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

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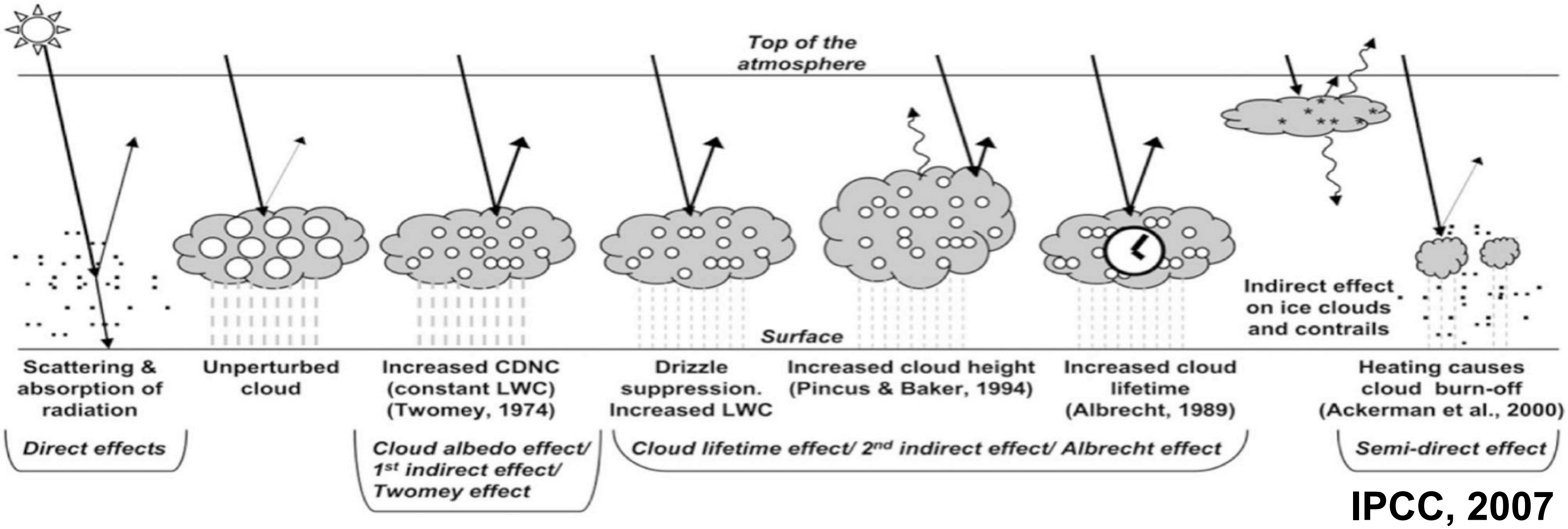
Introduction

There are still large uncertainties of aerosol indirect forcing



IPCC, 2007

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

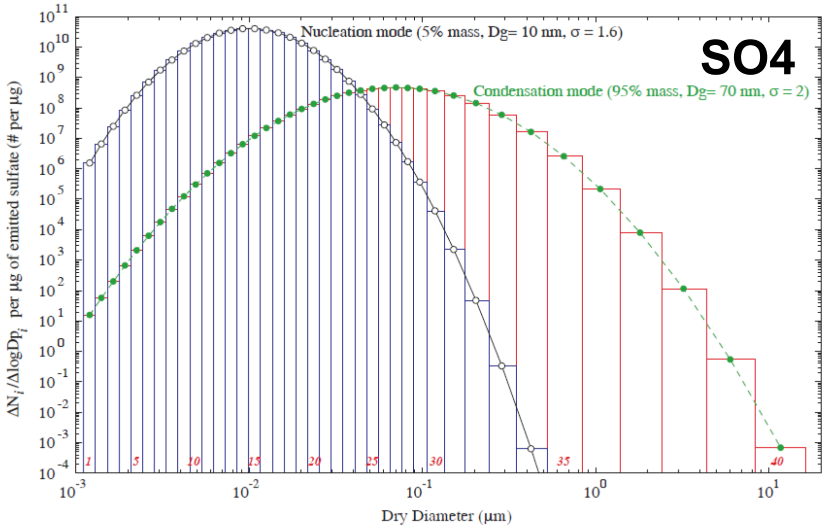
One of the most challenging parts is how to map CDNC globally

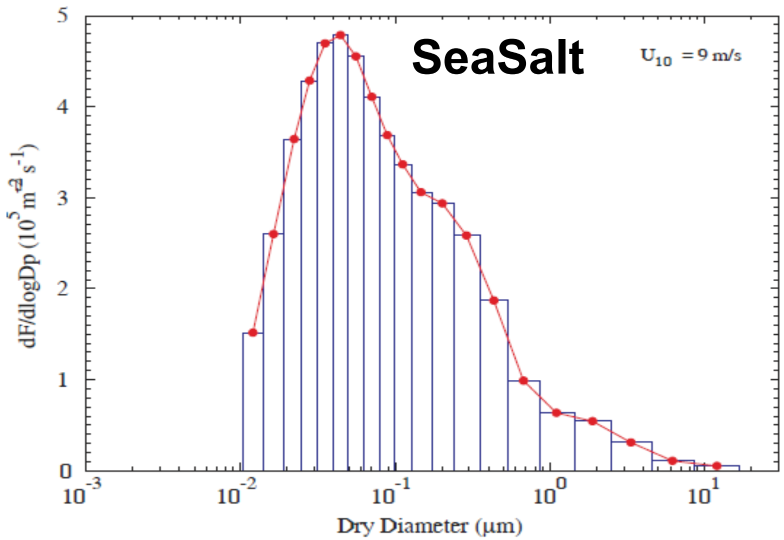
Model simulation? Satellite retrievals?

Model Features

SP: 40 bins; Sea-salt: 20 bins; Dust: 15 bins; BC: 15 bins; OC: 15 bins

Coating of SP on primary particles





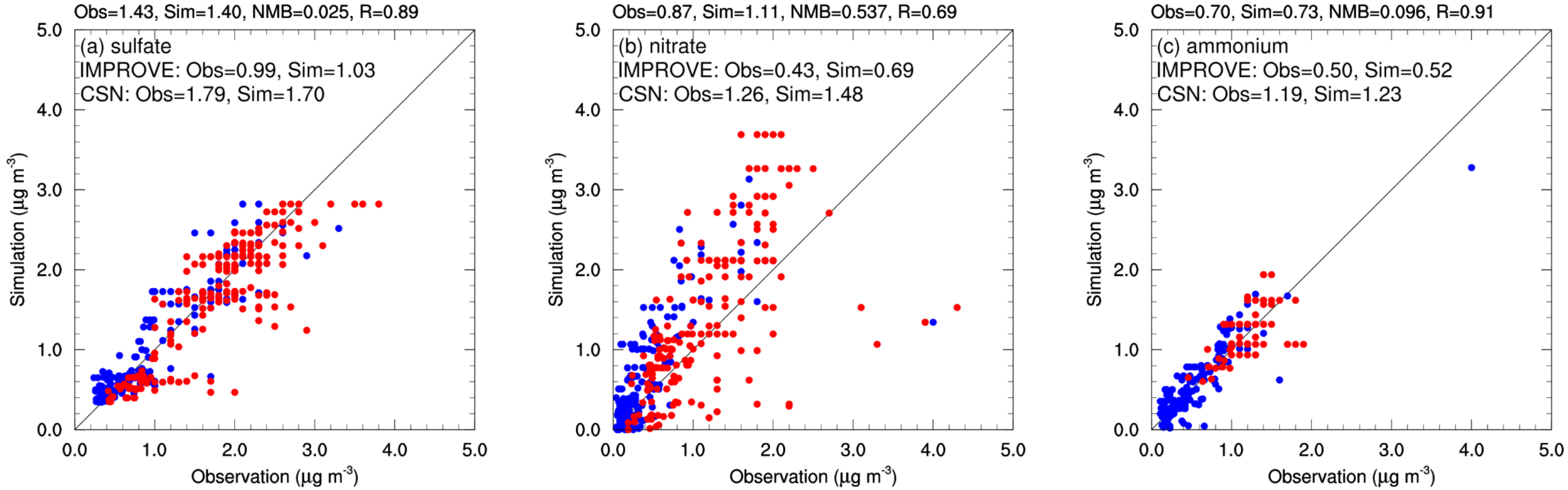
State-of-the-art new particle formation schemes and aerosol microphysics (Yu et al., ACPD, 2018)

