Hydrological trends in a warming climate

A daily trend analysis of 207 Norwegian catchments in 1963-2012 and 1983-2012

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Objectives

- Has streamflow in Norway changed in a warming climate through changes in rainfall and snowmelt?
  - To what extent can changes in streamflow be attributed to rainfall and snowmelt trends?
  - Are the trends dependent on altitude?
  - Differences between trends in 1983-2012 and 1963-2012 periods?

Data and study area

- A total of **207** catchments were analysed, of which only **107** were used in 1963-2012 period limited by record length (Fig. 1)
- Daily **streamflow** measurements from gauging stations of various data lengths [1]
- Daily **rainfall**, **snowmelt** and **temperature** data, spatially interpolated from station measurements [2]
- Catchments were divided into six runoff regions (Fig. 1), to limit the interference of latitude and hydro-climate
- The two with the largest altitude range, Vestlandet and Østlandet, are presented here

Methods

- Annual trend analysis using the Mann-Kendall test to detect significant trends and Sen's Slope Estimator to assess trend magnitude
- Daily trend analysis approach [3,4] using a 10-day moving average (10dMA) filter, Sen's Slope Estimator to estimate trend magnitude, for each day of year time series (Fig. 2)

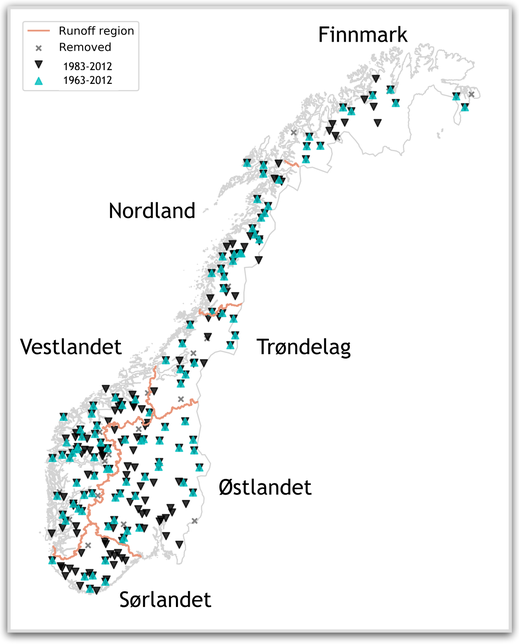

Fig. 1: Runoff regions and catchment location

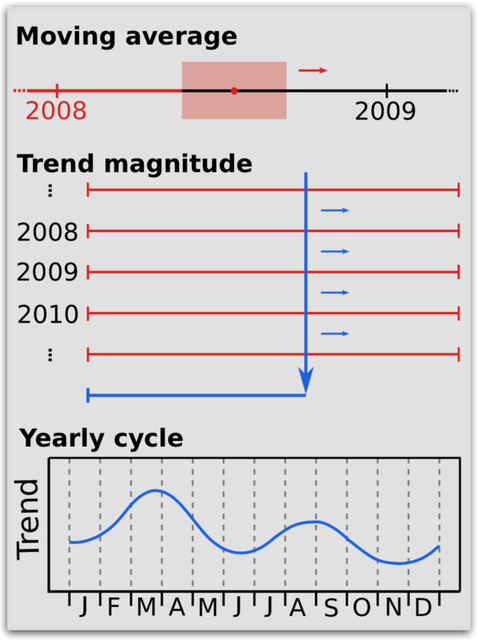

Fig. 2: Daily trend analysis (Source: [5])

Results and discussion

- Significant annual and significant seasonal warming in March-April, July-September and late November in both periods, with additional significant seasonal warming in January and February in 1963-2012 period
- Earlier start to snowmelt season due to spring warming (Fig.3c-d, Fig.4c-d)
- Later end to snowmelt season in high-elevation catchments due to increased snow accumulation in winter, more pronounced in 1963-2012 period (Fig.3d, Fig.4d)
- Increased summer rainfall in Østlandet likely linked to overall increase in precipitation (Fig. 4e-f)
- Streamflow changes are of small magnitude causing little to no noticeable change in the hydrological regime, although changes are more noticeable in smaller catchments (Fig.5)
- Daily trend patterns are generally consistent in both periods, except greater magnitude in 1983-2012
- Pronounced warming and increased rainfall in winter during the long-term period (e.g. Fig.3f), possibly linked to a decadal trend in winter North Atlantic Oscillation phase
- Rainfall and snowmelt trends appear to be driving streamflow changes (Fig.5), and the combined rainfall and snowmelt trend

