Sensitivity of stratospheric lidar ozone measurements to a change in ozone cross sections

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Retrieval of ozone number density

DIAL Method : DIfferential Absorption Lidar

$$n_{O_3}(z) = -\frac{1}{2\cdot\Delta\sigma_{O_3}(z)}\frac{d}{dz}Ln\left(\frac{S(\lambda_{on},z)-S_b(\lambda_{on},z)}{S(\lambda_{off},z)-S_b(\lambda_{off},z)}\right)+\delta n_{O_3}(z)$$

Differential ozone absorption cross-section — lidar signal — background

$$\sigma_{O_3}(\lambda_{on},z)-\sigma_{O_3}(\lambda_{off},z)$$

Laser wavelengths chosen so that the correction term is less than 10% of main term

$$\delta n_{O_3}(z) = \frac{1}{\Delta\sigma_{O_3}(z)}\left[\frac{1}{2}\frac{d}{dz}Ln\left(\frac{\beta(\lambda_{on},z)}{\beta(\lambda_{off},z)}\right)-\Delta\alpha(z)-\sum_i \Delta\sigma_i n_i(z)\right]$$

correction term — Backscatter — Extinction Rayleigh & Mie — Extinction by other species

Use of Raman signals in the presence of volcanic aerosols

$$n_{O_3}(z) = -\frac{1}{\Delta\sigma^R_{O_3}(z)}\frac{d}{dz}Ln\left(\frac{S(\lambda^R_{on},z)-S_b(\lambda^R_{on},z)}{S(\lambda^R_{off},z)-S_b(\lambda^R_{off},z)}\right)+\delta n^R_{O_3}(z)$$

Differential ozone absorption cross-section — lidar signal — background

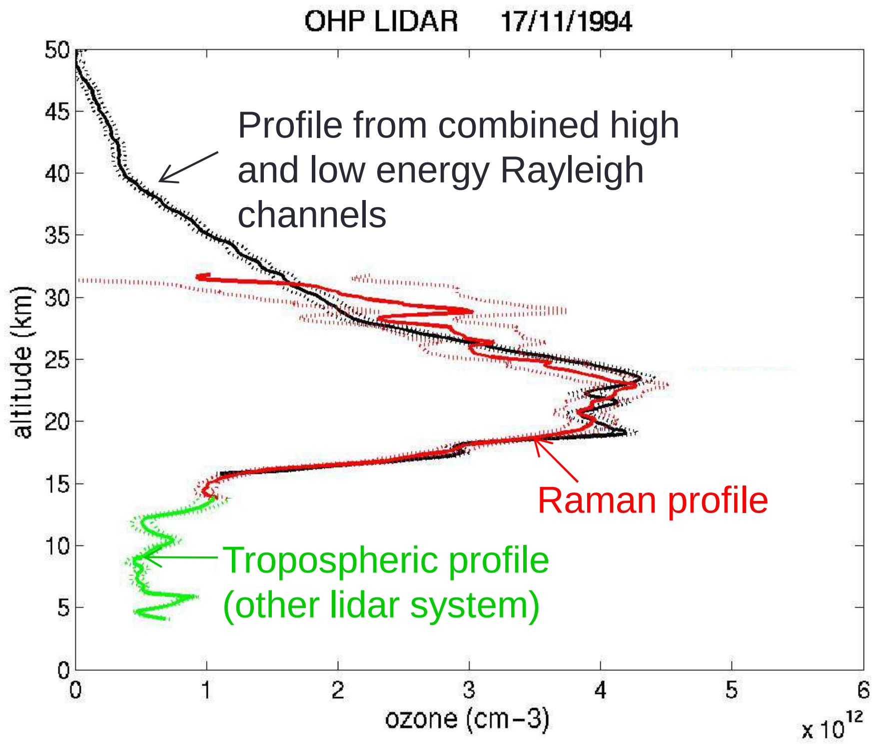
$$\sigma_{O_3}(\lambda_{on},z)-\sigma_{O_3}(\lambda_{off},z)+(\sigma_{O_3}(\lambda^R_{on},z)-\sigma_{O_3}(\lambda^R_{off},z))$$

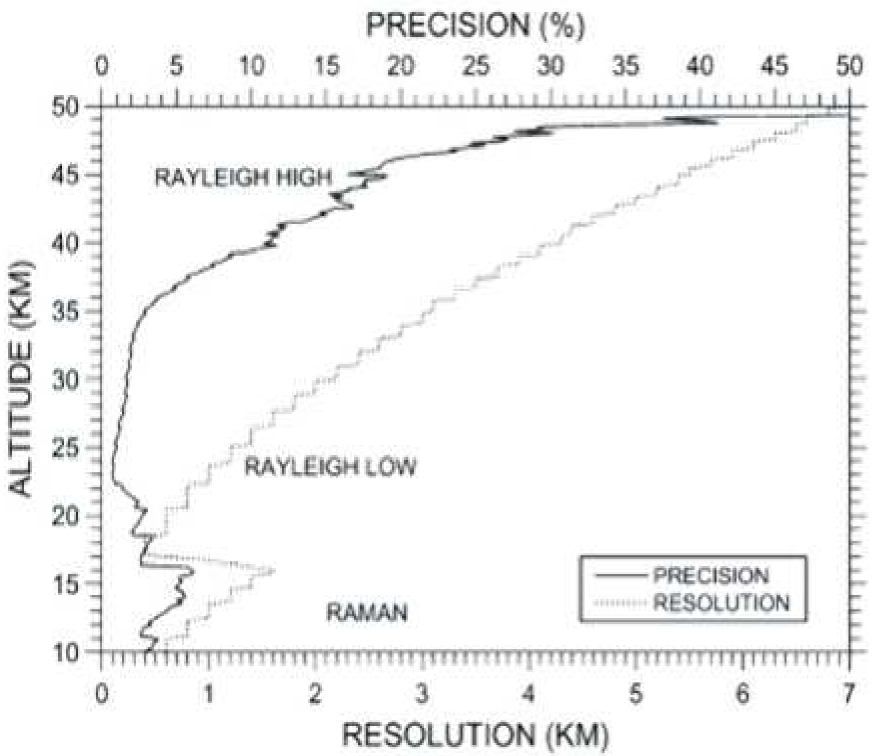
$$\delta n^R_{O_3}(z) = \frac{1}{\Delta\sigma^R_{O_3}(z)}\left[-\Delta\alpha^R(z)-\sum_i \Delta\sigma^R_i n_i(z)\right]$$