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

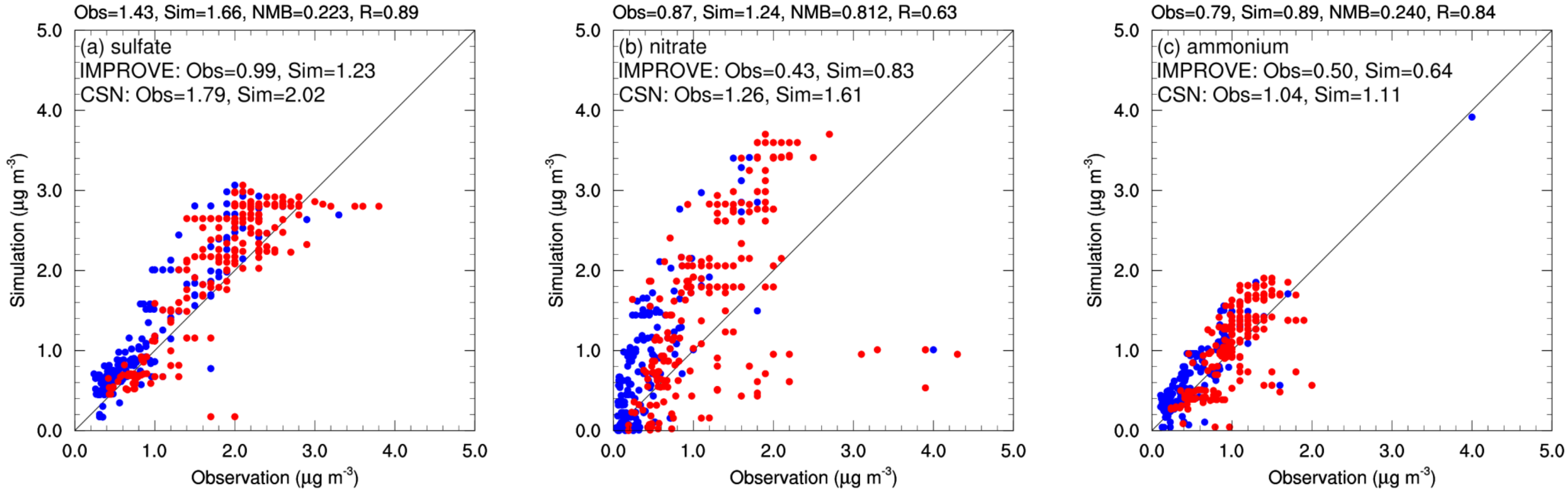
CAM-Chem-APM: size-resolved aerosol microphysics in CAM-Chem; MOZART tropospheric inorganic chemistry mechanism + two-product SOA formation; ACCMIP emission; nudging with MERRA2 atmospheric reanalysis

