Using EarthCARE to improve the representation of clouds in the IFS

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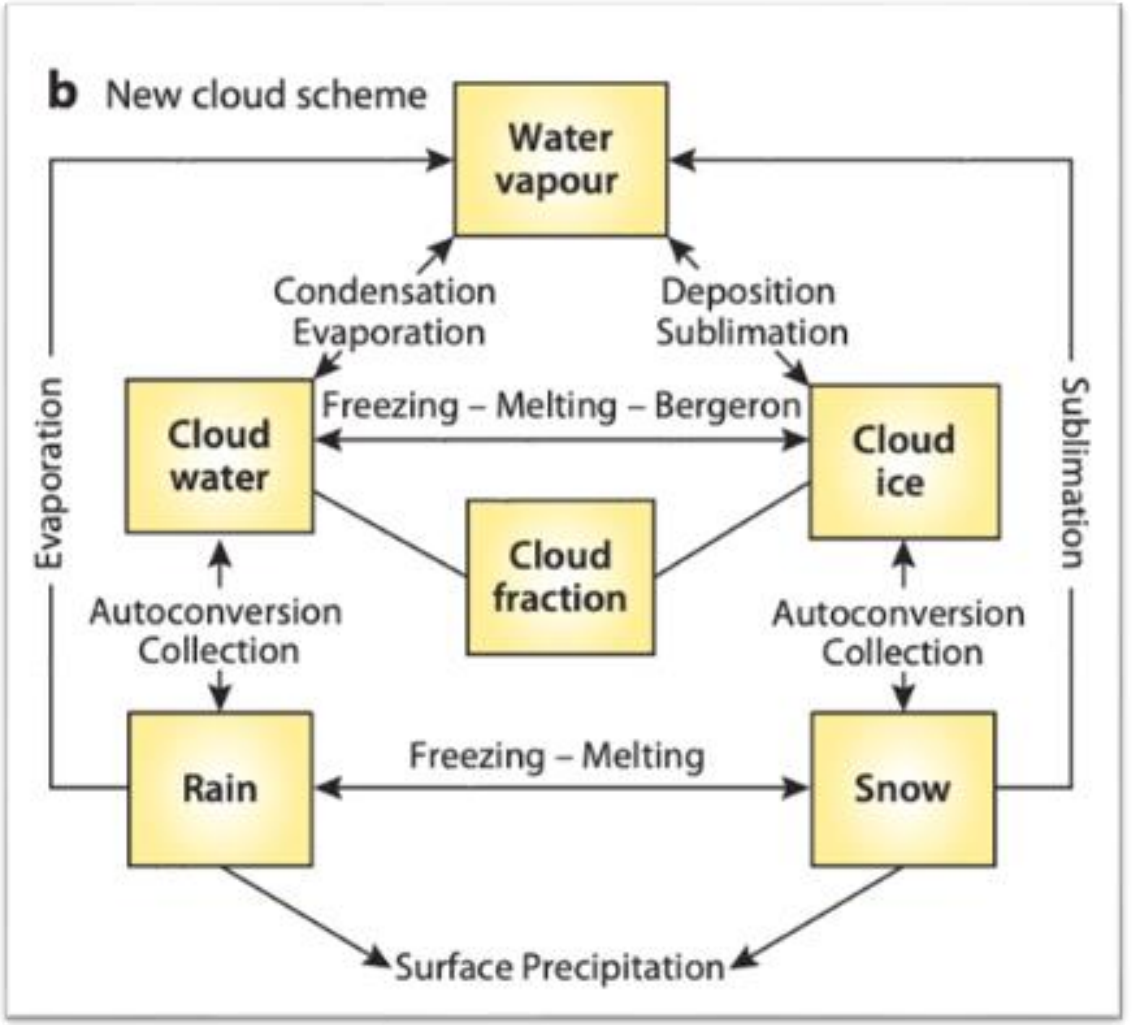
The importance of clouds to NWP

1. Reducing regime-dependent systematic errors
   - Clouds affect radiation, dynamics, precipitation prediction
   - Need to increase the realism, detailed representation of physical processes
2. Movement towards higher-resolution models (km-scale)
   - Resolving smaller scale motions (km-scale, convective resolving)
   - Microphysics handles more – details are important
3. Assimilating cloud and precipitation-affected observations
   - Cloudy areas are often meteorologically sensitive areas (reduce error growth)
   - More accurate cloud microphysics means more data can be used in the assimilation
   - Better analyses, better forecasts, and training data for AI/ML

IFS Cloud Scheme

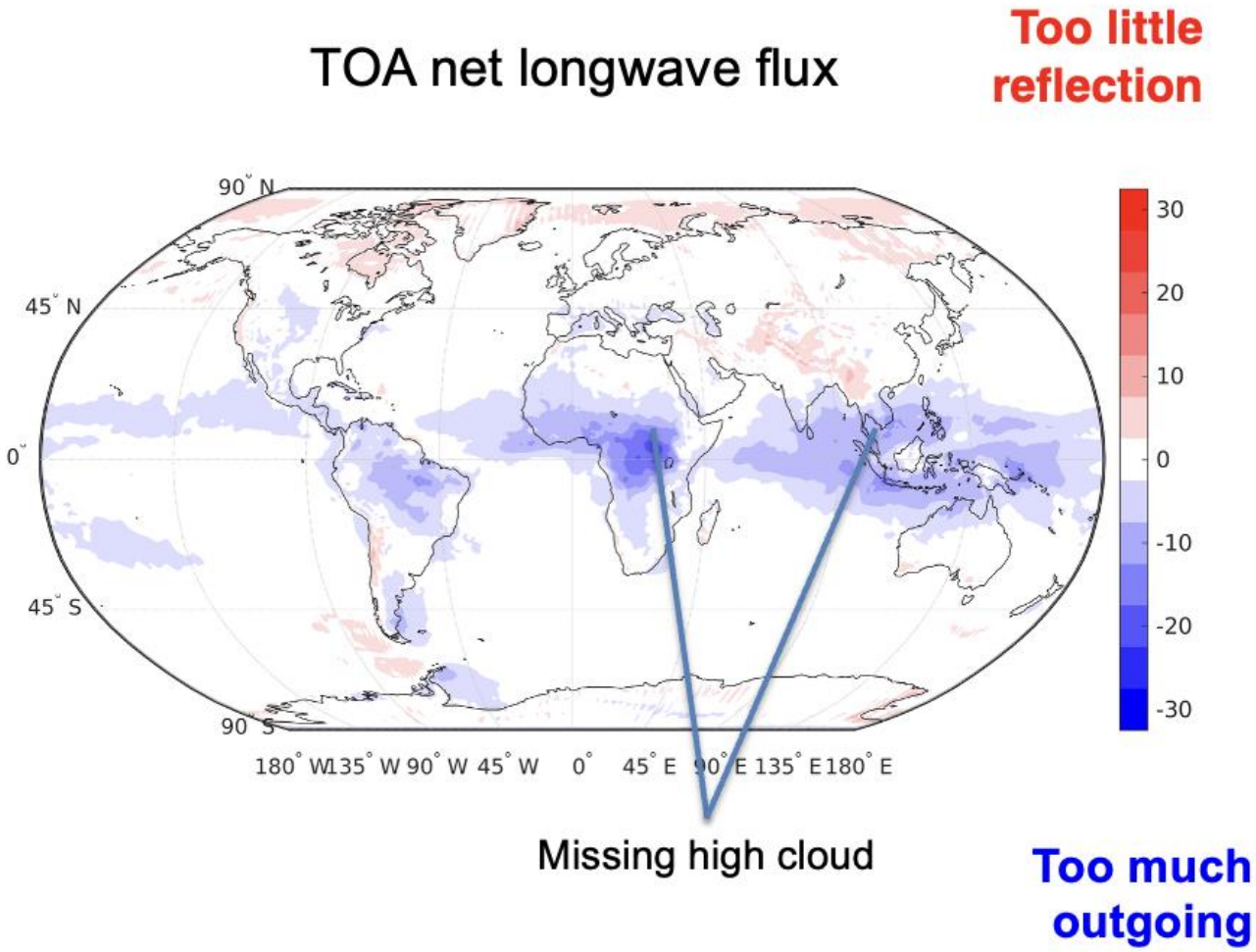


The LW Bias

- CERES shows too much LW escaping to space in the tropics – consistent with missing high cloud

- Why is the ice cloud missing?
  - Falling out too quickly?
  - Not forming enough in the first place?

