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Evaluation of extreme precipitation over the Nordic region using a convection-permitting regional climate model

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INTRODUCTION

- Locally concentrated prolonged or short intense precipitation events can result in river or urban flooding, landslides, erosion, and damages to infrastructure.
- There is evidence that high-resolution convection-permitting models (CPMs) (grid-mesh < 4 km) can represent short-duration precipitation extremes more accurately compared with coarser-resolution regional climate models (RCMs) due to switching from convection parameterized RCMs to CPMs that can resolve deep convection.
- We investigate daily and sub-daily precipitation characteristics from the HARMONIE-Climate (HCLIM) regional climate model over Fenno-Scandinavia 1998–2018 at 3-km and 12-km grid-mesh resolutions.
- We compare simulated precipitation to several sub-daily and daily observational products from April to September and investigate the added value of the high-resolution CPM in representing intense precipitation (i.e. high percentiles) and precipitation extremes (i.e. return values).

OBSERVATIONS

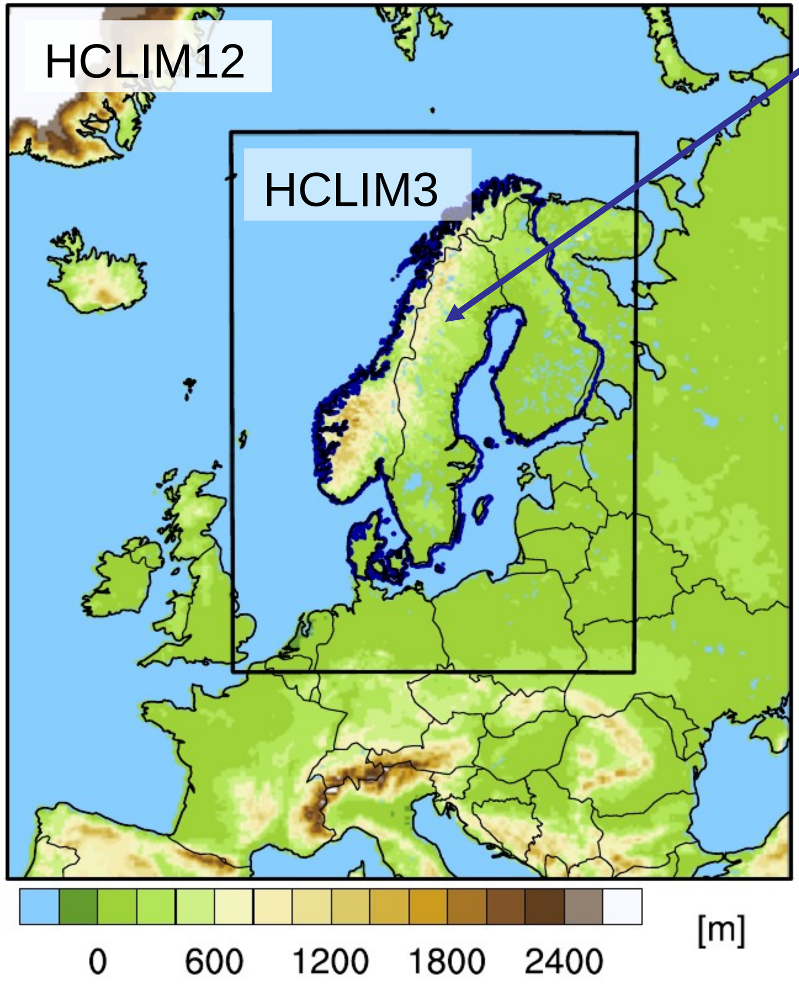
Data set	Description	Time period	Resolution (grid/time)	Reference
ERA5	Reanalysis	1998–2017	~30 km Hourly	Hersbach et al. (2018)
E-OBS	Gridded obs version 20.0e	1998–2018	0.1 degrees Daily	Cornes et al. (2018)
NGCD	Gridded obs over Sweden, Norway & Finland	1998–2018	1 km Daily	Lussana et al. (2018)
seNorge	Gridded obs over Norway	2010–2018	1 km Hourly	Lussana et al. (2018)
HIPRAD	Gridded gauge-corrected radar data over Sweden	2004–2014	2 km Hourly	Berg et al. (2016)
Klimagrid Danmark	Gridded obs over Denmark	2011–2018	1 km Hourly	Wang and Scharling (2010)

OBSERVATIONS: high-resolution & hourly

- It is good to note that especially high-intensity rainfall should be considered with care when using seNorge data as the density of stations that have hourly data is smaller than for daily data.
- For instance, interpolating station data onto a seNorge grid might cause shortcomings in the areas of sparse station density and over the mountainous areas as the stations usually locate in valleys – thus, the gridded dataset might miss the highest precipitation values.
- Interpolation of station data might also cause shortcomings in KLIMAGRID data as it is purely station-based and stations might miss some localized intense precipitation events.
- HIPRAD is a radar-based product, but strong convective systems might be underestimated.

MODEL EXPERIMENT

Fenno-Scandinavia



Reanalysis: **ERA-Interim**
~ 80 km x 80 km

ERA-I: Dee et al. (2011)

