Strategies for testing model parameterizations of aerosol-cloud interactions for global models

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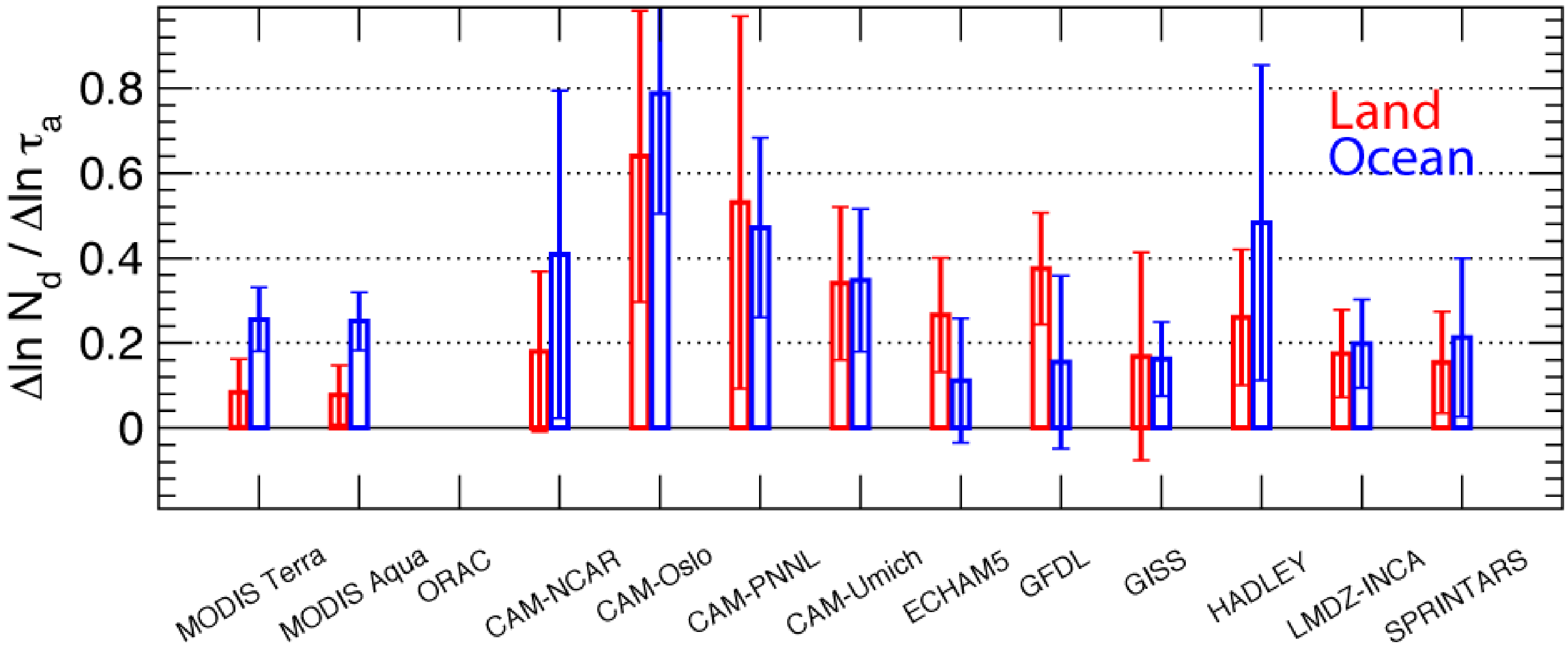
Will focus on first indirect effect.

Will mainly emphasize satellite observations.

Note coauthors and references throughout.

There is no best strategy, but complementary strategies.



Johannes Quaas et al. (2009)

Models compute N_d based on aerosol amount and cloud dynamics.

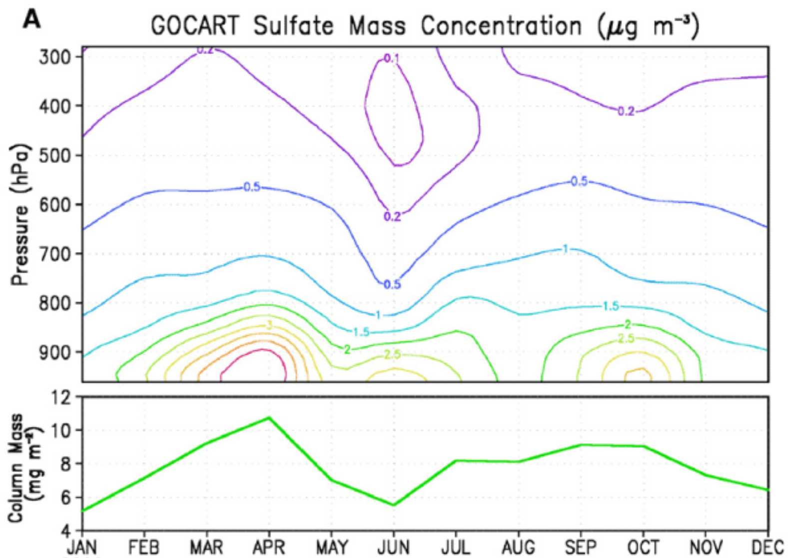
MODIS retrieves cloud drop effective radius (CER) and cloud optical thickness (COT):
assuming clouds fill the field of view
also assuming clouds are horizontally homogenous
result is only for the values averaged over a narrow layer at the top of the cloud.

