How well can the radiative forcing from aerosol-cloud interactions be constrained?

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Sylvaine Ferrachat, Steven Ghan, Andrew Gettelman, Jan Griesfeller, Zak Kipling, Ulrike Lohmann, Hugh Morrison, David Neubauer, Daniel Partridge, Philip Stier, Toshihiko Takemura, Hailong Wang, Minghuai Wang, Kai Zhang, Shipeng Zhang

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Diagnosing radiative forcing

$$\Delta F^{AIE} = f_{liq} \cdot A(f, \tau_c) \frac{1}{3} \cdot \frac{d \ln N_d}{d \ln \tau_a} \left[\ln \tau_a - \ln\left(\tau_a - \tau_a^{ant}\right) \right] \bar{F}^{\downarrow} \quad (10)$$

Quaas et al., JGR, 2008

Radiative forcing from aerosol indirect effects is proportional to sensitivity of droplet number to aerosol

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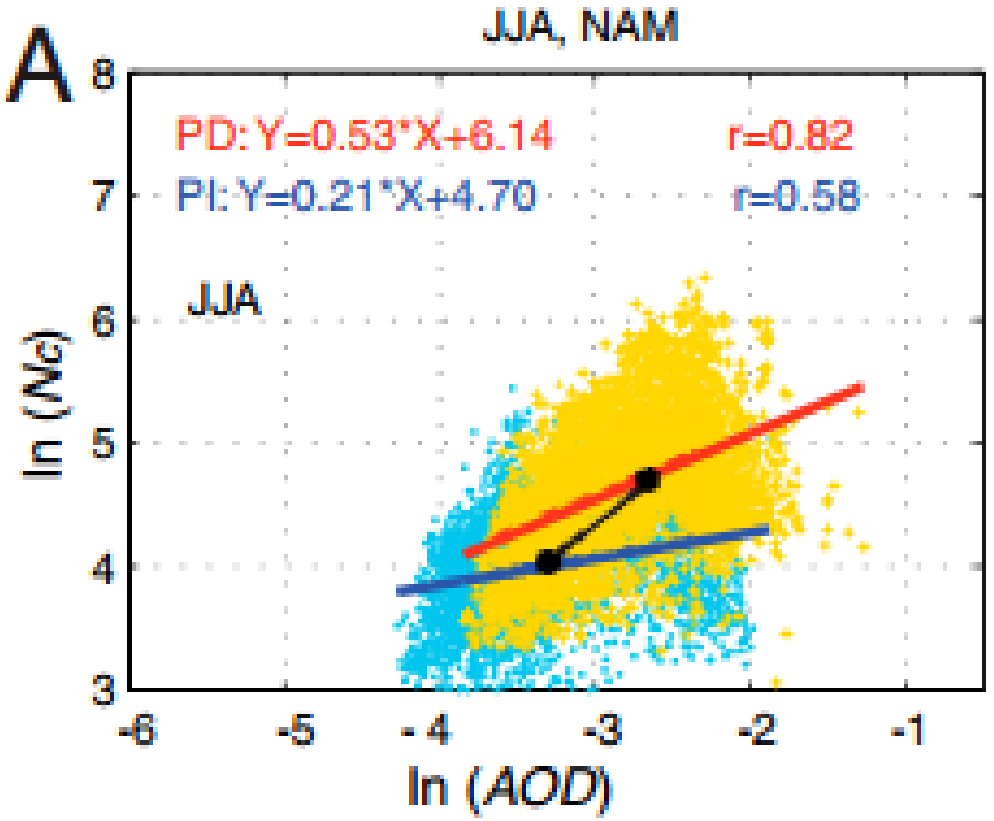
Radiative forcing from aerosol indirect effects is proportional to sensitivity of droplet number to aerosol

We need to be able to calculate the change in cloud droplet number concentration (CDNC) to diagnose the aerosol indirect forcing

Determining the CDNC change



Penner et al., PNAS, 2011

Linear regressions on the present day don’t give an accurate measure of the true susceptibility (when using AOD)

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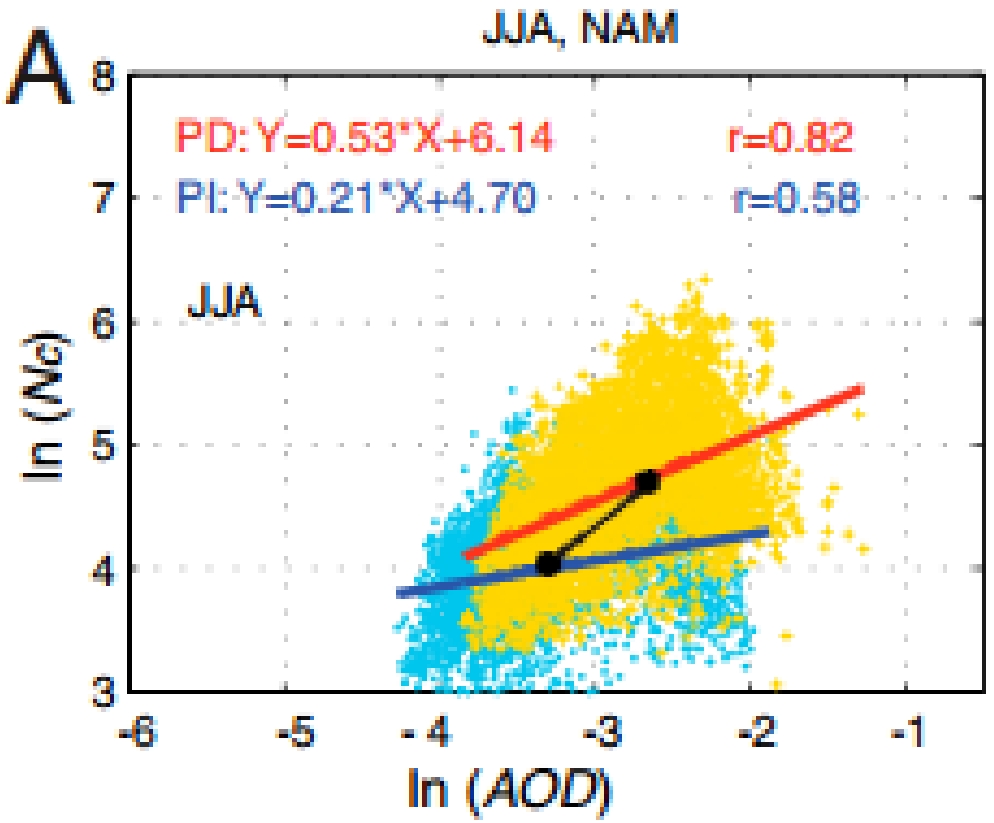

