Temperature and dew point scaling of convective cells in present and future conditions

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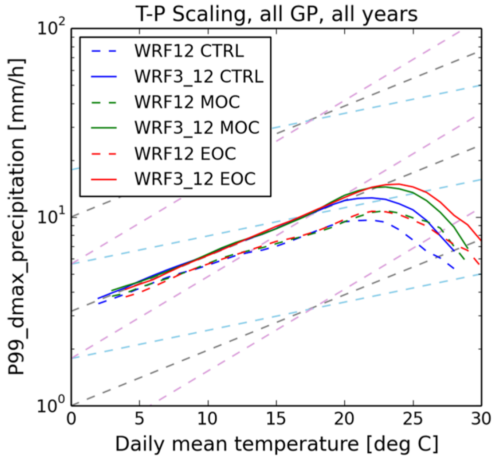
Introduction: How will extreme precipitation change in the future?

- Intensification of the hydrological cycle with higher temperatures
- Precipitation extremes could scale according to water holding capacity (CC-rate: 7%/K)
- Different scaling rates on sub-daily time scales
  - Convection permitting simulations show varying scaling rates close to Clausius-Clapeyron Rate or above
  - Similarity: scaling curve drops off at higher temperature and higher precipitation values in the future (e.g. Prein et al. 2017, Knist et al. 2018)


Thunderstorm near Hilter, Germany. © Bastian Kirsch



Knist et al. (2018)

Introduction: Limitations of temperature scaling

- 2m temperature is a proxy for absolute humidity only if relative humidity is constant
- Humidity is only 1 of at least 3 parameters (besides static stability and wind shear) to determine form and strength of convective storms (see e.g. Weismann & Klemp 1982)

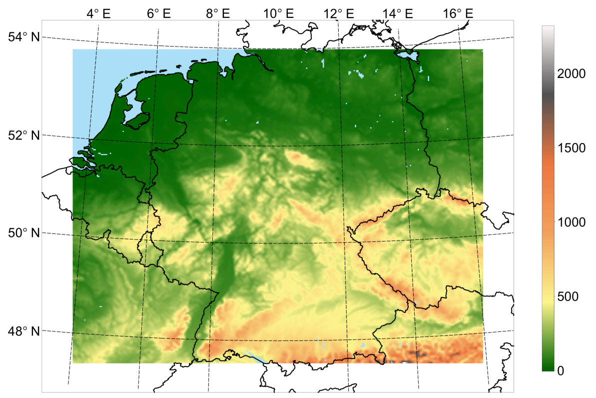
➢ Understanding of convective cell dynamics in convection-permitting simulations necessary

➢ Convective cell tracking

- Research questions:
  - (1) How will the characteristics of convective cells change with global warming?
  - (2) Is the temperature and moisture scaling of cell characteristics similar in present and future conditions and what is the influence of static stability?

Methods: Tracking rain cells in convection-permitting simulations

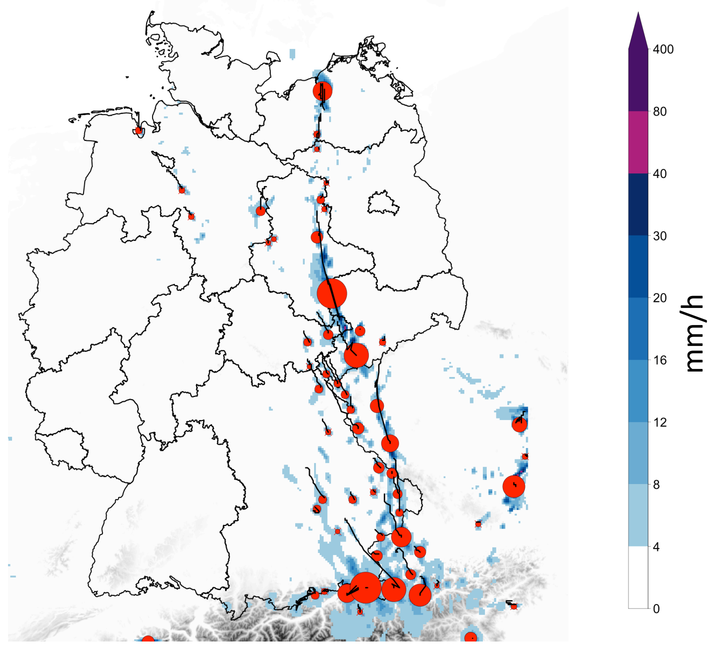
- 2 Continuous Simulations at 2.8 km grid size
  - 1976-2005 (Present) and 2070-2100 (Future, RCP8.5)
  - 1-moment microphysics with graupel
  - Nesting strategy:
    - EC-Earth GCM ->
      0.22° COSMO-CLM ->
      0.025° COSMO-CLM



