

Comparison of GEOS-Chem-APM and CAM-Chem-APM Simulated Cloud Droplet Number Concentrations with MODIS Retrievals

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, NSF

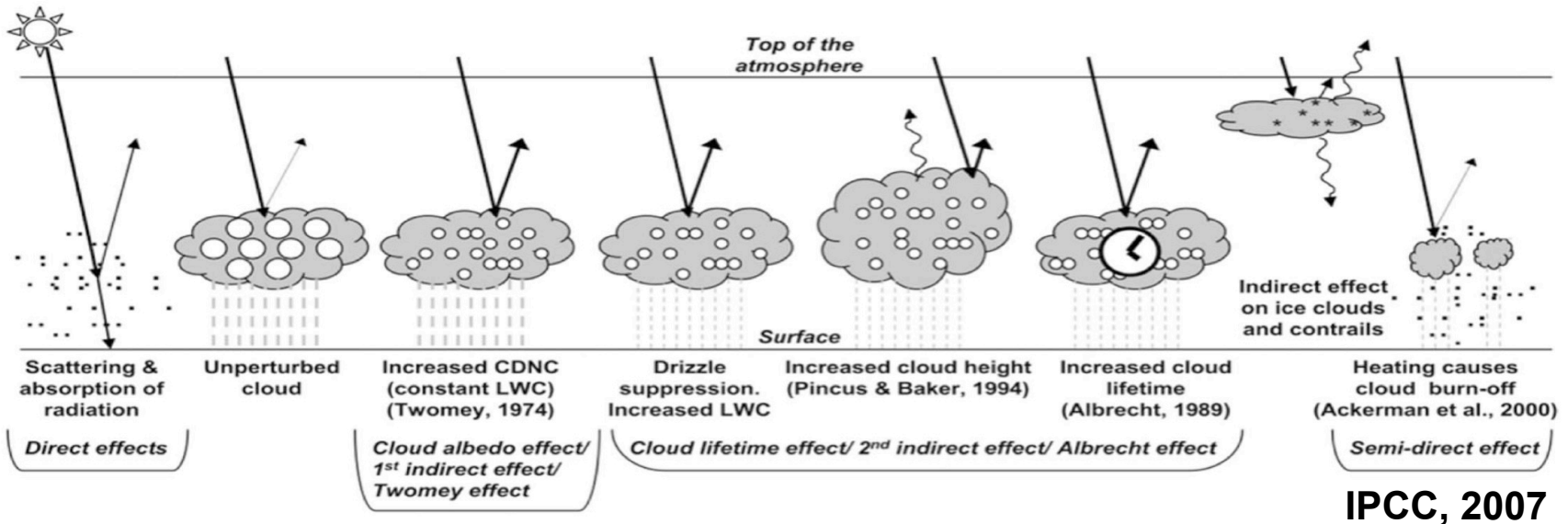


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State University of New York

Introduction

There are still large uncertainties of aerosol indirect forcing



Emission flux → aerosol number and size → cloud droplet number and size → cloud radiative forcing

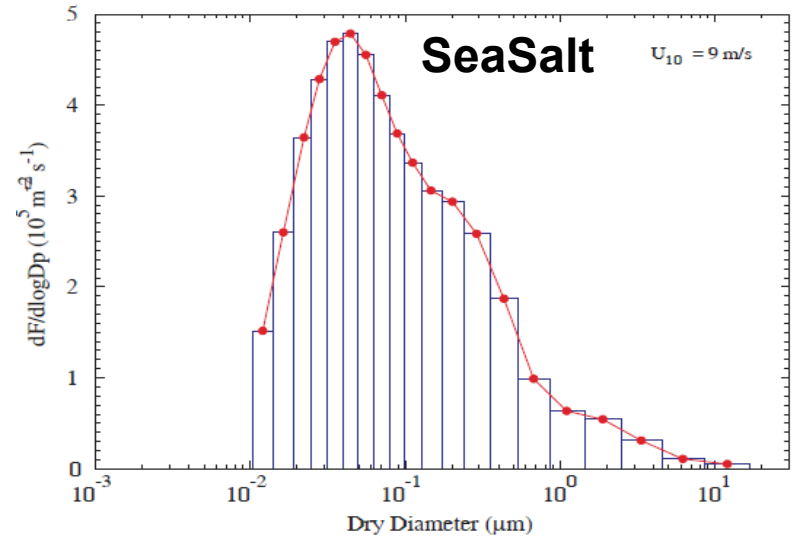
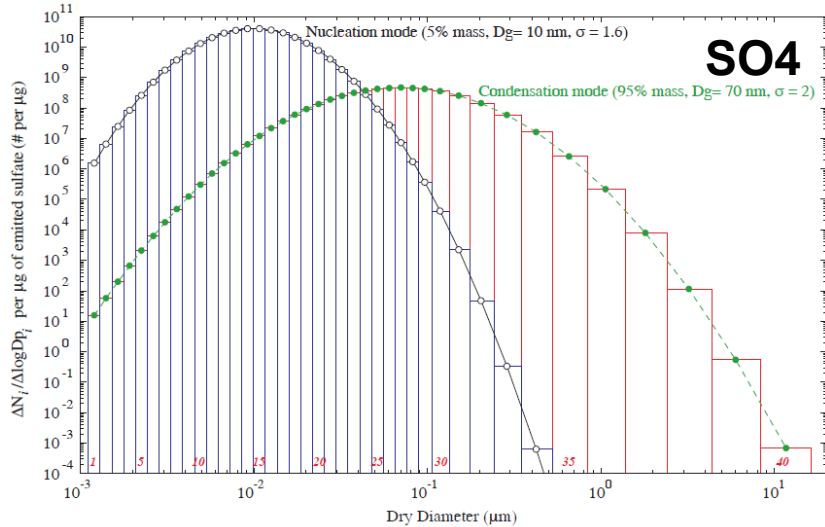
CDNC is a key variable associated with aerosol indirect radiative effects which have large uncertainties and low level of understanding

One of the most challenging parts is how to map CDNC globally

Model simulation? Satellite retrievals?

Model Features

SP: 40 bins; Sea-salt: 20 bins; Dust: 15 bins; BC: 15 bins; OC: 15 bins
Coating of SP on primary particles



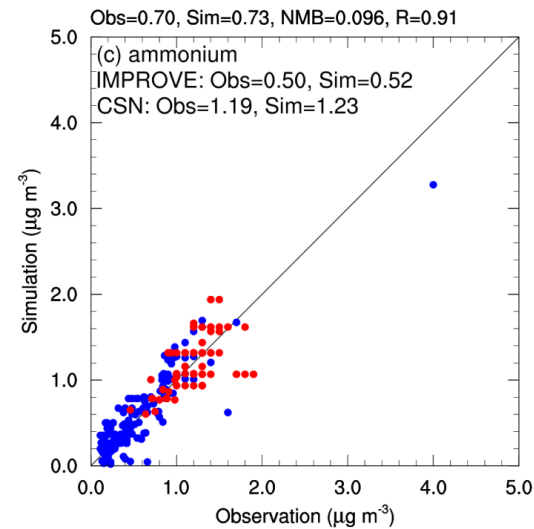
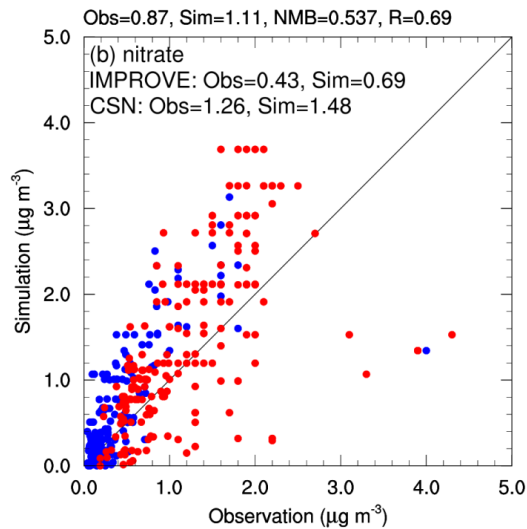
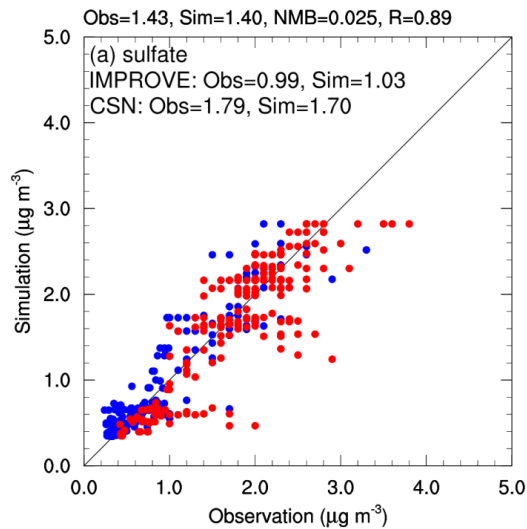
State-of-the-art new particle formation schemes and aerosol microphysics (Yu et al., ACPD, 2018)

