A model study of stomatal uptake of ozone in a costal Mediterranean maquis ecosystem

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Introduction

•Increased tropospheric background concentration of ozone have reached values of which adverse effects on vegetation such as reduced biomass production causing reduced biodiversity and economic loss due to reduced crop yield can be expected.

•Estimation of the total stomatal dose of ozone to the vegetation requires calculation of the stomatal flux of ozone from the ambient air into the vegetation.

•In this study, the stomatal flux estimated by the dry deposition scheme within the WRF- Chem model (Weather Research and Forecasting model with Chemistry) is compared to eddy covariance data gathered in Castelportziano, Italy, during the summer of 2007.

Model and methodology

•WRF-Chem V3.2 (Weather Research and Forecasting model with chemistry) (Grell et al., 2005)
•RADM2 chemistry scheme
•The modelled stomatal flux is compared to the flux derived from eddy covariance data from Castelportziano outside Rome, Italy (Gerosa et al. 2009) for the daytime hours.
•To account for the evaporative power of the atmosphere on the stomatal conductance, two different water vapor pressure deficit (VPD) functions were used:

$$fVPD = \frac{(1-0.1)(c-VPD)}{c-d} + 0.1$$

$$If \sum VPD \geq \sum VPD_{crit} \ then \quad g_{st,hour\ n+1} \leq g_{st,hour\ n}$$

•The VPD effect was only included in an off-line mode, but will later be included in on-line calculations

Simulation periods	2007, May 21-26 and June 23-28
Horizontal resolution	Nested 27x27km 9x9km 3x3km 1x1 km
Vertical resolution	27 layers in all domains
Antropogenic emissions	TNO/EMEP emissions dataset (www.tno.nl/emissions) RETRO (http://retro.enes.org)
Biogenic emissions	MEGAN v2.04 (Guenther et al., 2006)
Initial and boundary conditions	Meteorology: ECMWF-IFS Chemistry: Oslo CTM2

Dry deposition in WRF-Chem

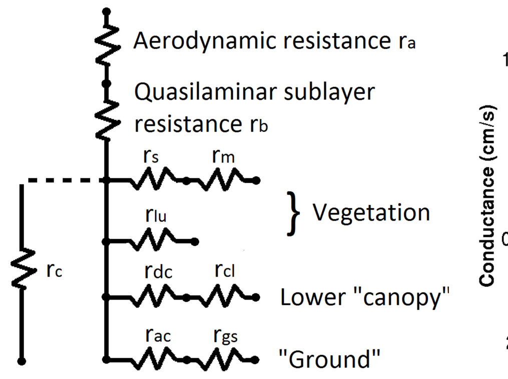

Figure 1: Resistance network from Wesely (1989)

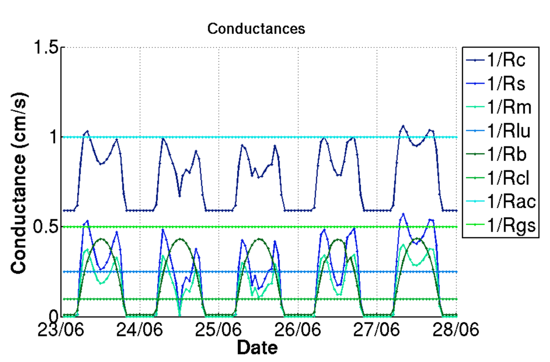

Figure 2: Surface conductances as modelled in WRF for the period June 23-28 2007

•Dry deposition scheme for ozone based on Wesely (1989)
•"Big leaf" approach
•Flux: $F = v_d * C$
•Deposition velocity: $v_d = \frac{1}{r_a + r_b + r_c}$

•Stomatal conductance is regulated by surface temperature and shortwave radiation:

$$r_{st} = r_i \left\{1 + \left[200 \frac{1}{G+0.1}\right]^2\right\}\left\{400 \frac{1}{T_s(40-T_s)}\right\}$$

Summary and conclusions

•The second of the two simulated periods was characterized by a lower measured stomatal flux, caused by overall dryer conditions at the measuring site, reducing the rate of evapotranspiration substantially, and thereby also uptake of ozone
•Introducing the reduction in ozone uptake due to VPD improved the model results in the second period in comparison with the measurements.