Tracking of 5-min precipitation output

Cell characteristics:

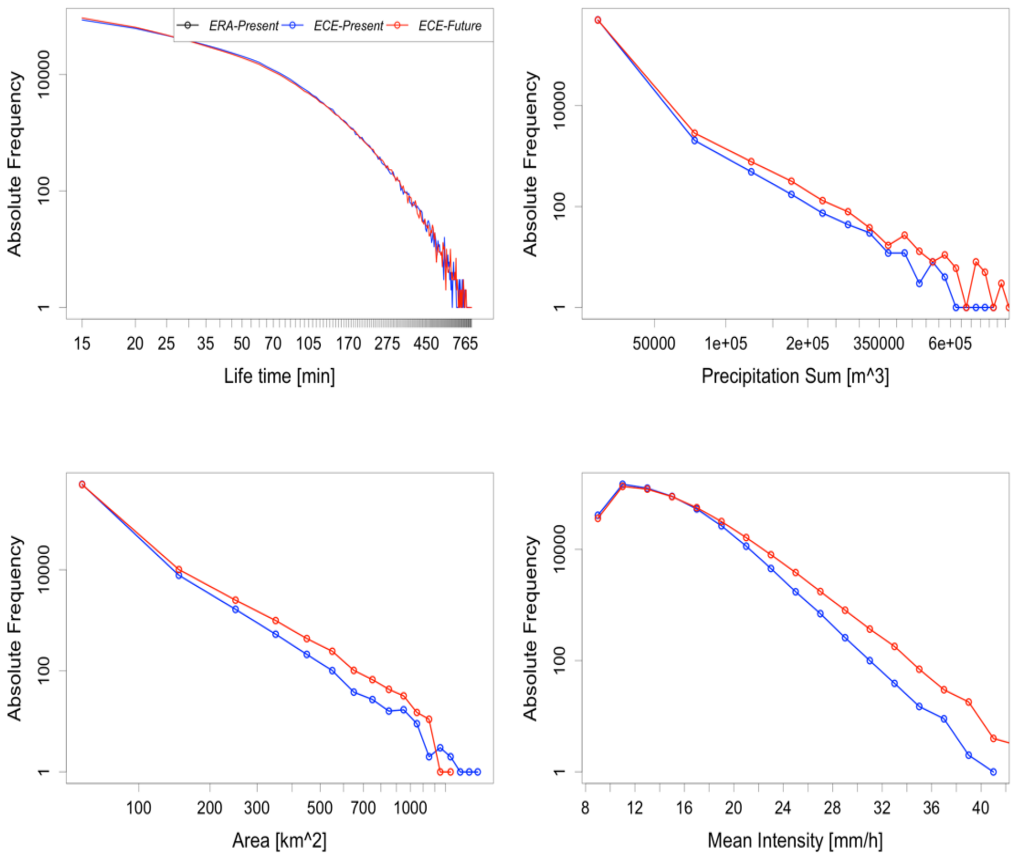
- Lifetime
- (mean and maximum) Intensity
- (maximum) Area
- Precipitation sum



