The Vicarious Calibration of Geosynchronous and Polar-orbiting Visible Sensors using Desert BRDF Models Based on the TRMM VIRS

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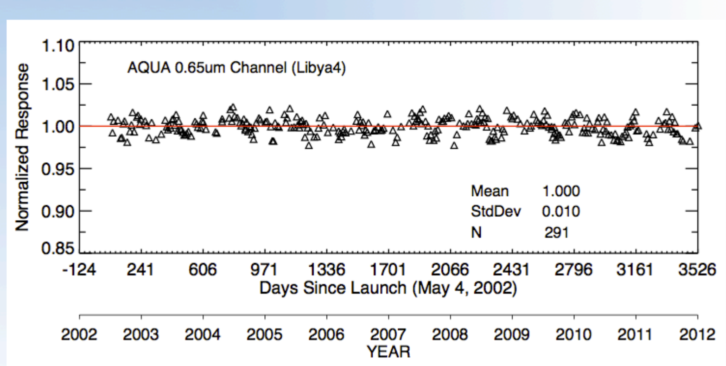
Introduction

The next generation of GOES satellite (GOES-R) and the Joint Polar Satellite System (JPSS) will carry onboard calibration for visible sensors. There will be a need for validating the onboard calibration of these sensors with invariant targets such as deserts and deep convective clouds. These independent approaches provide confidence that their calibrations are stable over time and the TOA fluxes and aerosol retrievals are of climate quality. The CERES geostationary calibration group at NASA Langley Research Center has developed a vicarious approach of calibrating geostationary (GEO) and low earth orbit (LEO) visible sensors using exoatmospheric desert radiance models, which are derived based on multiple years of clear-sky TOA radiance measurements from a well-calibrated visible instrument like MODIS. As a proof of concept, this technique has been applied to calibrate AVHRR visible sensors that do not have on-board calibration.

Prime Desert Candidates

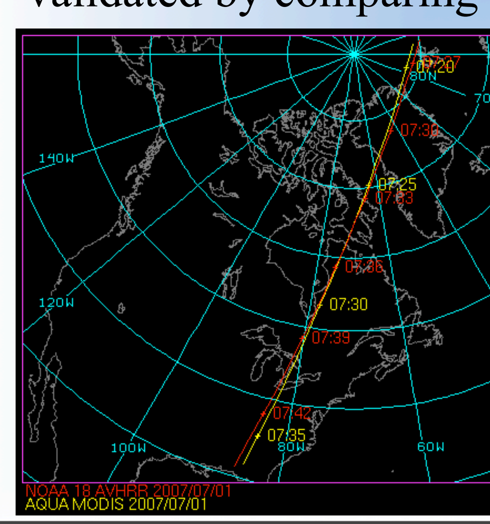
- Invariant desert targets have long served as benchmarks for post-launch calibration of satellite sensors.
- Four bright and homogeneous desert sites over Africa are selected for this study.
- Temporal stability of each of these sites is verified using 10 years of Aqua MODIS observations.

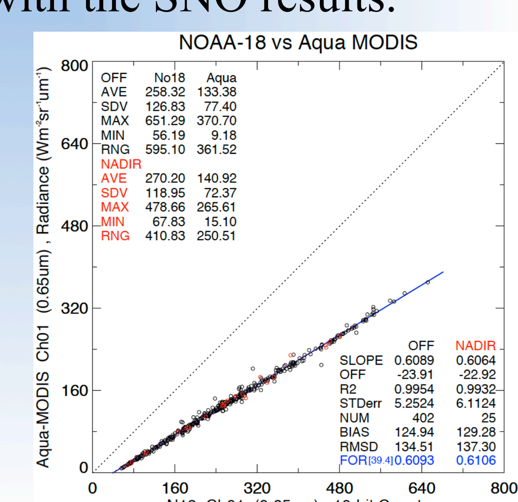
1: Libya-1, 2: Libya-4, 3: Niger-1, 4: Arabia-1



AVHRR-Aqua Intercalibration using SNO over poles

- AVHRR visible sensors are calibrated against Aqua MODIS using simultaneous nadir overpass (SNO) data over poles.
- The matching criteria are ΔTime < 15 minutes, and ΔVZA < 15°.
- Desert-based AVHRR calibration results are validated by comparing with the SNO results.

