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Biosphere-Atmosphere exchange of trace gases: Long-term measurements at the Höglwald site and climate change effects on alpine grassland

Michael Dannenmann, Klaus Butterbach-Bahl, Rainer Gasche, Hans Papen, Hans-Peter Schmid, Sebastian Unteregelsbacher, Benjamin Wolf, et al.

KIT
Karlsruhe Institute of Technology

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Some questions, which have been and will be adressed at the TERENO sites Höglwald and in the Ammer catchment

- Does silvicultural management affect the pedosphere-atmosphere exchange of non-CO_2 greenhouse gases (GHG), i. e. methane (CH_4) and nitrous oxide (N_2O)?
- How pronounced is the intra- and interannual variability of pedosphere-atmosphere-exchange of CH_4 and N_2O?
- How may climate change affect non-CO_2 GHGes in alpine grasland
  → first results of the *FORKAST* project situated at the TERENO alpine observatory

→ Do we need both *long-term* and *high temporal resolution* measurements to investigate biosphere-atmosphere exchange of GHGes at the TERENO large lysimeters?

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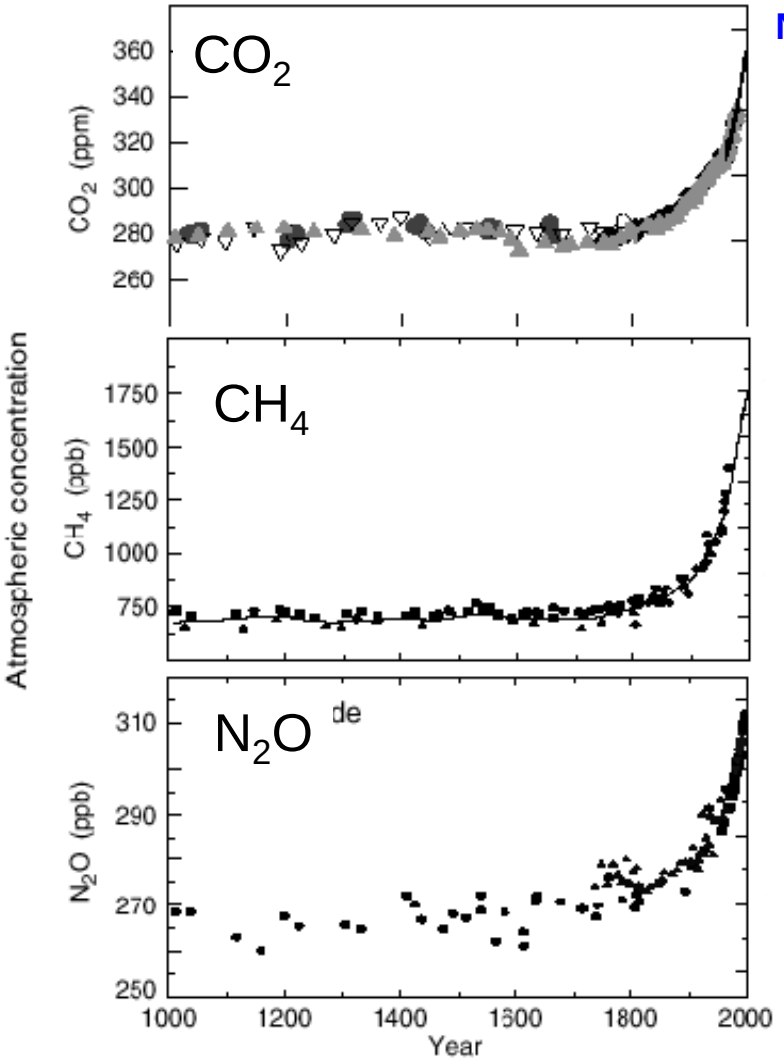
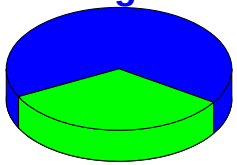
CO_2, CH_4 and N_2O: atmospheric increase and biogenic sources



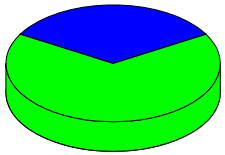
Non-biogenic sources



Biogenic sources

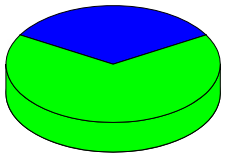
Dominant biogenic sources

Land use change



Rice agriculture, wetlands, enteric fermentation (ruminants)

Upland soils: sink



Forest-, grasland and agricultural soils

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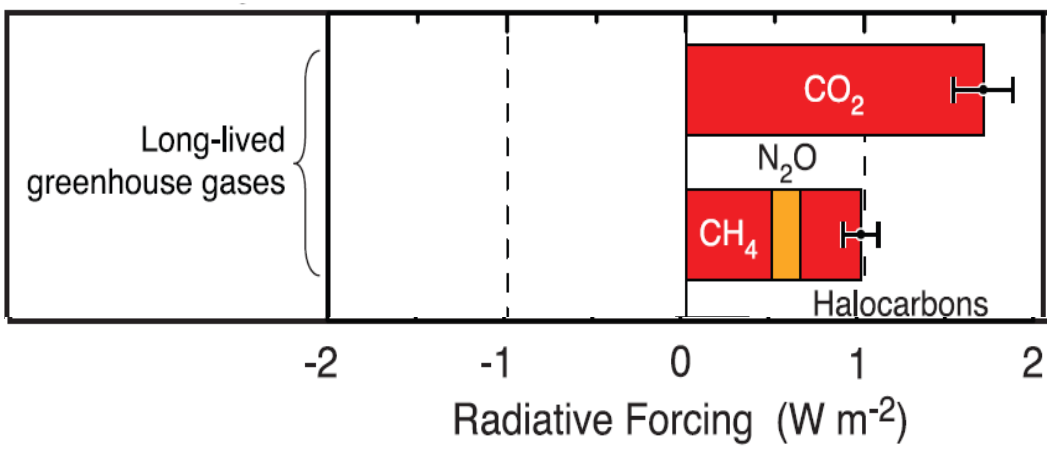
CH_4, CO_2 and N_2O as greenhouse gases



Radiative forcing of climate by long-lived greenhouse gases between 1750 and 2005. IPCC, 2007

GHG	Lifetime (years)	Radiative efficiency [W m^{-2} ppb^{-1}]	100-yr-global warming potential
CO_2	variable	$1.4x10^{-5}$	1
CH_4	12	$3.7x10^{-4}$	25
N_2O	114	$3.03x10^{-3}$	298

Lifetimes, radiative efficiencies and global warming potential of CH_4 and N_2O relative to CO_2. IPCC, 2007.

