Evaluating aerosol indirect effects in climate models using COSP and satellite measurements

AeroCom meeting

September 10-13, 2012

Susanne Bauer (GISS) and George Ban-Weiss (LBNL)

Collaborators: Ralf Bennartz, Jonathan Jiang, Xiaohong Liu, Yi Ming

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Goals

(1) Reduce uncertainty in aerosol indirect forcing, next steps after Quaas et al 2009.

(2) Compare signatures of aerosol-cloud interactions in global climate models and satellite products

(3) Understand process level differences among the models due to differences in cloud and aerosol parameterization

(4) Improve parameterizations in the models that do not perform as well, which cloud be caused by cloud macro or microphysics, aerosol scheme, aerosol – cloud coupling or even other parts such as turbulence scheme.

(5) Allow for fast testing of new and improved parameterizations in GCMs by building a robust framework that allows for model intercomparison and model/satellite comparison

(6) Current state involves three models, GISS (Bauer), CESM/CAM5 (Liu) and GFDL (Ming)

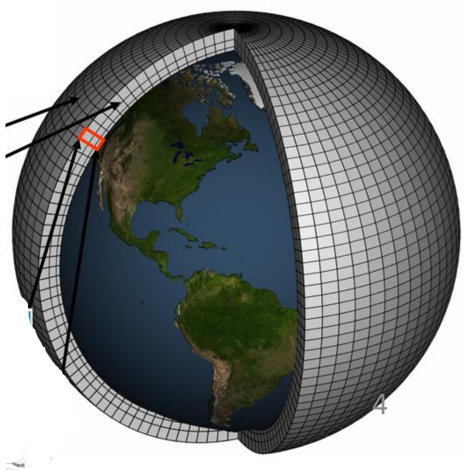
(7) Expansion to AeroCom models

Current GCM simulation details

- Simulation period: 1995-2012 or alternatively 2005 - 2010
- To maximize comparability of GCM and observations:
  - Prescribed sea surface temperatures
  - Nudged horizontal winds and non-nudged
  - CFMIP Observation Simulator Package (COSP)

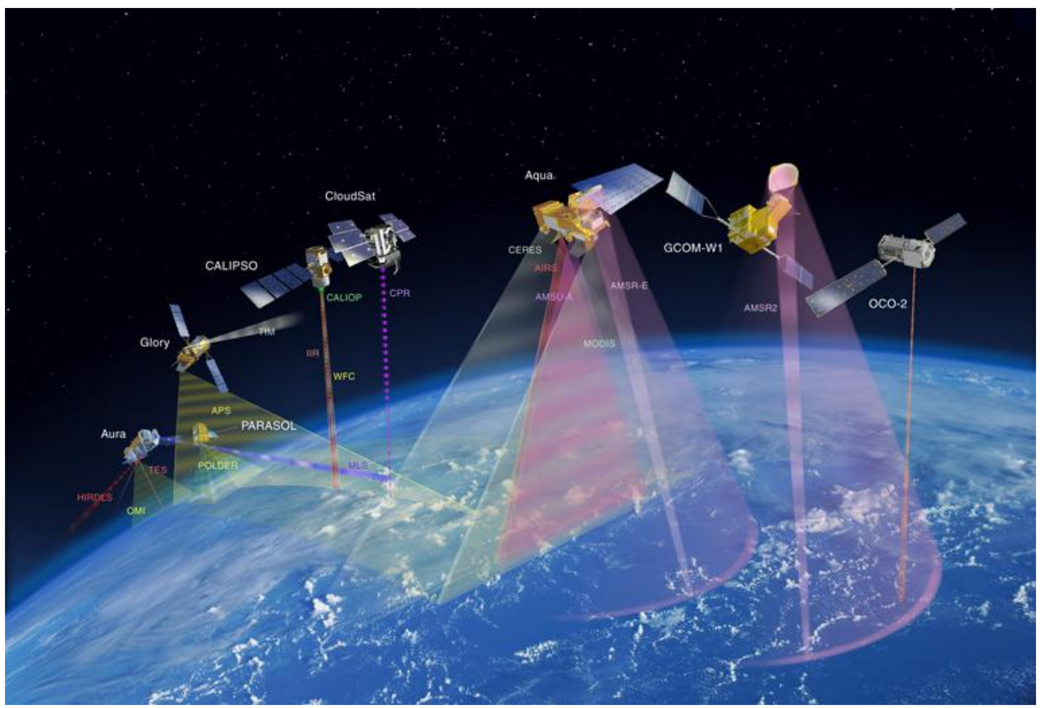
  (archived CMIP5 models lack aerosol information)
  - High frequency (6 hourly) GCM output
- We focus on three models to allow for deeper understanding rather than simply intercomparison