Simulated Aerosol Mass

GEOS-Chem-APM

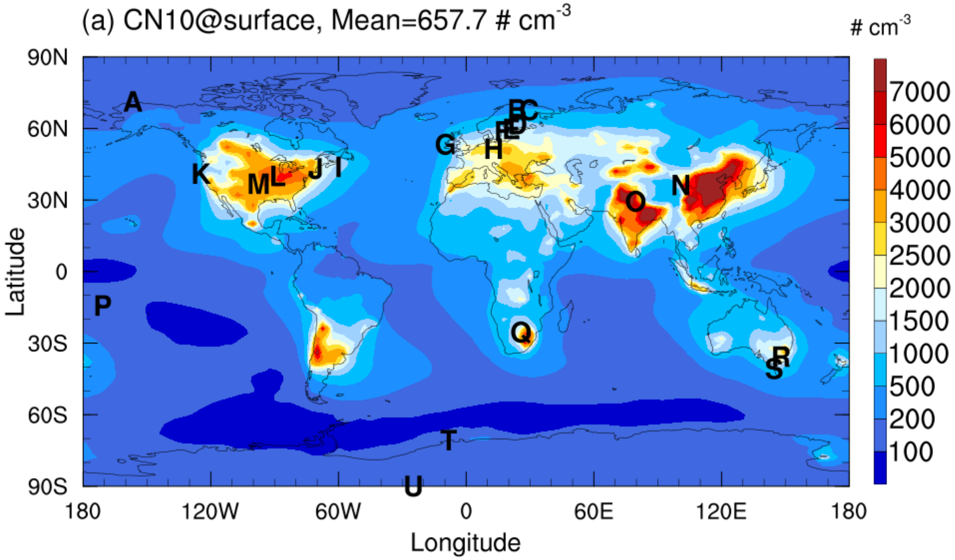


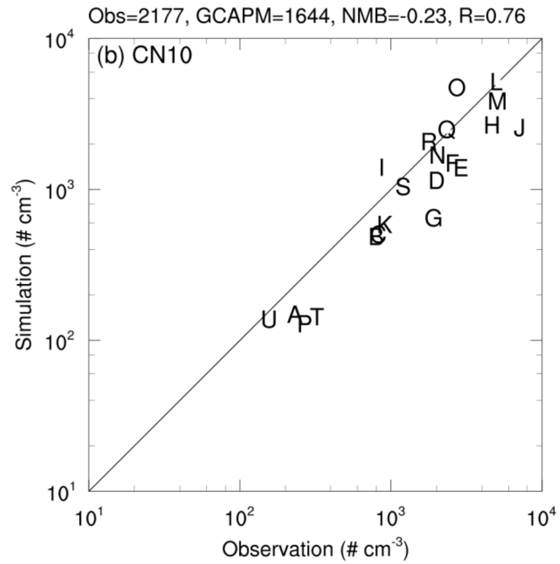
CAM-Chem-APM



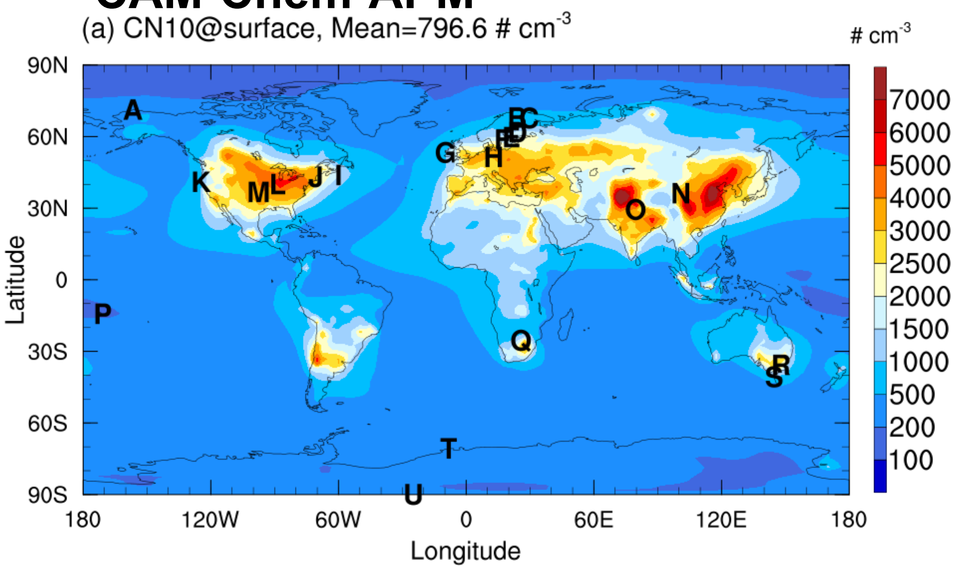
Aerosol Number > 10 nm

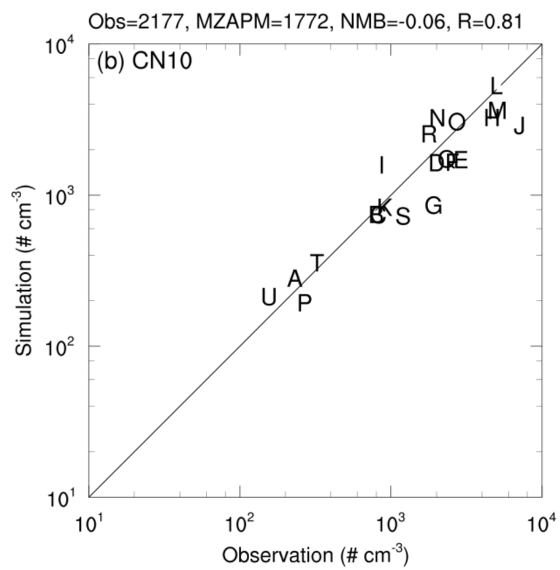
GEOS-Chem-APM





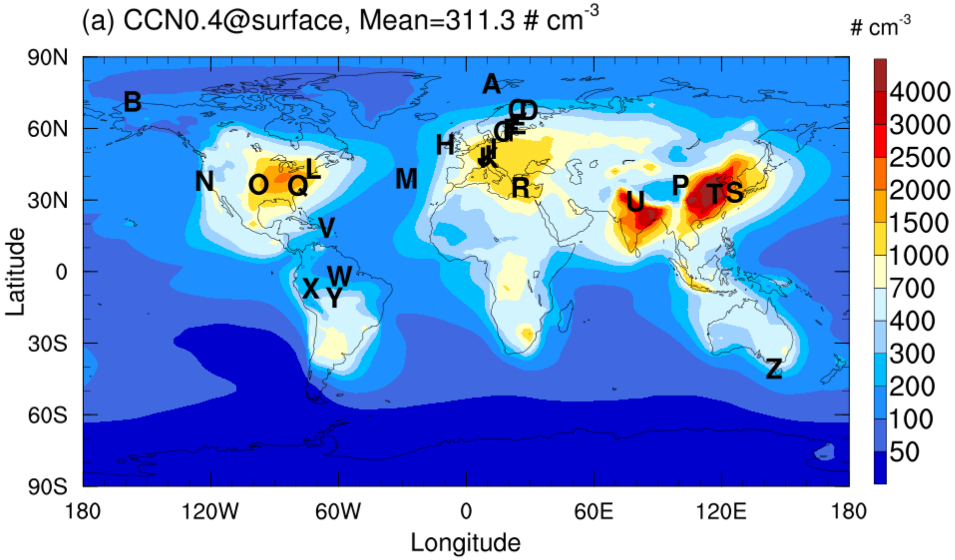
CAM-Chem-APM

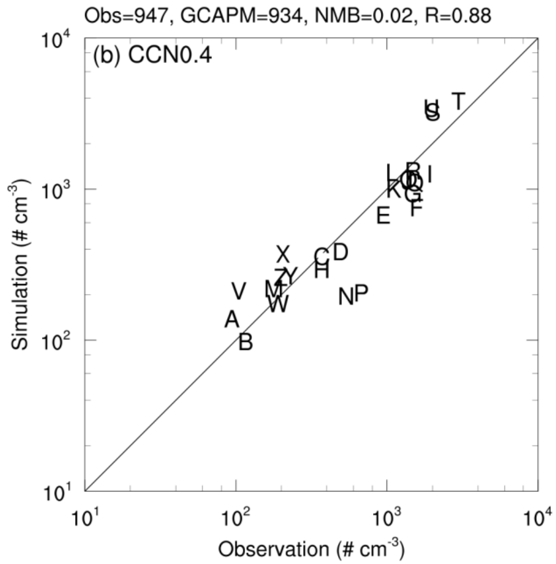




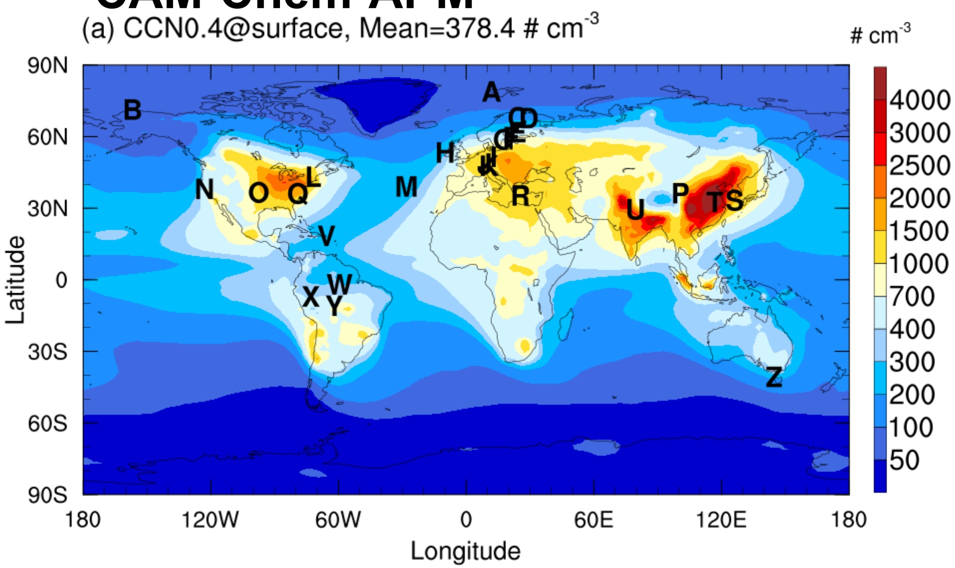
CCN number concentration

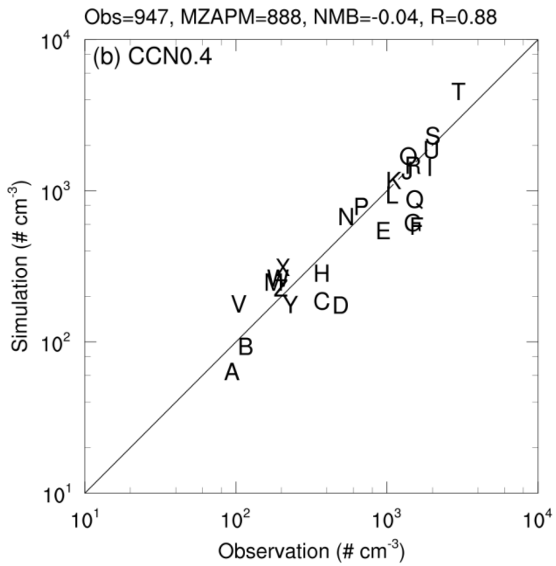
