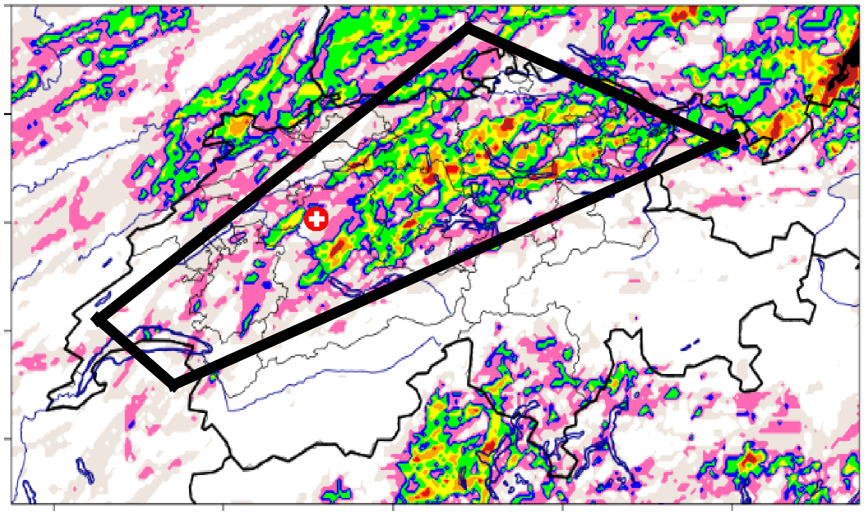


For comparison: WRF, JJA 2012-2015, days with simulated hail size > 5 mm

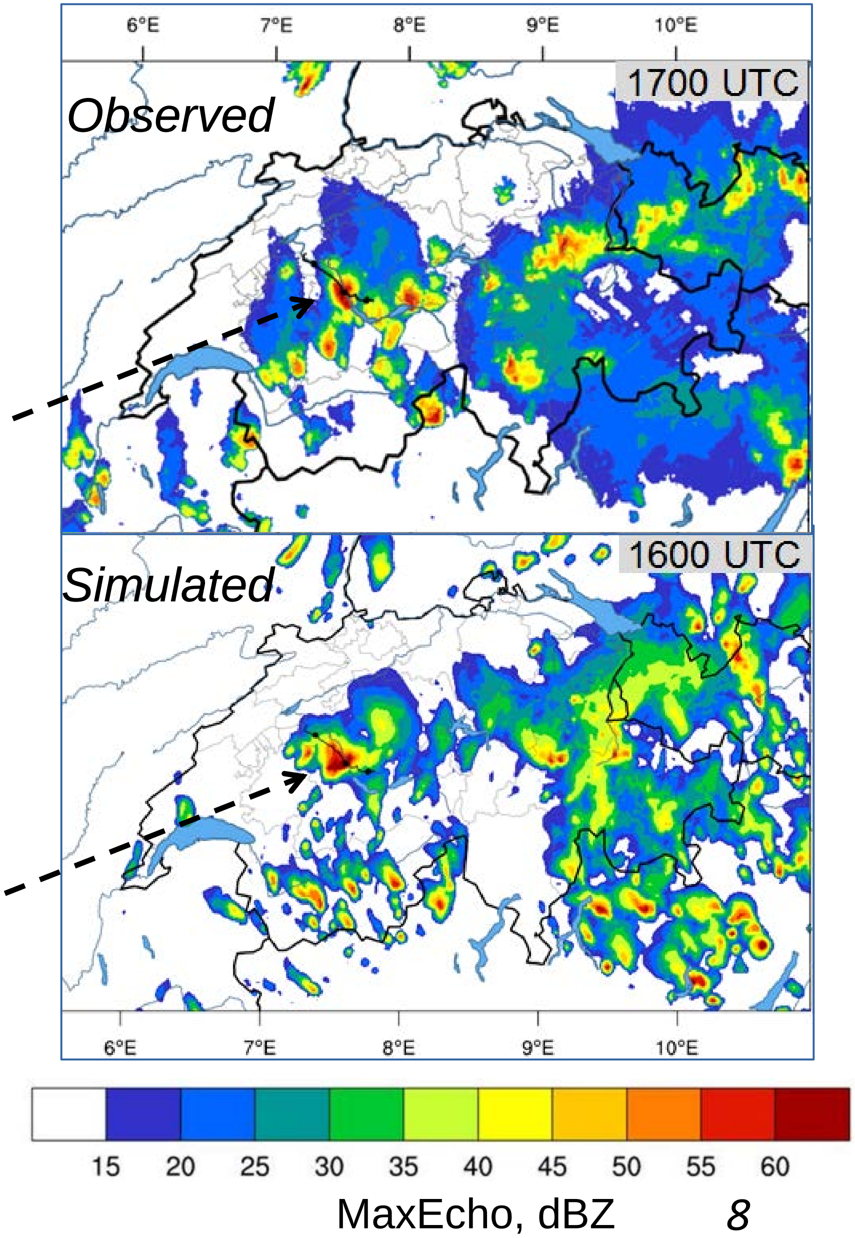
Assessment of hail simulation performance

