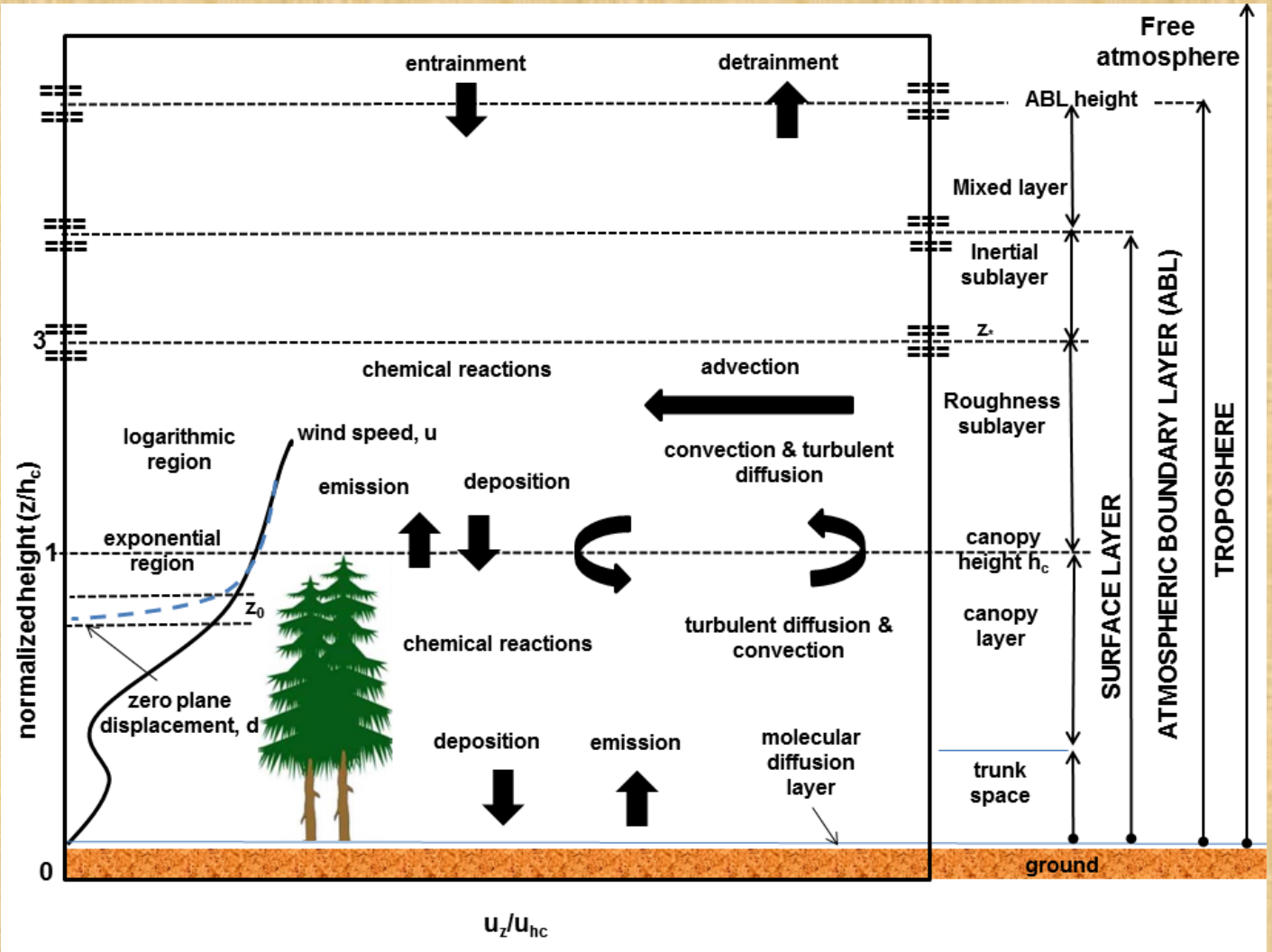
Reactive and non-reactive trace gas exchange within and above an Amazonian rainforest

Stefan Wolff, Matthias Sörgel, Antonio O. Manzi,
Leonardo Deane de Abreu Sá, Laurens Ganzeveld
Ivonne Trebs, Meinrat O. Andreae

Motivation

Trace gas exchange in the Amazonian rainforest



Physical and chemical processes of the Atmospheric Boundary Layer in and above a forest canopy including the wind profile characteristic [Tsokankunku, 2012; originally after Enders et al. (1992) and Amiro (1990)]

Photos of/from the walk-up tower

Fotos from/of the ATTO tower

Measurements

The profile system for CO2, H2O, O3, NO, NO2

Analysis of air from

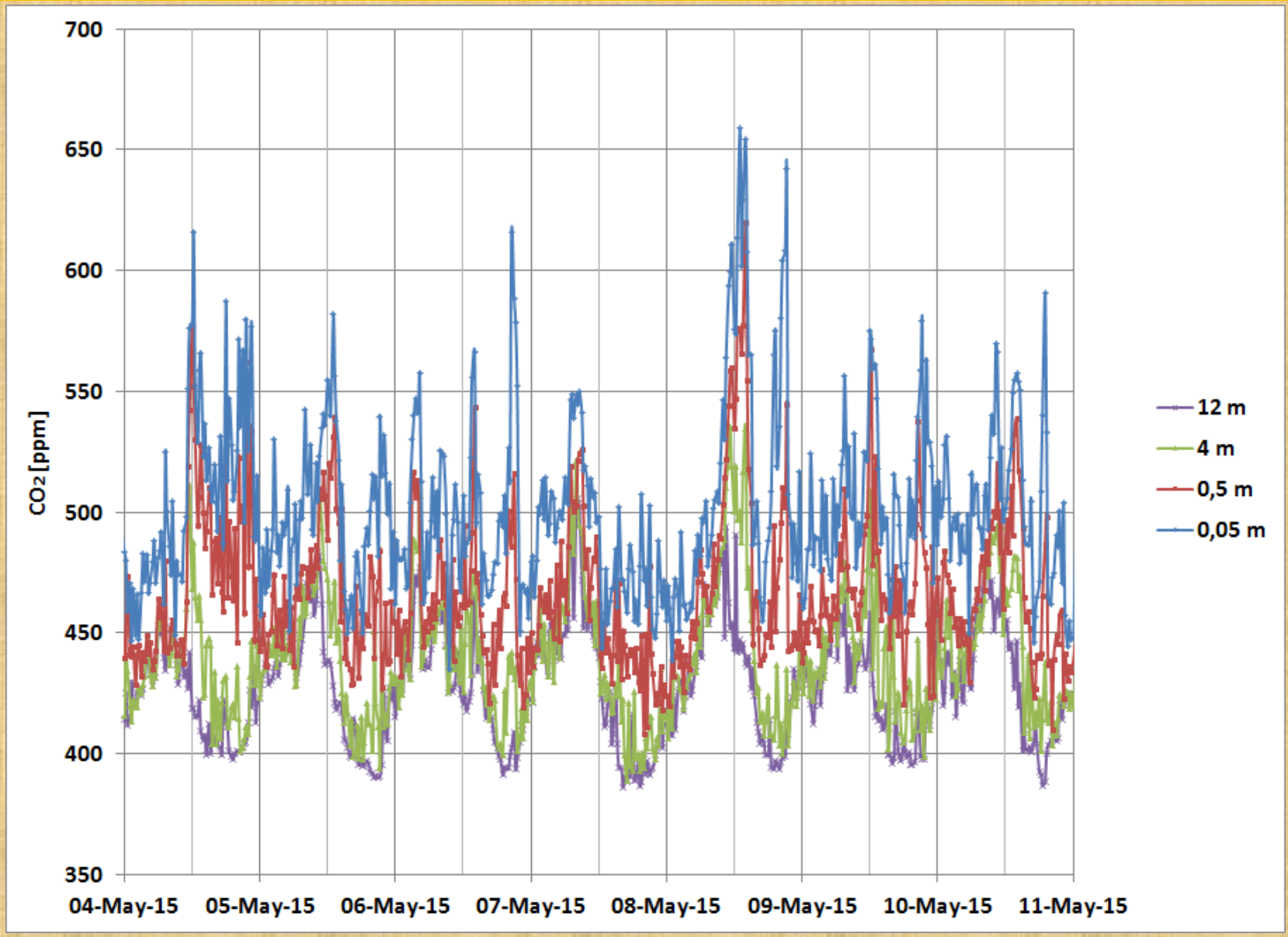
0,05 m
0,5 m
4 m
12 m
24 m
38,3 m
53 m
79,3 m

