SNPP OMPS performance and lessons learned

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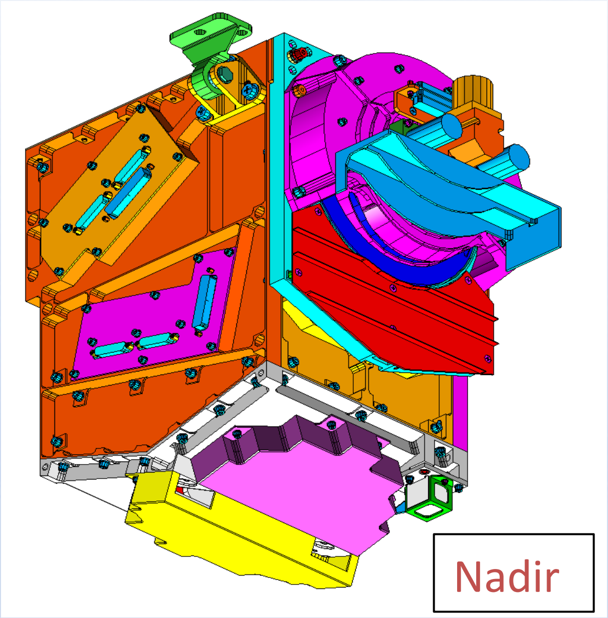
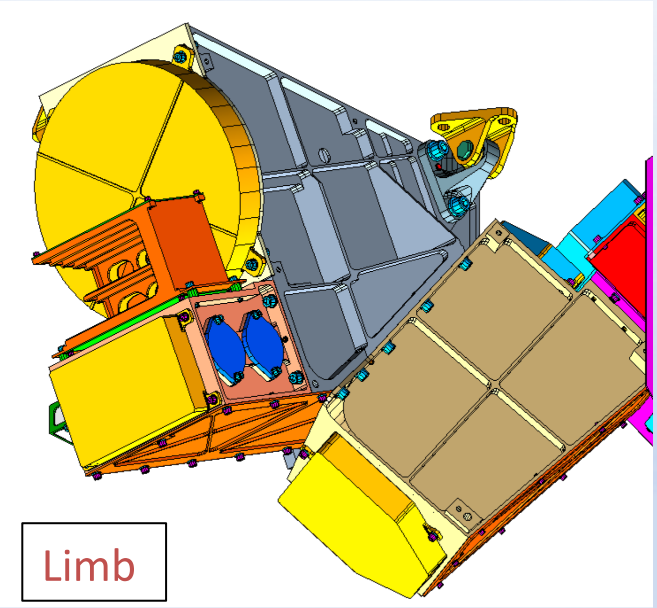
Ozone Mapping and Profiler Suite

Launched: Oct., 2011

The OMPS instruments





Images: courtesy of Ball Aerospace

Nadir Mapper & Profiler

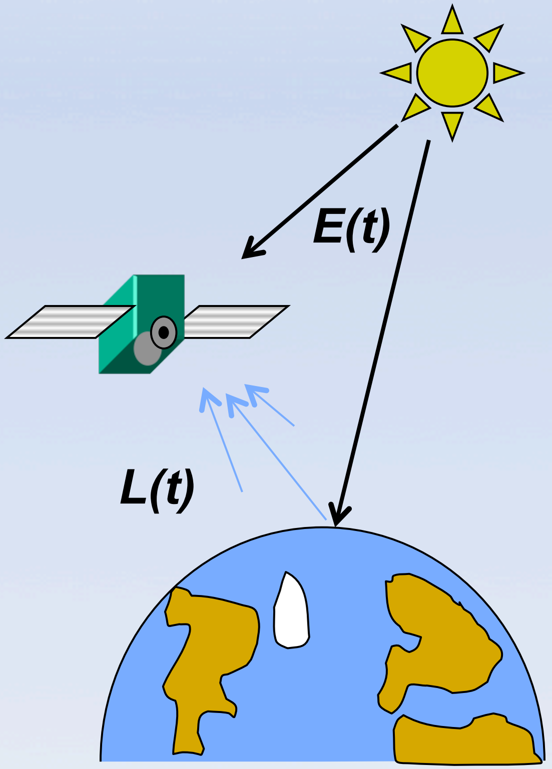
- 2 Grating spectrometers w/CCD detectors
- Heritage: TOMS, SBUV, GOME, GOME-2, OMI
- Wavelength: 250 –380 nm
- Spectral sampling .41nm; resolution 1 nm
- Push broom 110° FOV telescope
- Horizontal resolution: 50 km & 250 km
- Detectors: 0.25 megapixel CCD at -30 & -45 ^{o}C

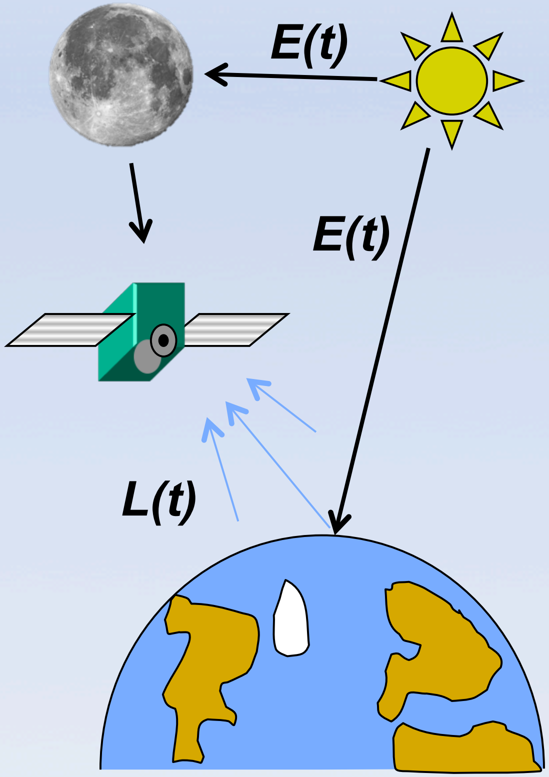
Limb Profiler

- Prism spectrometer with CCD detector
- Heritage: SOLSE / LORE, OSIRIS, SCIAMACHY, GOMOS
- Wavelength: 280 –1000 nm
- Spectral resolution: 1 - 30 nm
- Vertical Sampling: 1 km
- Vertical resolution: ~2 km
- Detector: 0.25 megapixel CCD at -45 ^{o}C