The model runs freely and creates its own weather. A perfect time/space match with observed hailstorms is not expected.

Presupposition:

If hailstorm-favorable conditions are recreated by the model at correct area and time, hailstorms will be simulated in the spacial and temporal vicinity of the observed events.

Example:
Strong hailstorm over Thun, 06.06.2015.
MaxEcho: observed vs simulated.
In WRF – one hour earlier.
S.Trefalt et al, to be submitted;
Talk: Friday morning



Assessment of hail simulation performance. Method.

We need a method allowing to quantitatively assess the model performance in simulating hailstorms.

One possible approach: using an appropriate forecast skill index, with an adaptation for “legitimate” spatial/temporal biases in simulations. Here is the way we construct it.

- Hail events detection is based on gridded diagnostic variables, exceeding preset threshold values. Similar and heterogeneous fields can be compared.

Currently studied variables and thresholds (aimed at hailstorm detection):

Radar observation data, hourly:
- Max Echo > 45 dBZ;
- Probability of Hail > 80%;
- Maximum Expected Hail Size > 20 mm.

Simulation data, hourly:
- Simulated Max Echo, microphysics-dependent > 45 dBZ;
- Simulated Max Echo, microphysics-independent (AFWA) > 45 dBZ;
- Mean Hail Size from HAILCAST 1D > 5 mm and 20 mm.

Assessment of hail simulation performance. Method.

- Observed and simulated fields are mapped on a common latlon grid.

- Two grid resolutions are initially used: 10x10 km (~ size of a hailstorm) and 30x30 km.

- Categorical observation data are compared with the simulation data in their nearest neighborhood in space (9 cells, 30x30 or 90x90 km area) and time (± 2 hours).

- Events at distances up to ~20 km and ~60 km, resp., can be matched.

- Matching events are removed from the further analysis, to avoid the frequency bias.

Assessment of hail simulation performance. Method.

- Once all matching events are found, a contingency table can be build – for each grid cell or for all events within a given subdomain (e.g. the Swiss Plateau).

- Simulation assessment criterion: Symmetric extremal dependence index, SEDI (Stephenson 2008, 2011), based on the of the hit rate and the false alarm rate. SEDI produces meaningful results for rare events (such as hailstorms).

SEDI answers the question: What is the association between forecast and observed rare events?

SEDI = 1 is a perfect match, 0: as good as random, negative: worse than random.

- Other forecast skill indexes can be applied in the same way.

Assessment of hail simulation performance. The role of neighborhood size.

Example:
July-August 2012, comparison of MESHS > 20 mm and simulated HS > 5 mm.

Direct match: 10x10km grid cells vs single grid cells, **same time and place.**
SEDI = 0.29, Hit rate = 1%

10x10 km grid cell vs time/space heighborhood: (biases up to 30 km, ± 2 hours):
SEDI = 0.81, Hit rate = 50%

30x30 km grid cell vs time/space heighborhood: (biases up to 90 km, ± 2 hours):
SEDI = 0.89, Hit rate = 72%

The strongest enhancement of SEDI and hit rate: at the 30 km-large neighborhood. Further increase of the heighborhood size leads to saturation. There is no need looking at 30x30 cell matching with its neiborhood.

