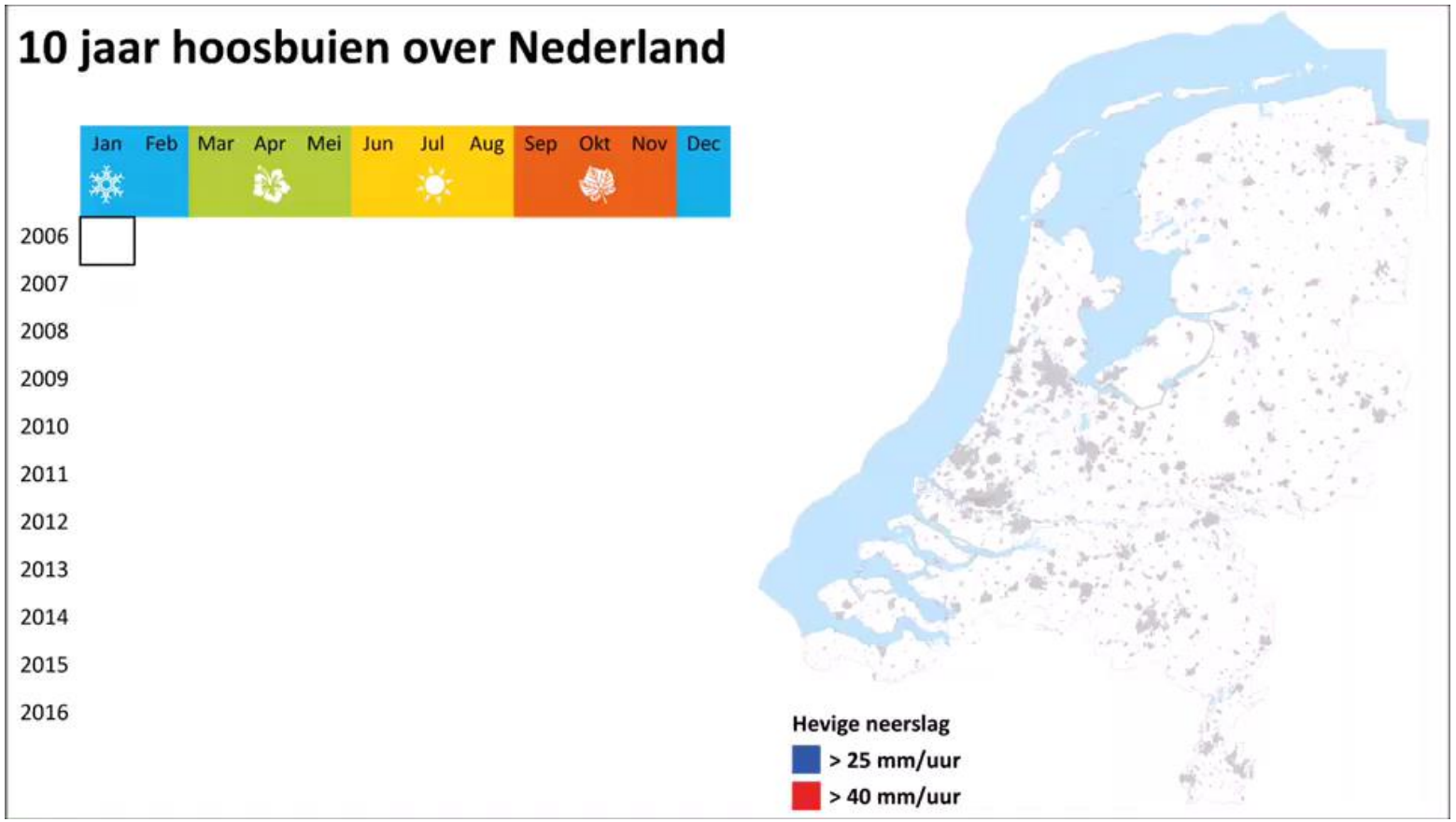
Buien van de toekomst: het project Space2rain en doorkijk naar de KNMI'21/23 scenario's.

Geert Lenderink en Kai Lochbihler (KNMI, TUD)

Pier Siebesma, Hayley Fowler, Renaud Barbero

- Stedelijk waterbeheer (Rioned)
- Waterschappen (STOWA, Rijnland)
- Ontwerp wegen (RWS)
- Erosie, veiligheid, landverschuivingen

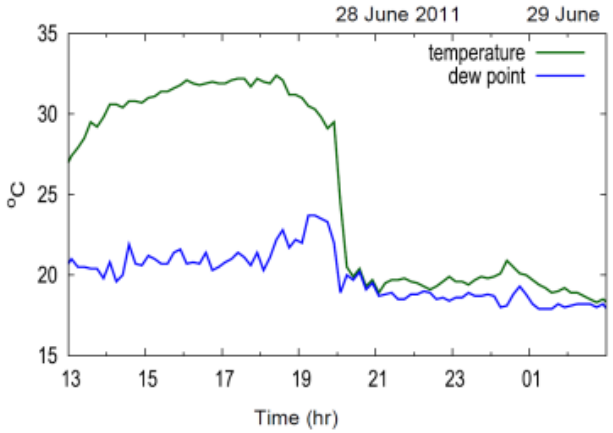
10 years of hourly extremes from rain radar data

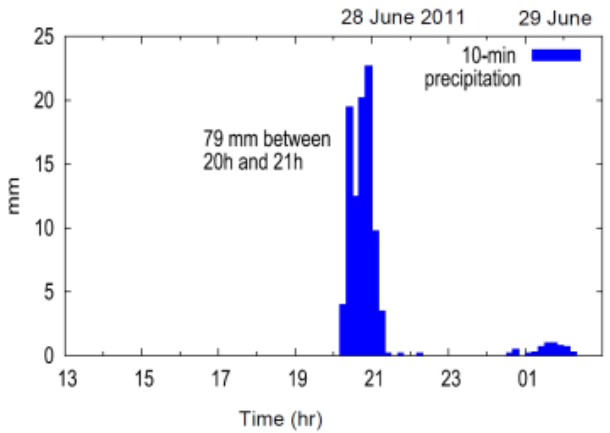


Met dank aan:
Arjen Koekoek
[arjen@climateadaptationservices.com]

Convective systems producing rain extremes, but hail, wind-gusts, and lightning as well

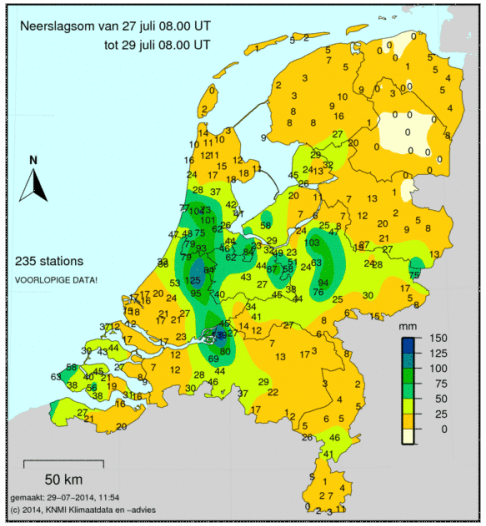
28 juni 2011





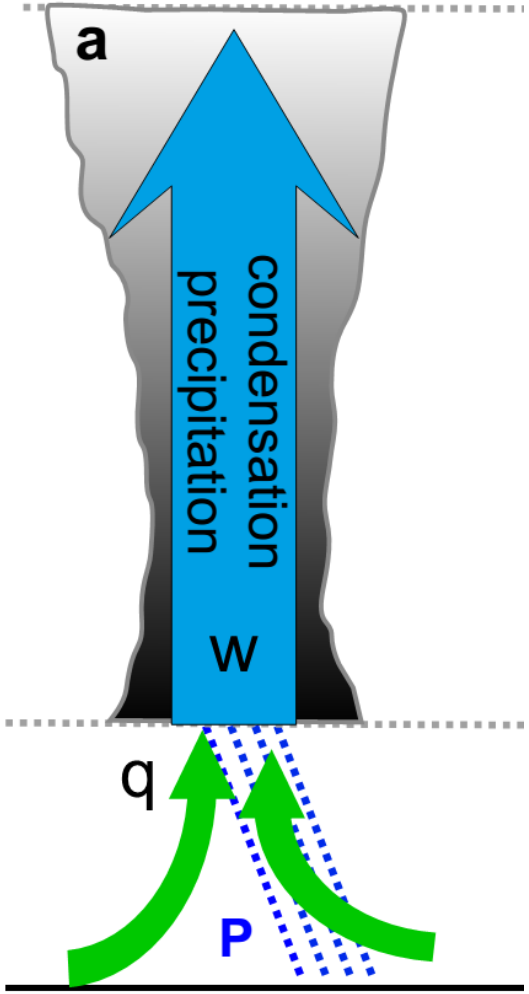
23 juni 2016

28 juli 2014

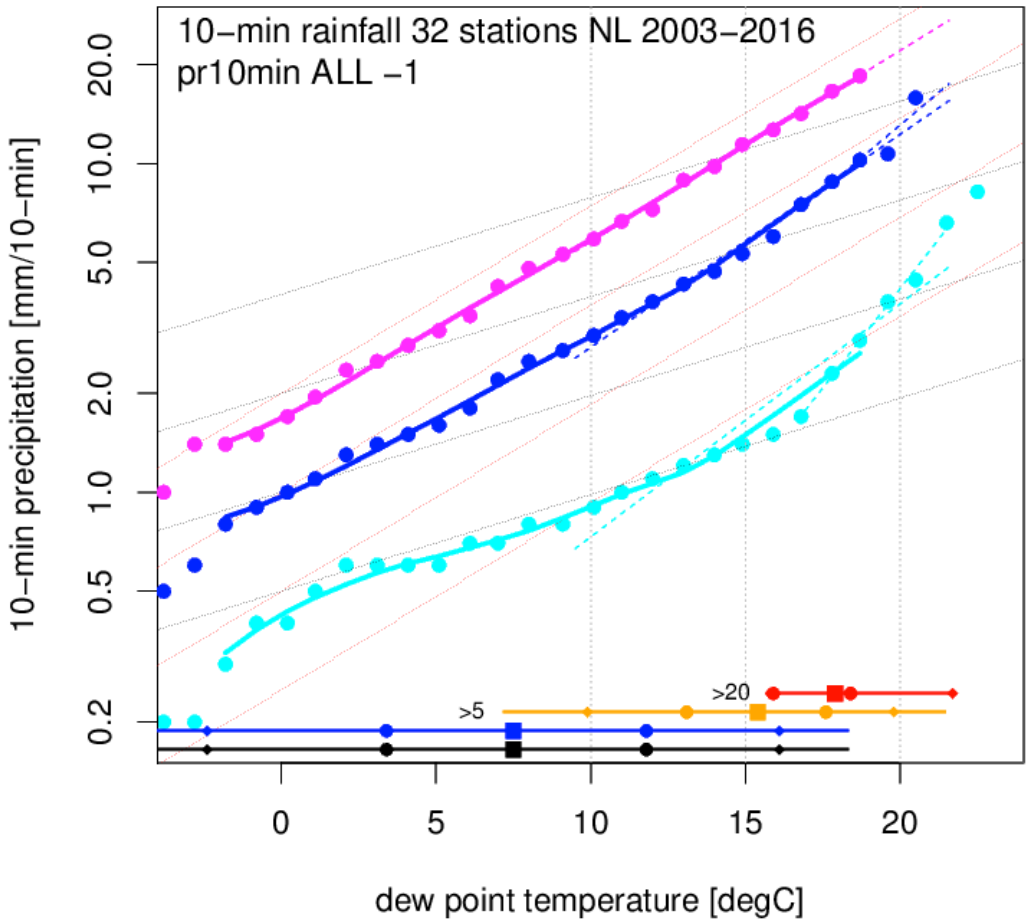


Why do we expect an increase of precipitation extremes due to global warming?

1. The Clausius-Clapeyron (CC): saturation specific humidity increases by 6-7 % per degree temperature rise (hard physics)
2. No major changes in relative humidity as climate changes (±well understood)
3. Changes in actual, absolute humidity increase with the CC rate (using temperature)
4. Alternative for 2 + 3: Changes in actual, absolute humidity scale as CC using **dew point** temperature
5. Changes in precipitation extremes are governed by humidity increases
6. Changes in extremes scale as CC (?)



However !
Derived from 10-minute precipitation

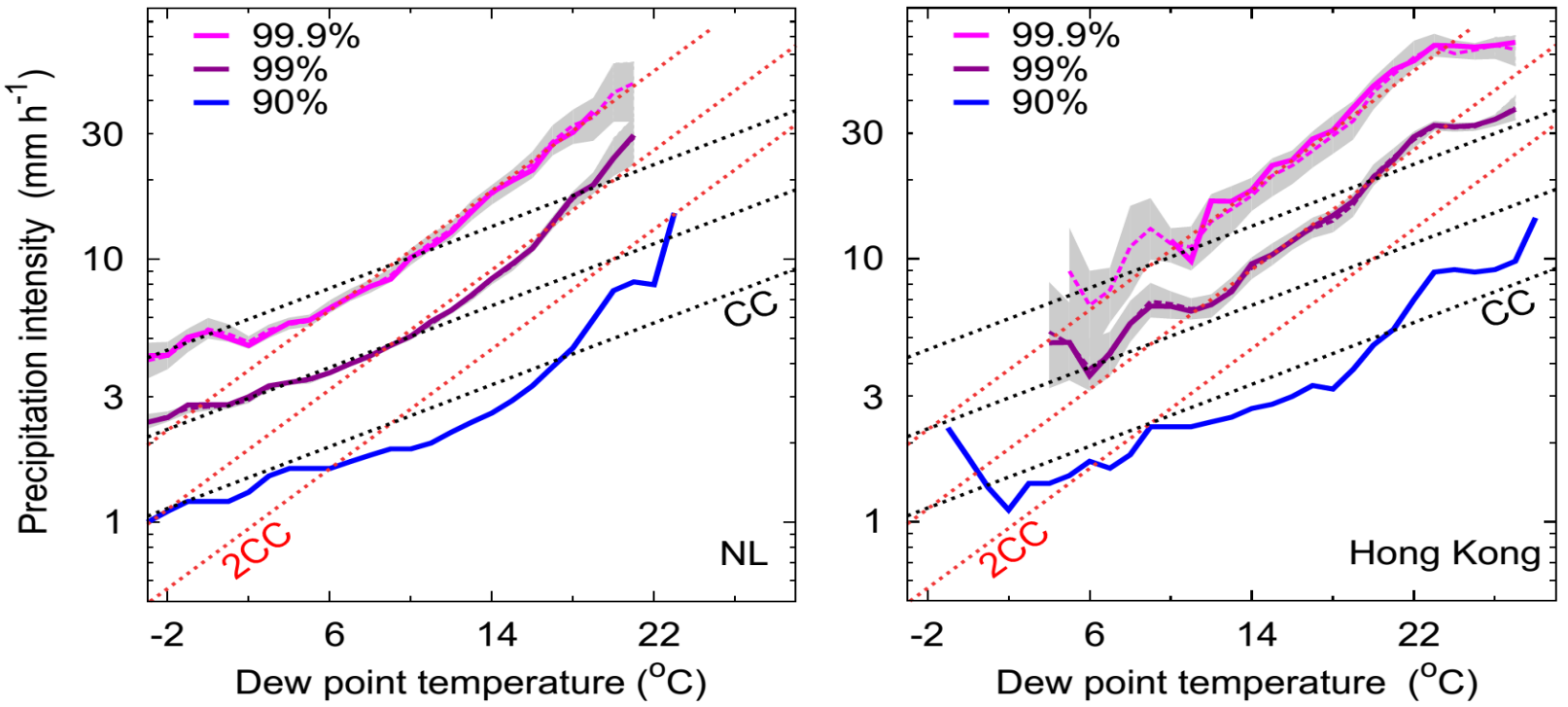


For the highest percentiles:

