What does nature tell us about anthropogenic aerosol indirect effects?

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Two stories

I: Aerosol-shallow cumulus cloud interactions

II: Aerosol-deep convective cloud interactions

- We use two natural events (volcanic degassing) to examine aerosol-clouds interactions in two cloud regimes with satellite observations.
- The volcanic degassing events allow for a better separation of aerosol and meteorological effects.

Part I:

Aerosol interactions with shallow cumulus clouds

Introduction: Aerosol indirect effects on warm clouds

'Classic' view:

Twomey (1976)
Albrecht (1989)

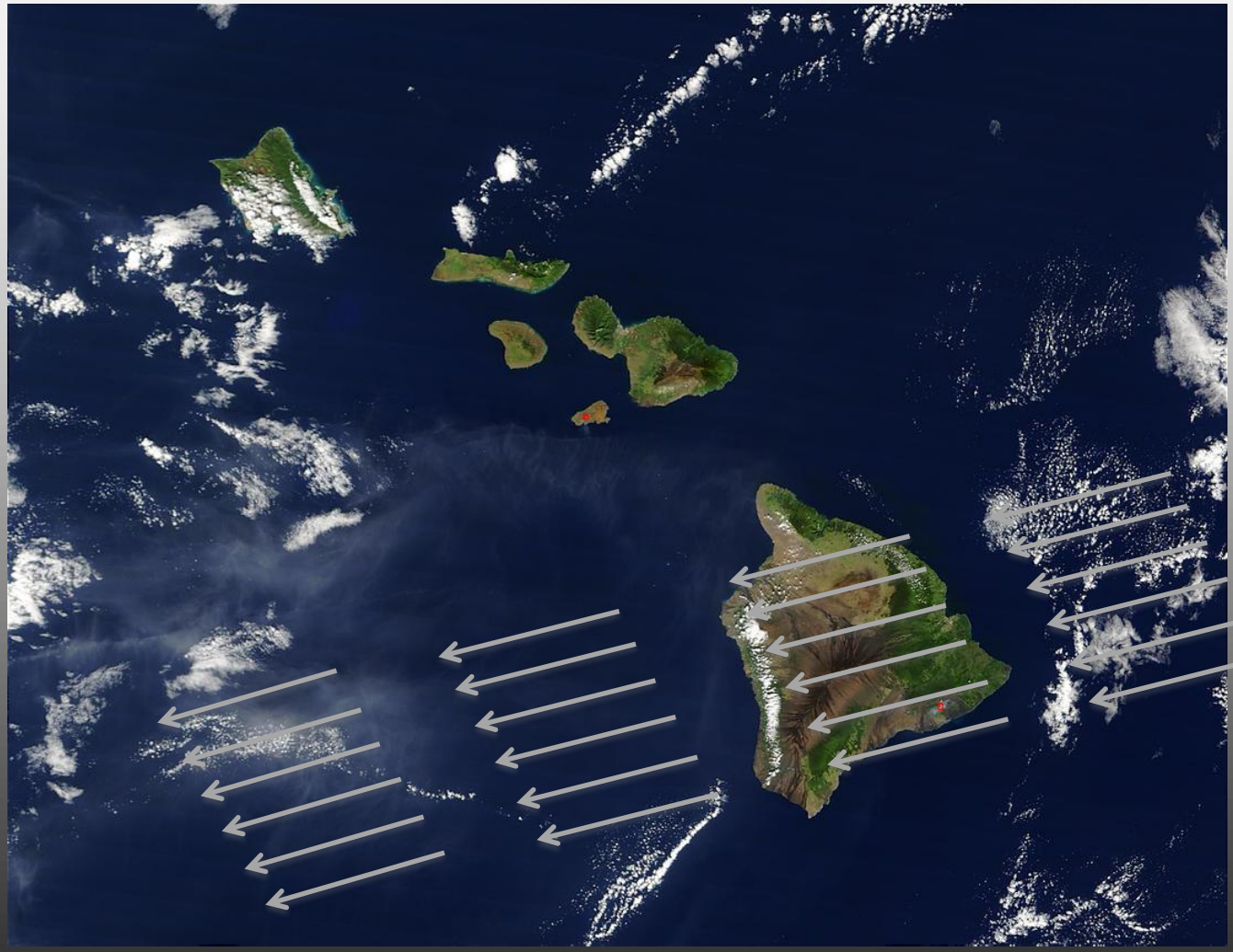
Other things (e.g., LWC) being equal, polluted clouds become brighter and may live longer because of less precipitation.

Updates:

Stevens and Feingold (2009), Rosenfeld et al. (2008), Khain (2009) and Tao et al. (2012), Wang and Feingold (2009)

