Simulation of the historical ecosystem state as a reference according to the Water Framework Directive

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Szczecin, 12.05.2014

Water Framework Directive (WFD)

Management: catchment area

Target: river loads

Target: inner coastal waters

Target: outer coastal waters

Good ecological state of the Baltic Sea

Landesamt für Landwirtschaft, Umwelt und ländliche Räume Schleswig-Holstein

Mecklenburg Vorpommern
Landesamt für Umwelt, Naturschutz und Geologie

Umwelt Bundesamt

THÜNEN

IGB
Leibniz-Institute of Freshwater Ecology and Inland Fisheries

Leibniz-Institut für Ostseeforschung Warnemünde
iow

German environmental agencies

Research Institutes

Using ERGOM for historical simulations

- European Marine Strategy Framework Directive MSFD
- EU Water Framework Directive`s WFD:

„good ecological status“ (GES)

“based on reference conditions:
high status with no, or very minor disturbance from human activities”

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Using ERGOM for historical simulations

Eutrophication-chain

River basins

Rivers

Transitional waters

Coastal waters

Baltic Sea

Marine Strategy Framework Directive (**MSFD**): Baltic Sea Action Plan (BSAP)

River basin

Approach:
Load reductions
Rivers

Transitional waters

Coastal waters

target: Good status
Baltic Sea

Water Framework Directive (**WFD**)

Approach: management
River basins

Target: rivers

Target:
Transitional waters

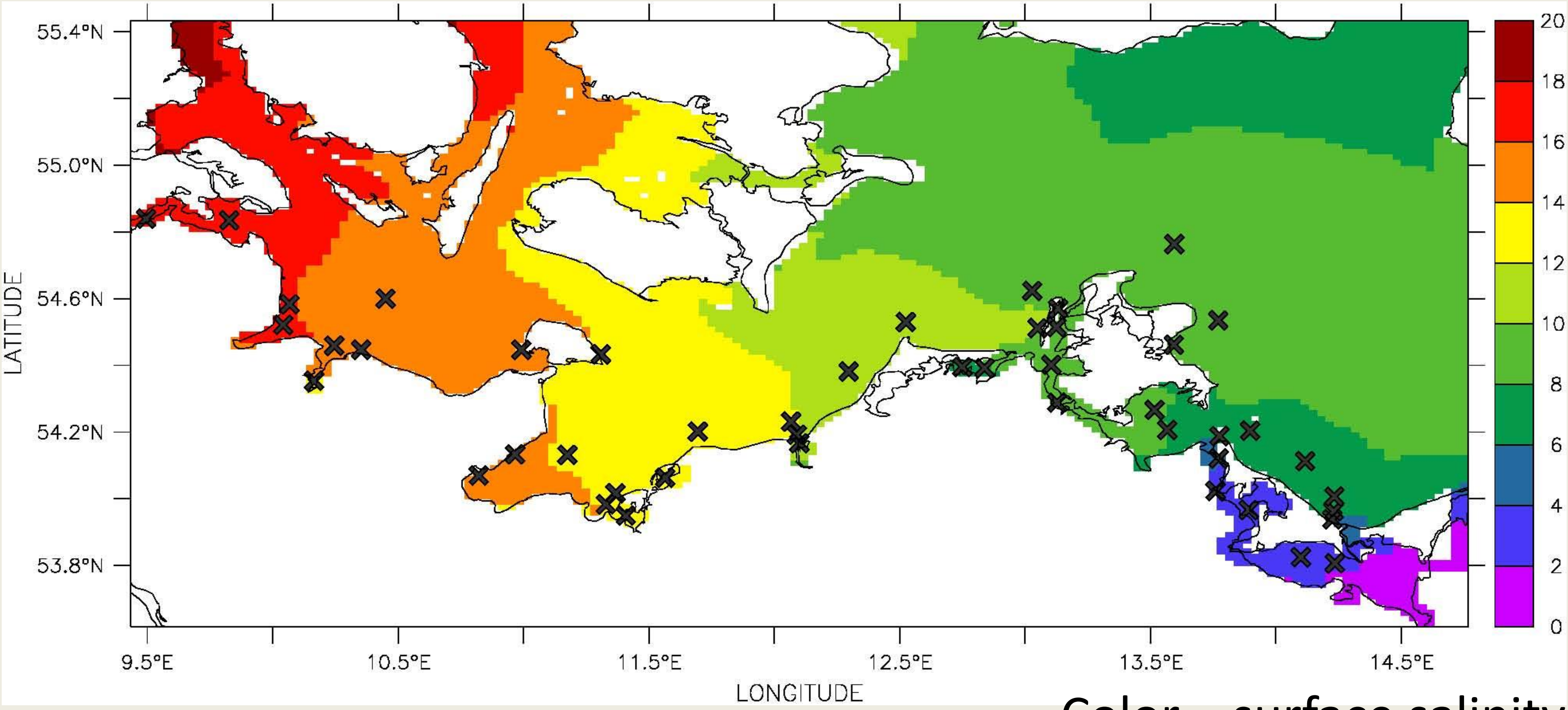
Target:
Coastal waters

Baltic Sea

Reference conditions

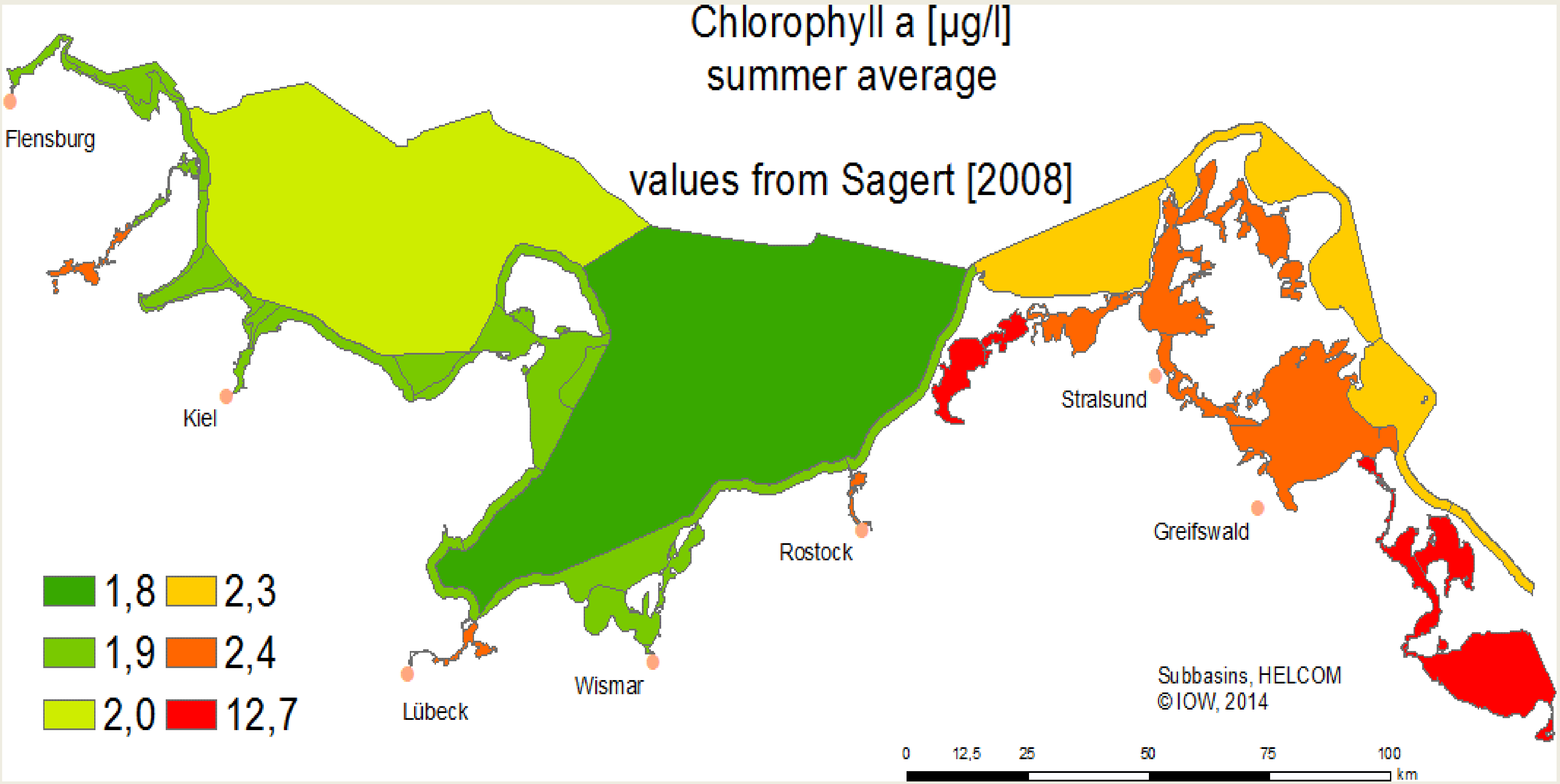
- We go back as far as reliable (ca. 1880)
- Same major cities and rivers as today
- Transfer the present measured concentrations to the historical state (Chlorophyll a [summer], Total Nitrogen & Phosphorus [annual average])
- But ignore changes in the ecosystem (e.g. occurrence of macrophytes or species distribution?
- Target value = reference value + 50 %

