Total and Regional Runoff to the Baltic Sea

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Key message

The total runoff in 2015 was above the 1950 – 2014 mean value, as was the situation in 2014. When looking at the period from 1950 to present, alternating between dry and wet periods in the length of decades is common. One example of a dry period occurred between 1968 and 1980 and the following decade (1981-1990) was a rather wet one. The five year running mean has been increasing since 2004, but it went down slightly with the 2013 runoff. It is still above the long term mean value though.

The total runoff to the Baltic Sea in 2015 was among the top 3 highest since 1950, mostly due to a record high runoff in the northern parts of the Baltic Sea. A large contribution to this overall high runoff is a record high runoff in the Gulf of Bothnia with +48% compared to mean values. The Gulf of Finland also experienced a high runoff of +11% while the runoff in the Baltic Proper and the Gulf of Riga was below average, -5% and -6% respectively. The total runoff to the Baltic Sea in 2015 was +12% compared to the long term mean of the annual runoff.

During the period 1950 – 2015, the total runoff to the Baltic Sea shows no long-term trend. This time period is characterised by dry and wet periods lasting for a couple of years to a decade generally following the NAO index.

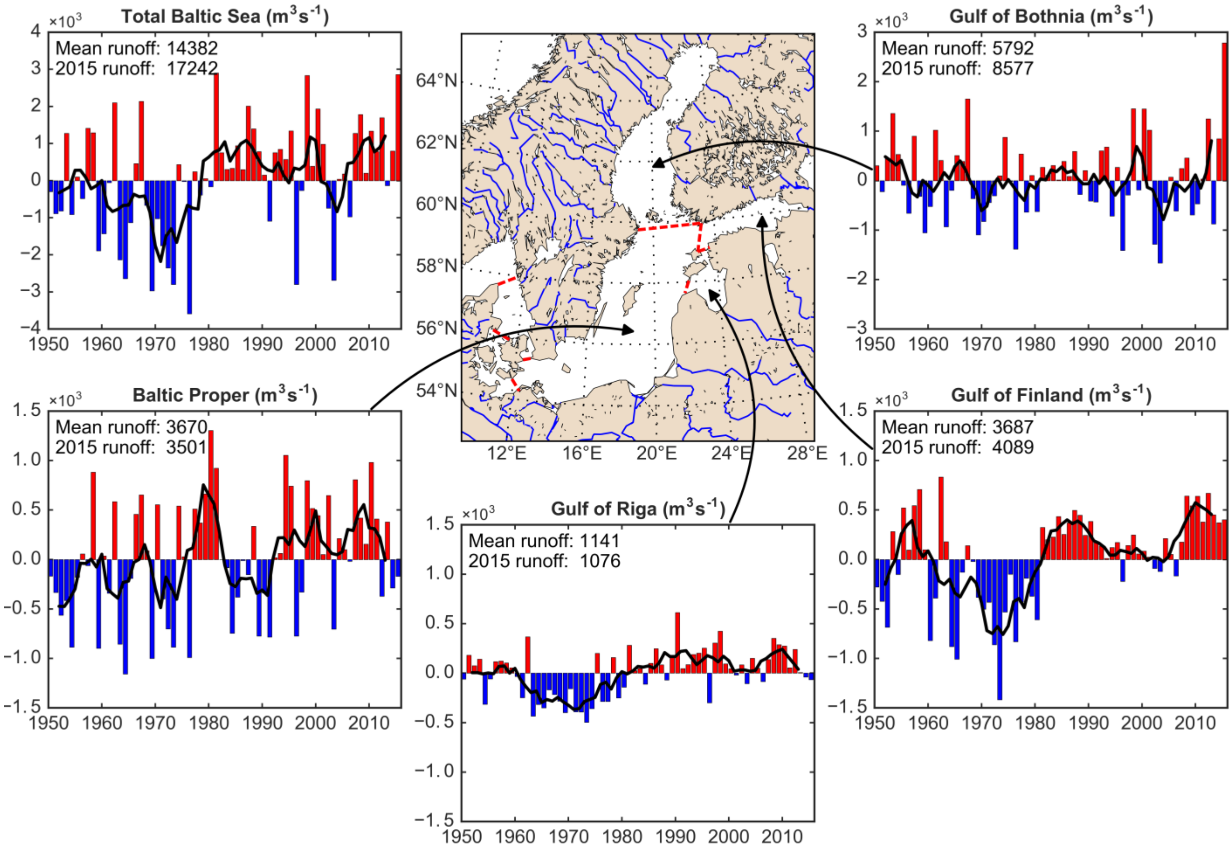

Figure 1. Total runoff deviation during the period 1950 – 2015 to the Baltic sub basins based on annual mean values. The mean runoff value and the 2015 value for each sub basin are written in the top left corner in each panel. The black line represents the five year running mean. The blue lines on the map represent all the major rivers within the Baltic region.

