Evaluating aerosols, clouds, and their interactions in three global climate models using COSP and satellite measurements

ASR meeting - FASTER breakout
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Research goals (for work presented here)

(1) Evaluate global distributions of aerosols and clouds in three global climate models by comparing to satellite observations

- Aerosol optical depth
- Cloud properties (cloud optical depth (COD), droplet effective radius (R_e), cloud droplet number concentration (CDNC))

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

- Focusing on regional analysis with specific cloud regimes

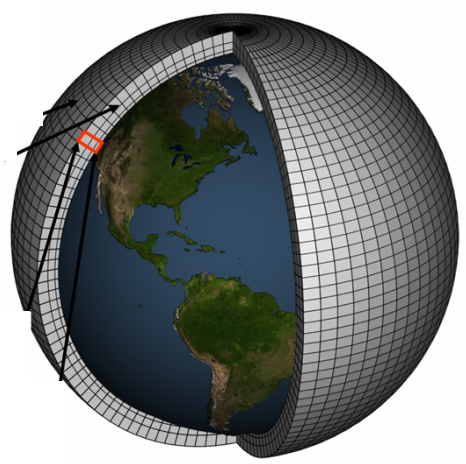
(3) Develop statistical techniques to evaluate various cloud regimes in global climate models (and satellite observations)

- Trying to keep in mind the idea of choosing regimes like in RACORO
- Keeping in mind the need for testing new parameterizations (developed in FASTER) in GCMs

GCM simulation details

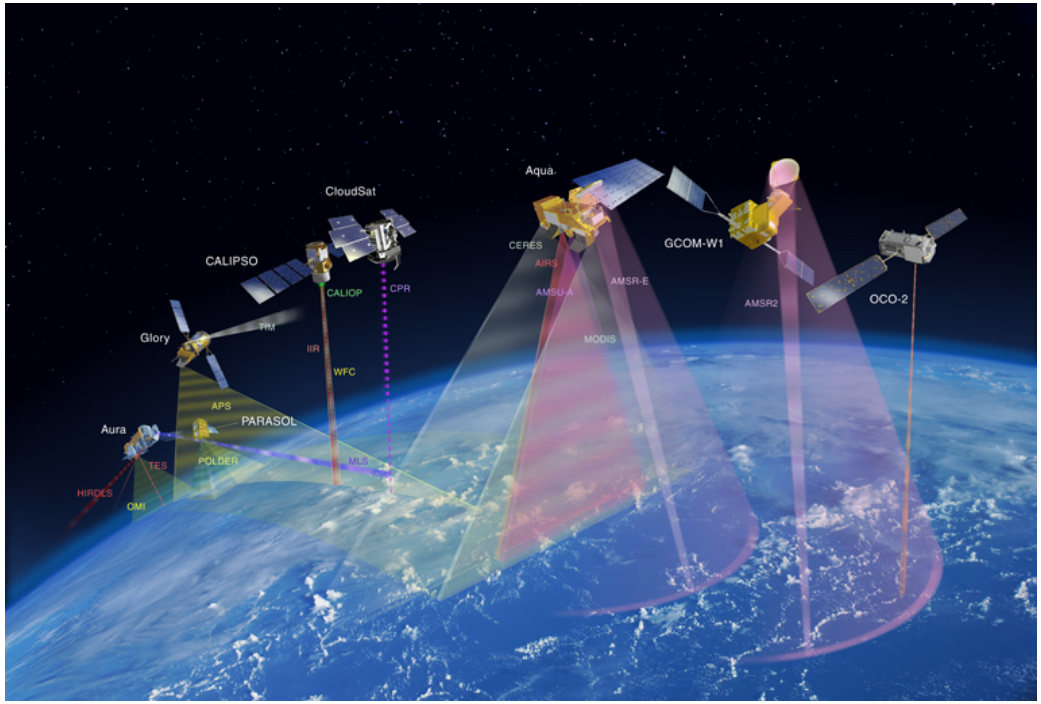
- Simulation period: 1997-2010
- CMIP5 emissions
- To maximize comparability of GCM and observations:
  - Prescribed sea surface temperatures
  - Nudged horizontal winds
  - CFMIP Observation Simulator Package (COSP)
  - High frequency (3 hourly) GCM output
  - Extract satellite overpass times