5-min Precipitation intensity, detected cells (red circles) and tracks (black lines)

Results (1): Frequency of cell characteristics

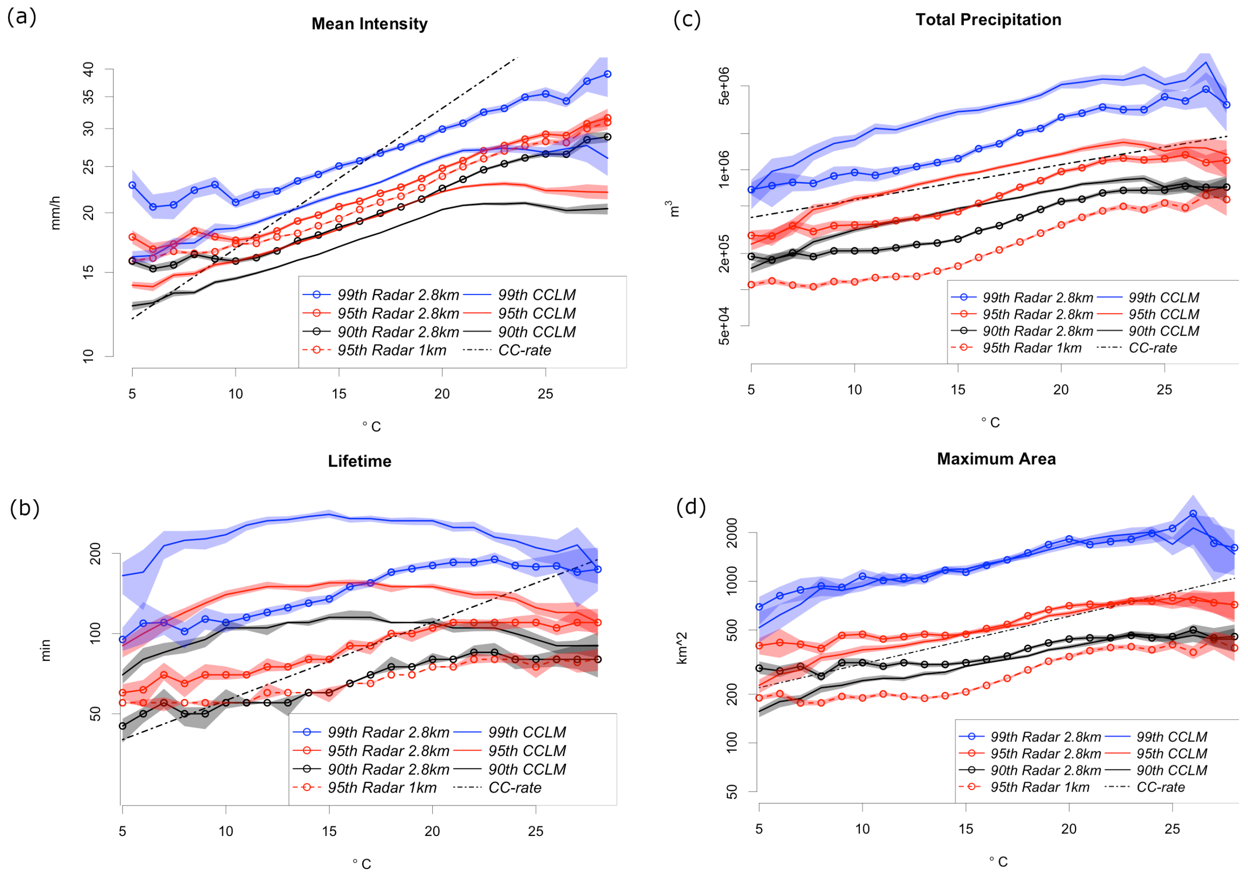
Change in %	Lifetime	Max. Area	Precipitation Sum	Mean Intensity	Max Intensity
Mean	-2,1	+13,4	+18,3	+3,3	+8,3
Median	0,0	+9,1	+3,2	+2,4	+5,8
75th perc	-7,7	+10,5	+6,4	+3,6	+8,9
90th Perc	0,0	+13,5	+12,0	+5,2	+11,1
99th Perc	0,0	+27,9	+27,0	+9,3	+15,8
Trend Scaling of 99th P. [%/K]	**0**	**+8.2**	**+7.9**	**+2.7**	**+4.6**



