Innovative Imaging & Research

Extending the Operational Envelope of Aerial Optical Imaging from Pre-sunrise to Post-sunset Operation

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Acknowledgements

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- NASA SSC Rodney McKellip
- Imagery
  - Midwest Aerial (Ken Scruggs) (DMCII)
  - Pictometry (Charles Mondello)
- Hexagon Z/I (Klaus Neumann and the Aalen team)

Pre-sunrise and Post-sunset Optical Imaging (What and Why?)

- Terrestrial optical imaging visible-near infrared (no thermal) in low natural and artificial lighting

- Why?
  - Disaster response for hurricanes, fires, earth quakes, tsunamis, etc. desire all weather all condition imagery
  - Human activity (mapping artificial lights)
  - Light pollution(environmental, astronomy & energy)
  - Improved cloud statistics

Aerial Digital Cameras

- Imagery is typically taken over a limited set of solar and atmospheric conditions even though information is needed all time

- Digital sensors can be very sensitive (both Bayer Array and high end TDI systems)

Bayer Pattern

DMCII (TDI)

Questions

- How much can the image acquisition period be expanded for digital cameras?
  - Under cloud cover
  - Sunrise to sunset
  - Twilight
  - Nighttime
    - Artificial lighting
    - Moonlight
- Can an operational set of guidelines be produced?

Nov. 11, 2011Canon EOS Rebel Moonrise f3.5 18 mm FL 20 Sec

Even low cost digital cameras can work at very low light (~ 250000 x dimmer than at noon)

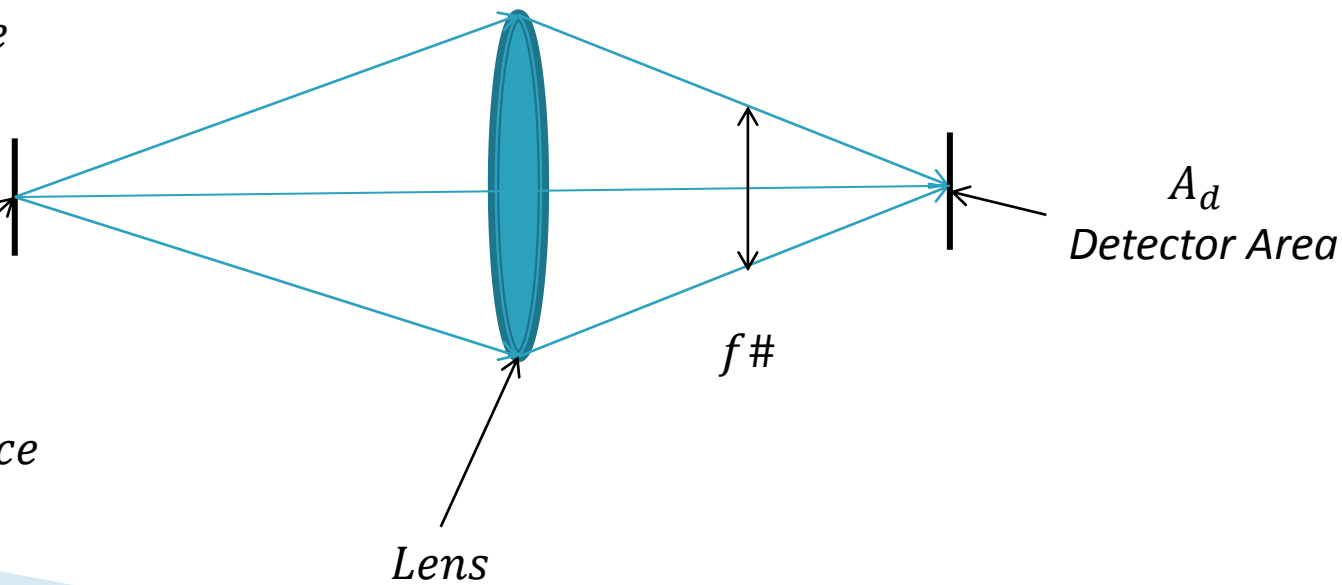
Methodology

- Understand the radiometric performance of digital cameras
  - Initial focus on cameras with TDI (DMCII)
  - Bayer array pattern camera (Pictometry and others)
- Measure the amount of light available during sunrise and sunset (Other times as well)
- Predict performance
- Work with data providers to get imagery under real world conditions

Digital Camera Radiometric Performance

$$DN = g\,\tau\,A_d\,\frac{\pi}{4\,f\#^2}\int_0^{\infty} L(\lambda)S(\lambda)d\lambda$$

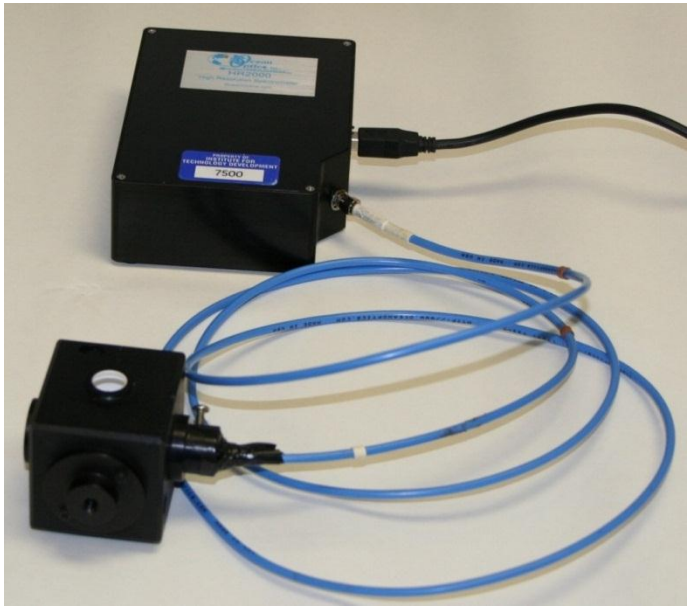
$DN - Digital\ Number$
$\lambda - Wavelength$
$L(\lambda) - Spectral\ Radiance$
$S(\lambda) - Spectral\ Response$
$\tau - Integration\ Time$
$g\ - Gain$
$f\# - f - number$



General Comments

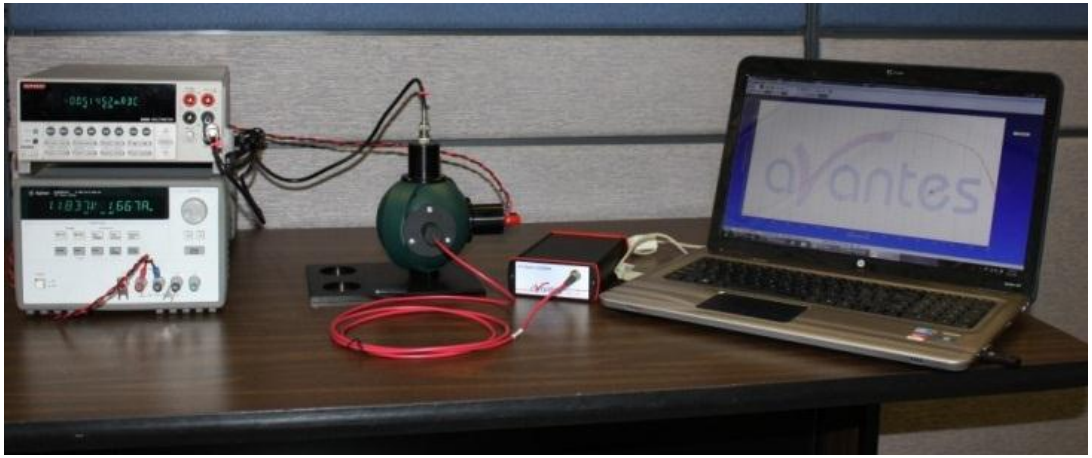
- High sensitivity is produced through increased exposure time, small f#s and noise reduction
  - Aerial cameras can have nearly 3 orders of magnitude dynamic range adjustments with f# and integration time
- Increasing the aperture and exposure time decreases image sharpness (Poorer Edge Response or MTF)
  - Image stabilizing helps with long exposure (Forward Motion Compensation)

