Universität Potsdam

# 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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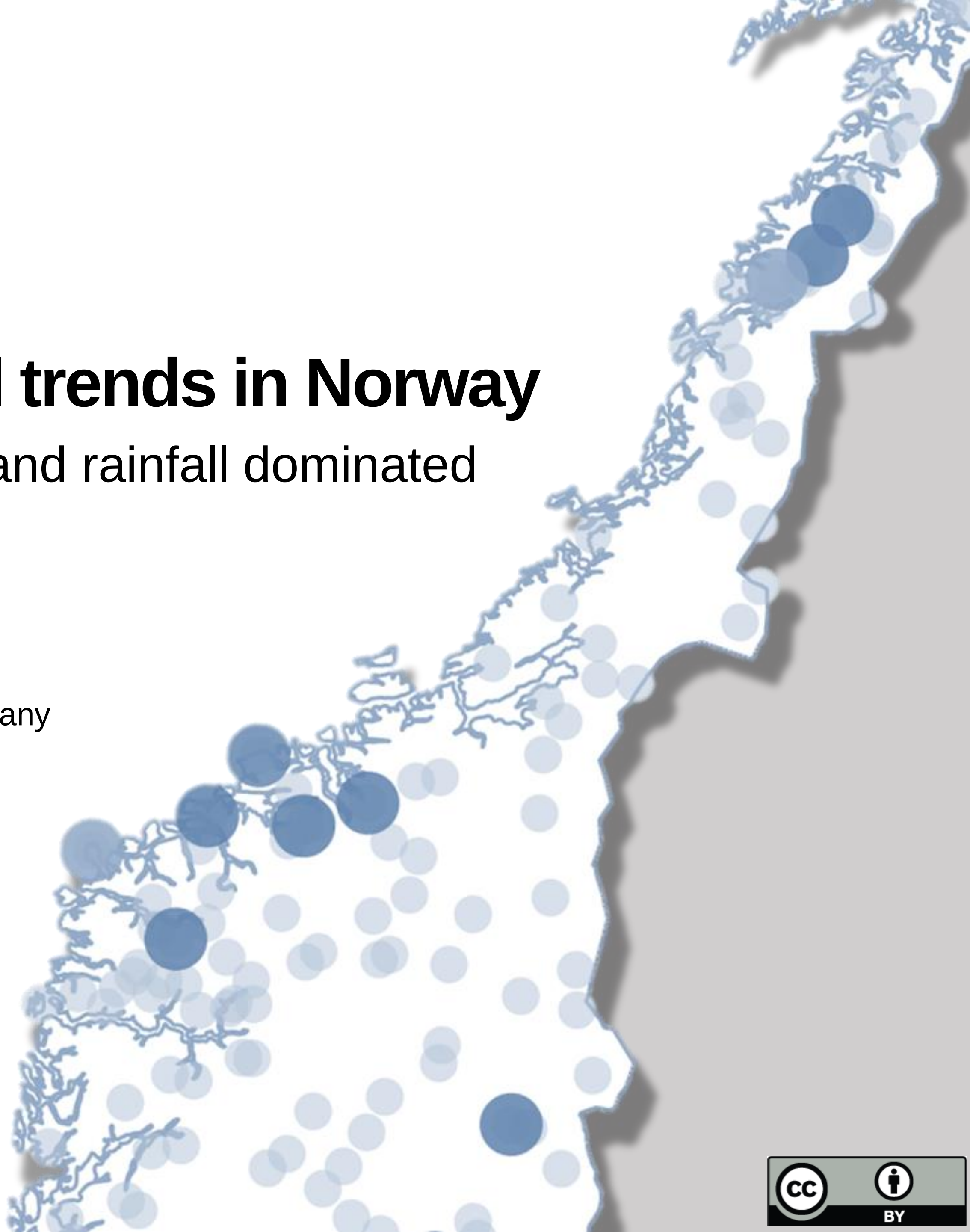

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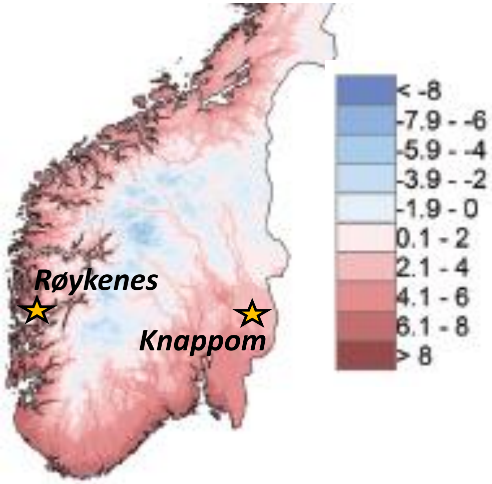
**Session HS2.4.7**

