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

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7^{th} Study Conference on BALTEX

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Motivation

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)

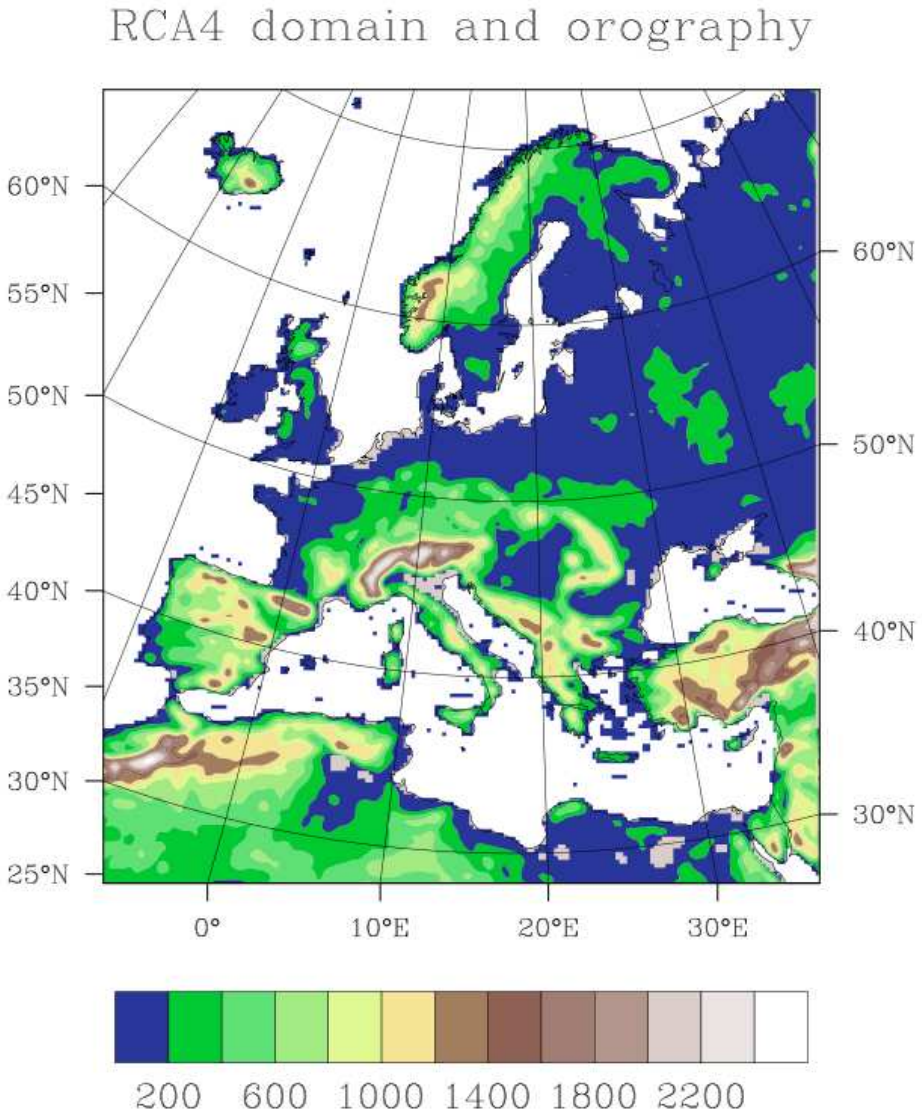
Modeling Approach

- How can upwelling be detected?
- (How well) can the model represent upwelling events?
- We can infer budgets of matter and heat fluxes
- We can look into feedbacks with the atmosphere in RCA4-NEMO

Outline

- Model Description
- Upwelling in the Baltic Sea: Basics
- Model Validation
- Projected changes in SST, Heat Flux and T2m
- Conclusions

RCA4-NEMO: Atmosphere Component



- Latest version of the Rossby Centre Atmosphere Model
- EURO-CORDEX setup for RCA4
- Resolution 25 km, 40 levels
- Coupled to BaltiX setup for NEMO
- Boundary conditions: ERA40, ERA-interim or AGCM data

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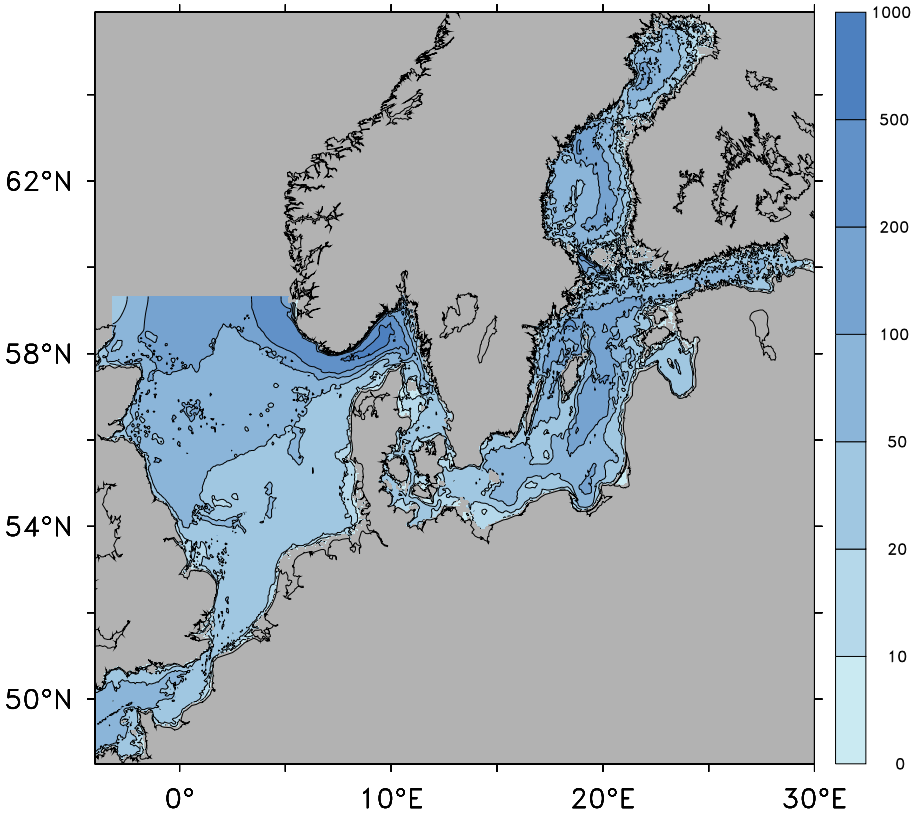
RCA4-NEMO: Ice-Ocean Component



- NEMO 3.3.1 with LIM 3
- BaltiX setup for NEMO
- Resolution 3.5 km, 56 levels, 5 ice classes
- Coupled to EURO-CORDEX setup for RCA4
- Boundary conditions: Climatologies, Reanalyses or OGCM data & OSU Tides
- Runoff: Data, Balt-HYPE or E-HYPE Reanalyses or coupled to CaMa-Flood

Mechanism for Coastal Upwelling

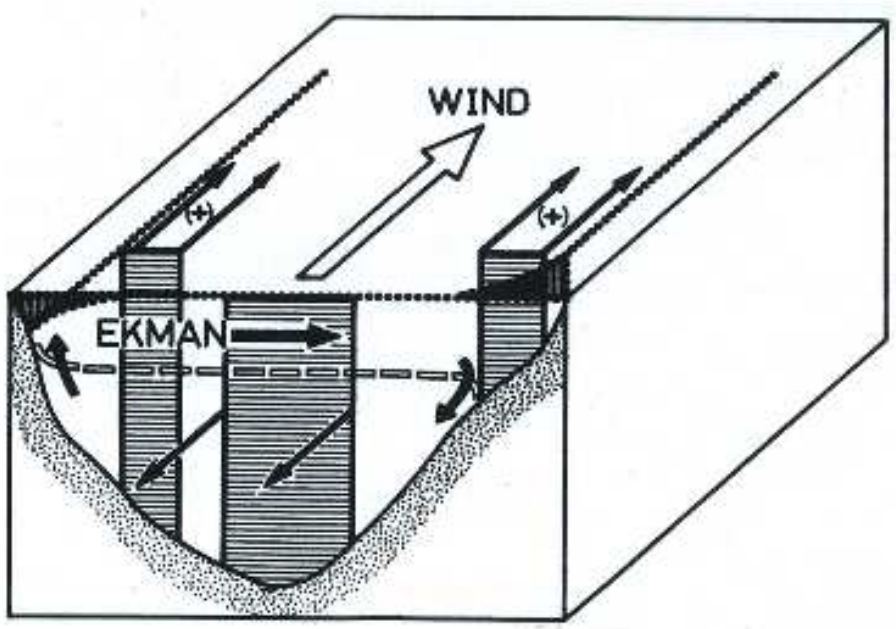
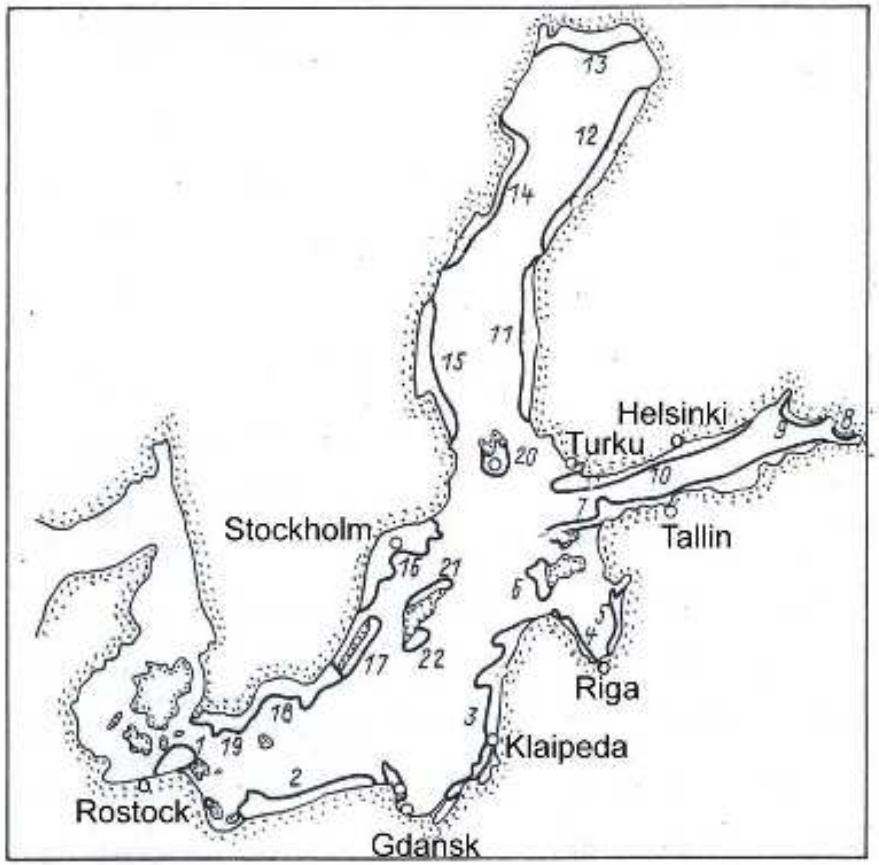


Figure 3. Principle response of an elongated basin to constant wind in length direction of the basin, redrawn from Krauss and Brügge (1991).

