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NATURAL ENVIRONMENT RESEARCH COUNCIL

Exploiting aircraft observations of infrared radiation to infer Arctic surface emissivity

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SUMMARY

Aircraft-based observations have been employed to derive, for the first time, estimates of far infrared (FIR, wavelengths > 15 µm) snow and ice surface emissivity. Analysis of measurements made from the upper troposphere show consistent behaviour with those derived from a low level flight, giving confidence that the Far infrared Outgoing Radiation Understanding and Monitoring (FORUM) instrument configuration will be able to derive more extensive estimates of this poorly known climate parameter.

1. MOTIVATION

- FIR surface emissivity: important role in determining the pace of change in polar regions through 'ice-emissivity' feedback[1].
- Feedback sign appears critically dependent on assumed snow/ice properties[2].
- Implementation of realistic emissivities in one Earth System Model reduces Arctic 'cold pole' wintertime bias[3].
- However, all findings based on theoretical estimates of FIR surface emissivity: do observations show similar behaviour?

2. MEASUREMENT CAMPAIGN

We exploit spectrally resolved radiances measured over the Greenland plateau by the Tropospheric Airborne Fourier Transform Spectrometer (TAFTS)[4] and the Airborne Research Interferometer Evaluation System (ARIES)[5] under the Cirrus Coupled Cloud Radiation Experiment/Cold-air Outbreak and Sub-millimetre Ice Cloud Study (CIRCCREX/COSMICS) campaign (Figure 1).

