# Spectral Energy Distribution of the Earth's Reflected Solar Radiation and Requirements for Spectral Coverage and Accuracy of Measurements

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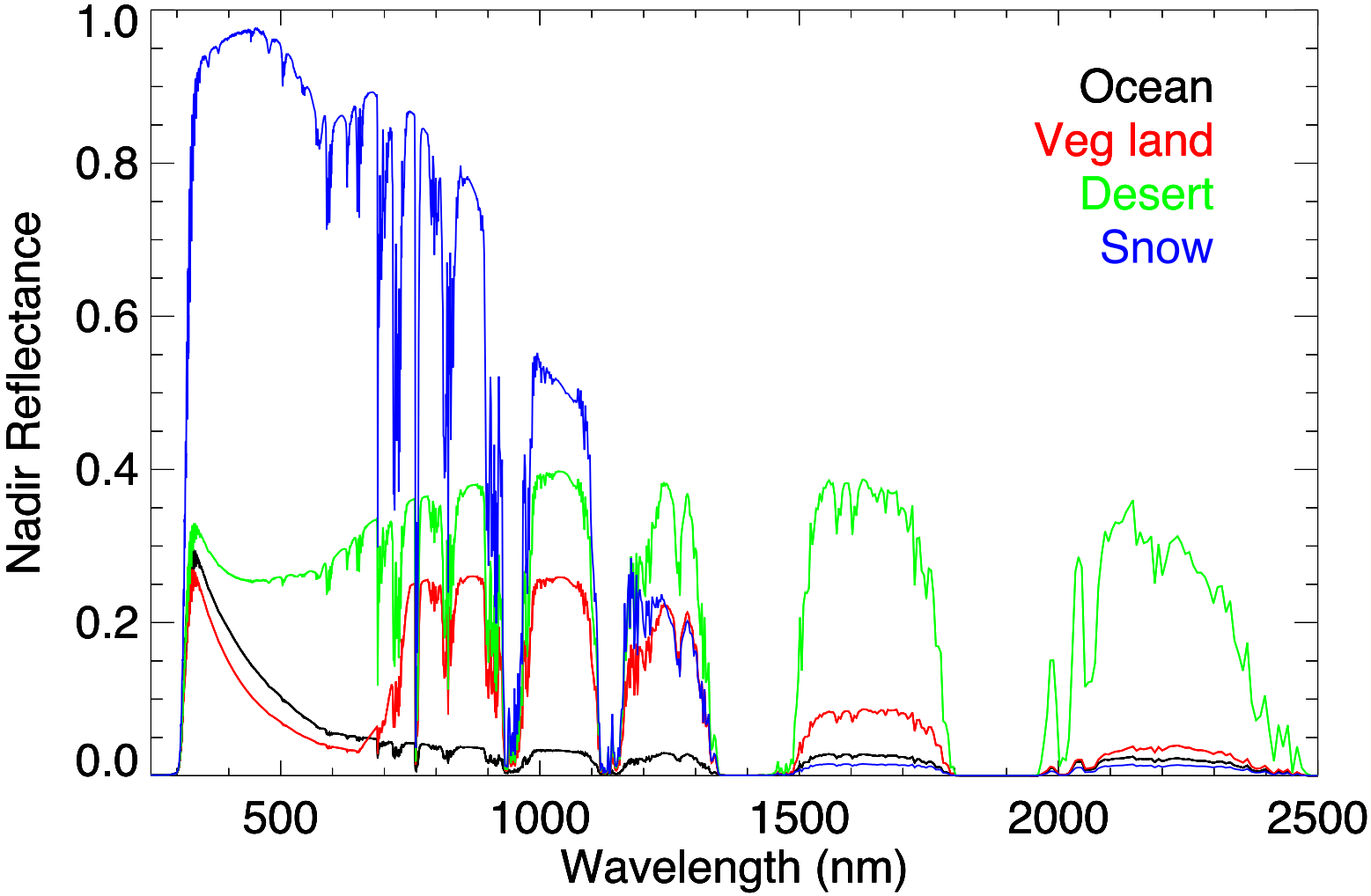
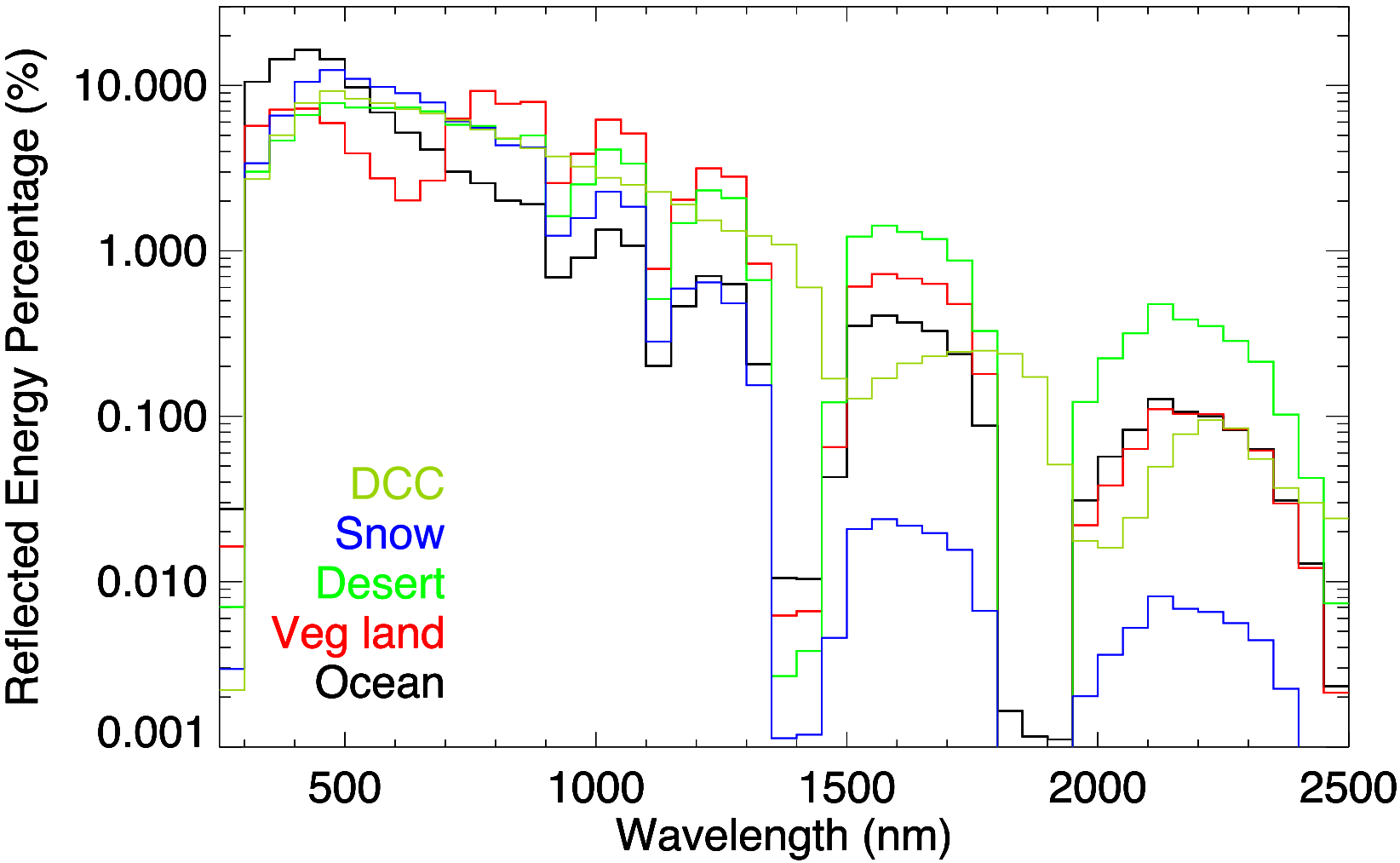
- The required spectral coverage for CLARREO RS measurement is dependent on the spectral energy distribution of the Earth's reflected solar radiation and the required broadband accuracy.

- The CLARREO measurement accuracy in the broadband radiation and its spectral distribution depend on the spectral energy distribution and the instrument error budget.