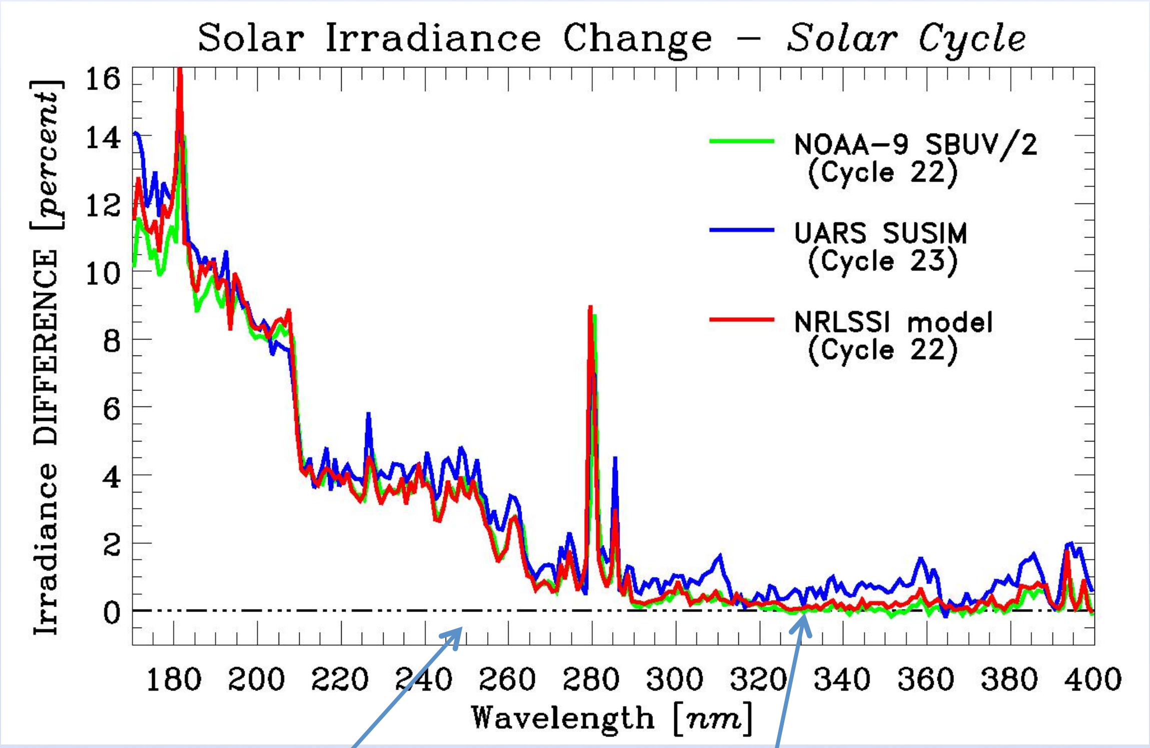
Definition of “BUV technique”

An approach for measuring the Earth’s directional reflectance (top of the atmosphere) by comparing to a solar reflector with known properties





Solar variability was original reason for BUV



Solar variability cancels when calculating TOA reflectance

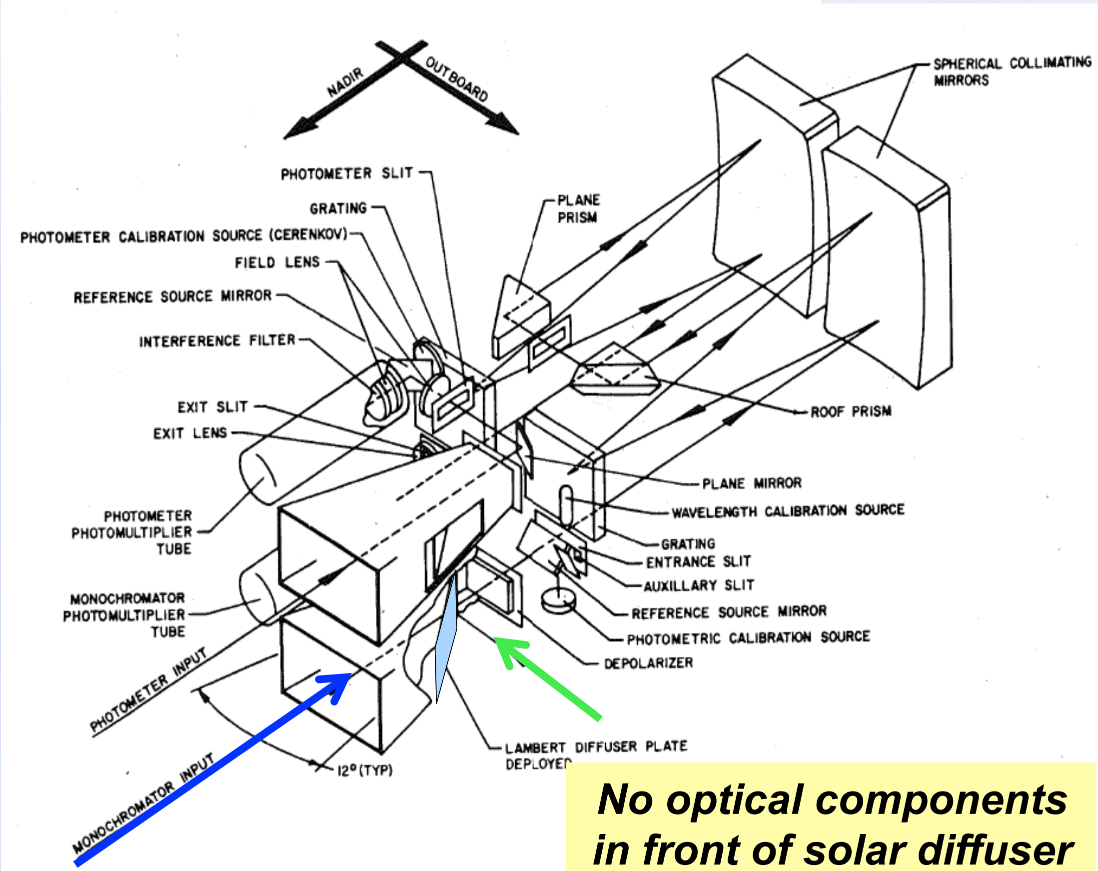
Easier to assume solar irradiance is constant when λ > 300 nm