Spectrometer and Cosine Receptor For Spectral Irradiance Measurements

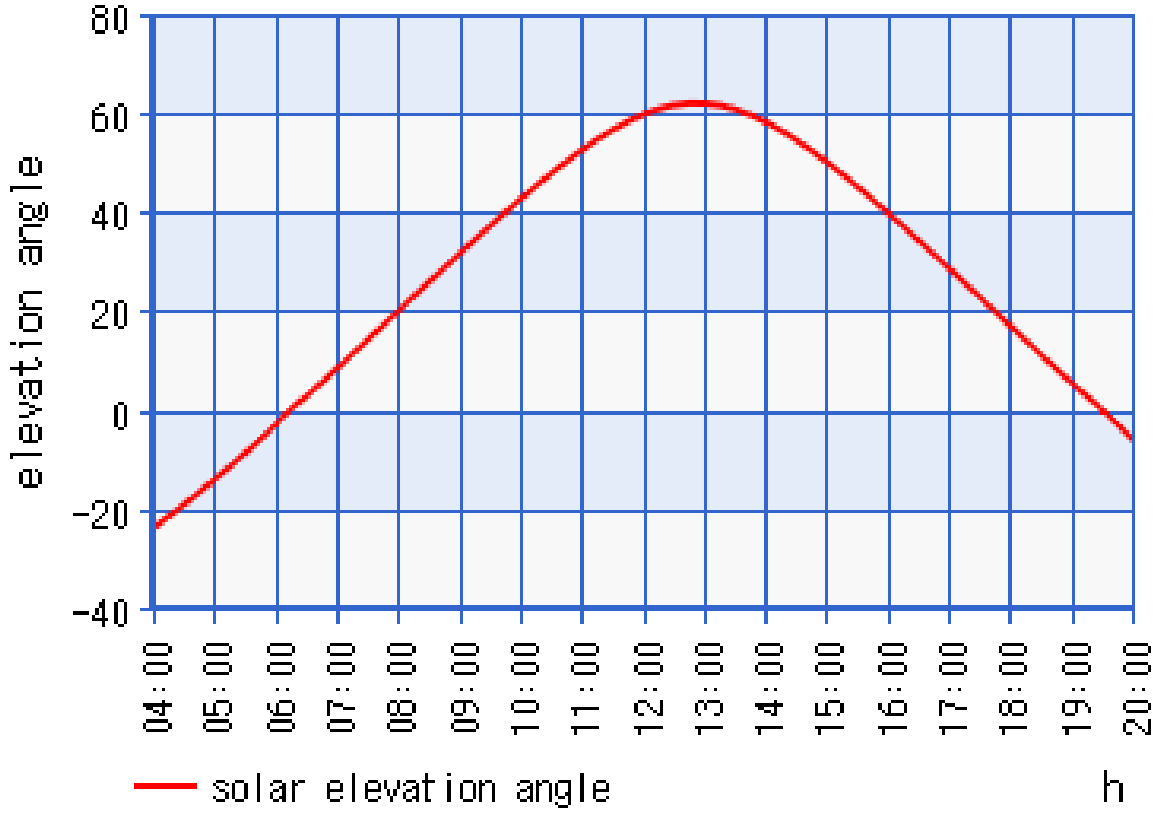


Small integrating sphere for cosine receptor

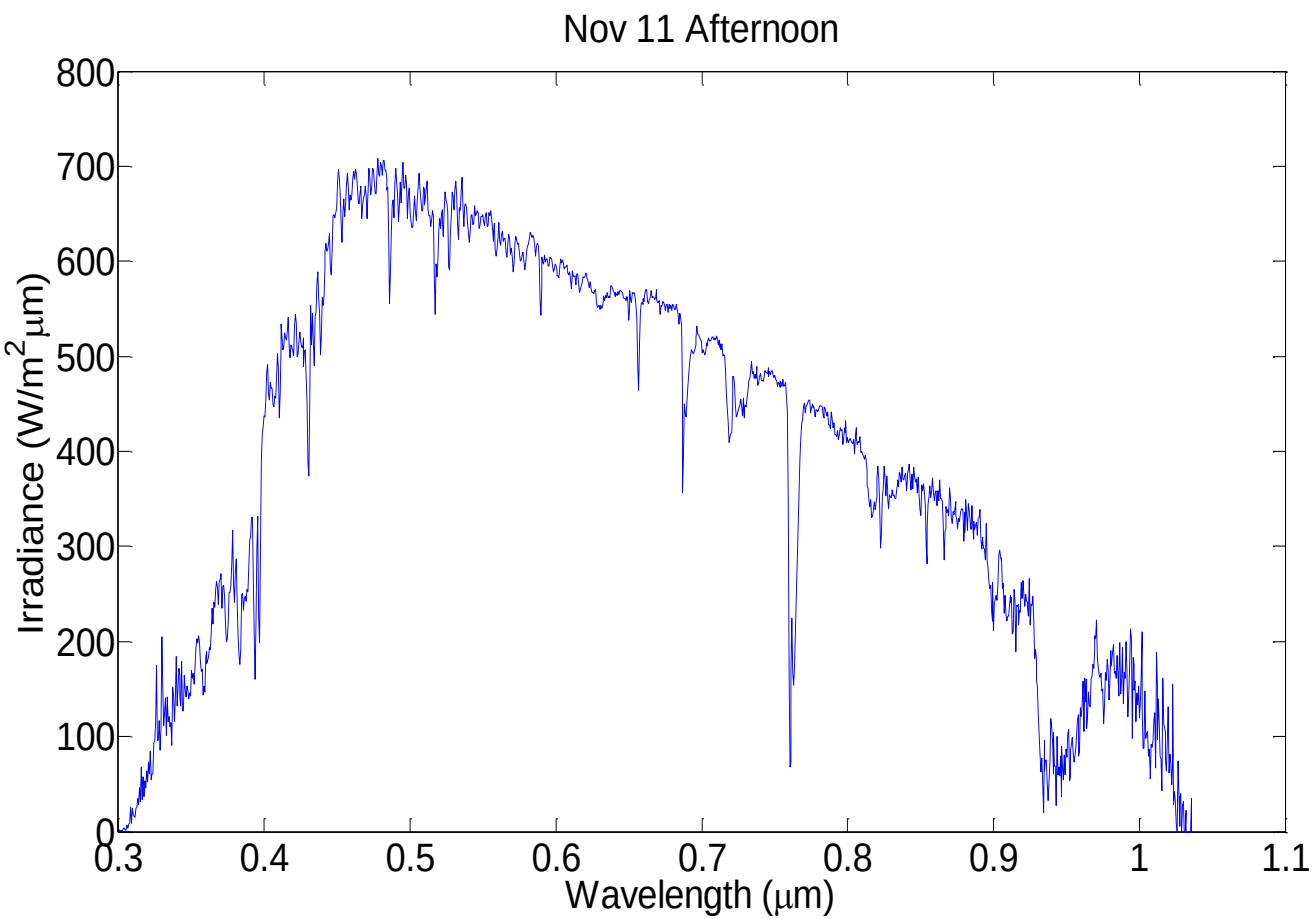
NIST Traceable Calibration with an Integrating Sphere