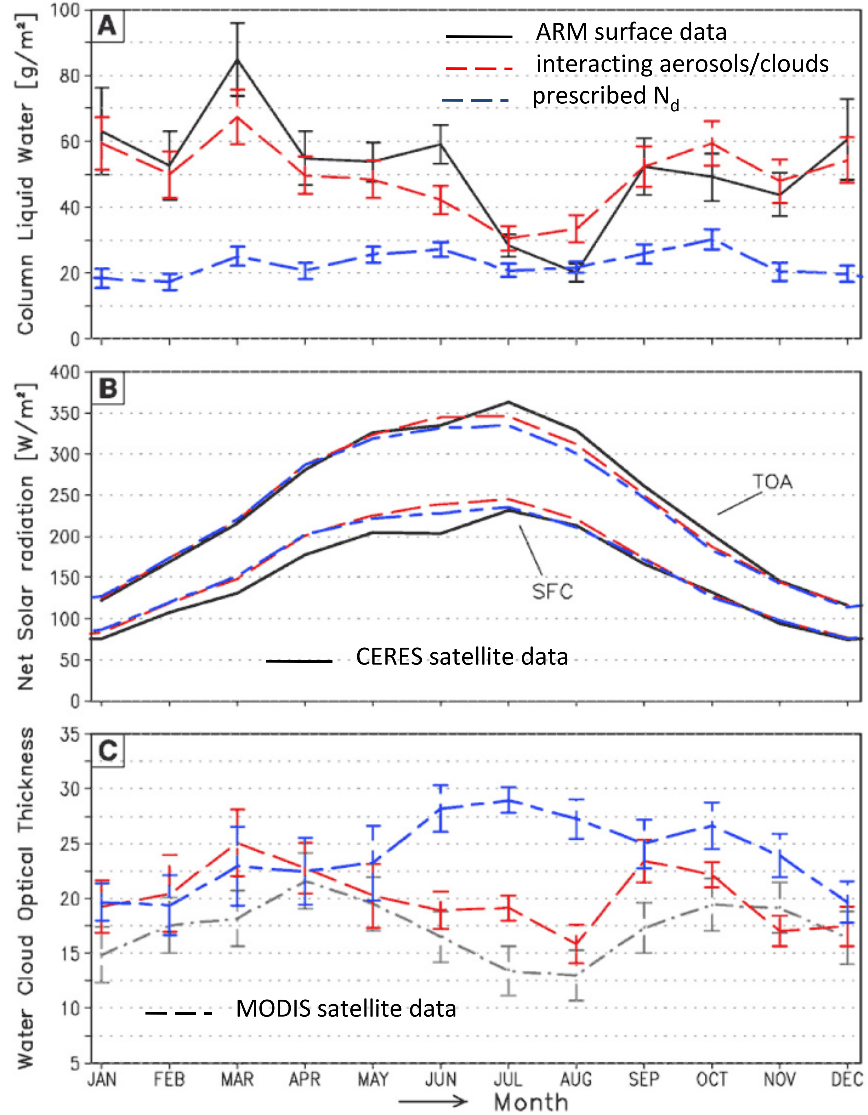
N_d retrieval makes further assumptions about the cloud structure.

So, once you properly screen the data, you are only looking at a subset of all clouds.

Correlation could be coincidental.

Single-column simulation of ARM-SGP site.



