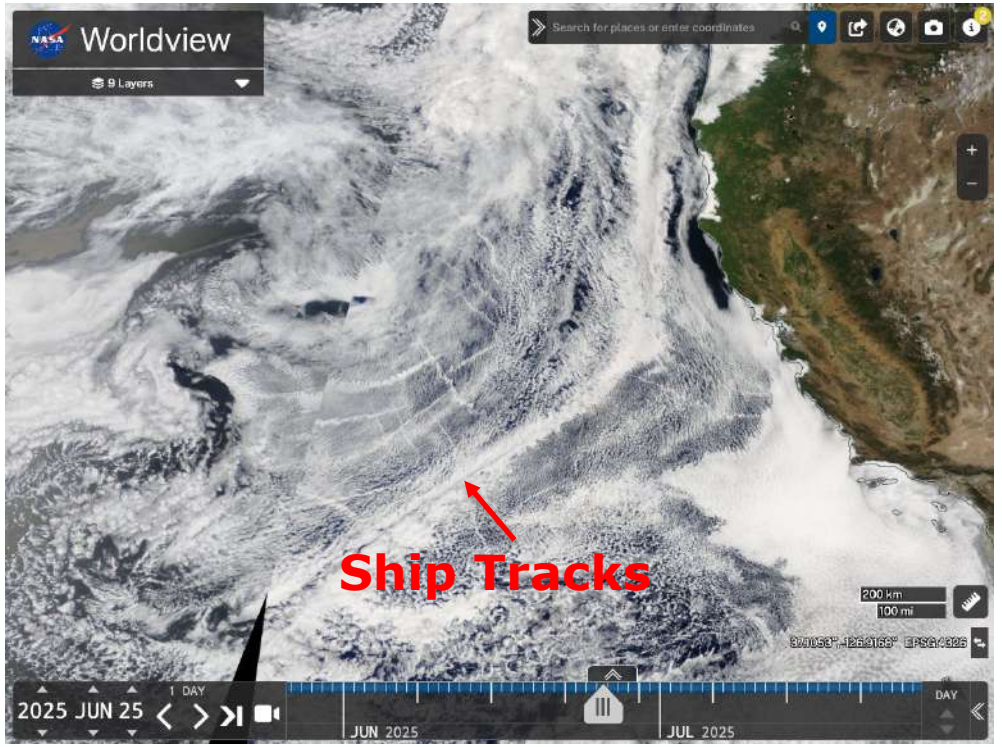
Examining the Vertical Structure and Motions of Visible and Invisible Ship Tracks

Sarah Smith, PhD

Postdoctoral Research Scientist

Collaborators: Philip Stier, Peter Manshausen, Kallista Angeloff

Background: Ship Tracks



~9-10 km in width (±5 km)

Twomey effect

Lifetime Effect

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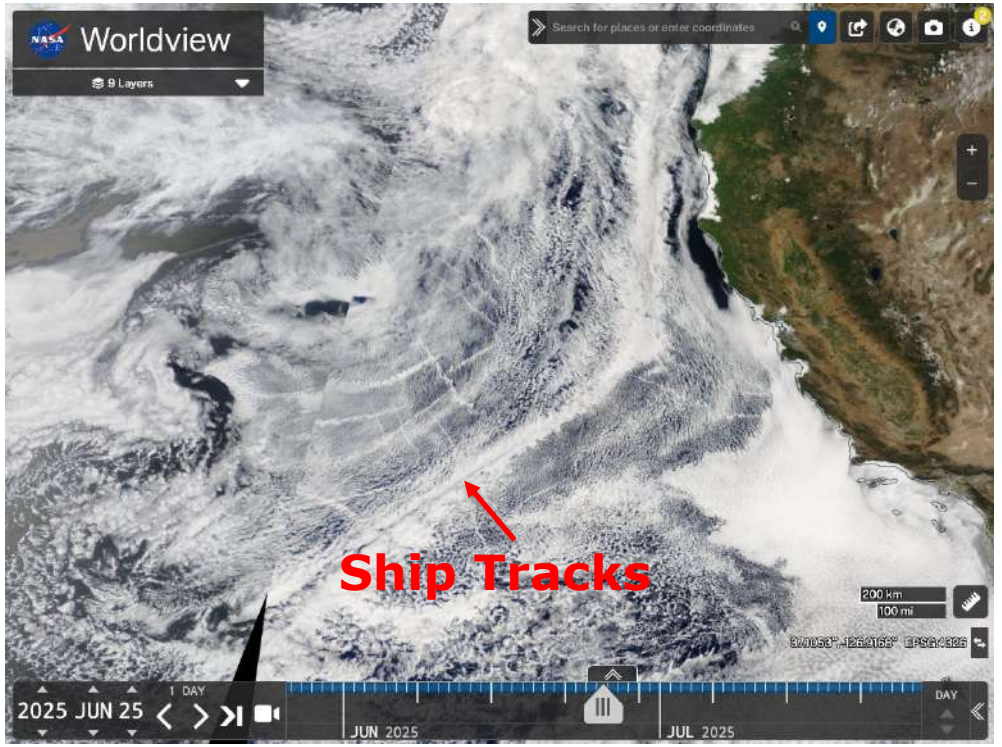

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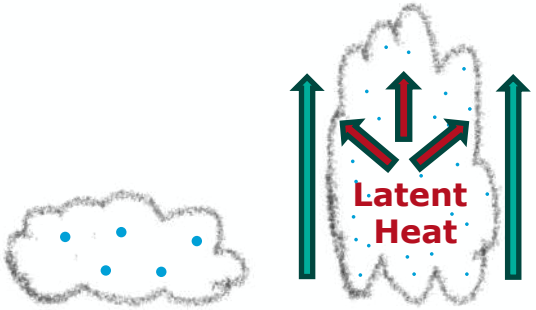
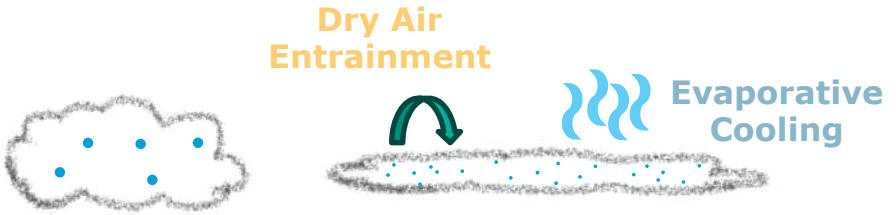


