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

***Feng Xu***

G. van Harten, D.J. Diner, F.C. Seidel, A.B. Davis, B. Rheingans and M.G. Tosca

*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA,USA*

M.D. Alexandrov and B. Cairns, *NASA Goddard Institute for Space Studies*

R.A. Ferrare, S.P. Burton, M.A. Fenn, and C.A. Hostetler

*NASA Langley Research Center, Hampton, VA, USA*

R. Wood, *University of Washington, Seattle, Washington, USA*

J. Redemann, *NASA Ames, Ventura, USA*


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# Motivation



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

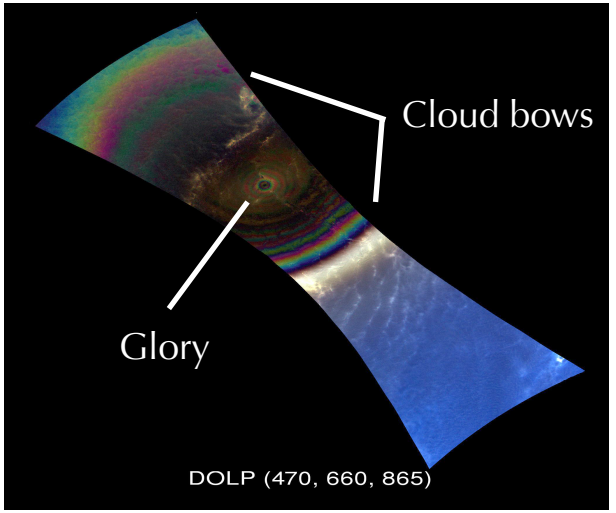
- investigating aerosol and cloud interactions
- characterizing cloud albedo, liquid water content and the rate at which the droplets coalesce into drizzle

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

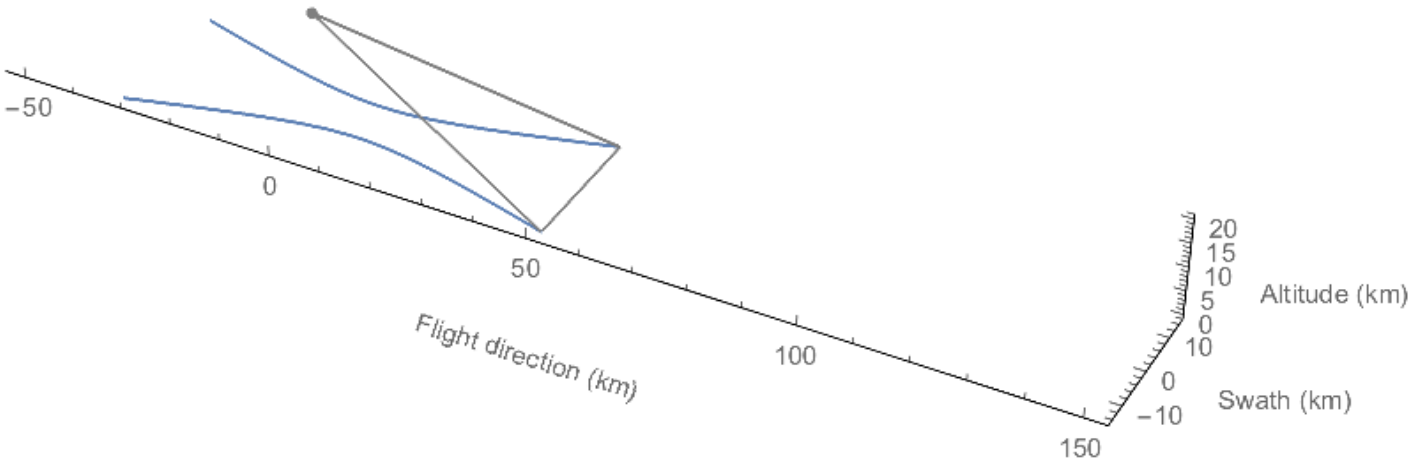







355, 380, 445, 470*, 555, 660*, 865*, 935 nm (*polarized)

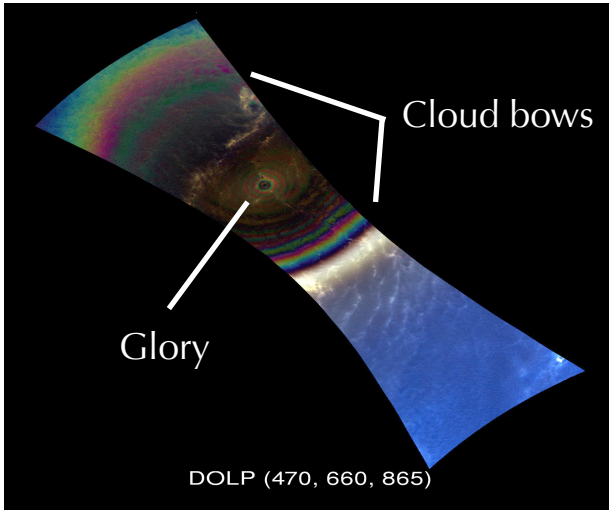
±67º FOV along track
25 m spatial resolution



# AirMSPI





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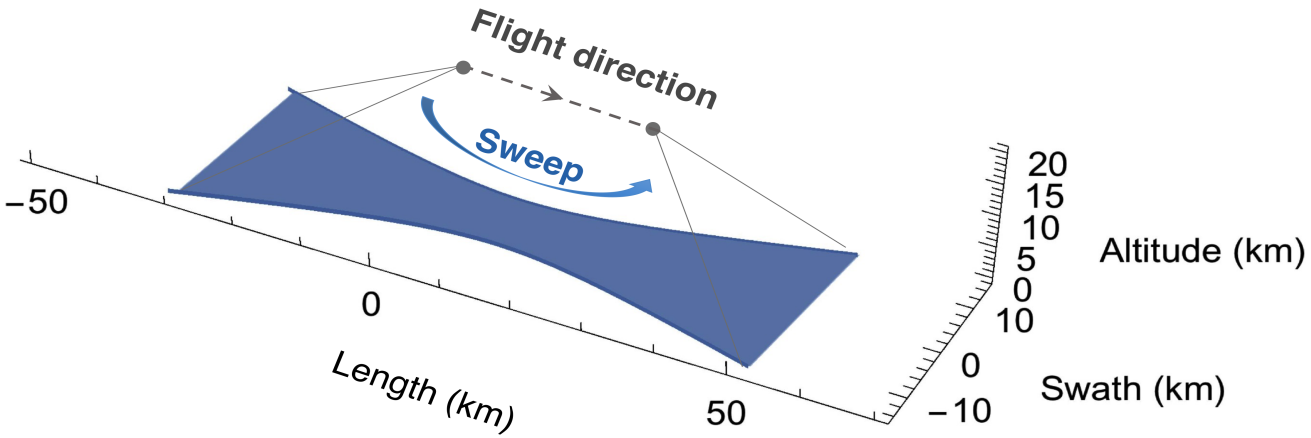


