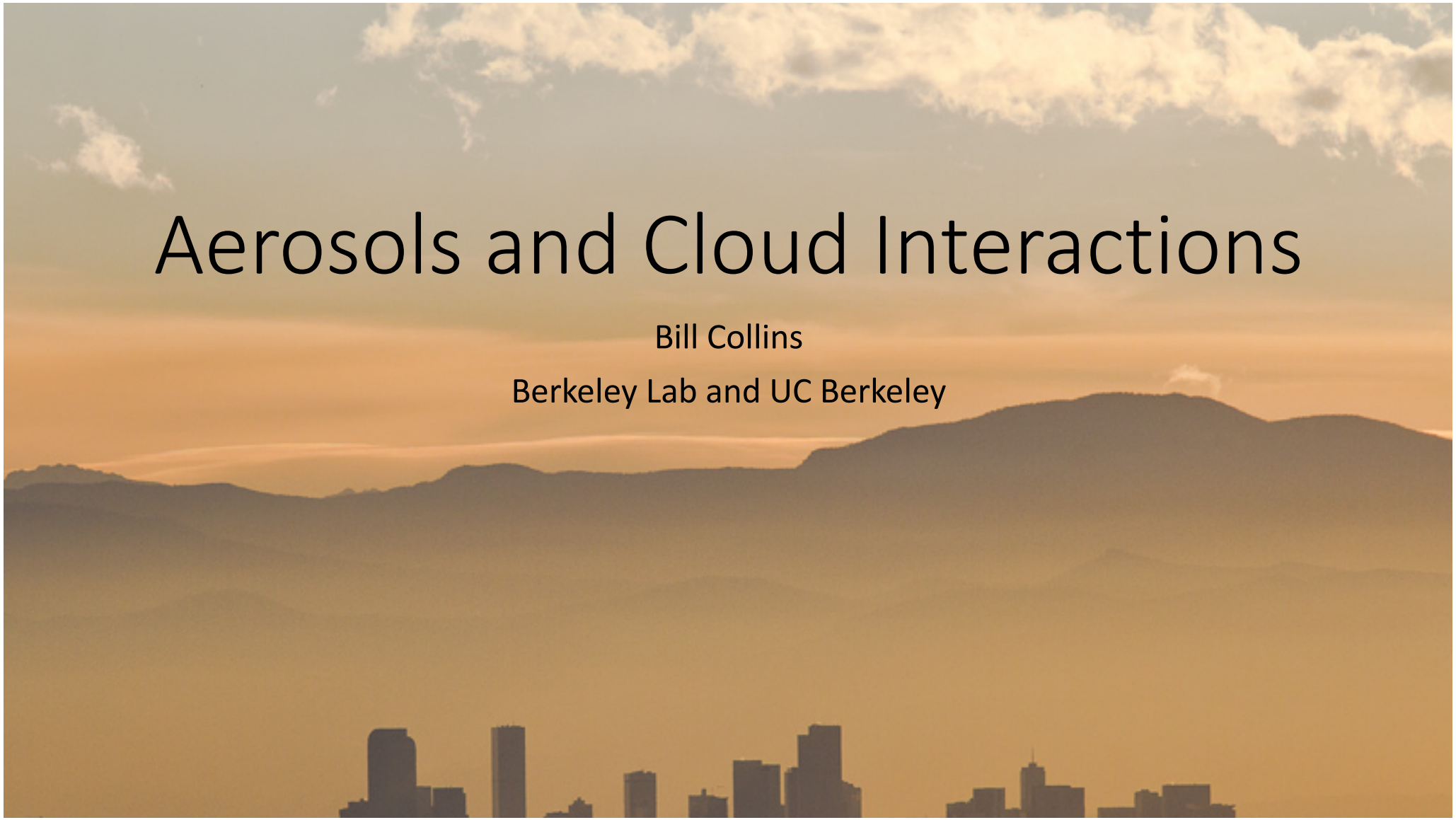


Aerosols and Cloud Interactions

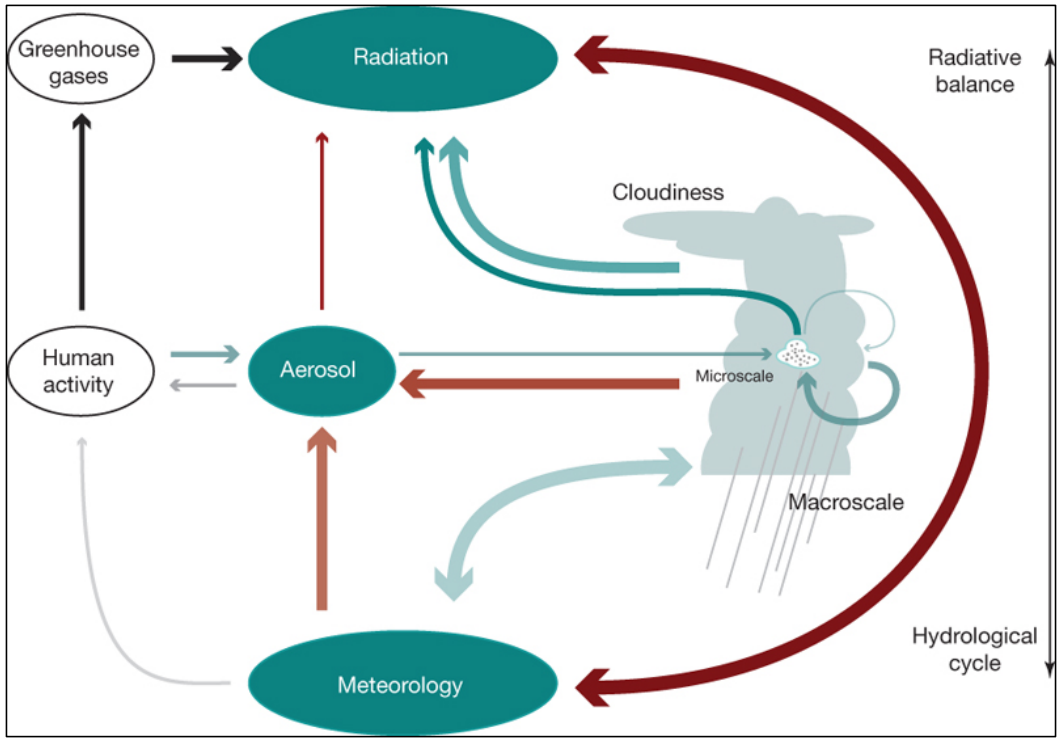
Bill Collins

Berkeley Lab and UC Berkeley

Outline

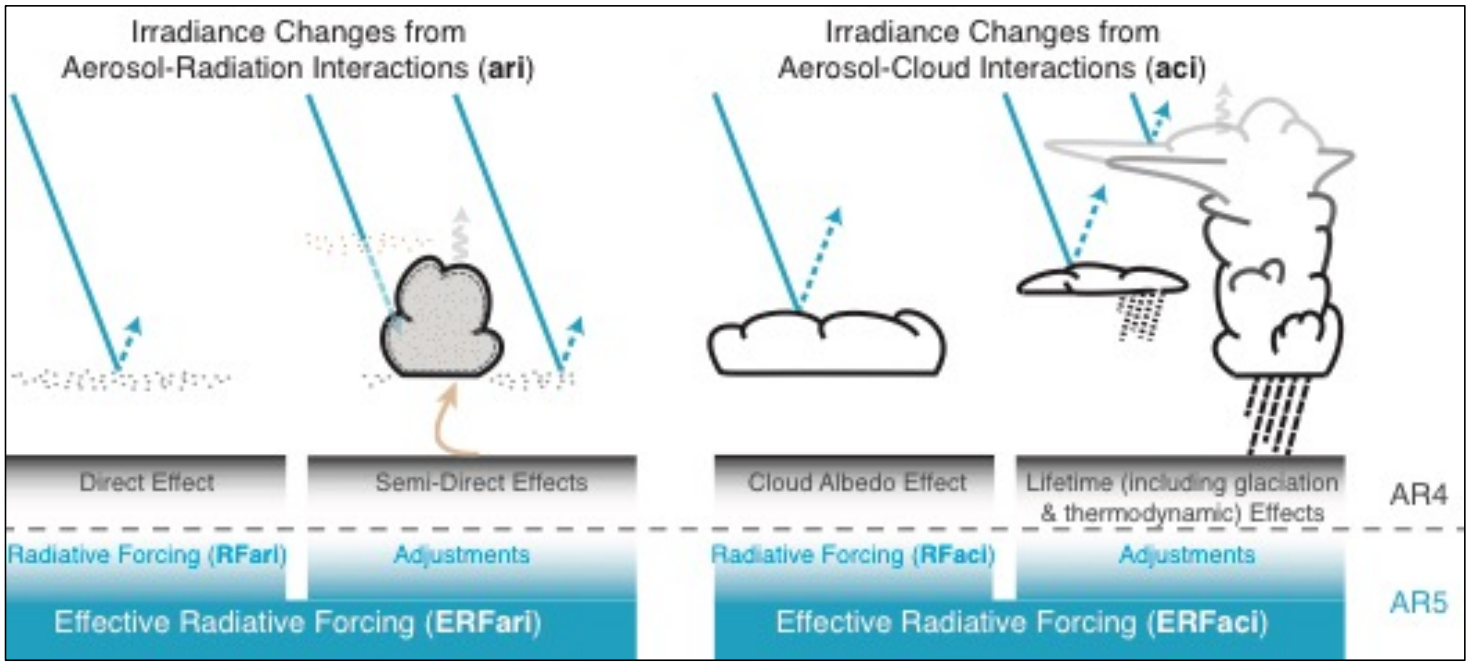
- Aerosol / Cloud Interactions circa IPCC AR5
- Implications of interaction uncertainties for climate projections
- Progress on the 1st indirect effect (RFaci) from anthropogenic aerosols
- Further progress using natural biogenic and volcanic aerosols
- Natural experiments suggest 2nd indirect effect is smaller than thought.
- Supporting satellite and model evidence for this conclusion
- New paradigms for understanding buffering effect of cloud dynamics