GEOS-Chem-APM: size-resolved aerosol microphysics in GEOS-Chem; NO_x-Ox-hydrocarbon-aerosol-Br chemistry mechanism; HEMCO emission; drove by MERRA2 atmospheric reanalysis

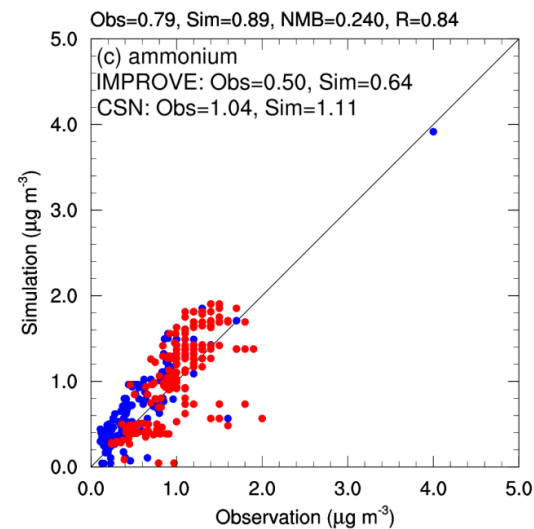
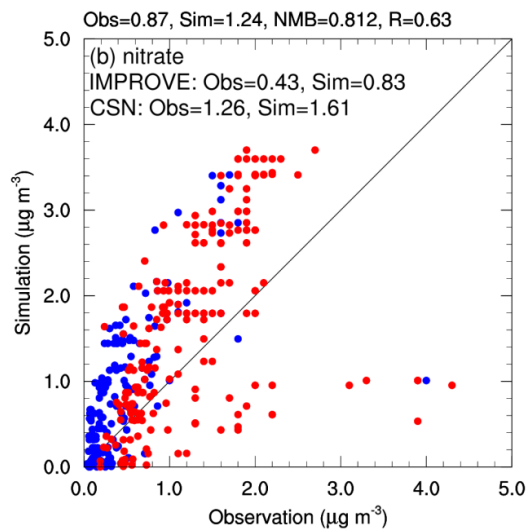
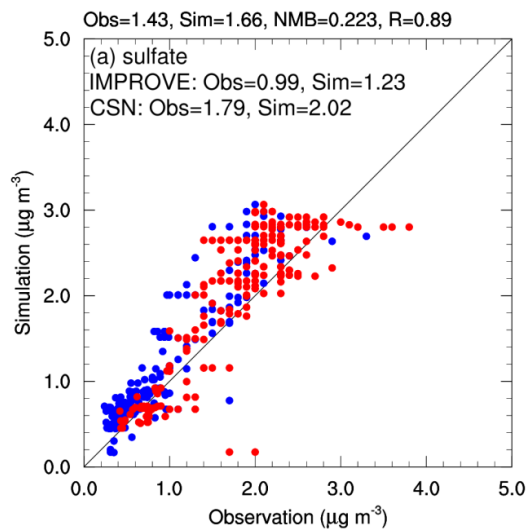
CAM-Chem-APM: size-resolved aerosol microphysics in CAM-Chem; MOZART tropospheric inorganic chemistry mechanism + two-product SOA formation; ACCMIP emission; nudging with MERRA2 atmospheric reanalysis

Simulated Aerosol Mass

GEOS-Chem-APM



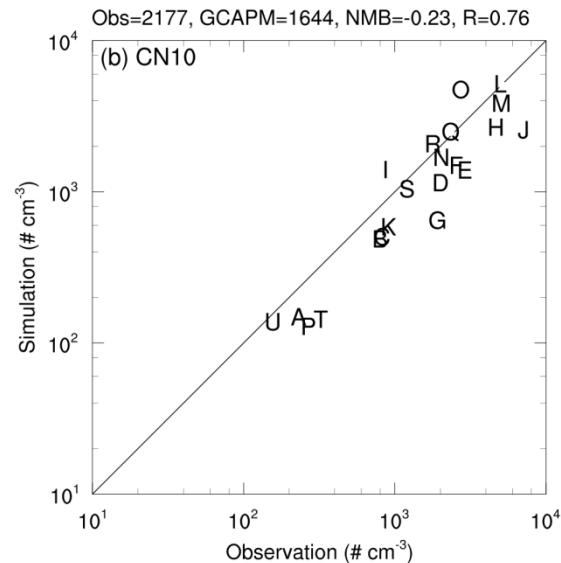
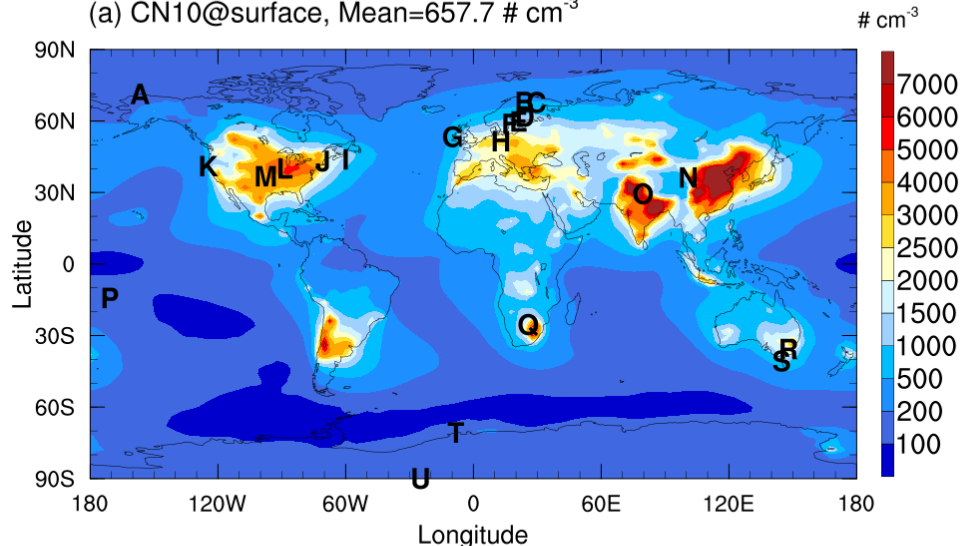
CAM-Chem-APM



Aerosol Number > 10 nm

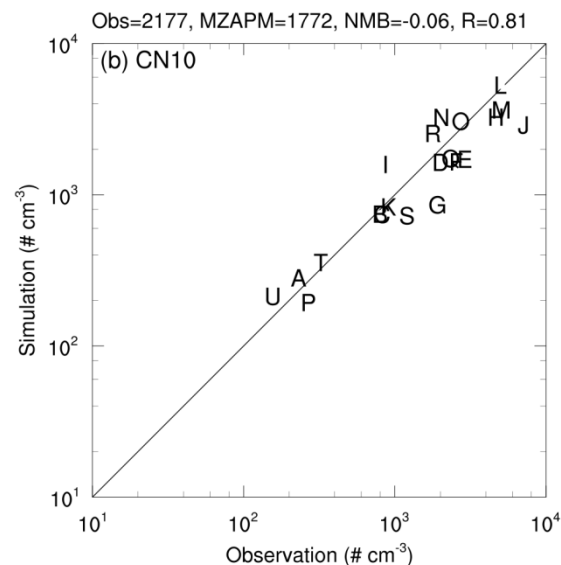
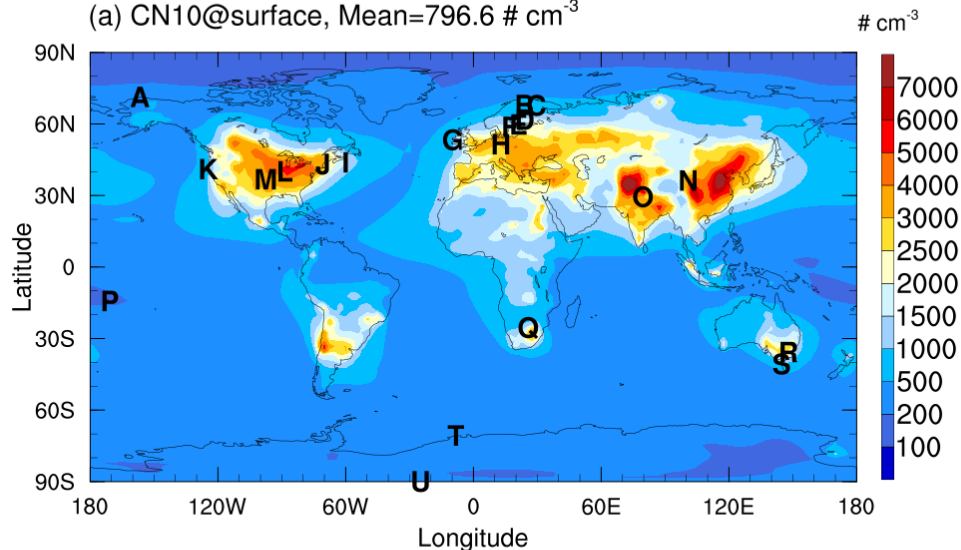
GEOS-Chem-APM

