Breathing of the Biosphere

A Decade of Ecosystem-Atmosphere Trace Gas Exchange Measurements at the LTER Austria Site Neustift

Georg Wohlfahrt[1*], Albin Hammerle[1,2], Alois Haslwanter[1], Lukas Hörtnagl[1], Christoph Irschick[1]

1 University of Innsbruck, Institute of Ecology, Biometeorology Research Group | 2 Now at: ETH Zürich, Institute of Plant, Animal and Agroecosystem Sciences | * Corresponding author (georg.wohlfahrt@uibk.ac.at)

BACKGROUND AND OBJECTIVES

The biosphere and the atmosphere are coupled by the exchange of momentum, mass and energy occurring at their interface - changes in the physical/chemical structure/composition of the atmosphere thus affect the state of the biosphere, conversely, changes in the structure and functioning of the biosphere feed back on to the atmosphere. The Biometeorology Research Group is conducting ecosystem-atmosphere trace gas exchange measurements at the LTER Austria site Neustift, a montane grassland managed as hay meadow, since 2001. The overarching objective of these long-term measurements is to quantify the magnitude of trace gas exchange rates, their seasonal and inter-annual variability and the biotic, abiotic and management factors which control the exchange rates. More specifically the objective is to study the interactive effects of climate/weather and grassland management on the role of this grassland as a source/sink of greenhouse gases and any biophysical/chemical feedbacks this grassland may be providing to ongoing climate change.

METHODS

Trace gas exchange rates between the investigated grassland and the atmosphere are quantified by micrometeorological methods. When possible, the eddy covariance method is used to directly quantify mass and energy fluxes – this way we are continuously measuring eddy covariance fluxes of carbon dioxide (CO_2), water vapour (i.e. evapotranspiration) and sensible heat since 2001. Between 2008 and 2009 we have been quantifying fluxes of several volatile organic compounds (so-called VOCs) and ozone (O_3). Since 2010 we are measuring fluxes of methane (CH_4) and nitrous oxide (N_2O). For other compounds we have been using indirect micrometeorological methods, such as the modified Bowen-ratio or the aerodynamic method for elemental mercury (Hg_0) and O_3. These flux measurements are accompanied by a suite of ancillary measurements (Fig. 1) which include the major physical driving forces and vegetation phytomass. These measurements are complemented by a suite of various periodic measurements, e.g. soil respiration, leaf photosynthesis and stomatal conductance, lysimeter evapotranspiration, dry deposition and many more. Vegetation and soil of the site have been described extensively. Site infrastructure consists of a climate-controlled instrument container, line power and internet access. Data are fed on a regular basis to the global FLUXNET data archive and have been used in 50+ published studies up to now.

MAJOR RESULTS

CO_2 fluxes since 2001 are shown in Figs. 2 and 3, emphasising the decisive influence of management activities (i.e. cutting) on exchange rates. Over these 9 years the meadow acted as a net sink for CO_2 in five, as a net source in four years (Fig. 3) – on average, and accounting for the various random and systematic uncertainties, the site Neustift can be regarded as carbon-neutral. Analysis of carbon exports (harvested hay) and imports (organic manure) from/to the site indicate that these two fluxes are of similar magnitude, causing the net ecosystem carbon balance not to deviate strongly from the average integral annual CO_2 flux. Attributing inter-annual variability of CO_2 fluxes remains a challenge, likely due to the interactive effects of weather and management. Evapotranspiration from the site shows little signs of stomatal down-regulation during drier years – as a consequence up to 90% of precipitation are evapotranspired during dry, but only 60% during wet years (Fig. 4). Provided these findings hold for other grasslands in the Alps we expect a reduction in the hydrologic surplus (i.e. precipitation minus evapotranspiration) during anticipated drier future summers.

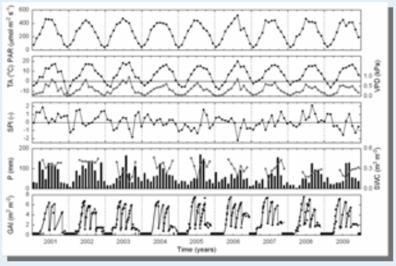

Figure 1 Monthly means/sums of photosynthetically active radiation (PAR), air temperature (TA), vapour pressure deficit (VPD), the standardised precipitation index (SPI), precipitation (P), volumetric soil water content (SWC) and the amount of photosynthetically active plant matter (green area index, GAI). Black bars in the lowermost panel indicated the presence of snow cover.

