Antuña Marrero– Welcoming TEMPO: Cuba validate AOD & IWV

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GOAC-INSMET, Cuba in cooperation with GOA,UVA Spain will contribute to TEMPO:

After TEMPO launch :

- TEMPO AOD validation with sun photometer AOD and phyrheliometer BAOD.
- TEMPO Integrated Water Vapor (IWV) with sun photometer IWV and GPS IWV.
- Develop local services w/ hourly TEMPO AOD & IWV to be scaled later to country.

Diagnostic Service of Solar Radiation for Cuba:

2012: Three actinometrical stations in the country joined, becoming the "Diagnostic Service of the Solar Radiation for Cuba". Guarantees the update of the stations observation's digital records up to the present.

The direct irradiance measurements used to devive the Brodband AOD (BAOD) at all the 4 sites.

http://www.goac.cu/actino

Comparing sun photometer AOD & pyrheliometer BAOD:

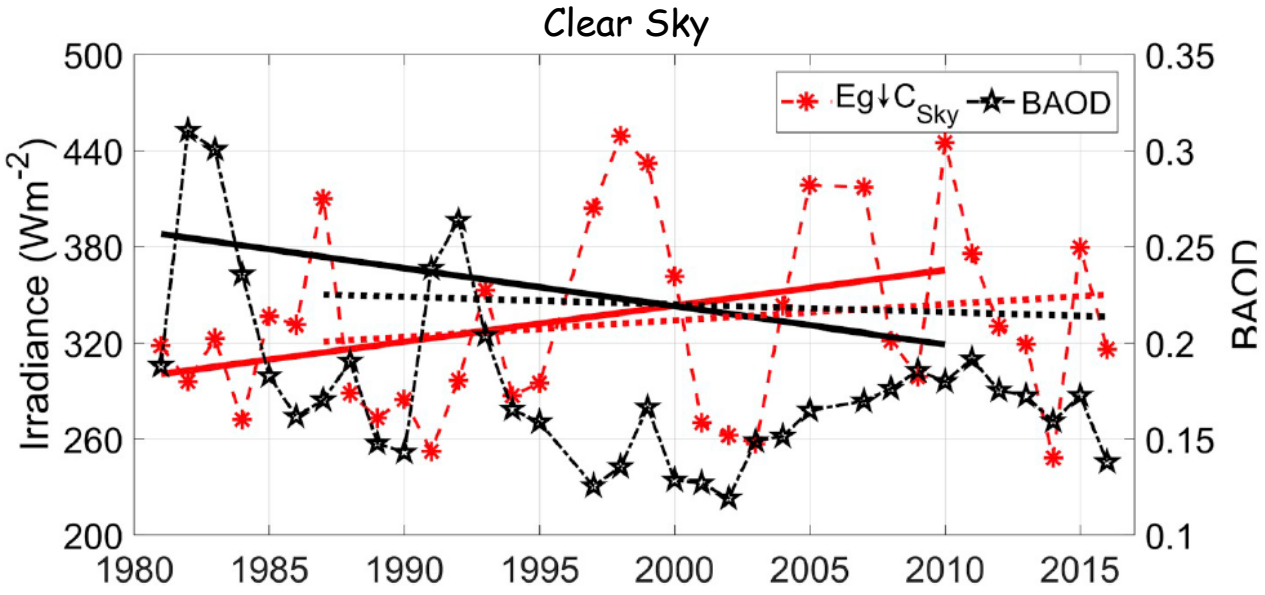
Temporal coincident sun photometer AOD (440, 500, 675 nm) & BAOD at Camagüey, Cuba.

Better results in bold.

BAOD vs. $AOD_{SP}(\lambda)$			
	675 nm	500 nm	440 nm
RMSE	0.048	**0.044**	0.056
MAE	0.037	**0.030**	0.040
BIAS	0.032	**-0.002**	-0.022

- García, F., R. Estevan, **J. C. Antuña-Marrero**, J. Rosas, I. Y. Platero, J. C. Antuña-Sánchez, N. Díaz, 2015, Determinación de la Línea Base del Espesor Óptico de Aerosoles de Banda Ancha y comparación con datos de fotómetro solar. *Opt. Pura Apl.*, **48**(4), 249-258. https://doi.org/10.7149/OPA.48.4.249

BAOD trend to explaining Brightening under clear sky at Camagüey.