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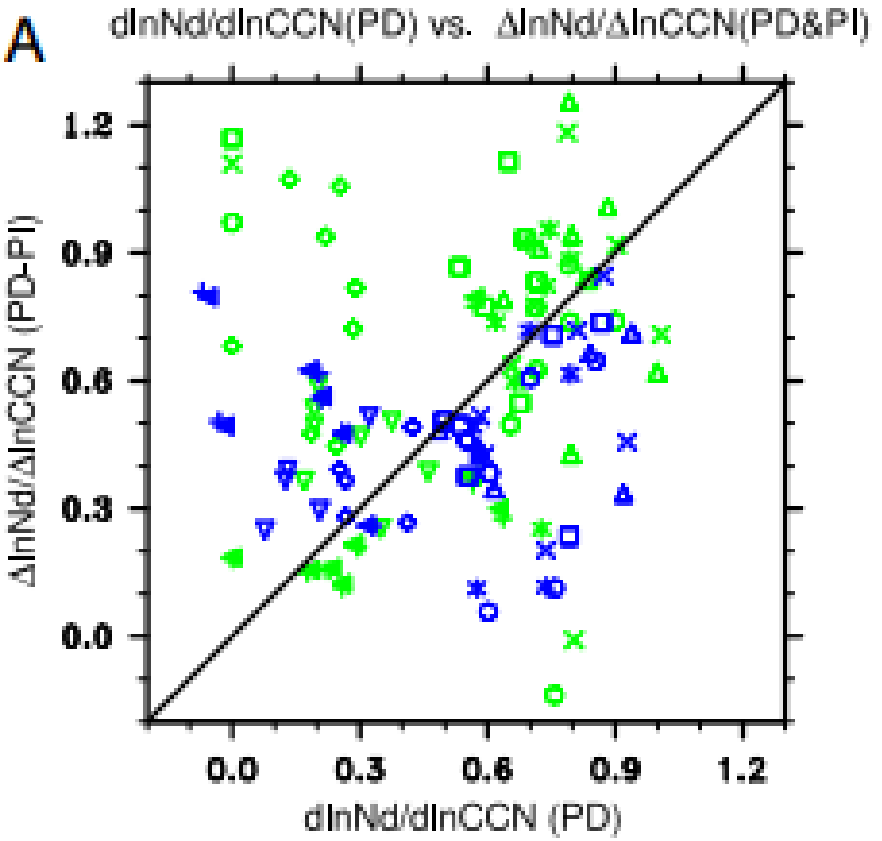

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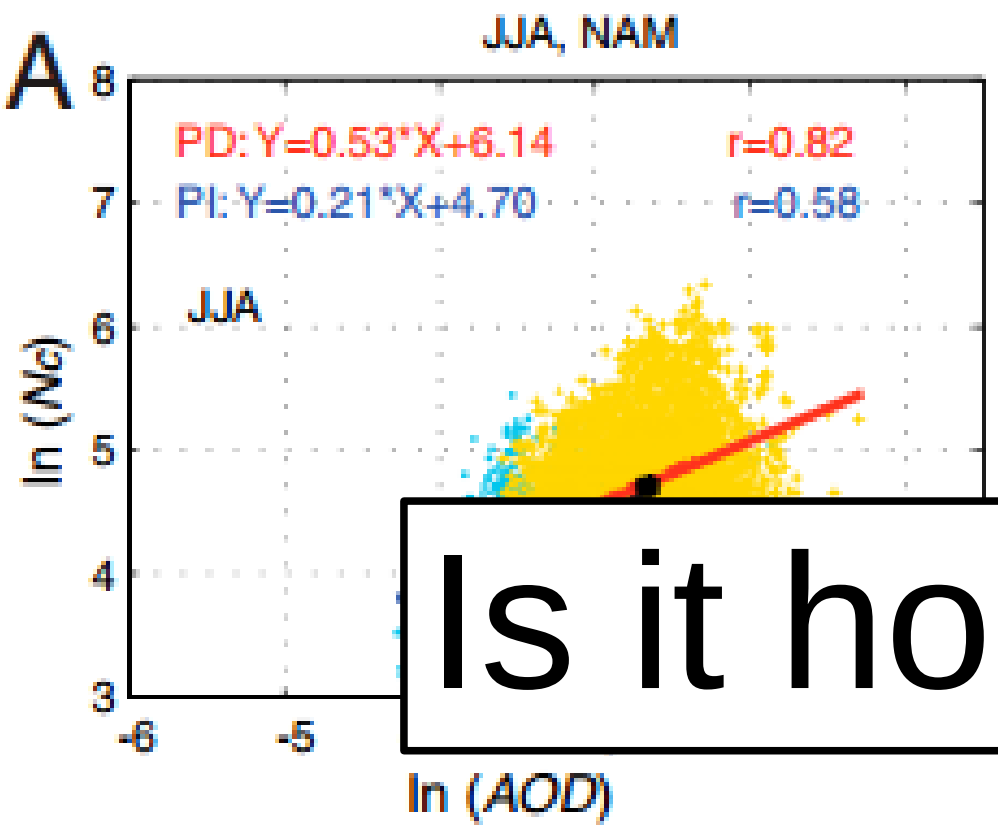
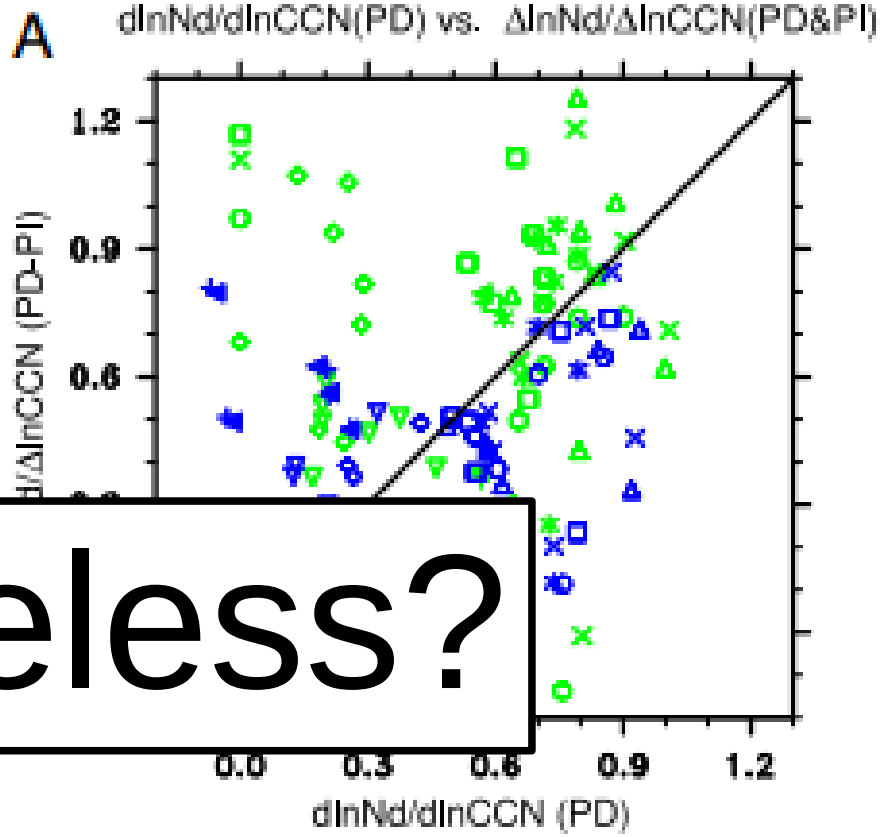
Present day variability doesn't tell you much about the 'real sensitivity' of clouds to aerosols (even using CCN doesn't fix this!)

Determining the CDNC change





Is it hopeless?