GEOS-Chem-APM





CAM-Chem-APM





MODIS retrieved CDNC

MODIS provides LWP, ER, CF, CTT, SZ

CDNC is not directly provided by MODIS

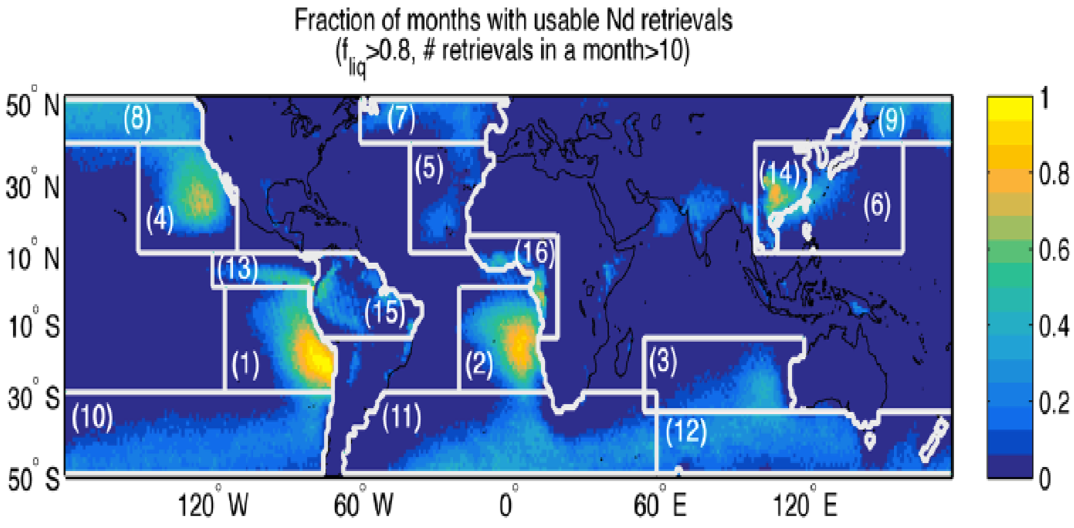
$$N_d = \sqrt{\Gamma_{\text{eff}}} \frac{\sqrt{10}\tau^{1/2}}{4\pi\rho_w{}^{1/2} r_e{}^{5/2} k}$$

τ (COD), r_e (ER), Γ_{eff} (effective lapse rate)

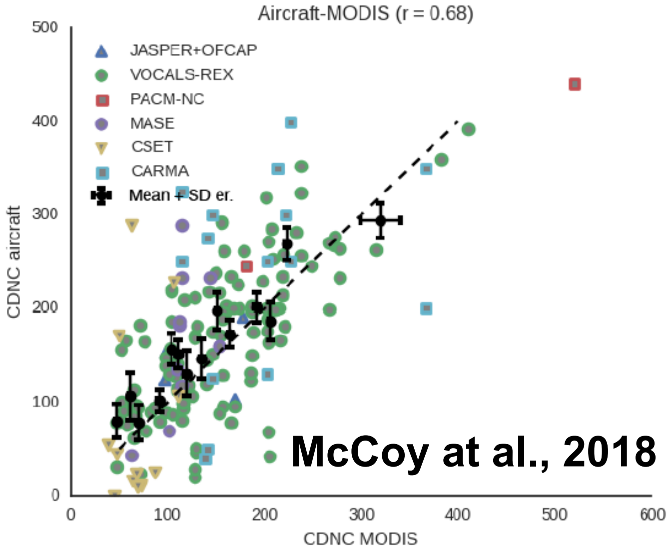
k (the skewness and dispersion of the cloud droplet size distribution)

ρ_w (water density)