by switching valves between inlets

Measurements

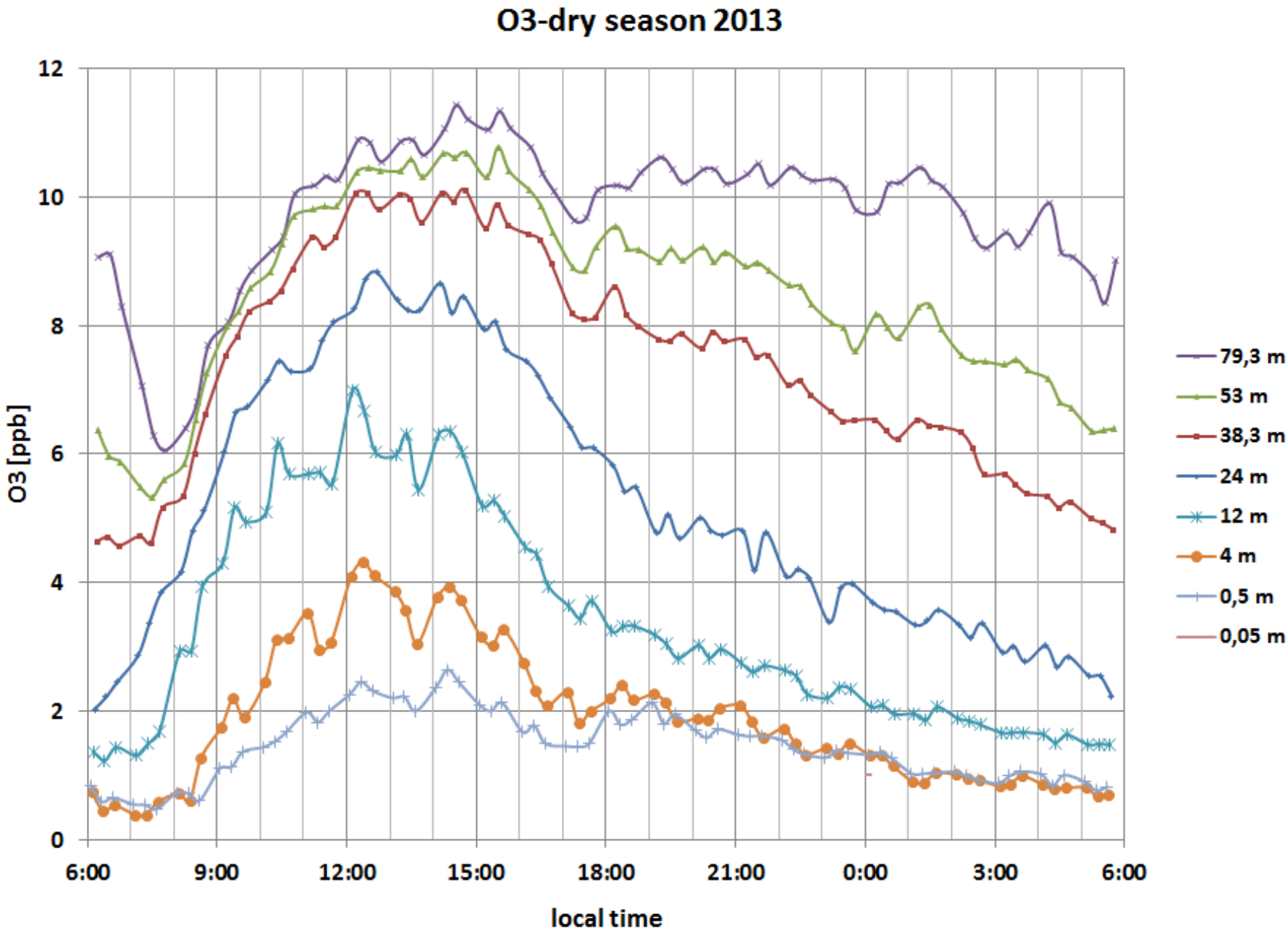
The profile system

CO2 mixing ratios inside the canopy

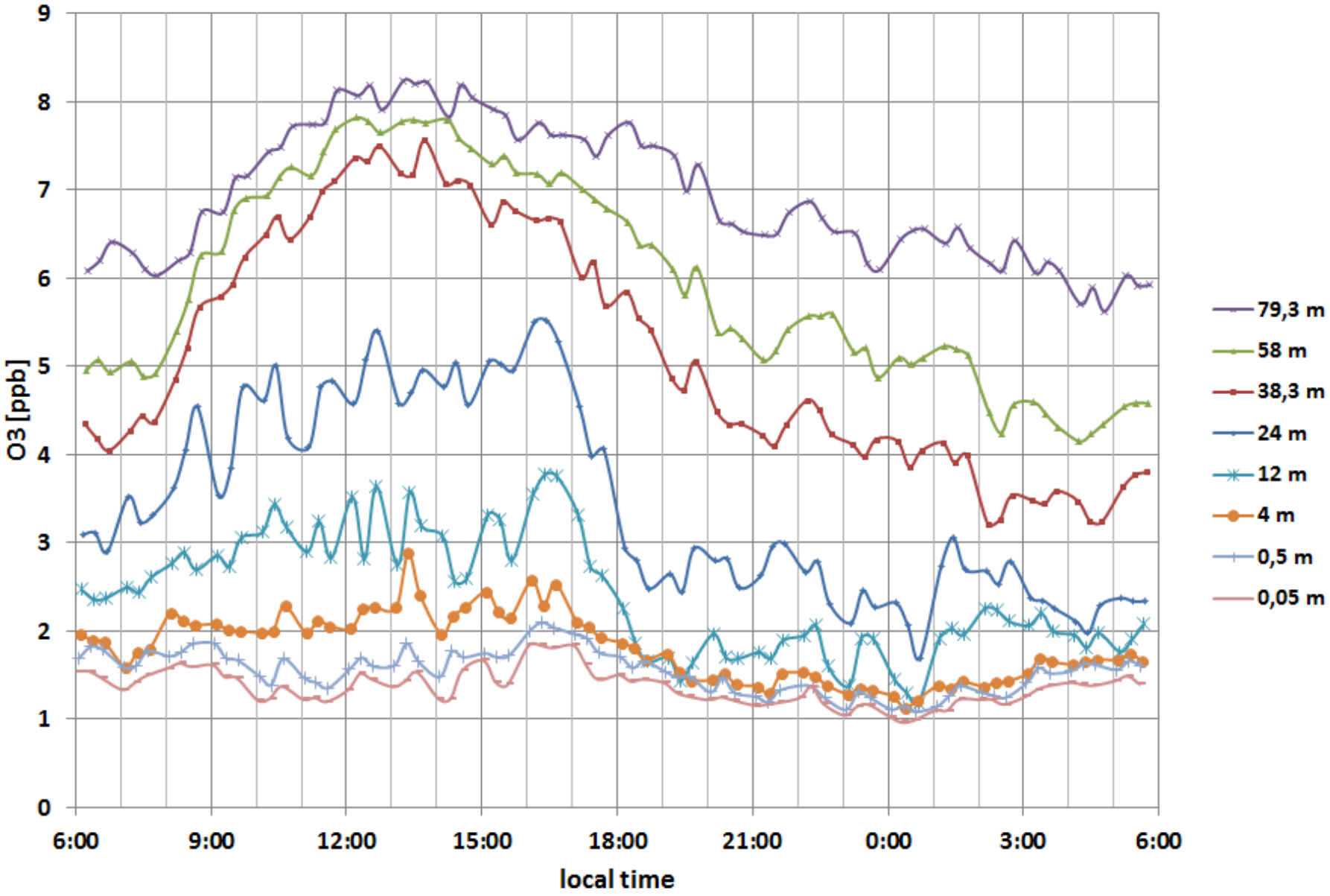


Time in UTC

Average gradients

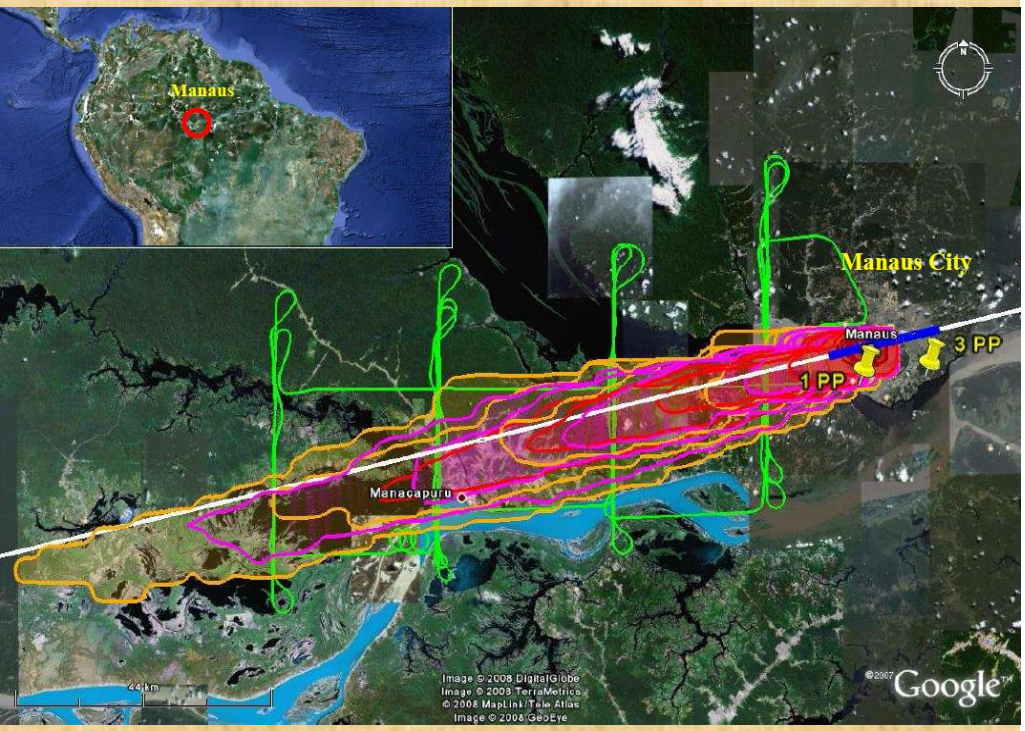


Average gradients



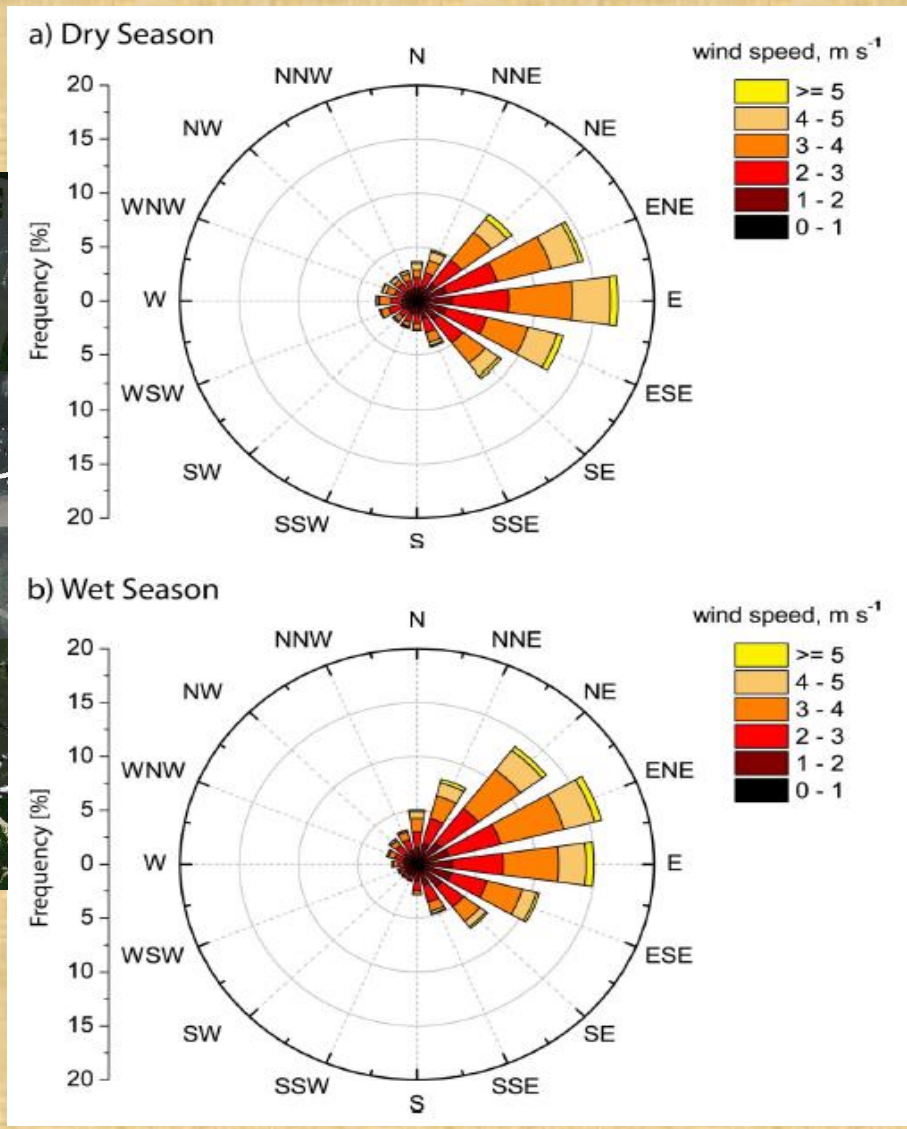
