BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

DAS Basisdienst Klima und Wasser

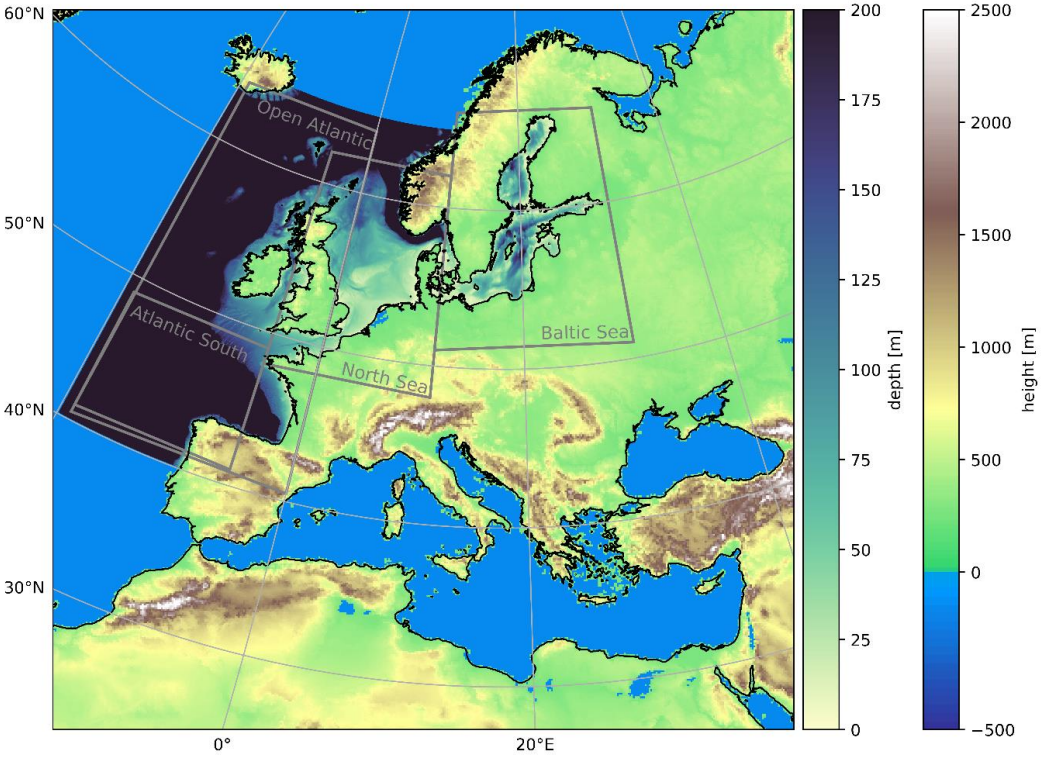
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Coupled ICON-NEMO simulations with ROAM-NBS for CORDEX-CMIP6

Vera Maurer, Simone Morak-Bozzo (DWD)
Janna Meyer, Birte-Marie Ehlers (BSH)
Wibke Düsterhöft-Wriggers (TH Lübeck)



The regional coupled model ROAM-NBS



„**R**egional coupled **o**cean-**a**tmosphere **m**odel for the **N**orth and **B**altic **S**ea“

- ICON-CLM atmosphere (EUR-12), NEMO (GCOAST-AHOI based) ocean, coupled via OASIS3-MCT
- NEMO setup provided by BSH (collaboration within the DAS-Basisdienst)

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- https://das.bsh.de/
- Maurer et al. (2026), GMD

ICON-CLM simulations for EURO-CORDEX (CMIP6)

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	EC-Earth3-Veg r1i1p1f1	MPI-ESM1-2-HR r1i1p1f1	CNRM-ESM2-1 r1i1p1f2	MIROC6 r1i1p1f1	CMCC-CM2-SR5 r1i1p1f1	NorESM2-MM r1i1p1f1
ICON-CLM	**historical** **SSP1-2.6*** **SSP2-4.5** **SSP3-7.0*** **SSP5-8.5**	**historical** **SSP1-2.6** **SSP2-4.5** **SSP3-7.0** **SSP5-8.5**	**historical** **SSP1-2.6** **SSP2-4.5** **SSP3-7.0** **SSP5-8.5**	**historical** **SSP1-2.6** **SSP2-4.5** **SSP3-7.0** **SSP5-8.5**	historical SSP1-2.6 SSP3-7.0	historical SSP1-2.6 SSP2-4.5 SSP3-7.0
ROAM-NBS	**historical** **SSP1-2.6** **SSP3-7.0**	**historical** **SSP1-2.6** **SSP3-7.0**				

UDAG
Updating the Data basis for Adaptation to climate change in Germany

contributions by DWD, Hereon, BTU, KIT, GERICS, FZJ, WEGC, IMGW, ETH

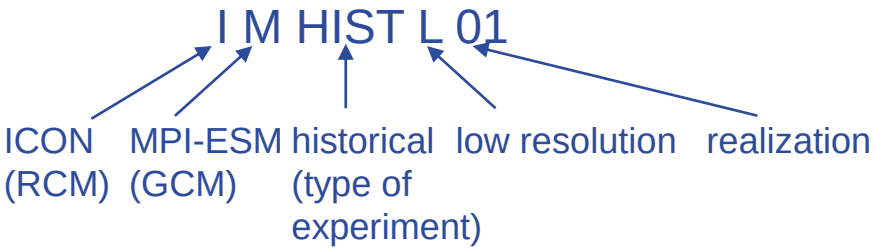
DWD-BSH

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bold = UDAG Black = other members of the CLM Community ***** = long-term extension to 2150

- ROAM-NBS simulations are finished and the atmospheric part is cmorized, QA checked, re-packed, and will be published on ESGF-DWD
- cmorization of ocean data under preparation (new mapping, grid filling, calculation of conservative temperatures), will also be published on ESGF-DWD

experiment IDs of UDAG (adopted for ROAM-NBS):



RCMs: **I**CON, **R**OAM-NBS, **A**HOI

GCMs / forcing: **M**PI-ESM1-2-HR, **E**C-Earth3-Veg, ER**A**5

evaluated experiments:
IAEVALL01, IMHISTL01, IEHISTL01, IMS370L01, IES370L01 (ICON, uncoupled)
RAEVALL01, RMHISTL01, REHISTL01, RMS370L01, RES370L01 (ROAM-NBS, coupled)

Questions addressed :

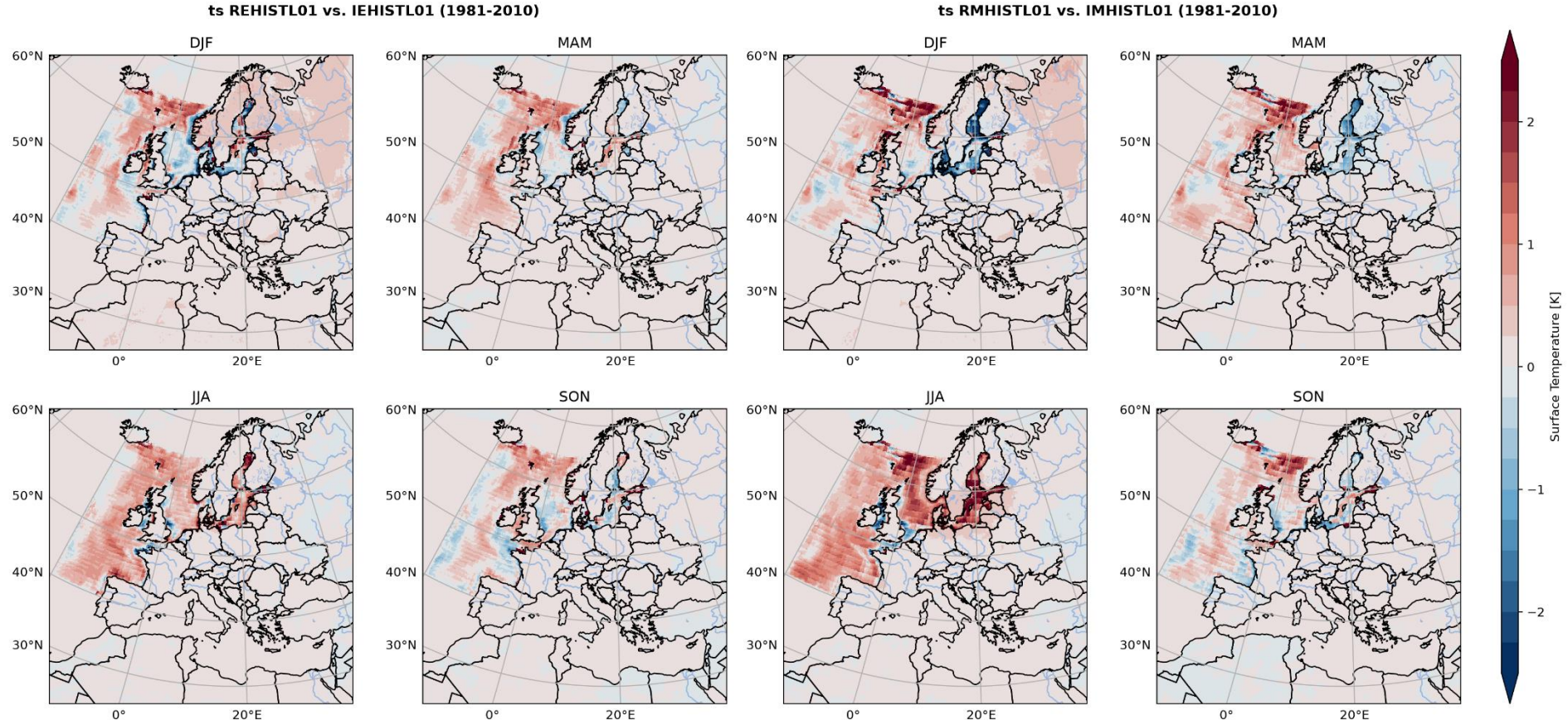
- What is the impact of the ocean coupling in the historical period?
- Climate change signal in the NBS region:
  - how does it look like in general?
  - influence of the coupling?

Questions addressed :

- What is the impact of the ocean coupling in the historical period?

