A REVISED DRY DEPOSITION SCHEME FOR LAND-ATMOSPHERE EXCHANGE OF TRACE GASES IN ECHAM/MESSy (PUBLISHED SOON)

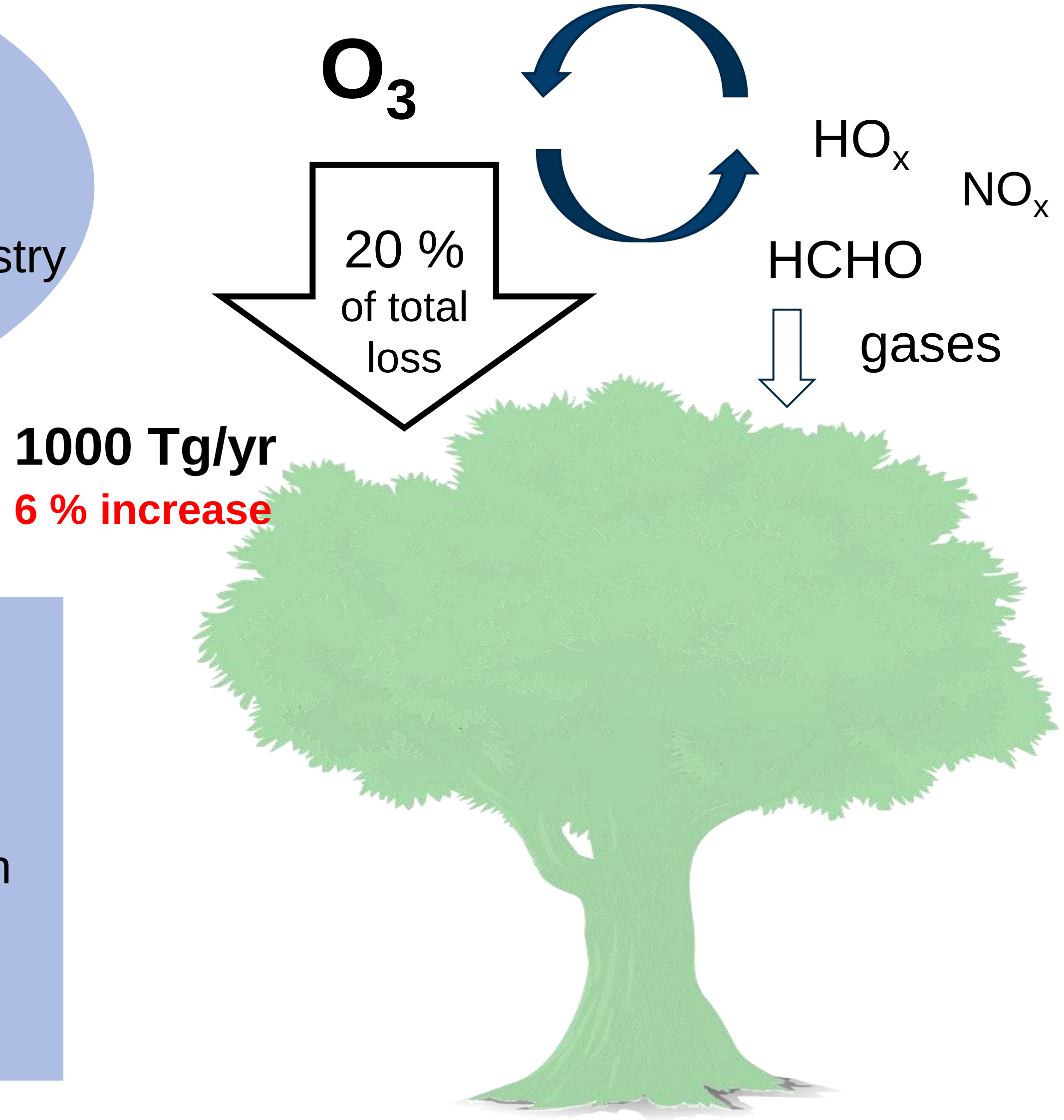
Tamara Emmerichs[1], Astrid Kerkweg[1], Huug Ouwersloot[2], Silvano Fares[3], Ivan Mammarella[4]
and Domenico Taraborrelli[1]
[1] Institute of Energy and Climate Research 8, Troposphäre, Forschungszentrum Jülich, Jülich, Germany
[2] Max Planck Institute for Chemistry, Mainz, Germany
[3] National Research Council, Institute of Bioeconomy, Rome, Italy
[4] Institute for Atmospheric and Earth System Research, Faculty of Science, University of Helsinki, Finland

