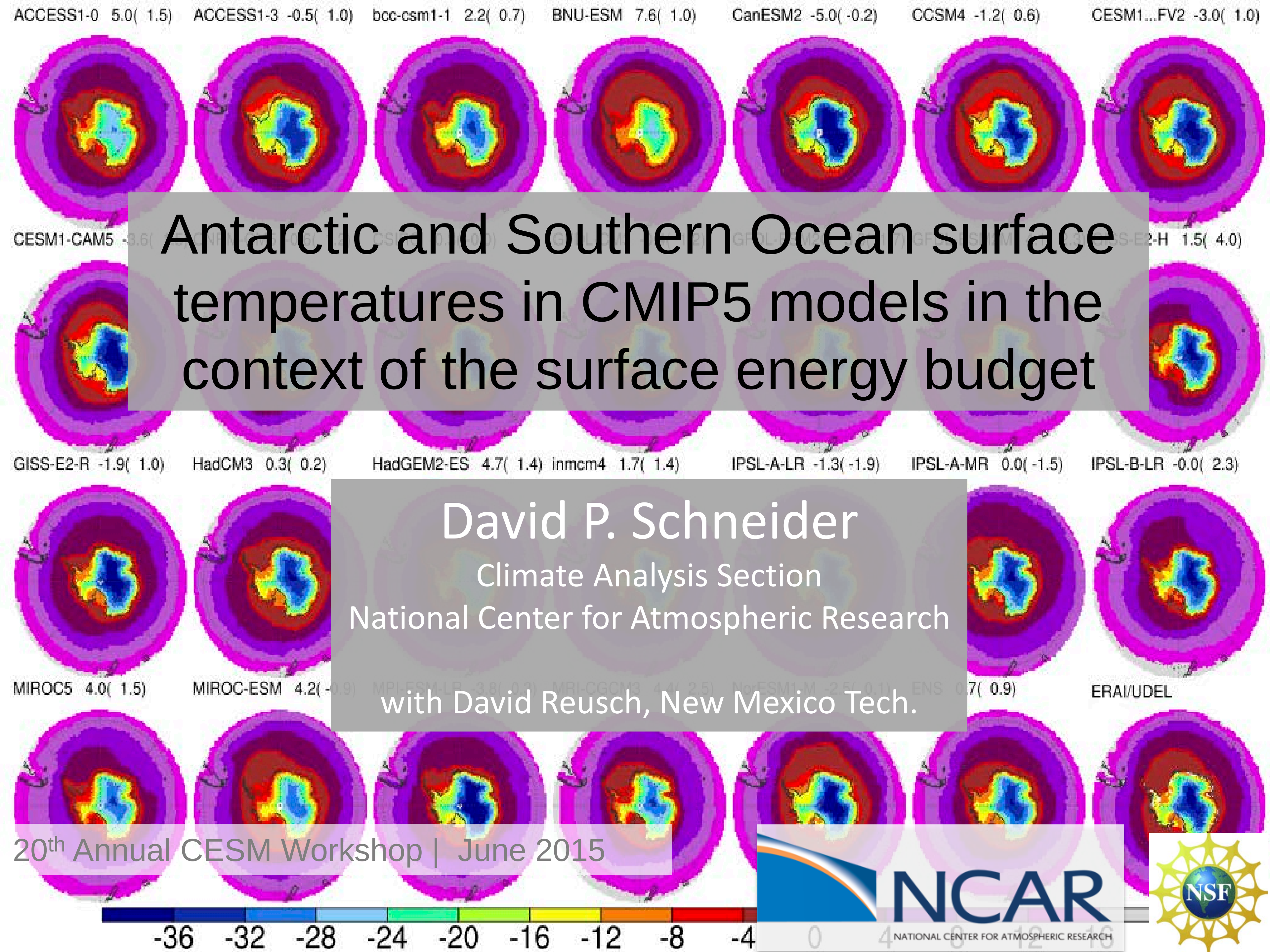

Antarctic and Southern Ocean surface temperatures in CMIP5 models in the context of the surface energy budget

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Climate Analysis Section

National Center for Atmospheric Research

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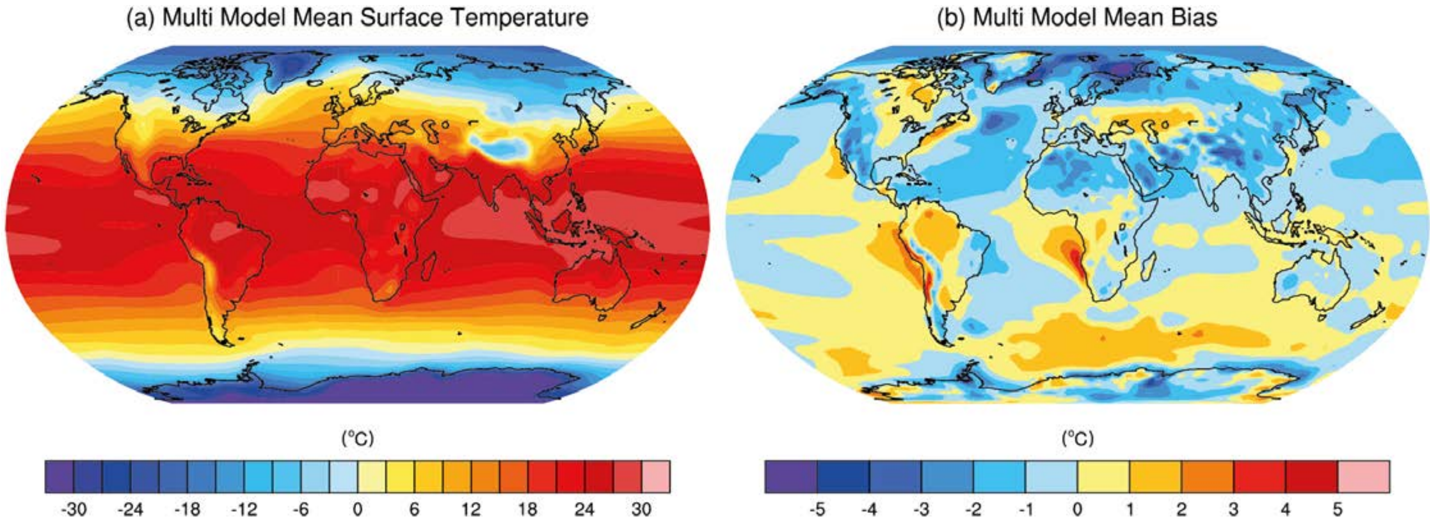
20th Annual CESM Workshop | June 2015

NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

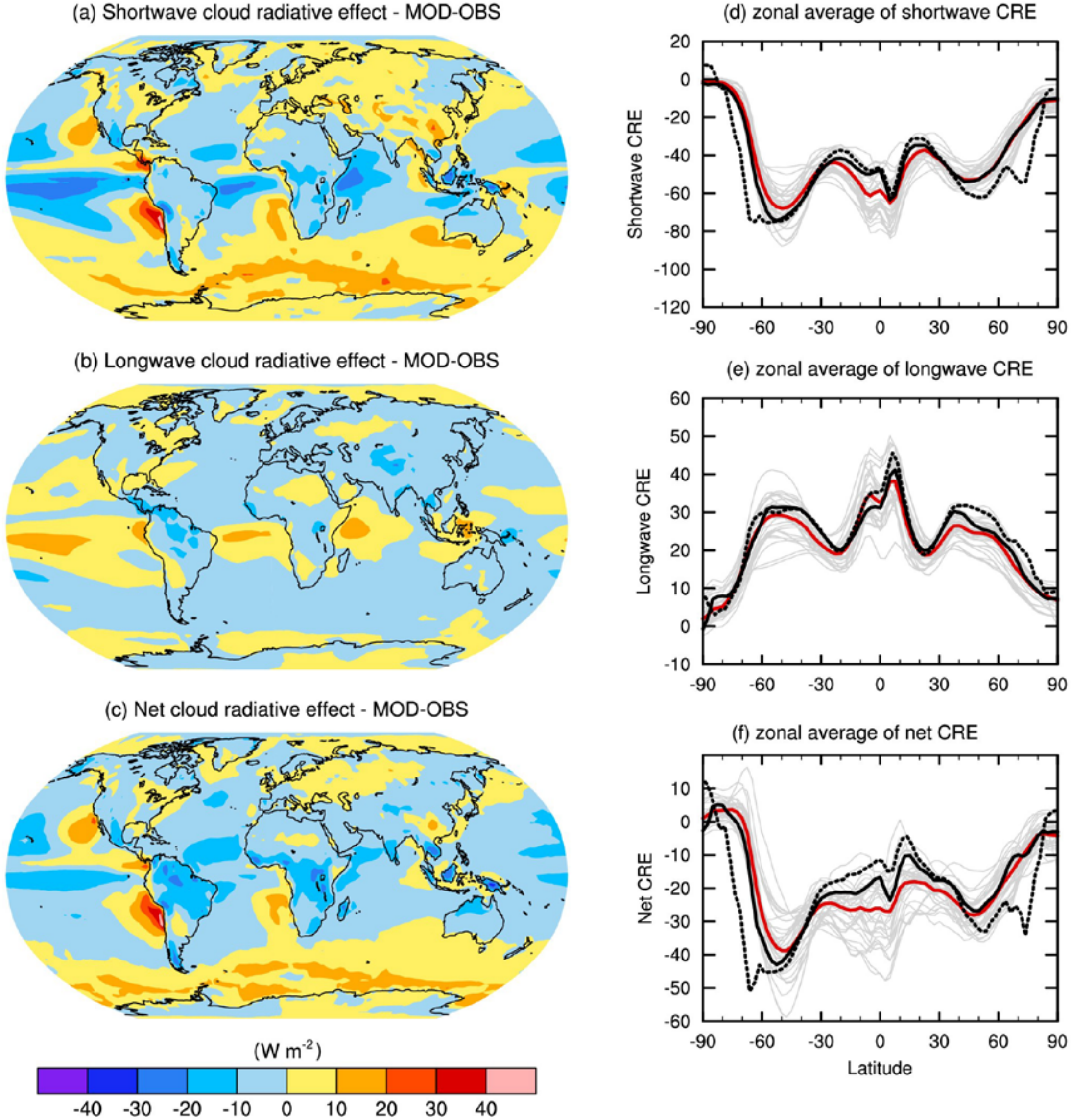
NSF

CMIP5 Surface Temperature mean & bias



IPCC AR5, WG1 Chapter 9, 2014

CMIP5 cloud forcing biases



shortwave

longwave

net

IPCC AR5, WG1 Chapter 9, 2014

Why study Antarctic & Southern ocean SAT & radiation biases?

Southern Ocean:

-most extensive region of positive surface temperature biases in CMIP5 ensemble mean

-problems with sea ice simulations

-global implication of biases
  double ITCZ problem (Hwang and Frierson, 2013)
  ocean heat transport (e.g. Trenberth and Fasullo, 2010)

Antarctic ice sheet:

-very little is known about model biases in the surface climate

-coupled ice sheet models – what biases in the atmopsheric forcing?

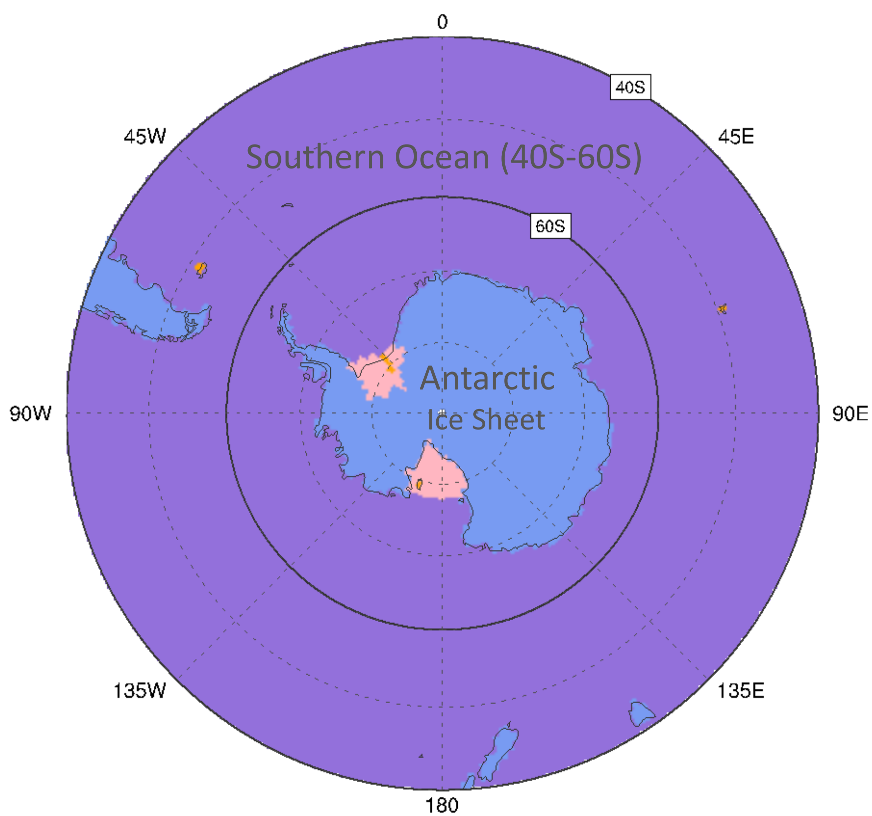
-global implications of biases
(sea level rise; heat sink)

This Study

⇒ 26 CMIP5 models; Historical Run, late 20C (1981-2000)

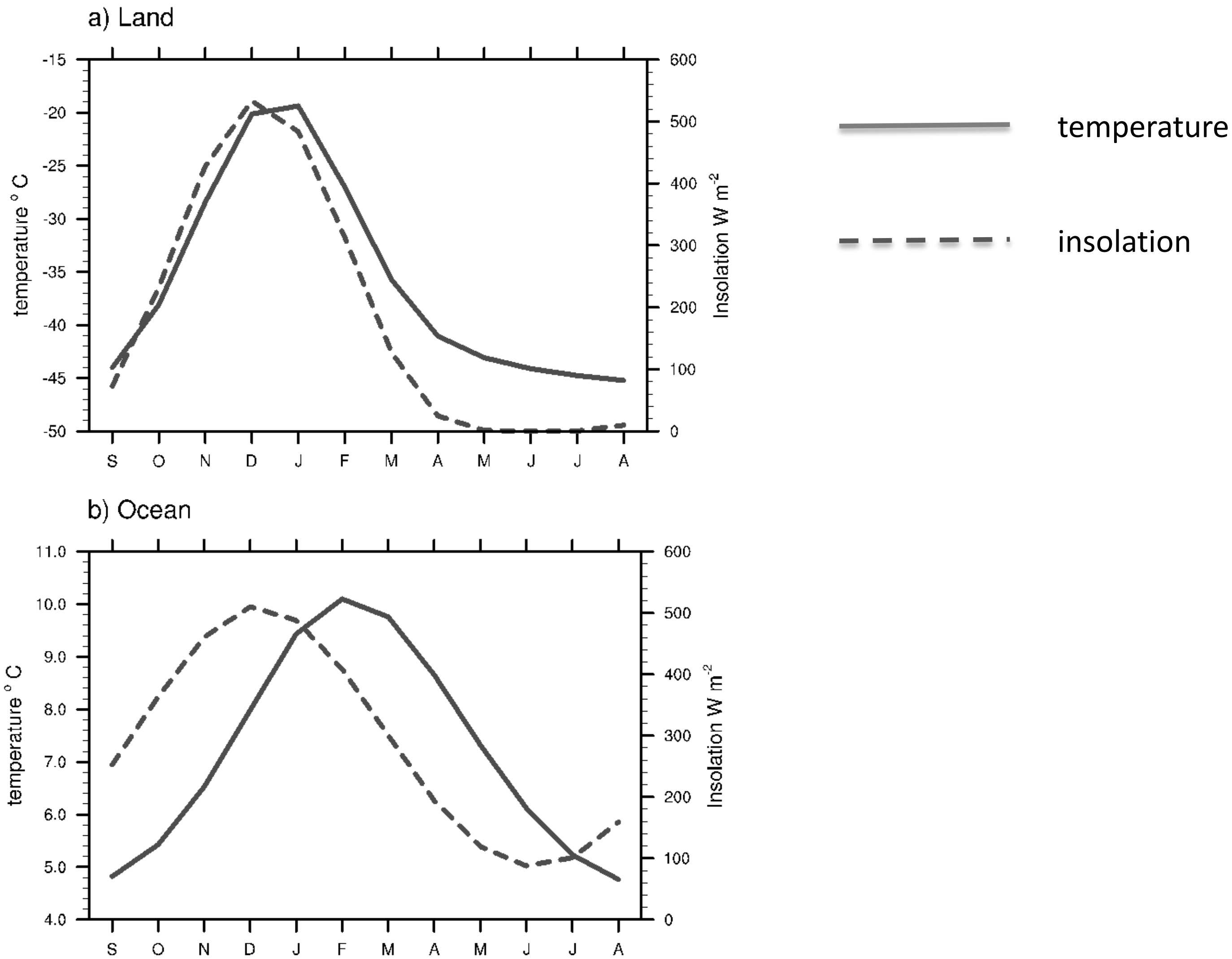
⇒ Observations: CERES-EBAF, ERA-Interim, MERRA, Matsuura & Wilmott (UDEL) surface temperatures