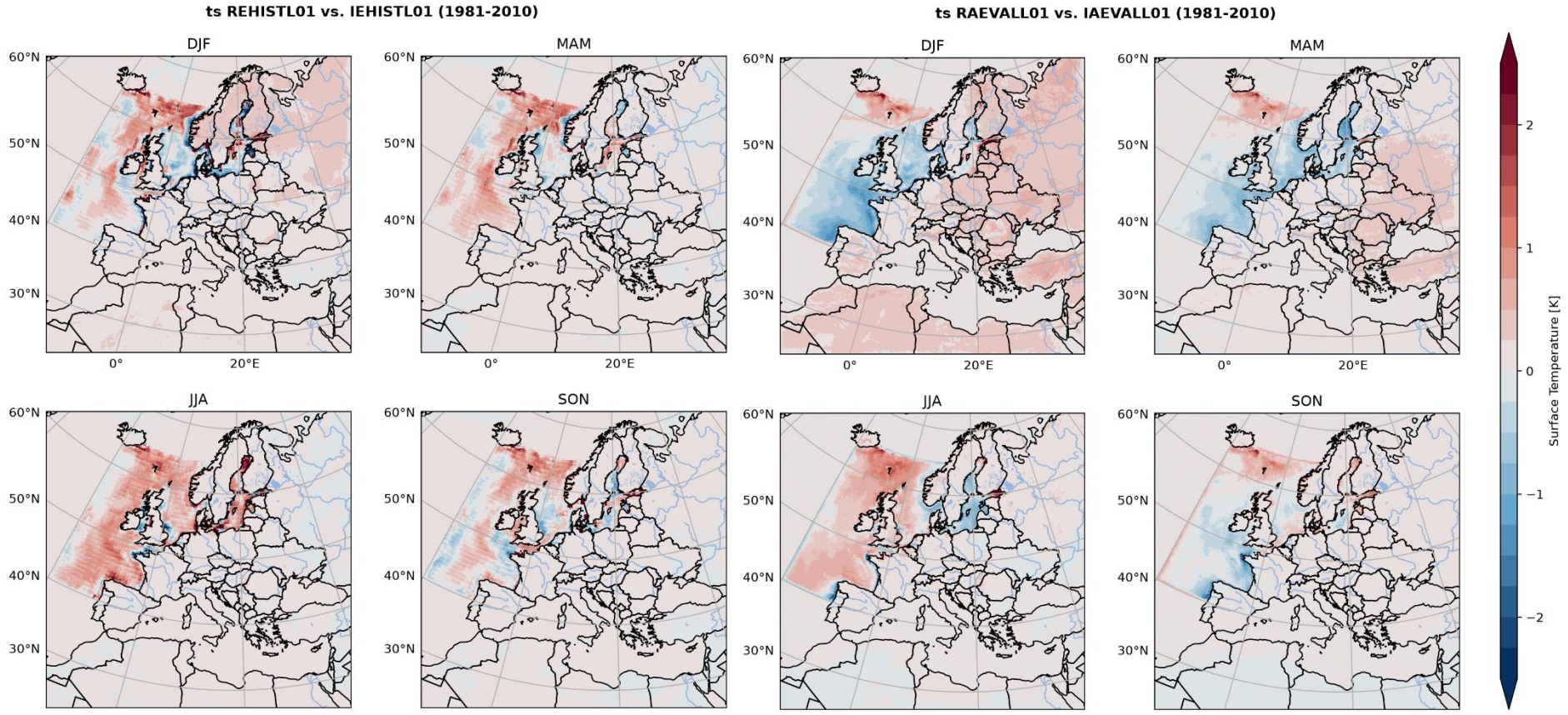
- Climate change signal in the NBS region:
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SST differences between coupled and uncoupled historical simulations



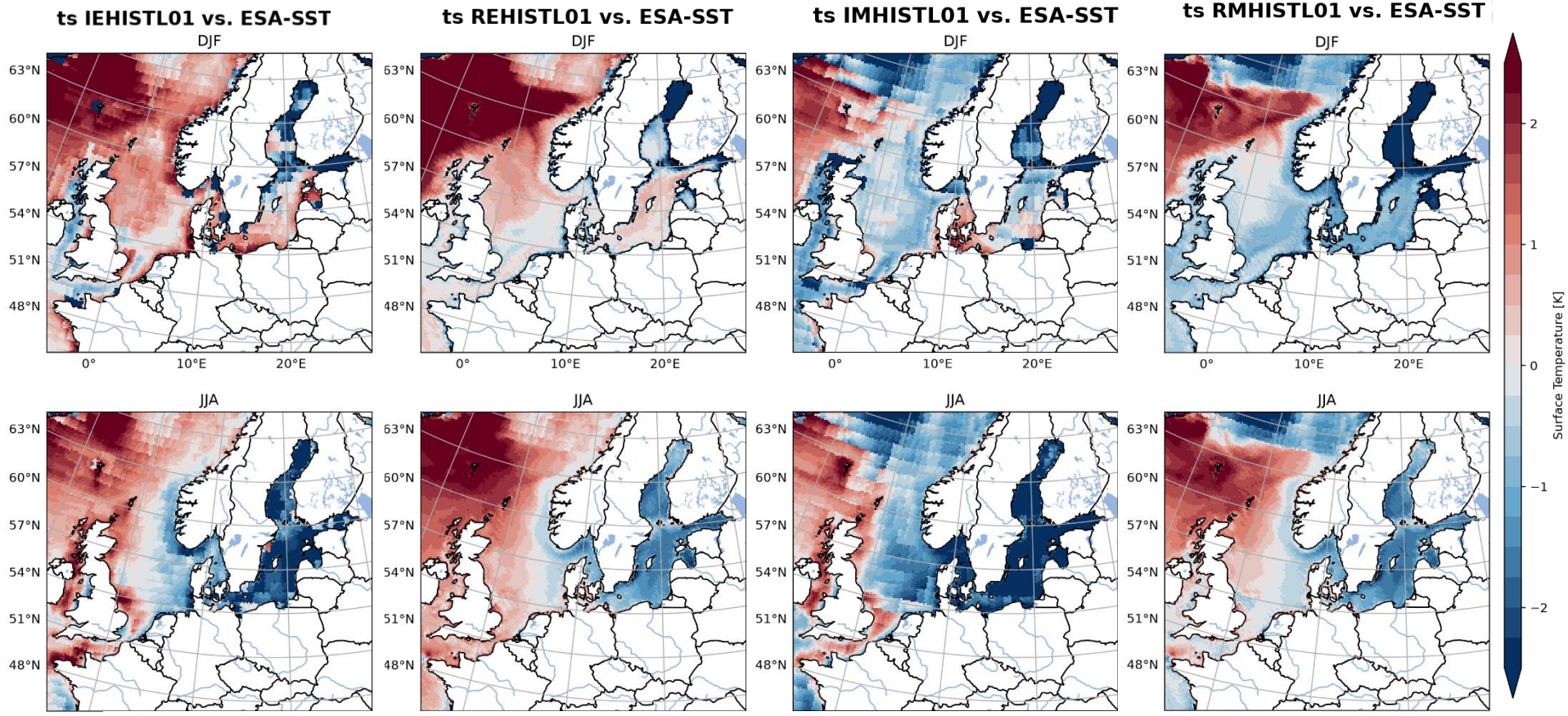
- differences between coupled/uncoupled ICON simulations mainly within the coupling area (NEMO domain)
- only systematic ts difference over land is caused by increased tkhmin in ROAM (reduces the wintertime cold bias)
- ocean areas: coupling mainly leads to higher ts, stronger in summer and in winter, and less in the Baltic Sea

SST differences between coupled and uncoupled historical + evaluation simulation



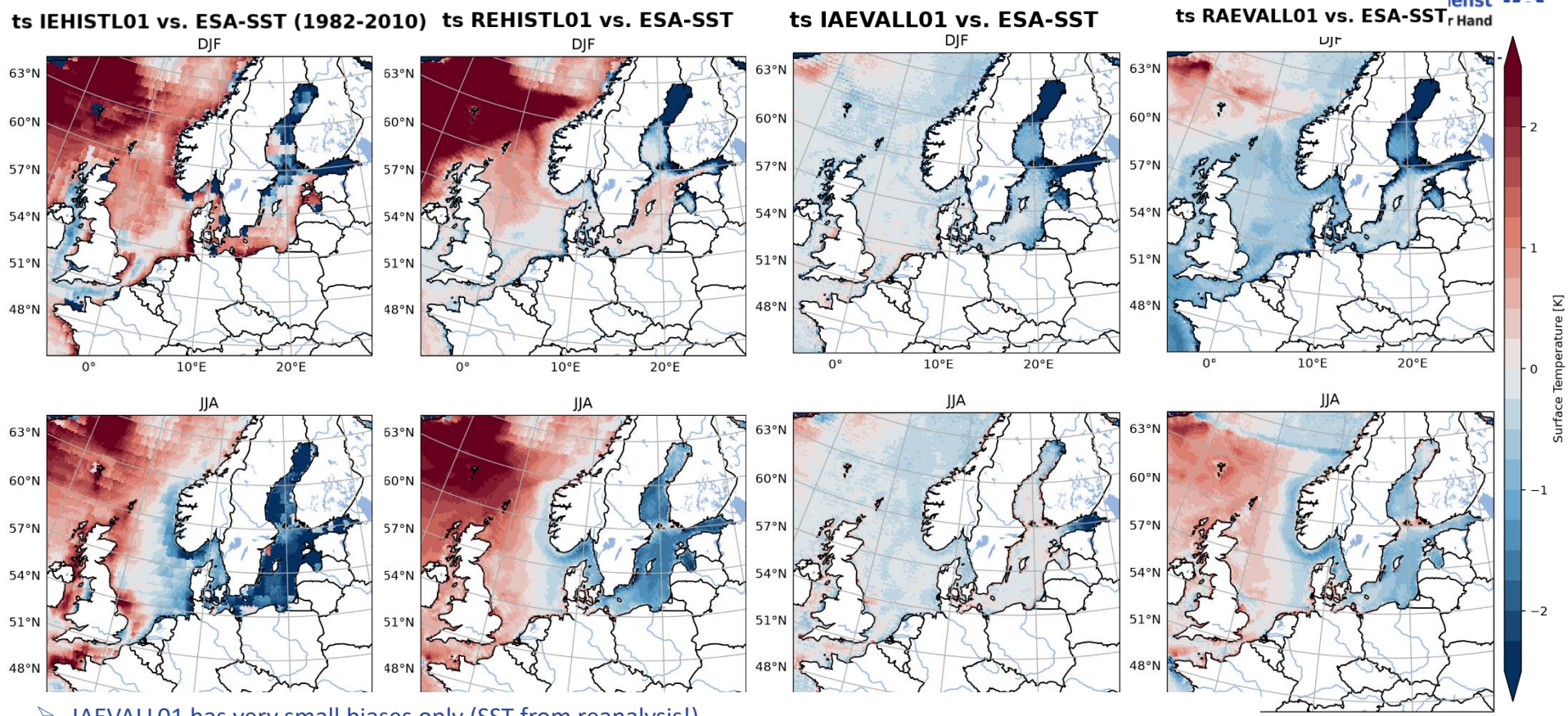
- mean ts differences between coupled and uncoupled different for the evaluation simulation than for the historicals, especially the cooler Atlantic in RAEVALL01
  → influence of the ocean BCs ?

SST biases of historical simulations vs. observations (1981-2010)



- enhanced Atlantic warm bias in the coupled historicals, but North and Baltic Sea have mainly smaller biases
- winter cold bias in Gulfs of Bothnia and Finland should not be considered (ocean covered by sea ice!)