Twomey effect

Convective Invigoration

Lifetime Effect

Entrainment-evaporation Effects



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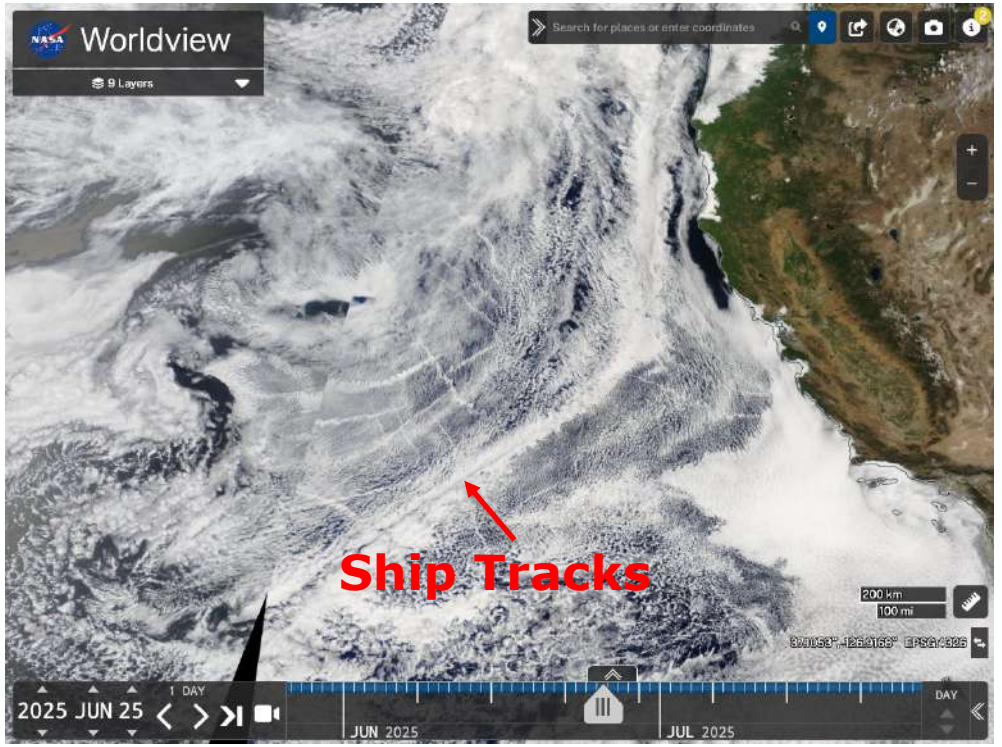

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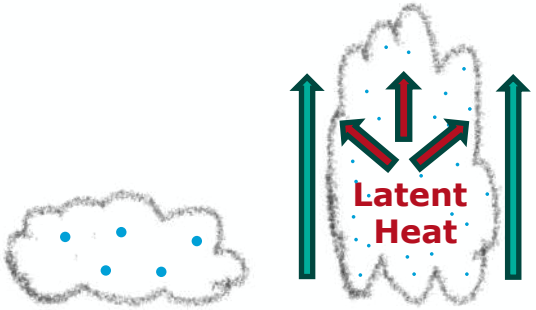

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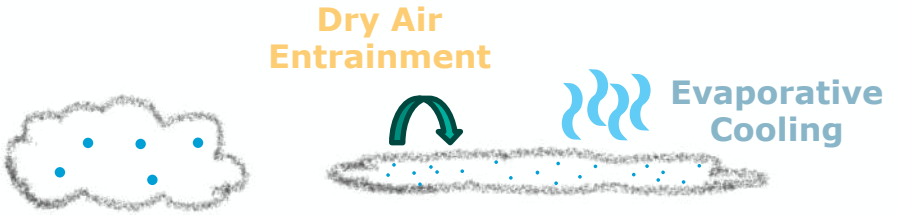


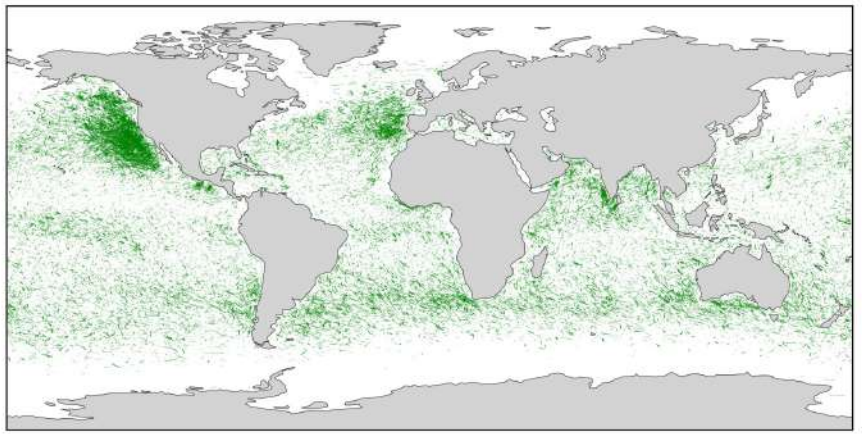
Macrophysical responses are much harder to constrain observationally

Aerosol → CCN → N_d / R_e → V_{air} → e.g. CTH

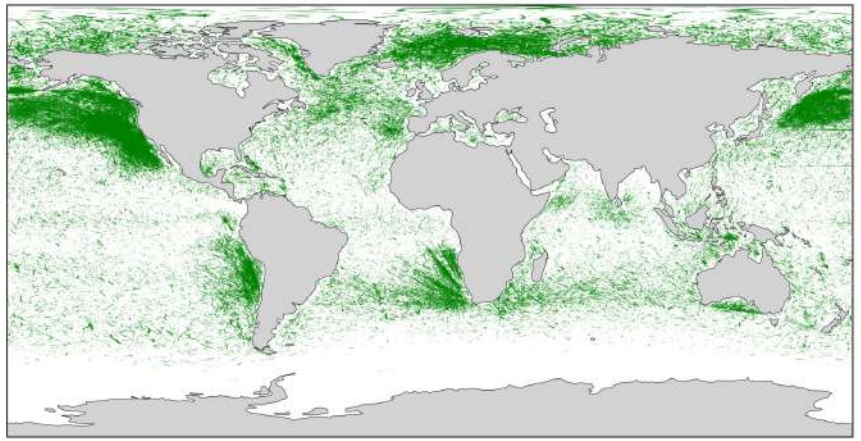
Background: Ship Tracks

Ship Tracks Detected from MODIS (2000-2022)