<u>Global Climate Models</u>
- GISS
- CESM/CAM5
- GFDL



Satellite products

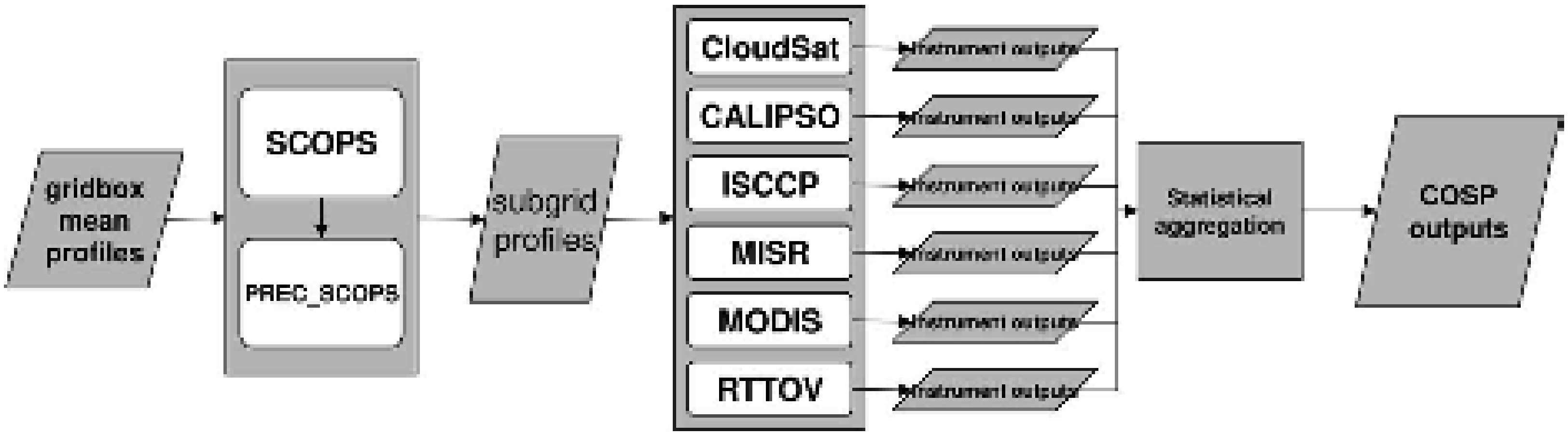
- Univ. of Wisconsin CDNC & LWP (MODIS, AMSR-E) (Ralf Bennartz)
- MODIS L3C5
- CERES SSF Ver2.6
- CALIPSO (Jonathan Jiang – JPL)
- CloudSat (Jonathan Jiang – JPL)



CFMIP Observation Simulator Package (COSP)

Bodas-Salcedo et al. BAMS 2011

- Converts model variables to pseudo-satellite observations
  - How would satellite see clouds in the climate model?



