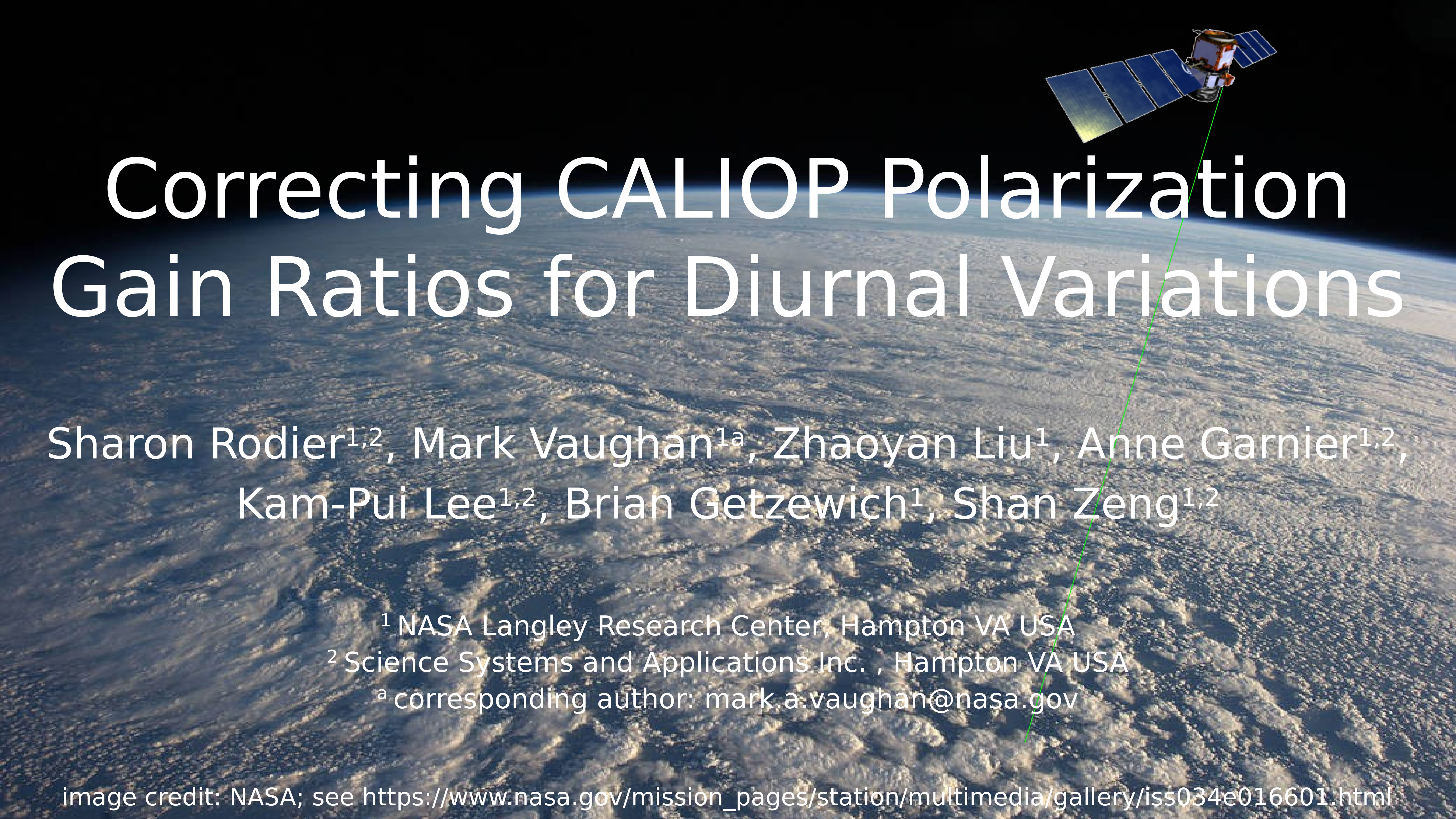

Correcting CALIOP Polarization Gain Ratios for Diurnal Variations

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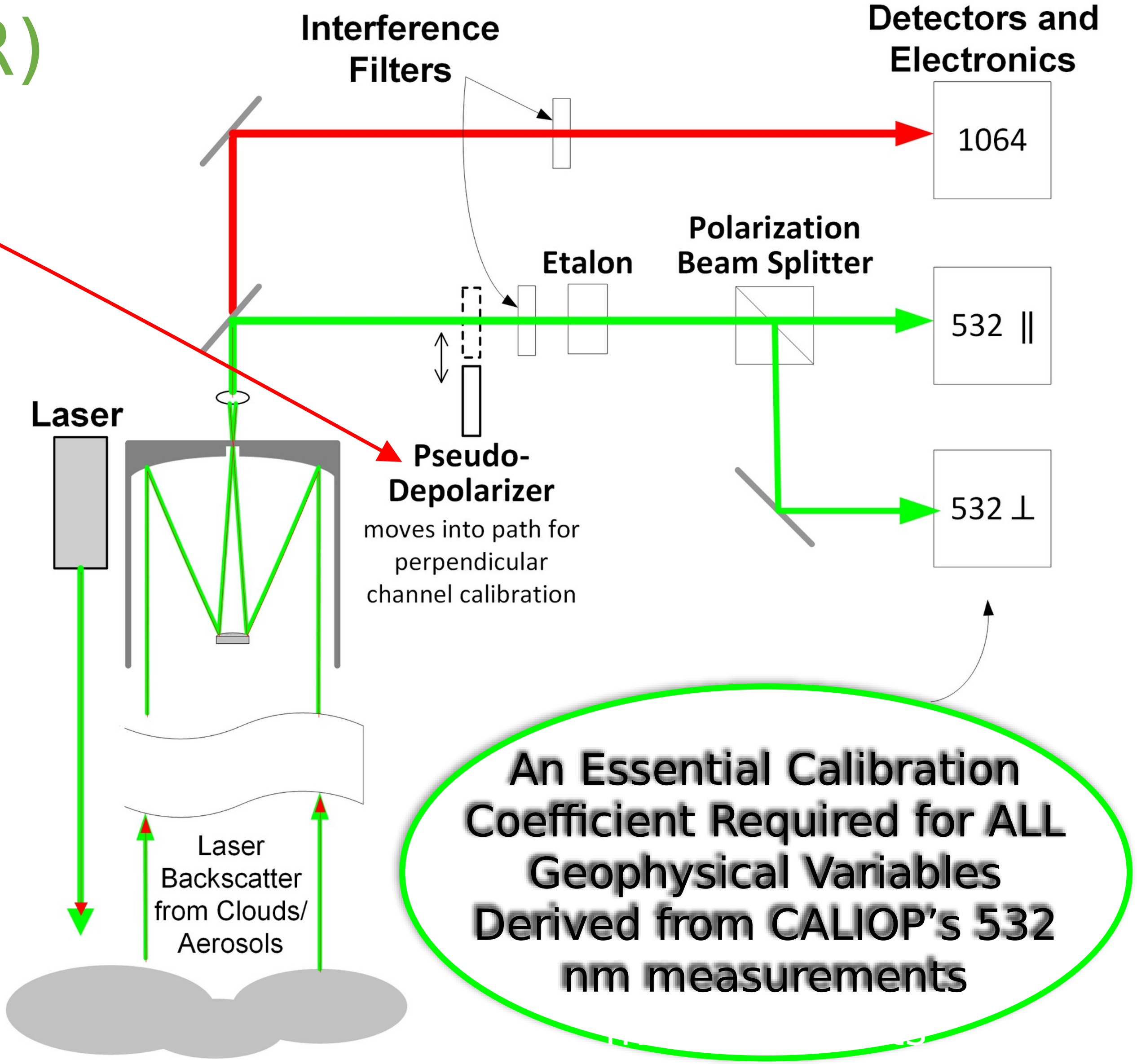
image credit: NASA; see https://www.nasa.gov/mission_pages/station/multimedia/gallery/iss034e016601.html

