
Satellite Instrument Calibration

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Abstract

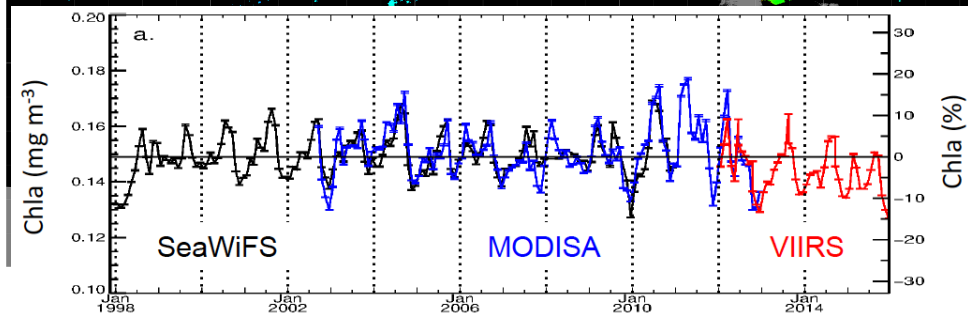
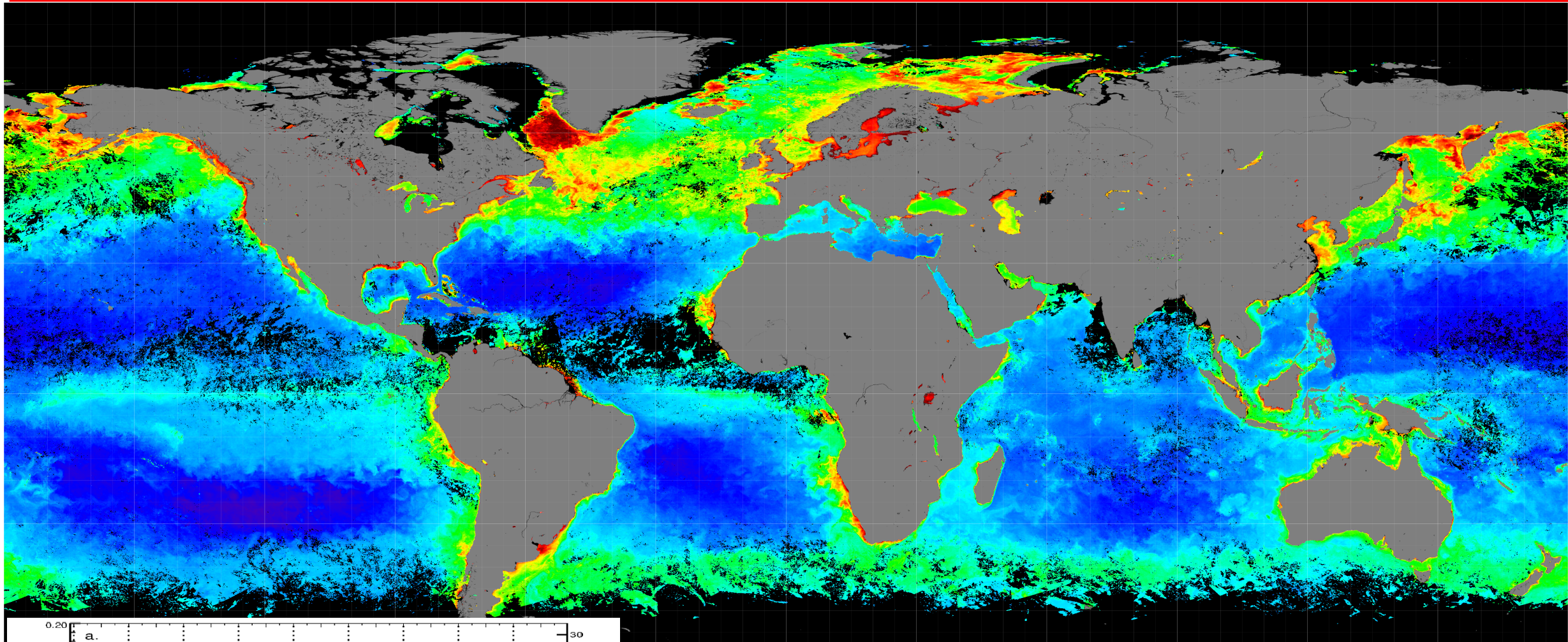
abstract: Satellite remote sensing is an integral part of global earth observation. Satellite remote sensing data enable us to observe the whole globe at a reasonably high frequency. To maintain the accuracy of satellite remote sensing data, it is critical to continuously perform instrument calibration throughout the lifetime of the mission. This presentation describes the common characteristics of earth observing satellite sensors, the calibration processes and potential issues, the implication on science data, and how we understand the globe.

Content

- Introduction: Satellite remote sensing
- Instrument calibration / characterization
 - pre/post launch
- Operational calibration update
- Calibration impact on Science

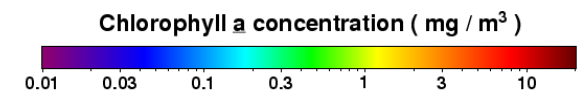
- Calibration enables the calculation of the actual radiance of the Earth target, from the corresponding digital counts produced by the satellite instrument - Eumetsat

Satellite observed global chlorophyll concentration

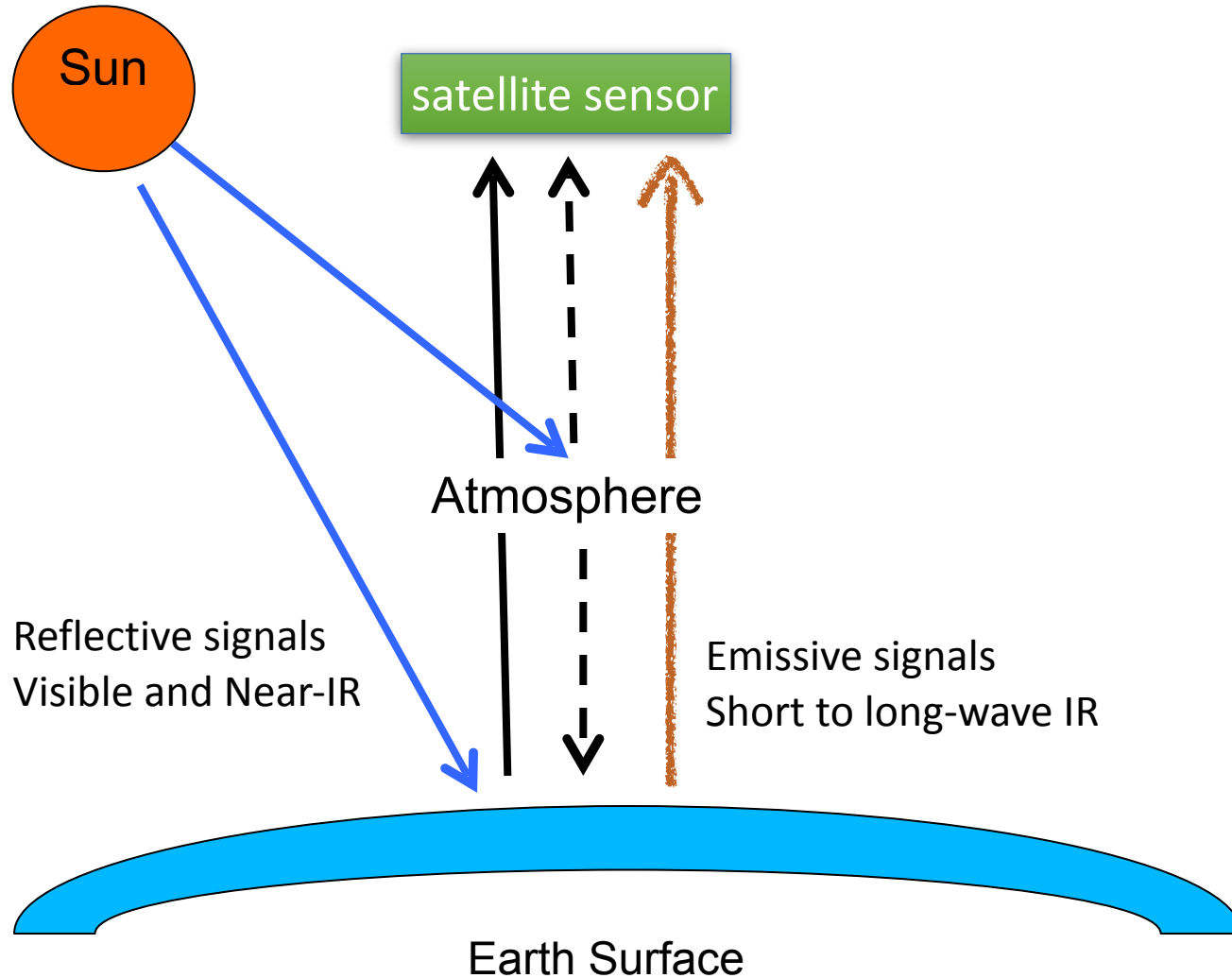


Satellite Data: spatial/temporal distribution of the geophysical parameters. Something we can't get from other kind of observations