January



July



Sensitivity to visible track formation varies in time and space

cloud + shipping emissions ≠ Twomey

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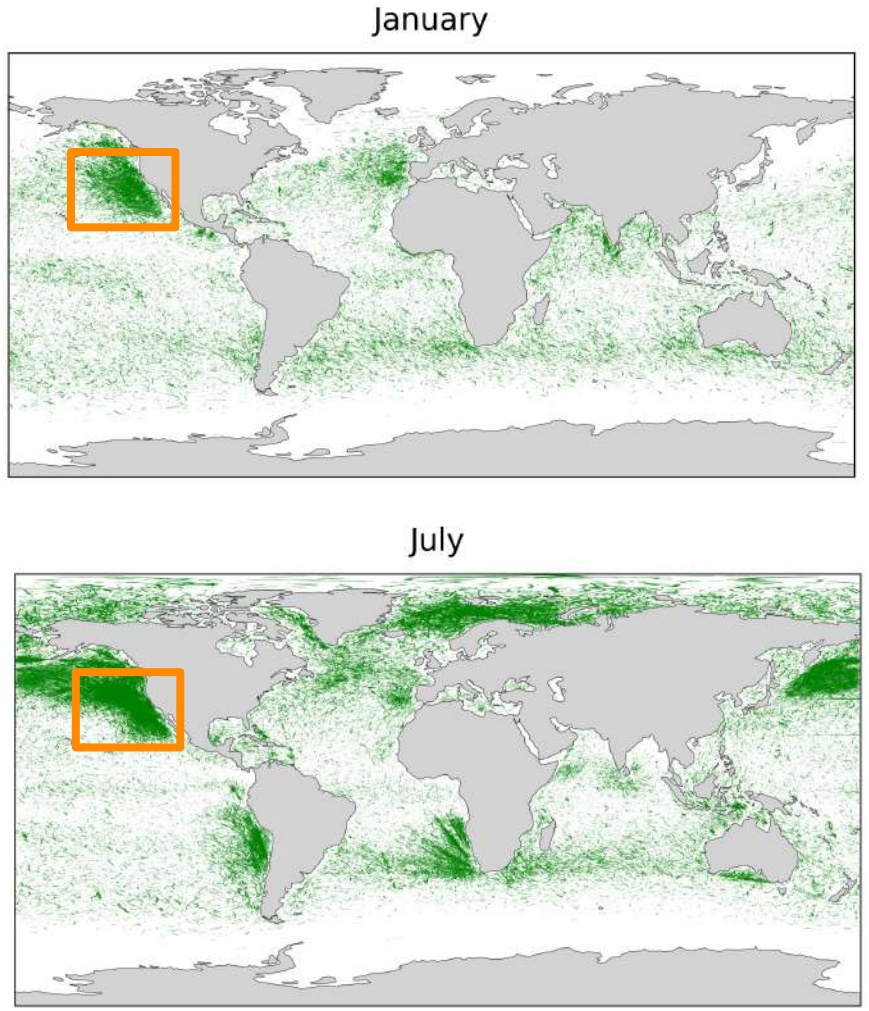

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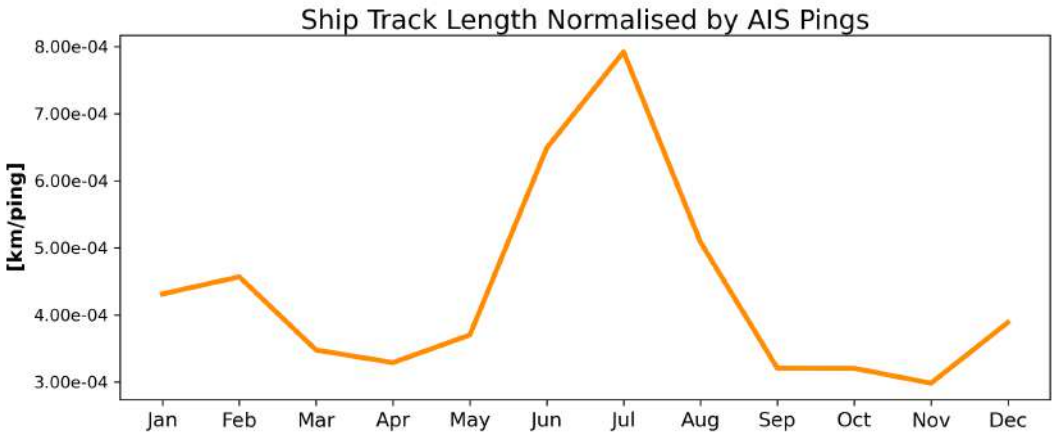

Background meteorology governs the cloud response to shipping emissions, but what exactly what variables lead to different effects still not known.

Background: Invisible Ship Tracks

Article

Invisible ship tracks show large cloud sensitivity to aerosol

https://doi.org/10.1038/s41586-022-05122-0
Received: 15 February 2022
Accepted: 19 July 2022
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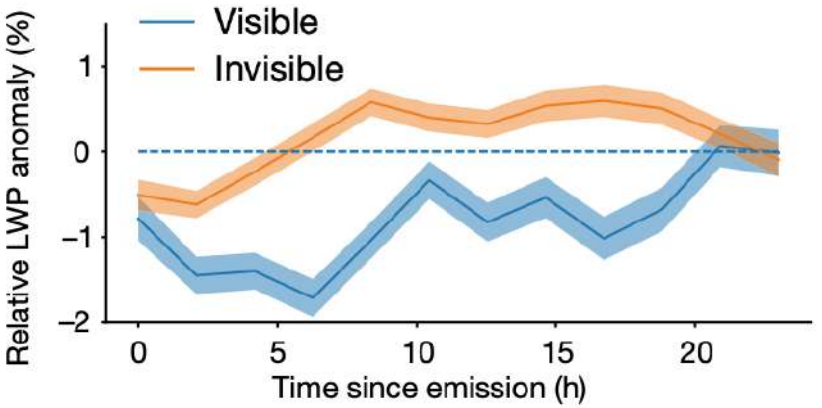
Peter Manshausen[1✉], Duncan Watson-Parris[1], Matthew W. Christensen[2], Jukka-Pekka Jalkanen[3] & Philip Stier[1]



"Invisible" tracks deepen clouds, presumably through convective invigoration.

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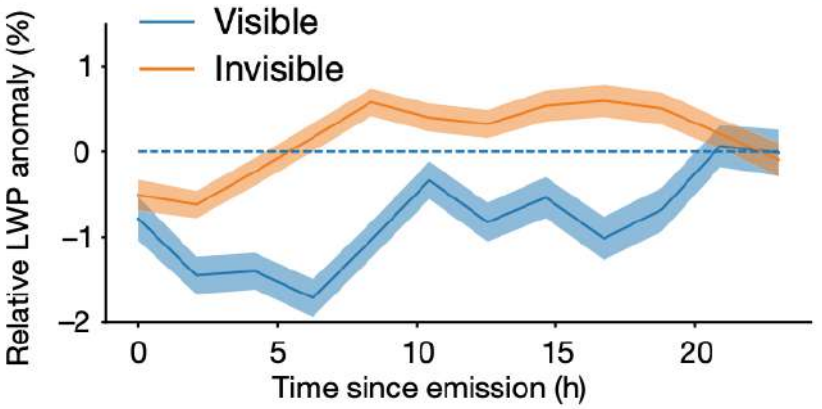
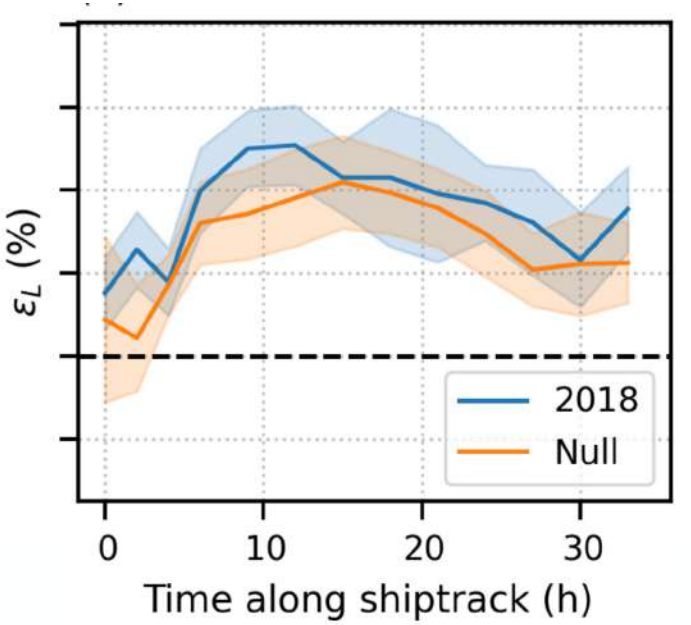


Shipping emissions are preferentially advected into clouds that are already deepening.



