VIIRS Day/Night Band (DNB) Trending

Changyong Cao

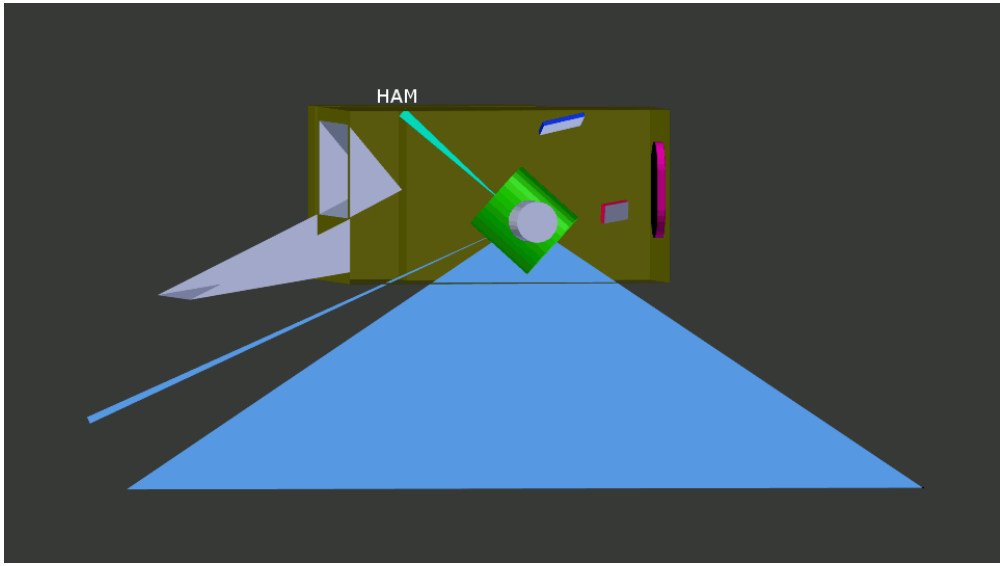
VIIRS SDR Team Lead
NOAA/NESDIS/STAR

ICVS Annual Meeting, May 8, 2015

The VIIRS Onboard Calibration

Challenge 1: complex calibration system

- VIIRS Onboard calibration relies on the solar diffuser (SD), solar diffuser stability monitor (SDSM), space view (SV), and the blackbody (BB).
- Calibration is performed per band, per scan, per half angle mirror side (HAM), and per detector.
- VIIRS DNB onboard calibration follows a similar scheme to that of the reflective solar bands (RSB), with the following exceptions:

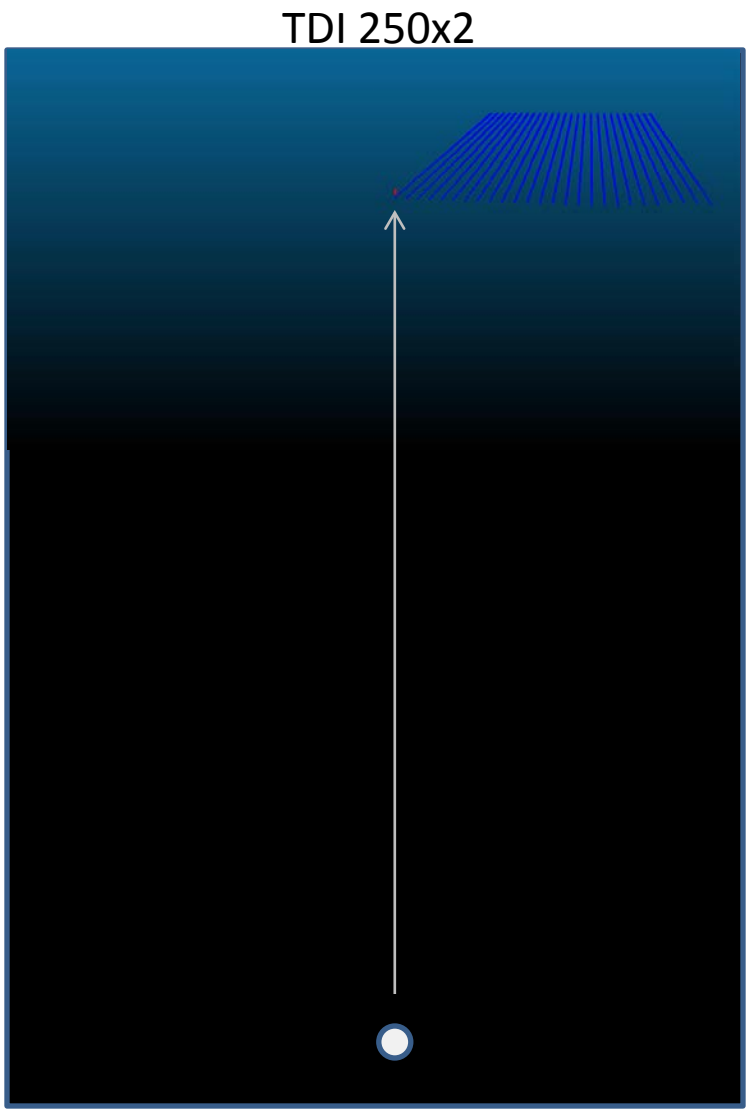


- Only the low gain stage(LGS) is calibrated using the solar diffuser; then transferred to the medium and high gains based on gain ratio
- DNB space view cannot be used as offset because it's "too bright". Blackbody and solar diffuser night views are better but also have issues
- Operationally the offset is determined using earth view during new moon in the darkest part of the pacific ocean (with airglow removed)
- Each DNB scan (LGS) only calibrates one of the 32 aggregation zones. As a result, a complete calibration involves at least 36x2 scans

The Concept of Time Delay and Integration (TDI)

Challenge 2: complicated onboard aggregation scheme

- TDI at subpixel level is the key to the DNB low light imaging
- With the High Gain FPA of 250x672 CCD arrays, an earth target is sampled 250 times by each CCD to increase the signal
- Redundant HGA and HGB averaging further improves the signal
- Subpixel aggregation in both cross scan and along track directions with 32 aggregation zones on each side of nadir

