Coupled retrieval of liquid water cloud and aerosol above cloud properties using the Airborne Multiangle SpectroPolarimetric Imager (AirMSPI)

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11 Dec 2017

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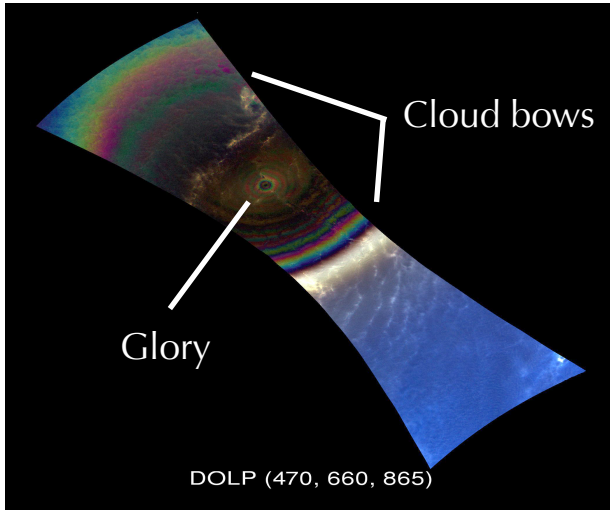
Motivation

Coupled retrieval of cloud optical depth, droplet size and aerosols above cloud (AAC) properties is important for:

- investigating aerosol and cloud interactions
- characterizing cloud albedo, liquid water content and the rate at which the droplets coalesce into drizzle

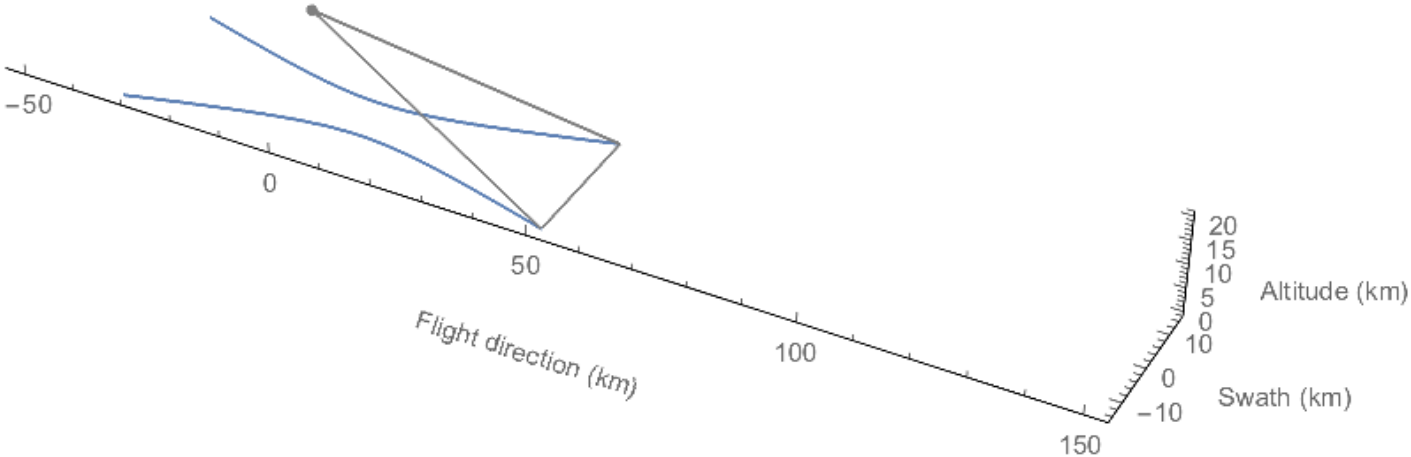
We have developed a coupled AAC and cloud retrieval approach using **multi-angular, multi-spectral, and polarimetric** AirMSPI observations acquired during NASA ORACLES/PODEX/SEAC^{4}RS field campaigns

AirMSPI

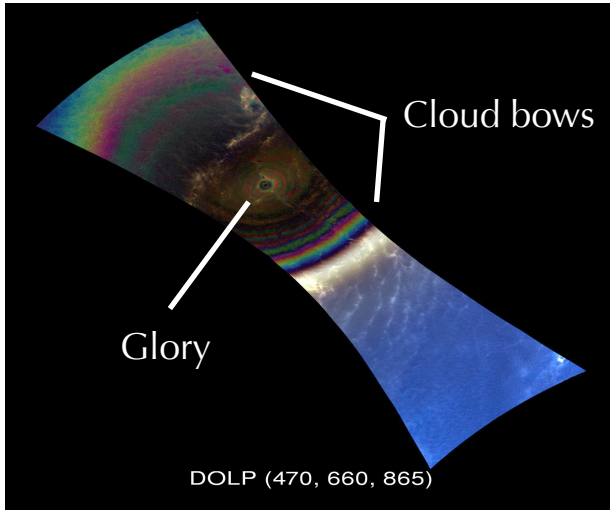


355, 380, 445, 470*, 555, 660*, 865*, 935 nm (*polarized)

±67º FOV along track
25 m spatial resolution



AirMSPI



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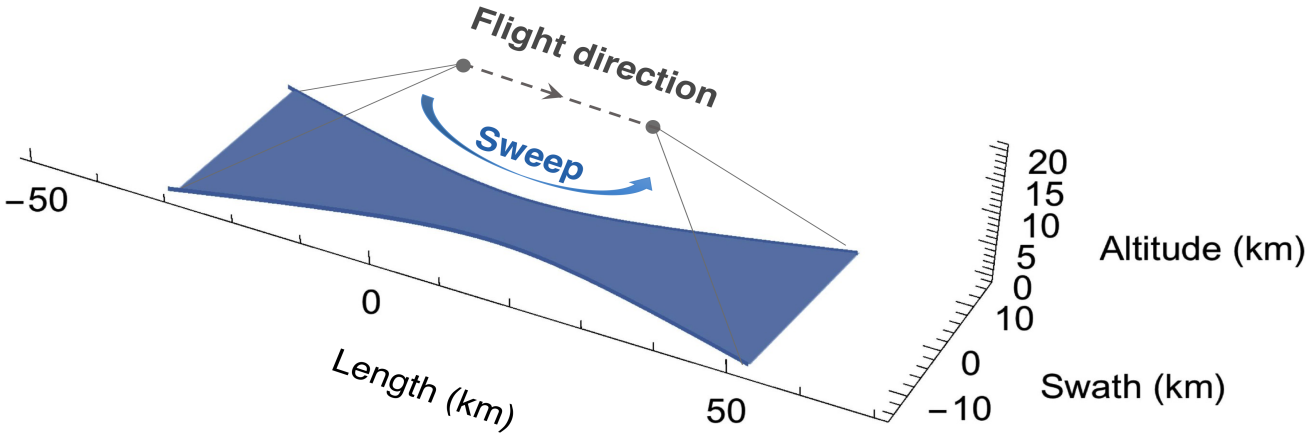