⇒ 2 domains: Southern Ocean (40°S-60°S); Antarctica (60°S-90°S)

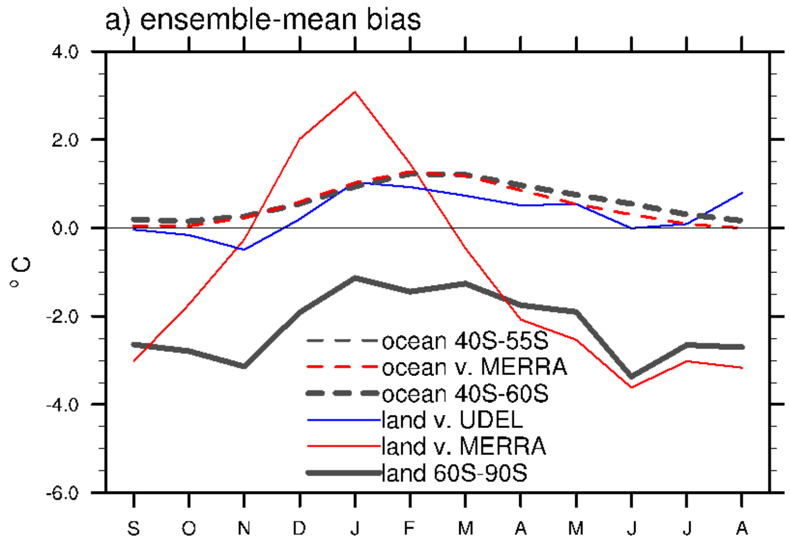


1. ACCESS 1-0
2. ACCESS 1-3
3. BCC-CSM 1.1
4. BNU-ESM
5. CanESM2
6. CCSM4
7. CESM1-CAM5
8. CESM1-CAM5-FV2
9. CNRM-CM5
10. CSIRO-MK3.0
11. GFDL-CM3
12. GFDL-ESM2G
13. GFDL-ESM2M
14. GISS-E2-H
15. GISS-E2-R
16. HAD-CM3
17. HadGEM2-ES
18. INMCM4
19. IPSL-CM5A-LR
20. IPSL-CM5A-MR
21. IPSL-CM5B-LR
22. MIROC5
23. MIROC-ESM
24. MPI-ESM-LR
25. MRI-CGCM3
26. NorESM1-M

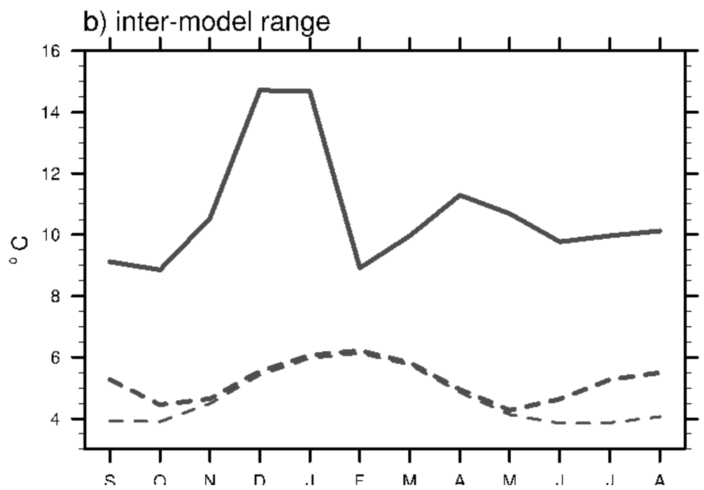
Ensemble mean, monthly mean surface air temperature (SAT) and insolation



Ensemble mean bias, inter-model range, and inter-model spread in SAT

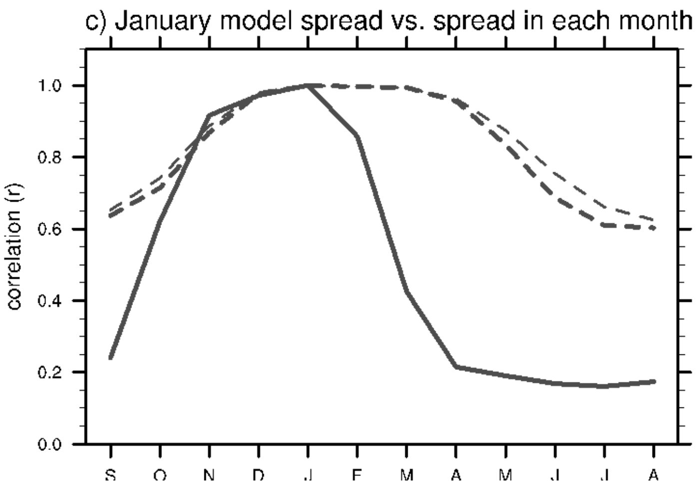


Bias



Range (max-min)

