Spatial variations of AOD-CCN correlations and implications for aerosol indirect radiative forcing

Fanggun Yu[1], Gan Luo[1], Hailing Jia[2], and Xiaoyan Ma[2]

[1]*Atmospheric Sciences Research Center, State University of New York at Albany*

[2]*Nanjing University of Information Science and Technology, Nanjing, China*

Geophysical Research Letter

RESEARCH LETTER

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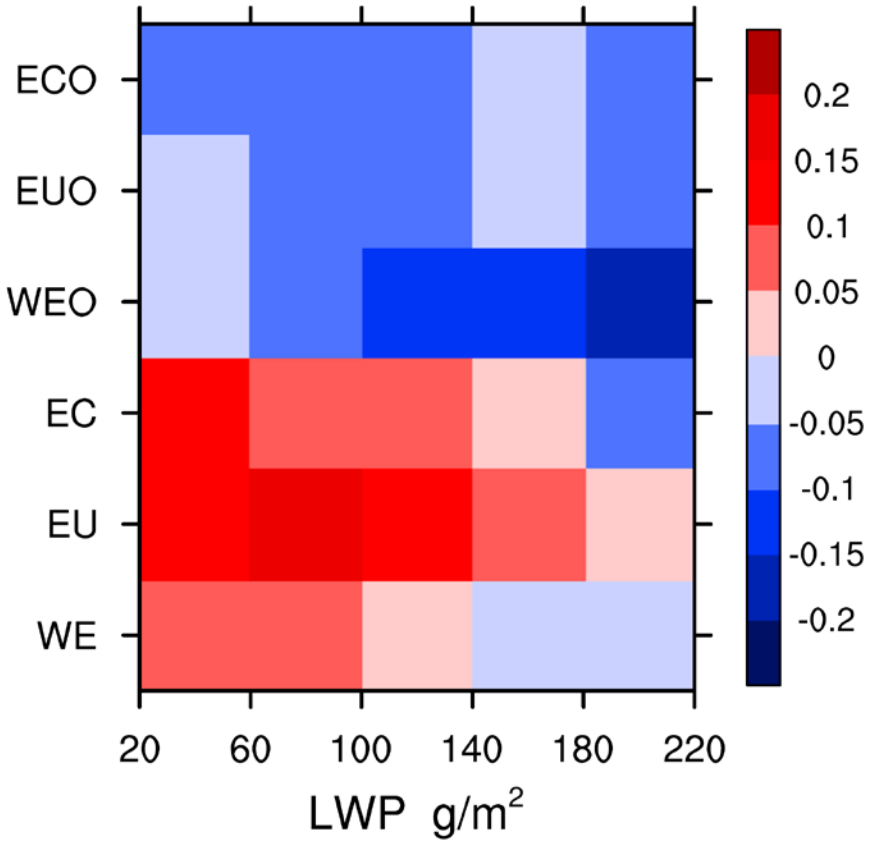
Opposite Ae
Correlations
and Their A

X. Ma[1], H. Jia[1]

[1]Key Laboratory of Met

Key Points:

- Cloud effective radius is positively correlated to aerosol index over three industrial regions, but negatively over adjacent oceans



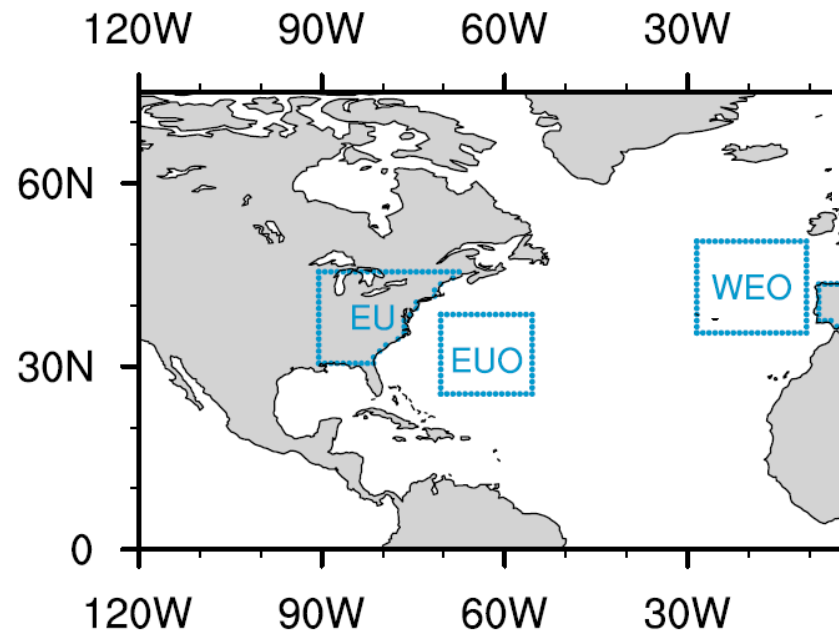
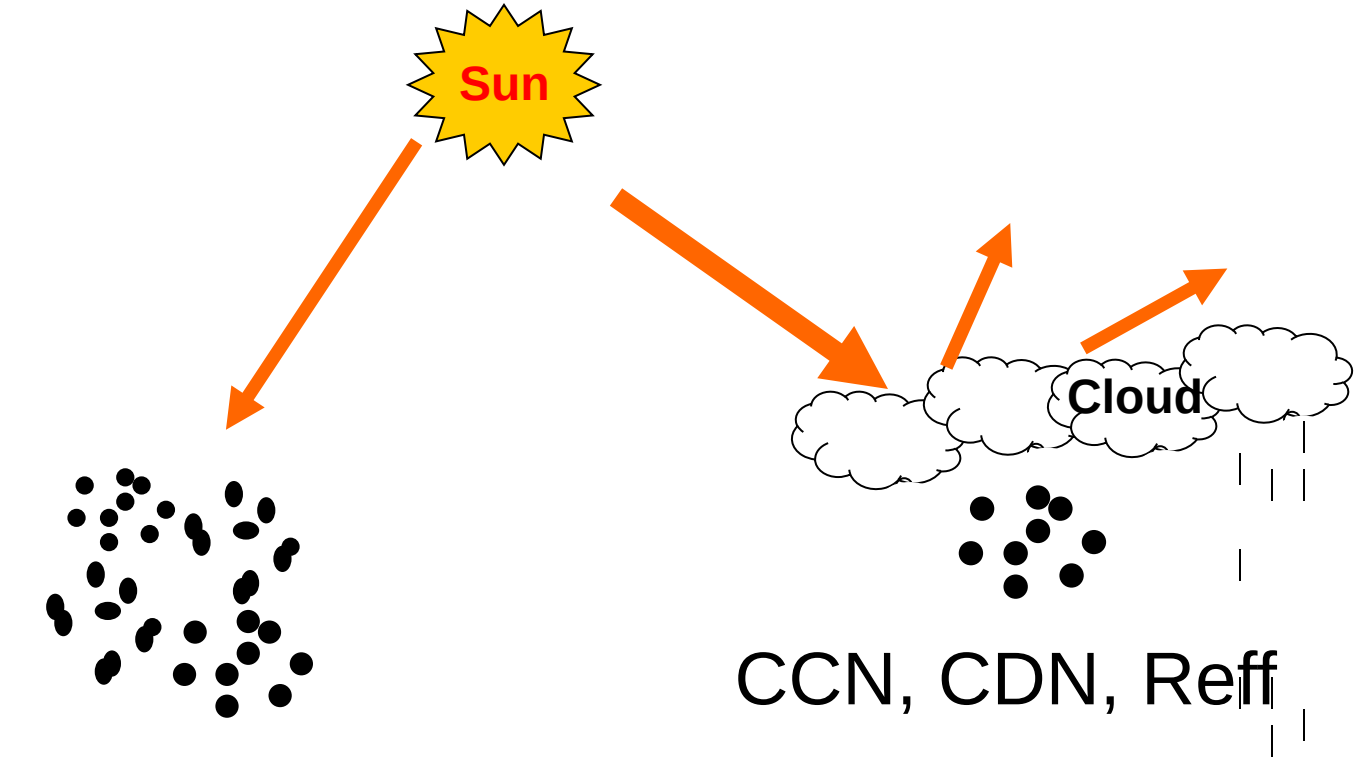


Figure 1. The computed slopes of CER versus AI on log-log scale, in which both CER and AI are stratified according to LWP.



AOD or AI ≠? CCN

Model Description

GEOS–Chem (Bey et al., 2001), v10.1

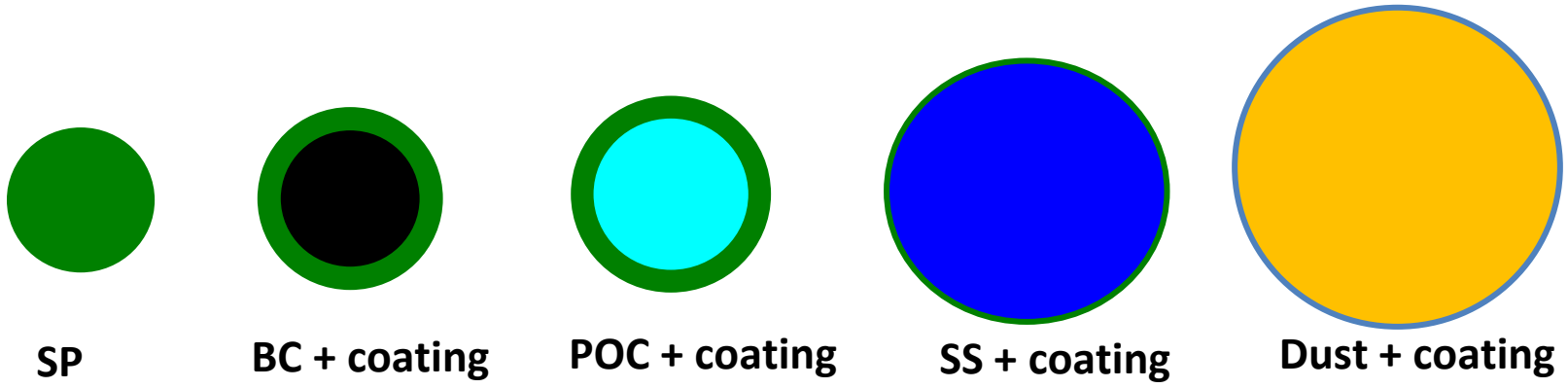
Horizontal resolution: $2^o \times 2.5^o$; Vertical layers: 47 (14 layers from surface to ~ 2 km above the surface)

Simulation period: 2000-2017, driven by MERRA2

Emission inventories: At the USA, Air Pollutant Emissions Trends Data reported by EPA is used to scale NEI2011 emission inventories from year 2011 to simulation years.

Advanced Particle Microphysics (APM) model (Yu and Luo, 2009)

Aerosol microphysics: the Advanced Particle Microphysics (APM)