Polarization Gain Ratio (PGR)

Hostetler et al., 2005: CALIPSO Lidar Level 1 Algorithm Theoretical Basis Document

A spatial **pseudo-depolarizer** is inserted into the 532 nm optical path upstream of the polarization beam splitter (Figure 5.1). Insertion of this device results in a randomly polarized backscatter signal, and thus nominally equal optical power is directed into the detectors for the two orthogonal polarization orientations, regardless of the target being measured. Inserting the pseudo-depolarizer allows the relative sensitivity of the two 532 nm receiver channels to be determined. The ratio of the two detection channel signals is called the **Polarization Ga[…]PGR)**



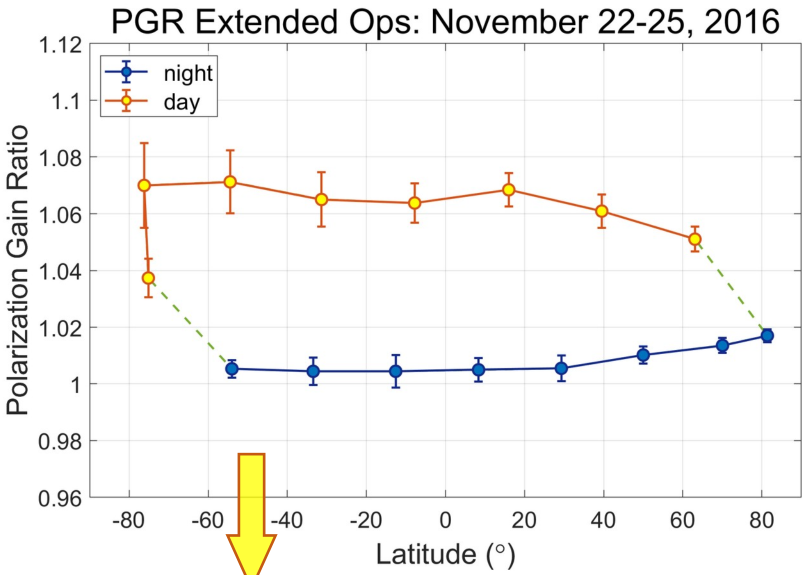
An Essential Calibration Coefficient Required for ALL Geophysical Variables Derived from CALIOP's 532 nm measurements

