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River runoff forcing for ocean modeling within the Baltic Sea Model Intercomparison Project

Germo Väli, H.E. Markus Meier, Manja Placke, Christian Dieterich

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Schriftleitung: Dr. Norbert Wasmund (norbert.wasmund@io-warnemuende.de)

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Adressen der Autoren:
1 Tallinn University of Technology, Department of Marine Systems, Akadeemia tee 15a, Tallinn, Estonia
2 Leibniz Institute for Baltic Sea Research (IOW), Seestraße 15, D-18119 Rostock-Warnemünde, Germany
3 Swedish Meteorological and Hydrological Institute, Folkborgsvägen 17, Norrköping, Sweden

E-mail der verantwortlichen Autoren: germo.vali@taltech.ee, markus.meier@io-warnemuende.de

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Kurzfassung

Das Baltic Sea Model Intercomparison Project (BMIP) wurde ins Leben gerufen, um unterschiedliche Prozesse in der Ostsee mit numerischen Modellen verschiedener Institute und Gruppen zu untersuchen, wobei alle Modelle mit denselben Atmosphärenbedingungen und Süßwassereinträgen angetrieben werden. Der vorliegende Bericht liefert eine Beschreibung und einen Überblick über den gemeinsam in BMIP genutzten Flusswasserantrieb für den Zeitraum 1961-2018. Dieser Antriebsdatensatz basiert ursprünglich auf Simulationen des hydrologischen Modells E-HYPE (Hindcast und Prognosen), die um verfügbare Beobachtungen des Flusses Newa und historische Rekonstruktionen erweitert wurden. Der endgültige Datensatz umfasst Flusswassereinträge mit täglicher Auflösung für 91 Standorte im Ostseeraum und stimmt gut mit den zuvor verfügbaren Datensätzen überein.

Abstract

The Baltic Sea Model Intercomparison Project (BMIP) aims to study different processes in the Baltic Sea using numerical models from different institutes and groups forced by the same atmospheric and freshwater forcing. In this report a description and an overview about the common freshwater forcing for the period 1961-2018 is given. Originally based on the hydrological model E-HYPE, the BMIP forcing is compiled from the available observations (Neva river), historical reconstruction and hydrological model simulations (hindcast and forecast simulations by the E-HYPE). The final homogenized dataset has daily resolution in freshwater discharge from 91 locations in the Baltic Sea region and is in good agreement with previously available datasets.

1 Introduction

The aim of the Baltic Sea Model Intercomparison Project (BMIP) is to compare simulations of the recent past from different ocean models for the Baltic Sea forced with the same atmospheric and hydrological data. Main objective is not only to compare statistical differences, but the ability of models to simulate different processes important to the Baltic Sea climate such as mixed layer dynamics, upwelling, sea ice cover, saltwater inflows etc.

In order to be comparable, within the project it is recommended that the different models use identical forcing and one key forcing for the Baltic Sea is the freshwater input. Therefore, all the models should use identical freshwater input (at least regarding the amounts and key locations). The aim of this document is to give an overview how the common forcing dataset was compiled.

2 Base forcing

The basis for the creation of the common runoff forcing is the NEMO-Nordic (Hordoir et al. 2019) forcing dataset. The runoff in NEMO-Nordic is introduced as a mass flux and it is already available on a 2 nautical mile model grid. In this dataset the long-term runoff is based on the E-HYPE (Hydrological Predictions for the Environment applied for Europe, e.g. Lindström et al. 2010) hindcast simulation for the period 1979-2011, which uses a regional downscaling of ERA-Interim (Dee et al. 2011) with RCA3 (Samuelsson et al. 2011) as a forcing. For the period 2012-2018, a forecast model product (Donnelly et al. 2016) based on E-HYPE is available and for the period 1961-1978 climatological runoff data were used. The climatological runoff was constructed from the years 1979 to 2008 of the E-HYPE ERA-Interim hindcast.

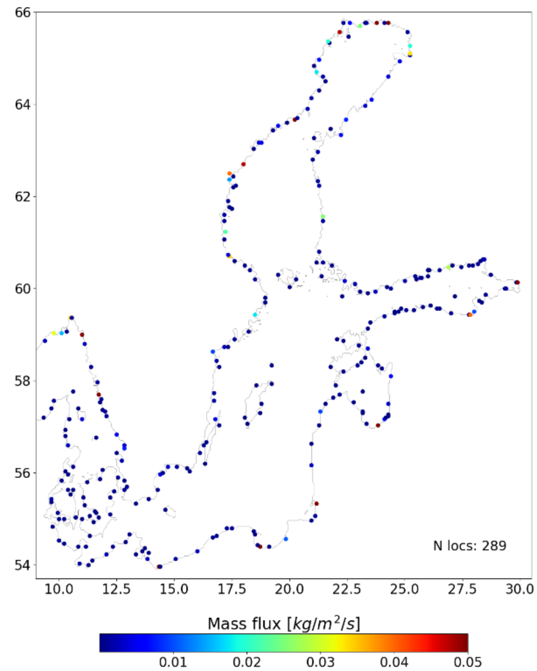

Figure 1: Long-term mean freshwater input to NEMO-Nordic during 1979-2011 based on E-HYPE hindcast. Colors mark the river flow from the location.

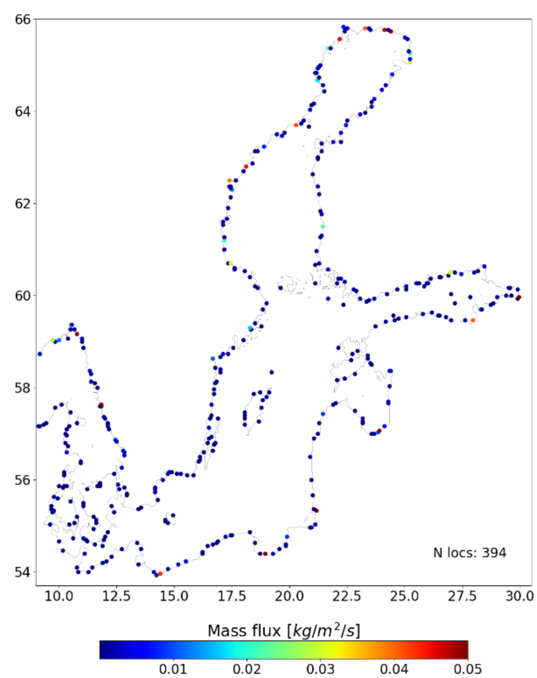

Figure 2: Long-term mean freshwater input to NEMO-Nordic during 2012-2018 based on an operational version of E-HYPE. Colors mark the river flow from the location.

The freshwater input locations differ between the products (Figs. 1 and 2) and in order to generate consistent forcing, common locations for freshwater sources have to be defined for both datasets.

3 Method

3.1 Spatial resampling of freshwater sources

In order to generate consistent forcing for the Baltic Sea, we defined 20x20 nautical mile boxes and used locations of freshwater input from the hindcast dataset larger than 10 $m^3 s^{-1}$ in order to define the initial locations of the rivers in the new forcing dataset. In total, we generated 97 possible river locations (Fig. 3), which were reduced to 91 locations in the final dataset (see Fig. 5 and page 9 for details). Freshwater sources, initially located outside the defined boxes, were added to the closest box.

