A Multi-Model Analysis of Aerosol Effects on Clouds Simulated by Global Climate Models

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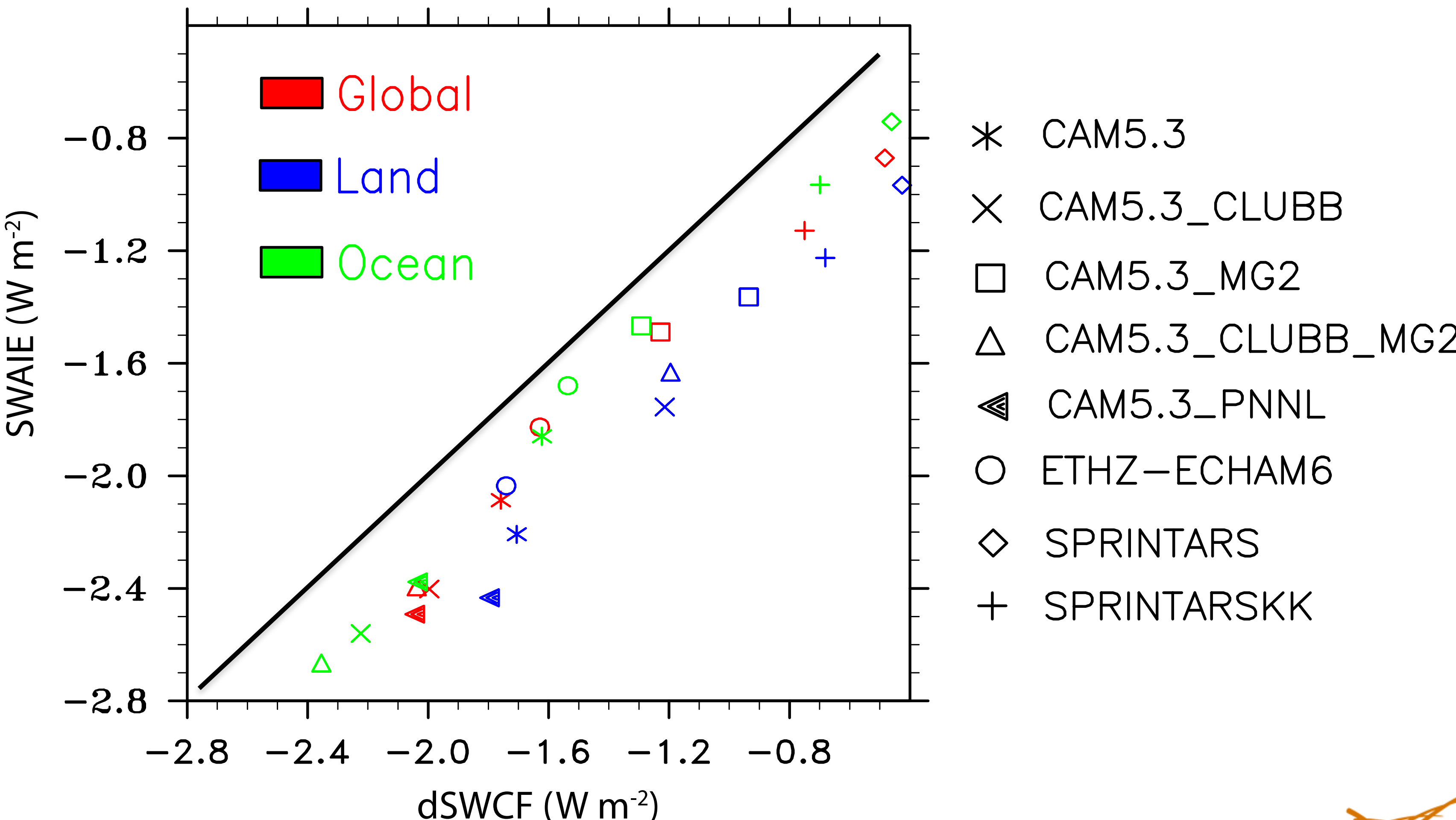
Aerosol shortwave indirect forcing (SWAIE)* vs change in shortwave cloud forcing (dSWCF)