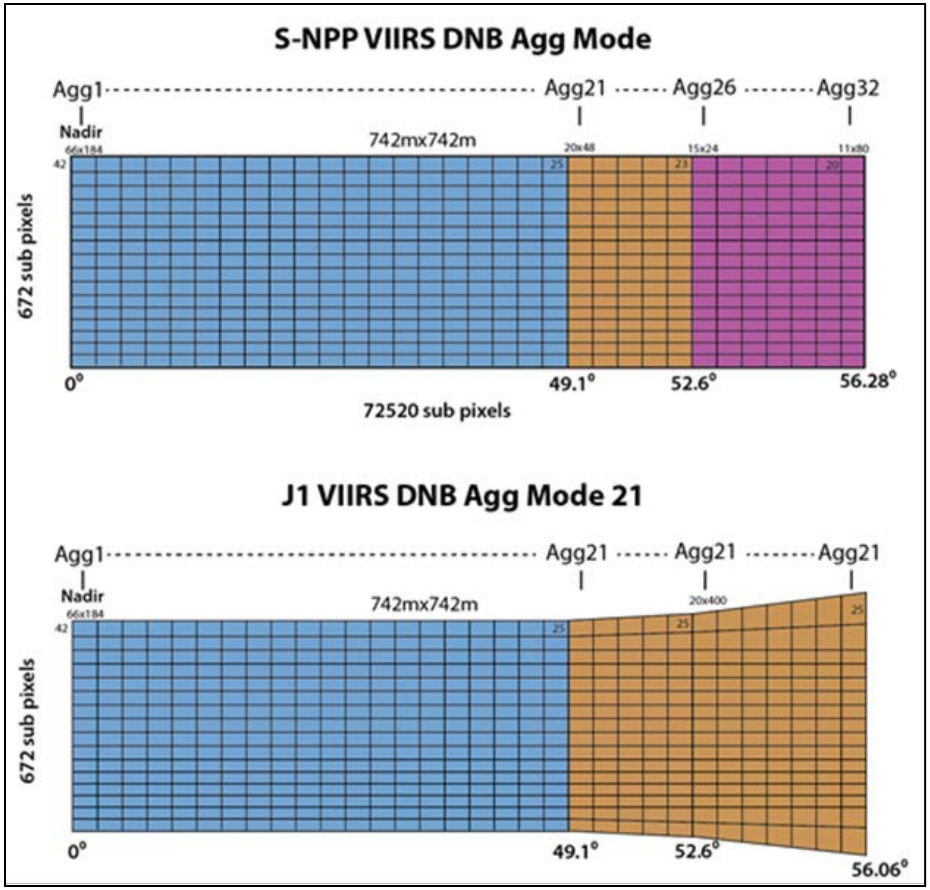


J1 VIIRS SDR Algorithms (Waiver Mitigation)

Challenge 3: additional complexity due to J1 Waivers (scan angle dependency)

- **DNB nonlinearity at high scan angles (Requires change in Aggregation Mode)**
  - Baseline is Agg Mode 21
    - Radiometric calibration:
      - » Spacecraft level testing in progress
      - » Develop LUTs; update later
      - » Do not expect code change
    - Geolocation (requires code change)

      In progress, supported by NASA/Geo, Aerospace, and STAR
- **Other changes are considered STAR research capabilities initially, and can be transitioned later**
  - DNB other agg modes (Agg21/26; dual calibration; pixel based cal. etc.)
  - SWIR nonlinearity
  - Saturation handling

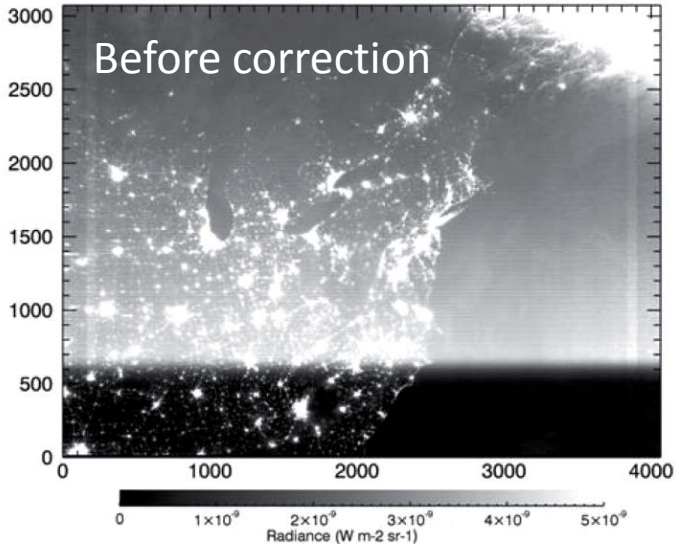


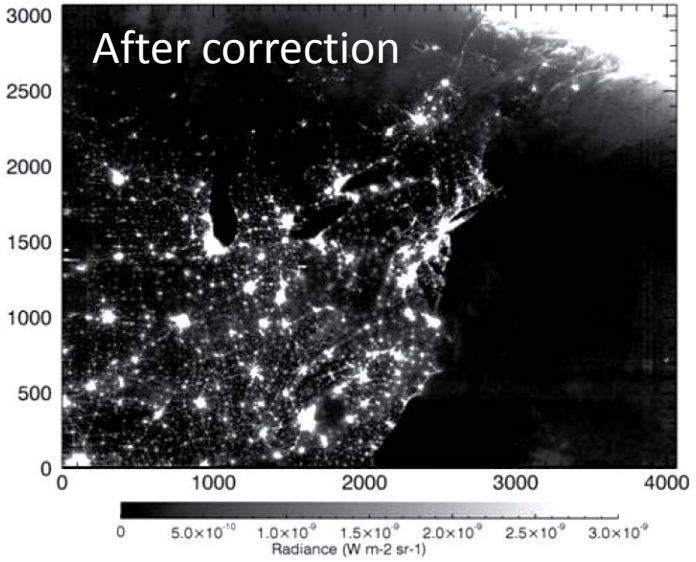
Notional drawing, not to scale; all values subject to change

DNB Straylight Correction

Challenge 4: Straylight

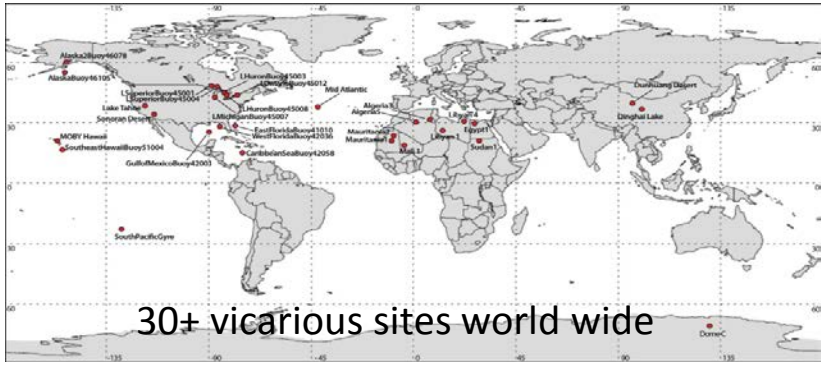
- Straylight intensity at Lmin (minimum detectable radiance)
- Empirical correction based on earth view data analysis
- Run the software in Matlab & generate Look Up Table (LUT) monthly (operational since Aug. 2013)
- Correction very effective for most data, except small residuals near South Pole
- Correction restores the correct radiances

