Continuous CO_2/CH_4 measurement at Zotino Tall Tower Observatory (ZOTTO) in Central Siberia

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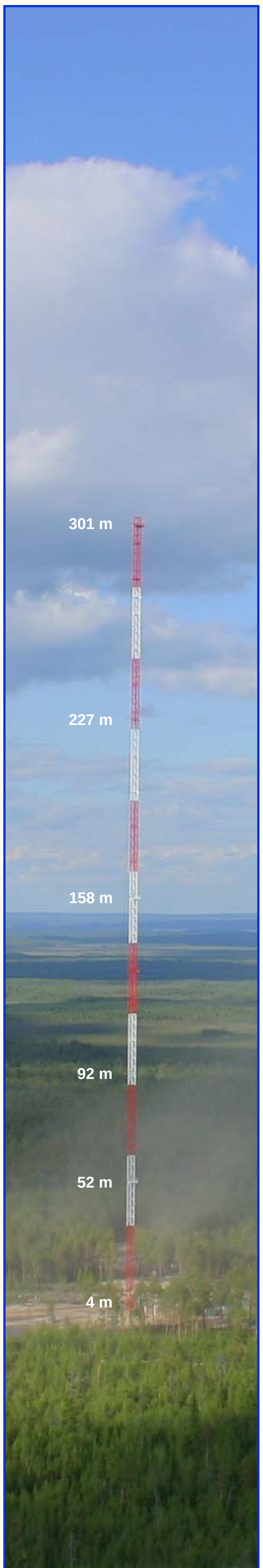


Introduction

In June 2004 the ZOTTO-Project (ZOtino Tall Tower Observatory) led to the construction of a *304 m tall tower* in central Siberia near the village Zotino (60° 75' N, 89° 38' E) at the Yenisei river. To explore the boreal ecosystem, the atmospheric gases CO_2, CH_4, CO, N_2O and O_2 were measured from November 2005 to June 2007 [1].

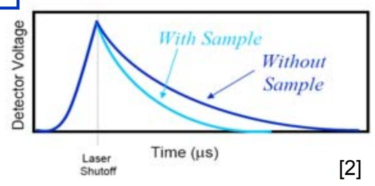
In April 2009 ZOTTO was reequipped within the PhD work presented here. The new *CO_2 and CH_4 measurement system* is robust and easy to maintain (no drying, few calibration gases). Hence, it is appropriate for such remote places like ZOTTO.

Objectives

- Set up a CO_2+CH_4 measurement system at ZOTTO
- Improve knowledge of carbon cycle in Siberian Taiga, esp. regional CH_4 budget
- Look for possible climate feedbacks (e.g. permafrost) – sign + magnitude, timescale, region

Methods - Experimental

Cavity Ring-Down spectroscopy:

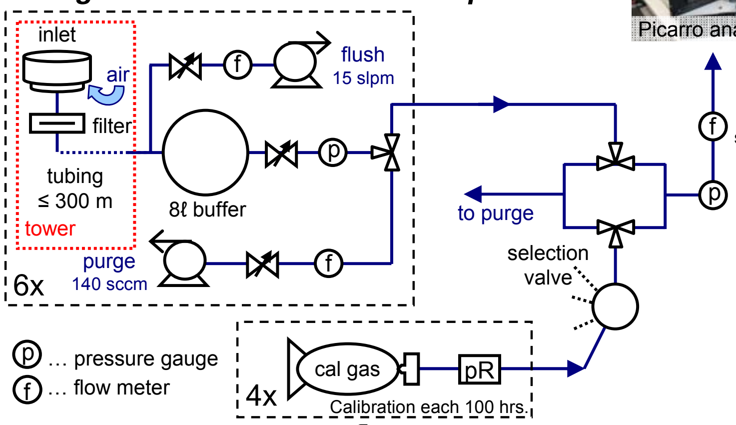


[2]

- Picarro ESP-1000 analyzer: Based on the detection of the decay time of laser light in the sample cavity cell the concentration of the trace gas is measured.
- Specific wavelength (~1,6 µm) = specific gas
- Instrument precision for Picarro CFADS17: ~ 0.06 ppm for CO_2 and ~ 0.4 ppb for CH_4 (1σ SD for 5 sec.)


Picarro analyzer

Plumbing scheme in ZOTTO since April 2009:

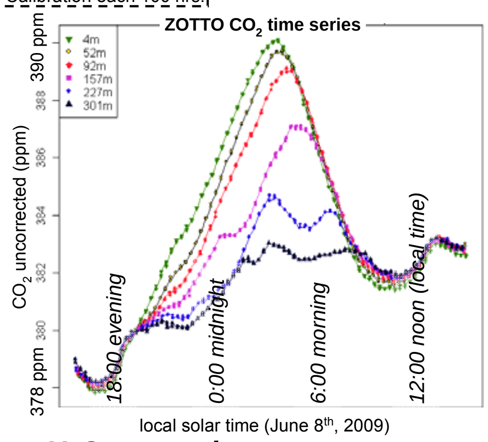


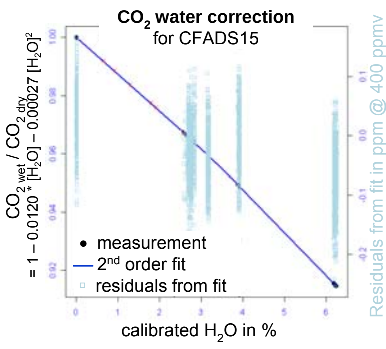
Measurement:

- Measurement of 6 height levels with one instrument
- 8 l buffer volume in each line act as analog integrator

➔ ***Smoothed quasi continuous measurements of CO_2, CH_4, and H_2O mixing ratios for each height level***

