Aerosol retrievals from the ACEPOL Campaign

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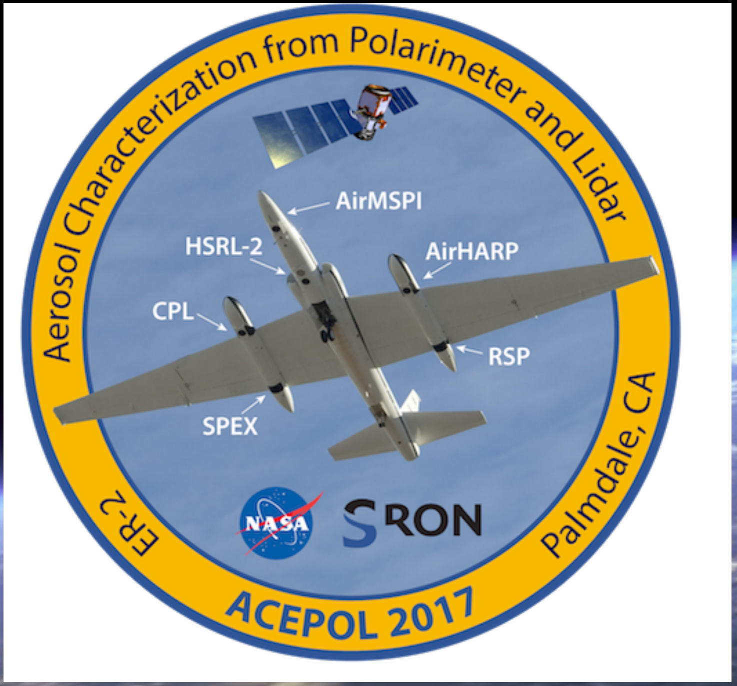

ACEPOL Oct-Nov 2017

Aerosol Characterization from Polarimeters and Lidars

ER-2 instruments
- SPEX airborne
- RSP
- HSRL-2
- AirMSPI
- CPL
- AirHARP

Ground-based instruments
- AERONET
- MPLNET

Satellite overpasses
- CALIPSO, CATS
- MSIR, MODIS, VIIRS

NASA and SRON collaborated in the ACEPOL field campaign to acquire data with advanced active and passive remote sensors. These data will be used to develop and assess algorithms for retrieving profiles of aerosol optical and microphysical properties for various atmospheric applications. The measurements and algorithms are applicable to future satellite missions such as ACE, PACE, METOP-SG, and EarthCare.

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NASA support: Hal Maring, Felix Seidel (HQ); Arlindo da Silva (GSFC)

Polarimeters

- **RSP**
  - ✓ High maturity polarimeter reference
  - ✓ Accurate along track scanner (not imager)
  - ✓ 155 view angles, 9 channel (410, 470, 555, 670, 865, 960, 1590, 1880, 2250 nm) Used 410-865 nm.
- **airMSPI**
  - ✓ High spatial resolution, 8 channel (355, 377, 443, 469, 553, 659, 863, 931nm)
  - ✓ Gimbaled system requires targeting, various possible # view angels
- **airHARP**
  - ✓ Wide swath, 4 channel (440, 550, 670, 870nm), 20 view angles (60 for 670nm)
  - ✓ Implementation on ER-2 requires targeting mode
  - ✓ First time on ER-2 - Ongoing work to improve data quality (not available yet)
- **SPEX airborne**
  - ✓ 400-800 nm continuously (used 450-750 nm), 9 angles, 7^{o} swath
  - ✓ Second time on ER-2

LIDARS

- **HSRL-2**
  - Lidar with backscatter at 355, 532, 1064nm, extinction at 355, 532nm, depolarization at 355, 532, 1064nm
- **CPL**
  - Lidar with backscatter at 355, 532, 1064nm, depolarization at 1064nm