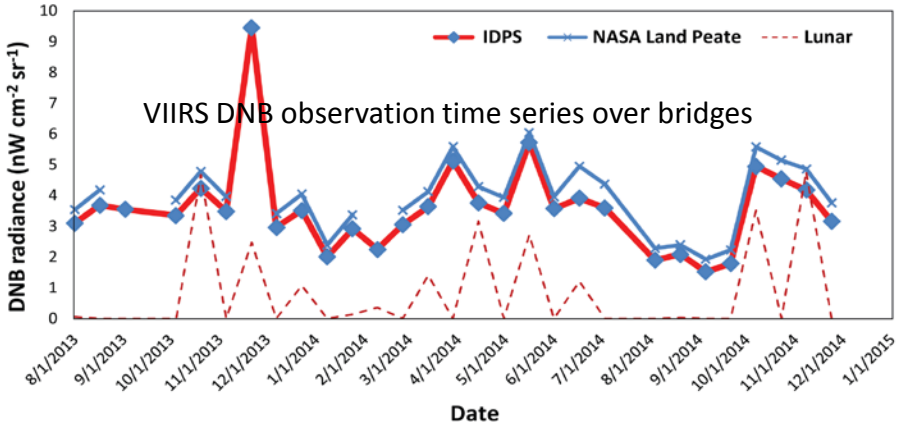


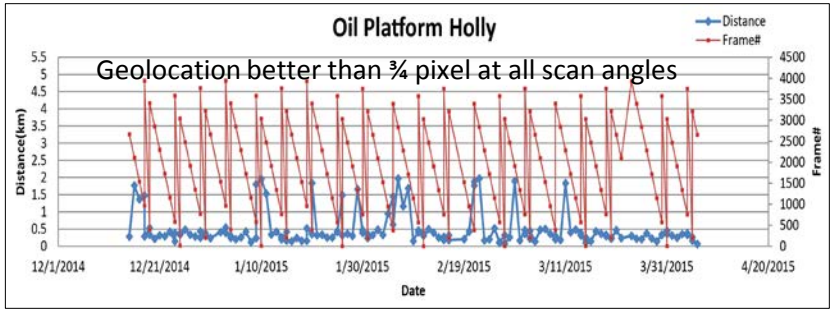


VIIRS Performance at 30+ Vicarious Sites Worldwide

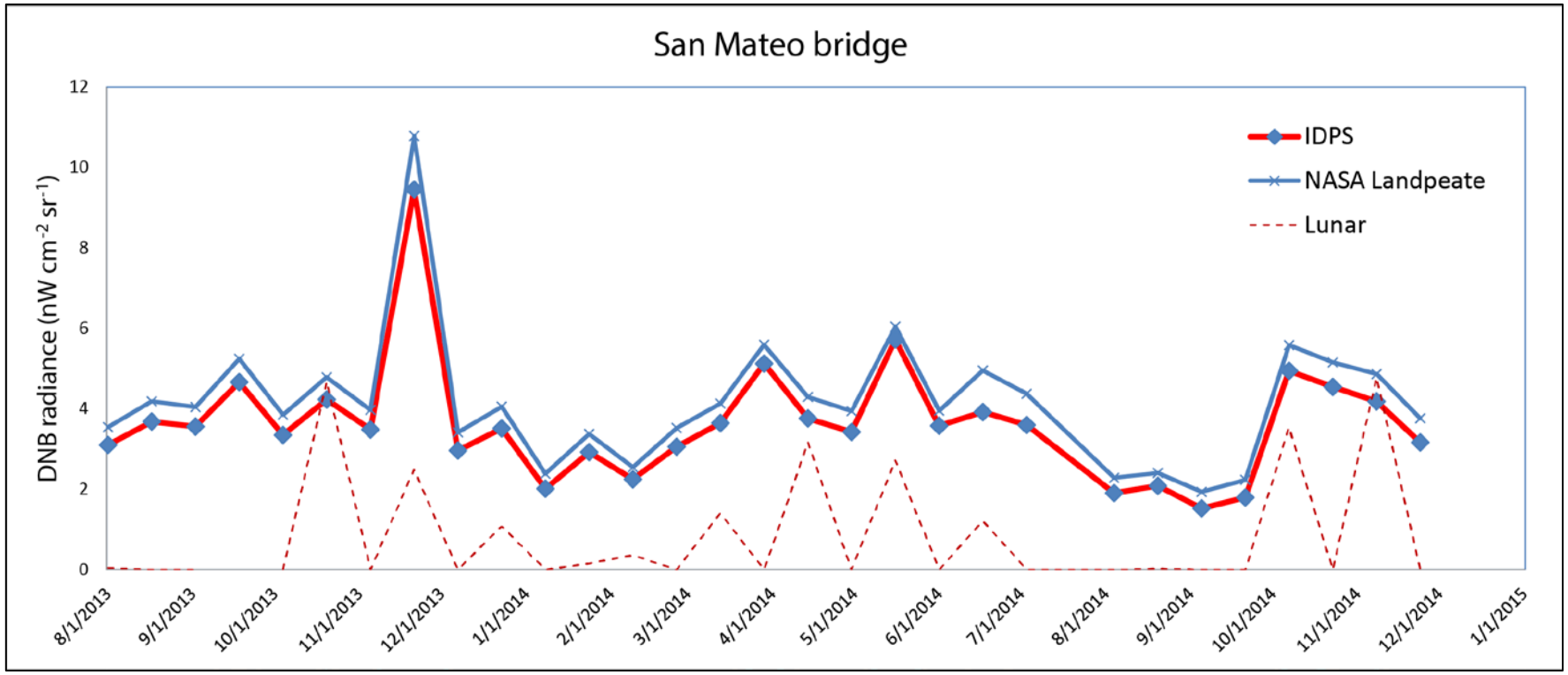
- VIIRS calibration is monitored at 30 vicarious sites with time series analysis for all bands;
- STAR developed novel techniques using night lights from oil platforms, and bridges for DNB calibration stability monitoring with quantitative analysis and in situ data;
- Geolocation and geometric performance monitoring using nightlights and thermal chips are currently being developed;
- VIIRS is gradually being recognized as the new on-orbit standard replacing MODIS in the reflective solar bands.