WFD = coastal waters (up to 1 nautical mile): Focus on inshore stations



Color = surface salinity

Present WFD targets: purely salinity dependent



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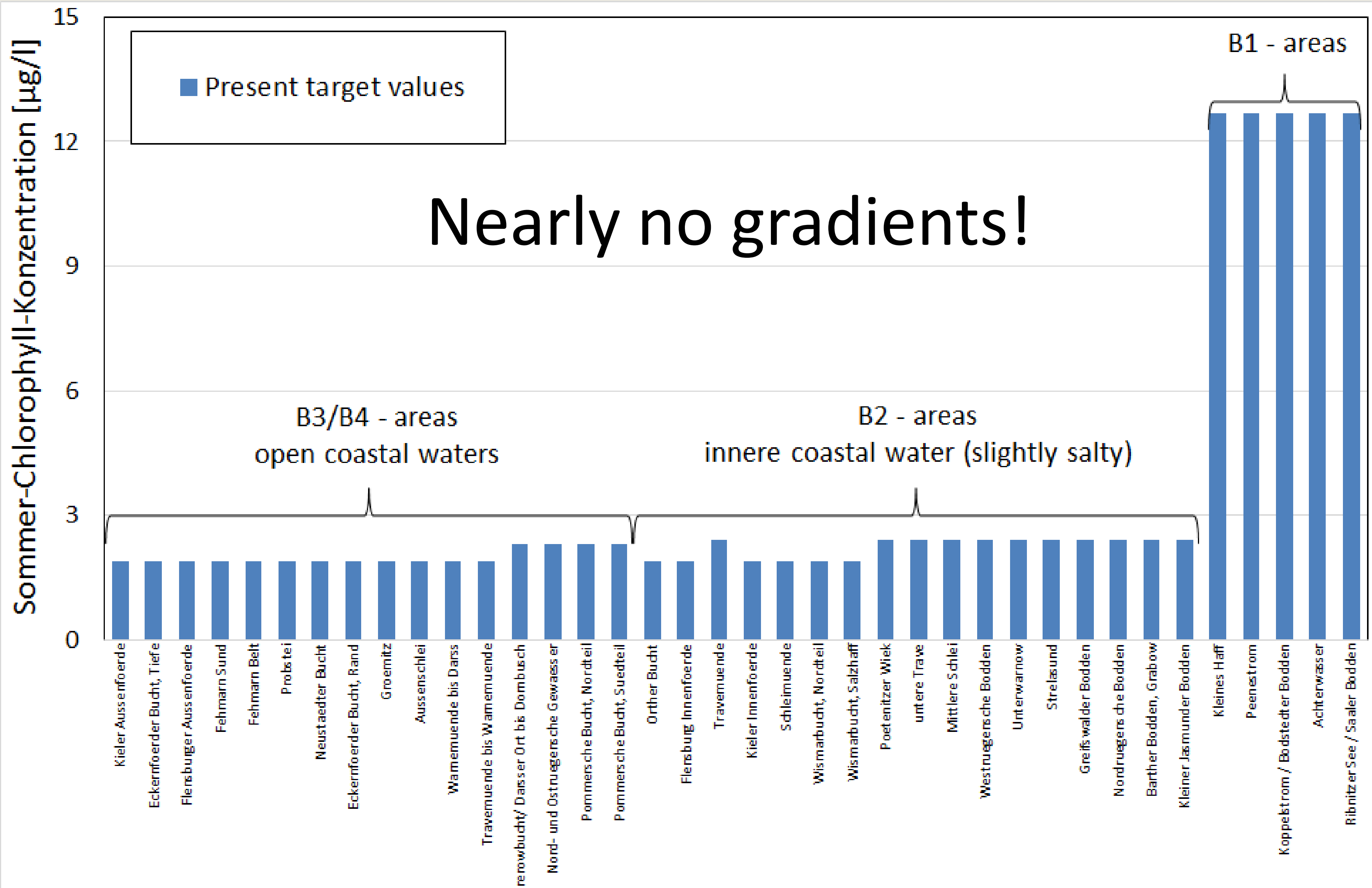

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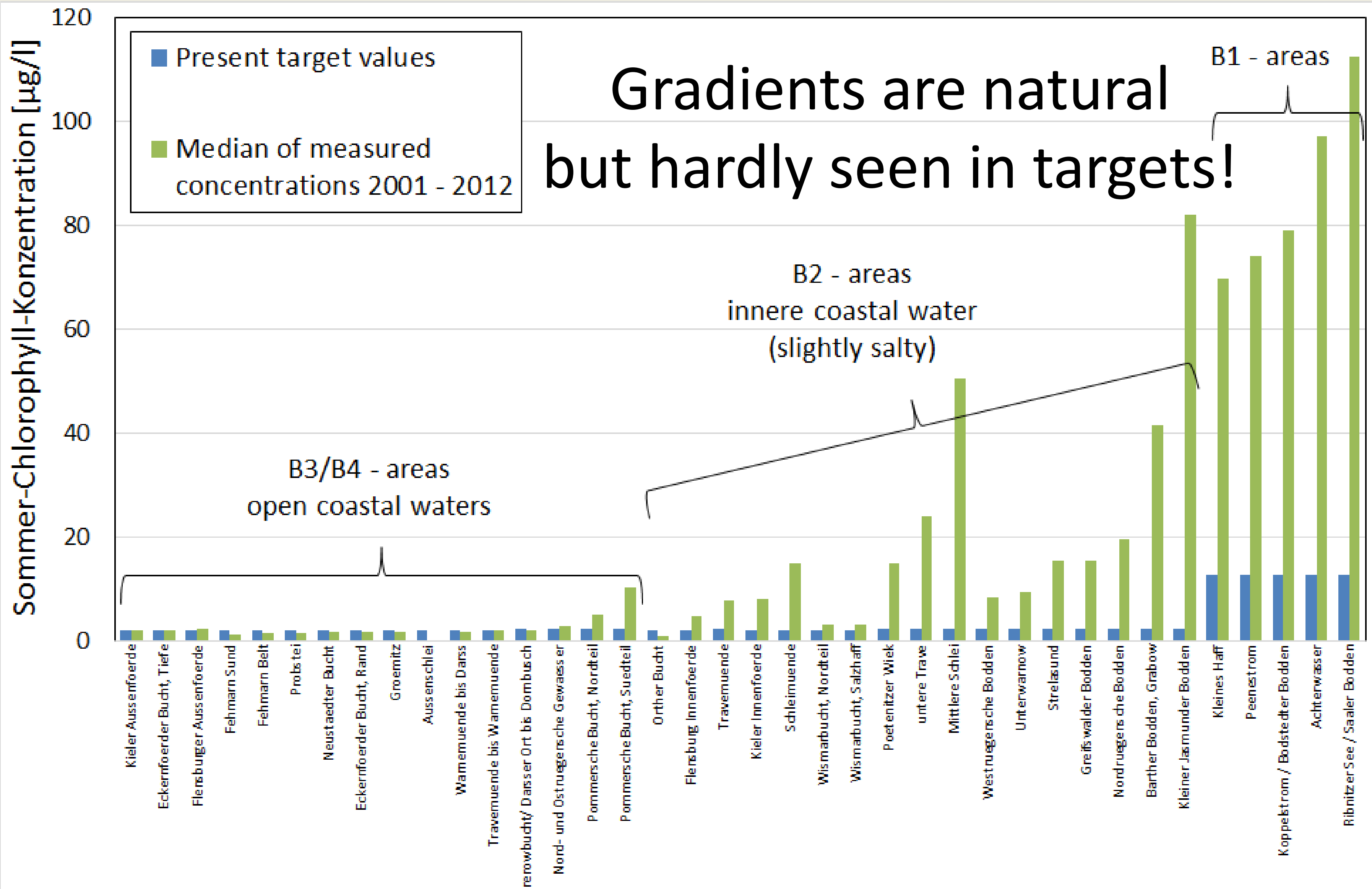


Shortcomings of the present targets

- Salinity alone is no sufficient approximation to divide water bodies
- The gradients from emission sources to the open sea and the specific reaction of the water bodies to changing nutrient loads are missing
- Changes in nutrient limitation are not included
- Reachability of targets not given
  (Oder target: 5.504 t TN/a [Brockmann et al. 2012]
  = 10% of present load)
- No harmonization with open sea‘s targets

Proposal for the German catchment: state of 1880 (approximately)

- Official statistics e.g. land usage exist (Kaiserliches Statistisches Amt 1879)
  - arable land covered 55%
  - forests 18%
  - grassland 15%
- Area used for agriculture comparable to present situation, but not intensified (before Haber-Bosch)
- Erosion 1/6 of today
- Tile drainage and sewer systems existed
- Population: 1.4 mill. (50% of today, but locally differing)

Nutrient loads to the Baltic Sea

- Germany (today's area):
  - Computed with catchment model MONERIS (Leibniz-Institute of Freshwater Ecology and Inland Fisheries)
  - Hirt et al. (2013): *Reference conditions for rivers of the German Baltic Sea catchment: reconstructing nutrient regimes using the model MONERIS*
  - TN: 5.127 t/a (today: 19.700 [PLC 5.5: reference loads 1997-2003])
  - TP: 227 t/a (526)

- Oder (MONERIS):
  - Gadegast et al. (2012): *Modelling changes in nitrogen emissions into the Oder River System 1875–1944*
  - TN: 13.425 t/a (today: 55.000 [2000-09])
  - TP: 950 t/a (3.200 [2000-09])

Reconstructed nutrient loads to the Baltic Sea

- 15 main rivers outside Germany
  - Gustafsson et al. (2012): *Reconstructing the development of Baltic Sea eutrophication 1850–2006*
  - TN/TP-ratio of 18 (today: 20) = stronger N-limitation

