Exploring EarthCARE MSI radiative closure with a variety of ice scattering models

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Introduction

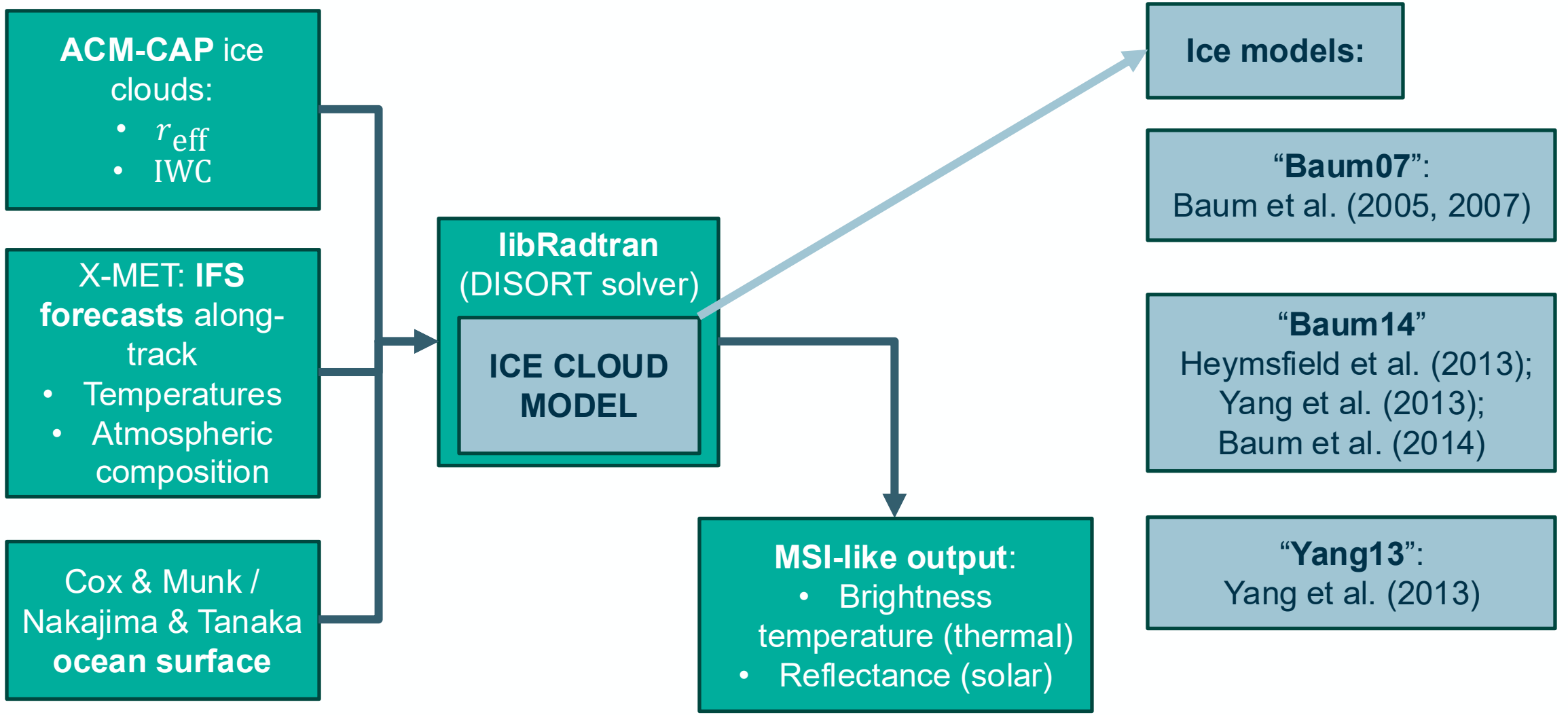
- Bulk optical property models of ice particles needed for modelling radiative transfer through clouds
  - Some models are found to perform inconsistently in different spectral regions
  - Treatment of radiation through ice clouds can vary within NWP models

- Radiative closure experiments allow us to test these models across different regimes
  - Probing the underlying ice scattering physics

