Preliminary study for improving the VIIRS DNB low light calibration accuracy with ground based active light source

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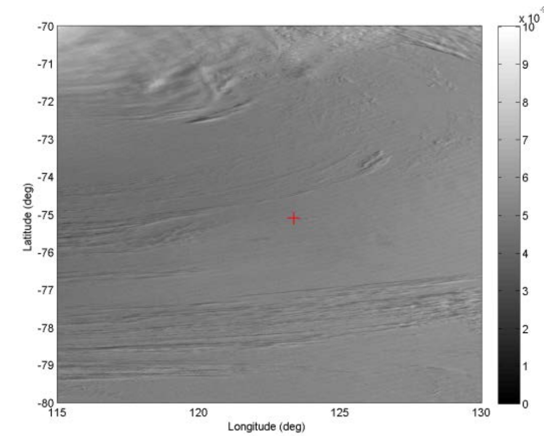
Background

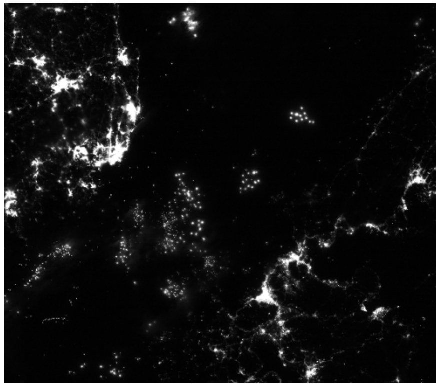
- Outstanding performance of the Suomi NPP VIIRS Day Night Band (DNB) enables a new era of low light imaging at night. High sensitivity to low lights has been demonstrated in numerous emerging applications: geophysical retrievals at night with lunar illumination, air glow, aurora, fishing boat rescue, etc. ;
- This unprecedented capability heavily relies on the onboard calibration, which unfortunately has one significant limitation: the solar calibration source is ~7 orders of magnitude brighter than the faint lights from fishing vessels; calibration transfer from LGS to HGS leads to great increase in uncertainties (from ~2% to ~30%);
- As a result, the absolute calibration accuracy for the low night light is no better than 15%. Also, the stability of the calibration at low light over time cannot yet be verified;
- Furthermore, for point sources such as fishing boats, both radiometric and spatial response of the DNB must be evaluated together, which is not possible with traditional methods with extended source.
- This leads to the unmet needs for more accurate active light sources at night to validate and monitor the DNB responses. This will improve the accuracy of low light measurements and enable more quantitative applications (physical, socio-economic, anthropogenic, etc.).

Suomi NPP VIIRS DNB Cal/Val

- Vicarious sites under lunar illumination
  - Dome C, Railroad valley, Deep convective clouds, etc;
  - Limitations: depends on lunar phase; lunar model accuracy, etc.; extended source;
- Are there existing point light sources?
  - Lights from bridges, oil platforms, power plants, flares, ships, and others;
  - Limitations: ground truth, stability, atmospheric effects, etc.



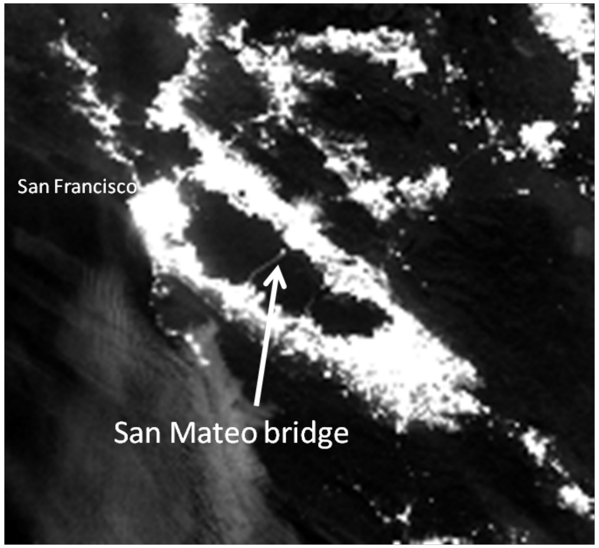
DNB observation of Dome C on 6/11/2014; local night , lunar phase angle -24.9 degrees