# Cloud and AAC retrieval strategy



**Polarized and total radiance**

↓

Retrieve AAC and cloud microphysical properties from polarized radiance

↓

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

↓

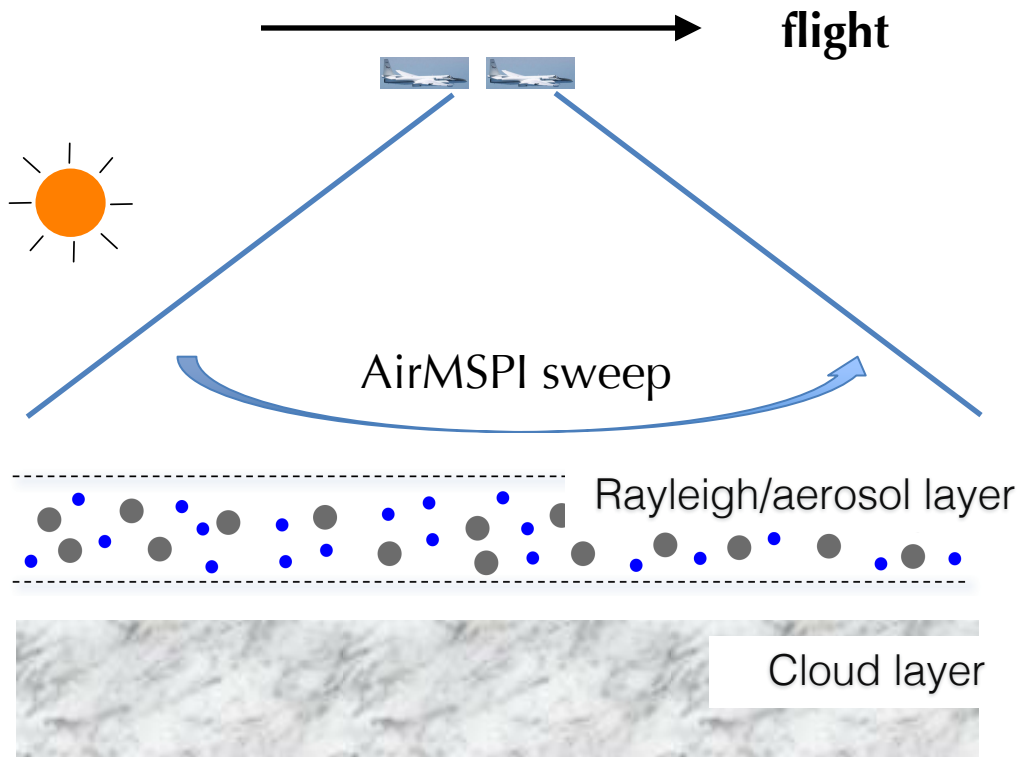
Retrieve droplet size distributions (DSDs) from different COD bins

↓

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

→

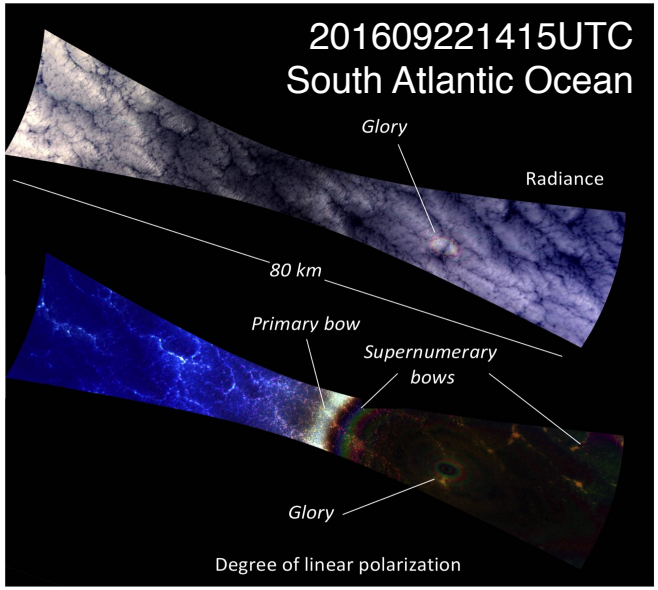
**Cloud properties:** pixel-scale COD and DSD
**AAC properties:** image-scale AOD, SSA, size distribution

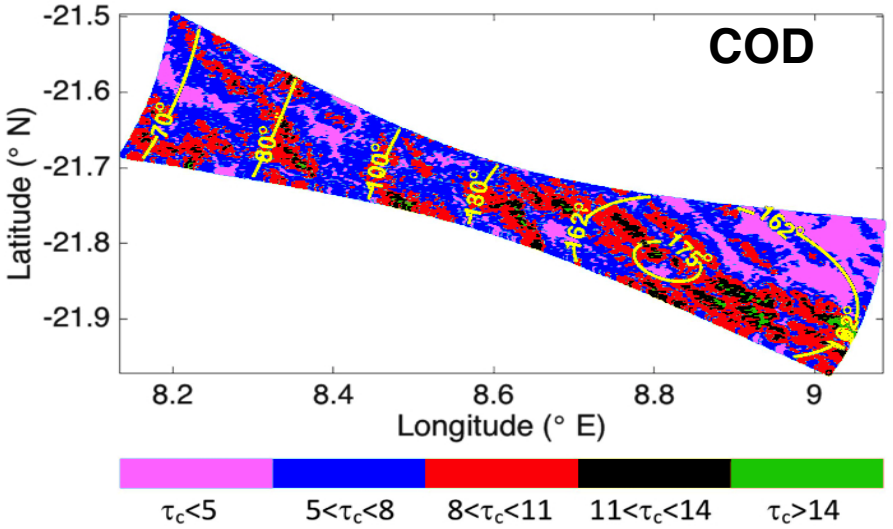



*Heritage: DSD and AAC retrievals for POLDER (Deschamps 1994; Bréon and Goloub,1998; Waquet et al., 2013), RSP (Cairns et al.1999; Knobelspiesse et al. 2011; Alexandrov et al. 2012) and AirMSPI (Diner et al. 2013)*

