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Rainfall-runoff modeling in arctic unglaciated catchment Fuglebekken (SW Spitsbergen)

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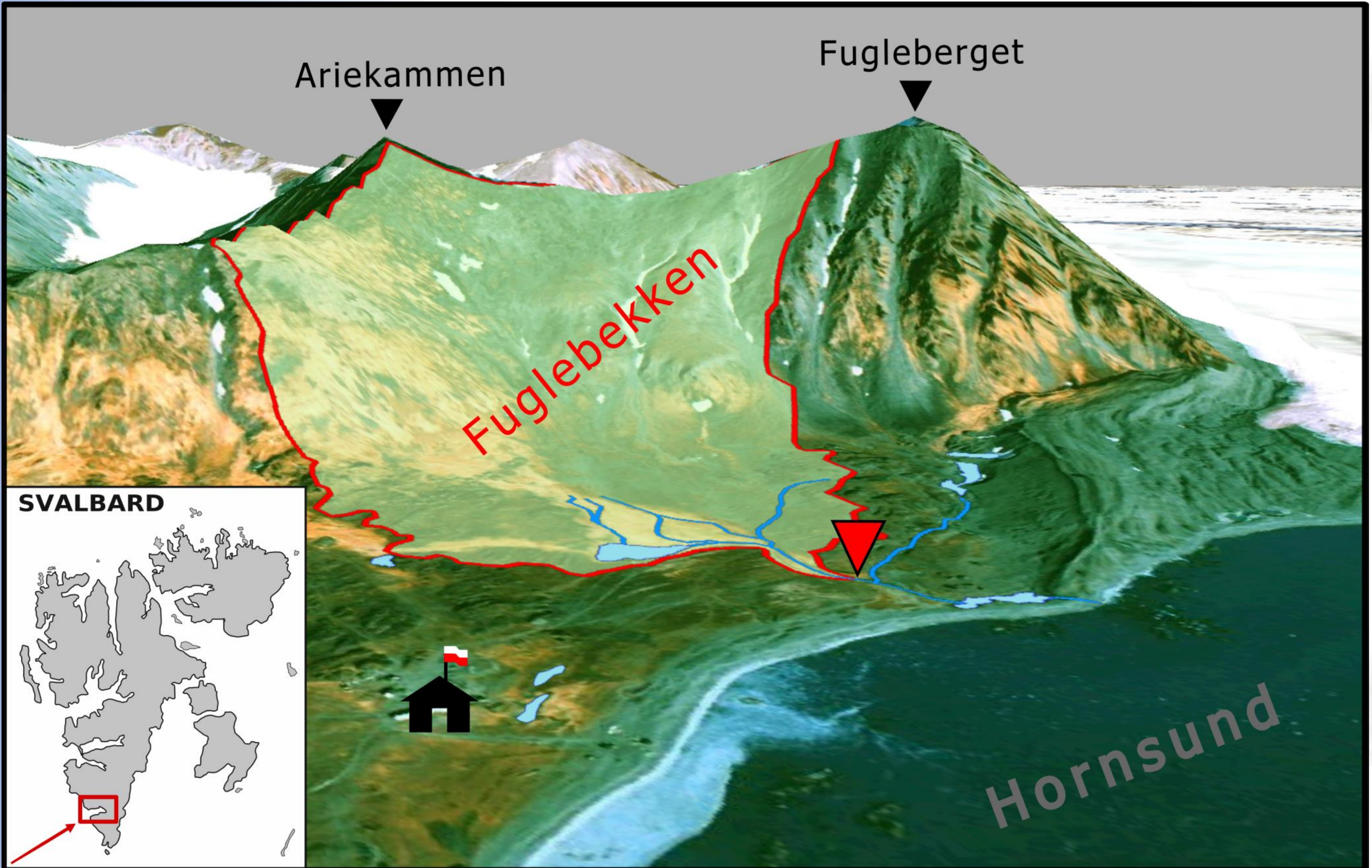
Aims of the study

Analysis of:

- **applicability of the conceptual catchment runoff HBV model to describe small non-glaciated arctic catchments on example of Fuglebekken.**
- **the influence of data time step on the calibration and validation results of the HBV model as well as on the values of parameters.**
- **an influence of input data averaging on the runoff modelling.**

Grant NSC 2013/09/N/ST10/04105



Catchment area
1.27 km^2

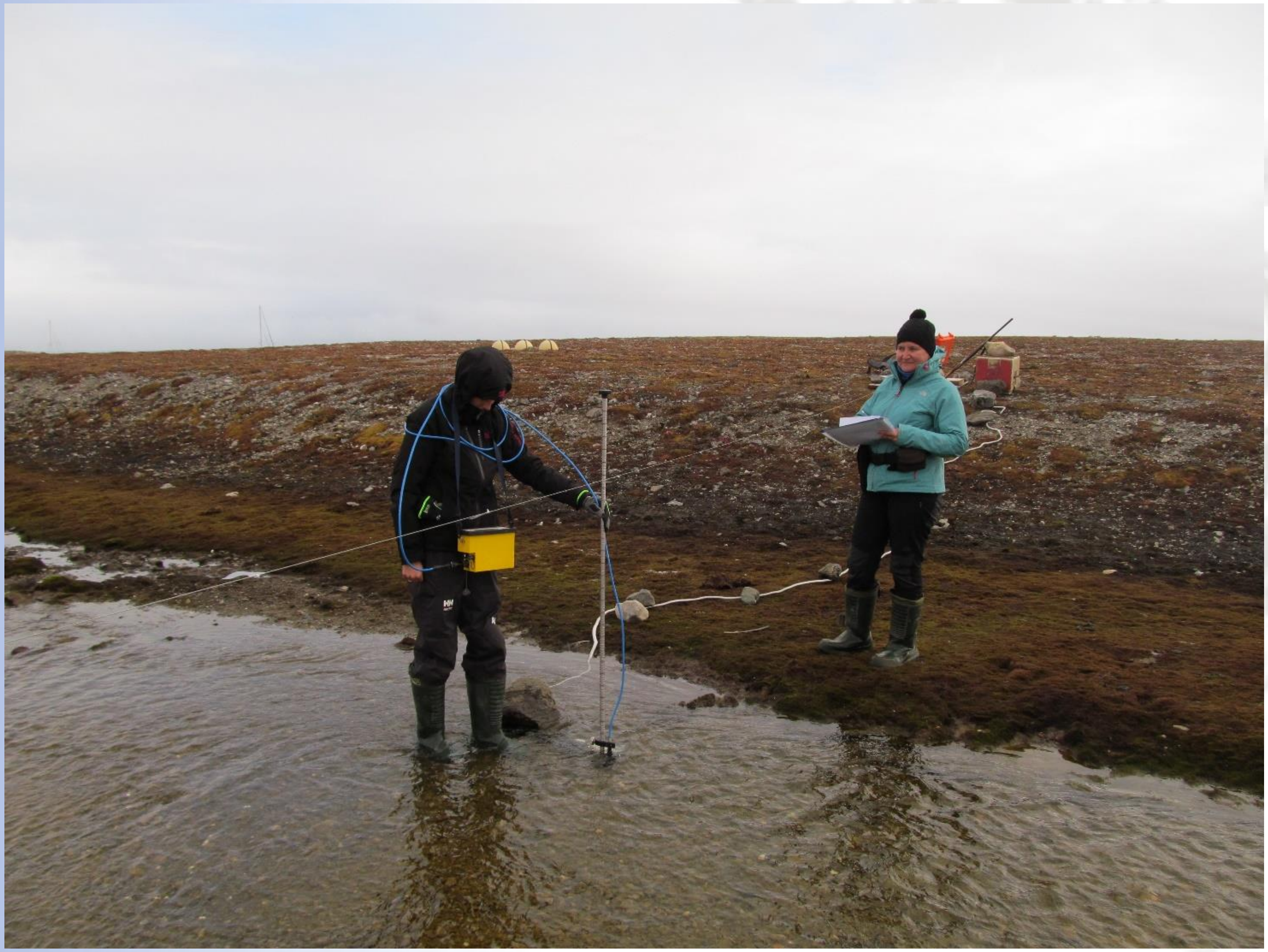
Polish Polar Station
Meteo data:
- since 1978 (3h interval)
- since 2001 (1m interval)

Hydrological profile
- since 2014 (10 min interval)

Flow meter Nivus PCM-F with Active Doppler sensor (KDA-KP 10)

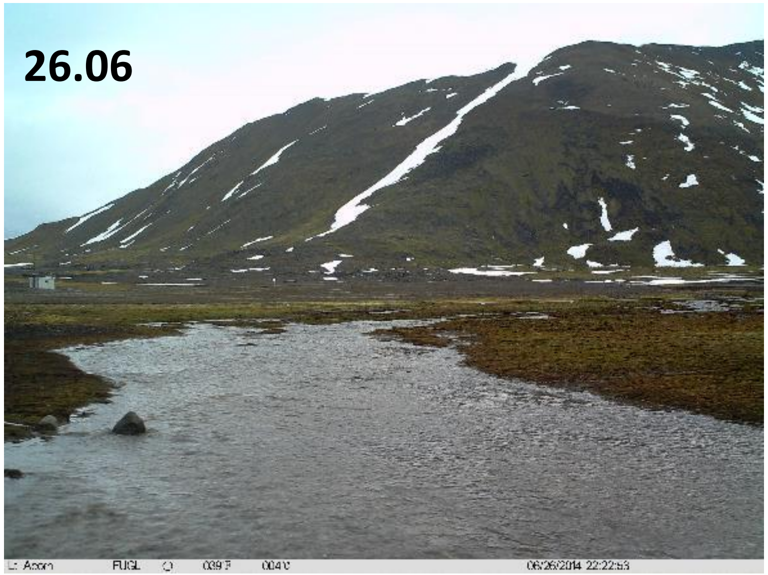
- velocity of particles in a remote sampling volume based upon the Doppler shift effect above the sensor and then automatically multiplied by the cross section area.

