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Simulated hailstorms over Switzerland in May 2018 in current and future climate conditions

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Motivation

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- Summer hailstorms over Switzerland cause massive 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

Outline

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- Pilot study, aimed at testing the model performance and data treatment methods for a longer series of simulations (April-September 2012-2019).
- May 2018: many hailstorms in Switzerland, convenient testbed.

- Current climate:
  - Convection-permitting simulations with WRF, different microphysics + HAILCAST
  - Hailstorm properties: object-based (cell-tracking) and "eulerian" methods;
  - Comparison with radar observation data for the Swiss Plateau.

- Climate change:
  - WRF simulations, using the Surrogate Climate Change approach.
  - Hailstorm properties: comparison with current climate simulations.

WRF settings

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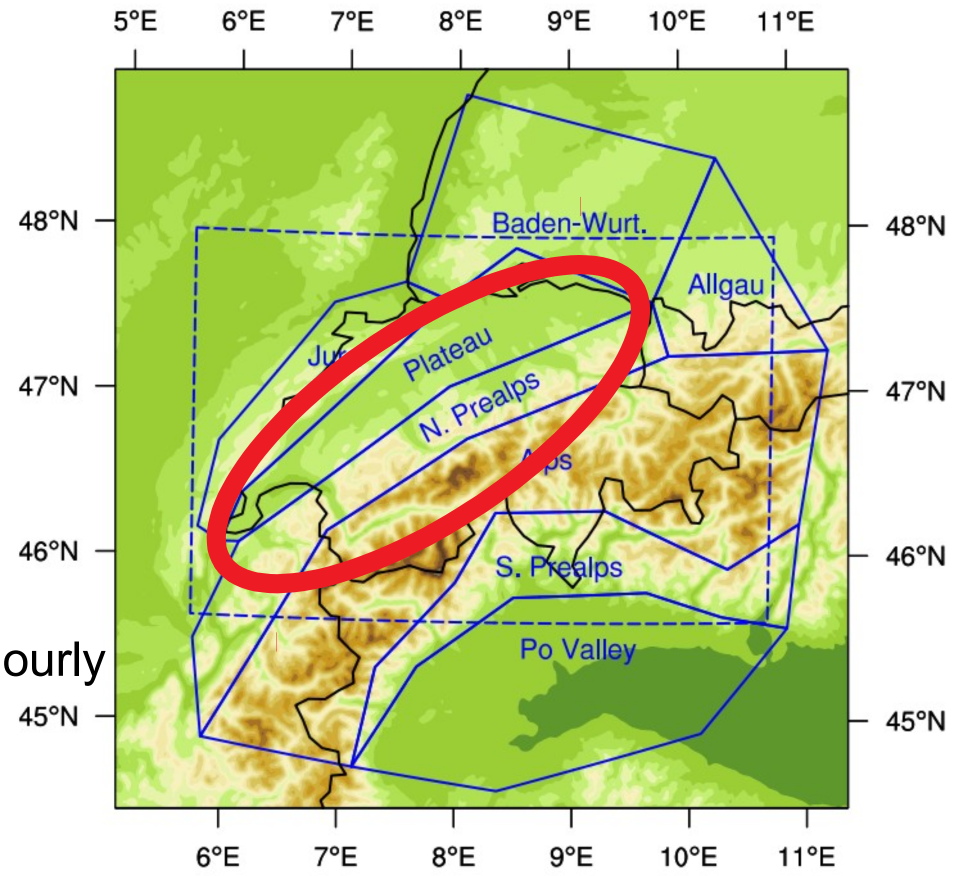
- WRF 4.0 model. Simulation period 25.04.2018 – 31.05.2018 (one week spin-up)

Two nested domains:

- Horizontal resolution: 4.5 and 1.5 km;
- 480 x 402 rotated latlon grid,
- 50 vertical levels up to10 hPa;
- **5-min output for cell-tracking.**

(Ubelix, 128 CPU: 3 days/day, 630GB/day)



- Forcing: ECMWF analysis, 1/8°, 6-hourly

- Explicit hail: HAILCAST 1D.