Urban pollution in the trade wind zone

Manaus Plume



Kuhn et al., 2010

Wind distribution at the ATTO site

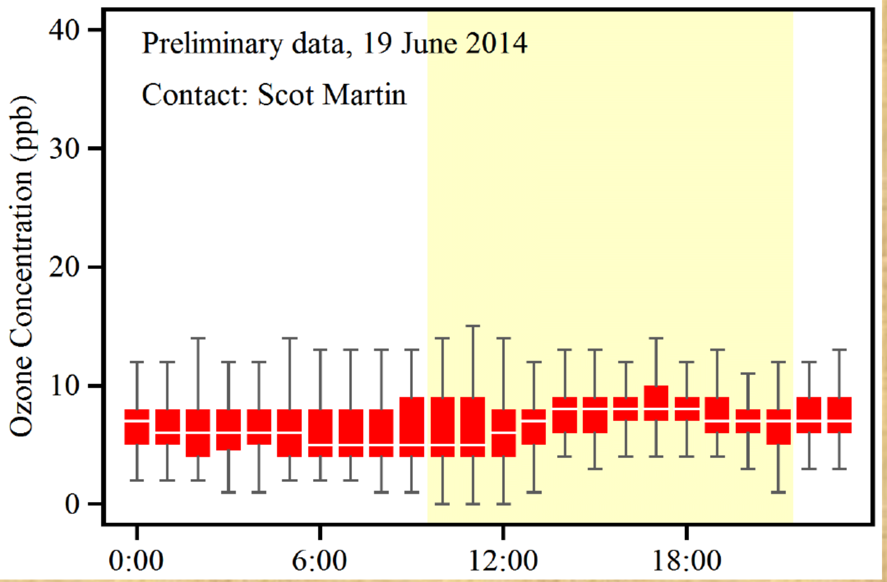


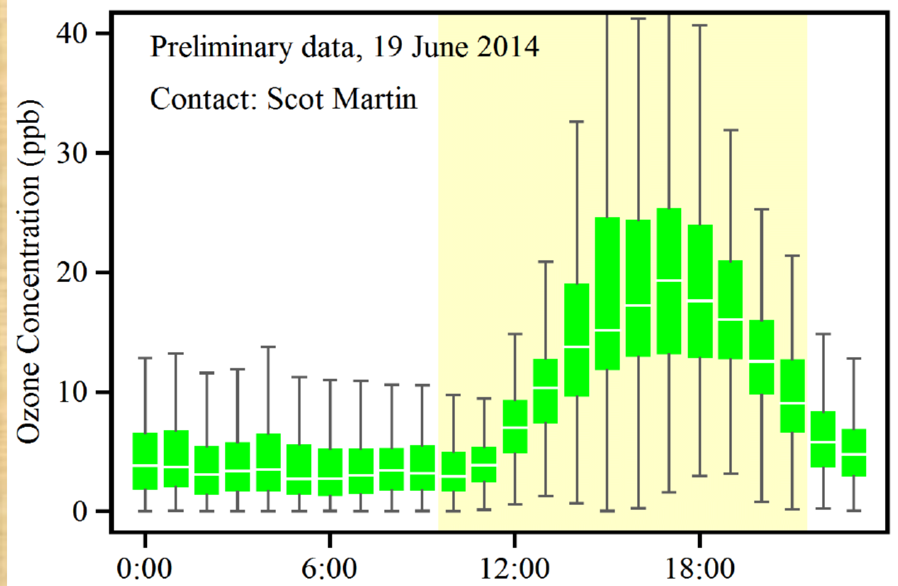
Andreae et al., 2015

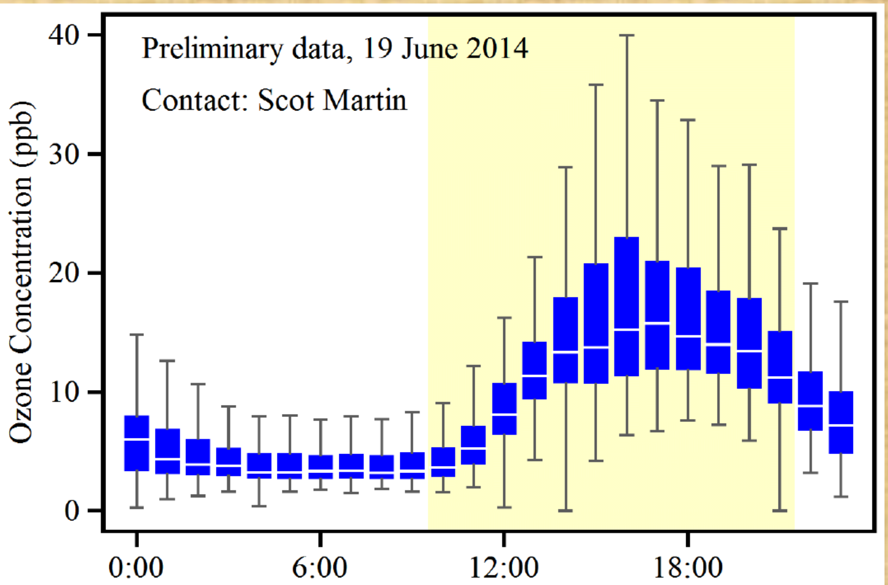
The ATTO site (T0) compared to (T2) and (T3)