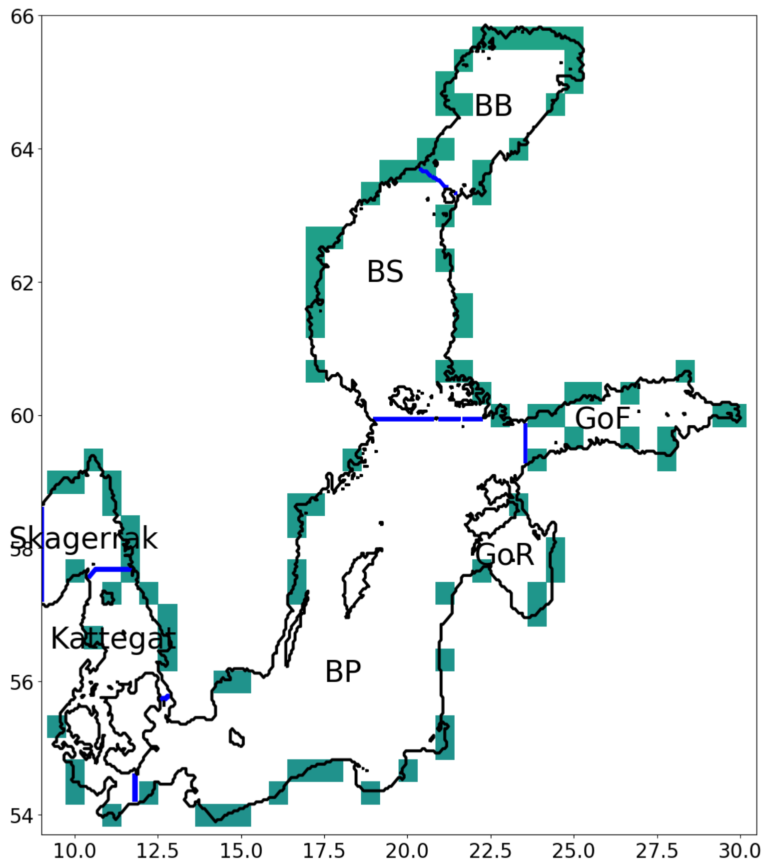

Figure 3: Location of boxes and the domains of different basins. BP – Baltic proper, GoF – Gulf of Finland, GoR – Gulf of Riga, BS – Bothnian Sea and BB – Bothnian Bay.

The freshwater input to the different basins of the Baltic Sea has previously been studied by different authors. BERGTRÖM & CARLSSON (1994), henceforth BC1994, investigated observations of the BALTEX Hydrological Data Center (BHDC) and calculated discharge time-series for the period 1950-1990. They divided the Baltic Sea into seven different sub-basins as shown in Figure 3. These sub-basins are from North to Southwest Bothnian Bay (BB), Bothnian Sea (BS), Gulf of Finland (GoF), Gulf of Riga (GoR), Baltic proper (BP), Sounds and Kattegat. In this study, we combined the runoff into Kattegat and the Sounds and added Skagerrak to the Baltic Sea runoff dataset. For the evaluation, we compared our results and runoff observations from the 30 largest rivers of the BHDC. From all observations of the BHDC, BC1994 calculated sub-basin averages (Fig. 4). These averages were compared with our sub-basin averages as well to ensure the consistency between the datasets. Data of the BHDC have previously also been used by MEIER et al. (1999) as forcing for a Baltic Sea model.

3.2 Temporal corrections

The E-HYPE hindcast simulation was done for the period 1979-2011 using downscaled ERA-Interim as atmospheric forcing. For the period 1961-1978 we have used the dataset by BC1994 interpolated linearly from monthly to daily values.

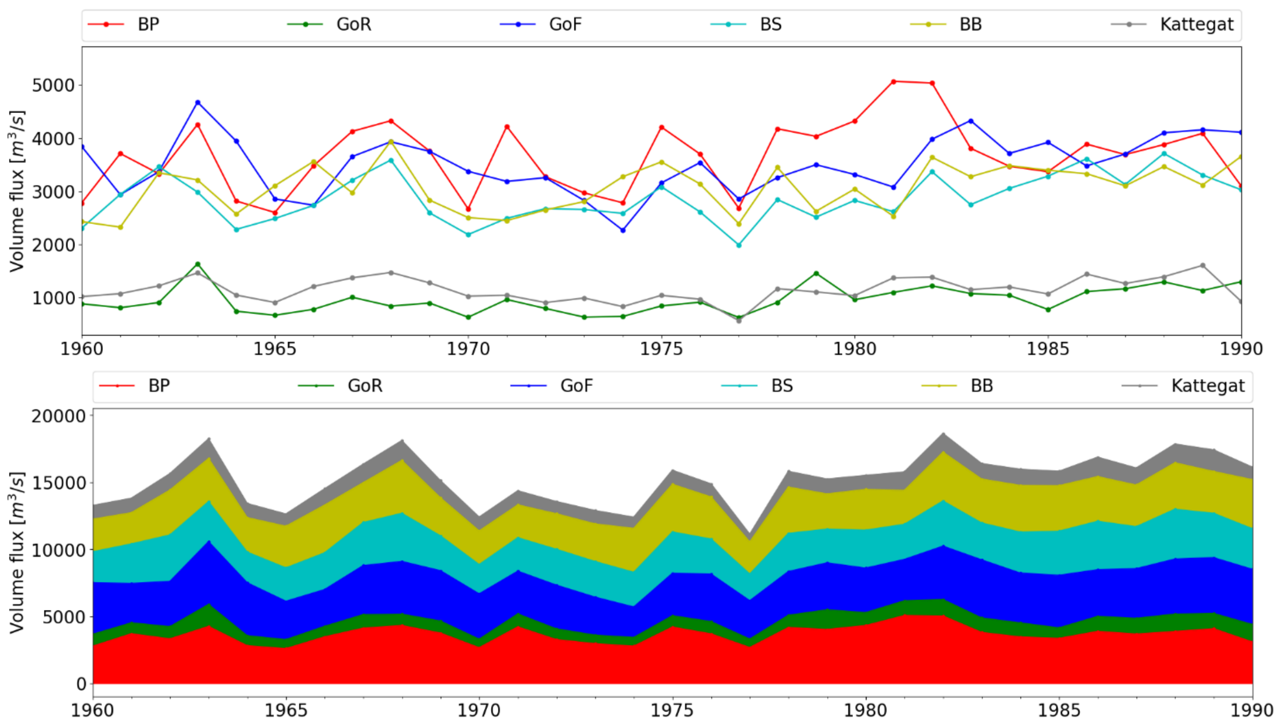

Figure 4: Upper panel: Runoff into the various sub-basins of the BC1994 dataset for the period 1960-1990. Lower panel: Cumulative runoff from BC1994 into various sub-basins.

For 1961-1978 the fractions of the total river discharge to the respective monthly sub-basin runoff from BC1994 based on the source contribution to the sub-basin during the period 1979-2011 have been used. As there is no information about the runoff to the Skagerrak from BC1994, climatological runoff from the NEMO-Nordic runoff forcing will still be used for that domain for 1961-1978.

3.3 Additional spatial and temporal corrections

The NEMO-Nordic forcing has previously been compiled from two simulations performed with two different versions of the E-HYPE model: the hindcast model for 1979-2011 and the operational model since 2012 with data availability for 1989-2018. As seen from Figs. 1 and 2, the grids of the two versions of the E-HYPE model differ and therefore some freshwater sources shift the location. Special care was taken with these freshwater sources in the compiled forcing dataset by combining these sources with the neighboring source. Neighbors were selected manually based on the thorough inspection and expert judgement of the obtained data series. In most of the cases, sums of two neighbors were considered as one freshwater source, but one exception was in the Skagerrak, where three sources had to be combined. In summary, the introduced changes in the compiled dataset do not change the overall freshwater input to the corresponding sub-basins. In total, 91 freshwater sources are in the compiled dataset (Fig. 3).

The segments used in BMIP were 20x20 nautical miles and the central coordinate of the segment was used as coordinate of the freshwater source. Some of these locations were compared with and shifted to the locations of the 30 largest rivers of the BHDC database (see Tab. A1 of the Appendix for details). In addition, the segment coordinates were finally shifted to the closest sea-point at the seashore defined by the widely used Baltic Sea bathymetry by SEIFERT et al. (2001).

