



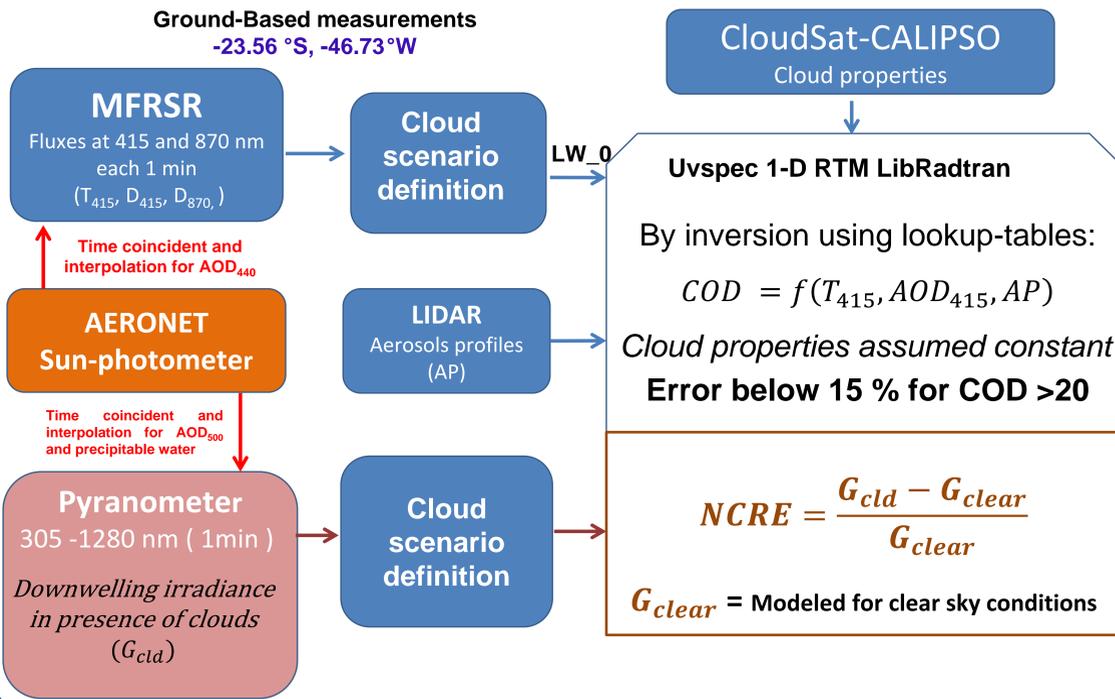
Cloud optical depth and cloud solar radiative effects computed at São Paulo, Brazil.

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At Metropolitan Area of São Paulo, effective cloud optical depth (ECOD) every 1 min of low clouds and high clouds was retrieved from total transmittance (T) at 415 nm channel of a Multi-filter Rotating Shadow band Radiometer (MFRSR) in the time period from June of 2012 up to September 2017. Cloud effects on solar radiation at surface were computed by the normalized shortwave cloud radiative effect (NCRE) where surface albedo is neglected and it is less sensitive to CSZA. Solar global irradiance at surface (G) under cloudy conditions were measured by pyranometer and clear sky irradiance was computed by the 1-D RTM.

Methods:



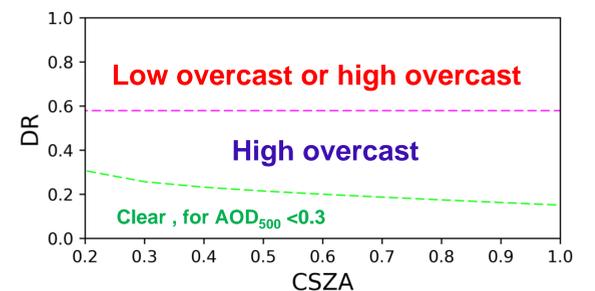
Cloud scenario definition:

- Visual definition:**
- Using visual reports of clouds made in meteorological station 20 km far away (6-2012 up to 9-2016).
 - Definition made from Sky camera regular pictures (since 9-2016)
- Direct Sun :**
- By comparison of direct sun transmittance modelled for clear sky and measured by MFRSR.

Visual	Direct Sun	DR	Cloud Scenario
Low clouds + total overcast	blocked	Low overcast	LW_0
Low clouds + not Total overcast	blocked	Not clear	LWBK_0
Low clouds + not Total overcast	clear	Not clear	LWBK_1
High clouds total overcast	blocked	Not clear	H_0
High clouds + not total overcast	blocked	Not clear	HBK_0
High clouds + not total overcast	clear	Not clear	HBK_1
Mid clouds + total overcast	blocked	Not clear	MID_0
Mid clouds + not total overcast	clear	Not clear	MIDBK_1