6 h

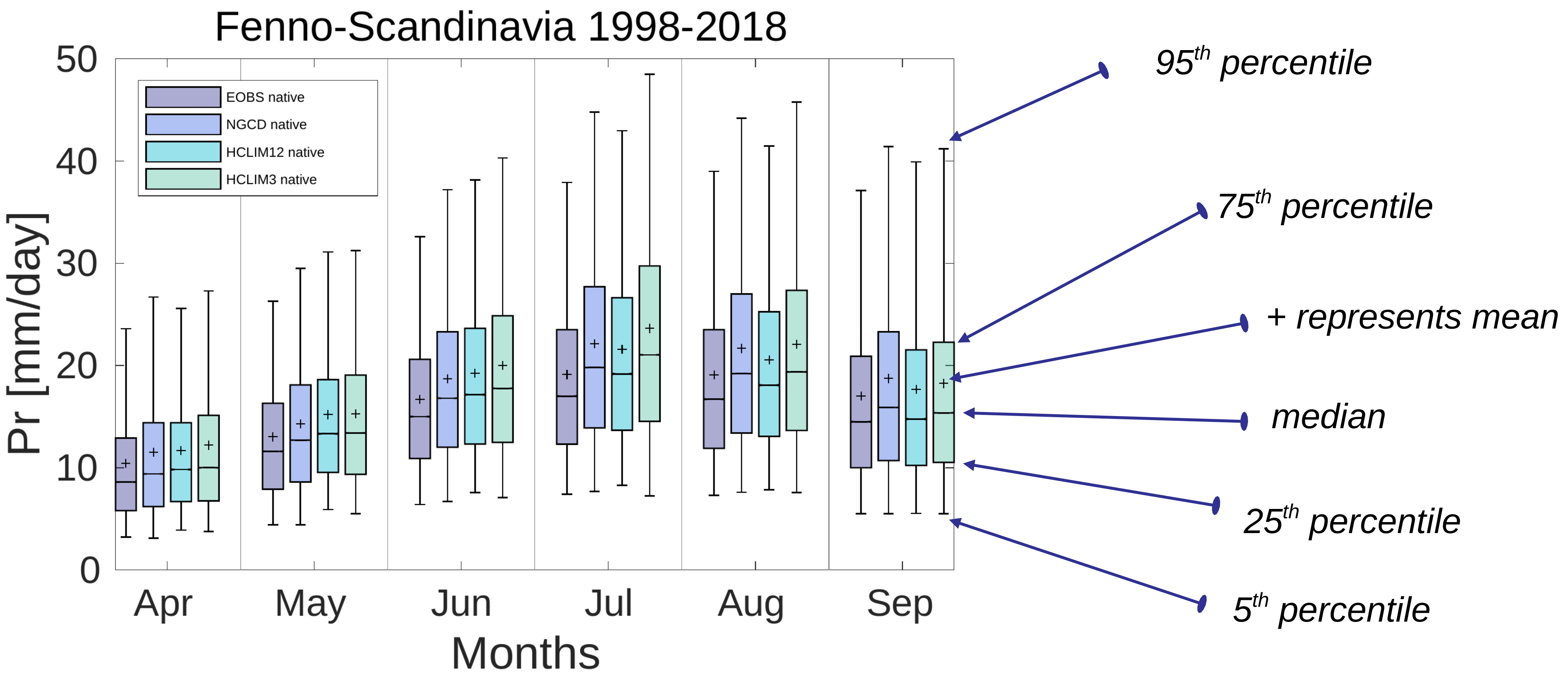
RCM: **HCLIM38-ALADIN (HCLIM12)**
12 km x 12 km, hydrostatic

HCLIM38: Belušić et al. (2020)

3 h

CPM: **HCLIM38-AROME (HCLIM3)**
3 km x 3 km, non-hydrostatic

RESULTS: seasonality of daily maxima



- The variability of daily maxima is well represented by HCLIM12 & HCLIM3 – no major differences between HCLIM12 & HCLIM3 on a daily scale.
- HCLIM3 more in line with NGCD than E-OBS.

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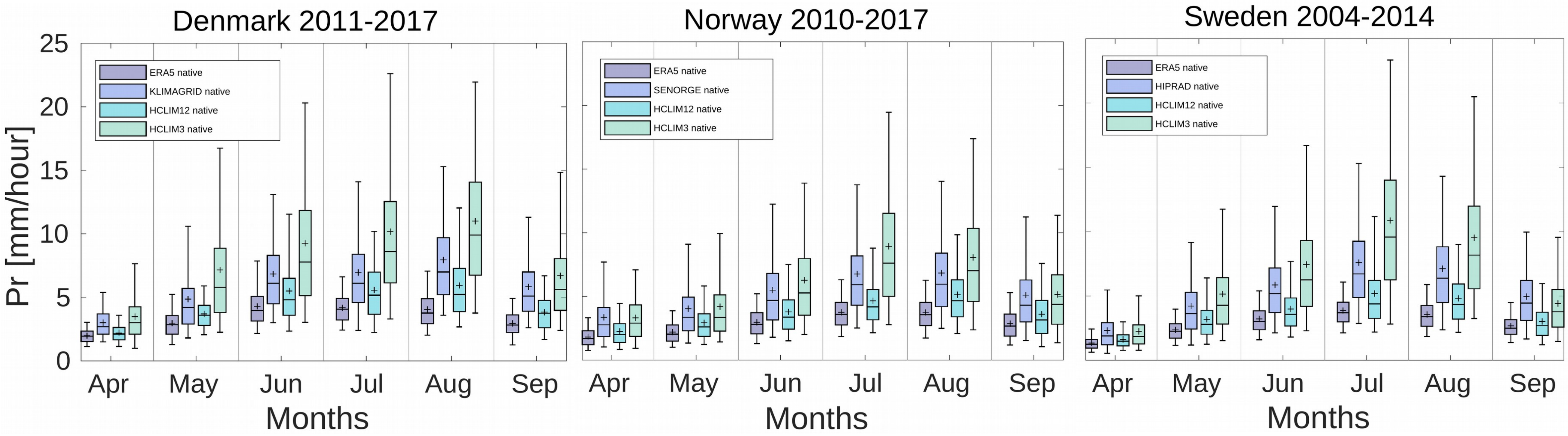
RESULTS: seasonality of hourly maxima



- HCLIM3 overestimates hourly maxima in the summer months (JJA in Norway & Sweden / MJJA in Denmark). Outside the convective season, HCLIM3 represents well the variability and outperforms HCLIM12 and ERA5.
- There are discrepancies between observational datasets as the variability of ERA5 is lower compared to high-resolution data – most probably due to the coarser resolution and convection parameterization scheme in ERA5.