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

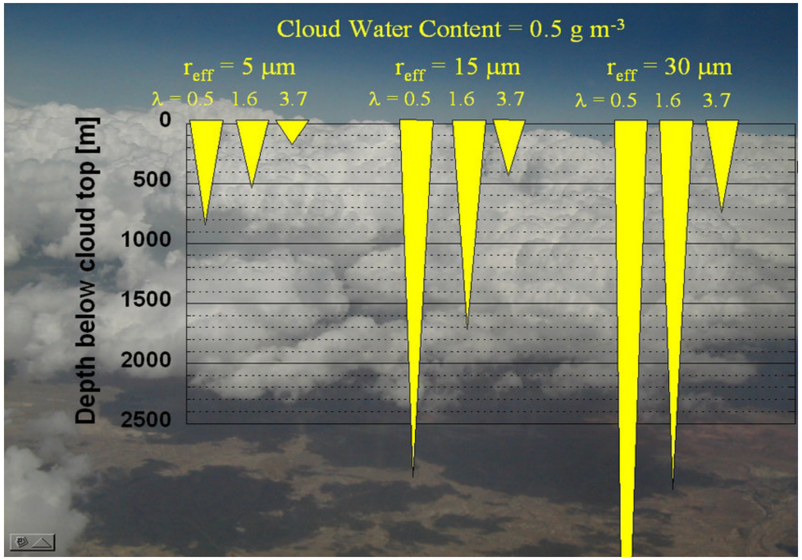


McCoy at al., 2017



McCoy at al., 2018

Bands: 1.6, 2.1, and 3.7 μm

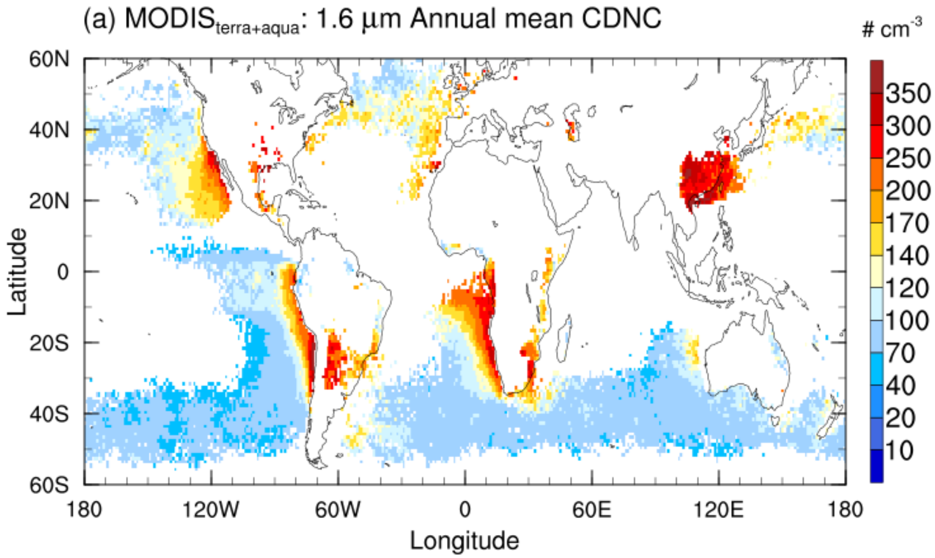


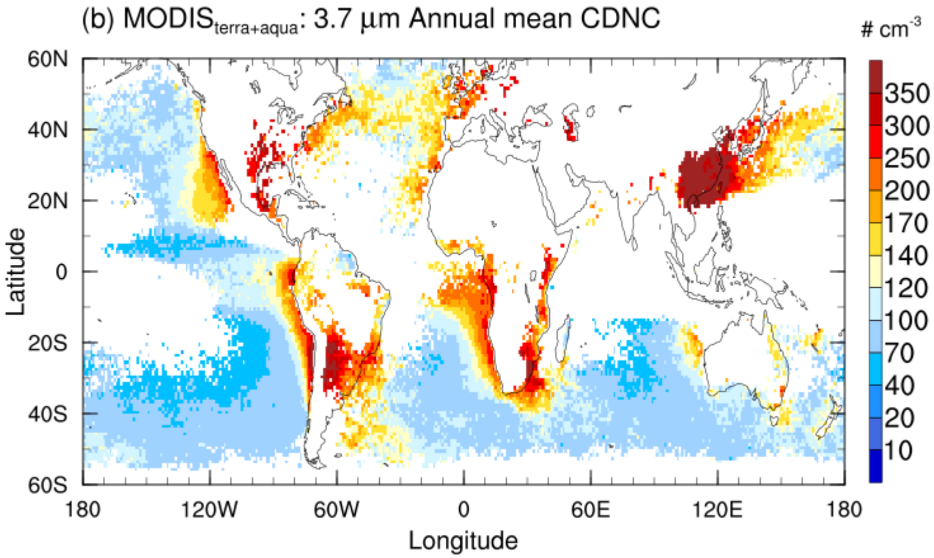
Levizzani et al., 2003

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)

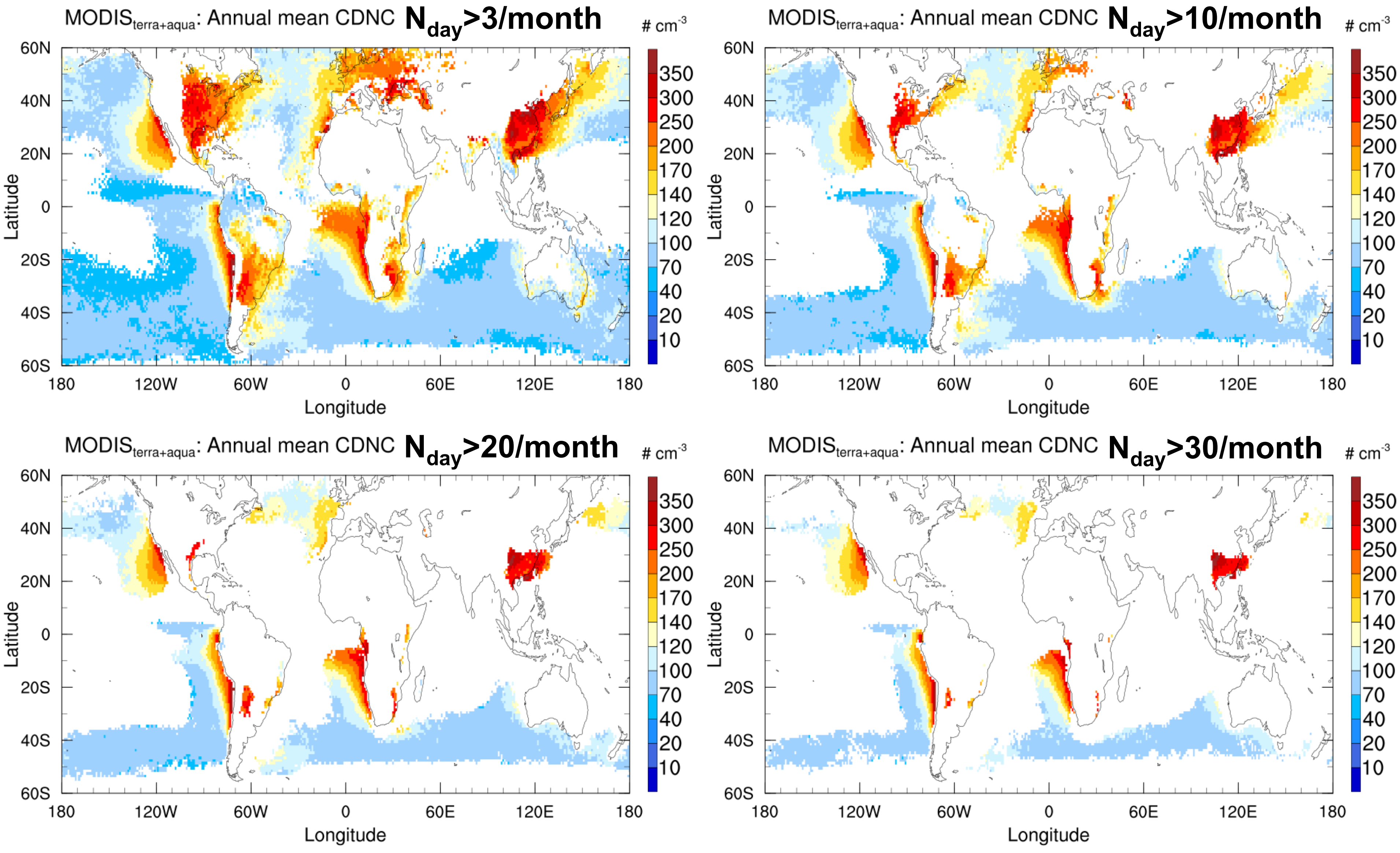
1.6 μm: better representation of column cloud