- Total number of cells is virtually constant (+0.4%)
- Intensity and area of cells increases while lifetime stays constant -> increase in precipitation sum per cell
- Strongest relative increase for highest precentiles -> strongest storms intensify the most

Interlude: Evaluation of temperature scaling of cell characteristics

- observations: Radar climatology (5-min precipitation for 15 years)
- Similar scaling rates
- deviations:
  - Total precipitation: constant slope
  - Mean intensity: drop-off at high temperatures
  - lifetime: everything



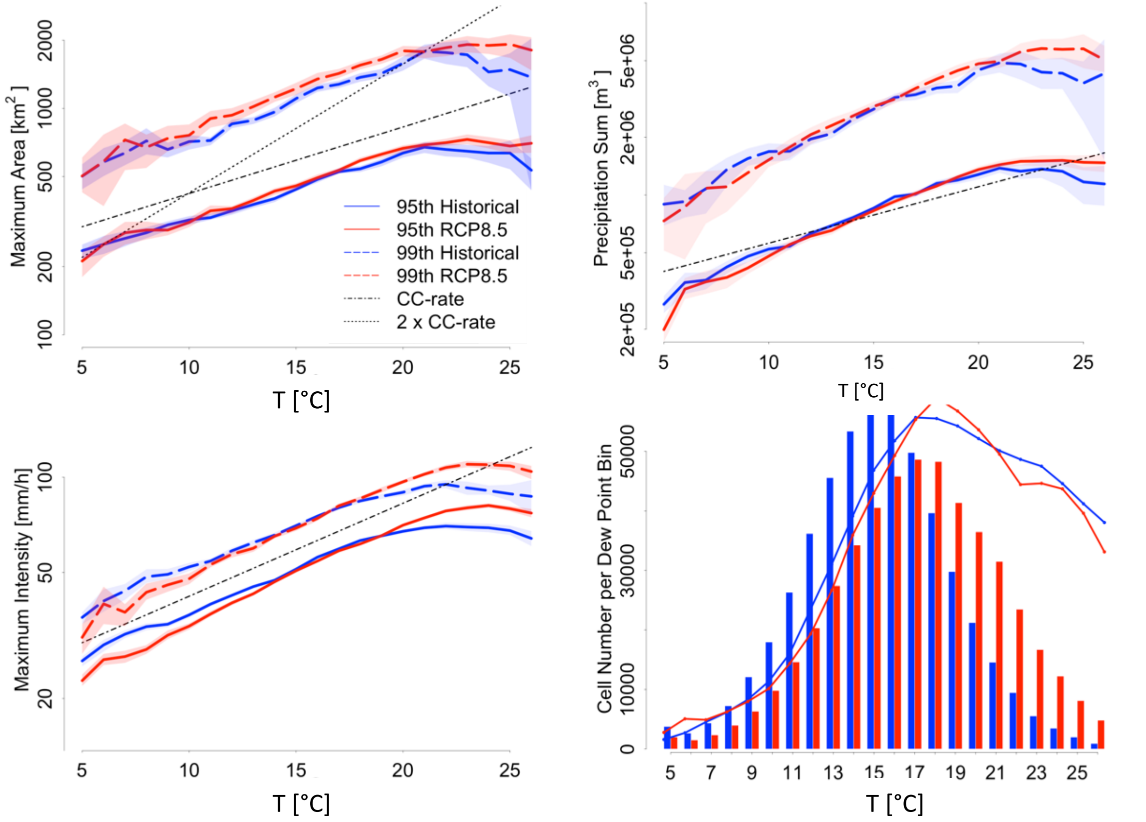
[Purr et al. (2019): Convective Shower Characteristics Simulated with the Convection-Permitting Climate Model COSMO-CLM]

Results (2): Temperature scaling of cell characteristics

- Exponential increase of area, intensity and precipitation sum at varying rates
- Drop-off at higher temperatures in the future

➢similar to scaling at fixed location

- Frequency of cells per temperature bin changes



Bars: absolute number of cells per bin.
Lines: number of cells per occurence of temperautre bin.

