Observation requirements

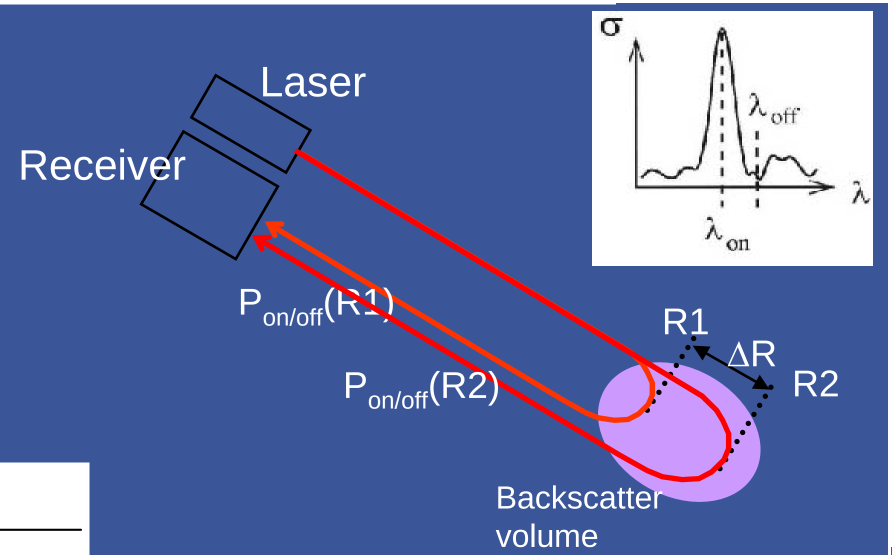
	CO_2	CH_4	N_2O
Vertical sampling	Planetary Boundary layer		
Height assignment	10 m		
Horizontal resolution	50-200km		
Precision	1 ppm	10 ppb	0.1 ppb
Temporal resolution	Week (revisiting time)		

Measurement errors shall be minimized and in particular regional dependency or temporally instability of biases shall be less than 0.1ppm. This additional constraint has been considered in the instrument driving requirements.

Observation principle

Different classes of lidar instruments :

- Range Resolved DIAL
- Integrated Path Differential Absorption
- Continuous Wave Laser measurement



$$\overline{\rho}(R_1,R_2)=\frac{\tau(R_1,R_2)}{\int_{R_1}^{R_2} n_a(R)\left(\tilde{\sigma}_{on}(R)-\tilde{\sigma}_{off}(R)\right)dR}$$

⇨ Profiling of the dry air mixing ratio by range-resolved measurements in the planetary boundary layer relying on weak atmospheric backscattering.

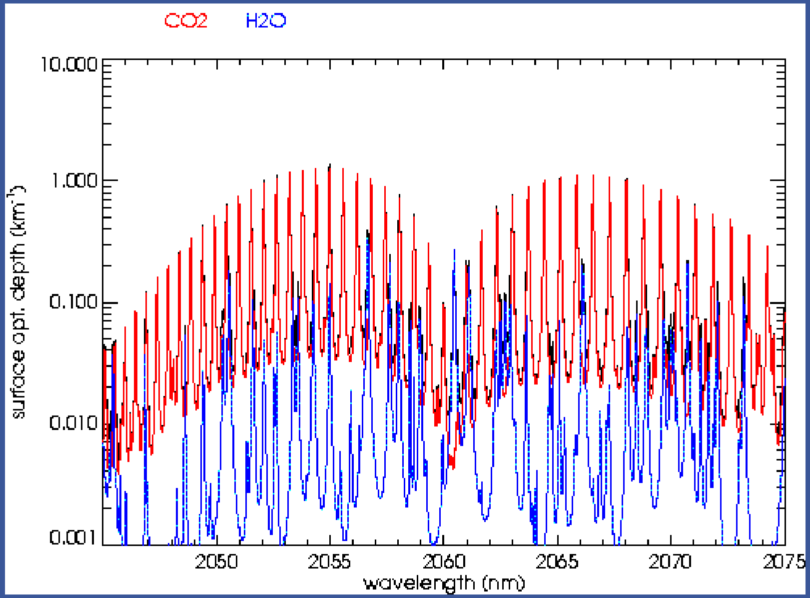
⇨ Monitoring the total column of the dry air mixing ratio.

