Large-scale industrial cloud perturbations confirm bidirectional cloud water responses to anthropogenic aerosols

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Cloud water responses

- The aerosol impact on clouds is the most uncertain mechanism of anthropogenic climate forcing
- Here we focus on aerosol-induced changes in cloud water content.
- It has been assumed before that aerosol–cloud–precipitation interactions will add to the initial albedo increase by increasing cloud water amount. In that case strong cooling effect would result from aerosol-cloud interaction.
- Our hypothesis is that cloud water can both increase and decrease as a result of aerosol pollution. This would lead to weak average change and associated forcing and would decrease the overall aerosol cooling effect.
- This question has been examined before on small scale, but now we study it on large scale to see if we can repeat the results.

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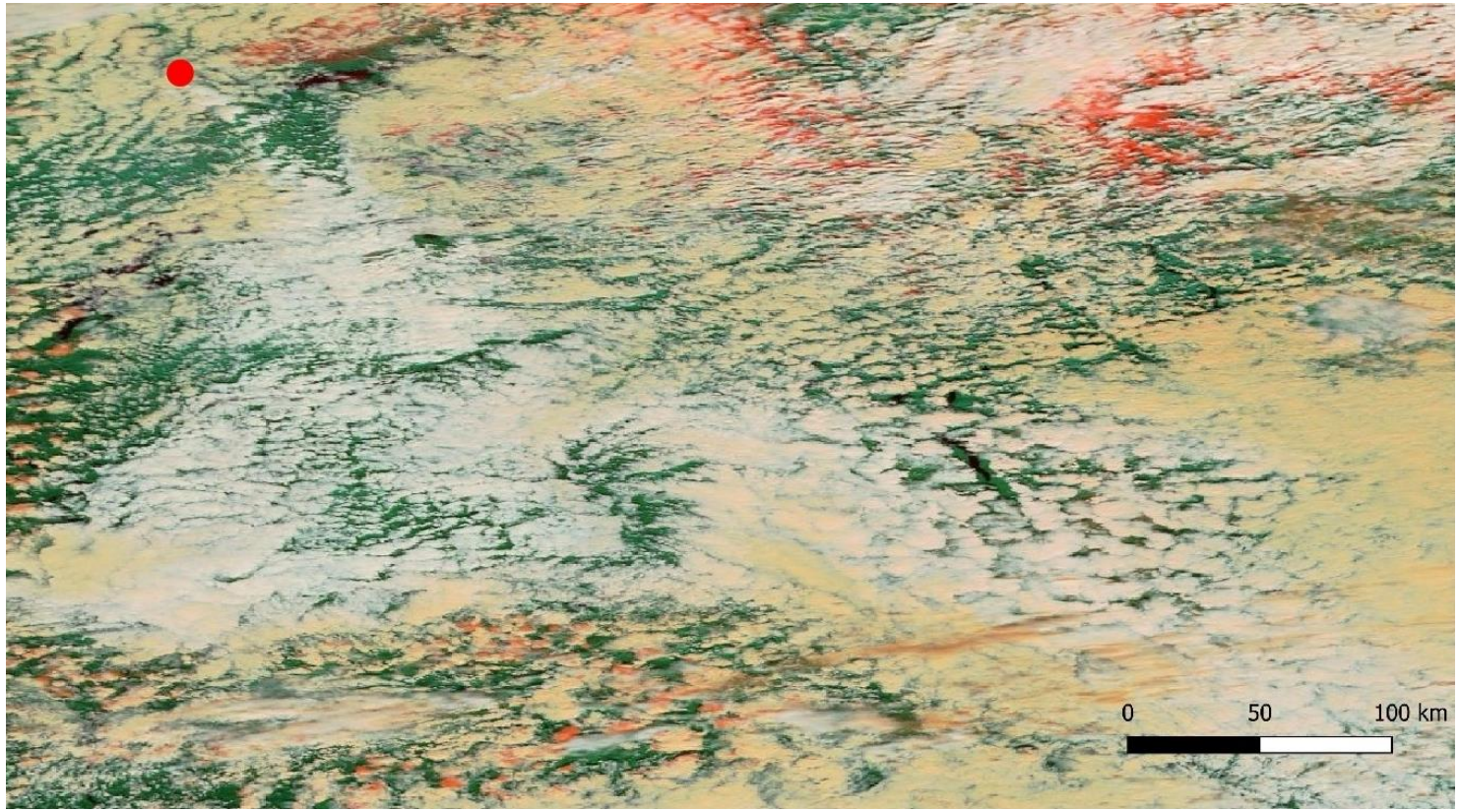
Detecting polluted clouds