Electromagnetic Open Channel Flow Meter Valeport (801) with a Flat Type sensor - velocity area method, vertical subsections (0.5m), in each outflow was computed by multiplying the subsection area by the measured velocity.



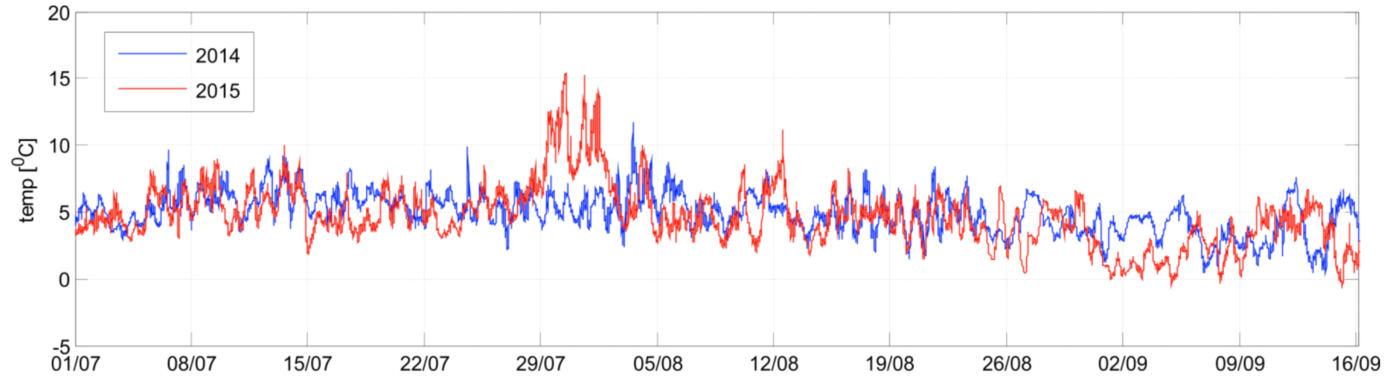
results varied up to 15%

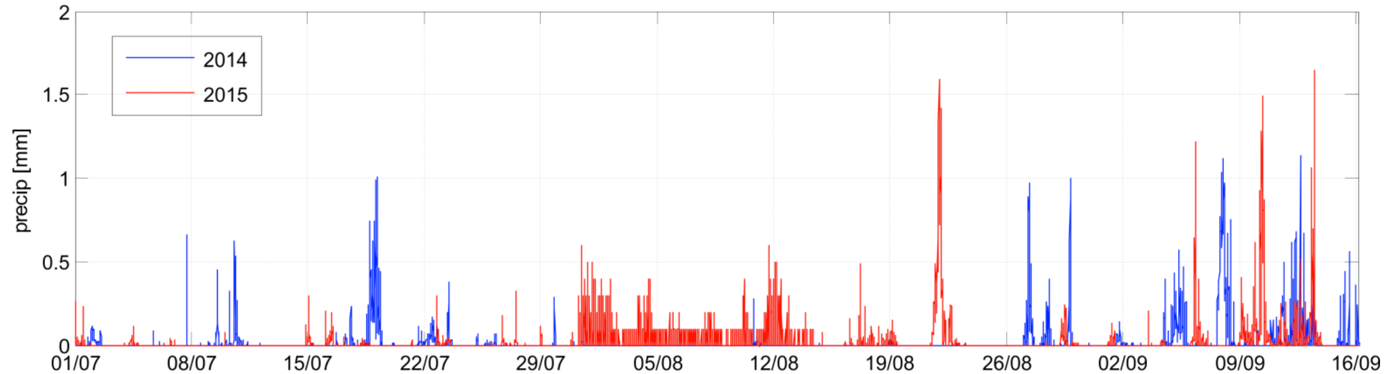
Fuglebekken 2014

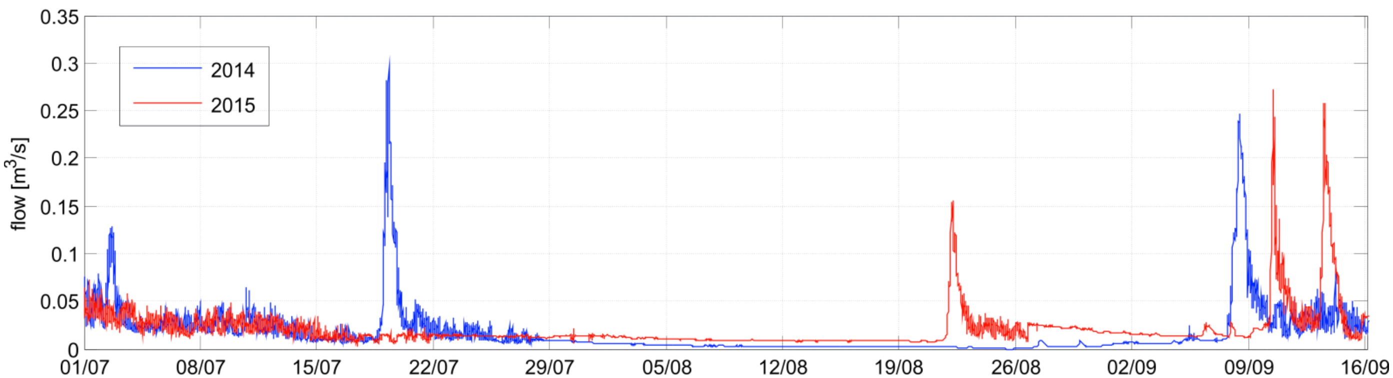


Fuglebekken 2015

Fuglebekken



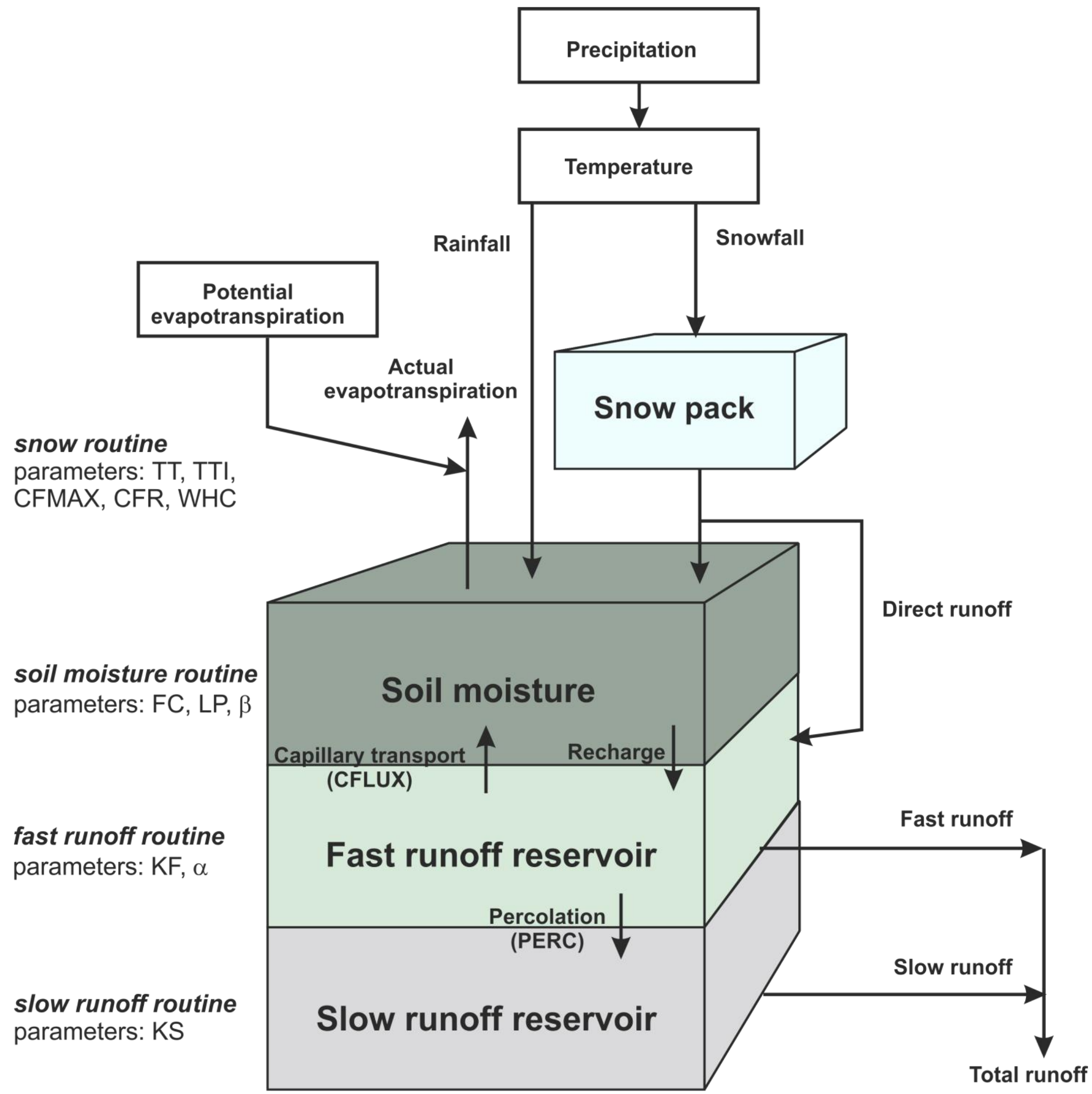




Model HBV has a structure with four conceptual storages taking into account dominant processes: snow accumulation and melting, soil moisture, fast and slow runoff. The appropriate description and simulation of these processes requires the input of hydro-meteorological data at appropriate temporal scale.