Figure 2.2 Functional block diagram of CALIOP

https://www-calipso.larc.nasa.gov/resources/pdfs/PC-SCI-201v1.0.pdf

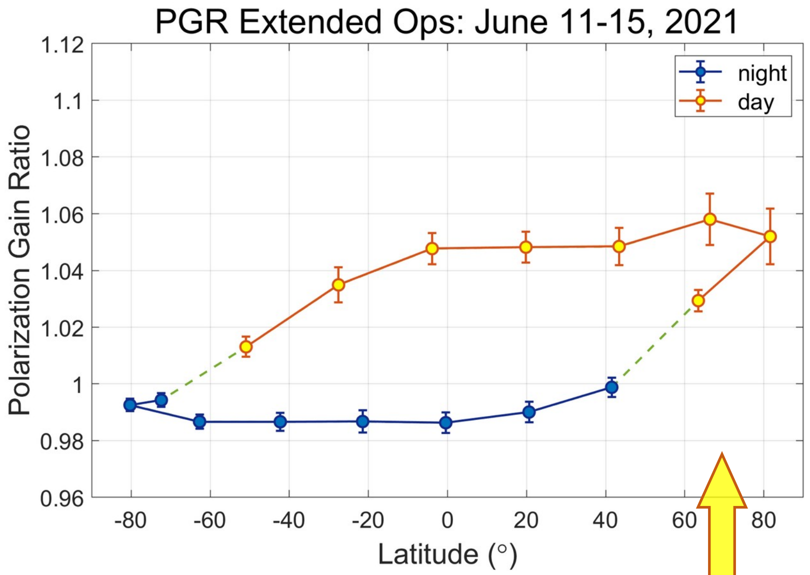
An Unexpected Discovery

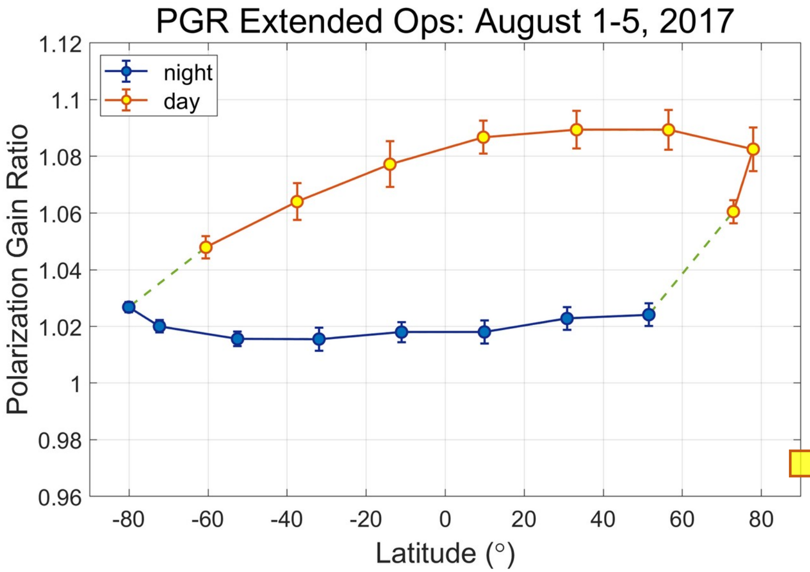
CALIOP PGR Varies Diurnally And Seasonally

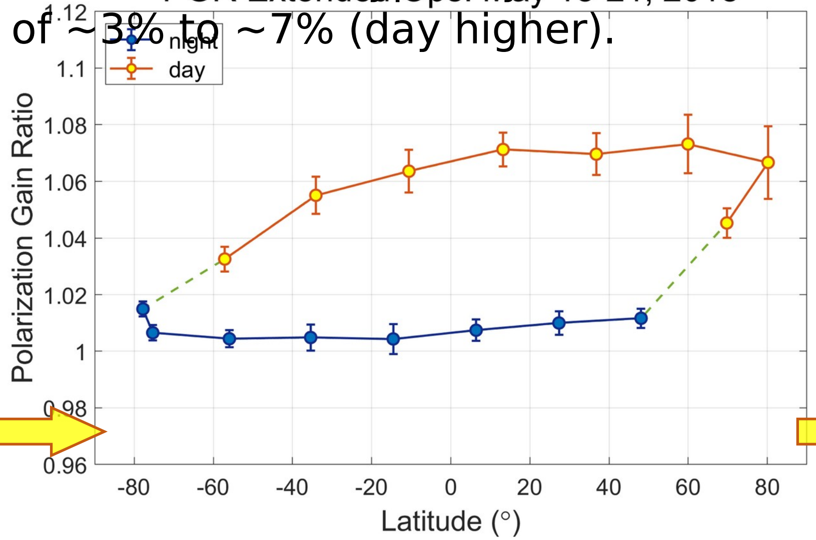


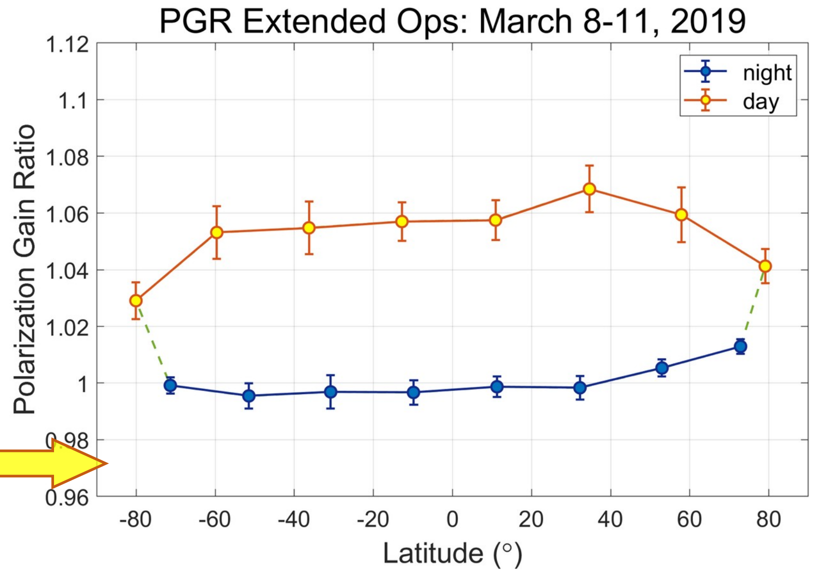
For the first 10+ years of the CALIPSO mission, PGR pseudo-depolarizer calibra-tions were conducted during night orbit segments only and the relative gain of the two receiver channels was ASSUMED to be diurnally invariant.

Beginning in November 2016, periodic day-time pseudo-depolarizer calibrations are now made to track diurnal PGR changes. Day-night differences are typically on the order of ~3% to ~7% (day higher).