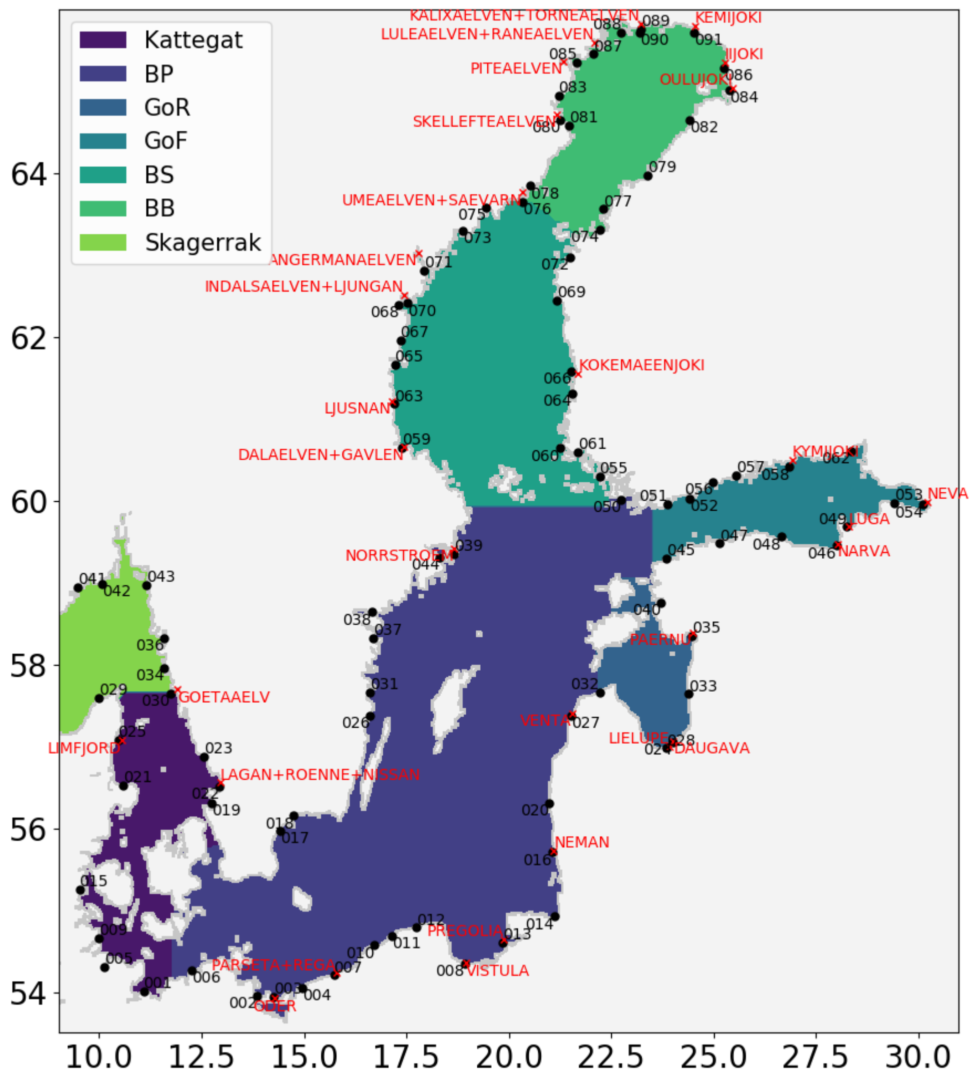

Figure 5: The locations of BMIP freshwater sources (black dots) with the sub-basin map (colored areas) and coastline (grey line). The locations of BHDC rivers from Table 1 are shown in red.

The constructed forcing dataset resulted in too high freshwater input to the GoF. As one of the largest rivers into the Baltic Sea, Neva is the main contributor to the GoF. The constructed time-series of the river discharge from Neva was compared against available observations for the period 1961-2016 and it was decided to use the observed Neva discharge in the final BMIP forcing. For the years 2017-2018 operational E-HYPE runoff was used for all rivers[1].

[1] As data for the final month December 2018 were not delivered yet (November 2019), climatological runoff was used. As soon as the data will become available, the records will be updated.

4 Results

Some examples of river runoff into the Baltic Sea from different datasets are shown in Figures 6 and 7. In the Appendix of this report, a comparison of monthly mean discharge from different datasets is shown for the different rivers of the Baltic Sea. To summarize the biases, the overall mean runoff values for different rivers are listed in Table 1.

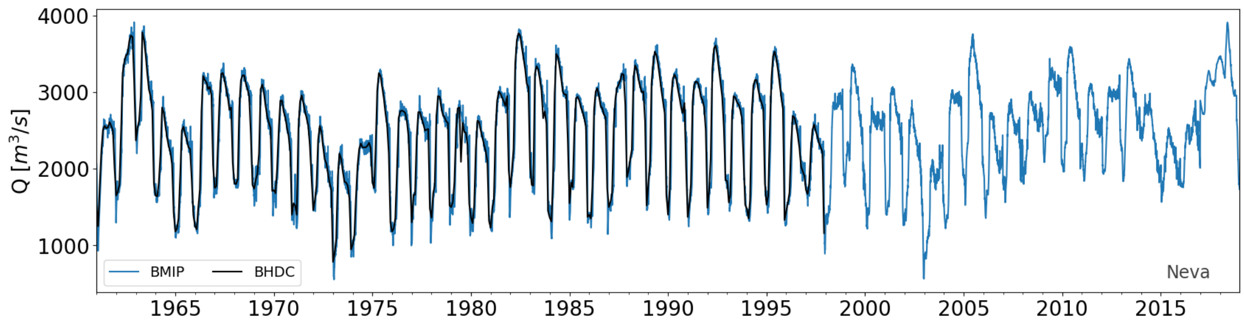

Figure 6: Neva runoff (river_054) in compiled forcing (blue line) and in observations from BHDC (black line) for the period 1961-2018. Note, BMIP and BHDC data have daily and monthly resolutions, respectively.

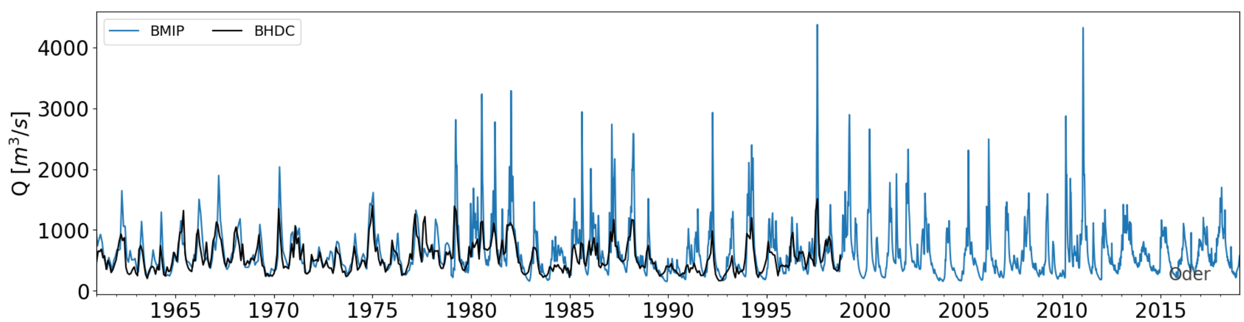

Figure 7: Same as in Fig. 6 but for the river Oder (river_043) located in the Baltic proper. Note, BMIP and BHDC data have daily and monthly resolutions, respectively. Although BMIP data have daily resolution, before 1979, the variability on timescales smaller than one month is zero because the sub-basin wide, historical reconstructions have only monthly values.

Table 1: Mean river runoff of 30 large rivers of the compiled dataset and observations.