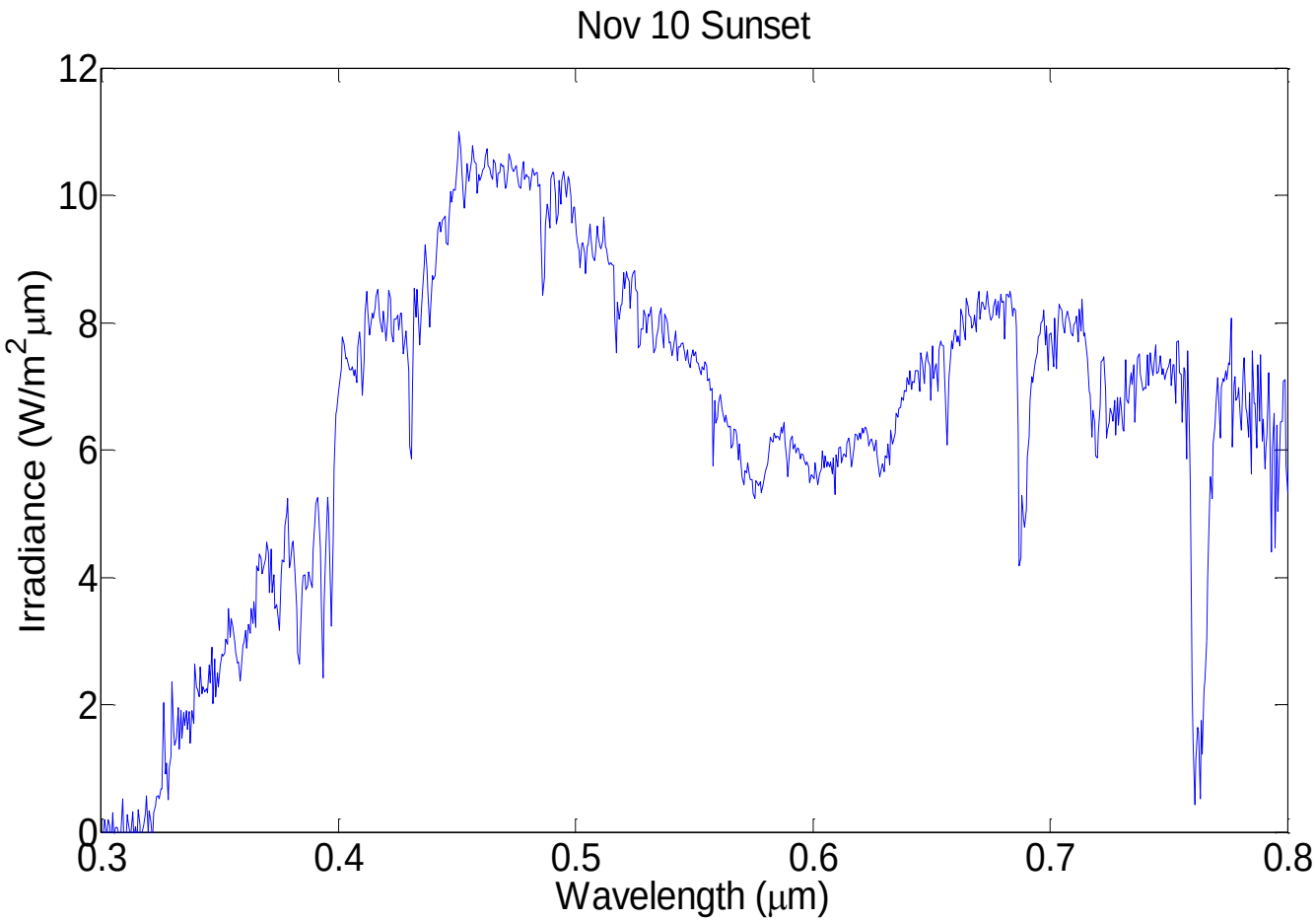
April 18 2012 Solar Elevation



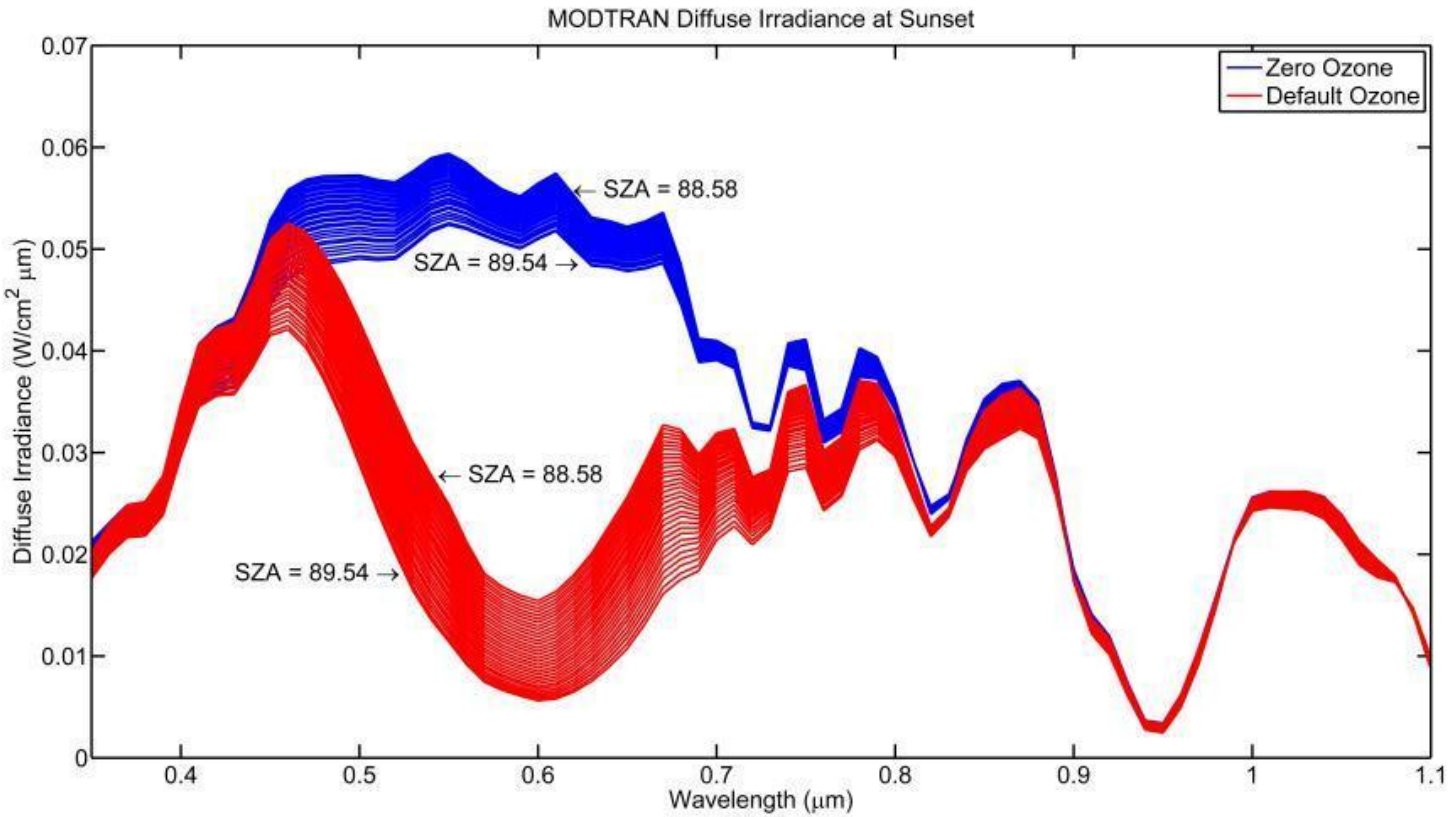
Spectral Irradiance Mid Afternoon



Spectral Irradiance at Sunset



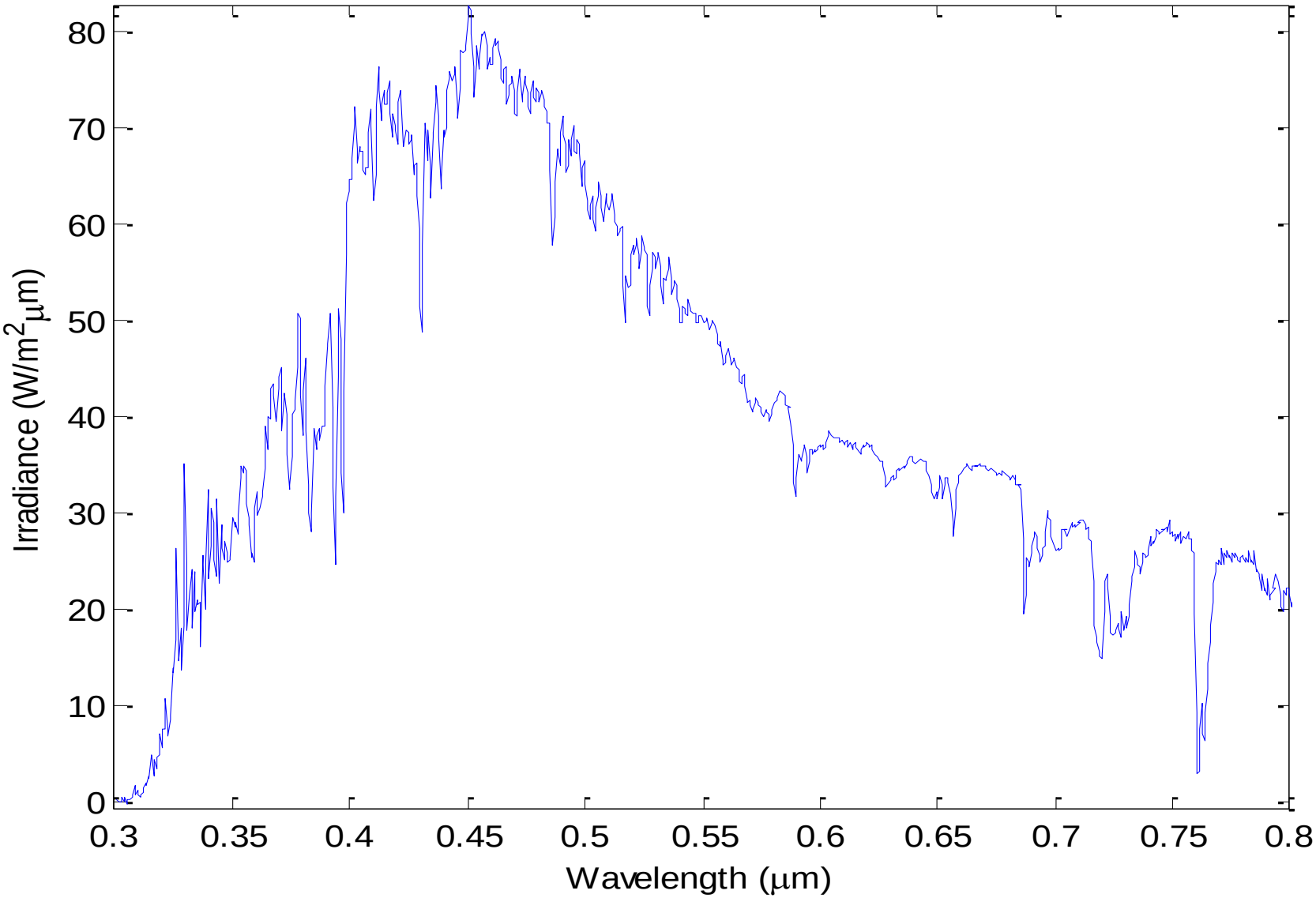