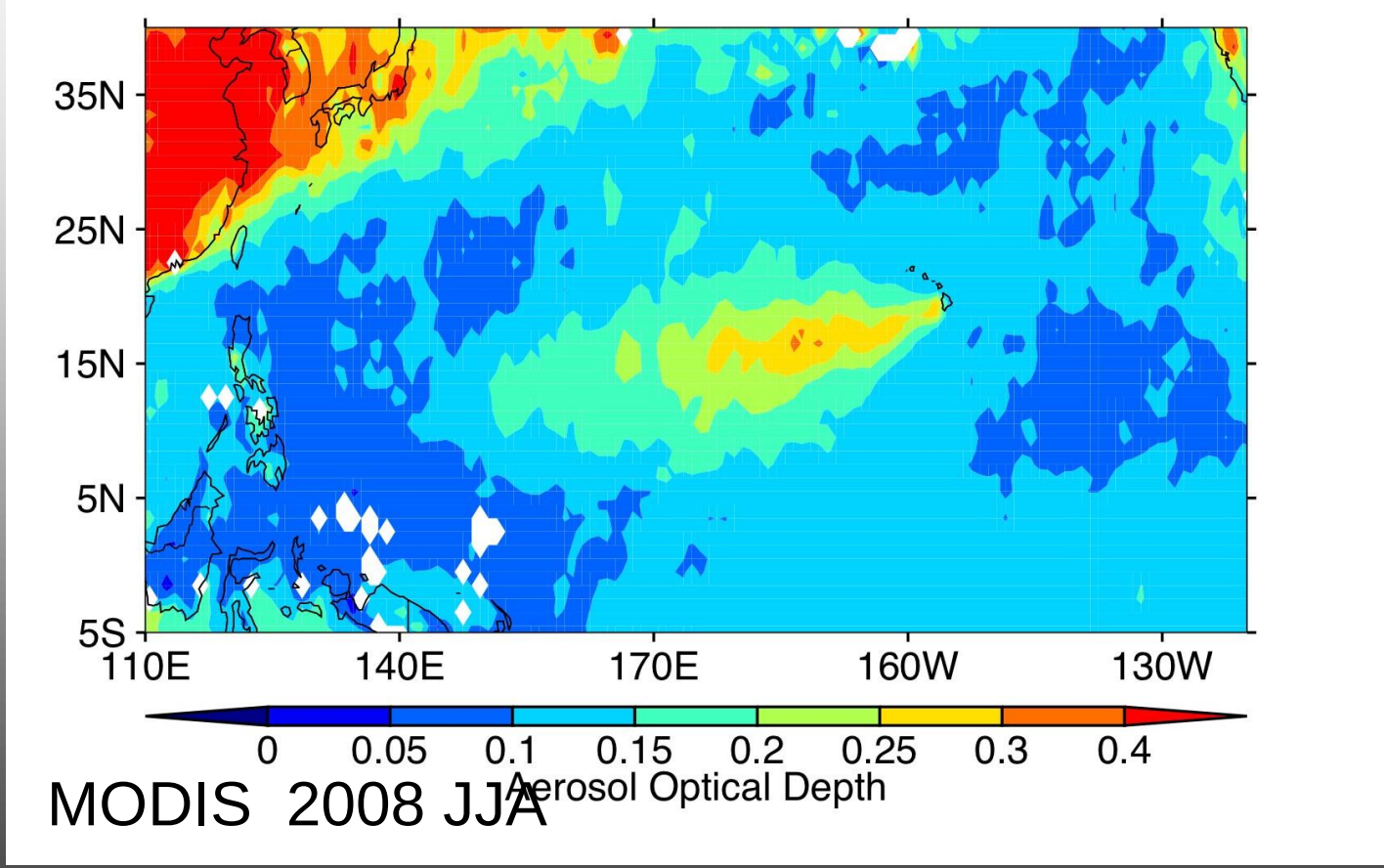
Other things are not equal. Clouds adjust in various ways to initial aerosol perturbation.

