EMPIRICAL POLARIZATION DISTRIBUTION MODELS: UPDATE

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RECENT RESULTS

- Motivation:
  - reflectance measurements need to be corrected for polarization effects
  - uncertainty due to polarization contributes to overall intercalibration uncertainty
- Finished work on Polarization Distribution Models (PDMs) for **clear sky ocean** scenes from 2006 PARASOL data. Used 3 available PARASOL polarization channels: 490, 670 and 865 nm and entire 2006 dataset
- **Little difference in degree of polarization P** and **angle of linear polarization** χ was found across the 3 channels (all-AOD and AOD < 0.1 cases, separately)
- Differences observed between the all-AOD and AOD < 0.1 cases. In this presentation **look at the influence of aerosols** on :
  - P and χ PDMs
  - CLARREO's relative intercal uncertainty
- Paper with these results submitted to JTECH

DEGREE OF POLARIZATION P AND P PDMs

_P_ as measured by POLDER/PARASOL

Polarized reflectance

Polarized radiance

$$P = \frac{\rho_p}{\rho} = \frac{I_p}{I} = \frac{\sqrt{Q^2 + U^2}}{I}$$

Total reflectance

Total radiance

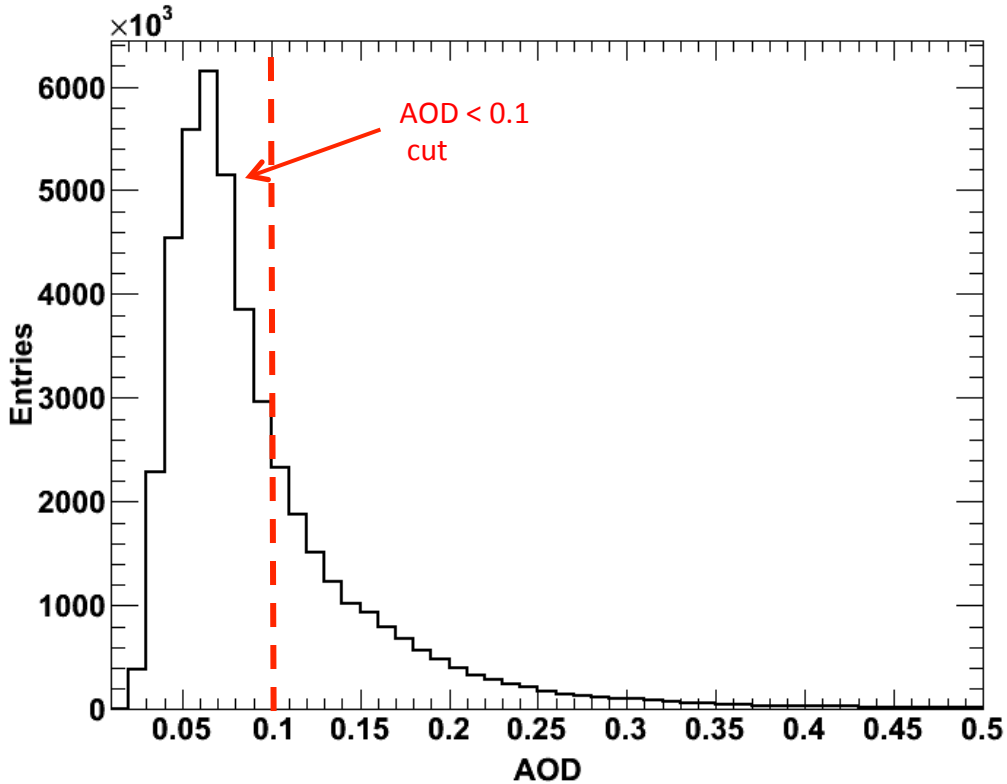
where

Stokes parameters (i.t.o. intensities)