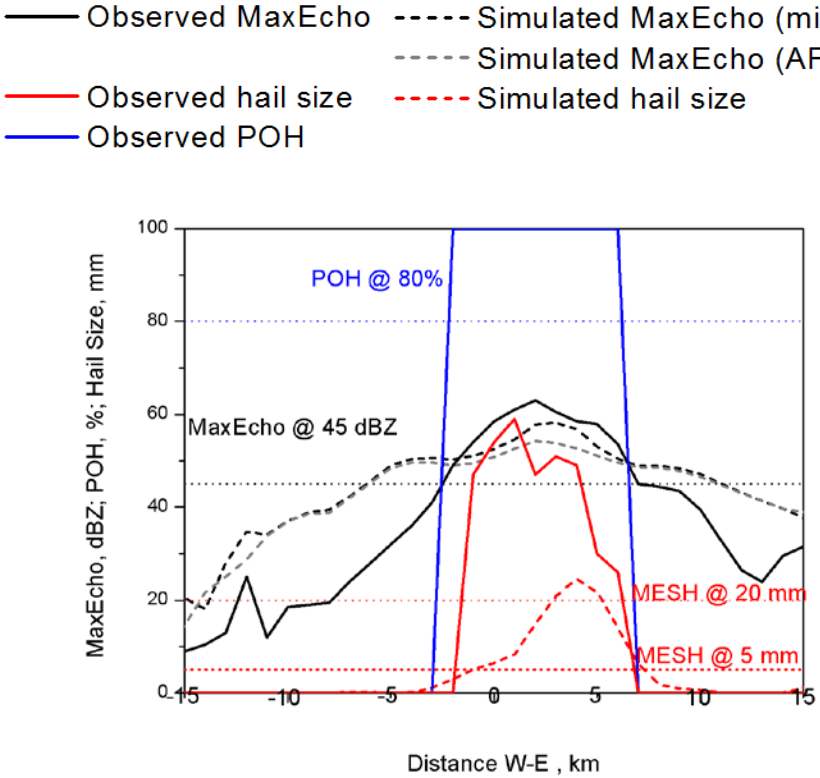
ESWD "large hail" events: 66% match to simulated hailstorms within 50 km and ±1 hour - in accordance with the hit ratio data.

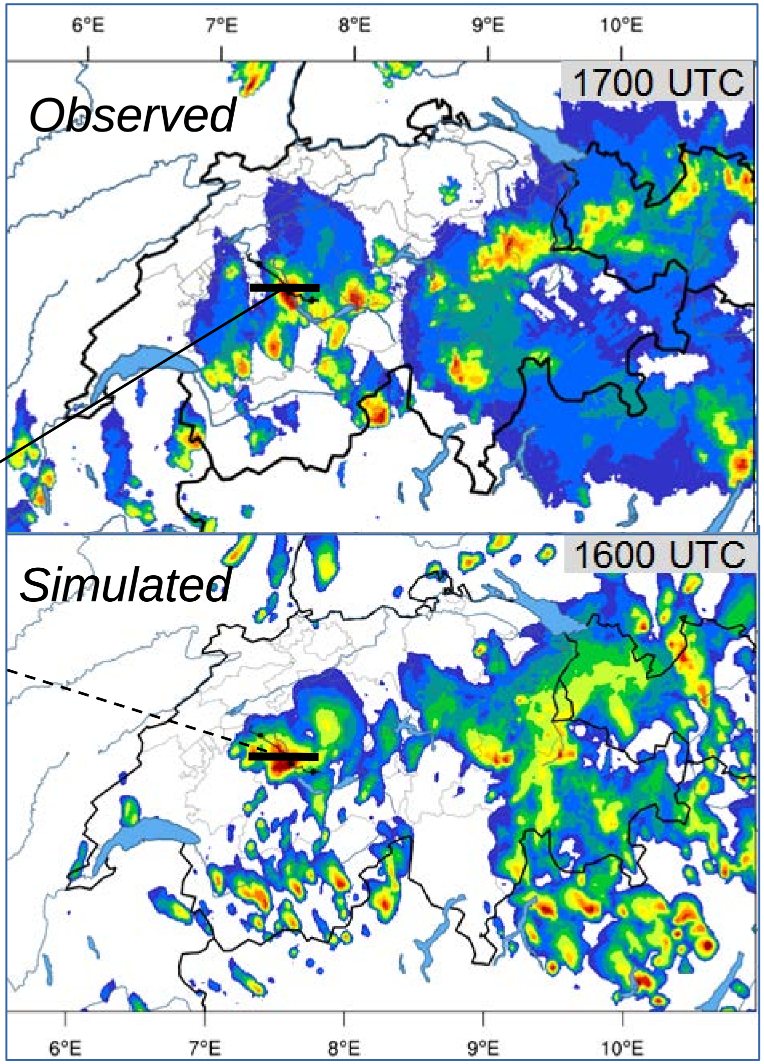
Swiss Plato SEDI, case 1, JJA 2012-2015 10x10 km, ±2h