VIIRS DNB Stability Monitoring using Night Bridge Lights

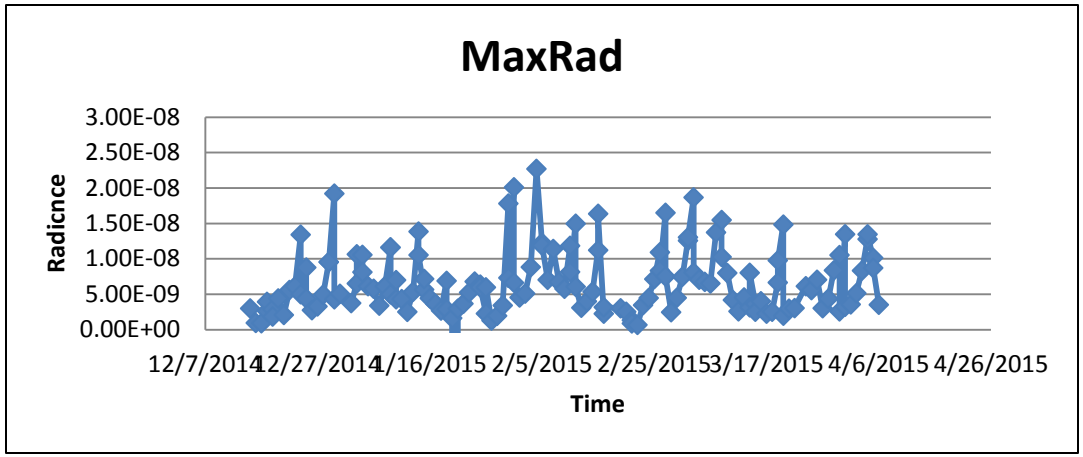


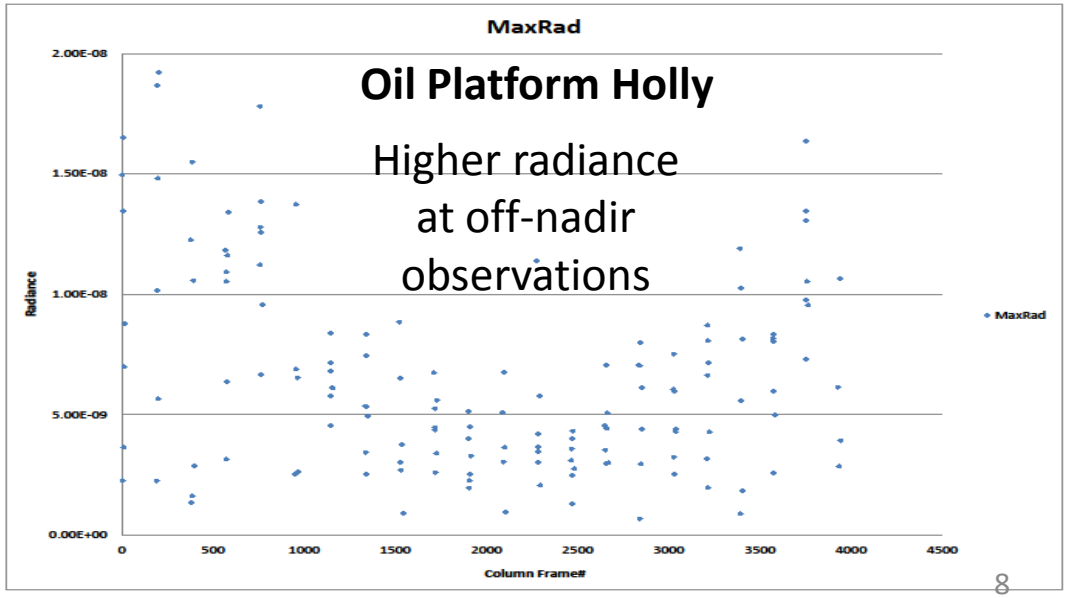
- Validation using San Mateo bridge lights near Lmin
- LEDs have replaced traditional light bulbs according to California Dept. of Transportation
- LandPeate ~15% higher than IDPS radiances
- Lunar has minimal impact in clear sky due to narrow bridge width
- Lunar has large impact in cloudy cases
- Further work expanded to oil platforms

Cao and Bai, Remote Sensing, 2014

Suomi NPP VIIRS DNB Radiance
Scan Angle/Frame vs. Radiance

- Raidometrically not as stable as bridge lights at oil platform holly
- More suitable for geolocation validation
- Scan angle vs. radiance show correlation
- Possible causes:
  - Atmosphere (requires RTM)
  - MTF
  - Time of day
  - RVS
- Useful for diagnosing the J1 aggregation mode





Overview of Satellite Geolocation Components

VIIRS (or other instrument)

Coordinate transformation

DNB Focal plane (timing& aggregation)

Aft optics

Instrument

Pixel Specific Exit View Vector

Function call to common geo:
ellipIntersect(outPt,inst2SC,exitVec, dlat,lon,satazm,satzen,range)

JPSS or any satellite

COMMON GEO

Spacecraft

Orbital

ECI

ECEF(ECR)

Geodetic

feedback

GEO VALIDATION

- SGP4 Off nadir (for agg zones)
- GCP/Maps/Ground truth
- DNB night light point sources (Bridge/Power Plant/Oil platforms/borders/Barrier Island)

Geolocate each pixel

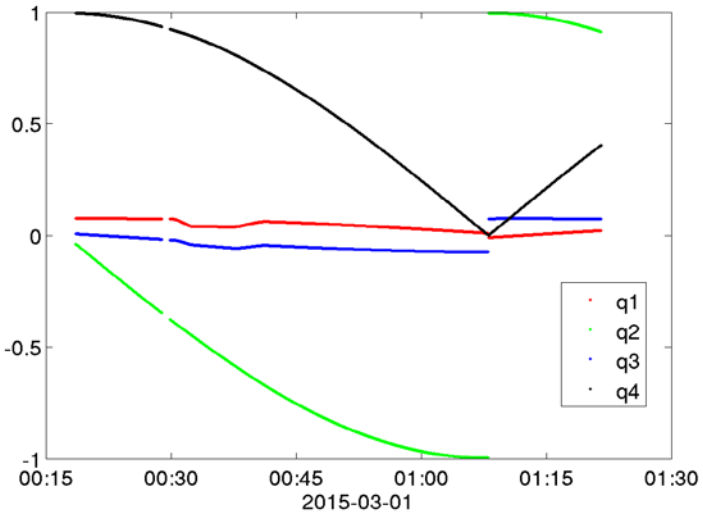
ADCS

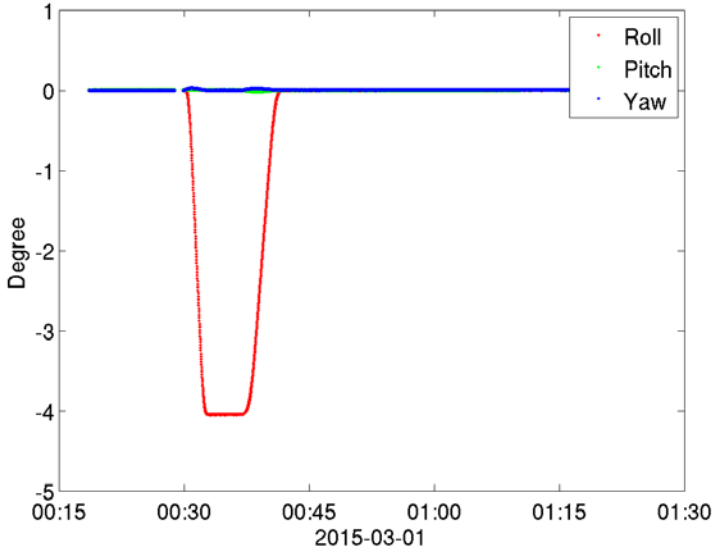
Pos/Vel/Quaternion (RPY)

