Projected Changes in Baltic Sea Upwelling from an Ensemble of RCP Scenario Simulations

MedCORDEX-Baltic Earth-COST Workshop on

Regional Climate System Modelling for the European Sea Regions

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Motivation

SMHI

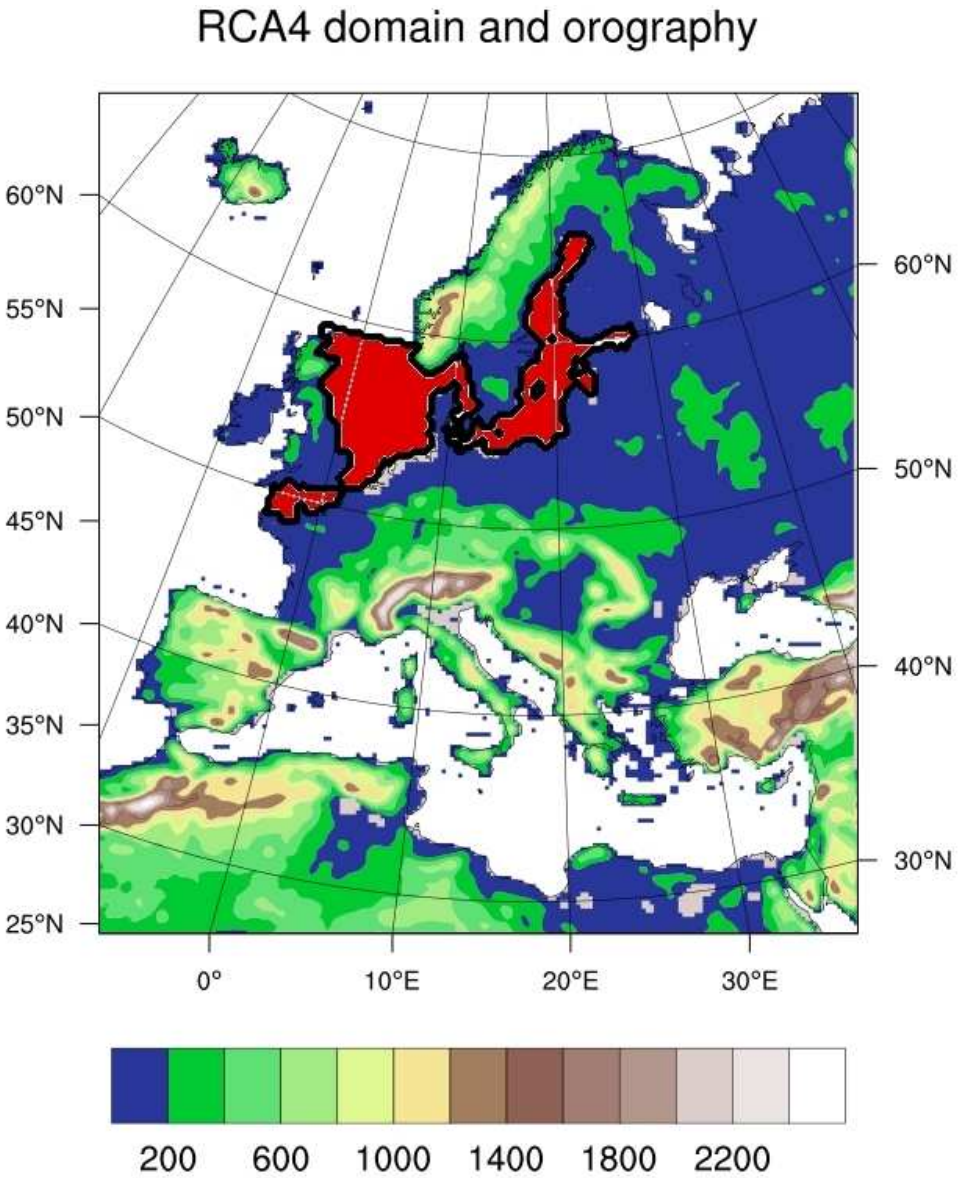
How does upwelling affect

- Vertical transport (of nutrients)?
- Communication between Coastal Zone and open Baltic?
- Feedback to the atmosphere?

Upwelling plays a potential role for

- Algae bloom forecast
- Fisheries
- Weather prediction
- Tourism (Lehmann & Myrberg, 2008)

Atmosphere-Ice-Ocean Model RCA4-NEMO



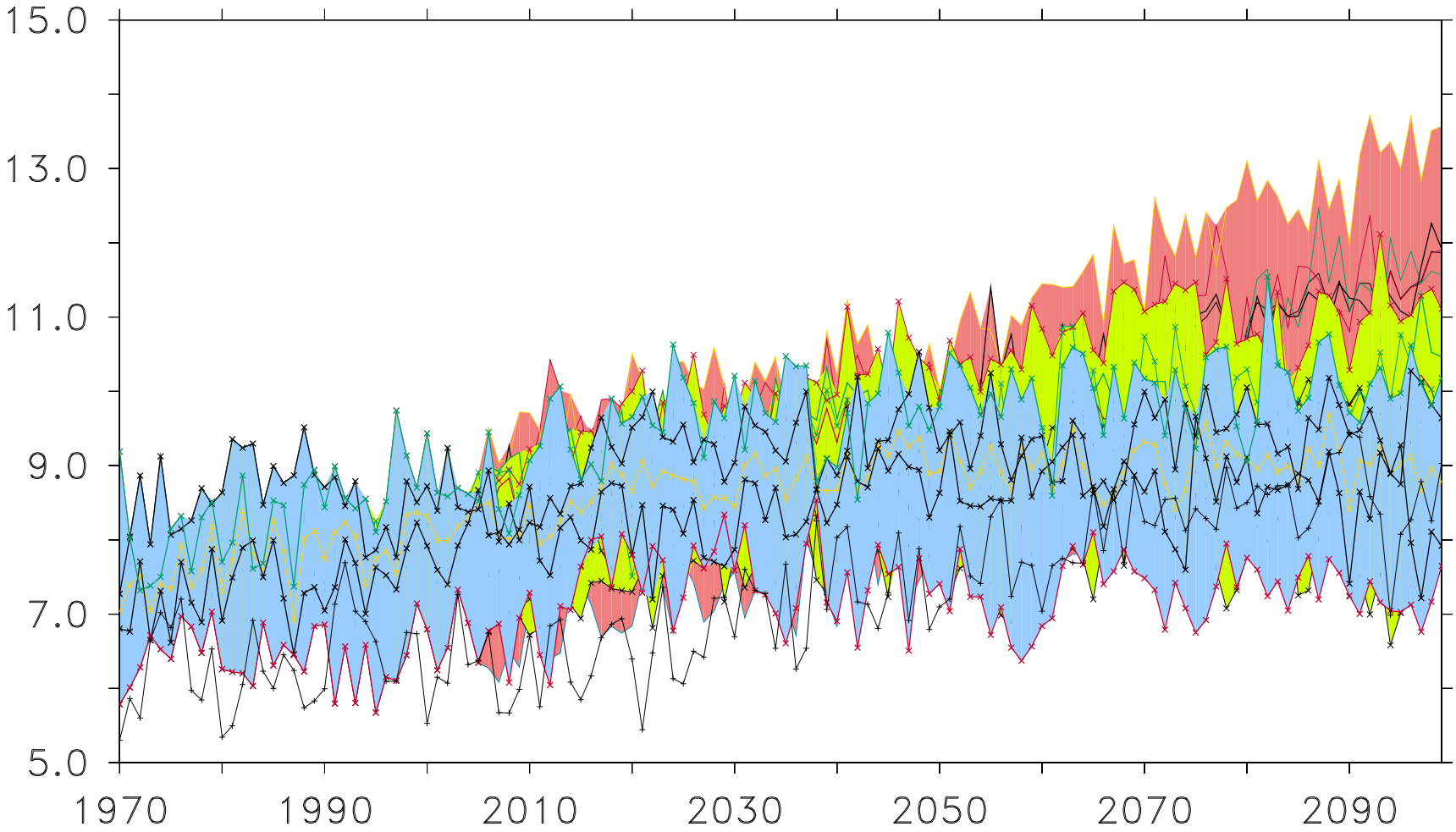
- EURO-CORDEX setup for RCA4
- Resolution: 0.22°, 40 levels
- Flux-coupled every 3 hours to NEMO-Nordic
- Resolution: 2 naut. miles, 56 levels, 5 ice classes
- Boundary conditions: GCM or reanalysis data
- Runoff: E-HYPE hindcast data