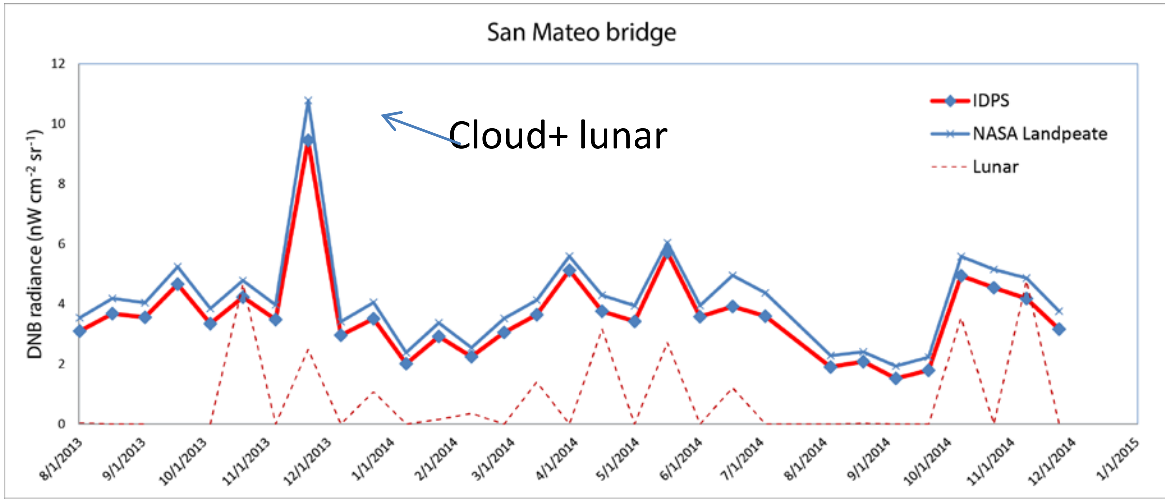


Night lights from fishing boats in the Sea of Japan

VIIRS DNB Stability Monitoring using Night Bridge Lights

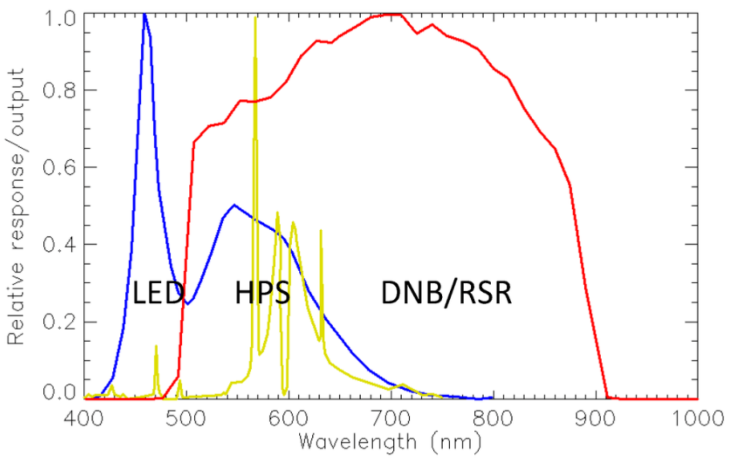
- Validation using San Mateo bridge lights (low light near Lmin of 3 nW/cm^2-sr)
- Time series shows NASA LandPeate is consistent with IDPS radiances
- Lunar has minimal impact in clear sky due to narrow bridge width, except in cloudy cases
- Further work expanded to oil platforms