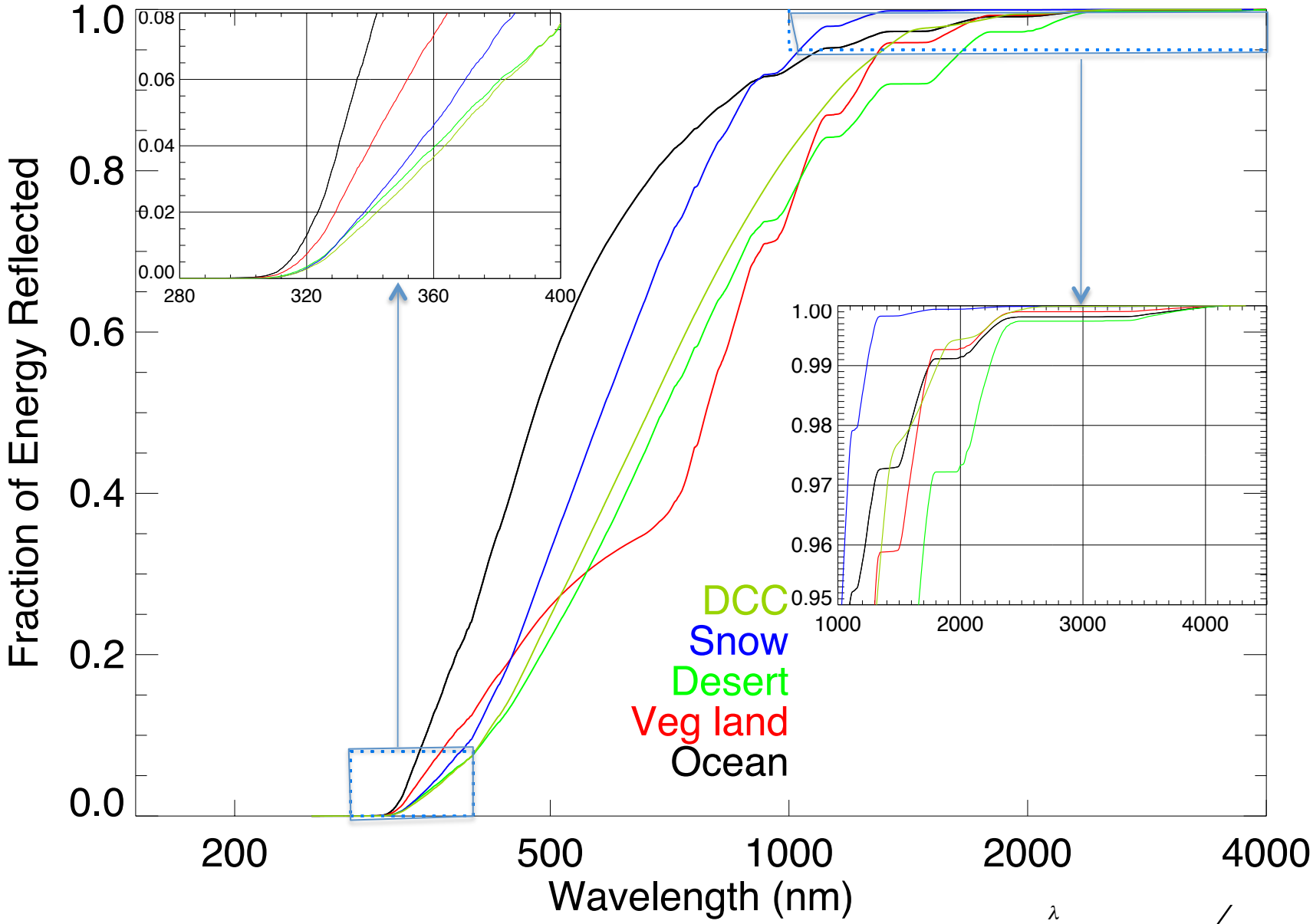



Spectral solar reflectance for typical surface types.
(SZA=45°, pristine MLA)

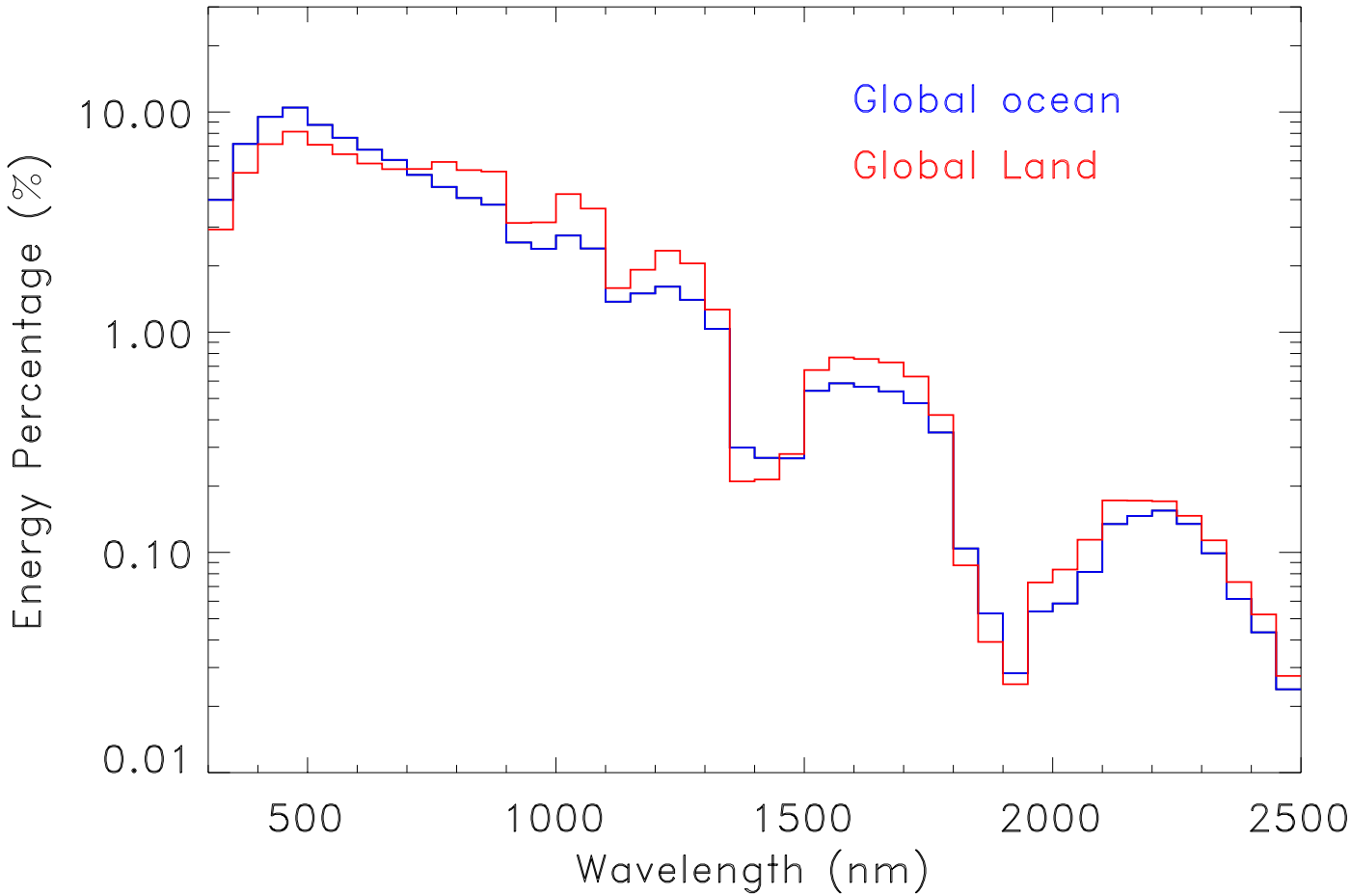



Spectral energy distribution of the reflected solar radiation for the typical surface types (plotted as the energy percentage in each 50 nm of band).

$$f_i = \int_{\lambda_i}^{\lambda_{i+1}} R(\lambda)\,d\lambda \Big/ R_{total} \times 100$$

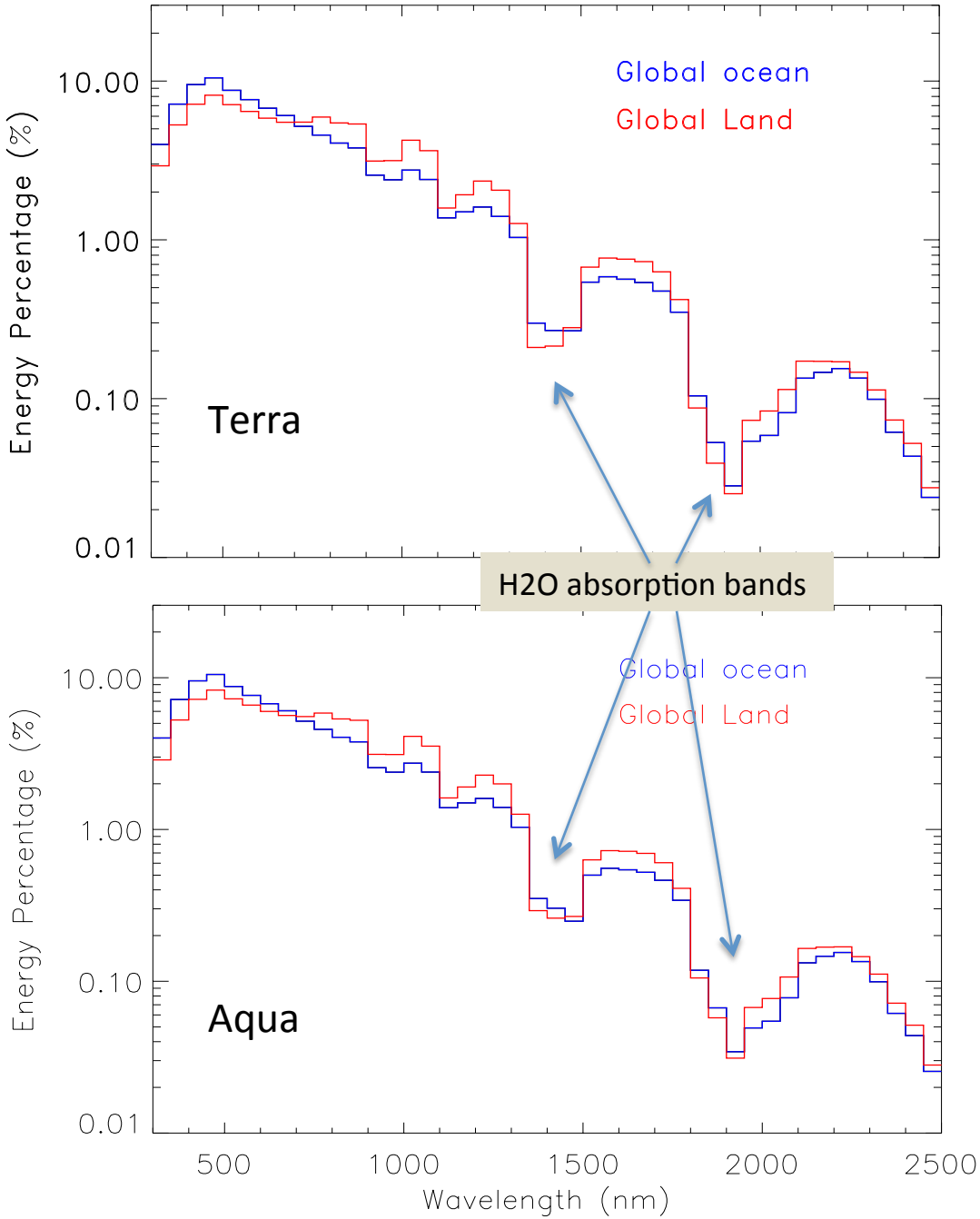



The cumulative RS energy fraction as a function of wavelength: $\int_{\lambda_0}^{\lambda} R(\lambda)\,d\lambda \Big/ R_{total}$