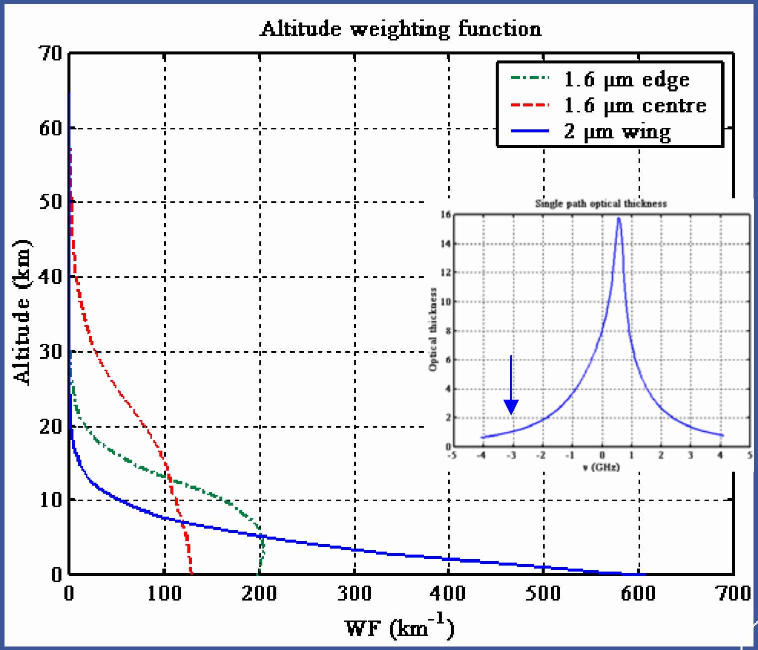
Observation principle

Absorption lines have been identified in 1.6-3.9µm for green house gases minimizing interferences with other trace gases

Oxygen absorption lines at 0.76µm are suitable for temperature and pressure sounding

	CO_2	CH_4	N_2O	O3	P/T
Absorption lines spectral position	1.6/2.05µm	2.3µm	3.9µm	0.31 µm	0.76 µm





esa

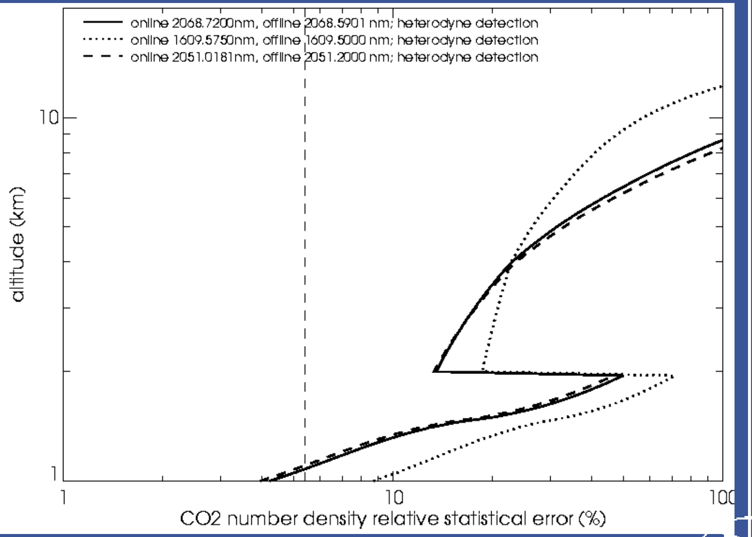
Lidar performance assessment

Green House Gases

- A DIAL providing full vertical concentration profiles proves to be too demanding (250Wm^2) with limited added value with respect to other measurement concepts

- Integrated Path Differential Absorption gives reasonable instrument size for both CO_2 and CH_4.

- Continuous Wave Laser appears very attractive (small instrument) but has inherent drawback : no range information to derive surface pressure, possible contamination by aerosols.