mid latitude ($\pm 40^\circ$) chlorophyll
source: NASA OBPG



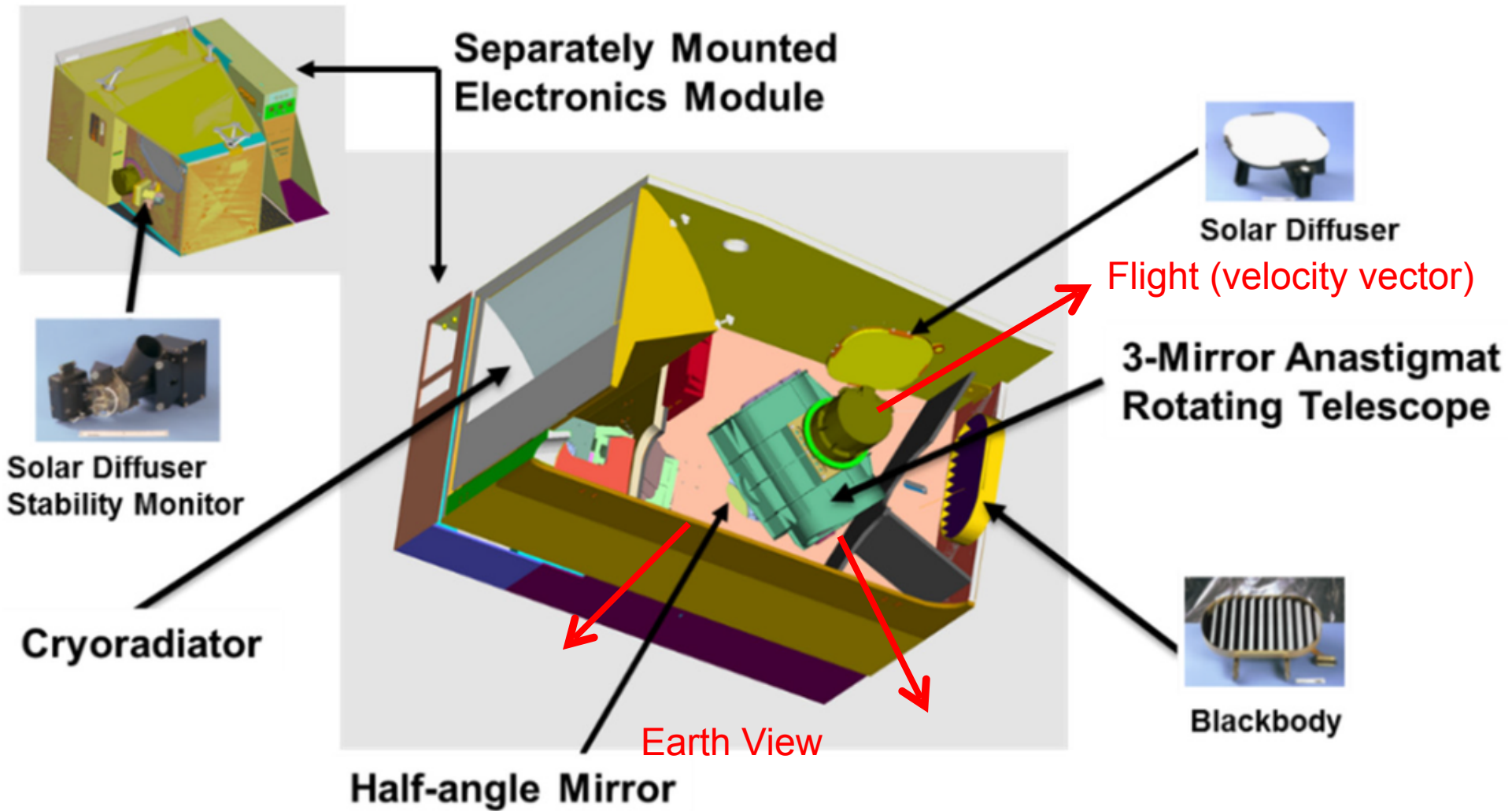
Satellite remote sensing data



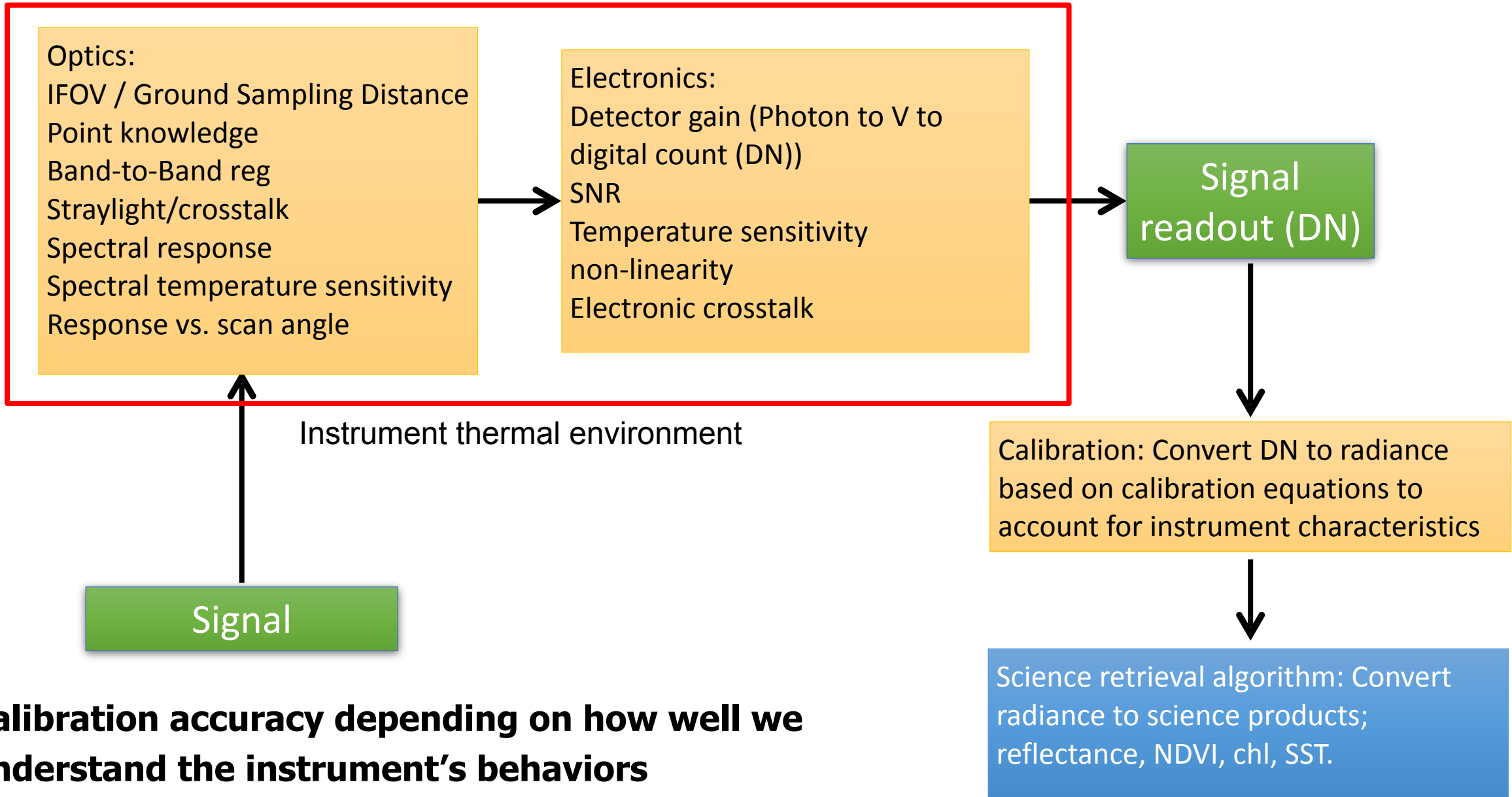
- Steps to compute the geophysical parameters
- Calibration: At satellite signals: convert instrument recorded at satellite signal to radiance
- *Retrieval algorithm: convert at satellite radiance to science products (i.e. ref., chl, temp):*
- *Both calibration and retrieval algorithm accuracies will impact science products*

Opto-electrical Sensor

VIIRS shown as an example



Opto-electrical Sensor characteristics



Calibration accuracy depending on how well we understand the instrument's behaviors

Satellite Instrument Calibration

- Pre-launch (laboratory)
 - Verify design requirements:
 - Critical: calibration hard to obtain on-orbit, i.e. temp sensitivity, response versus scan angle (RVS), polarization sensitivity, stray light, relative spectral response (RSR), non-linearity...
 - not-as-critical: re-calculate on orbit: detector gain, dynamic range ...

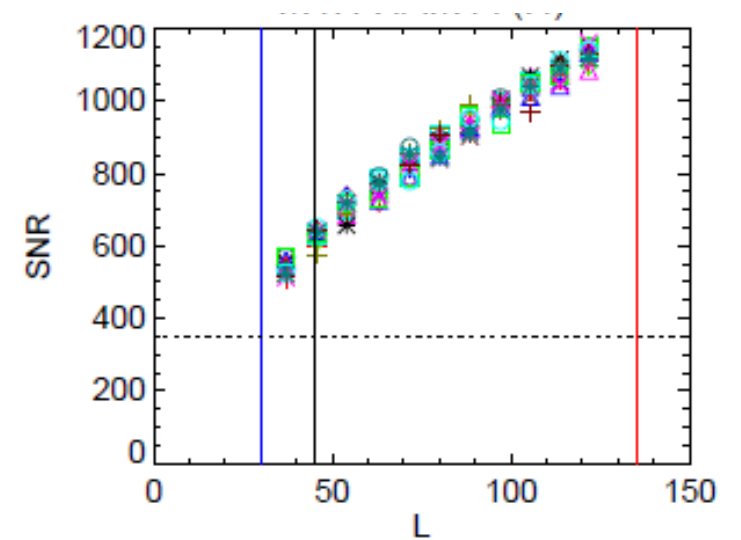
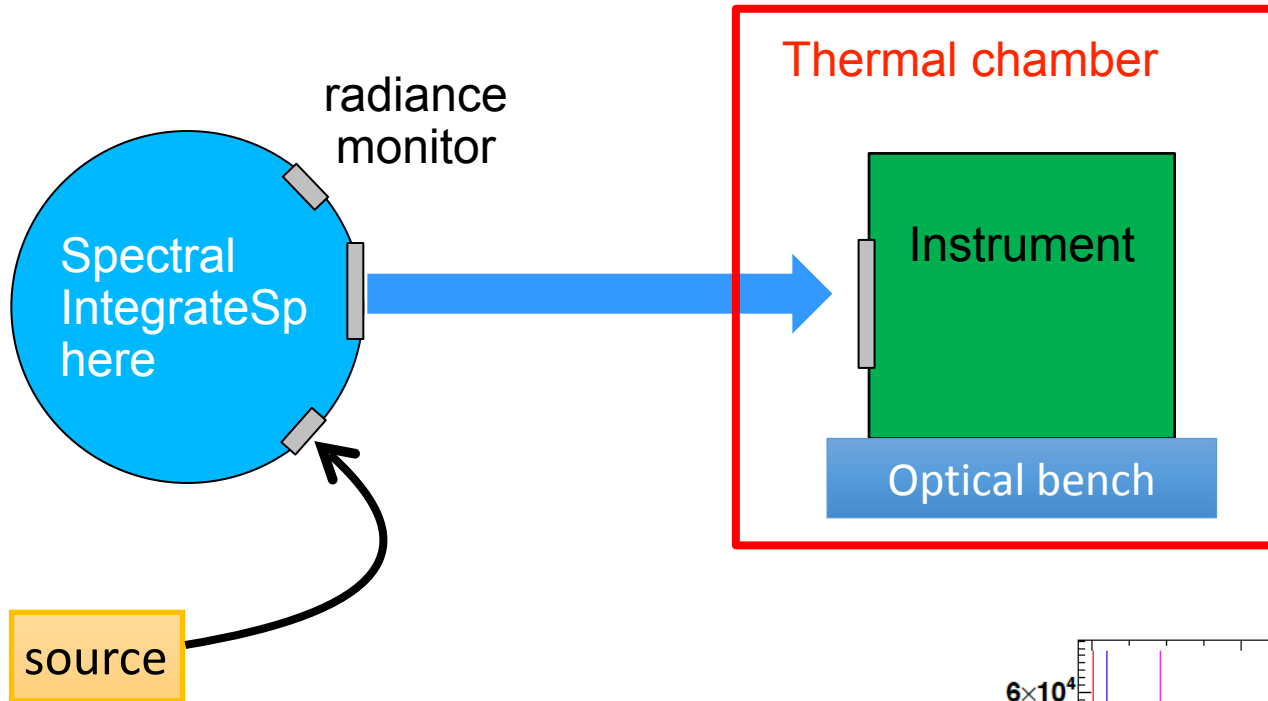
Examples:

SNPP-VIIRS: multi-spectral whisk broom (cross-track) sensor

PACE-OCI-ETU: hyper spectral whisk broom (cross-track) sensor

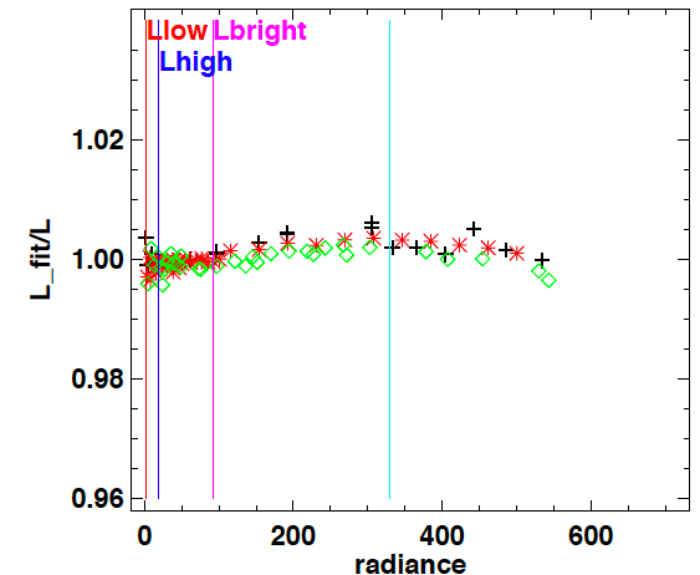
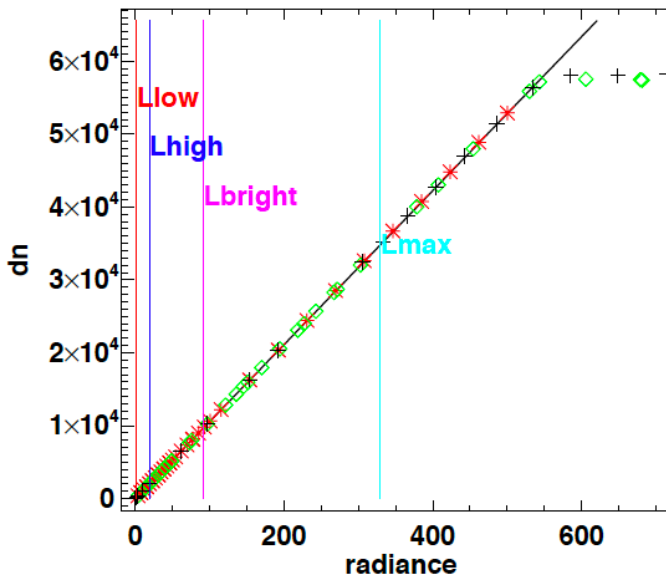
SeaHawk-Hawkeye: multi-spectral push broom (along-track) sensor (cube sat)

Pre-launch calibration:



