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

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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.

“Clear Sky Restoral”

probably clear  
clear  
cloudy  
probably cloudy

spatial/spectral tests  
edge detection  
250m cloud mask
How much of the planet is cloudy?

ISCCP: 66%

MODIS mask: 67%
How much of the planet is cloudy?

ISCCP: 66%

MODIS mask: 67%

MODIS retrievals: 50%
ISCCP
High
MODIS mask
Middle
MODIS retrievals
Low

Cloud fraction (%)
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 ($\sim 1/3$ 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.
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.