SST biases of historical and evaluation simulation vs. observations (1982-2010)

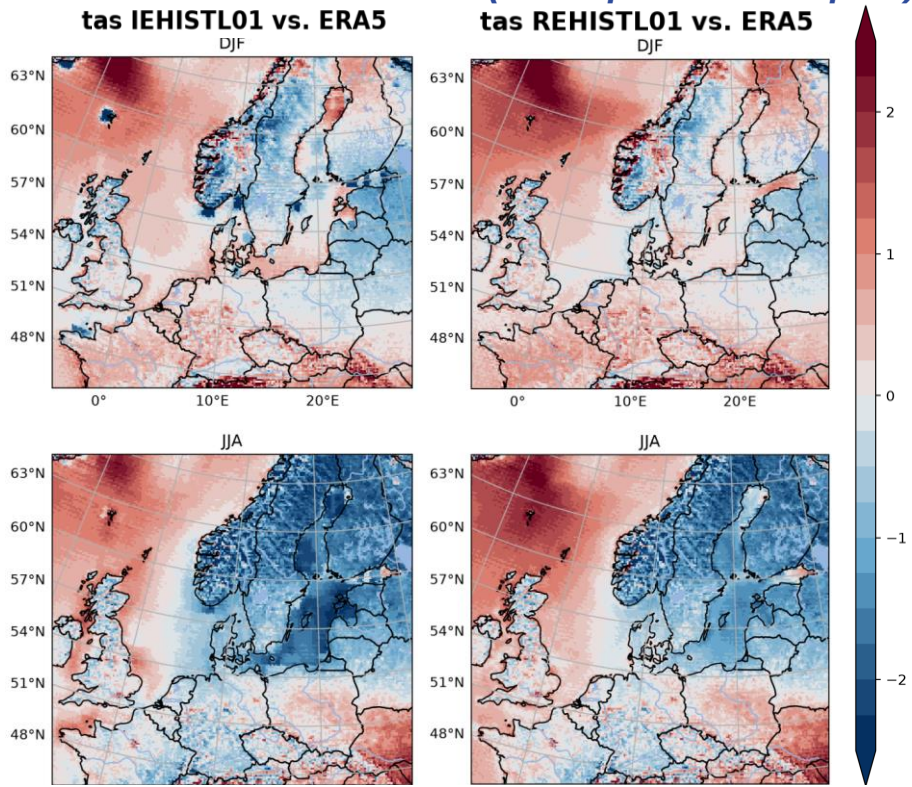


- IAEVALL01 has very small biases only (SST from reanalysis!)
- RAEVALL01 has sightly increased biases → inherent NEMO biases (of the NEMO-NBS setup, forced by ORAS5), but also positive feedback in the coupled model leading to enhanced warming in summer

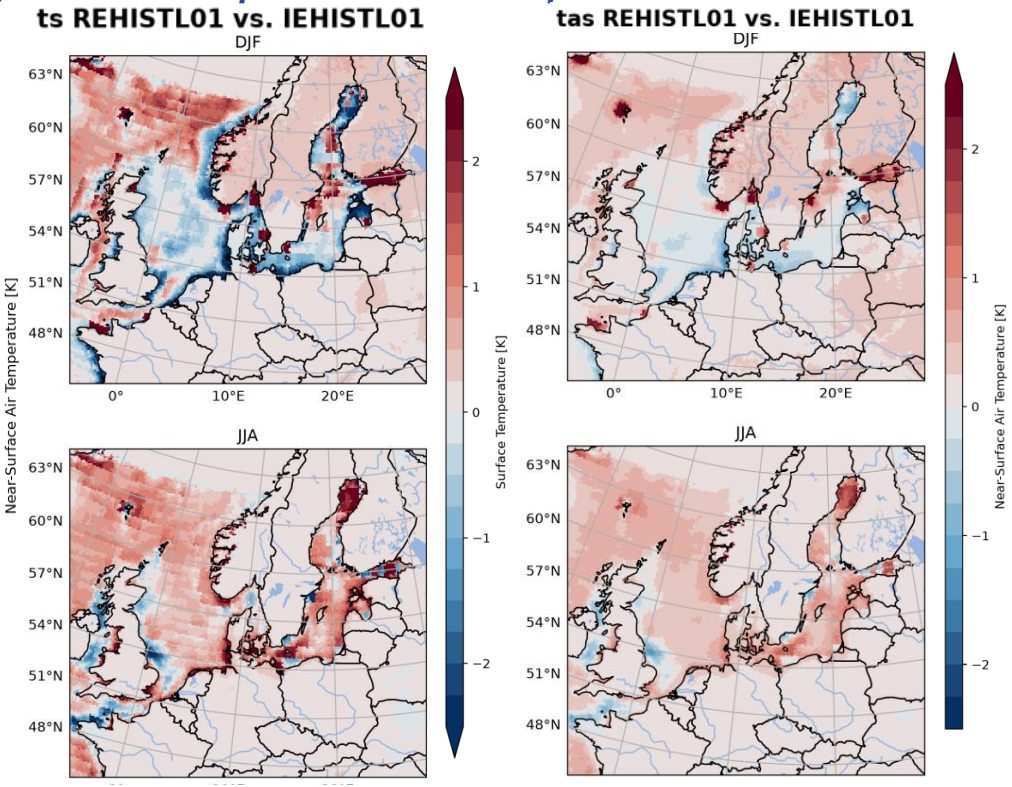
Near-surface temperature biases of historical simulation vs. ERA5 (1981-2010)

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historical minus reference (uncoupled and coupled)



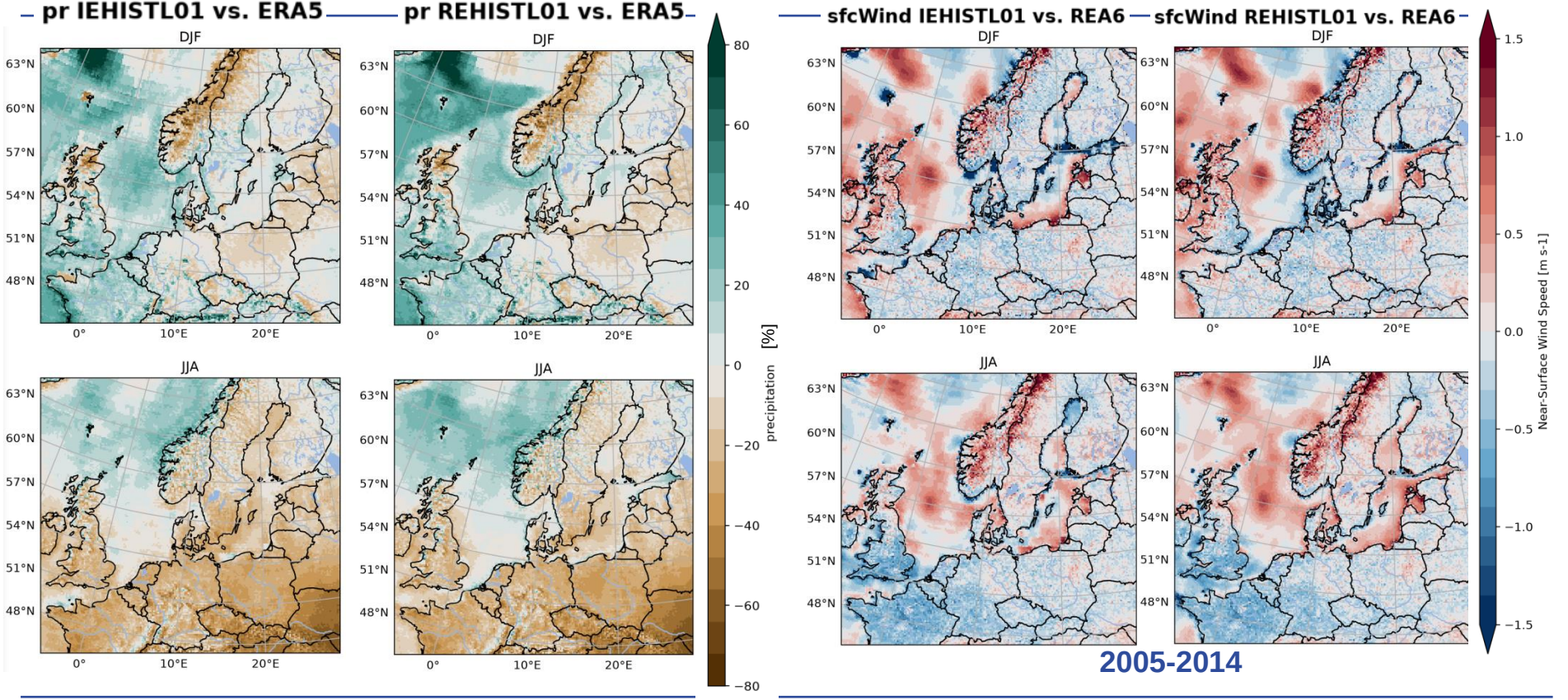
coupled minus uncoupled ts and tas



- DJF ts / tas cold bias in the Baltic Sea → again, no influence on the land areas
- obvious „wrong“ SST points in IEHIST → especially in winter, strong local cold biases; corrected by the coupling

Precipitation and wind biases of historical simulation vs. reanalyses

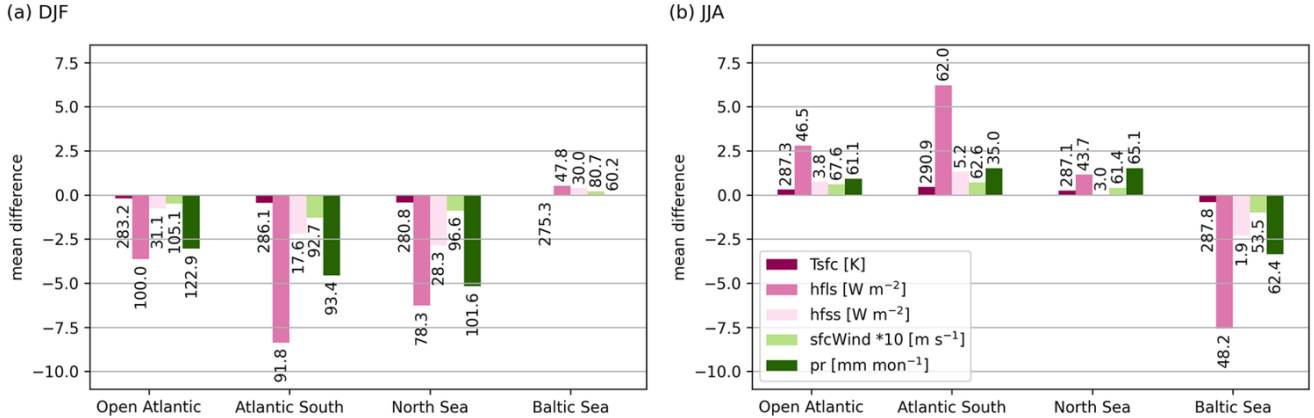
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- cooler / warmer SST → less / more precipitation → smaller biases

What is the impact of the ocean coupling in the historical period?

