Direct Observational Constraint of Optically Thin Cirrus Cloud Radiative Effects using EarthCARE ATLID and BBR

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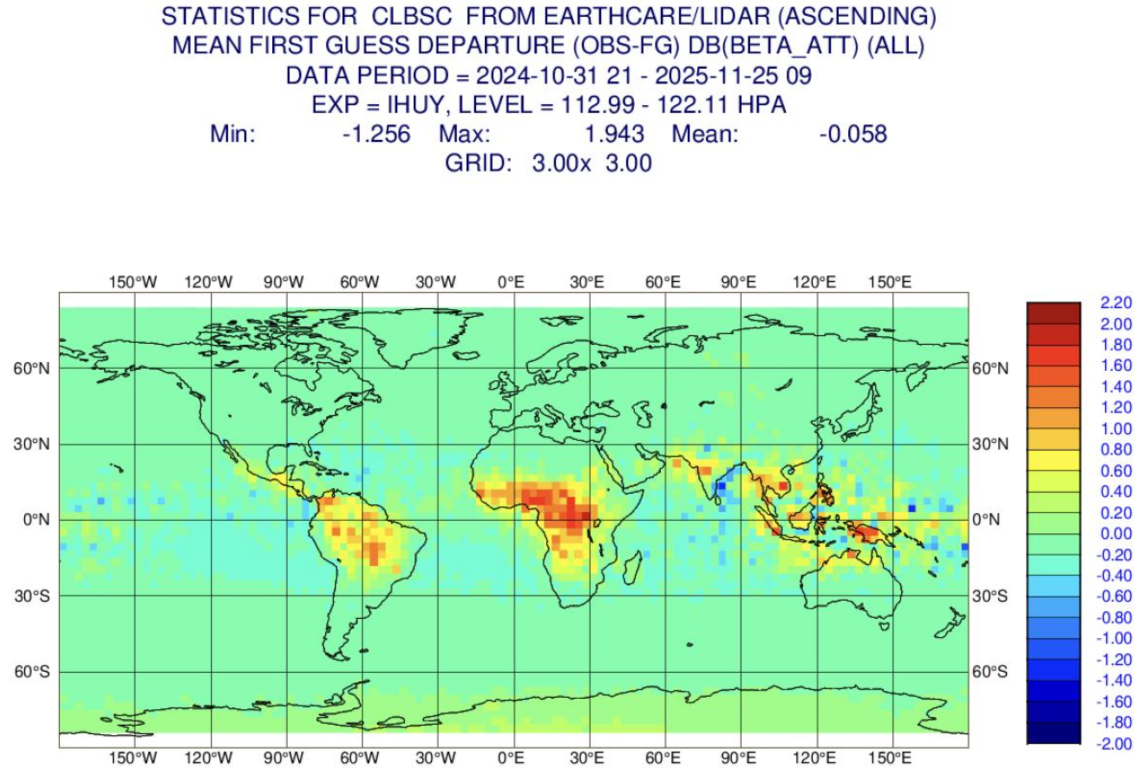
Monitoring of ATLID backscatter revealed missing ice cloud in IFS model

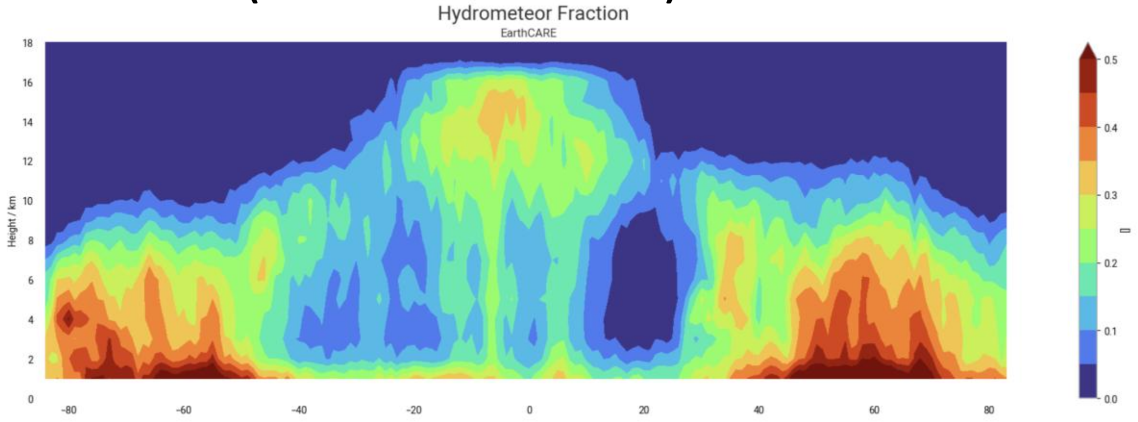
EarthCARE – IFS
total attenuated backscatter at 100 hPa



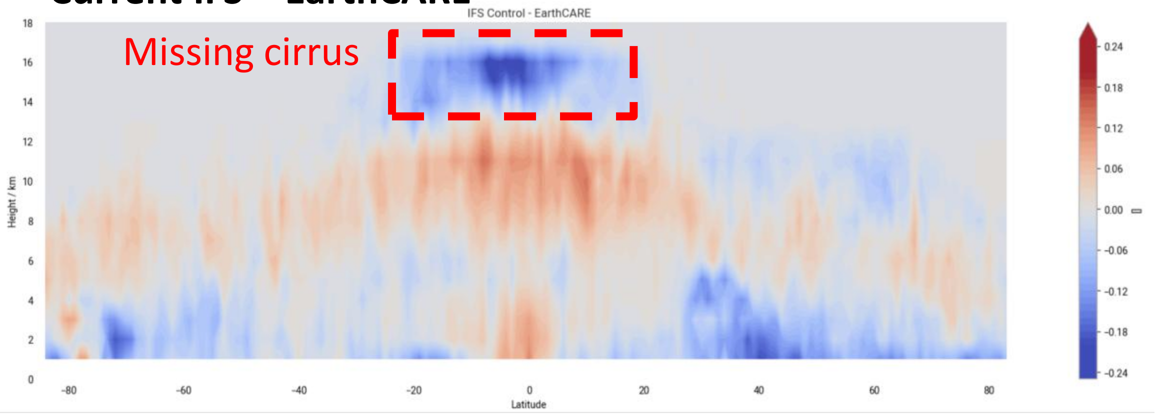
- What is the missing cloud’s effect on the radiation budget?

Hydrometeor fraction zonal cross-section

EarthCARE (ATLID + CPR detections)