Secondary particles (SP) : **40** bins, composed of SO4, NIT, NH4, SOA

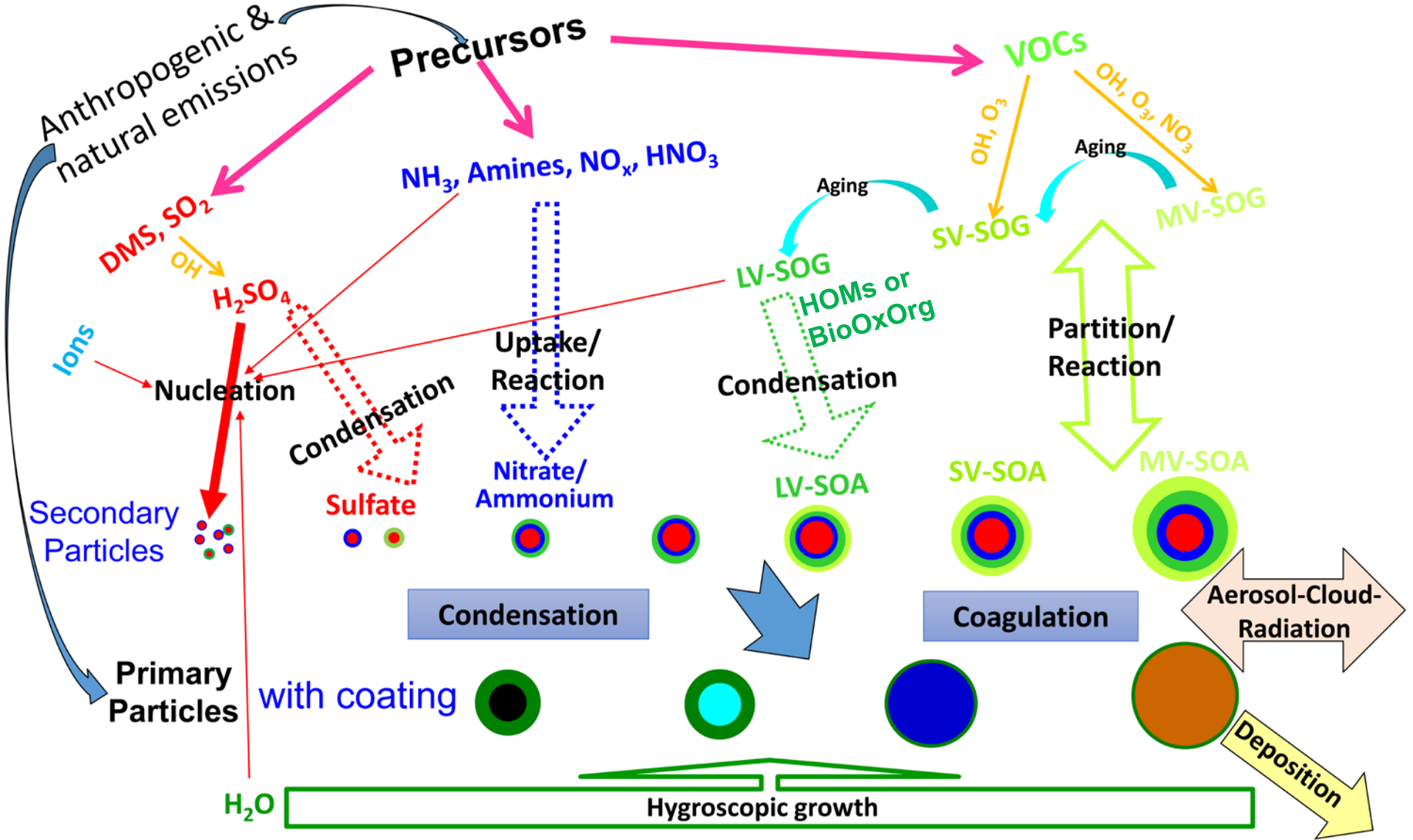
Sea salt (SS): 20 bins

Dust: 15 bins

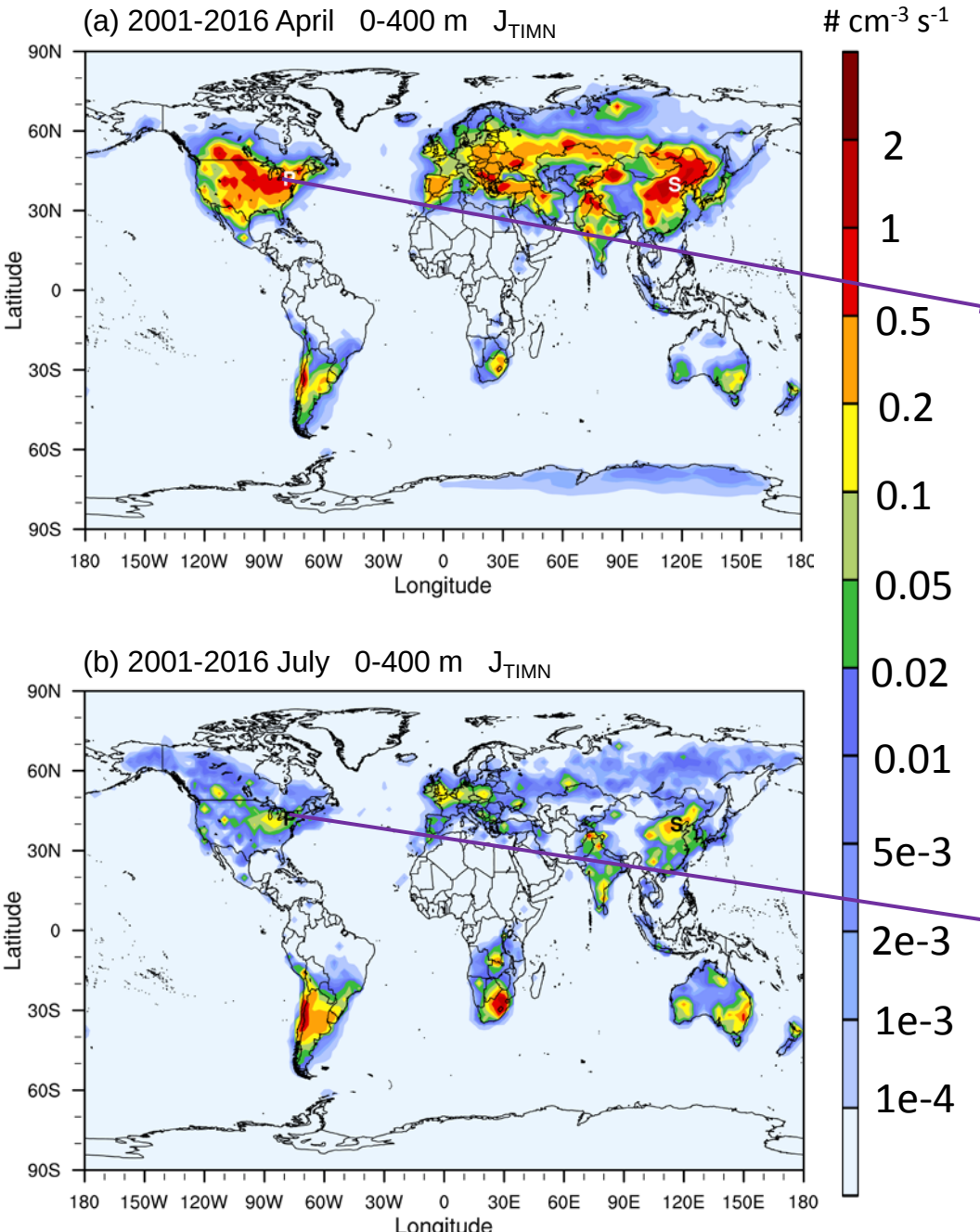
Black Carbon (BC): 15 bins

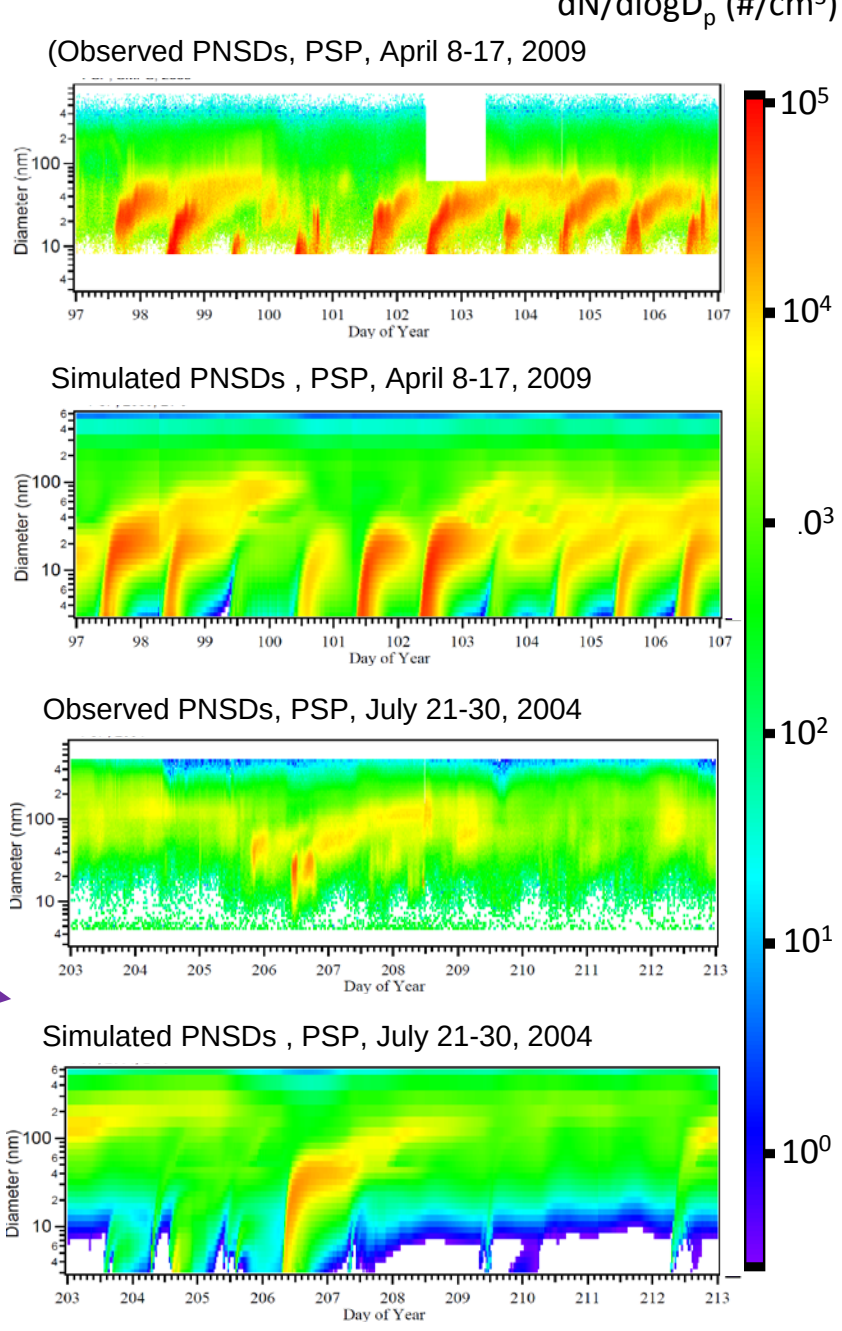
Primary OC (POC): 15 bins

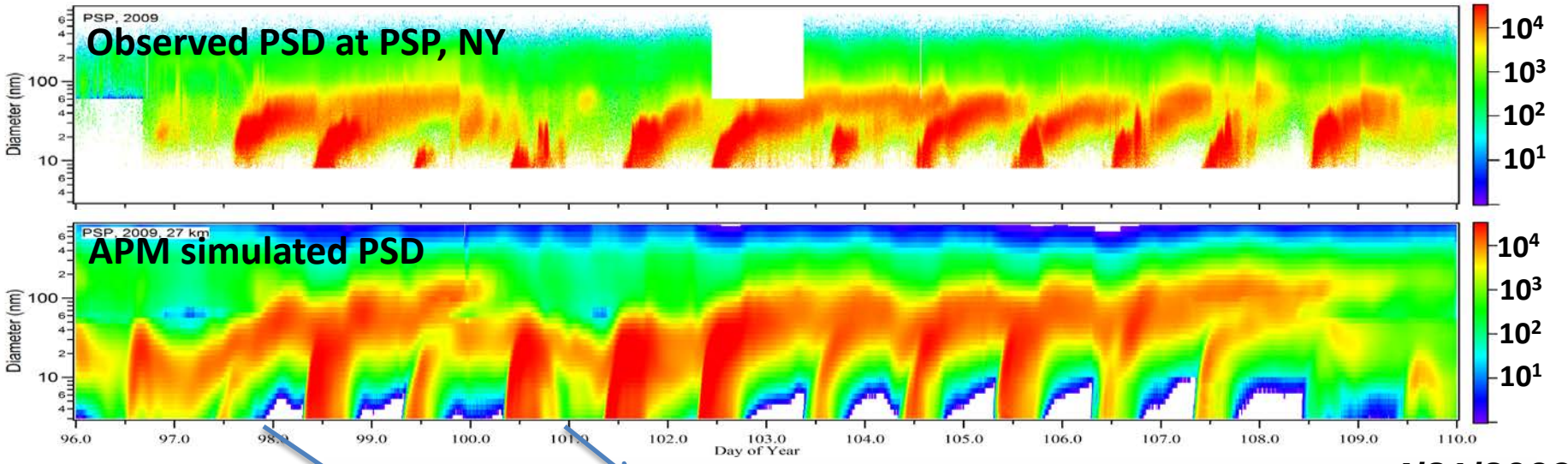
Particle formation and evolution processes treated in GEOS-Chem/APM



Pinnacle State Park, New York, US (PSP)