Observations Simulations	MaxEcho @ 45 dBZ	POH @ 80%	MESH @ 20 mm
MaxEcho ”micro” @ 45 dBZ	0.80	0.76	0.78
MaxEcho AFWA @ 45 dBZ	0.78	0.80	0.82
Hail size @ 5 mm	0.59	0.78	0.80
Hail size @ 20 mm	0.44	0.61	0.64

Assessment of hail simulation performance

Meridional cross-sections of the Thun cell: observed and simulated variables





- Max Echo and POH "signatures" are much broader than those of the hail size;
- Close MaxEcho, different hail sizes.

Assessment of hail simulation performance. July-August 2012: sensitivity tests

1 1 domain, Morrison microphysics,
35 vertical levels, start 25.05

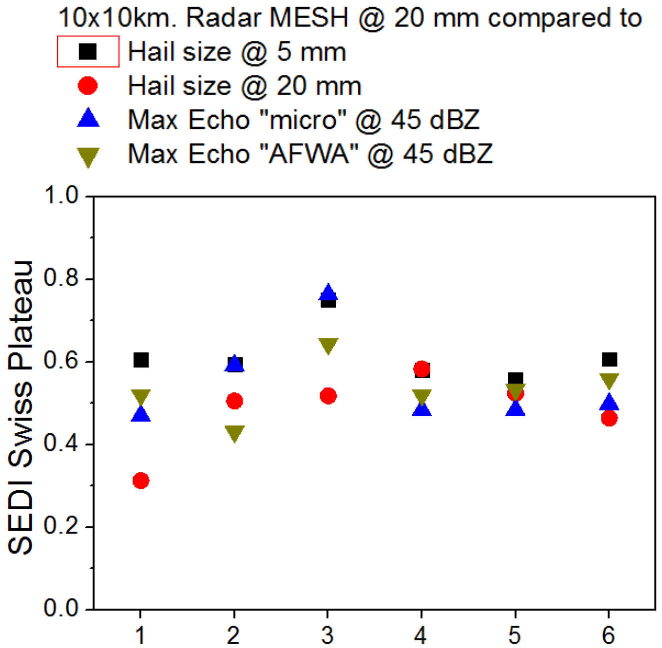
2 1 domain, Thompson microphysics,
35 vertical levels, start 25.05

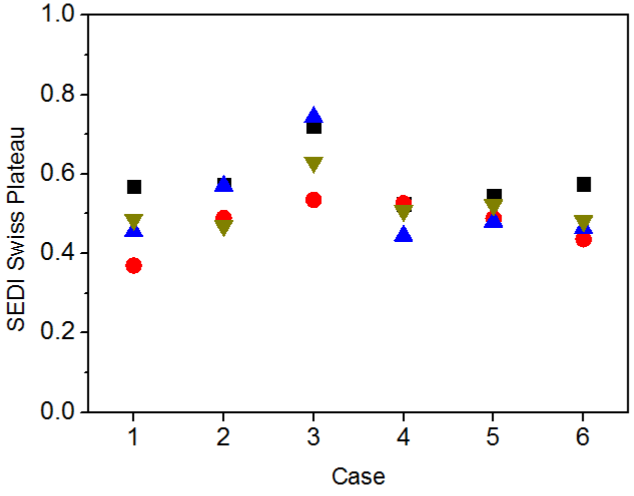
3 2 domains, Morrison microphysics,
35 vertical levels, start 25.05