Spread



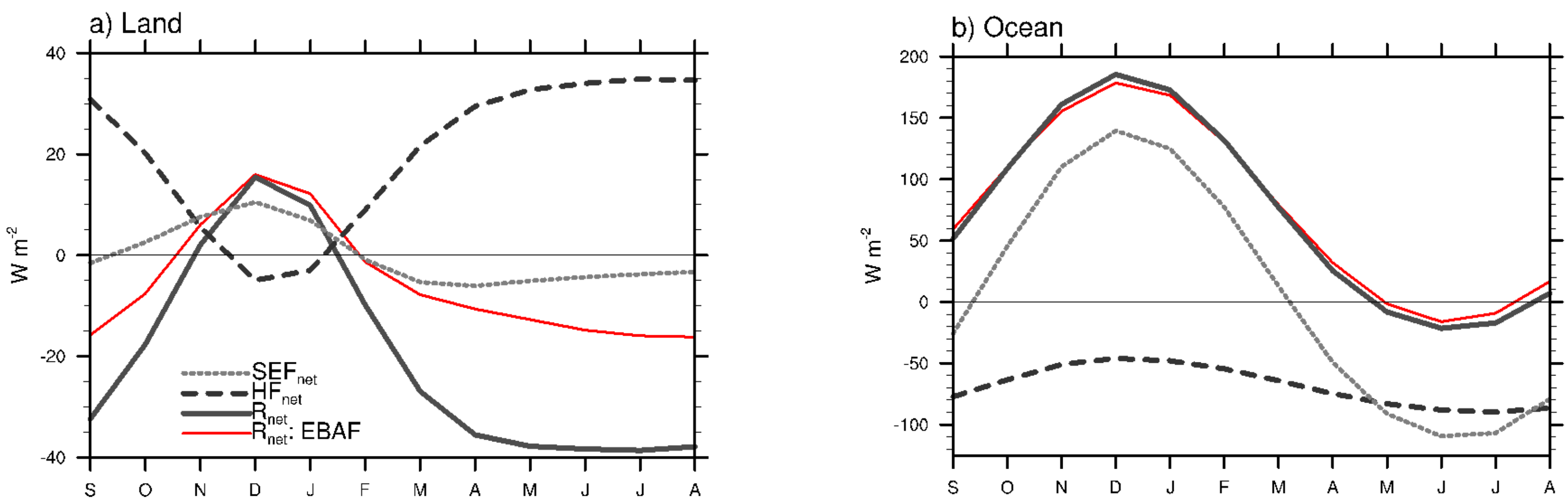
Surface energy fluxes

$$SEF_{net} = R_{net} + HF_{net}$$

$$SEF_{net} = SW_{net} + LW_{net} + HF_{net}$$

$$SEF_{net} = (SW_d - SW_u) + (LW_d - LW_u) + (SHF_{net} + LHF_{net}).$$

Ensemble mean



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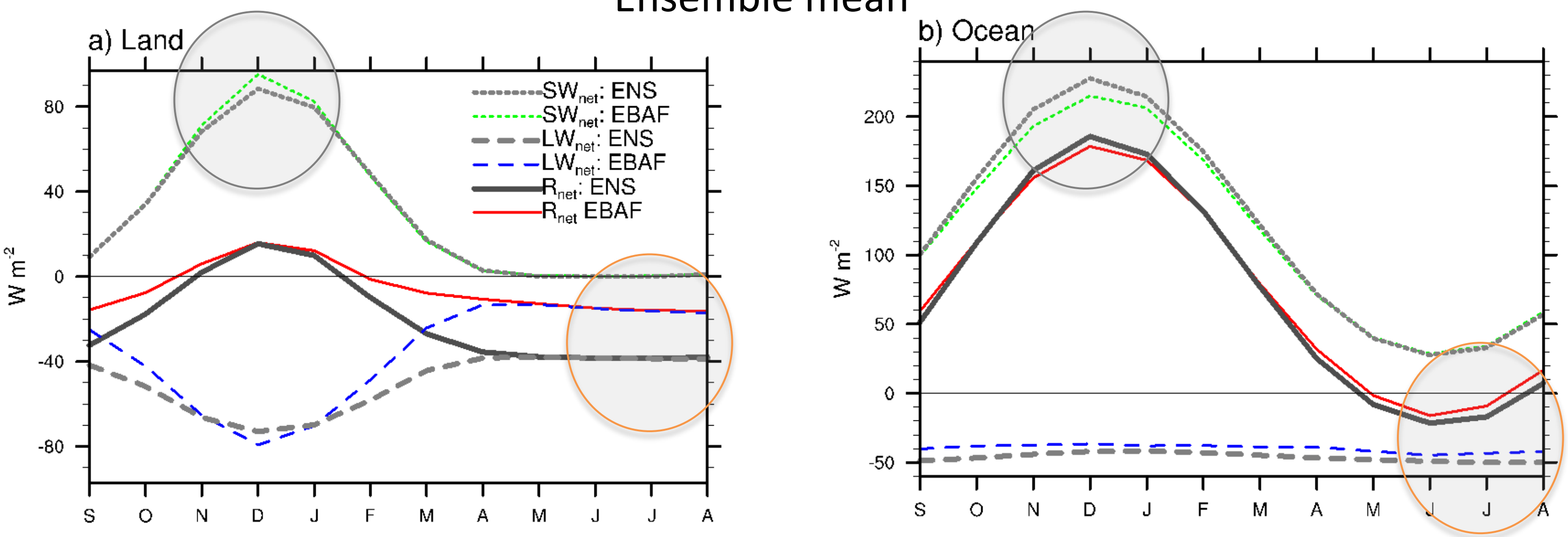
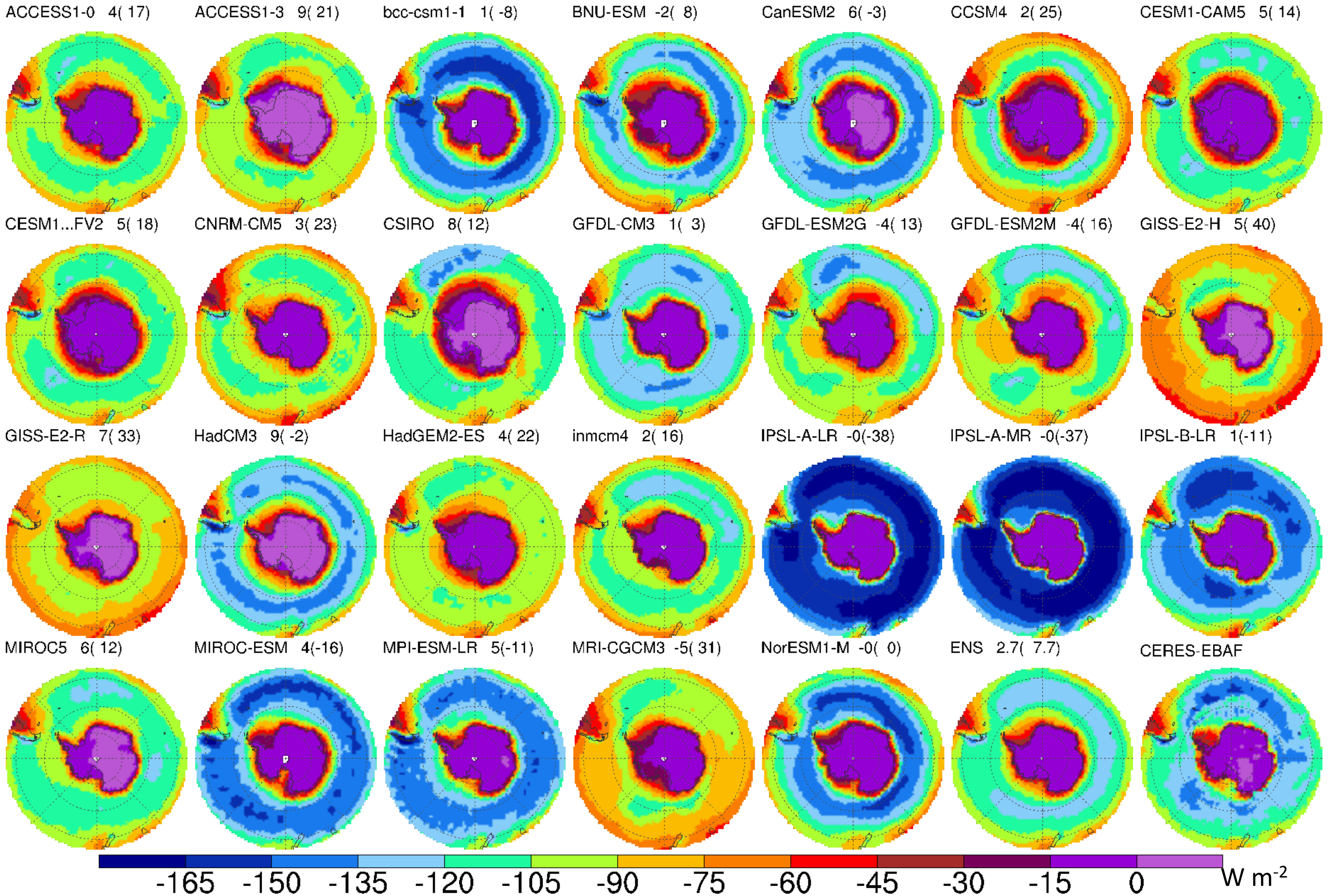
Ensemble mean

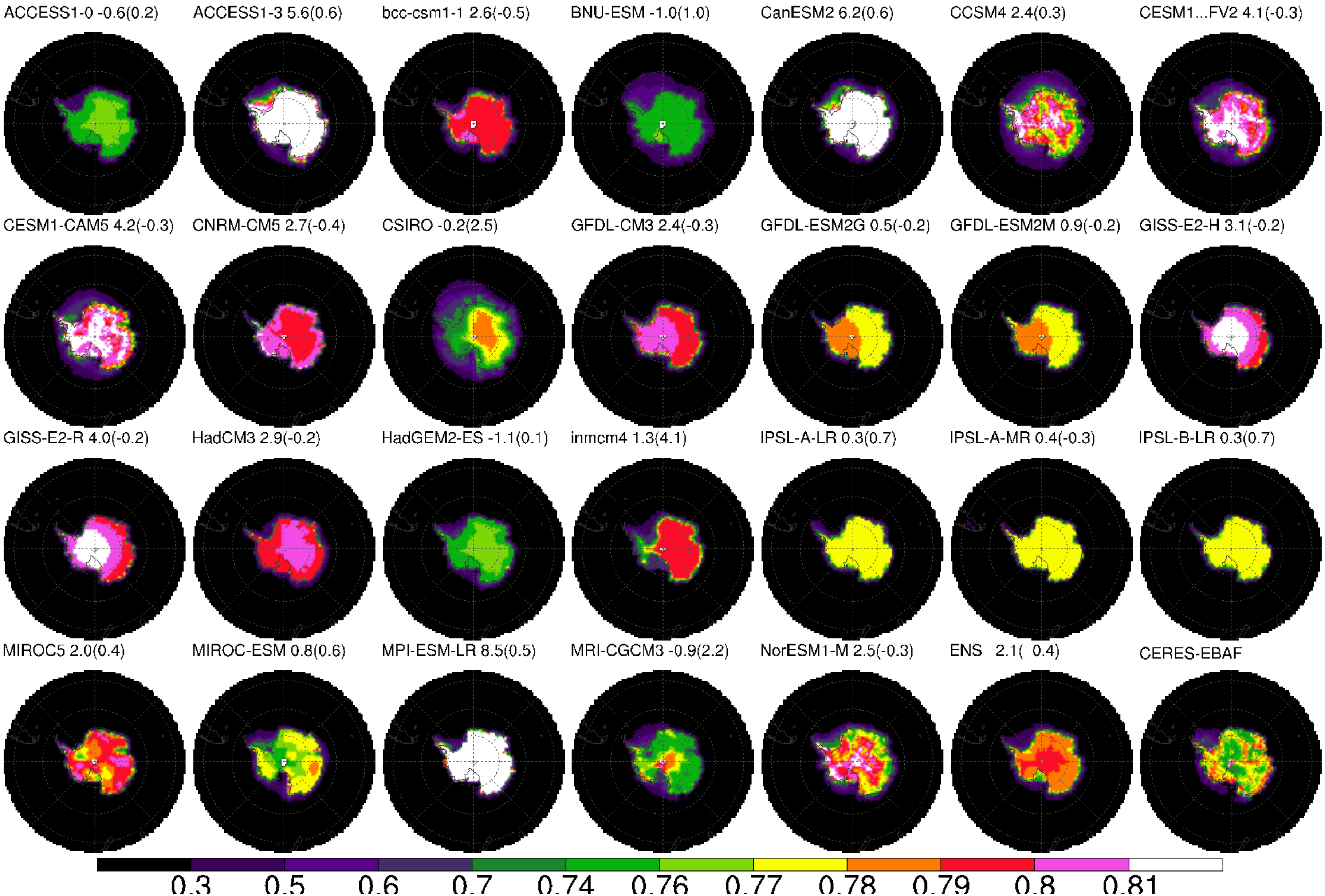


SWCF (DJF)