- We use cloud brightening/cloud albedo effect



Norilsk,
June 27, 2000

Image from:
https://worldview.earthdata.nasa.gov/

Manuscript by H. Trofimov, N. Bellouin, V. Toll submitted to JGR: Atmospheres

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Detecting polluted clouds

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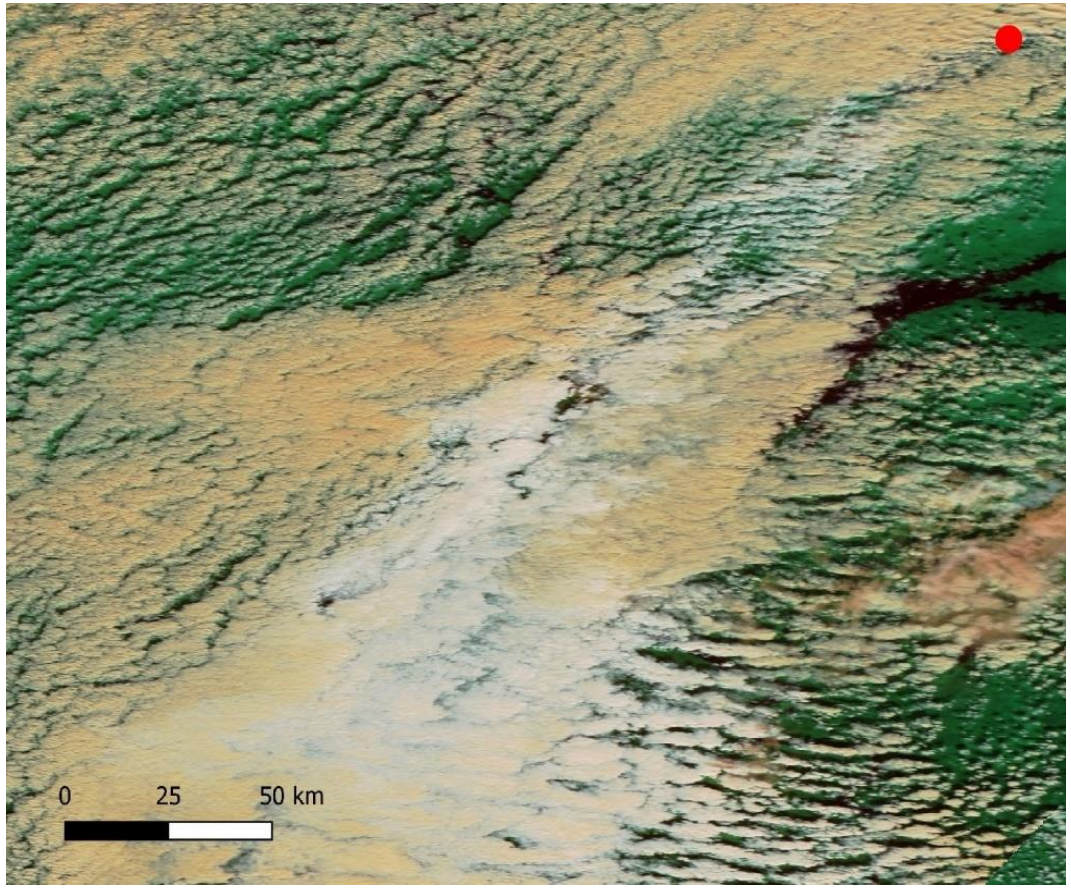

