ADVANCED BROADBAND DIAL SOUNDER OF METHANE

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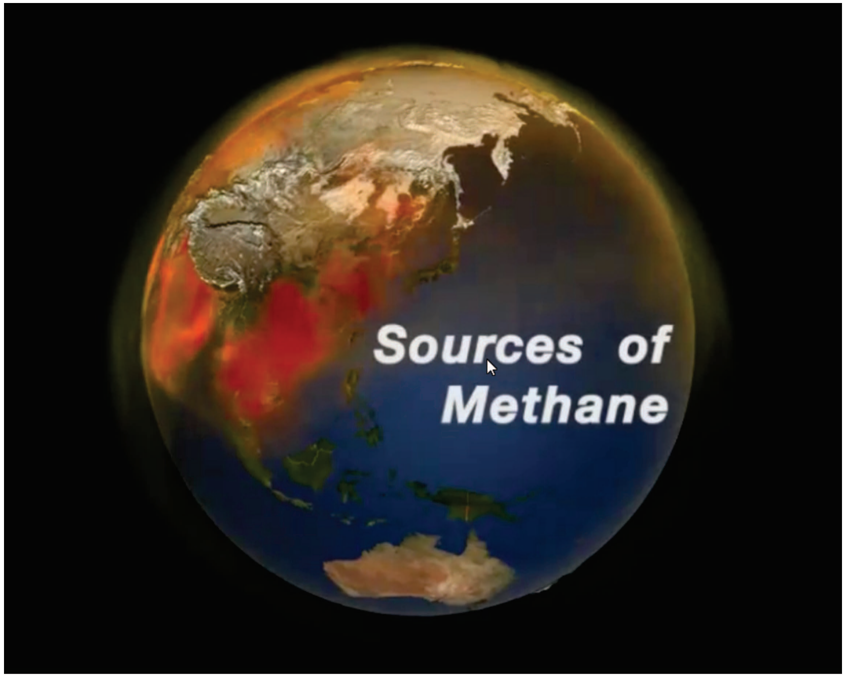
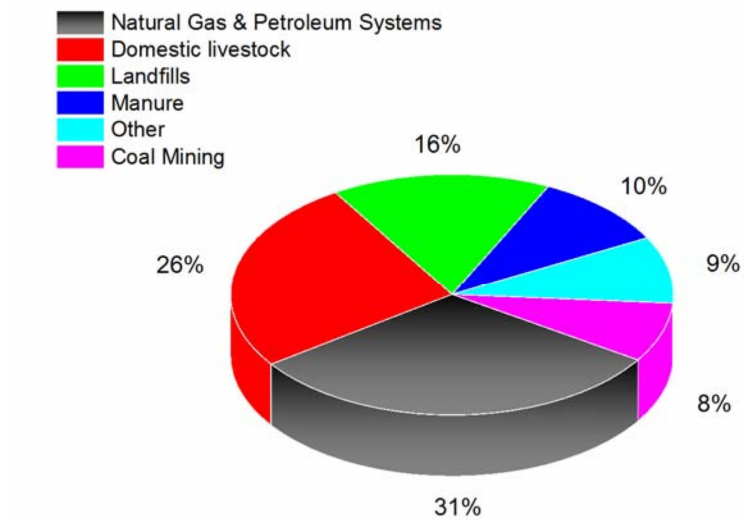
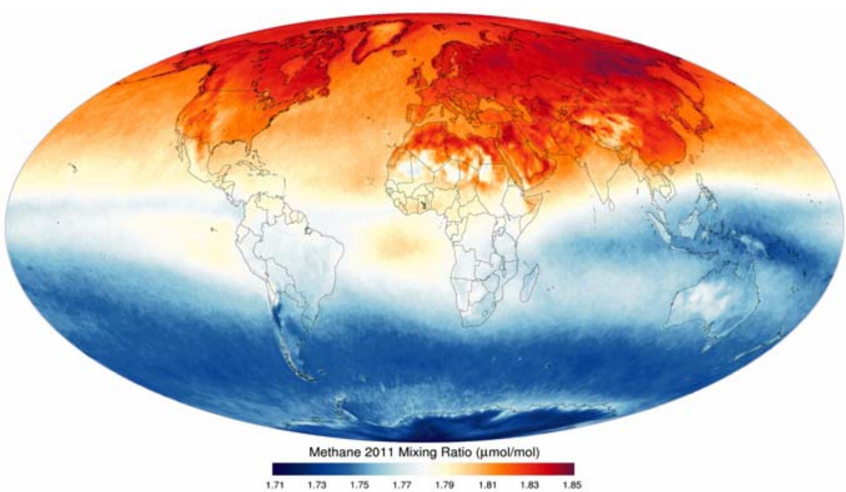
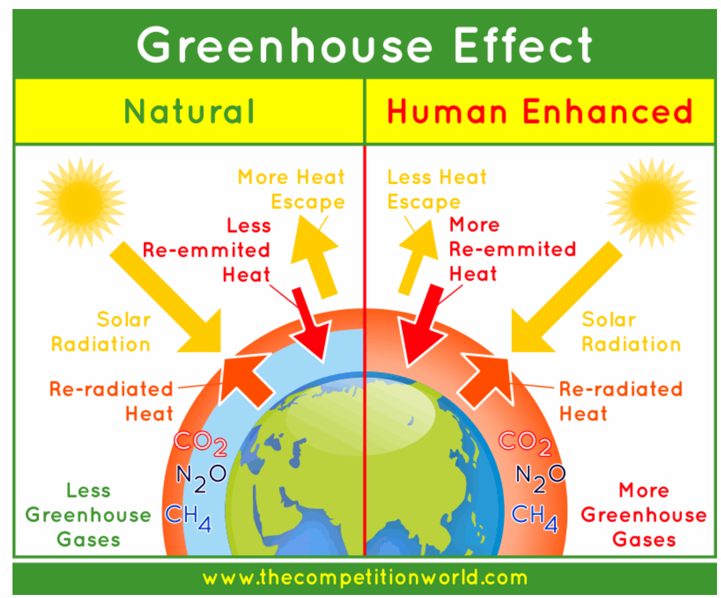
Why methane?