Bodas-Salcedo et al. 2011

COSP

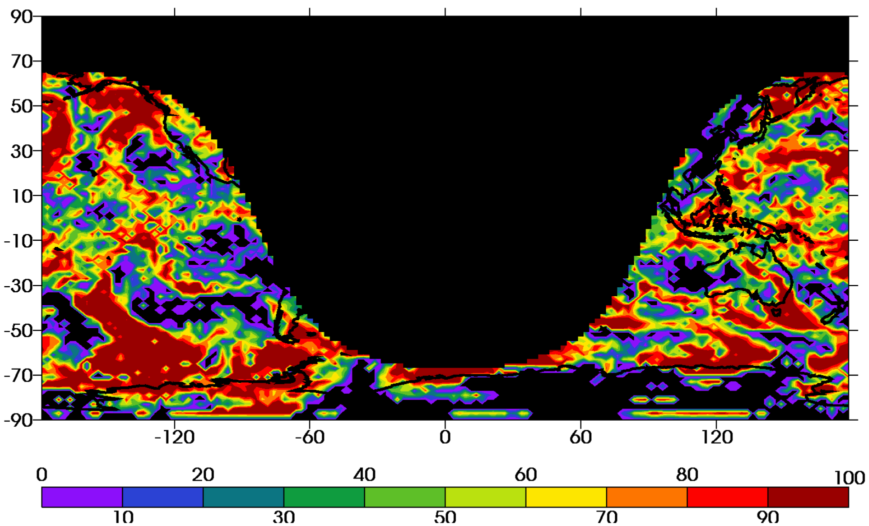
- Converts model variables to pseudo-satellite observations
    - How would satellite see clouds in the climate model?
- Allows for direct comparison of climate model to satellite
- Allows for accurate model inter-comparison
- We are running CALIPSO, MODIS, CLOUDSAT simulators
- Only cloud variables (no aerosol variables)

Simulator	Output diagnostics
CALIPSO	Lidar total backscatter (532 nm)
	Lidar molecular backscatter
	Height–scattering ratio histograms
	Low-level cloud fraction (CTP > 680 hPa)
	Midlevel cloud fraction (440 < CTP < 680 hPa)
	High-level cloud fraction (CTP < 440 hPa)
	3D cloud fraction
	Total cloud fraction
MODIS	Total cloud fraction
	Liquid cloud fraction
	Ice cloud fraction
	High-level cloud fraction
	Midlevel cloud fraction
	Low-level cloud fraction
	Total cloud optical thickness
	Liquid cloud optical thickness
	Ice cloud optical thickness
	Total cloud optical thickness [Log_{10}(mean)]
	Liquid cloud optical thickness [Log_{10}(mean)]
	Ice cloud optical thickness [Log_{10}(mean)]
	Liquid cloud particle size
	Ice cloud particle size
	CTP-τ histograms
	Cloud liquid water path
	Cloud ice water path
	Cloud area fraction
Combined	CALIPSO cloud fraction undetected by *CloudSat*
	Total cloud fraction from *CloudSat* and CALIPSO

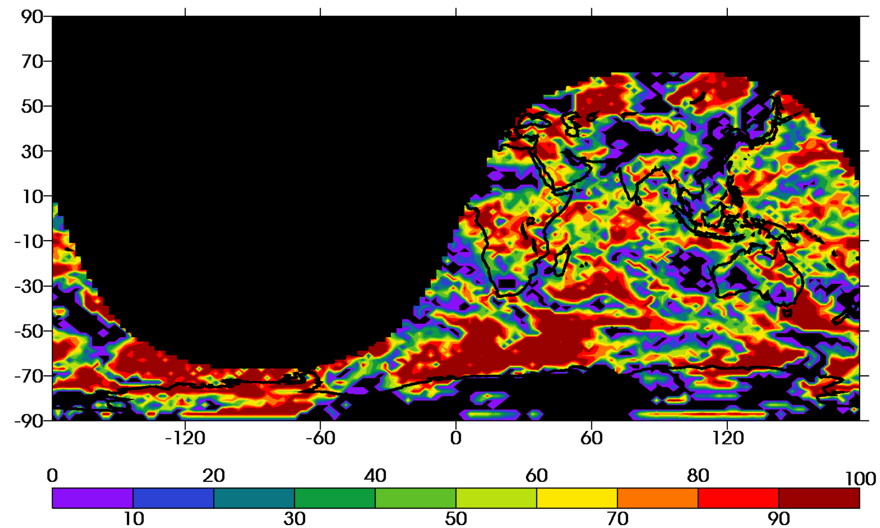
CFMIP Observation Simulator Package (COSP)

Example: GISS total cloud fraction (MODIS)

