The hygroscopic behavior of aerosols obtained by Raman LIDAR, radiosoundings and nephelometry - Experiences from three different sites

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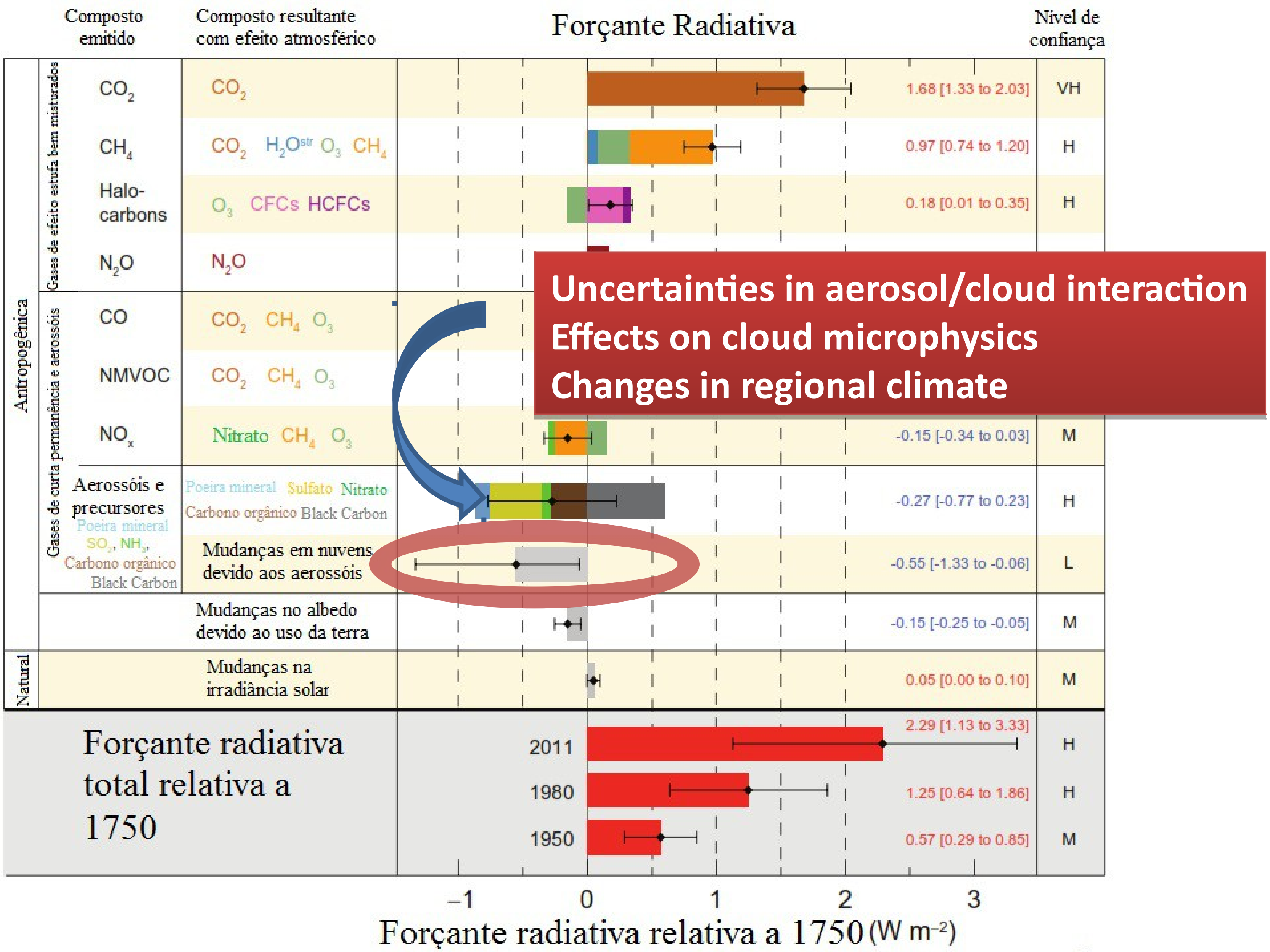
Motivation



