Determination of Aerosol Optical Depth, and Top Of Atmosphere Calibration Values With a Multi-Filter Rotating Shadowband Radiometer, Over a Five Year Long Period

Fred Denn[1] , Bryan Fabbri[1] , Greg Schuster[2]

1 Science Systems and Applications, Inc. (SSAI), Hampton, VA
2 NASA Langley Research Center, Science Directorate, Hampton, VA

We Thank Ali H. Omar and the AERONET Team for Maintaining the AERONET Network and providing AERONET data.

Abstract

Aerosol Optical Depth (AOD) is important because aerosols determine atmospheric energy deposition and cloud condensation nuclei. AOD can be determined with a sun photometer. The first step in determining AOD is the determination of the top of atmosphere values (V0). The sun photometer considered here is a Yankee Environmental Multi-Filter Rotating Shadowband Radiometer (MFRSR). Four methods of determining the top of atmosphere values are examined and applied to data taken during the Third Filter Radiometer Comparison (FRC-III), which took place during the Twelfth International Pyrheliometer Comparison Held in Davos, Switzerland during September and October of 2015. Data from a set of three Physikalisch – Meteorologisches Observatorium Davos (PMOD) manufactured Precision Filter Radiometers (PFRs), known as the PFR Triad, were used as the reference data set.

Data were collected over a five year period at CLH (Chesapeake Light House, twenty kilometers off the Virginia coast), and LRC (located in southwest Virginia) BSRN sites, and at PMOD.

In place long-term straight line fits of daily TOA values were found to result in AOD values that matched well with TOA values obtained with the Triad.

Measurement locations

Clouds and the Earth's Radiant Energy System (CERES) Ocean Validation Experiment COVE, (BSRN site CLH). COVE DATA 2000 - 2016.
This Study 2011 and 2012

NASA Langley (BSRN site LRC).
2013, 2014, & 2015.

Determination of Instrument V_0 at TOA

V_0 is needed to characterize instrument voltages in the absence of an atmosphere, and is determined by extrapolation of measurements at multiple solar zenith angles.

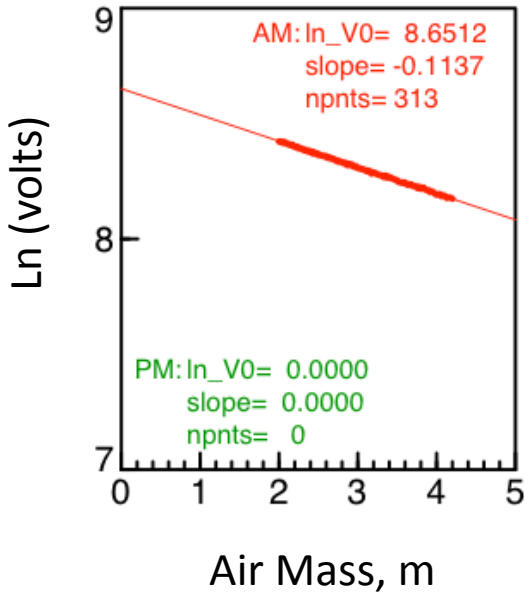
Beer's Law,

$V = V_0 * \exp(-t_0 m)$

Where $t_0 = t_{aerosol} + t_{Rayleigh} + t_{ozone} + t_{N02}$

V_0 = Top of Atmosphere value

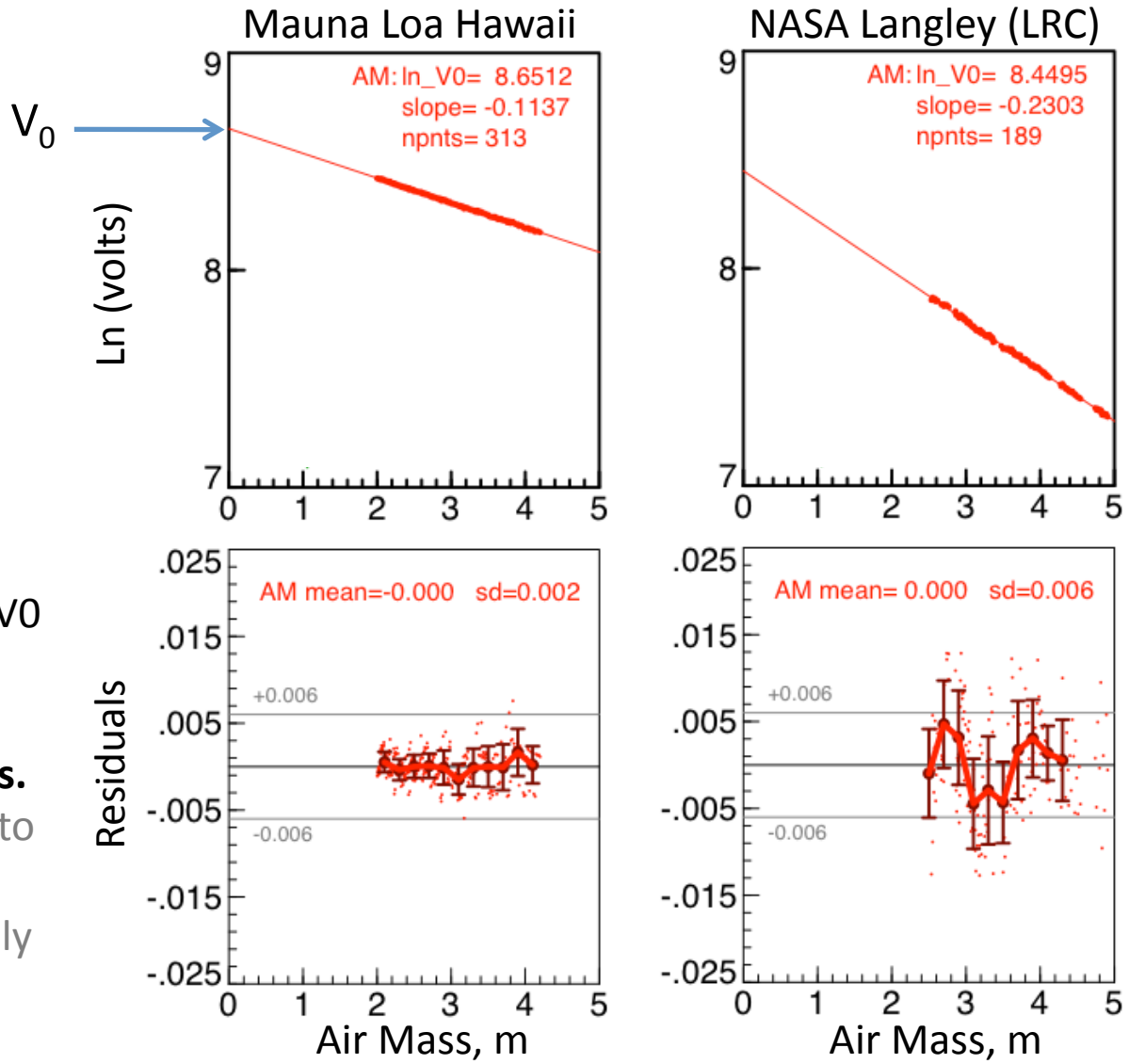
t = tau = optical depth



Four methods of determining V_0 were investigated

1) Fit to mountain points
2) Fit to all daily AM V_0 points.
3) 3-month running mean fit to daily AM V_0 points
4) Davos mountain points only