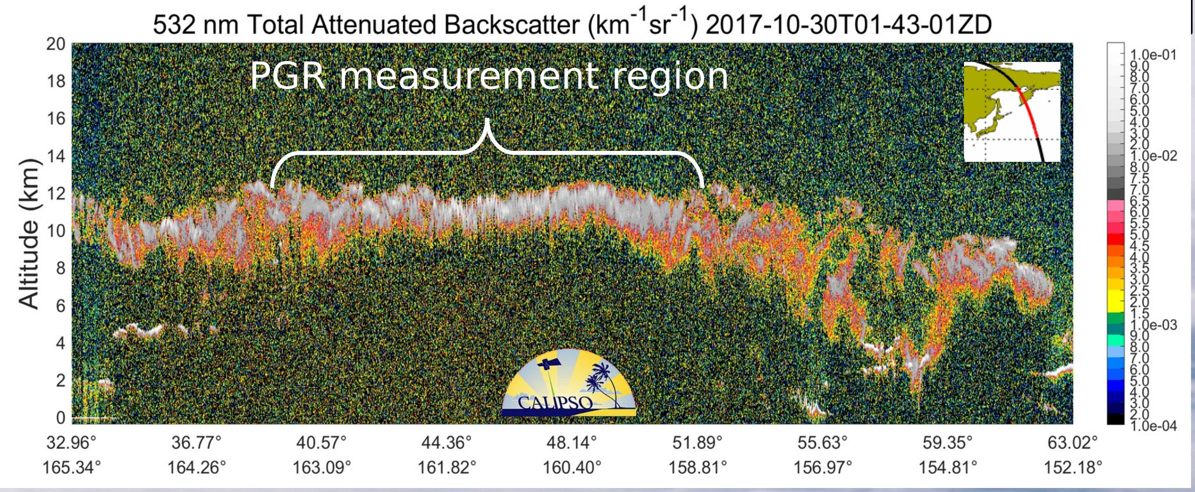


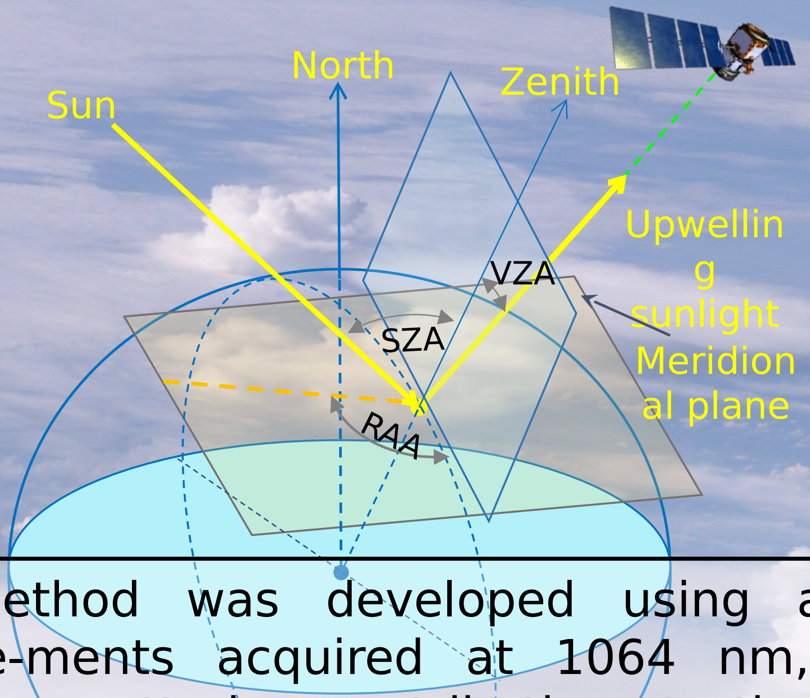
achieving daytime PGR uncertainties commensurate with prior nighttime values requires averaging

Deriving PGR from CALIOP Solar Background Measurements

Liu et al., 2004: Validating lidar depolarization calibration using solar radiation scattered by ice clouds, *IEEE Geosci. Remote Sens. Lett.*, **1**, 157–161, https://doi.org/10.1109/LGRS.2004.829613.

The solar background radiation measured above dense ice clouds is essentially unpolarized, due to multiple internal reflections within the ice crystals and the multiple scattering that occurs among these particles. By using an approach pioneered by Liu et al. (2004), we can derive PGR estimates using the ratio of CALIOP's polarization-sensitive background measurements acquired above strongly scattering ice clouds.