Composto emitido
Composto resultante com efeito atmosférico
Forçante Radiativa
Nível de confiança
Antropogênica
Gases de efeito estufa bem misturados
CO2
CO2
1.68 [1.33 to 2.03]
VH
CH4
CO2 H2Ostr O3 CH4
0.97 [0.74 to 1.20]
H
Halo-carbons
O3 CFCs HCFCs
0.18 [0.01 to 0.35]
H
N2O
N2O
Gases de curta permanência e aerossóis
CO
CO2 CH4 O3
NMVOC
CO2 CH4 O3
NOx
Nitrato CH4 O3
-0.15 [-0.34 to 0.03]
M
Aerossóis e precursores
Poeira mineral
SO2, NH3,
Carbono orgânico
Black Carbon
Poeira mineral Sulfato Nitrato
Carbono orgânico Black Carbon
-0.27 [-0.77 to 0.23]
H
Mudanças em nuvens devido aos aerossóis
-0.55 [-1.33 to -0.06]
L
Mudanças no albedo devido ao uso da terra
-0.15 [-0.25 to -0.05]
M
Natural
Mudanças na irradiância solar
0.05 [0.00 to 0.10]
M
Forçante radiativa total relativa a 1750
2011
2.29 [1.13 to 3.33]
H
1980
1.25 [0.64 to 1.86]
H
1950
0.57 [0.29 to 0.85]
M
−1
0
1
2
3
Forçante radiativa relativa a 1750 (W m-2)
Uncertainties in aerosol/cloud interaction
Effects on cloud microphysics
Changes in regional climate

Hygroscopic Growth

***f*(RH) or hygroscopic growth factor: ratio of humidified-to-dry aerosol light backscattering or extinction.**

How to study this property using LIDAR?

Backscatter LIDAR

- → Backscattering or extinction
- → RH from collocated sondes
- → RH from thermodynamic considerations and atmospheric models (cloud cover needed)

Using the Raman LIDAR

Pressure from sondes or standard atmosphere models

Vapor pressure $e_{(z)}$ over saturation vapor pressure $e_{w(z)}$

$$RH_{(z)} = \frac{e_{(z)}}{e_{w(z)}}$$

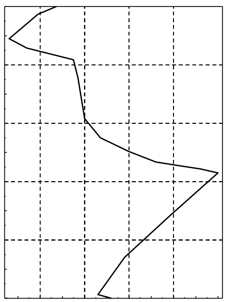
$$e_{(z)} = \frac{P_{(z)} WVMR_{(z)}}{0.622 + WVMR_{(z)}}$$

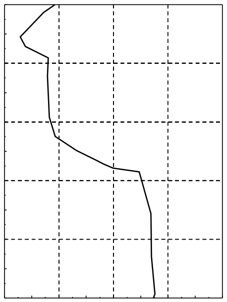
$$\text{Log } e_w = -0.58002206 \; 10^4 / T + 0.13914993 \; 10^1 - 0.48640239 \; 10^{-1} \; T + 0.41764768 \; 10^{-4} \; T^2 - 0.14452093 \; 10^{-7} \; T^3 + 0.65459673 \; 10^1 \text{ Log}(T)$$

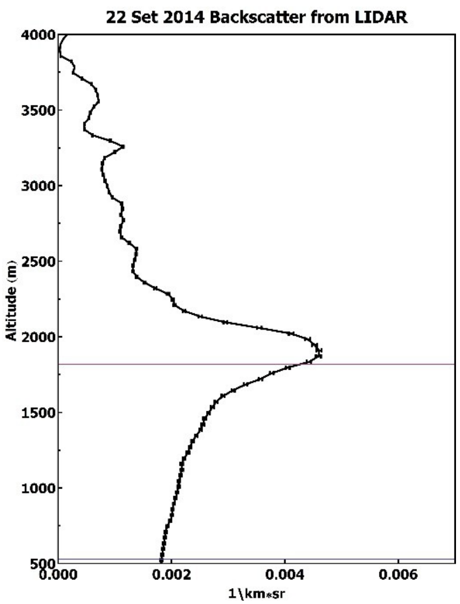
Temperature from sondes or microwave radiometers