Primary range for O_3 profile retrievals

From:
Solar UV variations during the decline of Cycle 23, DeLand and Cebula, *J. of Atmos. & Solar-Terr. Phys.*, 2012

Calibration is the main BUV advantage

Nimbus-4 BUV optical design (1968)



No optical components in front of solar diffuser

Many systematic calibration errors cancel in the ratio

(incl. Spectral Response Function)

Sun-Normalized Radiance:

$$\frac{L_{EV}}{E_{sun}} = \frac{k_r}{k_i} \cdot \frac{C_r}{C_i} = A \cdot \frac{C_r}{C_i}$$

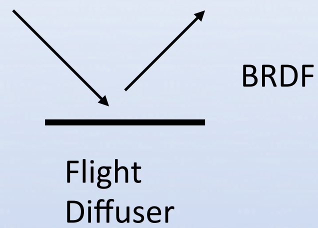
$$A \cong R_{Diffuser} \cos \Theta_i$$

L_{EV}	backscattered Earth radiance
E_{sun}	solar irradiance
C	measured signals
k	calibration coefficients
A	albedo calibration coeff.

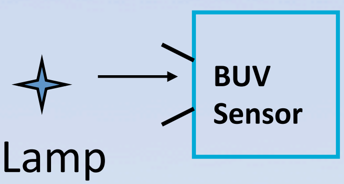
Laboratory Albedo (a.k.a. BSDF) Calibration

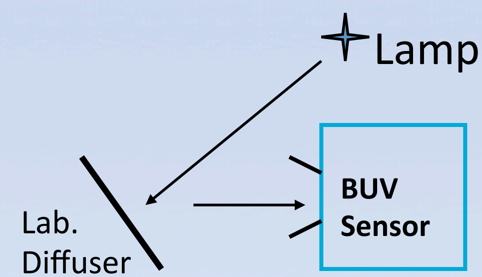
Irradiance | Radiance

Direct Calibration

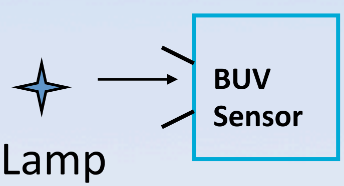


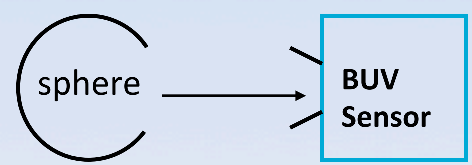
Diffuser-based Calibration





Sphere-based Calibration





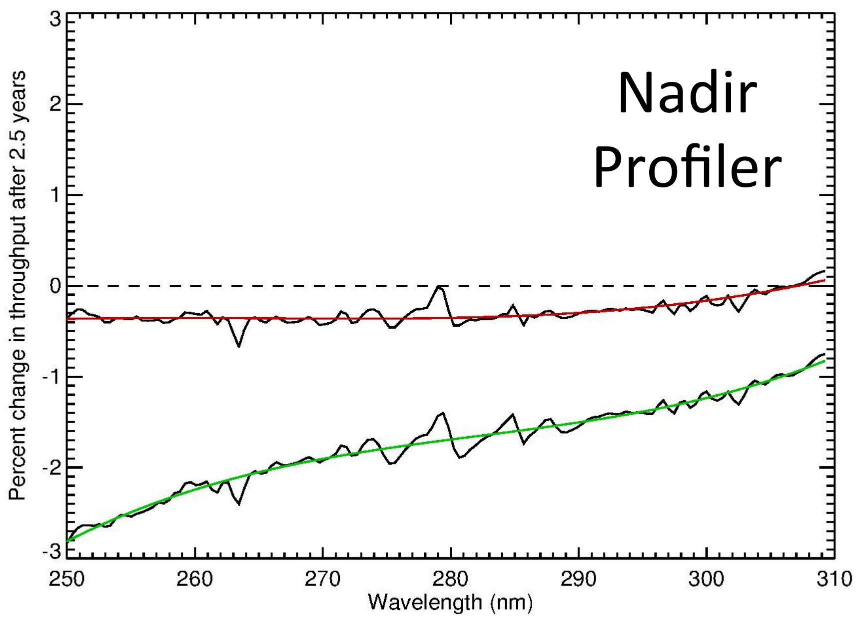
3 methods currently yield < 1% total ozone difference