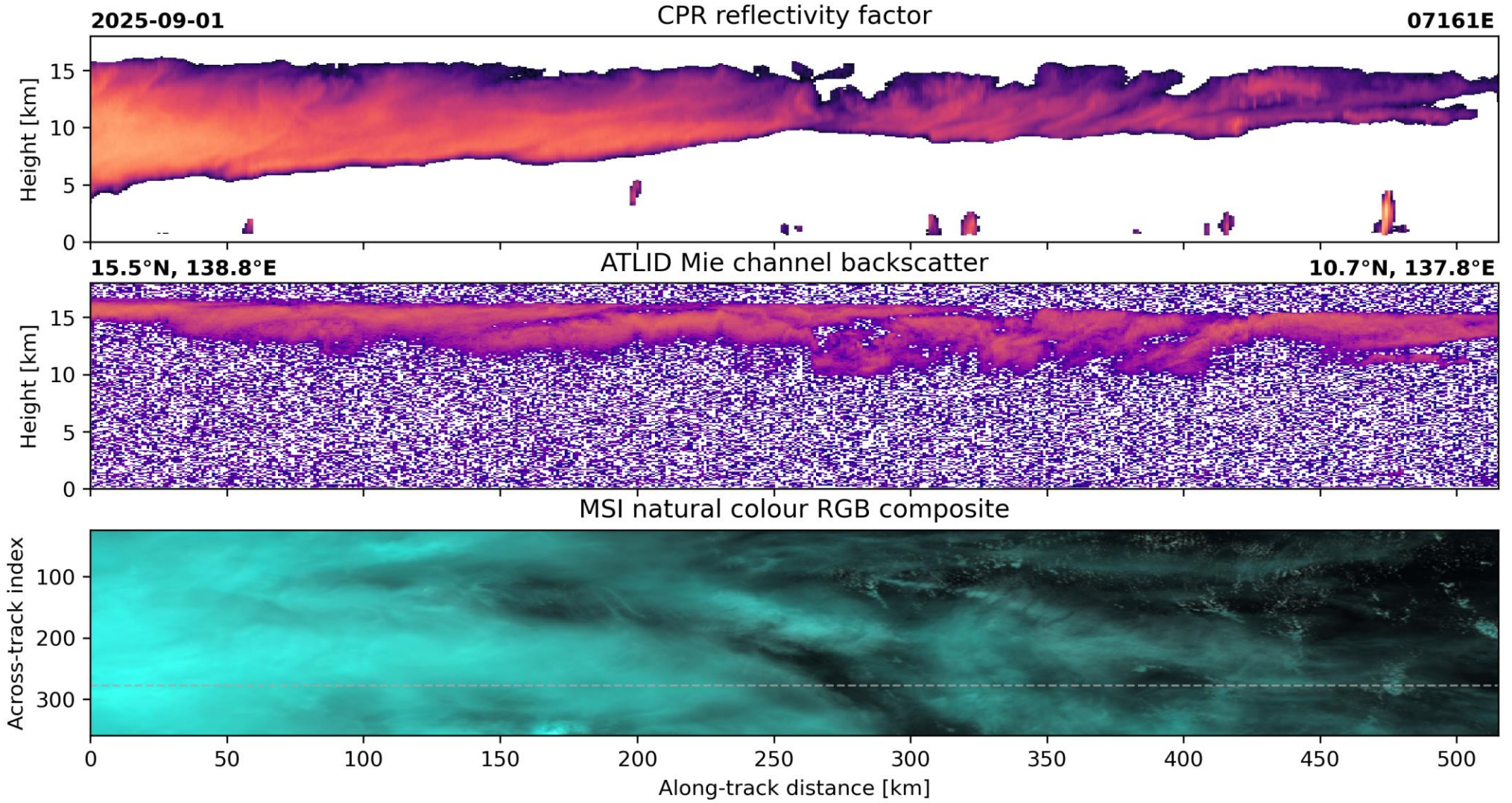
- EarthCARE instrument synergy lets us test this agreement on one platform
  - ACM-CAP retrieval can provide a ‘best guess’ of cloud properties
  - MSI observes the LW and SW radiance at 7 channels