Hyland and Wexler *(Hyland and Wexler, 1983):*

Well mixed atmosphere

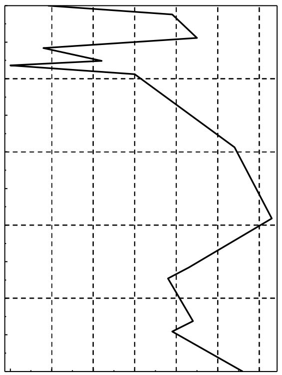


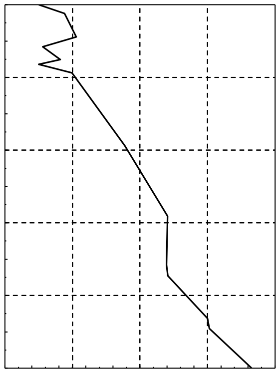


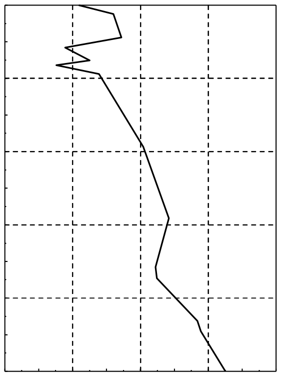


If the atmosphere is well mixed, than any changes in backscatter are due to changes in the size of the aerosols, and not because the aerosol population is changing