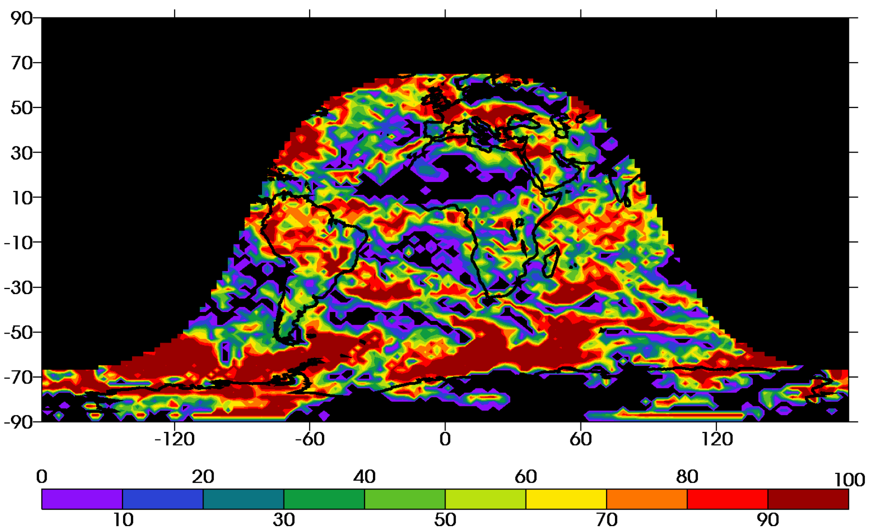
00:00 UTC



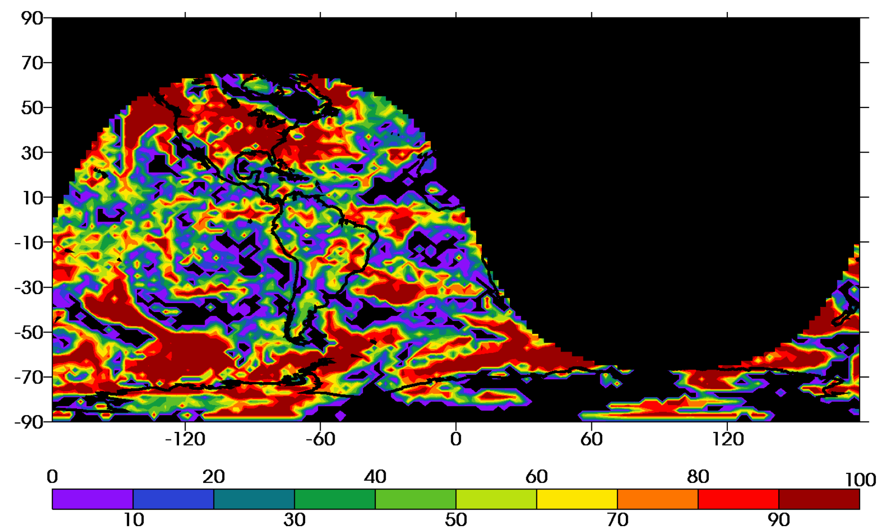
06:00 UTC



12:00 UTC



18:00 UTC



Early preliminary results / status update

First focus area: subtropical stratocumulus

Focus on subtropical stratocumulus

Simulations

- GISS simulations complete
- CESM and GFDL simulations underway

Satellite

- Processed satellite data
  - MODIS and CERES climatology 2003-2008

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, D02201, doi:10.1029/2006JD007547, 2007

Click Here for Full Article

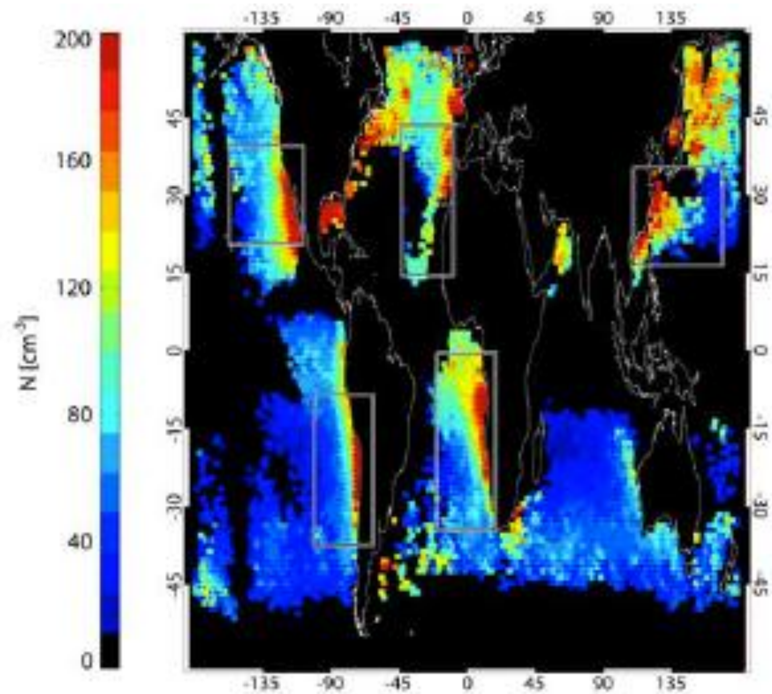
Global assessment of marine boundary layer cloud droplet number concentration from satellite

