Reconciling simulated and observed views of clouds: MODIS, ISCCP, and the limits of instrument simulators

Robert Pincus, University of Colorado
Steven Platnick, NASA/GSFC
Steve Ackerman, University of Wisconsin
Richard Hemler, NOAA/GFDL
R. J. Patrick Hofmann, University of Colorado

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For model evaluation want to be able to attribute *differences* between observations and models to *model errors*

Satellites don't observe climate model cloud states, so we require interpretive models of

sub-grid scale distribution of cloudiness

observational process at pixel- and grid-scale

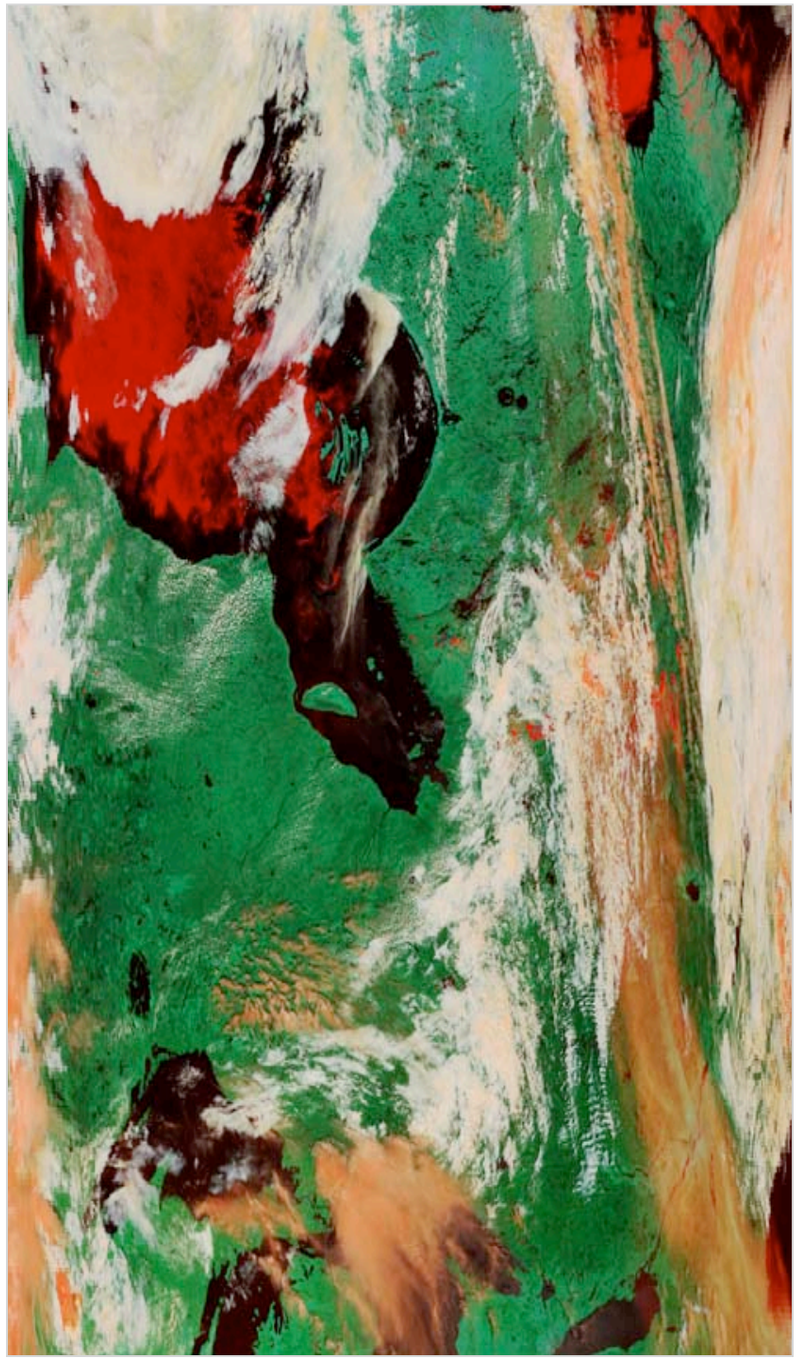
"Instrument simulators" embody these interpretive models

These models are incomplete

A tale of two simulators

- We built a MODIS simulator to complement the ISCCP simulator
  - (Nearly) identical estimates of cloudiness, optical thickness
  - Different estimate of cloud-top pressure
  - Additional observations of particle size, phase determination
- We built customized observational data sets for comparison with these simulators
  - ISCCP provides retrievals for every cloudy pixel
  - MODIS observations contain parallel estimates for cloudiness, cloud top pressure from cloud mask (detection) and retrievals (interpretation)

SWIR composite



Cloud Mask overall conf.