(Lehmann & Myrberg, 2008)

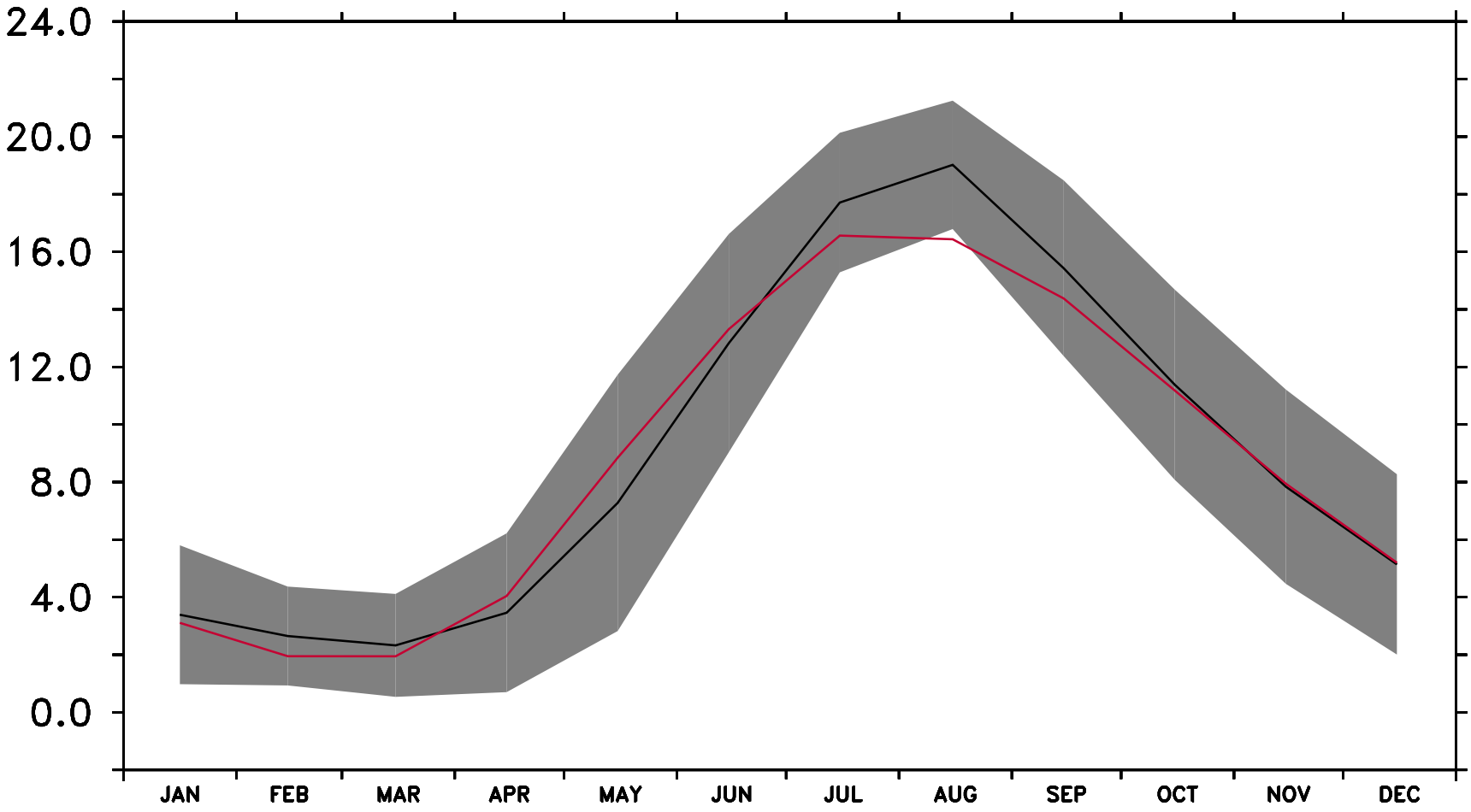
Coastal Upwelling in the Baltic Sea



(Lehmann & Myrberg, 2008)

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

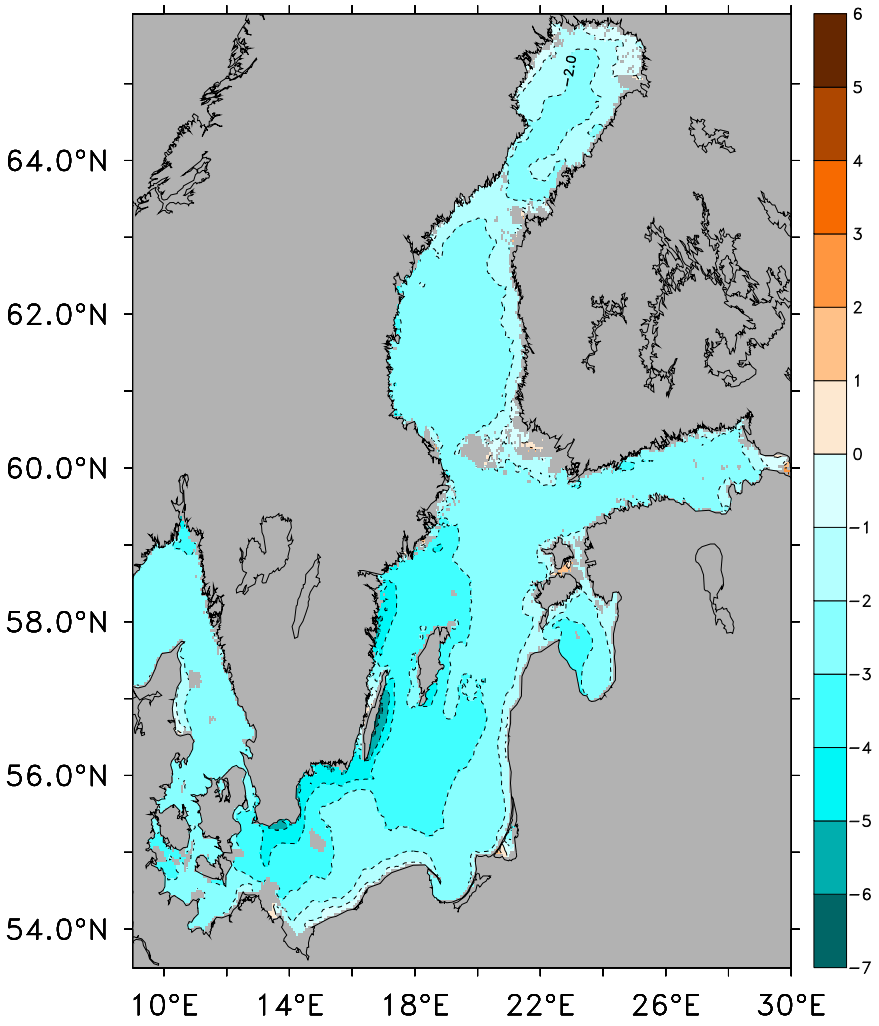
Model Validation



Baltic Sea SST, 1990 - 2009 [C]

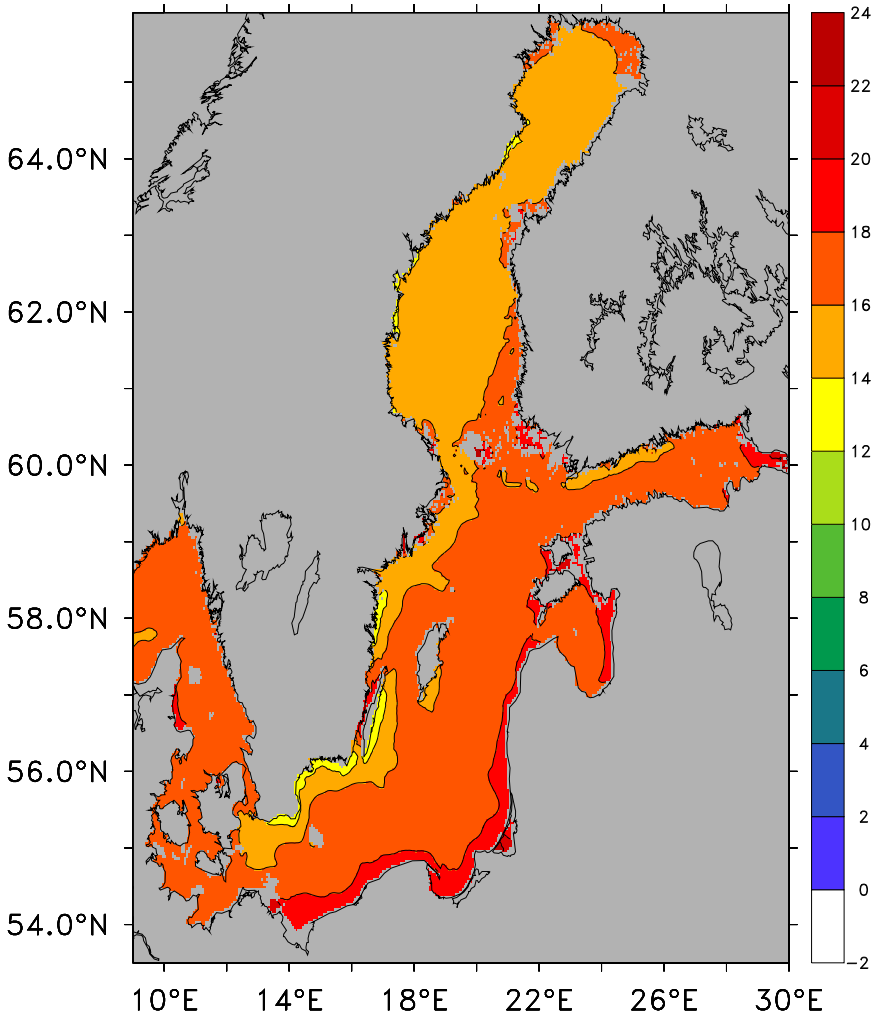
BSH SST (black), MPI-ESM-LR RCP4.5 (red)

Model Validation



August SST Bias 1990 - 2009 [C]