Global Climate Models
- GISS Model-E (2°x 2.5°)
  (Susanne Bauer – NASA)
- CAM5 (1.9°x 2.5°)
  (Xiaohong Liu - PNNL)
- GFDL AM3 (2°x 2.5°)
  (Yi Ming - GFDL)



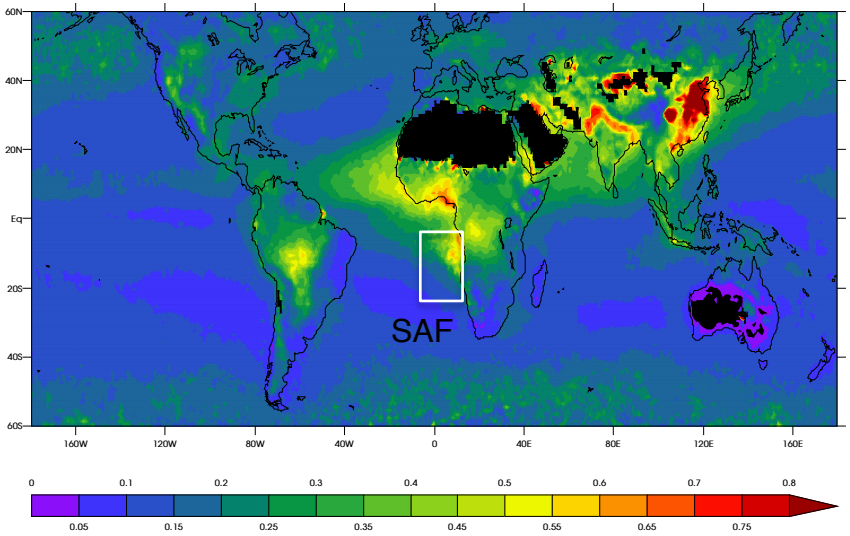
Satellite products

- MODIS L3C5
- Univ. of Wisconsin CDNC & LWP (Bennartz, 2007)
- Calipso, Cloudsat, CERES