(a) CN10@surface, Mean=657.7 # cm⁻³



CAM-Chem-APM

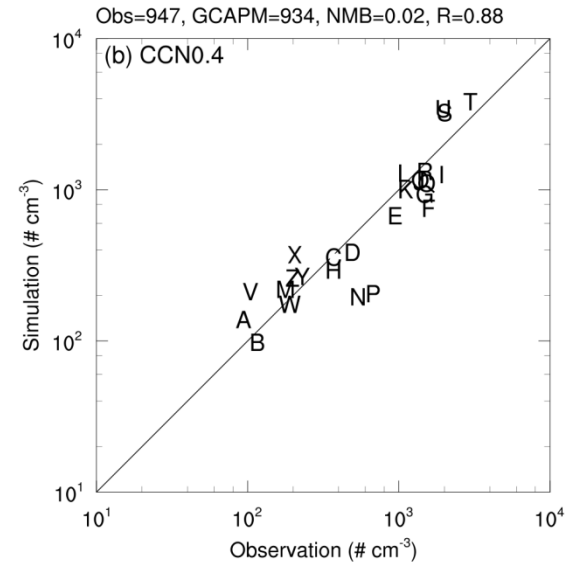
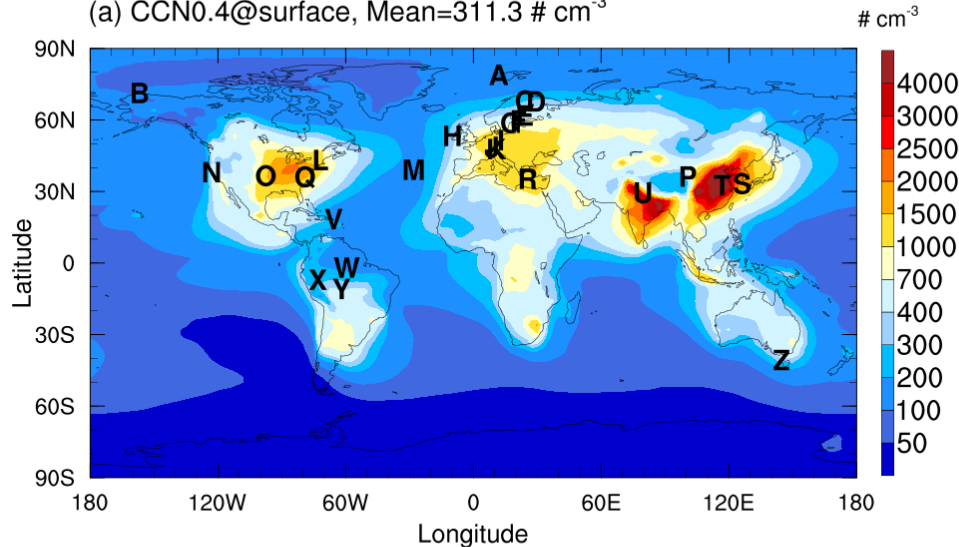
(a) CN10@surface, Mean=796.6 # cm⁻³



CCN number concentration

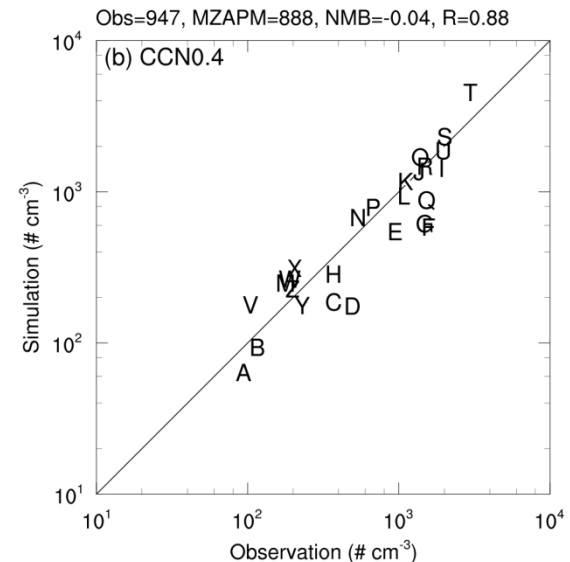
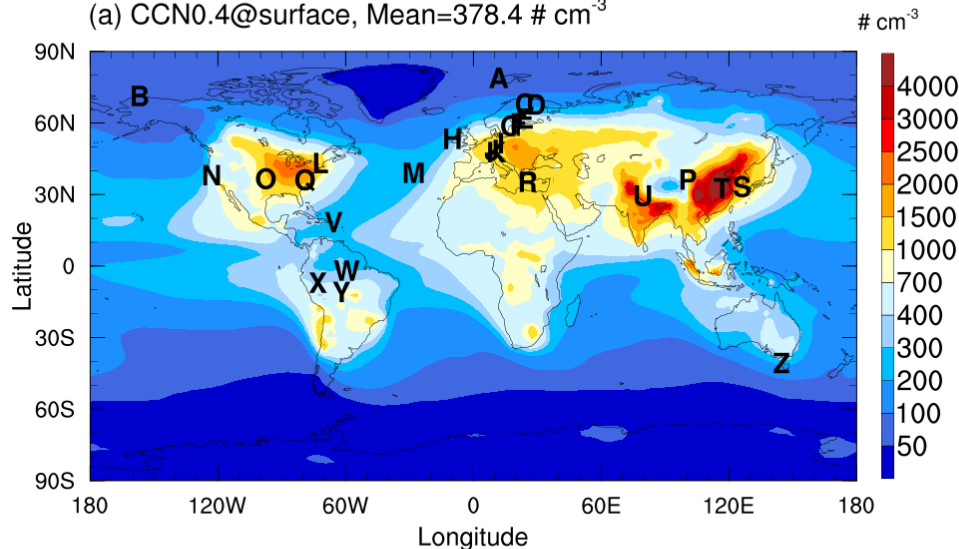
GEOS-Chem-APM

(a) CCN0.4@surface, Mean=311.3 # cm⁻³



CAM-Chem-APM

(a) CCN0.4@surface, Mean=378.4 # cm⁻³



MODIS retrieved CDNC

MODIS provides LWP, ER, CF, CTT, SZ

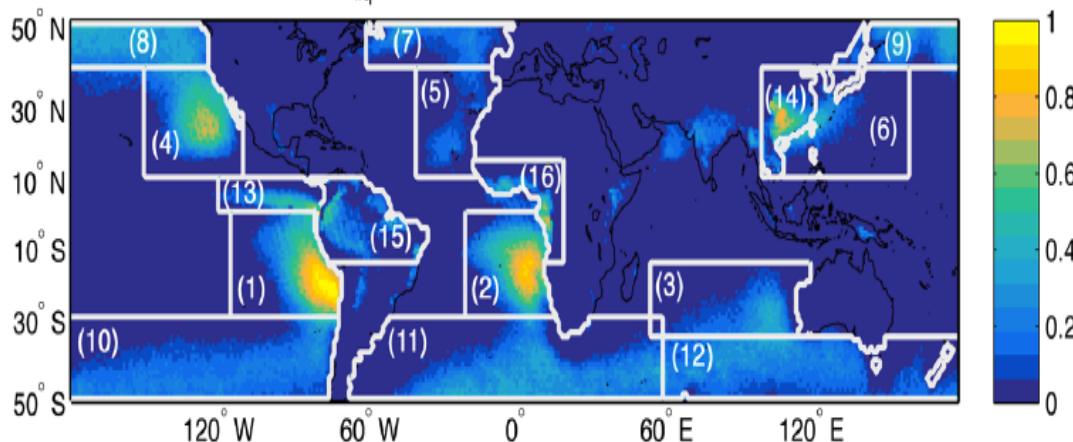
CDNC is not directly provided by MODIS

$$N_d = \sqrt{\Gamma_{\text{eff}}} \frac{\sqrt{10\tau^{1/2}}}{4\pi\rho_w^{1/2}r_e^{5/2}k}$$

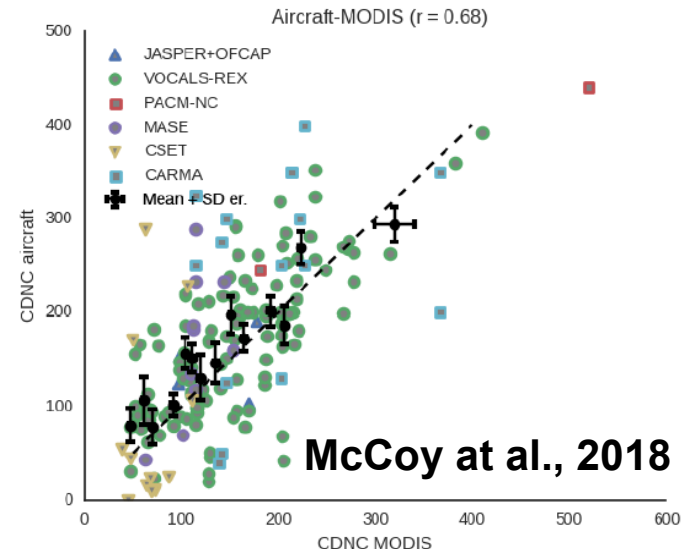
τ (COD), r_e (ER), Γ_{eff} (effective lapse rate)
 k (the skewness and dispersion of the cloud droplet size distribution)
 ρ_w (water density)