- generally **very small influence on land areas**
- while **SST (ts) biases** in the North and Baltic Sea become larger with the ocean coupling in the reanalysis-driven evaluation simulation, they are **largely reduced in the historical simulations**
  - small drawback: NEMO suffers from a warm bias in the Atlantic ocean, also affecting the North Sea
- specific SST issues in uncoupled simulations → remedied in coupled simulations
- smaller SST biases also help reducing other biases like tas, pr
  - sfcWind tends to positive biases; increased by higher SSTs in summer (stronger mixing)



SST, flux, sfcWind and pr differences between the coupled and uncoupled evaluation simulation in different ocean domains (1979-2020)

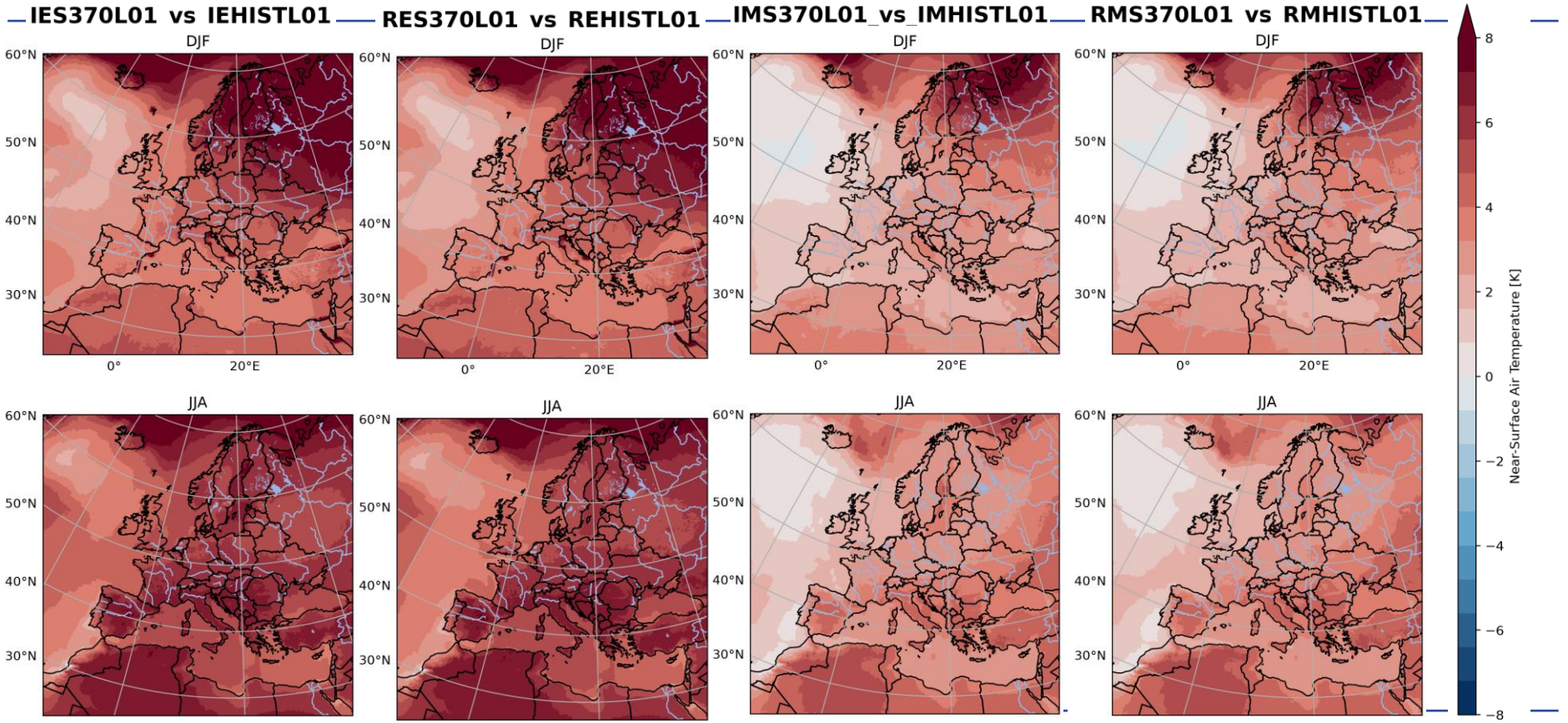
Questions addressed :

- What is the impact of the ocean coupling in the historical period?

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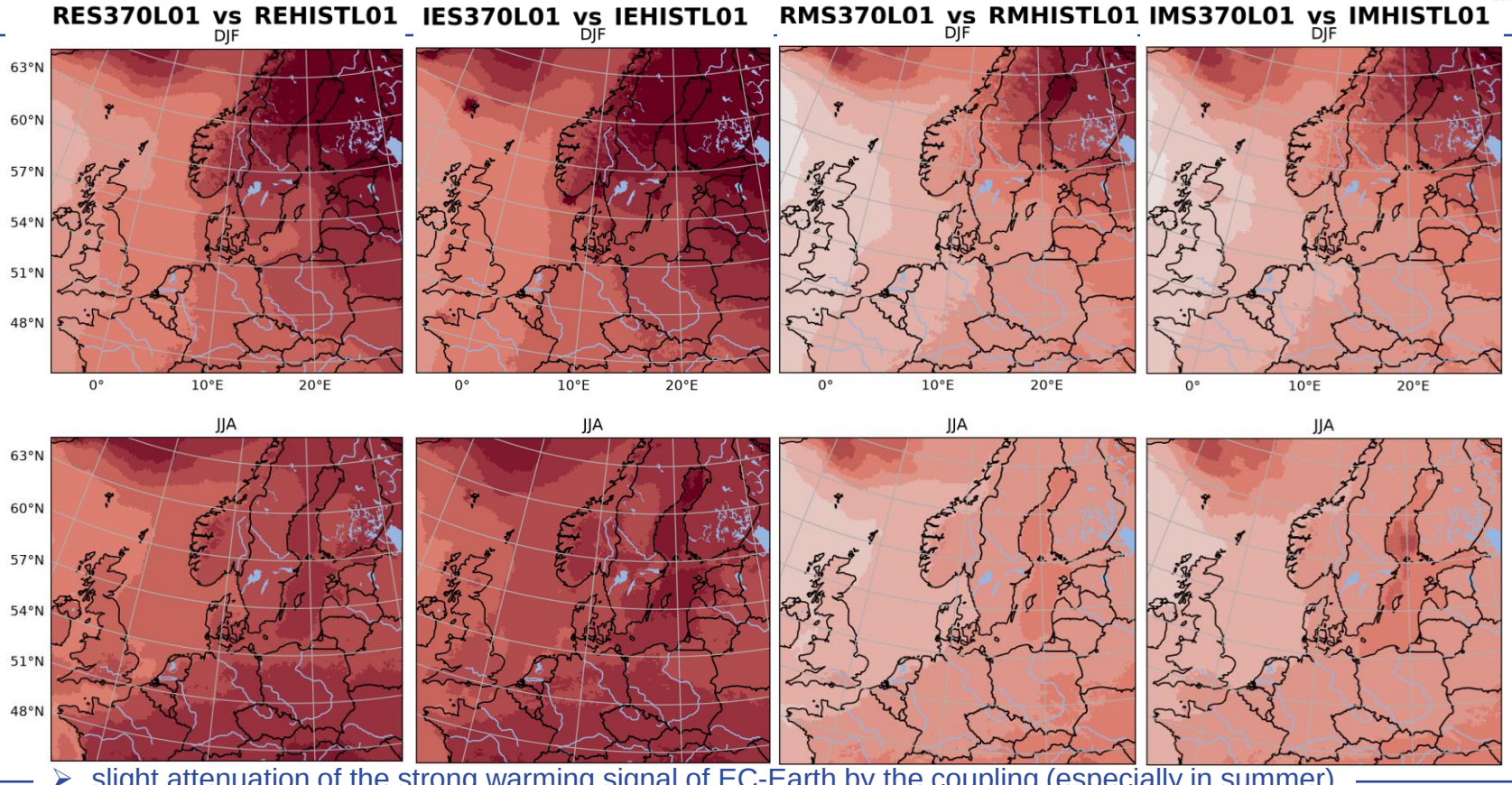
SSP3-7.0 : **tas** end-of-century differences to the historical period (2071-2100 vs. 1961-1990)

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- coupled and uncoupled climate change signals visually identical
- EC-Earth has high TCR → much stronger warming in all seasons than MPI-ESM

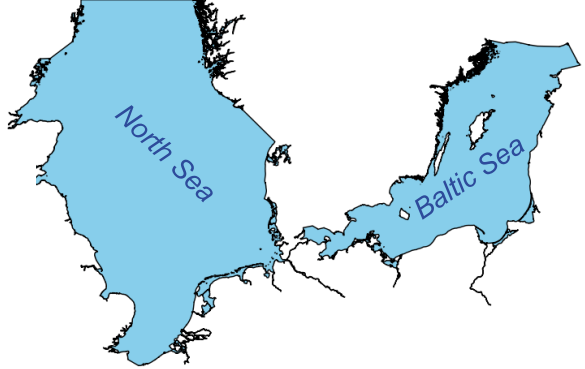
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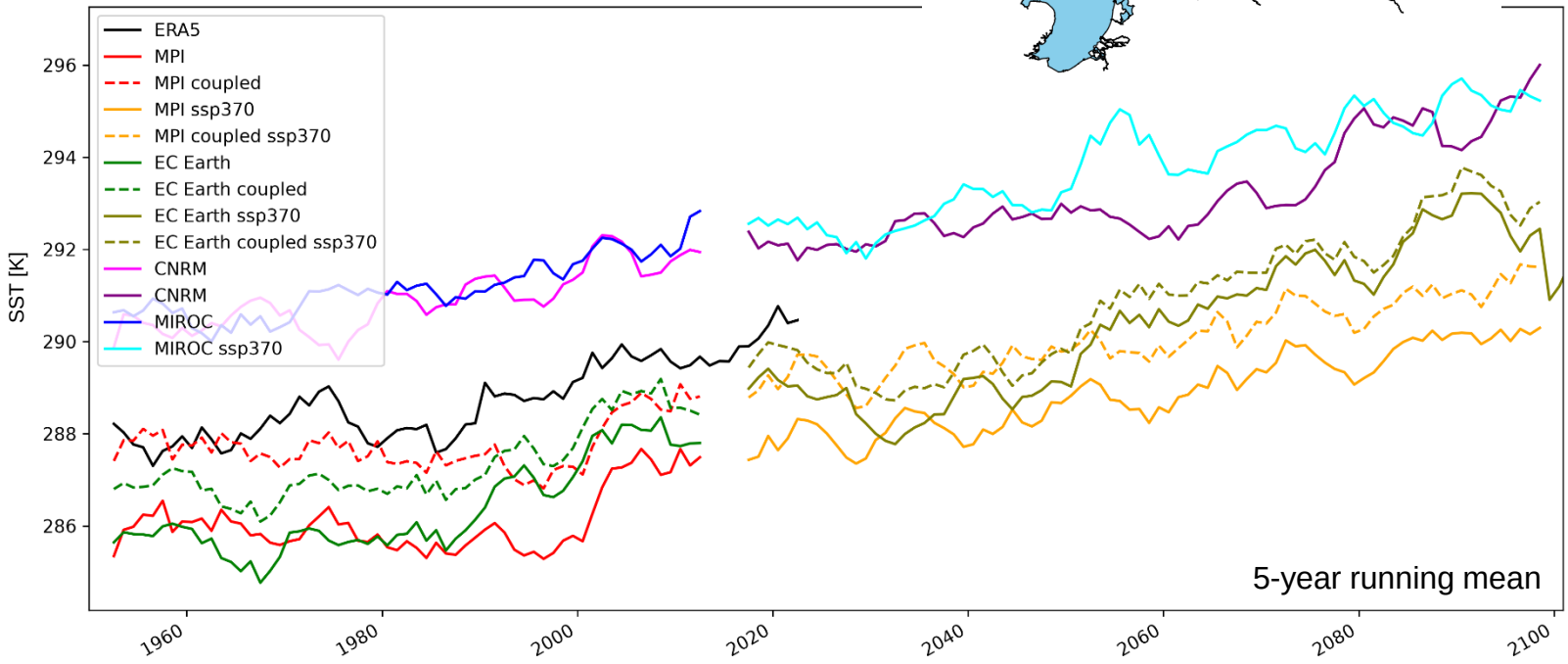


- slight attenuation of the strong warming signal of EC-Earth by the coupling (especially in summer)
- MPI-ESM-driven simulations: decreased warming in the Baltic Sea
- especially in summer: stronger warming of the Baltic Sea than of the North Sea