The natural experiment

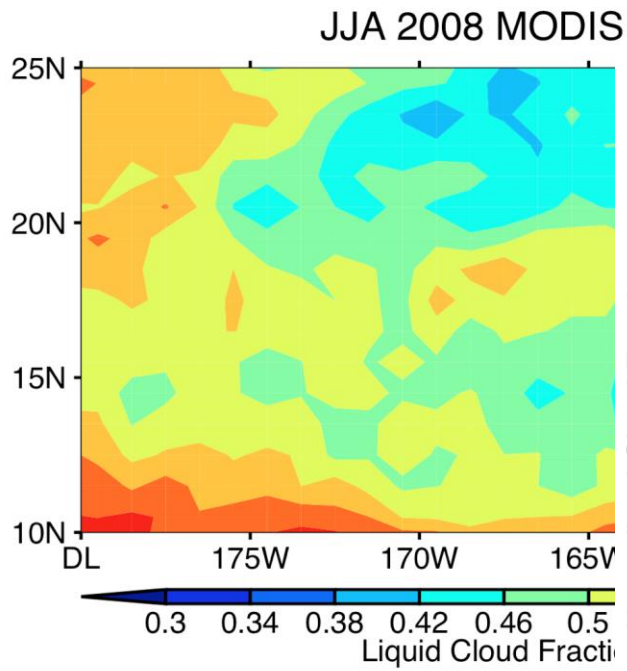


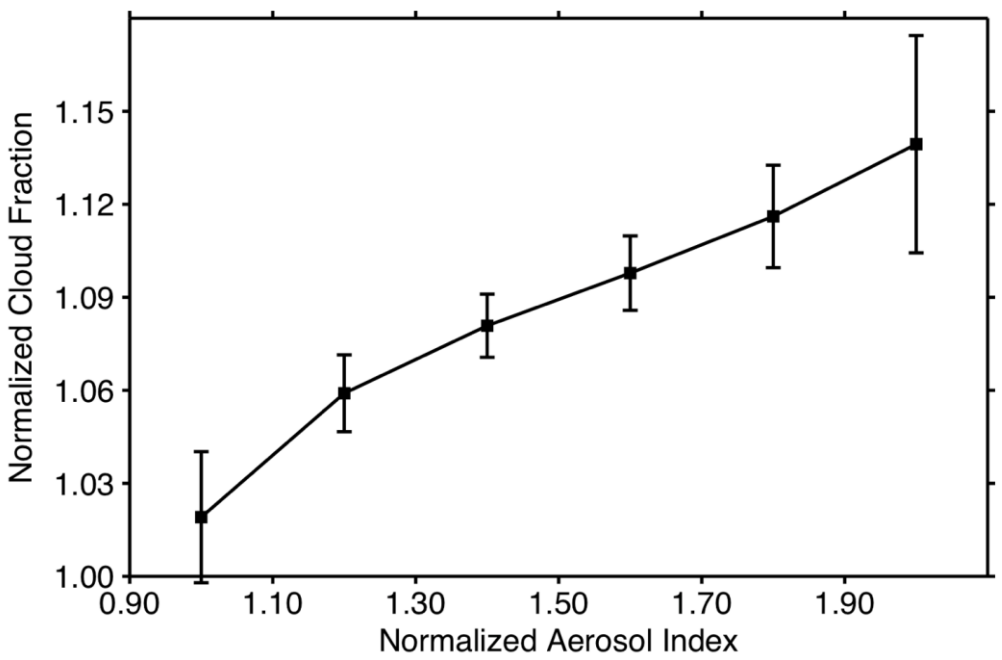
NASA MODIS

Volcanic aerosol plume



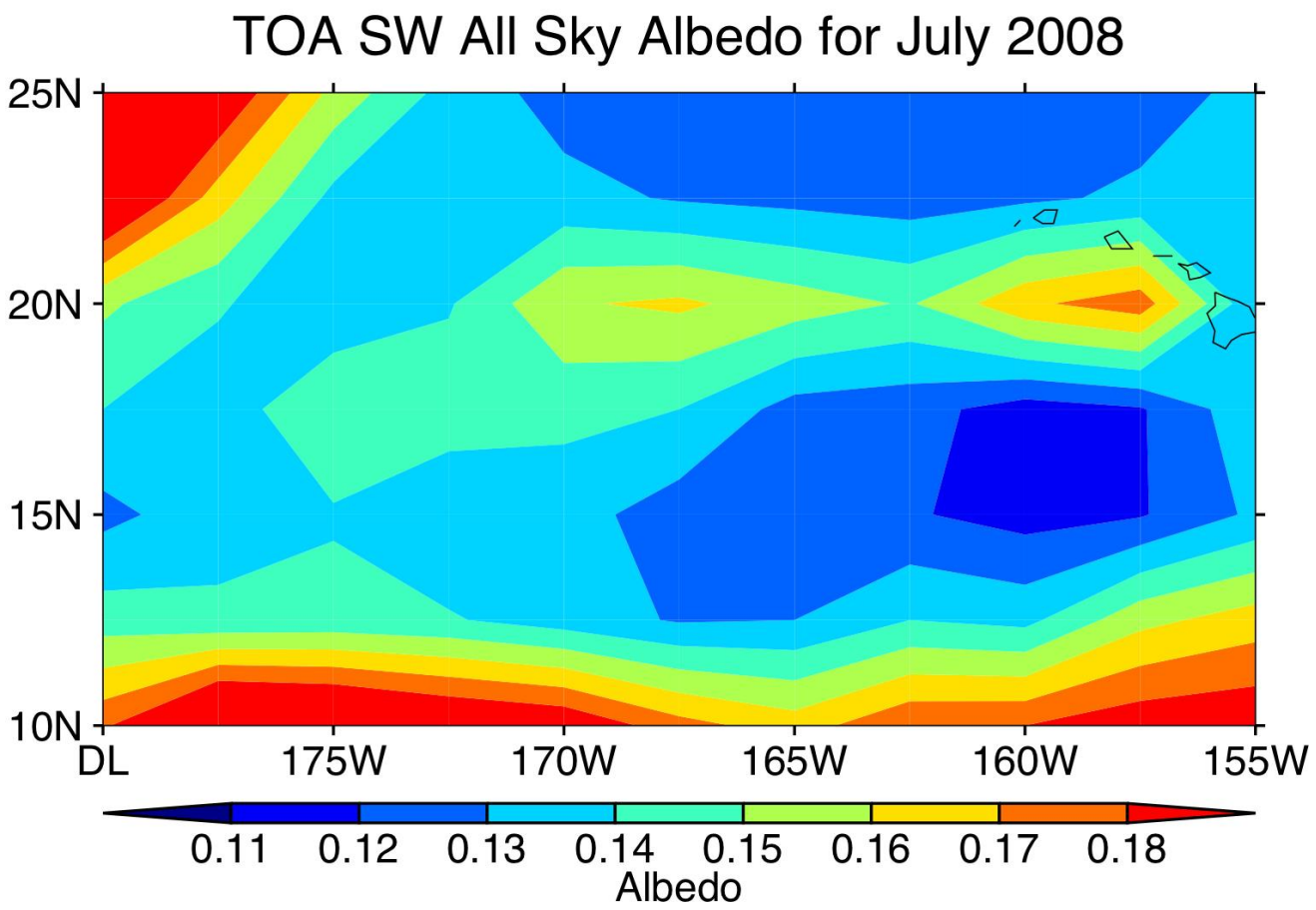
Aerosol increases cloud fraction





Holistic forcing

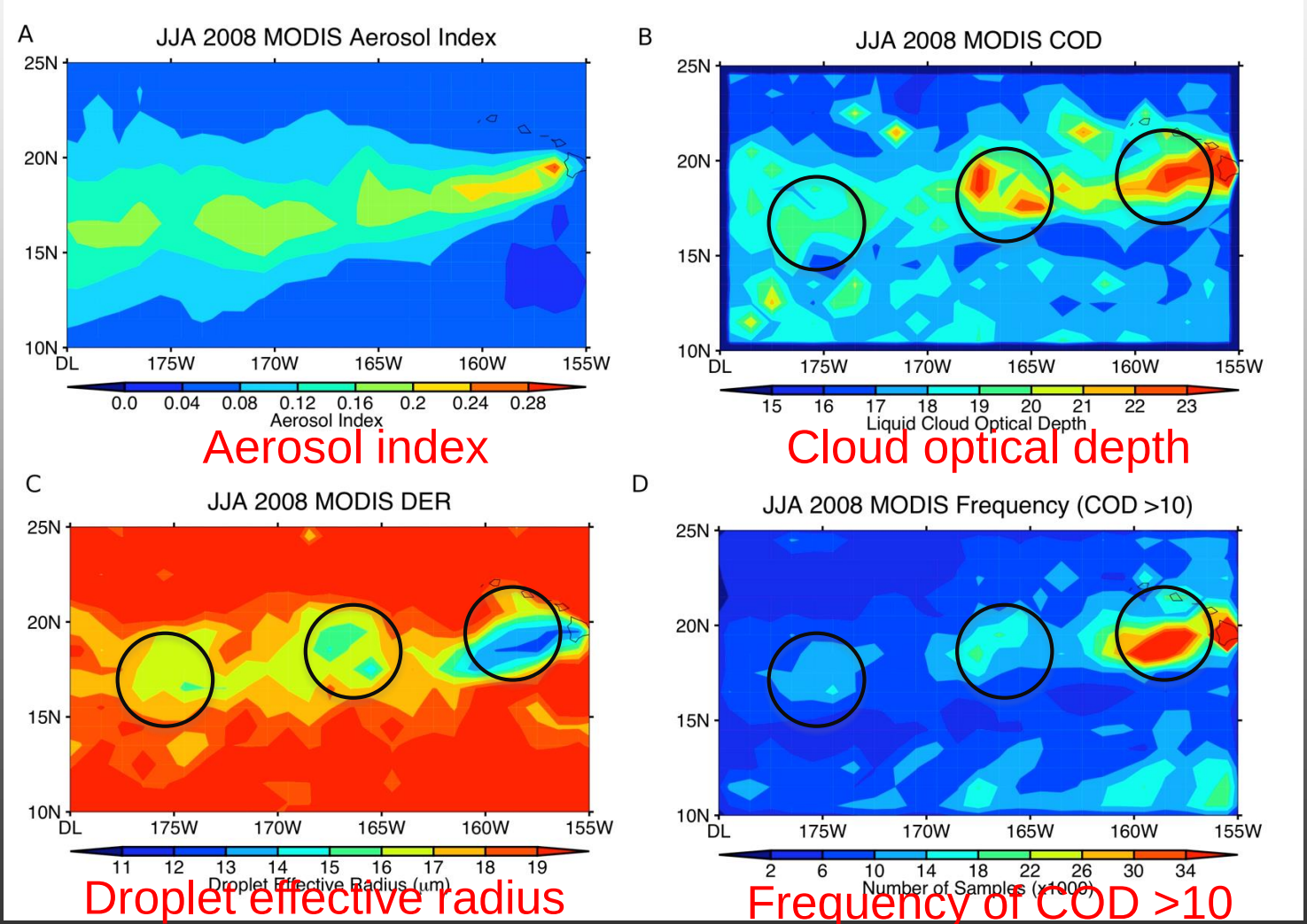
As large as 20Wm^{-2} of forcing is estimated.