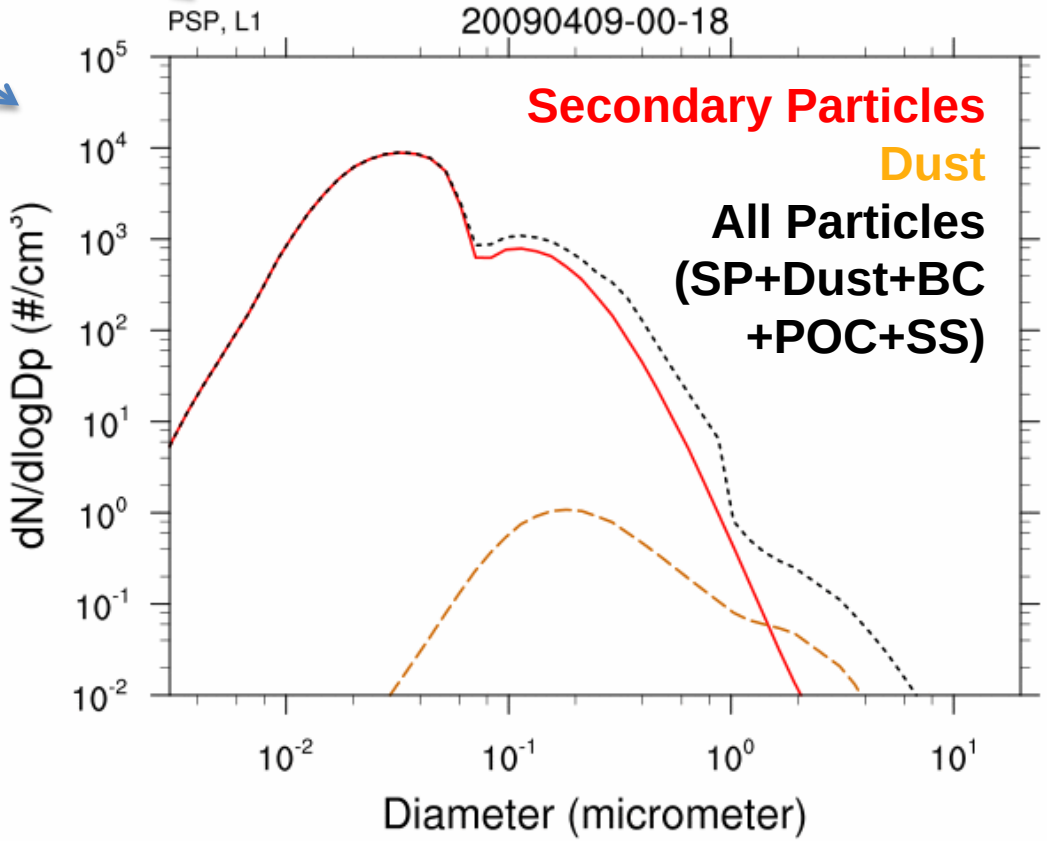


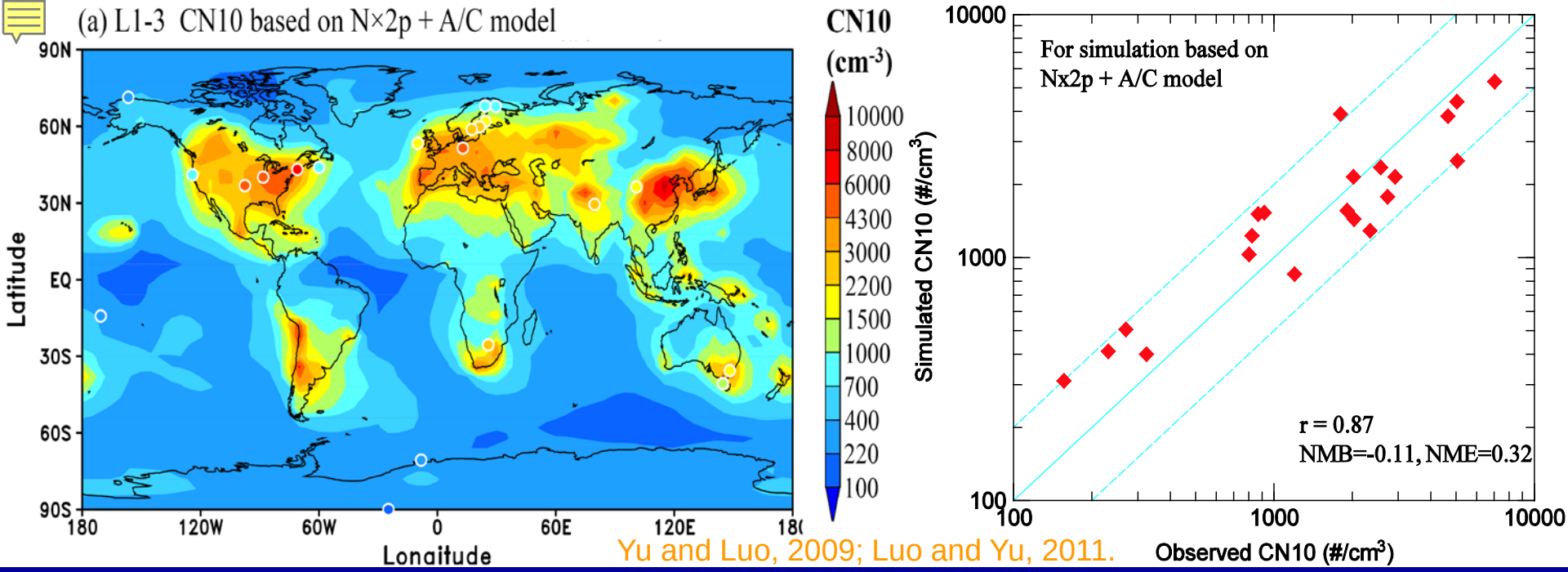


4/7/2009

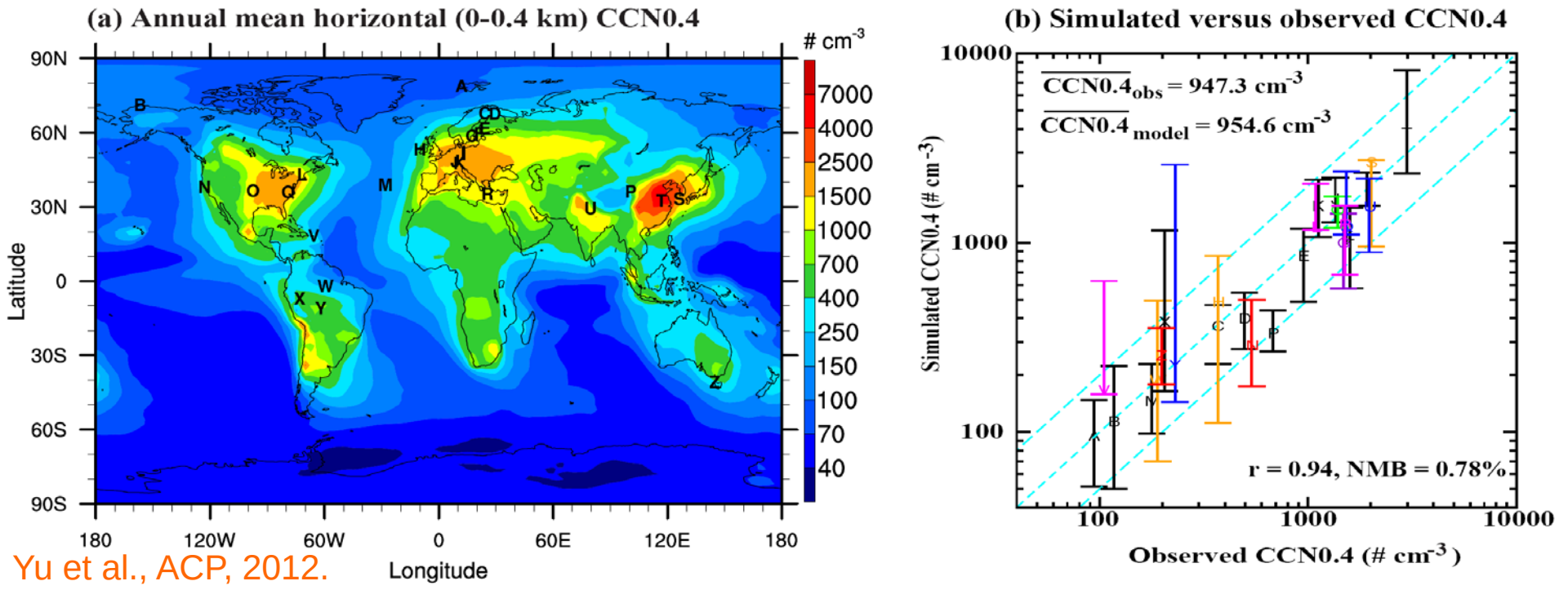
4/21/2009

Particle formation, growth and contribution to CCN

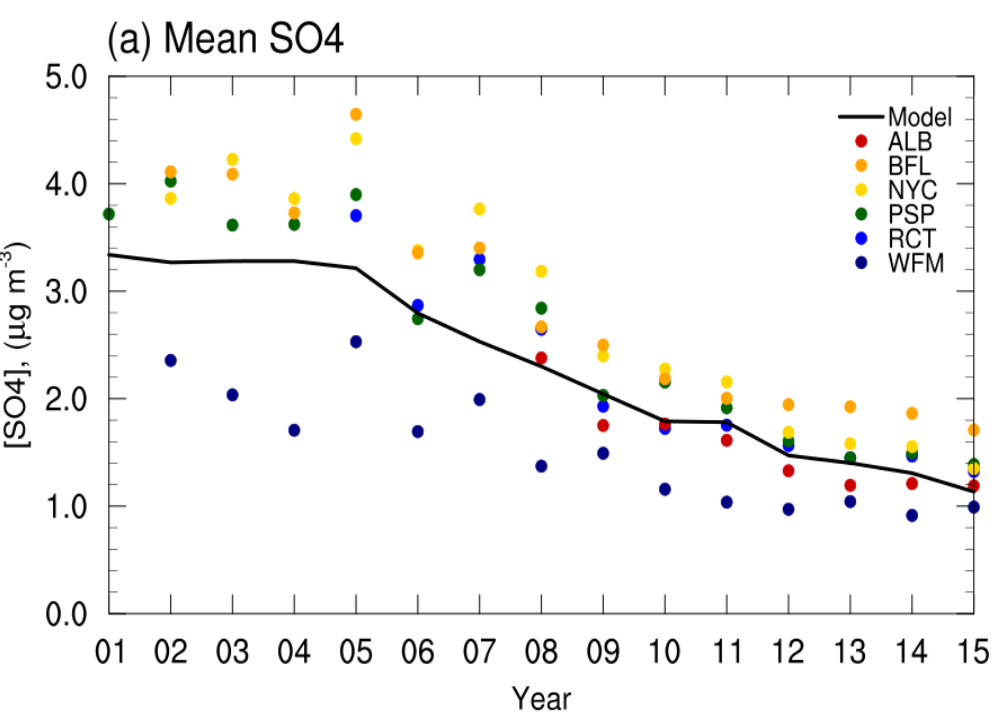


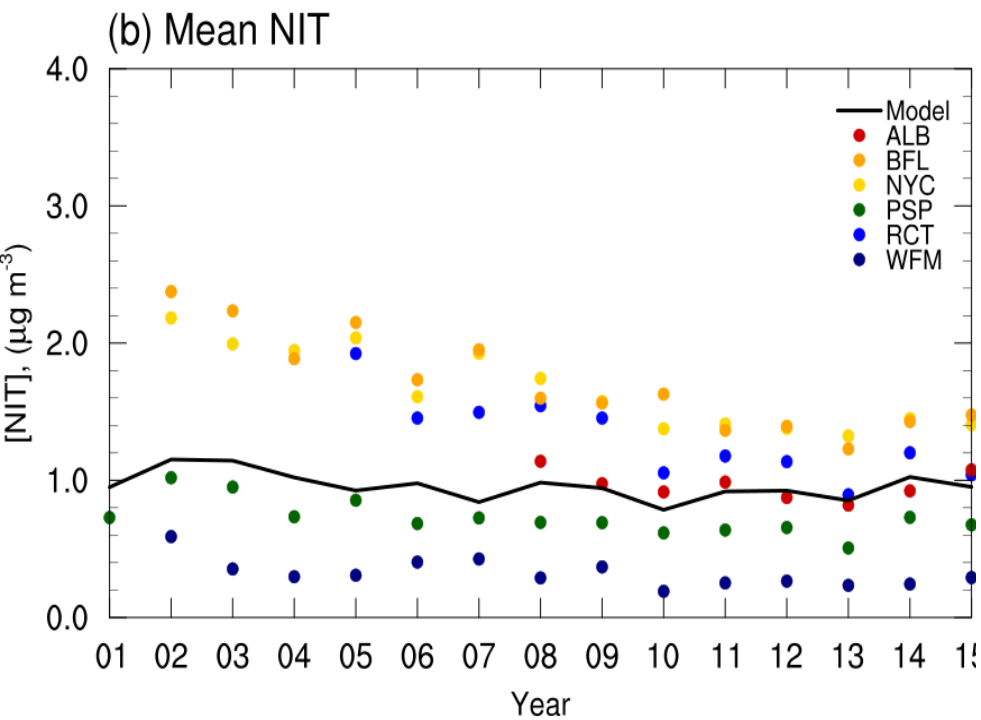


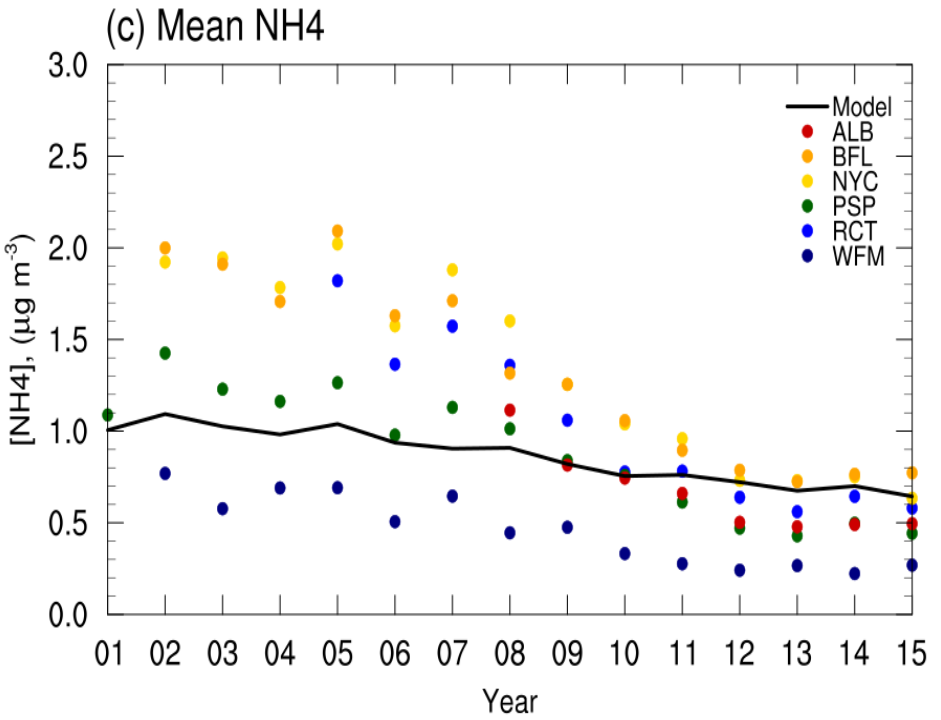
Yu and Luo, 2009; Luo and Yu, 2011.