Norilsk,
August 26, 2006

Image from:
https://worldview.earthdata.nasa.gov/

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Detecting polluted clouds

- We use cloud brightening/cloud albedo effect

Western Europe,
March 19, 2016

Image from:
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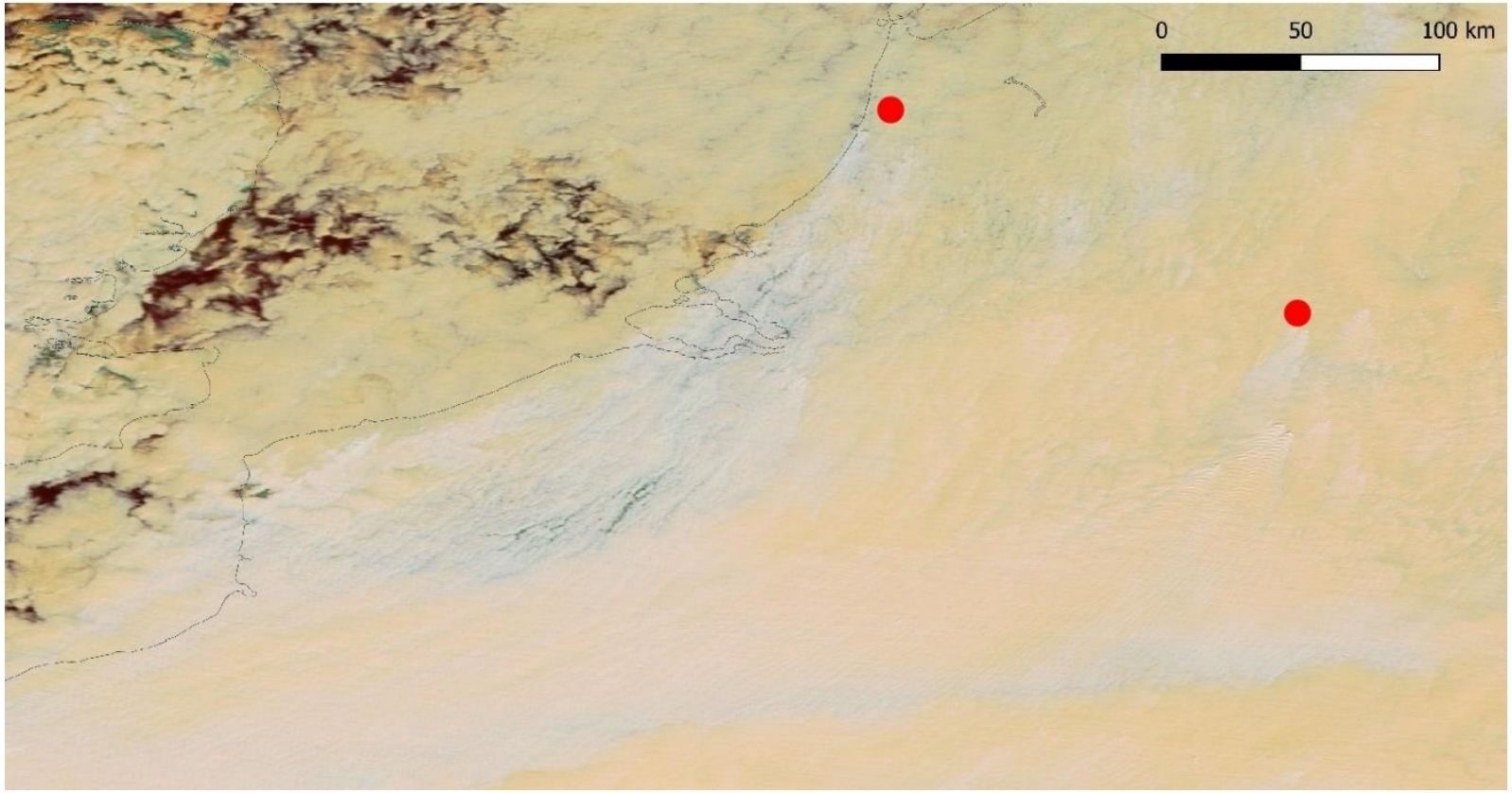