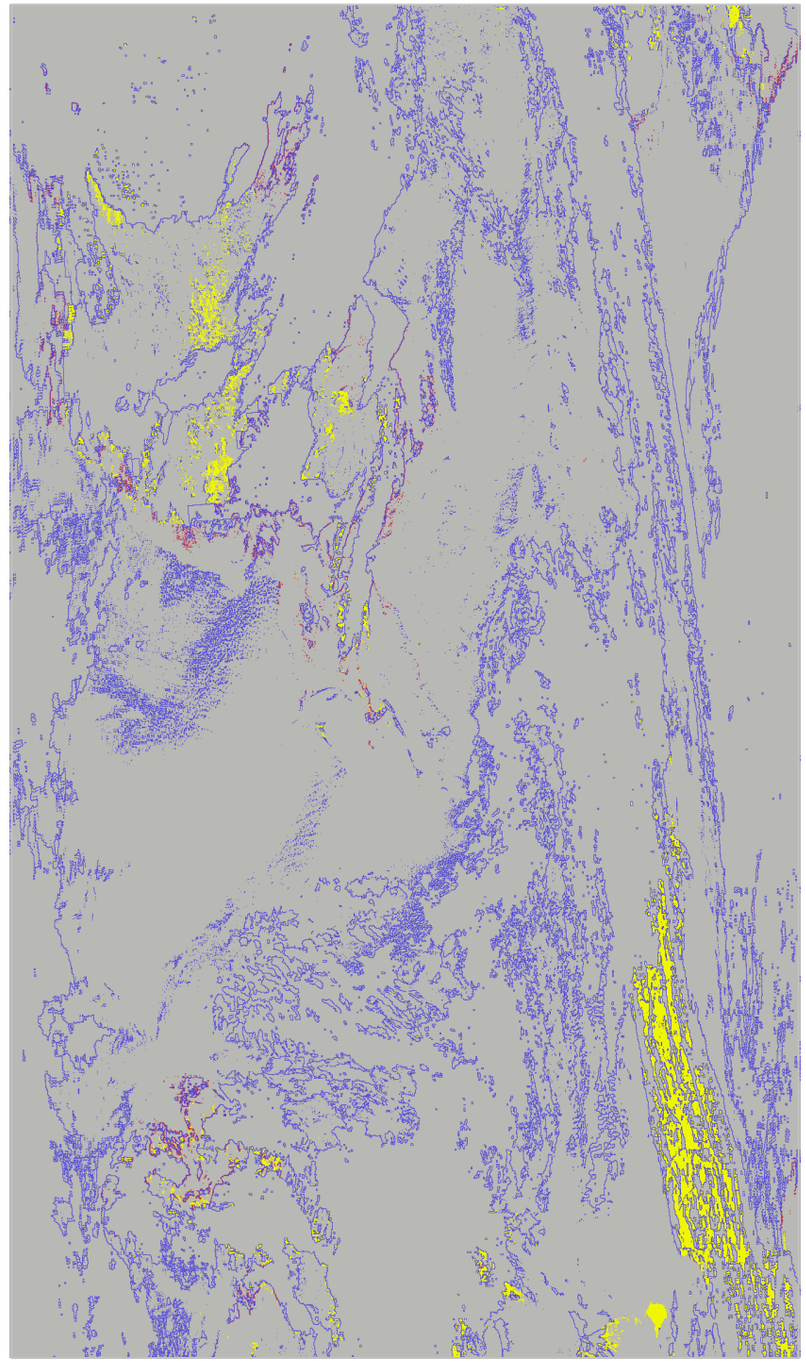
probably clear

clear

cloudy

probably cloudy

"Clear Sky Restoral"