Current IFS – EarthCARE



ECMWF

Clouds dominate remaining regional biases in ECMWF model

2022 operational day 1 forecast vs CERES

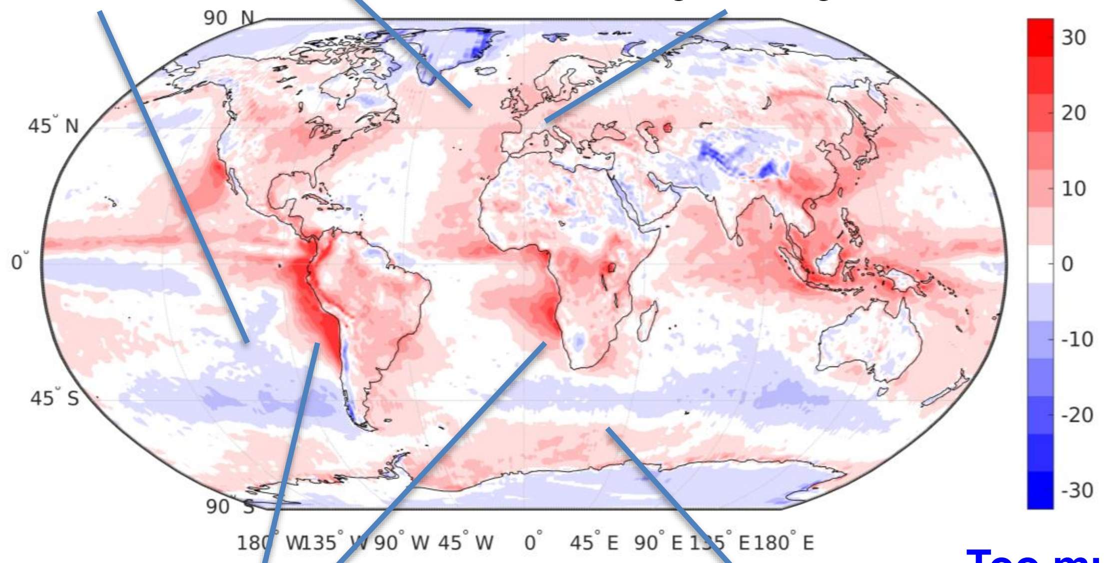
TOA net shortwave flux

Cold air outbreak errors

Too few cumulus

Continental clouds not bright enough

Too little outgoing



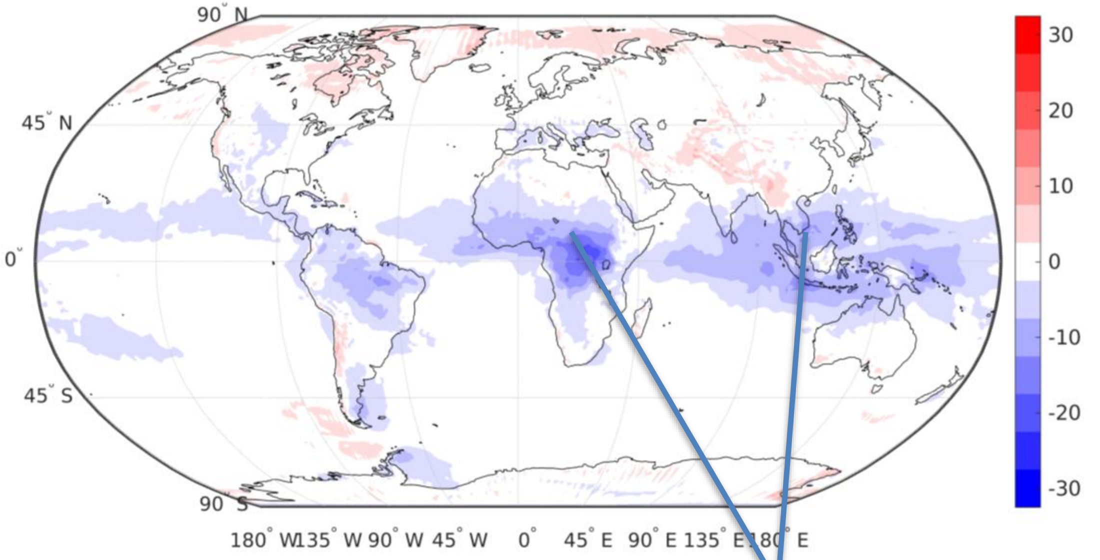
Too much reflection

Marine Scu not bright enough

Super-cooled LW in Southern Ocean difficult to constrain

TOA net longwave flux

Too little reflection

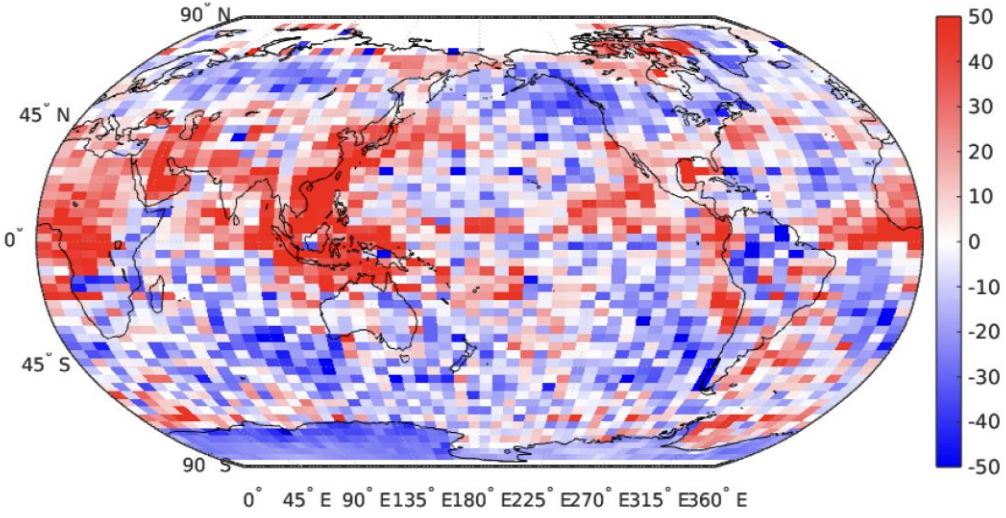


Errors associated with deep convection

Too much outgoing

TOA radiation bias compared with BBR (January 2025 – April 2025)

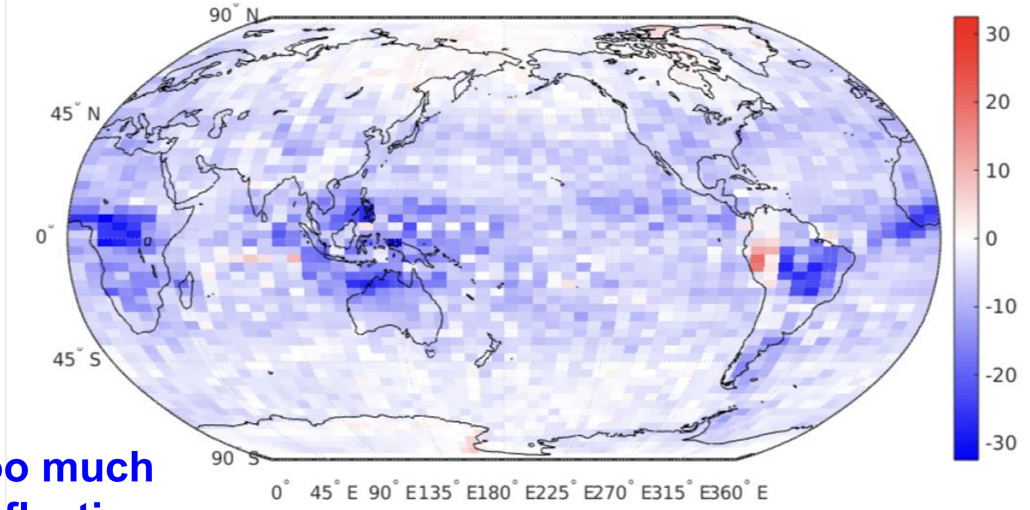
BBR SW – IFS (W m^{-2})



Too little reflection

Too much reflection

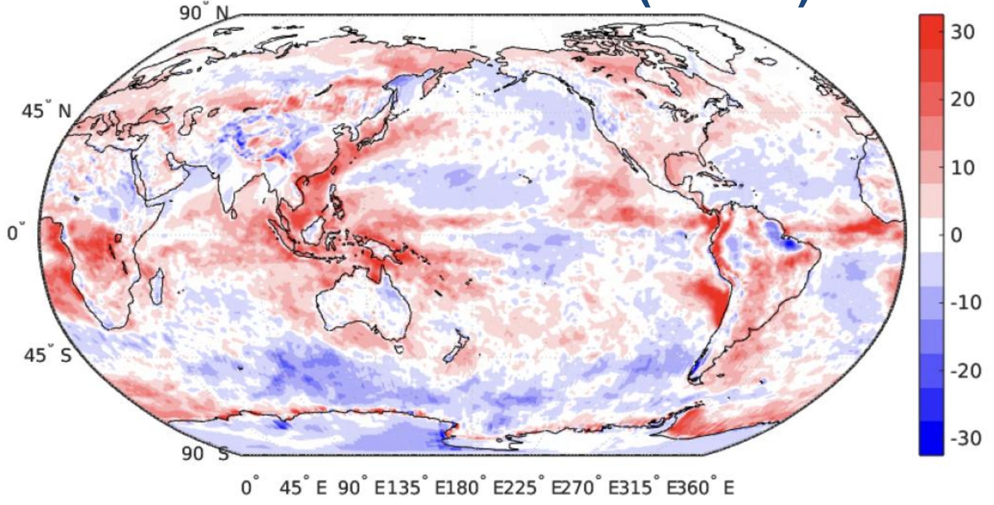
BBR LW – IFS (W m^{-2})