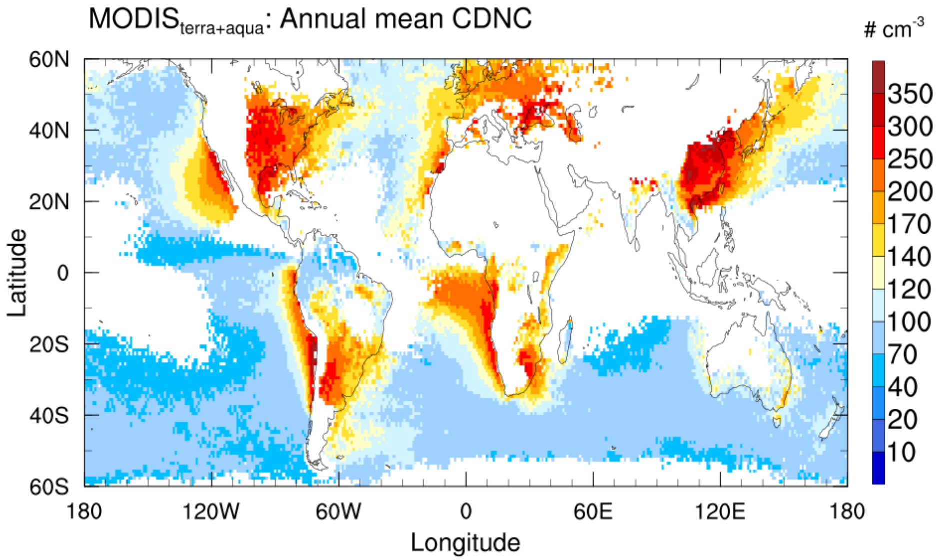


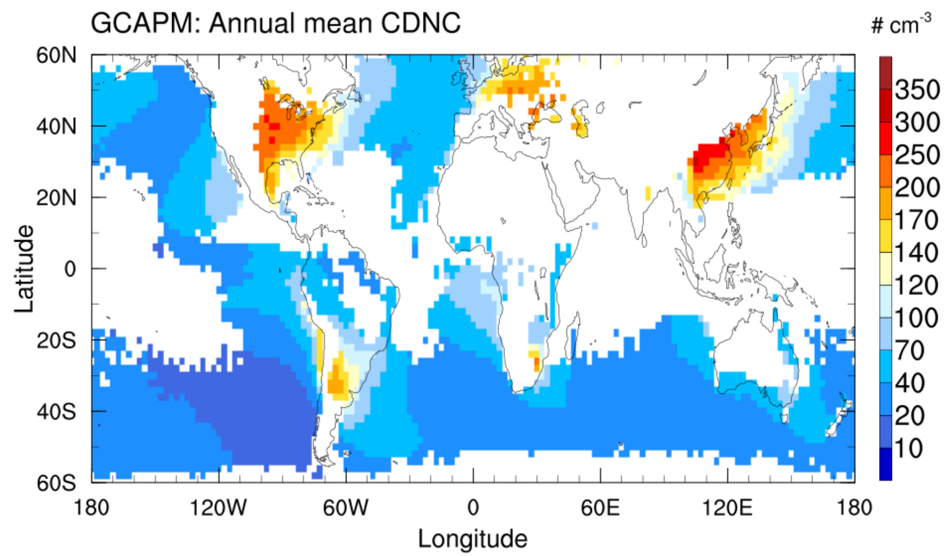
Sampling of Retrievals

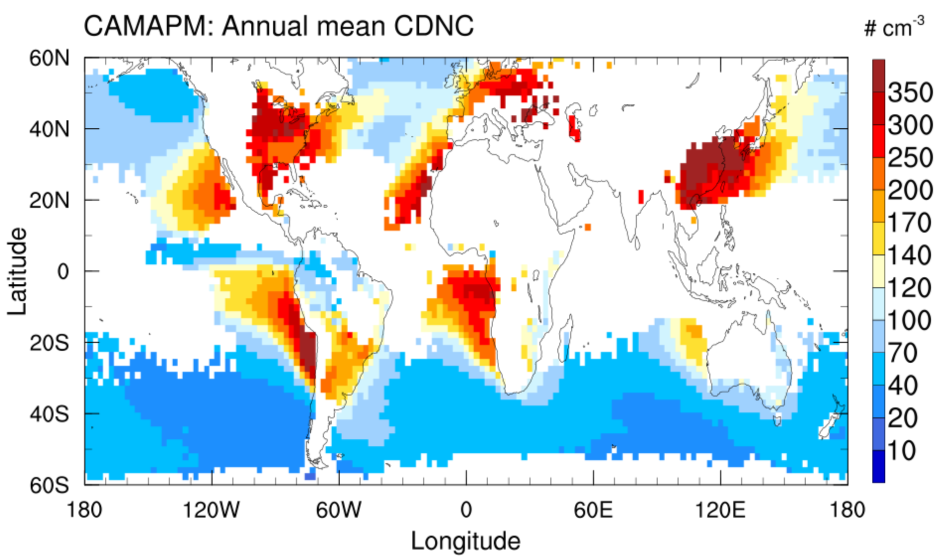
Multi-year data ➔ monthly mean values: N_{mon}>6/year ➔ annual mean



Maps of CDNC from Satellite and Model







High concentrations are located at continental and outflow regions

CAMAPM > MODIS > GCAPM

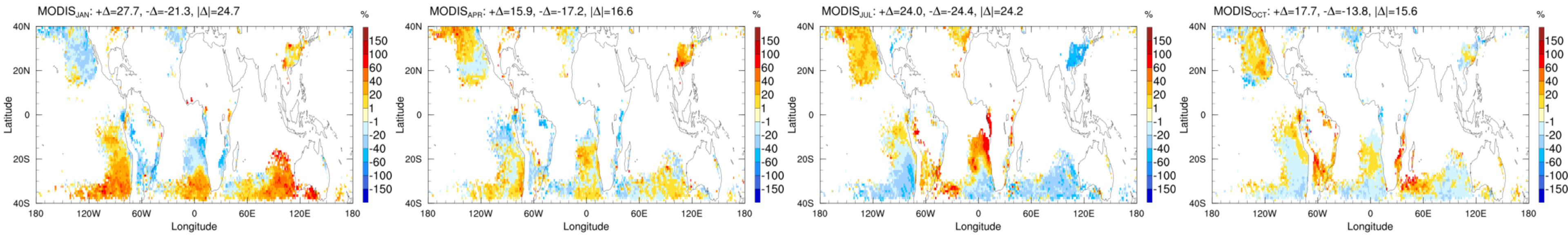
GCAPM significantly underestimate outflow

