Testing the Impact of Clouds on the Radiation Budgets of 19 Atmospheric General Circulation Models

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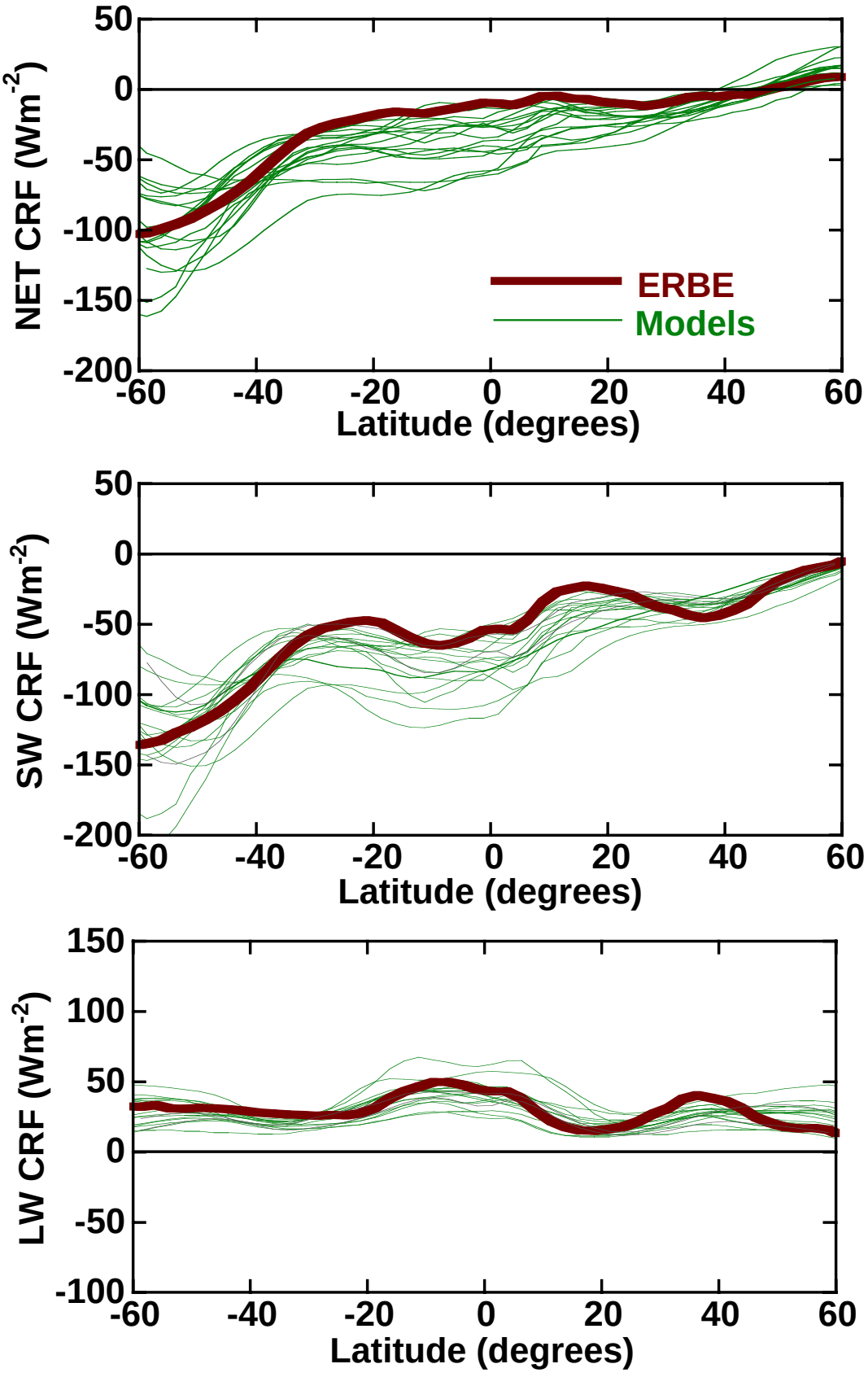
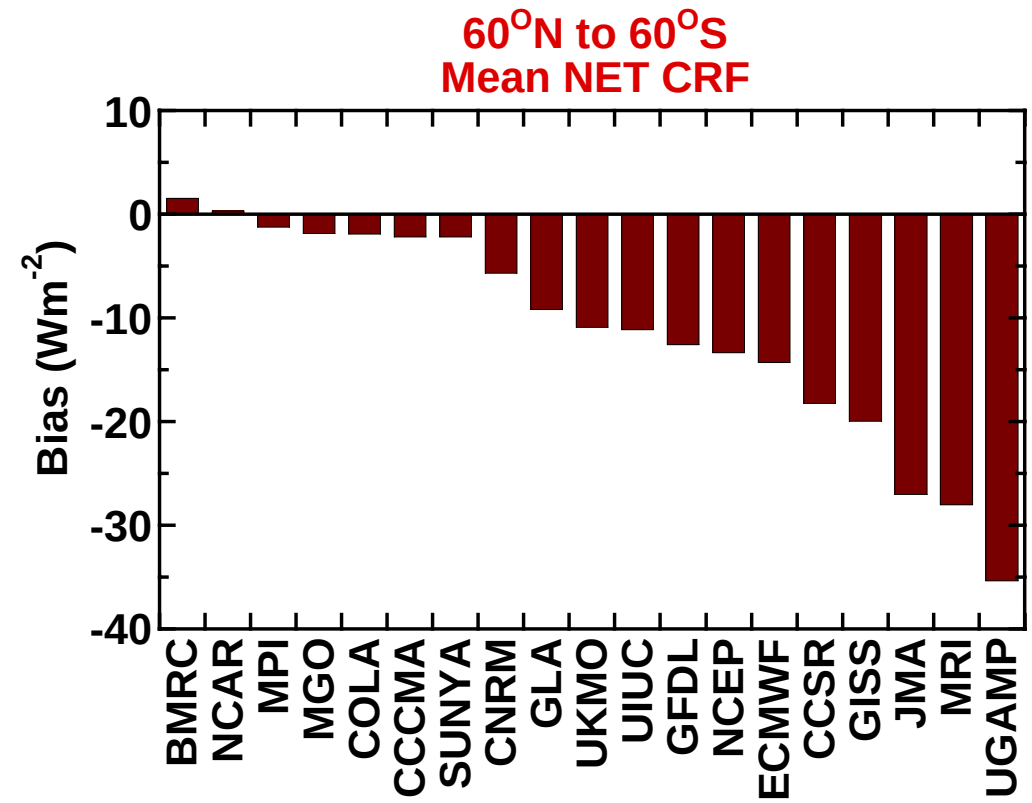
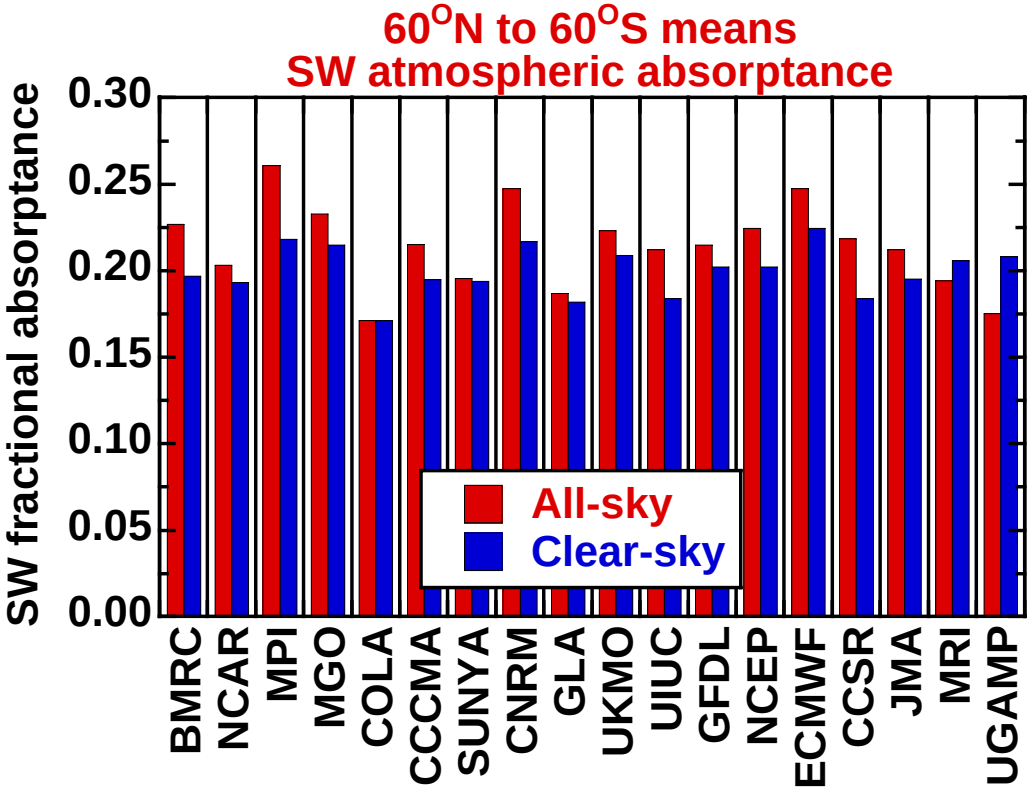
Objective

