Total and regional Runoff to the Baltic Sea

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SMHI

Key message

Gulf of Bothnia, Gulf of Finland and the Baltic Proper had a higher runoff in 2011 compared to the 1950 – 2010 mean values, while for the Gulf of Riga the runoff was just above its mean value. The difference from the mean value was about 6% in the Gulf of Bothnia, 2% in the Gulf of Finland, 0% in the Gulf of Riga and 26% in the Baltic Proper. When looking at the entire Baltic Sea, the difference from the mean value was almost 10%, hence the general runoff for the entire area was higher compared to the long term mean of the yearly runoff.

The last two years, the total runoff to the Baltic Sea has been above the 1950 – 2010 mean value. When comparing the last decade with previous decades, there are more similarities with the sixties and the seventies than with the eighties or nineties. If 2010 – 2011 are the first years of many to come with flow rates above mean, or if they are an exception in a longer period of lower flow rates, the future will tell. The 5-year running mean value has been increasing since 2004, and is now above the long term mean value.

For the period 1950 – 2011, the total runoff to the Baltic Sea area 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.

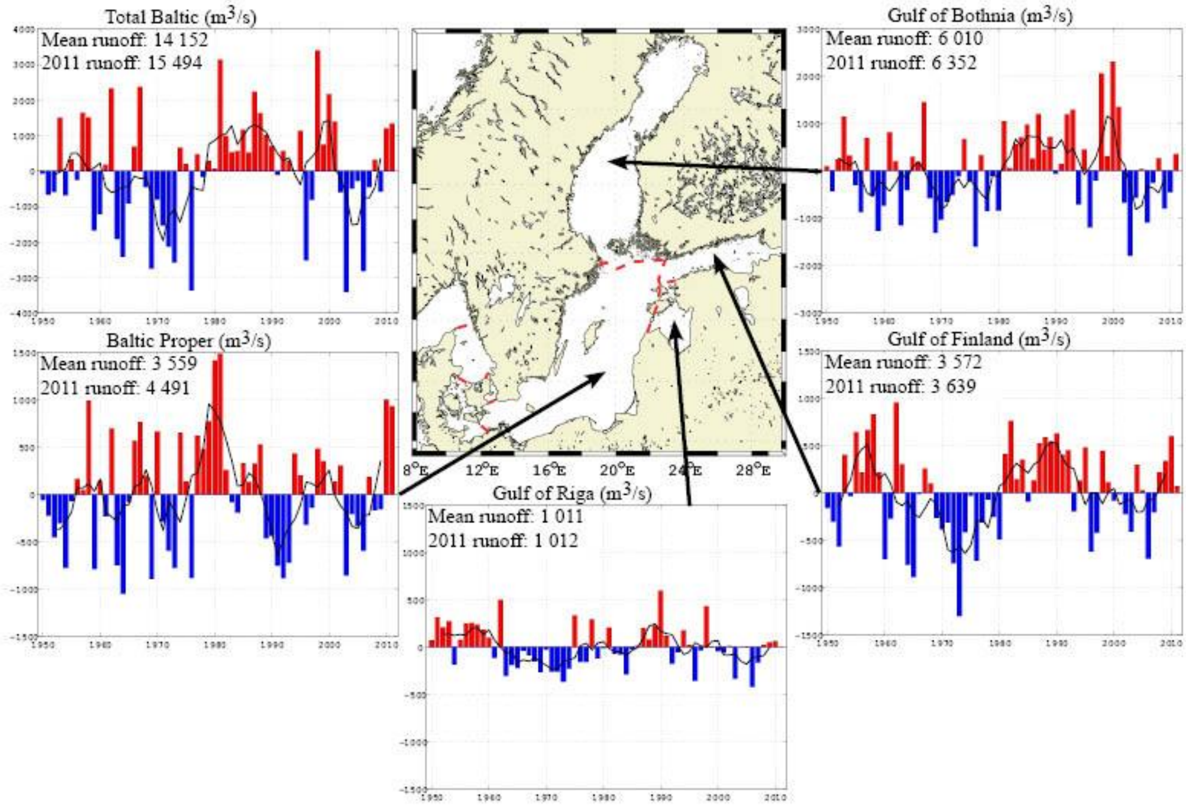

Figure 1. Total runoff deviation during the years 1950 – 2011 to the Baltic sub basins based on annual mean values. The mean runoff value and the 2011 value for each sub basin are written within each figure. The black line is the running mean over 5 years.

Results and Assessment

Relevance of the indicator for describing developments in the environment

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

Runoff is an important parameter for the change of pressure on nutrient supply due to varying climate and climate change. Also change in land-use can influence runoff. To evaluate the change of pressure on 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 deviations from their mean values based on runoff during 1950 to 2010. The mean values and the 2011 values are shown in the top left corner in each sub basin figure (Figure 1). Years with higher runoff compared to the mean value are displayed as red bars and lower values with blue bars. A 5-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 – 2011, 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. 2011 was a year with runoff above normal values in all sub basins, see Table 1.

