HOURLY PRECIPITATION EXTREMES

ANALYSIS OF TRENDS AND RELATED CAUSES FOR THE PERIOD 1958-2015 FOR THE NETHERLANDS

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INTRODUCTION

BACKGROUND AND CONTEXT

- AFFECTING SOCIETY
  “.. THE IMPACT IS DETERMINED BY THE OCCURRENCE, MAGNITUDE AND LOCATION OF EXTREME EVENTS. “
  (TRENBERTH AND PARSONS, 2003; STOCKER AND MIDGLEY,2007)

- CLIMATE CHANGE
  “..MORE REGIONS WITH STATISTICALLY SIGNIFICANT INCREASES IN HEAVY PRECIPITATION EVENTS THAN REGIONS WITH STATISTICALLY SIGNIFICANT DECREASES. “ (AR5 IPCC, 2007),
  , “ BUT STRONG SEASONAL AND (SUB)REGIONAL VARIATIONS”.

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INTRODUCTION

BACKGROUND AND CONTEXT

- DISPROPORTIONALITY

ENERGY BUDGET (GLOBAL MEAN) VS CLAUSIUS-CLAPEYRON (EXTREMES)

E = P

MOISTURE-HOLDING CAPACITY ~ 7 % PER DEGREE

"THE HEAVIEST EVENTS ARE EXPECTED WHEN ALL THE MOISTURE IN A VOLUME OF AIR IS PRECIPITATED OUT."

(PALL AND STONE, 2007; LENDERINK AND VAN MEIJGAARD, 2010 AND 2011;HARDWICK JONESAND SHARMA, 2010)

August-Roche-Magnus approximation

$$e_s(T) = 6.1094\ e^{\left(\frac{17.625\ T}{T+243.04}\right)}$$

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INTRODUCTION

RELEVANCE

- DAILY VS HOURLY DATA

  24H SUM — SHORT-LASTING EVENTS

- SEASONAL AND SPATIAL TRENDS
  - **WINTER:** SYNOPTIC WEATHER SYSTEMS VS **SUMMER:** LOCAL THUNDERSTORM-LIKE EVENTS
  - COASTAL VS NON-COASTAL

INTRODUCTION

THIS THESIS

- AIM: *"ASSESS HOW EXTREME HOURLY PRECIPITATION IN THE NETHERLANDS CHANGES IN TIME AND WHAT THE CAUSES ARE BEHIND THESE CHANGES " ,*

BY

i. ANALYSING SEASONAL AND SPATIAL CHARACTERISTICS OF HOURLY PRECIPITATION,

ii. APPLYING TREND ANALYSIS (INTENSITY, FREQUENCY AND PRECIPITATION SUMS) FOR 5 STATIONS,

iii. INVESTIGATING EXPLANATORY RELATIONSHIPS
E.G. TEMPERATURE, DEWPOINT TEMPERATURE, CONVECTIVE AVAILABLE POTENTIAL ENERGY (CAPE) AND WIND SPEED

METHOD

DATA

- TIME AND PLACE
  - 5 DUTCH STATIONS
  - 1958 – 2015
  - VARIABLES: TIME, HOURLY PRECIPITATION SUM, DURATION (DEFINED AS THE HOURLY TIME FRACTION OF PRECIPITATION), TEMPERATURE, DEW POINT TEMPERATURE, CAPE (01-03-1993 UNTIL 2015) AND WIND STRENGTH

- TYPE OF DATA AND INSTRUMENTS

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METHOD

Extreme events are defined using the 75-99.9%- quantiles, so hours with the highest 25-0.1% intensities.

