AGENDA

- Intro & Summary of SW Spectral Strategy Review meeting (30 min)
- Talks highlighting innovative use of SW spectral measurements (40 min)
  - Sasha Marshak — *ARM shortwave spectrometers to study the clear-cloud transition zone and mixing processes*
  - Dan Lubin—*Cloud optical properties over west Antarctica from shortwave spectroradiometer measurements during AWARE*
  - Jake Gristey—*Surface solar irradiance variability under shallow cumulus clouds at SGP: Insights from observations and LES*
  - Christine Chiu — *Using spectral radiance observations to constrain cloud-drizzle-aerosol processes*
- Discussion (50 min)
  - Science goals and instrument needs
  - Case studies—Planning for retrieval development and comparison at LASIC, TCAP, and ACE-ENA
  - Presentation of BAMS article plans & formation of a group for future discussion

SUMMARY OF SW SPECTRAL RADIOMETER STRATEGY MEETING FEBRUARY 25-27, 2019

Organizers: Laura Riihimaki, Connor Flynn, Allison McComiskey

Participants: Gary Hodges, Adam Theisen, Sasha Marshak, Hagen Telg, Evgueni Kassianov, Joe Michalsky, Kathy Lantz, Steve Jones, Diane Stanitski, Sam Leblanc, Sebastian Schmidt, Jake Gristey, Dan Lubin, Rick Wagener, Dan Feldman, Bruce Kindel, Herman Scott, Christian Herrera, Aron Habte, Mark Kutchenreiter

OUTLINE

- Motivation
- What is meant by SW Spectral Radiometers?
  - List of ARM SW Spectral Radiometers in categories—Slides from Connor
- Topics covered at workshop—What is the current state of the science driving these measurements?
  - Retrievals for process studies
  - Radiative Studies
- Outcomes/Action Plans

MEETING GOAL: *MAKE RECOMMENDATIONS TO HELP ARM INVEST MORE STRATEGICALLY IN GROUND-BASED SHORTWAVE SPECTRAL RADIATION MEASUREMENTS*

Why Now?

--We now have several years of measurements with the SASHe/Ze at multiple sites

--Upgrades to filter-based measurements in process (MFRSR, CIMEL) to expand capabilities (e.g. add 1.6 micron channel to MFRSR, add lunar tracking to CIMEL)

--New commercially available hyperspectral measurements

--More retrieval methodologies in literature that take advantage of shape of SW spectrum so depend less on absolute calibration

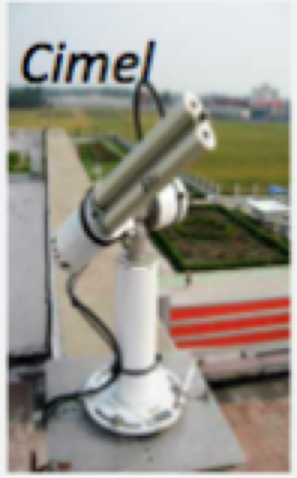
--ARM's focus on model-obs in LASSO need for cloud retrievals in challenging conditions (partially cloudy, low LWP, etc)

ARM SPECTRAL RADIOMETERS

Filter-based

(Gary/Christian, Rick/Laurie/Lynn)

- MFRSR (hemis. irr.)
- Cimel Sun Photometer (radiance)
- NFOV2ch (zen. radiance)
- NIMFR (direct normal irr.)



Hyper Spectral

(Connor, Joe Michalsky)

- SAS-ZE (zen. radiance 350-1700 nm)
- SAS-HE (hemis. irr. 350-1700 nm)
- SWS (zen. radiance 350-2170 nm)
- RSS (hemis. irr. 360-1070 nm, *retired*)

WORKSHOP TOPICS: WHAT ARE THE SCIENCE NEEDS FOR SW SPECTRAL MEASUREMENTS?

