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Extending PARMIO into the infrared: current status

Stu Newman

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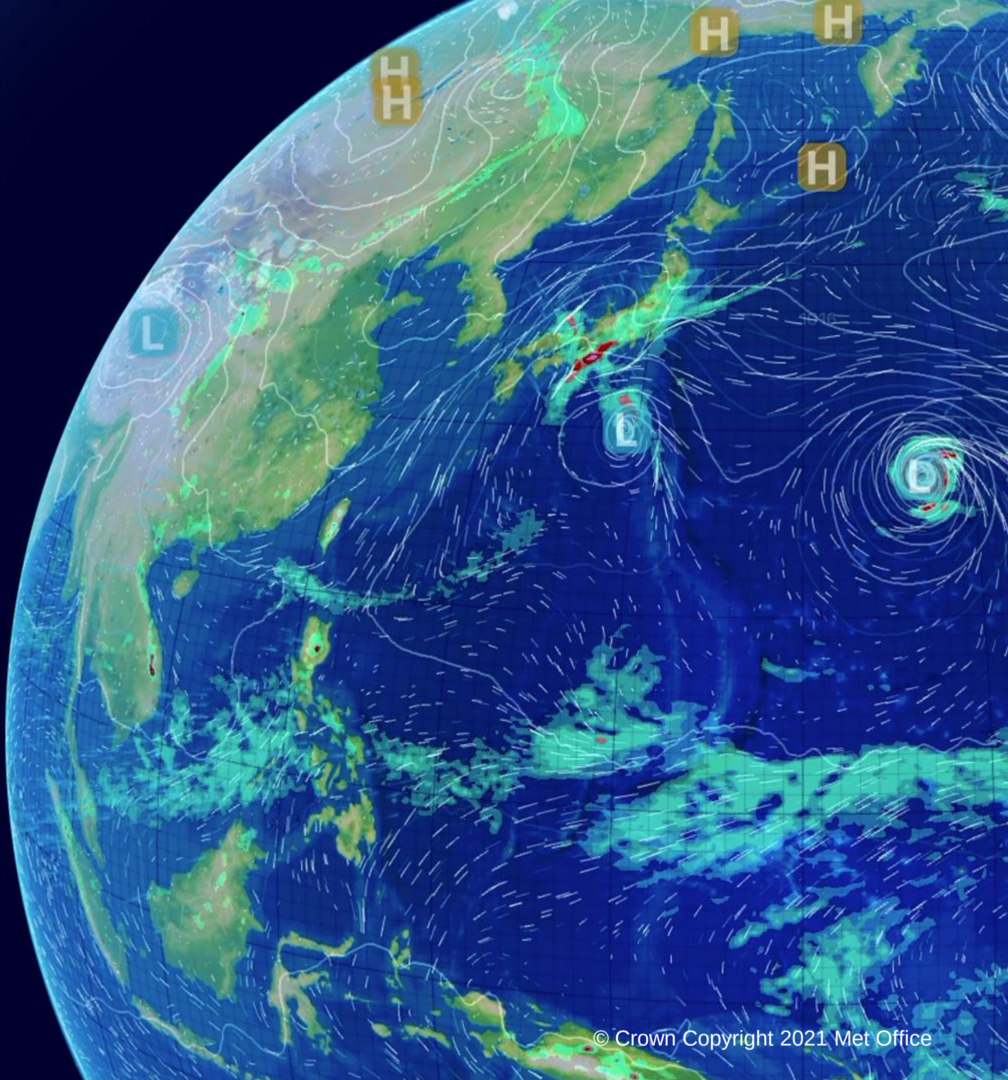
Thanks to contributions from the ISSI team and IREMIS developers (James Hocking and Marco Matricardi)