Effect of Ozone on Diffuse Irradiance



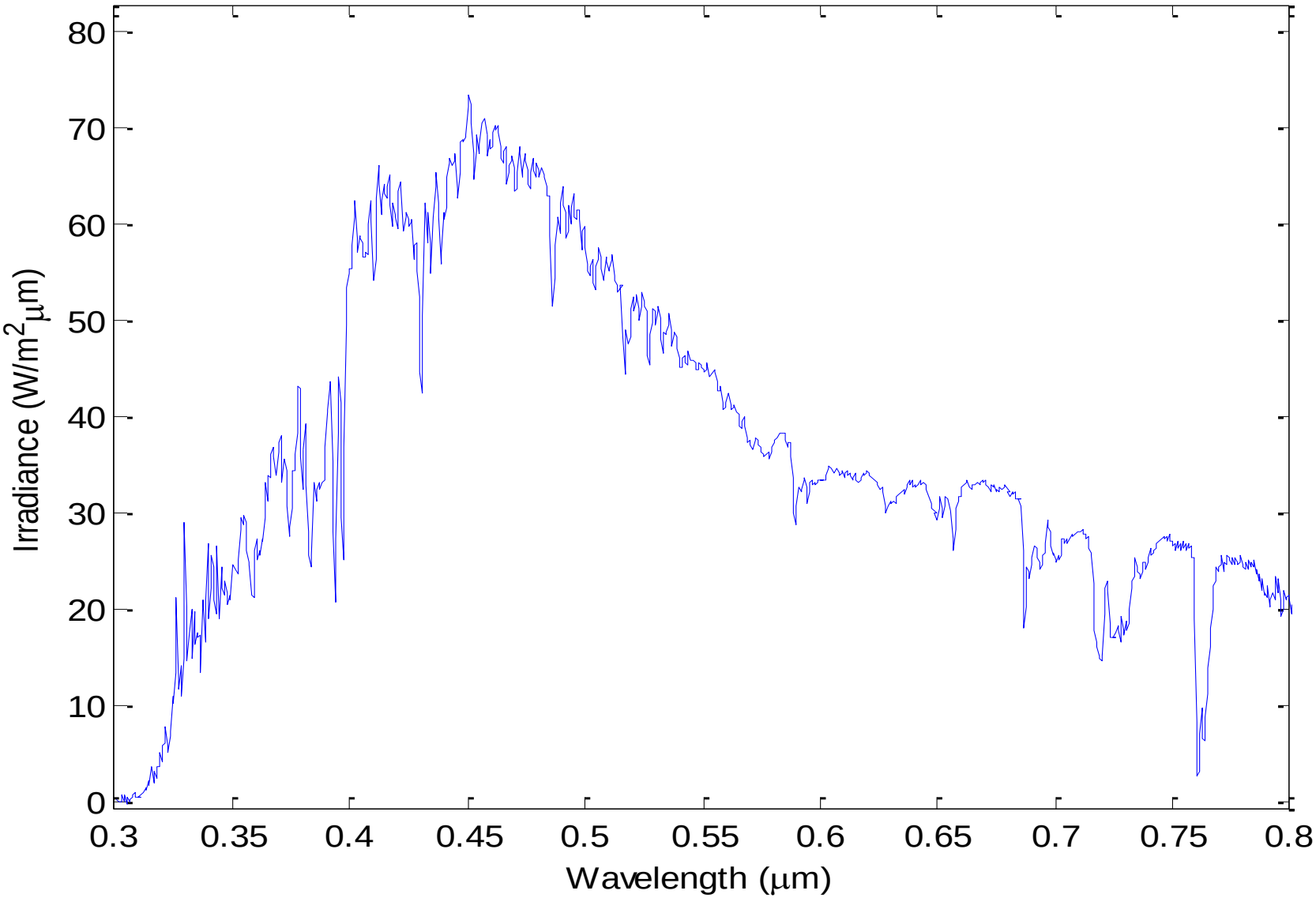
Solar Spectra Acquired between 6:37 and 7:17

March 29, 2012
Building 1103 Rooftop
Sunset occurred at 7:16 PM
100ms integration time, 10 scan average