Ensemble of Scenarios with RCA4-NEMO

experiment	historical	RCP 8.5	RCP 4.5	RCP 2.6
ERA40	1961 - 2010			
MPI-ESM-LR	1961 - 2006	2006 - 2099	2006 - 2099	2006 - 2099
EC-EARTH	1961 - 2006	2006 - 2099	2006 - 2099	2006 - 2099
GFDL-ESM2M	1961 - 2006	2006 - 2099	2006 - 2099	2006 - 2099
HadGEM2-ES	1961 - 2006	2006 - 2099	2006 - 2099	2006 - 2099
IPSL-CM5A-MR	1961 - 2006	2006 - 2099	2006 - 2099	

- 5 different GCMs
- 3 different scenarios
- ECHAM5/MPIOM, SRES A1B
- 1 RCM

Projected Baltic Sea SST

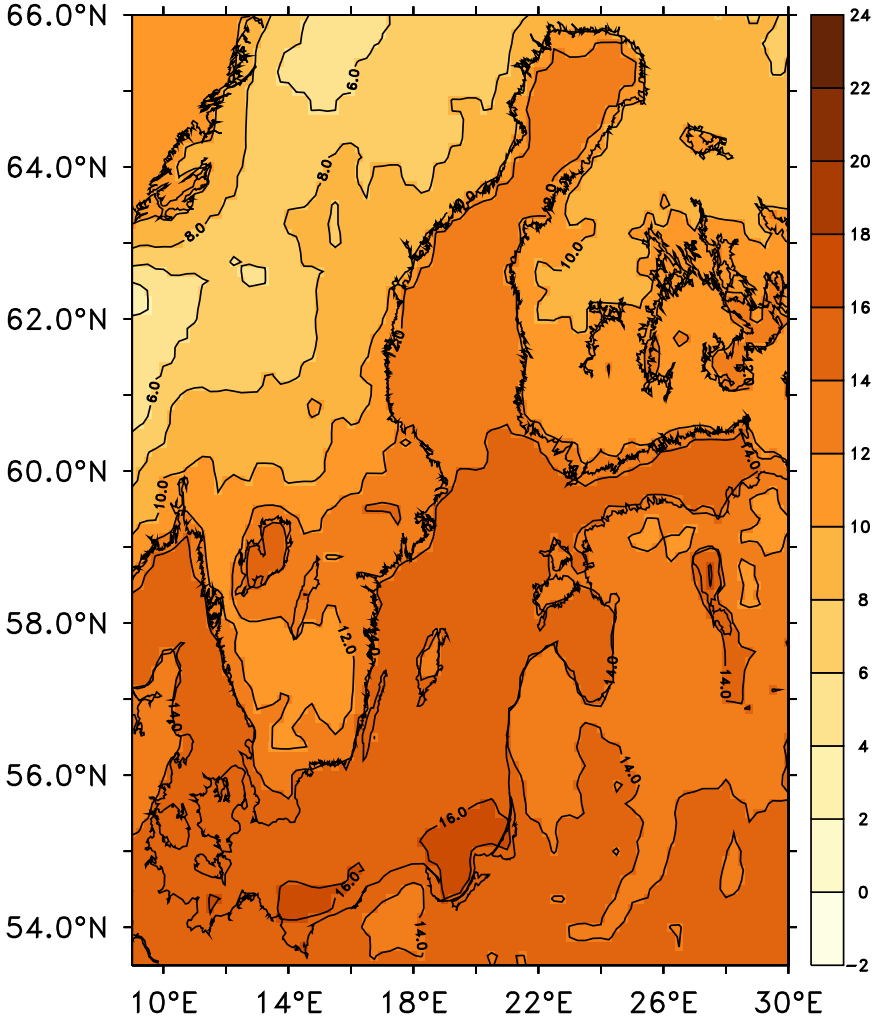


Baltic Sea SST 1970 - 2099 [C]

RCA4-NEMO RCP8.5 (red), RCA4-NEMO RCP4.5 (green),

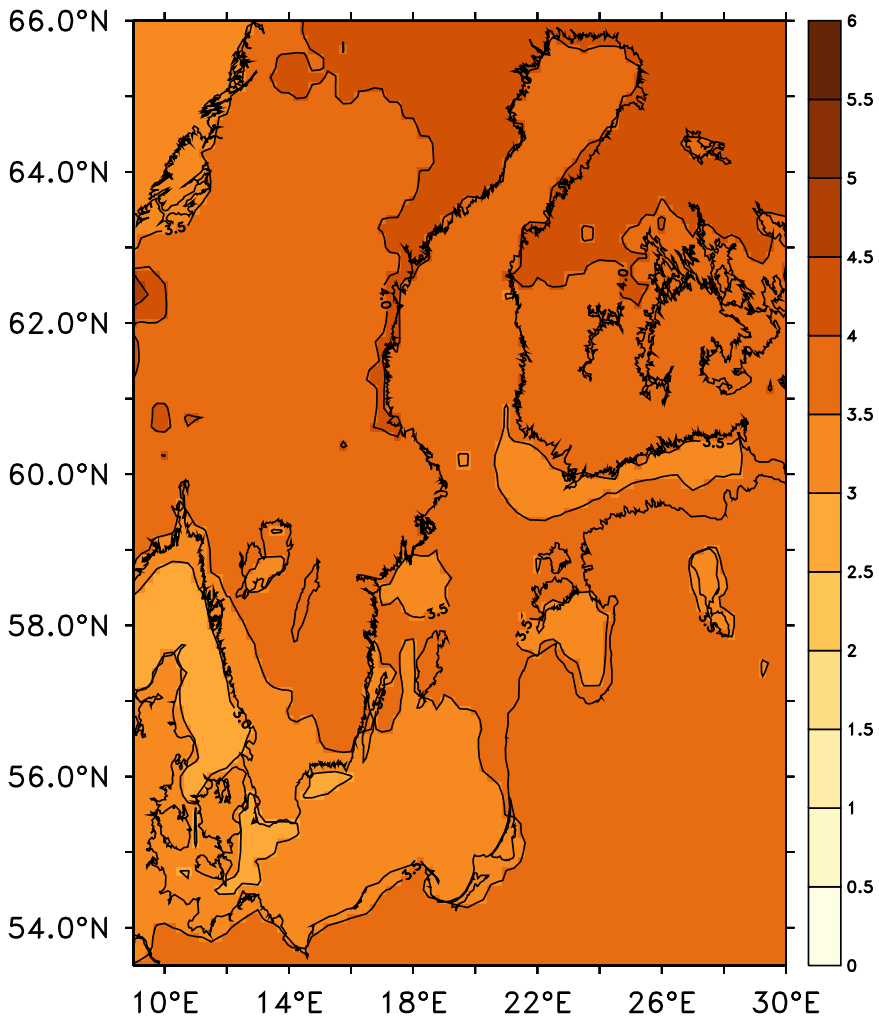
RCA4-NEMO RCP2.6 (blue)

Differential Heating Due to Climate Change



Summer air temperature [C]

Ensemble median RCP 8.5 1970 to 1999



changes in air temperature [C]

