Ozone absorption cross-section in ozone lidar algorithm

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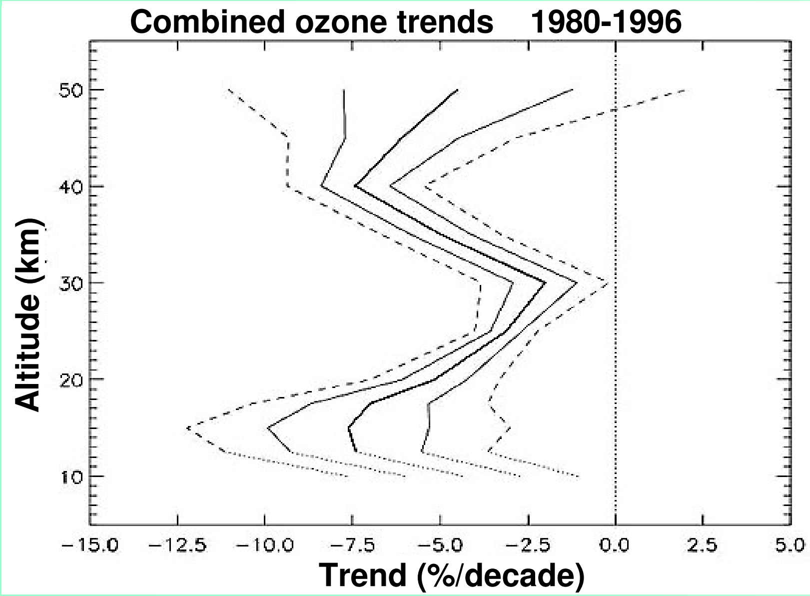
Main ground-based instruments for ozone profile measurements

- Ozone sondes (GAW, NDACC)
  - Balloon borne in situ chemical sondes
  - 0 – 30 km, best 0 – 25 km – high resolution
- Lidar (NDACC)
  - Active remote sensing, DIAL method
  - Strato: 10 – 50 km, best: 15 – 45 km – high resolution in the low-middle stratosphere
- Microwave (NDACC)
  - Passive remote sensing of ozone emission line in the microwave frequency range
  - Range: 20 – 60 km - Low resolution
- Umkehr: Dobson or Brewer spectrometers (GAW)
  - zenith sky observations at high solar zenith angle
  - Best range 20 – 45 km : Umkehr layers – Low resolution