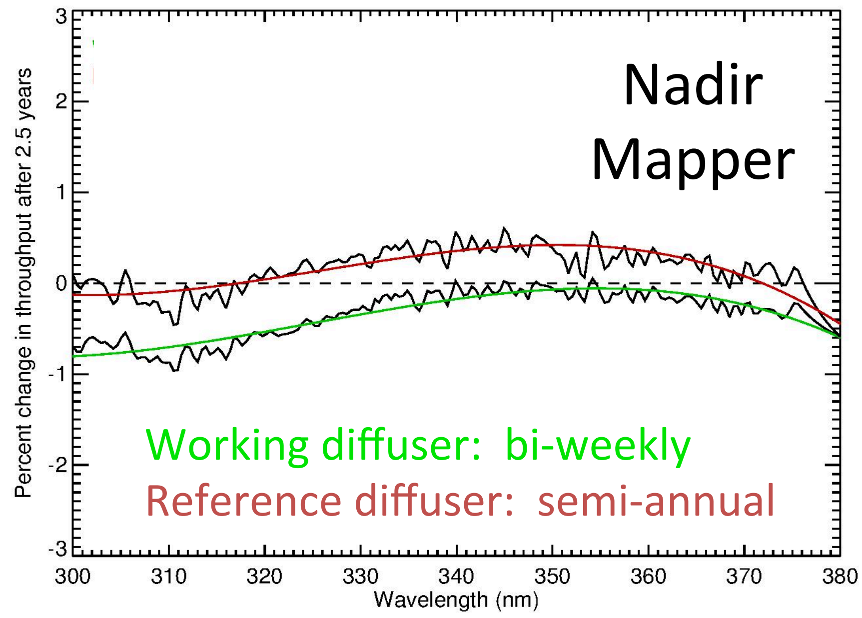
Calibrations performed in air at 20 °C

Instrument is radiometrically stable

Total solar signal = Diffuser change + Sensor change

Solar measurement ratio: 2.5 yrs / initial





- ***No Reference signal change means …***
- ***No statistically significant sensor change***

(excessive solar measurement can cause sensor degradation)

Are orbiting UV sensors destined to degrade?

	Sensor Response change (per 10 yr @ 300 nm)
TOMS Nimbus 7 (10 yr)	~0%
TOMS Meteor 3 (3.3 yr)	60%
TOMS Earth Probe (10 yr)	90%
TOMS ADEOS (0.75 yr)	100%
GOME (4.4 yr)	~90%
SCIAMACHY (3 yr)	~30%
GOME-2 Metop A (4 yr)	~80%

Many factors contribute to degradation….

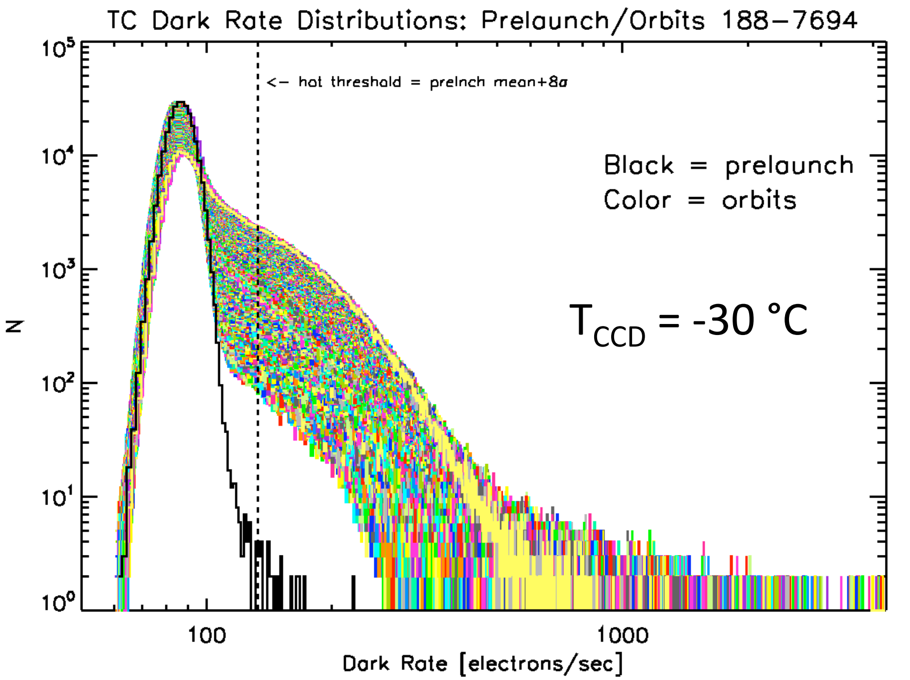
including contaminants on front optics and detector

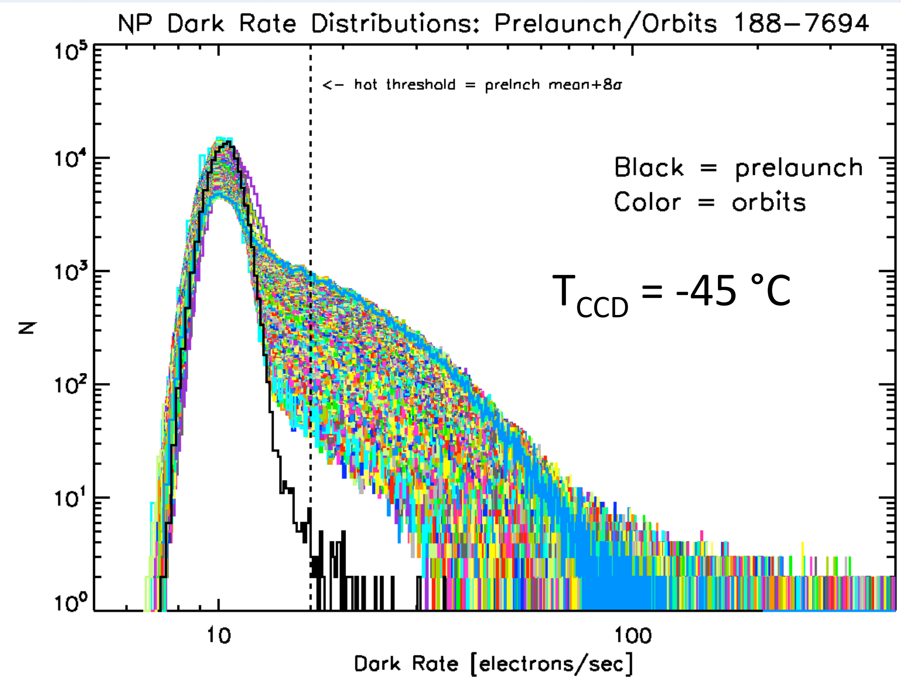
Scan mirror

No scan mirror

	Sensor Response change (per 10 yr @ 300 nm)
SBUV2 NOAA-16 (8 yr)	~5%
SBUV2 NOAA-17 (8.5 yr)	6%
SBUV2 NOAA-18 (6 yr)	10%
OMI (9.5 yr)	3%
OMPS (2 yr)	0%