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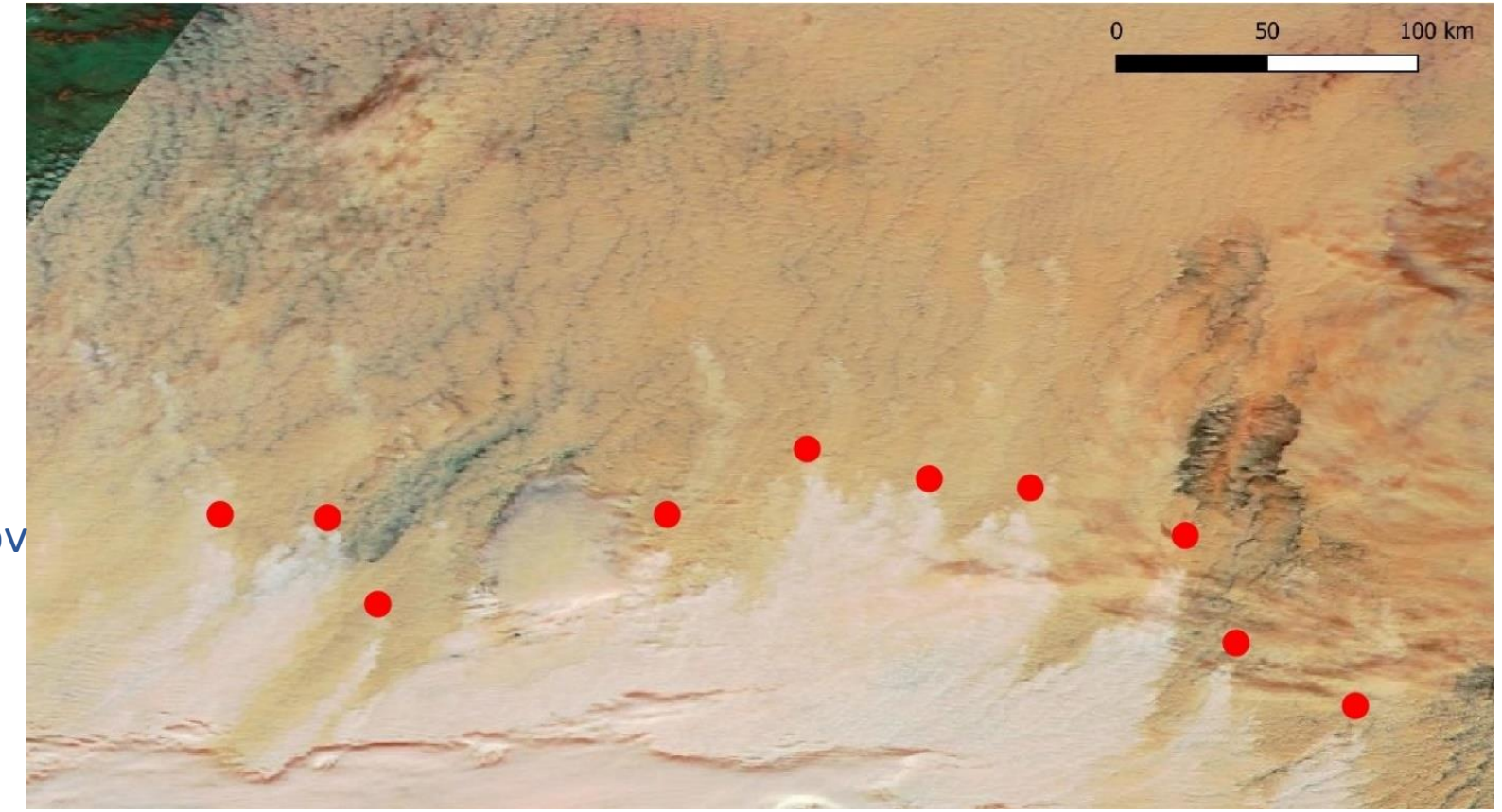
Detecting polluted clouds