Clear Sky Global Irradiance increasing trend 2.2 W m^{-2} $year^{-1}$ (BRIGHTENING) for 1981-2010.
BAOD had a decreasing trend of -2.8 x 10^{-3} $year^{-1}$

- Antuña-Marrero, J. C., et al., 2019, Simultaneous dimming and brightening under all and clear sky at Camagüey, Cuba (1981–2010), J. of Atmos. and Sol.-Terr. Phys., Volume **190**, 45-53. https://doi.org/10.1016/j.jastp.2019.05.004

Validation of MODIS AOD (Terra & Aqua) w/ sun photometer AOD & BAOD:

BAOD at the 4 solar radiation stations:

Camagüey, La Fe, Topes de Collantes & Jovellanos	BAOD vs. AOD_t		BAOD vs. AOD_a		BAOD vs. AOD_{ta}	
	DB	DT	DB	DT	DB	DT
RMSE	0.080	0.087	**0.073**	0.088	0.078	0.088
MAE	0.055	0.063	**0.048**	0.066	0.052	0.064
BIAS	**0.001**	0.027	0.014	0.049	0.005	0.035
R	0.455	0.325	**0.501**	0.417	0.468	0.355
Cases	373	436	191	268	564	704

AOD^{SP} shows, in general, a better performance for the DT than for the DB algorithm.

Small differences between AOD_t and AOD_a, justifying combining these observations in a single data set for climaological studies. DT & DB algorithms are better than expected (f ~ 80 %) from November to January, but in other months f = 68 %, ~ one standard deviation for DT and significantly lower for DB

	AOD_{SP} vs. AOD_t		AOD_{SP} vs. AOD_a		AOD_{SP} vs. AOD_{ta}	
	DB	DT	DB	DT	DB	DT
RMSE	0.084	0.060	0.065	0.062	0.078	0.061
MAE	0.062	0.045	0.046	0.047	0.056	0.046
BIAS	−0.053	−0.001	−0.033	0.006	−0.046	0.002
R	0.730	0.729	0.785	0.779	0.741	0.753
f	0.656	0.803	0.763	0.795	0.694	0.800
Cases	311	335	169	254	480	589

Tables Legend:

AOD_t: AOD Terra AOD_a: AOD Aqua AOD_{ta}:Terra & Aqua
AOD_{SP}: AOD Sun photometer DB: Deep Blue DT: Dark Target
f: MODIS/AERONET AOD retrievals in %

BAOD-MODIS comparison showed higher uncertainties than for MODIS-sun photometer,

but at the same order of magnitude.

- Antuña-Marrero, J. C. at al., 2018: Comparison of aerosol optical depth from satellite (MODIS), sun photometer and broadband pyrheliometer ground-based observations in Cuba. *Atmos. Meas. Tech.*, **11**, 2279–2293, https://doi.org/10.5194/amt-11-2279-2018