- **DEFINITION OF EXTREMES:**
- **2-DAY MAXIMA**

75, 90, 95% (> 1.6-6 MM/HR)	"MODERATE" EXTREMES
99-99.9% (> 8 MM/HR)	"HIGH" EXTREMES

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METHOD

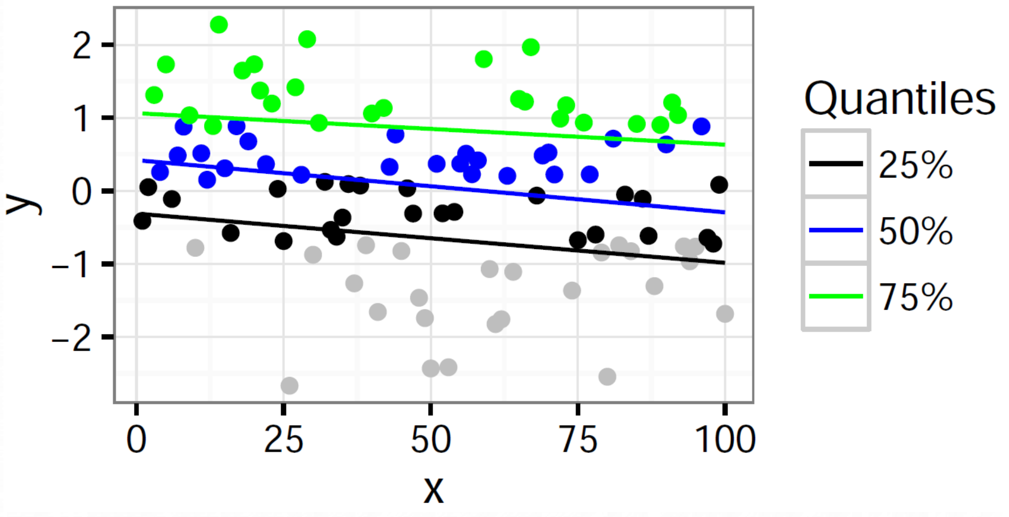
TREND ANALYSIS

- LEAST-SQUARES REGRESSION
- QUANTILE REGRESSION

$$\min_{\beta\in\mathbb{R}} \sum_{t=1}^{T} \left(\sum_{(y_t-\beta)\le 0} (\tau-1)(y_t-(\beta_0+\beta_1*t)) + \sum_{(y_t-\beta)>0} \tau(y_t-\beta_0+\beta_1*t) \right)$$

(Koenker and Ng, 2005)

- TIME DEPENDENCY
- TESTING OF SIGNIFICANCE



Example quantile regression

WHAT'S NEXT?

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TRENDS

TRENDS ON 2-DAY

- MAXIMA IN PRECIPITATION INTENSITY
- FREQUENCIES OF WET HOURS (P>0.05 mm)
- PRECIPITATION SUMS

TRENDS

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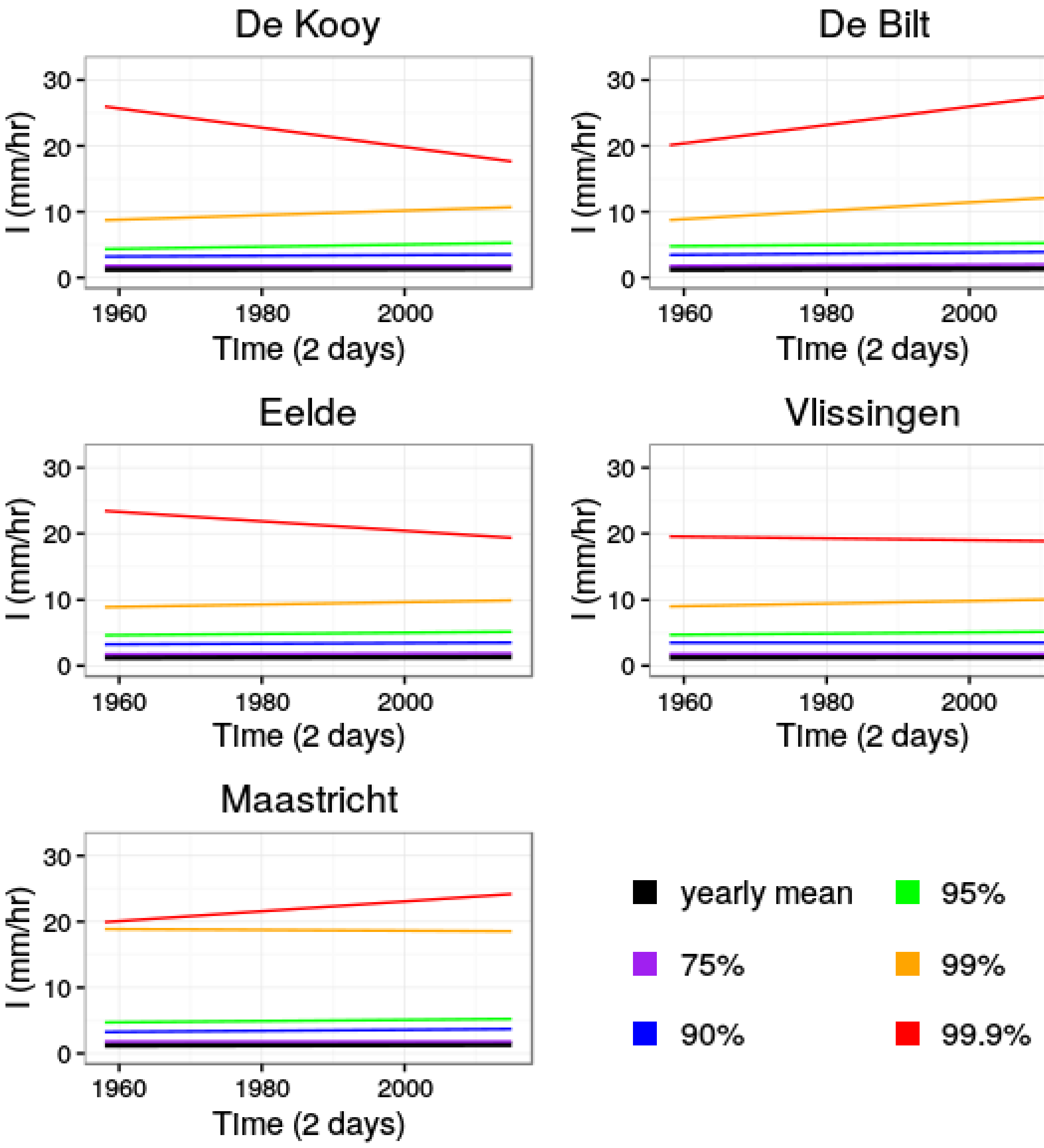