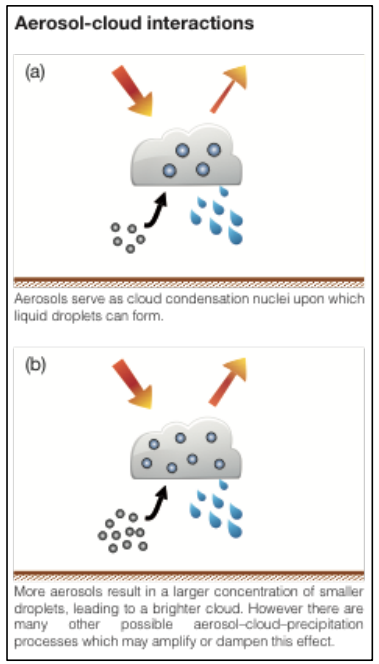
Aerosol / Cloud Interactions in Earth System



Stevens & Feingold, 2009

Radiative Aerosol / Cloud Interactions

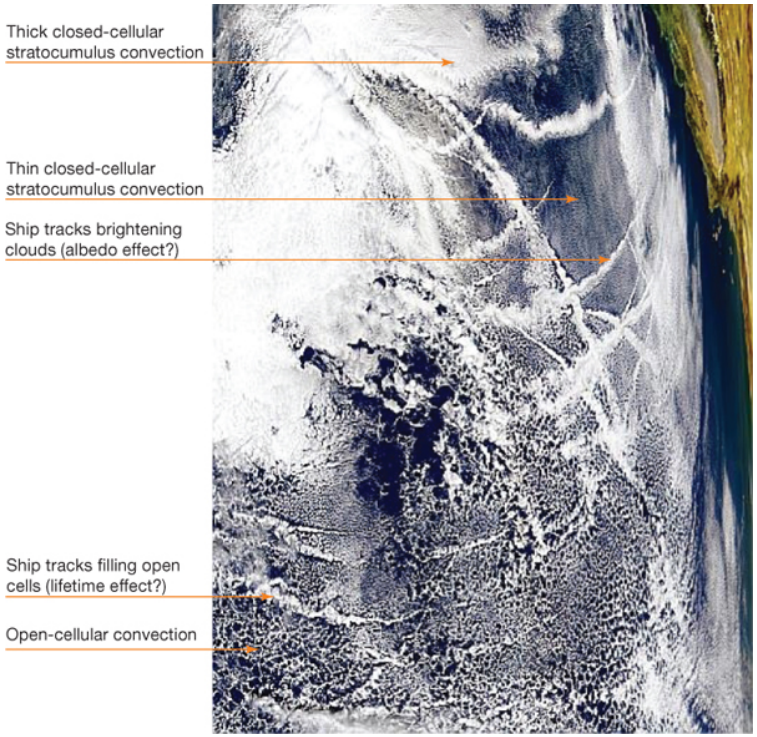




IPCC AR5 Fig 7.3, FAQ 7.2-2

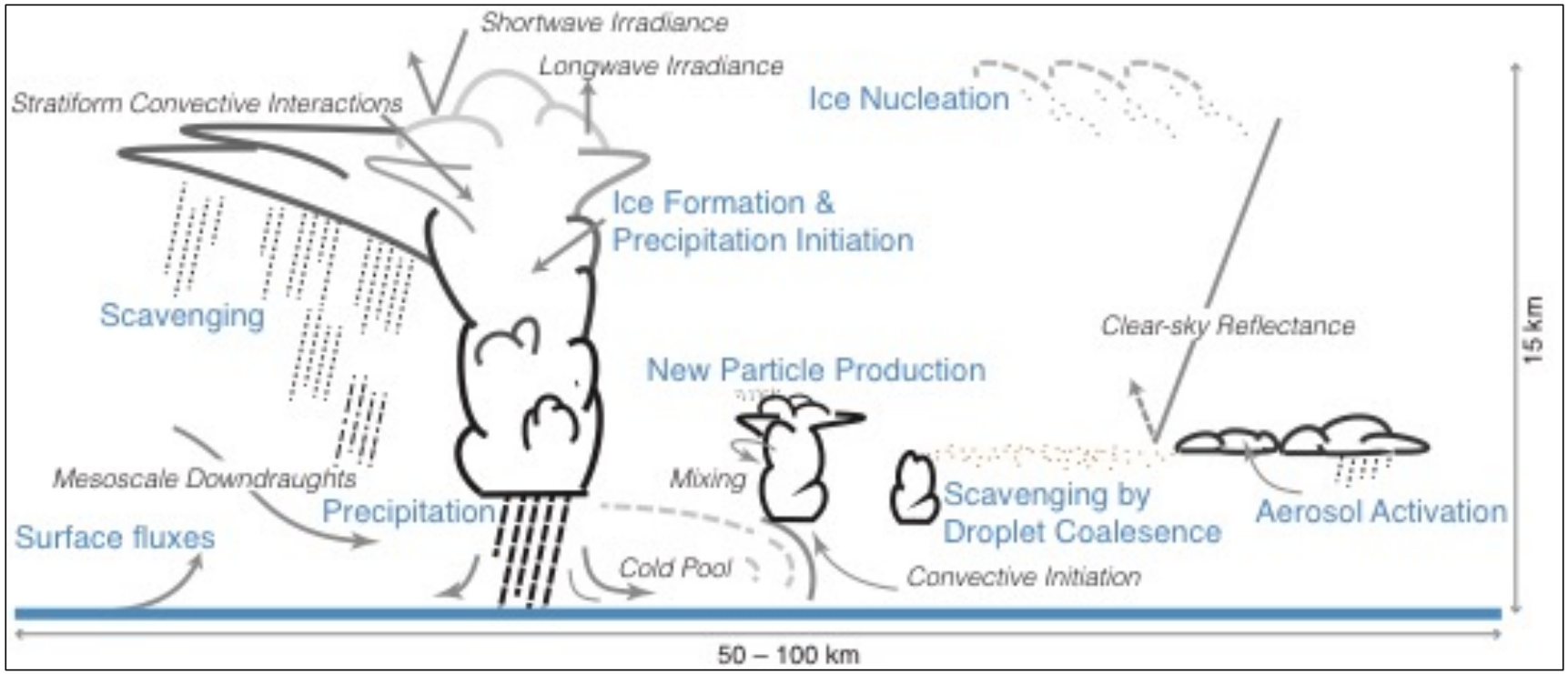
Cloud Albedo Effect is Readily Visible from Space

Satellite image of the northeast Pacific Ocean showing ship tracks, both in thin closed-cellular stratocumulus regions and in open-cellular regions.