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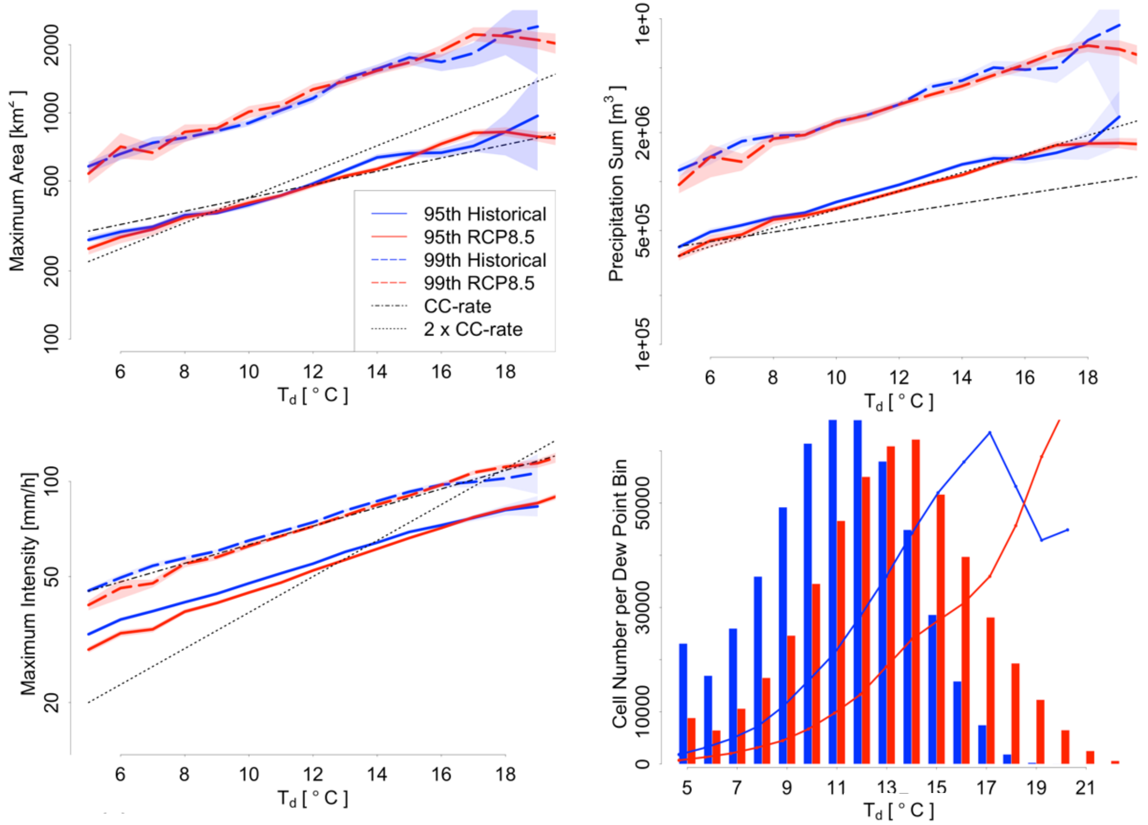
Results (2): Dew point scaling of cell characteristics