Quantile regression on 2-day intensity maxima (I)

INTENSITY MAXIMA

- Overall increasing trend
- Only visible on hourly resolution
- Rates of 0.001-0.01 mm/hr/yr

"Does it rain more intense nowadays than in the past ??"

Significance Test

Table p values Monte Carlo Permutation test

Location		Quantiles of fit					
Station	STN	50%	75%	90%	95%	Q99%	99.9%
De Kooy	235	0.15	0.06	0.96	1.00	0.84	0.07
De Bilt	260	0.05	0.99	1.00	0.95	0.91	0.90
Eelde	280	0.01	0.96	0.93	0.92	0.73	0.26
Vlissingen	310	0.91	0.07	0.30	0.96	0.82	0.47
Maastricht	380	0.25	0.11	0.98	0.95	0.45	0.67

($p > 0.95$ CL), so $\alpha > 0$

TRENDS

INTENSITY MAXIMA

- DISPROPORTIONALITY
- LARGE SUMMER-WINTER MAGNITUDE DIFFERENCE
  (HIGHEST 1%: WINTER >5-6 MM.HR VS SUMMER > 12-20 MM/HR)
- ROBUST INCREASING SIGNAL FROM SIGNIFICANCE TESTING

Location		Quantiles of fit			
		Summer			
Station	STN	50%	75%	90%	95%
De Kooy	235	0.90	0.99	0.99	0.94
De Bilt	260	0.28	0.99	0.84	0.86
Eelde	280	0.78	0.99	0.95	0.49
Vlissingen	310	0.86	0.71	0.96	0.97
Maastricht	380	0.53	0.73	0.98	0.86
		Winter			
De Kooy	235	0.21	0.91	0.97	0.98
De Bilt	260	0.95	0.86	0.97	0.78
Eelde	280	0.26	0.96	0.99	0.88
Vlissingen	310	0.97	0.87	0.29	0.37
Maastricht	380	0.12	0.99	0.92	0.97

(p>0.95CL so $\alpha>0$)

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TRENDS

"Does it rain more intense nowadays than in the past ??"

→

"YES, the 5-10% highest 2-day intensity maxima. have even increased with 0.5-1 mm/hr over the last 58 years"

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TRENDS

FREQUENCY OF WET HOURS

- Robust decreasing signal, but spatial differences in strength
- Summer vs winter

"Does it rain **more** often nowadays than in the past??"