Table 1. Mean of the annual mean runoff values [m^3/s] for the sub basins in the Baltic Sea compared to the 2011 values and the difference in %.

	Mean runoff 1950-2010 [m^3/s]	Runoff 2011 [m^3/s]	Difference from mean [%]
Gulf of Bothnia	6 010,0	6 351,7	5,7
Gulf of Finland	3 571,7	3 638,9	1,9
Gulf of Riga	1 010,9	1 012,2	0,1
Baltic Proper	3 559,2	4 490,7	26,2
Total Baltic Sea	14 151,9	15 493,5	9,5

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 at the end of the 80's and 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 pattern. The figure displaying the total runoff to the Baltic Sea represents, however, the general features of the different sub basins rather well. Hence, only the figure displaying the total runoff to the Baltic Sea is compared to the NAO index.

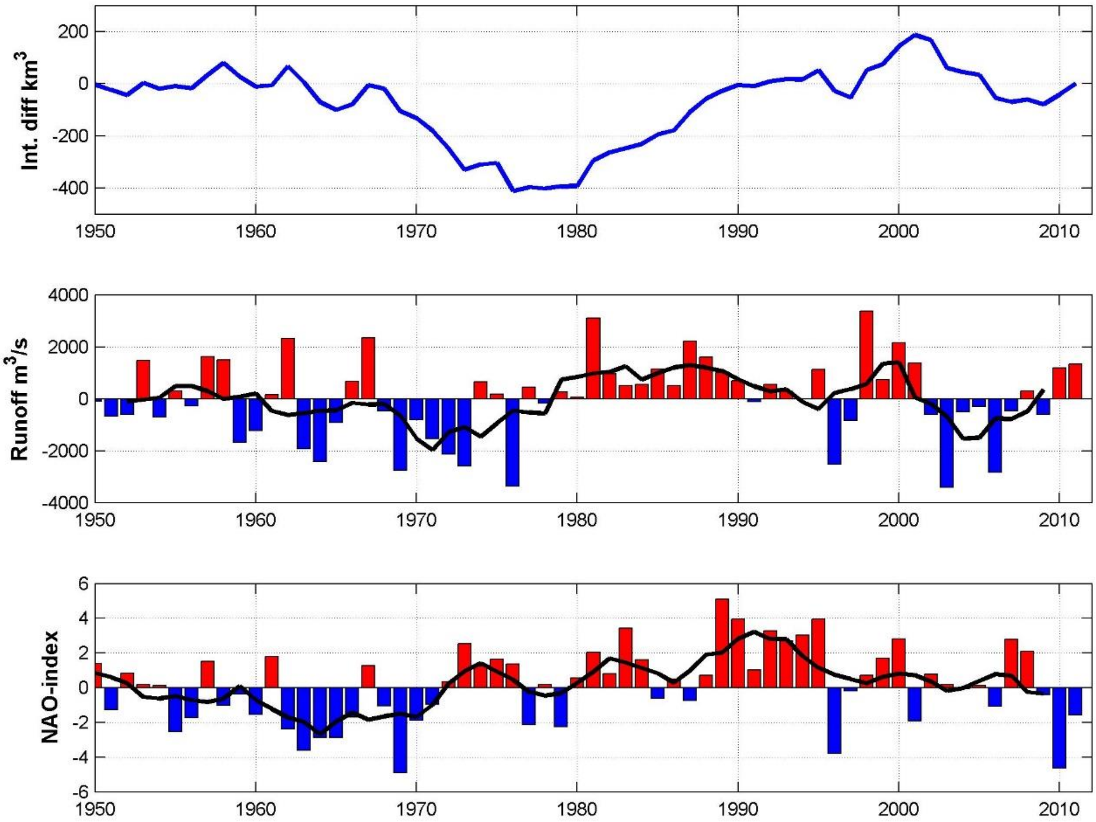

Figure 2. Total runoff deviation during 1950 – 2011 to the Baltic Sea and the NAO index during the years 1864 – 2011 based on winter mean values of the NAO index. Positive index indicates stronger westerly winds bringing warmer and wetter winters to Scandinavia. The black line shows the 5-year running mean. In the upper panel the integrated deviations of the runoff to the Baltic Sea is presented.

