


Hemispheric Contrasts in Satellite-Derived Cloud Microphysical Properties

Isabel L. McCoy[1], Daniel T. McCoy[2,3], Robert Wood[1], Leighton Regayre[3], Daniel P. Grosvenor[4], Jane Mulcahy[5], Yongxiang Hu[6], Frida A. M. Bender[7], Paul R. Field[3,5] , Ken Carslaw[2], Hamish Gordon[3]

1. Atmospheric Sciences, University of Washington, 2. Institute for Climate and Atmospheric Science, Leeds, 3. School of Earth and Environment, University of Leeds, 4. National Center for Atmospheric Science, Leeds, 5. Met Office, Exeter, 6. NASA Langley Research Center, 7. Department of Meteorology, Stockholm University

Motivation

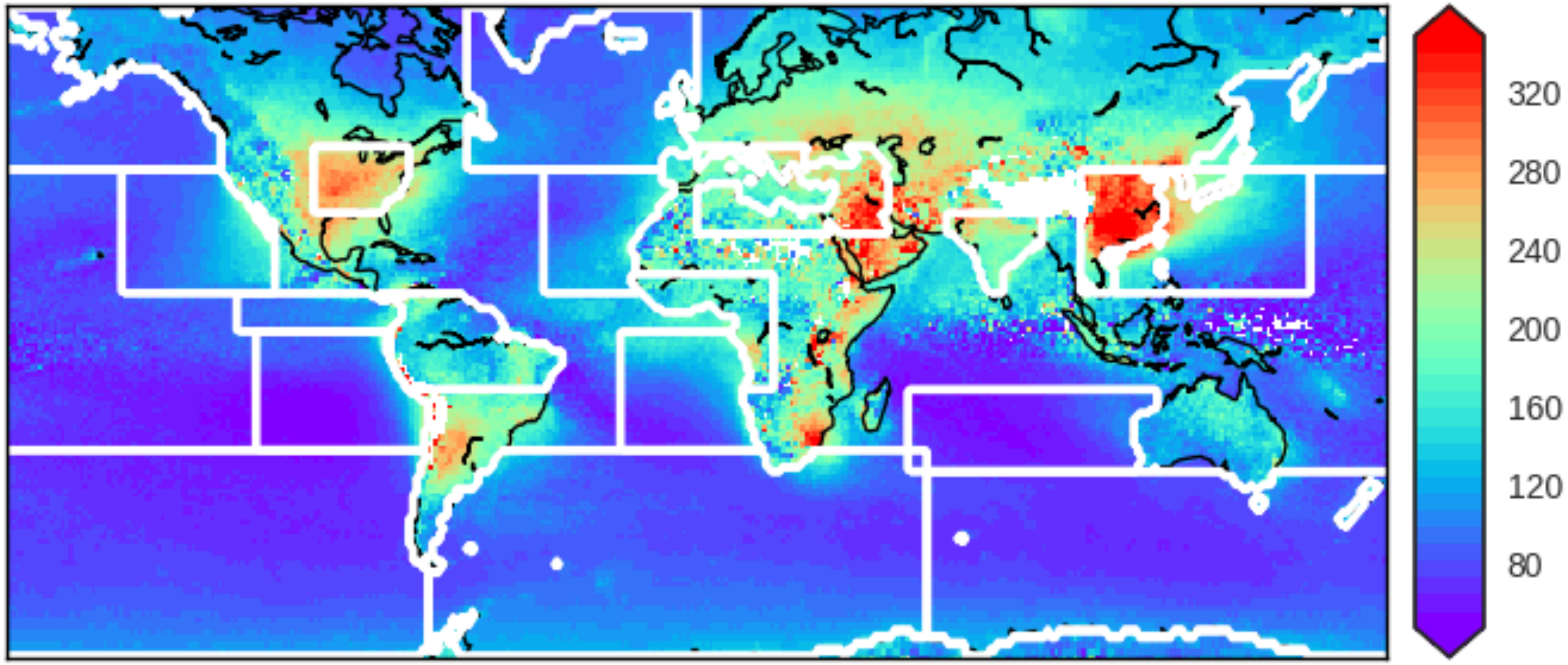
- Aerosol radiative forcing is a leading uncertainty in inferring climate sensitivity from the observational record (Andreae et al., 2005; Forster, 2016)

- Aerosol-cloud interactions (aci) in liquid cloud strongly contribute to the uncertainty in aerosol radiative forcing (Bellouin et al., 2019)

- To help us better infer climate sensitivity it is useful to develop multiple observational constraints on aerosol cloud interactions

Cloud Droplet Number Concentration (Nd)

MODIS Nd (cm^{-3})



D. T. McCoy et al. (2017), Wood (2012), Grosvenor and Wood (2014)

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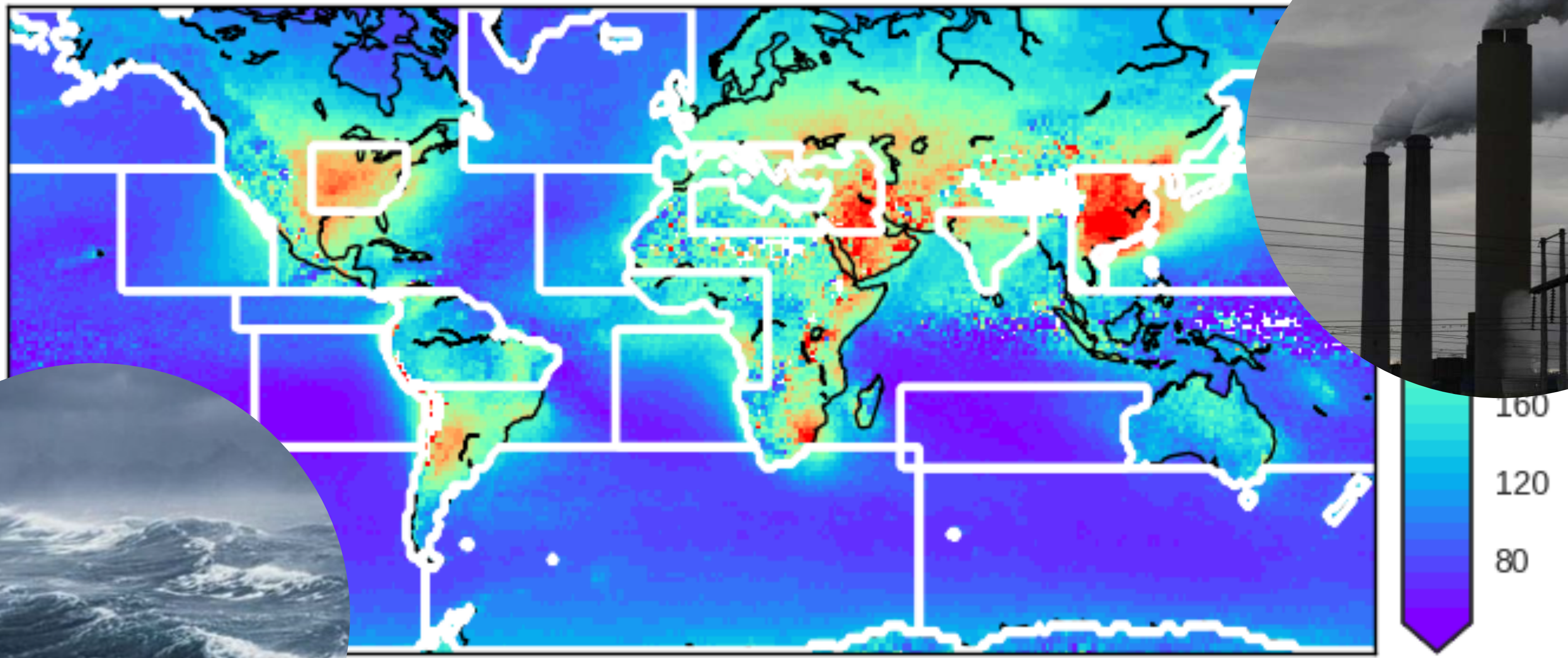


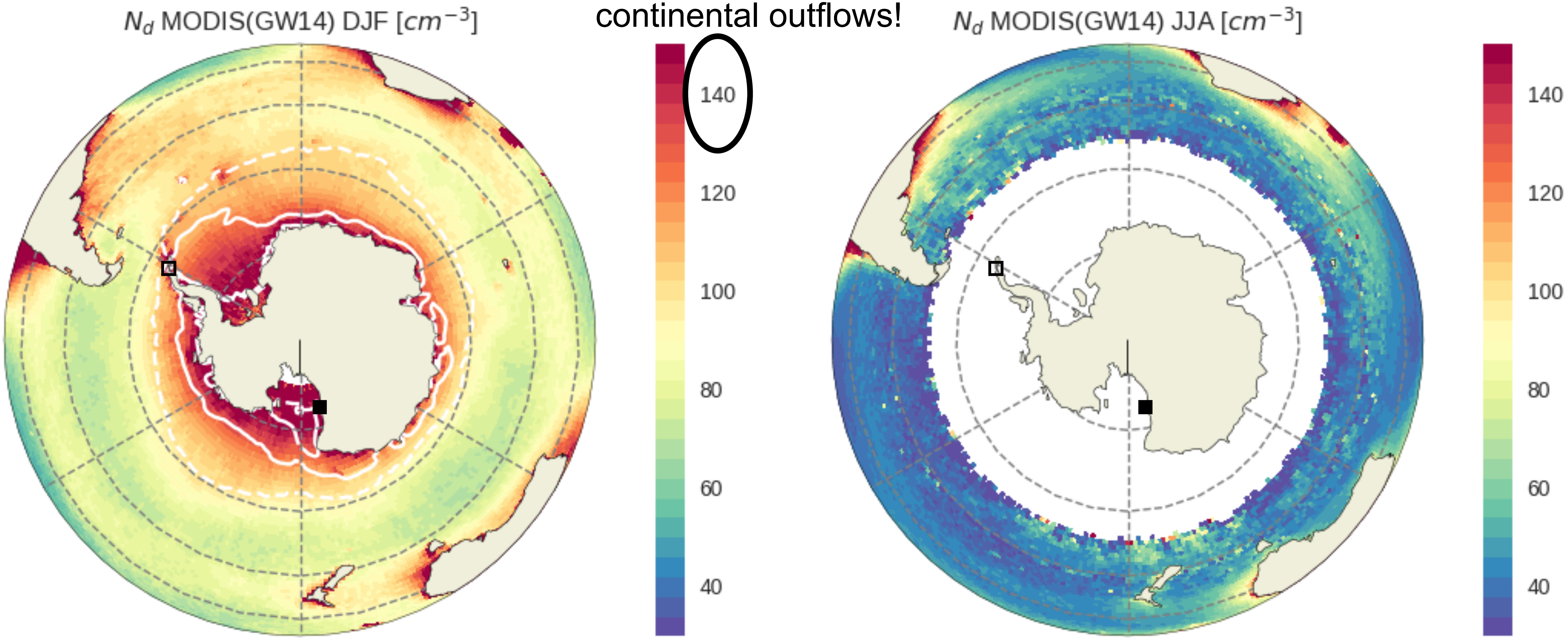
DMS,
MSA

D. T. McCoy et al. (2017), Wood (2012), Grosvenor and Wood (2014)

Southern Ocean Nd

■ McMurdo Station
□ King Sejong Station

Equivalent to NH continental outflows!