Wet season

Feb/Mar 2014





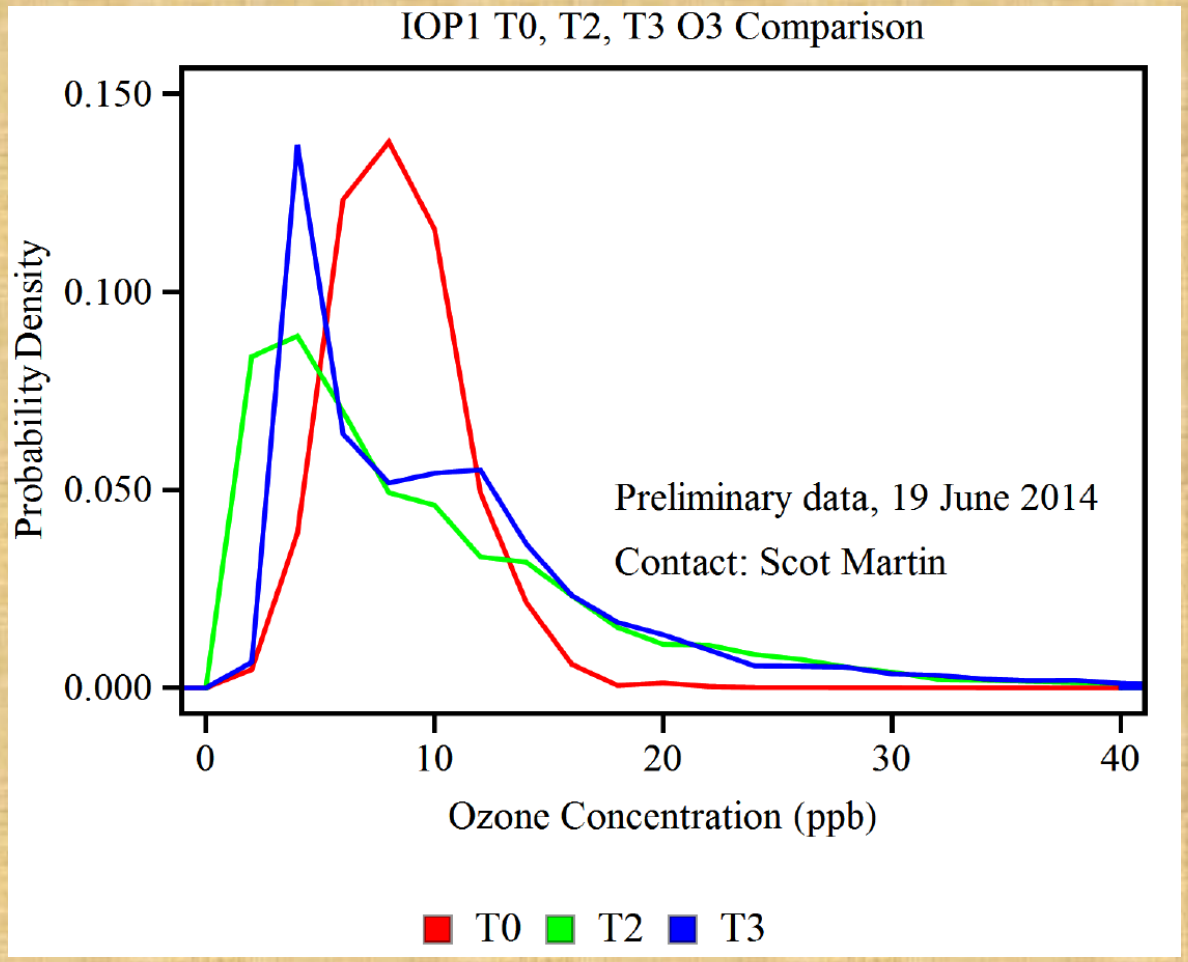


T0 T2 T3

Time in UTC

By courtesy of Scot Martin

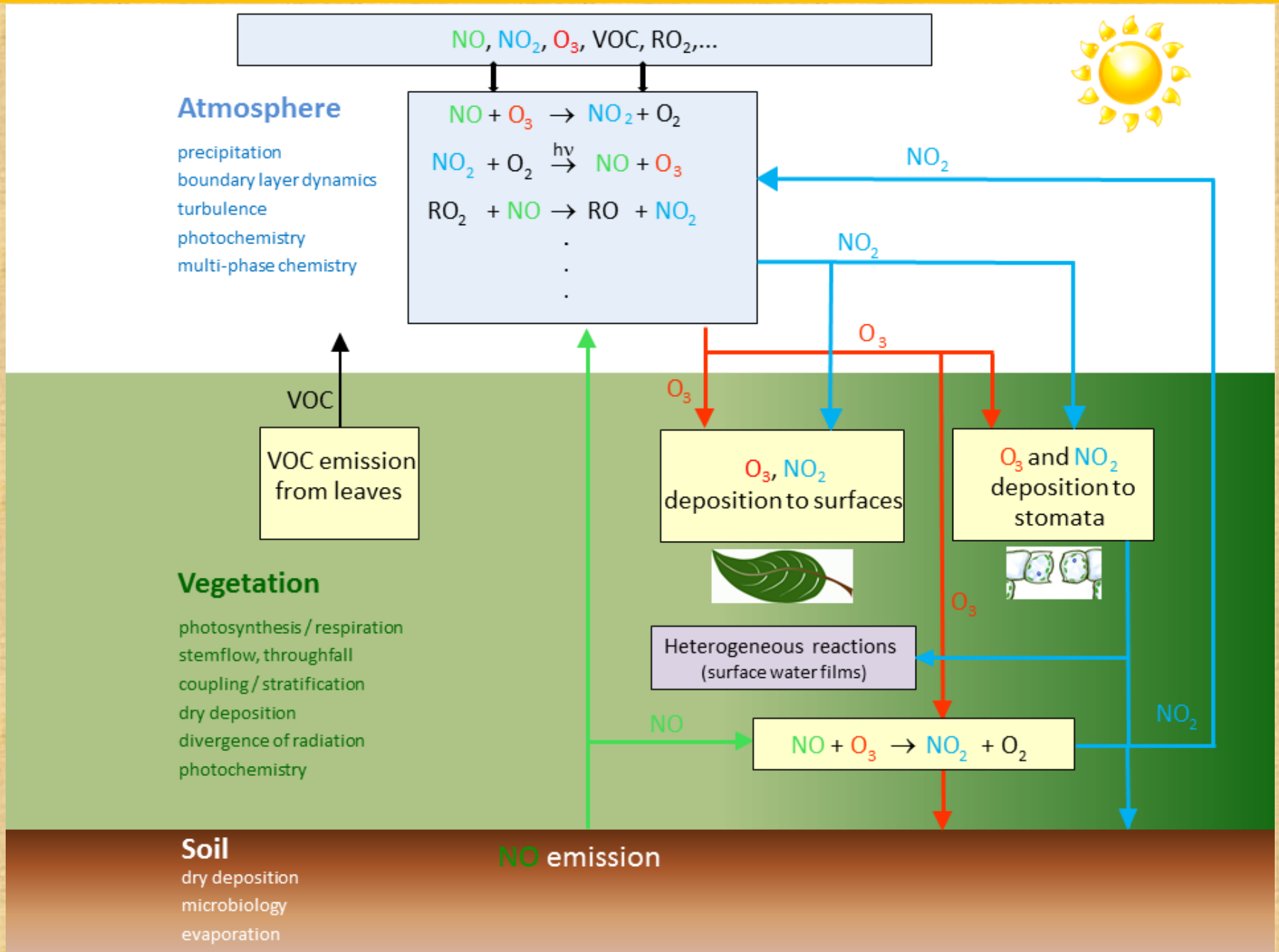
The ATTO site (T0) compared to (T2) and (T3)