Silicon detector radiation damage





Fraction of Pixels Damaged $= 1 - e^{-t/t_o}$

OMPS	T_{CCD}	1/e time
Nadir Mapper	-30	17.0 months
Nadir Profiler	-45	15.2 months
Limb	-45	16.3 months

Temperature stability as important as low temperature

Cold detectors force design considerations

- Detector is cold trap for contaminants when it's colder than instrument
- Tends to form ice in laboratory and on-orbit

Calibrate in air with warm detector

- High noise levels
- Longer testing
- Violates "test as you fly"

Calibrate in vacuum

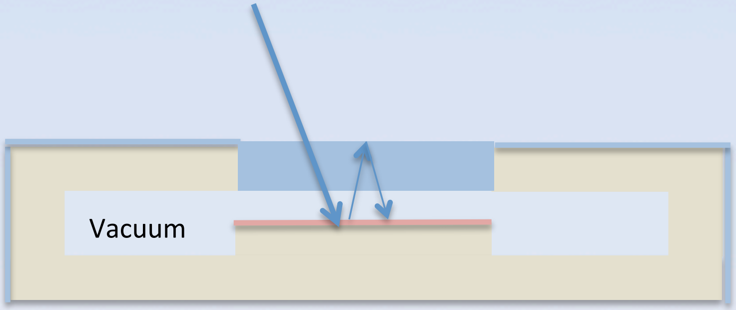
- Cold detector
- Cold instrument
- Expensive testing
- Difficult to modify tests

Calibrate in air with sealed detector (OMPS)

- Cold detector - Warm window
- Warm instrument
- Expensive focal plane pkg.
- Violates "test as you fly"
- Window ghosts

Can satellite sensors be accurately calibrated in air ?

