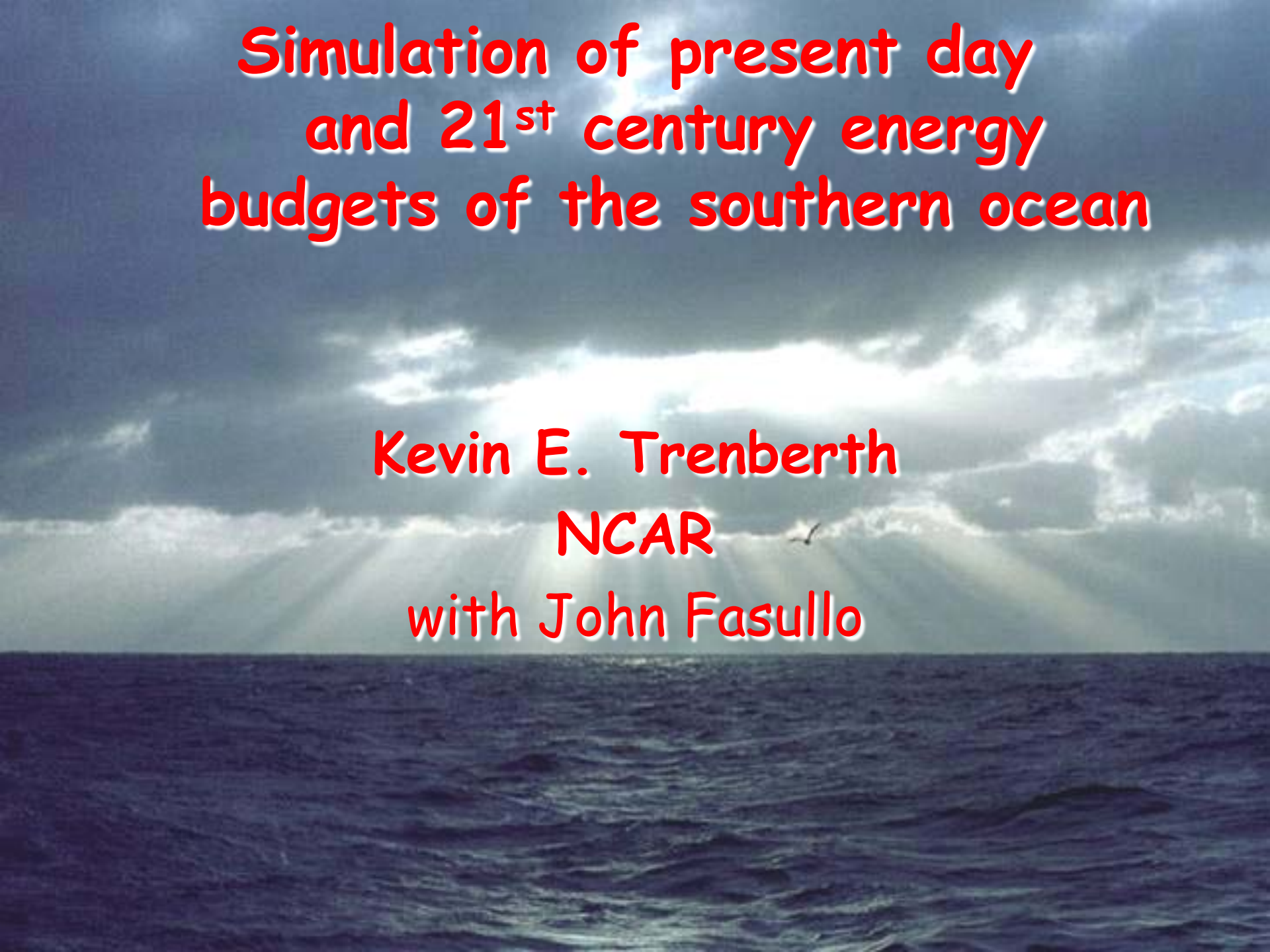
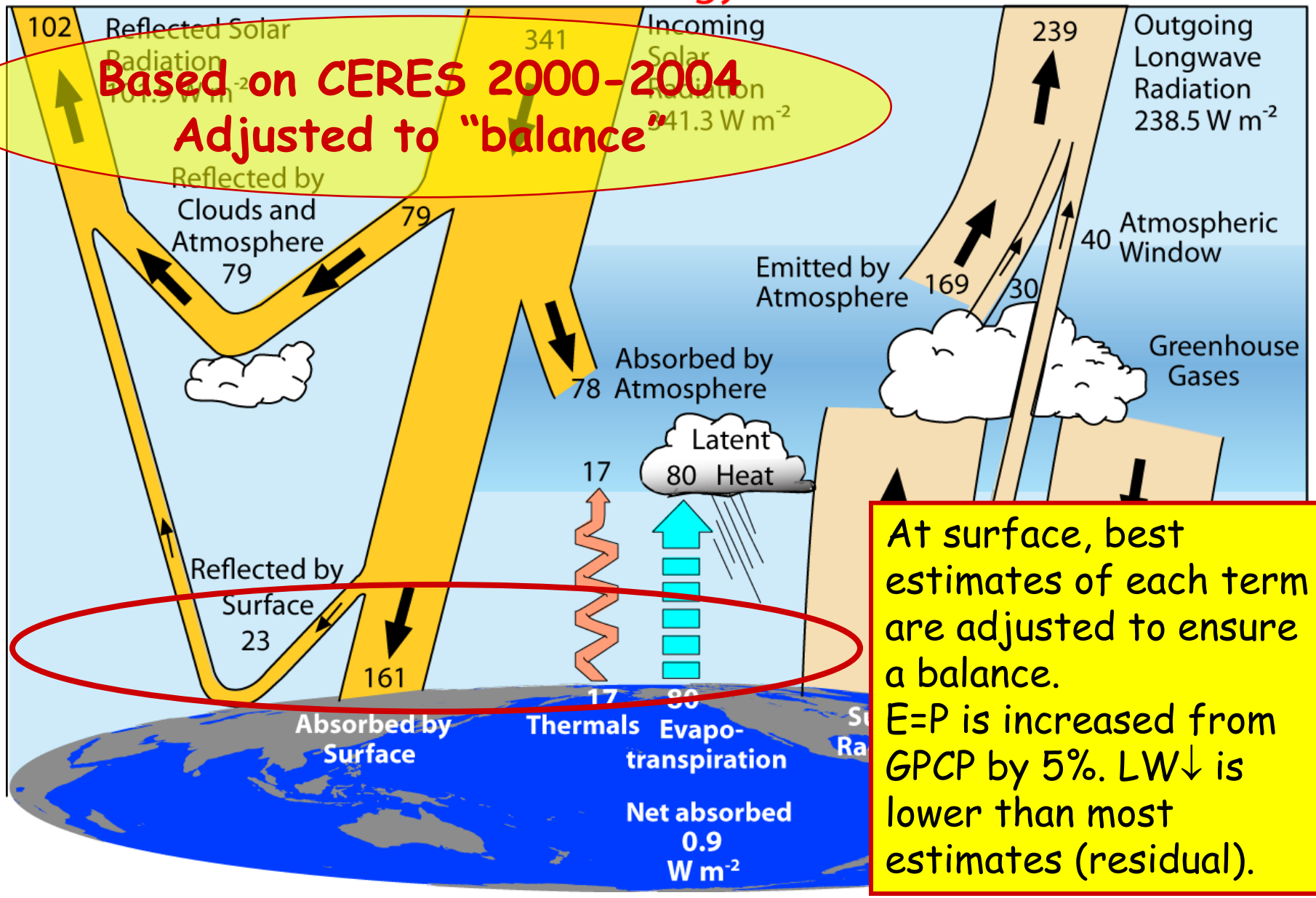