River	Mean discharge 1961-1990 [$m^3 s^{-1}$]	
	BMIP	**BHDC**
ANGERMANAELVEN	460.1	511.1
DALAELVEN GAVLEN	440.1	396.7
DAUGAVA	786.7	637.1
GOETAAELV	608.9	577.5
IIJOKI	189.9	168.1
INDALSAELVEN LJUNGAN	569.7	598.1
KALIXAELVEN TORNEAELVEN	709.5	700.9
KEMIJOKI	610.3	620.6
KOKEMAEENJOKI	299.9	240.1
KYMIJOKI	355.7	308.3
LAGAN ROENNE NISSAN	144.2	164.3
LIMFJORD	74.7	154.6
LJUSNAN	277.1	242.4
LUGA	131.6	107.4
LULEAELVEN RANEAELVEN	478.6	549.8
NARVA	478.6	363.7
NEMAN	753.9	613.6
NEVA	2421.7	2417.0
NORRSTROEM	254.2	176.9
ODER	651.6	561.5
OULUJOKI	338.6	259.6
PAERNU	62.9	129.6
PARSETA+REGA	60.6	127.7
PITEAELVEN	185.7	188.6
PREGOLIA	143.1	156.7
SKELLEFTEAELVEN	163.7	172.3
UMEAELVEN SAEVARN	485.4	462.1
LIELUPE	99.5	127.6
VENTA	133.6	171.2
VISTULA	1078.6	1128.5

The comparison between different datasets for some of the sub-basins is shown in Figures 8-10 and mean discharges into the sub-basins for the period 1961-1990 are summarized in Table 2.

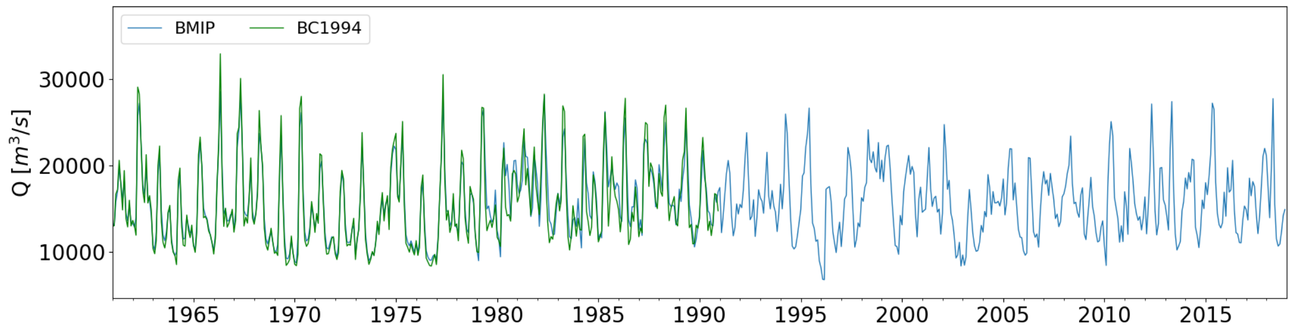

Figure 8: Monthly mean runoff to the Baltic Sea (including Kattegat) for the period 1961-2018.

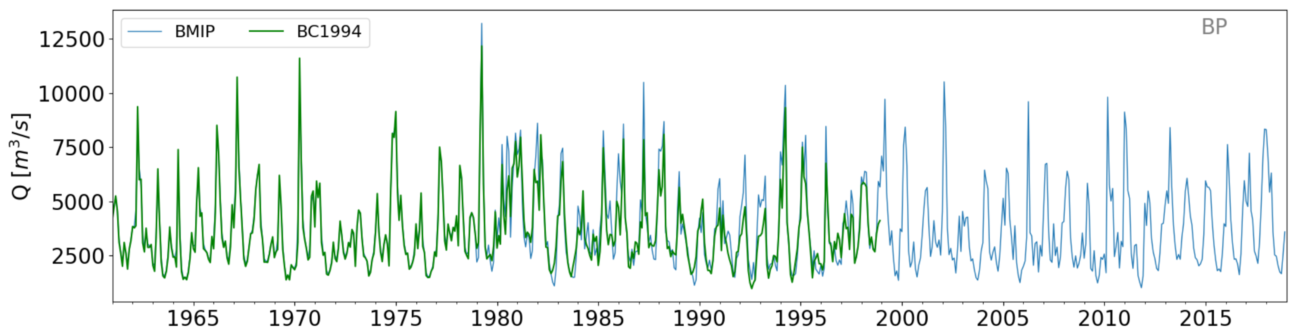

Figure 9: As Fig. 8 but for the monthly mean runoff to the Baltic proper.

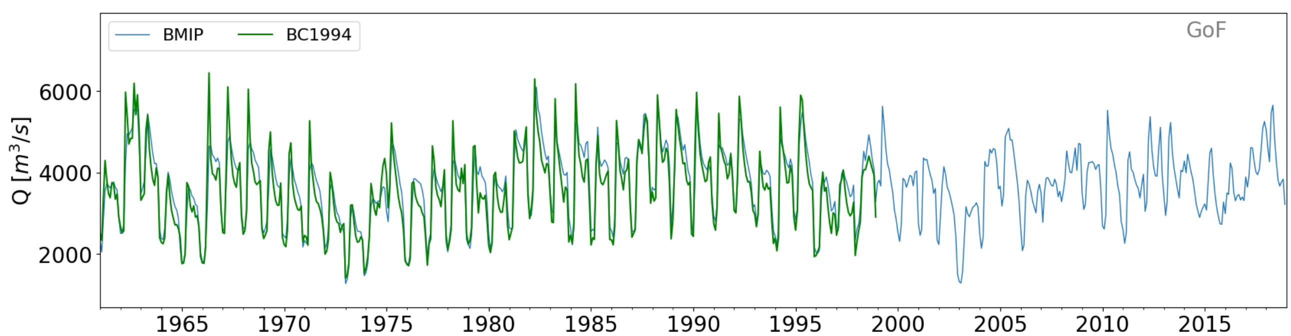

Figure 10: As Fig. 8 but for the monthly mean runoff to the Gulf of Finland.

Table 2: Mean runoff ($m^3\ s^{-1}$) for 1961-1990 in different datasets for different sub-basins.

Basin	BMIP	BC1994
Total Baltic Sea (including Kattegat)	15572.3	15367.2
Kattegat	1190.4	1157.4
Baltic proper	3769.7	3674.8
Gulf of Finland	3641.6	3540.3
Gulf of Riga	1041.9	993.7
Bothnian Sea	2891.1	2892.6
Bothnian Bay	3076.2	3108.4

In principle, the BMIP runoff dataset is in good agreement with the historical dataset of observations for different rivers and with the entire observational dataset compiled by BERGSTRÖM & CARLSSON (1994). Some differences occur in some of the sub-basins, but they are less than 5% (Gulf of Riga) and close to 1% for the overall Baltic Sea.

Summary

For the Baltic Sea catchment area consistent river runoff forcing was constructed and evaluated. The dataset of 91 discharge locations covers the period 1961-2018 with monthly (prior 1978) and daily (after 1979) resolutions and is in good agreement with the earlier available datasets.

In the compiled dataset, the total discharge to the different basins for the period 1961-1978 equals the data by Bergström & Carlsson (1994) and from 1979 onwards it is mainly based on the E-HYPE model results, i.e. hindcast simulation for 1979-2011 and operational forecast for 2012-2018. The only exception is the Neva river for which observations from 1961-2016 are used.