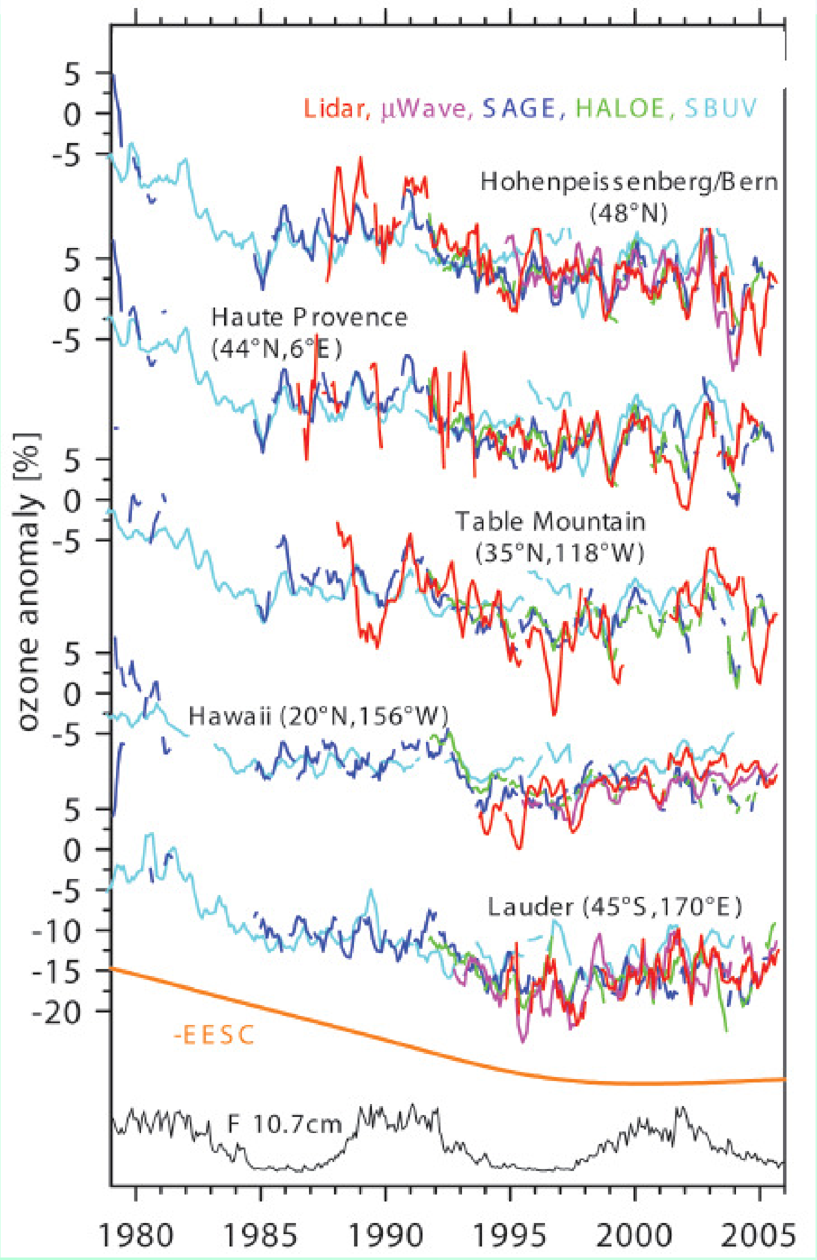
Importance of monitoring ozone in the high stratosphere