- Microphysics: Thompson, Morrison, P3

Current climate: observation data

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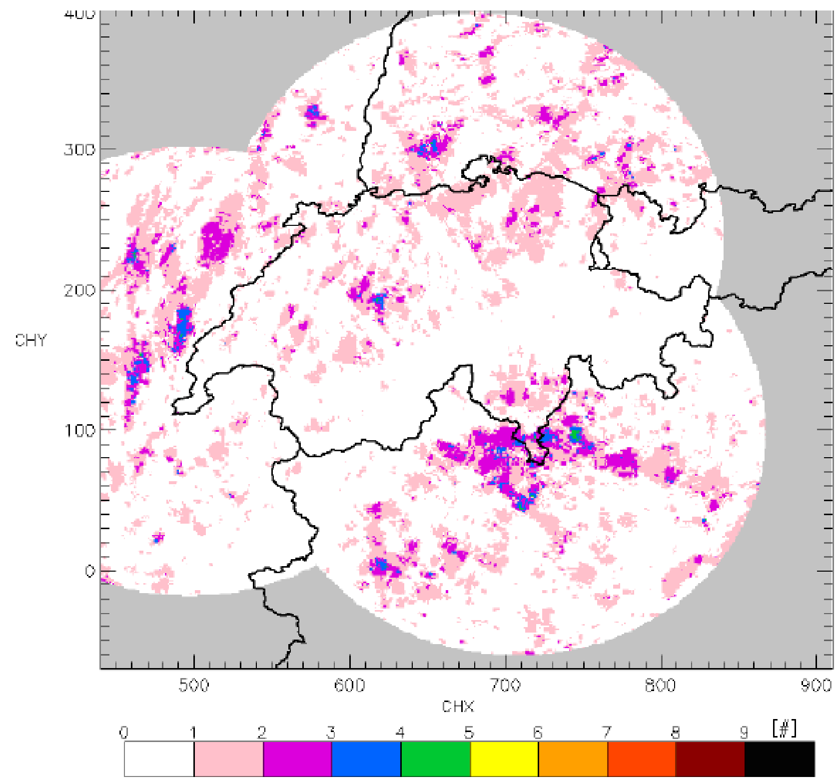
MeteoSwiss radar data (5 C-band radas):

- Radar reflectivity:
  MaxEcho [dBZ], 2D fields, 5 min.

- Maximum Expected Severe Hail Size:
  (Treloar, 1998) – only if > 20mm!
  MESHS [mm], 2D fields, 5 min.

- Probability of hail:
  (Waldvogel et al. 1979, Foote et al. 2005)
  POH [%], 2D fields, 5 min.

Number of days with POH > 80% per km² in May (2018)



Luca Nisi, MeteoSwiss Locarno

ESWB: 11 "large hail" events.

MeteoSwiss smartphone application: 813 hail events reported by users.

Hailstorm analysis methods

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- Object-based methods: cell identification and tracking tools

For WRF data: TITAN (*Dixon and Wiener, 1993*):

- 3D radar reflectivity field, 5-min frequency.
- Constant threshold, requires adjustment to microphysics.

For MeteoSwiss data data: TRT (*Hering et al 2004*)

- 2D radar reflectivity field, 5-min frequency.
- Adaptive threshold

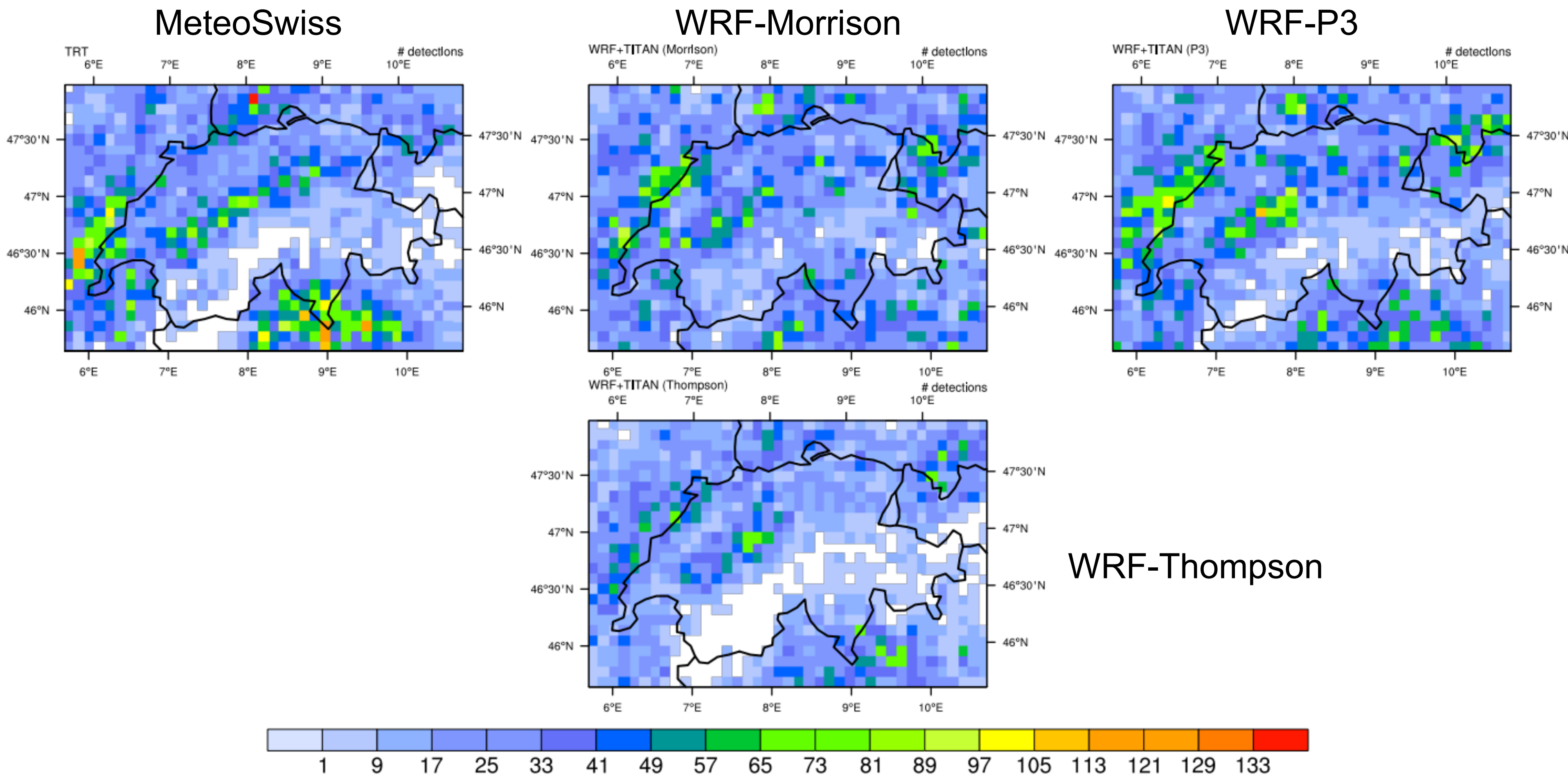
Output: properties of individual cell tracks (initiation place and time, trajectory direction and length, duration of existence, etc.).

