Use of ARM-NSA products to evaluate Arctic cloud and radiative simulations in global models

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Objectives

- **Use ARM/NSA measurements to assess simulated clouds and surface radiation fluxes in global models**
- **Diagnose cloud/radiation performance based on characteristics of model parameterizations**

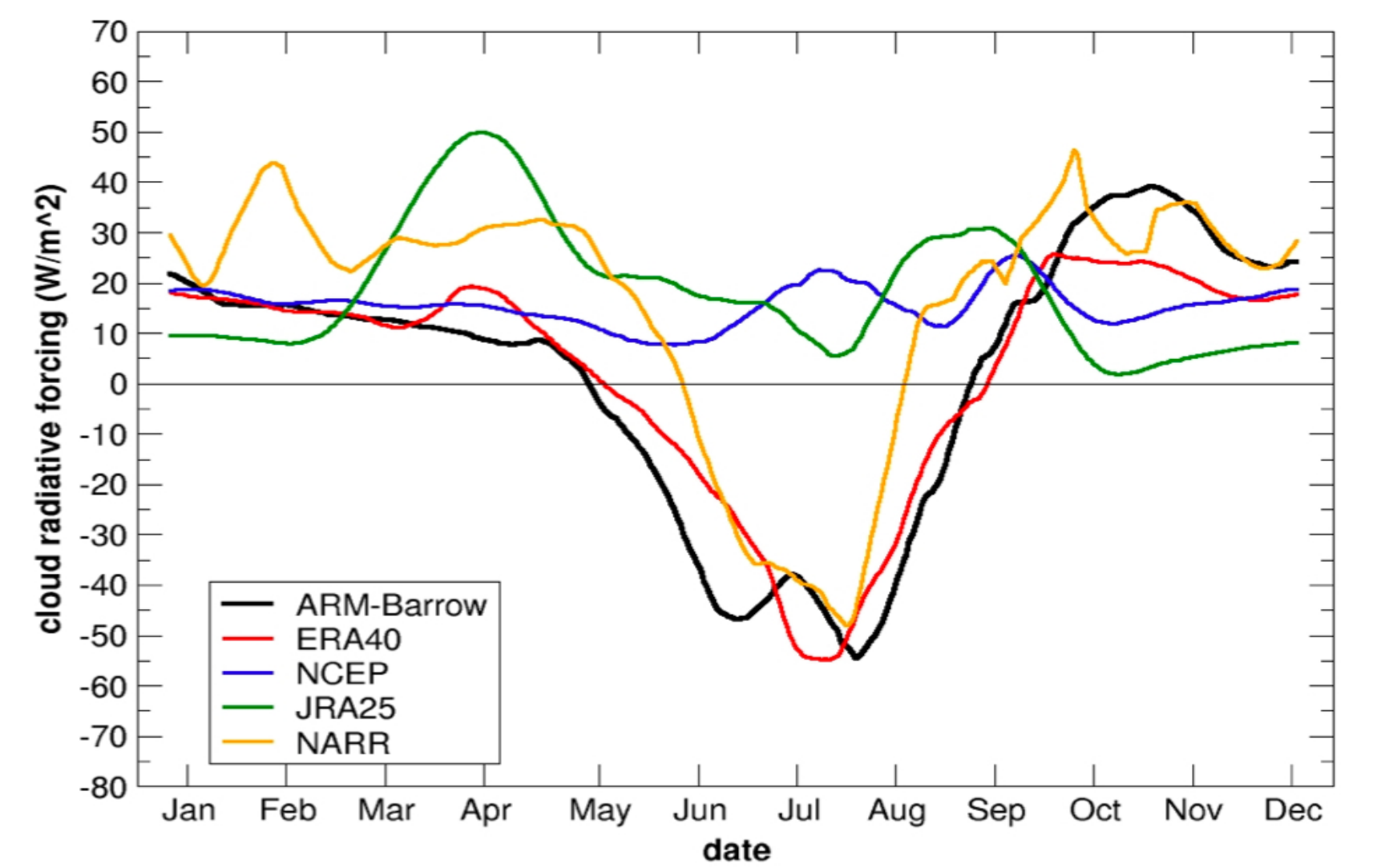
Motivation:
Cloud-radiative forcing in atmospheric reanalyses

- **NCEP/NCAR**
- **ERA40 (ECMWF)**
- **NARR (North American Regional Reanalysis)**
- **JRA-25 (Japan)**

Validation with ARM/NSA data, 1999-2006

Cloud-Radiative-Forcing (CRF):

Net surface radiation (SW + LW) with actual cloudiness *minus* clear-sky net surface radiation



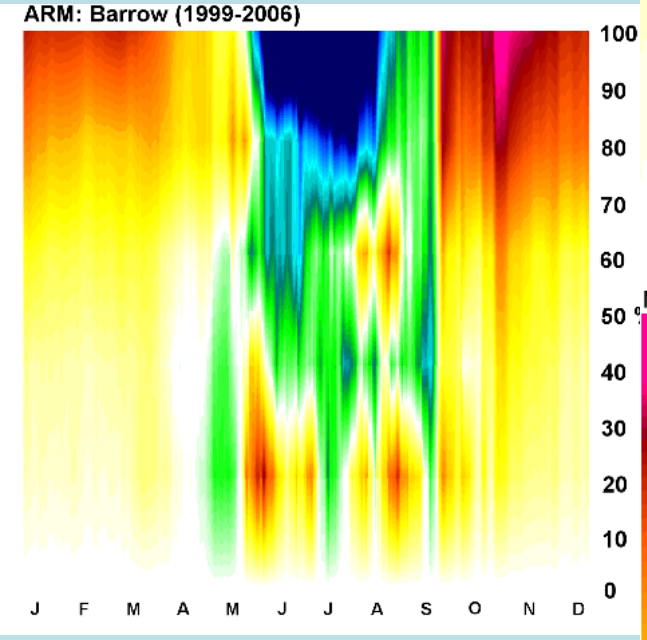
- **Variable Cloud-Radiative-Forcing:**

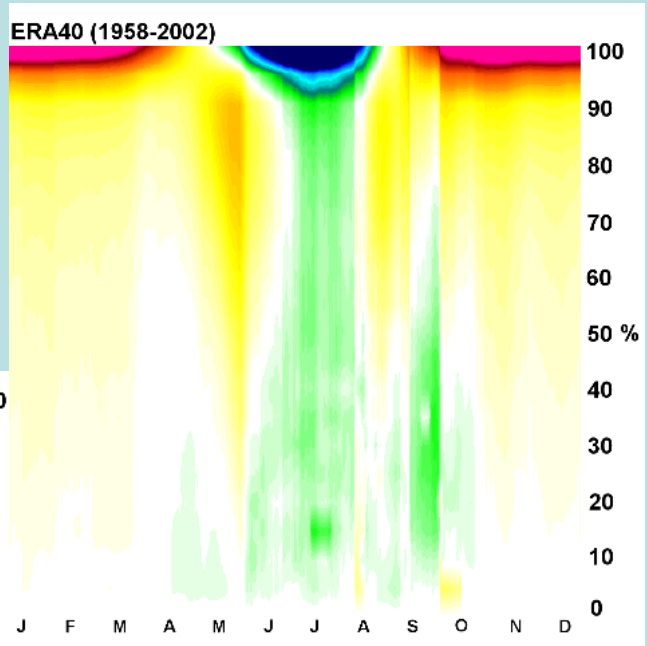
  Net surface radiation (SW + LW) with specific cloud fraction (f) ***minus*** **clear-sky net surface radiation**