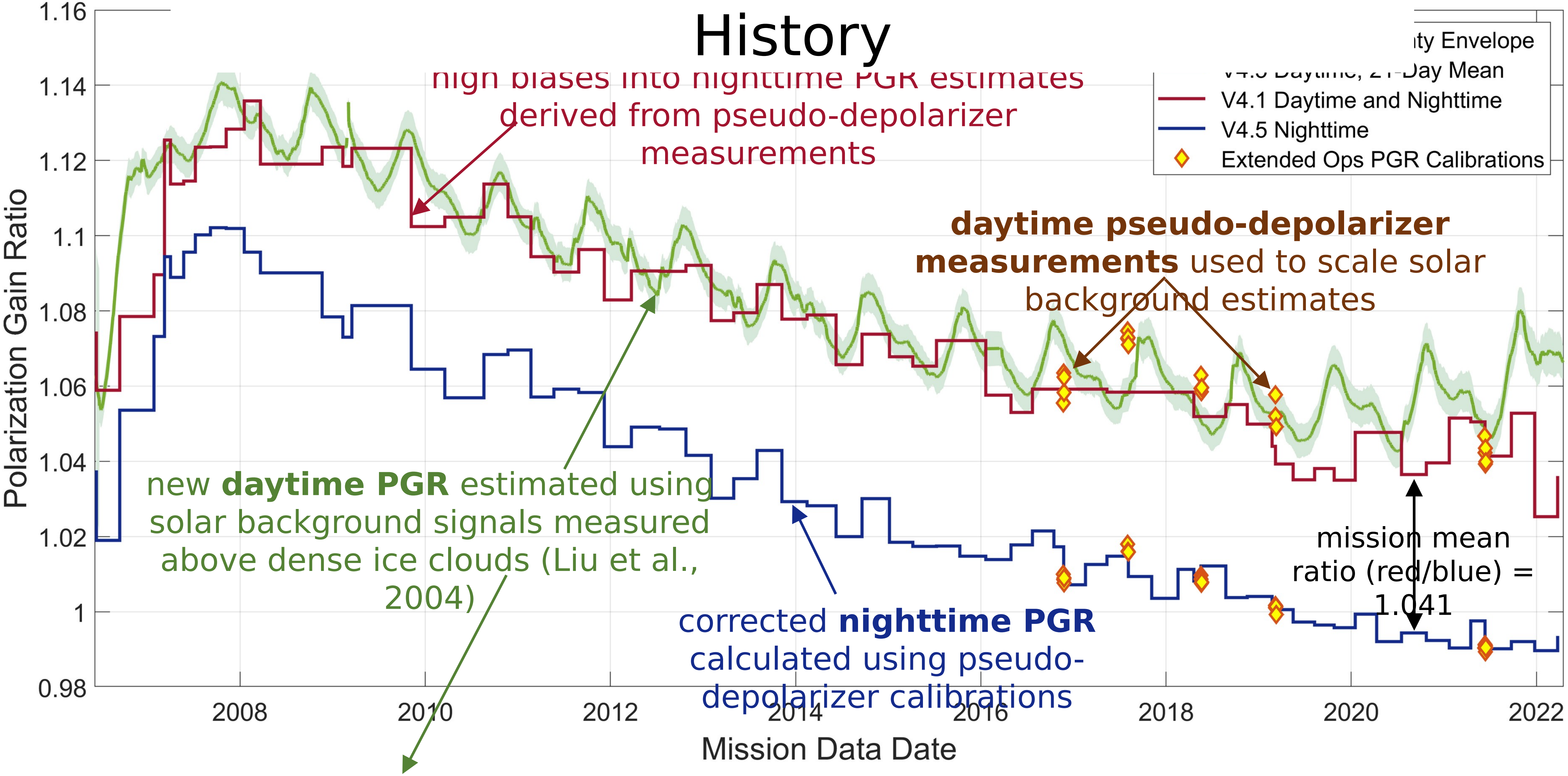




Liu's method was developed using airborne measure-ments acquired at 1064 nm, where molecular scattering contributions to the above-cloud background signals are negligible. But because the polarizing characteristics of molecular scattering at 532 nm cannot be neglected, the CALIOP implementation of Liu's method accounts for molecular contributions via a look-up table created using a polarization-sensitive radiative transfer model (Zhai et al.,

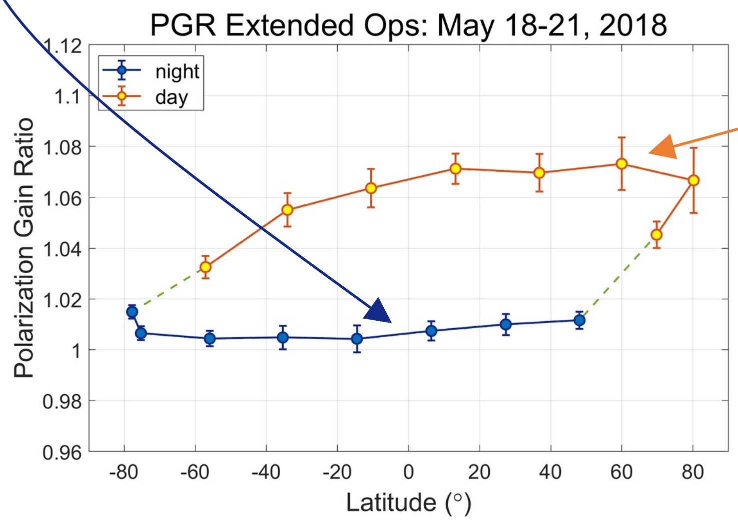
image credit : NASA's Johnson Space Center; see https://www.nasa.gov/topics/earth/features/icing-forecast.html

CALIOP Polarization Gain Ratio Time History



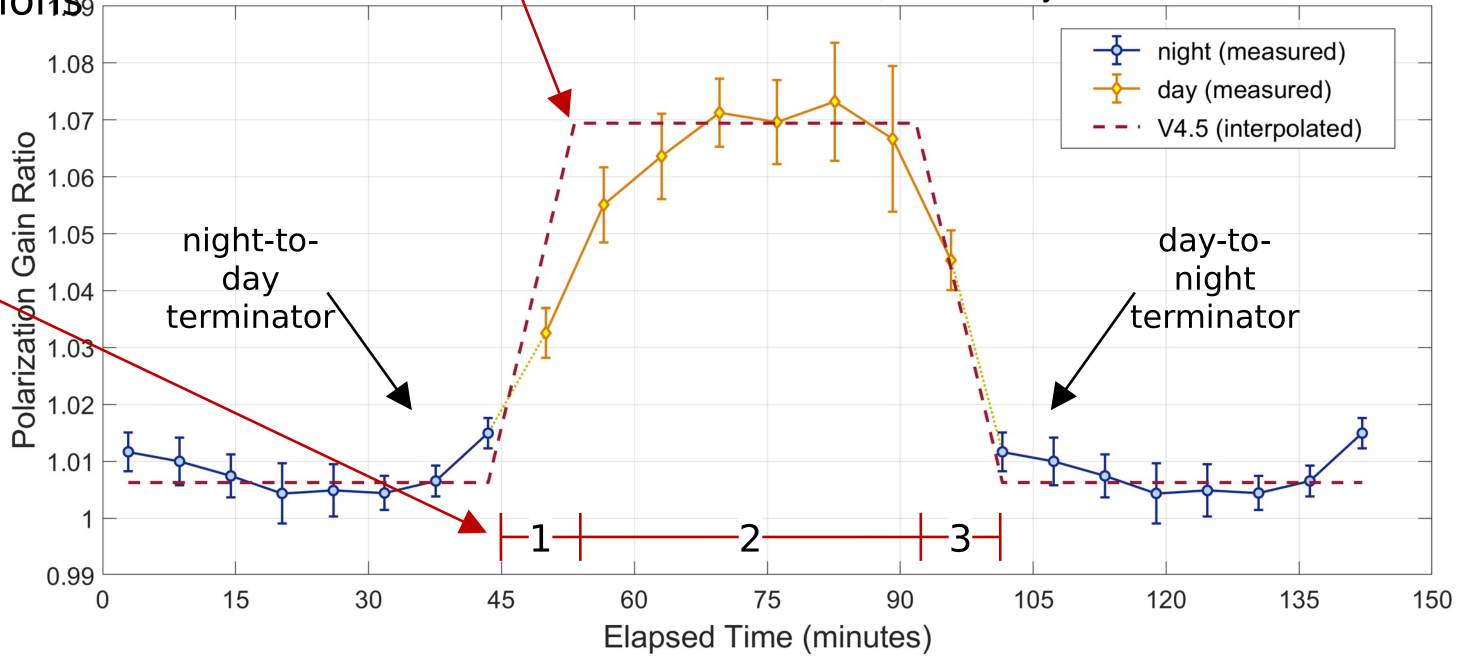
Daytime PGR estimated from CALIOP parallel and perpendicular channel RMS baseline measurements acquired above opaque ice clouds with top heights higher than 6-km. Each data point represents the mean PGR for a single daytime orbit segment

Creating a Continuous Record of PGR Change



The transition between the stable, near-constant nighttime PGR and the much more variable daytime PGRs does not occur instantaneously. Based on an assess-ment of the five extended time PGR calibrations accumulated to date, the transition period between stable states lasts approximately 585 seconds. To characterize the variability of the PGR throughout an orbit we use a piecewise linear approximation, as illustrated by the red dashed line in the figure below. As in all previous data releases, the PGR is held constant at night, using the most recent PGR estimate obtained from the standard nighttime only PGR calibration operations.