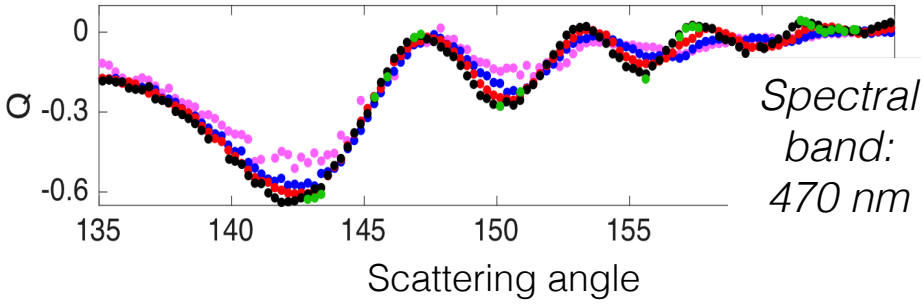
# AirMSPI observes COD-dependent cloudbow shifts



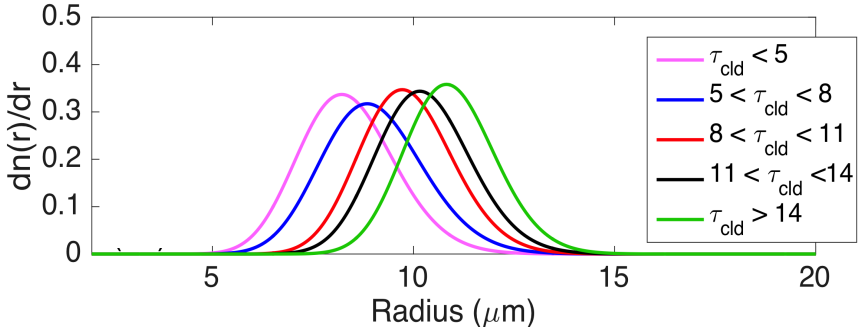



Cloudbows associated with 5 COD bins

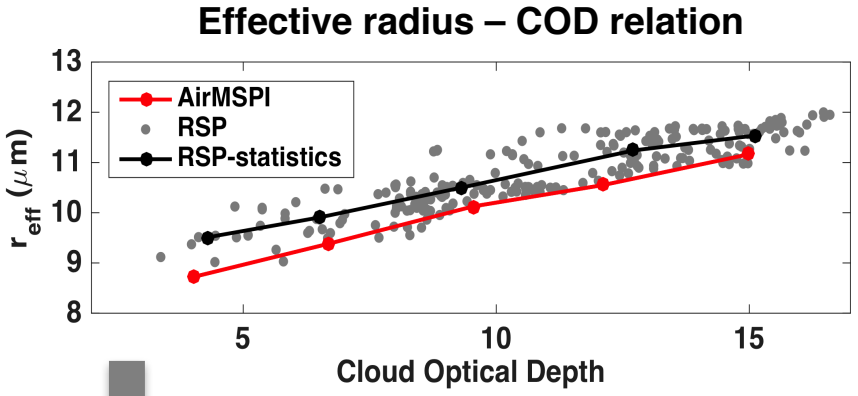


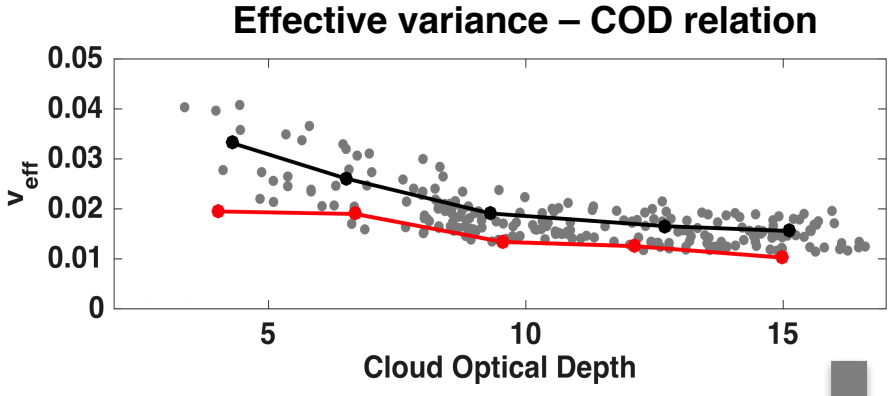

**DSD** retrieved from COD bins



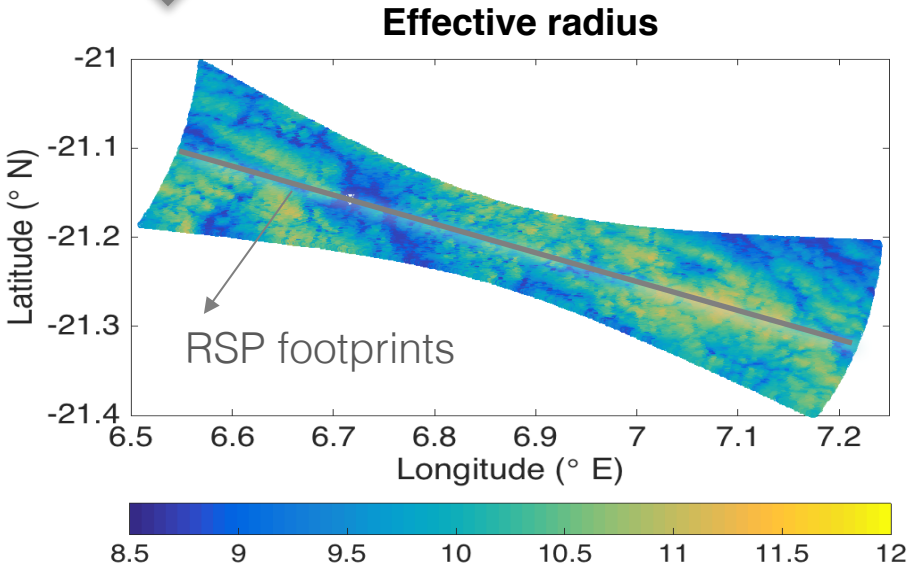
# COD-droplet size distribution relations