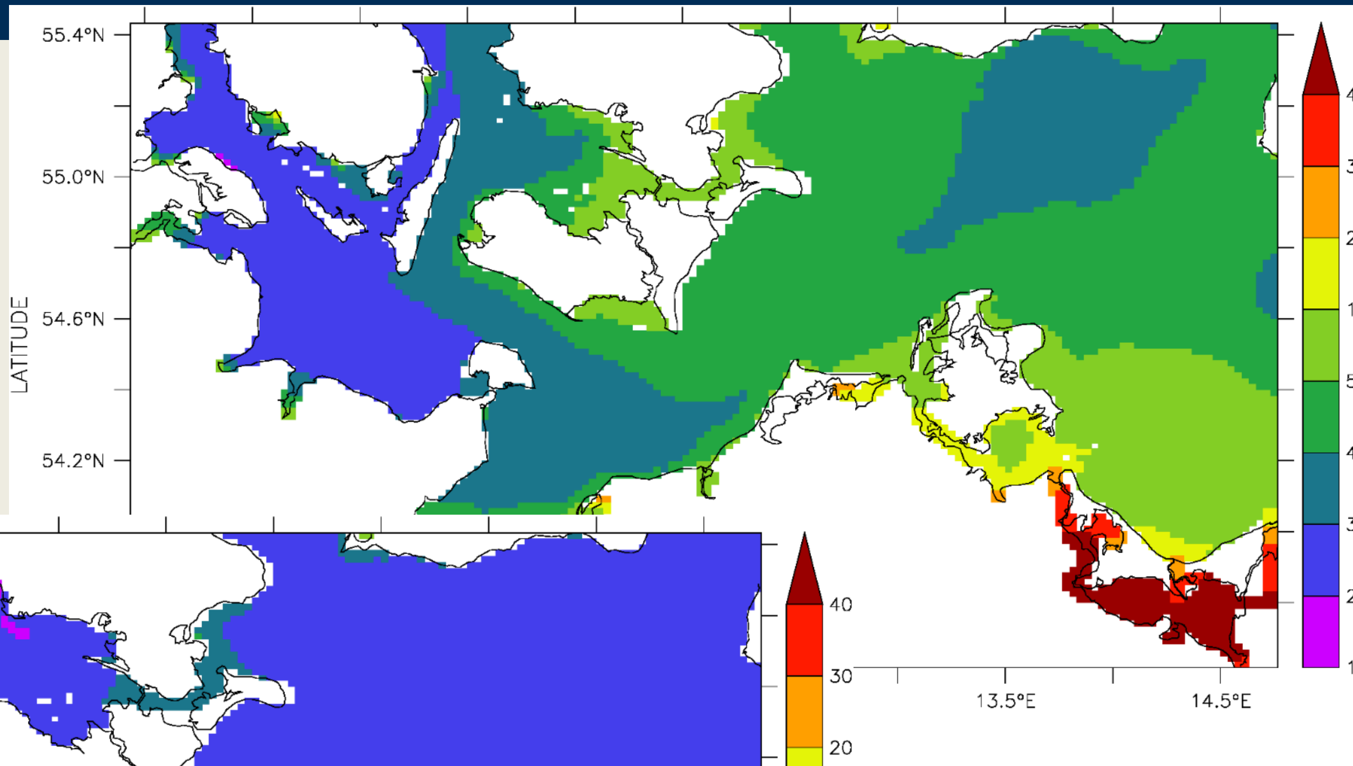
- Atmospheric Deposition
  - Ruoho-Airola et al. (2012): *Atmospheric nutrient input to the Baltic Sea from 1850–2006: A reconstruction from modeling results and historical data*
  - Savchuk et al. (2012): *Long-term reconstruction of nutrient loads to the Baltic Sea, 1850-2006*
    - TN: 66.200 t/a (217.300 t/a)
    - TP: 3.300 t/a (6.200 t/a)

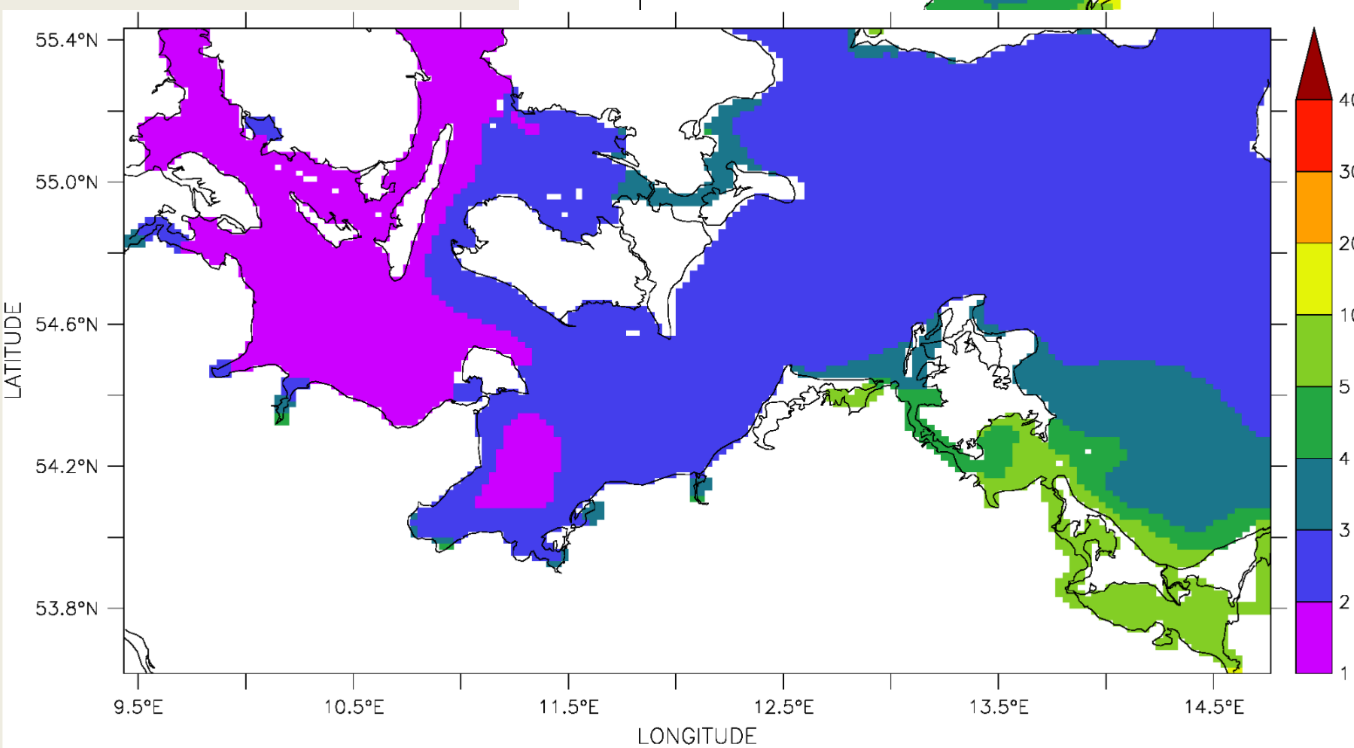
Model Setup & Forcing

- Weather
  - Reconstruction of 1850-2006
  - Schenk & Zorita (2012): *Reconstruction of high resolution atmospheric fields for Northern Europe using analog-upscaling*
- Open boundary
  - Sea surface height: reconstructed by using the sea level pressure
  - Temperature & salinity: climatology from present
- Bathymetry
  - 1 n.m. in the south-western part of the Baltic Sea
  - 3 n.m. elsewhere (including a transition zone)
- Time span 1875 – 1885
  - 5 years spin up, 1880 – 1885 only evaluated
  - initial value from previous simulation (started 1850)

Using ERGOM for historical simulations

Chlorophyll a (µg/l, Summer)





Historical simulatio: Chlorophyll (MJJAS)

Compared with present simulation

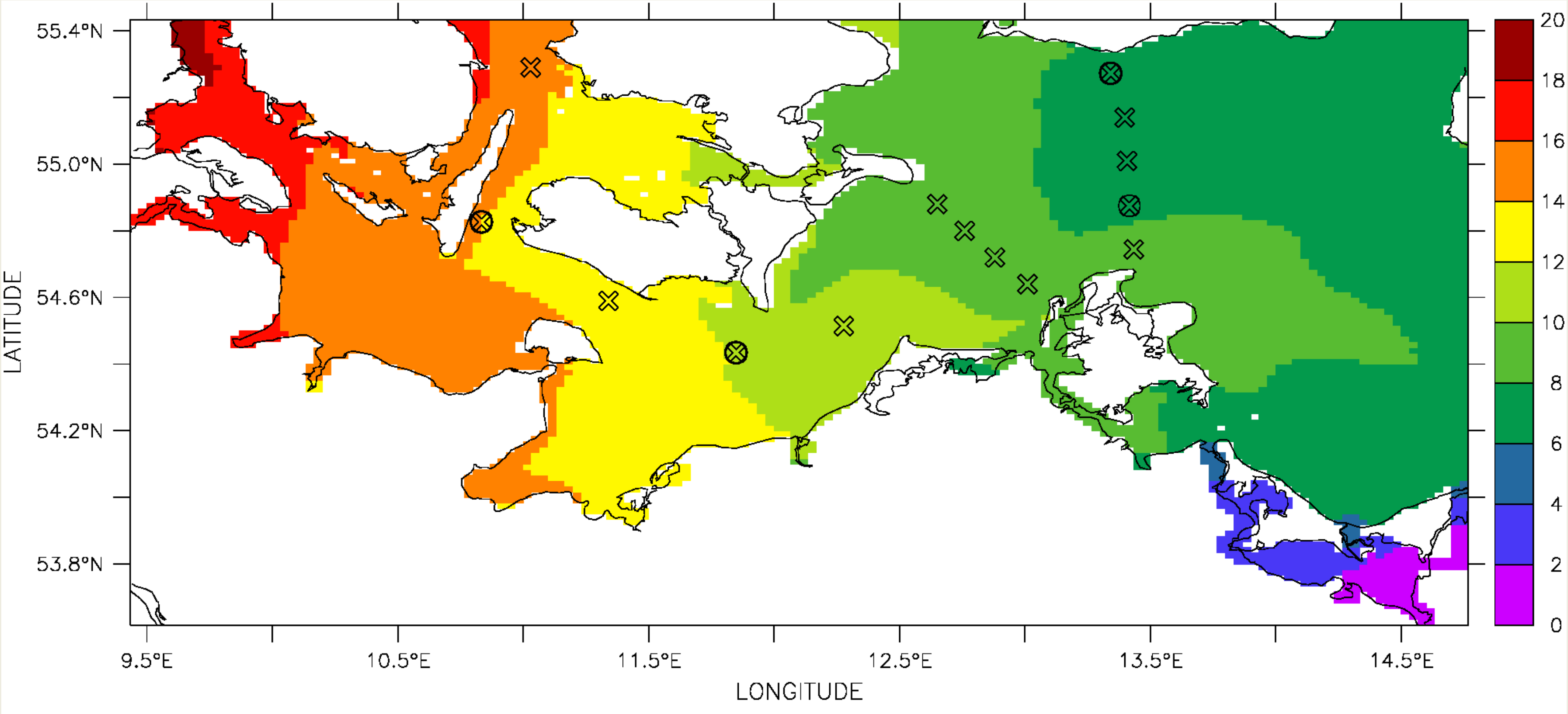
LOOKS NICE!

BUT HOW CAN WE DECIDE,

IF THE HISTORICAL SIMULATION

IS GOOD?