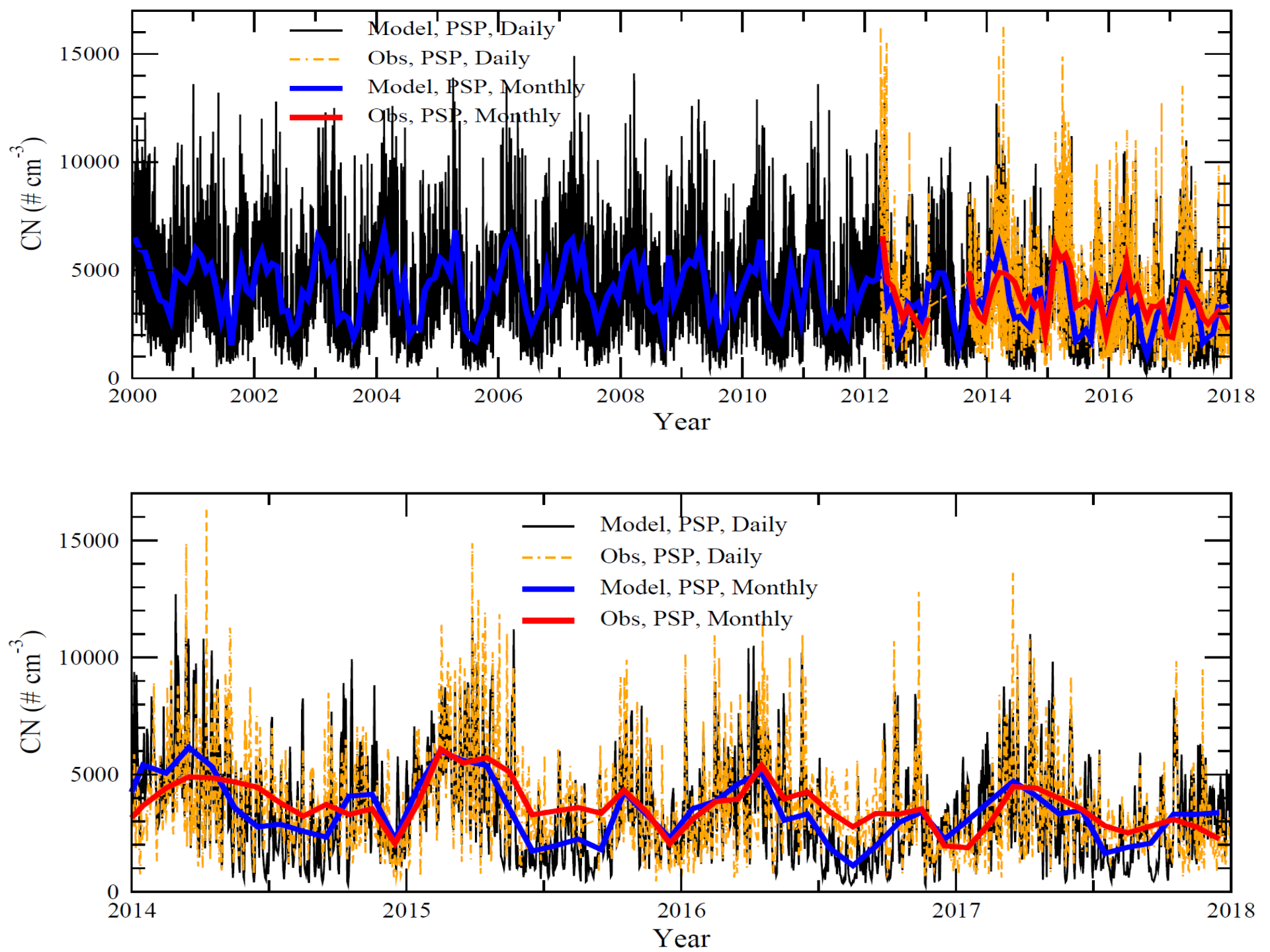


Yu et al., ACP, 2012.

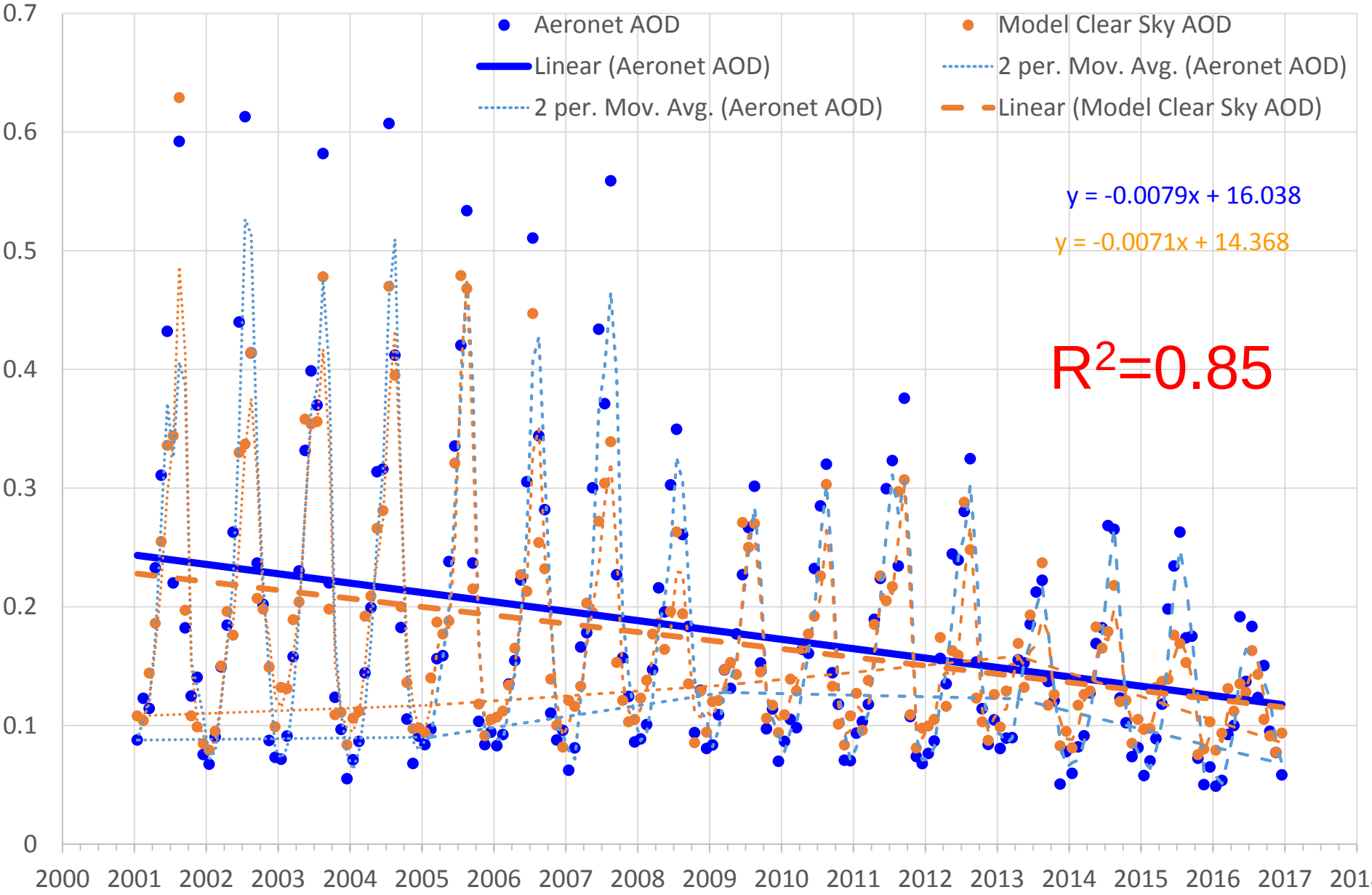

(a) Mean SO4
[SO4], (µg m-3)
Year
Model
ALB
BFL
NYC
PSP
RCT
WFM


(b) Mean NIT
[NIT], (µg m-3)
Year
Model
ALB
BFL
NYC
PSP
RCT
WFM

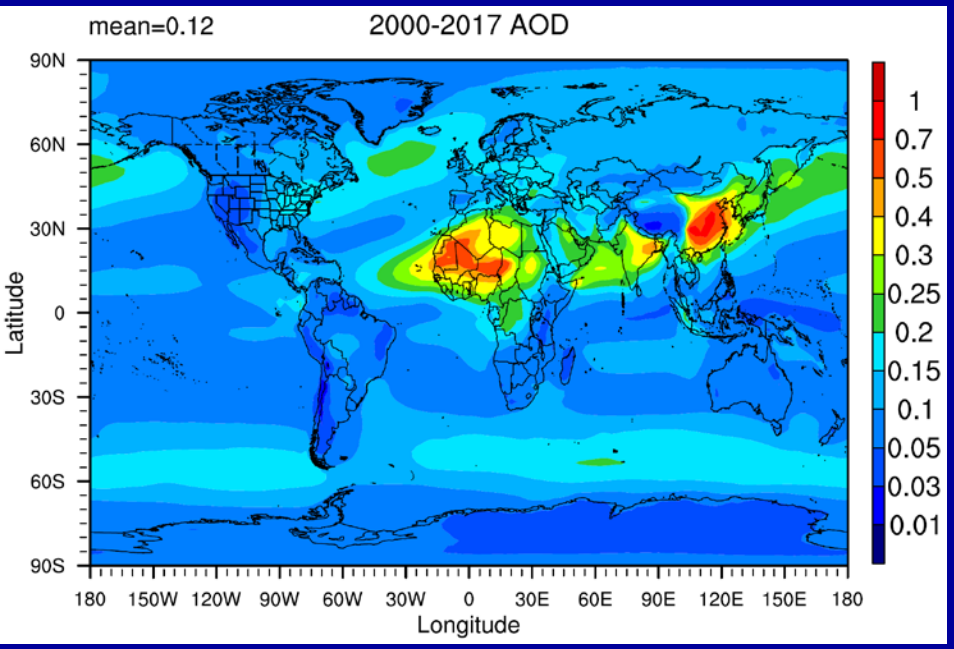

(c) Mean NH4
[NH4], (µg m-3)
Year
Model
ALB
BFL
NYC
PSP
RCT
WFM


Model, PSP, Daily
Obs, PSP, Daily
Model, PSP, Monthly
Obs, PSP, Monthly
CN (# cm-3)
Year
0
5000
10000
15000
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Model, PSP, Daily
Obs, PSP, Daily
Model, PSP, Monthly
Obs, PSP, Monthly
CN (# cm-3)
Year
0
5000
10000
15000
2014
2015
2016
2017
2018

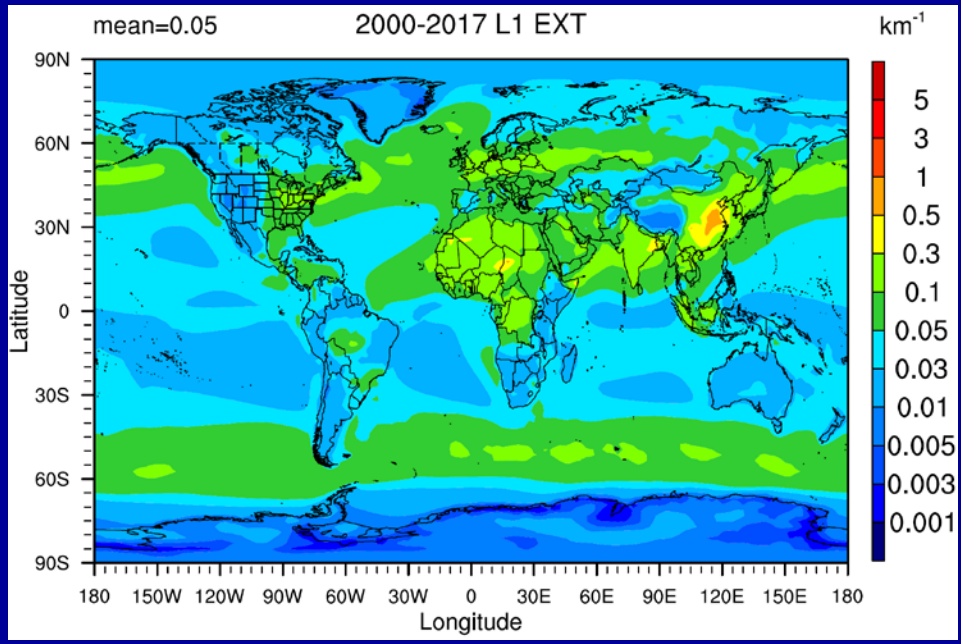
Long term trends of observed and modeled AOD at GSFC AERONET site