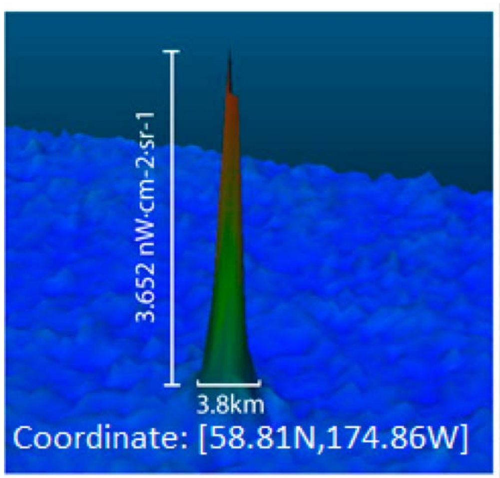




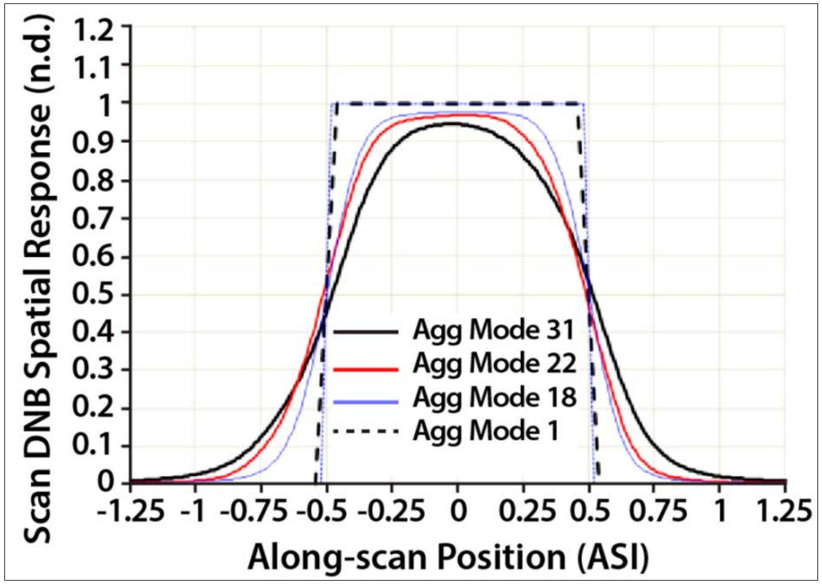
After Cao&Bai, 2014, Remote Sens.

Spectral, Spatial, and Radiometric Response of the VIIRS DNB





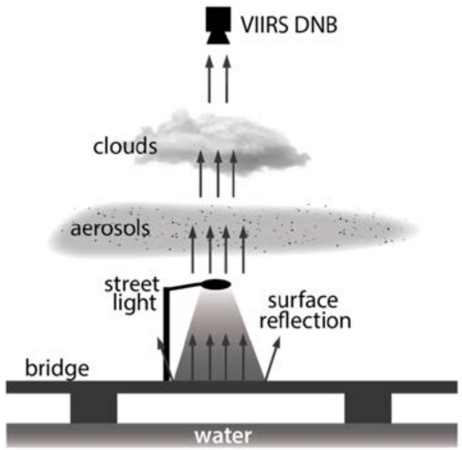
DNB view of fishing boat
(Cao & Bai, 2014, Remote Sens.)