- "Eulerian" methods: comparison of gridded data, no cell identification.

Neighborhood method: does the model produce hail near the observed hail events?

Typical neighborhood size: 2 hours, 30 km

Current climate: cell detections



The overall number of cell detections in each 10_x0002_x10 km^2 grid point

Current climate: cell properties

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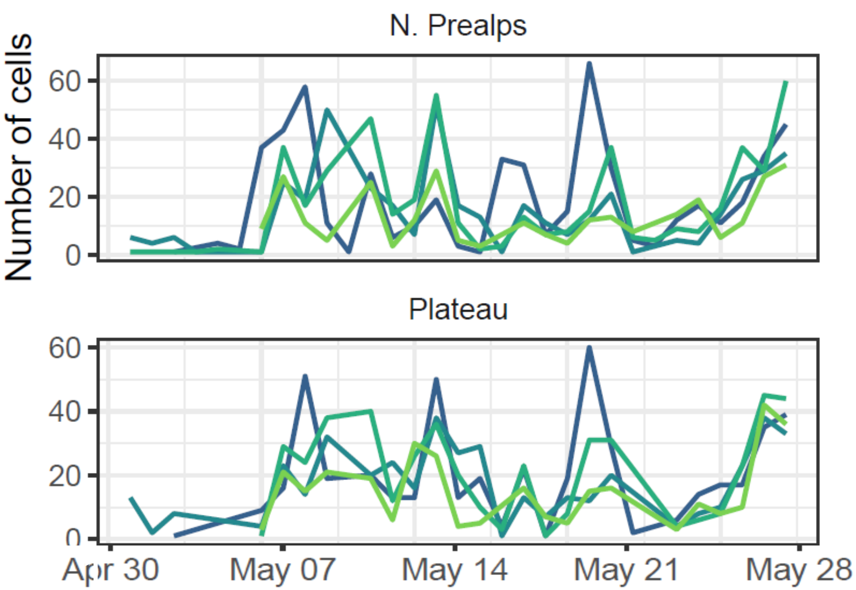
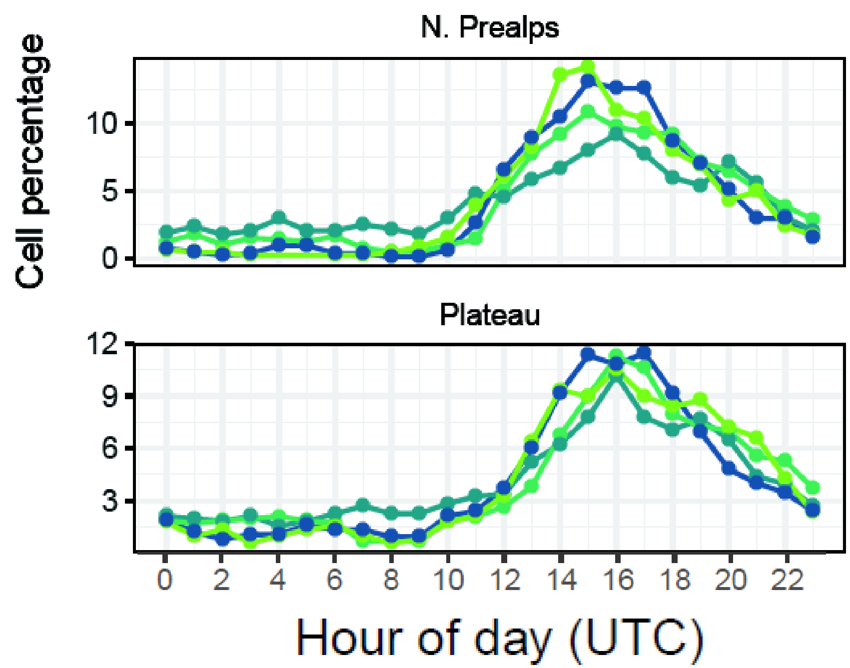
Method	Num. cells	Num. tracks	First cell (UTC)	Last cell (UTC)
WRF+TITAN (P3)	27612	2457	2018-05-01 14:40:00	2018-05-31 23:55:00
WRF+TITAN (Morrison)	26540	2417	2018-05-01	2018-05-31 23:55:00
WRF+TITAN (Thompson)	17710	1768	2018-05-03 05:20:00	2018-05-31 23:35:00
TRT	25936	2831	2018-05-02 19:10:00	2018-05-31 23:55:00