This dataset is open access and publicly available from:
https://thredds-iow.io-warnemuende.de/thredds/catalogs/projects/bmip/catalog_bmip_rivers.html

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Appendix

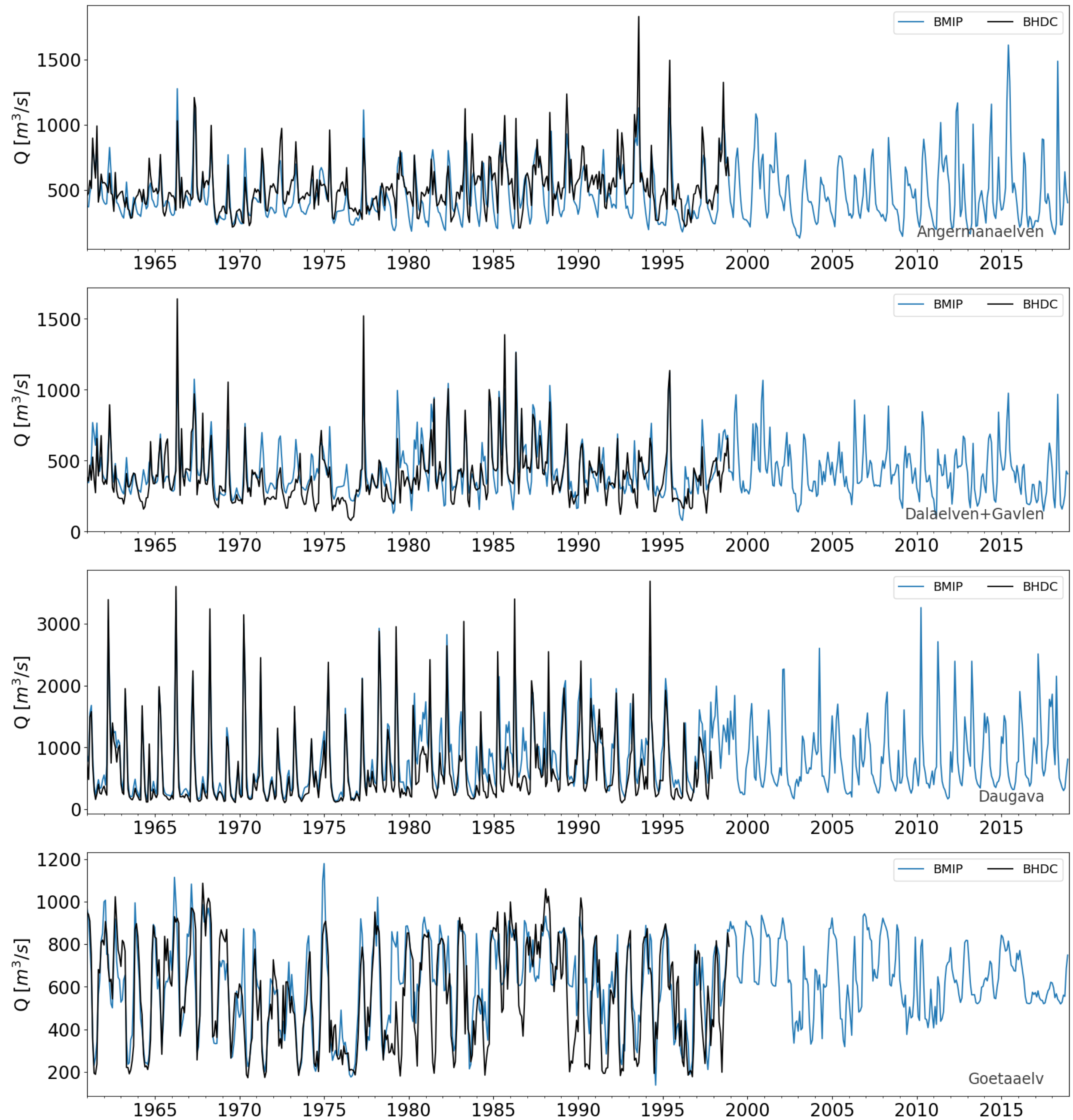

Figure A1: Monthly mean river runoff to the Angermanaelven, Dalaelven with Gavlen, Daugavgriva and Goetaaelv in the BMIP dataset (blue line) and BHDC observations (black line) for the period 1961-2018.

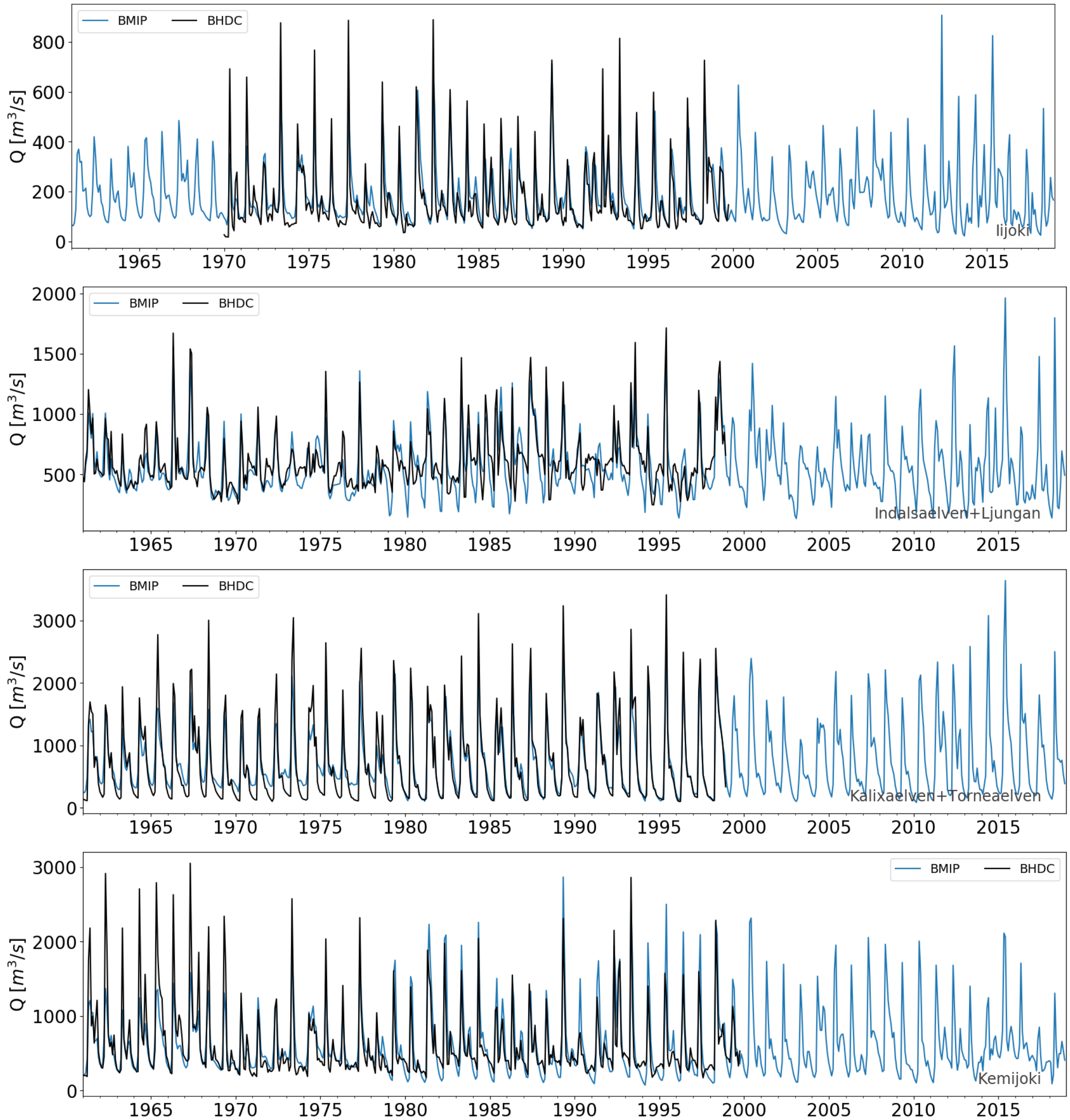

Figure A2: Same as in Fig. A1 but for the rivers Iljoki, Indalsälven and Ljungan, Kalixälven and Torneälven, and Kemijoki.