Sources of
Methane


Natural Gas & Petroleum Systems
Domestic livestock
Landfills
Manure
Other
Coal Mining
16%
10%
9%
8%
31%
26%

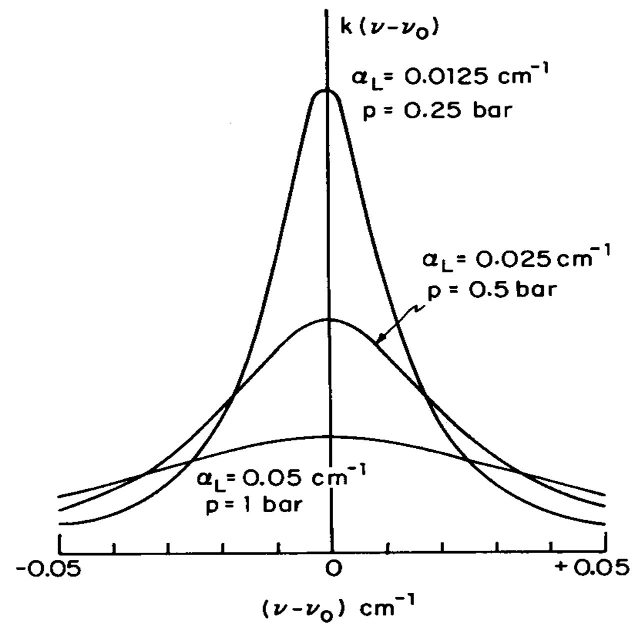

Methane 2011 Mixing Ratio (µmol/mol)
1.71
1.73
1.75
1.77
1.79
1.81
1.83
1.85


Greenhouse Effect
Natural
Human Enhanced
More Heat Escape
Less Re-emmited Heat
Solar Radiation
Re-radiated Heat
CO_2
N_2O
CH_4
Less Greenhouse Gases
Less Heat Escape
More Re-emmited Heat
Solar Radiation
Re-radiated Heat
CO_2
N_2O
CH_4
More Greenhouse Gases
www.thecompetitionworld.com

Infrared Atmospheric Sounding Interfero,eter (IASI)

Geophysical variables	Vertical resolution	Horizontal resolution
Humidity profile	1-2 Km (low Troposphere)	25 Km (cloud free)
CO, CH_4, N_2O	Integrated content	100 Km