Total number of cells and tracks detected

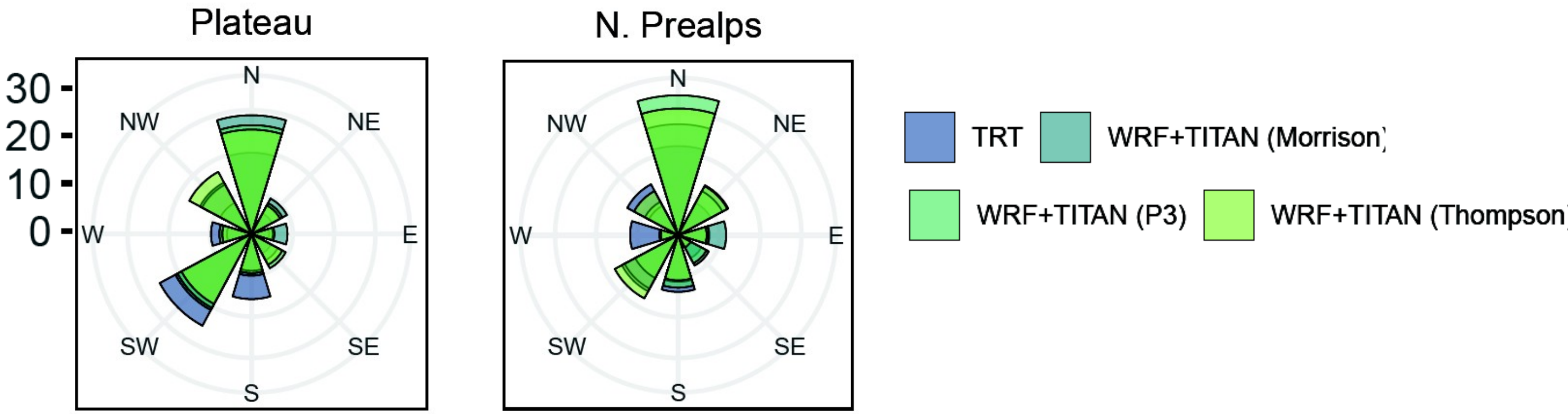


Storm cells detected per day

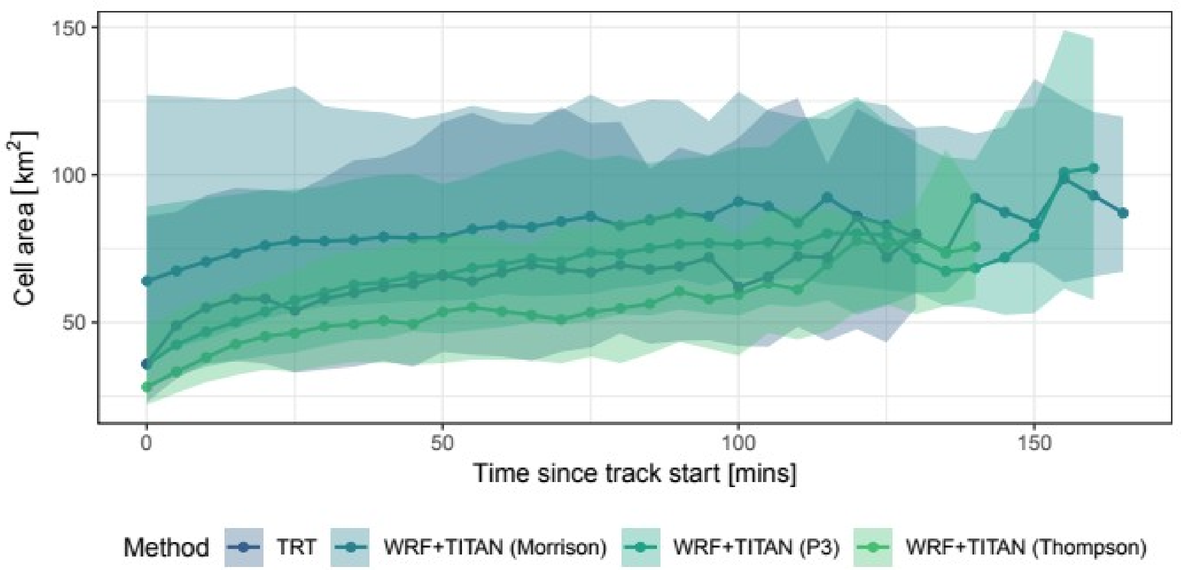


Method — TRT — WRF+TITAN (Morrison) — WRF+TITAN (P3) — WRF+TITAN (Thompson)