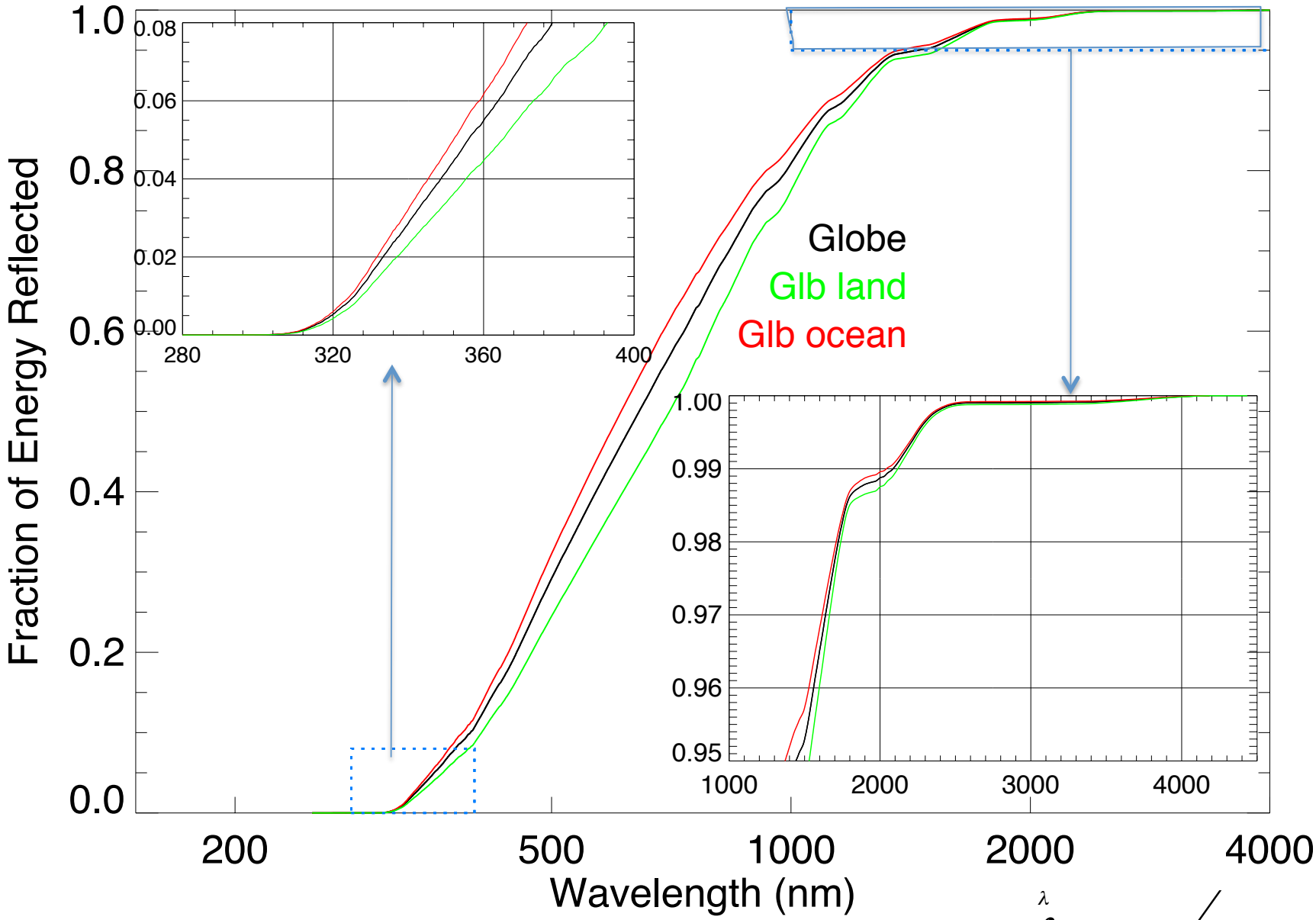



Spectral energy distribution for globally averaged RS radiation.
(calculated using CERES SSF data for 2006)

$$f_i = \int_{\lambda_i}^{\lambda_{i+1}} R(\lambda)\,d\lambda \Big/ R_{total} \times 100$$




Except for the strong water vapor absorption bands, the global mean RS spectral distributions between Terra and Aqua orbits are very similar.

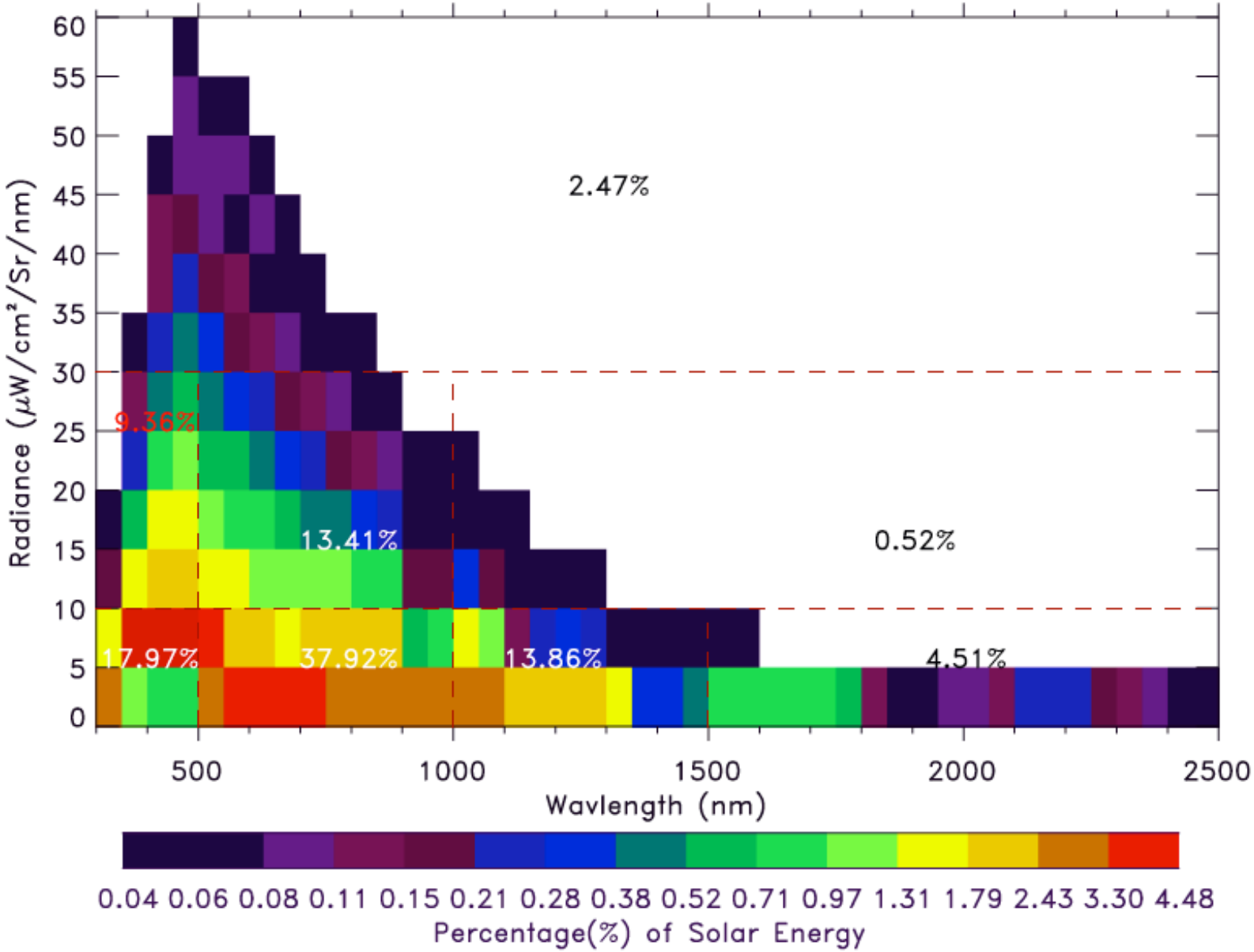



The cumulative RS energy fraction as a function of wavelength: $\int_{\lambda_0}^{\lambda} R(\lambda)\,d\lambda \Big/ R_{total}$