2070 to 2099 minus 1970 to 1999

Mechanism for Coastal Upwelling

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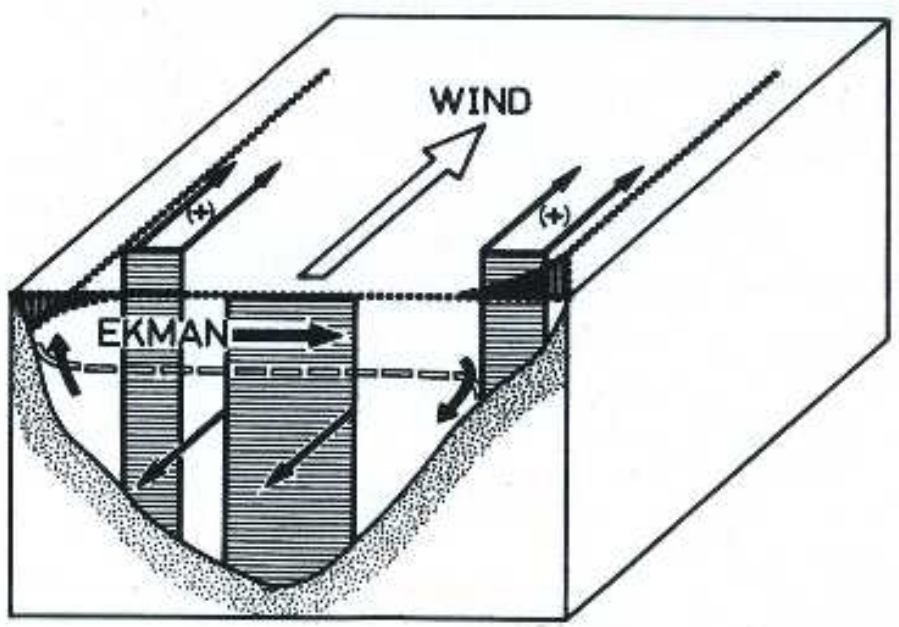

Figure 3. Principle response of an elongated basin to constant wind in length direction of the basin, redrawn from Krauss and Brügge (1991).

(Lehmann & Myrberg, 2008)

Coastal Upwelling in the Baltic Sea

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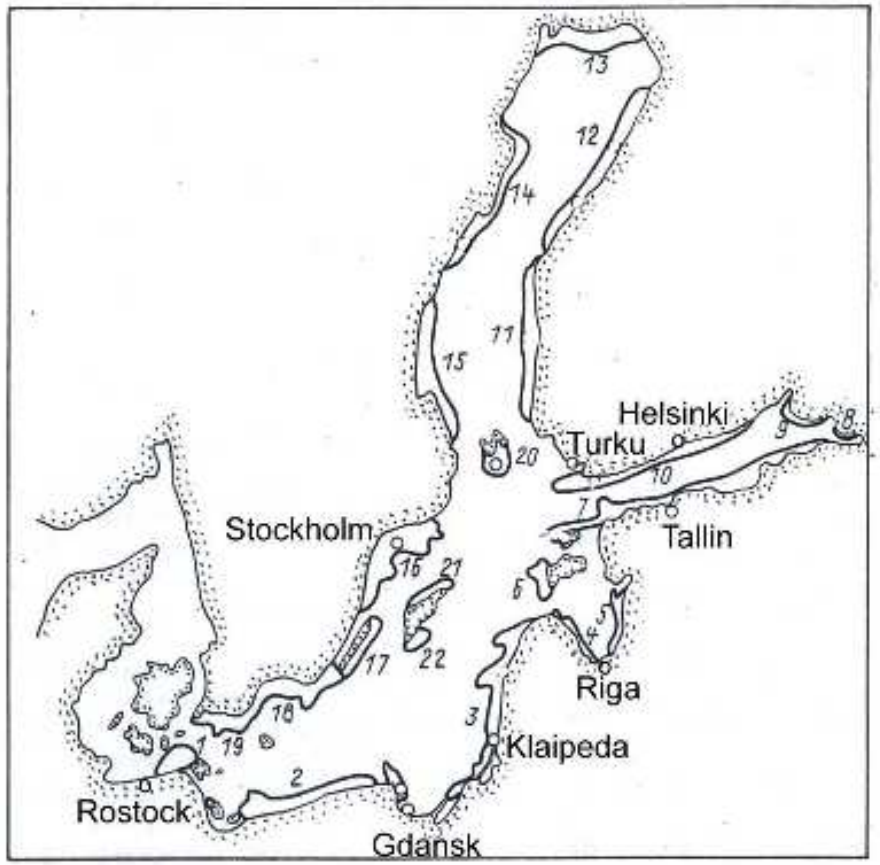
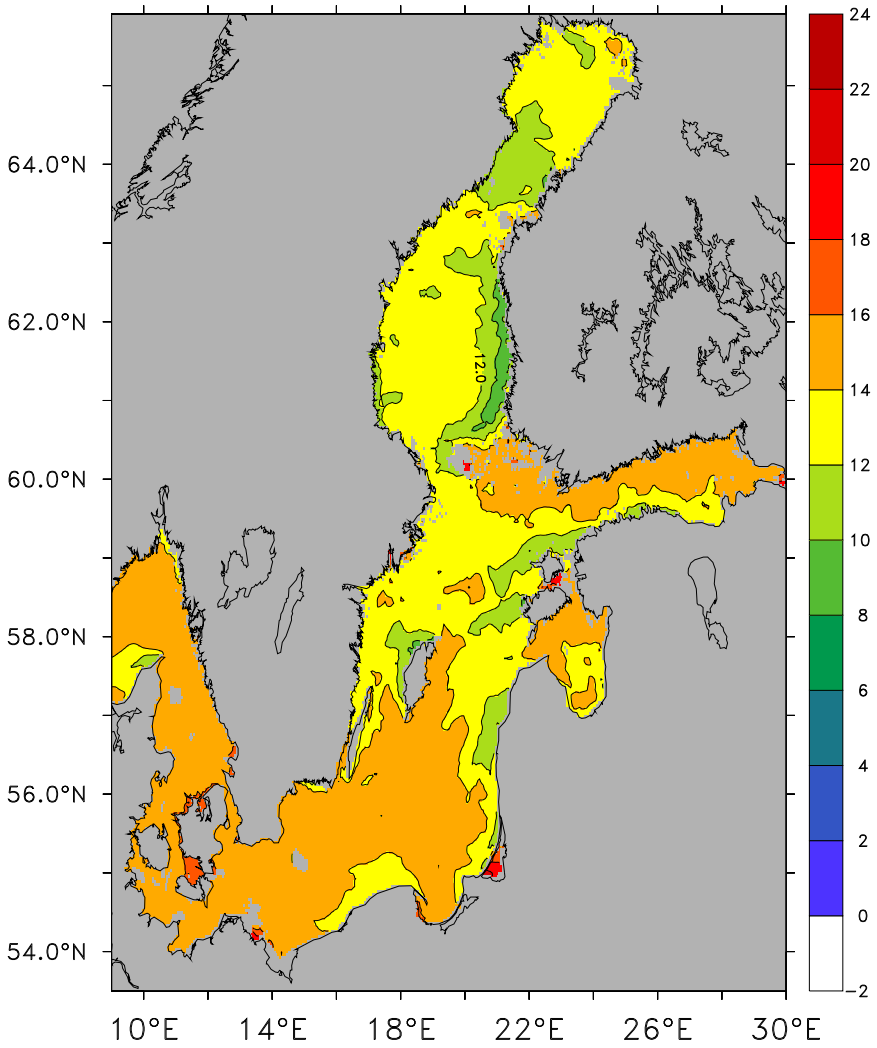


(Lehmann & Myrberg, 2008)

