Climate model ARTS-ESM

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Climate system model includes:

1. Atmospheric dynamics block, land surface, soil and vegetation, including land carbon cycle, electric phenomena
2. Oceanic dynamics, including sea ice dynamics and thermodynamics
3. Aerosol block

Can include also:

4. Atmospheric chemistry
5. Oceanic biogeochemistry

Model versions for CMIP6:

INMCM48
Atmosphere 2x1.5 degrees and 21 levels, ocean 1x0.5 and 40 levels

INMCM50
Atmosphere 2.x1.5 degrees and 73 levels, ocean 0.5x0.25 and 40 levs

INMCM5H
Atmosphere 0.67x0.5 и 73 levels, ocean 0.167x0.125 and 40 levels

Main improvements with respect to CMIP6 versions:

1. Replacing of diagnostic cloud scheme by prognostic one
2. More sophisticated treatment of aerosol radiation properties, and indirect aerosol effect
3. Land snow evolution treatment
4. Land surface flux parameterization
5. Atmospheric PBL parameterization
6. Land carbon cycle (including of land use and vegetation type changes)
7. Monotonic schemes for scalar advection, Coriolis term and sea level calculation in ocean model
8. Monotonic schemes for sea ice advection
9. Unified atmospheric electricity (flashes and ionospheric potential) parameterization for land and ocean

Model code is placed in version control system Git. User can download the model easily.

Many model developers can work in parallel.

ARTS-ESM:
All Range Time Scales Earth System Model

CMIP7 versions:

ARTS-ESM-L (Low resolution)

Atmosphere 2x1.5 degrees and 21 levels up to 30 km, ocean 1x0.5 and 40 levels

For: interactive climate-carbon cycle runs;
methodical runs (ERF, feedback estimation, …)
paleoclimate simulation

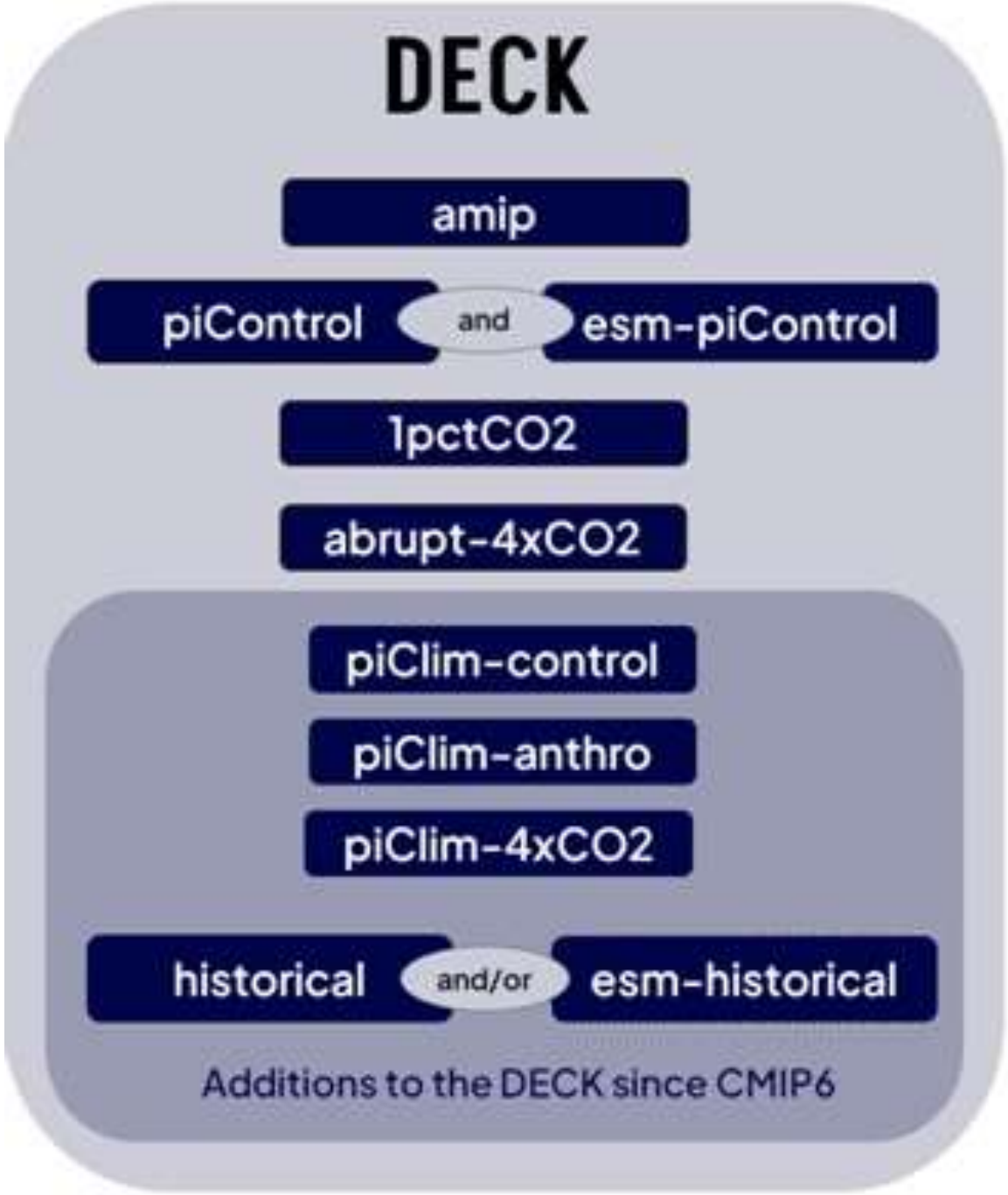
ARTS-ESM-M (Medium resolution)

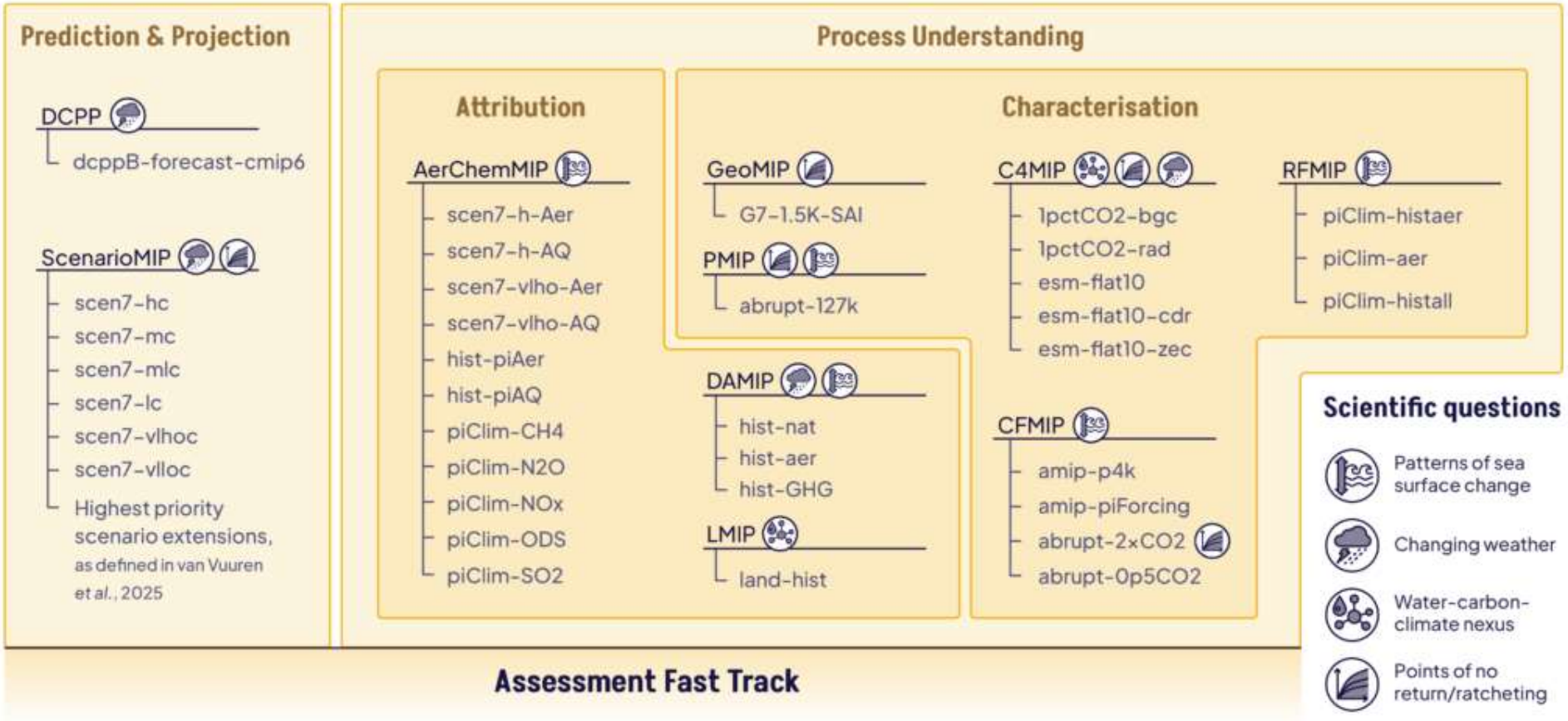
Atmosphere 1.25x1 degrees and 73 levels up to 60 km, ocean 0.5x0.25 and 40 levels

For: exact simulation of present climate, historical and future climate changes; seasonal, annual and decadal prediction

CMIP7 structure

1. DECK
2. Fast track: 2026г
3. Subprojects: 2026-2028г


DECK
amip
piControl
and
esm-piControl
1pctCO2
abrupt-4xCO2
piClim-control
piClim-anthro
piClim-4xCO2
historical
and/or
esm-historical
Additions to the DECK since CMIP6


Prediction & Projection
DCPP
dcppB-forecast-cmip6
ScenarioMIP
scen7-hc
scen7-mc
scen7-mlc
scen7-lc
scen7-vlhoc
scen7-vlloc
Highest priority scenario extensions, as defined in van Vuuren et al., 2025
Process Understanding
Attribution
AerChemMIP
scen7-h-Aer
scen7-h-AQ
scen7-vlho-Aer
scen7-vlho-AQ
hist-piAer
hist-piAQ
piClim-CH4
piClim-N2O
piClim-NOx
piClim-ODS
piClim-SO2
Characterisation
GeoMIP
G7-1.5K-SAI
PMIP
abrupt-127k
DAMIP
hist-nat
hist-aer
hist-GHG
LMIP
land-hist
C4MIP
1pctCO2-bgc
1pctCO2-rad
esm-flat10
esm-flat10-cdr
esm-flat10-zec
CFMIP
amip-p4k
amip-piForcing
abrupt-2×CO2
abrupt-0p5CO2
RFMIP
piClim-histaer
piClim-aer
piClim-histall
Scientific questions
Patterns of sea surface change
Changing weather
Water-carbon-climate nexus
Points of no return/ratcheting
Assessment Fast Track

Presentation of ARTS-ESM results for CMIP7:

Estimation of effective and instantaneous radiation forcings - Bragina V., poster