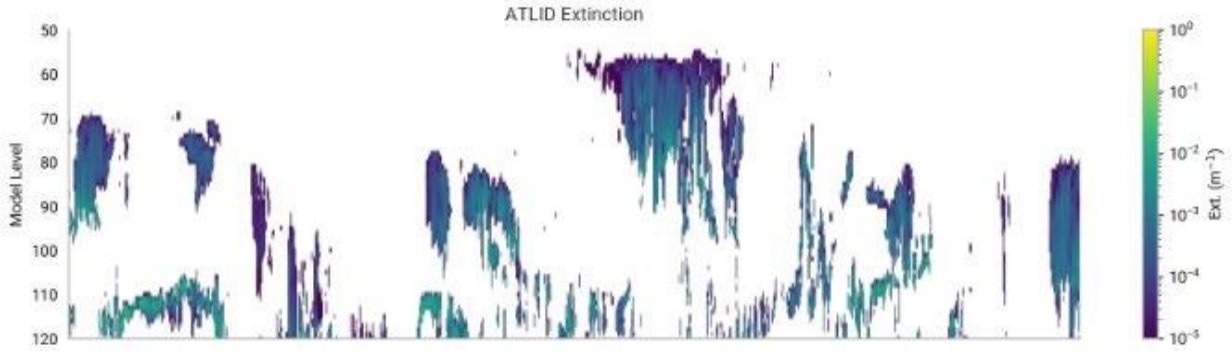
- EarthCARE's provides the vertical cloud information needed to diagnose the problem



Mark Fielding

The LW Bias

- ATLID detects optically ice clouds – which are missing from the model
- Missing cloud occurs primarily at high altitudes and low temperatures
  - Relative humidity with respect to ice is often sufficient for cloud formation, suggesting a microphysical deficiency
- Clouds are radiatively important despite low water contents



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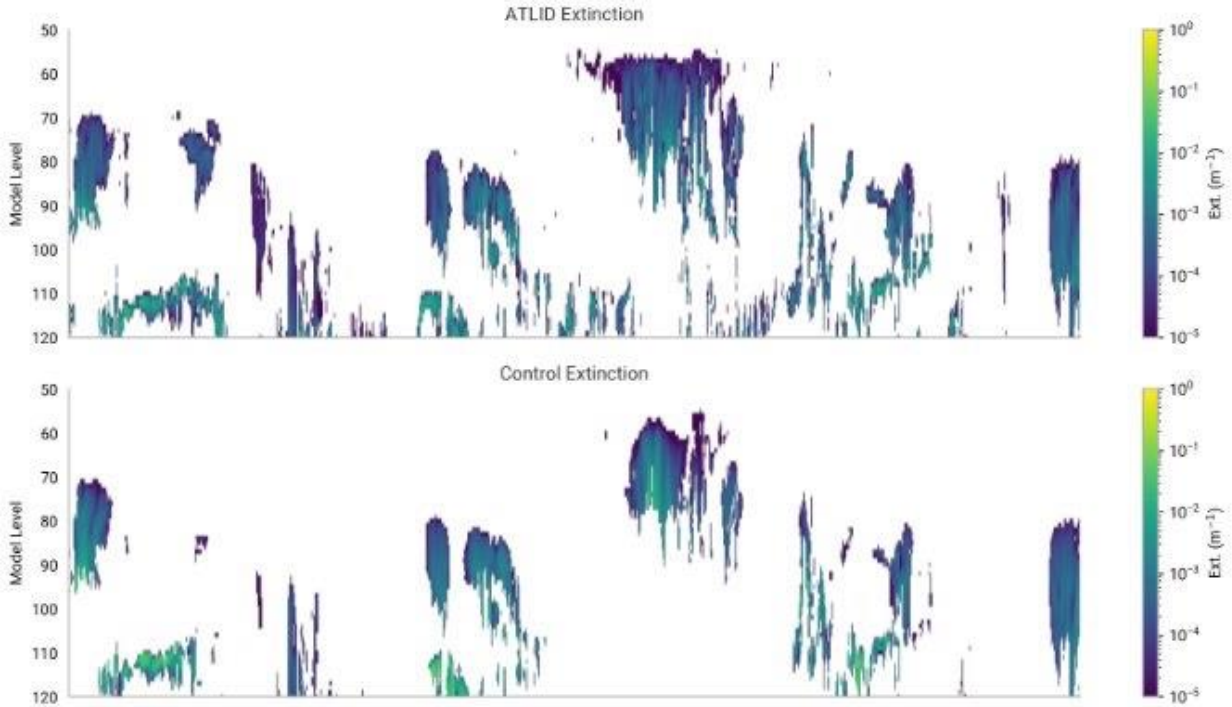

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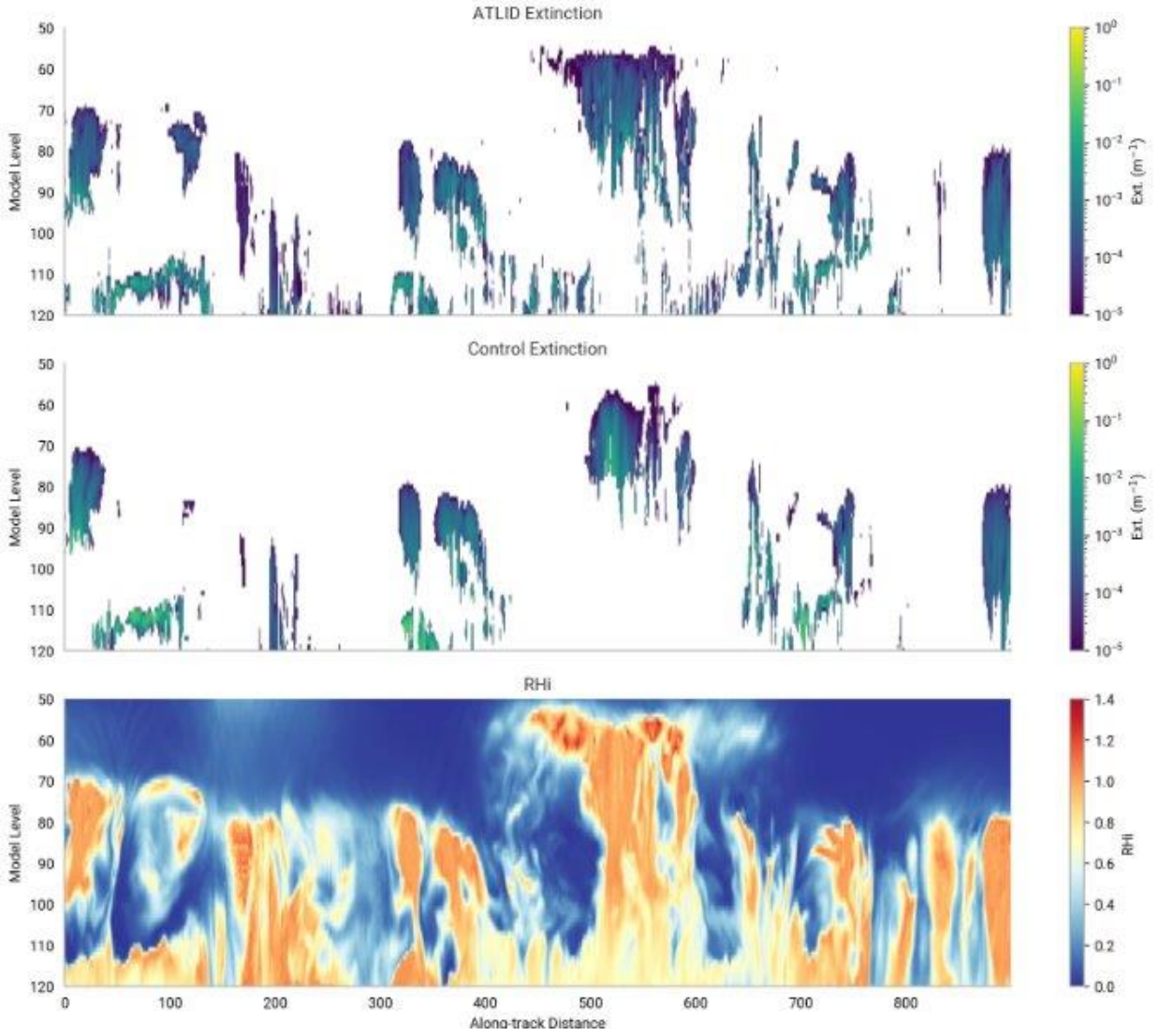

