A physically-based method for classification of precipitation types and the implications for future changes over Norway

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22 AUGUST, 2019 LATSIS SYMPOSIUM, ETH ZURICH SWITZERLAND

1. NORCE & the Bjerknes Centre; 2. École Normale Supérieure; 3. Met Office

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16 OCTOBER, 2019 ICRC-CORDEX
BEIJING CHINA
SESSION A2

1. NORCE & the Bjerknes Centre; 2. École Normale Supérieure; 3. Met Office

Motivation

Western Norway: Flooding, multiple landslides, 200yr. rainfall [local measurements: 92-108mm/24hr

Foto: John Arne Holmlund / HA / NTB scanpix

Eastern Norway: high intesnity short duration event wiped out roads and cutoff residents [local measurements: 15-20mm/hr and 40-55mm/3hr]

Foto: Audun Braastad / NTB scanpix

Three of the top five 24hr local rain totals for western Norway have occurred in 2019.

- Events lead to questions about future scenarios
- Strong evidence that mean and extremes increase in a warming climate
- We don’t know the specifics
- CPM can help*

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Motivation

- Earlier work confirms expected increases in precipitation with CPM
- Community now moving beyond description of results (see right)
- We aim for a physical description of changes in precipitation characteristics
- *And* elucidate the underlying processes

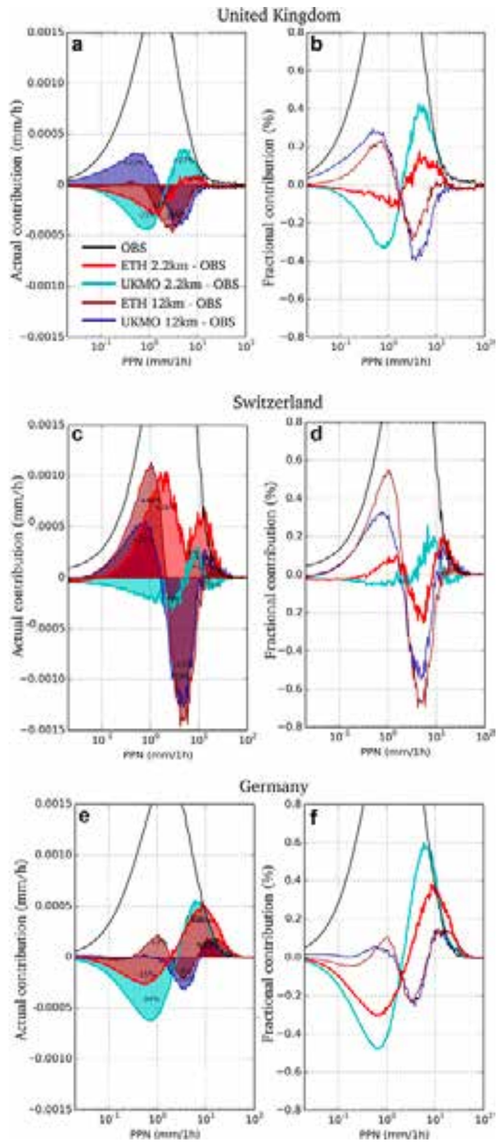
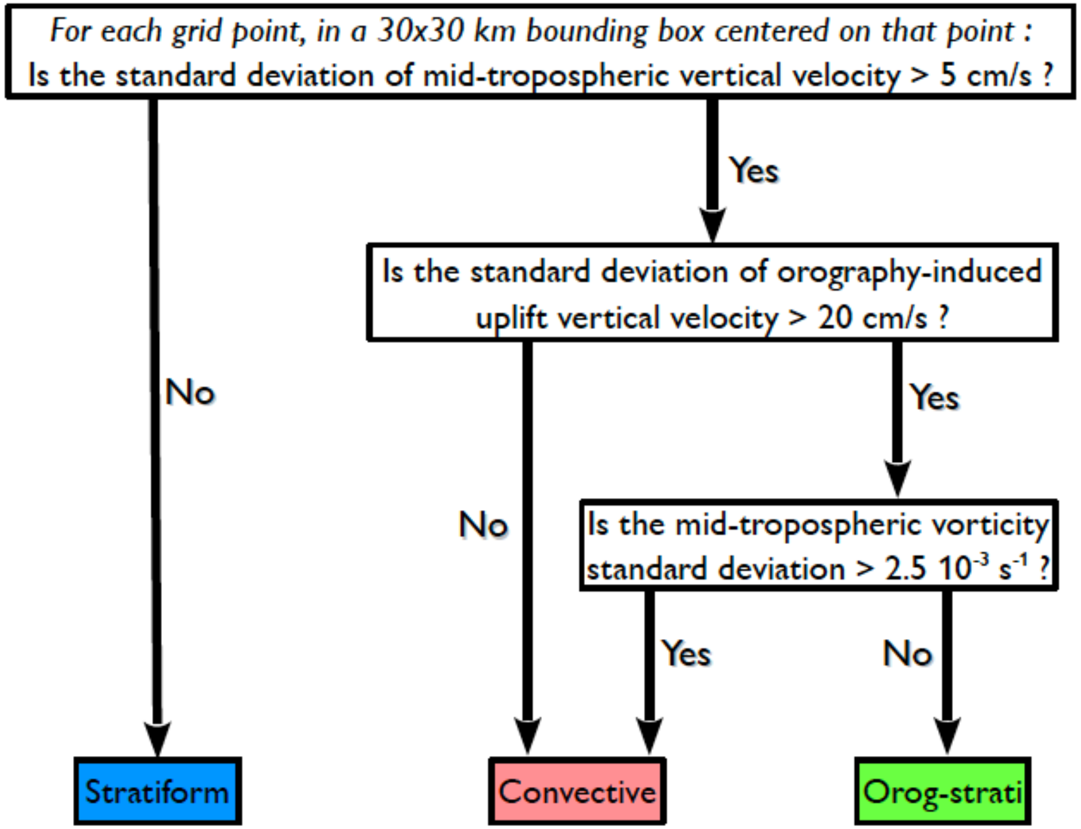


Figure 6 from *Berthou et al. (2018)* Illustrates the shift to larger contribu-tions from moderate to high intensity events in JJA (focus on red and turquoise lines)