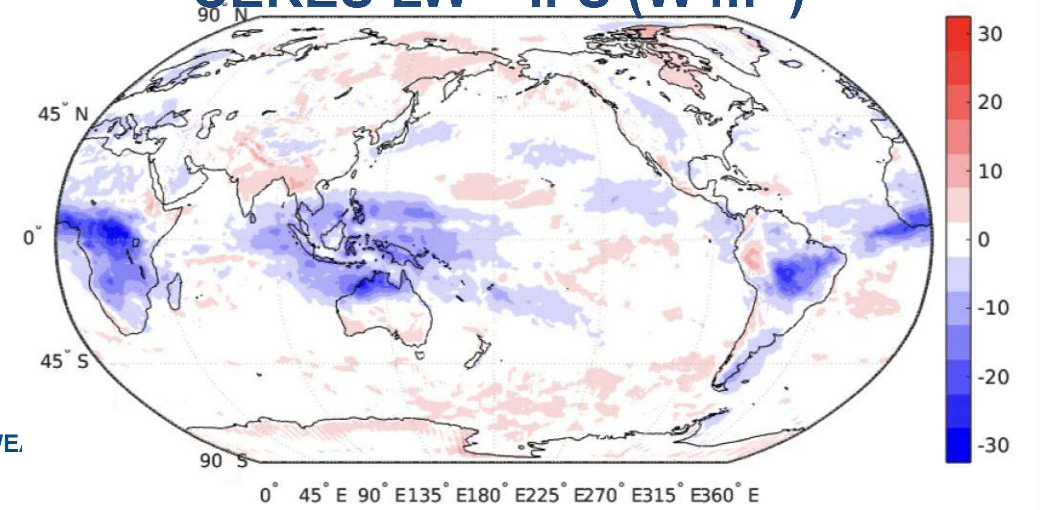
Too little outgoing

Too much outgoing

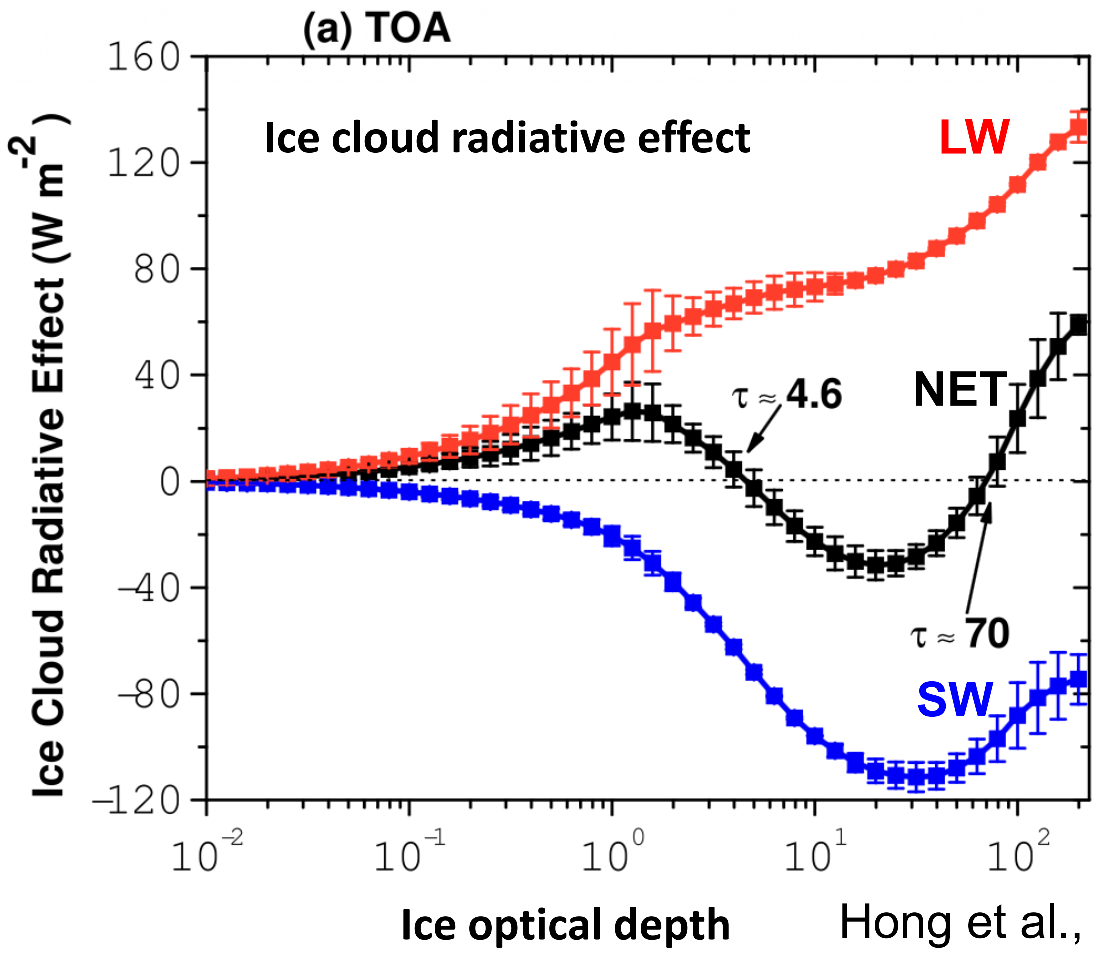
CERES SW – IFS (W m^{-2})



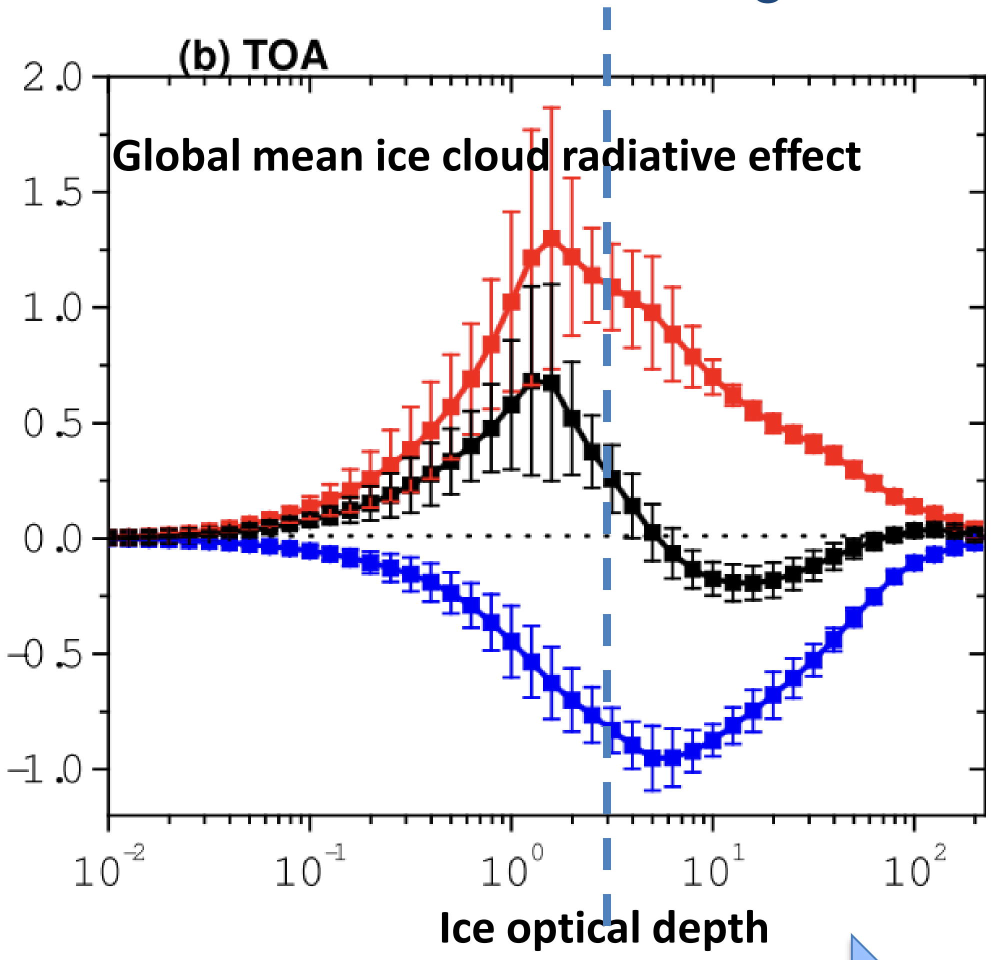
CERES LW – IFS (W m^{-2})



Optically thin ice clouds are key components of Earth's Radiation Budget



Hong et al., 2016



$$CRE_{ICE} = F^{\downarrow}_{TOA} - F^{\downarrow}_{TOA,noice}$$

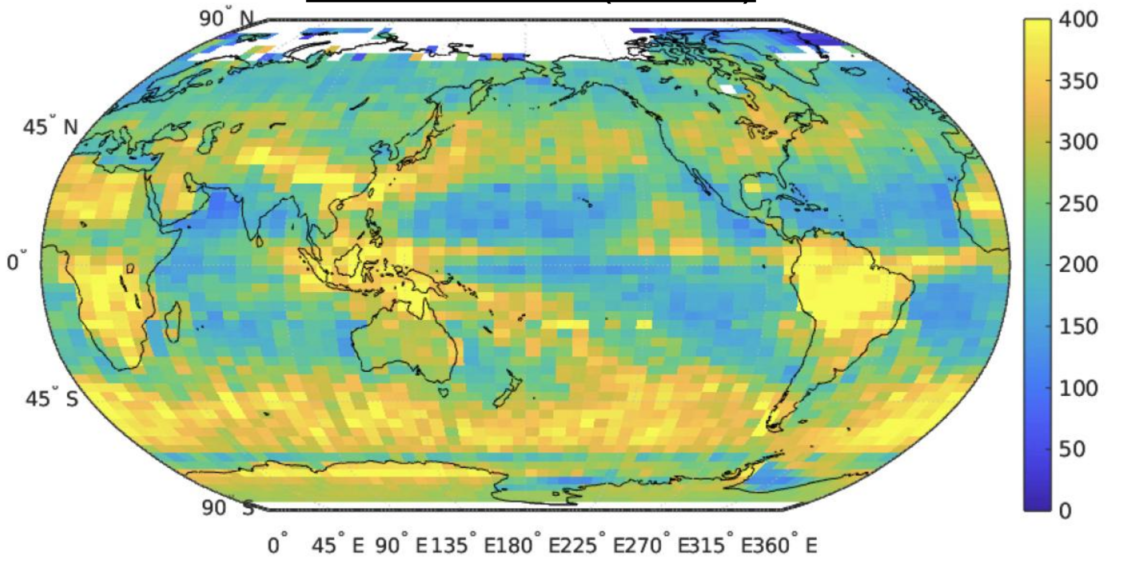
ATLID fully observes over 50% of total ice cloud LW radiative effect!