→

"NOO! The 50-0.1% highest 2-day frequencies of wet hours **have decreased with 12.5-18.6%** over the last 58 years"

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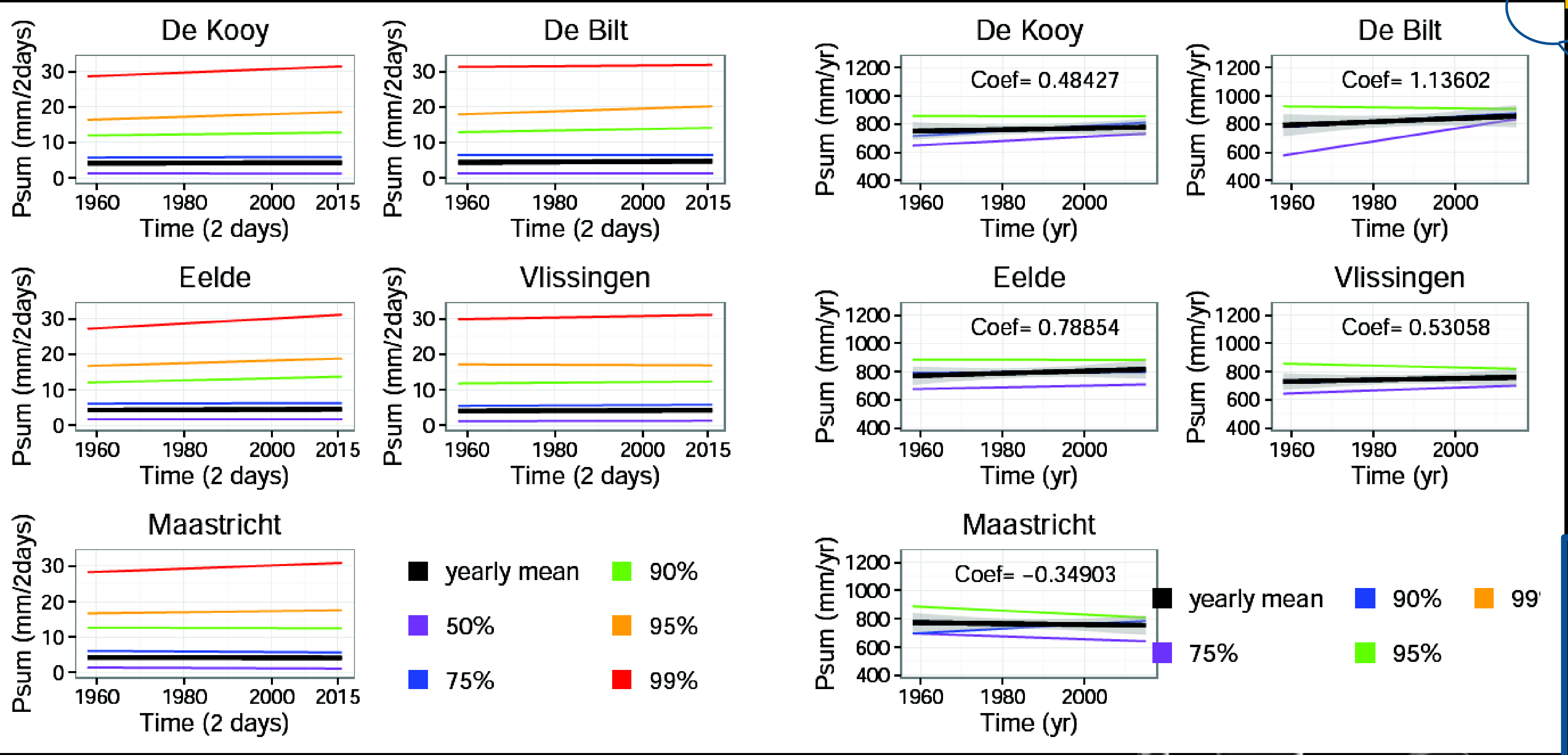
TRENDS

PRECIPITATION SUMS

All 2-day

Yearly sums



Quantile regression on 2-day precipitation sums

"And in total .. ?
Do my plants get
more water a day?"

- Constant to increasing
- Significant?
  Only for 90-99%-quantiles

"YES, the 10-1% highest 2-days sums have increased with 1.2-2.7 mm over the last 58 years"

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RECAP TREND ANALYSIS

1. Significant changes in precipitation characterstics between 1958-2015
   - i. Increasing intensity maxima
   - ii. Decreasing frequencies of wet hours
   - iii. Constant to increasing (only 10-1% highest) precipitation sums

   → First 2 are only possible with data on hourly resolution

2. Disproportionality; more and stronger significant trends for the “high”extremes compared to the mean and “low” extremes

WHAT'S NEXT?