Cloud and AAC retrieval strategy

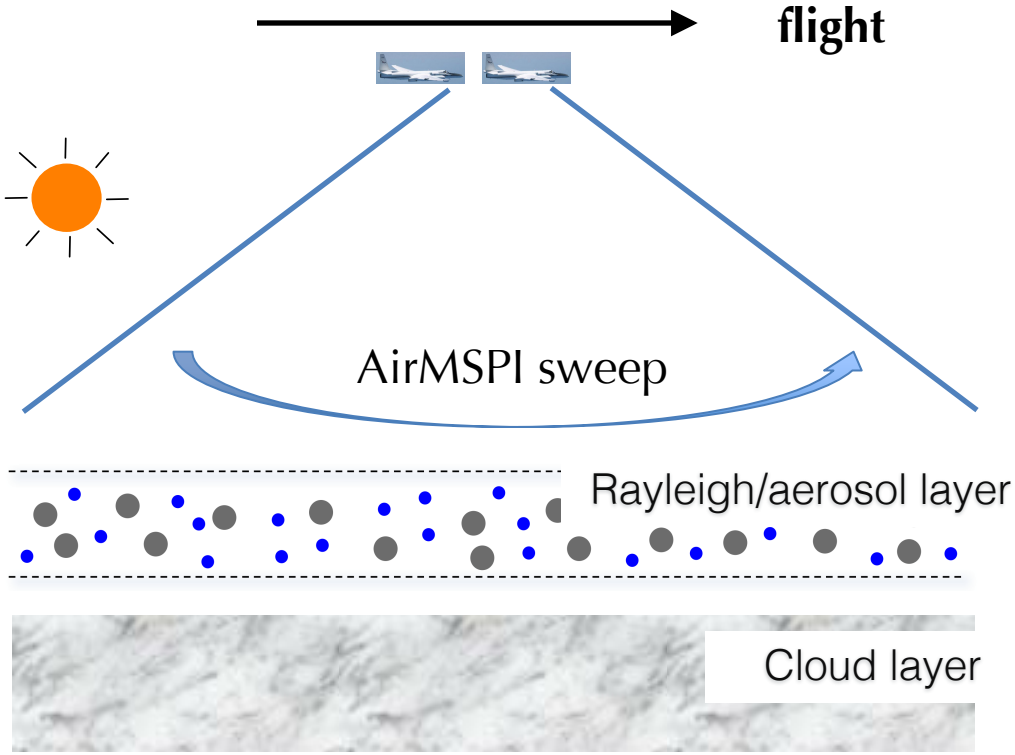
Polarized and total radiance

Retrieve AAC and cloud microphysical properties from polarized radiance

Retrieve pixel-scale cloud optical depth (COD) from total radiance

Retrieve droplet size distributions (DSDs) from different COD bins

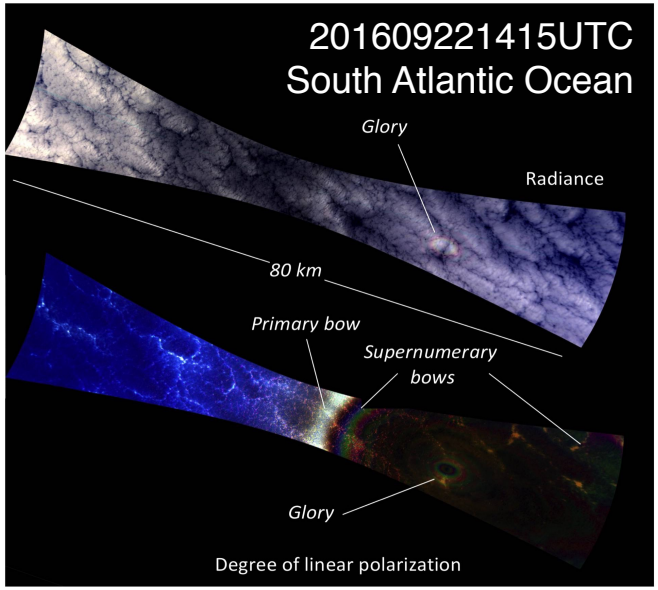
Get COD vs DSD relations and map DSD from pixel-scale COD

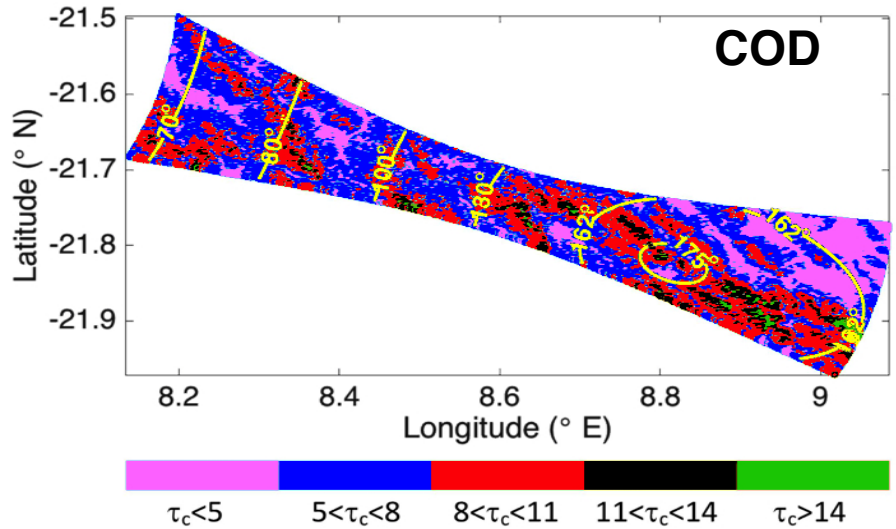


Cloud properties: pixel-scale COD and DSD
AAC properties: image-scale AOD, SSA, size distribution

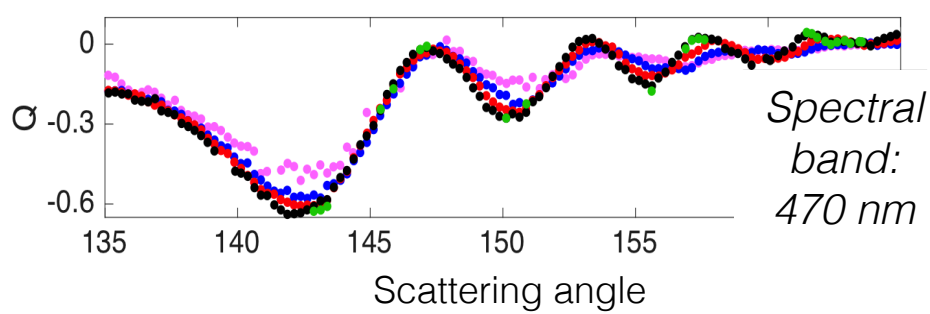
Heritage: DSD and AAC retrievals for POLDER (Deschamps 1994; Bréon and Goloub,1998; Waquet et al., 2013), RSP (Cairns et al.1999; Knobelspiesse et al. 2011; Alexandrov et al. 2012) and AirMSPI (Diner et al. 2013)