Current climate: stormtrack properties



Advection direction (% of all cells)



Cell area evolution

Climate change towards 2100 over Switzerland in summertime

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- CMIP5, RCP8.5 scenario,

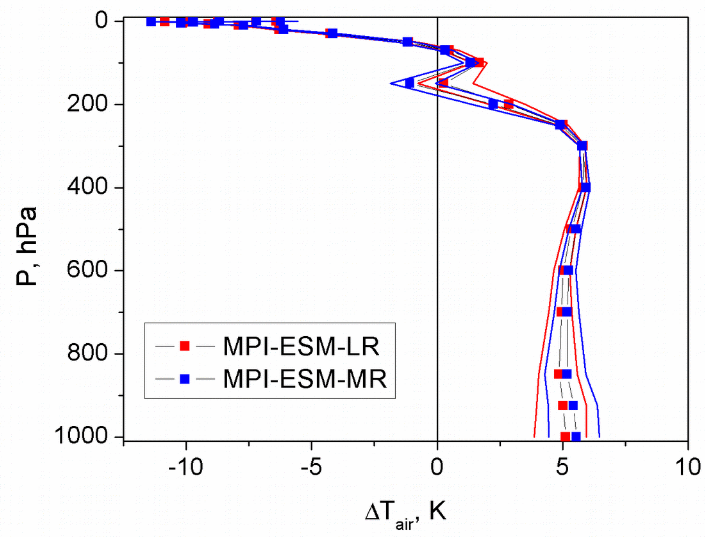
2070-2100 – 1970-1999, JJA

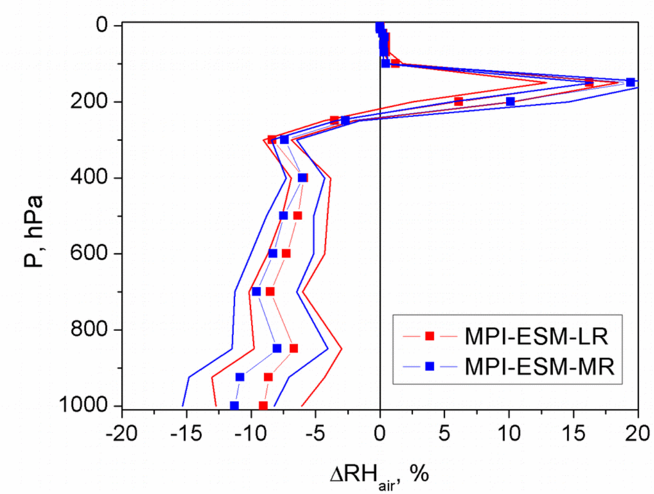
MPI-ESM-LR, **MPI-ESM-MR**

- Strong warming in lower troposphere, stratospheric cooling

- 0% to 15% mean RH decrease in lower troposphere,

(last-saturation-temperature constraint, *Sherwood et al. 2010*).





Surrogate climate change: biases in initial and boundary conditions

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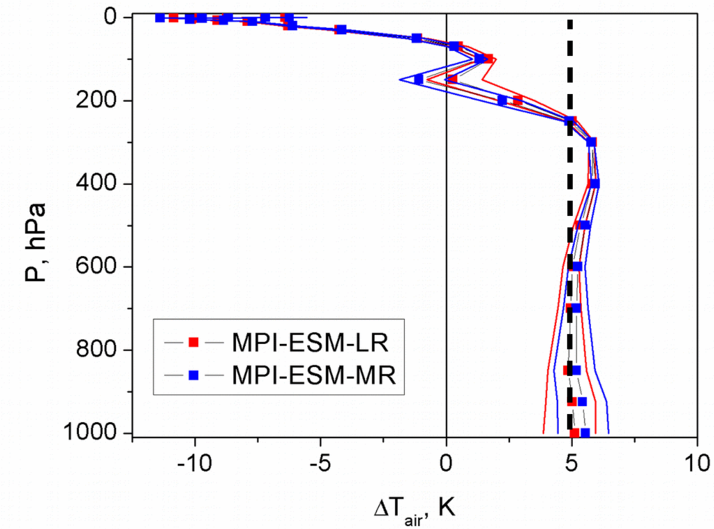
- Surrogate climate change
- *(Schär et al. 1996, Keller et al 2018, etc.):*

adding artificial biases to air temperature and humidity for simulating the changed climate conditions.

