Baltic Sea Model Intercomparison Project (BMIP)

Baltic Earth
Earth System Science for the Baltic Sea Region

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Kickoff workshop in Warnemünde 22 November 2018

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SMHI

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Universität Hamburg

Danmarks Meteorologiske Institut

BSH
Bundesamt für Seeschifffahrt und Hydrographie

PAN

MOM, GETM, NEMO, HBM, SCHISM, ECOSMO, POP-CICE, etc.

frontiers in Marine Science

ORIGINAL RESEARCH
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Long-Term Mean Circulation of the Baltic Sea as Represented by Various Ocean Circulation Models

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The skill of the state-of-the-art ocean circulation models GETM (General Estuarine Transport Model), RCO (Rossby Centre Ocean model), and MOM (Modular Ocean Model) to represent hydrographic conditions and the mean circulation of the Baltic

- evaluating long-term simulations of ocean circulation models of the Baltic Sea
- different setups, grid resolutions, atmospheric and hydrological forcing

Database (BED). Further, we analyze current velocities and volume transports both in the horizontal plane and through three transects in the Baltic Sea. Simulated current velocities are validated against 10 years of Acoustic Doppler Current Profiler (ADCP) measurements in the Arkona Basin and 5 years of mooring observations in the Gotland Basin. Furthermore, the atmospheric forcing datasets, which drive the models, are evaluated using wind measurements from 28 automatic stations along the Swedish coast. We found that the seasonal cycle, variability, and vertical profiles of temperature and salinity are simulated close to observations by RCO with an assimilation setup. All models reproduce temperature well near the sea surface. Salinity simulations are of

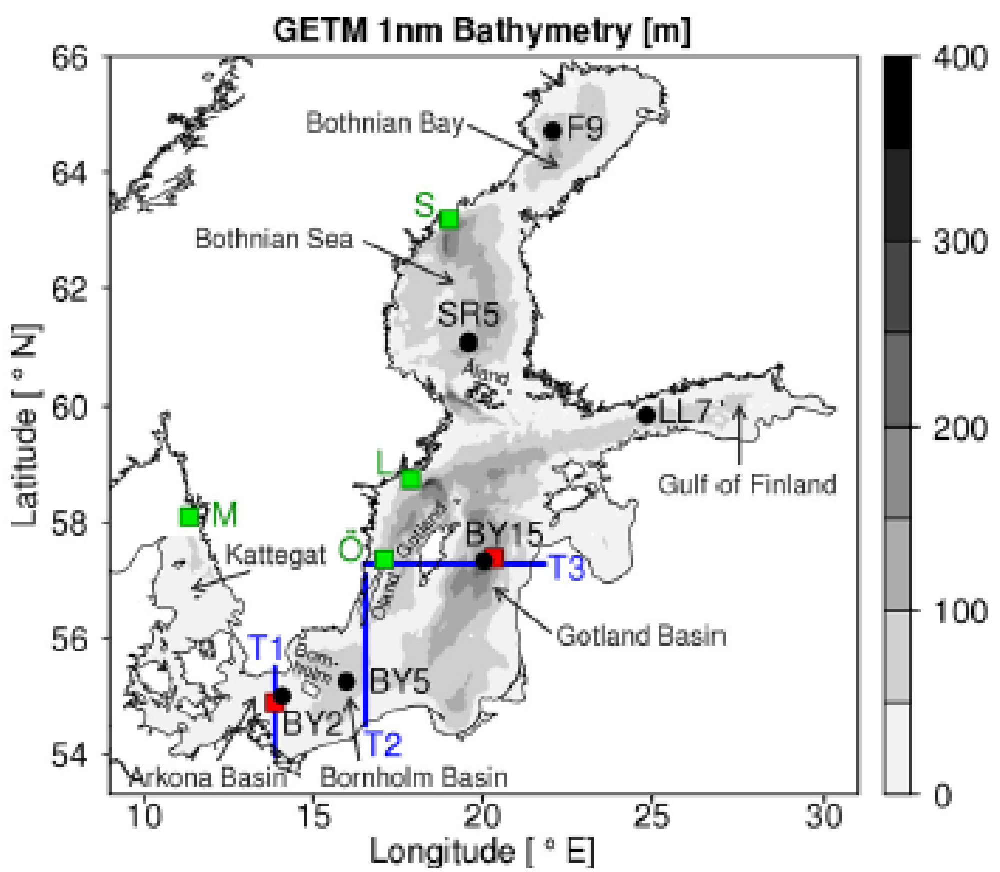
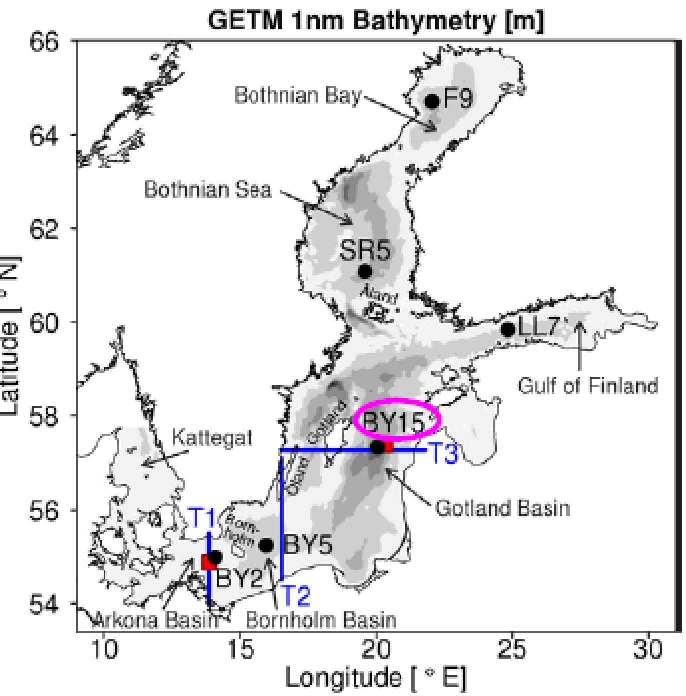
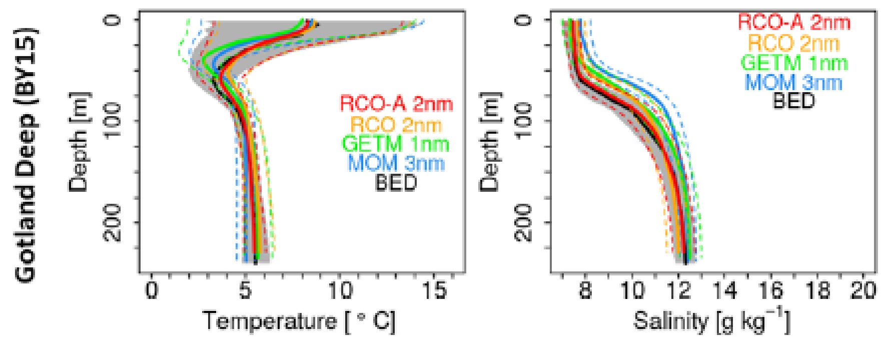
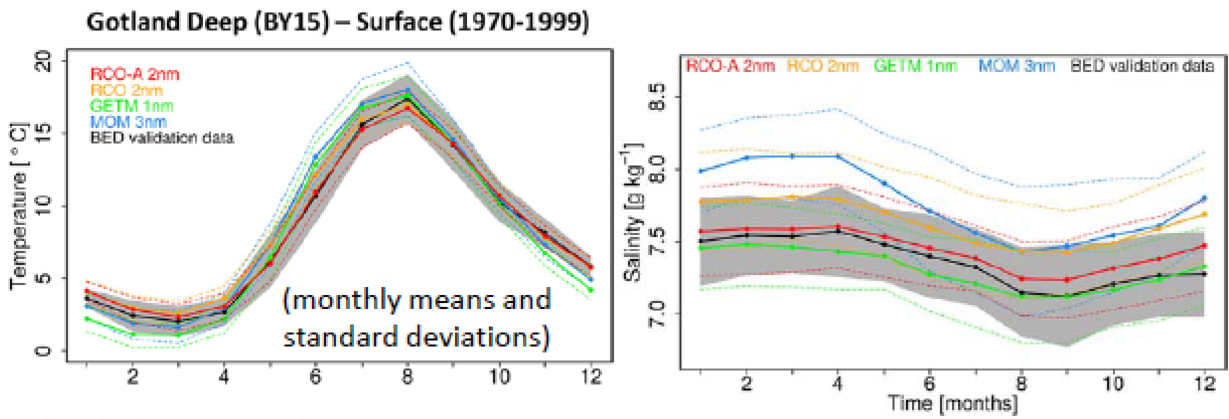