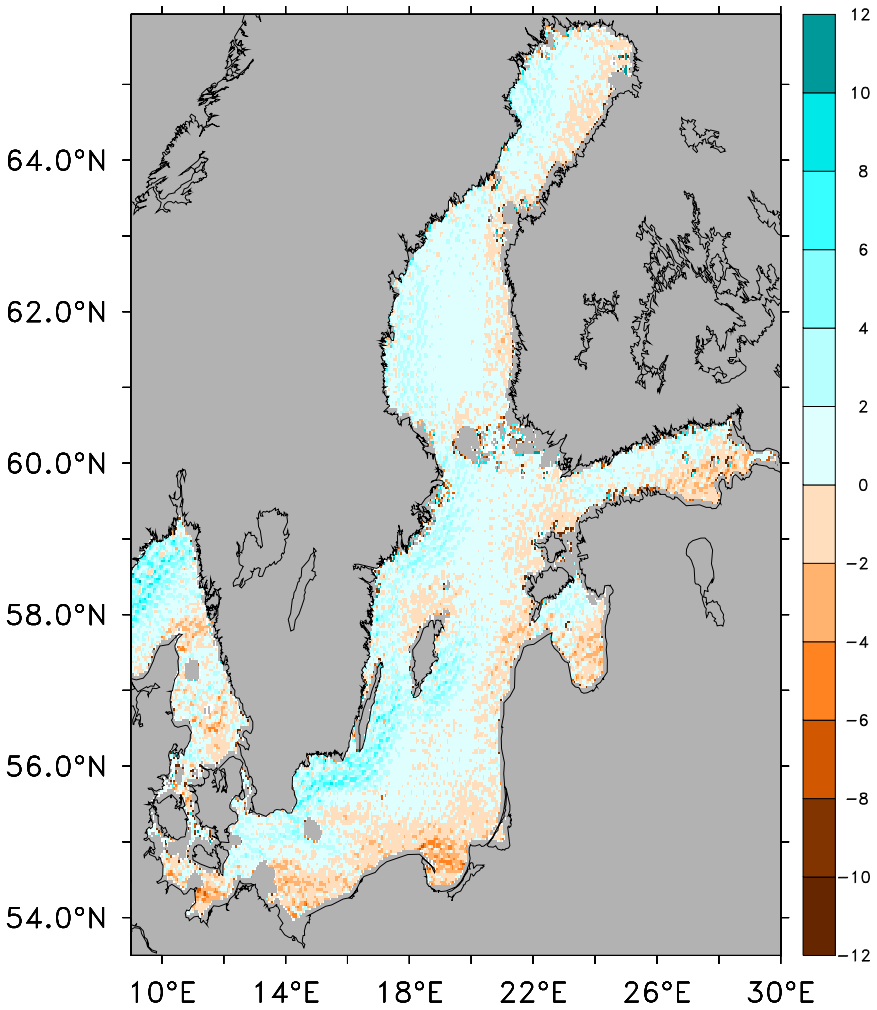
MPI-ESM-LR RCP4.5 - BSH SST



August SST 1990 - 2009 [C]

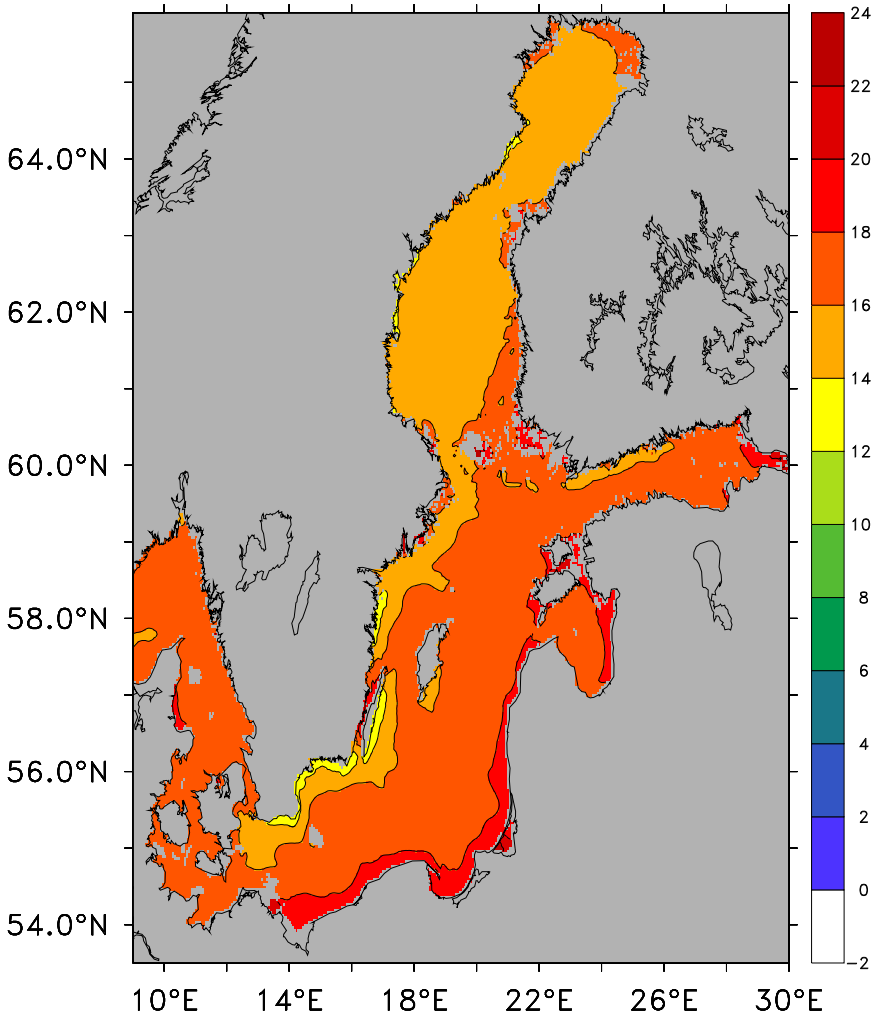
MPI-ESM-LR RCP4.5

Upwelling Signature



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

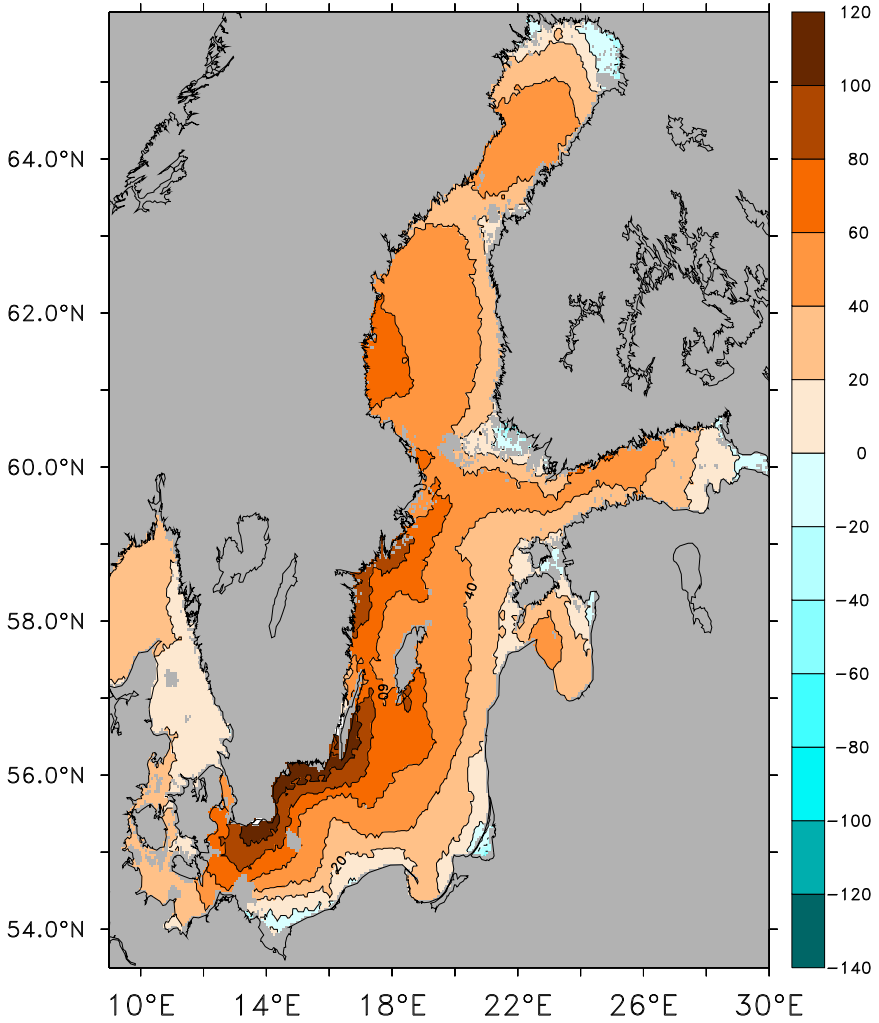
MPI-ESM-LR RCP4.5



August SST 1990 - 2009 [C]