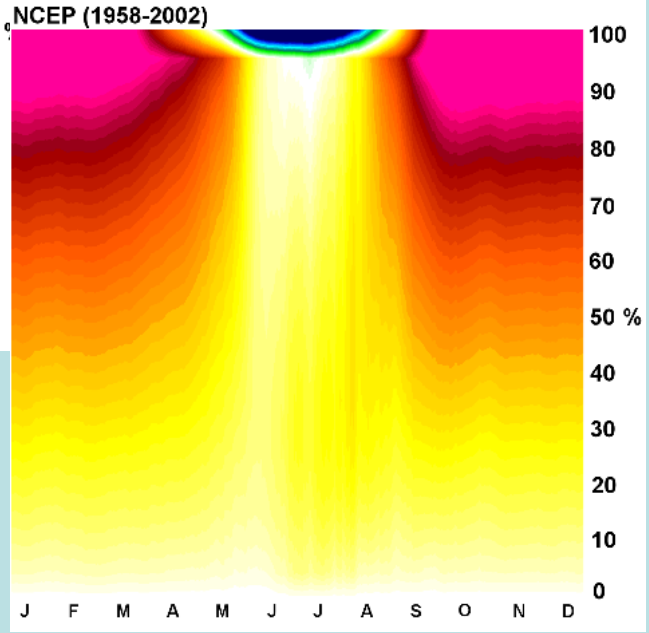
Variable Cloud Radiative Forcing

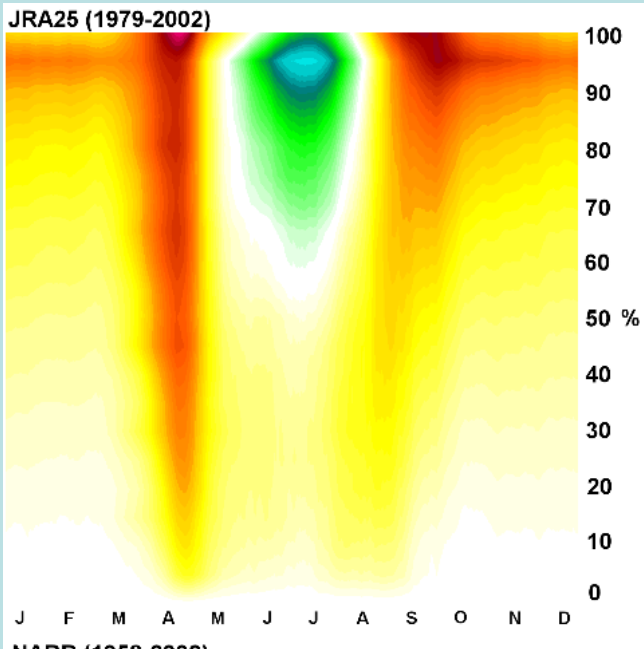
x axis = month,
y axis = cloud fraction (f)