correction term — Extinction Rayleigh & Mie — Extinction by other species

➜ A change in ozone cross-section data will affect the retrieved ozone number density

Example of DIAL ozone profile





Ozone measurements performed during the night

Temporal resolution 3 – 4 hours, depending on laser power and repetition rate

Require clear skies

Wavelengths used in lidar measurements

- ✓ DIAL ozone retrieval requires determination of ozone cross-sections in the range 266 nm – 387 nm, with accurate temperature dependence.

- ✓ For ozone observations, the selected pair of laser wavelengths differs according to the altitude range of the measurements

- ✓ For <u>tropospheric measurements</u>, the wavelength pair is chosen between 266 nm and 320 nm.

- ✓ For <u>stratospheric measurements</u>:

  - ➢ Most instrumental set-ups are based on XeCl excimer laser (XeCl) sources that emit several radiations in the range 307.9 -308.2 nm (Rayleigh channel)

  - ➢ In the presence of volcanic aerosols, the range of wavelength in the Raman lidar signal is 331.7-332.1 nm

Ozone X-section used in this study

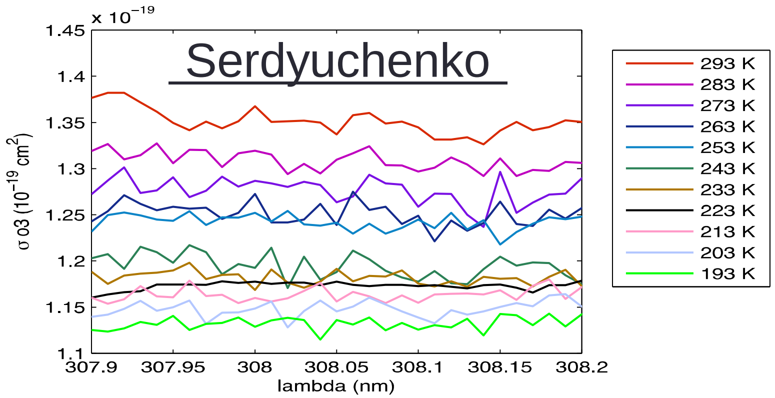
	Temperature (K) (number of T level)	Spectral Resolution(nm)
Bass and Paur (1984)	203 – 280 (6)	0.05
Brion Daumont and Malicet (1995)	218- 295 (5)	0.01
Serdyuchenko (2012)	193- 293 (11)	0.01

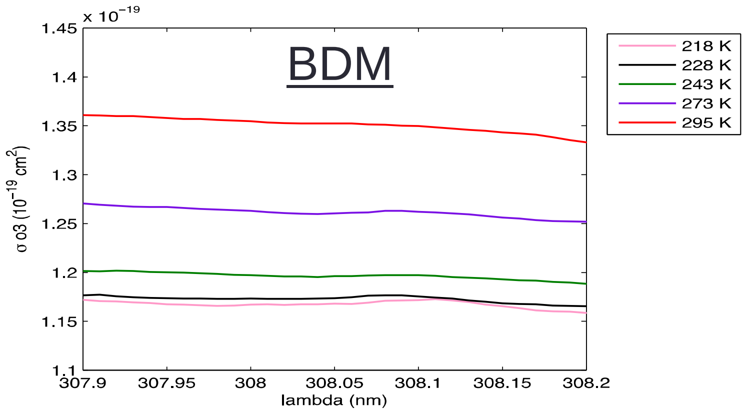
Serdyuchenko should be more appropriate for lidar measurements :

