A regional biogeochemical model outperforms Earth System Models in NW North Atlantic shelf waters

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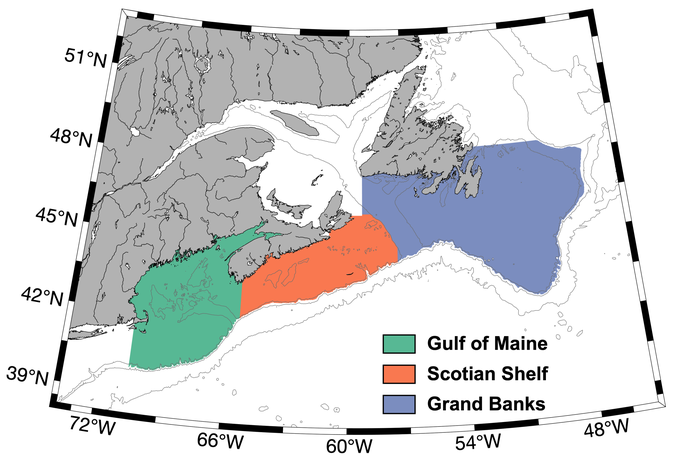
A regional model and 29 ESMs from the Climate Models Intercomparison Projects (CMIP) 5 and 6 were compared with observations of the NWA shelf. Confidence in ESMs is important prior to their use for regional climate projections, moreover in the biologically productive NWA, particularly sensitive to climate change.

Study area

Region: northwest North Atlantic shelf (NWA)



Methodology

Monthly, spatially resolved climatologies of surface chlorophyll (CHL; SeaWiFS), nitrate (NO3; WOA) and temperature (T; OSTIA) are compared with historical simulations. Scores are calculated for each variables and the models ranked from their skills

Models

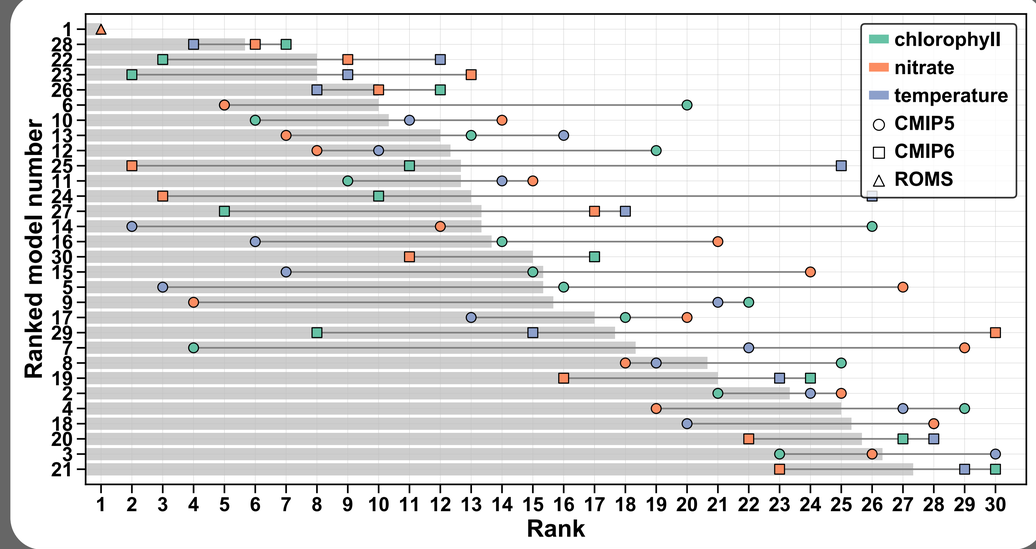
1 regional model (1), 17 CMIP5 ESMs (2-18) and 12 CMIP6 ESMs (19-30), see details and scores below.

Model		Shelf resolution	Scores			Ocean BGC component
Name	ID	(*n* cells)	CHL	NO3	T	
ACM-ROMS	1	6875	0.64	1.27	1.14	FENNEL
CanESM2	2	54	1.18	3.14	4.20	CMOC
CESM1-BGC	3	165	1.29	4.21	7.84	BEC
CMCC-CESM	4	26	1.40	2.39	5.18	PELAGOS
CNRM-CM5	5	102	1.11	6.54	1.78	PISCES
GFDL-ESM2-G	6	74	1.17	1.67	2.12	TOPAZ2
GFDL-ESM2-M	7		0.95	7.14	3.89	
GISS-E2-H-CC	8	72	1.35	2.29	3.64	NOBM
GISS-E2-R-CC	9	56	1.19	1.62	3.84	
HadGEM2-CC	10	72	1.02	2.11	2.58	Diat-HadOCC
HadGEM2-ES	11		1.06	2.12	2.90	
IPSL-CM5A-LR	12	26	1.17	1.91	2.52	PISCES
IPSL-CM5A-MR	13		1.09	1.80	3.07	
IPSL-CM5B-LR	14		1.36	2.03	1.51	
MPI-ESM-LR	15	119	1.10	3.12	2.38	HAMOCC 5.2
MPI-ESM-MR	16	416	1.09	2.57	2.14	
MRI-ESM1	17	149	1.15	2.53	2.78	MRI.COM3
NorESM1-ME	18	165	1.40	6.99	3.71	HAMOCC 5.1
CanESM5	19	102	1.35	2.16	4.05	CMOC
CESM2	20	165	1.38	2.61	5.40	MARBL
CESM2-WACCM	21		1.42	2.78	5.71	
CNRM-ESM2-1	22	102	0.92	1.91	2.74	PISCES
GFDL-ESM4	23	74	0.81	2.10	2.49	COBALTv2
GISS-E2-1-G	24	56	1.08	1.47	4.79	NOBM
GISS-E2-1-G-CC	25		1.08	1.44	4.66	
IPSL-CM6A-LR	26	102	1.09	1.94	2.47	PISCES
MIROC-ES2L	27	81	1.02	2.17	3.14	OECO2
MPI-ESM1-2-HR	28	416	1.03	1.75	2.05	HAMOCC
NorESM2-LM	29	102	1.04	13.26	2.98	HAMOCC
UKESM1-0-LL	30	102	1.15	1.96	3.08	MEDUSA2