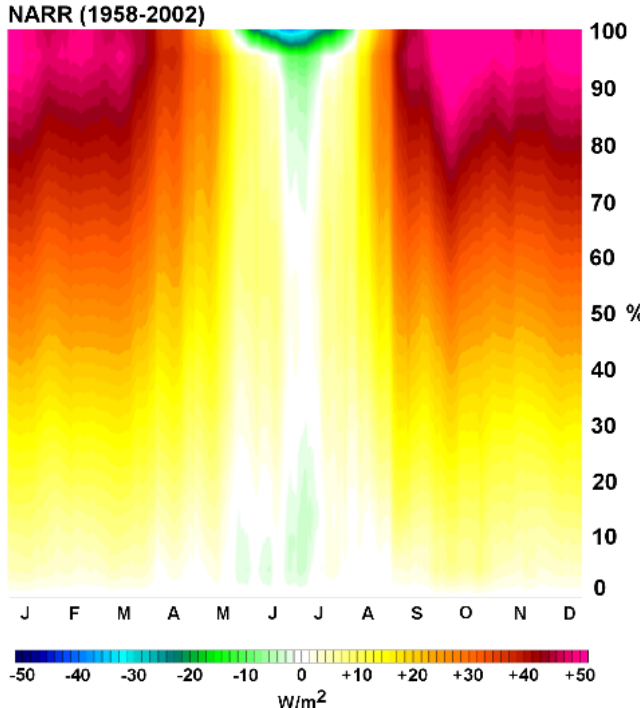
ARM/NSA



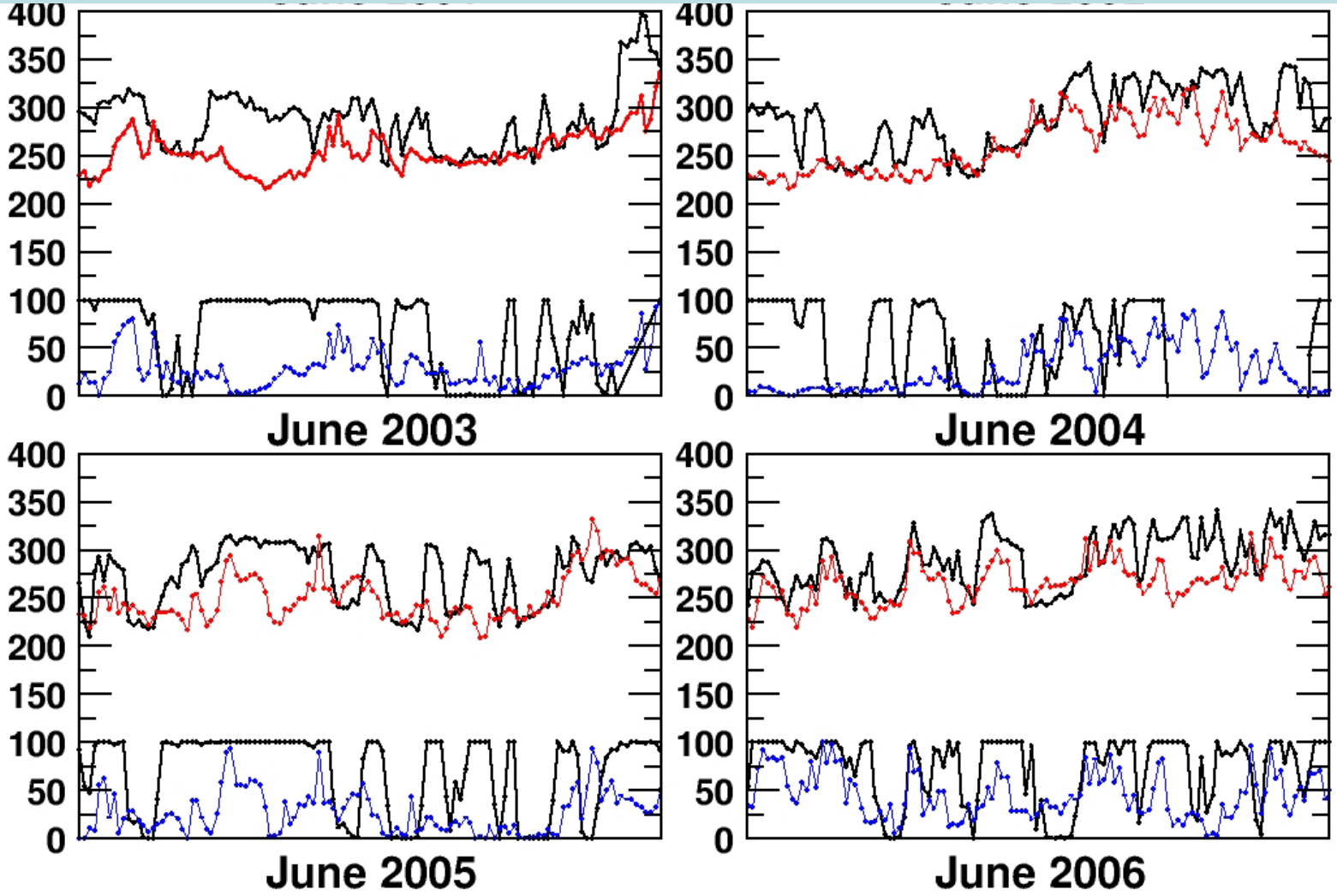




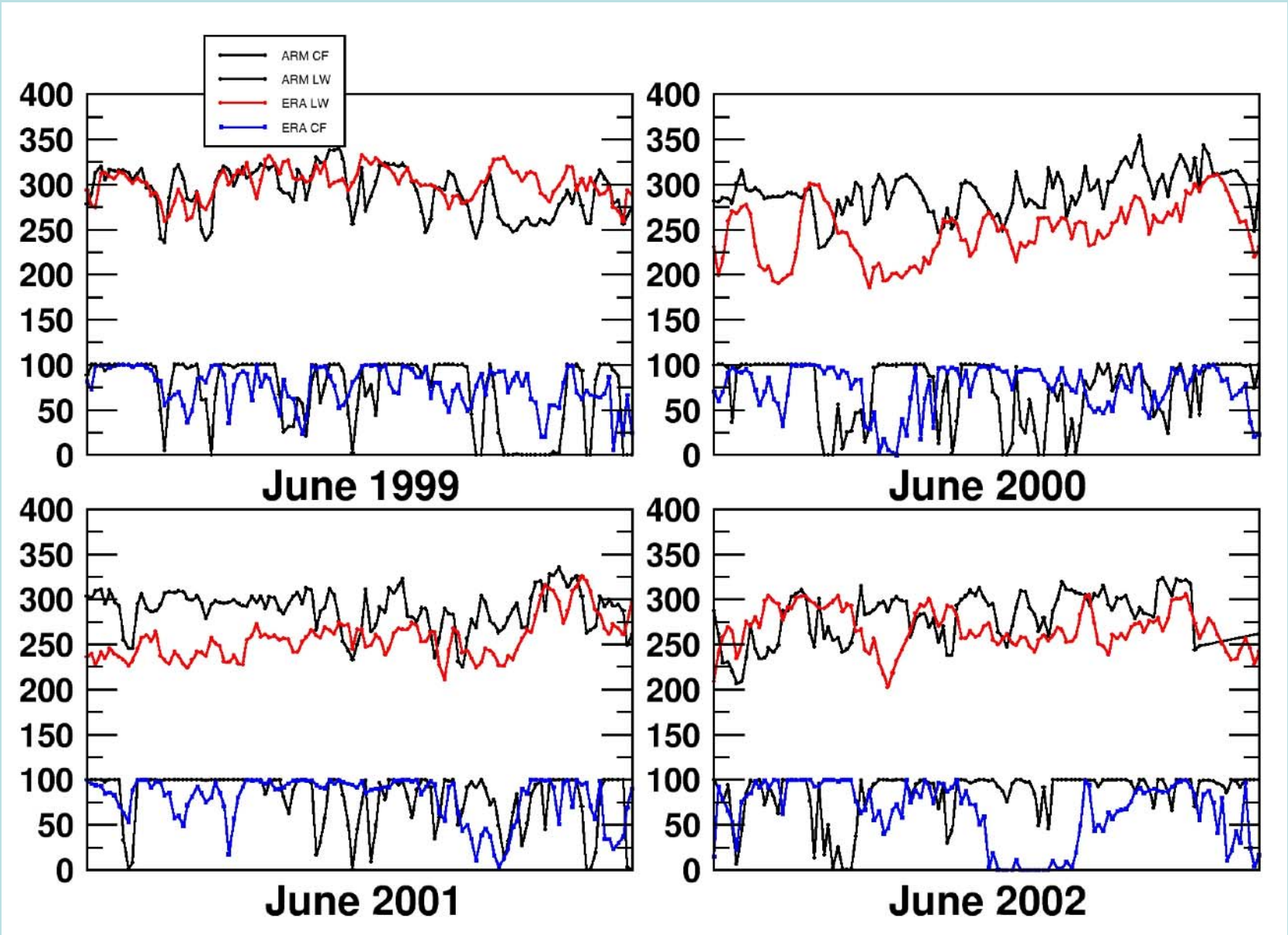




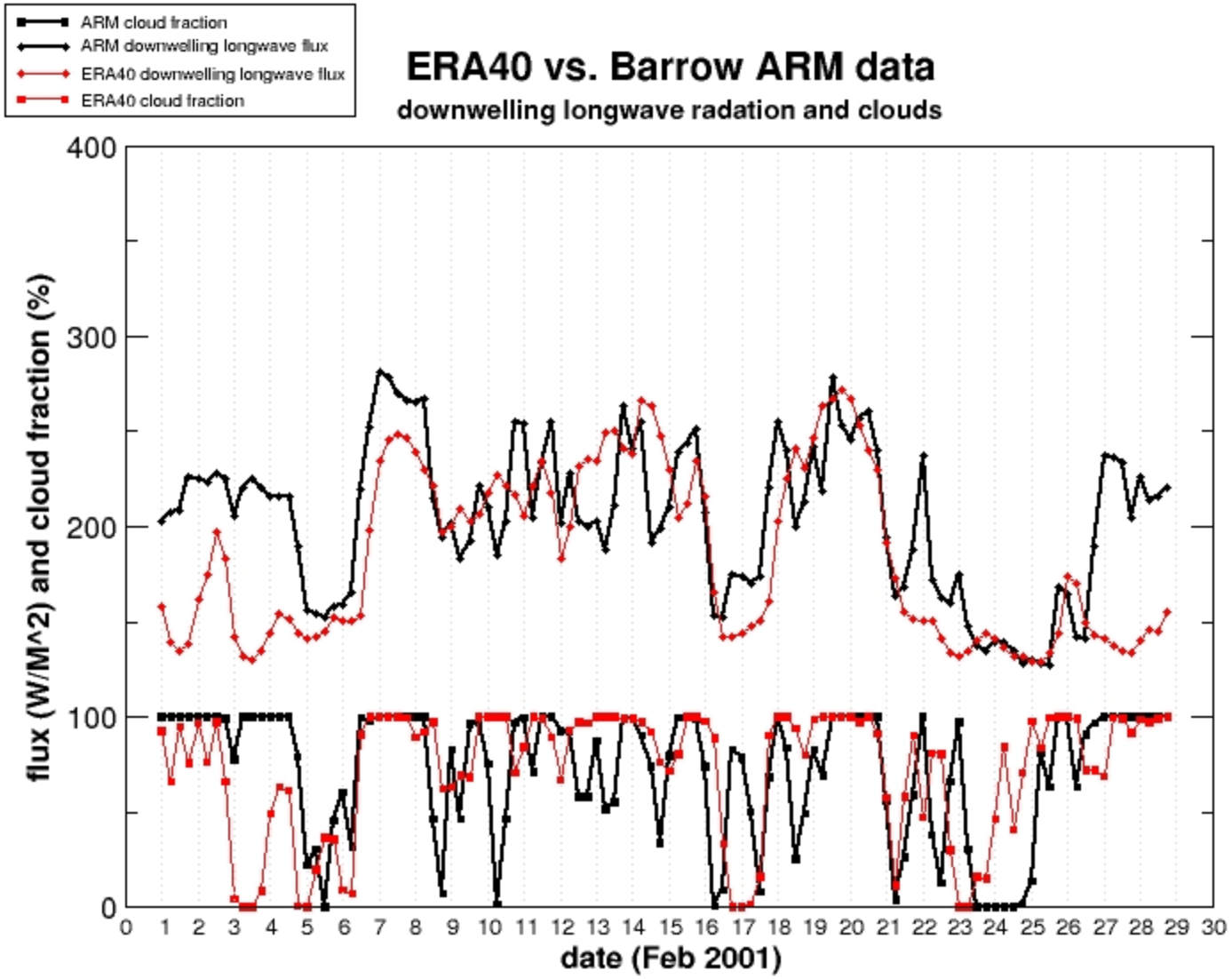
NCEP (red/blue) vs. ARM (black) downward longwave fluxes, cloud fractions: June