*Ghan, *Atmos. Chem. Phys*. (2013)

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Factorization

$$\Delta R = R \frac{d \ln R}{d \ln \tau} \frac{d \ln \tau}{d \ln N_d} \frac{d \ln N_d}{d \ln CCN} \Delta \ln CCN$$

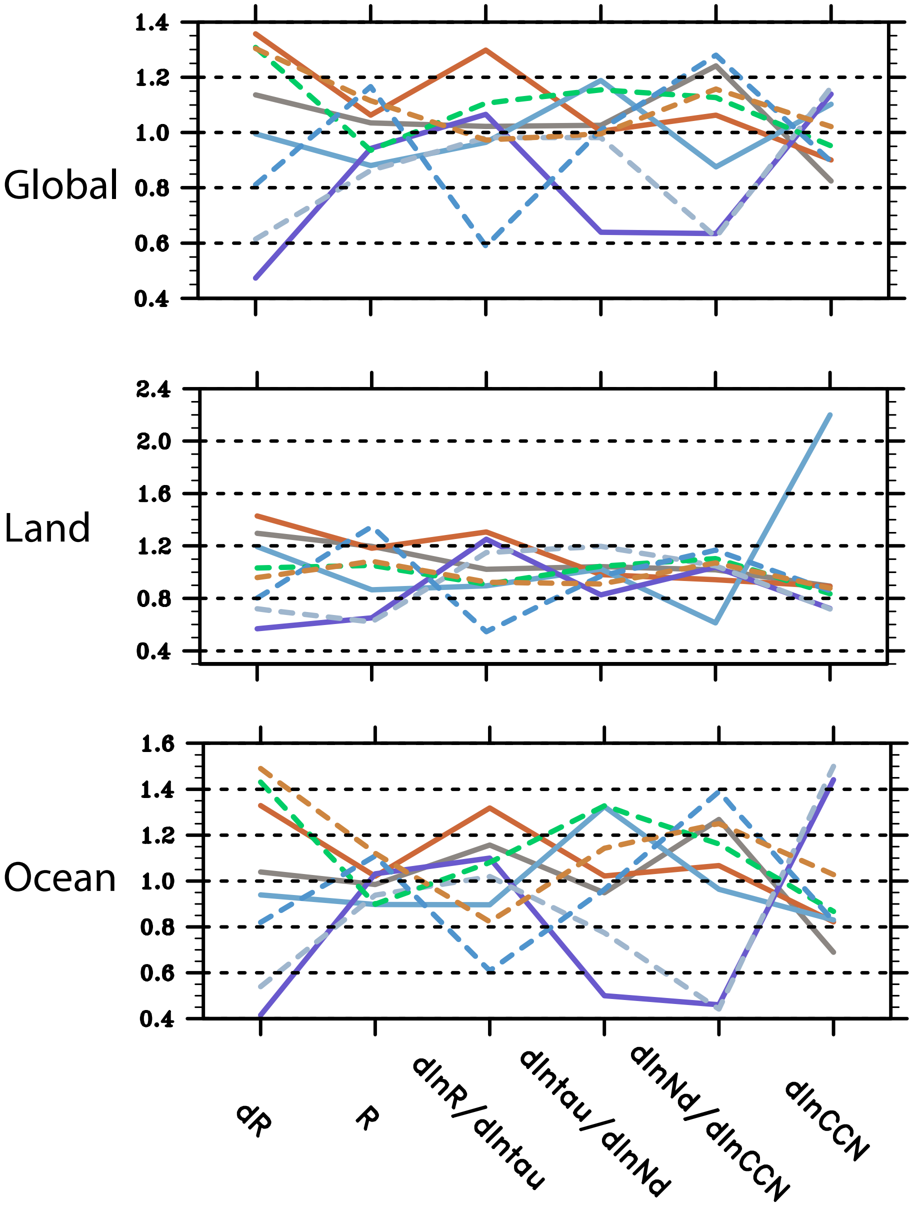
R: "clean-sky" shortwave cloud forcing
ΔR: aerosol indirect forcing, aka ERFaci
τ: cloud optical depth
N_d: cloud droplet number
L: liquid water path
r_e: droplet effective radius
CCN: CCN at 1 km (0.1% supersaturation)