Contact: t.emmerichs@fz-juelich.de

Ozone

- Noxious air pollutant harmful for humans and vegetation
- Greenhouse gas
- Important oxidant in tropospheric chemistry

Positive model bias (1)



O_3

20 % of total loss

1000 Tg/yr

6 % increase

HO_x

NO_x

HCHO

gases

Project

Revision of ozone dry deposition in the global atmospheric chemistry model ECHAM5/MESSy

Objectives

- More realistic diurnal and seasonal variability of dry deposition
- Adaption of stomatal aperture in extreme events
- Better representation of soil moisture
- Better agreement of surface ozone with global observations

Dry deposition parametrization (2)

Multiple resistance analogy:

- Resistances represent compartments (stomata, cuticle etc.)
- Combination to dry deposition velocity

One big-leaf approach:

- Single resistances correspond to the whole canopy
- Neglecting of detailed canopy structures
  - ➢ Only Leaf Area index[1]

[1] leaf area/surface area (m^2/m^2) - LAI

Two main dry deposition pathways

Stomata

$$R_{stom,corr}(X) = \frac{R_{stom}(PAR, \boxed{LAI})}{fws \cdot \boxed{f(T) \cdot f(VPD)}} \cdot \frac{D_{H_2O}}{D(X)} \quad (3)$$

new

new

D: molar diffusivity of water and species X
$R_{stom}(X)$: stomatal resistance
$f(T)$: temperature stress factor
$f(VPD)$: Vapour pressure deficit stress factor
fws: soil mosture stress factor
PAR: fraction of solar radiation

$$f(T) = 0.008 \cdot (T - T_l)(T_h - T)^{0.5} \quad (3)$$

$T_l = 268.15K$
$T_h = 318.15K$

$$f(VPD) = VPD^{-0.5}$$

VPD: difference between actual and saturated vapour pressure (4)

Cuticle (dry)

$$R_{cut}(X) = \frac{\boxed{R_{cut,d}(O_3)}}{10^{-5} \cdot H(X) + s_{reac}(X)} \quad (5)$$

Constant replaced

$R_{cut}(X)$: cuticular resistance of the gas X
$R_{cut,d}(O_3)$: dry cuticular resistance of the ozone
$H(X)$: solubility
$s_{reac}(X)$: reactivity

$$R_{cut,d}(O_3) = \frac{R_{cut,d0}(O_3)}{\exp(0.03 \cdot RH) \cdot LAI^{0.25} \cdot u_*} \quad (6)$$