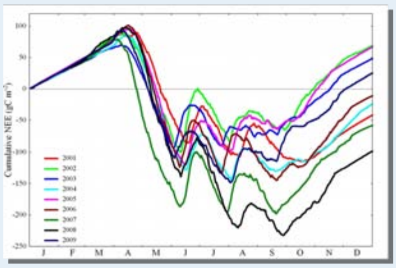

Figure 3 Cumulative net ecosystem CO_2 exchange for 2001-2009. Note the cutting dates which cause the grassland to temporarily turn into a source of CO_2. Intercepts of the lines with the right y-axis indicate the annually integrated source (positive) or sink (negative) strength.

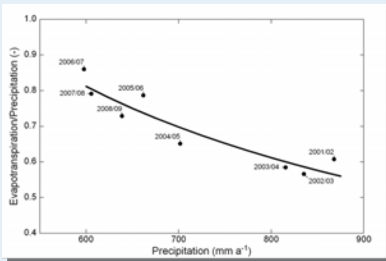

Figure 4 Fraction of annual precipitation that is evapotranspired as a function of precipitation. Data refer to the hydrologic year, i.e. 1st November to 31st October.

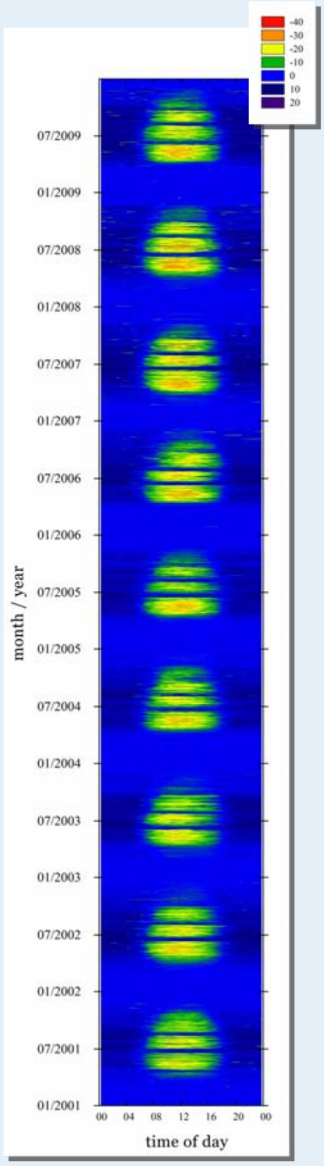

Figure 2 Net ecosystem CO_2 exchange as a function of time of day and date. Colour codes indicate net uptake (negative sign) or release (positive sign) of CO_2. Note the cutting dates which cause the grassland to temporarily turn into a source of CO_2.

KEY REFERENCES

Teuling A.J., Seneviratne S.I., Stöckli R., Reichstein M., Moors E., Ciais P., Luyssaert S., van den Hurk B., Ammann C., Bernhofer C., Dellwik E., Gianelle D., Gielen B., Grünwald T., Klumpp K., Montagnani L., Moureaux C., Sottocornola M., Wohlfahrt G. (2010) Contrasting response of European forest and grassland energy exchange to heat waves. *Nature Geoscience* **3**, 722-727.

Bamberger I., Hörtnagl L., Schnitzhofer R., Graus M., Ruuskanen T., Müller M., Dunkel J., Wohlfahrt G., Hansel A. (2010) BVOC fluxes above mountain grassland. *Biogeosciences* **7**, 1413-1424.

Wohlfahrt G., Hammerle A., Haslwanter A., Bahn M., Tappeiner U., Cernusca A. (2008) Seasonal and inter-annual variability of the net ecosystem CO_2 exchange of a temperate mountain grassland: effects of weather and management. *Journal of Geophysical Research* 113, D08110, doi:10.1029/2007JD009286.

Hammerle A., Haslwanter A., Tappeiner U., Cernusca A., Wohlfahrt G. (2008) Leaf area controls on energy partitioning of a temperate mountain grassland. *Biogeosciences* **5**, 421-431.

Wohlfahrt G., Anfang Ch., Bahn M., Haslwanter A., Newesely Ch., Schmitt M., Drösler M., Pfadenhauer J., Cernusca A. (2005) Quantifying nighttime ecosystem respiration of a meadow using eddy covariance, chambers and modelling. *Agricultural and Forest Meteorology* **128**, 141-162.

FUNDING

Funding for these activities has been provided through a series of both national and international grants including: FWF, EU FPs 4, 5 and 7, TWF, ÖAW, ÖFG, BM.W_F.

LTER Austria

Austrian Long-Term Ecosystem Research Network

visit us: **www.biomet.co.at**