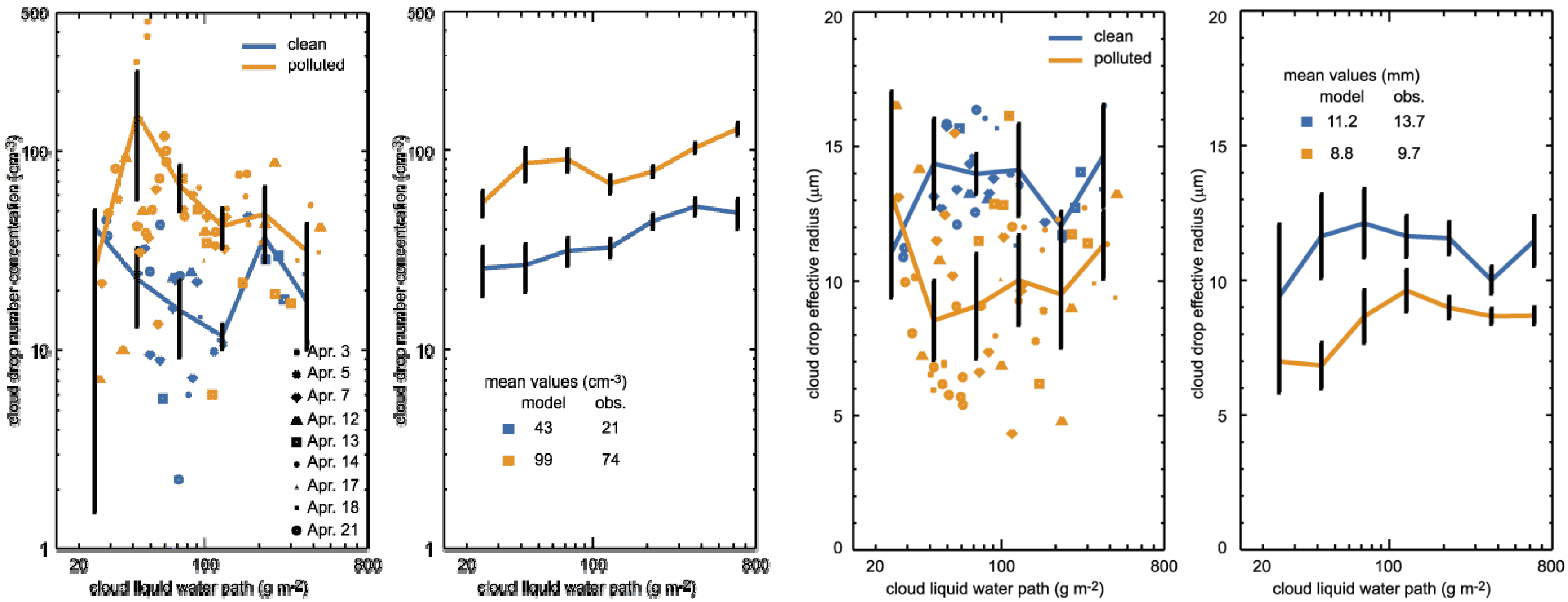


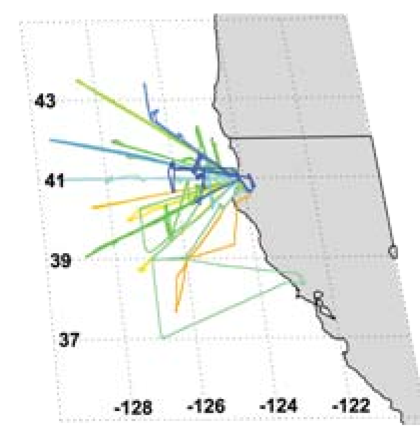
NASA GEOS-4 simulations with and without cloud drop number/size based on aerosol amount (Yogesh Sud and Dongmin Lee, 2007; and continuing work of Partha Bhattacharjee).

cloud drop concentration

cloud drop size

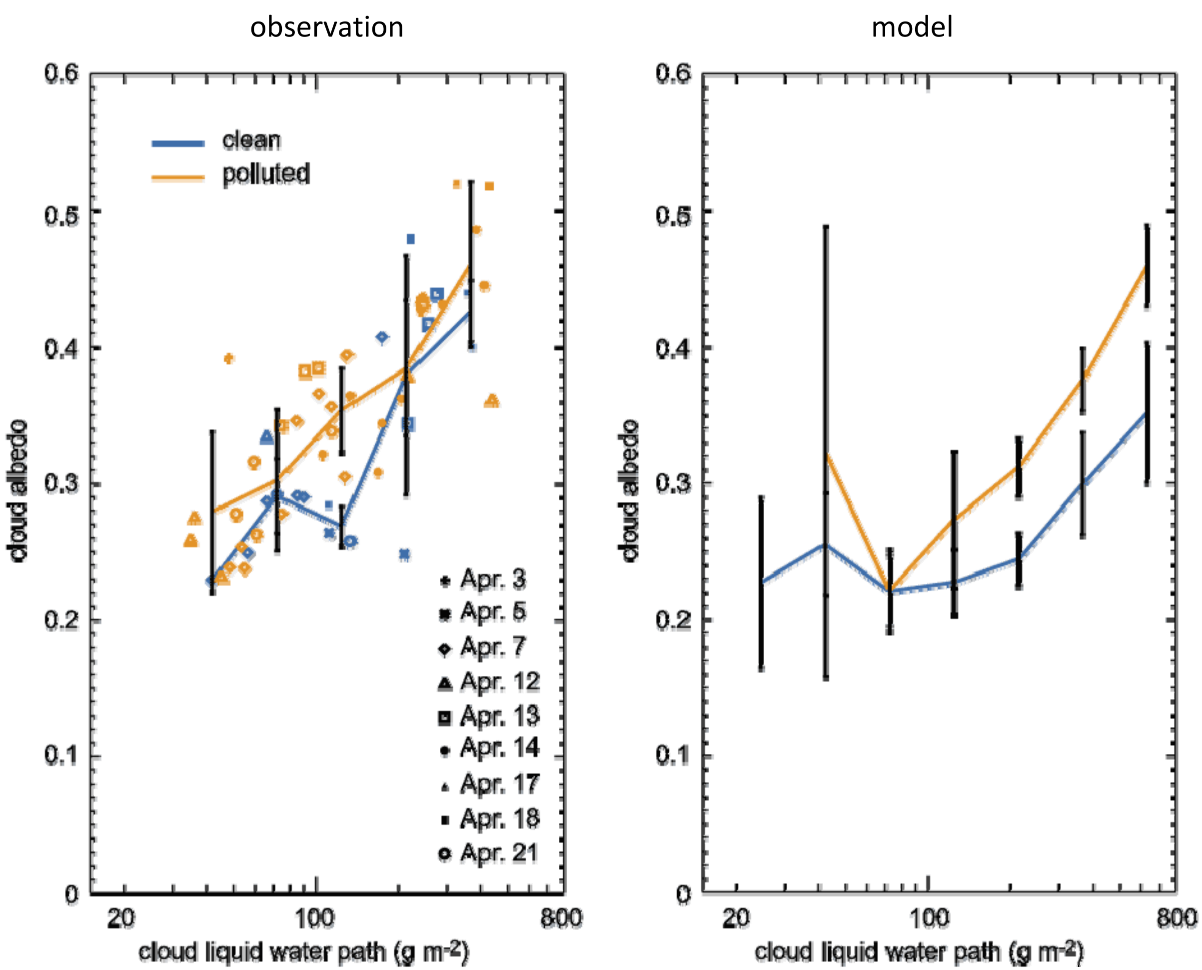
observation | model | observation | model





Observations from offshore of N. California [Wilcox, Roberts and Ramanathan (2006)].
Simulations from NASA GEOS-4.