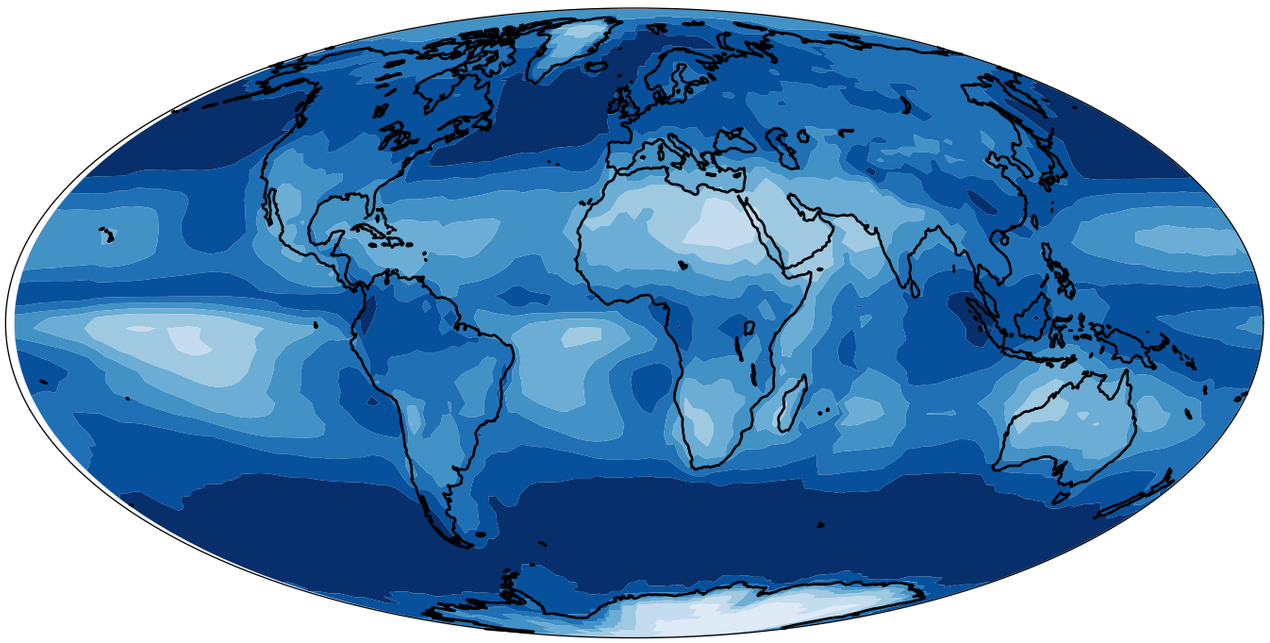
spatial/spectral tests

edge detection

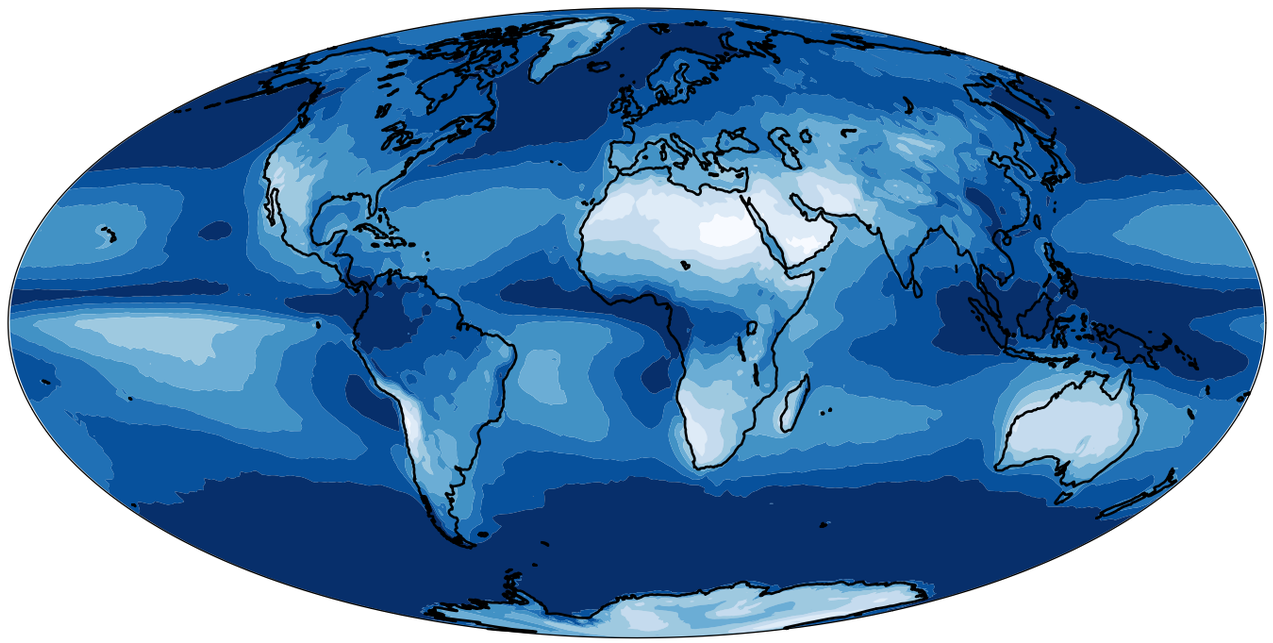
250m cloud mask

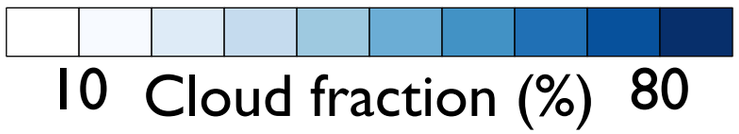
How much of the planet is cloudy?