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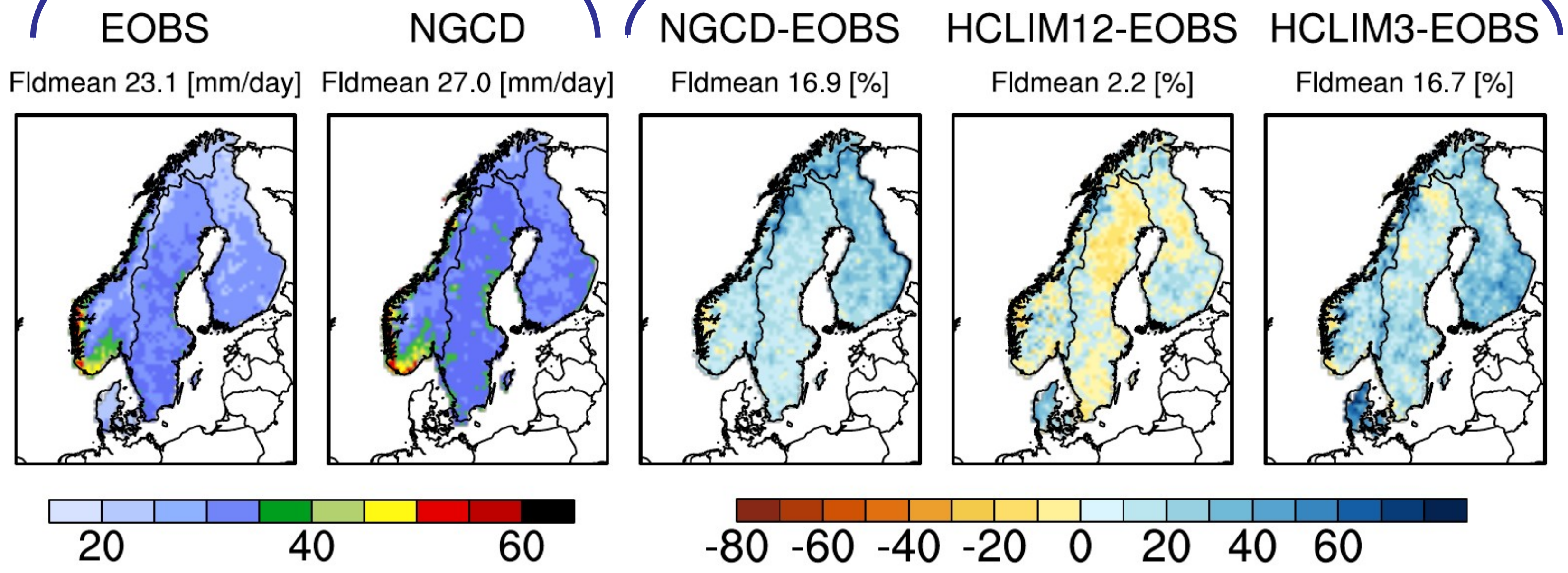
RESULTS: mean daily pr above the 95th percentile

Native grids (E-OBS ~12.5 km & NGCD 1 km)

Remapped conservatively onto E-OBS prior the computation

1998–2018



Only wet days (pr > 1 mm) considered!

- HCLIM12 has mainly a dry bias and HCLIM3 a wet bias compared to E-OBS.
- The biases between high-resolution obs (NGCD) and HCLIM3 are very similar, increasing the likelihood of E-OBS underestimating intense precipitation.

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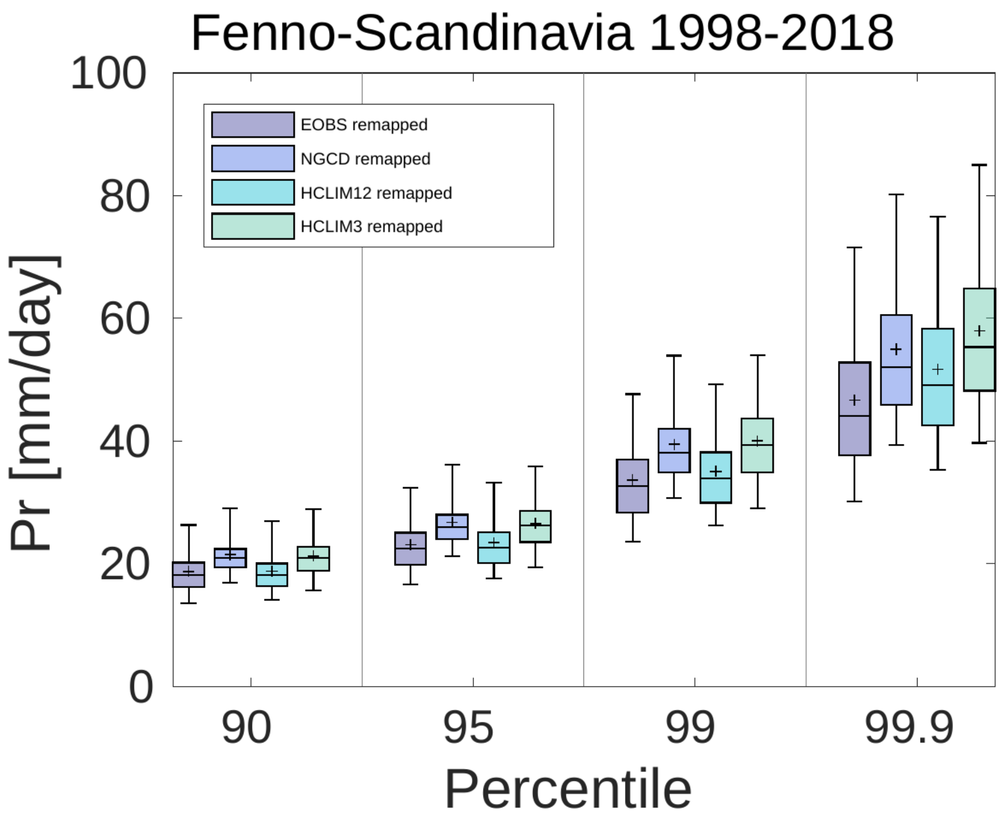
RESULTS: mean daily pr above certain percentiles



Only wet days (pr > 1 mm) considered!

