Trace gas exchange at the forest floor

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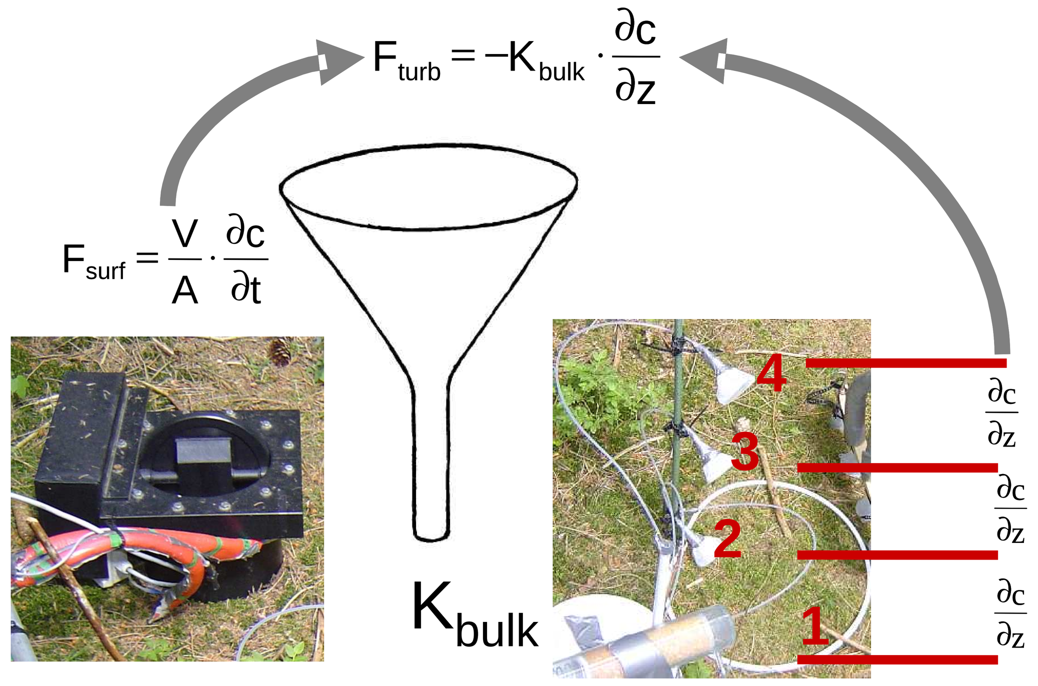
Challenges

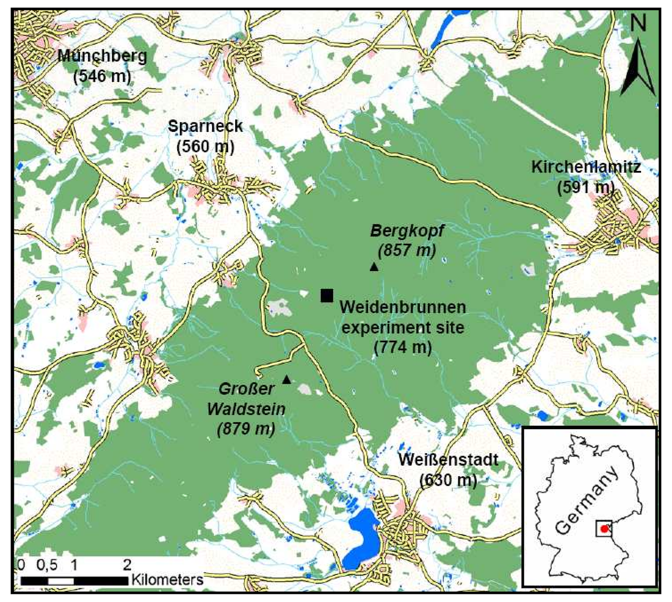
- The determination of surface fluxes of the reactive trace gases NO, NO_2, and O_3 at the forest floor requires consideration of characteristic turbulent timescales and (photo-) chemical interconversions
- Using a flux-gradient approach for chemically inert tracers, such as the radioactive noble gas radon (Rn) and CO_2, the turbulent transport regime may be characterized

Bulk diffusion coefficient from flux-gradient relationship for non-reactive tracers



- The vertical profile measurement of the short-lived isotope ^{220}Rn ($t_{1/2}$ = 55.6 s) is used to calculate turbulent transport times and corresponding bulk transfer velocities (v_{tr})
- These parameters can be applied to vertical concentration differences of NO, NO_2, and O_3 in order to separate turbulent transport from chemical and biological processes

Project and Research area



The EGER-project (ExchanGE processes in mountainous Regions) is a multiscale approach to investigate diurnal and annual cycles of energy, water and trace gases in a spruce forest. Measurements were conducted during two Intensive Observation Periods:

IOP1: autumn 2007 (August - October)
IOP2: summer 2008 (May - July)

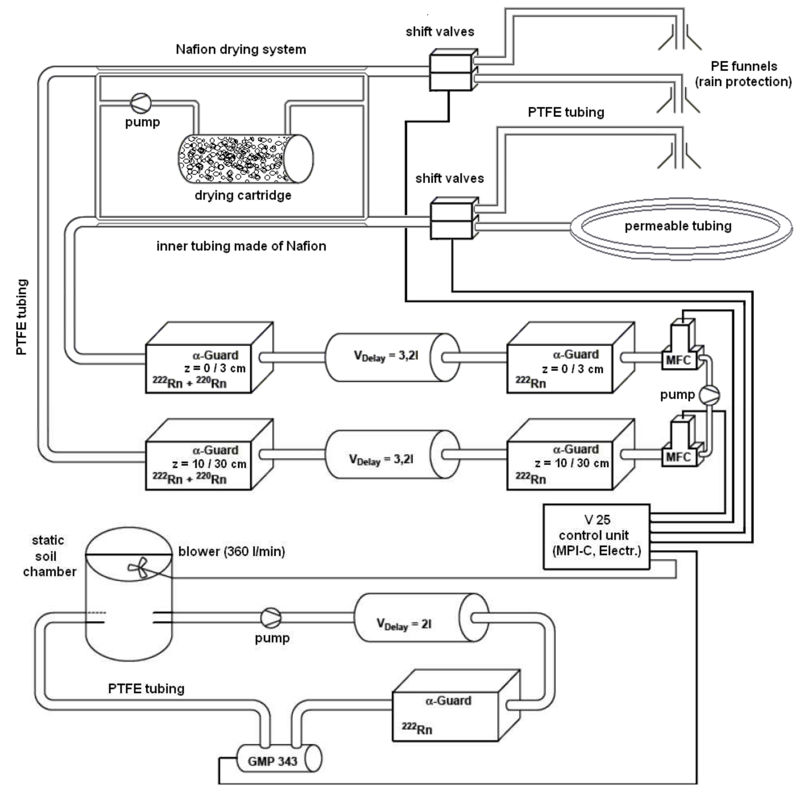
Weidenbrunnen, Fichtelgebirge, Germany (50°08'31" N, 11°52'01" E ; 775 m a. s. l.)

