Daily streamflow trends in Norway (1983-2012)

Altitude-dependencies and consistencies with driving processes

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Motivation and objectives

- Mountainous regions are experiencing more rapid temperature changes than at lower elevation, which impacts the hydrology of these regions particularly through cryosphere and seasonal snowpack changes [1,2]. Daily hydrological trends in historical records from 112 Norwegian catchments were assessed to highlight the impact of changes in snowmelt and rainfall on streamflow and the hydrological regime, focusing on:
  - To what extent changes in streamflow are connected to changes in snowmelt and rainfall?
  - Are these changes dependent on altitude?

Study area

- A total of **112** catchments were analysed (Fig. 3), divided between two runoff regions in **Norway**, with different hydro-climates and similar altitude ranges (0-1500 m.a.s.l.):
  - **Vestlandet:** 61 catchments, west of the Scandinavian Mountains. Atlantic climate, with very high precipitation rates and mild winters, and steep topography resulting in generally smaller catchments.
  - **Østlandet:** 51 catchments, east of the Scandinavian Mountains. More continental climate with dry, cold winters, and highest precipitation rates in summer.

Data and methods

- Period: **1983-2012**
- Daily **streamflow** measurements from gauging stations [3]
- Daily **rainfall** and **temperature** data, spatially interpolated from station measurements to 1x1 km grid [4]
- Modelled daily **snowmelt** data [4]
- 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 [5,6] using a 10-day moving average (10dMA) filter to smooth daily data, then calculating the trend magnitude of each day of year with Sen's Slope Estimator, resulting in a daily resolved trend graph (Fig. 1)

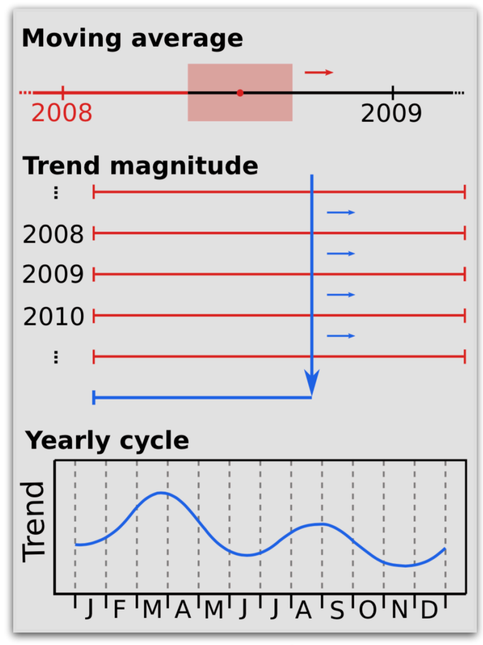

Fig. 1: Daily trend analysis (Source: [7])

Results and discussion

- Significant annual and significant seasonal warming (positive temperature trend) in March-April, July-September and late November
- Earlier start to snowmelt season due to spring warming (Fig.2b, Fig.4b)
- Positive snowmelt trend during summer in high-elevation catchments due to increased snow accumulation in winter
- Streamflow and temperature trend magnitudes are not correlated with altitude. Snowmelt and rainfall trend magnitudes display some altitude dependence, with snowmelt changes being generally greater at lower altitudes in Østlandet and rainfall changes being greater at mid-altitudes in Vestlandet.
- 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)
- Rainfall and snowmelt trends appear to be driving streamflow changes (Fig.5)