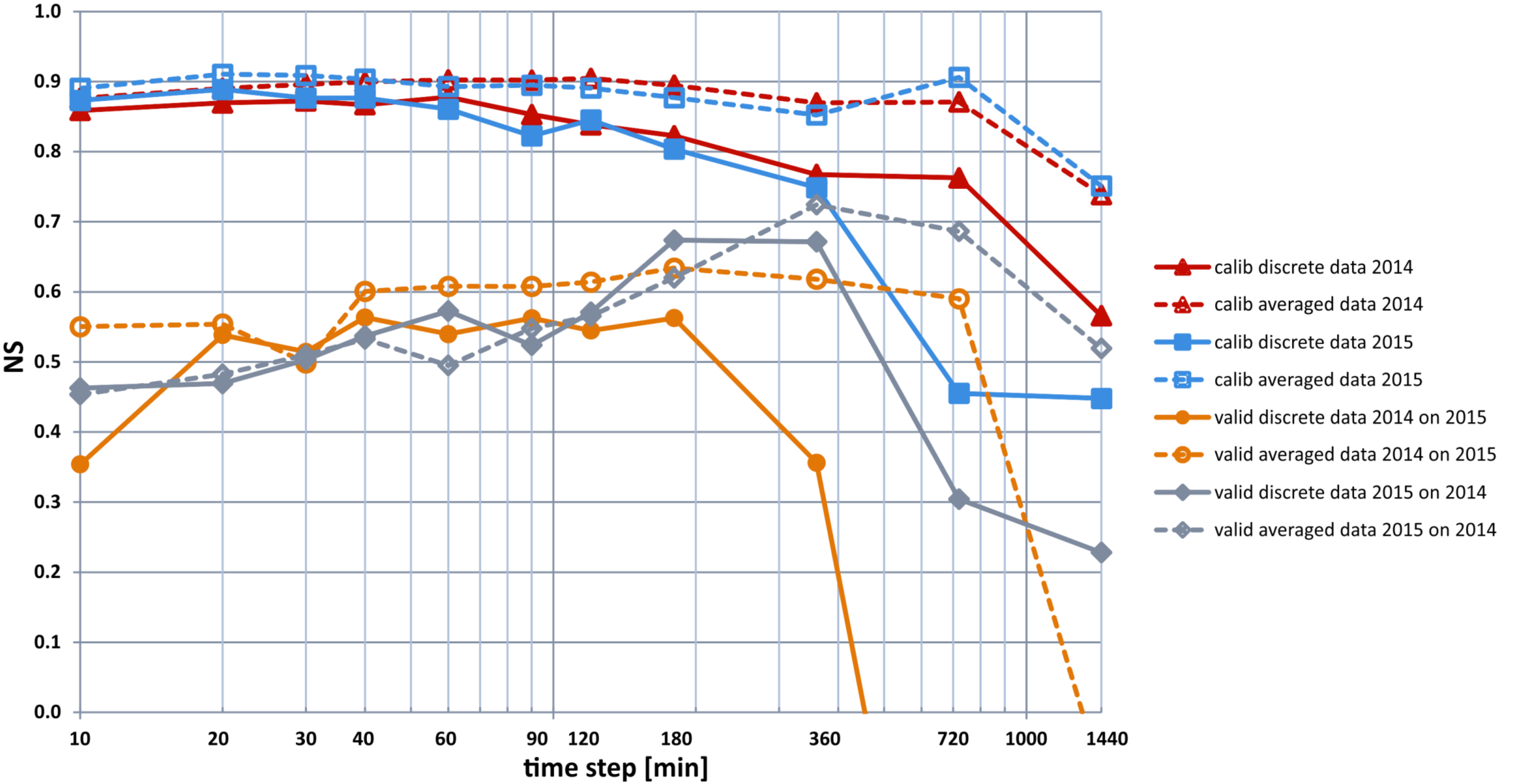
In this study the HBV model was calibrated independently for:

- two ablation seasons (2014 and 2015);
- eleven time steps (10, 20, 30, 40, 60, 90 min; 2, 3, 6, 12, and 24 h);
- discrete (instantaneous) and averaged over time interval data.

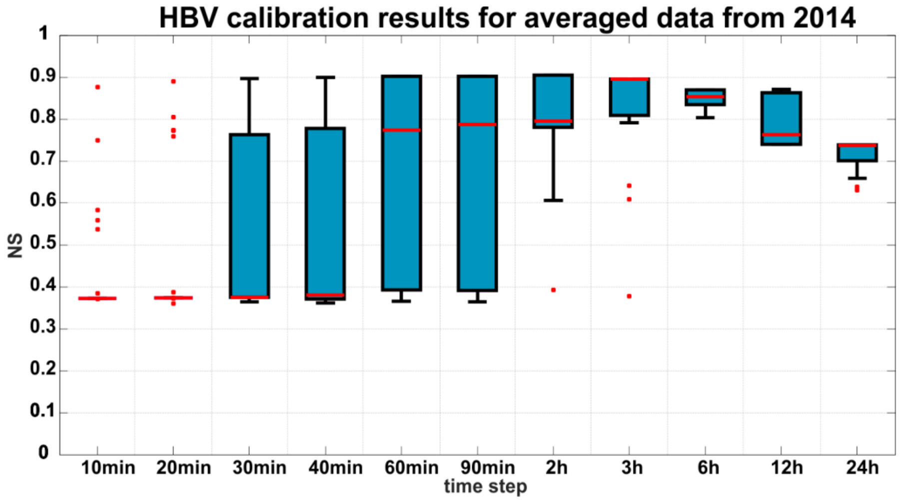


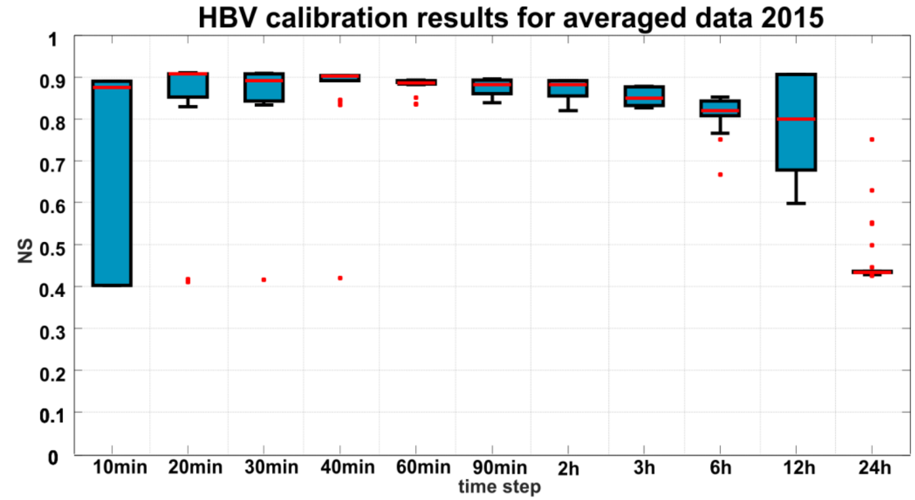
- Model calibration, by global optimisation method - Differential Evolution with Global and Local neighbours (DEGL).
- Stopping criterion - 30 000 iterations.
- Algorithm was run independently 30 times for randomly generated initial conditions.
- Objective function the Nash-Sutcliffe coefficient (NS)
- The HBV model was calibrated independently for:
    - two ablation seasons (2014 and 2015);
    - eleven time steps (10, 20, 30, 40, 60, 90 min; 2, 3, 6, 12, and 24 h);
    - discrete (instantaneous) and averaged over time interval data.
- Validation of the model on data from other season

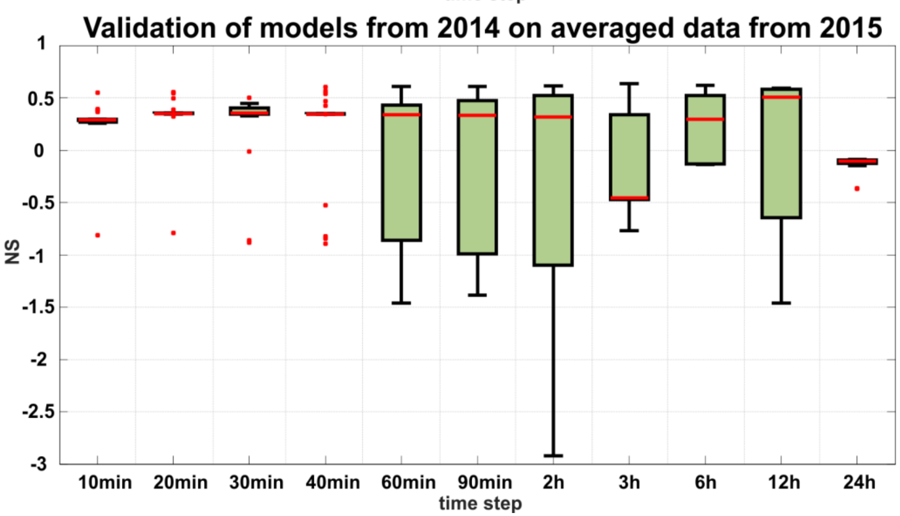
Comparison of the best calibration and validation results from 30 runs of optimization procedure for discrete (continuous lines) and averaged (dotted lines) over time step data