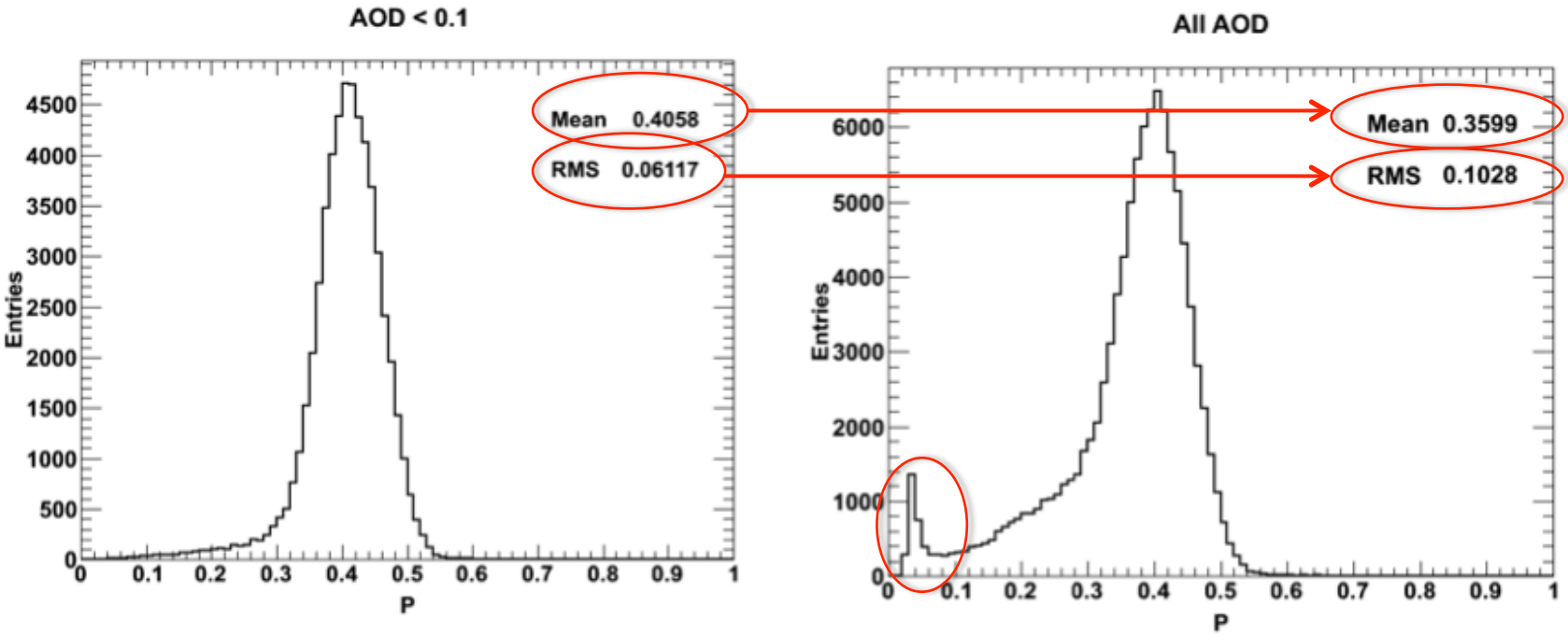
$$I = I_{0^\circ} + I_{90^\circ} \ ,$$
$$Q = I_{0^\circ} - I_{90^\circ} \ ,$$
$$U = I_{45^\circ} - I_{135^\circ} \ ,$$

- PDMs are $P(\phi,\theta)$ and $\chi(\phi,\theta)$ distributions averaged over time (here, over 1 year)
  - Use std. dev. which shows natural variability (with sufficient stats)