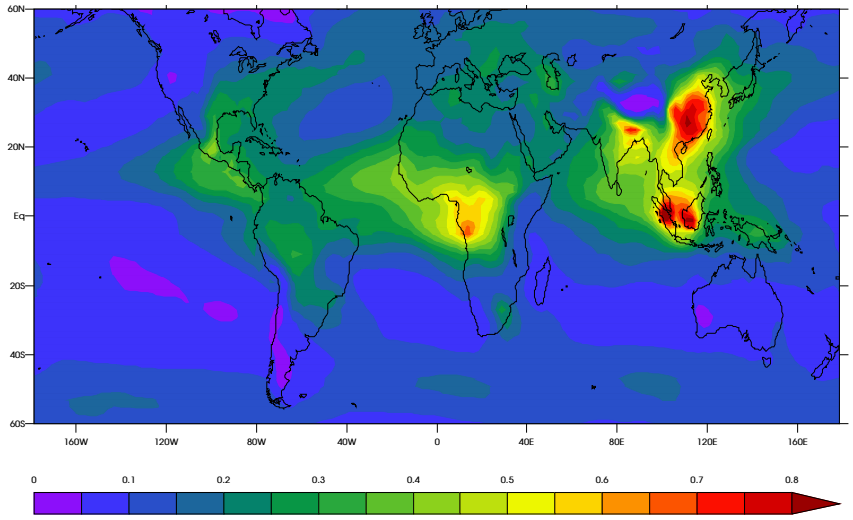


Aerosol optical depth – annual mean

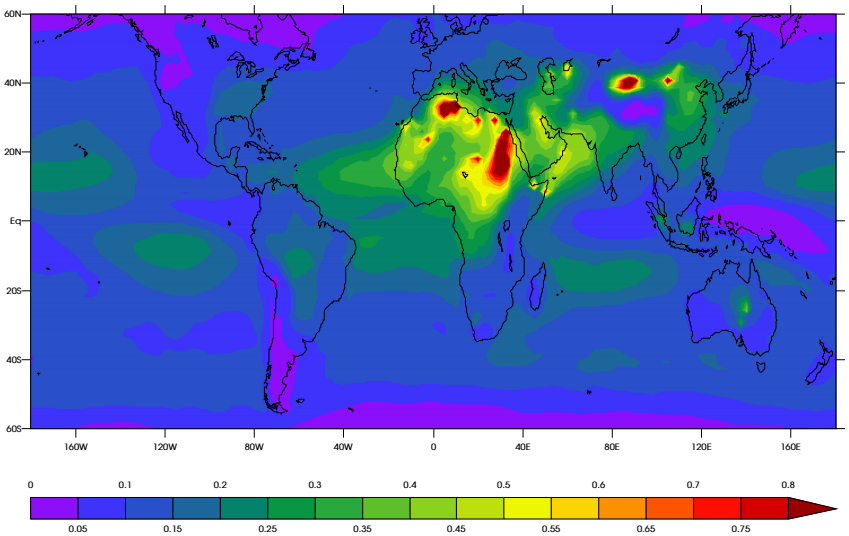
MODIS (observation)



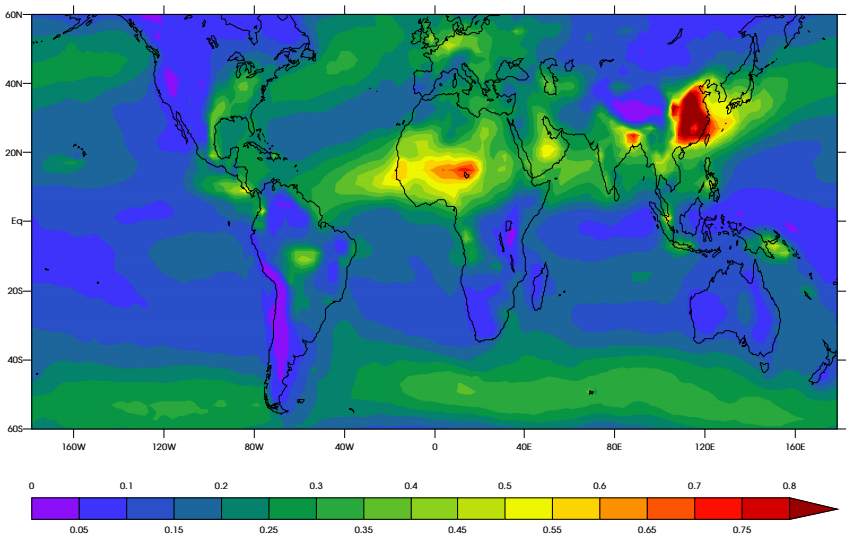
GFDL (model)



CAM5 (model)