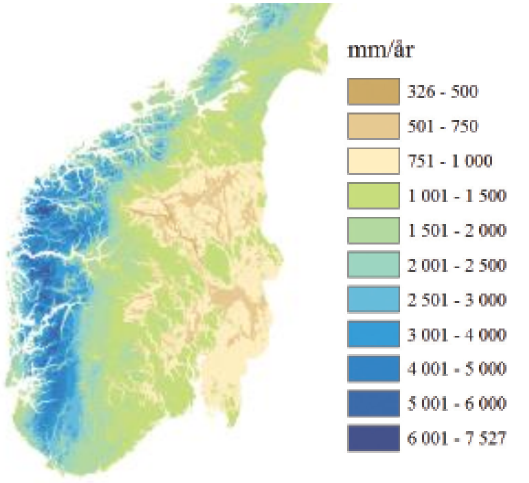
# Motivation

- 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 apropriate

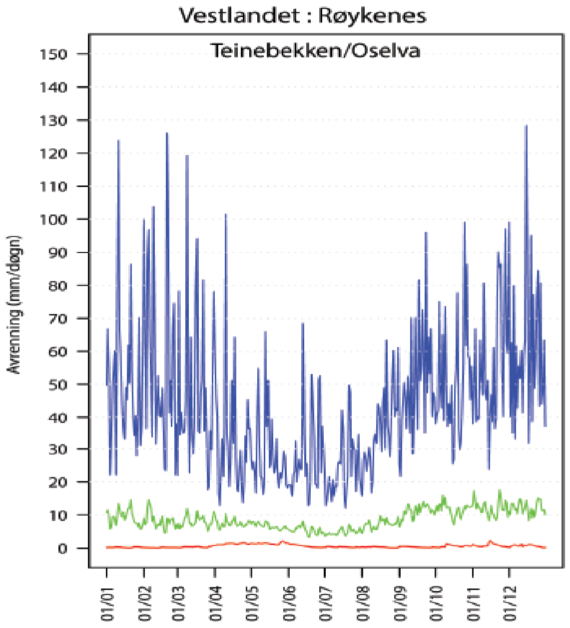
- *What are the daily trends in streamflow, rainfall, and snowmelt between 1983-2012?*
- *How has the relative contribution of rainfall vs. snowmelt to streamflow changed?*
- *What are the differences between both regions?*
- *To what extent can changes in hydro-meteorological drivers explain trends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