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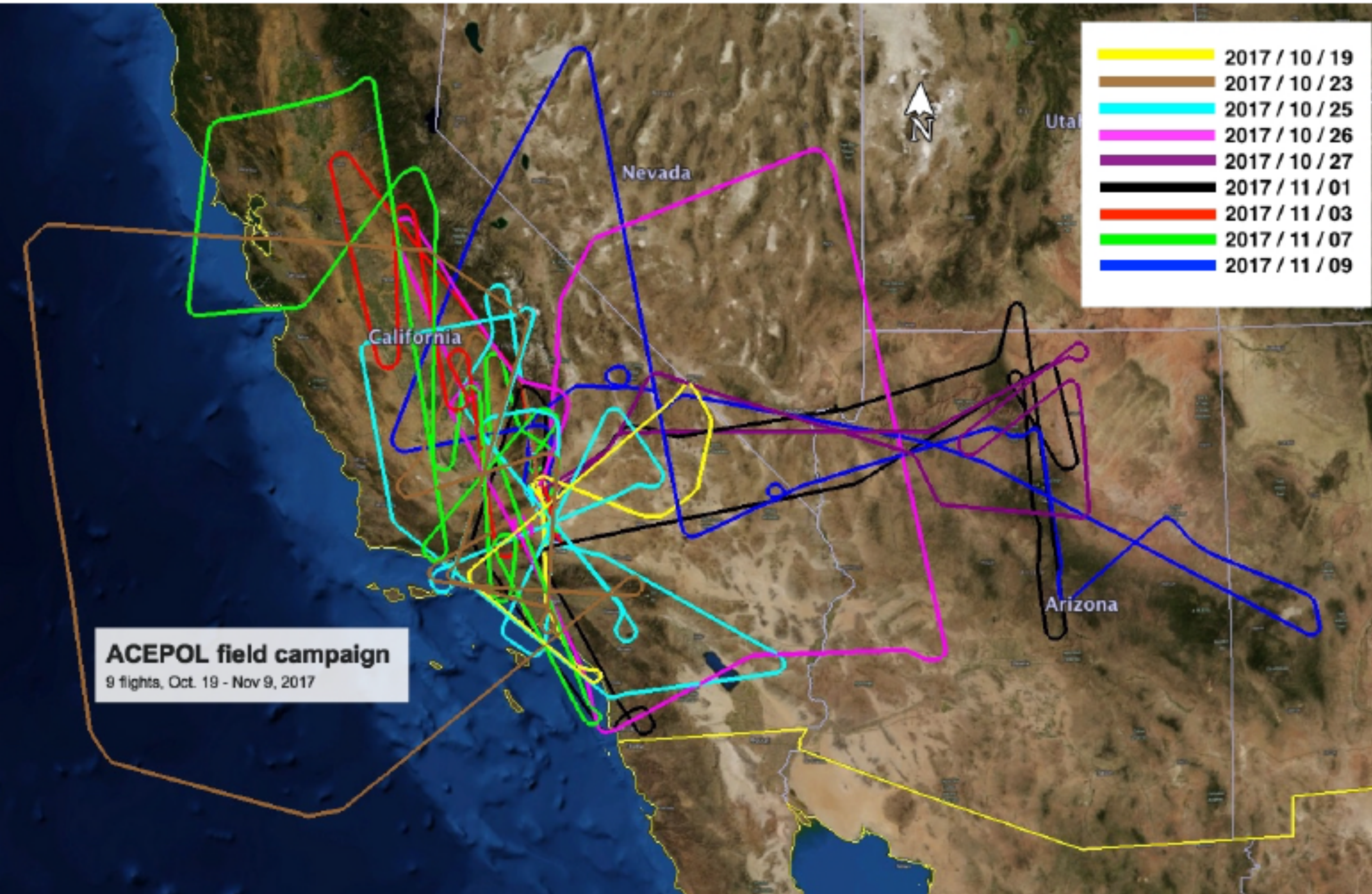
ACEPOL: 9 flights, 41.3 hours



Retrieval approach:

SRON Aerosol multimode retrieval algorithm.

Fu, G. and Hasekamp, O.: Retrieval of aerosol microphysical and optical properties over land using a multimode approach, Atmospheric Measurement Techniques, 11, 6627–6650, https://doi.org/10.5194/amt-11-6627-2018, 2018.