4 1 domain, Morrison microphysics,
70 vertical levels, start 25.05

5 1 domain, Morrison microphysics,
35 vertical levels, start 26.05

6 1 domain, Morrison microphysics,
35 vertical levels, start 27.05


10x10km. Radar MESH @ 20 mm compared to


10x10km. Radar Probability of Hail @ 80%

Summary

- Observed hailstorms were compared with those simulated in their spatial and temporal vicinity (allowing for time bias up to 2 hours and spatial biases of up to circa 30 and 90 km) and the SEDI index was build for all events over the Swiss Plateau.
- Using a neighborhood of and time bias of up to 2 hours is strongly increasing SEDI and hit rate values. The hit rate is in agreement with the distances between ESWD large hail events and observed hailstorms. If SEDI is used, comparing observation data in 10x10 grid cells with their nearest neighborhood is sufficient, no need to increase the cell size.
- For JJA2012-2014, simulated radar reflectivity and HAILCAST-1D- produced hailstone size estimation are in very good match with the observed hailstorms.
- Sensitivity tests: at low “hailstorm-detection”-thresholds the SEDI values do not depend strongly on the model settings, such as microphysics or number of vertical levels. At higher thresholds (e.g. comparing strong hailstorms) the sensitivity is expected to become stronger. The domain setting turns out to be important.
- Correct choice of threshold values is essential!

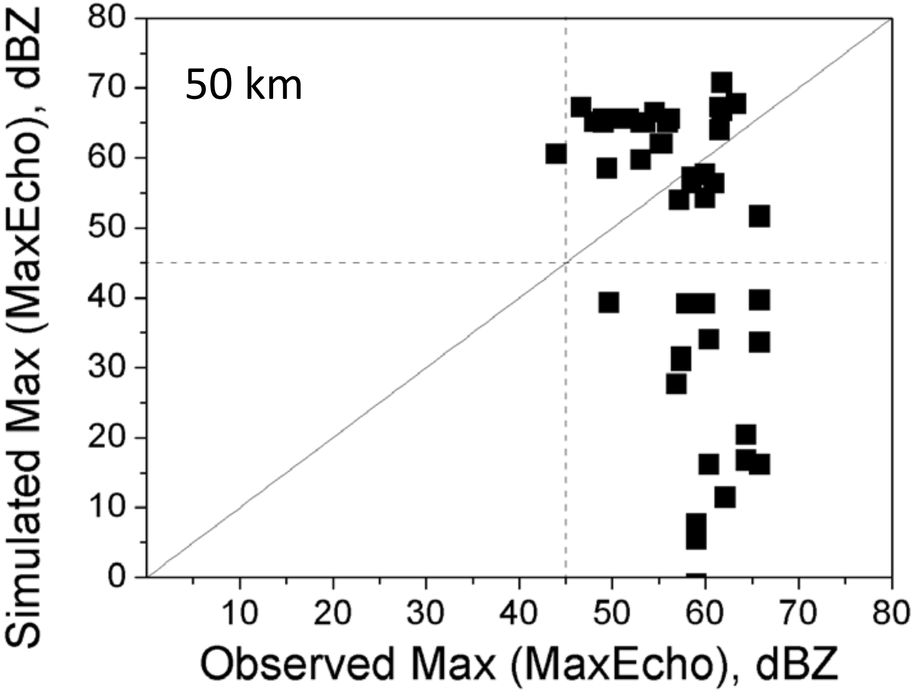
How close are observed and simulated hailstorms from ESWD cases?

- 83 "Large hail" ESWD events were compared with observed and simulated MaxEcho fields in their 50-km vicinity, ±1 hour. Threshold: 45 dBZ.

82 events: strong observed radar echo match.

55 events (66%) : strong simulated radar match within 50 km.

(28 remaining events also have simulated matches, but at larged distances)



This result is in agreement with the hit ratio values (50% at 30 km, 72% at 90 km).