**Temperature**

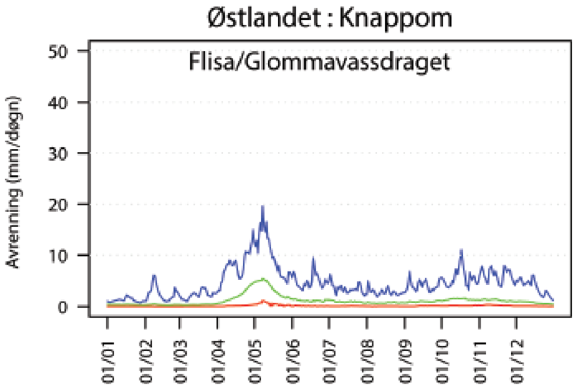



**Precipitation**

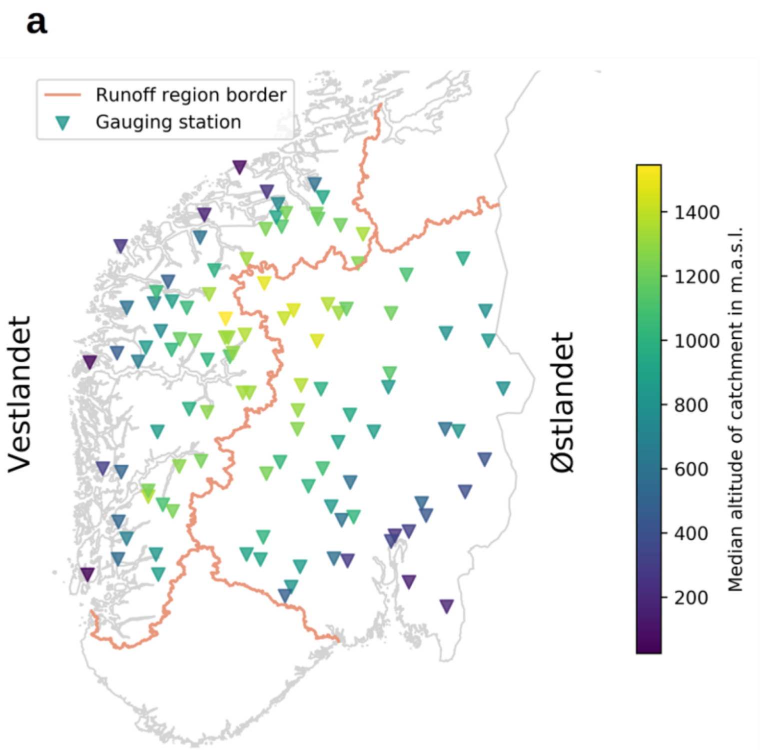


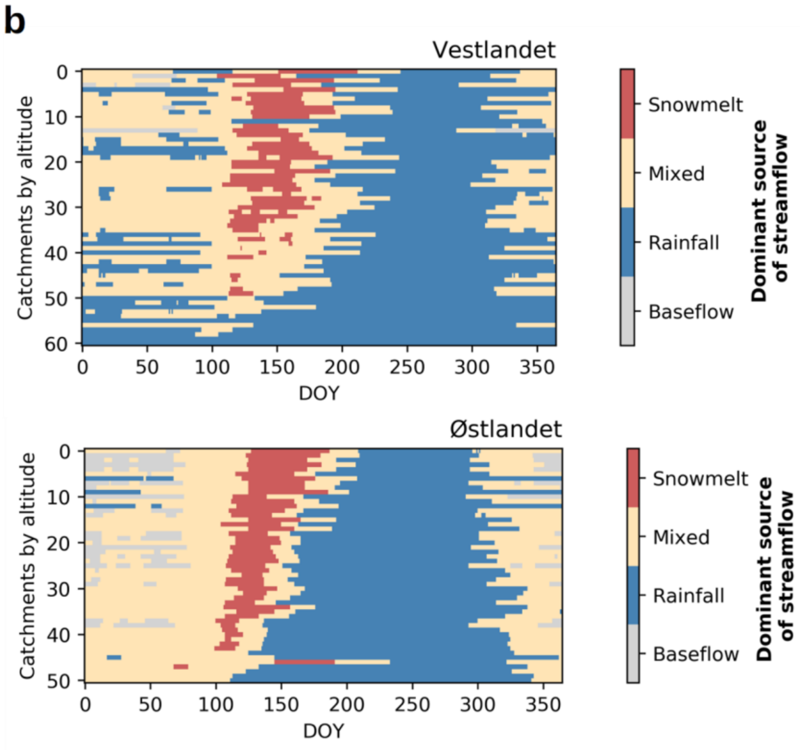

**Runoff regimes**
[Examples]




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

# Study Area & Data




**a|** Location of the investigated gauging stations and the median altitude of the corresponding catchments

**b|** Dominant contribution* to daily streamflow for catchments in Vest- and Østlandet sorted by altitude

** A contributor is dominant if >2/3 of streamflow at a certain day over 1983-2012 stem from rainfall or snowmelt, respectively.*

## Vestlandet:

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

## Østlandet:

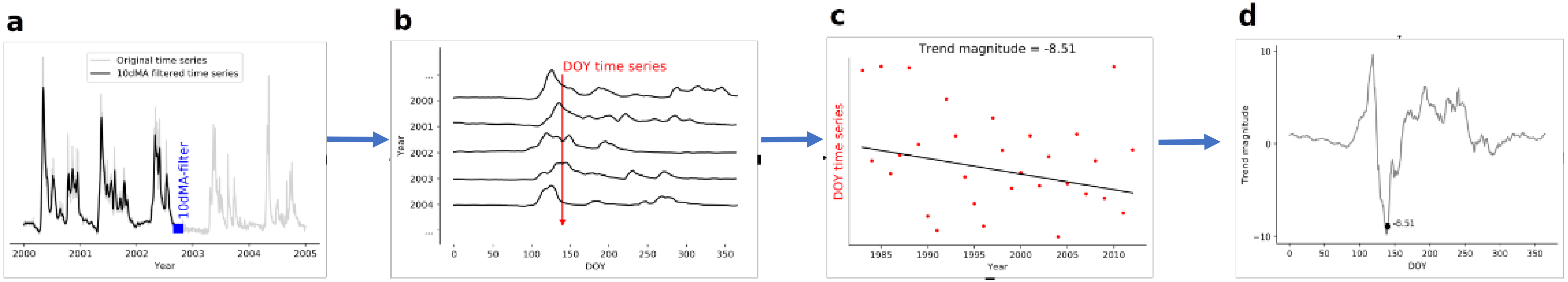
- 51 prestine or near-natural catchments, east of the Scandinavian Mountain range
- Lower precipitation (~ 500 mm)
- Colder winters, warmer summers