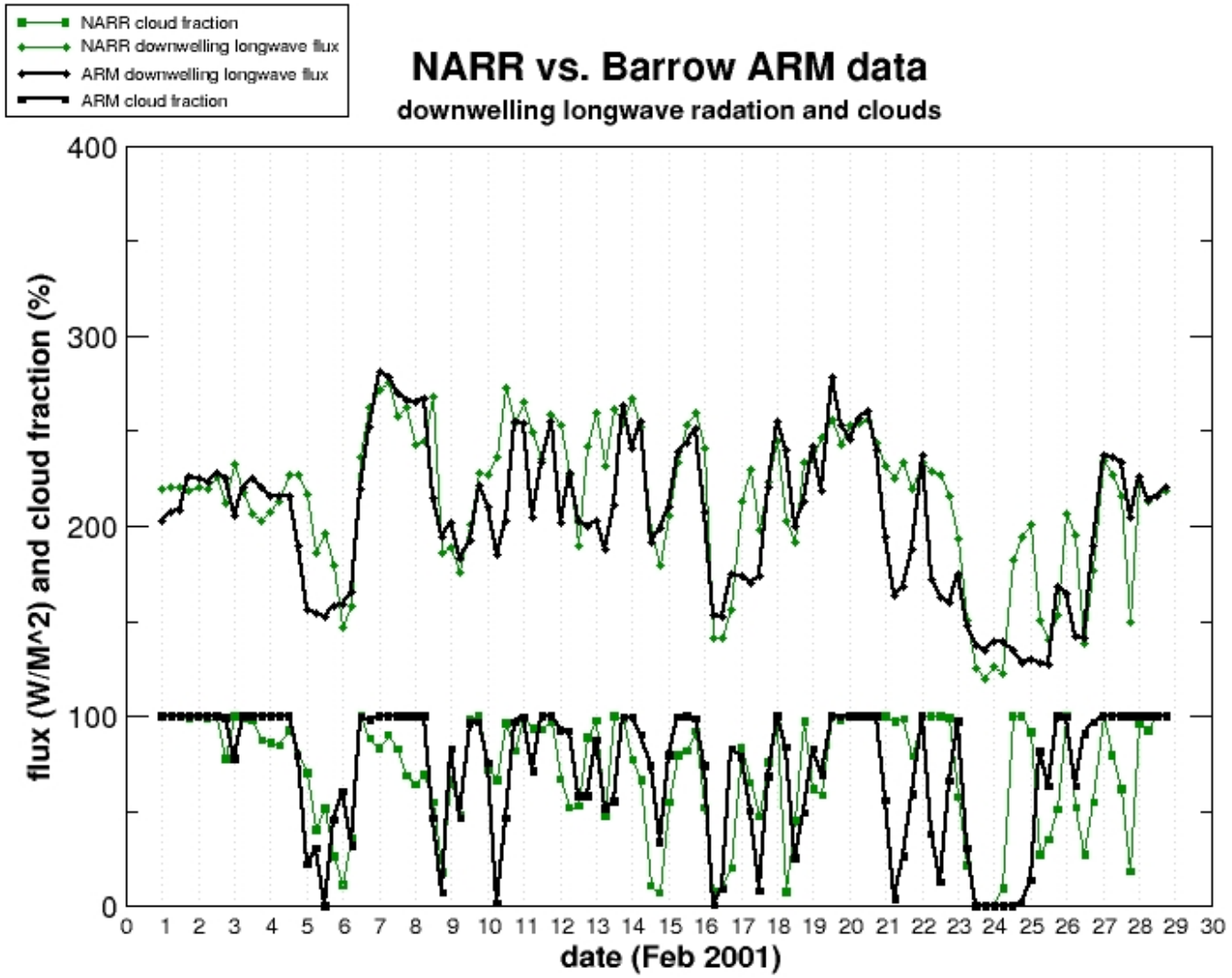
ERA40 (red/blue) vs. ARM (black) downward longwave fluxes, cloud fractions: June



ERA40 red) vs. ARM (black) downward longwave fluxes: Feb. 2001



NARR (green) vs. ARM (black) downward longwave fluxes: Feb. 2001



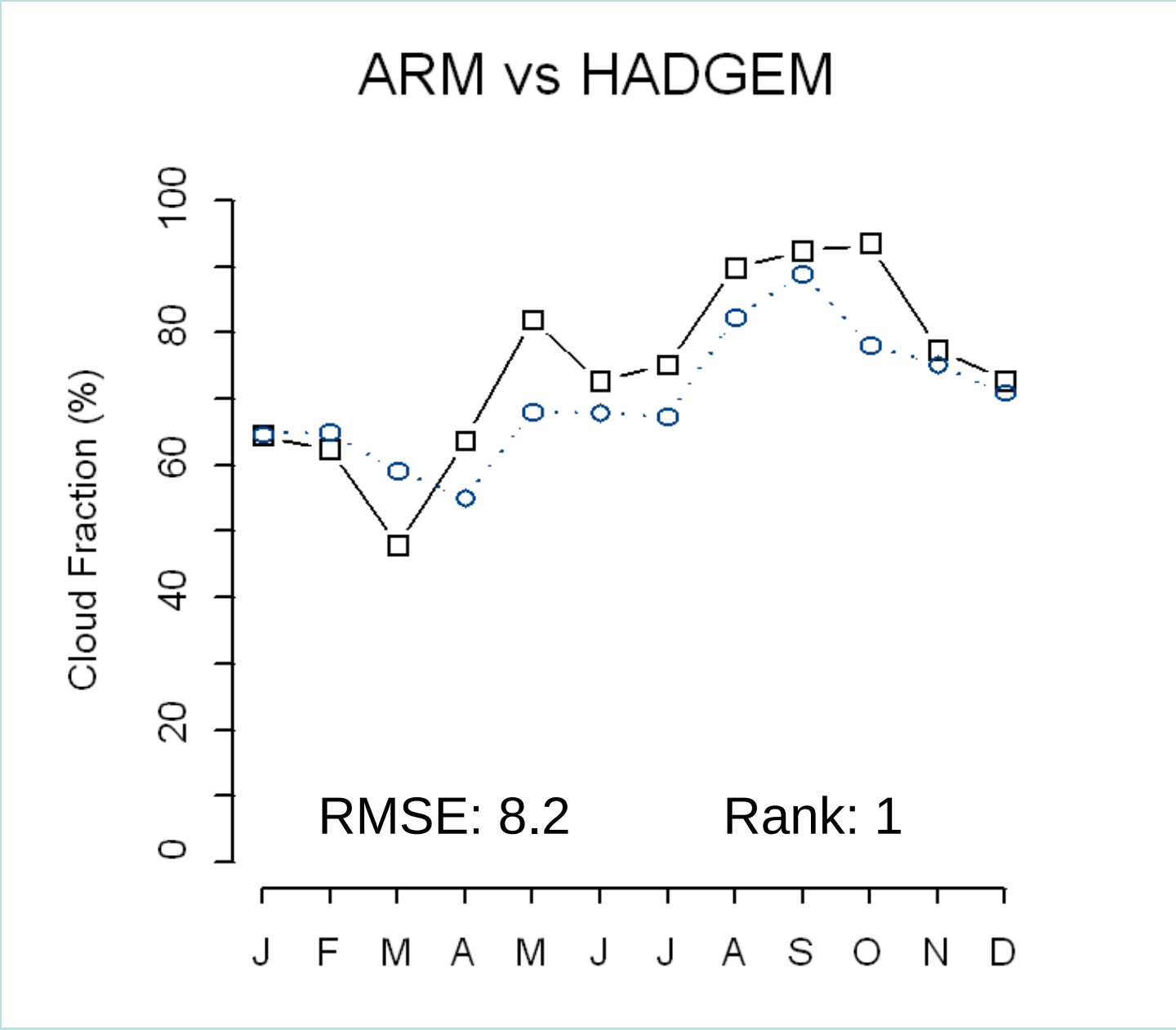
Evaluation of GCMs:

- **Determine monthly mean RMSE of GCM- and reanalysis-derived cloud fraction, downwelling solar and longwave flux from corresponding observations at the Barrow ARM site**
- **Create an "integrated model rank" based on sums of ranks for cloud, solar and longwave flux**
- **Characterize cloud and radiative model formulations associated with high- and low-ranking performance**