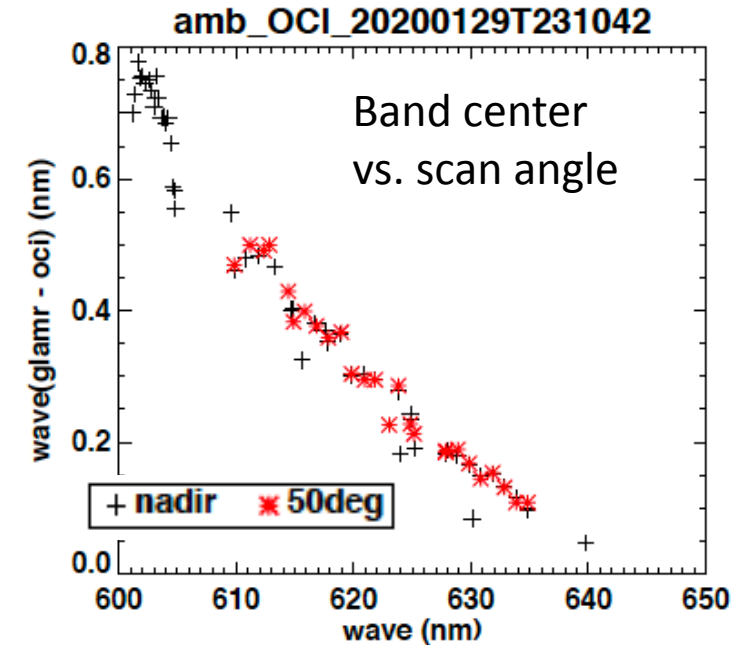
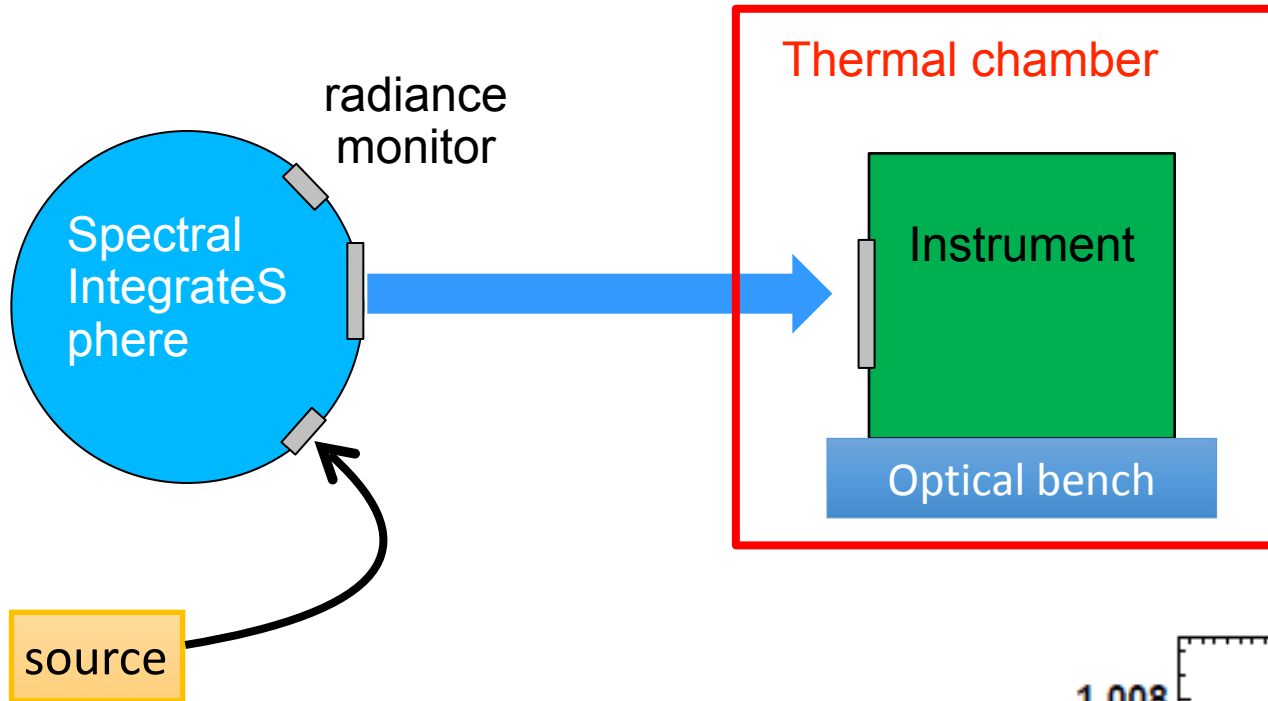
Varying source intensity

- Gain, SNR, nonlinearity, dynamic range
- uncertainty: radiance monitor accuracy, source stability, atmospheric absorption



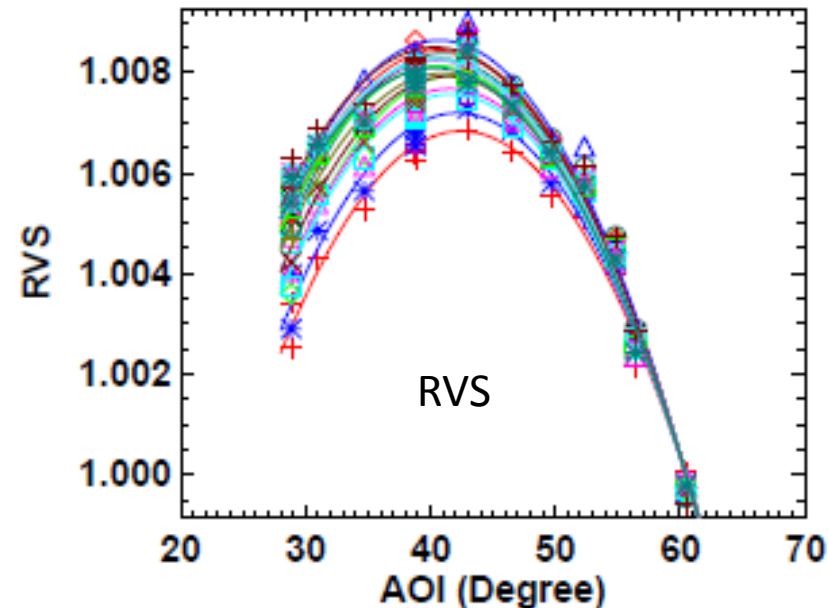
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Pre-launch calibration:

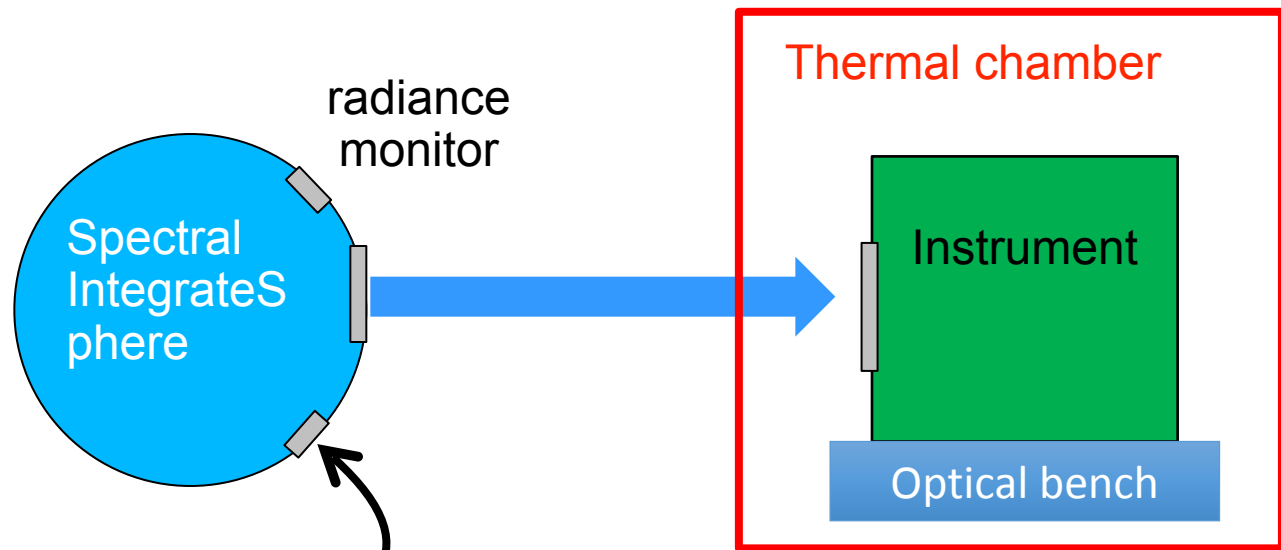


Varying instrument view angle

- Response versus scan angle (RVS), other angular dependency
- uncertainty: radiance monitor accuracy, atmospheric absorption ...

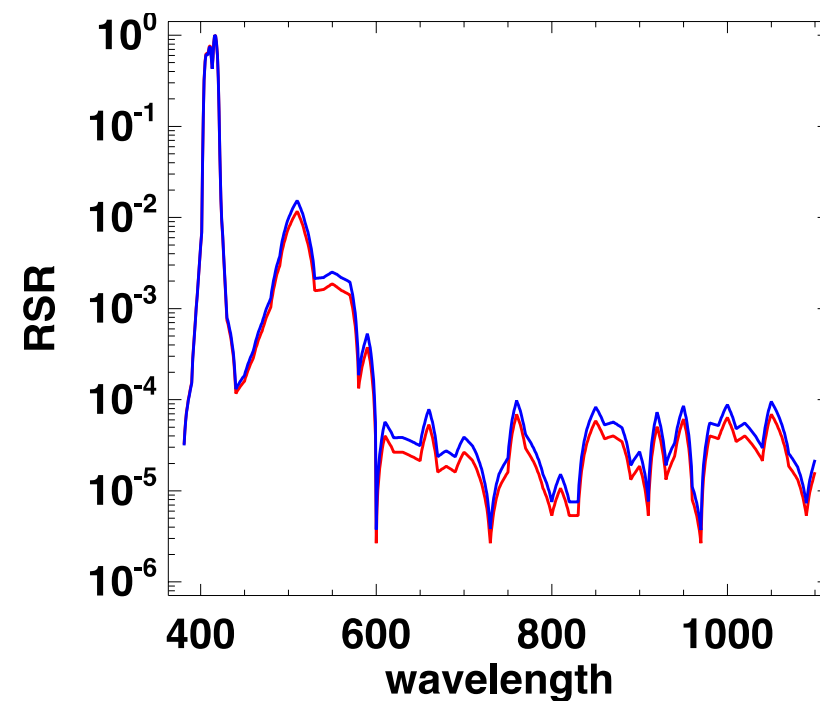
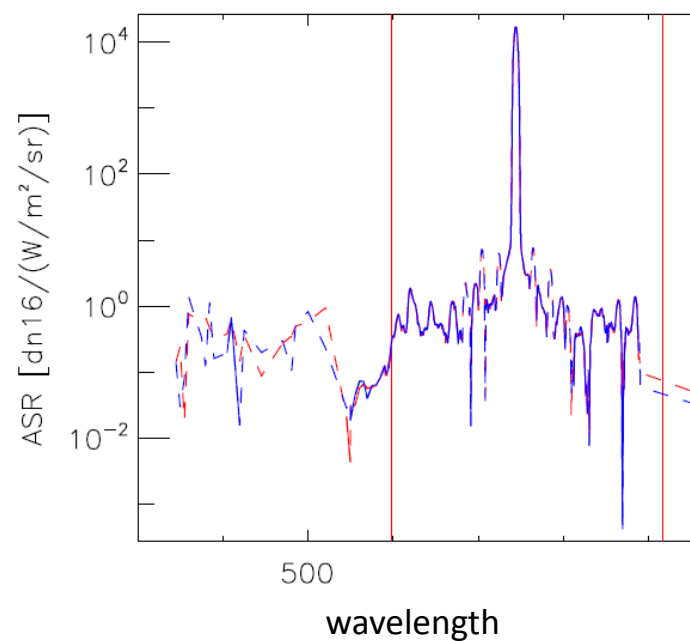


Pre-launch calibration:

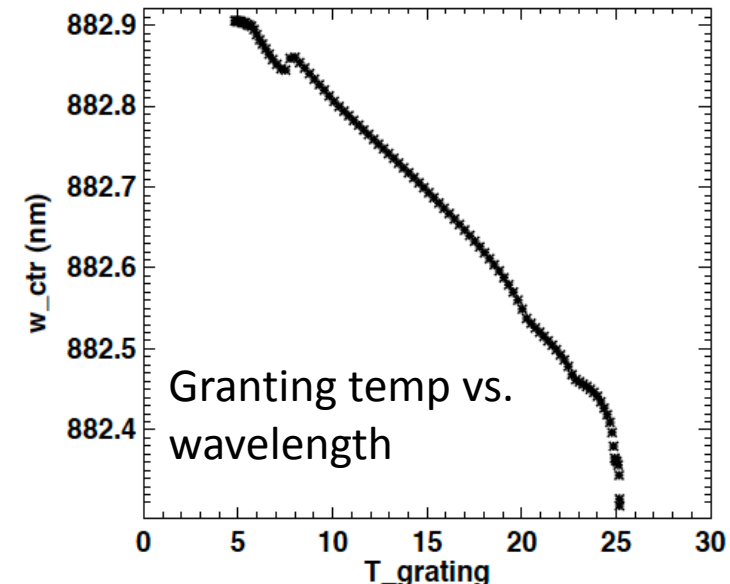
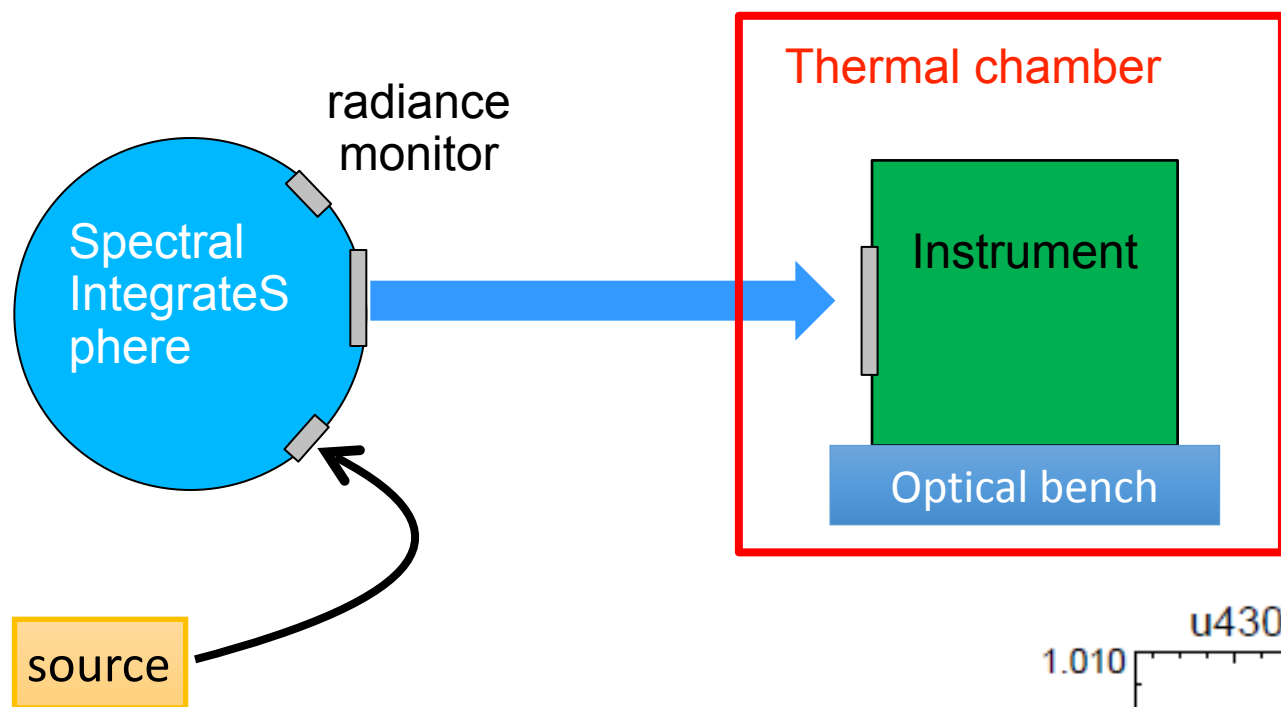


Varying source wavelength

- absolute/relative response, gain.
- uncertainty: radiance monitor accuracy, source stability, noise floor ...

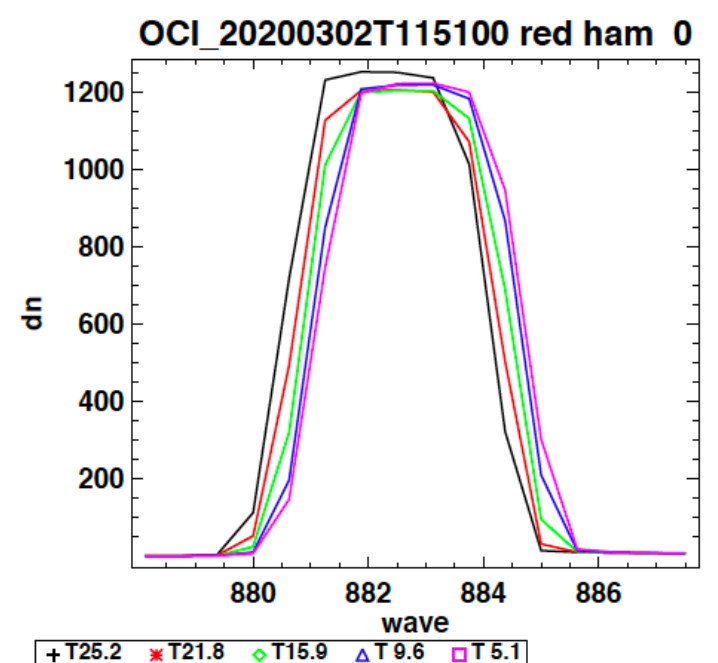
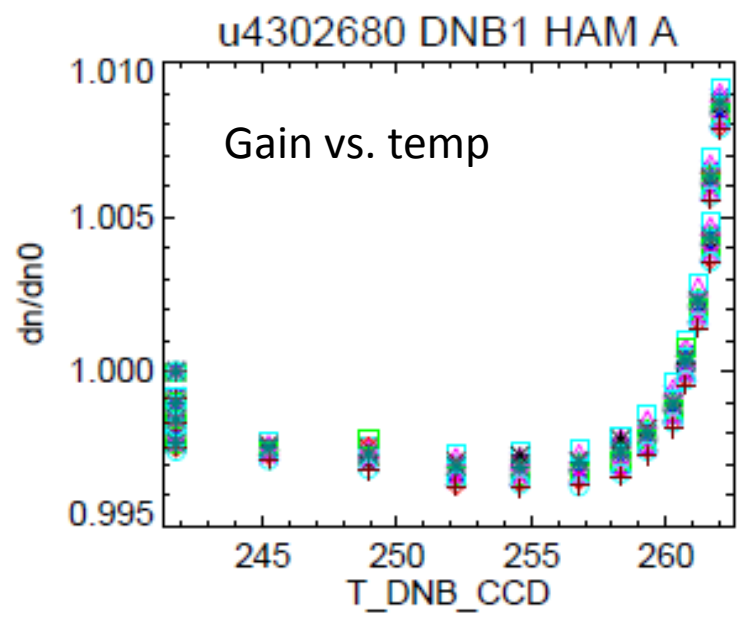


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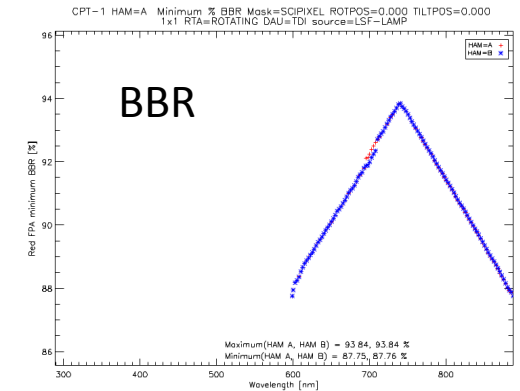
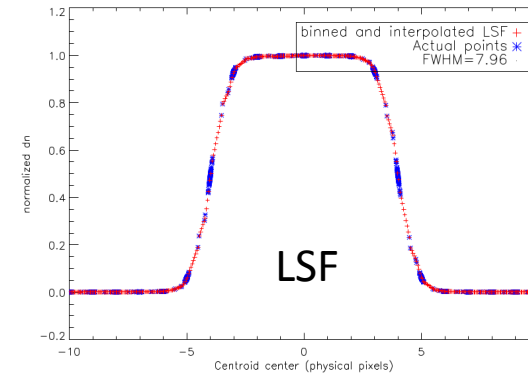
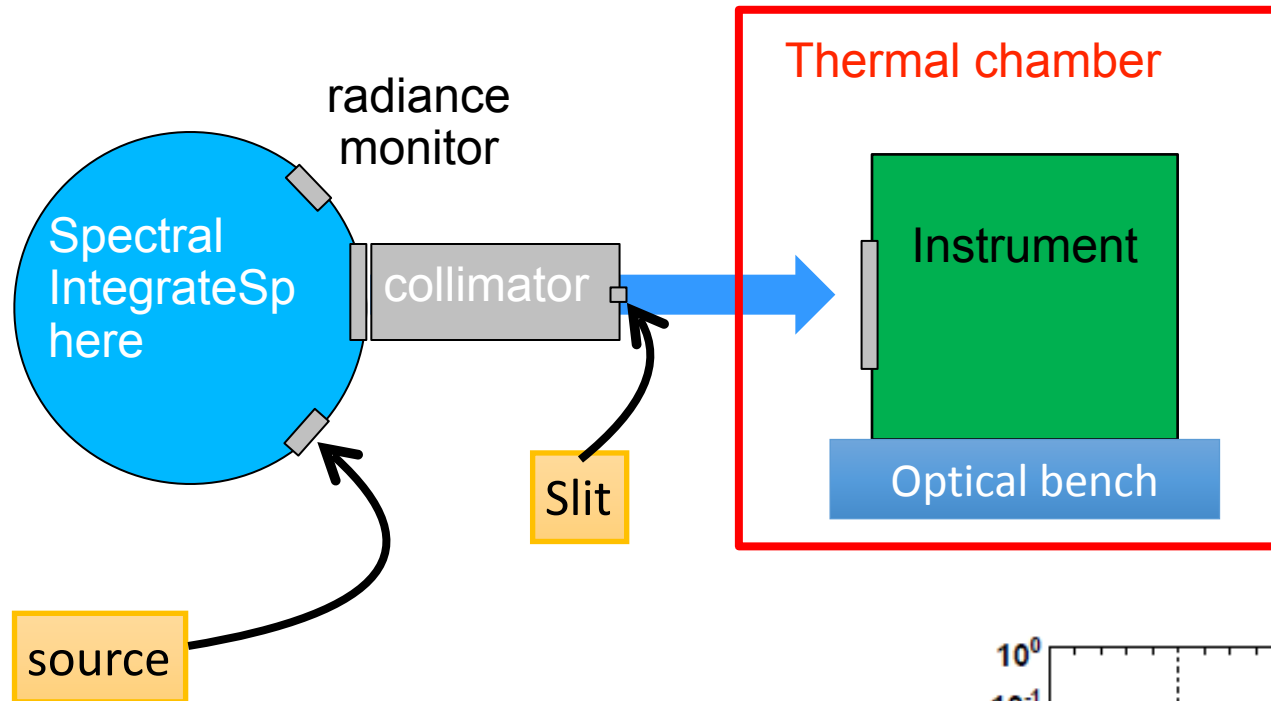


Varying instrument temperature

- Temperature sensitivity, gain, spectral shift
- uncertainty: radiance monitor accuracy, source stability (spectral) ...