State vector:

- **Aerosol column number for 5 modes.**
- **Fine and coarse mode complex refractive index.**
- **Fraction of spherical particles**
- **Aerosol Layer Height (ALH)**

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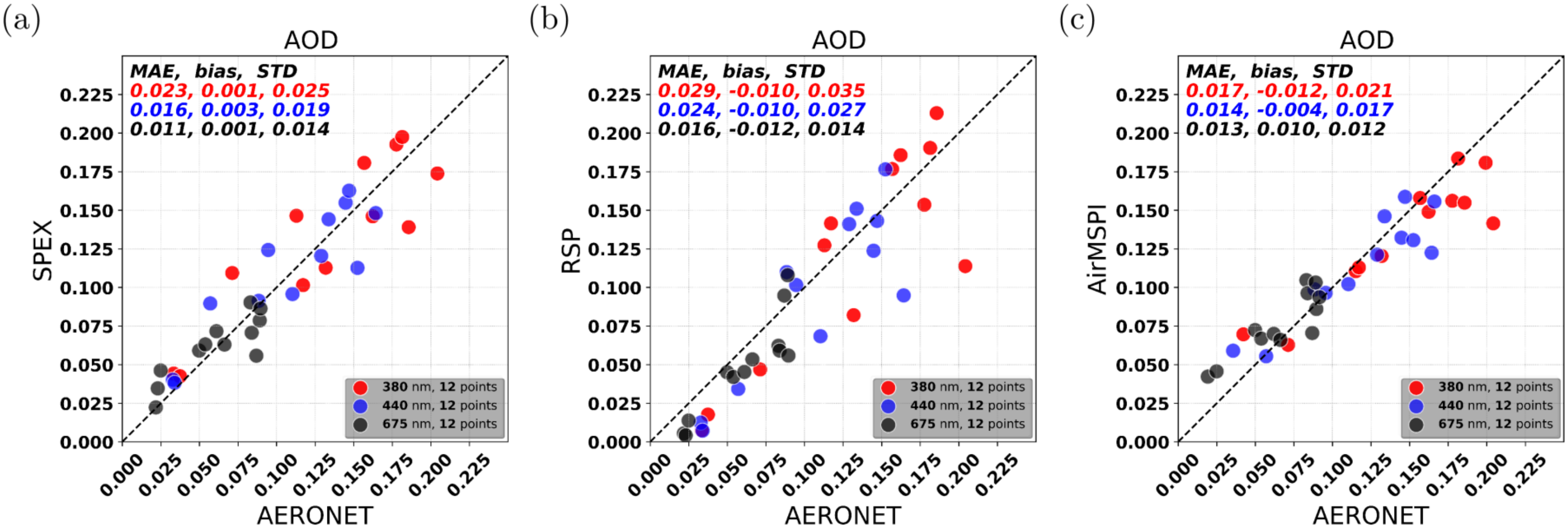
Comparison with AERONET