Very regular behaviour over 20 degrees dew point range, or intensity range of more than factor 10

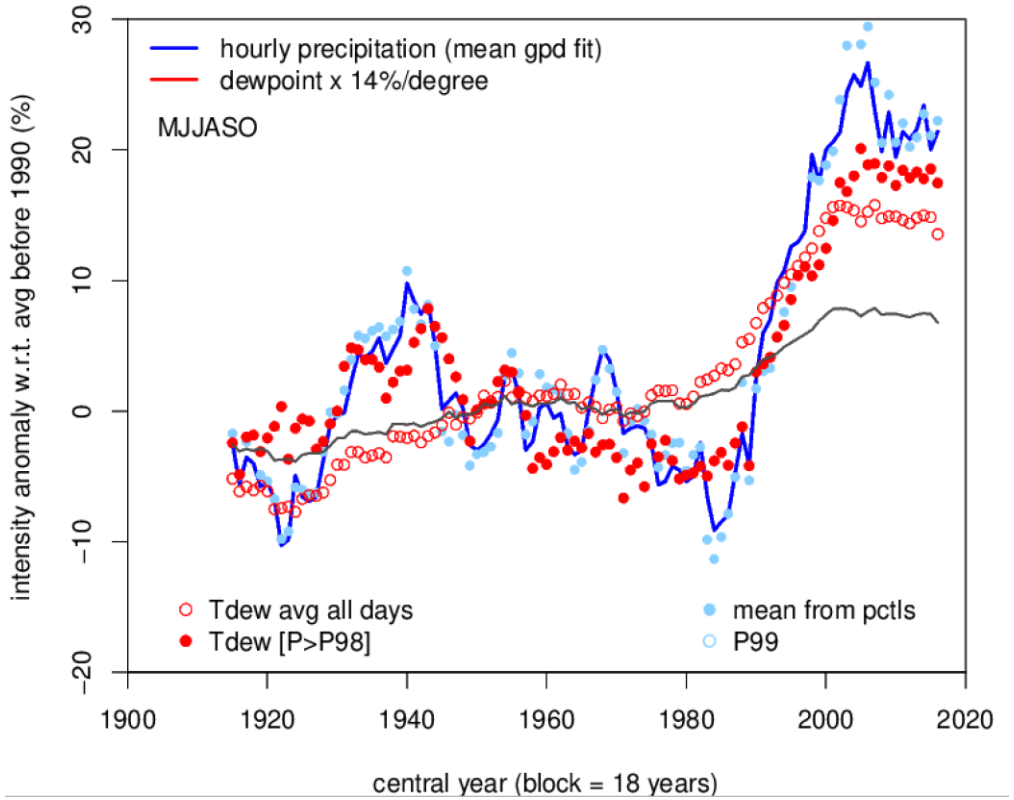
Intensities follow a slope approximately **2 times the expected Clausius-Clapeyron** relation.

and …
Hourly precipitation in NL and Hong Kong



Some degree of universality between different climatic zones

Scaling and long-term trends hourly precipitation ”extremes” in De Bilt



Anomaly compared to period before 1990

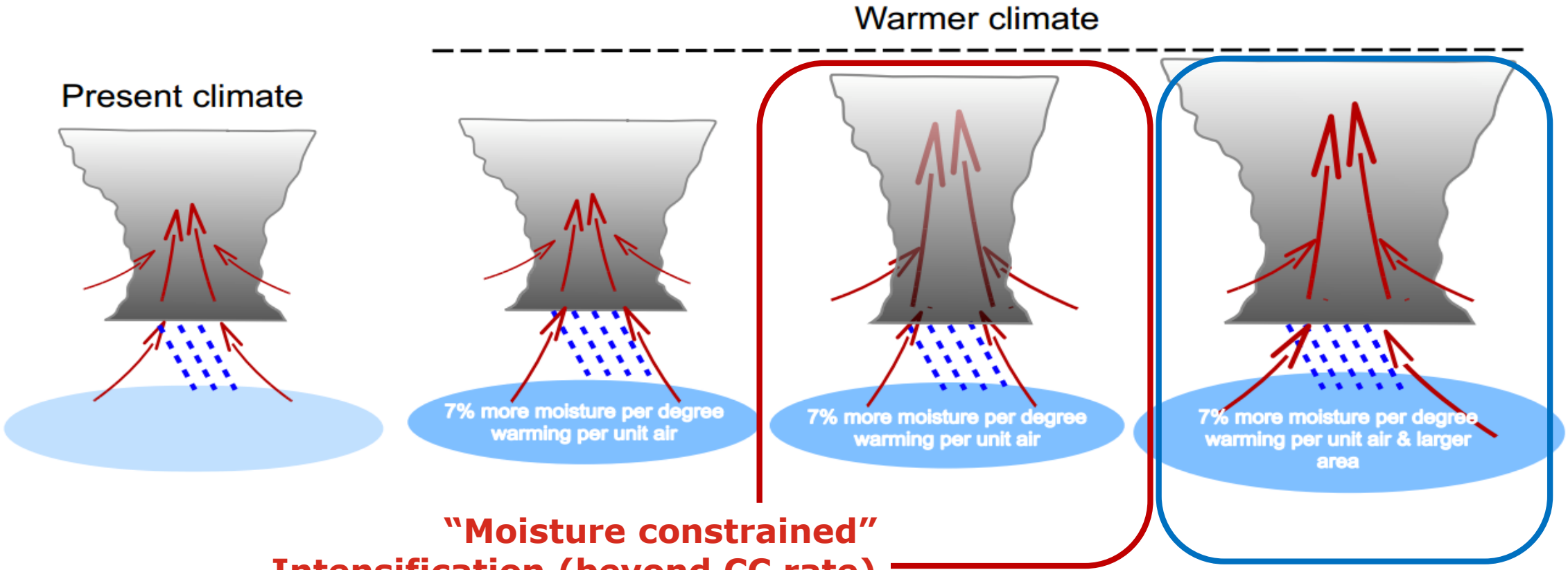
Red: dew point anomaly
x 14 %/K
Solid dots: on very wet days

Blue: soft extremes hourly precipitation
(±10 mm/hour)

MJJASO: averages over months May to October

…**but it is not clear** that we can **extrapolate in the future**

Space2rain:
Bigger or smaller convective clouds in warming climate?



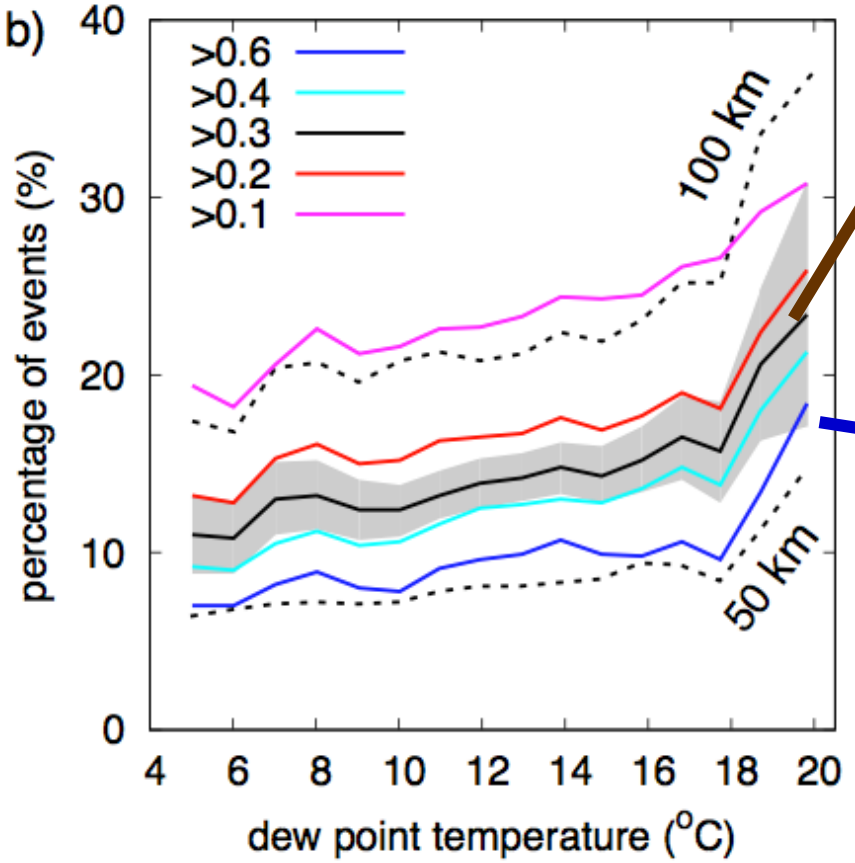
"Moisture constrained"
Intensification (beyond CC rate) of core of cloud at expense of cloud size or lifetime

"Dynamical constrained"
Feedback dynamics at mesoscale determine cloud size and lifetime

Do we observe larger convective “shower clusters” at high dew points (high humidity) ?

Based on hourly rainfall at ~30 stations in the Netherlands

Statistics is number of stations with rain connected to a rain events

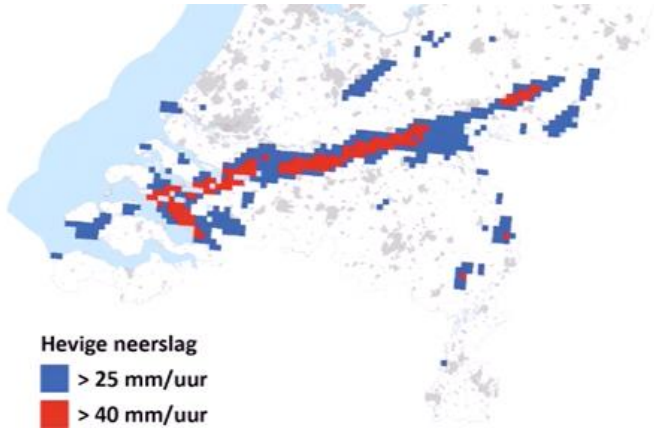


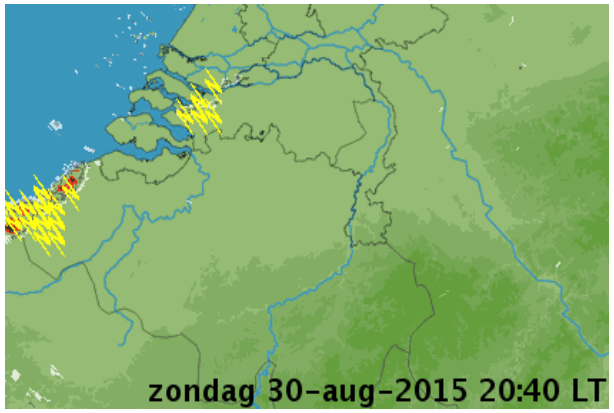
Percentage of events that produced rain at at least 30 % of the stations (±10 stations):

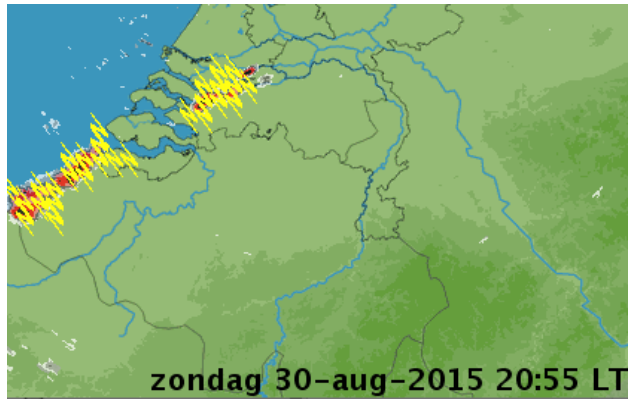
Percentage of events that produced rain at at least 60 % of the stations (±20 stations)

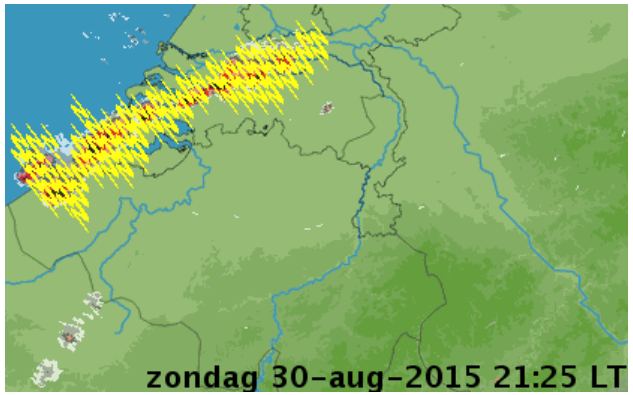
Very rapid development of showers at very high humidity: 30 august 2015

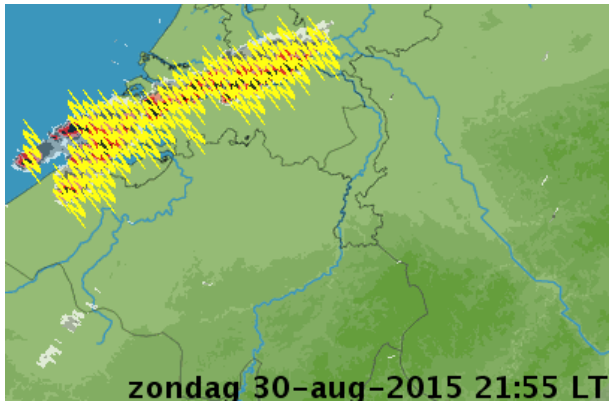
dew point ~ 22 degrees (close to) tropical value