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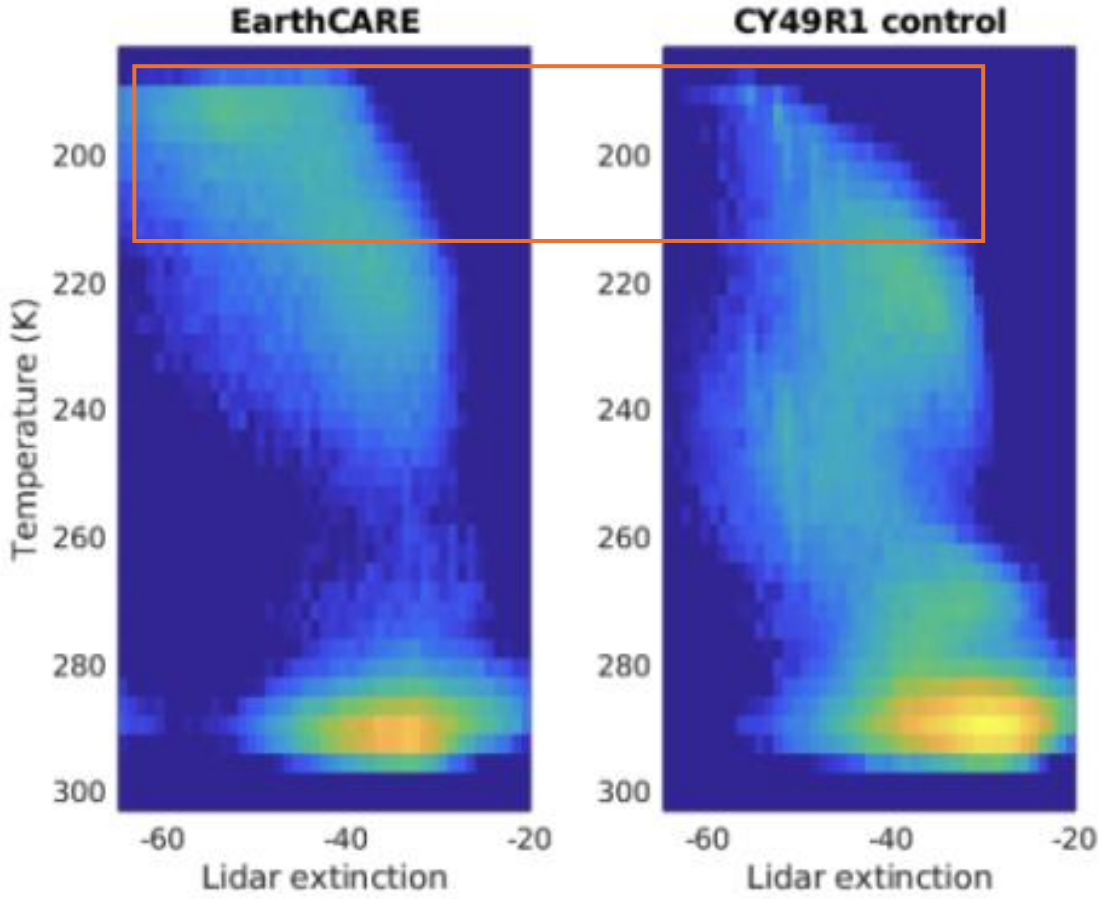
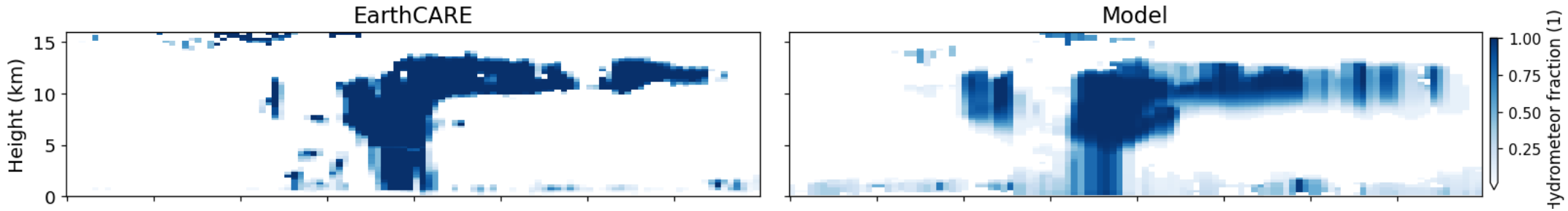


Mark Fielding – tropical clouds

Another bias emerges: too much falling snow



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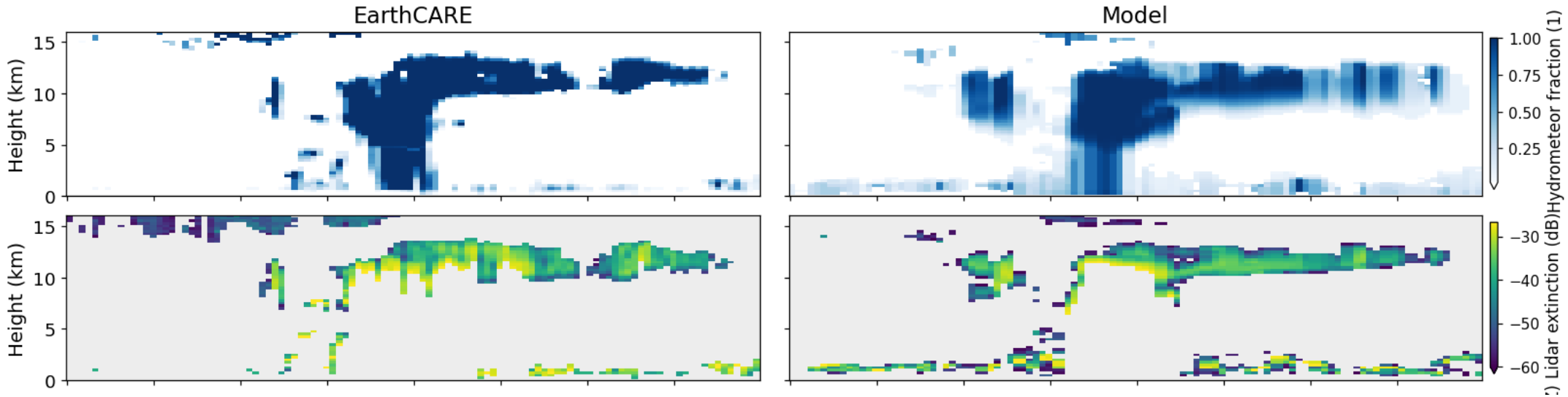