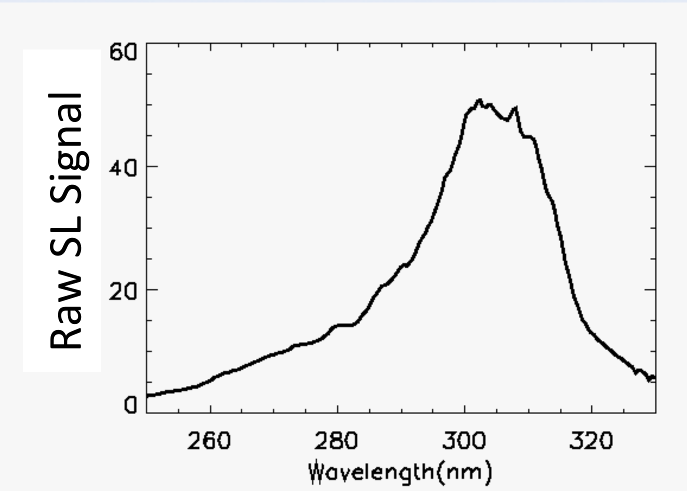
OMPS Focal Plane Package

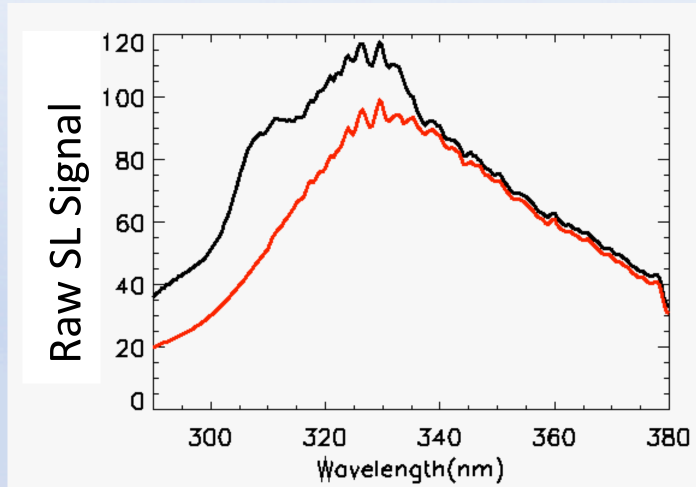


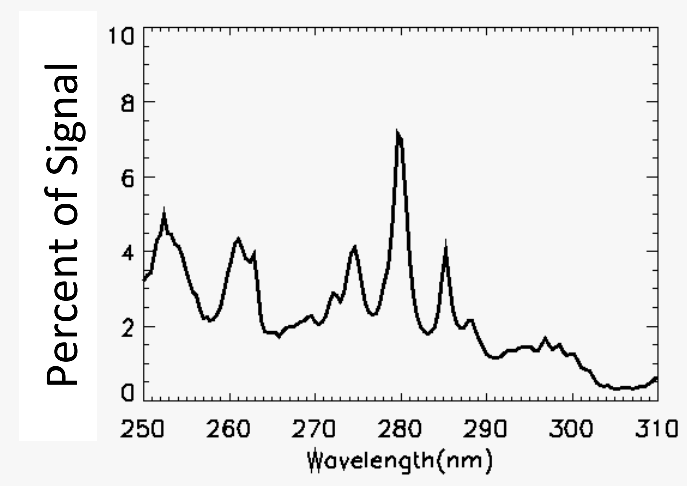
OMPS stray light is manageable

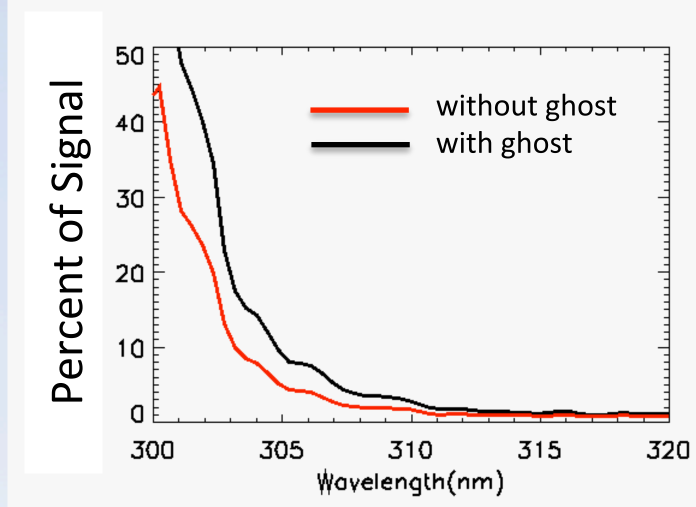
Nadir Profiler

Nadir Mapper







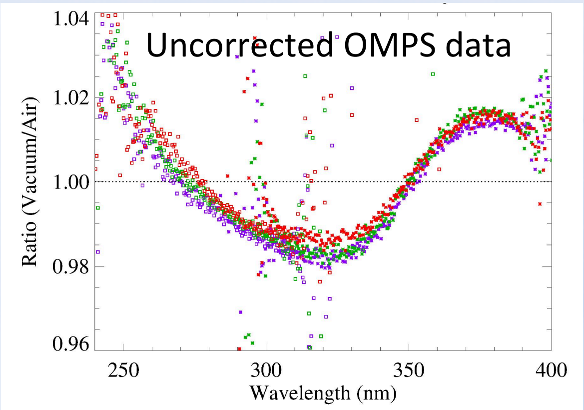


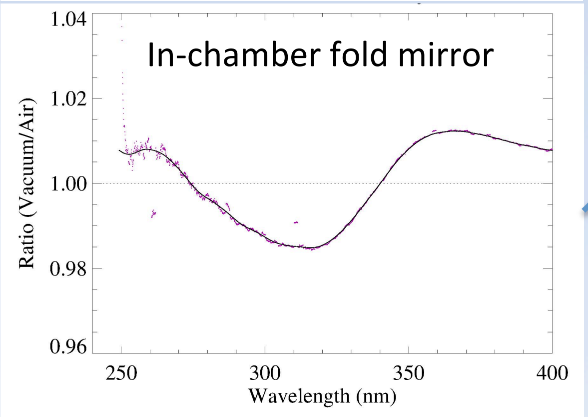
Stray light model is the basis for data correction

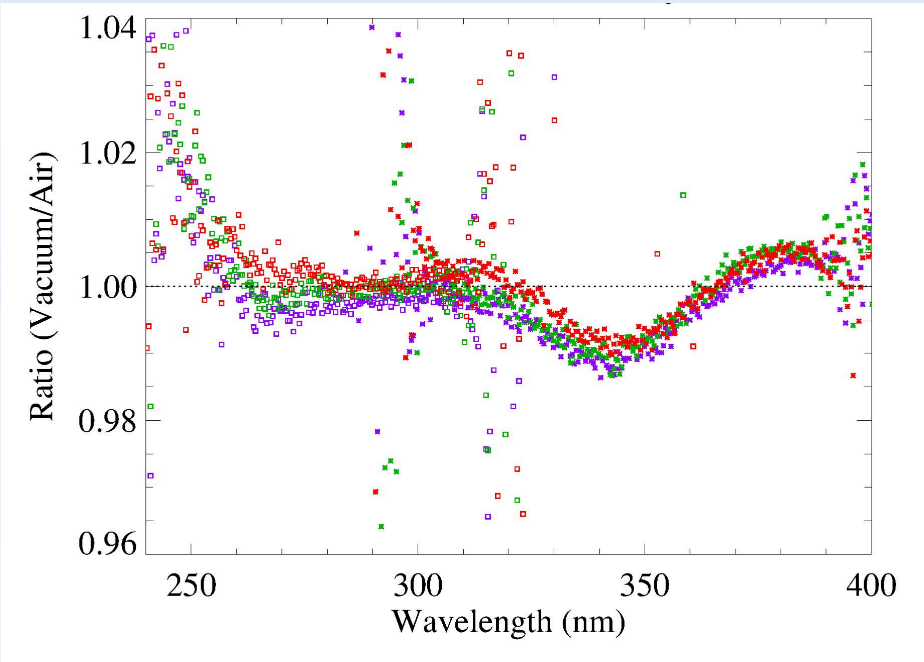
Detector window ghost can be mitigated through optical design