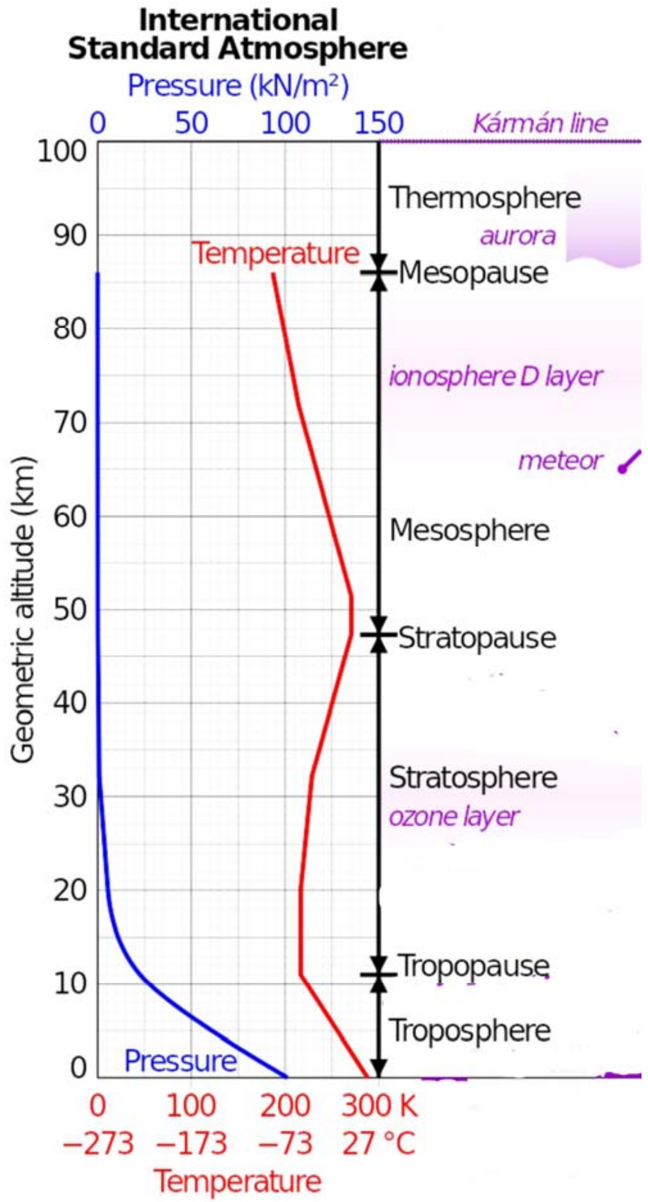
A lidar sounder is advantageous for retrieval of range- resolved data of the atmospheric gas GMR. The conventional DIAL signal on dual wavelengths on/off an absorption line is replaced by the ratio of confined, integral absorption bands. The result depends on the absorption linestrength instead of the line amplitude subjected to pressure- broadening