Polluted is N_a (>0.1μm diameter) greater than 30 cm^{-1} from aircraft.
Liquid water path from AMSR-E satellite.



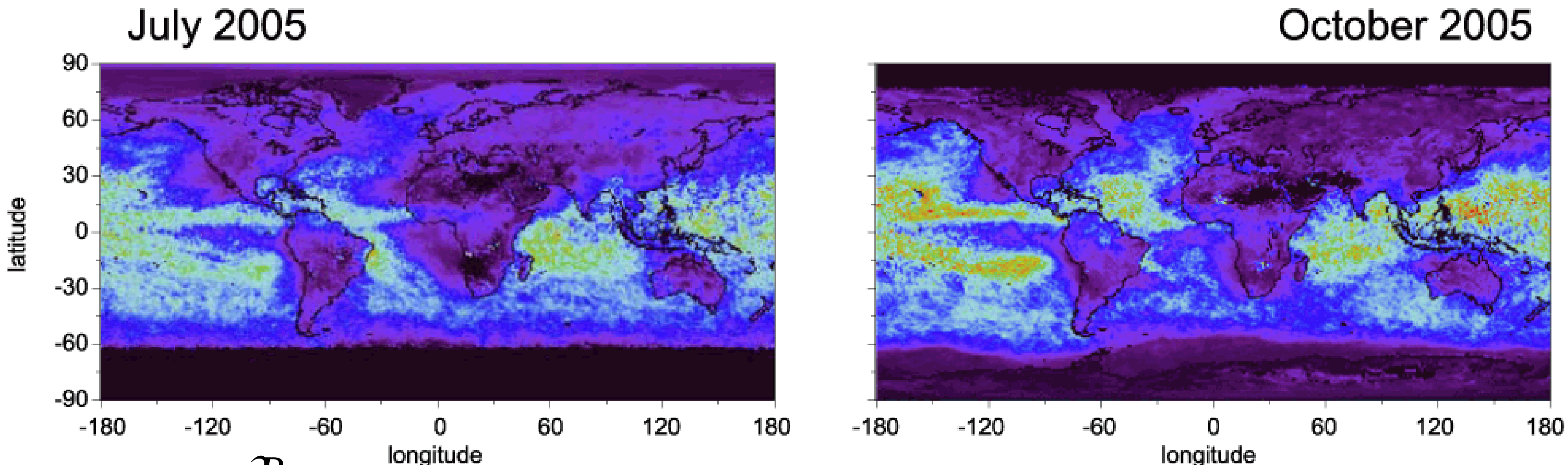
Radiative effect:

observed = -9.9 ± 3 W m^{-2}

simulated = -15.0

Observations from offshore of N. California [Wilcox, Roberts and Ramanathan (2006)].
Simulations from NASA GEOS-4.

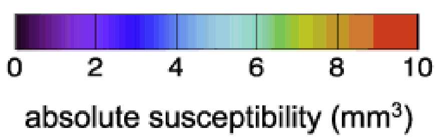
Although the simulated magnitude of the microphysical response of the clouds is reasonable, the nature of the simulated clouds is such that the radiative forcing is greater than observed.