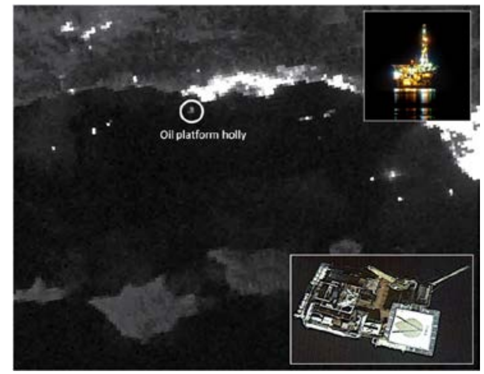


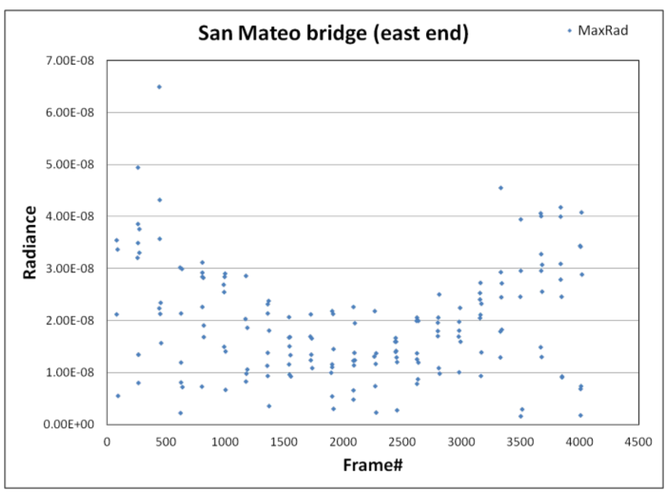
Courtesy of G. Lin

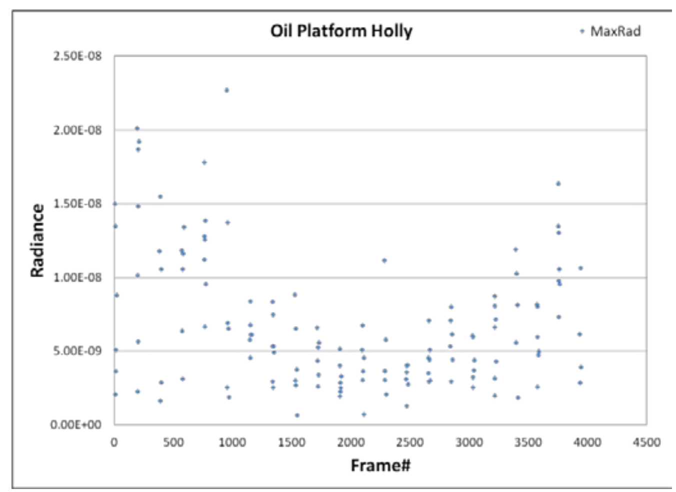
- DNB has 32 aggregation zones from nadir to edge of scan, each with its own calibration
- The response across the 32 zones are not the same and may not be linear at high scan angles
- Point spread function is also aggregation zone dependent, with a near square response at nadir

Radiometric Response versus Scan Angle









Lack of ground truth, instability of the background, inability to control the lights, are major impediments for using existing light sources for DNB cal/val

See poster 9607-77: Bai et al. Assessment of scan-angle dependent radiometric bias of Suomi-NPP VIIRS day/night band from night light point source observations

Active Nightlight Source SBIR Project

NOAA Small Business Innovation Research FY2015

Agency:	Department of Commerce
Program/Year:	SBIR / 2015
Solicitation Number:	NOAA-2015-1

Release Date:	October 15, 2014
Open Date:	October 15, 2014
Close Date:	January 14, 2015

- 8.1: Resilient Coastal Communities and Economies
- 8.2: Healthy Oceans
- 8.3: Climate Adaptation and Mitigation
- 8.4: Weather-Ready Nation
  - 8.4.1W: Monitoring Active Region Development on the Far-Side of the Sun
  - 8.4.2R: Ultrasonic Anemometers/Thermometers with Increased Spatial Resolution
  - 8.4.3D: Accurate Nightlight for Satellite Calibration for Weather and Climate Applications

New SBIR initiative to develop active nightlight for VIIRS DNB validation, working closely with NIST and NASA scientists