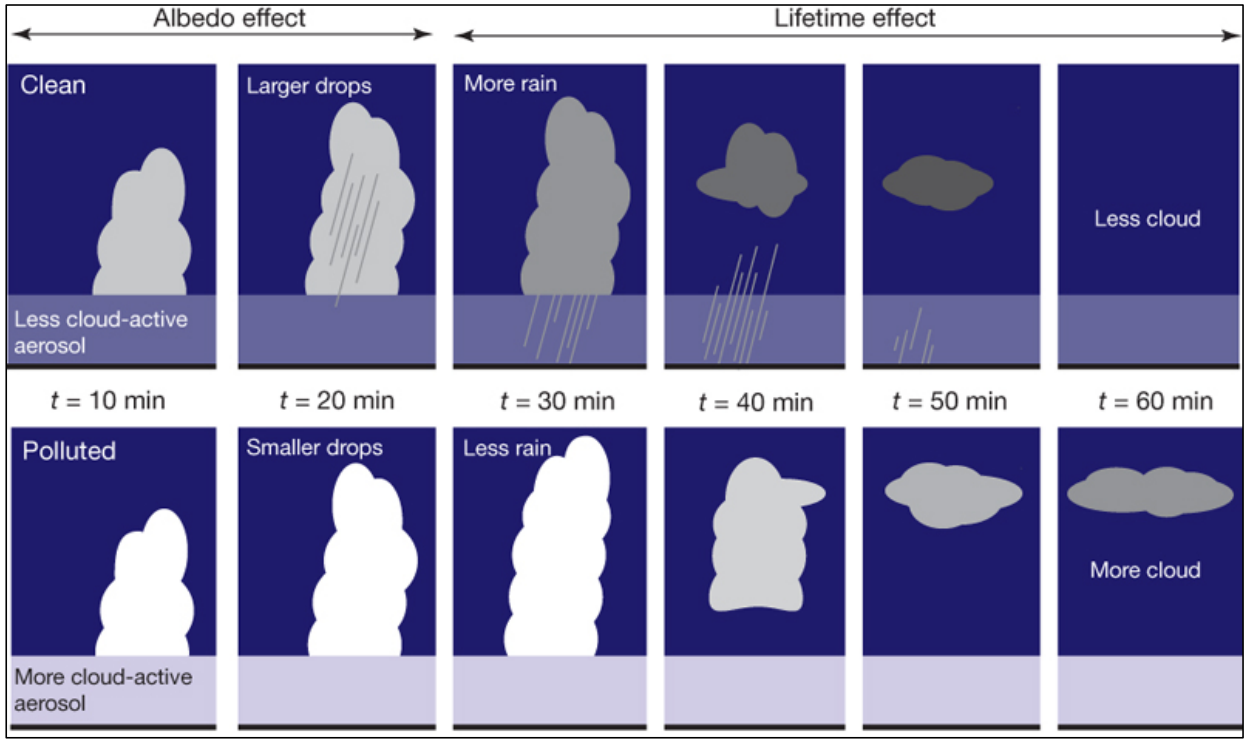
Stevens & Feingold, 2009

Relevant Aerosol / Cloud / Precipitation Processes



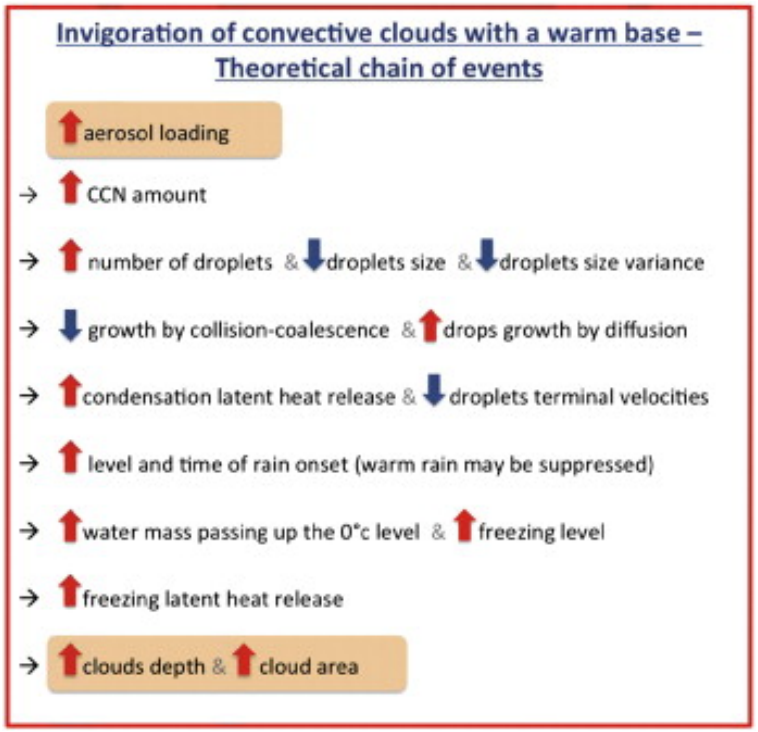
IPCC AR5 Fig 7.16

Lifetime and Albedo Effects as Originally Proposed



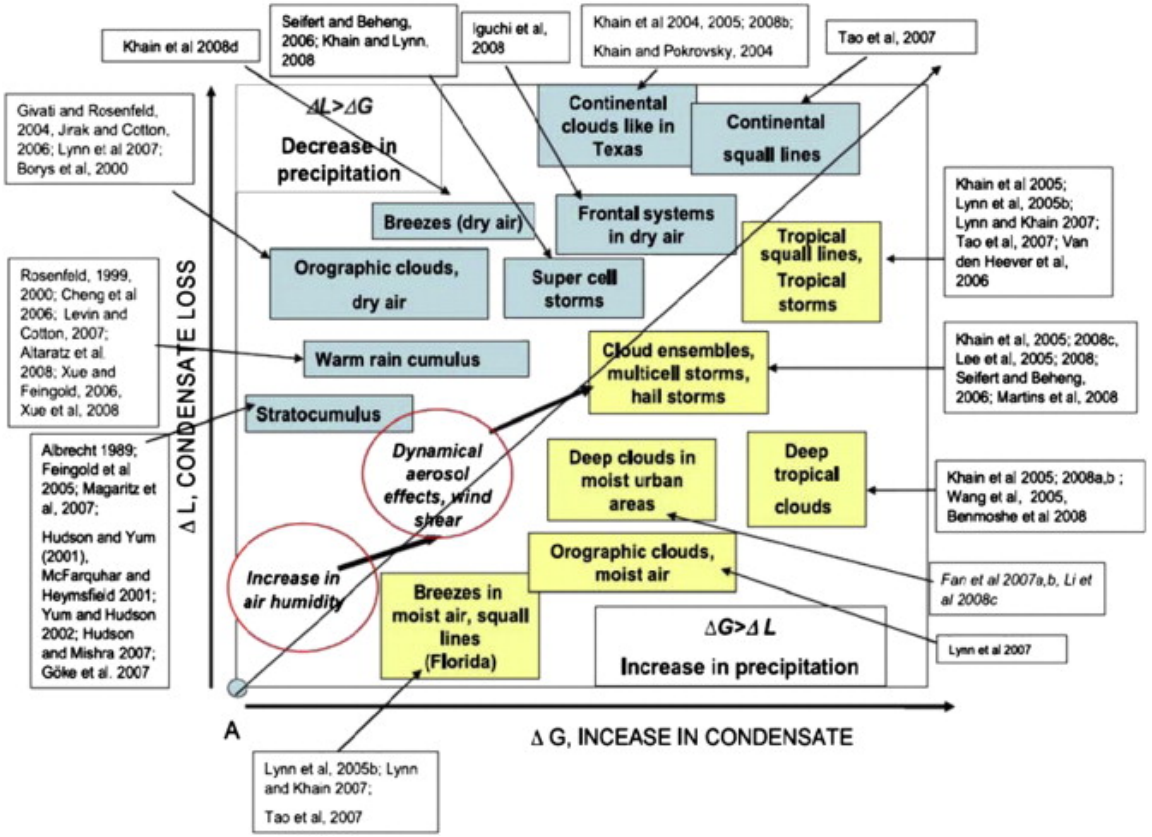
Stevens & Feingold, 2009

Process Paradigm for 2nd Indirect Effect



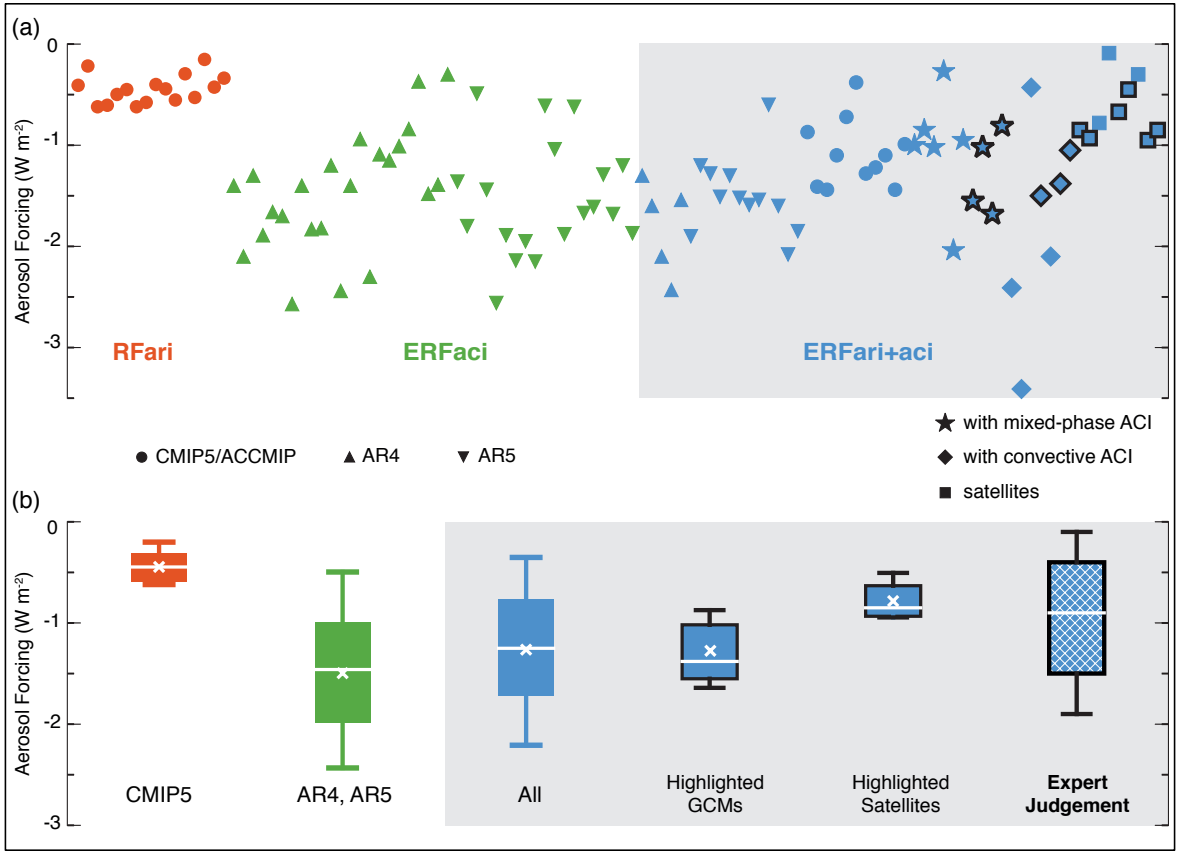
Altaratz et al, 2014

No Clear Consensus on Cloud Invigoration by Aerosols