AEROSOLS AOD DISTRIBUTION

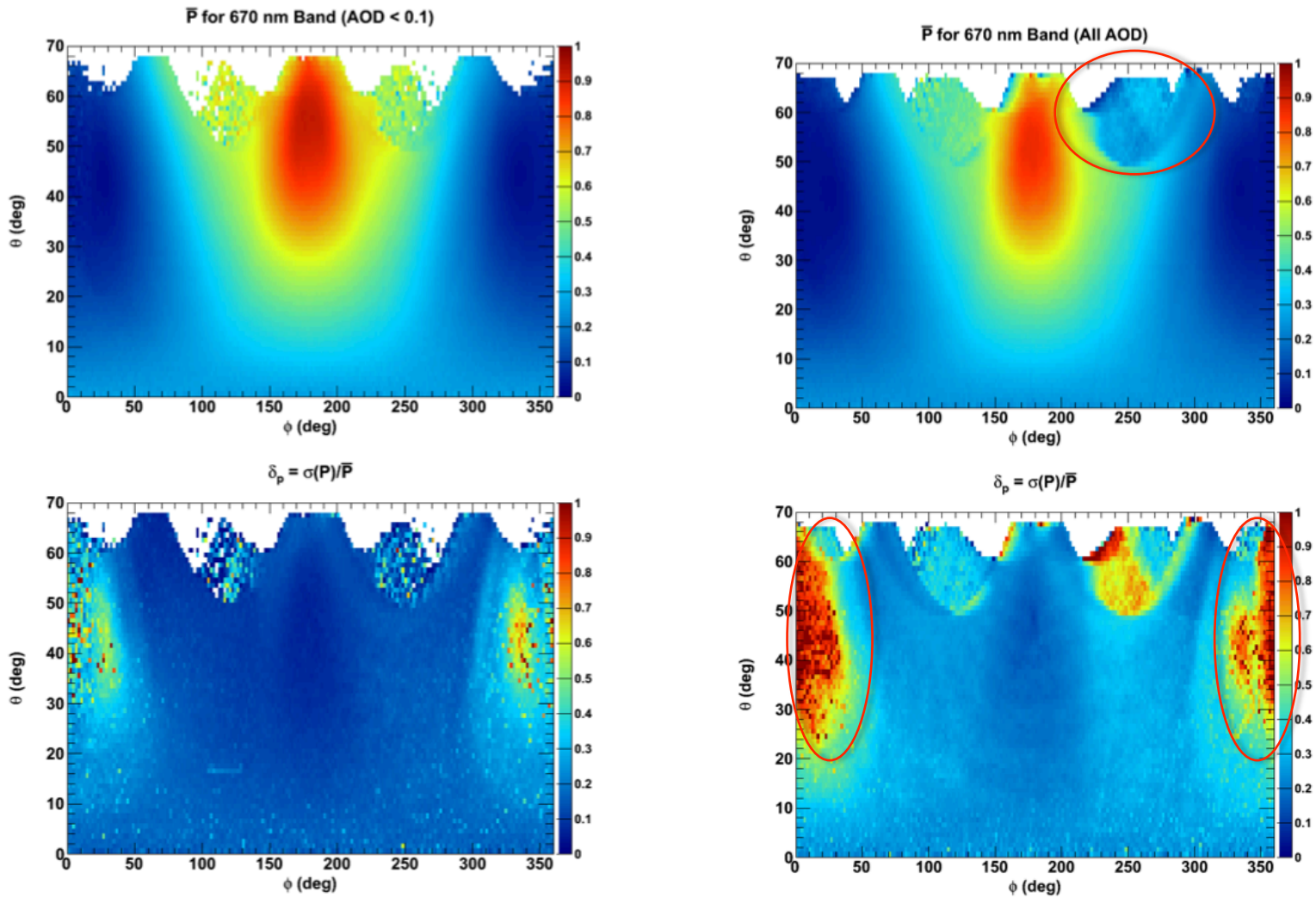


AEROSOLS' INFLUENCE ON P



Aerosols introduce extra low-P peak, reducing PDM means and increasing std. dev.

P PDMs: AOD < 0.1 AND ALL AODs



Aerosols (mostly dust) depolarize and increase uncertainty in *P*

UNCERTAINTY ON REFLECTANCE DUE TO POLARIZATION EFFECTS

target imager calibrated reflectance

target imager uncalibrated reflectance

$$\rho^{sensor} = \frac{\rho_0}{(1+mP)}$$

[C. Lukashin et al., 2013]
[J.-Q. Sun and X. Xiong, 2007]

target imager sensitivity to polarization

degree of polarization

Error propagation

Reference intercalibration uncertainty

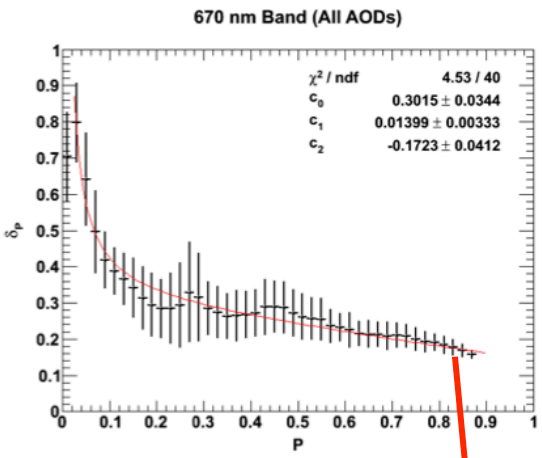
Relative uncertainties:
$\sigma(\rho_0)/\rho_0$, $\sigma(m)/m$, $\sigma(P)/P$

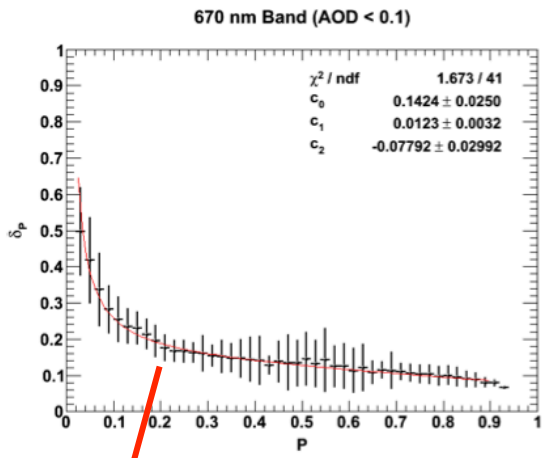
$$\delta_{RI} = \sqrt{\delta_0^2 + \left(\frac{mP}{1+mP}\right)^2 (\delta_m^2 + \delta_P^2)}$$