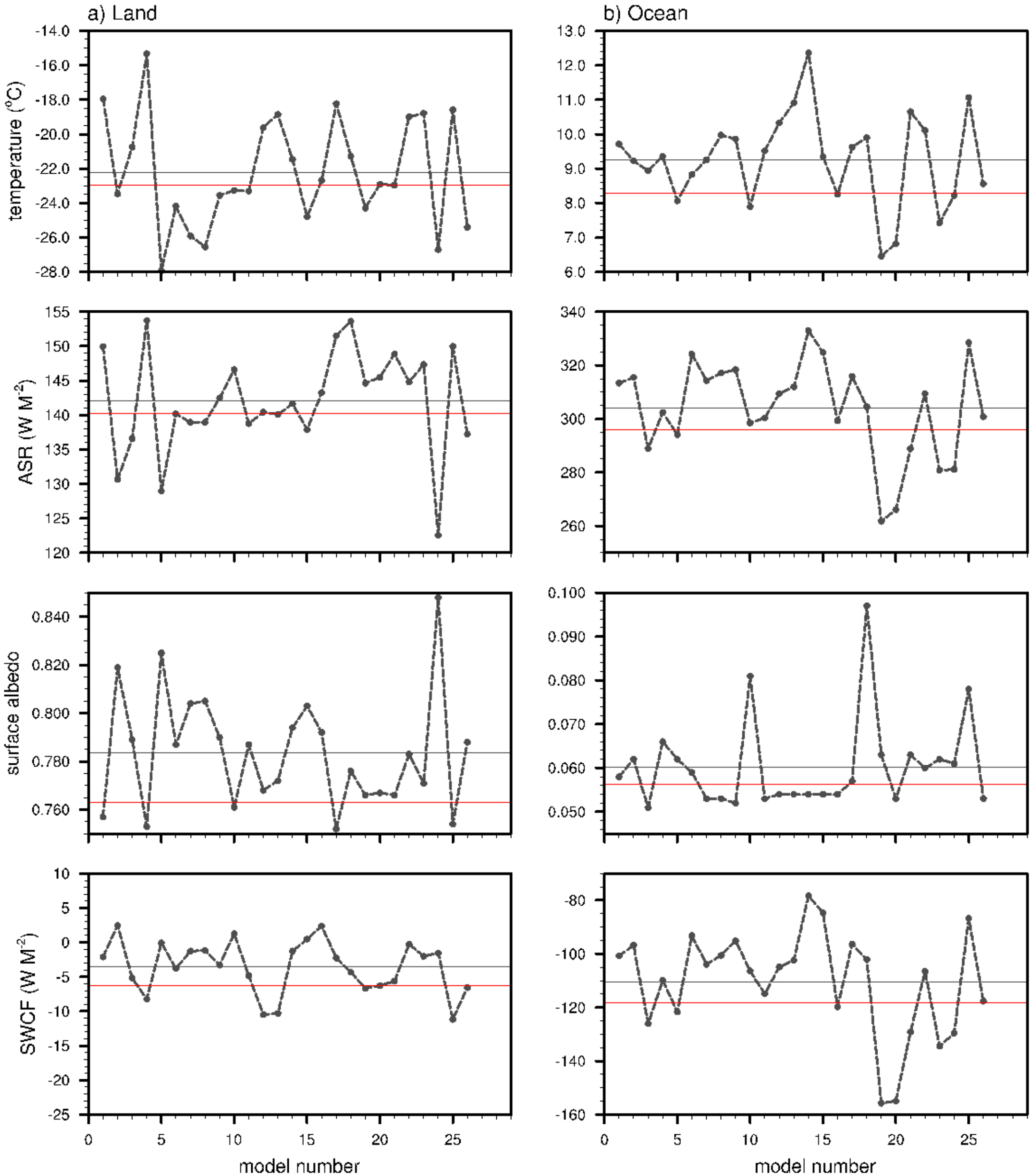


ACCESS1-0 4(17)
ACCESS1-3 9(21)
bcc-csm1-1 1(-8)
BNU-ESM -2(8)
CanESM2 6(-3)
CCSM4 2(25)
CESM1-CAM5 5(14)
CESM1...FV2 5(18)
CNRM-CM5 3(23)
CSIRO 8(12)
GFDL-CM3 1(3)
GFDL-ESM2G -4(13)
GFDL-ESM2M -4(16)
GISS-E2-H 5(40)
GISS-E2-R 7(33)
HadCM3 9(-2)
HadGEM2-ES 4(22)
inmcm4 2(16)
IPSL-A-LR -0(-38)
IPSL-A-MR -0(-37)
IPSL-B-LR 1(-11)
MIROC5 6(12)
MIROC-ESM 4(-16)
MPI-ESM-LR 5(-11)
MRI-CGCM3 -5(31)
NorESM1-M -0(0)
ENS 2.7(7.7)
CERES-EBAF
-165 -150 -135 -120 -105 -90 -75 -60 -45 -30 -15 0
W m-2

surface albedo (DJF, clear-sky)



Inter-model spread (DJF)