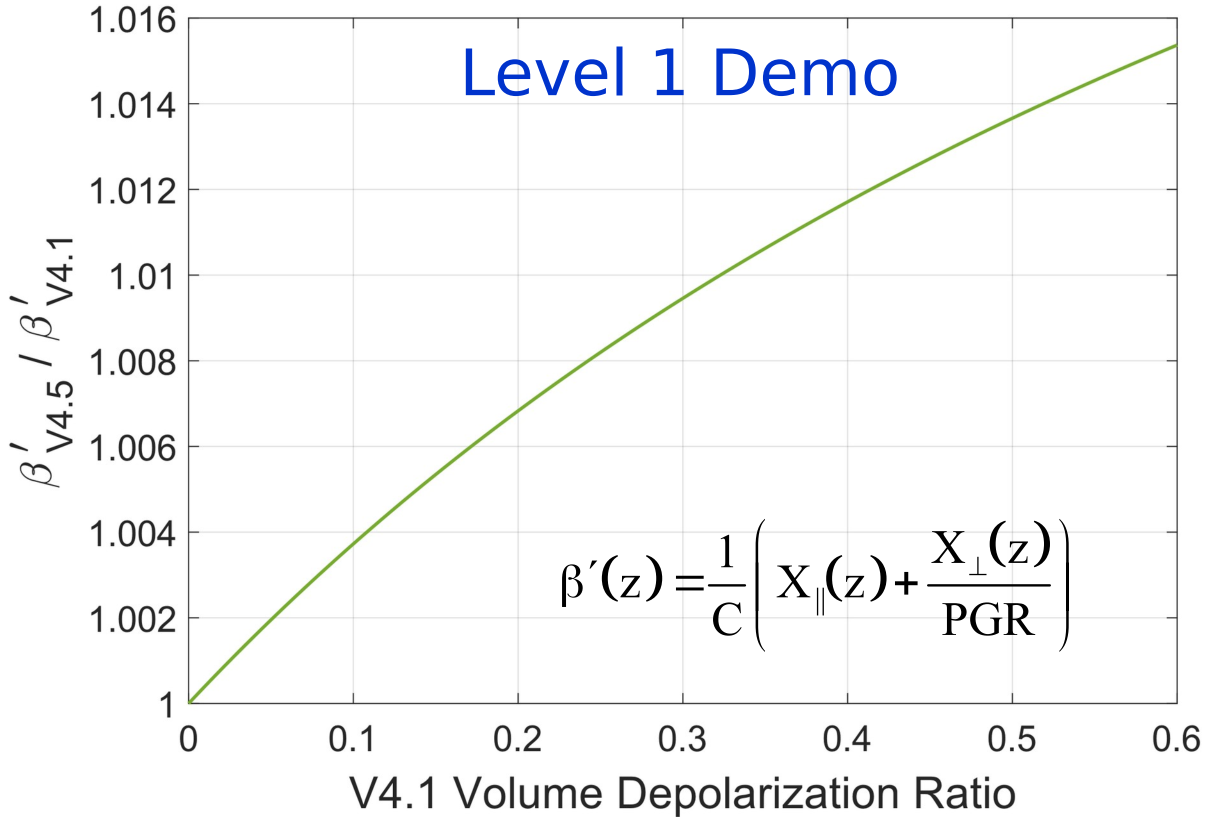
Daytime values are assigned by partitioning the into three segments. The first extends 585 seconds forward in time from the night-to-day terminator, and the third extends 585 seconds backward in time from the day-to-night terminator. The PGR is held constant throughout the center segment (#2) at the Liu's method value calculated for the data acquisition date. PGRs in daytime segments 1 and 3 are then linearly interpolated as a function of time between the segment end points and the segment 2 Liu's method value.



CALIOP PGR Corrections: Take Home Message for Data Users

By happenstance, the high biases in the PGR used in all CALIPSO data releases prior to version 4.5 are largely consistent with the revised daytime PGR estimates, hence daytime changes in 532 nm attenuated backscatter coefficients (β'_{532}) and volume depolarization ratios (δ_v) will generally be insignificant. At night, previous PGRs are biased high relative to the corrected values, leading to underestimates (ranging from ~3% to ~6%) in nighttime δ_v and small underestimates (less than 1.5%) in nighttime β'_{532}, with relative differences varying as a function of δ_v. For both quantities, V4.5 values will be slightly higher than in V4.2