R. Bennartz[1]

- CDNC ~ $(\tau_{liq}{}^{3})(LWP^{-5/2})$

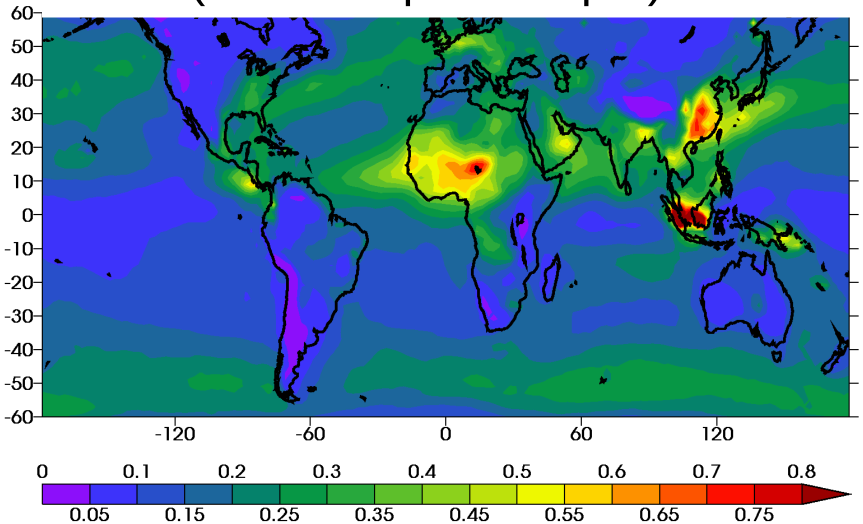
  ~ $(\tau_{liq}{}^{1/2})(R_{eff}{}^{-5/2})$