Carbon cycle simulation and climate change feedbacks – Chernenkov A., poster

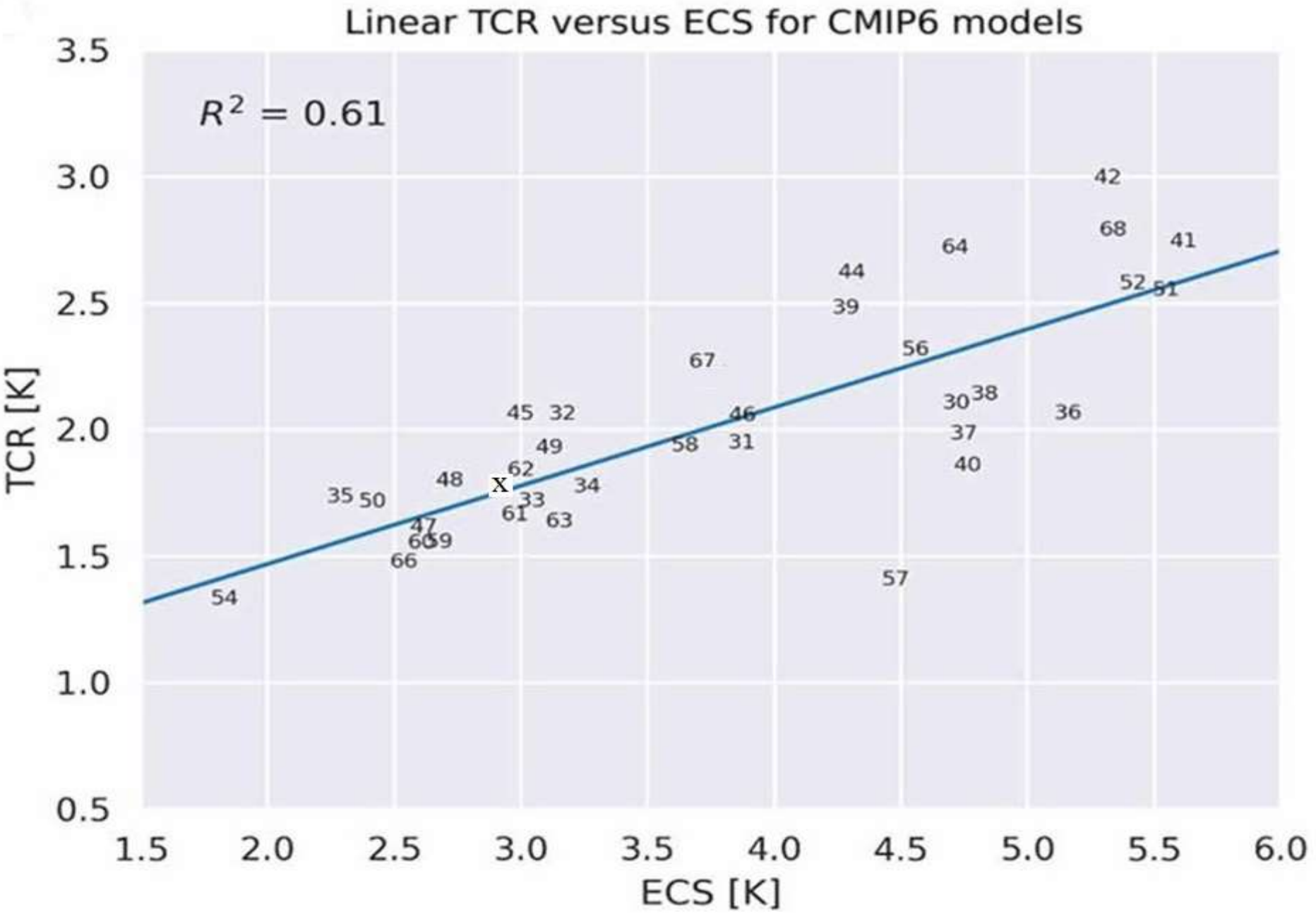
Simulation of natural variability and extreme indicies – Tarasevich M., poster

Simulation of climate response to injection and absorption of CO2 in FLAT-10 experiment. Kostrykin S.

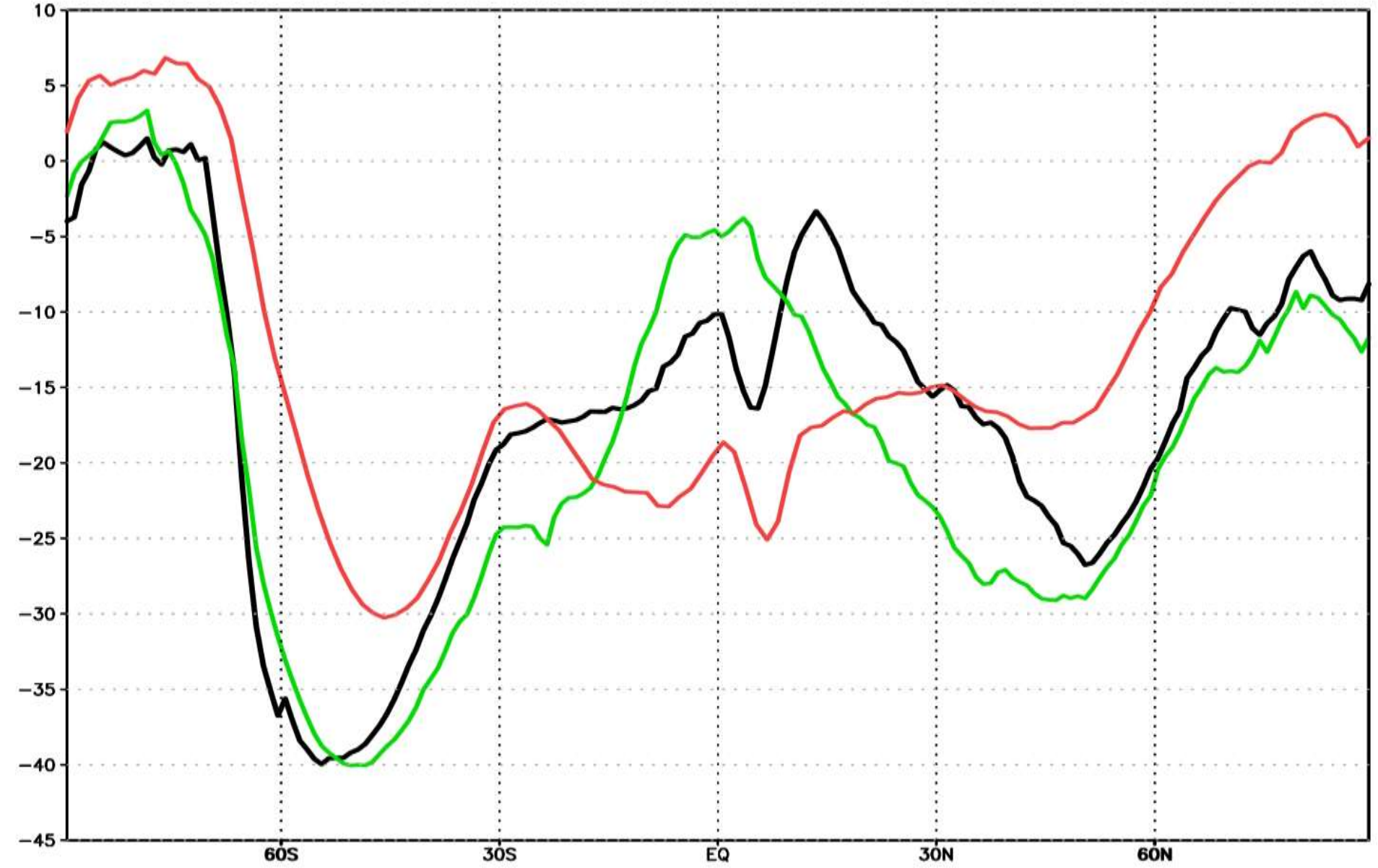
Climate decadal prediction. Gritsun A.

Equilibrium climate sensitivity (ECS), transient climate response (TCR), and effective radiation forcing ERF for doubling of CO_2

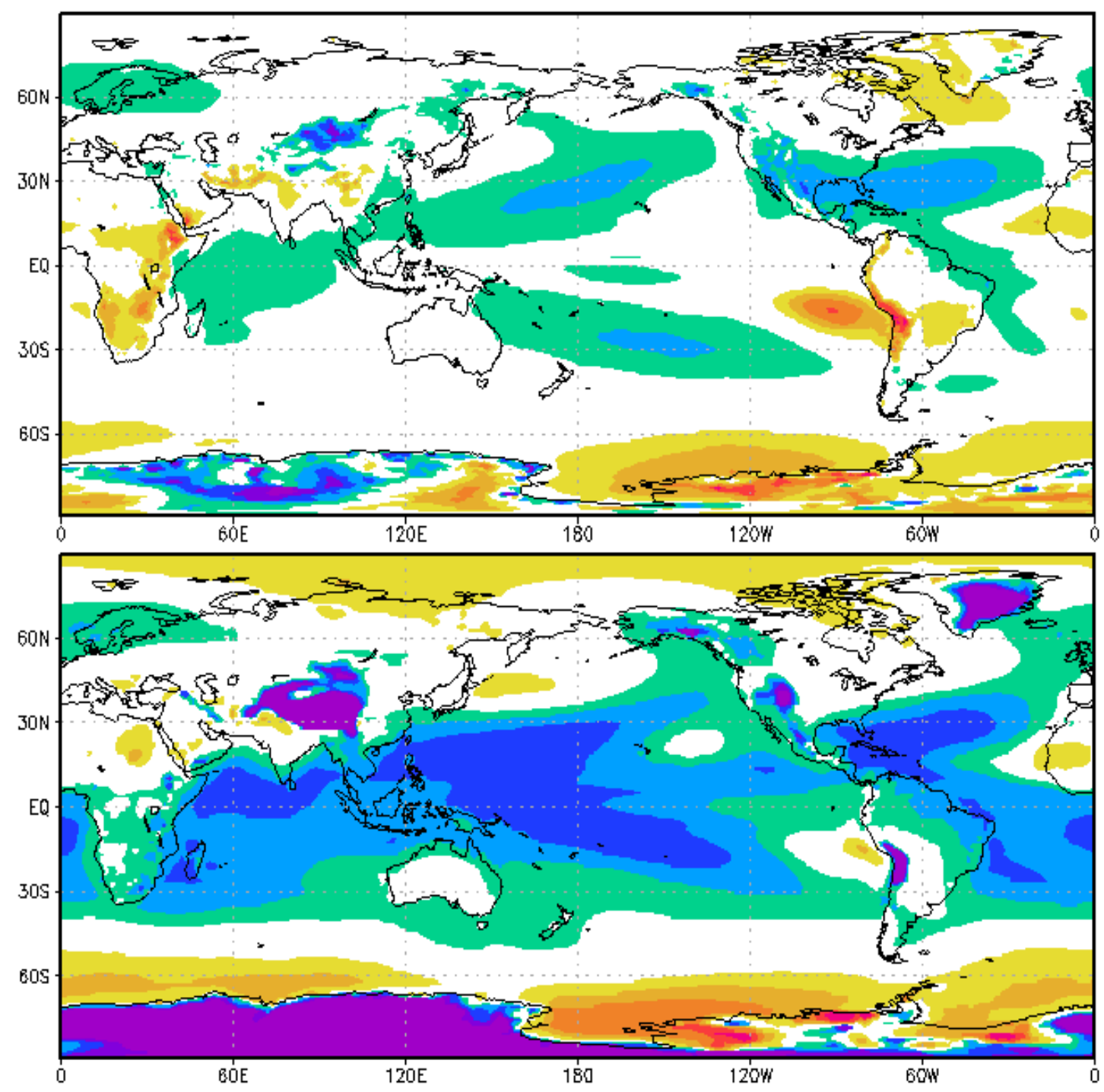
	INMCM48	ARTS-ESM-L	CMIP6
ECS, K	1.8	2.9	1.8-5.6 (3.7)
TCR, K	1.3	1.8	1.3-3.0 (2.0)
ERF, W/m2	2.7	3.2	2.7-4.2 (3.5)