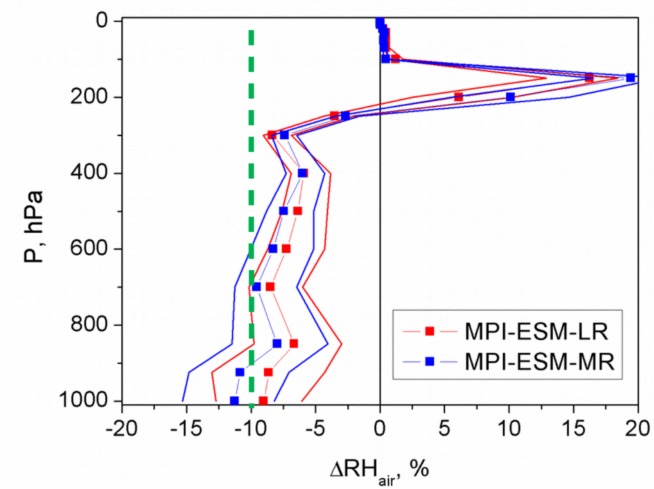


Current experiment:

homogenous +5 °C temperature bias

homogenous 10% RH decrease

Morrison microphysics (more to come)



Data analysis with TITAN: similar settings

(no threshold adjustment)

Climate change: cell distribution

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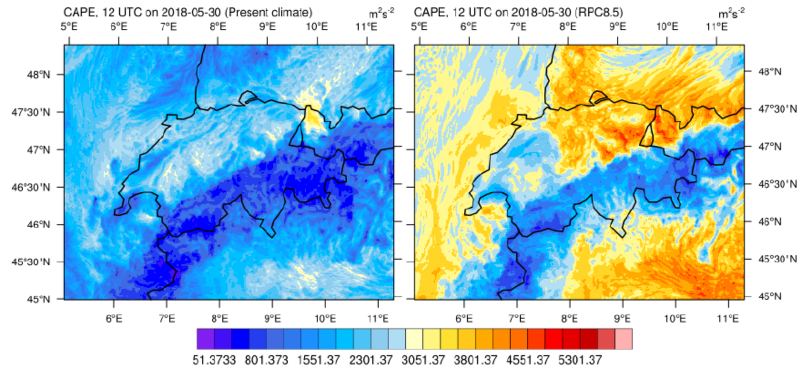
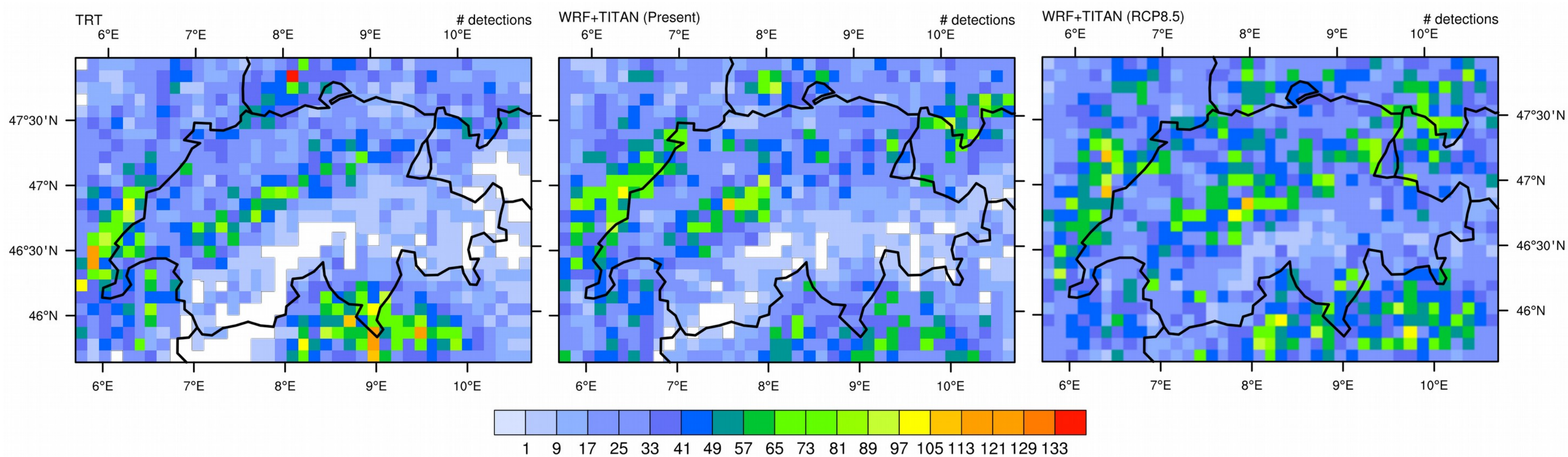
Present-day **RCP 8.5**



Above: Convective Available Potential Energy (CAPE) in present and future simulations for 30th May 2018.