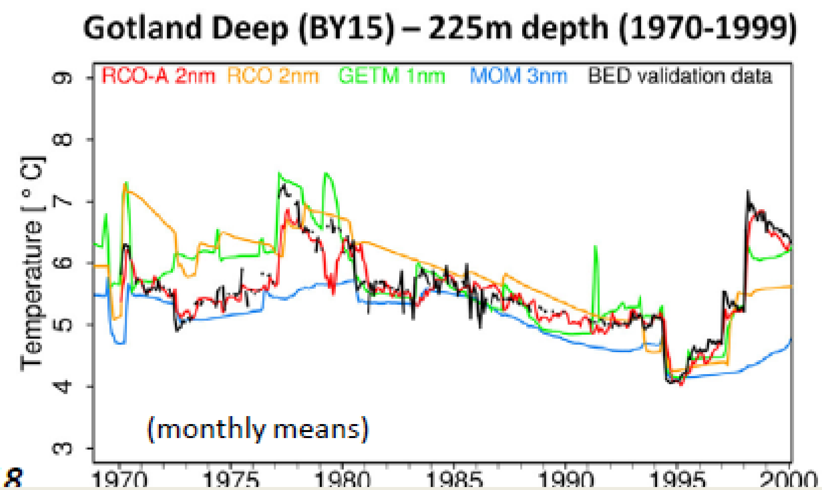
FIGURE 1 | Locations of the used monitoring stations for the assessment of temperature and salinity (black dots) and current velocities (red squares) as well as the analyzed transects (blue lines) in the Baltic Sea. The background color (gray shading) shows the bathymetry [m] from the GETM-1 nm-run. Exemplary stations for atmospheric wind data comparison are shown as green squares. See text for further information.

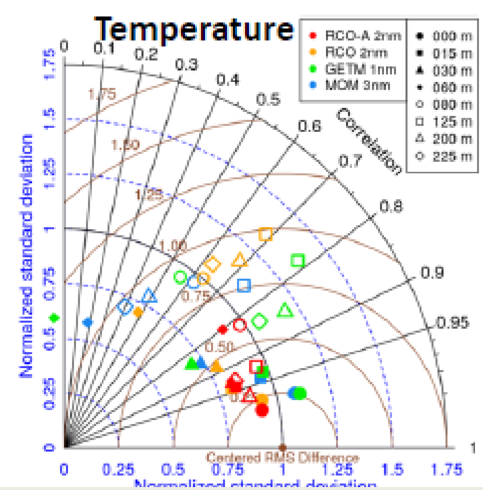




30-year means (1970-1999)