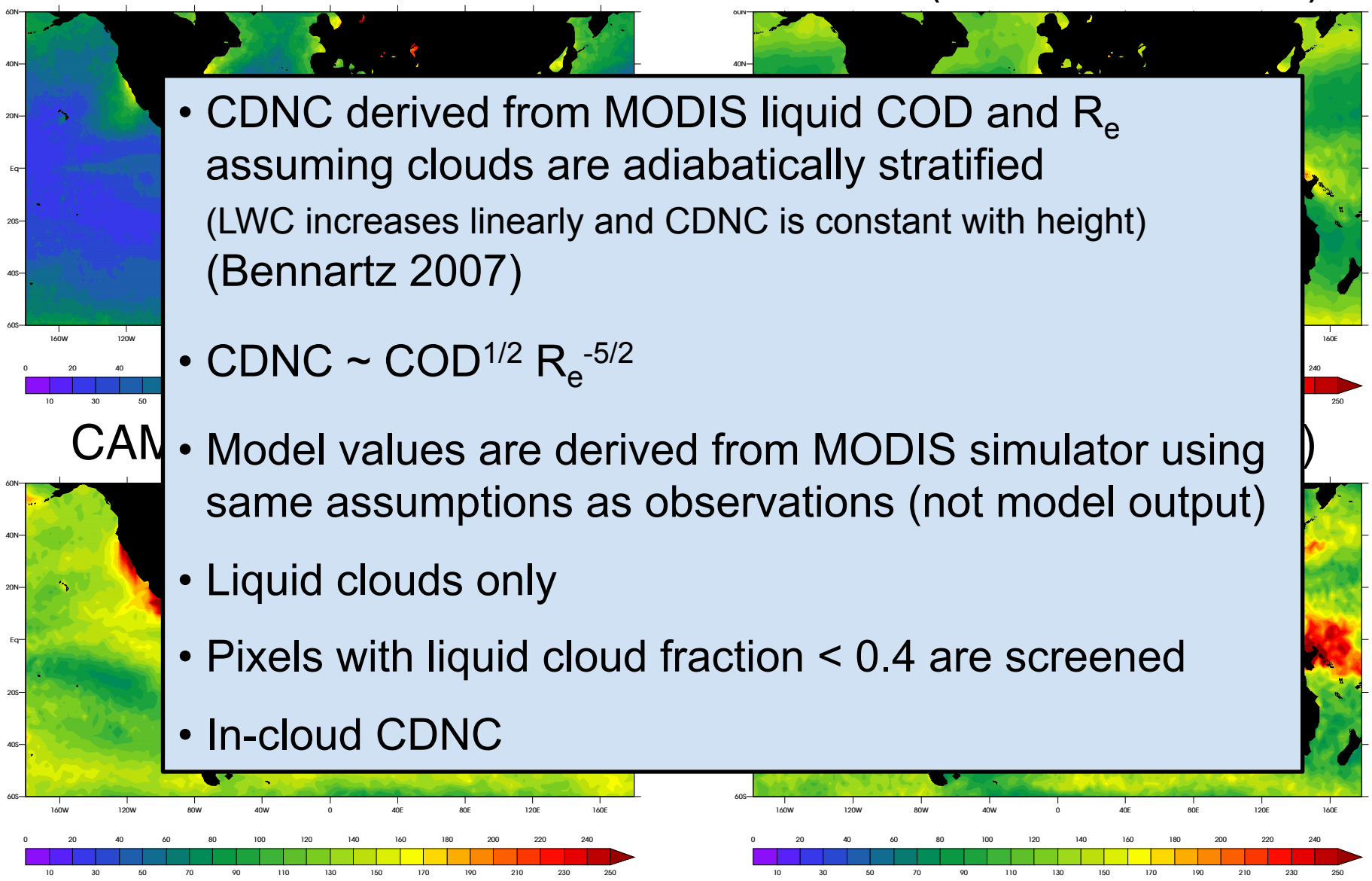
GISS (model)



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

MODIS (observation)

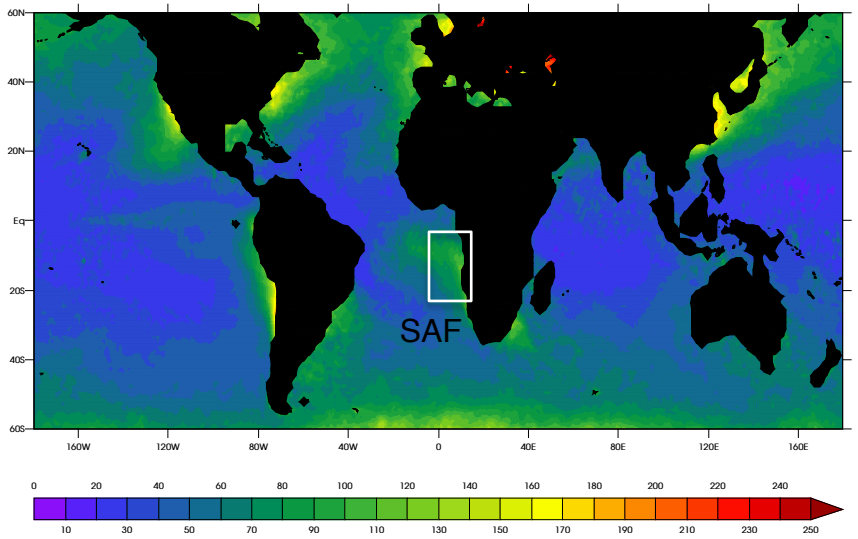
GFDL (MODIS simulator)