Simulation of present day and 21st century energy budgets of the southern ocean

Kevin E. Trenberth
NCAR
with John Fasullo

Global Energy Flows W m^{-2}



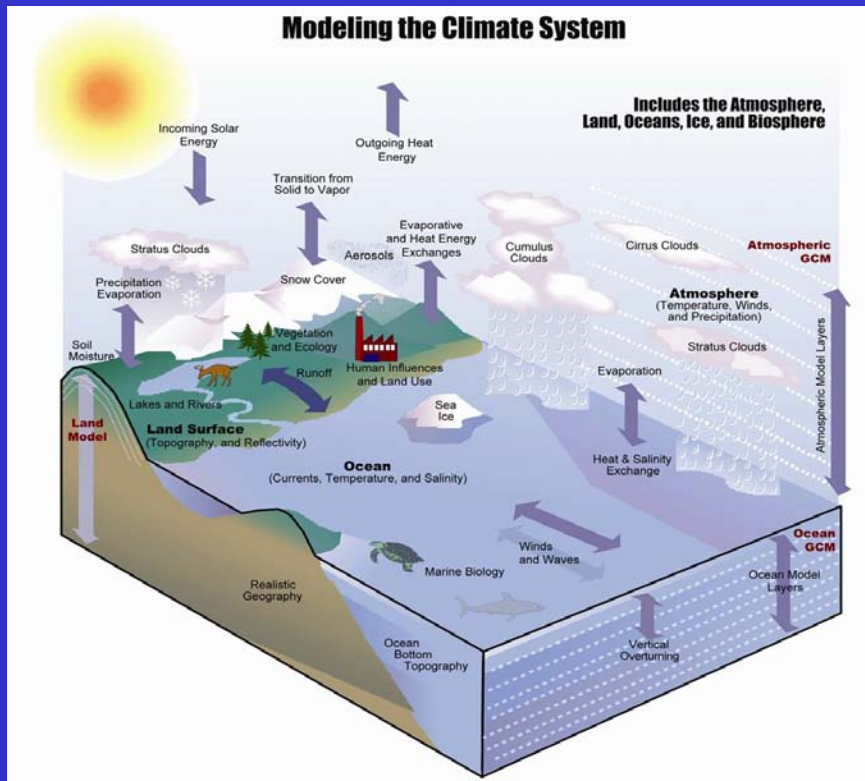
At surface, best estimates of each term are adjusted to ensure a balance.
E=P is increased from GPCP by 5%. LW↓ is lower than most estimates (residual).

Trenberth et al 2009 BAMS

Evaluation of models

- Reanalysis models: atmospheric
- CMIP3 AR4 models

- Focus on energy



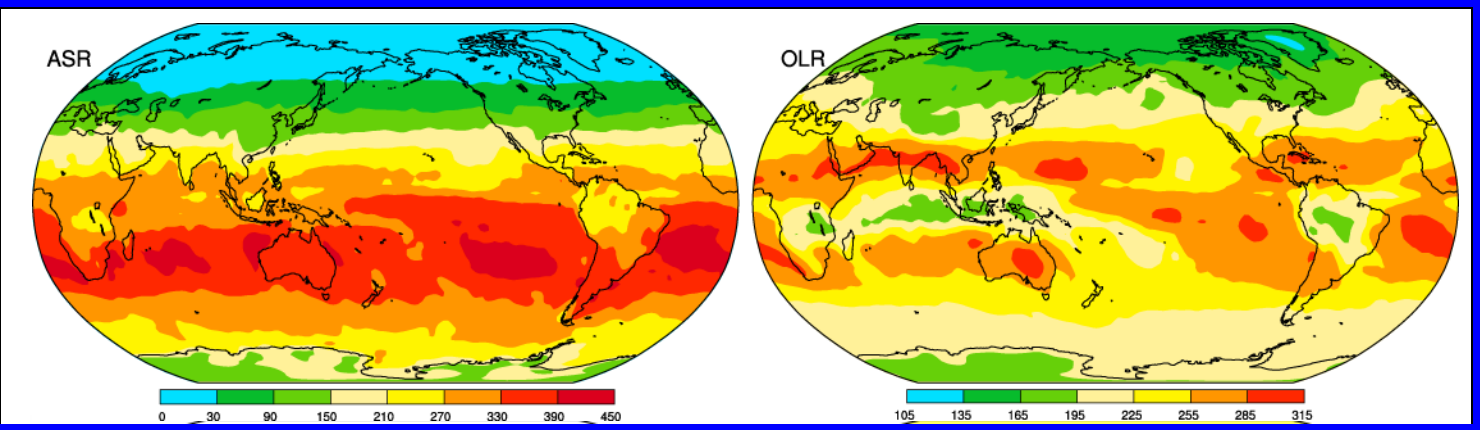
Energy budget: Reanalyses

- At TOA, most climate models are tuned to get balance or replicate ERBE/CERES
- Depends on equilibrium simulation
- No longer works in reanalyses
  - Specified SSTs
- Global imbalances (hide even bigger local)

	NRA	ERA-40	JRA	MERRA	
ASR	-15	-3	+5	+6	W m^{-2}
OLR	-1	+6	+15	+4	
Net(TOA)	-14	-9	-10	+2	
Net (sfc)	0	+4	-14	+14	