$$\delta_{V4.5} = \left(\frac{PGR_{4.2}}{PGR_{4.5}}\right)\delta_{V4.2}$$

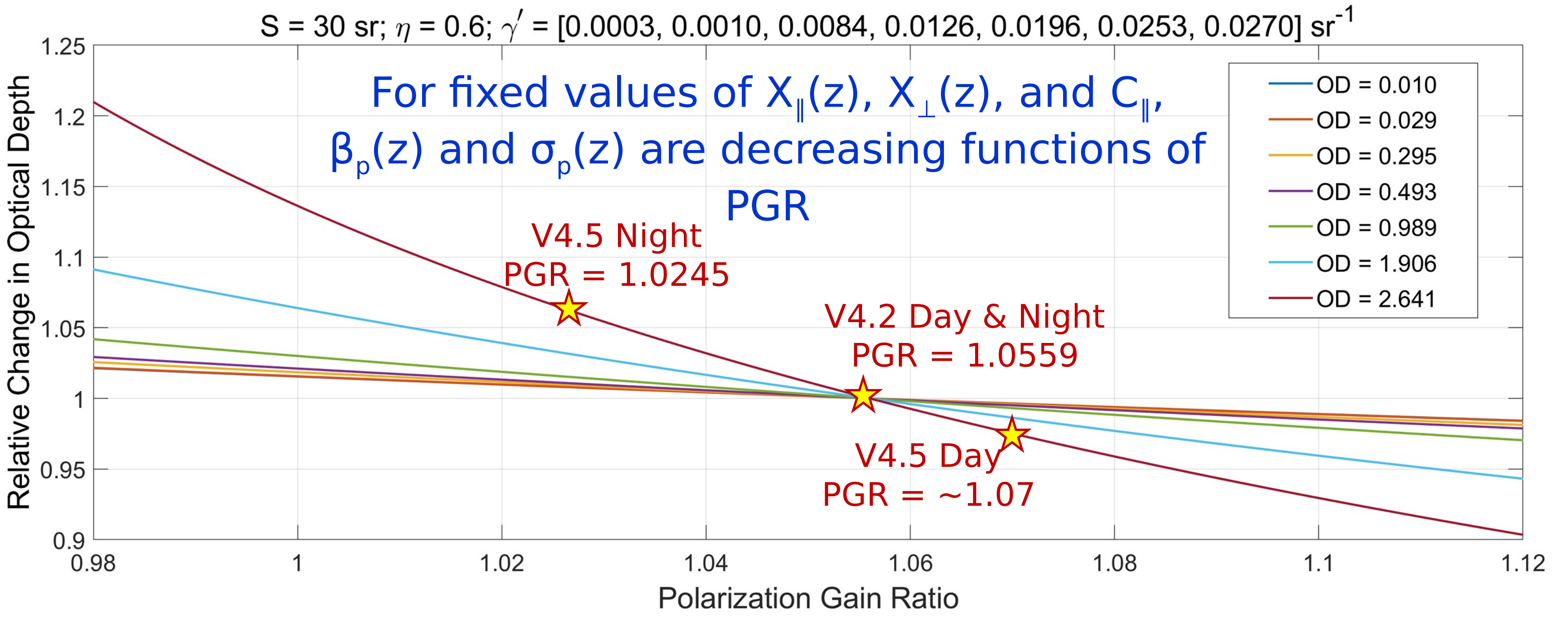


Nighttime: expected change in V4.5 β'_{532} relative to V4.1 as a function of V4.1 δ_v

CALIOP PGR Corrections: Take Home Message for Data Users

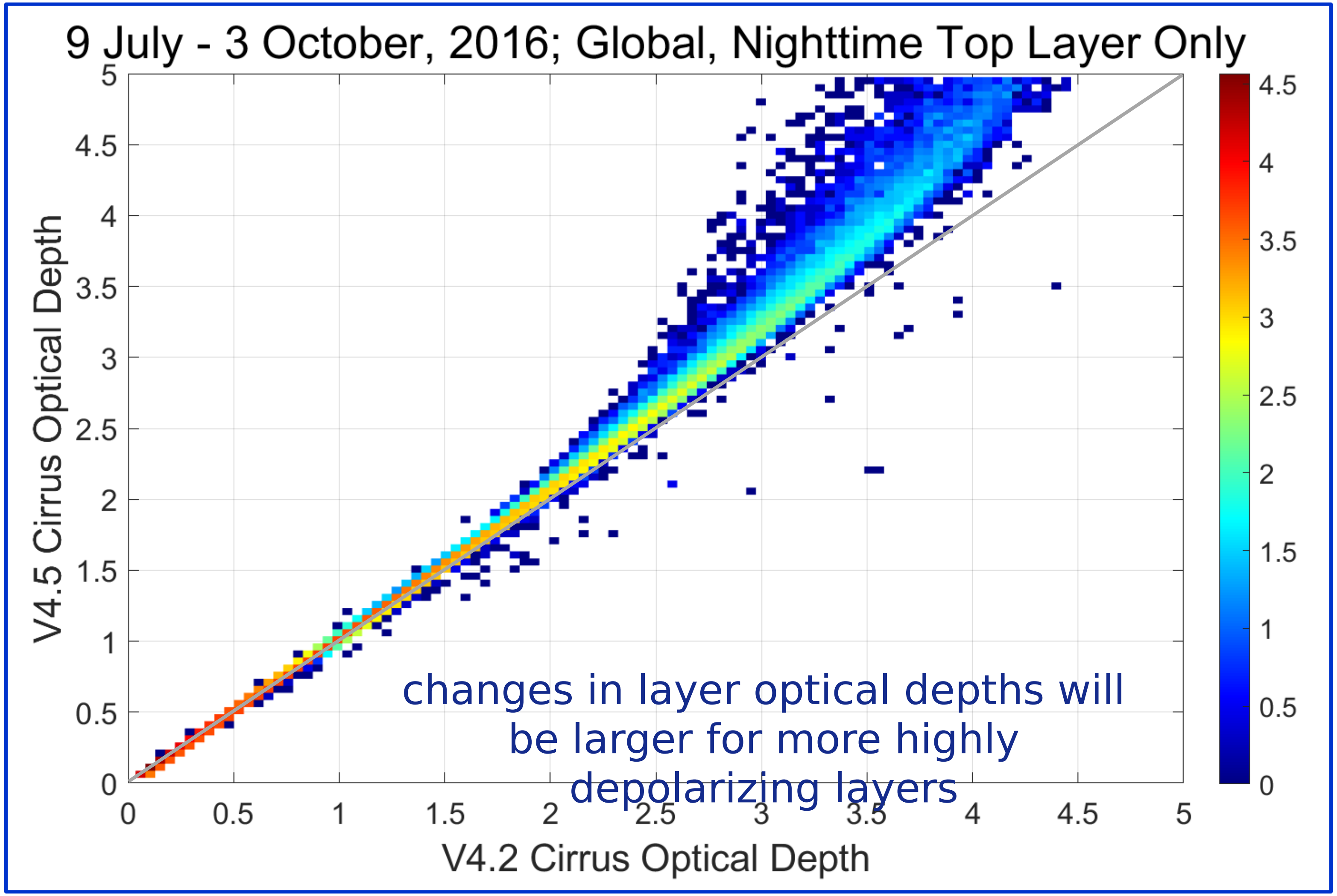
Level 2 demo: relative change in optical depth (τ_c) as a function of PGR