Penner et al., PNAS, 2011

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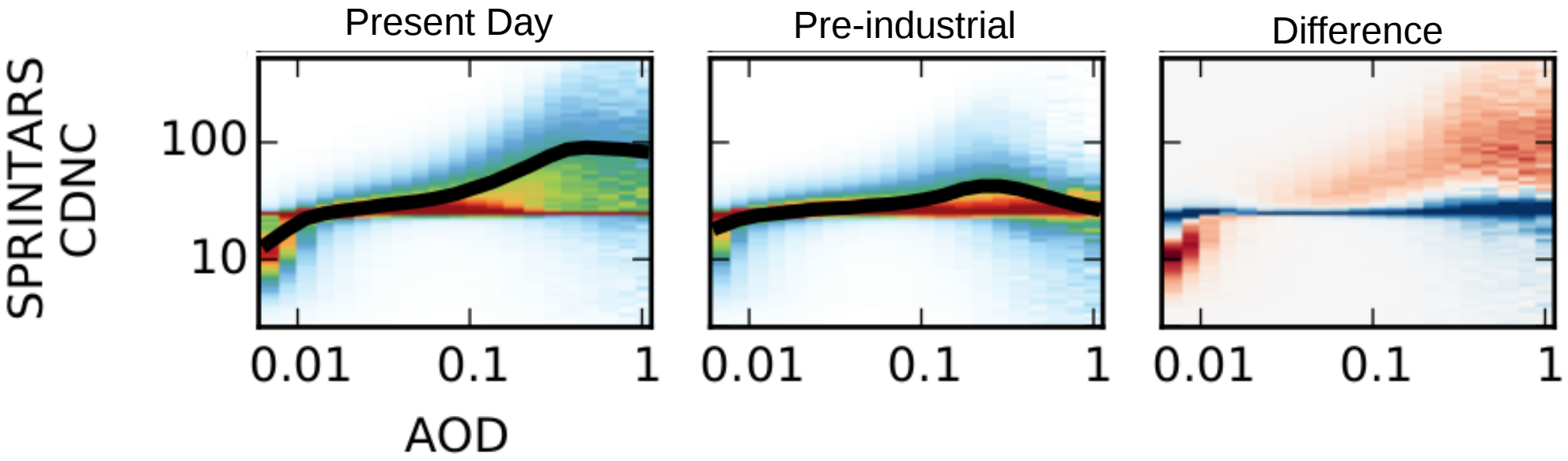
A non-linear relationship?