Mostly for 1979-2001 vs climatology

ASR OLR Jan 1989

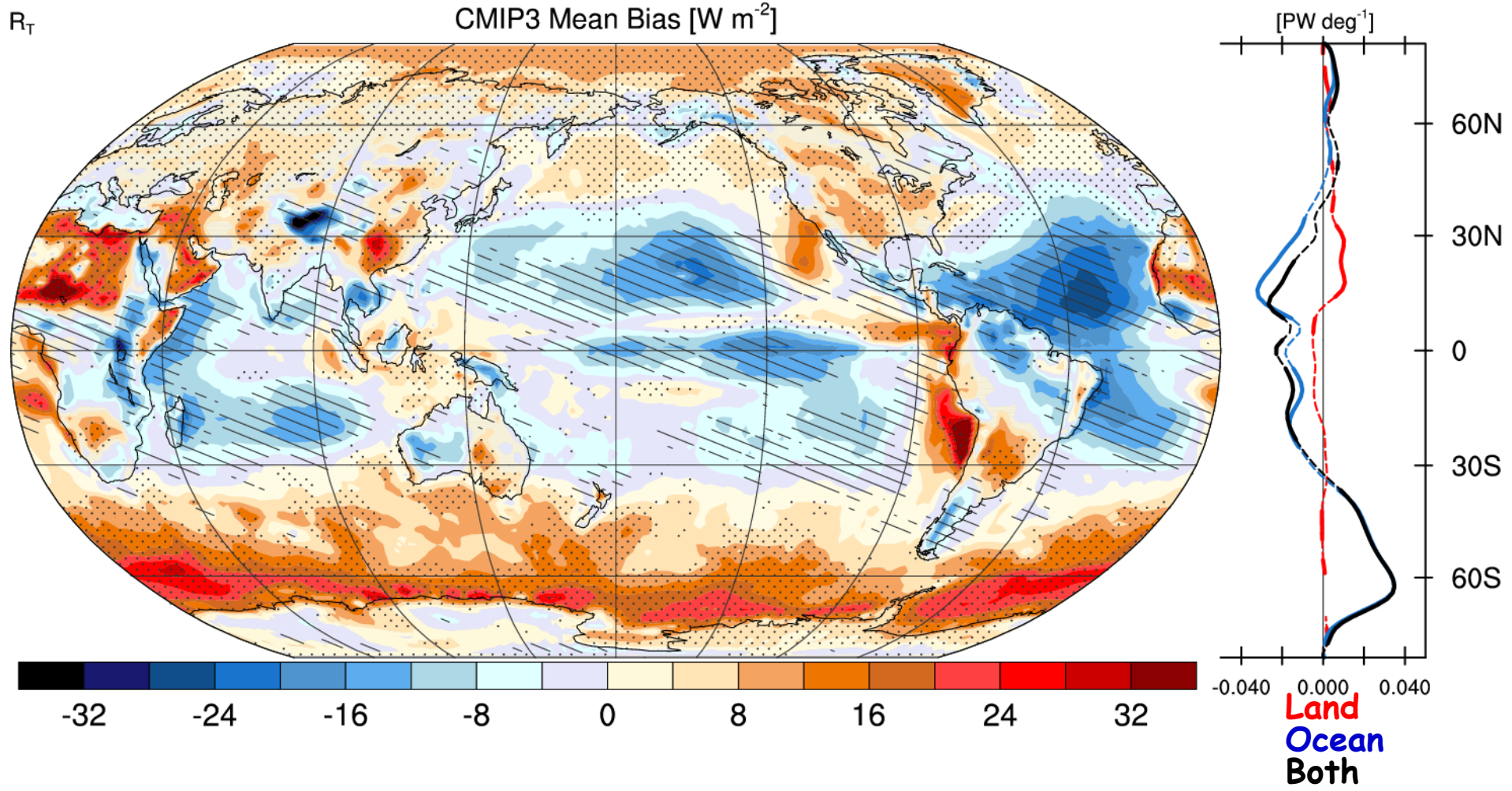


ERBE

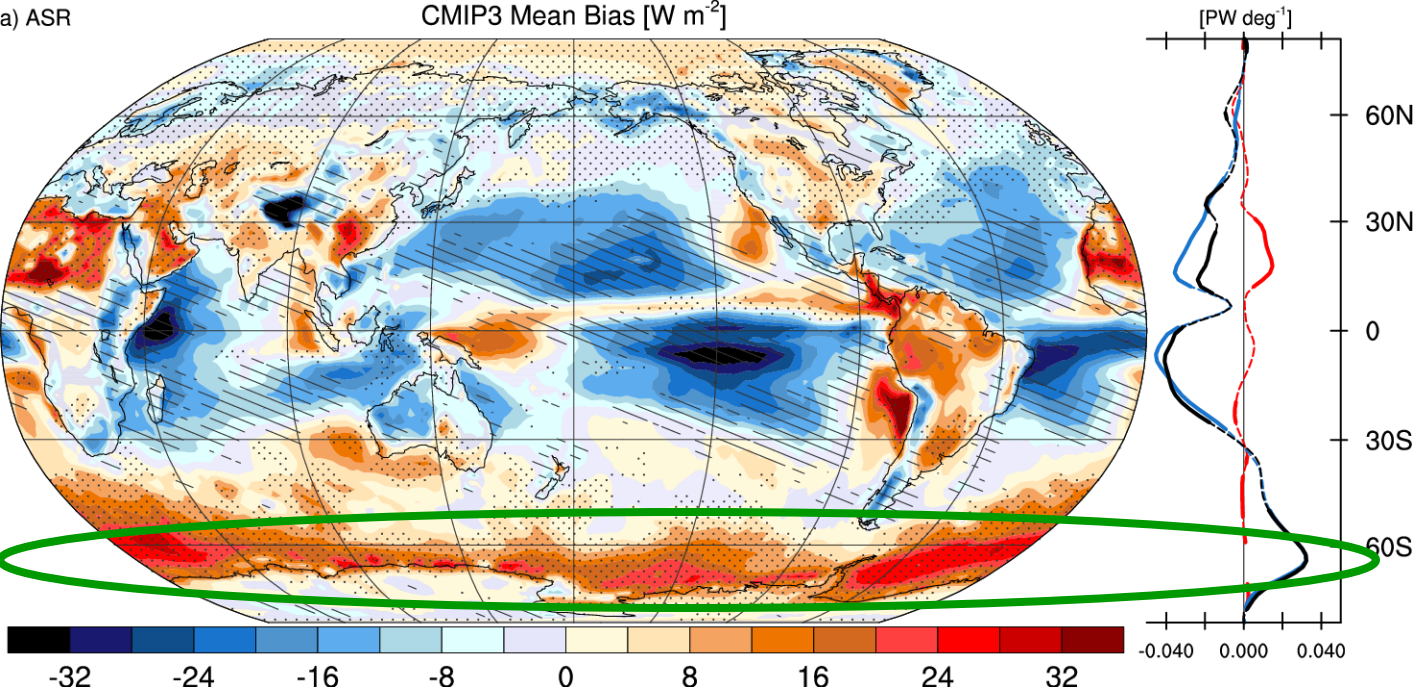
W m^{-2}

CMIP3 model biases: 1990-99

Net TOA radiation down

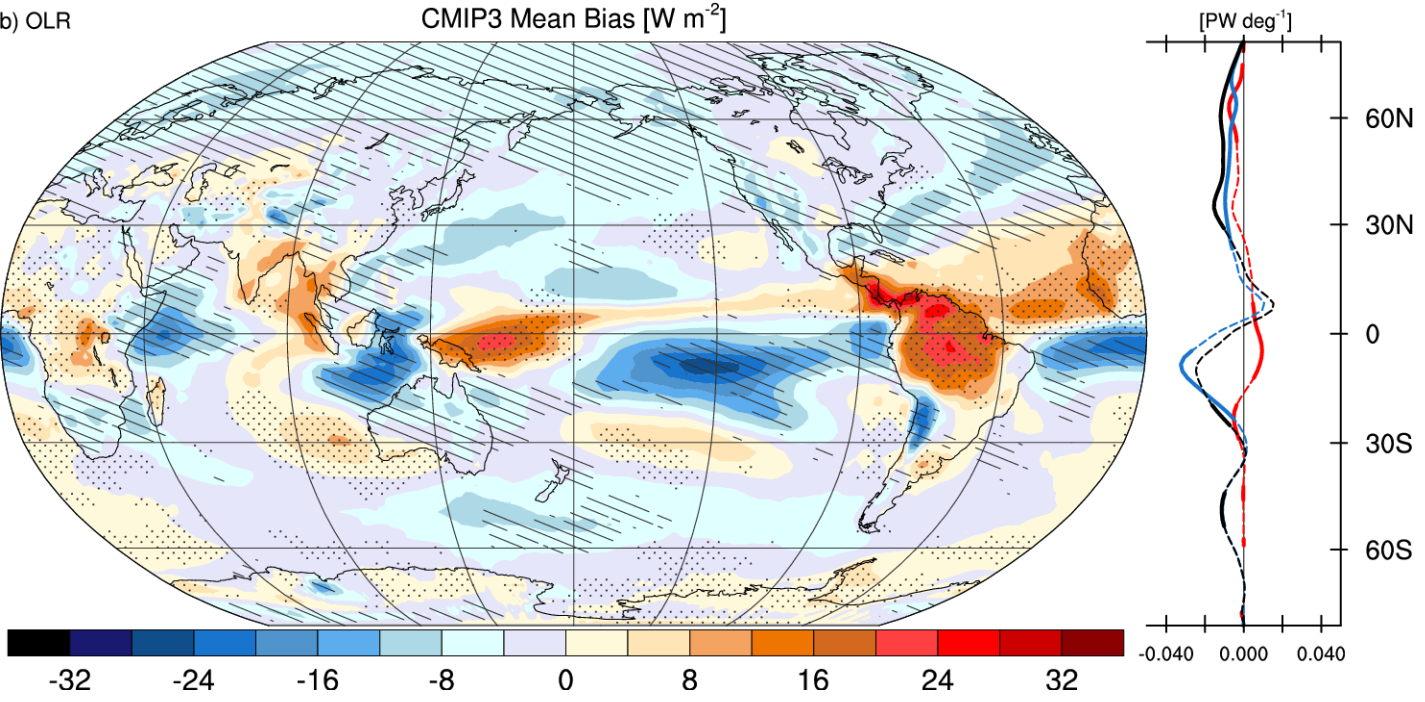