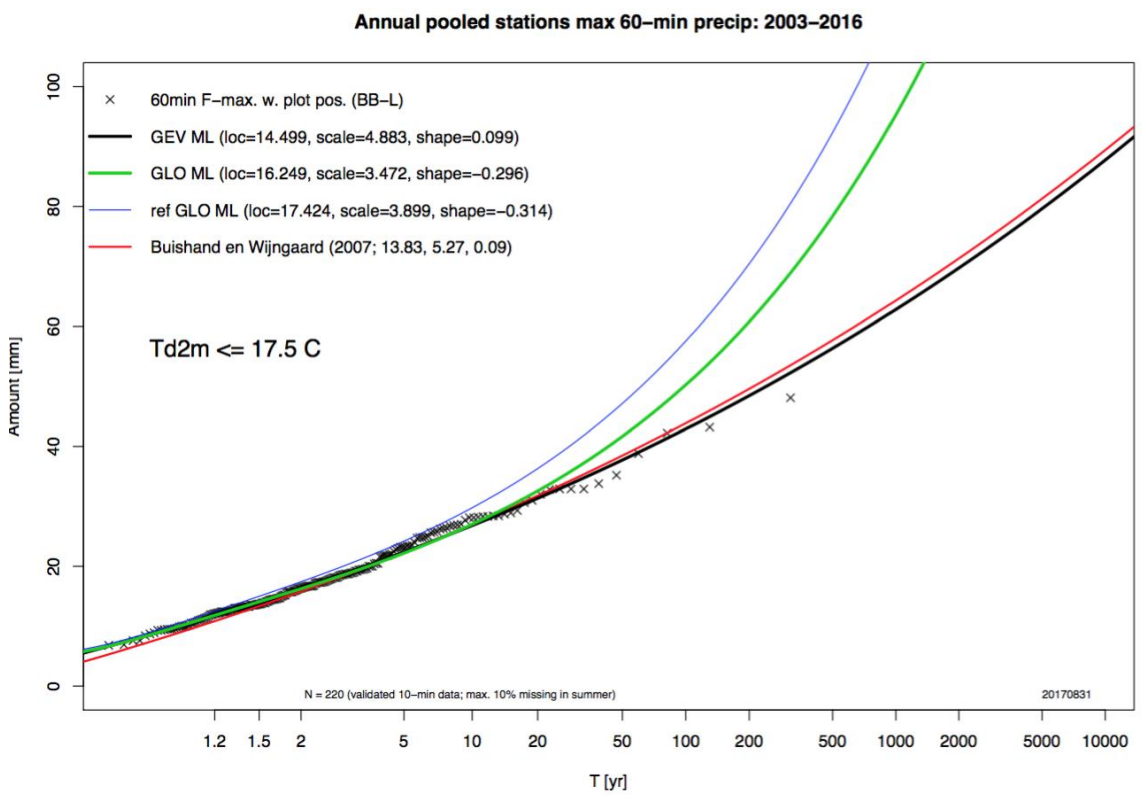




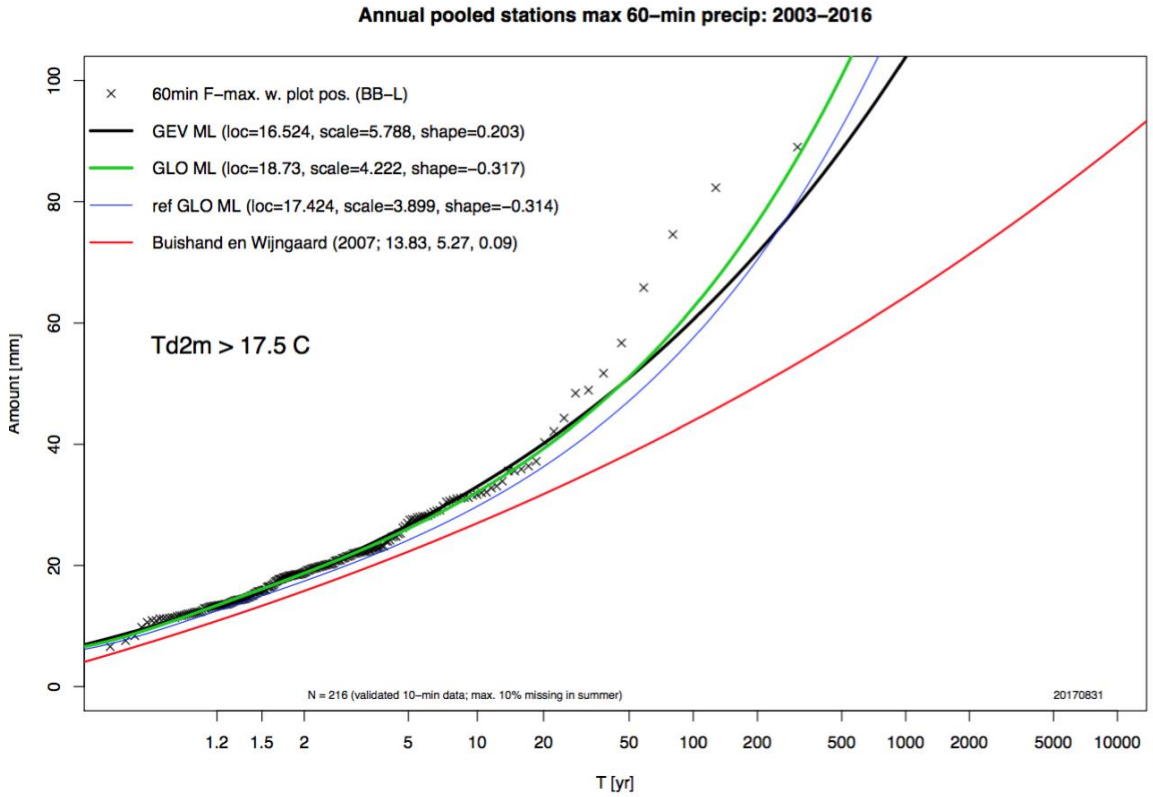


GEV fits hourly precipitation extremes for the Netherlands

Dew point < 17.5 °C



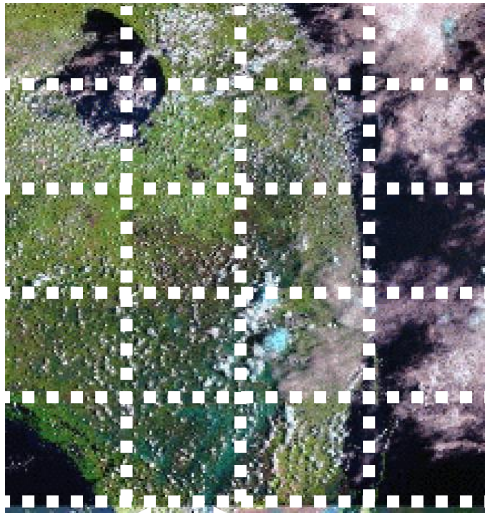
Dewpoint > 17.5 °C



Usual climate models, used in IPCC and KNMI climate scenarios, lack resolution to resolve convective clouds

Summertime precipitation mostly fall from the type of convective clouds

Grids climate models to coarse for these type of clouds



Climate models use simple statistically based schemes, called parameterizations

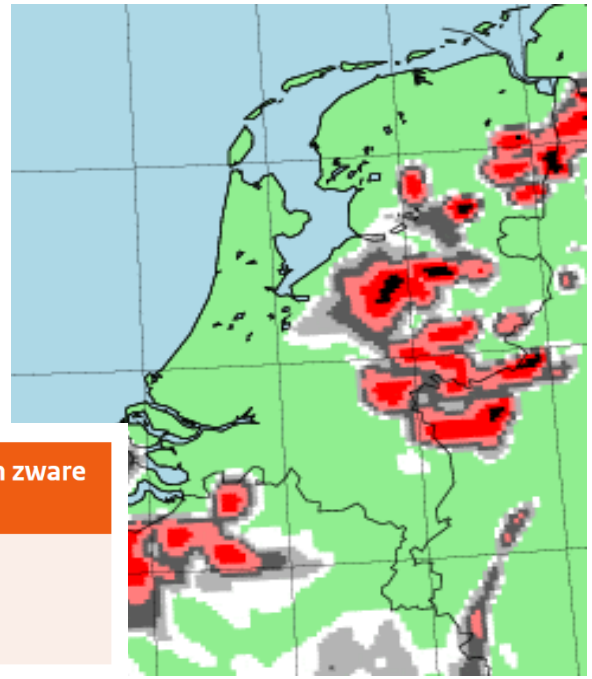
KNMI’14 scenarios for extreme (summer) precipitation

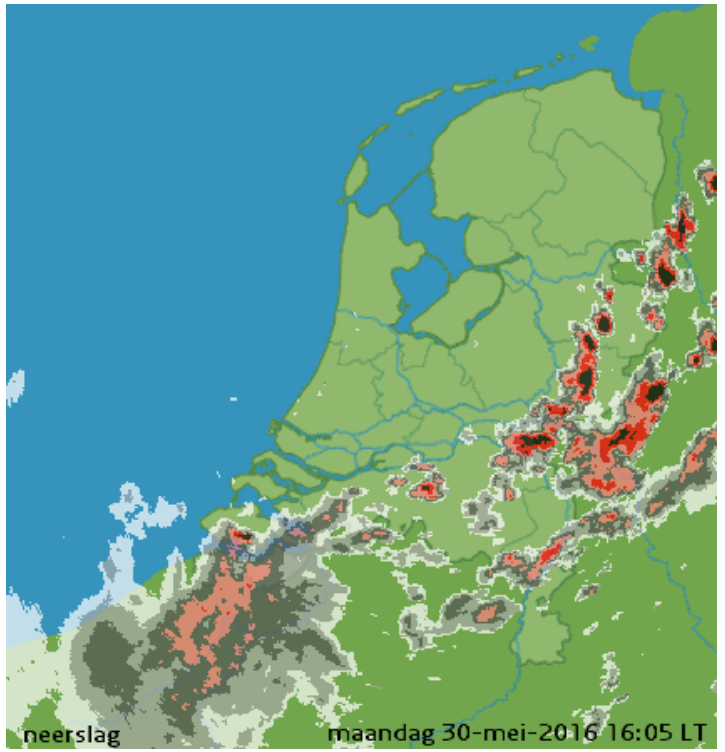
- Have **not** been based primarily on climate modelling output
- Instead: a combination of climate modelling output, mixed with observed based relations and expert judgement
- Yet, a revolution is going on right now

A new type of climate model originating from weather forecasting is now applied in climate research: convection-permitting climate models

At KNMI we use Harmonie Climate (HCLIM)

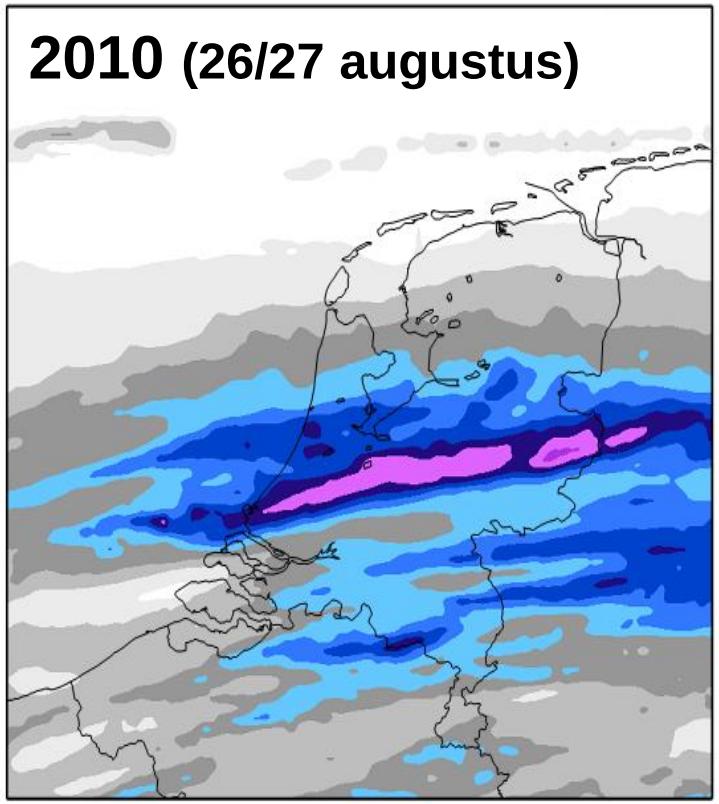
HCLIM is **very, very** expensive:
2 months on supercomputer for a 10-year simulation



