The AMOC in CMIP5 Models: RCP and Historical Simulations

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discussions with Gokhan Danabasoglu, Steve Yeager, Mingfang Ting

CLIVAR Climate Model Evaluation Project (CMEP2011), funding from NOAA Climate Program Office

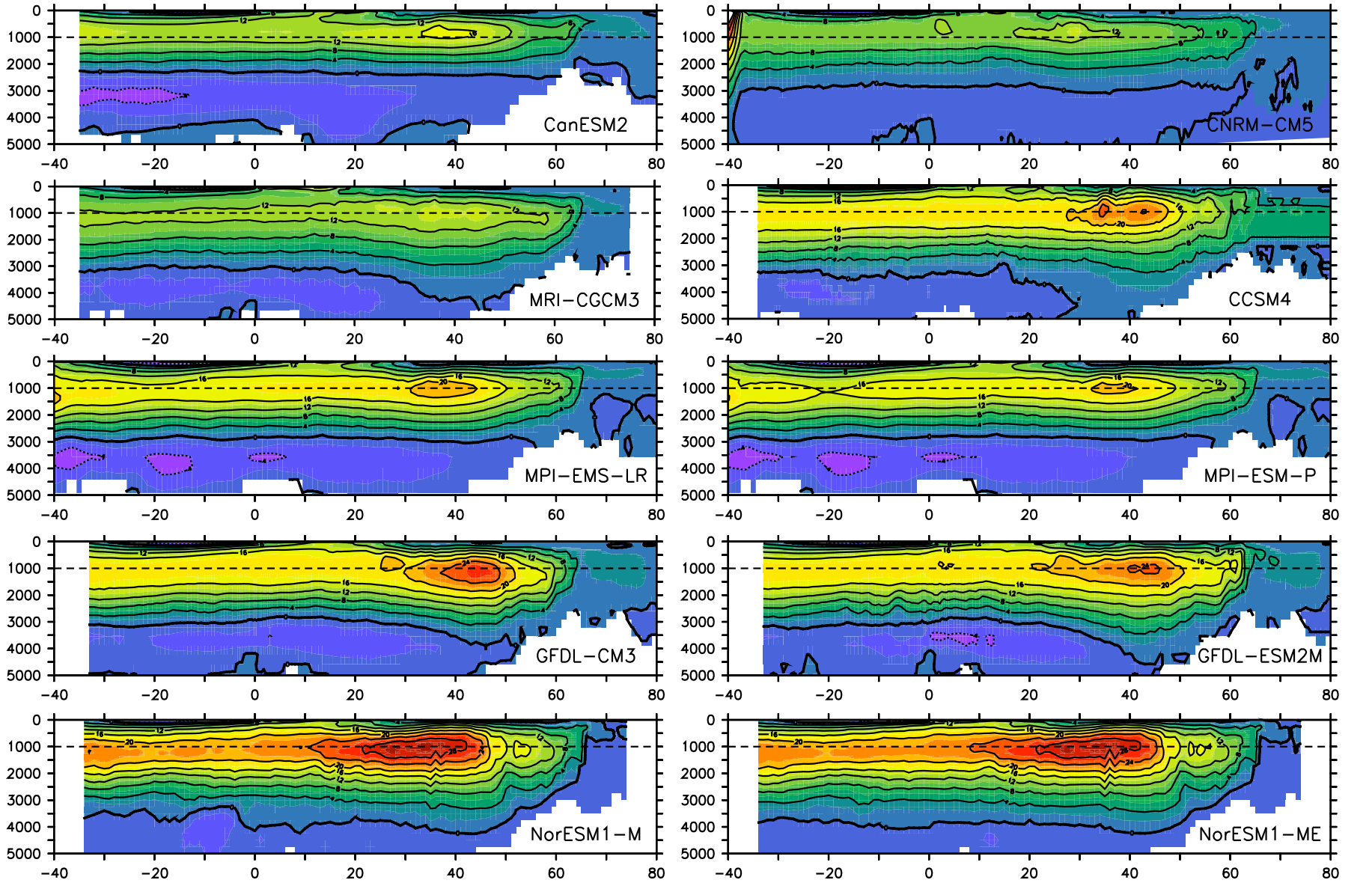
Purpose: to examine the AMOC across CMIP5 models, investigating common model behavior and inter-model spread

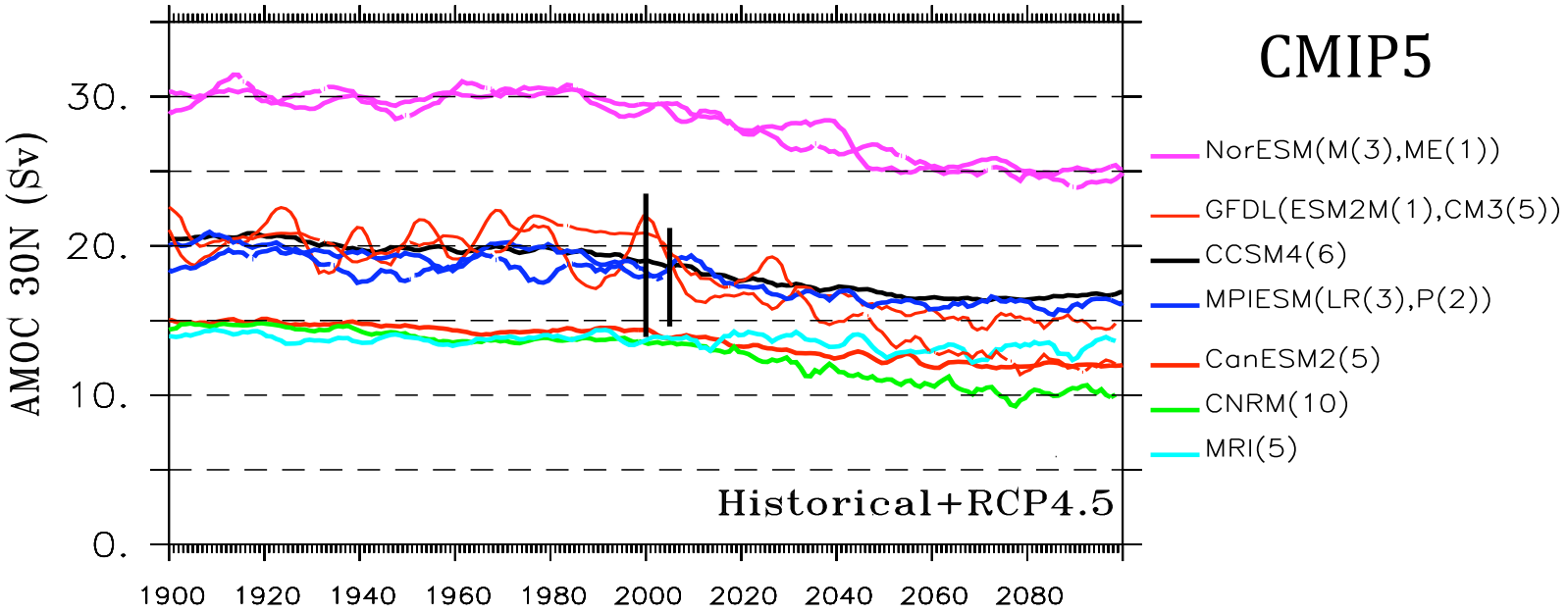
Data Source: basin overturning stream functions submitted to the PCMDI data sever, including ten models from seven modeling centers. 41 ensemble runs in "historical" time (1850-2005), RCP4.5 and RCP8.5 forcing runs for the future, and other variables

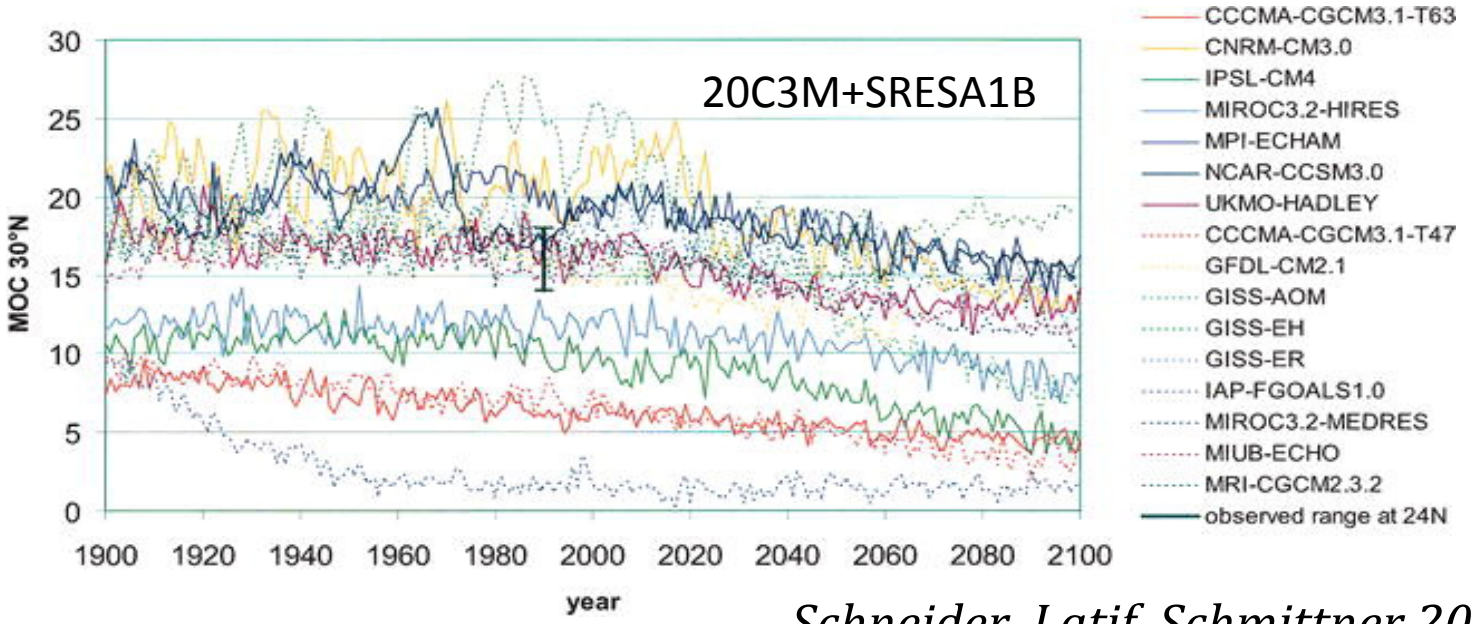
Outline

1. CMIP5 AMOCs in historical runs and changes in the future, compare with obs. and CMIP3 runs
2. multi-model ensemble mean AMOC in "historical" runs: multi-decadal variability and mechanisms
3. summary and remaining questions