Well mixed atmosphere



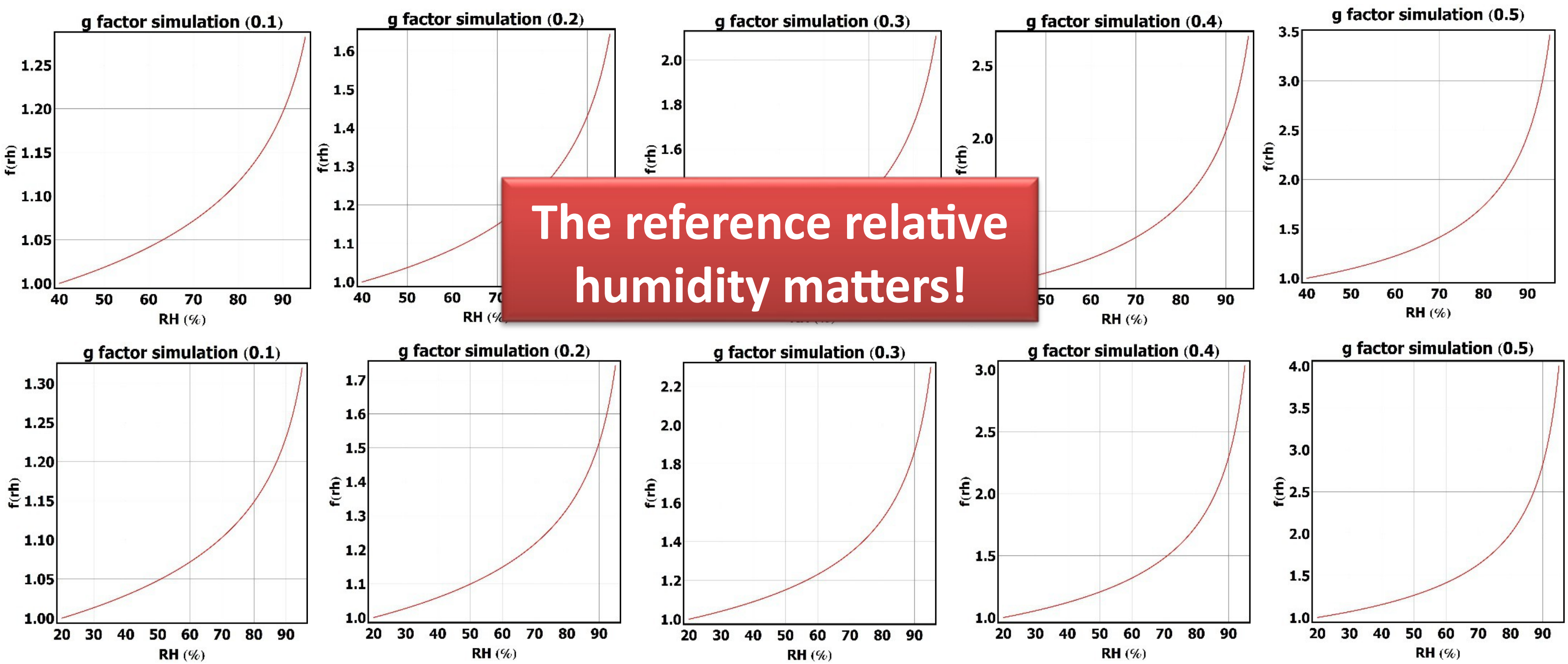




The "γ" parameter

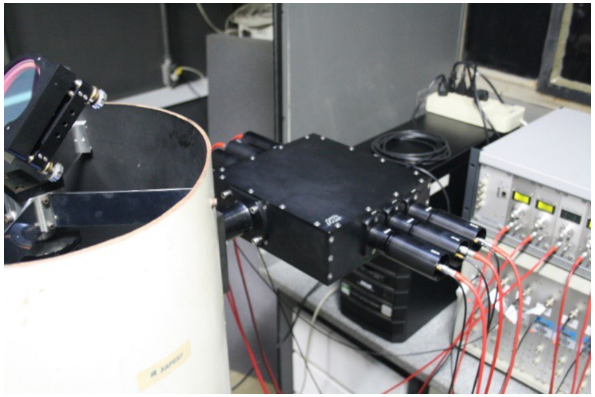
$$f(RH) = \frac{\beta(RH)}{\beta(RH_{ref})} \;\Rightarrow\; \frac{\beta(RH)}{\beta(RH_{ref})} = \left(\frac{1-RH}{1-RH_{ref}}\right)^{-\gamma}$$

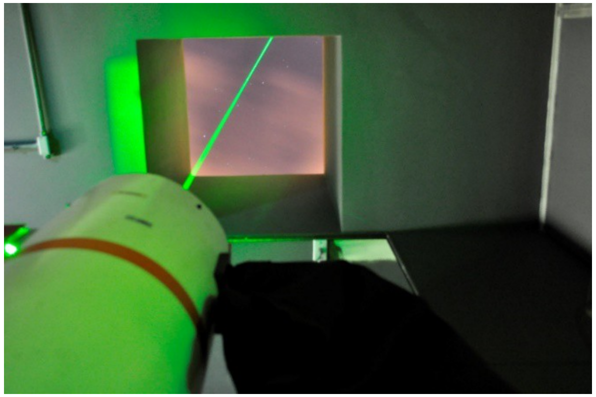
"γ" fator is a parameter that depends on each aerosol chemical composition, mixing state and dry particle distribution of the aerossol population

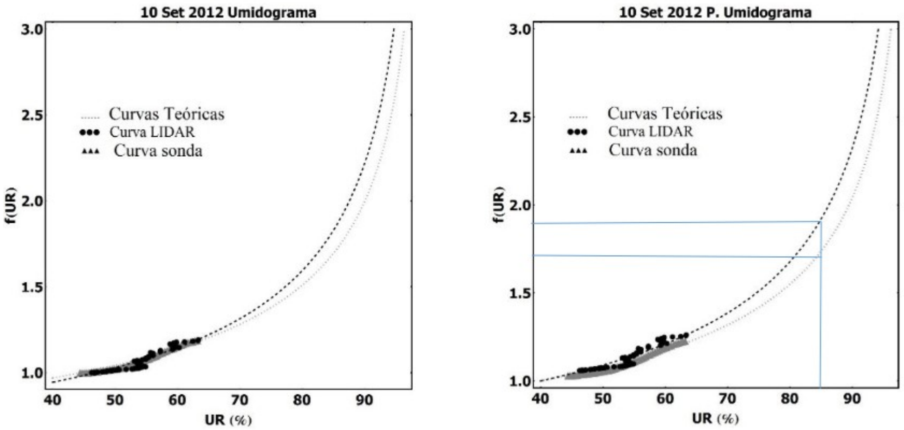


The reference relative humidity matters!