Attitude Determination & Control System (ADCS)

SGP4

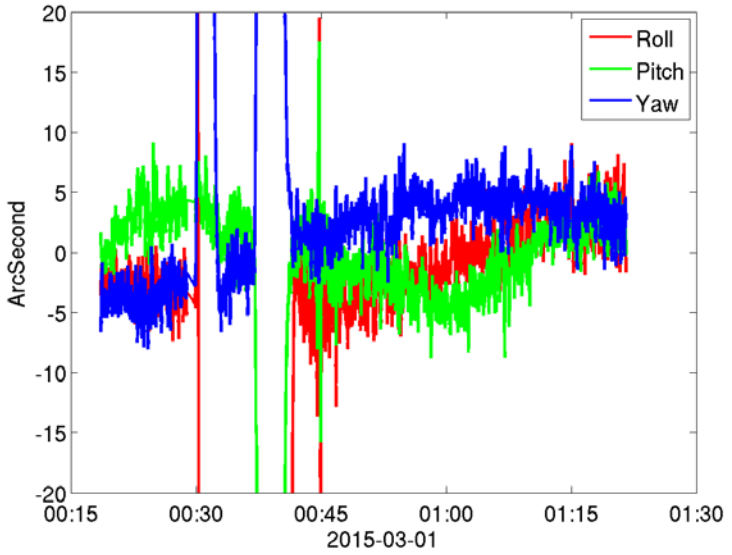
Common Geo
Quaternion and Roll/Pitch/Yaw Example





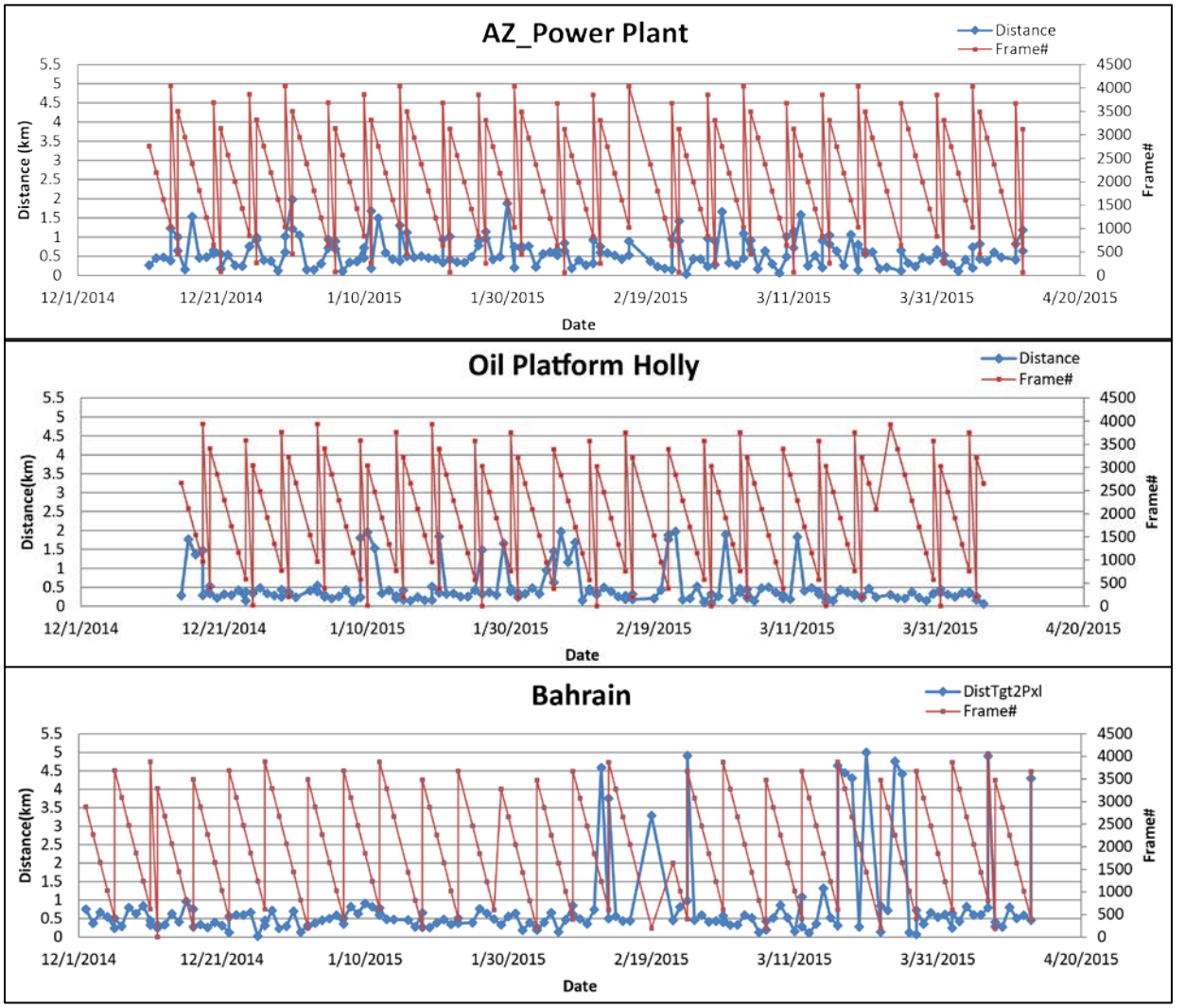
Satellite Maneuver to look at moon during 00:28:52-00:41:53.