Compare with measurements: Ekman's cruise from July 1877



Mean sea surface salinity and Ekman's stations from 1877

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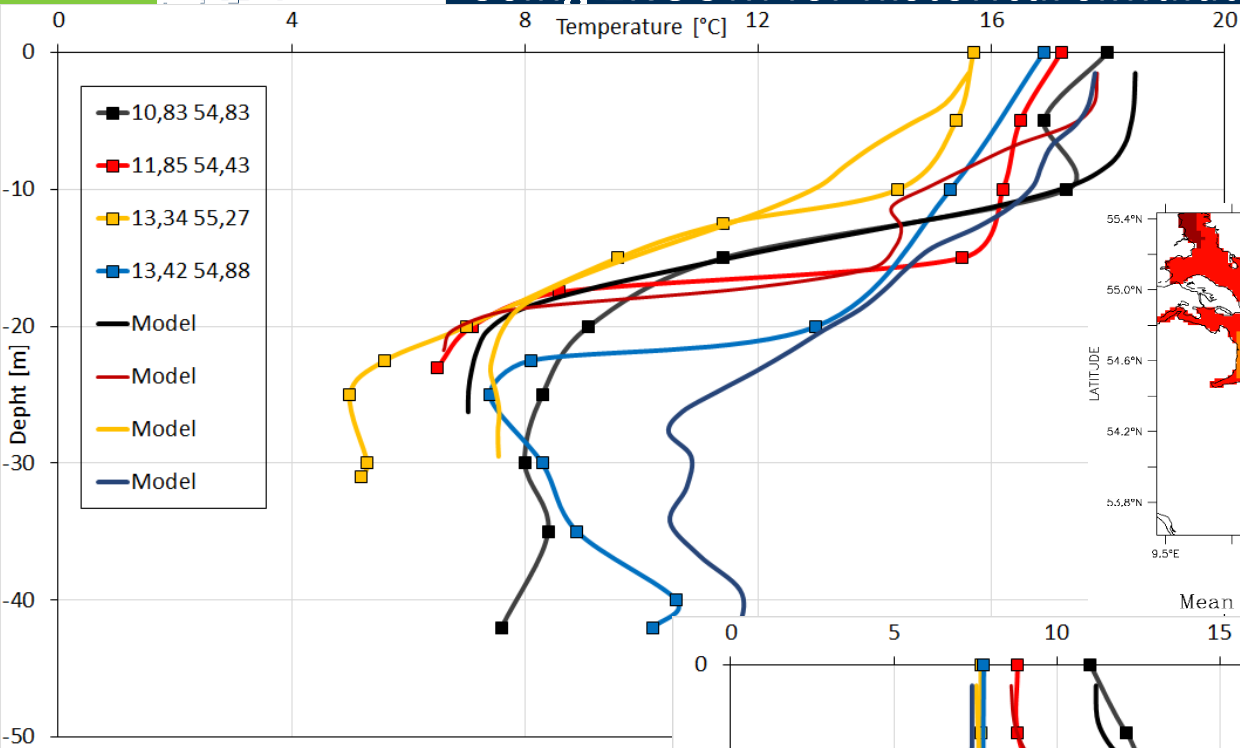
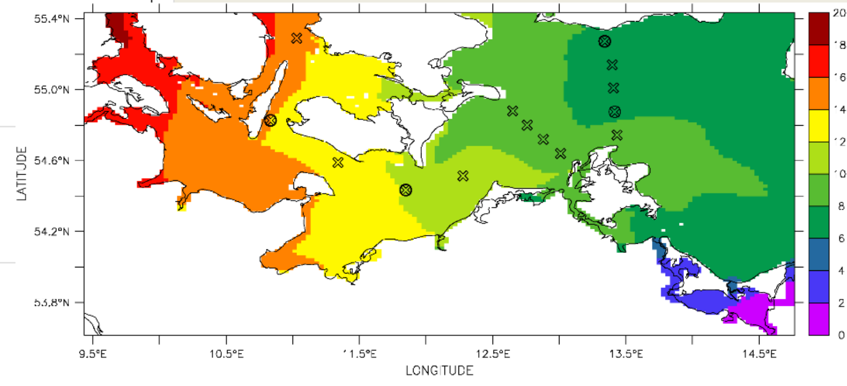
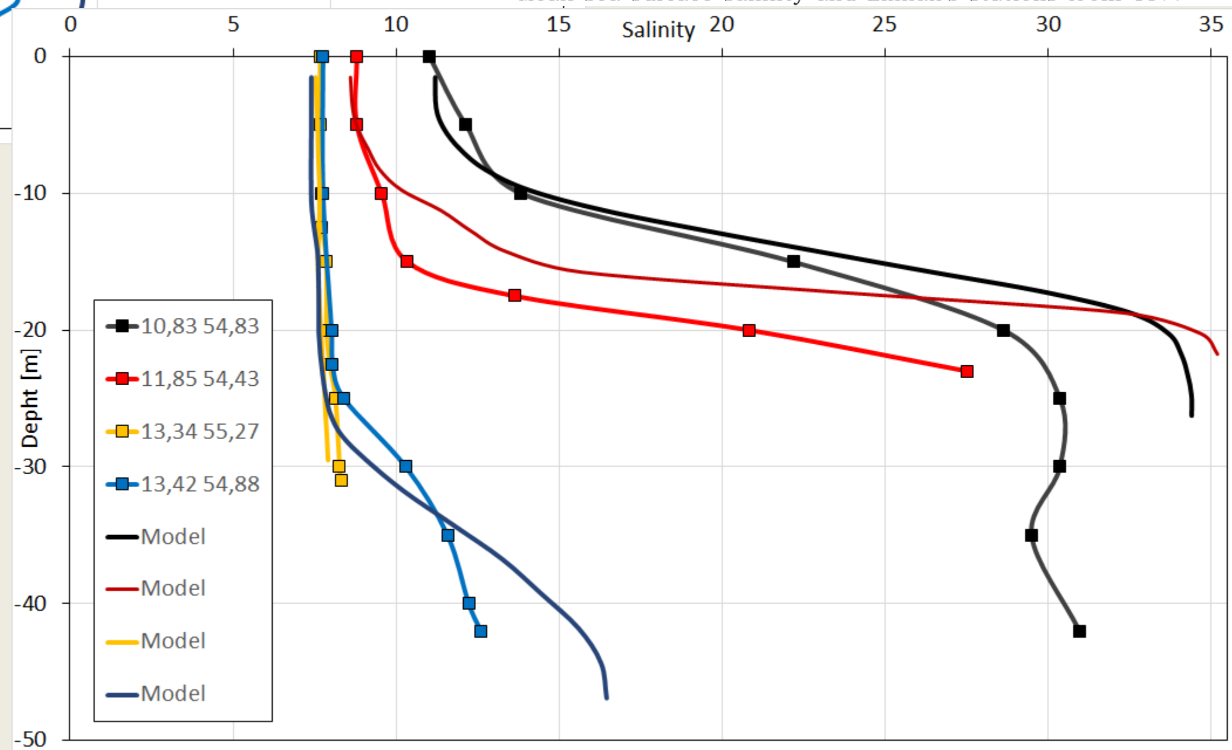




Mean sea surface salinity and Ekman's stations from 1877



Measured values taken from IOW's database ODIN

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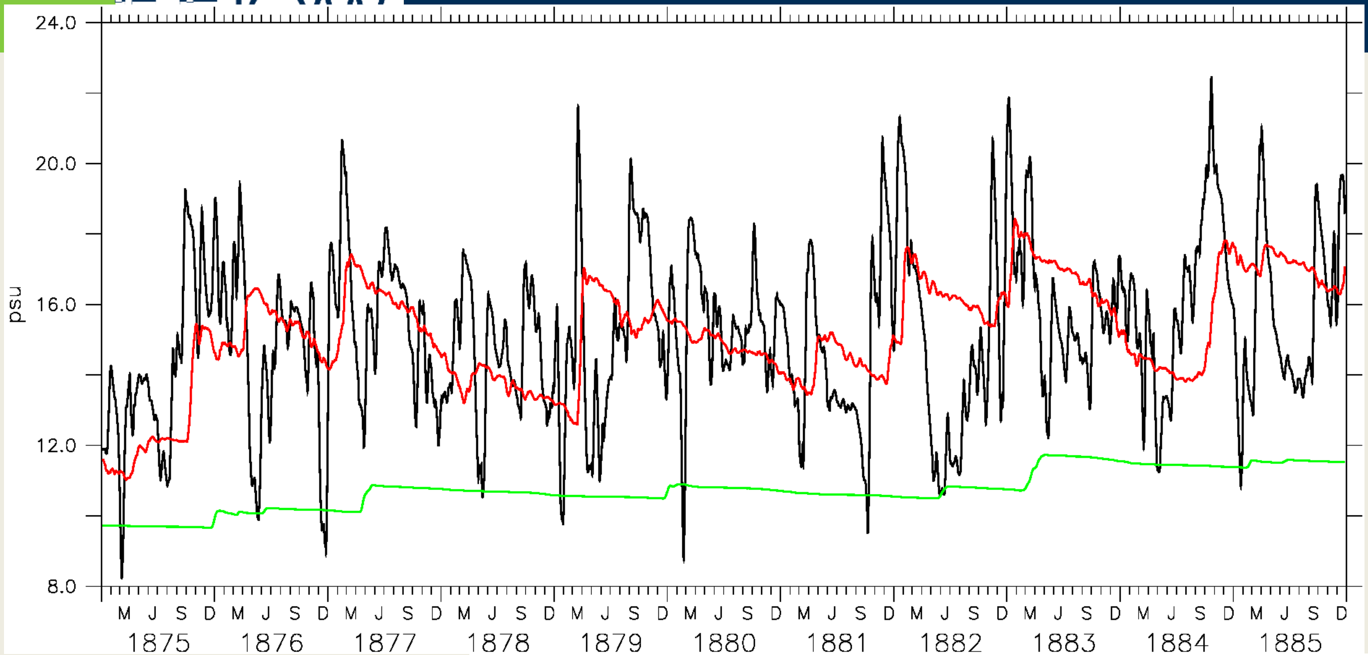


