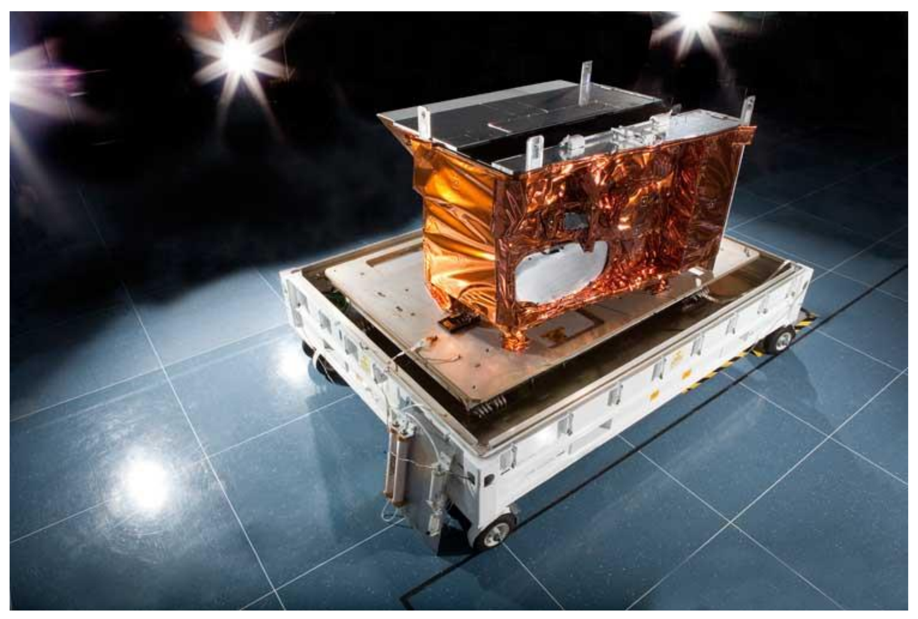
# Benefits of an explicit calibration procedure for VIIRS reflective solar bands

Qiang (Jack) Ji[*a], Jeff McIntire[a], Tom Schwarting[a], Hassan Oudrari[a],
Jinan Zeng[b], Xiaoxiong (Jack) Xiong[c], Boryana Efremova[d]
[a]SSAI, [b]Fibertech, [c]NASA, [d]ERT

## 1. Background

Visible Infrared Imaging Radiometer Suite (VIIRS) is a scanning radiometer with reflective solar bands (RSB) and thermal bands (TEB). The RSB is calibrated prelaunch using an integrating sphere.

| RSB | Wavelength (nm) |
|---|---|
| M1 | 412 |
| M2 | 445 |
| M3 | 488 |
| M4 | 555 |
| M5 | 672 |
| M6 | 746 |
| M7 | 865 |
| M8 | 1240 |
| M9 | 1378 |
| M10 | 1610 |
| M11 | 2250 |
| I1 | 640 |
| I2 | 865 |
| I3 | 1610 |



VIIRS Photo courtesy of Raytheon Space and Airborne Systems (http://npp.gsfc.nasa.gov/viirs.html)

## 2. Calibration

$$L = c_0 + c_1 x + c_2 x^2$$

The equation can be solved using *linear* algebra, but all $c_0$, $c_1$, and $c_2$ are affected by the calibration of $L$. An attenuator method adds

$$\tau \cdot L = c_0 + c_1 y + c_2 y^2$$

The two equations with $h_0 = c_0 / c_1$ and $h_2 = c_2 / c_1$ lead to

$$\tau = \frac{h_0 + y + h_2 y^2}{h_0 + x + h_2 x^2} \quad \text{and} \quad c_1 = \frac{L}{h_0 + x + h_2 x^2}$$

where $L$ only affects $c_1$ (which is calibrated on-orbit). However, the equation for $\tau$ (the attenuator transmittance), $h_0$ and $h_2$ (which are fixed on-orbit) becomes *nonlinear*.

## 3. Motivation

Nonlinear procedures for solving $\tau$, $h_0$, and $h_2$ together can be tricky to track and to verify. For example, there are hidden assumptions in minimization routines, and the solutions are asymptotic.

We want to visualize step by step how a procedure works.