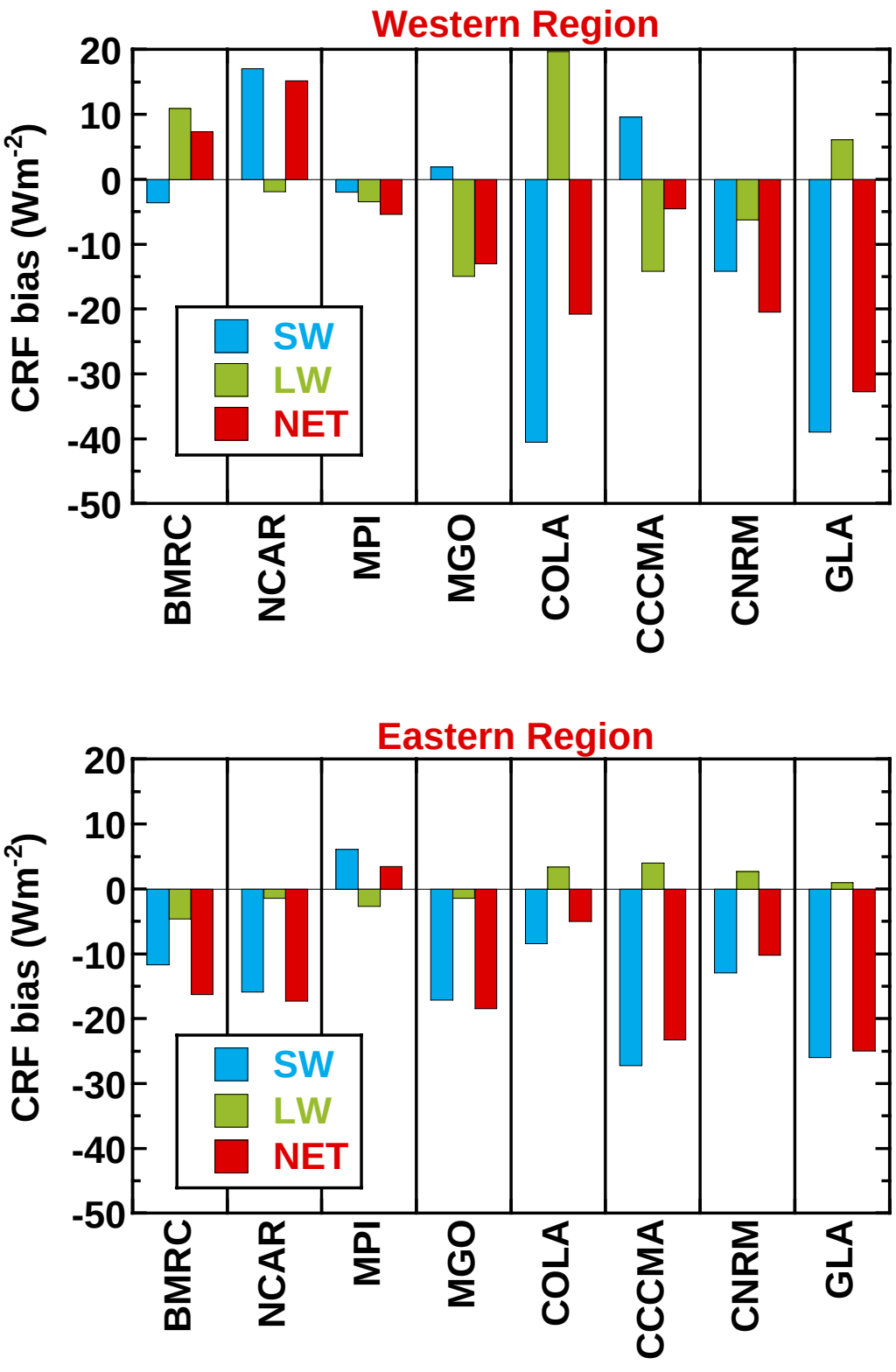
To compare cloud-radiative forcing (CRF), produced by simulations with 19 atmospheric general circulation models using prescribed SSTs, to satellite measurements of CRF by the Earth Radiation Budget Experiment (ERBE), and for the following spatial and temporal domains:

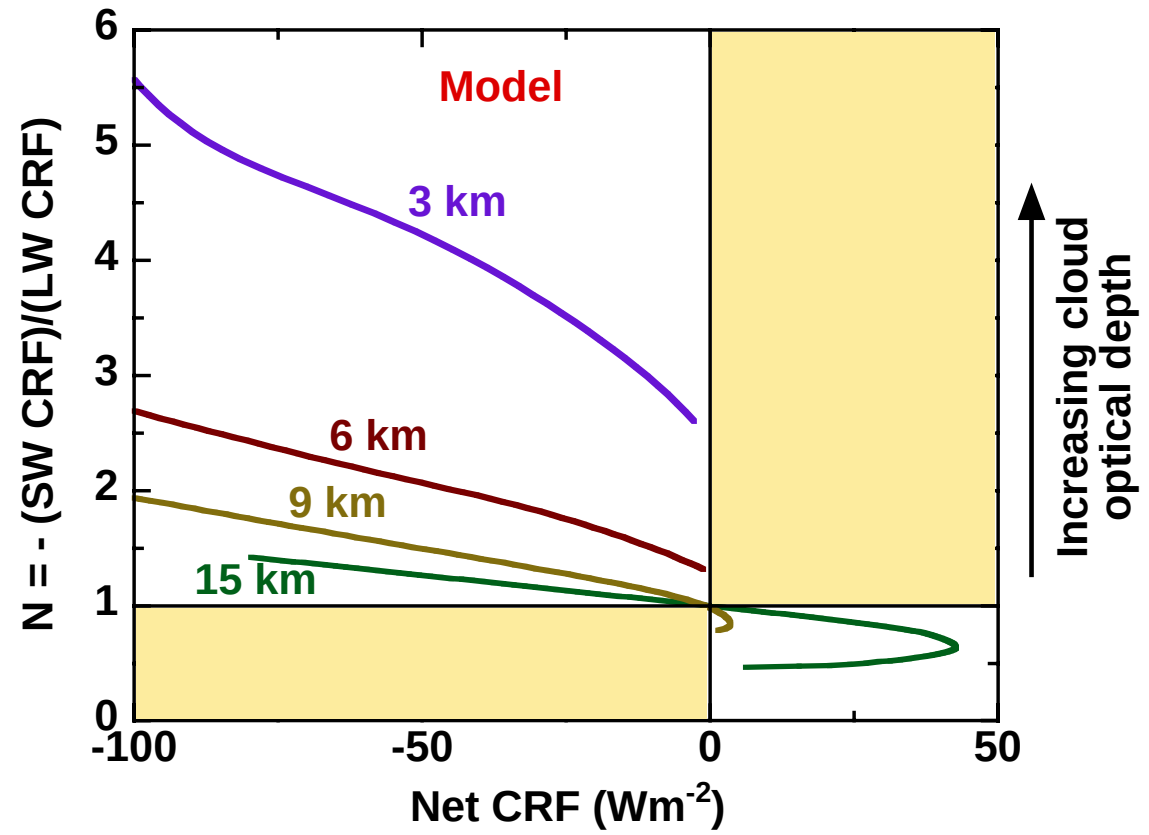
1. **Three-month (DJF) temporal means and zonal means from 60^{O}N to 60^{O}S, averaged over the five-year ERBE period.**
2. **Three-month (DJF) temporal means spatially averaged over two regions of the Pacific: a western region (5^{O}S-10^{O}N, 100^{O}E-170^{O}E) which incorporates the warm pool, and an eastern region (30^{O}S-0^{O}N, 90^{O}W-125^{O}W) within which there is a transition from stratus to trade cumulus.**
3. **Monthly-mean gridded results for each DJF period within the ERBE period.**