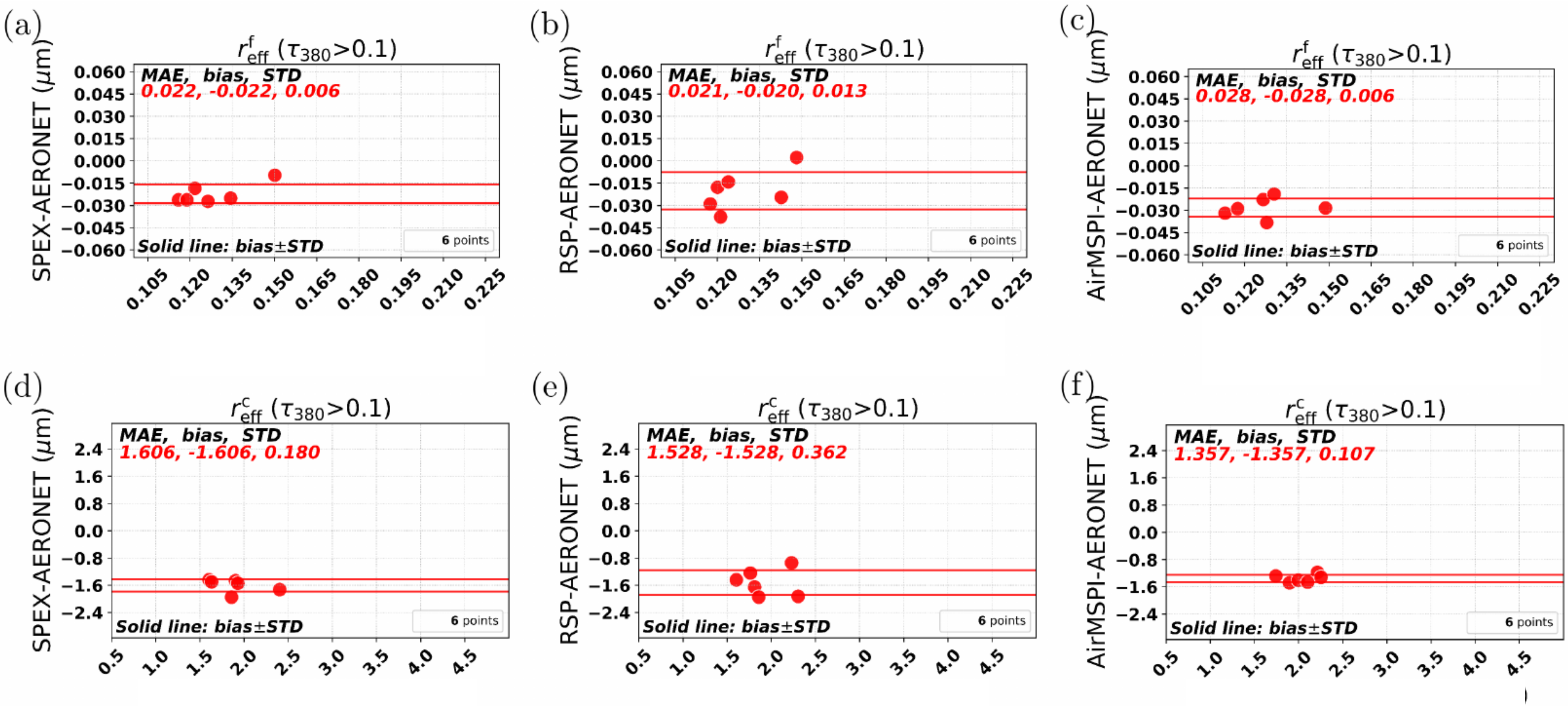
Aerosol optical depth (AOD)



12 overpasses

Results: SPEX, RSP, and AirMSPI have similar performance for AOD

Fine and coarse mode Effective radius



Results: Reasonable agreement given the small AOD. Differences between the different instruments caused by 1 or 2 points.

Remarks from comparison with AERONET

- SPEX, RSP, and AirMSPI achieve similar performances on AOD, and they all agree well with AERONET.
- For the fine and coarse mode effective radius and the fine and coarse mode AOD, reasonable agreements were found between polarimeters and AERONET, given the small AOD.

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Comparison to HSRL-2: Lidar Definitions

$$\tilde{\mathbf{F}}(\Theta) = \begin{bmatrix} a_1(\Theta) & b_1(\Theta) & 0 & 0 \\ b_1(\Theta) & a_2(\Theta) & 0 & 0 \\ 0 & 0 & a_3(\Theta) & b_2(\Theta) \\ 0 & 0 & -b_2(\Theta) & a_4(\Theta) \end{bmatrix}$$

$$S = \frac{4\pi}{\omega a_1(180^o)}$$

Sensitive to SSA and phase function

$$\beta = \frac{\alpha\omega a_1(180^o)}{4\pi}$$

$$\delta = \frac{a_1(180°) - a_2(180°)}{a_1(180°) + a_2(180°)}$$

Sensitive to particle shape

S = lidar ratio
δ = Linear Depolarization Ratio
β = backscatter coefficient
α = exctinction coefficient
ω = Single Scattering Albedo (SSA)