"Invisible" tracks deepen clouds, presumably through convective invigoration.

Weak liquid water path response in ship tracks

Anna Tippett[1], Edward Gryspeerdt[1], Peter Manshausen[2], Philip Stier[2], and Tristan W. P. Smith[3]

[1]Department of Physics, Imperial College London, London, UK
[2]Department of Physics, University of Oxford, Oxford, UK
[3]UCL Energy Institute, University College London, London, UK

Correspondence: Anna Tippett (a.tippett22@imperial.ac.uk)

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Revised: 28 September 2024 – Accepted: 1 October 2024 – Published: 2 December 2024

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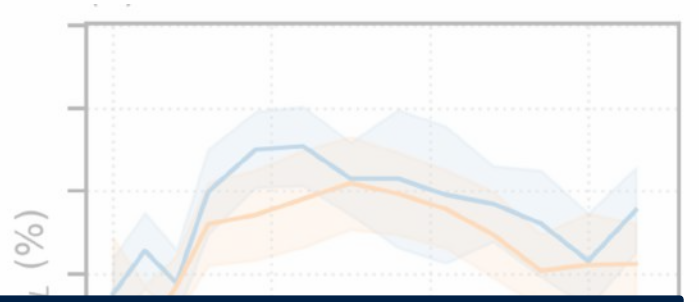

Do ship track vertical profiles show evidence of convective invigoration, convective inhibition, or preferential advection?

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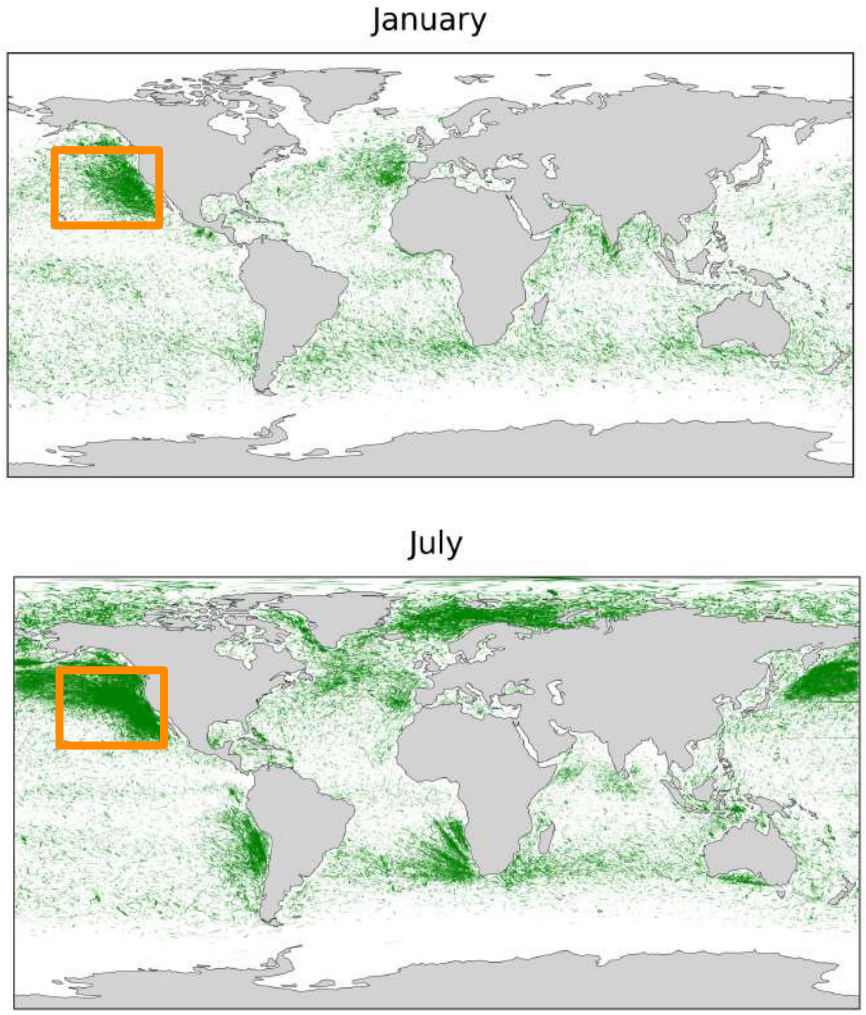

1. **Use AIS data off California Coast in January (low ship track month) and July (high ship track month)**
2. Advect emissions (HYSPLIT)
3. Co-locate advected “tracks” with EarthCARE (daytime, descending)
4. Examine vertical profiles and velocities against background state (CPR Products)

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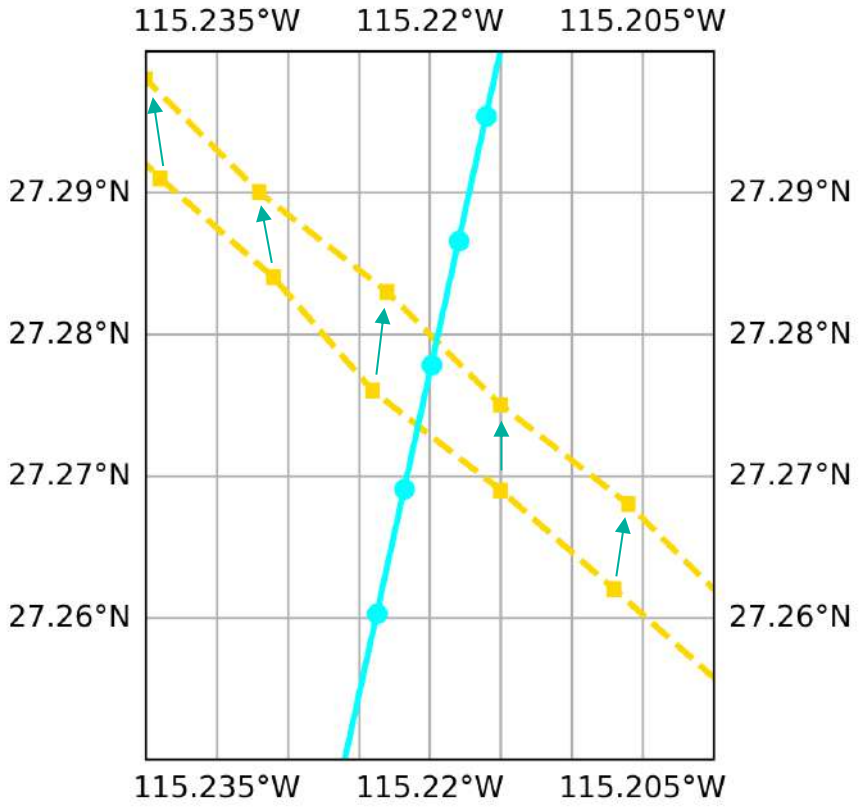