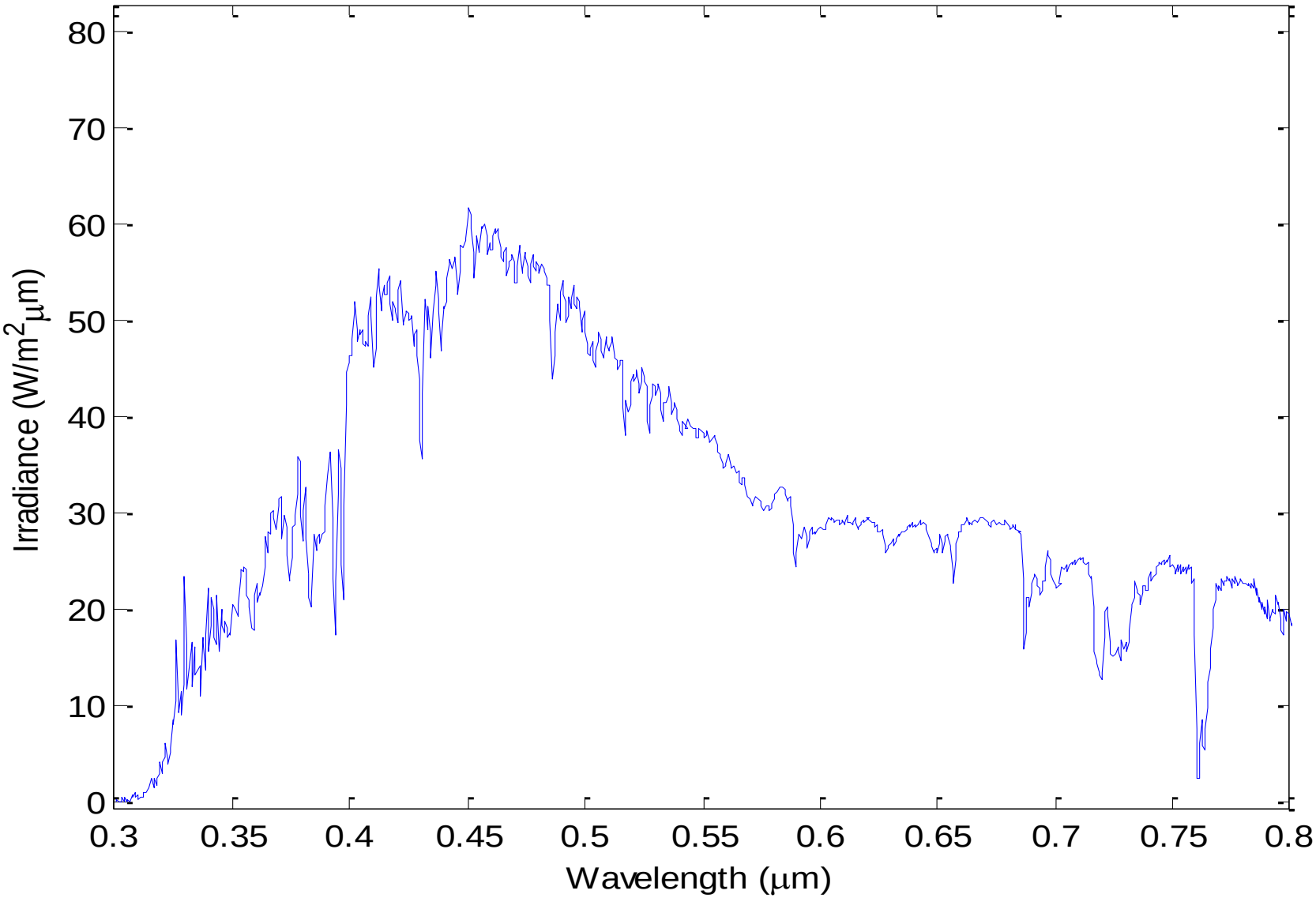
Spectral Irradiance at 6:37 PM



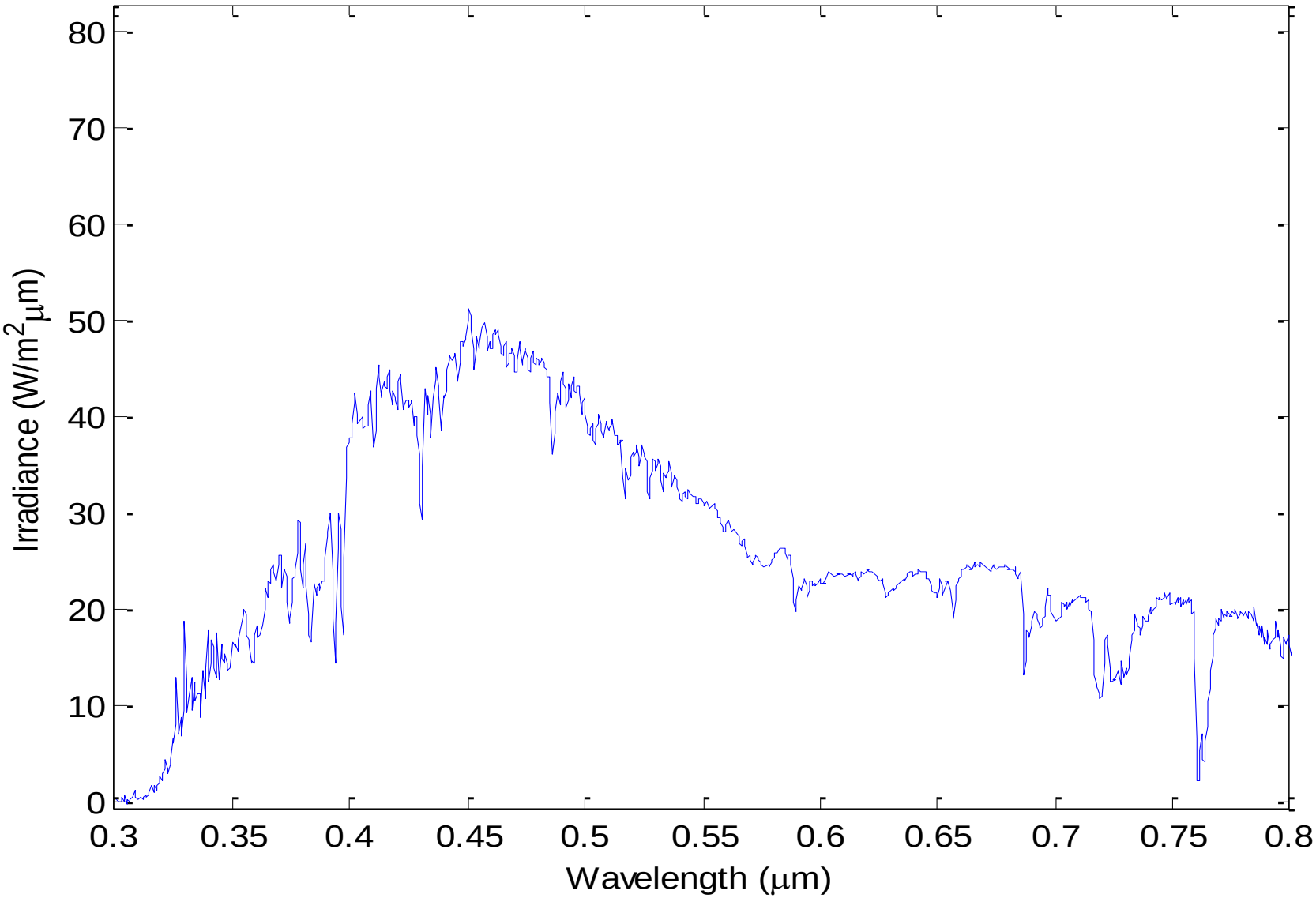
Spectral Irradiance at 6:43 PM



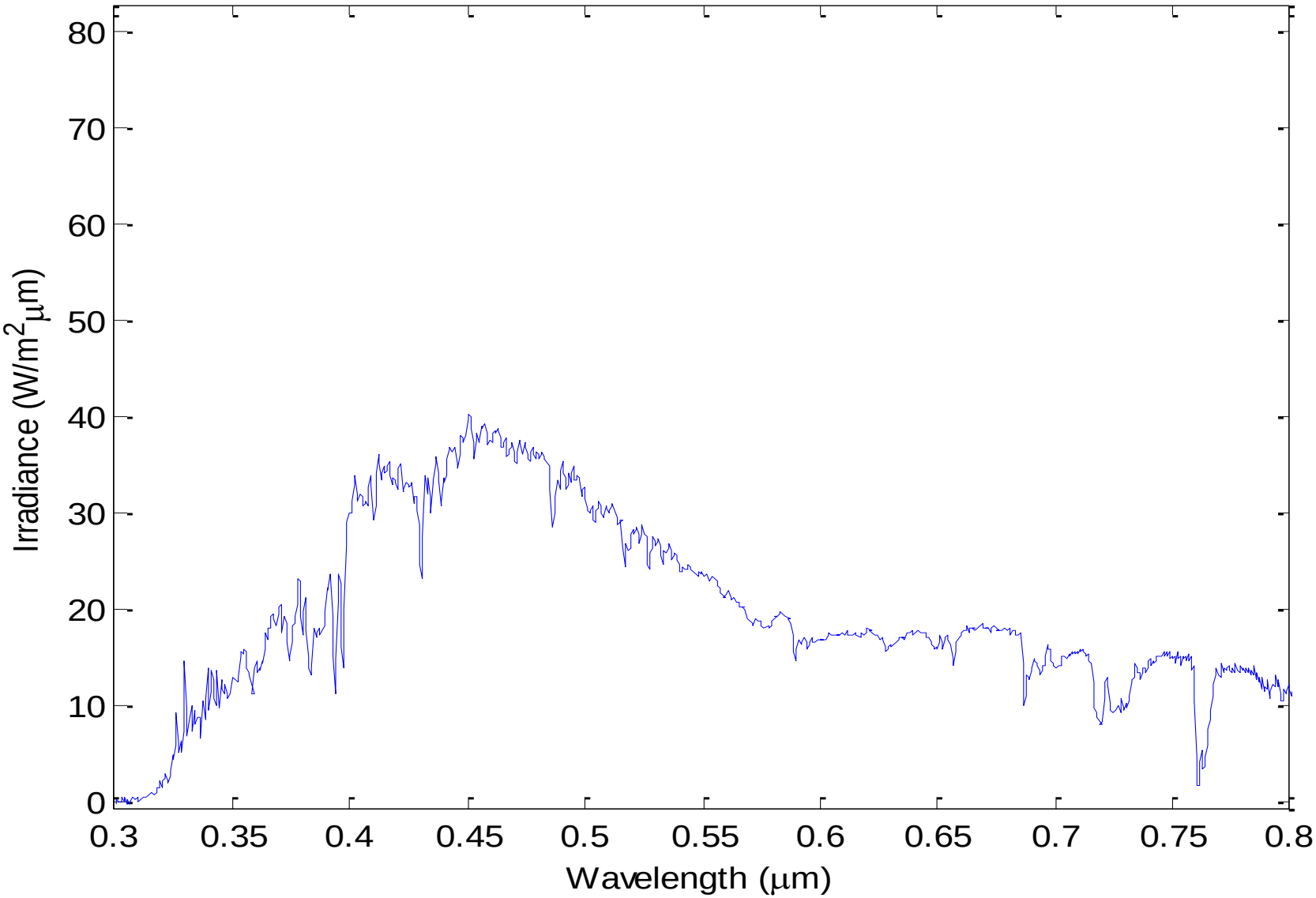
Spectral Irradiance at 6:48 PM



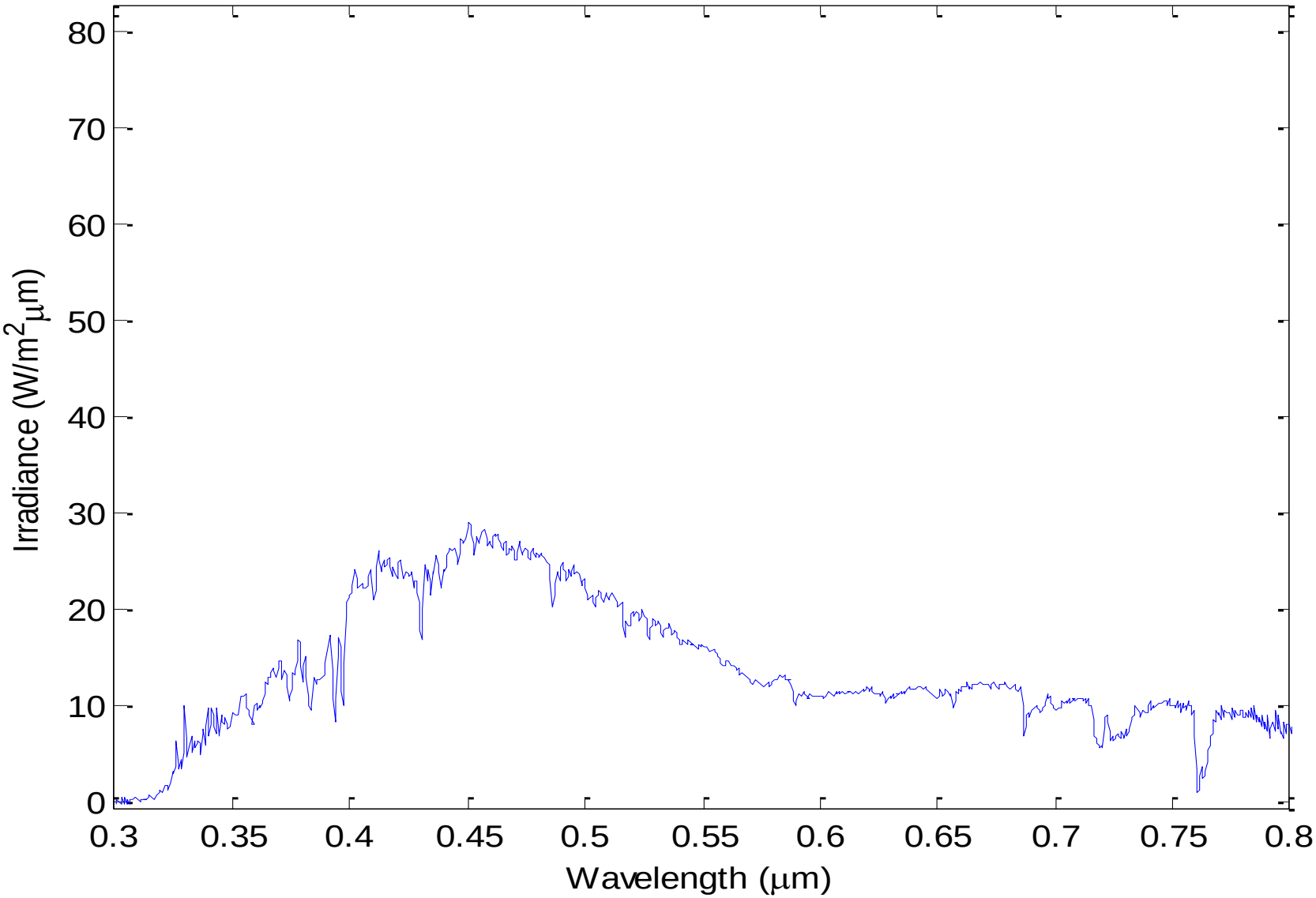
Spectral Irradiance at 6:53 PM



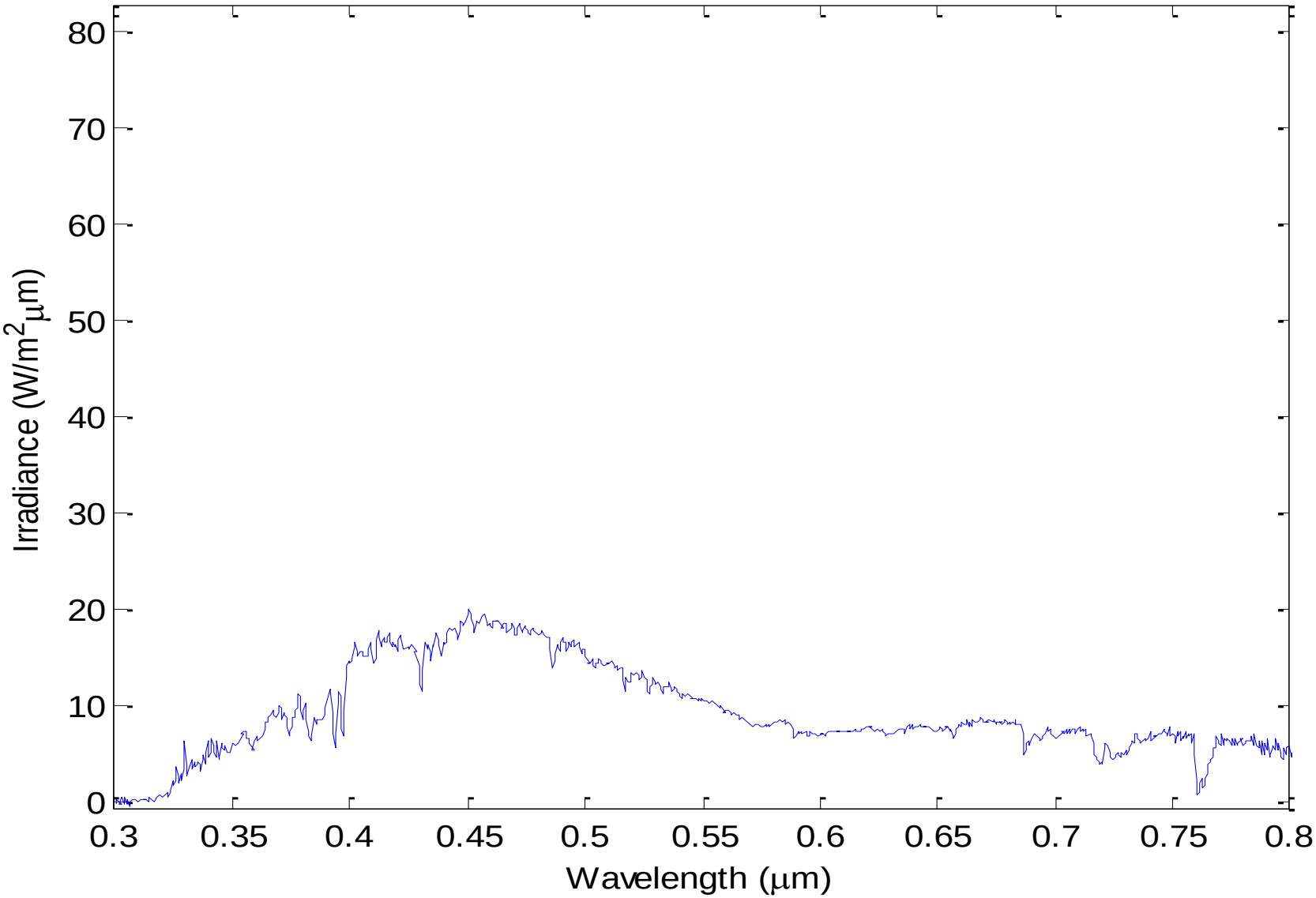
