Highly-resolved hydro-meteorological trends in Norway
Impacts of observed climate change on snowmelt- and rainfall dominated streamflow in Western vs. Eastern Norway

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Motivation

• Differences between Western (Vestlandet) and Eastern (Østlandet) Norway →
  • Hydro-climatological regimes
  • Observed (seasonal) climate change signals
• Probably different impacts on changes in sub-seasonal streamflow (rainfall vs. snowmelt)
• Annual trend analyses neglect (sub-)seasonal changes
• High-resolution trend analyses more appropriate

○ What are the daily trends in streamflow, rainfall, and snowmelt between 1983-2012?
○ How has the relative contribution of rainfall vs. snowmelt to streamflow changed?
○ What are the differences between both regions?
○ To what extent can changes in hydro-meteorological drivers explain trends in streamflow?

[normal (green), highest (blue), lowest (red) observed streamflow 1971-2000; Figures from Hanssen-Bauer et al., 2015]
Study Area & Data

**Vestlandet:**
- 61 pristine or near-natural catchments, west of the Scandinavian Mountain range
- High precipitation rates (> 3000 mm)
- Maritime climate; mild winters

**Østlandet:**
- 51 pristine or near-natural catchments, east of the Scandinavian Mountain range
- Lower precipitation (~ 500 mm)
- Colder winters, warmer summers

**Data:**
- Daily streamflow records (NVE)
- Daily snowmelt (modelled) and rainfall extracted from 1x1 km² gids (seNorge data) for each catchment
- Time period considered 1983-2012 (30 years)

A contributor is dominant if >2/3 of streamflow at a certain day over 1983-2012 stem from rainfall or snowmelt, respectively.
Methods 1
High-resolution trend analyses

Step 1: Filtering the original time series [10-day moving average]

Step 2: Extract time series for a certain ‘day of the year’ (DOY) from the filtered data

Step 3: Trend detection [Mann-Kendall test], and trend magnitude estimation [Thiel-Sen slope] for the extracted DOY time series

Step 4: Repeat Steps 2 and 3 for all days of the year (DOY)

Daily trend analysis approach for a single catchment
Methods 1
High-resolution trend analyses

How to read the plots...

- orange bars indicate field-significance

- each row represents the result of Step 4 (i.e. daily trends) for a certain catchment; catchments sorted by median altitude

Daily trend analysis approach for a single catchment

Step 1: Filter
Step 2: Extract DOY
Step 3: Trend analysis one DOY
Step 4: Summarize for all DOYs

Step 5: Summarize for all catchments within a certain runoff region

Summarizing trend analysis results for all catchments per runoff region

...sum of daily trends throughout the year either positive (limegreen) or negative (magenta)

...colours indicate trend direction and magnitude

...hatched patterns indicate trend significance (p>0.01); no hatching -> sign. trend
Methods 2

Trend attribution

- Data-based trend attribution using annual and seasonal multiple regression
- Trend in streamflow is the dependent variable (predictant)
- Trends in hydro-meteorological drivers, i.e. rainfall, snowmelt, and/or temperature are the independent variables (predictors)
- Increasing model complexity: gradually increasing the number of predictors
  → which drivers explain trends in daily streamflow best?

\[ Q_{\text{trend}}[m^3 s^{-1} yr^{-1}] \sim SM_{\text{trend}}[mm yr^{-1}] + RF_{\text{trend}}[mm yr^{-1}] + T_{\text{trend}}[^\circ C yr^{-1}] \]
Results 1
Streamflow Trends

- Sequence of positive-negative trends during spring for both regions. Some (No) altitude dependency in Østlandet (Vestlandet)
- Positive trends during summer in Østlandet (altitudes up to 1000 m asl); Negative (positive) trends during late summer (early winter) in Vestlandet
- Annual sum of daily streamflow trends mainly negative (positive) in Vestlandet (Østlandet)
Results 2

Rainfall Trends

Absolute trends
- Negative-positive sequence in autumn/winter matches with streamflow trends
- Mixed pattern regarding annual sum of daily trends

Contribution of RF to streamflow
- Increasing during spring and late winter (positive annual sum)
- Decreasing early winter
- Altitude-dependency

Absolute trends
- Positive trends during summer match with streamflow trends
- Short periods of negative trends
- Annual sums consistently positive

Contribution of RF to streamflow
- Increasing during spring and early winter (positive annual sum)
- Altitude-dependency
Results 3
Snowmelt Trends

Absolute trends
- Earlier snowmelt matches with timing of streamflow trends
- Annual sums mostly negative
- Altitude-dependency

Contribution of SM to streamflow
- Decreasing overall role, particularly during spring
- Small increases during winter

Contribution of SM to streamflow
- Shift in timing
- Remains important in many catchments
- Positive annual sums between 500-1000 m asl.
1. Neither trends in rainfall nor snowmelt alone can explain streamflow trends at the annual scale.

2. However, at the seasonal scale they can (regional differences)...

3. Combining RF and SM as predictors improves $R^2$ considerably.

4. Adding temperature as additional predictor leads to highest $R^2$ scores.
Results 4

Trend Attribution

By no surprise:
Catchments with comparatively large glacier coverage in Vestlandet show the largest improvements. Large improvements for non-glaciated catchments (particularly in Østlandet) indicate the increasing relevance of evapotranspiration for daily streamflow trends (see previous maps for Summer).
Conclusions

- High-resolution trend analyses allow for in-depth (sub-)seasonal insights into hydrological response to changes in the hydro-meteorological drivers
- Temporal consistencies regarding trends in streamflow and hydro-meteorological drivers
- Increasing (decreasing) relevance of rainfall (snowmelt) – however, considerable differences between Vestlandet and Østlandet
- Daily streamflow trends can be explained best by adding temperature as an additional predictor to snowmelt and rainfall
  → Glacier-melt and changing relevance of evapotranspiration
Thank You… for visiting our contribution and for your feedback on our work!

References


Data | Funding | Support

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