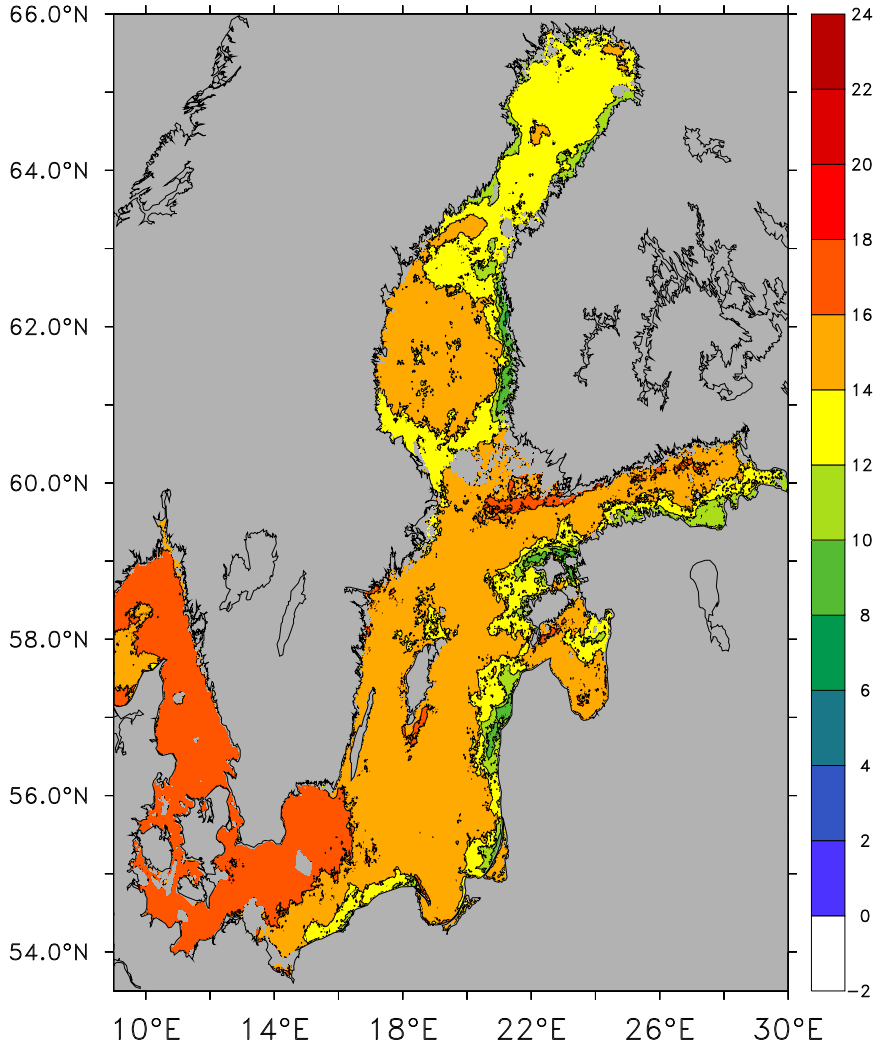
Figure 4. Main upwelling regions in the Baltic Sea due to corresponding general weather conditions, redrawn from Bychkova et al. (1988).

An Example of an Upwelling Event



September 1996, SST [C]

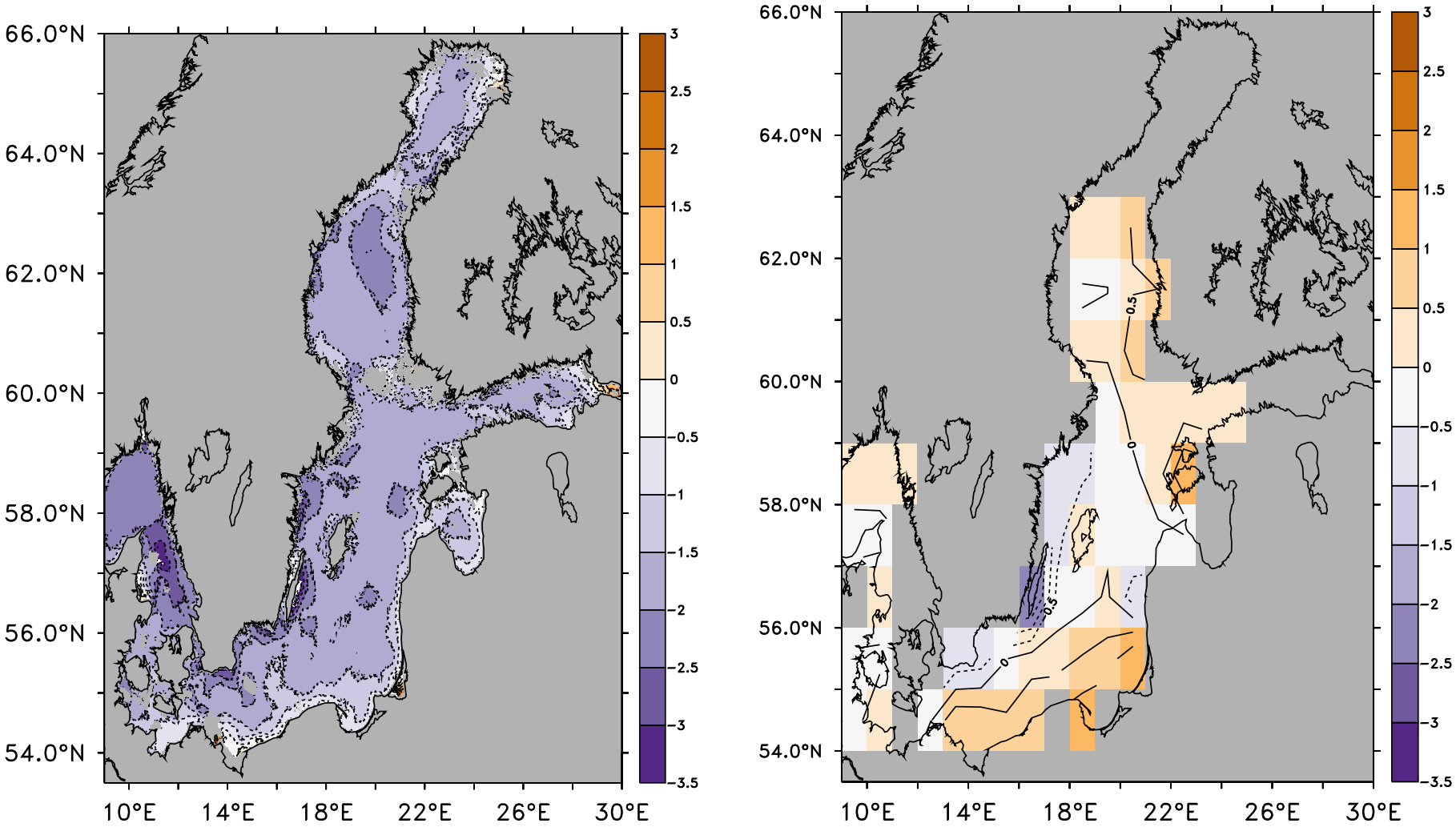
RCA4-NEMO ERA40



September 1996, SST [C]