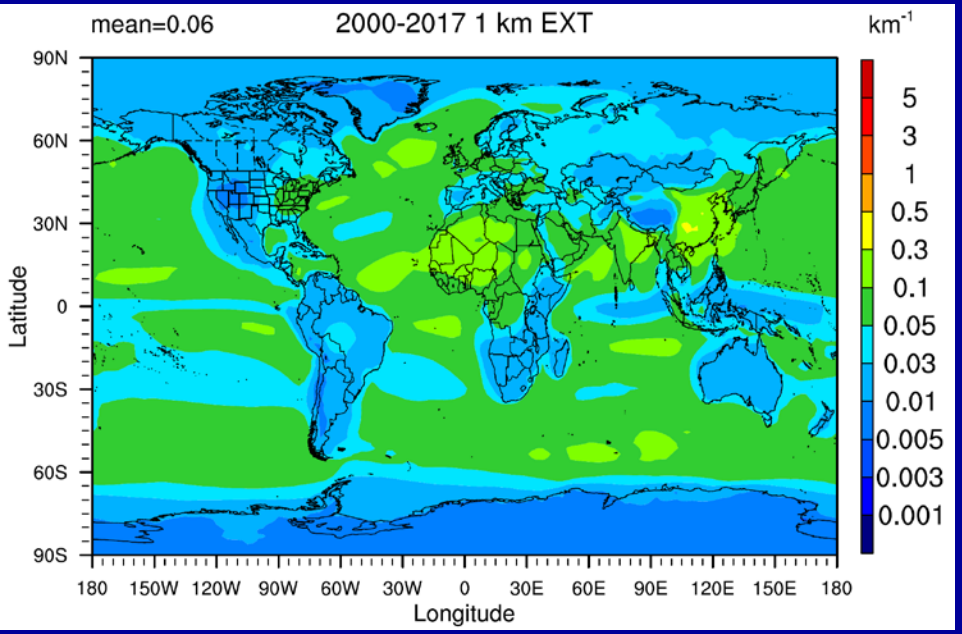
AOD



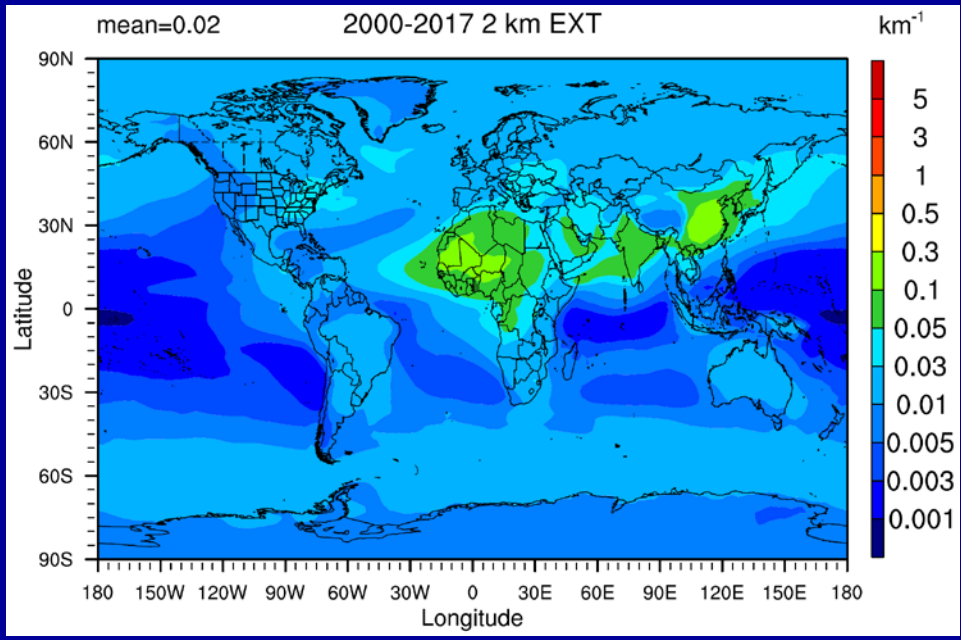
Ext Coef., Surface Layer



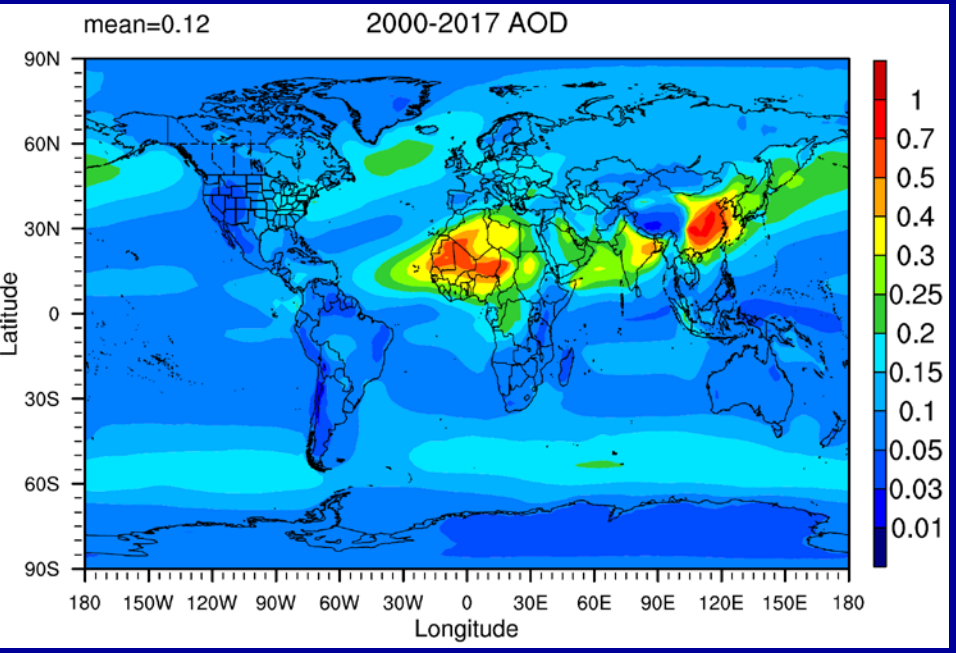
Ext Coef., 1 km



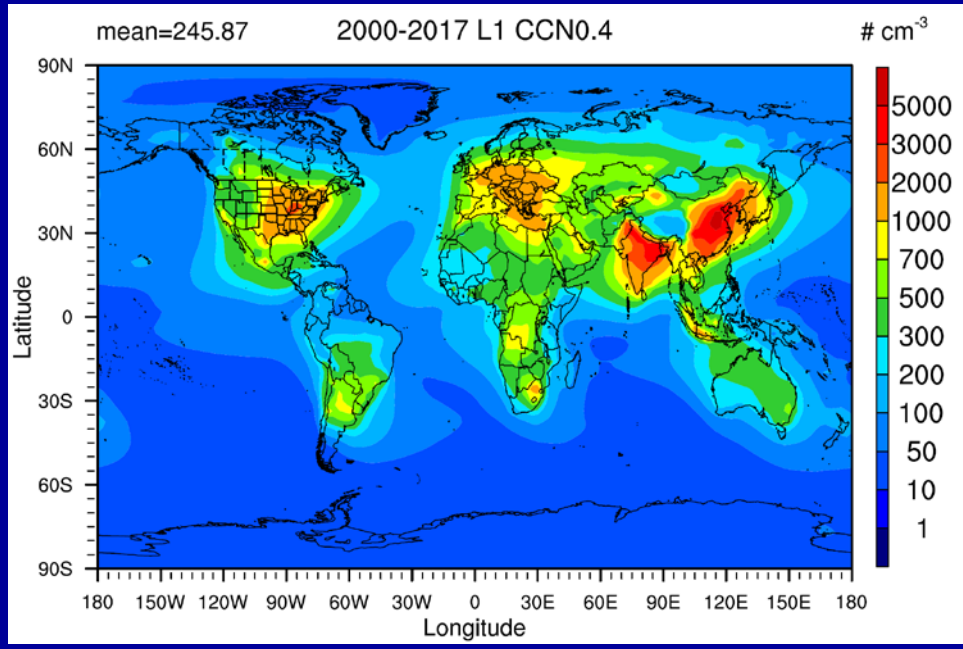
Ext Coef., 2 km



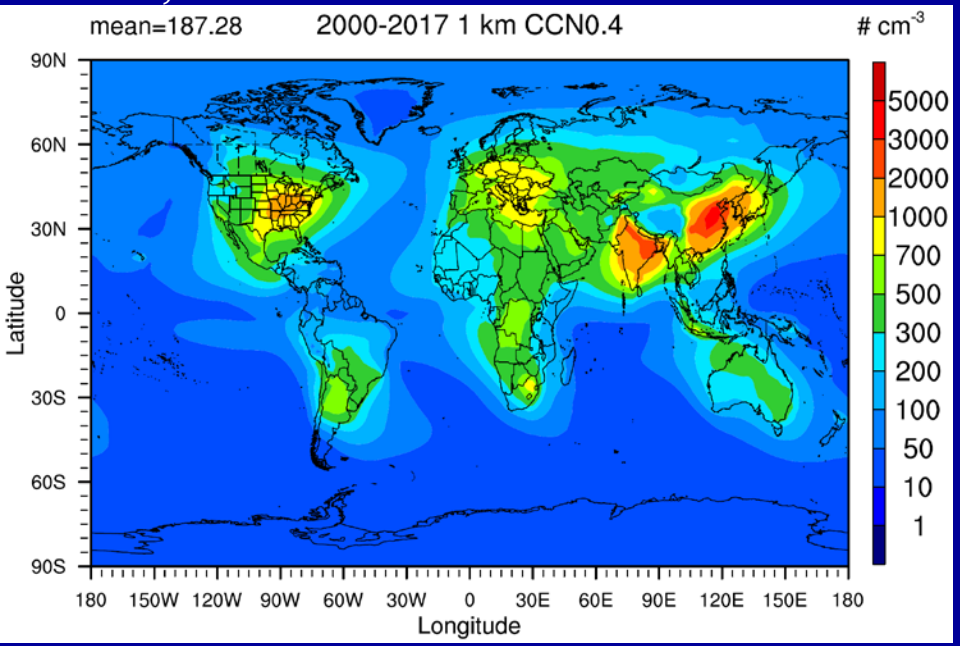
AOD



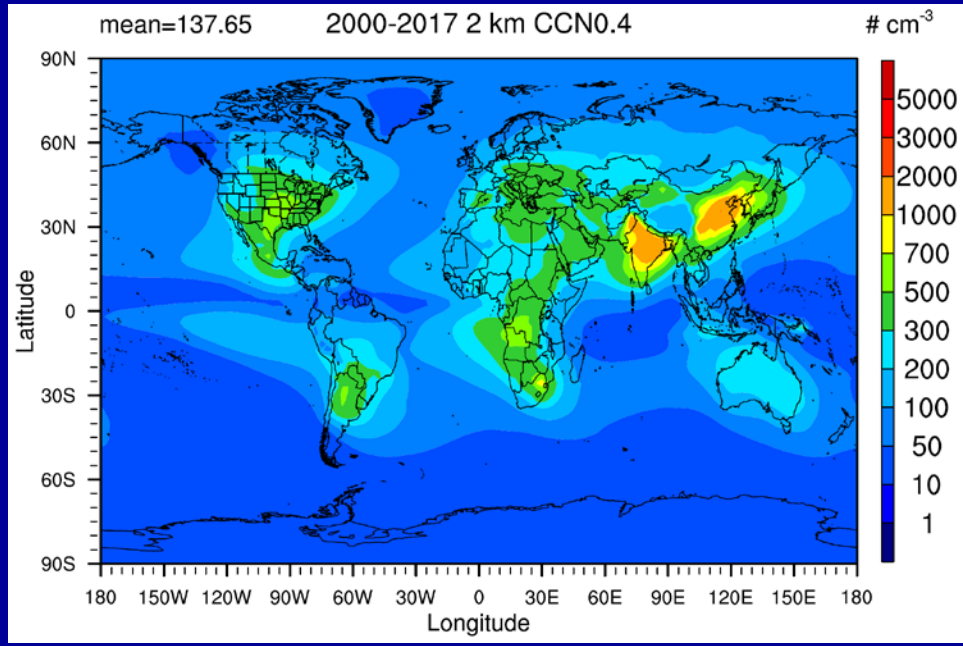
CCN0.4, Surface Layer



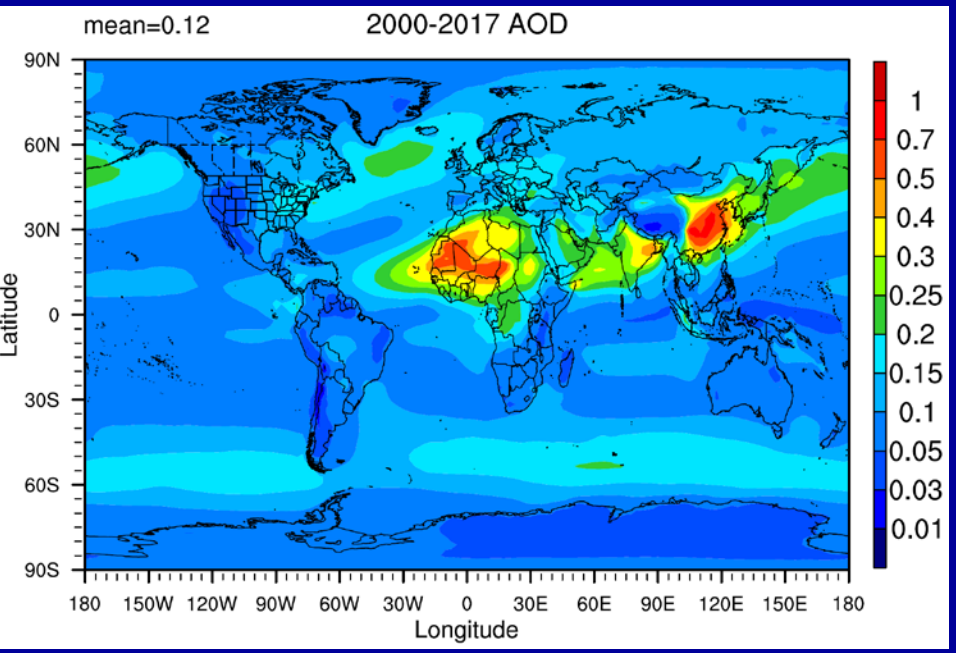
CCN0.4, 1 km



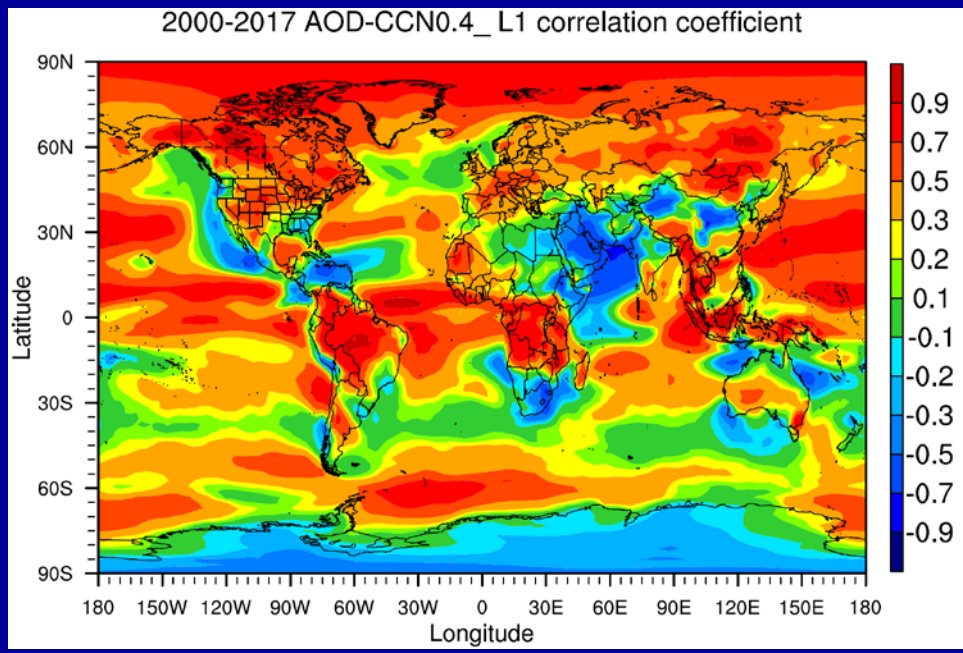
CCN0.4, 2 km