Results and Assessment

Data

During the assessment of this report, a new model, E-HYPE (http://hypeweb.smhi.se/), was introduced and used to estimate the runoff to the Baltic Sea. E-HYPE produced runoff values for the period 1981-2015, for the earlier period 1950-1980 the runoff is based on observations. Previous years the latter period was simulated by a combination of observations and two models HBV-model (Graham 1999) and Balt-HYPE (Arheimer et al. 2012). The HBV- and the Balt-HYPE model are no longer operational, thereby the switch to the E-HYPE model.

Due to the change of data for this assessment, the results are somewhat different from fact sheets in the past. In general, the E-HYPE model estimates a larger runoff in relation to data published in the past, the overall patters are more or less the same though.

Relevance of the indicator for describing developments in the environment

Runoff is a quantitative background indicator of the freshwater discharge, carrying the nutrients from the drainage areas to the coast.

Runoff is an important parameter for the change of pressure of nutrient supply due to varying climate and climate change. Also change in land-use can influence runoff. To evaluate the change of pressure of nutrient supply to the Baltic region it is necessary to know the variability of runoff and normalise for this natural variability. Dry periods, like the one during the 70's, can mask the marine eutrophication since the runoff was lower than average and hence also the total load of nutrients. Extended dry periods should also lead to a slight increase in surface layer salinity. During wet periods, the total nutrient load (pressure) increases, making marine eutrophication (effects) even worse.

The indicator shows the annual runoff from drainage areas integrated over the Baltic sub-regions. Runoff is governed by the precipitation - evaporation on land areas and is also influenced by air temperature. It is the sum of direct river and diffusive runoff. In all sub-regions a strong seasonal, annual and decadal variability can be distinguished. Especially wet and dry periods are characterising the runoff. The 70's was a fairly dry period compared with the 80's and the later part of the 90's. Geographically, the runoff is of about the same size in the Gulf of Finland and the Baltic Proper, whereas the Gulf of Riga contributes to a lesser extent and the Gulf of Bothnia to a larger extent to the total runoff.

Assessment

Four different sub basins are described by the deviation from their mean values based on runoff during 1950 to 2014. The mean values and the 2015 values are shown in each sub basin panel (Figure 1). Years with higher runoff compared to the mean value are displayed as red bars and lower values with blue bars. A five year running mean is displayed as a black line overlaying the bars in the figure. The sub basins are displayed in the centre of Figure 1 and the sub basins described are the Baltic Proper, the Gulf of Riga, the Gulf of Finland and the Gulf of Bothnia. A figure with the sum of the Baltic Sea sub basins is also included, partly to give an overview of the entire Baltic Sea and partly to compare the annual changes to the NAO index.

During the period 1950 – 2015, there is no obvious trend in the annual runoff, neither in the total runoff to the Baltic Sea area, nor in the sub-regions. Instead, this time period is characterised by dry and wet periods lasting for a couple of years to a decade. During 2015 the runoff were above mean values in the Gulf of Bothnia and the Gulf of Finland, while in the Gulf of Riga and the Baltic Proper the runoff were below mean values, see Table 1.

Table 1. 2015 runoff values [m^3s^{-1}] are compared to the 1950-2014 mean of the annual averages for the sub basins in the Baltic Sea and the difference in % are displayed.

	Runoff 2015 [m^3s^{-1}]	**Mean runoff 1950-2014 [m^3s^{-1}]**	**Difference from mean [%]**
Gulf of Bothnia	**8 576.6**	**5 792.2**	**48.1**
Gulf of Finland	**4 088.9**	**3 687.2**	**10.9**
Gulf of Riga	**1 075.8**	**1 141.0**	**-5.7**
Baltic Proper	**3 500.6**	**3669.6**	**-4.6**
Total Baltic Sea	**17 241.9**	**14 381.0**	**19.9**

At times, there have been similar features in the changes of runoff values for all the sub basins. Other time periods, the changes are similar only in some of the sub basins. All the sub basins had low runoff values in the early to mid 70's and higher in the end of the 90's. In the Baltic Proper, the Gulf of Riga and the Gulf of Finland, there were high values from the mid 50's to the beginning of the 60's. In the Gulf of Bothnia, the Gulf of Riga and the Gulf of Finland, there was an episode of increasing values during the 80's while in the Baltic Proper, there was a tendency of decreasing values. There were low values in the Baltic Proper in the early 90's while there were high values in the end of the 80's and at the start of the 90's in the Gulf of Riga, the Gulf of Finland and the Gulf of Bothnia.