Langley plots based on Beer's Law (one transit)

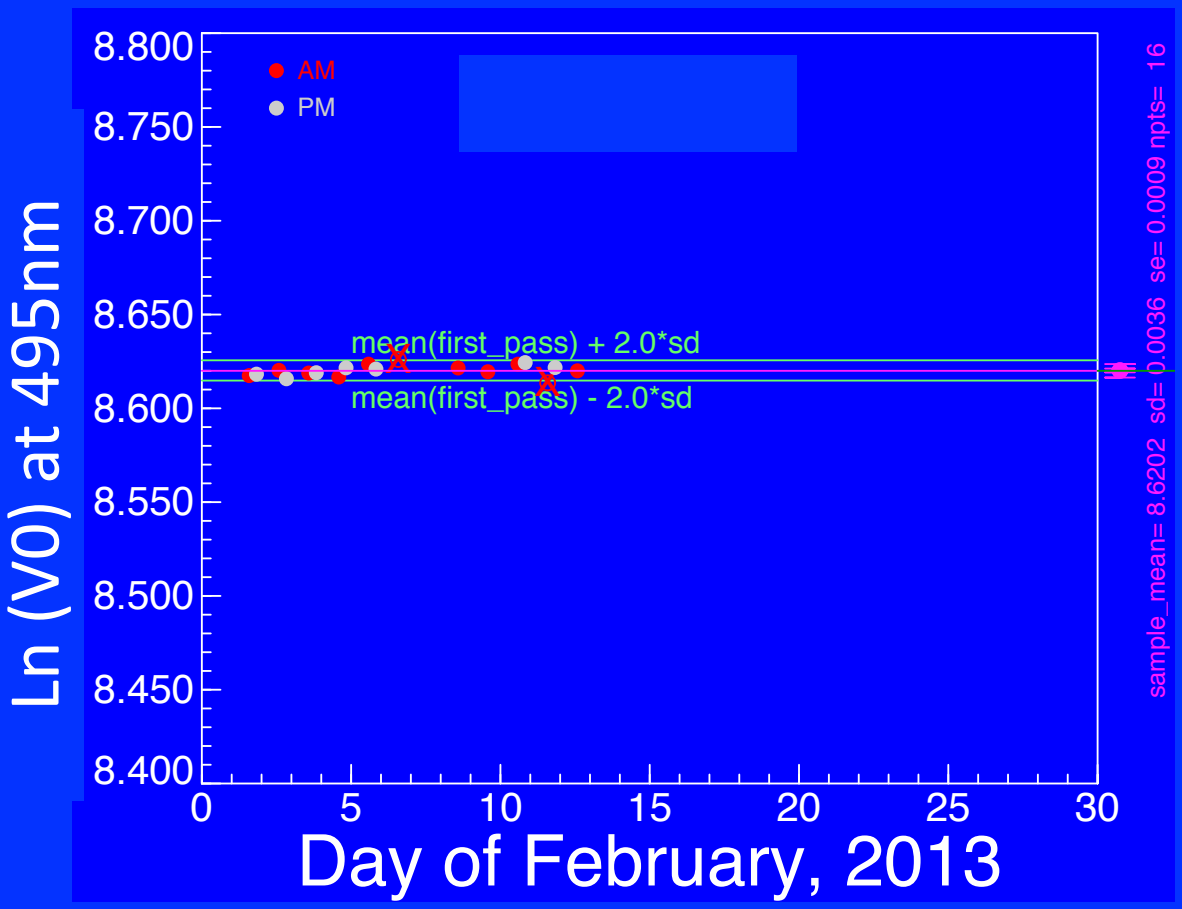


Four methods of determining V0 were investigated

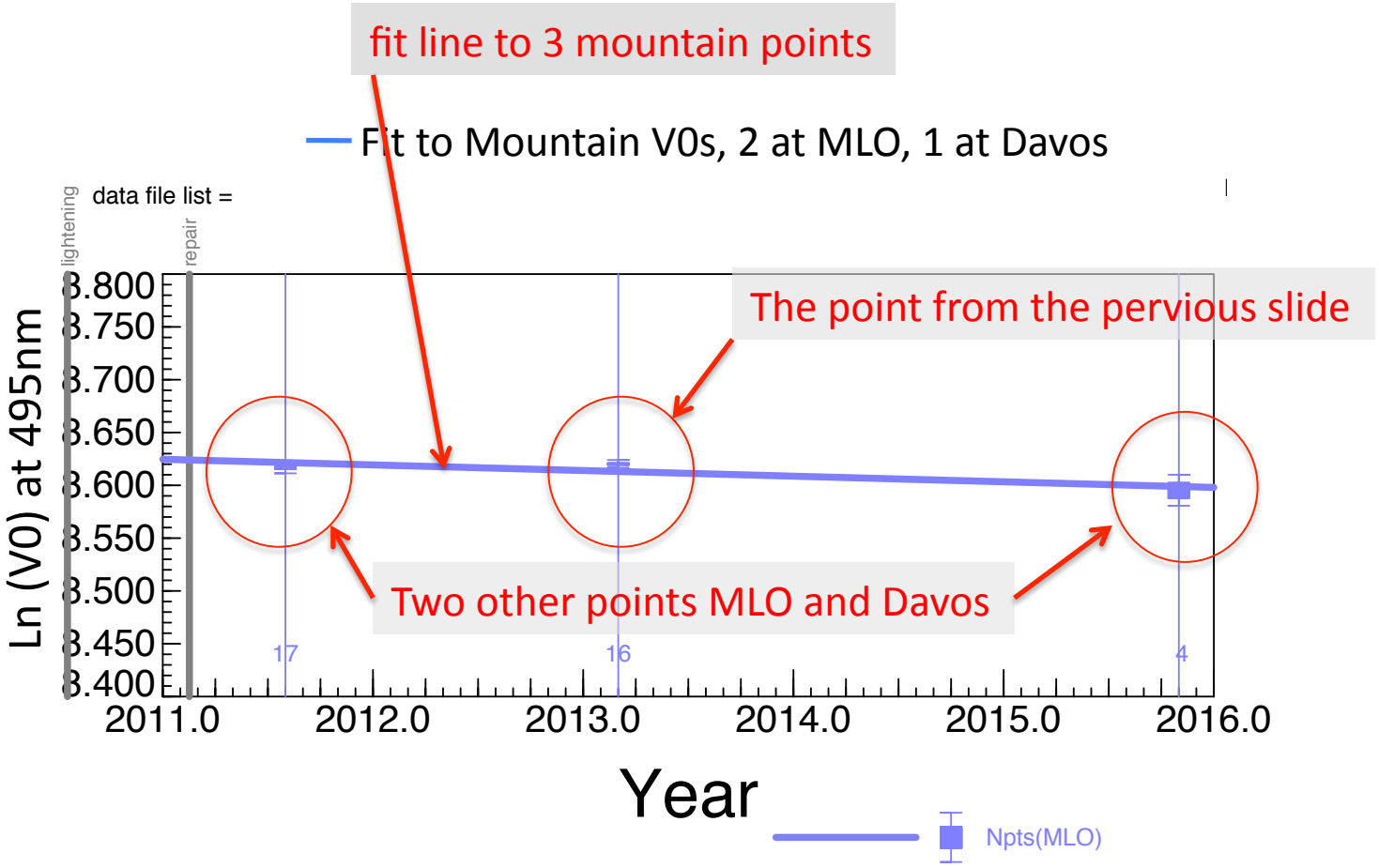
1) **fit to mountain points**
2) **fit to all daily AM V0 points.**
3) 3-month running mean fit to daily AM v0 points
4) Davos mountain points only