Linear TCR versus ECS for CMIP6 models
$R^2 = 0.61$
TCR [K]
ECS [K]
3.5
3.0
2.5
2.0
1.5
1.0
0.5
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
42
68
41
64
44
52
51
39
56
67
45
32
46
30
38
36
49
58
31
37
62
40
48
34
35
50
33
61
63
47
66
57
54

Total (SW+LW) cloud radiation forcing (W/m2) at TOA in CERES-EBAF (black), INMCM5 (red) and ARTS-ESM-M (green)

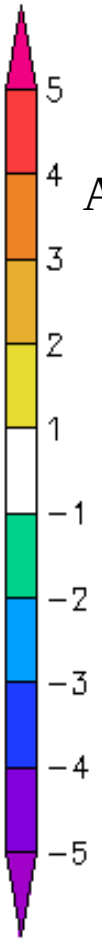


Model bias in T850, K

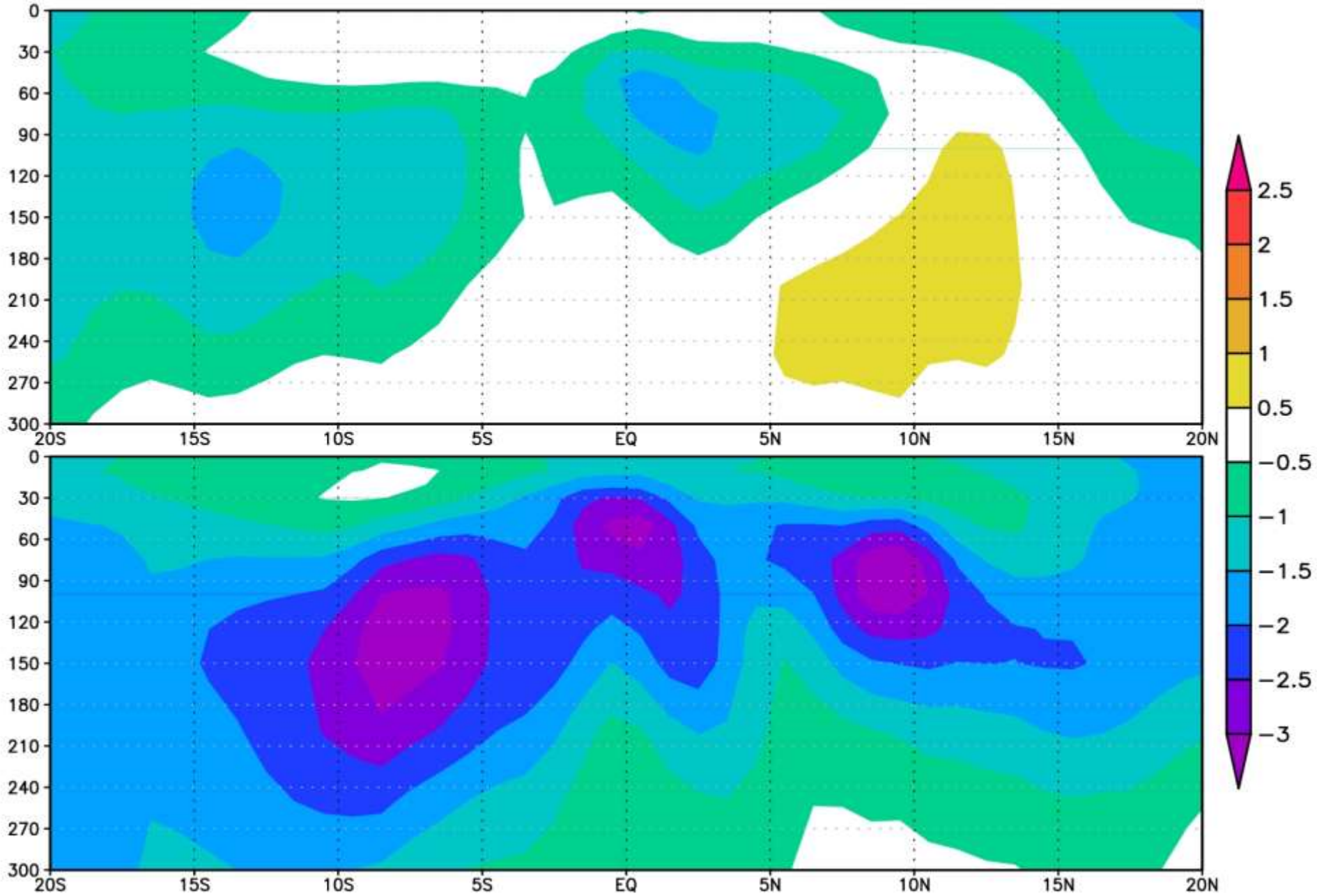


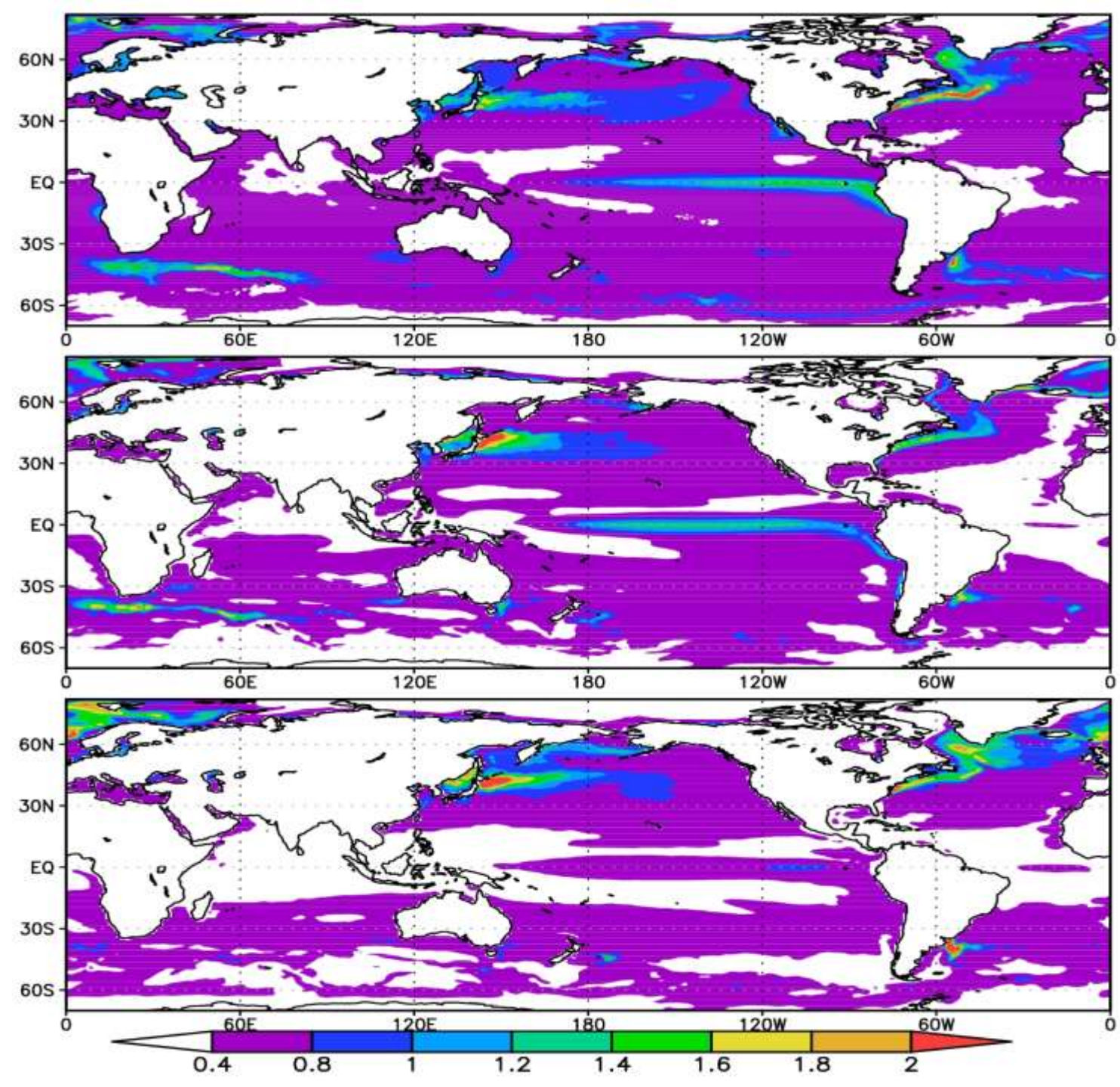
ARTS-ESM-M

INMCM5



Model temperature bias (K) in tropical ocean 300m layer for ARTS-ESM-M (top) and INMCM50 (bottom)



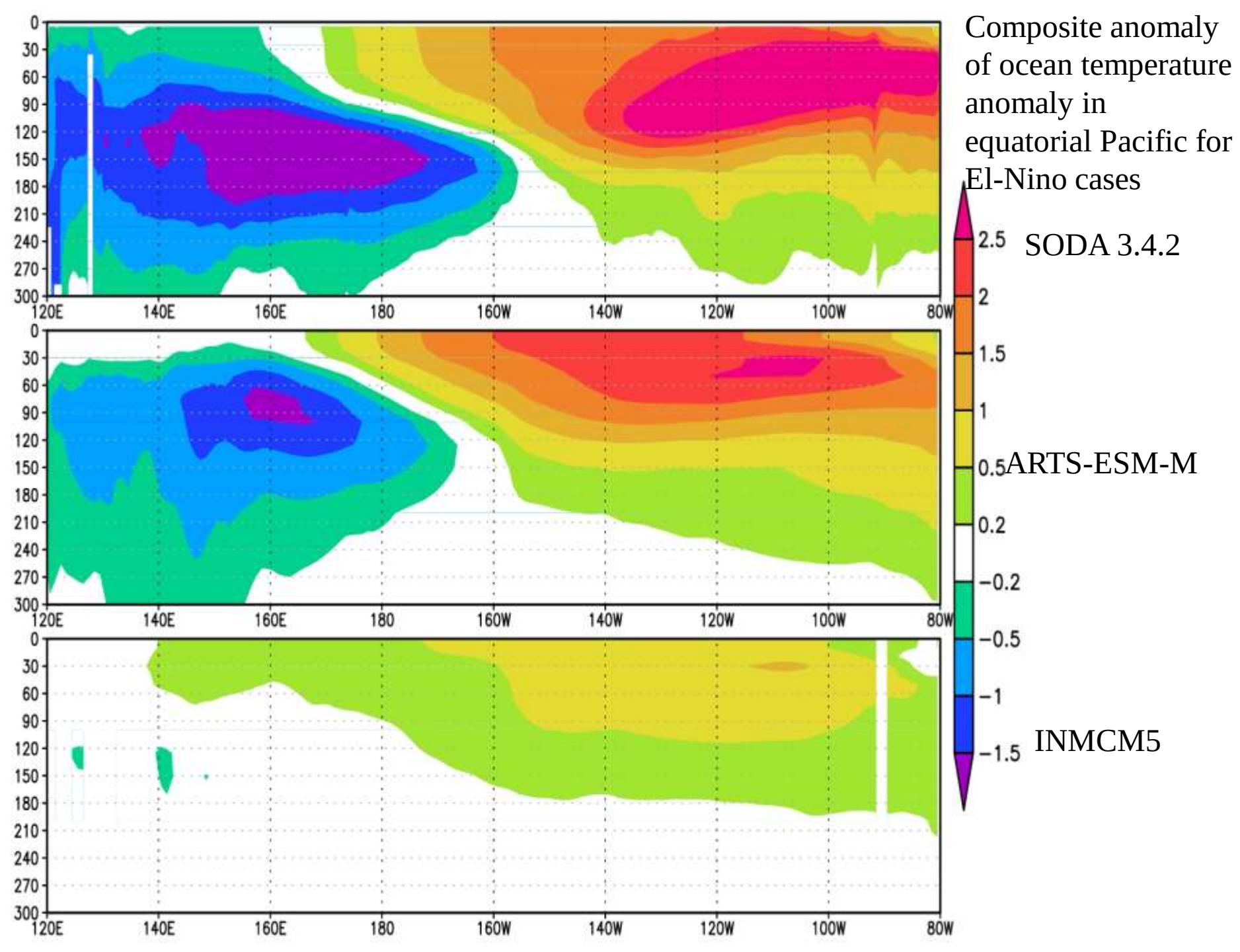


RMS of monthly mean SST (K)