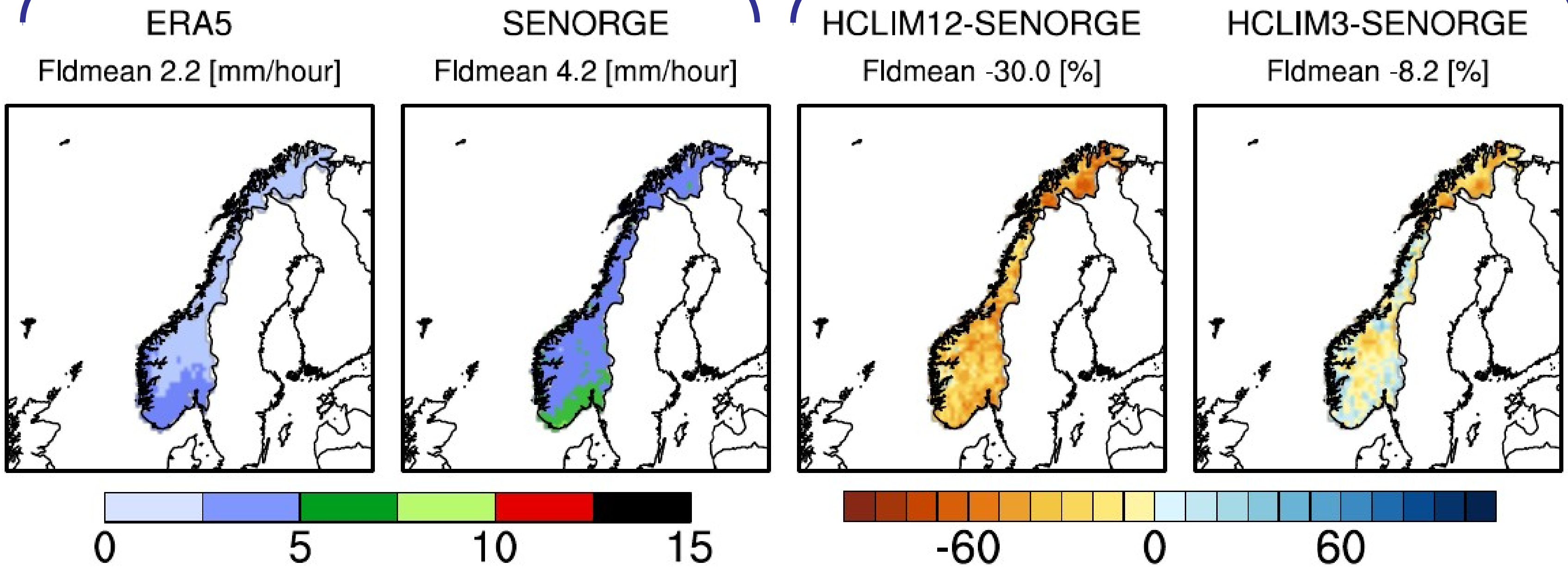
***Reminder**: grid resolutions of E-OBS ~12.5 km & NGCD 1 km*

- The daily variability is overall well captured by HCLIM12 & HCLIM3.
- The spread of HCLIM3 is closer to high-resolution obs (NGCD) than to E-OBS.
- HCLIM12 underestimates the values compared to NGCD.

RESULTS: mean hourly pr above the 95th percentile in Norway

Native grids (ERA5 ~30 km & seNorge 1 km)

Remapped conservatively onto HCLIM12 prior the computations



Only wet hours (pr > 0.1 mm) considered!

- HCLIM12 has a dry bias and HCLIM3 both dry and wet biases.
- In Denmark and Sweden, mean hourly pr above the 90th percentile is mainly overestimated by HCLIM3 and underestimated by HCLIM12 (not shown).

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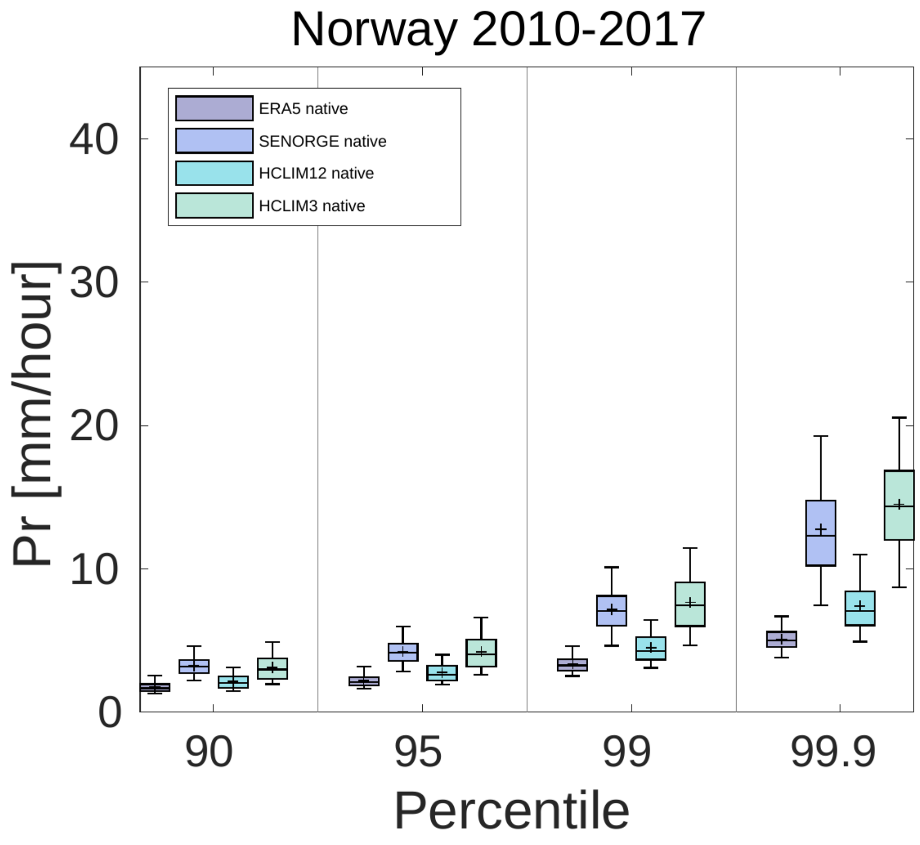
RESULTS: mean hourly pr above certain percentiles in Norway