Example of a Calibration Mission to Mauna Loa Hawaii

Eight Days of Data February 2013.

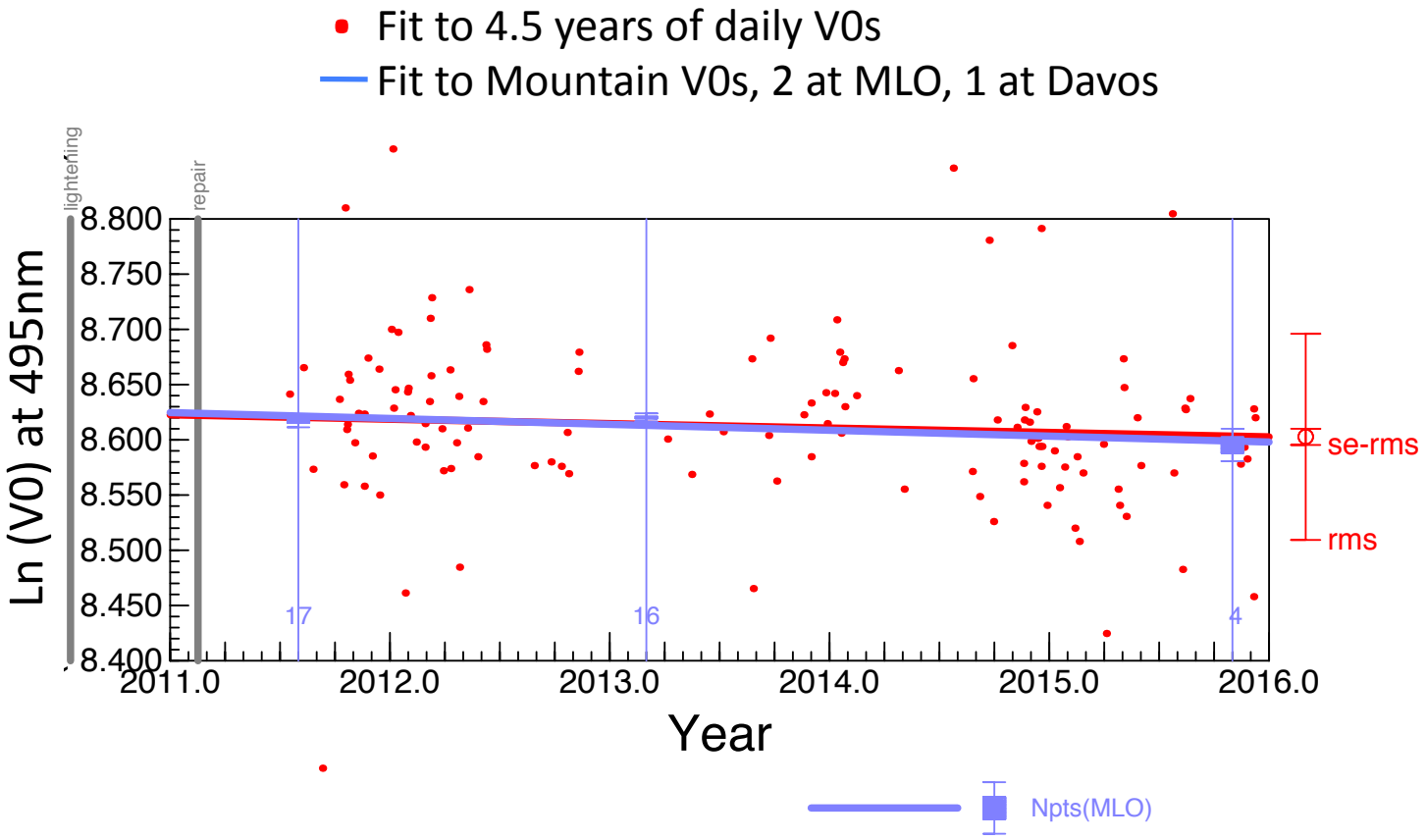


Example of a Mountain Calibration at MLO & Davos



Example of a Calibration in Place at LRC & CLH

Four and a half Years of Data
Compared to Mountain calibrations

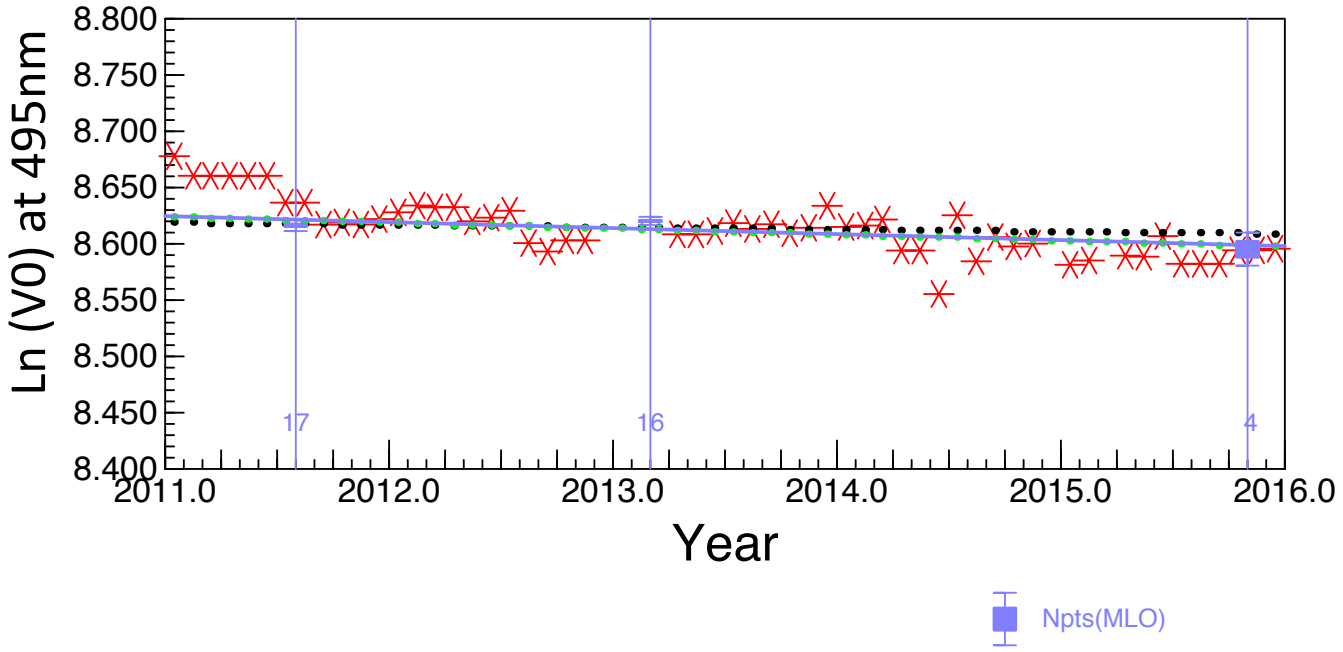