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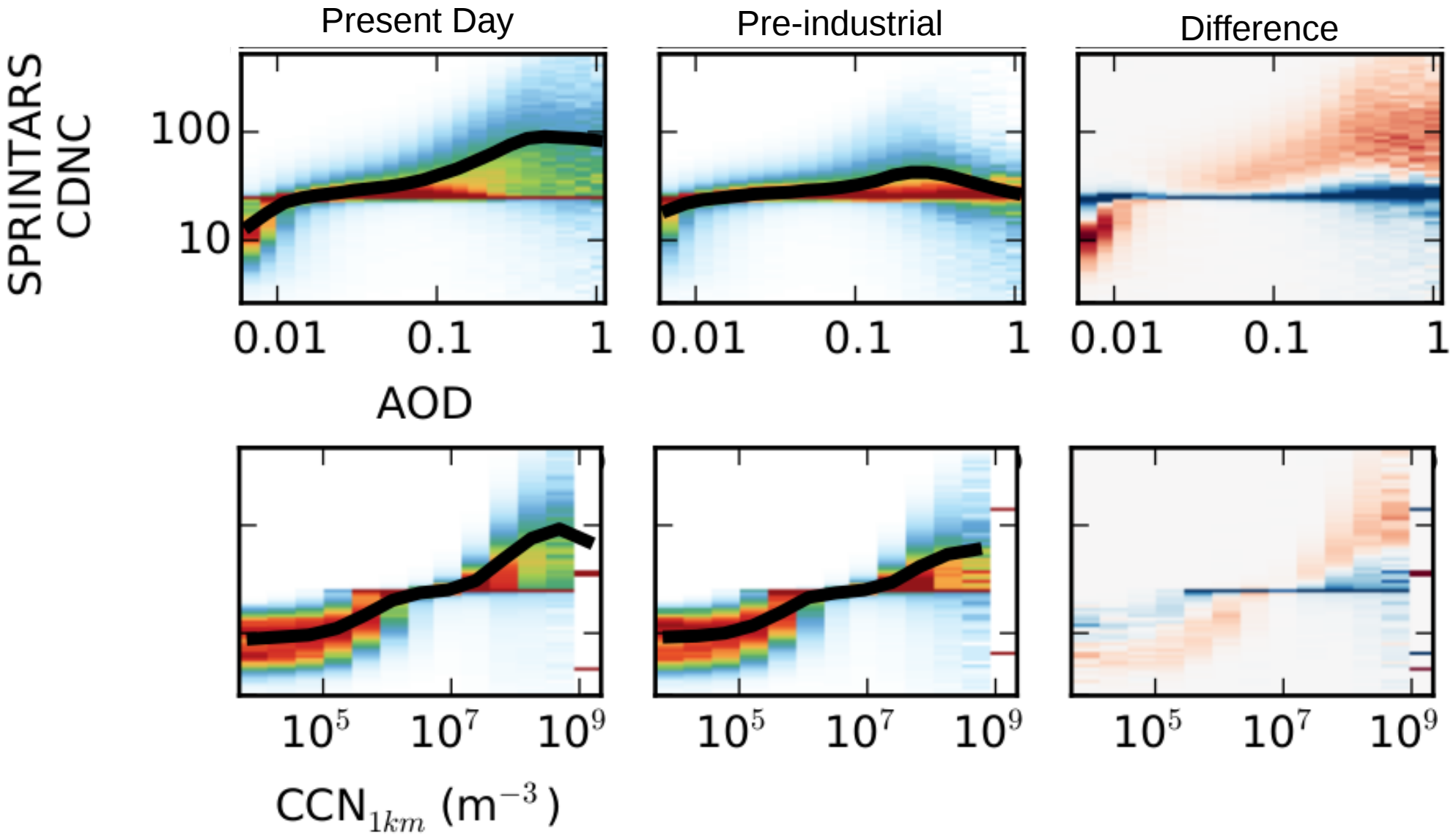
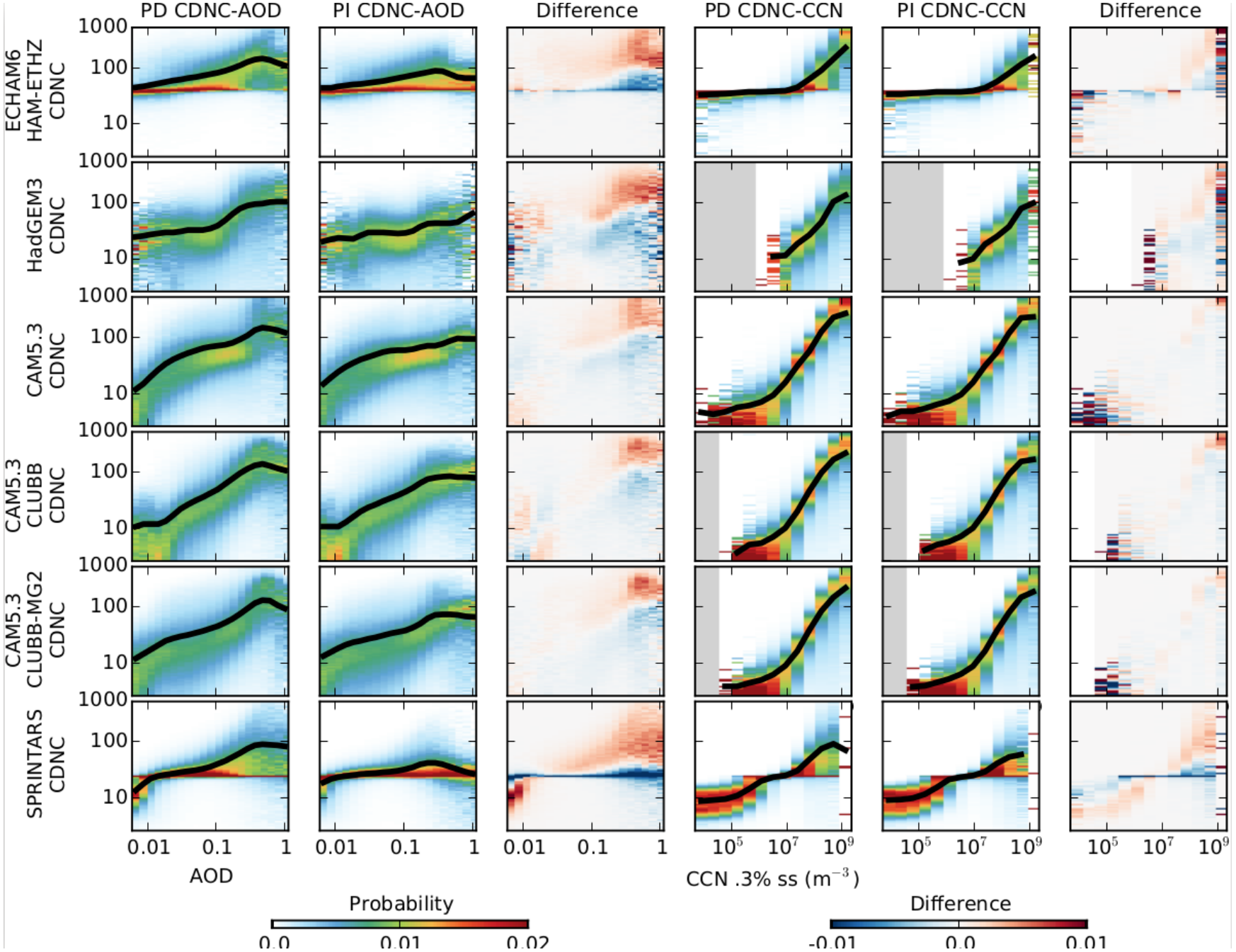
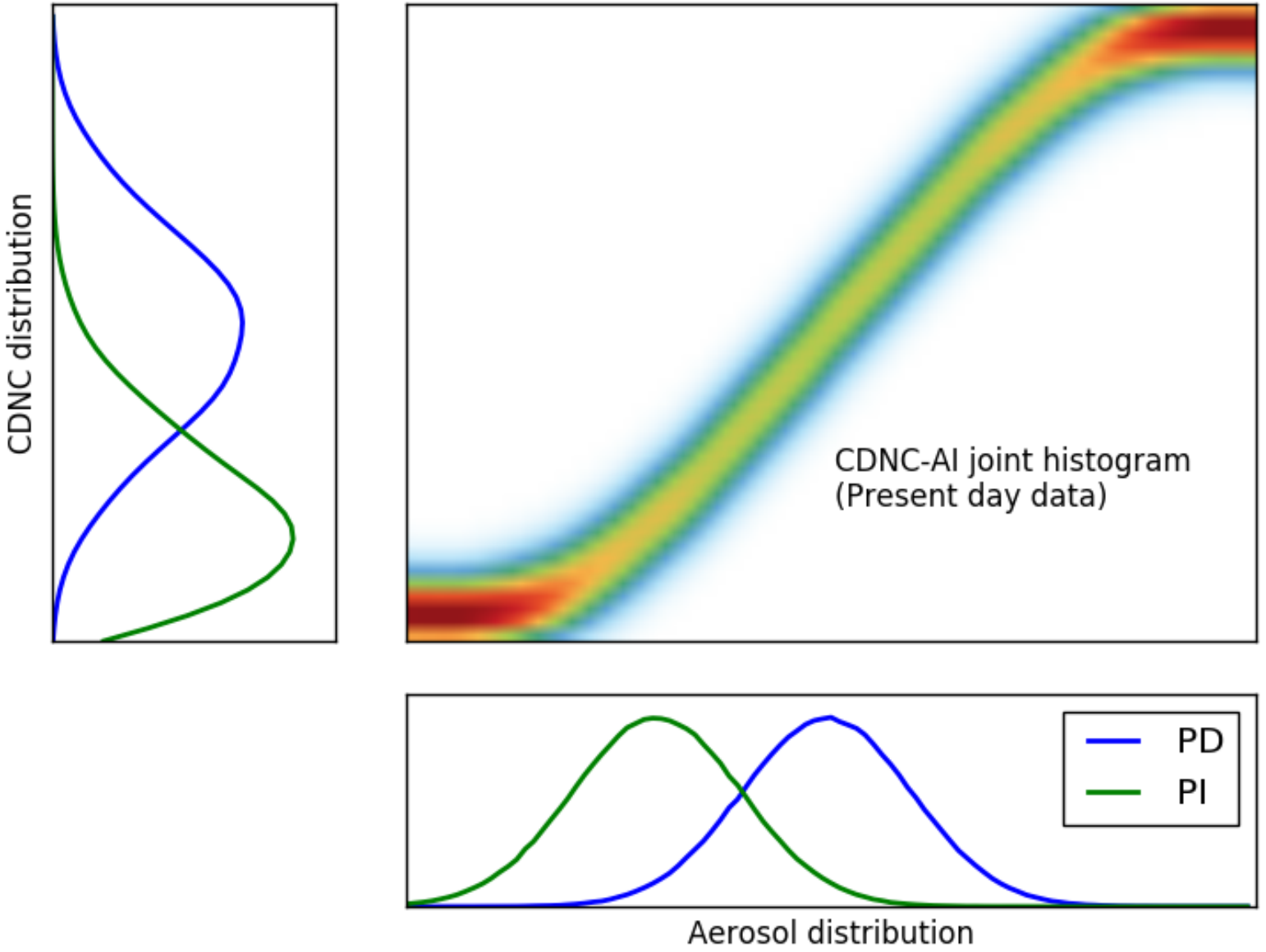


Joint histograms to the rescue!



