MRD 140- Resampled OVIRS Calibrated Radiance

Data Product Overview

Before the OVIRS calibrated radiance spectra are used for further scientific processing, they will be "resampled" onto a standard sampling such that each channel of the OVIRS spectra will have a fixed position in the wavelength dimension. The Solar Flux Model to be used in conversion from Calibrated Radiance (I) to I/F in a processing step further down the pipeline has also been resampled to the same spectral resolution, (channel or pixel number to wavelength) and this will greatly aid in processing speed during operations, as well as uniform data products from the SAWG.

Data Product Structure and Organization

The OVIRS Calibrated Radiance spectra will be resampled at 2-nm spacing from 0.392 to 2.4 microns and 5-nm spacing
from 2.4 - 4.34 microns, as defined by the SAWG. This spacing was determined by looking at the OVIRS spectral resolution, as well as the resolution of the available solar flux models. This is described in more detail in:

2015 03 02

OSIRIS-REx

Mike Nolan made an interpolated Solar spectrum spectral energy density model:

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Dennis Reuter suggests using Rieke 2008 (R08) as the reference solar spectrum. It was designed for a very similar purpose to what we want, generating an air-free solar spectrum for referencing spacecraft spectrometers and thermal modeling. Reading the paper, it has a quite detailed discussion of what is needed. There were several other spectra suggested. Several of them were the work of Thuillier et al (2002, 2003, 2004), but those only go out to 2.4 microns, shorter than the OVIRS cutoff. The others were mostly based on older data, and are discussed by Thuillier et al.

We noticed that the sample spacing of the R08 spectrum in the visible is lower than the resolution of the OVIRS instrumentation suite. Looking into the details of R08. It turns out to be a combination of several spectra from different instruments. In the range from 200 to 2400 nm, the spectrum used is that of Thuillier 2003, resampled to a lower resolution. We considered whether we could use the full-resolution spectrum for that part of the spectral range.

Resampling all of the spectra I had to a common high resolution (just a spline fit to a resolution of 0.01 nm, higher than any of the input spectra), the ratio of the various of Thuillier spectra to R08 is a noisy flat line. That is, it appears to have the same large-scale shape and integral as R08, but with finer structure. The Thuillier et al 2003 T03 paper instructs the reader to contact the author for the data, so I did that. The author recommended instead using the updated spectra from Thuillier 2004 (T04). He provided two spectra, one for "solar max" and one for "solar min", differing only shortward of 0.41 microns. As the encounter will occur nearer solar minimum, I used that one, but the difference is very small and over an almost negligible portion of the OVIRS range.

According to T04, they used a different solar constant than in earlier work, 1.4% higher. Plotting the ratio of T04/R08, that difference is clearly visible. T04 states that this is within the uncertainty of 2-4% for the various spectra.

To make a composite spectrum, I divided the spectrum from T04 by 1.014d0 and rescaled the axis units to those of R08. I then concatenated the portion of the T04 spectrum longward of 0.2 microns with the portion of the R08 spectrum longer than 2.398 microns.

The result is a spectrum that is everywhere higher resolution than the OVIRS instrumentation (perhaps by quite a bit too much over most of the spectrum). It has the solar constant of R08, but the spectral shape and sampling of T04.

2015 02 26
I rescaled again by a small factor (0.2 %) to make the integral (on the whole hi-res spectrum) come out to 1367 exactly.

I convolved the spectrum with a Gaussian to the approximate OVIRS resolution and
then resampled at 2-nm spacing from 0.39 to 2.4 microns and 5 nm spacing
from 2.4 - 4.37 microns. There are a few places where this spacing doesn't quite double-sample (from about 0.4 to 0.5 and 2.4 to 2.5 microns). The Gaussian FWHM was taken from an estimate from Dennis Reuter (see below). The Gaussian width was linearly interpolated and/or extrapolated in wavelength space using the given points and the cutpoints for the ~linear strip regions at 1100, 1800, and 2900 nm.

Error bars are from T04, 3% from 0.4 to 2.4 microns, and from R08, 2% above 2.4 microns.