The total runoff to the Baltic Sea is mostly influenced by the sub basins with the largest contributions, obviously. The highest contribution is from the Gulf of Bothnia followed by the Gulf of Finland and the Baltic Proper. When comparing the Gulf of Bothnia to the Gulf of Finland, there is a rather good correlation in the features of the running mean values. When comparing the Gulf of Bothnia to the Baltic Proper, there are some correspondences but also some deviations in the patterns. The panel displaying the total runoff to the Baltic Sea represents, however, the general features of the different sub basins rather well. Hence, only the panel displaying the total runoff to the Baltic Sea is compared to the NAO index.

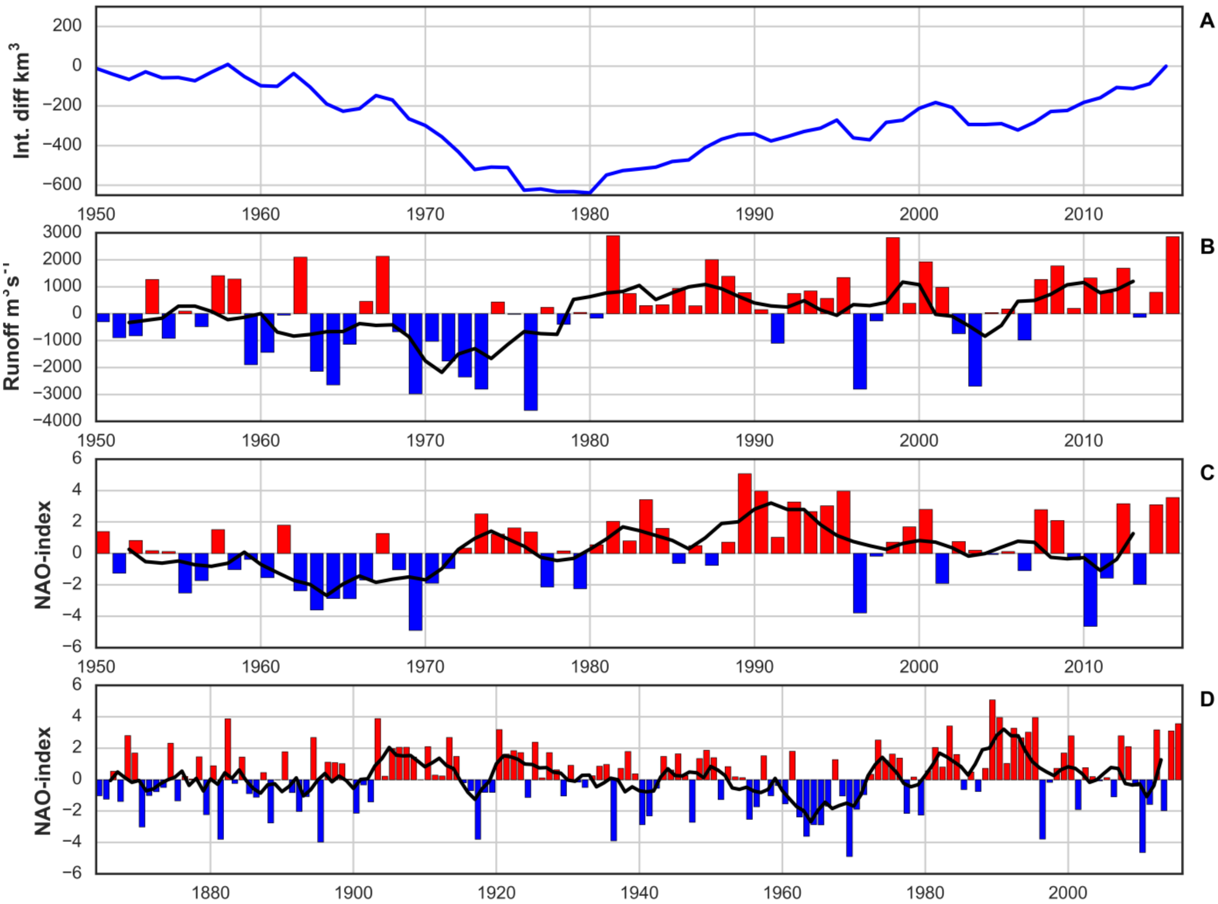

Figure 1. Panel A: The integrated deviations of the runoff to the Baltic Sea. B: Total runoff deviation during 1950 – 2015 to the Baltic Sea. C: NAO index during 1950 – 2015 based on winter mean values of the NAO index. Positive index indicates stronger westerly winds bringing warmer and wetter winters to Scandinavia. D: NAO index during the years 1864 – 2015. B-D: The black line represents the five year running mean for each panel.