Outline

- Introduce a physically-based algorithm for separation of precipitation types in CPM simulations
- Briefly show performance
- Future precipitation characteristics from a 3km PGW experiment over Norway
- Discuss mechanisms (preliminary)
- Summary, limitations & the way forward

Algorithm for separation of precipitation in complex terrain



Poujol et al. (in revision)

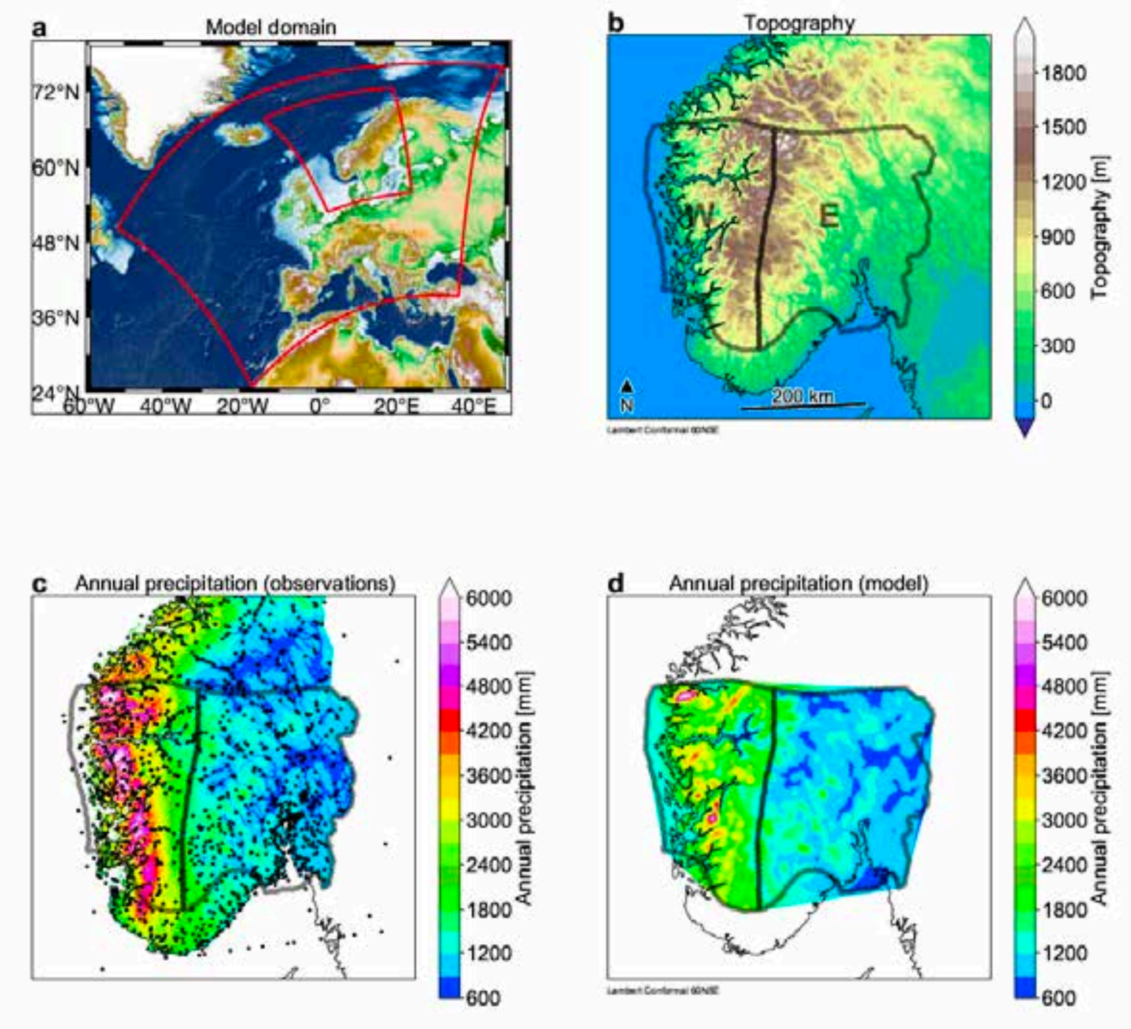
Aim1: classify precipitation types according to physical processes
Aim2: do so in a relatively simple framework with commonly available variables

Variables (hourly): Precipitation, Three dimensional wind speed (*u*,*v*,*w*) at the middle of the troposphere (500hPa), Horizontal wind speed (*u*,*v*) at a level close to the ground (700hPa), but above most of the topography in the dataset domain

Criteria:

- Vertical velocity criterion
  - mid-troposphere vertical velocity criterion
  - orographic uplift vertical velocity criterion
- Potential vorticity dipoles criterion

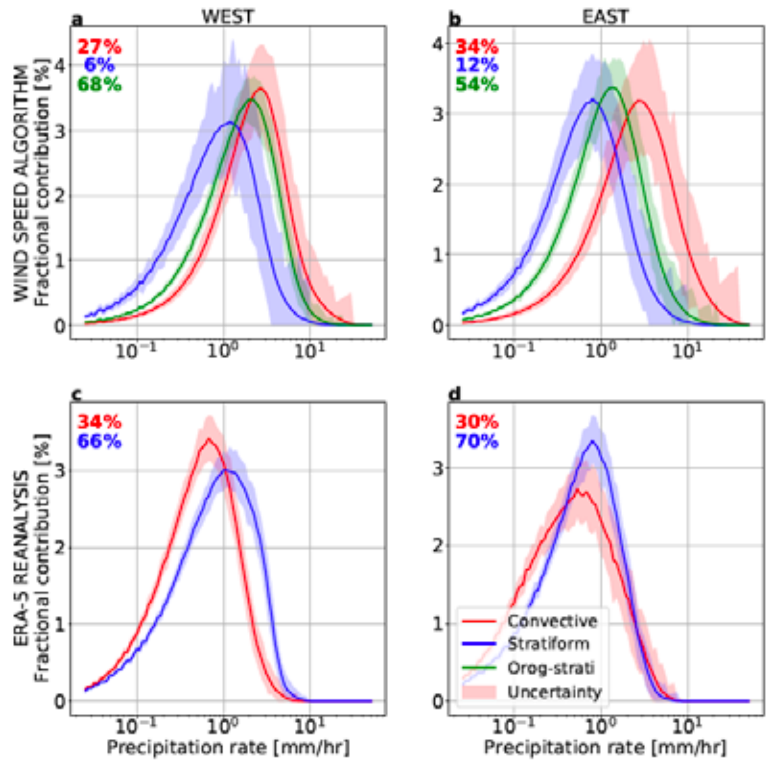
Model Stuff



- WRF3.9.1 one-way nest 15km, 3km
- All convection turned off at 3km
- Thompson microphysics
- Present day simulation: ERA-Interim driven [1996-2005] +
- Future simulation: PGW based on RCP8.5 [2035-65]