RETRIEVALS FOR PROCESS STUDIES: CLOUDS

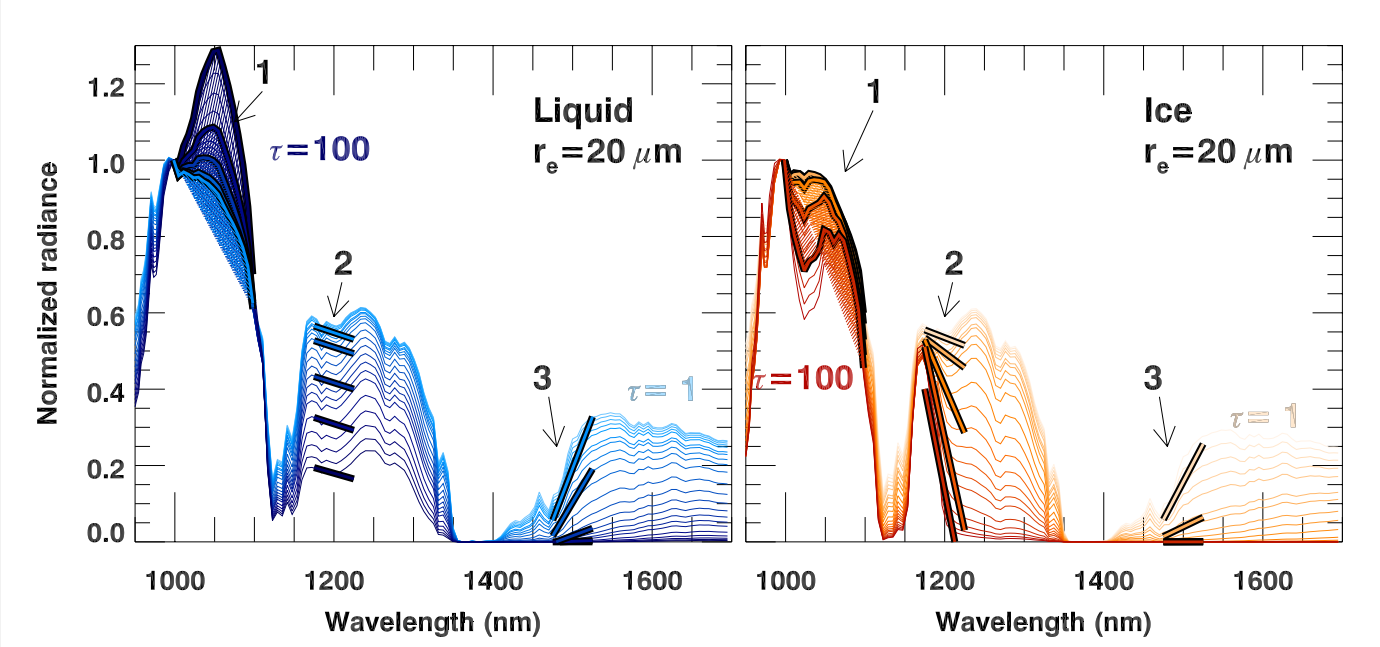
Cloud microphysical retrievals identified as opportunity & need for SW spectral measurements

- Currently only operational cloud retrieval is MFRSRCLDOD
  - Uses hemispheric irradiance, so limited to overcast conditions
  - Assumes small albedo at 440 nm, so doesn't work over ice/snow
  - Only valid for liquid clouds
- Christine Chiu's work has shown the utility and importance of zenith radiance measurements for constraining liquid cloud optical properties (Tau, Re) in combination with active sensors & microphysical process studies
  - Ideally high temporal resolution, constraint in near IR helpful for Re, accuracy of better than 10%