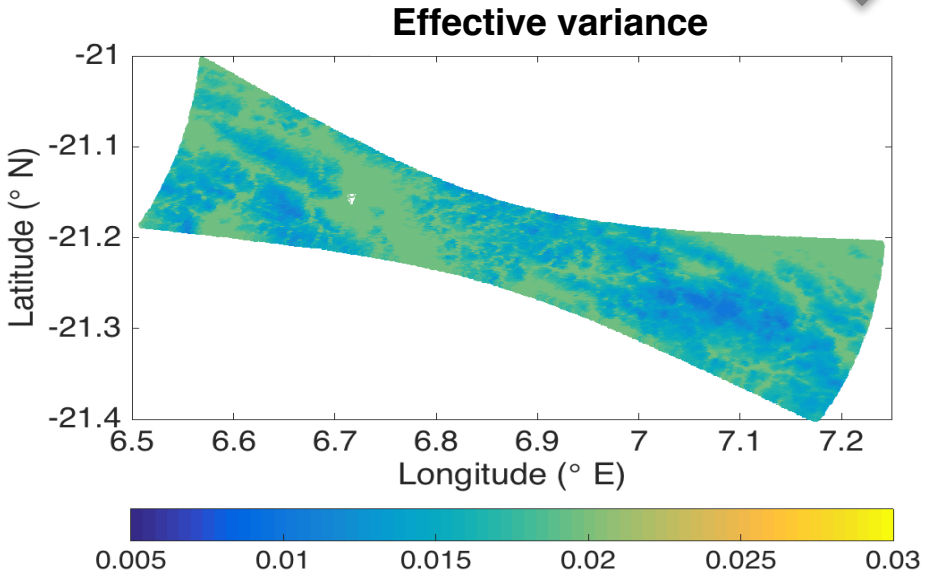




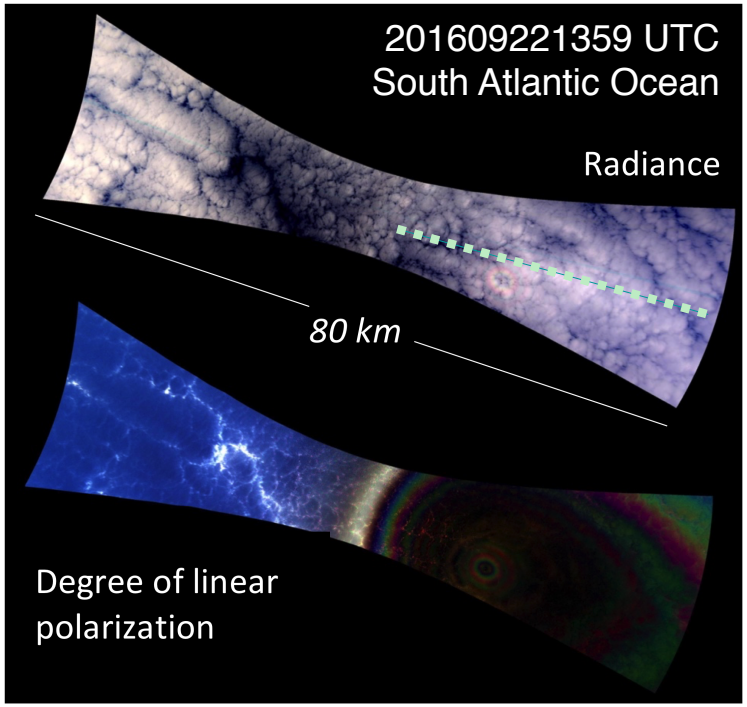

COD-Droplet size relation enables mapping DSD from pixel-scale COD

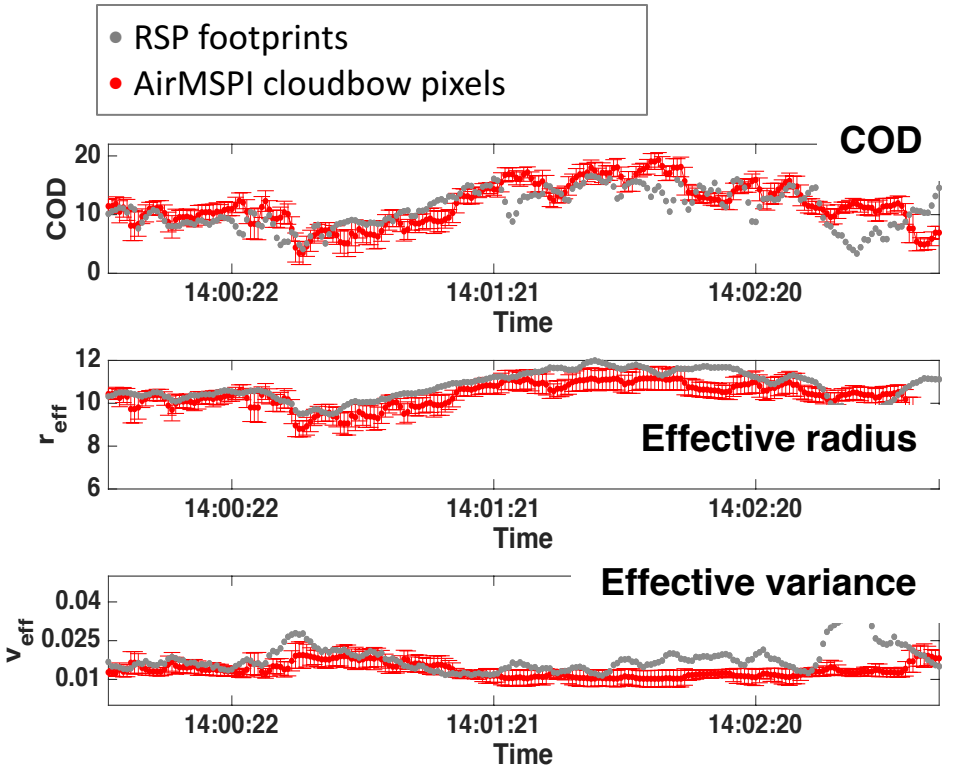


# Pixel-scale cloud retrieval comparison to RSP



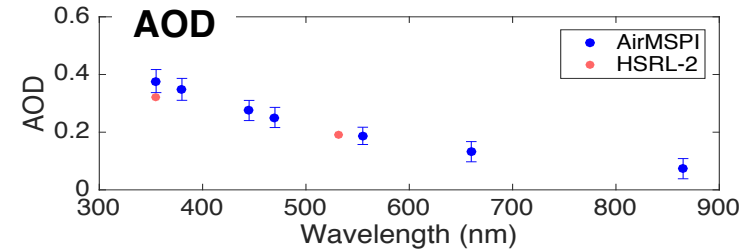


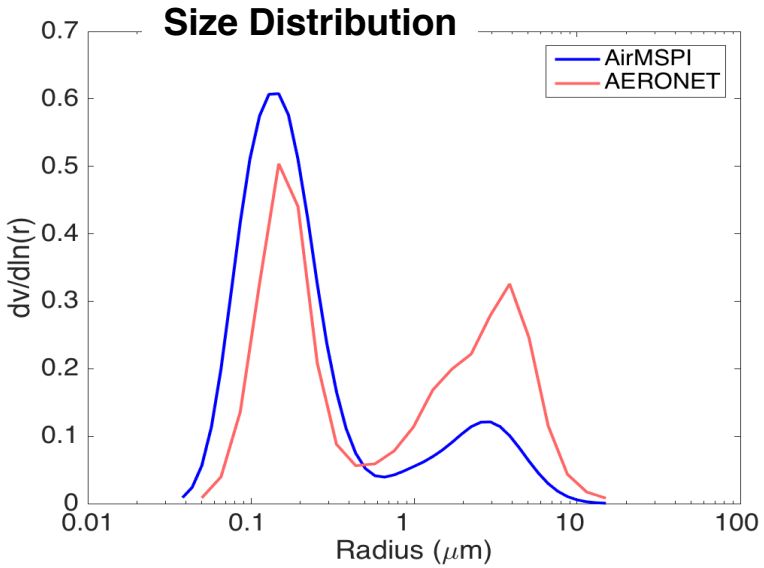




AirMSPI pixel-scale COD and DSD retrievals show consistency with RSP results for marine stratocumulus clouds off the coast of Namibia.