## 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)

# 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

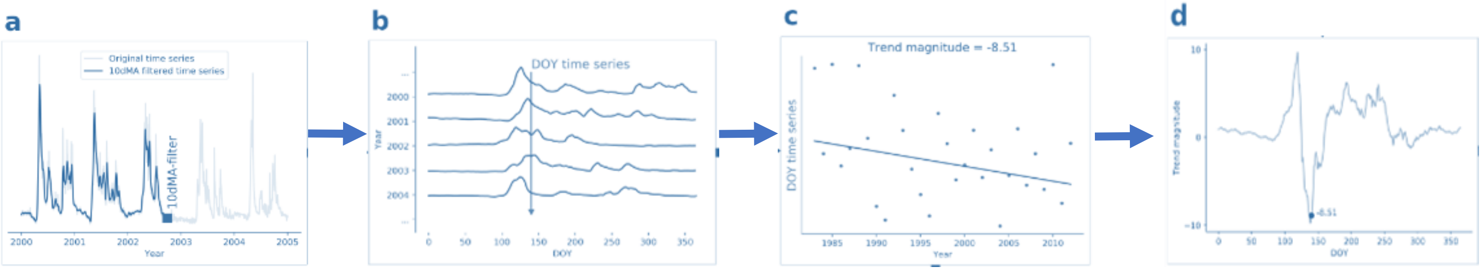
**Step 4:** Repeat Steps 2 and 3 for all days of the year (DOY)