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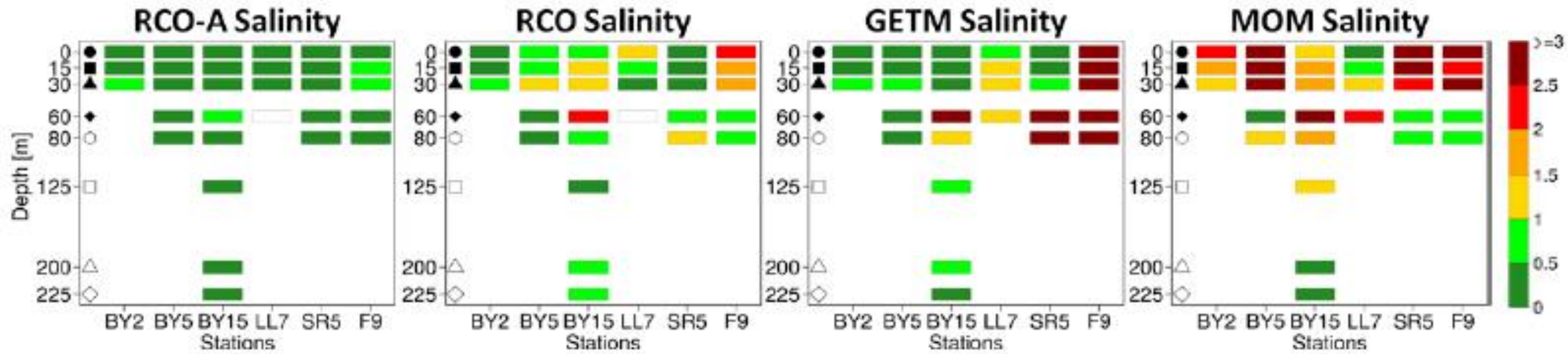
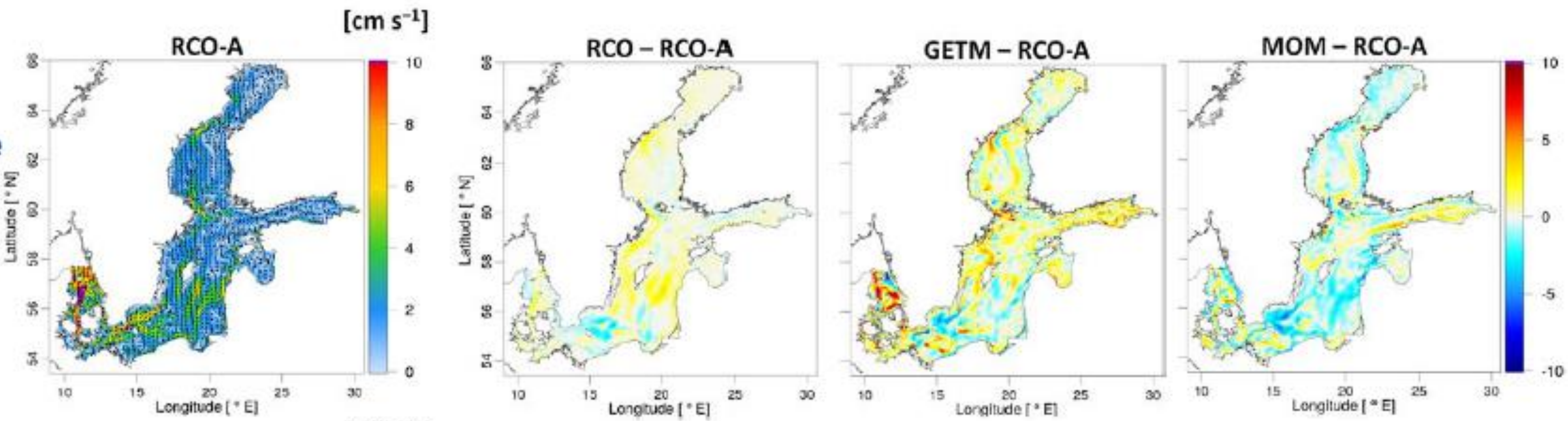
30-year cost function values (1970-1999)

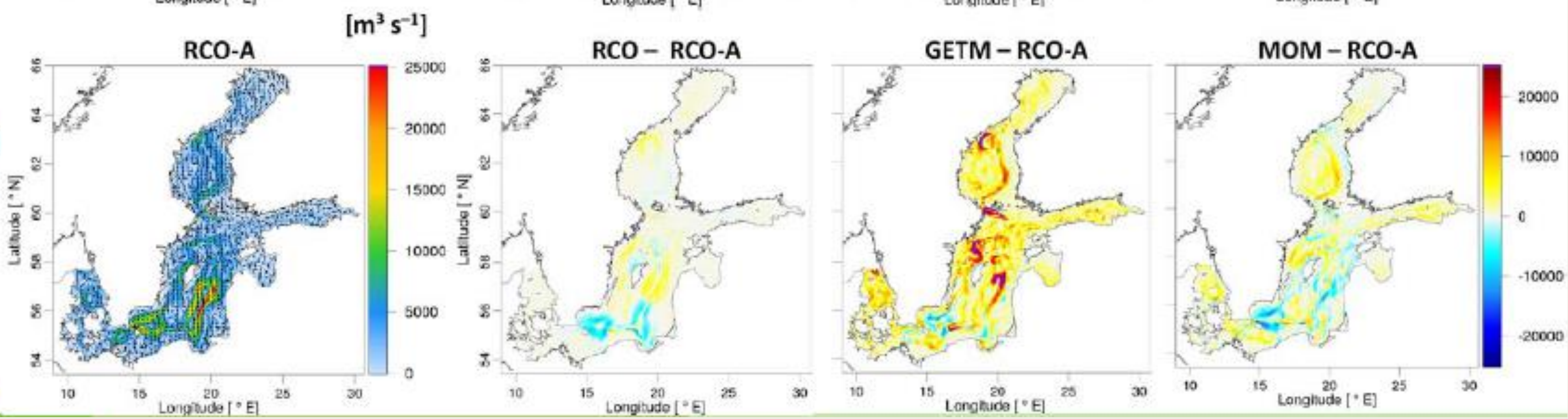
$$C_i = \left| \frac{M_i - B}{STD} \right|$$



30-year mean surface velocity (0 to 10 m depth)