Underestimation over remote marine

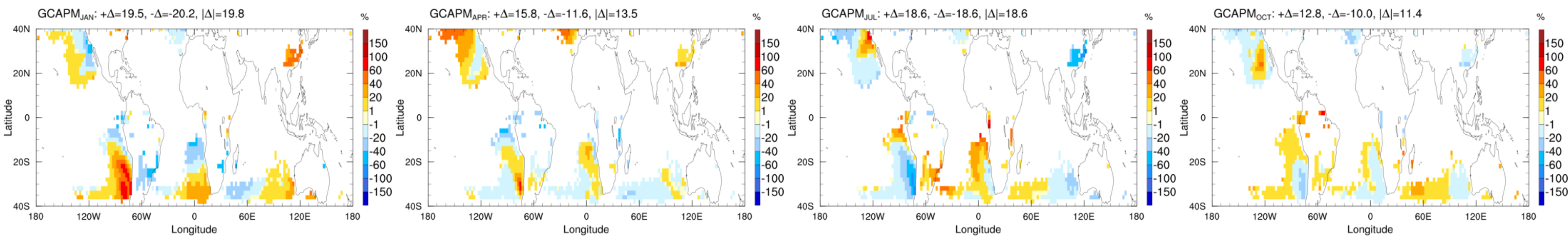
Signals of Seasonal Variation

JAN **APR** **JUN** **OCT**

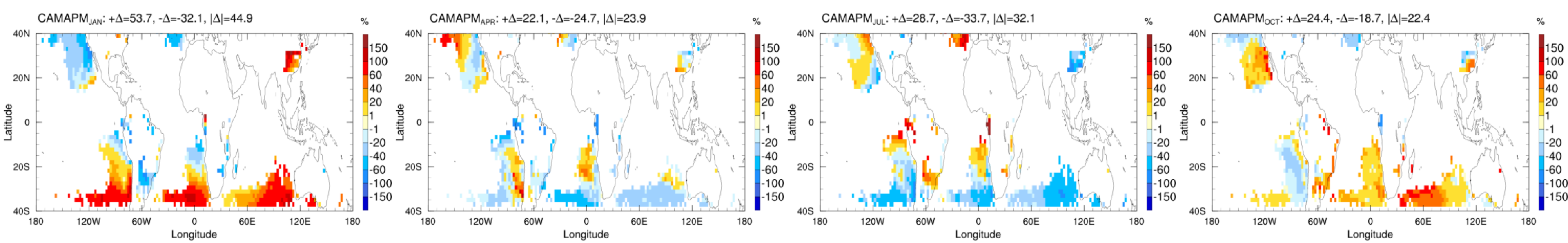
MODIS



GEOS-Chem-APM



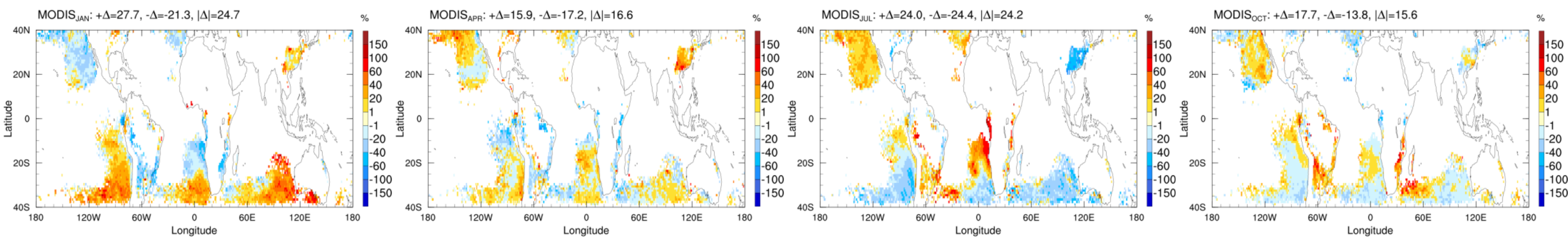
CAM-Chem-APM



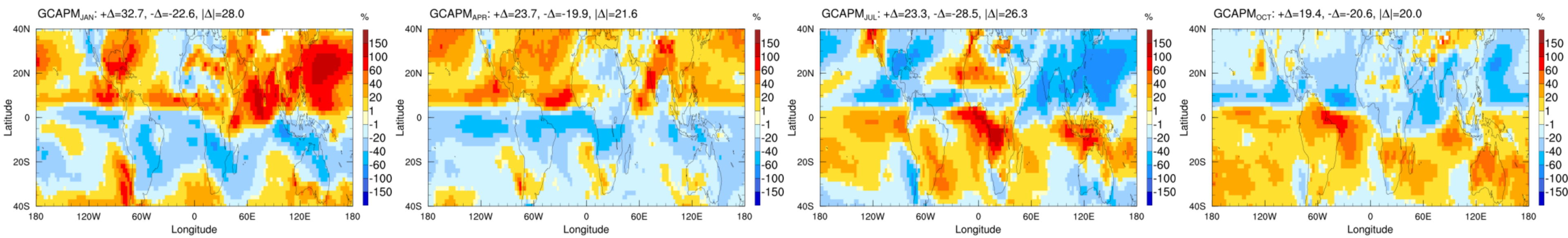
Signals of Seasonal Variation

JAN **APR** **JUN** **OCT**

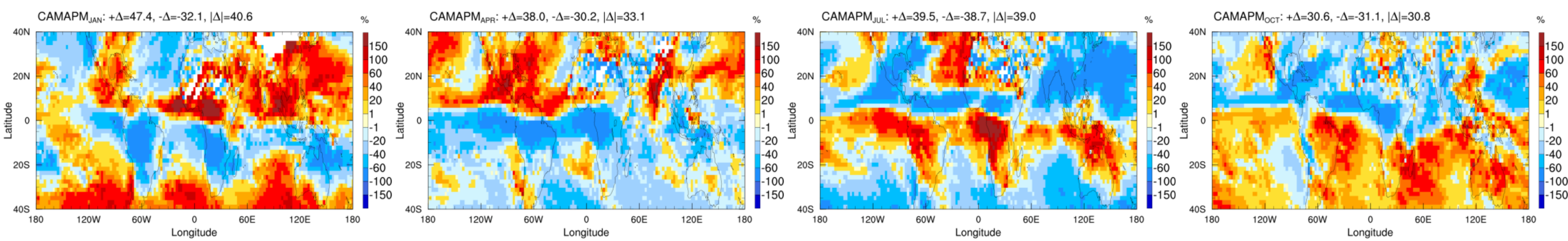