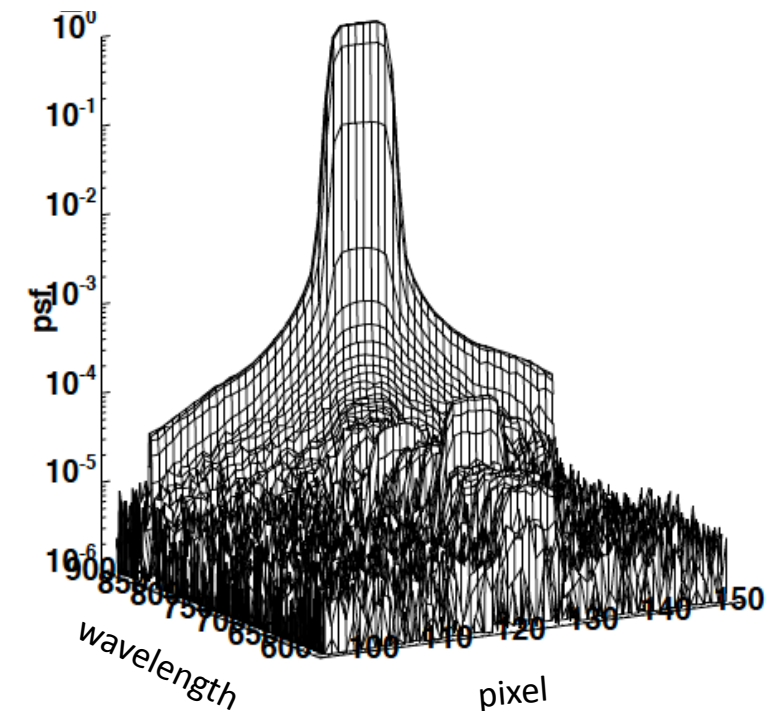
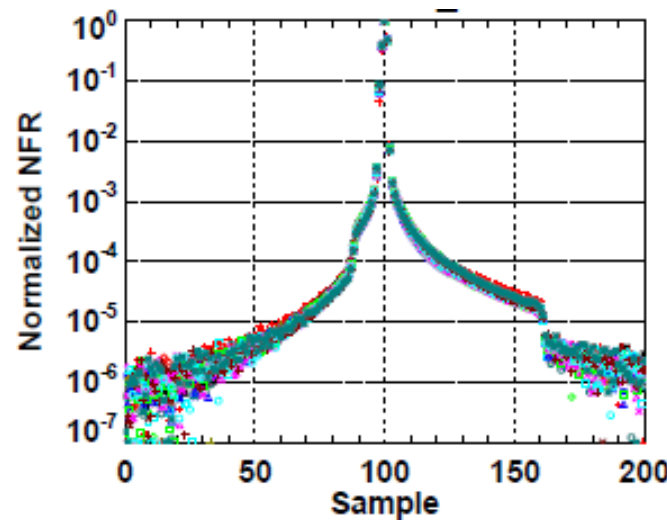


Pre-launch calibration:

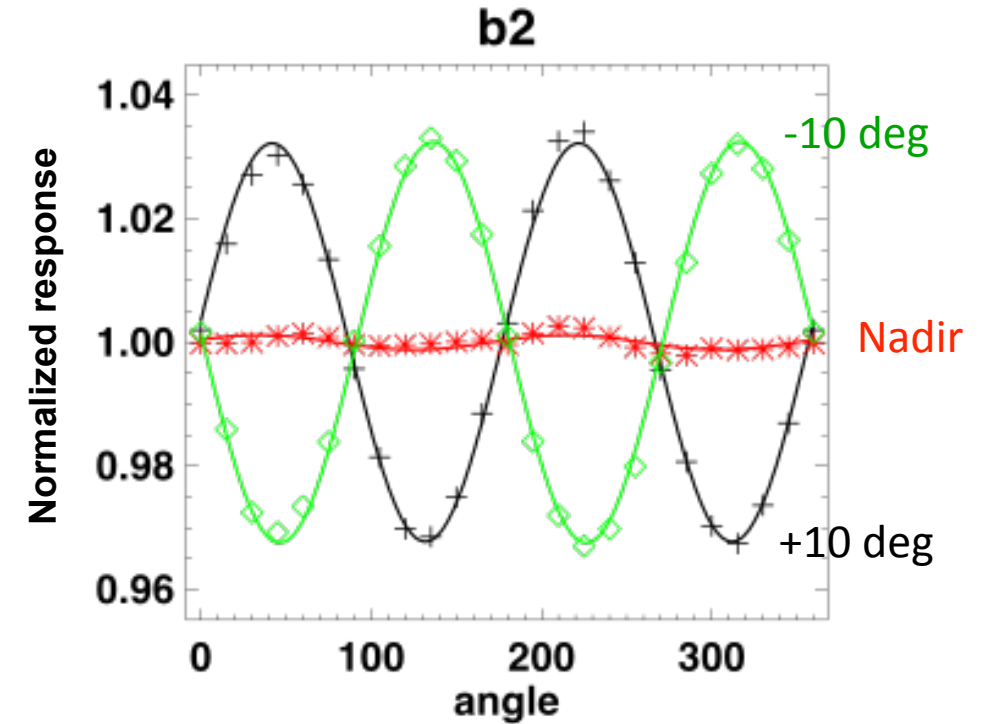
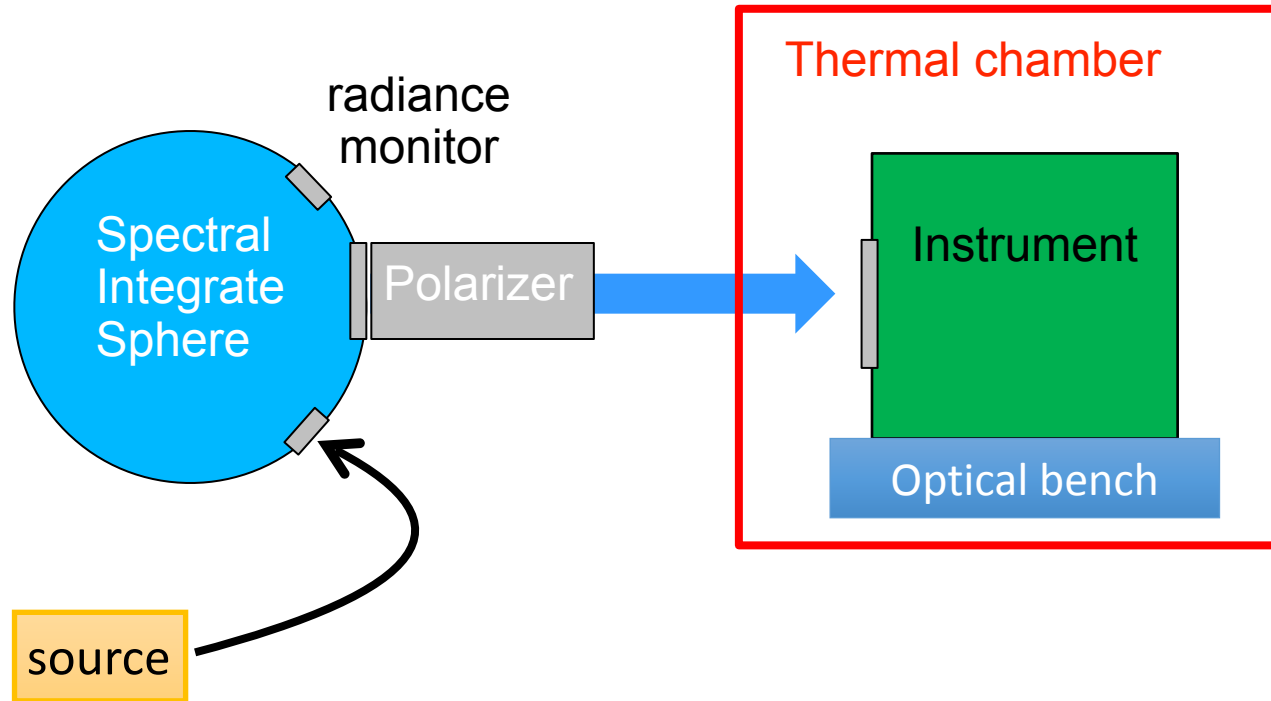


Varying instrument wavelength, slit shape

- pointing, line spread function (LSF), instantaneous field of view (IFOV), band-to-band registration (BBR), straylight, crosstalk
- uncertainty: noise floor...

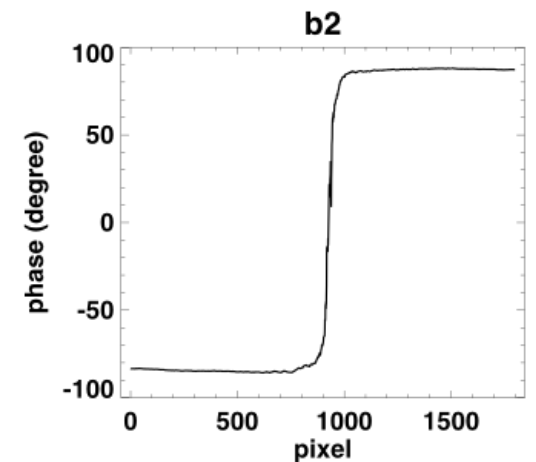
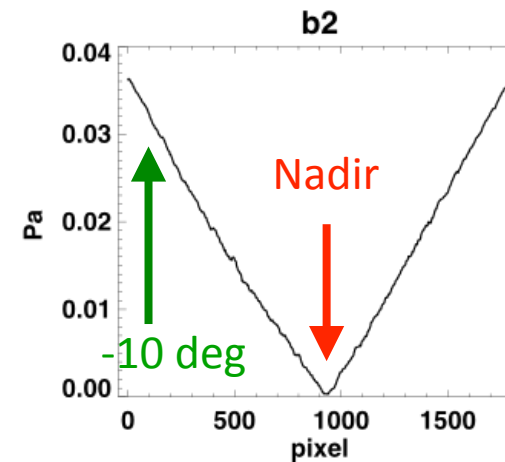


Pre-launch calibration:



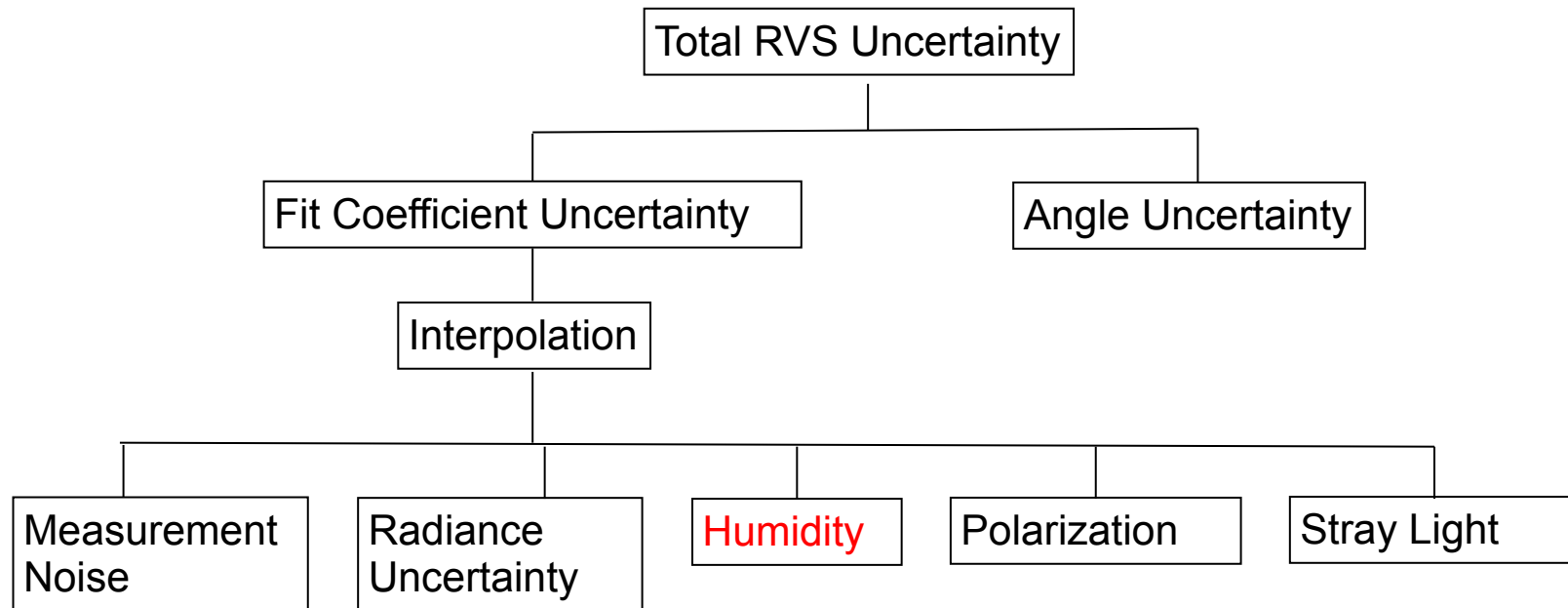
Varying polarizer angle, view angle

- Polarization sensitivity
- uncertainty: polarizer angle/efficiency, alignment...



Estimate Calibration Uncertainty

- Absolute vs. relative
- Uncertainty tree
- Need to identify the key elements
 - Did we include everything that is relevant?
 - How good is each of the element can be estimated?