- **Do modelled MSI radiances agree with observations above ice clouds?**

Ice cloud radiative transfer modelling

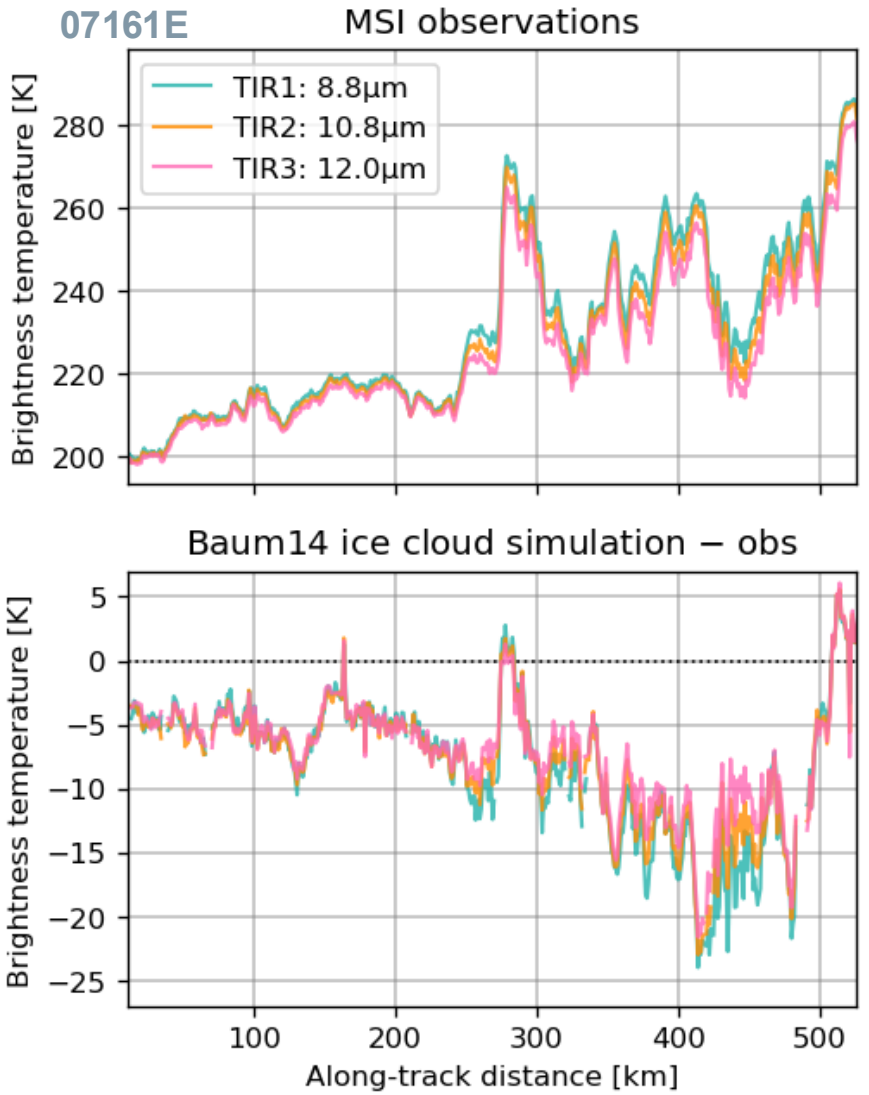


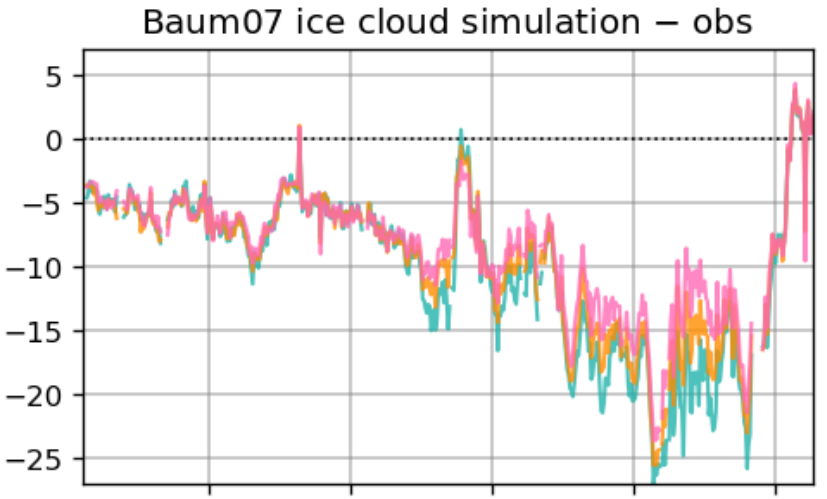
Case study

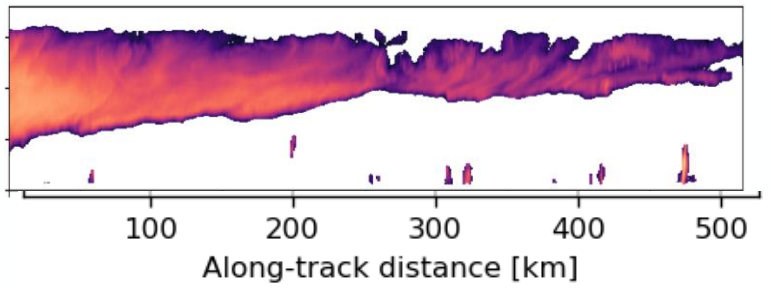

2025-09-01
CPR reflectivity factor
07161E
Height [km]
15
10
5
0
15.5°N, 138.8°E
ATLID Mie channel backscatter
10.7°N, 137.8°E
Height [km]
15
10
5
0
MSI natural colour RGB composite
Across-track index
100
200
300
0
50
100
150
200
250
300
350
400
450
500
Along-track distance [km]