- Larger Temperature range
- Larger Temperature sampling

<u>Inconvenience of Serdyuchenko cross section:</u>

O_3 cross section as a fonction of Lambda in lidar rayleigh absorbed wavelength



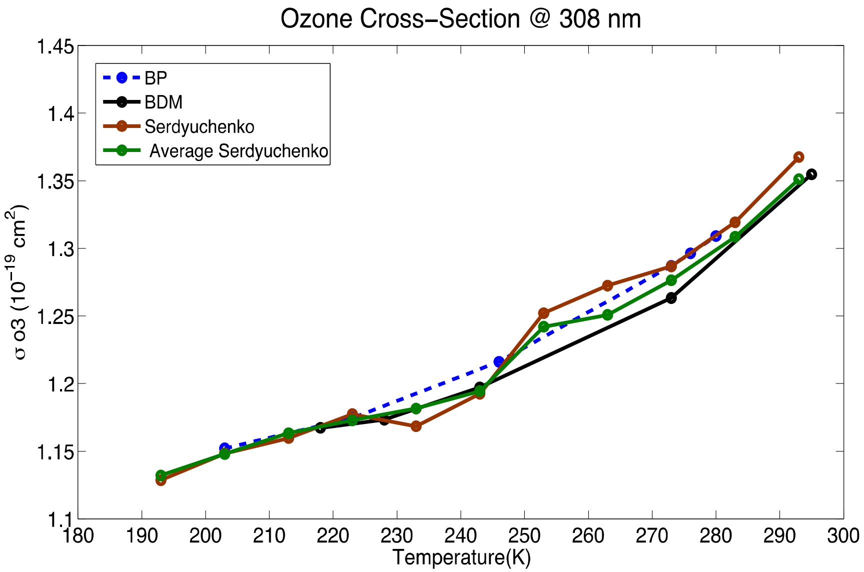


→ Serdyuchenko cross section noisier with respect to BDM

Variation of ozone X-section with temperature

Rayleigh absorbed wavelength: 308 nm

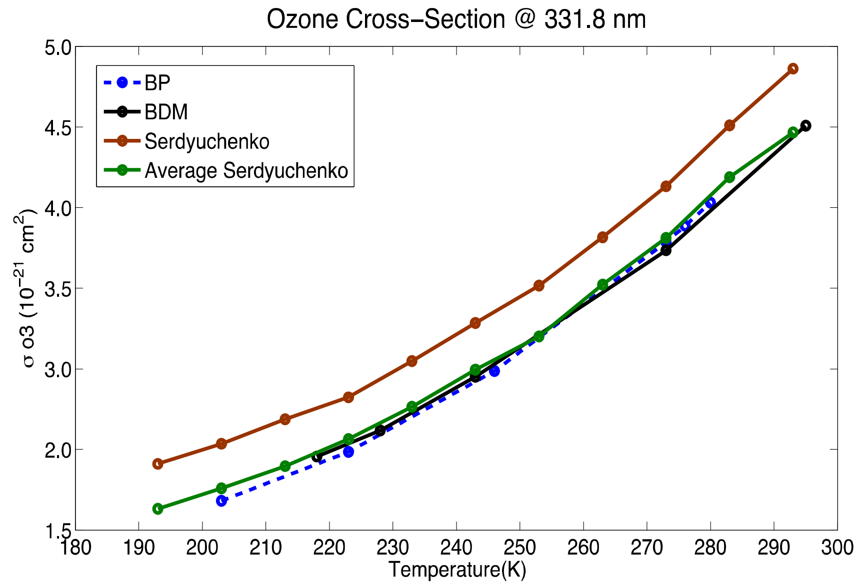
Average Serdyuchenko: mean (307.9 - 308.2 nm)



- Serdyuchenko X section Jump ($0.1*10^{-21}$ cm^2) at 242K
- Jump less seen on Average Serdyuchenko

Raman absorbed wavelength: 331.8 nm

Average Serdyuchenko: mean (331.7 - 332.1 nm)



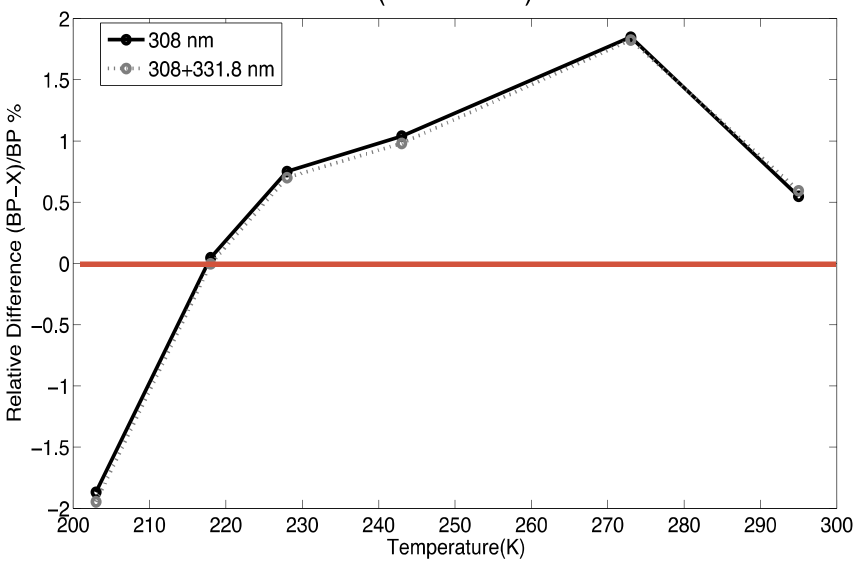
- Serdyuchenko (at 331.8 nm) higher than BP constant bias ~0.4 10^{-21} cm^2

To compare each cross section an extrapolation of Temperature has to be made

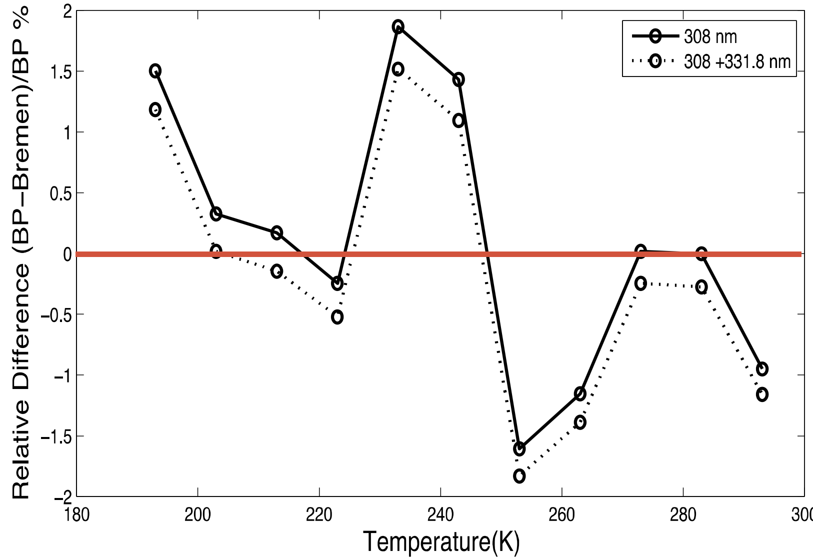
	BP	BDM	Serdyuchenko	Average Serdyuchenko
Original range	203 – 280 K	218- 295 K	193- 293 K	193- 293 K
BP-X		203-295 K	193-293 K	193-293 K

