Imperial College London

THE ROYAL SOCIETY

Identifying observational constraints for aerosol-cloud interactions

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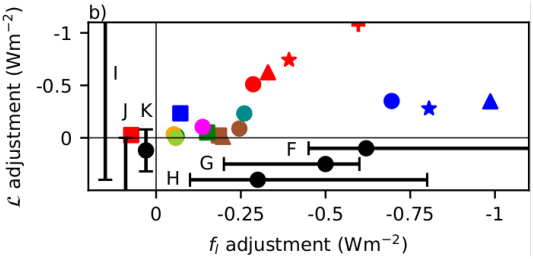
Thanks also to Dipu S. (Leipzig) and Johannes Mülmenstädt (PNNL)

Liquid water path (LWP) adjustments



LWP adjustments to aerosol vary significantly between models

- Up to 0.5Wm^{-2} cooling

How does aerosol impact LWP?

Gryspeerdt et al, ACP, 2019; Gryspeerdt et al., ACP, 2020

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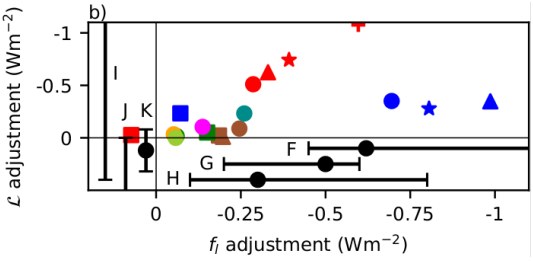

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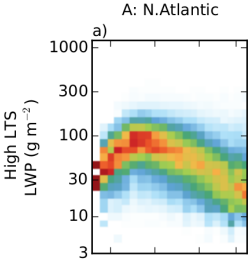

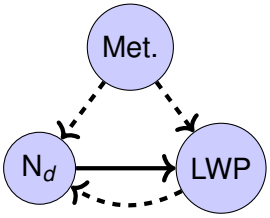

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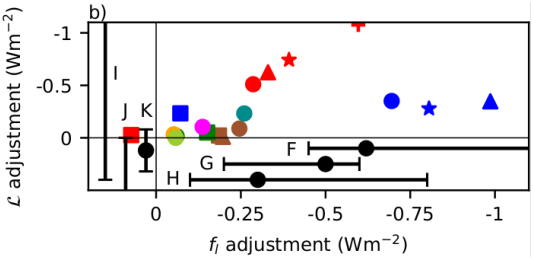

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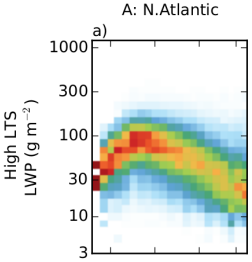
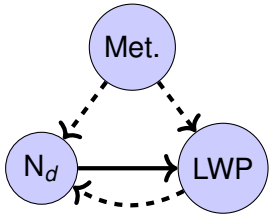
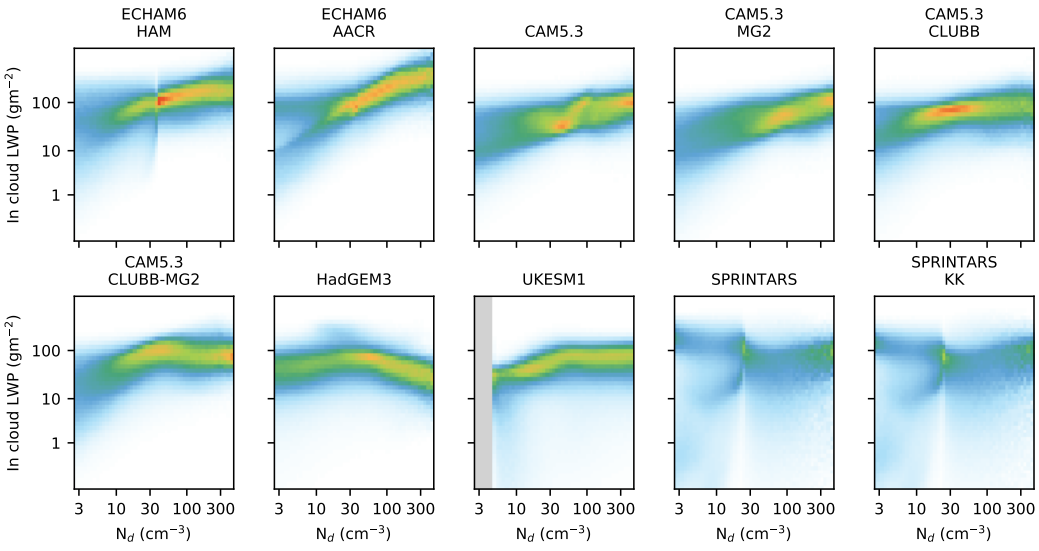




Is the observed relationship useful?