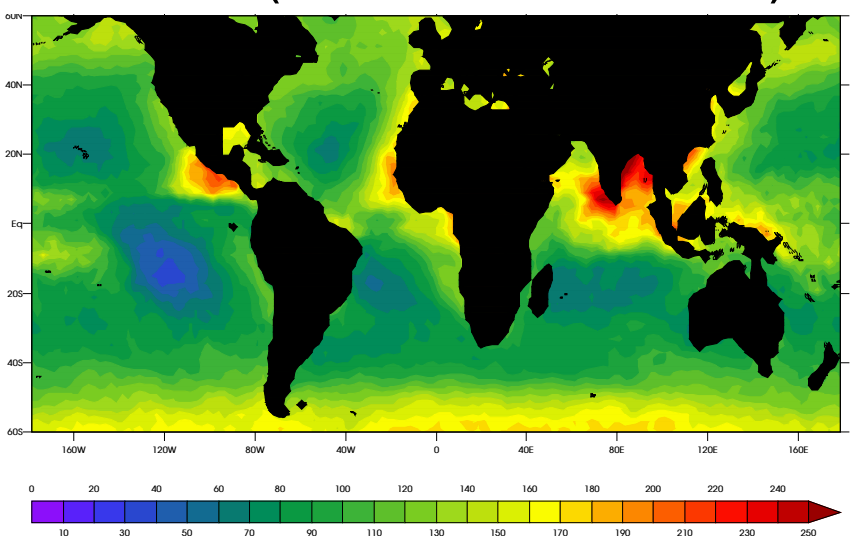
- CDNC derived from MODIS liquid COD and R_e assuming clouds are adiabatically stratified
  (LWC increases linearly and CDNC is constant with height)
  (Bennartz 2007)
- CDNC ~ $COD^{1/2}$ $R_e^{-5/2}$
- Model values are derived from MODIS simulator using same assumptions as observations (not model output)
- Liquid clouds only
- Pixels with liquid cloud fraction < 0.4 are screened
- In-cloud CDNC

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

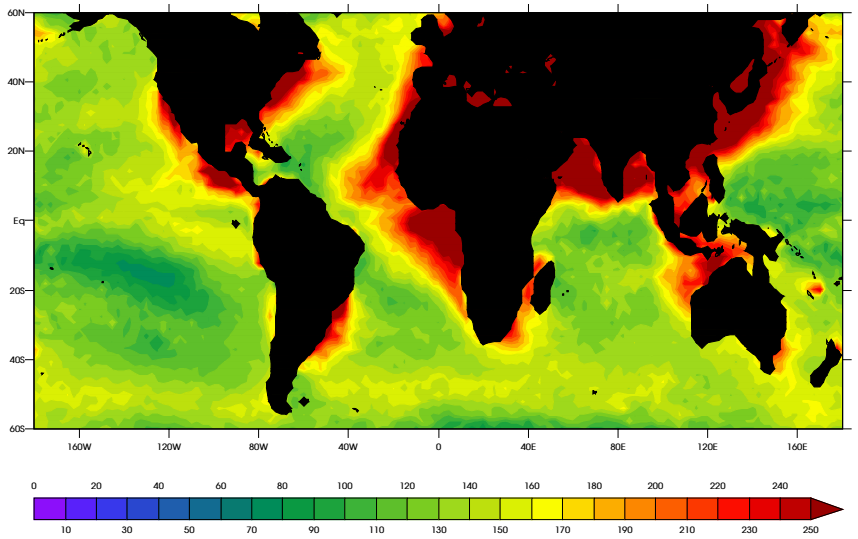
MODIS (observation)



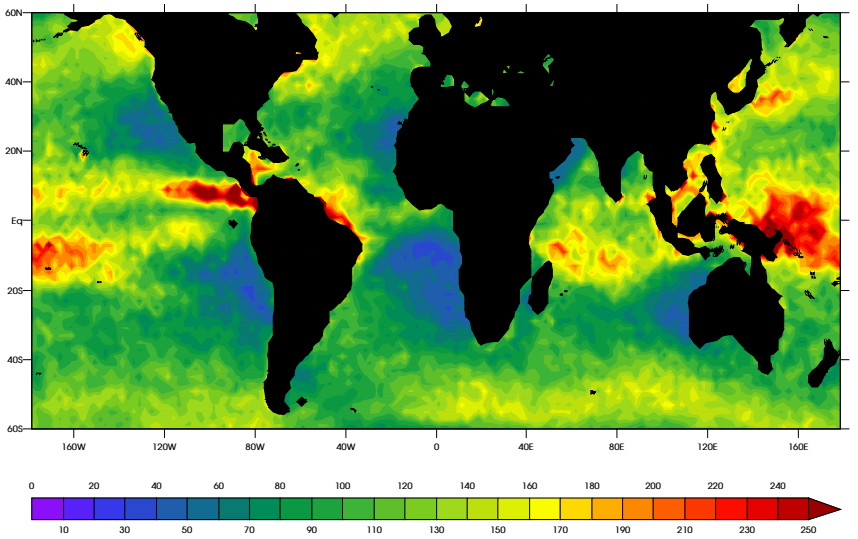
GFDL (MODIS simulator)