Modified ADL code to output Quaternion and RPY



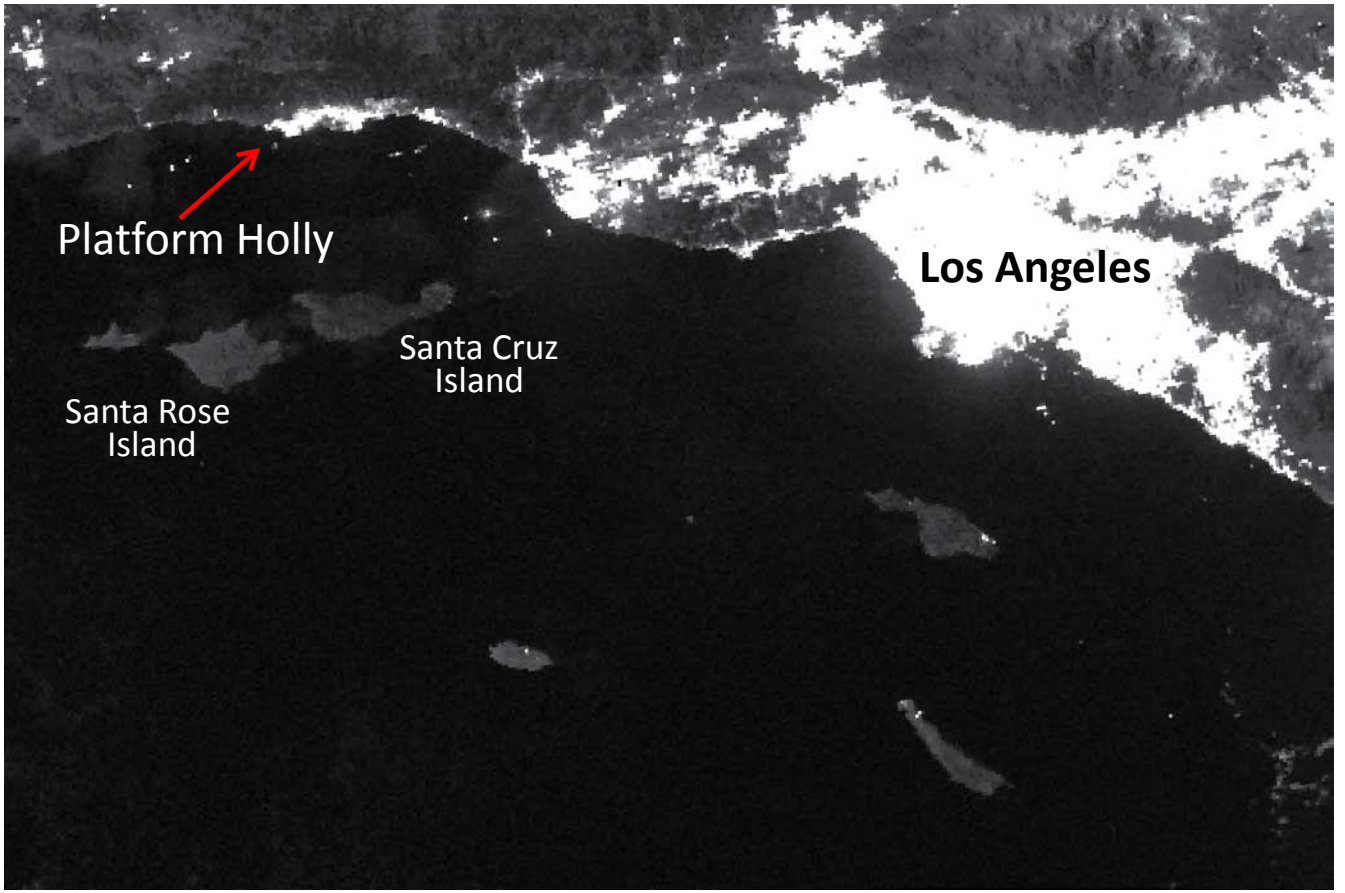
Suomi NPP VIIRS DNB Geolocation Validation Site Time Series

- Sites include power plants, oil platforms, gas flares, volcanoes, and bridges;
- Time series at these sites developed since Dec. 2014;
- Single pixel geolocation error uncertainty about ½ pixel;
- Error not correlated with scan angle or frame number;
- Further work needs to perform cloud screening.



Using Oil Platform Holly for VIIRS DNB Monitoring

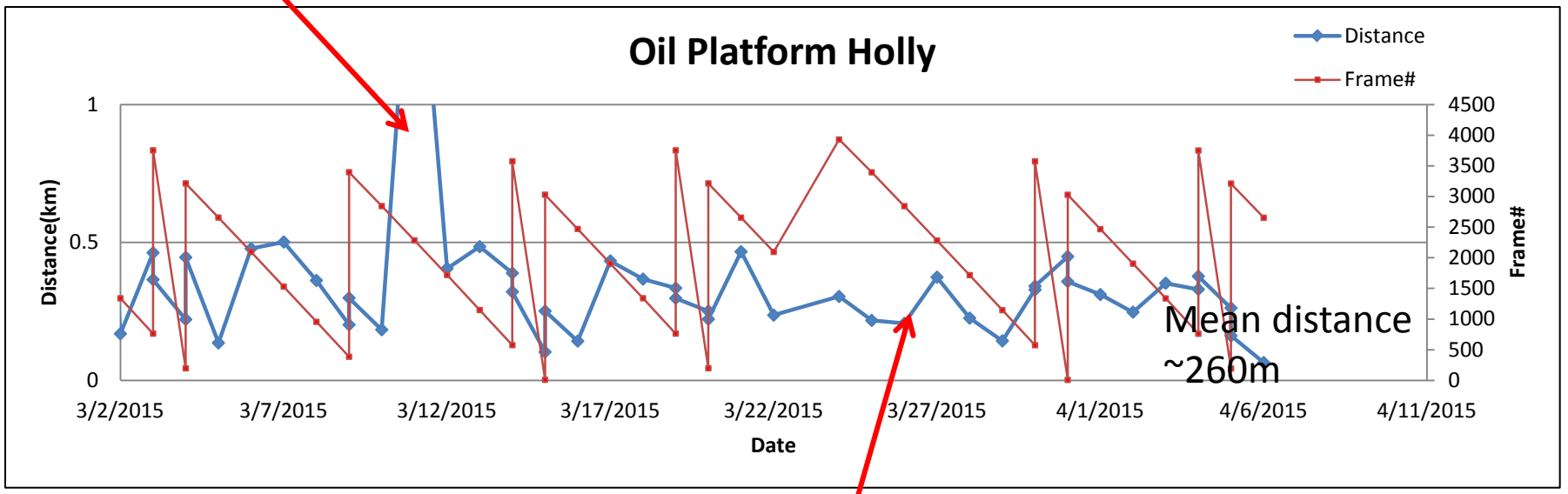
- Relatively stable nightlight
- Single DNB pixel
- Isolated in the ocean near Los Angeles
- Most useful for geolocation validation and radiometric stability monitoring