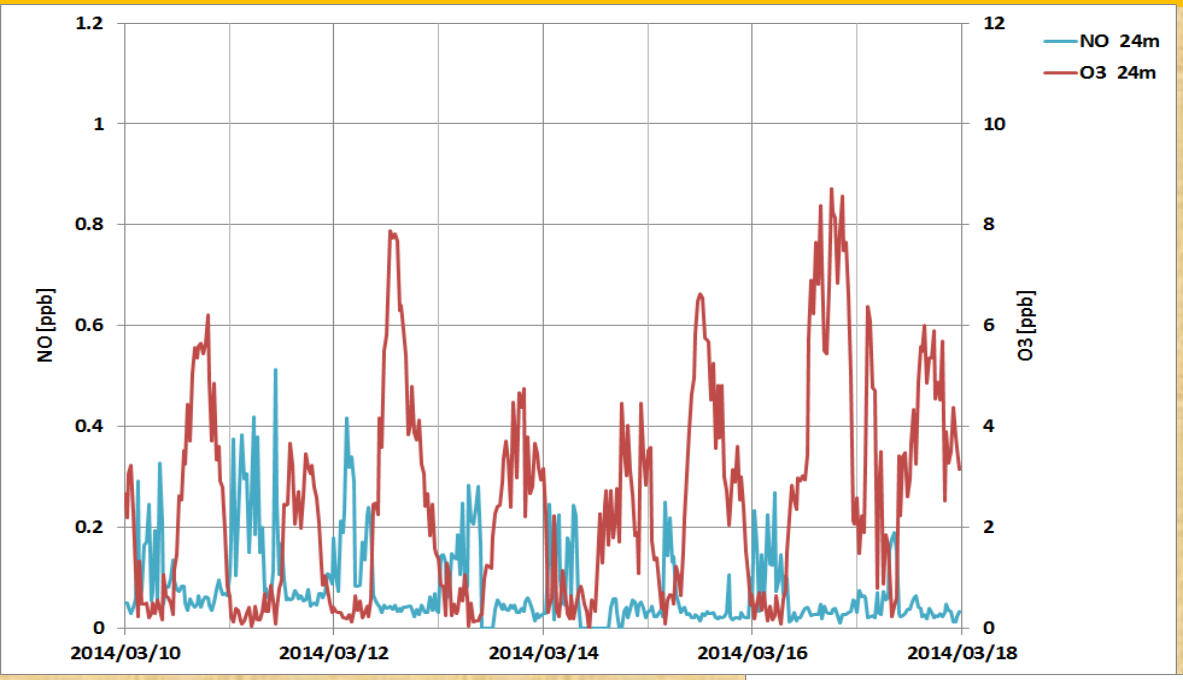
By courtesy of Scot Martin

Maximum at the ATTO site higher than at T2 and T3 – due to reactions with NO

Theory

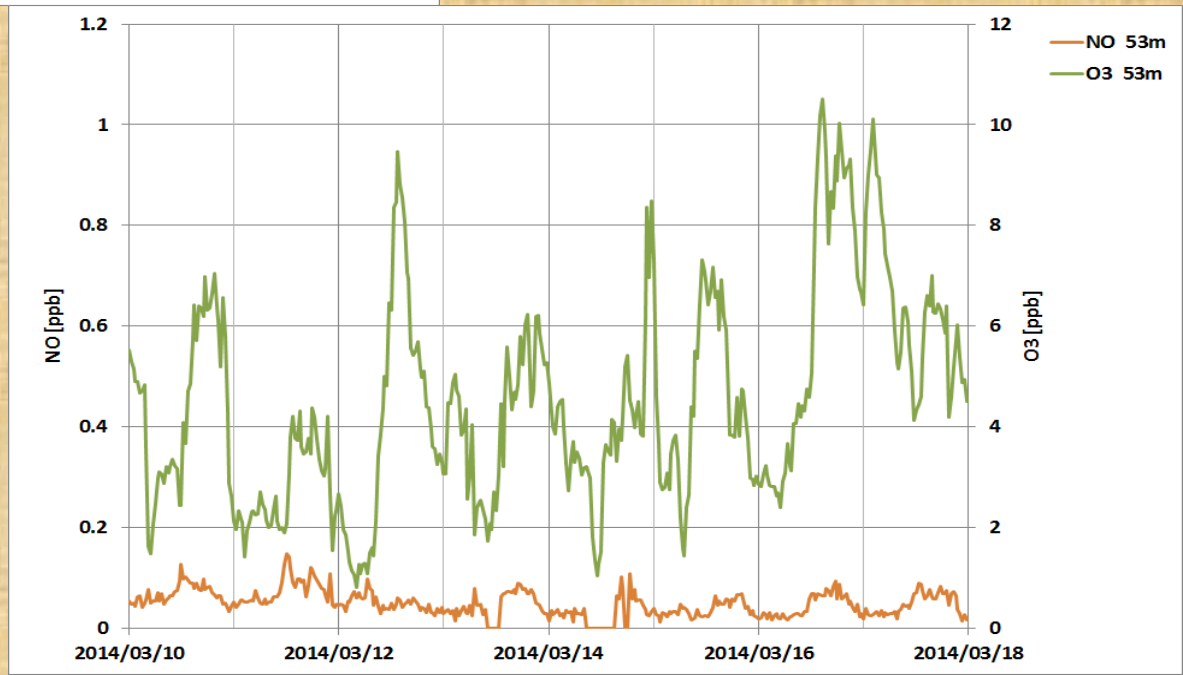

NO, NO2, O3, VOC, RO2,...
Atmosphere
precipitation
boundary layer dynamics
turbulence
photochemistry
multi-phase chemistry
NO + O3 → NO2 + O2
NO2 + O2 hν→ NO + O3
RO2 + NO → RO + NO2
NO2
NO2
O3
O3
VOC
VOC emission from leaves
O3, NO2 deposition to surfaces
O3 and NO2 deposition to stomata
Vegetation
photosynthesis / respiration
stemflow, throughfall
coupling / stratification
dry deposition
divergence of radiation
photochemistry
Heterogeneous reactions (surface water films)
O3
NO
NO + O3 → NO2 + O2
NO2
Soil
dry deposition
microbiology
evaporation
NO emission