I. L. McCoy et al. (2019a, *in prep*)

Grosvenor et al., (2018); Bennartz & Rausch, (2017a); D. T. McCoy et al., (2017); Painemal et al., (2012a); Painemal & Zuidema, (2011); Witte et al., (2018); Ahn et al., (2018); D. T. McCoy et al., (2018)

Southern Ocean Nd

■ McMurdo Station
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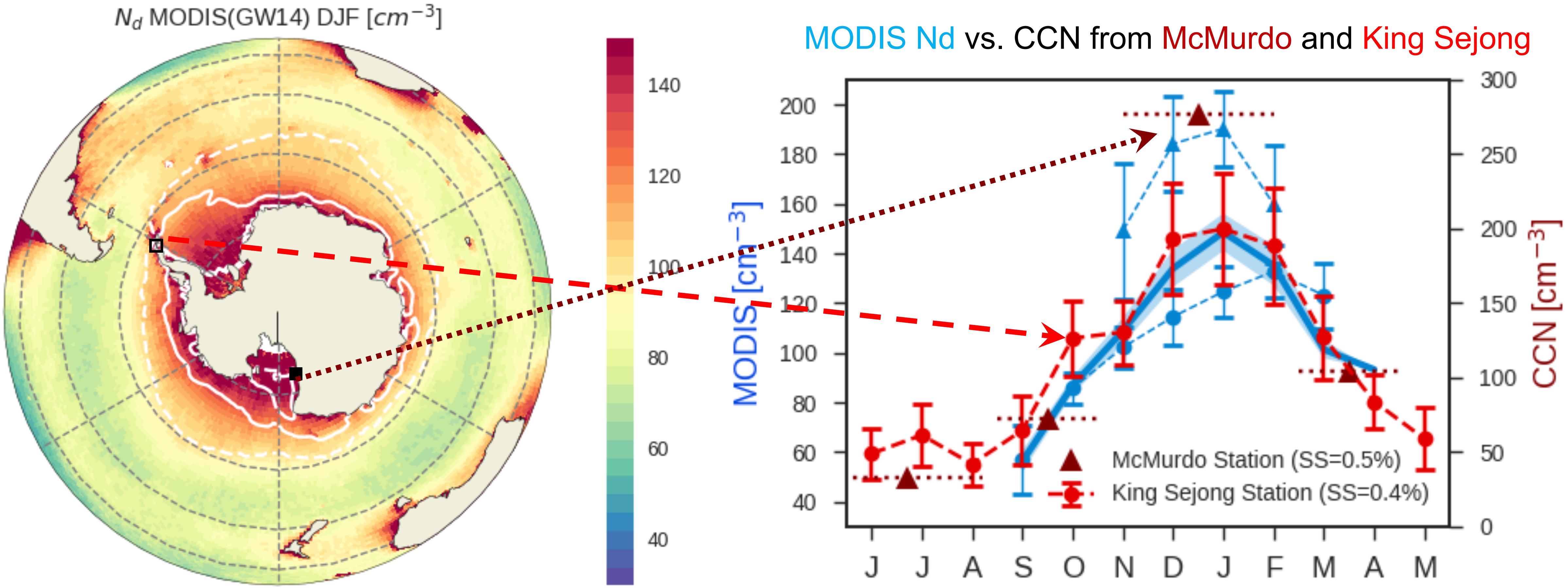
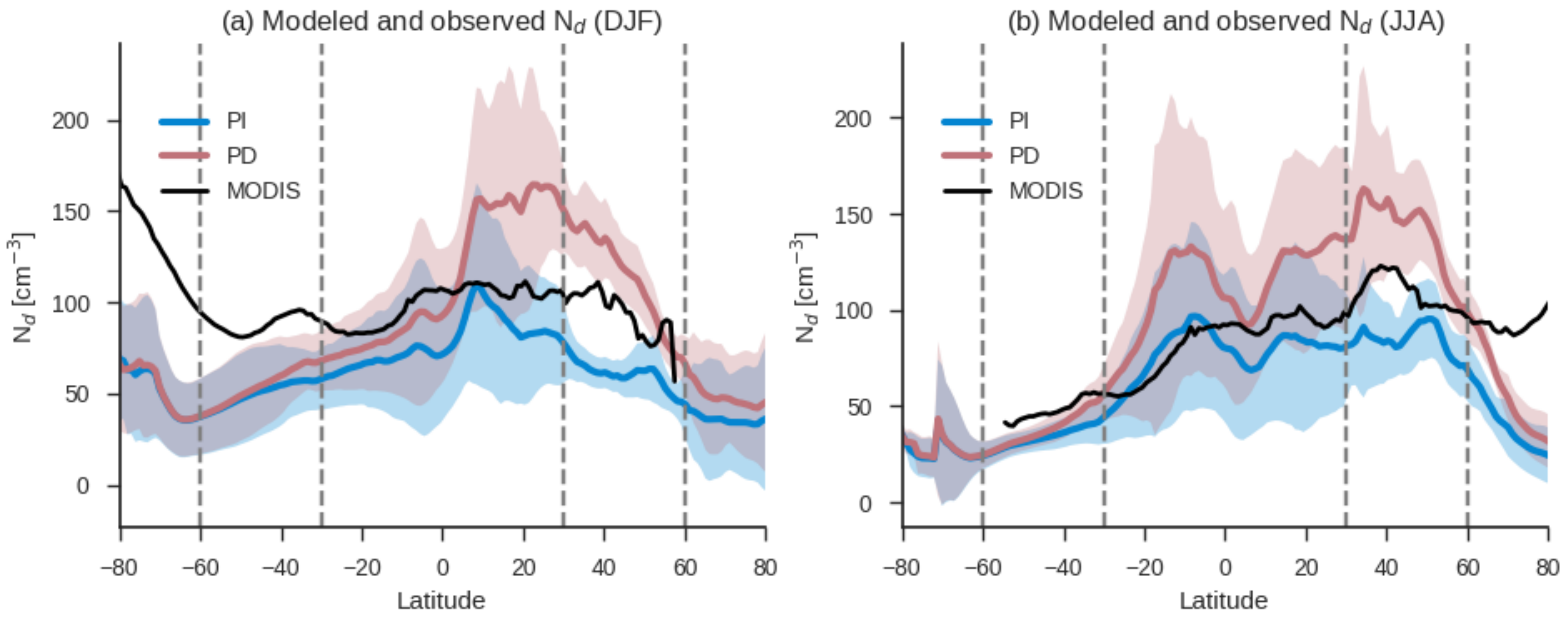


I. L. McCoy et al. (2019a, *in prep*)
Liu et al., (2018); Kim et al. (2017)

Nd Datasets

- **MODIS** Aqua 2003-2015 (Grosvenor and Wood 2014)
- **Aerocom phase II indirect 3**: CAM5, CAM5-PNNL, CAM5-CLUBB, CAM5-MG2, CAM5-CLUBB-MG2, ECHAM6.1.0-HAM2.2, SPRINTARS, and SPRINTARSKK
- Sensitivity studies in **HadGEM3-GA6 to 7.1** (Mulcahy et al. 2018)
- **Perturbed Physics Ensemble (PPE) from HadGEM-GA4-UKCA** with 26 aerosol process, emission and deposition parameters simultaneously perturbed (Collins et al., 2010, Yoshioka et al., submitted)

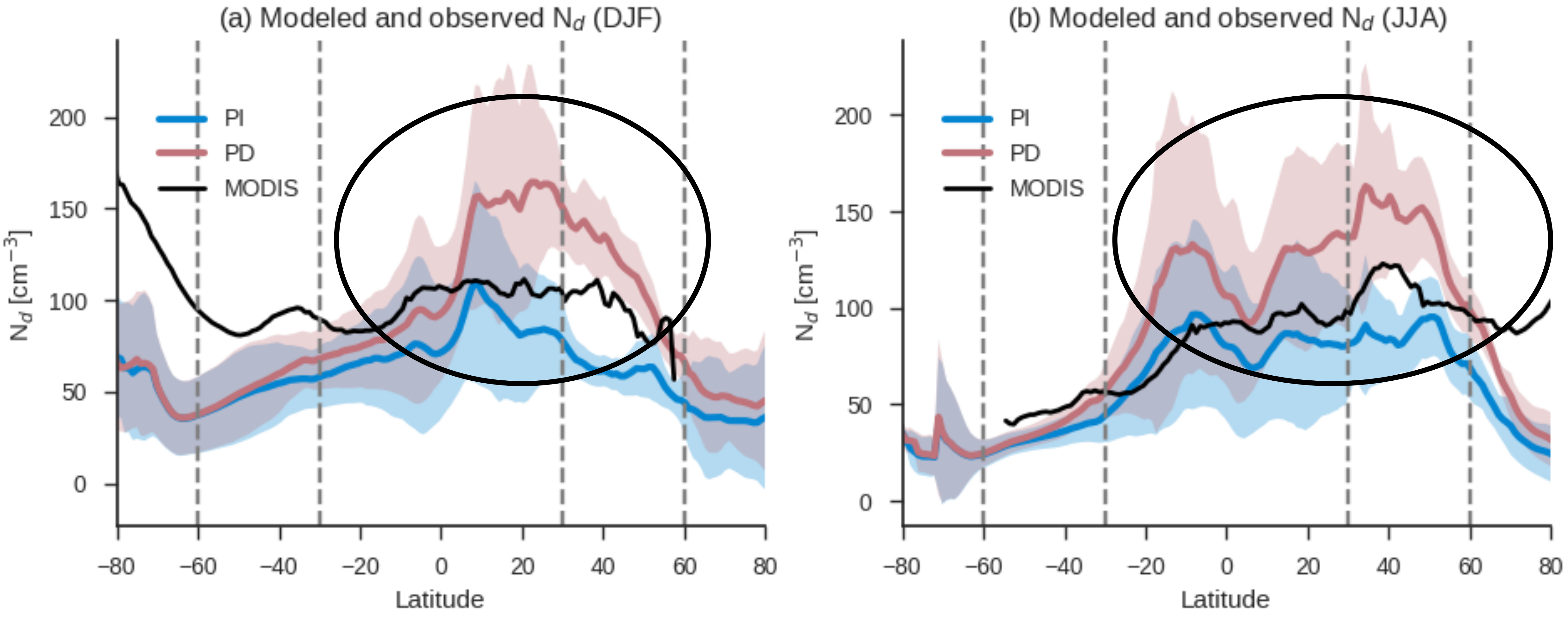
MODIS vs. Aerocom, HadGEM3 Nd



I. L. McCoy et al. (2019a, *in prep*)

Multi-model mean and Standard deviation
(Calculated only over oceans)

MODIS vs. Aerocom, HadGEM3 Nd



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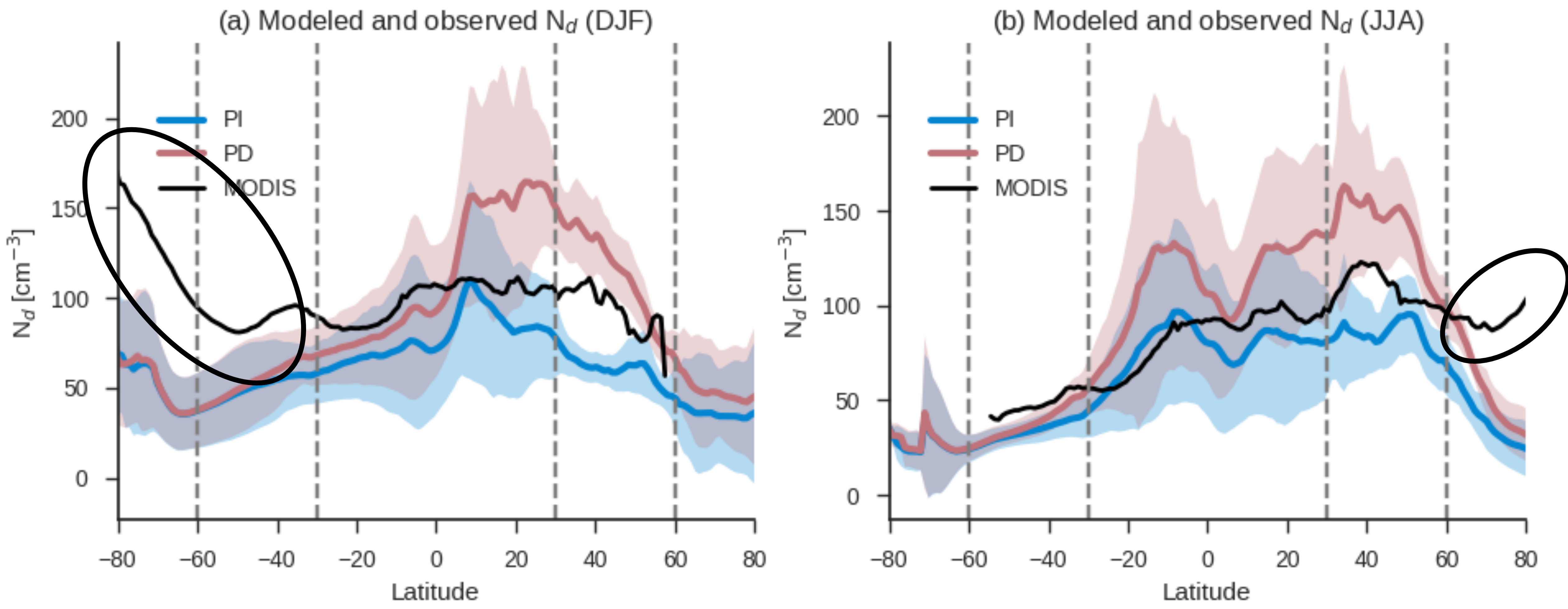