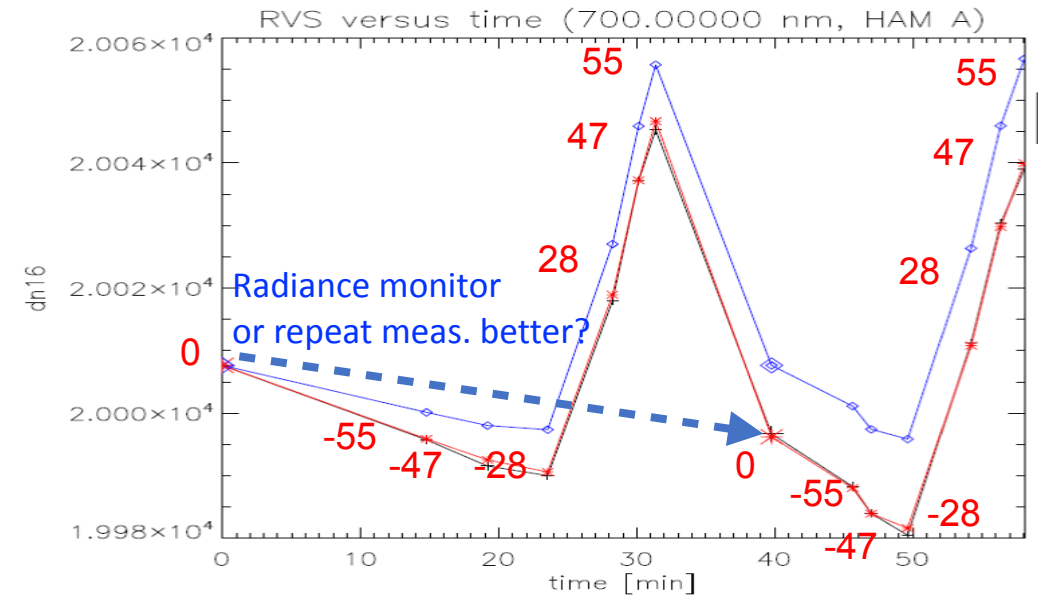
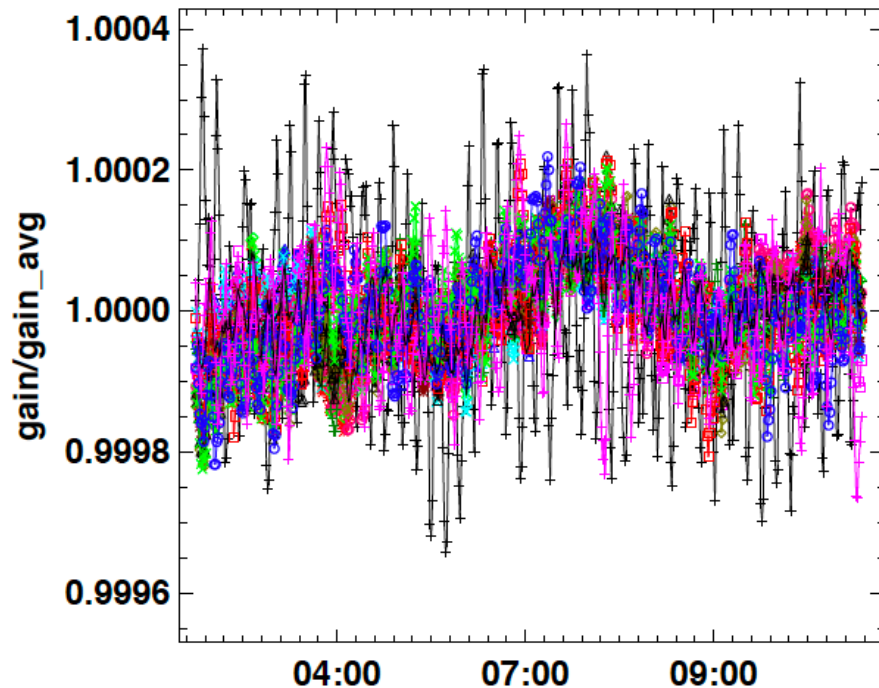
Source: J. McIntire

Measurement Uncertainty: test equipment

Instrument or radiance monitor a better radiometer?

Instrument gain stability test

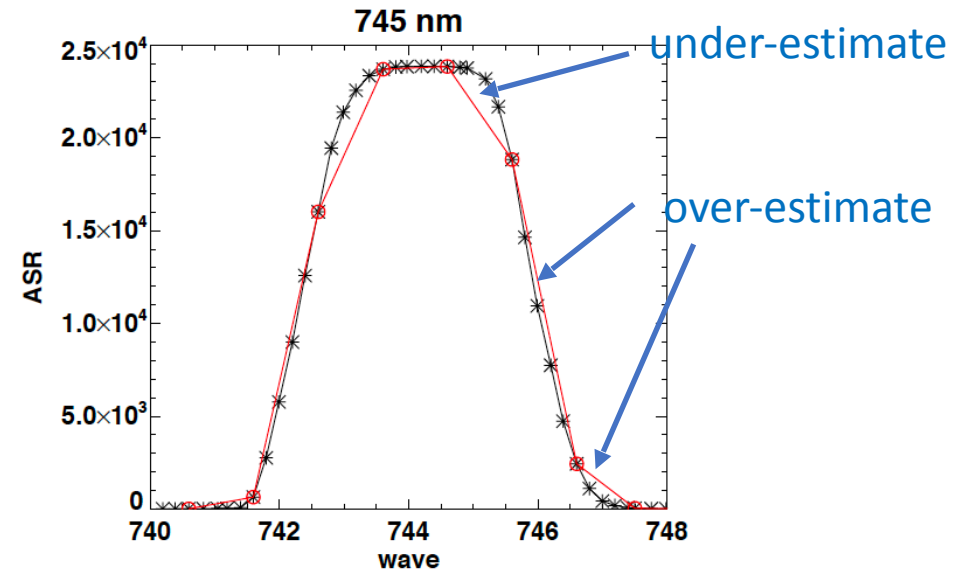
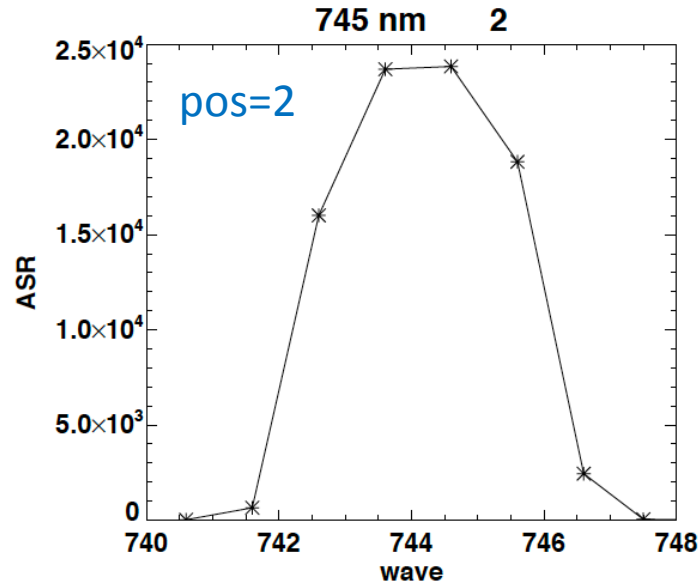
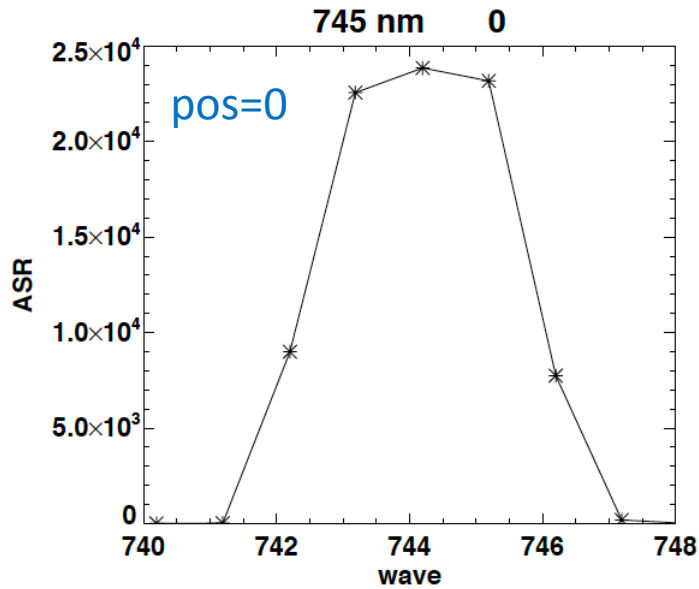
- Track instrument gain over time
- Use radiance monitor as truth: what is the radiance monitor uncertainty?



RVS characterization

- Radiance monitor and instrument has 0.05% drift in 1 hr
- Use repeat angle de-trend the data: same response at same angle
- Use instrument as truth: what is the de-trend uncertainty?

Measurement Uncertainty: test design



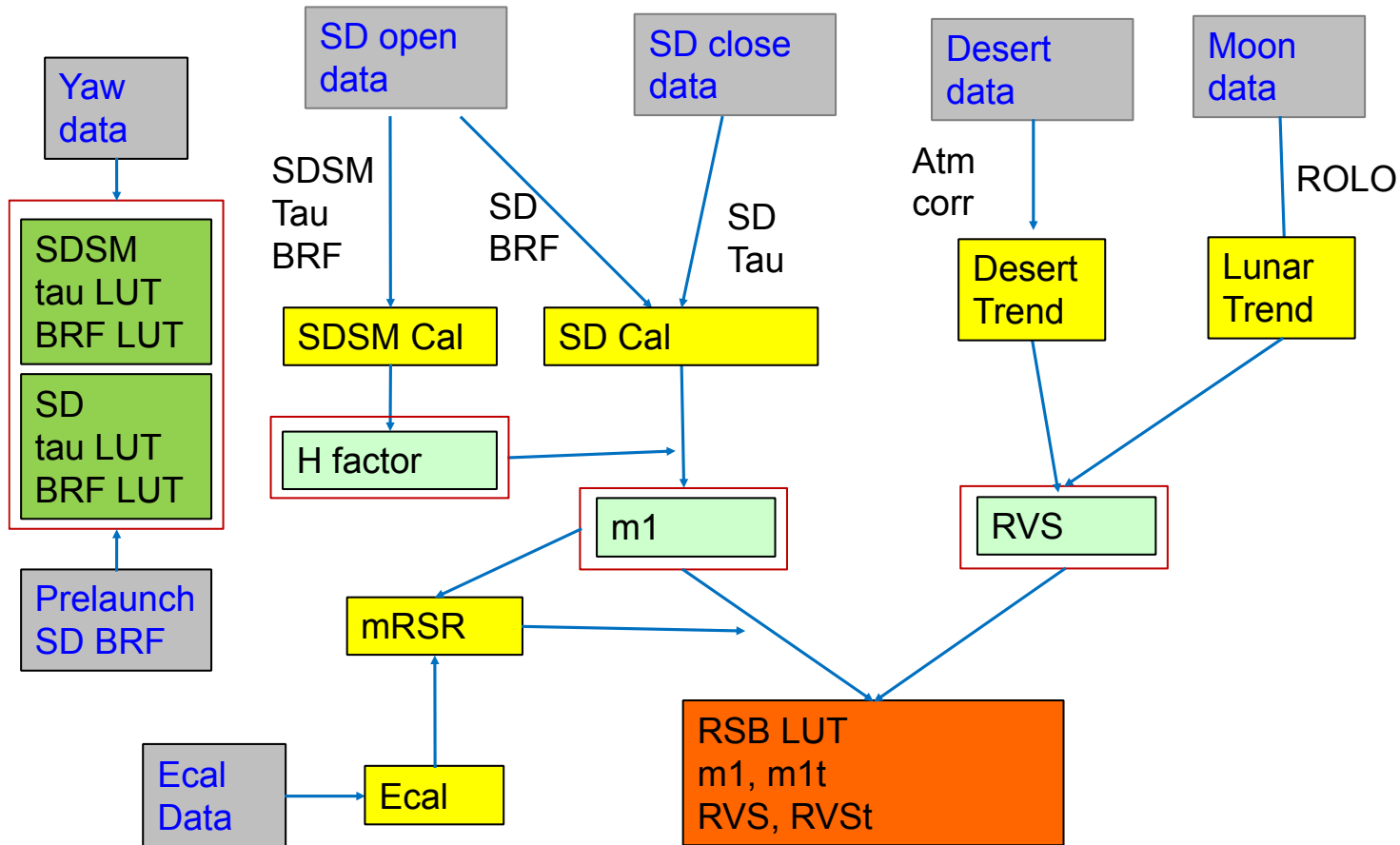
Measurement density and accuracy

- At coarse measurement resolution, the measured ASR shape and gain varies depending on the sampled wavelengths
- What is the uncertainty due to coarse measurement?
- Detail measurement sometimes not practical due to resource and time constrain, work around?