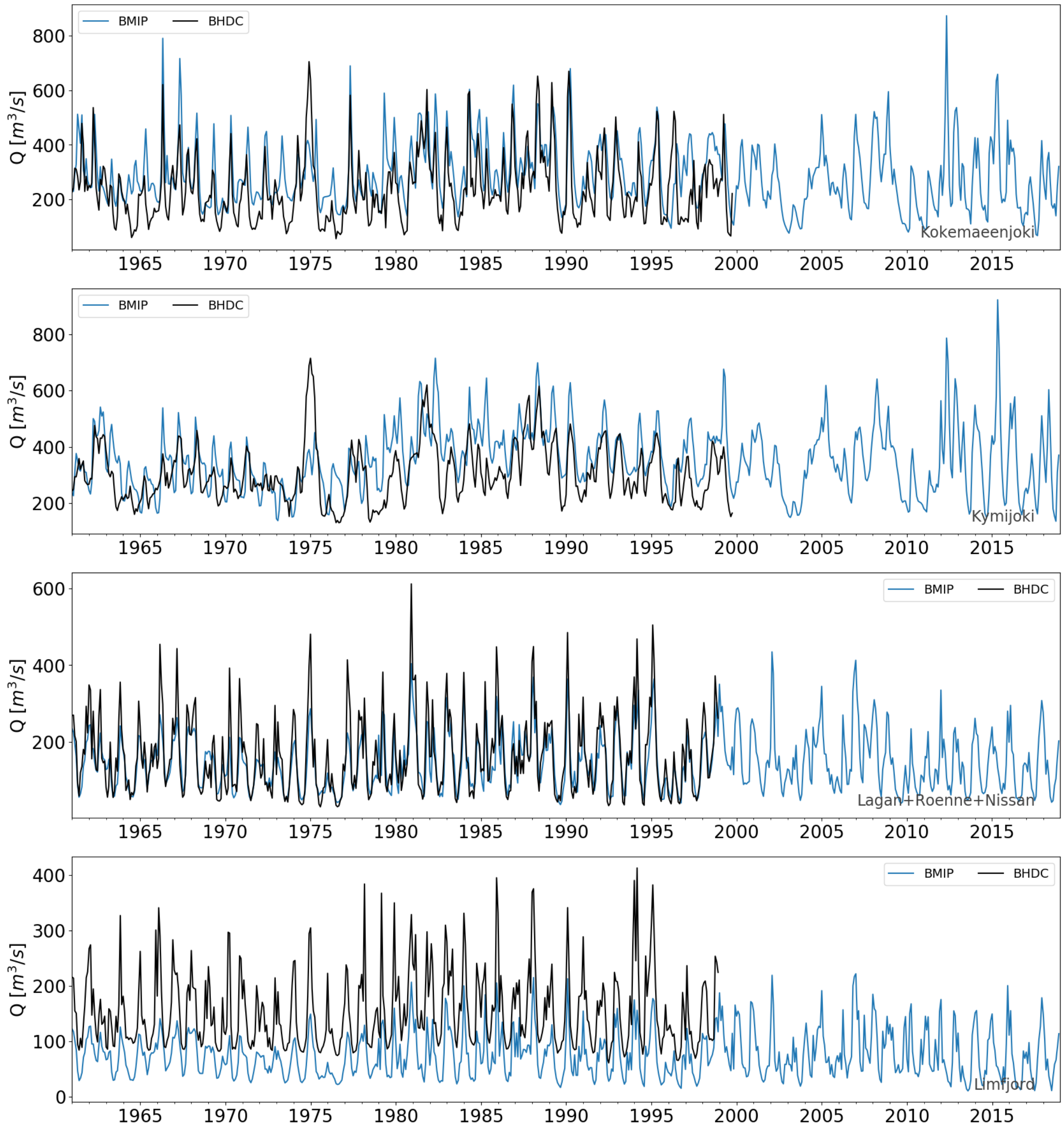

Figure A3: Same as in Fig. A1 but for the rivers Kakemaeenjoki, Kymijoki, Lagan with both Roenne and Nissan, and Limfjord.

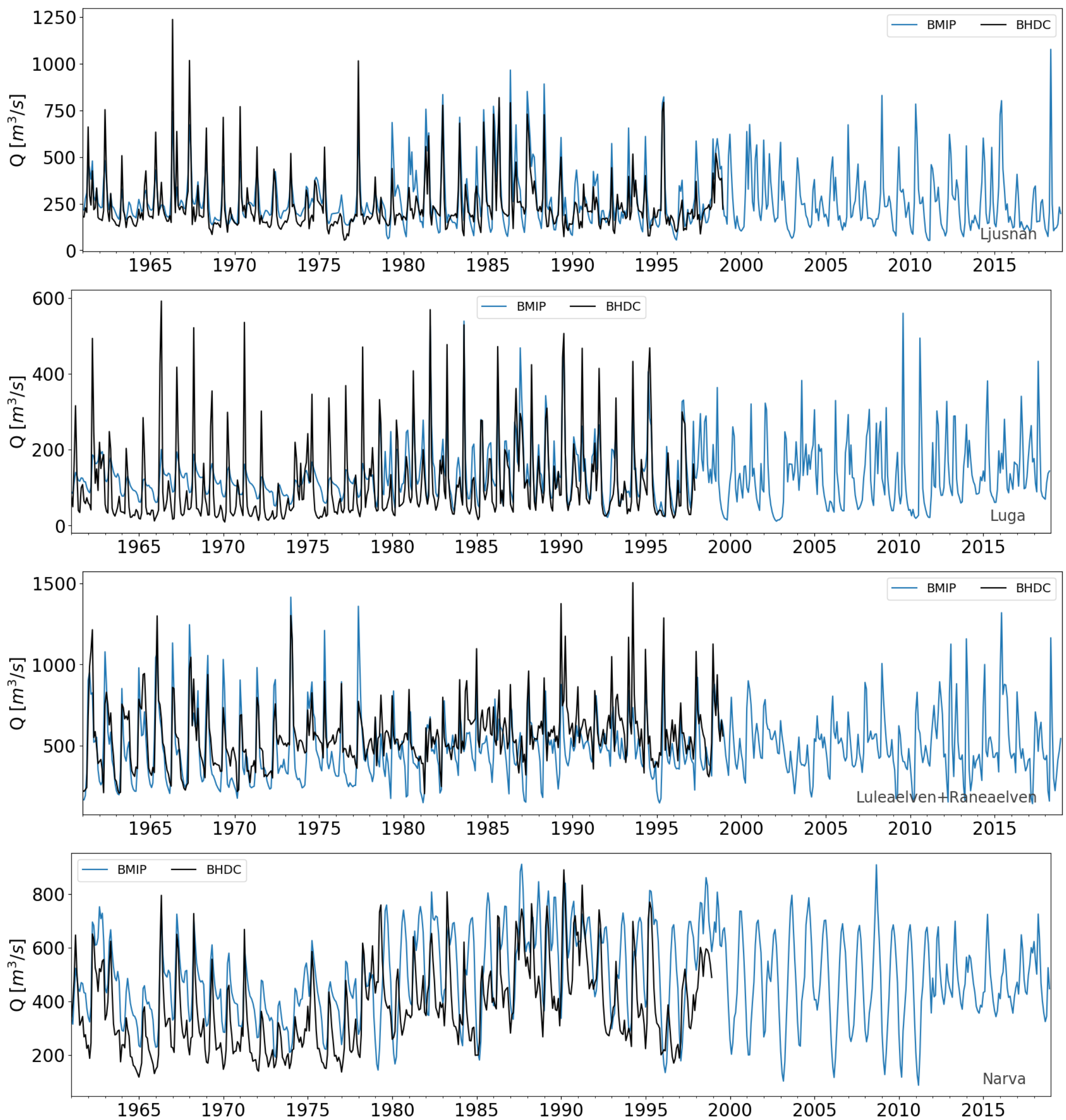

Figure A4: Same as in Fig. A1 but for the rivers Ljusnan, Luga, Luleaelven with Raneaelven and Narva.

