Aerosol indirect effect in satellite observations and the LMDZ GCM

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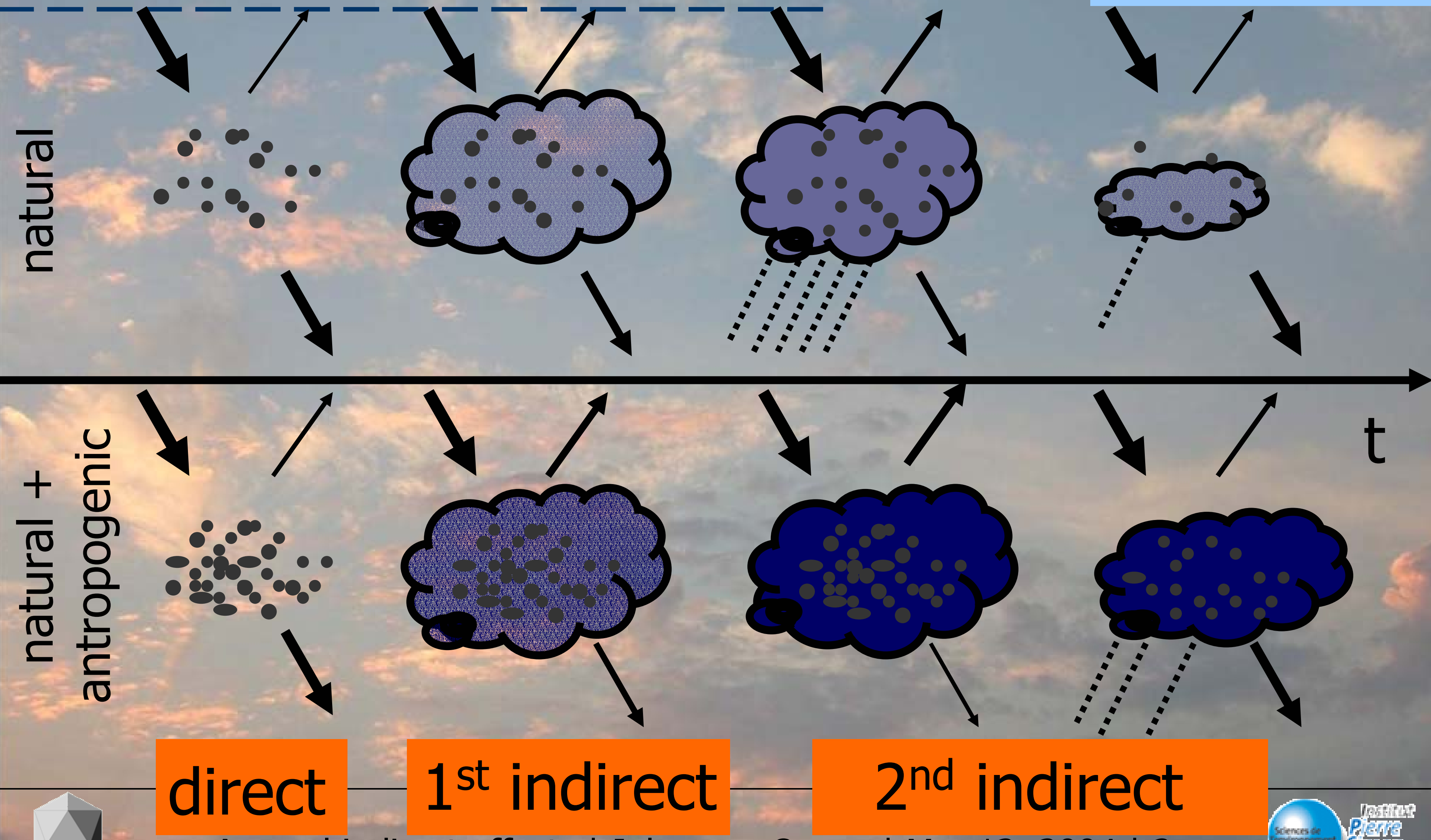
Sciences de l'Environnement
Institut Pierre Simon Laplace

Aerosol radiative effects

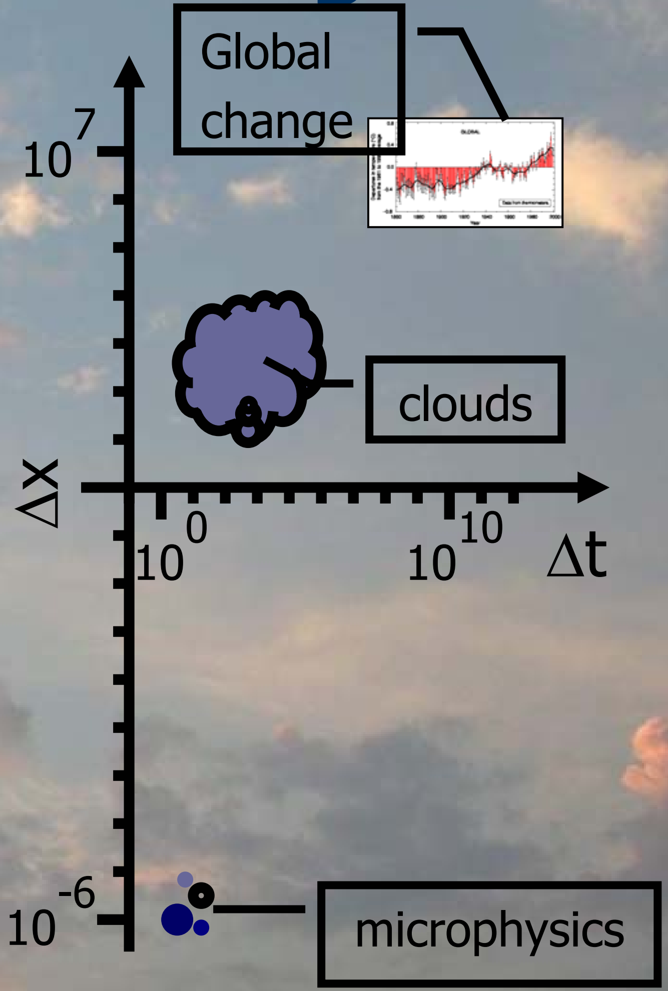
$$\tau_c = \frac{3}{2}\frac{LWP}{\rho_w r_e}$$



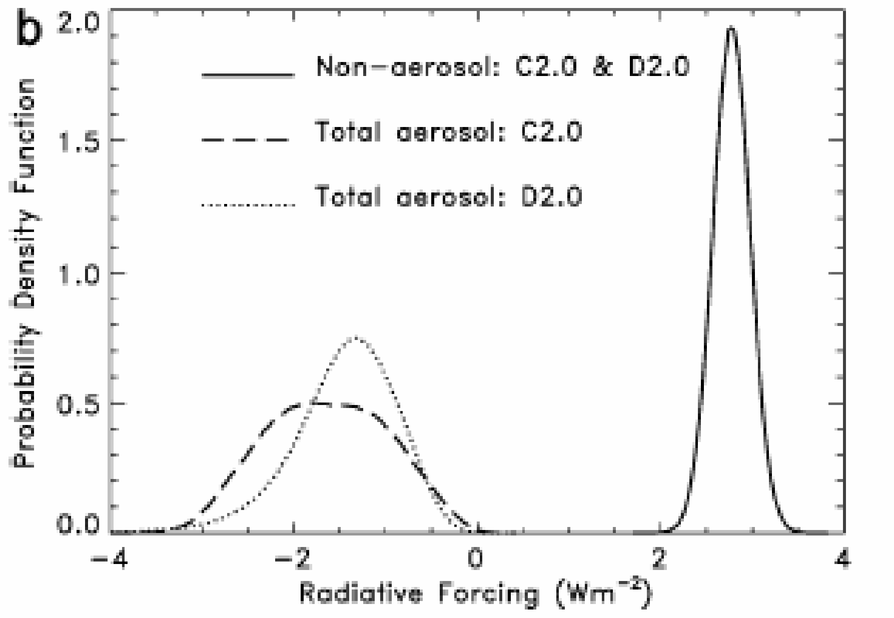
Aerosol indirect effects – from microphysics to global change

- Microphysics – 10^{-6} m, 10^{0} s
- Global change – 10^{7} m, 10^{10} s

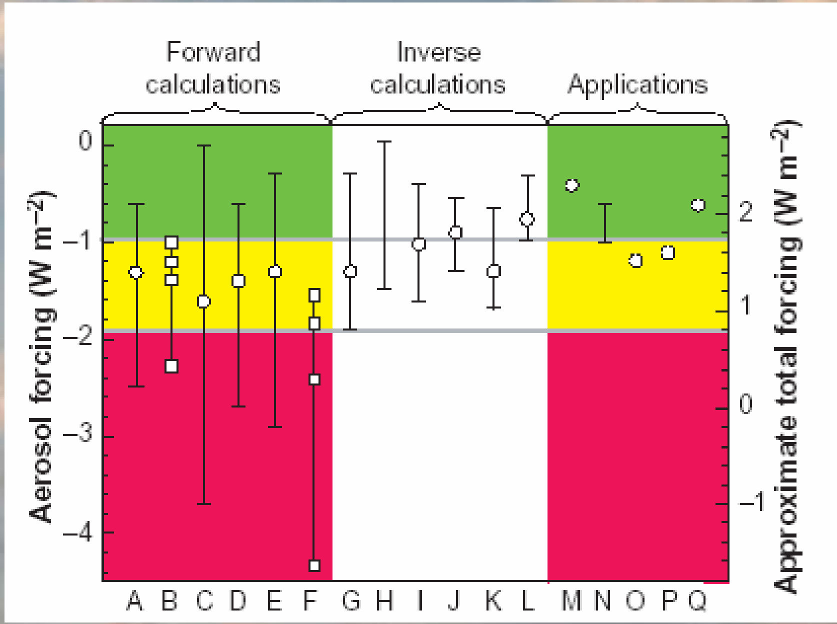
- *IPCC* (2001): Level of scientific understanding „very low“