Post-Launch (on-orbit) Calibration

- How much calibration changed (optical, electronics) between pre-launch and first on-orbit measurement?
- Continuing calibration to maintain data accuracy and continuity
- methods: on-board calibrators, lunar calibration, desert, deep convection cloud (DCC), cross sensor calibrations ...
- validation: science products knowledge, ground targets, cross sensor comparison ...

OBPG MODIS on-orbit Calibration Update

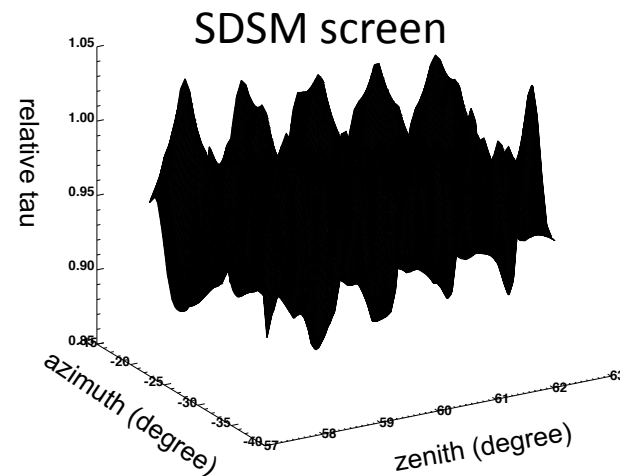
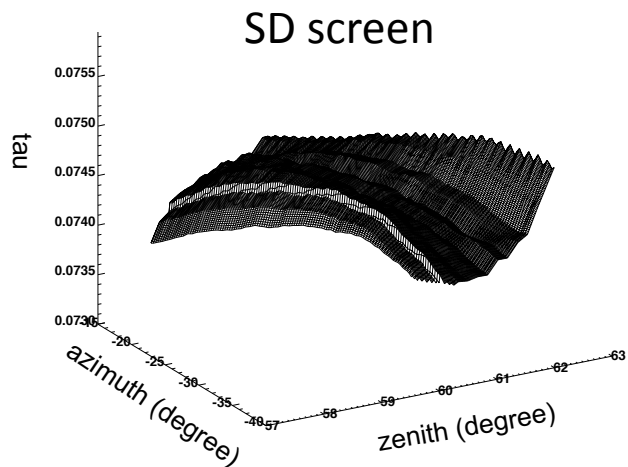
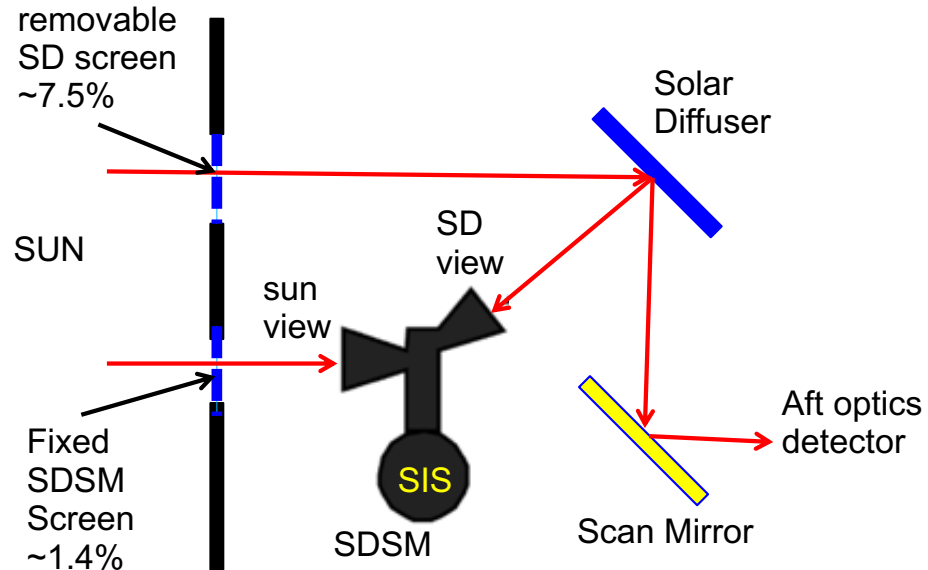


OBPG R2018 calibration process

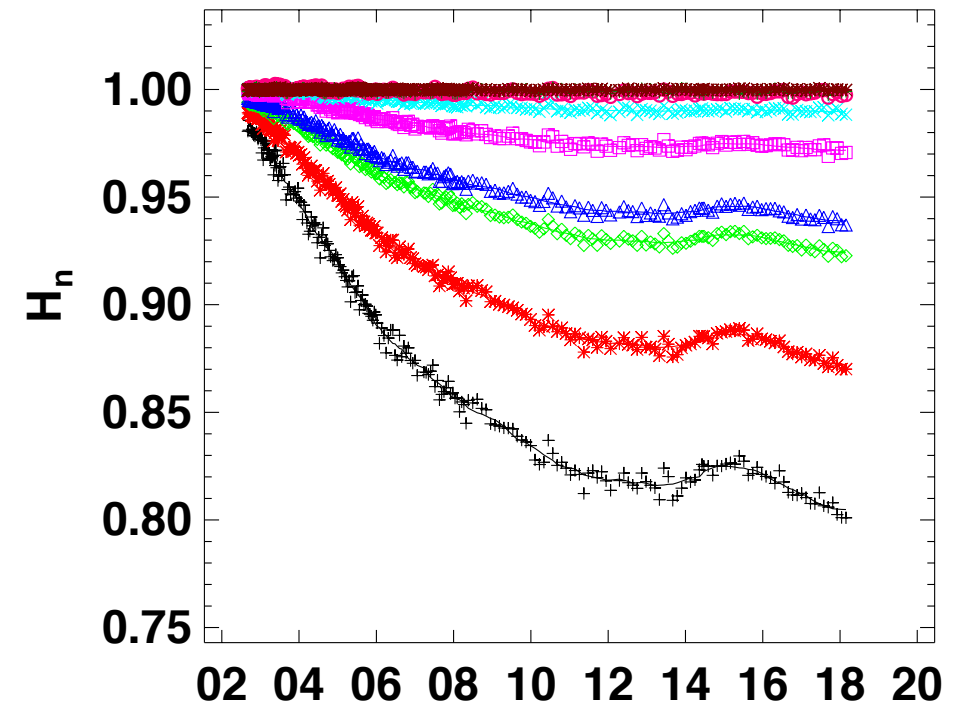
- Each month, calibration is updated based on instrument data (grey), running through calibration algorithm to produce a LUT
- The required calibration update frequency and complexity depending on instrument design, performance ...

MODIS on-orbit Calibration: nominal gain

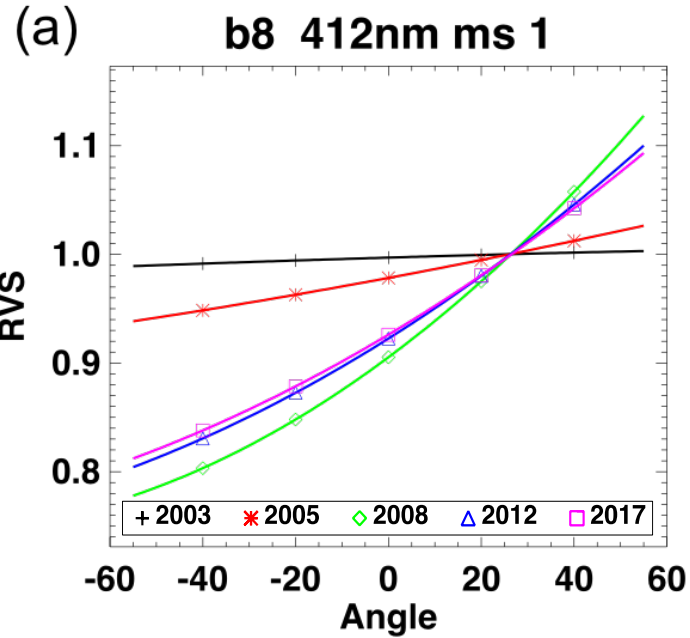
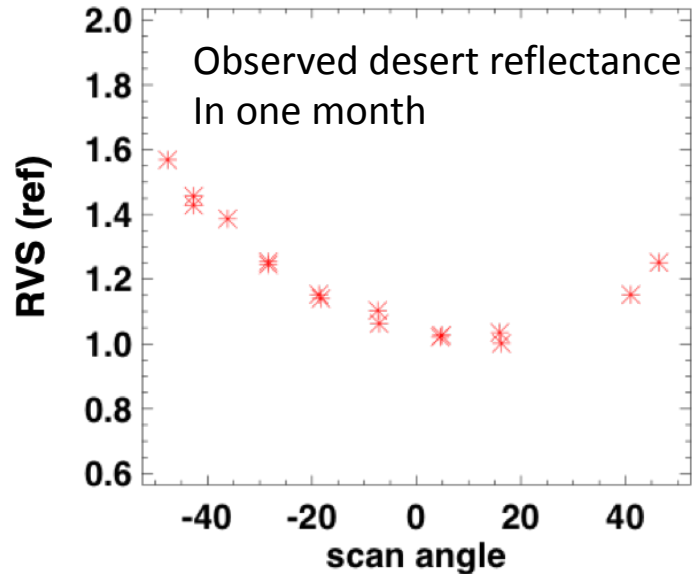
- Solar Diffuser (SD) reflectivity is key to gain accuracy
- Large variation in SDSM screen transmission post challenges to quantifying SD reflectivity
- Design: avoid screens, SDSM ...



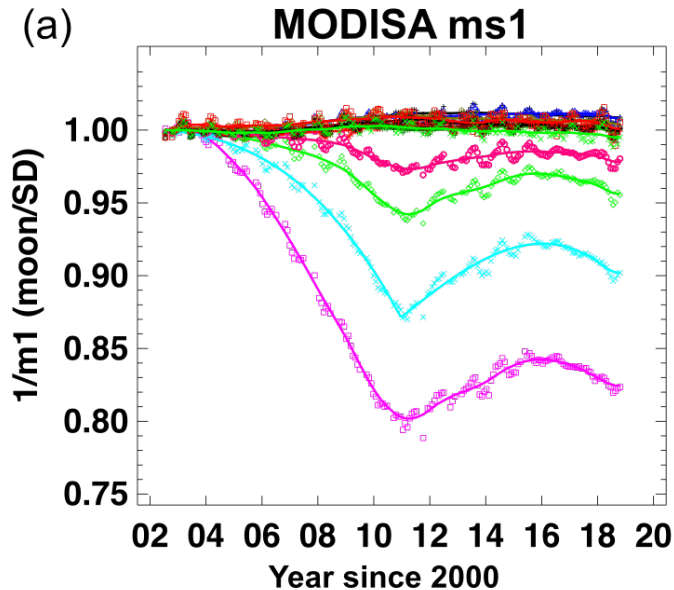
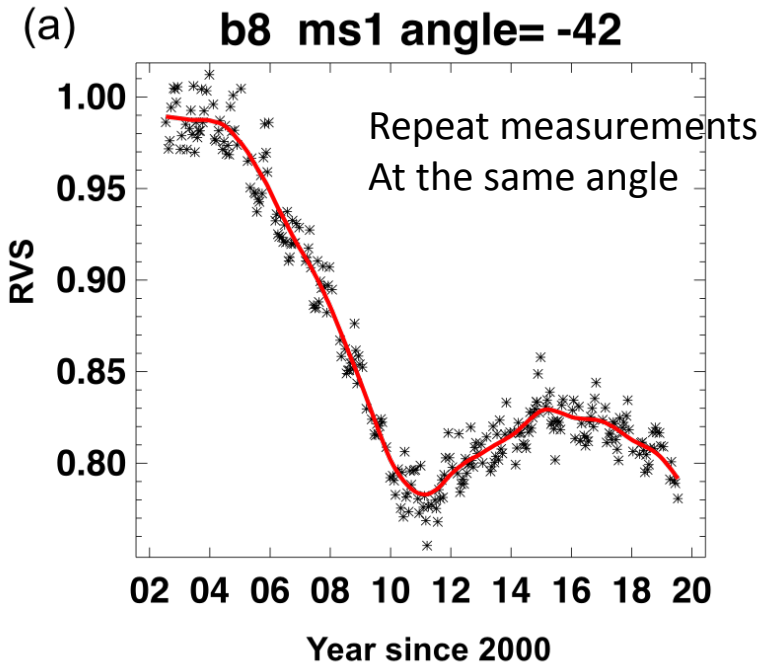
Aqua SDSM