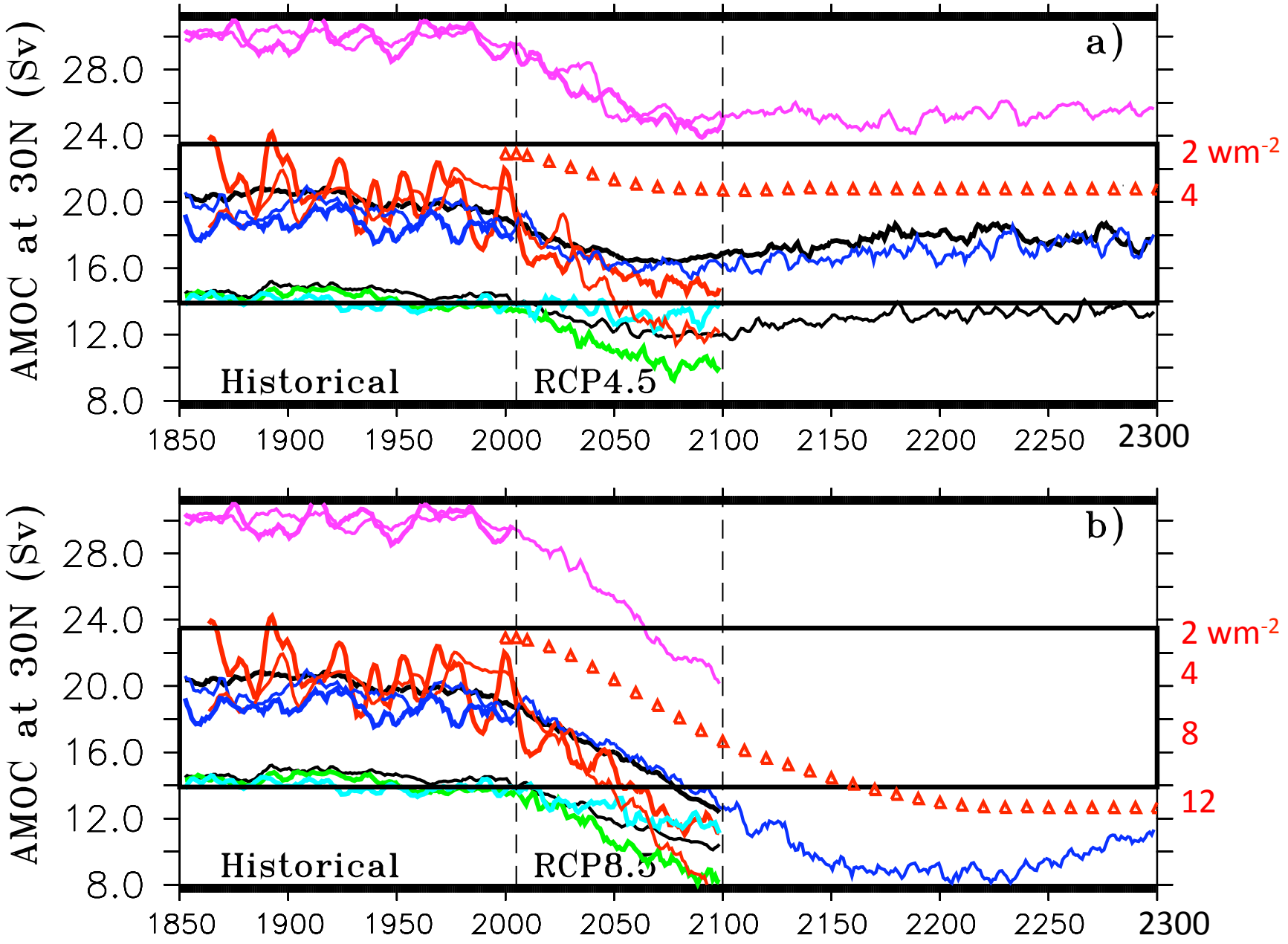
historical mean spatial structures

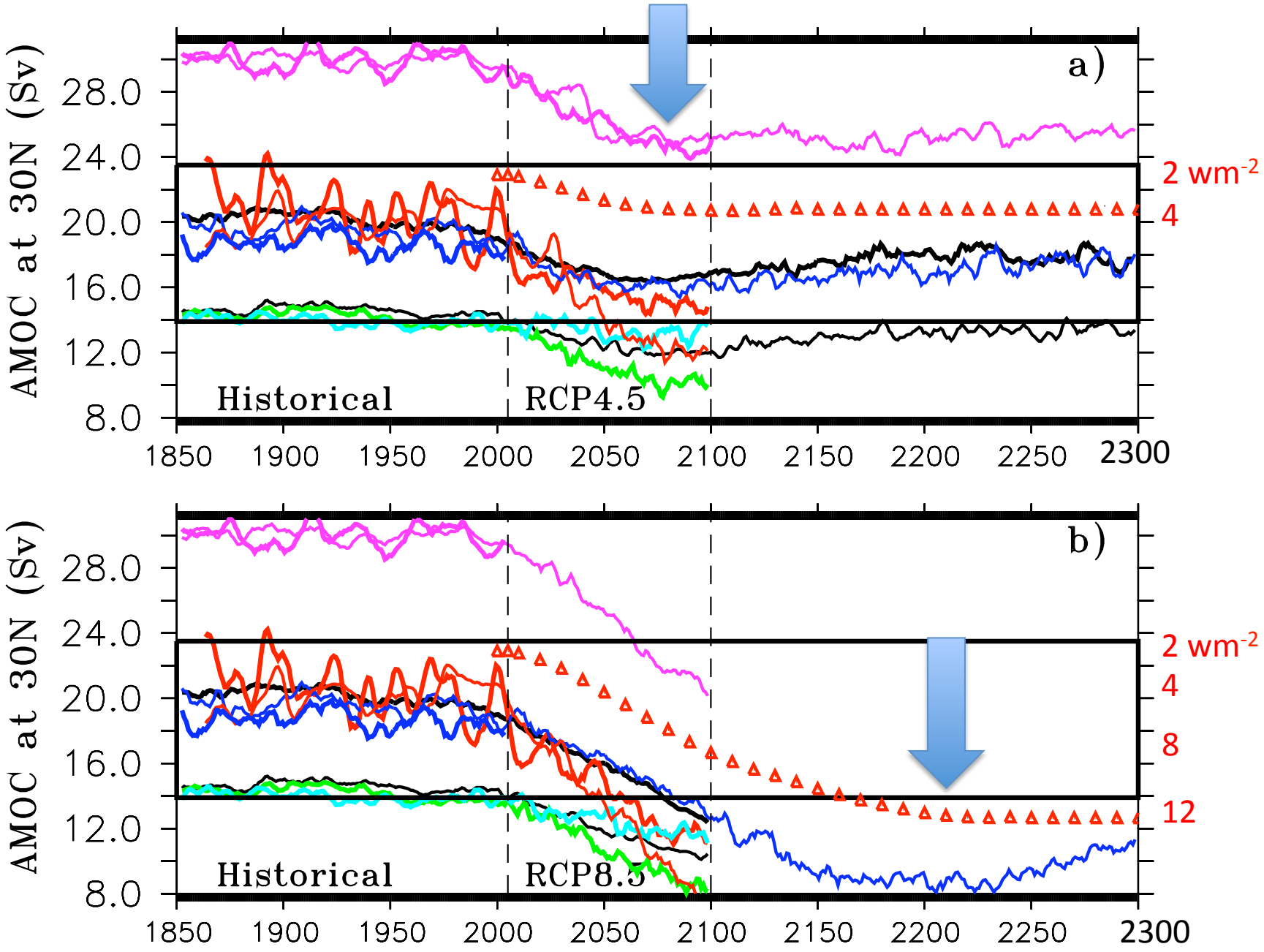


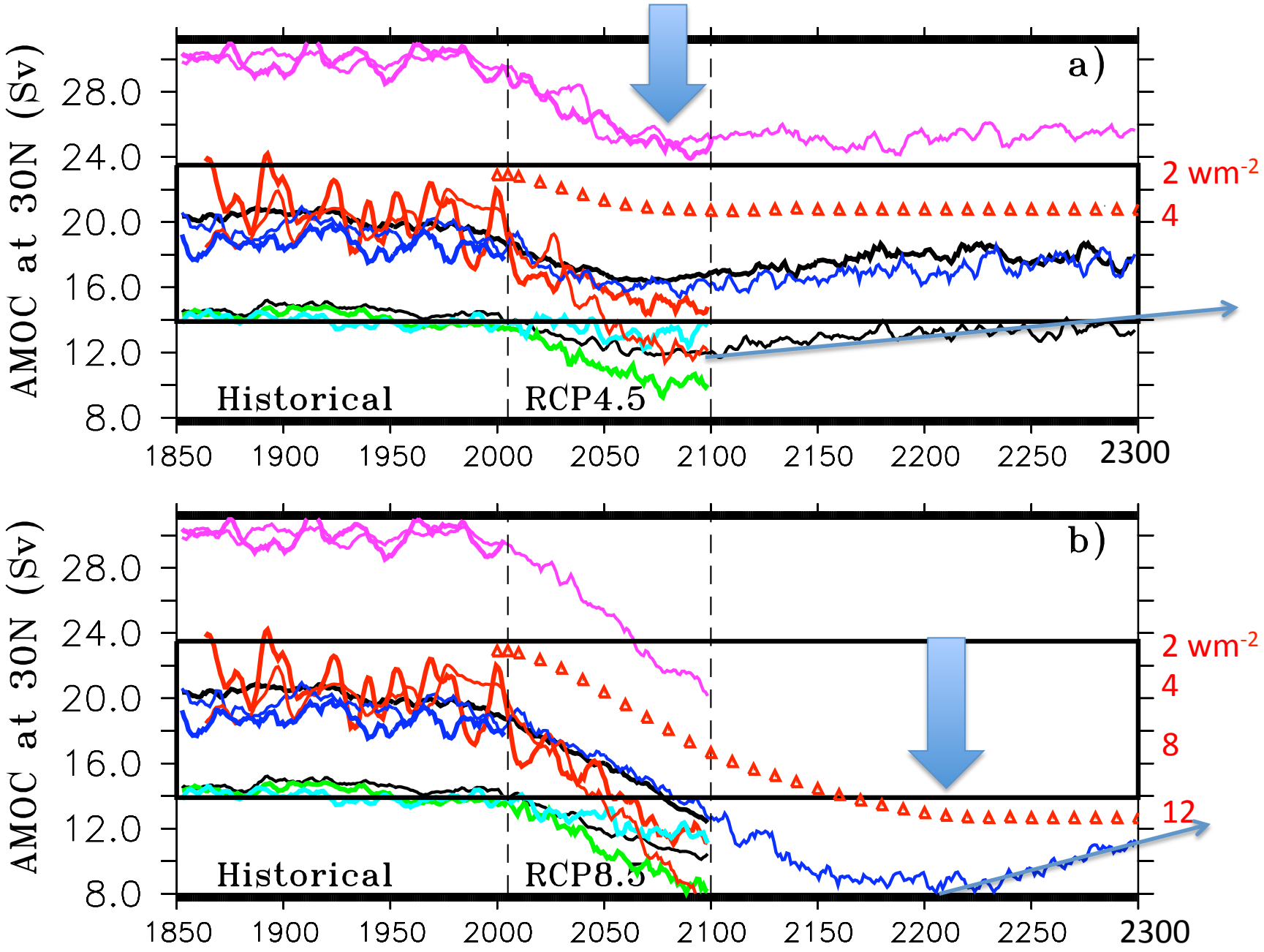




Schneider, Latif, Schmittner 2007


a)
b)
AMOC at 30N (Sv)
28.0
24.0
20.0
16.0
12.0
8.0
1850
1900
1950
2000
2050
2100
2150
2200
2250
2300
Historical
RCP4.5
RCP8.5
2 wm-2
4
8
12