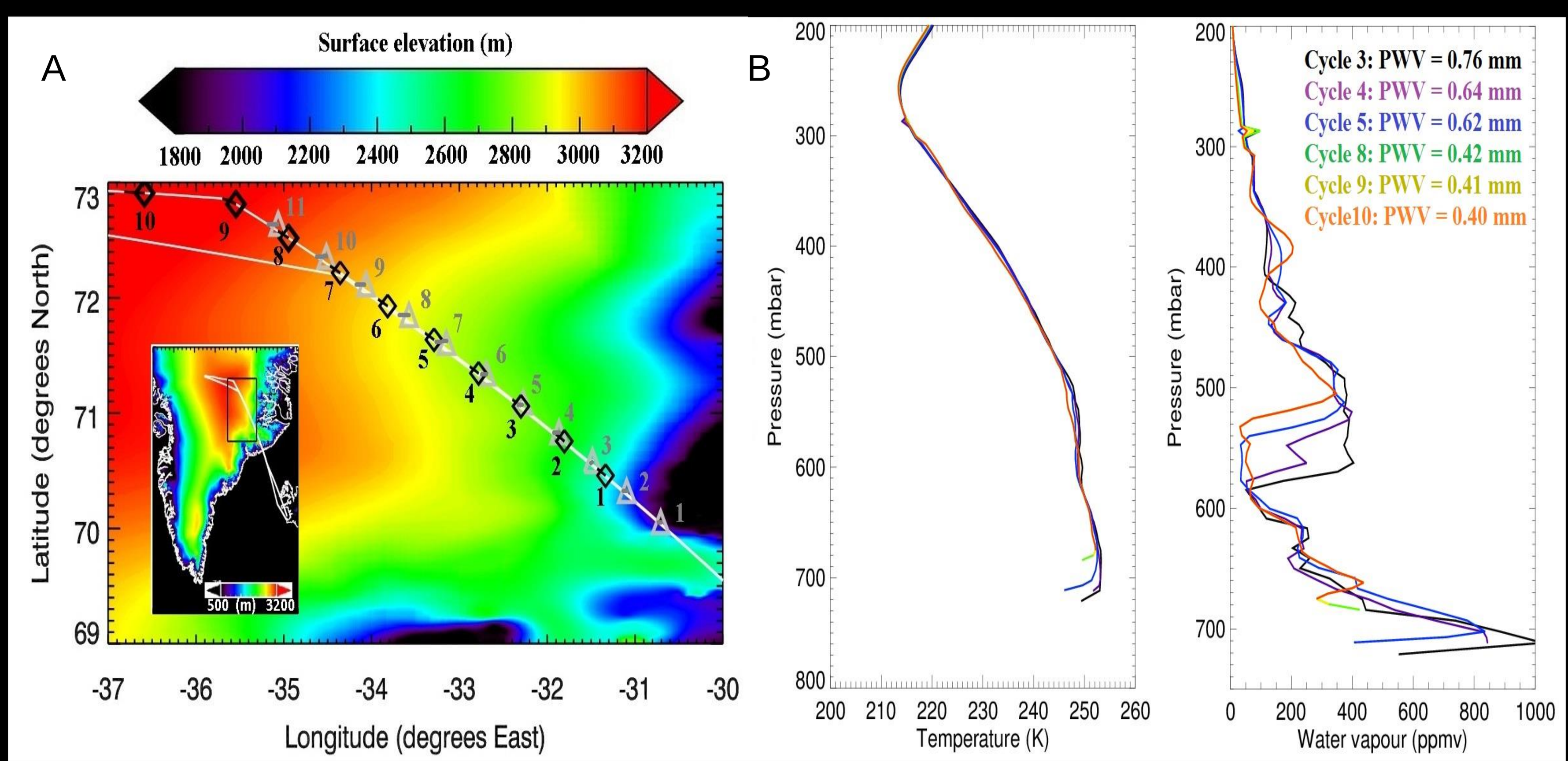

FIGURE 1: (A) Inset: Flight track and surface elevation. Black box indicates the region highlighted in the main image. Main Image: Dropsonde release points (grey triangles) and location of TAFTS nadir scan cycles (black diamonds). (B) Dropsonde temperature and water vapour profiles.

3. RETRIEVAL METHODOLOGY

Solves:

$$\varepsilon_\nu = \frac{L\nu^{\uparrow}_{aircraft} - \tau_\nu L^{\downarrow}_{\nu,eff} - L^{\uparrow}_{\nu}}{\tau_\nu\left(B_\nu(T_s) - L^{\downarrow}_{\nu,eff}\right)} \qquad (1)$$

Main challenges:

- Accounting for atmospheric absorption and re-emission (retrievals only attempted when transmittance, τ_ν > 50 %)
- Estimating surface temperature, T_s (Figure 2)