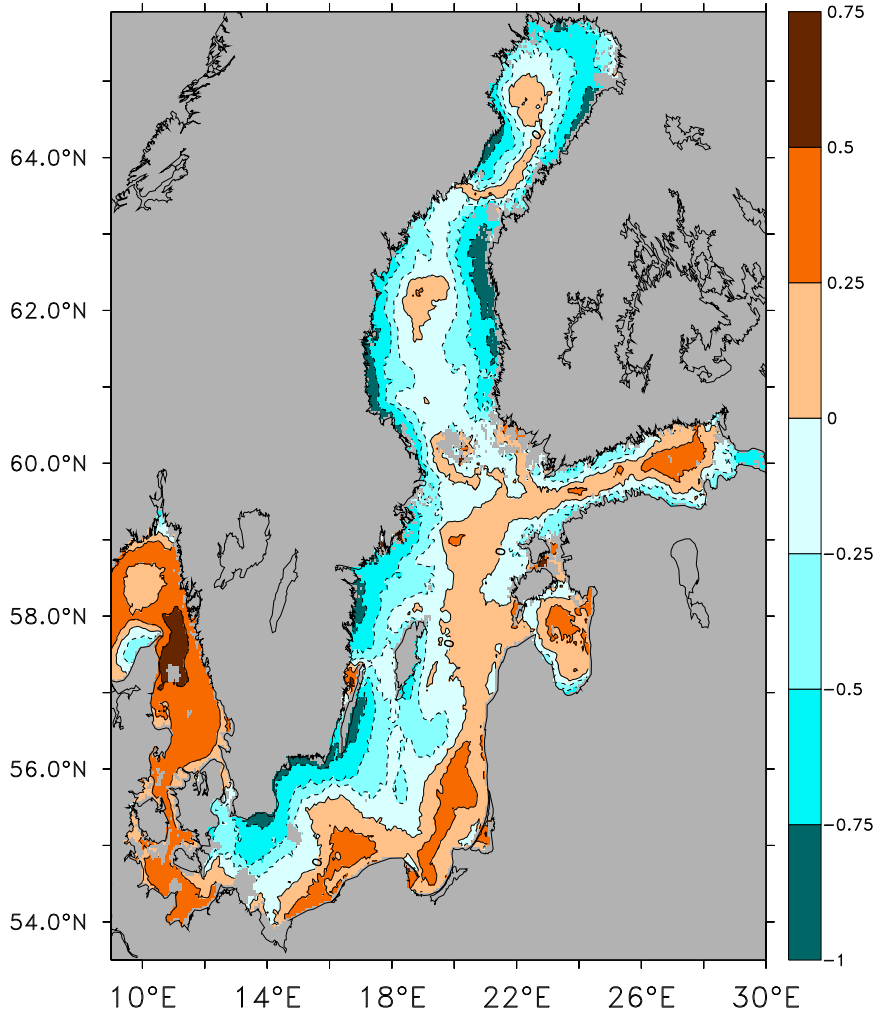
MPI-ESM-LR RCP4.5

Upwelling Signature



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

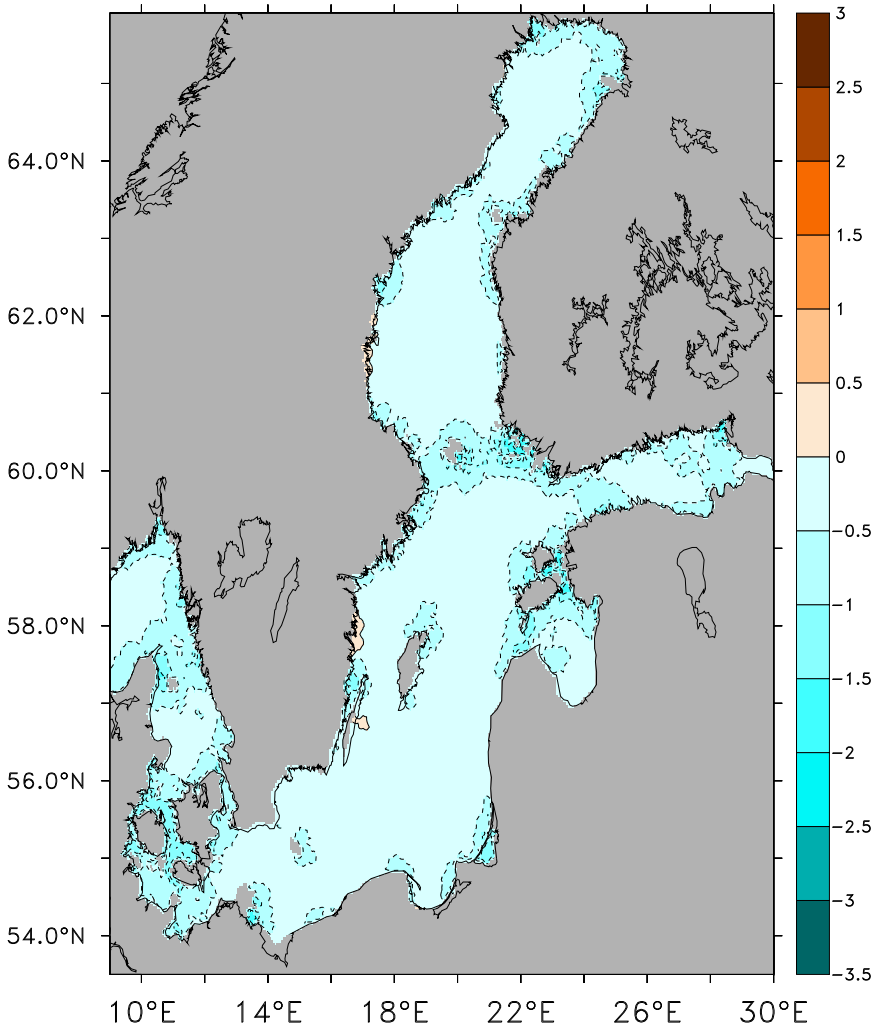
MPI-ESM-LR RCP4.5



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

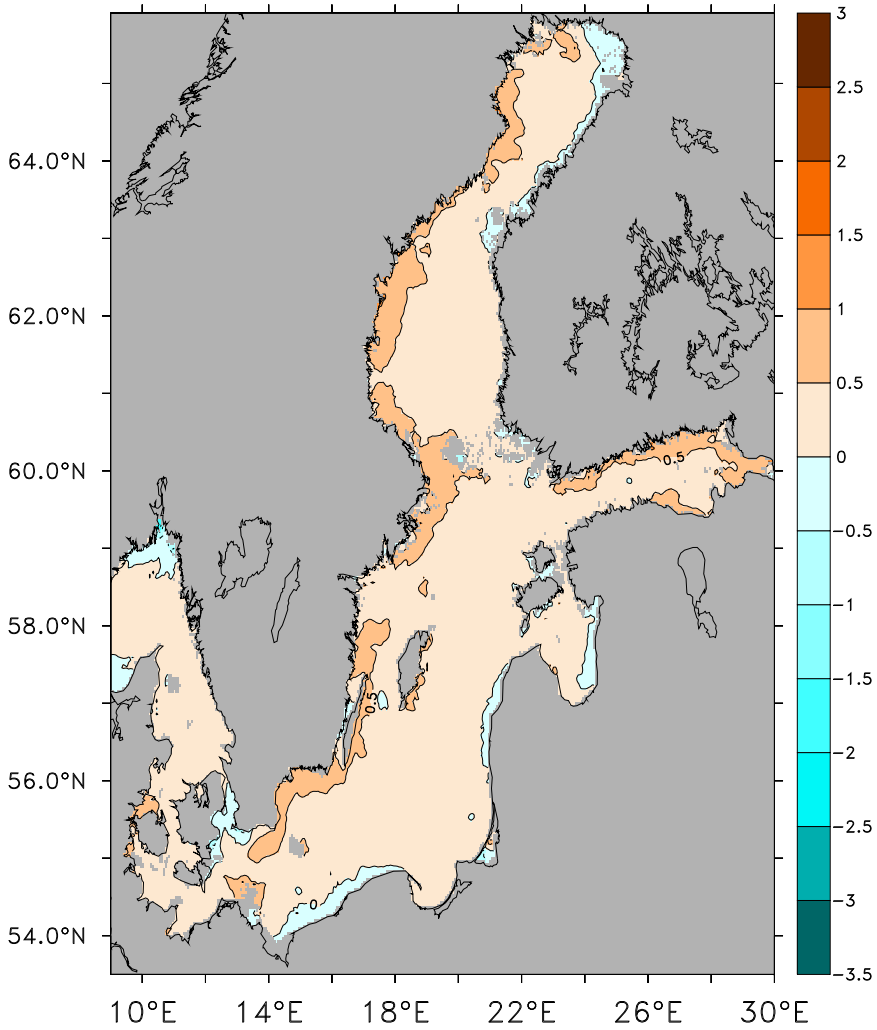
MPI-ESM-LR RCP4.5

Model Sensitivity



August wind speed 1990 - 2005 [C]

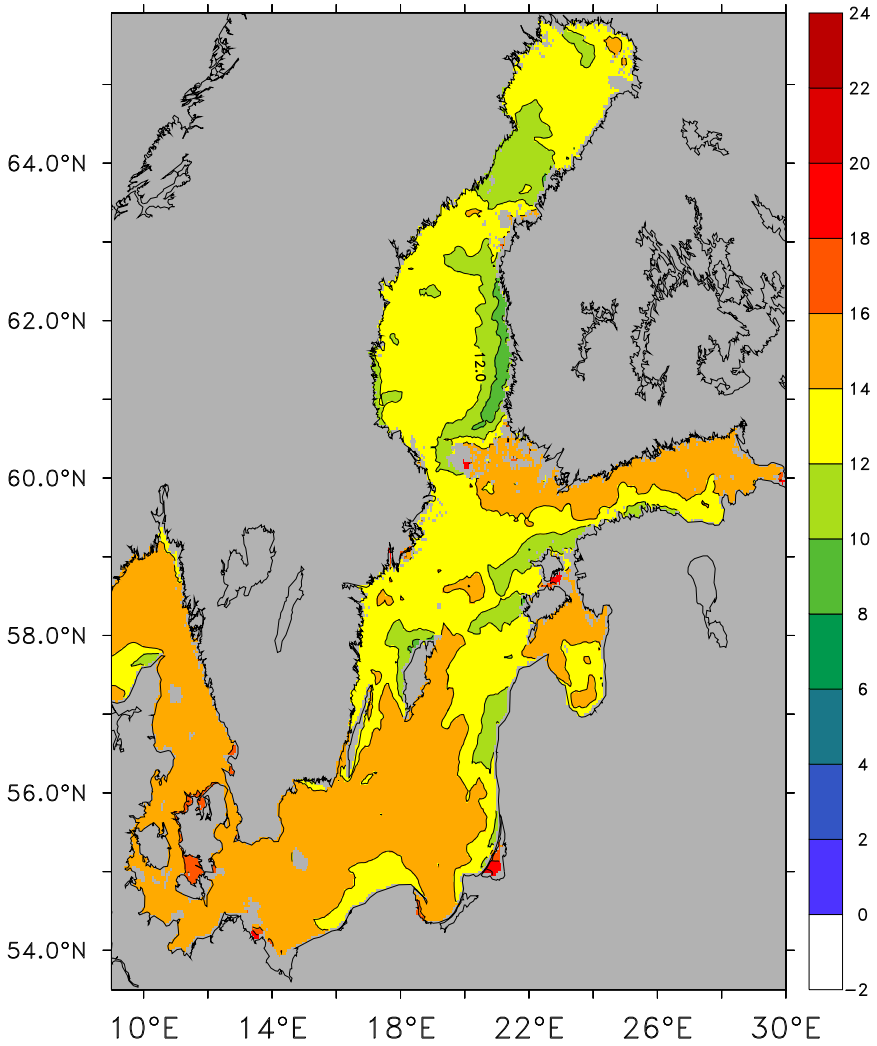
RCA4-NEMO AO 456 - AO 455



August SST 1990 - 2005 [C]

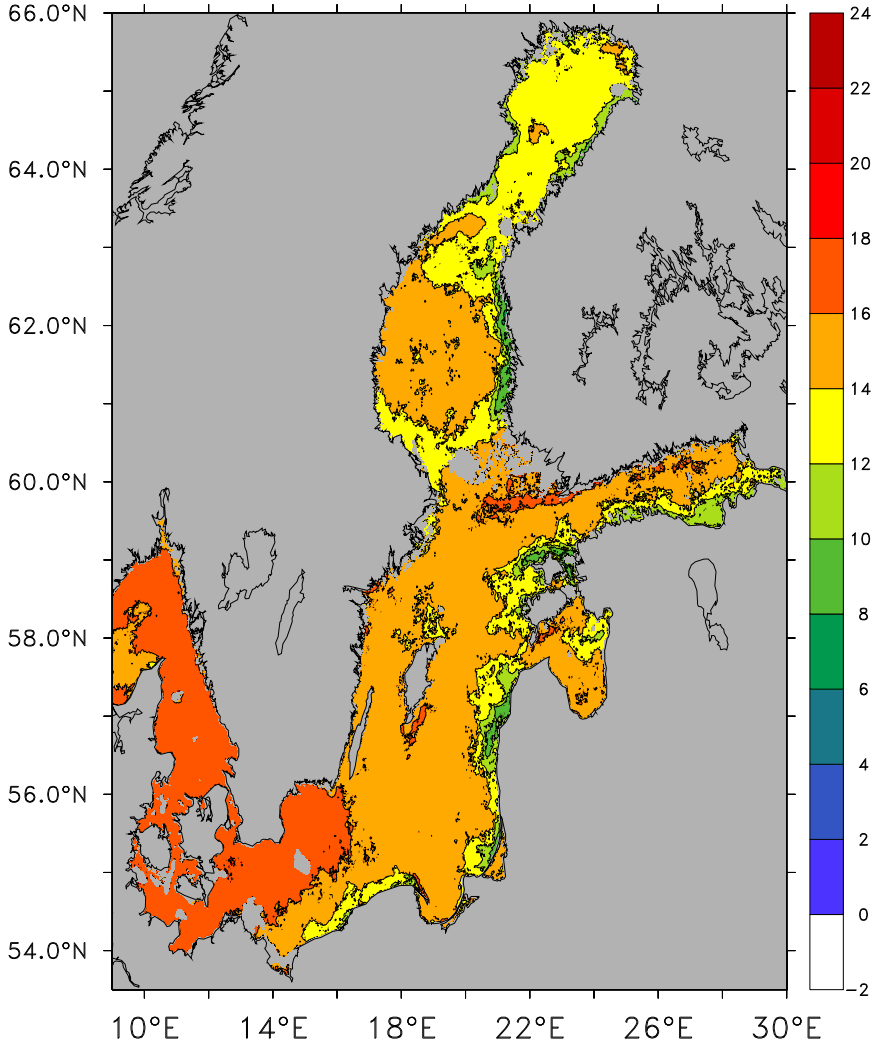
RCA4-NEMO AO 456 - AO 455

An Example of an Upwelling Event



September 1996, SST [C]

RCA4-NEMO ERA40



September 1996, SST [C]