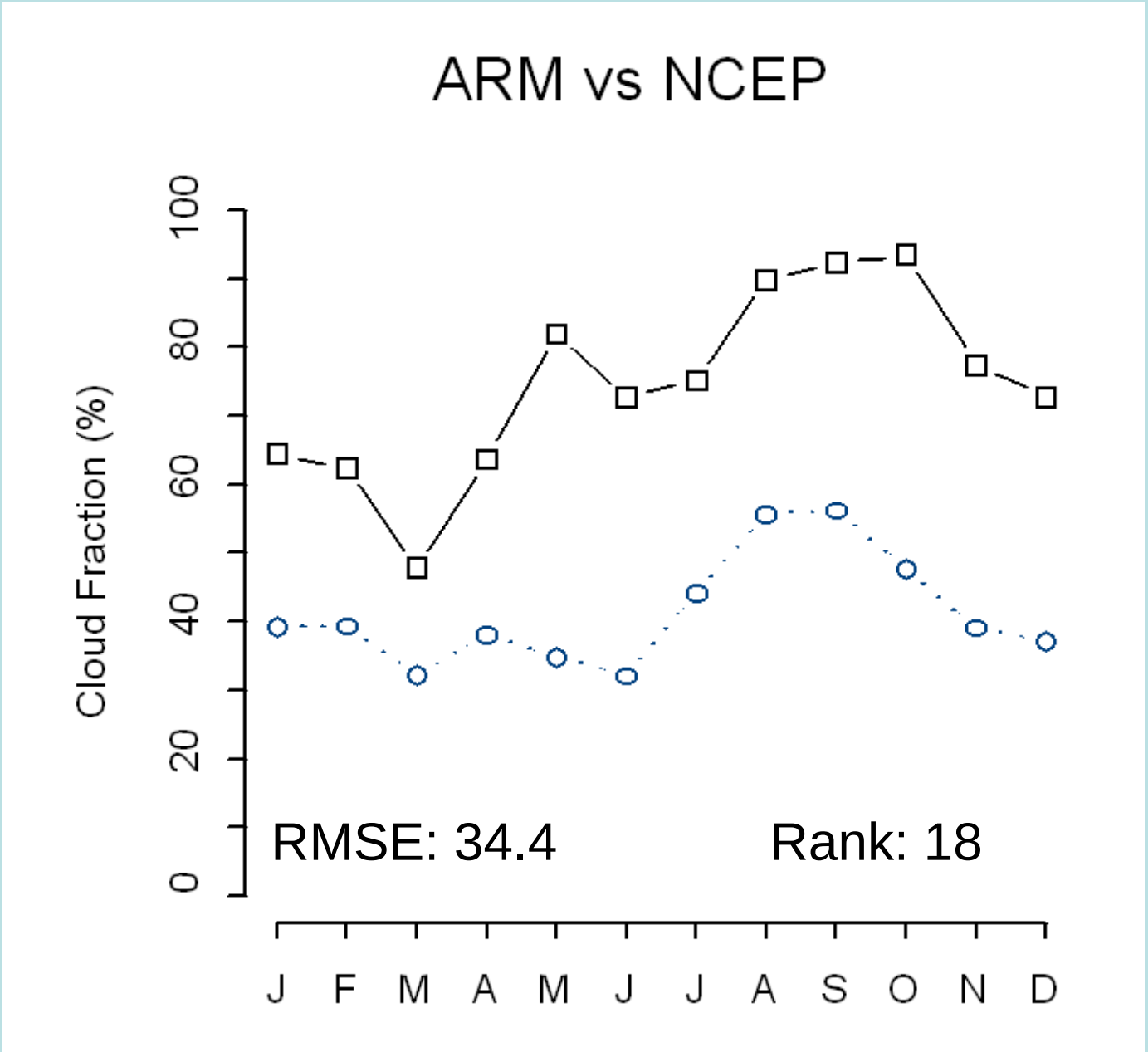
IPCC AR4 global climate models used here:

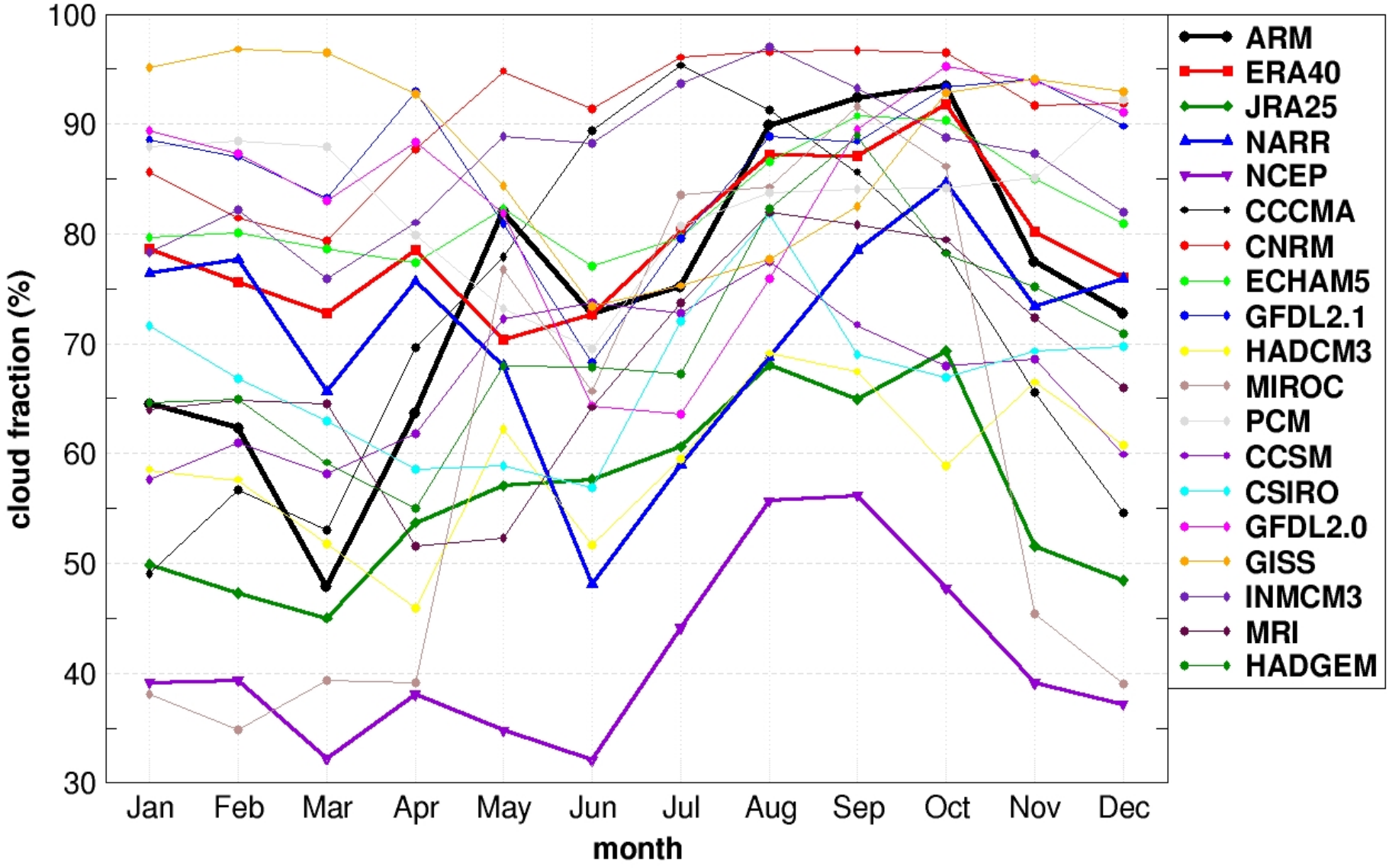
CCSM3 (USA)
CGCM3 (Canada)
CNRM-CM3 (France)
CSIRO-Mk3.0 (Australia)
ECHAM5/MPI (Germany)
GFDL-CM2.0 (USA)
GFDL-CM2.1 (USA)
GISS-ER (USA)
INM-CM3.0 (Russia)
MIROC3.2 (Japan)
MRI CGCM2.3.2 (Japan)
NCAR PCM (USA)
UKMO-HadCM3 (U.K.)
UKMO-HadGEM (U.K.)