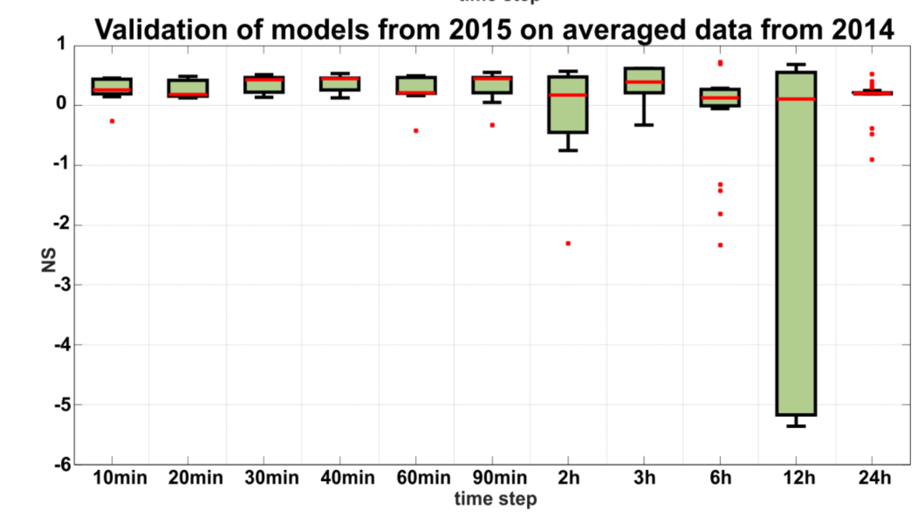


A comparison of the calibration and validation results for averaged data from year 2014 and 2015

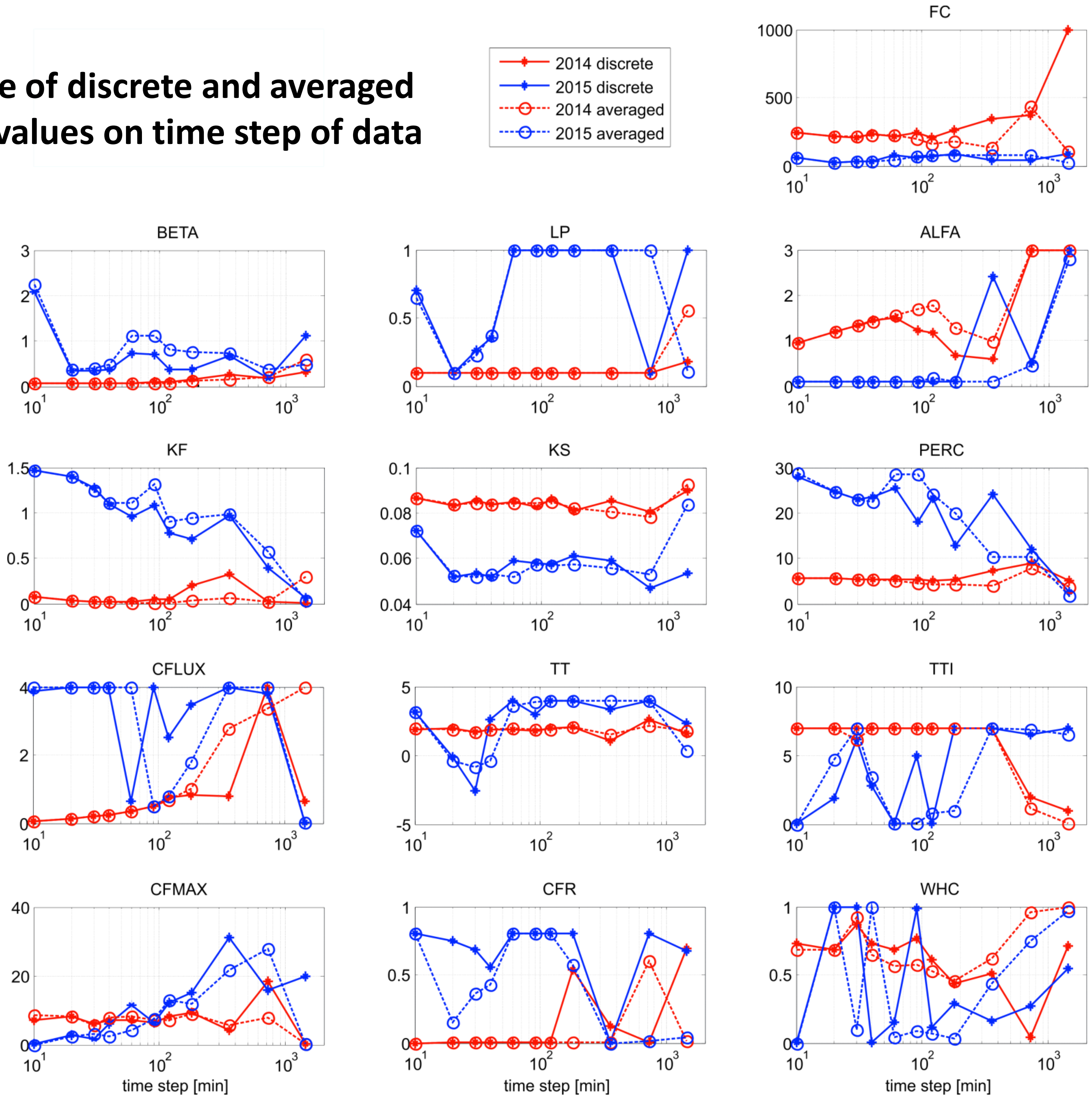








Dependence of discrete and averaged parameter values on time step of data



Conclusions

- **More than satisfactory results of calibration and validation were obtained which can justify the application of the HBV model in other years at Fuglebekken watershed and may give the opportunity to assess the actual state, as well as simulate future changes.**
- **A comparison of the calibration and validation results between different time steps indicated that the best results for the model were obtained for 3 and 6 hours. Those time steps are recommended for further use in hydrological simulations (hindcast and projections).**

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Changes in seasonality of snow cover, air temperature and precipitation in western Spitsbergen

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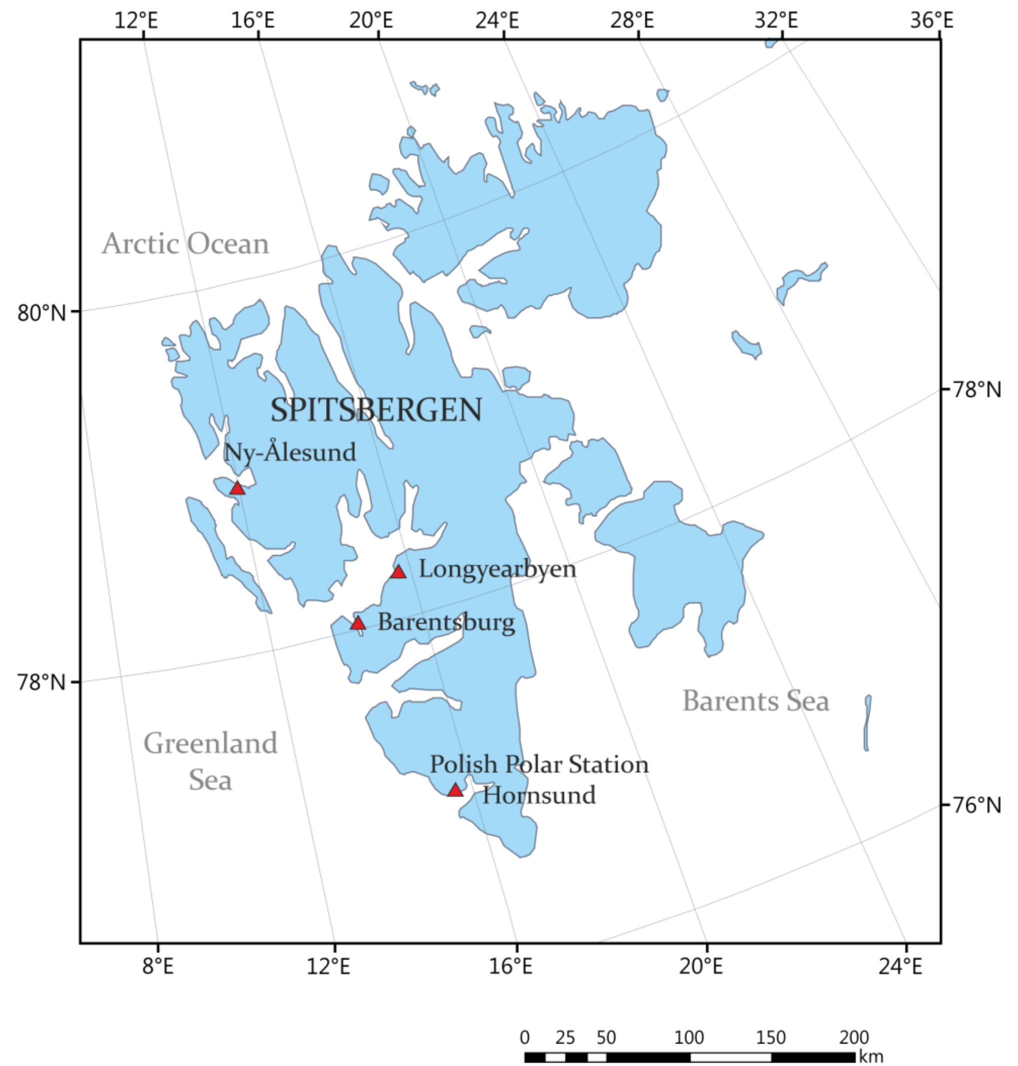
Aims