- Assumes adiabatically stratified clouds

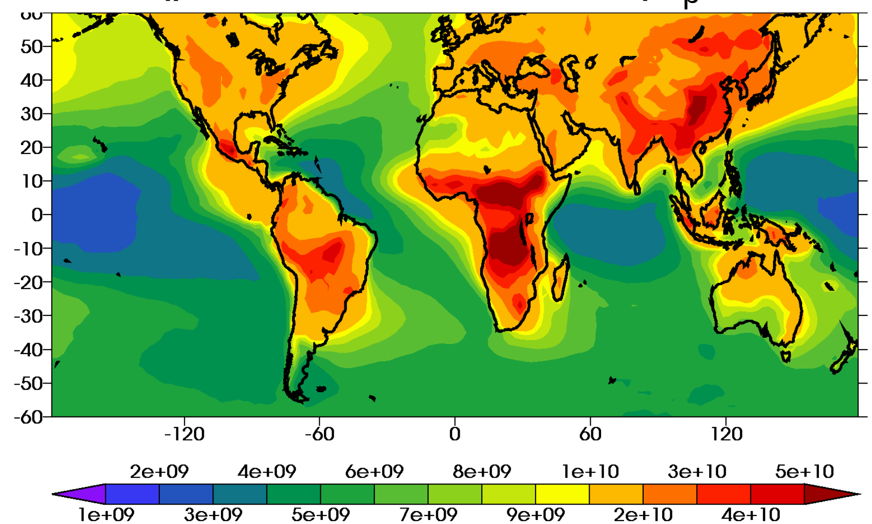


Aerosol optical depth, particle number concentration

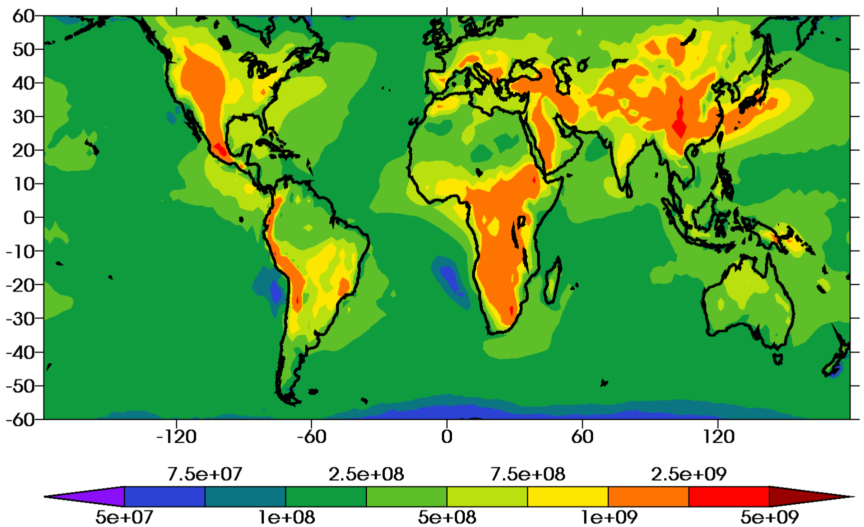
GISS (aerosol optical depth)



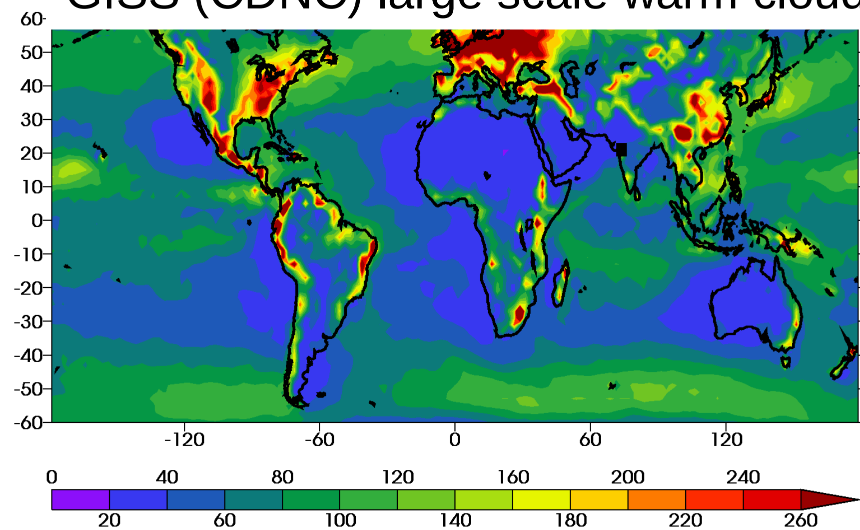
GISS (particle number # m^{-2} (D_p>100nm))



GISS (activated particles (# m^{-2}))