**Liquid Cloud Retrieval Fraction > 0.8; Cloud top temperature > 268K;
 Solar Zenith < 65°** (Bennartz et al., 2007, 2017; McCoy et al., 2017, 2018)

Fraction of months with usable N_d retrievals
 ($f_{\text{liq}} > 0.8$, # retrievals in a month > 10)

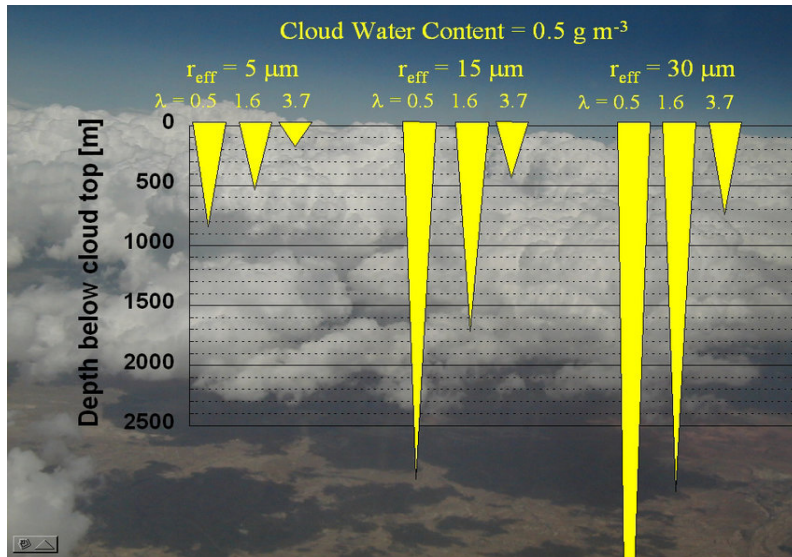


McCoy et al., 2017



McCoy et al., 2018

Bands: 1.6, 2.1, and 3.7 μm



Levizzani et al., 2003

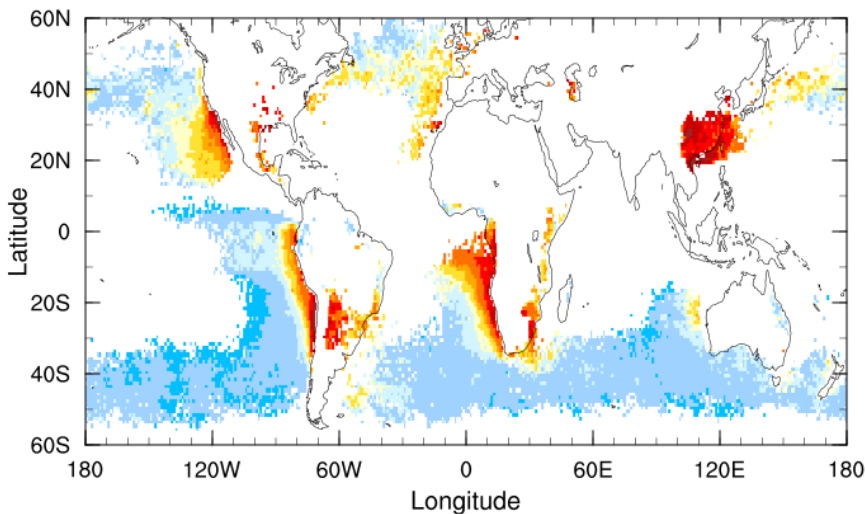
Band6 (1.6 μm) is deeper than Band20 (3.7 μm)

$Re_{3.7} < Re_{2.1} < Re_{1.6}$ is not well explained
(King and Vaughan, 2012)

1.6 μm : better representation of column cloud

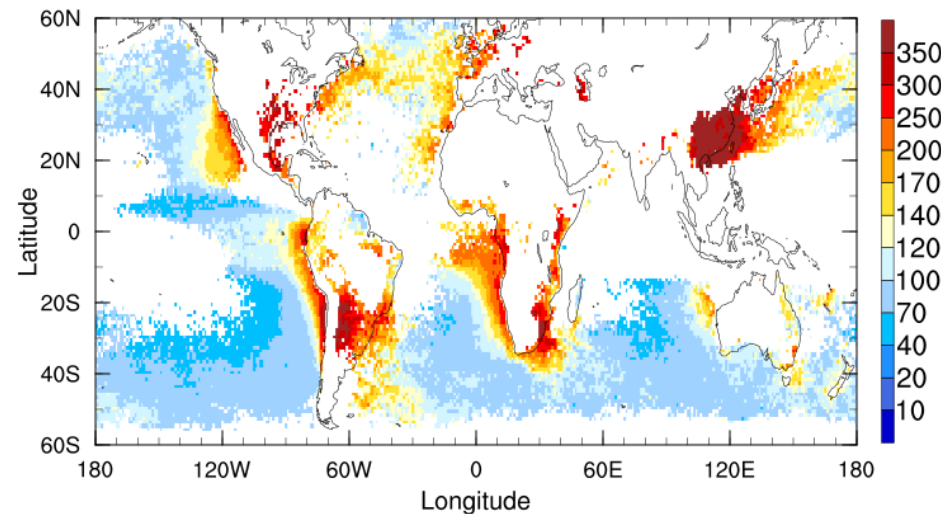
(a) MODIS_{terra+aqua}: 1.6 μm Annual mean CDNC

cm^{-3}



(b) MODIS_{terra+aqua}: 3.7 μm Annual mean CDNC

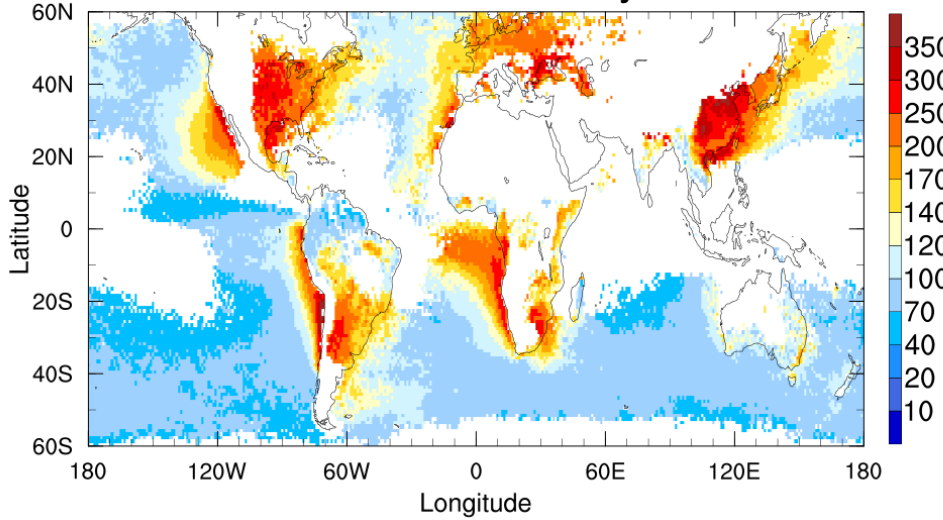
cm^{-3}



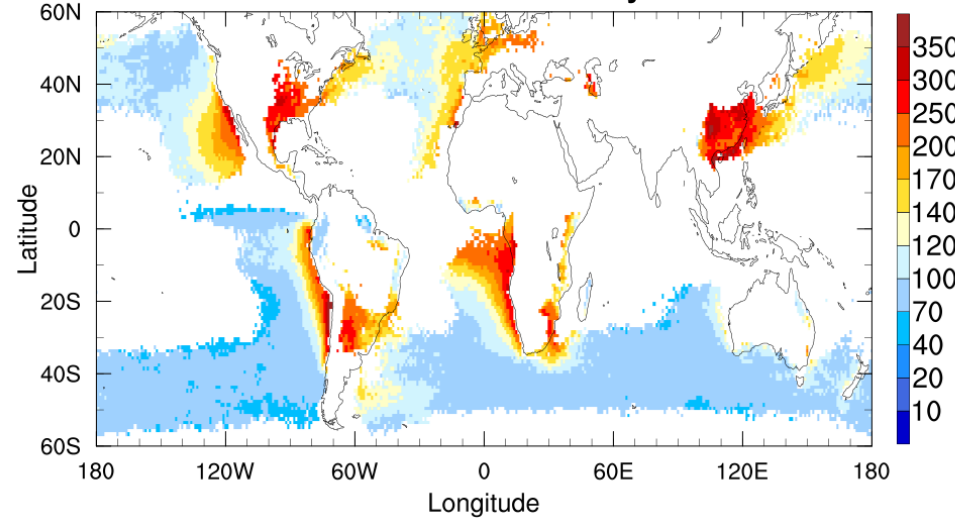
Sampling of Retrievals

Multi-year data → monthly mean values: $N_{\text{mon}} > 6/\text{year}$ → annual mean