BSH SST

Model Validation

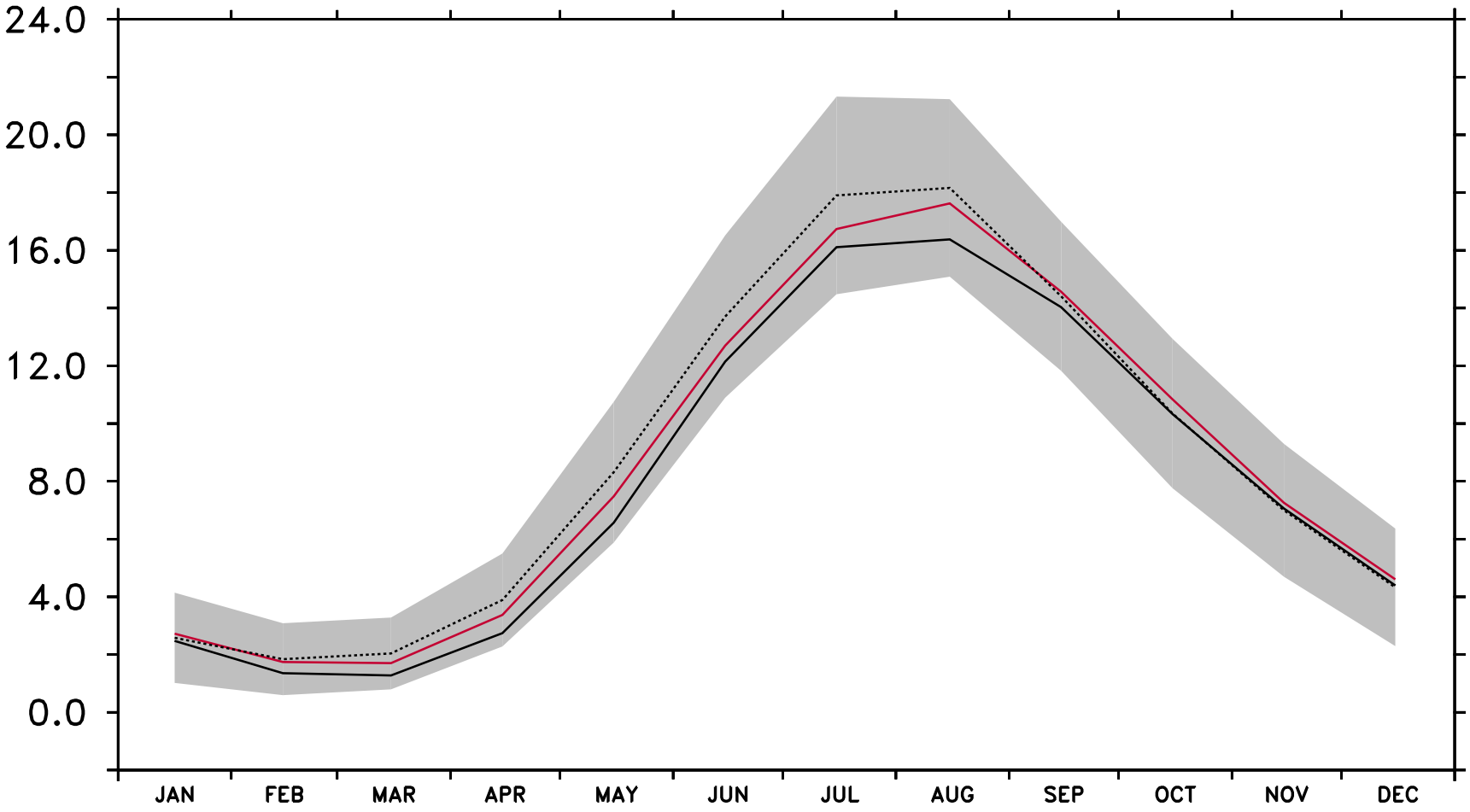


SST bias [C] for RCA4-NEMO Ensemble Median

BSH SST (August 1990 to 2009)

ASMD94 (August 1970 to 1989)

Model Validation

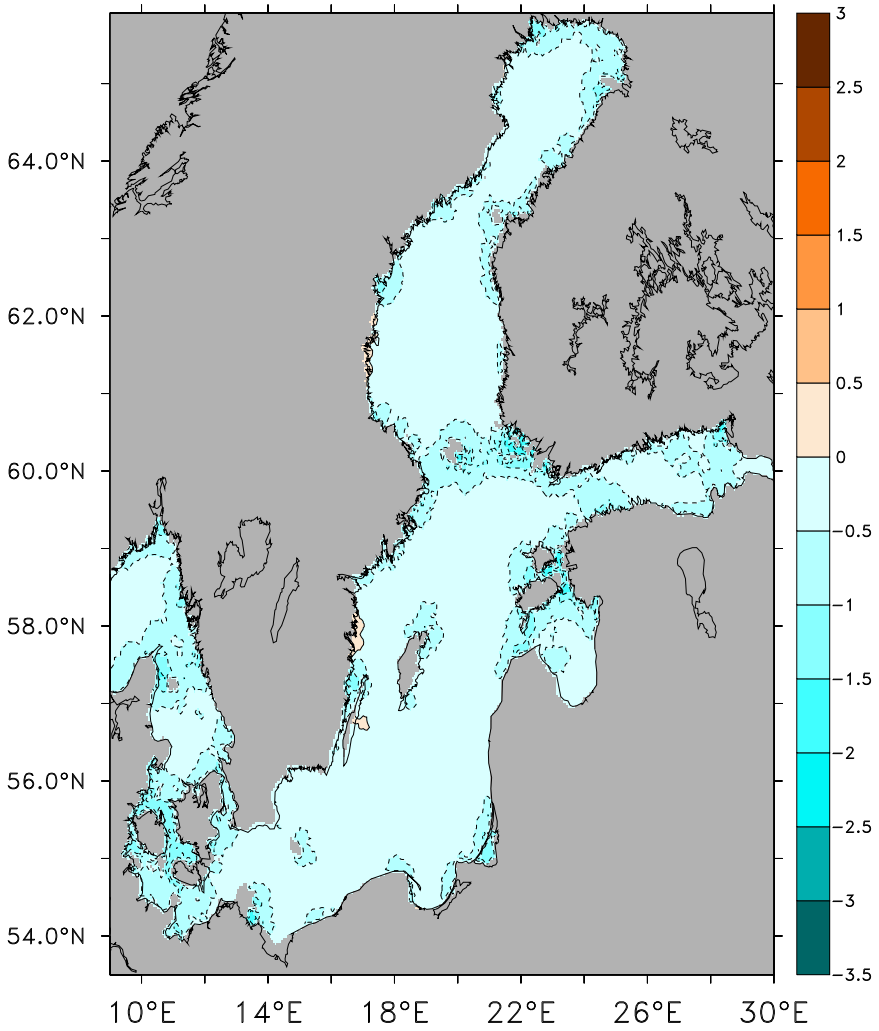


Baltic Sea SST, 1990 - 2009 [C]

BSH SST (dotted, shading), RCA4-NEMO Ensemble Median (black),

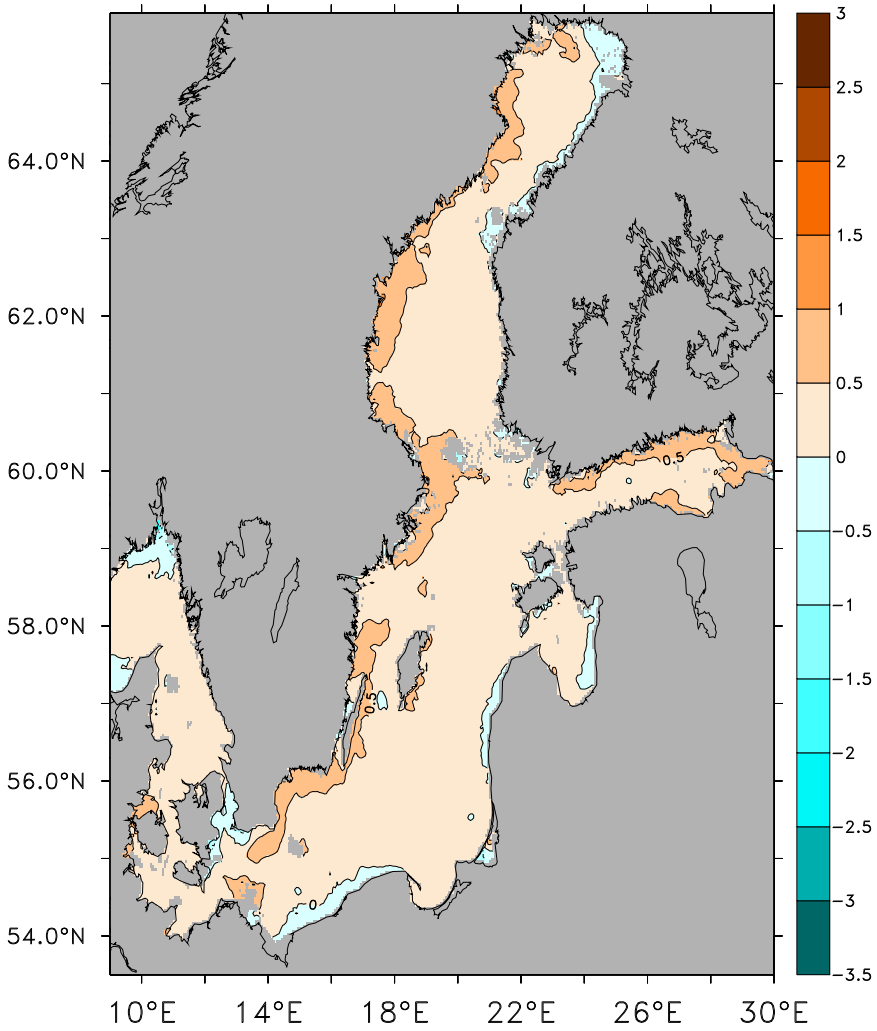
RCA4-NEMO ERA40 Hindcast (red)