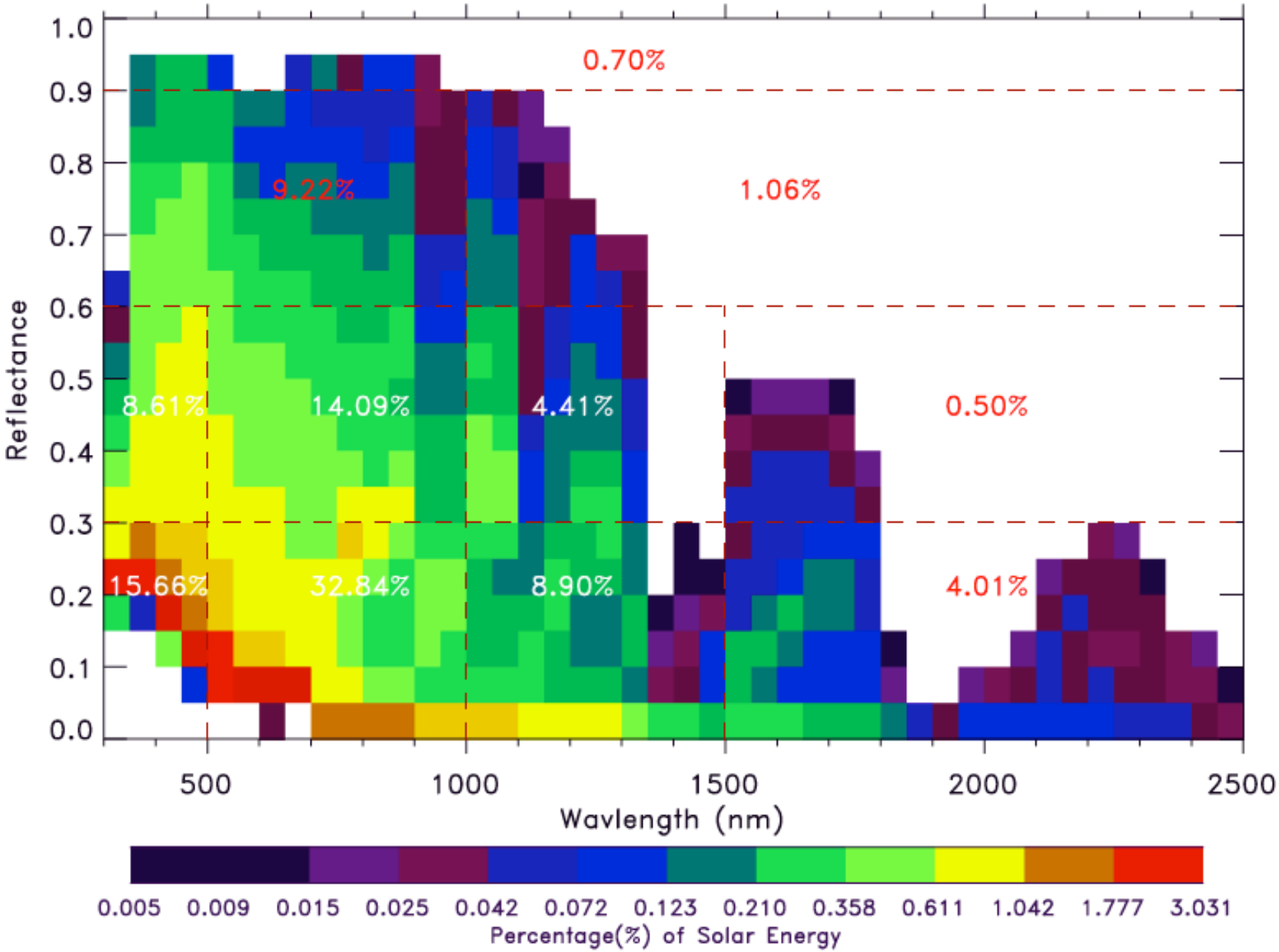
| Scene Type | Spectral Range (nm) | | | | |
|---|---|---|---|---|---|
| | 320-2300 | 320-2400 | 310-2300 | 330-2300 | 330-2200 |
| Global mean | 0.09 | 0.07 | 0.05 | 0.20 | 0.23 |
| Global ocean | 0.10 | 0.08 | 0.04 | 0.21 | 0.25 |
| Global land | 0.08 | 0.06 | 0.05 | 0.17 | 0.20 |
| Clr-sky ocean | 0.16 | 0.15 | 0.05 | 0.42 | 0.44 |
| Clr-sky desert | 0.10 | 0.07 | 0.07 | 0.17 | 0.24 |

The error in the broadband solar energy is estimated based on the missing energy in the UV and NIR spectra that are not covered by the RS measurement and a given modeling uncertainty of 10%.

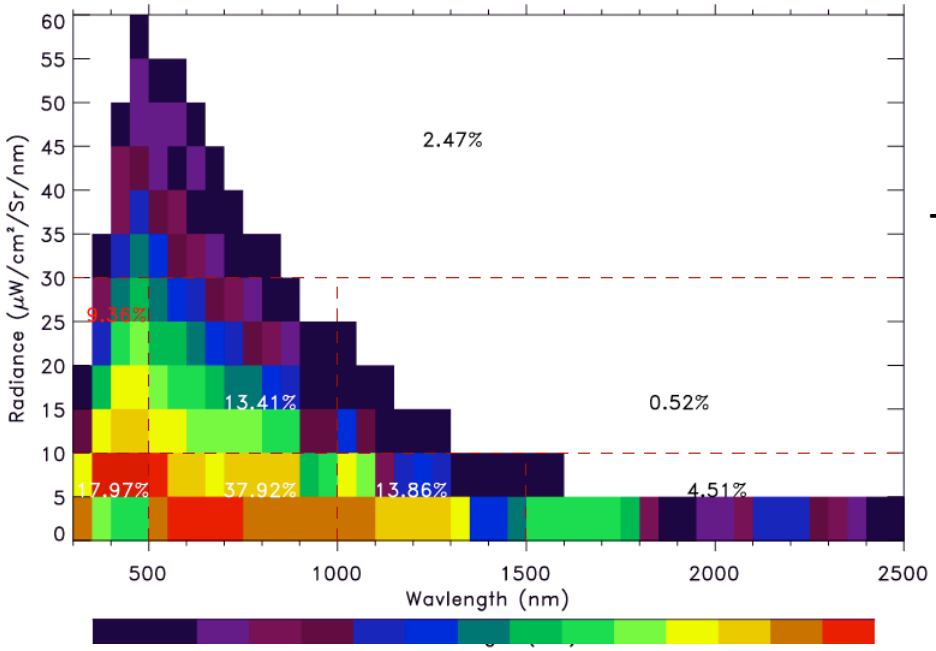
Based on these errors estimated for different spectral coverage and considering the 0.3% accuracy requirement and instrument design, **the spectral range of 320-2300 nm was recommended for CLARREO RS measurement**. Further extending the spectral range won't increase the accuracy substantially, but further reducing the spectral coverage will increase the broadband error rapidly.



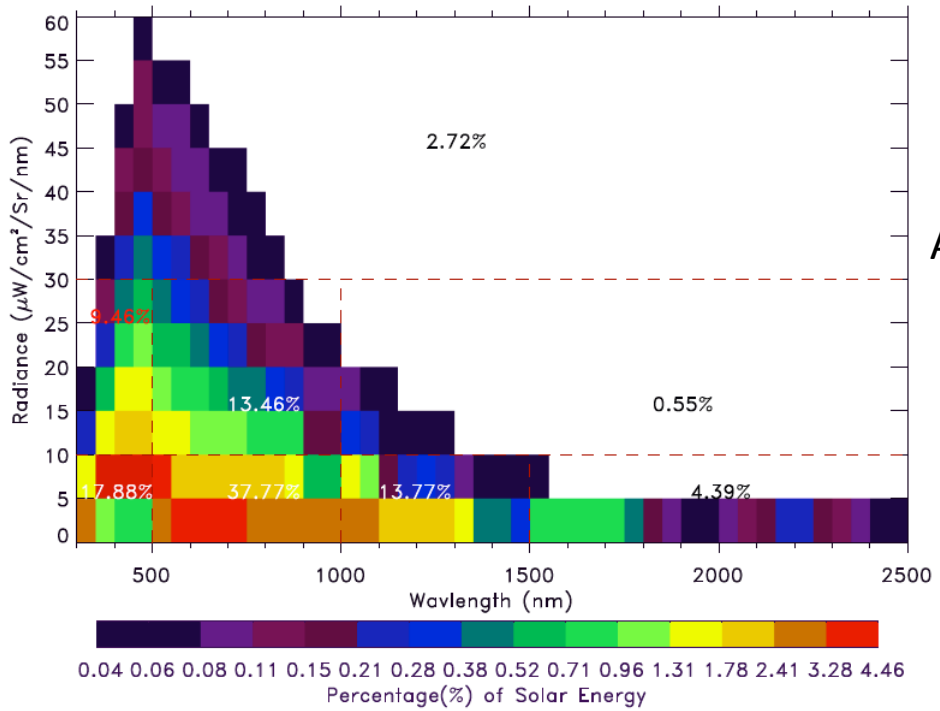

Global RS energy distribution in the wavelength-radiance space (plotted as the energy percentage in each 50 nm in each radiance level).



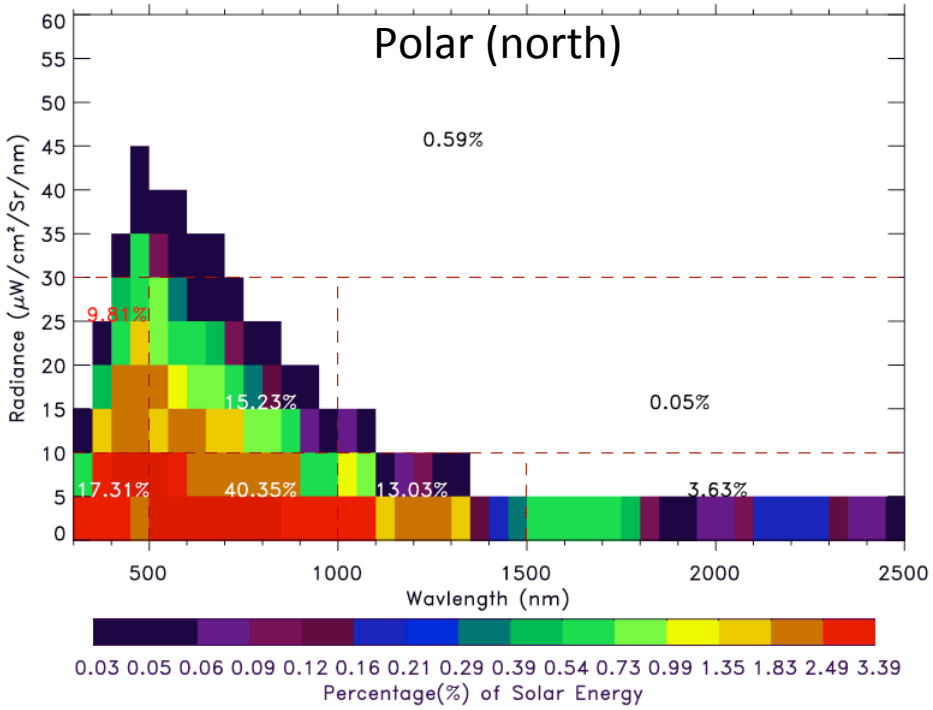

Global RS energy distribution in the wavelength-reflectance space (plotted as the energy percentage in each 50 nm of wavelength in each 0.05 of reflectance interval).