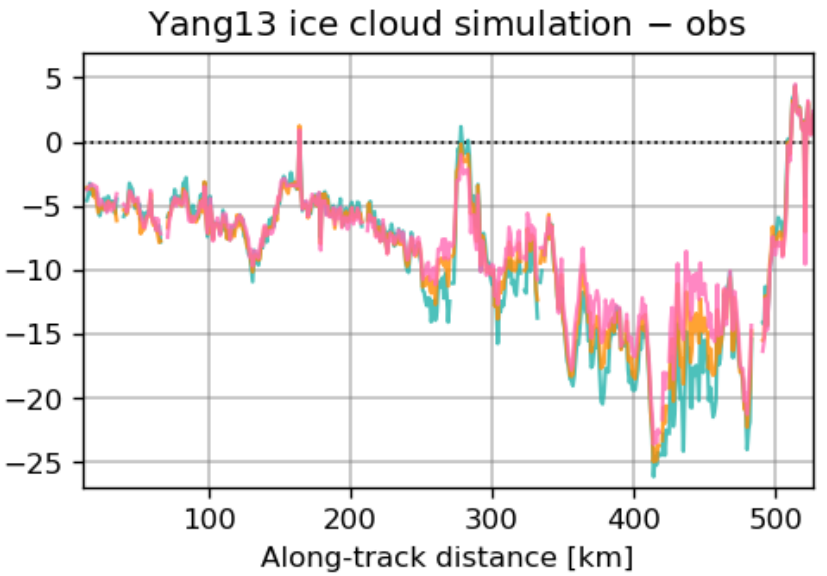
Closure in thermal IR channels

ACM-CAP BA baseline





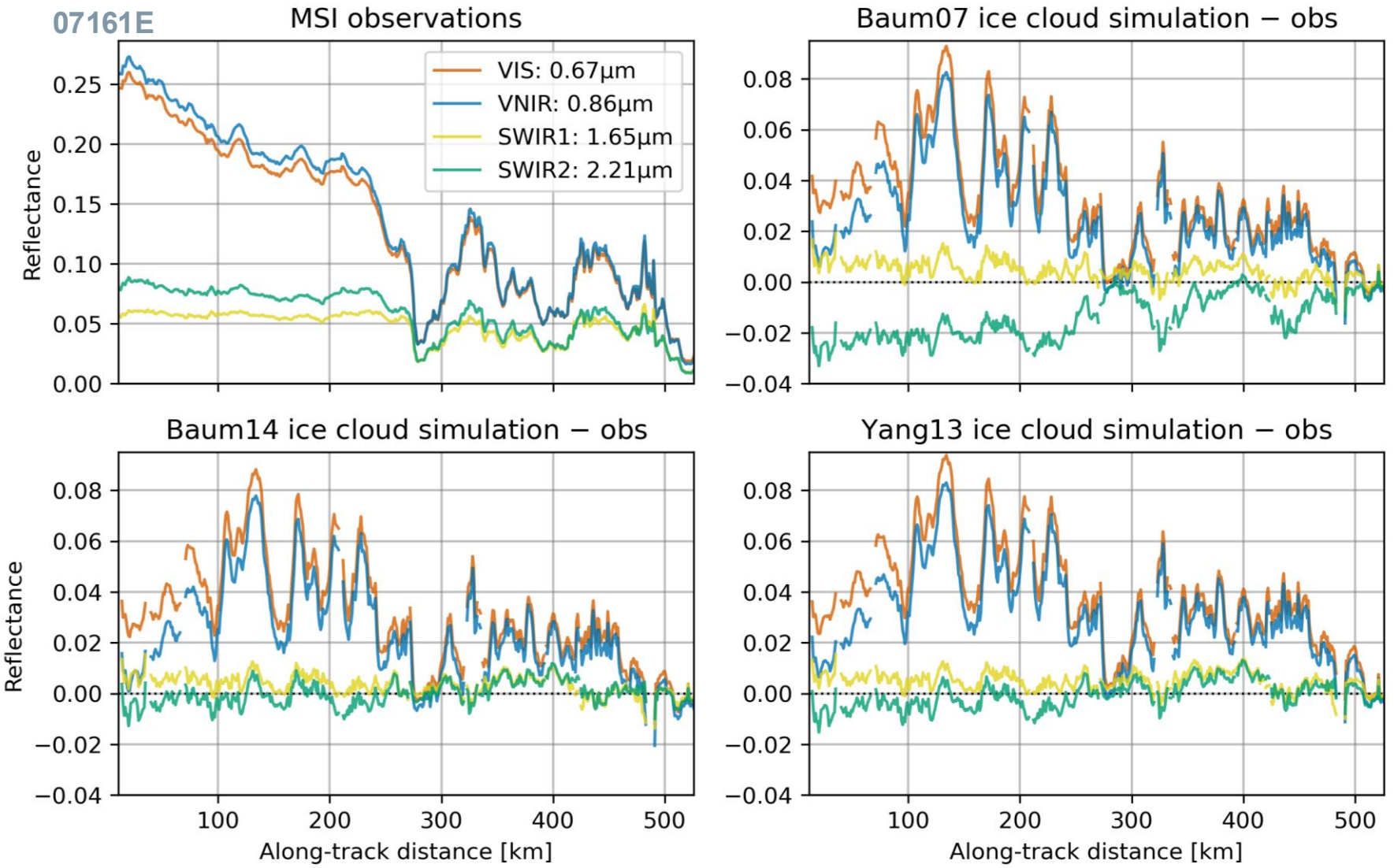


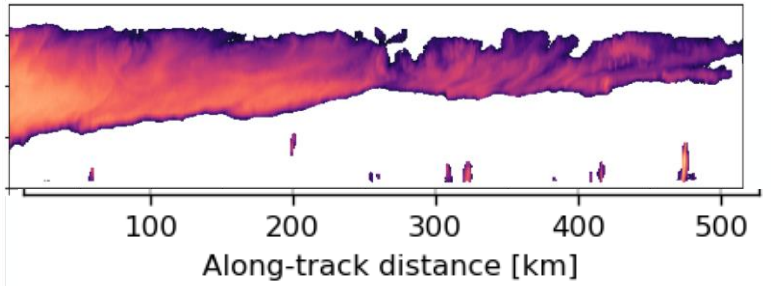


- **ALL** models are wrong?!
- Modelled brightness temperatures too cold
- ⇒ Cloud is too optically thick, especially in thin cloud