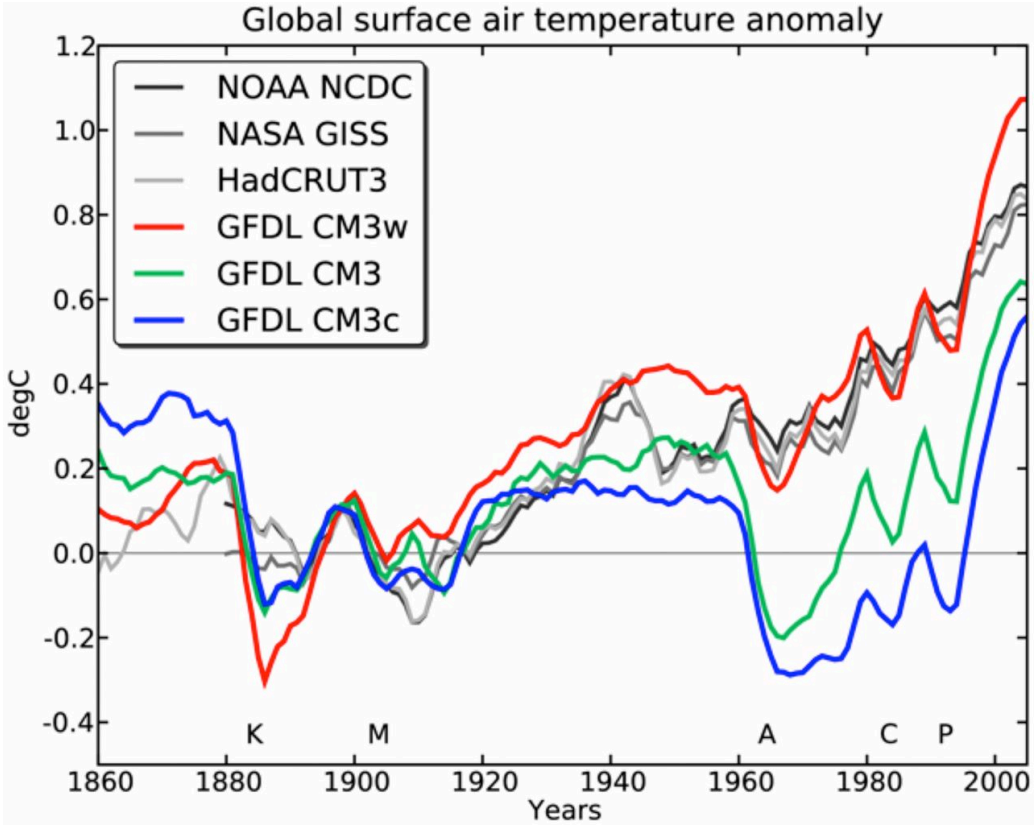
Altaratz et al, 2014

Spread in Radiative Aerosol / Cloud Interactions



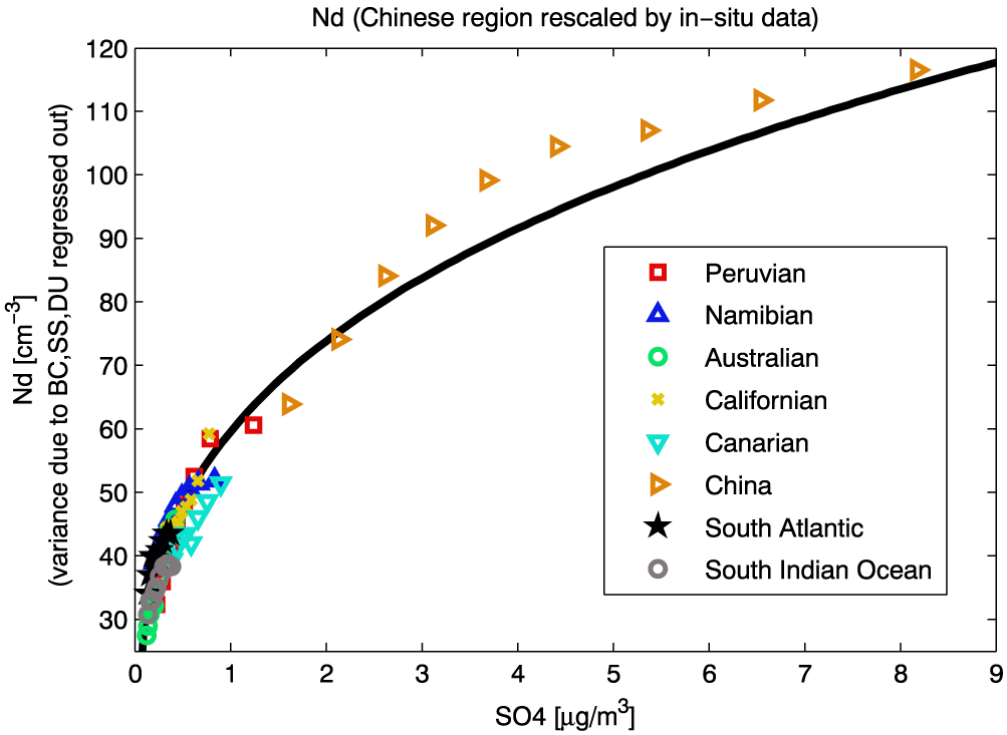
IPCC AR5 Fig 7.19

Sensitivity of temperatures aerosol–cloud processes



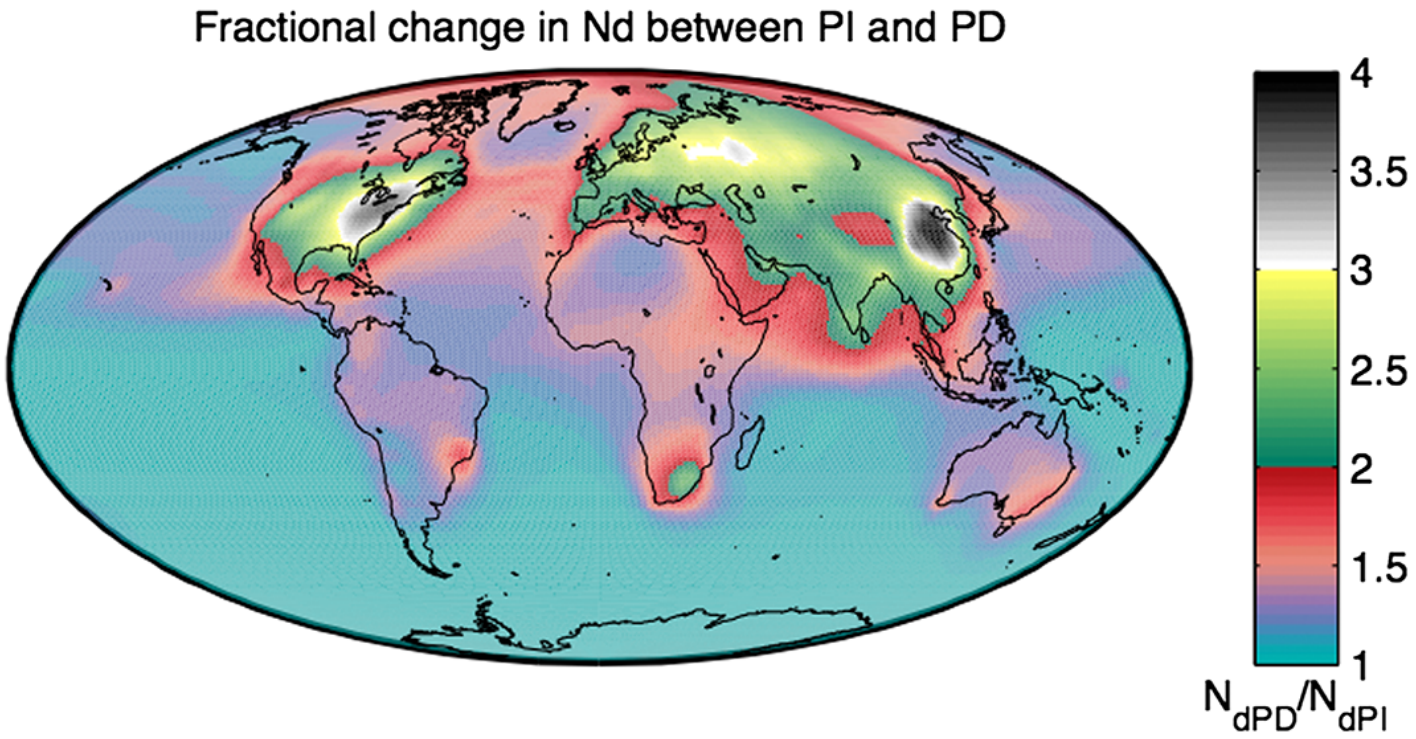
Seinfeld PNAS 2016

Measured Sensitivity of Droplet Number to Aerosols



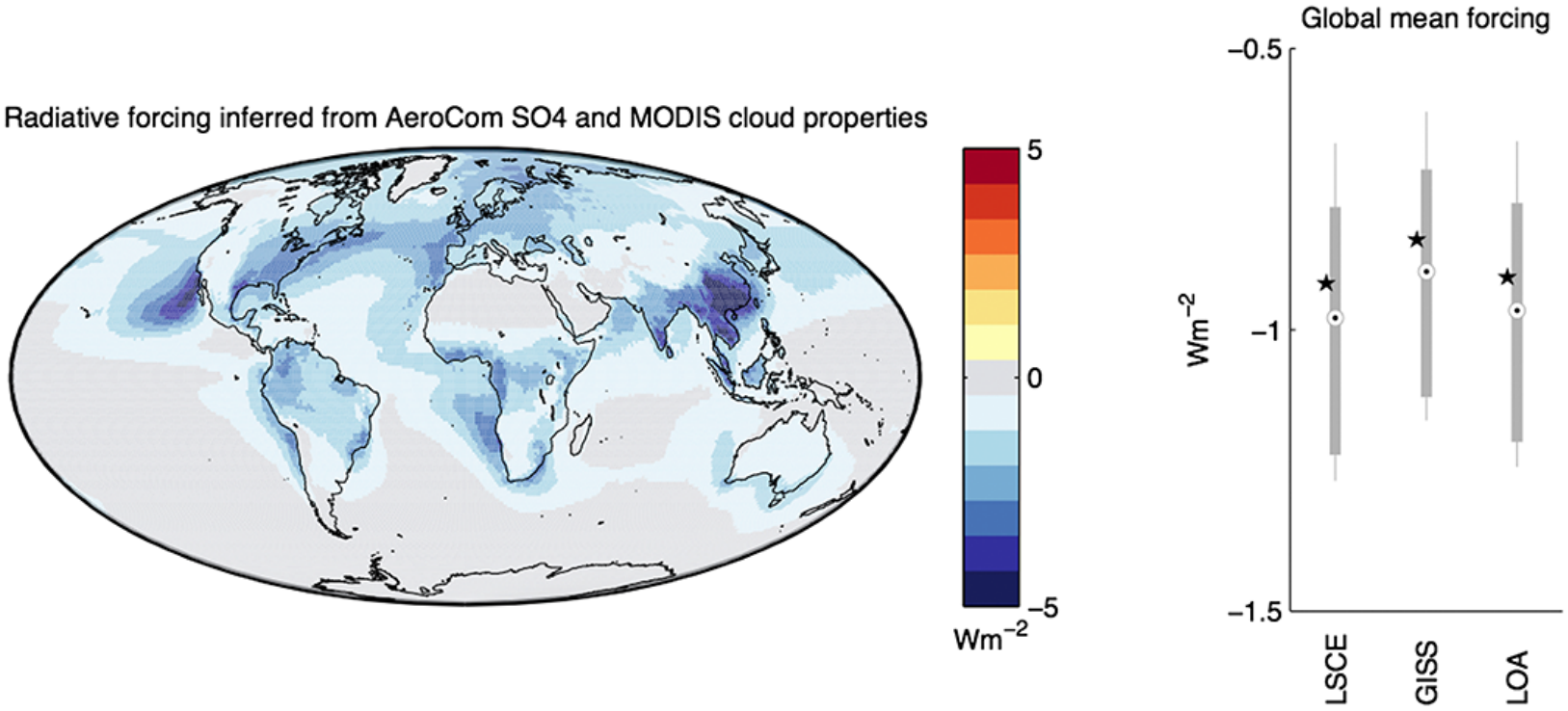
McCoy et al, JGR, 2017

Anthropogenic Change in Droplet Number