- High-intensity hourly rainfall events simulated by HCLIM3 are in close agreement with high-resolution obs over Norway.
- Both the coarser HCLIM12 model and, even more ERA5, underestimate high intensities.
- The lower values in ERA5 and HCLIM12 are expected given the coarser resolutions and convection parameterization schemes of ERA5 and HCLIM12.

Only wet hours (pr > 0.1 mm) considered!

***Reminder**:*
grid resolutions of ERA5 ~30 km & seNorge 1 km

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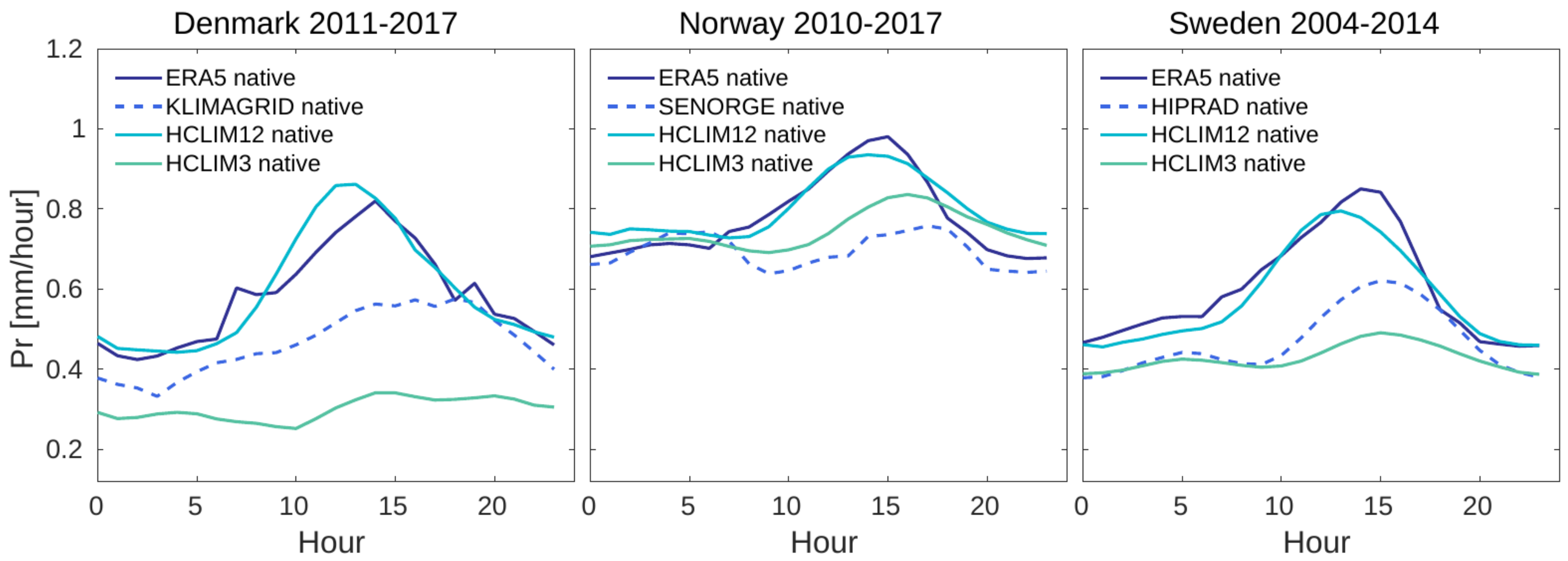
RESULTS: diurnal cycle of the 95th percentile – all hours



***Reminder**:*
grid resolutions of ERA5 ~30 km & seNorge 1 km

- Afternoon peak is generally better represented by HCLIM3.
- The coarser-scale HCLIM12, and to some extent the ERA5 reanalysis, shifts the diurnal peak too early.
- In Sweden & Norway, HCLIM3 represents the intensities better than HCLIM12 when compared to high-resolution obs.