Spectral Irradiance at 6:57 PM



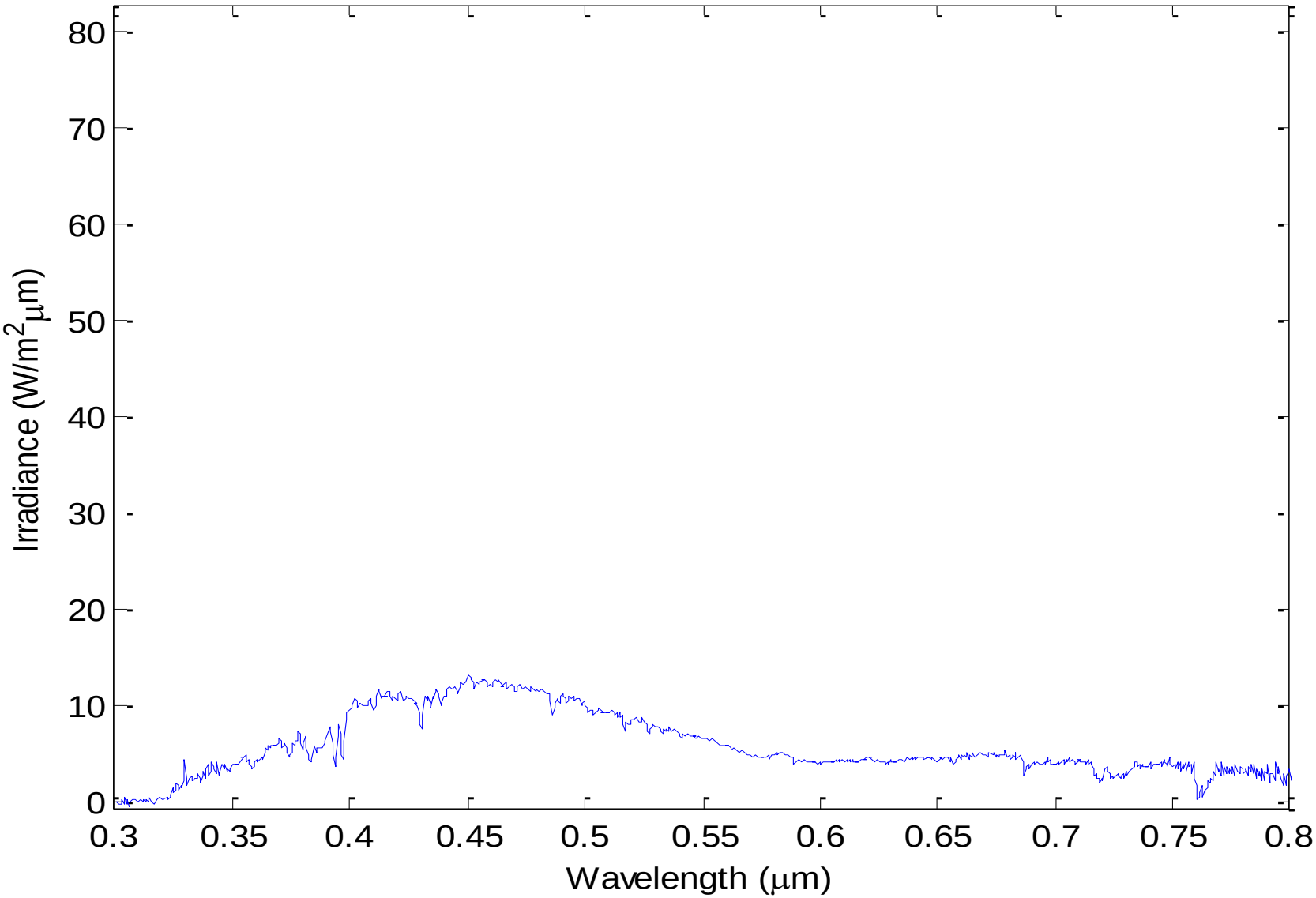
Spectral Irradiance at 7:03 PM



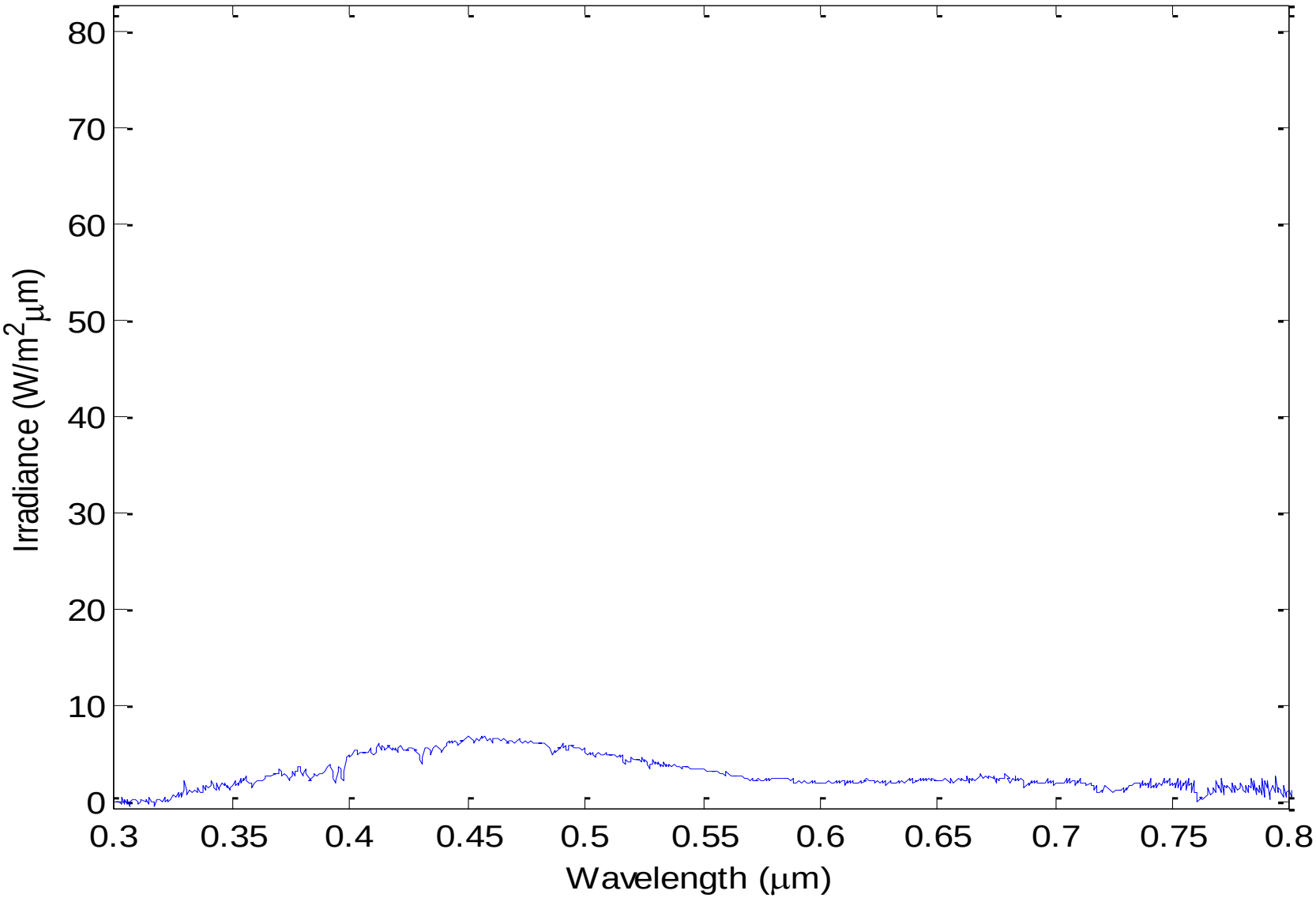
Spectral Irradiance at 7:08 PM



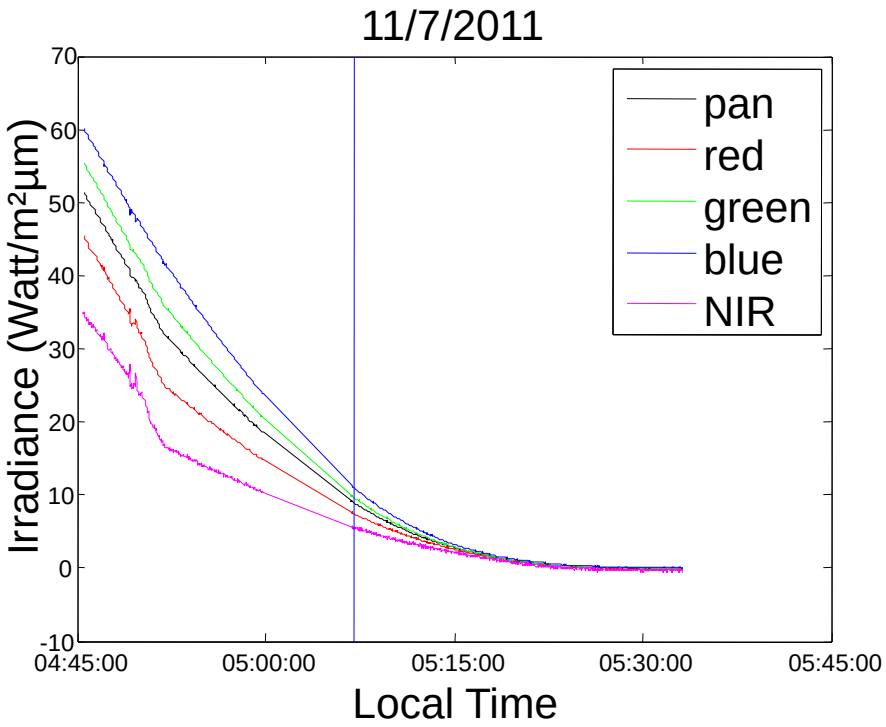
Spectral Irradiance at 7:12 PM

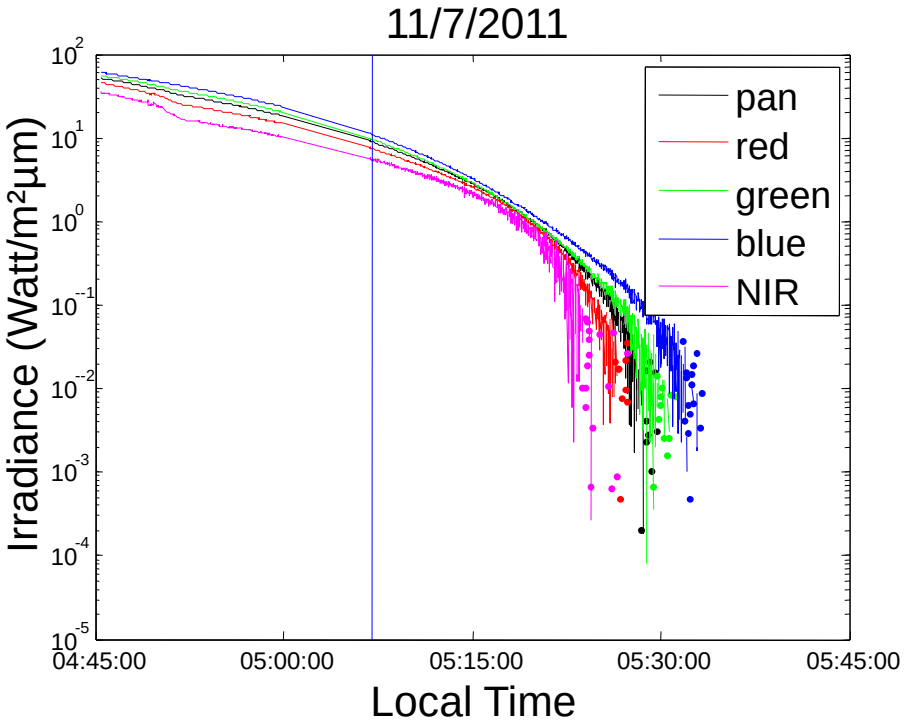


Spectral Irradiance at 7:17 PM



Sunset November 7, 2011





Midwest DMCII Aerial Photography

- Midwest Aerial is located in Columbus Ohio and owns and operates a state-of-the-art Z/I DMCII140 digital camera
  - 4 multispectral bands (RGBN)
  - 140 megapixel pan band
  - Imagery acquired at 10, 0 and -10 degrees solar elevation over West Broad Street in Columbus
- Absolutely Radiometrically Calibrated