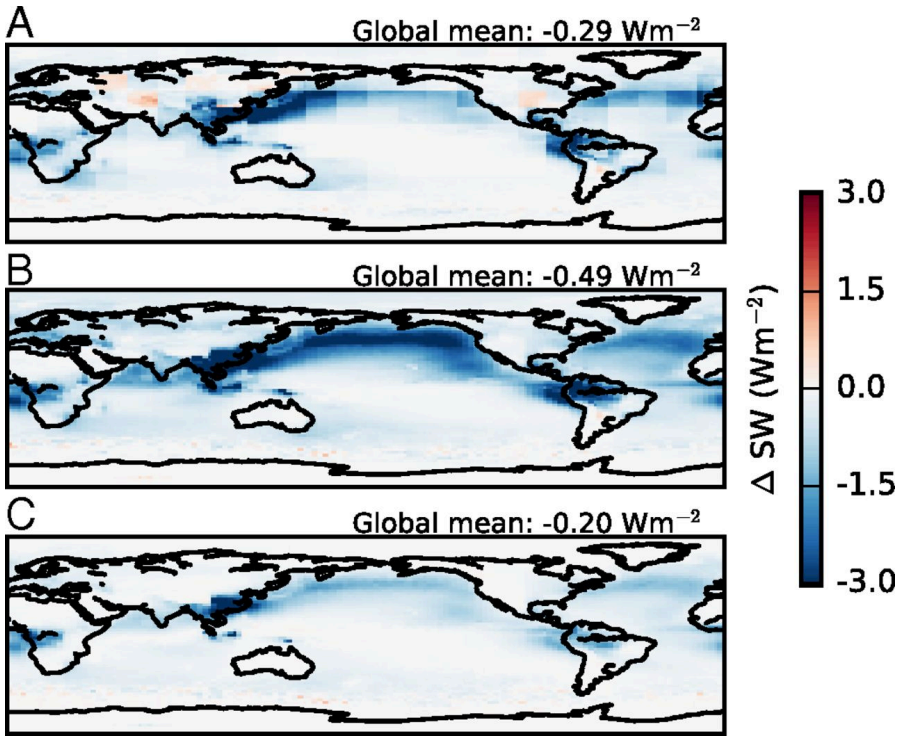
McCoy et al, JGR, 2017

Radiative Forcing from First Aerosol Indirect Effect



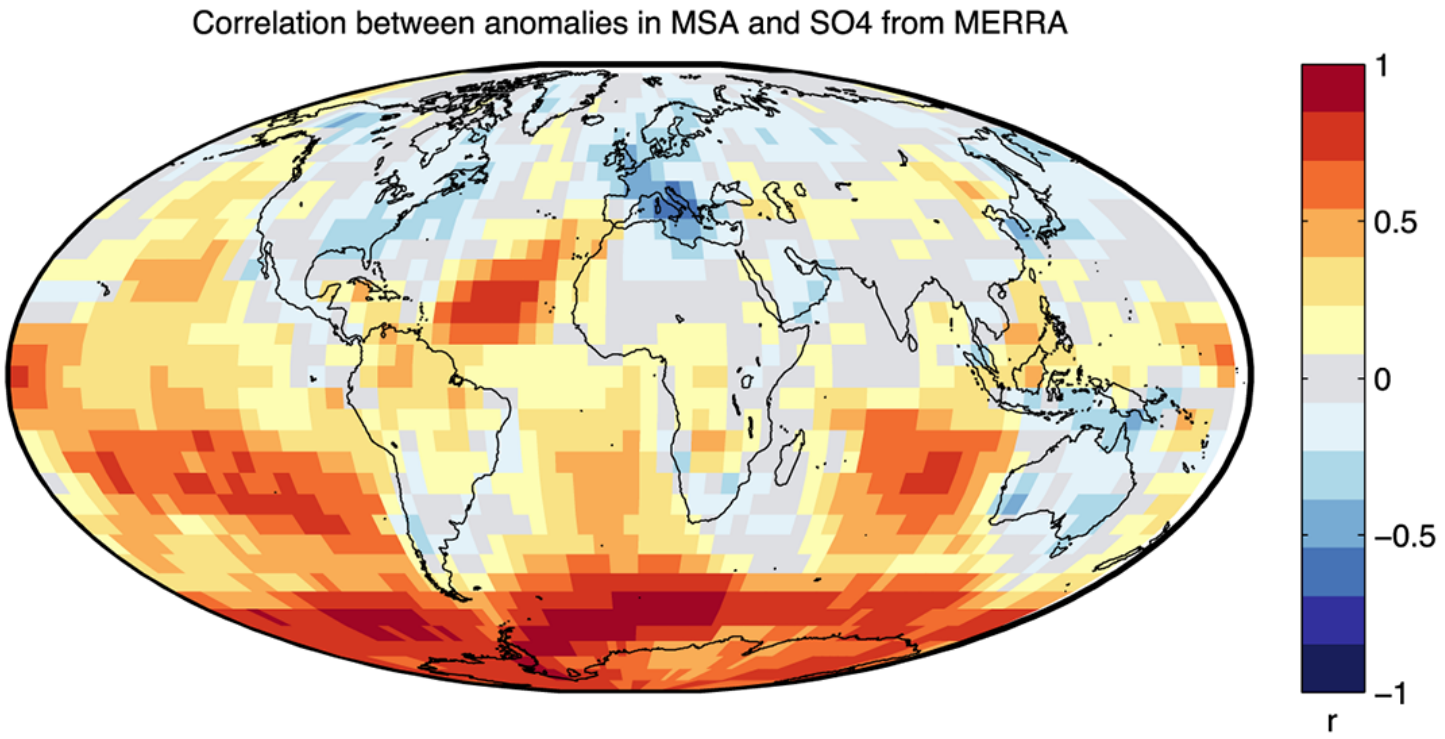
McCoy et al, JGR, 2017

Alternate Estimates of First Indirect Effect Forcing



Gryspeerdt et al. PNAS 2017

Oceanic Sources for Biogenic Hydrophilic Aerosols



McCoy et al, JGR, 2017

Biogenic Aerosols also Trigger Droplet Formation

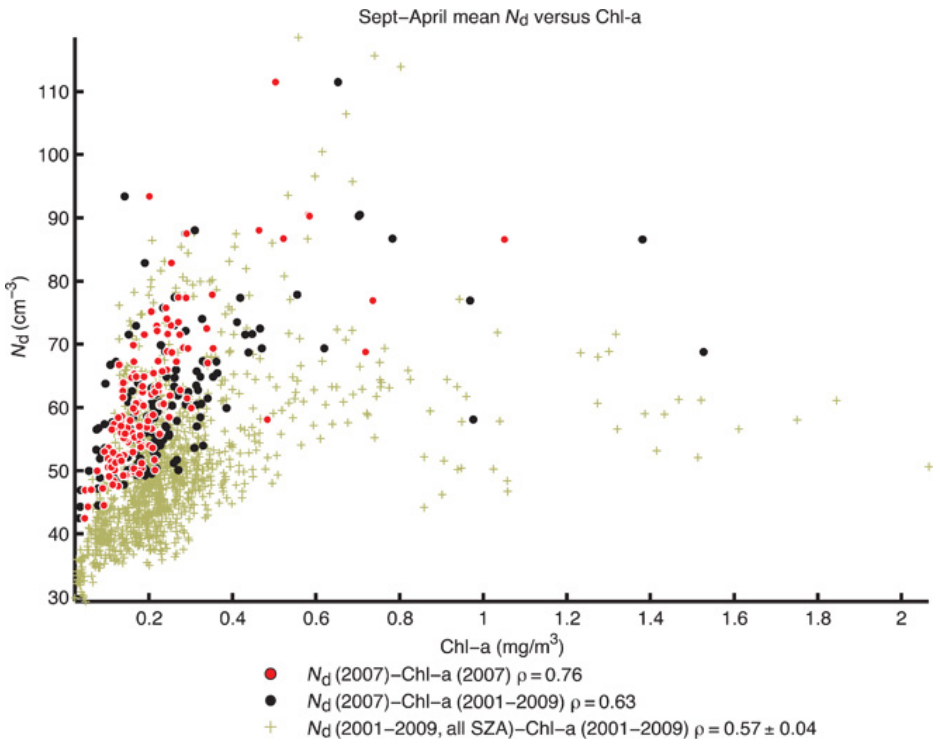
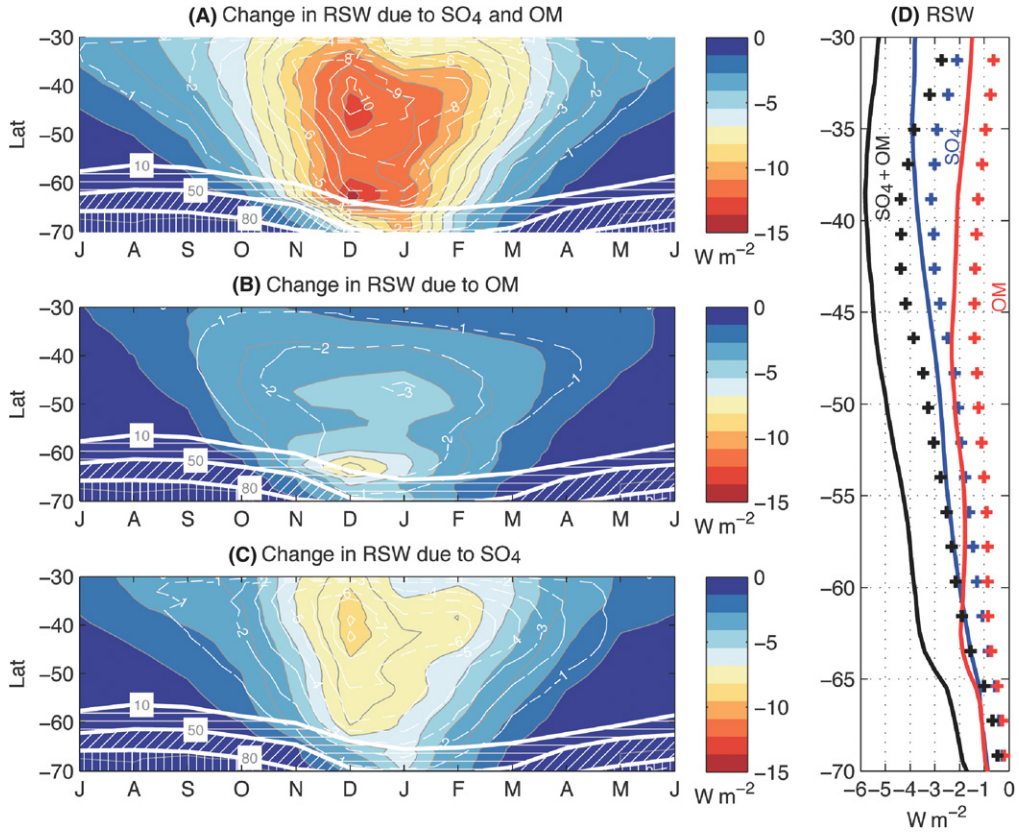