Uncertainties

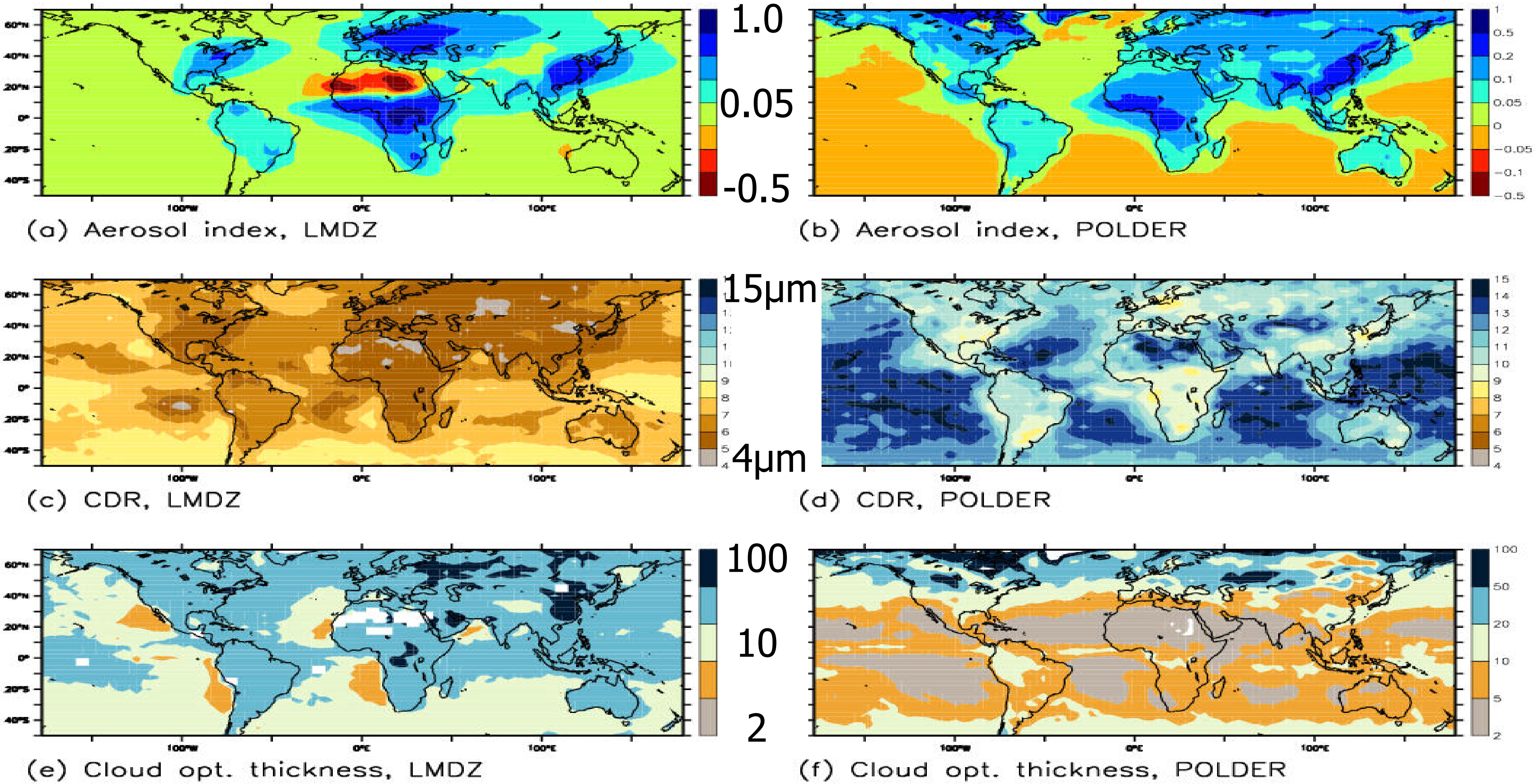


Boucher and Haywood, CD 2001

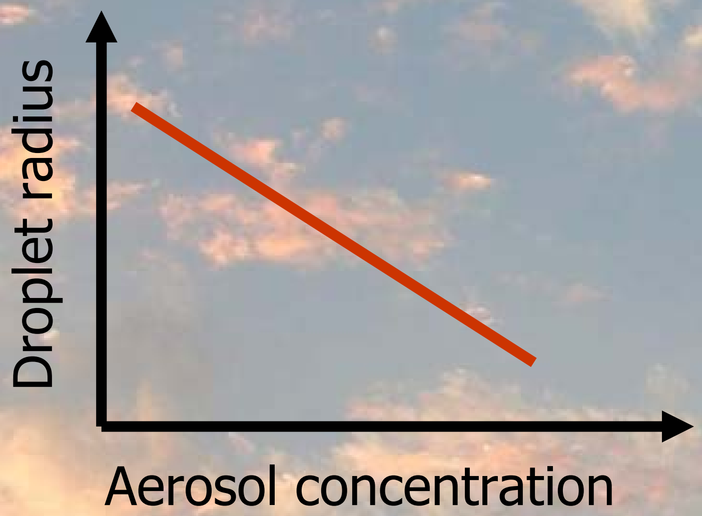


Anderson et al., Science 2003

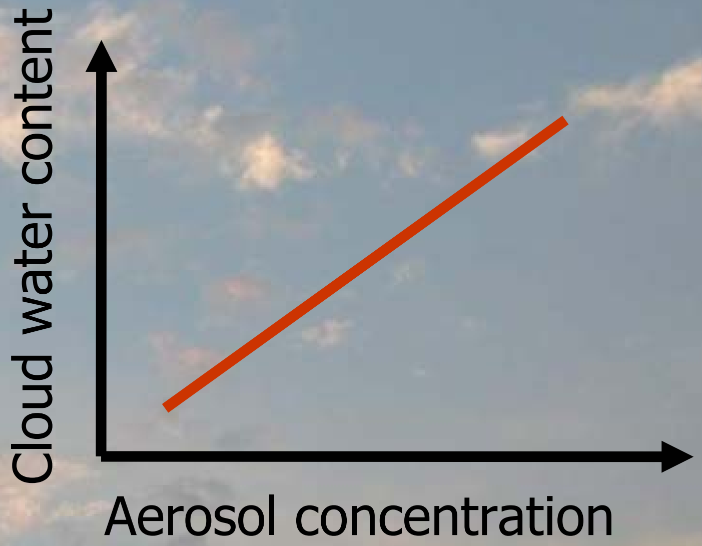
Satellite observations



Statistical description