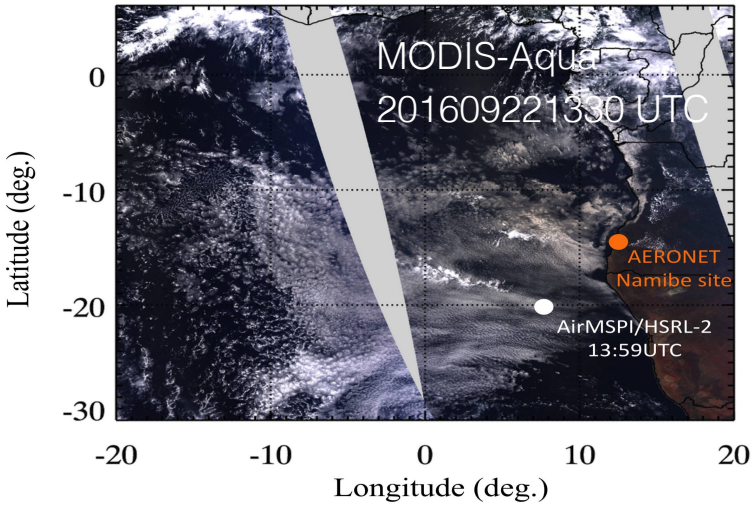
# Aerosol retrieval comparison to HSRL-2 and AERONET