- We use cloud brightening/cloud albedo effect

wildfire smoke in
Russia,
September 30, 2016

Image from:
https://worldview.earthdata.nasa.gov



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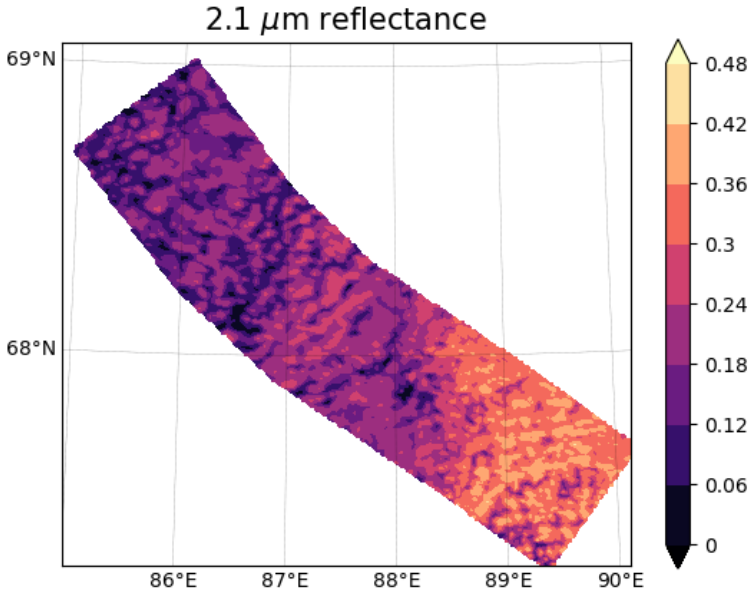
Dividing cloud pixels to polluted and unpolluted



Blue line – mean reflectance within the first 20% of the line length

Red line – two standard deviations above the blue line

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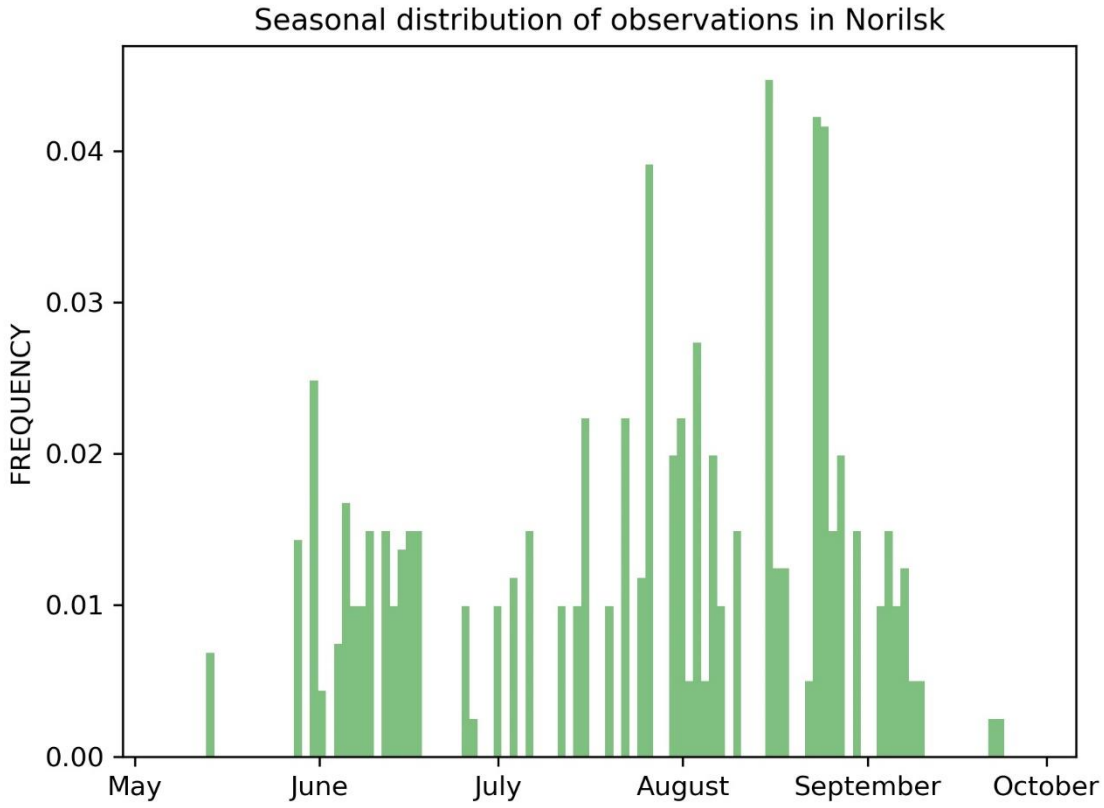
Results