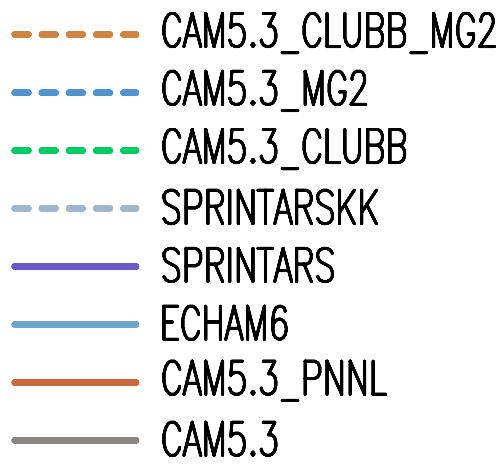
$$\frac{d \ln \tau}{d \ln N_d} = \frac{\partial \ln \tau}{\partial \ln L} \frac{\partial \ln L}{\partial \ln N_d} + \frac{\partial \ln \tau}{\partial \ln r_e} \frac{\partial \ln r_e}{\partial \ln N_d}$$

$$\approx \frac{\partial \ln L}{\partial \ln N_d} - \frac{\partial \ln r_e}{\partial \ln N_d}$$

$$\tau \propto \frac{L}{r_e}$$

Factorization





dR: AIE
R: shortwave cloud forcing
tau: cloud optical depth
Nd: cloud droplet number
CCN: CCN concentration

$$\Delta R = R \frac{d\ln R}{d\ln \tau} \frac{d\ln \tau}{d\ln N_d} \frac{d\ln N_d}{d\ln CCN} \Delta\ln CCN$$

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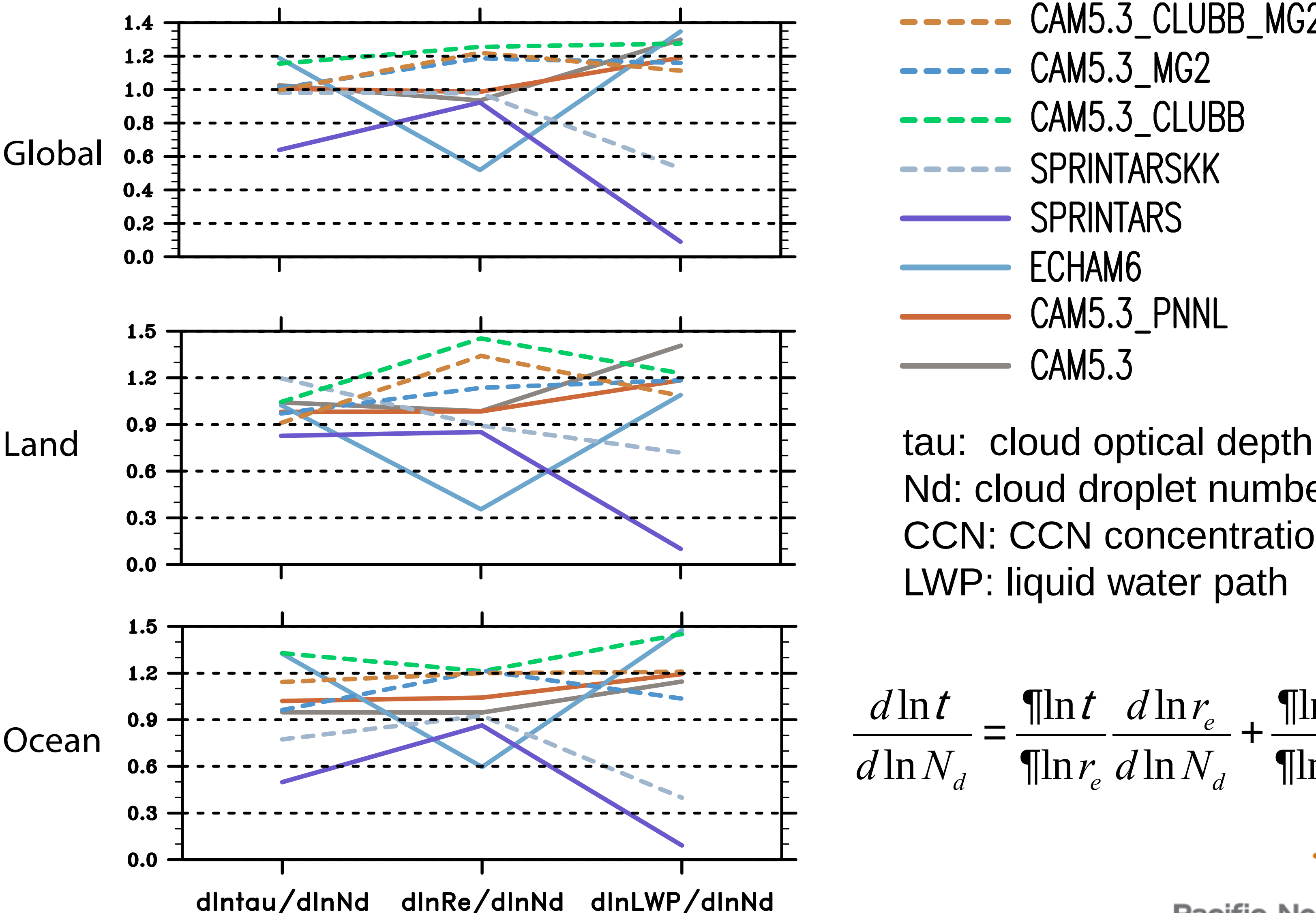
Factorization: dlntau/dlnN_d