a)
b)
AMOC at 30N (Sv)
28.0
24.0
20.0
16.0
12.0
8.0
1850
1900
1950
2000
2050
2100
2150
2200
2250
2300
Historical
RCP4.5
RCP8.5
2 wm-2
4
8
12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1850
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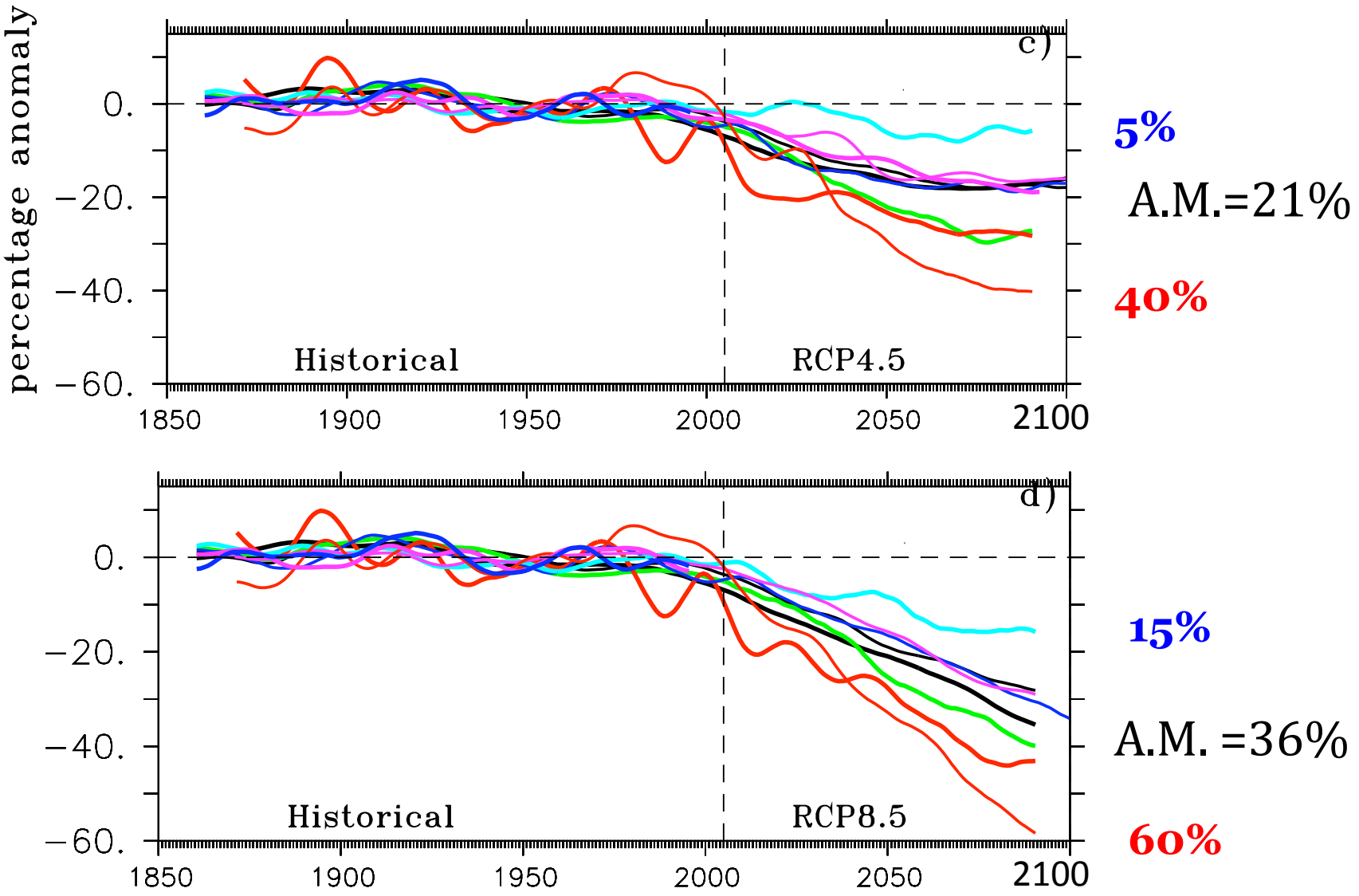
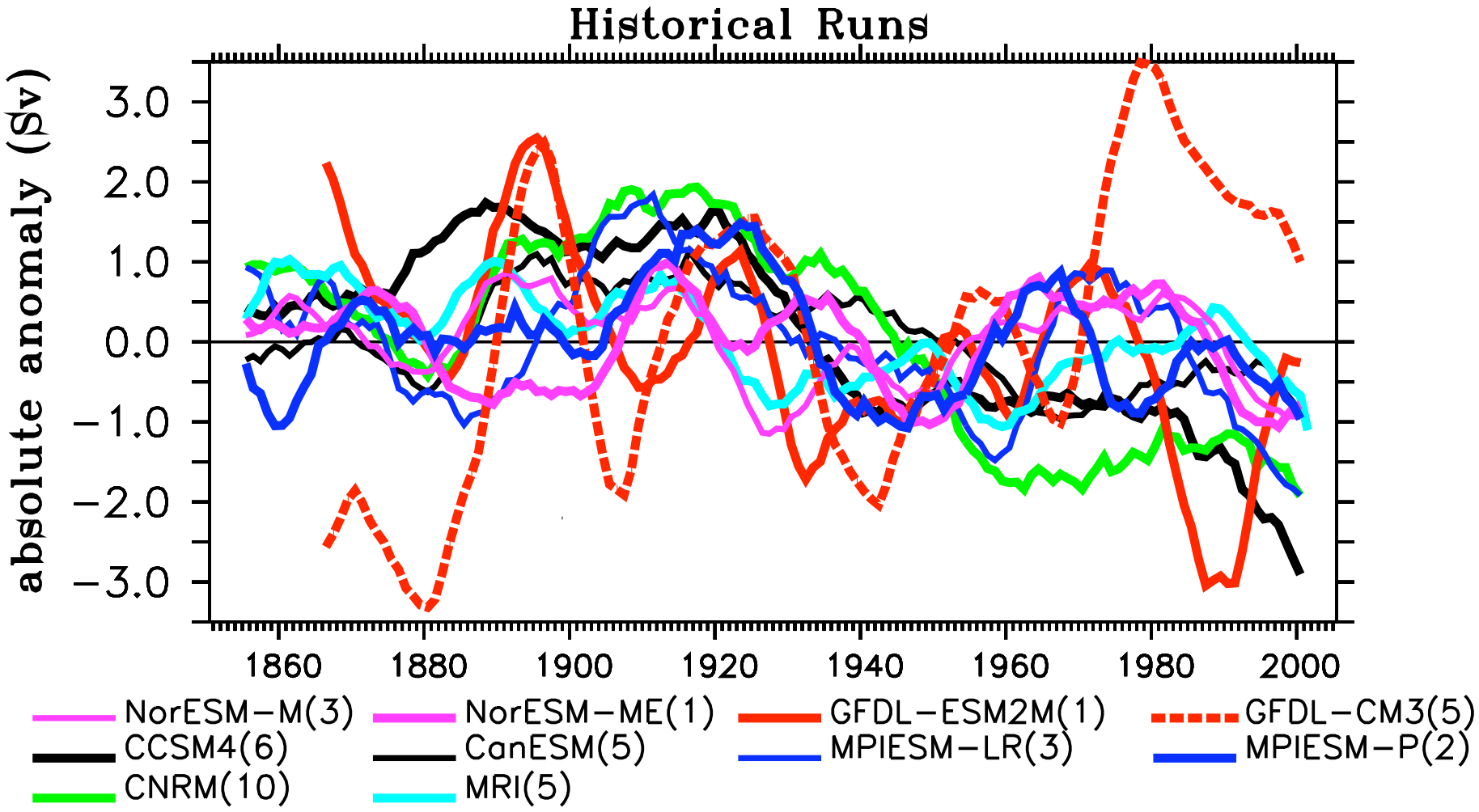
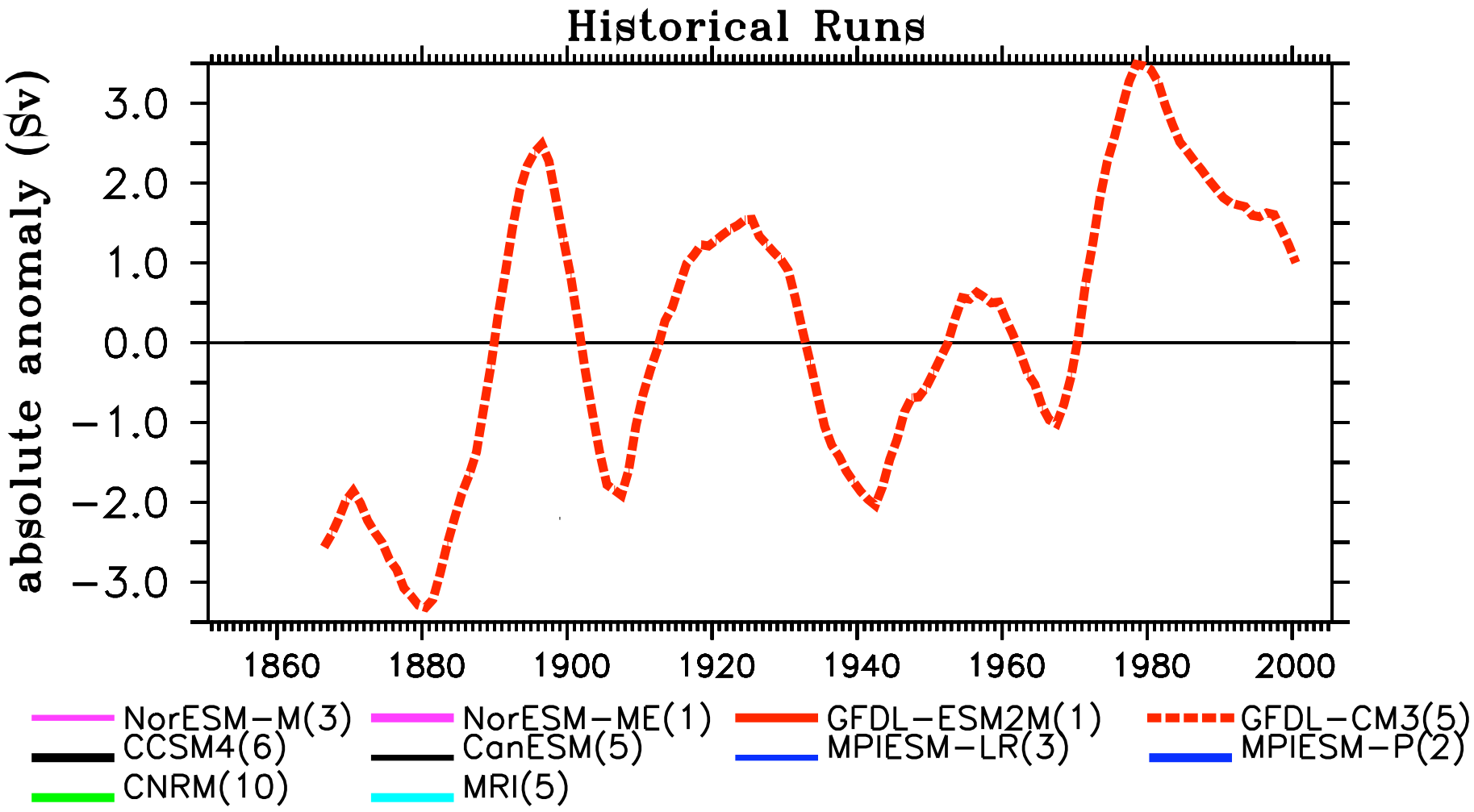


CMIP3 A1B "best estimate": 25-30%,
Schmittner et al. 2005; Schneider et al. 2007

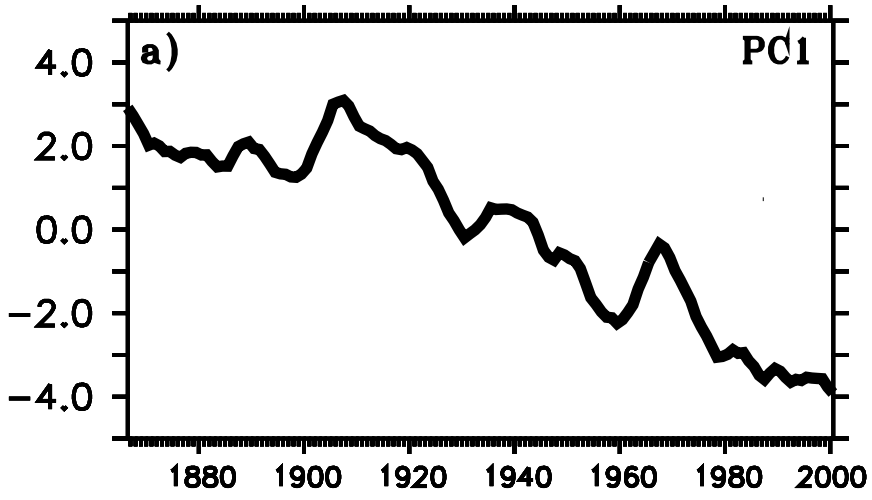
anomalies relative to “historical” mean state

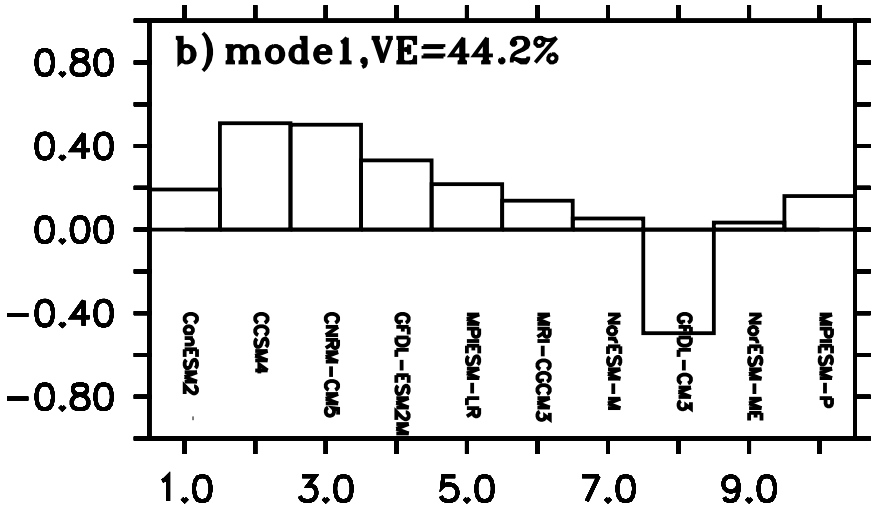


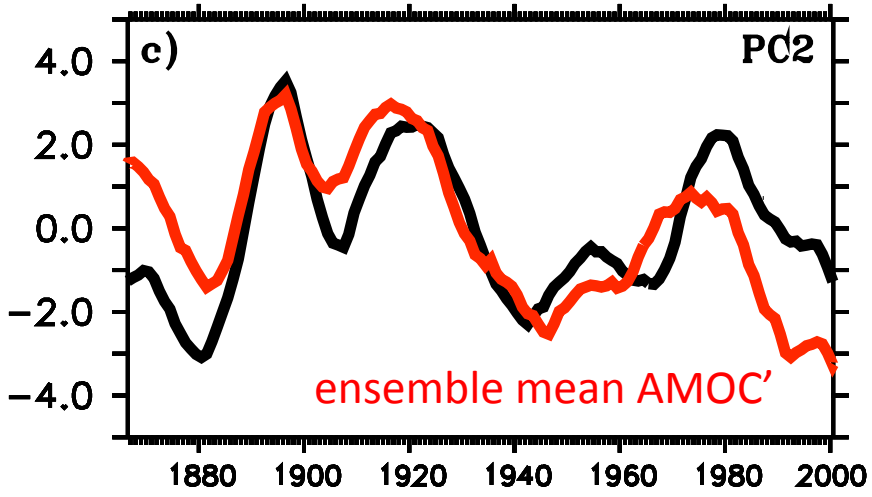
anomalies relative to “historical” mean state