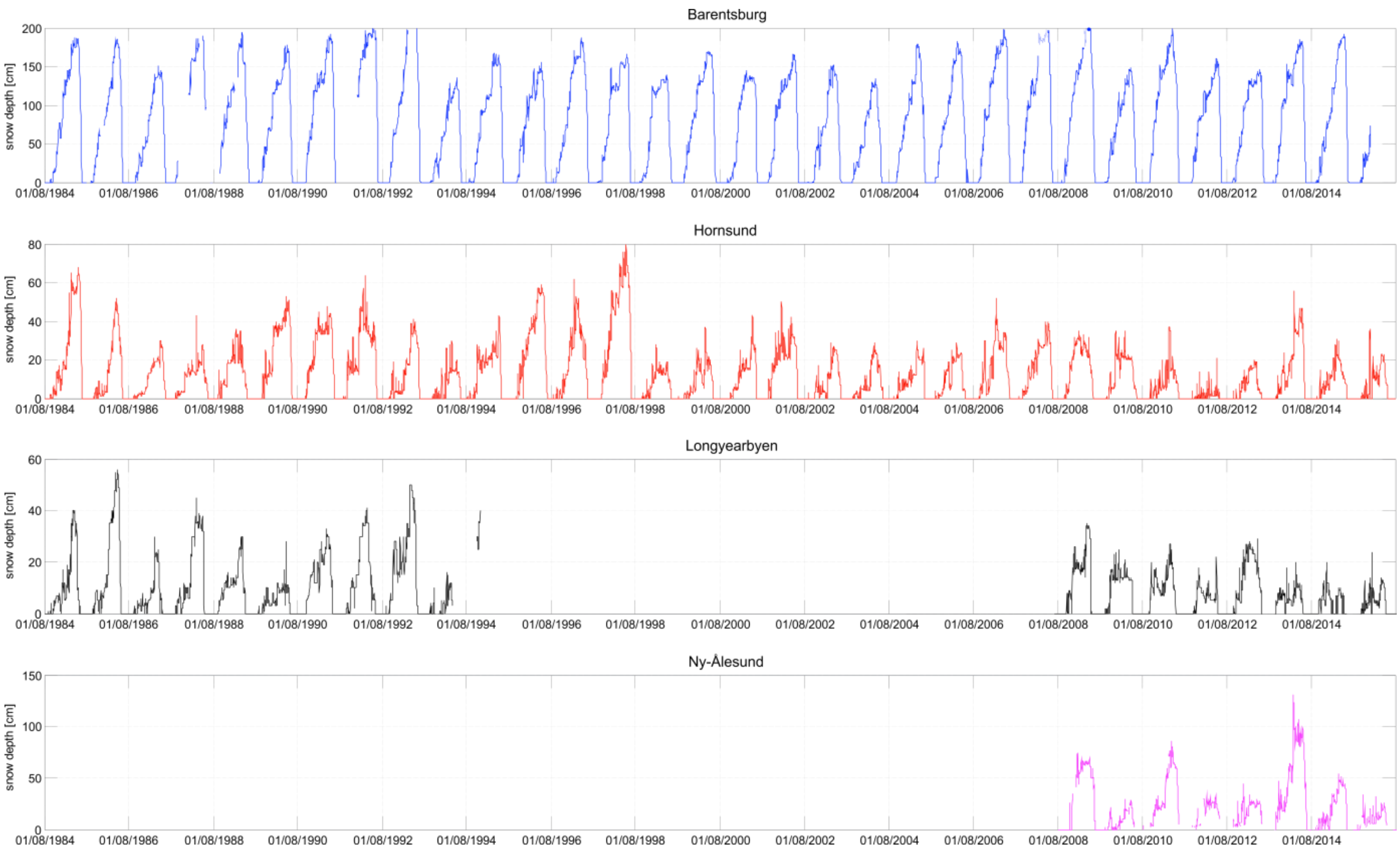
– Analysis of variability of daily snow cover depth, air temperature and precipitation using the newly proposed tool ‘Moving Average over Shifting Horizon’
– identification of changes in seasonality with statistical change detection test,
– comparison of the estimated trends between stations,
– analysis of potential sources of changes in air temperature and precipitation

Study area

- Four stations:
  - Hornsund,
  - Barentsburg,
  - Longyearbyen,
  - Ny-Ålesund
- Period: 01/08/1984 to 31/07/2016
- Analyses of 32 snow seasons
- Each season starts on 01/08 and ends on 31/07 next calendar year

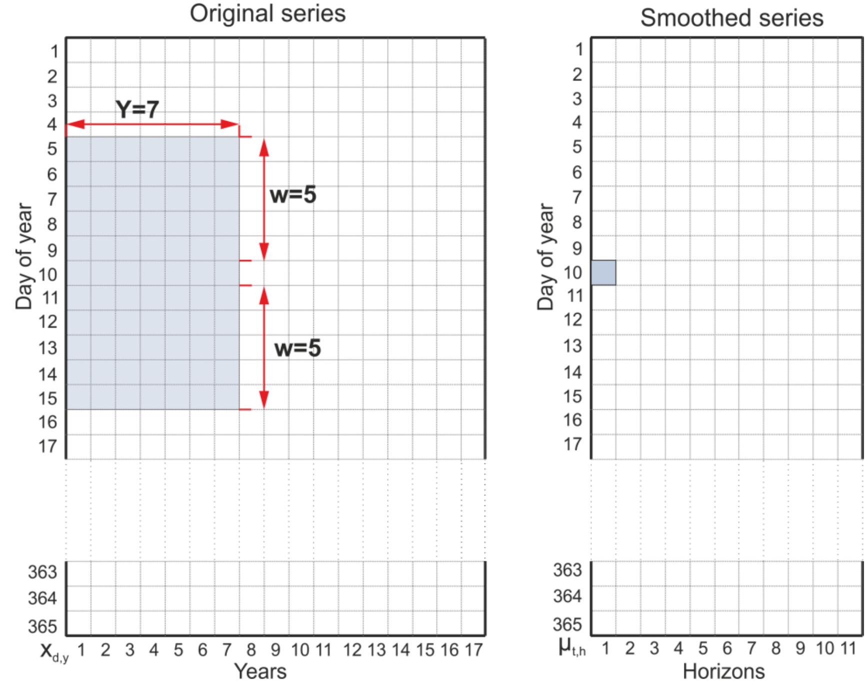


Available time series



Method

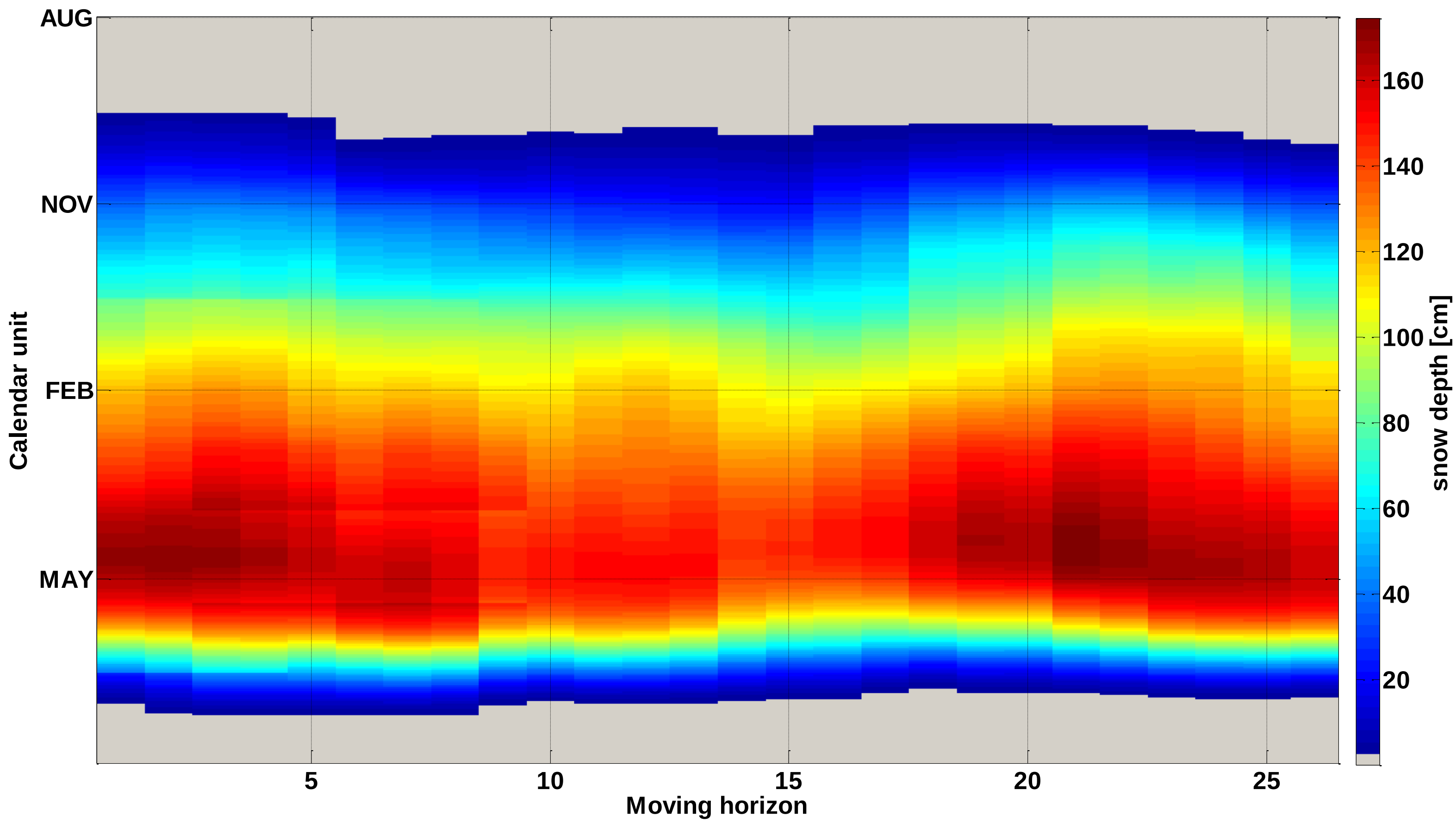
- Moving Average over Shifting Horizon (MASH) introduced by Anghileri *et al.* (2014)
- the data are arranged into array and than averaged in two dimensions: over the same days in the consecutive years and over consecutive days in the same year.
- This averaging is performed over shifting horizon which is parametrized by w and Y.
  - w describes number of consecutive days taken during averaging. The average over 2w+1 days.
  - *Y* is related to the averaging over years.
- In this study w=15 days and Y=7 years
- Trend analysis of the filtered data – Mann Kendall method