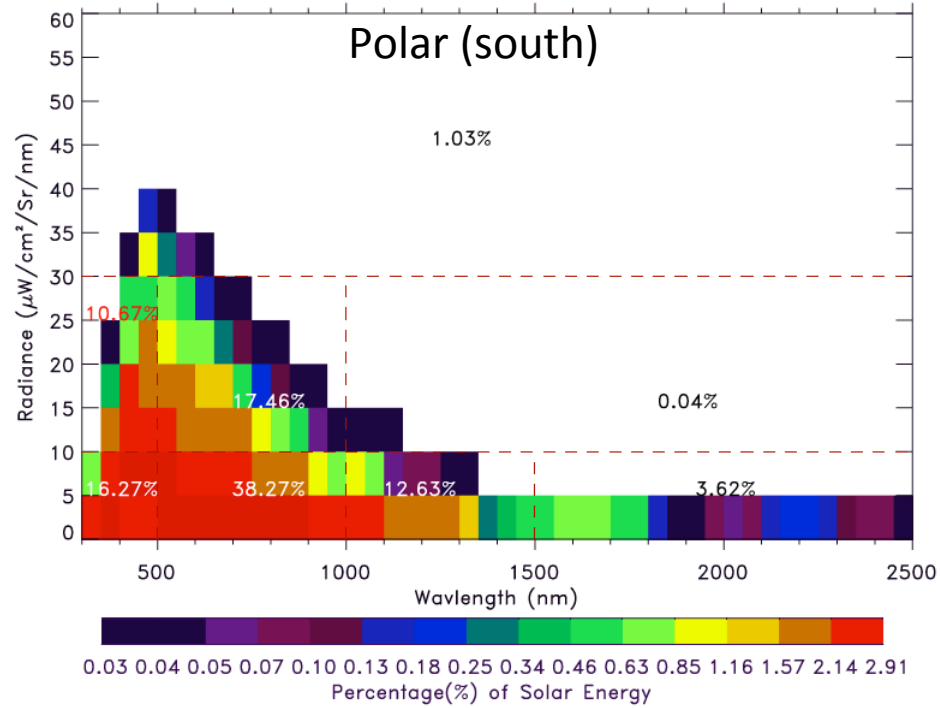

Radiance (μW/cm²/Sr/nm)
Wavlength (nm)
2.47%
9.36%
13.41%
0.52%
17.97%
37.92%
13.86%
4.51%

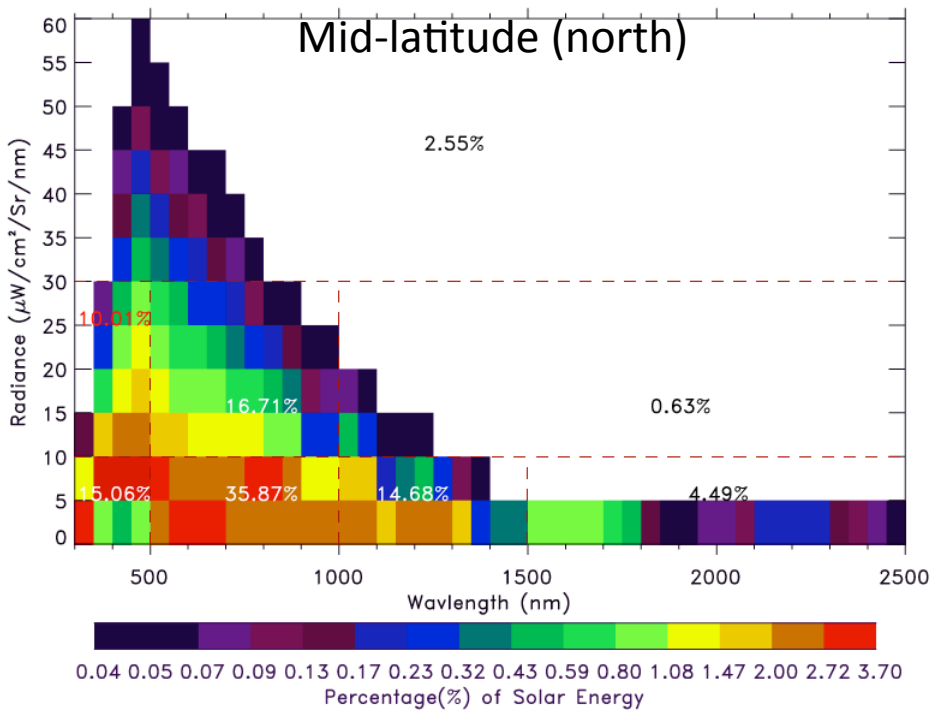
Terra

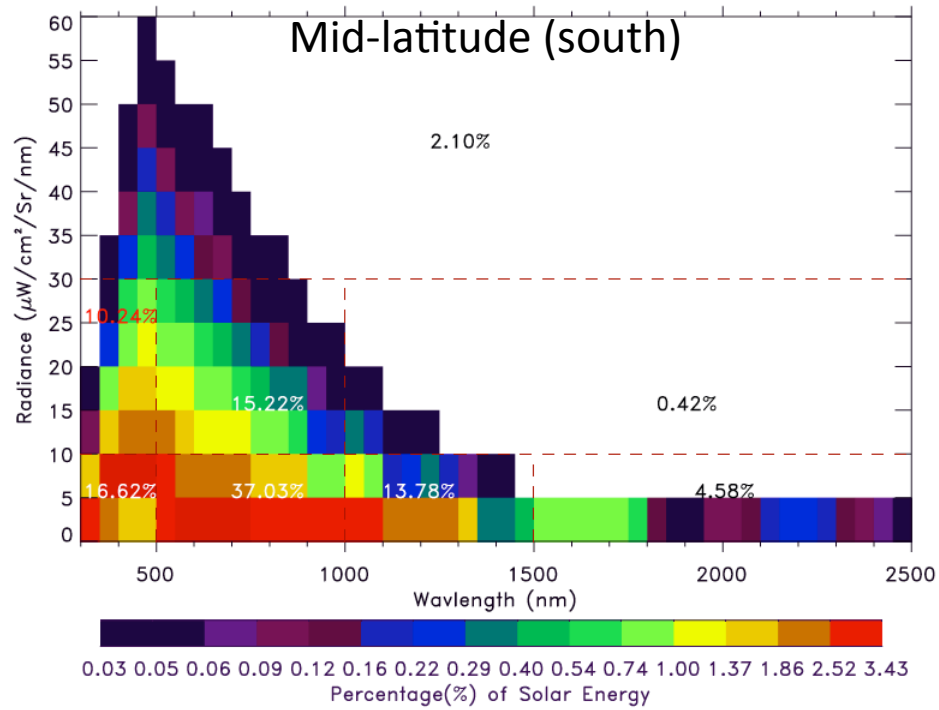

Radiance (μW/cm²/Sr/nm)
Wavlength (nm)
2.72%
9.46%
13.46%
0.55%
17.88%
37.77%
13.77%
4.39%
0.04 0.06 0.08 0.11 0.15 0.21 0.28 0.38 0.52 0.71 0.96 1.31 1.78 2.41 3.28 4.46
Percentage(%) of Solar Energy