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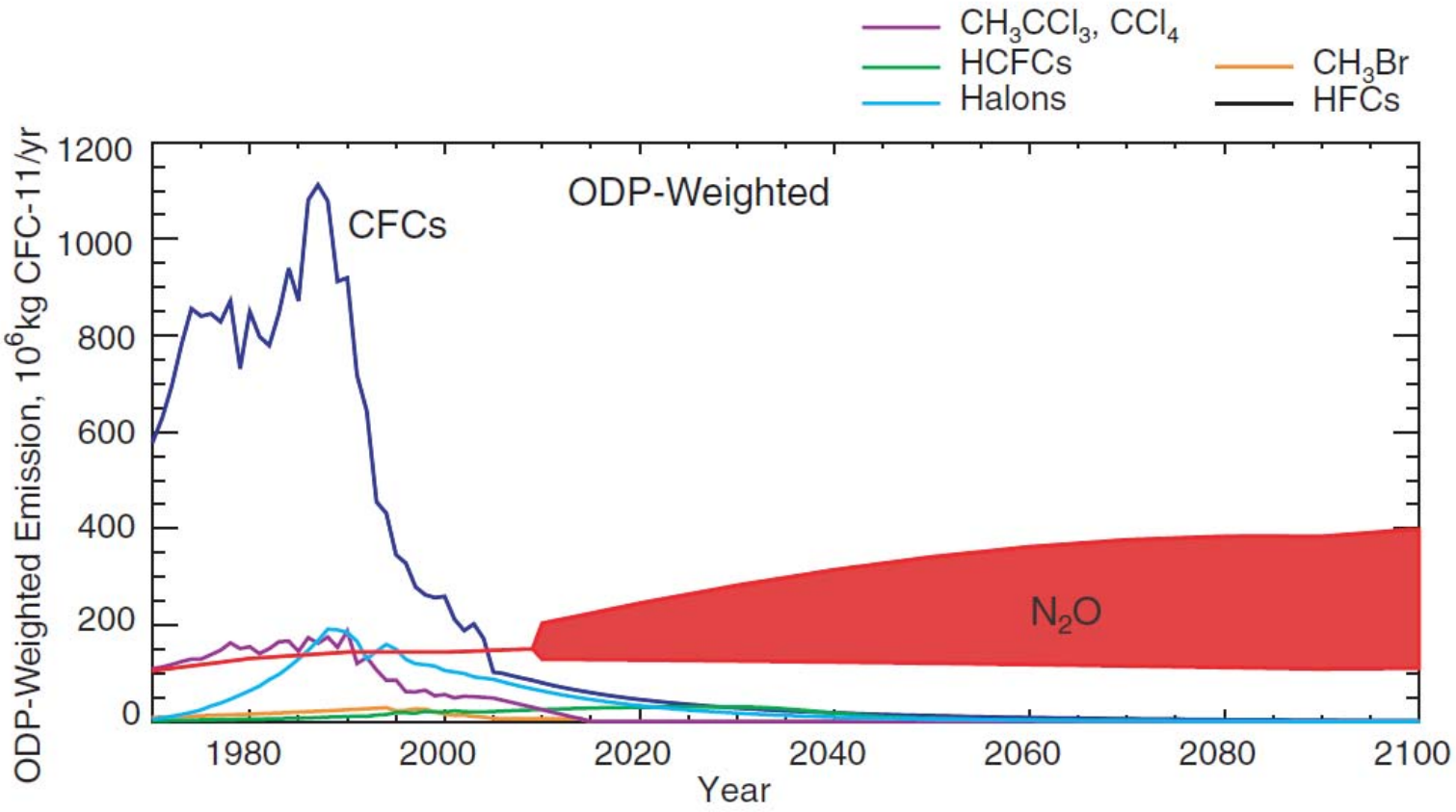
Apart from radiative forcing: N_2O is the dominant ozone-depleting substance today and in future



ODP:

ozone depleting potential

Ravishankara et al. 2010, Science

→ The recovery of the stratospheric ozone hole will be dependent on future N_2O emission in the 21st century