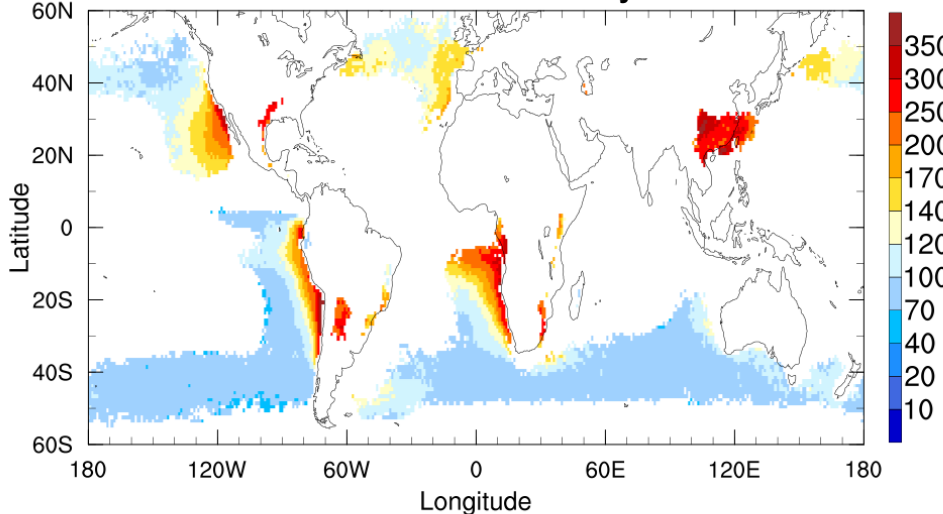
MODIS_{terra+aqua}: Annual mean CDNC $N_{\text{day}} > 3/\text{month}$ # cm⁻³



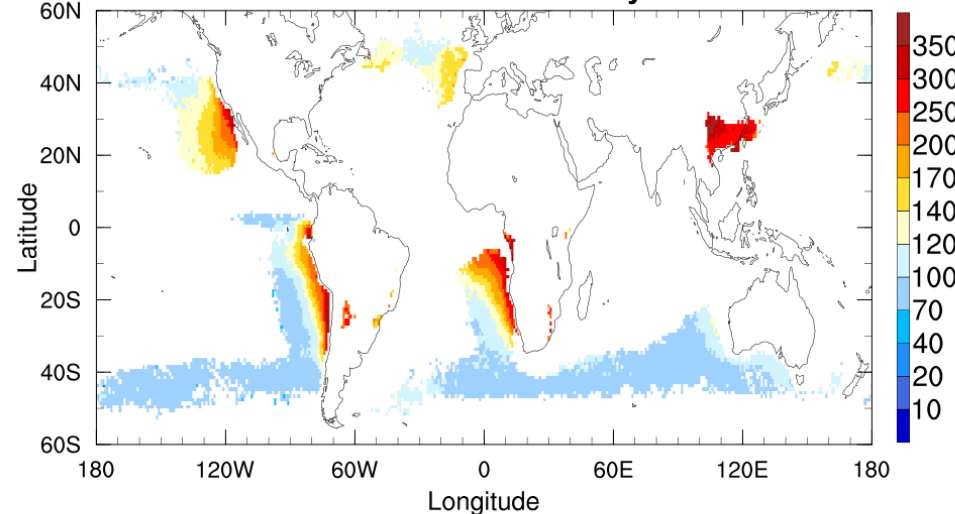
MODIS_{terra+aqua}: Annual mean CDNC $N_{\text{day}} > 10/\text{month}$ # cm⁻³



MODIS_{terra+aqua}: Annual mean CDNC $N_{\text{day}} > 20/\text{month}$ # cm⁻³

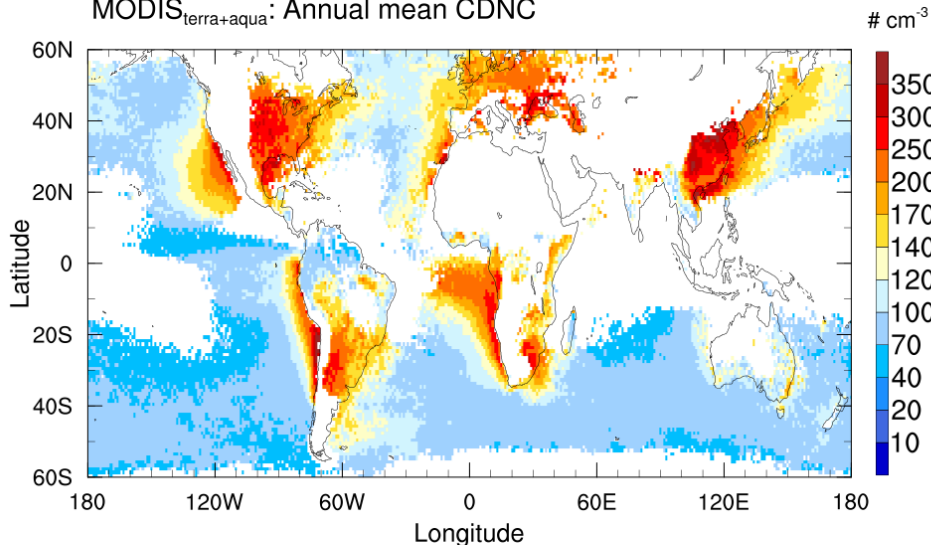


MODIS_{terra+aqua}: Annual mean CDNC $N_{\text{day}} > 30/\text{month}$ # cm⁻³

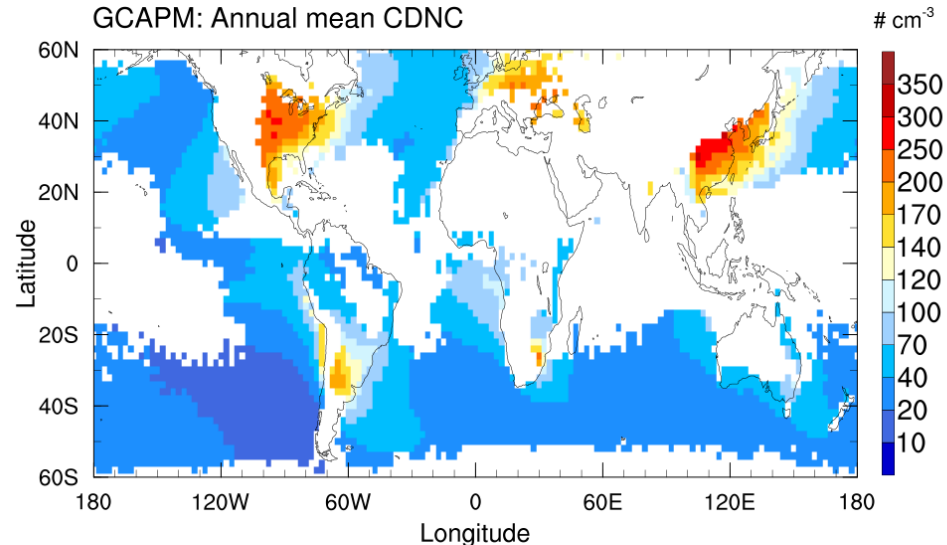


Maps of CDNC from Satellite and Model

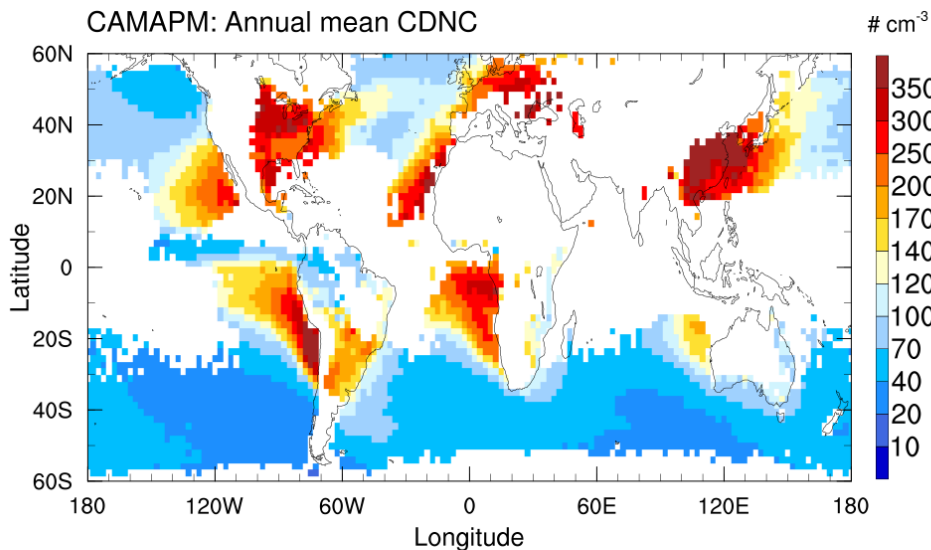
MODIS_{terra+aqua}: Annual mean CDNC



GCAPM: Annual mean CDNC



CAMAPM: Annual mean CDNC



High concentrations are located at continental and outflow regions

CAMAPM > MODIS > GCAPM

GCAPM significantly underestimate outflow

Underestimation over remote marine

Signals of Seasonal Variation

JAN

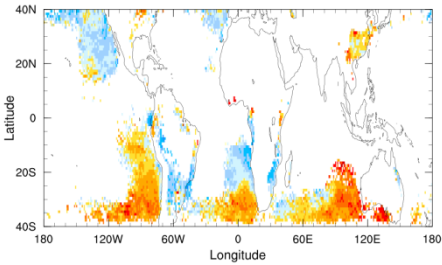
APR

JUN

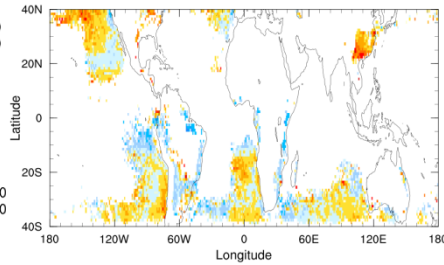
OCT

MODIS

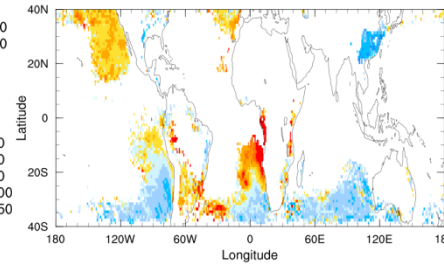
MODIS_{JAN}: $+\Delta=27.7, -\Delta=-21.3, |\Delta|=24.7$