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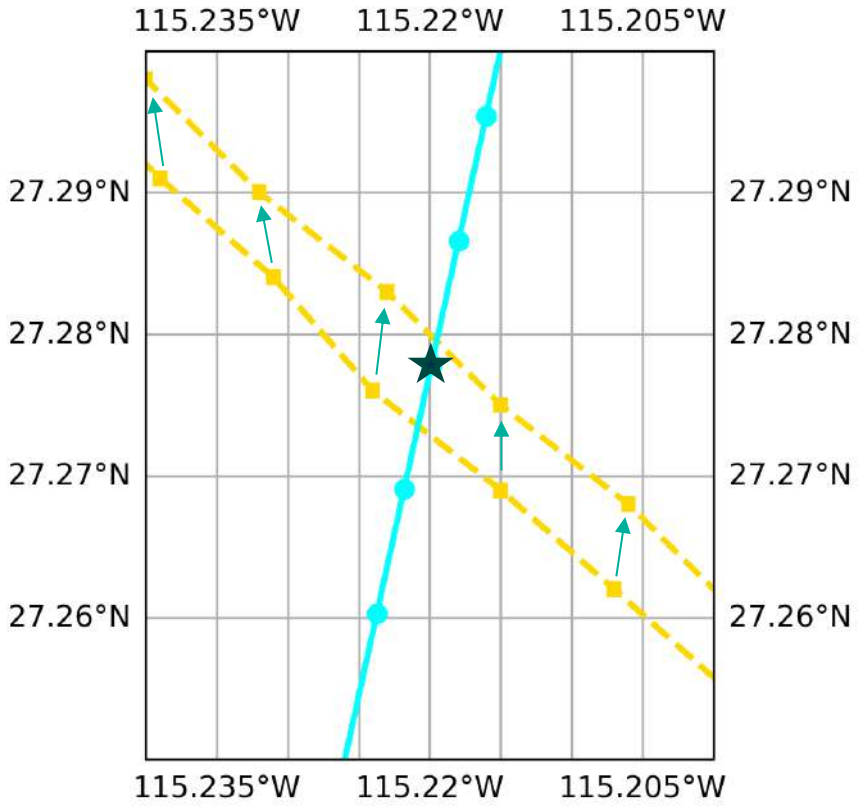

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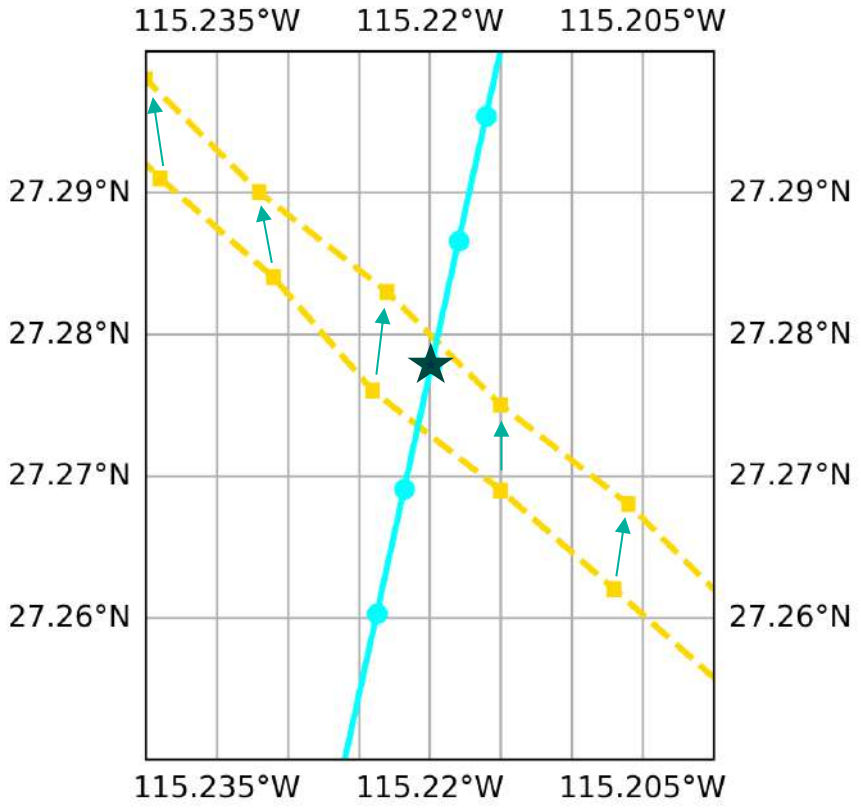

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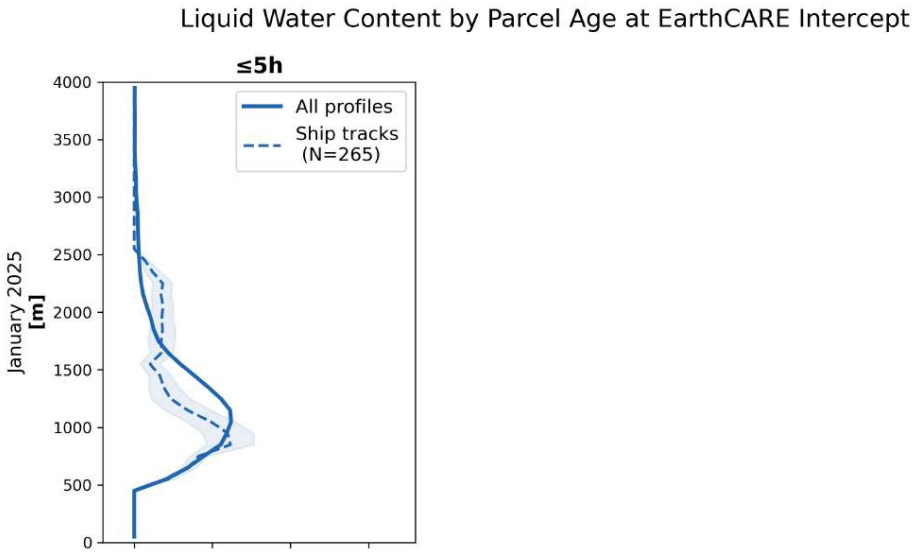