stratospheric ozone recovery

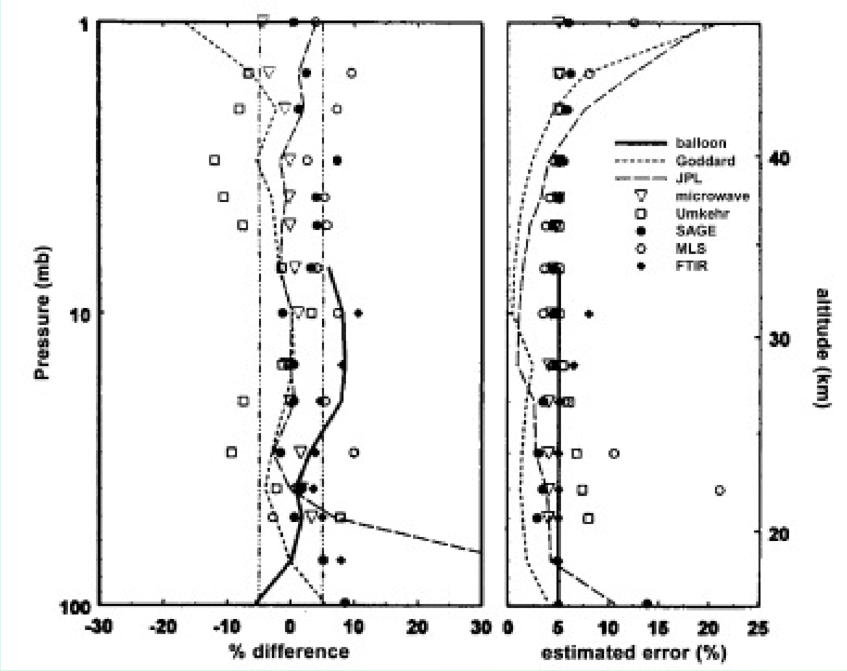


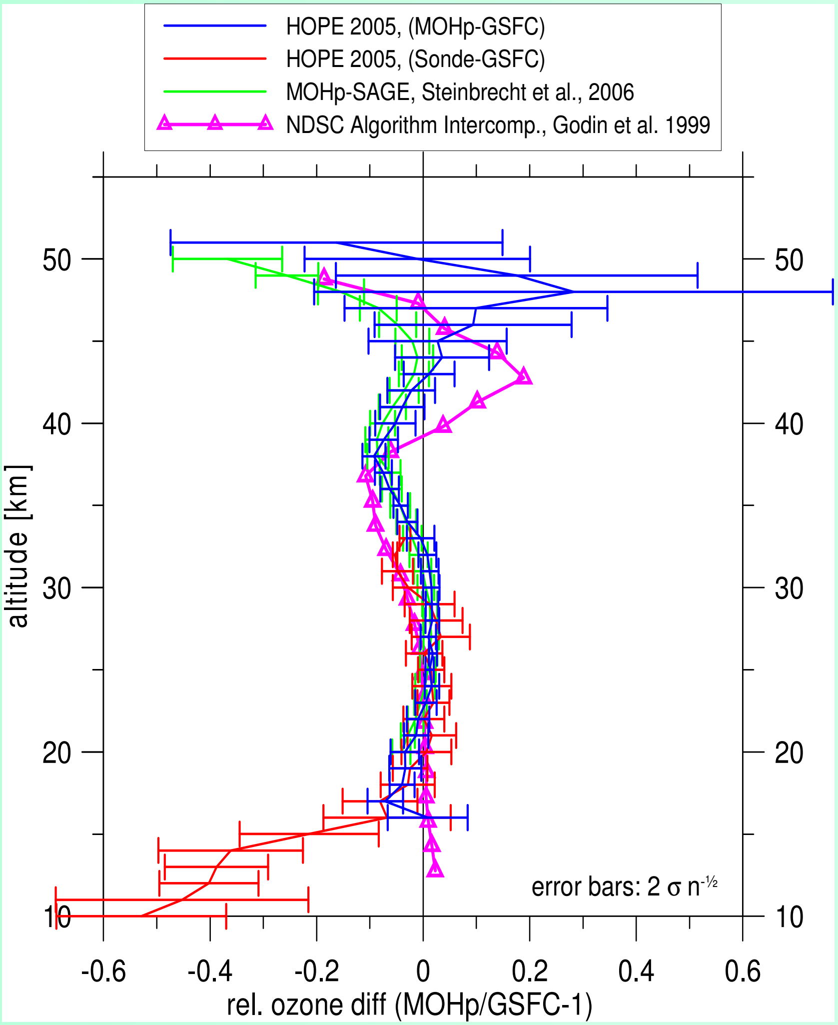
Ozone evolution at 35-45 km altitude range from various lidar measurements time series