RETRIEVALS FOR PROCESS STUDIES: CLOUDS

Hyperspectral retrieval techniques based on ratios & shape of spectra promising

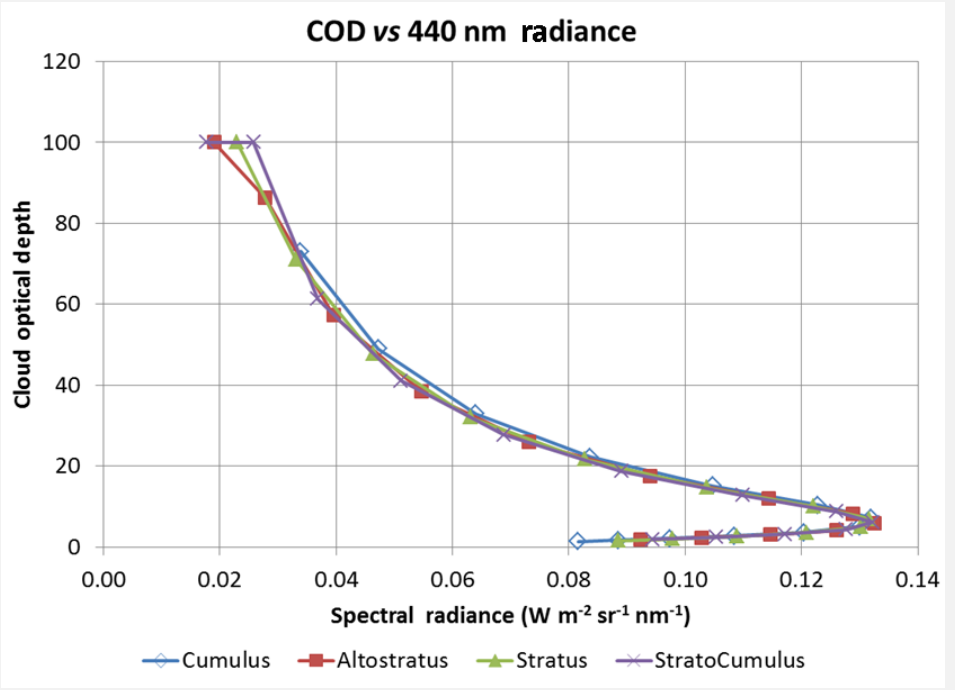
- Outcome of previous spectral breakout session was to start with science problems that don't necessarily need SW spectral calibration to be perfect
  - E.g. Sam Leblanc's method:
  - 15 parameters from spectra shape
  - Identifies liquid/ice
  - Optical depth, Re for both
  - Flexible over high or low albedo

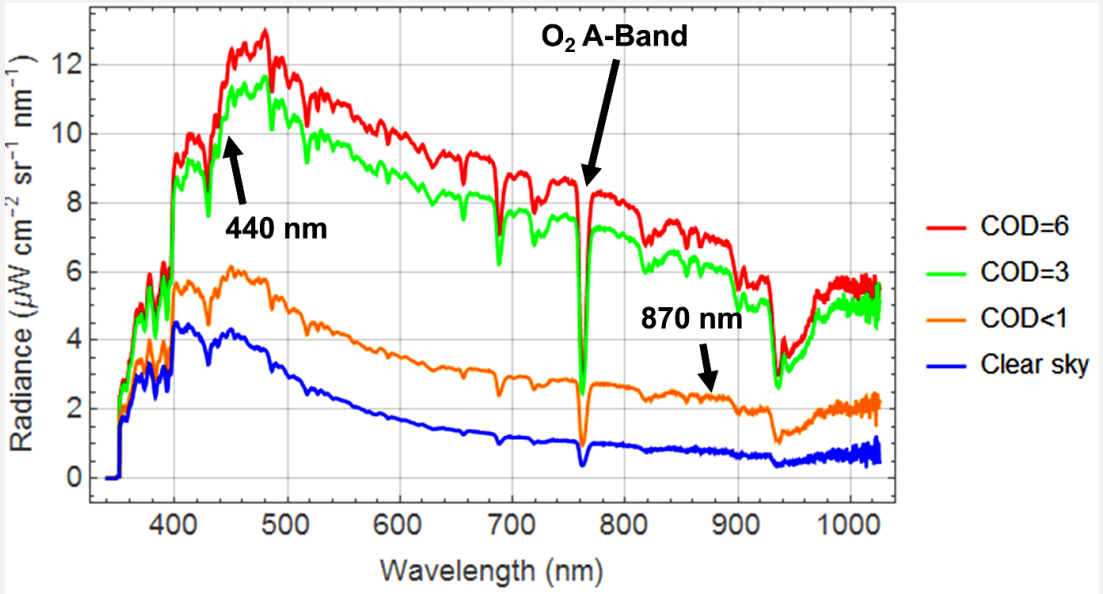


From Leblanc et al. 2015 AMT

TWST (THREE WAVEBAND SPECTRALLY AGILE TECHNIQUE)

- New instrument by Aerodyne + proprietary optical depth retrieval
  - Retrieval uses the oxygen A-Band shape to distinguish low and high optical depths
- High Temporal resolution, zenith radiance
- Currently only Silicon sensor for 350-1000 nm, working on expanding to add NIR spectrometer to be able to also retrieve effective radius