Effect of a change of X-sections on ozone
Bass and Paur used as the reference

(BP – BDM)

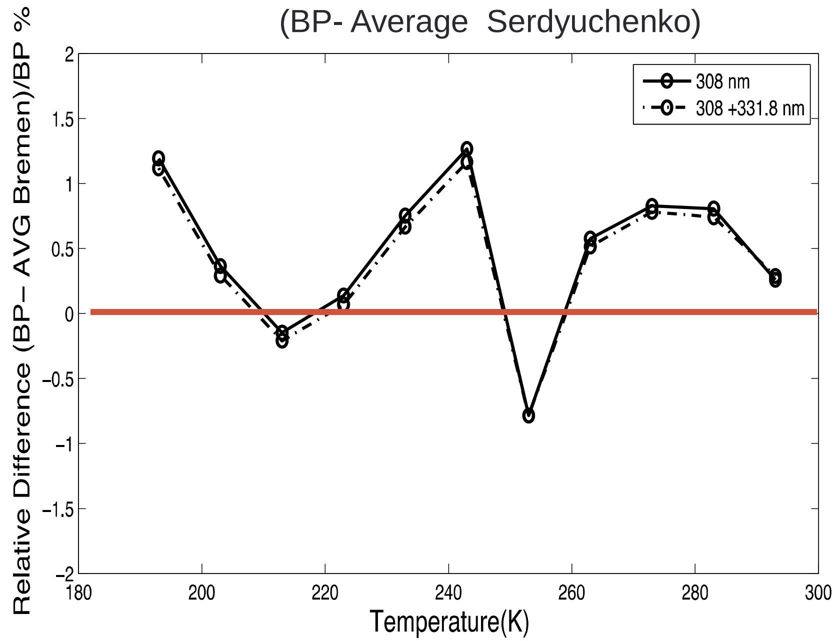


(BP- Serdyuchenko)



Impact on the X-sections more important on the rayleigh channel (308 nm)

(BP- Average Serdyuchenko)



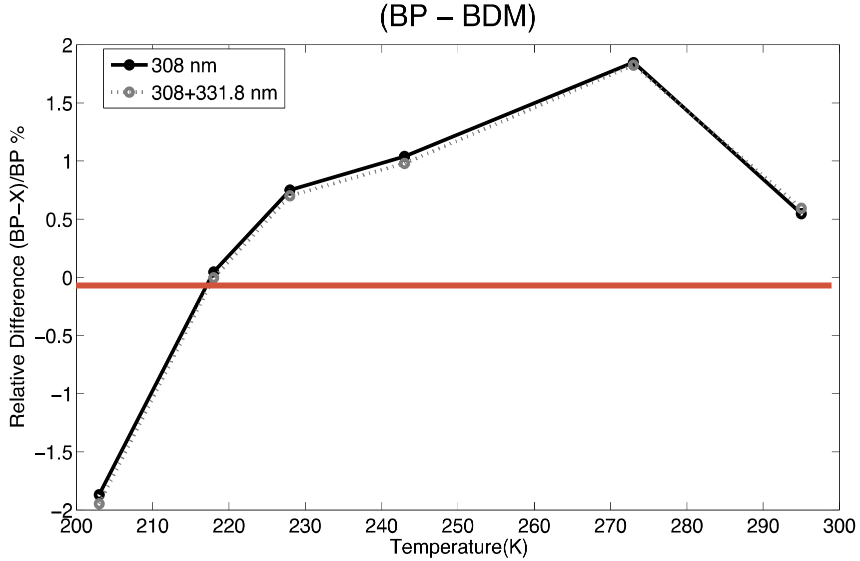
At 308 nm

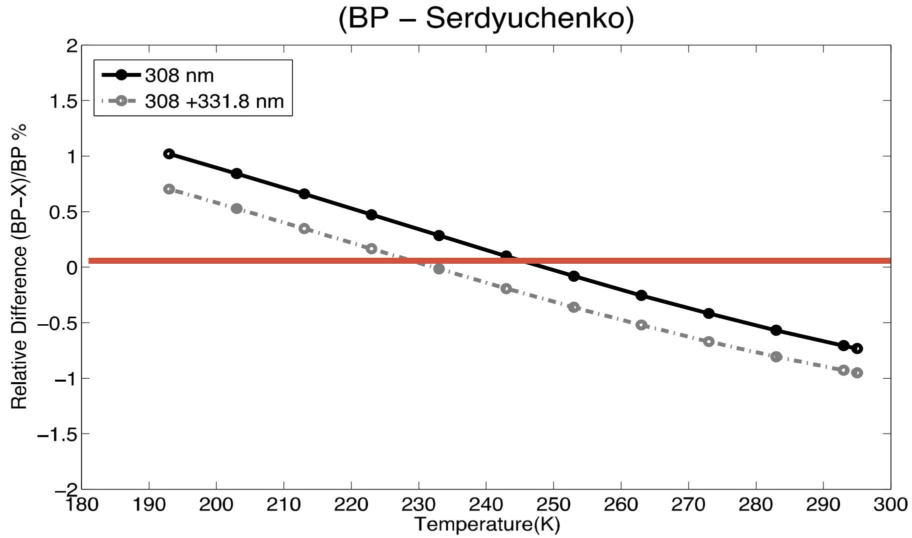
	BP-BDM	BP-Serdyuchenko	BP- Average Serdyuchenko
Min	-1.9% at 203 K	-1.7% at 253 K	0.7% at 203 K
Max	1.9% at 273K	1.9% at 233 K	1.2% at 233 K