u_*: friction velocity
RH: relative humidity

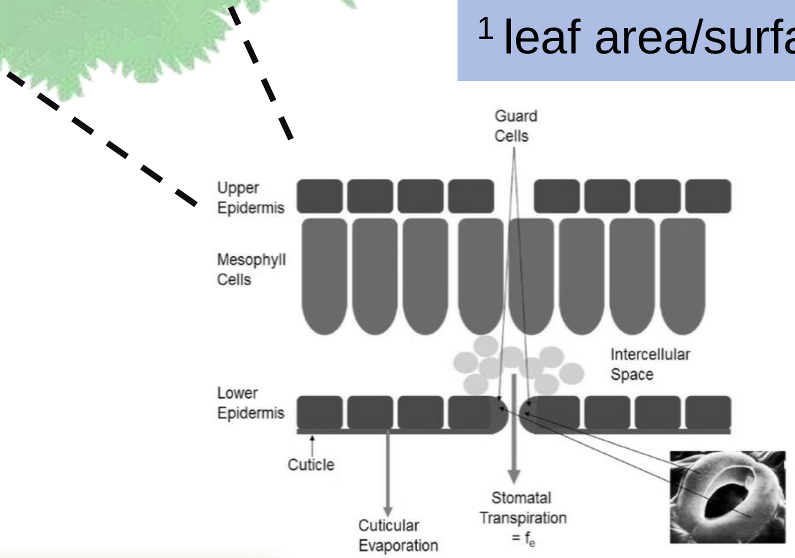
Radiation

Leaf Area Index

Temperature

Humidity

Soil moisture



Two main dry deposition pathways

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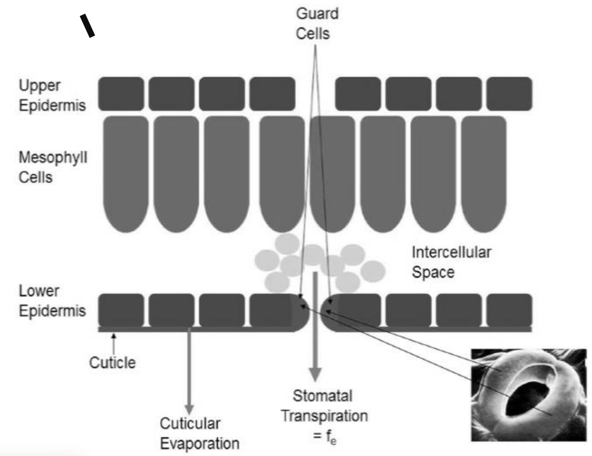


Radiation

Leaf Area Index

Temperature

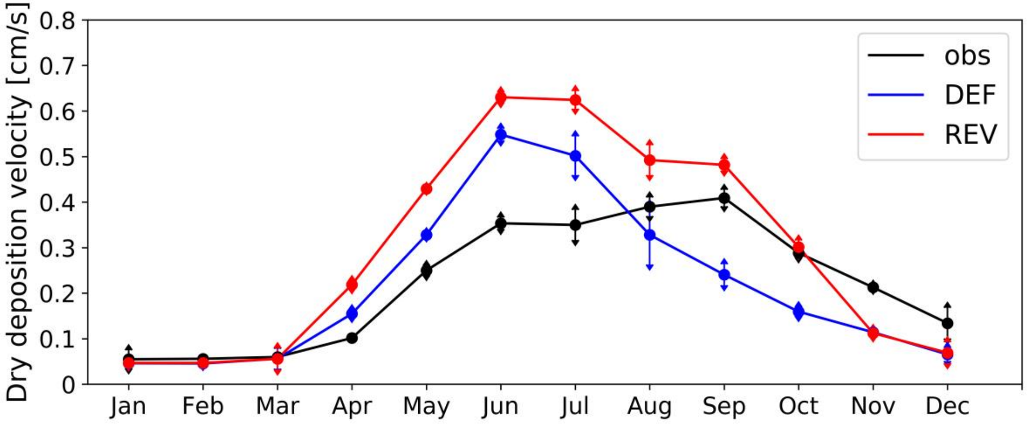
Humidity

Soil moisture

Impact

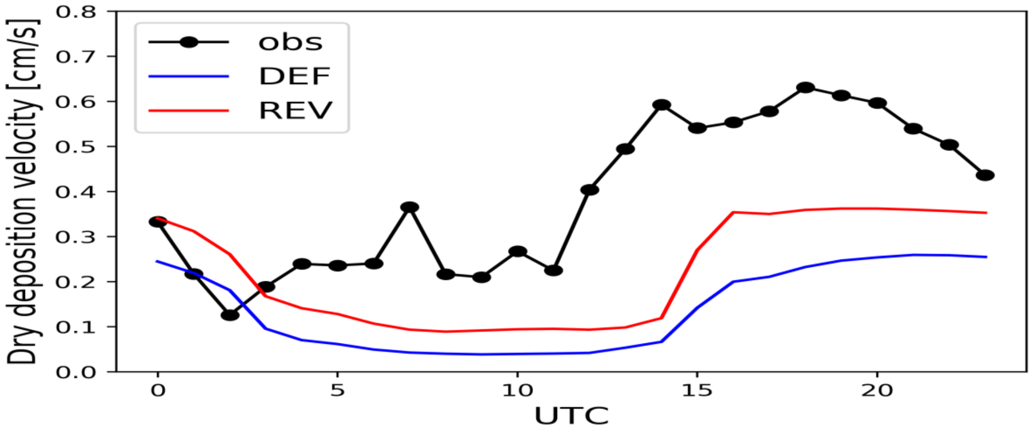
Mean annual cycle of dry deposition velocity at Hyytiälä research station (Finland)