MeteoSwiss (reference) WRF-Morrison, present climate WRF-Morrison, RCP 8.5



The overall number of cell detections in each 10_x0002_x10 km^2 grid point

Climate change: cell properties

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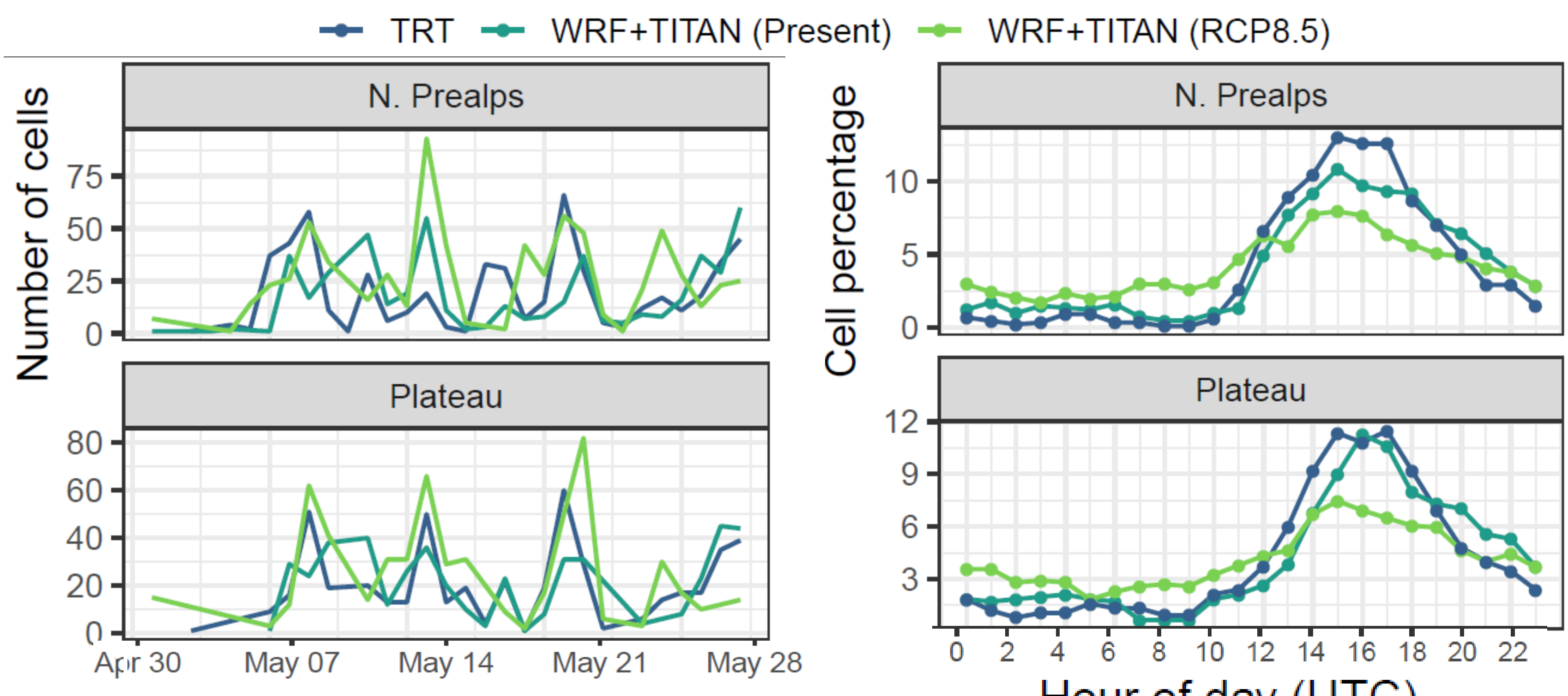
Method	Num. cells	Num. tracks	First cell (UTC)	Last cell (UTC)
WRF+TITAN (Present)	27612	2457	2018-05-01 14:40:00	2018-05-31 23:55:00
WRF+TITAN (RCP8.5)	36390	3459	2018-05-01	2018-05-31 23:55:00
TRT	25936	2831	2018-05-02 19:10:00	2018-05-31 23:55:00

Total number of cells and tracks detected



Storm cells detected per day

Climate change: stormtrack properties

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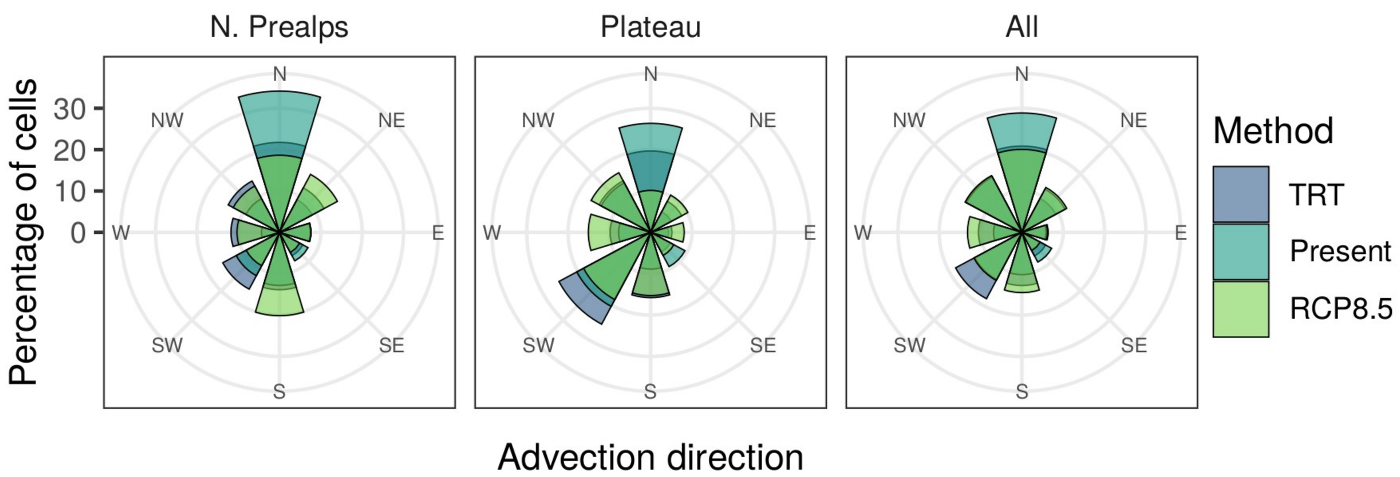