Steinbrecht et al., 2006; 2008



Intercomparisons within NDACC



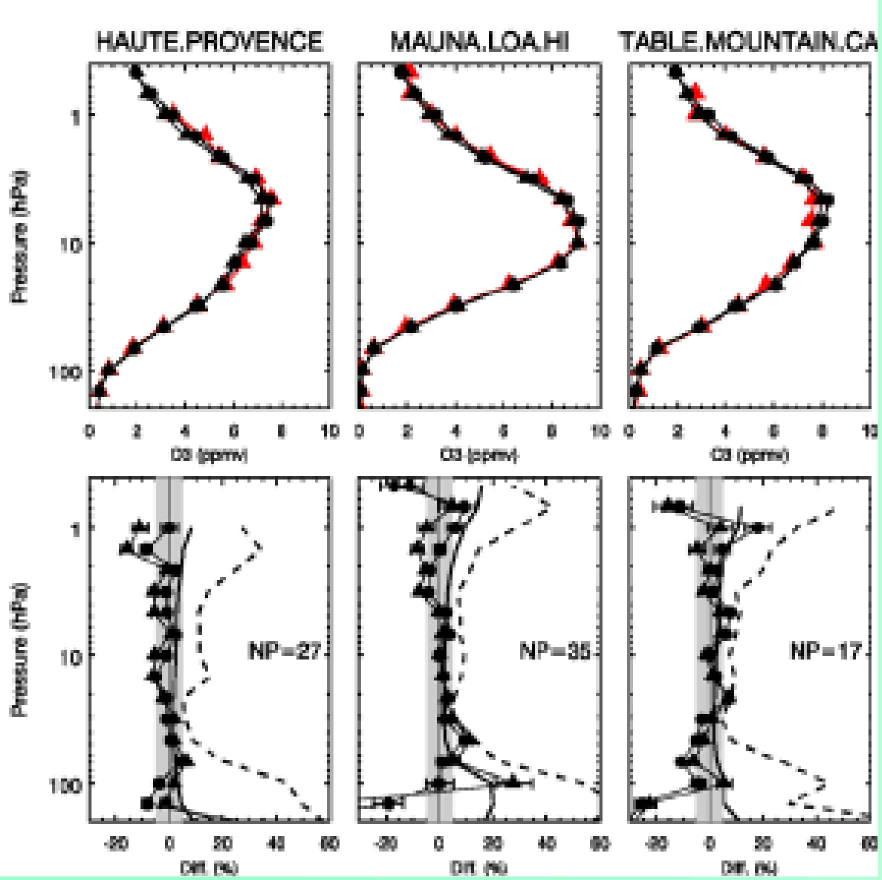


Numerous campaigns involving several lidars, sondes, microwave spect., satellites (SAGE, HALOE, …)

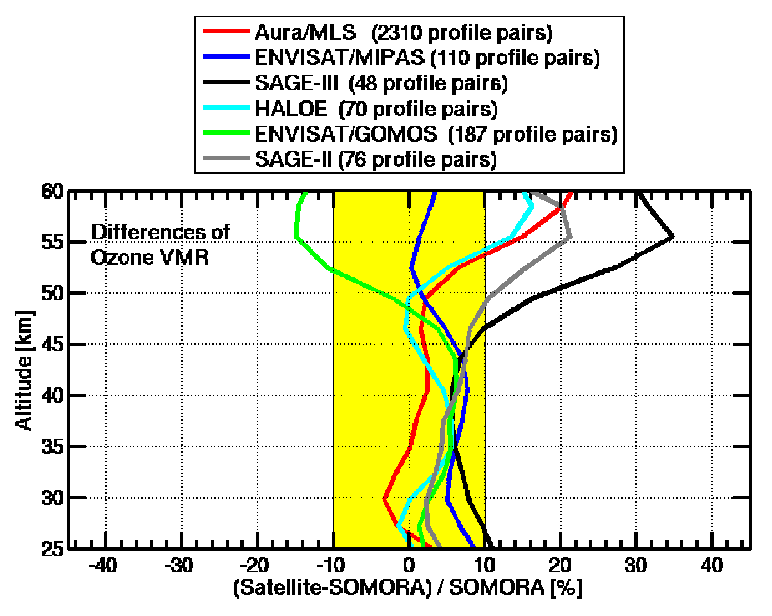
Best agreement in 20 – 40 km range

Satellite validation

- NDACC strongly involved in satellite validation
- Provides intercalibration of successive satellite missions