Setup

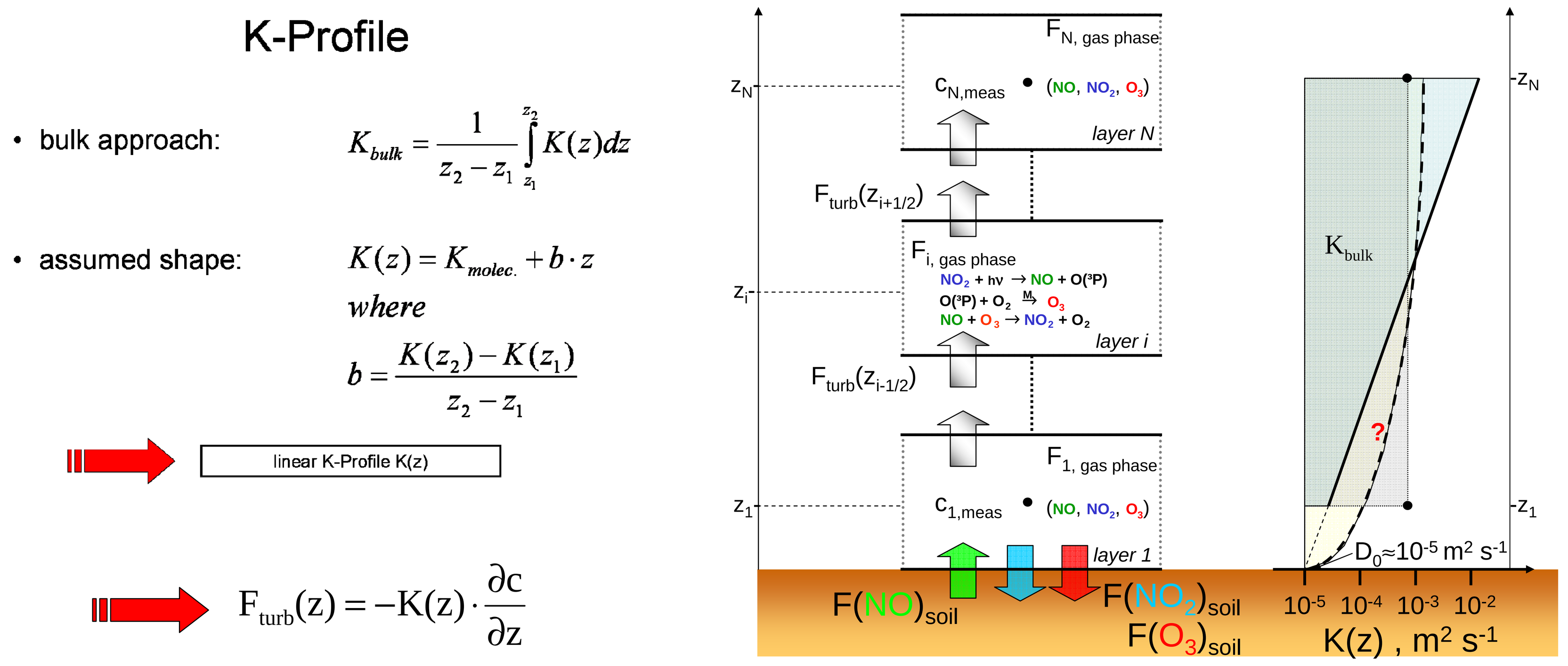
Radon system

Radon concentrations were measured at 0.03 m and 0.30 m a.g.l. to determine vertical gradients. During IOP2 additional measurements were conducted at 0.005 m and 0.10 m a.g.l.

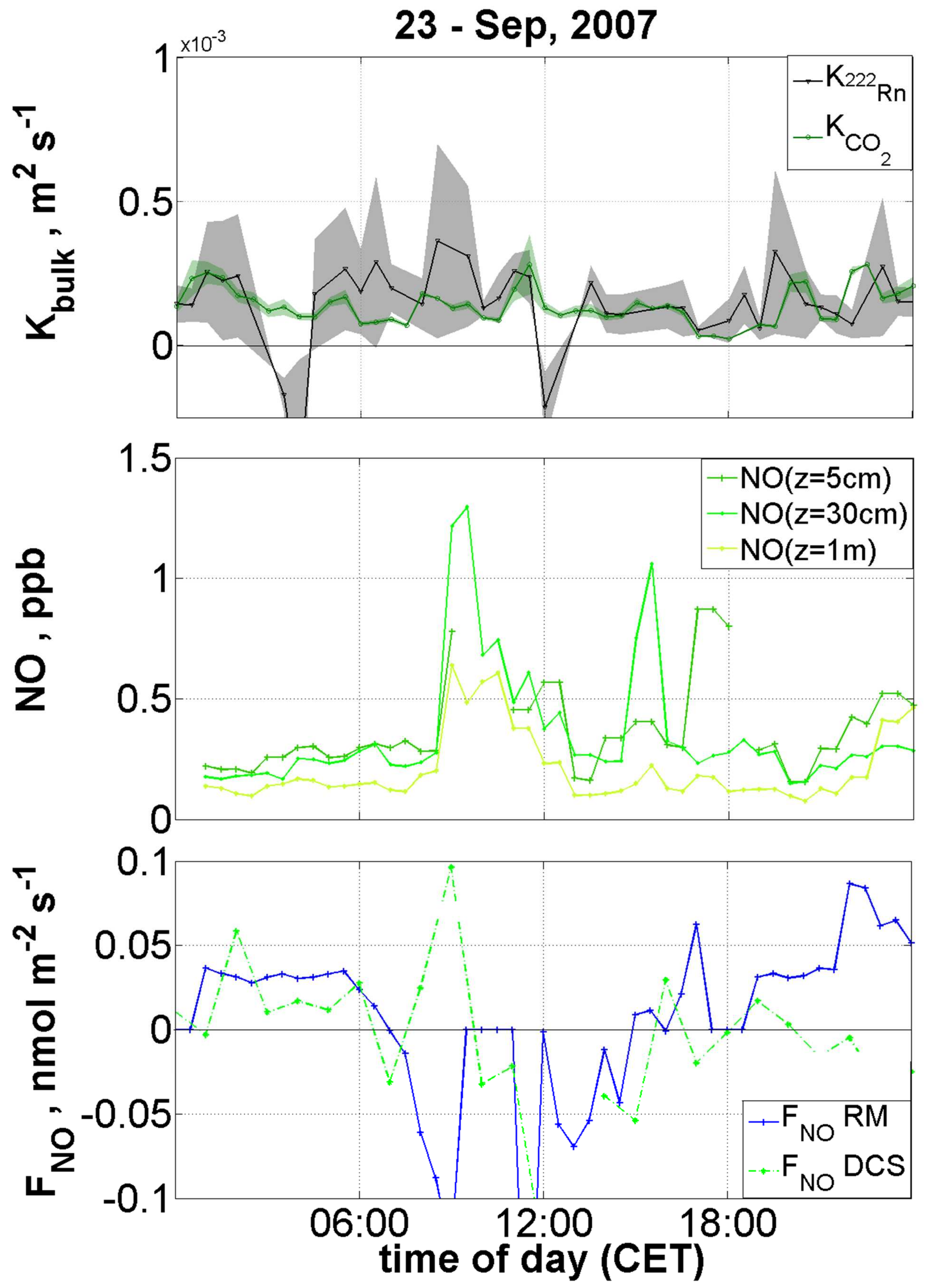
The selectivity of isotopes was derived from the difference between the half-life of ^{222}Rn ($t_{1/2}$ =3.8 d) and ^{220}Rn ($t_{1/2}$ = 55.6 s). One AlphaGuard radon monitor (built by Genitron, Franfurt) detects the sum of both isotopes at each measurement height. After a delay period of the tenfold half-life of ^{220}Rn more than 98% of the short-lived isotope decayed. An additional AlphaGuard and CO_2 sensor (GMP343, Vaisala, Helsinki) was used to measure the gas fluxes out of the soil in a static chamber.