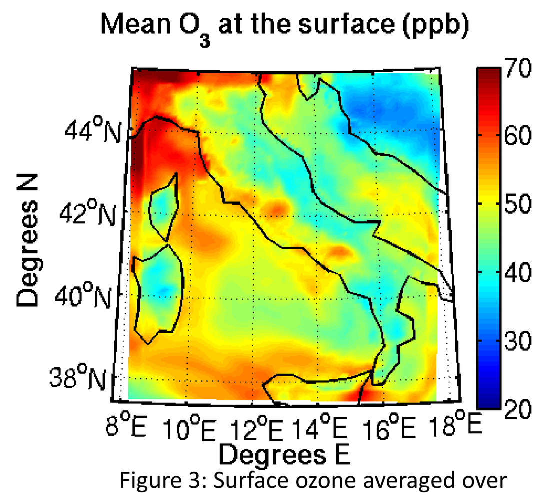

Figure 3: Surface ozone averaged over daylit hours (6-17 UTC) in the May period.

Results May 21-26

Diurnal mean measured ozone at site: 42.1 ppb
Diurnal mean modelled ozone at site: 46.2ppb

Mean measured flux (daylit hours)	Mean modelled flux without VPD (daylit hours)	Mean modelled flux with VPD limitations
5.24nmol/m^{2}s	5.31 nmol/m^{2}s	4.61 nmol/m^{2}s

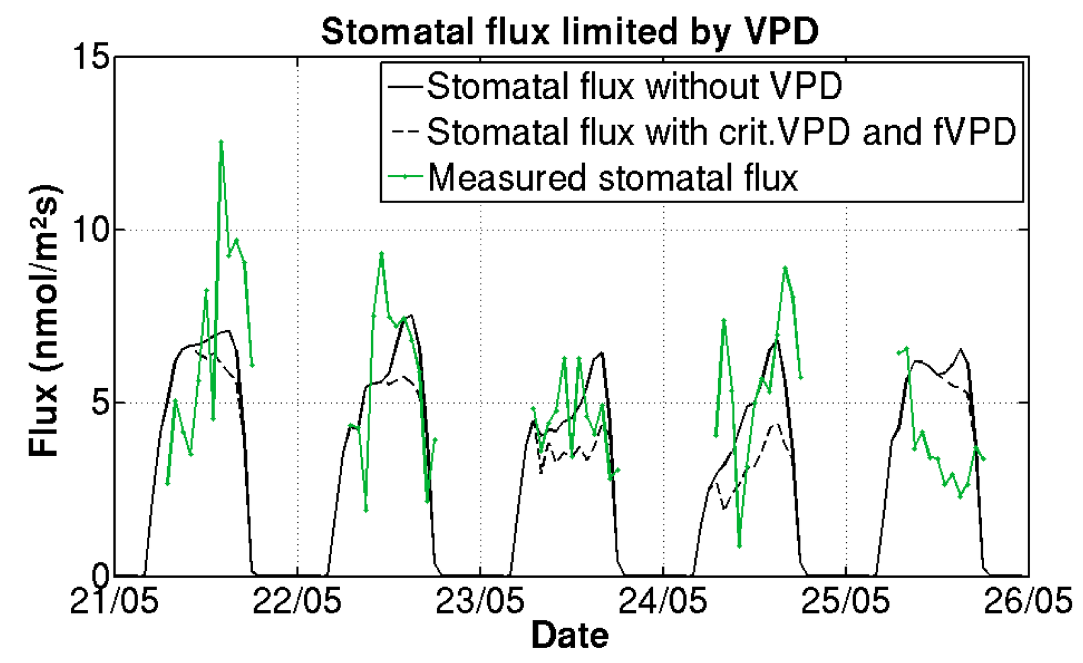

Figure 4: Measured and modelled stomatal fluxes.