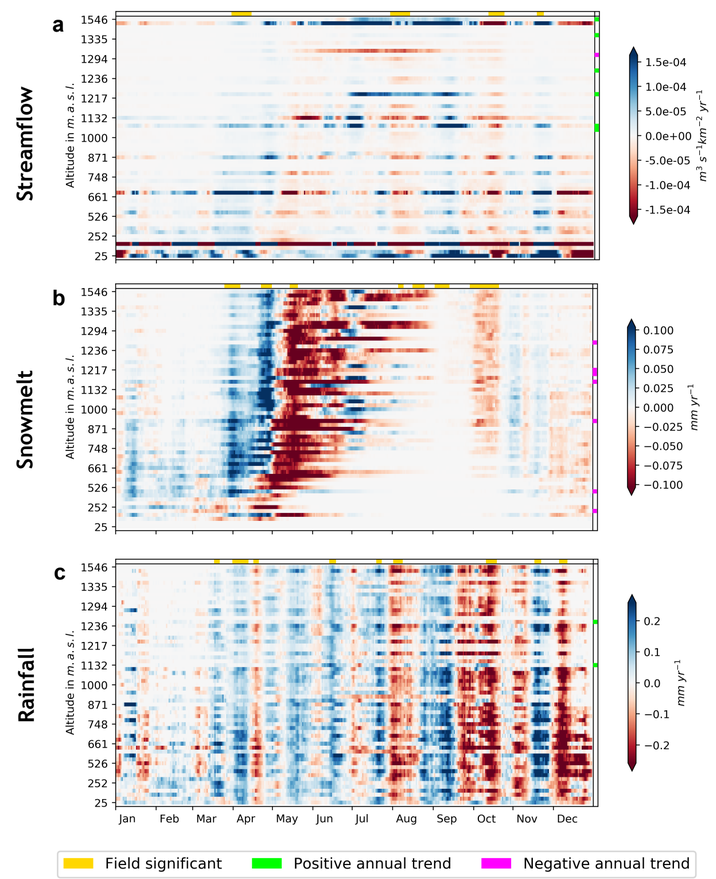

Fig. 2: 10dMA trends in Vestlandet (1983-2012)

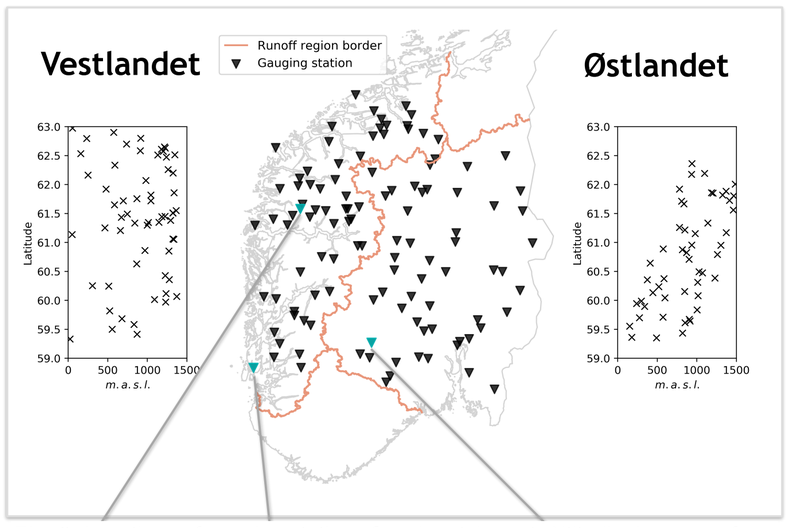

Fig. 3: Locations of gauging station of each catchment. Altitudinal ranges of runoff regions are show in scatterplots of median catchment altitude and latitude.

