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

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1. NORCE & the Bjerknes Centre; 2. École Normale Supérieure; 3. Met Office
A physically-based method for classification of precipitation types and the implications for future changes over Norway

Stefan Sobolowski¹; Basile Poujol¹,²; Ségolène Berthou³; Steven Chan³; Torge Lorenz¹; Priscilla Mooney¹

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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]

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

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*
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 contributions 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

For each grid point, in a 30x30 km bounding box centered on that point:
Is the standard deviation of mid-tropospheric vertical velocity > 5 cm/s?

Yes

Is the standard deviation of orography-induced uplift vertical velocity > 20 cm/s?

No

Is the mid-tropospheric vorticity standard deviation > $2.5 \times 10^{-3}$ s$^{-1}$?

No

Yes

Convective

Orog-strati

No

Stratiform

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

Poujol et al. (in revision)
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

Western Norway

Eastern Norway
ASoP plots show convective precipitation makes largest contribution to actual change.

Positive all seasons; Shifts towards higher intensities

In summer precipitation from moderate intensities decreases

Western Norway

Eastern Norway
In fractional terms the changes come from moderate to high intensities

Convective and orographic precipitation show the same pattern of shifting

Convective and orographic precipitation show the same pattern of shifting
Complex interplay of processes drives these changes (we think)

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<th>Variable [Unit]</th>
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<tr>
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<td>DJF</td>
<td>MAM</td>
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<td>CAPE [J/kg]</td>
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<td>change</td>
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- 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
References


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

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<th>JJA</th>
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Extra slides: IDF Convection
Extra slides: IDF Stratiform
Extra slides: IDF Orographic

OROGRAPHIC WEST

OROGRAPHIC EAST

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