Previous plot with all available morning V0s
The red line is a fit to the several years of data
it almost lies on on the blue mountain fit line.

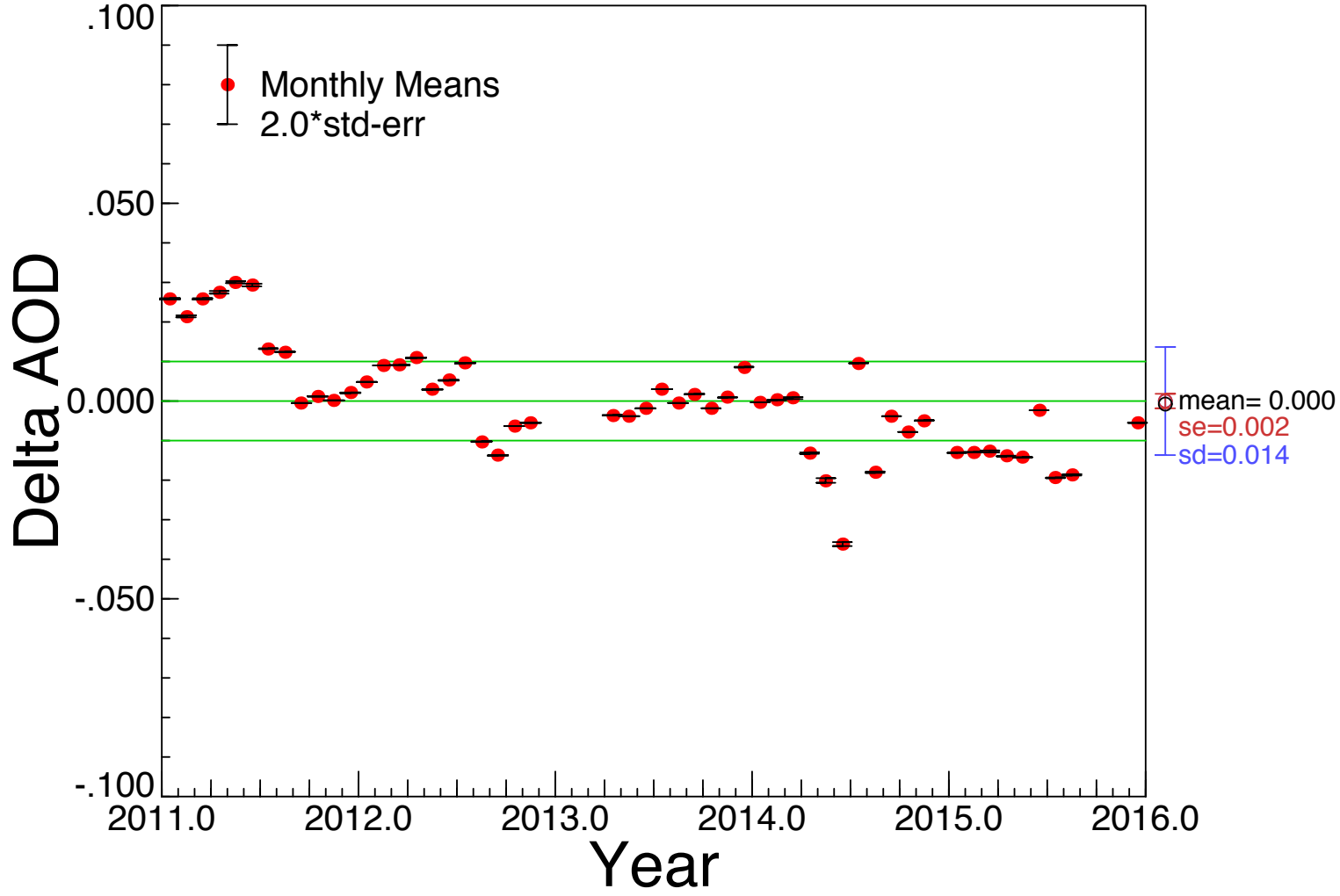
Three Calibration Methods 495nm,

Four and a half Years of Data at CLH and LRC.

* 3 Month Running Means
• Fit to 4.5 years of daily V0s
— Fit to Mountain V0s, 2 at MLO, 1 at Davos