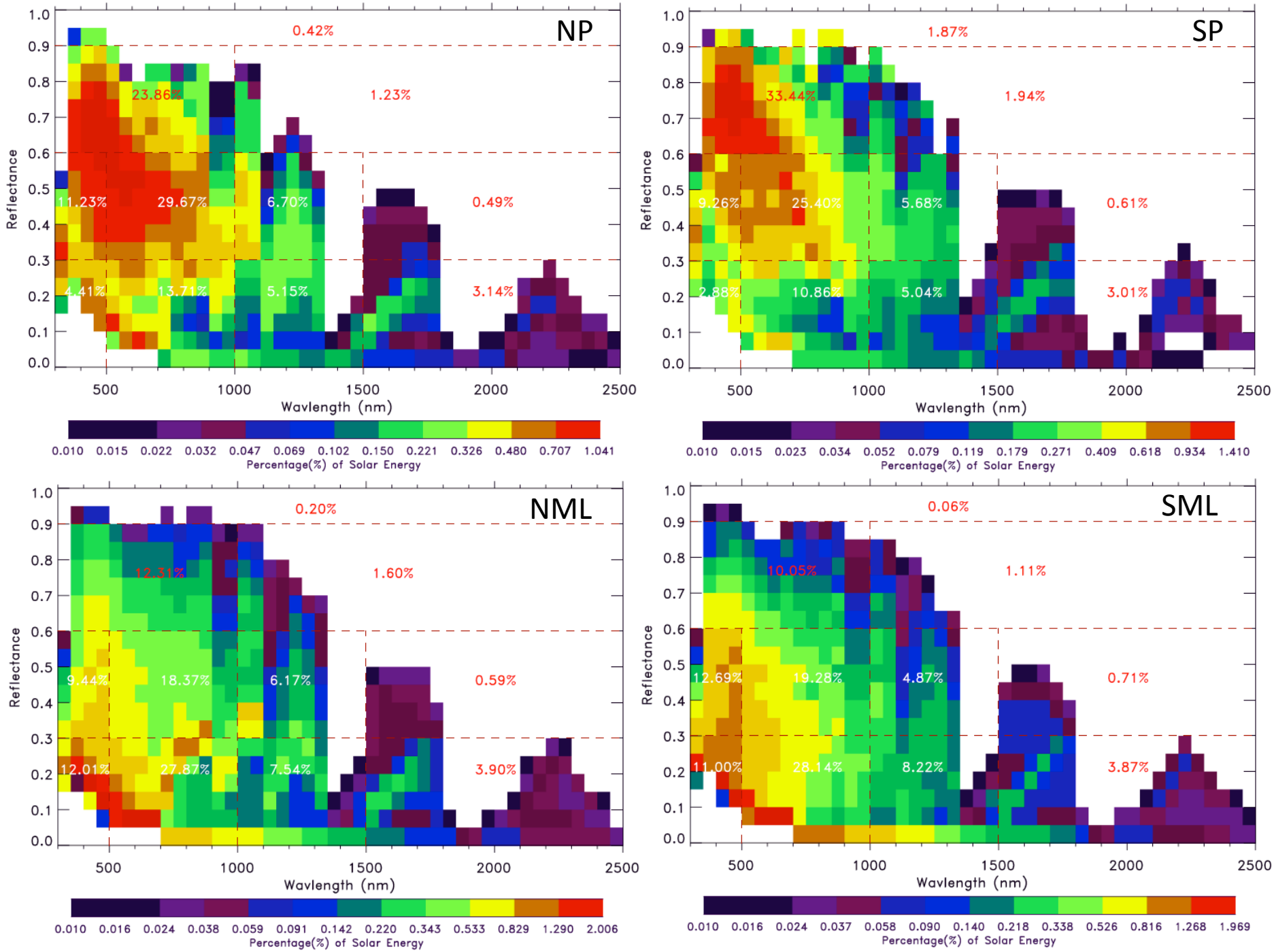
Aqua


Polar (north)
0.59%
9.81%
15.23%
0.05%
17.31%
40.35%
13.03%
3.63%
Radiance (μW/cm²/Sr/nm)
Wavlength (nm)
0.03 0.05 0.06 0.09 0.12 0.16 0.21 0.29 0.39 0.54 0.73 0.99 1.35 1.83 2.49 3.39
Percentage(%) of Solar Energy

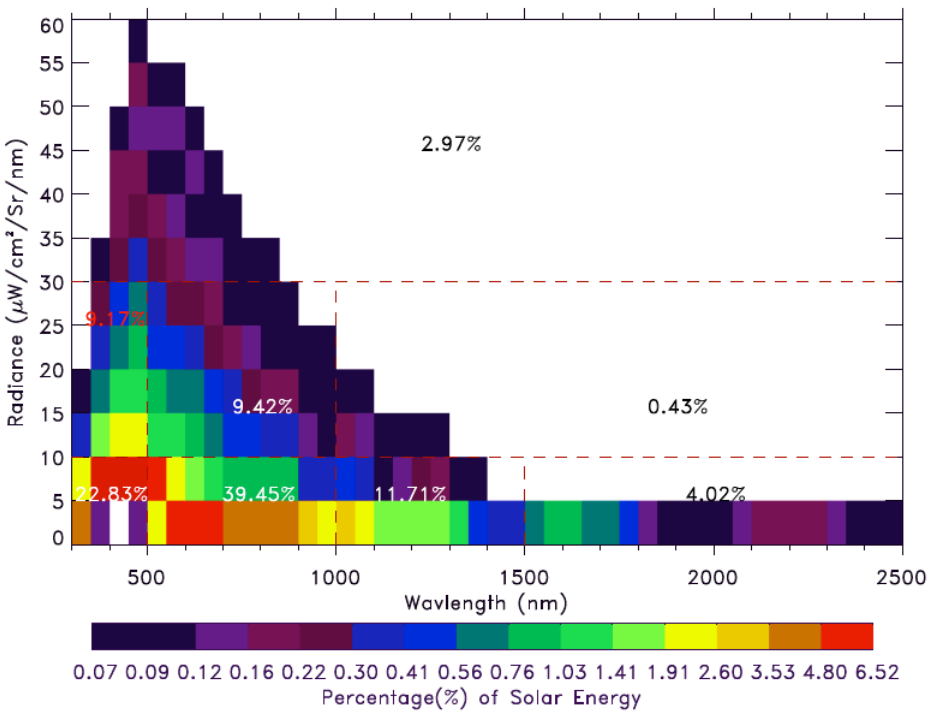

Polar (south)
1.03%
10.67%
17.46%
0.04%
16.27%
38.27%
12.63%
3.62%
Radiance (μW/cm²/Sr/nm)
Wavlength (nm)
0.03 0.04 0.05 0.07 0.10 0.13 0.18 0.25 0.34 0.46 0.63 0.85 1.16 1.57 2.14 2.91
Percentage(%) of Solar Energy


Mid-latitude (north)
2.55%
10.01%
16.71%
0.63%
15.06%
35.87%
14.68%
4.49%
Radiance (μW/cm²/Sr/nm)
Wavlength (nm)
0.04 0.05 0.07 0.09 0.13 0.17 0.23 0.32 0.43 0.59 0.80 1.08 1.47 2.00 2.72 3.70
Percentage(%) of Solar Energy

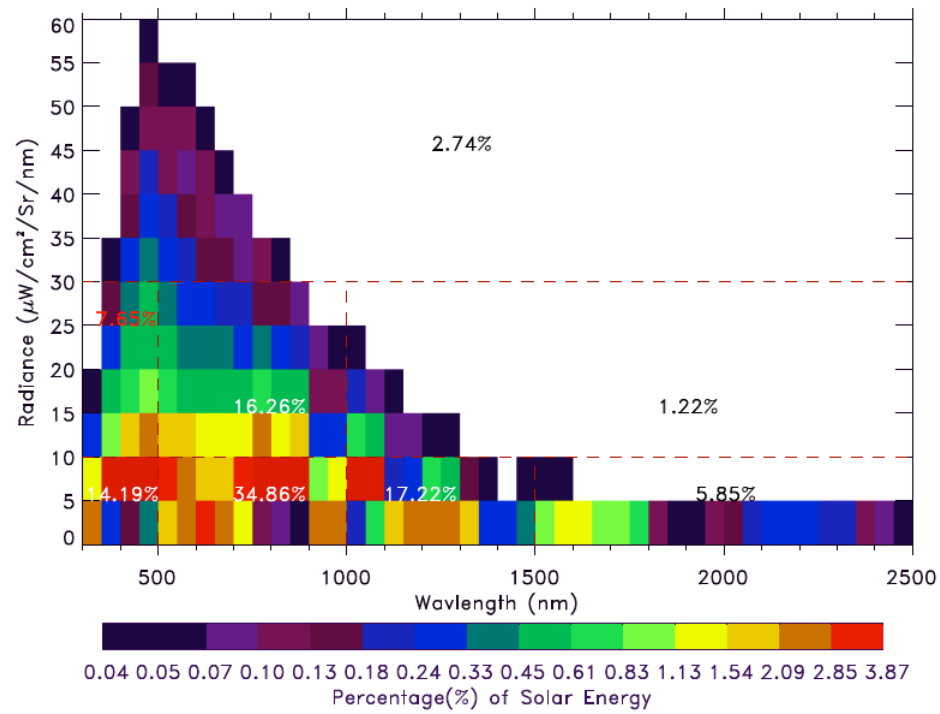

Mid-latitude (south)
2.10%
10.24%
15.22%
0.42%
16.62%
37.03%
13.78%
4.58%
Radiance (μW/cm²/Sr/nm)
Wavlength (nm)
0.03 0.05 0.06 0.09 0.12 0.16 0.22 0.29 0.40 0.54 0.74 1.00 1.37 1.86 2.52 3.43
Percentage(%) of Solar Energy


NP
0.42%
23.86%
1.23%
11.23%
29.67%
6.70%
0.49%
4.41%
13.71%
5.15%
3.14%
Reflectance
Wavlength (nm)
0.010 0.015 0.022 0.032 0.047 0.069 0.102 0.150 0.221 0.326 0.480 0.707 1.041
Percentage(%) of Solar Energy
SP
1.87%
33.44%
1.94%
9.26%
25.40%
5.68%
0.61%
2.88%
10.86%
5.04%
3.01%
Reflectance
Wavlength (nm)
0.010 0.015 0.023 0.034 0.052 0.079 0.119 0.179 0.271 0.409 0.618 0.934 1.410
Percentage(%) of Solar Energy
NML
0.20%
12.31%
1.60%
9.44%
18.37%
6.17%
0.59%
12.01%
27.87%
7.54%
3.90%
Reflectance
Wavlength (nm)
0.010 0.016 0.024 0.038 0.059 0.091 0.142 0.220 0.343 0.533 0.829 1.290 2.006
Percentage(%) of Solar Energy
SML
0.06%
10.05%
1.11%
12.69%
19.28%
4.87%
0.71%
11.00%
28.14%
8.22%
3.87%
Reflectance
Wavlength (nm)
0.010 0.016 0.024 0.037 0.058 0.090 0.140 0.218 0.338 0.526 0.816 1.268 1.969
Percentage(%) of Solar Energy