1. INTRODUCTION

2. METHOD

3. RESULTS

   - TRENDS IN PRECIPITATION CHARACTERSTICS

   - CAUSES BEHIND TRENDS

4. DISCUSSION & CONCLUSIONS

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CAUSES BEHIND TRENDS

1. THEORY

- Temperature
- Dewpoint temperature
- Vertical instability
- Wind strength

2. CORRELATION COEFFICIENTS

3. TRENDS

4. TIME RELATED DISTRIBUTION OR RELATIONSHIP CHANGE

"Why? Has it to do with **climate change**??"

"YES, LIKELY THE TIMEWISE SHIFTING OF (DEWPOINT) TEMPERATURE DISTRIBUTIONS LEADS VIA CC EQUATION TO INTENSIFICATION OF PRECIPITATION EXTREMES!

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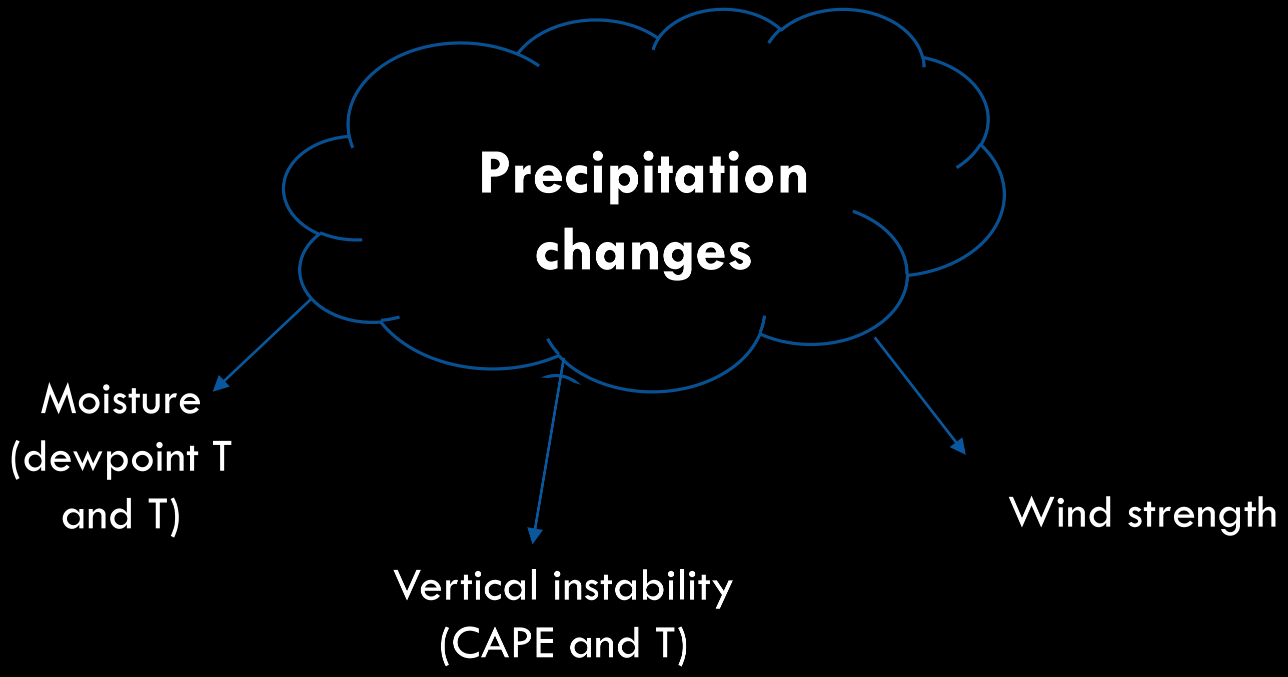
DISCUSSION & CONCLUSIONS



Aim: *"assess how extreme hourly precipitation in the Netherlands changes in time and what the causes are behind these changes "*

DISCUSSION & CONCLUSIONS

STRENGTHS OF THIS THESIS

- MANY SIGNIFICANT TRENDS FOR PRECIPITATION CHARACTERSTICS
- FOR MULTIPLE STATIONS

WEAKNESSES

- STRATIFORM VS CONVECTIVE INSTEAD OF WINTER VS SUMMER
- TREND IN CAPE

FUTURE RECOMMENDATIONS

- RADAR/SATELLITE DATA
- OTHER EU COUNTRIES → NORTH-SOUTH CONTRAST?