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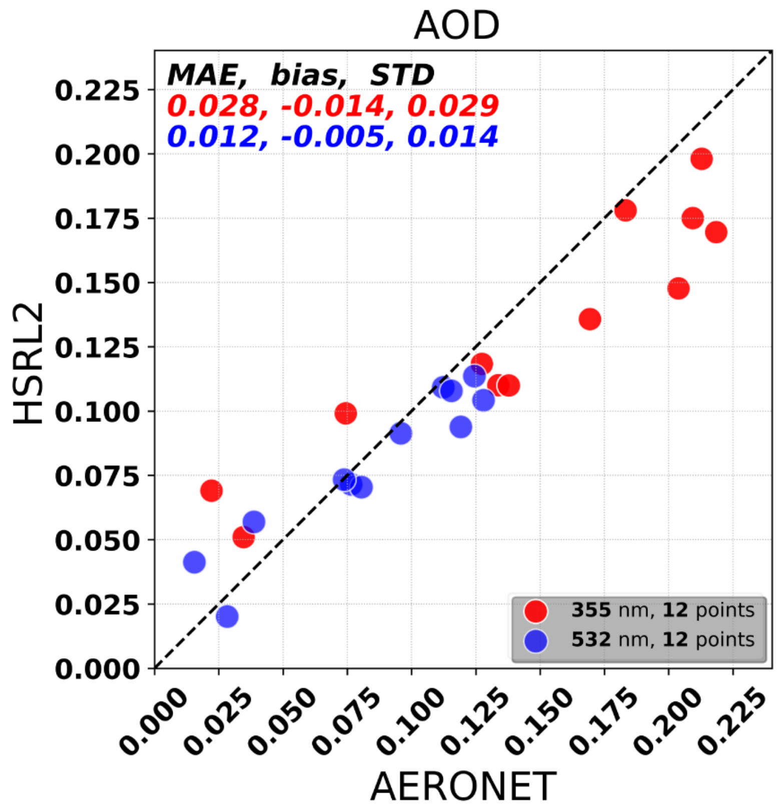
Comparison with HSRL-2