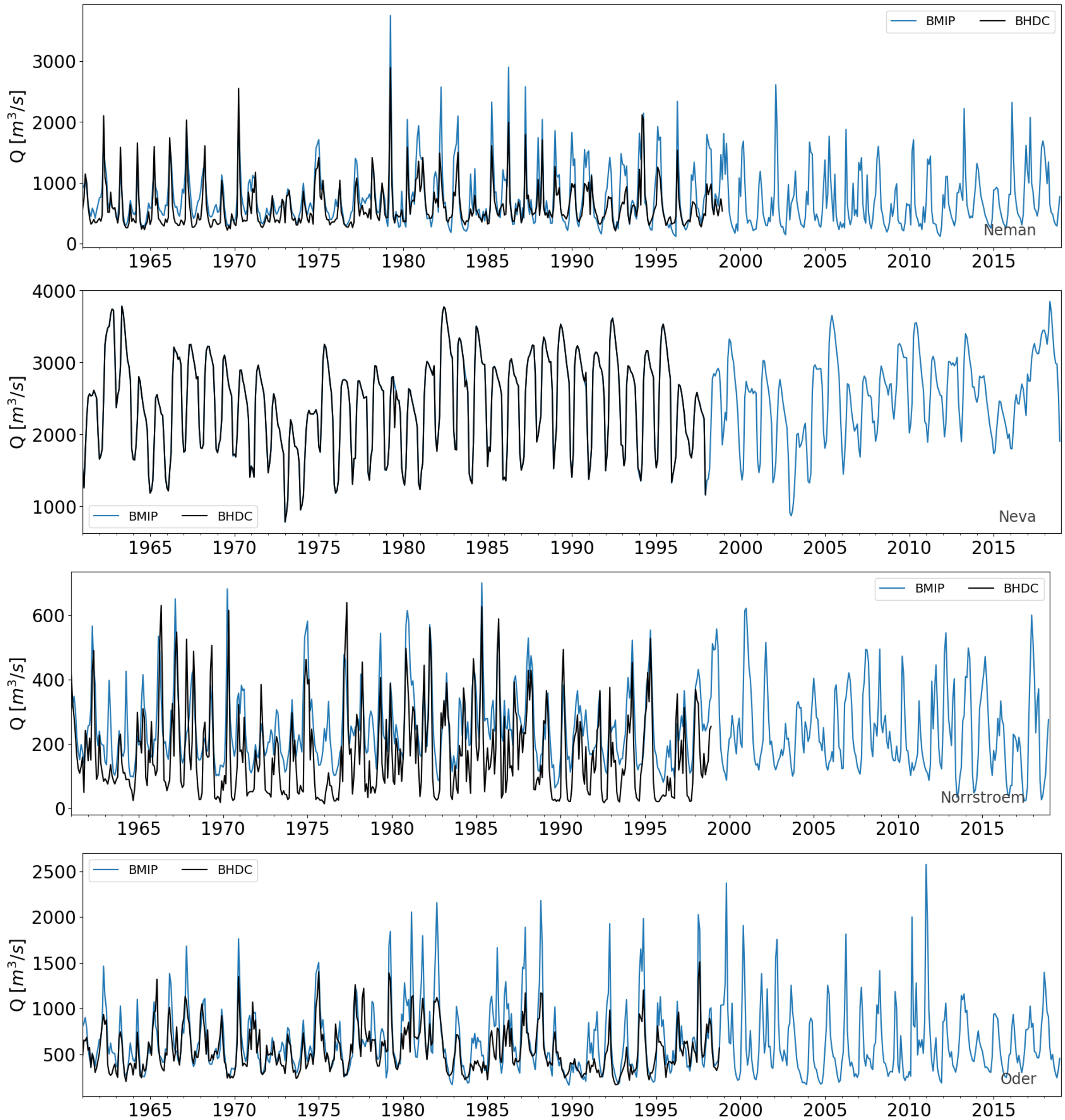

Figure A5: Same as in Fig. A1 but for the rivers Neman, Neva, Norrström and Oder.

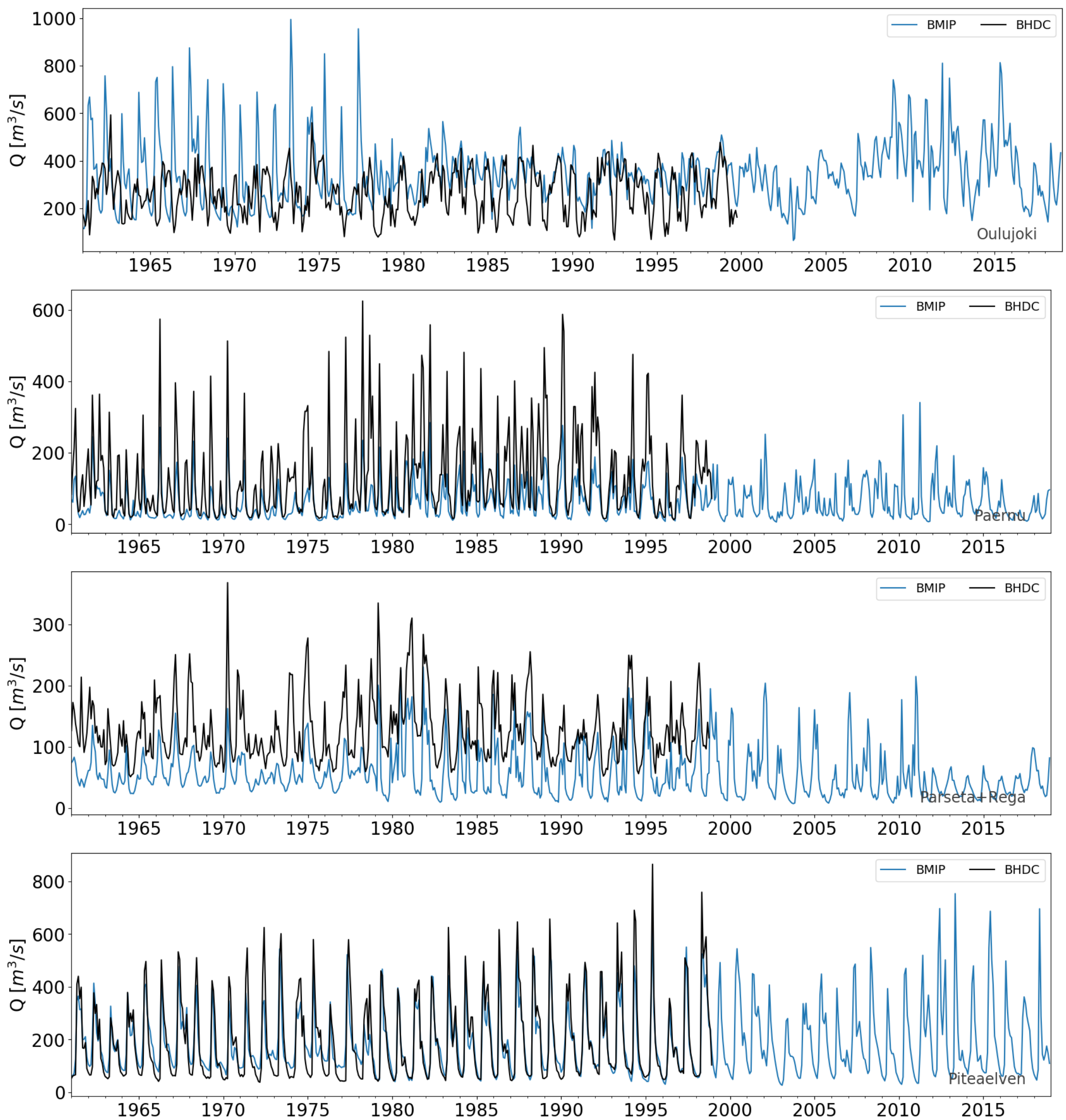

Figure A6: Same as in Fig. A1 but for the rivers Oulujoki, Pärnu, Parseta with Rega and Piteaelven.