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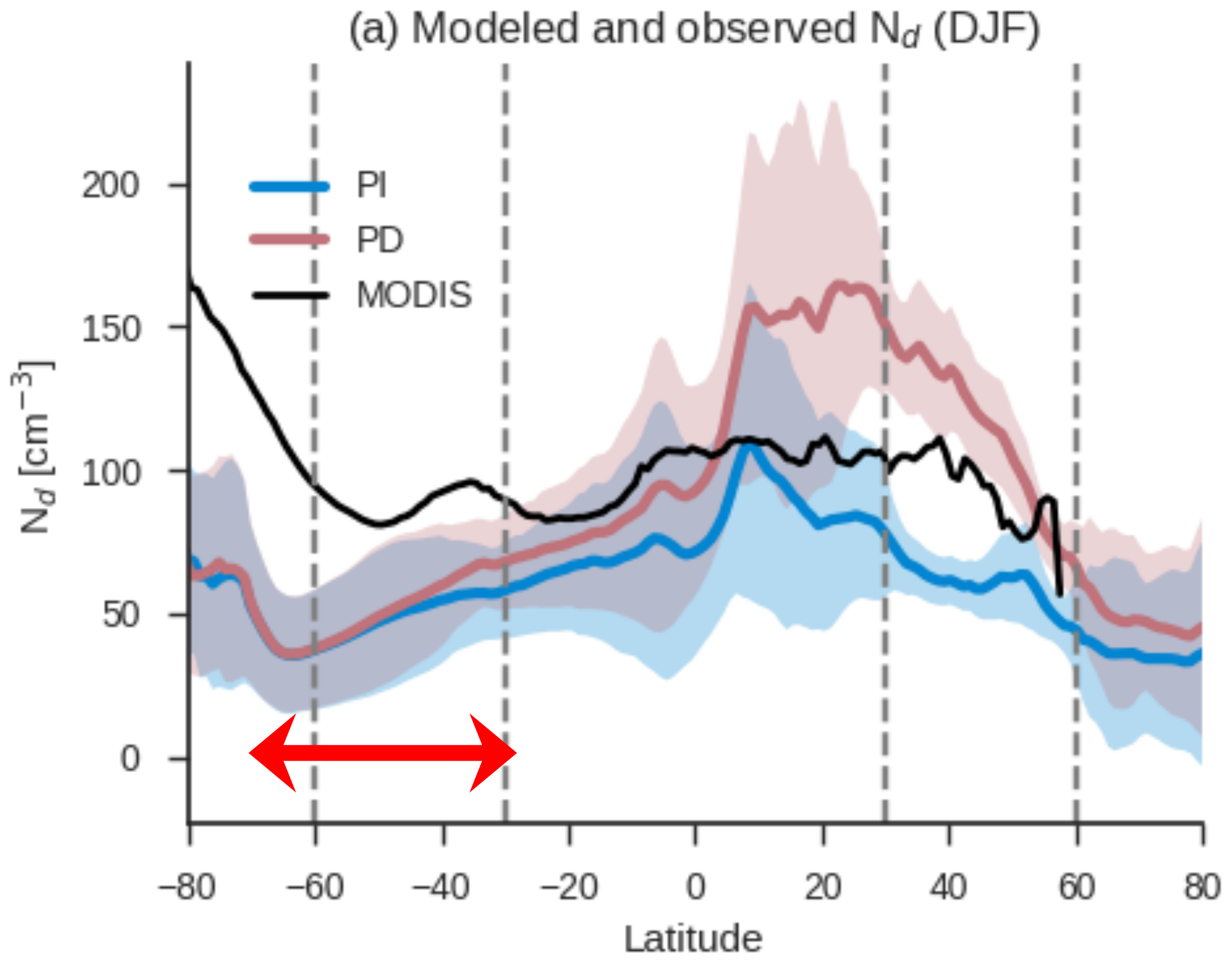
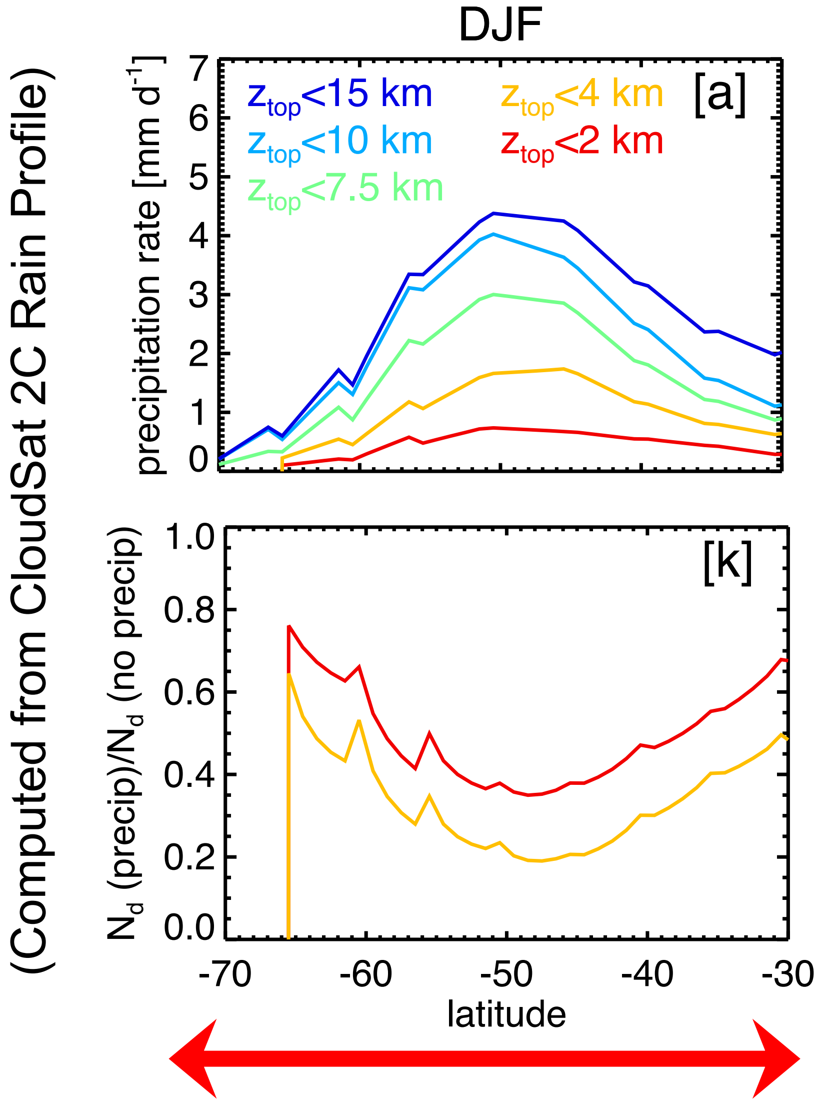
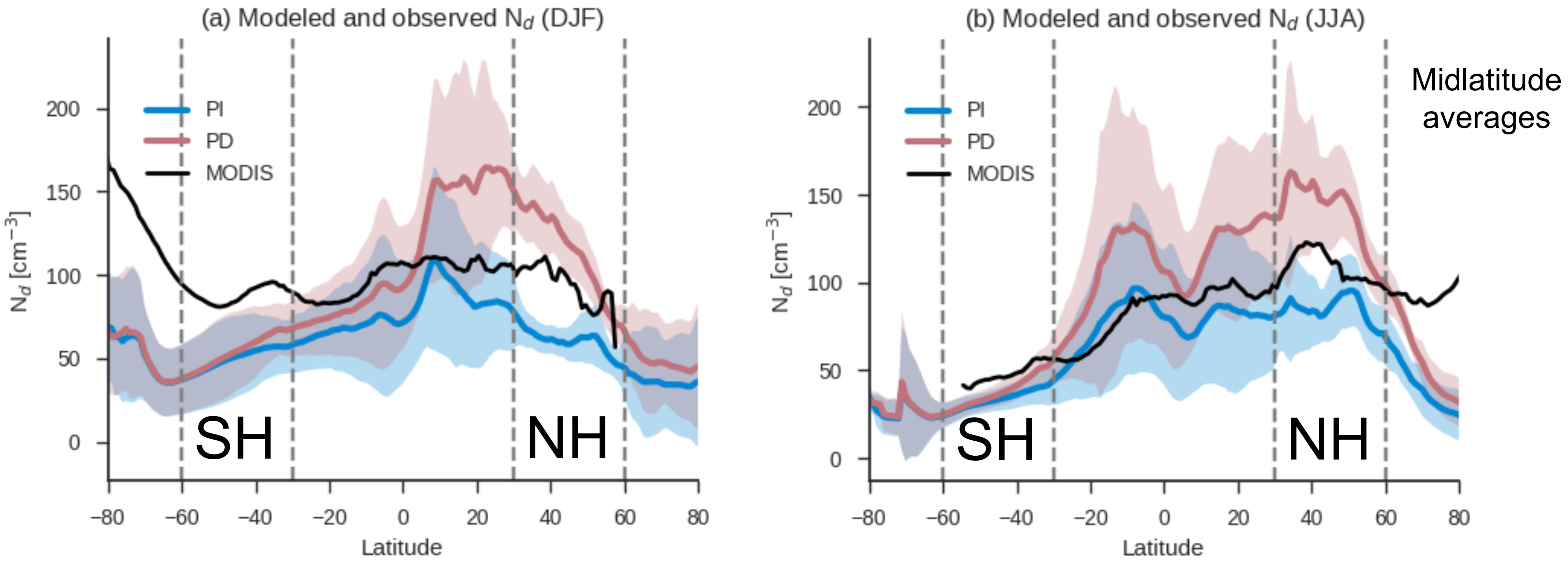
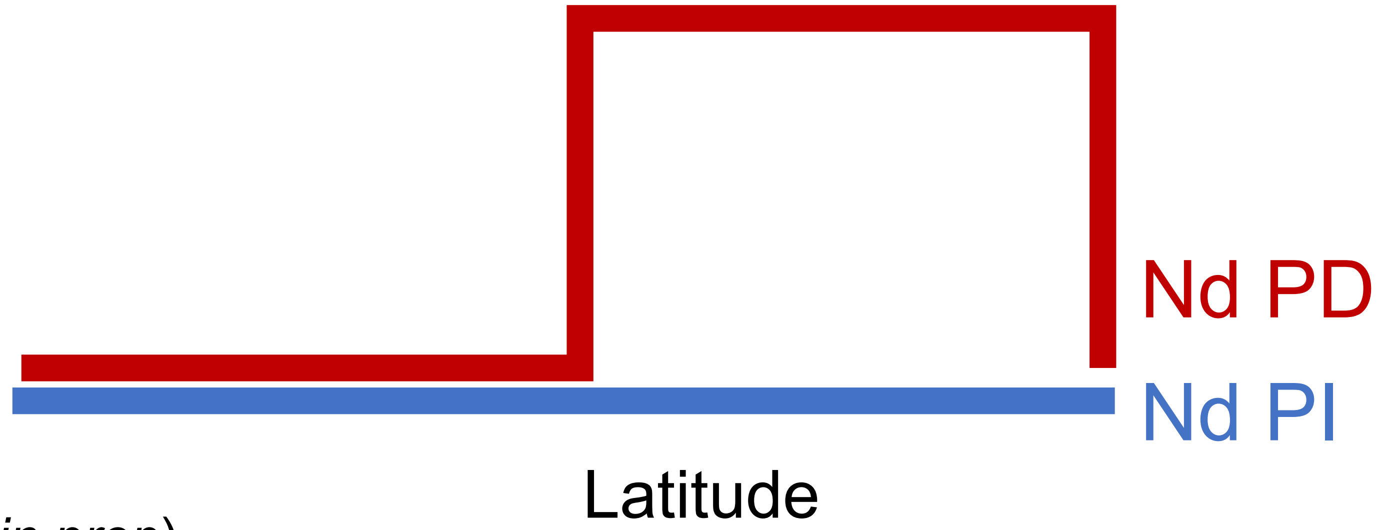