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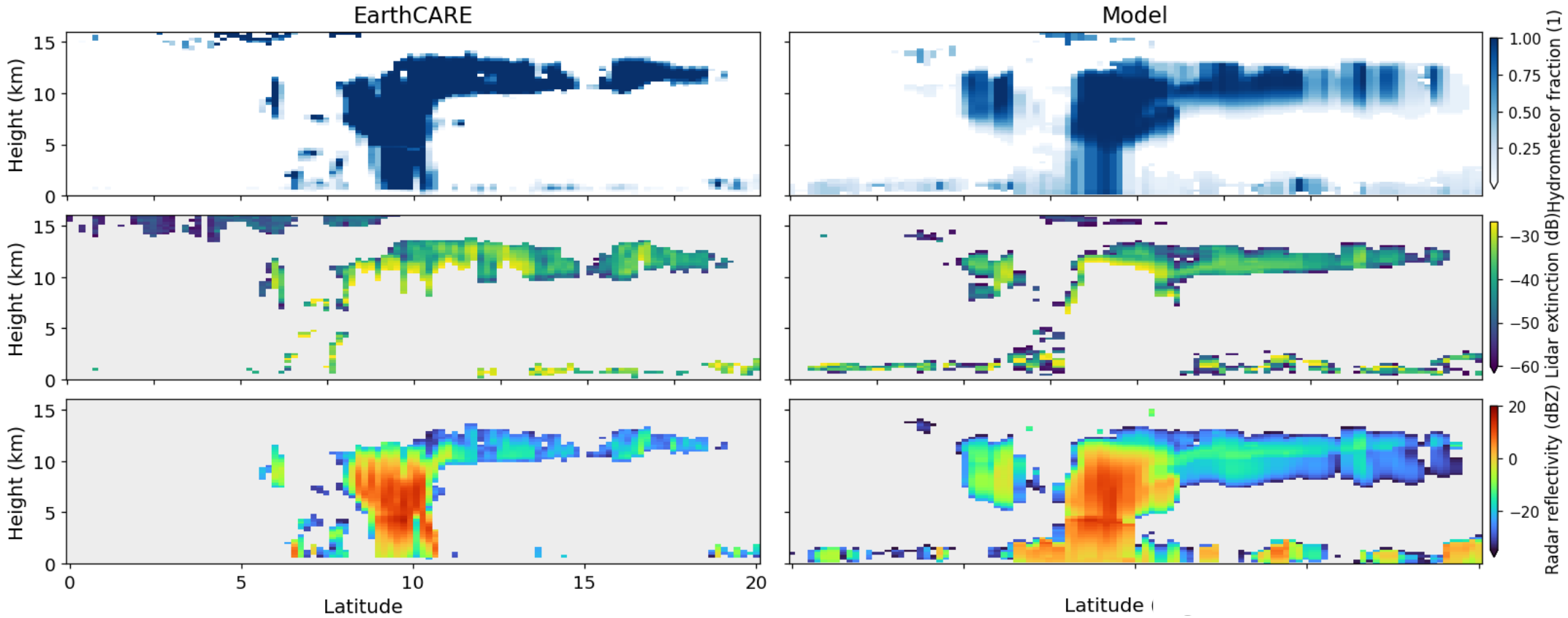
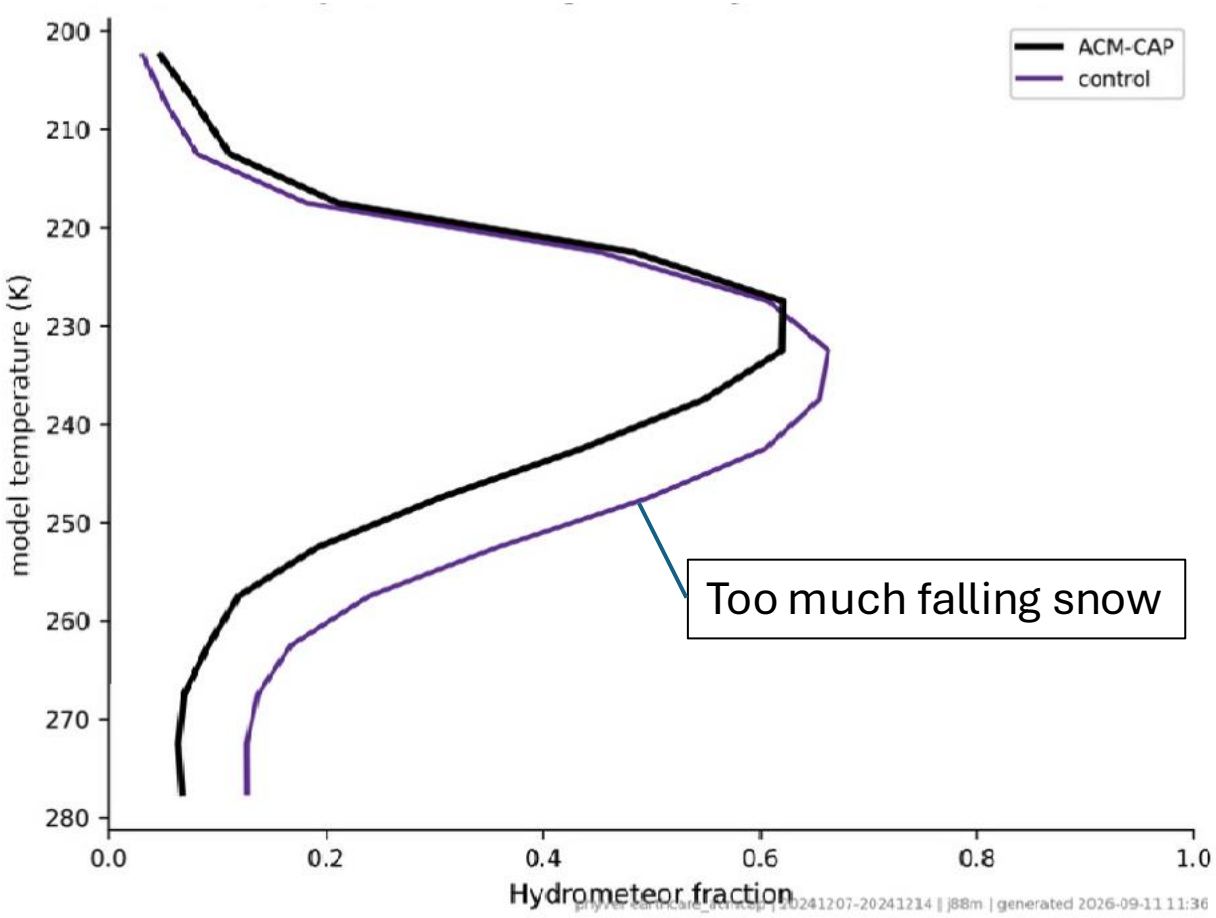
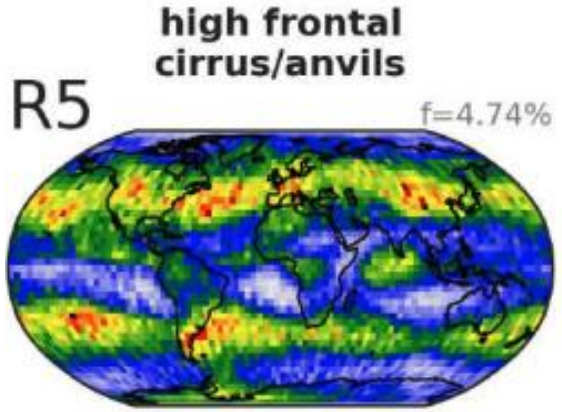


Looking beyond profiles – global statistics and regimes

High frontal cirrus





- Can use regime analysis for more detailed investigation of model biases
- Clustering from Shannon Mason
  - See here
  - K-means clustering based on profiles of cloud/precipitation fraction and thermodynamic phase