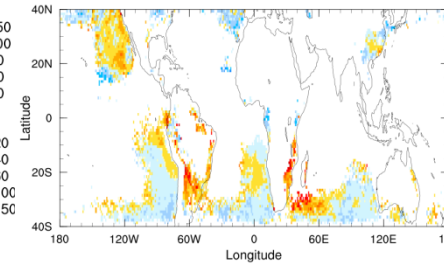
MODIS_{APR}: $+\Delta=15.9, -\Delta=-17.2, |\Delta|=16.6$



MODIS_{JUL}: $+\Delta=24.0, -\Delta=-24.4, |\Delta|=24.2$

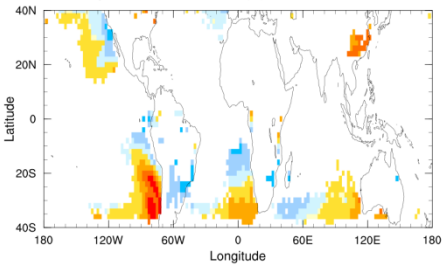


MODIS_{OCT}: $+\Delta=17.7, -\Delta=-13.8, |\Delta|=15.6$

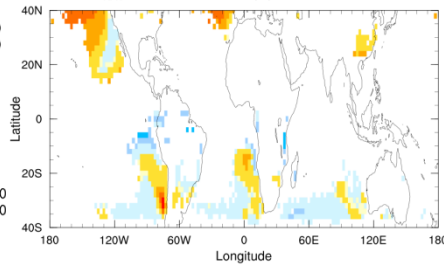


GEOS-Chem-APM

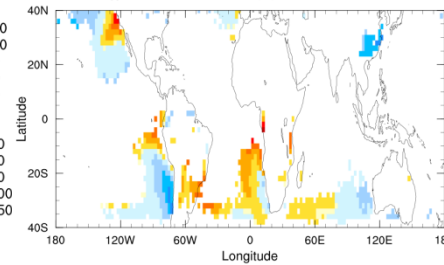
GCAPM_{JAN}: $+\Delta=19.5, -\Delta=-20.2, |\Delta|=19.8$



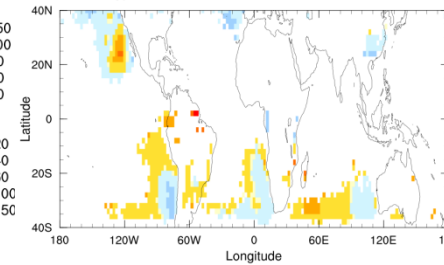
GCAPM_{APR}: $+\Delta=15.8, -\Delta=-11.6, |\Delta|=13.5$



GCAPM_{JUL}: $+\Delta=18.6, -\Delta=-18.6, |\Delta|=18.6$

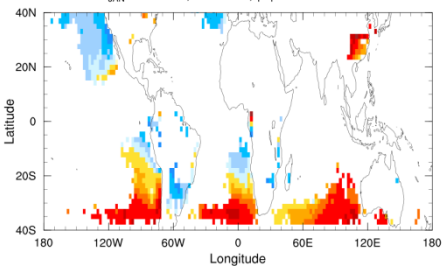


GCAPM_{OCT}: $+\Delta=12.8, -\Delta=-10.0, |\Delta|=11.4$

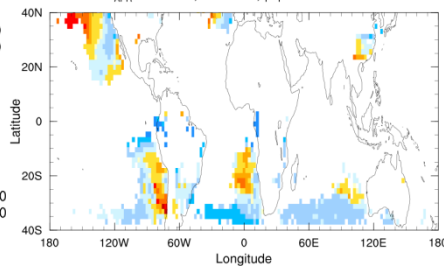


CAM-Chem-APM

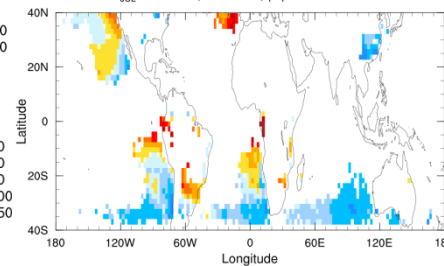
CAMAPM_{JAN}: $+\Delta=53.7, -\Delta=-32.1, |\Delta|=44.9$



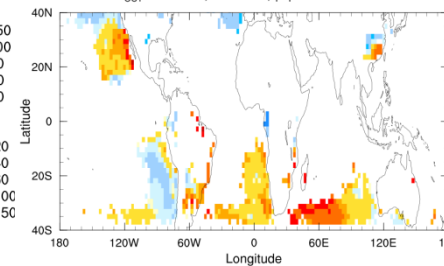
CAMAPM_{APR}: $+\Delta=22.1, -\Delta=-24.7, |\Delta|=23.9$



CAMAPM_{JUL}: $+\Delta=28.7, -\Delta=-33.7, |\Delta|=32.1$



CAMAPM_{OCT}: $+\Delta=24.4, -\Delta=-18.7, |\Delta|=22.4$



Signals of Seasonal Variation

JAN

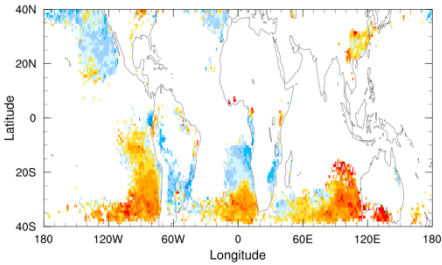
APR

JUN

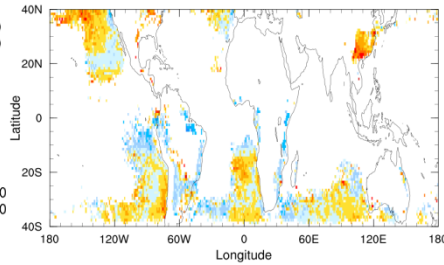
OCT

MODIS

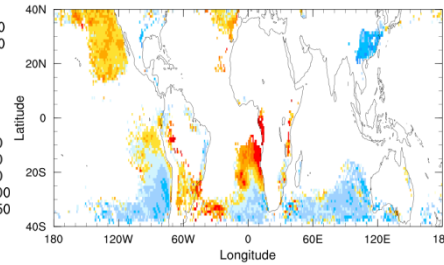
MODIS_{JAN}: $+\Delta=27.7, -\Delta=-21.3, |\Delta|=24.7$



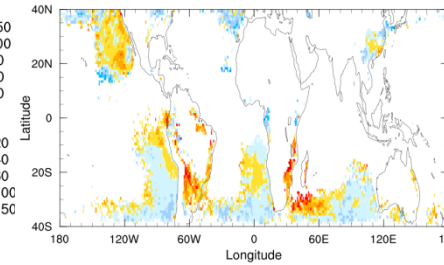
MODIS_{APR}: $+\Delta=15.9, -\Delta=-17.2, |\Delta|=16.6$



MODIS_{JUL}: $+\Delta=24.0, -\Delta=-24.4, |\Delta|=24.2$

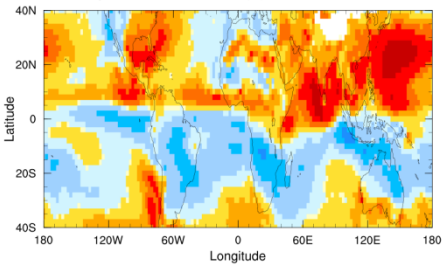


MODIS_{OCT}: $+\Delta=17.7, -\Delta=-13.8, |\Delta|=15.6$

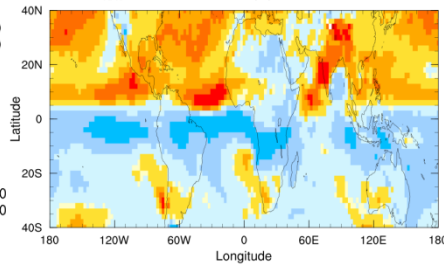


GEOS-Chem-APM

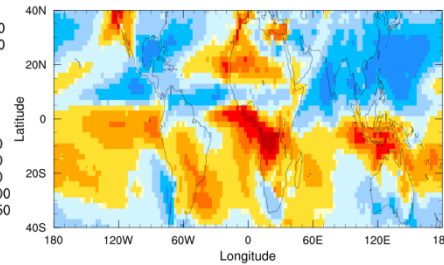
GCAPM_{JAN}: $+\Delta=32.7, -\Delta=-22.6, |\Delta|=28.0$