Closure in solar channels

ACM-CAP BA baseline

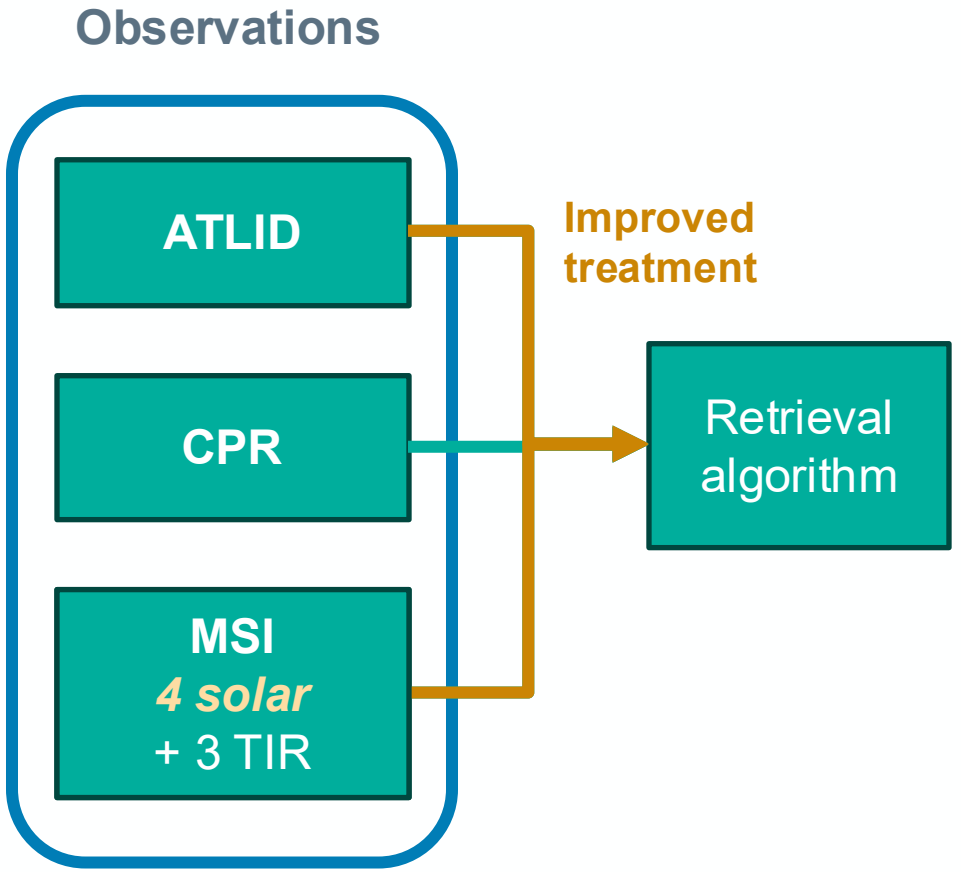




- Solar channels mostly tell a similar story
  - VIS + VNIR channels too reflective: cloud too optically thick
  - SWIR channels seem to match? (–Baum07)
- Revisit ACM-CAP retrieval that our MSI model rests on