The four columns in the list are wavelength (microns), spectral energy
density (W m^-2 nm^-1), uncertainty (W m^-2 nm^-1, assumed to be the absolute
uncertainty reported for the underlying high-res spectrum), and smoothing
resolution (lambda / delta lambda FWHM). I'm not sure whether the last column
is useful or not.

This may need to be redone once we get the OVIRS as-built wavelength calibration, but it should already be pretty good.

2015 03 03
The definition of "Solar constant" isn't spelled out in the papers,
but it's intended to be at 1 AU above the Earth's atmosphere. The
exact value varies among authors, usually +/- 2 in the last digit,
but with a recent value as different as 1361. I adopted 1367 W/m^2 as
a nominal value. At that level you just scale to what you want. Yes,
you need to correct for 1/r^2 for Bennu.

The idea is that the OVIRS fluxes will
be interpolated to the *same* scale, and that the scale is oversampled
by ~2, so all you need to do is linearly interpolate if you need to
tweak things. The values are per nm, not per bin, so if you rebin gently you
don't have to integrate. If you rebin a lot you do, as you'll be averaging
out the absorption lines. The raw OVIRS spectrum is more complicated,
and Amy Simon-Miller's description of what's needed to get from there
to the sampled spectrum involved some less-than-polite words suggesting

that it's non-trivial.

I used a Gaussian as the estimated filter bandpass, though that's probably
not really right. I would guess that the real bandpass is both squarer
in the middle and has wider tails.

We could distribute a higher-resolution version if people want to do
the smoothing and interpolation themselves using the same base spectrum.
There are also some later papers with yet more modern results, but I doubt
that the practical differences will be meaningful.

The variations in the higher-res solar spectrum are real, not (in
general) noise, so you have to do flux-conserving smoothing with the
filter bandpass if the resolutions don't match; you can't just spline or
resample. It should work to spline them both to a much higher resolution
and do your averaging there.

R08 Rieke, G. H.; Blaylock, M.; Decin, L.; Engelbracht, C.; Ogle, P.; Avrett, E.; Carpenter, J.; Cutri, R. M.; Armus, L.; Gordon, K.; Gray, R. O.; Hinz, J.; Su, K.; Willmer, Christopher N. A. (2008). Absolute Physical Calibration in the Infrared. Astron. J. 135, 2245-2263. DOI:dx.doi.org/10.1088/0004-6256/135/6/2245

R08 spectrum obtained from http://iopscience.iop.org/1538-3881/135/6/2245/fulltext/aj271287_mrt7.txt

T03 Thuillier, G.; Hersé, M.; Labs, D.; Foujols, T.; Peetermans, W.; Gillotay, D.; Simon, P. C.; Mandel, H. (2003). The Solar Spectral Irradiance from 200 to 2400 nm as Measured by the SOLSPEC Spectrometer from the Atlas and Eureca Missions. Solar Physics, 214:1-22. DOI: dx.doi.org/10.1023/A:1024048429145

T04 Thuillier, G., F. Linton, T. N. Woods, R. Cebula, E. Hilsenrath, M. Hersé, and D. Labs 2004. Solar Irradiance Reference Spectra. In Solar Variability and its Effect on Climate, AGU monograph 141, eds J. Pap and P. Fox, p. 171. DOI: dx.doi.org/10.1029/141GM13

T04 spectrum provided by the author

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Resolution estimate from Dennis Reuter 2015 March 2.

All
The resolution vs. wavelength (both in nm) is fairly well represented by:

wavelength	full width at half maximum intensity
400	2.1
600	4.3
800	5.7
1000	7.5
1200	7.5
1500	8.3
1800	10
2000	8.5
2400	10
2800	11.7
2900	7.8
3200	8.7
3500	9.5
3800	10.3
4100	11.1
4300	11.6

The sampling of every 2 nm from 400 to 2400 and 5 nm from 2400 to 4300 is a simplified representation of what will actually occur in the spectrometer. That is, the spectrum from 400 to 2400 will be measured using ~ 900 pixels (sometimes spaced less than 2 nm apart, sometimes greater than 2 nm apart) and the spectrum from 2400 to 4300 will be measured using ~ 380 pixels (sometimes spaced less than 5 nm apart, sometimes greater than 5 nm apart).