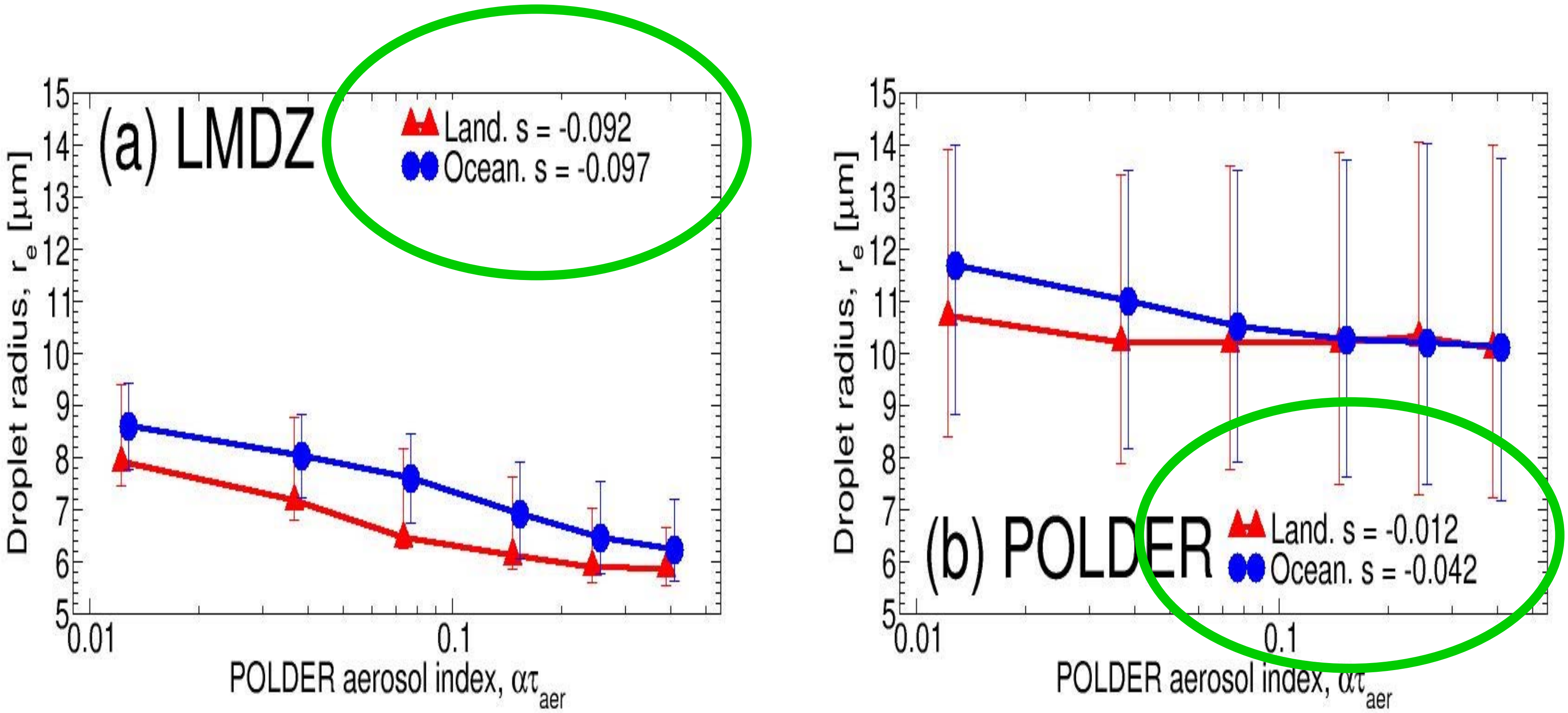


First aerosol indirect effect



Second aerosol indirect effect

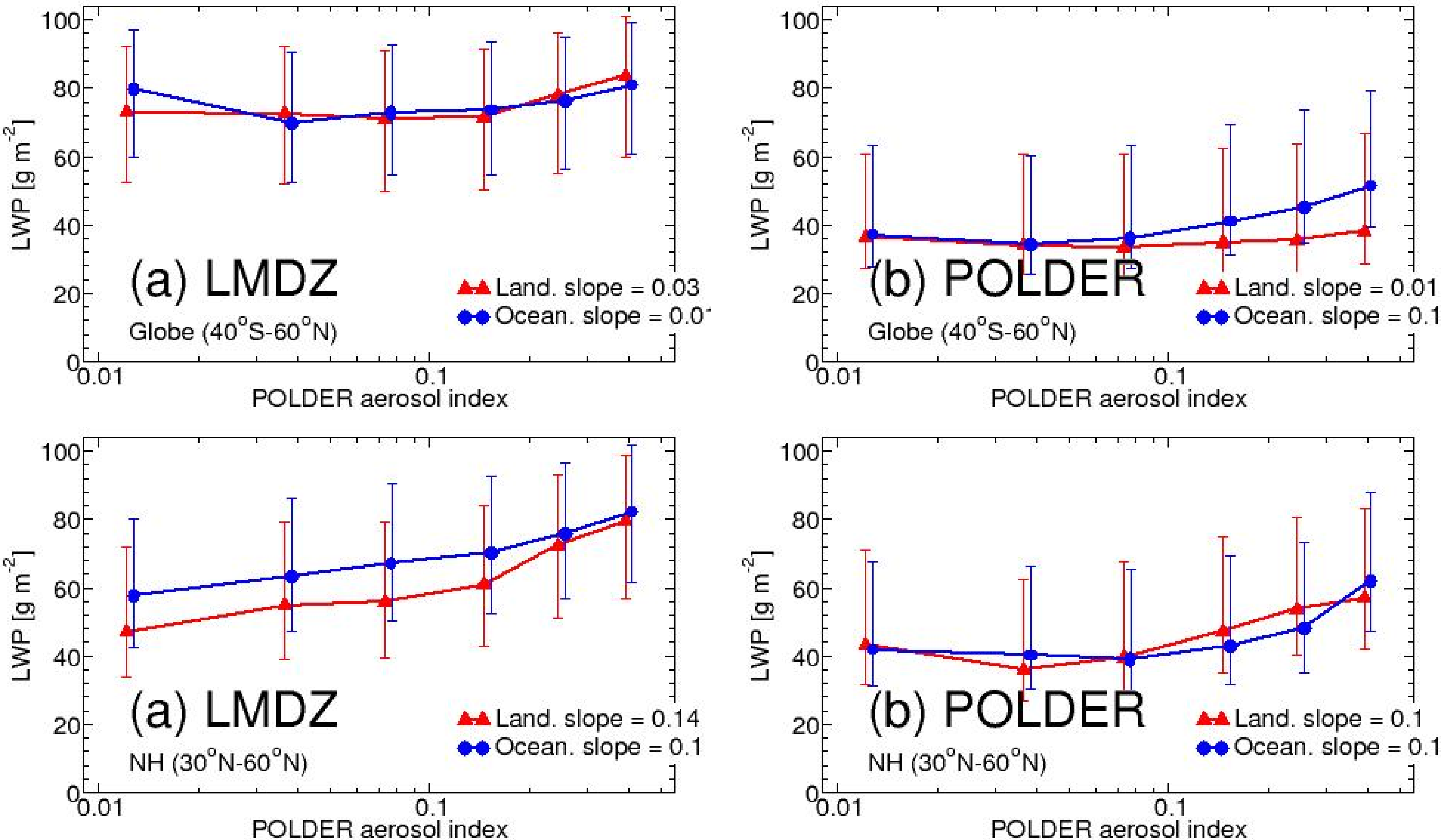
Droplet radius – aerosol index



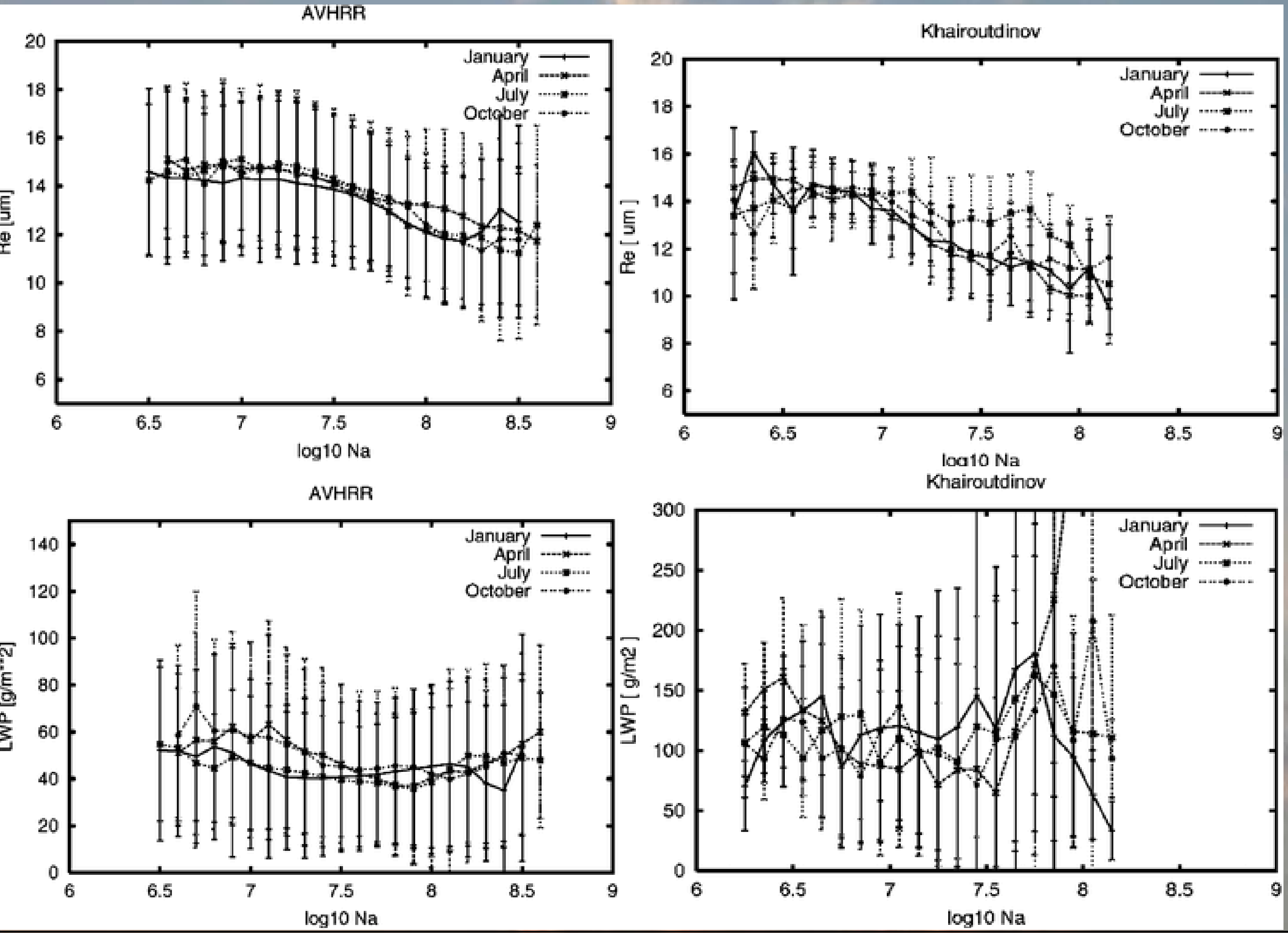
- Slope: $s = \partial \log r_e / \partial \log \alpha\tau$