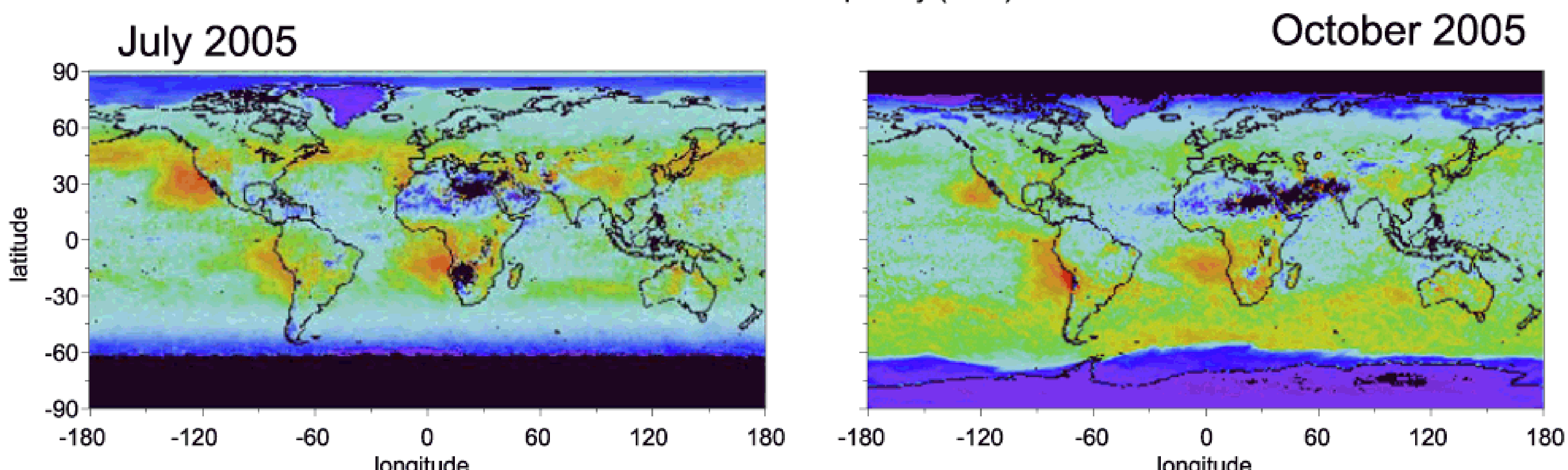


$$\Delta R \propto \frac{\tau}{w}\frac{\partial R}{\partial \tau} r_e^3 \Delta N$$

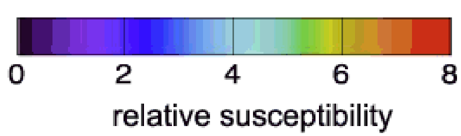
$\Delta N = 1\ cm^{-3}$

$w = 0.3\ g\ m^{-3}$



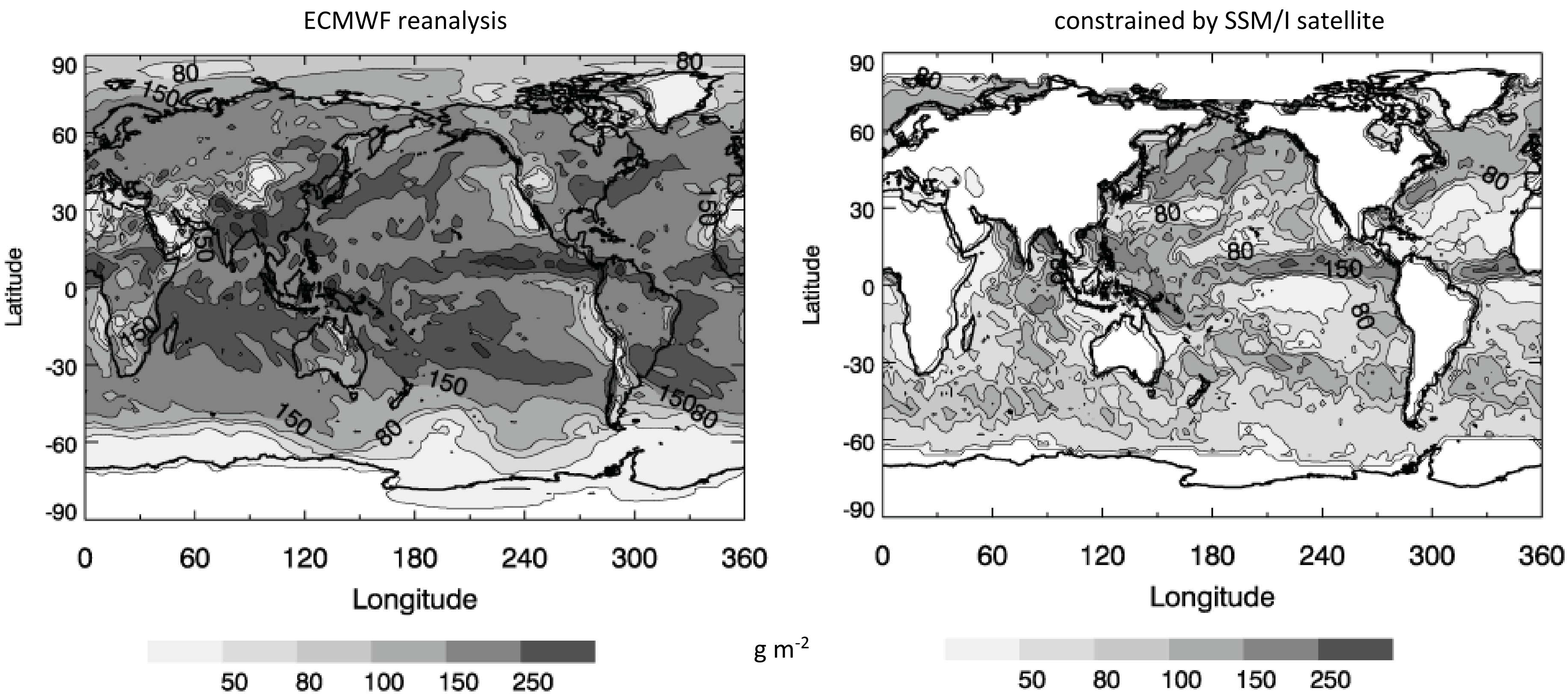


$$\Delta R_{rel} \propto \tau \frac{\partial R}{\partial \tau}\frac{\Delta N}{N} \qquad \frac{\Delta N}{N} = 10\%$$



Lazaros Oreopoulos and Steven Platnick (2008)

Cloud Liquid Water Path (g m^{-2})



Chemical transport model simulating aerosols, clouds and interactions (liquid clouds) driven by ECMWF reanalysis. Constrained cloud liquid water path by SSM/I passive microwave liquid water path retrieval.