30-year mean depth-integrated volume transport



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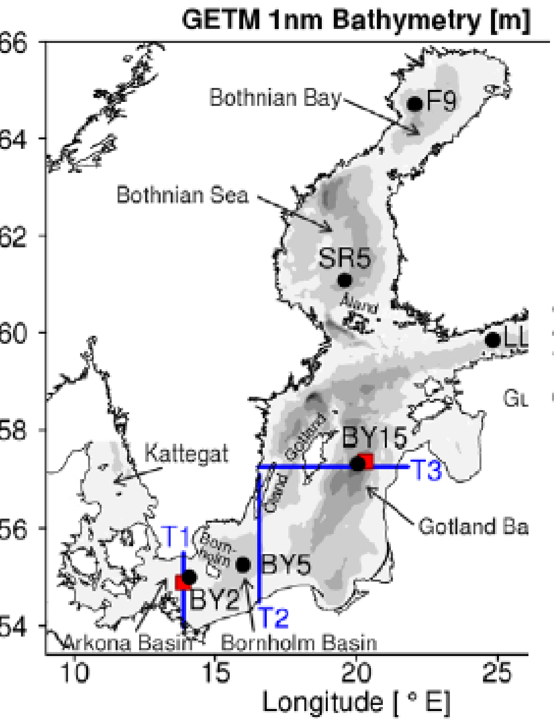
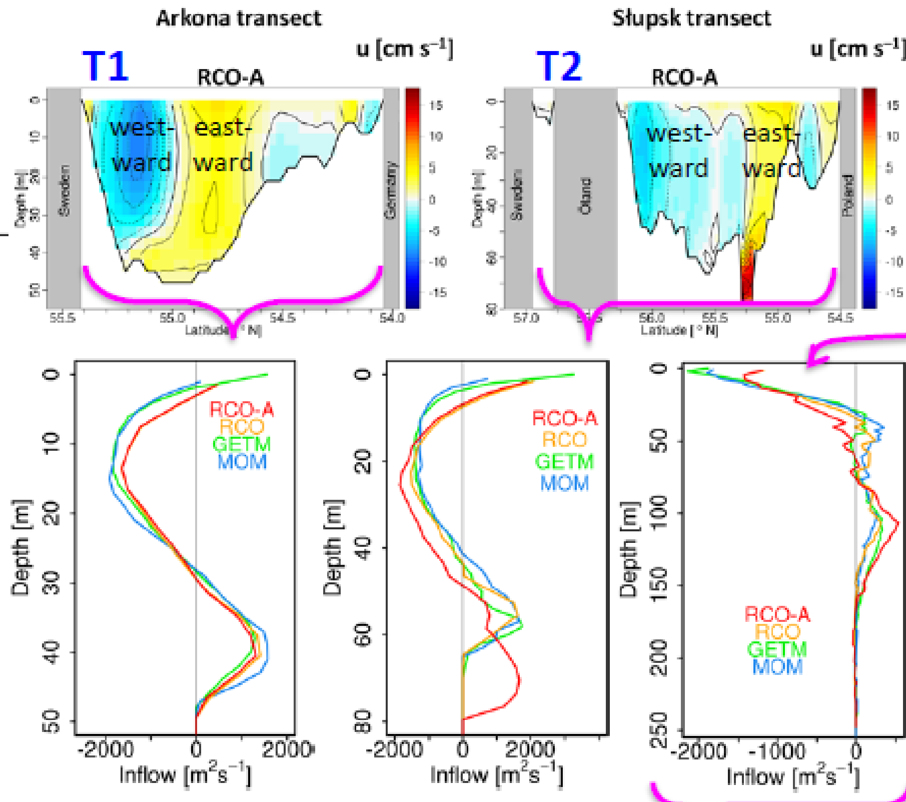
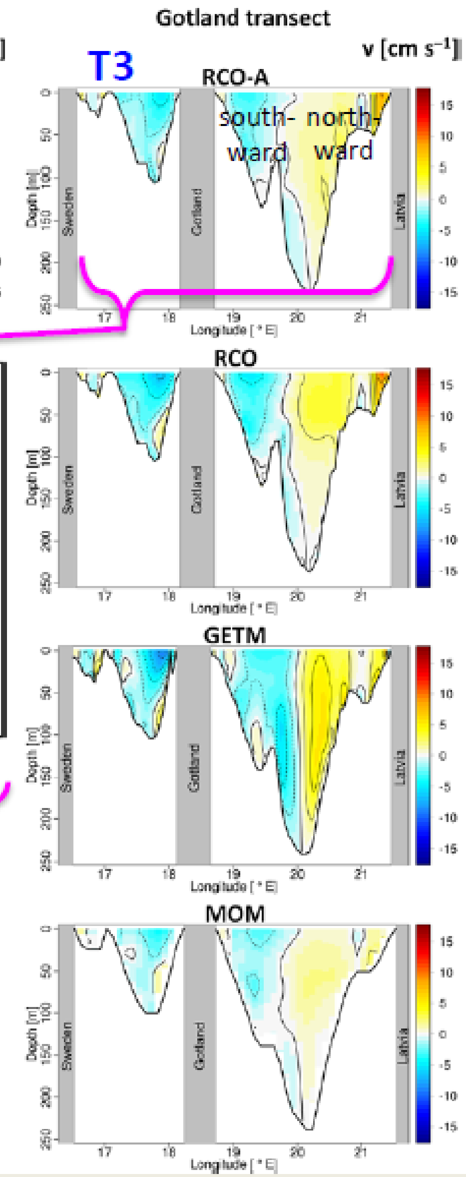
30-year mean absolute current velocities through transects (1970-1999)







	Reversal depth [m]	Net outflow [m³ s⁻¹]	Runoff [m³ s⁻¹]	P – E [m³ s⁻¹]
RCO-A	63	-15000	-12000	-
RCO	34	-13000	-12000	-1000
GETM	29	-14000	-14000	-1000
MOM	30	-12000	-11000	-1000