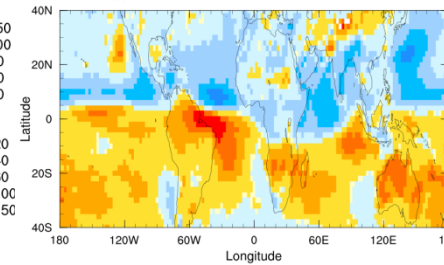
GCAPM_{APR}: $+\Delta=23.7, -\Delta=-19.9, |\Delta|=21.6$



GCAPM_{JUL}: $+\Delta=23.3, -\Delta=-28.5, |\Delta|=26.3$

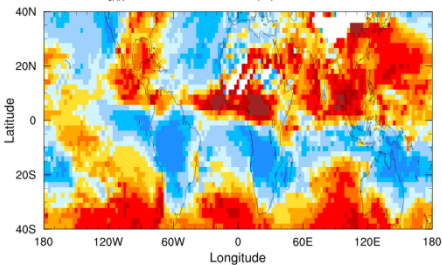


GCAPM_{OCT}: $+\Delta=19.4, -\Delta=-20.6, |\Delta|=20.0$

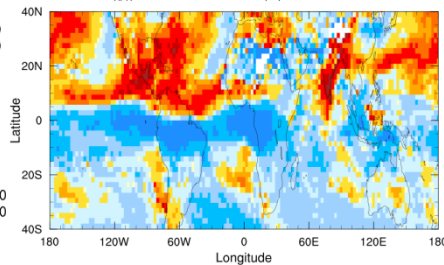


CAM-Chem-APM

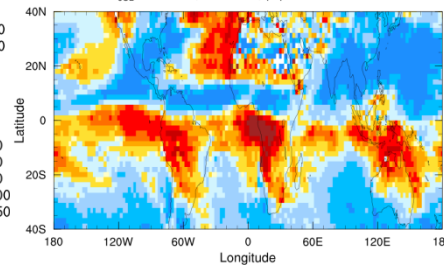
CAMAPM_{JAN}: $+\Delta=47.4, -\Delta=-32.1, |\Delta|=40.6$



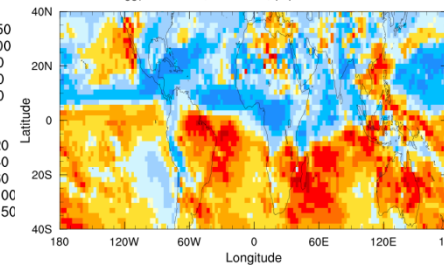
CAMAPM_{APR}: $+\Delta=38.0, -\Delta=-30.2, |\Delta|=33.1$