Stipple or hatching: where 75% of models agree in sign

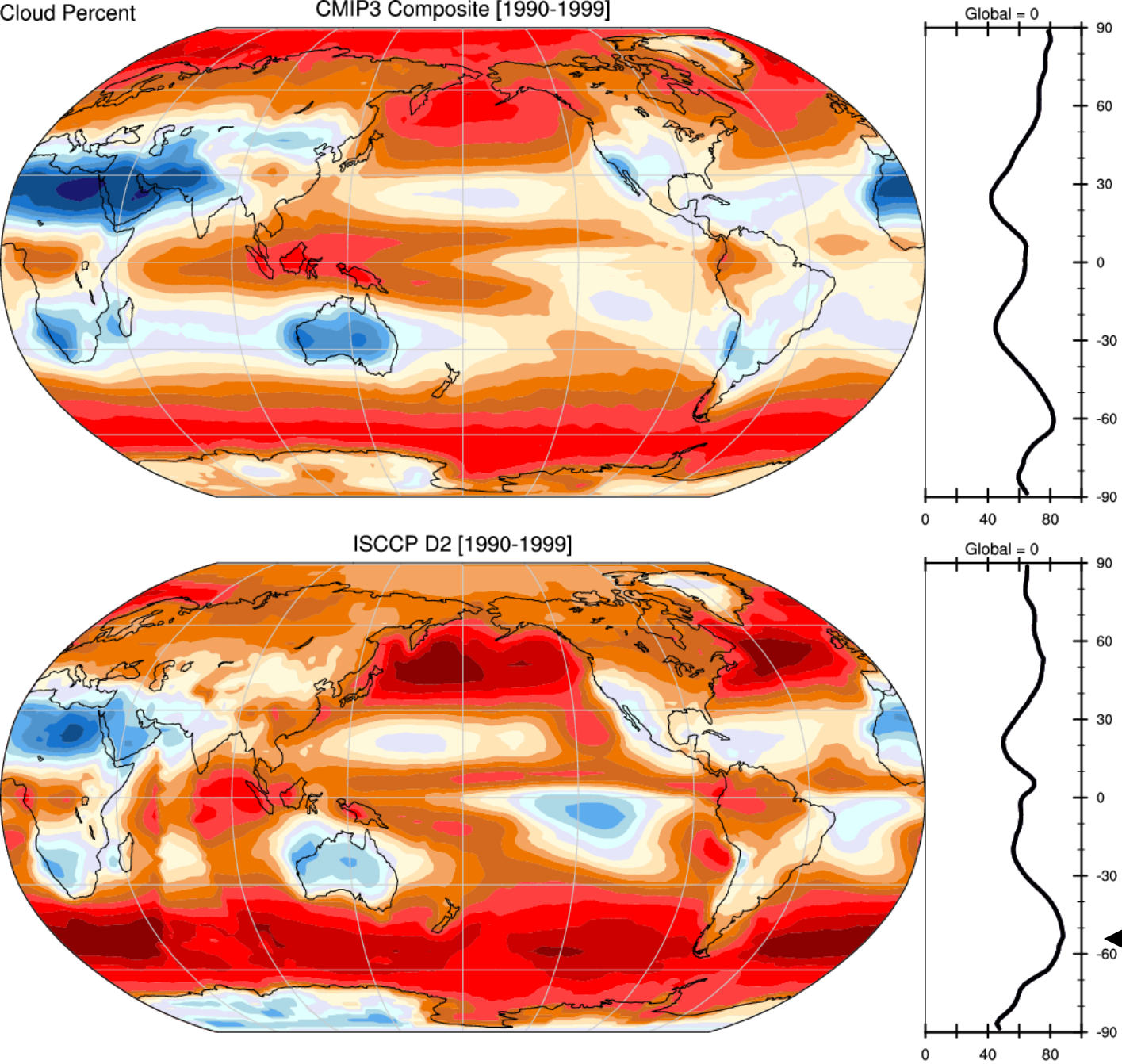


CMIP3 model biases

Too much

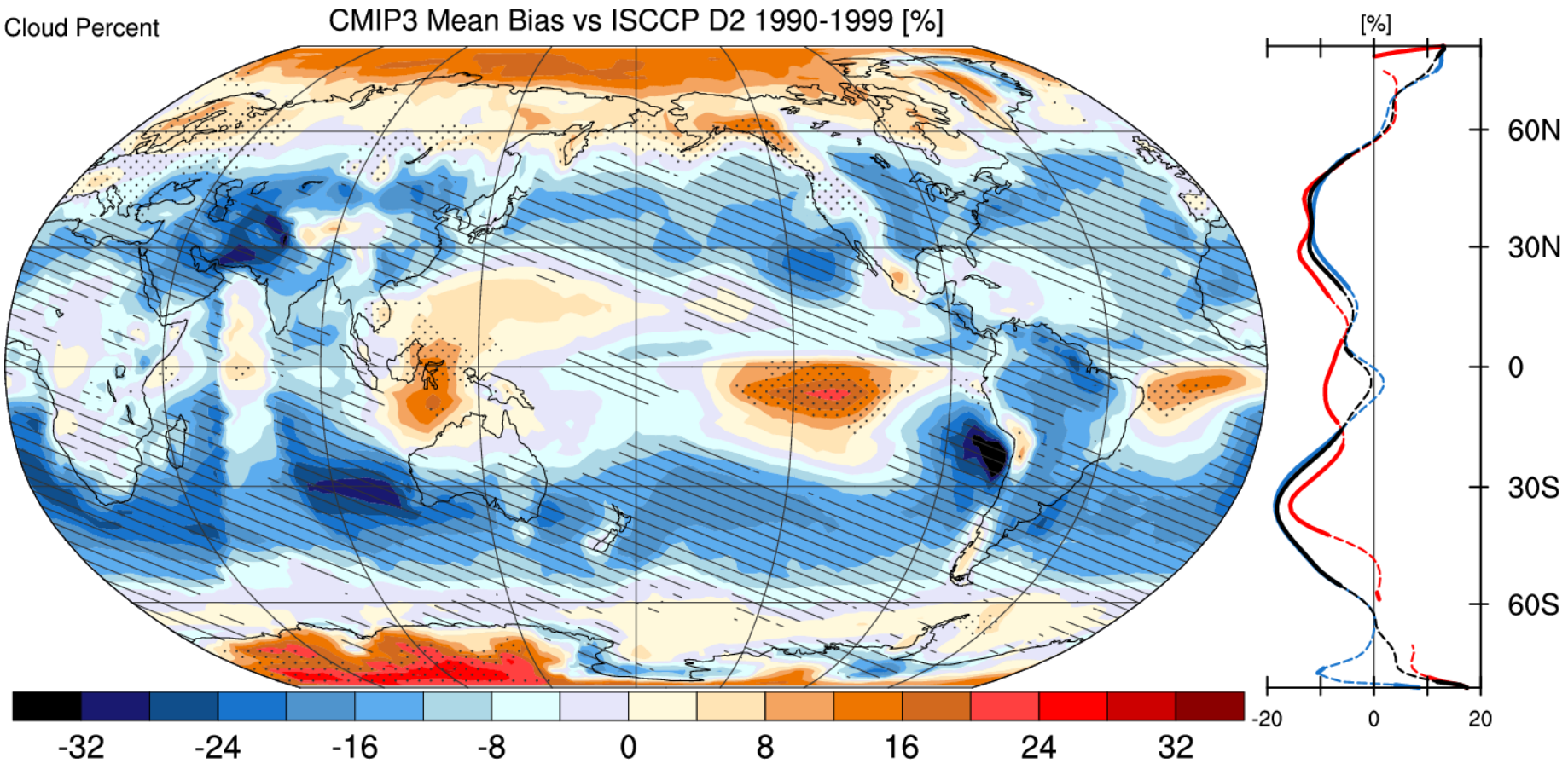


Stipple or hatching: where 75% of models agree in sign