From July ‘24 to May ‘26

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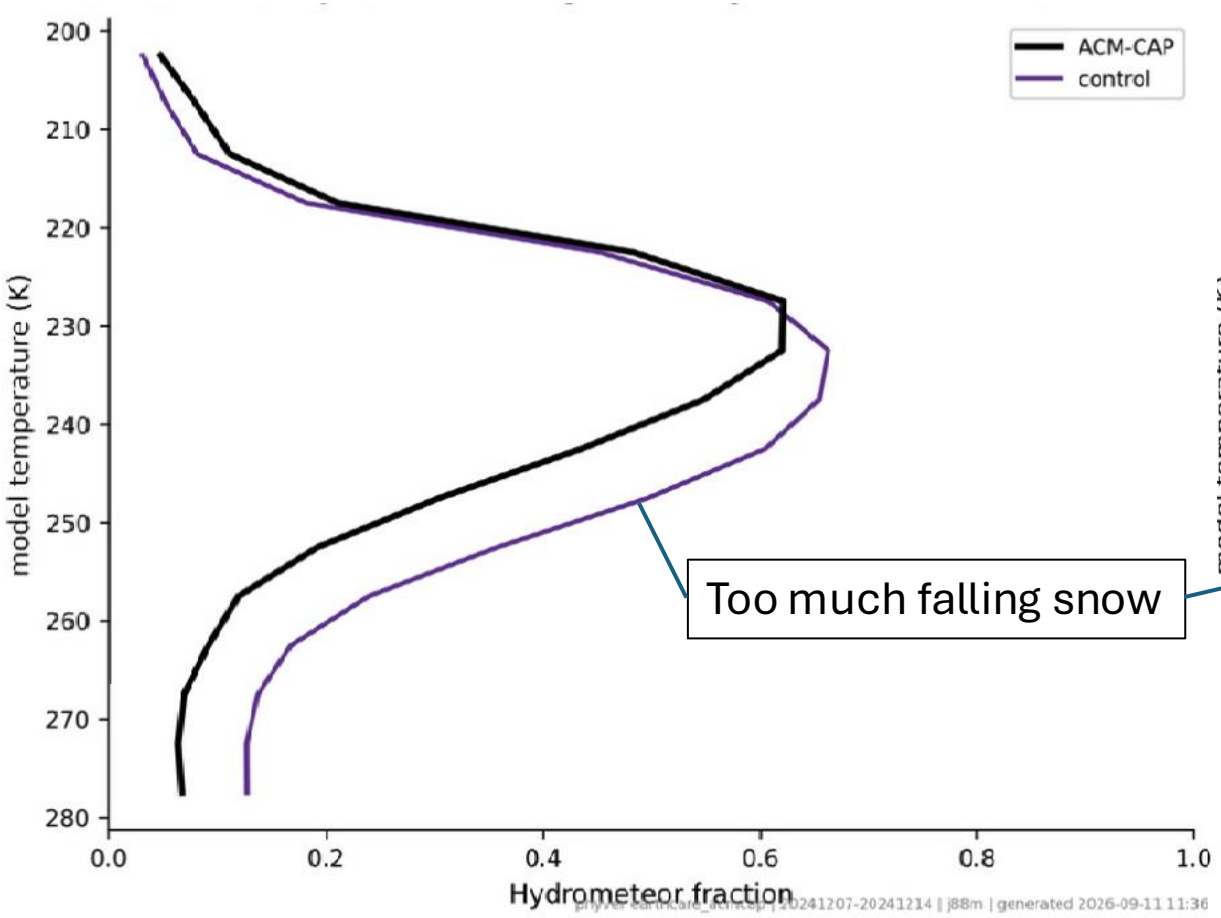
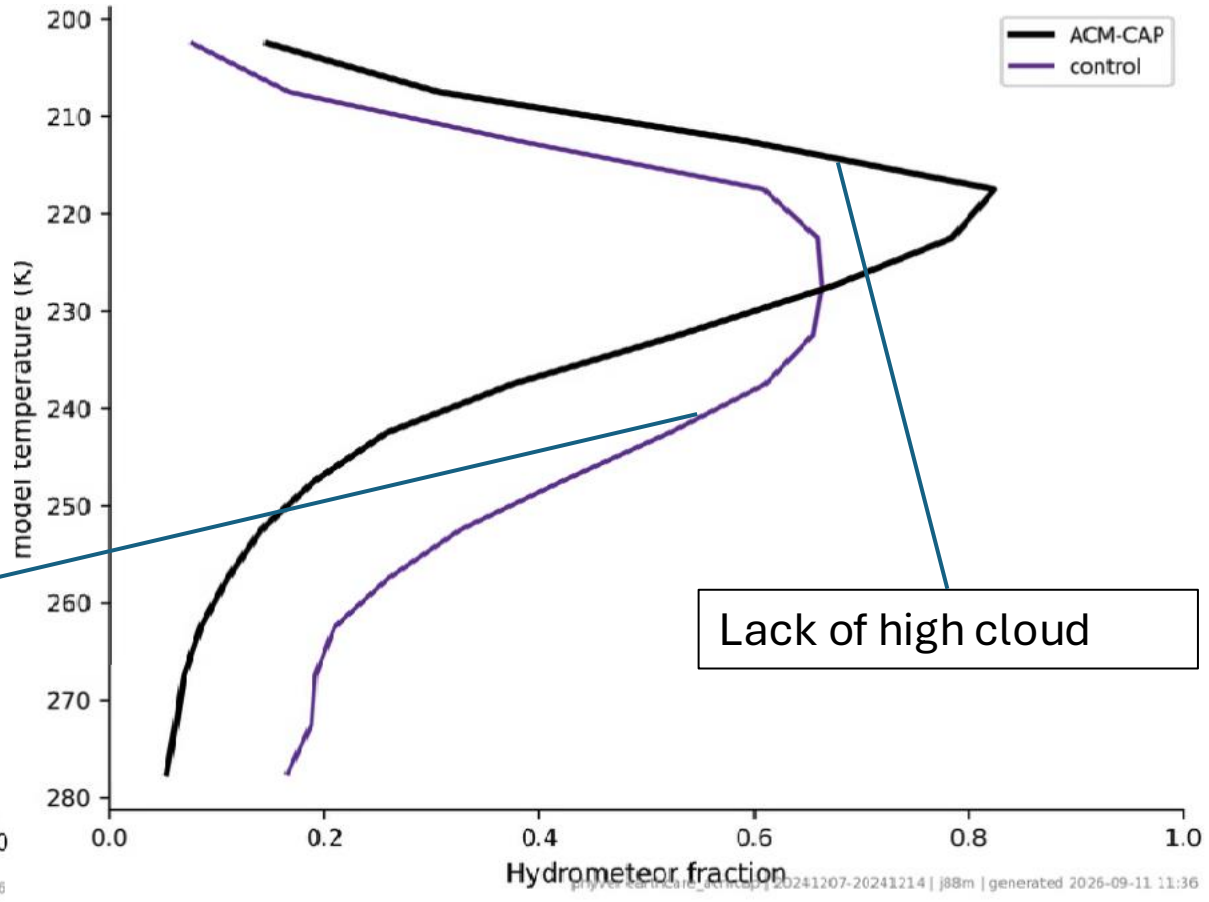