Figure 2 displays the total runoff deviation during 1950 to 2011 to the Baltic Sea, both as integrated difference (sum of abnormalities, starting and ending with 0 km^3 1950 and 2011) and with bars displaying the year to year deviation from the mean. The NAO index during the years 1864 – 2011, based on winter mean values of the NAO index, is displayed at the bottom of the figure. The integrated difference gives an idea of the total amount of runoff in the Baltic Sea. The black line shows the 5-year running mean. By comparing the running mean of the two lower figures between 1952 and onwards, the features correspond rather well with each other. Since there seems to be some positive correlation, the NAO indices may be used to indicate general runoff to the Baltic Sea back in time. This is the motivation of including the longer time series of the NAO indices. There is a slight tendency to high NAO indices around 1910 and 1990 and low values around 1960.

References

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Bergström, S. and B. Carlsson 1994. River runoff to the Baltic Sea 1950 – 1990. AMBIO Vol. 23, No. 4-5, 280-287.

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Data

Observations are collected at the BALTEX Hydrological Data Centre (http://www.smhi.se/sgn0102/bhdc/bhdc.htm), whereas modelled data is obtained at SMHI using the HBV-model (Graham-99) and Balt-HYPE (Arheimer et al. 2012). Gulf of Riga runoff is based observations up through 2001, while simulations are used for 2002. Gulf of Finland runoff is based on observations up through 1997, while simulations are used for 1998 – 2002. Baltic Proper runoff is based on observations up through 1996, while simulations are used for 1997 – 2003. For 2003 to 2009 all data is based on HBV model simulations. From 2010 onwards all data is based on the Balt-HYPE model. Please note the change of model from HBV to Balt-HYPE made in 2010. There might be inconsistency regarding the result from the two models. The NAO indices are collected from https://climatedataguide.ucar.edu/sites/default/files/cas_data_files/asphilli/nao_station_djfm.txt

Table 2. NAO index and annual mean values of runoff [m^3/s] to the sub basins in the Baltic Sea during 1950 to 2011.