$$\mu_{t,h} = \underset{y\in[h,h+Y-1]}{\text{mean}} \left[\underset{d\in[t-w,t+w]}{\text{mean}} x_{d,y} \right]$$

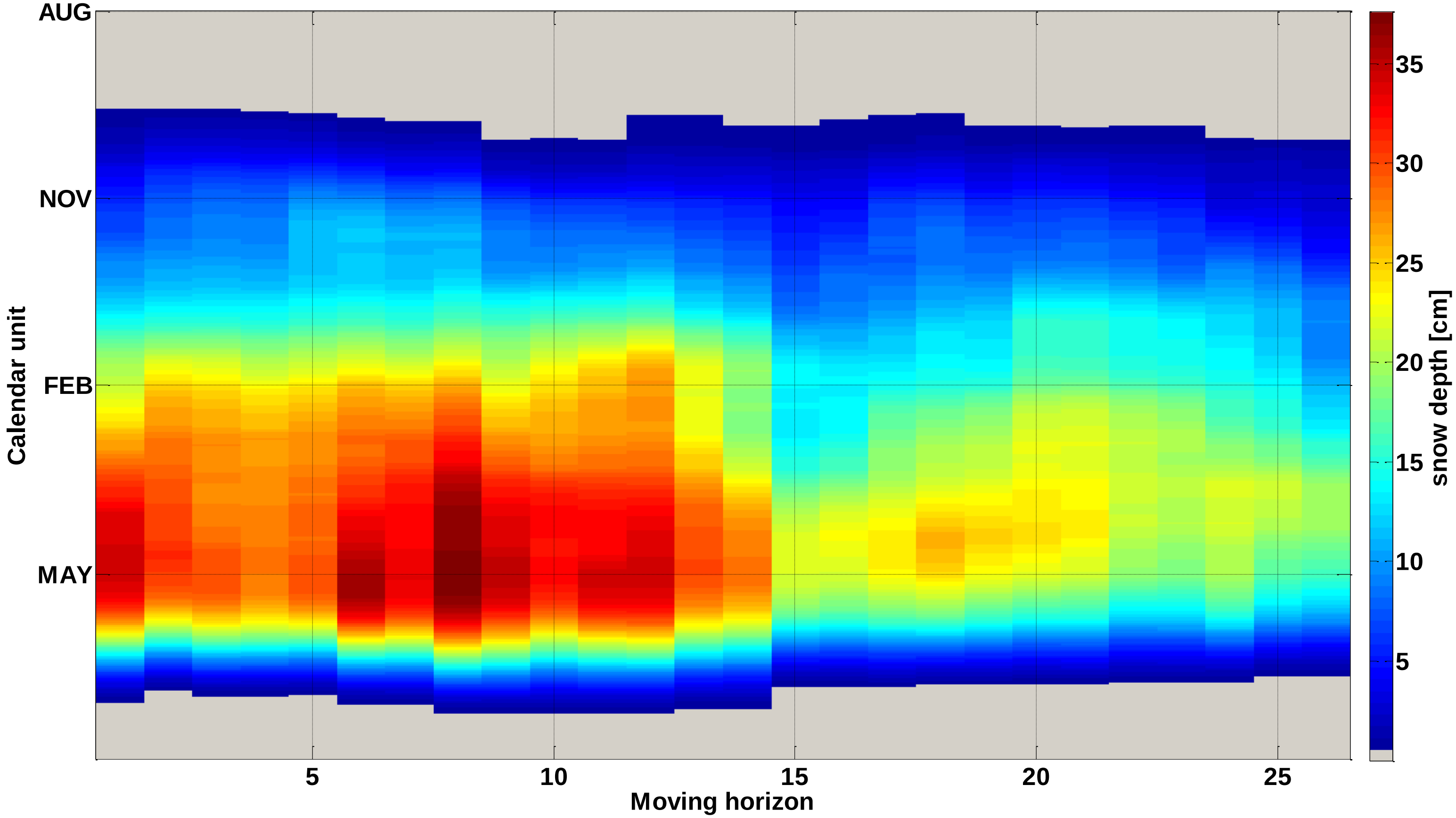
$$\text{MASH} = \begin{bmatrix} \mu_{1,1} & \mu_{1,2} & \cdots & \mu_{1,N_h} \\ \mu_{2,1} & \mu_{2,2} & \cdots & \mu_{2,N_h} \\ \cdots & \cdots & \cdots & \cdots \\ \mu_{365,1} & \mu_{365,2} & \cdots & \mu_{365,N_h} \end{bmatrix}$$

Results snow depth Barentsburg



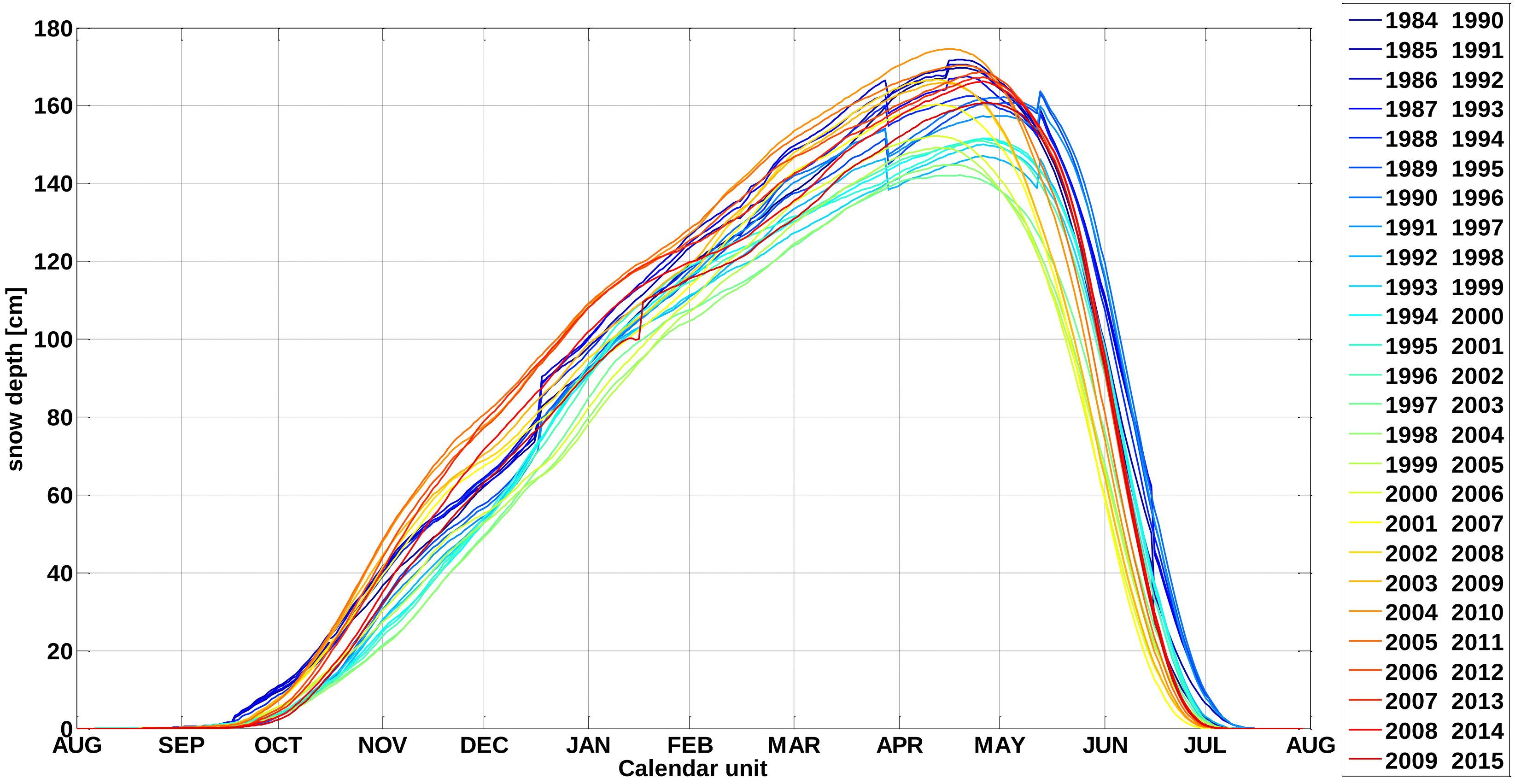
Original time series covers period *Ny* = 32 seasons, from 1984 to 2015, so MASH is composed of *Nh* = 26 patterns. A consistency in the results is visible despite small changes in snow depth over time.