MODIS



GEOS-Chem-APM

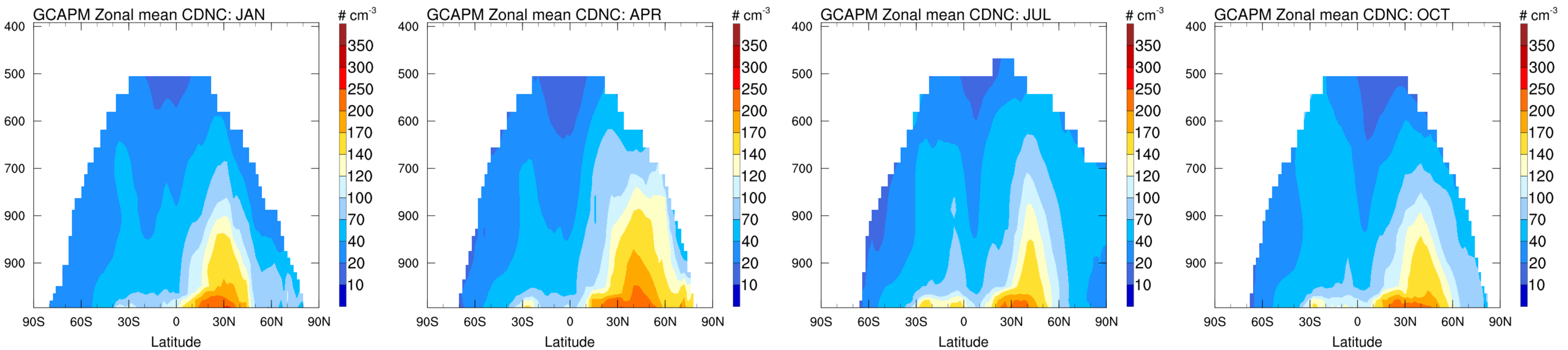


CAM-Chem-APM

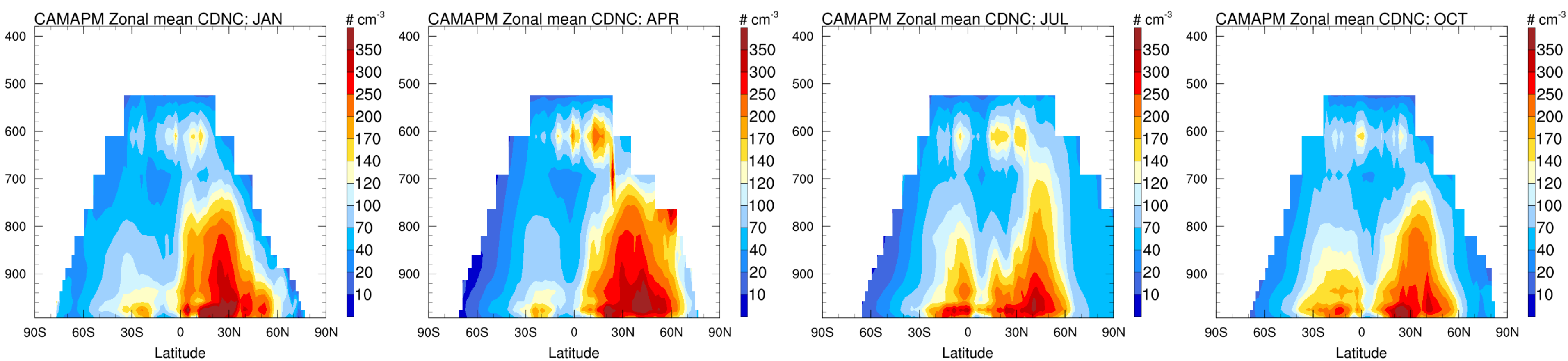


Vertical Profile of CDNC

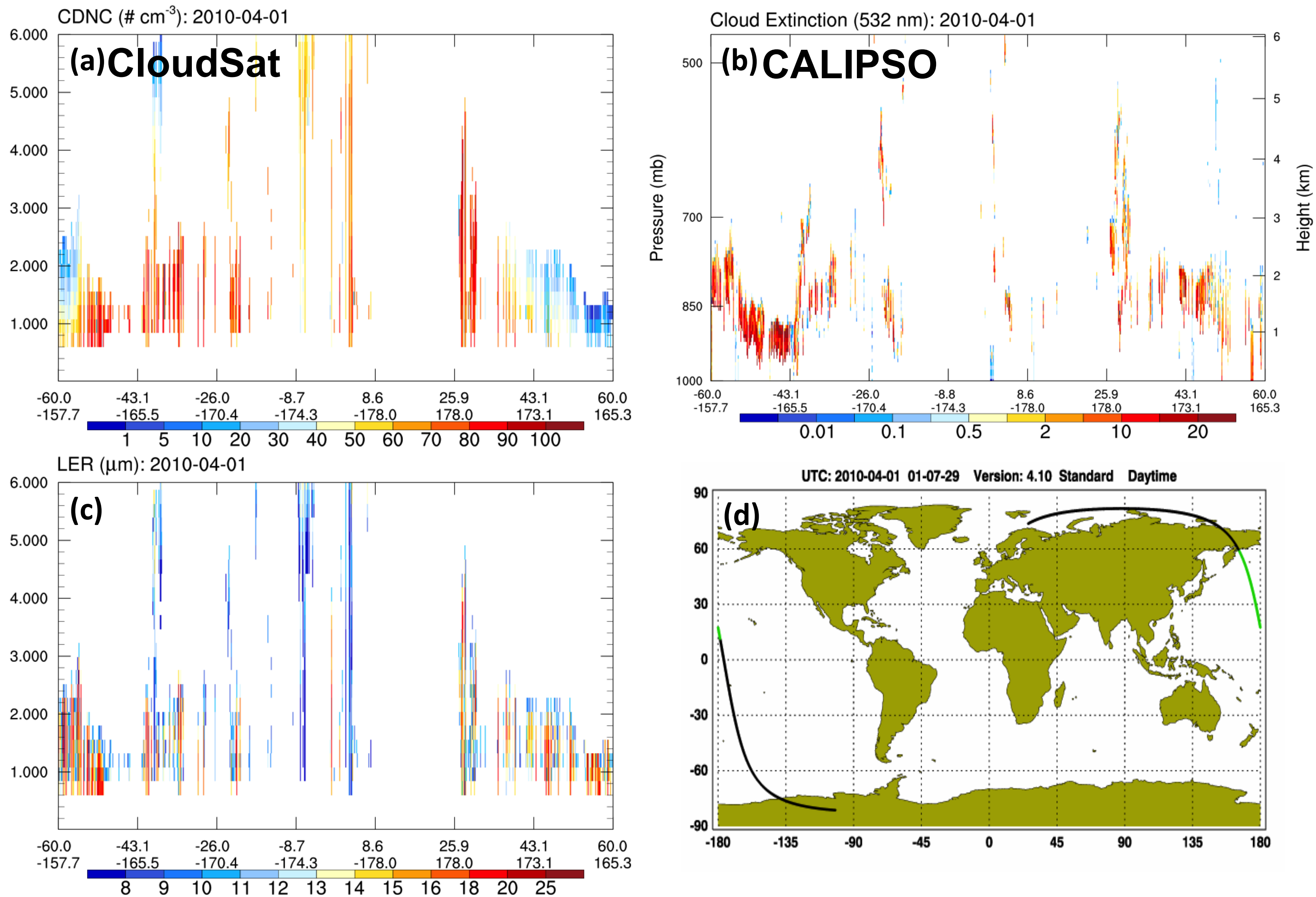
GEOS-Chem-APM



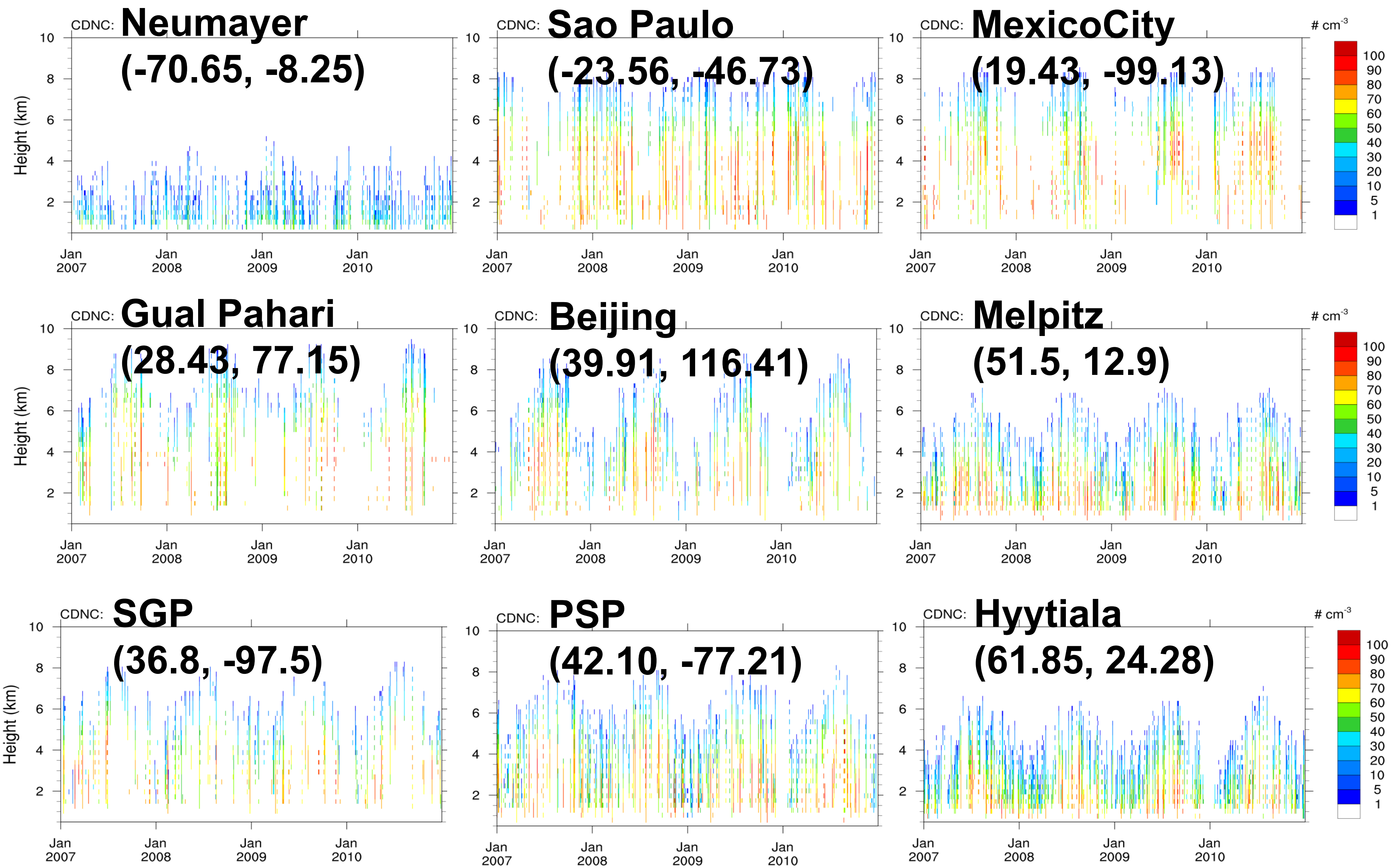
CAM-Chem-APM



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

Supported by NASA , NSF

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