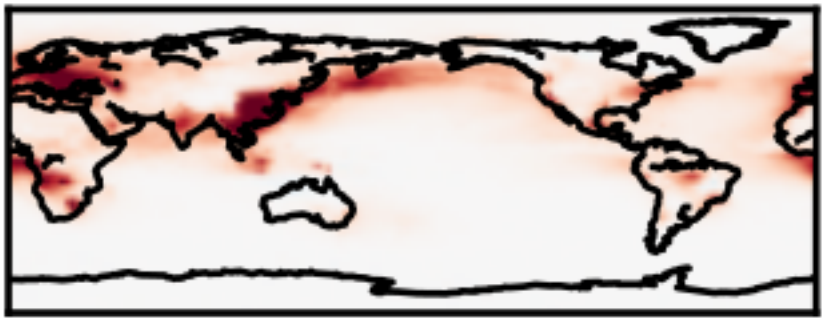
Predicting the CDNC change



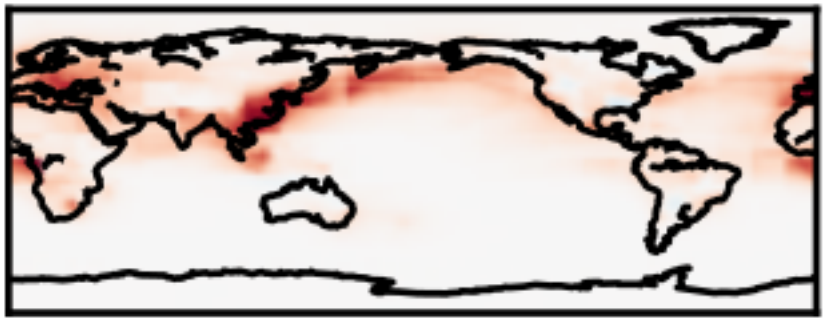
Predicting the CDNC change

SPRINTARS

Actual CDNC change



Diagnosed CDNC change