ERA5

ARTS-ESM-M

INMCM5

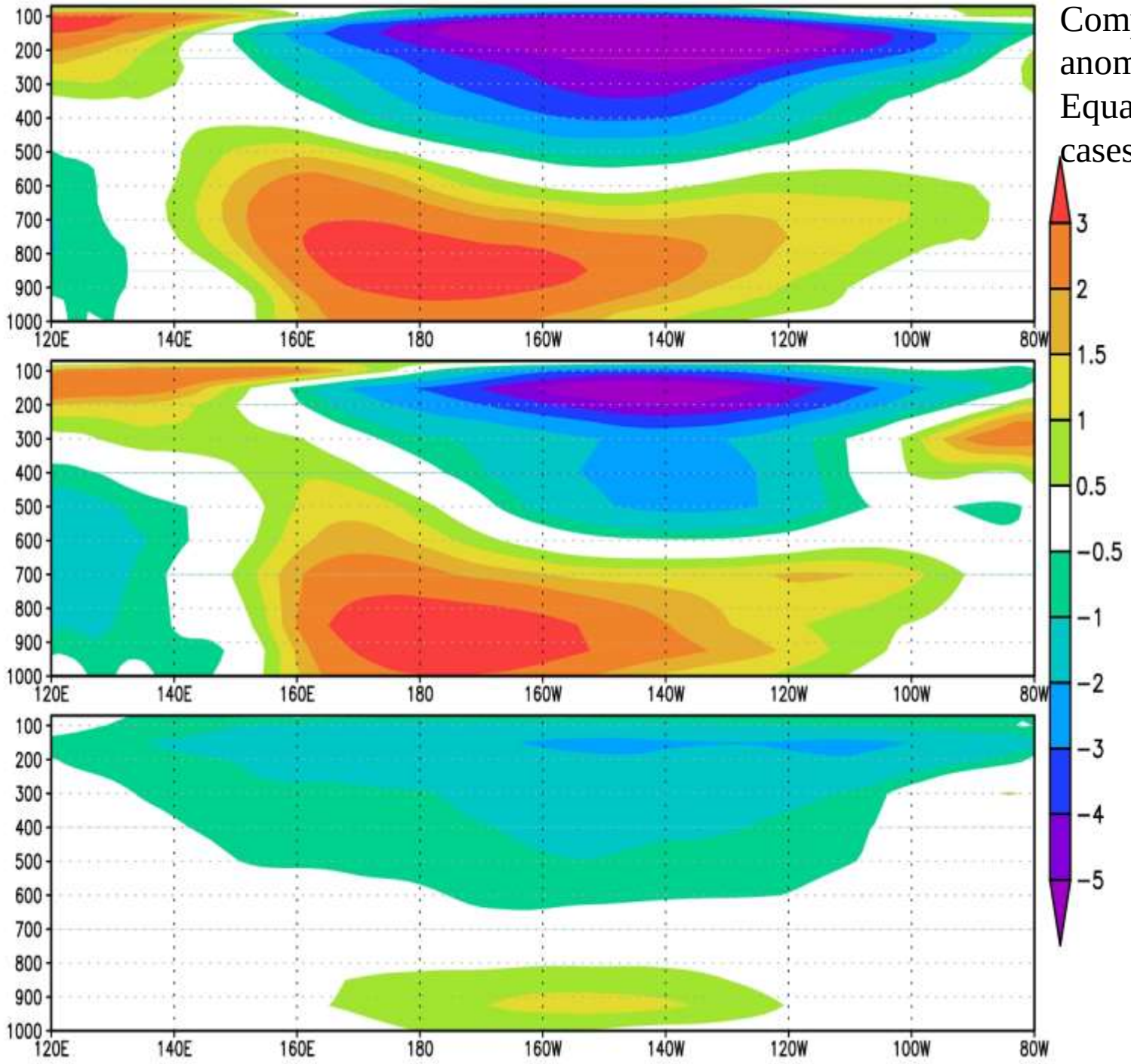


Composite anomaly of ocean temperature anomaly in equatorial Pacific for El-Nino cases