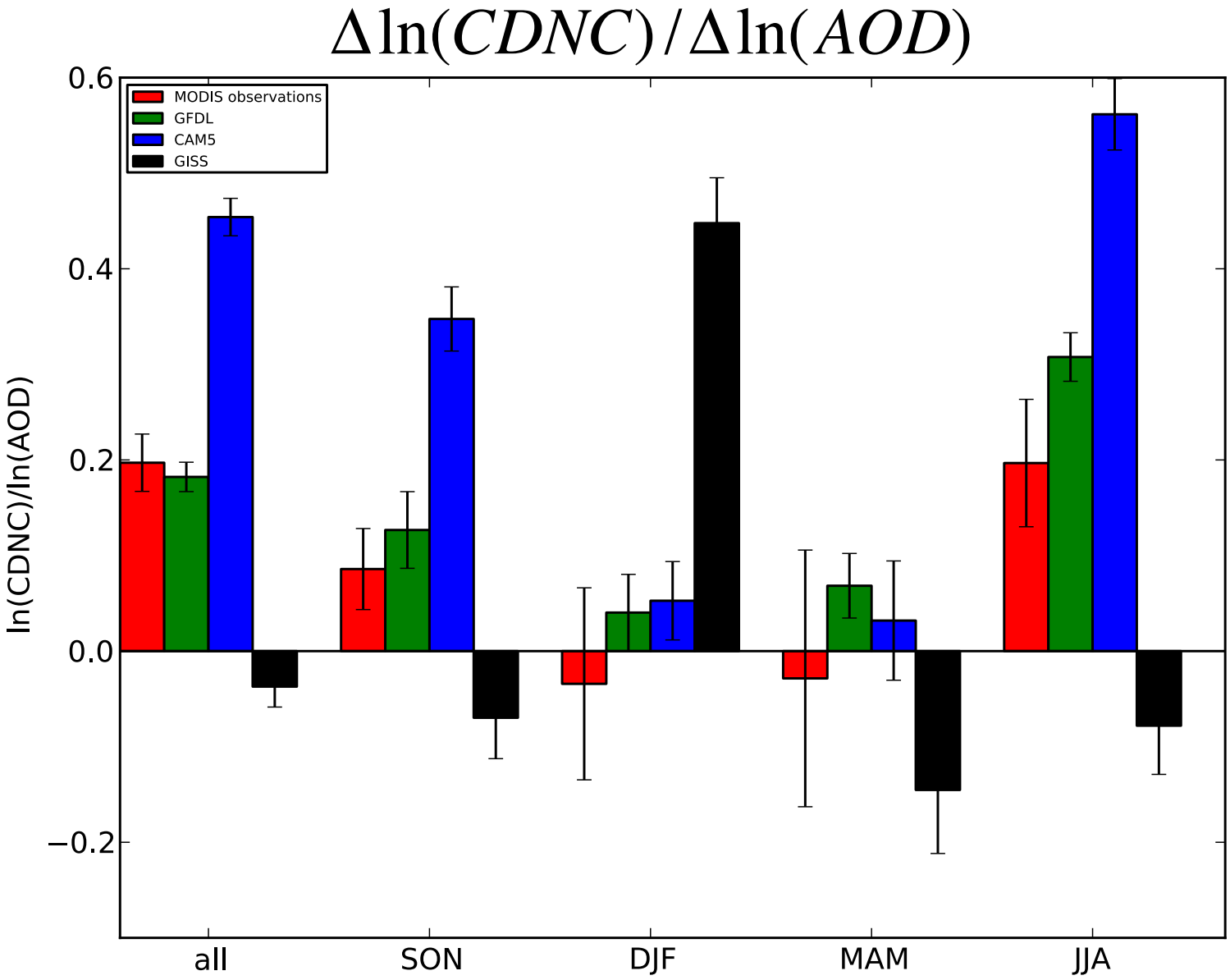
CAM5 (MODIS simulator)