- Stronger amplitude of the difference with BDM
- Strong impact of the Serdyuchenko noise in the relative ozone difference

Effect of a change of X-sections on ozone
Bass and Paur used as the reference

Reduction of the noise : An order 2 polynomial fit applied on Serdyuchenko sections



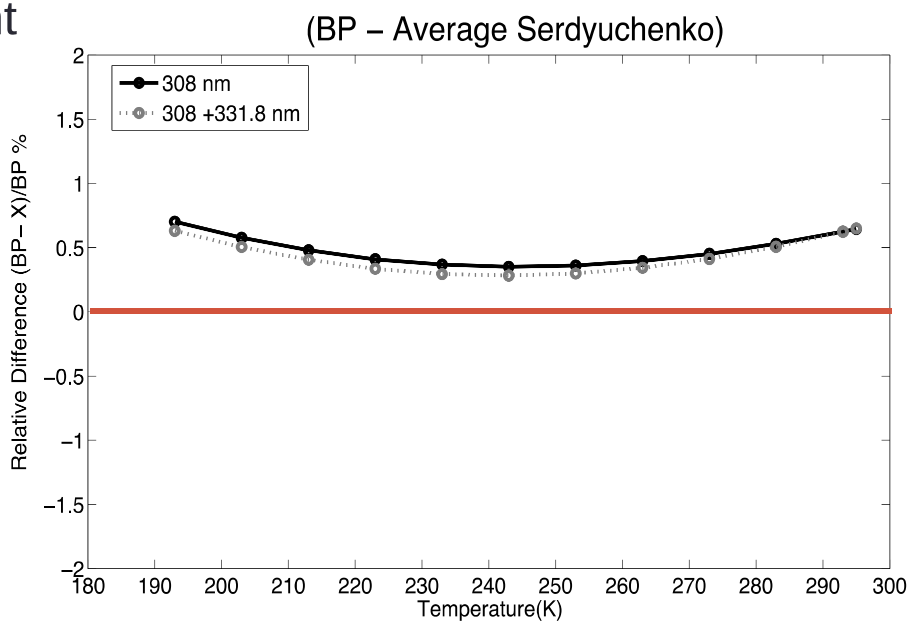


Impact on the X-sections still more important on the rayleigh channel (308 nm)

At 308 nm

	BP-BDM	BP-Serdyuchenko	BP- Average Serdyuchenko
Min	-1.9% at 203 K	-0.7% at 295 K	0.3% at 243 K
Max	1.9% at 273K	1% at 193 K	0.7% at 193 K

- Stronger amplitude of the difference with BDM
- Reduction of the Serdyuchenko noise



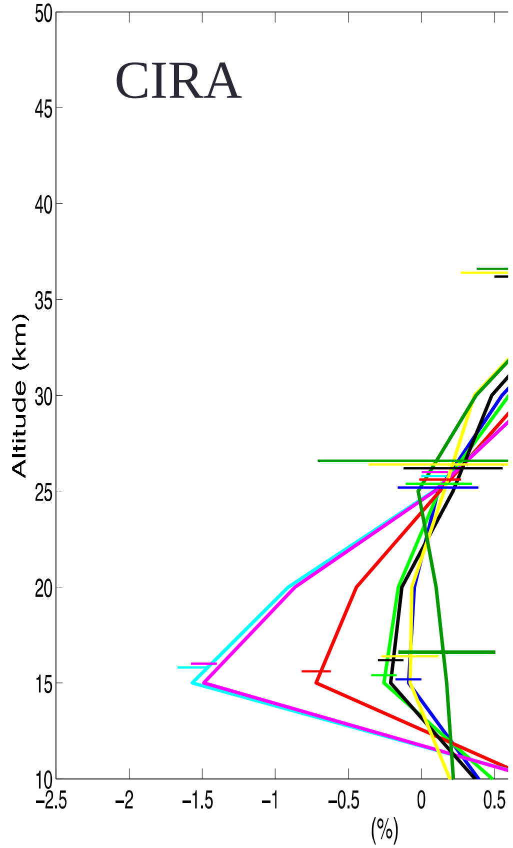
Relative ozone difference **(BP - BDM)** using different temperature models at NDACC lidar latitudes