ECMWF

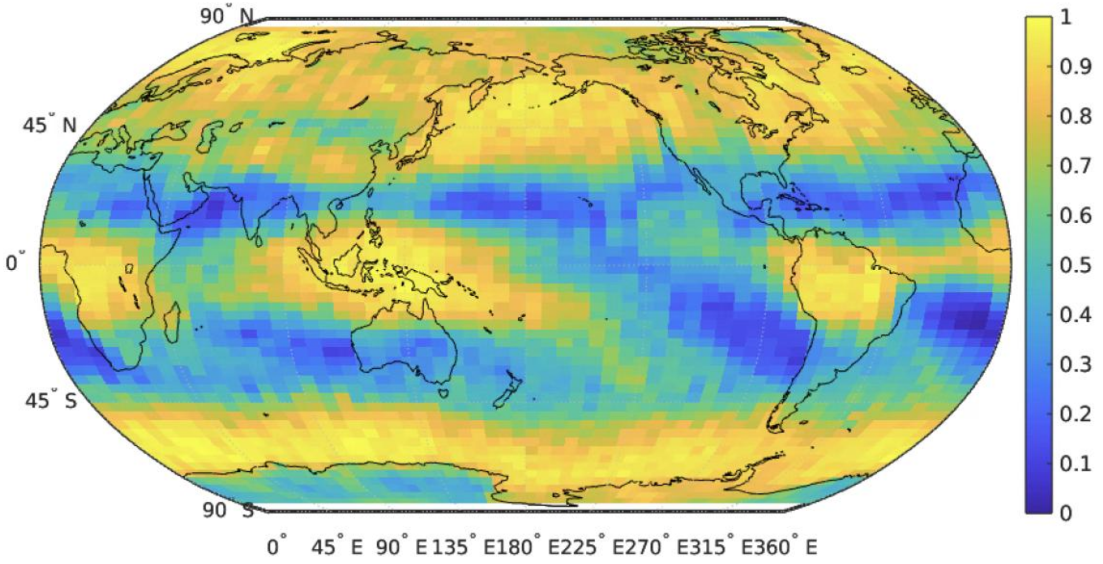
Joint ice cloud and radiation climatology (January – April 2025)

- L2 ATLID EBD cloud extinction using simple classification.
- L2 BMA FLX shortwave and longwave fluxes.
- All observations superobbed to ~40 km then regridded to 3 degree lat lon.

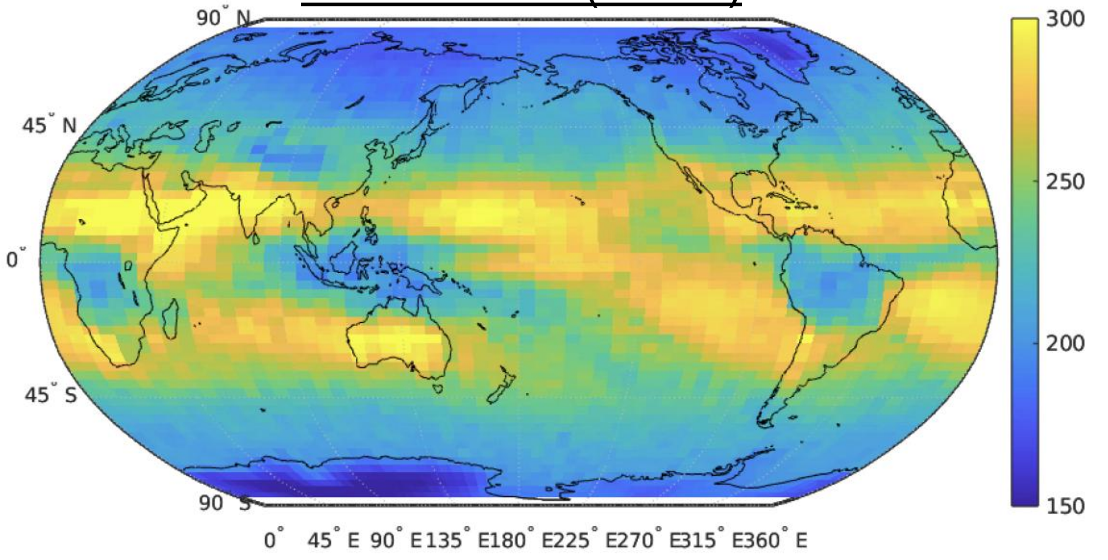
BBR SW flux (W m^{-2})



ATLID ice cloud fraction



BBR LW flux (W m^{-2})



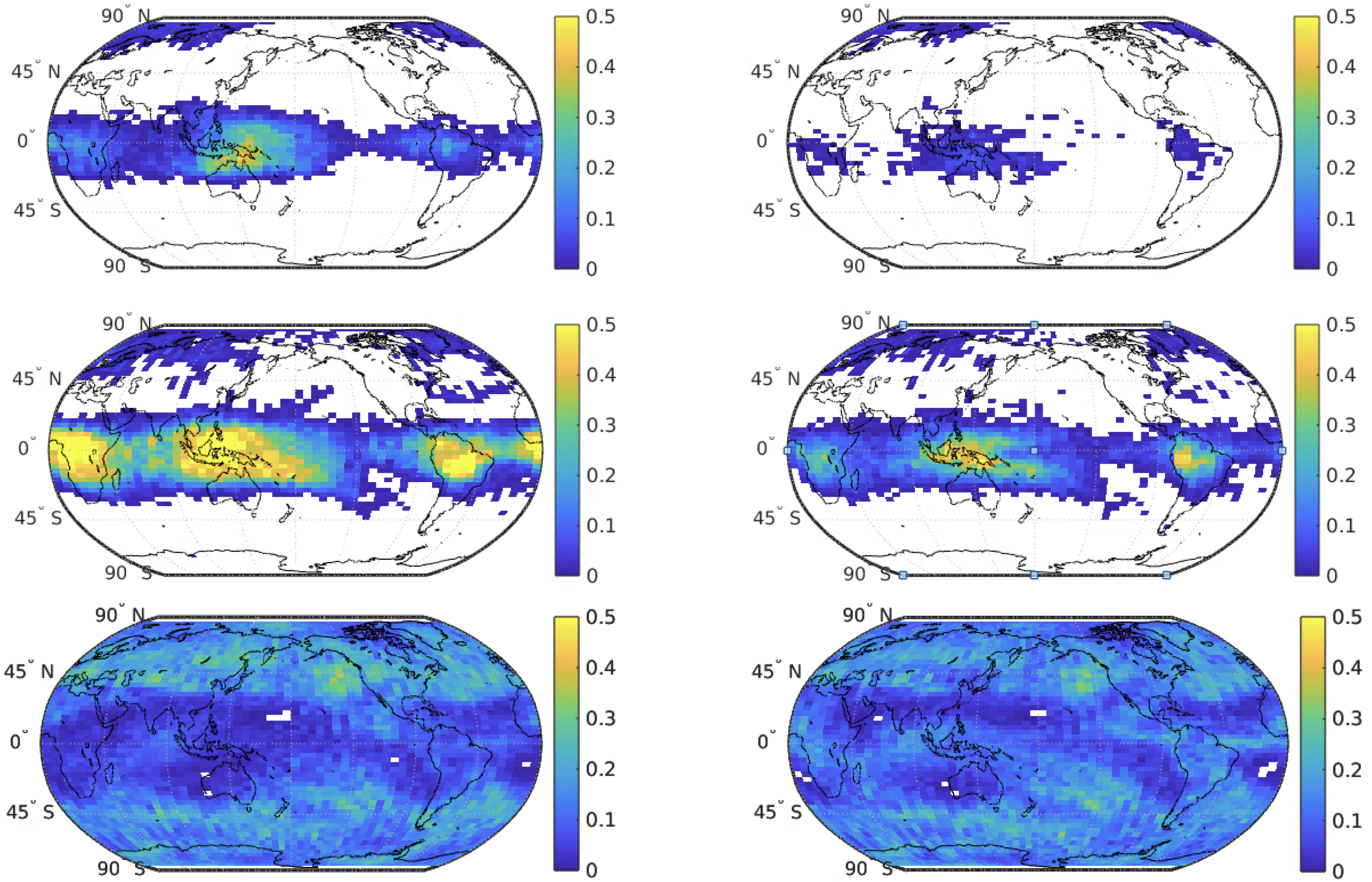
Probability of cirrus CTT (January 2025 – April 2025)