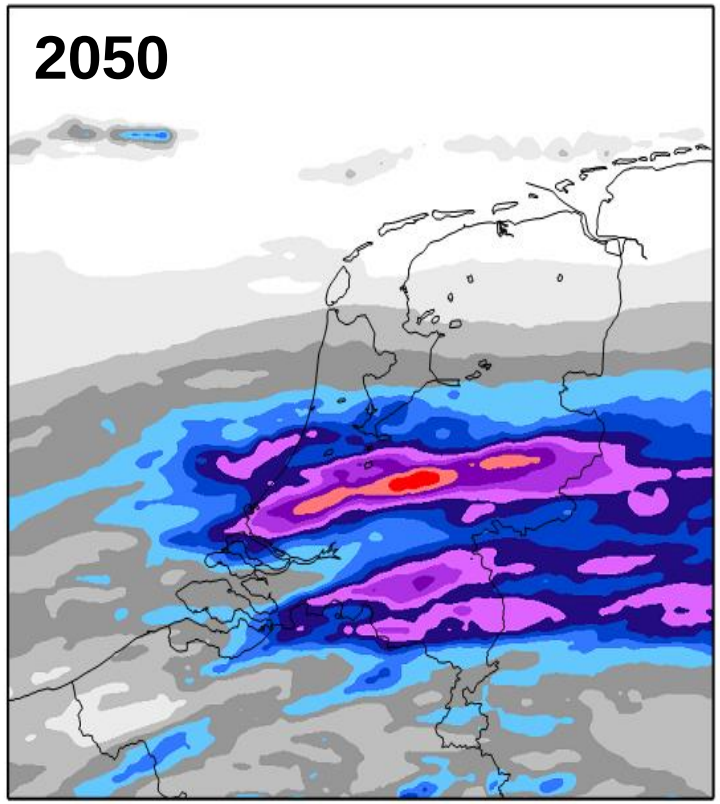


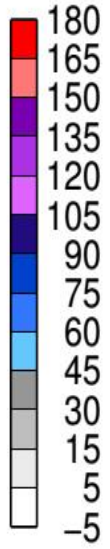
Monday 30 May 2016

Harmonie climate (HCLIM) applied in case studies in KNMI'14 scenarios



piek: 130 mm

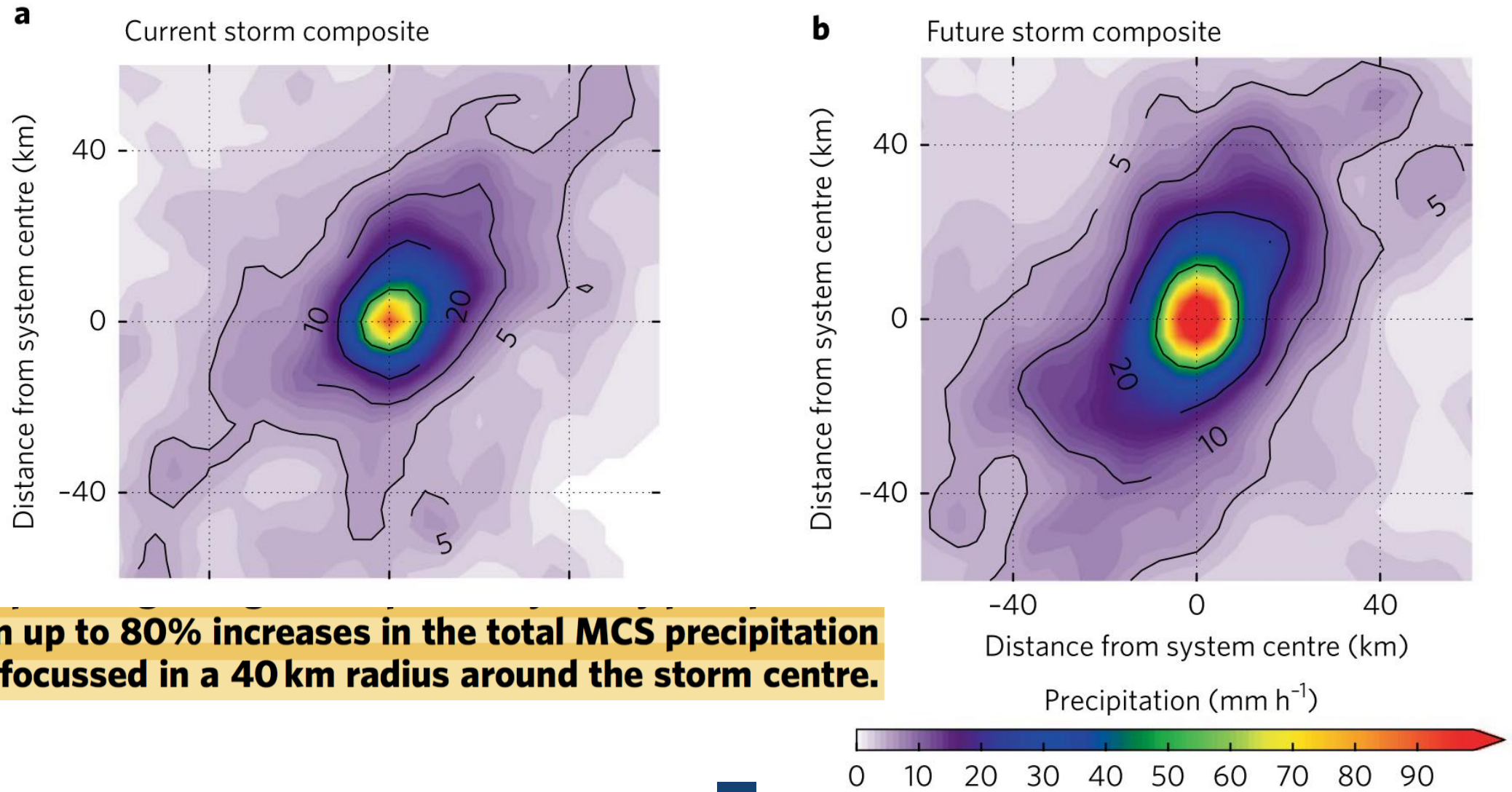




piek: 170 mm (+30% bij 2 graden opwarming)

Composite clustered shower from a convection-permitting model simulation

Prein et al, Nature Climate Change 2017



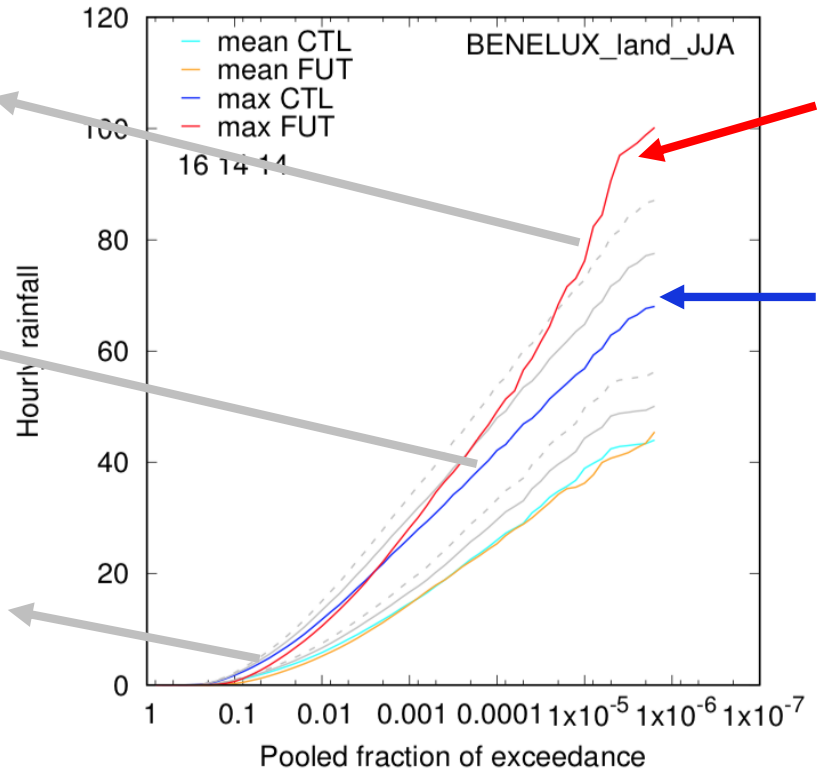
results in up to 80% increases in the total MCS precipitation volume, focussed in a 40 km radius around the storm centre.

HCLIM climate scenario runs 2091-2100 versus 1995-2005 (**preliminary analysis!**)

Increase in intensity most extreme showers by 2CC rate or higher

Increase in intensity intense showers by CC rate (7% per degree)

Decrease in intensity moderate intense showers (<15 mm hour



Local hourly extremes future

Local hourly extremes present

Note: at the end of the century this simulation projects strong summer drying feedbacks. Results may not be general.

Take away points

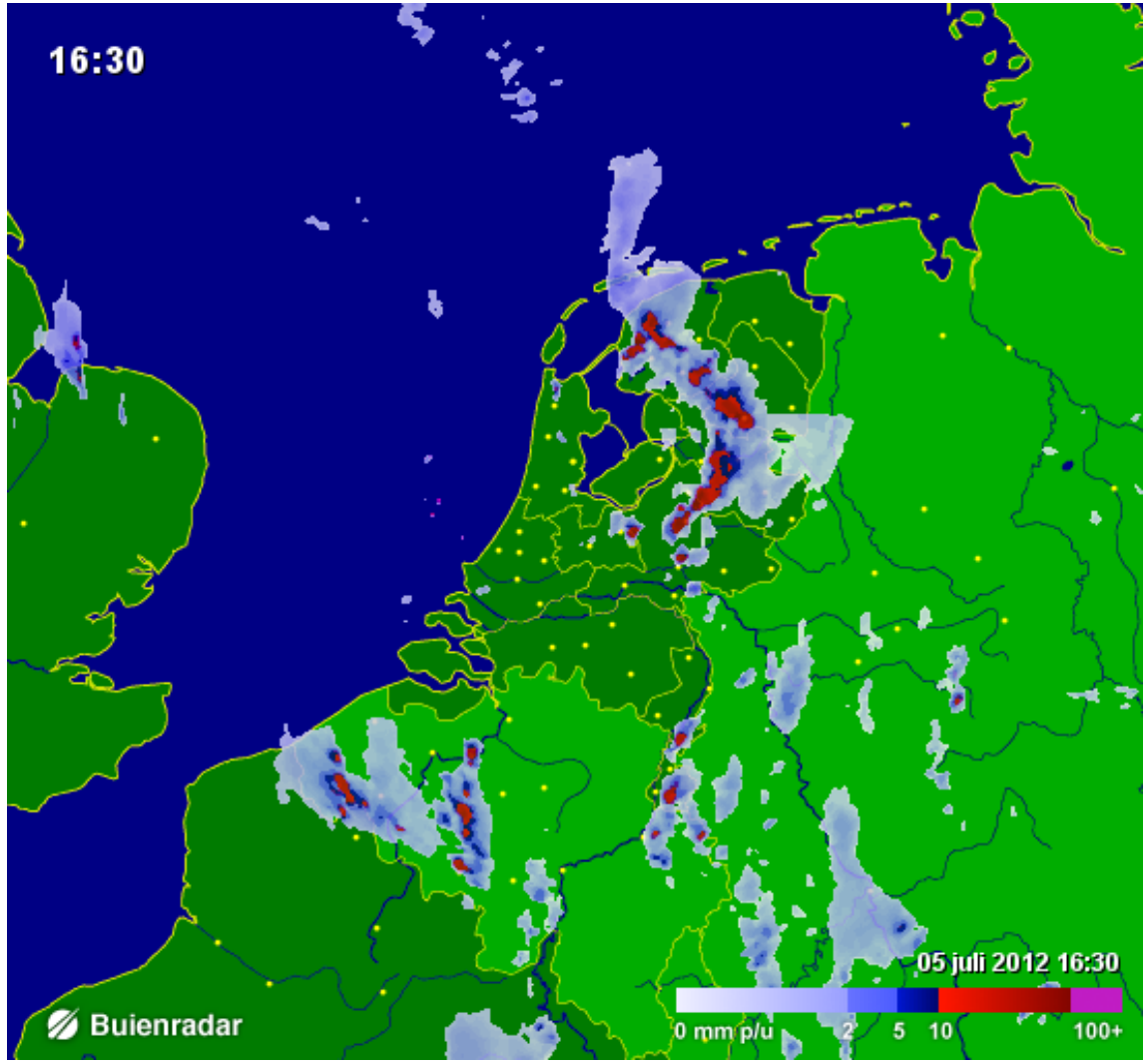
- Response of extreme showers is a new and fast developing – new modelling tools, observations, and understanding – research area
- Prepare for changes in insights
  - KNMI'14: ~ one change factor for all rainfall types (similar events, but just more intense)
  - KMMI'21/23: The character of convective precipitation changes. Changes in rainfall amount strongly depend on size, duration and severity.

    Preliminary results: the most extreme events could reveal the strongest increases, at least locally.
- Despite this: most extremes are still expected to increase

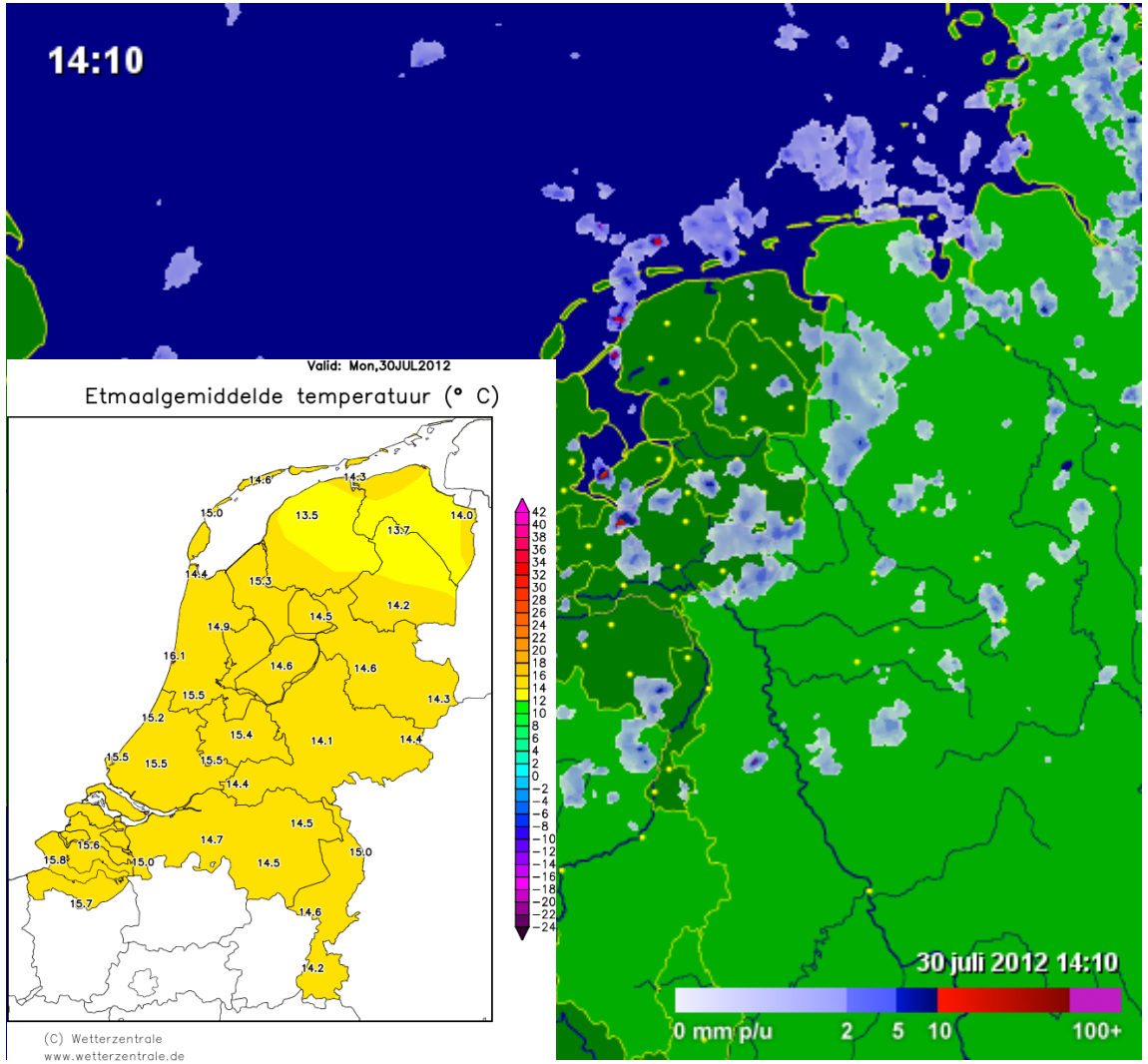
Convective extremes under warmer conditions