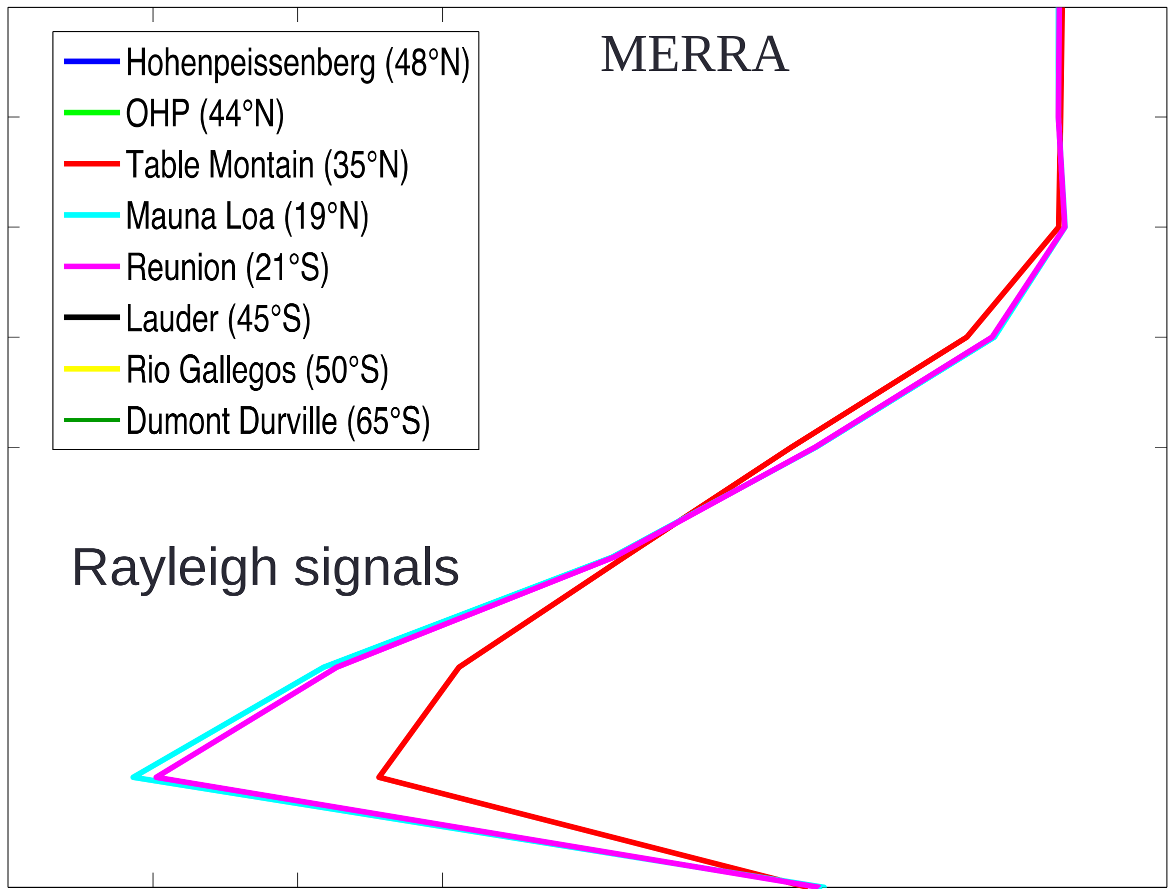
Temperature models

CIRA : altitude from 0 to 80 km (16 levels), spatial : 10° , mean zonal

MERRA : altitude from 1000 to 0.1 hPa (42 levels), spatial : 1.25° x1.25°

Error bars = annual variations

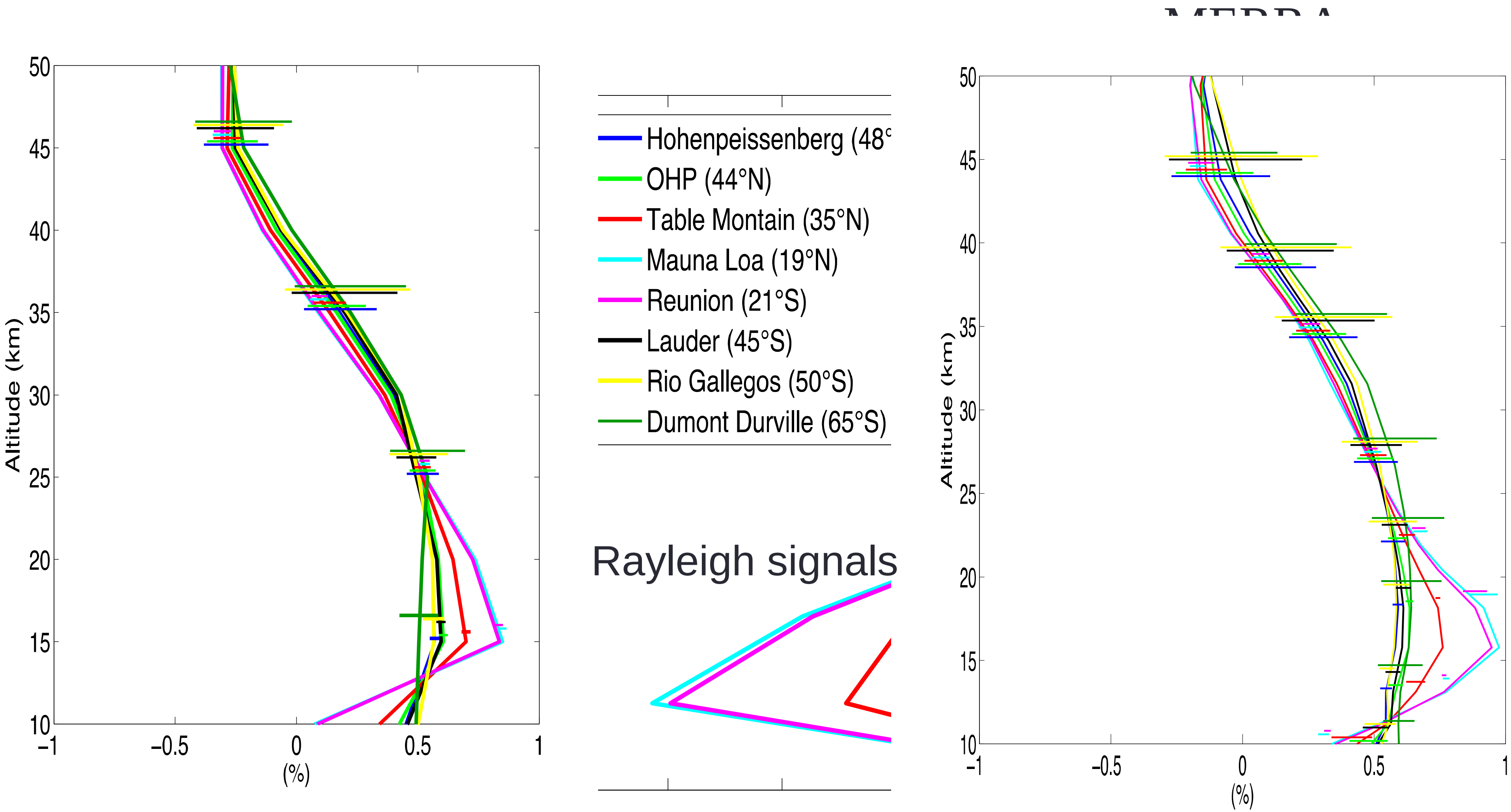




In the tropics and Table M

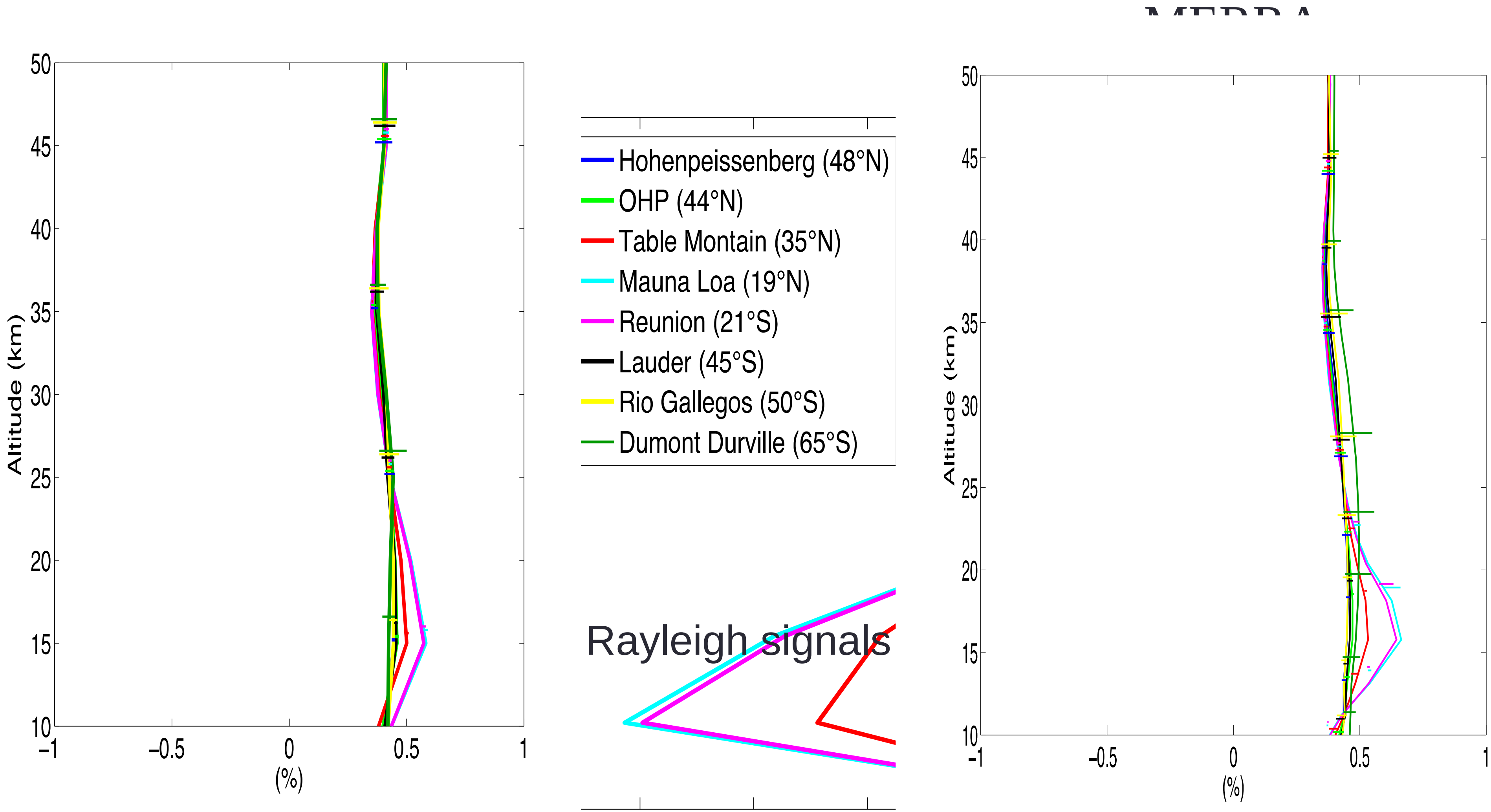
Other stations : simil

Relative ozone difference **(BP – Serdyuchenko)** using temperature models at various lidar NDACC latitude bands



At each stations (except in the tropics) : similar variation for both T models
In the tropics: max bias at ~ 15 km, more pronounced with MERRA (~ 0.9 %)

Relative in ozone difference **(BP – Average Serdyuchenko)** using temperature models at various lidar NDACC latitude bands