Results

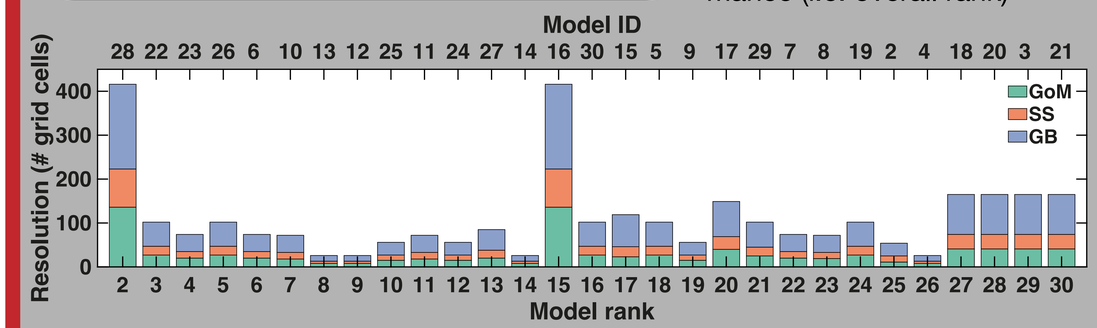
- Large mismatch with biological observations in most ESM
- CMIP ensembles represent poorly surface conditions
- Grid resolution does not influence ESM skills
- Biological variables improved in the CMIP6 models
- None of the ESM performed equally well for all variables

In this context, using single downscaled projections with top ranked ESMs is the best strategy for regional projections.



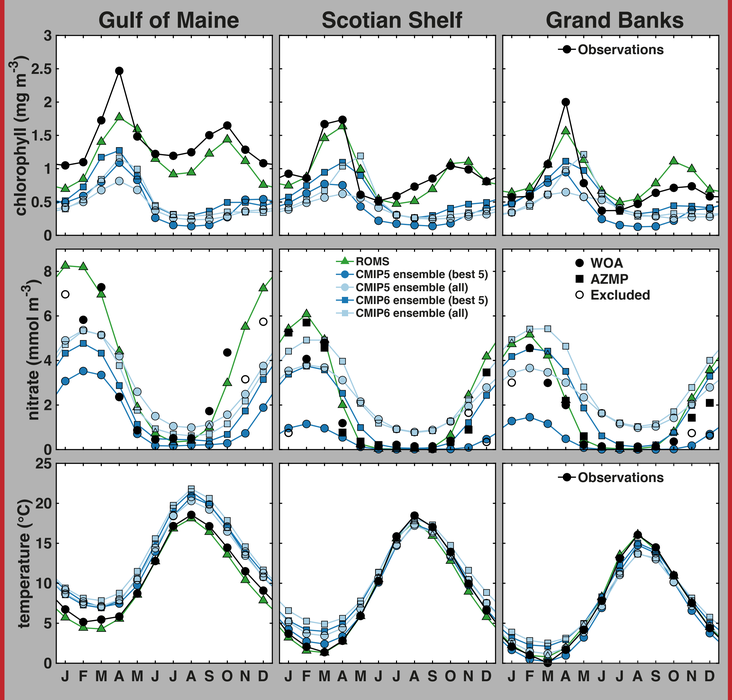
ESM resolution

Higher model resolution does not result in better performance (i.e. overall rank)



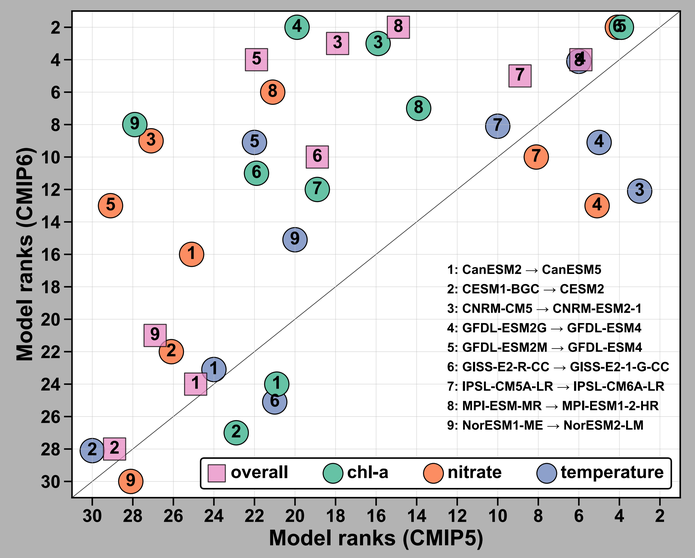
Model ensembles

ESM ensembles are a poor representation of biological conditions on the NWA, whereas temperature discrepancies indicate a spatial mismatch in the large-scale circulation. The use of ensembles for climate projection is not recommended in the NWA.



CMIP5 vs. CMIP6

The overall model skills improved in the new generation of ESMs (CMIP6), mostly due to an improvement in the biology (CHL, NO3). However, the improvement was not consistent across models: CMIP5 models with low ranks did not improve significantly.



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