Year	NAO index	Bothnian Bay [m^3/s]	Bothnian Sea [m^3/s]	Gulf of Finland [m^3/s]	Gulf of Riga [m^3/s]	Baltic Proper [m^3/s]	Total Baltic Sea [m^3/s]	% Notes:
1950	1,40	2 867,7	3 225,7	3 409,3	1 081,9	3 501,7	14 086,3	%BB & BS are observations
1951	-1,26	2 904,1	2 667,8	3 264,0	1 322,5	3 336,7	13 495,1	%GOR is observations up through 2001
1952	0,83	3 625,1	2 614,6	3 001,8	1 216,7	3 106,0	13 564,3	%GOR uses HBV simulations for 2002
1953	0,18	3 785,6	3 363,7	3 969,4	1 282,4	3 255,4	15 656,5	%GOF is observations up through 1997
1954	0,13	3 512,3	2 810,4	3 536,1	825,7	2 782,8	13 467,3	%GOF uses HBV simulations for 1998-2002
1955	-2,52	3 251,4	2 448,4	4 209,0	1 082,9	3 489,8	14 481,4	%BP is observations up through 1993
1956	-1,73	2 563,8	2 569,5	3 784,0	1 258,2	3 725,2	13 900,7	%BP uses replacement stations for 1994-1996
1957	1,52	3 468,6	3 223,0	4 231,5	1 264,2	3 607,6	15 794,9	%BP uses HBV simulations for 1997-2002
1958	-1,02	3 025,8	2 451,4	4 395,9	1 244,8	4 552,2	15 670,1	
1959	-0,37	2 433,1	2 304,4	3 785,3	1 194,0	2 771,3	12 488,2	
1960	-1,54	2 329,2	2 940,5	2 868,0	1 107,4	3 704,6	12 949,6	
1961	1,80	3 352,8	3 458,4	3 296,4	892,5	3 329,4	14 329,4	
1962	-2,38	3 217,2	2 982,8	4 521,3	1 507,7	4 254,7	16 483,7	
1963	-3,60	2 577,2	2 282,3	3 867,8	707,1	2 814,5	12 248,8	
1964	-2,86	3 109,3	2 487,2	2 807,6	824,5	2 511,9	11 740,6	
1965	-2,88	3 566,1	2 734,0	2 679,8	790,4	3 479,7	13 250,1	
1966	-1,69	2 976,7	3 206,1	3 560,0	973,1	4 126,8	14 842,6	
1967	1,28	3 946,0	3 499,1	3 826,6	924,6	4 323,2	16 519,5	
1968	-1,04	2 838,1	2 593,1	3 667,5	859,2	3 757,2	13 715,1	
1969	-4,89	2 510,1	2 185,6	3 304,5	743,3	2 669,0	11 412,5	
1970	-1,89	2 473,5	2 492,3	3 185,0	983,3	4 223,2	13 357,4	
1971	-0,96	2 674,7	2 674,3	3 255,2	751,1	3 272,3	12 627,6	
1972	0,34	2 829,6	2 657,2	2 826,7	749,4	2 966,9	12 029,9	
1973	2,52	3 303,5	2 585,6	2 268,5	644,1	2 783,3	11 585,0	
1974	1,23	3 581,6	3 085,2	3 156,8	783,3	4 209,5	14 816,4	
1975	1,63	3 167,1	2 612,5	3 538,2	1 342,0	3 698,2	14 358,1	
1976	1,37	2 413,4	1 993,0	2 855,7	855,0	2 678,5	10 795,7	
1977	-2,14	3 484,4	2 844,5	3 256,7	855,5	4 180,1	14 621,2	
1978	0,17	2 642,0	2 514,1	3 498,4	1 299,9	4 038,7	13 993,0	
1979	-2,25	3 069,3	2 828,7	3 315,3	890,4	4 331,8	14 435,4	
1980	0,56	2 549,7	2 617,0	3 078,4	999,9	4 974,8	14 219,8	
1981	2,05	3 678,8	3 367,9	3 977,1	1 212,6	5 045,6	17 281,8	
1982	0,80	3 305,4	2 749,0	4 327,9	937,8	3 816,1	15 136,2	
1983	3,42	3 513,1	3 053,8	3 711,3	930,5	3 477,5	14 686,1	
1984	1,60	3 421,0	3 284,5	3 918,5	721,6	3 371,0	14 716,7	
1985	-0,63	3 360,8	3 611,7	3 476,7	988,9	3 886,7	15 324,7	
1986	0,50	3 131,2	3 129,3	3 700,3	1 024,4	3 691,3	14 676,4	
1987	-0,75	3 492,0	3 711,2	4 092,6	1 210,5	3 883,0	16 389,3	
1988	0,72	3 140,2	3 306,3	4 153,9	1 088,7	4 088,5	15 777,5	
1989	5,08	3 691,6	3 028,3	4 109,4	1 237,6	3 100,4	15 167,3	
1990	3,96	2 840,6	3 101,3	4 194,2	1 603,5	3 124,4	14 864,0	
1991	1,03	3 353,6	2 791,9	3 971,7	1 127,8	2 809,2	14 054,3	
1992	3,28	3 972,9	3 215,8	4 018,8	834,5	2 675,8	14 717,7	
1993	2,67	3 765,1	3 522,8	3 373,1	955,0	2 840,1	14 456,0	
1994	3,03	2 786,7	2 504,2	3 699,4	1 184,5	3 990,6	14 165,4	%replacement stations used for BP!
1995	3,96	3 249,8	3 204,2	4 047,0	1 029,5	3 761,0	15 291,5	%replacement stations used for BP!
1996	-3,78	2 795,7	2 013,4	2 950,6	651,5	3 239,3	11 650,4	%replacement stations used for BP!
1997	-0,17	3 056,3	2 739,6	3 147,8	975,7	3 420,7	13 340,1	%HBV simulations used for BP!
1998	0,72	4 173,6	3 883,9	4 009,2	1 437,0	4 040,9	17 544,5	%HBV simulations used for BP & GOF!
1999	1,70	3 390,0	2 916,5	3 679,1	1 015,1	3 908,6	14 909,3	%HBV simulations used for BP & GOF!
2000	2,80	4 204,0	4 099,0	3 487,6	967,3	3 567,0	16 324,9	%HBV simulations used for BP & GOF!
2001	-1,90	3 541,0	3 803,7	3 554,4	953,4	3 696,5	15 548,9	%HBV simulations used for BP & GOF!
2002	0,76	2 800,6	2 532,9	3 344,4	1 018,0	3 864,2	13 560,0	%HBV simulations used for BP, GOF & GOR!
2003	0,20	2 354,0	1 856,0	3 160,0	677,0	2 706,0	10 752,0	%HBV simulations used for all subbasins
2004	-0,07	3 190,0	2 245,0	3 864,0	1 011,0	3 354,0	13 665,0	%HBV simulations used for all subbasins
2005	0,13	3 357,5	2 684,4	3 592,2	1 013,5	3 228,7	13 876,2	%HBV simulations used for all subbasins
2006	-1,09	2 593,0	2 320,4	2 873,6	588,7	2 967,5	11 343,2	%HBV simulations used for all subbasins
2007	2,79	3 421,3	2 327,3	3 365,8	849,2	3 744,0	13 707,5	%HBV simulations used for all subbasins
2008	2,10	3 727,2	2 537,7	3 784,5	1 031,1	3 392,0	14 472,5	%HBV simulations used for all subbasins
2009	-0,41	2 557,0	2 648,2	3 905,5	1 060,7	3 404,0	13 575,3	%HBV simulations used for all subbasins
2010	-4,64	3 062,2	2 489,4	4 165,0	1 073,6	4 562,3	15 352,5	%Balt-Hype simulations used for all subbasins
2011	-1,57	3 818,2	2 533,5	3 638,9	1 012,2	4 490,7	15 493,5	%Balt-Hype simulations used for all subbasins

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