Albedo cal. vac. / air tests on JPSS-1 OMPS

Albedo calibration is insensitive to wavelength shifts





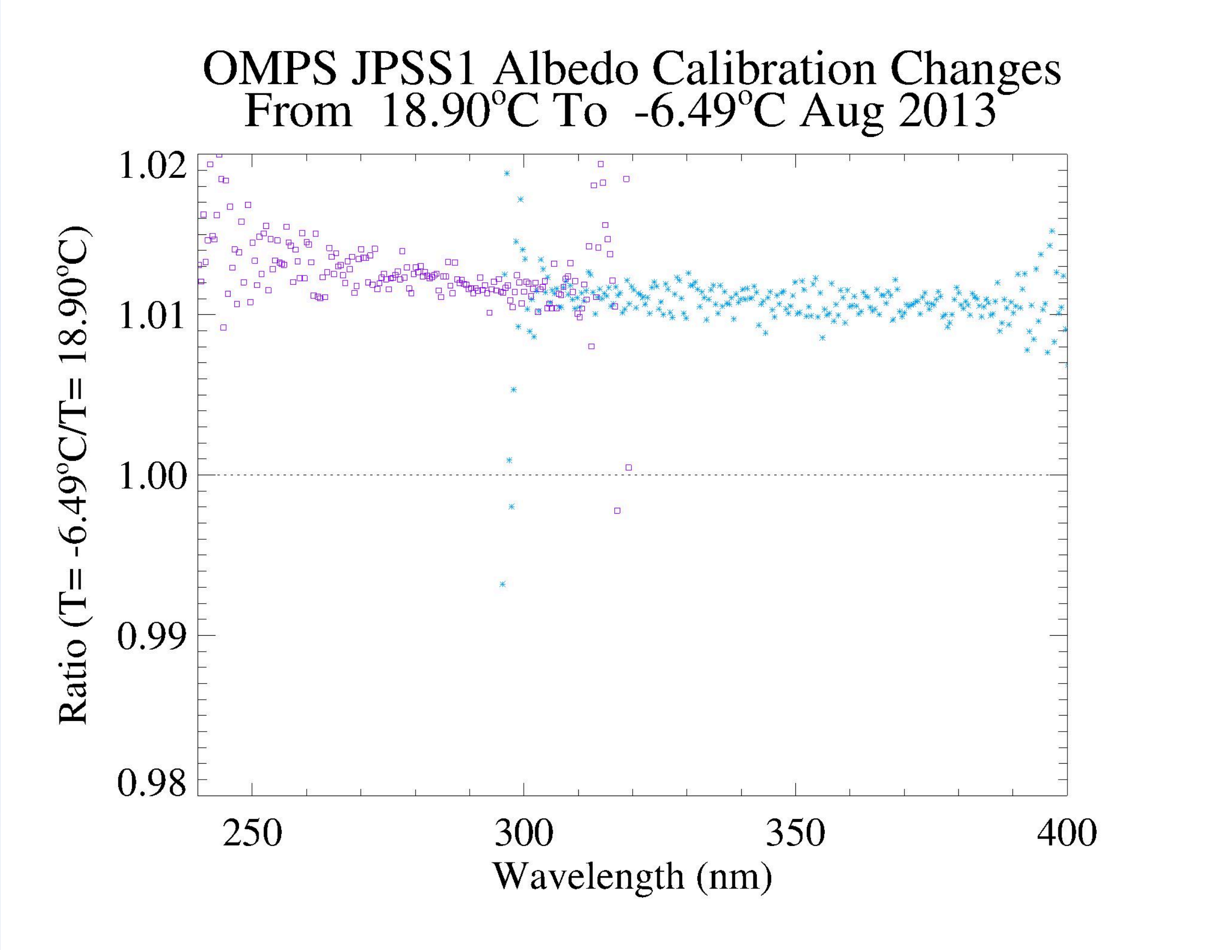


Coated fold mirror was used at 45°

Indications are that albedo calibrations do not change between air and vacuum

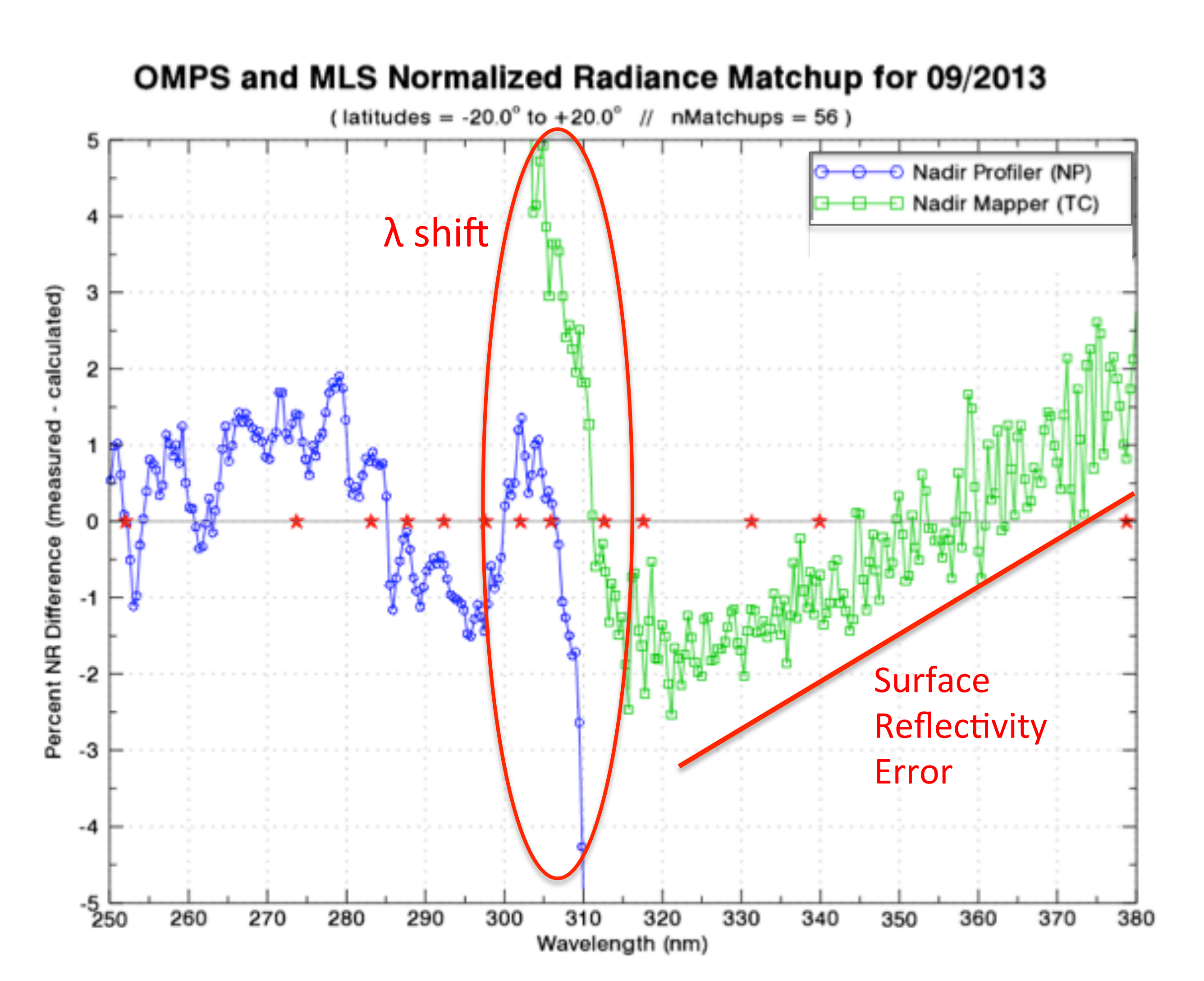
Temperature tests on JPSS-1 OMPS

Ground-to-orbit temperature change of SNPP OMPS



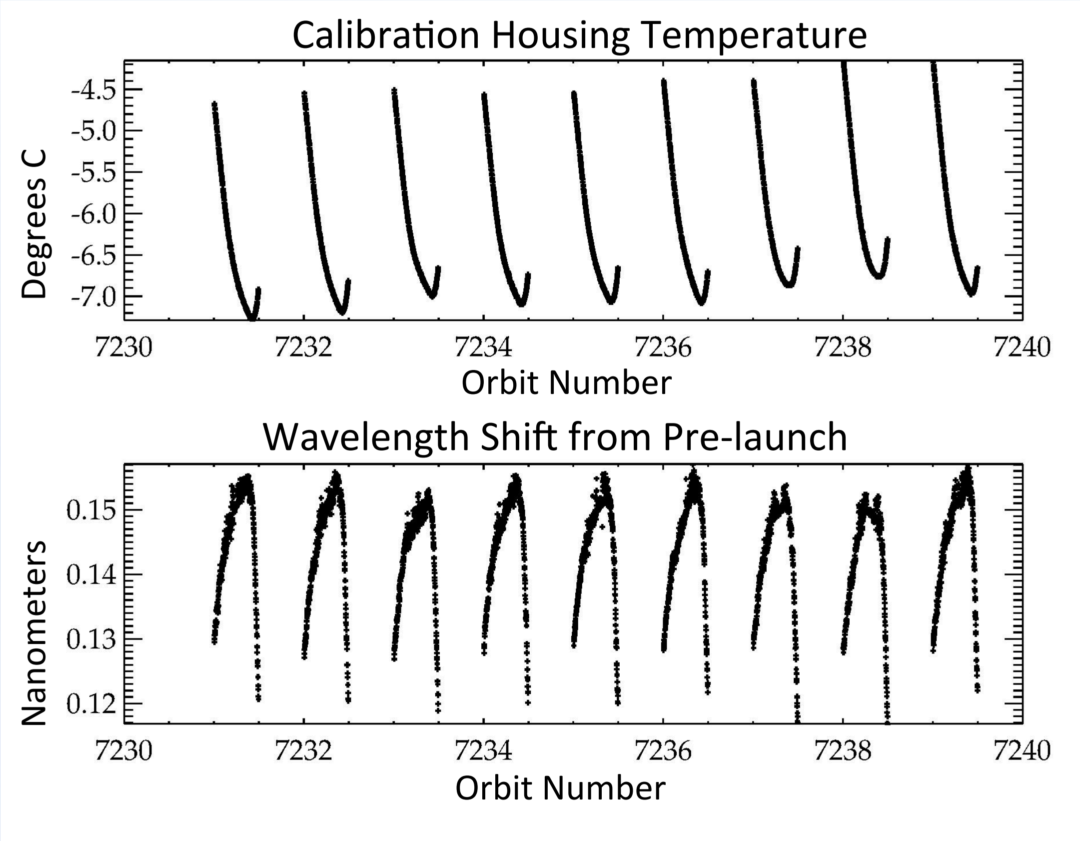
Cause of the 1% calibration change is not yet understood

Matchup comparisons between SNPP OMPS and Aura MLS

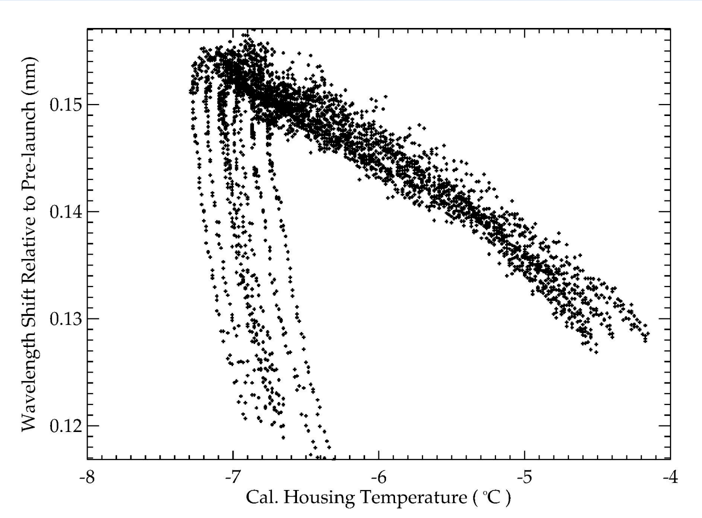


Nadir Profiler is most difficult to calibrate accurately

Lack of thermal stability leads to wavelength shifts



Shifts are correlated with temperature until point in the orbit where sunlight strikes the instrument



OMPS would benefit from active temperature control of optical bench

Main Lessons Learned

- Calibration at ambient temperature and pressure is accurate
  - improved by, but not dependent upon, a sealed detector
  - "test as you fly" requirements can be applied selectively
- It's possible to build and fly UV instruments with low degradation
  - low degradation improves long-term calibration accuracy
  - limiting solar measurements is an important component
- Thermal control should be standard equipment
  - wavelength shifts cause many downstream problems
  - optics temperature should remain constant from lab. to orbit (i.e. "fly as you test")