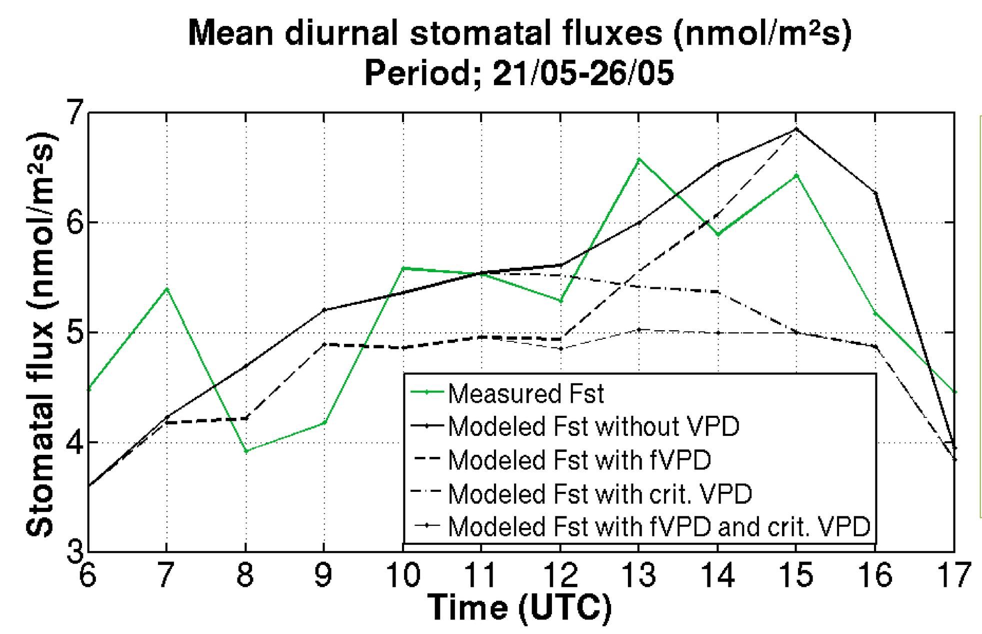

Figure 5: Measured and modelled stomatal fluxes, averaged over the 5 days in the period.

Correlation coefficients
Without VPD: 0.70
fVPD: 0.69
VPDcrit: 0.51
Both VPD: 0.63

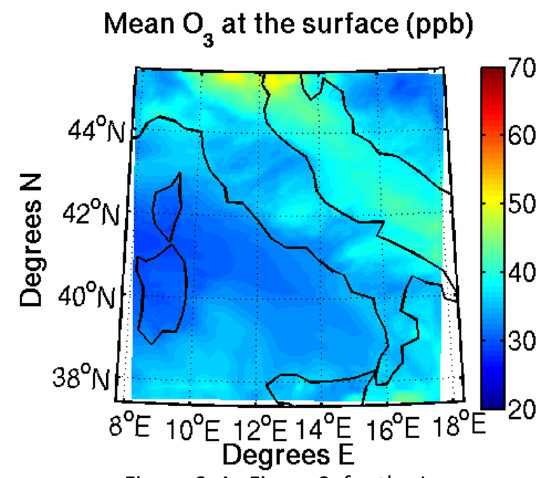

Figure 6: As Figure 3, for the June period.

Results June 23-28

Diurnal mean measured ozone at site: 43.2 ppb
Diurnal mean modelled ozone at site: 35.6 ppb

Mean measured flux (daylit hours)	Mean modelled flux without VPD (daylit hours)	Mean modelled flux with VPD limitations
1.98 nmol/m^{2}s	3.02 nmol/m^{2}s	2.16 nmol/m^{2}s