From Niple et al (2016) AMT

RETRIEVALS FOR PROCESS STUDIES: AEROSOLS

- Aerosol optical depth—mature product, one of most downloaded ARM products from MFRSR, Cimel, and SASHE
- Aerosol optical properties (eg. SSA, Asymmetry parameter)—will use additional info in near IR to constrain coarse mode aerosols
- Multi-instrument aerosol property retrievals
  - Incorporate additional measurements (e.g. TSI) to better determine clear conditions
  - Different approaches are complementary an improve information content and accuracy
  - Needed constraint to improve accuracy in lidar derived profiles

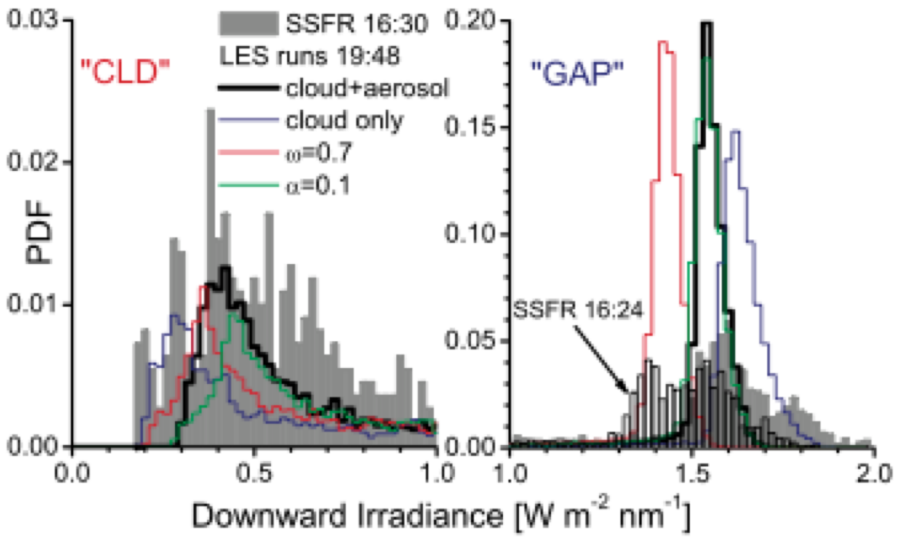
RETRIEVALS FOR PROCESS STUDIES: LAND SURFACE HETEROGENEITY

- Spectral Albedo
  - Potential of 1.6 micron MFR channel to provide a better constraint on albedo
  - Use spectral measurements to understand ice melt at high latitudes
  - As we start looking at distributed cloud/aerosol effects at high spatial resolution with projects like LASSO we also need to think about the land surface heterogeneity (combine with distributed measurements and/or aircraft measurements, new areal average retrievals like Kassianov et al. 2014)
- Other parameters
  - Photosynthetically Active Radiation (PAR)—BSRN planning an instrument intercomparison campaign, could contribute MFRSRs to study

Radiative Processes & Distributed Measurements

spectral measurements can enhance understanding of changes in the radiation budget and the processes that are driving them

- Radiative effects in <u>complex aerosol-cloud-surface fields</u> (Christine Chiu)
  - can be achieved without hyperspectral for aerosol and maybe cloud
    - large gap between 1 and 1.6 um in filter measurements
  - for aerosol UV measurements would be useful for BrC studies, hyperspectral desired
    - subsets of high quality data to explore (LASIC/ORACLES)



Schmidt et al. 2009

Radiative Processes & Distributed Measurements

- Clear-to-cloud continuum is a large piece of the radiation budget – ground-base measurements are critical (Sasha Marshak):
  - to inform radiation budget studies from space
  - novel measurement options: NIMFR (NFOV)
  - better characterization of aerosol near cloud to improve aerosol-cloud interaction process understanding
  - understanding cloud edge transition zone can also inform mixing processes (homogeneous vs. inhomogeneous)

Radiative Processes & Distributed Measurements

- <u>Distributed Measurements for characterizing spatial heterogeneity</u>
  - Spectral irradiance for model evaluation and diagnosing flux contributions
    - evaluating simulated radiative effects in process-scale models requires spatially distributed measurements
    - modeling of Radiation Budget through cloud properties characterization (Jake Gristey)
  - Spectral surface albedo/properties
    - provides surface cover characteristics
    - contributes understanding of cloud development processes and surface drivers
    - required for accuracy in retrieval of aerosol and cloud properties.
  - How do distributed measurements fit in to modeling frameworks?