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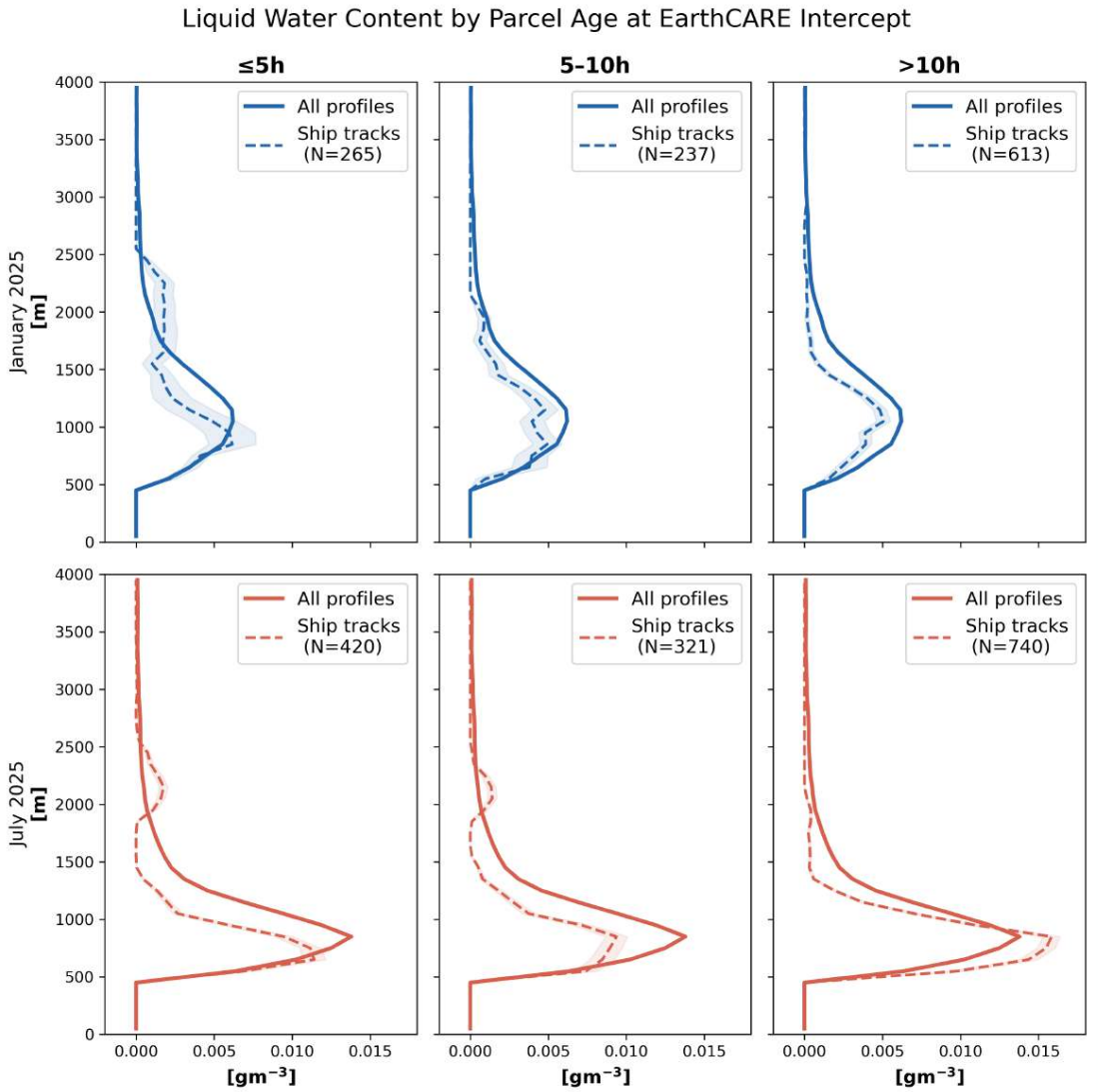

In almost all cases, reductions in LWP and lower center of mass in ship tracks

- Consistent with entrainment-related drying

- Except: older, July ship track
- Except: young January ship tracks

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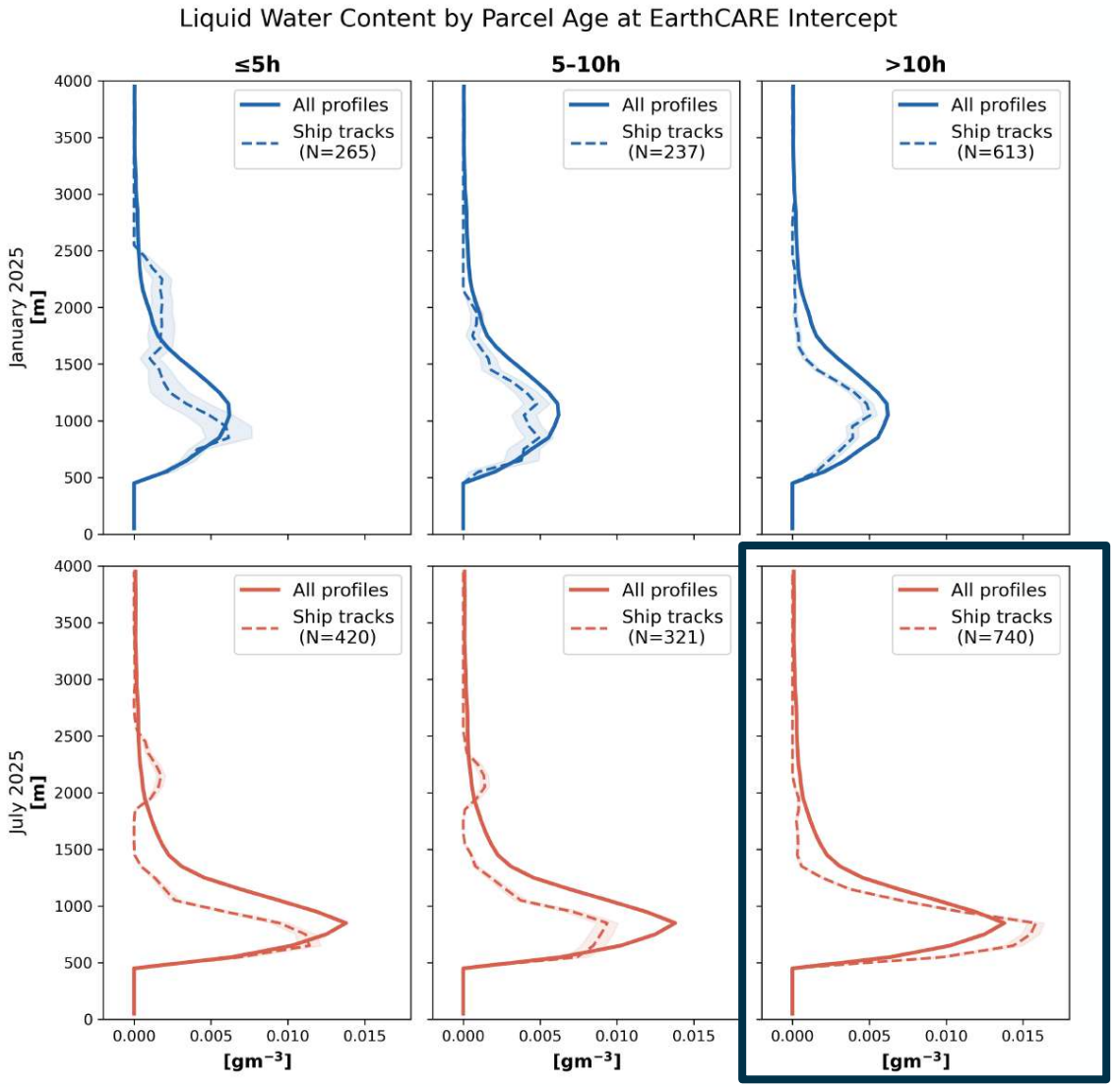