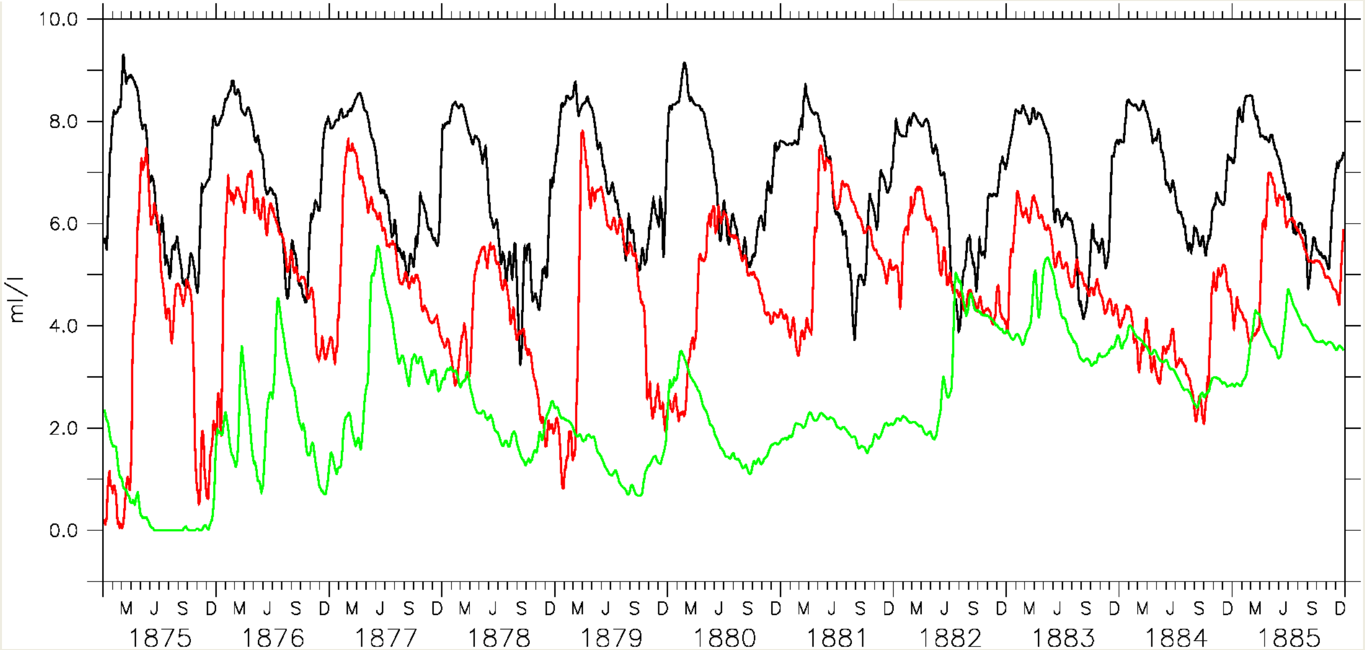
Occur inflows?

Bottom salinity & oxygen:

Arkona Sea

Bornholm Sea

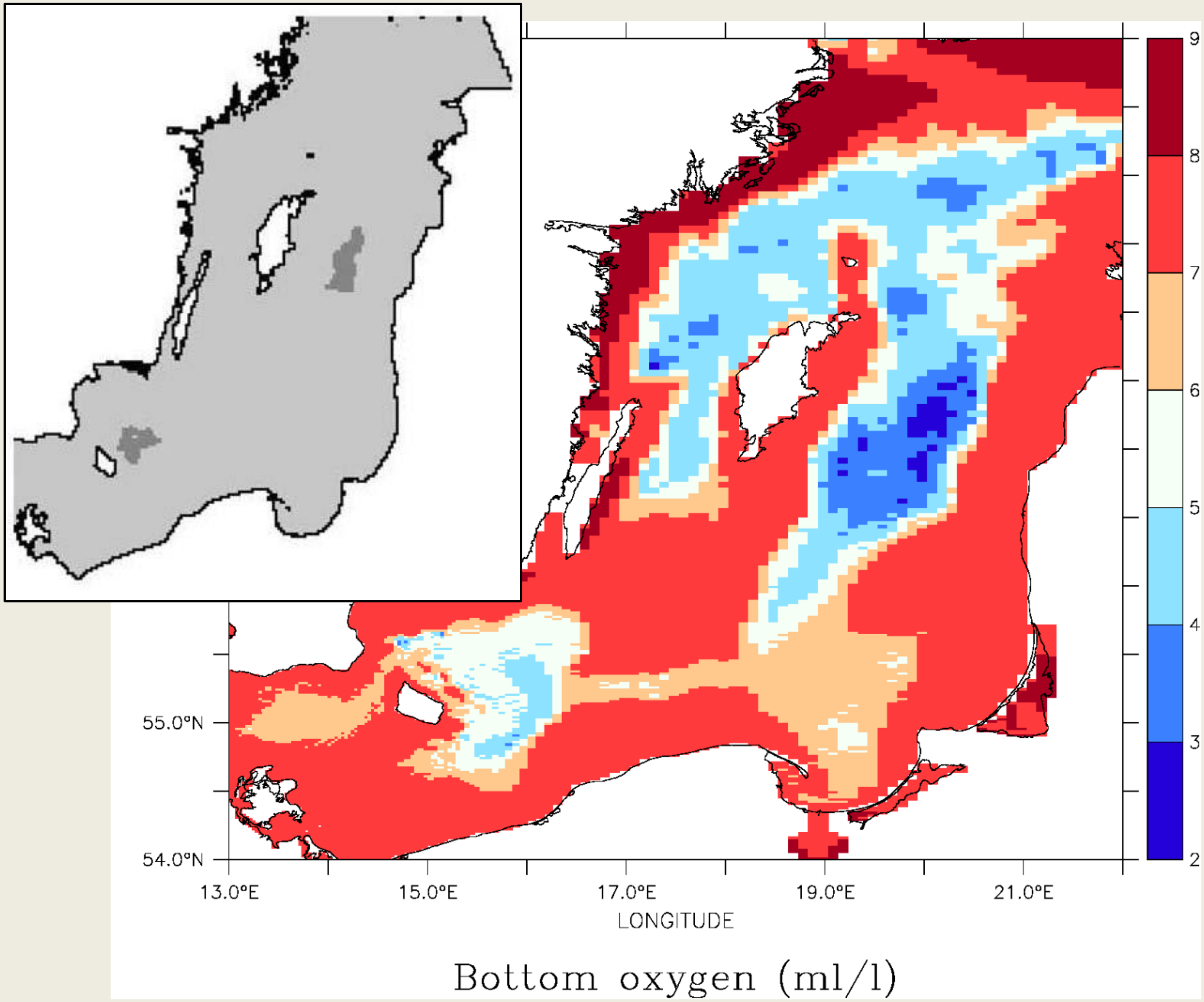
Gotland Deep



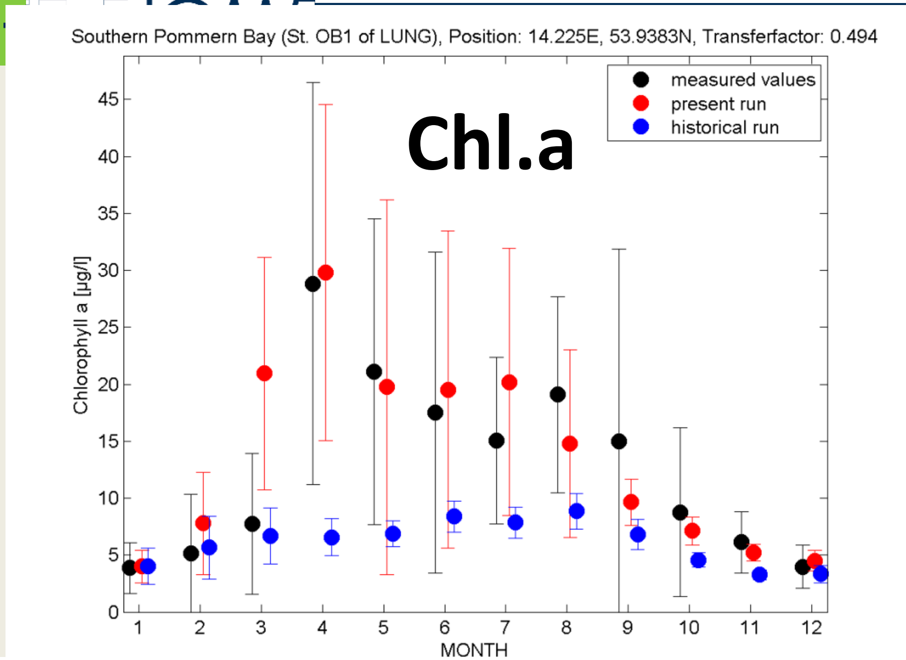
Look for literature estimates

Savchuk et al. (2008):

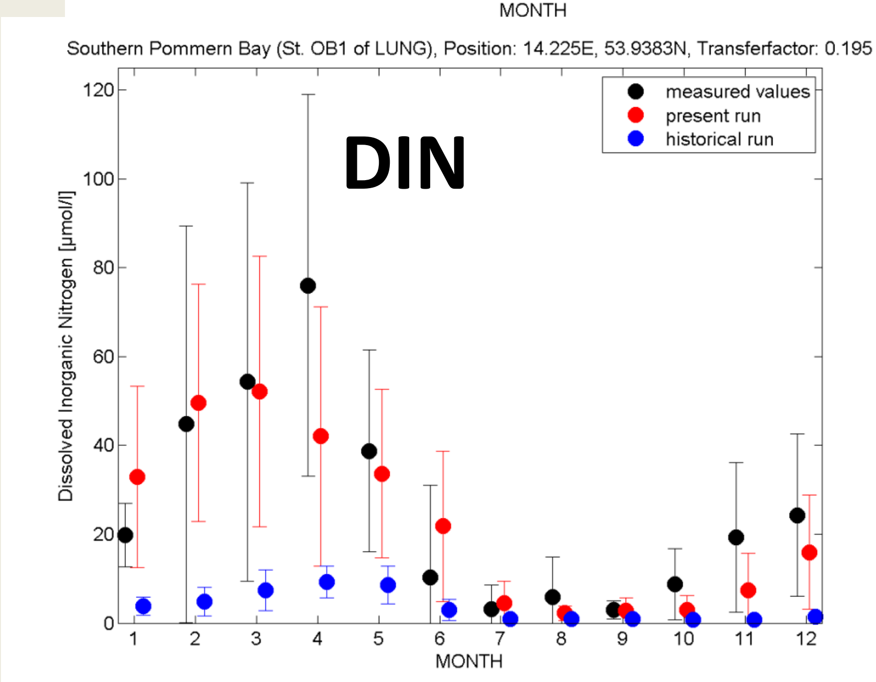
Hypoxic area reconstructed from observations (1905/06)

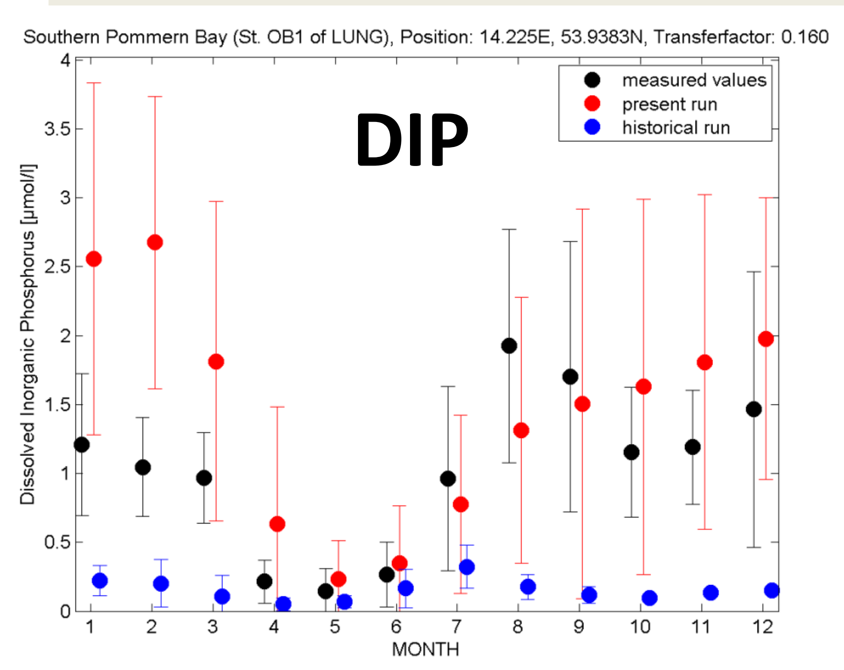


Using ERGOM for historical simulations



Annual cycle: Southern Pommern Bay





Using ERGOM for historical simulations

We have **problems** to fully reproduce the annual cycle!