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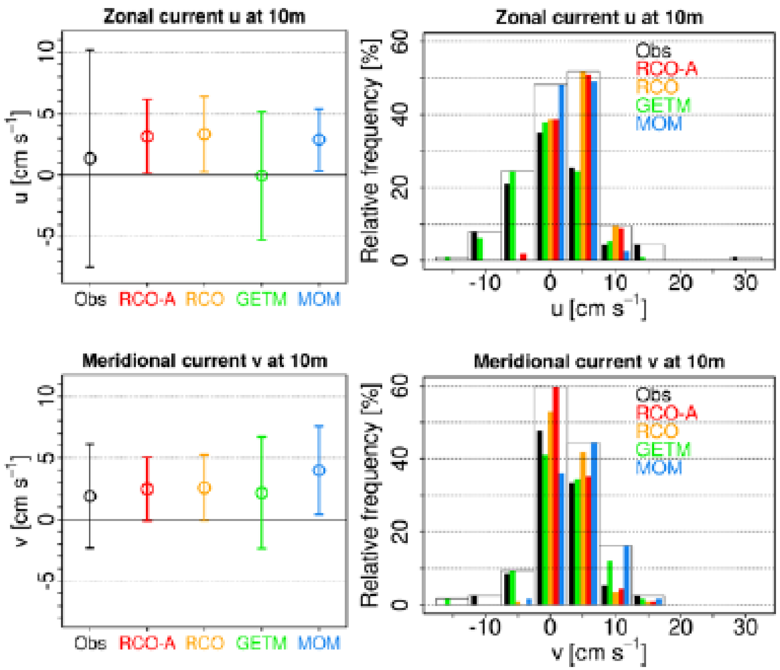
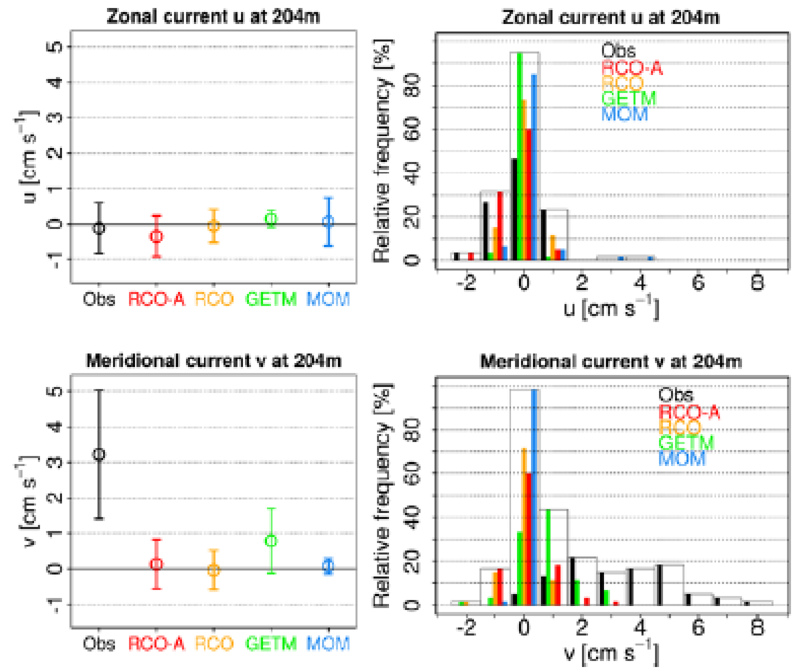
ADCP (2005-2014)

Arkona Basin



Current meter (2000-2004)

Gotland Basin



Mean current velocities and their relative frequency

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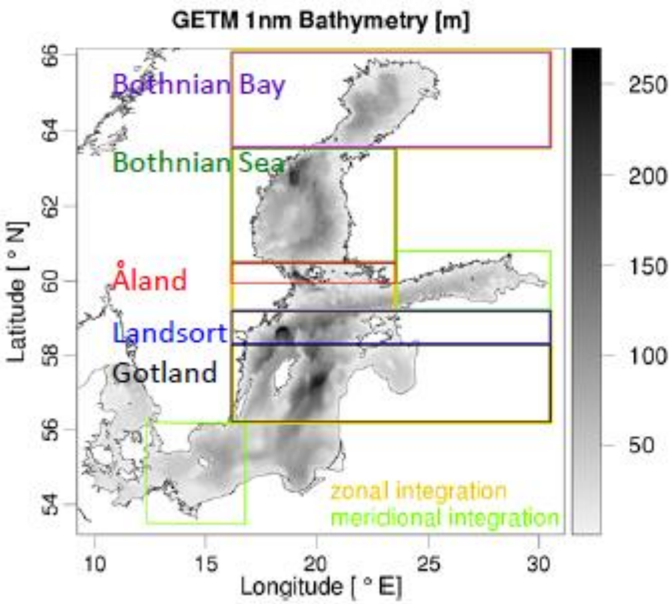
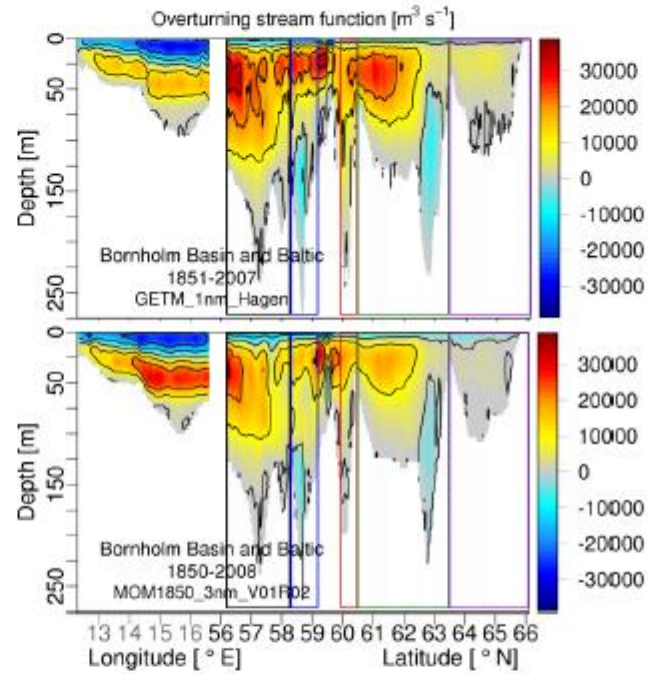
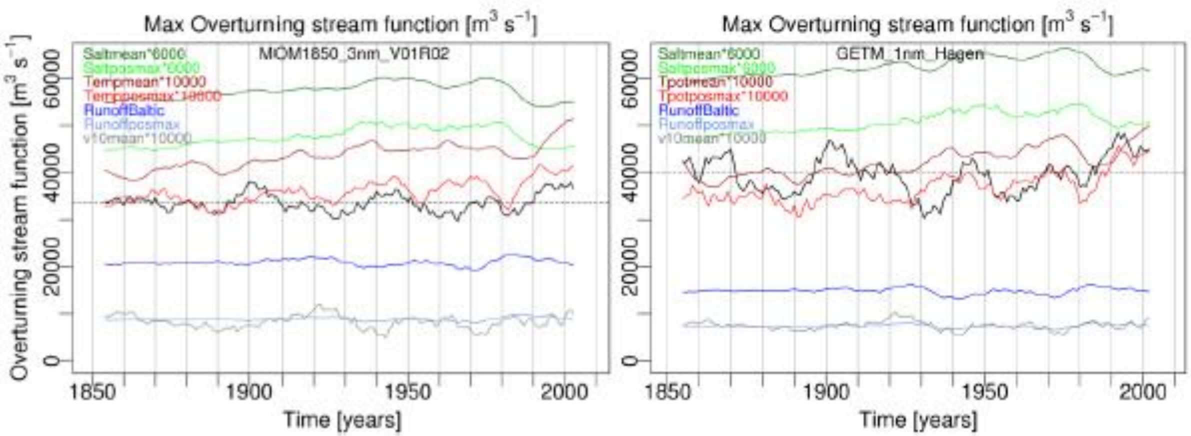
Present work:

Overturning circulation





Gotland



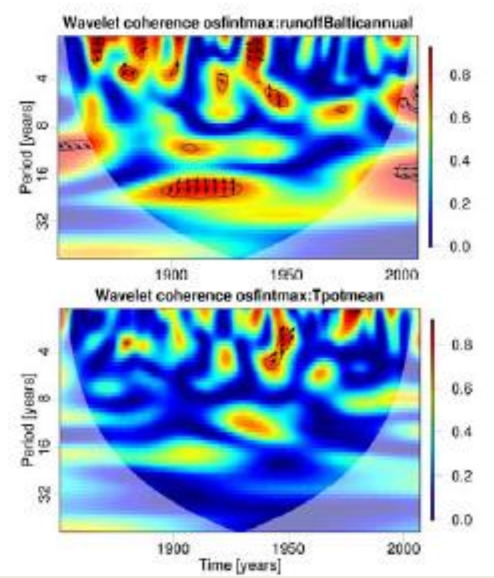


TABLE 2 | Mean volume transports through Gotland transect calculated from the vertical profiles shown in **Figure 9** for the ocean models RCO-A, RCO, GETM, and MOM as well as runoff and precipitation (P) minus evaporation (E) for this transect (numbers rounded to thousands).

	Reversal depth [m]	Outflow above [m^3 s^{-1}]	Inflow below [m^3 s^{-1}]	Net outflow [m^3 s^{-1}]	Runoff [m^3 s^{-1}]	P minus E [m^3 s^{-1}]	Total runoff [m^3 s^{-1}]	Total P minus E [m^3 s^{-1}]
RCO-A	63	–36,000	21,000	–15,000	–12,000	–	–16,000	–
RCO	34	–28,000	15,000	–13,000	–12,000	–1,000*	–16,000	–2,000*
GETM	29	–31,000	17,000	–14,000	–14,000	–1,000	–17,000	–1,000
MOM	30	–30,000	18,000	–12,000	–11,000	–1,000	–15,000	–2,000

*Numbers in the last two columns relate to the entire Baltic Sea including the Kattegat. (*according to Meier and Döscher, 2002. For RCO-A P minus E is not available).*

TABLE 3 | Mean zonal wind speed (u), meridional wind speed (v), and total wind speed (ws) with their standard deviations (σ) for observations, coastDat2, and RCA3-ERA40 dataset as well as mean and root mean square difference (RMSD) between the reanalysis datasets (rea) and the observations (obs) for zonal, meridional, and total wind speed.

	Observations		coastDat2		RCA3-ERA40	
	Mean	σ	**Mean**	σ	**Mean**	σ
u	1.02	3.90	0.98	4.18	1.18	3.73
v	0.66	4.09	0.36	4.33	0.41	3.81
ws	5.81	2.68	5.94	2.89	5.18	2.67
			Mean	**RMSD**	**Mean**	**RMSD**
$u_{rea} - u_{obs}$	–		–0.04	1.99	0.16	2.39
$v_{rea} - v_{obs}$	–		–0.30	2.09	–0.24	2.56
$ws_{rea} - ws_{obs}$	–		0.14	1.86	–0.62	2.26

Calculations are done over all stations for the time period 1996–2008. The unit of all parameters is [m s^{-1}].

BMIP

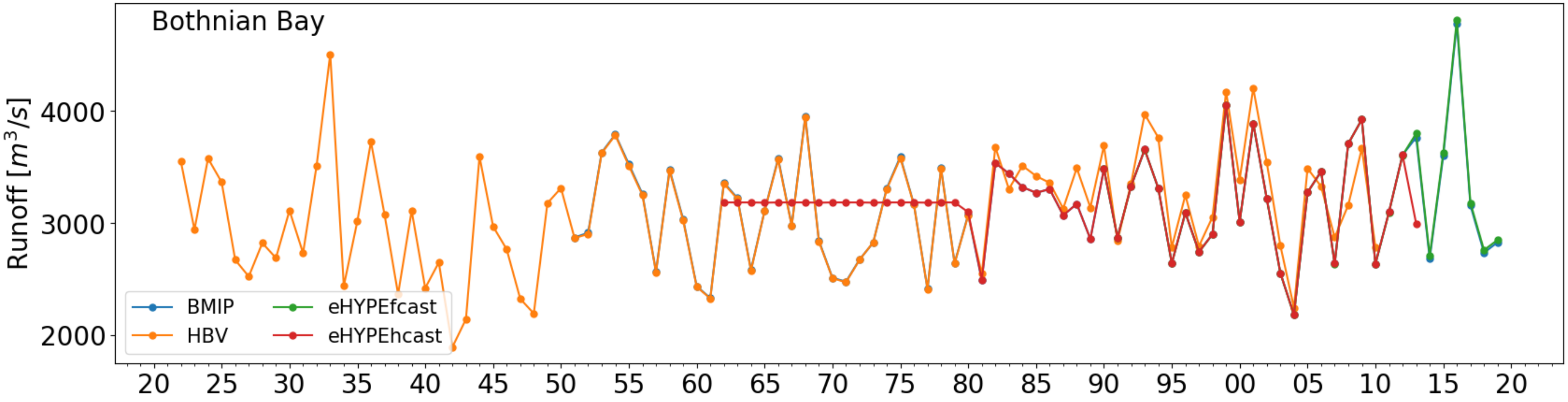
- UERRA (SMHI), 1961-2018
- E-HYPE (SMHI):