BSH SST

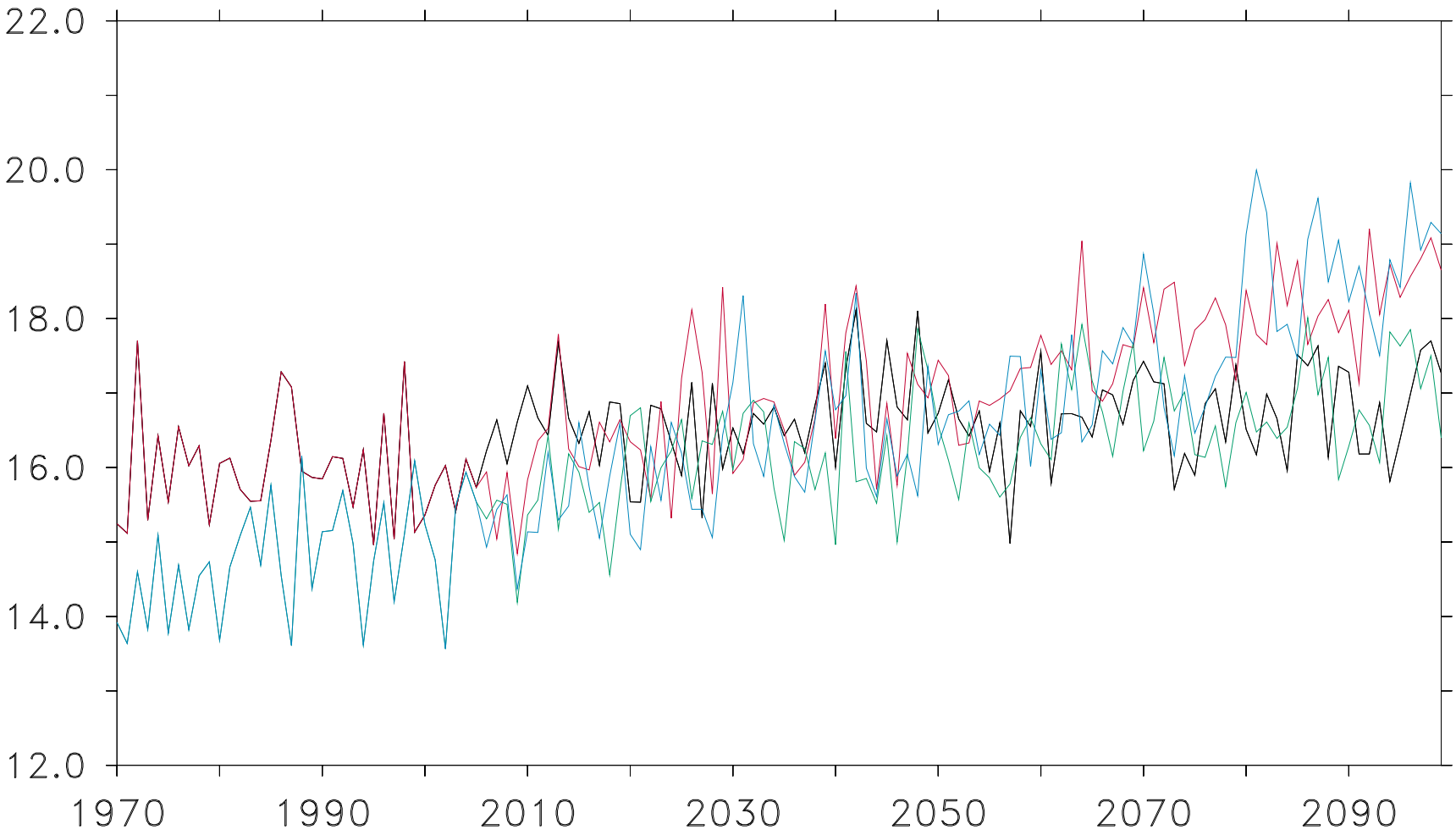
KLIWAS Scenarios with RCA4-NEMO

experiment	historical	RCP 4.5	RCP 8.5
ERA40 *)	completed	n/a	n/a
MPI-ESM-LR	completed	completed	completed
EC-EARTH	completed	completed	completed

experiment	coupled	atmosphere only	ocean only
ERA40	completed	completed	completed

*) SMHI-Report, RO 47, 2013

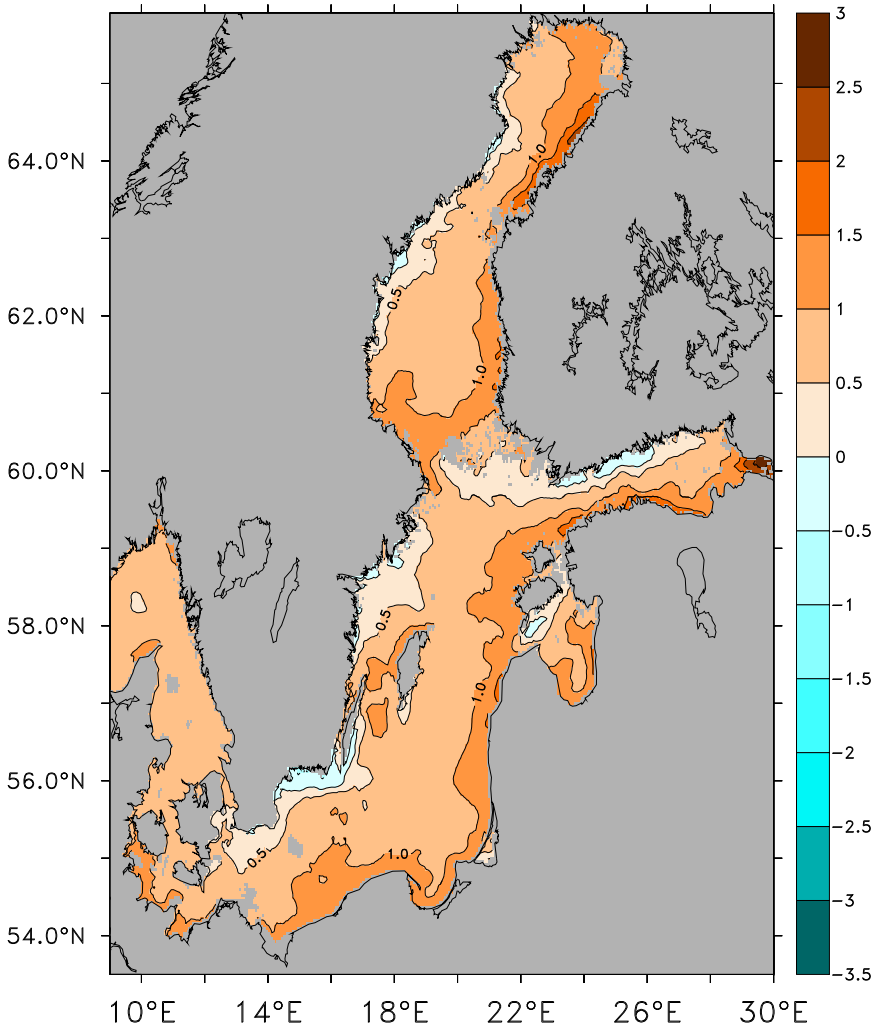
Projected Baltic Sea SST



Summer mean Baltic Sea SST 1970 - 2099 [C]

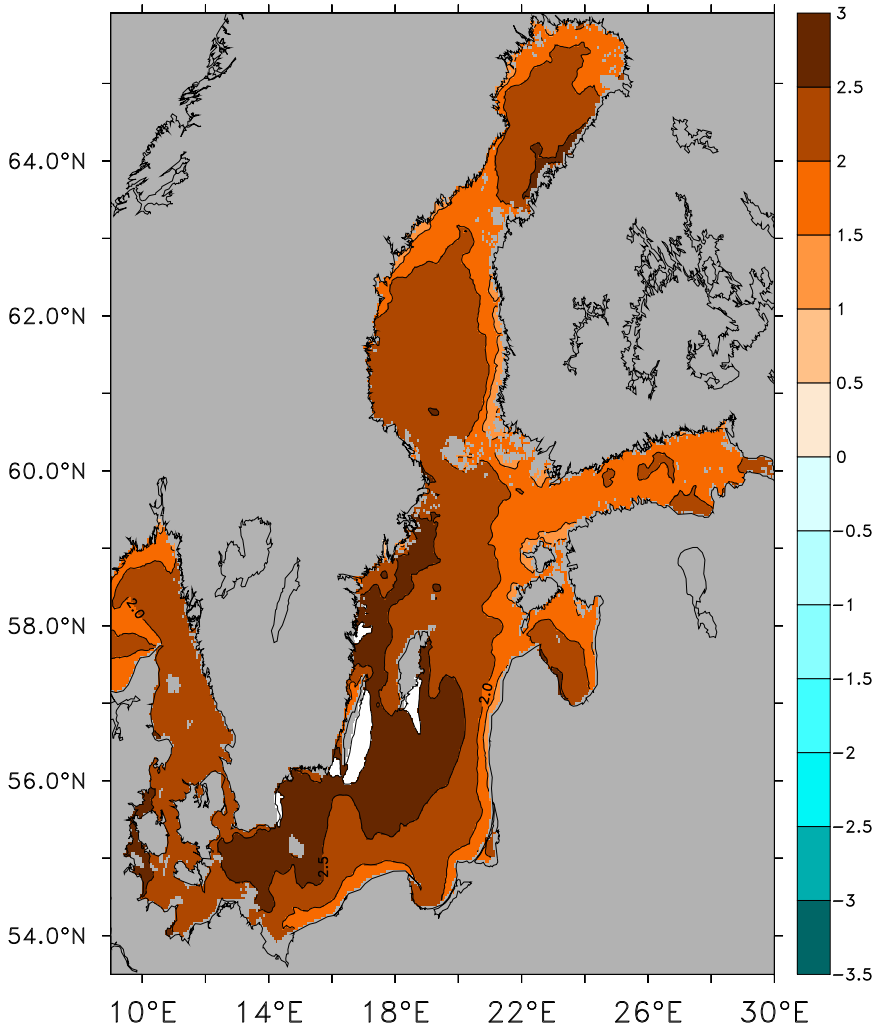
MPI-ESM-LR RCP 4.5 (k), RCP 8.5 (r), EC-EARTH RCP 4.5 (g), RCP 8.5 (b)

Projected Changes in Baltic Sea SST



August SST difference P2 - P0 [C]