Fig. 1 Elevated mean September to April cloud droplet concentrations over the SO are associated with regions of high Chl-a (indicating the presence of phytoplankton biomass).

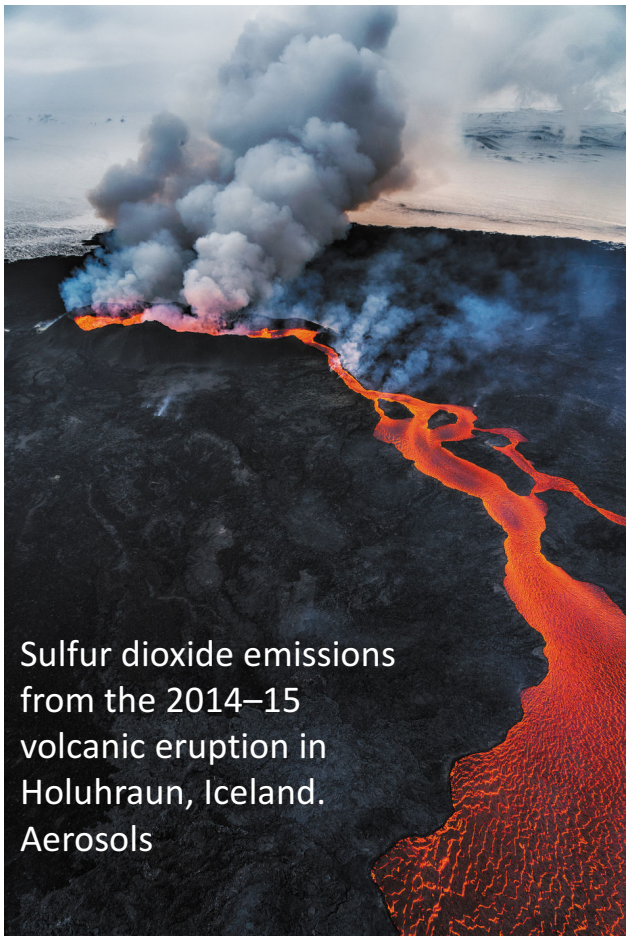
McCoy et al. Science 2015

Biogenic Aerosols increase Shortwave Cloud Effects



McCoy et al. Science 2015

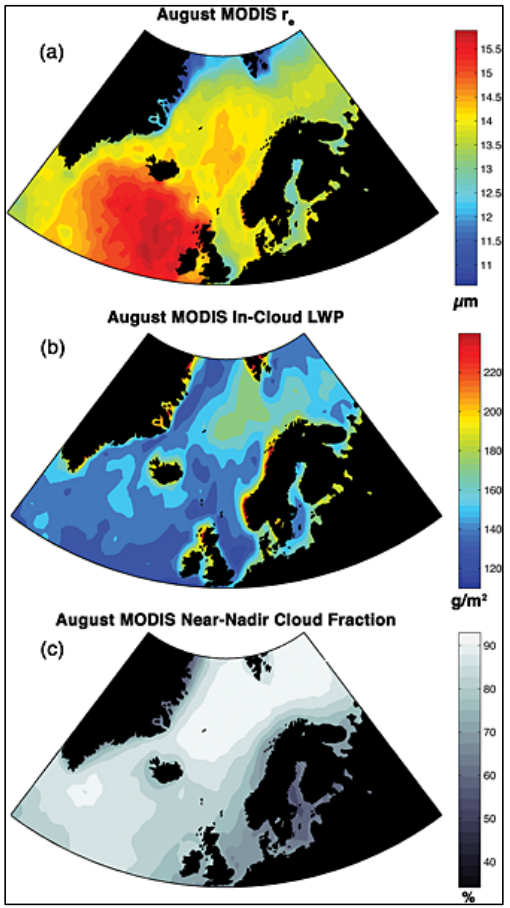
Tests using Volcanic Aerosol / Cloud Interactions



Sulfur dioxide emissions from the 2014–15 volcanic eruption in Holuhraun, Iceland. Aerosols