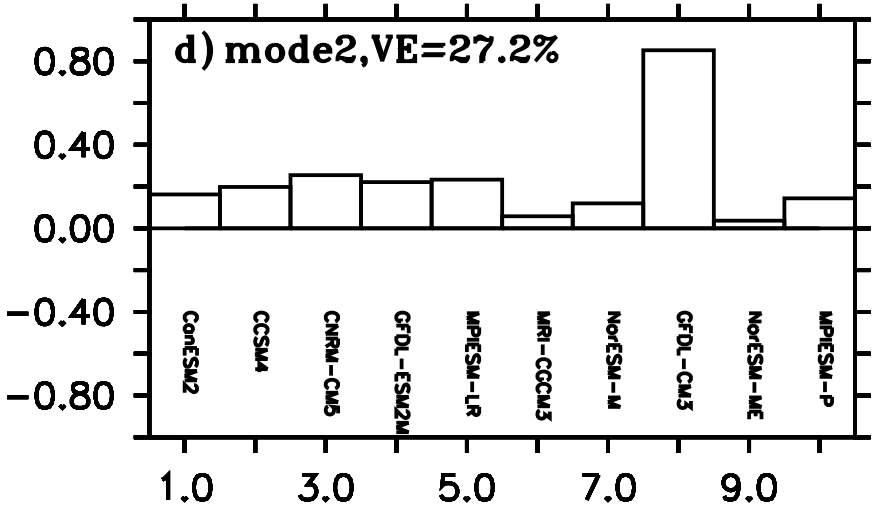


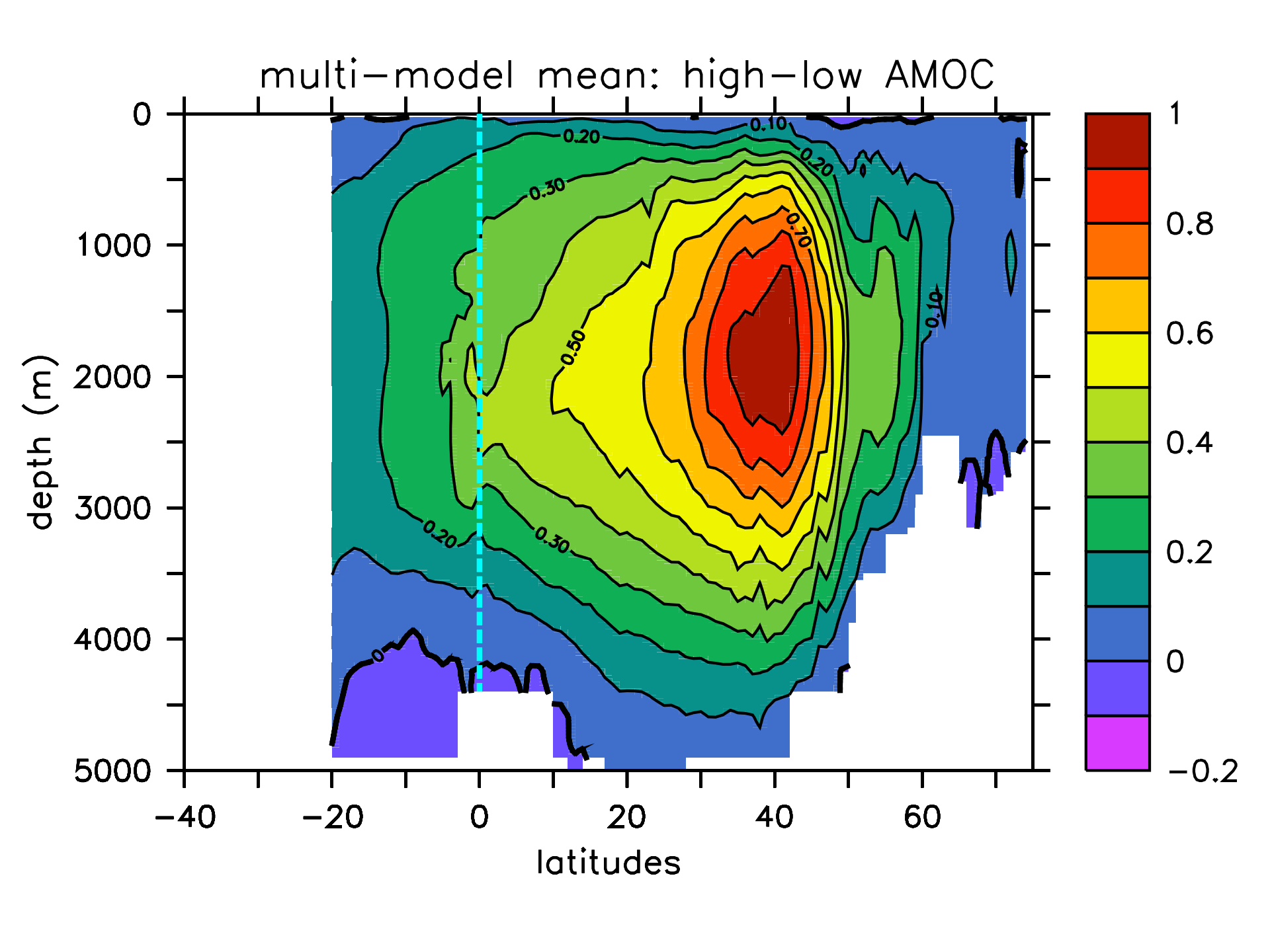
multi-model EOF modes

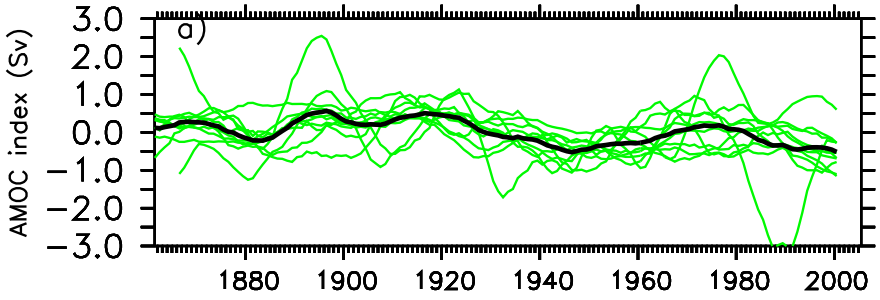


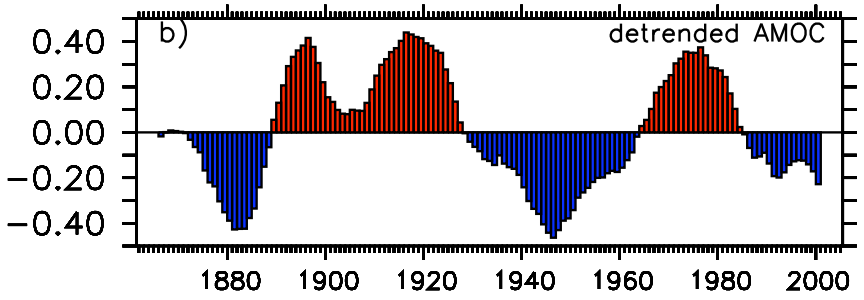




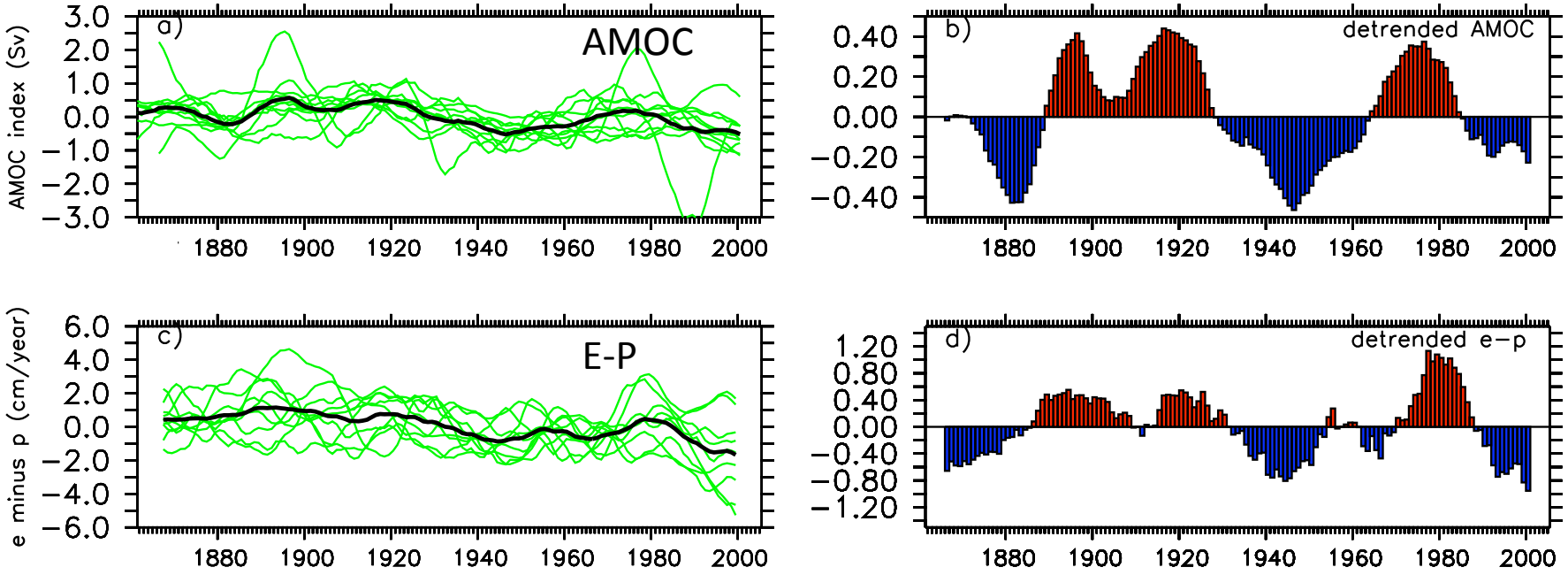



multi−model mean: high−low AMOC
depth (m)
0
1000
2000
3000
4000
5000
−40
−20
0
20
40
60
latitudes
0.10
0.20
0.30
0.70
0.50
0.10
0.20
0.30
0
1
0.8
0.6
0.4
0.2
0
−0.2

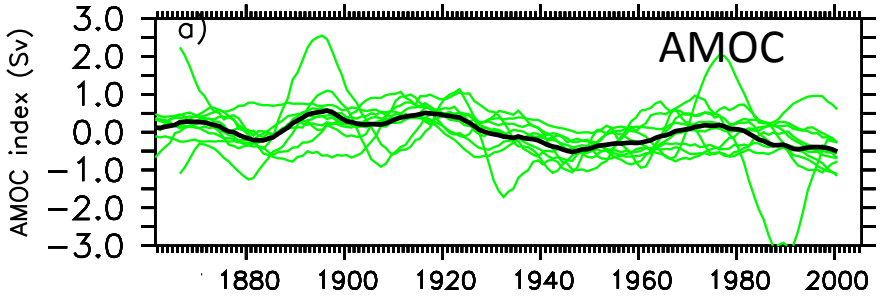

a)
AMOC index (Sv)
3.0
2.0
1.0
0.0
−1.0
−2.0
−3.0
1880
1900
1920
1940
1960
1980
2000