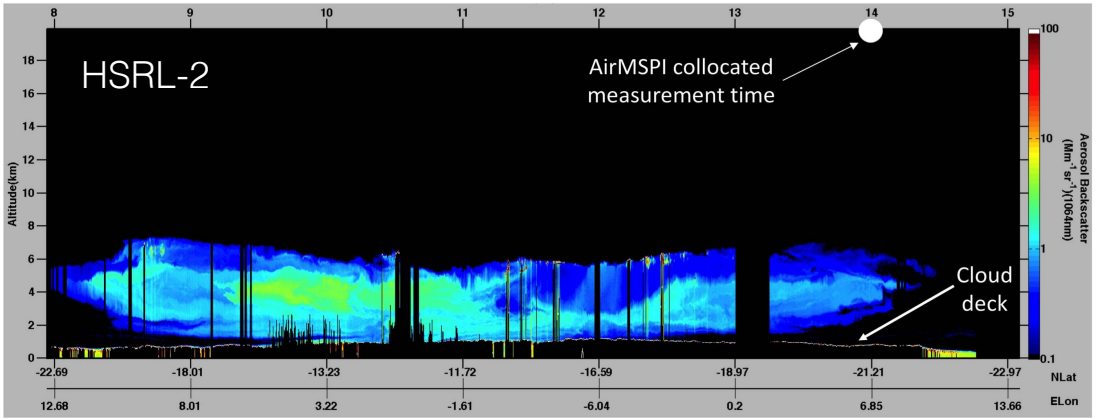




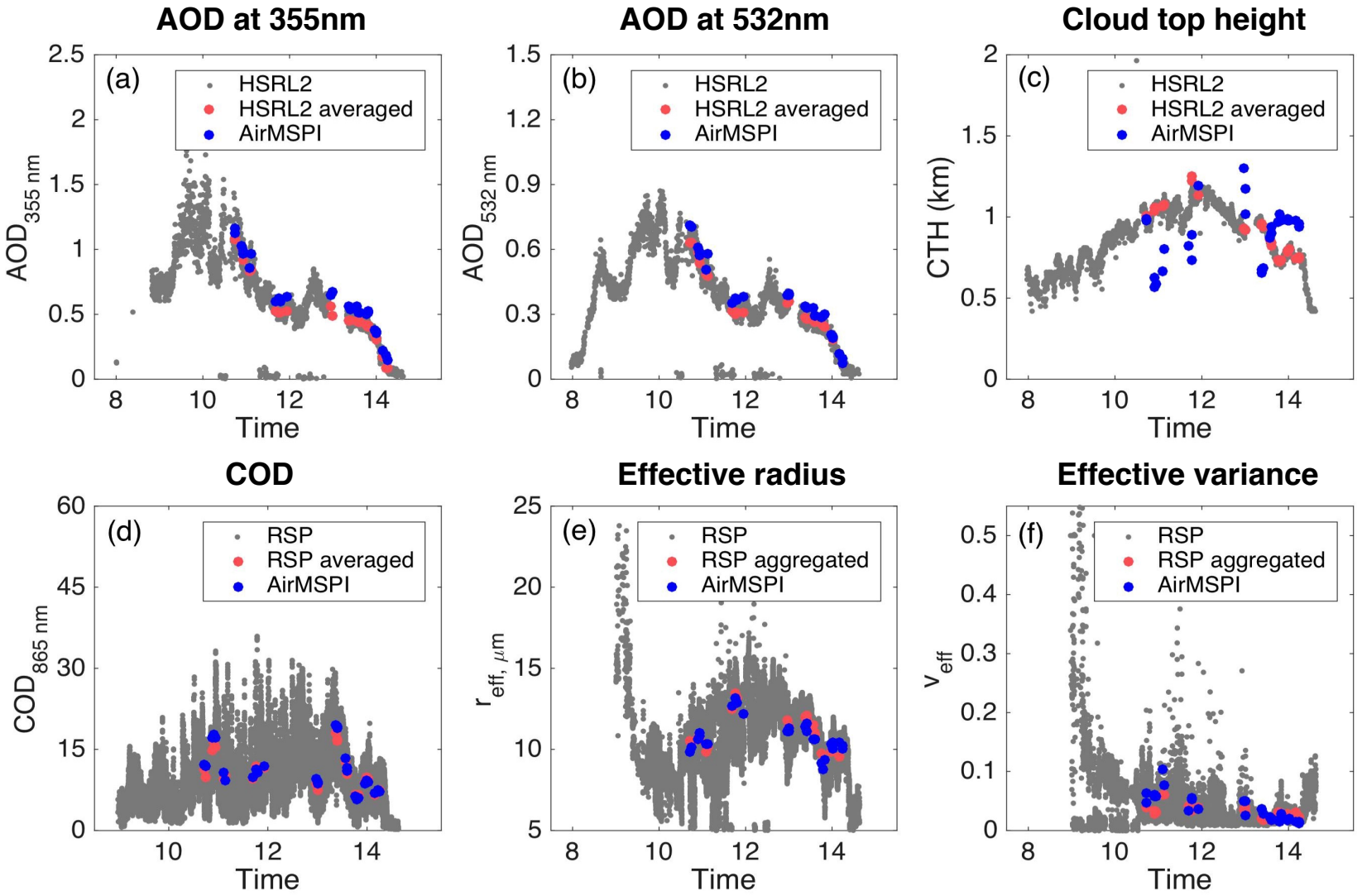

AirMSPI AOD, SSA, and aerosol size distribution retrievals show consistency with HSRL-2 (Hair et al. 2008) and AERONET (Holben et al.,1998) results.



# Temporal variation of AAC and cloud properties

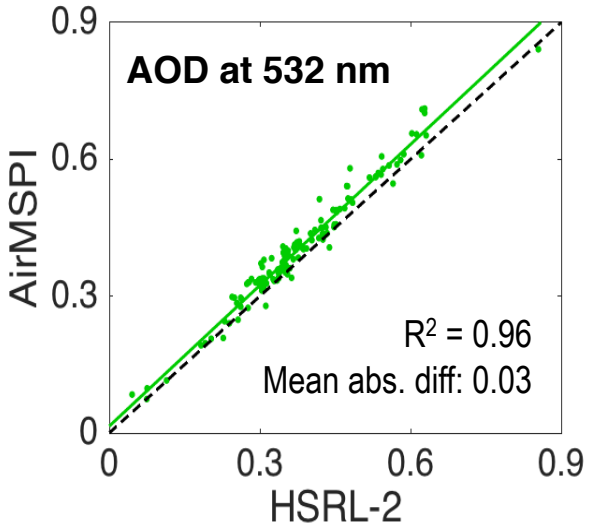


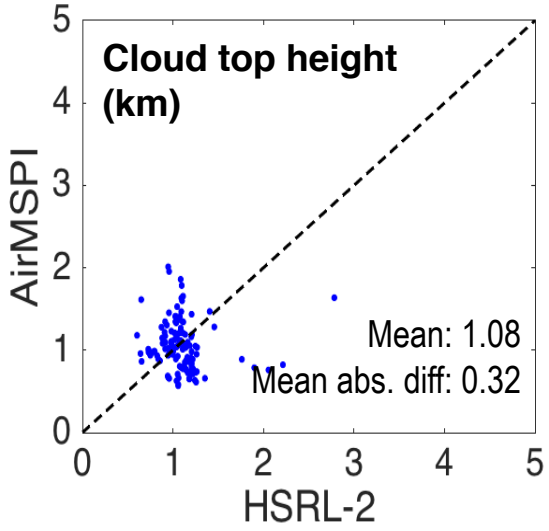


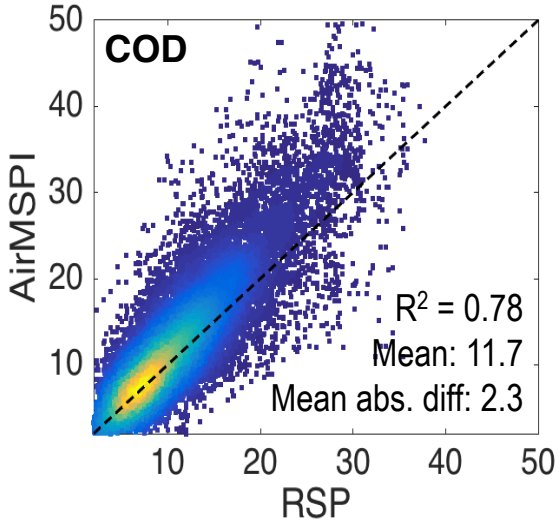

Data source: 29 AirMSPI/RSP/HSRL-2 collocated scenarios from ORACLES flight on 22/09/2016

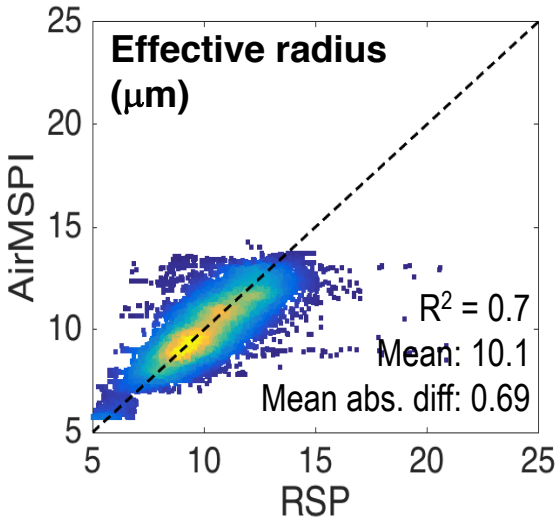
# More validation against HSRL-2 and RSP






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 ~850 cloud scenarios AirMSPI acquired during ORACLES campaign

***Work in progress:*** 1) Combine with "UV band ratio" method (Torres et al. 2012) 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

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AirMSPI L2 cloud product preparation

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


Data sources:

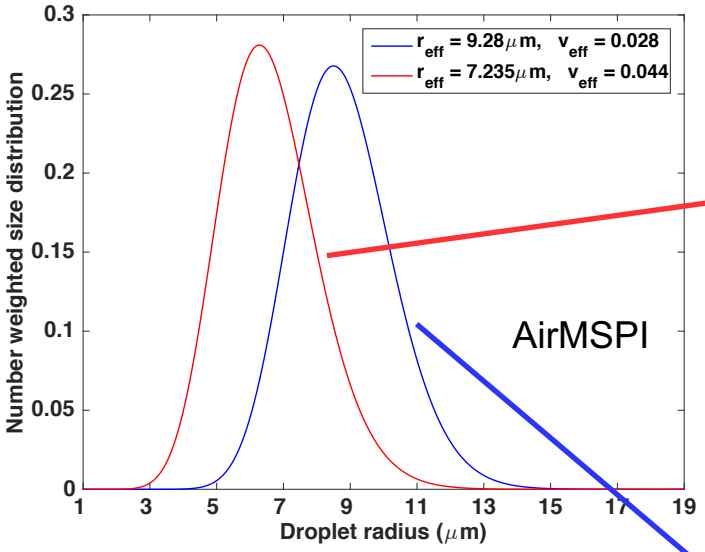
*AirMSPI ORACLES data: https://eosweb.larc.nasa.gov/project/airmspi/airmspi_oracles_ellipsoid_table*