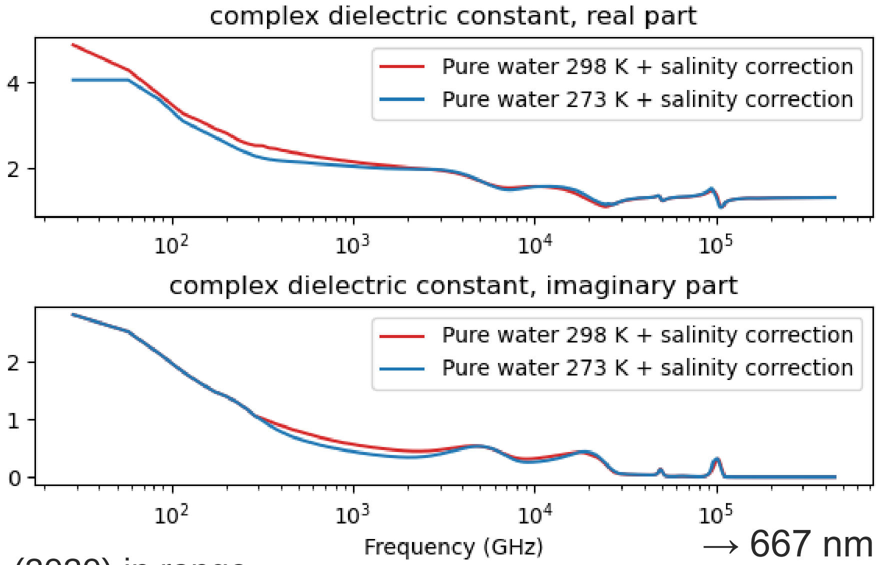


Outline

- Extension of PARMIO into the infrared with tabulated water dielectric properties
- Code stability in geometric optics and two-scale modes
- Applicability of foam modelling into the infrared
- Comparison of PARMIO with RTTOV emissivity model (IREMIS)

PARMIO infrared extension

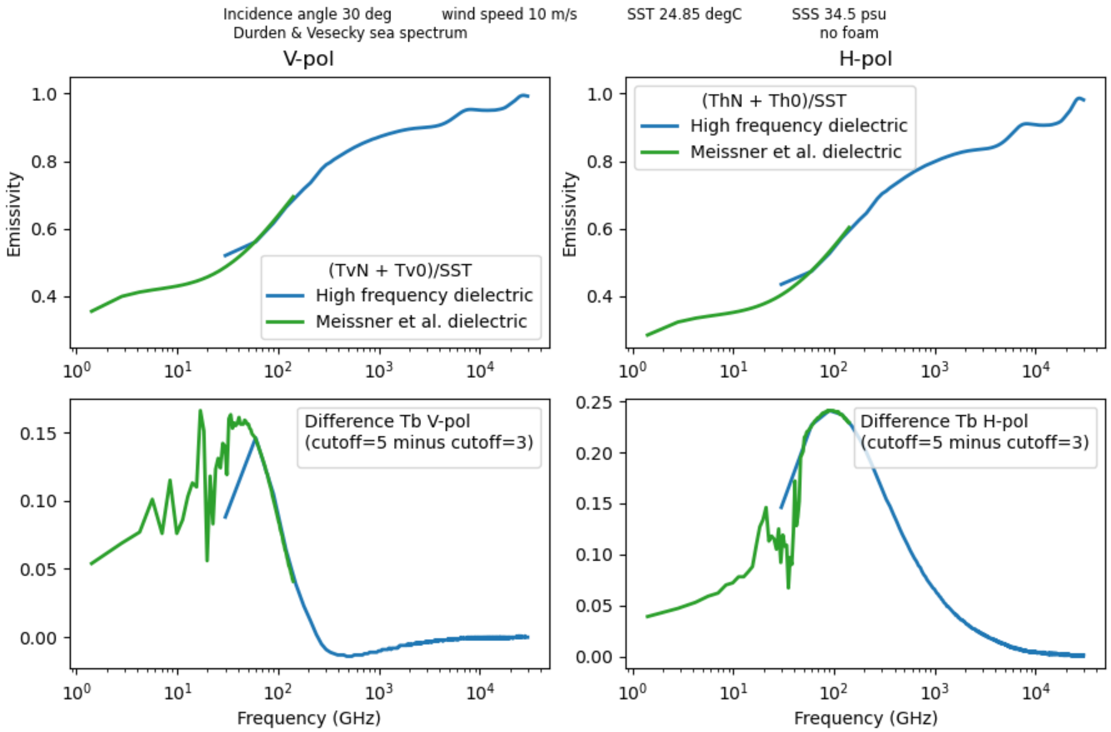
https://github.com/edinnat/Ocean-reference-model