AirMSPI observes COD-dependent cloudbow shifts

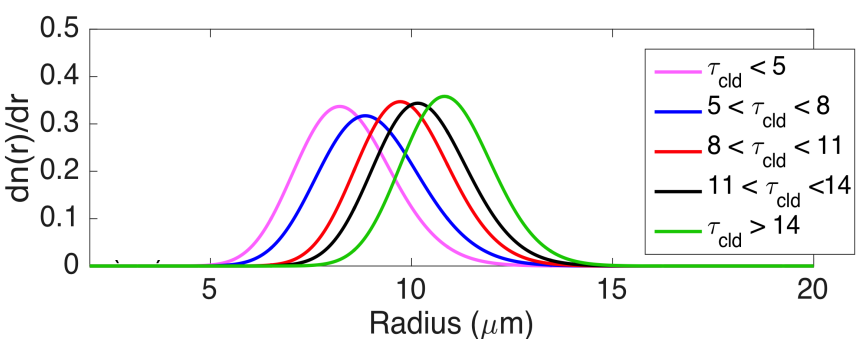




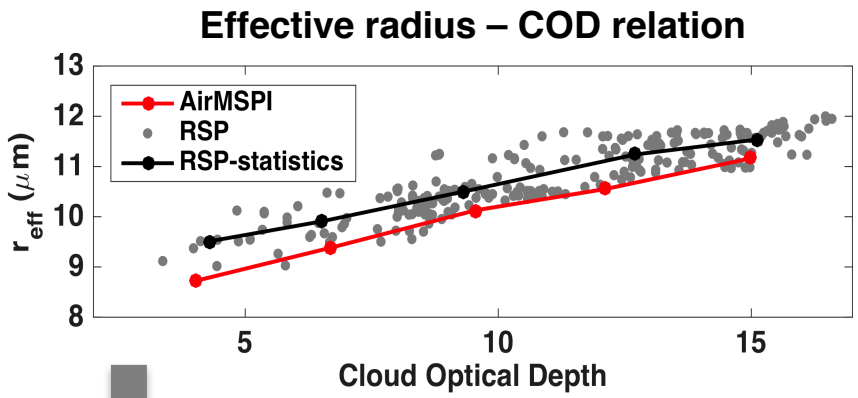
Cloudbows associated with 5 COD bins

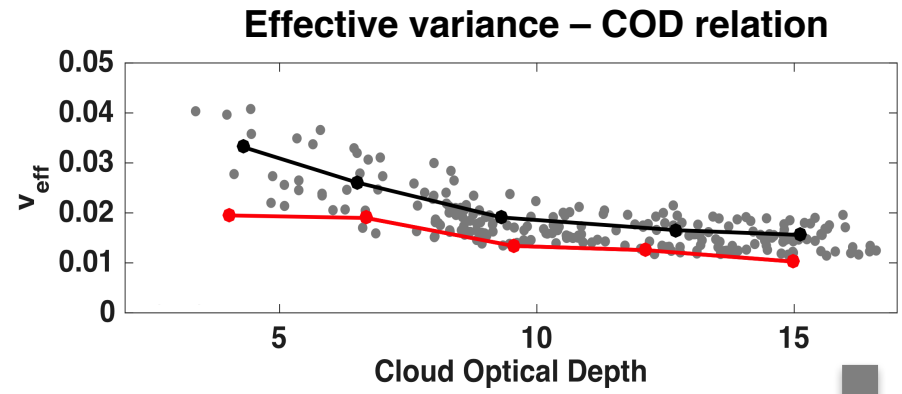


DSD retrieved from COD bins

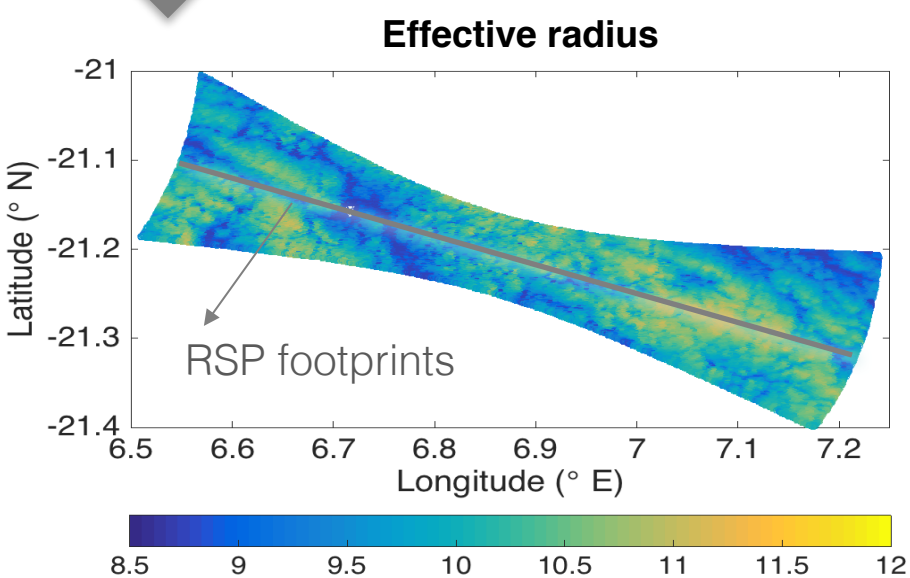


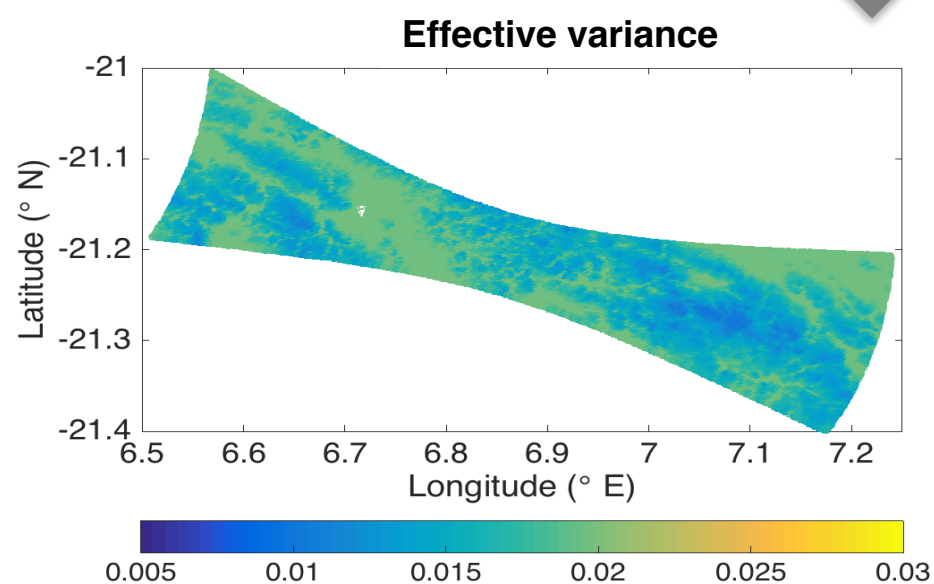
COD-droplet size distribution relations



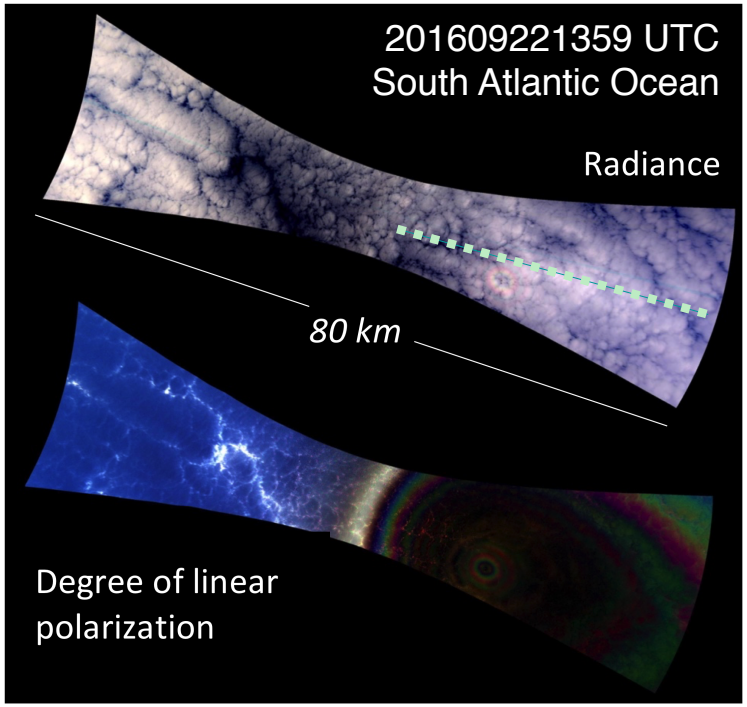


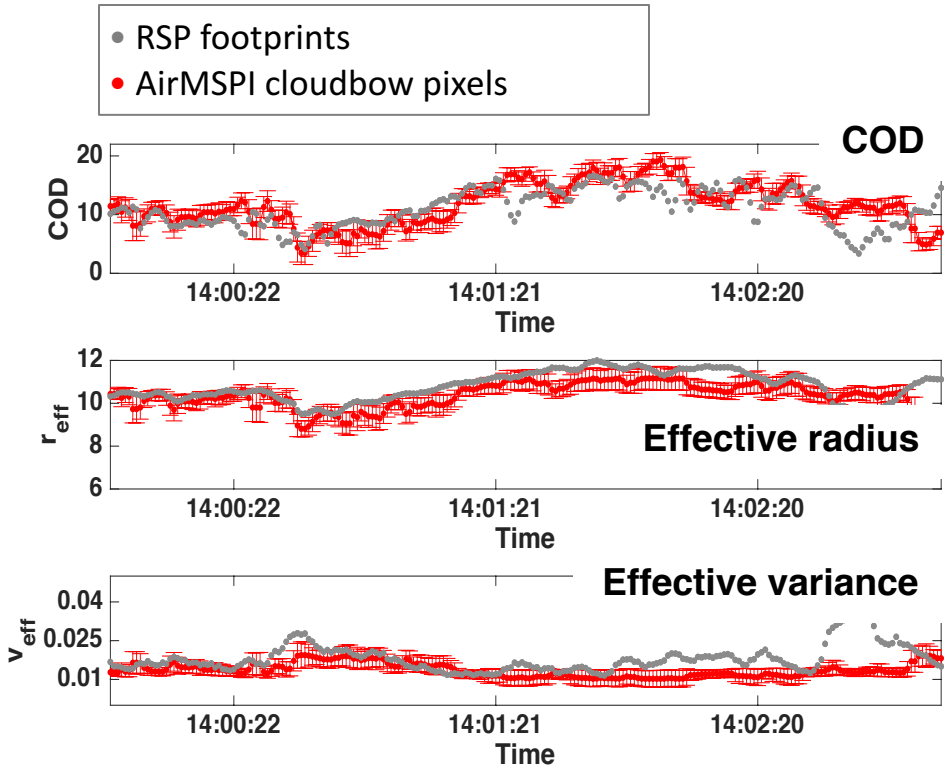