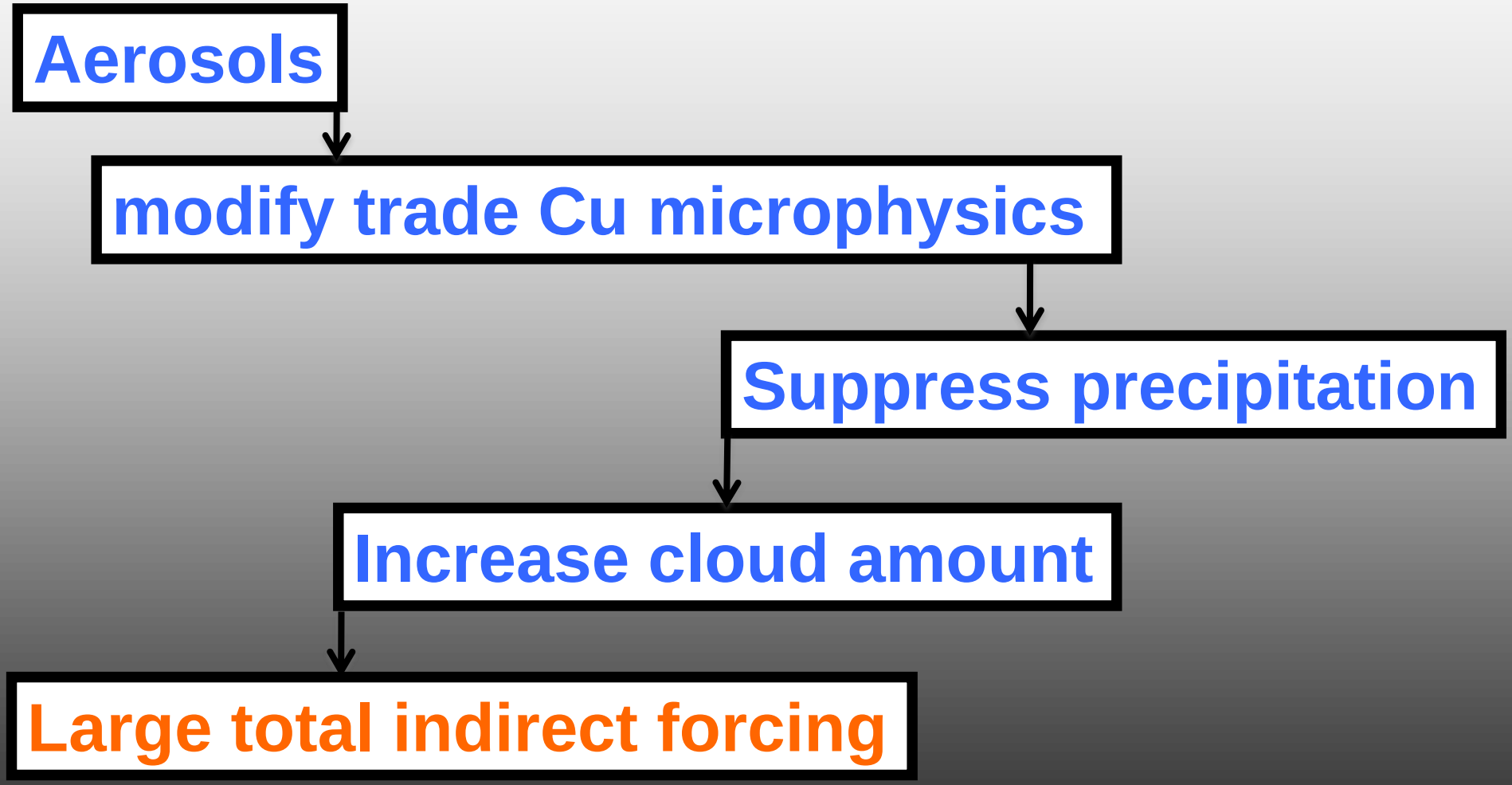
CERES SW Albedo at TOA

Large scale volcano tracks

See details in Yuan et al. (2011)



Part I Summary



Part II:

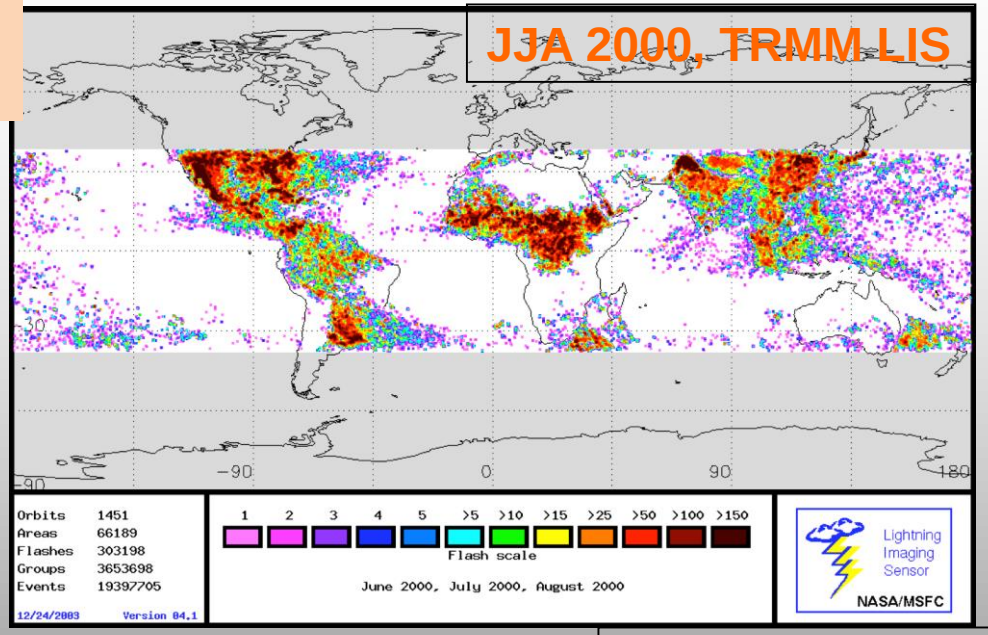
Aerosol interactions with deep convective clouds

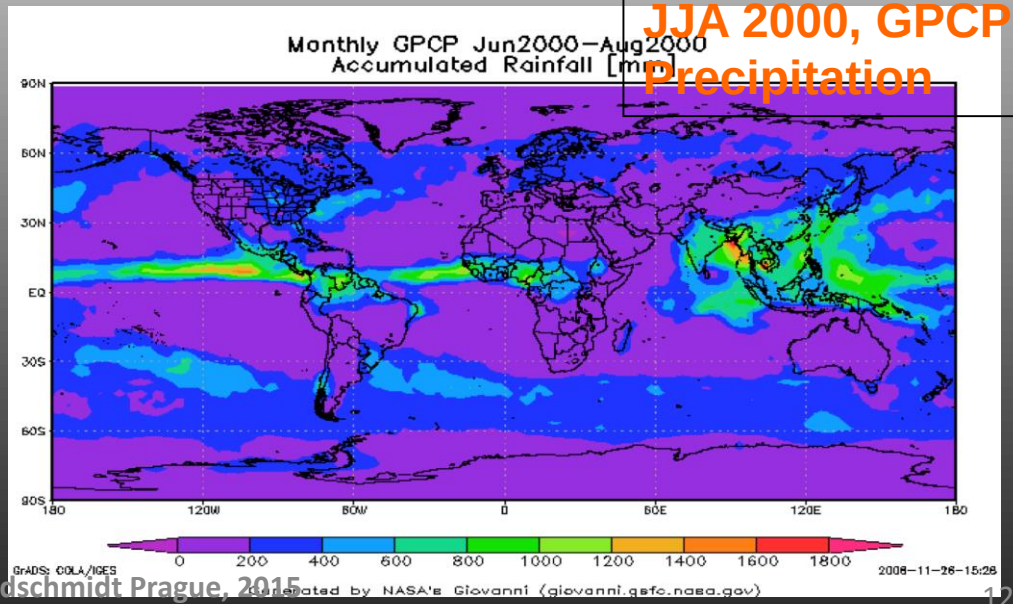
The SLAC* conundrum

*Scarce Lightning Ample Convection

- Lightning as a proxy for strong convection.
- Rainfall amount as a proxy for convective activity.

Much more convection but fewer thunderstorms over ocean than over land





Two hypotheses for SLAC

Thermodynamic and dynamic

Williams and Stanfill (2002); Williams et al. (2002). Williams and Santori (2004) Williams (2005)

- Higher Bowen Ratio over land
- Higher cloud base over land
- Lightning increases with island size

Aerosol

Orville et al., (2001) Lyons et al. (1998, Science); Altaraz et al. (2010)

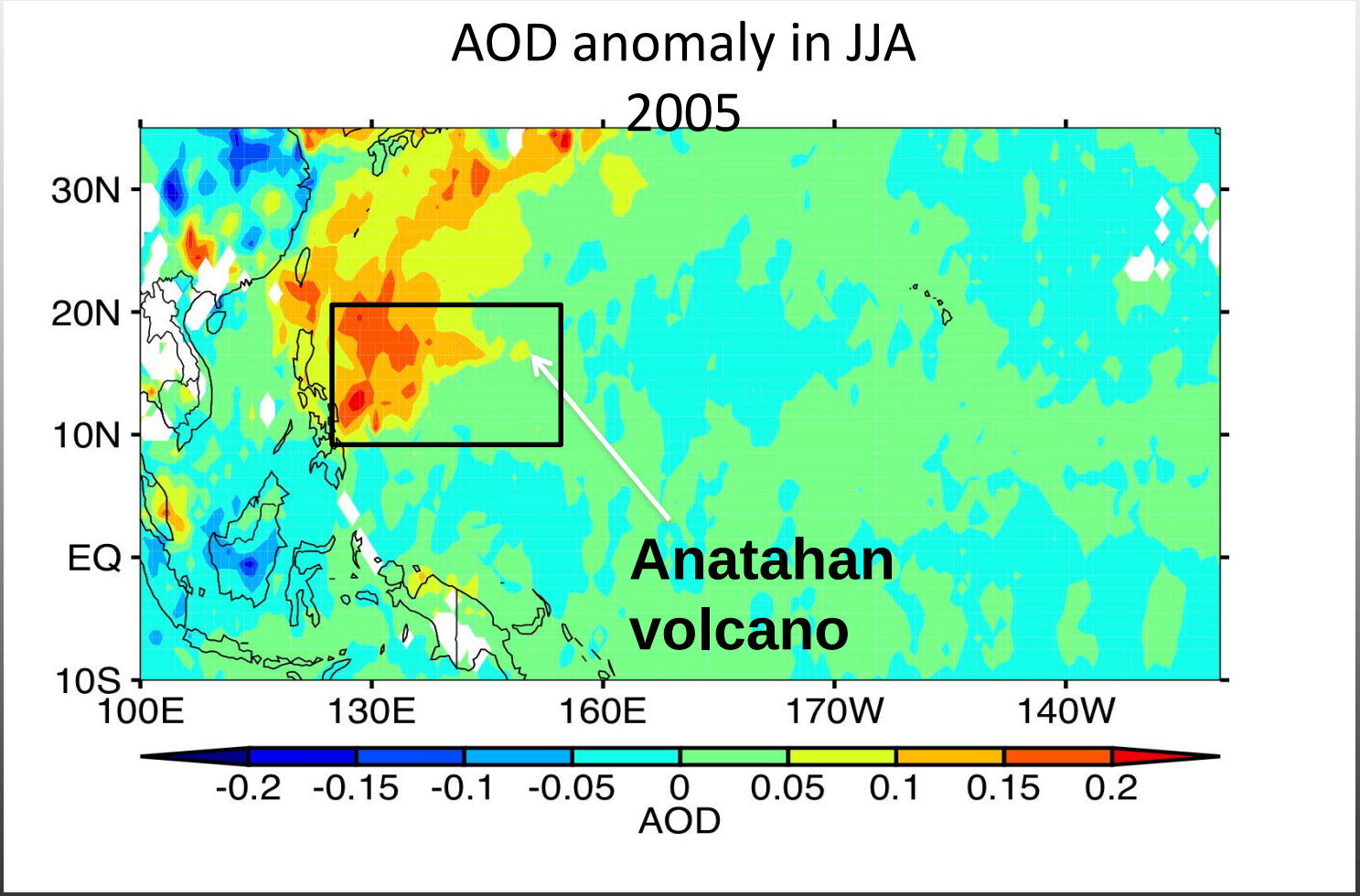
Sherwood et al. (2006)