SSP3-7.0 : **ts** time series for the Baltic Sea for summer

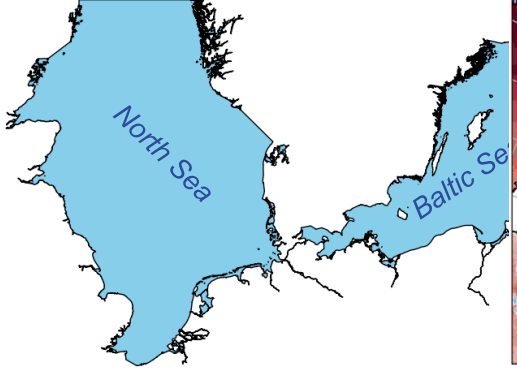
- clear warming in the Baltic Sea in all simulations from about 15°C in 1950 to about 17-19 °C by 2100
- very small decrease in coupled/uncoupled differences over time

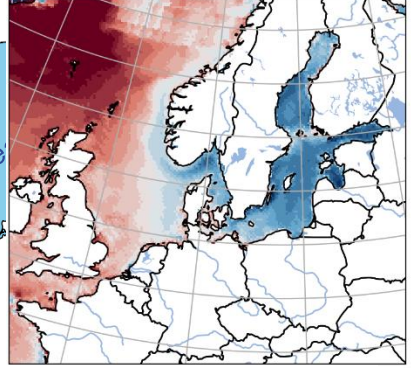




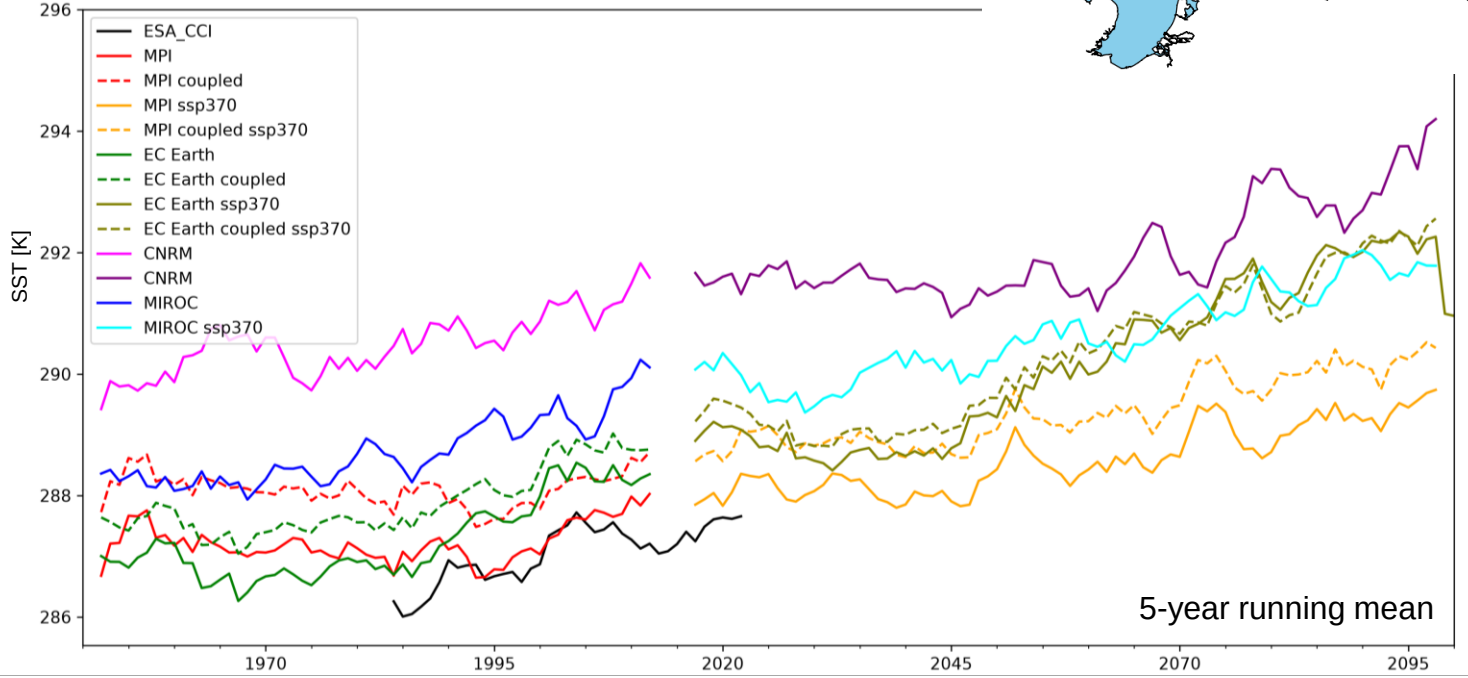
SSP3-7.0 : **ts** time series for the North Sea for summer

- compared to the Baltic Sea, slightly less warming in the North Sea
- all models too warm in the historical period; models underestimate temperature contrasts between the North and the Baltic Sea



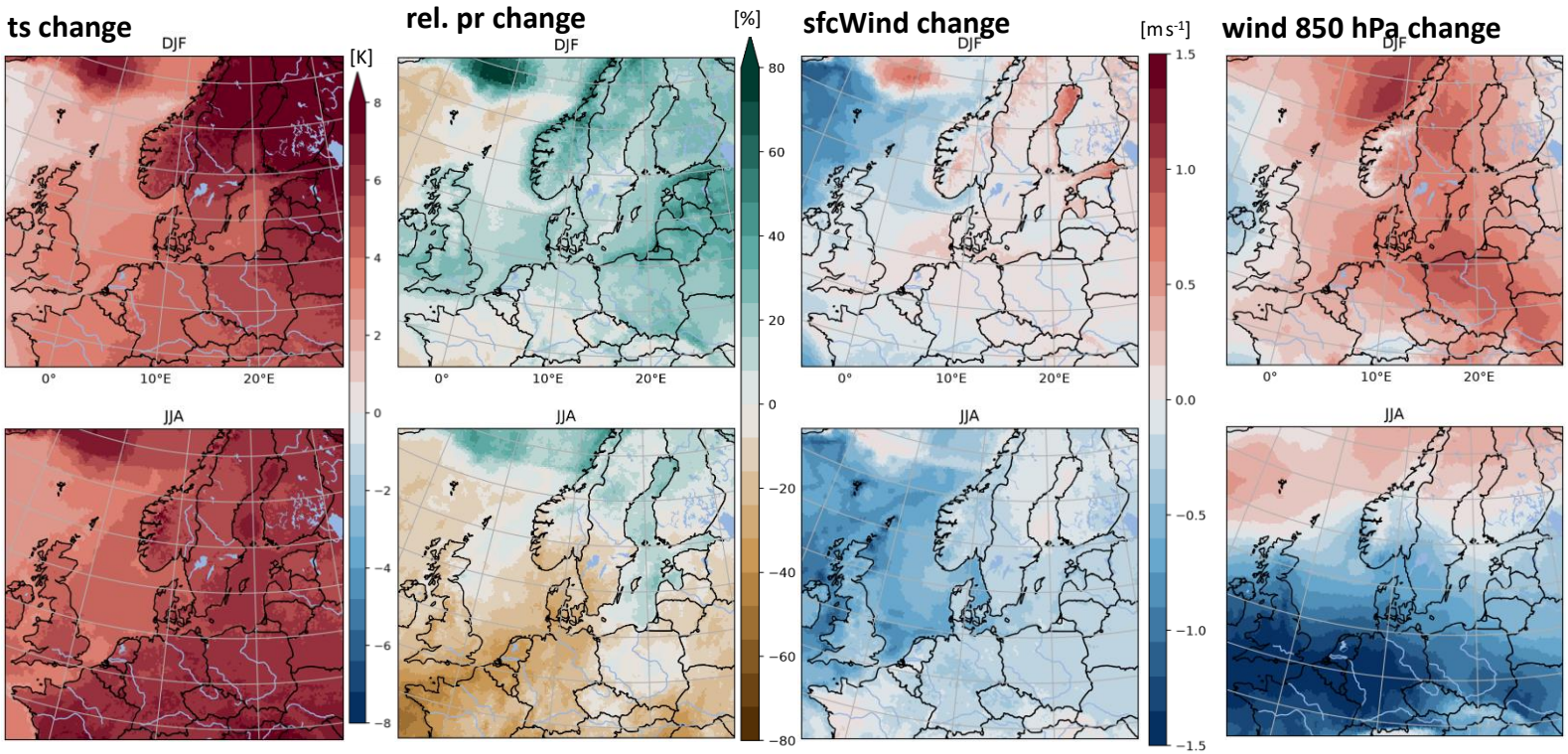


ts REHISTL01 vs. ESA-SST



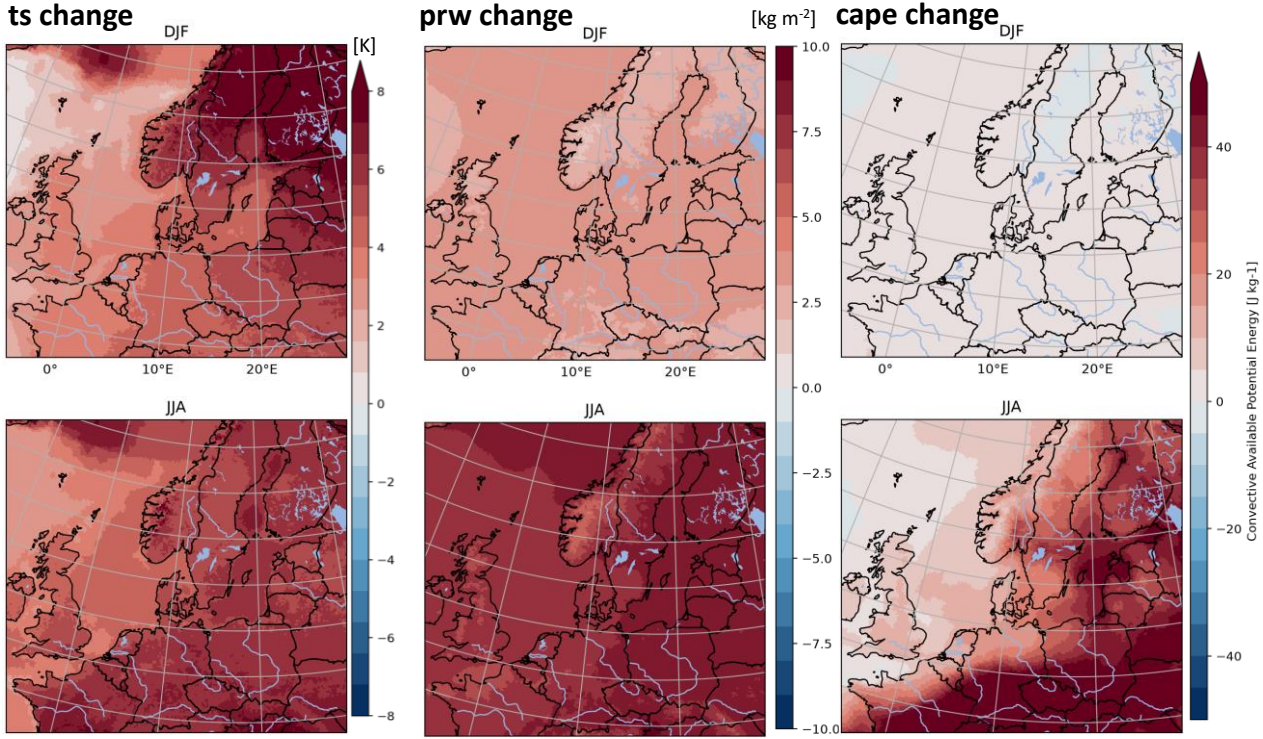
SSP3-7.0 : RES370L01/REHISTL01 differences (2071-2100 vs. 1961-1990)