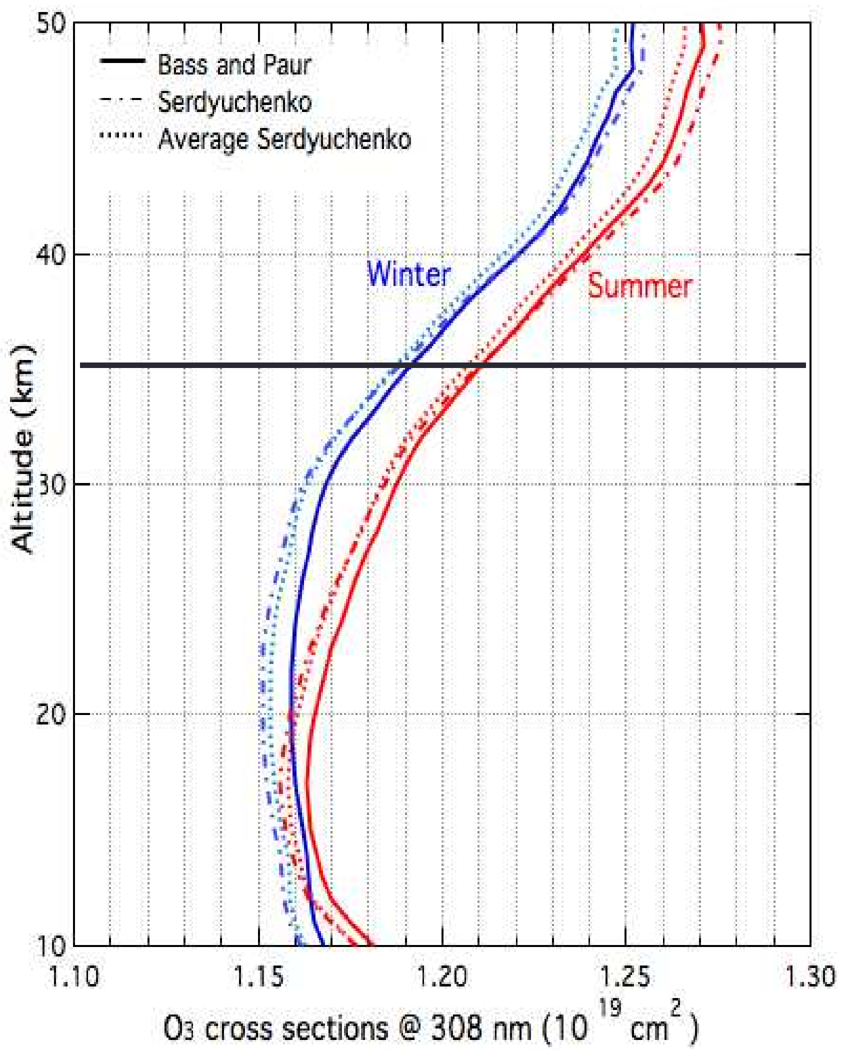
At each stations (except in the tropics) : constant bias (~ 0.5 %) for both T models
In the tropics: max bias at 15 km, more pronounced with MERRA (~ 0.6 %)

Variation of $\sigma_{o3}(\lambda)$ with temperature and altitude at OHP

<u>Temperature data used:</u>

meteorological radiosoundings (10 to 25 km)

climatological model: NCEP(25 to 40 km) + CIRA (40 to 60 km)



For each cross sections : Sensitivity at 308 nm ~ 0.2%/K

<u>From 10 to 35 km:</u>

Both Serdyuchenko sections: Similar variations smaller than Bass and Paur

<u>Above 35 km:</u>

Serdyuchenko cross sections at 308 nm: larger than Bass and Paur (0.3%)

Average Serdyuchenko sections: constant bias with Bass and Paur

Conclusions

- Serdyuchenko cross section at 308 nm noisier as a function of temperature than average Serdyuchenko (307.9 -308.2)

- The difference on ozone between BP and BDM in both the classical DIAL retrieval based on elastic scattering and the retrieval based on Raman scattering is below 1.5 % in absolute value from 10 to 30 km.

- The difference on ozone between BP and Serdyuchenko is below 0.5 % in absolute value and around 0.5 % for Averaging Serdyuchenko from 10 to 50 km except in the tropics

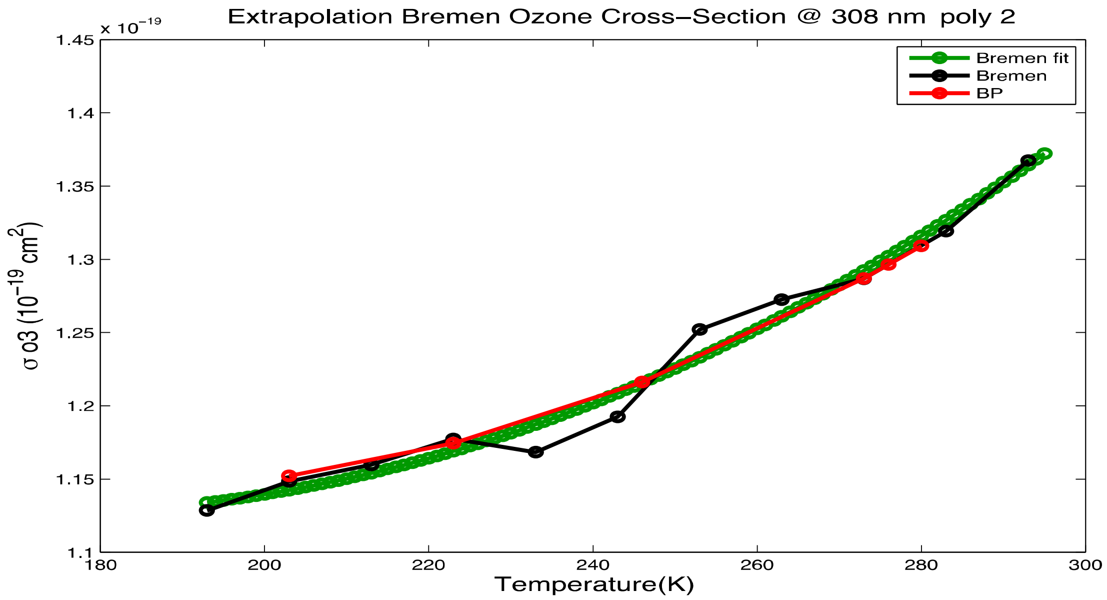
At OHP:

- From the temperature data set used at OHP, each cross sections present an avg sensitivity at 308 nm of ~ 0.2%/K consistent with the literature.

- Above 30 km, the difference estimated between Bass and Paur and Serdyuchenko on the O_3 profils can reach a maximum of 0.3% .

- The used of the fit average Serdyuchenko cross section can be considered for the Lidar at OHP.

Extrapolation Bremen (308 nm)



Extrapolation AVG bremen (307.9-308.2)