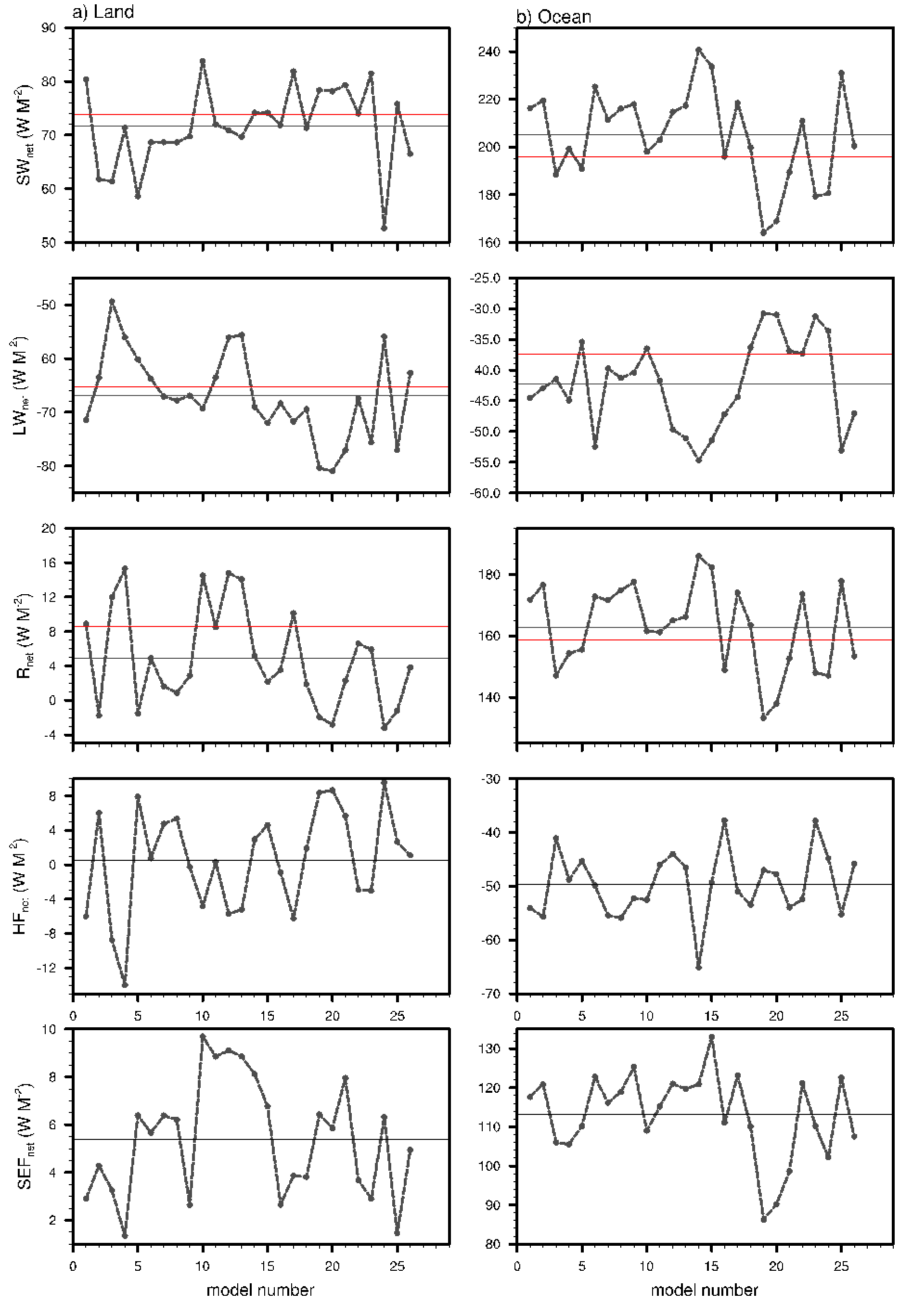
temperature

ASR

surface albedo

SWCF

Inter-model spread (DJF): $SEF_{net} = (SW_{net} + LW_{net}) + HF_{net}$



SW_{net}

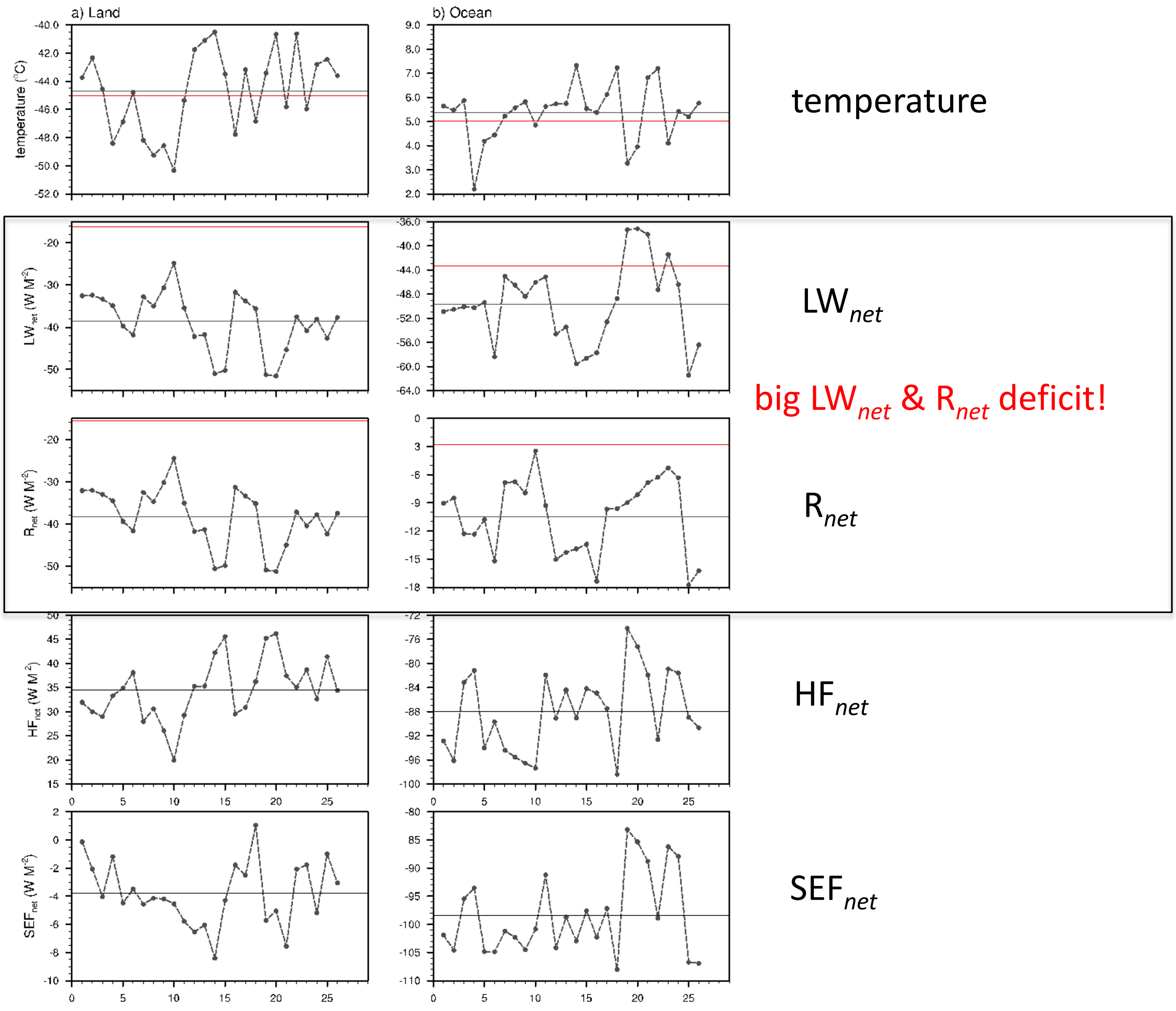
LW_{net}

R_{net}

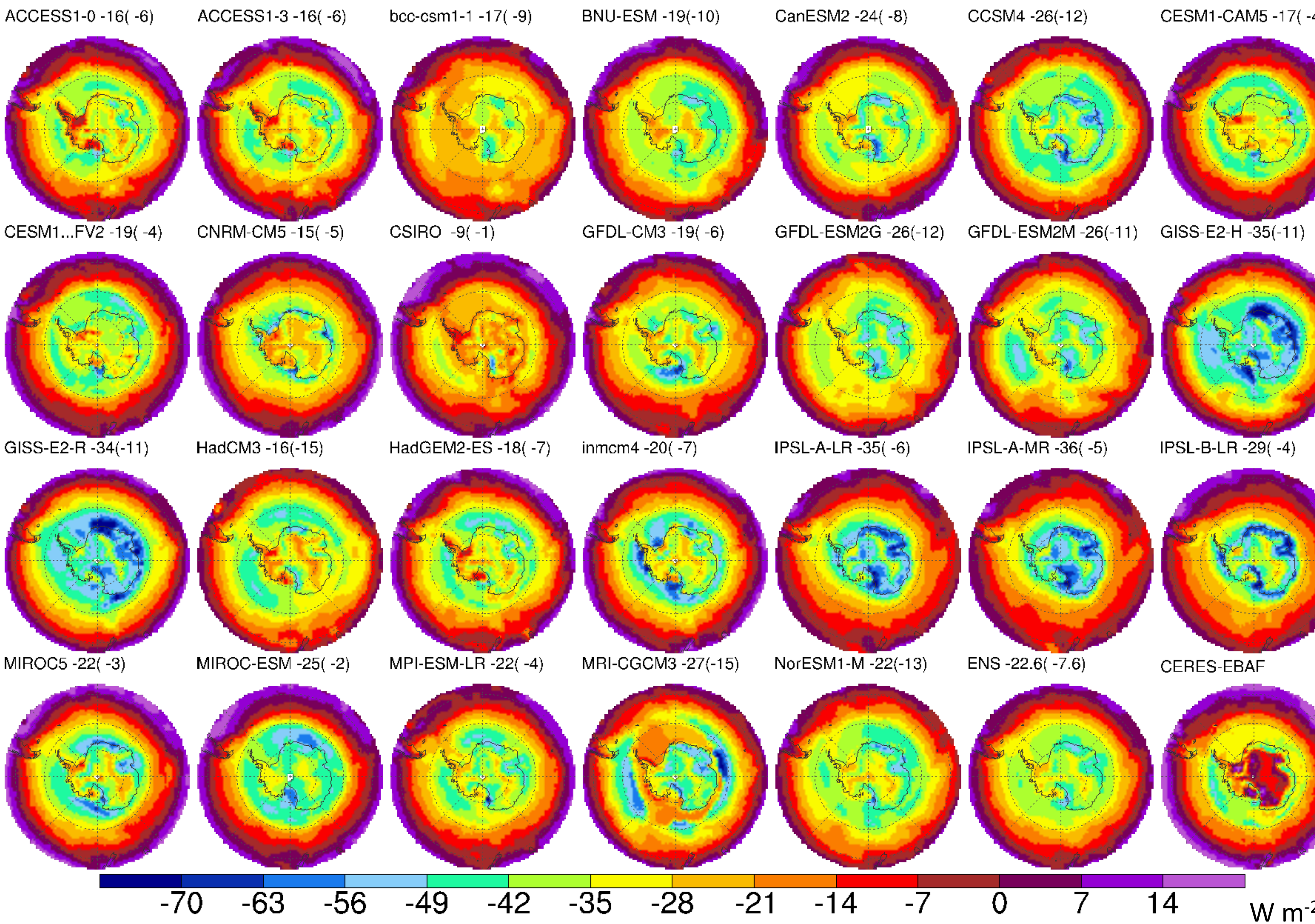
HF_{net}

SEF_{net}

Inter-model spread (JJA): $SEF_{net} = (SW_{net} + LW_{net}) + HF_{net}$

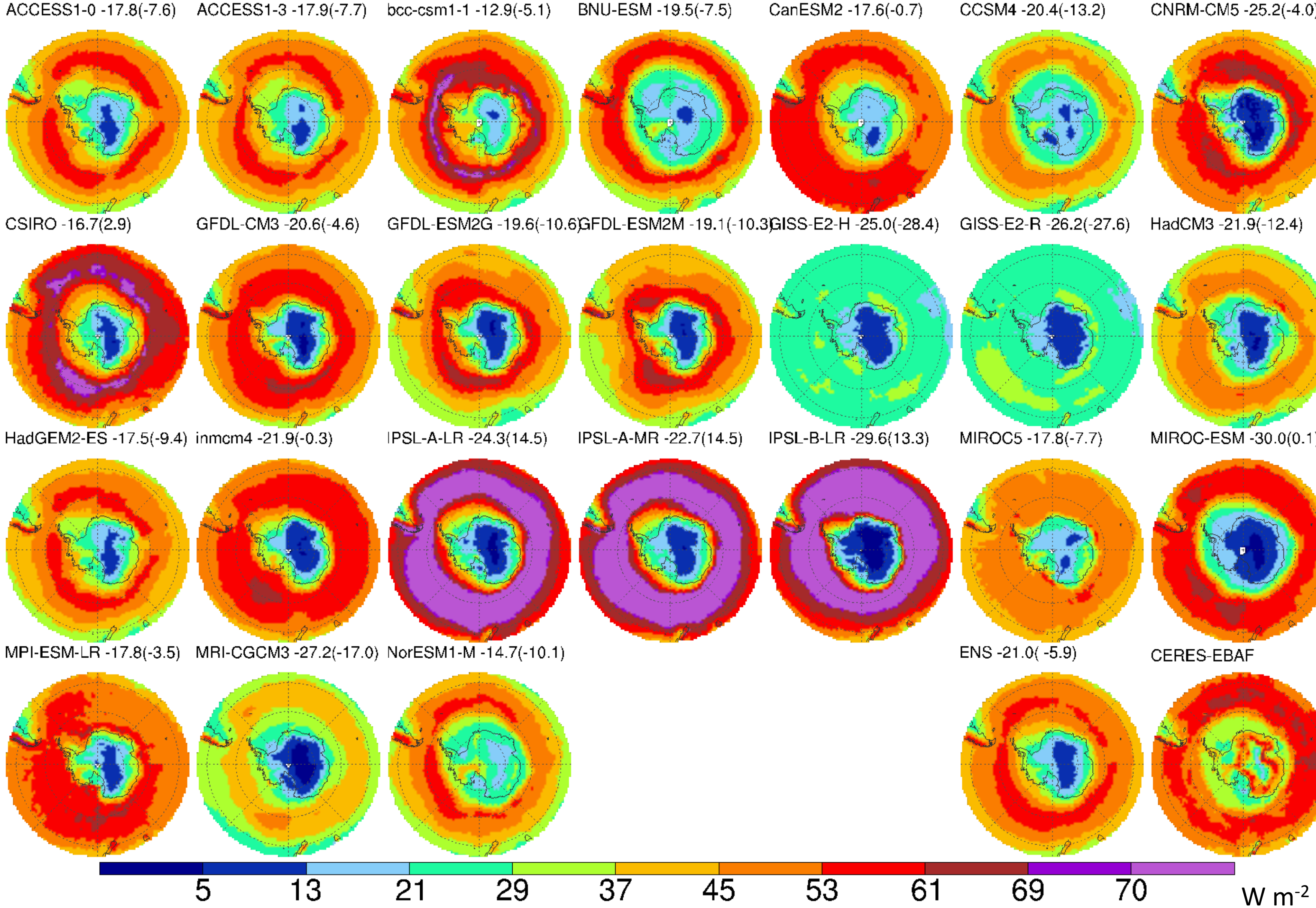


R_{net} (JJA)



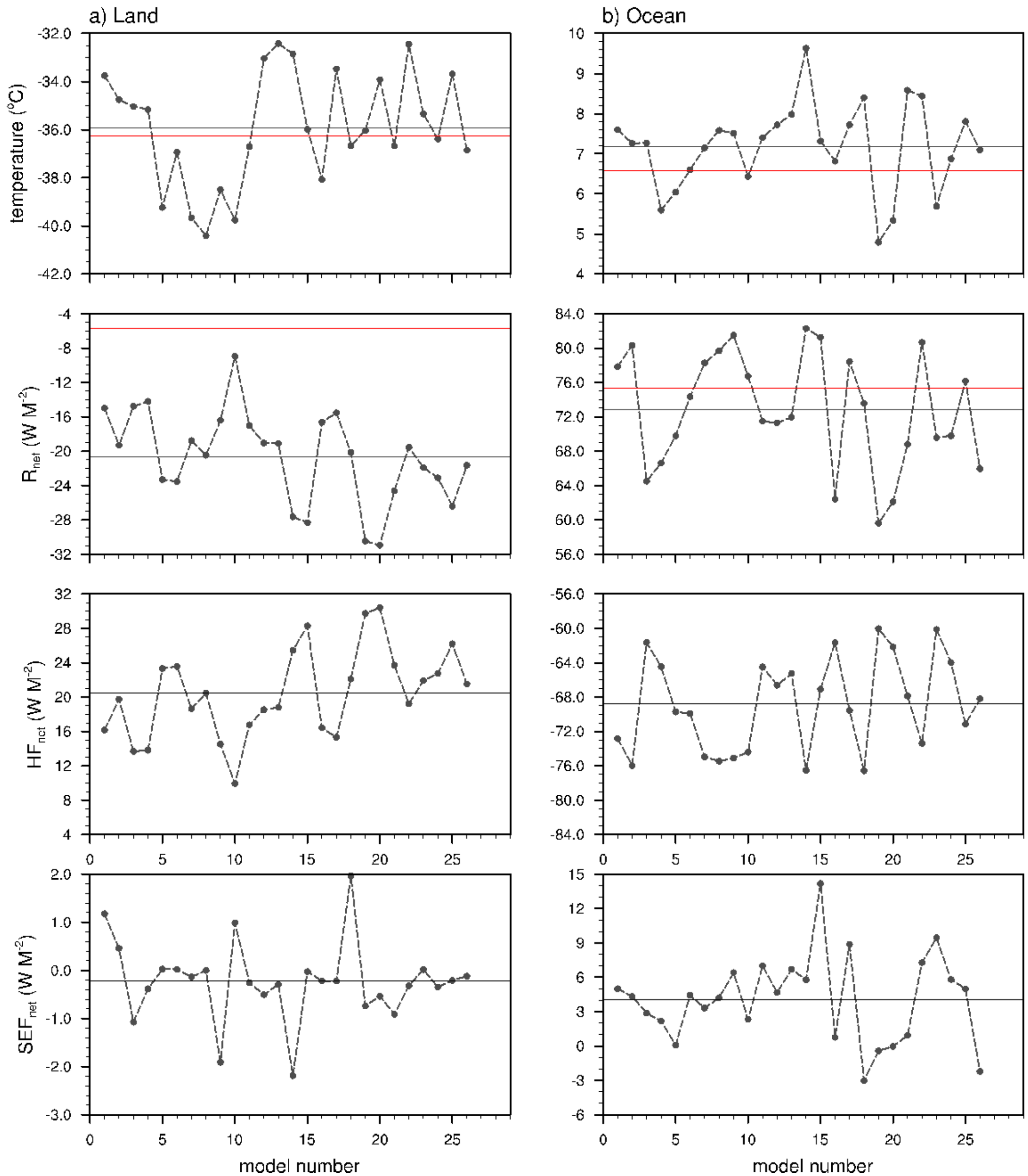
ACCESS1-0 -16(-6)
ACCESS1-3 -16(-6)
bcc-csm1-1 -17(-9)
BNU-ESM -19(-10)
CanESM2 -24(-8)
CCSM4 -26(-12)
CESM1-CAM5 -17(-4)
CESM1...FV2 -19(-4)
CNRM-CM5 -15(-5)
CSIRO -9(-1)
GFDL-CM3 -19(-6)
GFDL-ESM2G -26(-12)
GFDL-ESM2M -26(-11)
GISS-E2-H -35(-11)
GISS-E2-R -34(-11)
HadCM3 -16(-15)
HadGEM2-ES -18(-7)
inmcm4 -20(-7)
IPSL-A-LR -35(-6)
IPSL-A-MR -36(-5)
IPSL-B-LR -29(-4)
MIROC5 -22(-3)
MIROC-ESM -25(-2)
MPI-ESM-LR -22(-4)
MRI-CGCM3 -27(-15)
NorESM1-M -22(-13)
ENS -22.6(-7.6)
CERES-EBAF
-70 -63 -56 -49 -42 -35 -28 -21 -14 -7 0 7 14
W m-2