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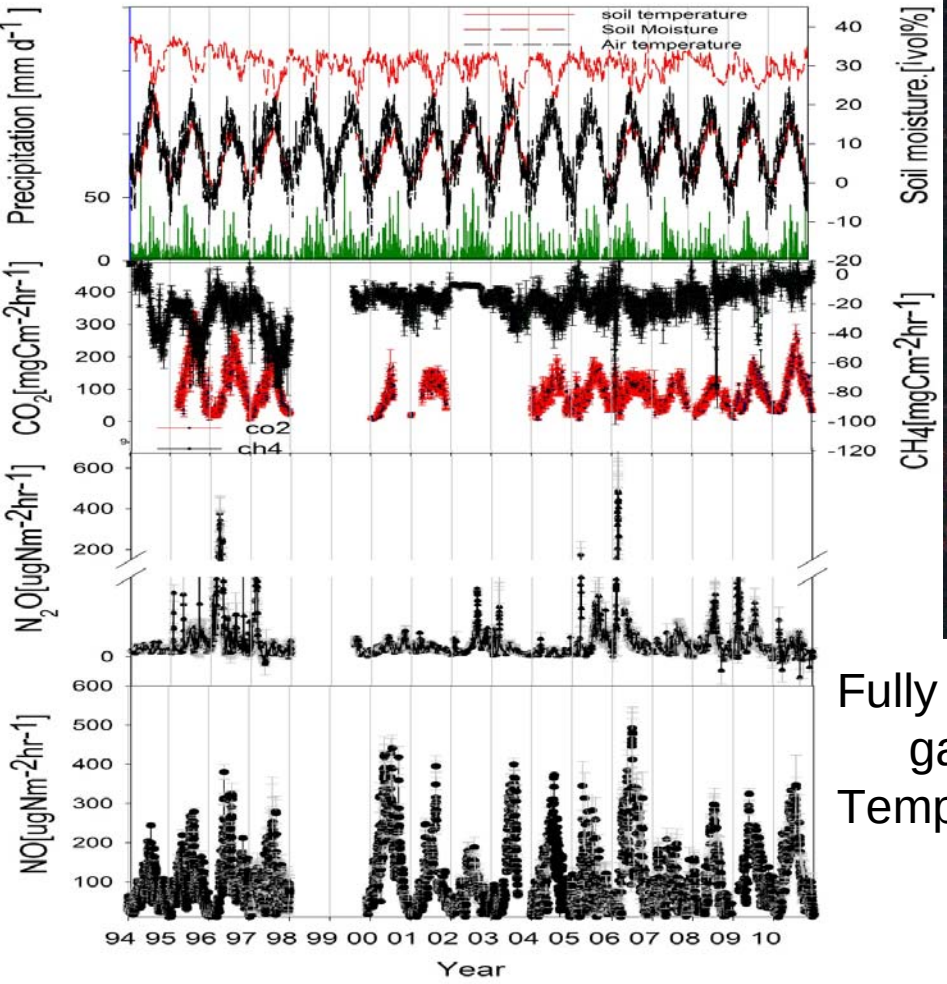
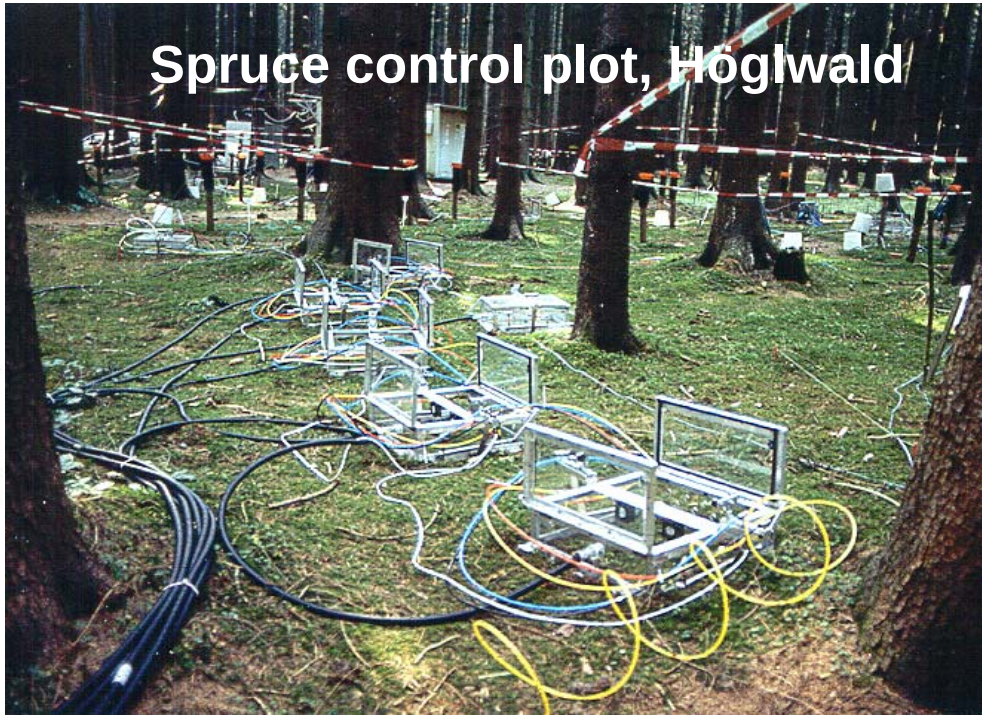
The Höglwald long-term flux data set: 15 years of automated measurements of soil-atmosphere exchange of CO_2, N_2O, CH4





Fully automated static chambers with online-gaschromatographic analysis of CO_2, N_2O, CH_4

Temporal resolution: 2 hours

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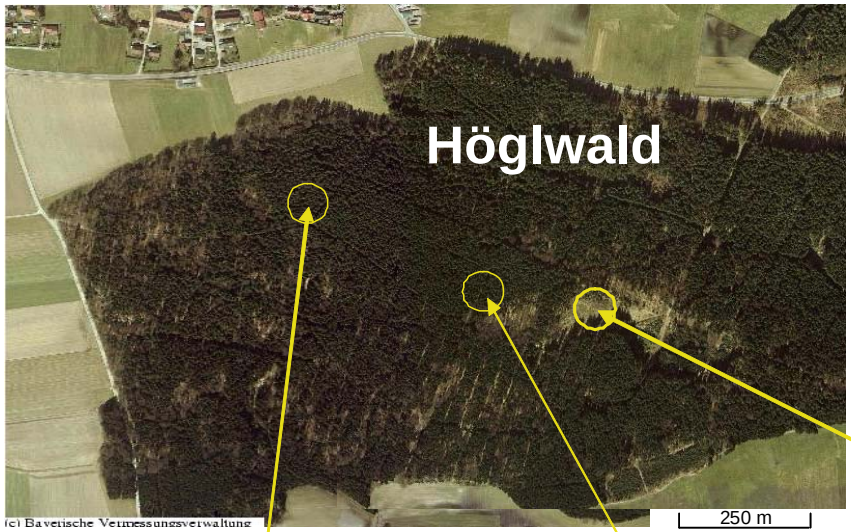
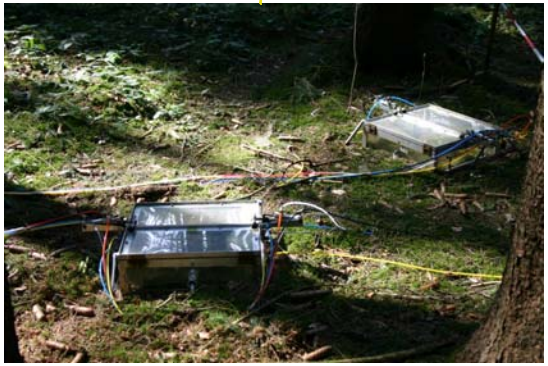
Is forest management a neglected source for non-CO_2 GHGes?



Forest:	Approx. 100-yr-old spruce
Location:	11°11‘E, 48°30‘N
Elevation:	540 m.a.s.l.
Climate:	Suboceanic
Mean annual temperature:	7.7 °C (1984-2001)
Mean annual precipitation:	933 mm (1984-2001)
Vegetation zone:	Temperate broad-leaf zone
Soil type:	Typic Hapludalf (USGS)
	Dystric Cambisol (FAO)
Humus type:	Moder (~7 cm)
pH in $CaCl_2$:	< 3 (organic layer)
	< 4 (A horizon)