GISS (MODIS simulator)



Sensitivity of CDNC to AOD in SAF region



Current work

- Regional analysis
  - Time series analysis so we can do better than

    $$\Delta \ln(CDNC) / \Delta \ln(AOD)$$

  - Partial correlation analysis (removing co-variation due to weather), principle component analysis
  - Marine stratocumulus areas for now (will add continental areas to be more consistent with RACORO in future)
  - Conditional sampling to extract meteorological regimes (could try to pick regimes as has been done with RACORO)

Current work

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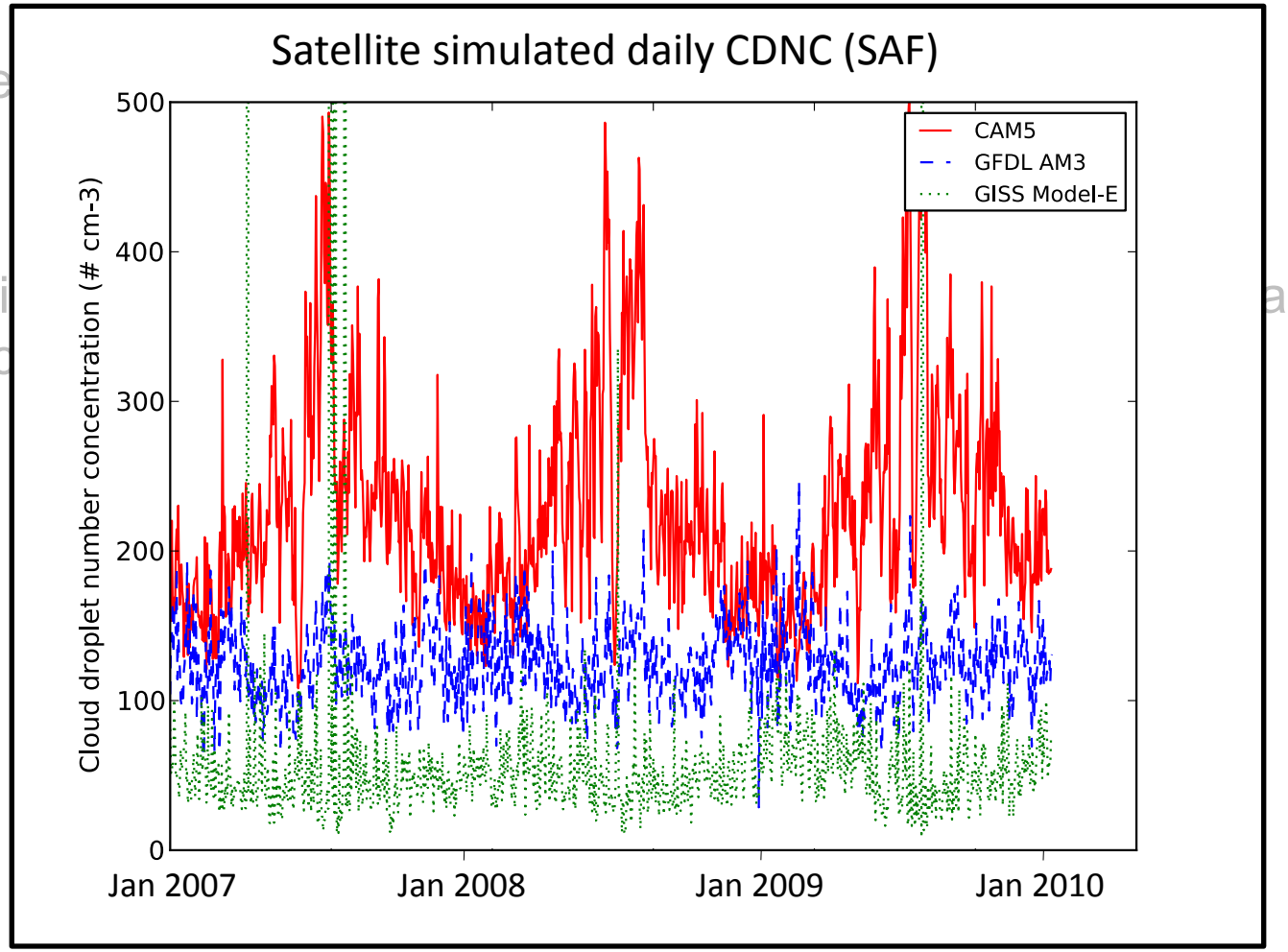
  - Time
  - Parti ather), princ