ISCCP: 66%



MODIS mask: 67%





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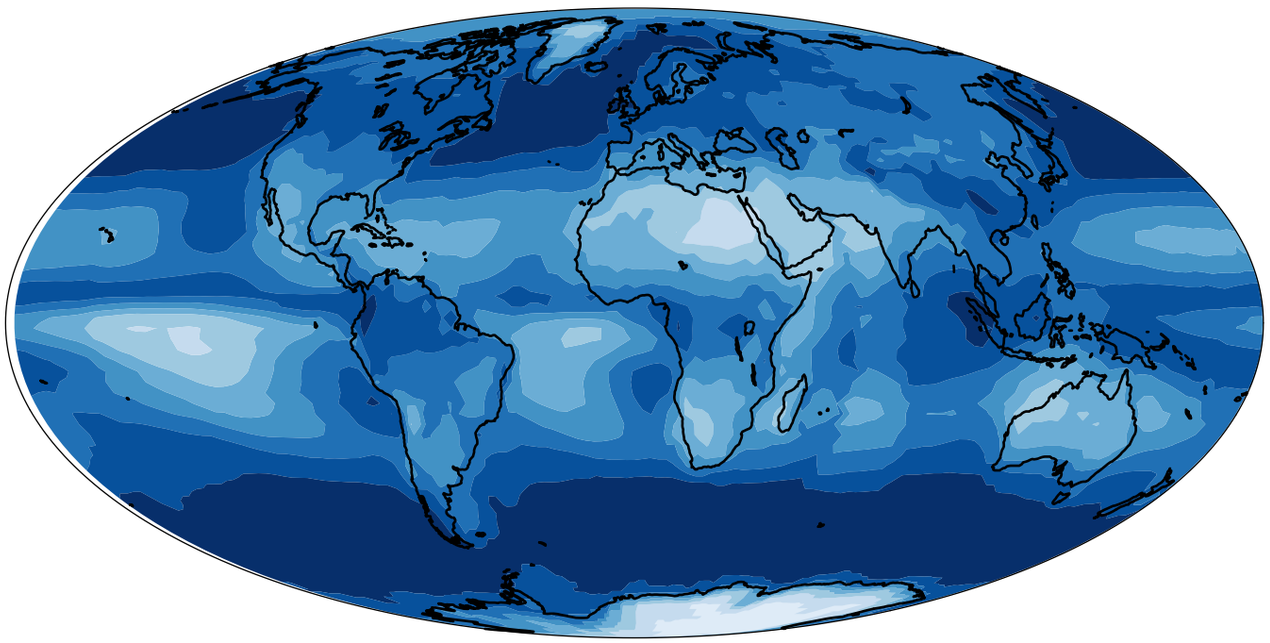
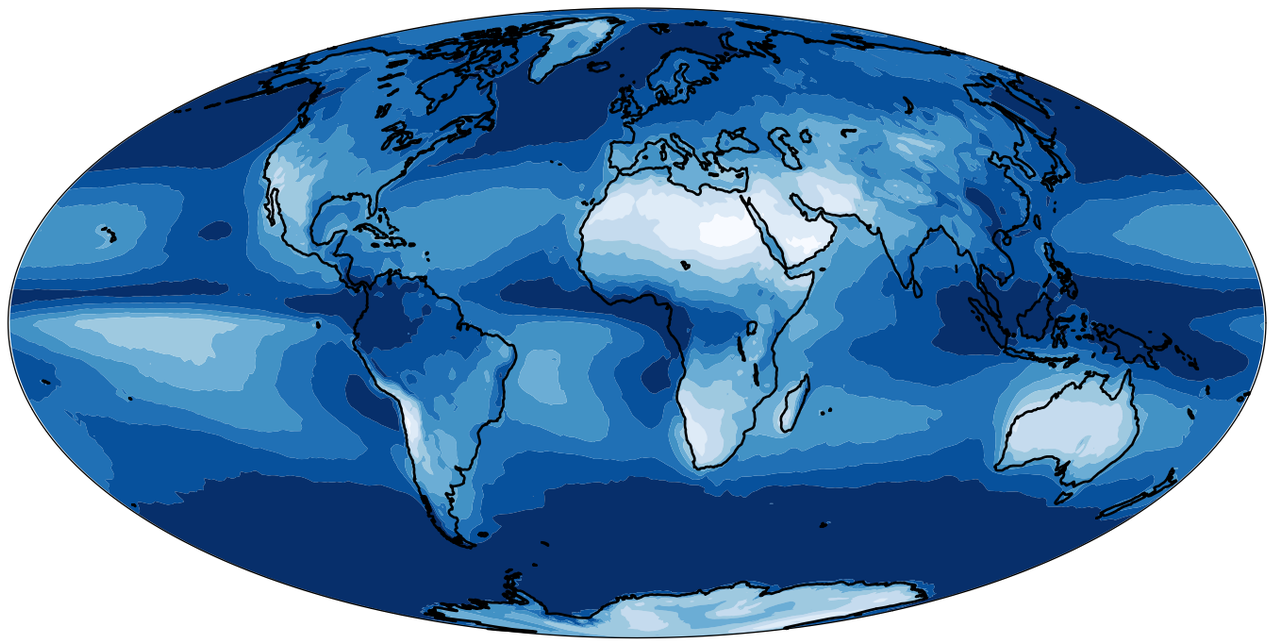
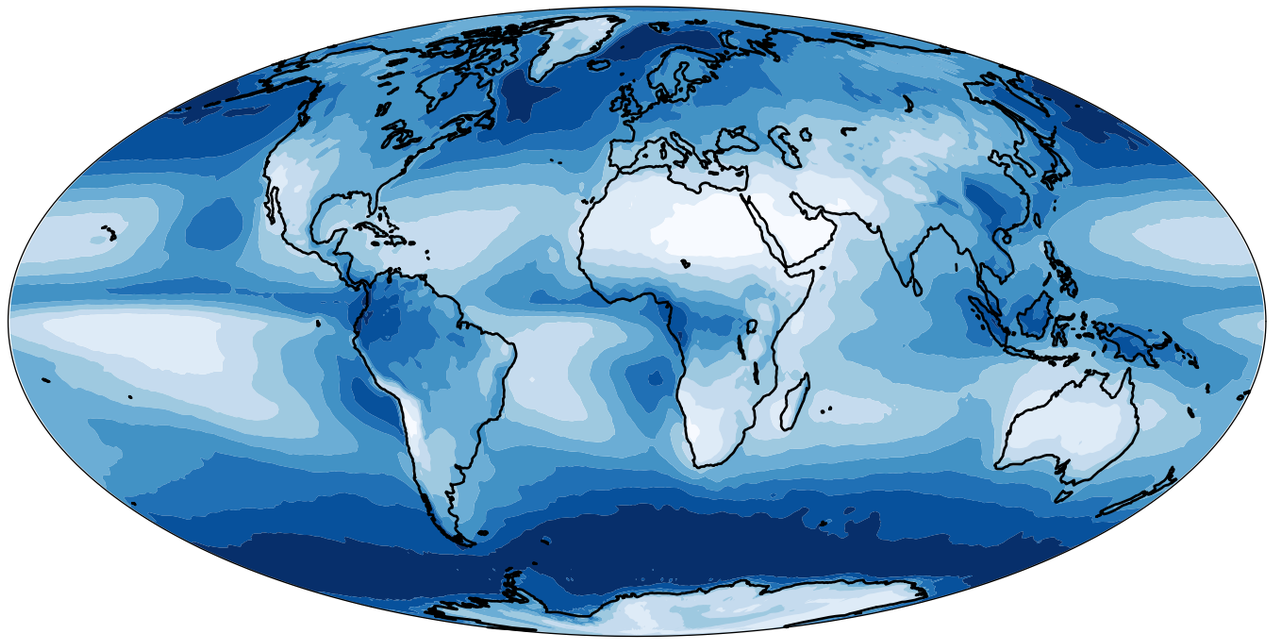