Spruce control



Selective cutting

Clearcut

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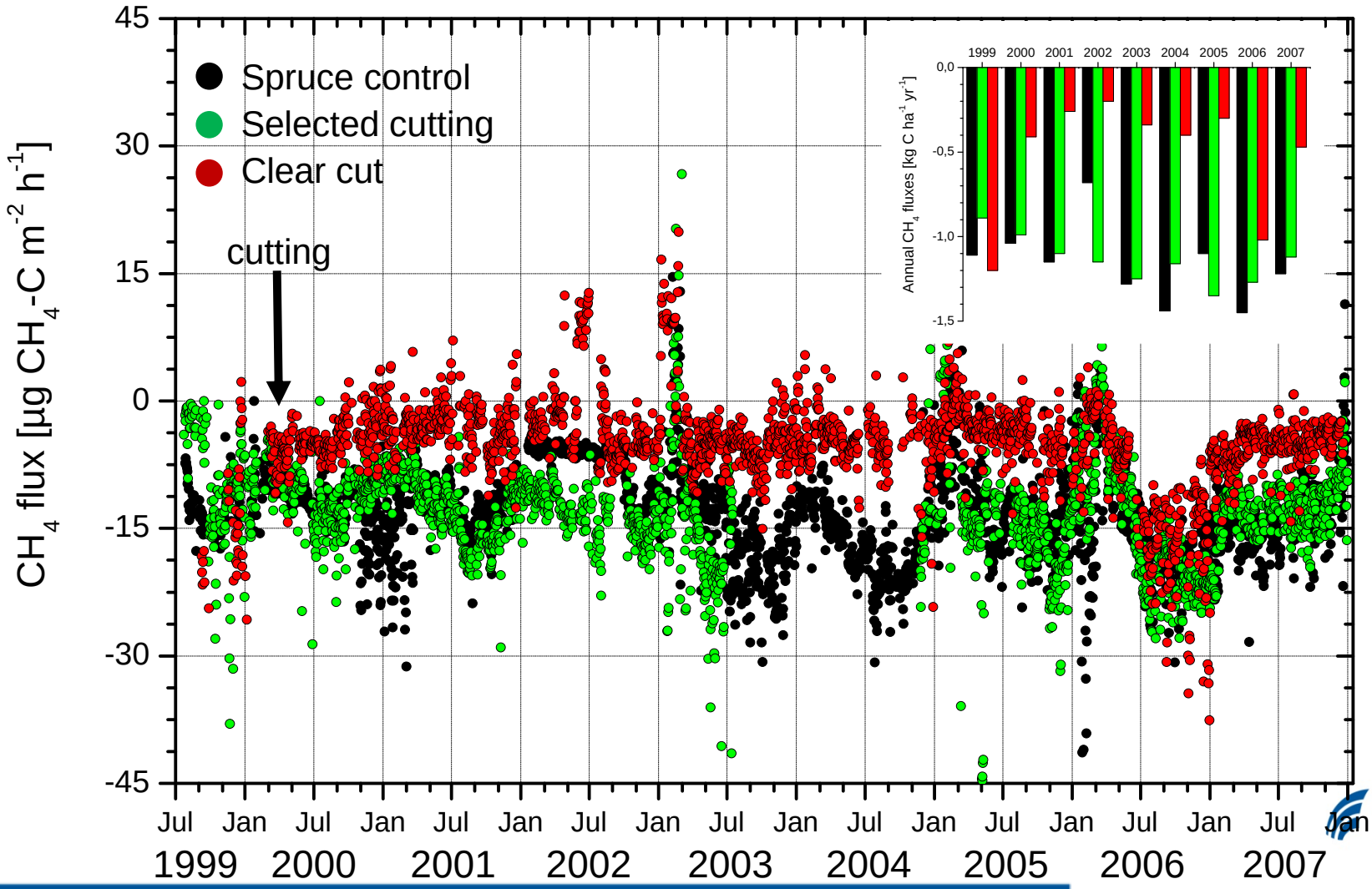
Clear cutting significantly decreased the CH_4 sink strength of the Höglwald soil for more than 7 years



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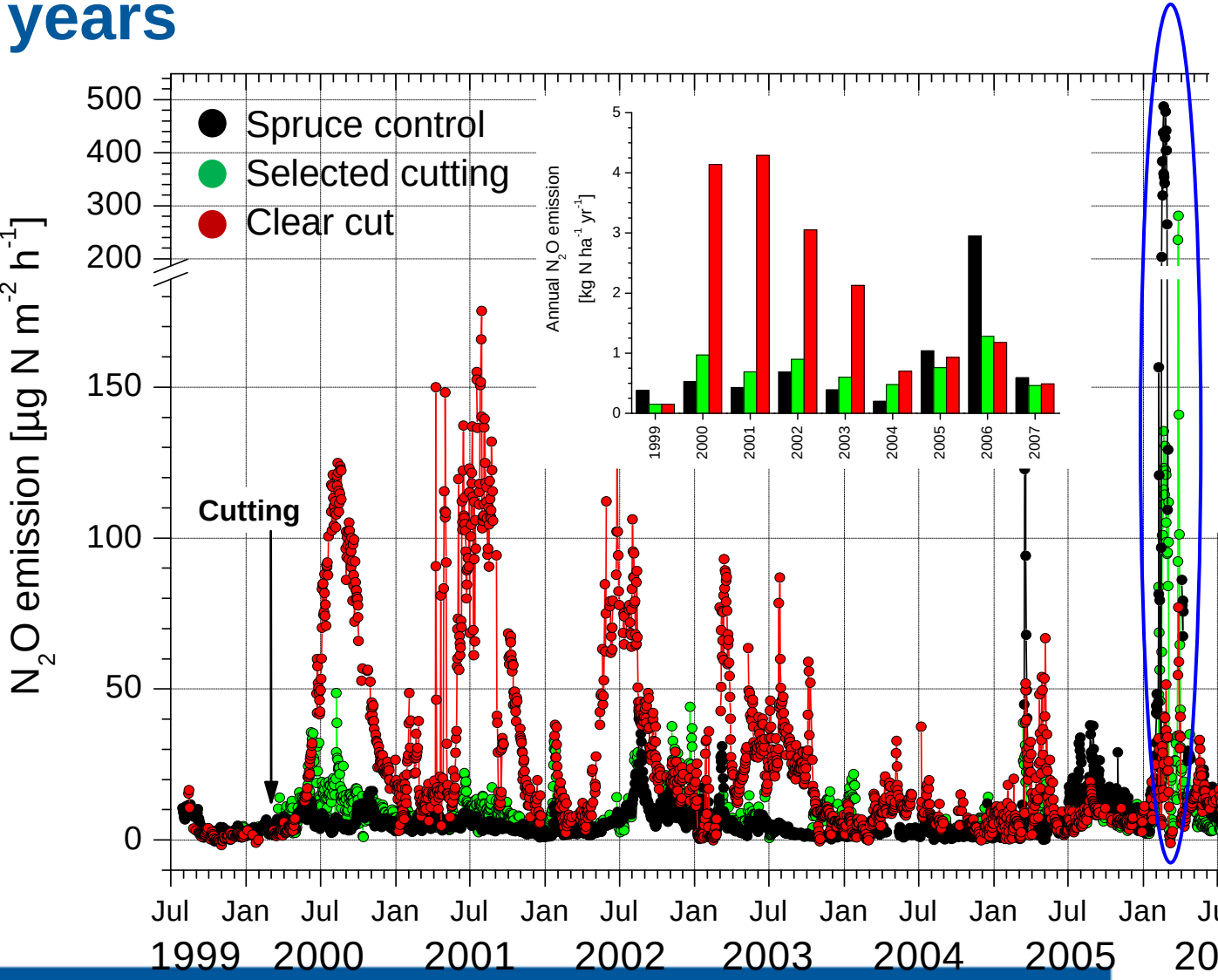
Clear cutting strongly increased N_2O emissions for 7 years



Over a rotation period of 80 years at a clear-cutted site, CO_2-fixation is offset by non-CO_2 GHGes by **14%**

→ Avoiding clear cutting as a measure to mitigate non-CO_2 GHG emission

Huge N_2O pulse at spruce control plot?