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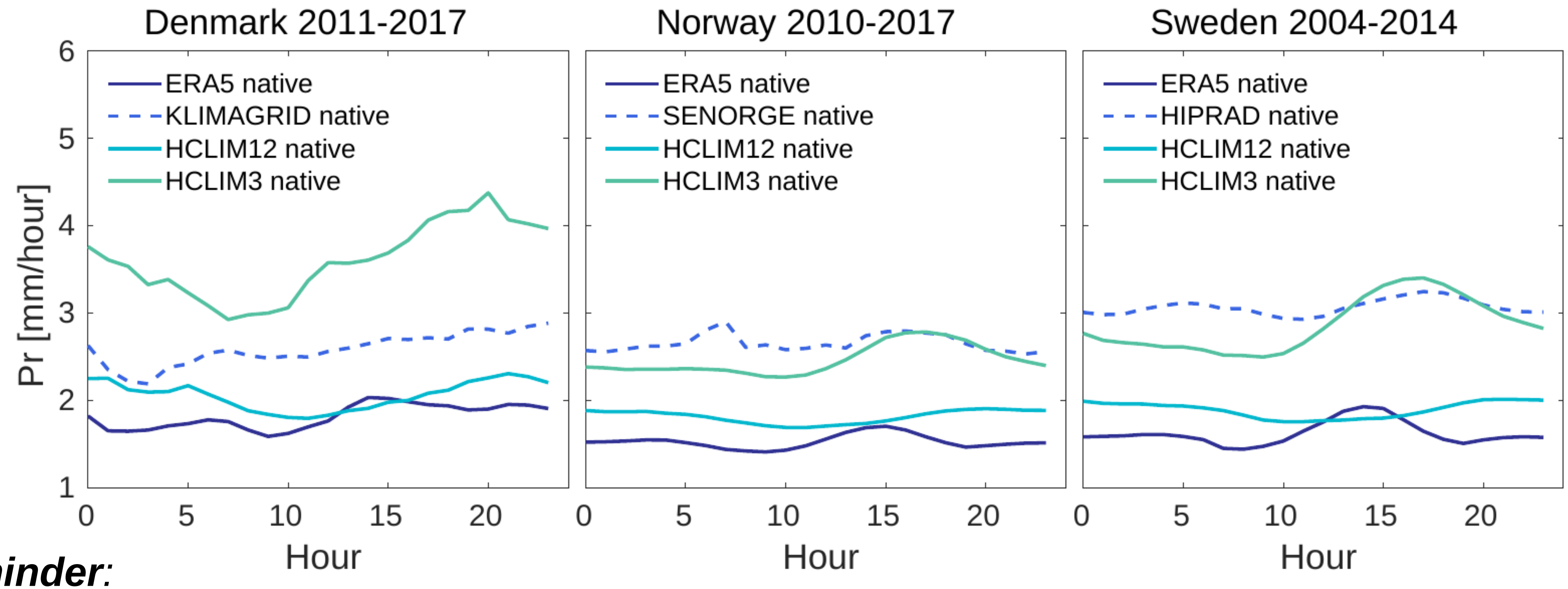
RESULTS: diurnal cycle of the 95th percentile with a threshold



***Reminder**: grid resolutions of ERA5 ~30 km & seNorge 1 km*

Only wet hours (pr > 0.1 mm) considered!

- No clear peak hours in high-resolution obs.
- Overall, HCLIM3 represents well the intensities when compared to high-resolution obs over Norway and Sweden.

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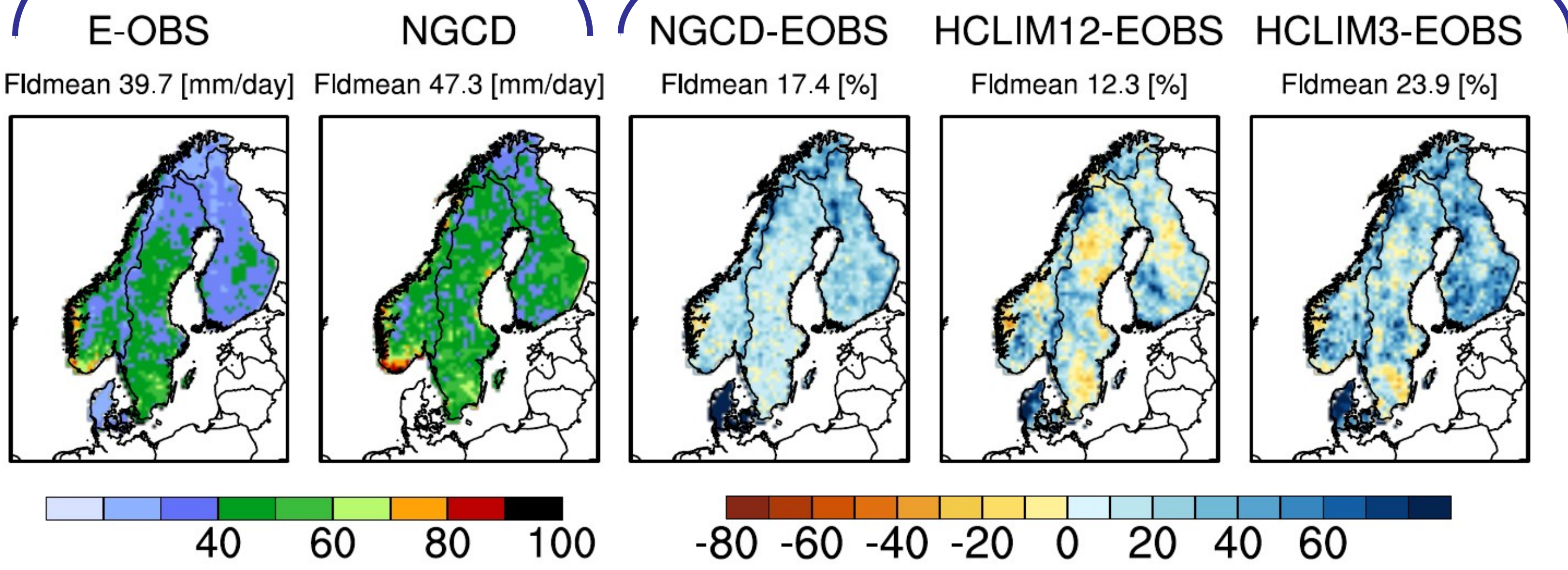
RESULTS: daily return values of a 10-year return period

Native grids (E-OBS ~12.5 km & NGCD 1 km)

Remapped conservatively onto E-OBS prior the computation

1998–2018



METHOD:
GEV & L-moments

Note*: here NGCD covers only 2014–2018!*

- HCLIM12 has both dry and wet biases compared to E-OBS, whereas HCLIM3 has mainly wet biases.
- Again, the biases between high-resolution obs (NGCD) and HCLIM3 are very similar, increasing the likelihood of E-OBS underestimating extreme precipitation.