Cloud Fraction

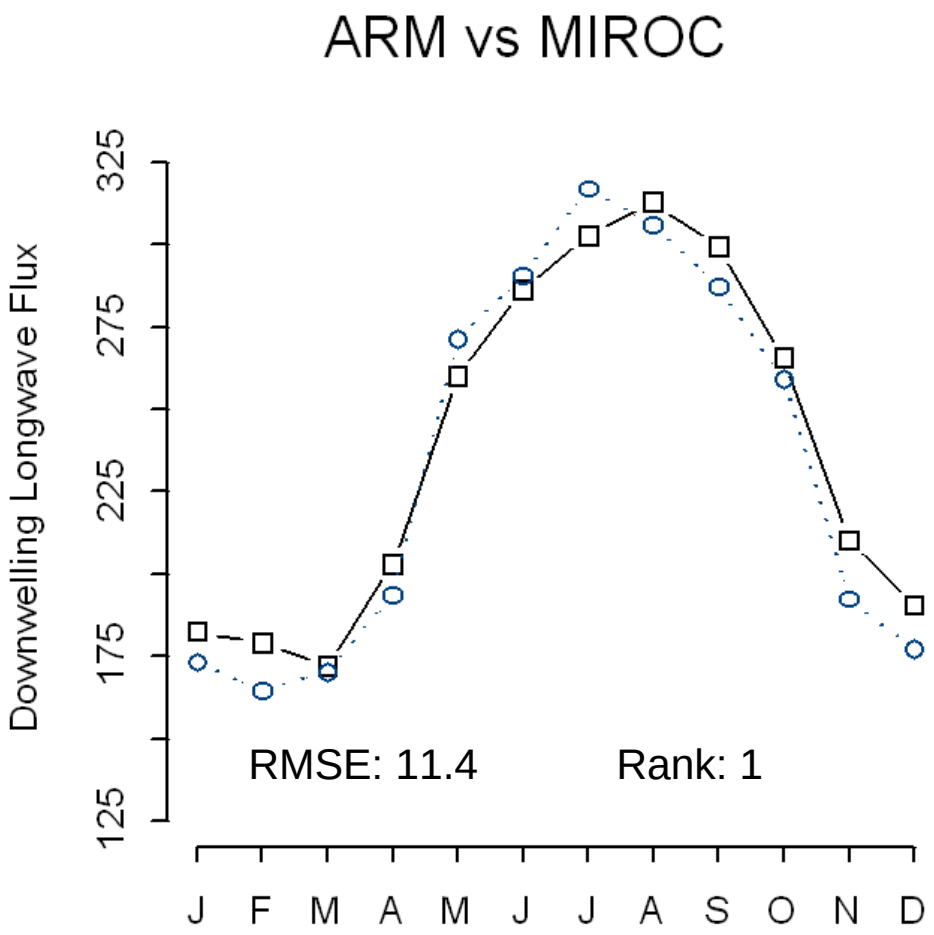


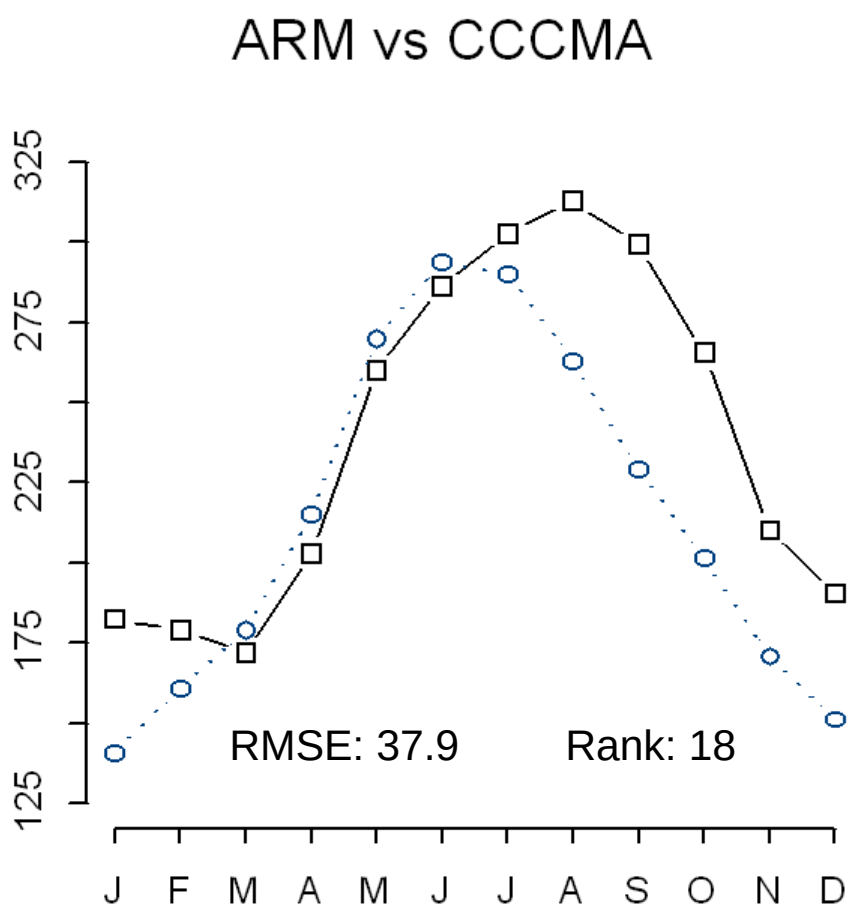
Cloud Fraction

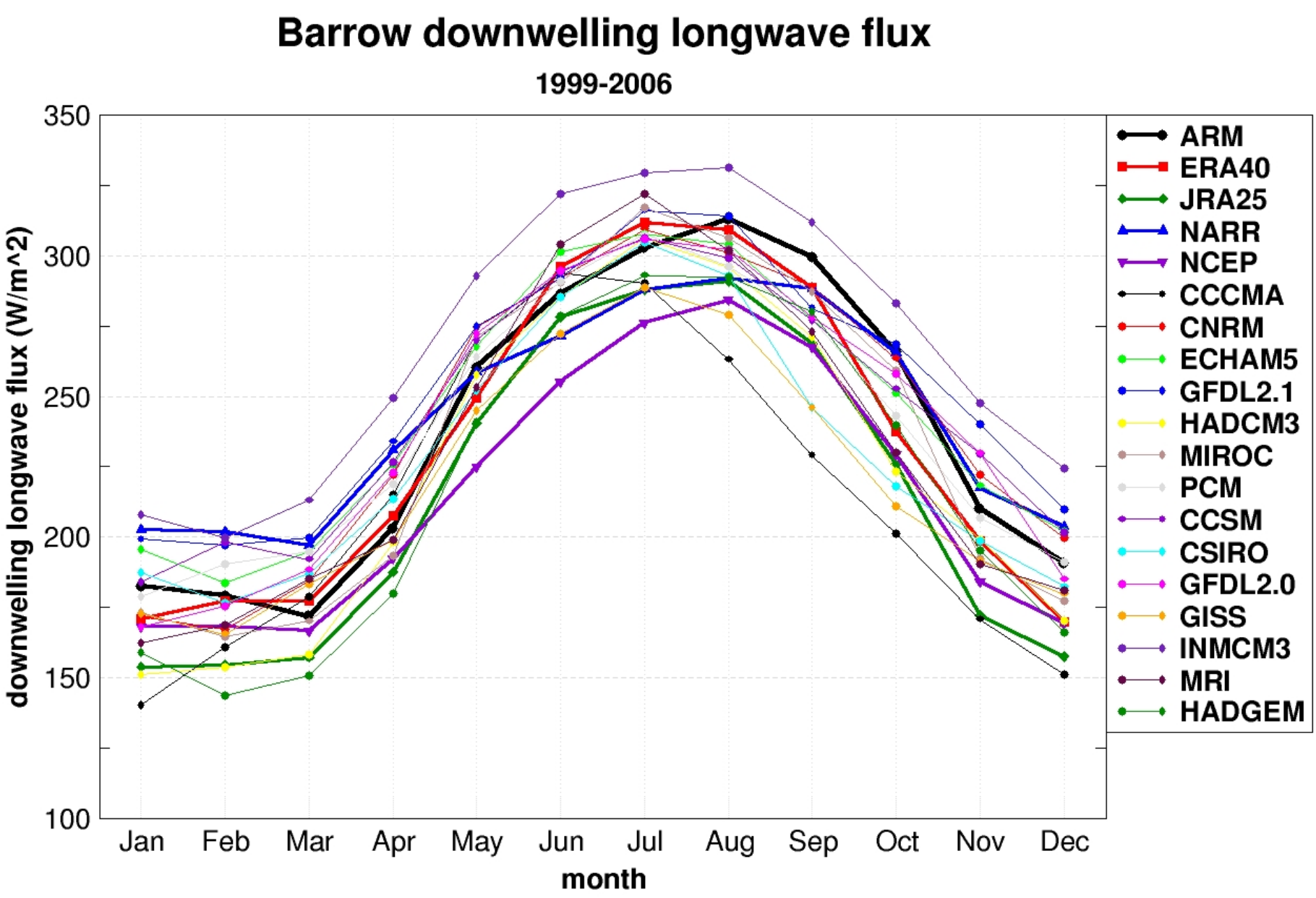



Barrow cloud fraction
1999-2006
cloud fraction (%)
100
90
80
70
60
50
40
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
month
ARM
ERA40
JRA25
NARR
NCEP
CCCMA
CNRM
ECHAM5
GFDL2.1
HADCM3
MIROC
PCM
CCSM
CSIRO
GFDL2.0
GISS
INMCM3