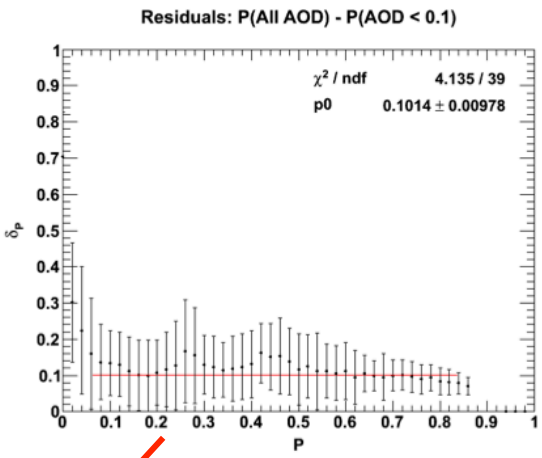
(CLARREO accuracy)^2 + (intercal sampling uncert.)^2 + (target sensor stability uncert.)^2

δP VS P: AOD < 0.1 AND ALL AODs

- *P* values from PDM means
- δP values from PDM standard deviations





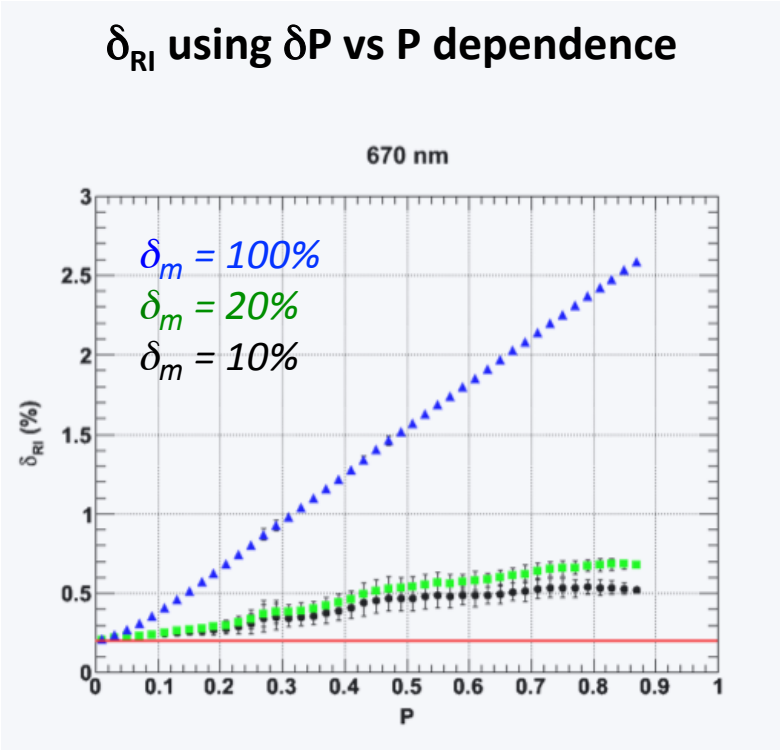


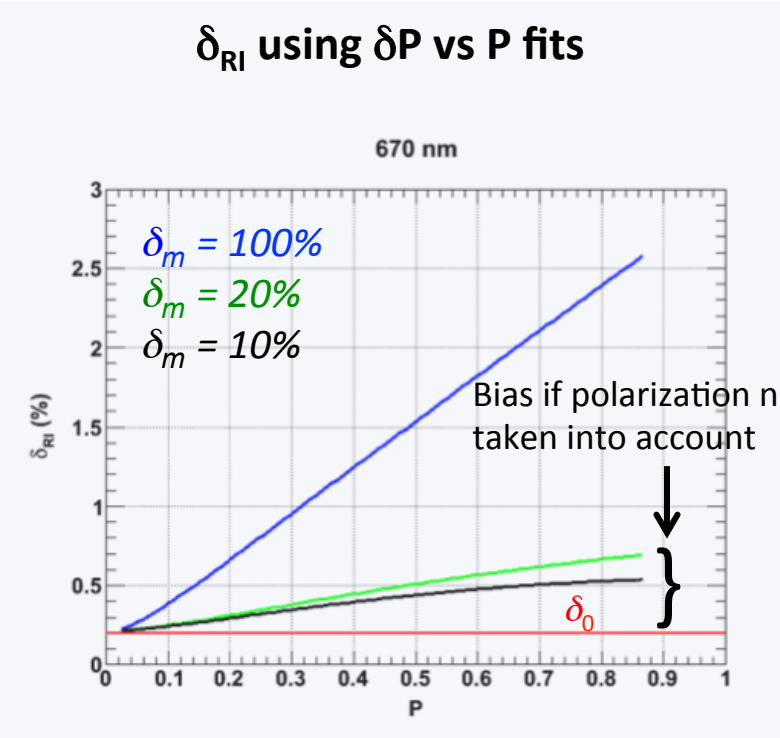
Fits: $\delta_P = c_0 + c_1 P^{-1} + c_2 P$