SODA 3.4.2

ARTS-ESM-M

INMCM5

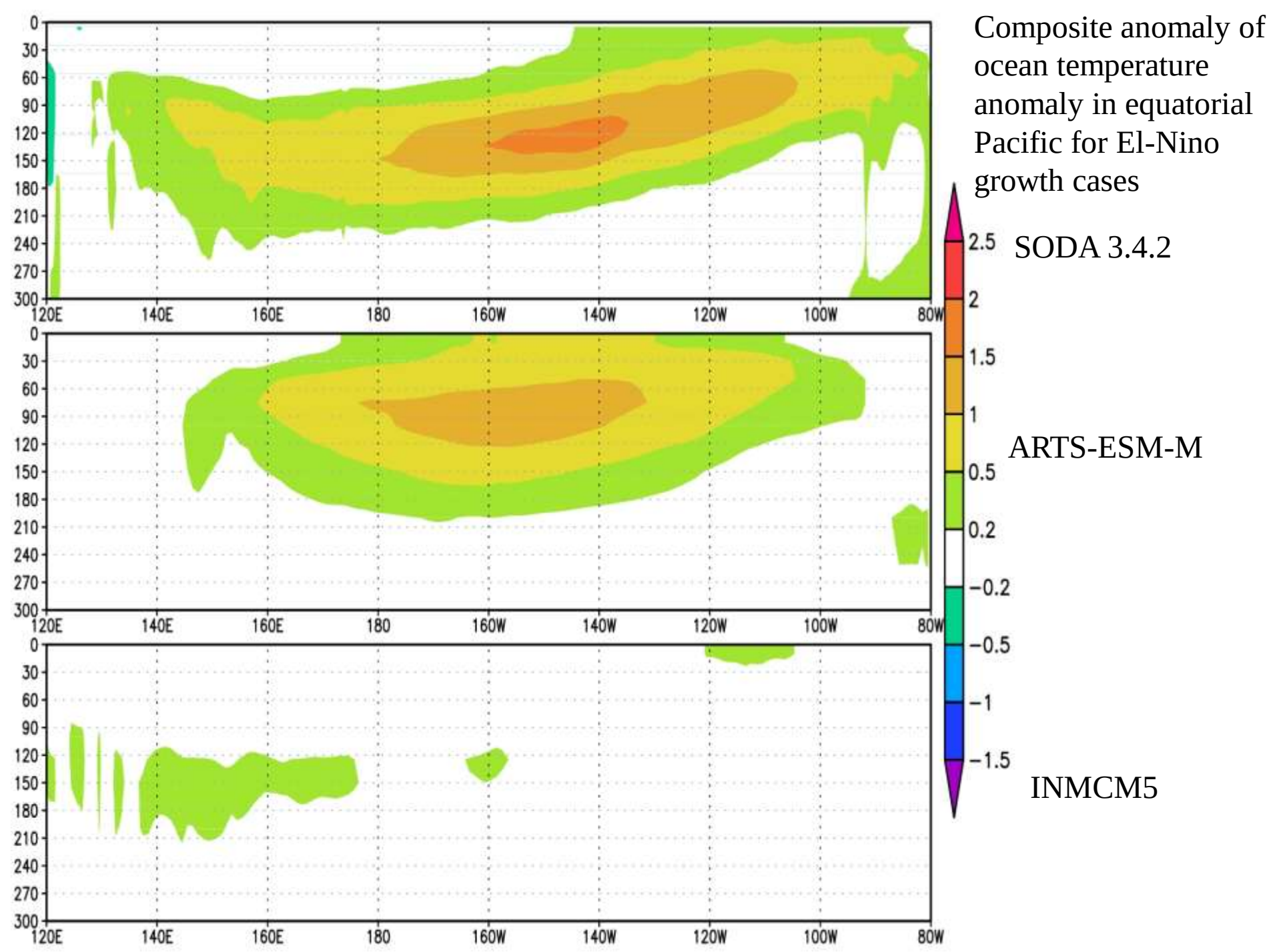


Composite of zonal wind anomaly at Pacific Equator for El-Nino cases

ERA5

ARTS-ESM-M

INMCM5

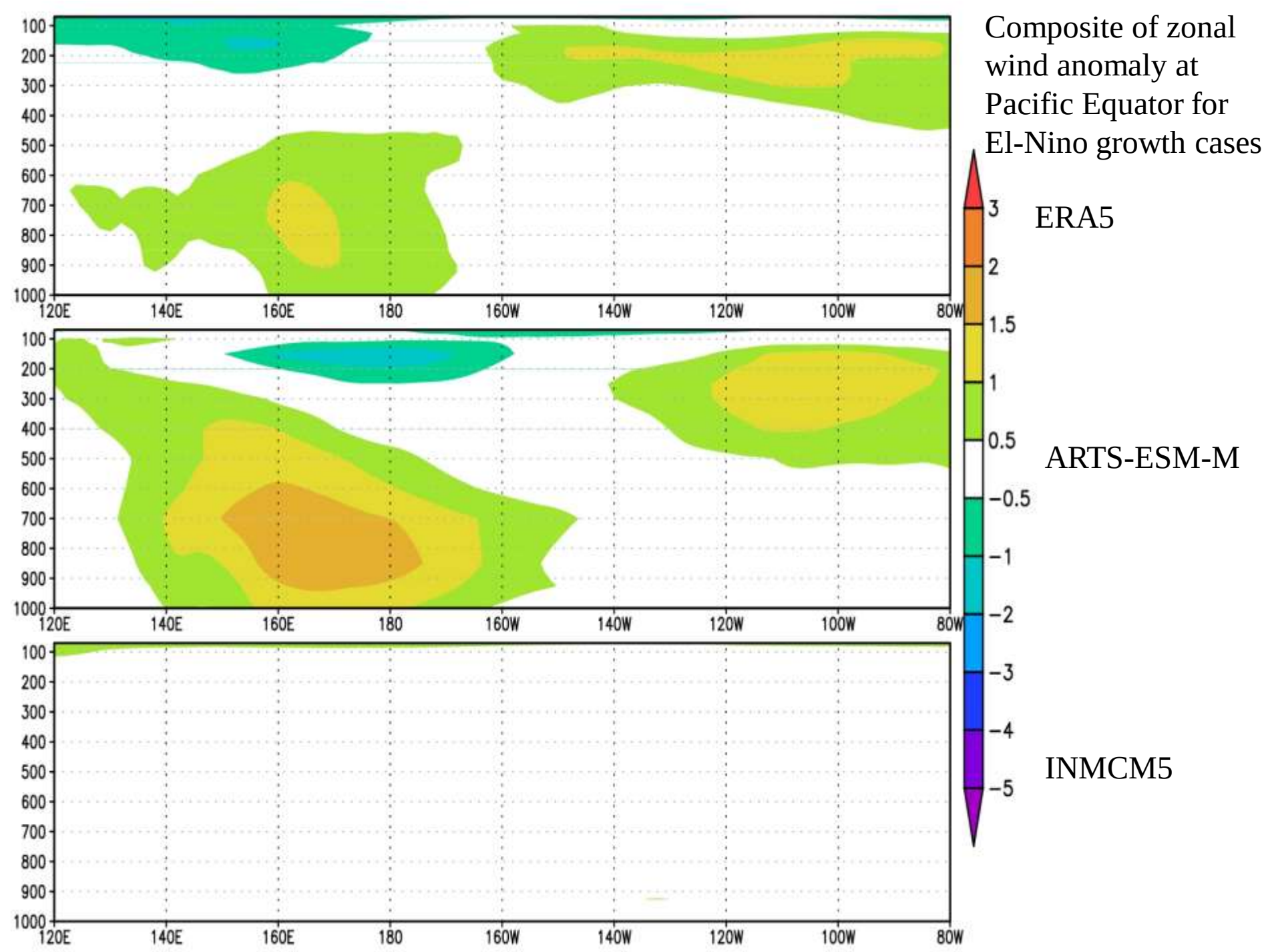


Composite anomaly of ocean temperature anomaly in equatorial Pacific for El-Nino growth cases

SODA 3.4.2

ARTS-ESM-M

INMCM5



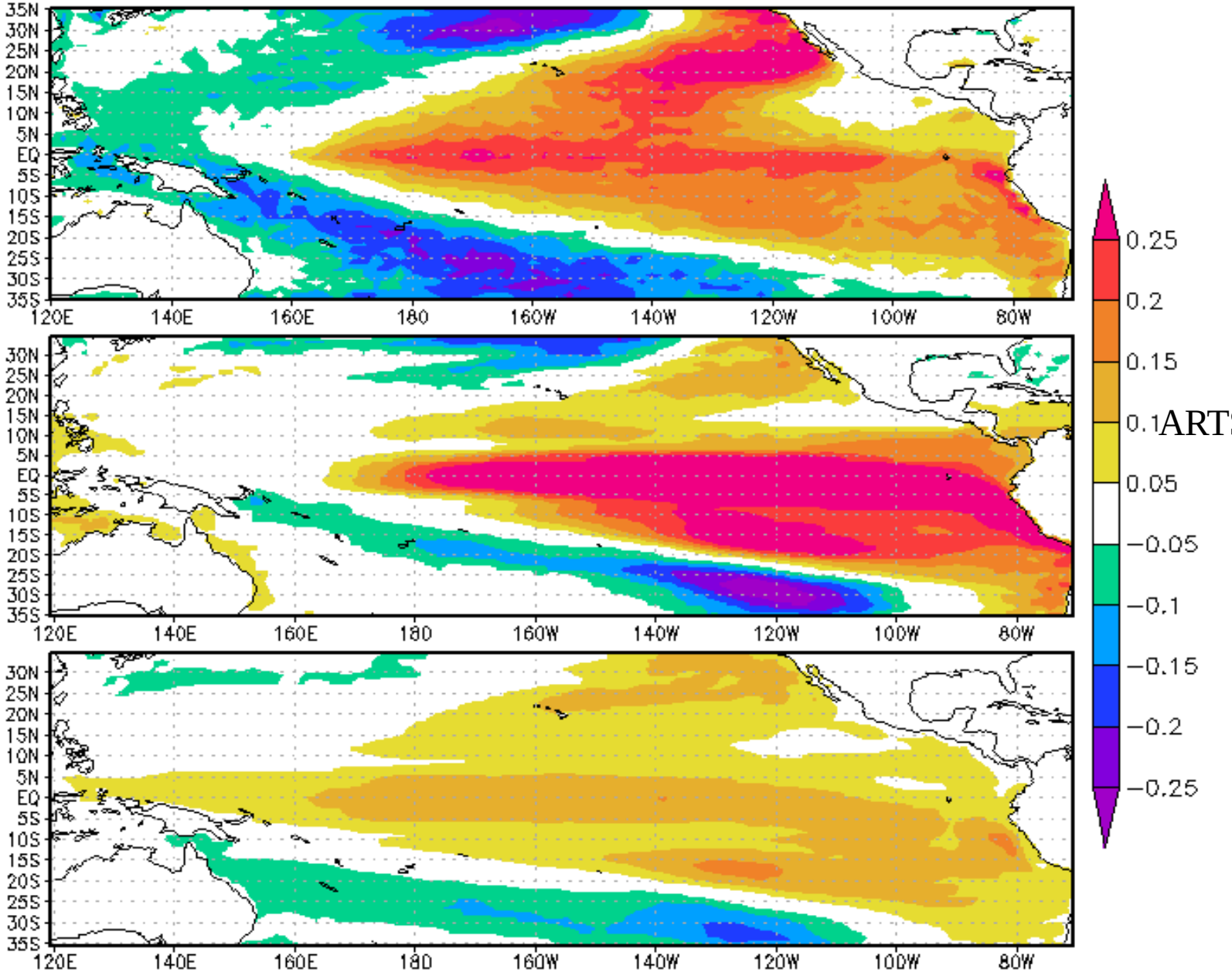
Composite of zonal wind anomaly at Pacific Equator for El-Nino growth cases