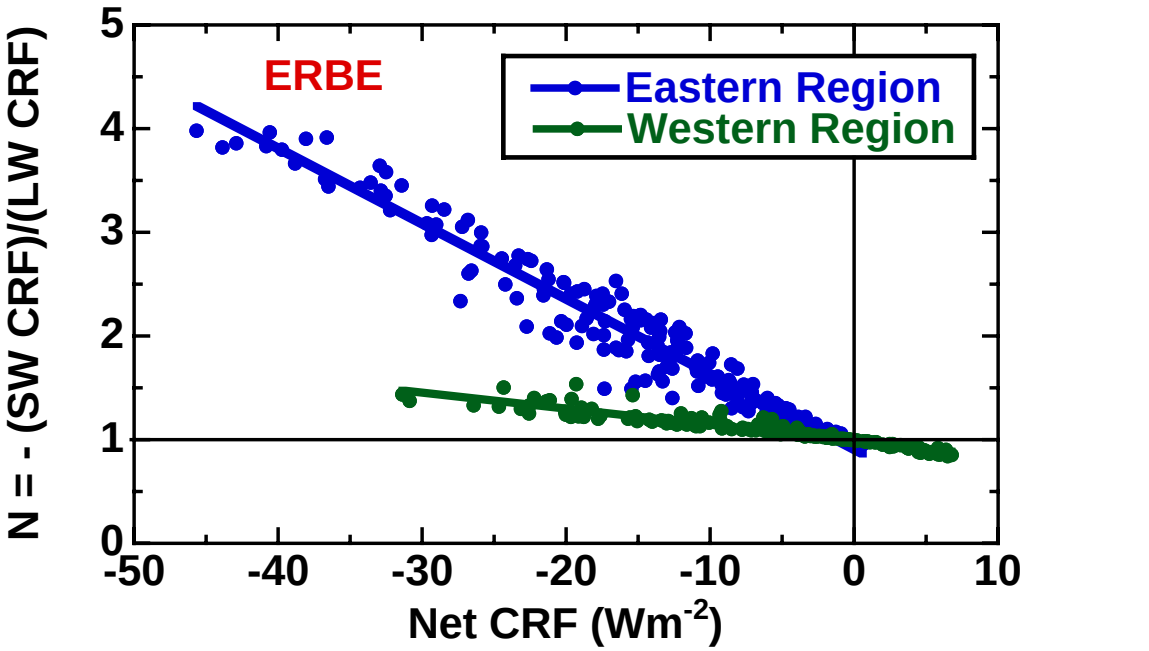

NET CRF (Wm-2)
SW CRF (Wm-2)
LW CRF (Wm-2)
Latitude (degrees)
ERBE
Models
50
0
-50
-100
-150
-200
150
100
-60
-40
-20
0
20
40
60