## 4. New procedure

Rewrite the two calibration equations into

$$\frac{\tau \cdot x - y}{1 - \tau} = h_0 + h_2 \frac{y^2 - \tau \cdot x^2}{1 - \tau}$$

and using measurements from 3 or 4 radiance levels

$$\frac{(\tau \cdot x_i - y_i) - (\tau \cdot x_j - y_j)}{(\tau \cdot x_m - y_m) - (\tau \cdot x_n - y_n)} = \frac{(\tau \cdot x_i^2 - y_i^2) - (\tau \cdot x_j^2 - y_j^2)}{(\tau \cdot x_m^2 - y_m^2) - (\tau \cdot x_n^2 - y_n^2)}$$

which is a quadratic equation of $\tau$, with *analytical* solutions.

Once $\tau$ is calculated across all combinations of measurements, $h_0$ is the intercept, and $h_2$ is the slope of a *linear* fit.

## 5. Benefits of the new procedure

The new procedure is straightforward. Solving for $\tau$ is similar to driving it using a calibrated detector, simply repeat the measurement at various radiance levels and look at the statistics.

The nonparametric technique is numerically stable, without the nonlinear fitting, the guesses plus inexplicit iterations, and the hidden assumptions, associated with those existing procedures.

Also becomes straightforward is the uncertainty analysis, with the impact of individual data points easily seen.

By making the selections of $\tau$ and the relative calibration coefficients explicit, how the new procedure works is directly exposed. A trade-off, depending on perspective, is that the consistency of results and a global optimization may have to be considered explicitly.