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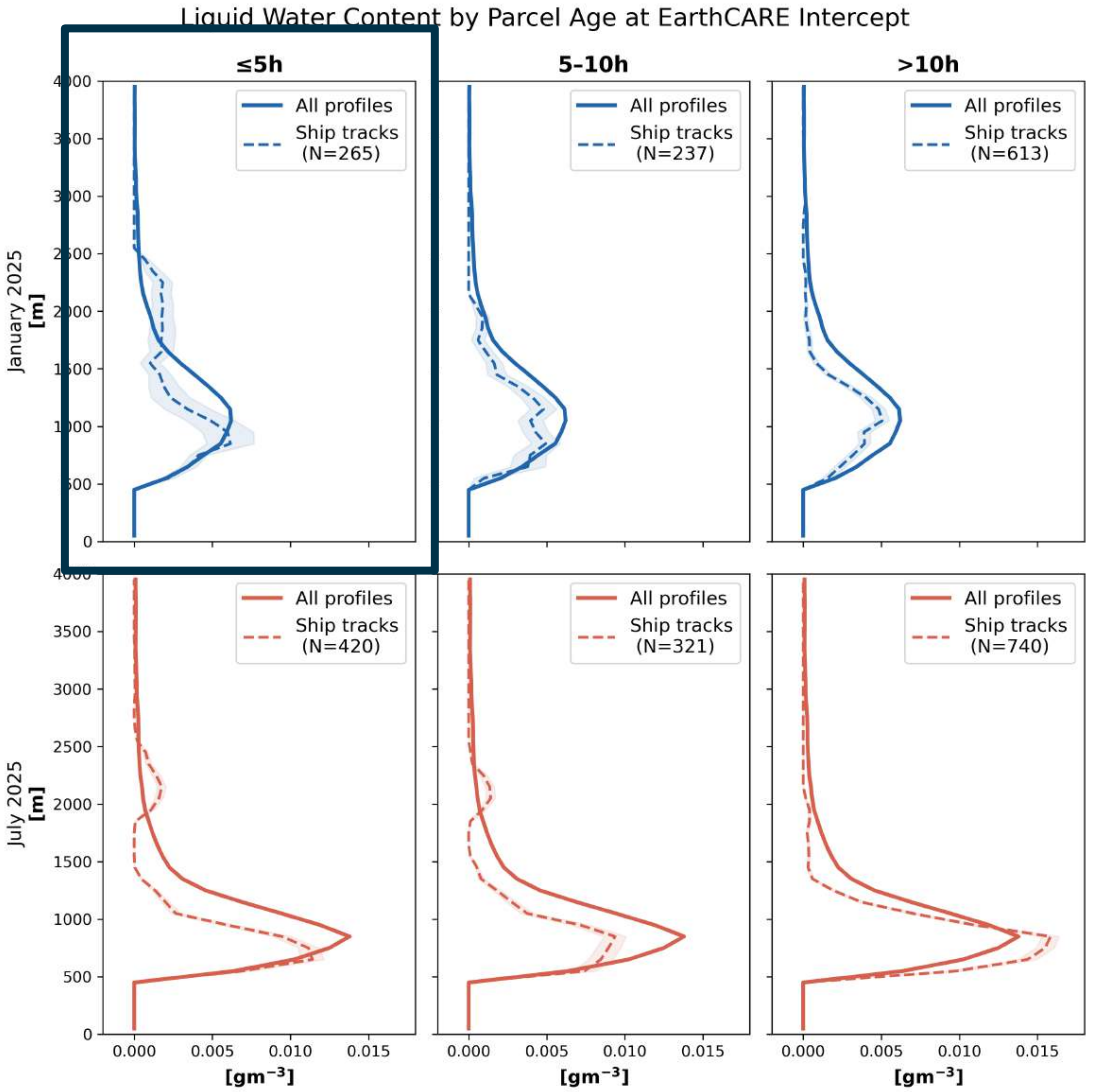

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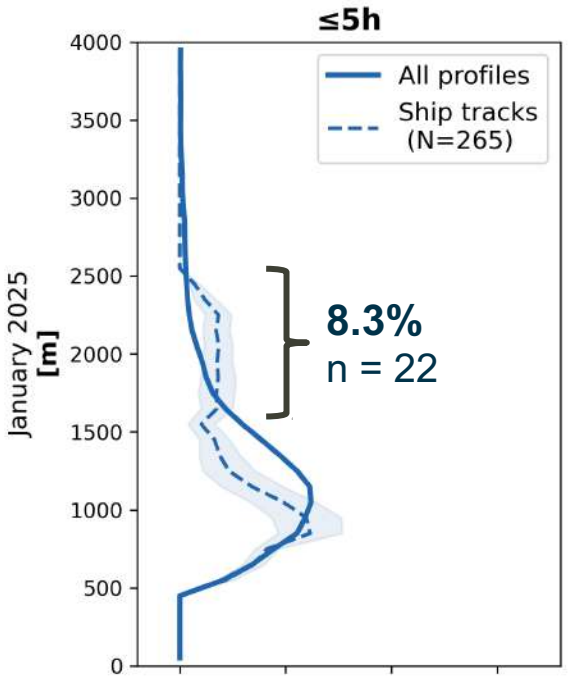

No single profile looks like the median profile

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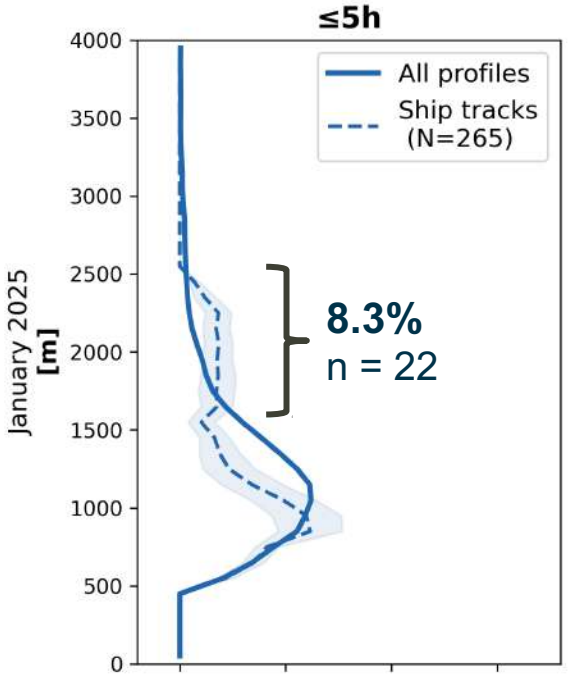