NOAA 2014 SBIR call for proposal Project goals

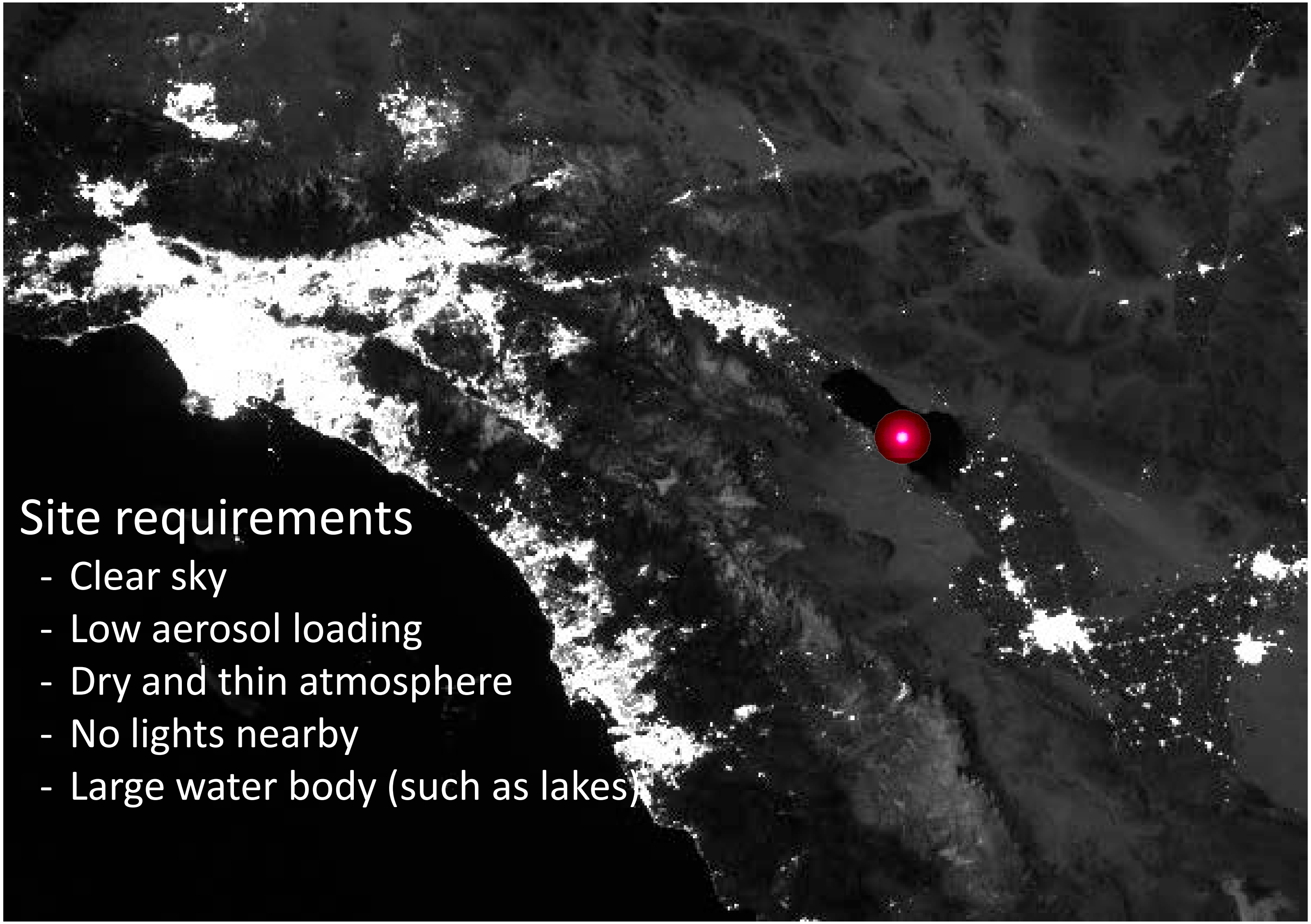
Accurate Nightlight for Satellite Calibration for Weather and Climate Applications (8.4.3D)

- Develop and deploy accurate active light sources (AALS) to selected calibration sites for the calibration/validation of the VIIRS DNB low light performance.
- The long term stability of the AALS, after characterizing and correcting any systematic drift, should be maintained at 1%, and the absolute accuracy of the light sources should be better than 5%.
- The AALS will only be turned on during the VIIRS DNB overpass at night around 1:30am local time.
- The light intensity should be higher than 3×10^{-9} W/cm^2·sr in order to be useful for DNB calibration.
- These light sources will be used as benchmarks for comparisons with objects of interest on the DNB imagery. Once the methodology is demonstrated at one site, it can be expanded to many other sites, potentially internationally.