ATLID | **IFS**

190 K to 200 K

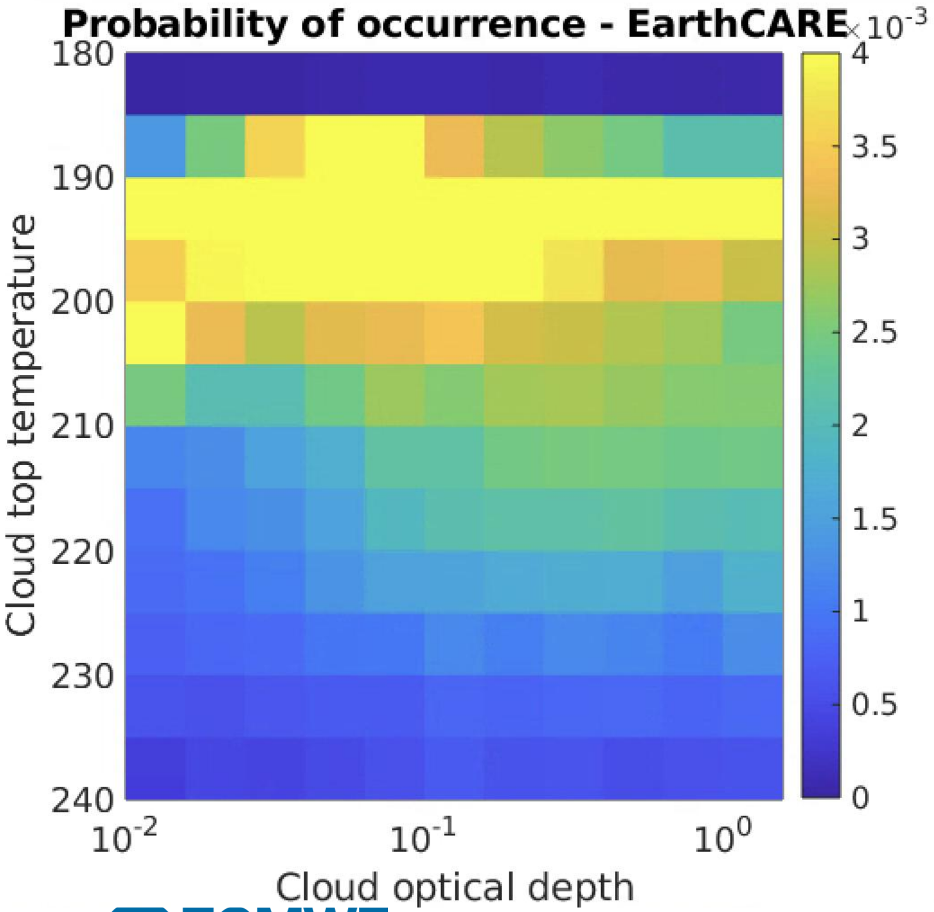
200 K to 210 K

210 K to 220 K

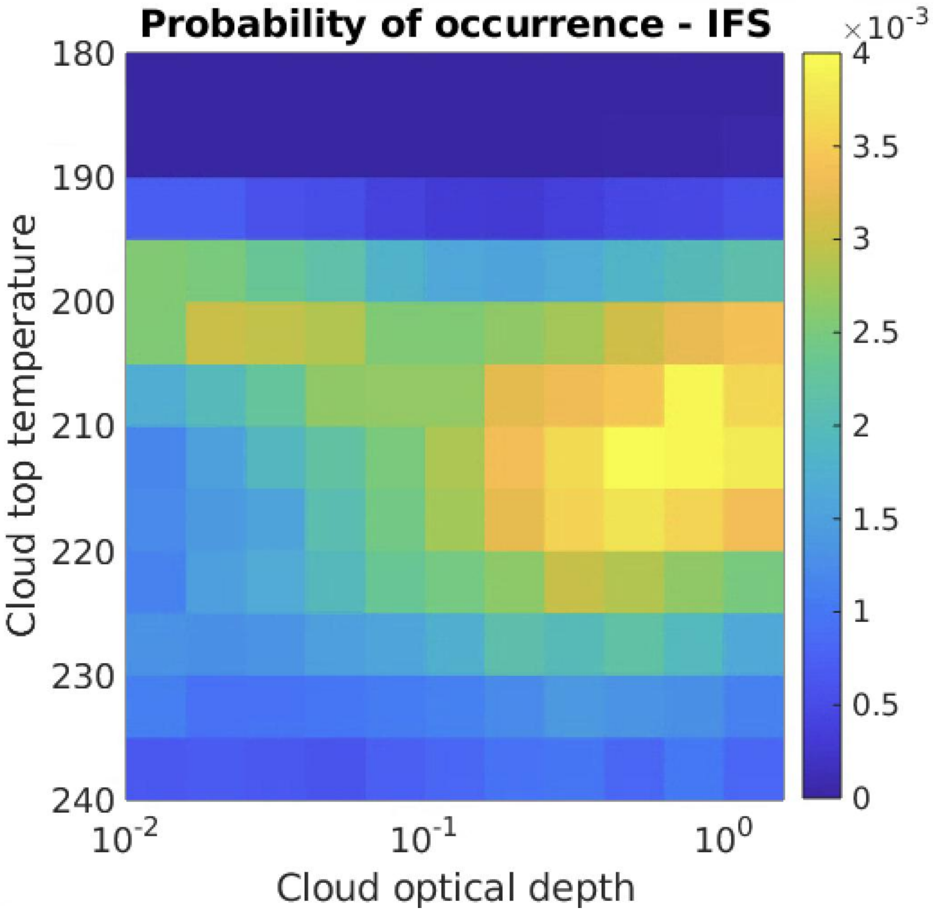


Probability of cirrus CTT (January 2025 – April 2025)

ATLID (Tropics ocean only)



IFS (Tropics ocean only)



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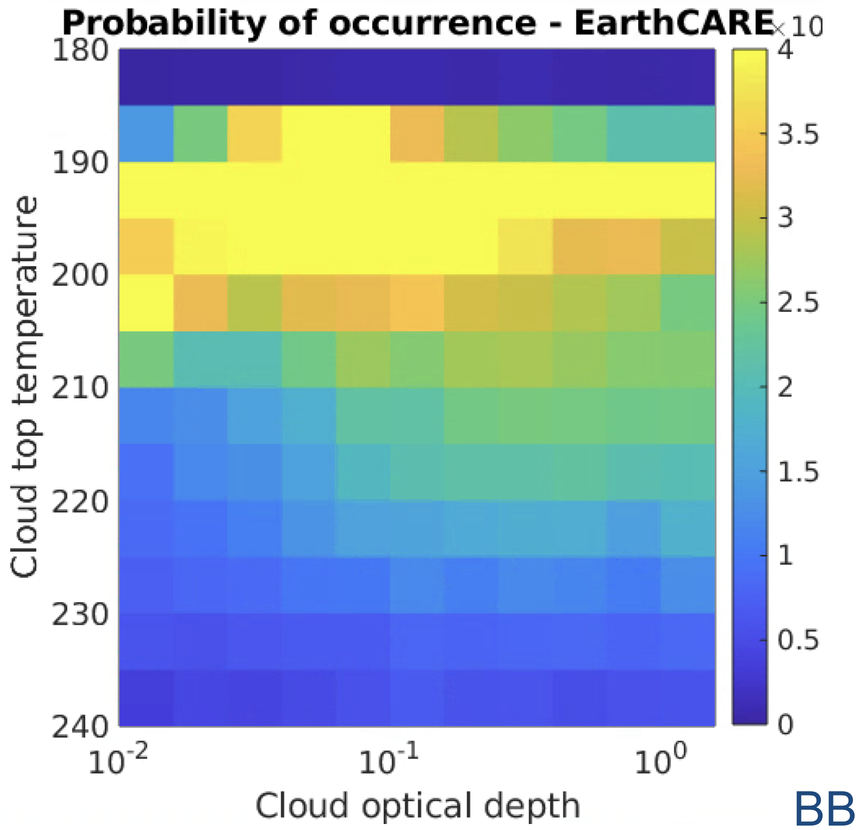
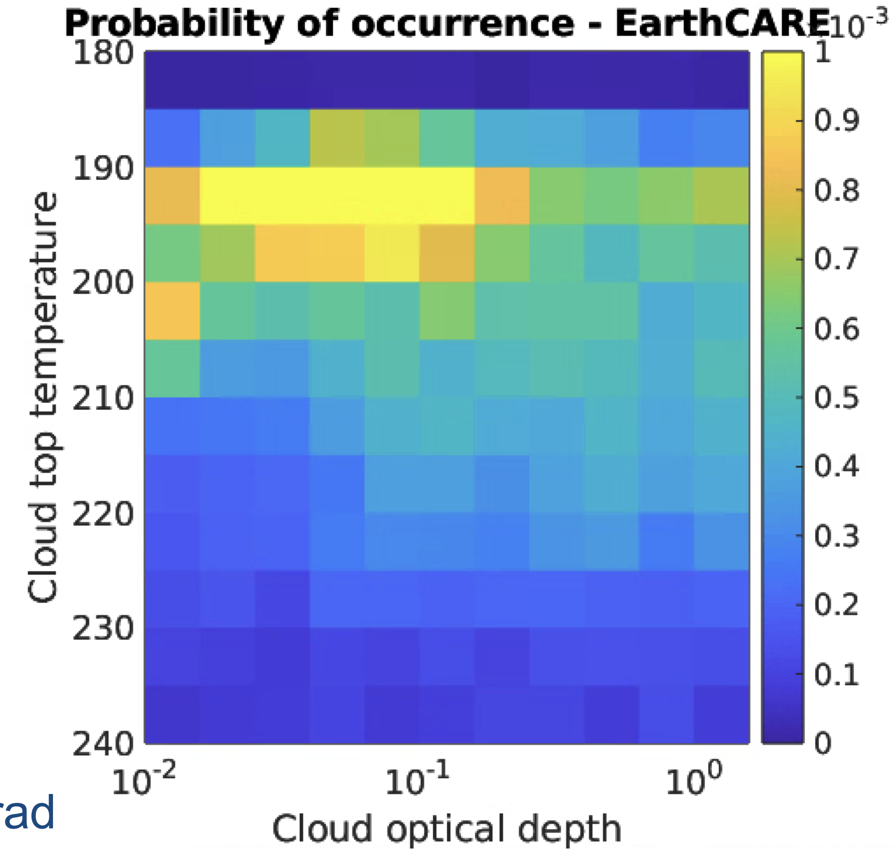
Method for computing thin cirrus cloud radiative effect