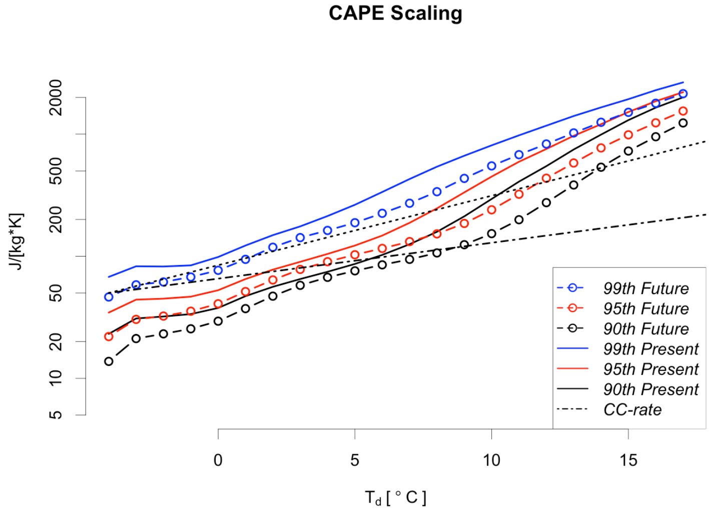
- Exponential increase without drop-off at high dew point temperatures
- Dew point scaling similar in present and future
- BUT: Frequency of cells per dew point bin changes (in absolute and relative terms)

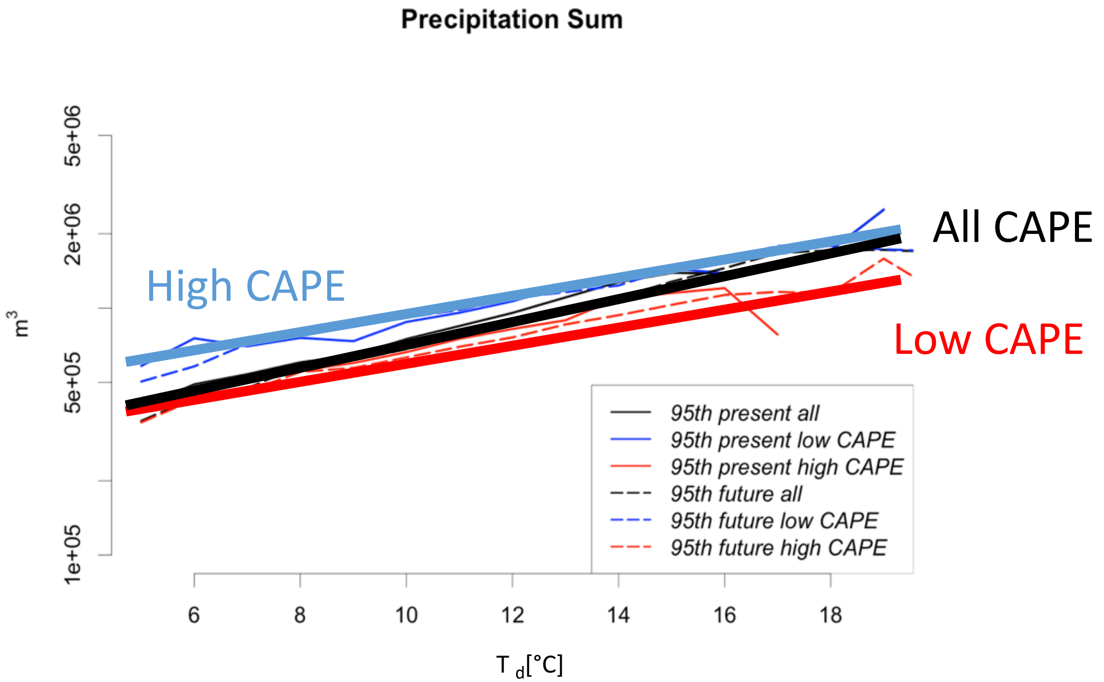


Bars: absolute number of cells per bin.
Lines: number of cells per occurence of dew point bin.