Too much falling snow

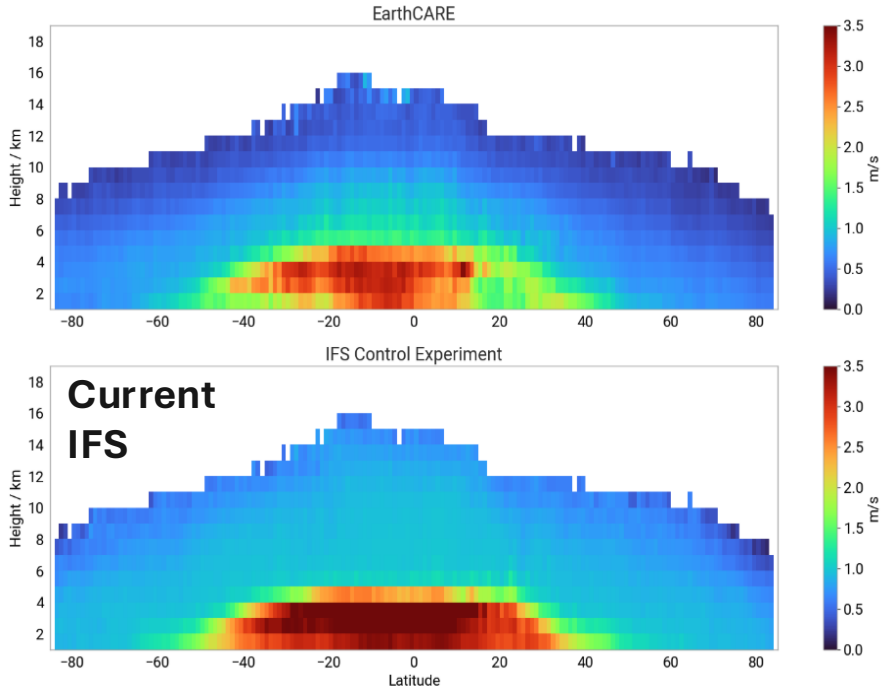
Thick tropical cirrus/anvils

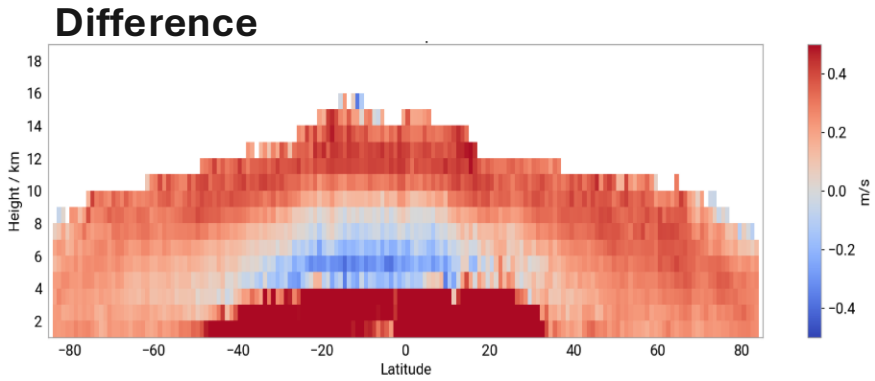


Lack of high cloud

EarthCARE enables targeted process-level fixes

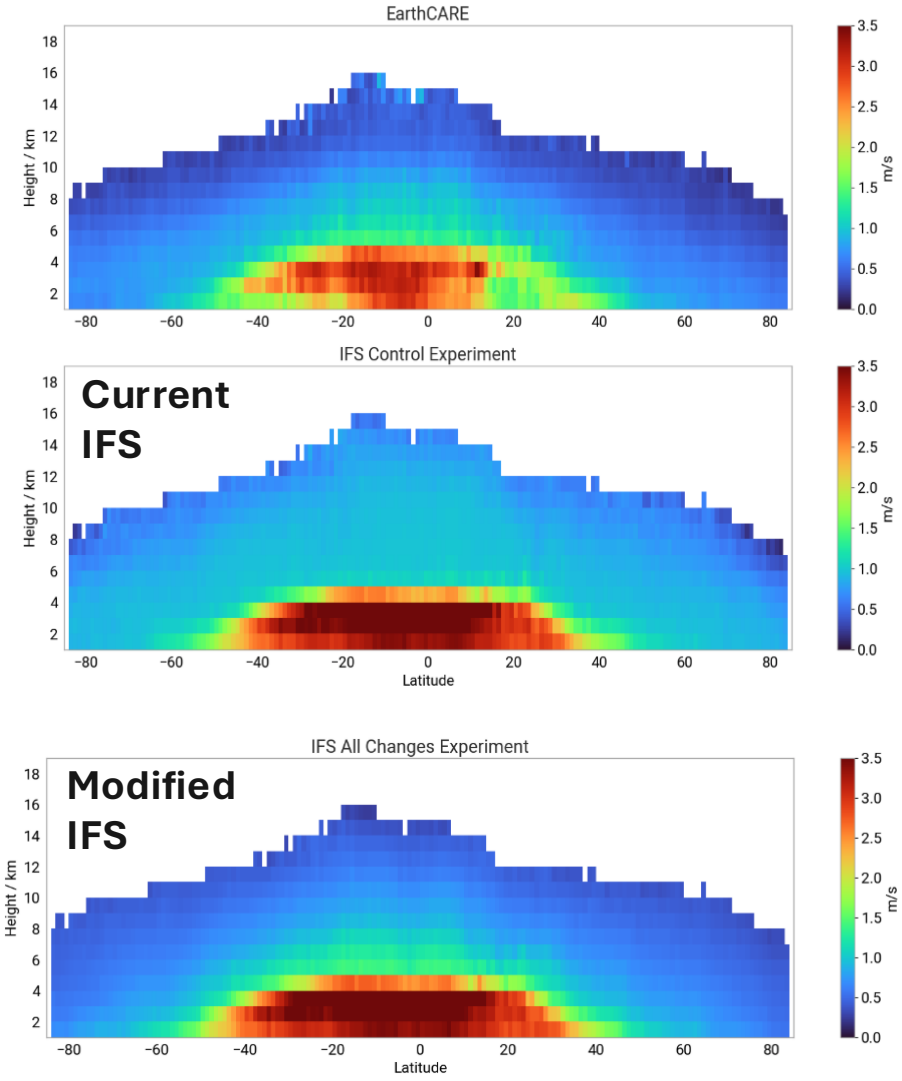
- Snow at 1 m/s – too fast at cold temperatures, too slow for graupel

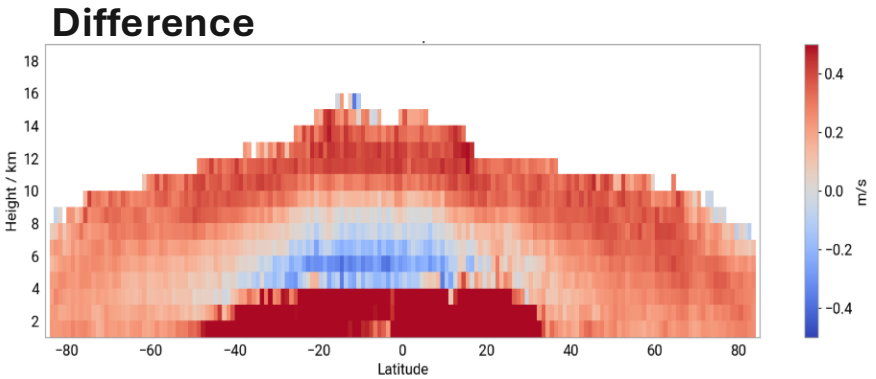


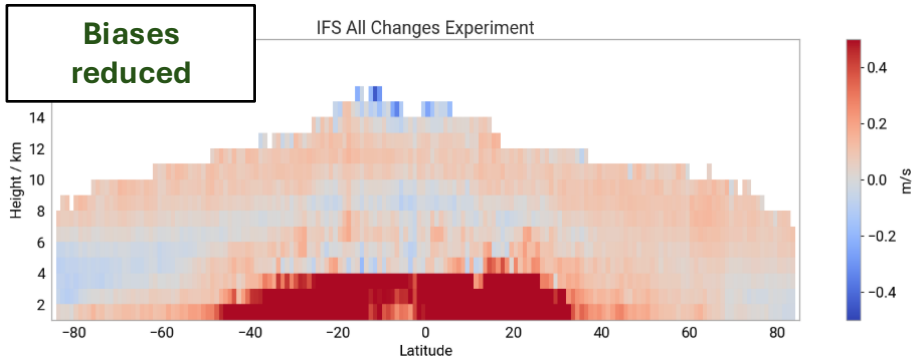


EarthCARE enables targeted process-level fixes

- Introduce mass-weighted snow and ice fall speeds
- Change PSD assumptions
- Introduce diagnostic riming fraction



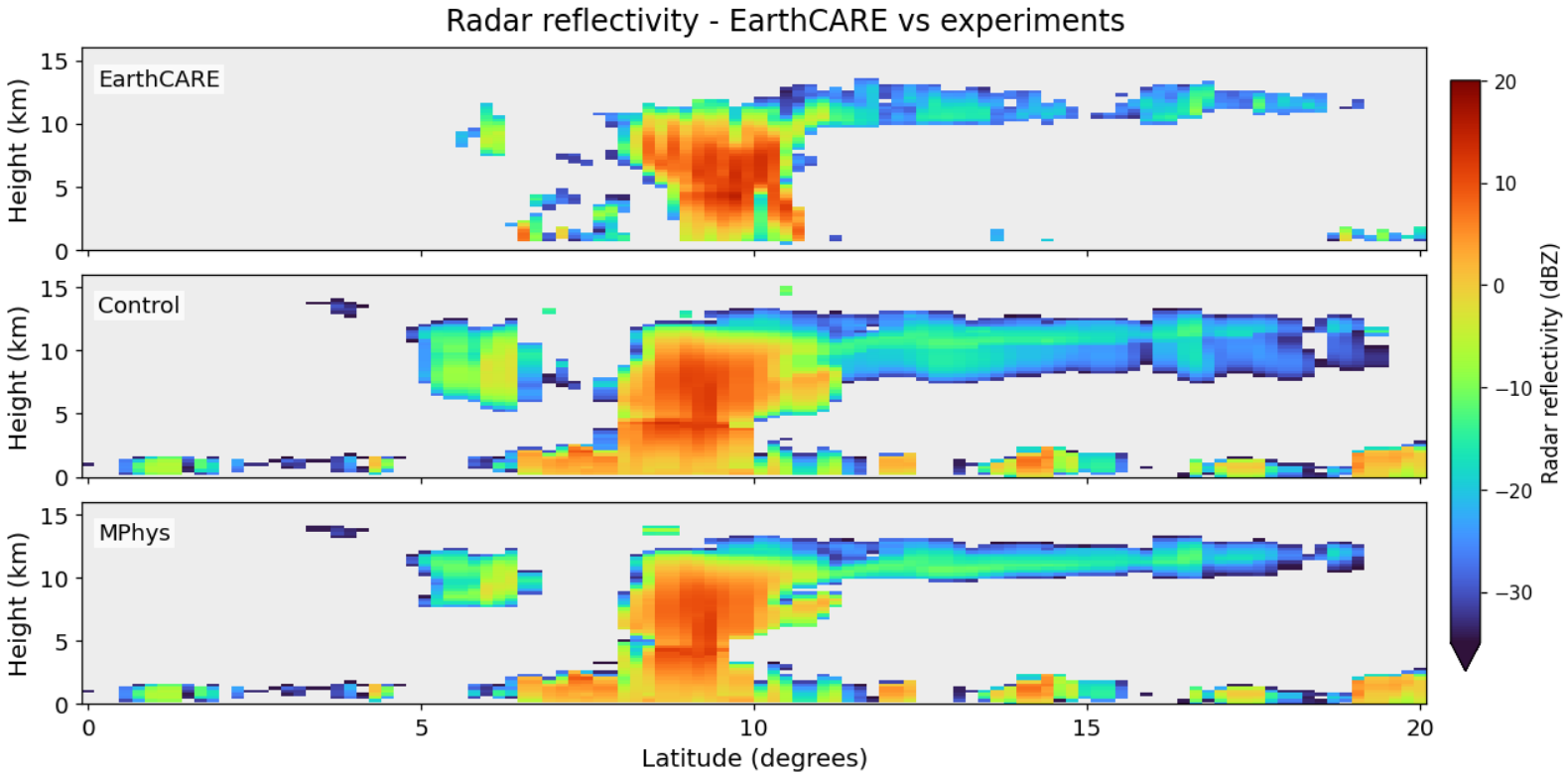




EarthCARE enables targeted process-level fixes

Used EarthCARE to evaluate a range of parameterisations

- Variable snow and ice fall speed
- Diagnostic riming fraction
- More physical snow sublimation
- Changes to ice sublimation
- Changes to subgrid humidity assumptions
- Introducing heterogeneous nucleation
- Snow-accretes-ice process
- Changes to deposition assumptions