- Option to choose 'hifreq' permittivity model:
  - Tabulated pure water refractive index from Rowe et al. (2020) in range 28.8 - 449677 GHz at 273 K and 298 K (vary linearly in T)
  - Salinity dependence from Pinkley and Williams (1976) only in IR range
  - Temperature dependence from Newman et al. (2005) in mid-IR range
- Without the atmosphere term, outputs appear numerically sensible

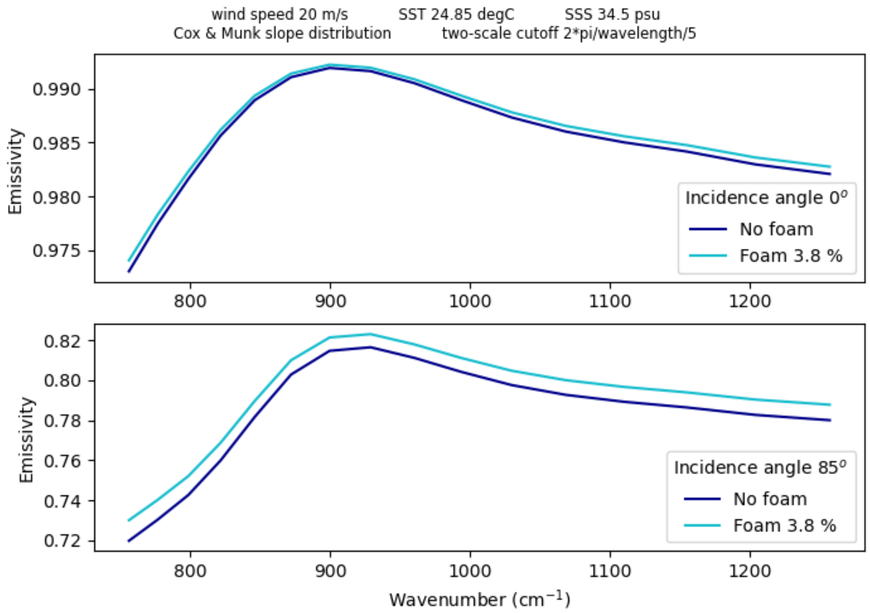
Geometric optics and two-scale modes

- Wave number cutoff k_d to separate treatment of large-scale (geometric optics) and small-scale waves (small perturbation method)
- Typically a value is chosen k_d = 2π/wavelength/N for an expected range $3 < N < 5$