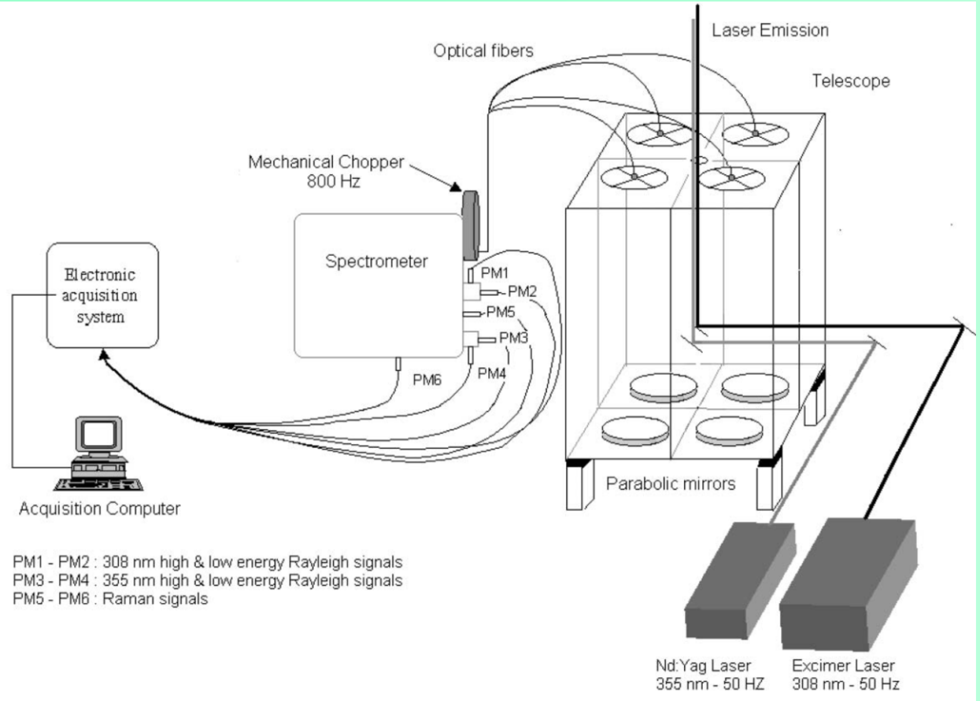
AURA validation



SOMORA microwave spectrometer (Switzerland)

Principle of lidar ozone measurement

DIAL Method : DIfferential Absorption Lidar



Common wavelengths pairs used:
stratospheric systems: 308, 351-355 nm
Tropospheric: 266, 289, 299, 316 nm

- ✓ Emission of 2 laser beams in the UV range ($\lambda_{on,}$, λ_{off})
- ✓ Different ozone absorption cross-section
- ✓ Pulsed laser sources: range resolved measurement
- ✓ Large dynamic of the lidar signals: several acquisition channels
- ✓ N_2 Raman wavelengths: volcanic aerosols
- ✓ Self calibrated measurement

Retrieval of ozone number density

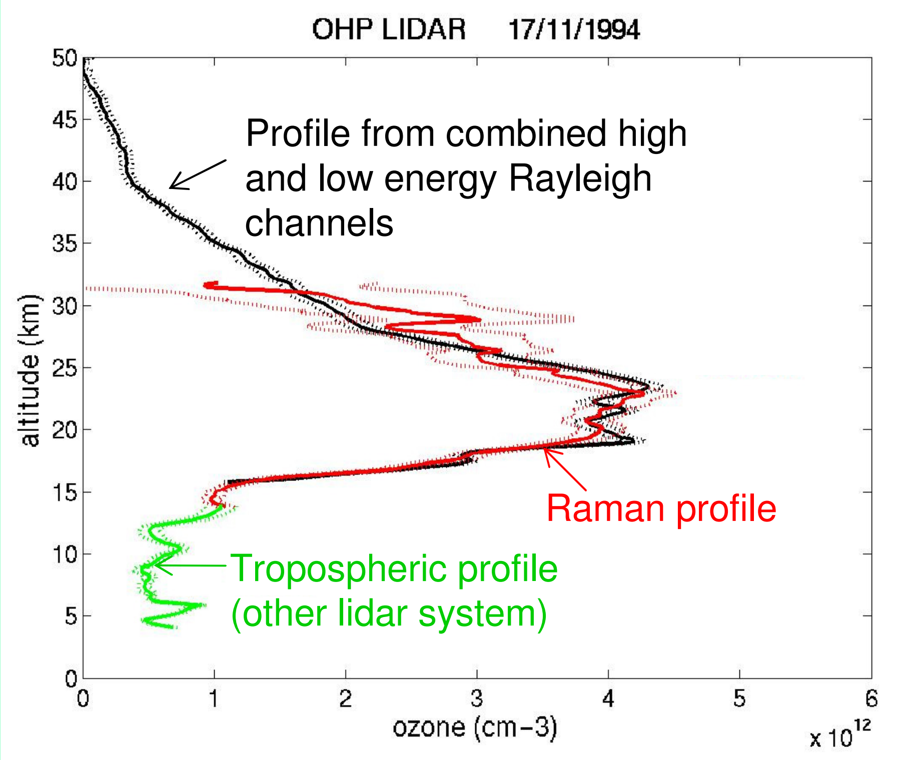
DIAL Method : DIfferential Absorption Lidar