Figure 2 displays the total runoff deviation during 1950 to 2015 to the Baltic Sea, both as integrated difference (**A**) (sum of abnormalities from the mean (1950-2015), starting and ending with 0 km^3) and with bars displaying the year to year deviation from the mean (**B)**. The integrated difference gives an idea of the total amount of runoff in the Baltic Sea. The NAO index during the years 1950 – 2015 based on winter mean values of the NAO index is presented in panel **C**. The black line shows the five year running mean. By comparing the running means of panel **B** and **C** between 1952 and onwards, the features correspond rather well with each other. Note though, that there are exceptions where the NAO index does not reflect the total runoff from the Baltic Sea e.g. in 1962, 1976 and 2010.

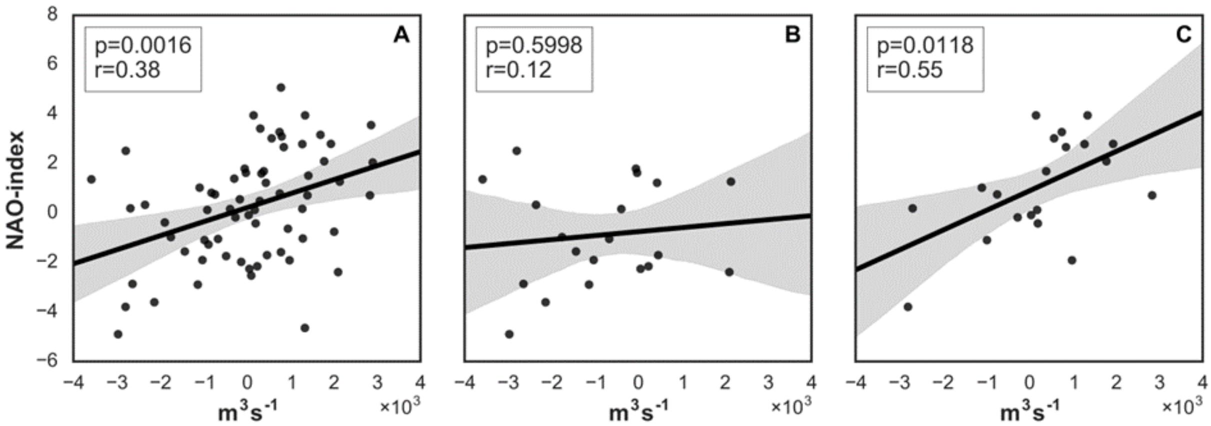

Figure 2. Correlation patterns between the NAO index and the total runoff to the Baltic Sea for different time periods. A: Time period 1950-2015. B: 1960-1979. C: 1990-2009. A low p-value (<0.05) is often used to determine a statistical significance of a dataset. A high r-value is used to determine how strong a correlation is, r-values >0.5 is considered to be a moderate correlation.

However, based on a positive correlation with a p-value of 0.0016 (Figure 3), the NAO indices may be used to indicate general runoff to the Baltic Sea back in time. This motivates the inclusion of the NAO indices for longer time series presented in panel D (Figure 2). Furthermore, looking at certain time periods, the correlation between the NAO index and total runoff deviation is rather good (r=0.55, 1990-2009). For other time periods there seems to be no correlation at all (r=0.12, 1960-1979), which indicates a more stochastic behaviour of the cohesion between Baltic Sea runoff and NAO index.

Many discussions have focused on whether global warming would increase river runoff in the Baltic Sea region, as suggested by most models and climate scenarios. A 500 year reconstruction of river runoff has, on the other hand, indicated a decrease of the total runoff to the Baltic Sea with increasing temperature as an effect of increased evaporation (Hansson et al., 2010). There are clearly uncertainties associated to river runoff that need to be further investigated.

References

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http://climatedataguide.ucar.edu/guidance/hurrell-north-atlantic-oscillation-nao-index-station-based

Data

Observations are collected at the BALTEX Hydrological Data Centre (http://www.smhi.se/sgn0102/bhdc/bhdc.htm) (1950-1980), whereas modelled data is obtained at SMHI using the E-HYPE model (1981-2015) (http://hypeweb.smhi.se/). There might be some inconsistencies regarding the result from the observations and the model. The NAO indices are collected from https://climatedataguide.ucar.edu/sites/default/files/nao_station_djfm.txt