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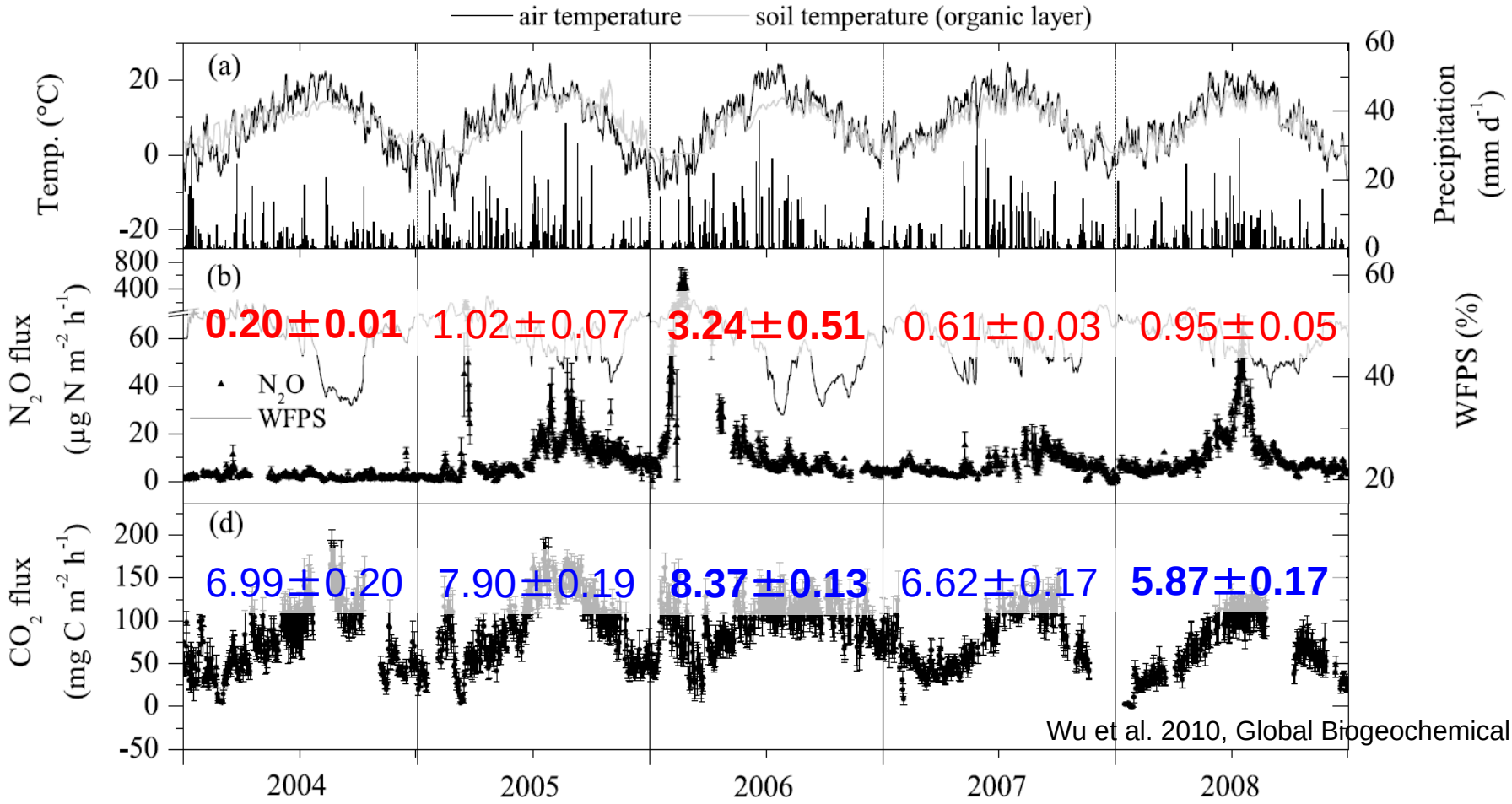
Höglwald flux data illustrate the need for long-term measurements (in particular concerning N_2O)



Wu et al. 2010, Global Biogeochemical Cycles

Annual N_2O flux [kg N ha^{-1} yr^{-1}]

Annual soil respiration [t C ha^{-1} yr^{-1}]