Potential use of the Active Night Light Source

- VIIRS/DNB Cal/Val
  - Reduce absolute radiometric uncertainties
  - Improve calibration stability over time
  - Validate the scan vs. radiance bias across aggregation zones (especially useful for J1 VIIRS due to nonlinearity at high scan angles)
  - Geolocation/geometric validation at different scan angles
- Enables active remote sensing using passive instrument with well known ground truth
  - Use as a reference for existing point sources (boat light, etc)
  - Study night atmosphere (aerosol, cloud, etc)
  - Validate radiative transfer for point sources
  - Perform spectral studies using different color LEDs, Tungsten-Halogen, Incandescent, etc. as source.
- Collaborate with UAS programs to support cal/val, and nightlight remote sensing

Ideal Sites

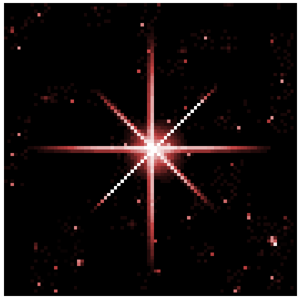


Site requirements

- Clear sky
- Low aerosol loading
- Dry and thin atmosphere
- No lights nearby
- Large water body (such as lakes)

Major Challenges: Scintillation

- Terrestrial scintillation (twinkling), is the variations in apparent brightness or position of the light source viewed through the atmosphere.
- Factors:
  - Point source
  - Atmospheric path length
  - Air density/temperature gradients



- Mitigations:
  - Select sites with thin atmosphere
  - TDI to reduce scintillation (time scale)
  - Conduct further research to optimize the light source spectral, spatial, and radiometric characteristics
  - Leverage previous scintillation studies (Gbur 2014; Gu and Gbur, 2012)

Summary

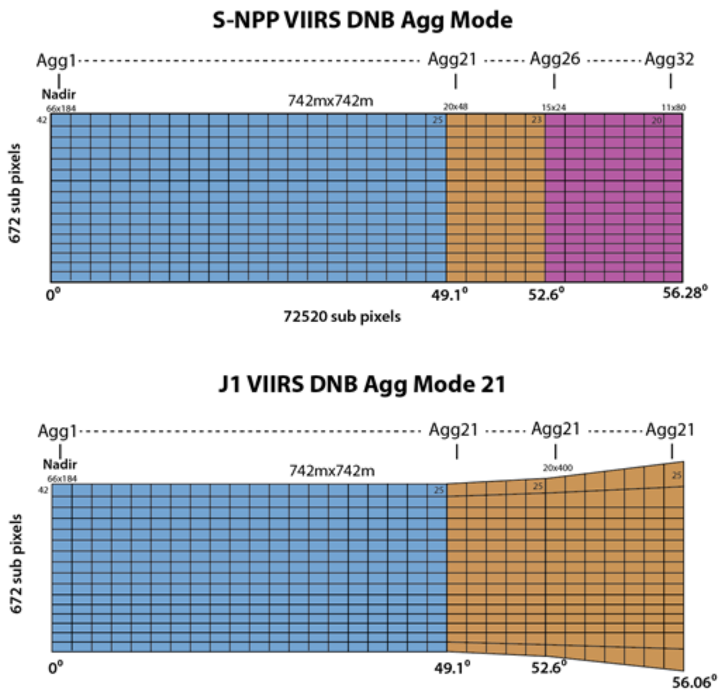
- Low light imaging radiometry at night is an enabling capability of the VIIRS DNB, but the calibration accuracy needs to be further improved;

- Solar diffuser calibration is good for day time observations but falls short for night lights due to increased uncertainty in calibration transfer;

- Studies of existing night light source is encouraging that a ground based source can be developed for improved accuracy;

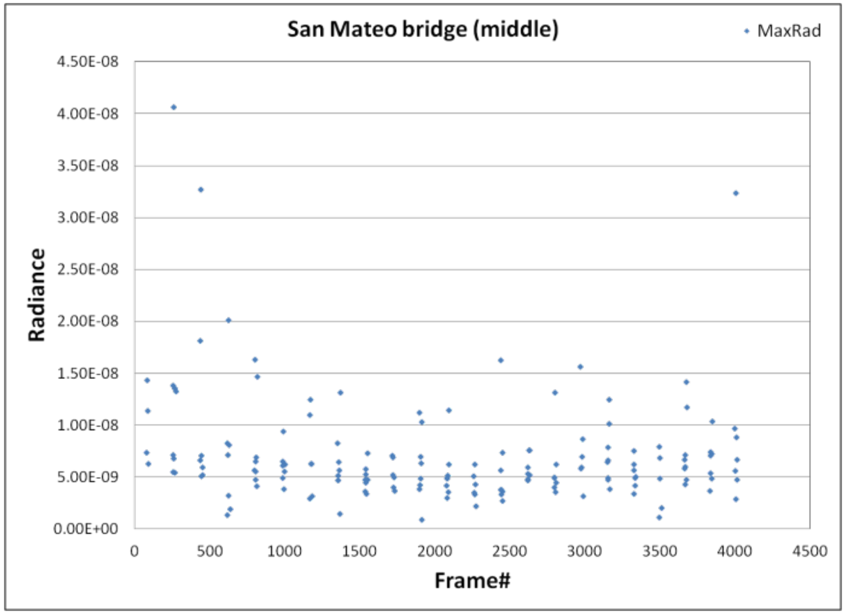
- NOAA 2015 SBIR project is currently being developed, and we will work together to address the challenges.