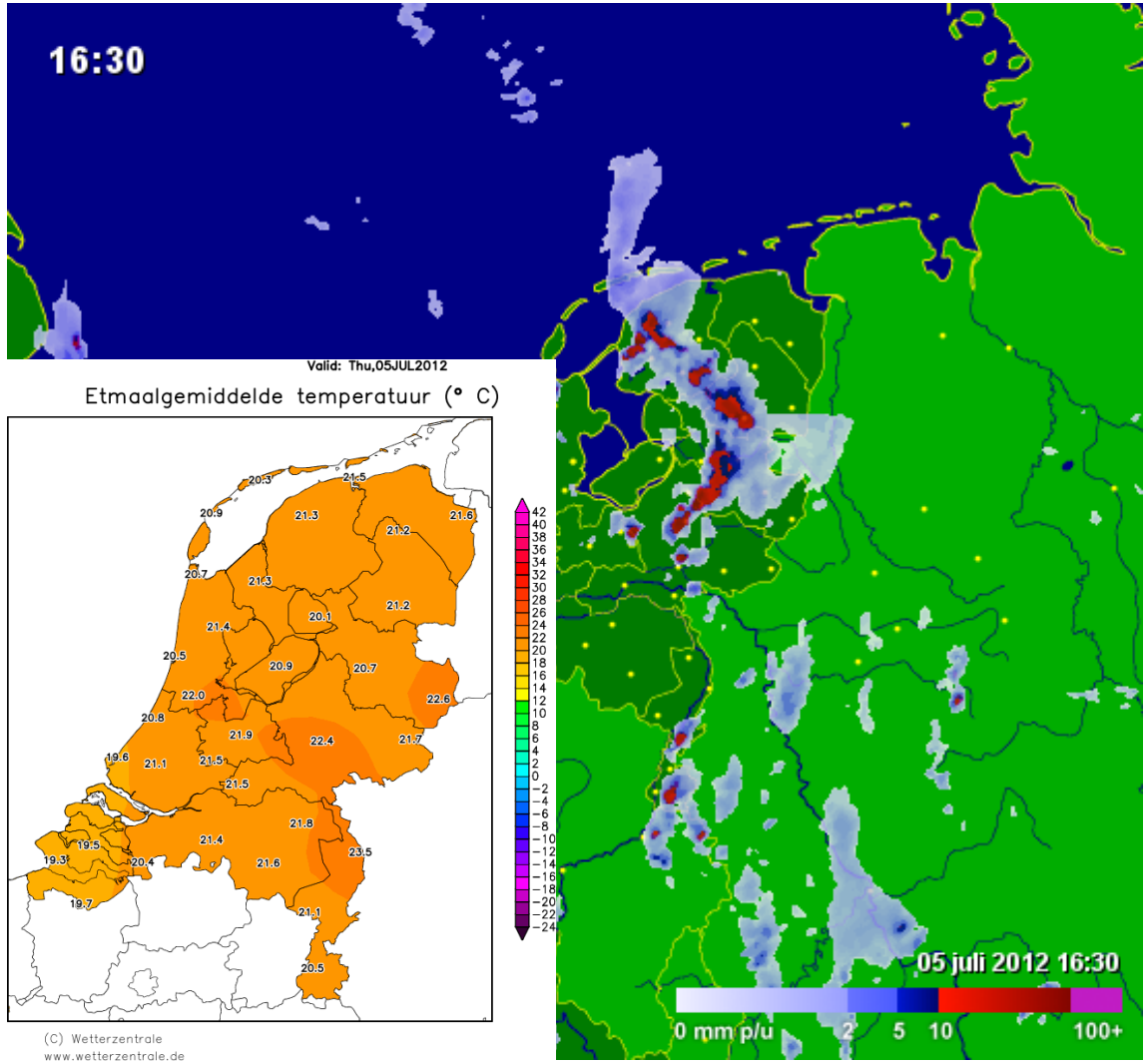
NWO Space2rain project

Introduction



Introduction





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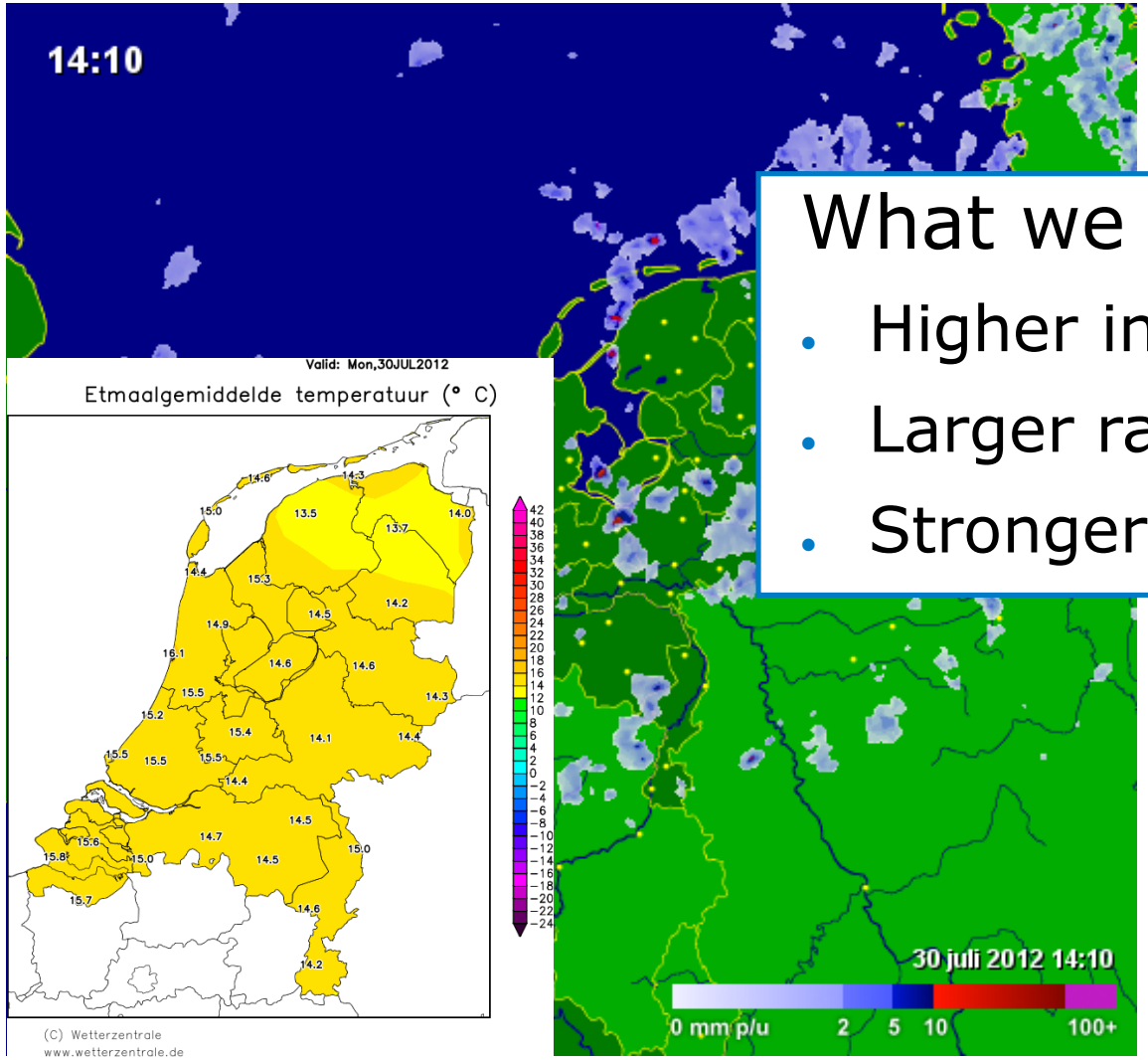
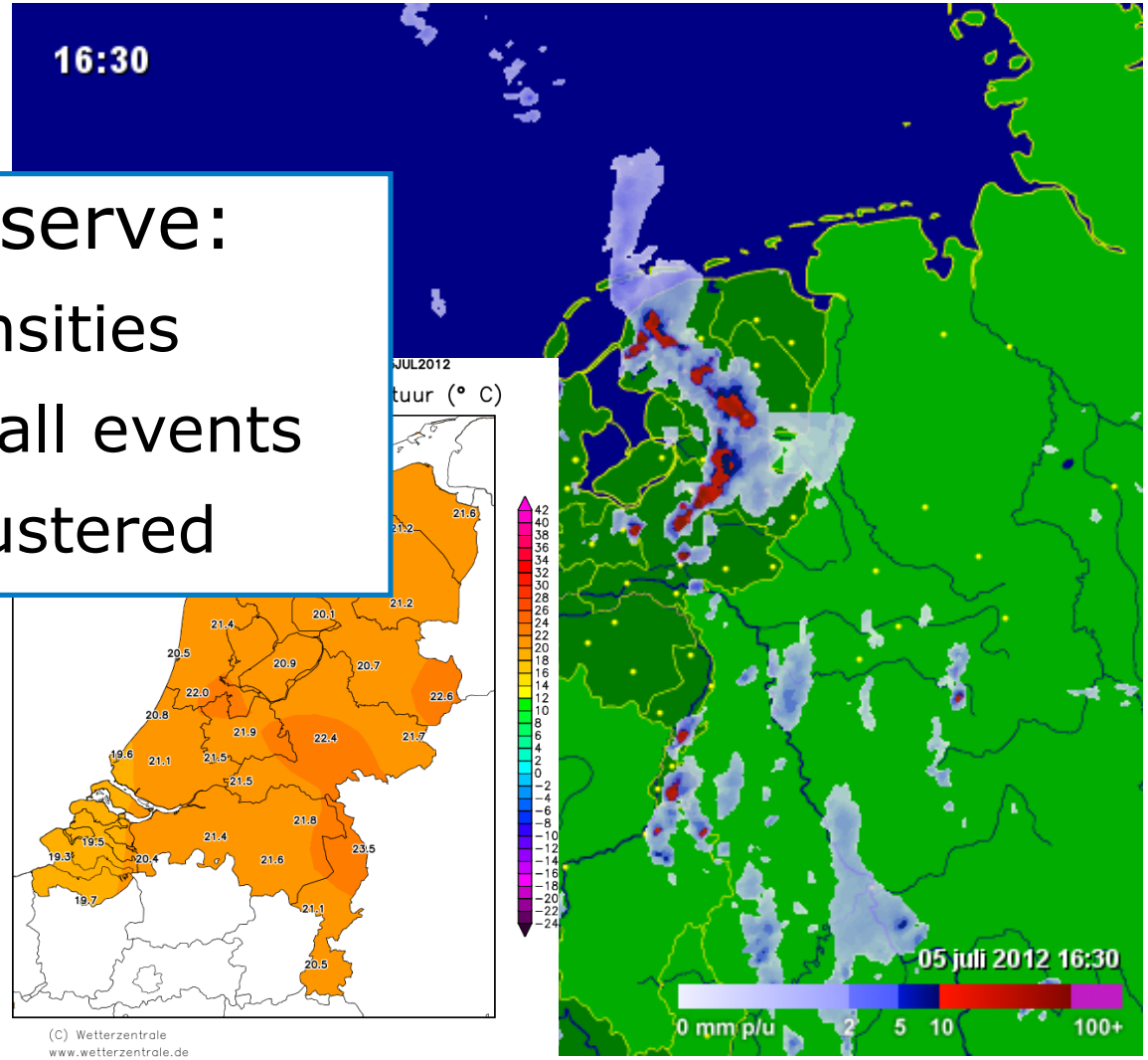


What we observe:

- Higher intensities
- Larger rainfall events
- Stronger clustered



Questions

- How will intensities of small-/mesoscale convective systems change with warming?
- What about their size?
- Is there a change of other spatial properties such as organization or clustering?

Content

- In-depth analysis of the relation between intensity and size of convective rain events in NL.
- Results from RADAR observations to investigate temperature rain intensity relations of small-scale rainfall events; also examine spatial properties
- High resolution model results of convective precipitation extremes

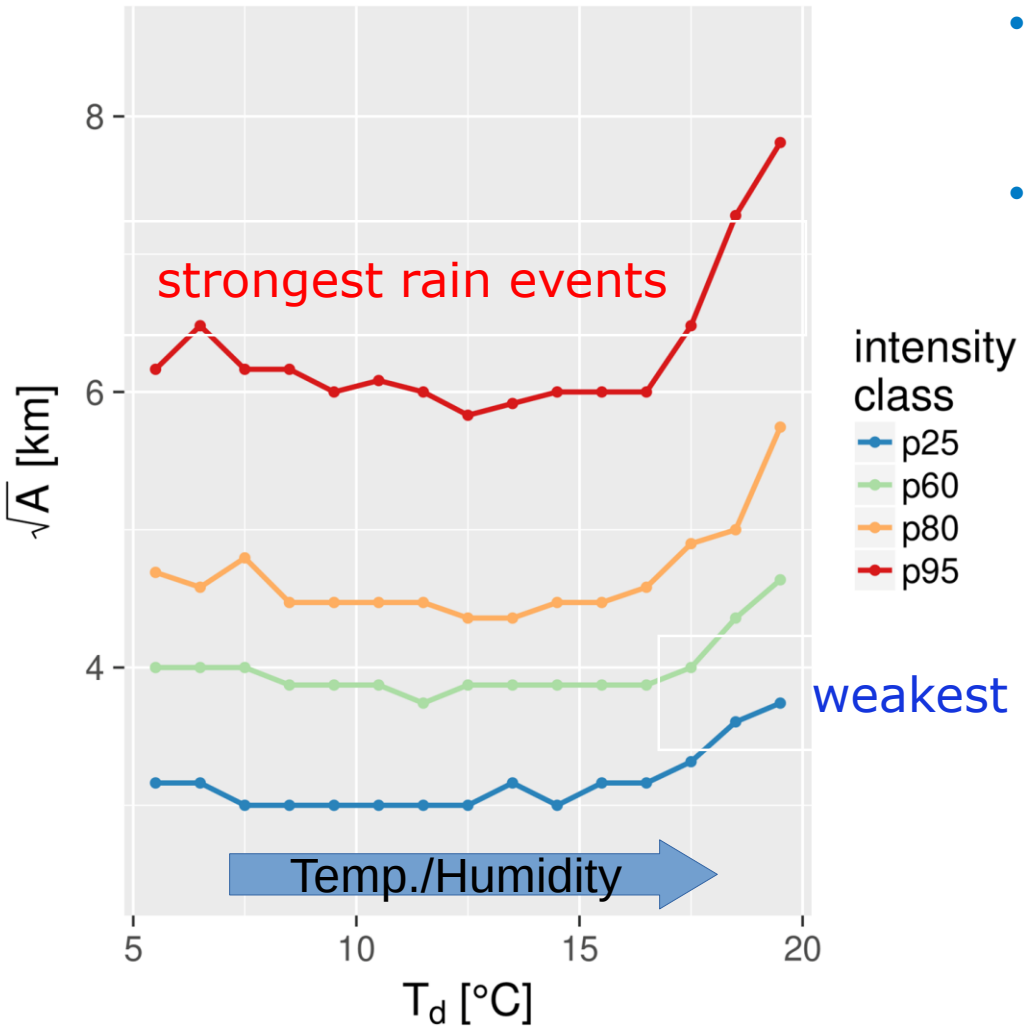
Tracking of rain events

- Data set: 9 years of RADAR data (5 minutes, summertime)
- Identify rain cells
- Connect them in time to rainfall events
- Select the moment with maximum intensity
- Pair with (dew point) temperature