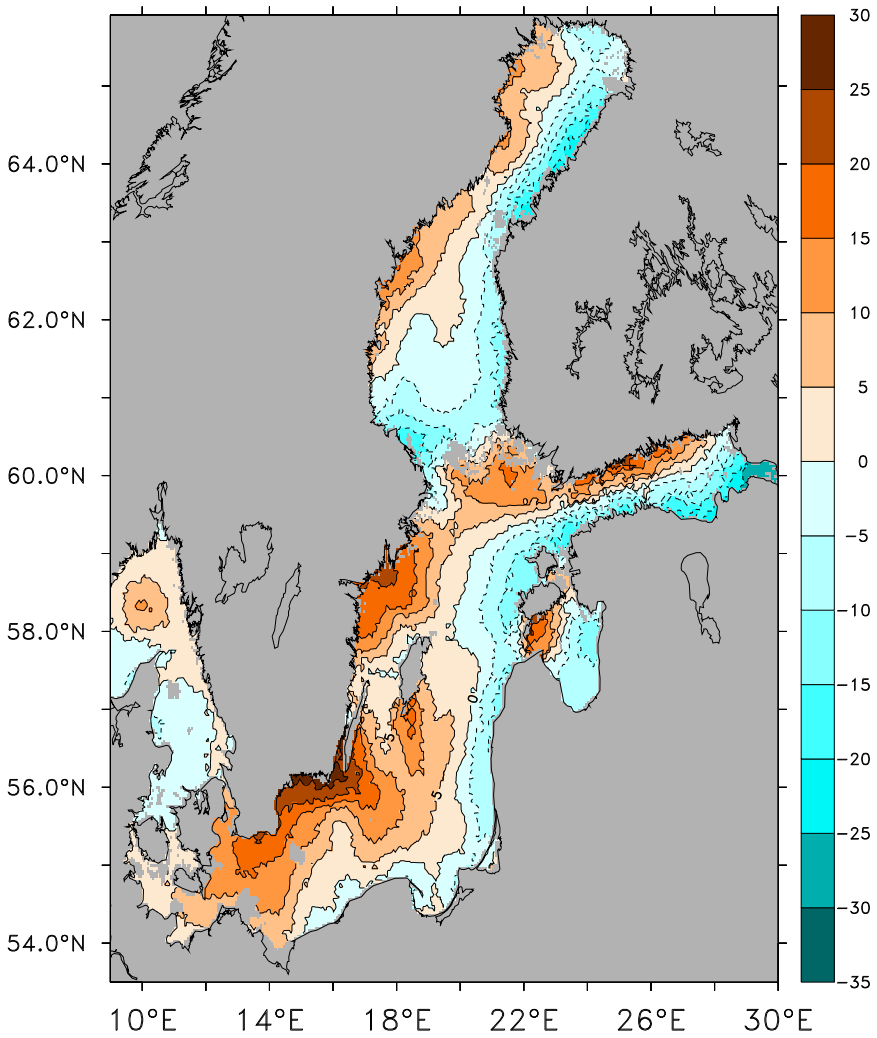
MPI-ESM-LR RCP4.5



August SST difference P2 - P0 [C]

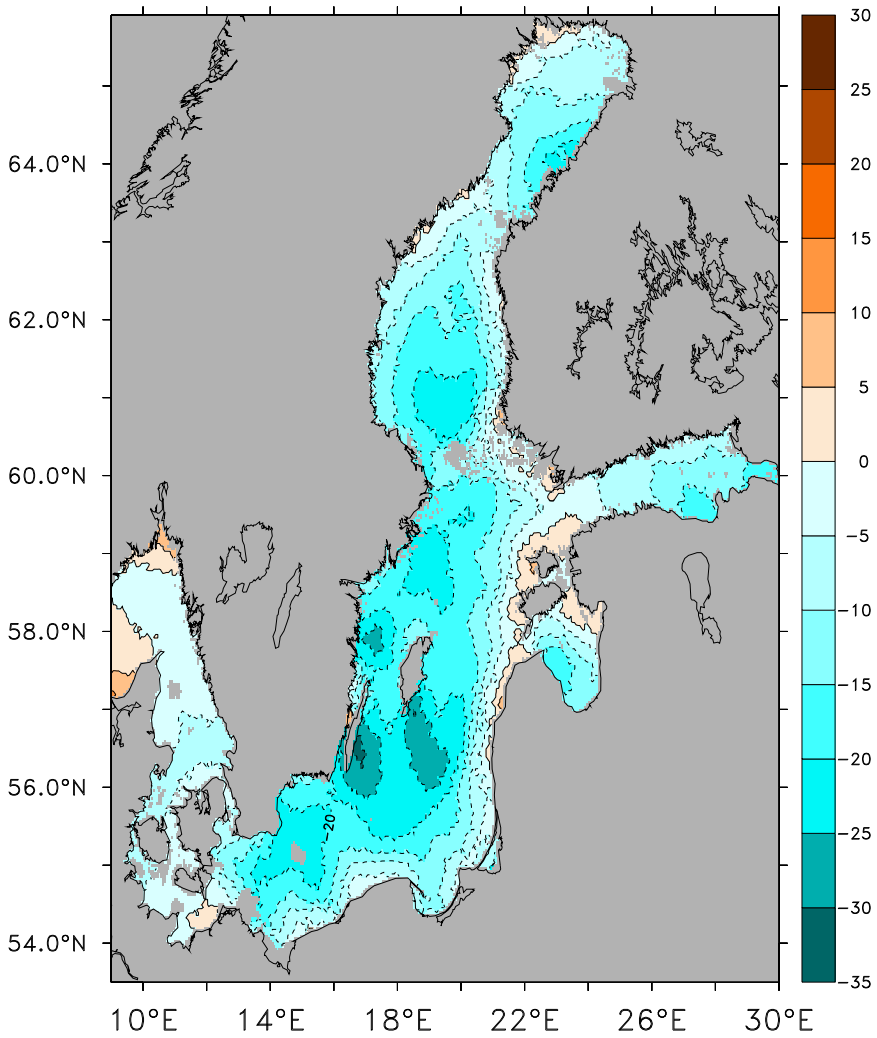
EC-EARTH RCP4.5

Projected Changes in Net Heat Flux



August SHF diff P2 - P0 [W/m^2]

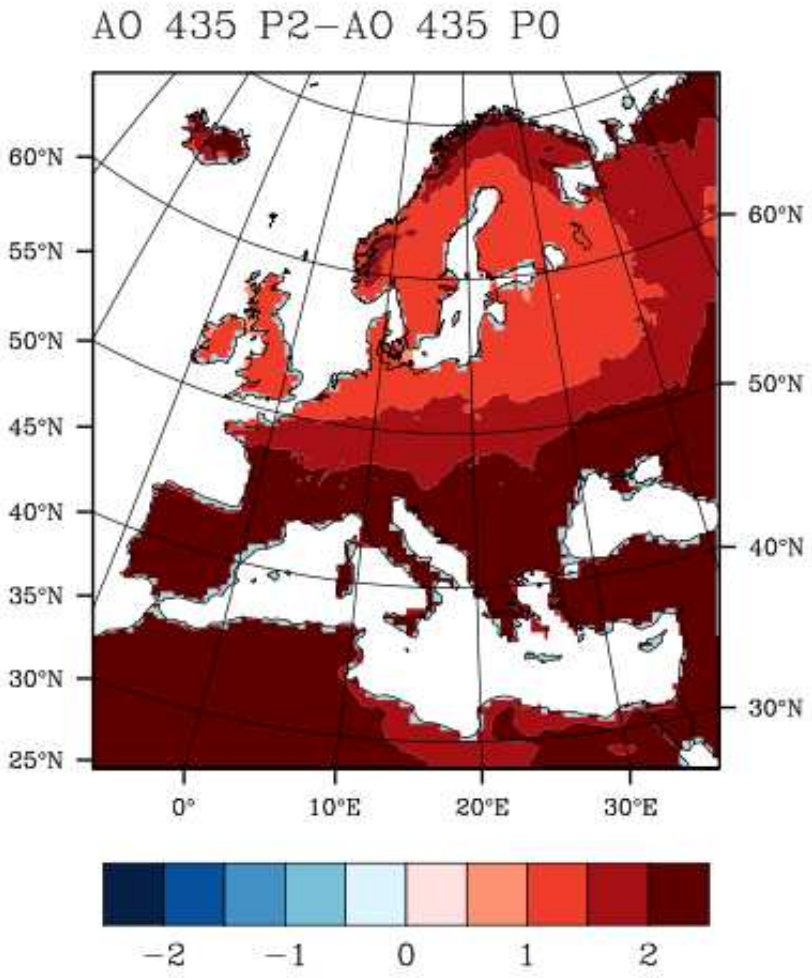
MPI-ESM-LR RCP4.5



August SHF diff P2 - P0 [W/m^2]

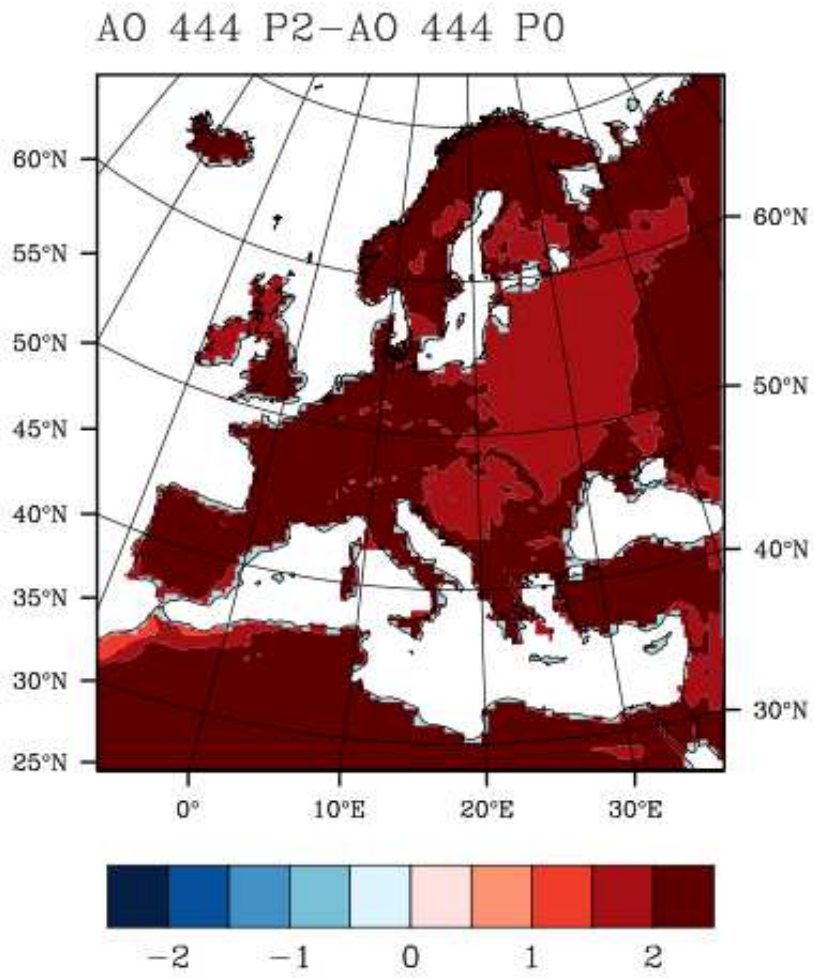
EC-EARTH RCP4.5

Projected Changes in 2m Temperature



Summer T2m diff P2 - P0 [C]

MPI-ESM-LR RCP4.5



Summer T2m diff P2 - P0 [C]

EC-EARTH RCP4.5

Conclusions

Upwelling in RCA4-NEMO KLIWAS Scenarios

- Projected SST changes in RCA4-NEMO indicate changes in upwelling frequency and/or intensity
- Projected SST changes in RCA4-NEMO go along with changes net surface heat fluxes
- In the RCA4-NEMO MPI-ESM-LR RCP scenarios Baltic Sea tends to cool the atmosphere downstream
- Wind over Baltic Proper gets stronger in MPI-ESM-LR scenarios, weaker in EC-EARTH scenarios
- Need more ensemble members to pin down a trend in upwelling circulation