Backup slides



VIIRS DNB aggregation scheme for NPP and J1
(Notional drawing, not to scale, subject to change)

Backup slide



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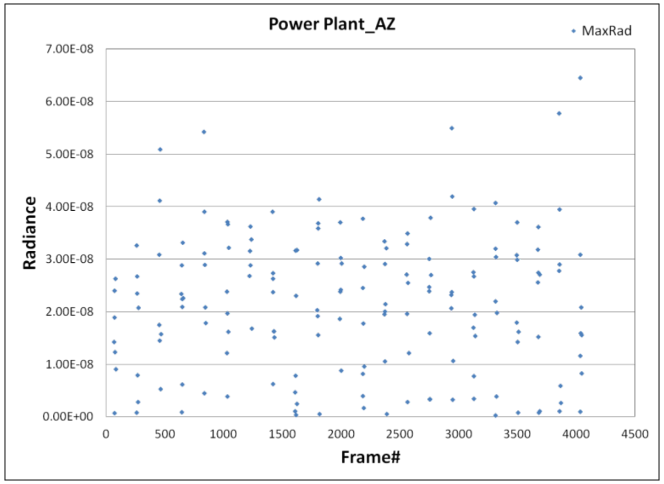
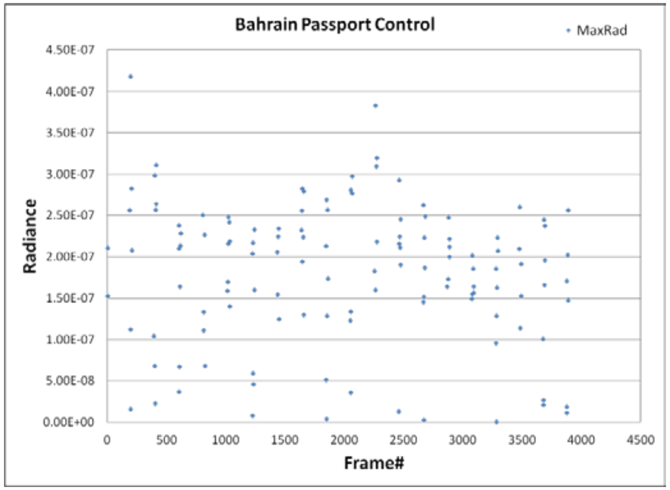
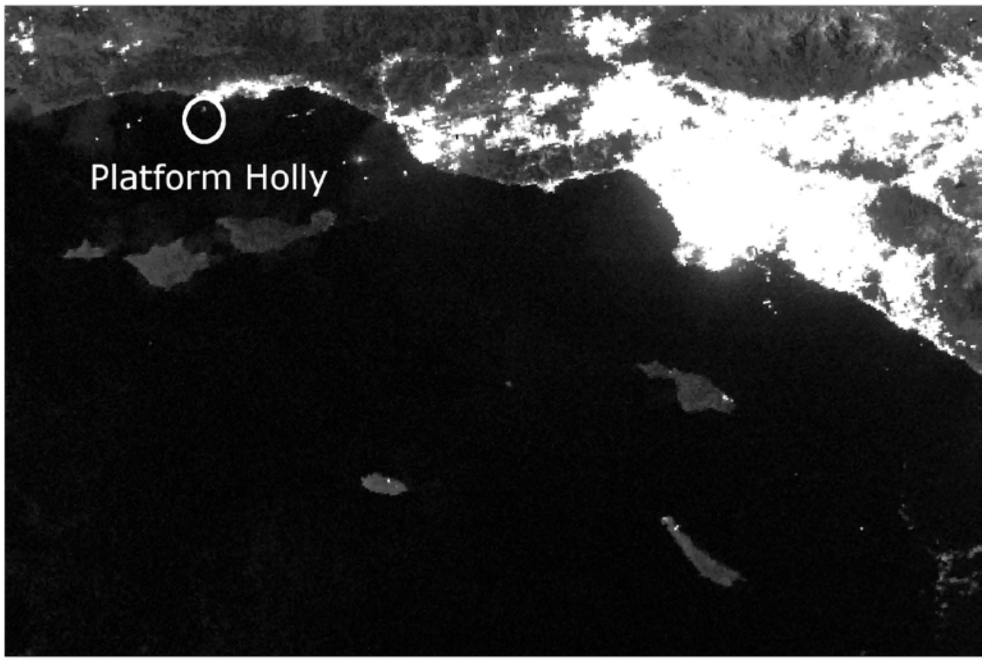