Quaas et al., JGR 2004

LWP – aerosol index



Other studies

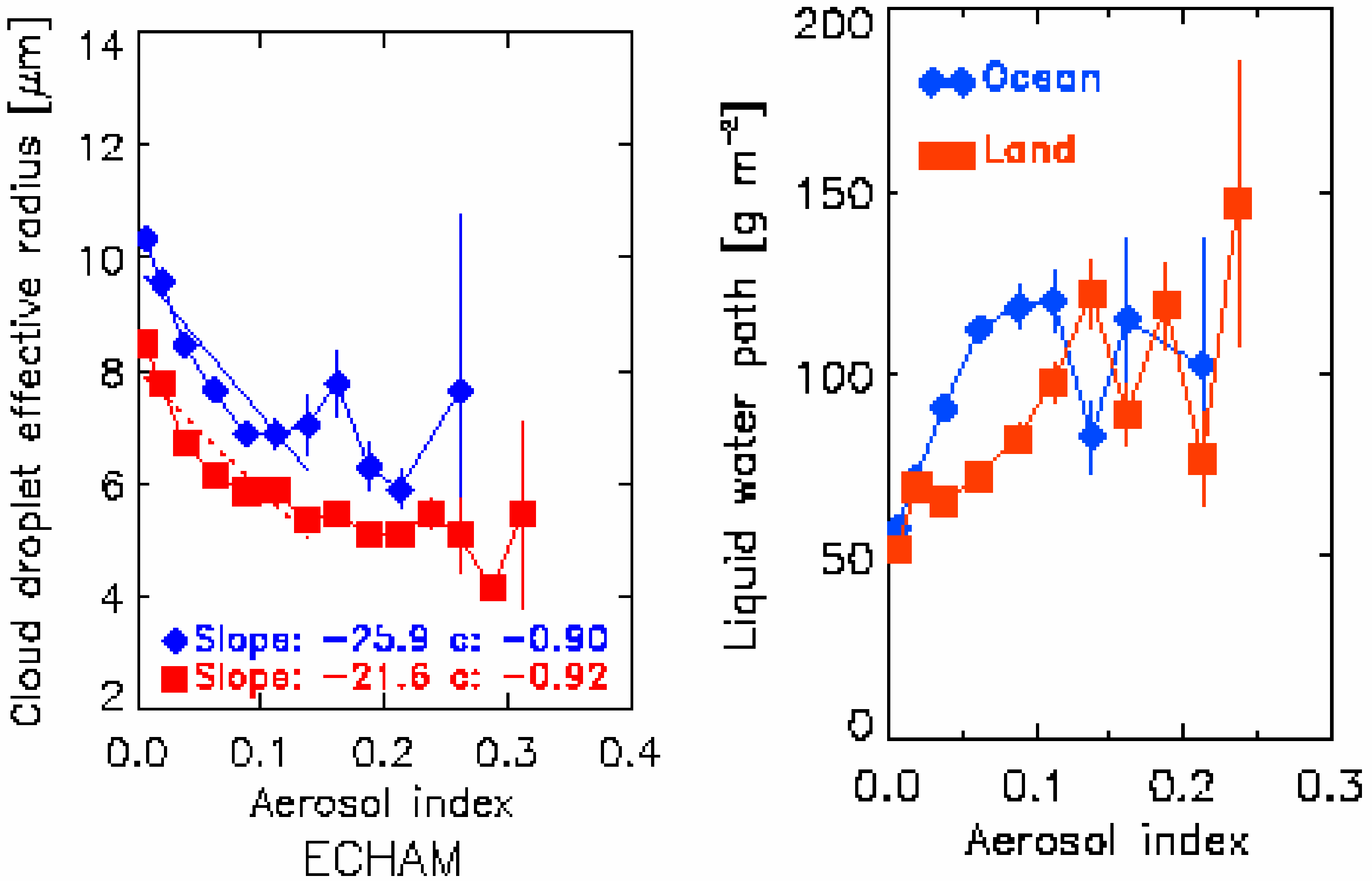


CDR- N_a

LWP- N_a

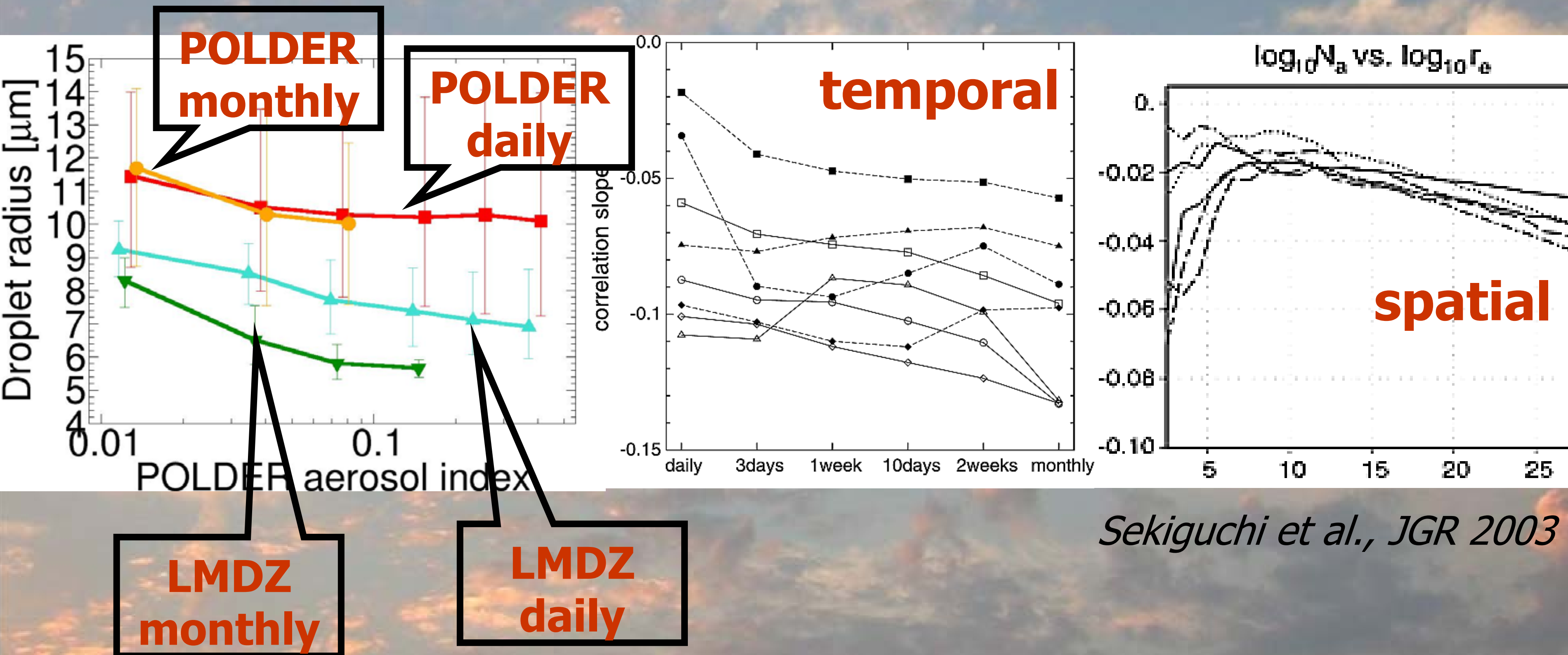
Suzuki et al., JAS 2004

Other studies (2)



Lohmann and Lesins, GRL 2003

Resolution dependency



Sekiguchi et al., JGR 2003

Evaluations of the first aerosol indirect radiative forcing

Use in ensemble simulations

Jean-Louis Dufresne: *Aerosol indirect effects in an ensemble climate change scenario with the ISPL Earth system model*

- Aerosols:
  - sulfate only
  - from files
- No detailed microphysical scheme
- CDR size to be fitted

Simplicity

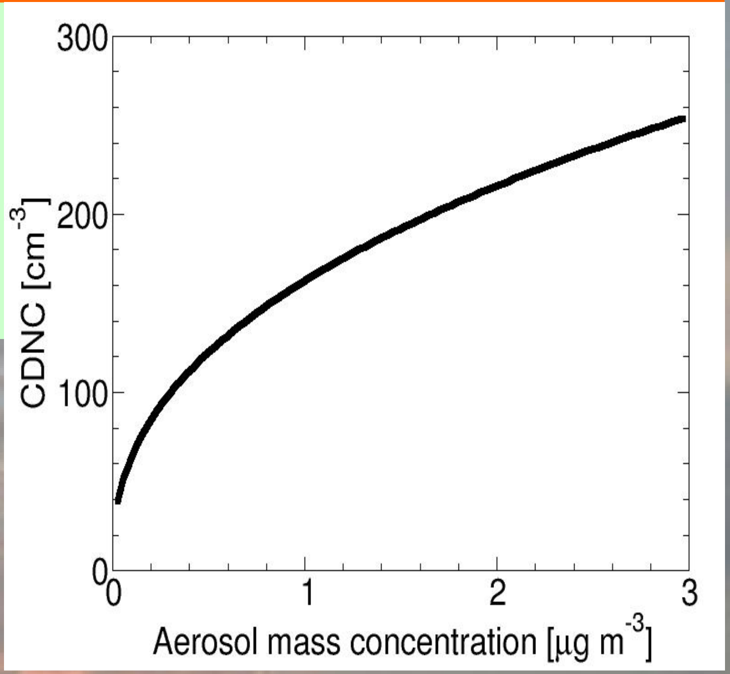
Cloud droplet number linked to sulfate aerosol

$$N_d = \exp\left(a_0 + a_1 \ln m_a\right)$$

Boucher and Lohmann, Tellus 1995

Consider LWC const.:

$$r_e \propto N_d^{-1/3}$$



Simplicity

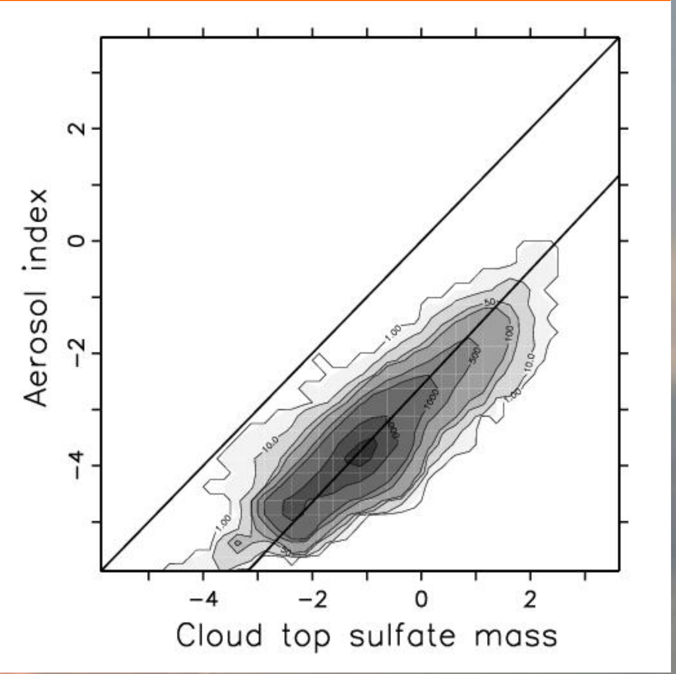
Cloud droplet number linked to sulfate aerosol

$$N_d = \exp\left(a_0 + a_1 \ln m_a\right)$$

Boucher and Lohmann, Tellus 1995

Link mass to opt depth:

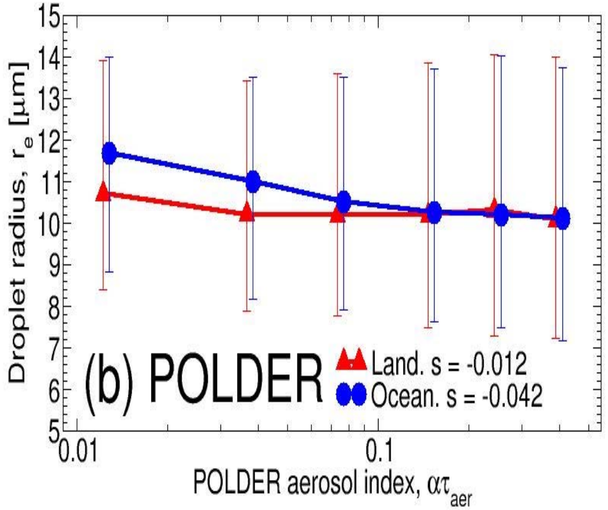
$$\ln m_a = d_0 + d_1 \ln \tau_a$$



Simplicity

$$r_e \propto \exp\left(-\frac{a_1}{3} d_1 \ln \tau_a\right)$$

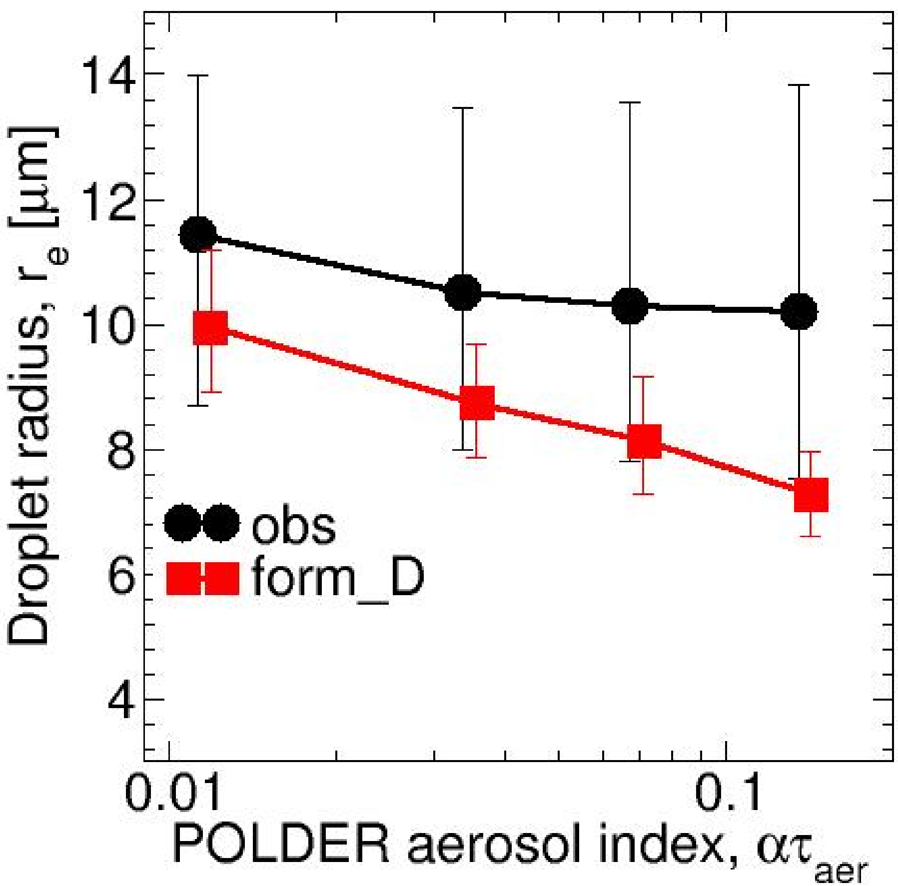
$$IE = \frac{\partial \ln r_e}{\partial \ln \tau_a} = -\frac{a_1}{3} d_1$$

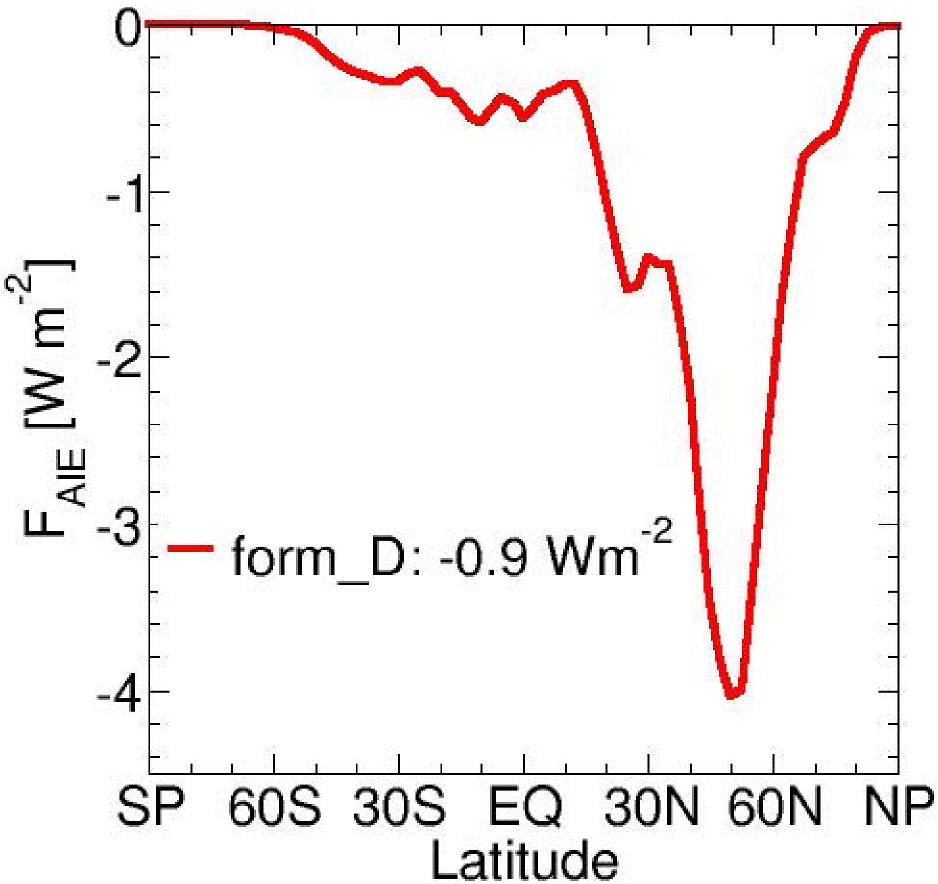


Standard (Formula "D"): **a_1=0.41**

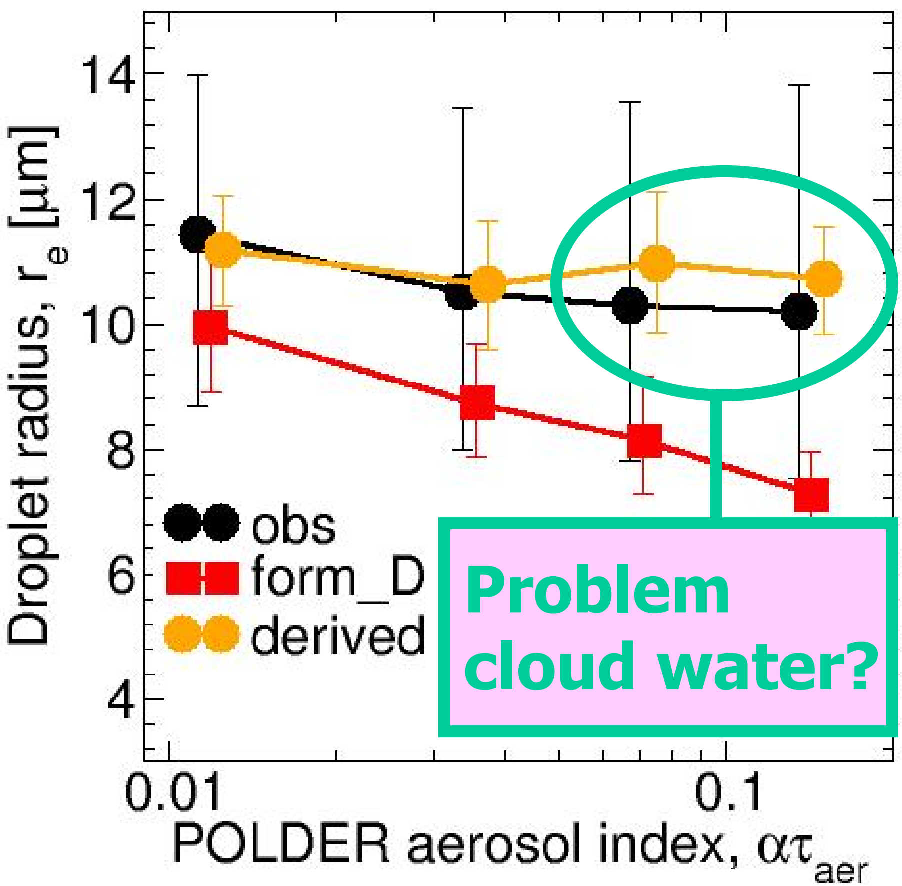
Derived: d1=0.97, IE=-0.042 -> **a_1=0.13**

