# COS interactions with biosphere and soil.

## Georg Wohlfahrt – COS and optimal leaf gas exchange

COS is expected to have close to 0 COS concentration within the leaf compared to CO2, so no internal concentration should be needed for calculations

The stomatal conductance can easily be converted between COS and CO2

History:

COS as constraint for net primary productivity

Eliot Campbell related COS to GPP

Stimler using the term LRU

Asaf applied LRU on ecosystem scale

Whelan paper: LRU range with median of about 1.6

LRU found in studies decreased over time

Optimality model says LRU should depend on the ratio of the leaf internal to ambient CO2 concentration and the ratio of stomatal to leaf internal COS conductance.

P-model:

Least cost hypothesis: cost of respiration, cost of carboxylation capacity

Coordination theory: photosynthesis is either radiation or CO2 limited

Advantage: model only has 2 calibrated constants and needs limited inputs.

LRU should be lower as previously stated (0-1.2)

Stimlers values are high due to the high ci/ca and low gs/gi ratios

Modelling on ecosystem scale and into deeper layers of the canopy more complicated. Vapor pressure deficit, temperature, humidity, and light within the canopy will yield higher LRUs.

If LRU is lower, global models would overestimate terrestrial uptake.

## Roisin Commane – Advancing OCS as an independent atmospheric tracer for global photosynthesis through quantification of microbial-mediated sources and sinks in understories

Annual maximum OCS uptake in late September/October, later than the maximum net uptake for CO2. Strong depletion of OCS very late in the season.

More ground observational data in the arctic is needed.

Mosses are a strong sink for COS and were still active when measurement campaign ended. They just need to be wet to take up COS, and it is always wet in this area.

New instrument: Aeris OCS pico, battery powered and portable. Careful – water vapour dependence!

More measurements needed!

## Yasmin L. Bohak – Chamber measurements of soil and branch fluxes

Eddy covariance and soil chamber measurements at Yatir forest.

Control (dry) and irrigated forest plot.

Summer: higher COS and CO2 uptake at the control

Winter: higher uptake of COS and CO2 at the irrigated plot

Hourly branch chamber measurements for nearly a year

LRU around 2 under high light conditions

Soil chambers (dark) at 3 positions: under the tree, chambers without canopy cover and chambers in between

Similar COS fluxes of all 3 soil chambers

Soil relative uptake – no real influence of temperature on irrigated plots

## Wu Sun – Carbonyl sulfide as a tracer for stomatal behavior

Stomates control transpiration, surface energy balance and fluxes of O3, NH3 etc.

COS can be used as a stomatal tracer since quantify it can be challenging above the leaf scale

A wide range of models incorporated LRU

LRU is light dependent

LRU is humidity dependent

Modelling LRU based on stomatal conductance-photosynthesis coupling

Theory based on leaf COS uptake by Stimler, LRU equation using the COS and CO2 deposition velocities, the Ball-Berry stomatal conductance equation and the Farquhar model of photosynthesis

Implications:

LRU decreases with light

LRU reaches an asymptotic value at high light

LRU increases with ambient CO2 concentration

LRU may be lower in the afternoon due to lower relative humidity (same light conditions as morning hours)

Using the equation, it is possible to use the COS uptake to constrain CO2 fertilization.

Conclusion: Observed variability in the LRU on leaf level embodies coupled photosynthetic and stomatal responses to environmental variables

Understanding physiological controls of LRU allows us to better track space-time patterns of photosynthesis on regional to global scales using COS observations

## Ara Cho – COS leaf flux and its relation to GPP, understanding the different

## responses to temperature and stomatal changes

Why does the COS leaf flux under high PAR and high VPD decrease, and the CO2 flux stays constant while gs decreases?

- Hypothesis 1 COS leaf uptake responds more strongly to stomatal changes

- Hypothesis 2 COS production by leaves

- Hypothesis 3 Different temperature optimum of CO2 and COS assimilation.

Lab experiment on leave level with

* gs changes, Temperature fixed
* COS mixing ratio changes, fixed temperature and gs (test under low and high temperature)
* Temperature changes and gs is constant

Results:

* LRU is gs sensitive
* Sunflowers leaves emit COS under low ambient COS
* COS uptake decreases with higher temperatures

In progress: build conductance model and COS emission by leaves and the temperature dependence of the carbonic anhydrase. Optimize state variables by minimizing a cost function.