COD-Droplet size relation enables mapping DSD from pixel-scale COD





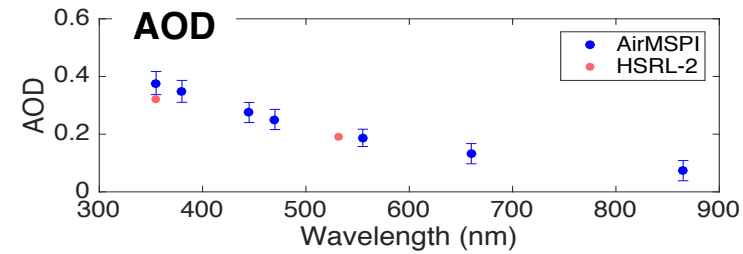
Pixel-scale cloud retrieval comparison to RSP

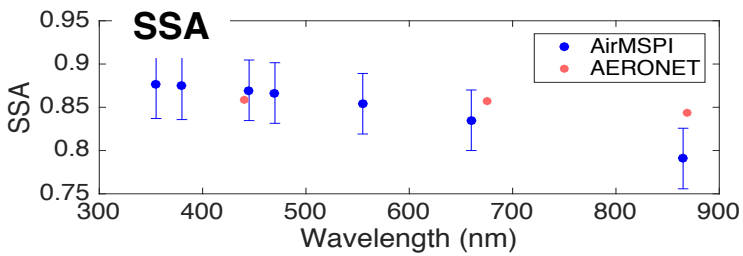


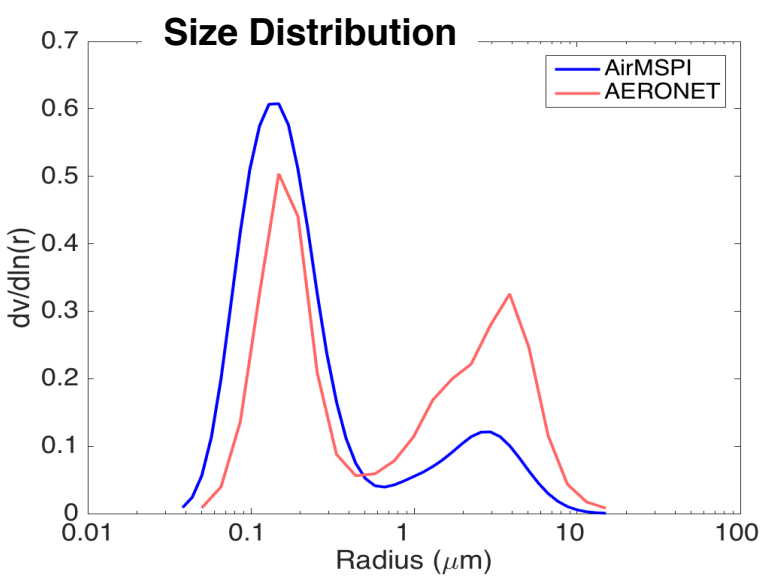


AirMSPI pixel-scale COD and DSD retrievals show consistency with RSP results for marine stratocumulus clouds off the coast of Namibia.

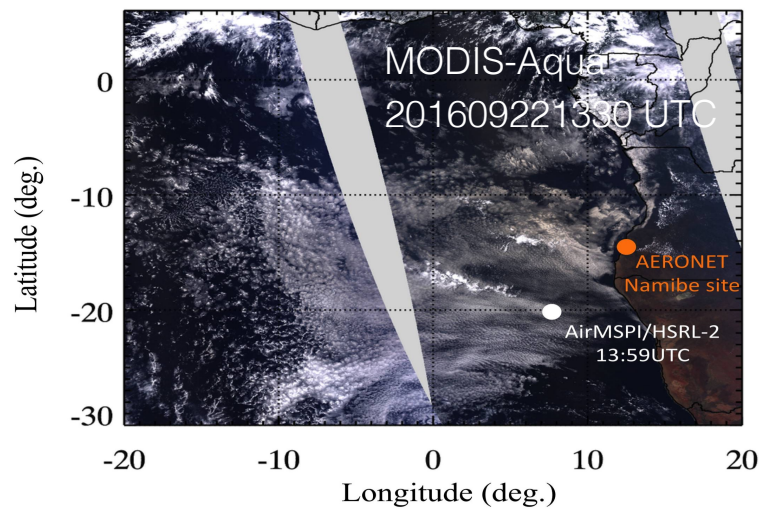
Aerosol retrieval comparison to HSRL-2 and AERONET