Remove cases where liquid water cloud detected (T > 270 K)



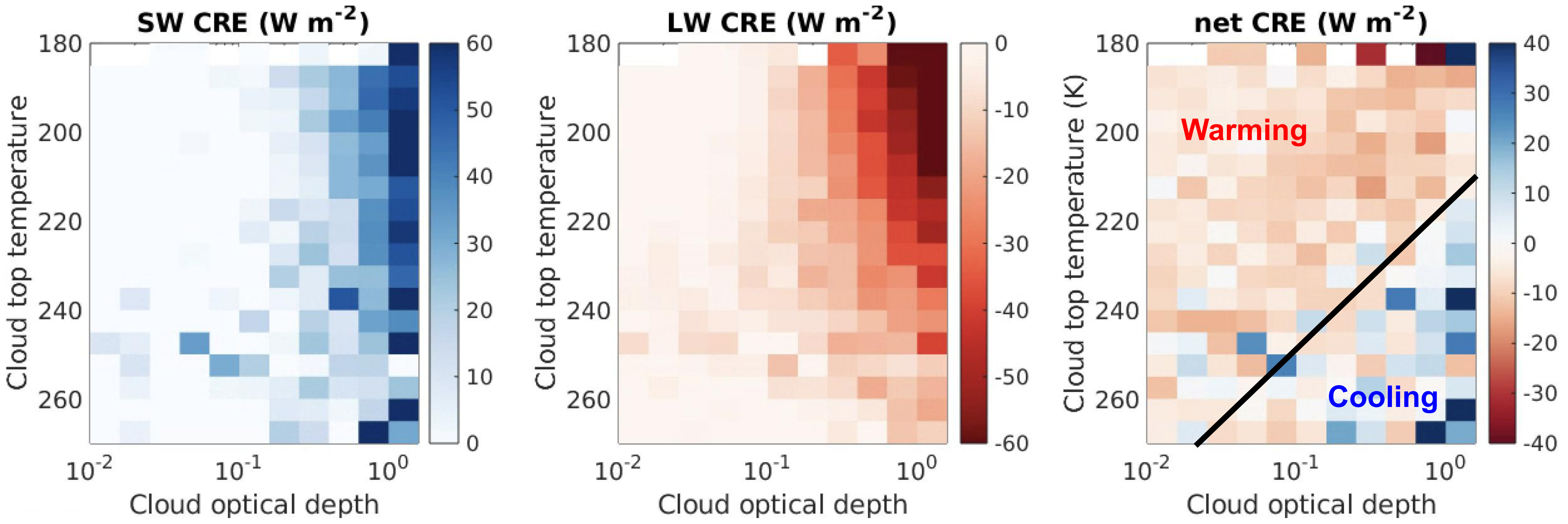
BBR flux climatology

ecrad

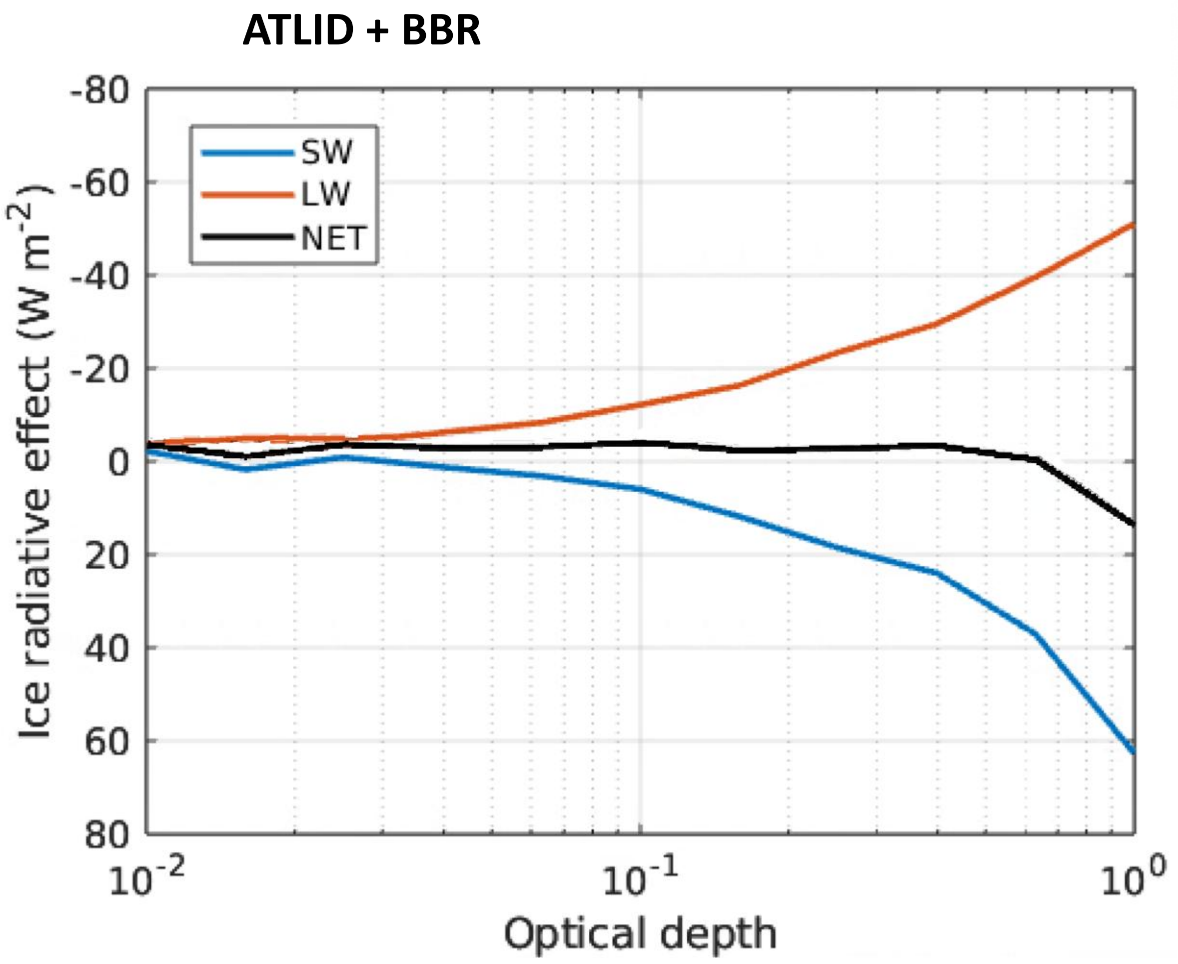
$$CRE_{ICE\ only} = F^{\downarrow}_{TOA,ice\ only} - F^{\downarrow}_{TOA,clearsky} - bias$$