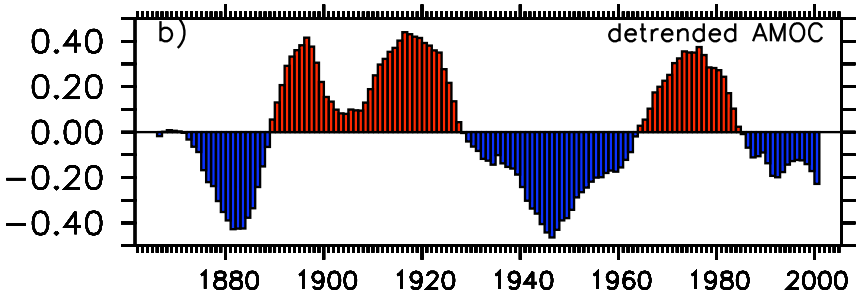

b)
detrended AMOC
0.40
0.20
0.00
−0.20
−0.40
1880
1900
1920
1940
1960
1980
2000

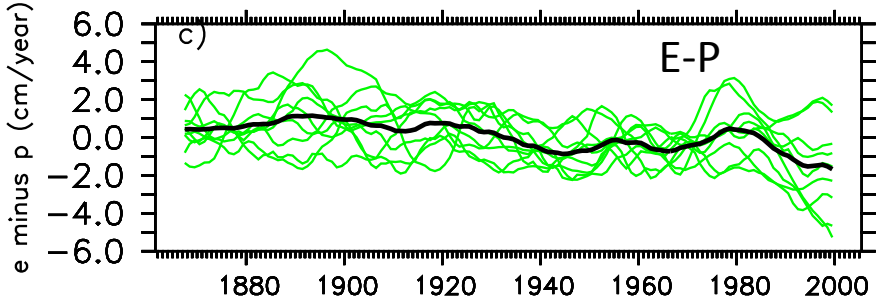
AMOC index

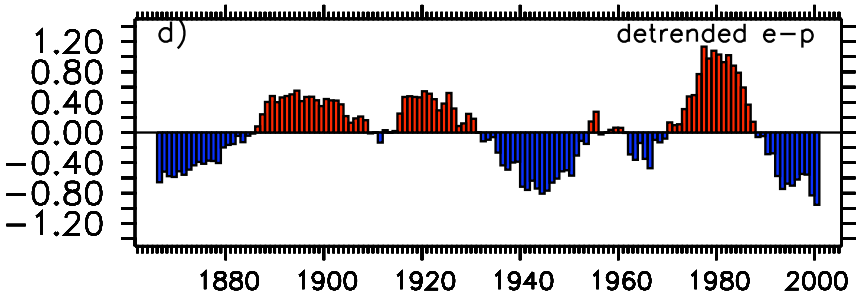


AMOC vs. subpolar E-P

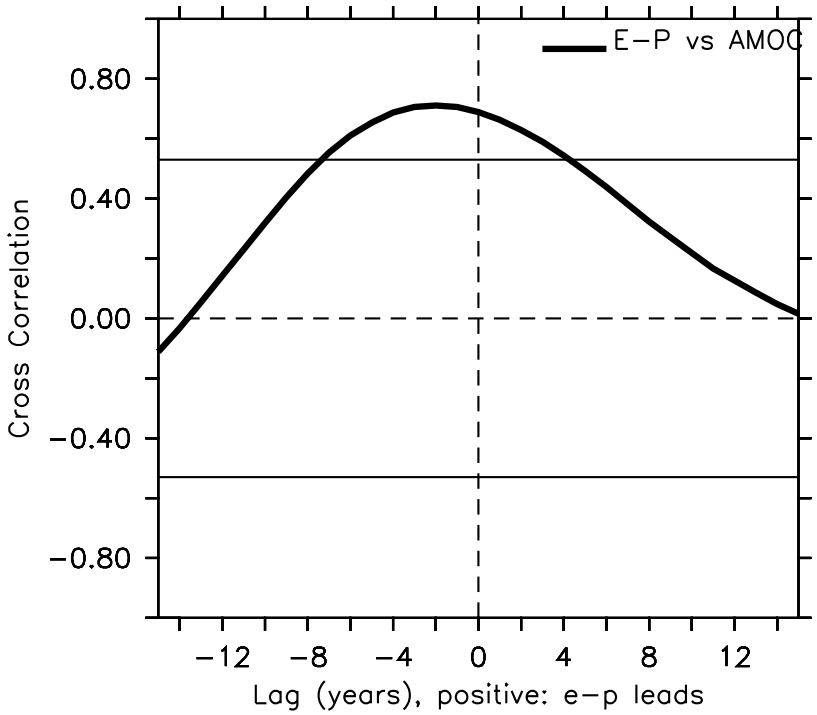


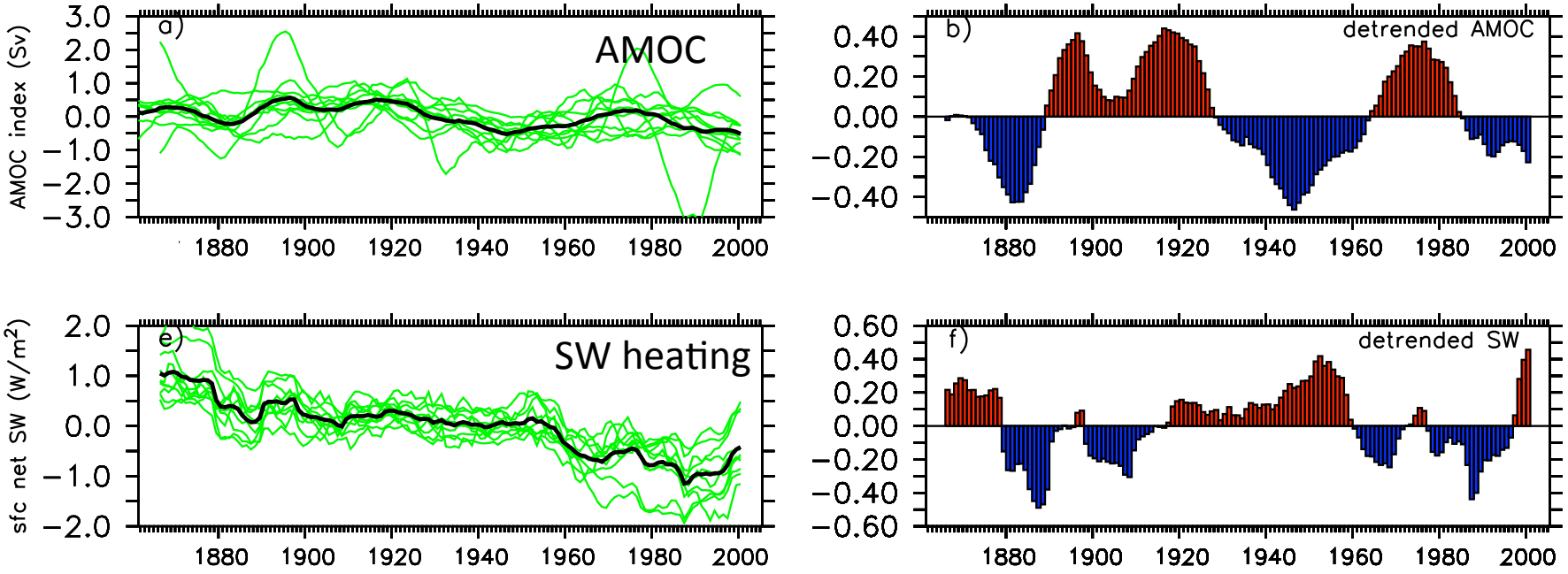




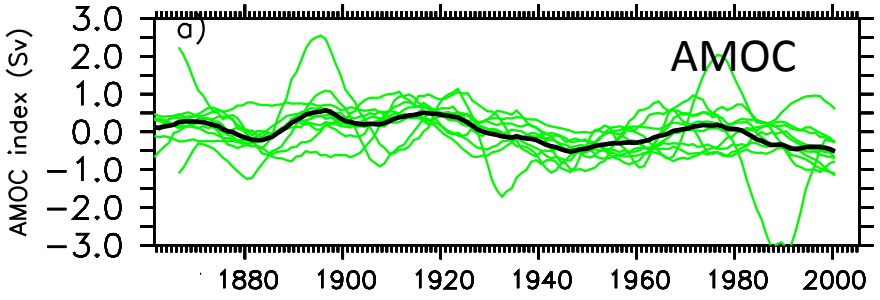


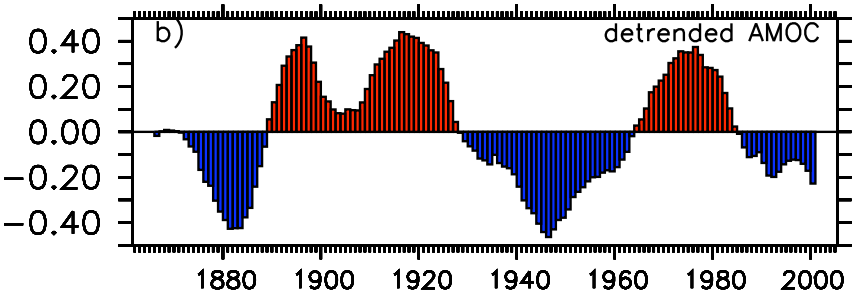