MRI
HADGEM

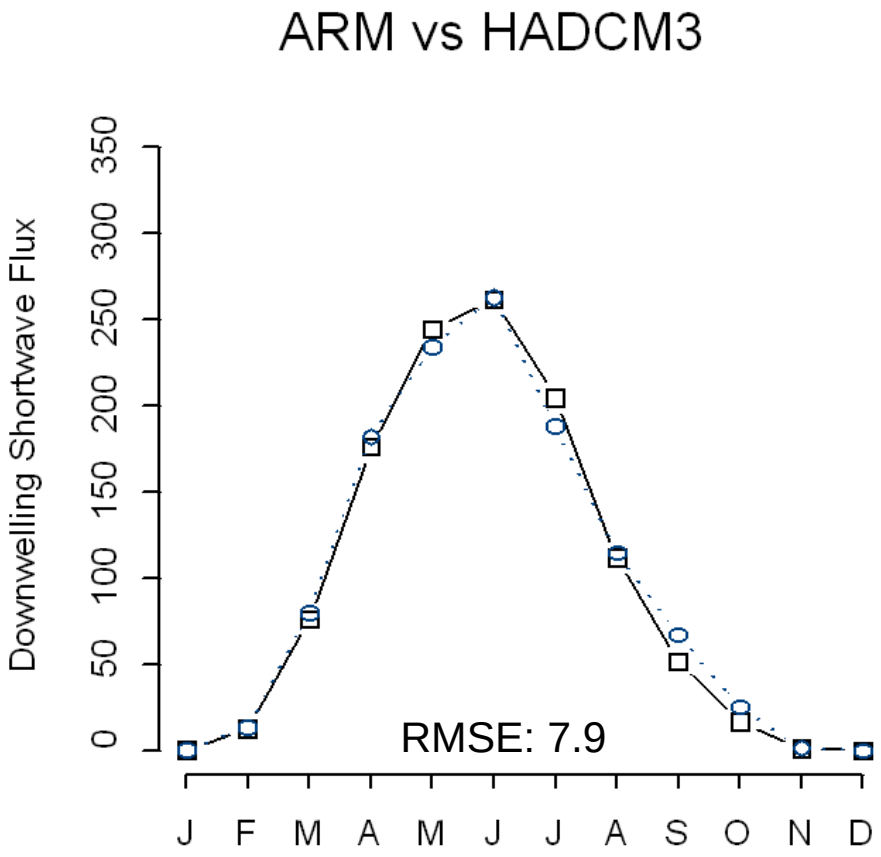
Downwelling Longwave

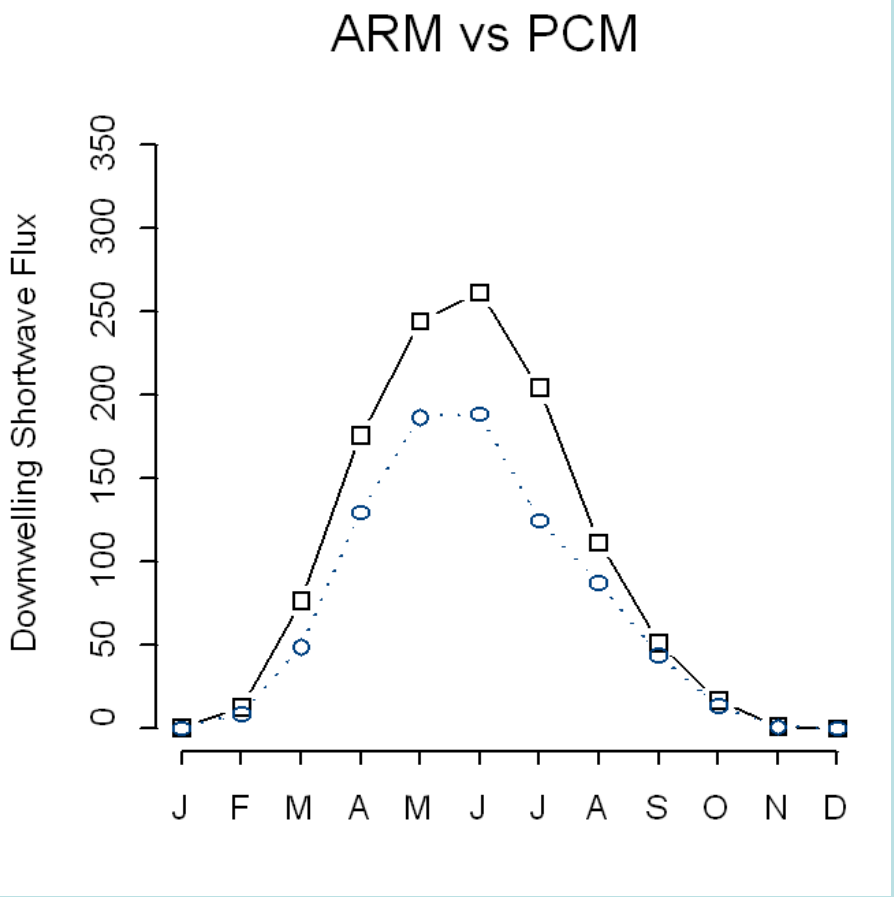





Barrow downwelling longwave flux
1999-2006
downwelling longwave flux (W/m^2)
350
300
250
200
150
100
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
month
ARM
ERA40
JRA25
NARR
NCEP
CCCMA
CNRM
ECHAM5
GFDL2.1
HADCM3
MIROC
PCM
CCSM
CSIRO
GFDL2.0
GISS
INMCM3
MRI
HADGEM