- 1164 data tracks from Norilsk
- 99 data tracks from rest

of the world



Results

	Norilsk cases (1164)		
	Unpolluted area	Polluted area	Fractional change
R_{eff}	15.9 (4)	7.9 (2)	−50%
LWP	142.0 (80)	125.6 (74)	−10%
COD	14.1 (8)	25.6 (15)	+80%

	Non-Norilsk cases (99)		
	Unpolluted area	Polluted area	Fractional change
R_{eff}	14.4 (3)	8.4 (2)	−40%
LWP	184.5 (79)	141.0 (71)	−20%
COD	21.6 (12)	26.8 (12)	+20%

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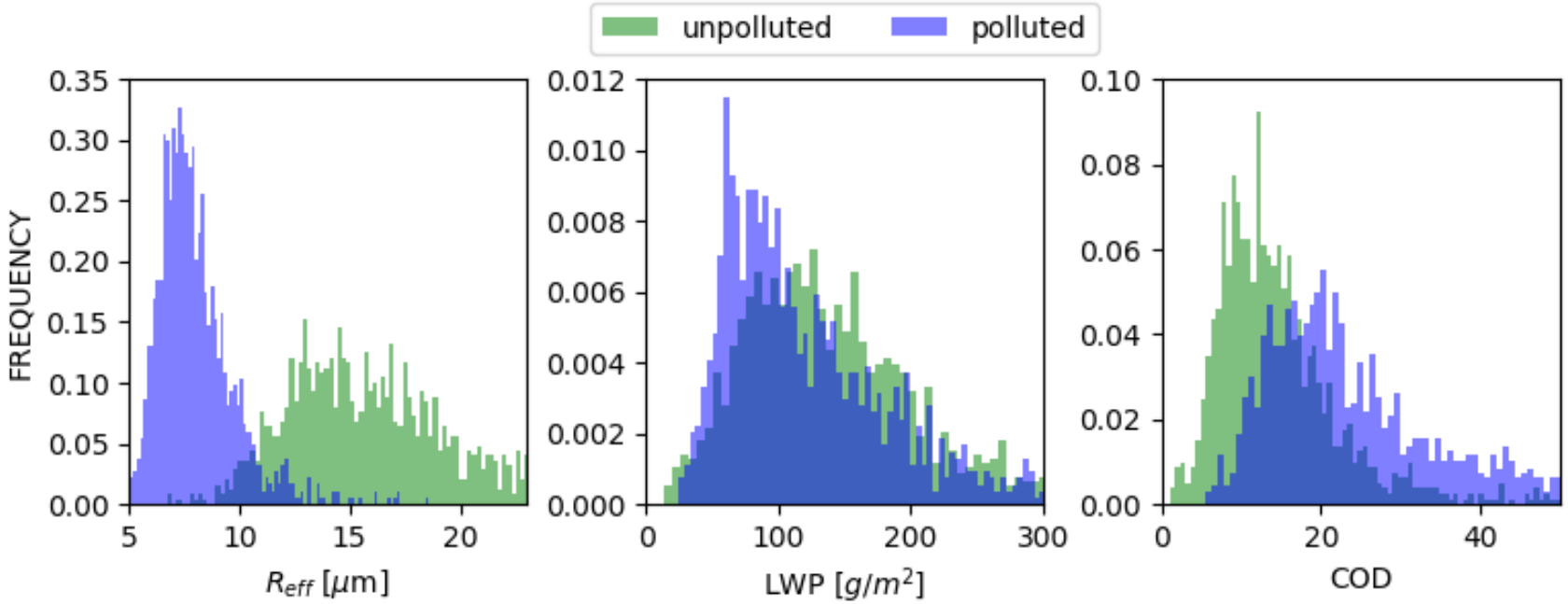
Results