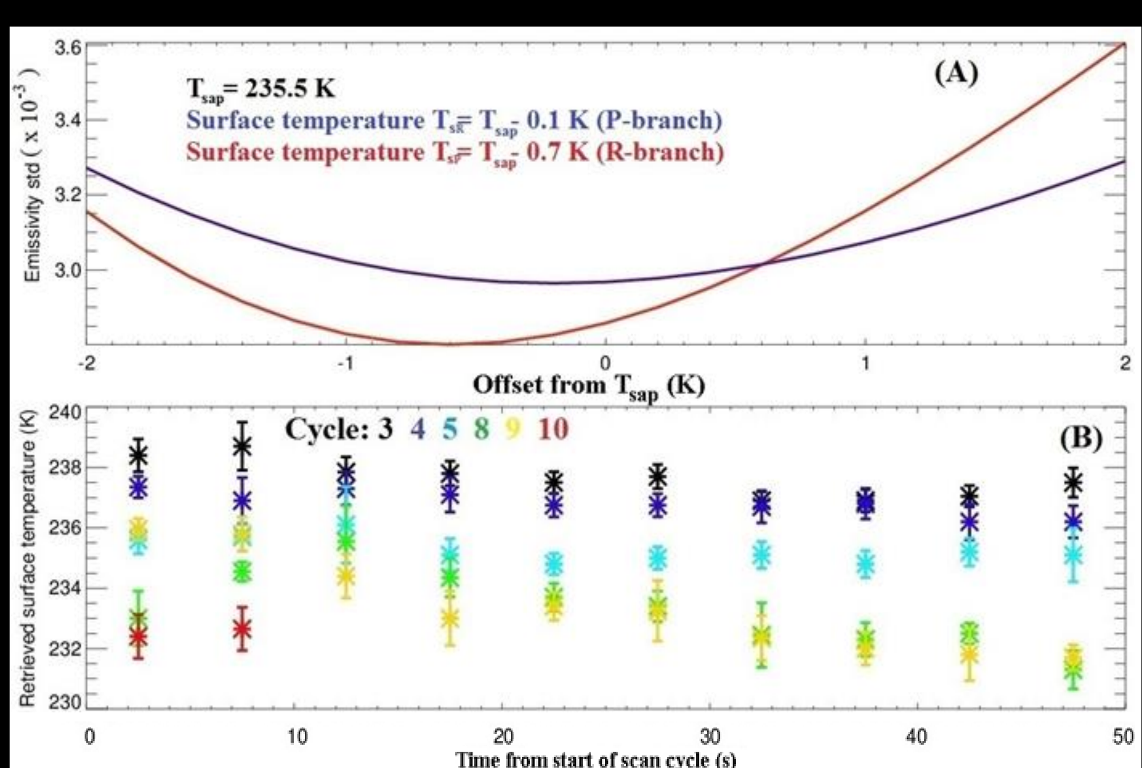

FIGURE 2: We iteratively solve (1) in two micro-windows from 930-960 and 960-990 cm^{-1} and find the value of T_s that minimises spectral variation in ε_s[6] (A). We combine values from both windows and within scan variability to assess uncertainty in the T_s retrieval. Uncertainties in T_s are ~ 0.45 K (B)