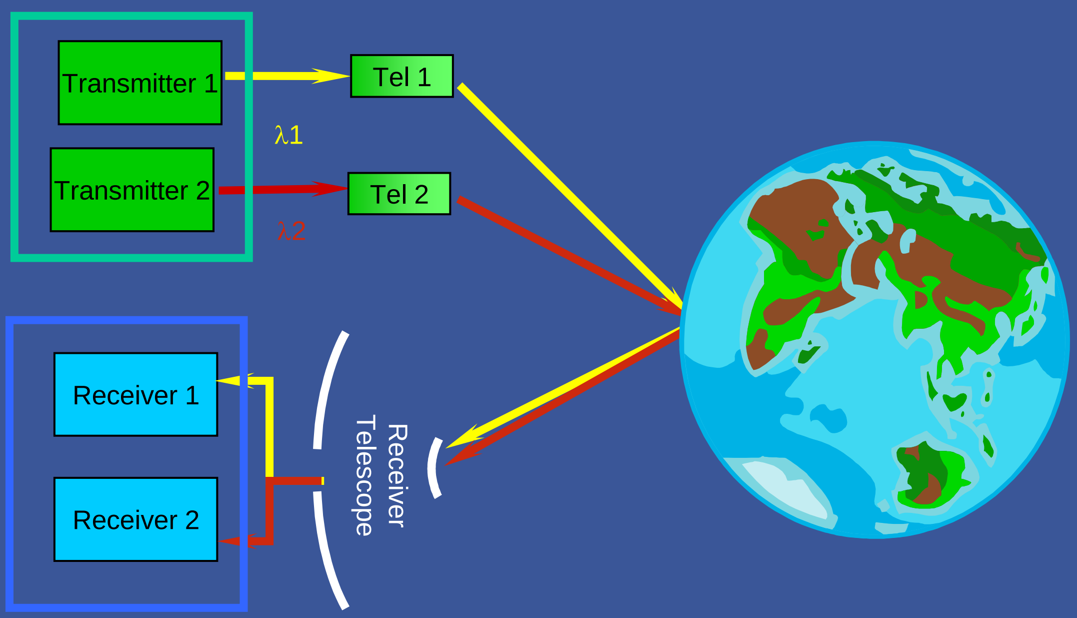
Power aperture product (W.m^2)	Wavelength	DIAL	IPDA	CWLAS
CO2	1.6/2.1 µm	250	7	~1
CH4	2.3 µm	100	2	0.3
N2O	3.9 µm	Too large	Too large	>10

Instrument overview

Instrument definition focussed on CO_2 application : high scientific priority, reasonable instrument size.

Both 1.6 and 2µm wavelength range have been considered: However, 1.6µm weighting functions are less pronounced close to the ground (maximum around 10km altitude).

Pulsed and continuous modes have been further assessed.



Laser sub-system

Wavelength range	1.58 µm or 2.05 µm
Beam quality	$M^2 < 2$
Emitted optical power	~ 2-4 W (for 2 wavelengths)
Laser frequency stability	< 1 MHz
Laser linewidth	<60 MHz with a knowledge <6MHz
Laser spectral purity	**>99.98 %**

•In a pulsed integrated path differential absorption measurement, the spectral requirement are very demanding, especially the spectral purity.

•Using heterodyne detection relaxes the spectral purity requirement. This was considered in CW system. However laser spectral stability of 10kHz are required.