CAMAPM_{JUL}: $+\Delta=39.5, -\Delta=-38.7, |\Delta|=39.0$

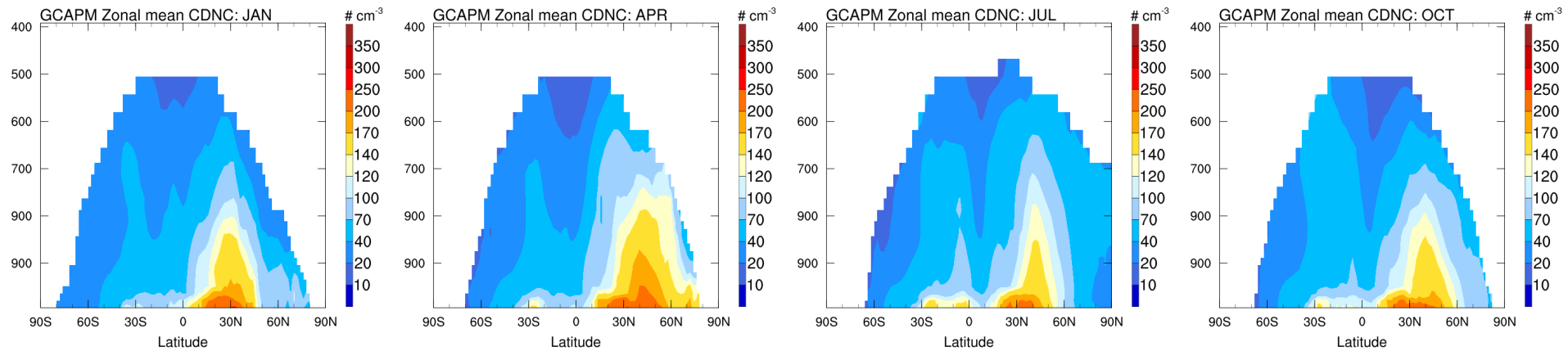


CAMAPM_{OCT}: $+\Delta=30.6, -\Delta=-31.1, |\Delta|=30.8$

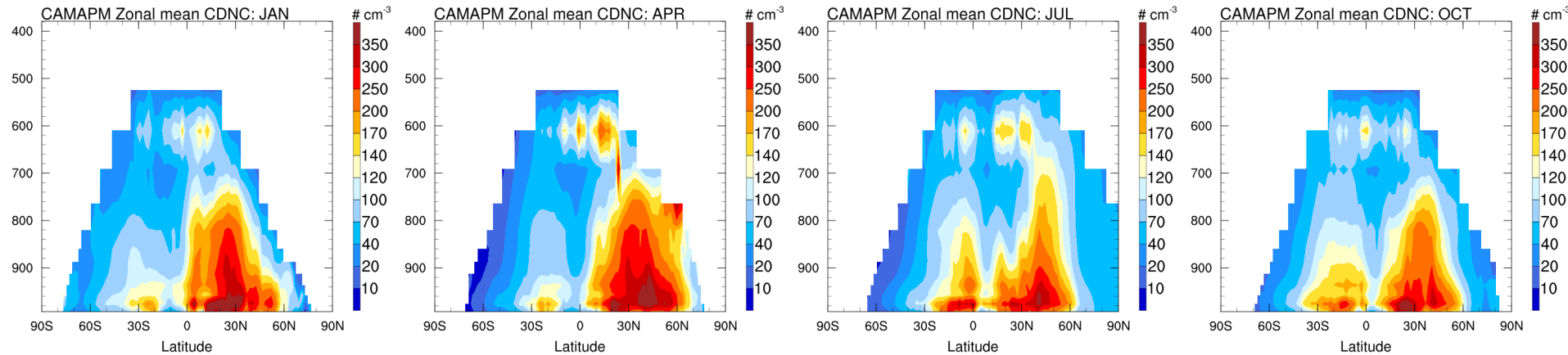


Vertical Profile of CDNC

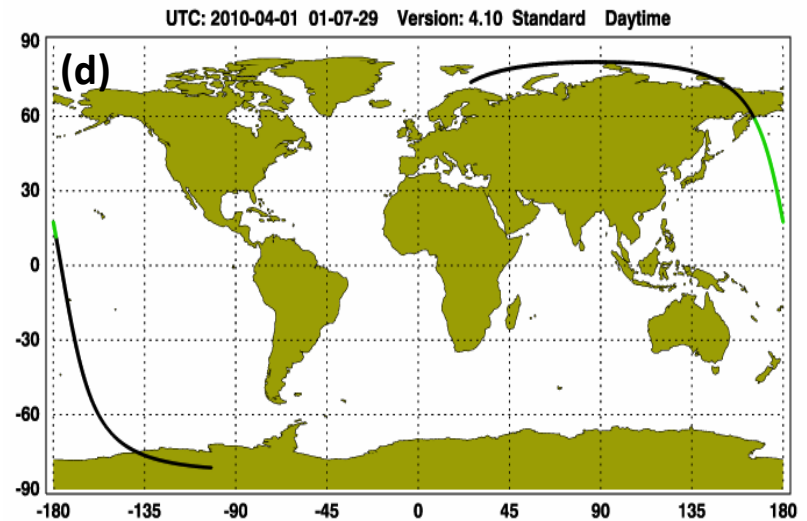
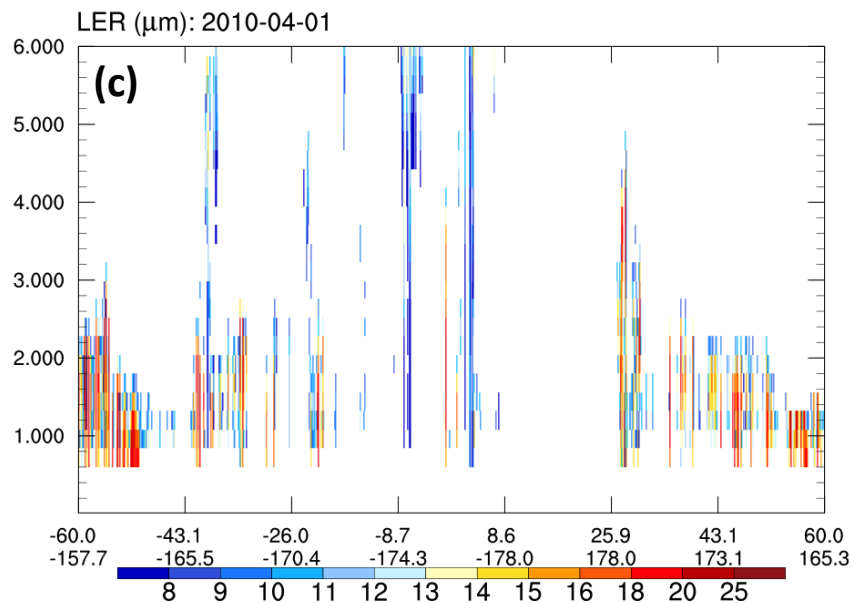
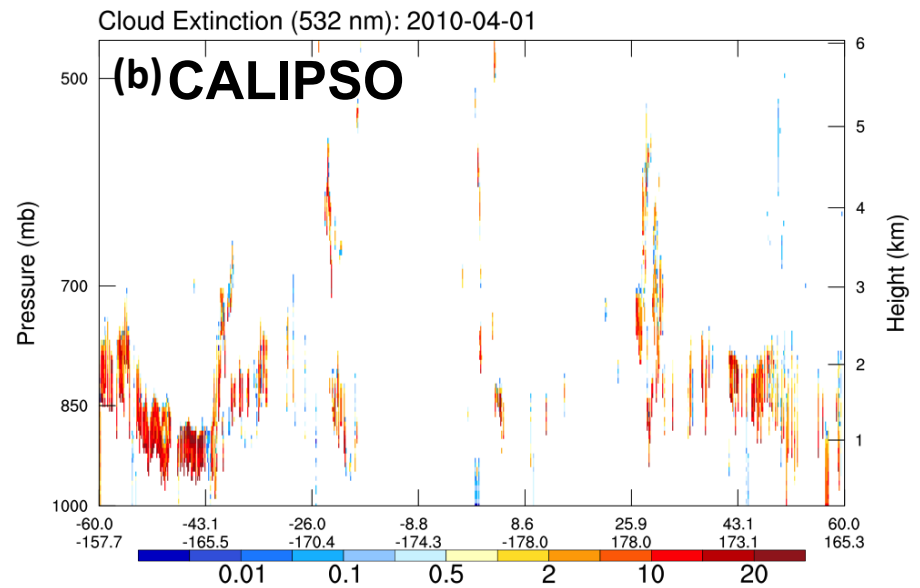
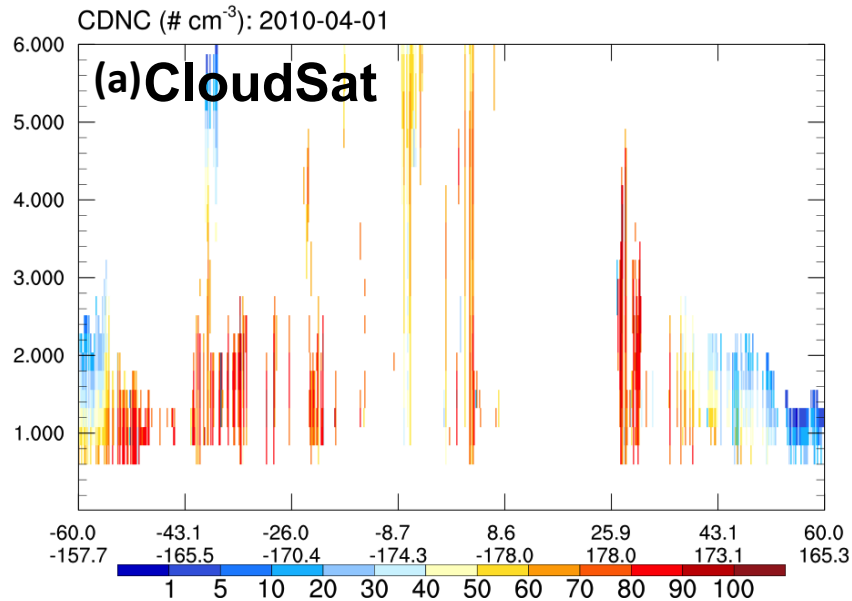
GEOS-Chem-APM



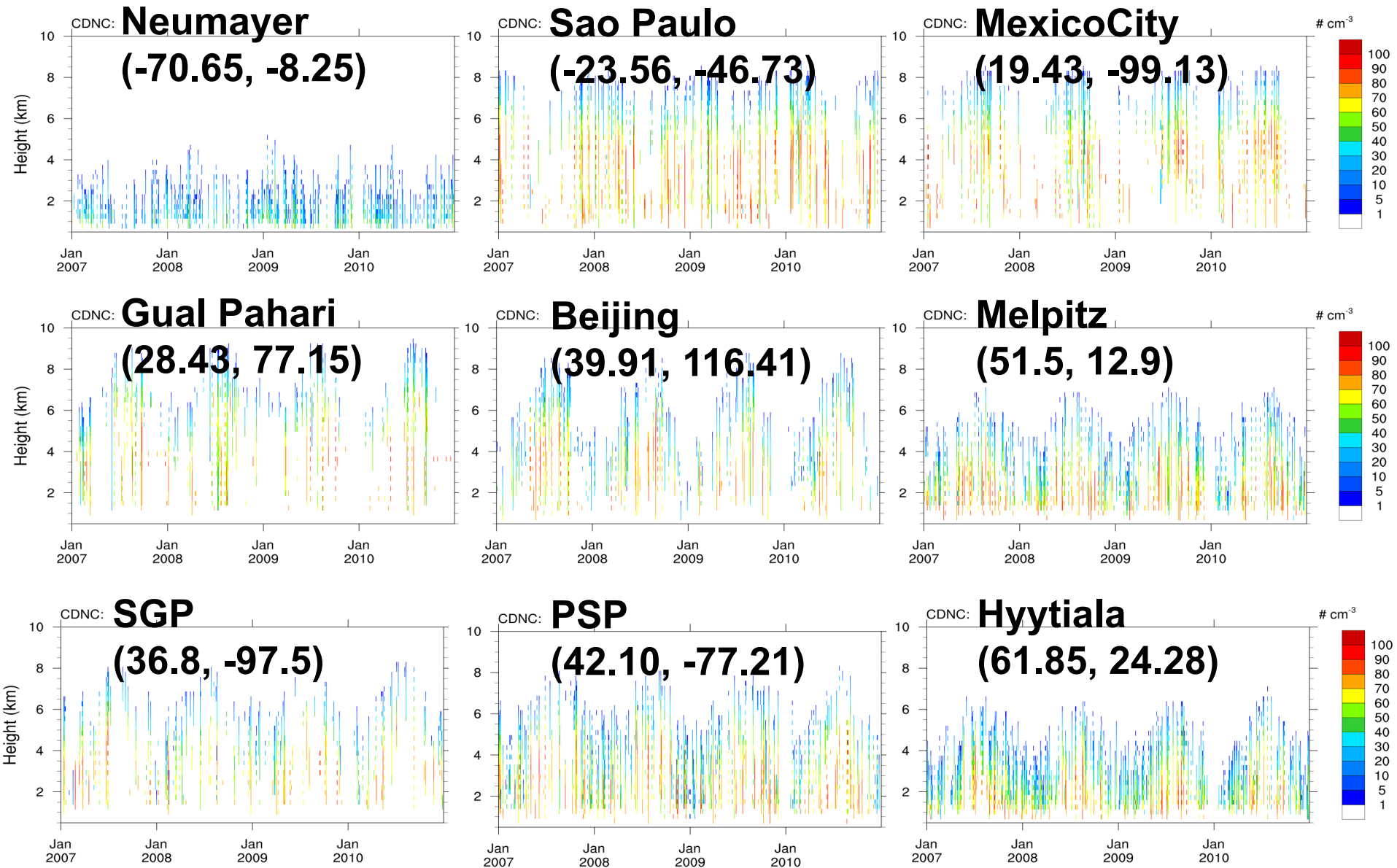
CAM-Chem-APM



Vertical CDNC: View from Satellite



CloudSat Level 2 CDNC



Thank You

- **Both GEOS-Chem-APM and CAM-Chem-APM captured observed aerosol mass and number**
- **MODIS, GEOS-Chem-APM, and CAM-Chem-APM shown similar global distribution of CDNC**
 - High at continental and outflow regions
- **Retrieved and simulated CDNCs have similar signal of seasonal variation**
- **Models can fill the missing parts of CDNC in satellite products but need additional validations**
- **Vertical profile of CDNC is important for cloud forcing**
 - Available satellite product: CloudSat Level 2
 - Long-term and globally validation of model results