MEETING OUTCOMES

SCIENCE GOALS AND INSTRUMENT NEEDS

*Meeting approach create **summary tables** of:*

- Retrieval methods appropriate for different science applications
- Measurement availability/quality from current ARM sensors
- Instrument capabilities from new commercial instruments

	Papers / name	Result / Physical quantities	Focus	Where/Notes	Zenith radiance	Zenith irradiance	Hyper-spectral?	Surface-based?
Retrieval								
	Cloud retrievals							
	McBride et al., 2011, 2012, 2013	tau, ref, lwp (liq)	liquid cloud retrieval	ship, dark surfaces	x	x	x	x
	LeBlanc et al., 2015	tau, ref, phase, (liq+ice)	liquid/ice cloud retrieva	ground site, various surfaces	x		x	x
	Coddington et al., 2012	tau, ref, lwp ?	sensitivity to surface al	?	x		x	x
	Chiu et al., 2006, 2009, 2010	tau	cloud	vegetated surfaces	x		m/s	x
	Wilson et al., 2018	tau, ref	cloud ice	Antartic, snow/ice	x		x	x
	Niple et al., 2016	tau	cloud retrieval	TCAP, using oxygen-a band	x		x	x
	Marshak et al., 2004	tau	cloud	over vegetated surfaces	x		m/s	x
	Min & Harrison, 1996, 1999	tau, lwp				x	m/s	x
	Min et al., 2008	cloud fraction				g/d	m/s	x
	Min & Duan, 2004	lwp, ref	thin clouds	forward scattered lobe, multiple shadown band measurements		g/d	m/s	x
	Min et al., 2004	tau	thin clouds					
	Kikuchi et al., 2006	tau, ref (liq)	liquid clouds, in absen	Using w				
				DOAS				

CASE STUDIES: PROVIDE USER COMMUNITY WITH QUALITY DATA & RETRIEVALS FROM SPECIFIC PERIODS

These three campaigns were identified as periods with science questions being worked on by those in the group, interesting spectral measurements, and/or potential *in situ* data for comparison

- LASIC—Retrievals/radiative effects in complex environments—partially cloudy, absorbing aerosol & cloud, etc
  - NFOV2ch, SASHE, SASZE, MFRSR, CIMEL
- TCAP—Aerosol Cloud Interactions, different aerosol loadings, data from new measurements
  - MFRSR with 1.6 micron, TWST, CIMEL, SASZE, SASHE, NFOV2ch
- ACE-ENA—drizzle formation/low cloud retrievals
  - SWS, MFRSR, CIMEL