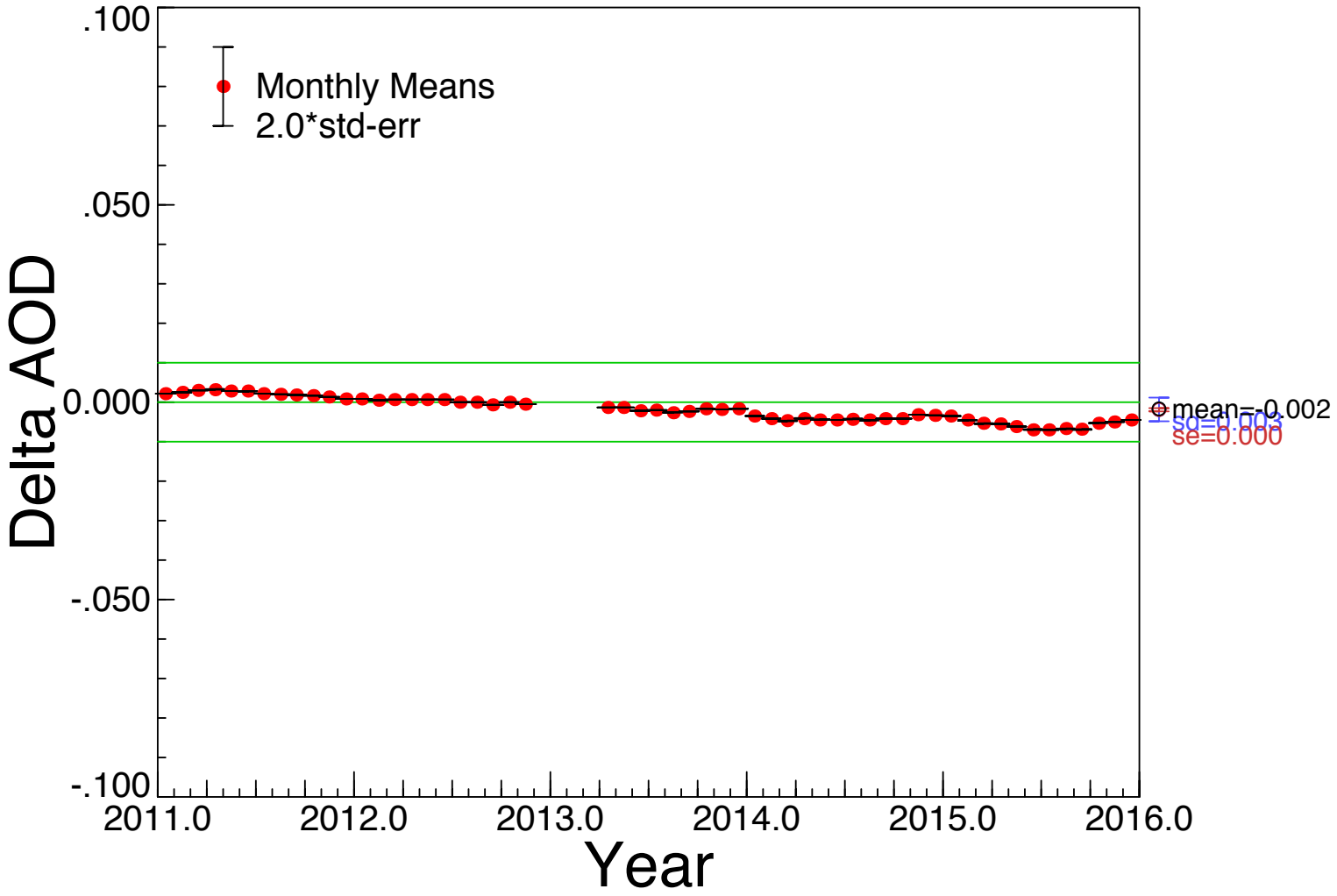


AOD Differences (495nm)
MFRSR (Daily fit V0) - MFRSR (3 month mean V0).



case_2011_larc_550_DailyLinearV0_vs_3mnMeanV0.500nm_deltas_monthly.eps
Apr 13 17.35.28 2016
/Users/denn/Forsun/SRB/MFRSR/MFRSR_AOD_compair_two_MultiYear.NoStddev

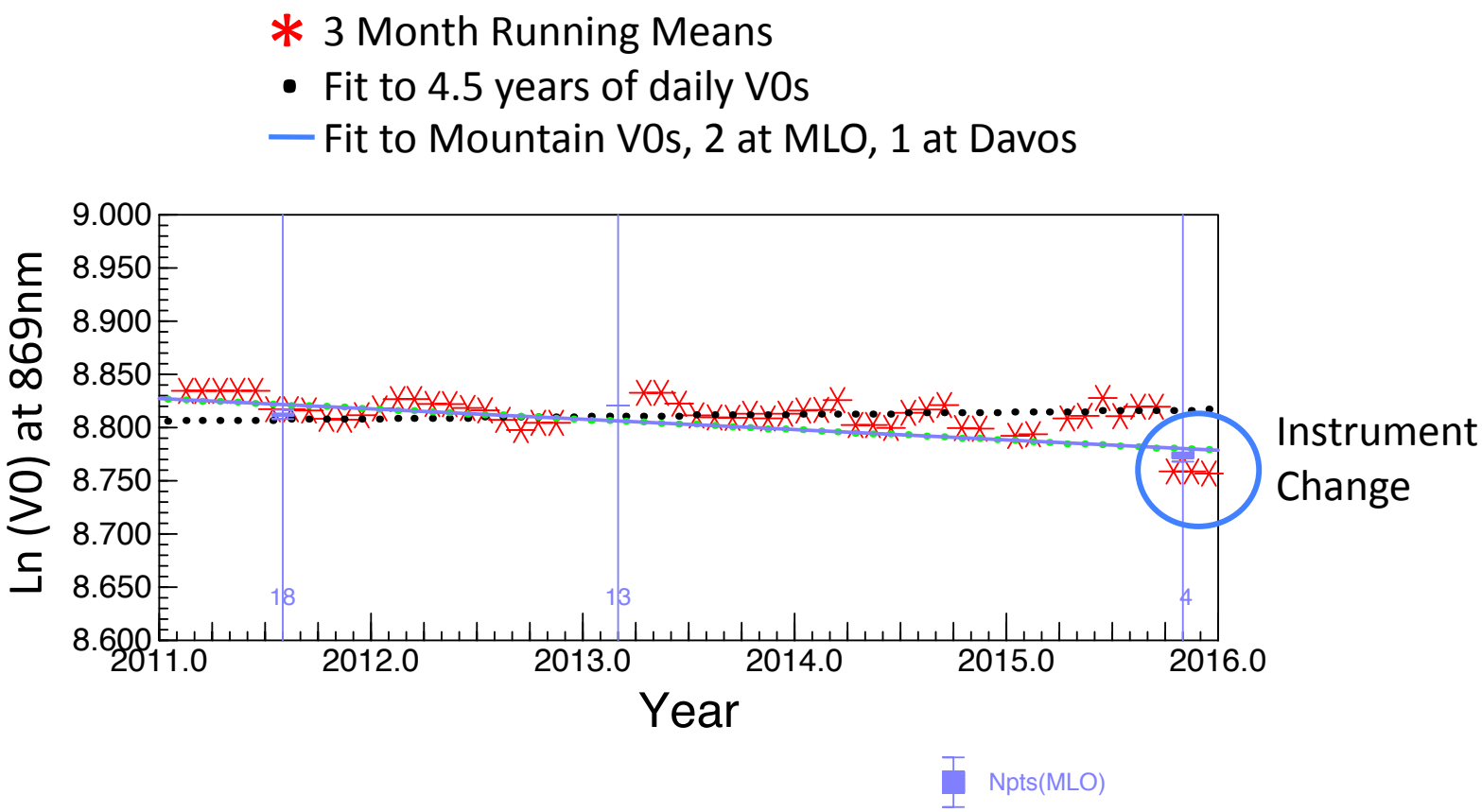
AOD Differences (495nm)
MFRSR (Daily fit V0) - MFRSR (Mountain V0)



case_2011_larc_550_DailyLinearV0_vs_MountainV0.500nm_deltas_monthly.eps
Apr 13 17.49.16 2016
/Users/denn/Forsun/SRB/MFRSR/MFRSR_AOD_compair_two_MultiYear.NoStddev