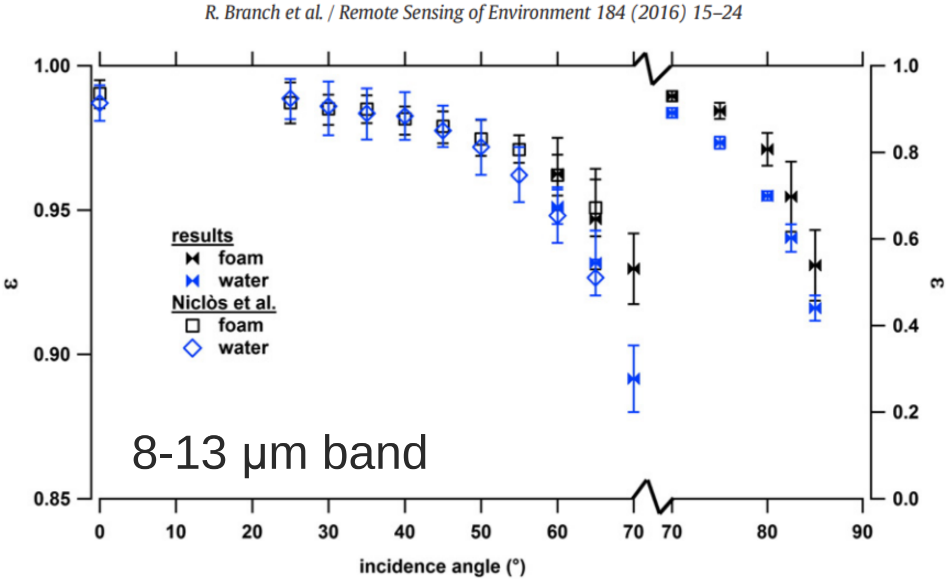
Foam modelling in the infrared

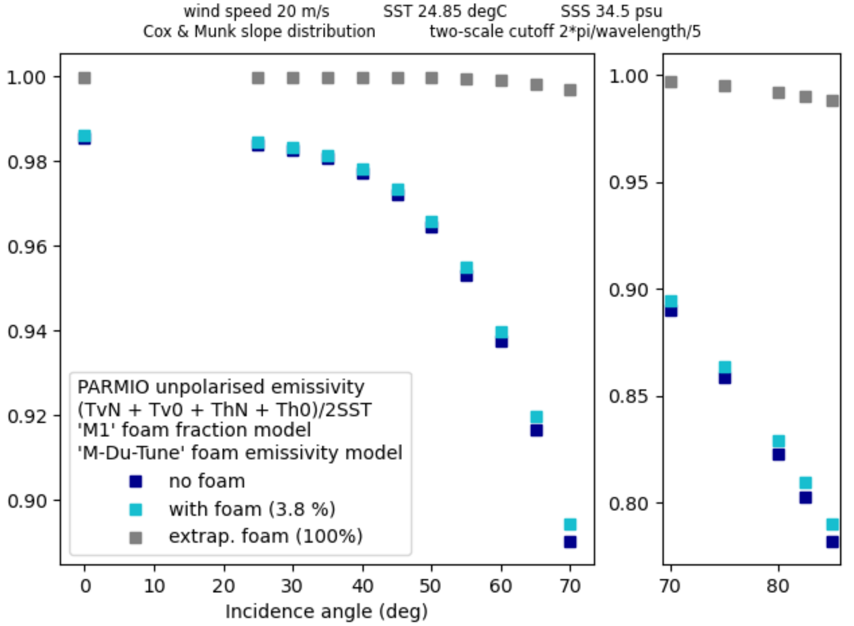
- Test branch *test_hiFreqPermittivity_foam* (Emmanuel)
- Frequency tuned model of foam emissivity (Maggie)
- M1 foam fraction model due to Monahan '86



Foam modelling in the infrared

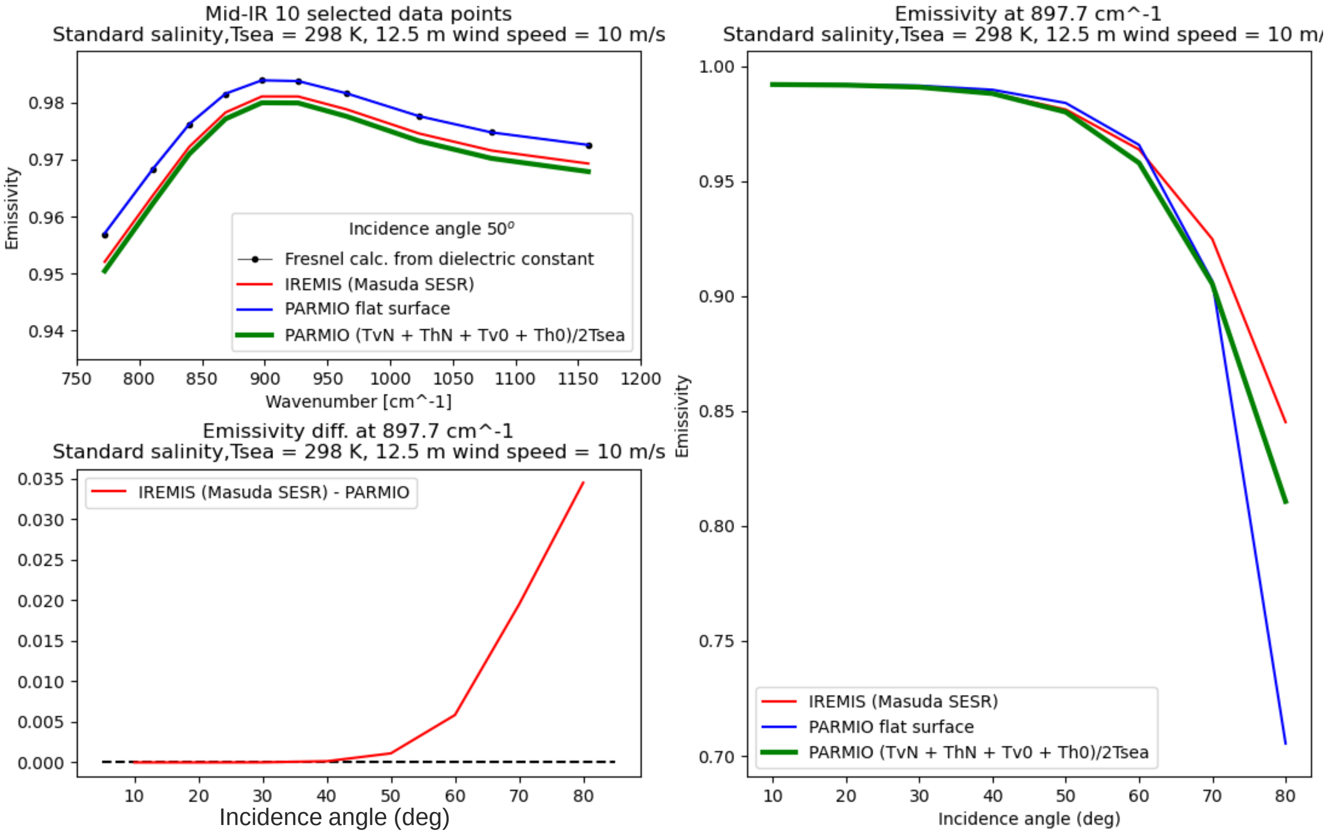
- Compare Branch et al. (2016) foam emissivity measurements with PARMIO output
- "First look" data: PARMIO foam emissivity appears to be higher than experimental data