- Overestimation of observations (obs)
  - Default (DEV) scheme: oversimplified usage of LAI
  - REVISED (REV) scheme: too high cuticular uptake due to mismatching humidity, too low stomatal soil moisture stress in summer



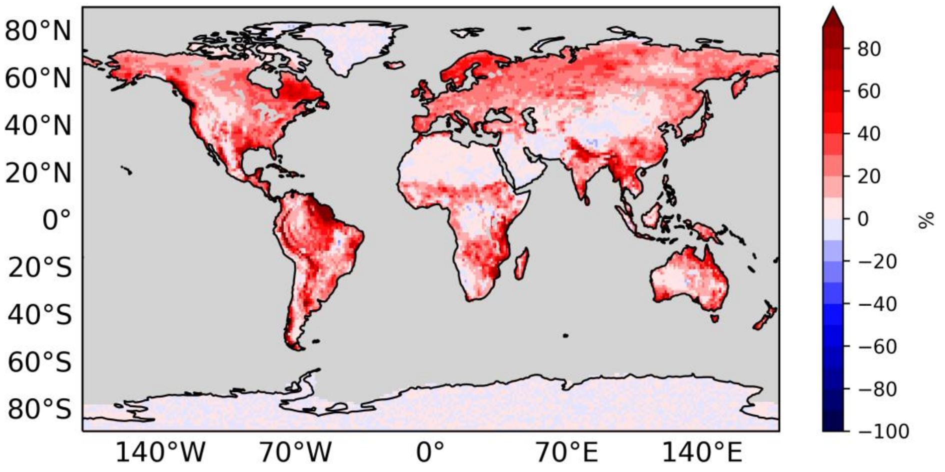
Mean summer diurnal cycle of dry deposition velocity at Lindcove research station (California)

- Underestimation of observations (obs)
  - Default (DEF) scheme: only stomatal uptake
  - REVISED (REV) scheme: too high reduction of stomatal uptake due to mismatching meteorology & too less in-canopy reactions



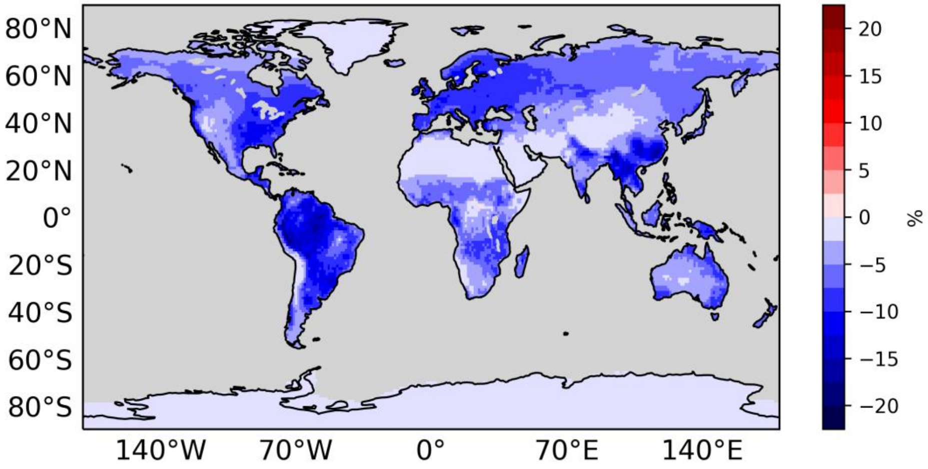
Relative change of annual mean dry deposition velocity

- Increase dominated by cuticular uptake
  - Favoured at moist surfaces
  - During night
- Larger variability of stomatal uptake
  - Heat and drought (± 45 %)
  - Soil moisture (increase at dry soil)



Relative change of annual mean surface ozone mixing ratio

- Combined effect
  - Change of O_3 dry deposition
  - Changed removal of O_3 precursors
- **Regional: up to 20 %**
- Global: small change



Conclusion

- Revision increases the dry deposition of ozone
- Impact of VPD adjustment > temperature adjustment
  - Regional variable
- Dominant increase cuticular uptake is favoured in humid climate
- Decrease of surface ozone regionally > 20 %
  - Indirect and direct effect
  - Impacts the related chemistry
- Potential to reduce the positive bias of surface ozone in global models

Comparison with observations:

New scheme enables a more realistic representation of dry deposition

- Strong limitation due to limits in representation of the local meteorology

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