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

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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

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

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

ERA-I: Dee et al. (2011)

HCLIM38: Belušić et al. (2020)
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.
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.
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

EOBS NGCD
Fldmean 23.1 [mm/day] Fldmean 27.0 [mm/day]

NGCD-EOBS HCLIM12-EOBS HCLIM3-EOBS
Fldmean 16.9 [%] Fldmean 2.2 [%] Fldmean 16.7 [%]

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.
RESULTS: mean daily pr above certain percentiles

- 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.

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

Only wet days (pr > 1 mm) considered!
RESULTS: mean hourly pr above the 95th percentile in Norway

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

- **ERA5**
  - Fldmean 2.2 [mm/hour]

- **SENGORE**
  - Fldmean 4.2 [mm/hour]

**Remapped conservatively onto HCLIM12 prior the computations**

- **HCLIM12-SENGORE**
  - Fldmean -30.0 [%]

- **HCLIM3-SENGORE**
  - Fldmean -8.2 [%]

- 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).
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
RESULTS: diurnal cycle of the 95\textsuperscript{th} percentile – all hours

- 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.

Reminder: grid resolutions of ERA5 ~30 km & seNorge 1 km
RESULTS: diurnal cycle of the 95\textsuperscript{th} percentile with a threshold

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

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

Only wet hours (pr > 0.1 mm) considered!
RESULTS: daily return values of a 10-year return period

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

E-OBS
Fieldmean 39.7 [mm/day]

NGCD
Fieldmean 47.3 [mm/day]

Remapped conservatively onto E-OBS prior the computation

NGCD-EOBS
Fieldmean 17.4 [%]

HCLIM12-EOBS
Fieldmean 12.3 [%]

HCLIM3-EOBS
Fieldmean 23.9 [%]

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.
RESULTS: daily return values

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

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

Native grids (ERA5 ~30 km & seNorge 1km) vs Remapped conservatively onto HCLIM12 prior the computation

- ERA5: Fidmean 6.1 [mm/hour]
- SENORGE: Fidmean 14.3 [mm/hour]
- HCLIM12-SE NORGE: Fidmean -28.9 [%]
- HCLIM3-SE NORGE: Fidmean 19.0 [%]

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).
RESULTS: hourly return values in Norway

- 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.

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

METHOD:
GEV & L-moments
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!)
REFERENCES


Thank you!