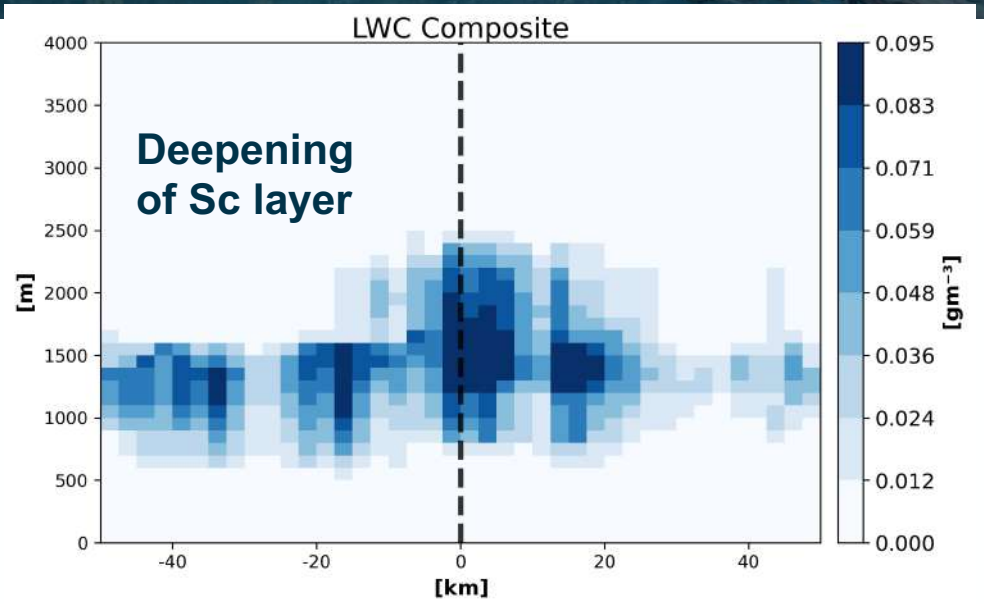

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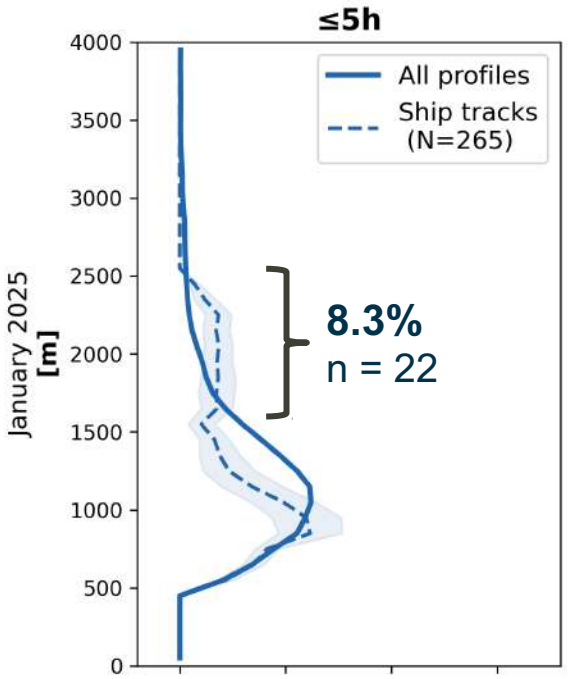

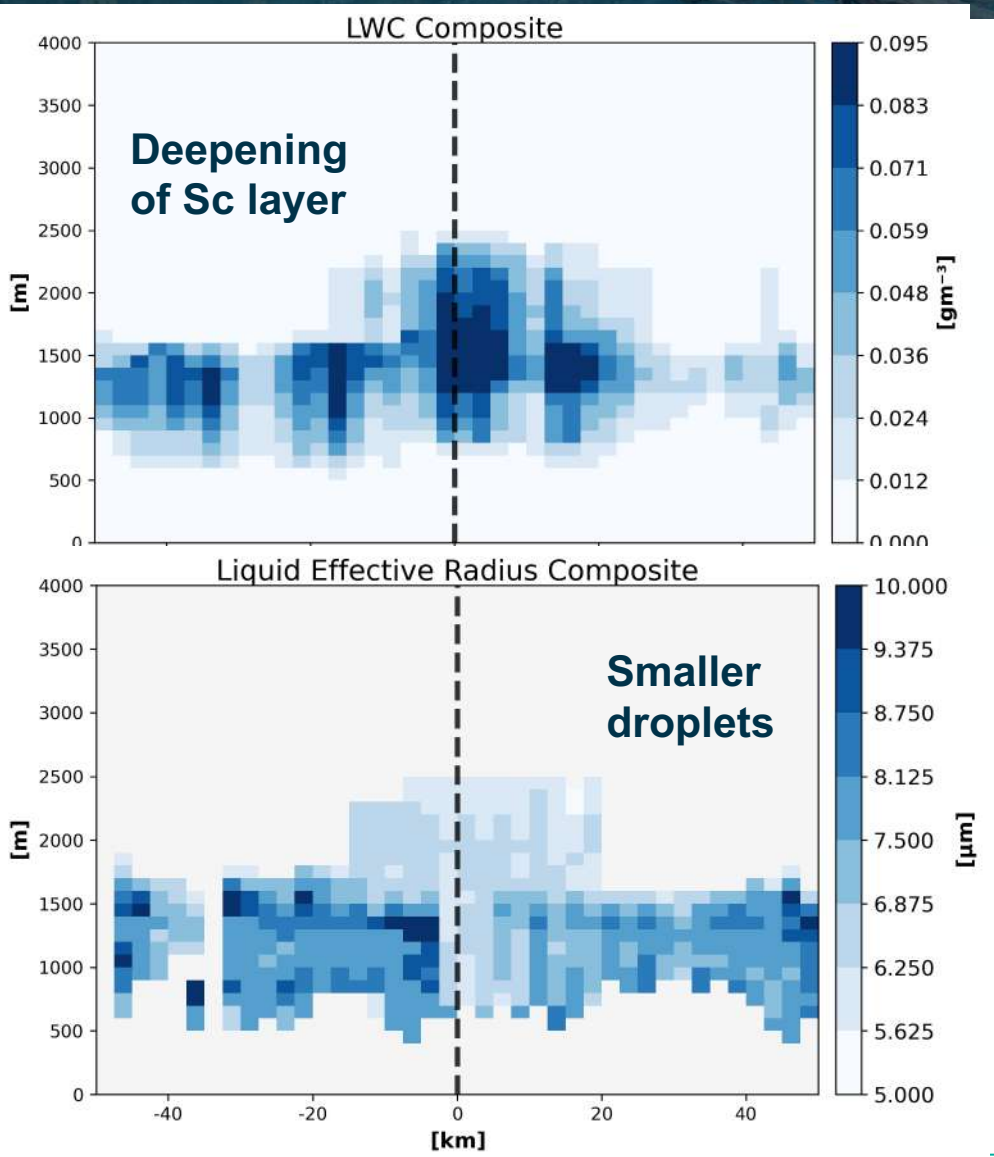

What we would expect with convective invigoration

Discussion

Convective invigoration appears plausible at least some of the time

- Tippett et al., (2024) argue for “weak” LWP effect

EarthCARE may allow us link these in these processes by which ship track perturbations give rise to macrophysical changes in cloud structure

Final Thoughts

A workflow to co-locate moving point source emissions with EarthCARE

More information on data products, their utility & limitations in stratocumulus

Early Career Event

6:00pm Glass Pavilion