Results (2): Influence of static stability

- peak CAPE increases with temperature and humidity (Agard & Emanuel, 2017)





- Change in CAPE with dew point not linear

- Dew point scaling of precipitation sum dependent on CAPE
- Lower scaling rate of precipitation sum for low and high CAPE values

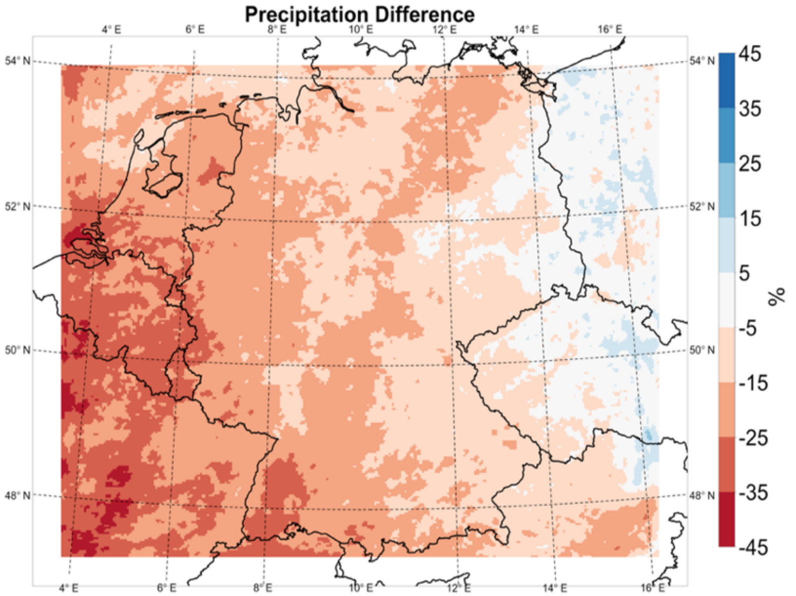
Summary

- Change in convective cell characteristics (RCP8.5, end-of-century):
  - Cell number and cell life time stay approx. constant
  - Shift towards more intense and larger cells, leading to increased precipitation sums per cell
  - Increase is highest for the most intense events

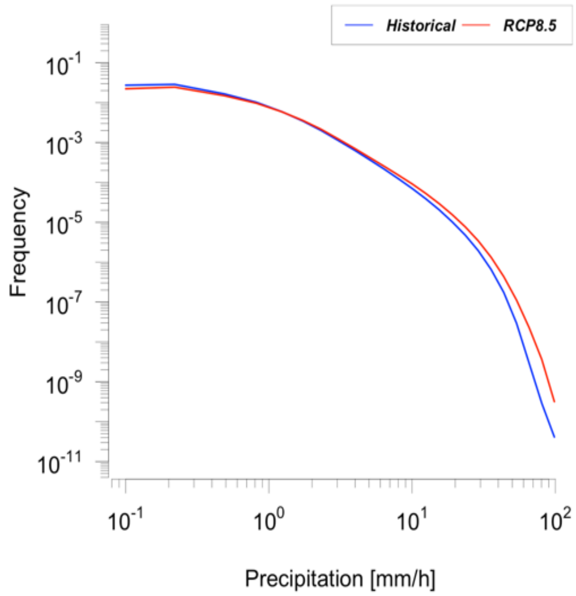
- Temperature and dew point scaling of cell characteristics
  - Temperature: scaling similar to fixed location scaling -> area, intensity and precipitation sum increase exponentially and drop-off at high temperatures
  - Dew point:
    - No drop-off at high moisture levels
    - Scaling rates similar for present and future, BUT: number of cells per dew point bin changes (preventing simple statistical inference of convective precipitation from dew point)
    - Scaling rate of precipitation sum exactly 2 x CC, BUT: dependent on CAPE

Appendix – Eulerian Precipitation Statistics

- Convection permitting simulation:
  - Mean decrease in summer precipitation of 14%
  - Increase in high hourly (and 5-min) precipitation intensity



Mean precipitation change
RCP8.5 (2070-2100)-HIST (1976-2005)



Hourly precipitation