$$\frac{\tau_{c,V4.5}}{\tau_{c,V4.2}} = \frac{\ln\left(1-2\eta_c S_c \gamma'_{V4.5}\right)}{\ln\left(1-2\eta_c S_c \gamma'_{V4.5}\right)} = \frac{\ln\left(1-2\eta_c S_c\left(\int_{top}^{base}\frac{X_\parallel(z)}{C_\parallel}dz + \int_{top}^{base}\frac{X_\parallel(z)}{C_\parallel}\left(\frac{X_\perp(z)}{PGR_{V4.5}\times X_\parallel(z)}\right)dz\right)\right)}{\ln\left(1-2\eta_c S_c\left(\int_{top}^{base}\frac{X_\parallel(z)}{C_\parallel}dz + \int_{top}^{base}\frac{X_\parallel(z)}{C_\parallel}\left(\frac{X_\perp(z)}{PGR_{V4.2}\times X_\parallel(z)}\right)dz\right)\right)}$$



CALIOP PGR Corrections: Take Home Message for Data Users

Level 2 demo: relative change in optical depth (τ_c) as a function of PGR



CALIOP PGR Corrections: Take Home Message for Data Users

Level 2 demo: characteristics of opaque water clouds

integrated volume depolarization ratio

$$\delta_v = \frac{\overline{X_\perp}}{PGR \times \overline{X_\parallel}} = \delta_v(PGR)$$

integrate… bac…

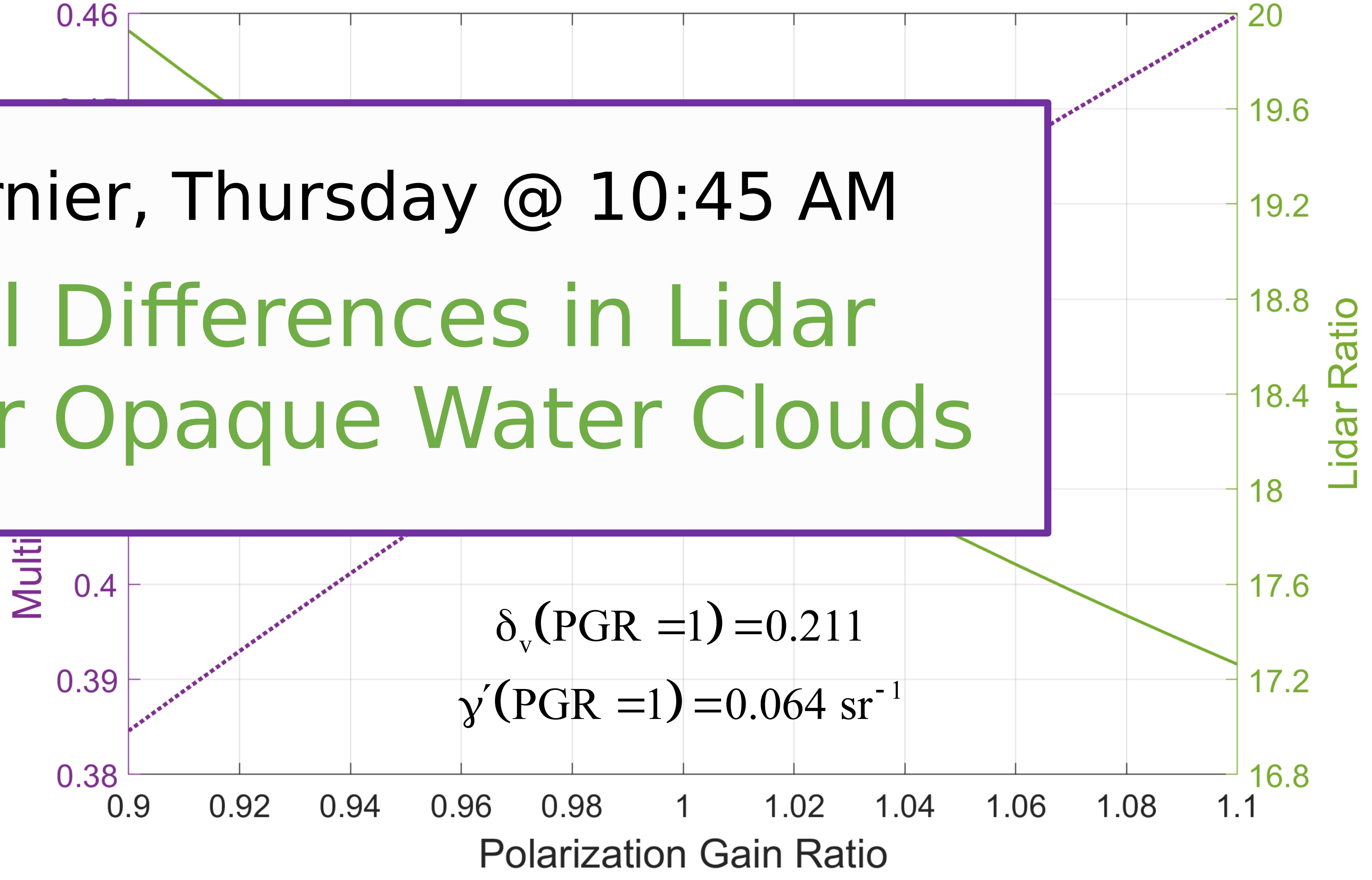
$$\gamma'(PGR) = \frac{1}{C_\parallel}\left(\int_{top}^{base} X_\parallel(z) + \frac{X_\perp(z)}{PGR}\, dz\right)$$

multiple… factor

$$\eta = \left(\frac{1-\delta_v}{1+\delta_v}\right)^2 = \eta(PGR)$$

opaque layer lidar ratio

$$S = \frac{1}{2\eta\gamma'} = S(PGR)$$



Anne Garnier, Thursday @ 10:45 AM

Diurnal Differences in Lidar Ratios for Opaque Water Clouds

Thank You For Your Attention

CALIPSO & CloudSat Science Team Meeting 2022

image source https://www.weather.gov/jetstream/clouds_intro

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