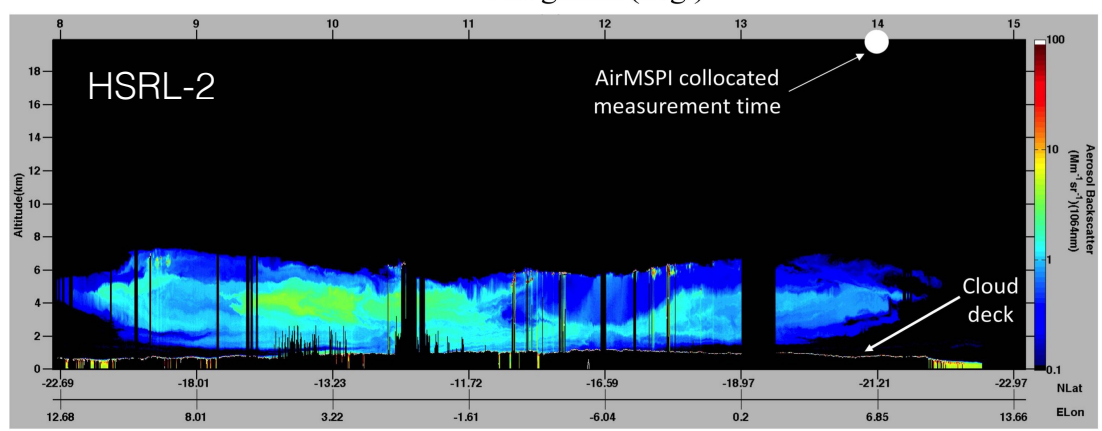




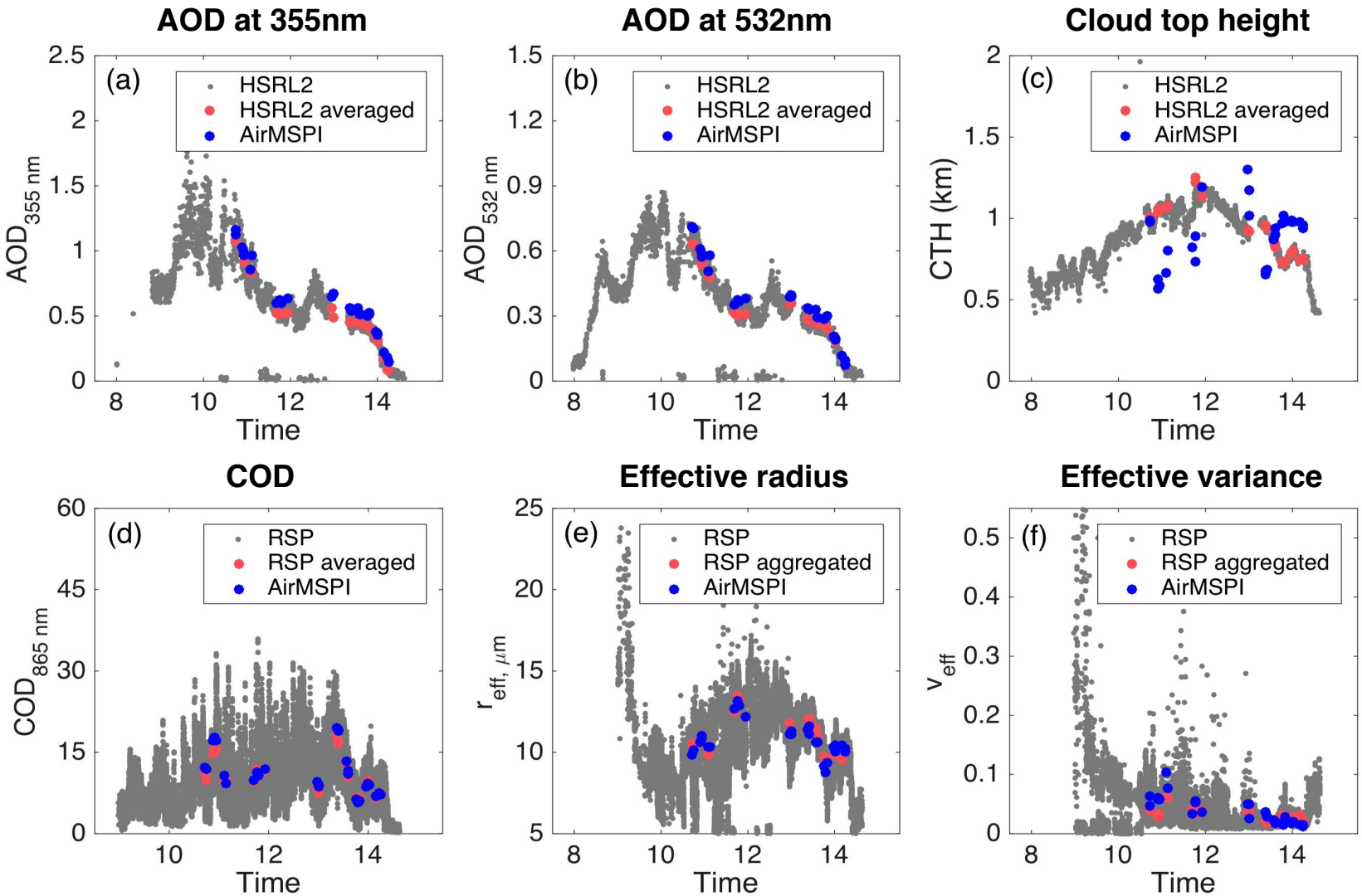


AirMSPI AOD, SSA, and aerosol size distribution retrievals show consistency with HSRL-2 (Hair et al. 2008) and AERONET (Holben et al.,1998) results.



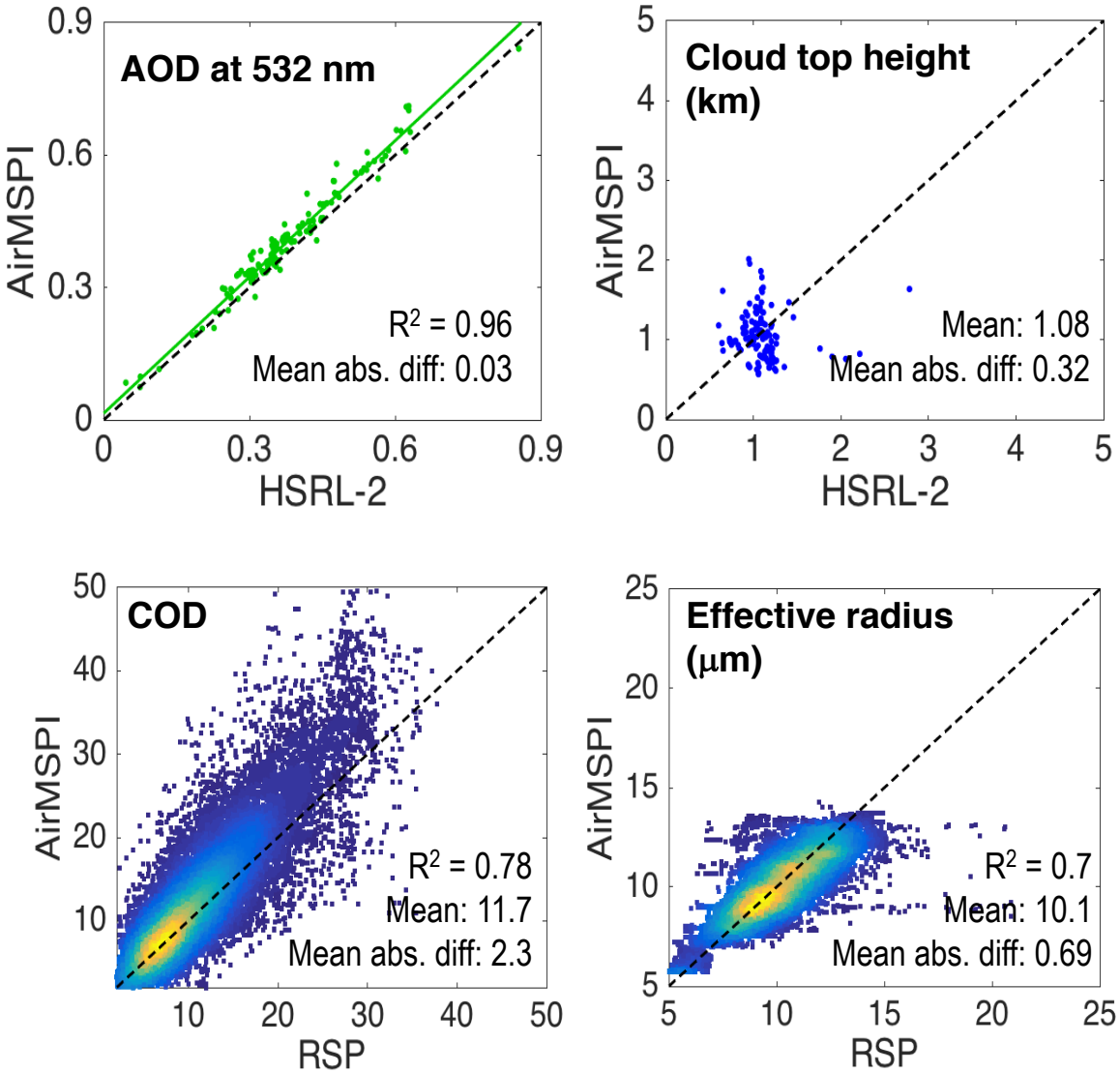


Temporal variation of AAC and cloud properties



Data source: 29 AirMSPI/RSP/HSRL-2 collocated scenarios from ORACLES flight on 22/09/2016