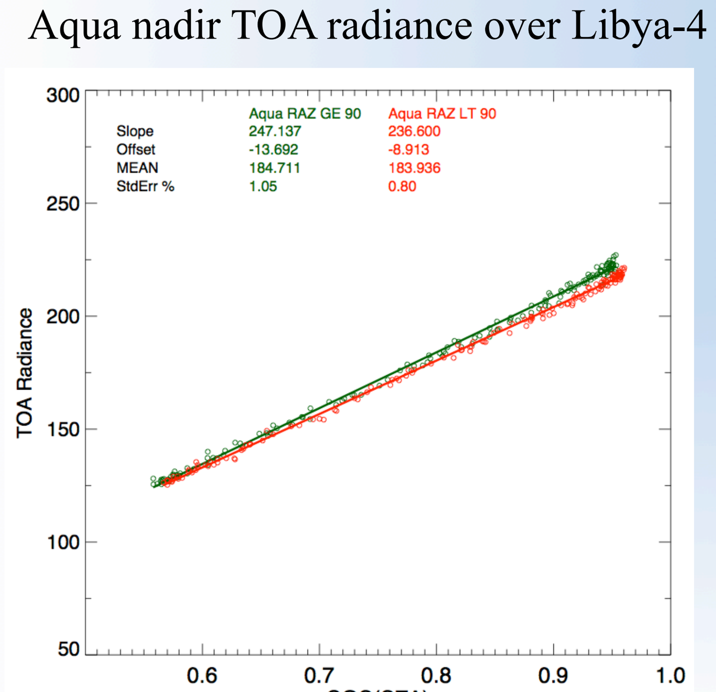




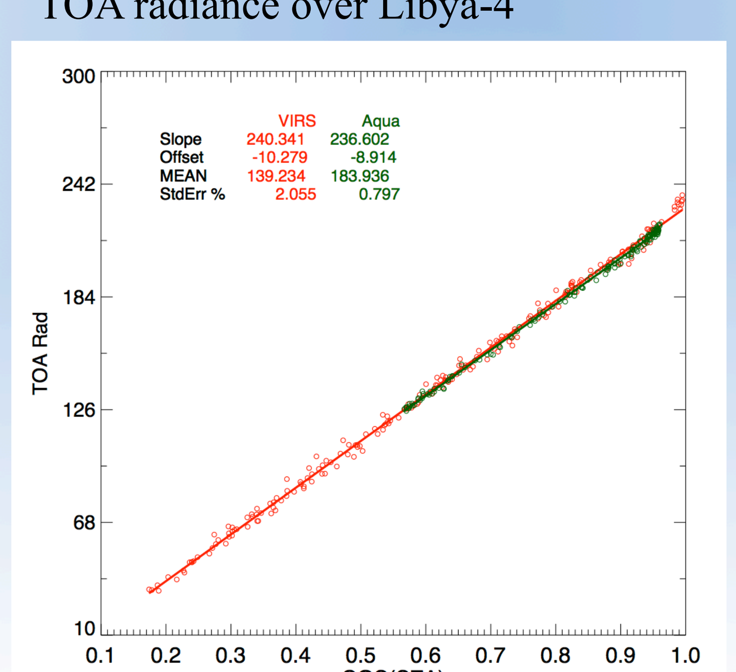
Nadir TOA Radiance Models for Deserts

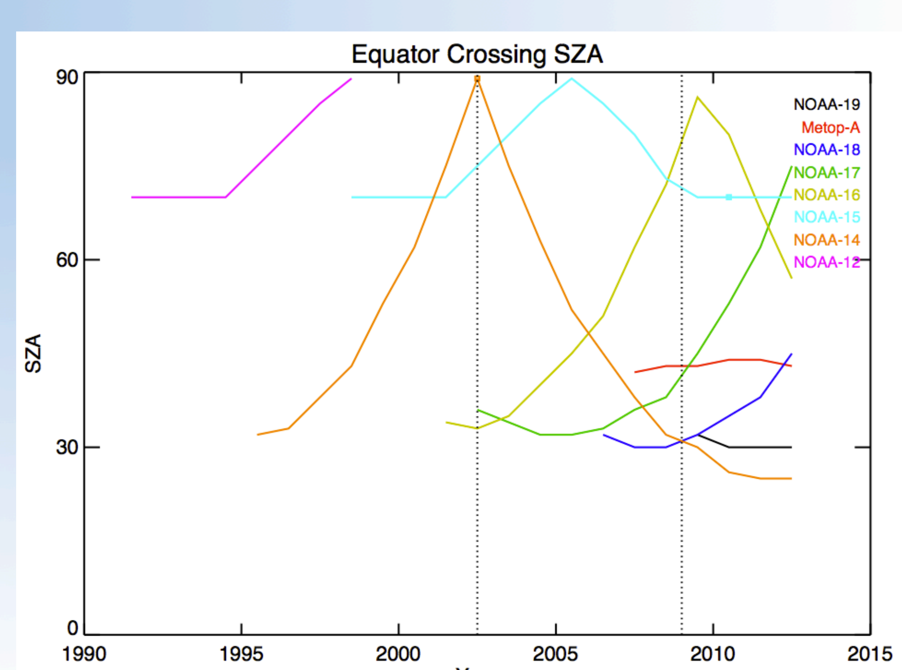
- Ten years of clear-sky nadir measurements from Aqua MODIS are used to derive a linear model between TOA radiance and cosine of the solar zenith angle for each desert region. The model is defined separately for both forward and back scatter measurements.
- VIRS measurements show that the nadir TOA radiance and cosine of solar zenith angle bear a linear relationship throughout 0°<SZA<80°.
- A direct comparison of VIRS and Aqua-MODIS nadir TOA radiance over the deserts shows the two data sets are radiometrically consistent. Thus the Aqua-based model can be extrapolated for higher solar zenith angles to calibrate historical AVHRR satellites with degrading orbits.