## 6. Examples

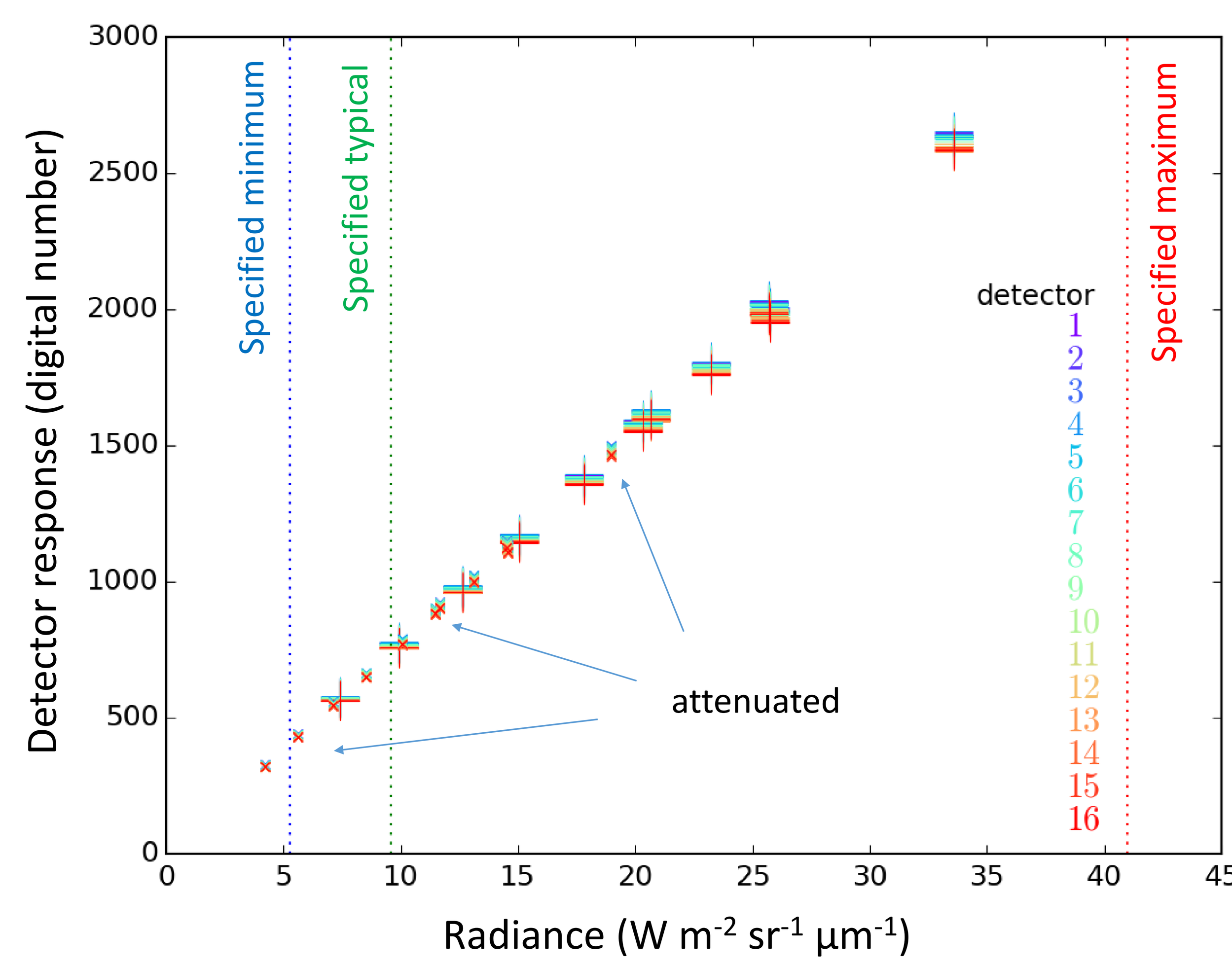



**Fig 1.** There are 16 detectors in band M6. The response of detector is almost linear to the given radiance.

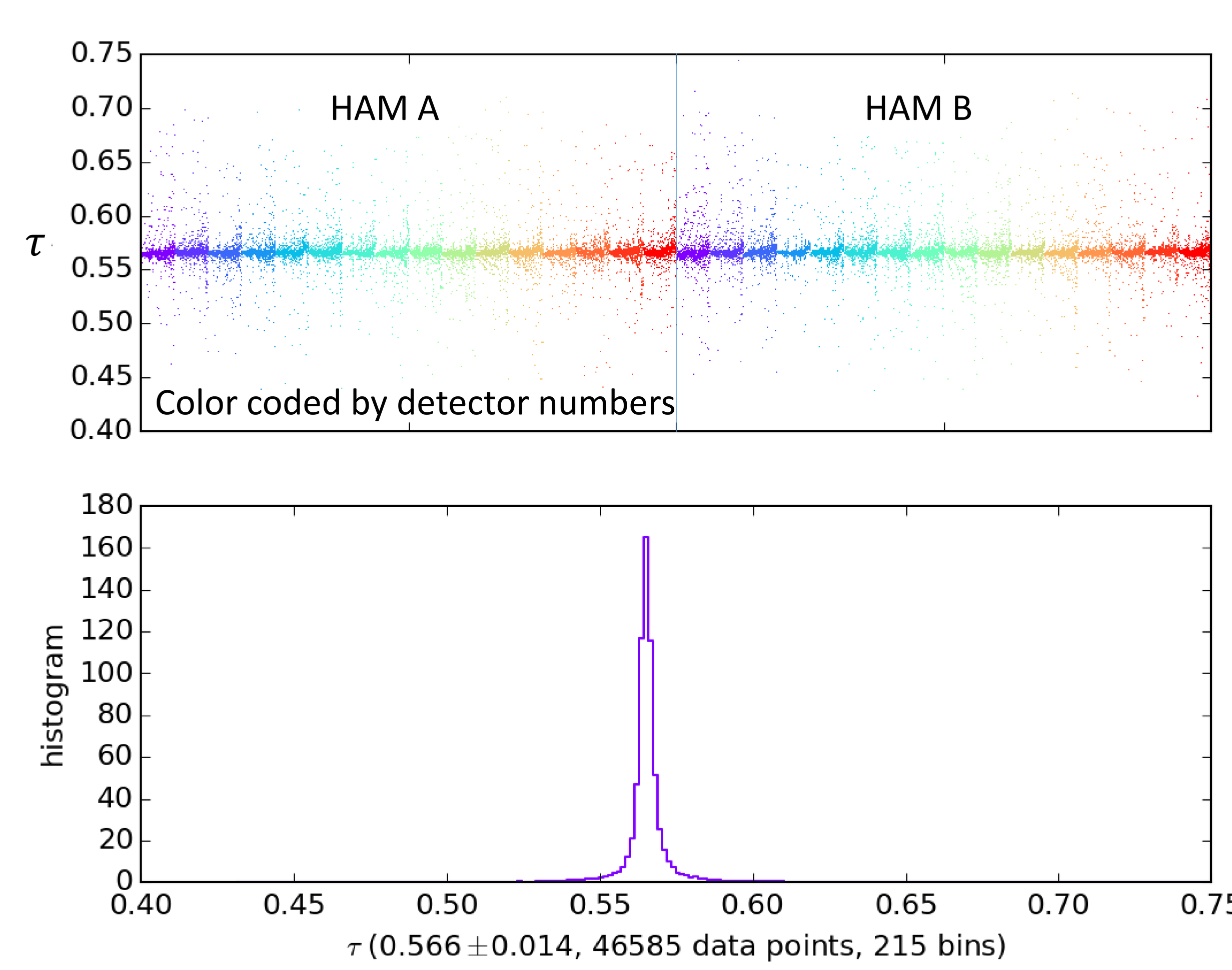



**Fig 2.** Each data point in the scatter plot (upper panel) corresponds to a combination of measurements.