- We first check agreements between the HSRL-2 and AERONET



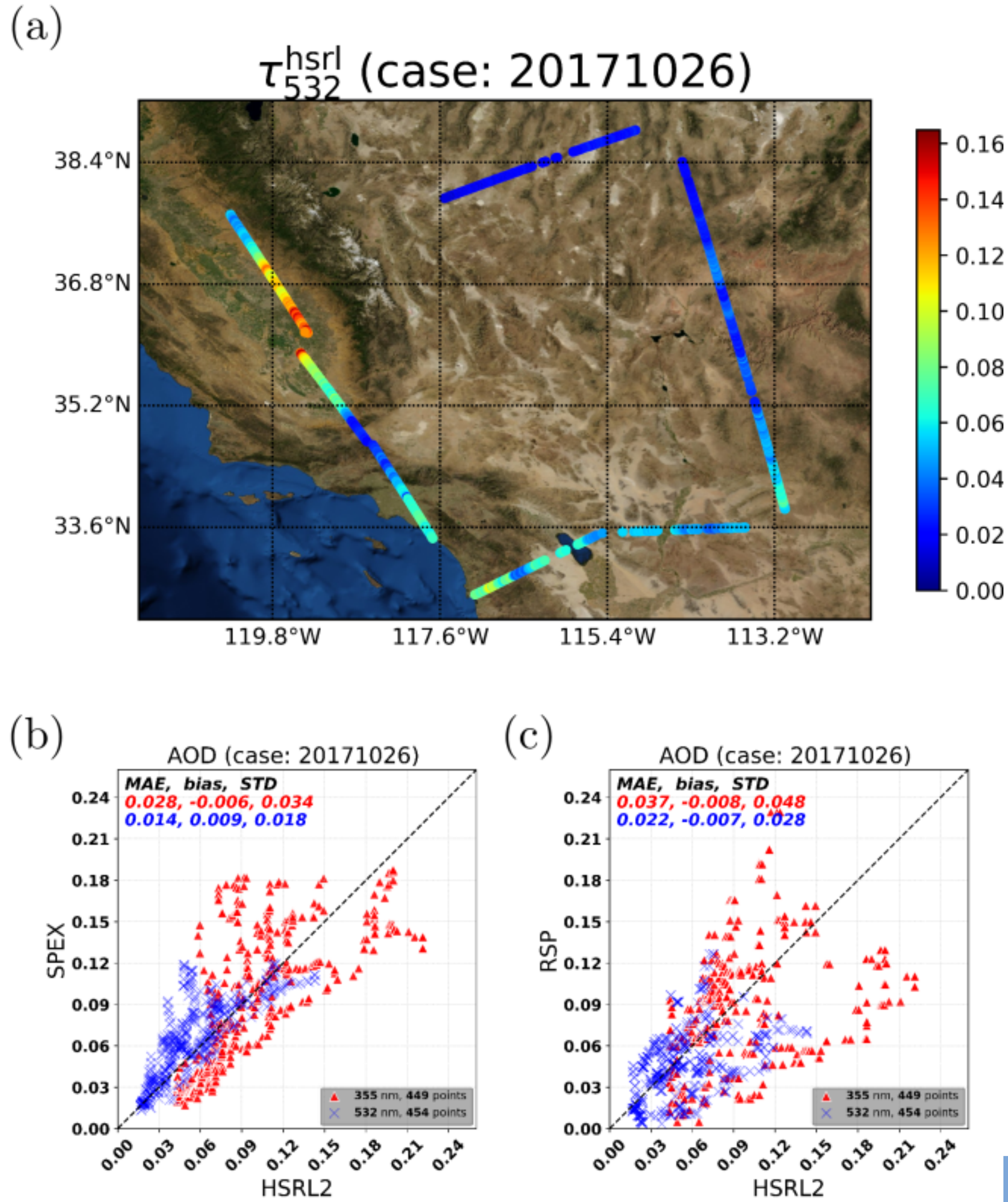
Results: Good agreements between HSRL-2 and AERONET indicate that HSRL-2 is capable of validating polarimeter retrieved properties.

Comparison with HSRL-2

- Comparisons are on two days.
- Day 1: low AOD (AOD ranges 0.02 – 0.14) on 26 Oct 2017
- Day 2: high AOD, with measurements of inhomogeneous smoke plume with high AOD (including AOD values > 1.0) on 9 Nov 2017

Comparison with HSRL-2 for low AOD case

Aerosol optical depth (AOD)



Results: for low AOD cases, SPEX compares a bit better with HSRL-2 for AOD.