$$n_{O_3}(z) = -\frac{1}{2\,\underbrace{\boxed{\Delta\sigma_{O_3}(z)}}_{\substack{\textbf{Differential ozone}\\ \textbf{absorption cross-section}\\ \sigma_{O_3}(\lambda_{on},z)-\sigma_{O_3}(\lambda_{off},z)}}}\frac{d}{dz}Ln\left(\frac{S(\lambda_{on},z)-S_b(\lambda_{on},z)}{\underbrace{S(\lambda_{off},z)}_{\textbf{lidar signal}}-\underbrace{S_b(\lambda_{off},z)}_{\textbf{background}}}\right)+\underbrace{\delta n_{O_3}(z)}_{\substack{\textbf{correction}\\ \textbf{term}}}$$

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

$$\delta n_{O_3}(z) = \frac{1}{\Delta\sigma_{O_3}(z)}\left[\frac{1}{2}\frac{d}{dz}Ln\underbrace{\left(\frac{\beta(\lambda_{on},z)}{\beta(\lambda_{off},z)}\right)}_{\substack{\textbf{backscatter}\\ \textbf{Rayleigh \& Mie}}}-\underset{\substack{\textbf{extinction}\\ \textbf{Rayleigh \& Mie}}}{\Delta\alpha(z)}-\underbrace{\sum_i \Delta\sigma_i n_i(z)}_{\substack{\textbf{Extinction by}\\ \textbf{other species}}}\right]$$