I. L. McCoy et al. (2019a, *in prep*)
Wood et al. (2012)





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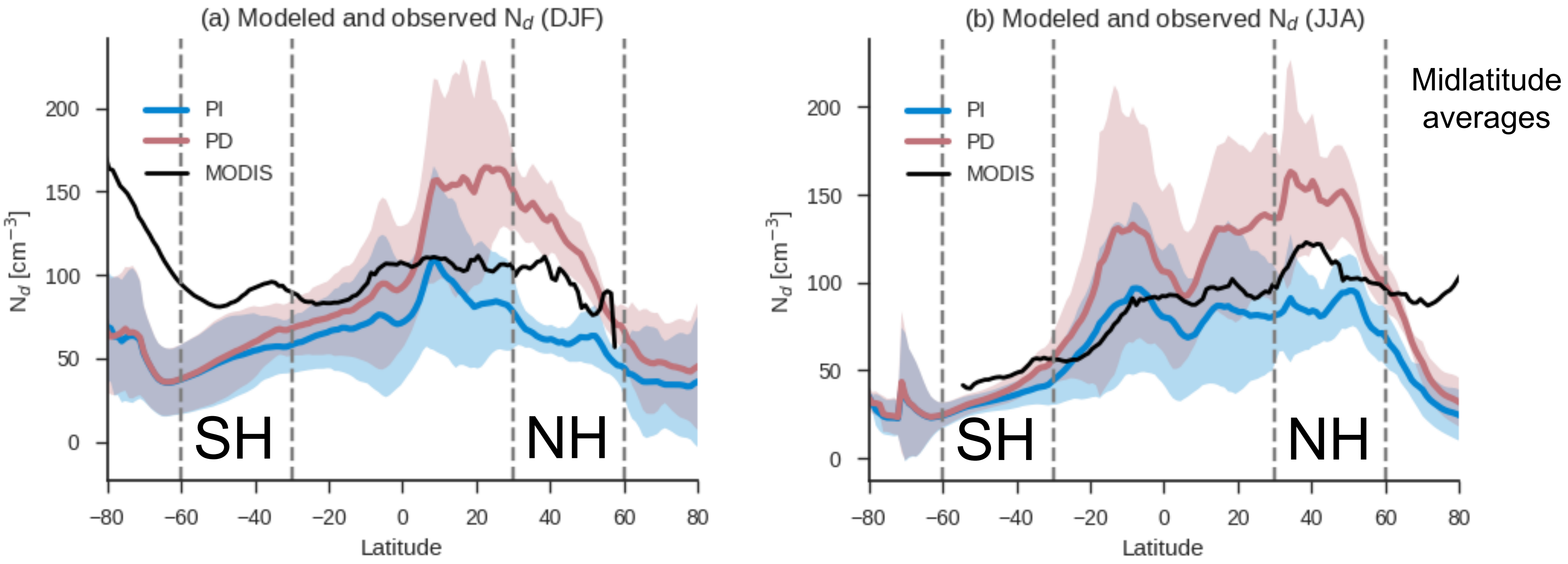
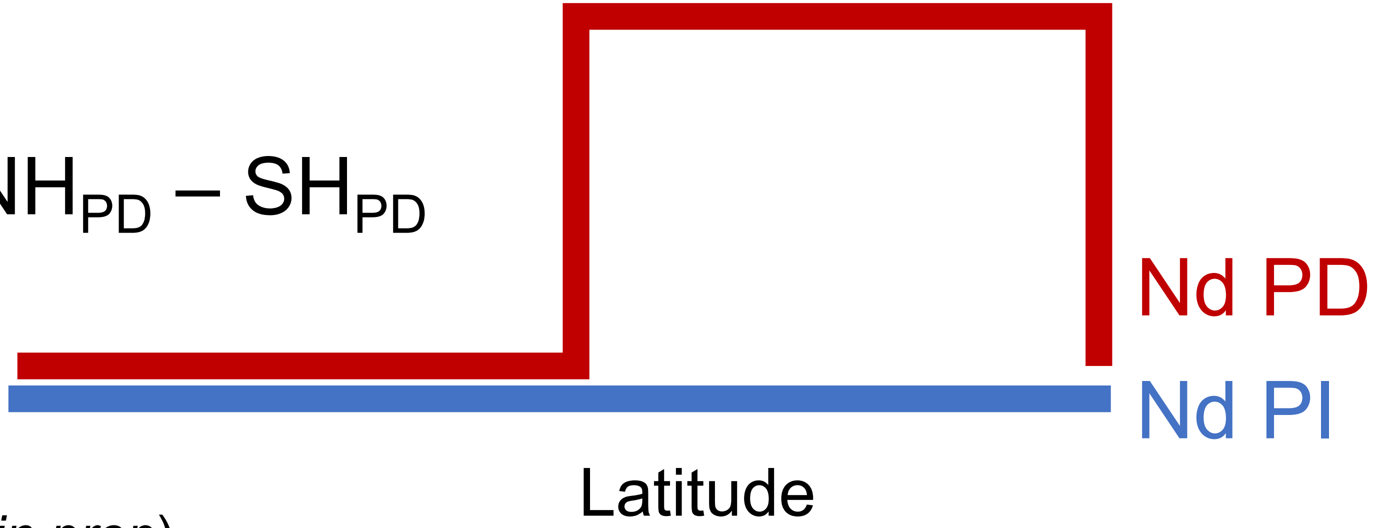
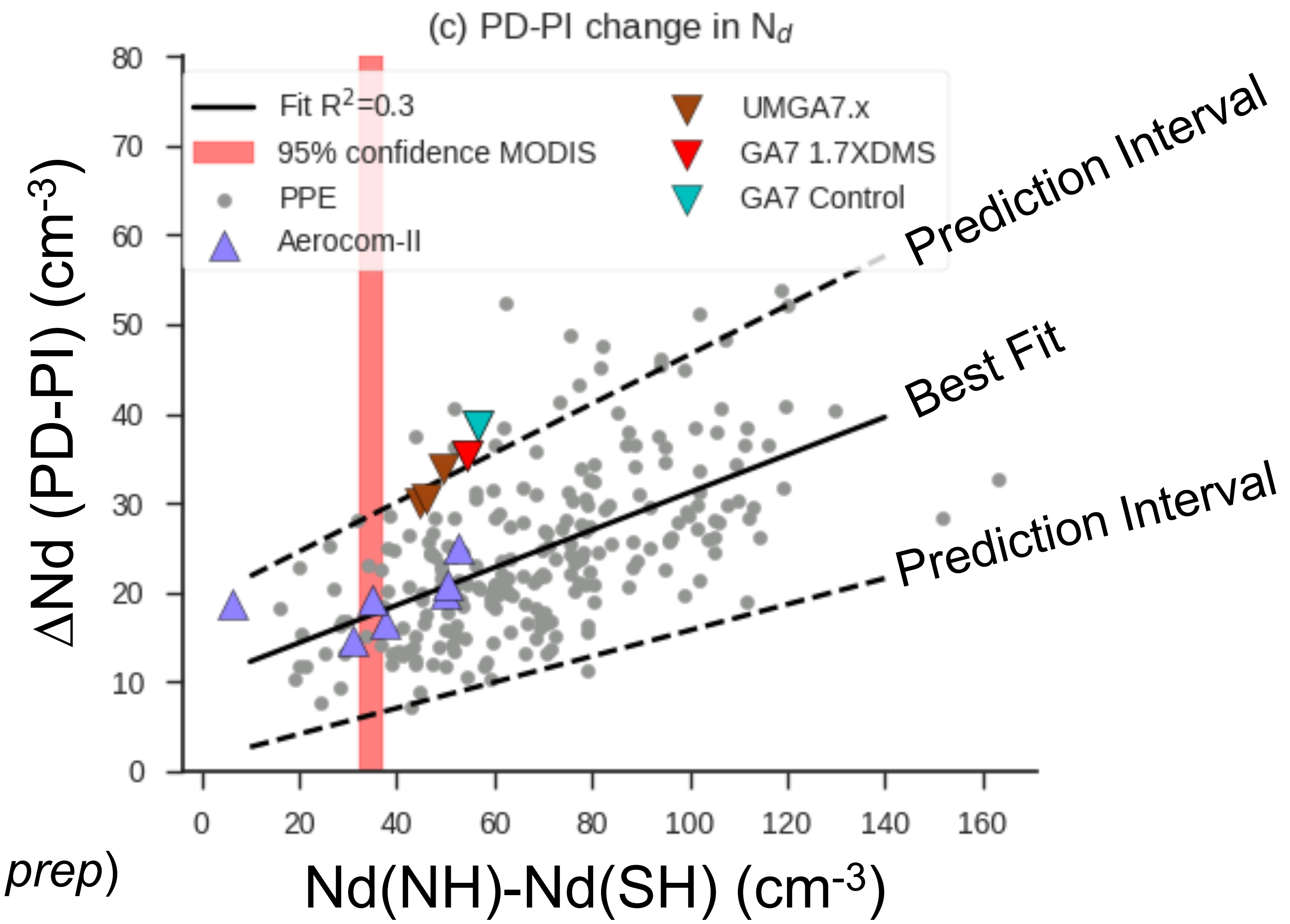


$$PD - PI \cong NH_{PD} - SH_{PD}$$



I. L. McCoy et al. (2019a, *in prep*)

Nd Difference between Present-Day & Pre-Industrial correlated with Nd Difference between NH & SH



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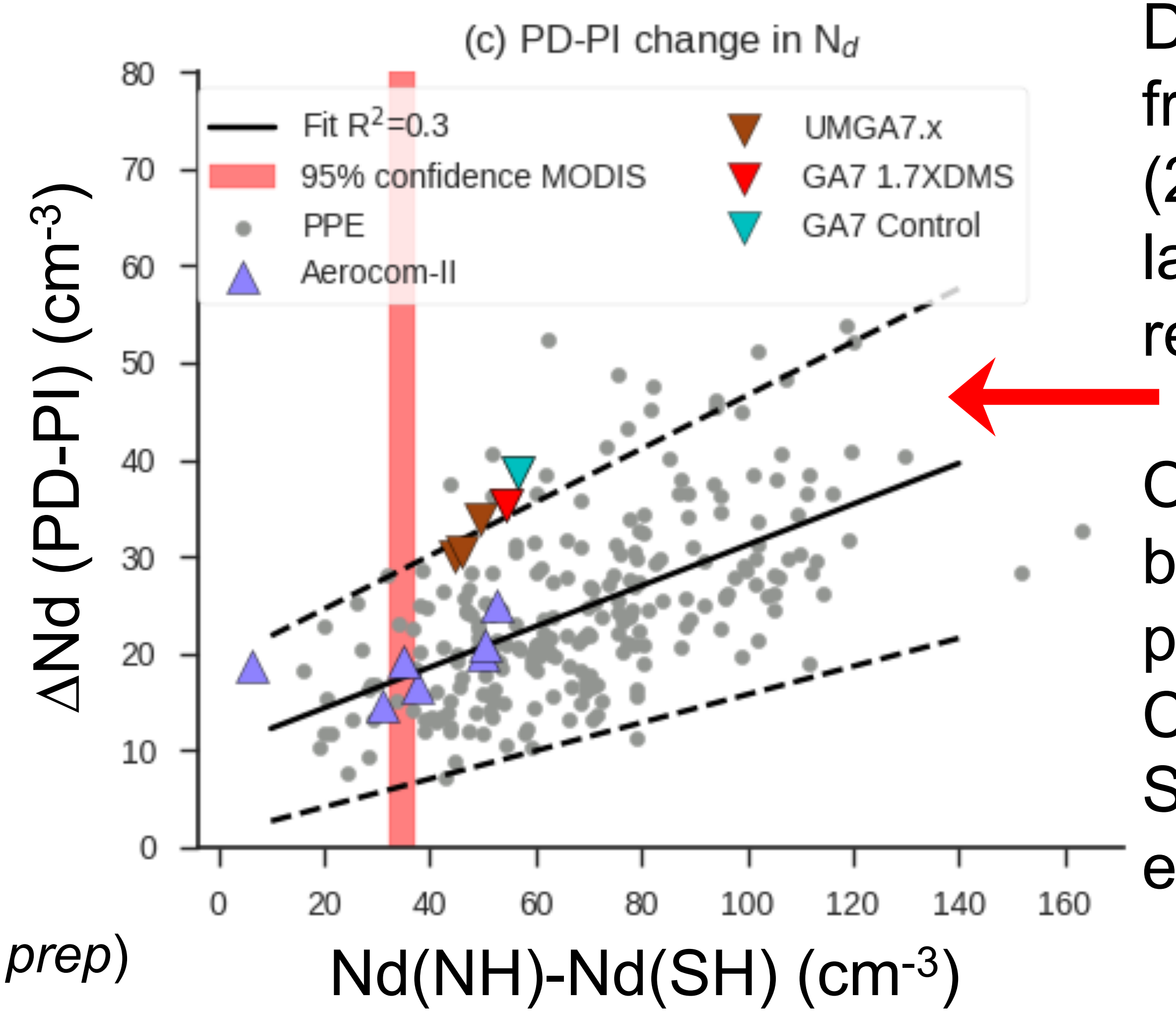