More validation against HSRL-2 and RSP



AirMSPI retrievals of above-cloud AOD and CTH at image scale, and cloud optical depth (COD) and droplet effective radius and variance at pixel scale compare favorably with collocated HSRL-2 and RSP results

Data source: 134 AirMSPI/RSP/HSRL-2 collocated cloud scenarios from ORACLES science flight (from Sep.10 to 29, 2016)

Summary

- An optimization approach was developed for coupled retrieval of liquid water cloud and AAC properties using AirMSPI
- AirMSPI high spatial resolution enables the observation of COD-dependent cloudbow angular shifts. Image-specific COD *vs* droplet size relations are found for marine stratocumulus clouds, which further enable a pixel-scale DSD estimate
- COD and DSD retrievals show consistency with RSP results
- Above cloud AOD retrievals agree with HSRL-2 results
- Retrieval has been applied to process >1000 cloud scenarios AirMSPI acquired during ORACLES campaign (cf. *poster by G. van Harten*)

Work in progress: 1) Combine with "color ratio" method (Torres et al. (2012); Jethva et al. (2013)) to enhance AAC retrieval; 2) Quantify 3D effect on AirMSPI COD retrieval (A. Davis, in progress); 3) investigate COD vs DSD relations for broken cumulus clouds

Acknowledgments

Retrieval algorithm development

Oleg Dubovik, Jérôme Riedi, and Laurent C.-Labonnote (U. Lille)

Kirk D. Knobelspiesse (GSFC)

Jun Wang and Richard Xu (U. Iowa)

Zhibo Zhang (U. Maryland)

AERONET data for validation

Brent N. Holben (GSFC)

AirMSPI field organization, calibration and L1B2 data generation

Carol Bruegge, V. Jovanovic, and Michael Garay (JPL)

AirMSPI L2 cloud product preparation

James L. McDuffie and Irina N. Tkatcheva (JPL)

Data sources:

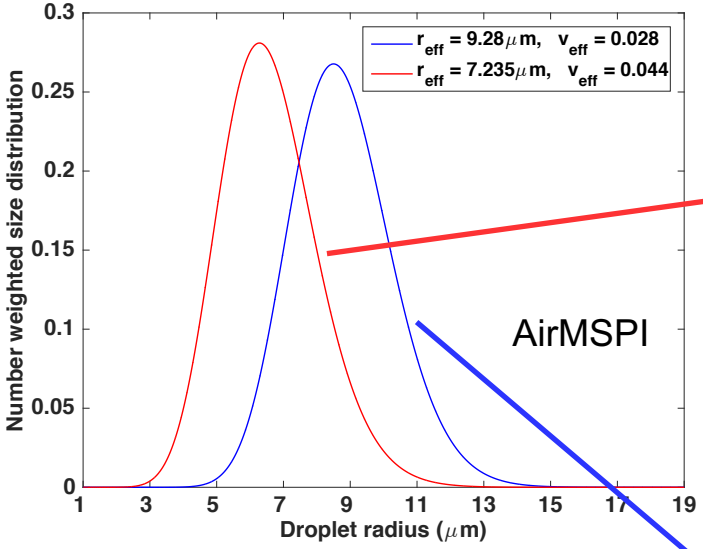
AirMSPI ORACLES data: https://eosweb.larc.nasa.gov/project/airmspi/airmspi_oracles_ellipsoid_table

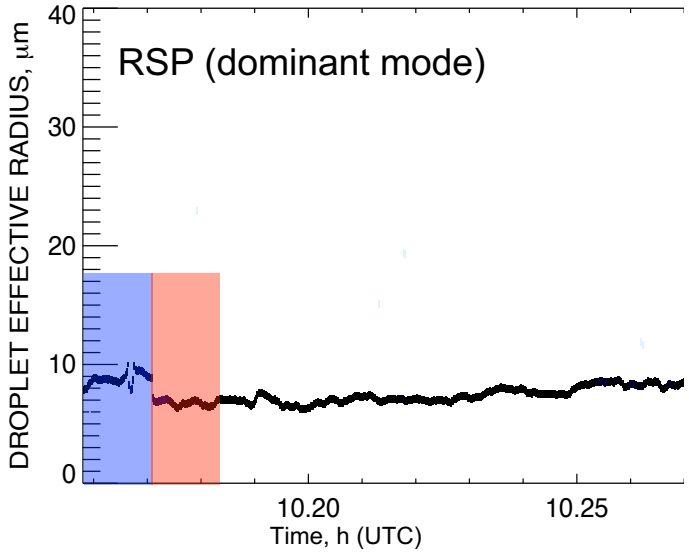
HSRL-2 retrieval products: https://espoarchive.nasa.gov/ archive/browse/oracles/ER2/HSRL2

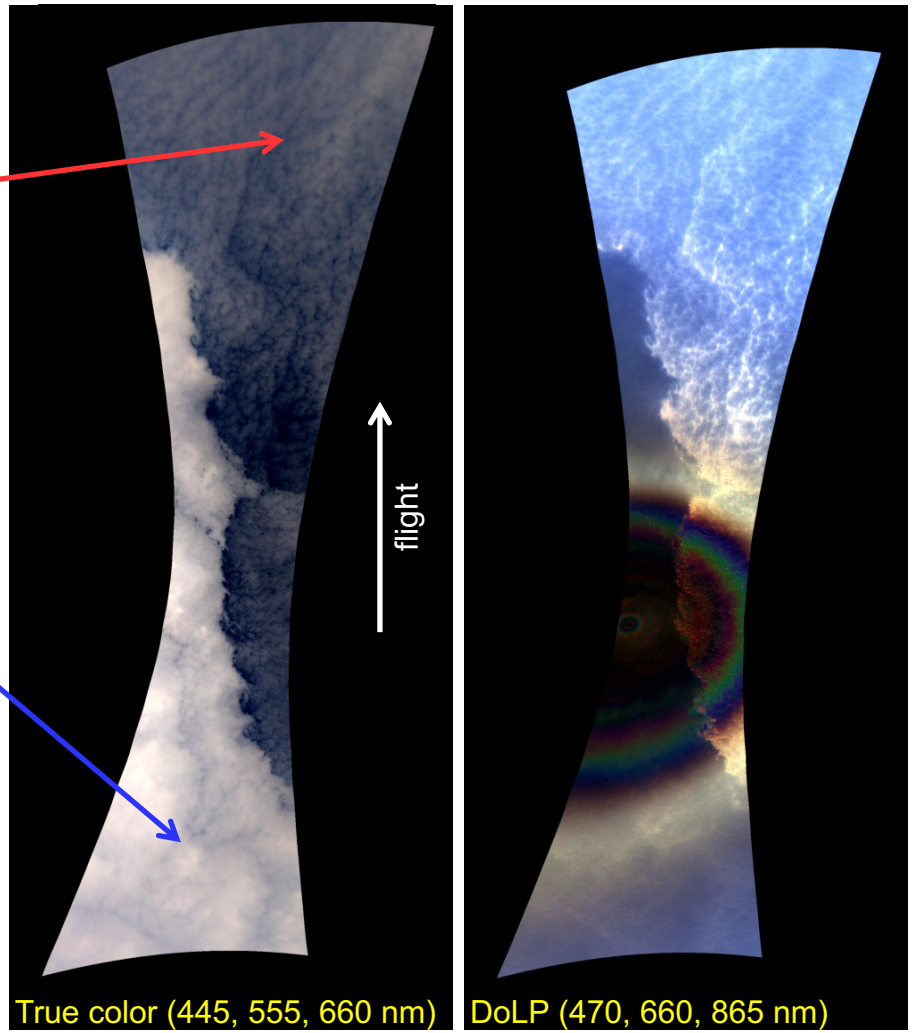
RSP retrieval products: https://data.giss.nasa.gov/pub/ rsp/ ORACLES_2016/

AirMSPI / RSP reff comparison: double bow !