**Daily trend analysis approach for a single catchment**

# Methods 1

## High-resolution trend analyses

Daily trend analysis approach for a single catchment




**Step1:** Filter

**Step2:** Extract DOY

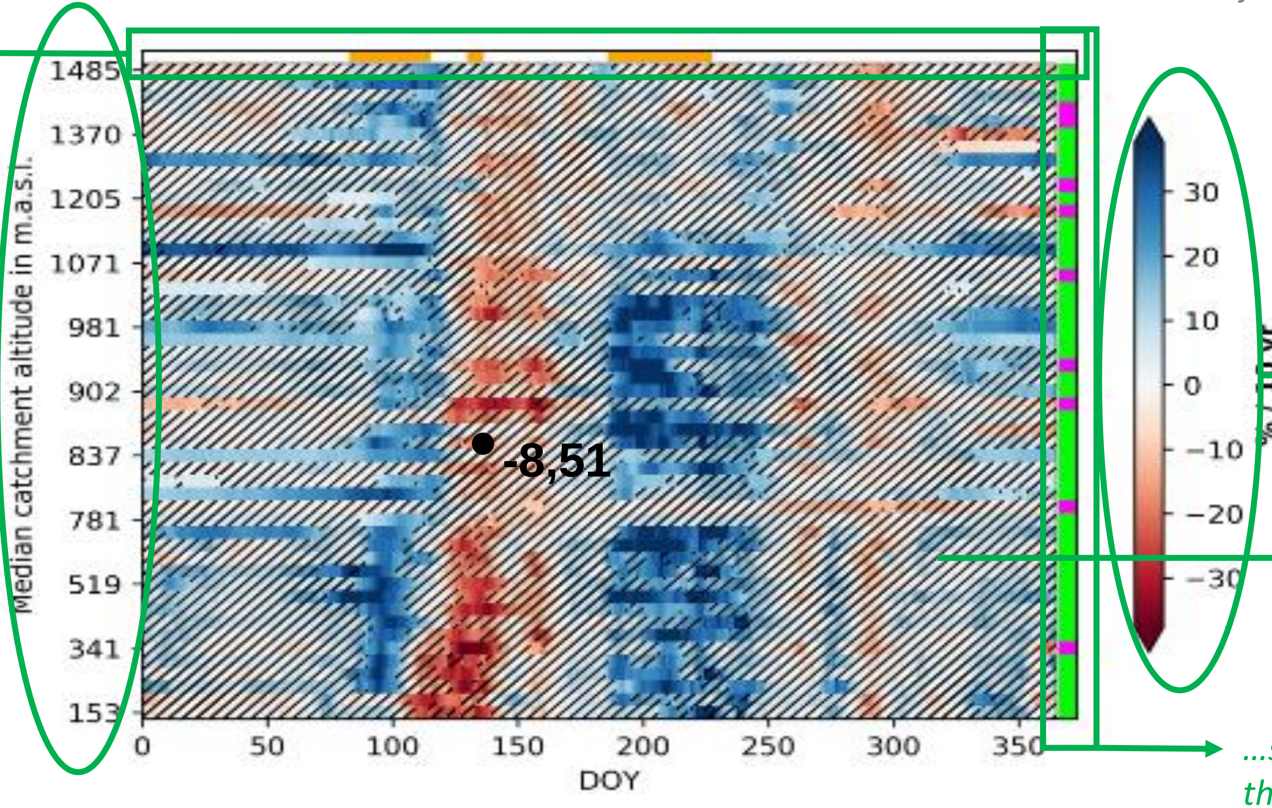
**Step3:** Trend analysis one DOY

**Step4:** Summarize for all DOYs

*How to read the plots…*

*…orange bars indicate field-significane*

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




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

*…colours indicate trend direction and -magnitude*

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

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