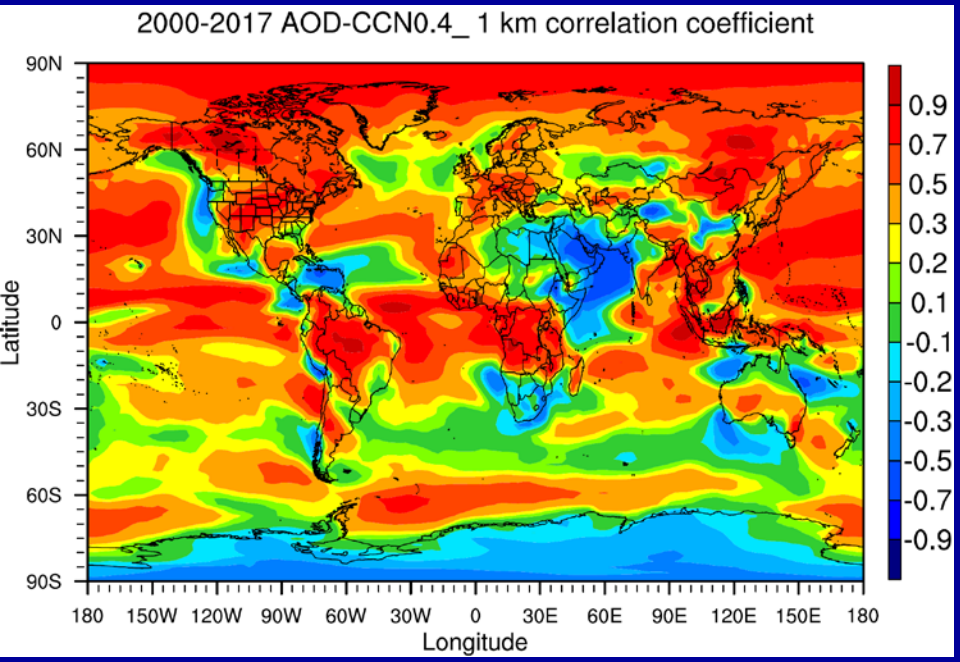
AOD



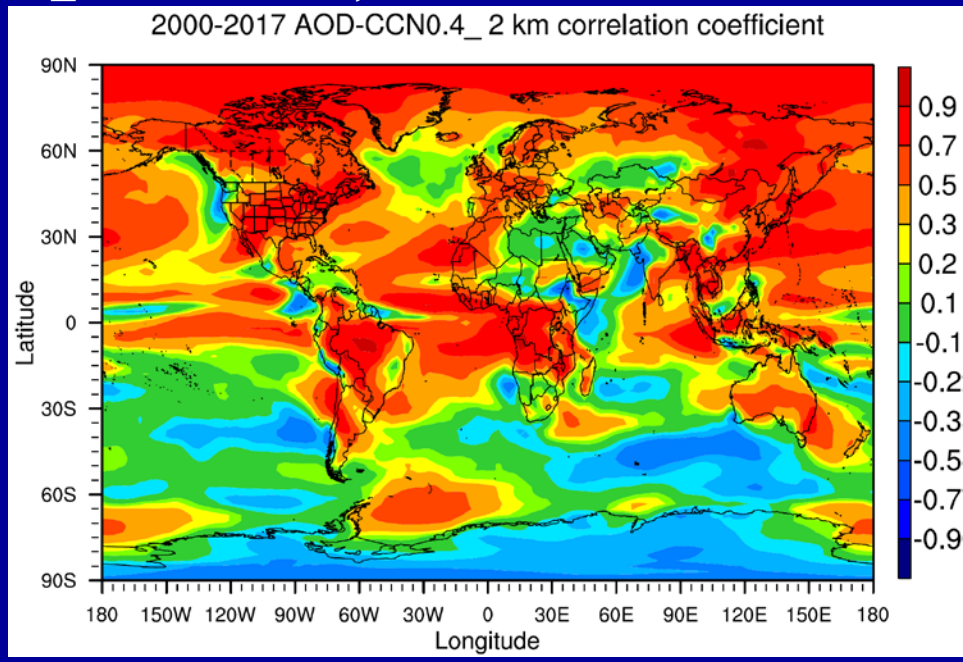
R_AOD-CCN0.4, Surface Layer



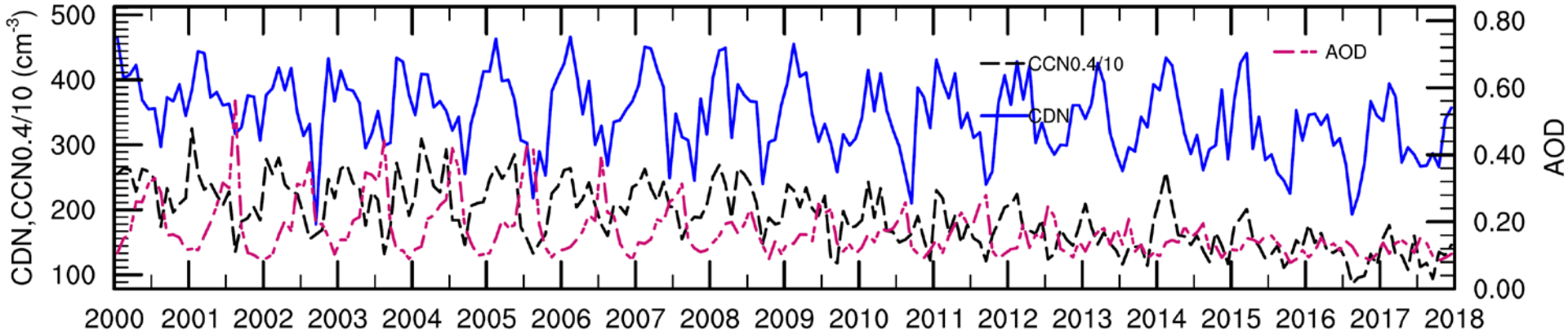
R_AOD-CCN0.4, 1 km



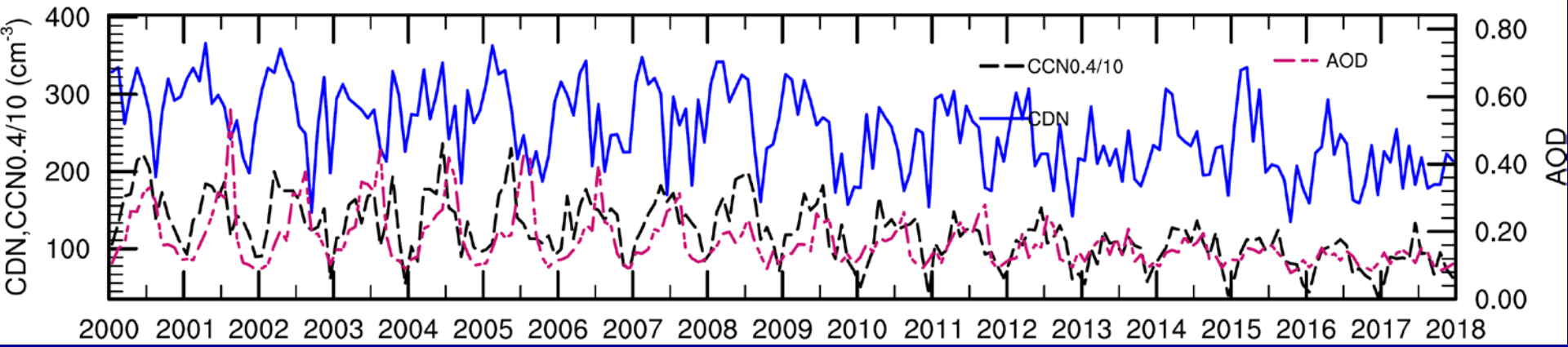
R_AOD-CCN0.4, 2 km



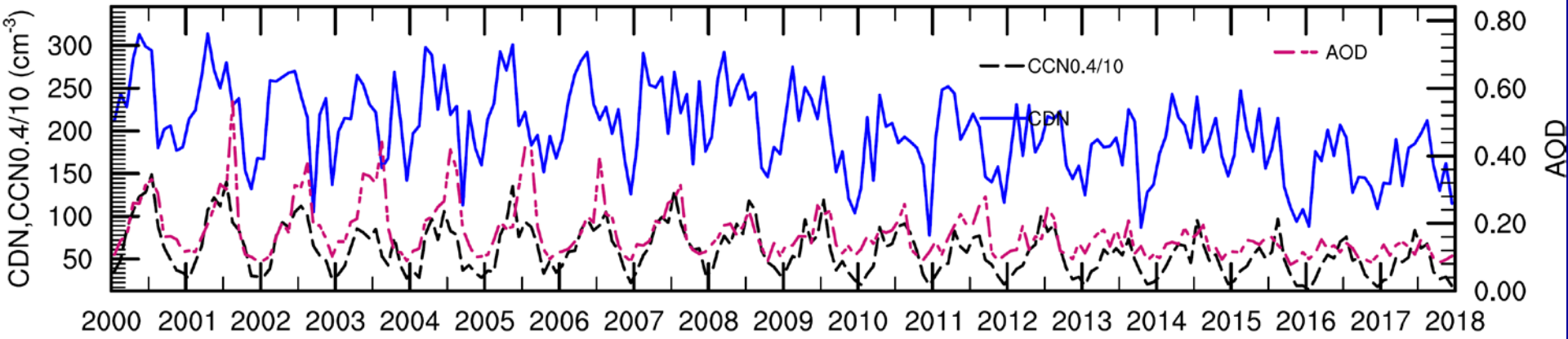
GSFC, Surface Layer, R_AOD-CCN = 0.03, R_AOD-CDN = -0.18, R_CCN-CDN=0.72



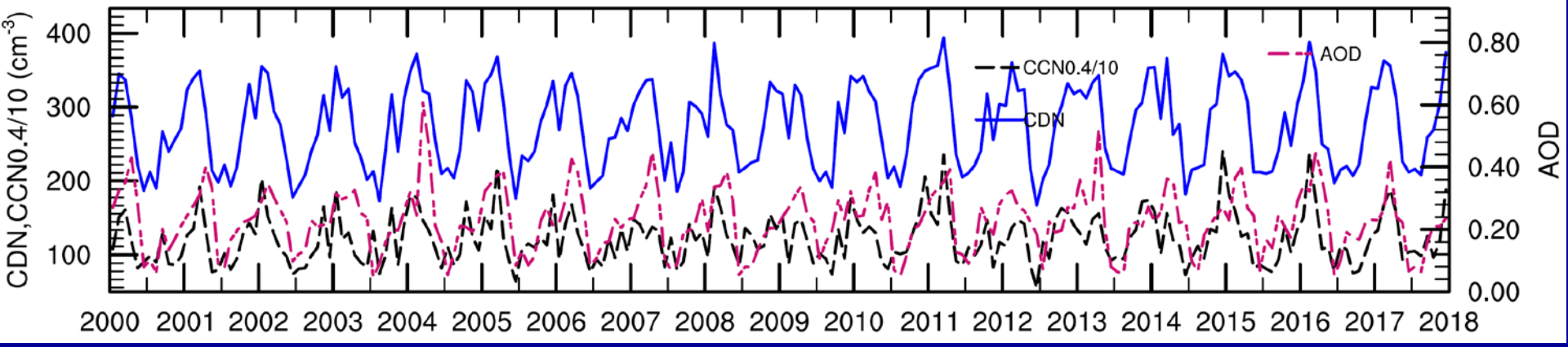
GSFC, 1 km , R_AOD-CCN = 0.51, R_AOD-CDN = 0.13, R_CCN-CDN=0.57