Are our simulation results good enough to enter the **law**?

How can we include the **present measured concentrations** in the target definition?

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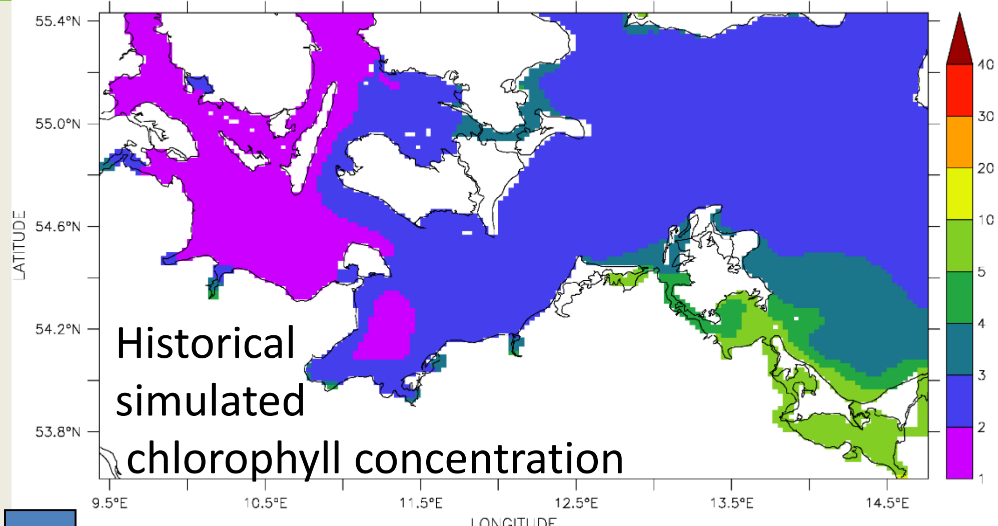
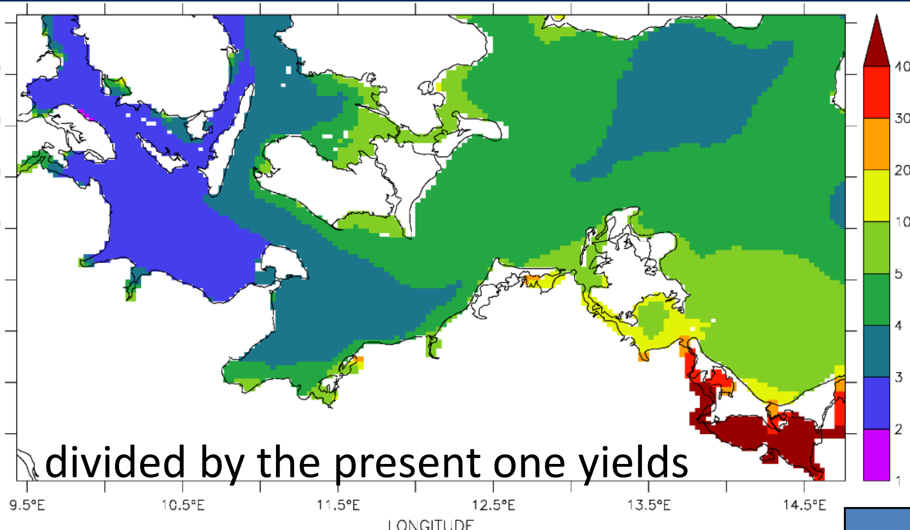
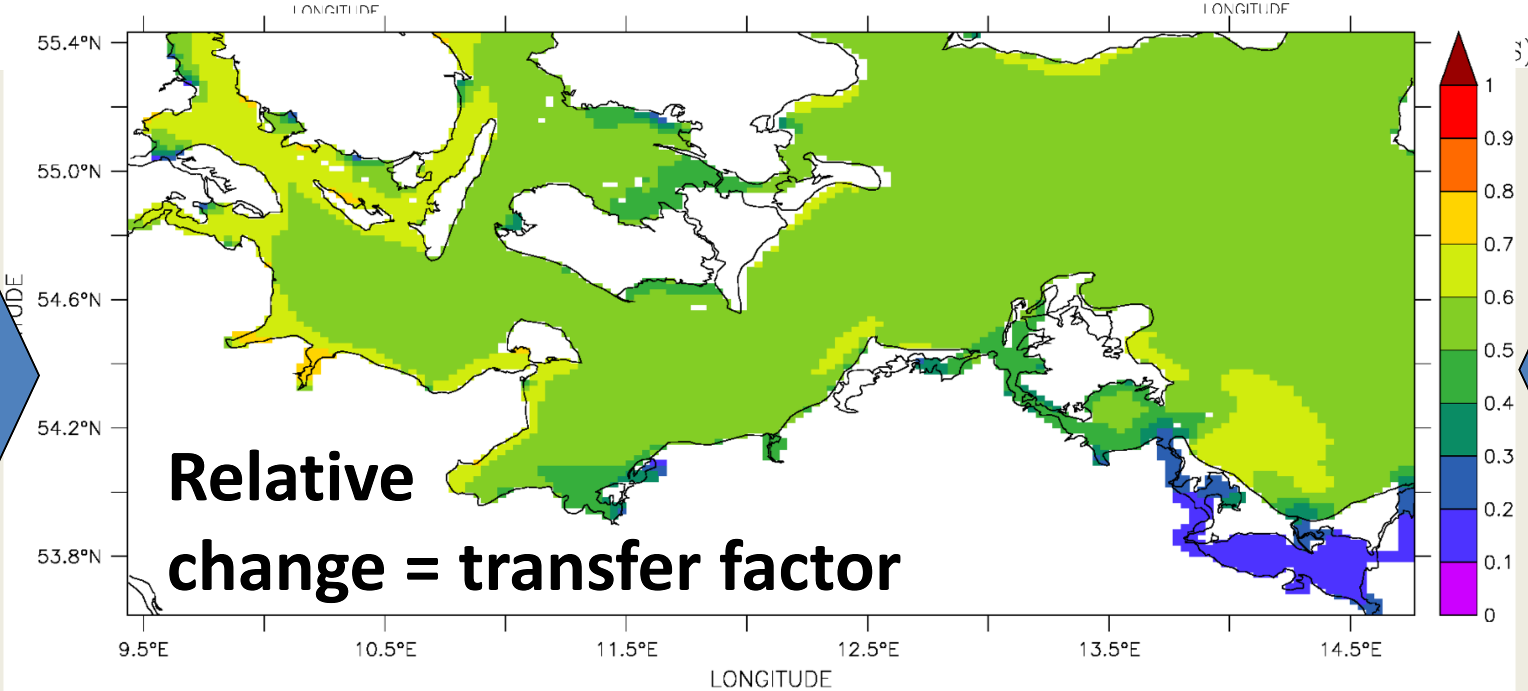
Using ERGOM for historical simulations