Aerosols increase polarization uncertainty by 10%

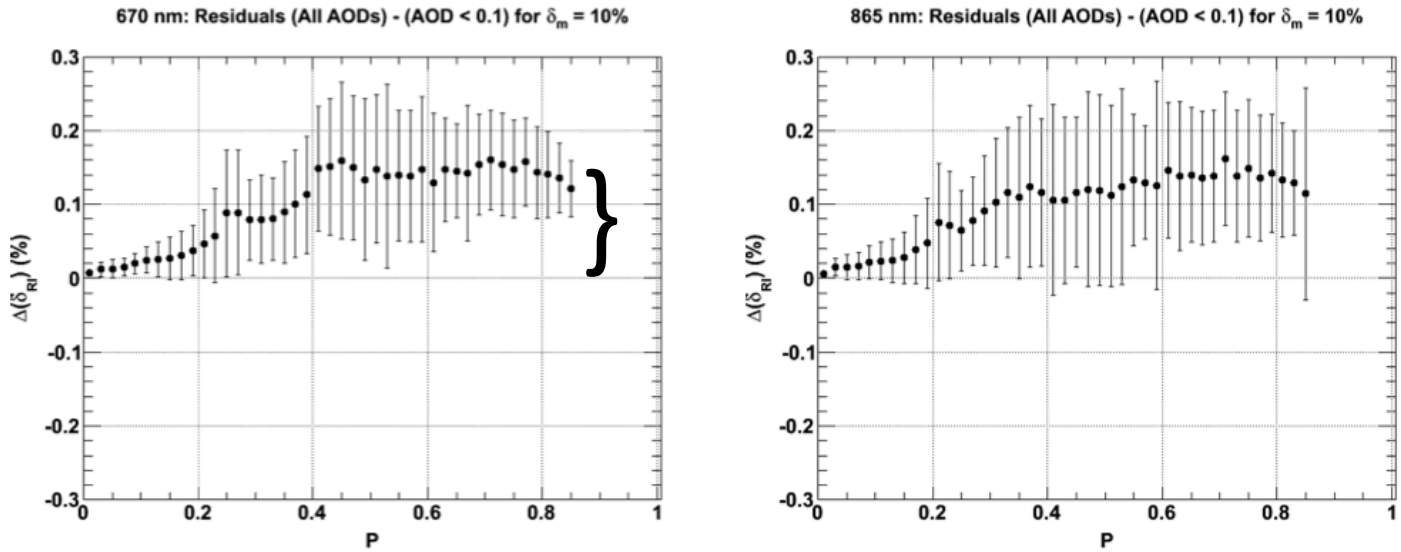
δ_{RI} VS P: ALL AODs

- Take values from MODIS and VIIRS:
  - Sensitivity to polarization m = 0.3 (MODIS and VIIRS)
  - δ_m = 10% and 20% (MODIS), 100%
  - δ_0 = 0.2