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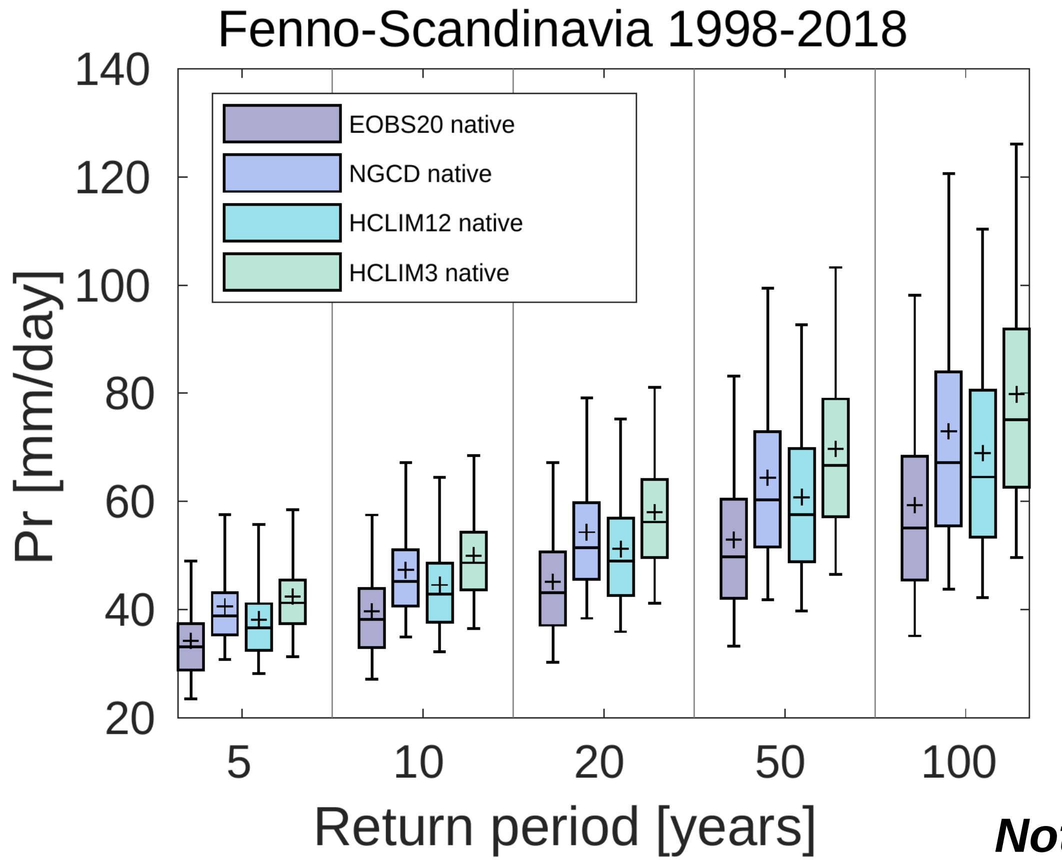
RESULTS: daily return values



***Reminder**:*
grid resolutions
of E-OBS ~12.5 km
& NGCD 1 km

METHOD:
GEV & L-moments

- The variability of daily return values is well captured by HCLIM12 & HCLIM3.
- HCLIM3 mainly overestimates while HCLIM12 underestimates return values compared to high-resolution obs (NGCD).
- E-OBS has lower values compared to NGCD indicating E-OBS does not capture well the extreme precipitation events.

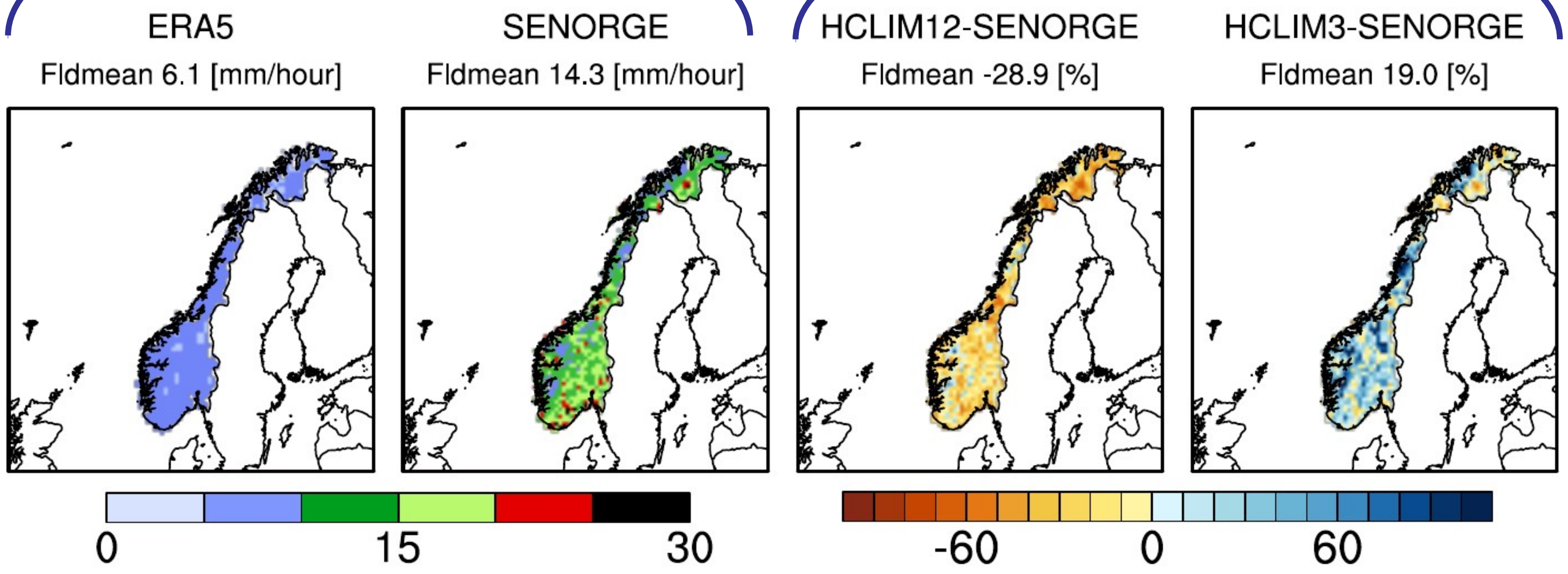
***Note**:*
here NGCD covers
only 2014–2018!