DNB_npp_d20150102_t0939178_e0940420

Oil Platform Holly Geolocation Validation

Cloud + moon

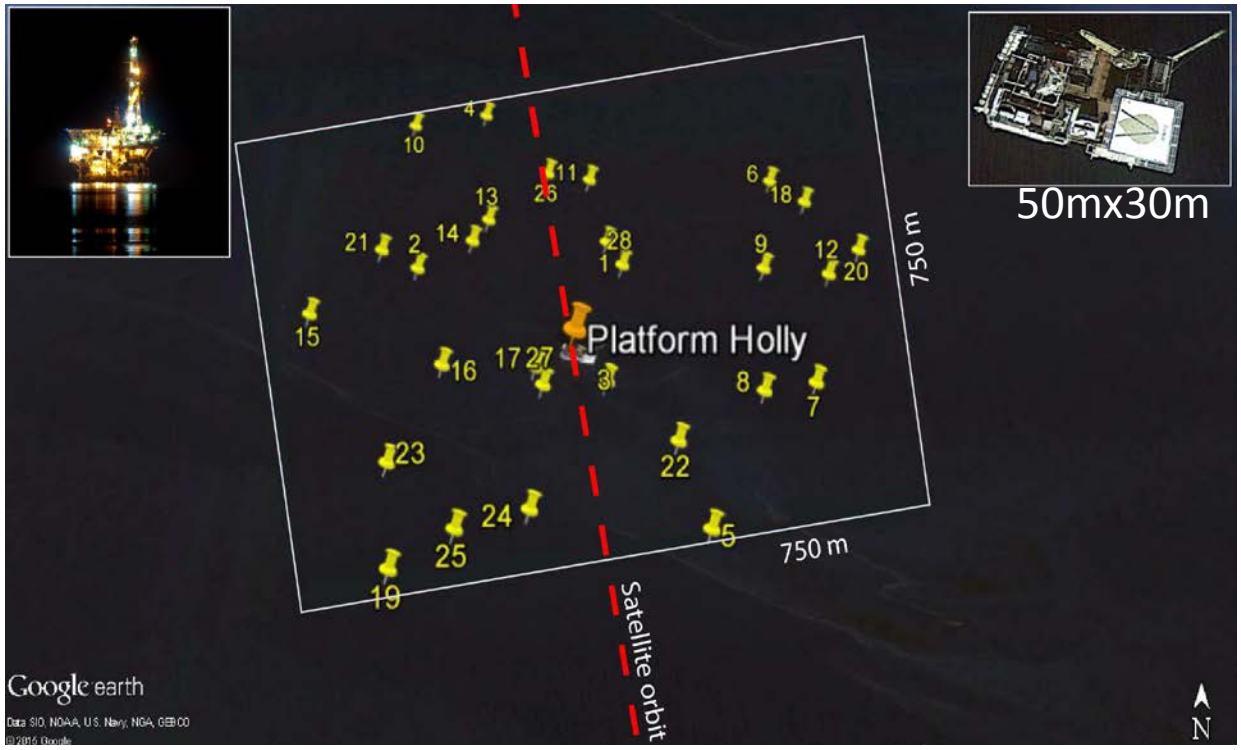


No systematic error related to scan angle/frame#

- Capability most useful for J1 VIIRS Agg mode geolocation validation
- Will be expanded to include gas flares

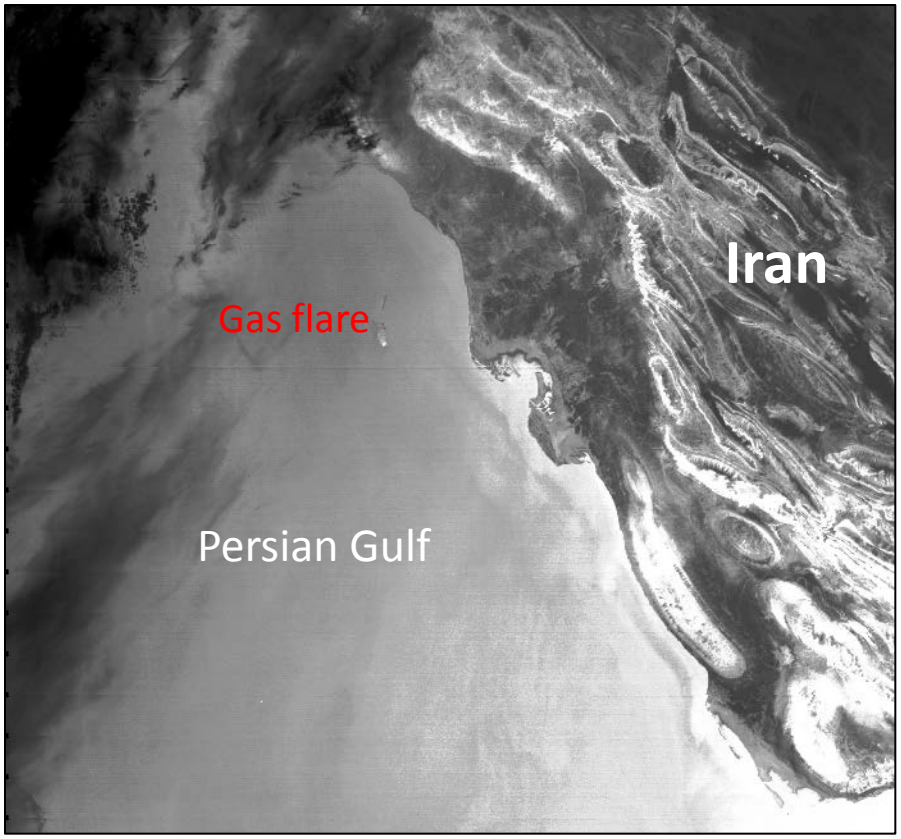
Oil Platform Holly Geolocation Validation (Spatial distribution)

- 28 samples from March-April, 2015
- All within 750x750m pixel
- Centered around the Oil Platform Holly
- Statistics:
  - **Mean bias: 29m** (or <4% of a pixel)
  - N Samples: 28
  - Single point uncertainty: ½ pixel
  - Larger errors when cloudy