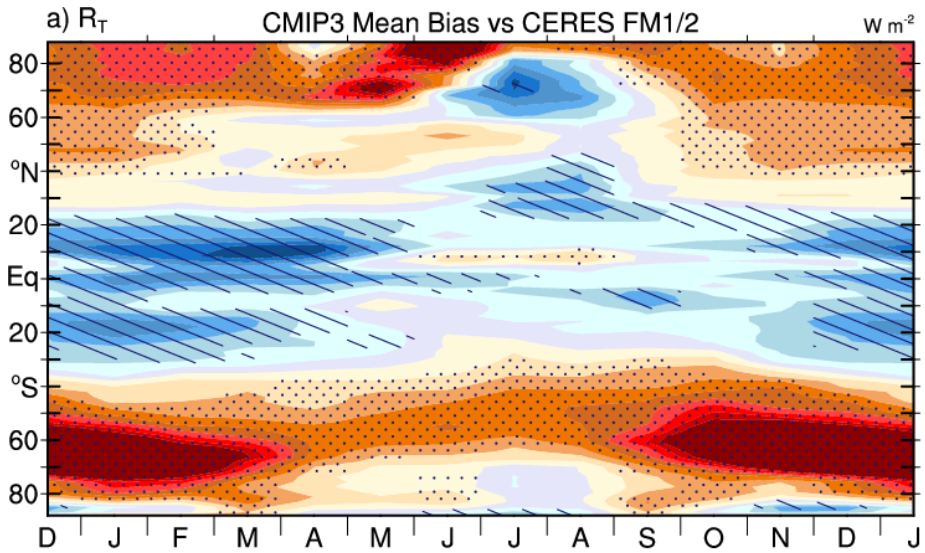

Cloud Percent
CMIP3 Composite [1990-1999]
Global = 0
90
60
30
0
-30
-60
-90
0
40
80
ISCCP D2 [1990-1999]
Global = 0
90
60
30
0
-30
-60
-90
0
40
80
10
20
30
40
50
60
70
80
90