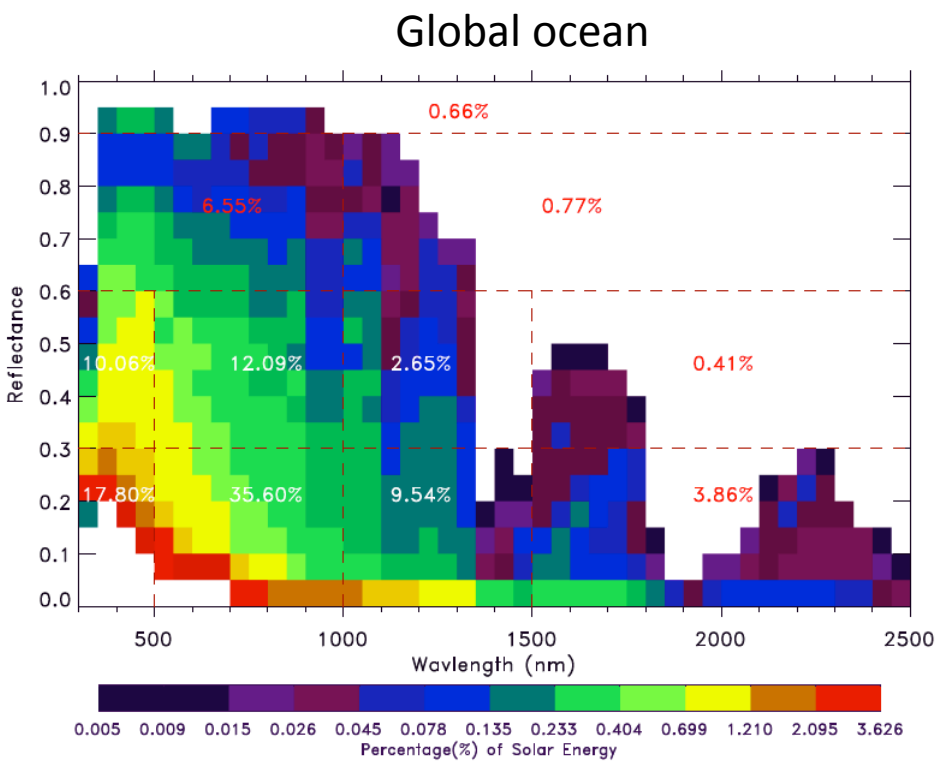
Tropic ocean

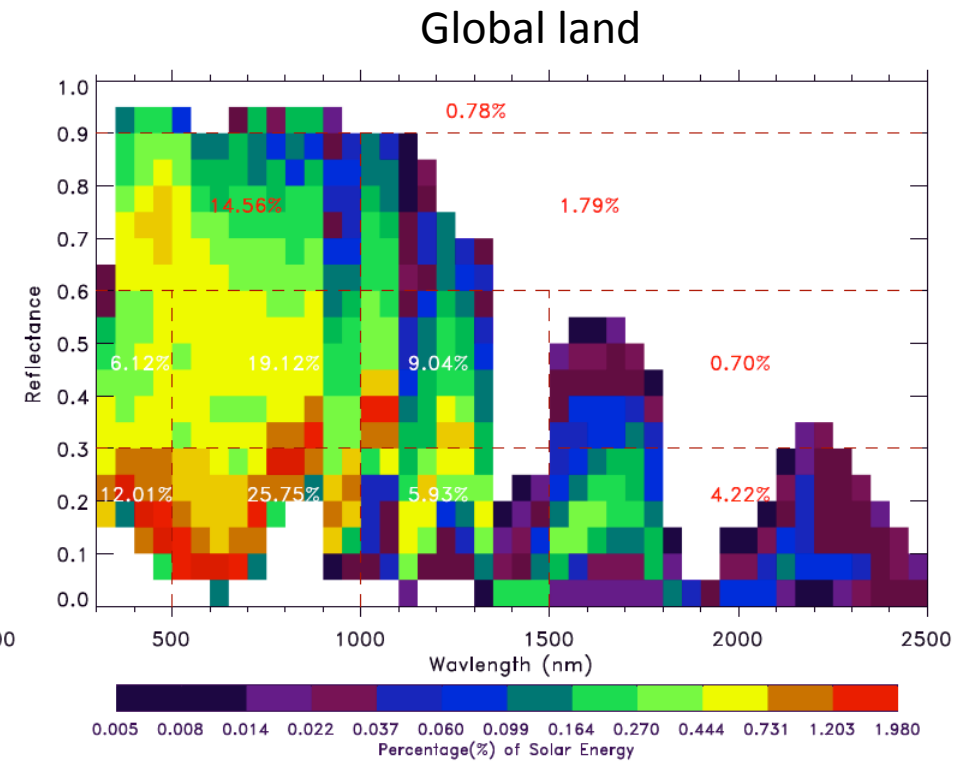



Tropic land



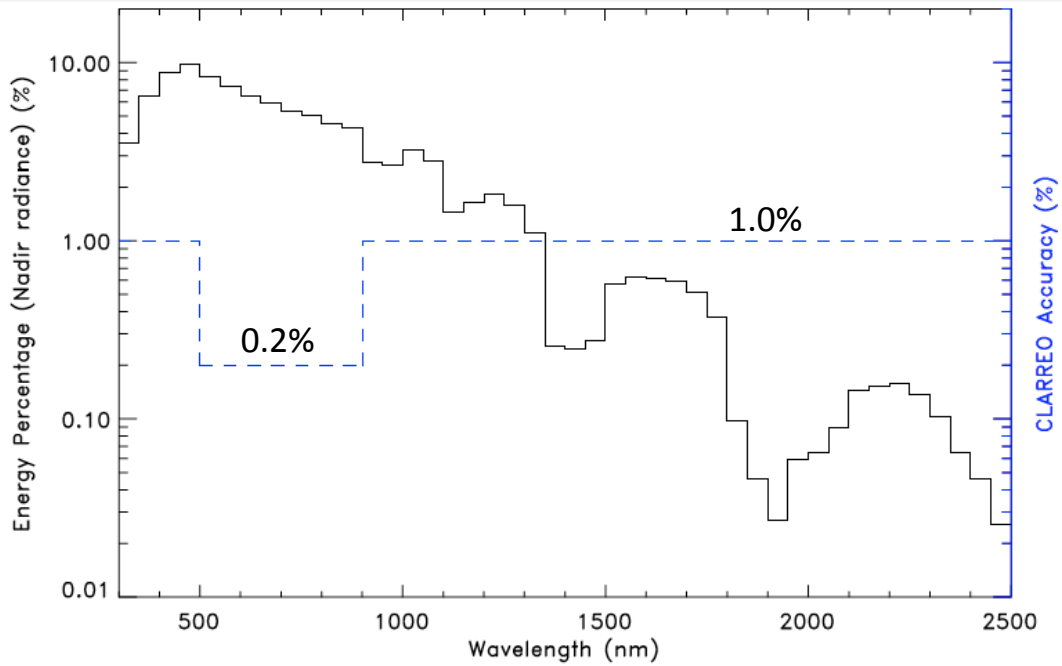

Ocean-land comparison (Tropic region, 30N-30S).



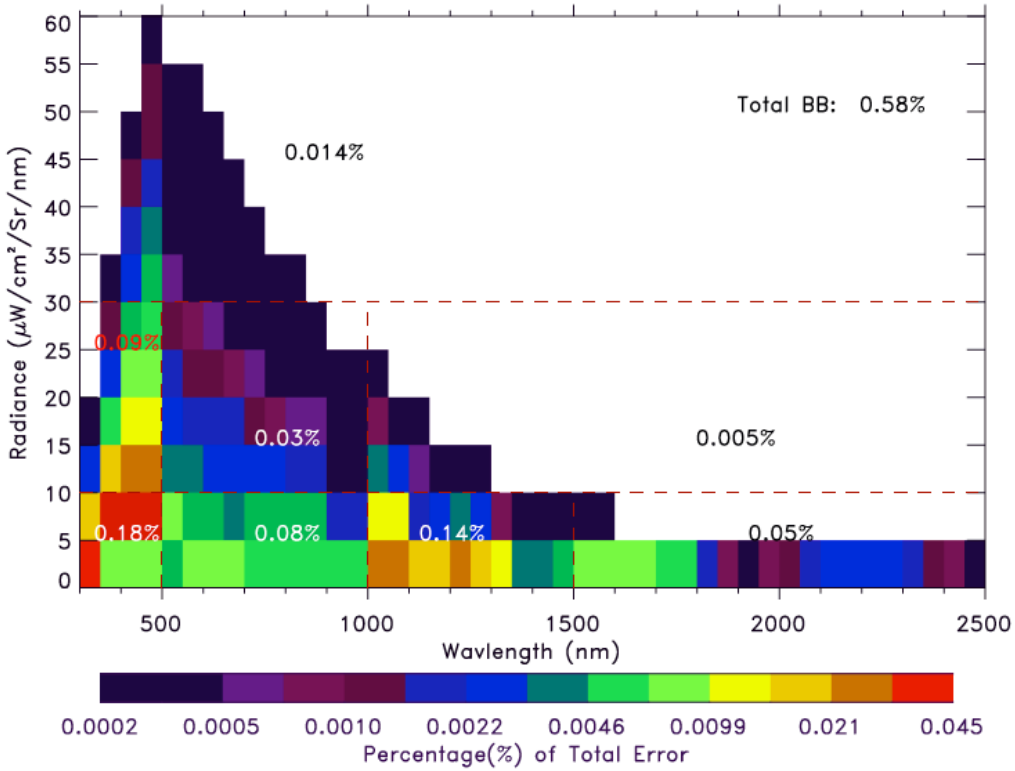




Ocean-land comparison (global).

Known the global spectral energy distribution as shown, we can convolve it with the CLARREO instrument error budget to obtain the spectral accuracy distribution and the global mean broadband error.