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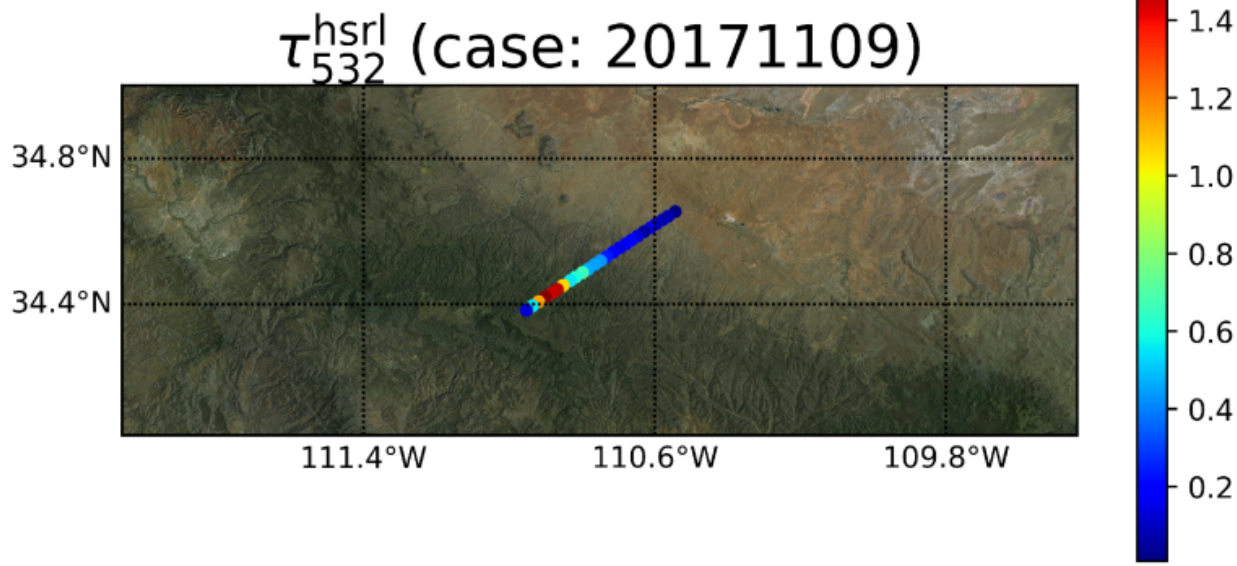
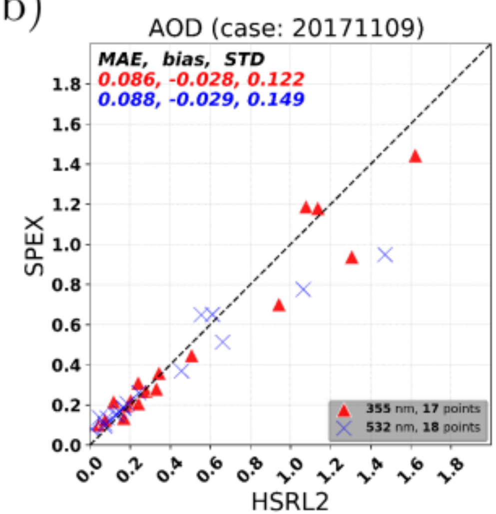
Comparison with HSRL-2 for high AOD case (smoke)

(a)

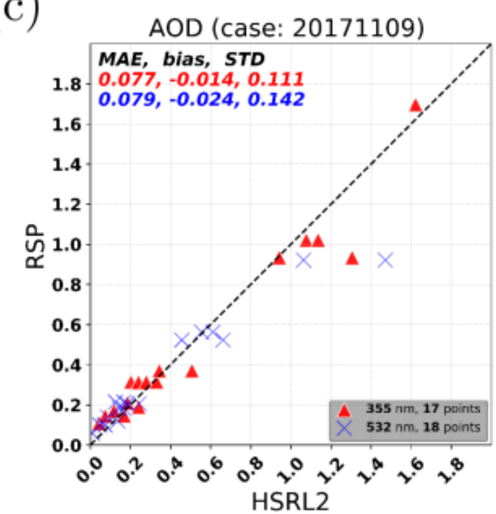


Results: for smoke case, good agreements are found between SPEX and HSRL-2 and also between RSP and HSRL-2.