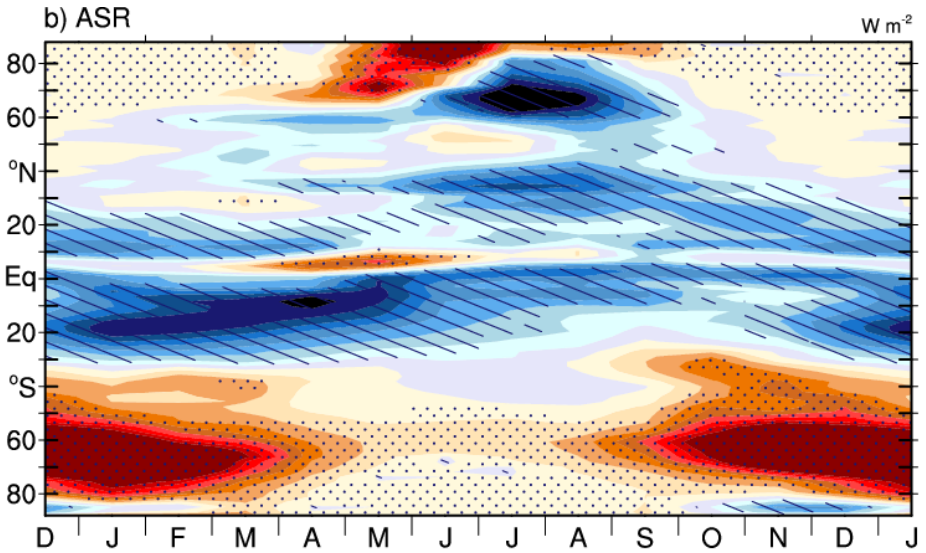
Clouds

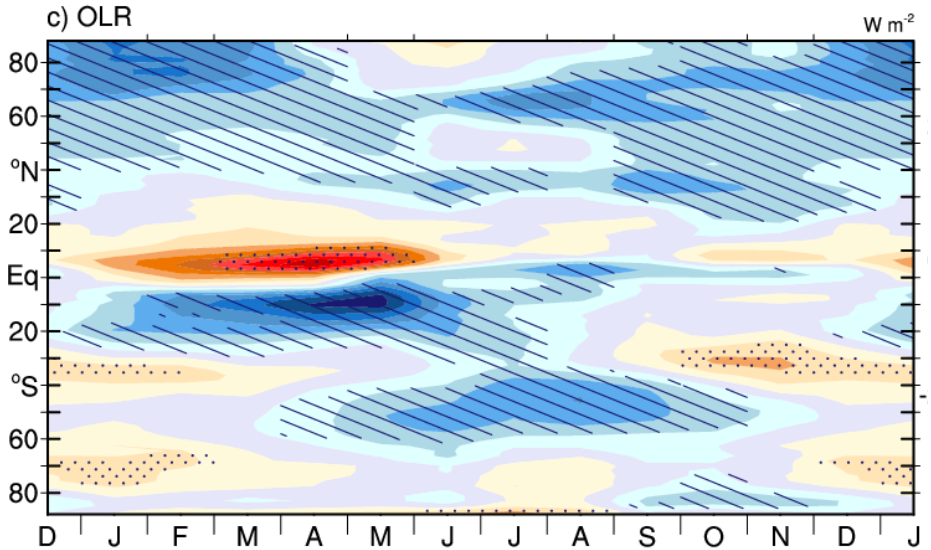
Cloud biases



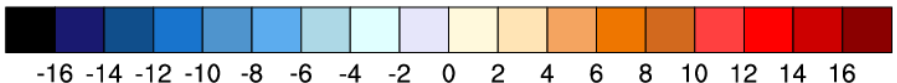
Annual cycle of biases



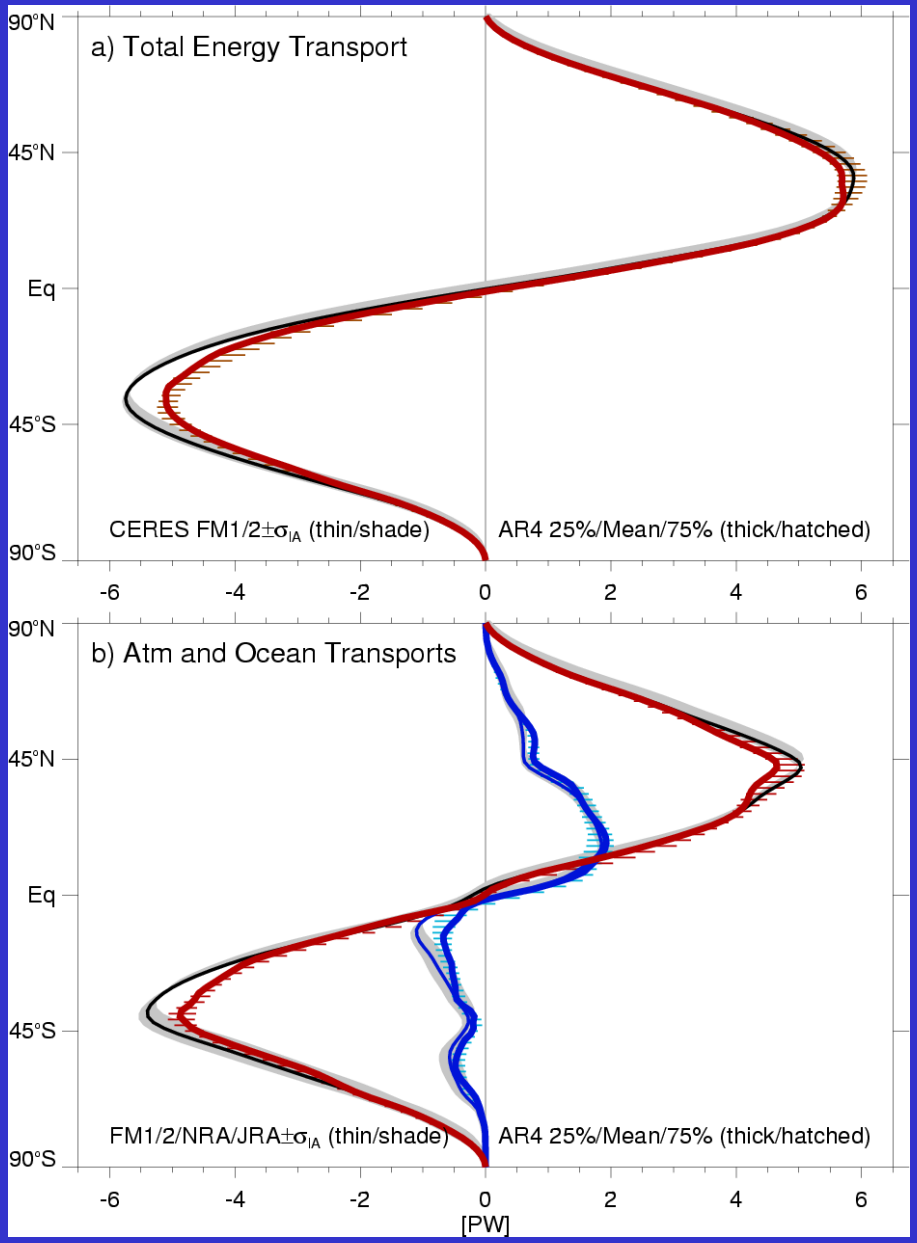




Similar errors all year round, but biggest over southern ocean in summer



CMIP3 model energy transports

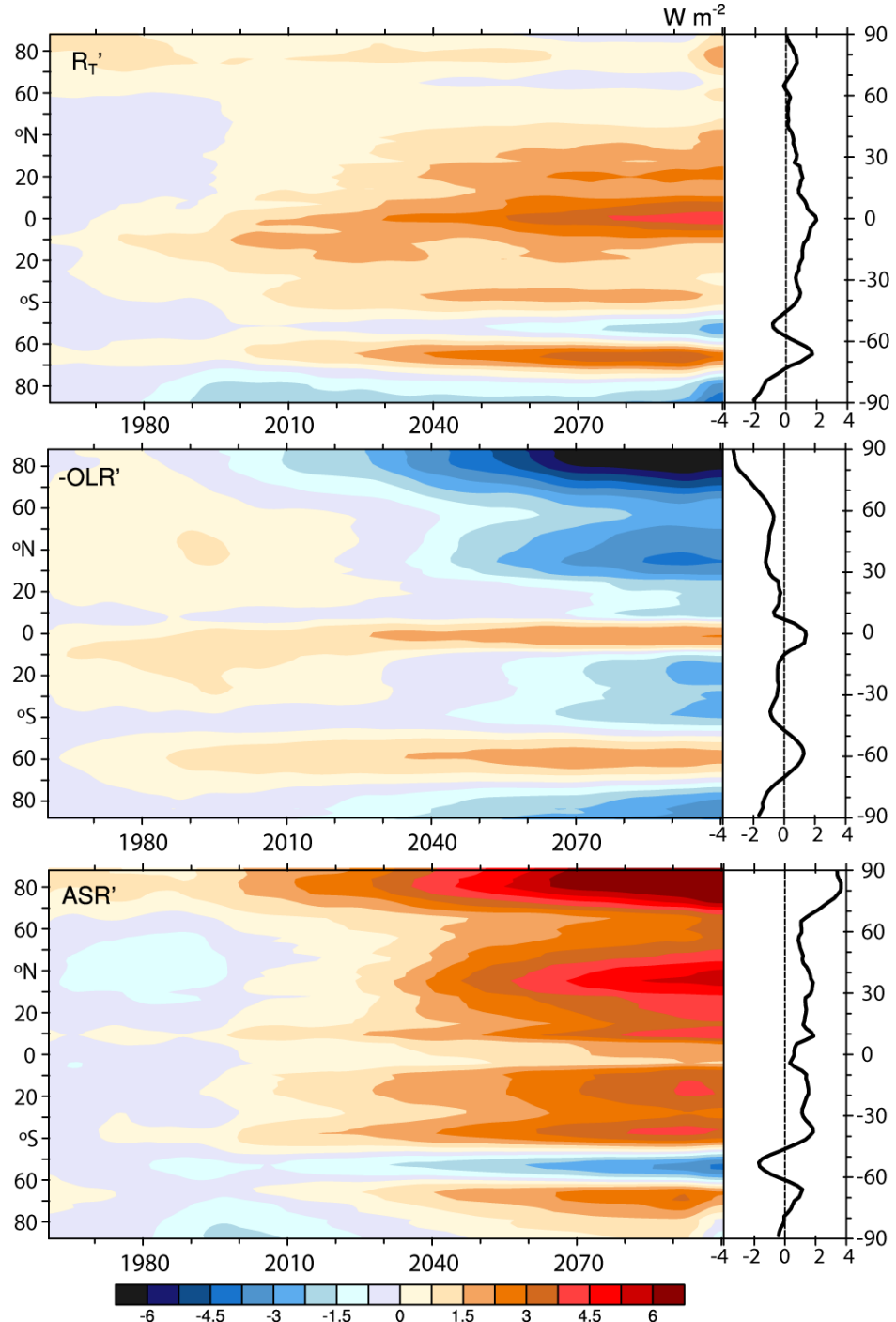


Poleward transports too low in many models owing especially to deficient cloud:

e.g. too much solar radiation absorbed in southern oceans.

