Figure 11 shows the reference irradiance spectrum proposed by Thuillier et al (2004).

Figure 12 shows the Kitt Peak absolute irradiance spectrum smoothed using a 0.5 nm triangular bandpass that approximates the resolution of Thuillier et al and then compares the two spectra. Note the probable overestimation of the ozone below 320 nm and around 600 nm in the Kitt Peak atlas. (Remember that ozone has been divided out.) I will probably have to re-reduce those scans. Note the flux discrepency in the G band. It appears that model ASUN does not produce enough flux, perhaps becase of insufficient opacity below 300 nm that results in too low a temperature gradient. I am adding more line opacity. I will try to produce a better model. Of course, there may also be errors in Thuillier et al as well.

Figure 13 shows the Kitt Peak irradiance spectrum subjectively normalized to the Thuillier et al irradiance spectrum. I recommend this spectrum as the high resolution irradiance spectrum. The procedure for removing telluric lines introduces noise into the irradiance spectrum where there were telluric lines. The flux atlas itself should be used for abundance analysis or other critical work.

Funding

NASA discontinued my funding on May 15, 2004 and I was laid off. I decided to do this project using my retirement funds in order to try to get interest and funding from other NASA programs, or the Air Force, NOAA, DOE, or anyone else. Producing the irradiance spectrum took 129 12-hour days at $1000/day. I made 115,000 11x17 plots at $0.28/page. I cannot continue to subsidize NASA, or the Air Force, or NOAA with my retirement funds. I will sell a CD and a set of plots for $161,000 that I will return to my retirement fund. If I am to extend the irradiance spectrum into the infrared (to 5400 nm) and to upgrade the visible as new line data or better spectra become available, I need at least $300,000/year in grants to the Smithsonian Astrophysical Observatory so that I can be rehired.

References

Anderson, G. et al 1986. AFGL-TR-86-0110.

Kurucz, R.L. 1992. Model atmospheres for population synthesis. Presented at IAU Symp. 149, Angra dos Reis, Brazil, August 5-9. in Stellar Population of Galaxies, (eds. B. Barbuy and A. Renzini) Kluwer, Dordrecht, pp. 225-232.

Kurucz, R.L., Furenlid, I., Brault, J., and Testerman. L. 1984. *Solar Flux Atlas from 296 to 1300nm.* National Solar Observatory, Sunspot, New Mexico, 240 pp.

Thuillier, G., Floyd, L., Woods, T.N., Cebula, R., Hilsenrath, E., Herse, M., and Labs, D. 2004. Solar irradiance reference spectra. in *Solar Variability and its Effect on the Earth's Atmosphere and Climate System*, eds. J.M. Pap et al AGU, Washington, DC, pp. 171-194.

Figure 1 shows the old Kitt Peak Solar Flux Atlas. There are eight overlapping FTS scans that were normalized and pieced together to form a continuous residual spectrum. The observational data for the scans is listed in Table 1. (There are only seven scans in this figure because the eigth is beyond 1000 nm.) The next figures show the re-reduction of these scans.

Figure 2 shows broad atmospheric features of O_3 and $[O_2]_2$ that were present in the scans but not considered. Each scan was assigned to an atmospheric model listed in Table 1. The O_3 and $[O_2]_2$ transmission was computed using programs available on my website, kurucz.harvard.edu, and divided out. (The transmissions for the seven scans were pieced together for the plot.)

Figure 3 shows the beginning of one of the FTS scans in green. A continuum, smooth green line, is subjectively fitted to the scans by comparing to predictions from calculations of the solar spectrum and the telluric spectrum. When a reasonable looking fit has been obtained through iteration, the spectrum is divided by the continuum value to produce a residual spectrum shown in red. The top 1 percent of the residual spectrum is replotted in red as well. The blue curve is the the transmission curve for O_3 and $[O_2]_2$ that has already been divided out.

In Figure 4 the scans were blueshifted to remove the gravitational red shift and pieced together in the solar laboratory frame in air. This is the revised spectrum of the Kitt Peak Solar Flux Atlas.

Figure 5 shows telluric lines of O_2 and H_2O that were computed from the atmospheric model for each scan in the solar laboratory frame with gravitational red shift removed. (The seven scans are pieced together.)

Figure 6 shows a sample calculation of the spectrum for a relatively empty angstrom at 599.1 nm in the Solar Flux Atlas shown in Figure 4. The telluric, solar, and observed spectra are labelled at normal scale and 10 times scale.

Figure 7 shows the irradiance spectrum obtained from the spectra in Figure 6 by dividing out the telluric spectrum. For stronger telluric lines and lines with incorrect wavelengths, there are artifacts that appear in the irradiance spectrum that were removed by hand and replaced with a linear interpolation.

Figure 8 shows the residual irradiance spectrum after all the scans have been processed and pieced together in the solar laboratory fram in vacuum with gravitational red shift included.

Figure 9 shows the predicted level of the continuum for theoretical solar model ASUN (Kurucz 1992).

Figure 10 shows the absolute irradiance spectrum obtained by normalizing the residual irradiance spectrum shown in Figure 8 to the continuum level shown in Figure 9.

High Resolution Irradiance Spectrum from 300 to 1000 nm

Robert L. Kurucz
Harvard-Smithsonian Center for Astrophysics
60 Garden Street, Cambridge, MA, USA

June 15, 2005

The FTS scans that made up the Kitt Peak Solar Flux Atlas by Kurucz, Furenlid, Brault, and Testerman 1984 have been re-reduced. The scans were smoothed with a 3-point Gaussian to simplify continuum placement and matching overlapping scans. An approximate atmospheric model was determined for each FTS scan. Large-scale features produced by O_3 and O_2 dimer were computed and divided out. The telluric line spectrum was computed using HITRAN and other line data for H_2O, O_2, and CO_2. The line parameters were adjusted for an approximate match to the observed spectra. The wavelength scale for the scans was redetermined. The solar continuum level was found by fitting a smooth curve to high points in the observed spectrum while comparing with the product of the computed solar spectrum times the computed telluric spectrum. The spectrum was normalized to the fitted continuum to produce a residual flux spectrum for each FTS scan. Those scans were divided by the computed telluric spectra to produce residual irradiance spectra. Artifacts from wavelength mismatches, deep lines, etc, were removed by hand and replaced by linear interpolation. Overlapping scans were fitted together to make a continuous spectrum from 300 to 1000 nm. All the above steps were iterative. The monochromatic error varies from 0.1 to 1.0 percent.

Given a calculated or semiempirical solar model, the continuum level can be computed and multiplied by the residual irradiance spectrum to produce the absolute irradiance spectrum at high resolution. Alternatively, the high resolution residual irradiance spectrum can be broadened and smoothed to match the resolution of any low resolution irradiance spectrum and normalized to the low resolution spectrum. That normalization can be applied to the high resolution spectrum to obtain a high resolution absolute irradiance spectrum. An example for each method is presented below. This is the spectrum that illuminates the Earth and all other bodies in the solar system. This is a typical G star spectrum like those that illuminate extra-solar planets.

A revised solar flux atlas, a central intensity atlas, and a limb intensity atlas will be produced. Atlases with sample computed spectra and line identifications will be produced. This work, and the extension to longer wavelengths, requires funding, as indicated below.

Presented at the AFRL Transmission Meeting, 15-16 June 2005, Lexington, Mass.