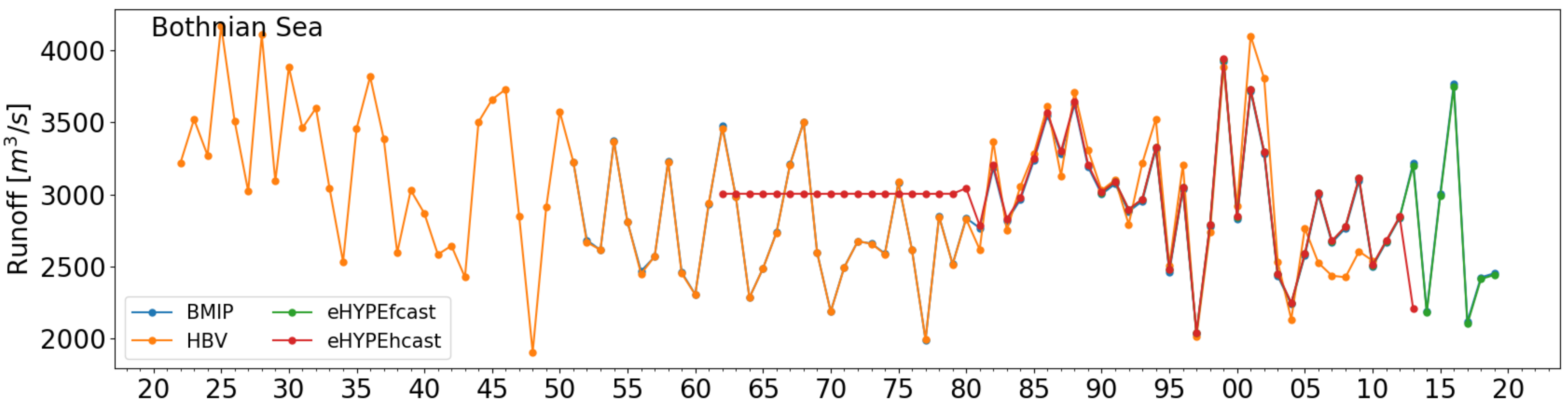
1961-1978 (HELCOM/HBV),

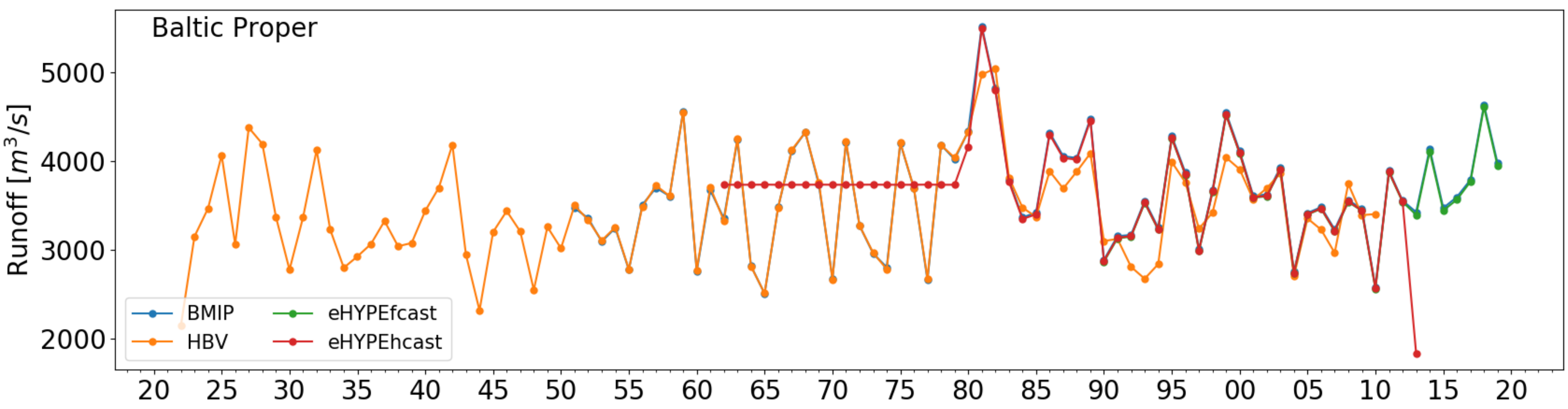
1979-2012 (E-HYPE-ERA Interim),

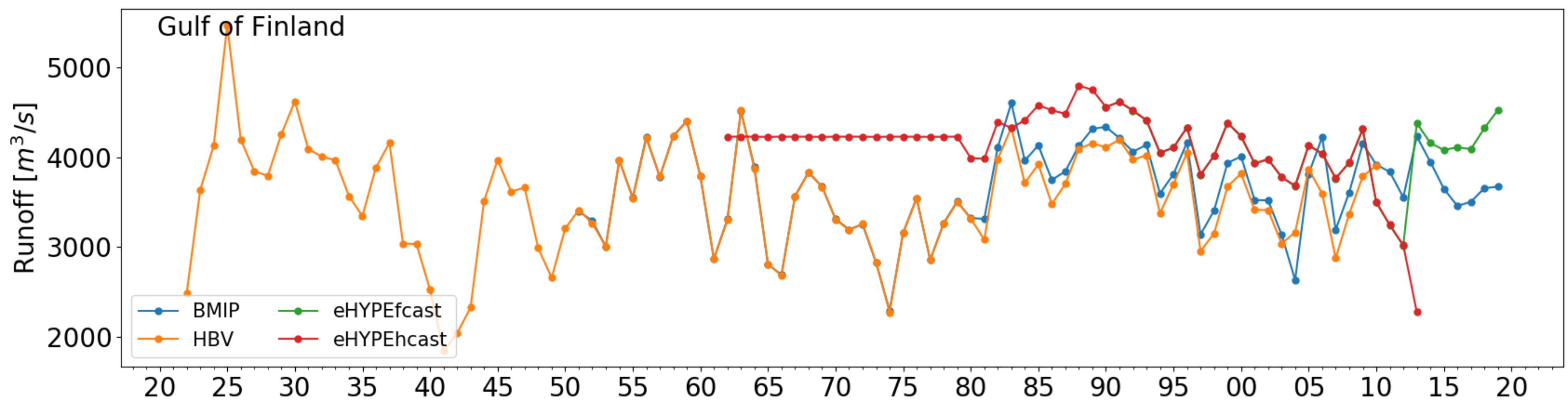
2013-2018 (E-HYPE forecast)