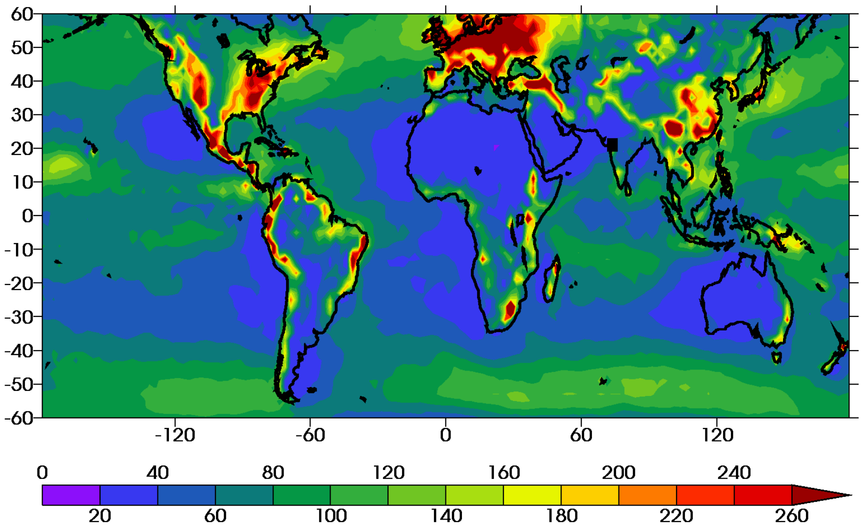


GISS (CDNC) large scale warm clouds



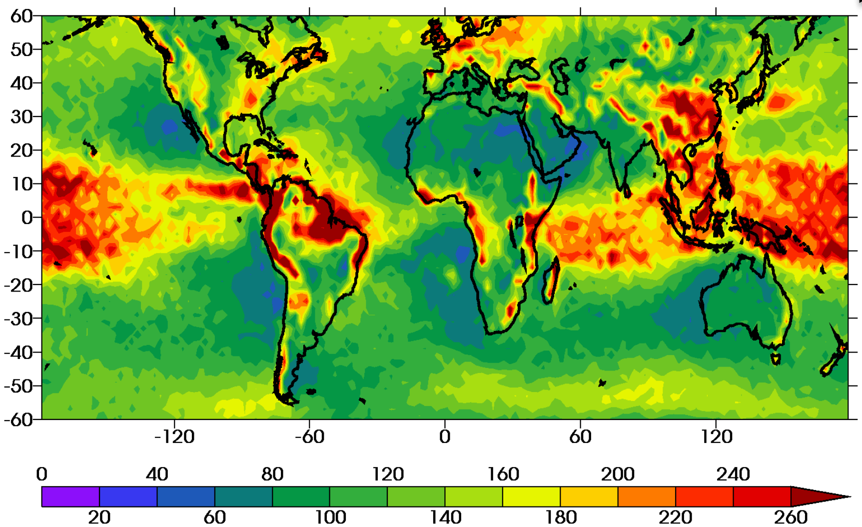
Cloud droplet number concentration (# cm^{-3})

GISS (model output)
large scale warm clouds

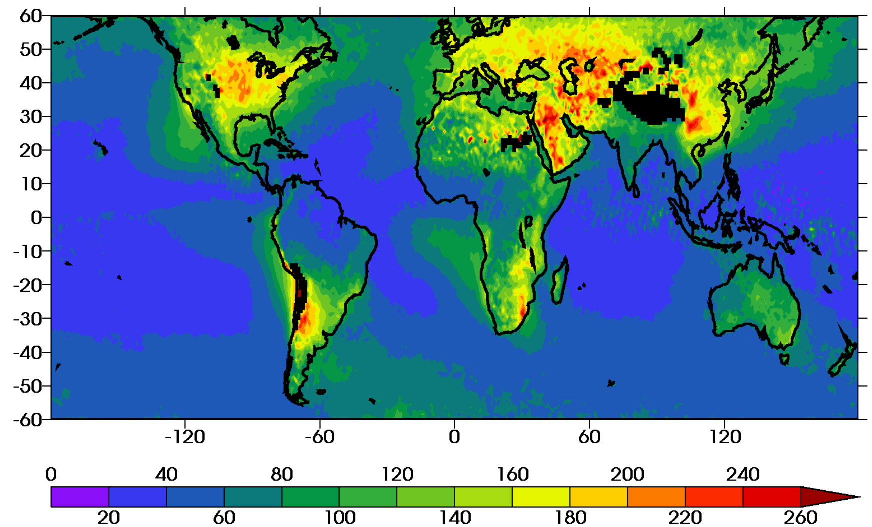


$$CDNC \sim (\tau_{\mathrm{liq}}{}^{1/2})(R_{\mathrm{eff}}{}^{-5/2})$$

GISS (calculated using COSP)



Bennartz (calculated using MODIS)



Status

- We are currently developing the evaluation testbed
- Model requirements may change (we will inform the AeroCom community and ask for participation early next year)
- Diagnostics will include vertical profiles, high frequency outputs and multiple COSP simulators (eventually extended including aerosol properties)
- Focus area, marine stratus
- In-situ measurement component: evaluation of models and satellites
- Participation of all three communities are welcome:

  field, remote sensing and modeling

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