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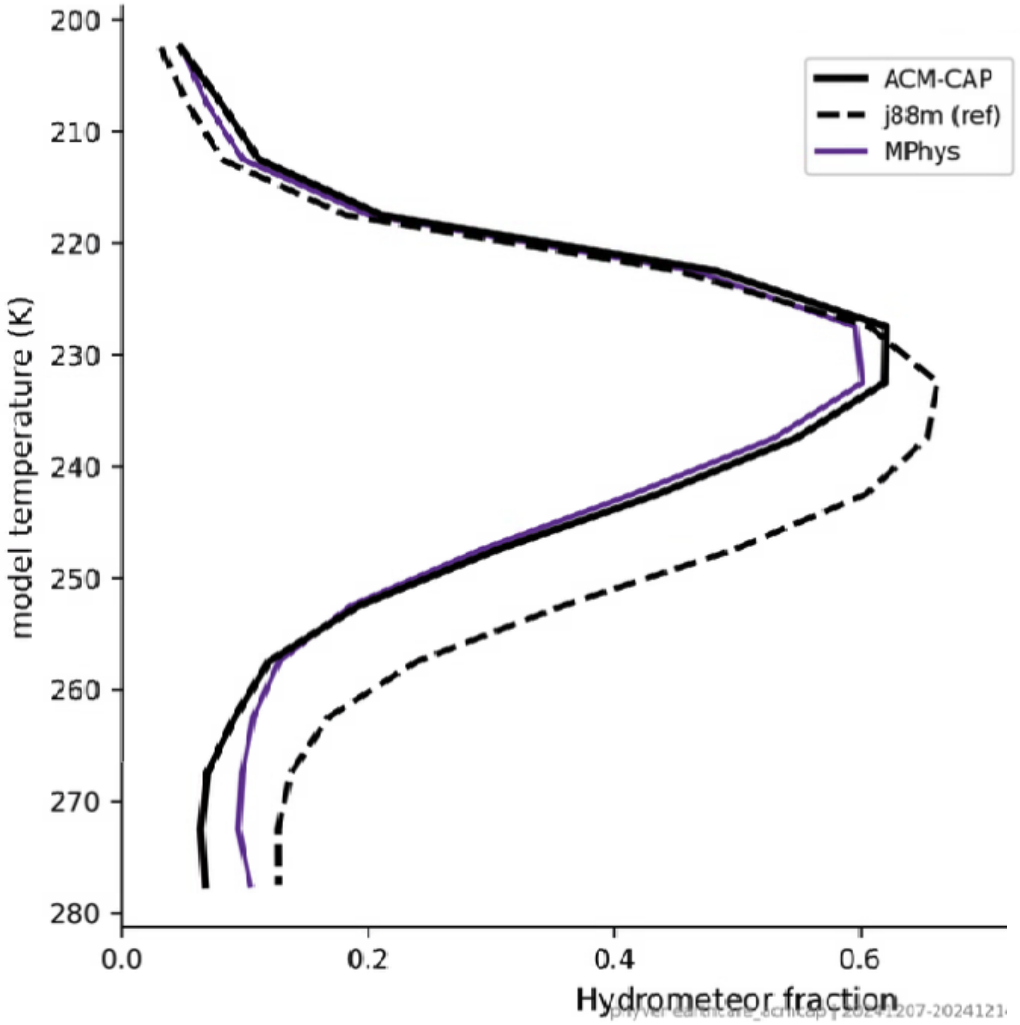
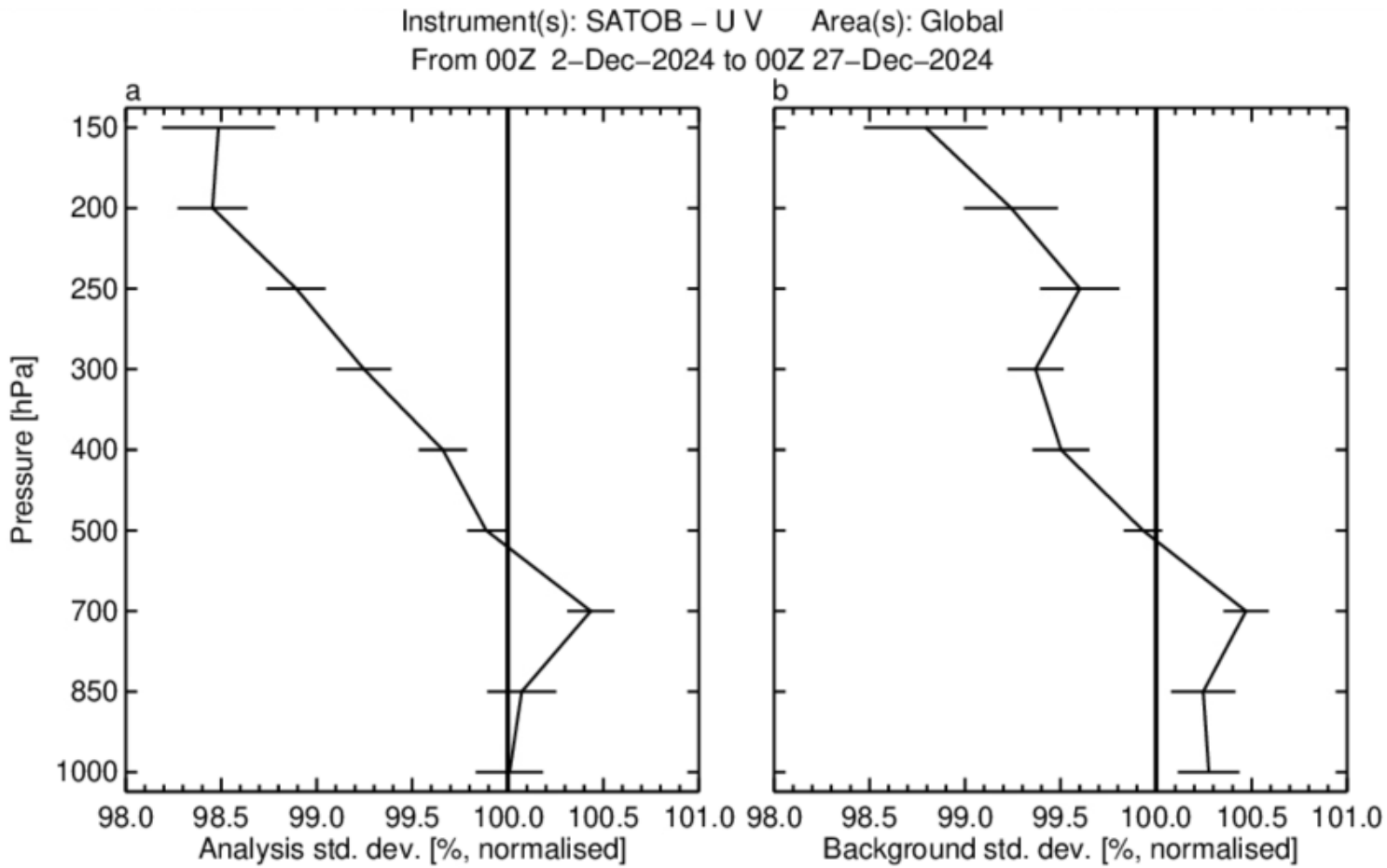


EarthCARE-informed changes can benefit the IFS…

- See improvements to various comparisons against observations in analysis experiments, e.g. better use of atmospheric motion vectors at higher altitudes