Difference in Forward and backscatter Aqua nadir TOA radiance over Libya-4



Comparison of VIRS and Aqua nadir TOA radiance over Libya-4





Desert Calibration Methodology

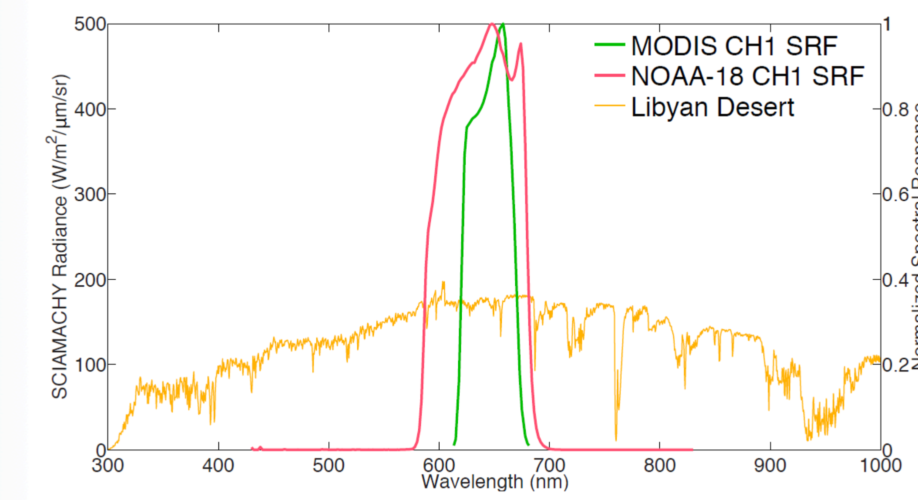
- Clear-sky nadir pixel counts of a target sensor are averaged over the desert region on a scene basis. For a given value of the target sensor's solar zenith angle, the corresponding TOA radiance is predicted from the Aqua-based TOA radiance model.
- Any difference in relative spectral response functions between Aqua and the target sensor is accounted for by deriving a spectral band adjustment factor (SBAF) for the pair using the SCIAMACHY hyperspectral radiances over the deserts.
- The SBAF is used to adjust the Aqua radiance to the target sensor radiance.

TOA radiance of target sensor = SBAF * Aqua Radiance

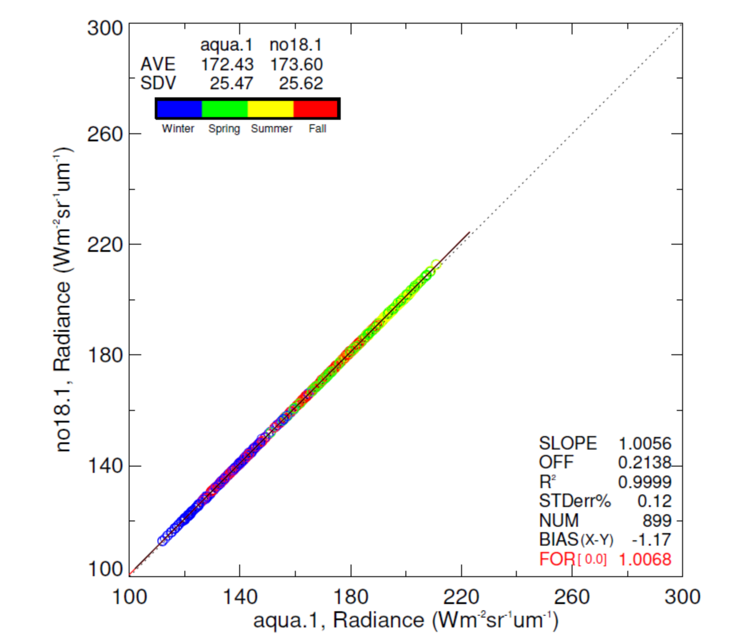
- Finally, the radiometric gain of the target sensor is derived using the equation,

Gain = Predicted Radiance/(Mean count – Spacecount),

where Spacecount is an offset term corresponding to zero input radiance.