ERA5

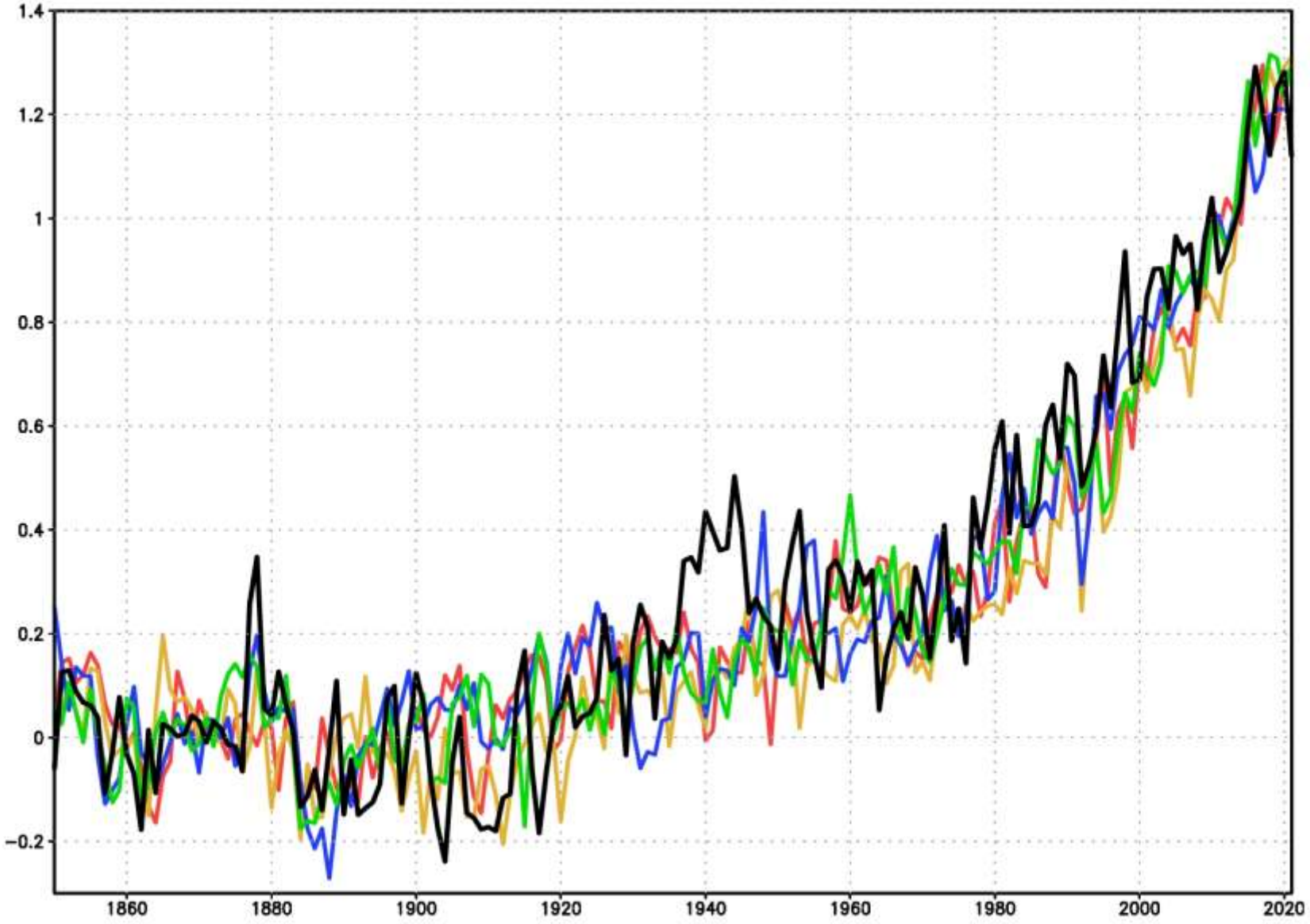
ARTS-ESM-M

INMCM5

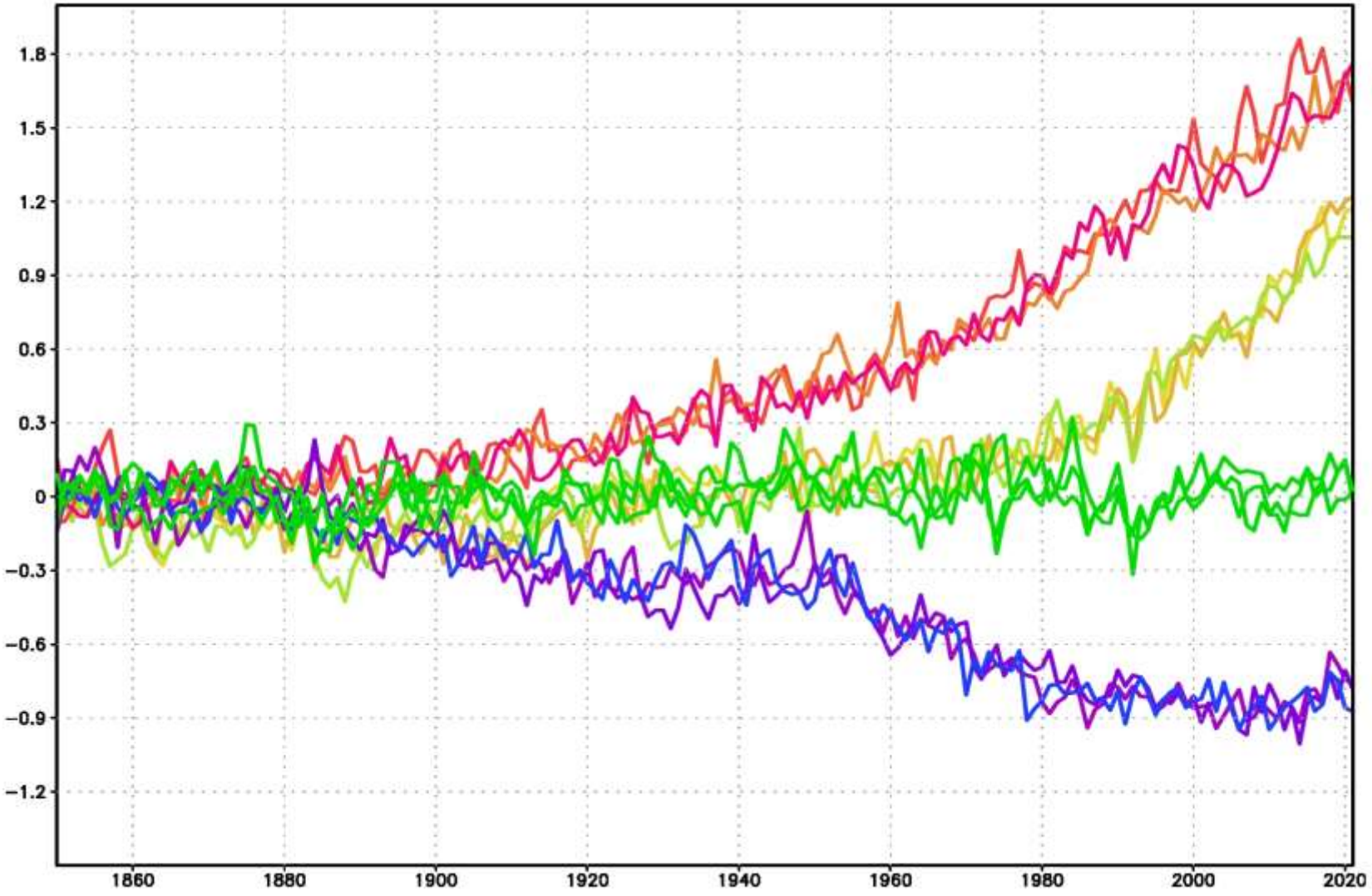
EOF-1 of 5 year mean SST in tropical Pacific (IPO pattern)



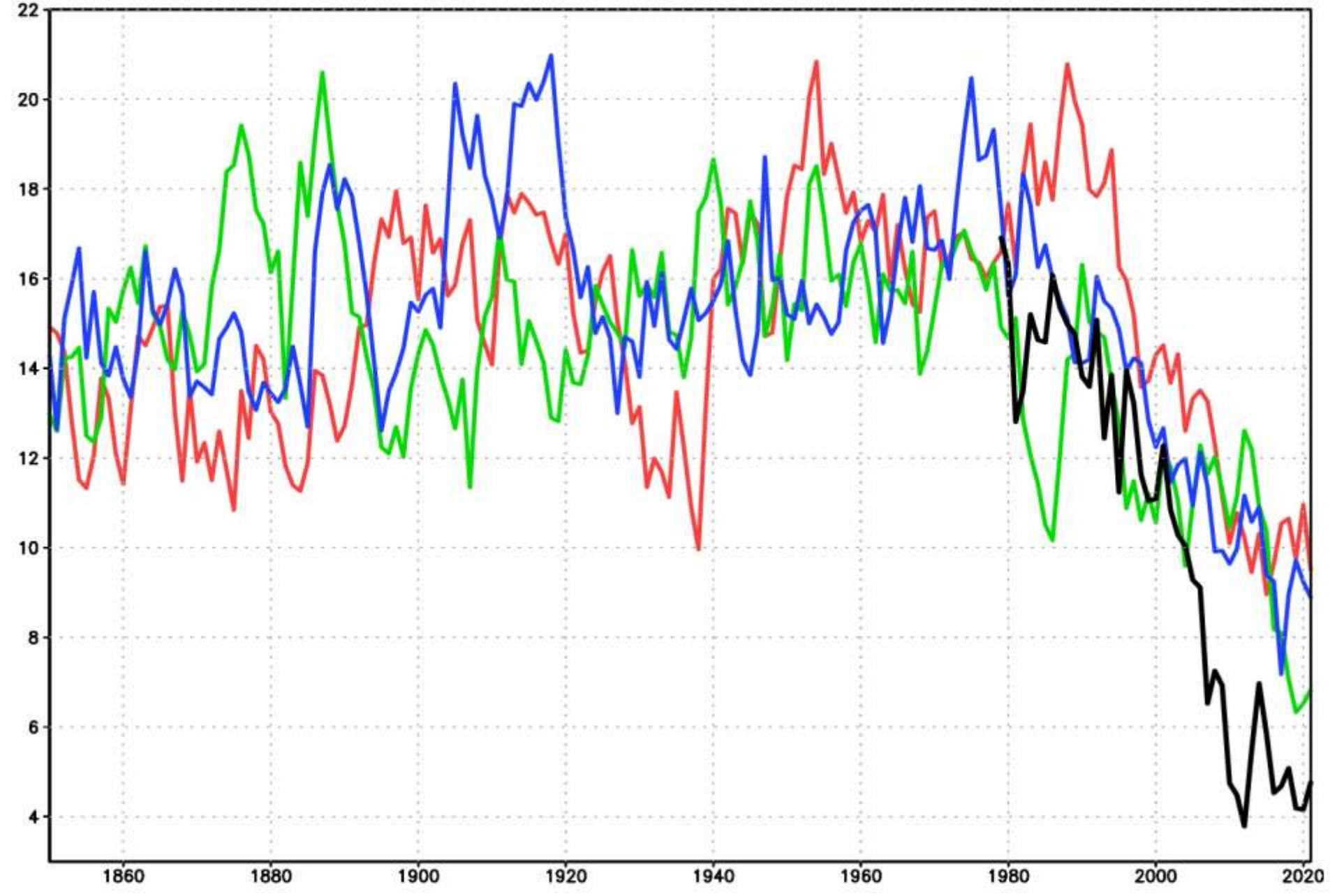
Global mean surface temperature (GMST) anomaly from 1850-1899 for HADCRUT5 (black) and historical runs with ARTS-ESM-L (colors)



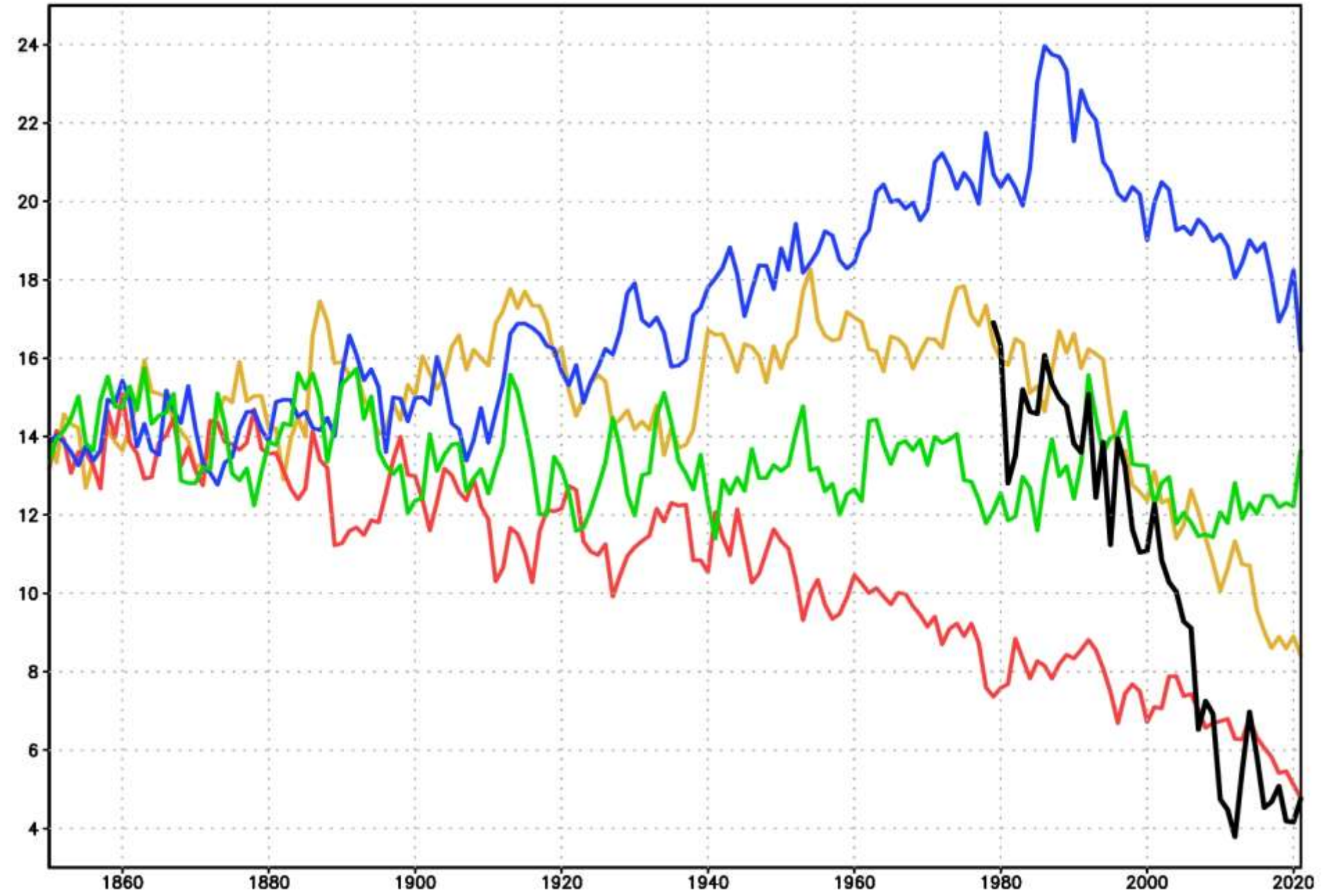
GMST anomaly in ensemble of model runs: hist (yellow), hist-ghg (red), hist-aer (blue) и hist-nat (green)