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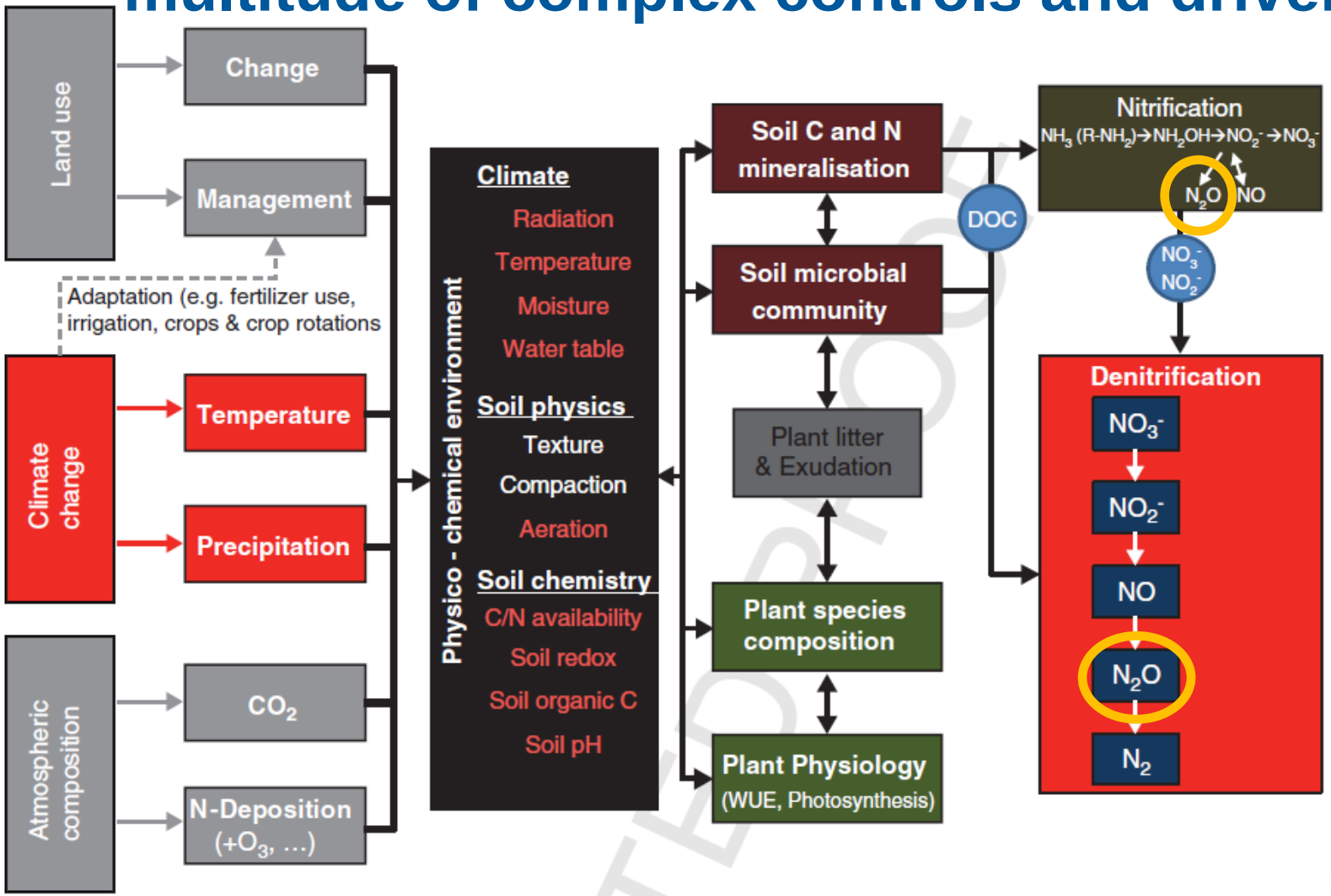
High variability of N_2O fluxes is caused by the multitude of complex controls and drivers



Butterbach-Bahl and Dannenmann 2011, Current Opinion in Environmental Sustainability, *in press*

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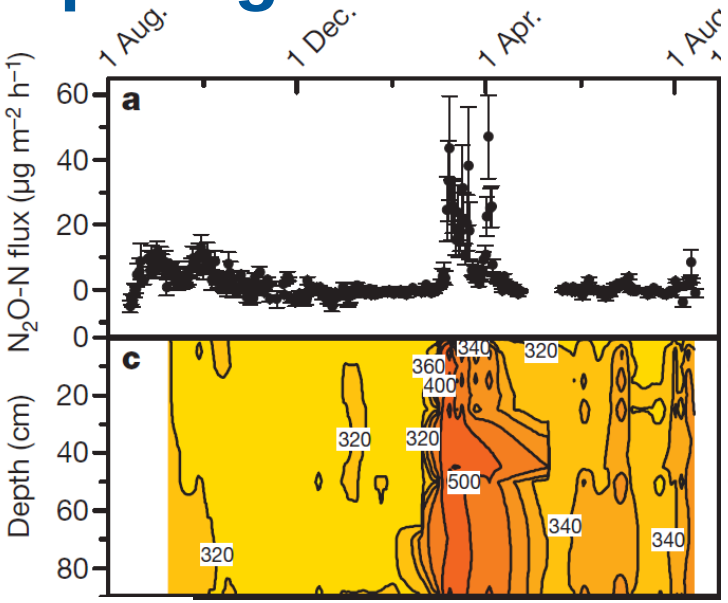
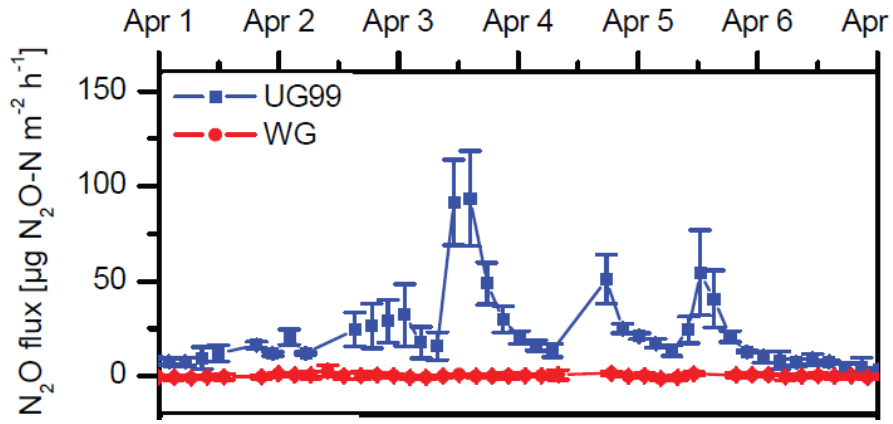
Do we have to expect freeze-thaw peaks of N_2O fluxes also at the TERENO alpine grasland sites?



Inner Mongolian continental grasland: Short-lived N_2O pulse emissions in the freeze thaw period can account for up to 80% of the annual N_2O flux

Wolf et al. 2010, Nature



Huge diurnal variations of N_2O emissions during the freeze thaw period

Wolf et al. 2010, Nature (Supplementary material)