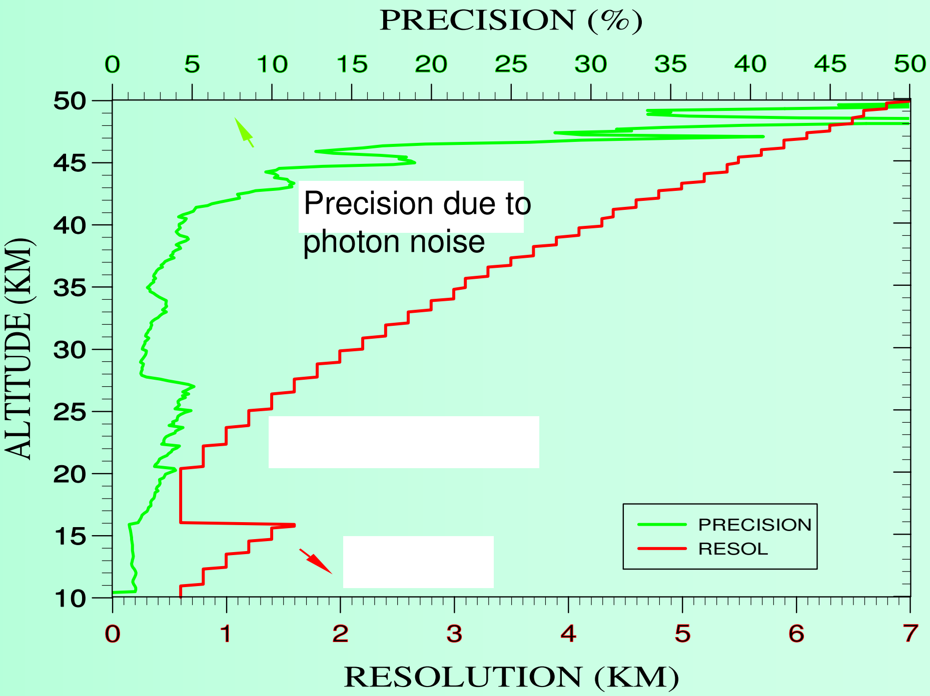
Example of DIAL ozone profile



Profile from combined high and low energy Rayleigh channels

Raman profile

Tropospheric profile (other lidar system)



Precision due to photon noise

- **Ozone measurements performed during the night**

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

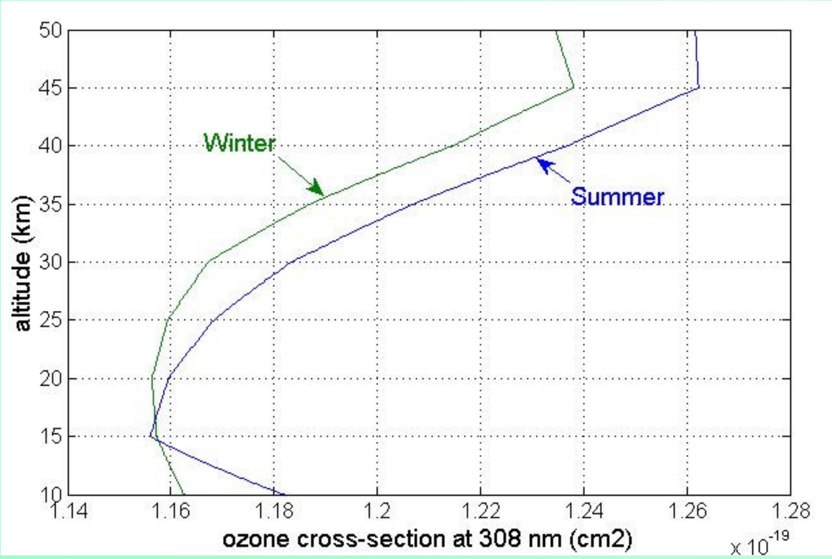
- **Require clear skies**

Ozone absorption cross-sections

- Evaluation of $\sigma_{o3}(\lambda)$ at emitted laser (308 nm & 355 nm) and 1st Stokes N_2 Raman wavelengths (332 nm & 387 nm)
- Variation of $\sigma_{o3}(\lambda)$ with temperature T taken into account :
  ⇨ $\sigma_{o3}(\lambda)$ varies with altitude

$\sigma_{o3}(\lambda)$ variation with temperature (from Bass & Paur)

$$\sigma_{O_3}(\lambda, z) = (a + b.(T - 273.15) + c.(T - 273.15)^2)^{20} \text{ cm}^2$$