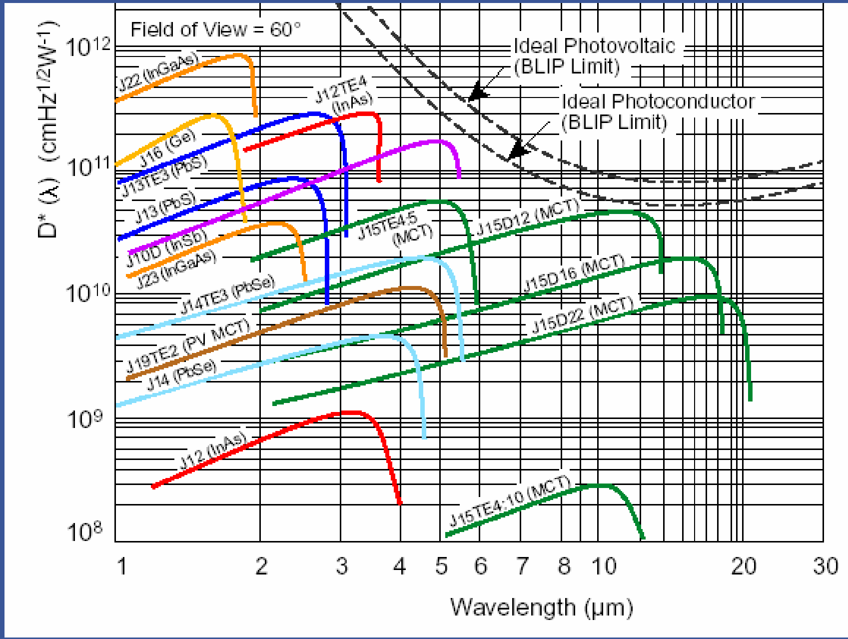
Receiver sub-system

The receiver is made of three main elements:

- A 1m-diameter class telescope
- An optical filtering (not needed in heterodyne detection)
- A detector operating in low signal levels, requiring an amplification stage

The availiblity of suitable detector performance is the main issue

	Performance
Quantum efficiency/F	> 0.2
Gain	10-100
Noise equivalent power (fW/√Hz)	< 50
Detectivity (cm.√Hz/W)	> 4. 10^{11}



Most promising instrument concepts

Most promising instrument concepts are building on the availability of technologies and on the criticality of the concept with respect to potential biases.

1-Pulsed IPDA associated with a direct detection receiver is a well-developed technique, both 1.6 and 2 µm were recommended. 2µm more favourable because of the weighting function:

- High spectral requirements for the transmitter, development needed
- Low noise detector, development needed

2- Continuous Wave Laser measurement would require a smaller instrument:

- Less sensitive to the transmitter performance
- Associated with heterodyne detection does not require high performance detection
- A modulation can be added to provide the range information necessary to get the altitude and surface pressure knowledge

Systematic errors

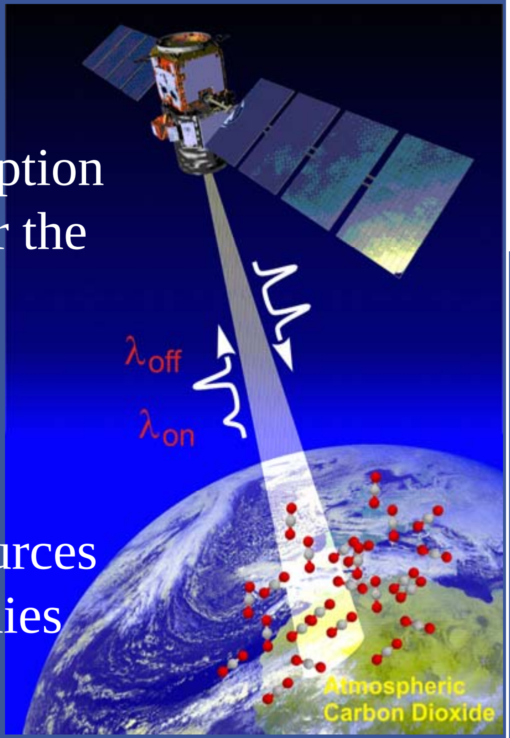
A global bias or systematic error is not be a problem as it might be corrected using other data or sensors.

On the contrary, regional or temporal dependent systematic errors would induce large retrieval errors on CO_2 fluxes and have to be minimised.

Error source	**Expected Bias [ppm]**	**Assumption/Uncertainty**
Path length	0.08	3 m
Surface pressure	0.2	0.5 hPa
H2O mixing ratio	0.08	5% in the tropics
Laser Frequency drift	0.1	0.3 MHz
Laser Spectral purity	0.08	99.9% with 2 GHz filter
Rel. detection channel calibration (on-,off-line)	0.1	10^{-4}accuracy
Error budget	**0.28**	

Conclusion

Monitoring of CO_2 and CH_4 are of high scientific relevance because they are the most important greenhouse gases also banned by international conventions



Active remote sensing by Integrated Path Differential Absorption may meet the stringent observational requirements even over the ocean

Instrument size seems reasonable, there are still potential sources of errors that may be difficult to account for. Additional studies will be needed.