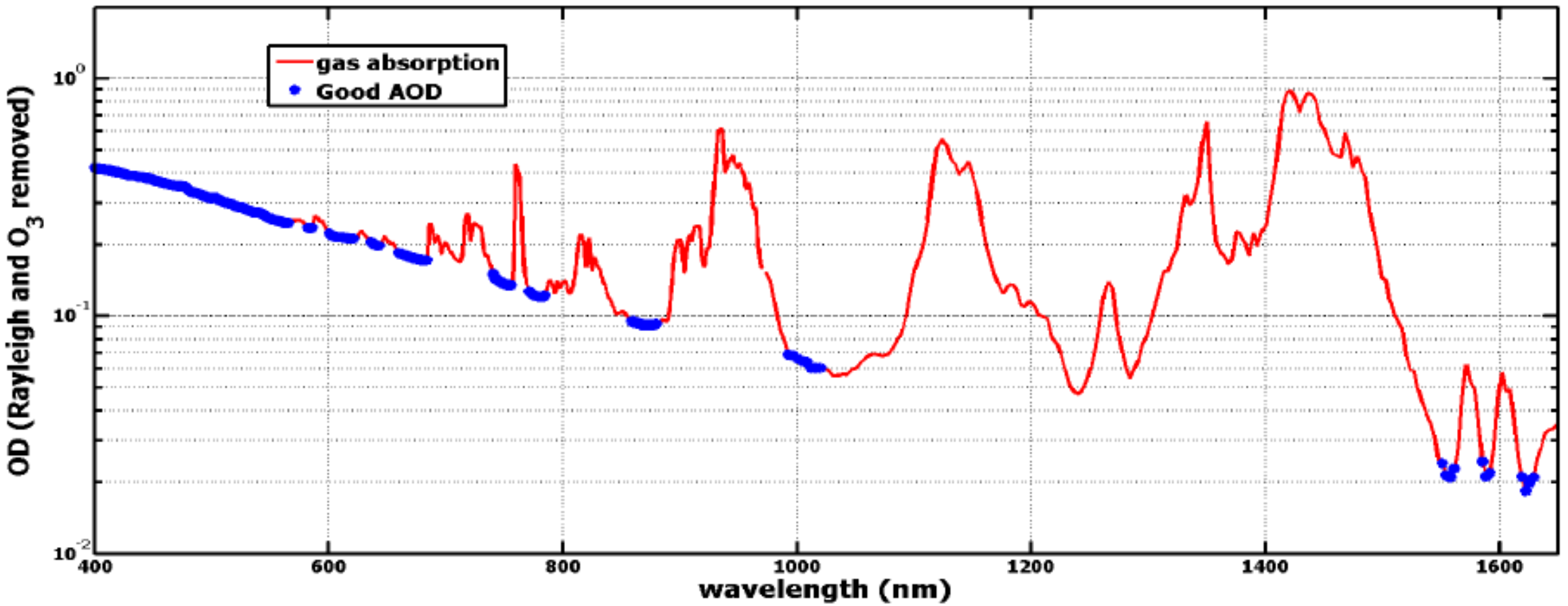
BAMS ARTICLE: "ADVANCES IN ARM SHORTWAVE SPECTRAL RADIOMETRY FOR ATMOSPHERIC AND CLIMATE SCIENCE"

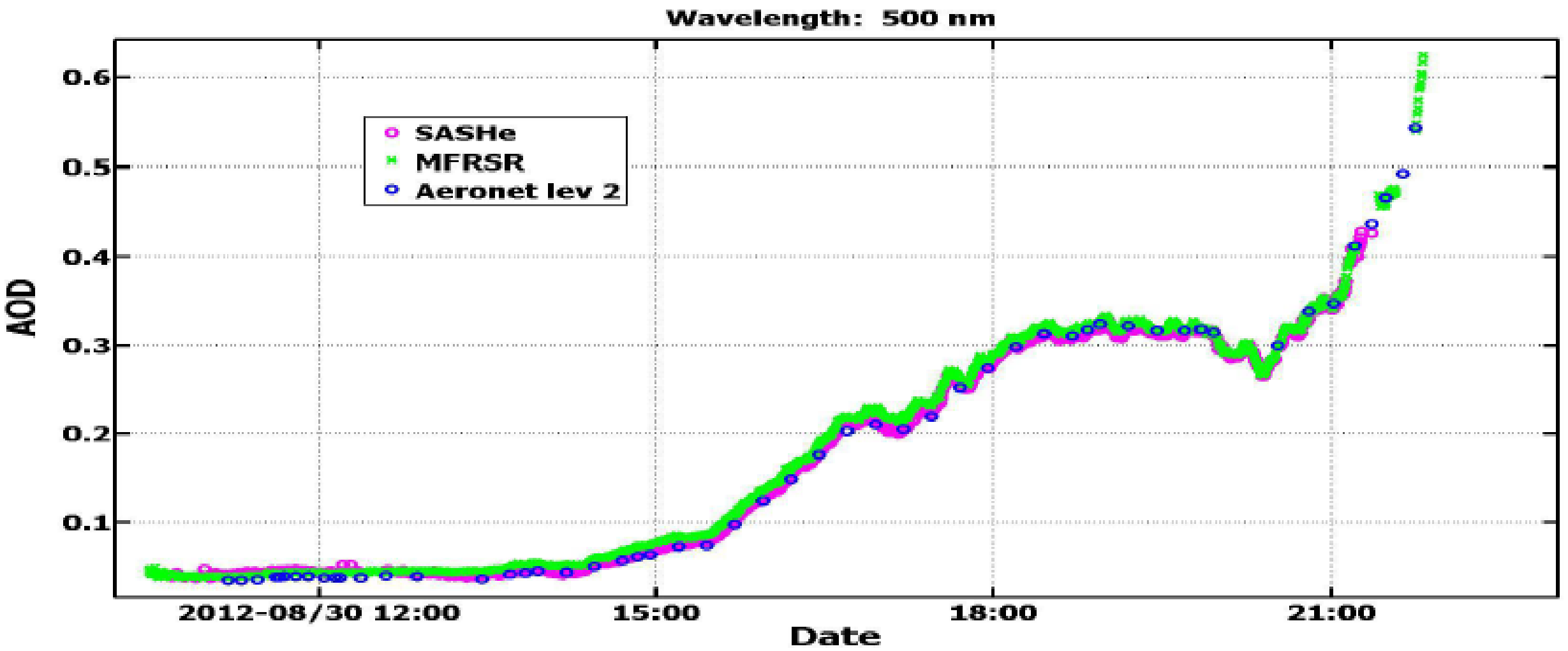
LAURA RIIHIMAKI, CONNOR FLYNN, ALLISON MCCOMISKEY, DAN LUBIN, DAN FELDMAN, JAKE GRISTEY, CHRISTIAN HERRERA, GARY HODGES, EVGUENI KASSIANOV, SAM LEBLANC, SASHA MARSHAK, JOE MICHALSKY, SEBASTIAN SCHMIDT, RICK WAGENER