Results snow depth Hornsund



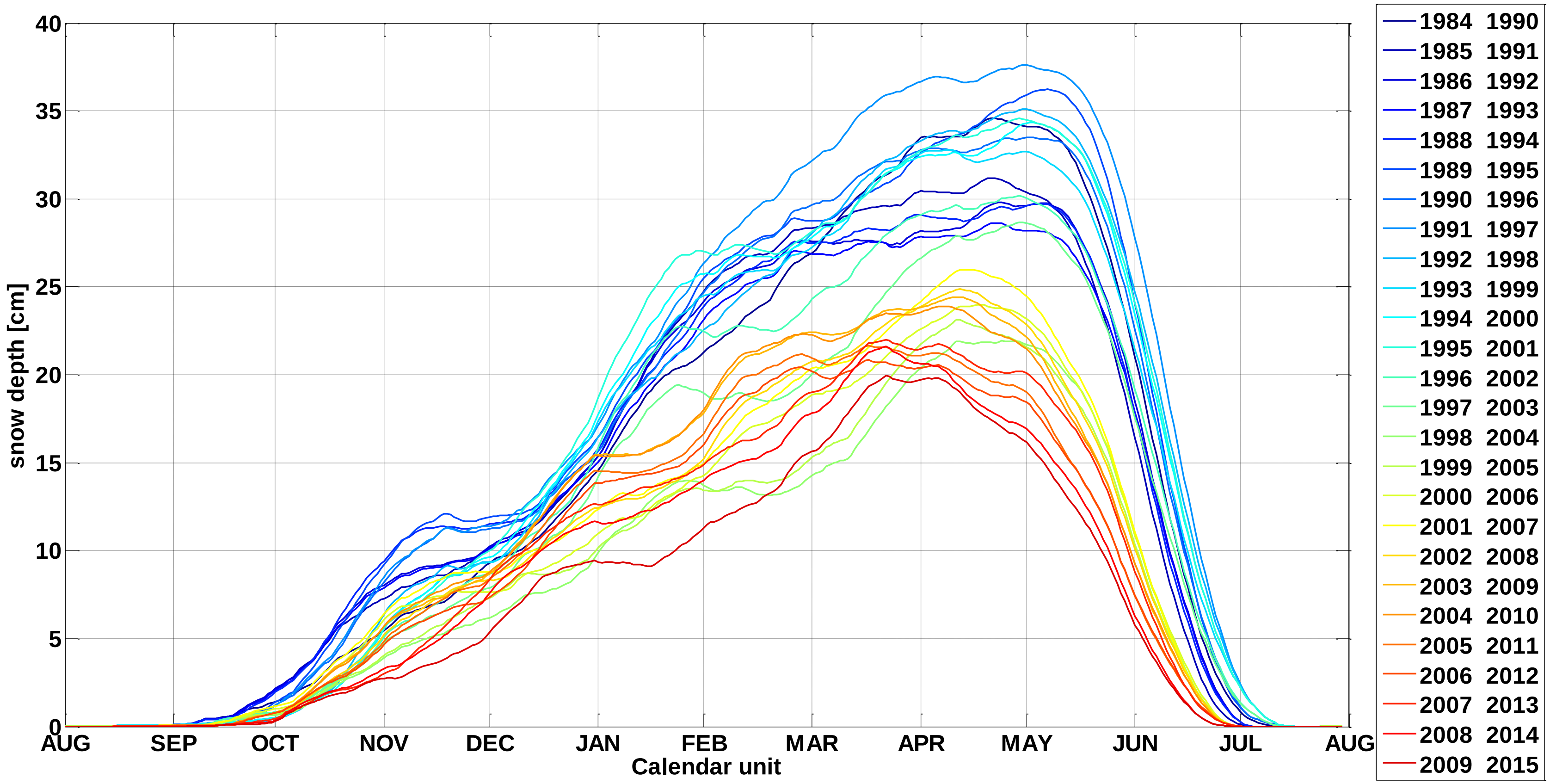
In the case of results for Hornsund station changes in data are visible. The outcomes up to horizon no 14 (hydrological year 1997/1998) are characterized by higher values of snow depths. From the horizon no 15 (hydrological year 1998/1999) together with smaller depths of snow cover also the snow accumulation periods are shorter.

Results snow depth Barentsburg



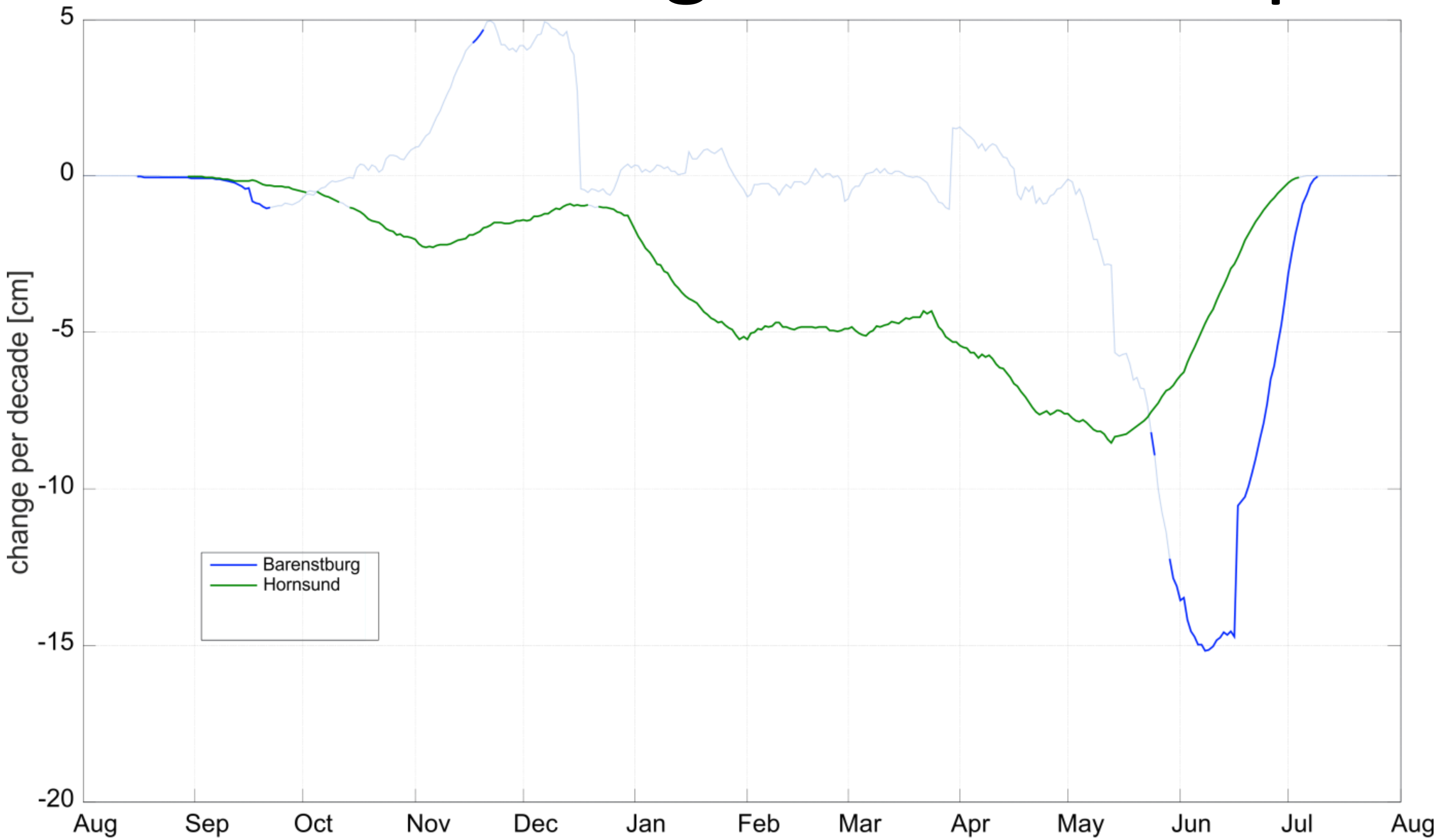
Another way of visualizing results using MASH, the lines represent snow depth averaging over 7 years. Blue lines represent older horizons while red lines more recent horizons. The results are biased due to missing data. Changes in annual runs of snow depth are visible. These results indicate rather additional periodicity than any trend.