Model Sensitivity



August wind speed 1990 - 2005 [C]

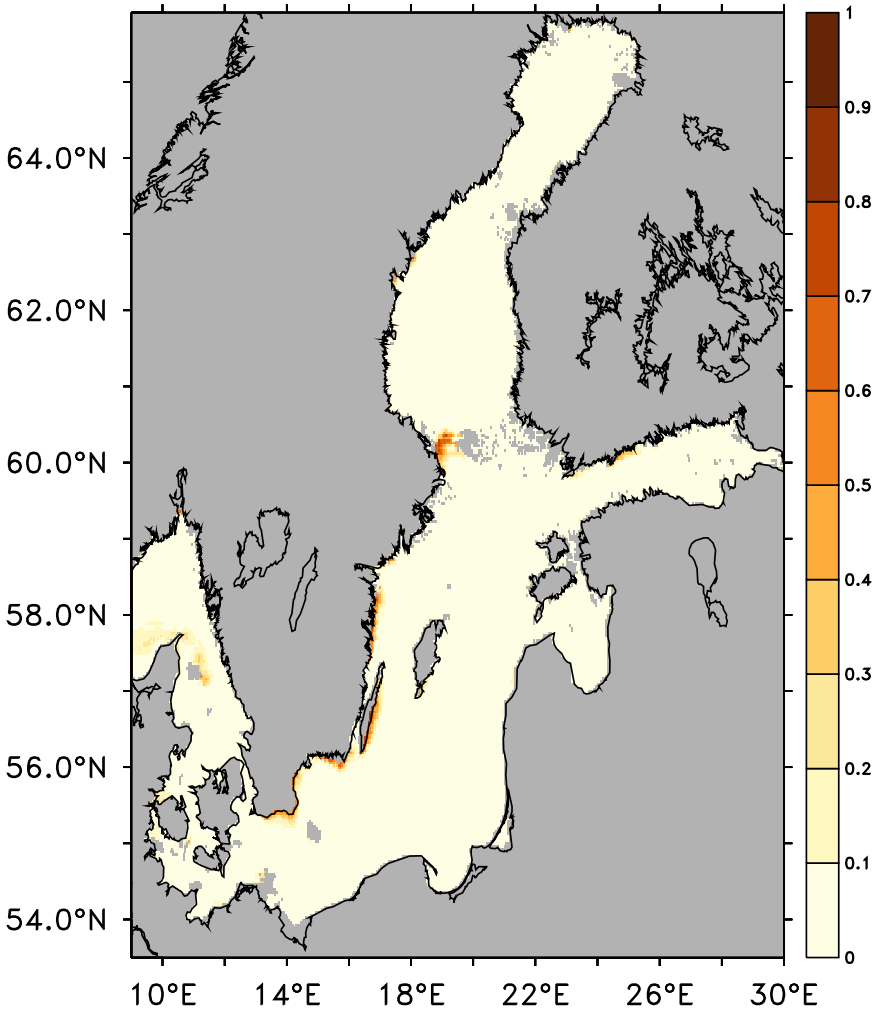
RCA4-NEMO AO 456 - AO 455



August SST 1990 - 2005 [C]

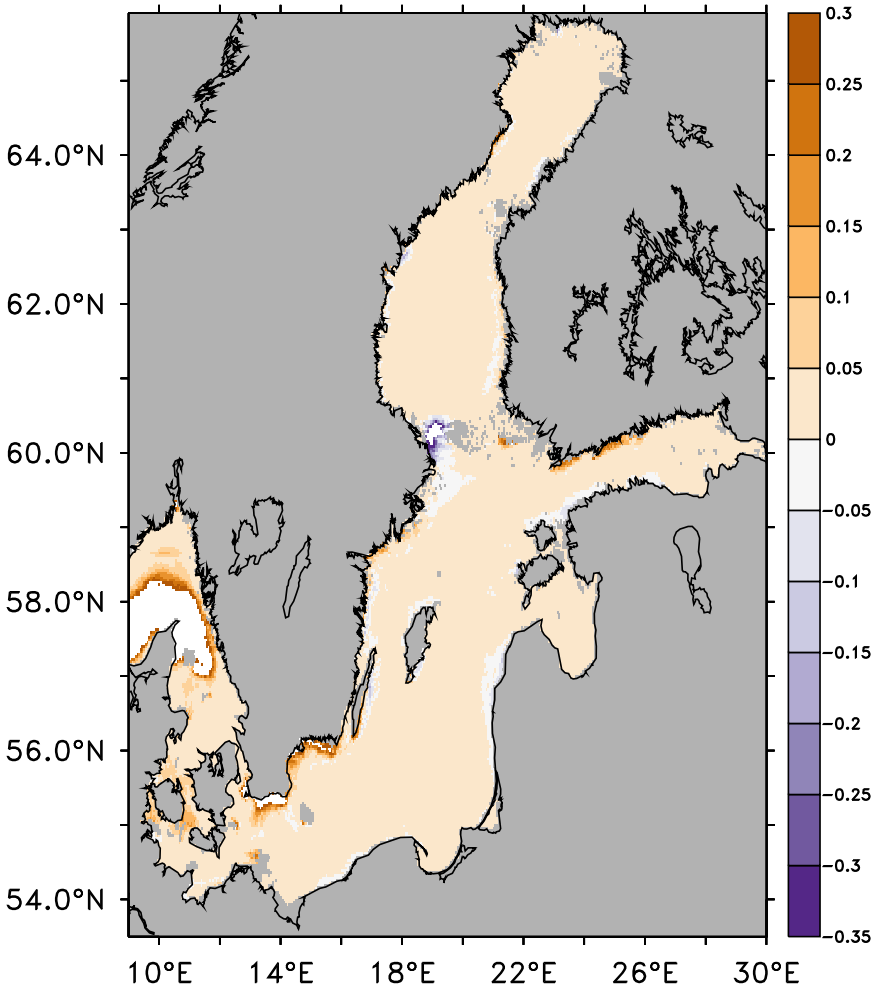
RCA4-NEMO AO 456 - AO 455

Changes in Upwelling Frequency



Summer upwelling frequency [1]