**Summarizing trend analysis results for all catchments per runoff region**

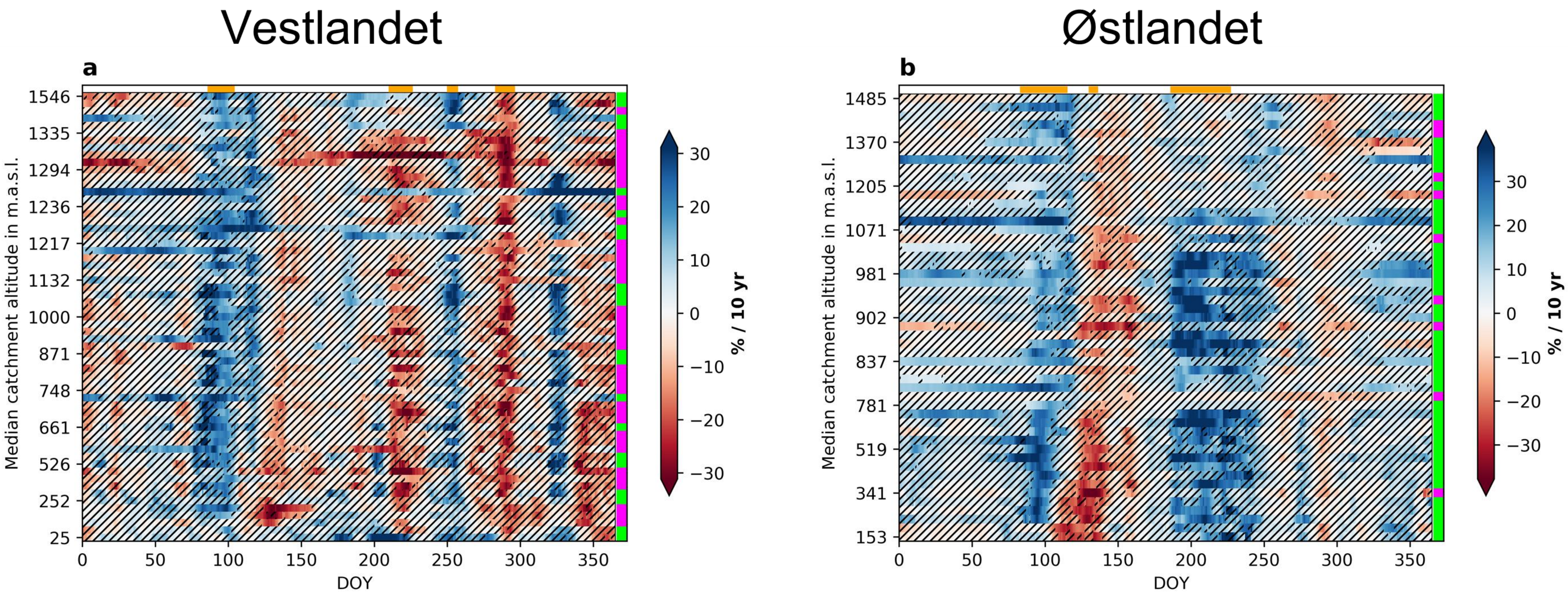
# Methods 2
## Trend attribution

- 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?*

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

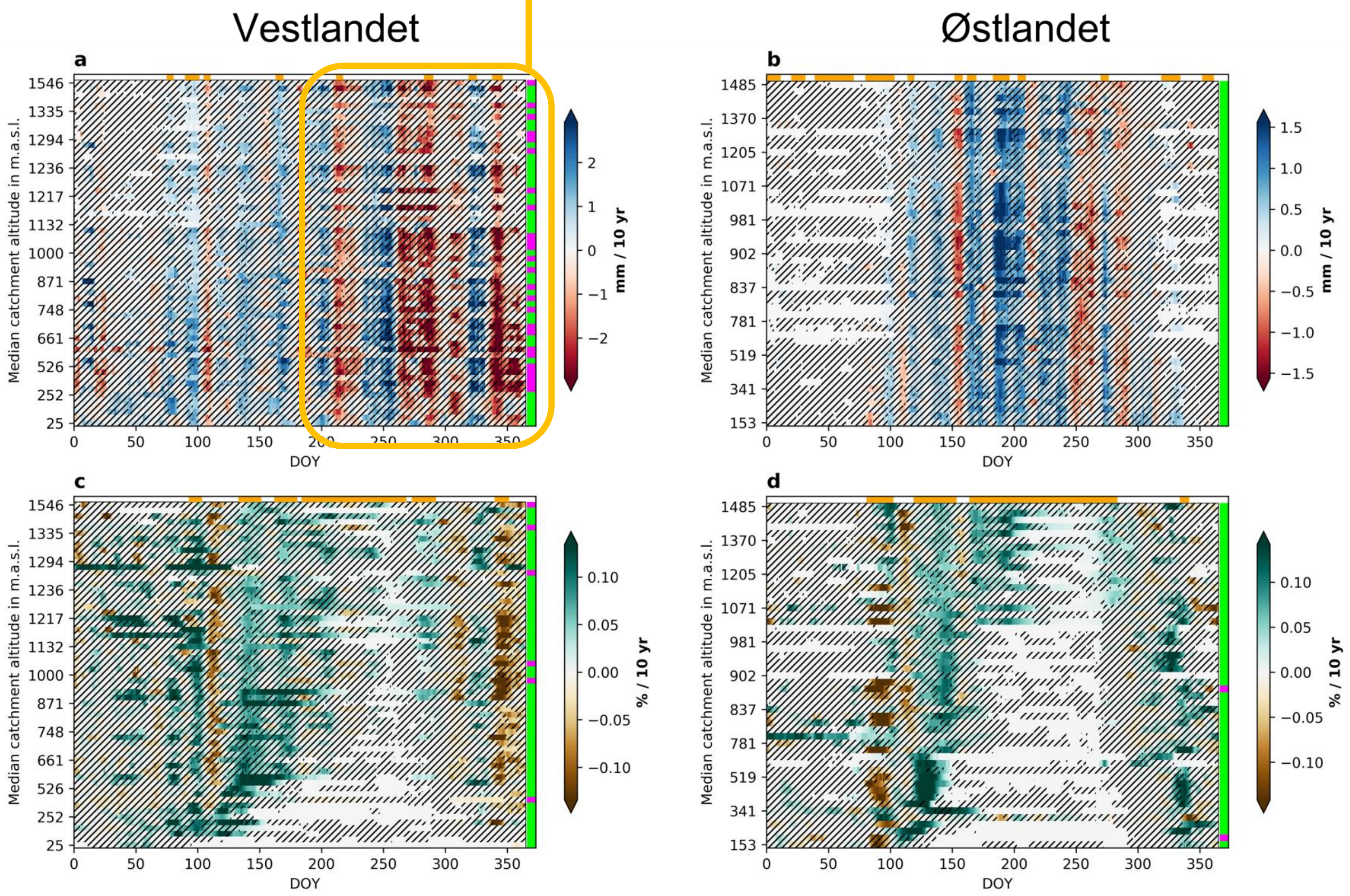
# Results 1
## Streamflow Trends




- Sequence of positve-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

We would appreciate your ideas regarding this pattern…




### 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 (positve annual sum)
- Decreasing early winter
- Altitude-dependency

### Absolute trends

- Positve 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 (positve annual sum)
- Altitude-dependency