Results snow depth Hornsund



Significant temporal changes are visible. The outcomes for recent horizons indicate that snow cover appears later and disappears earlier, and snow cover is thinner comparing to data from eighties and nineties. In addition changes of dates of occurrence of maximum snow cover are visible. In the eighties and nineties maximum snow cover was measured in May. Recently it is measured in March and April.

Changes in snow depth



Stat. significant changes at the 0.05 level are represented by blue line (Barentsburg) or green line (Hornsund). The results for both stations are similar for August, September and June when statistically significant decreases of snow depth were estimated.

Osuch and Wawrzyniak 2016 (International Journal of Climatology)

Changes in air temperature

Similar tendency of changes at all stations. Statistically significant increase almost throughout the year, except March at Hornsund and Longyearbyen. In December, January and February changes higher than $2^{0}C$ per decade were estimated for all stations.

Osuch and Wawrzyniak 2016 (International Journal of Climatology)

Changes in precipitation

In this case differences between stations were found. In August and September high positive trend was estimated only for Hornsund station. In October statistically significant positive trend for all stations. Increases are visible in second part of December and first part of January. A decrease in precipitation for March, April, and May.

Potential sources of changes

Station	Month	Air temperature							Precipitation						
		SIE	NAO	AO	SCA	POL	EA	EA/WR	SIE	NAO	AO	SCA	POL	EA	EA/WR
Hornsund	Jan	-0.73	-0.29	-0.33	0.38	-0.81	-0.16	-0.50	-0.45	0.04	0.06	0.50	-0.27	-0.04	-0.12
	Feb	-0.56	-0.54	-0.51	0.32	-0.67	0.02	-0.31	0.00	-0.52	-0.62	0.89	-0.03	-0.35	-0.66
	Mar	-0.26	0.13	0.34	-0.05	0.01	-0.30	-0.18	0.40	0.09	0.16	0.56	0.43	-0.14	-0.14
	Apr	-0.95	0.02	0.23	-0.32	-0.27	0.28	0.25	-0.03	0.43	0.48	0.09	0.07	0.17	-0.17
	May	-0.94	-0.61	-0.30	-0.15	-0.23	0.10	-0.22	0.46	0.56	0.22	0.27	0.21	-0.29	-0.22
	Jun	-0.92	-0.06	-0.16	-0.09	-0.14	0.16	-0.04	-0.01	0.64	-0.10	0.79	0.30	-0.66	-0.38
	Jul	-0.90	0.03	-0.15	0.25	0.02	0.33	-0.19	-0.51	0.06	0.16	0.16	0.57	0.13	0.20
	Aug	0.33	-0.09	-0.23	0.16	0.37	0.35	-0.30	-0.57	-0.02	0.16	0.61	0.44	0.49	-0.22
	Sep	-0.54	0.16	-0.07	0.15	0.11	0.22	-0.24	-0.74	0.07	-0.21	0.74	0.36	0.11	-0.57
	Oct	-0.95	-0.13	-0.28	0.26	-0.40	0.24	-0.45	-0.92	-0.33	-0.39	0.34	-0.46	0.23	-0.59
	Nov	-0.66	-0.34	0.04	0.54	-0.48	0.43	-0.88	-0.02	-0.05	0.22	0.45	0.10	0.42	-0.18
	Dec	-0.83	-0.48	-0.42	0.85	-0.11	-0.11	-0.63	-0.54	-0.29	-0.14	0.42	0.35	0.25	-0.20
	All	-0.81	-0.60	-0.13	0.12	-0.10	0.02	-0.11	-0.71	-0.26	-0.11	0.40	0.12	0.00	-0.08
Longyearbyen	Jan	-0.82	-0.38	-0.36	0.40	-0.78	-0.14	-0.49	0.01	-0.03	-0.15	0.50	-0.06	-0.11	-0.31
	Feb	-0.63	-0.59	-0.53	0.26	-0.75	0.03	-0.27	0.73	0.30	0.03	0.49	0.71	-0.44	-0.45
	Mar	-0.52	-0.07	0.19	-0.30	-0.26	-0.10	0.03	0.80	0.64	0.53	0.62	0.85	-0.50	-0.56
	Apr	-0.97	-0.08	0.19	-0.34	-0.33	0.34	0.33	0.70	0.60	0.19	0.38	0.54	-0.42	-0.57
	May	-0.96	-0.64	-0.27	-0.20	-0.33	0.20	-0.24	0.40	0.47	-0.04	0.32	0.36	-0.58	-0.30
	Jun	-0.96	-0.17	-0.20	-0.18	-0.23	0.24	-0.04	-0.46	0.33	-0.05	0.47	0.29	-0.25	-0.17
	Jul	-0.94	-0.29	-0.41	0.52	-0.08	0.66	-0.44	-0.65	0.04	0.03	0.28	0.29	0.23	0.01
	Aug	0.18	-0.20	-0.32	0.27	0.46	0.46	-0.42	-0.07	0.23	0.08	-0.04	-0.48	-0.36	0.30
	Sep	-0.53	0.16	-0.10	0.17	0.10	0.18	-0.23	-0.29	-0.17	-0.56	0.62	-0.02	-0.16	-0.05
	Oct	-0.95	-0.12	-0.27	0.25	-0.38	0.21	-0.42	-0.54	-0.28	-0.38	0.32	-0.46	0.44	-0.63
	Nov	-0.63	-0.32	-0.01	0.55	-0.50	0.44	-0.87	0.21	0.15	0.16	0.39	0.14	0.28	-0.06
	Dec	-0.82	-0.50	-0.46	0.86	-0.10	-0.07	-0.65	-0.63	-0.37	-0.23	0.50	0.40	0.29	-0.28
	All	-0.80	-0.61	-0.14	0.10	-0.12	0.04	-0.10	-0.28	0.14	-0.04	0.35	0.21	-0.03	-0.11
Ny-Ålesund	Jan	-0.85	-0.36	-0.30	0.36	-0.75	-0.11	-0.44	-0.24	0.04	-0.14	0.53	-0.39	-0.03	-0.34
	Feb	-0.65	-0.58	-0.50	0.23	-0.76	0.05	-0.23	0.30	-0.07	-0.23	0.72	0.34	-0.37	-0.58
	Mar	-0.63	-0.28	-0.07	-0.34	-0.47	0.01	0.19	0.55	0.40	0.27	0.48	0.52	-0.23	-0.24
	Apr	-0.94	-0.05	0.18	-0.29	-0.28	0.31	0.29	0.52	0.50	0.13	0.33	0.50	-0.27	-0.41
	May	-0.92	-0.58	-0.32	-0.09	-0.25	0.09	-0.24	0.69	0.54	0.15	0.24	0.42	-0.42	-0.02
	Jun	-0.92	-0.07	-0.18	-0.06	-0.14	0.15	-0.06	-0.32	0.45	-0.07	0.55	0.29	-0.34	-0.24
	Jul	-0.89	-0.30	-0.44	0.54	-0.16	0.68	-0.49	-0.61	-0.18	-0.21	0.54	0.25	0.50	-0.21
	Aug	0.36	-0.06	-0.27	0.19	0.30	0.30	-0.29	-0.15	0.08	0.05	-0.02	-0.44	-0.22	0.19
	Sep	-0.41	0.13	-0.17	0.13	-0.01	0.10	-0.11	0.01	-0.11	-0.51	0.47	-0.25	-0.49	0.07
	Oct	-0.93	-0.10	-0.26	0.25	-0.38	0.20	-0.40	-0.82	-0.35	-0.49	0.51	-0.61	0.29	-0.65
	Nov	-0.54	-0.28	-0.13	0.59	-0.56	0.48	-0.84	0.24	0.22	0.26	0.39	0.15	0.31	-0.15
	Dec	-0.79	-0.47	-0.46	0.87	-0.14	-0.09	-0.67	-0.57	-0.28	-0.17	0.41	0.35	0.24	-0.18
	All	-0.80	-0.61	-0.14	0.10	-0.12	0.03	-0.09	-0.07	0.24	-0.05	0.33	0.07	0.00	-0.08

- sea ice extent (SIE),
- North Atlantic Oscillation (NAO),
- Arctic Oscillation (AO),
- Scandinavia pattern (SCE),
- Polar/Eurasia pattern (POL),
- East-Atlantic pattern (EA)
- East Atlantic/West Russia pattern (EA/WR)

- Temp=f(SIE)
- Precip=f(SCA)

The strengths of these relationships were tested by the Spearman correlation coefficient

Conclusions

- The MASH method combined with the Mann-Kendall test was successfully applied for trend estimation in daily snow cover depth, air temperature and precipitation.
- Data filtering allows for the signal separation into two bins, weather (with small-scale variability and influence of local factors) and climate (with large-scale variability and regional and global factors that have influence).
- More details are available in the paper: Osuch M., Wawrzyniak T. (2016) Inter- and intra-annual changes in air temperature and precipitation in western Spitsbergen, International Journal of Climatology.
- The available in-situ measurements of snow depth in Spitsbergen are rare. The data are available from a few sites. There are problems with homogeneity of the data.
- Further investigations and snowpack modelling are required to explain the differences in observations at Hornsund.

Future plans

- Uncertainty and sensitivity analysis of HBV model for the simplification of the model (done)
- Projections of future conditions – cooperation with met.no (Andreas Dobbler)
- Assimilation of snow data

Thank you for your attention

HORNSUND
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