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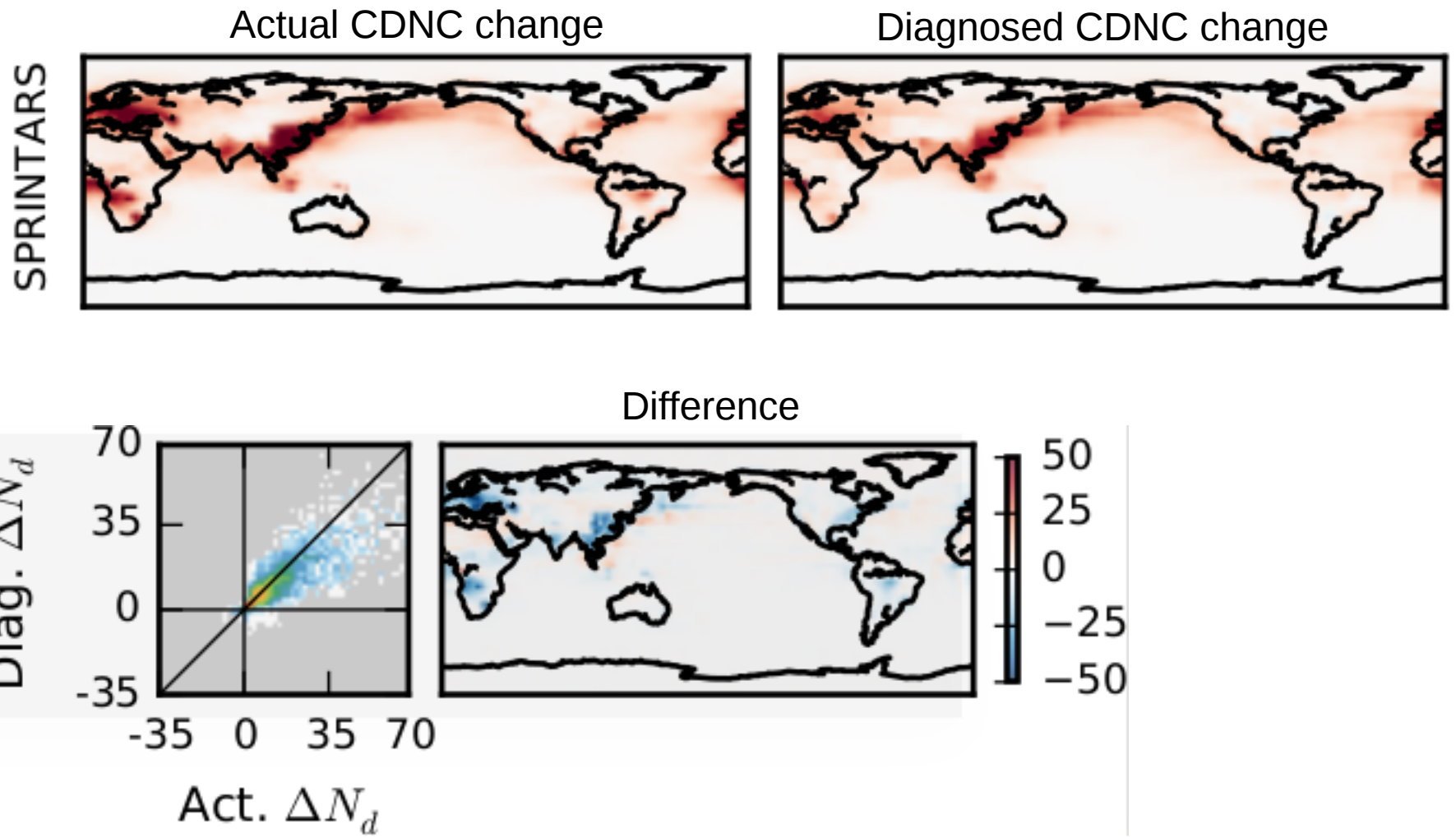
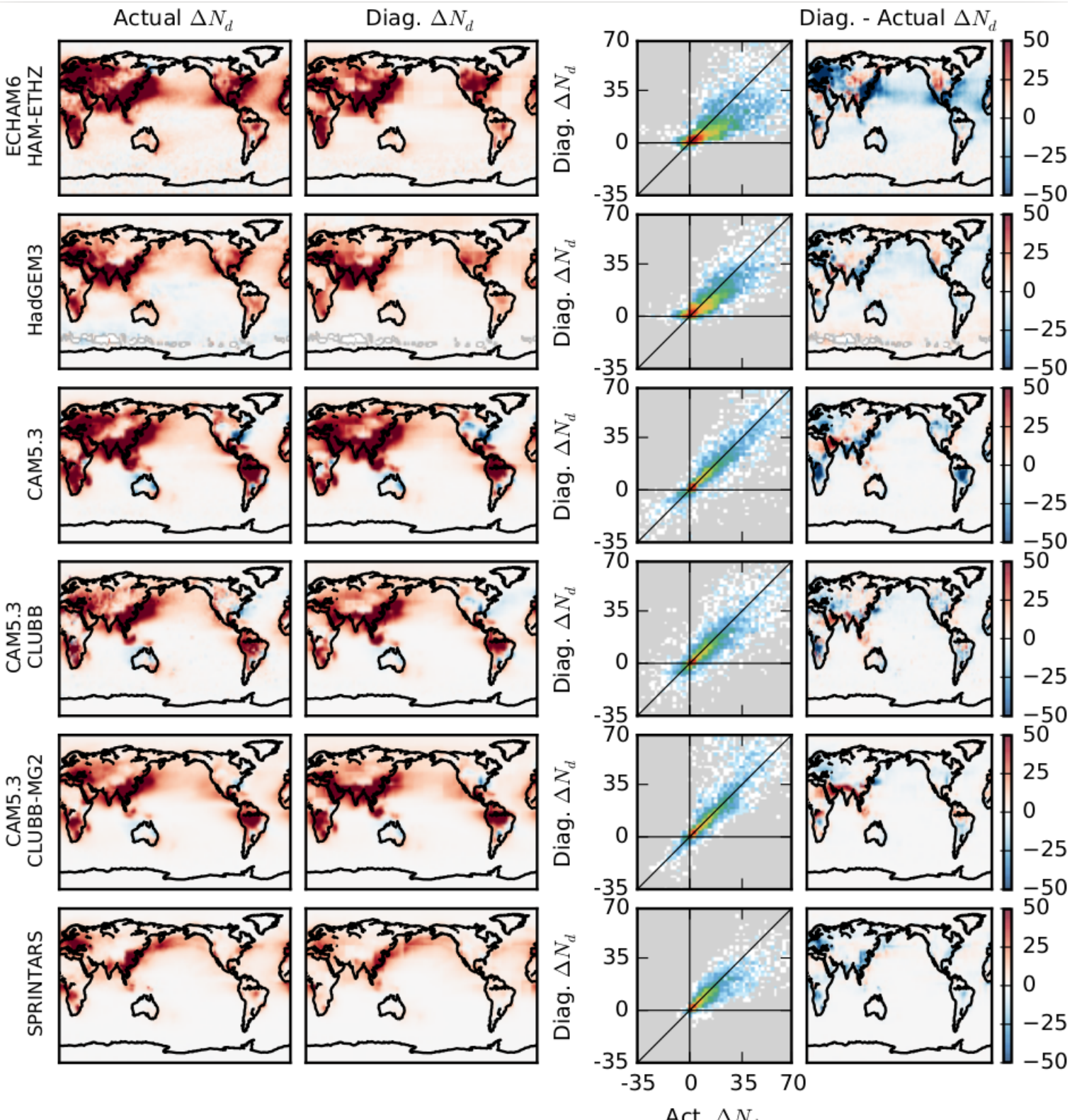
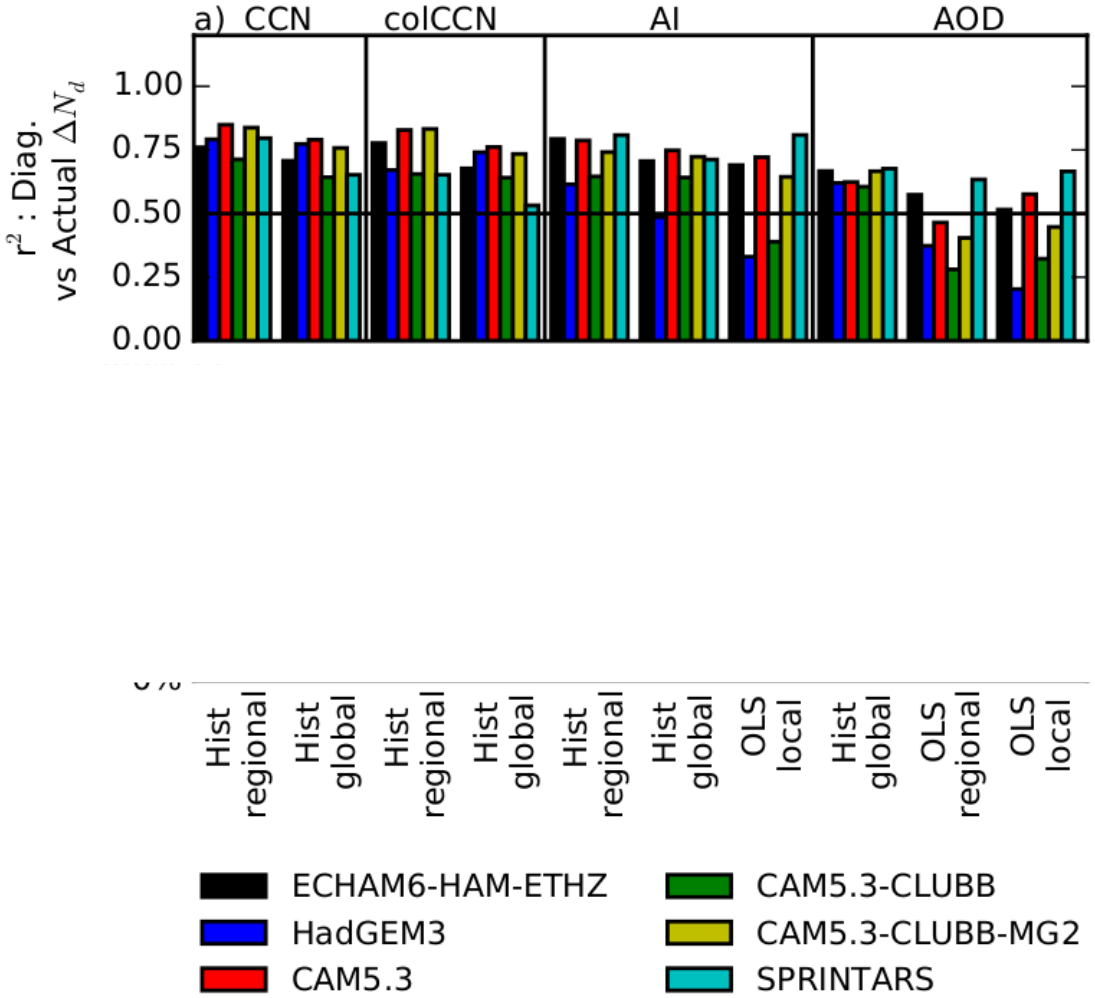