São Paulo case







a) γlidar = 0.47, γsonda = 0.40

b) γplidar = 0.47, γpsonda = 0.40

$f_\beta LIDAR(85\%) = 1.92$

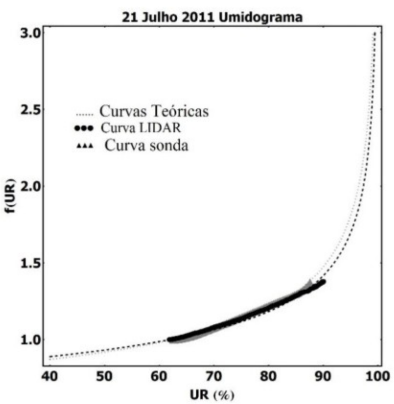
$f_\beta SONDA(85\%) = 1.73$

Date	γ LIDAR	γ sonde	$f_\beta(85\%)$ LIDAR	$f_\beta(85\%)$ sonde
03/05/2013	0.12±0.02	0.12±0.01	1.19±0.03	1.18±0.02
12/09/2013	0.36±0.03	0.58±0.04	1.65±0.08	2.25±0.13
10/09/2012	0.47±0.03	0.39±0.02	1.92±0.09	1.73±0.05
11/07/2013	0.53±0.06	1.49±0.12	2.09±0.17	7.95±1.30
30/01/2014	0.98±0.07	0.81±0.04	3.92±0.37	3.07±0.19

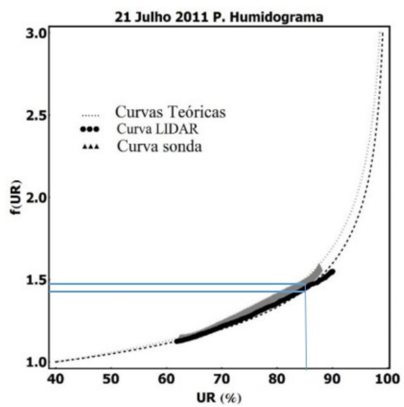
Author / year	Local	Natureza do Aerossol	Instrument	λ (nm)	Optical parameter	$f(85\%)$	g
Zieger (2013)	Jungfraujoch (Suitzerland)	Polluted maritime	Nephelometer	550	σ	1.95±0.14	-
Gasso (2000)	Sagres (Portugal)	Polluted maritime	Nephelometer	550	σ	1.4	0.27
Zieger (2013)	Jungfraujoch (Suitzerland)	Little Polluted maritime	Nephelometer	550	σ	2.97±0.20	-
Zieger (2013)	Jungfraujoch (Suitzerland)	Clean maritime	Nephelometer	550	σ	3.38±0.31	-
Gasso (2000)	Sagres (Portugal)	Clean maritime	Nephelometer	550	σ	1.8	0.60
Granados-Munhoz (2014)	Granada (Spain)	Polluted Continental	LIDAR	532	β	2.1	0.56±0.01
Granados-Munhoz (2014)	Granada (Spain)	Polluted Continental	LIDAR	532	β	3.5	1.07±0.01
Este trabalho 10 Set 2012	Sao Paulo	Polluted Urban	LIDAR	355	β	1.92±0.09	0.47±0.03
Este trabalho 12 Set 2013	Sao Paulo	Polluted Urban	LIDAR	355	β	1.65±0.08	0.36±0.03
Este trabalho 30 Jan 2014	Sao Paulo	Polluted Urban	LIDAR	355	β	3.92±0.37	0.98±0.07
Randriamiarisoa (2006)	Paris	Polluted Urban	Nephelometer	550	σ	1.2-4.5	0.47-1.35
Este trabalho 03 Mai 2013	Sao Paulo	Polluted Urban/ Maritime	LIDAR	355	β	1.19±0.03	0.12±0.02
Este trabalho 11 Jul 2013	Sao Paulo	Polluted Urban/ Maritime	LIDAR	355	β	2.09±0.17	0.53±0.06
Veselovski (2009)	D.C.	Maritime with antropogenic inf	LIDAR	355	α	2.1	0.9
Zieger (2013)	Jungfraujoch (Suiça)	Saharian dust	Nephelometer	550	σ	1.28±0.10	-

Belstville DC case

Ziemba (2013) 05 Jul 2011	D.C	Continental	Nephelometer	550	σ	1.45±0.07	-
Ziemba (2013) 21 Jul 2011	D.C	Continental	Nephelometer	550	σ	1.70±0.06	-
This work 05 Jul 2011	D.C.	Continental	LIDAR	355	β	1.41±0.06	0.25±0.04
This work 21 Jul 2011	D.C.	Continental	LIDAR	355	β	1.43±0.07	0.26±0.04