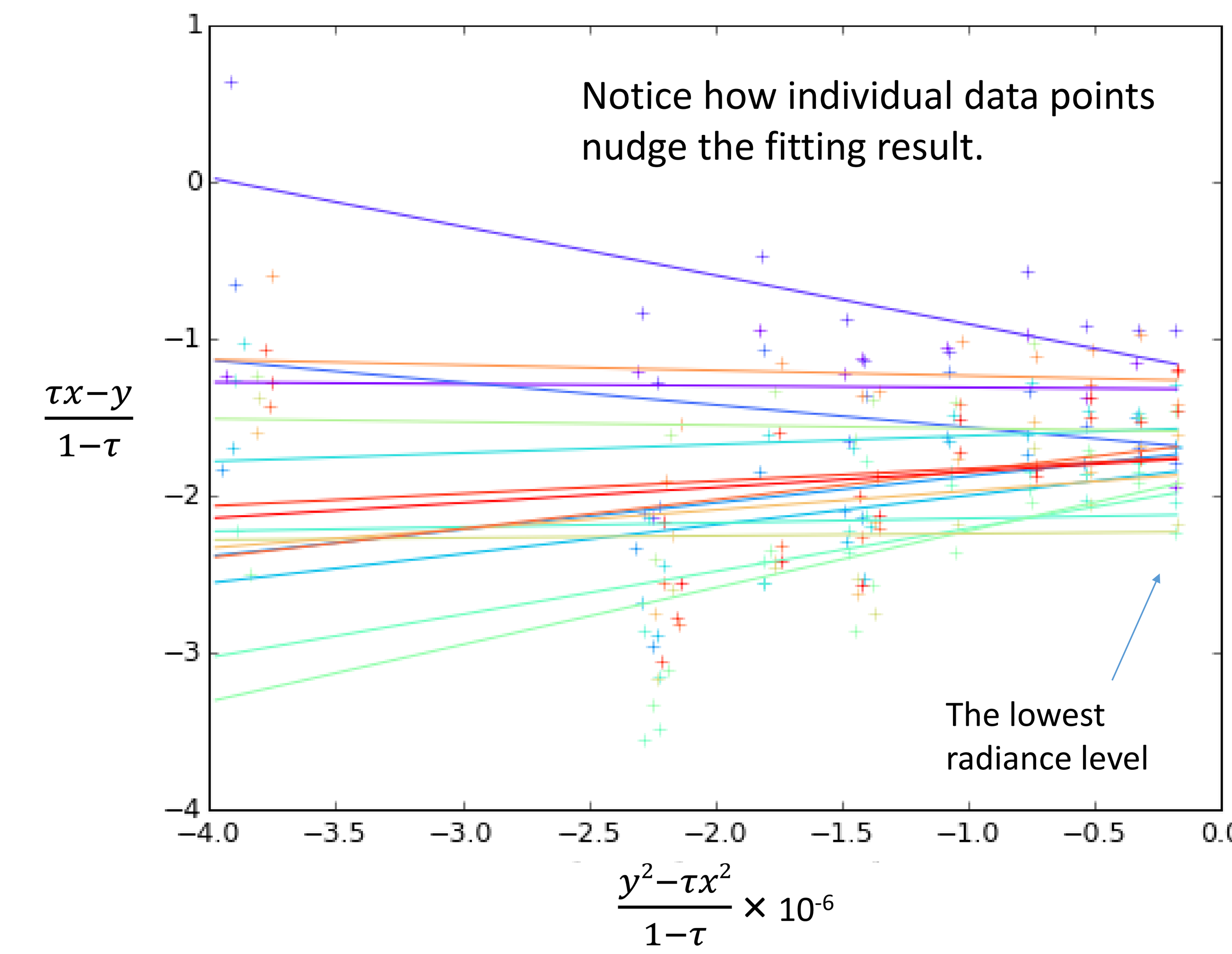



**Fig. 3.** The data points for a detector would follow a straight line if the measurements obeyed a quadratic calibration equation. The choice of fitting method is subjective. The results shown are from an ordinary least squares method.