A1





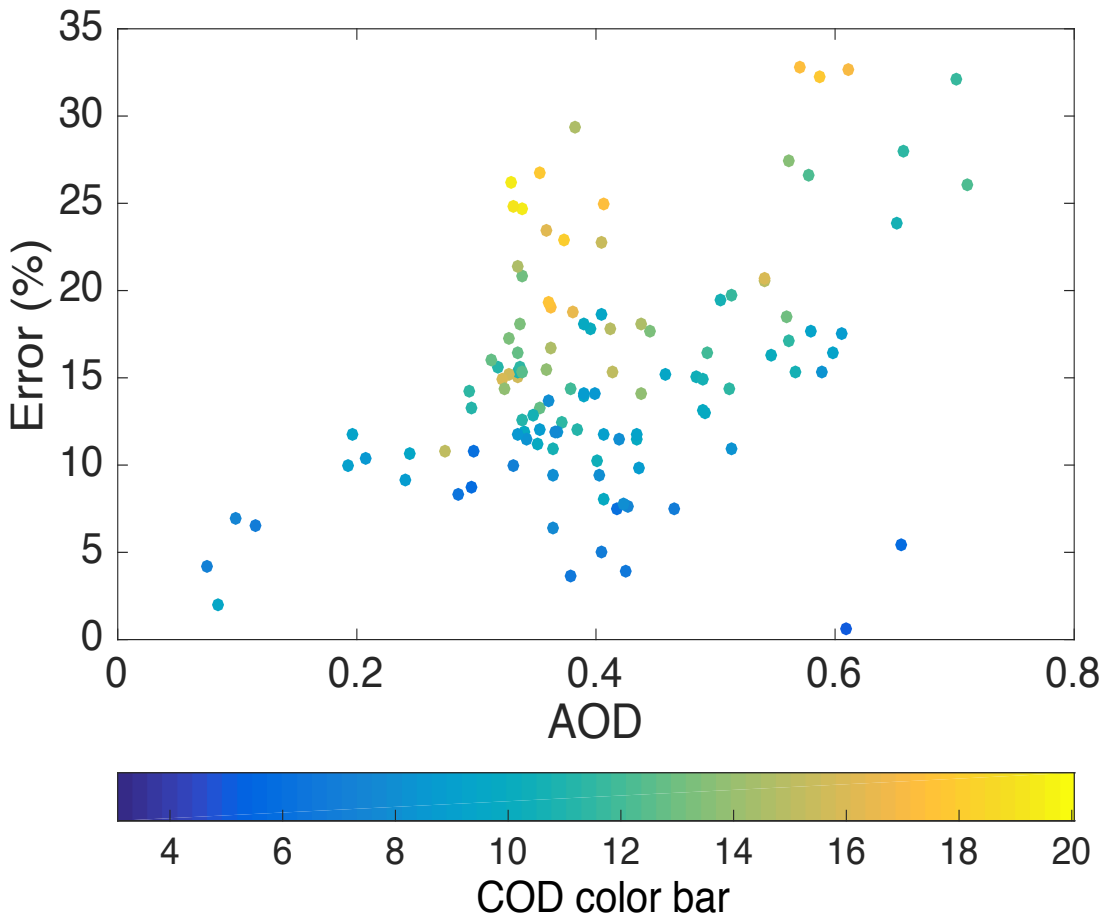


18 September 2016,10:11 UTC

COD error induced by neglecting absorbing AAC

A2

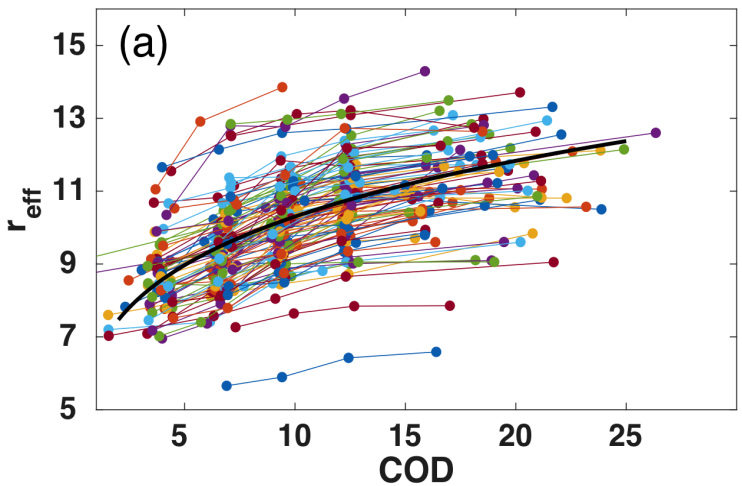
$$\text{Error} = 100\times[(\text{COD}_{\text{with-aerosols}}-\text{COD}_{\text{w/o-aerosols}})/\text{COD}_{\text{with-aerosols}}]$$



- Neglect of smoke AAC leads to an underestimate of image-averaged COD by an average of ~15%, which is close to the number (10-20%) given by Alfaro-Contreras et al. (2014)
- COD retrieval error is proportional to COD

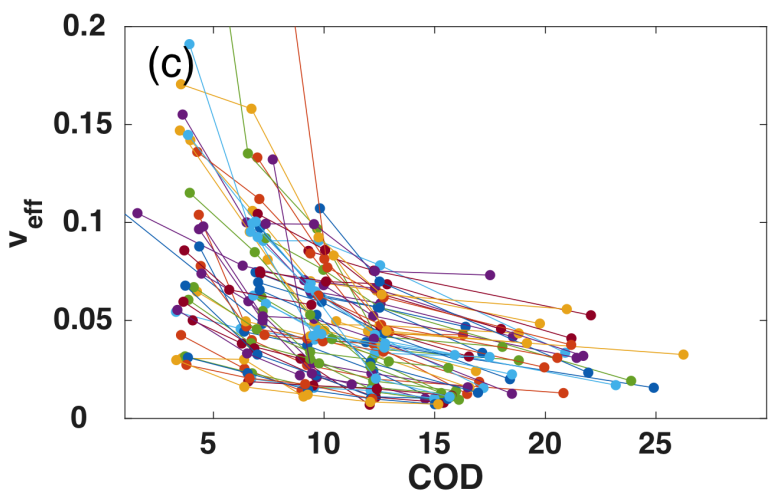
More image-specific COD-droplet size relations

A3



About 80% retrievals over 134 cloud scenarios AirMSPI acquired during ORACLES shows positive r_{eff} *vs* COD relation

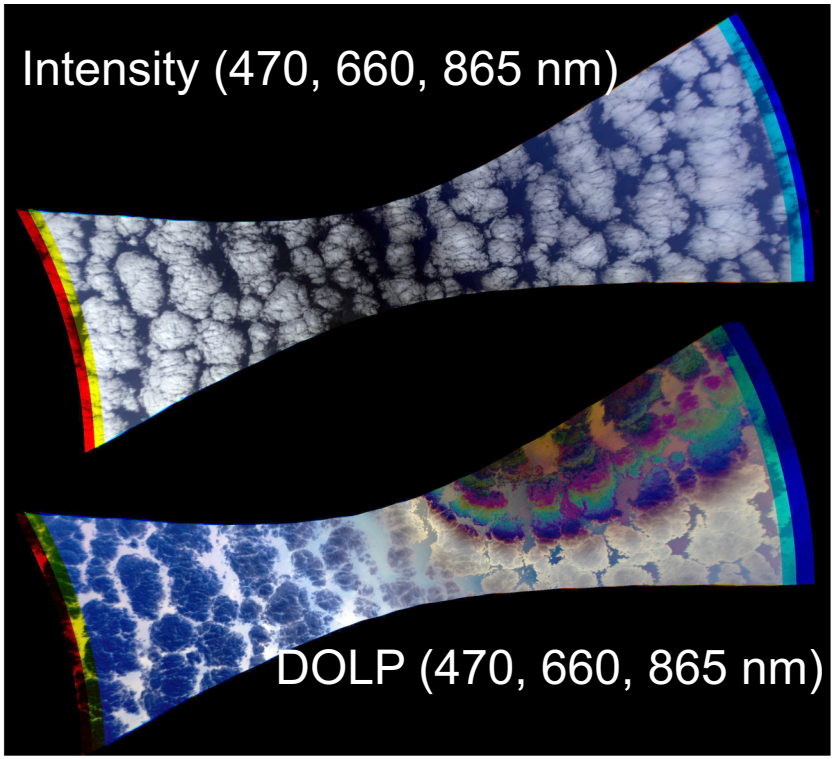
Black line: model (Szczodrak et al. (2001))