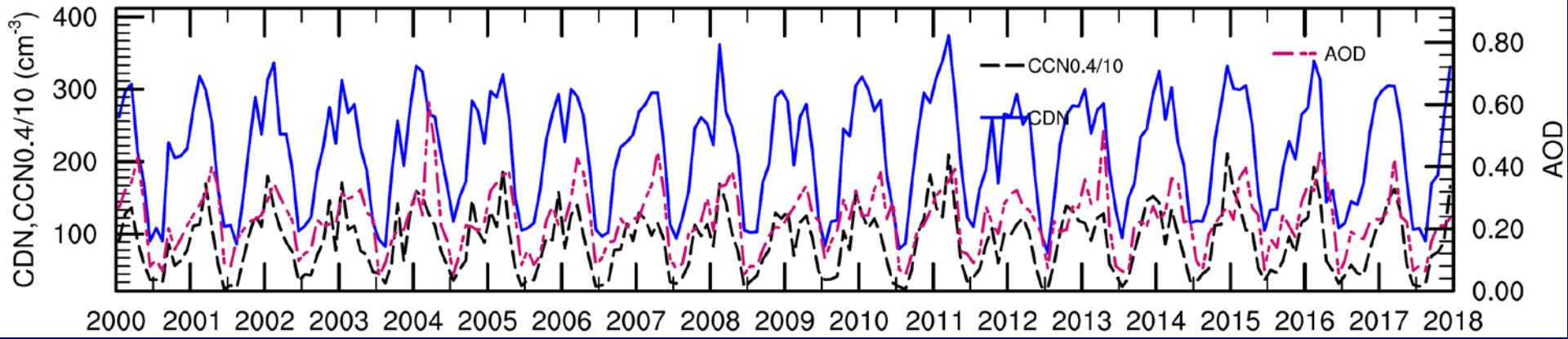
GSFC, 2 km , R_AOD-CCN = 0.67, R_AOD-CDN = 0.4, R_CCN-CDN=0.72



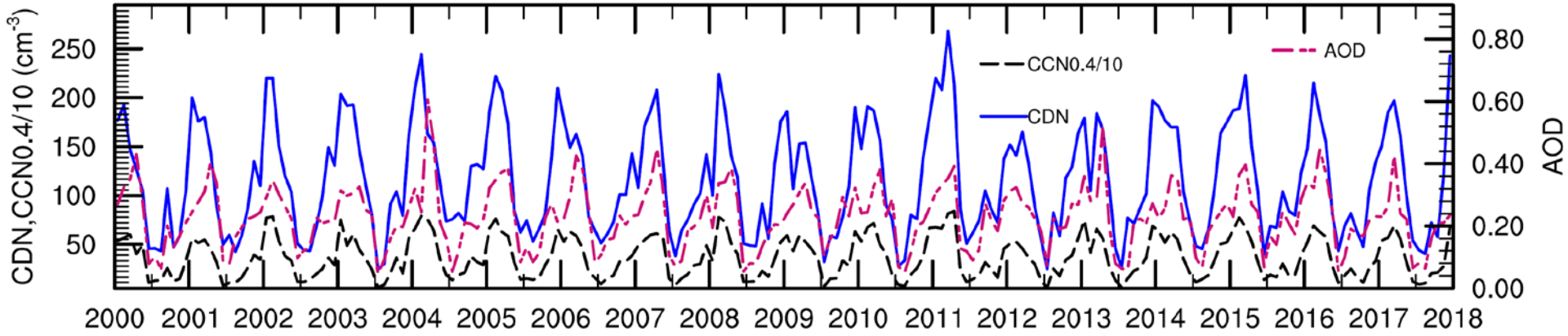
LLN, Surface Layer , R_AOD-CCN = 0.51, R_AOD-CDN = 0.67, R_CCN-CDN=0.87

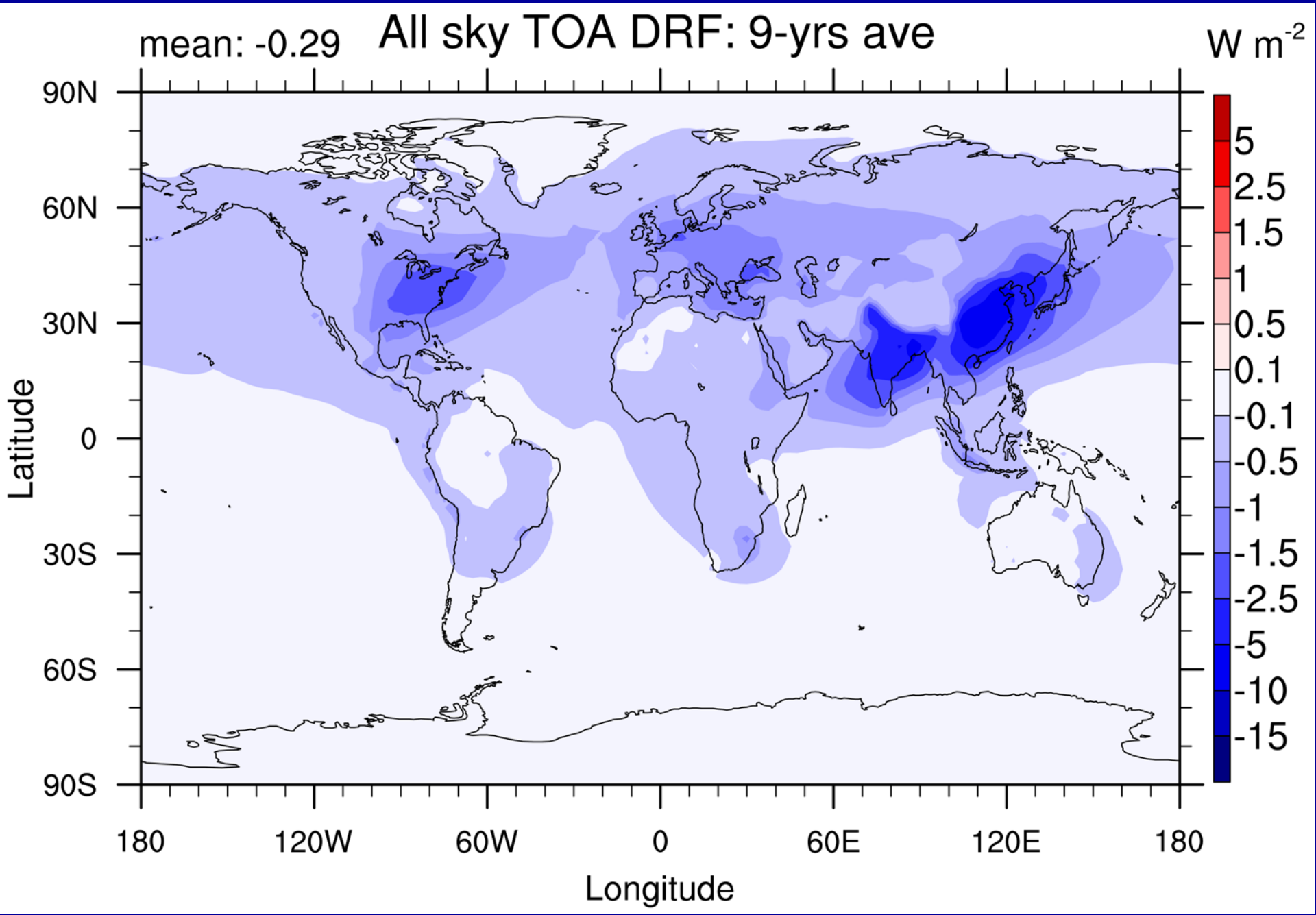


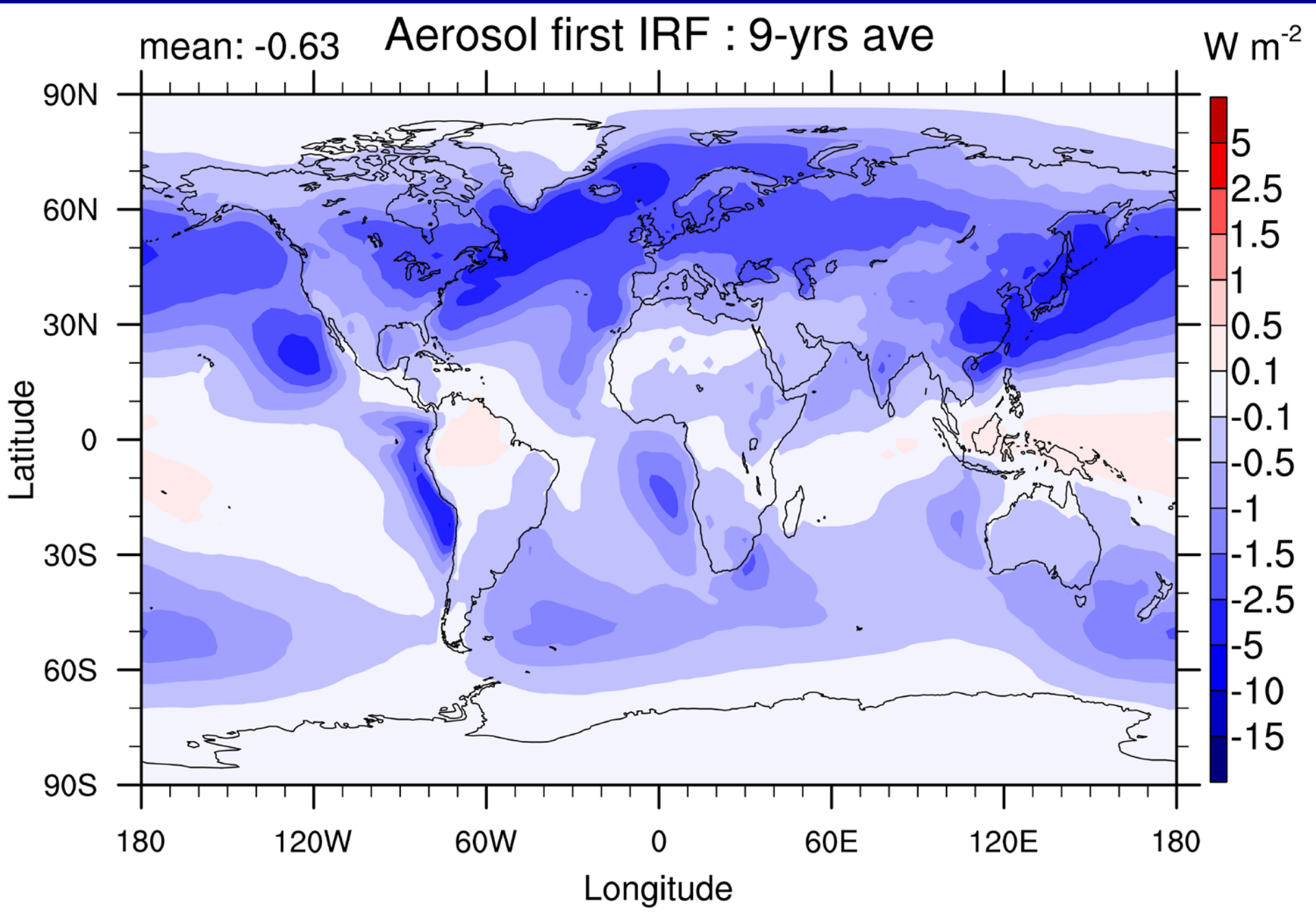
LLN, 1 km , R_AOD-CCN = 0.69, R_AOD-CDN = 0.72, R_CCN-CDN=0.94