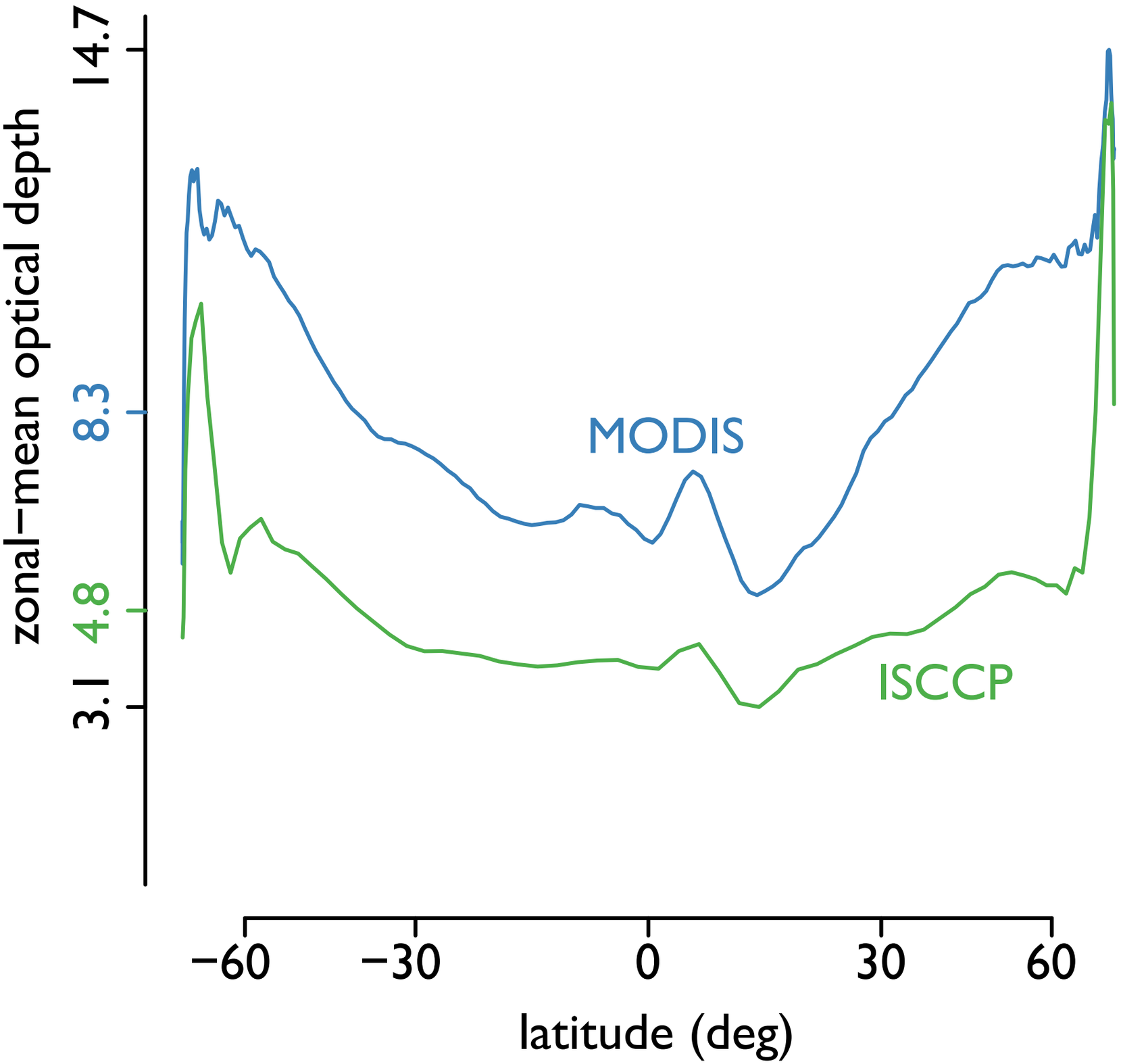
MODIS mask: 67%

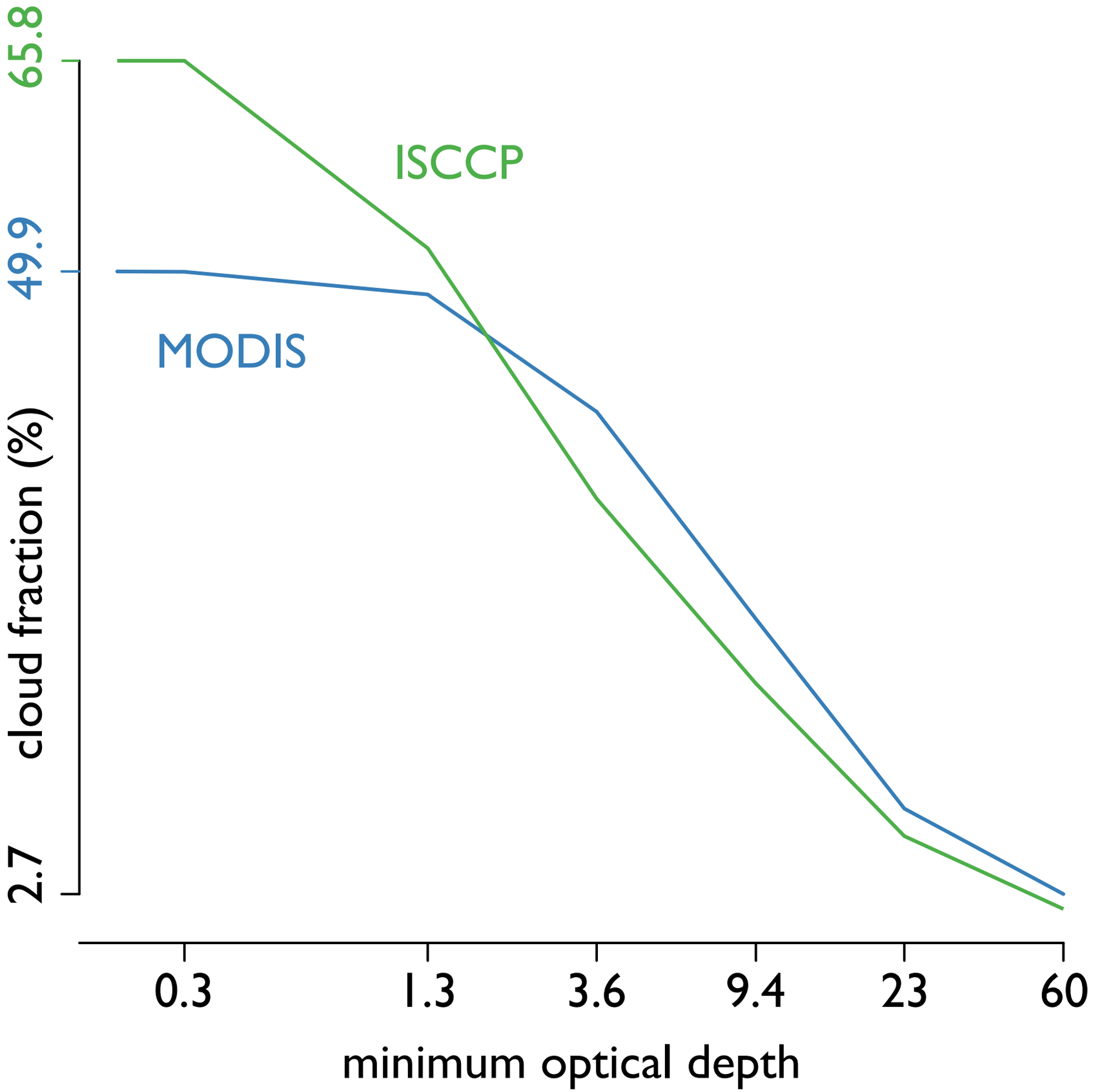


10 Cloud fraction (%) 80

MODIS retrievals: 50%




zonal−mean optical depth
14.7
8.3
3.1
4.8
MODIS
ISCCP
−60
−30
0
30
60
latitude (deg)


65.8
49.9
2.7
cloud fraction (%)
ISCCP
MODIS
0.3
1.3
3.6
9.4
23
60
minimum optical depth

ISCCP

MODIS mask

MODIS retrievals

High

Middle

Low

10

Cloud fraction (%)

90

Observation (i)

Pixels are removed by MODIS clear-sky restoral mostly because they are near cloud edges or are inhomogeneous at 250 m scale

This population turns out to be

nearly all the clouds observed by ISCCP with $\tau < 1.3$

assigned high cloud top pressure by MODIS but
distributed through the atmosphere by ISCCP
(~1/3 are consistent with failed retrievals by ISCCP)

Interpretation (i)

The pixels removed by clear-sky restoral are partially cloud

Roughly 15% of the planet is covered by clouds less than 1 km in size

Omitting these pixels is a truncation error

Literal interpretations of retrievals are misleading

Observation (ii)