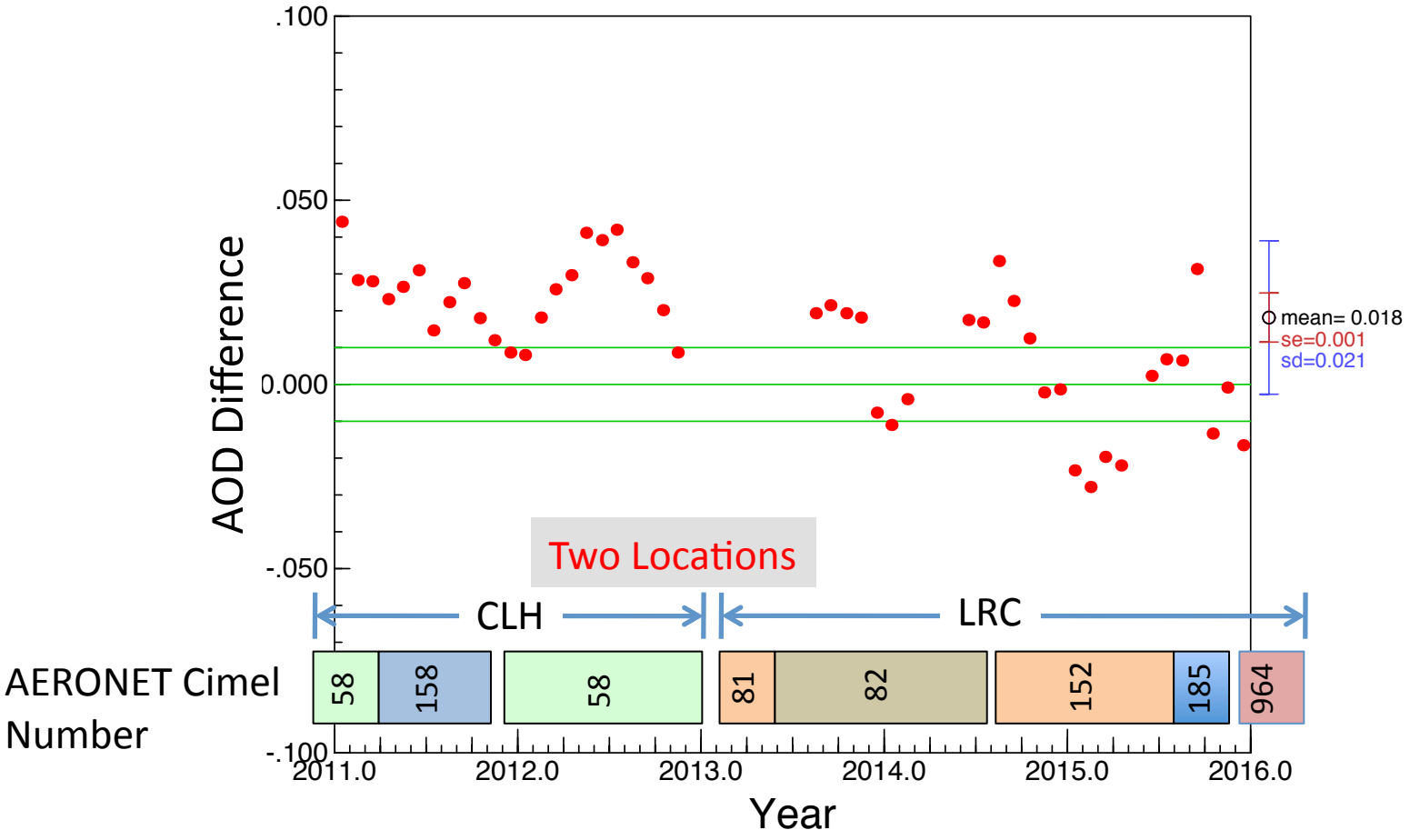
Instrument Transport Issues

Instrument Change Caused by Shipping



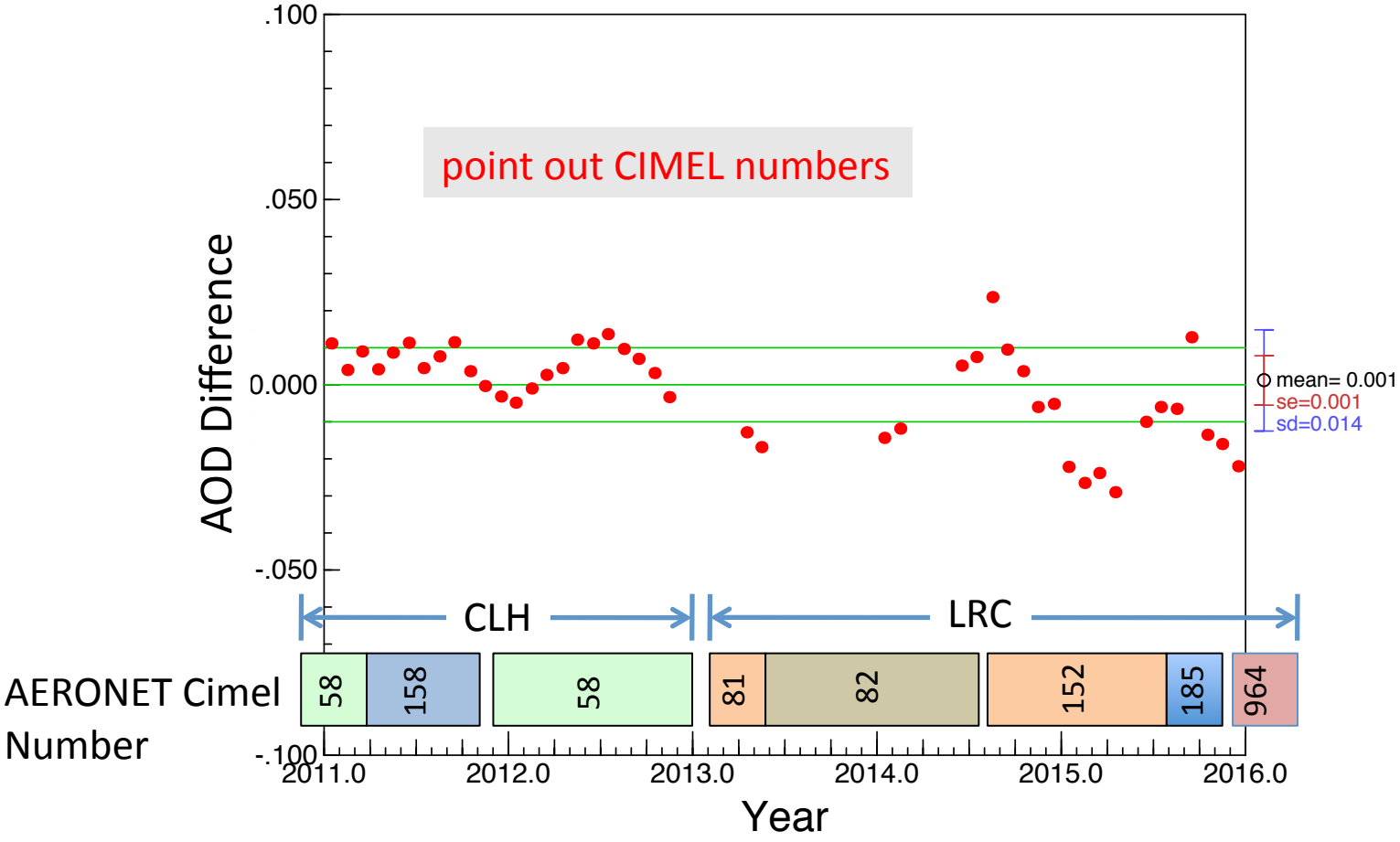
Comparison with AErosol Robotic NETwork AERONET Cimel Sun Photometer

AOD Differences MFRSR (Daily fit V0) - AERONET (495nm) Can be Substantial



Several different cimels were used during the 5 year period.