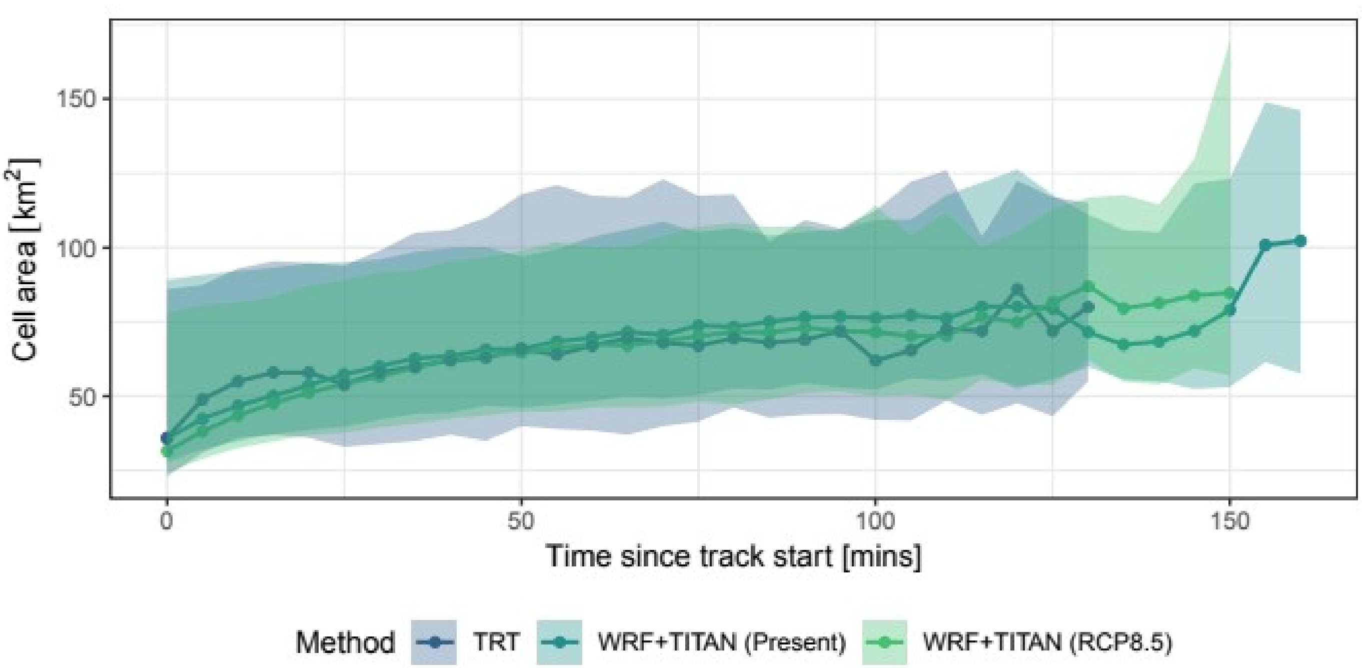

Summary and conclusions

- The WRF model in the selected configuration reproduced reasonably well the main properties of hailstorms, that occurred over the most inhabited regions of Switzerland. Both spatial and temporal distrubution of hailstorms and the properties of individual storm cells have in general been reproduced.
- Distinctions between different microphysical schemes are considerable, but as they depend on tuning parameters, such as the hailstorm detection threshold, it is difficult to definitively determine the best one.
- Surrogate climate change experiment: ~30% more hailstorms can be expected than in the current conditions. No considerable change of individual hailstorm properties.

Hail size: HAILCAST-1D + WRF

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- "Alberta Hail Growth model“, originally from South Africa.

1D one-dimensional coupled cloud and hail model

Poolman 1992, Brimelow et al. 2002.

- Input: proximity atmospheric soundings (steady-state)

- Perturbations are added to the soundings to create a representative ensemble.

- A set of hail embryos is “injected” to these perturbed soundings and let evolve.

Validation over the CONUS, offline version*: Jewell, Brimelow 2009*

- Modified version coupled with WRF since 3.6.1.

Considerable modifications of the hail model were required.

Description and validation: *Adams-Selin R. D., Ziegler C.L. "Forecasting hail using a one-dimensional hail growth model within WRF", MWR 2016, DOI: 10.1175/MWR-D-16-0027.1*