Outlook

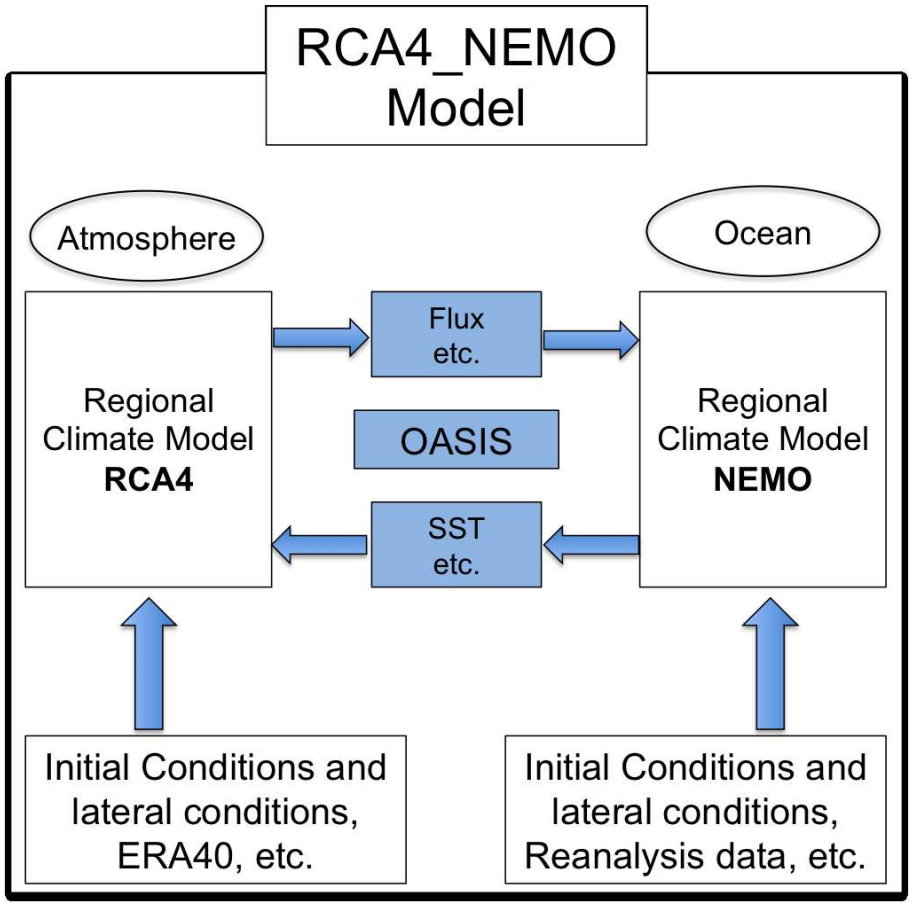
Follow-up

- Settle for an upwelling index (w_{Ek} + SST gradient)
- Budget upwelling contribution to vertical exchange
- Look into feedback in atmosphere circulation

Hints and To-Do for Model Development

- RCA4-NEMO has a large SST bias in the Baltic Sea during summer
- RCA4-NEMO is sensitive to wind stress changes
- Wind stress in RCA4-NEMO could be too large

RCA4-NEMO: Coupler Oasis3



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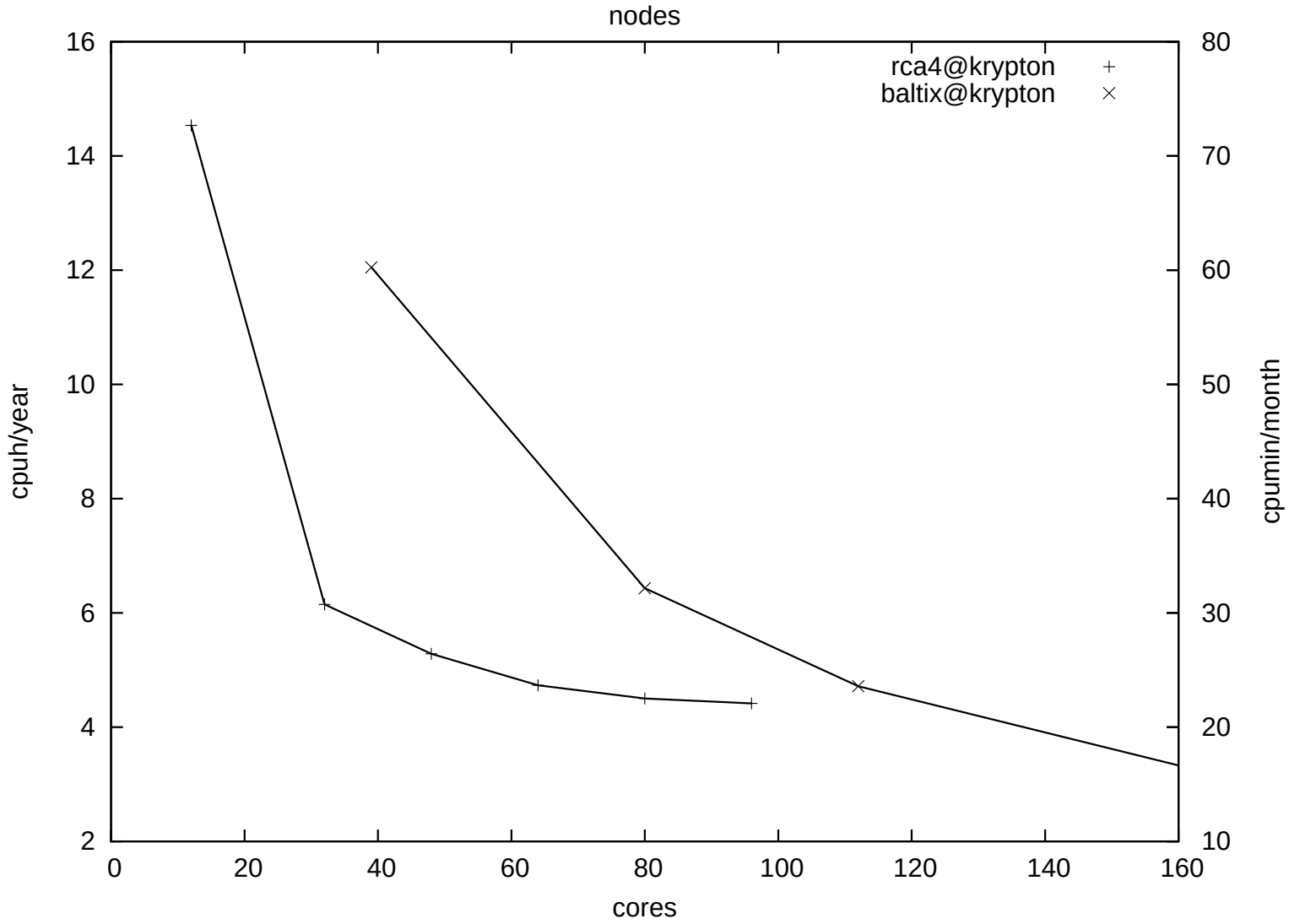
- Oasis3
- Flux-coupling every 3 hours
- RCA4 $\rightarrow$ NEMO: heat, freshwater and momentum fluxes
- NEMO $\rightarrow$ RCA4: SST, IST, ice fraction, albedo
- RCA4 $\rightarrow$ CaMa-Flood: runoff
- CaMa-Flood $\rightarrow$ NEMO: river discharge

RCA4-NEMO: Performance



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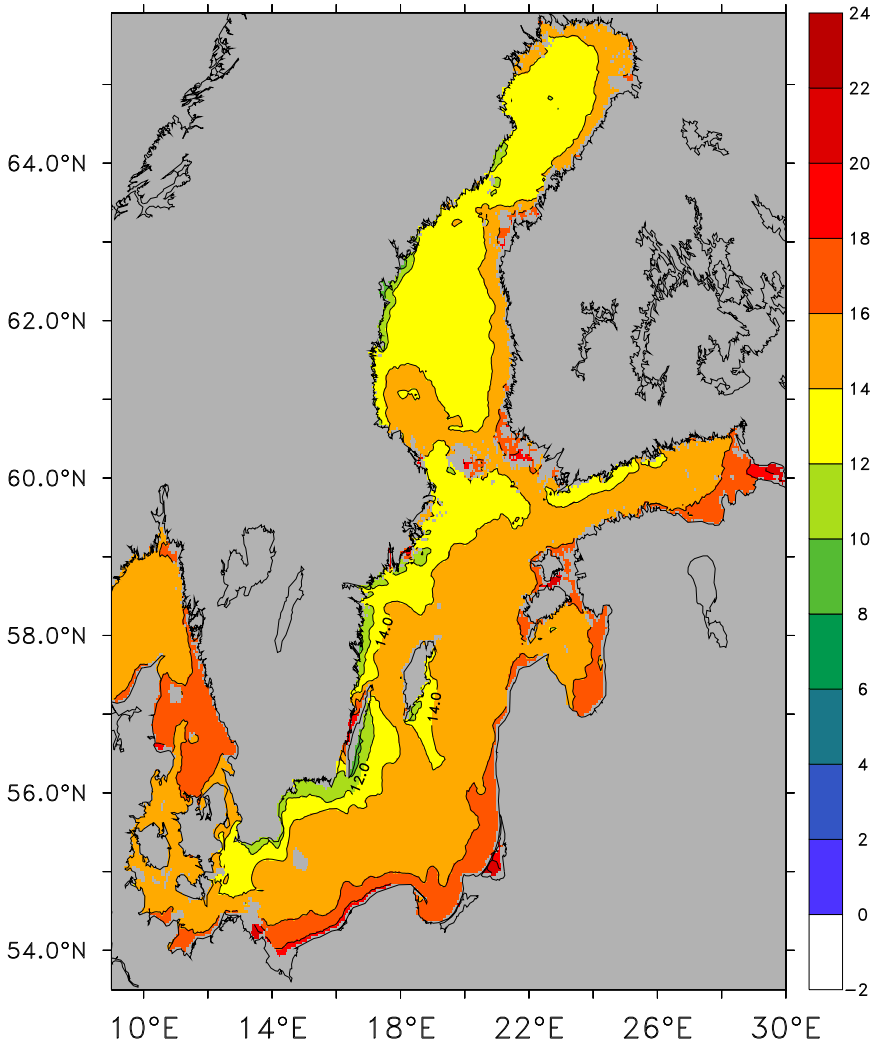
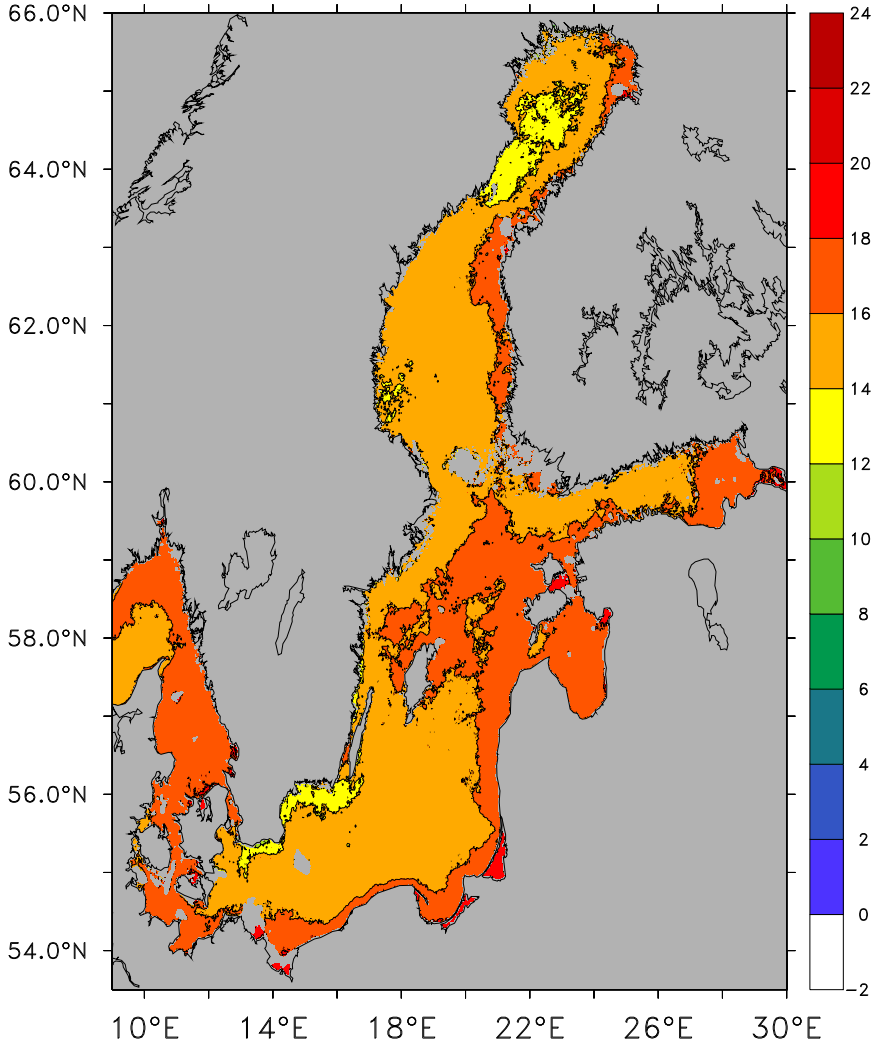