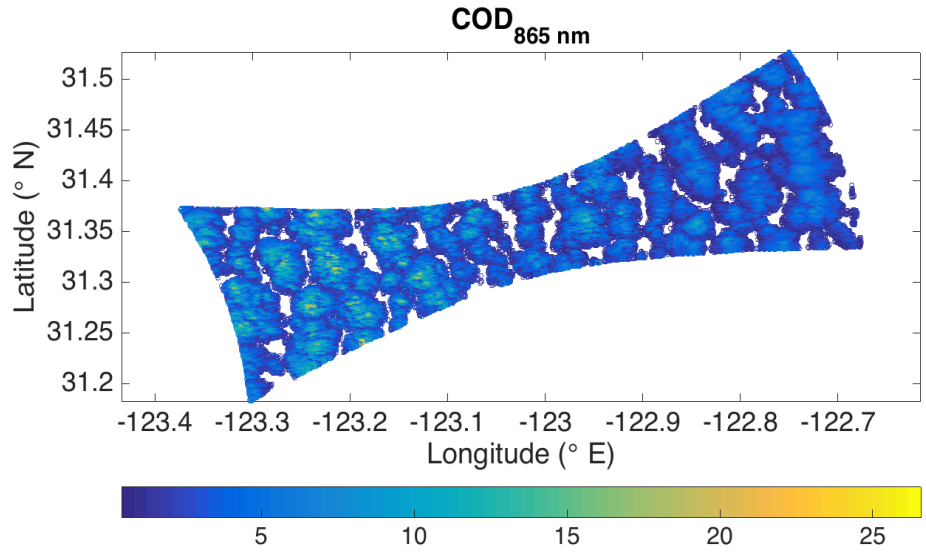
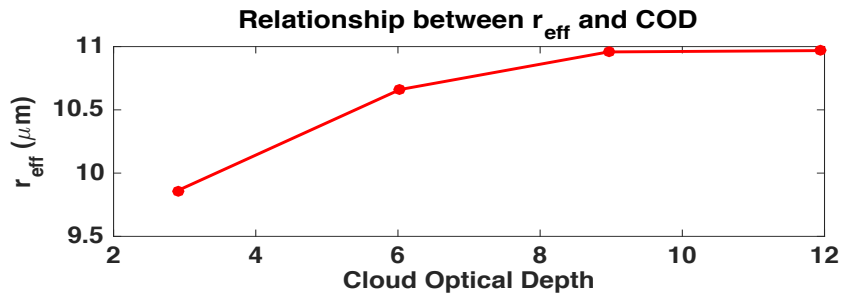
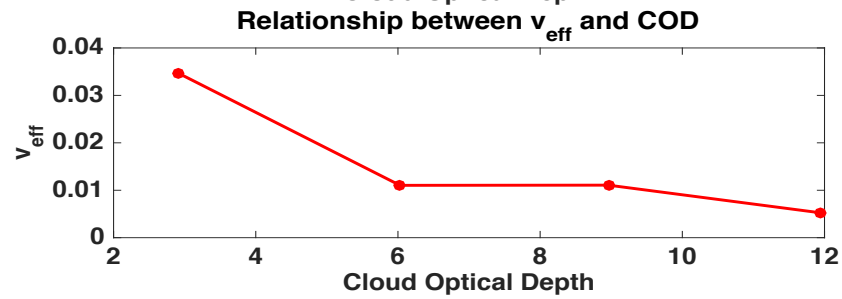
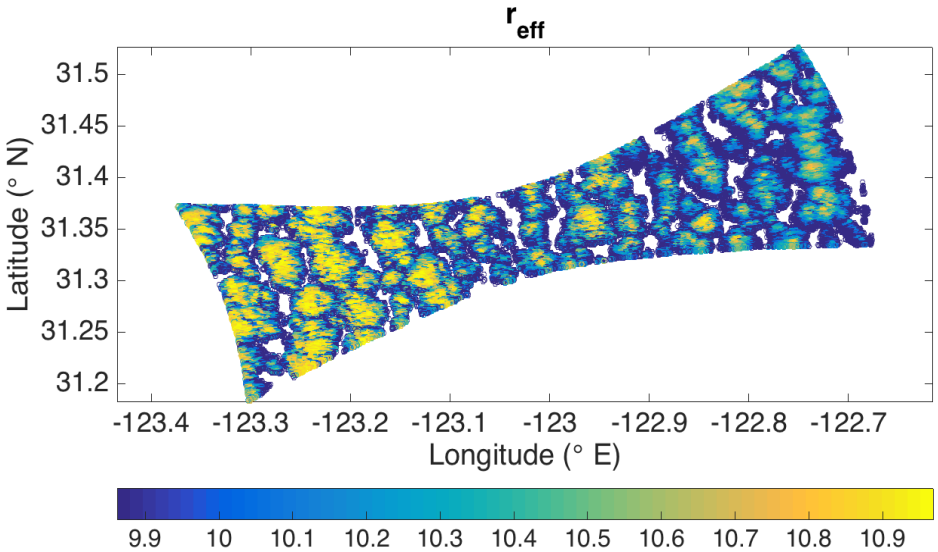
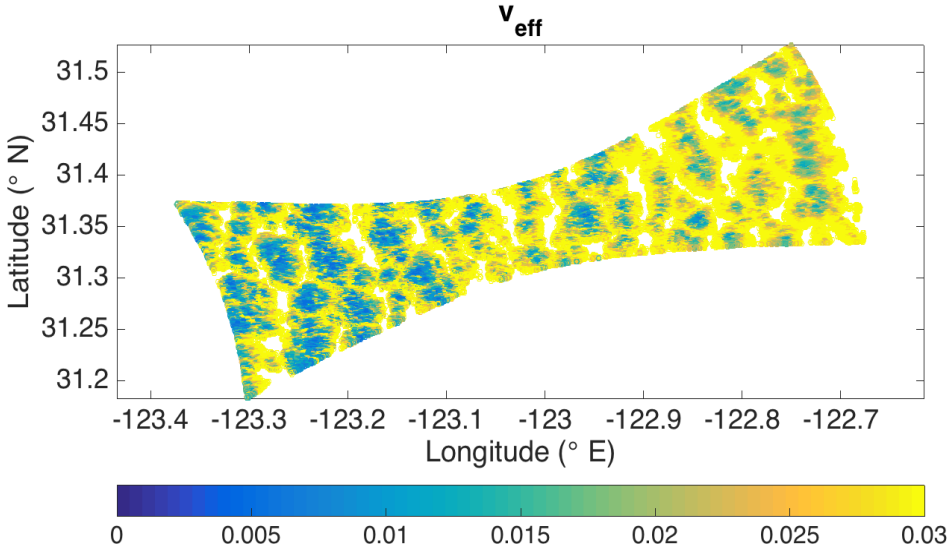
About 50% retrievals over 134 cloud scenarios shows negative v_{eff} *vs* COD relation

Preliminary analysis of broken cumulus

A4



6 February 2013, 2226 UTC - Pacific sweep image

Preliminary analysis of broken cumulus

A5