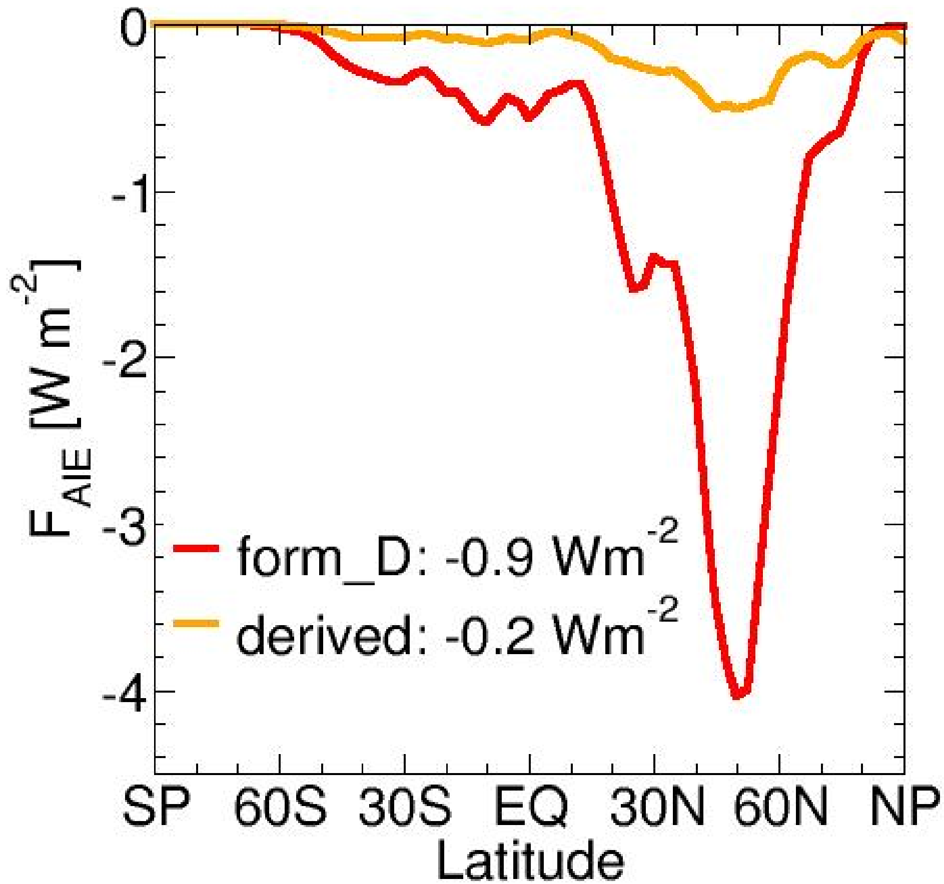
CDR-AI relationships and forcing



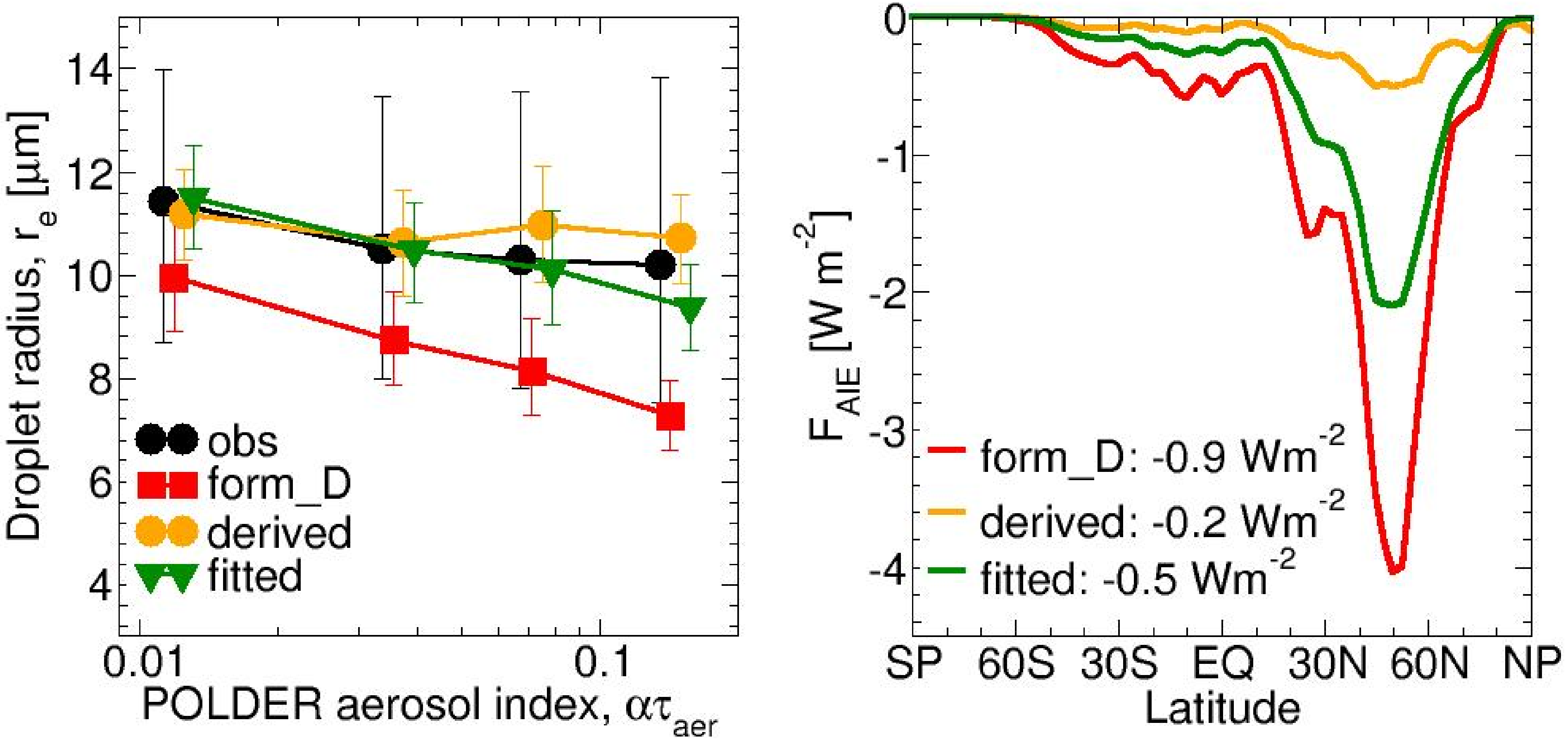


CDR-AI relationships and forcing



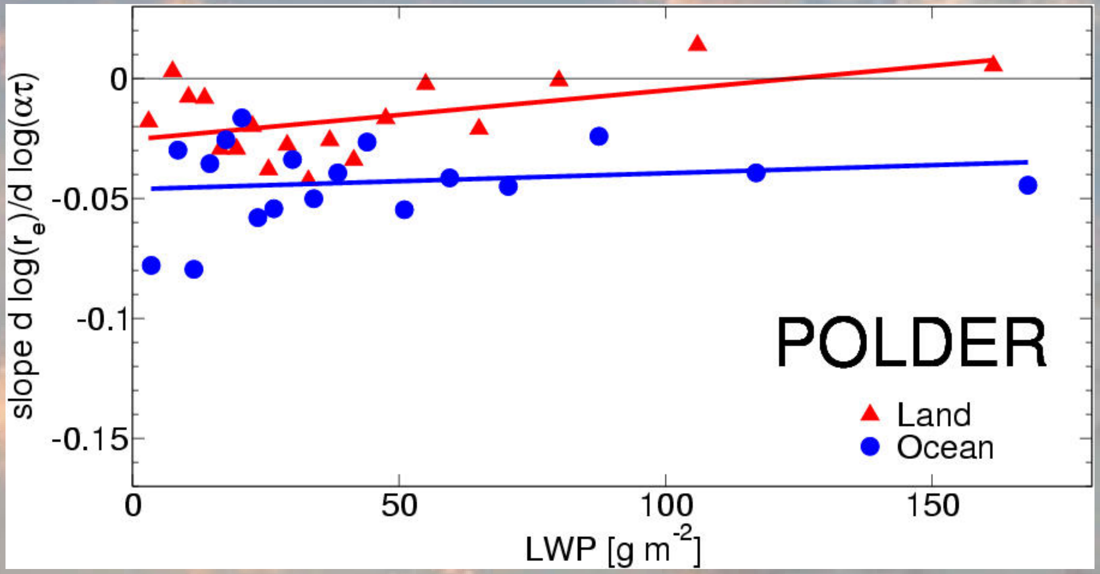


CDR-AI relationships and forcing



Cloud type dependency?

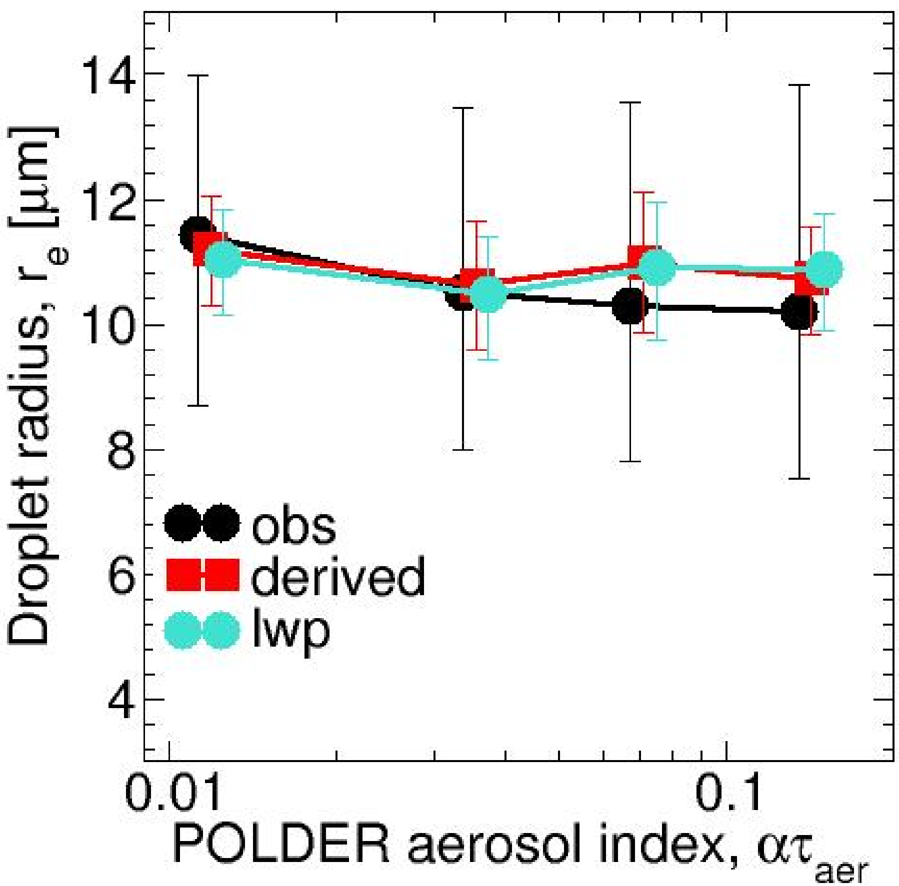
Hans Feichter: *Look at different cloud types!*