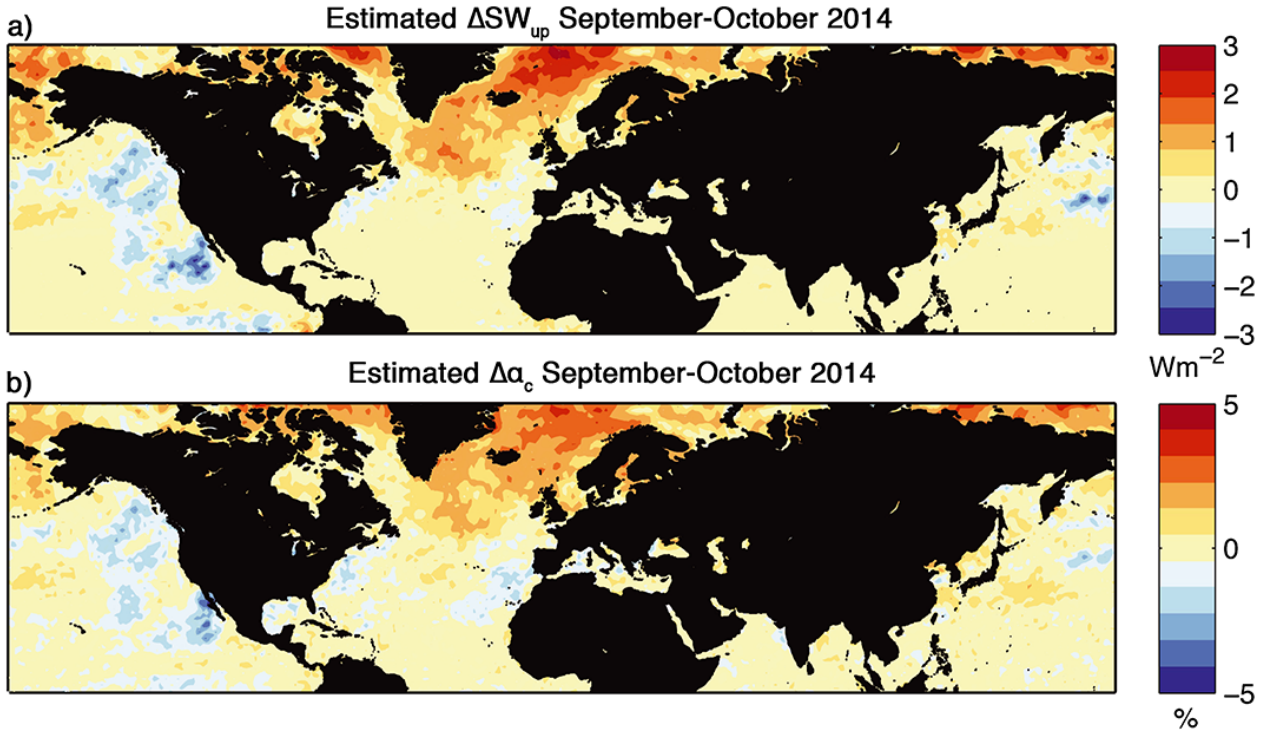
Stevens Nature 2017

Volcanic Emissions Decrease Cloud Droplet Size



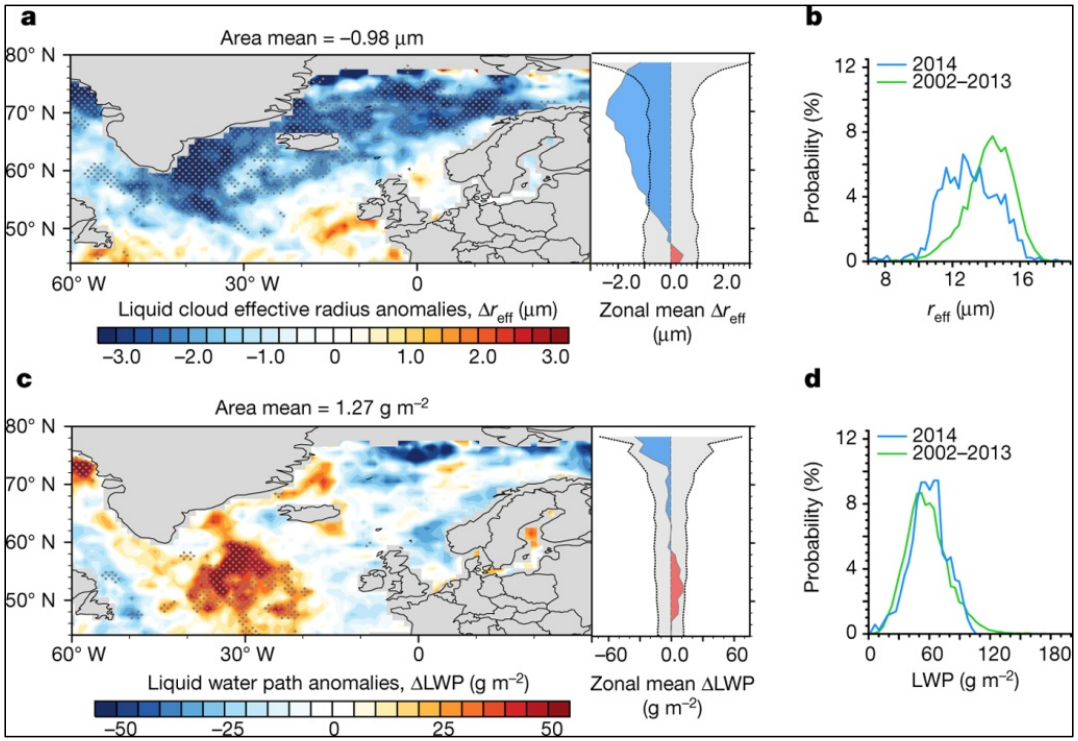
McCoy et al GRL 2015

Elevated Cloud Reflection from Volcanic Aerosols



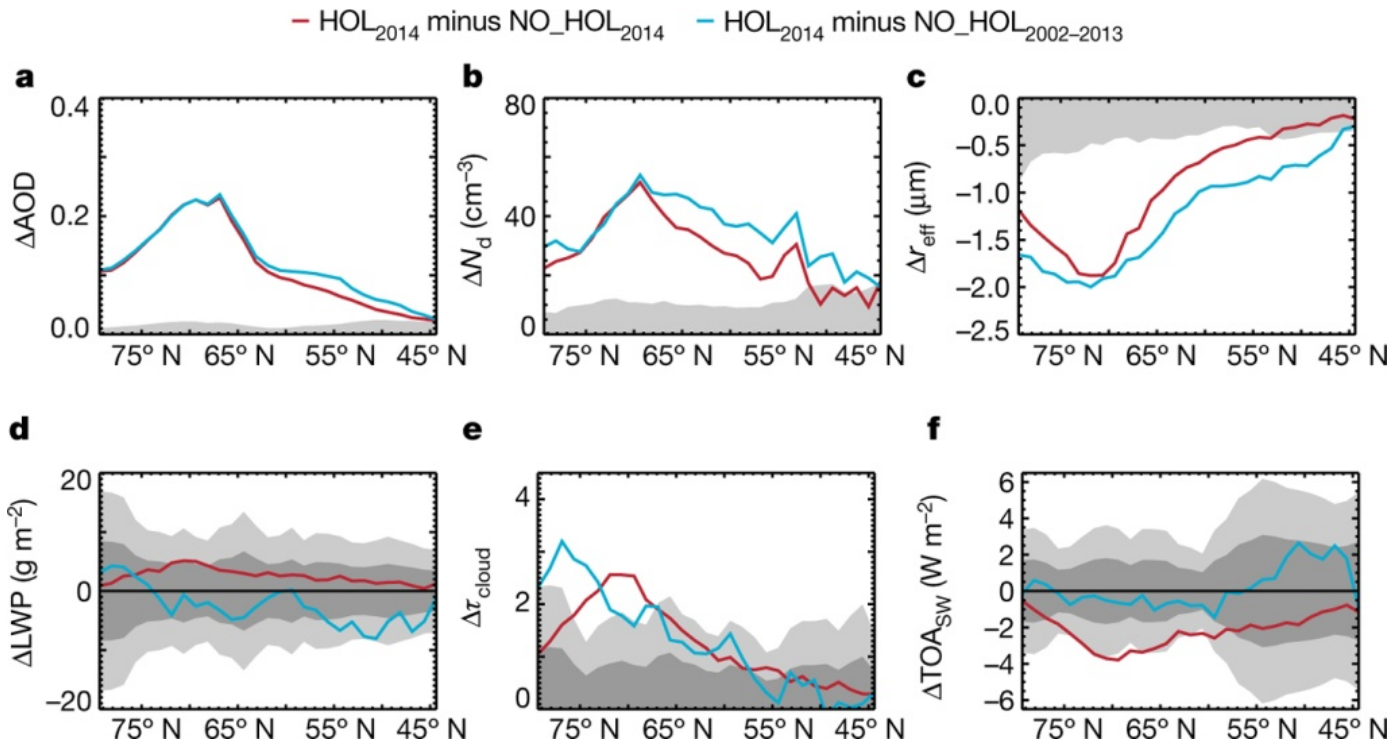
McCoy et al GRL 2015

Small Volcanic Impacts on Cloud Liquid Water Paths



Malavelle et al Nature 2017

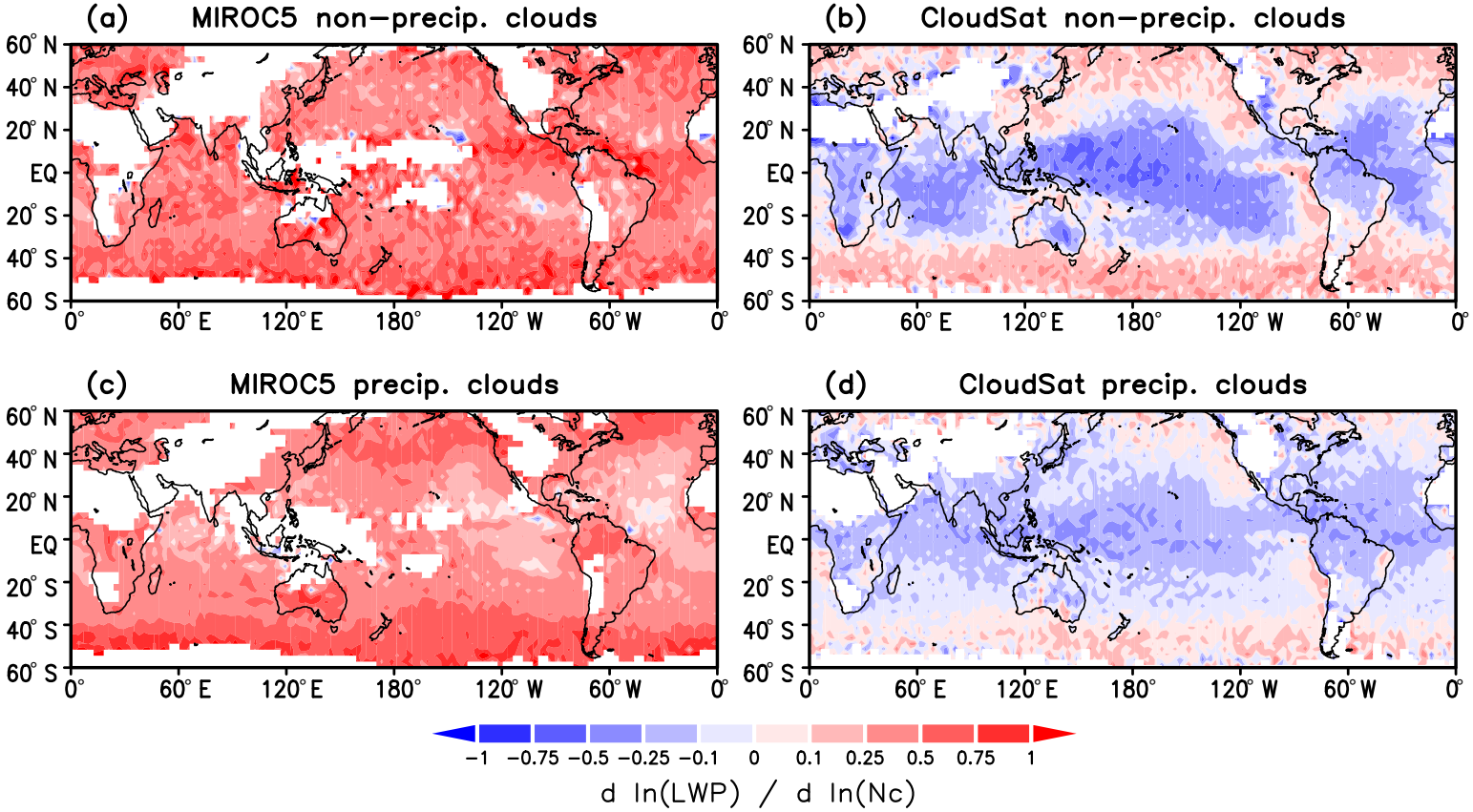
Models Confirm Small Volcanic 2nd Indirect Effect