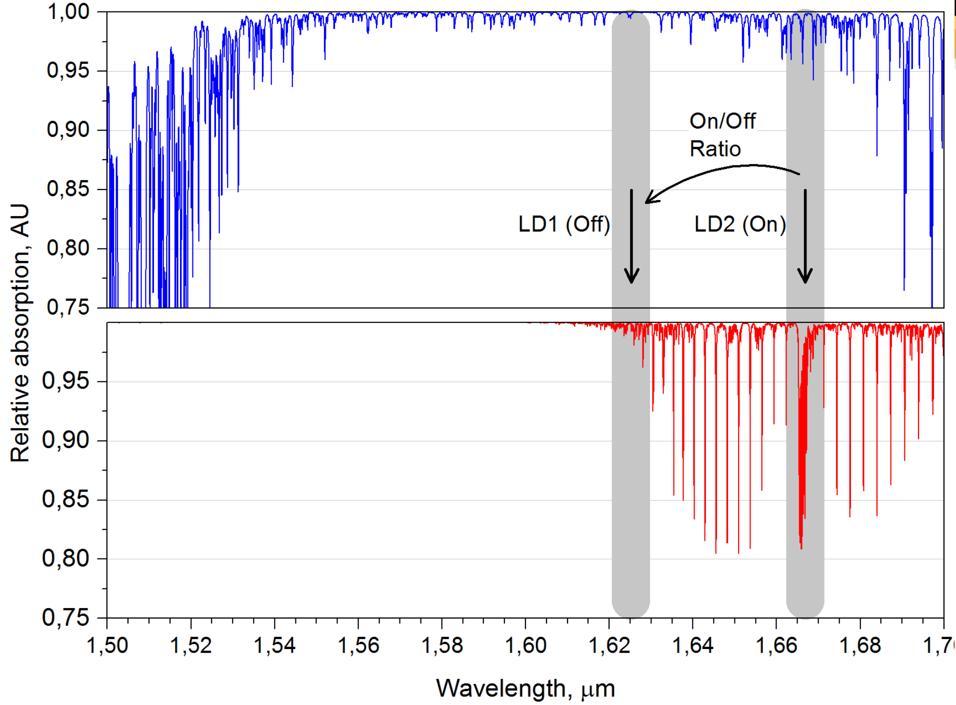
Barometric formula approximation

$$P = P_b \exp\left[\frac{-g_0 M\left(h - h_b\right)}{R^* T_b}\right]$$

P_b reference pressure [Pa]
T_b reference temperature [K]
h height [m]
h_b reference height [m]
R^* universal gas constant 8.3 [J.mol^{-1}K^{-1}]
g_0 gravitational constant 9.8 [m.s^{-2}]
M molar mass of air 0.029 [kg.mol$_{-1}$]



Broadband CH4 DIAL on powerful LD



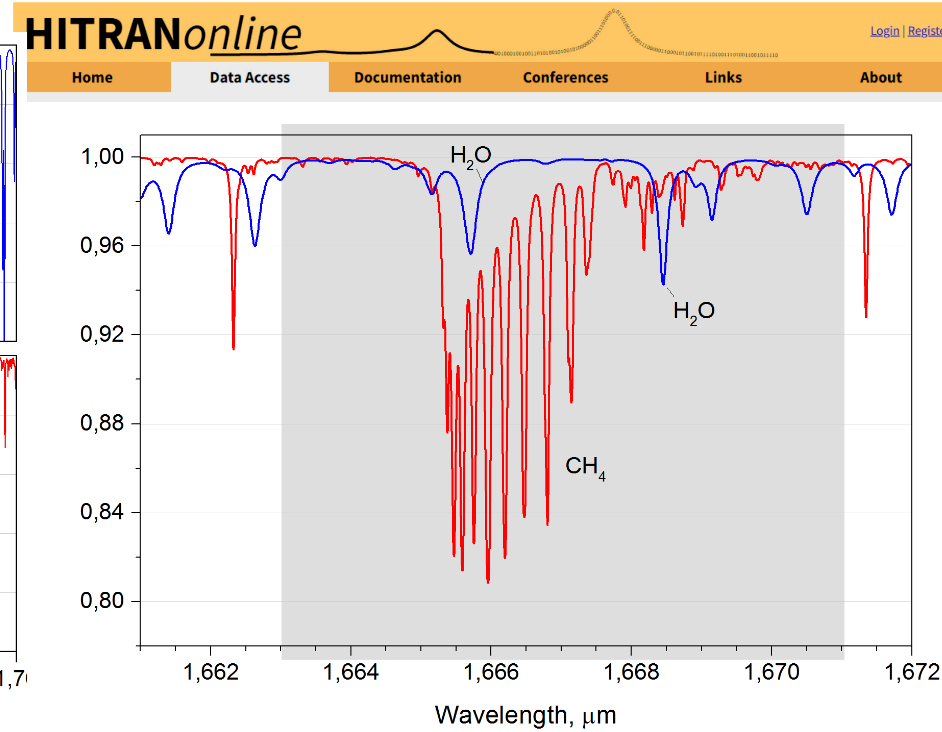


Fig.1 Differential absorption bands (vertical bars) of 8nm linewidth centered at 1.625µm and 1.667µm wavelengths matching CH_4 (red) and H_2O (blue) spectra

Fig.2 Scaled - up spectrum confined around 1.667µm wavelength

[1] Penchev S. et.al. (2012). Comptes rendus de l'Académie bulgare des Sciences, 65, 669-674.
[2] Thomas B. et.al. (2013), Applied Physics B, 113, 265– 75.