So cloud microphysics responds to aerosol variations, but meteorology and cloud macrophysics are constrained by observations.

Yan Feng and V. Ramanathan (in press)

	All latitudes		Between 45 S and 45 N	
	CTM - all aerosols	CTM - natural aerosols only	CTM - all aerosols	Obs_M or Obs_S
	Column-mean droplet effective radius (µm)			
NH oceans	9.7	12.4	10.4	12.1
SH oceans	11.2	11.9	12.9	13.0
Total oceans	10.7	12.1	11.8	12.7
	Cloud optical depth			
NH oceans	15.2	11.8	14.7	12.6
SH oceans	12.9	12.3	12.1	12.1
Total oceans	13.8	12.1	13.2	12.3

Simulated inter-hemispheric difference in COD and CER are larger than observed although possibly within observational uncertainties.

Yan Feng and V. Ramanathan (in press)

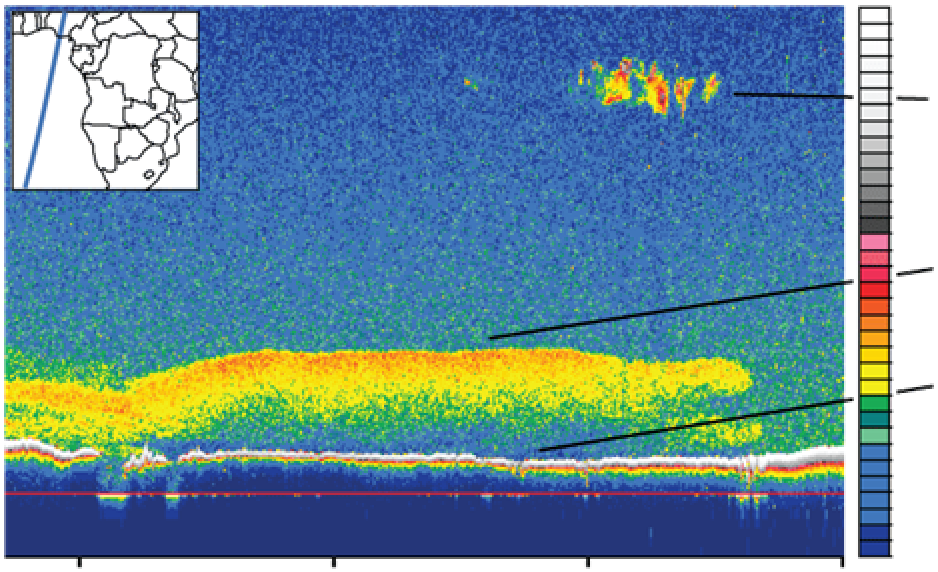
Summary

Quantitative retrievals of cloud properties are only available for a subset of all clouds.

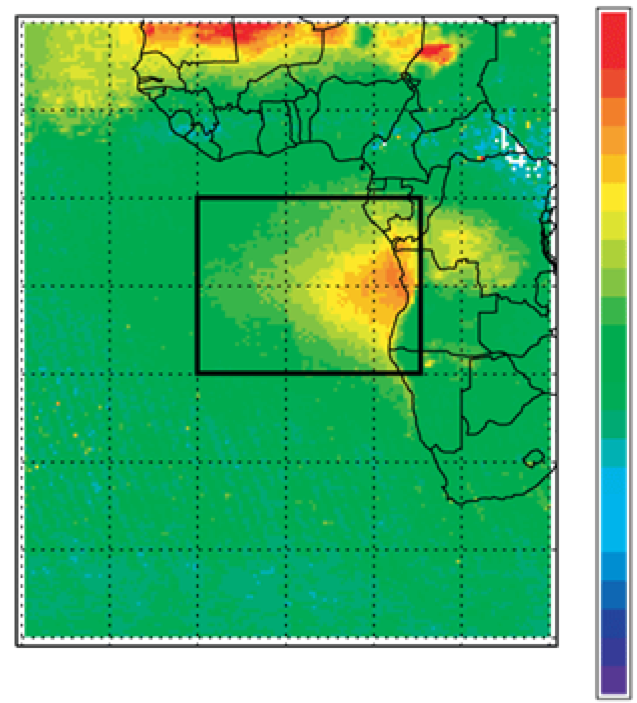
A combination of in-situ and satellite data can estimate the magnitude of the indirect effect which can be compared to model output.

Computation of cloud susceptibility can help separate errors attributable to the physical parameterization of aerosol/cloud interactions from errors in the simulated cloud fields.