Gryspeerdt et al, ACP, 2019; Gryspeerdt et al., ACP, 2020

Variation between models



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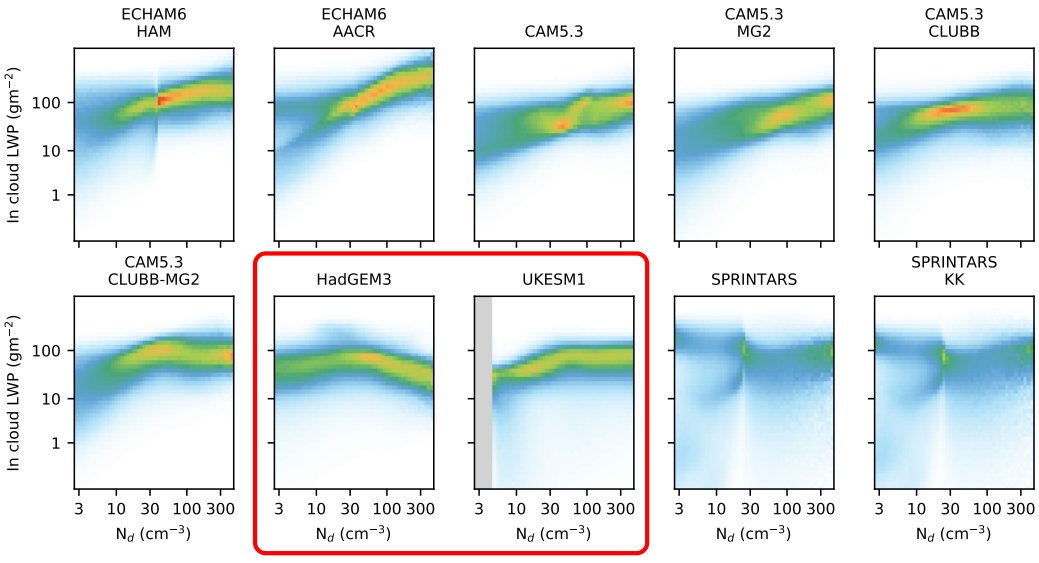
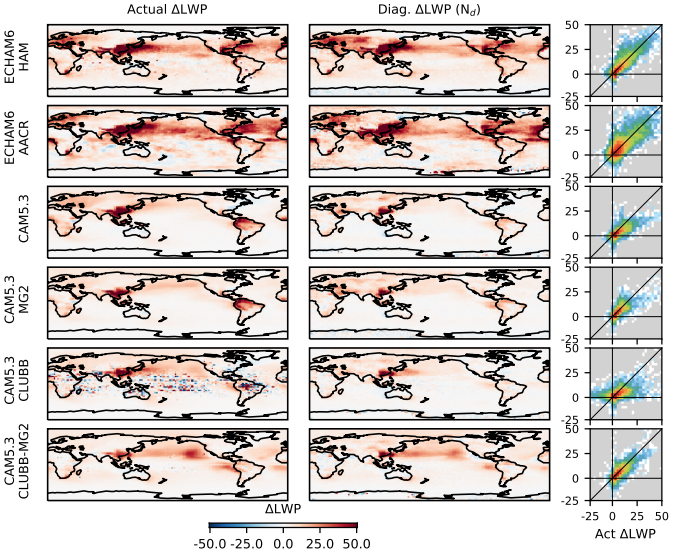


Is the N_d-LWP relationship a useful constraint?