DISCUSSION & CONCLUSIONS

1. MULTIPLE SIGNIFICANT TRENDS ARE SHOWN ON A SPATIAL AND SEASONAL LEVEL.

→ ROBUST SIGNALS FOR THE PERIOD 1958-2015 IN INCREASING INTENSITY OF HEAVY HOURLY PRECIPITATION, DECREASING FREQUENCY OF WET HOURS AND CONSTANT TO INCREASING PRECIPITATION SUMS.

2. DISPROPORTIONALITY

→ STRONGER/MORE SIGNIFICANT TREND OF “HIGHER” EXTREMES COMPARED TO “LOWER” EXTREMES OR MEAN

CONCLUSIONS

4. TEMPERATURE, DEWPOINT TEMPERATURE, WIND STRENGTH AND CAPE ARE IMPORTANT KEY VARIABLES

5. TRENDS IN PRECIPITATION INTENSITY MORE LIKELY CAUSED BY TIMEWISE SHIFTING OF (DEWPOINT) TEMPERATURE DISTRIBUTIONS, THAN TO CHANGES IN THE P-T (P-TD) RELATIONSHIPS

- CONFIRMS CLAUSIUS-CLAPEYRON EQUATION OF INTENSIFCATION OF HEAVY HOURLY PRECIPITATION DUE TO ENHANCED MOISTURE AVAILIBILITY BY INCREASING T

- MATCHES WITH A DECREASE IN FREQUENCY OF WET HOURS (HIGHER SATURATION VAPOR PRESSURE NEEDED)

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DISCUSSION & CONCLUSIONS

1. MULTIPLE SIGNIFICANT TRENDS ARE SHOWN ON A SPATIAL AND SEASONAL LEVEL.

→ ROBUST SIGNALS FOR THE PERIOD 1958-2015 IN INCREASING INTENSITY OF HEAVY HOURLY PRECIPITATION (2-DAY MAXIMA), DECREASING FREQUENCY OF (2-DAY) WET HOURS AND CONSTANT TO INCREASING (2-DAY) PRECIPITATION SUMS.

2. DISPROPORTIONALITY

→ STRONGER/MORE SIGNIFICANT TREND OF “HIGHER” EXTREMES COMPARED TO “LOWER” EXTREMES OR MEAN

3. TEMPERATURE, DEWPOINT TEMPERATURE, WIND STRENGTH AND CAPE ARE IMPORTANT KEY VARIABLES

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EXTRA DISCUSSION

- 2 DAY MAXIMA

Why not a shifting window?

- The variables (f.e. T and P) occur most of the time simultaneously
- Convective extreme precipition constrained by hours of most insolation (12-18h)

EXTRA DISCUSSION

-EXTREME DISTRIBUTIONS

Why not a GEV?

- Quantile regression is ideal for spatial comparison
- Less time consuming

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EXTRA DISCUSSION

- NEGATIVE TRENDS IN WIND SPEED PERIOD 1993-2015

- SMITS, KLEIN TANK, AND KÖNNEN (2005) FIND NEGATIVE TRENDS FOR PERIOD 1962-2002 FOR NL
- LOWER WIND SPEEDS COULD RESULT IN BACKBUILDING OF CONVECTIVE SYSTEMS (in combination with wind shear)

"A thunderstorm in which new development (e.g. updraft) takes place on the upwind side, such that the storm seems to remain stationary or propagate in a backward direction.

→ LONGER INTENSIVE PRECIPITATION AT A SPECIFIC LOCATION

EXTRA DISCUSSION

- NEGATIVE TRENDS IN CAPE PERIOD 1993-2015

- GETTELMAN ET AL. (2002) FOUND MOSTLY POSITIVE TRENDS FOR THE PERIOD 1958-1997.
- RIEMANN-CAMPE ALSO SHOWS POSITIVE TRENDS,
- BUT NEGATIVE OR WEAK FOR OUR PERIOD
- MIGHT BE DUE TO CHANGE IN RESOLUTION
- OF CAPE MEASUREMENTS