Layer model



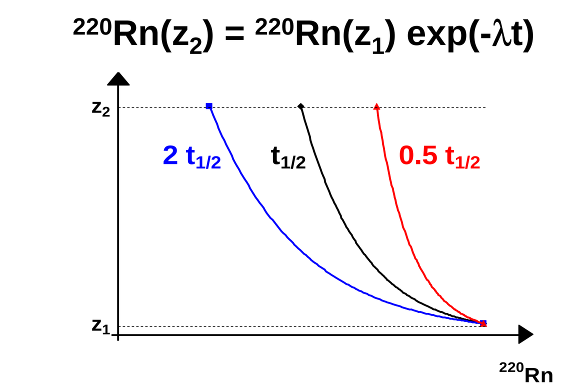
RESULTS



- radon method can be used to characterize near-surface gas exchange, even under conditions of (very) low turbulence
- during advection events CO_2 gradients are more robust than Rn gradients → $K_{bulk,Rn}$ can be replaced by K_{bulk,CO_2}
- calculated turbulent surface fluxes of NO are compared to simultaneously performed surface flux measurements by dynamic soil chambers (DCS).
- both methods show upward turbulent NO fluxes during night-time and downward turbulent fluxes in the day-time, especially during periods with strong instationarities

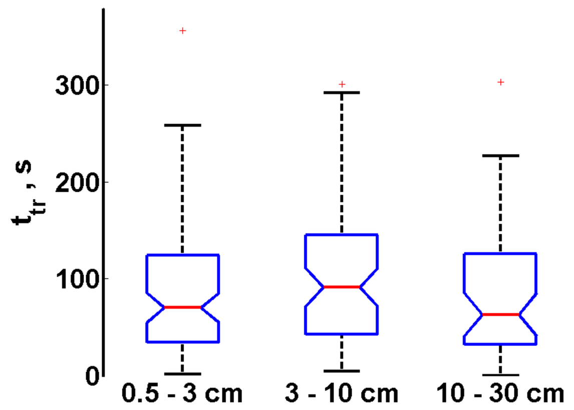
Turbulent transport time

Direct approach [1]**:**



$t_{z1->z2} = \ln[{}^{220}Rn(z_1) / {}^{220}Rn(z_2)] / \lambda$

- Timescales of the turbulent transport found in the first meter about forest floor are in the order of chemical timescales
  → gradients of reactive species may be affected
  → decoupled layers within the first meter?



Conclusions and Outlook

- Under stable and very stable conditions, when turbulence is small ($u_* < 0.08$ m s⁻¹) state-of-the-art methods (e.g., eddy covariance) fail. The presented approach is a first attempt to determine K(z) close to the forest floor. It can be used to characterize near-surface exchange of non-reactive and reactive trace gases.
- Four-point gradient measurement of Rn and highly resolved vertical temperature profile during IntensiveObservationPeriod2 give first hints that decoupled layers exist within the first meter
  → further evaluation is necessary
- Downward turbulent NO fluxes cannot be explained by instationarities alone
  → compensation point of NO in the O-horizon was ~4-7ppb. Can $c_{NO}(z=0)$ be higher ?

References

[1] Lehmann, B. ; Lehmann, M. ; Neftel, A. ; Gut, A. ;Tarakanov, S.V.: Radon-220 Calibration of Near-Surface Turbulent Gas Transport. In: Geophysical Research Letters 26 No.5 (1999), p. 607–610

Acknowledgements

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