$$\Delta LWP \stackrel{?}{=} \left.\frac{dLWP}{dN_d}\right|_{PD} \Delta N_d$$

$$\Delta LWP_{actual} \stackrel{?}{=} \Delta LWP_{diag}$$

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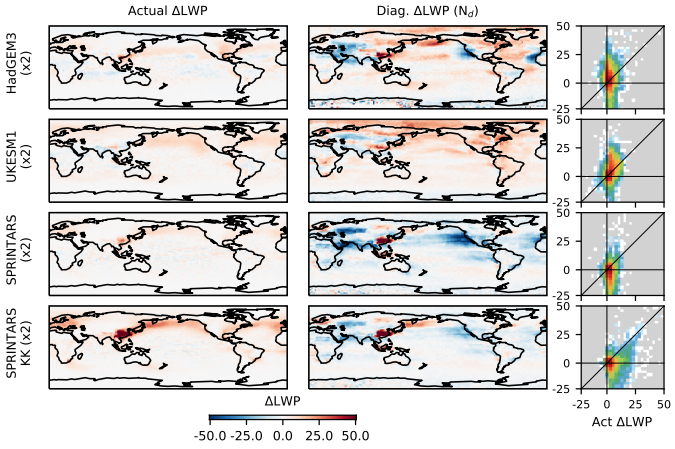

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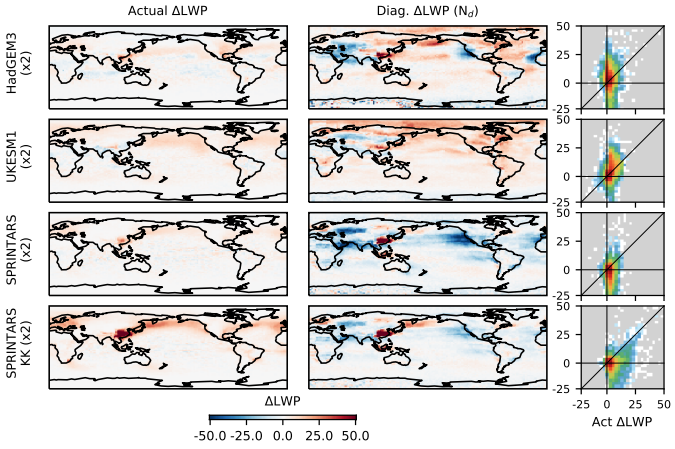

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- Cloud adjustments (what we want)
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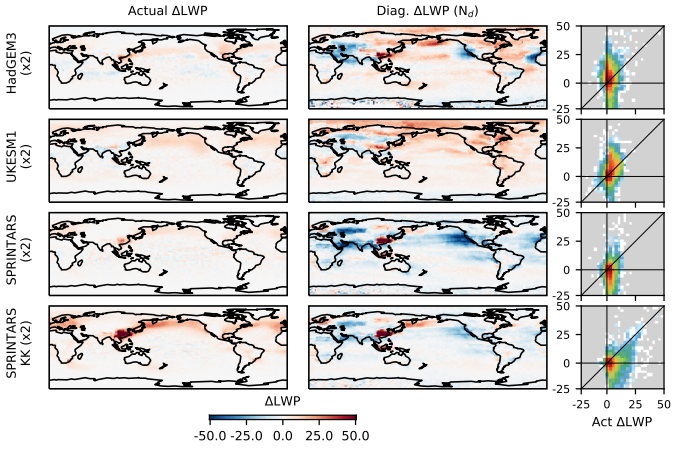

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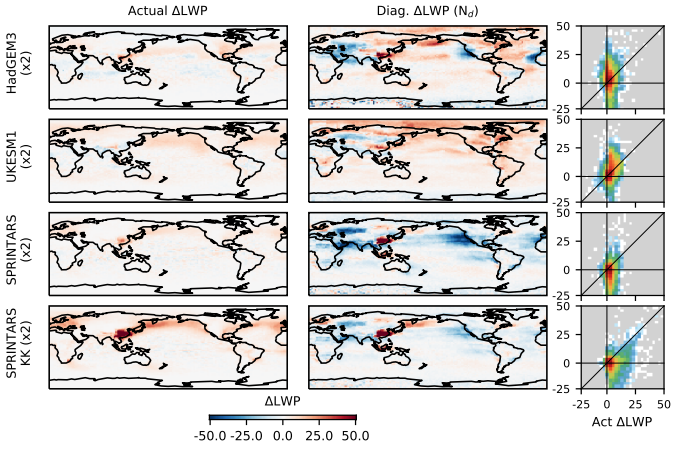