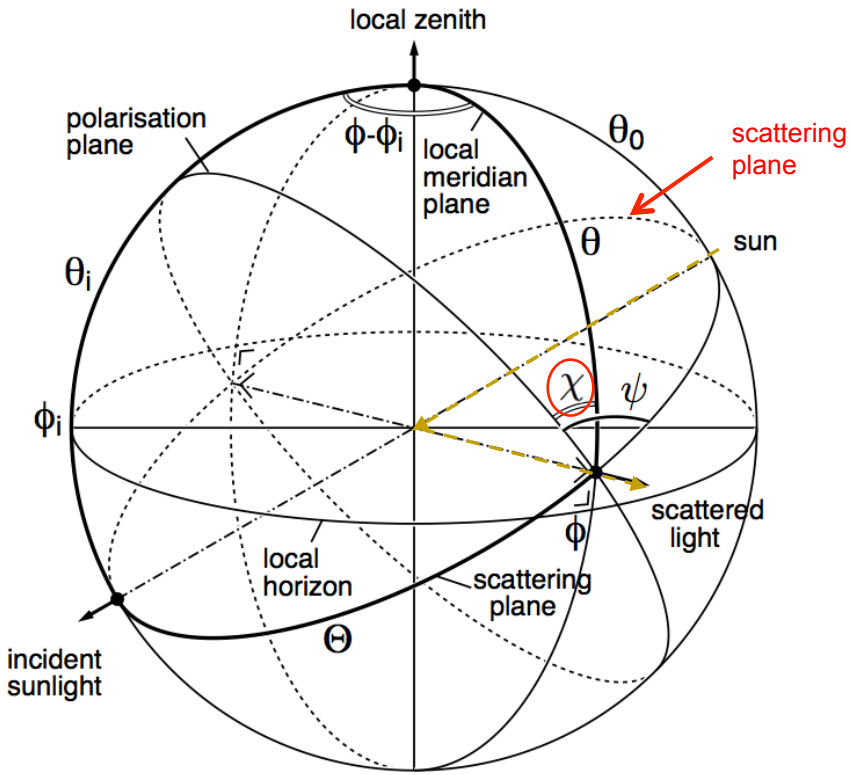


δ_{RI} AND AEROSOLS



Up to 3σ difference between intercal uncertainties for all AODs and AOD < 0.1

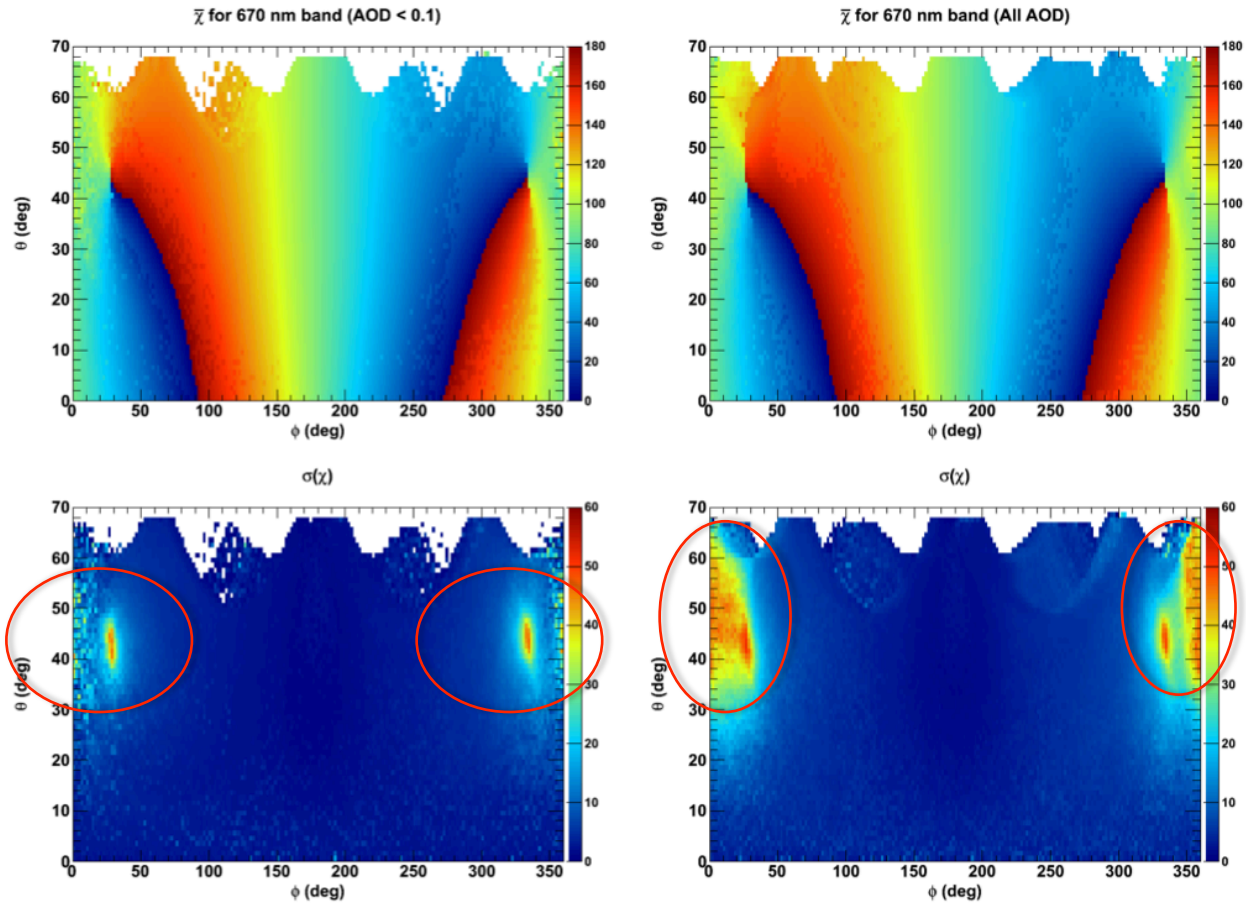
χ PDMs



Angle of Linear Polarization relative to viewing plane:

$$\chi = \frac{1}{2}\arctan(U/Q).$$

χ PDM WITH AOD < 0.1 AND ALL AODs



PLANS

- Considered aerosol effects on PDMs and CLARREO intercal
- Aerosols result in depolarization in *P* and larger PDM uncertainties for *P* and χ
- Aerosols contribute up to 0.1% uncertainty to overall intercal uncertainty for clear-sky ocean
- Differences significant enough for minimized aerosol and aerosol-inclusive cases to be stratified separately
- Continuing work on stratification by IGBP numbers

NEXT STEPS: WORKING PDM MODULE FOR PATHFINDER

- This year: Produce working version of PDM Module (Edition 1)
  - Start with clear sky ocean with and without aerosols
- **Module inputs**: Solar Azimuth, Detector Azimuth, VZA, SZA, IGBP, wind speed (if ocean), cloud phase (if cloudy), cloud fraction, AOD (if clear) from MODIS/VIIRS
- **Module outputs**: empirical mean P, mean χ, δP, $\delta\chi$, theoretical P and χ (ADRTM)
- **Inside the module**:
  - Variables stored in **HDF files**
  - Each of the 6 variables multidimensional. Dimensions: *RAZ, VZA, SZA, AOD, IGBP, Wind Sp, Cloud Phase*
  - If memory capacity allows, all variables to be read in at initialization and will reside in memory (for faster access)
  - Given SZA, AOD/Cloud Phase, IGBP, Wind Sp bin retrieves corresponding P(RAZ,VZA), χ(RAZ,VZA),… PDMs

HDF FILE CONFIGURATION EXAMPLE

Given this binning:

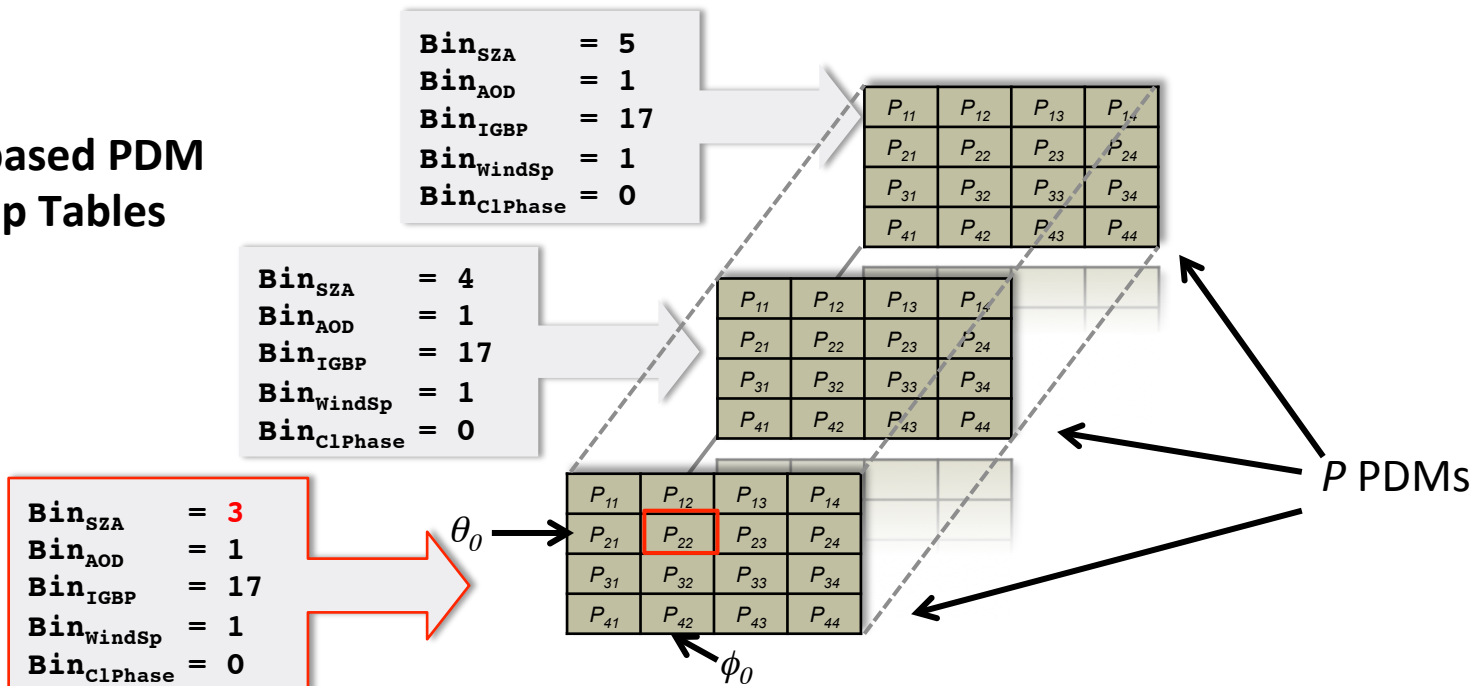
Dimension name	# bins	bins
SZA	7	[0°, 10°), [10°, 20°), [20°, 30°), [30°, 40°), [40°, 50°), [50°, 60°)
AOD	2	[0, 0,.1), [0.1,inf)
IGBP	10	Variable
Wind Sp.	4	[0, 3.5), [3.5, 5), [5, 7.5), [7.5,10)
Cloud Ph.	4	Clear (0), Water (1), Ice (2) , Mixed (3)