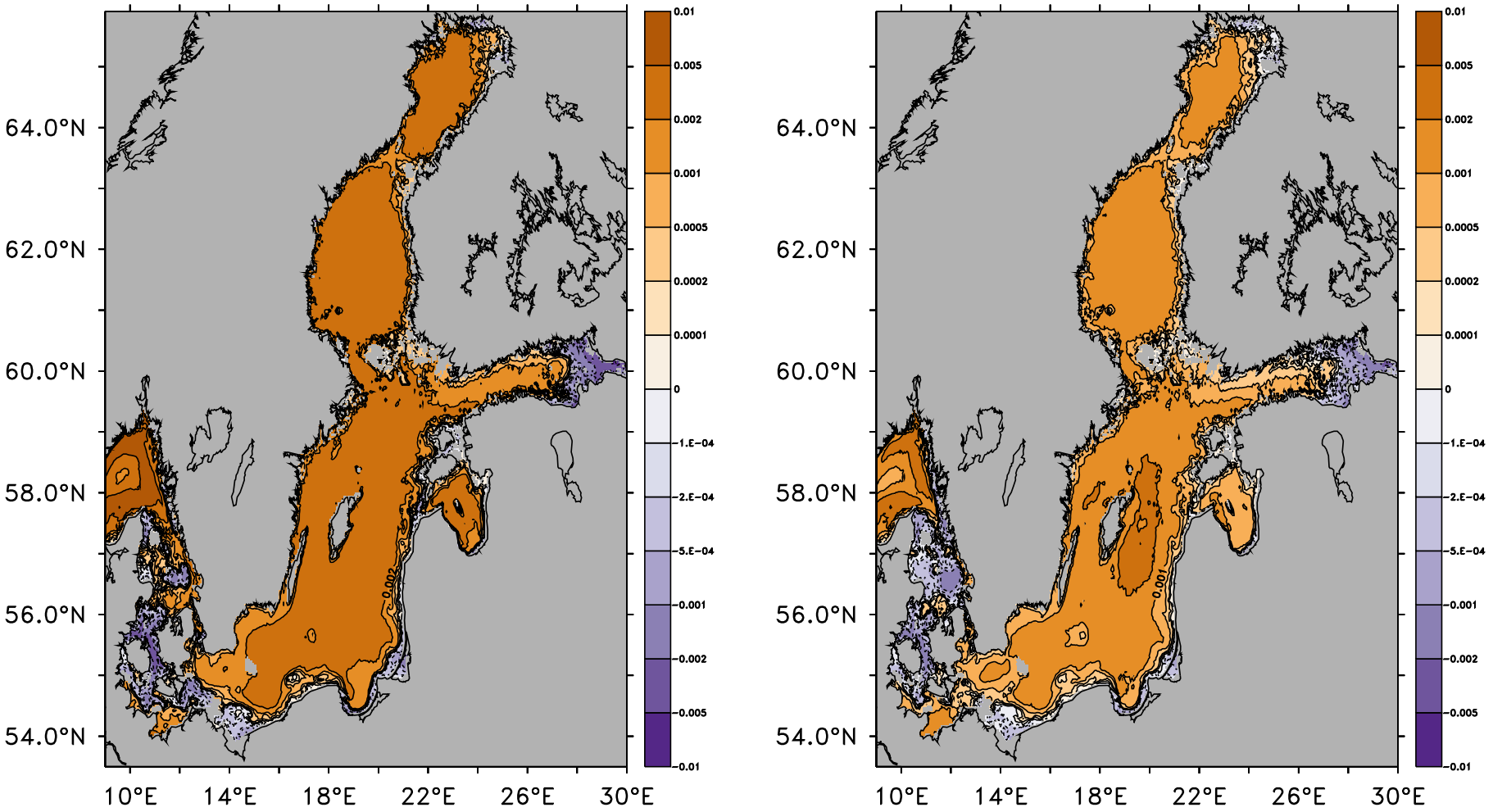
Ensemble median RCP 8.5 1970 to 1999



Changes in upwelling frequency [1]

2070 to 2099 minus 1970 to 1999

Changes in Reduced Gravity



Summer buoyancy [m/s^2] change 2070 to 2099 minus 1970 to 1999

Ensemble median RCP 8.5

Ensemble median RCP 2.6

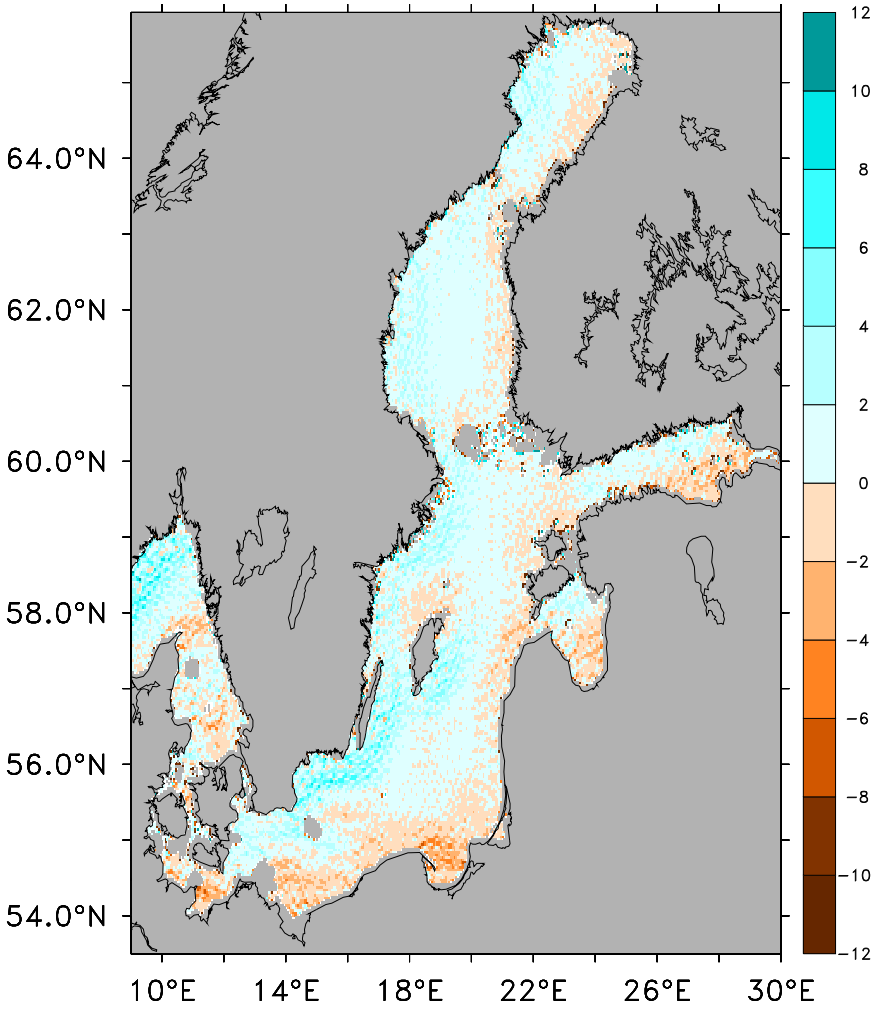
Conclusions and To-Do List

SMHI

- Projected SST changes indicate increase in upwelling frequency
- One contributor is increased buoyancy