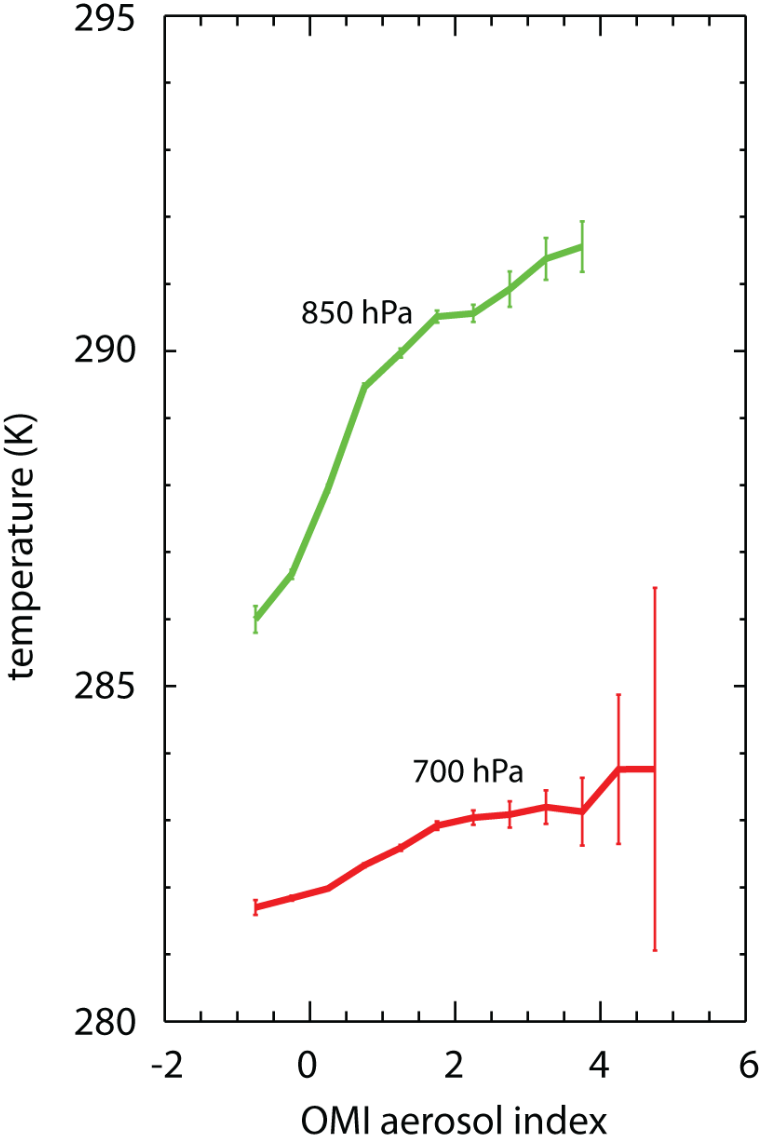
Creative use of single-column models and constrained transport models can help isolate the microphysical interaction from dynamical correlations of aerosol and cloud.



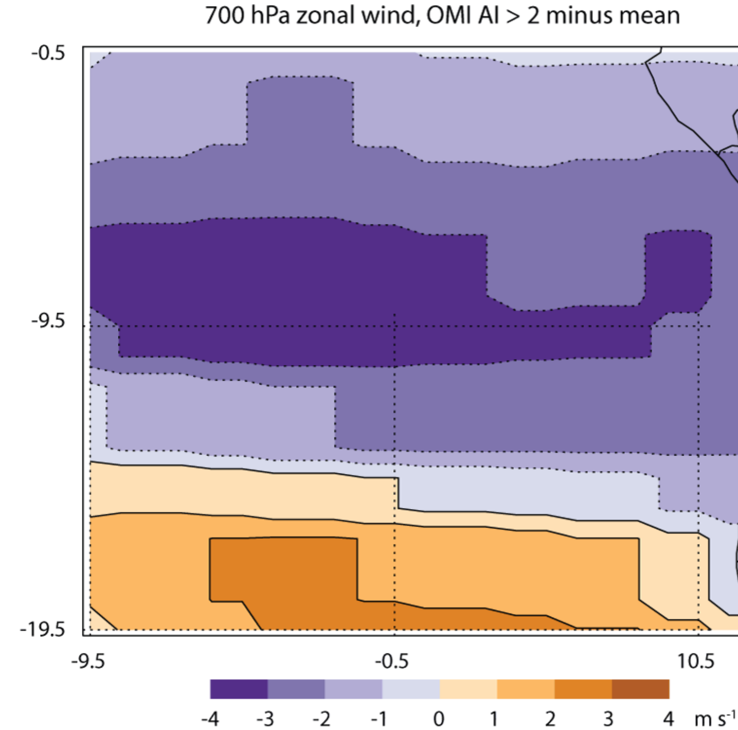
mean aerosol $ssa_{0.55\mu m}$ = 0.91 (*Haywood et al. 2004*)



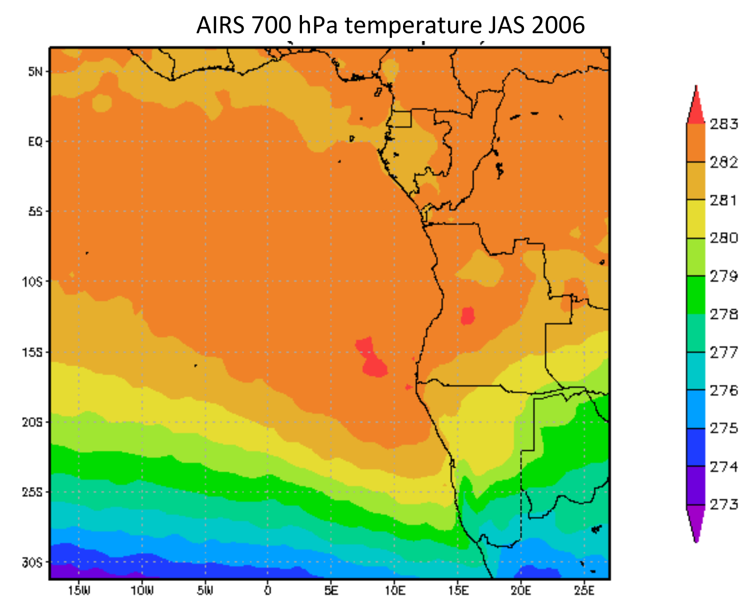
Wilcox, Harshvardhan, and Platnick (2009)