- Summary of available measurements/instruments/data products with brief description of recent advances/current state of data quality (Connor, Gary, Rick, Laura, Evgueni, Joe, others)
- Examples of process level science that has currently been done with ARM SW spectral data
  - Polar work—Dan Lubin
  - Clear-Cloudy Transition zone—Sasha Marshak
  - Spectral surface albedo—Evgueni Kassianov
- Potential new science that could be done with ARM measurements
  - Table of retrieval methodology (from Sam and Sebastian), Sebastian's figure summarizing information from SW spectra
  - Distributed measurements/3D effects—Jake Gristey
  - Spectral Radiative Closure in conjunction with CLARREO--Dan Feldman

EXTRA SLIDES

HYPERSPECTRAL AOD, PVC SASHE




Wavelength: 500 nm
SASHe
MFRSR
Aeronet lev 2
AOD
0.6
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0.3
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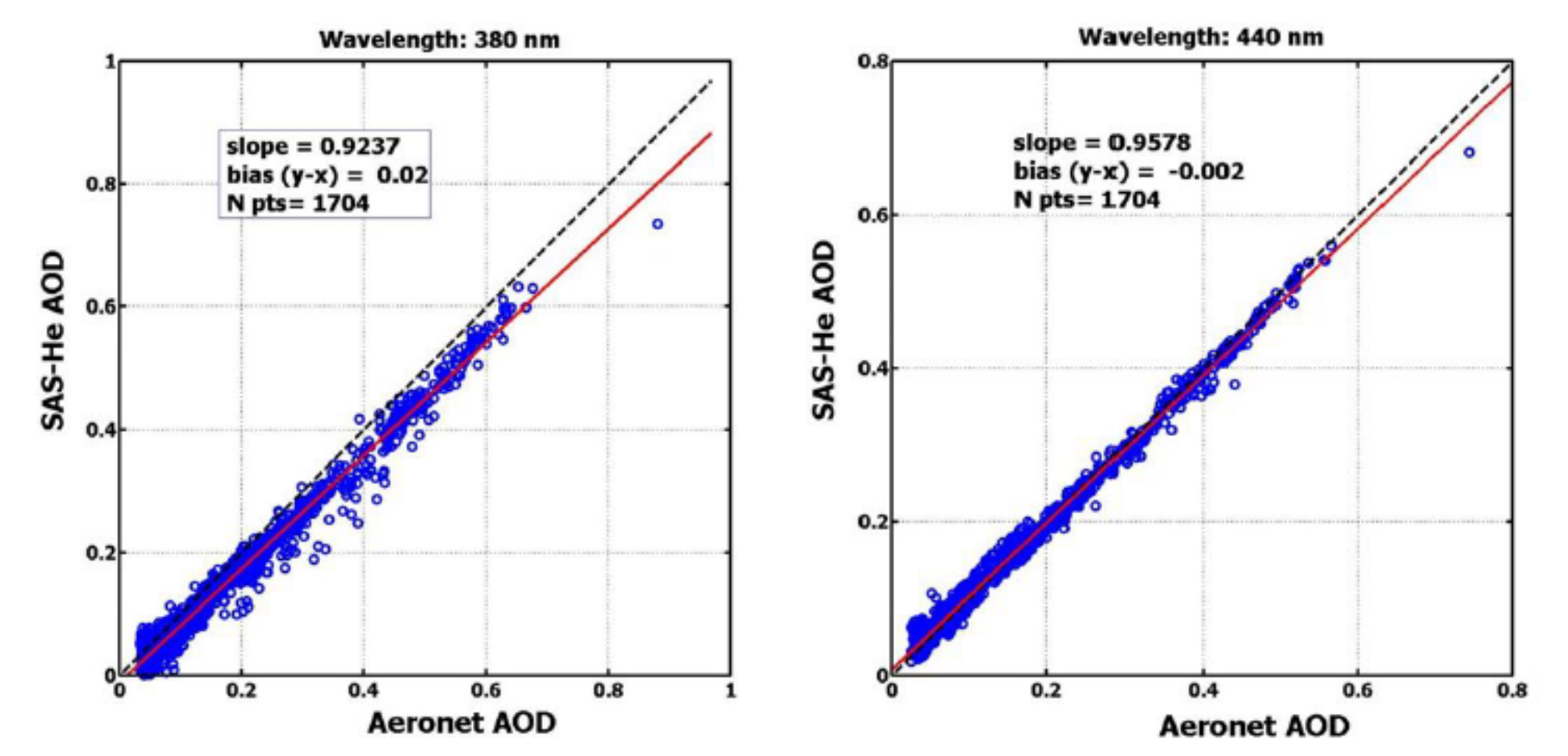
0.1
2012-08/30 12:00
15:00
18:00
21:00
Date