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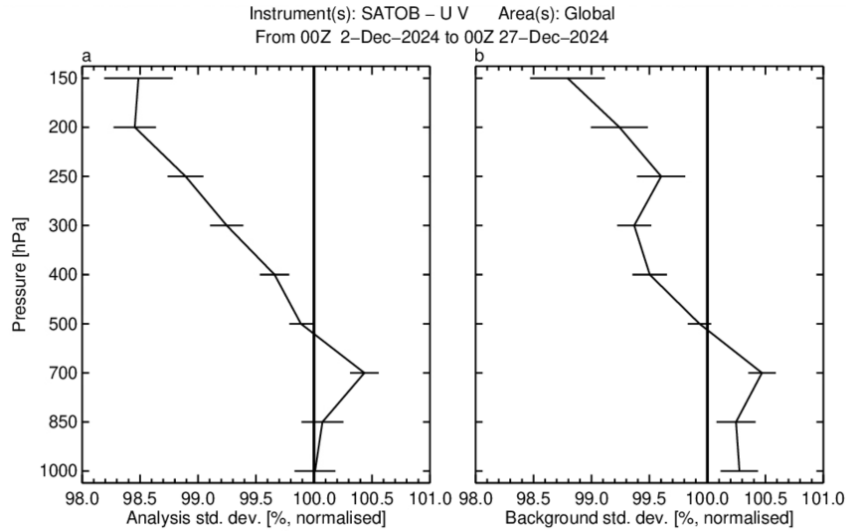
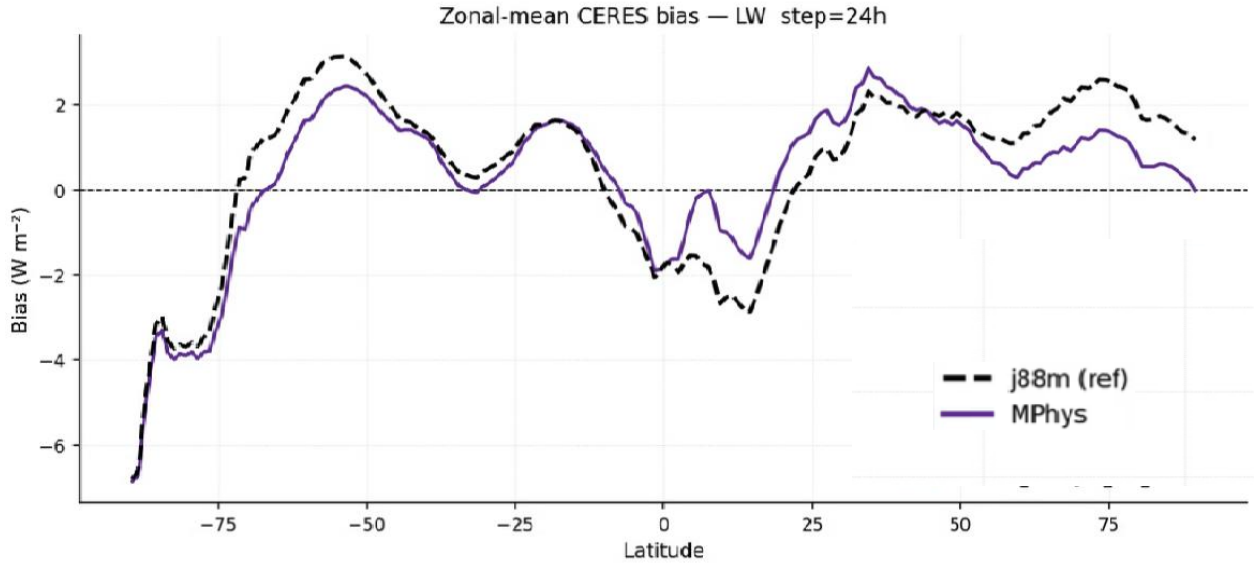
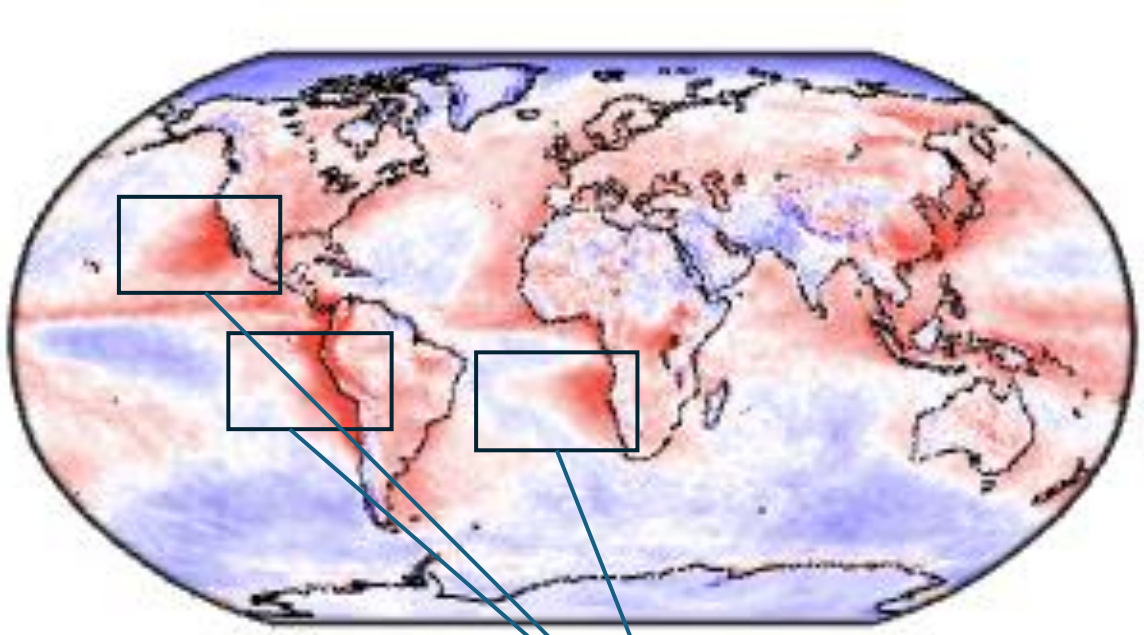


- Also reduction in biases in the LW radiation in the tropics
- Outstanding forecast issues (e.g., cold bias) remain



What about shortwave biases?

- Again, CERES capable of telling us about the nature of the bias
- Long-standing issues in the stratocumulus decks
- But why?
  - Stratocumulus cloud not being formed at all?
  - Decks transitioning to cumulus clouds too early?
  - Too much drizzle?
  - Clouds too thin?



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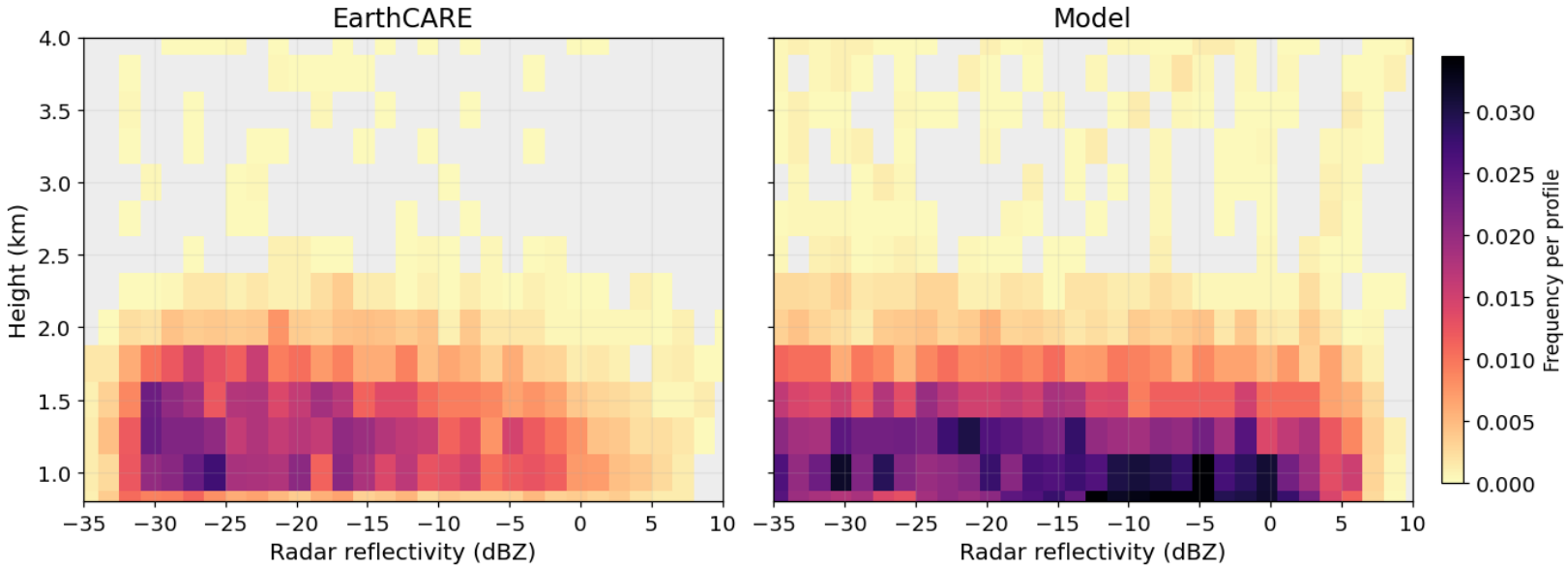

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