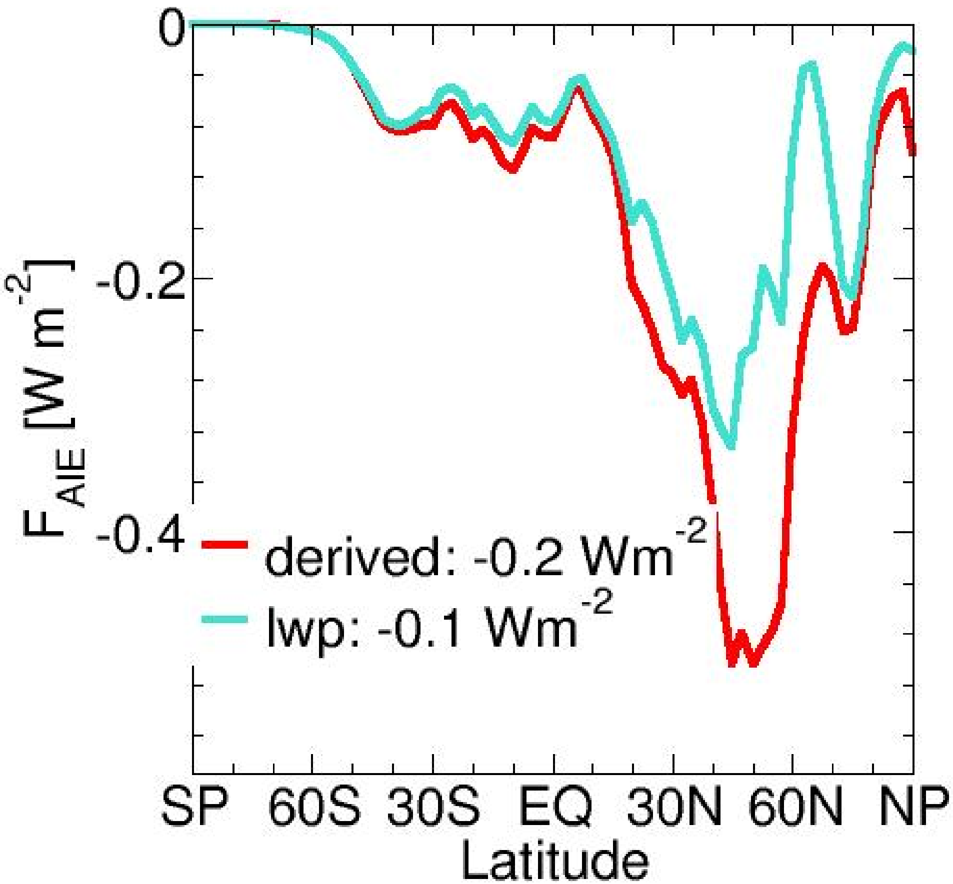


$$IE = k_0 + k_1 LWP$$

$$a_1 = -\frac{3}{d_1}\left(k_0 + k_1 LWP\right)$$

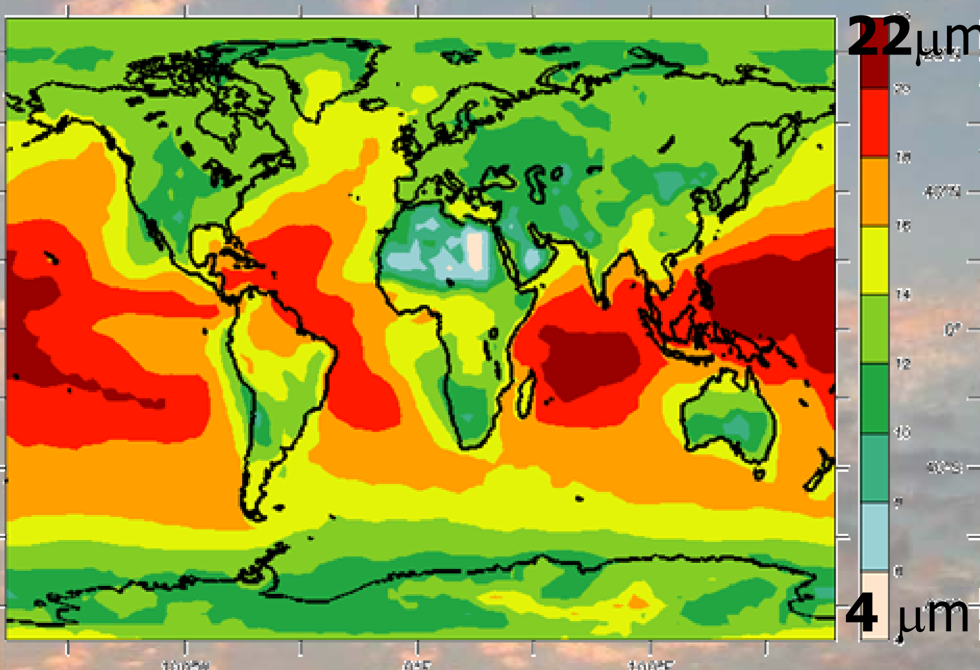
CDR-AI relationships and forcing

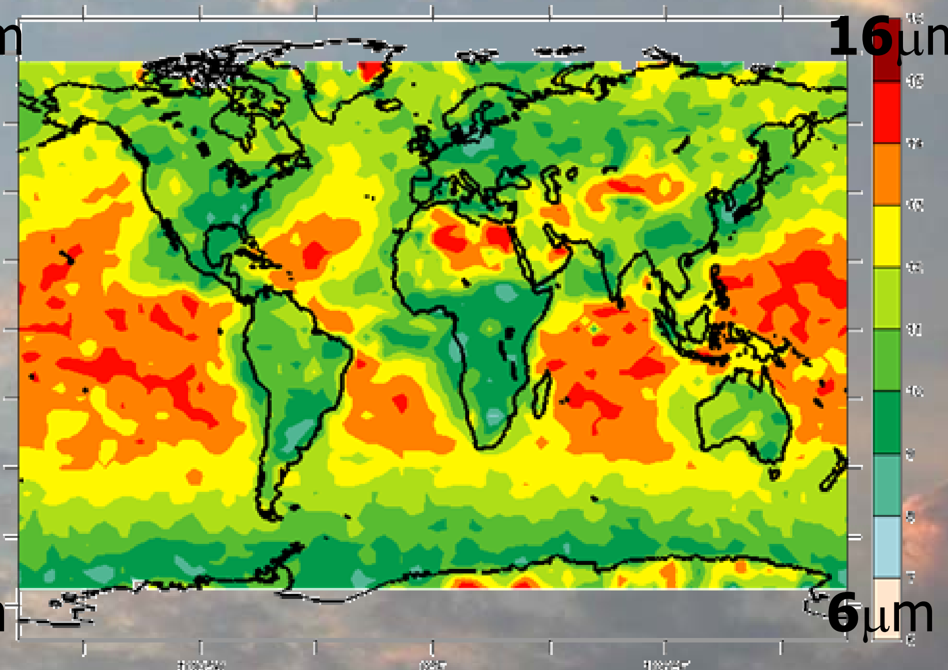




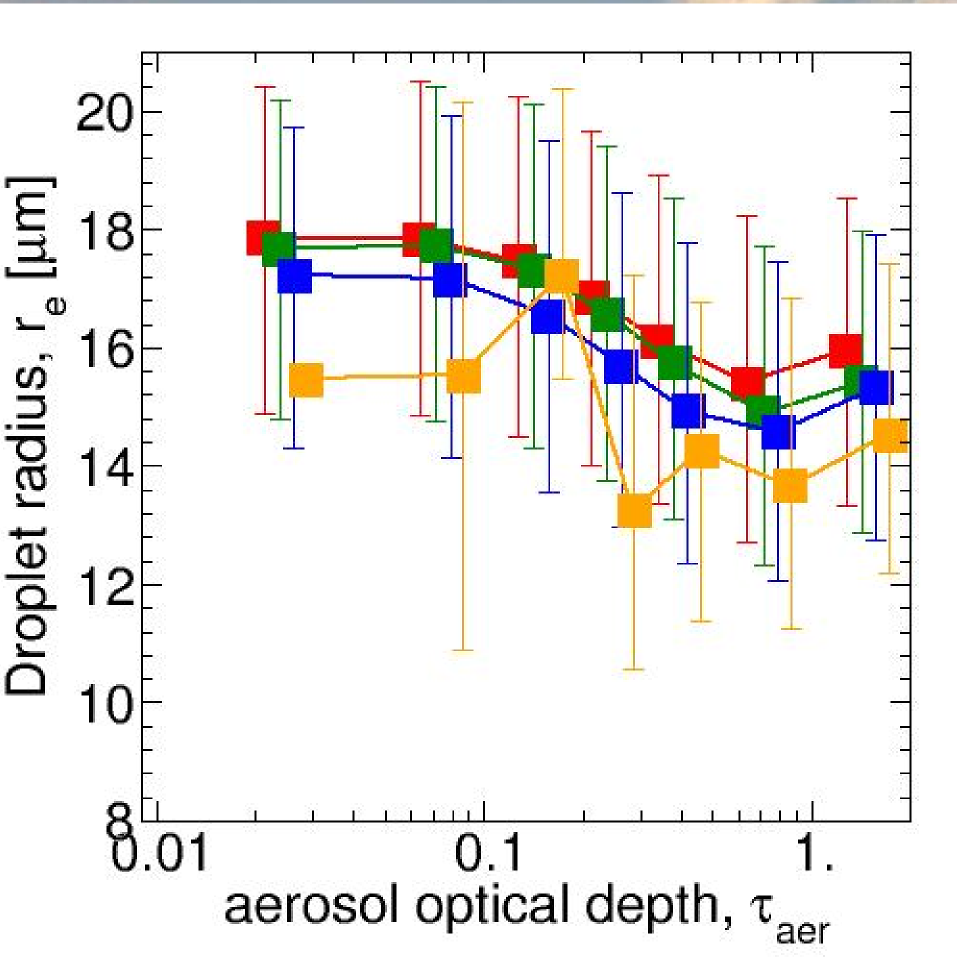
MODIS observations

- Stefan Kinne: *Look at MODIS data!*





MODIS observations



POLDER observations for "homogeneous" liquid water clouds

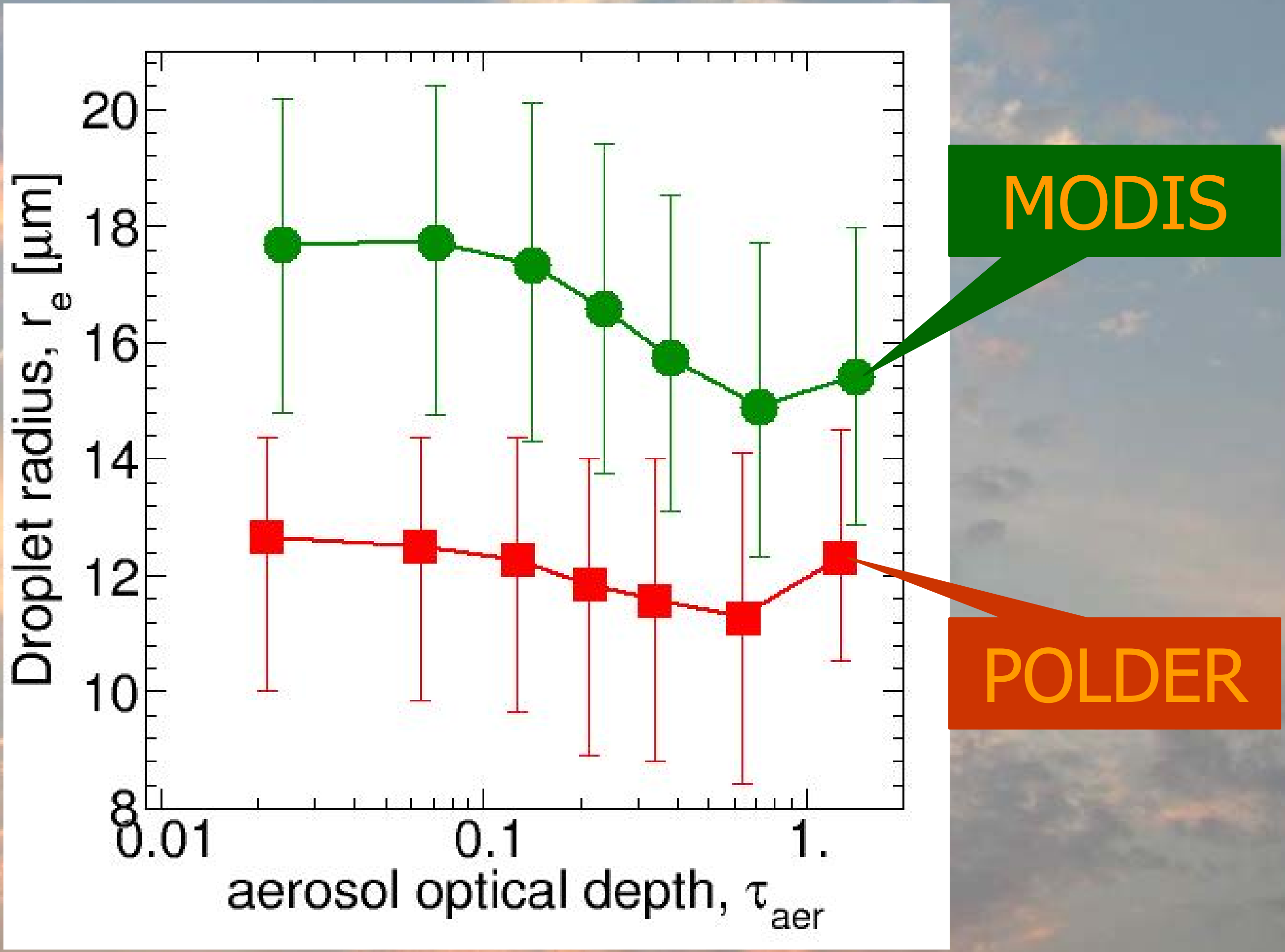
f_{liq} > 10% at each point

f_{liq} > 25%

f_{liq} > 50%

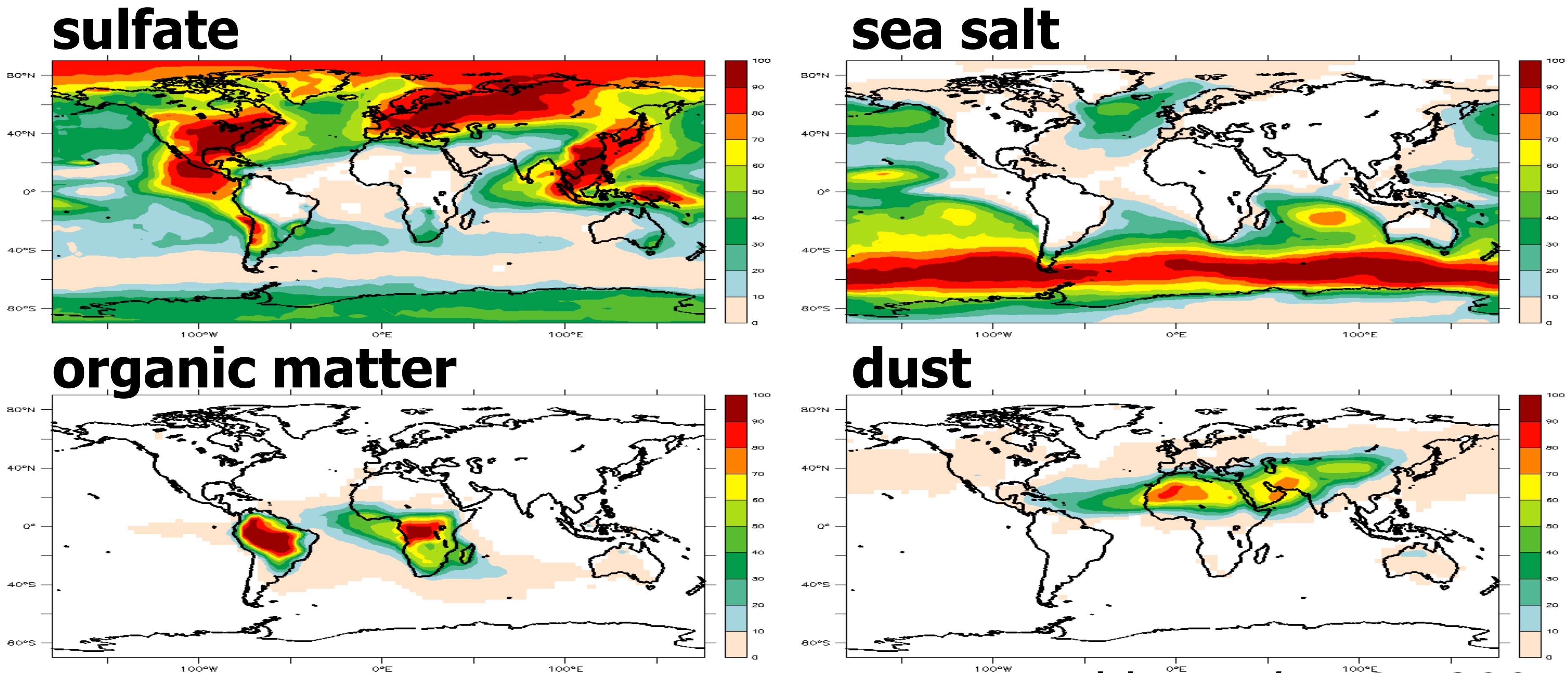
f_{liq} = 100%

MODIS observations



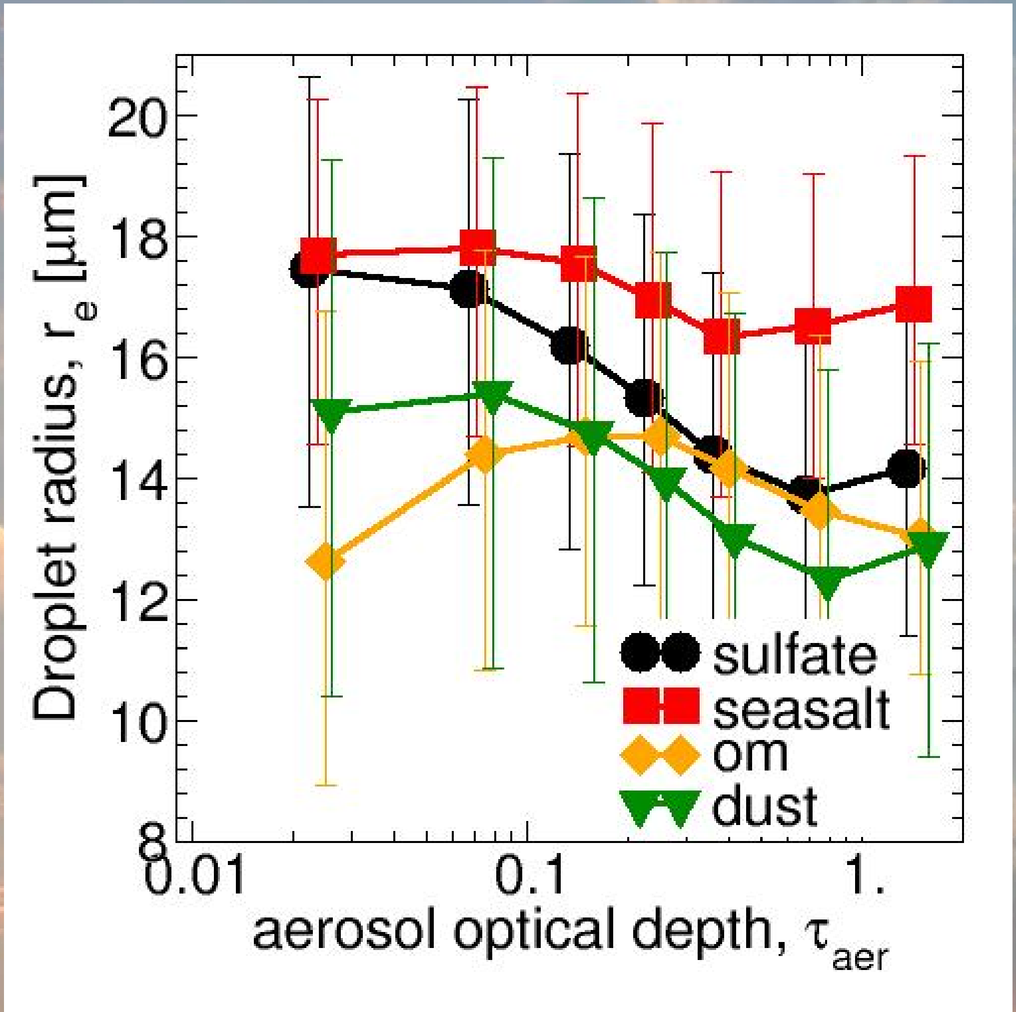
Different aerosol types

- Yves Balkanski: *Look at different aerosol types!*



Reddy et al., JGR 2004

Different aerosol types



MODIS data

Aerosol classification from LMDZ/LOA model

Conclusions (1/2)

- Statistical relationships show AIE
- Spatial and temporal resolution influences relations

- Simple parameterization useful to analyze aerosol indirect forcing
- Analytical fit unsatisfying (problems with cloud description?)
- Fit to POLDER data: Aerosol indirect forcing reduced by 50%
  - 0.9 Wm^{-2} to -0.5 Wm^{-2}
  - Influence of resolution!

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Conclusions (2/2)

- LWP dependent fit shows no significant difference
- MODIS data shows larger indirect effect compared to POLDER (perhaps MODIS CDR too large)
- Sulfate provokes by far strongest indirect effect

- Near future:
  - Quantify differences in forcing from POLDER and MODIS
  - Include different aerosol types in analysis

Thank you.

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