and the inputs:

SZA = **27°**, AOD = **0.06**, IGBP = **17**, Wind Speed = **2.5** and **Clear** Scene, RAZ = ϕ_0, VZA = θ_0

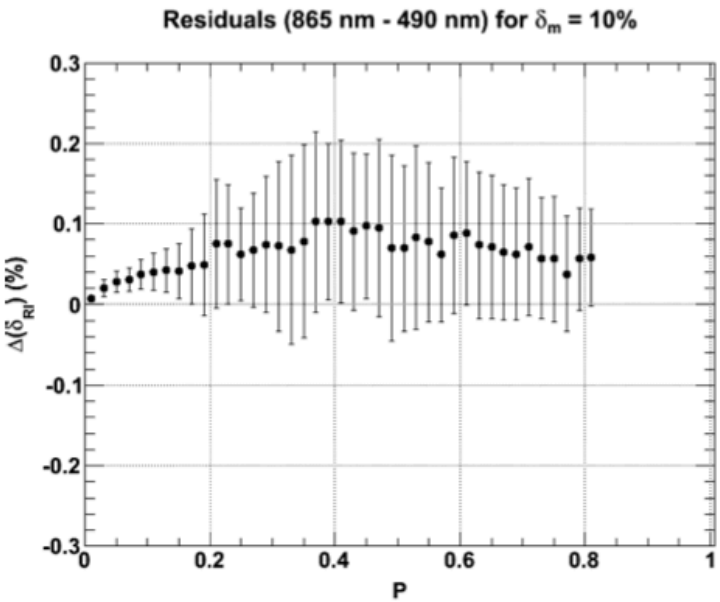
Find corresponding degree of polarization:

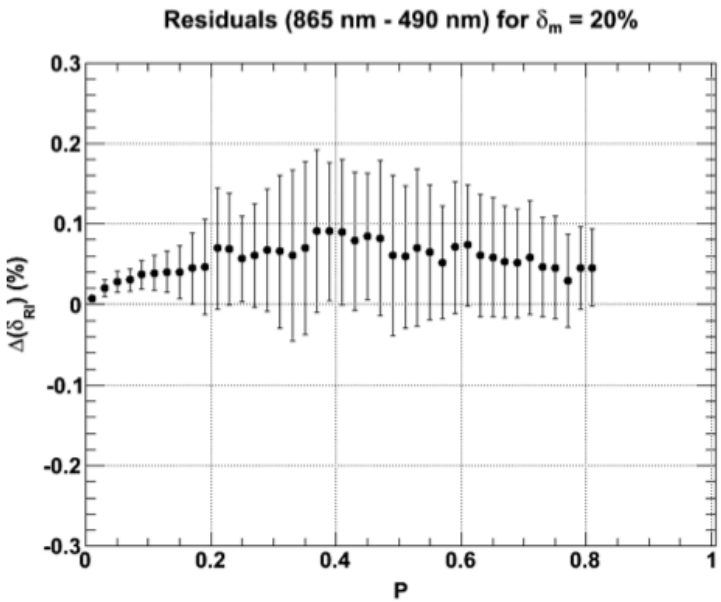
HDF-based PDM Lookup Tables



BACKUP

δ_{RI} FOR 2 UNCERTAINTIES ON IMAGER'S SENSITIVITY TO POLARIZATION δ_m





- No difference in intercal error across 2 polarization channels (865 nm and 490 nm)
- No difference in intercal error for 0% < δ_m< 20%