I. L. McCoy et al. (2019a, *in prep*)

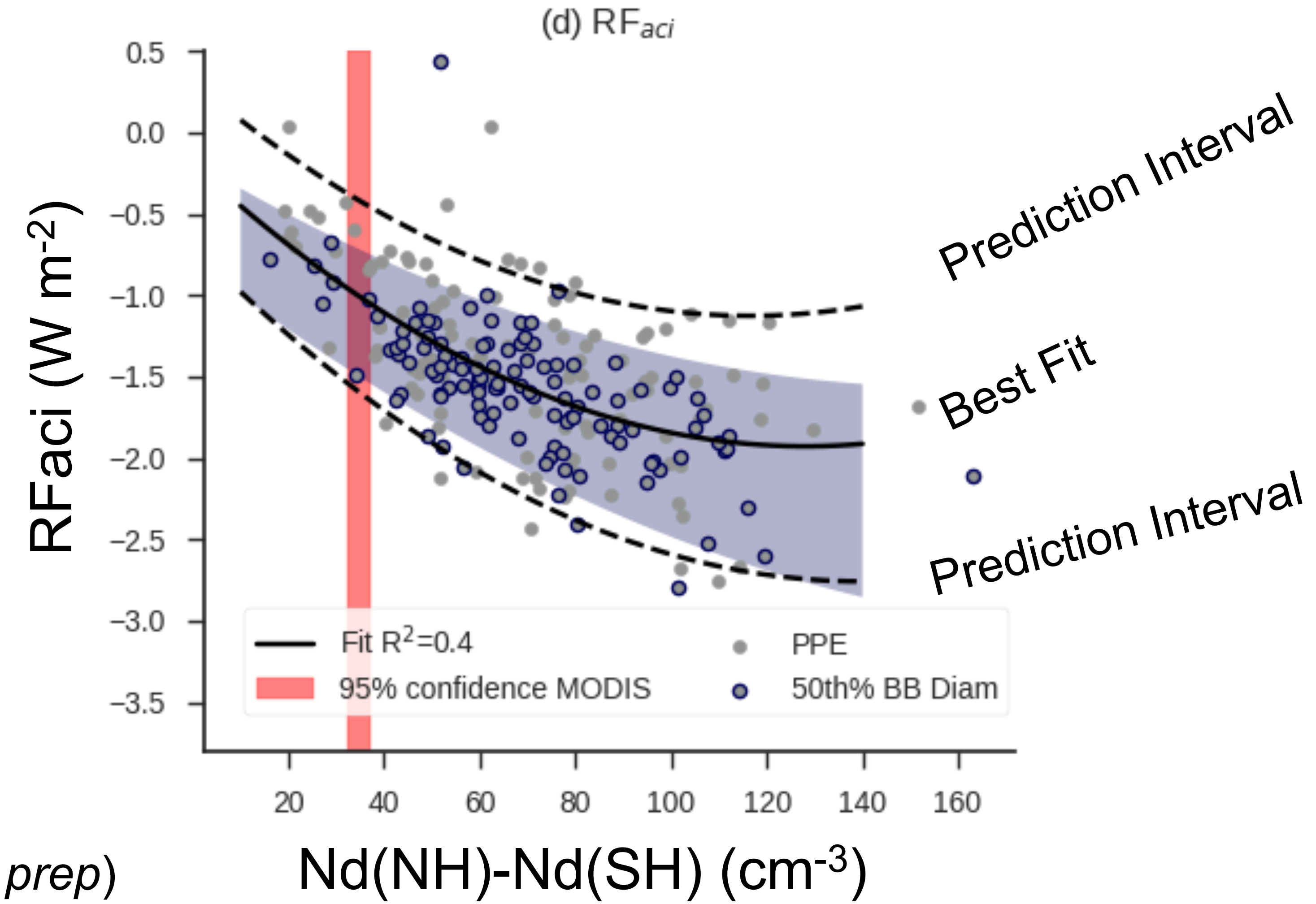
DMS sensitivity studies from Mulcahy et al. (2018) do not have a large effect on ΔNd relationship

Other mechanisms may be important > new particle formation? Consistent with SOCRATES (I. L. McCoy et al. 2019b, *in prep*)

Radiative Forcing for Aerosol Cloud Interactions Constrained by Nd(NH-SH)

The constrained RFaci range is:
-1.70 to -0.40 Wm^{-2}

This is comparable to the synthesis range from GCM and remote sensing:
-1.2 to -0.35 Wm^{-2}
(Bellouin et al. 2019)



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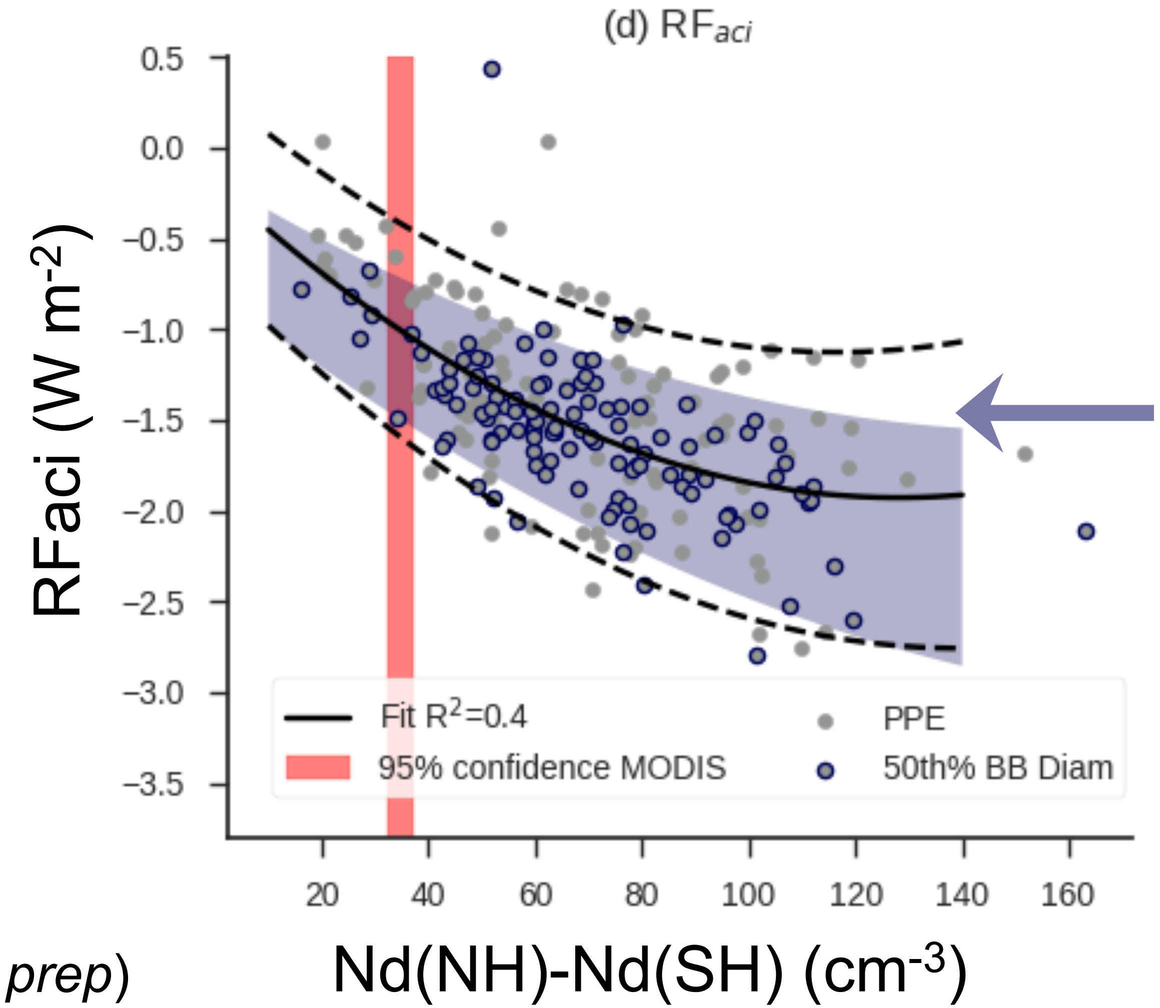
Radiative Forcing for Aerosol Cloud Interactions Constrained by Nd(NH-SH)



Each PPE member has a different biomass burning diameter, influencing PI and PD number…

Reducing biomass burning size range to 25-75th percentile (diameter of 143-246 nm from 90-300 nm) reduces range of RFaci (**-1.5 to -0.7 Wm^{-2}**)

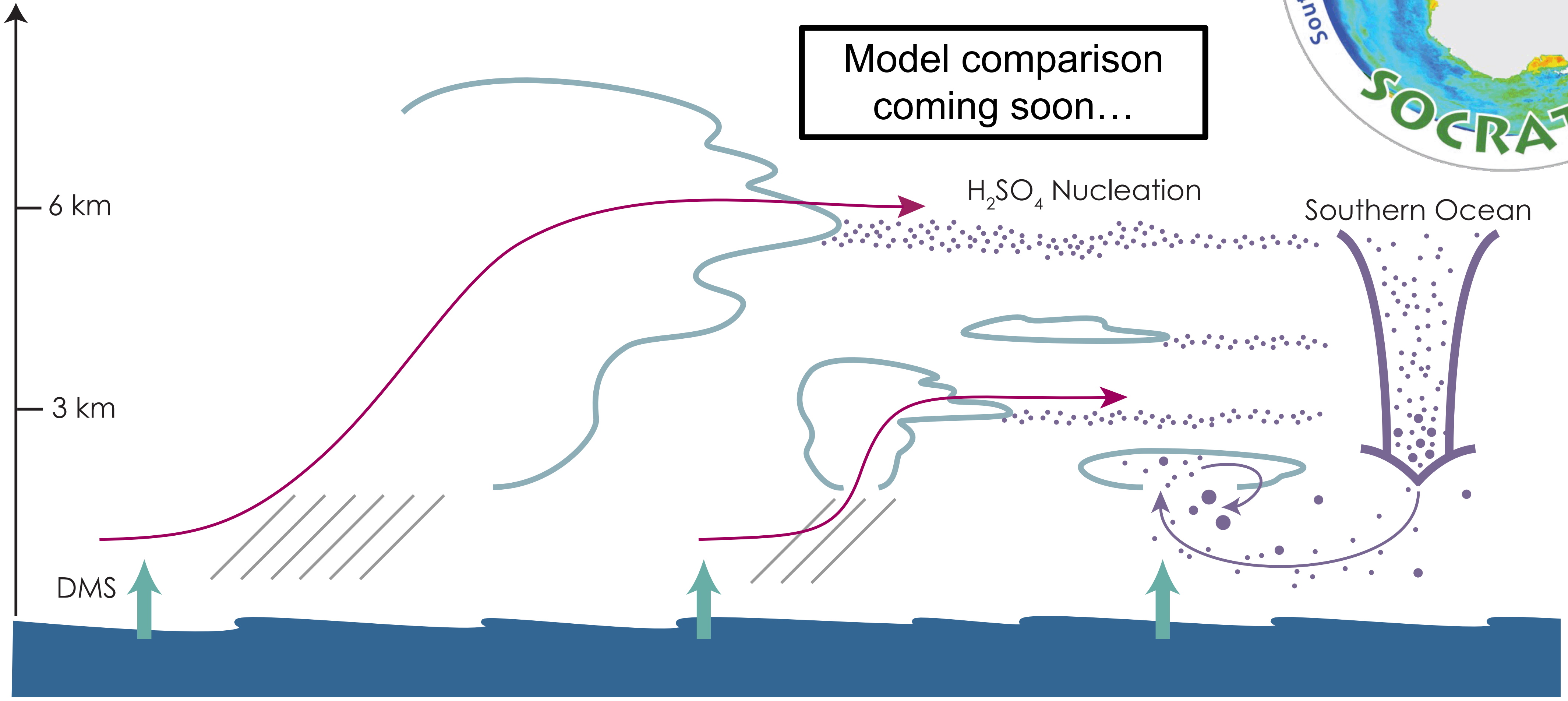
I. L. McCoy et al. (2019a, *in prep*)