AMOC vs. subpolar E-P

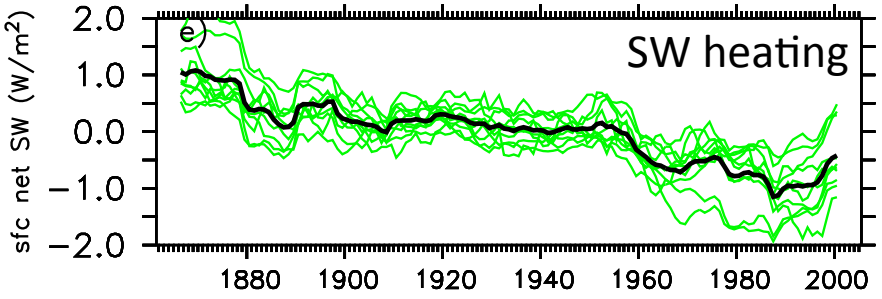


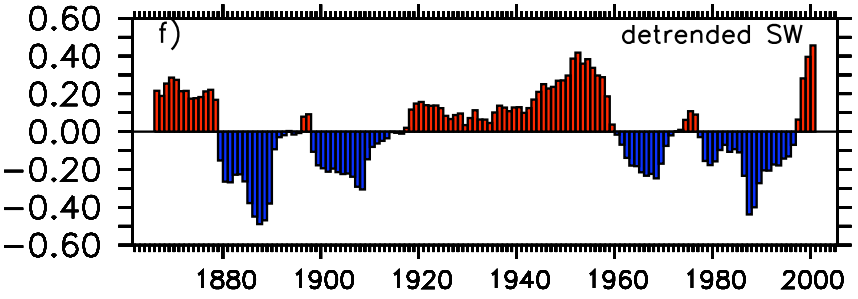


AMOC vs. NA Sfc SW Radiation

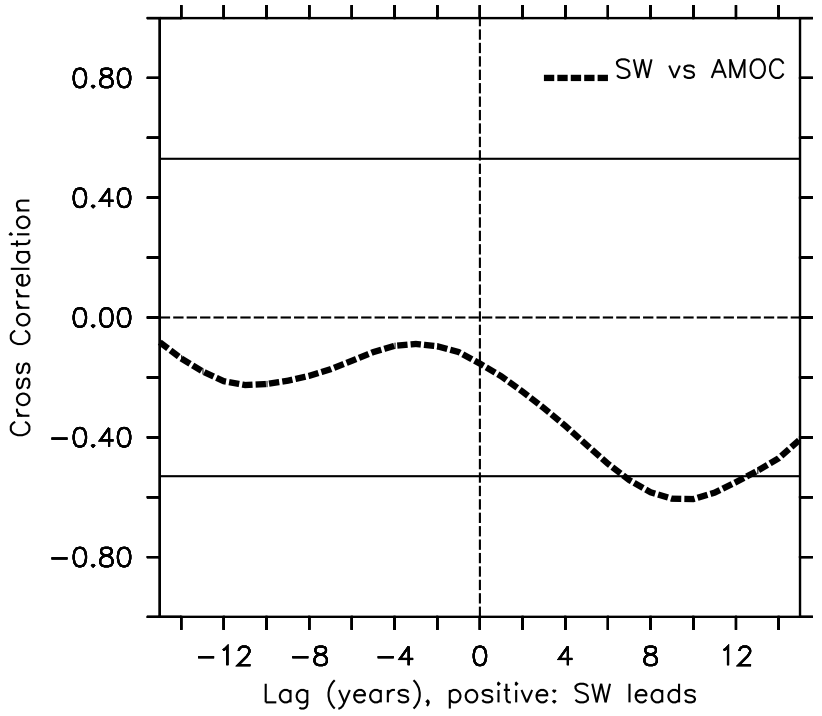




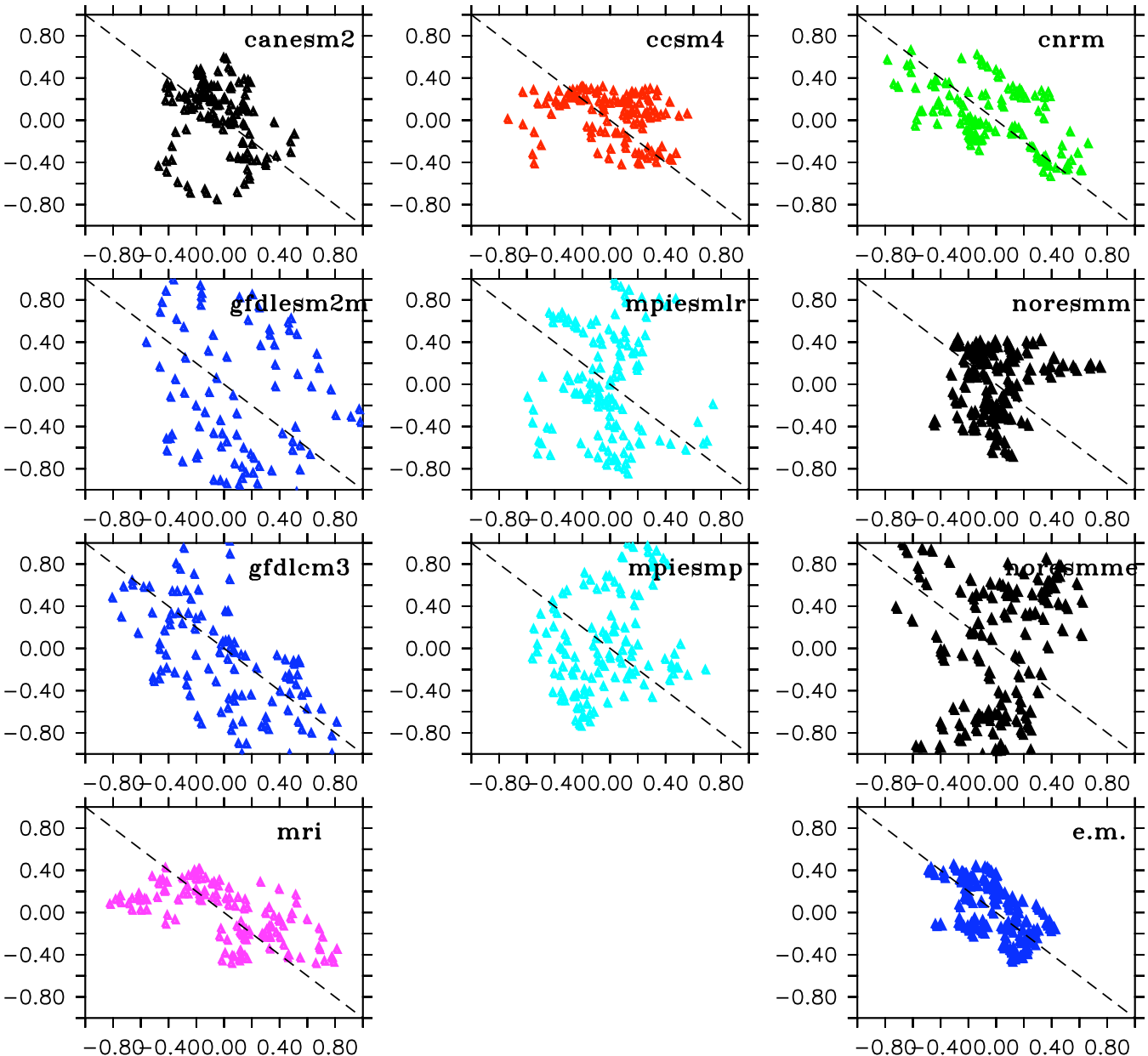


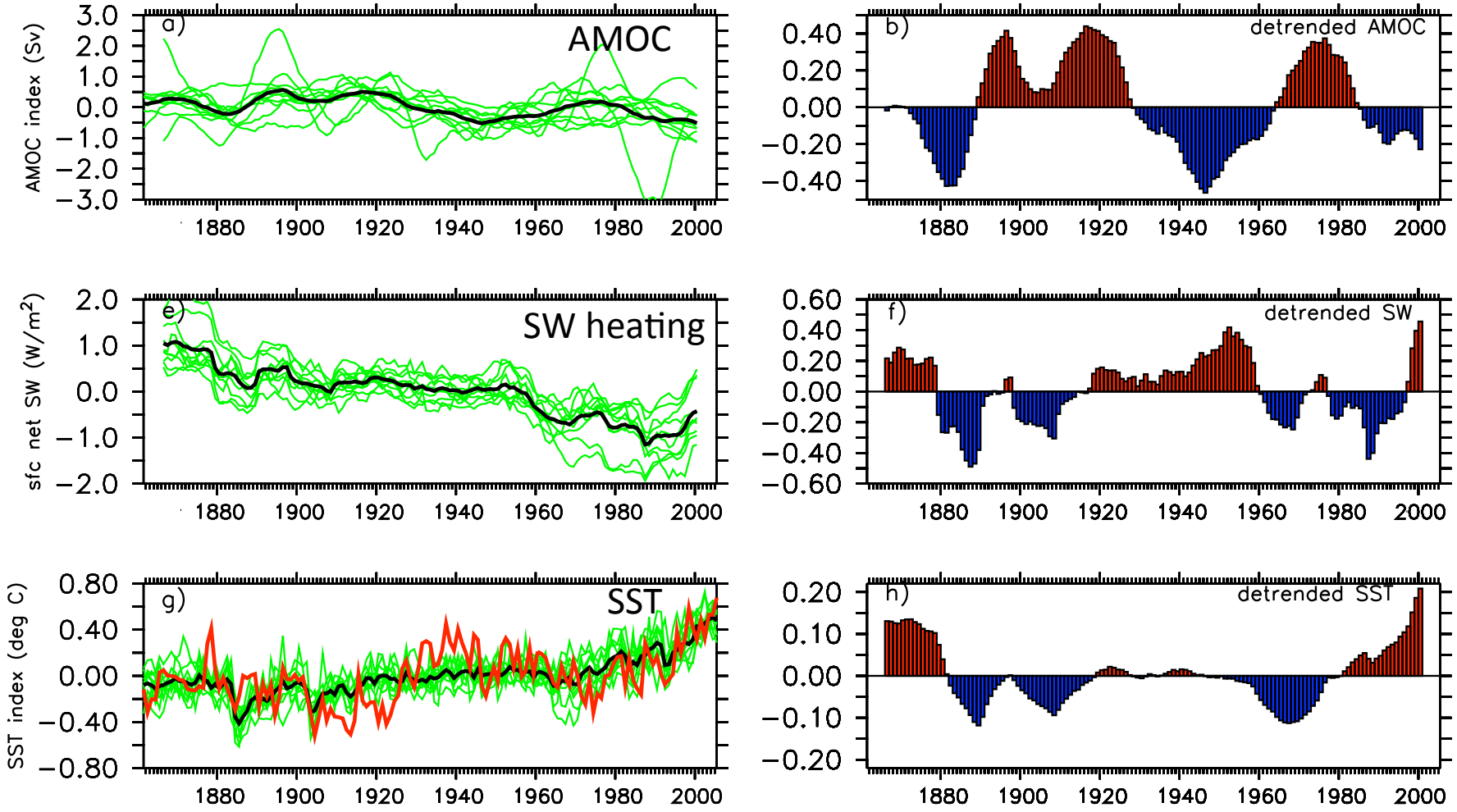


AMOC vs. NA Sfc SW Radiation

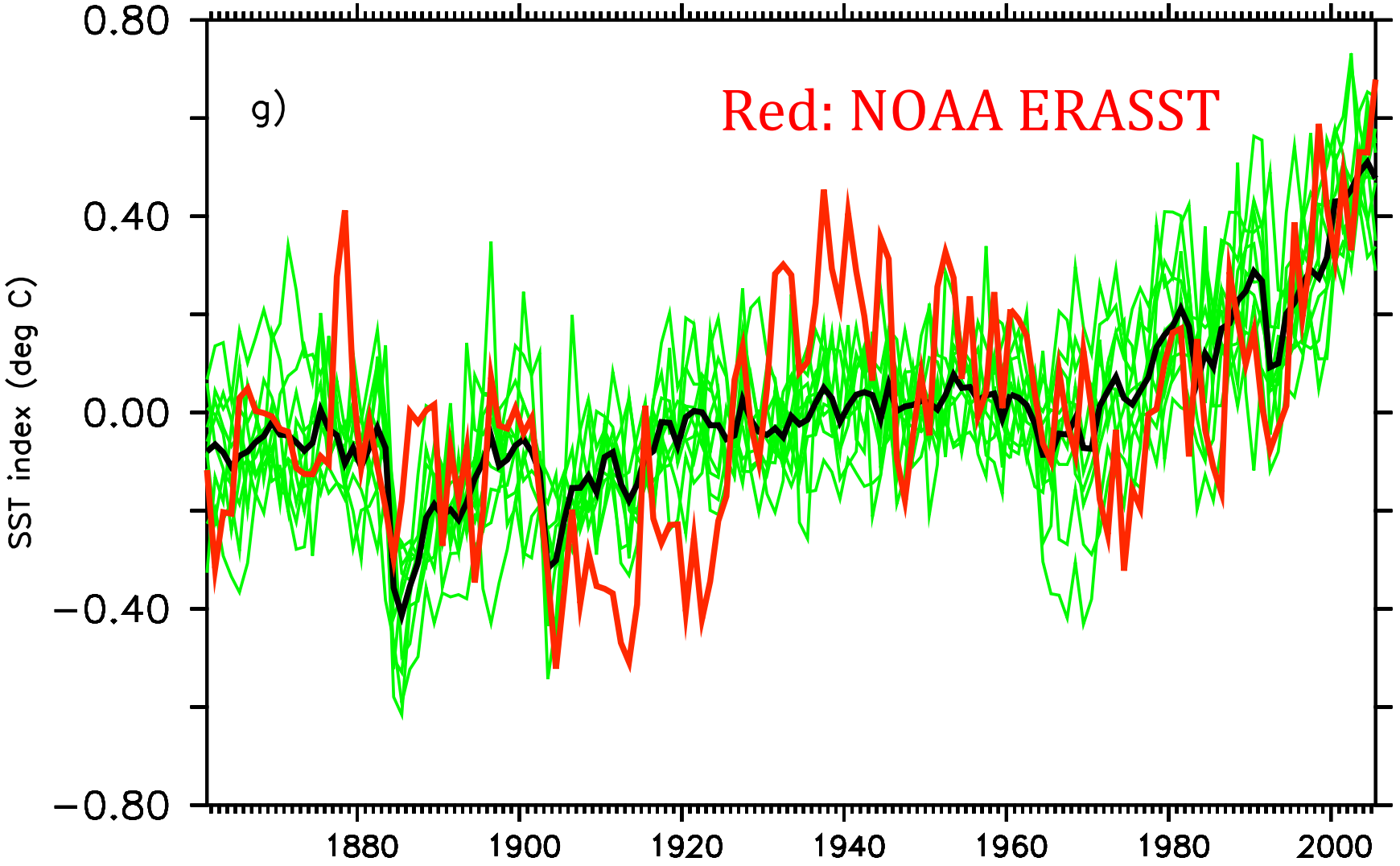


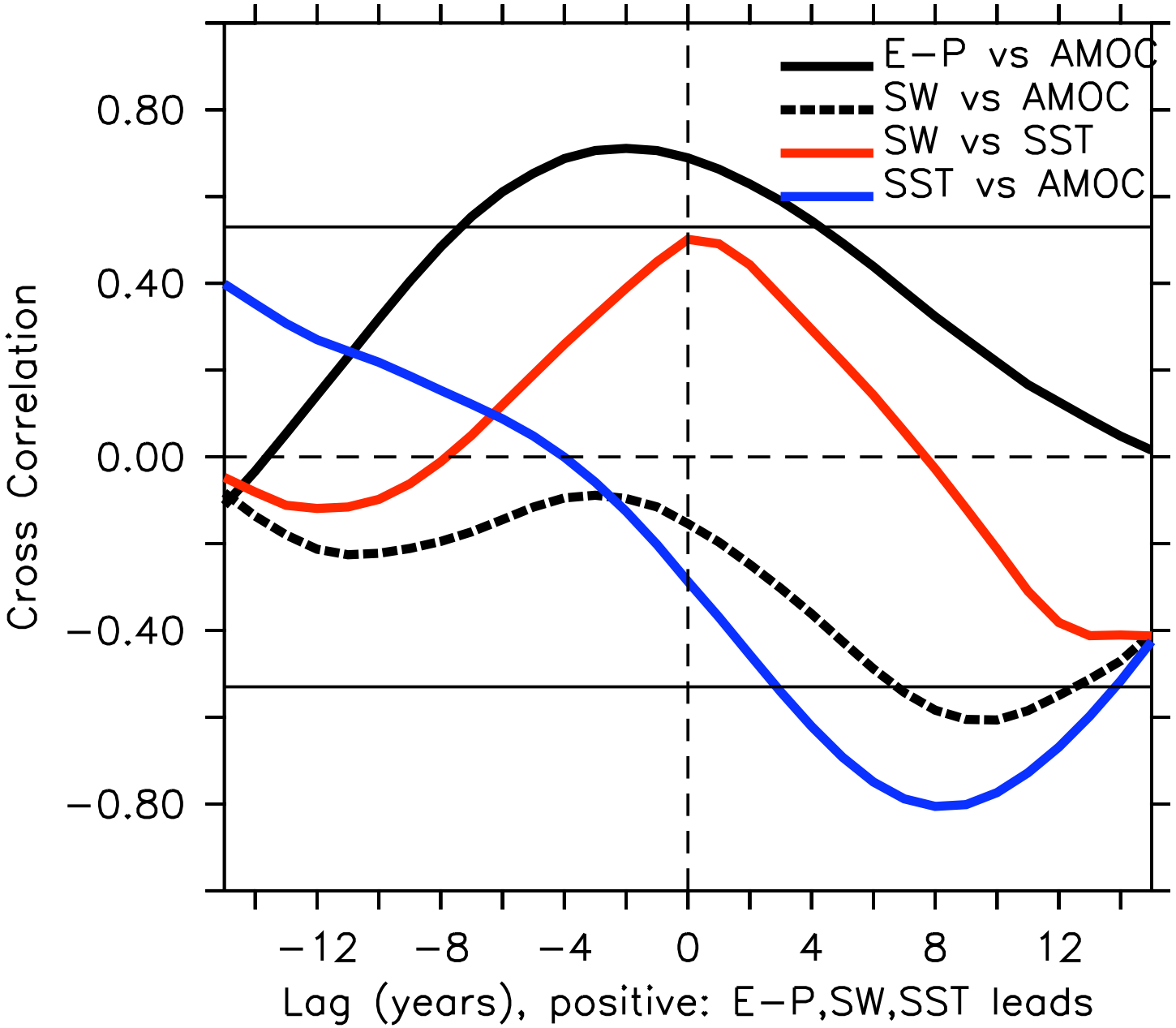
sfc SW radiation and AMOC anomalies in each model