O3-NO anticorrelation – wet season

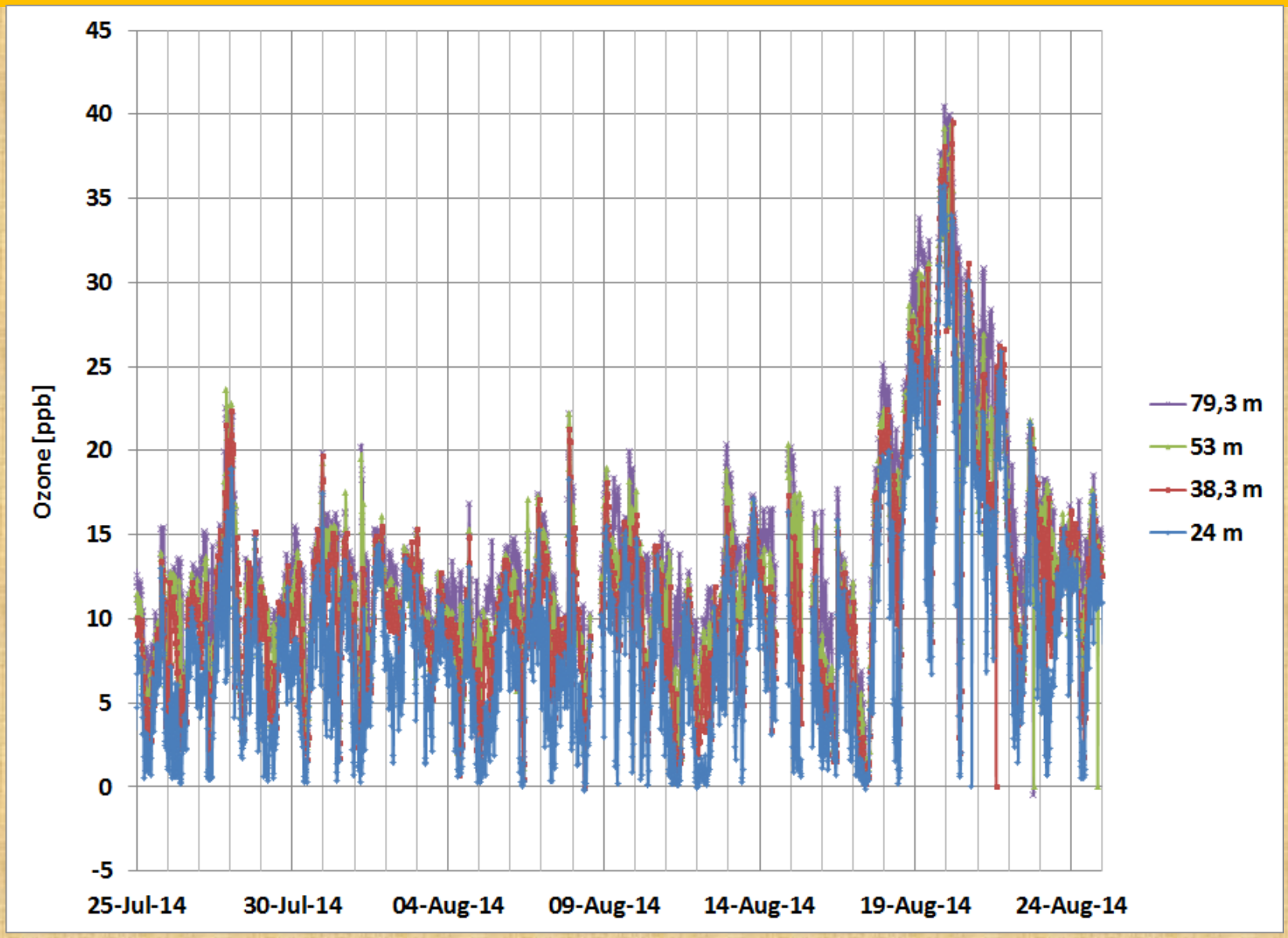


Decoupled forest at night

Photostationary equilibrium depending on incoming solar UV-ratiation

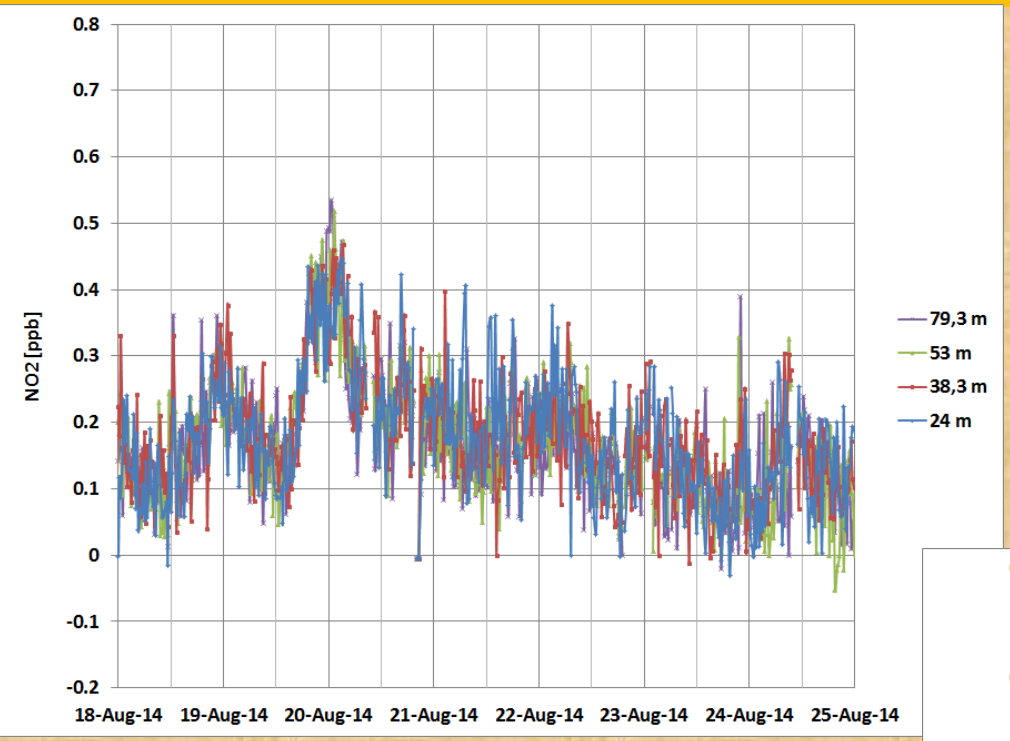


Biomass burning effects on air composition



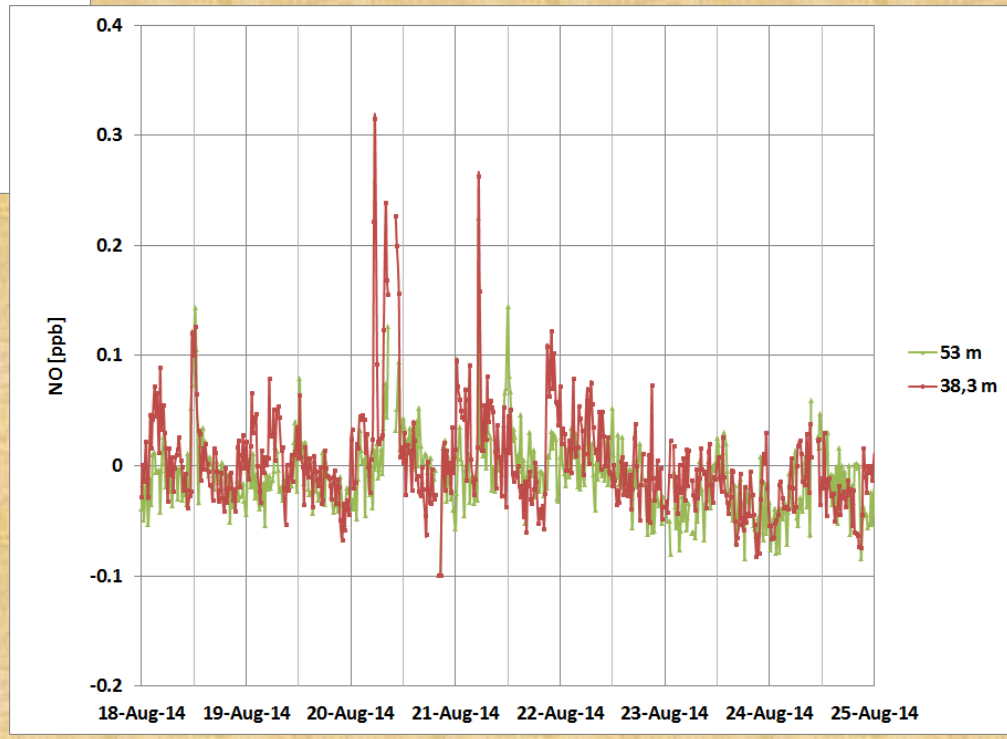
O3 mixing ratios – Example for the drier season 2014

Biomass burning effects on air composition