Multiplexation of DIAL signal

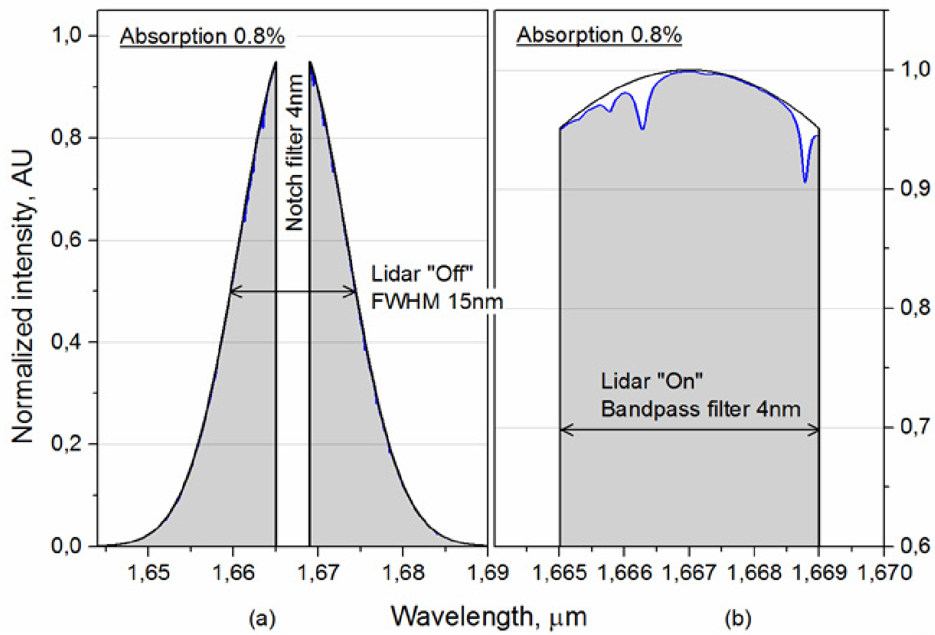


Fig.3 Multiplexed laser line of 1.667μm wavelength modulated by H_2O spectrum of 10gm^{-3} GMR on 1.5km lidar path: (a) "Off" band formed by a notch filter; (b) "On" band formed by a bandpass filter (scaled up along x-axis)

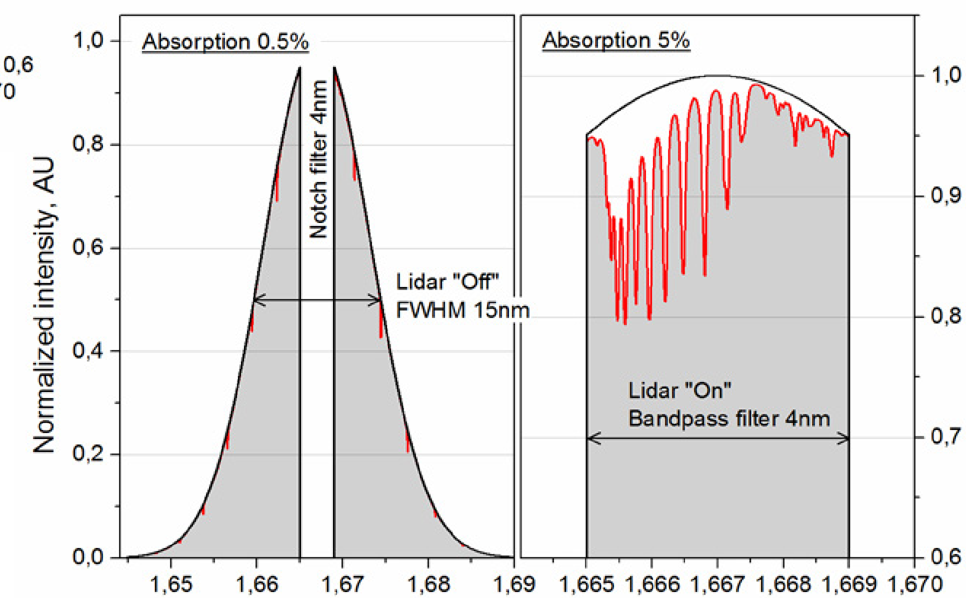


Fig.4 Multiplexed laser line as on the previous Figure 3 modulated by CH_4 spectrum of 10ppm GMR

[3] S.Penchev, V.Pencheva, T.Dreischuh, BG Utility model, Reg. № 4239, 2022.