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- RES370L01 (extreme scenario!) predicts precipitation increase in winter and decrease in summer
- wind increase in winter and decrease in summer
- precipitation and wind changes are influenced by changes of circulations

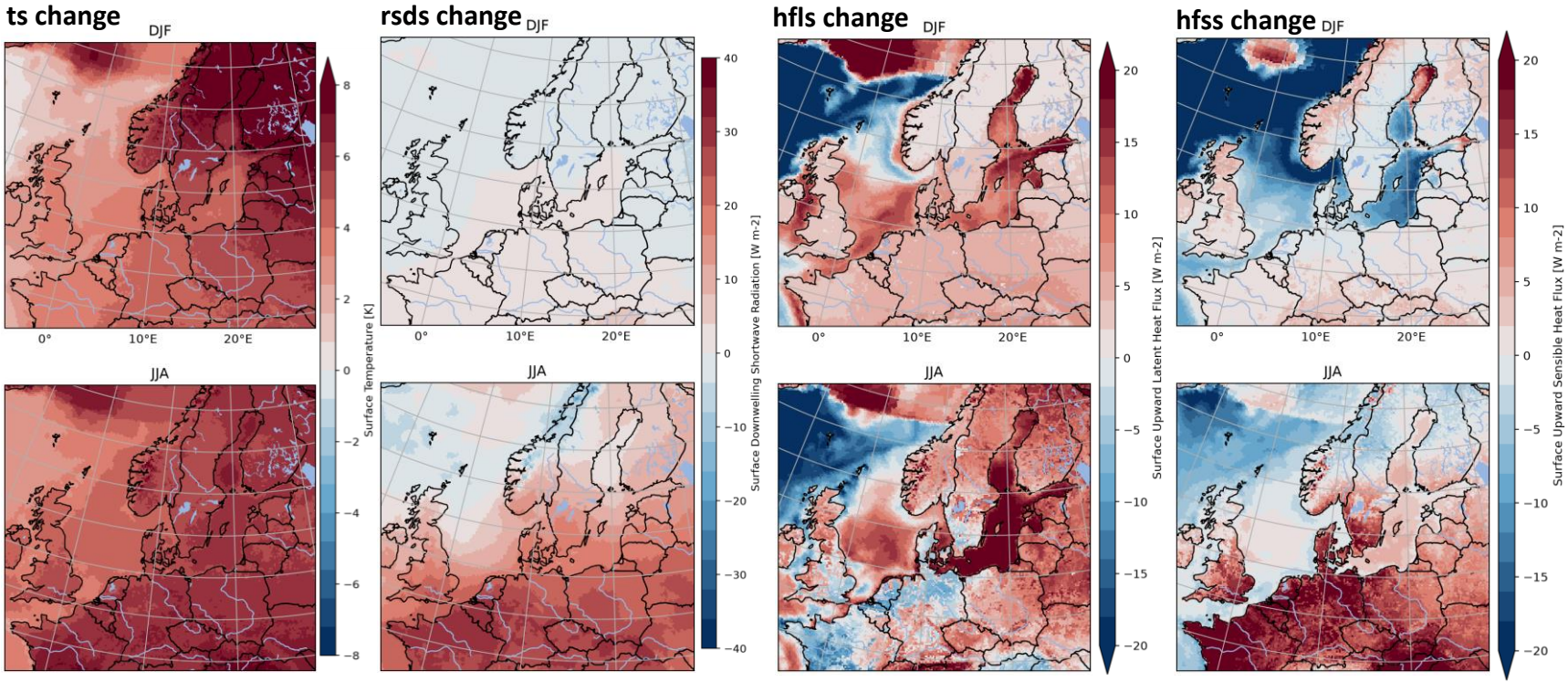
SSP3-7.0 : RES370L01/REHISTL01 differences (2071-2100 vs. 1961-1990)



- water vapor increase in both seasons, very strong (up to 10 kg $m^{-2)}$ in summer (MPI-forced ICON: 4-6 kg m^{-2})
- strong increase in CAPE for summer

SSP3-7.0 : RES370L01/REHISTL01 differences (2071-2100 vs. 1961-1990)

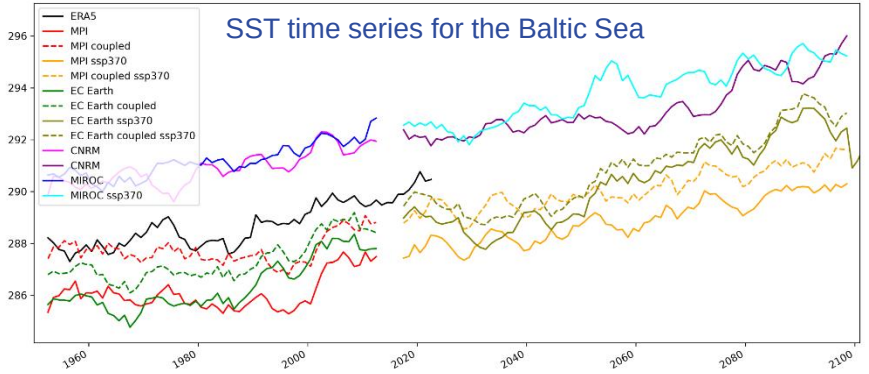
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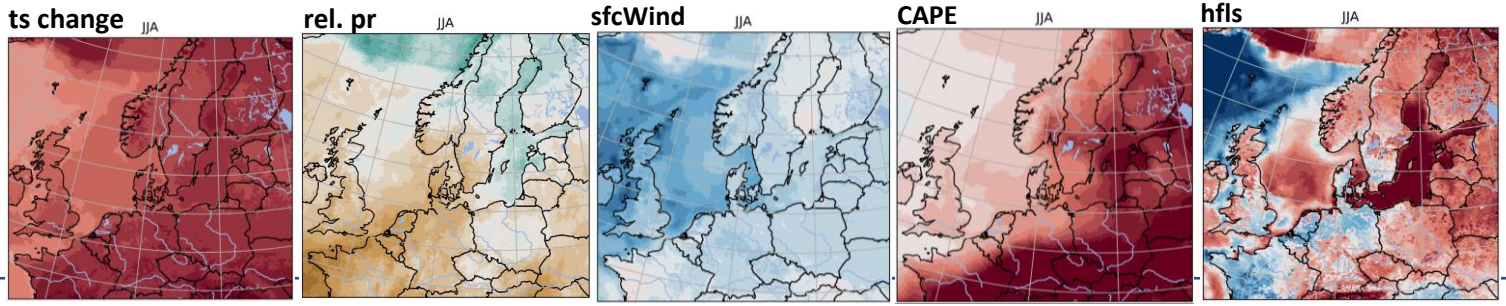


Climate change signal in the NBS region

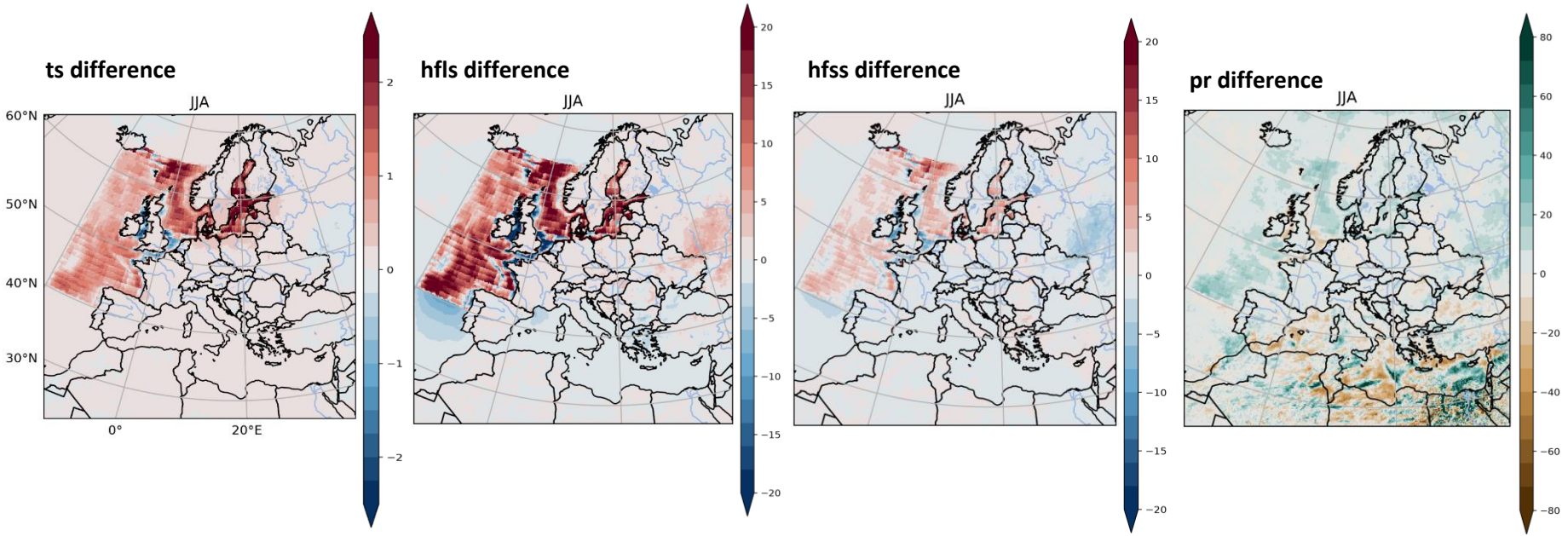
- impact of the coupling: very small, slightly attenuating

- climate change in general:
  - as in other regions, EC-Earth shows strongest warming
  - Baltic Sea heats stronger than the North Sea
  - extreme scenario predicts by 2100:
    - increasing wind and precipitation in winter, decreasing in summer
    - strong integrated water vapor increase in summer by up to 10 kg m^{-2} over the whole domain, CAPE increase over the Baltic Sea by up to 50 J kg^{-1}
    - clearly increased downwelling radiation in summer
    - strong evaporation increase over NBS in both seasons