Revisiting ACM-CAP

ACM-CAP: BE baseline



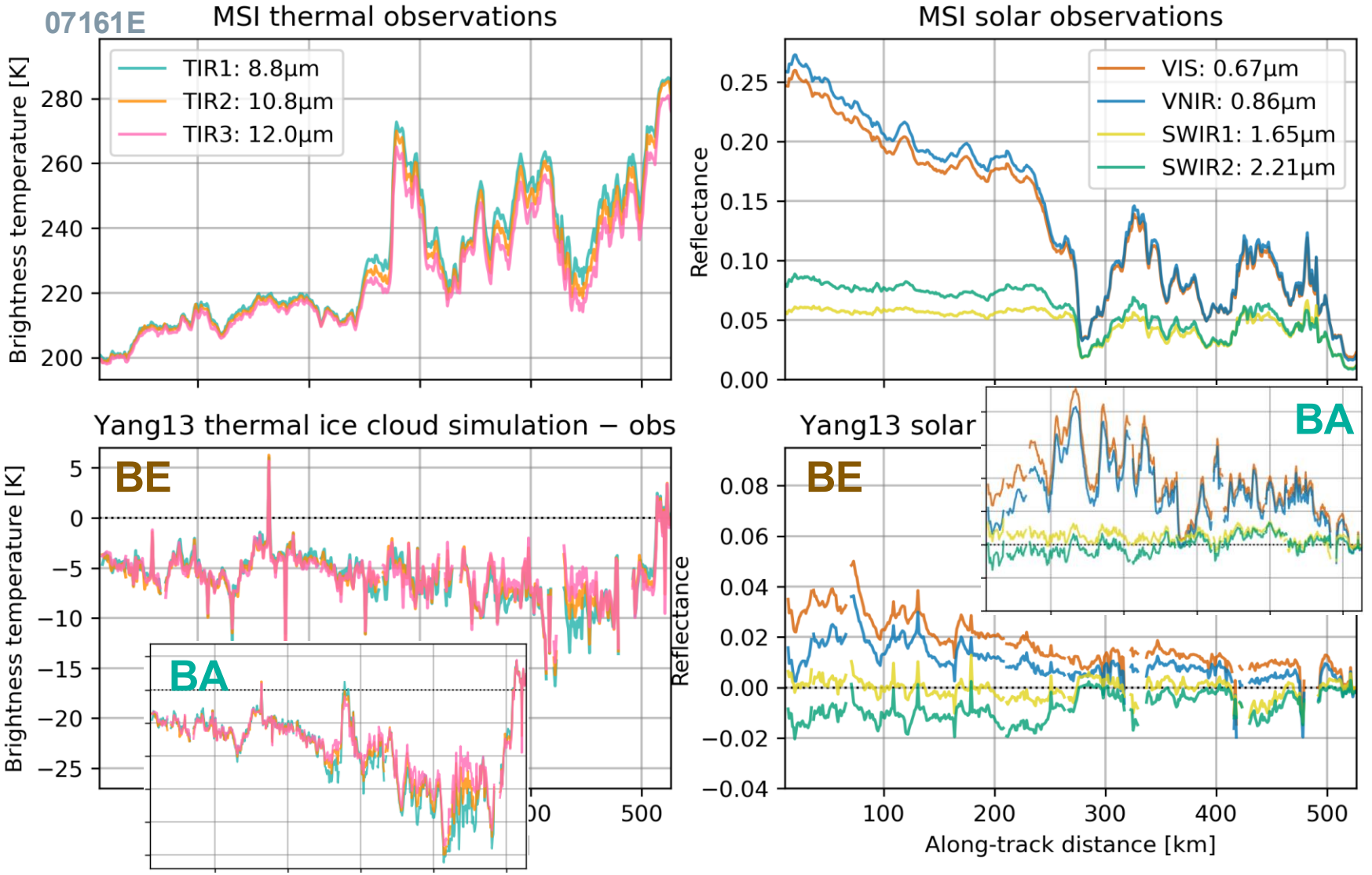
- Takes observations from **ATLID** (backscatter), **CPR** (reflectivity, Doppler velocity), **MSI** (radiances)
  - Only some observations “assimilated”
  - **BA** baseline used for this frame (07161E) operationally