NO and NO2 mixing ratios

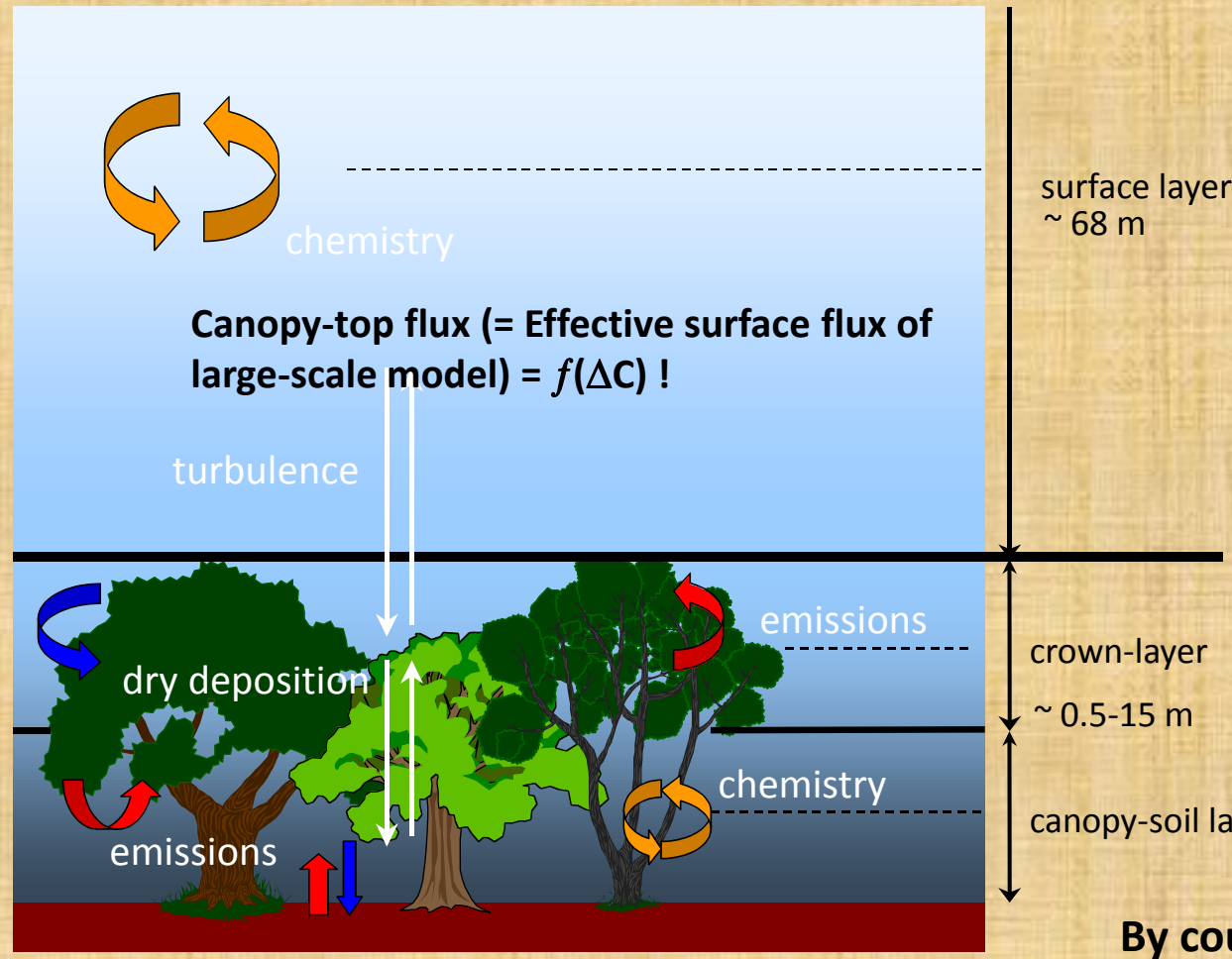
Example for the drier season 2014



MLC_CHEM: Multi-Layer Canopy Chemical Exchange Model

Multi-layer model of atmosphere-biosphere exchanges of reactive compounds and aerosols

- site-scale studies, e.g., analysis of surface & in-canopy observations
- large-scale studies of atmosphere-biosphere exchange