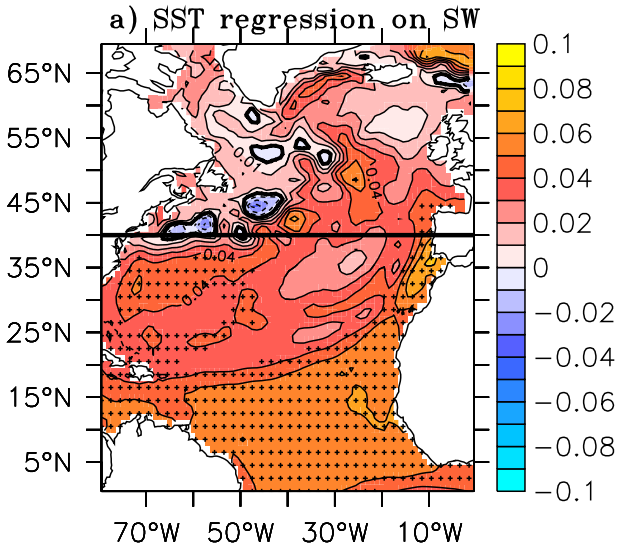
AMOC ~ NA sfc SW radiation ~ NA SST

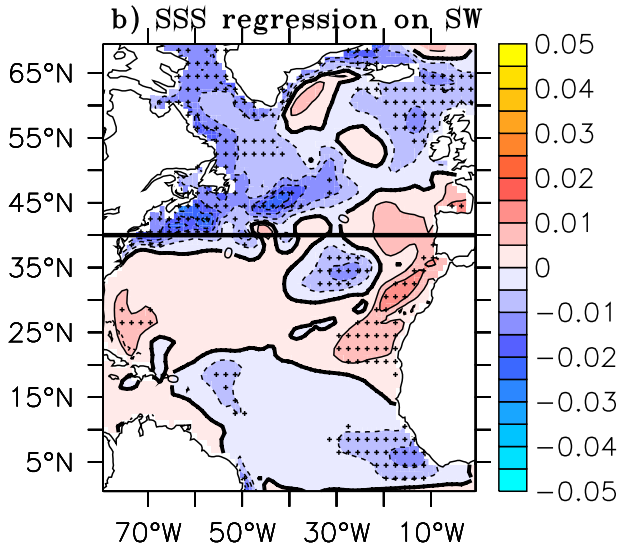

NA SST Anomalies
g)
Red: NOAA ERASST
SST index (deg C)
0.80
0.40
0.00
−0.40
−0.80
1880
1900
1920
1940
1960
1980
2000


E−P vs AMOC
SW vs AMOC
SW vs SST
SST vs AMOC
0.80
0.40
0.00
−0.40
−0.80
Cross Correlation
−12
−8
−4
0
4
8
12
Lag (years), positive: E−P,SW,SST leads