Compare infrared models

- Compare PARMIO with IREMIS (RTTOV model), using consistent input parameters
- IREMIS emissivity is higher than PARMIO at larger incidence angles



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Geometric optics

1. Wave shadowing

Waves can block some sea surface emission from reaching the sensor

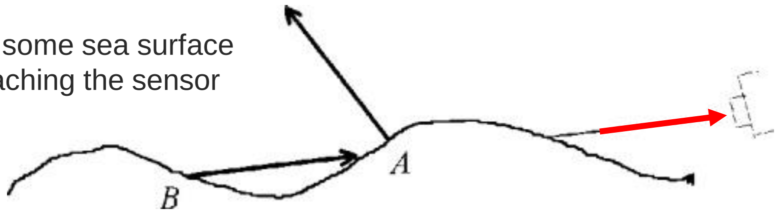

Fig. 2 from Wu and Smith, Appl. Opt., 36, 2609-2619 (1997)

- Limit to range of integration over wave slope facets and normalisation
- Treatment of wave shadowing in PARMIO is the same as in RTTOV (IREMIS)

$$I_s = \int_{-\infty}^{\infty} dS'_y \int_{-\infty}^{\cot\theta} dS'_x I_{sl}(1 - S'_x \tan\theta) P(S_x, S_y) \qquad (7)$$

S. H. Yueh, IEEE Trans. Geosci. Rem. Sens., 35, 1400-1418 (1997)

Geometric optics
2. Reflected emission

Include probability of reflected radiance originating from the sea surface rather than the sky

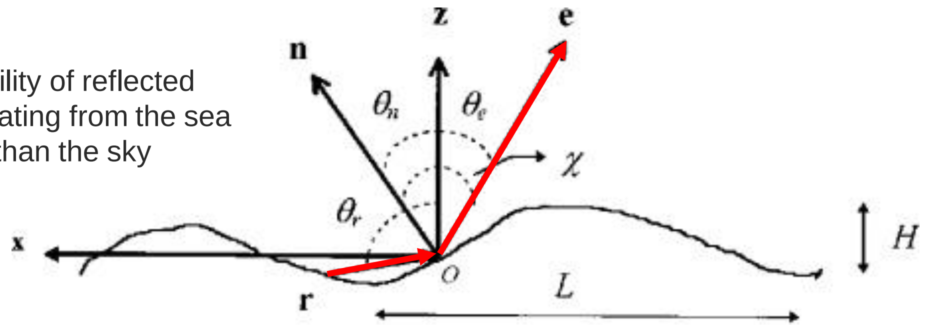

Fig. 5 from Wu and Smith, Appl. Opt., 36, 2609-2619 (1997)
Similarly in Masuda, Rem. Sens. Environ., 103, 488-496 (2006)

- IREMIS accounts for surface-emitted surface-reflected (SESR) radiation
- Wu & Smith and Masuda formulations of SESR
- SESR in IREMIS is the main difference compared with PARMIO code