Diffuse ratio (DR)

$$DR = \frac{D_{870}}{D_{415}}$$



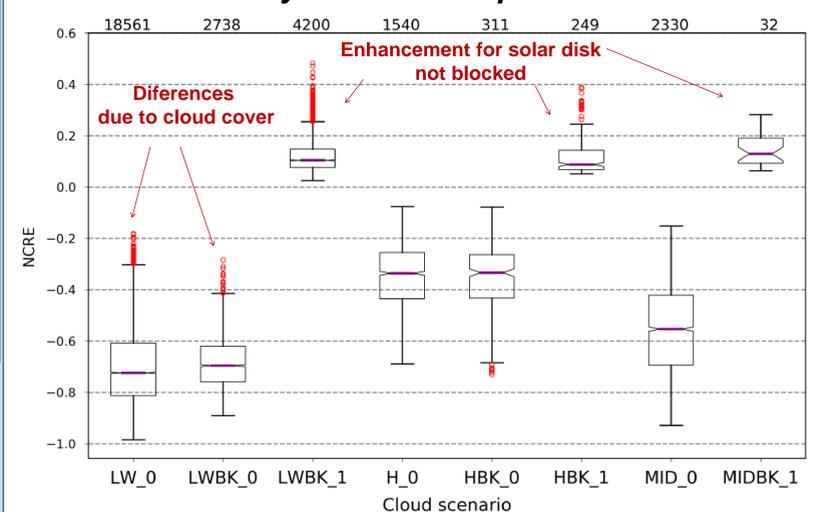
Results: Seasonal and diurnal statistic of ECOD (LW_0):

	time	mean	std	5th	95th	Number
Season	DJF	31.89	32.25	7.33	79.44	11758
	MAM	32.95	31.52	6.46	86.46	9713
	JJA	26.90	21.44	5.17	68.19	11852
	SON	34.36	24.42	7.90	80.50	22436
Diurnal	SUN	25.49	23.82	4.58	64.74	4309
	MOR	26.75	20.41	5.52	64.37	13724
	MID	35.02	26.73	9.55	83.30	20442
	AFT	34.22	32.78	5.87	87.09	11942.00

- Seasonal variability with maximum in spring and minimum in winter
- Diurnal variability, maximum after midday and minimum observed in sunrise.

SUN <= 8:00 LT
 MOR >8:00 LT and <=10:00 LT
 MID >10:00 LT and <=14:00 LT
 AFT >14:00 LT

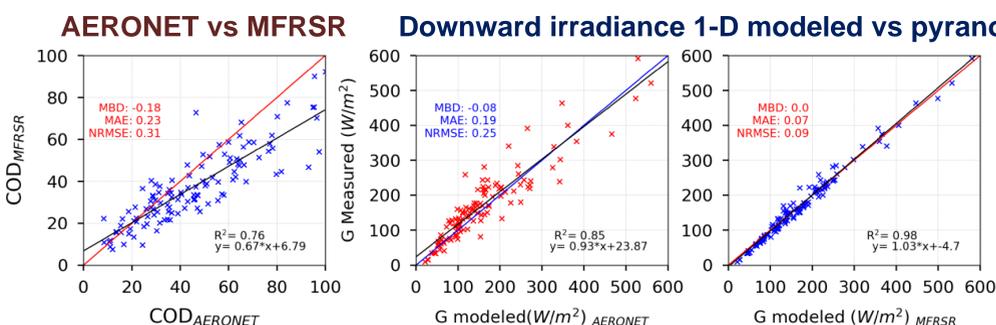
Broadband Cloud effects on solar radiation (1 min): January 2016 until September 2017



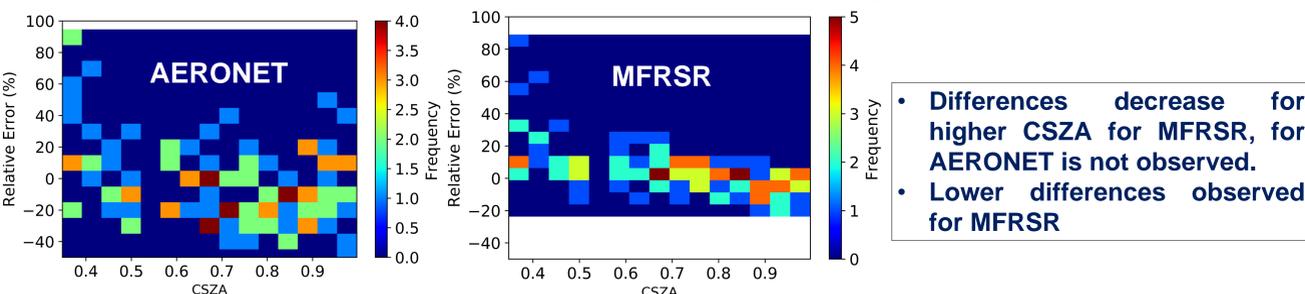
- Cooling effects when solar disk is blocked, with maximum for low clouds for total overcast conditions.
- Enhancement effects for all cloud types when solar disk is clear, the highest is observed for low clouds.

Comparison with COD AERONET:

Collocated comparison of COD AERONET (1.5 min) and ECOD for MFRSR (1 min) for total overcast of low clouds defined by Sky camera. 119 coincident cases.



Differences between downward irradiance modeled vs pyranometer respect to CSZA



Conclusions:

- ECOD was retrieved for low clouds with total overcast conditions using MFRSR, showing a seasonal and diurnal variability in São Paulo.
- Comparison with downward irradiance modeled using the COD or ECOD and measured by pyranometer shows the best agreement by ECOD obtained for MFRSR, specially for higher CSZAs.
- Cloud radiative effects depend on conditions of solar disk, cloud type and cloud cover. Maximum of cooling when solar disk is blocked by low clouds with total overcast. Enhancement are observed in all cloud types with the highest for low clouds.

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