→ ~ 150 000 rain events

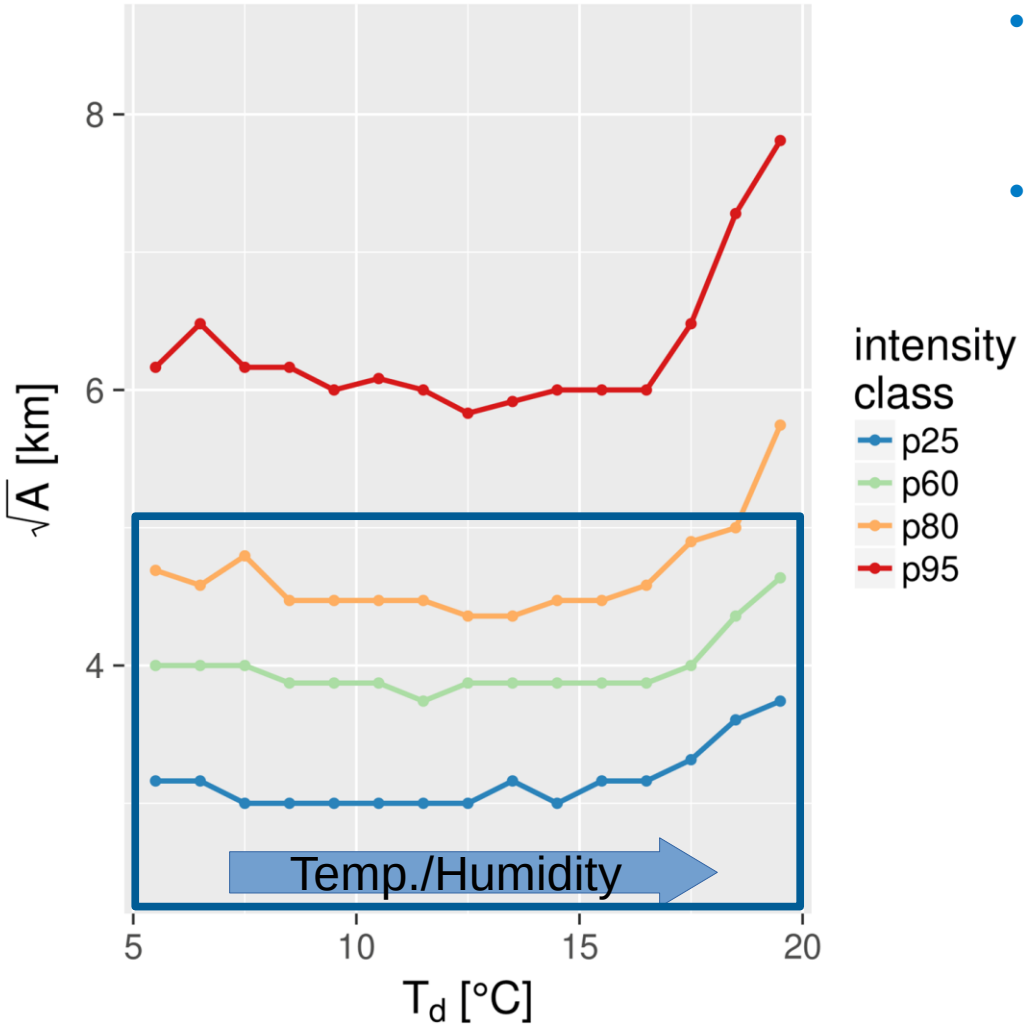
Size and intensity of rain showers

Size and intensity of rain showers



- Events of higher intensity are generally larger in spatial extent
- Steep increase of size at highest temperatures

Size and intensity of rain showers



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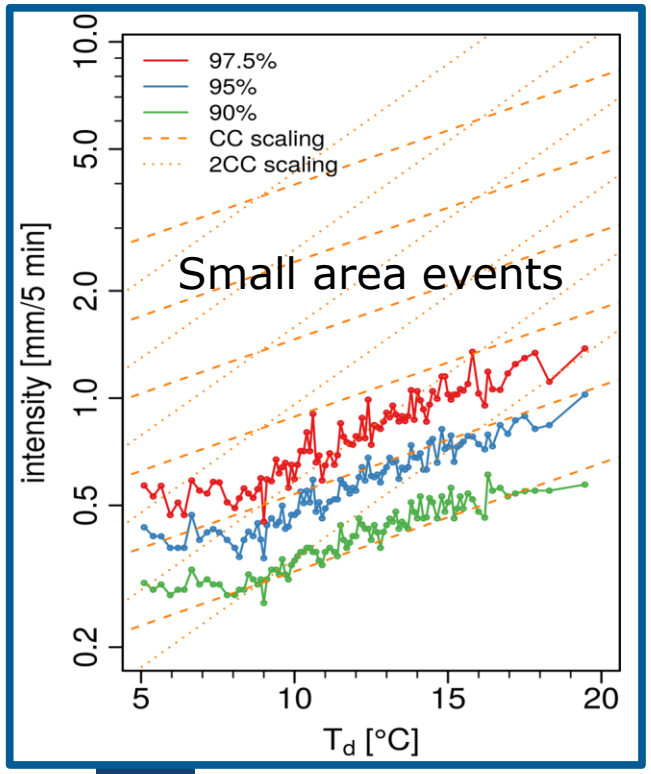
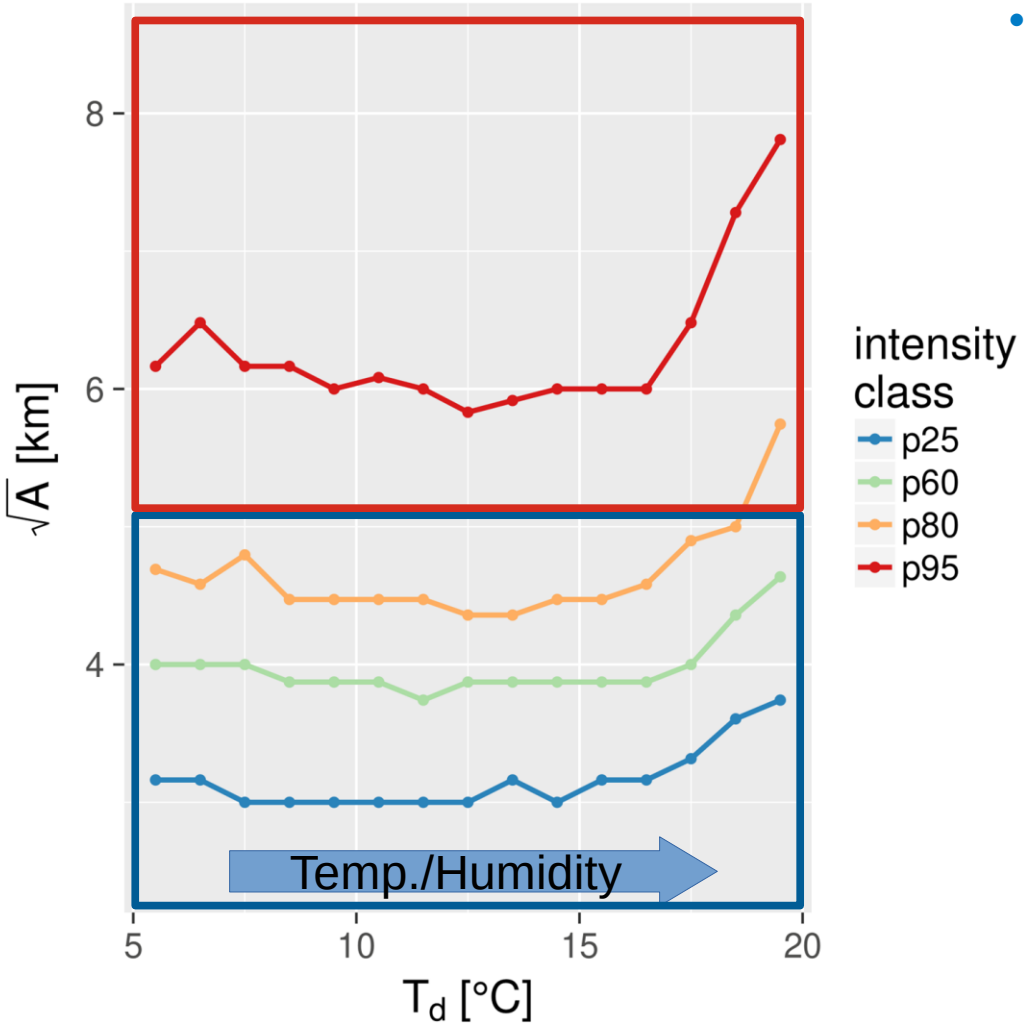
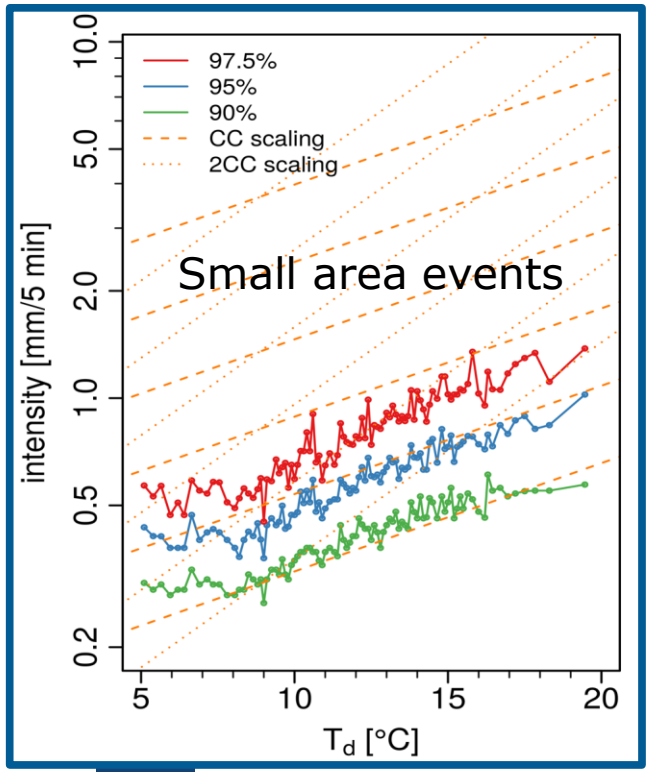
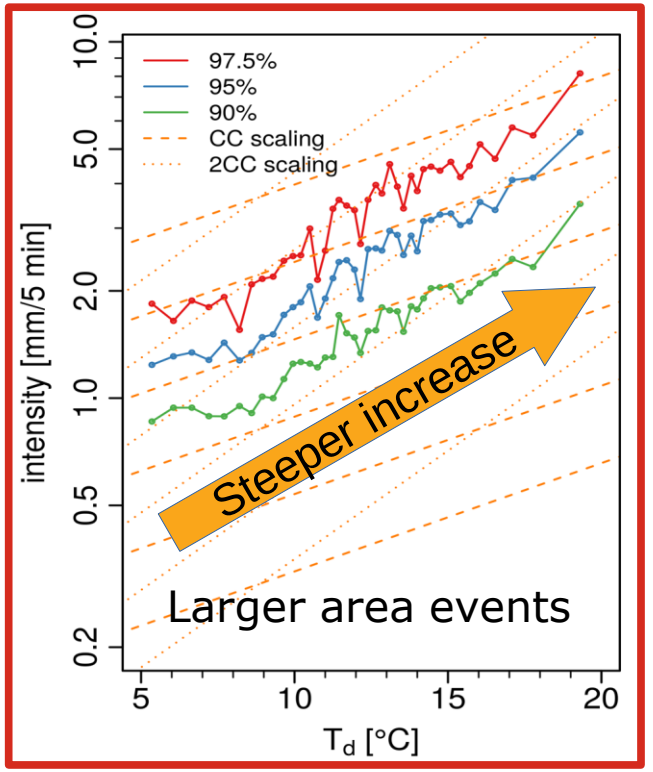


Size and intensity of rain showers

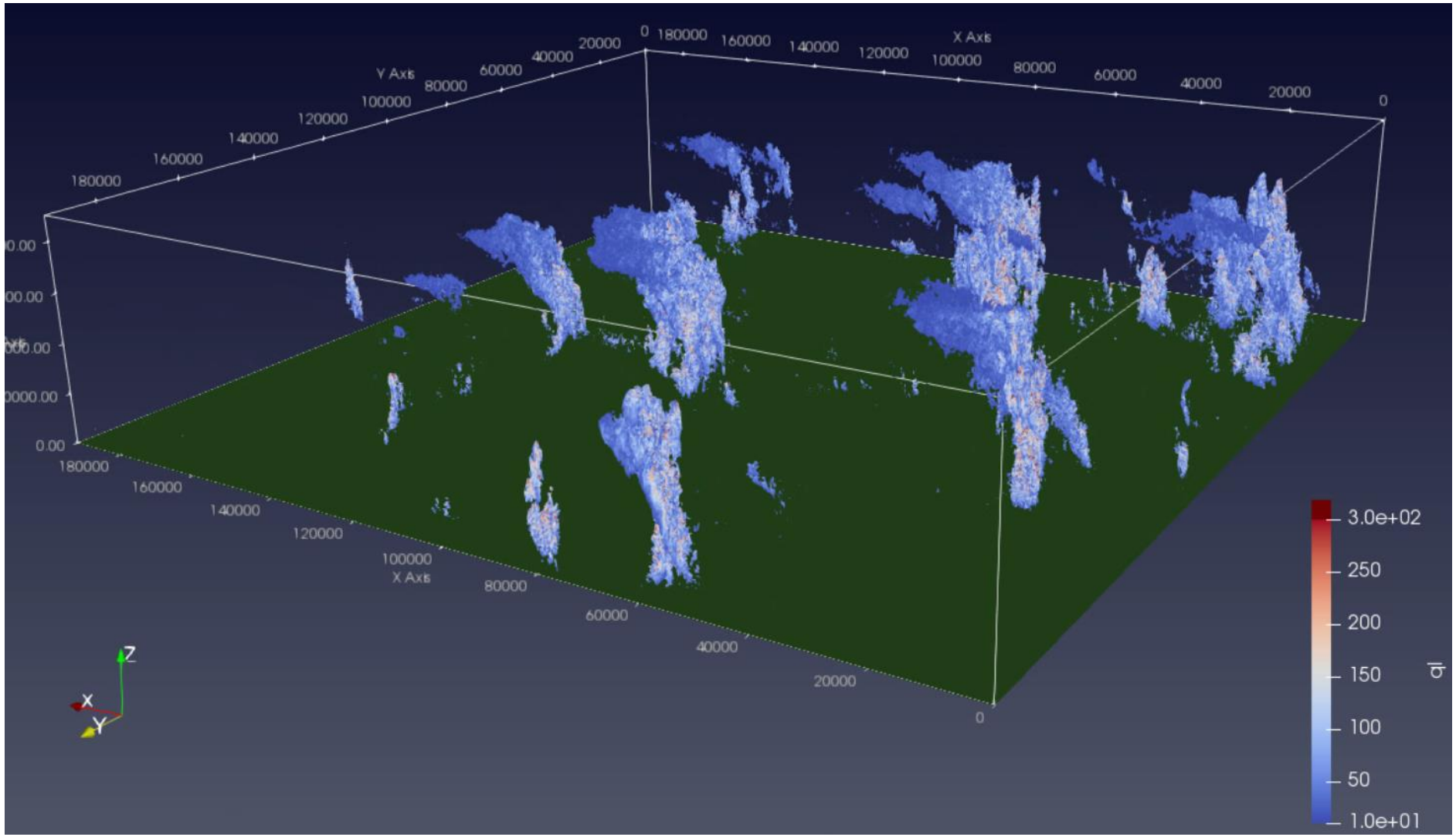


- Large area events show a strong increase of intensities with (dew point) temperature