2 MONTH COMPARISON SASHE & AERONET AT PVC



Instrument	Measure	WL (nm)	Comment, modes:
mfr 10m	irrad	415, 500, 615, 673,870,940,Si	upwelling hemisp, 10 m tower
mfr 25m	irrad	415, 500, 615, 673,870,940,Si	upwelling hemisp, 25 m tower
MFRSR C1	dirh, difh, toth	415, 500, 615, 673,870,940,Si	shadowband direct horizontal, diffuse hemisp, total hemisp
MFRSR E13	dirh, difh, toth	415, 500, 615, 673,870,940,Si	shadowband direct horizontal, diffuse hemisp, total hemisp
CIMEL C1	dirn, rad	340, 380, 440, 500, 675, 870, 1020, (1640)	sun-tracking, sky-scanning, cloud-zenith, 1640 nm after 2007-03
NIMFR C1	dirn	415, 500, 615, 673,870,940,Si	direct normal
CIMEL S01	dirn, rad	340, 380, 440, 500, 675, 870, 1020, 1640	sun-tracking, sky-scanning, cloud-zenith, 1640 nm after 2007-03
NFOV	rad	870,	1.2 deg zenith
NFOV2		673, 870	1.2 deg zenith, moved to AMF1 after 2006-11
SWS	rad	Si (350-1000), InGaAs (970-2200)	1.4 deg zenith, moved to ENA in 2016-04
SASHe	dirh, difh,toth	Si (350-1000), InGaAs (970-1700)	
SASZe	rad	Si (350-1000), InGaAs (970-1700)	1 deg zenith

TWST	Aerodyne			Si (350-1000)	Aerodyne, Scott, AMF1 TCAP 2013/5-6, AMF1 BAECC 2014/7-8
TWST-NIR	Aerodyne			Si (350-1000), InGaAs (950-1650)	
ASD				Si (350-1000), InGaAs (970-2200)	Lubin, NSA 2008/4-5 (ISDAC), NSA 2009/4-10, AWARE
Stellarnet					
MS-700N	EKO	350	1050		
MS-701	EKO	300	400		
MS711	EKO	300	1100		
MS-712	EKO	900	1700		
MS-713	EKO	900	2550		
MS-711-DNI	EKO	300	1100		
HPN	DeltaT				