Radiance vs. scan angle for the power plant in Arizona

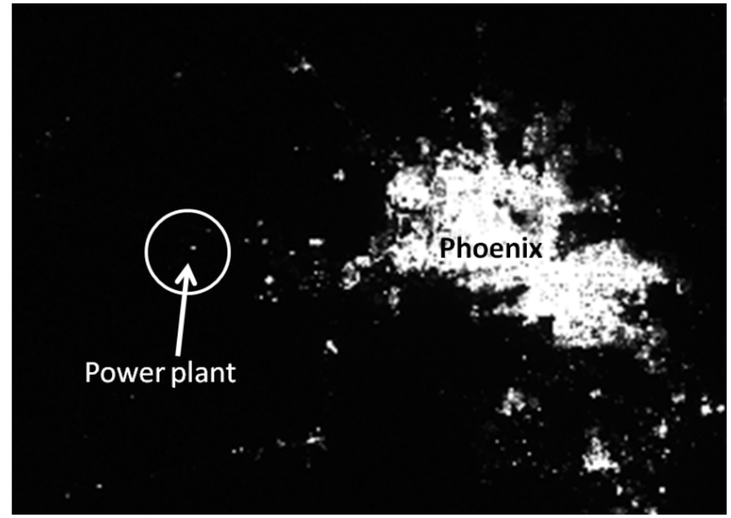


Radiance vs. scan angle for the passport control of Bahrain

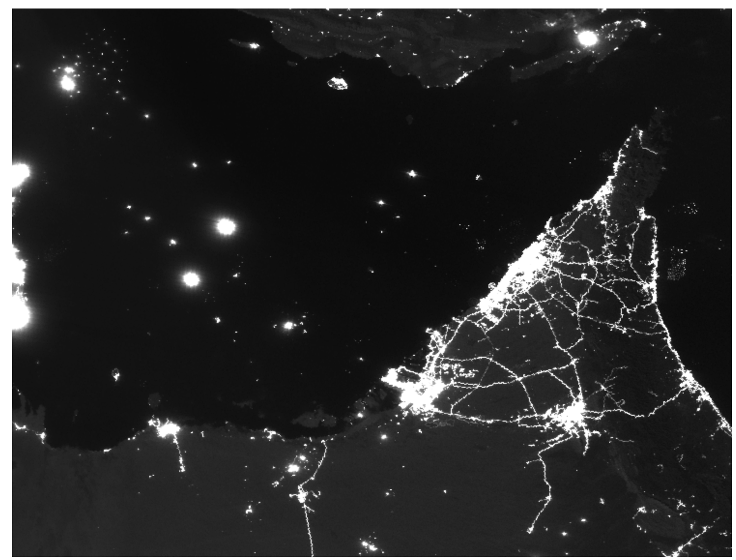
VIIRS DNB Point Source Evaluations



DNB image of the oil platform Holly



DNB image of the power plant near Phoenix, Arizona



Gas flares in the Persian gulf