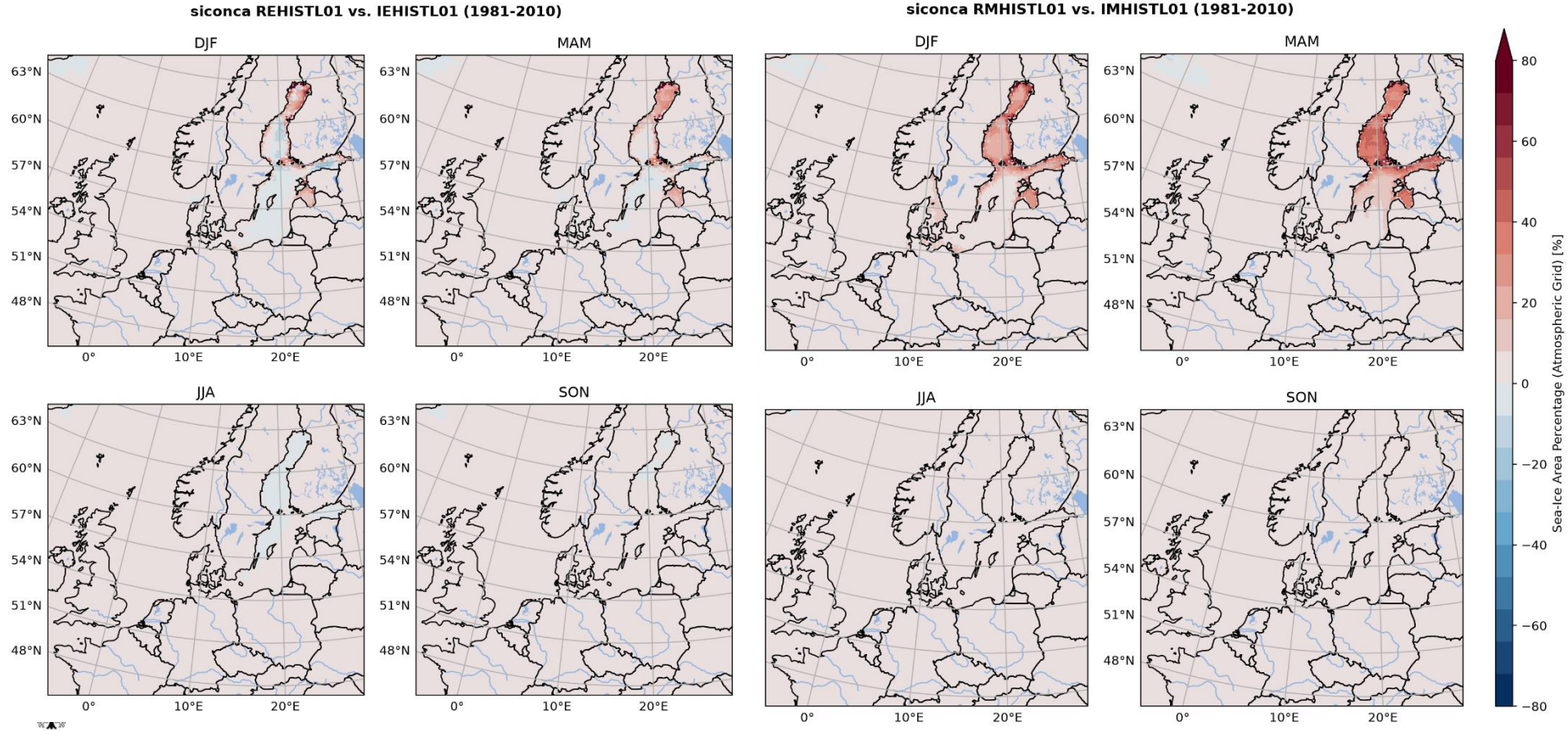




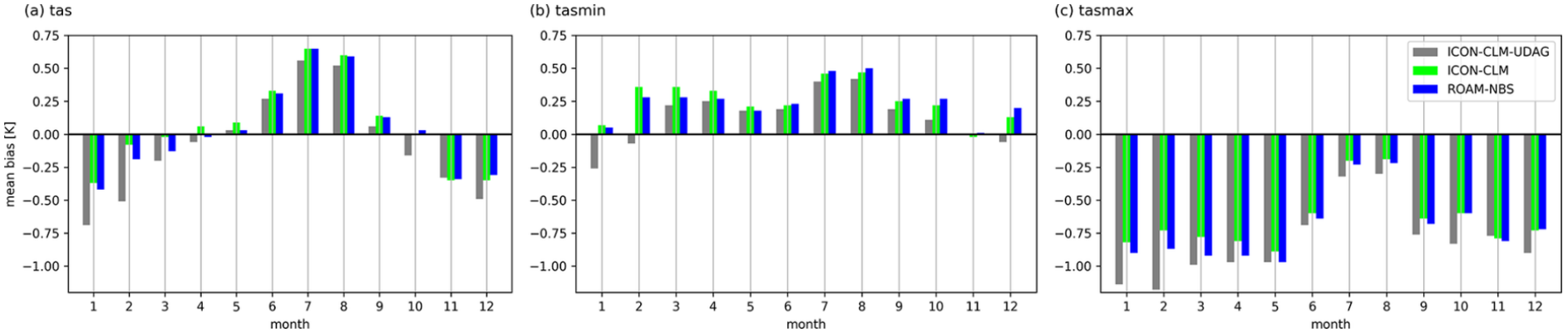
Coupled/uncoupled differences in the historicals



Coupled/uncoupled seaice differences in the historicals

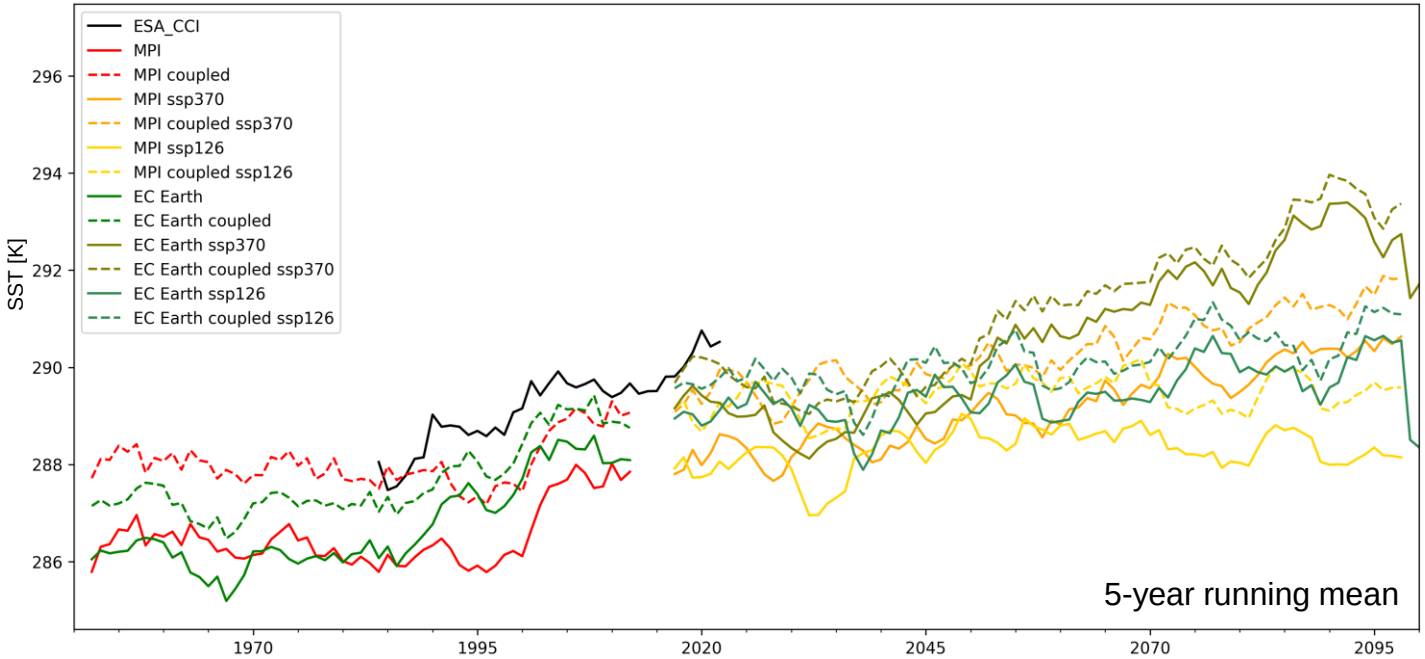


tas, tasmin and tasmax biases against E-OBS (1979-2020) for IAEVALL01, RAEVALL01, and ICON-CLM with increased tkhmin



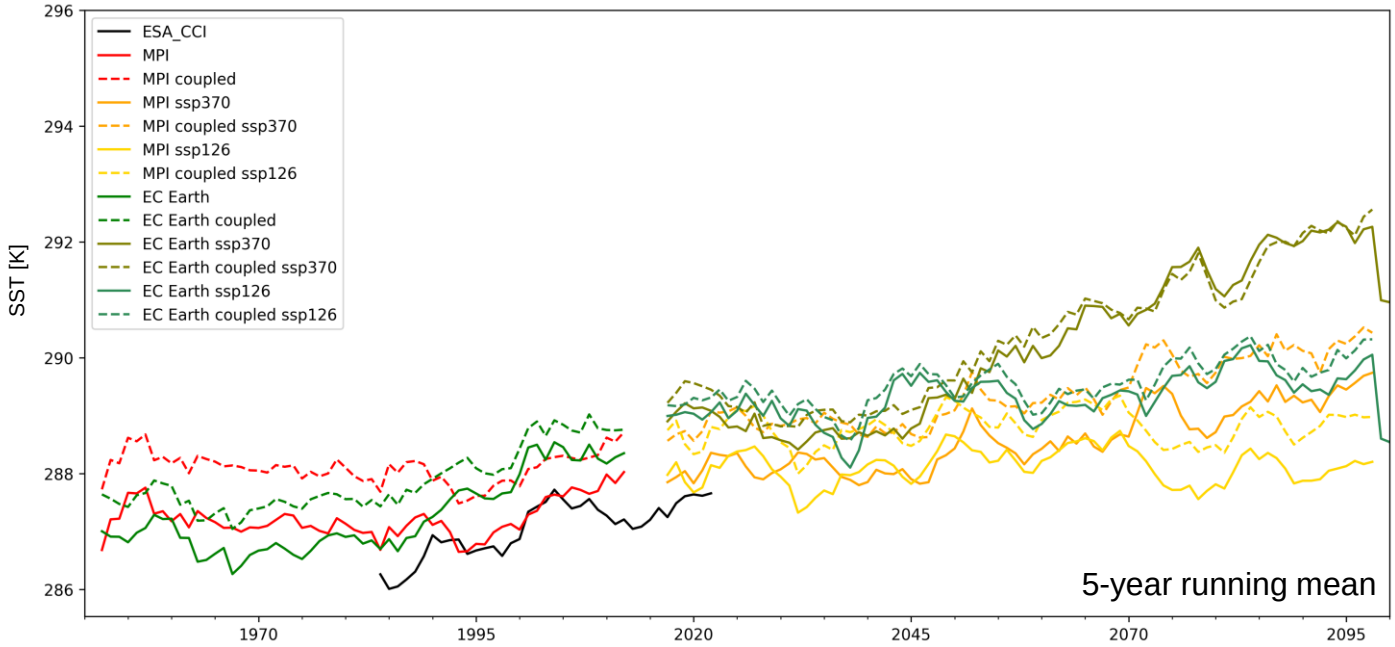
SSP1-2.6 and SSP3-7.0 : **ts** time series for the Baltic Sea for summer

- EC-Earth-forced ssp126 very close to MPI-ESM-forced ssp370
- larger coupled/uncoupled differences for MPI-ESM-forced simulations than for EC-Earth-forced



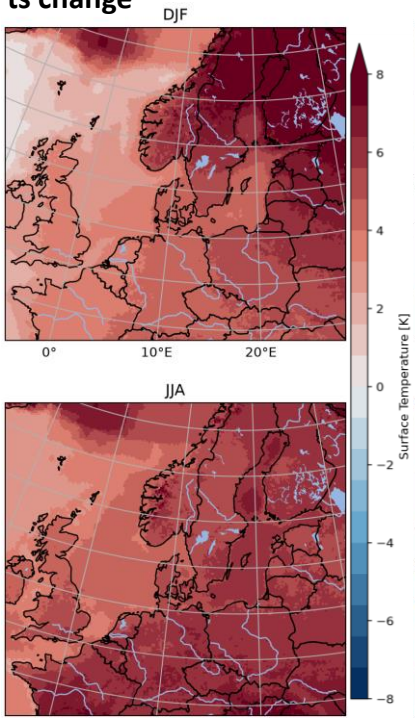
SSP1-2.6 and SSP3-7.0 : **ts** time series for the North Sea for summer