MODIS on-orbit Calibration: RVS

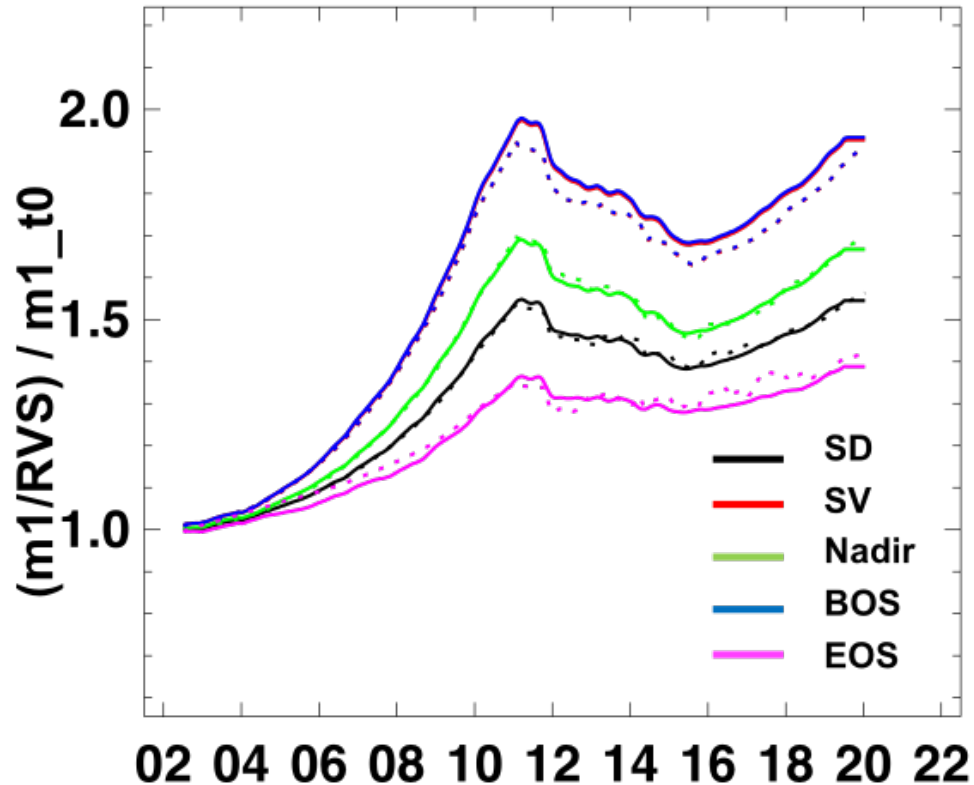


- Track RVS change using desert and moon
- Difficult to accurately characterize RVS on orbit
- Design: avoid RVS change on orbit



Lunar calibration:
Gain trending at lunar
Observation angle

MODIS on-orbit Calibration: requirement



MODIS Aqua band 8 gain at various scan angle

Solid: OBPG

Dashed: MCST

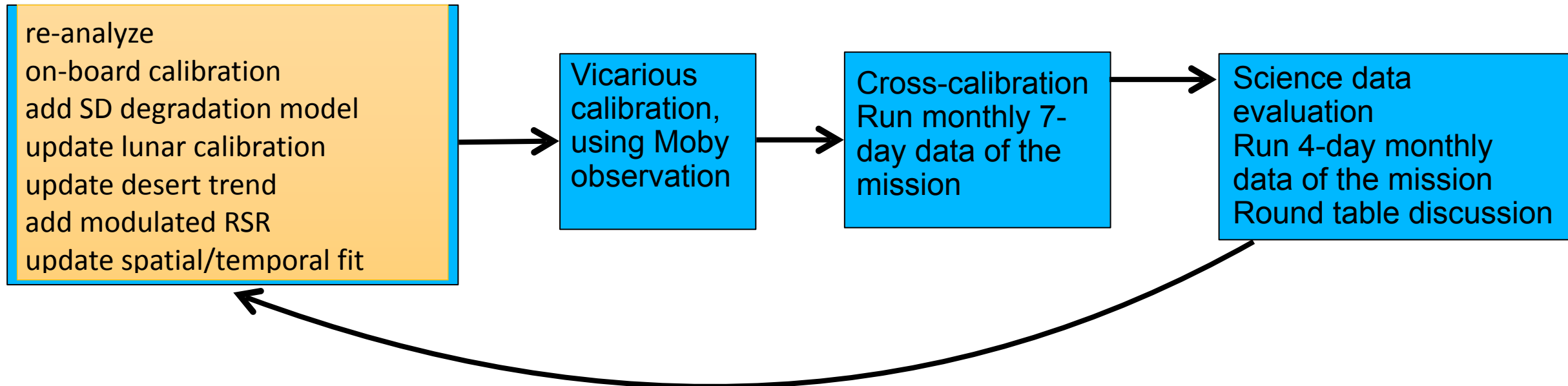
- Comparison of OBPG and MCST calibration
- The change in gain is up to 2x at the most extreme scan angle
- Hard to described as functional form
- Limitation in monthly update
- Differences of up to 5% at certain angle, does it matter?
- What is the calibration accuracy requirement to produce meaningful science products?

Maintaining Calibration Accuracy

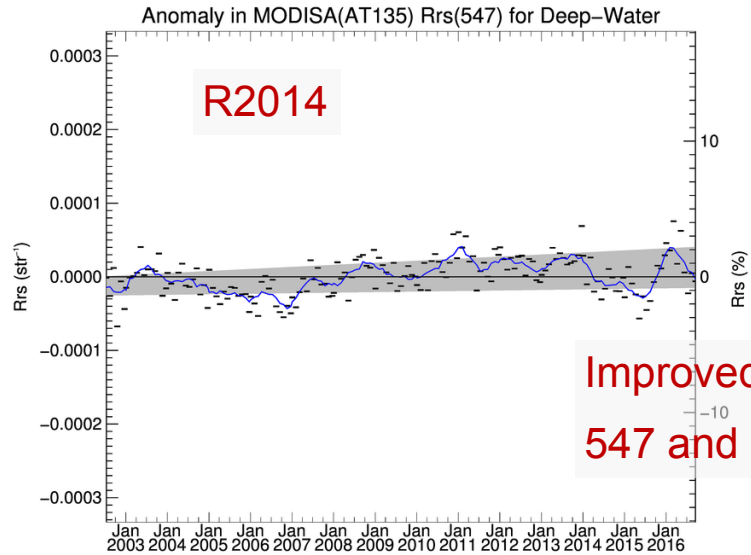
- Satellite data provider work with end users to maintain products accuracy
- If satellite data disagree with common science knowledge/observation and deemed caused by calibration, then calibration needs to be updated through re-analysis and the whole mission data is re-processed
- During each calibration update analysis, time series of science products are produced and evaluated by the community (OBPG staff)
- Updating calibration is a time consuming, iterative process and requires efficient team work to be successful

Mission Calibration Update

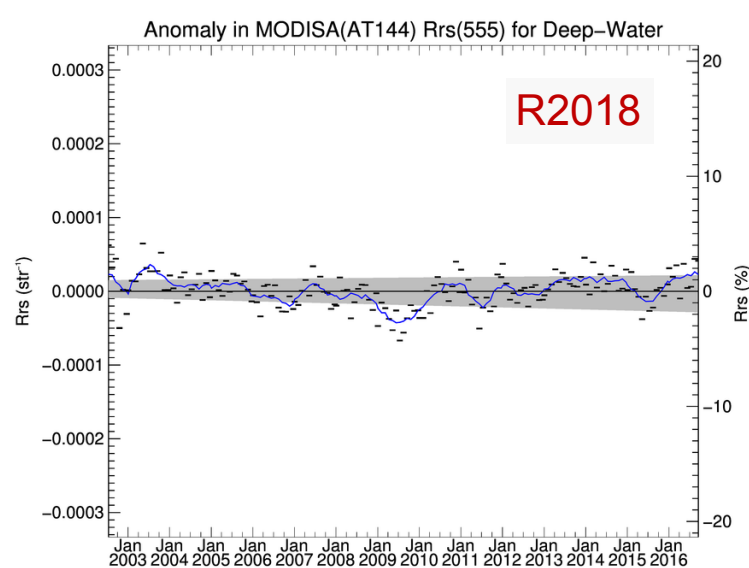
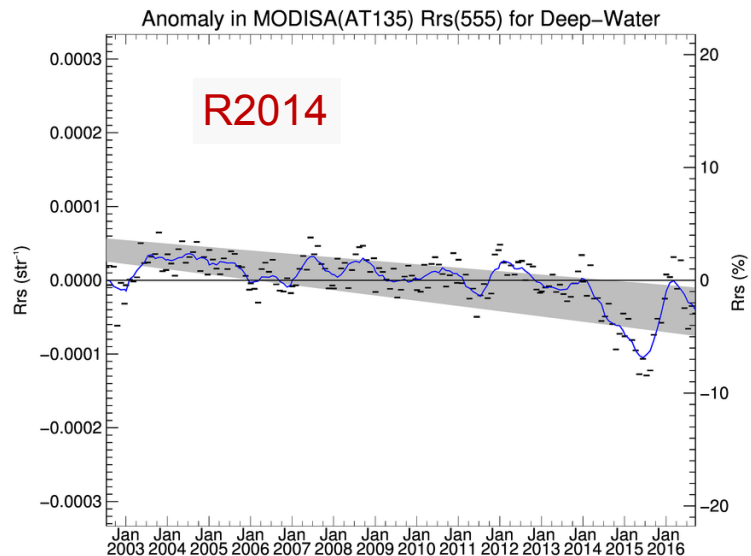
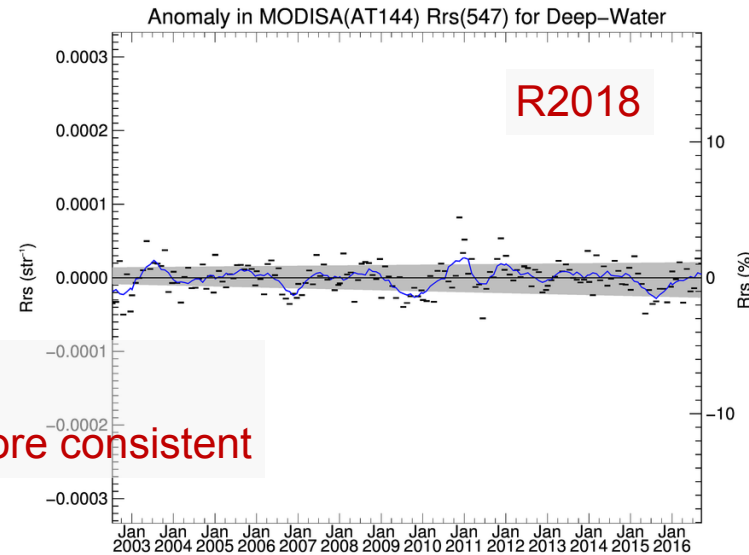
- Calibration, data processing and review by science team
- Short turn around time for each analysis is key, weeks, months, years?
- OBPG: Stream lined end-to-end radiometric, vicarious, and cross-calibration
- OBPG: efficient processing system: <1 week to reprocess 20 years of MODIS data



OBPG calibration update: R2018



Improved trends
547 and 555 nm more consistent



OBPG R2018 vs. R2014
product, temporal anomaly
trend

The change in remote
sensing reflectance (Rrs)
trend is ~0.5% in calibration
(TOA radiance)

Calibration Impact on Science

- Calibration induced anomaly or actual events?
 - The discovery of ozone hole.
- 2010 MODIS Science Team argument:
 - Did Amazon green-up during 2005 drought season? Opposite results from different version of MODIS data
- OBPG R2018 calibration update
 - Is there a trend in global ocean mean ocean surface reflectance in green?
-

Summary

- The role of calibration in satellite remote sensing
- General calibration strategy, data processing, challenges, and impacts on satellite data products

Thank you!

Questions:

backup

Satellite observed sea surface temperature