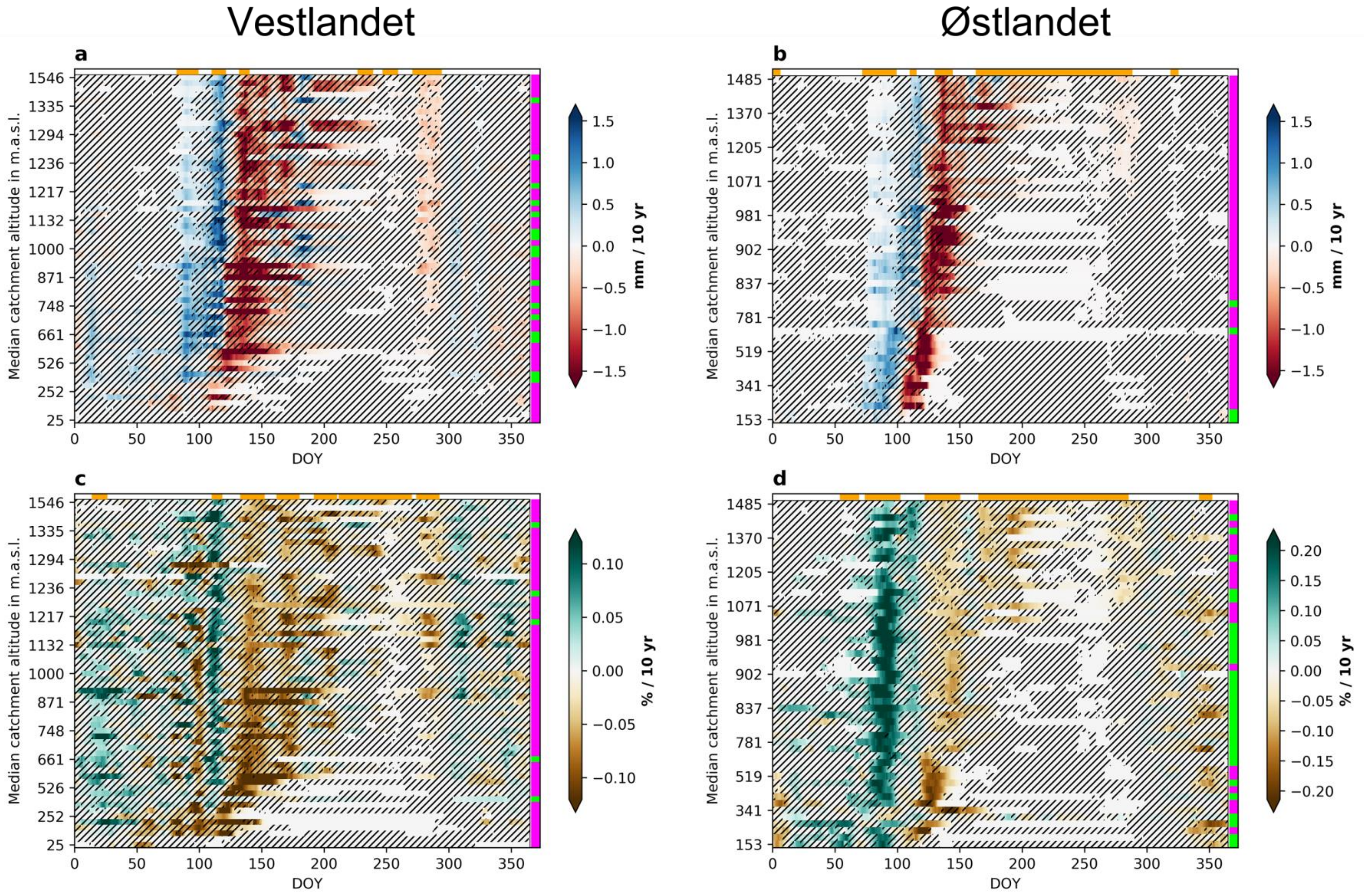
# Results 3
## Snowmelt Trends

**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




**Absolute trends**

- Earlier snowmelt matches with timing of streamflow trends
- Annual sums alm. consistently negative
- Altitude-dependency

**Contribution of SM to streamflow**

- Shift in timing
- Remains important in many catchments
- Positve annual sums between 500-1000 m asl.