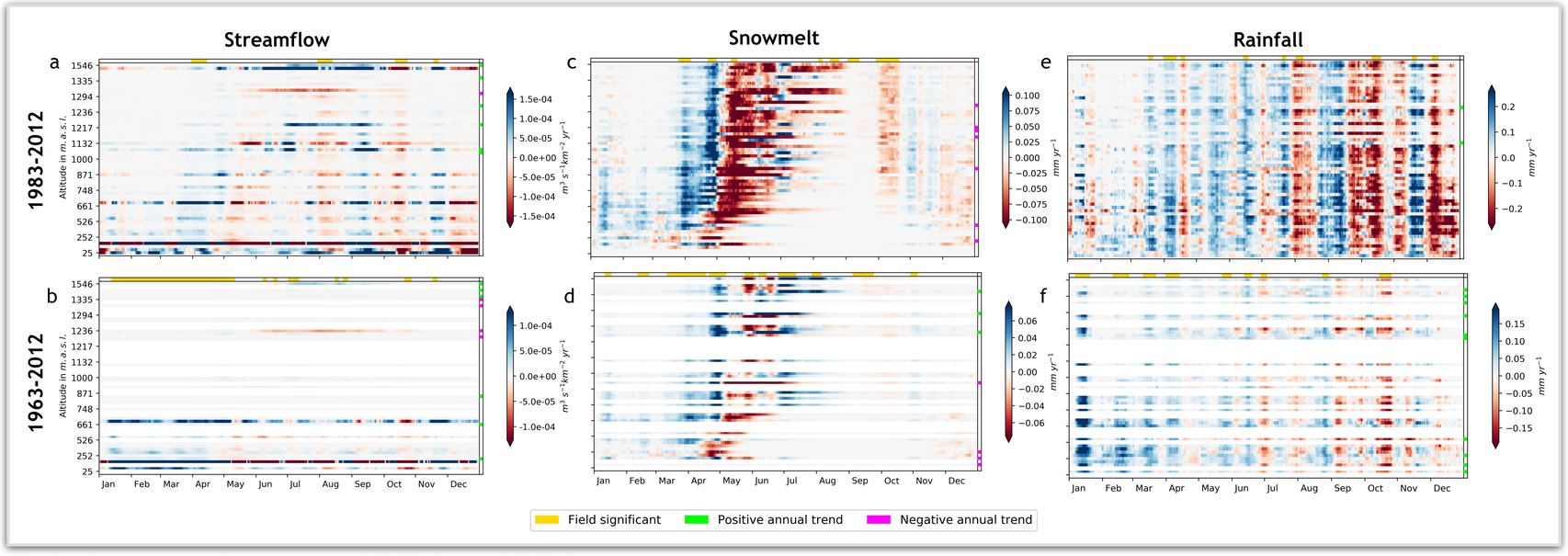

Fig. 3: 10dMA trends in **Vestlandet** in 1983-2012 and 1963-2012

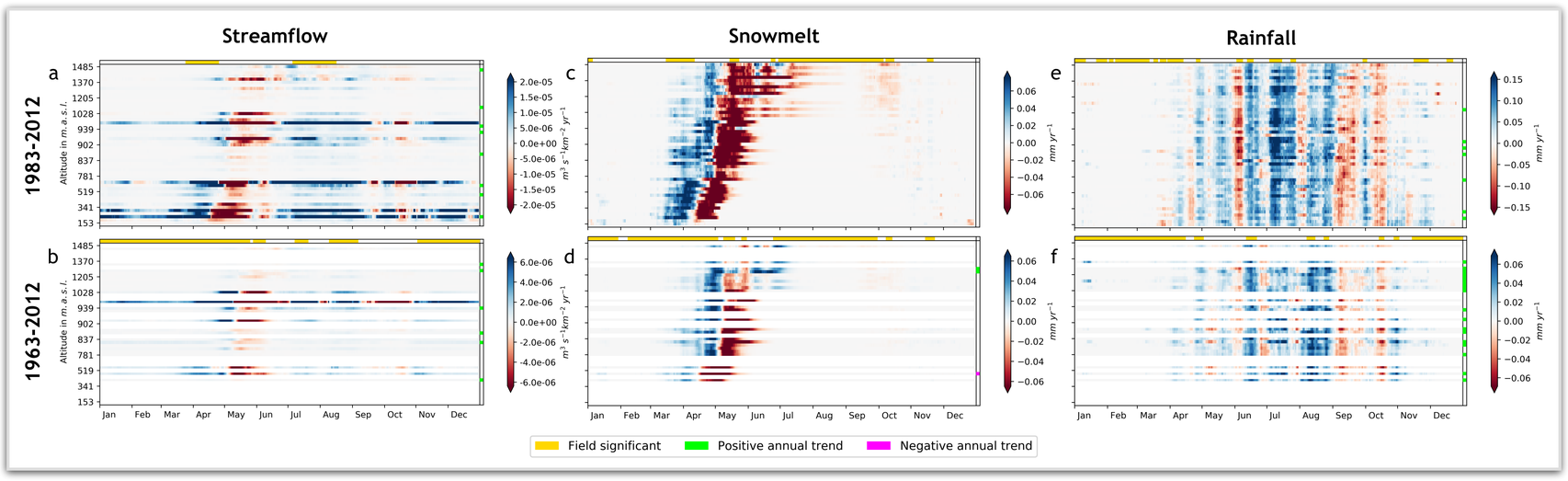

Fig. 4: 10dMA trends in **Østlandet** in 1983-2012 and 1963-2012

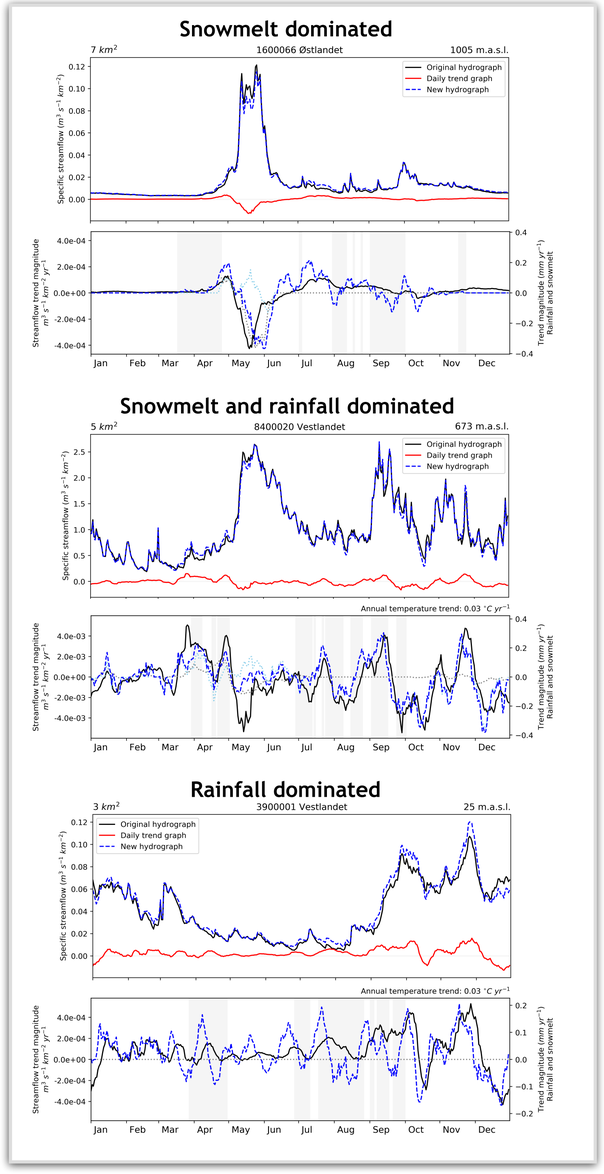

Fig. 5: Hydrographs and 10dMA trends in selected catchments in 1983-2012

Conclusions

- Rainfall and snowmelt were the main drivers of streamflow trends in Norway during a period of significant annual and seasonal warming
- While some changes only occur at certain altitudes, trend magnitudes appear to not be correlated with altitude
- Changes are generally consistent in both periods, except their magnitude

References

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