Actual ΔN_d
Diag. ΔN_d
Diag. - Actual ΔN_d
ECHAM6 HAM-ETHZ
HadGEM3
CAM5.3
CAM5.3 CLUBB
CAM5.3 CLUBB-MG2
SPRINTARS
Diag. ΔN_d
Act. ΔN_d
70
35
0
-35
50
25
0
−25
−50

How accurate is it?



CCN explains almost 80% of the CDNC variance

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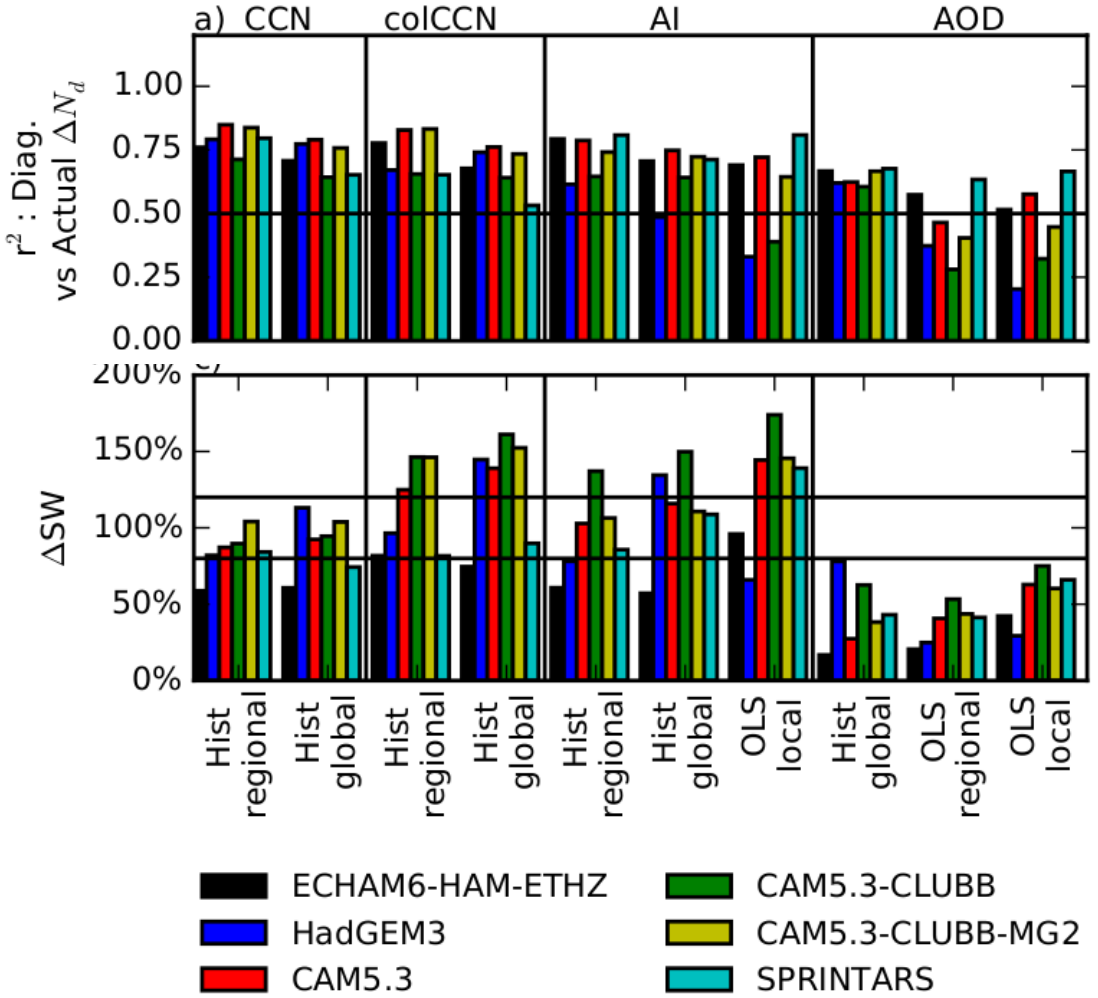


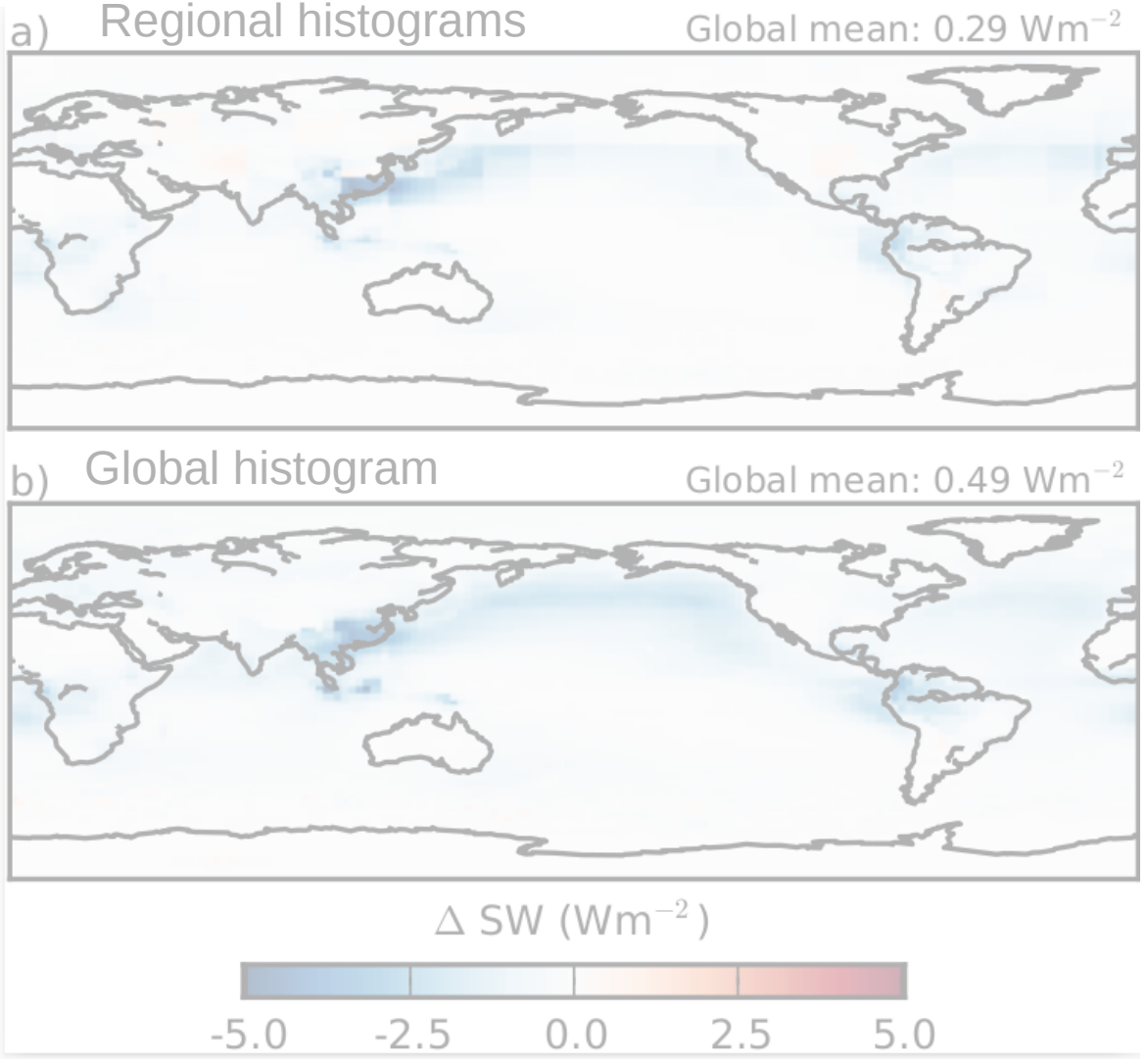
CCN explains almost 80% of the CDNC variance

Forcing predicitons also reasonably accurate, except for AOD where there Is a big underestimate

Notice that AI is pretty good (almost as good as CCN!)

Updated radiative forcing estimate (Twomey)

- Create AI-CDNC histograms from MODIS data
- Use anthropogenic AI estimates from AeroCom models



Mean/Median value around
-0.3 Wm^{-2} (regional hsitograms)
-0.5 Wm^{-2} (global histogram)