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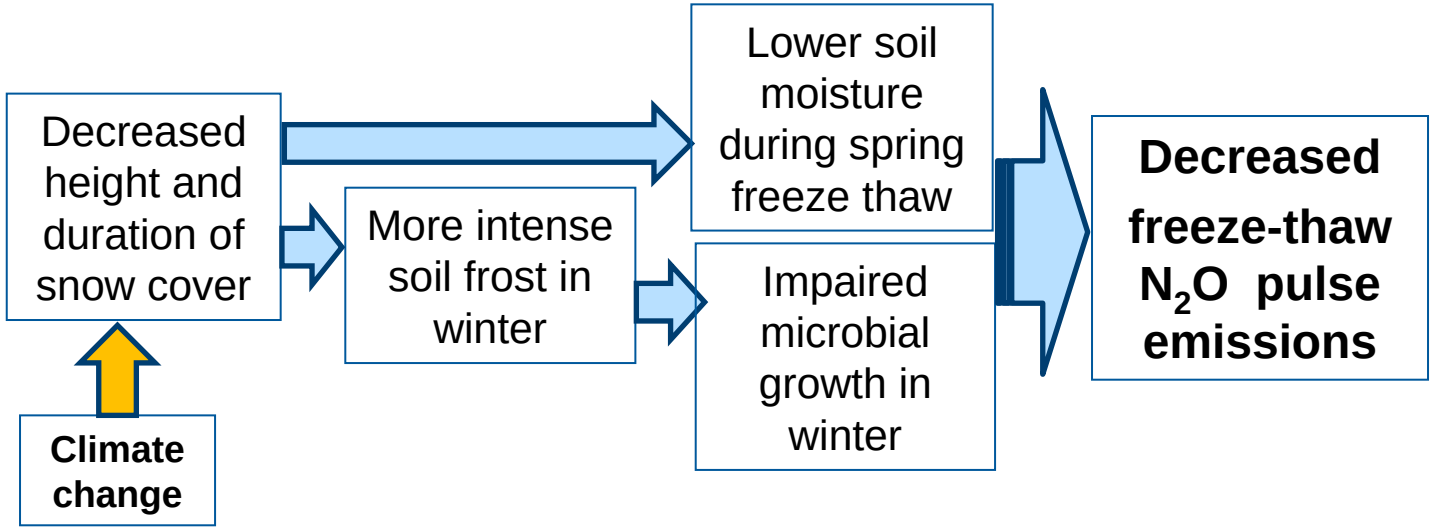
Climate change and freeze-thaw N_2O emissions in alpine grassland – what do we expect?



Climate change → reduced snow cover →colder soils in a warmer world

→smaller freeze-thaw pulse emissions of N_2O

→ Long-term measurements and high temporal resolution needed at TERENO large lysimeters

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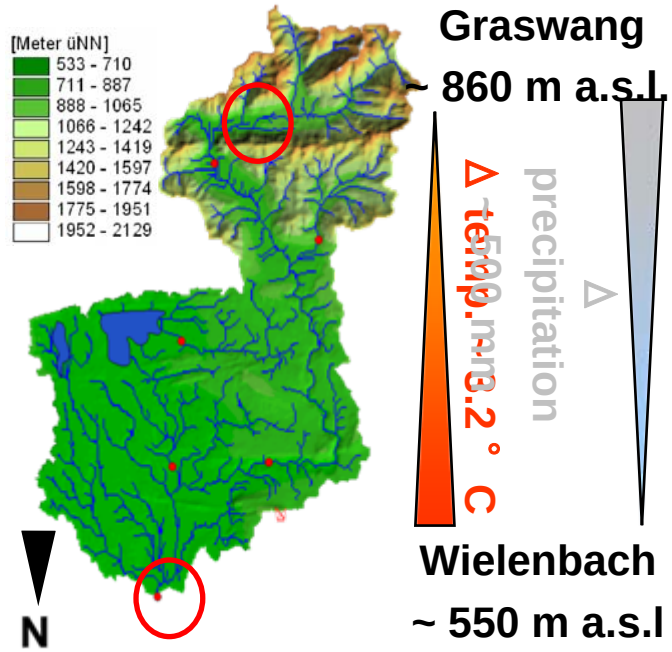
FORKAST project situated at the TERENO pre-alpine observatory sites



Graswang
~ 860 m a.s.l.

Δ temp. max. 3.2 °C

Δ precipitation

Wielenbach
~ 550 m a.s.l

Dislocation of lysimeters along climatic gradient to simulate climate change, GHG-exchange measurements

Small soil cores/mini lysimeters
diam. 16.4 cm, 25 cm height

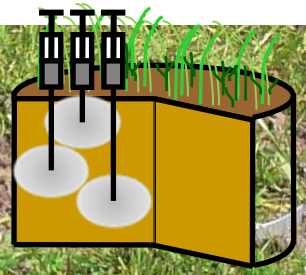
Large lysimeters

Years 2009-2012

Long-term observatory

FORKAST
Bayerischer Forschungsverbund
Auswirkungen des Klimas auf Ökosysteme und klimatische Anpassungsstrategien

Funded by the Bavarian government



Isotope-based process studies
Destructive harvests
>400 soil cores/mini lysimeters

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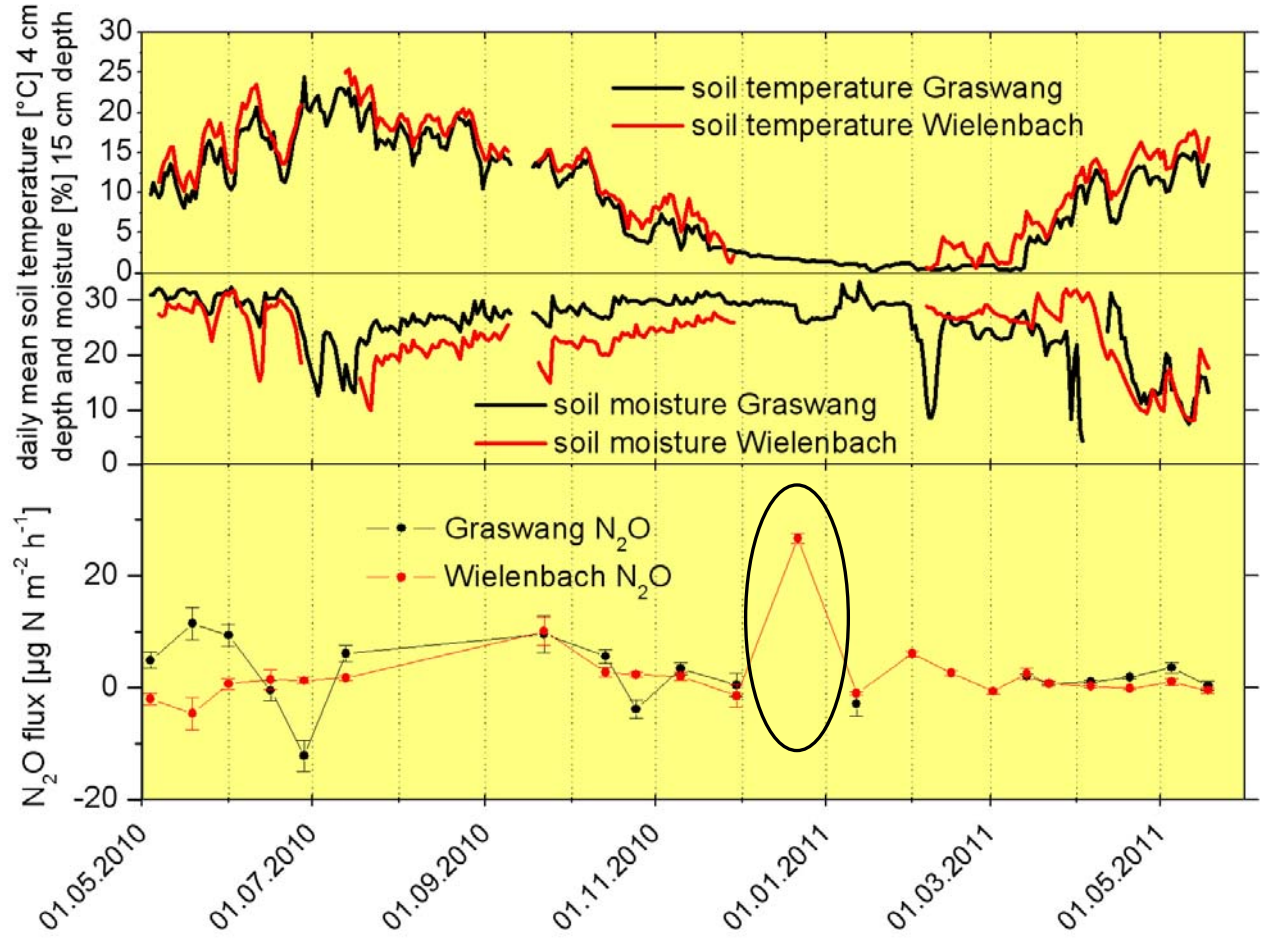
FORKAST: N_2O fluxes