Multiplexation of DIAL signal

Lidar returns of laser frequency ν_0 modulated by multiple absorption lines of frequencies ν_n are given by a convolution integral:

$$C = \int_{\nu} \exp\left[-4\ln 2 \left(\frac{\nu - \nu_0}{\Delta \nu_1} \right)^2 - K \sum_n S_n \frac{\Delta \nu_a^2 / 4}{(\nu - \nu_n)^2 + \Delta \nu_a^2 / 4} \right] d\nu$$

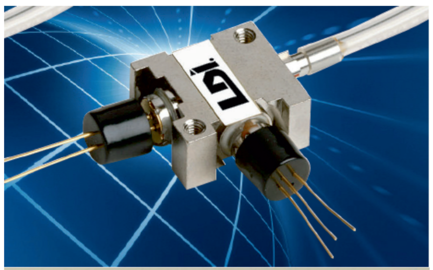
For weak absorption, the exponent in Exp.1 is approximated by difference, modulated by step- functions β and (1-β) taking values of unity and zeros:

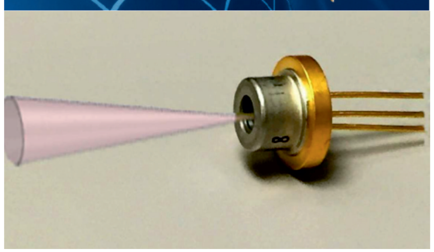
$$I_{\mathrm{DIAL}} = C_{\mathrm{on}} / C_{\mathrm{off}} = \frac{\int_{\nu} \beta f_G \left(1 - K \sum_n f_L \right) \mathrm{d}\nu}{\int_{\nu} (1 - \beta) f_G \mathrm{d}\nu}$$

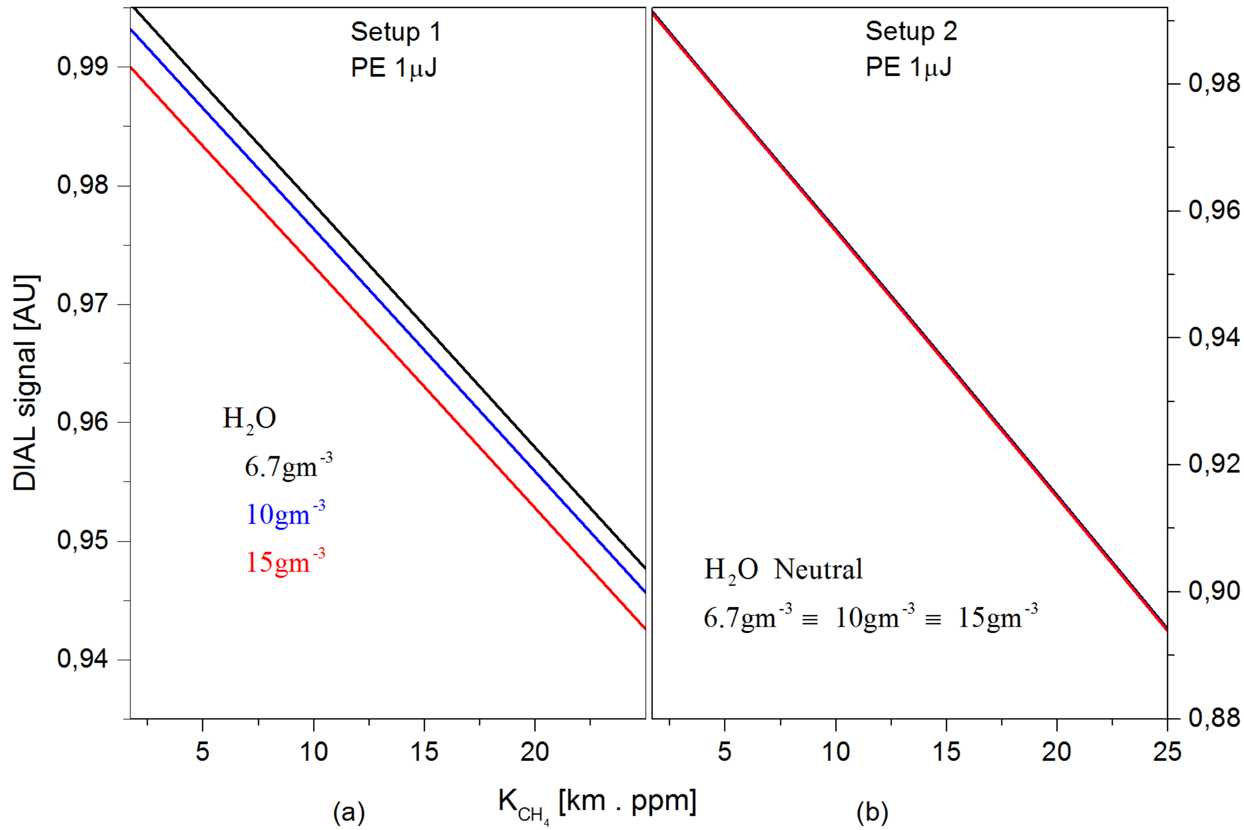
Assuming equal intensities of absorption by water vapor in both spectral channels, results in an expression which depends solely on methane GMR:

- $$I_{\mathrm{DIAL}} \approx 1 - \frac{\int_{\nu} \beta f_G \left(K \sum_n f_L \right)_{CH_4} \mathrm{d}\nu}{\int_{\nu} \beta f_G \mathrm{d}\nu}$$

Validation of absorption function





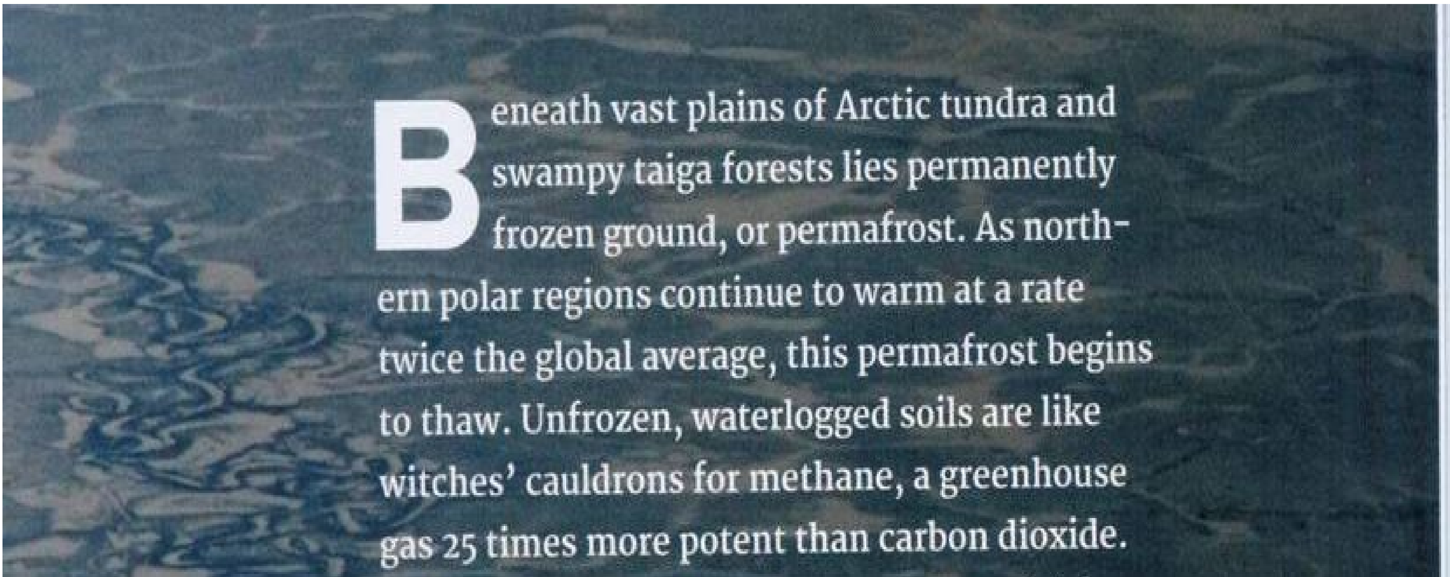


Absorption function for two LD types of 1μJ pulse energy vs. product K of CH_4 GMR and lidar path for different values of humidity:

(a) paired LD of 1.625μm- 1.667μm wavelengths and 8nm linewidth;

(b) multiplexed LD radiation of 1.667μm wavelength and 15nm linewidth

Prospective application



Beneath vast plains of Arctic tundra and swampy taiga forests lies permanently frozen ground, or permafrost. As northern polar regions continue to warm at a rate twice the global average, this permafrost begins to thaw. Unfrozen, waterlogged soils are like witches' cauldrons for methane, a greenhouse gas 25 times more potent than carbon dioxide.

- Diurnal monitoring of greenhouse gases affecting the global climate
- Mobile and airborne surveillance, particularly of inaccessible areas
- On demand safety controll of gas pipeline leaks
- Reconnaisance of energy resources

Q&A