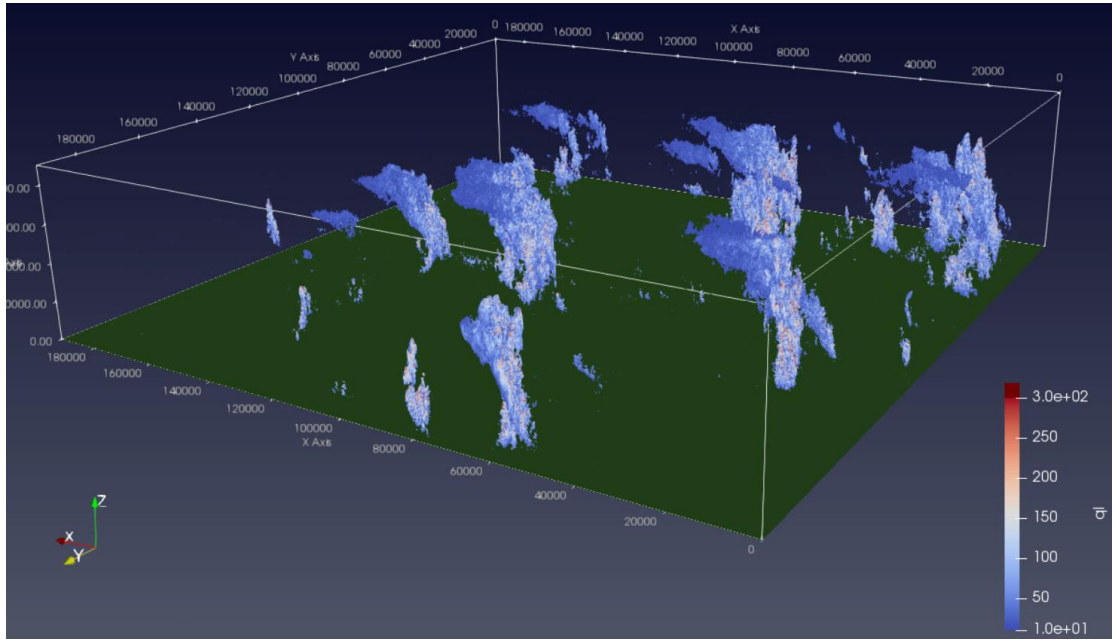


Modeling convective rainfall extremes

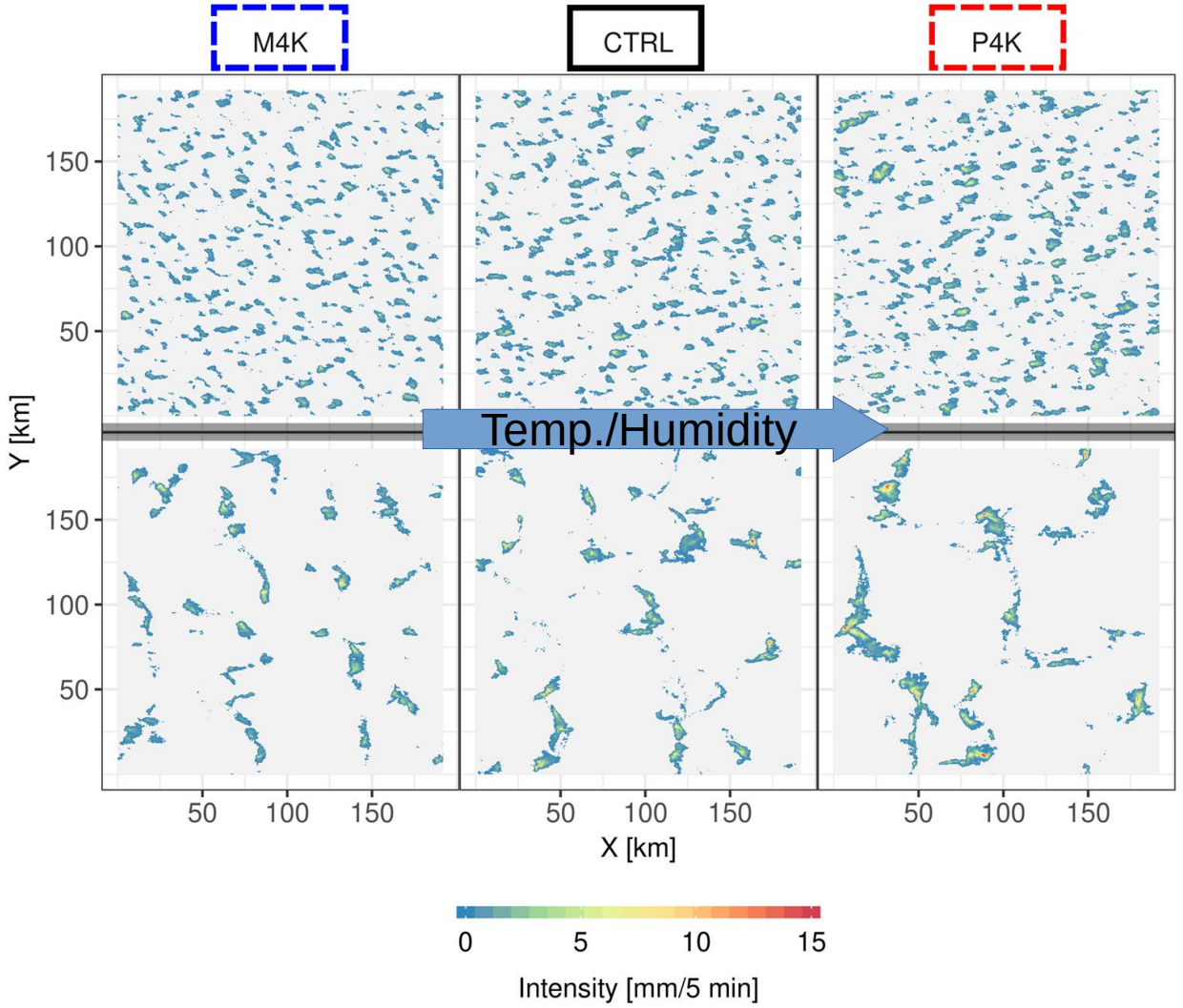


Model

- Simulation at very high resolution (200 m) on 200 km by 200 km domain size
  - Typical day of heavy precipitation in the Netherlands (composite)
  - Derived from observations/reanalysis
    - ~300 events
    - Average dew point: ~16 °C
    - Average precipitation: ~15 mm/h
- Modify conditions
  - increase/decrease (dew point) temperature
  - Increase/decrease relative humidity
  - increase/decrease stability
  - Modify large scale conditions



Size and intensity with increasing temperature



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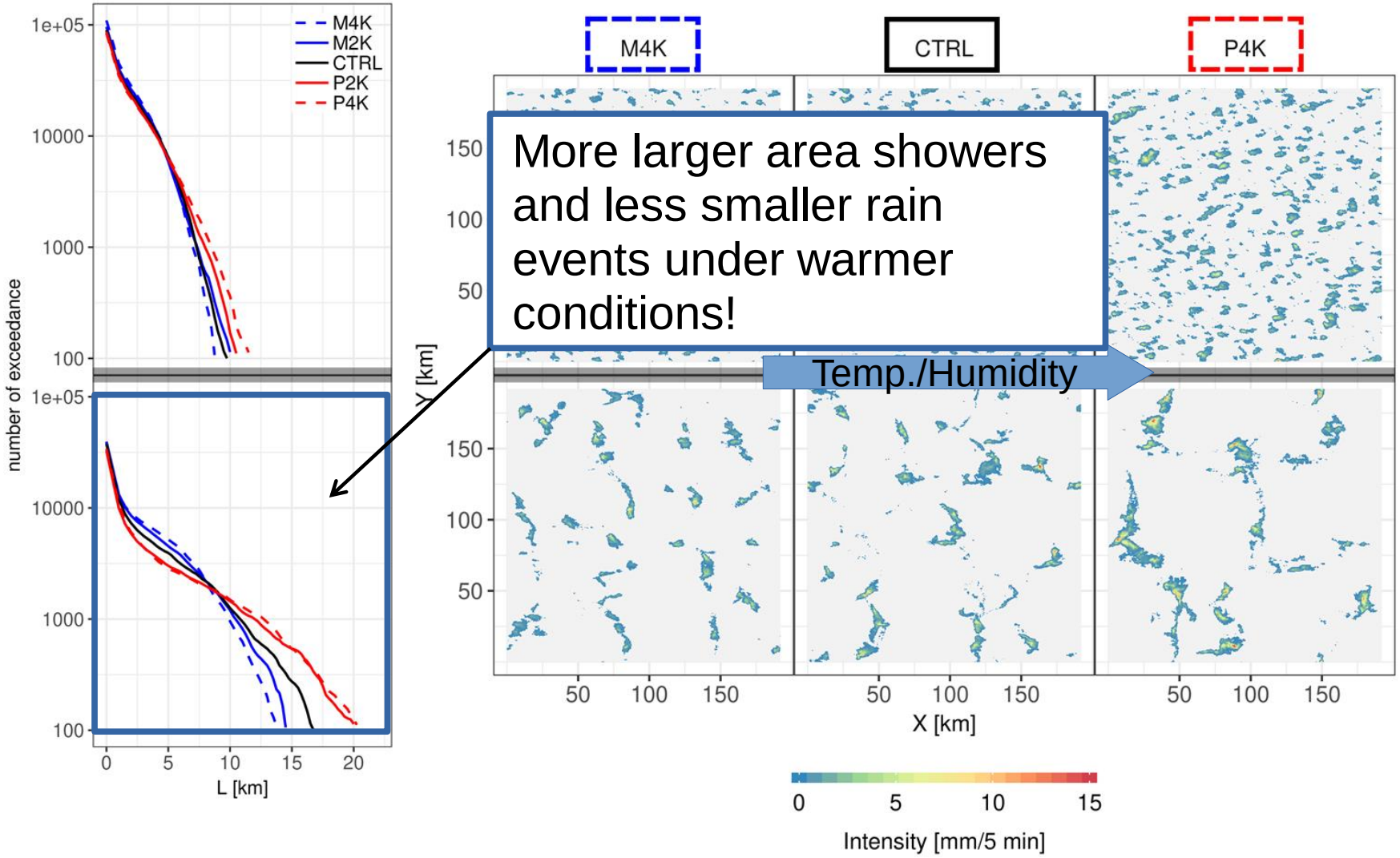

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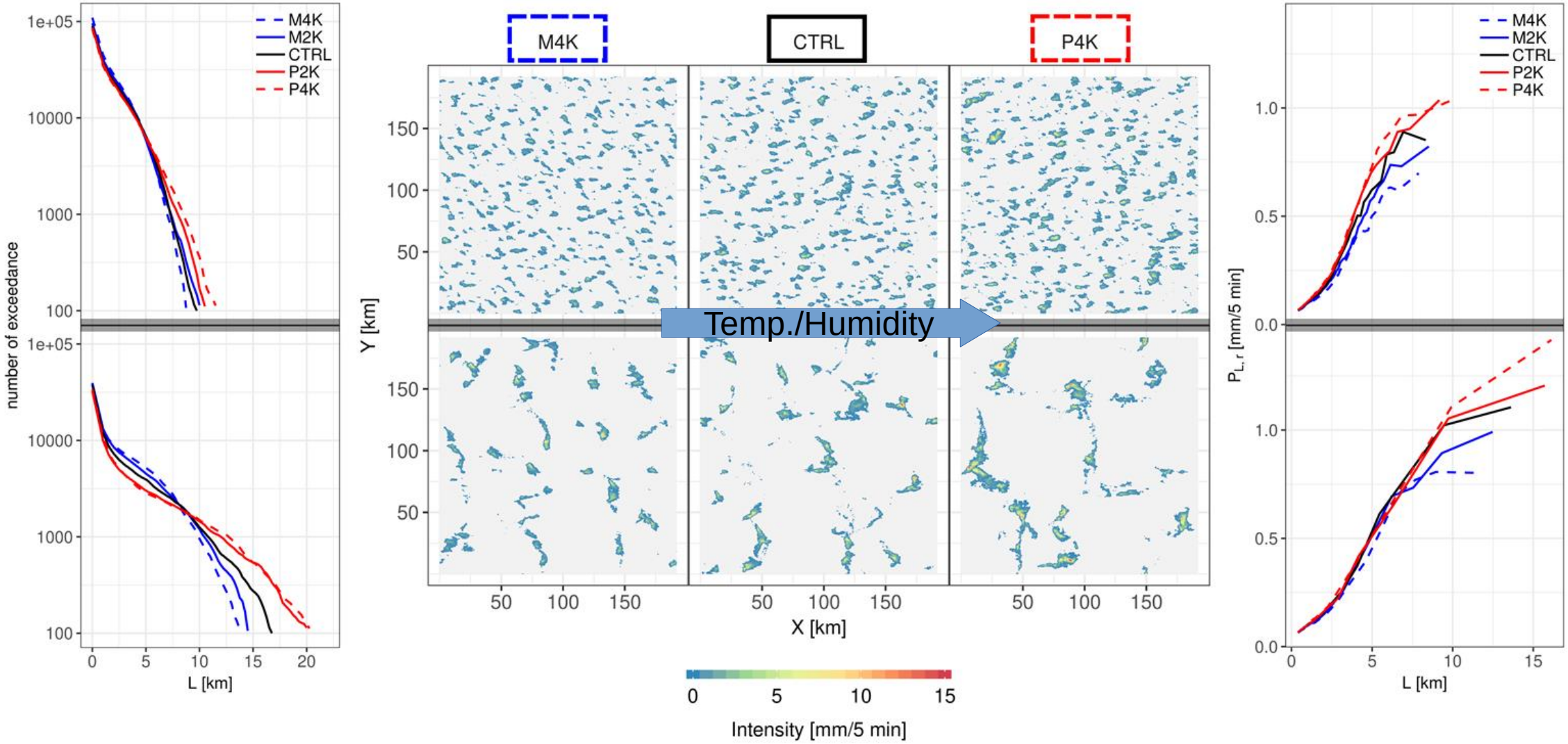