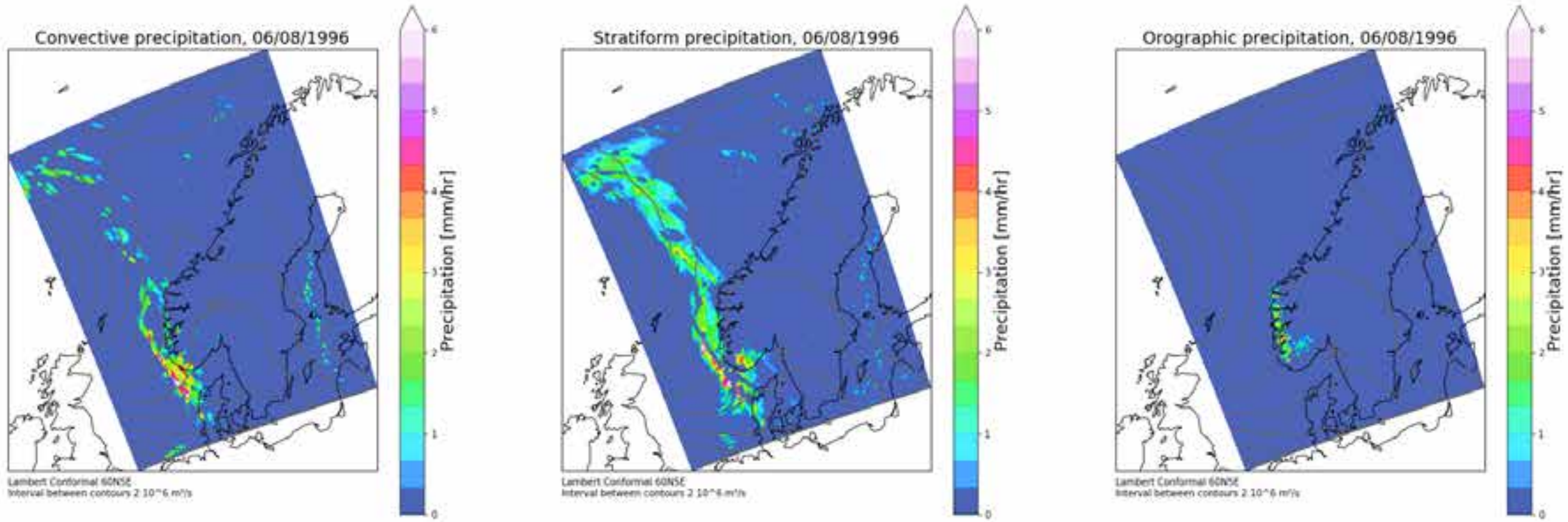
Algorithm performance: Present day

- Good separation in eastern Norway
- Not as good in west (likely due to misclassification in presence of orography)
- Still much better than parameterization-based separation (ERA-Interim)
- Relative amounts are similar (percentages)



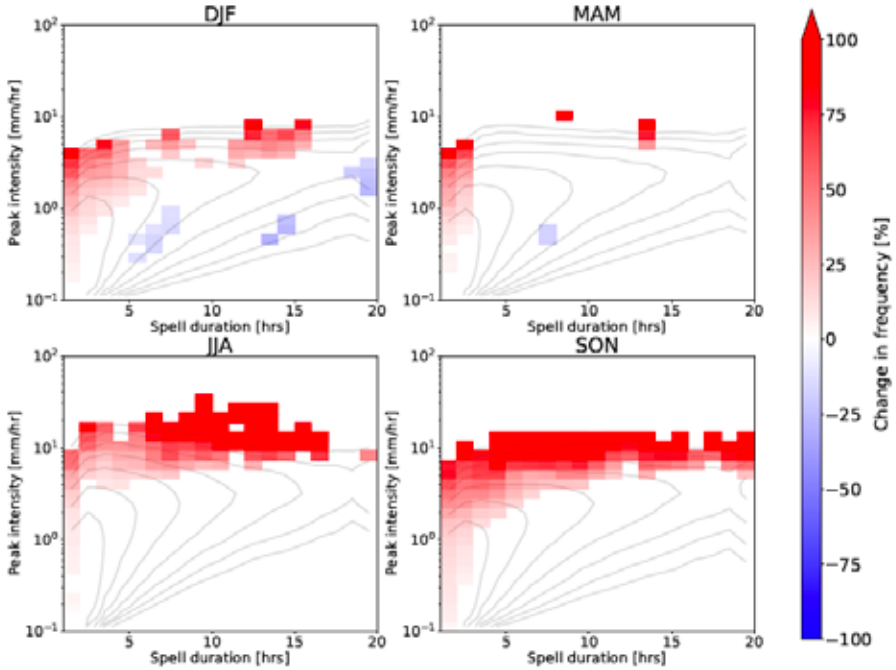
Distribution curves based on ASoP methods see Klingaman et al. (2017) and Berthou et al. (2018)