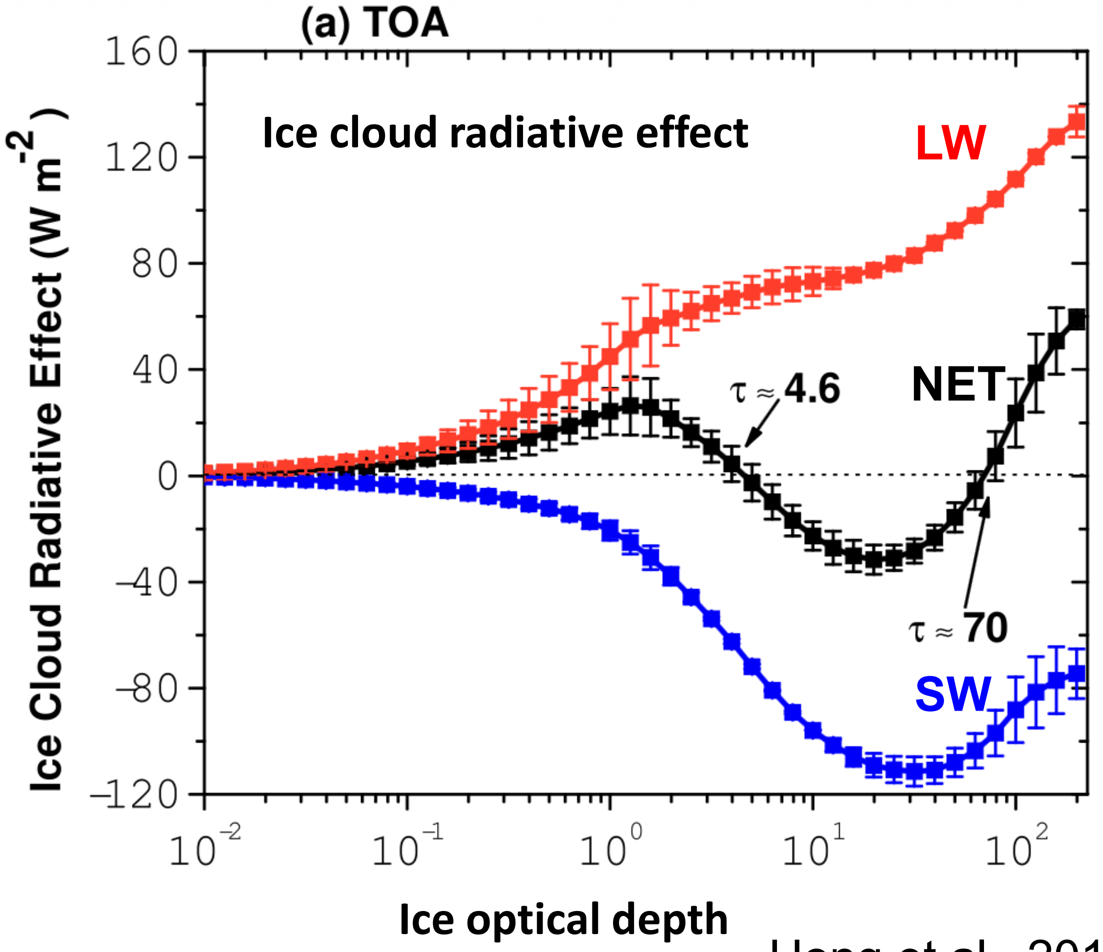
Mean bias in modelled flux with BBR in clear-sky conditions

Direct observations of cirrus cloud radiative effect from ATLID and BBR



Initial comparison with Hong et al., 2016 shows good agreement

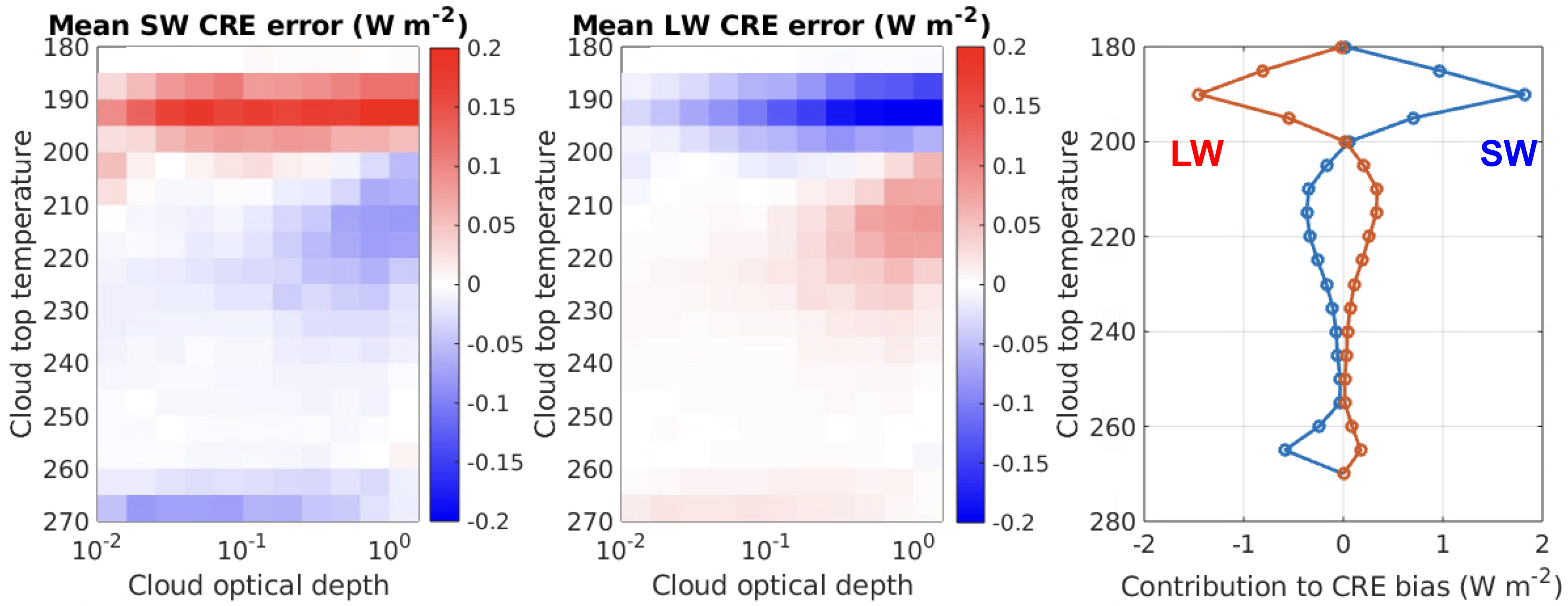




Hong et al., 2016

What is the contribution to the total CRE error in the tropics?

- Multiply the difference in probability of occurrence in each bin by the mean SW CRE seen by BBR



Summary

- ATLID and BBR can be used synergistically to provide direct estimates of thin cirrus cloud radiative effect
- IFS often misses thin cirrus cloud associated with deep convective outflow.
- Missing thin cirrus clouds over ocean in the tropics contribute 4 W m-2 SW and -3 W m-2 LW to total TOA radiation bias.

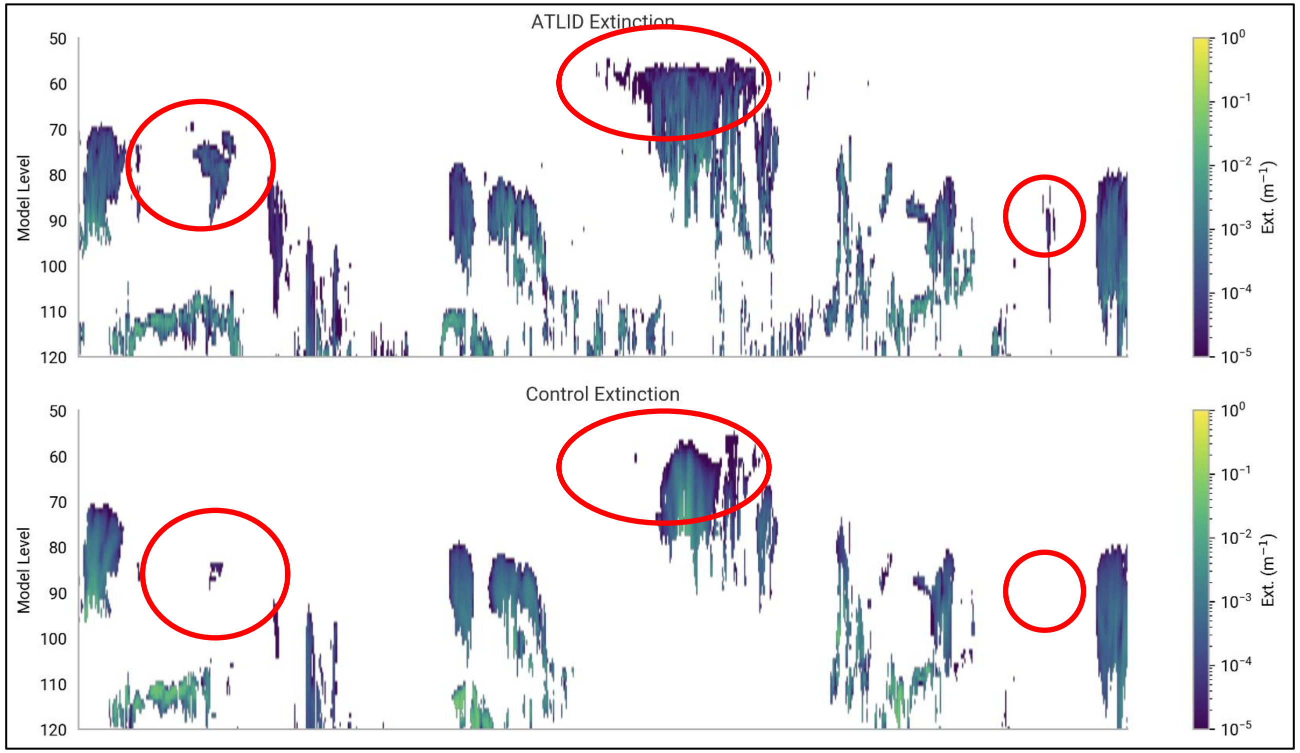
Future work

- Improve representation of heterogeneous ice nucleation for T<233 K
- Investigate sensitivity of other model processes, such as ice fall speed, convective detrainment, tropopause mixing etc
- Make gridded climatology of ATLID, BBR and CRE observations available for others to explore.