ARTICLES

COOPERATION ON GPS METEOROLOGY BETWEEN THE UNITED STATES AND CUBA

BY RICHARD ANTHES, ALAN ROBOCK, JUAN CARLOS ANTUÑA-MARRERO, OSWALDO GARCÍA, JOHN J. BRAUN, AND RENÉ ESTEVAN ARREDONDO

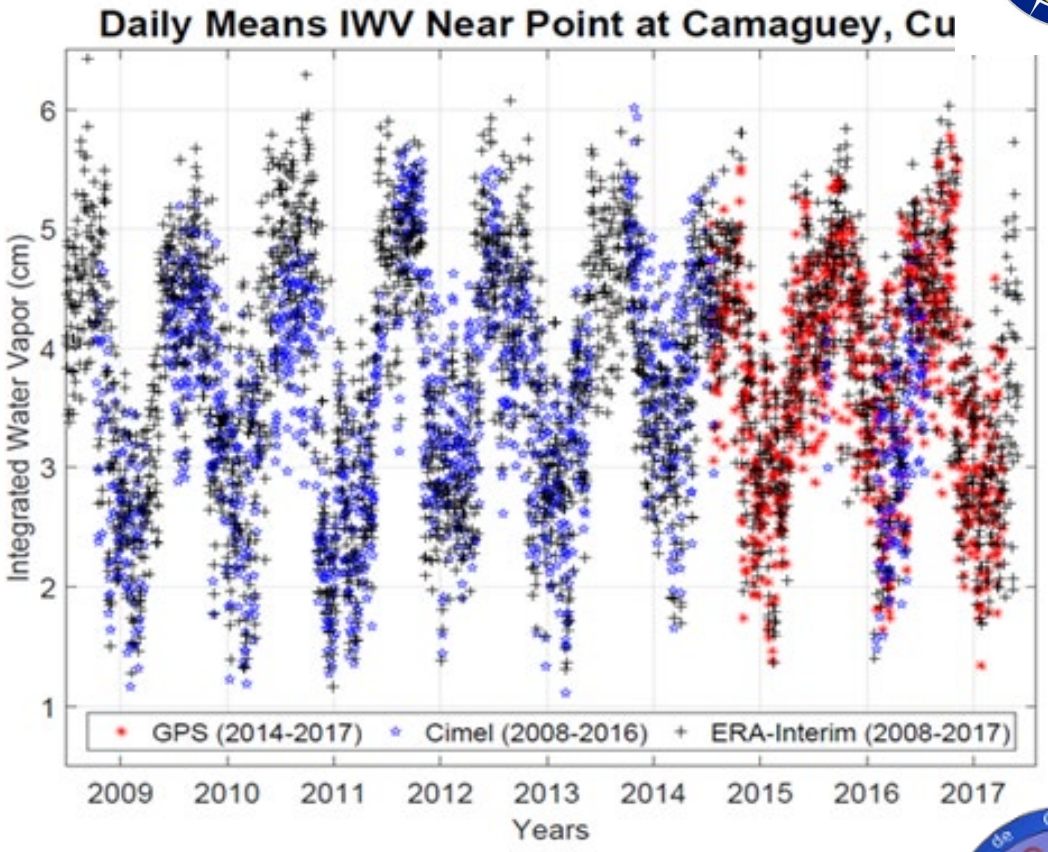
The events leading to the installation of a U.S. GPS receiver to measure precipitable water in Camagüey, Cuba, and the related collaboration of U.S. and Cuban scientists are described.

GPS operative at GOAC: May 22nd 2014 to the present.

- Anthes, R., Robock, A., Antuña-Marrero, J. C., García, O., Braun, J.J., and Estevan Arredondo, R., 2015: Cooperation on GPS Meteorology between the United States and Cuba. Bull. Amer. Meteor. Soc., **96**, 1079–1088.

http://dx.doi.org/10.1175/BAMS-D-14-00171.1

Preliminary validation of IWV from ERA-I w/ sun photometer & GPS Measured at Camagüey by GOAC