Algorithm performance: an example with a bit of everything

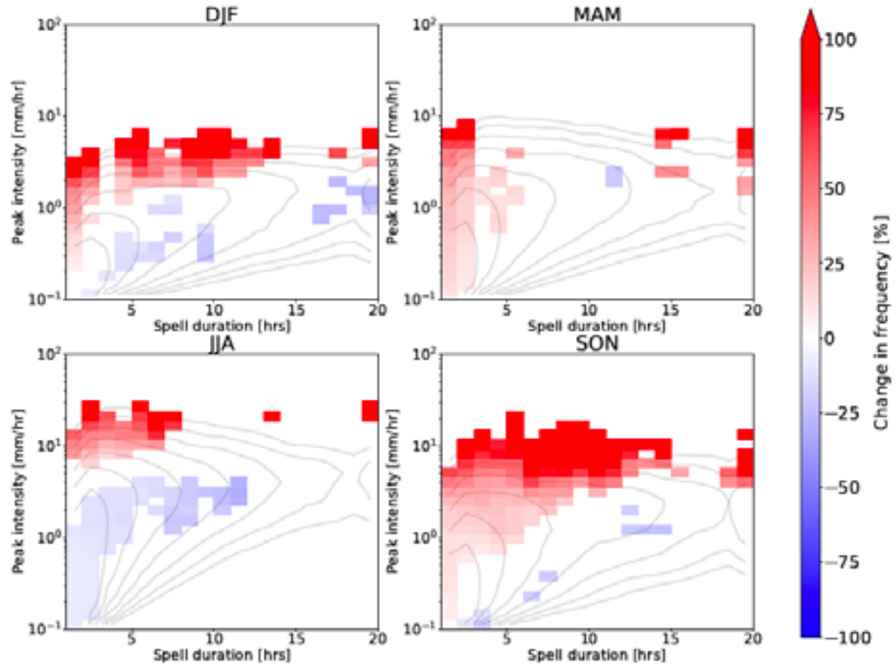


Intensity - duration plots indicate robust shifts with distinct spatial and seasonal flavors

NORCE



Western Norway



Eastern Norway

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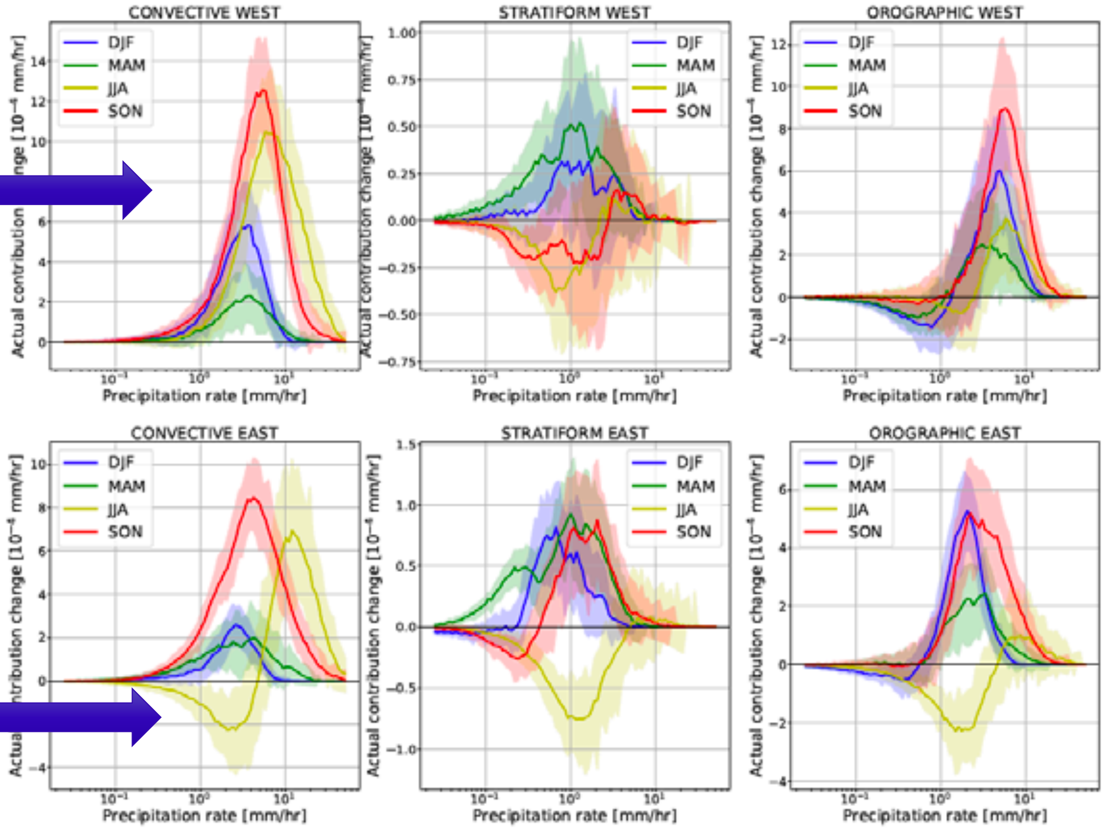
ASoP plots show convective precipitation makes largest contribution to actual change