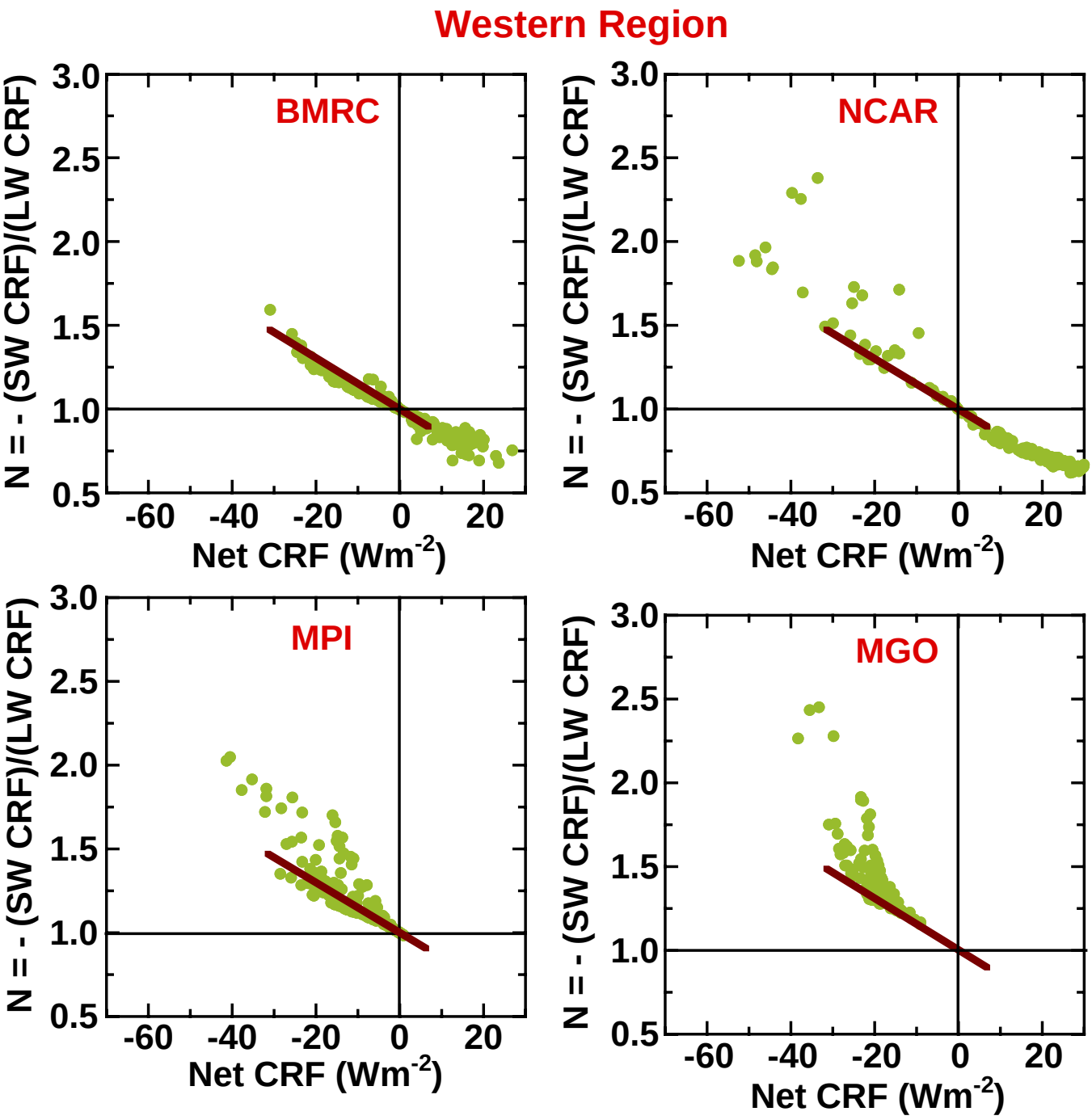

60°N to 60°S
Mean NET CRF
Bias (Wm-2)
10
0
-10
-20
-30
-40
BMRC
NCAR
MPI
MGO
COLA
CCCMA
SUNYA
CNRM
GLA
UKMO
UIUC
GFDL
NCEP
ECMWF
CCSR
GISS
JMA
MRI
UGAMP