For comparison:
Quaas et al., 2008 (using AOD)
-0.2 Wm^{-2}

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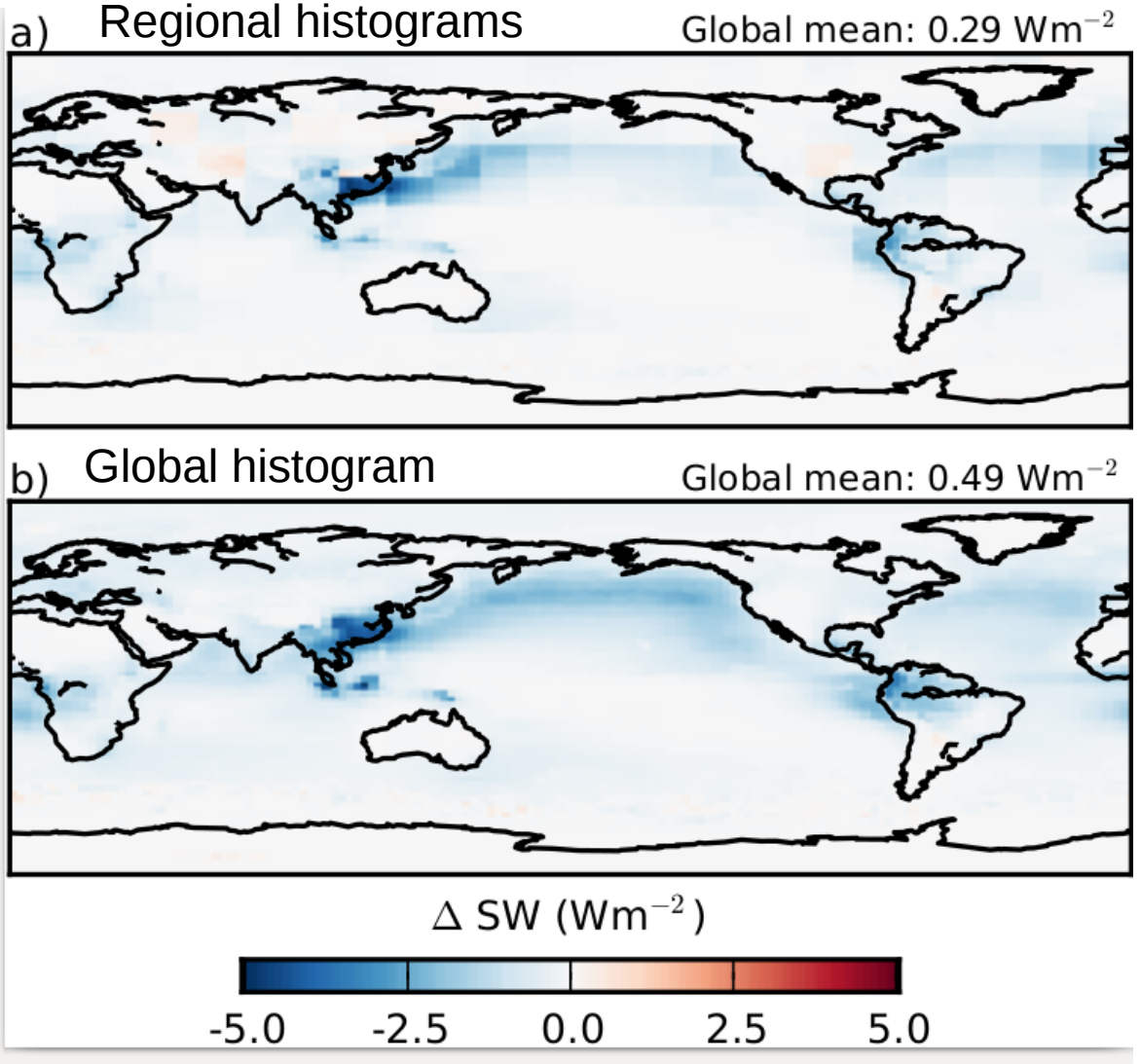

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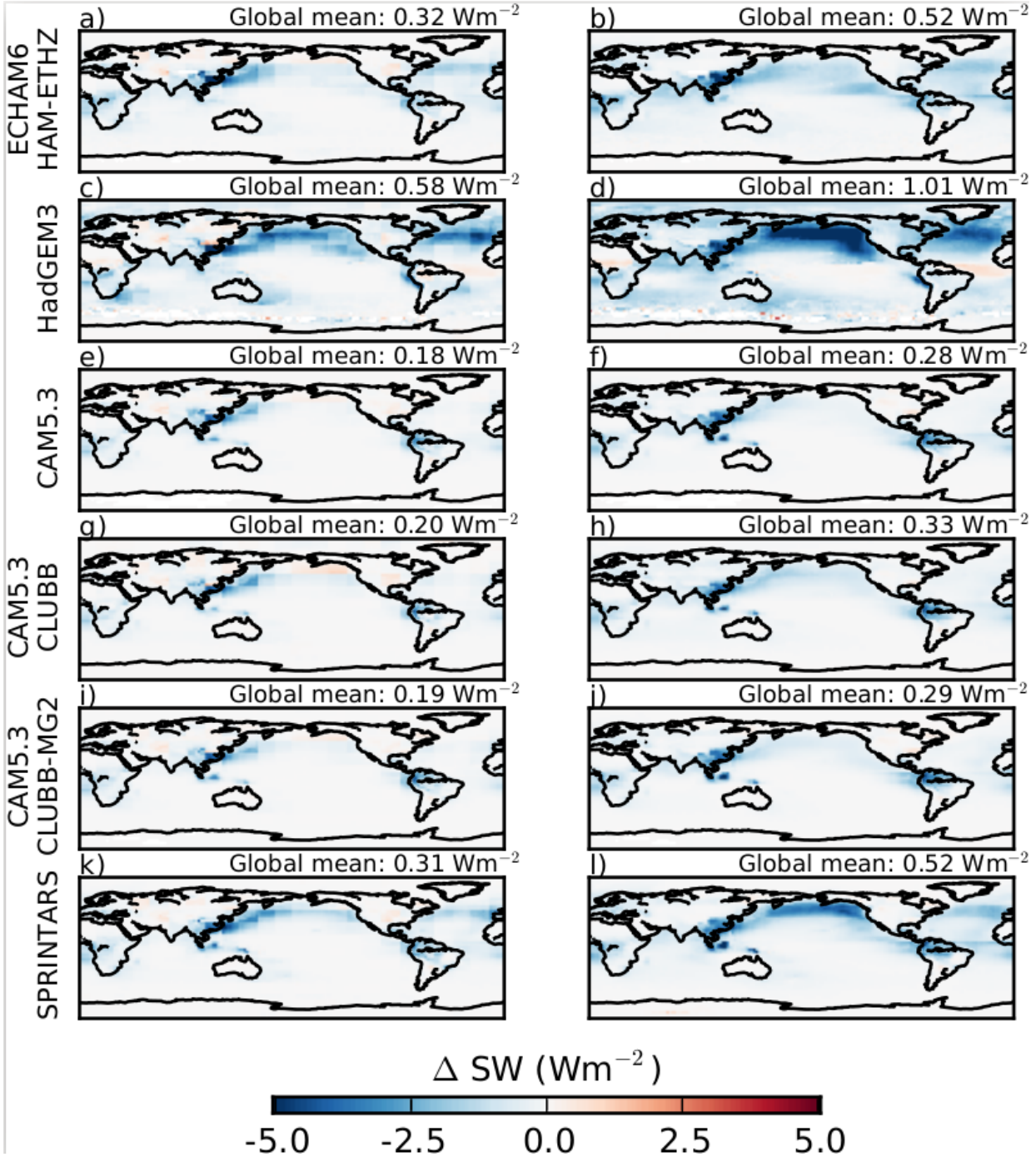
Summary

- Joint histograms can represent the non-linearity better than linear regression
- Predicting the CDNC change is easier than predicting the sensitivity
- Using AOD as an aerosol proxy gives a large underestimation in the aerosol forcing

Updated estimate for forcing from the Twomey effect



Large model variation due to uncertainty in anthropogenic aerosol fraction