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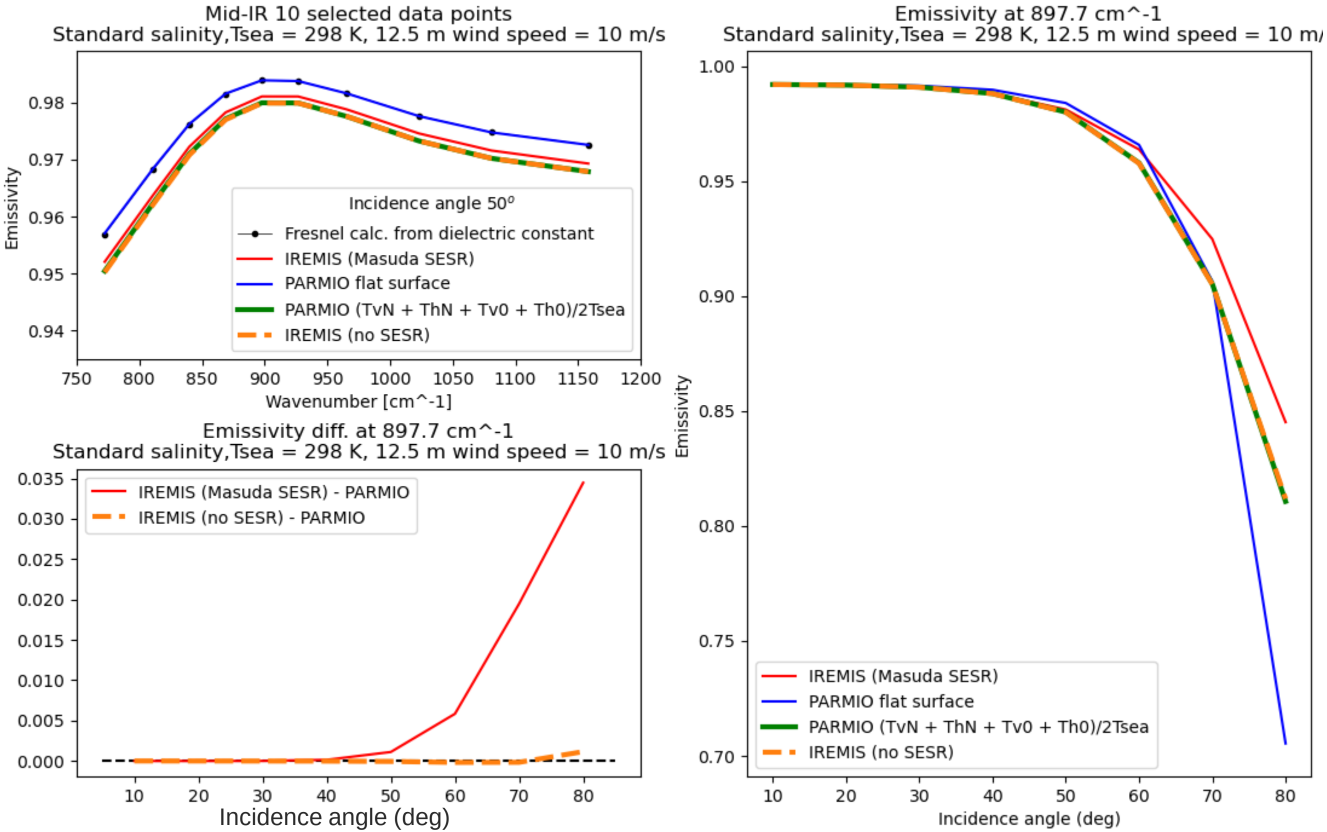
Geometric optics
2. Reflected emission

- Experiment removing SESR from IREMIS to estimate size of effect
- Without SESR the results of PARMIO and IREMIS match closely



Summary

- High-frequency tabulated optical constants for seawater are available in PARMIO, these could be supplemented by other available data sets
- Two-scale model does not seem overly sensitive to the wave number cutoff, and simulations converge smoothly to the geometric optics limit at high frequency
- Preliminary results with the foam model in the infrared seem to indicate the foam emissivity is higher than literature results
- Comparisons with IREMIS show close agreement with PARMIO when neglecting the SESR correction term – possible future development for geometric optics code