4. FIR RADIANCE MEASUREMENTS

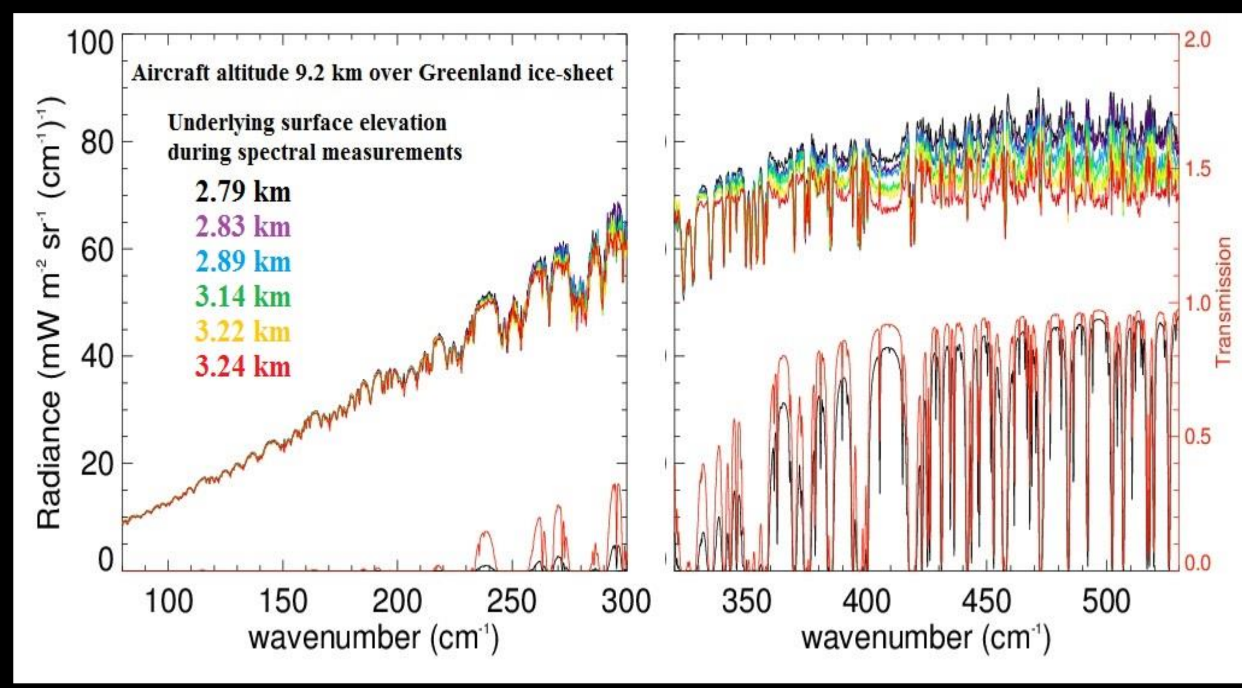

FIGURE 3: Cycle averaged TAFTS nadir radiances in longwave and shortwave channels for cycles 3-5 and 8-10. Simulated transmission of the atmosphere below the aircraft is also shown for cycles 3 (black) and 10 (red)

5. UNCERTAINTY ANALYSIS

We assess the impact of uncertainties in all contributing factors on the retrieved emissivity. Figure 4 shows differences in the retrieved emissivity for perturbed relative to baseline case for each factor.