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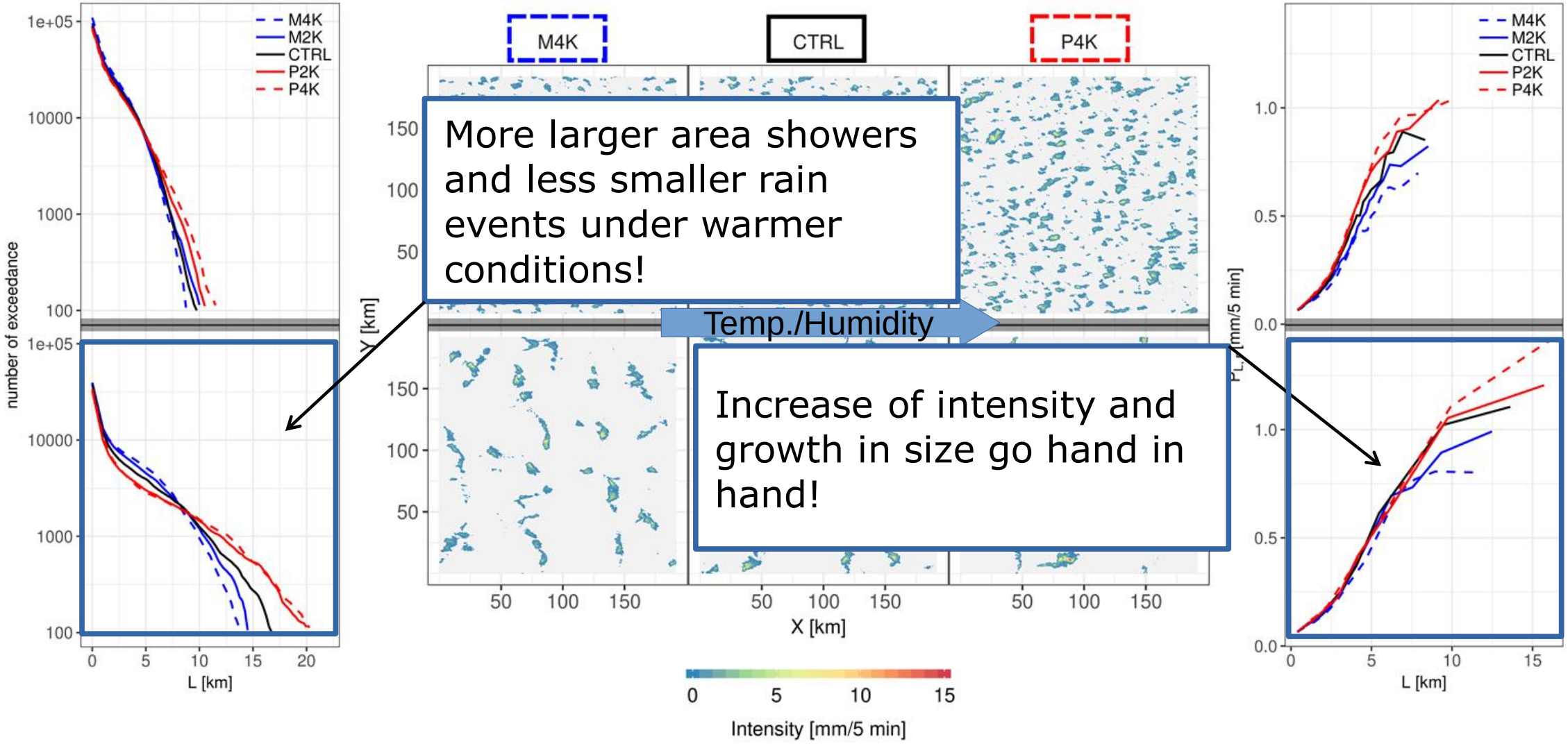
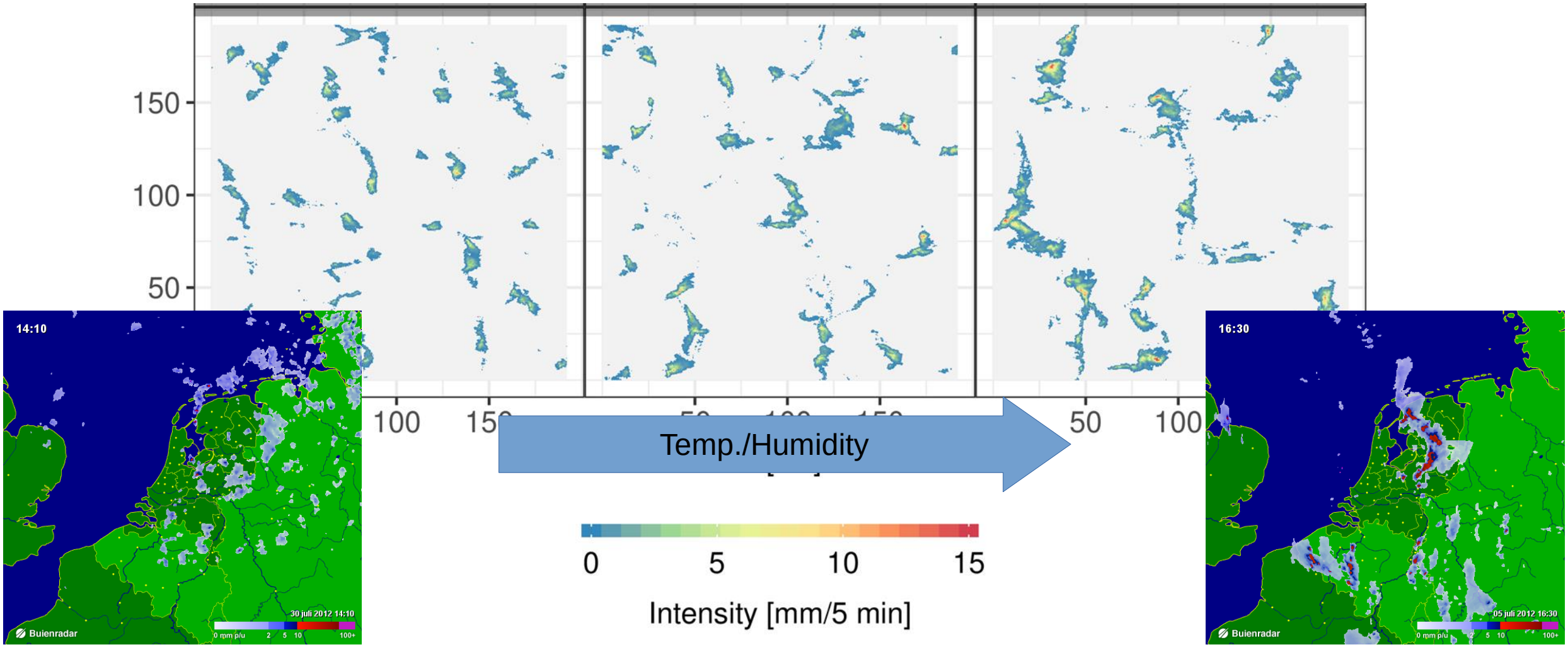


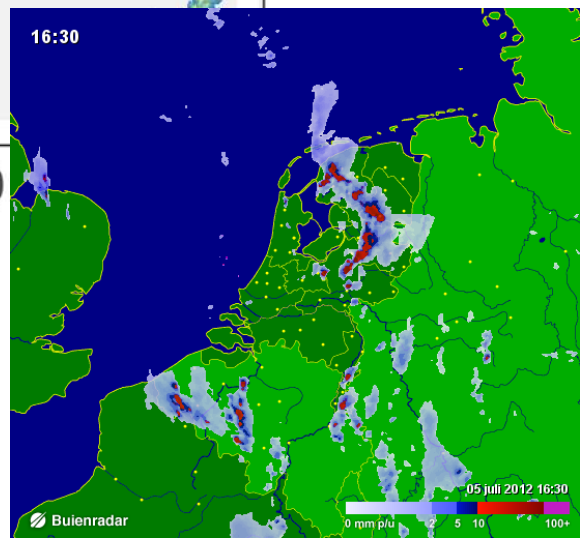
A tendency to more clustered/organized events



A tendency to more clustered/organized events

What we observe:

- Higher intensities
- Larger rainfall events
- Stronger clustered
- <u>Highly interactive and complex structures at high temperatures</u>

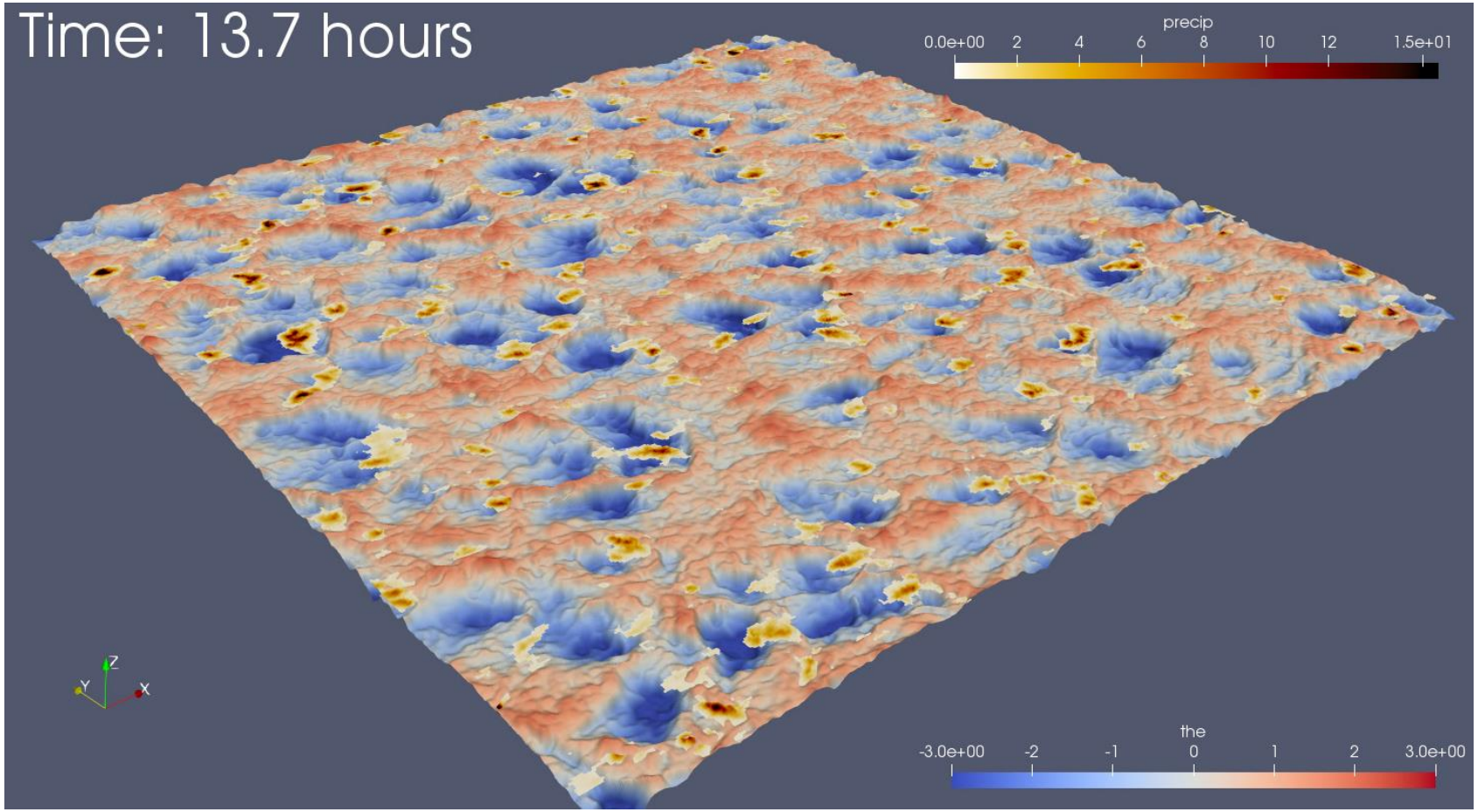


Temp./Humidity

0 5 10 15

Intensity [mm/5 min]

More complex cloud structures at high temperature due to complex near surface dynamics driven by cold air outflow from convective clouds



Summary

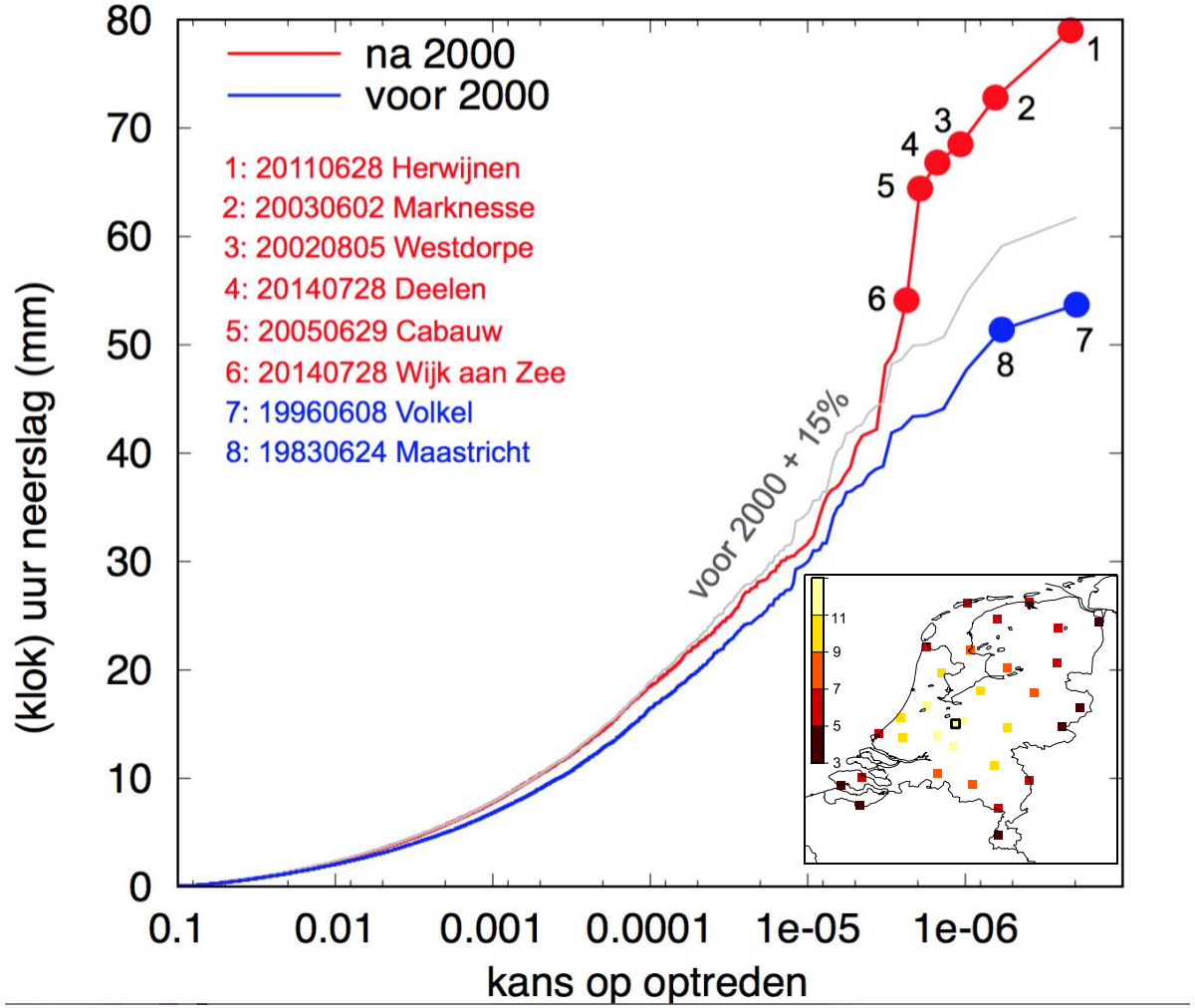
- RADAR observations and model experiments show under warmer conditions:
  - Higher intensities
  - Larger rain events
  - More larger cells at the cost of smaller cells
  - Tendency of stronger organization
- General remarks:
  - Impact depends also on life-time and how fast a cloud propagates
  - Processes leading to organization are highly complex and cause inherent uncertainties (also in weather forecasting)
  - We use here extremely expensive models; currently these processes are not resolved in mainstream climate models
  - But development of a new type of climate models that start to resolve these is ongoing (Harmonie climate at KNMI)

Take away points

- Response of extreme showers is a new and fast developing – new modelling tools, observations, and understanding – research area
- Prepare for changes in insights
  - KNMI'14: ~ one change factor for all rainfall types (similar events, but just more intense)
  - KMMI'21/23: The character of convective precipitation changes. Changes in rainfall amount strongly depend on size, duration and severity.

    Preliminary results: the most extreme events could reveal the strongest increases, at least locally.
- Despite this: most extremes are still expected to increase

Hourly precipitation extremes measured at KNMI stations: before and after 2000



1. Until 25 mm/hour ("wolkbreuk") change + 15 %

2. 5 unprecedented high values after 2000 (> 60 mm)

Number of stations not constant over time, but total number of observation before and after 2000 are ~ equal