Low Light Imaging

- Remote sensing of emissions sources that can be more readily observed in the absence of sunlight (at night or in atmospheric absorption bands).
- Remote sensing of reflected light from dim illumination sources – such as moonlight.
- May be based on a sensor with extremely low detection limits (e.g. DMSP-OLS).
- Or may be accomplished by collecting specific “daytime” sensor channels at night.
The U.S. Air Force Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) has a Unique capability to collect low-light imagery.

- Polar orbiting
- 3000 km swath
- 2.7 km ground sample distance (GSD)
- Two spectral bands: visible and thermal
- Nightly global coverage
- Flown since 1972
- Will continue till ~2012
Originally designed for the detection of moonlit clouds, the OLS detects lights from cities, towns, villages, gas flares, fires, and heavily lit fishing boats.
Sorting of visible band scene components:

The following features are identified in this step:

1. Lights
2. Glare
3. Sunlit data
4. Marginal data
5. Missing data
6. Bad scan lines

Creates flag image (.flg)
Geolocated Visible Band

Geolocated Thermal Band
Average DN of cloud free light detections
Eighteen Annual Cloud-Free Composites Available By FTP

http://www.ngdc.noaa.gov/dmsp/global_composites_v2.htm

Version 2 DMSP-OLS Nighttime Lights Time Series

The files are cloud-free composites made using all the available archived DMSP-OLS smooth resolution data for calendar years. In cases where two satellites were collecting data - two composites were produced. The products are 30 arc second grids, spanning -180 to 180 degrees longitude and -65 to 65 degrees latitude.

More Information

Download:

**NOTE:** Disk space required for compressed data is ~300 MB and uncompressed data is ~3 GB.

**NOTE:** These files are gzipped and added to tar files under linux. Winzip and some other windows utilities may convert newline characters in the data into a windows linefeed. To avoid this in WinZip go to -> Options -> Configuration -> Miscellaneous and uncheck the TAR file smart CRLF conversion.

<table>
<thead>
<tr>
<th>Year</th>
<th>Sat.</th>
<th>F10</th>
<th>F12</th>
<th>F14</th>
<th>F15</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td></td>
<td>F101992</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td></td>
<td>F101993</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td></td>
<td>F101994</td>
<td>F121994</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td></td>
<td>F121995</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td></td>
<td>F121996</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td></td>
<td>F121997</td>
<td>F141997</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td></td>
<td>F141998</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td>F141999</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>F142000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td>F142001</td>
<td>F152001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td>F142002</td>
<td>F152002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>F152003</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Stans
1992 = blue   1998 = green   2003 = red
1992 = blue
1998 = green
2003 = red

Dark North Korea and swirl of squid fishing boats offshore.
Beijing Region
1992 = blue
1998 = green
2003 = red
Detection of Power Outages From Hurricane Katrina

- Stable lights green
- Incoming lights red
- Incoming thermal blue (inversed)

http://dmsp.ngdc.noaa.gov/interest/katrina.html
Can DMSP Detect The Recovery of Lighting?

Gulf Coast USA

Radiance Calibrated Lights
2006=red
2003=green
2000=blue
New Orleans Dimmer in 2006

2006 = red
2003 = green
2000 = blue

2006 minus 2003
New Orleans Dimmer in 2006

2006 = red
2003 = green
2000 = blue

2006 minus 2003
Shortcomings of DMSP Lights

- Coarse spatial resolution
  2.7 km GSD
  5+ km GIFOV
- OLS lights are larger than sources on the ground
- “Overglow” surrounds bright sources
- No visible band calibration
- 6 bit quantitization
- Urban centers saturate in operational data
- No 3-5 um band for fires

Contrast enhanced to show dim lighting
User Requirements For Nighttime Lights

- Global coverage multiple times per year
- Spatial resolution sufficient to observe primary features found in cities and towns
- Detection of sparse development
- Estimation of annual rates of development
- More quantitization levels than OLS
- Calibration to radiance
- Thermal bands for cloud and fire screening
- Multispectral to discriminate lighting types
- Overpass time in 20:00 to 22:00 range
Crosswalk of User Requirements and the NPOESS VIIRS – Day/Night Band