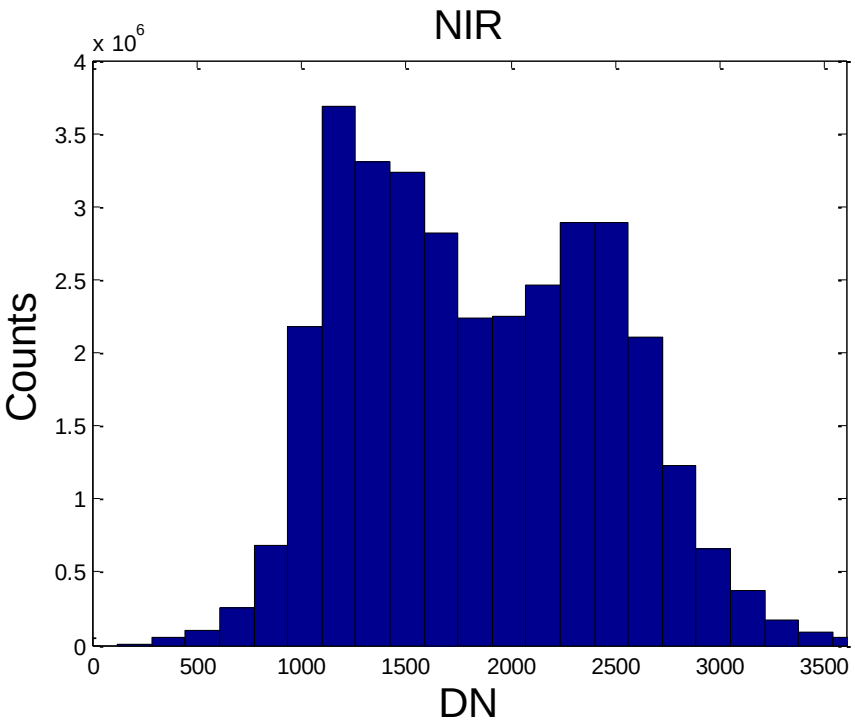
Late Winter Columbus Ohio Examples

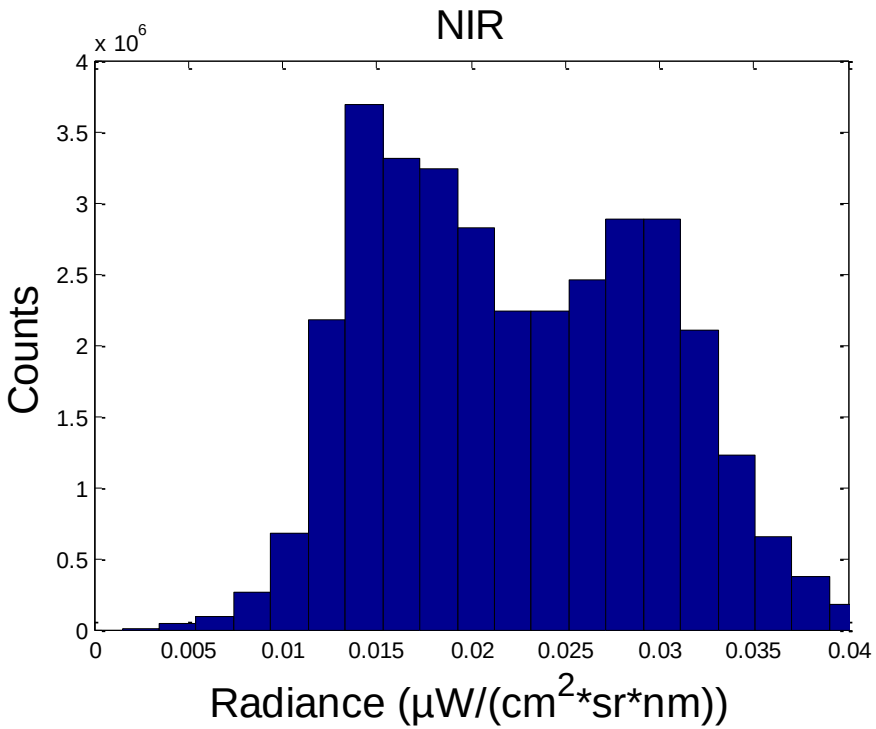
~5 minutes prior to sunset

~sunset

4500
5000
5500
6000
6500
7000
7200
7400
7600
7800
8000
8200
8400
8600
8800

DMCII NIR Histogram





~5 minutes past sunset

~10 minutes past sunset

Fall/Winter Collect Examples

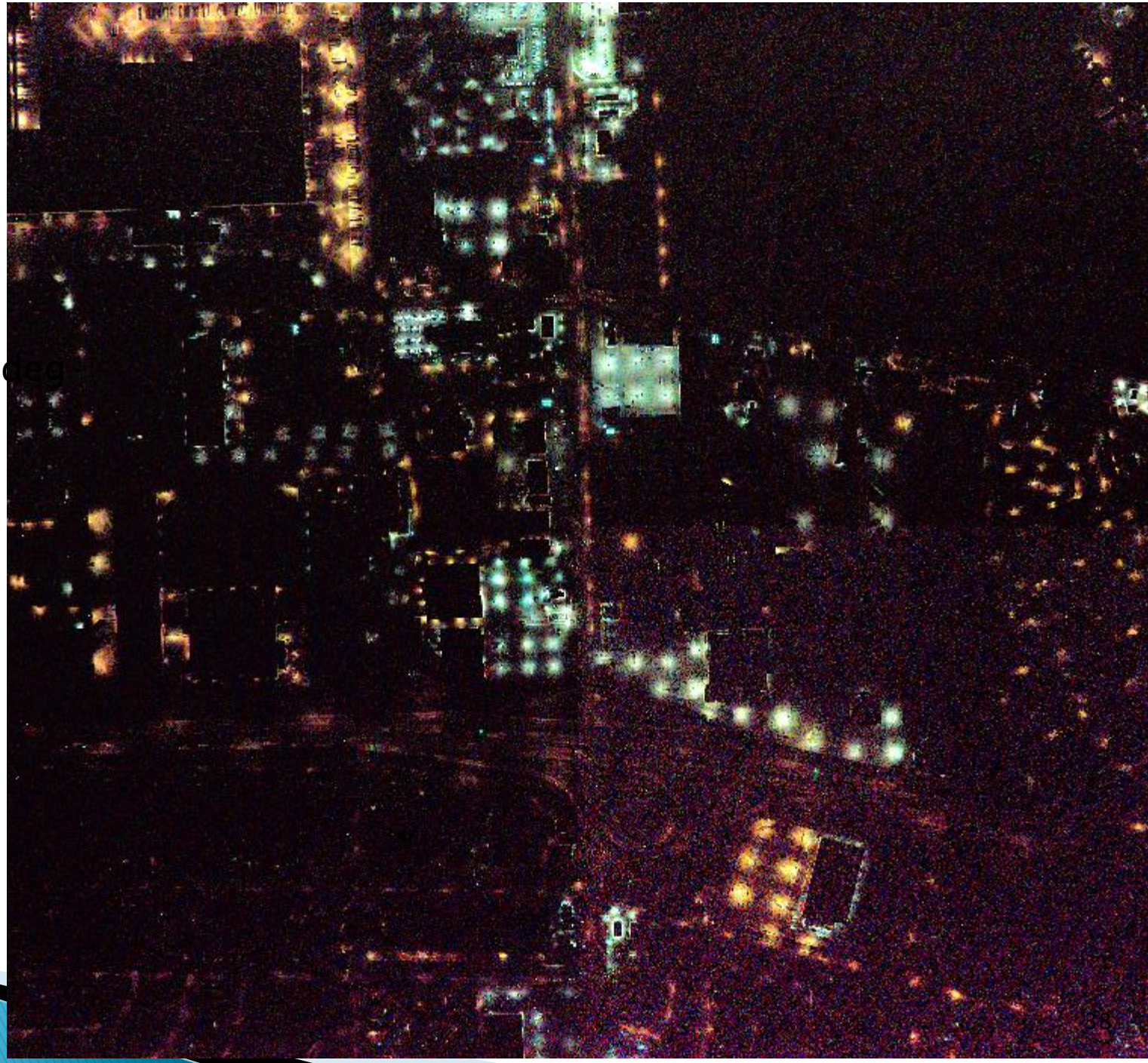
Standard
Pan Sharpened
Solar Elev. 10 deg

Standard
Pan Sharpened
Solar Elev. 10 deg
Zoom

Standard
Pan Sharpened
Solar Elev. 0 deg

Standard
Pan Sharpened
Solar Elev. 0 deg
Zoom

Standard
Pan Sharpened
Solar Elev. -10 deg



GREEN BAY
PACKERS
KICKOFF
KICKOFF
10 20 30 40 50 40 30 20 10
10 20 30 40 50 40 30 20 10

Pictometry Bayer Array Imagery

Sep 29, 2011 19:15 EDT
Solar Elevation: 0.09 Sunset19:16

Sep 29, 2011 19:19 EDT
Solar Elevation: -0.65 Sunset19:16

Sep 29, 2011 19:20 EDT
Solar Elevation: -0.85 Sunset19:16

Summary

- Both multihead camera cones and Bayer array framing cameras produce useful imagery under a wide range of conditions
  - Near zero solar elevation angle produces excellent no shadow imagery
- Approximately 40 minutes a day of increased imagery for many digital cameras using natural lighting
  - Road lighting and automobile illumination also provides reasonable imagery in many locations
- Atmospheric effects are more significant at low solar angles
  - Ozone absorption in the red can be significant
- Current systems are not fully optimized for this type of conditions
  - Radiometric calibration being used to optimize performance