tau: cloud optical depth
Nd: cloud droplet number
CCN: CCN concentration
LWP: liquid water path

$$\frac{d\ln\tau}{d\ln N_d} = \frac{\partial\ln\tau}{\partial\ln r_e}\frac{d\ln r_e}{d\ln N_d} + \frac{\partial\ln\tau}{\partial\ln L}\frac{d\ln L}{d\ln N_d}$$

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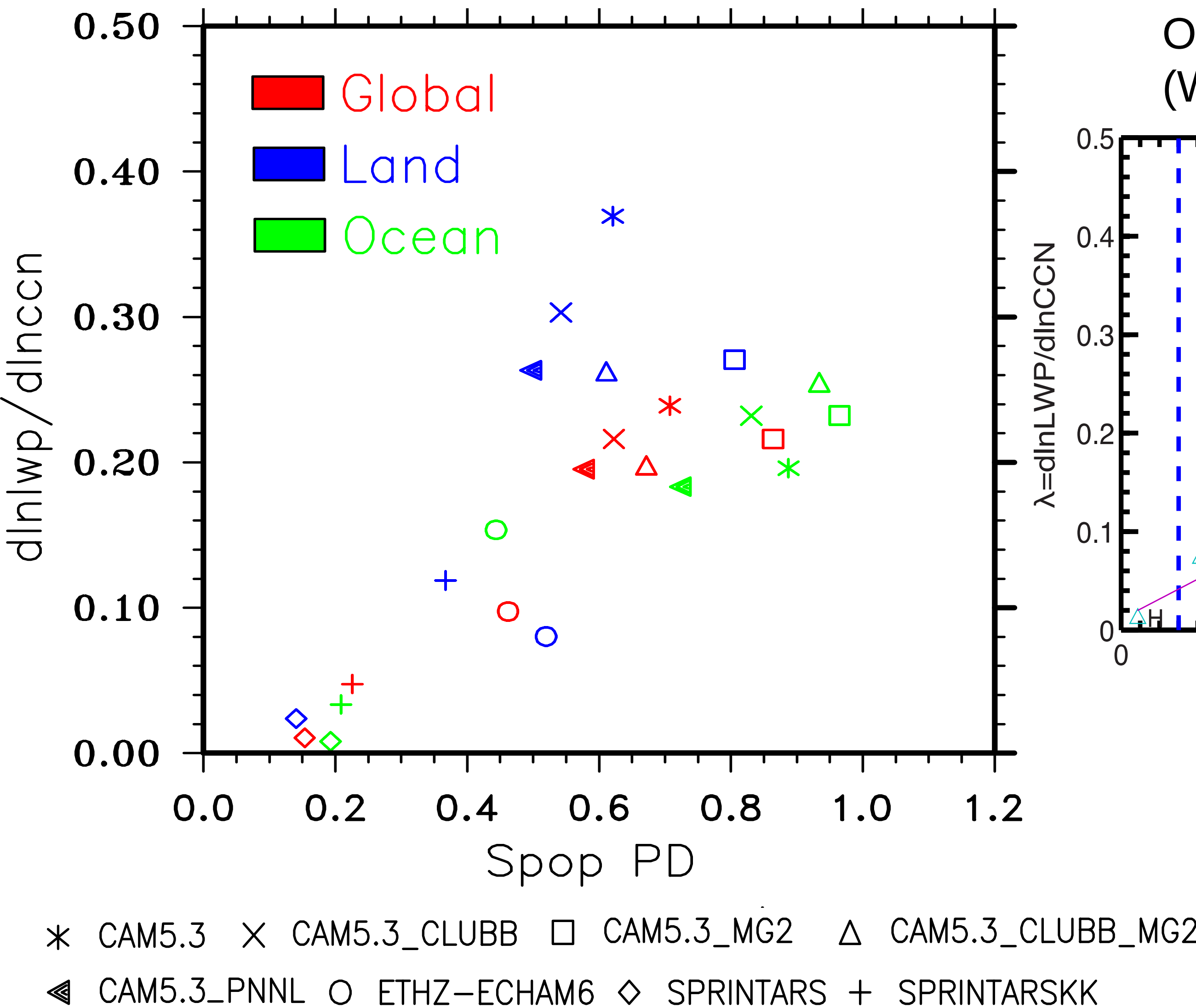
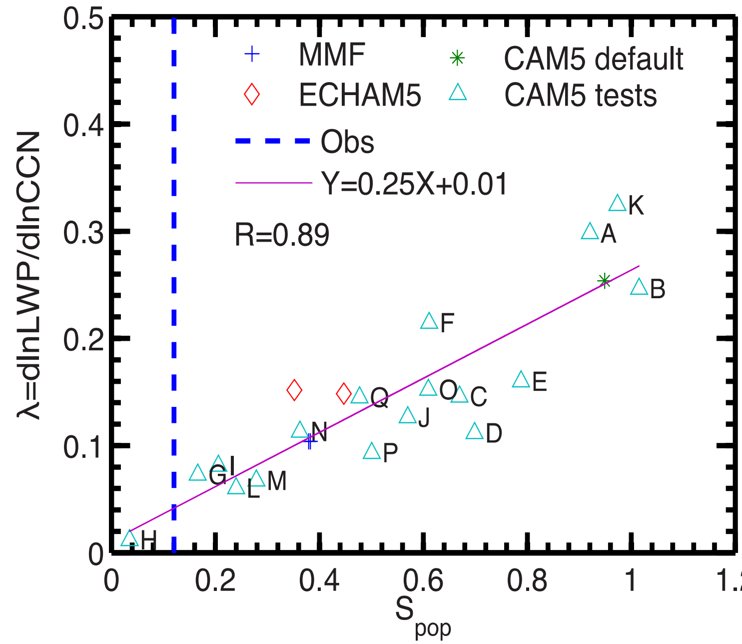
Spop vs. dlnLWP/dlnCCN



Over ocean
(Wang et al., 2012, GRL)



Spop=-dlnPOP/dlnAI

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Conclusions

- Constraints on sensitivity of LWP to aerosol are helpful
- Sensitivity of droplet number to CCN also contributes to uncertainty in indirect effects; constraints are needed
- Compare sensitivities from present day spatial variability with sensitivities from anthropogenic change
- Examination of results from other models will fill out the exploration of parameter space

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THANKS!

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