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.
What does nature tell us about AIE?

The natural experiment

NASA MODIS
What does nature tell us about AIE?

Volcanic aerosol plume

MODIS 2008 JJA
What does nature tell us about AIE?

Aerosol increases cloud fraction

[Graph showing the relationship between normalized aerosol index and normalized cloud fraction.]
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**Holistic forcing**

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

**TOA SW All Sky Albedo for July 2008**

**CERES SW Albedo at TOA**
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Large scale volcano tracks

See details in Yuan et al. (2011)
What does nature tell us about AIE?

Part I Summary

Aerosols

modify trade Cu microphysics

Suppress precipitation

Increase cloud amount

Large total indirect forcing
What does nature tell us about AIE?

Part II:

Aerosol interactions with deep convective clouds
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**The SLAC* conundrum**

- 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.
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**Two hypotheses for SLAC**

**Thermodynamic and dynamic**
- Higher Bowen Ratio over land
- Higher cloud base over land
- Lightning increases with island size

**Aerosol**
- 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
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Our experiment

AOD anomaly in JJA 2005

Anatahan volcano

AOD anomaly in JJA 2005
What does nature tell us about AIE?

**Aerosol increases lightning**

![Graph showing time series and AOD vs TRMM Flash Counts](chart.png)

- **Time Ser**
  - JJA total
  - JJA data

![Graph](chart.png)
What does nature tell us about AIE?

**Aerosol-lightning**

Yuan et al. (2011)

\[ P < 0.001 \]
What does nature tell us about AIE?

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

Detailed view

Land-ocean contrast nearly disappears

See details in Yuan et al. (2012)
What does nature tell us about AIE?

Part II Summary

Aerosols

Invigorate convection

More graupel and supercooled water

Increases charge separation

More lightning

Anthropogenic lightning

Yuan et al. (2012 & 2011)
What does nature tell us about AIE?

References


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