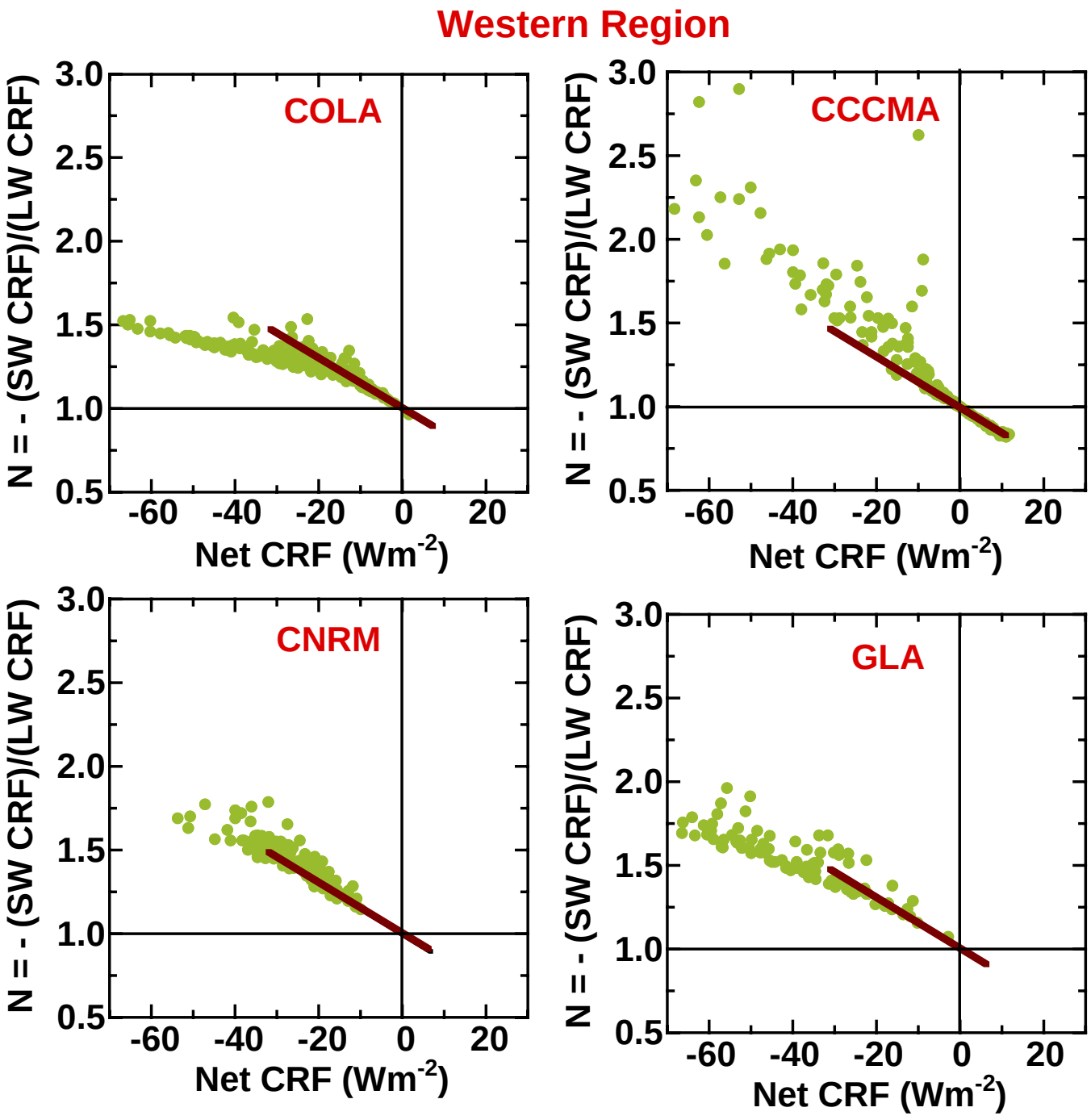

60°N to 60°S means
SW atmospheric absorptance
SW fractional absorptance
0.30
0.25
0.20
0.15
0.10
0.05
0.00
All-sky
Clear-sky
BMRC
NCAR
MPI
MGO
COLA
CCCMA
SUNYA
CNRM
GLA
UKMO
UIUC
GFDL
NCEP
ECMWF
CCSR
JMA
MRI
UGAMP

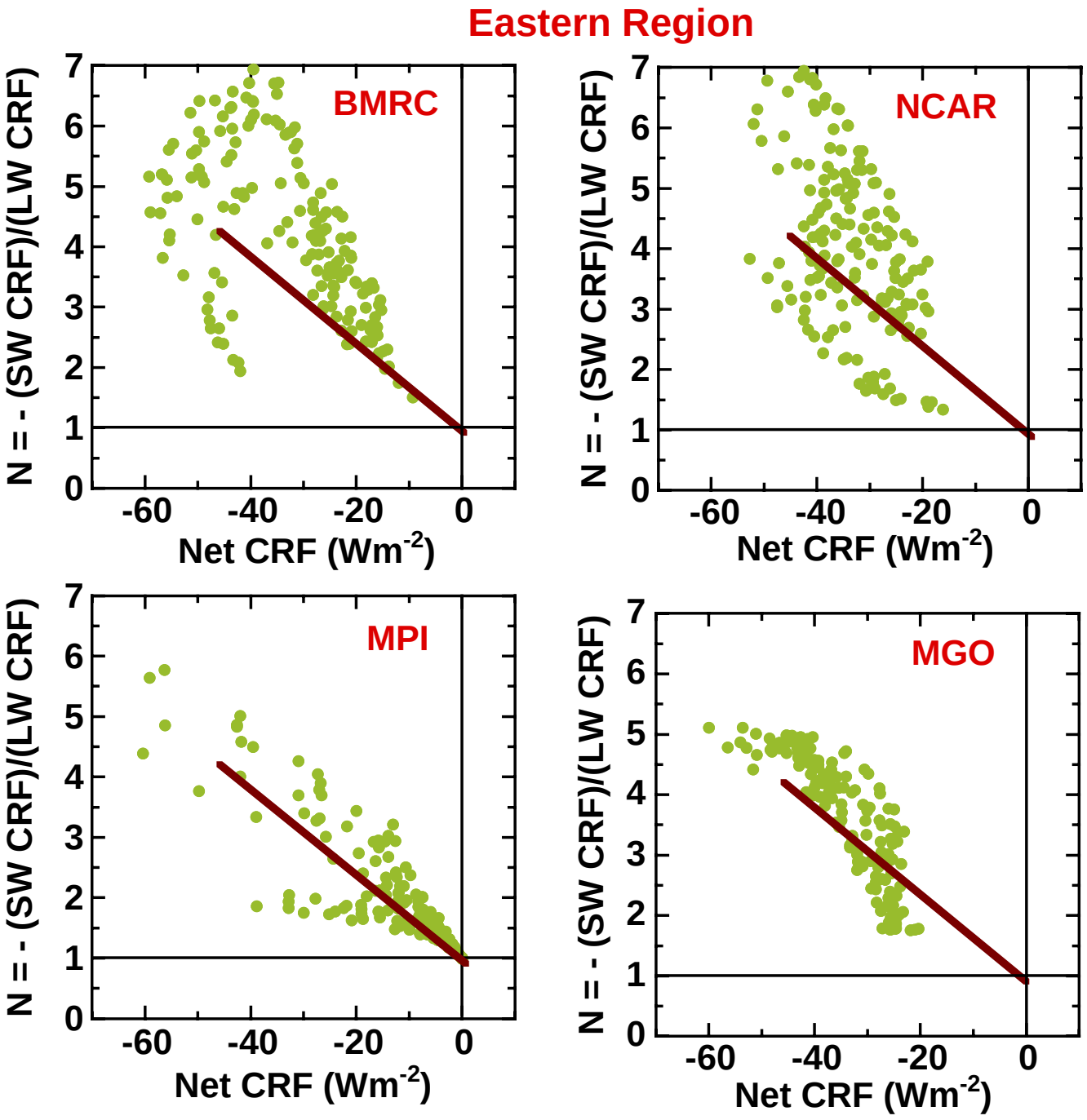

Western Region
CRF bias (Wm-2)
20
10
0
-10
-20
-30
-40
-50
SW
LW
NET
BMRC
NCAR
MPI
MGO
COLA
CCCMA
CNRM
GLA
Eastern Region
CRF bias (Wm-2)
20
10
0
-10
-20
-30
-40
-50
SW
LW
NET
BMRC
NCAR
MPI
MGO
COLA
CCCMA
CNRM
GLA