Longwave cloud radiative effect at surface (JJA): $CRE_{LW} = (LW_{d\ all\text{-}sky} - LW_{d\ clear\text{-}sky})$*



*e.g. Stephens et al., 2012, J. Climate

Inter-model spread (ANN): $SEF_{net} = R_{net} + HF_{net}$



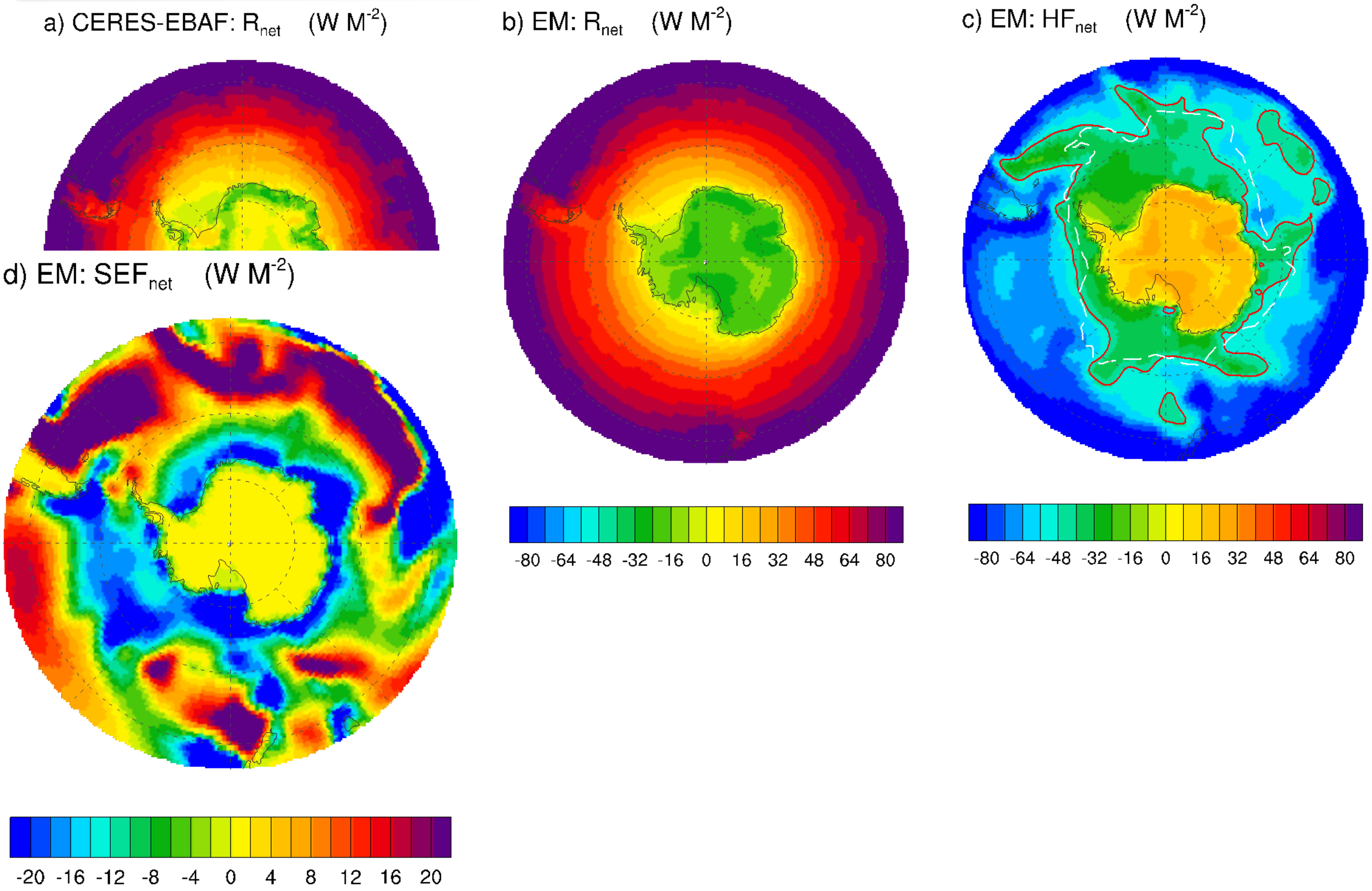
temperature

R_{net}

HF_{net}

SEF_{net}

Ensemble mean (ANN): $SEF_{net} = R_{net} + HF_{net}$



Marshall and Speer, 2012

Summary

1. In summer: Warm bias over Southern Ocean in majority of models and ensemble mean

   -lags biases in SW_{net} and SWCF in late spring thru mid summer
   -SWCF explains model spread in SAT, ASR, R_{net}, etc. and model spread in SAT persists throughout year
   -however, annual R_{net} bias on ocean is negative in ensemble mean

2. In winter: Strong negative R_{net} and LW_{net} bias on the Antarctic ice sheet in ***all models (!)***

   -largely accounted for by LW_d
   -suggests lower atmosphere too stable (strong inversion)
   -associated with longwave CRE
   -compensated by large sensible heat flux
   -leads to annual R_{net} negative bias on ice sheet

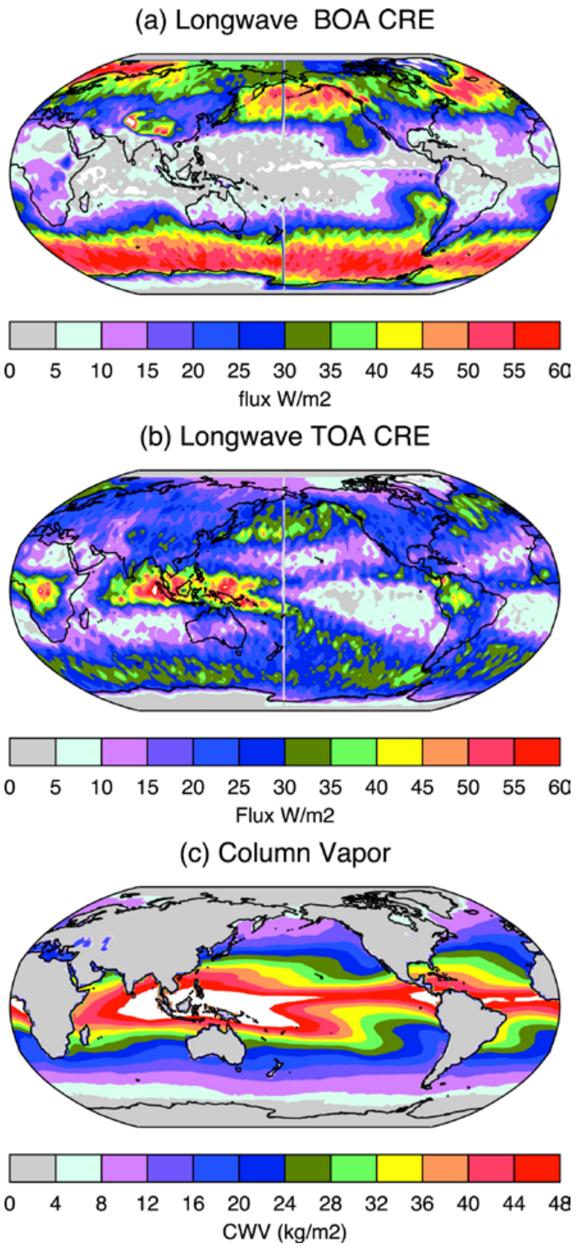
3. Models exhibit a relatively wide range of surface albedo on the ice sheet

   -regulates amount of shortwave radiation absorbed and contributes to model spread in SAT
   -some models have uniform albedo and some have complex spatial structure

4. Several biases are difficult to quantify

   -SAT bias on the Antarctic Ice Sheet? Reanlayses are very problematic for addressing this.
   -heat fluxes on both the ocean and ice sheet
   *turbulent heat fluxes (sensible + latent) are probably too large in most models on the ice sheet
   *ensemble mean net annual air-surface heat flux (radiation + sensible + latent) pattern looks reasonable over ocean but too uniform over land

TOA vs BOA CRE



Stephens et al., 2012, J. Climate