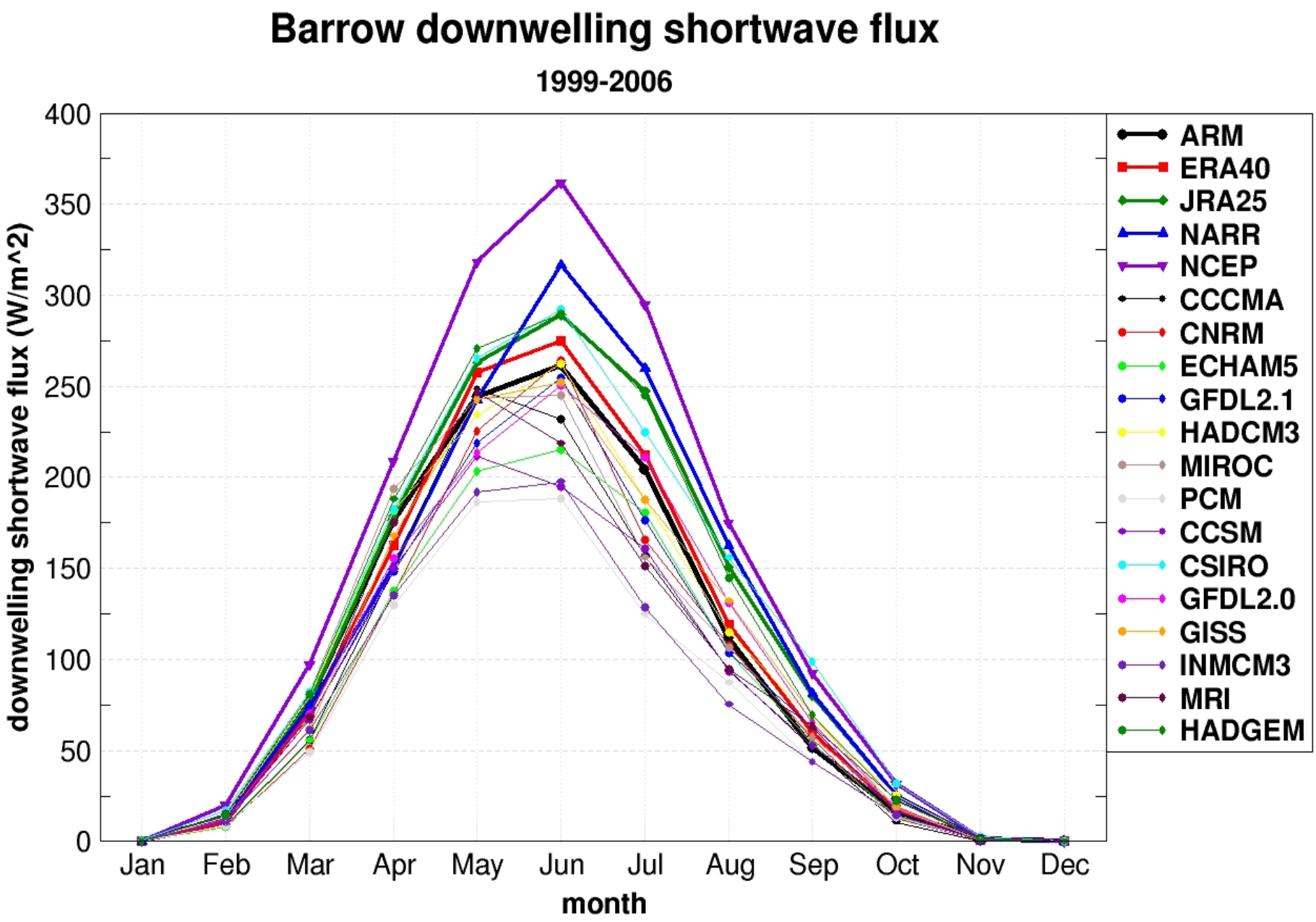
Downwelling Shortwave





Rank: 1

Rank: 17


Barrow downwelling shortwave flux
1999-2006
downwelling shortwave flux (W/m^2)
400
350
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
month
ARM
ERA40
JRA25
NARR
NCEP
CCCMA
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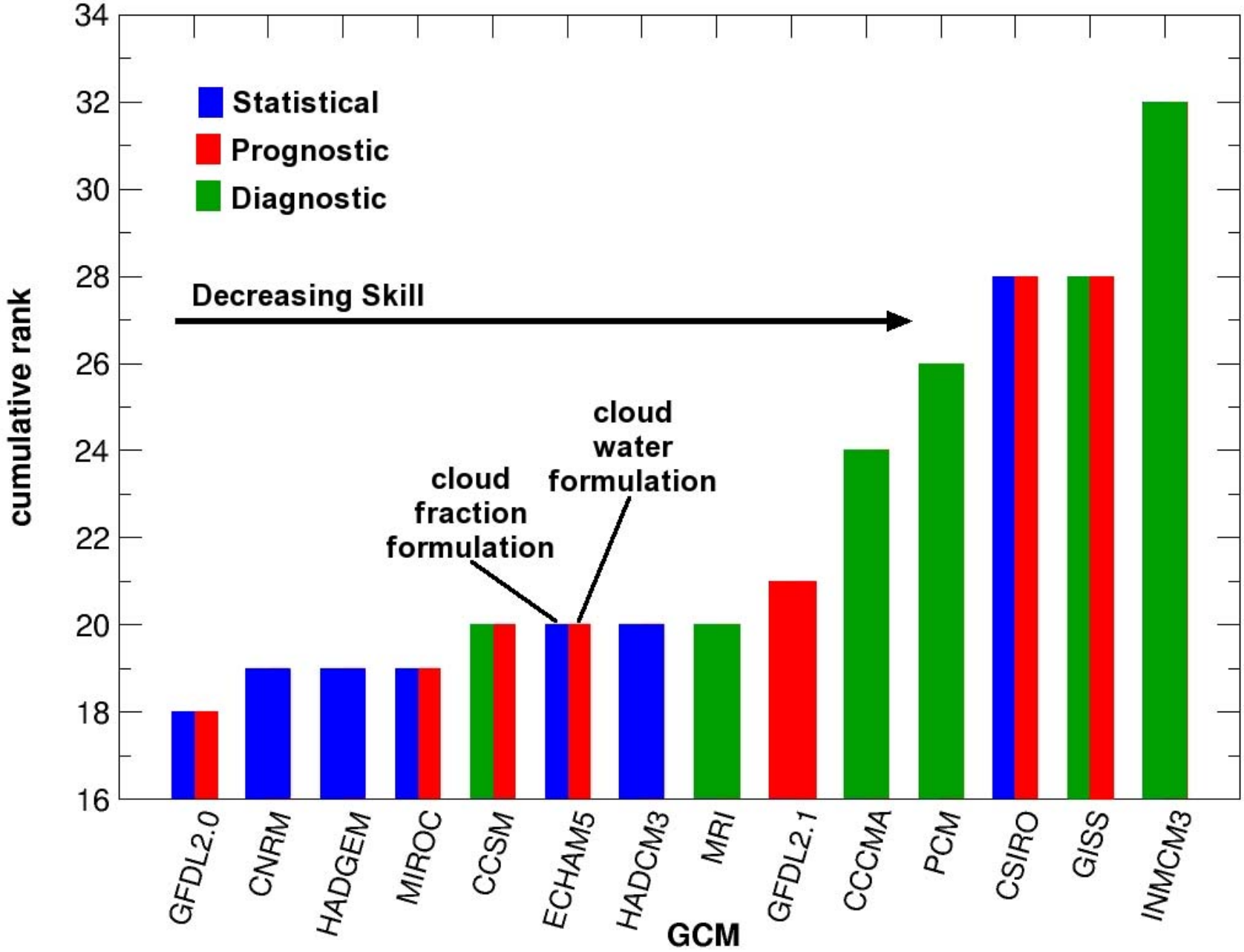
Statistical
Prognostic
Diagnostic
Decreasing Skill
cumulative rank
34
32
30
28
26
24
22
20
18
16
cloud fraction formulation
cloud water formulation
GFDL2.0
CNRM
HADGEM
MIROC
CCSM
ECHAM5
HADCM3
MRI
GFDL2.1
CCCMA
PCM
CSIRO
GISS
INMCM3
GCM

Conclusions:

- **On balance, models using statistical formulations for cloud condensate and cloud fraction outperform those using diagnostic (RH threshold-based) formulations;**
  mixed results for prognostic cloud-radiative treatments.

- **Some GCMs outperform reanalysis products -- a positive result for GCMs given that reanalyses are constrained by observations.**

- **Models that perform well with respect to cloud fraction do not necessarily rank highly for radiation variables.**