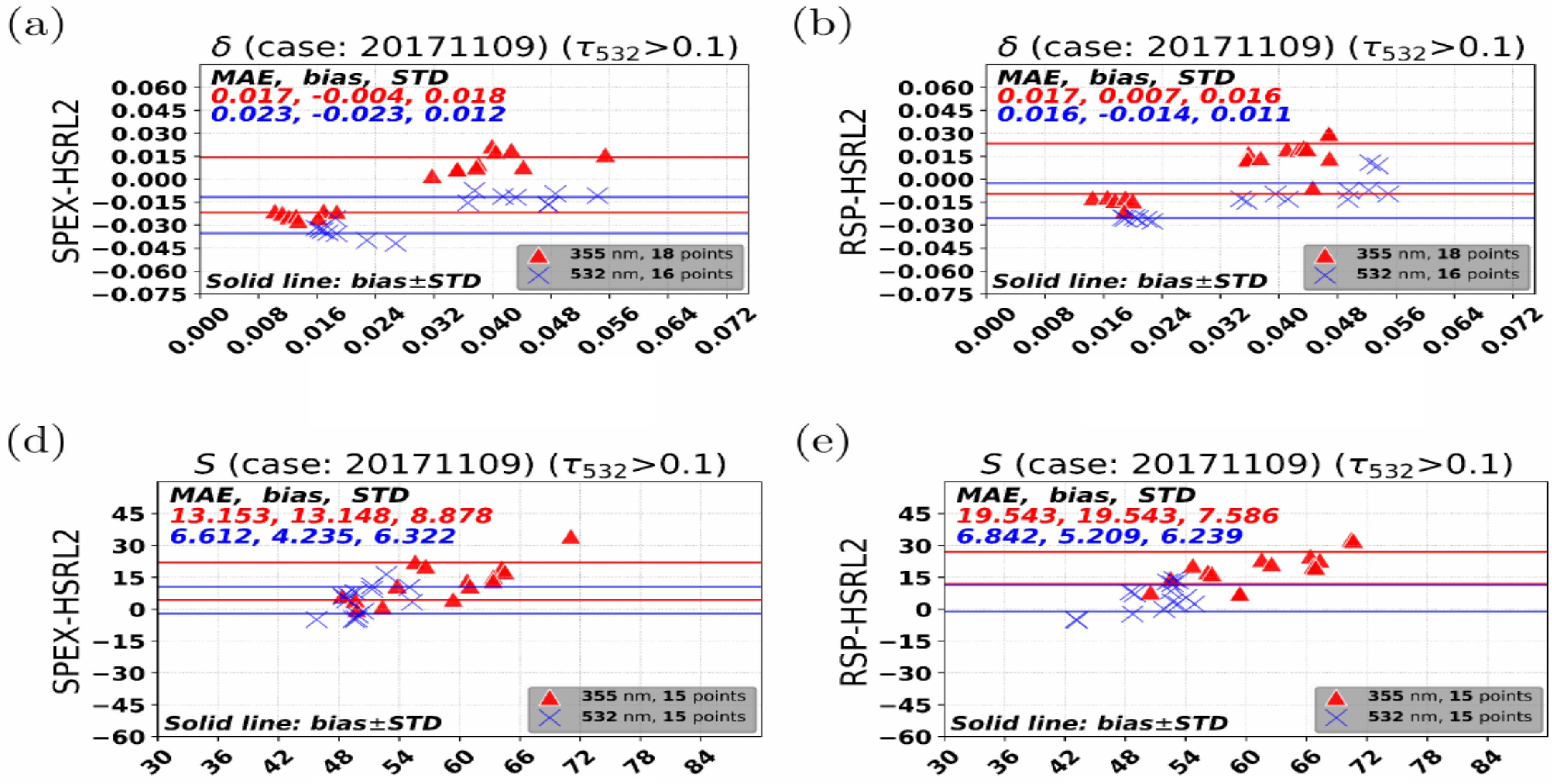
(b)



(c)



Aerosol Depolarization Ratio and Lidar Ratio



Results: (1) Good comparison for aerosol depolarization ratio (a for SPEX-HSRL2, b for RSP-HSRL2) indicates the polarimetric capability of retrieving particle shape parameter.

(2) SPEX and RSP show similar agreement with HSRL2.

Comparison with HSRL-2 for smoke case

Mean properties of the smoke plume for SPEX and RSP when AOD > 0.2 at 532 nm.

	SPEX	RSP
Fine mode real part of refractive index ($m^{f}_{r,532}$)	1.579	1.556
Fine mode imaginary part of refractive index ($m^{f}_{i,532}$)	0.038	0.036
Fine mode effective radius (r^{f}_{eff})	0.116	0.119
Fine mode AOD (τ^{f}_{532})	0.554	0.509
Coarse mode AOD (τ^{c}_{532})	0.016	0.040
Aerosol layer height (ALH) (km)	4.417	1.585
SSA (ω_{532})	0.815	0.829
Fraction of spherical particles (f_{sphere})	0.989	0.846

Results: There is good agreement between SPEX and RSP on the microphysical and optical properties of the smoke plume.

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Remarks from comparison with HSRL-2

SPEX and RSP agree well to HSRL-2 in both low and high AOD cases

Thank YOU!