## Felix Spielmann – The leaf-internal conductance to COS

Ecosystem COS, CO2 and H2O fluxes for soybean wildtype and chlorophyll deficient mutant

Higher COS fluxes and LRU at the mutant plot (1.7) compared to the wildtype (1.5).

Drought reduced LRU down to 1.1 and 0.6 for the mutant and the wildtype respectively.

After rewetting LRUs of both variants down to 0.4 for the wildtype and 0.8 for the mutant. Change was mainly caused by reduction in the COS deposition velocity. Nearly full recovery for the mutant after 2nd rewetting and a slight recovery for the wildtype.

The internal conductance to COS was of similar magnitude as the stomatal conductance before the drought. The stomatal conductance to COS increased and became the major resistance to COS during the drought. After the irrigations the internal conductance to COS became the major limiting factor for the COS uptake in the wildtype.

Possible cause for the changes in internal resistance can be COS emissions of leaves.

Lab measurements showed COS leave emissions under drought stress of some soybean plants. Possibly originating from high cysteine content in the plant leaves.

Lab study of Rapeseed plants showed consequent emissions of COS and no net uptake!

Drought induced LRU changes

COS leaf emissions

## Florian Kitz – Plant roots and litter contributions to the COS exchange

Up to now plant roots and plant litter have been neglected in most studies focusing on soil COS exchange. An experimental setup was constructed to measure the contribution of live beech tree roots to the soil COS flux. Pots with roots had higher soil respiration compared to pots without roots, but lower COS emissions. Soil COS fluxes varied throughout the season, with trees in different phenological stages, even though the temperature and light exposure didn’t change between measurements. Diurnal variations were nearly parallel between root and non-root pots indicating little influence of the diurnal cycle of the plant on the rhizosphere. Diurnal variations were primarily influenced by changes in soil temperature.

The same experimental setup was used to measure plant litter from four different broadleaf tree species (plane, willow, beech and oak). COS litter fluxes varied between the tree species, with plane primarily emitting COS, beech consuming COS and oak and willow being on average neutral (willow with a huge variance). COS litter fluxes within a species seem to correlate with litter moisture.

## Le Kuai – Constraint on northern high latitude gross primary productivity with carbonyl sulfide

GPP second largest uncertainty in modelling the Alaskan arctic

Model framework to use COS to constrain Alaskan GPP:

Use global GPP data to simulate COS concentrations – compare simulated COS concentration to Alaskan COS observations – use observations to optimize COS plant uptake flux and global GPP data

COS observations: CARVE airborne campaign and four observation sites in Alaska

Simulated vertical draw down too weak in comparison with CARVE observations and too high boundary layer concentrations – optimized run (polar region sinks where amplified) in better agreement with observations

Comparisons of models vs in situ measurements: TRD4, CLM, GOSAT slightly overestimate but simulate the seasonality; GOME, SIB, CARDAMON underestimate seasonality (not enough summer drawdown)

At the Forest site models simulate the increase in GPP in Spring approximately a month too late in comparison to observations; at the tundra site models (except SIB) simulate the increase in GPP too early

The optimized model, TRD4, CLM, GOSAT simulate strong CO2 uptake in Alaska while GOME, SIB, CARDAMOM simulated weak uptake

Strong linear relationship between GPP and COS plant uptake flux

Less than 33 PgCyr-1 GPP and 247 GgSyr-1 plant uptake of COS for the region of 40°N ~ 90°N

## Ulli Seibt – COS as stomatal conductance tracer in a tropical rainforest

Data from the tropics!!

Eddy covariance, soil chambers and leaf/branch chambers on 3 heights: “sun”, “partial-sun” and “shaded”. Branch chambers contained different species.

The highest COS and CO2 uptake was found in the partial sun chamber, followed by the sun and the shaded chamber. The shaded chamber also had the highest LRU under high light conditions.

Only 2/3 species take up COS during nighttime!

Leaf fluxes show seasonal changes and depend on the location of the canopy. Leaves of the species in sun chambers during dry season have holes/are damaged.

No reliable soil chambers data yet.

Eddy data shows uptake for COS and CO2 of up to around -50 pmol/m2s and -20 pmol/m2s but likely to be underestimated!

The understory is decoupled at almost all times: ground level CO2 is always elevated; ground level COS is always depleted!