Bell et al. (2008)

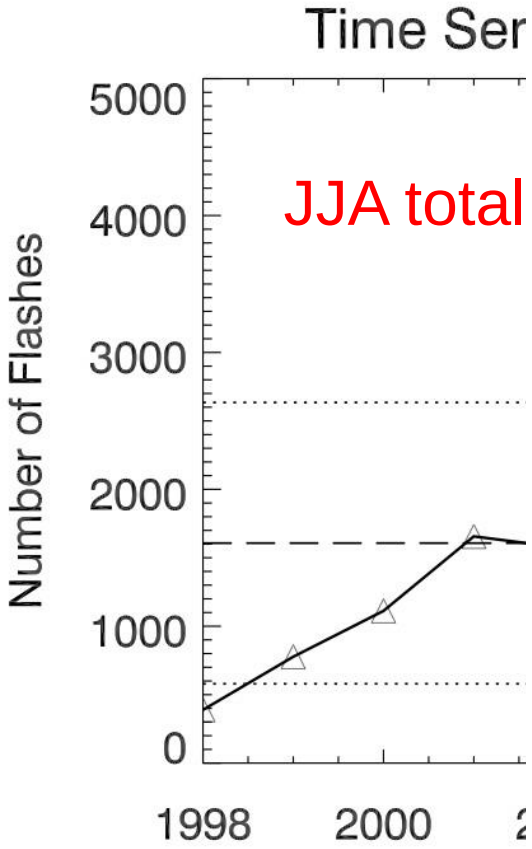
- More lightning over urban areas
- More lightning in smoky air
- Ice size smaller over land
- Weekly cycle

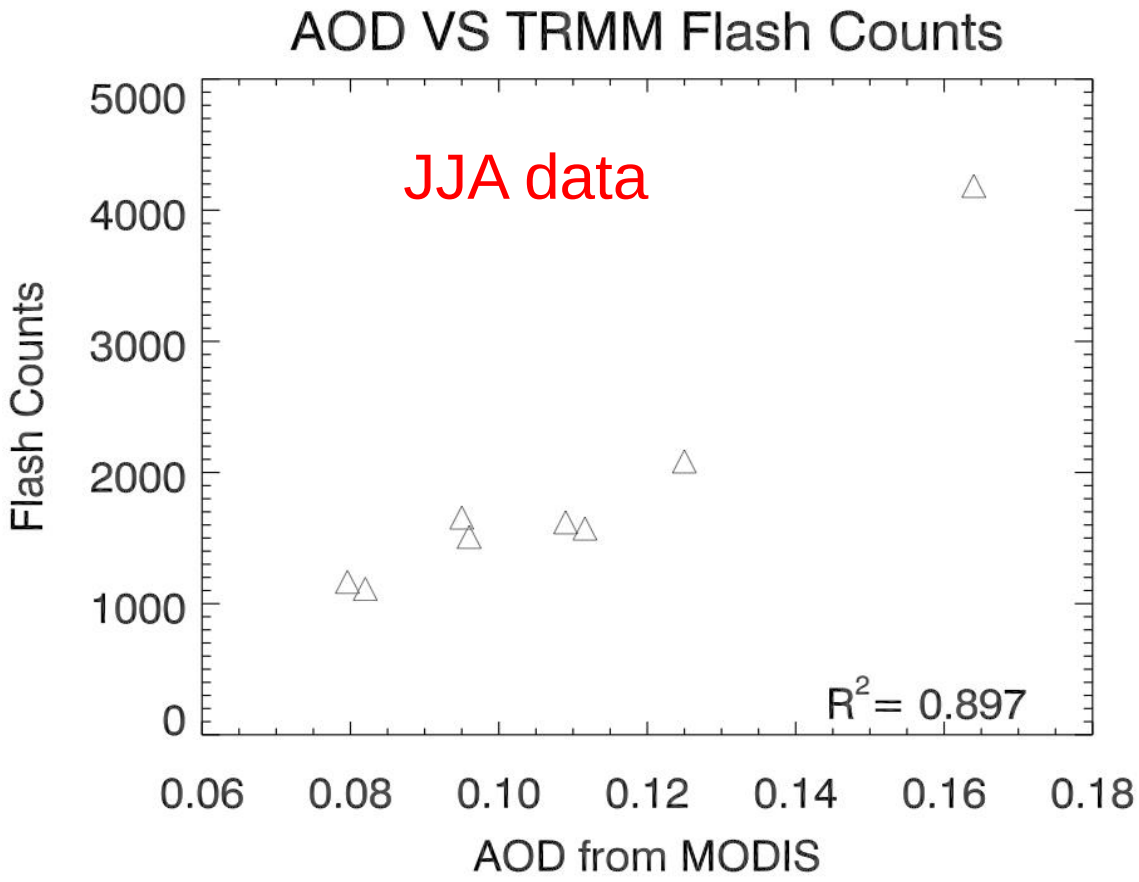
We use a natural experiment to avoid the convolution and examine aerosol invigoration