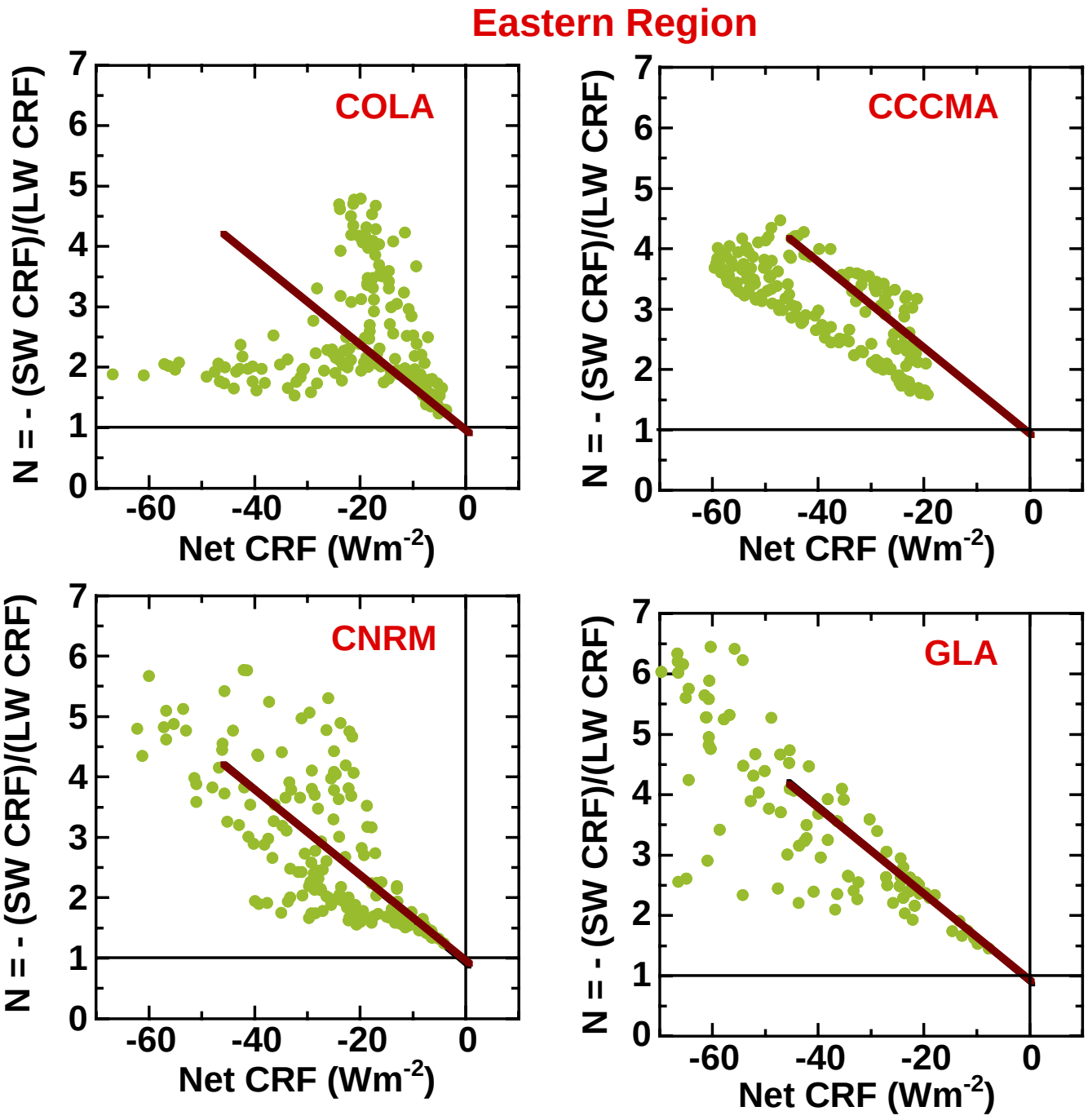

Model
3 km
6 km
9 km
15 km
N = - (SW CRF)/(LW CRF)
Net CRF (Wm-2)
Increasing cloud optical depth
6
5
4
3
2
1
0
-100
-50
0
50