Take Home Points

- Droplet Number Concentration (Nd) is a useful variable for looking at cloud aerosol interactions and for testing models
- SH Nd can be used as a rough proxy for PI Nd
- SH Nd in GCMs is too low - the PI may have had a higher Nd than predicted by models
- Using our methodology RFaci is predicted as -1.70 to -0.40 Wm^{-2} and narrows to -1.5 to -0.7 Wm^{-2} with weak constraints on biomass burning. Compare to synthesis range: -1.2 to -0.35 Wm^{-2} (Bellouin et al. 2019)

Questions? Contact: imccoy@uw.edu

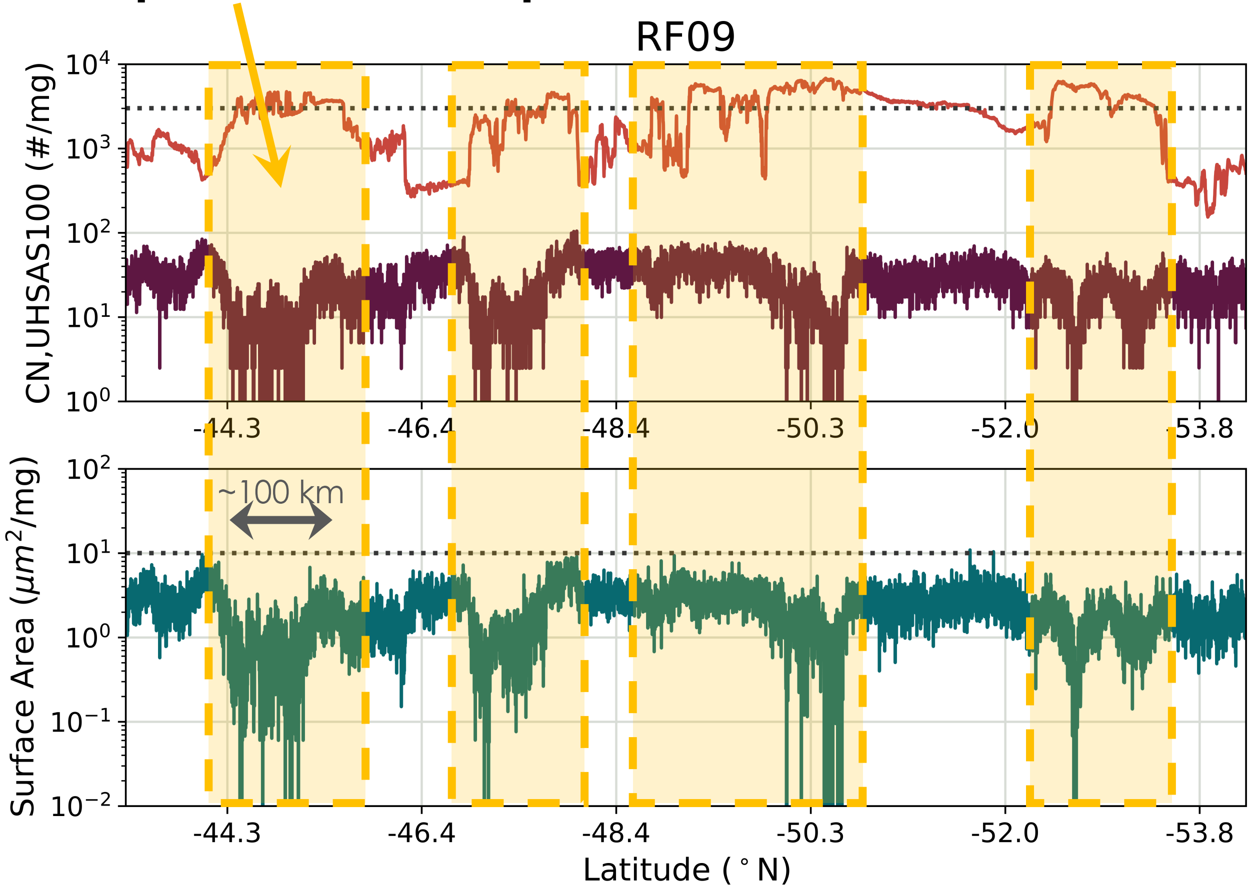
Cyclonic Uplift Mechanism for Recent Particle Formation

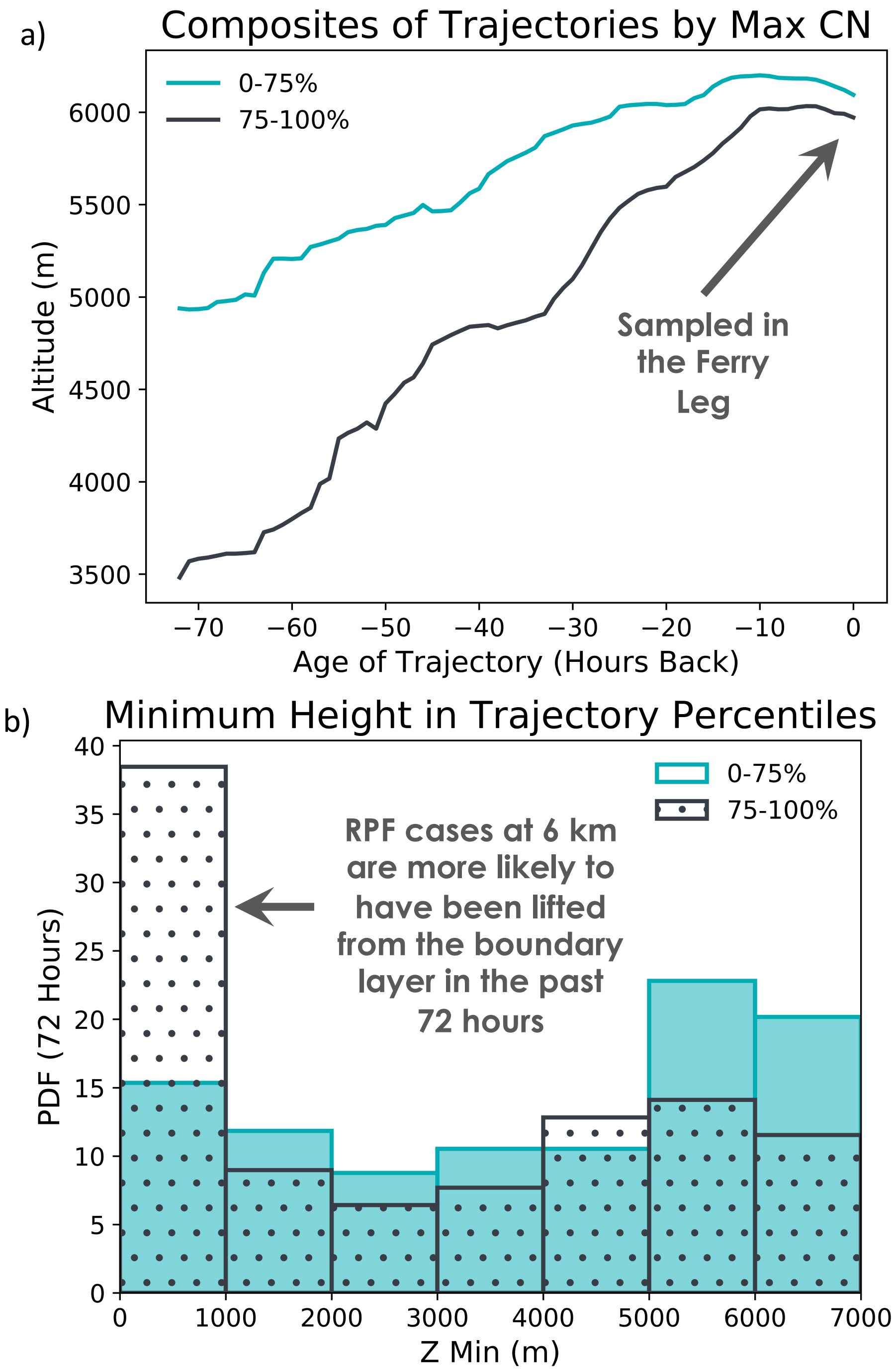


I. L. McCoy et al. (2019b, *in prep*)

SOCRATES

Suspected recent particle formation at ~6km





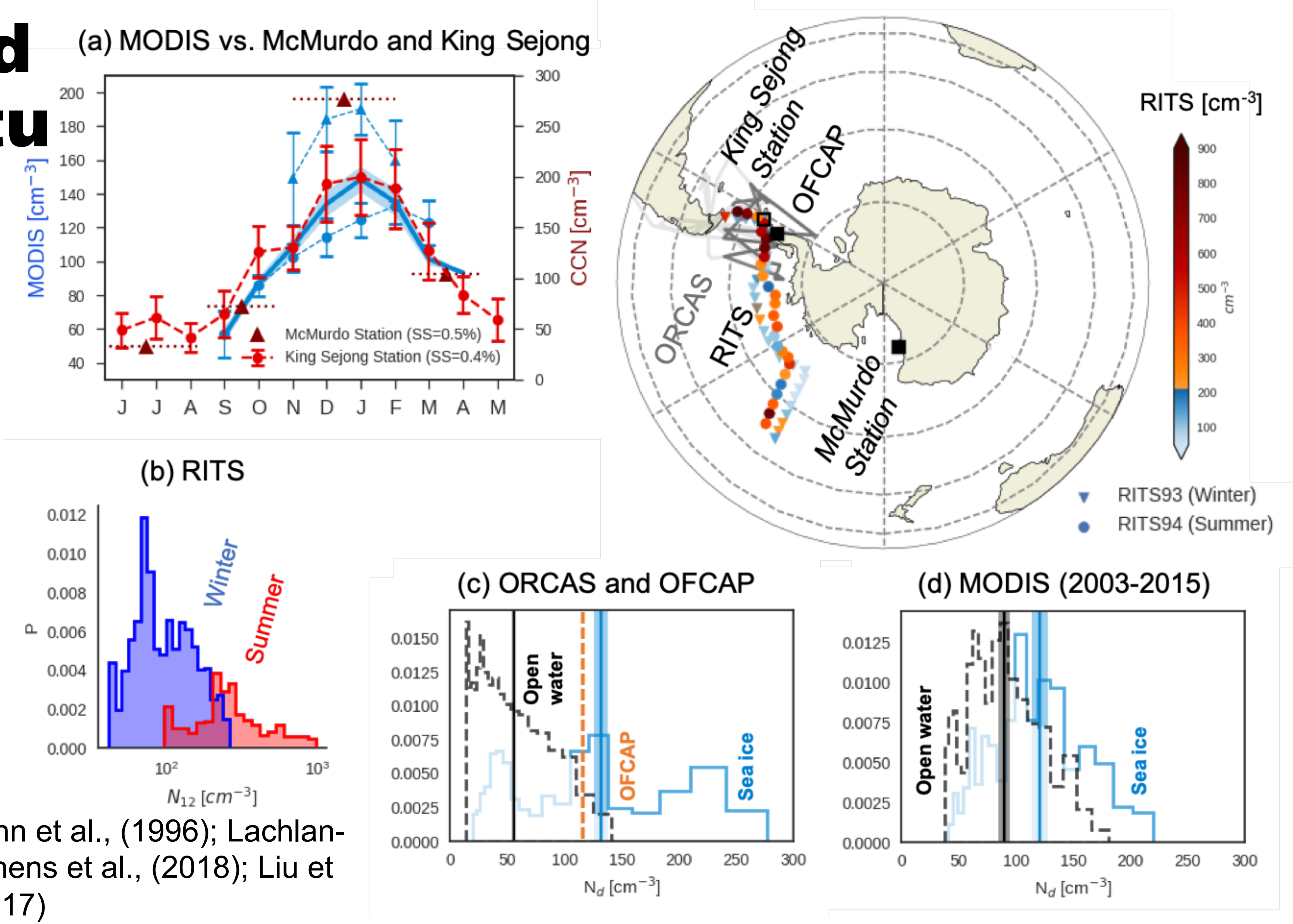
I. L. McCoy et al. (2019b, *in prep*)