Our experiment



Aerosol increases lightning

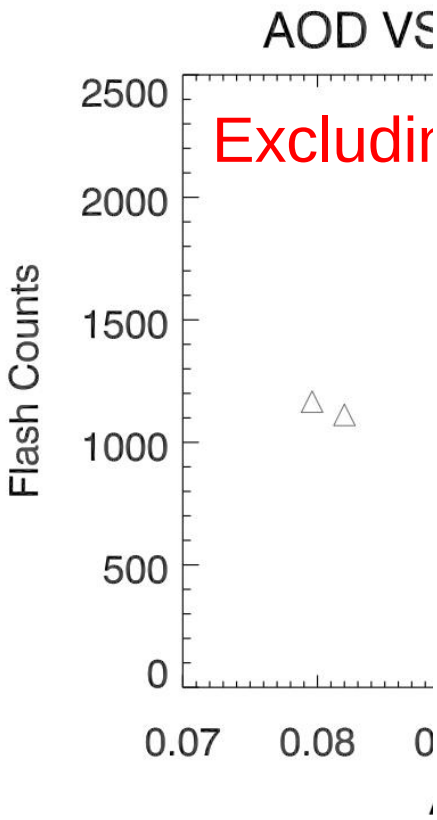


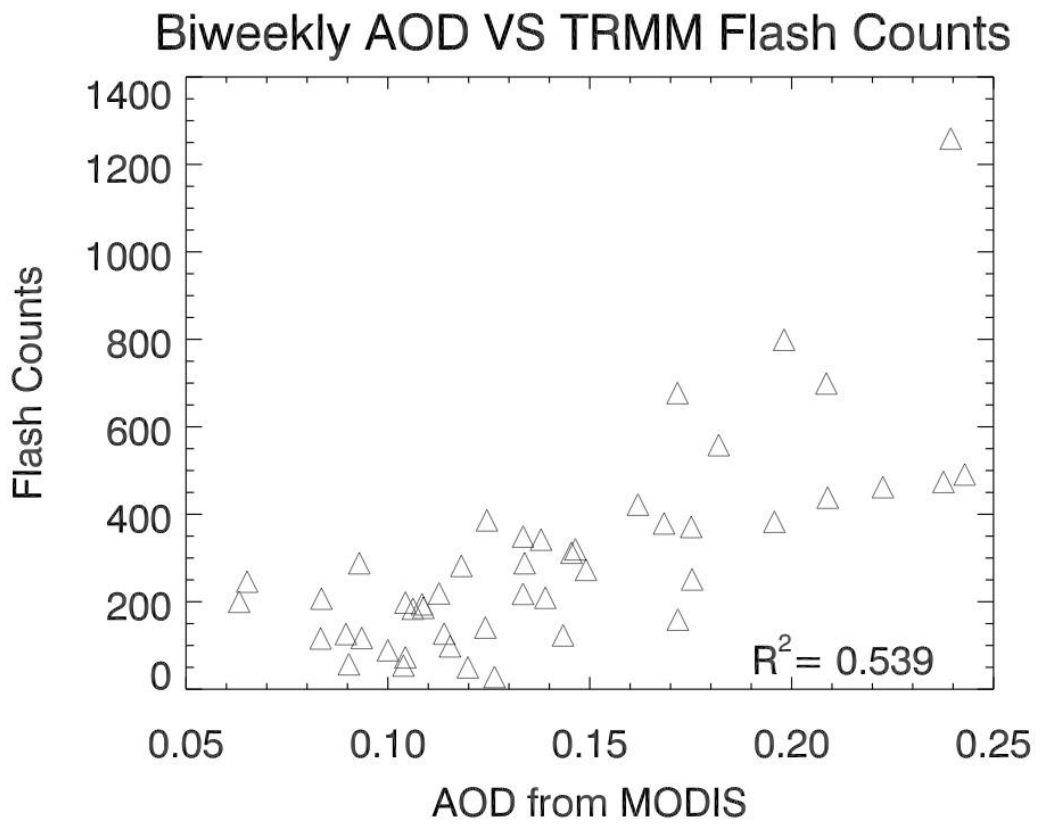


Aerosol-lightning

P<0.001

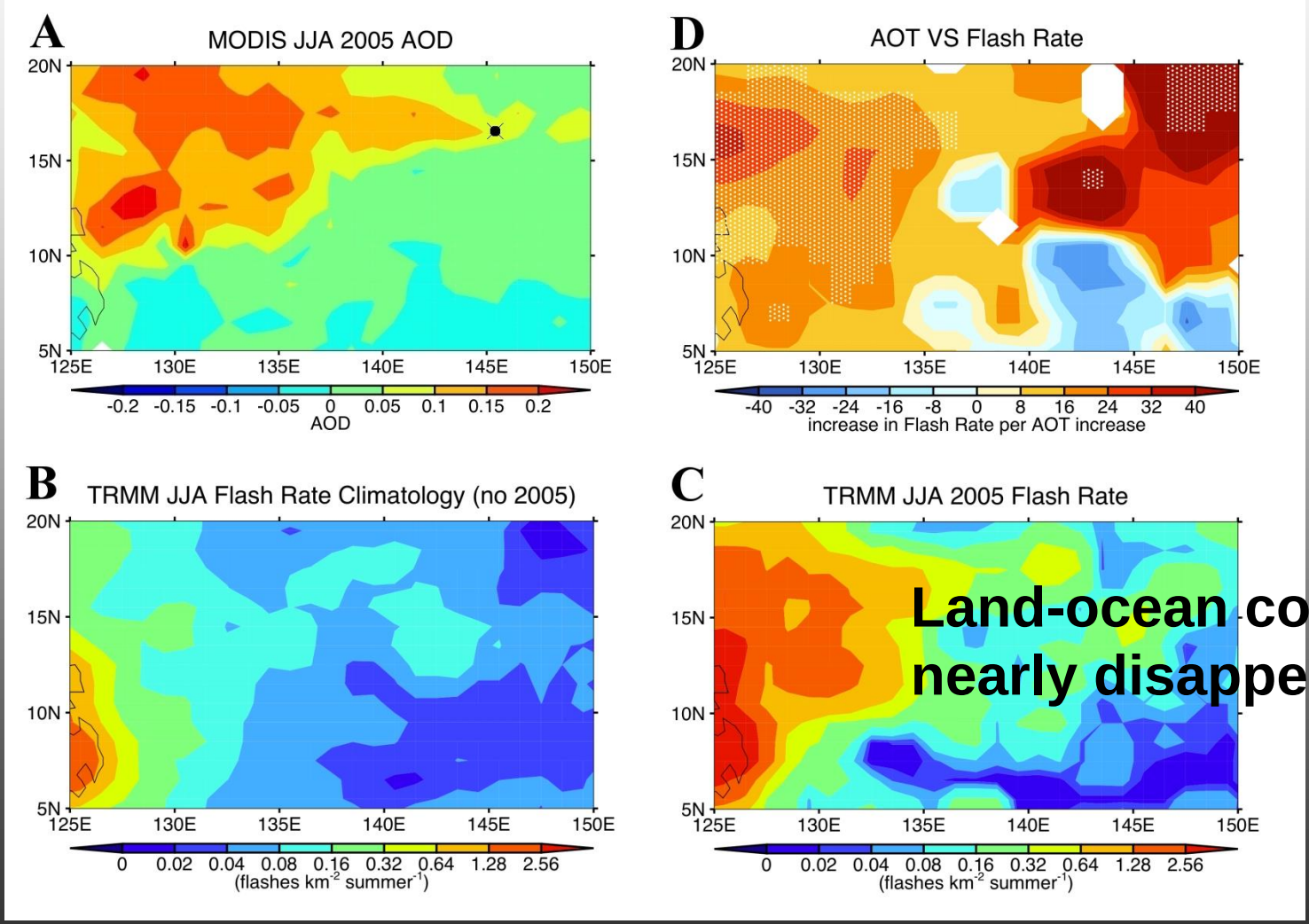
Yuan et al. (2011)