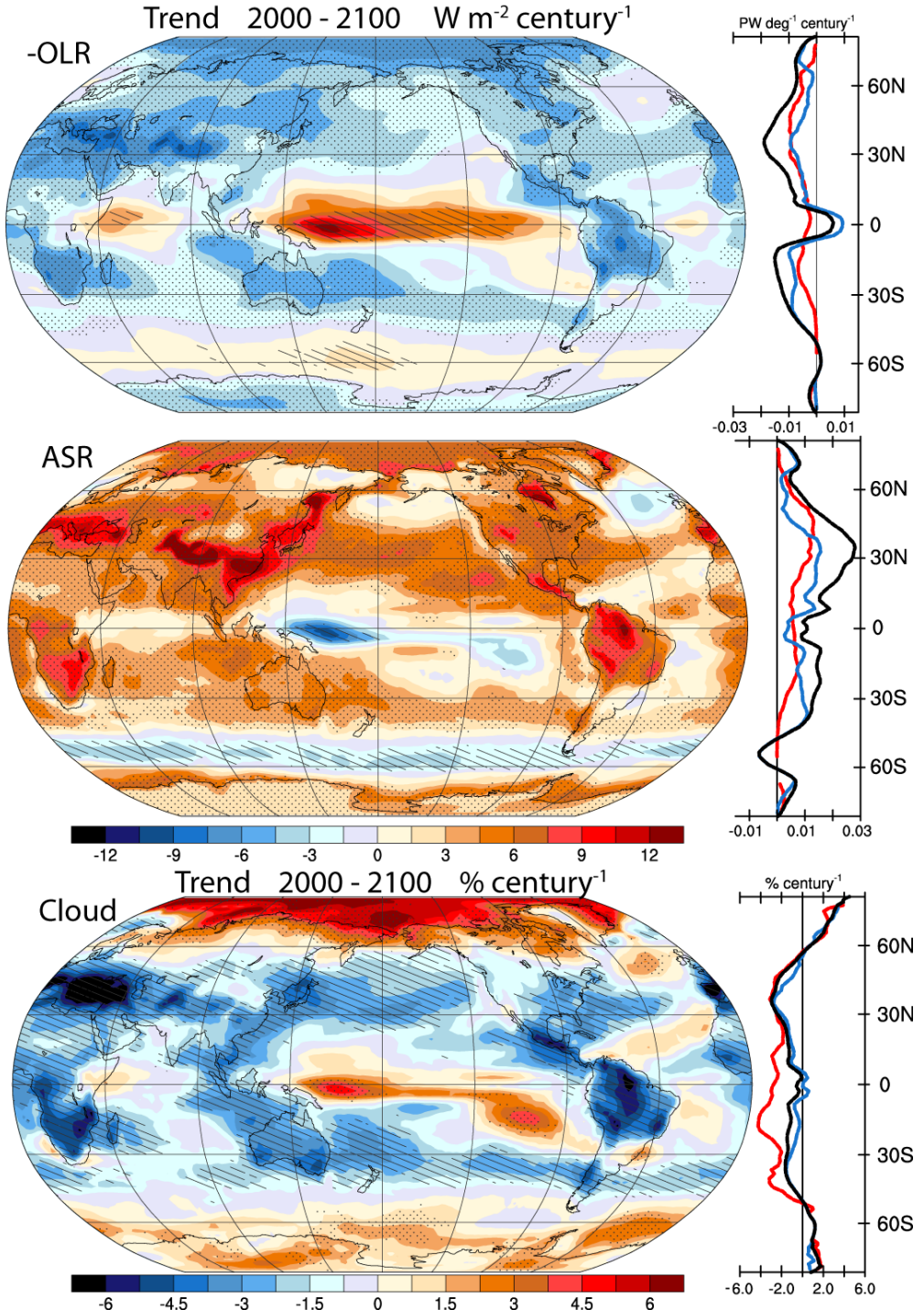
Consequences of Southern Hemisphere SW Biases

- All models have too much incoming solar radiation in southern oceans: too much heating of ocean
- And too little in lower latitudes
- True in reanalyses and climate models
- Diminishes ocean and atmospheric poleward heat transports
- Increased annual cycle of ocean temperature / energy content at middle and high-latitudes
- Increased annual cycle of net TOA radiation - projects disproportionately on SH summer