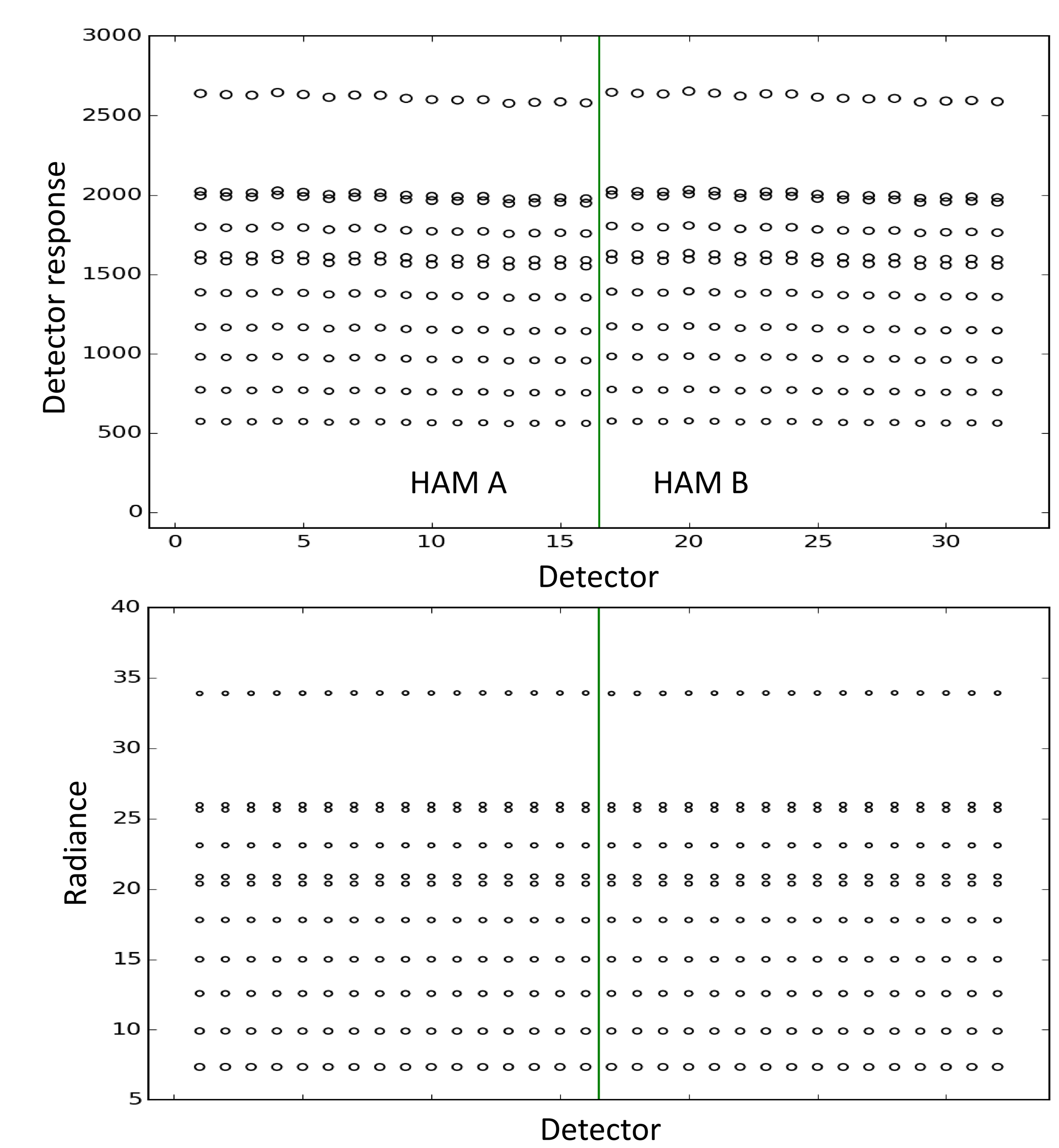



**Fig. 4.** Before calibration each detector has its own response (top panel); after calibration all detectors report the same radiance at a given radiance level (bottom panel).

## 7. Summary

Visualizing step by step how the new procedure works helped us gaining insight on our measurements and the calibration.

*Reference*: Ji et al, A robust method for determining calibration coefficients for VIIRS reflective solar bands, SPIE, 2015.

* qiang.ji@ssaihq.com