Manual sampling of chamber headspace with syringes → gas chromatographic analysis of CH_4 and N_2O

→ Temporal resolution approx. fortnightly

No effect of lysimeter dislocation on N_2O fluxes visible after 1.5 years,

But: freeze-thaw peak?

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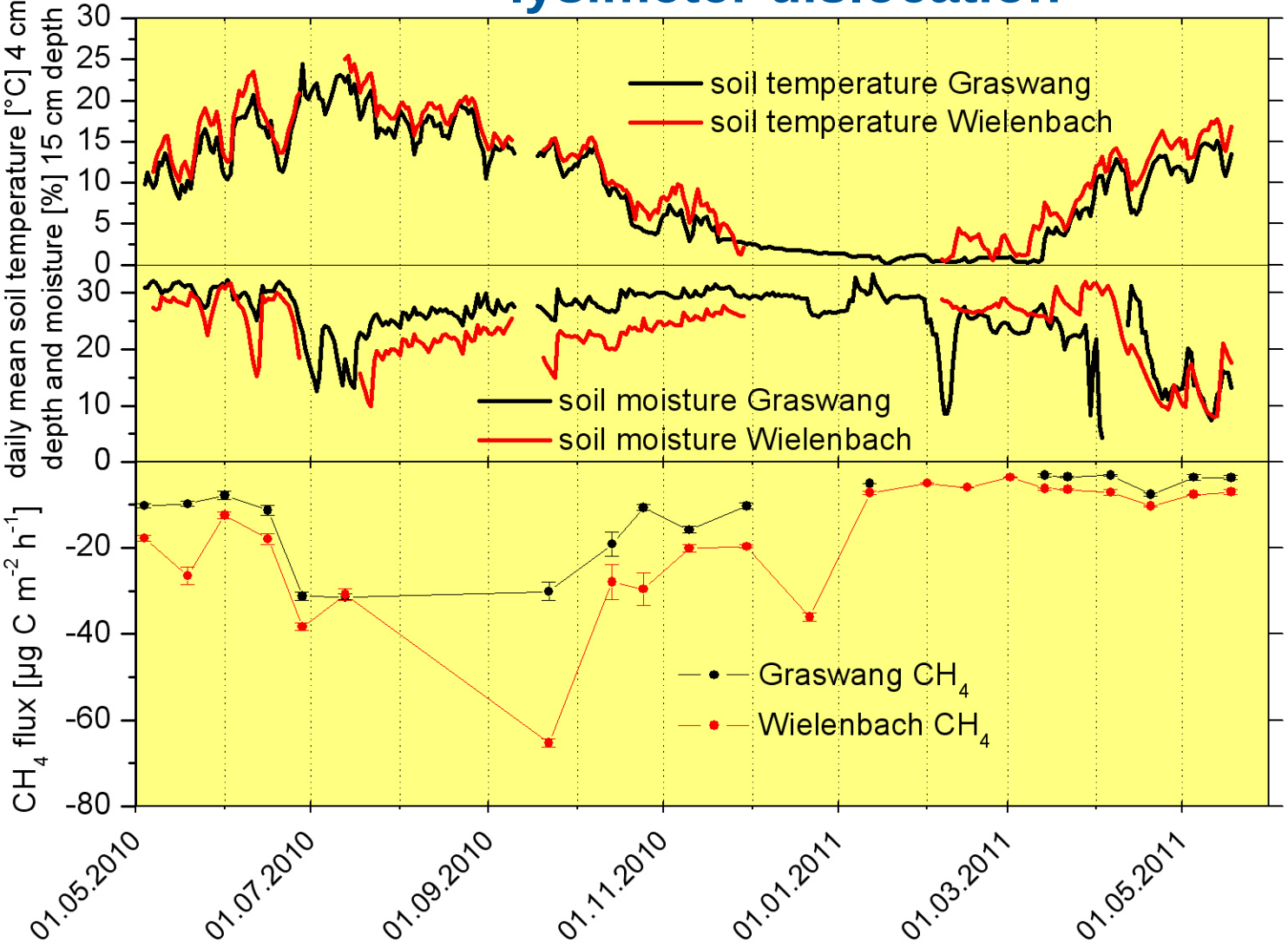
FORKAST: Net CH_4 uptake immediately increases after lysimeter dislocation



Climate change treatment:

Increased soil temperature

Reduced soil moisture

Increased CH_4 sink strength of alpine grassland soils

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Summary

- Forst management (in particular clear cutting) can be a significant source of non CO_2-greenhouse gases
- Pedosphere-atmosphere exchange of methane and, in particular, nitrous oxide is characterized by enormous temporal variablity from hourly to interannual scales
- CH_4 emissions in alpine grasland show fast response to simulated climate change via lysimeter transfer (increased CH_4 sink strength under climate change conditions)
- Both *long-term measurements* and *high temporal resolution* are indispensable prerequisites to draw conclusions on pedosphere-atmosphere exchange of C and N trace gases (in particular for N_2O) and to calculate the total GHG balance of ecosystems…….

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