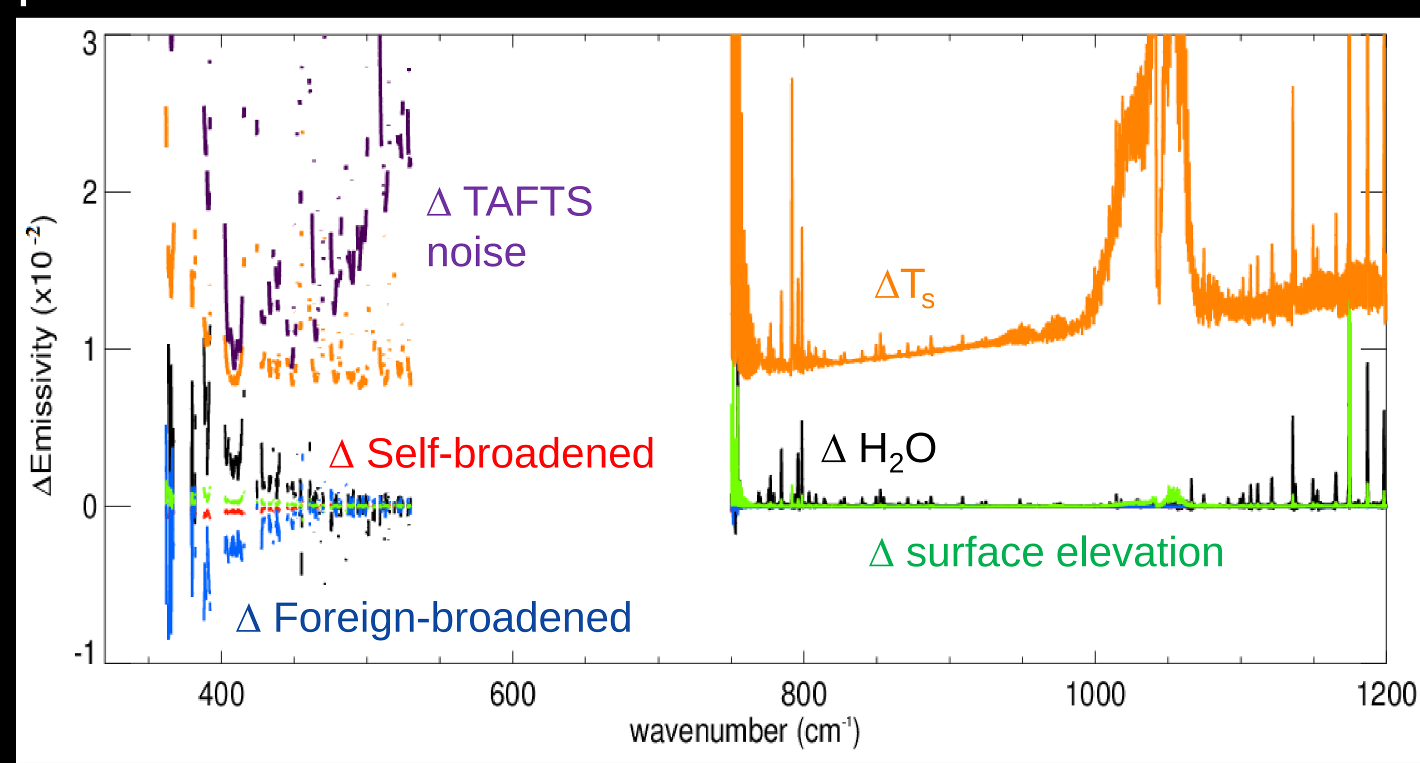

FIGURE 4: Impact of uncertainty in T_s (reduction by 0.45 K); water vapour (increase by 5 %); surface elevation (reduction by 10 m); self and foreign-broadened continuum coefficients (reduction by 10 %); TAFTS instrument noise and calibration offsets, on retrieved emissivity across the FIR and MIR

6. RETRIEVED EMISSIVITY

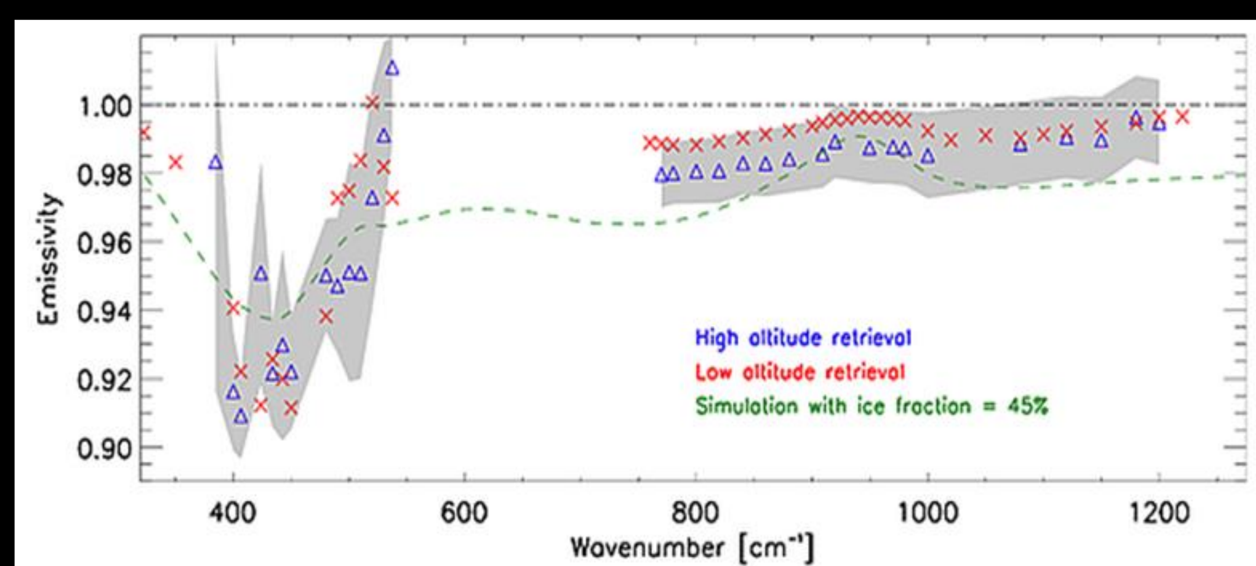

FIGURE 5: Emissivity retrieved from cycle 10. Retrievals from low level run at 330 m agl[7] made within 40 km and 50 minutes of cycle 10 are also shown. Shading is uncertainty in the high level retrievals. A theoretical model of surface emissivity[8] is also over-plotted.

7. CONCLUSIONS

- Transparency of atmosphere above Greenland Plateau can be high enough to retrieve surface emissivity across much of the infrared from relatively high altitude (9.2 km)
- Uncertainty in FIR retrievals is dominated by instrument noise and knowledge of the surface temperature
- Instrumentation used here can obtain emissivities with an accuracy of ~ 0.01 or better in the main atmospheric window and FIR micro-windows

Acknowledgements

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References

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