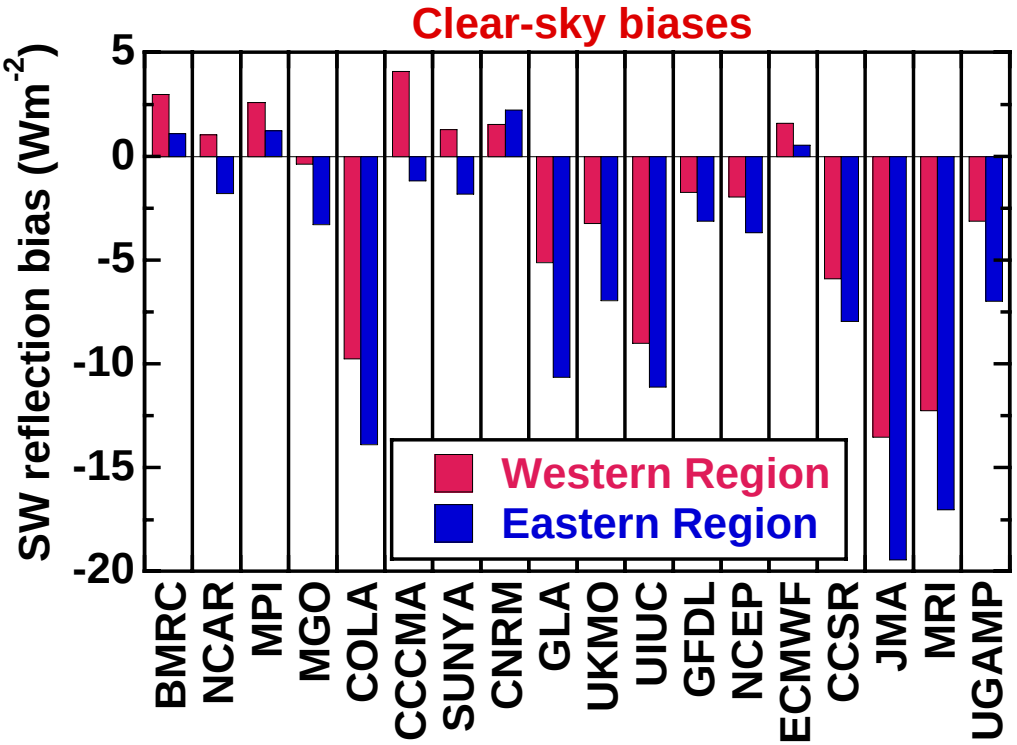

ERBE
Eastern Region
Western Region
N = - (SW CRF)/(LW CRF)
Net CRF (Wm-2)
5
4
3
2
1
0
-50
-40
-30
-20
-10
0
10

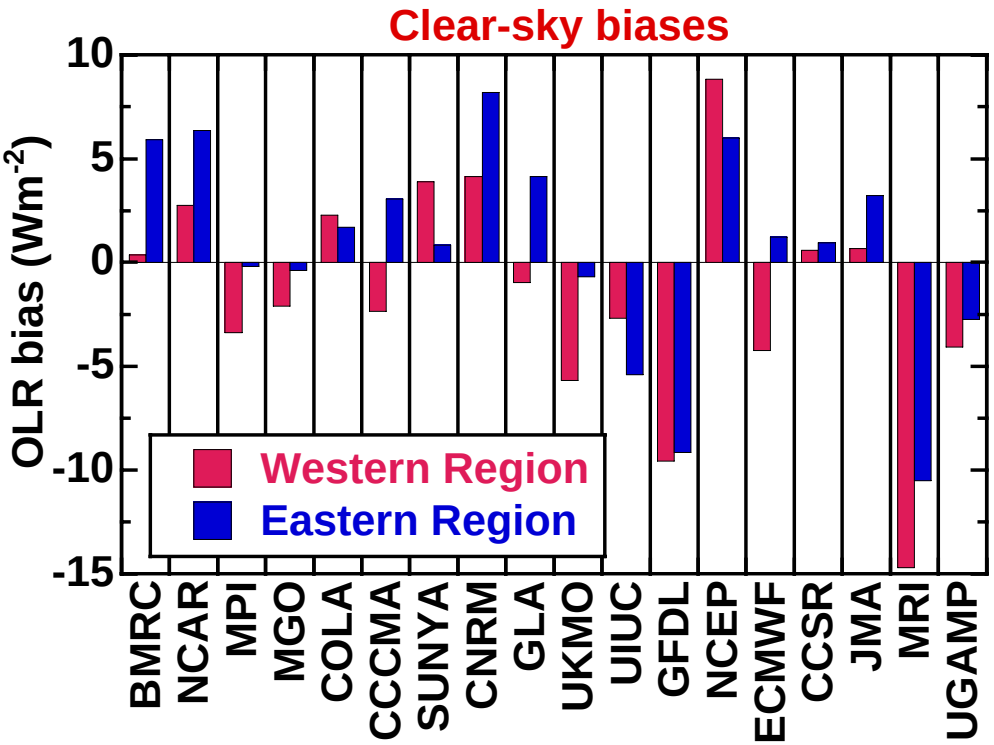

Western Region
BMRC
NCAR
MPI
MGO
N = - (SW CRF)/(LW CRF)
Net CRF (Wm-2)
3.0
2.5
2.0
1.5
1.0
0.5
-60
-40
-20
0
20


Western Region
COLA
CCCMA
CNRM
GLA
N = - (SW CRF)/(LW CRF)
Net CRF (Wm-2)
3.0
2.5
2.0
1.5
1.0
0.5
-60
-40
-20
0
20


Eastern Region
BMRC
NCAR
MPI
MGO
N = - (SW CRF)/(LW CRF)
Net CRF (Wm-2)
0
1
2
3
4
5
6
7
-60
-40
-20
0


Eastern Region
COLA
CCCMA
CNRM
GLA
N ≡ - (SW CRF)/(LW CRF)
Net CRF (Wm-2)
0
1
2
3
4
5
6
7
-60
-40
-20
0


Clear-sky biases
SW reflection bias (Wm-2)
5
0
-5
-10
-15
-20
Western Region
Eastern Region
BMRC
NCAR
MPI
MGO
COLA
CCCMA
SUNYA
CNRM
GLA
UKMO
UIUC
GFDL
NCEP
ECMWF
CCSR
JMA
MRI
UGAMP


Clear-sky biases
OLR bias (Wm-2)
10
5
0
-5
-10
-15
Western Region
Eastern Region
BMRC
NCAR
MPI
MGO
COLA
CCCMA
SUNYA
CNRM
GLA
UKMO
UIUC
GFDL
NCEP
ECMWF
CCSR
JMA
MRI
UGAMP

Conclusions

For zonal means, the models either produce realistic NET CRF or overestimate its negative value due to overestimating the negative value of SW CRF.

For the western and eastern regions, some models produce reasonable CRF means as the result of compensating errors in either cloud type, cloud amount, or both. Likewise, a model that produces reasonable CRF in the western region might not do so in the eastern region where there are different cloud types. Typically, some model errors seem to be traced to the model clouds being too bright.

The clear-sky biases are worrisome.

We need focussed approaches for testing how well models replicate the present climate.