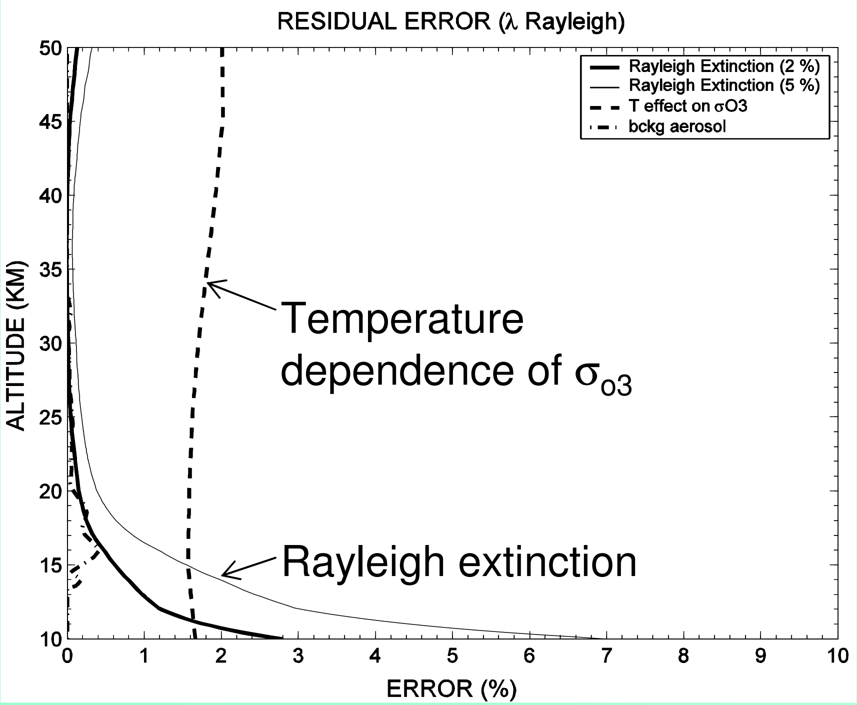


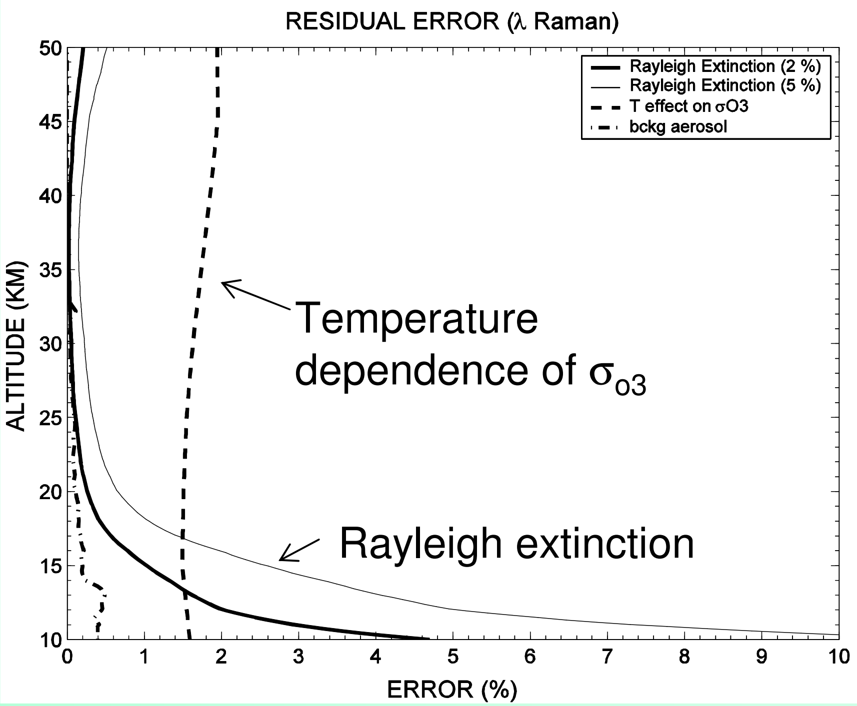
Sensitivity at 308 nm~ 0.2%/K

Temperature data from
- **off-wavelength lidar signal**
- **meteorological analyses**
- **climatological model**

Accuracy of DIAL ozone profiles

Residual error after correction of δno3 (not including the photon noise)





- Atmospheric number density 5% error
- 1.5 % precision in ozone cross-section, Temperature : error of 5 K

Above ~15-20km, residual error dominated by error on σo3(λ,z)

Conclusions

- DIAL ozone retrieval requires determination of ozone cross-sections in the range 266 nm – 332 nm, with accurate temperature dependence.
- Correct evaluation of ozone cross-section temperature dependence important for ozone trends evaluation, taking into account temperature trends in the stratosphere.
- At present, most lidar groups within NDACC use Bass & Paur ozone cross-sections but DIAL ozone measurements can easily be re-computed from archived raw data in case of change in recommended ozone cross-section.