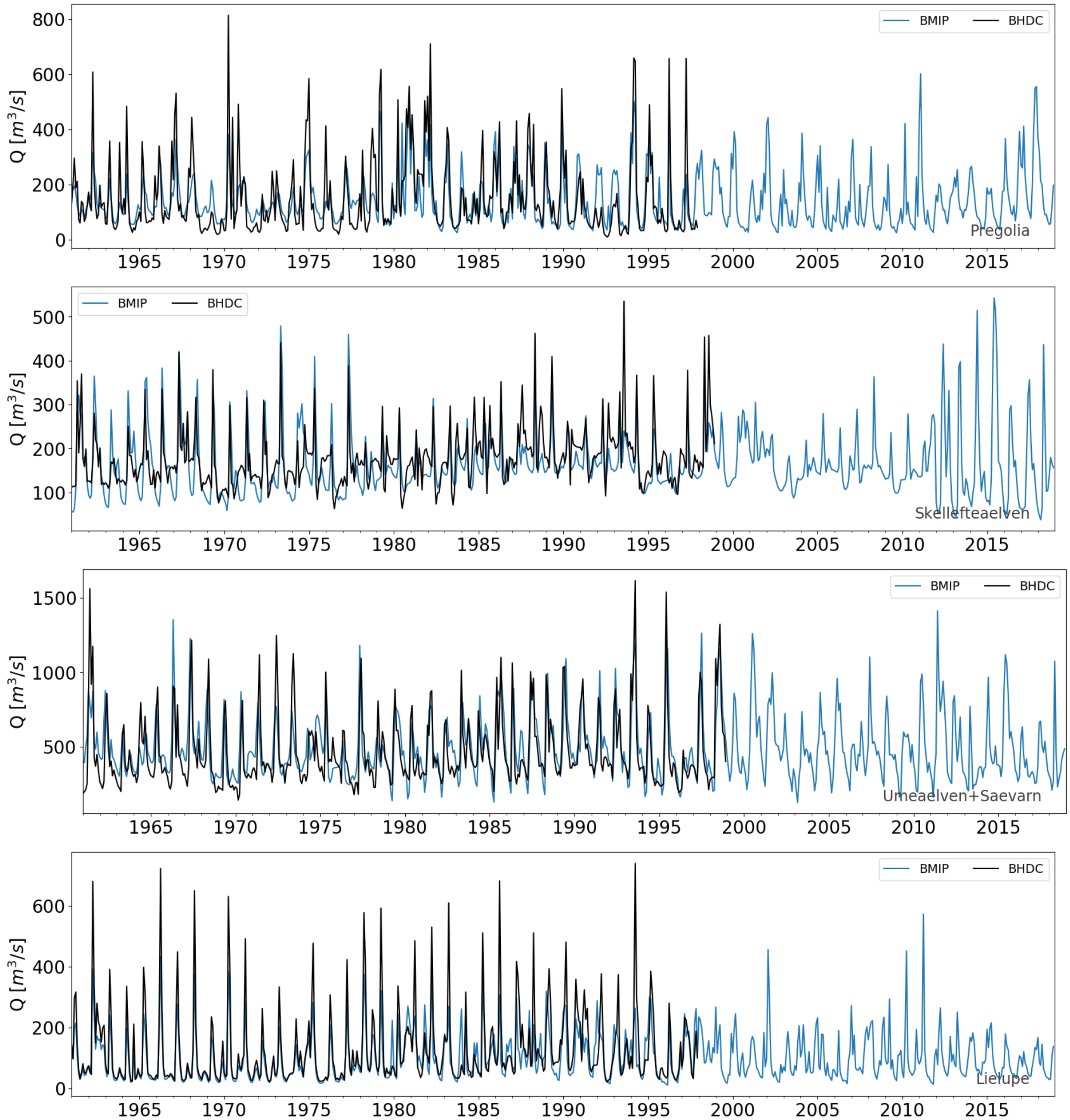

Figure A7: Same as in Fig. A1 but for the rivers Pregolia, Skellefteaelven, Umeaelven with Saevarn and Lielupe.

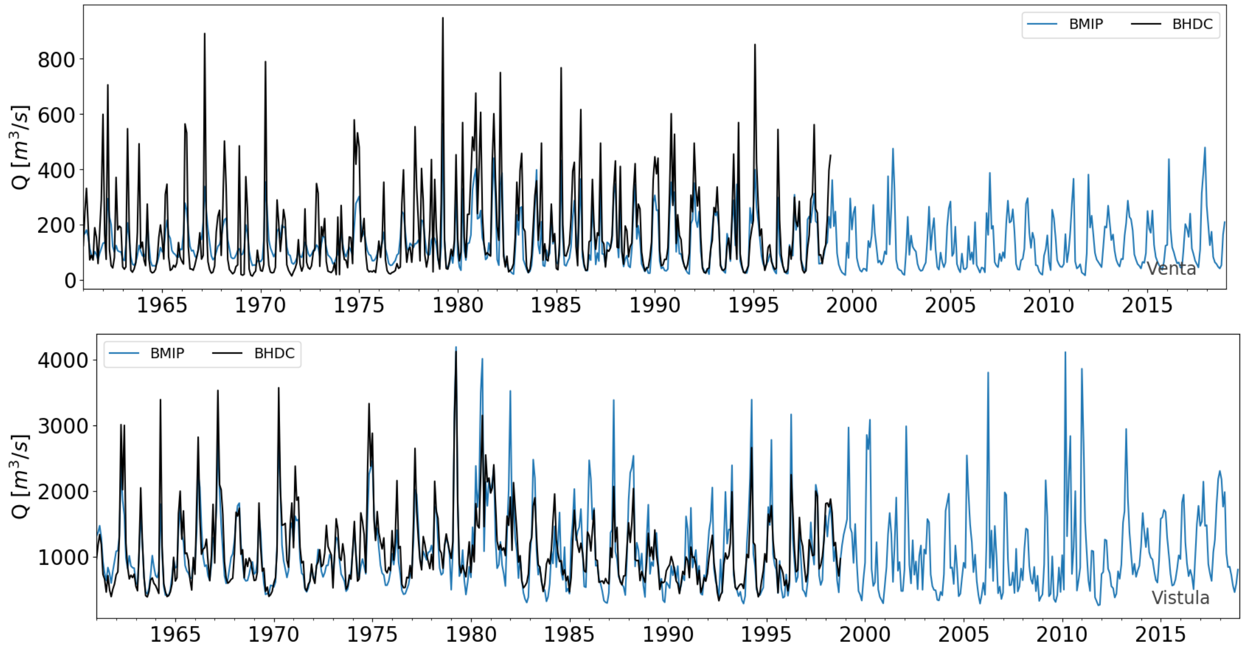

Figure A8: Same as in Fig. A1 but for the rivers Venta and Vistula.

Table A1: The locations of the 30 largest rivers of the BHDC in the Baltic Sea.

Nr.	Latitude	Longitude	River
1	59.99	30.23	NEVA
2	54.36	18.96	VISTULA
3	65.82	23.22	KALIXAELVEN TORNEAELVEN
4	57.07	24.02	DAUGAVA
5	62.51	17.45	INDALSAELVEN LJUNGAN
6	55.73	21.11	NEMAN
7	65.60	22.09	LULEAELVEN RANEAELVEN
8	57.70	11.90	GOETAAELV
9	65.79	24.55	KEMIJOKI
10	63.03	17.79	ANGERMANAELVEN
11	53.93	14.29	ODER
12	63.76	20.33	UMEAELVEN SAEVARN
13	59.47	28.03	NARVA
14	60.65	17.45	DALAELVEN GAVLEN
15	60.50	26.92	KYMIJOKI
16	61.55	21.70	KOKEMAEENJOKI
17	65.03	25.47	OULUJOKI
18	61.21	17.14	LJUSNAN
19	65.37	21.33	PITEAELVEN
20	57.40	21.54	VENTA
21	64.71	21.17	SKELLEFTEAELVEN
22	59.42	18.67	NORRSTROEM
23	54.65	19.88	PREGOLIA
24	56.56	12.95	LAGAN ROENNE NISSAN
25	65.35	25.28	IIJOKI
26	57.07	10.55	LIMFJORD
27	58.39	24.48	PAERNU NAVESTI
28	57.00	23.93	LIELUPE
29	59.68	28.30	LUGA
30	54.24	15.80	PARSETA REGA

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CONTENT

Leibniz-Institut für
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