Please remember that for the actual data each spectral sample will be associated with its correct wavelength, which might vary a bit as a function of temperature and some other parameters. The purpose of the simplified spectral scale is just so that direct comparisons can be made quickly among various site selection map products. The actual spectra will always be available for more detailed science studies.

Thanks

Dennis

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and on the Bond Albedo description page:

https://sciwik.lpl.arizona.edu/wiki/pages/p810J770/Bond_albedo.html

The product is a spectrum with radiance units of W/cm2/µm/sr per spectral element.   The purpose of this product is to standardize the number of spectral elements and their wavelengths for all subsequent science processing algorithms, as each OVIRS spectrum could potentially have slightly different wavelengths. The resultant spectra are stored as double precision floating point arrays of 1393 x 3 elements (wavelength, radiance, radiance uncertainty)

Data Format Descriptions

At present, the resampled OVIRS radiance data will be archived in the PDS and the SPOC database as double-precision floating point format according to the algorithm description page and SAWG SIS. The spacecraft clock time will be used to associate the resampled spectra with the predecessor data (calibrated radiance) and other ancillary information in the database (e.g., geometry).

Data Product Generation

Processing of OVIRS calibrated radiance spectra will produce resampled spectral data using IDL scripts. This software will be installed on the SPOC system for use on all spectral data processing.

Required inputs and formats are:

• OVIRS spot calibrated radiance data (W/cm^2/sr/micron) with temperature-dependent wavelength assignment

• Two-dimensional double precision floating-point array (1 x 20 x 512 x 2 spectrum) with corresponding geometry keywords

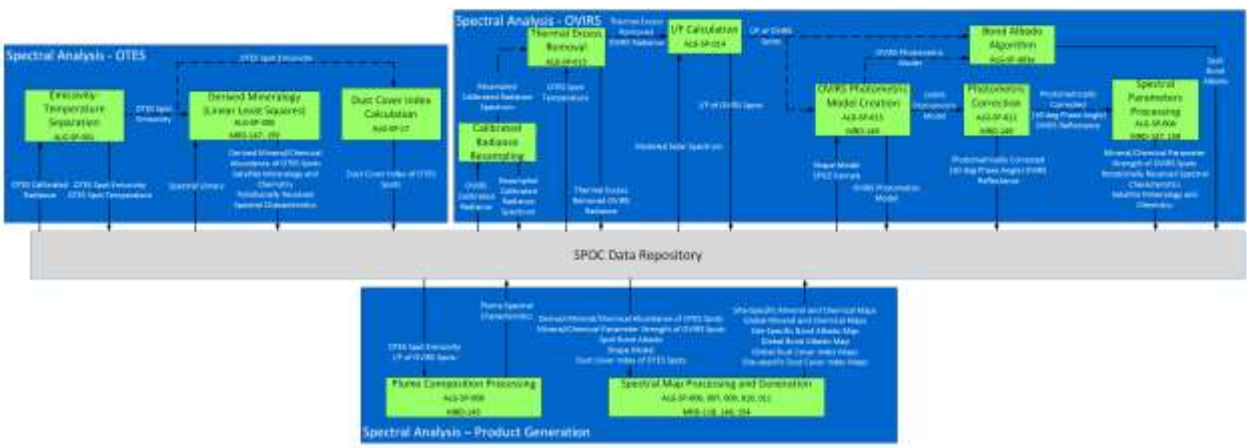
OVIRS IE Lunsford has been assigned to this product

Data Product Validation

If a wavelength calibration or performance shift is noted in flight, the algorithm would need to be run again with the corrected wavelength data. In addition, any changes in desired uniform axis, based on science team needs, would require changing the input to the algorithm and running on the needed spectra, or the entire database. Periodic in flight calibration will be used to determine if wavelength adjustments are needed.

Data Flow

The following diagram shows the Data Flow for OVIRS spectra, in overview. This diagram illustrates the general context in which this data processing step belongs.



Observations Requirements

Resampled calibrated radiance spectra will be generated from any OVIRS calibrated radiance spectrum of the target (Bennu), regardless of observation conditions. For the resulting data to meet the expected areal coverage and spatial resolution requirements, the spacecraft must be within the stated delivery uncertainty of the range, latitude, and longitude for the given mission phase.