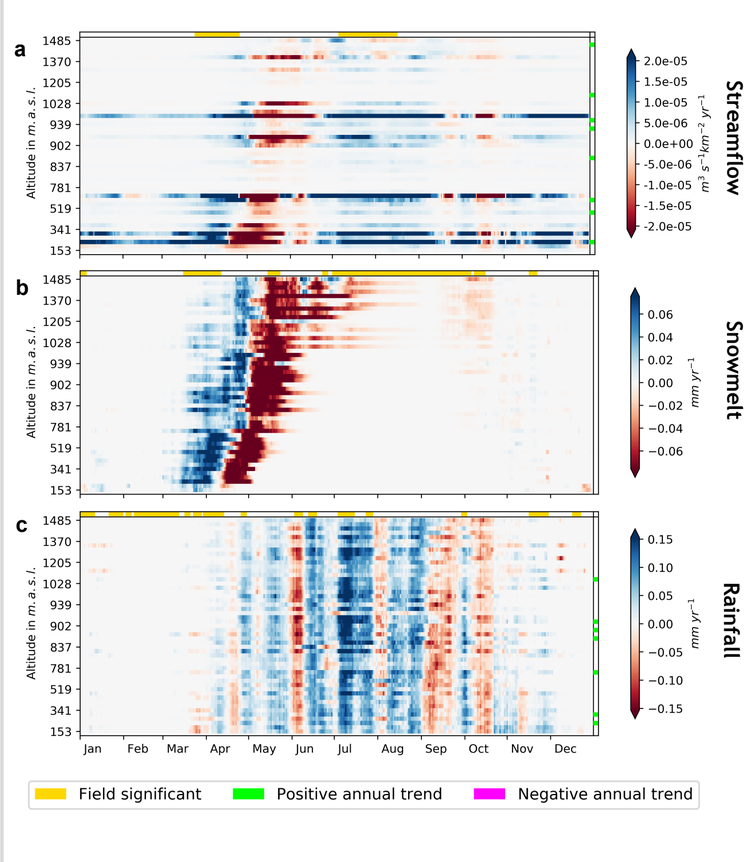

Fig. 4: 10dMA trends in Østlandet (1983-2012)

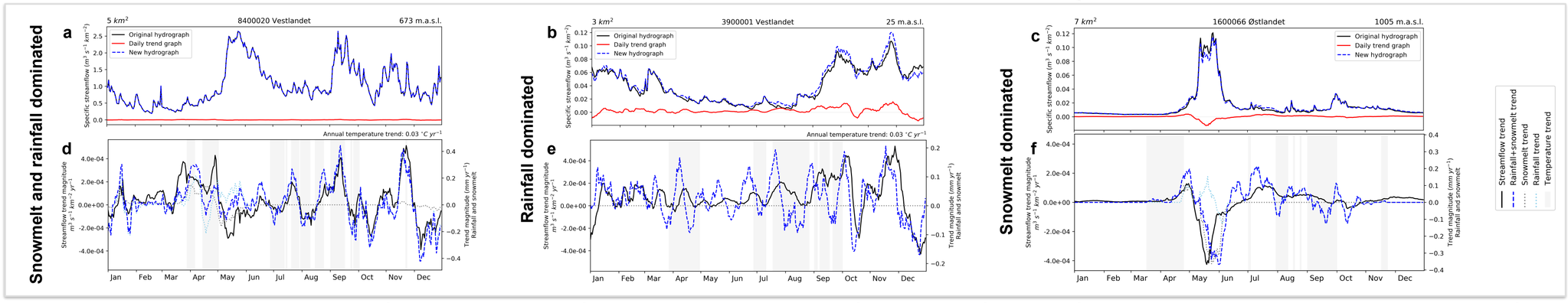

Fig. 5: Hydrographs (a,b,c) and 10dMA trends (d,e,f) in selected catchments. *Original hydrographs* were generated from daily streamflow records from 1973-1982, to which the *daily trend graphs* (endpoint of the 1983-2012 streamflow trend [$m^3\ s^{-1}\ km^{-2}\ 30yr^{-1}$]) were added to create the *new hydrograph*. 10dMA trends (d,e,f) indicates the daily *streamflow*, *rainfall+snowmelt*, *snowmelt*, and *rainfall* trends, in addition to days with *positive temperature* trends (grey).

Conclusions

- Rainfall and snowmelt were the main drivers of streamflow trends in Norway during a period (1983-2012) of significant annual and seasonal warming
- The magnitude of streamflow changes are not altitude dependent.
- The magnitude of snowmelt and rainfall changes display some altitude dependency, but not consistently in both regions.

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