Trends
A1B
Zonal means
R_T = ASR-OLR
departures from 1900-1950

ASR increases everywhere except southern ocean



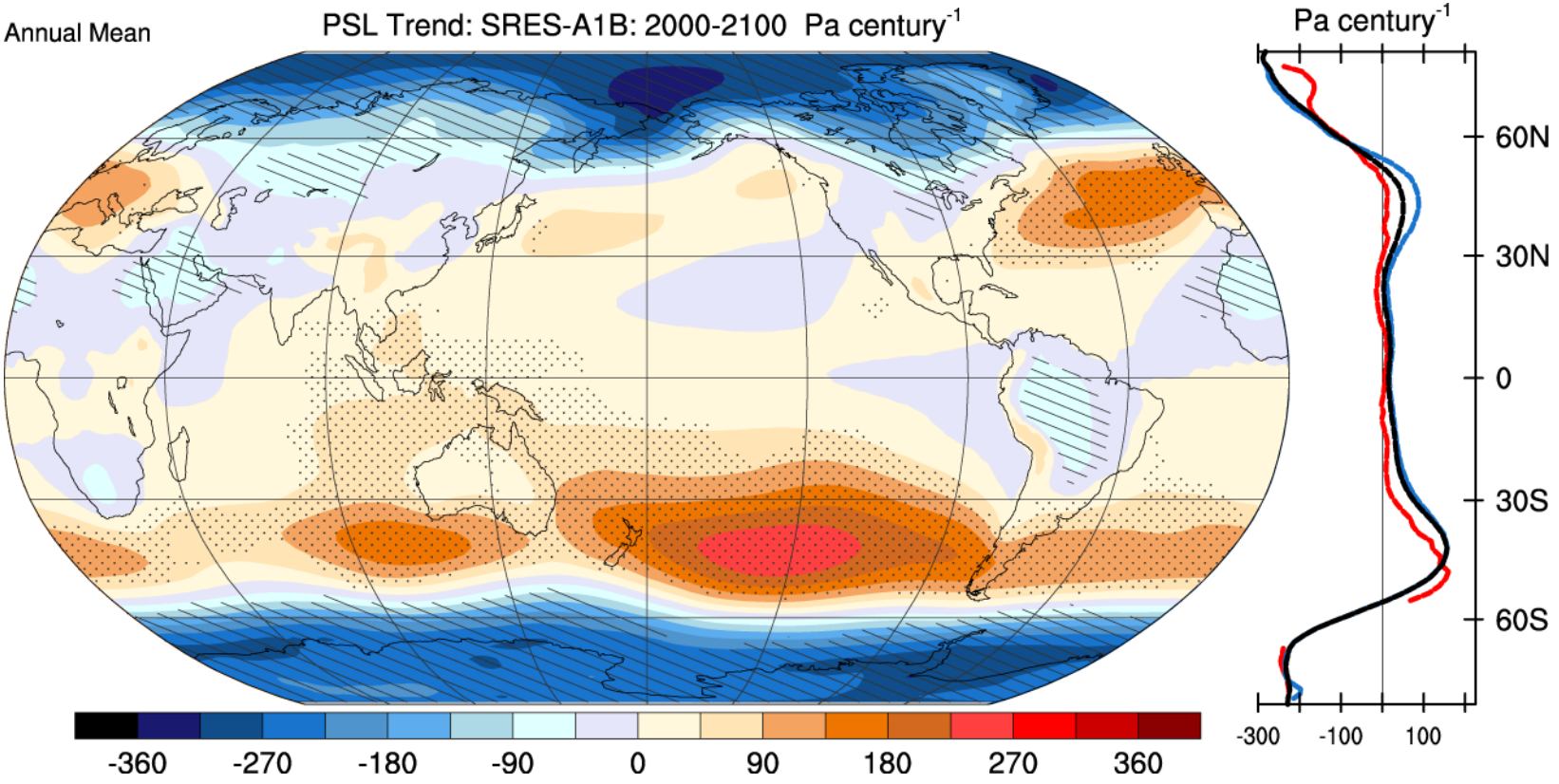
Trend 2000-2100

-OLR

ASR

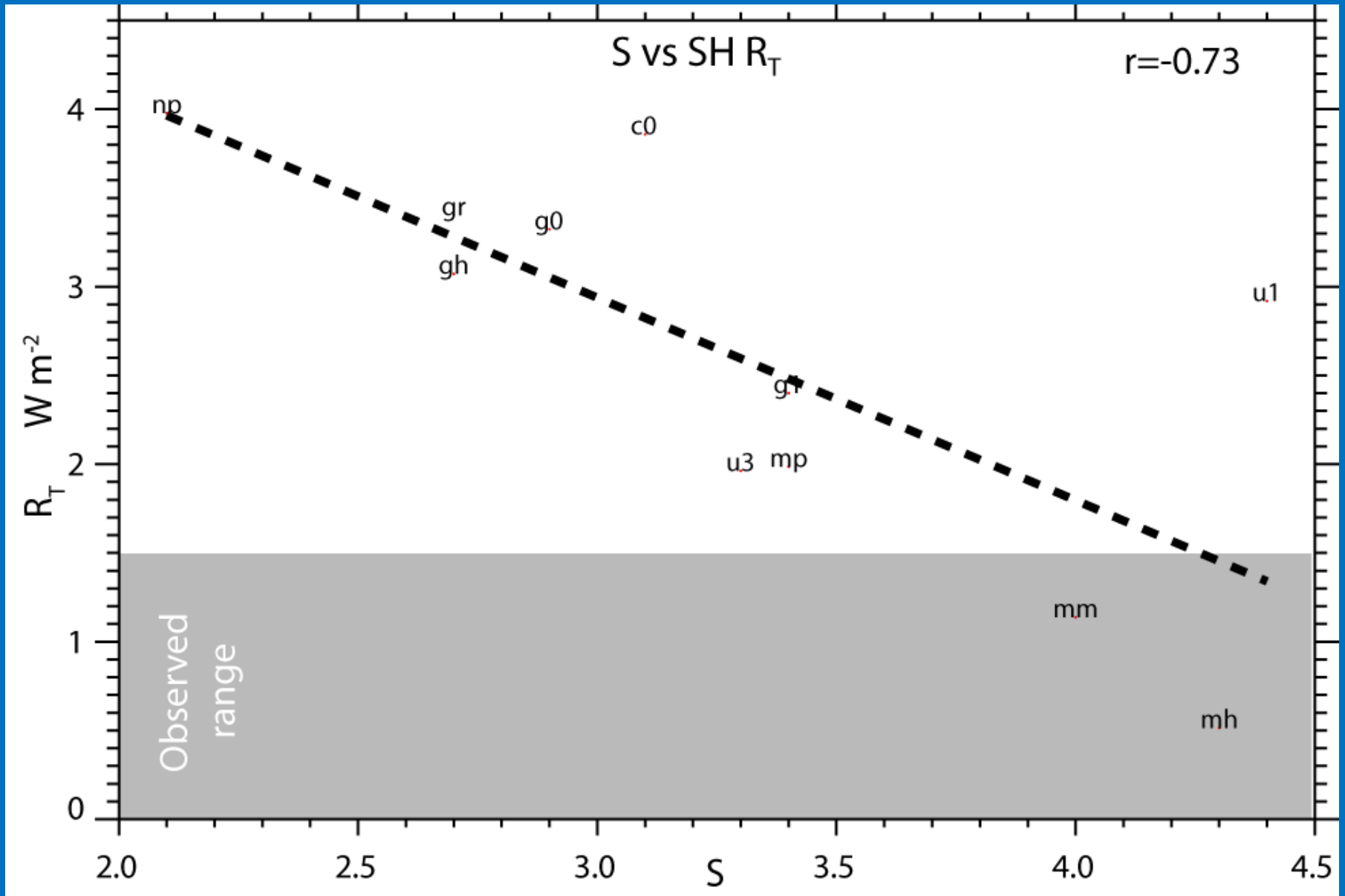
Cloud

SL pressure trend



Poleward shift in storm tracks (Yin 2005)

Climate sensitivity



Trends in Southern Hemisphere clouds and radiation

- Clouds mostly decrease in low-mid latitudes
- Clouds increase in polar areas where sea ice decreases
- These increases extend over southern oceans
- The increases relate to more cyclonic conditions (lower SLP) and poleward shift in storm tracks
- Such increases in cloud are unlikely, and can only occur because of the low bias in the model climatology