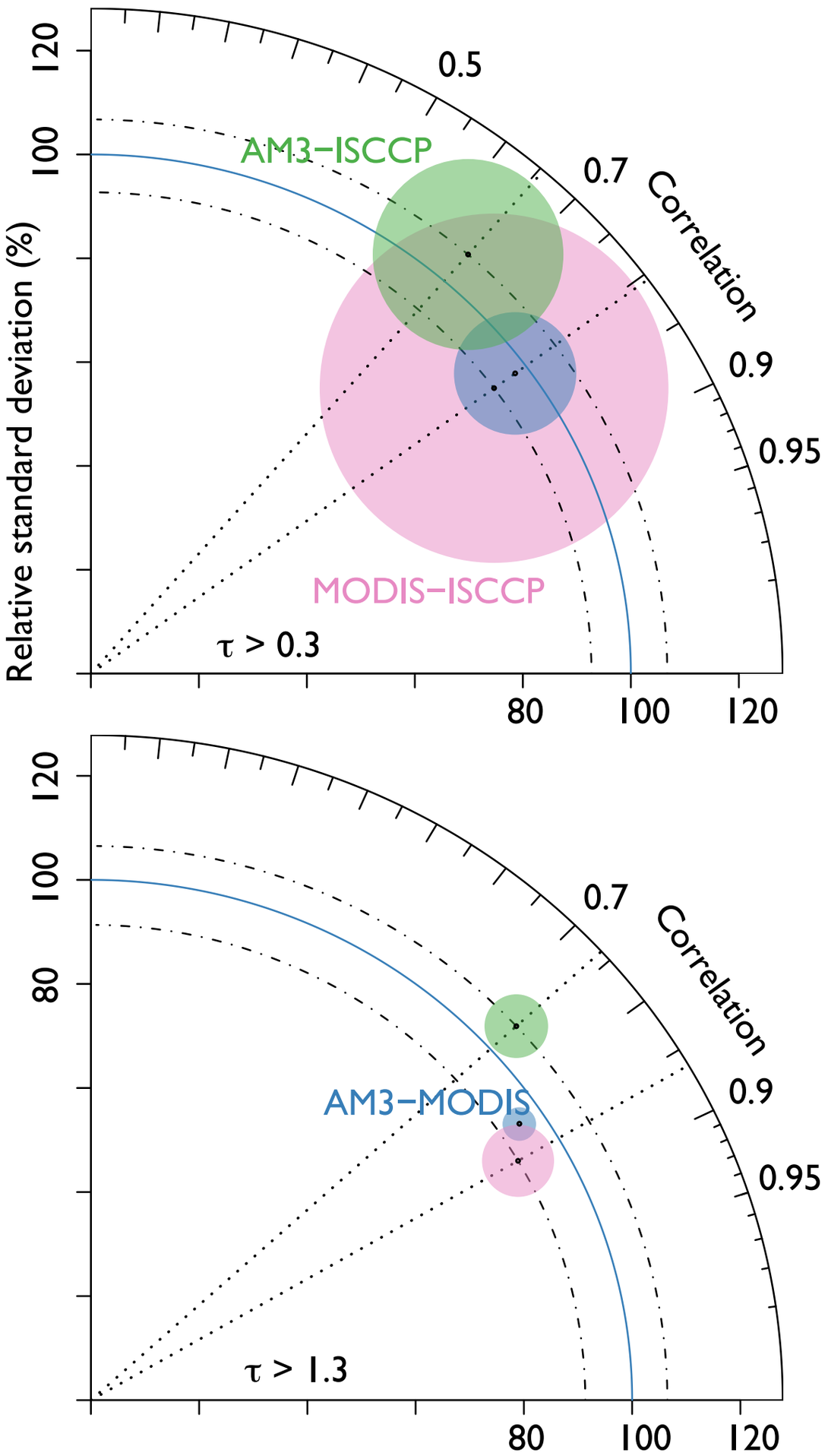
Large-scale models have no concept of spatial scale below the grid size

Cloud fraction is explicitly a function of spatial scale and sensitivity

Implications

Comparisons among observations (and between models and observations) are fair only when the same population is included

Total cloudiness is a fragile basis for comparison


Relative standard deviation (%)
120
100
80
0.5
0.7
0.9
0.95
Correlation
AM3–ISCCP
MODIS–ISCCP
τ > 0.3
80
100
120
120
100
80
0.7
0.9
0.95
Correlation
AM3–MODIS
τ > 1.3
80
100
120

Interpretation (ii)

A substantial portion of the planet's cloudiness is poorly observed

Simulators are necessary but can't be the end of the conversation