Wood et al 2012

$$N_{eq} = \frac{\left(N_{FT} + \frac{F(\sigma)U_{10}^{3.41}}{Dz_i}\right)}{\left(1 + \frac{hKP_{CB}}{Dz_i}\right)}$$

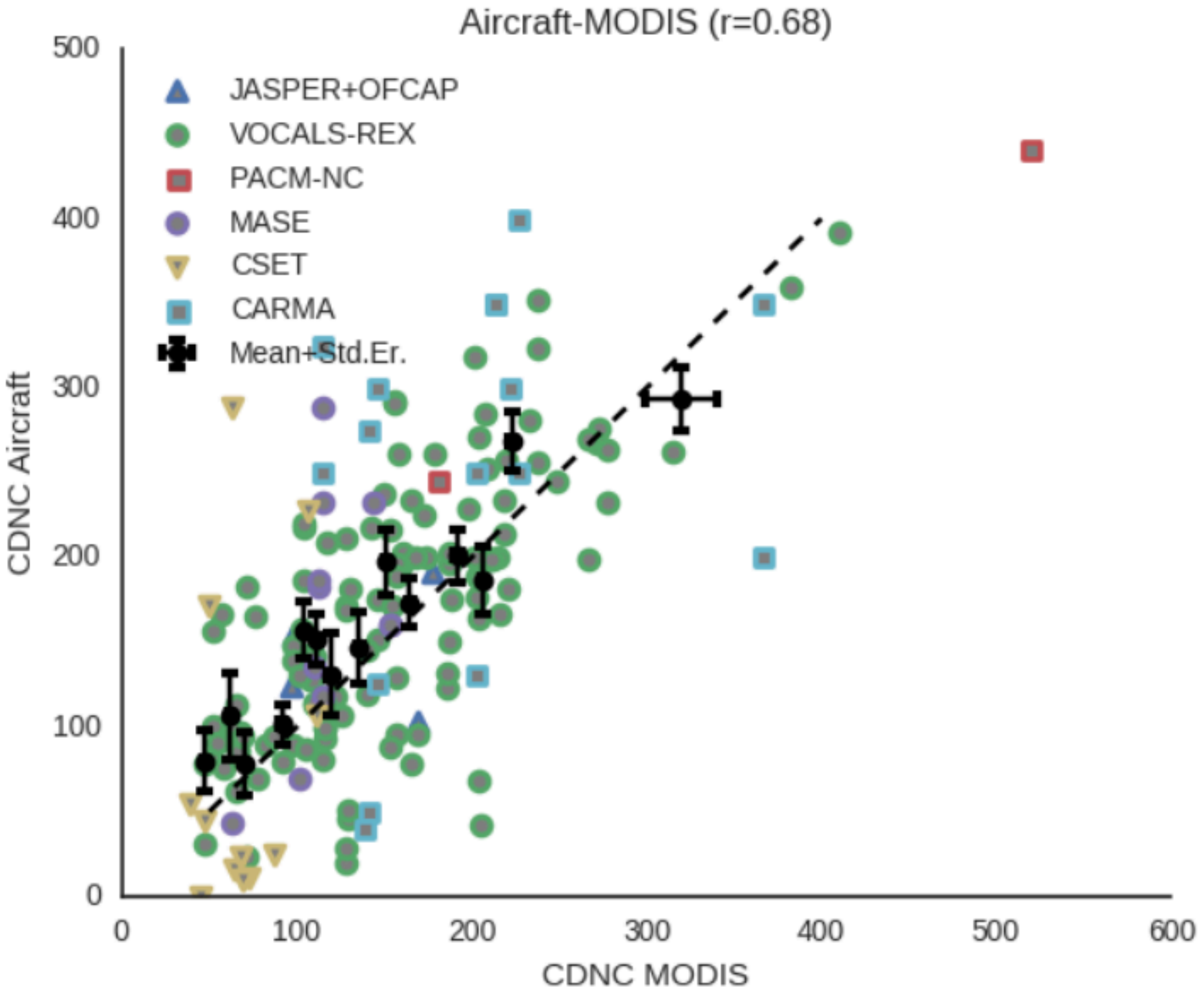
N(precip)/N(no precip) ~ $(1 + hKP_{CB}/Dz_i)$ = f(Precip)

MODIS Nd and In-situ

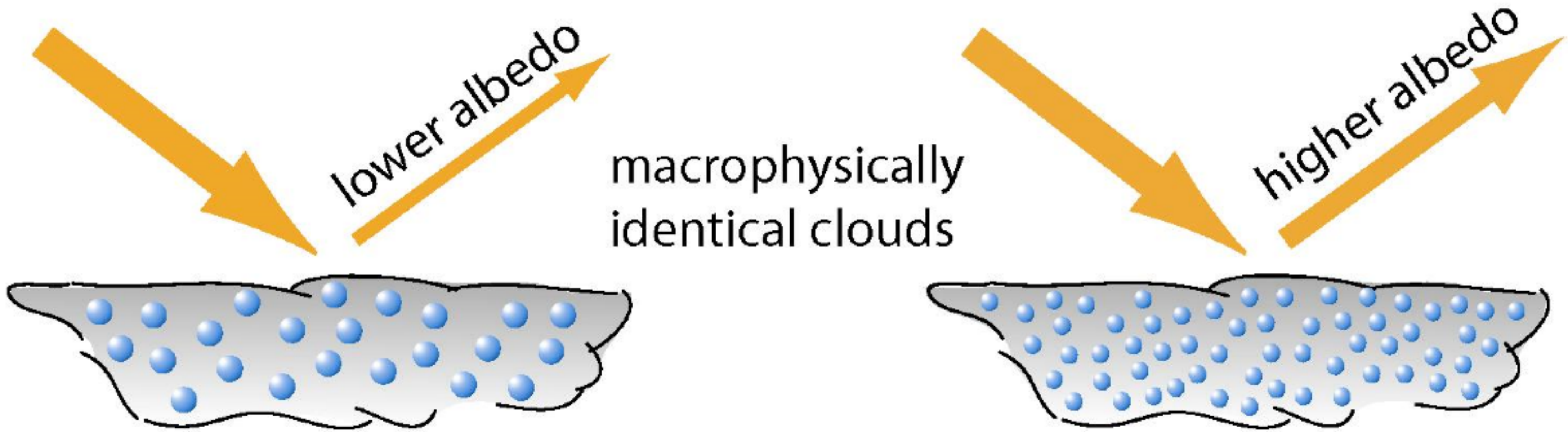


Covert et al., (1996); Quinn et al., (1996); Lachlan-Cope et al., (2016); Stephens et al., (2018); Liu et al., (2018); Kim et al., (2017)

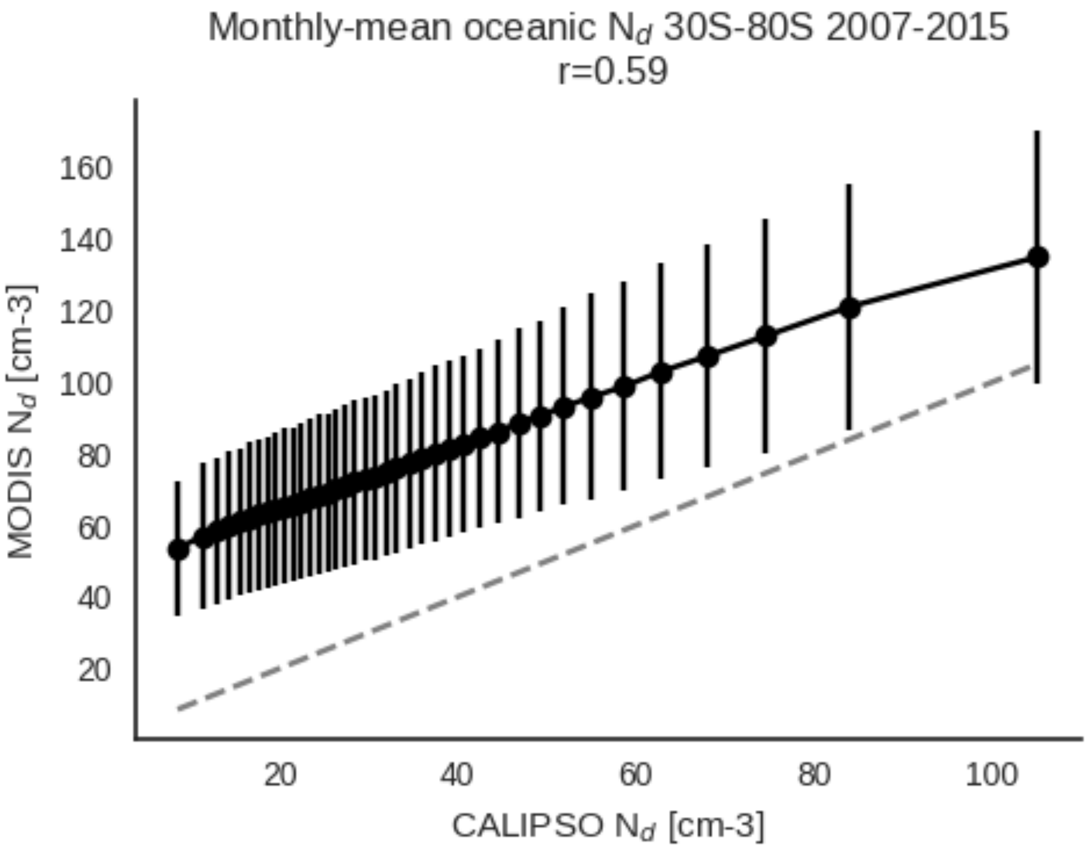
D. T. McCoy et al. (2017)