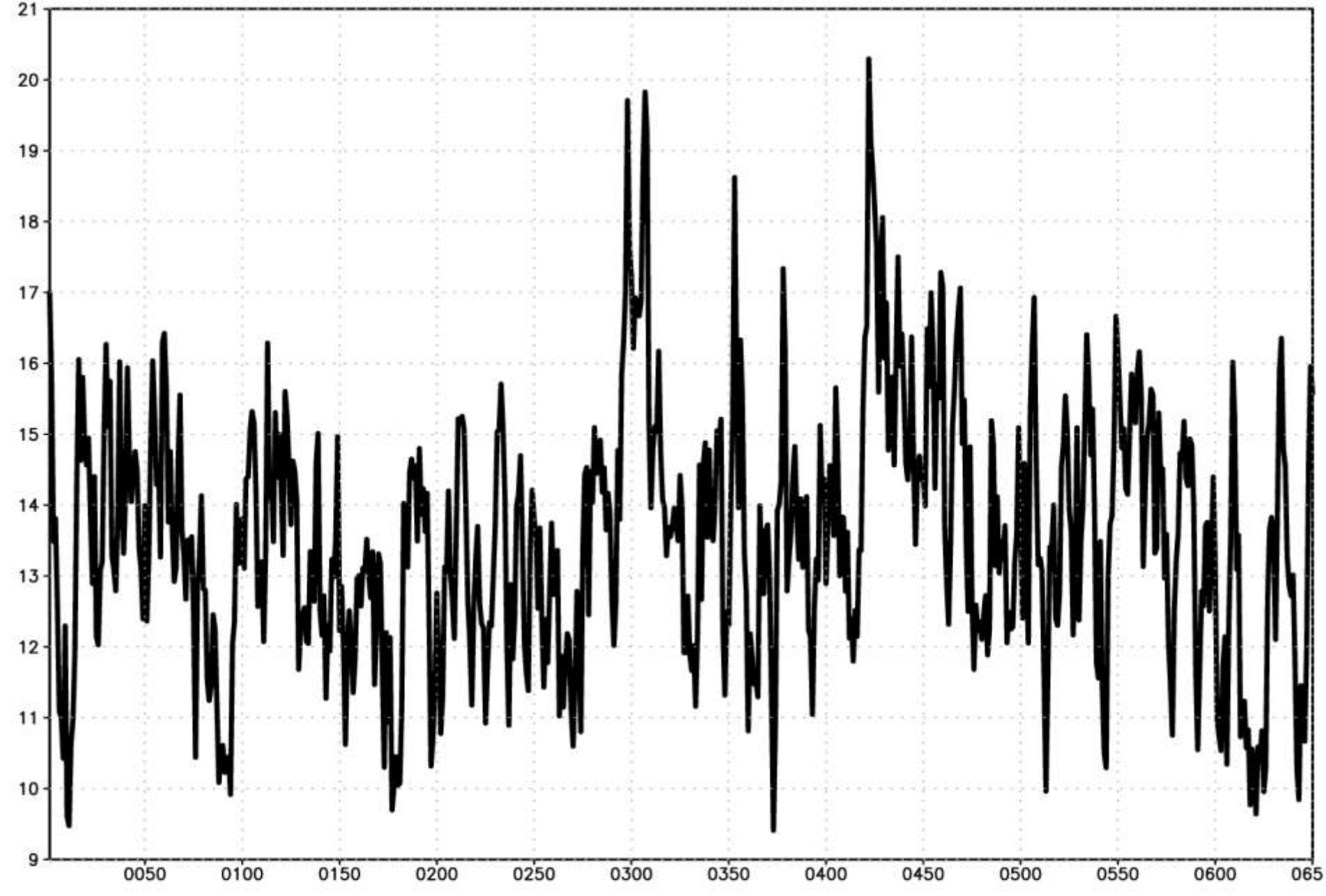
Arctic sea ice volume (10^3 km3) in September for PIOMAS (black), and historical model runs (colors)



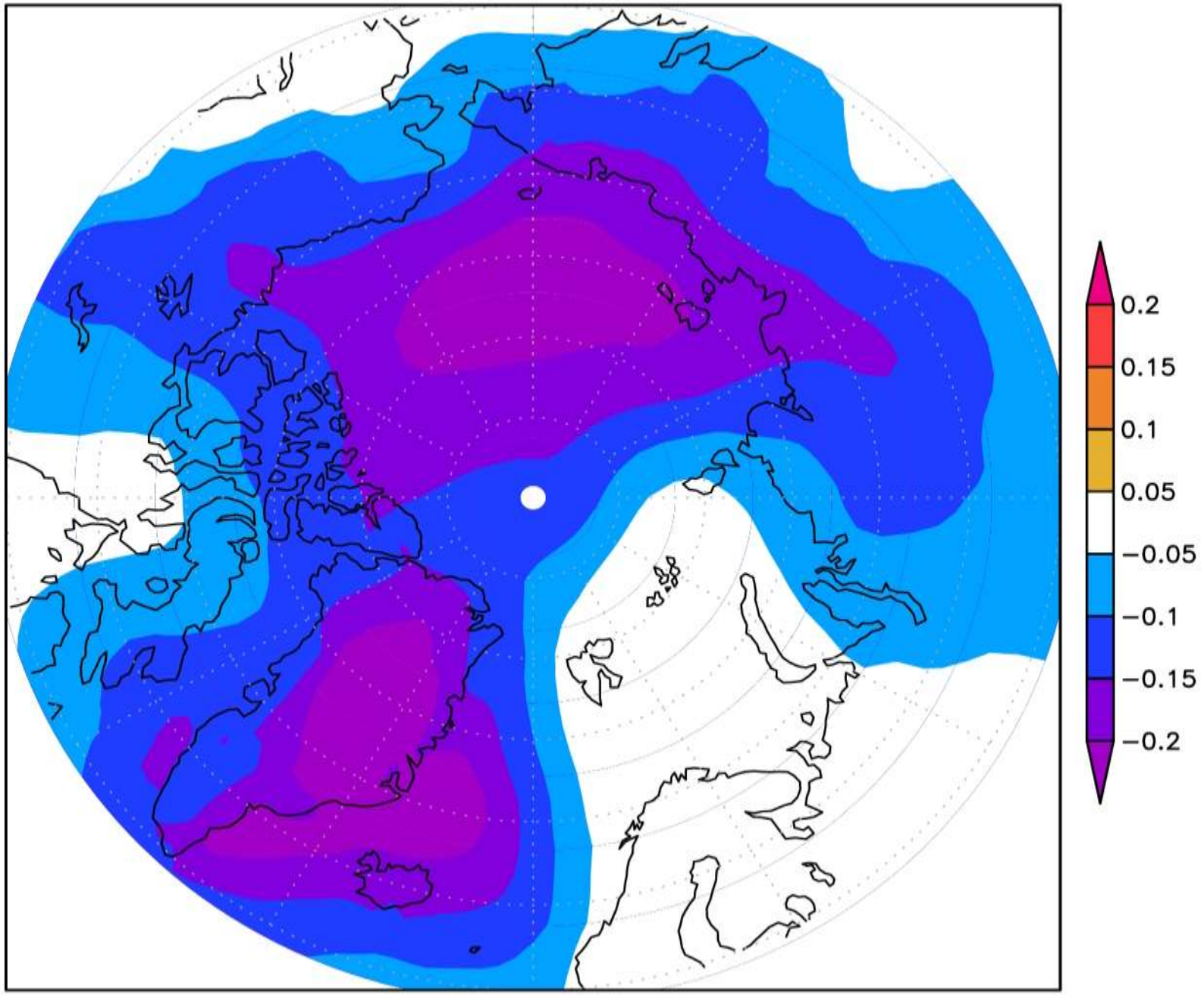
Arctic September sea ice volume in PIOMAS (black), mean over ensemble of historical runs (yellow), hist-ghg runs (red), hist-aer runs (blue) and hist-nat runs (green)



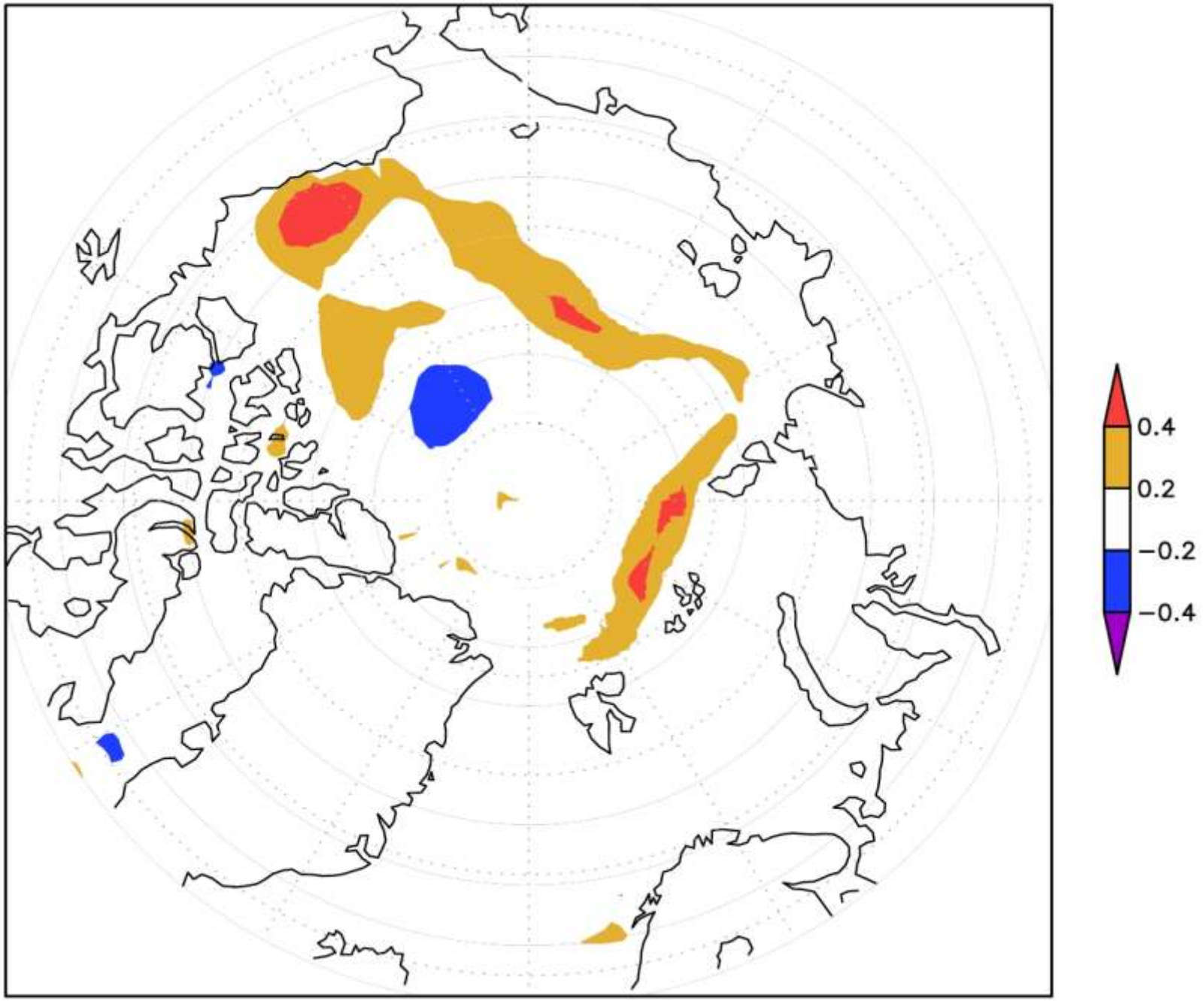
Arctic sea ice volume in September in 650 years of model preindustrial run