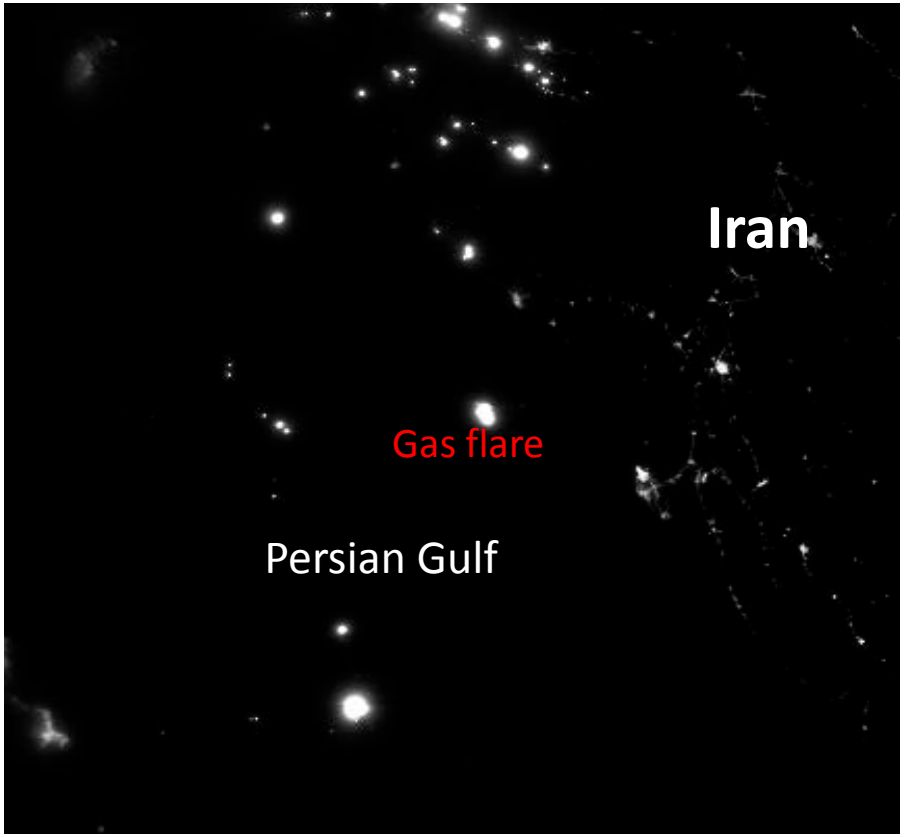


28 Samples from March-April 2015, all within one pixel

Going forward: DNB monitoring using Gas Flares & Thermal Chips



GIMGO-SVI05_npp_d20150427_t2210416_e2216220_PersianGulf_crop

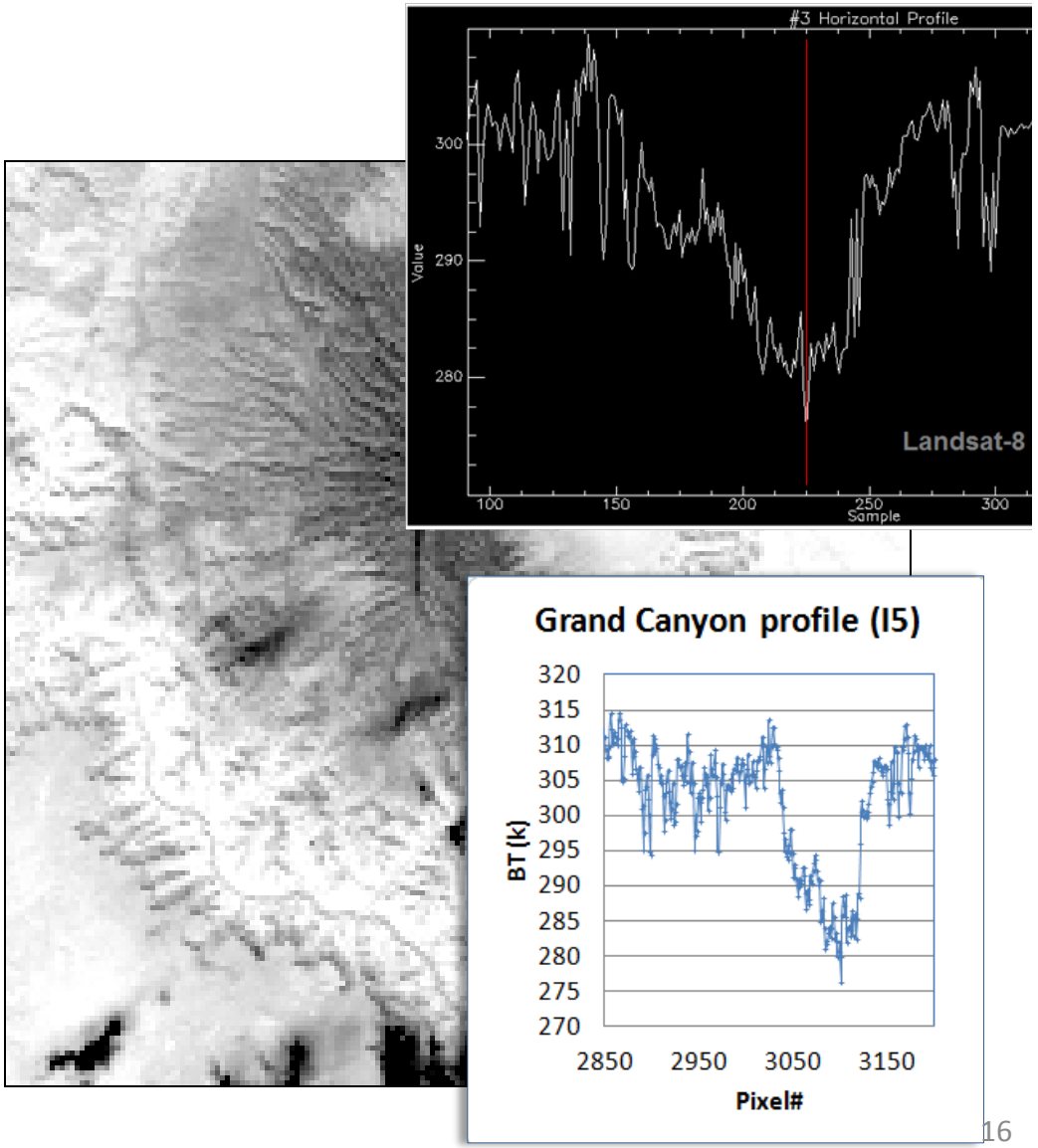


GDNBO-SVDNB_npp_d20150427_t2210416_e2216220_PersionGulf_crop

- In addition to radiometric and geolocation monitoring, gas flare can also be used for band to band coregistration monitoring
- Need to find out:
  - How long the flares last; stability; size; ownership, etc.

Suomi NPP VIIRS Thermal Chips for Geolocation Validation

- Using imagery and LandSat 8 bands to develop thermal chips;
- Unique land features include the Grand Canyon, with delta T near 40 degree C within a few pixels;
- Other features include gas flares, volcanoes, coast lines, and islands;
- Using IASI/CrIS for spectral matching;
- Complement geolocation chips for RSB bands.



Active Nightlight Source SBIR Project

NOAA Small Business Innovation Research FY2015

Agency:	Department of Commerce	Release Date:	October 15, 2014
Program/Year:	SBIR / 2015	Open Date:	October 15, 2014
Solicitation Number:	NOAA-2015-1	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

Summary

- STAR VIIRS SDR team has made great progress developing DNB radiometric and geolocation trending capabilities:
  - Radiometric trending using bridge lights and oil platforms;
  - VIIRS DNB geolocation validation using point sources at different scan angles;
  - Capabilities will be extremely useful for J1 VIIRS for aggregation mode validation;
  - Will expand the trending capability at more locations worldwide, including gas flares & thermal chips;
  - Recommend ICVS to include spacecraft roll, pitch, yaw plots with finer resolution and value range for attitude monitoring.