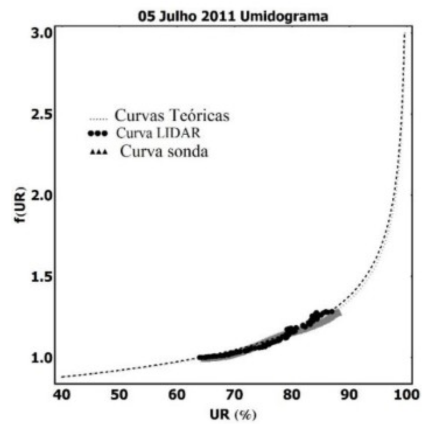
a) $\gamma_{lidar} = 0.26$, $\gamma_{sonda} = 0.29$



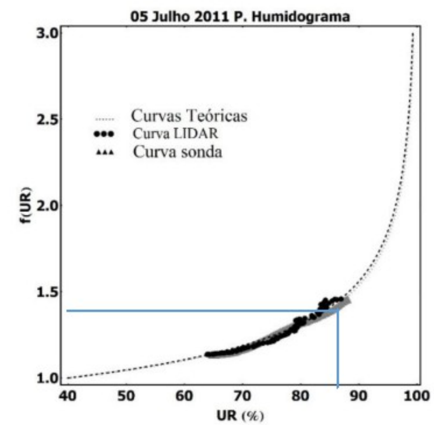
b) $\gamma p_{lidar} = 0.26$, $\gamma p_{sonda} = 0.29$

$f_{\beta} LIDAR(85\%) = 1.39$

$f_{\beta} SONDA(85\%) = 1.50$



a) $\gamma_{lidar} = 0.25$, $\gamma_{sonda} = 0.24$



b) $\gamma p_{lidar} = 0.24$, $\gamma p_{sonda} = 0.24$

$f_{\beta} LIDAR(85\%) = 1.41$

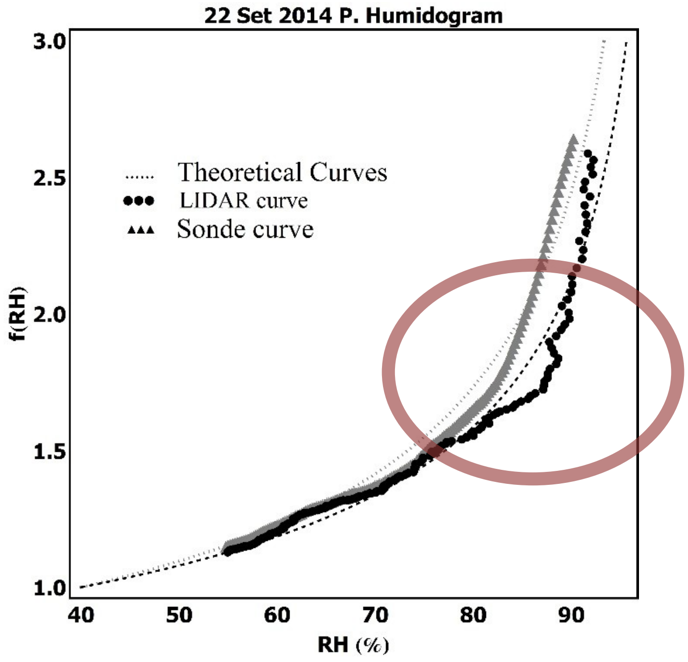
$f_{\beta} SONDA(85\%) = 1.39$

LIDAR can provide more information than nephelometer on RH over 85%

HURL system was not prepared to study aerosols

Amazon case

γ lidar = 0.42
γ sonde = 0.50
fβ(85%) lidar = 1.80
fβ(85%) lidar = 2.01



Site	Measurements	condition	"Perfect" condition
São Paulo	63 nights (2 years)	3 cases	0
Washington DC	80 cases (day and night – one month)	4 cases	1
Amazon	**3 years**	**More than 100 cases**	**12**

Is the LIDAR a good instrument to study hygroscopicity and aerosol/cloud interaction?

Continuous LIDAR measurements over many years, as the condition is not often present

Prediction of the atmospheric conditions using the historical data from radiosondes (Wyoming) to address the frequency for each place

Test more than one fitting equation

Synergy between LIDAR and other instruments (size distribution, chemical composition, deliquescence point and hysteresis)

Continuous measurements with higher time resolution (using microwave radiometer?)

Thank you!