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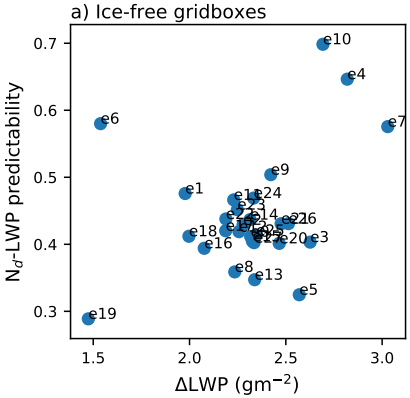
Predictability = $r(\Delta LWP_{actual}, \Delta LWP_{diag})$

Is this just the weak-response models?

Stronger adjustment → clearer signal → better predictability?



- Using an ensemble of runs from E3SM
  - Variety of perturbed cloud processes
- Ice-free gridboxes only (like a satellite)
- Weak correlation between response magnitude and predictability
- Variability driven by precipitation processes
  - Autoconversion, accretion

E3SM ensemble - Ma et al., *in prep.*

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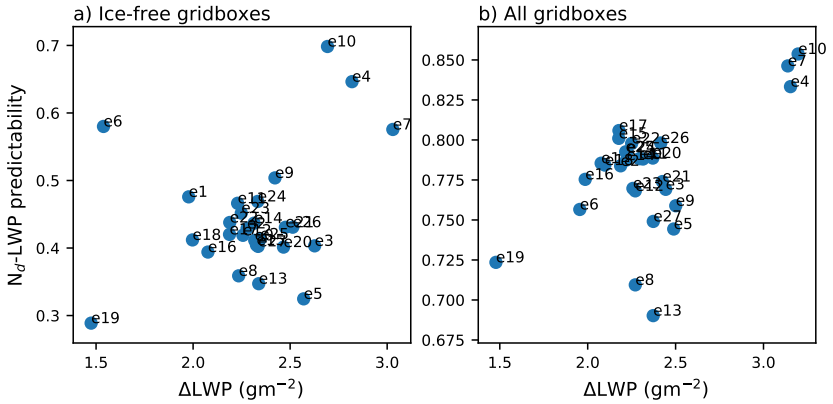

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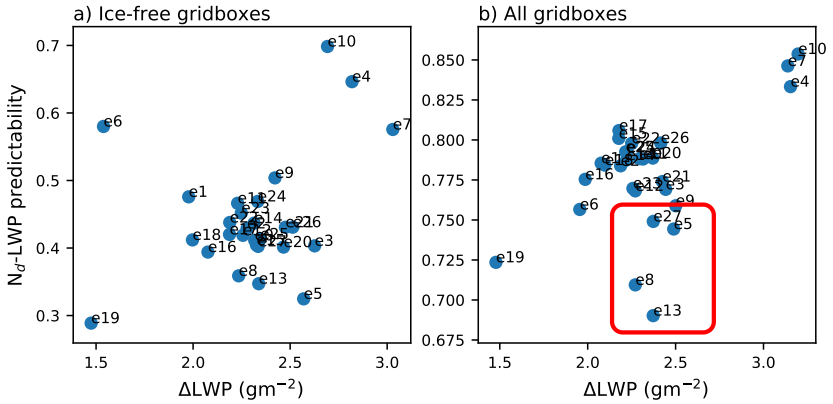


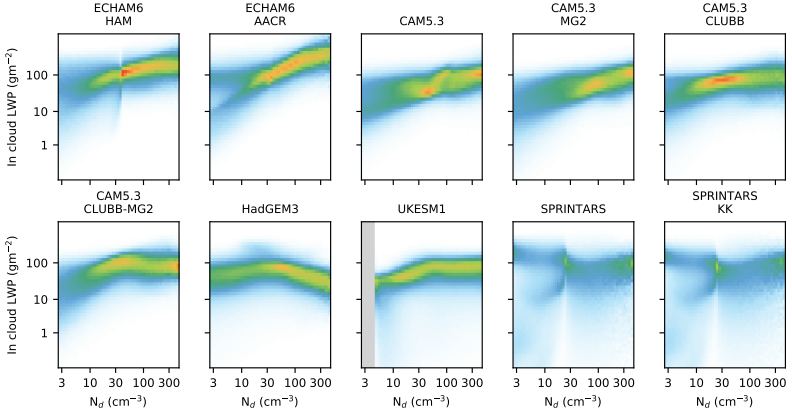
Slightly more optimistic picture when using all data

- Big changes in predictability from non-precip. processes (TKE, sedimentation)

E3SM is already predictable, an "unpredictable" model would be interesting!