RESULTS: hourly return values of a 10-year return period in Norway

Native grids (ERA5 ~30 km & seNorge 1km)

Remapped conservatively onto HCLIM12 prior the computation

2010–2017



METHOD: GEV & L-moments

- The biases in hourly return levels are mainly negative for HCLIM12 and positive for HCLIM3 when compared to high-resolution obs (seNorge).
- ERA5 underestimates hourly extremes compared to seNorge.
- In Denmark and Sweden, return values are mainly overestimated by HCLIM3 and underestimated by HCLIM12 (not shown).

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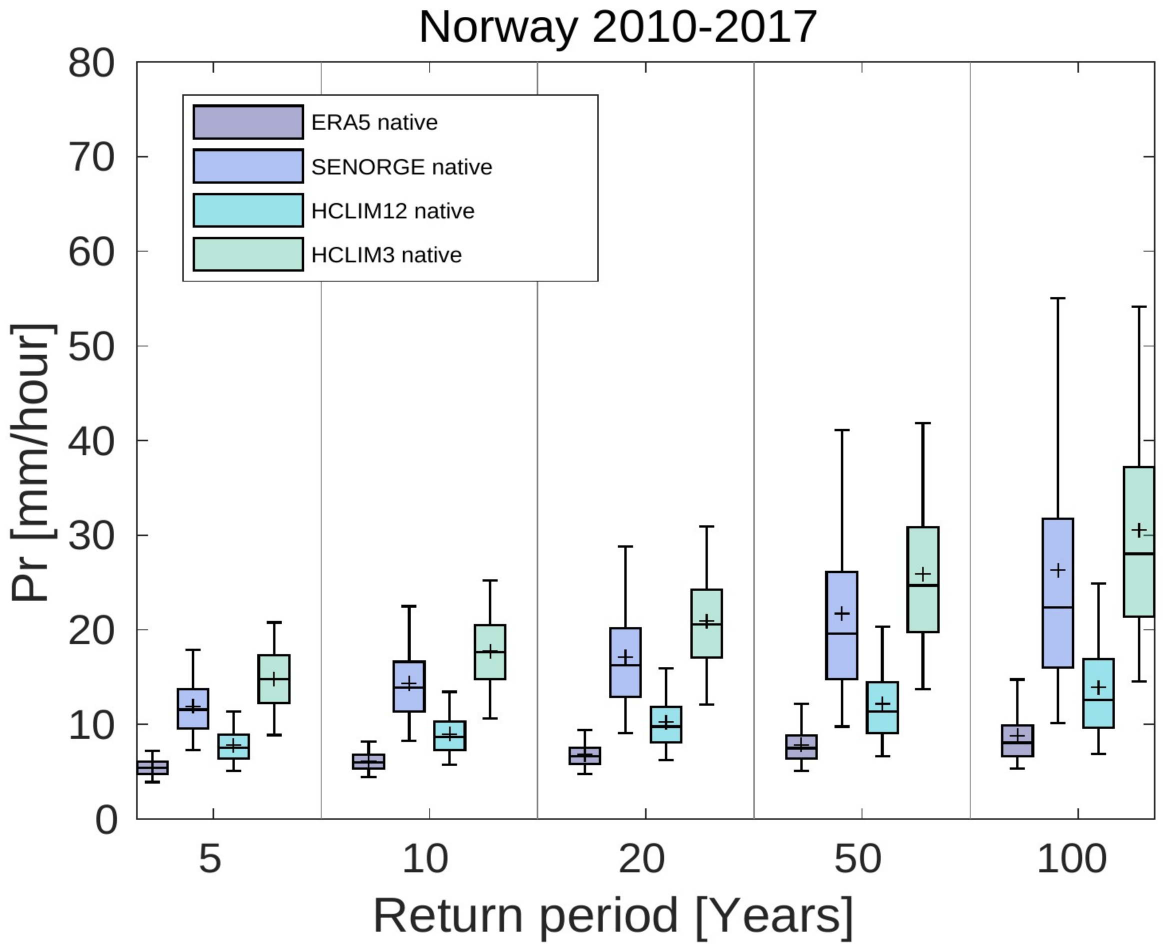
RESULTS: hourly return values in Norway



***Reminder**:*
grid resolutions of ERA5 ~30 km & seNorge 1 km

METHOD:
GEV & L-moments

- The variability of hourly return values is much better resolved by HCLIM3, especially for longer return periods.
- The spread of HCLIM12 is closer to ERA5 – it is very likely that ERA5 underestimates hourly return values due to its coarse grid resolution and convection parameterization scheme.

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SUMMARY

- Overall, the characteristics of intense and extreme precipitation are well captured by HCLIM
- On a daily time scale, HCLIM12 and HCLIM3 give similar results, although:
    - HCLIM12 underestimates and HCLIM3 overestimates intense precipitation and extremes compared to E-OBS
    - HCLIM3 gives very similar results to high-resolution observations (NGCD)

      → important to consider high-resolution observations when evaluating CPMs!
- Added value of high-resolution CPM found on a hourly scale, especially for:
    - higher percentile values
    - diurnal cycle
    - longer return periods (although longer return periods include uncertainty due to the used time period and the selected EVA method!)

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Thank you!