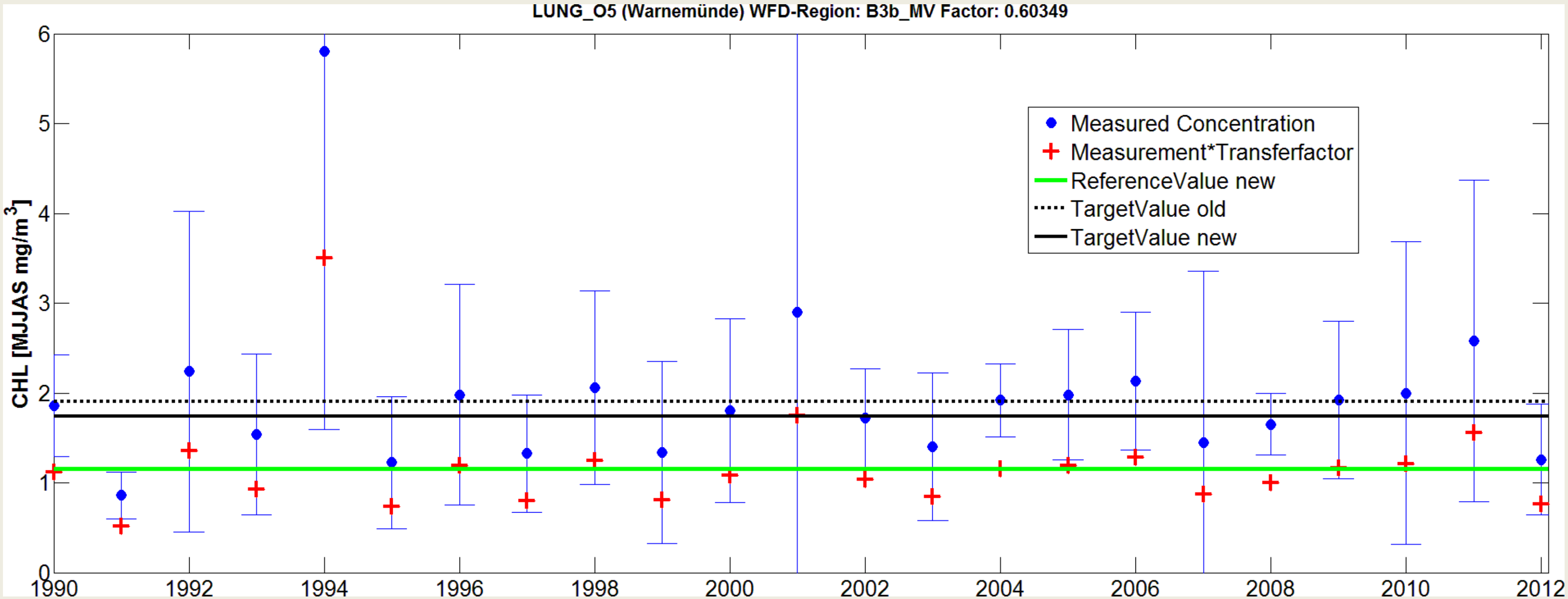




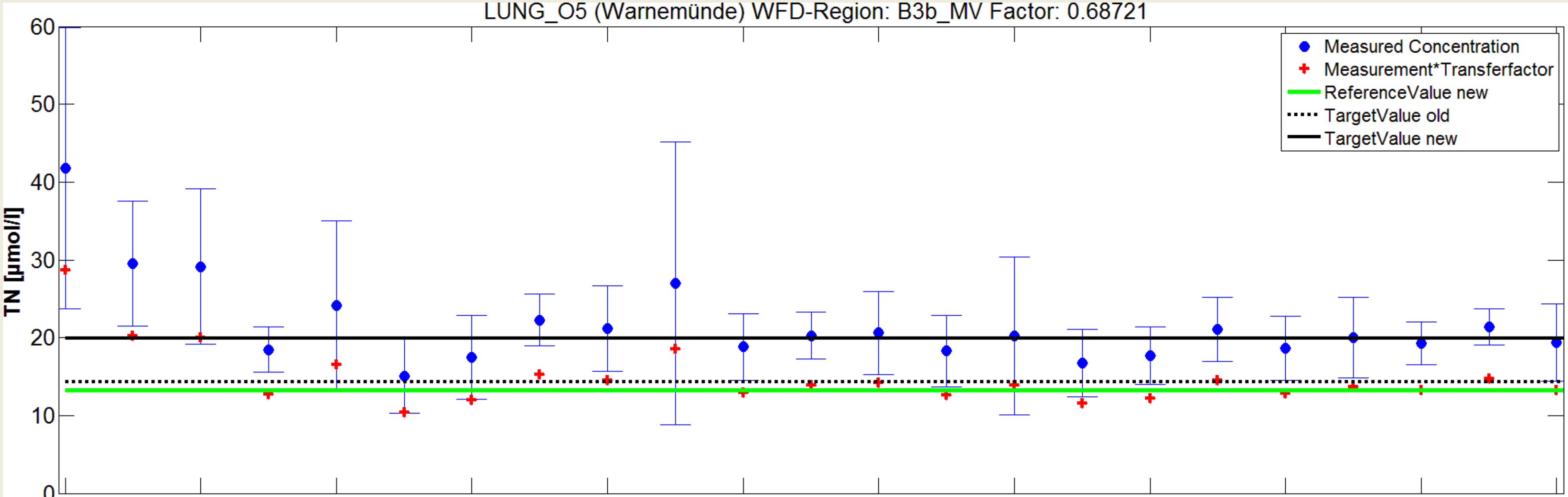
Relative change from historical to present nutrient loads: Chlorophyll (MJJAS)

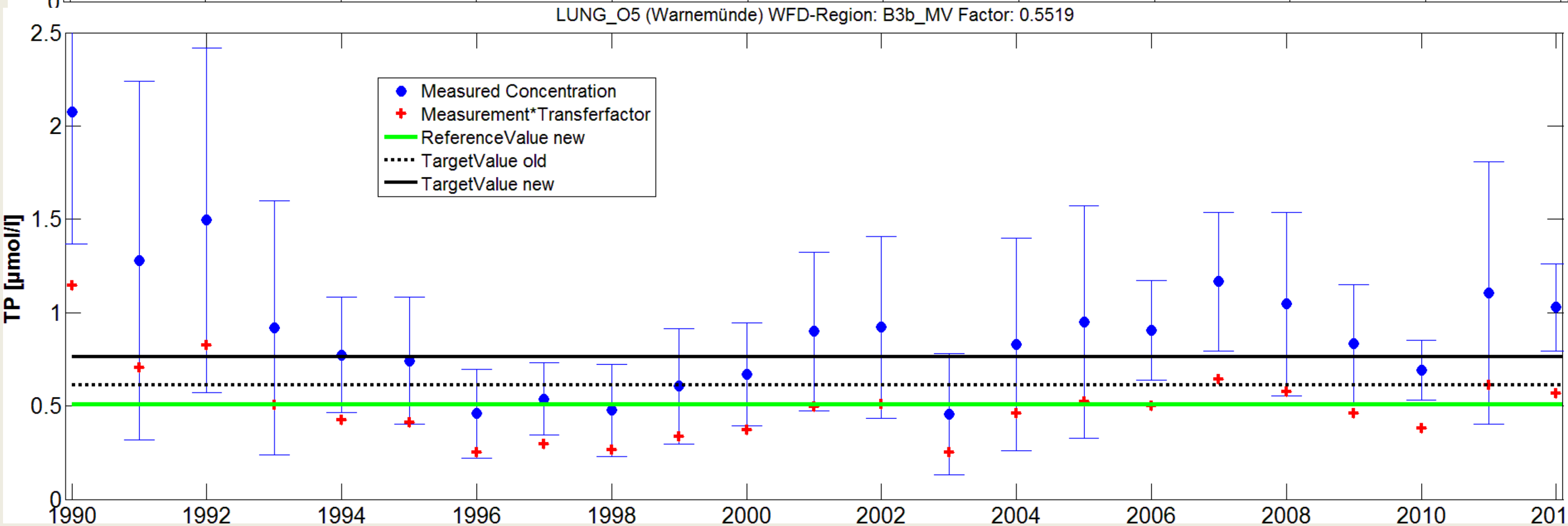
Multiplication of the relative change with the present measured concentrations yields the **reference state** and the new **target value**

Example: Station O5 (near Warnemünde)



Analog for TN & TP (annual averages)