BE baseline:

- ATLID backscatter & MSI solar radiance treatment improved in forward model
- All **4 MSI solar radiances** now assimilated

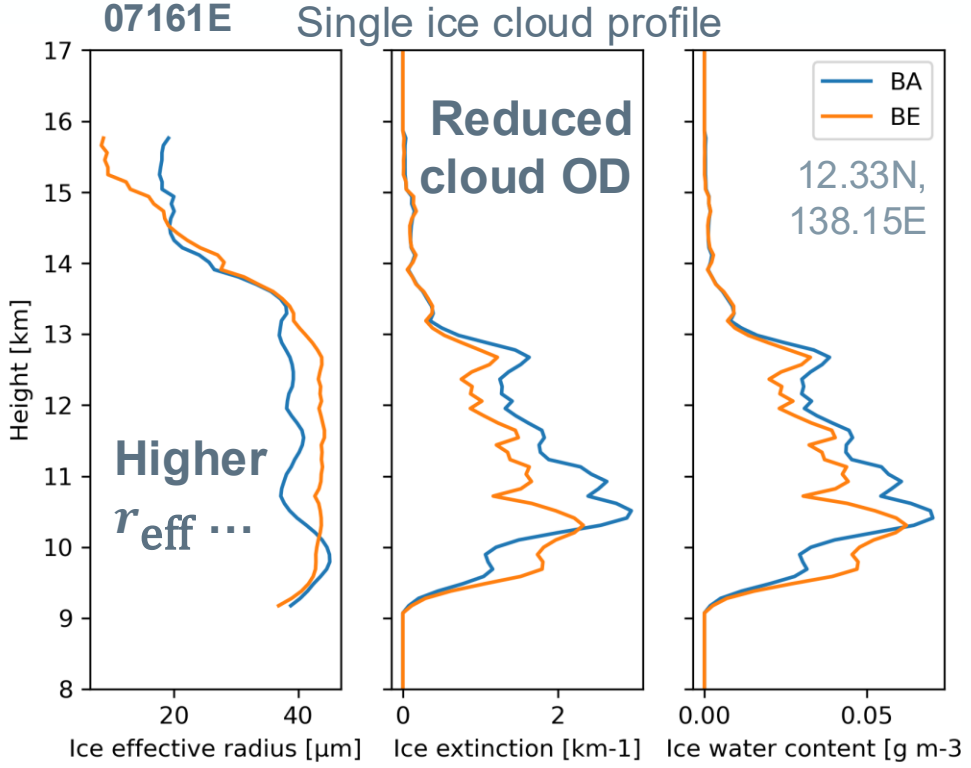
- **How does the retrieval update impact our closure test?**