- Global coverage - yes
- Spatial resolution sufficient to observe primary features found in cities and towns - ????
- Detection of sparse development – better than OLS?
- Estimation of annual rates of development - ????
- More quantitization levels than OLS - yes
- Thermal bands for cloud and fire screening - yes
- Calibration to radiance – yes
- Multispectral – no
- 20:00-22:30 local time overpass - no
Lights Not Detected With Nighttime Landsat
Combustion Detected in TM BAND 7 (2.2 um) Nighttime Landsat UAE

Band 6 - Thermal

Band 7 – 2.2 um
Combustion Detected in TM BAND 7 (2.2 um)
Nighttime Landsat UAE

Band 6 - Thermal

Band 7 - 2.2 um
Combustion Detected in TM BAND 7 (2.2 um)
Nighttime Landsat San Diego, CA

Band 6 - Thermal

Band 7 – 2.2 um
Use of Nighttime NASA ER-2 Data To Explore Options For Improved Remote Sensing of Nighttime Lights

- AVIRIS – LA (August 30, 2004)
- MAS - LA (August 30, 2004), Las Vegas, Laughlin, LA (September 27, 2004)
- Cirrus DCS digital camera Las Vegas, Laughlin, LA (September 27, 2004)
- Airborne video - Las Vegas, Laughlin, LA (September 27, 2004)
Nighttime AVIRIS – Long Beach Harbor

0.366 μm
MAS Data – Long Beach Harbor
AVIRIS Band 194 (2.21 um) Exhibits More Lighting Features Than Other Bands
AVIRIS Band 194 (2.21 um) Exhibits More Lighting Features Than Other Bands
Airborne camera data helps define both spatial resolution and detection limits.

Downtown Los Angeles.
One and a half meter resolution nighttime visible band imagery acquired from an altitude of 12 km by the NASA ER-2. Camera was radiometrically calibrated by NASA-ARC.
Cirrus camera mosaic of the Las Vegas flight lines. Minimum detectable radiance was $10^{-5}$ W/cm$^2$/sr.
What do moderate spatial resolution satellite observed nighttime lights look like?
Chicago
Digital camera image from the International Space Station.
Astronaut Don Pettit improvised an image motion compensation device for nighttime imaging of cities from the International Space Station.
Baltimore & DC

Digital camera image from the International Space Station.
El Paso, Texas
Digital camera image from the International Space Station.
Tokyo
Digital camera image from the International Space Station.
Simulation of a Range of Spatial Resolutions

1.5 meter

25m

50m

100m

200m

742m

VIIRS
Detection Limits of Tested Systems

Radiance for a single DN

- Landsat 7 Panchromatic Band
- Landsat 7
- MAS (Sept. 27, 2004)
- Cirrus DCS Camera (Sept. 27, 2004)
- DMSP F-15 OLS

Wavelength (um): 0.4 to 2.4

Radiance (watts/m^2sr/um): 1E-10 to 10
Detection Limits vs GSD

- DMSP-OLS
- NPOESS-VIIRS

Nightsat

- Landsat 7 Band 3
- Landsat 7 Pan

Detection Limit (watts/cm^2/sr/um)
Spectral Signatures of Lights
Spectra Collected for Nine Types of Lights

1. Liquid oil
2. Pressurized fuel
3. Incandescent (including quartz halogen)
4. Fluorescent
5. Mercury vapor
6. Metal halide
7. High pressure sodium
8. Low pressure sodium
9. Light emitting diode
Spectral Signatures of Lights
Summary

- Low light imaging can be used to detect fires and power outages.
- This has been demonstrated with DMSP-OLS data.
- There is substantial potential for nighttime fire detection with short-wave infrared data, however these bands are typically not collected at night.
- It is possible to distinguish major lighting types spectrally.
- A Nightsat mission proposal is being developed by NASA Ames Research Center and the Goddard Space Flight Center.