AOD Differences MFRSR (Daily fit V0) - AERONET (670nm)
Substantial ?

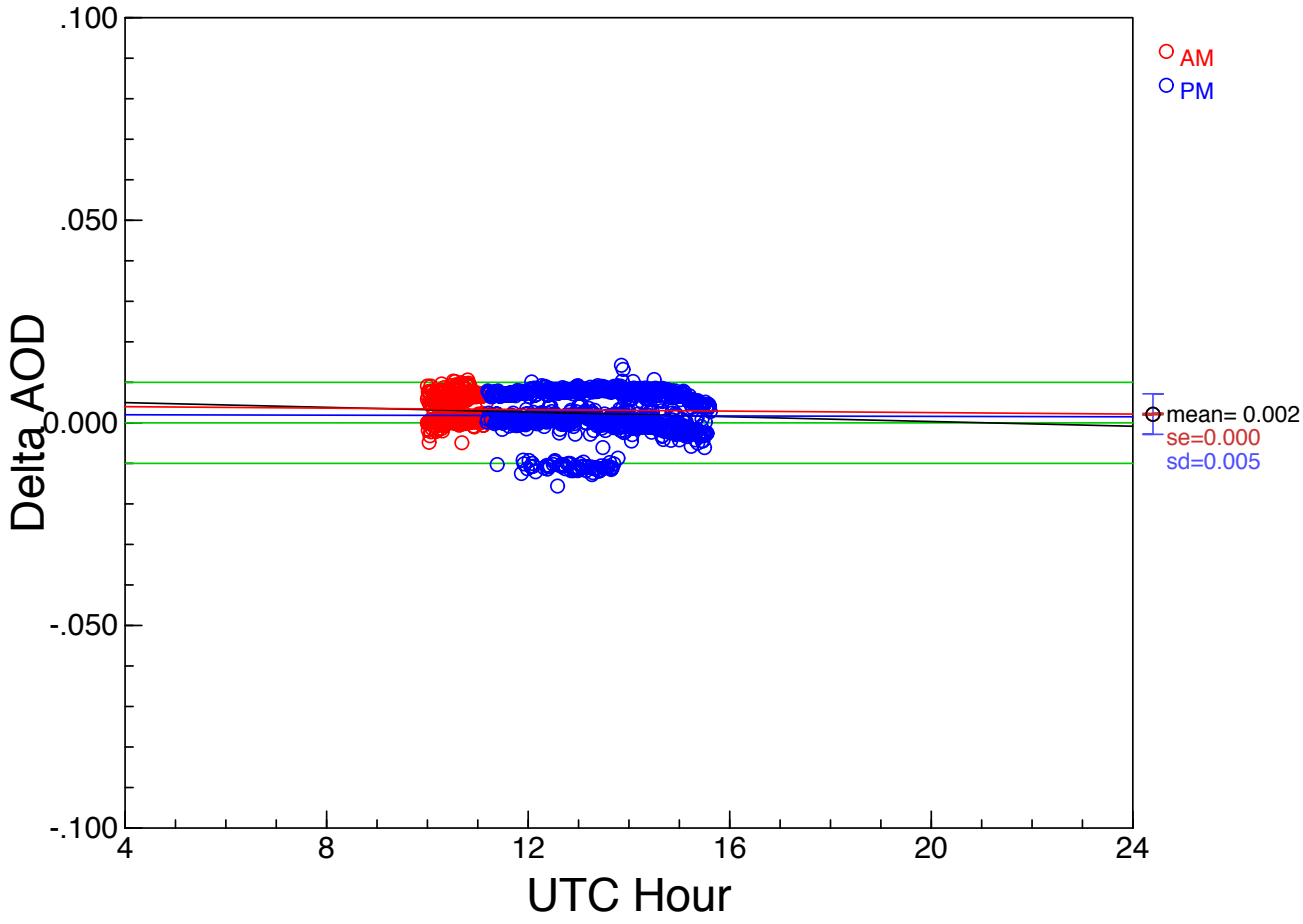


Comparison with PMOD-WRC Precision Filter Radiometer (PFR) Triad

Four methods of determining V0 were investigated

1) fit to mountain points
2) fit to all daily AM V0 points.
3) 3-month running mean fit to daily AM v0 points
4) **Davos mountain points only**