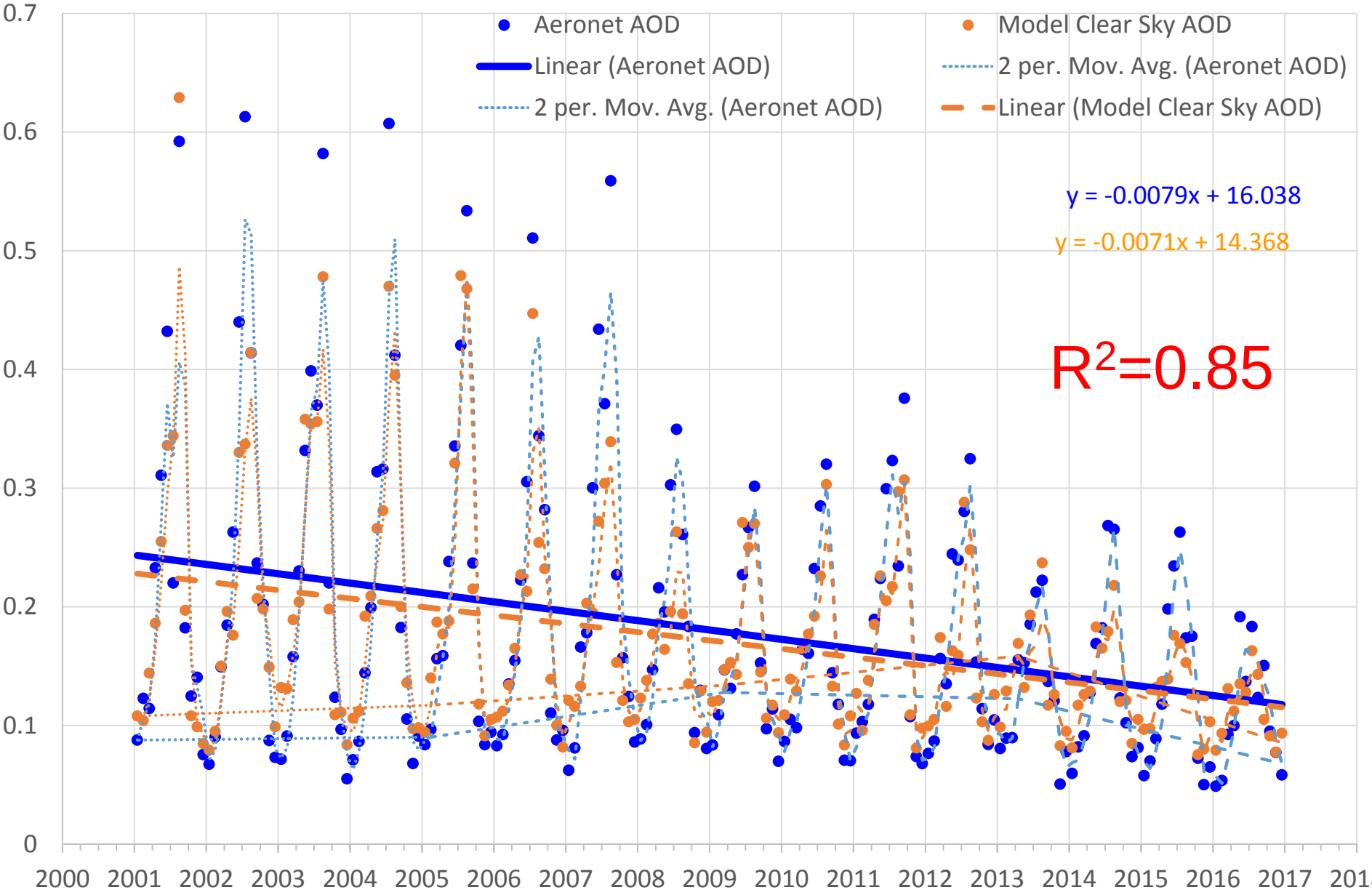
LLN, 2 km , R_AOD-CCN = 0.82, R_AOD-CDN = 0.72, R_CCN-CDN=0.96

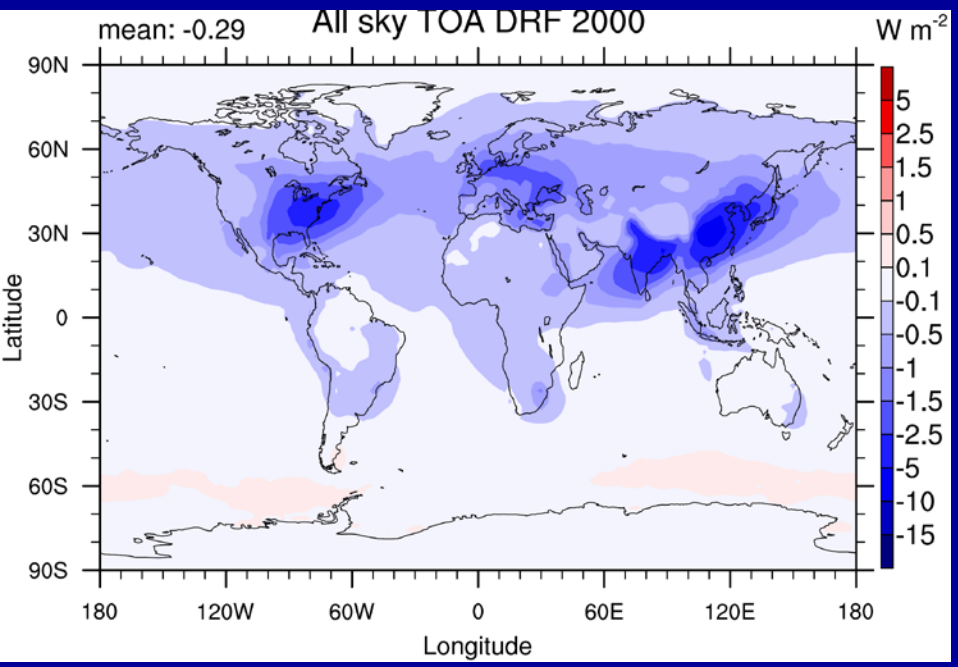


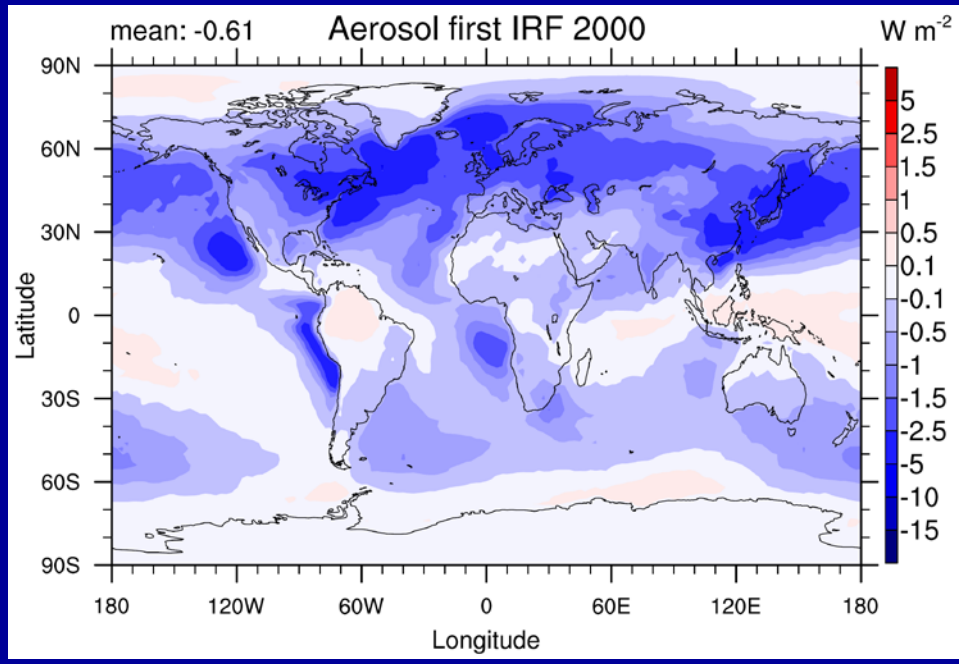

mean: -0.29
All sky TOA DRF: 9-yrs ave
W m-2
5
2.5
1.5
1
0.5
0.1
-0.1
-0.5
-1
-1.5
-2.5
-5
-10
-15
90N
60N
30N
0
30S
60S
90S
Latitude
180
120W
60W
0
60E
120E
180
Longitude

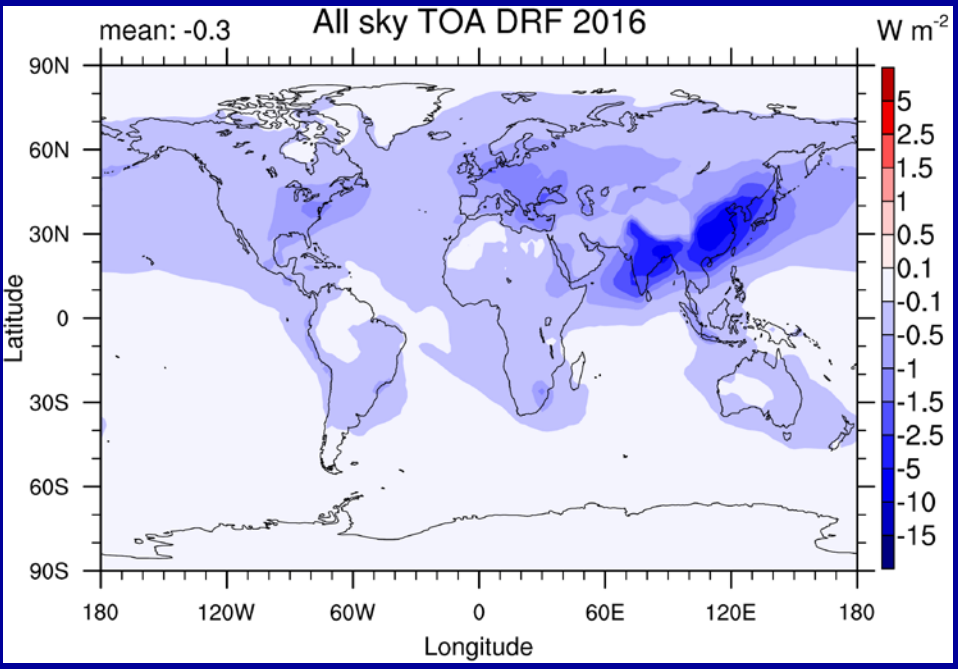

mean: -0.63
Aerosol first IRF : 9-yrs ave
W m-2
90N
60N
30N
0
30S
60S
90S
Latitude
180
120W
60W
0
60E
120E
180
Longitude
5
2.5
1.5
1
0.5
0.1
-0.1
-0.5
-1
-1.5
-2.5
-5
-10
-15

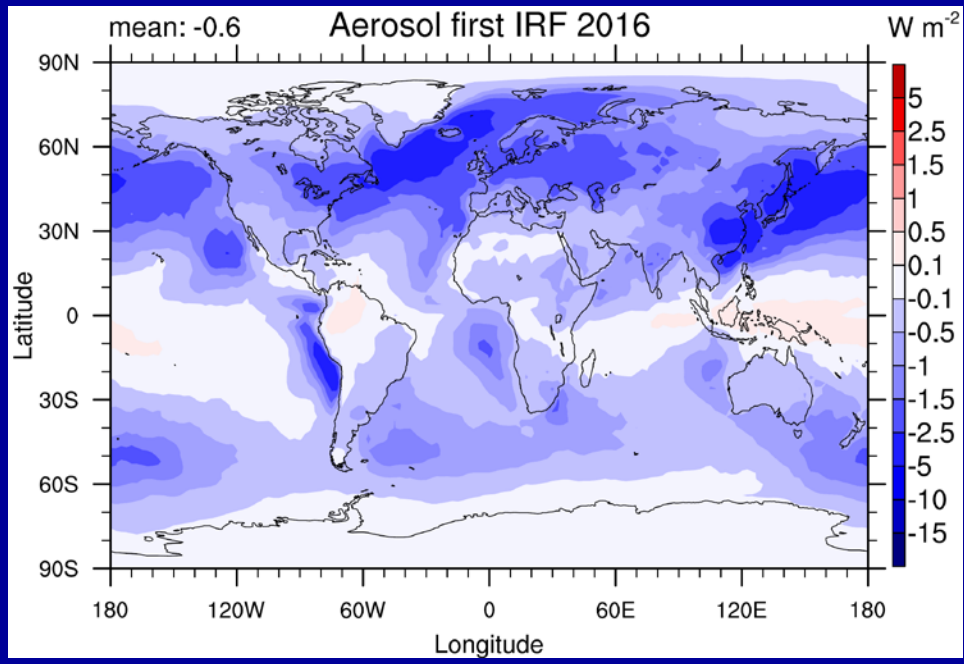
Long term trends of observed and modeled AOD at GSFC AERONET site




mean: -0.29
All sky TOA DRF 2000
W m-2
5
2.5
1.5
1
0.5
0.1
-0.1
-0.5
-1
-1.5
-2.5
-5
-10
-15
90N
60N
30N
0
30S
60S
90S
Latitude
180
120W
60W
0
60E
120E
180
Longitude


mean: -0.61
Aerosol first IRF 2000
W m-2
5
2.5
1.5
1
0.5
0.1
-0.1
-0.5
-1
-1.5
-2.5
-5
-10
-15
90N
60N
30N
0
30S
60S
90S
Latitude
180
120W
60W
0
60E
120E
180
Longitude


mean: -0.3
All sky TOA DRF 2016
W m-2
5
2.5
1.5
1
0.5
0.1
-0.1
-0.5
-1
-1.5
-2.5
-5
-10
-15
90N
60N
30N
0
30S
60S
90S
Latitude
180
120W
60W
0
60E
120E
180
Longitude


mean: -0.6
Aerosol first IRF 2016
W m-2
5
2.5
1.5
1
0.5
0.1
-0.1
-0.5
-1
-1.5
-2.5
-5
-10
-15
90N
60N
30N
0
30S
60S
90S
Latitude
180
120W
60W
0
60E
120E
180
Longitude

Summary

Previous studies on aerosol-cloud interactions through analysis of the connection between CER and AOD (or AI) largely rely on the assumption that AI or AOD can be used as a proxy for CCN. We employ GEOS-Chem-APM, a global chemical transport model with size-resolved particle microphysics, to investigate the relationship between column-integrated AOD and CCN/CDN in different altitudes under different environments.

Our results indicate that AOD is not well representative of the CCN over some industrial regions, but they correlate well with CCN over adjacent oceans in the layers where warm clouds typically form. The correlations also vary with altitudes.

In the last two decades, AOD in northeast US decreased by a factor of ~ 2. Similar magnitude of decrease in aerosol DRF but much less change in aerosol first IRF in the region.