Positive all seasons; Shifts towards higher intensities



Western Norway

In summer precipitation from moderate intensities *decreases*

Eastern Norway

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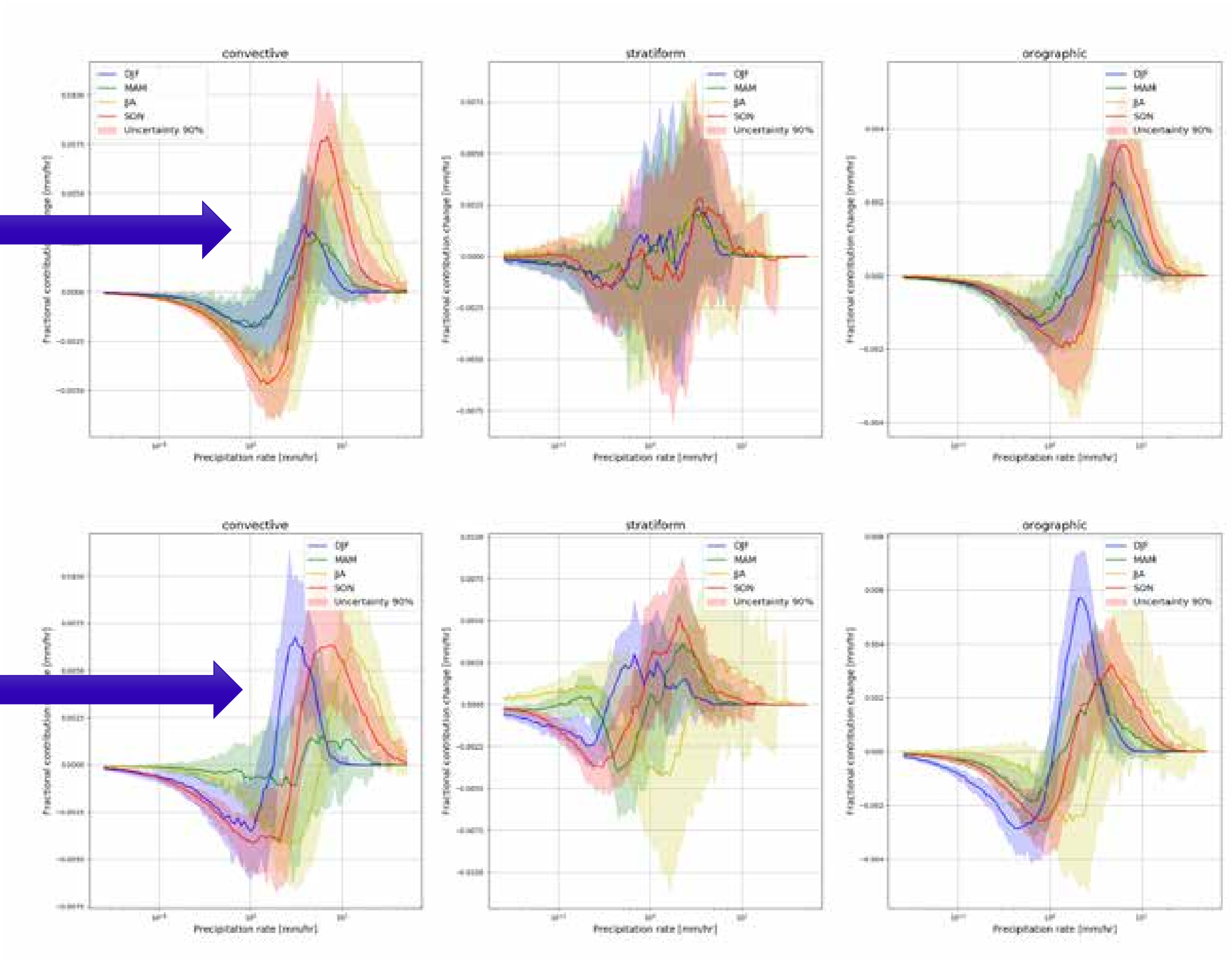
In fractional terms the changes come from moderate to high intensities

NORCE

Convective and orographic precipitation show the same pattern of shifting



Western Norway

Convective and orographic precipitation show the same pattern of shifting

Eastern Norway

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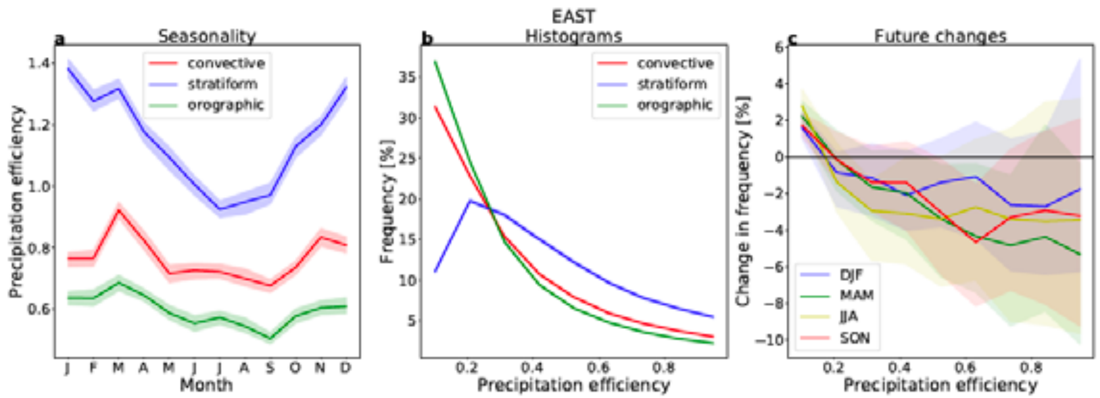
Complex interplay of processes drives these changes (we think)

	WEST				EAST			
Variable [Unit]	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
CAPE [J/kg]	49.2	37.9	66.8	47.7	15.1	33.2	99.8	38.3
change	*+1.0*	-2.6	+19.8	+10.0	+5.0	+5.2	+32.5	+10.1
CIN [J/kg]	0.8	4.4	9.4	1.8	1.8	7.3	13.9	3.5
change	-0.1	-0.6	+4.5	+0.8	-0.4	+0.6	+4.3	+1.6
RH [%]	62	65	69	66	67	68	71	70
change	+0.5	+0.7	+0.6	+2.1	+0.2	+1.1	+0.2	+1.6

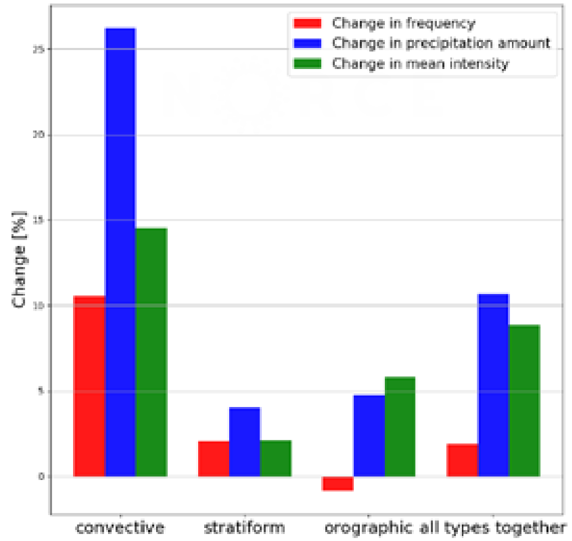


- Winter changes are well explained thermodynamics, consistent with theory (relative humidity nearly constant, scalings as expected)
- Summer response in eastern Norway (decrease in low to moderate rates; large increase in high intensities) due to increase in both CAPE and CIN
- Summer & Fall western Norway (strong increases in both convective and orographic) CAPE and CIN increase and RH increases/efficiency decreases (fall only) may contribute to apparent super cc-scaling (see extra slides)
- Spring responses generally weak but frequency of stratiform precipitation increases. Why?
- Microphysical changes likely matter as melting level shifts, RH increases, IWC and LWC change asymmetric, decreased efficiency (right)