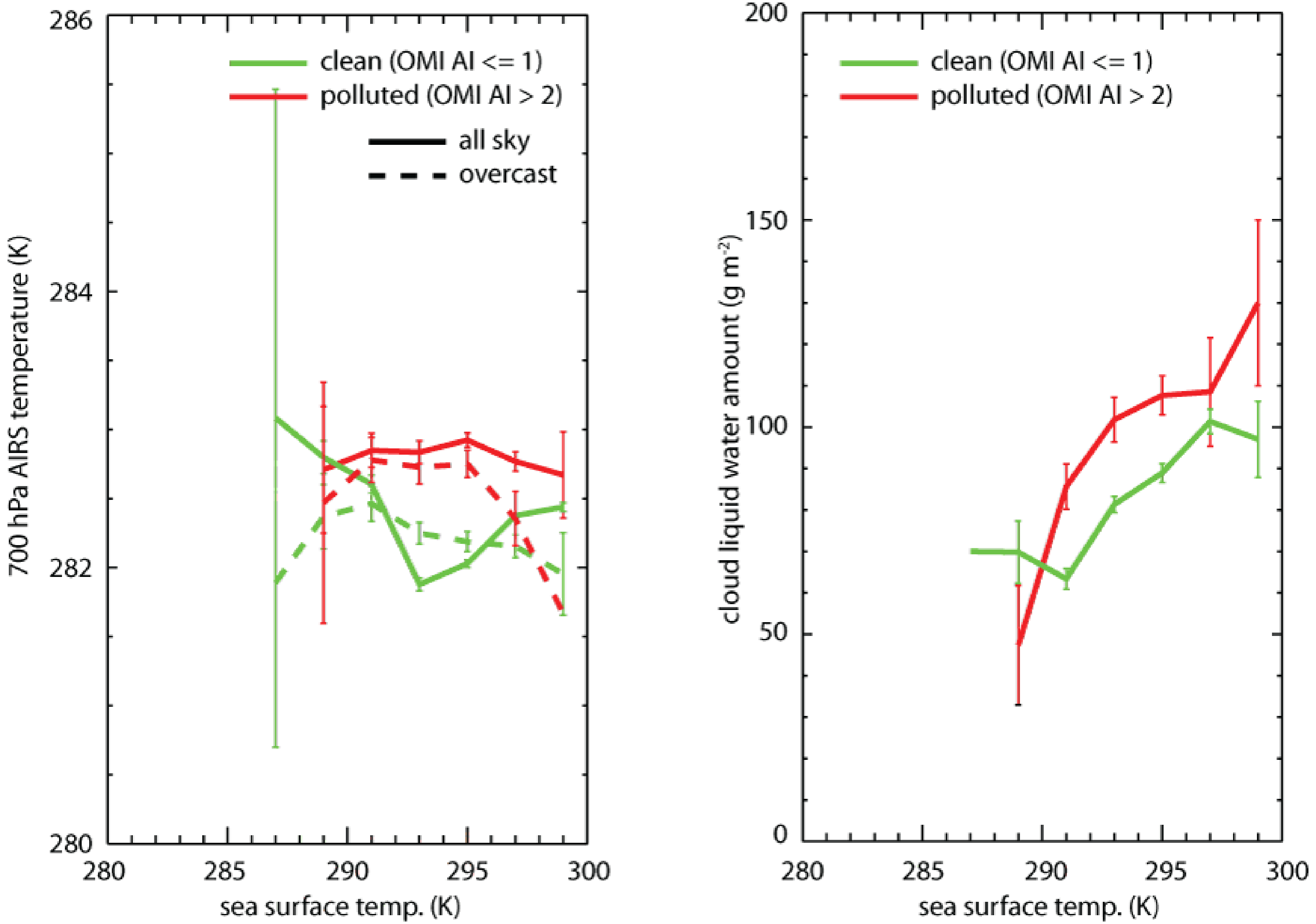
temperature (K)
295
290
285
280
-2
0
2
4
6
OMI aerosol index
850 hPa
700 hPa



700 hPa zonal wind, OMI AI > 2 minus mean
-0.5
-9.5
-19.5
-9.5
-0.5
10.5
-4
-3
-2
-1
0
1
2
3
4
m s-1



AIRS 700 hPa temperature JAS 2006
5N
EQ
5S
10S
15S
20S
25S
30S
15W
10W
5W
0
5E
10E
15E
20E
25E
283
282
281
280
279
278
277
276
275
274
273



clean (OMI AI <= 1)
polluted (OMI AI > 2)
all sky
overcast
700 hPa AIRS temperature (K)
286
284
282
280
280
285
290
295
300
sea surface temp. (K)
clean (OMI AI <= 1)
polluted (OMI AI > 2)
cloud liquid water amount (g m-2)
200
150
100
50
0
280
285
290
295
300
sea surface temp. (K)

$LWP \approx COT * CER$

LWP = Cloud liquid water path
COT = Cloud optical thickness
CER = Cloud drop effective radius