Extra slides

Example 2: Using EarthCARE to constrain thin cirrus cloud (Lidar extinction)

Lidar extinction



Good agreement of lidar extinction between the IFS and EarthCARE ATLID

…but the IFS often misses high altitude ice cloud…

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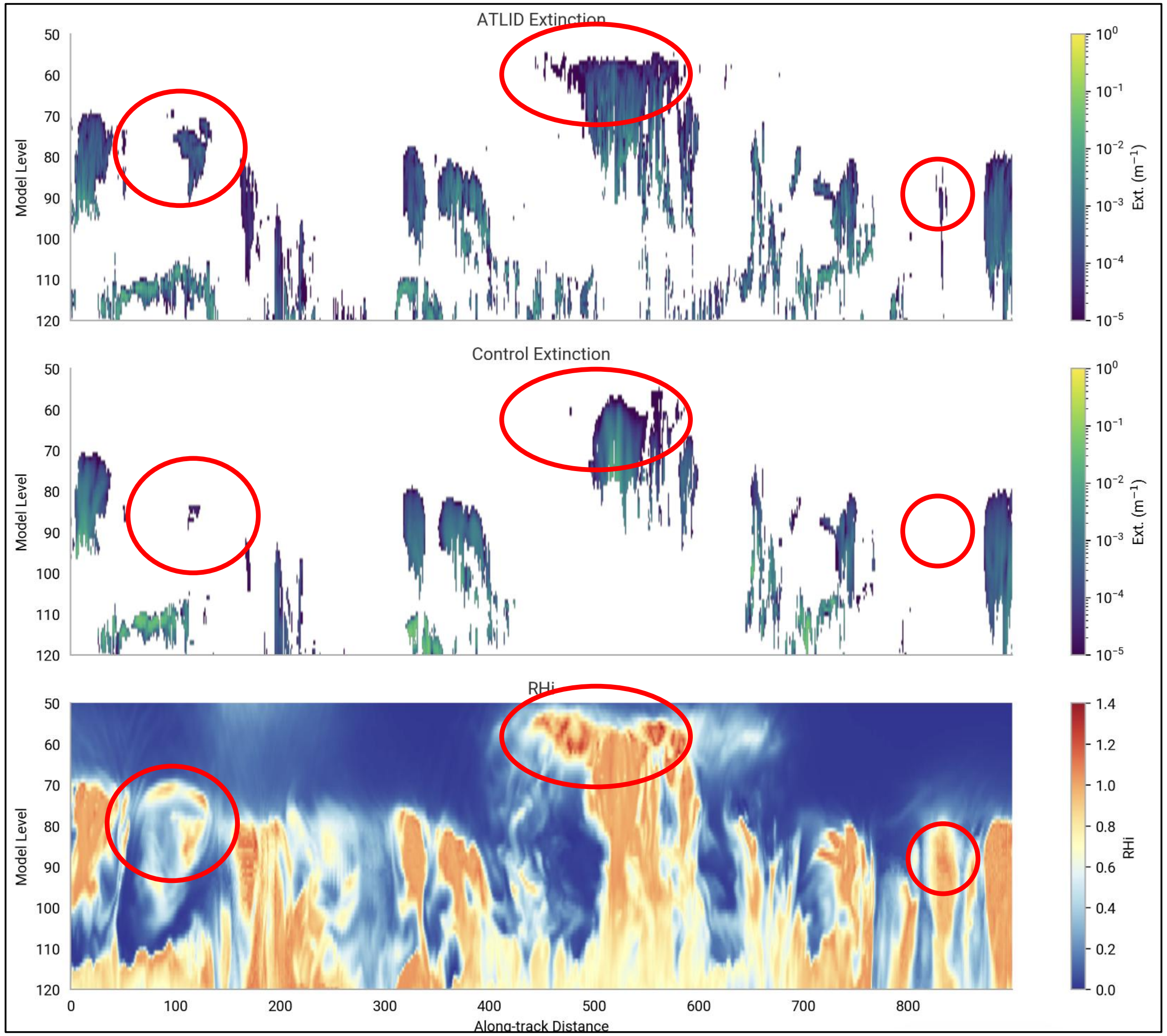
Example 2: Using EarthCARE to constrain thin cirrus cloud (Lidar extinction)

Lidar extinction

Relative humidity wrt ice



Good agreement of lidar extinction between the IFS and EarthCARE ATLID

…but the IFS often misses high altitude ice cloud…

…associated with regions supersaturated with respect to ice…

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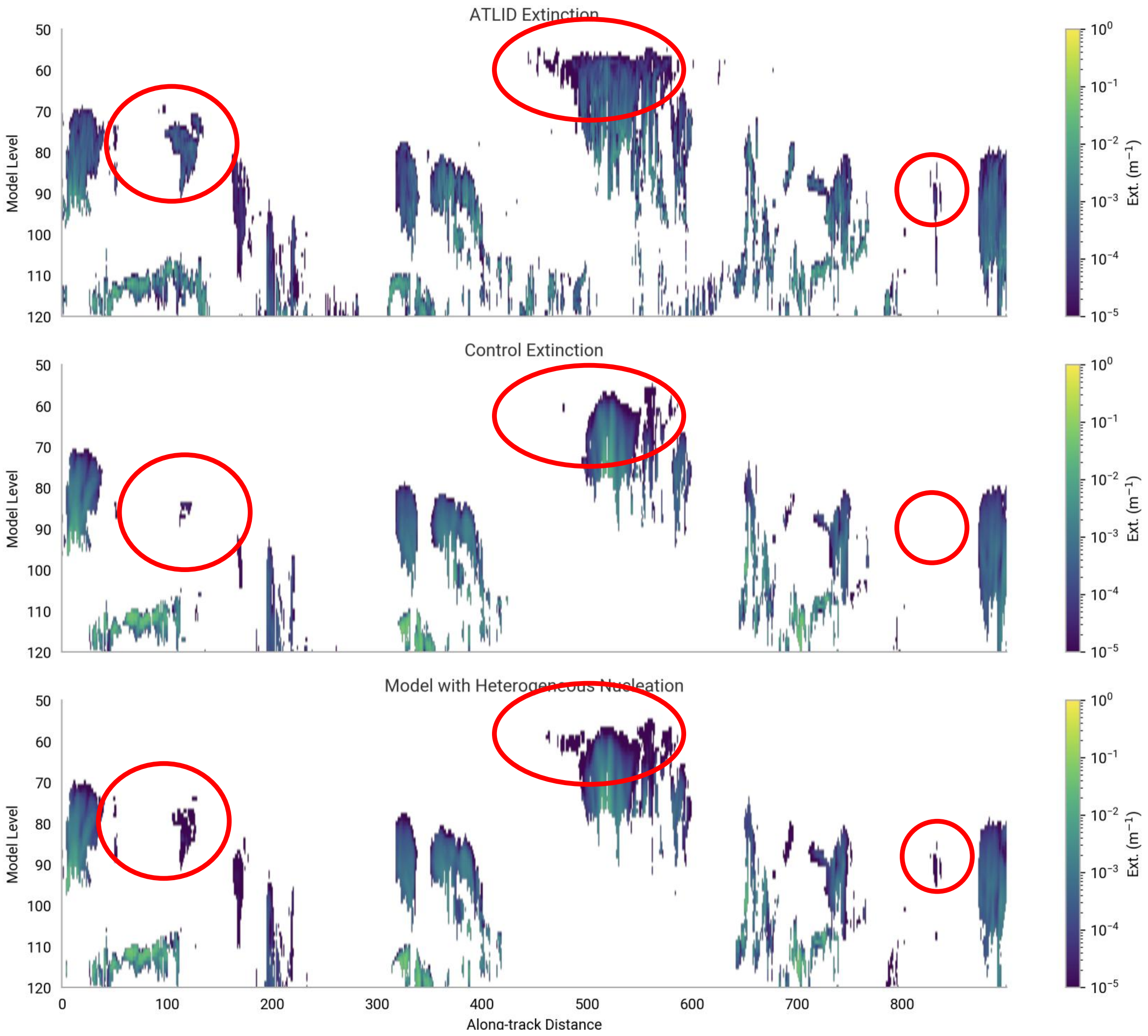
Example 2: Using EarthCARE to constrain thin cirrus cloud (Lidar extinction)

Lidar extinction



Good agreement of lidar extinction between the IFS and EarthCARE ATLID

…but the IFS often misses high altitude ice cloud…

…associated with regions supersaturated with respect to ice…

…we can get this cloud with an improved representation of heterogeneous ice nucleation. Work in progress.

EarthCARE can help to constrain this process

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Modelled cirrus cloud radiative effect