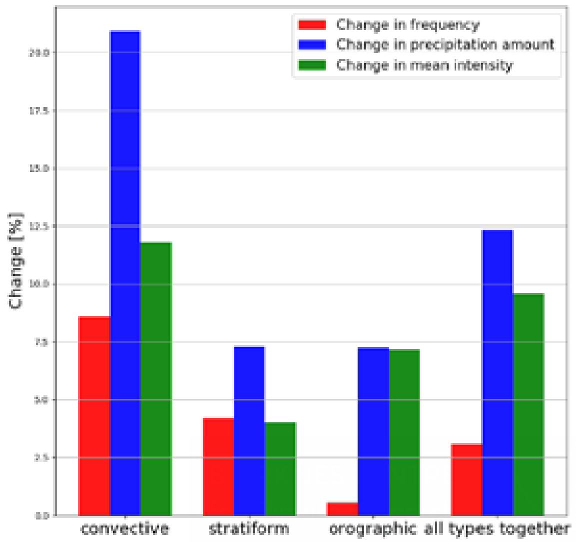
Summary

- A relatively simple physically-based algorithm separates precipitation types in a CPM
- This allows for deeper understanding of changing characteristics of precipitation
- Convective precipitation increases substantially
- Changes come from shift to more intense rates (nearly universal)
- Not all changes are uniform in space or time (i.e. location and season)
- Physical explanations also vary depending on season & location

Western Norway



Eastern Norway



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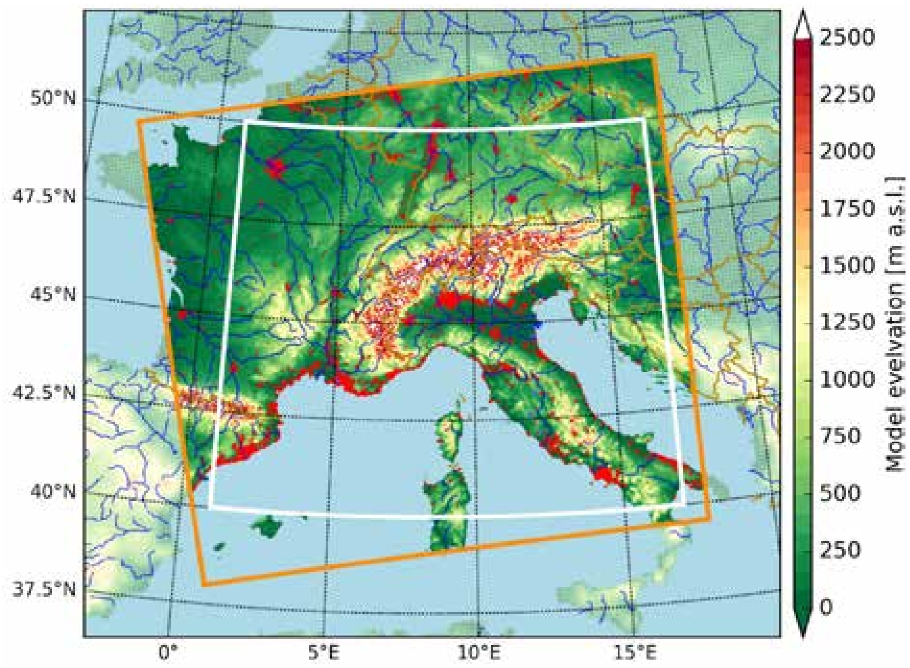
Extra slides: Caveats and future directions

- Single model, no shallow convection, PGW (largely) ignores dynamical changes, Algorithm can be improved, etc., etc.…
- Apply to multi-model ensemble from CORDEX FPS-Convection
- Apply to CPM simulations driven by CMIP5/6 to capture large scale dynamical aspects



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Extra slides: Percentage change and temperature scaling (theory vs. simulation)

		WEST					EAST				
Category	**Theory**	**Annual**	DJF	MAM	JJA	SON	**Annual**	DJF	MAM	JJA	SON
Convective	**10-21%**	**14%**	7%	7%	24%	18%	**12%**	12%	*3%*	14%	26%
Stratiform	**-**	***2%***	5%	4%	*2%*	4%	**4%**	7%	*2%*	*-1%*	14%
Orographic	**10%**	**6%**	6%	5%	4%	6%	**7%**	11%	6%	4%	8%

	WEST				EAST			
Seasons	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
ΔT	1.7	1.7	1.8	1.9	2.2	1.8	1.9	2.2