July 1996, SST [C]

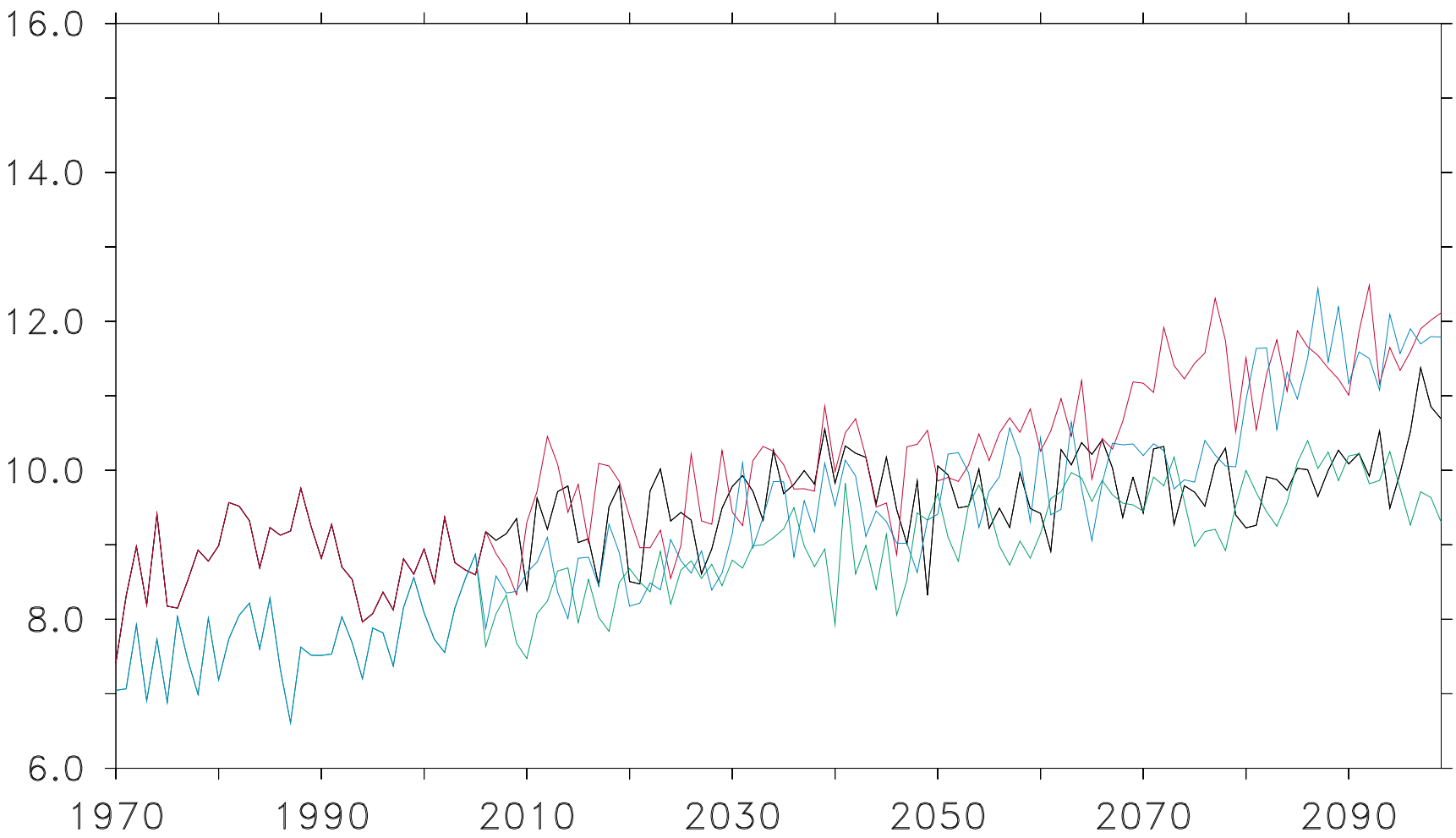
RCA4-NEMO ERA40



July 1996, SST [C]

BSH SST

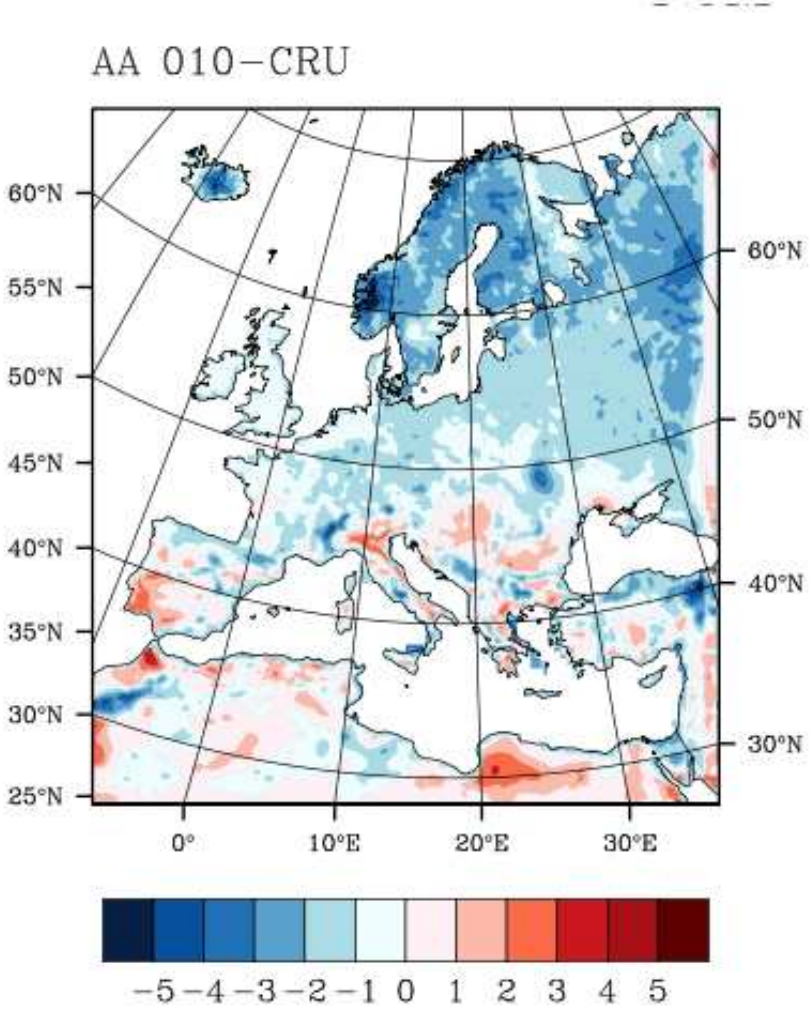
Projected Baltic Sea SST



Annual mean Baltic Sea SST 1970 - 2099 [C]

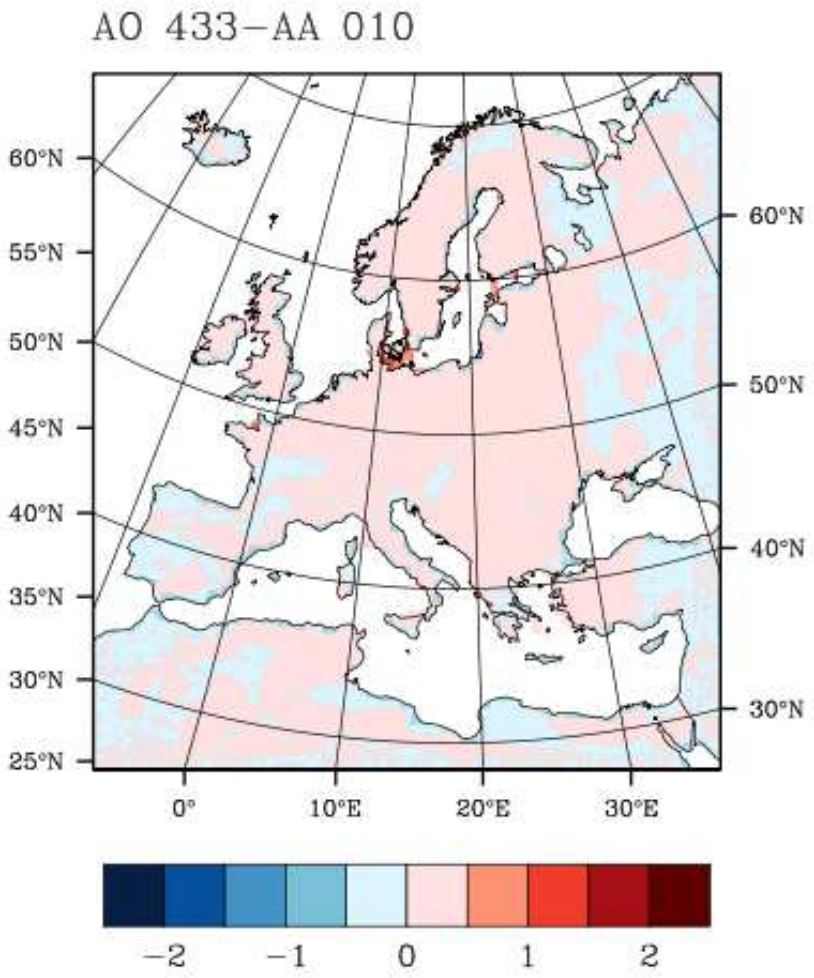
MPI-ESM-LR RCP 4.5 (k), RCP 8.5 (r), EC-EARTH RCP 4.5 (g), RCP 8.5 (b)

2m Temperature



Summer T2m bias AA - CRU [C]

RCA4-NEMO ERA40 1970-1999



Summer T2m diff AO - AA [C]

RCA4-NEMO ERA40 1970-1999