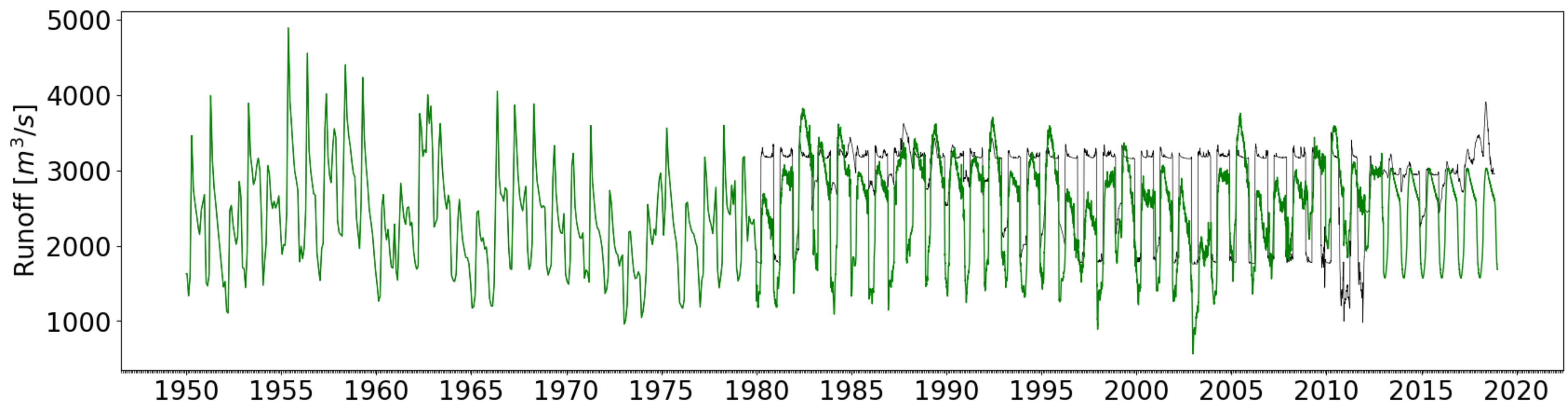
- horizontal resolution of 2 nm or finer
- 1. step only physics, Baltic Sea
- No other specifications

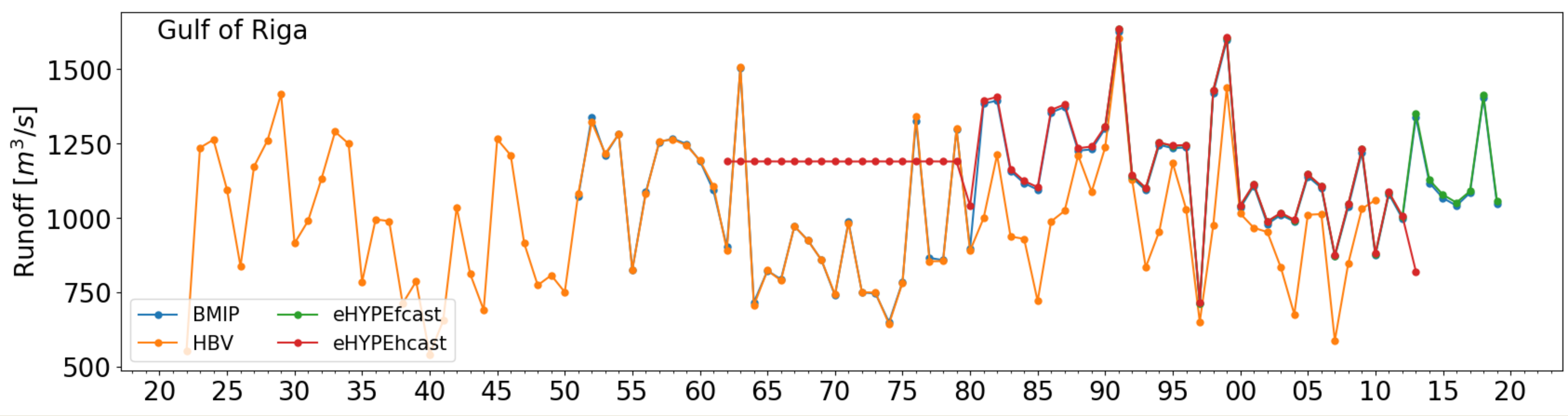

Bothnian Bay
Runoff [m^3/s]
4000
3000
2000
BMIP
HBV
eHYPEfcast
eHYPEhcast
20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 00 05 10 15 20


Bothnian Sea
Runoff [m^3/s]
4000
3500
3000
2500
2000
BMIP
HBV
eHYPEfcast
eHYPEhcast
20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 00 05 10 15 20


Baltic Proper
Runoff [m^3/s]
5000
4000
3000
2000
20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 00 05 10 15 20
BMIP
HBV
eHYPEfcast
eHYPEhcast


Gulf of Finland
Runoff [m^3/s]
5000
4000
3000
2000
BMIP
HBV
eHYPEfcast
eHYPEhcast
20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 00 05 10 15 20


Runoff [m^3/s]
5000
4000
3000
2000
1000
1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020


Gulf of Riga
Runoff [m^3/s]
1500
1250
1000
750
500
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
00
05
10
15
20
BMIP
HBV
eHYPEfcast
eHYPEhcast

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Conclusions

(1) External nutrient loads are the main driver of oxygen depletion.

(2) Future climate change will amplify oxygen depletion. The impact of climate change is larger in case of higher nutrient loads.

(3) Hence, the implementation of the BSAP is needed. The BSAP will lead to significantly improved oxygen conditions.

(4) The response of the Baltic Sea to nutrient load changes is slow.