Summary

- Large variation in the N_d-LWP relationship between models



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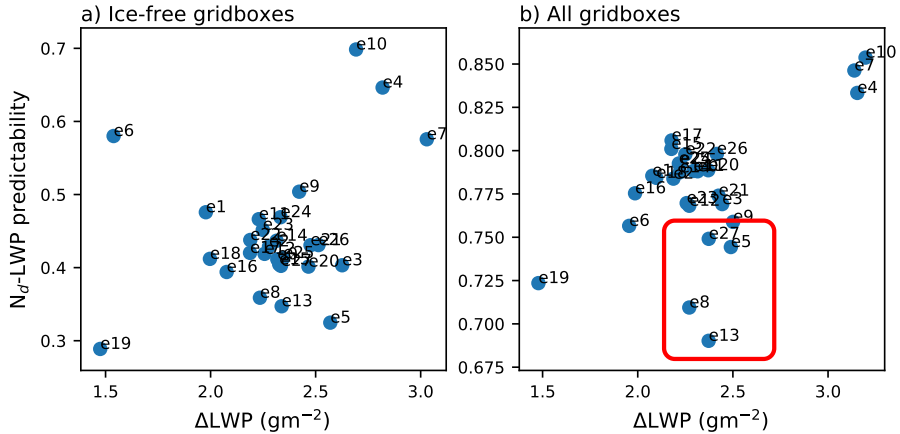
- Large variation in the N_d-LWP relationship between models
- Power as a constraint varies significantly (currently model specific)



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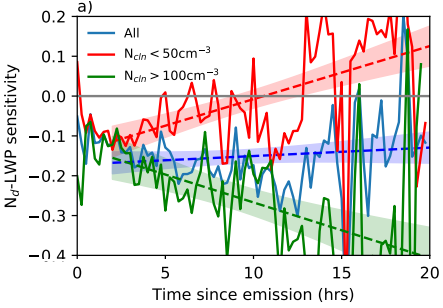

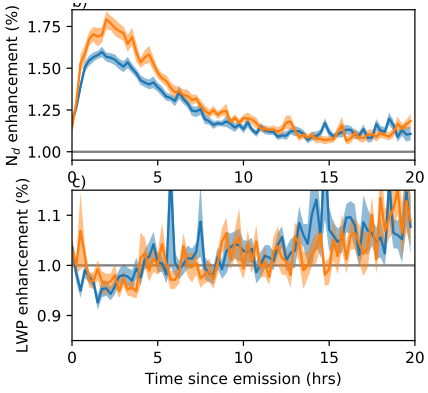

- Excellent evidence of aerosol effects
- Can be difficult to generalise

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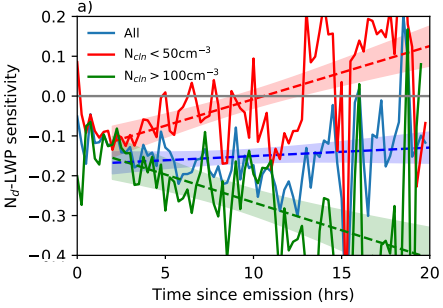

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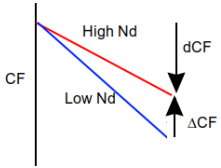
Temporal responses



How does aerosol effect cloud evolution?

- Short-term (Matsui, JGR, 2006)
- Longer-term development (Christensen et al PNAS, 2020)

Summary

- Large variation in the N_d-LWP relationship between models
- Power as a constraint varies significantly (currently model specific)
- Some techniques (e.g. natural experiments) may get around this
  - If we can generalise them...

Future experiment design

- The AeroCom indirect effect experiment is *very* useful to analyse observational studies
  - Due to foresight in output selection
- Some of these models are older versions now
  - Some more recent model data around (UKESM)
- Doesn't require a large amount of output (2D daily, PD and PI runs)
  - Could be added to forcing calculation simulations
  - Or other experiments?
  - Just replicating the existing AIE experiment might be an easy start