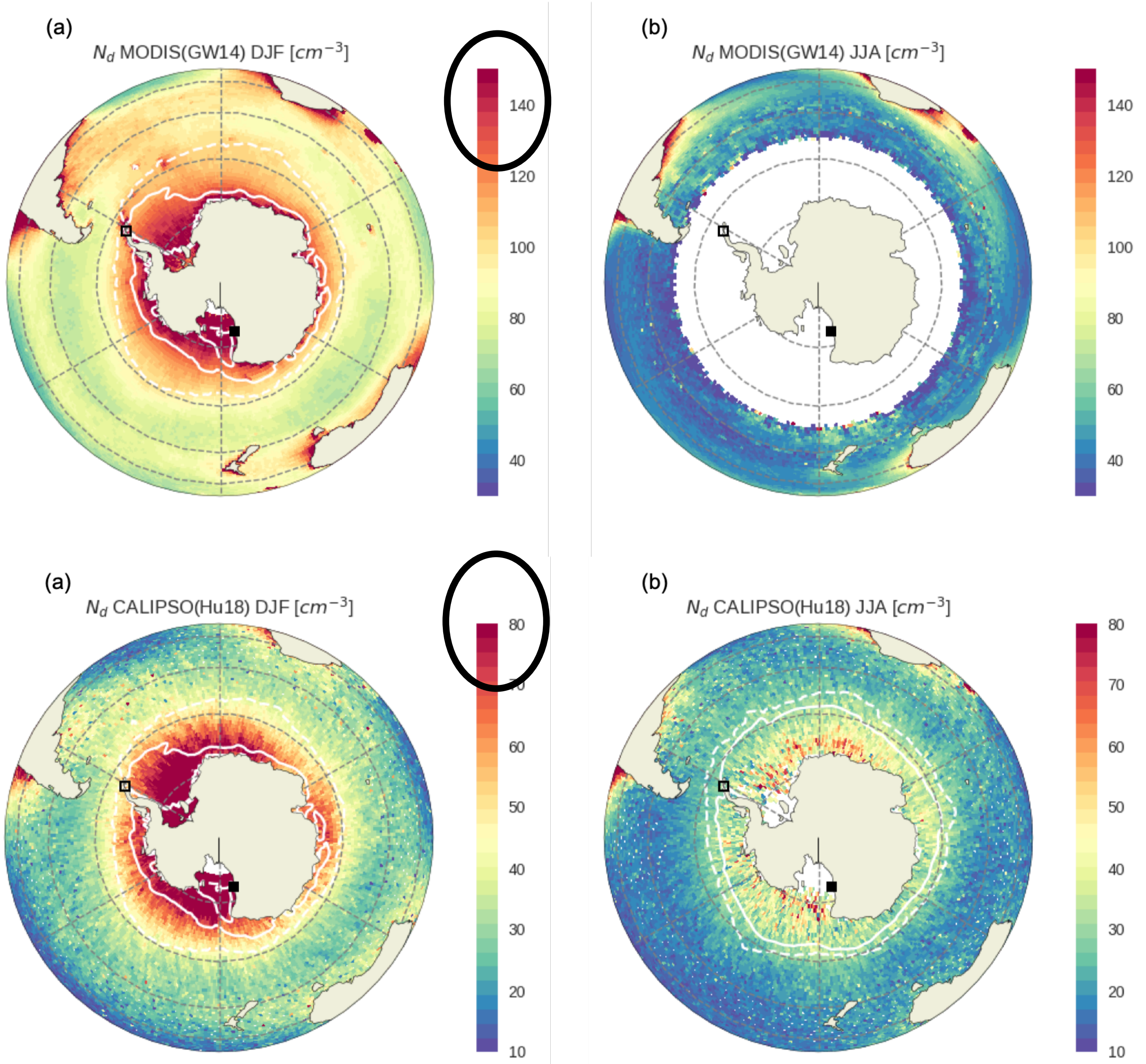


First indirect effect



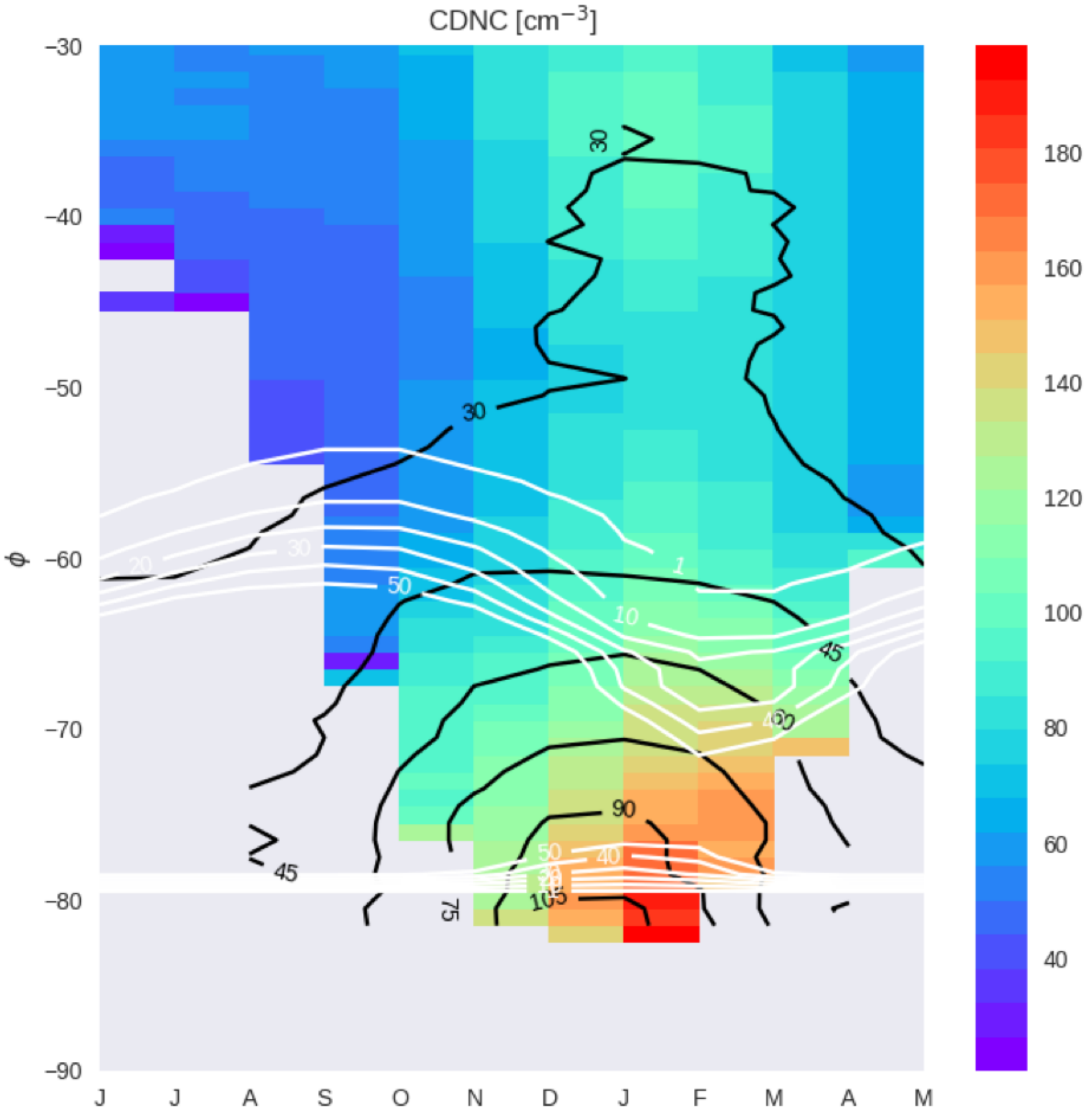
Calipso Nd


Monthly-mean oceanic N_d 30S-80S 2007-2015
r=0.59
MODIS N_d [cm-3]
CALIPSO N_d [cm-3]


(a)
N_d MODIS(GW14) DJF [cm^{-3}]
(b)
N_d MODIS(GW14) JJA [cm^{-3}]
(a)
N_d CALIPSO(Hu18) DJF [cm^{-3}]
(b)
N_d CALIPSO(Hu18) JJA [cm^{-3}]

Sea Ice and Nd

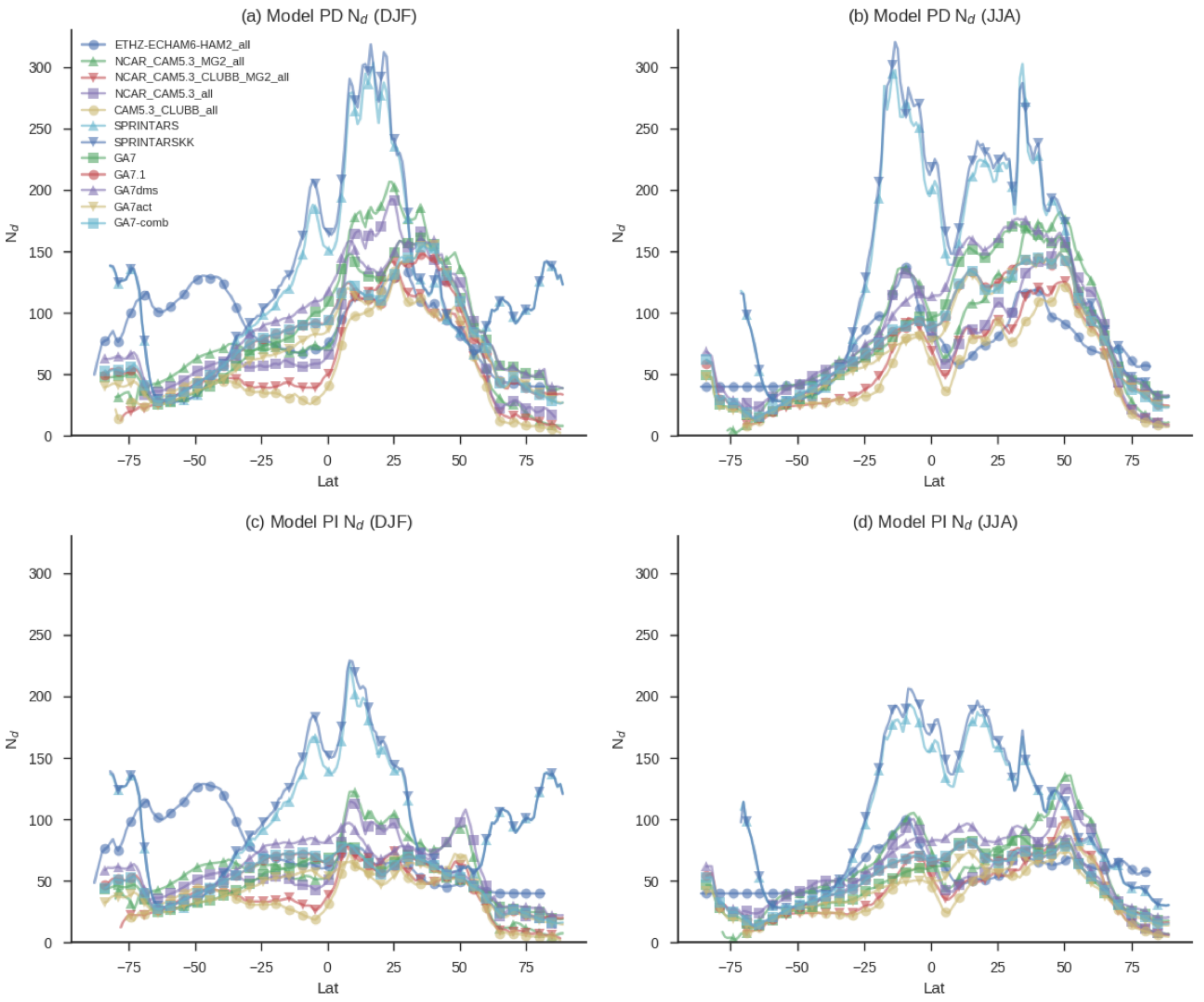
- Nd from Calipso (black lines)
- Nd from MODIS (colors)
- Sea Ice Extent from OSTIA (white lines)



PPE Details

- 235 model variants, each with a unique combination of the parameter values.
- Each PPE member simulated PD Nd resolved in space and time, PI global-mean Nd, and top-of-the-atmosphere radiative fluxes (used to calculate RFaci).
- Horizontal winds and temperature fields were relaxed (Telford et al., 2008) towards 2008 meteorology from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-Interim reanalyses and forced with year 2008 anthropogenic aerosol emissions from the MACCity emission inventory (Granier et al., 2011).
- Each of the 235 simulations has a partner simulation with identical parameter values, but anthropogenic emissions from 1850 prescribed, so that uncertainty in changes over the industrial period can be quantified.
- Configured so that the 1st indirect effect of aerosols can be quantified in the absence of rapid adjustments. Aerosols do not feedback onto simulated temperature or precipitation.
- Variations in Nd over the ensemble are caused entirely by differences in aerosol size distributions due to combinations of the 26 parameter values.

Aerocom and HadGEM3 PD and PI



Aerocom, HadGEM3, and PPE PD