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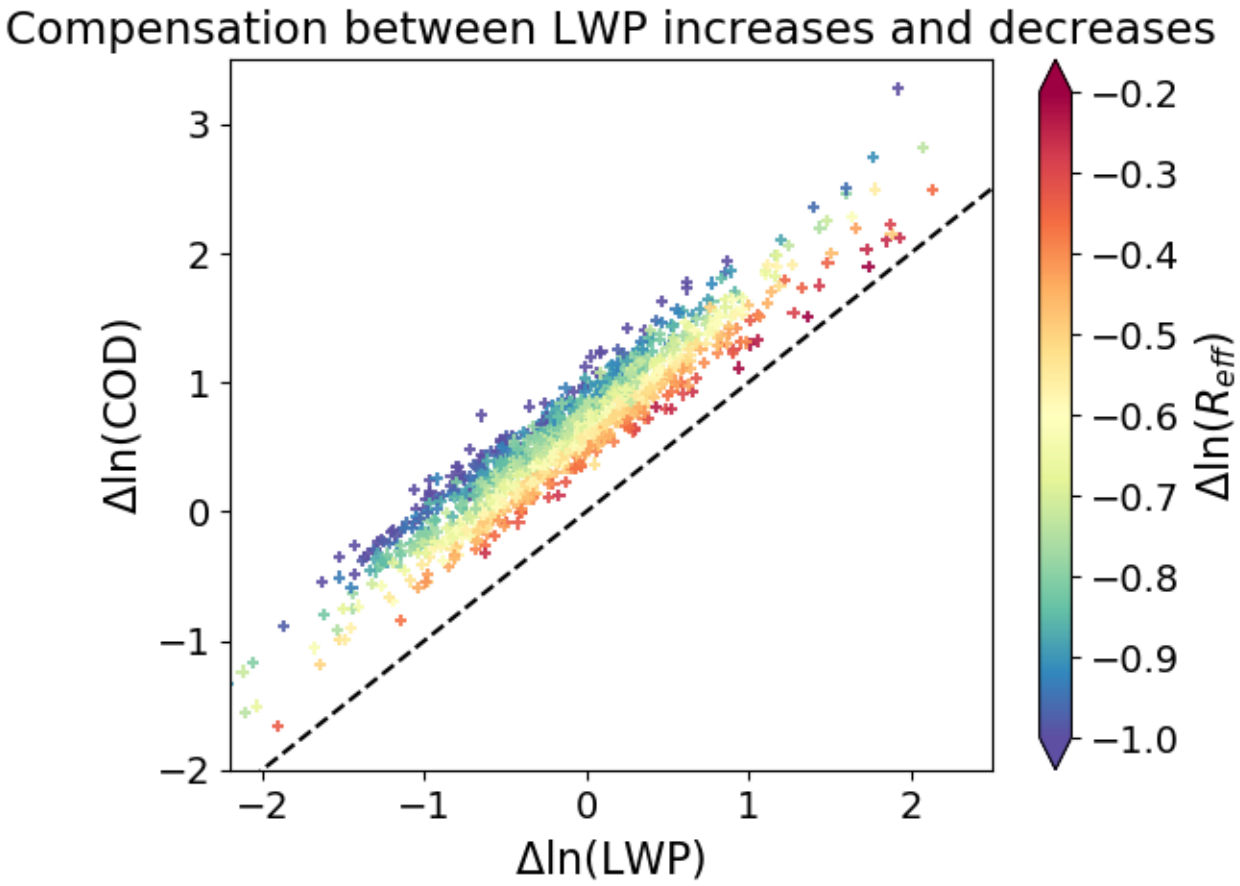
Results

- There is very close compensation between LWP increases and decreases, both in terms of frequency and magnitude
- Cloud droplet effective radius only decreases



dln(COD) = dln(LWP) - dln(Reff)

Conclusions

- On average, liquid cloud water response is relatively weak, because there is close compensation between aerosol-induced cloud water increases and decreases
- This is in good agreement with previous studies on smaller-scale tracks
- The Twomey effect (cloud brightening) dominates over the effect of cloud water response in the radiative forcing
- Our finding of a weak average LWP change in response to aerosols strongly disagrees with the assumption of universally increased LWP used in global climate models
- Our results help to reduce the uncertainty associated with the anthropogenic aerosol impacts on clouds

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Thank you for your attention.

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