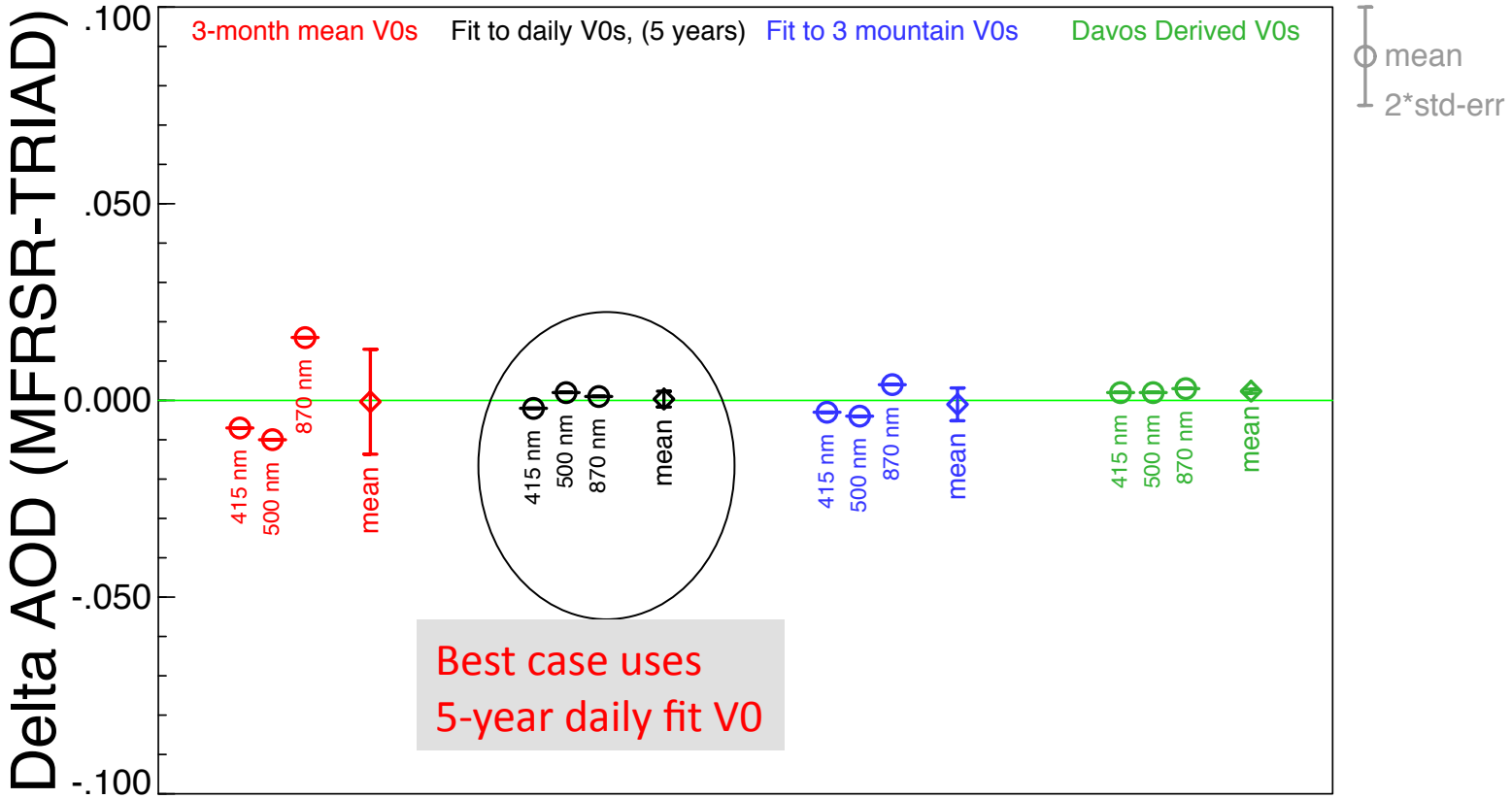
AOD Comparison with PMOD PFR Triad, 495nm
MFRSR (Daily fit V0) - Triad



case_2015_davos_500nm_fit_to_daily_V0s_delta_AOD_vs_time_of_day.eps
Apr 8 14.55.36 2016
/Users/denn/Forsun/SRB/MFRSR/MFRSR_AOD_compair_two_ZEN+TEMP_zones

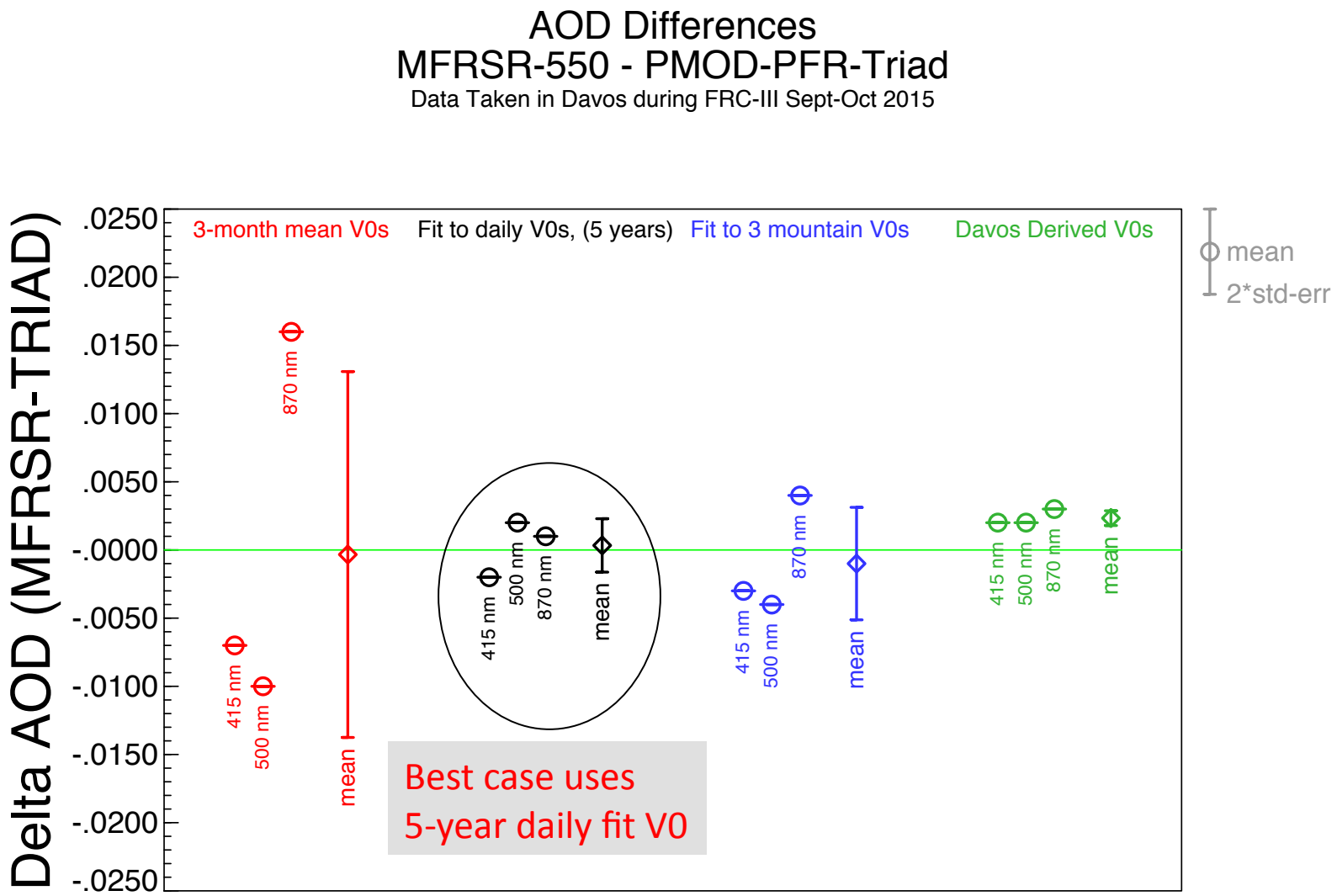
Th

AOD Differences
MFRSR-550 - PMOD-PFR-Triad
Data Taken in Davos during FRC-III Sept-Oct 2015



he
us
an
wa
de
me

Same plot different scale, again point out means and differences.



Conclusions

1) Calibration of AOD instrumentation onsite using long term daily regressions works better than mountain top calibration

2) Calibration in place eliminates possible instrument damage caused by shipping and keeps the data continuous.

3) AERONET shows a probable temperature dependence.

END