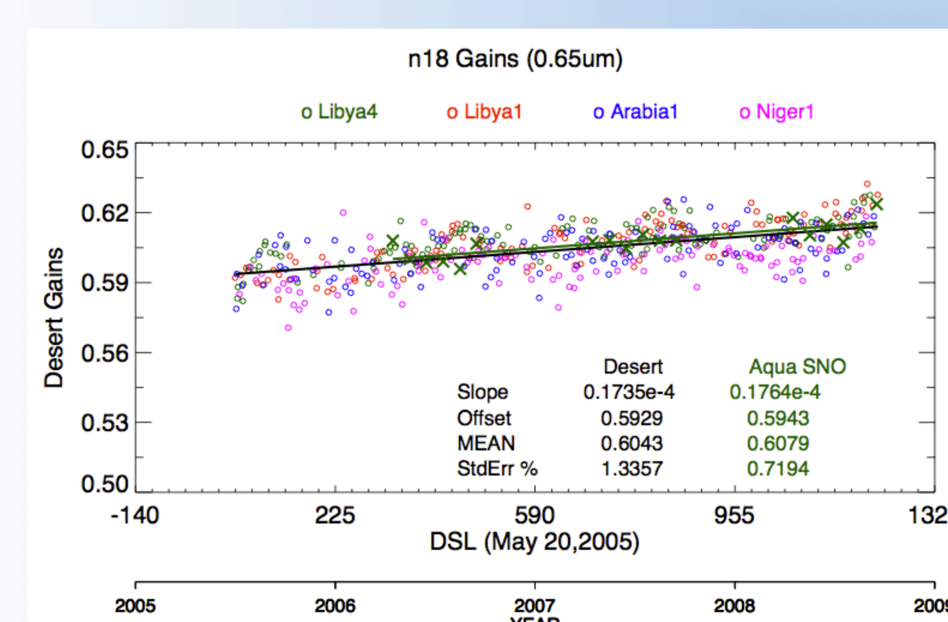
Normalized spectral response functions (SRF) of N18 and MODIS visible channel (0.65μm) along with the spectral signature of Libya-4 obtained from SCIAMACHY

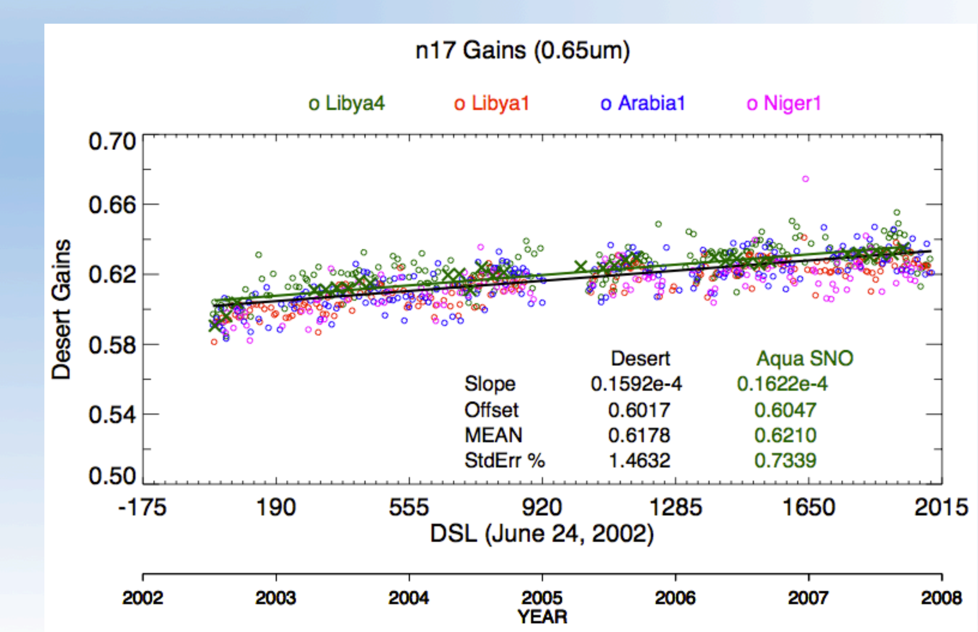


Regression of N18 and Aqua pseudo-radiances obtained by convolving their visible channel SRFs with reflected SCIAMACHY solar spectra from Libya-4

Results

This method is applied to calibrate the N17 and N18 AVHRR visible (0.65um) sensors. The desert-based gains match with the SNO results within 0.6% for both sensors. Individual desert gains are consistent within 0.7%.





Summary/Future Work

- The temporal stability of the site is key for the desert technique to work.
- The results indicate that the SNO and combined desert method are within 0.6%, which is well-within the uncertainty of either method.
- Desert-based absolute calibration technique has potential to calibrate historical, current, and future satellite sensors to the same calibration reference.
- SCIAMACHY hyperspectral radiances can be used to derive correction factors to mitigate the effect of spectral band differences between the reference and target sensor.
- The technique will be extended further to calibrate another visible channel (0.86um) of AVHRR.

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