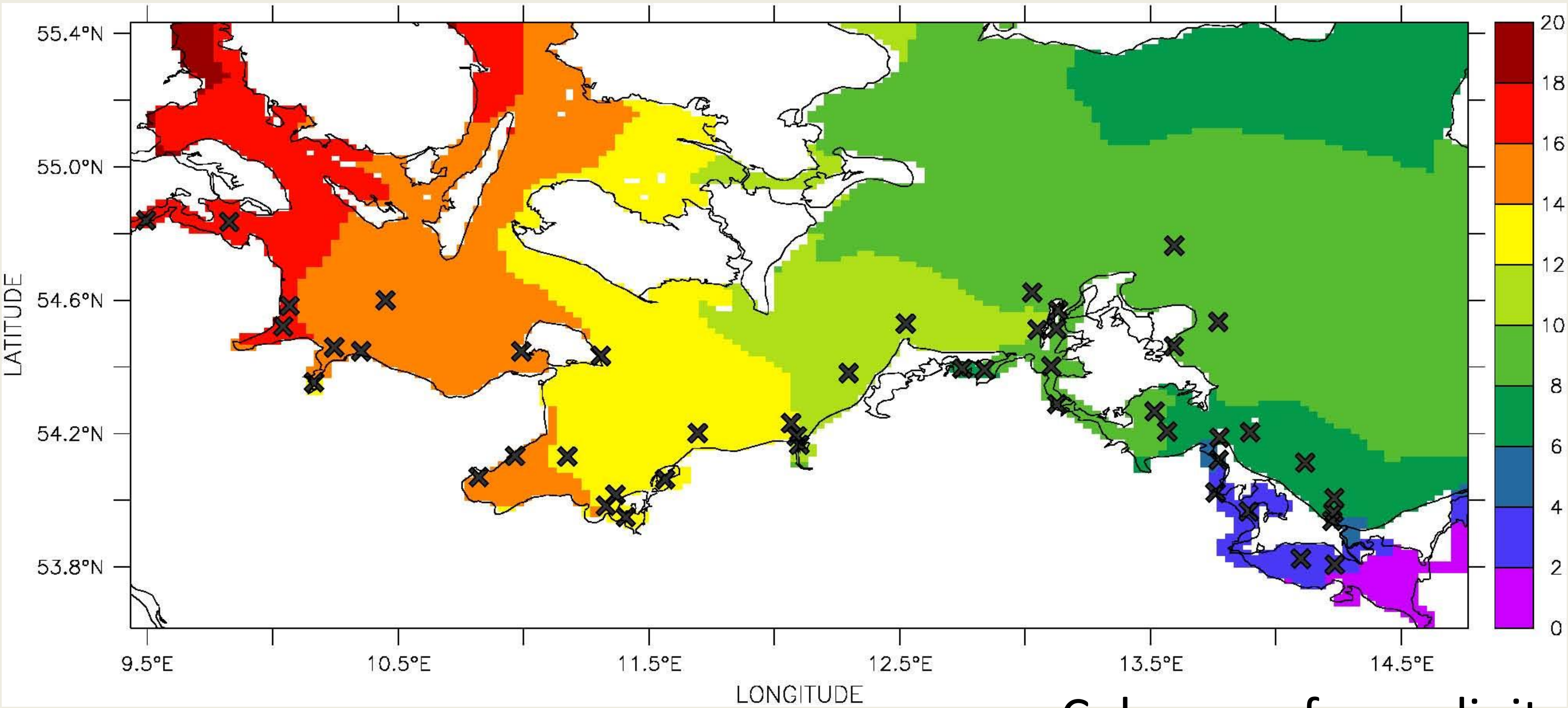




Advantages

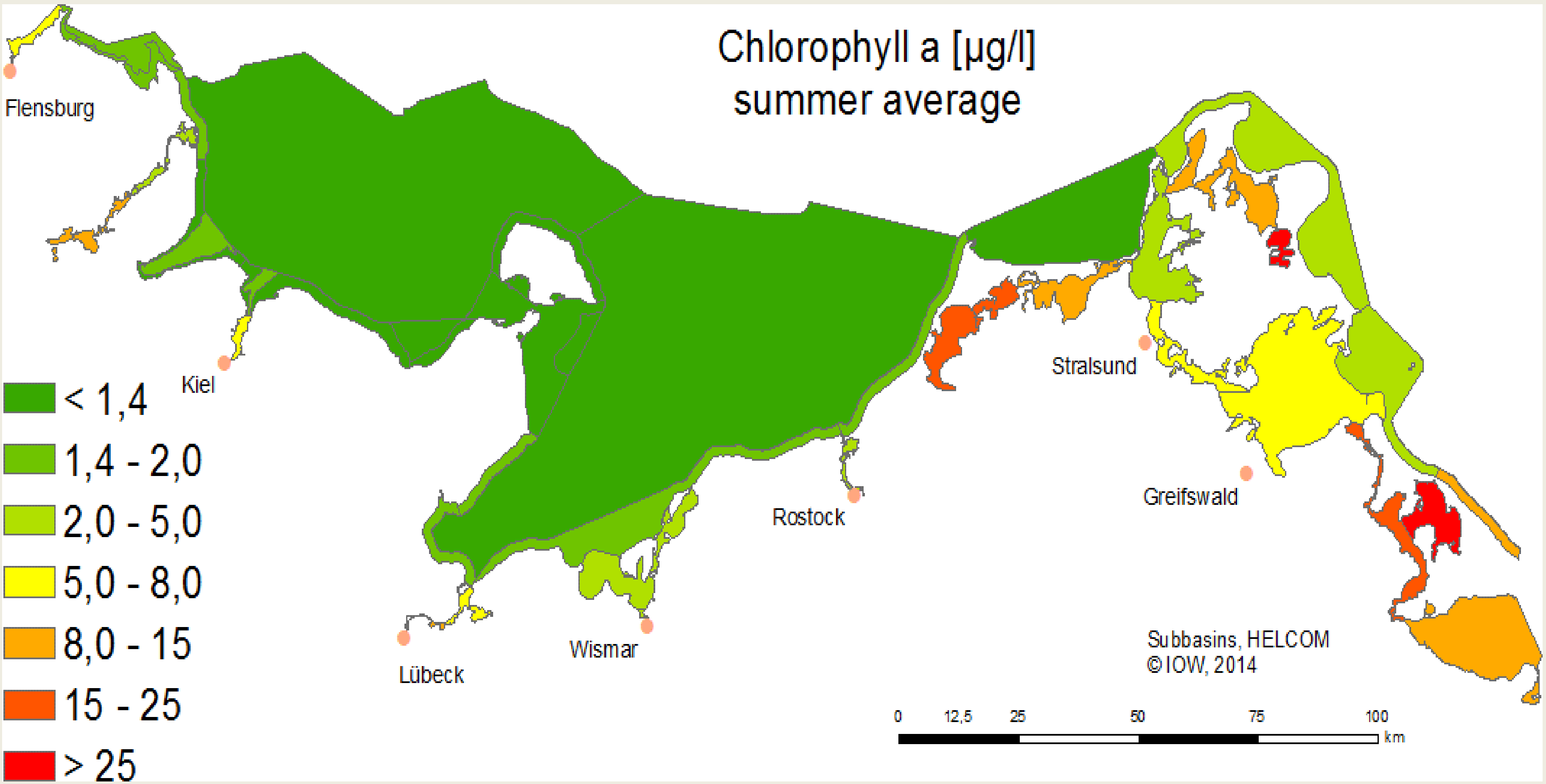
- Methodical bias of ERGOM levels out
- Method yields specific relative changes for every water quality parameter
- Reference values are consistent with present situation and include gradients from emission sources to the open sea (due to gradients within the measured concentrations and the computed relative changes)
- WFD-targets can be easily harmonized with the HELCOM targets for the open sea waters

For every WFD-station we computed specific reference values and combined the stations within one water body.



Color = surface salinity

New proposed WFD targets: CHL.a (MJJAS)



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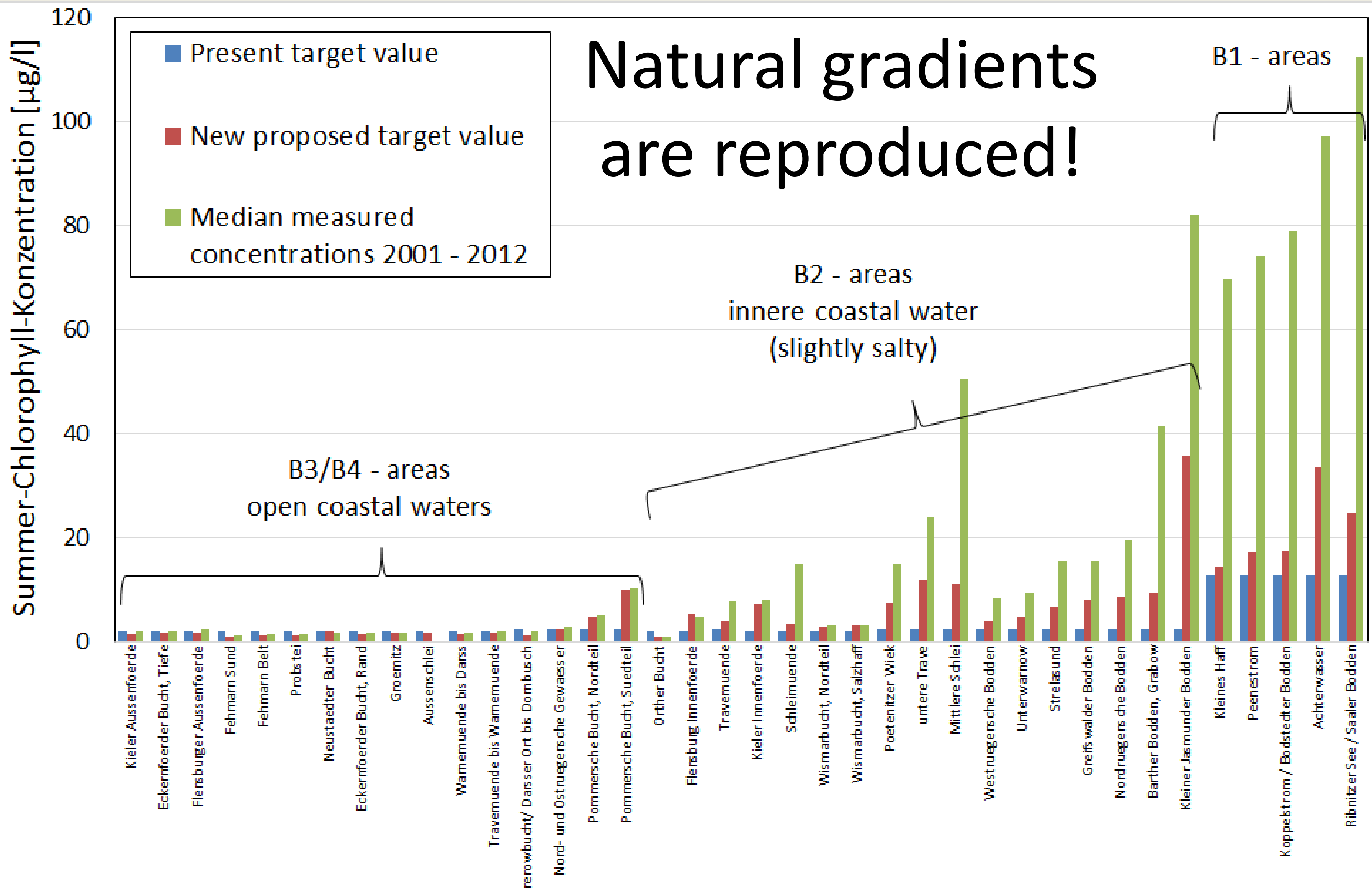
IOW

Using ERGOM for historical simulations



Harmonization of WFD with HELCOM's targets possible

	TARGREV (2013)			Schernewski et al. (submitted)		
	CHL.a [µg/l]	TN [µmol/l]	TP [µmol/l]	CHL.a [µg/l]	TN [µmol/l]	TP [µmol/l]
Danish Straits	1,44	21,8	0,97	1,56 (+)	19,3 (-)	0,47 (-)
Arkona Basin	1,89	17,4	0,66	1,79 (-)	19,3 (+)	0,52 (-)
Bornholm Basin	2,44	16,3	0,57	1,97 (-)	16,7 (+)	0,46 (-)

Using ERGOM for historical simulations

Eutrophication-chain

River basins

Rivers

Transitional waters

Coastal waters

Baltic Sea

Marine Strategy Framework Directive (**MSFD**):
Baltic Sea Action Plan (BSAP)

River basin

Approach: Load reductions
Rivers

Transitional waters

Coastal waters

target: Good status
Baltic Sea

Water Framework Directive (**WFD**)

Approach: management
River basins

Target: rivers

Target:
Transitional waters

Target:
Coastal waters

Baltic Sea

TN-load reduction of 34% necessary (in the complete box including southern Denmark and the Oder) to decrease the summer Chlorophyll-concentration with 20%

Maximum allowable German loads

	Total N [t/a]	Atmospheric TN [t/a]	Waterborne TN [t/a]	River conc. TN [mg/l]	Total P [t/a]	Average Chl.a [µg/l]
Reference 1997-2003 (PLC 5.5)	32.697	13.007	19.690	**4,7**	526	4,5
TN-Reduction (34%) only in rivers	21.477	13.007	8.470	**2,0**	526	3,6
Gothenburg Protocol (atmosph. TN -20%)	21.477	10.406	11.072	**2,6**	526	3,6
TN-Reduction (34%) evenly distributed	21.477	8.544	12.934	**3,1**	526	3,6
TN-Reduction (34%) + TP acc. to BSAP (2013)	21.477	8.544	12.934	**3,1**	356	4,0
TN-Reduction (47%) + TP acc. to BSAP (2013)	17.310	6.886	10.424	**2,5**	356	3,6
Reference loads (1880)	9.027	3.900	5.127	**1,2**	227	2,4

Schernewski, Friedland, Carstens, Hirt, Leujak, Nausch, Neumann, Petenati, Sagert, Wasmund & von Weber:
Implementation of European marine policy:
New water quality targets for German Baltic waters
(submitted to Marine Policy)

Using ERGOM for historical simulations

Bundesministerium für Bildung und Forschung

FONA Forschung für Nachhaltige Entwicklungen BMBF

PtJ Projektträger Jülich Forschungszentrum Jülich

SECOS

MOSSCO

RA:dOst Regional Adaptation Strategies for the German Baltic Sea Coast

HLRN

Supercomputing power was provided by the North-German Supercomputing Alliance