- EC-Earth-forced ssp126 very close to MPI-ESM-forced ssp370
- smaller scenario, larger coupled/uncoupled differences for MPI-ESM-forced simulations than for EC-Earth-forced

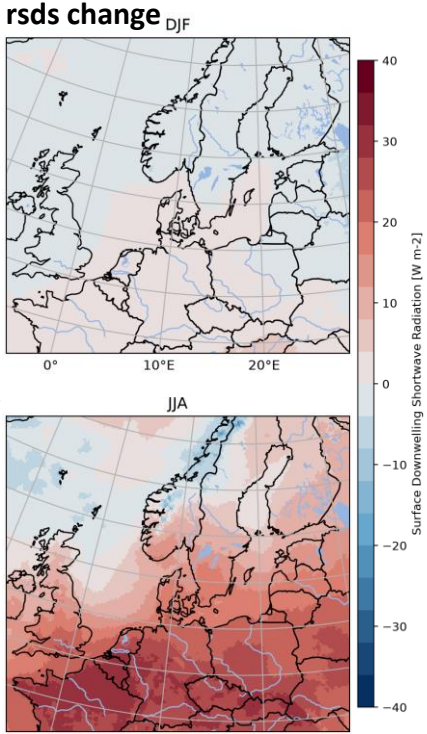


SSP3-7.0 : other RES370L01/REHISTL01 differences (2071-2100 vs. 1961-1990)

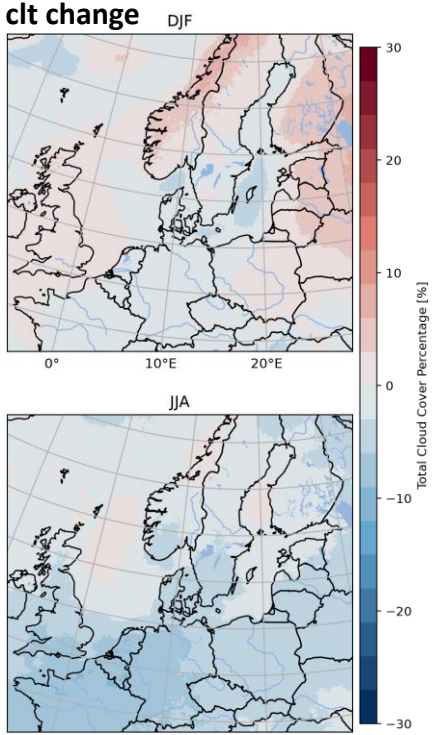
ts change



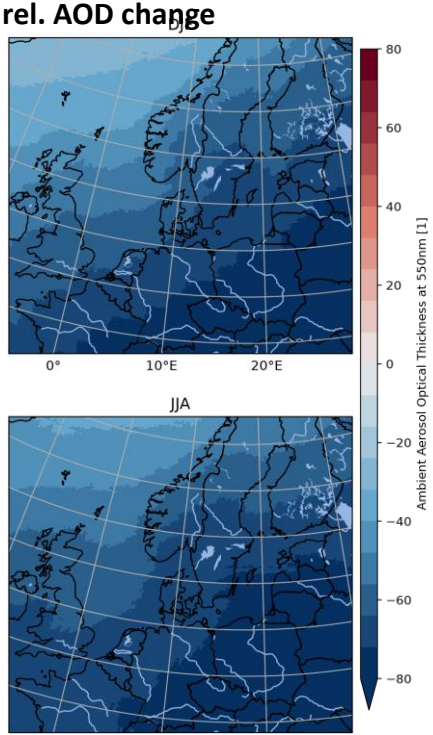
rsds change



clt change

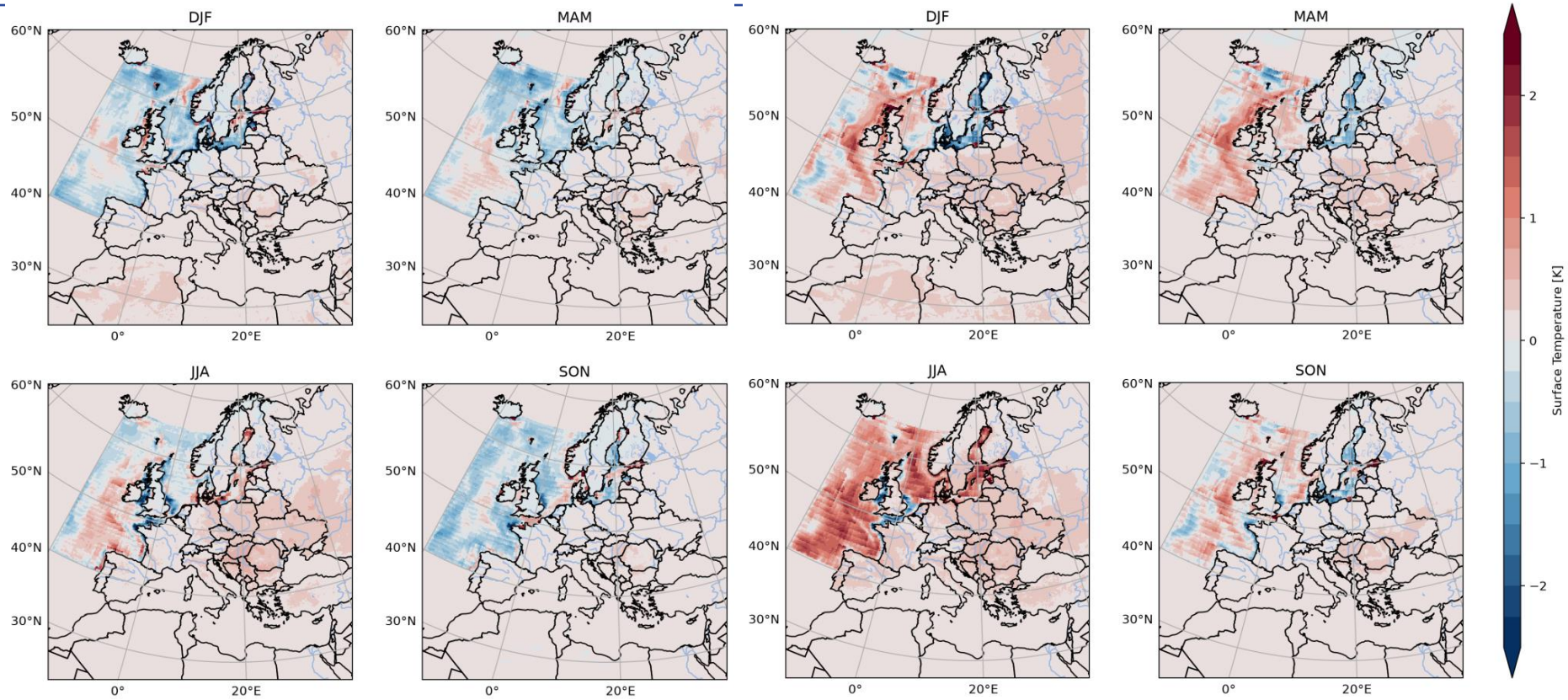


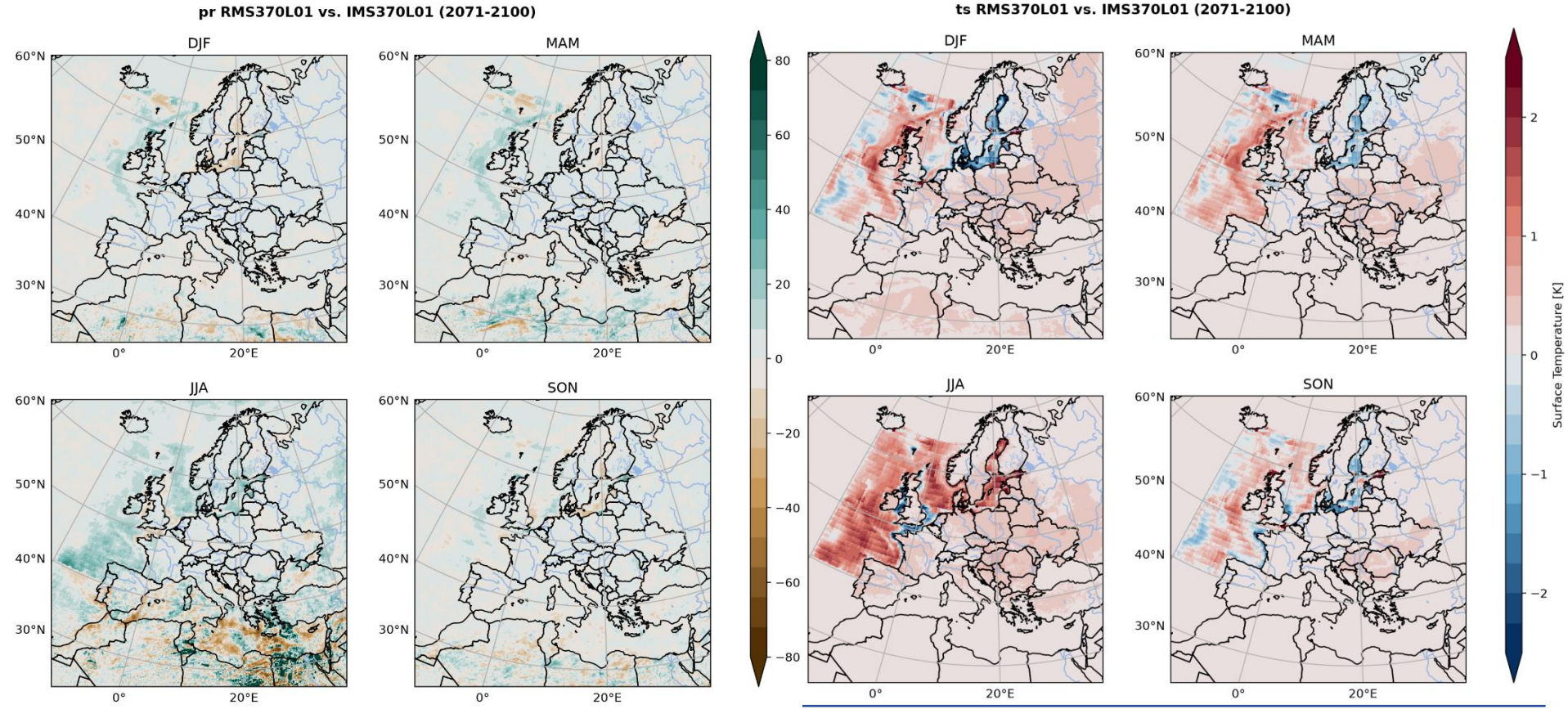
rel. AOD change



ts RES370L01 vs. IES370L01 (2071-2100)

ts RMS370L01 vs. IMS370L01 (2071-2100)




pr RMS370L01 vs. IMS370L01 (2071-2100)
DJF
MAM
JJA
SON
60°N
50°N
40°N
30°N
0°
20°E
ts RMS370L01 vs. IMS370L01 (2071-2100)
80
60
40
20
0
−20
−40
−60
−80
2
1
0
−1
−2
Surface Temperature [K]