- Calibration every 100 hrs. to achieve aimed accuracy (CO_2: 0.1 ppm, CH_4: 3 ppb)





H_2O corrections:

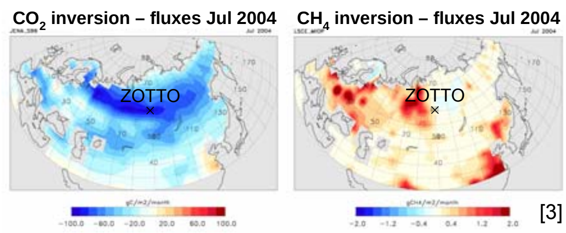
- Empirical H_2O corrections for dilution and pressure broadening effects
- Quadratic fit achieved from various laboratory experiments:
  $[c_{wet}] / [c_{dry}] = 1 - a * [H_2O] - b * [H_2O]^2$
- Calculate dry gas concentrations $[c_{dry}]$

→ Residuals: CO_2: 0.005 ± 0.053 ppm
CH_4: 0.001 ± 0.530 ppb
for 400 ppm CO_2, 2000 ppb CH_4

➔ ***No air drying necessary***

Methods - Modeling

How to detect sources and sinks of gases?



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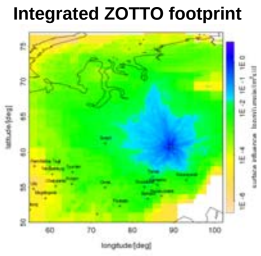
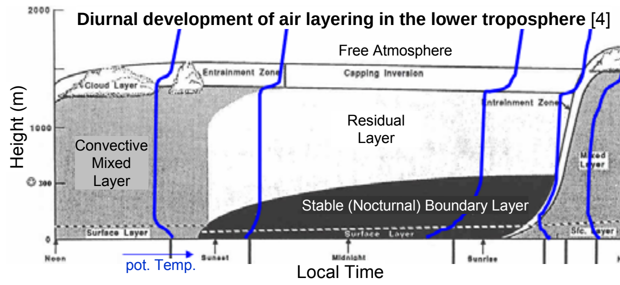


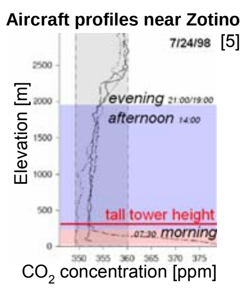
from STILT transport model 22.4.-30.6.2009, 301 m

- Driven by meteorological analysis fields *transport models* detect air origin. Hence, embedded in global trace gas simulations, regional nested *inverse models* can produce maps of sources + sinks, which optimally fit the measured gas mixing ratios.

Data usage:

- 301 m level measurement + regional/global inversion system
  ➔ ***Regional (global) CO_2+CH_4 source & sink estimates***
- Comparison to more marine stations
  ➔ ***Estimation of continental influence***
- CO_2+CH_4 built-up in Nocturnal Boundary Layer → Integration of concentration profiles of 6 heights ➔ ***Night-time emissions***





Conclusions

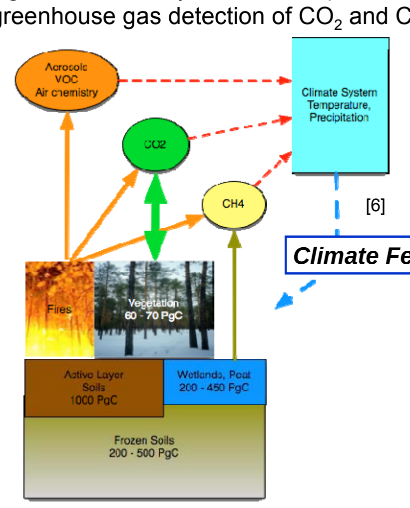
- A new CO_2+CH_4 instrument for ZOTTO tall tower was set up in April 2009.
- This constitutes a major but only initial step towards a long-term continental observation strategy.
- It is an aim to get better knowledge of the carbon cycle in central Siberia, based on inverse modeling approaches, esp. with regard to regional CH_4 observation.

Open Questions

- What is the balance of CO_2 vs. CH_4 emissions within the carbon cycle?
- How to use information of all 6 height levels in the best way for flux estimation?
- What are the reasons for peculiar events like winter inversions, ...?

Background

Atmosphere is used as an integrating signal of carbon cycle fluxes, esp. for greenhouse gas detection of CO_2 and CH_4.



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Why Siberia?

- Boreal forest is significant for the global carbon cycle:
  - ~ 10 % of global terrestrial carbon (vegetation + soils)
  - ~ 5-10 % of global terrestrial productivity
  - ~ 65 % of Siberian forests contain permafrost
- Modest anthropogenic impacts (e.g. logging, fire, agriculture)
- Expected large climate change impacts

Why tall towers?

- Tall towers extend beyond the surface layer, thus they are representative of larger scales than ground based stations. The corresponding area, that influences the gas concentration at the tower (footprint) reaches scales of 1000 km.
- Furthermore, during most nights they extend above the nocturnal stable boundary layer (SBL), which means that the top level measures residual layer air (previous days mixed layer) with large scale representativeness.

Climate Feedbacks:

- Longer vegetation period
- Soil decomposition increase
- Permafrost carbon release
- Changes in fire regimes, hydrology, carbon export by runoff, wetland degradation, and ecosystem composition

References

[1] Kozlova et. al., GBC, 2008
[2] Courtesy by E. Crosson
[3] ICOS homepage, 2008: http://inversions.lsce.ipsl.fr/
[4] R.B. Stull, "An Introduction to Boundary Layer Meteorology" Kluwer Acad. Publ., 1988
[5] J. Styles et. al., Tellus B, 2002
[6] M. Heimann, ZOTTO presentation, 2009 from McGuire et al., 2009, Ecological Monographs

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