Detailed view

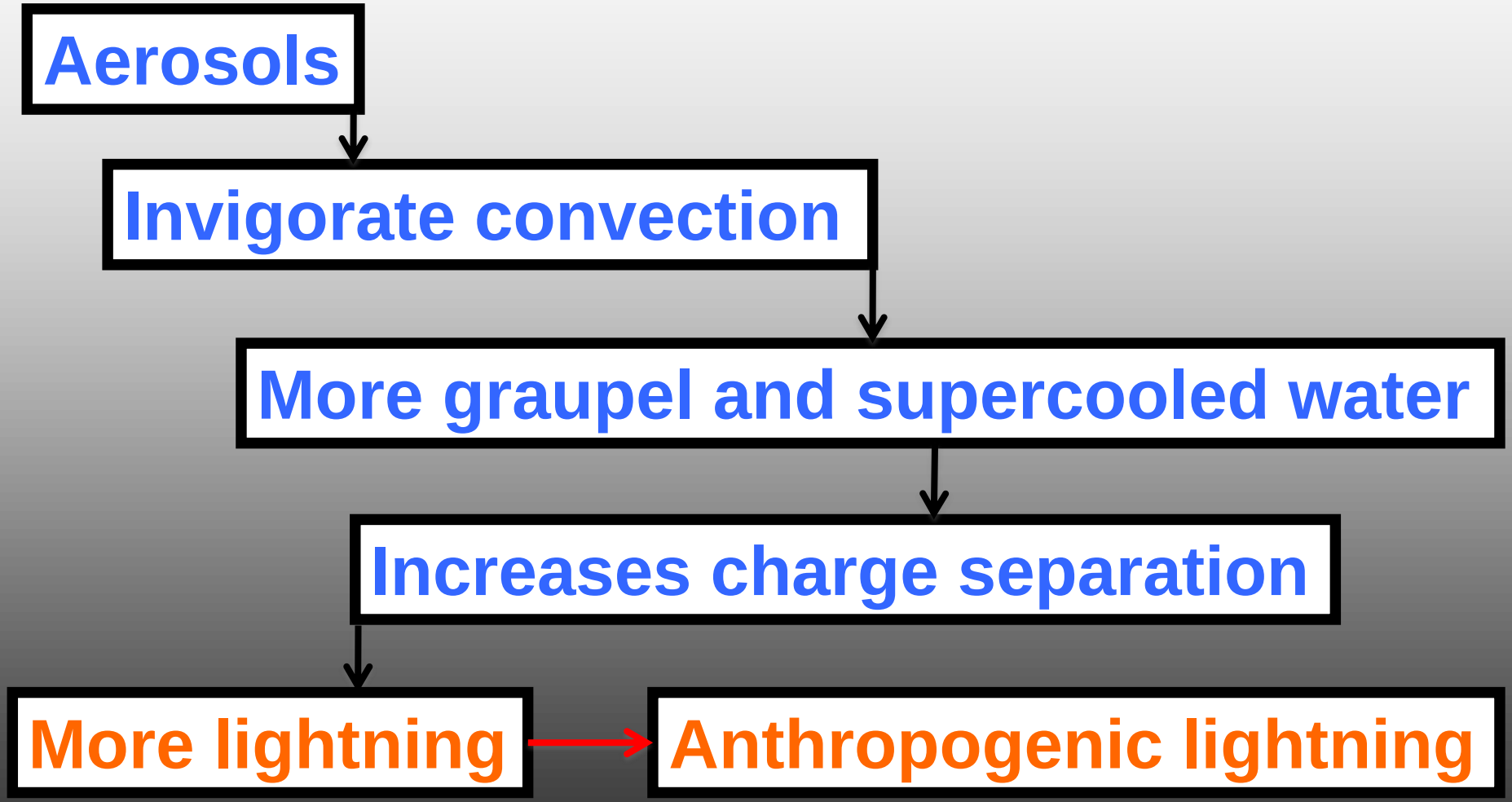
1. Aerosols explain a big portio of land-ocean contrast
2. Maritime is highly sensitive to aerosol perturbations.



Land-ocean contrast nearly disappears

See details in Yuan et al. (2012)

Part II Summary



Yuan et al. (2012 & 2011)

References

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Yuan T., et al. (2012): Aerosol indirect effect on tropospheric ozone via lightning, *J Geophys Res-Atmos , 117, D18213, doi:10.1029/2012JD017723.*

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