Regression Patterns

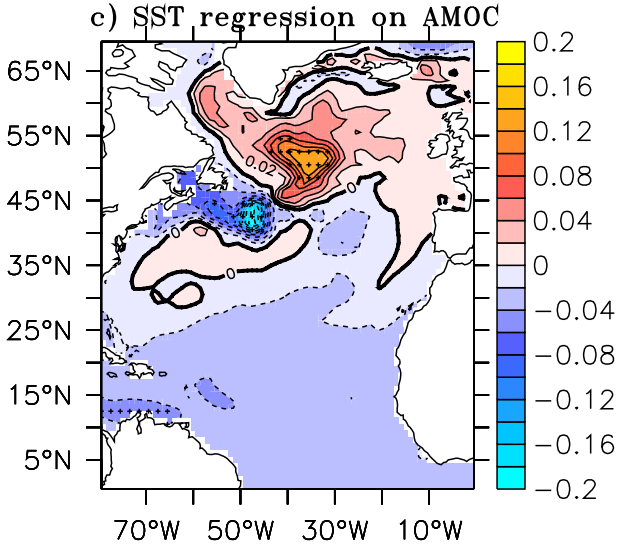
SST on SW↓

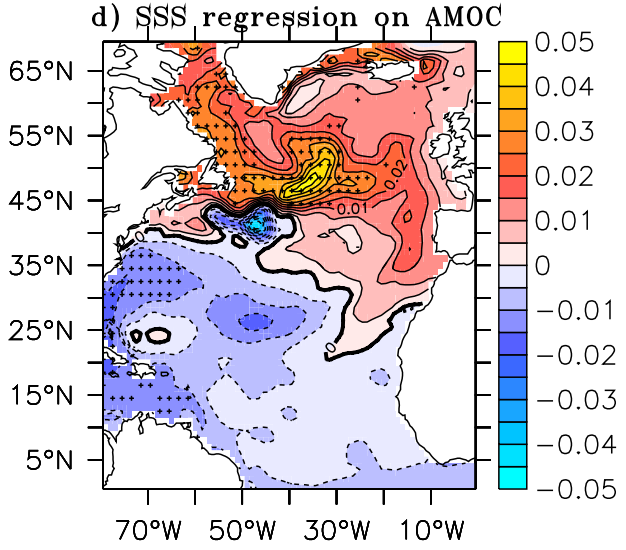




SSS on SW↓

SST on AMOC

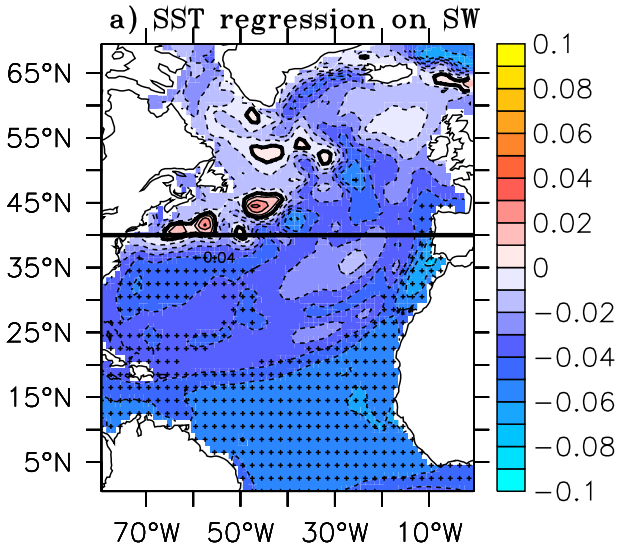


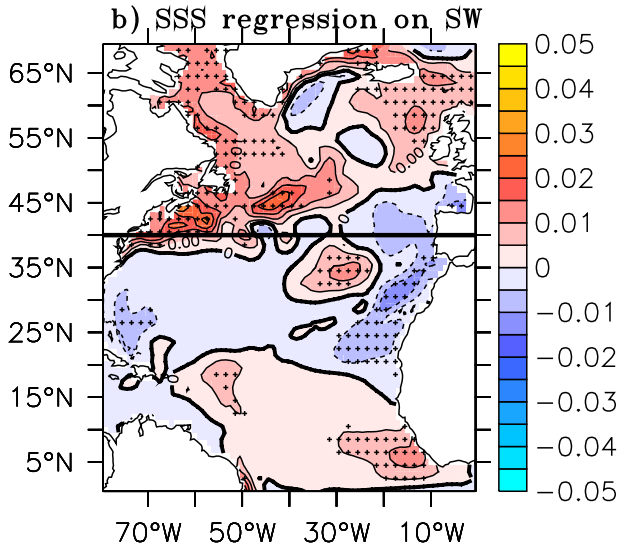


SSS on AMOC

Regression Patterns

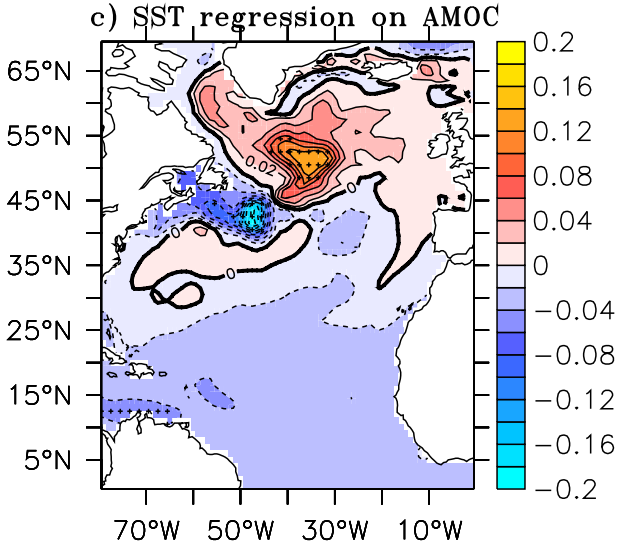
SST on SW↓ flip

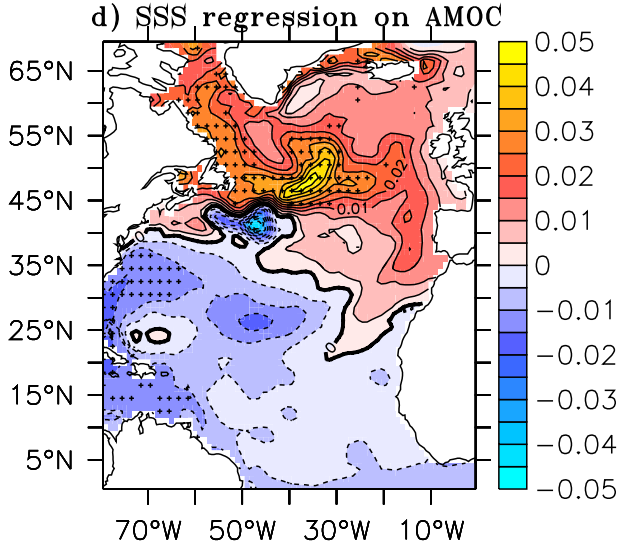




SSS on SW↓ flip

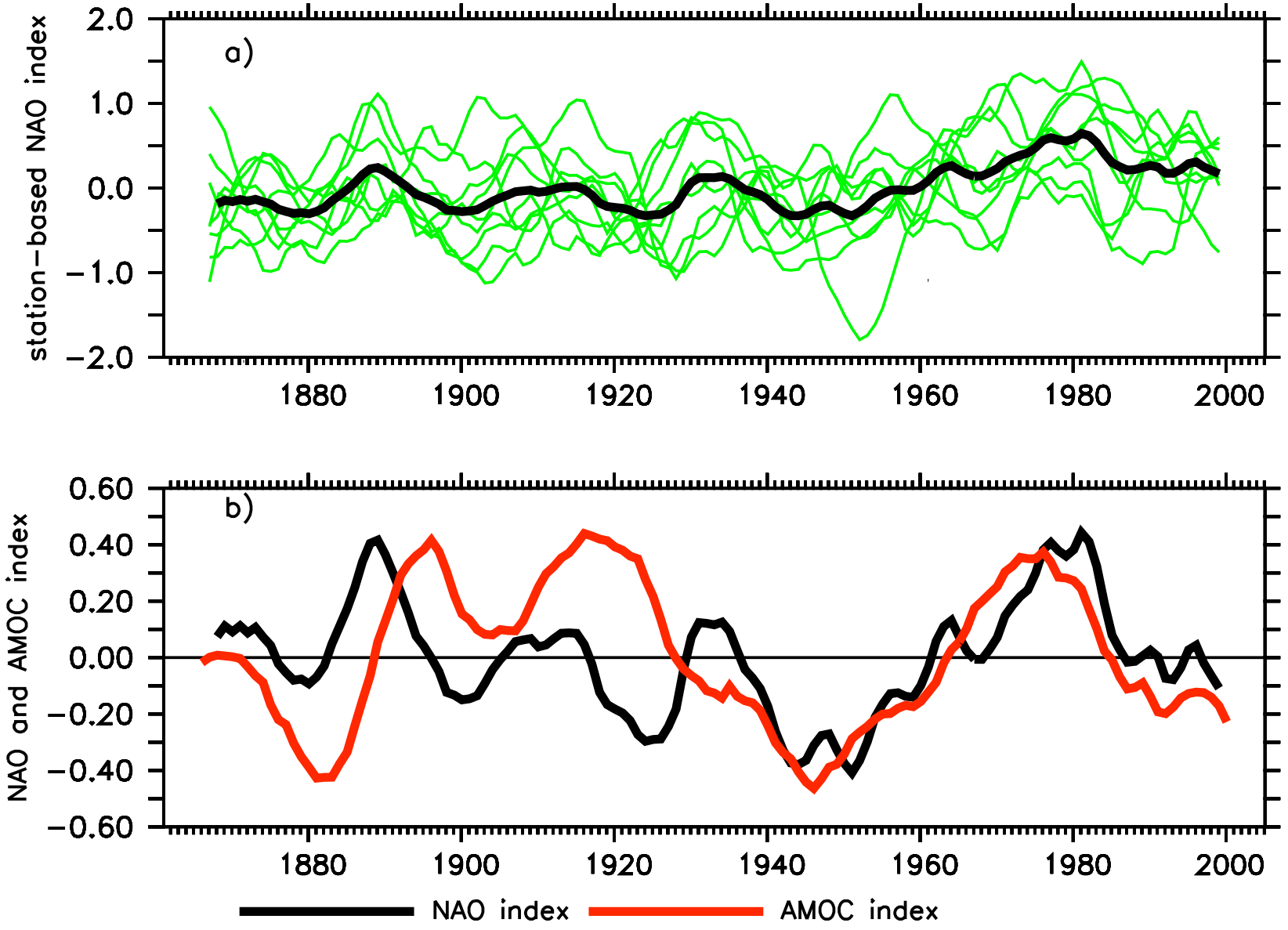
SST on AMOC



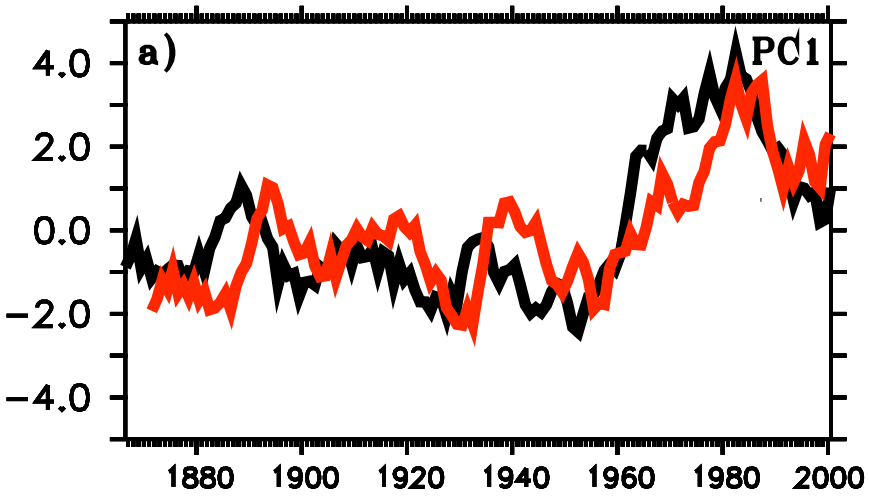


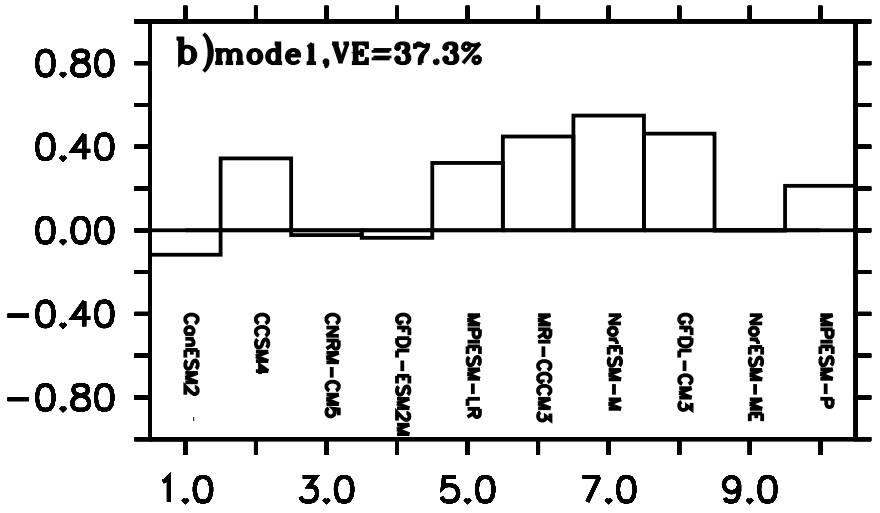
SSS on AMOC

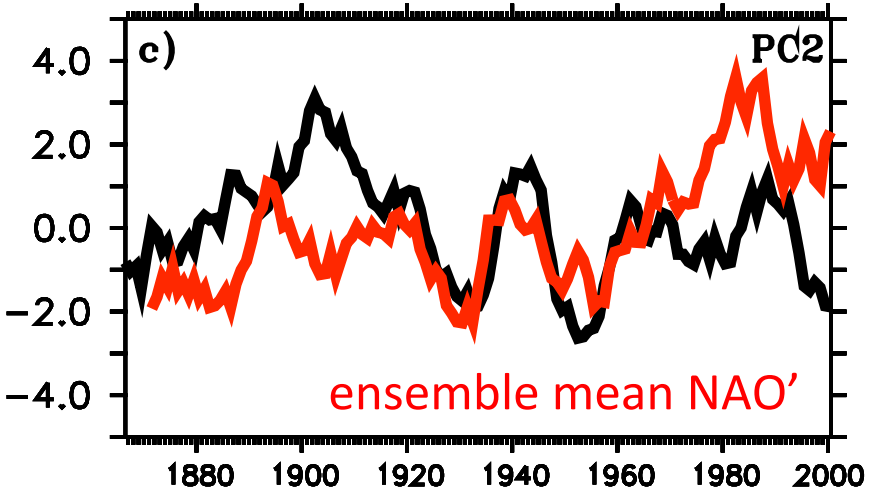
Roles of NAO?

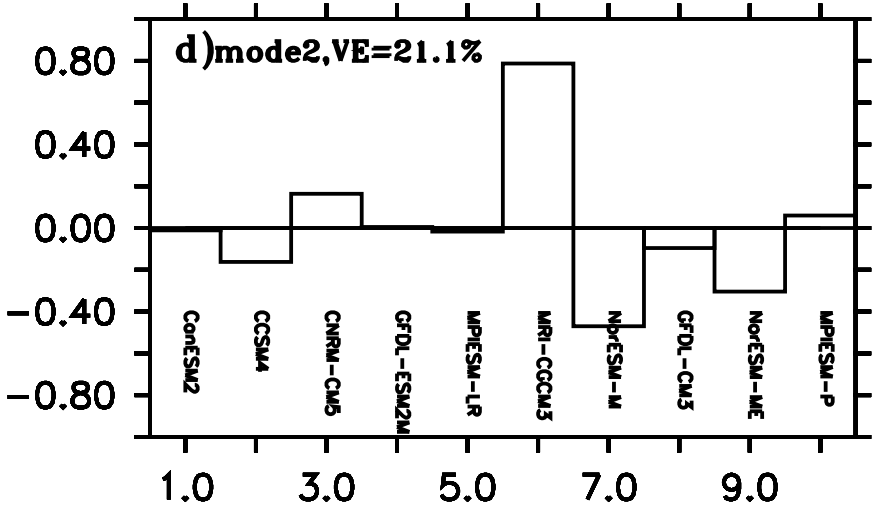

a)
station−based NAO index
2.0
1.0
0.0
−1.0
−2.0
1880
1900
1920
1940
1960
1980
2000
b)
NAO and AMOC index
0.60
0.40
0.20
0.00
−0.20
−0.40
−0.60
1880
1900
1920
1940
1960
1980
2000
NAO index
AMOC index

NAO multi-model EOF modes









Summary

1. The AMOC in CMIP5 “historical” runs matches better with observations than CMIP3 (?)
2. Weak but noticeable weakening in the 20thC by majority of models; weakening by 2100 is 21%– 36% of the 20thC mean (depending on forcing strength), consistent with CMIP3 results
3. The AMOC recovers after forcing is stabilized; recovers faster in the stronger forcing case
4. Multi-model ensemble mean “historical” AMOC shows a multidecadal variation with ~60yr quasi-periodicity, consistent with ensemble mean subpolar E-P and NA surface net SW radiation flux anomalies
5. Multi-model ensemble NAO is correlated with the ensemble mean AMOC in the second half of the 20thC

More questions than answers…

- What drives the fluctuations in NA surface net SW radiation flux? Roles of external forcing agents, e.g., GHGs vs. aerosols?

- Inter-model variations? Model categorization?

- Lead time of SW radiation to AMOC fluctuations in the ensemble mean vs in individual models? Controlling dynamics?

- Local (e.g., NAO) vs remote forcing (e.g., tropical rainfall anomalies) on the NADW formation?

Acknowledgments

WCRP Coupled Modeling WG, responsible for CMIP.

Modeling groups for making available their model output

DoE PCMDI data server for housing the CMIP data

http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-12-00496.1

Thank you!