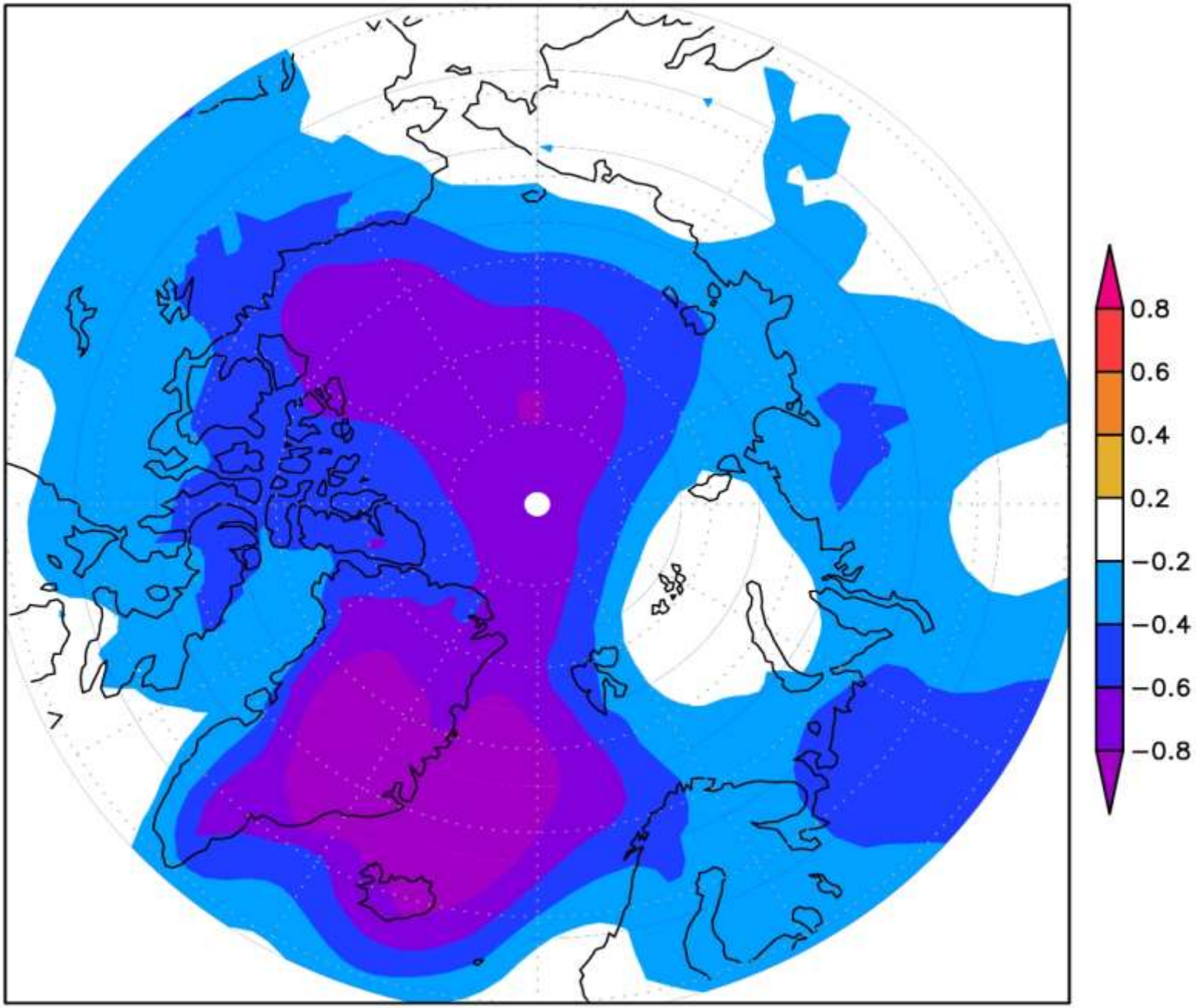
Composite model SLP anomaly for cases of decrease Arctic sea ice volume



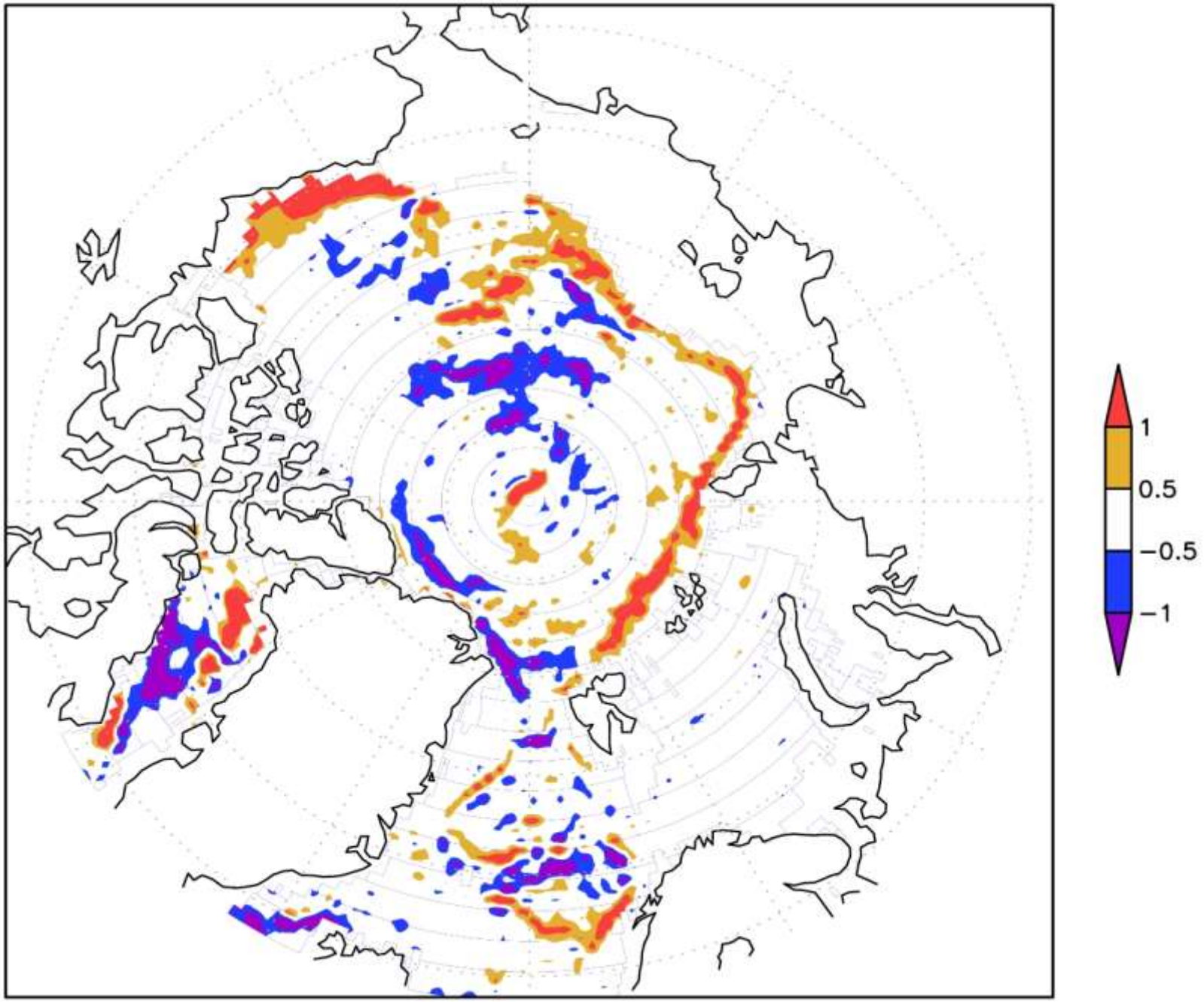
Model composite anomaly of zonal current at 100m for cases of Arctic sea ice volume decrease



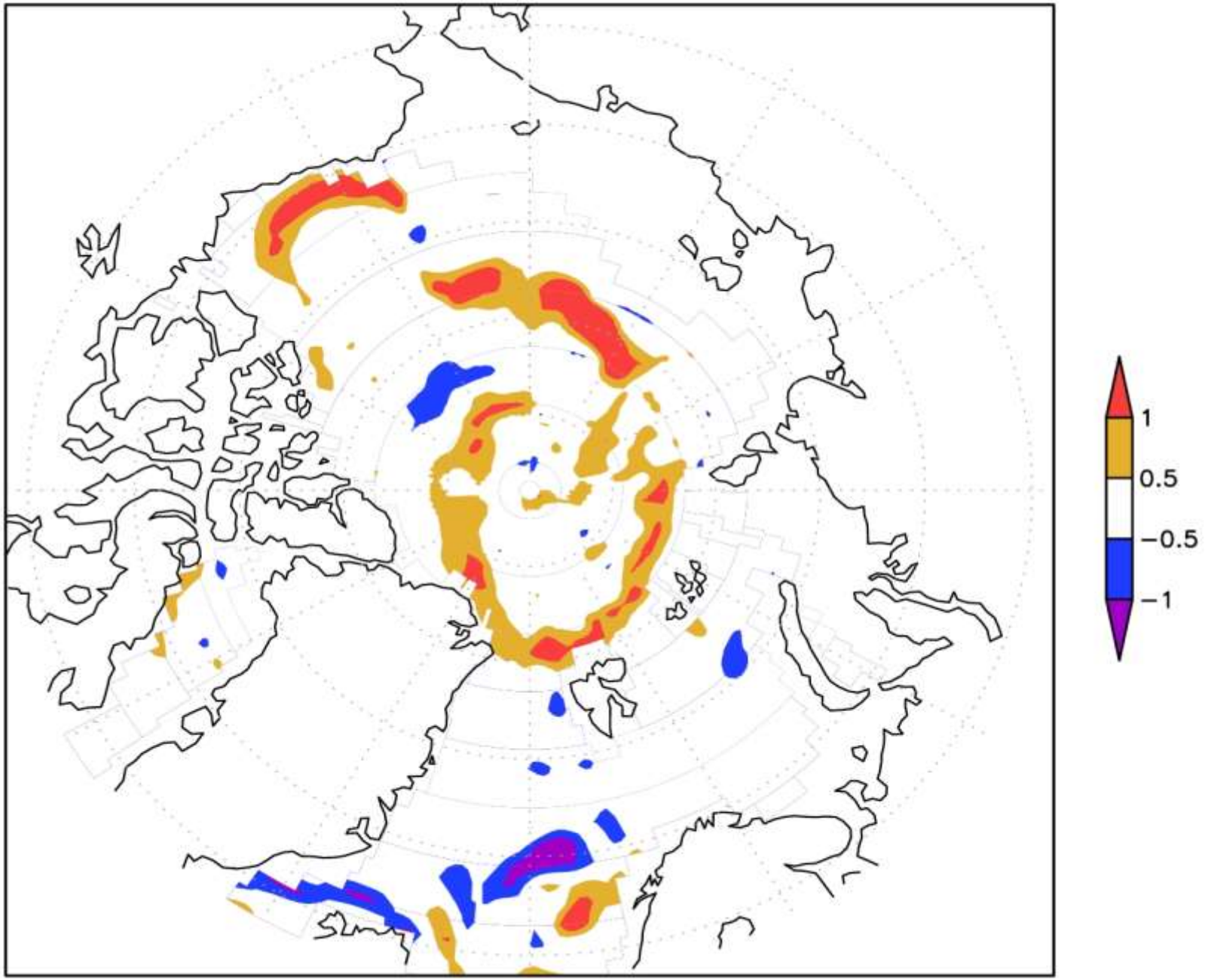
SLP anomaly in 1990-1999 with respect to 1980-2022 for ERA5



Anomaly of zonal current (cm) at 100m in 1990-1999 with respect to 1980-2019 in SODA 3.4.2



Anomaly of zonal current at 100m in 1990-1999 with respect to 1978-2007 in CORE2 run



Conclusions

Two climate model versions are developed for participation in CMIP7

The model is a powerful tool for simulation, studying and prediction of climate and climate changes