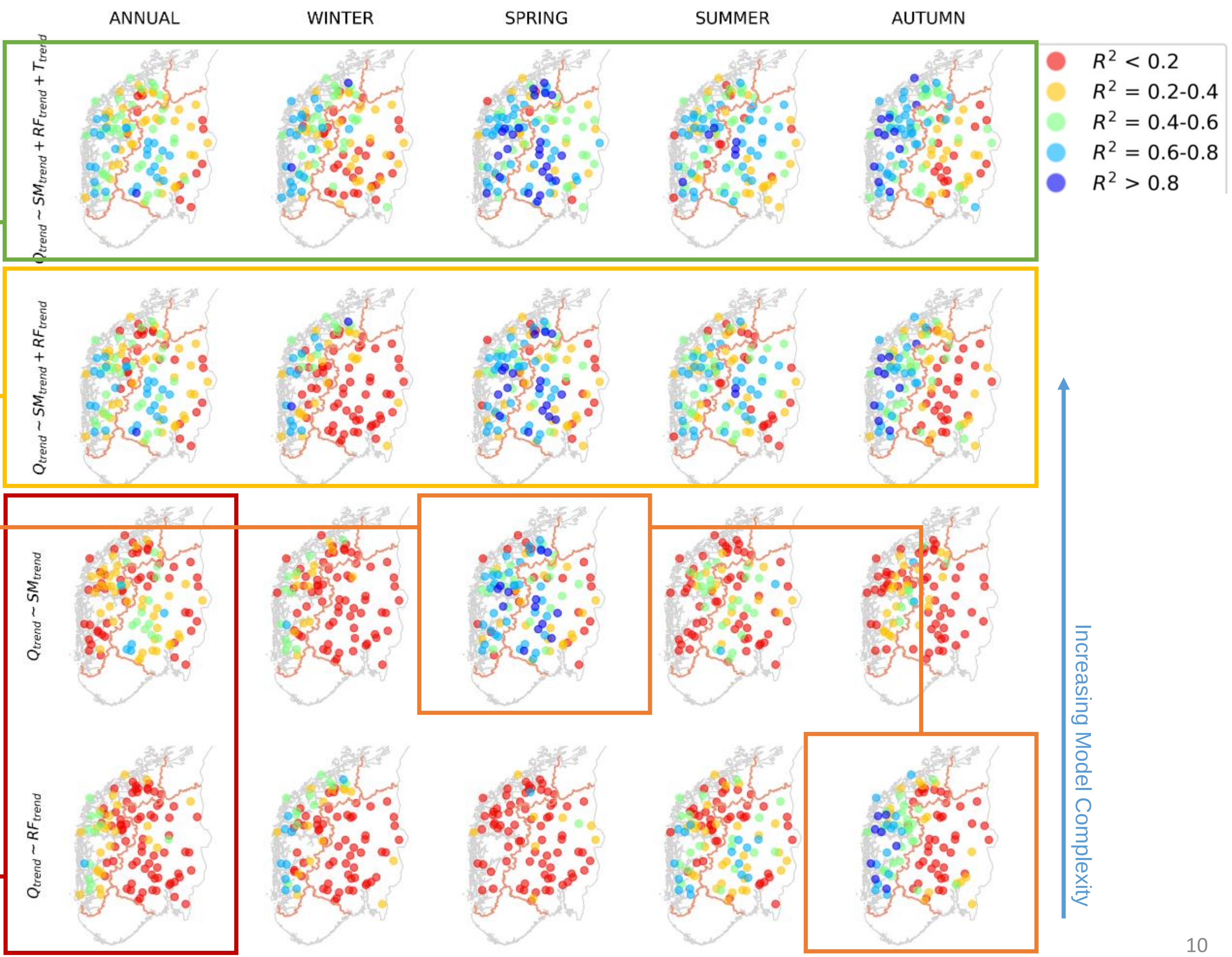
# Results 4
## Trend Attribution

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

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

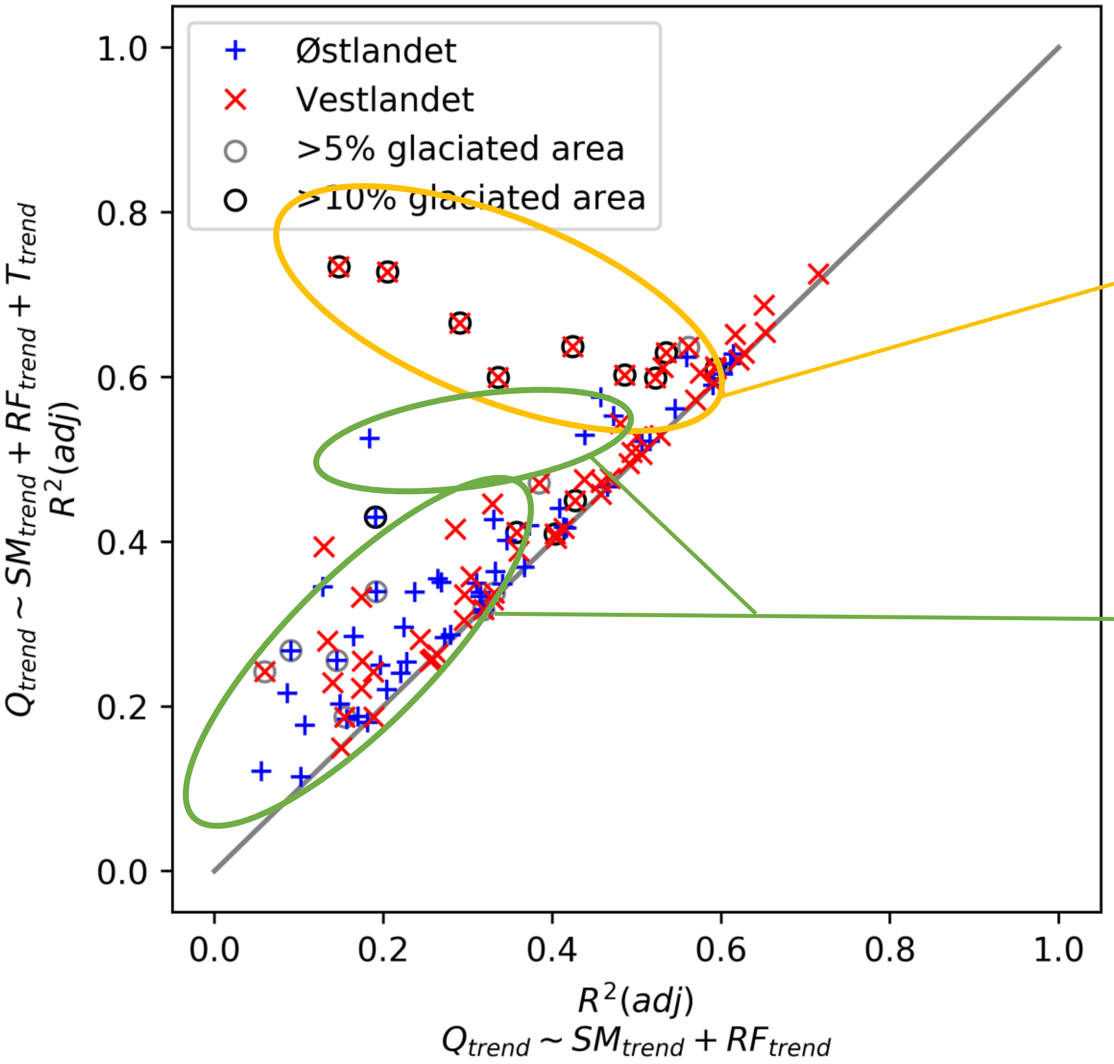
2. However, at the seasonal scale they can (regional differences)…

1. Neither trends in rainfall nor snowmelt alone can explain streamflow trends at the annual scale



# Results 4

## Trend Attribution




**Adding temperature as an additional predictor:**

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

[picture: NVE]

# Thank You…

for visiting our contribution and for your feedback on our work!

# References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# Data | Funding | Support


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