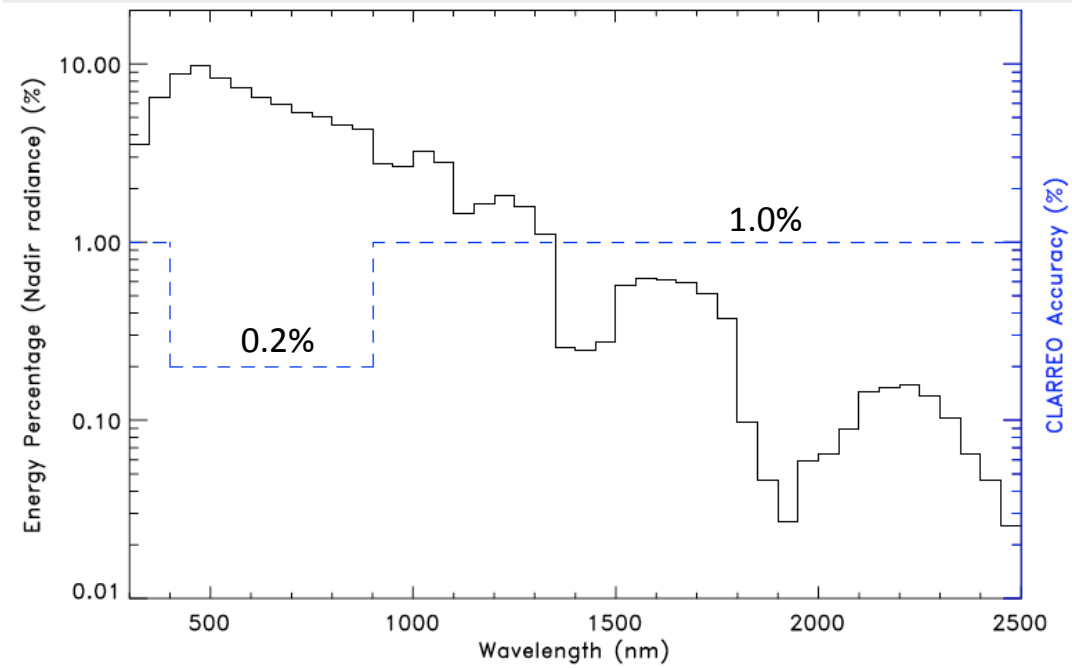



a). Measurement error 0.2% for spectral range 500-900 nm and 1.0% for other spectra.

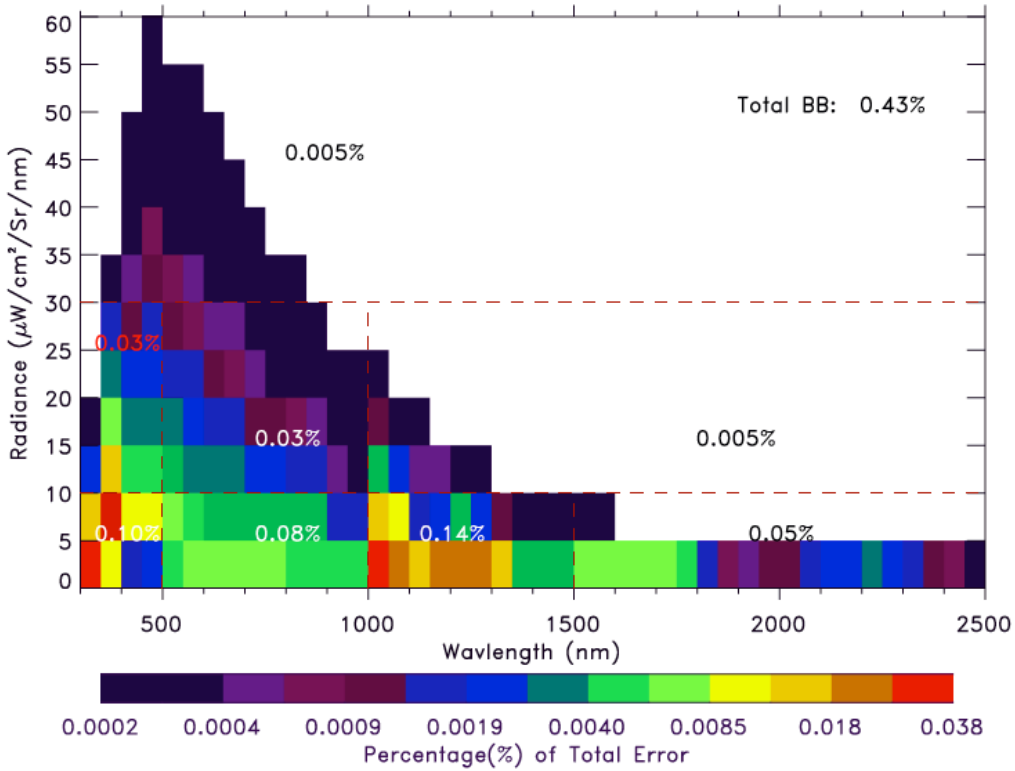



The convolved error distribution.

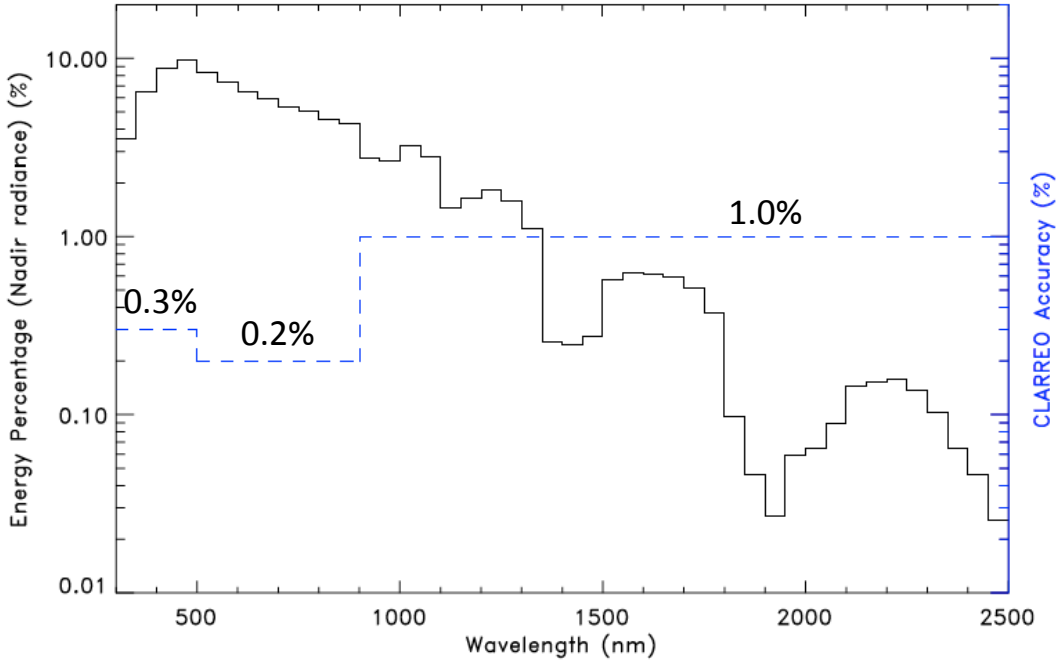
For this case, the convolved global mean broadband error is **0.58%**.



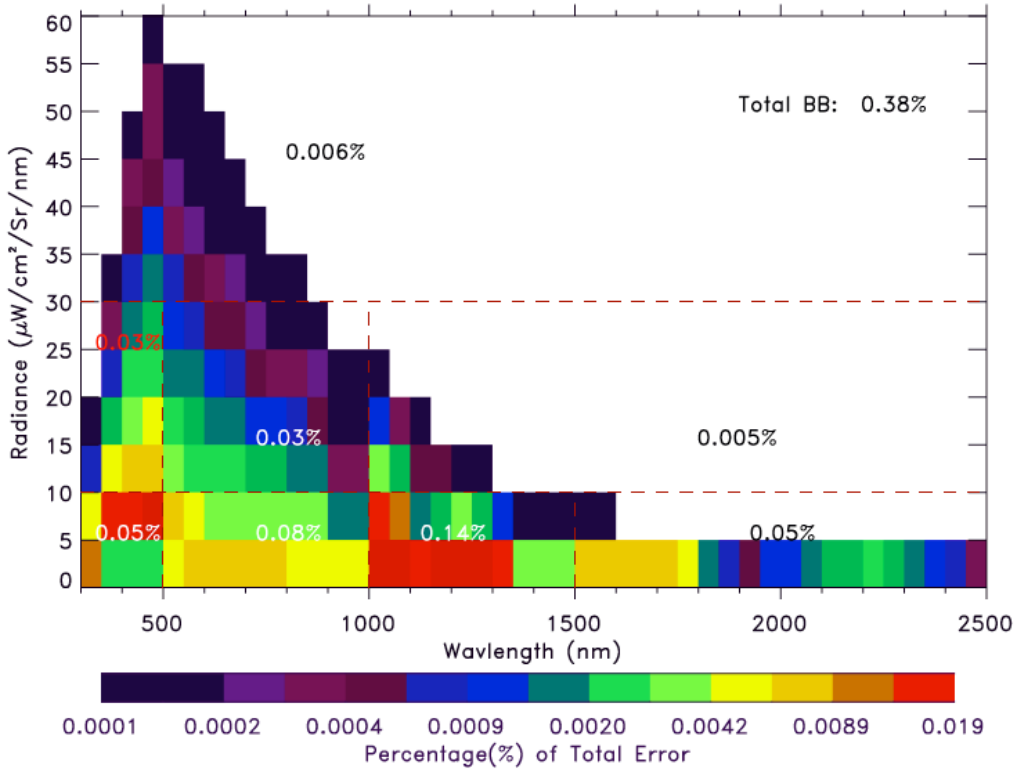

b). Measurement error 0.2% for spectral range 400-900 nm and 1.0% for other spectra.
(error budget from K. Thome)




For this case, the convolved global mean broadband error is **0.43%**.




c). Same as case a, but use accuracy 0.3% for wavelength less than 500 nm.




For this case, the convolved global mean broadband error is **0.38%**.

## Summary

- The global spectral energy distribution for the reflected solar radiance is simulated based on real observational data.
- Convolving this energy distribution with the CLARREO RS instrument error budget, we can now easily obtain the global measurement error distribution in the spectral radiance and the global mean error in the broadband radiance.
- Based on the spectral RS energy distribution for global mean and for typical surface types, **the spectral range of 320-2300 nm is required and suitable for CLARREO RS measurement**, further reducing the spectral coverage increases the measurement error in broadband radiation rapidly.