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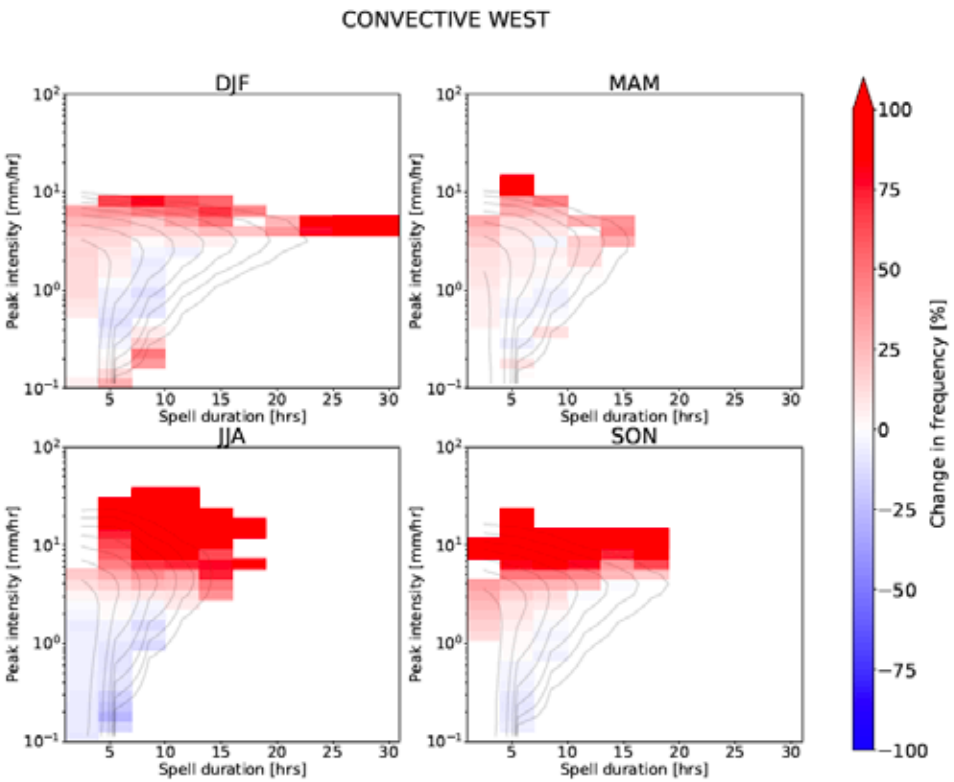
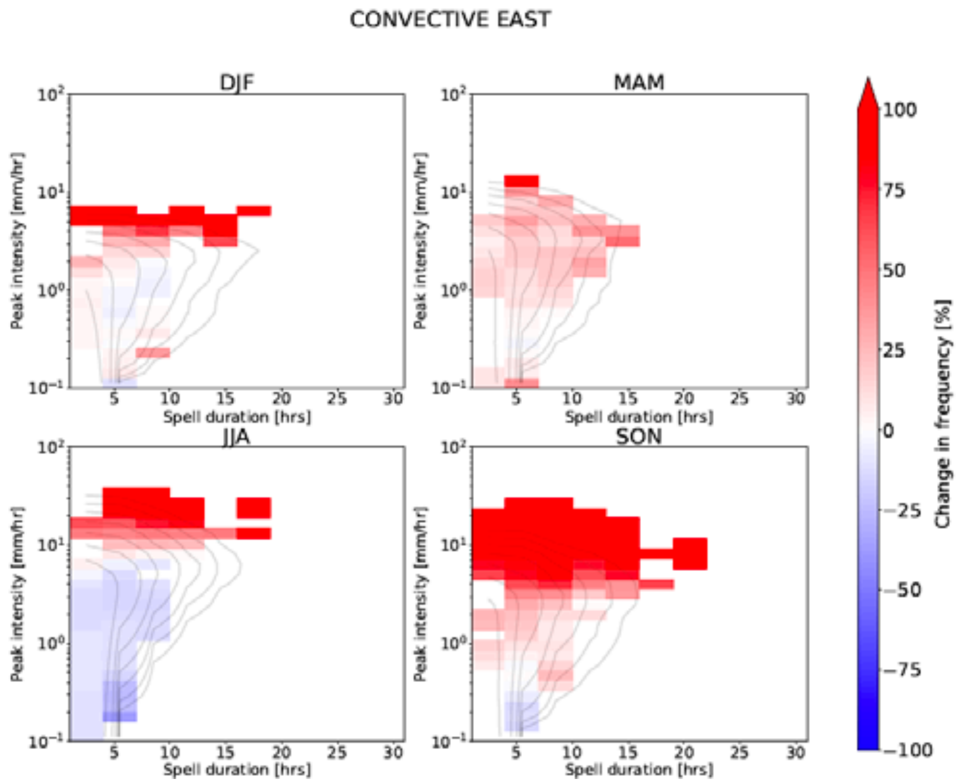
Extra slides: IDF Convection