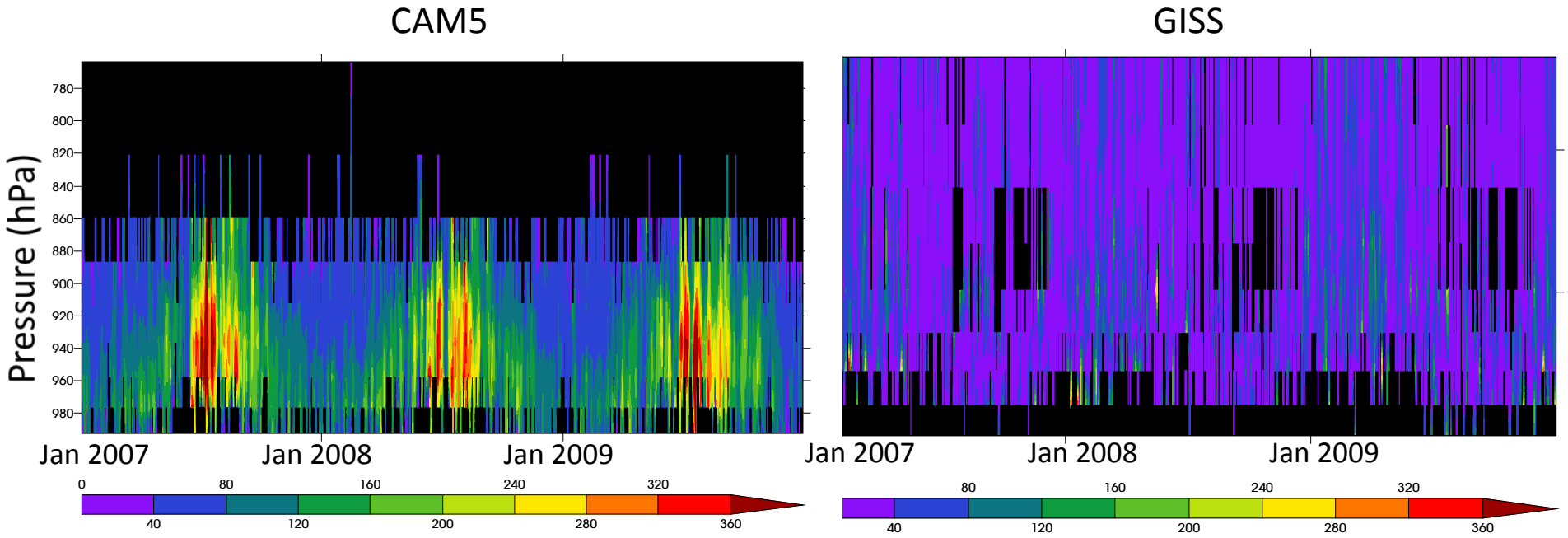


Current work

- Regional analysis
  - Time series analysis so we can do better than $\Delta \ln(CDNC) / \Delta \ln(AOD)$
  - Partial correlation analysis (removing co-variation due to weather), principle component analysis
  - Marine stratocumulus areas for now (plan to add continental areas to be more consistent with RACORO in future)
  - Conditional sampling to extract meteorological regimes (could try to pick regimes as has been done with RACORO)
  - Time series of spatial-mean vertical profiles from model output (not satellite simulated) to further understand differences in model results

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

Model output (not satellite simulated)
SAF (spatial mean)
Daily vertical profiles (satellite overpass times)



Future work

- Focus on satellite simulated vertical profiles of clouds and aerosols
  - GCMs outputting 3-hourly vertical profiles (including COSP)
  - CALIPSO / CloudSat
  - Use model to understand collocation of aerosols/CCN/CDNC in the vertical column. What fraction of aerosols in the vertical column are satellites missing?