Modelled perturbations from HadGEM3 using UKCA for September–October 2014

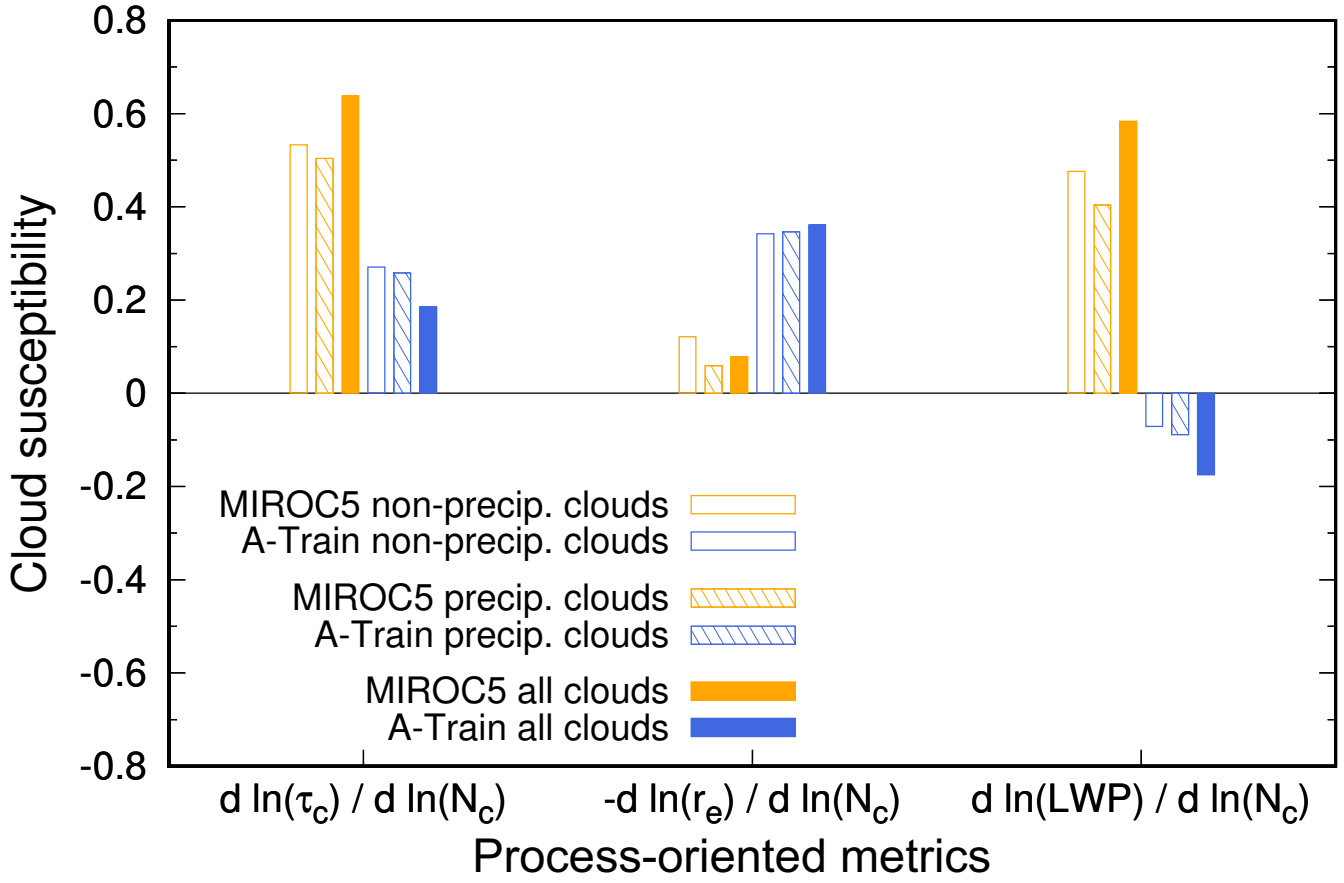
Malavelle et al Nature 2017

GCMs Overestimate Cloud LWP Aerosol Sensitivity



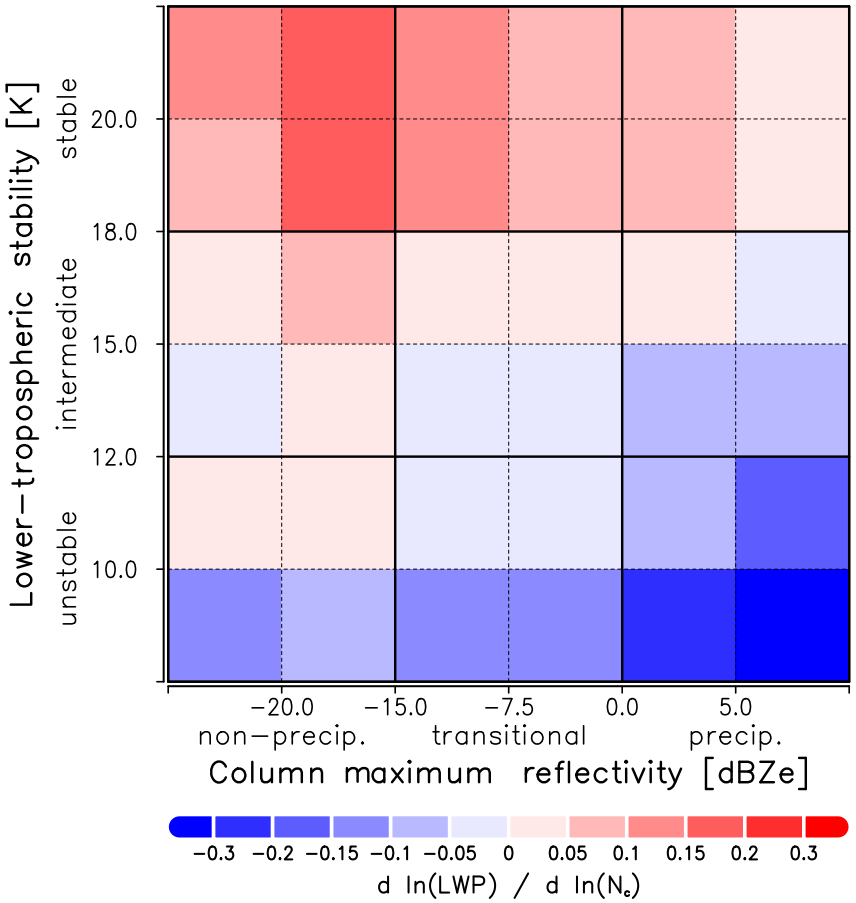
Michibata et al ACP 2016

Modeled / Measured Aerosol-Cloud Interactions



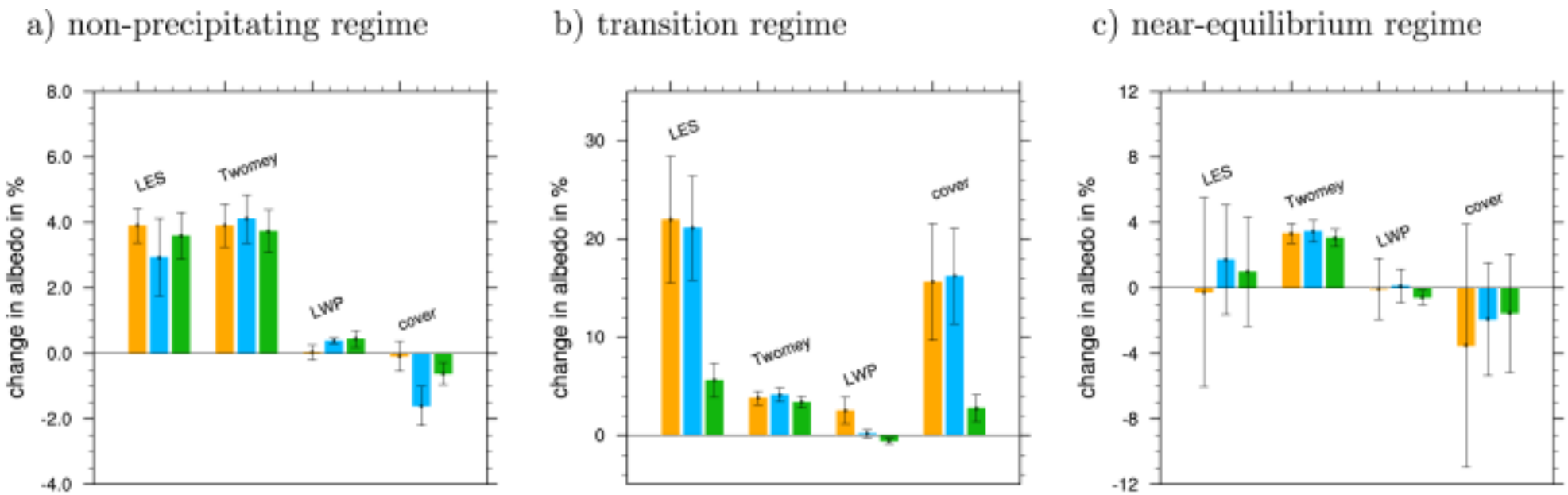
Michibata et al ACP 2016

Susceptibility of Cloud LWP Response to Aerosols



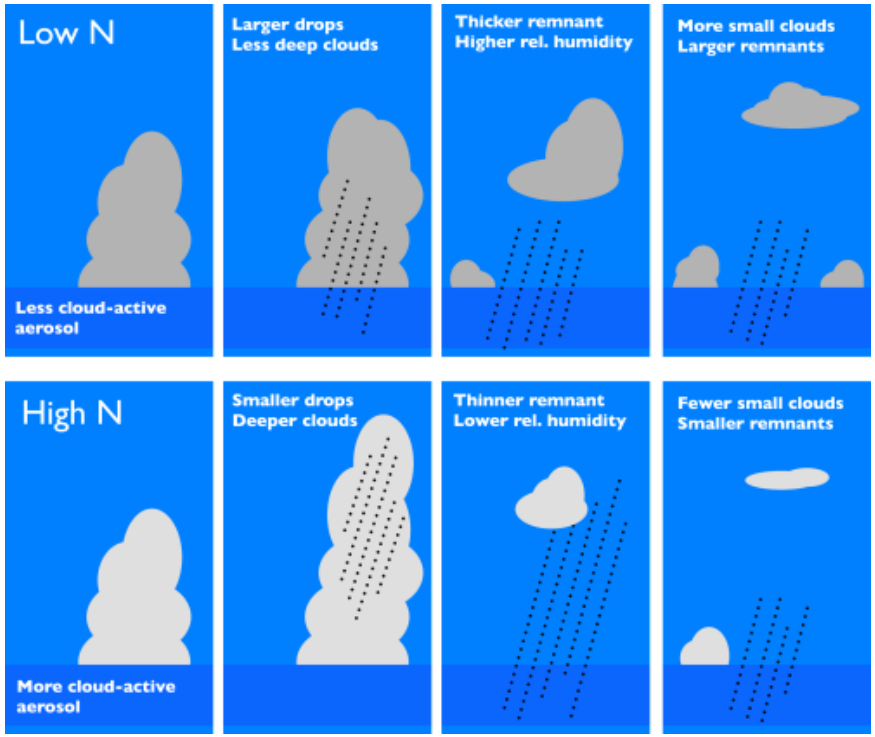
Michibata et al ACP 2016

Large Eddy Simulations of Indirect Effects



Seifert et al JAMES 2015

New Paradigm for Precipitating Cloud Susceptibility



Seifert et al JAMES 2015

What we've discussed

- Aerosol / Cloud Interactions circa IPCC AR5
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