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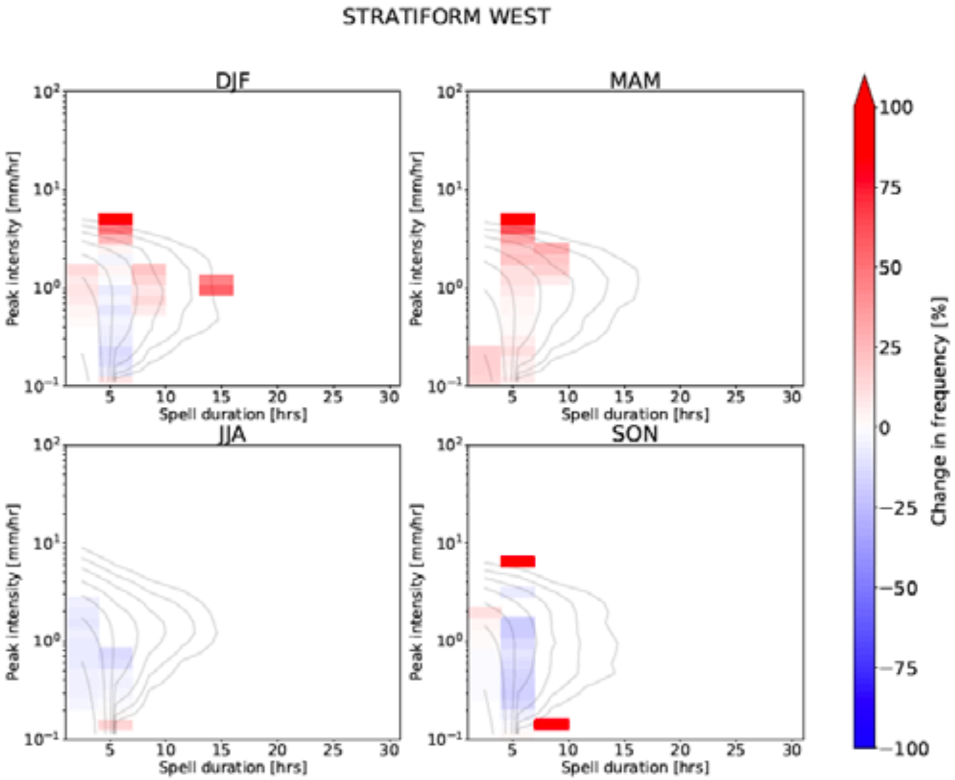
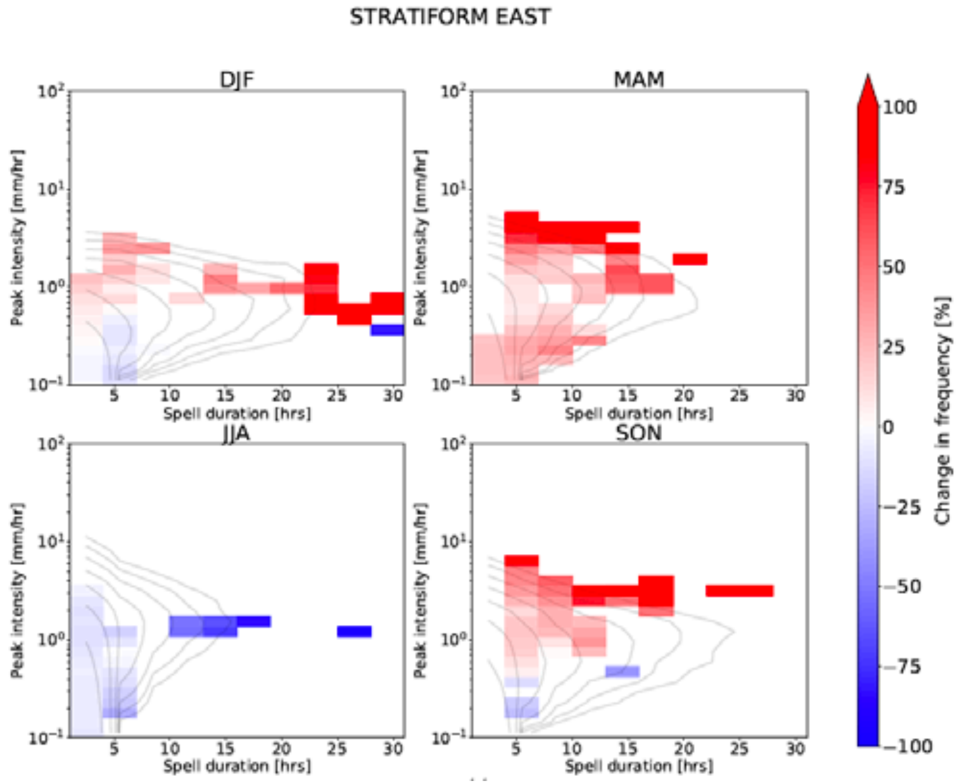
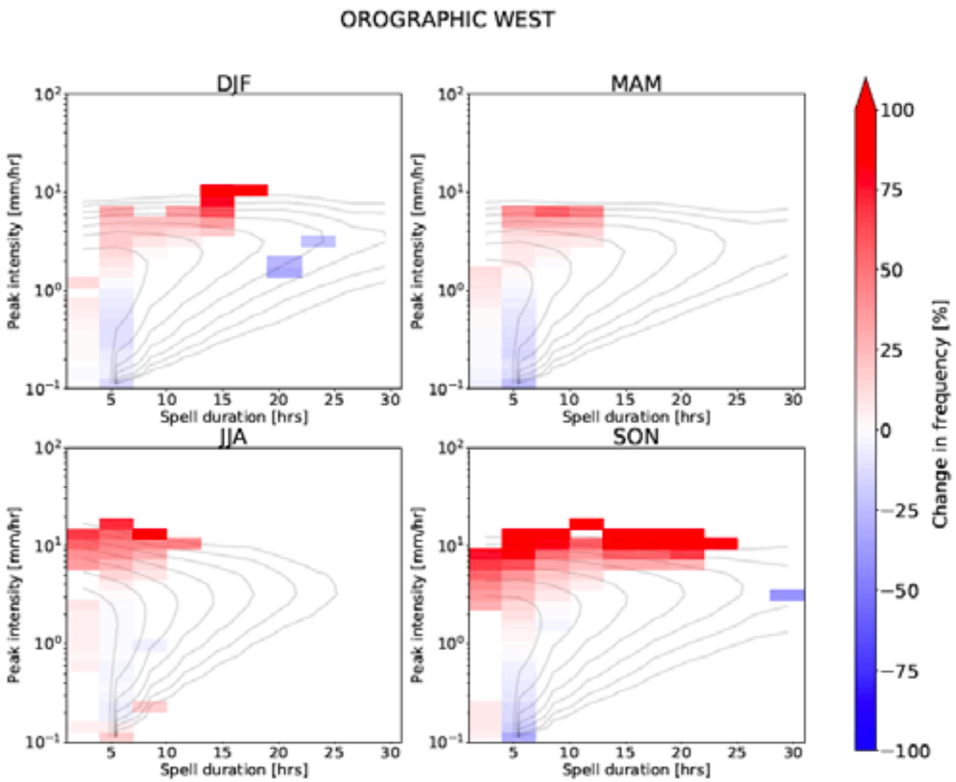
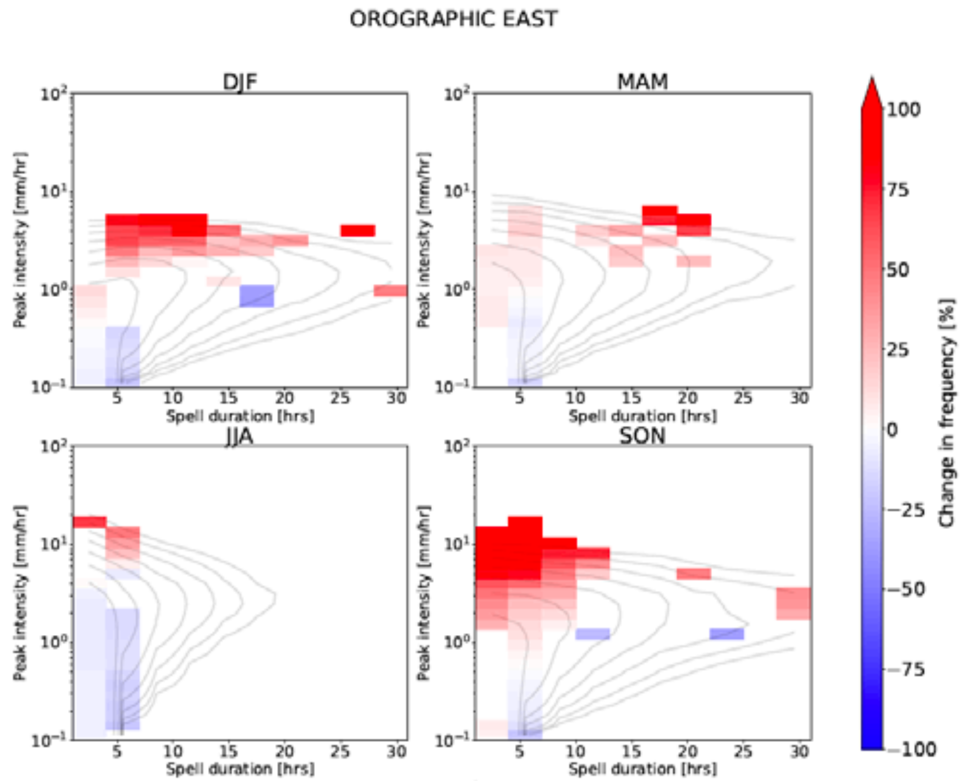
Extra slides: IDF Stratiform





Extra slides: IDF Orographic





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