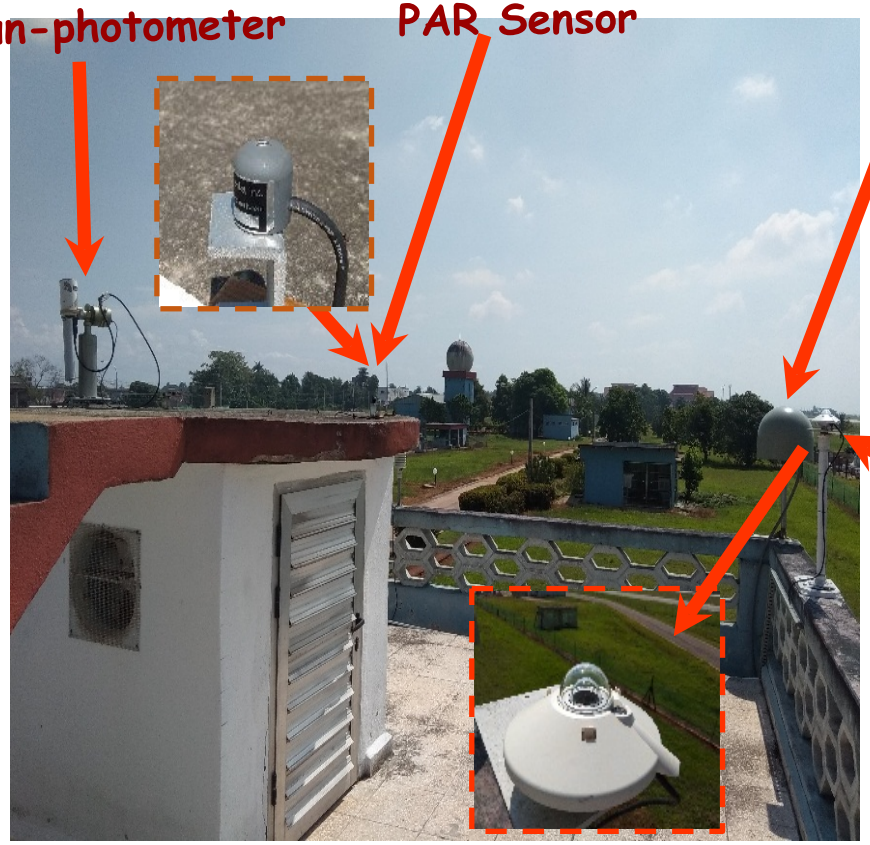


Instrument	RMSE	MAE	BIAS	R	N
SP/GPS	0.406	0.335	-0.240	0.935	146
SP/ERA-I	0.806	0.623	-0.123	0.683	1638
GPS/ERA-I	0.885	0.682	-0.108	0.548	911

SUMMARY: GOAC measurements capabilities:

Radiation, Aerosols, Clouds and IWV(GPS)

GOA - Univ. Of Valladolid, Spain
(GOA-UVA)



GPS (IWV)
UNAVCO
NCAR, US

Pyranometer
Prof. Alan Robock,
Rutgers Univ., US

Sun-photometer
Contributing to
AERONET

Supported by Cooperation Agreement
GOA-UVA & INSMET (2007-present)
http://www.goac.cu/uva/

Cloud Sky Camera
Built & operated
in cooperation with
GOA-UVA
Operative from 2018

Main Contributors to the GOAC Observational Facilities:

Stratospheric lidar setup, operation & maintenance 1988-1991. Know-how & soft transfer.
Tyfun, Obninsk former Soviet Union.

More than 10 years of sustained cooperation.

- Sun photometer & its calibration (2008-2021)
- PM impactor.
- Photosynthetic Active Radiation sensor
- Calibration bench for radiation sensors.
- Computing & hardware resources
- PhD fellowship: Cloud Camera photometry.
- Broad know-how transfer & multiple trainings.
- Support for GOAC & LALINET publications

Prof. Ángel de Frutos, Prof. Victoria Cachorro, & GOA-UVA team, Univ. Valladolid, Spain.

Promoting and facilitating GOAC International Cooperation :

- PhD fellowship: Pinatubo lidar & satellite validation.
- Earlier contacts and exchanges with AERONET.
- Contributor to design, promote, support and setup LALINET.
- Key role in US-Cuba contacts for GPS setup at GOAC.
- Promoted GOAC invitation to Norway funded XCUBE project.
- Earlier contacts with TEMPO Science Team.
- Pyranometer CM-21 & Data logger LOGBOX SD (Kip & Zonen).

Prof. Alan Robock, Rutgers University, USA

Data Rescue know-how transfer and promotion of cooperation:

- PhD fellowship: for Pinatubo lidar & satellite validation.

Prof. Ricardo García Herrera, Complutense Univ. Madrid, Spain

Relevant contributors for GPS setup at GOAC.
Prof. Rick Anthes, UCAR, Dr. John Braun, NCAR, Prof. Oswaldo Garcia, San Francisco State University, CA, US