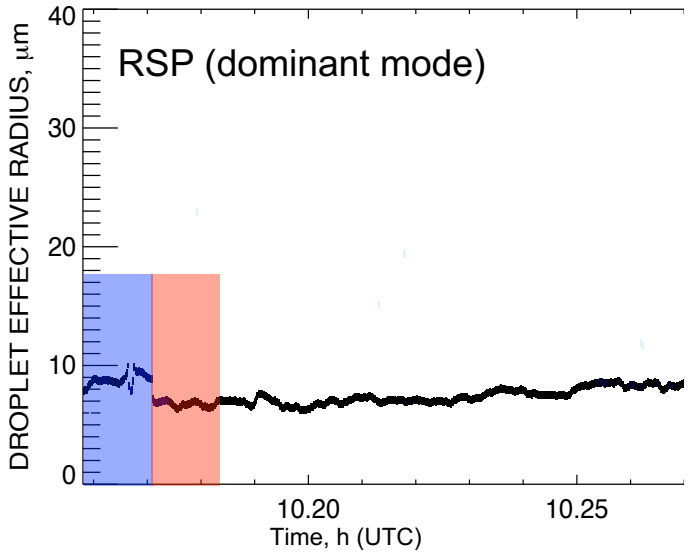
*HSRL-2 retrieval products: https://espoarchive.nasa.gov/ archive/browse/oracles/ER2/HSRL2*

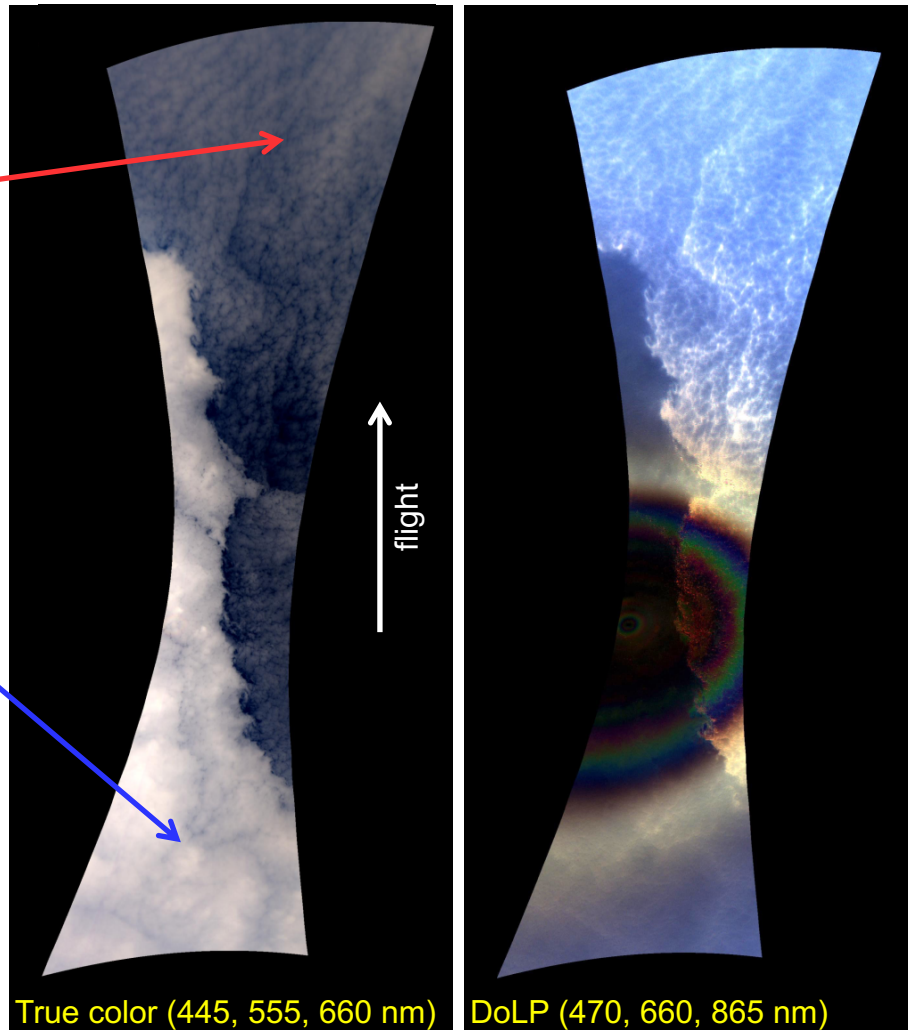
*RSP retrieval products: https://data.giss.nasa.gov/pub/ rsp/ ORACLES_2016/*