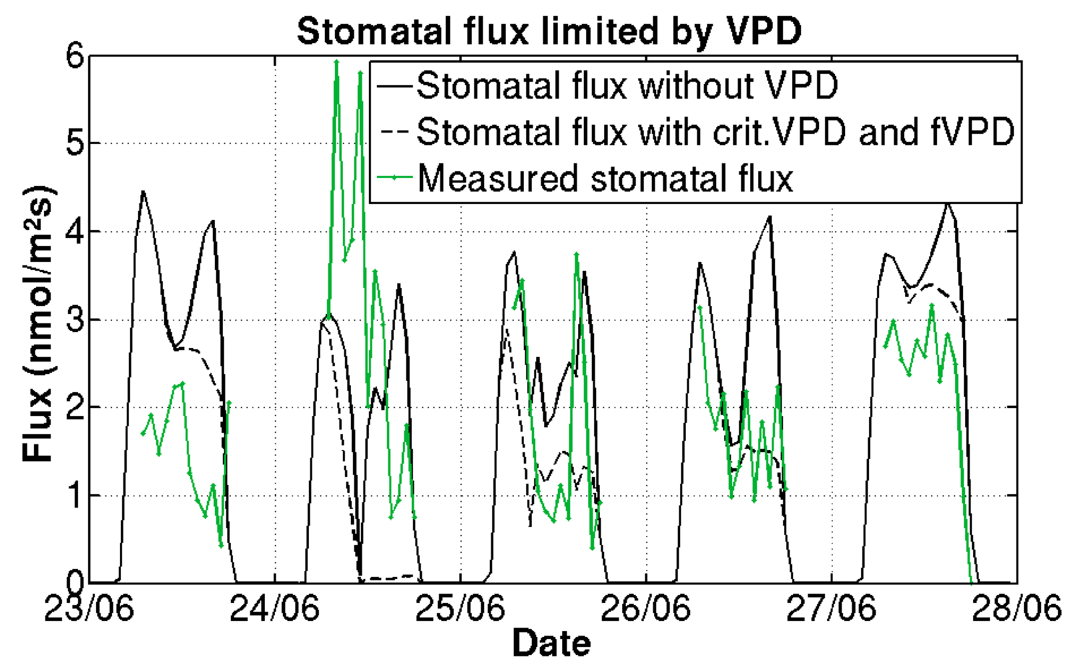

Figure 7: Measured and modelled stomatal fluxes.

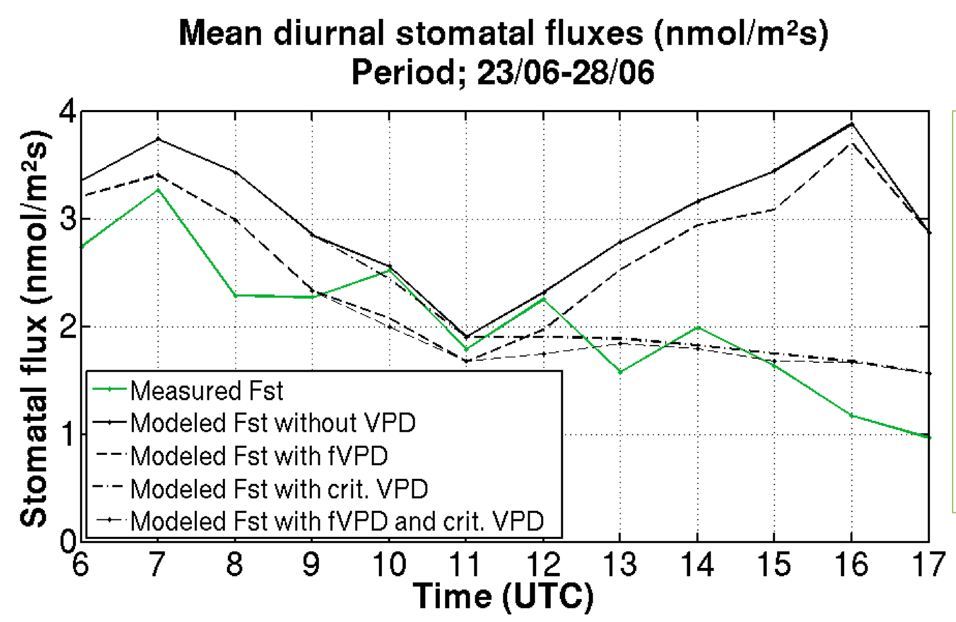

Figure 8: Measured and modelled stomatal fluxes, averaged over the 5 days in the period.

Correlation coefficients
Without VPD: 0.06
fVPD: -0.03
VPDcrit: 0.85
Both VPD: 0.81

References

•**Gerosa, G., A. Finco, et al. (2009)**. "Interactions among vegetation and ozone, water and nitrogen fluxes in a coastal Mediterranean maquis ecosystem." Biogeosciences 6(8): 1783-1798.
•**Guenther, A., Karl, T., Harley, P., et al. (2006)**. "Estimates of global terrestrial isoprene emissions using MEGAN (Model of emissions of gases and aerosols from Nature)". Atmospheric Chemistry and Physics 6, 3181-3210
•**Grell, G. A., S. E. Peckham, et al. (2005)**. "Fully coupled "online" chemistry within the WRF model." Atmospheric Environment 39(37): 6957-6975.
•**Wesely, M. L. (1989)**. "Parameterization of surface resistances to gaseous dry deposition in regional-scale numerical-models." Atmospheric Environment 23(6): 1293-1304.

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