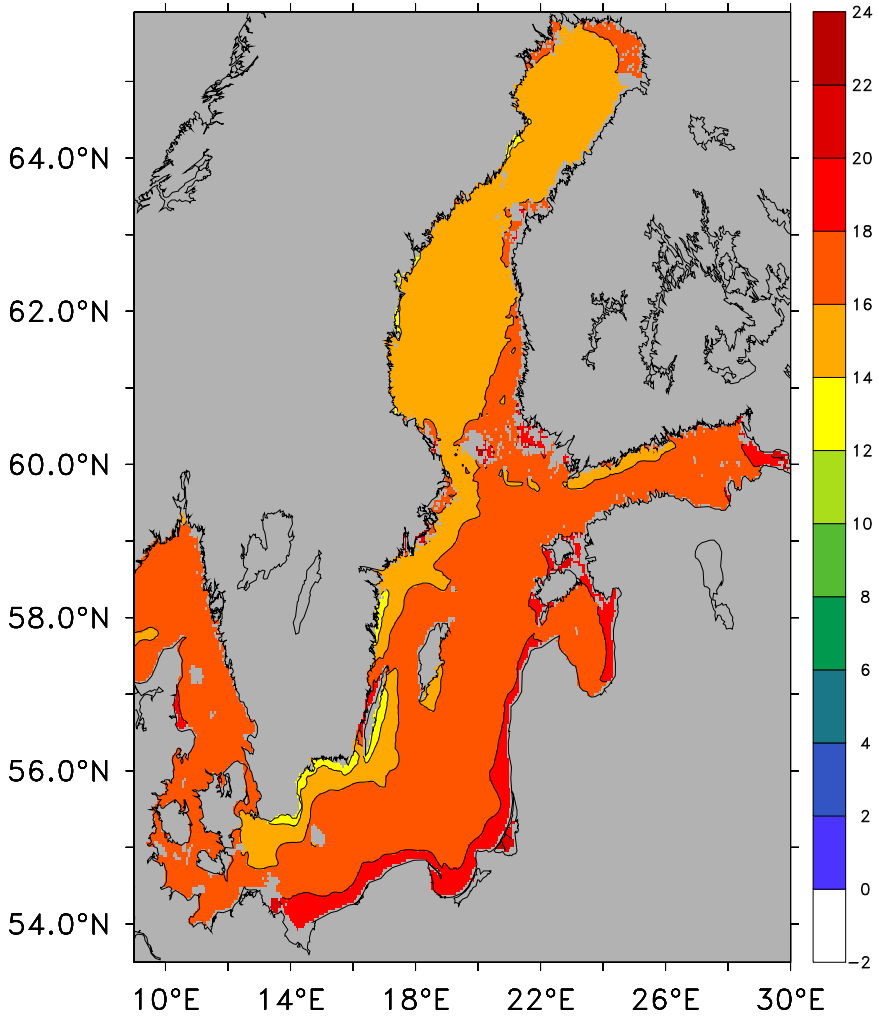
- Estimate favorable wind (wind impulse)
- Calculate offshore Ekman transport (upwelling index)
- Budget upwelling contribution to vertical exchange
- Look into feedback in atmosphere circulation

Upwelling Signature



August w_{Ek} 1990 - 2009 [10^{-5} m/s]

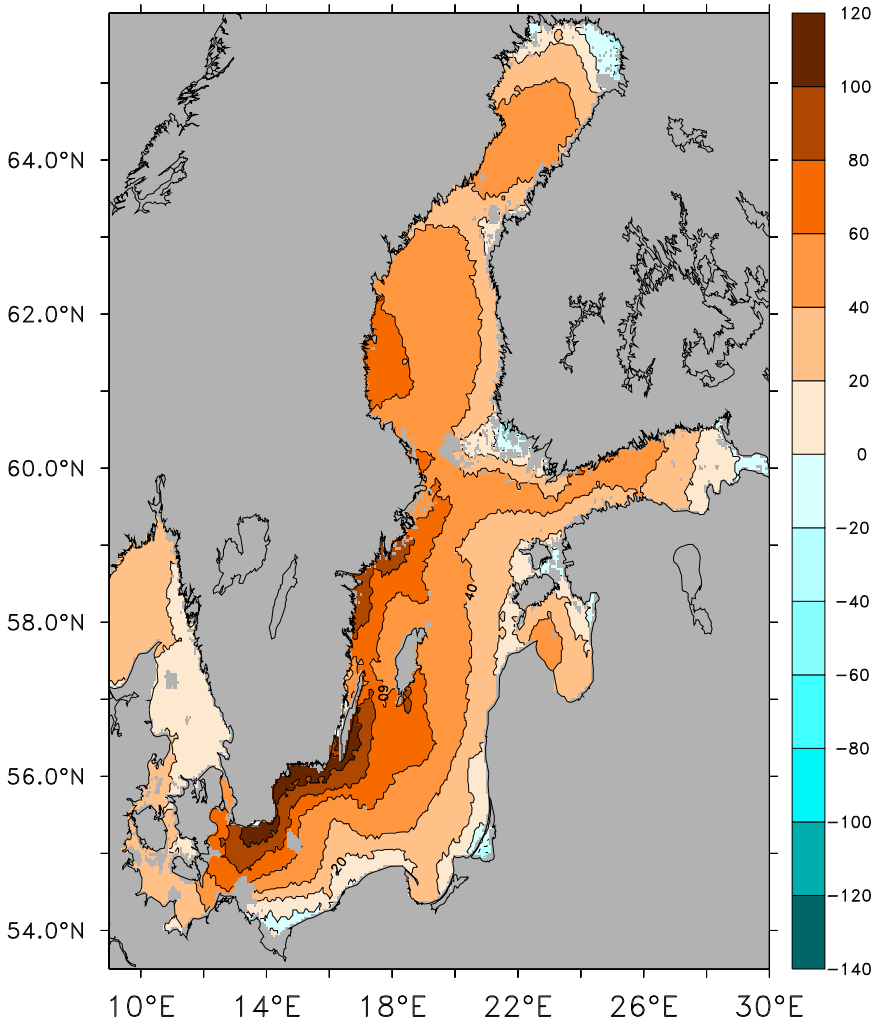
MPI-ESM-LR RCP4.5



August SST 1990 - 2009 [C]

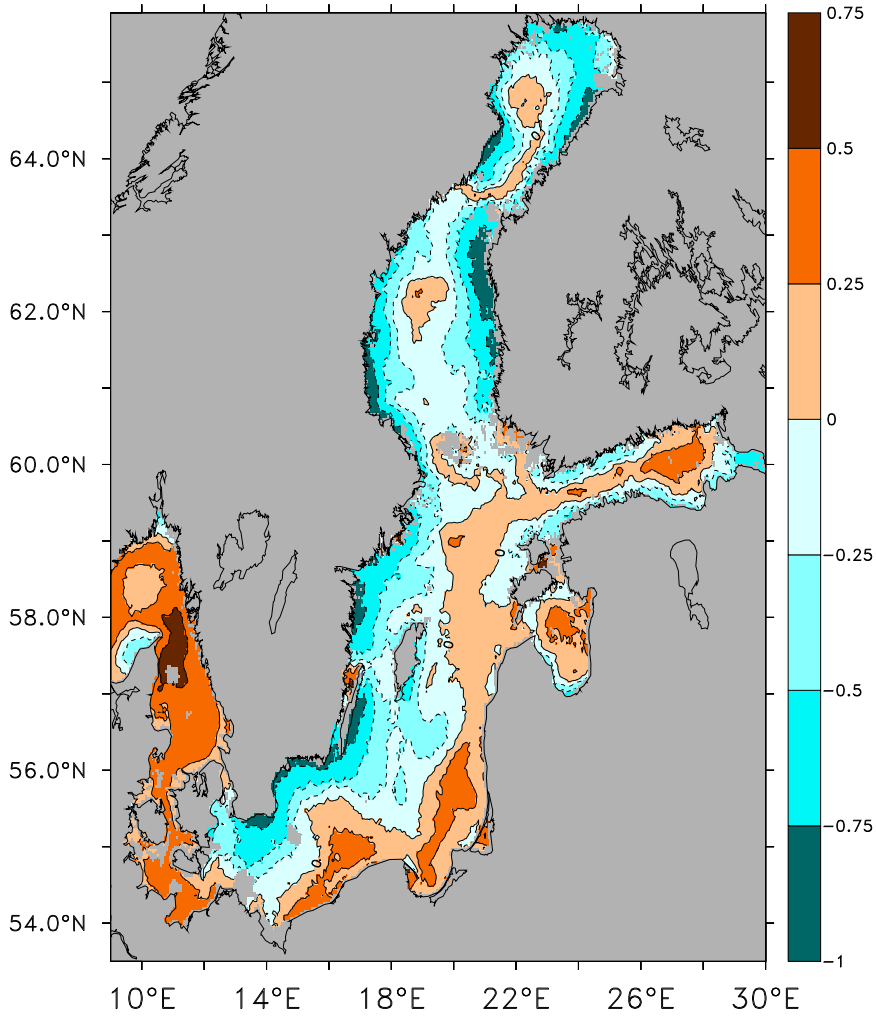
MPI-ESM-LR RCP4.5

Upwelling Signature



August SHF 1990 - 2009 [W/m^2]

MPI-ESM-LR RCP4.5



August COR(SST, SHF) 1990 - 2009 [1]

MPI-ESM-LR RCP4.5