# AirMSPI / RSP reff comparison: double bow !

A1



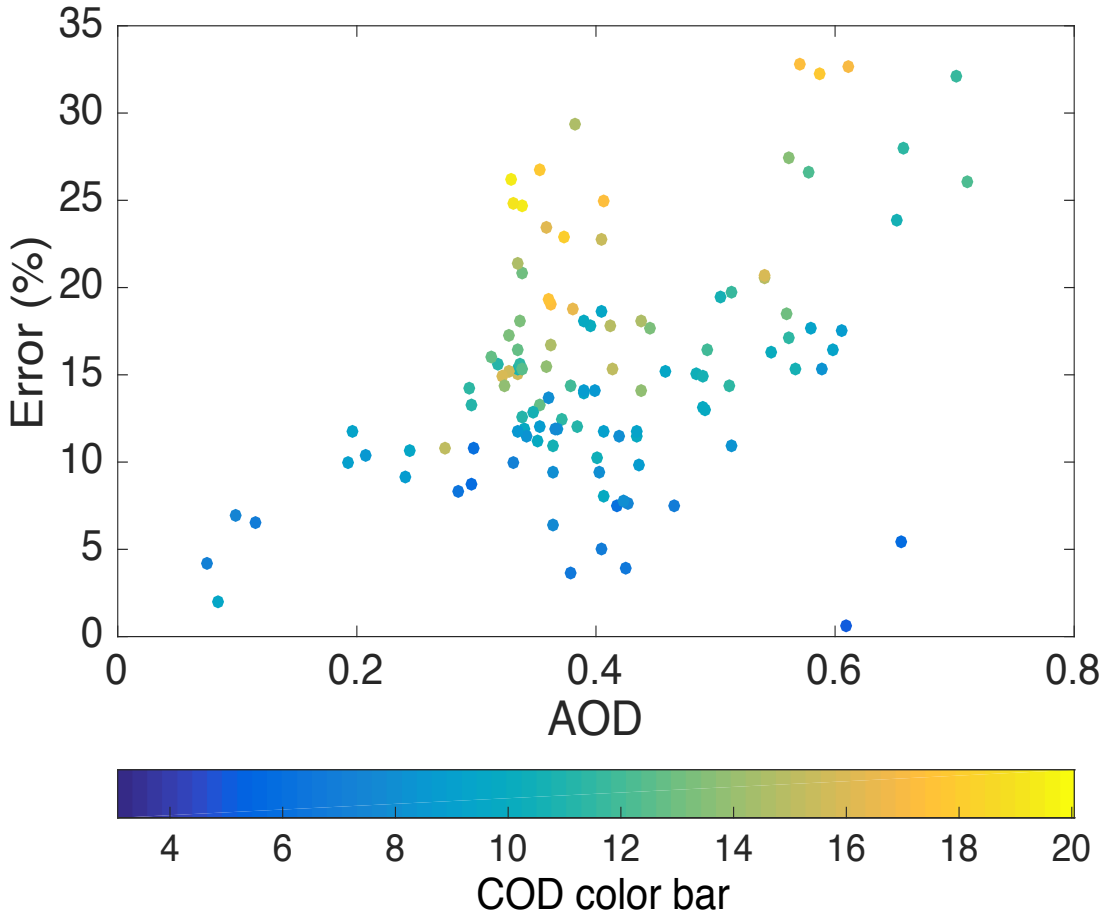




18 September 2016,10:11 UTC

# COD error induced by neglecting absorbing AAC

A2

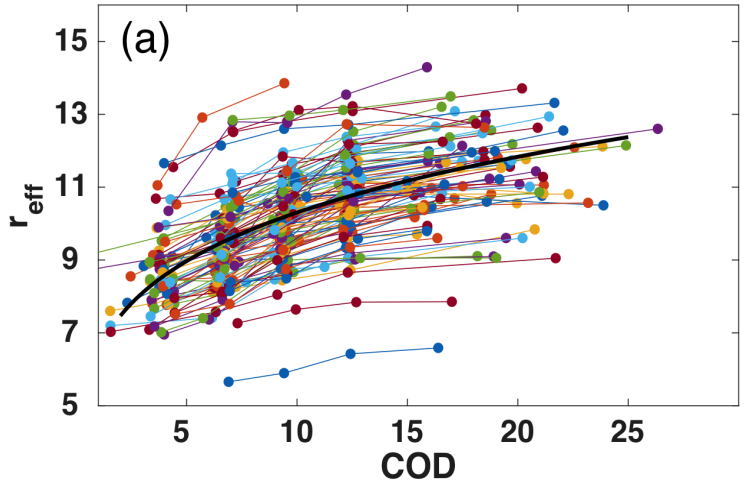
$$\text{Error} = 100\times[(\text{COD}_{\text{with-aerosols}}-\text{COD}_{\text{w/o-aerosols}})/\text{COD}_{\text{with-aerosols}}]$$




- 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

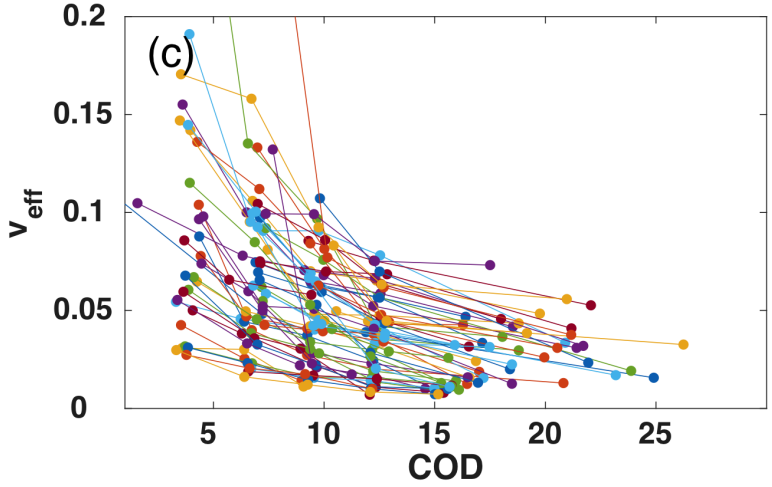
# More image-specific COD-droplet size relations

A3




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

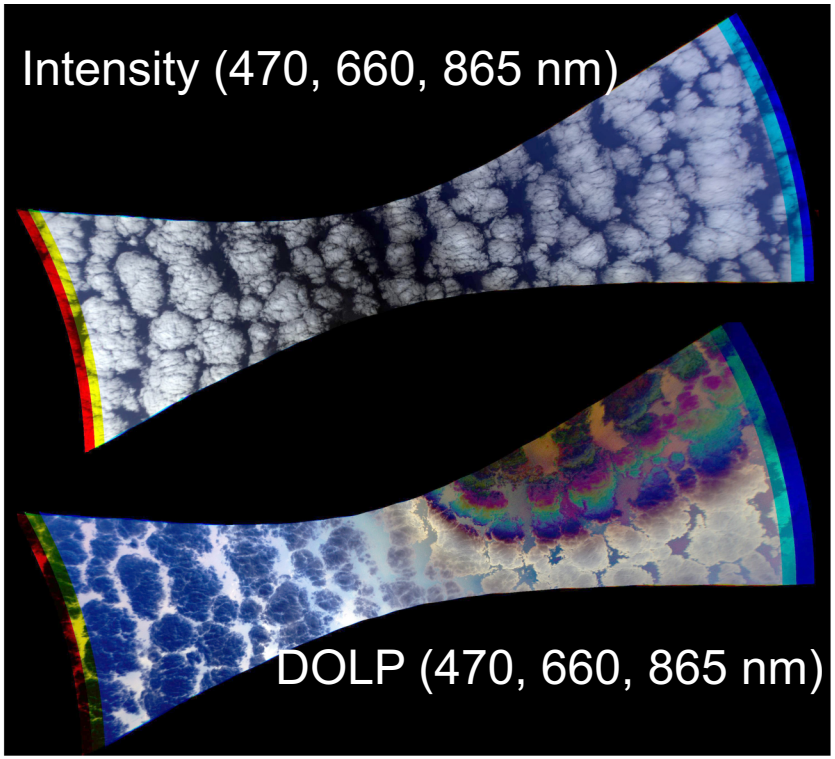
Black line: model (Szczodrak et al. (2001))




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