Closure with the ACM-CAP BE baseline

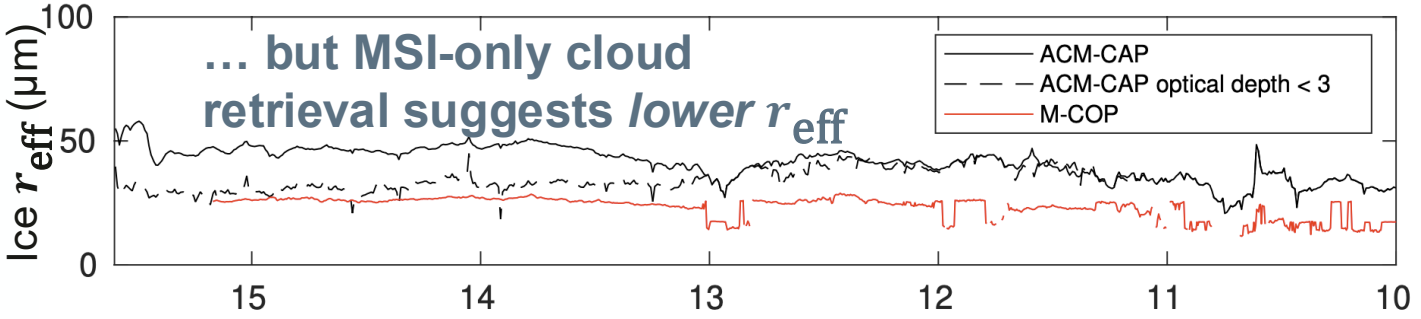


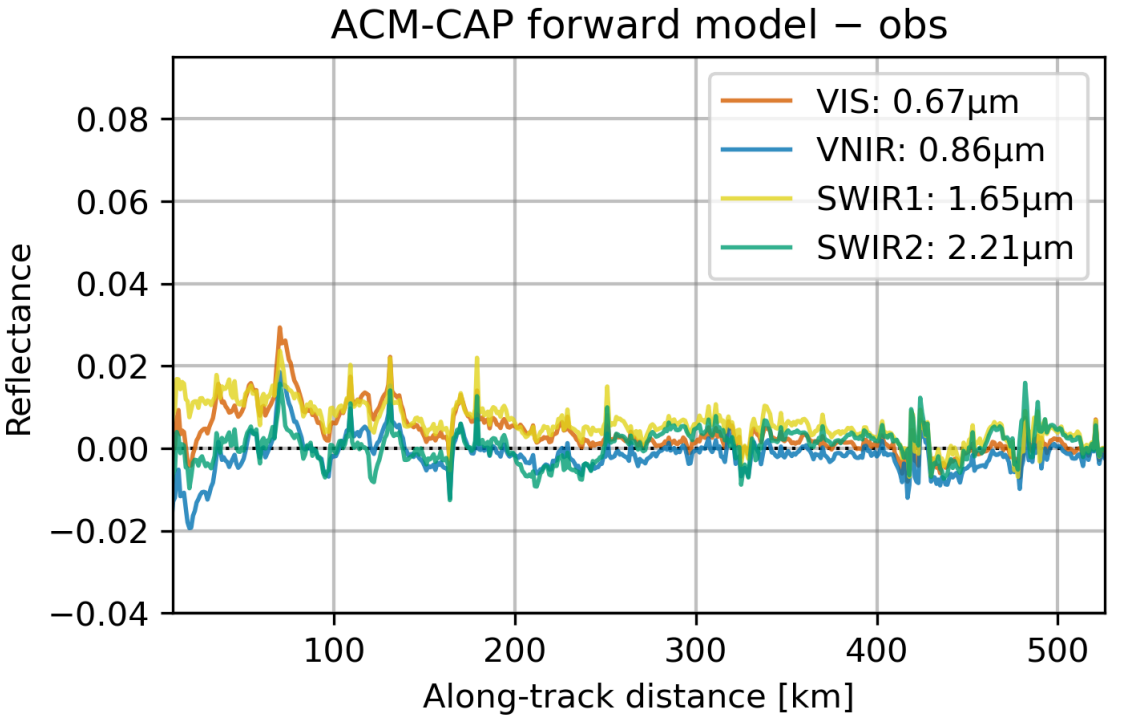
- Consider just one ice model (Yang13) to compare BE vs BA baseline
- Closure gets better in almost all channels
  - But still cold bias in thermal ~5K
  - VIS + VNIR still a bit too reflective
- SWIR2 2.21µm channel (particle size sensitivity) gets too dark?
- What's getting better (and still missing) in ACM-CAP?

Changes in the retrieved cloud?



Hints at inconsistency between retrieval treatment of ice microphysical info from the three instruments?





FLOTSAM forward model in retrieval very closely matches observations in solar…

Even closer than DISORT simulation reaches: potential issues with FLOTSAM ice cloud treatment?

Conclusions and future work

Conclusions

- Some small differences between ice radiance models
  - Currently we believe this signal is dominated by issues in the ACM-CAP retrieval
- Closure improvement with the BE baseline further validates upgrades, compared to BA
- There are still biases in the radiative closure, suggesting more work to be done on retrieval
- Also hints to inconsistency between information used from MSI vs ATLID/CPR

Future work

- Effect of different crystal habits / further ice scattering models
- Further investigation into the ice cloud retrieval, e.g.:
  - Comparison to single-sensor cloud properties
  - Validation against in-situ measurements
- Use satellite matchups to test ice cloud agreement:
  - High-resolution sounders to test full IR spectrum e.g. MTG-IRS, CrIS
  - Far-infrared e.g. PREFIRE, FORUM (future)

Thank you!