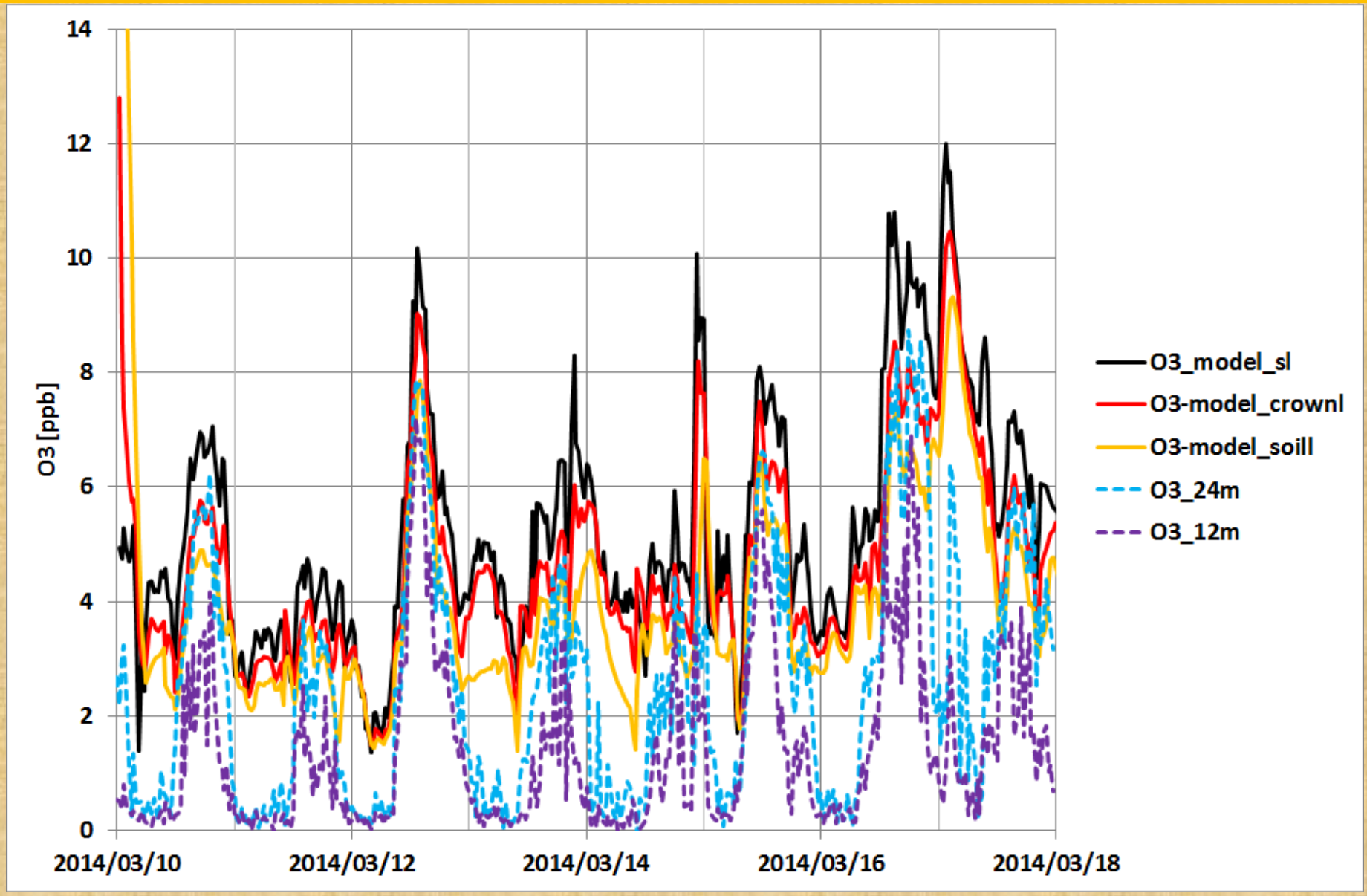


- Soil NO, Rn emission
- Foliage NO_x and HONO emissions
- BVOC emissions
- Dry deposition gases & aerosols
- Compensation point (e.g., NO_2, NH_3, OVOCs)
- Extinction of radiation (BVOC emissions, dry deposition and photolyis)
- Canopy wind speed profile
- Gas-phase chemistry (CBM4)
- Turbulent exchange

Ganzeveld et al., JGR, 2002a
Ganzeveld et al., AE, 2006
Kuhn et al., ACP, 2007

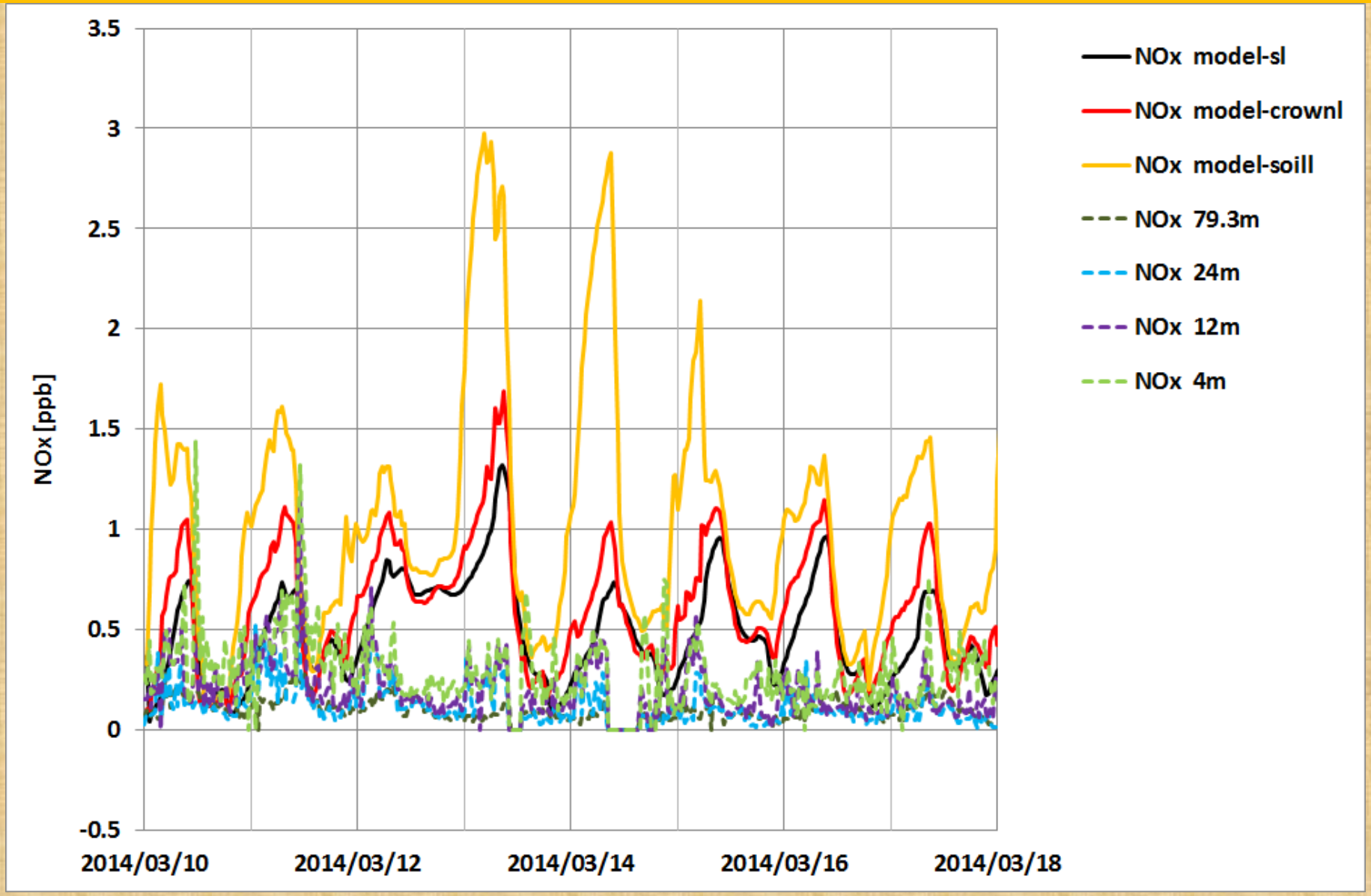
By courtesy of Laurens Ganzeveld

O3 gradients – comparison with MLC-Chem-model



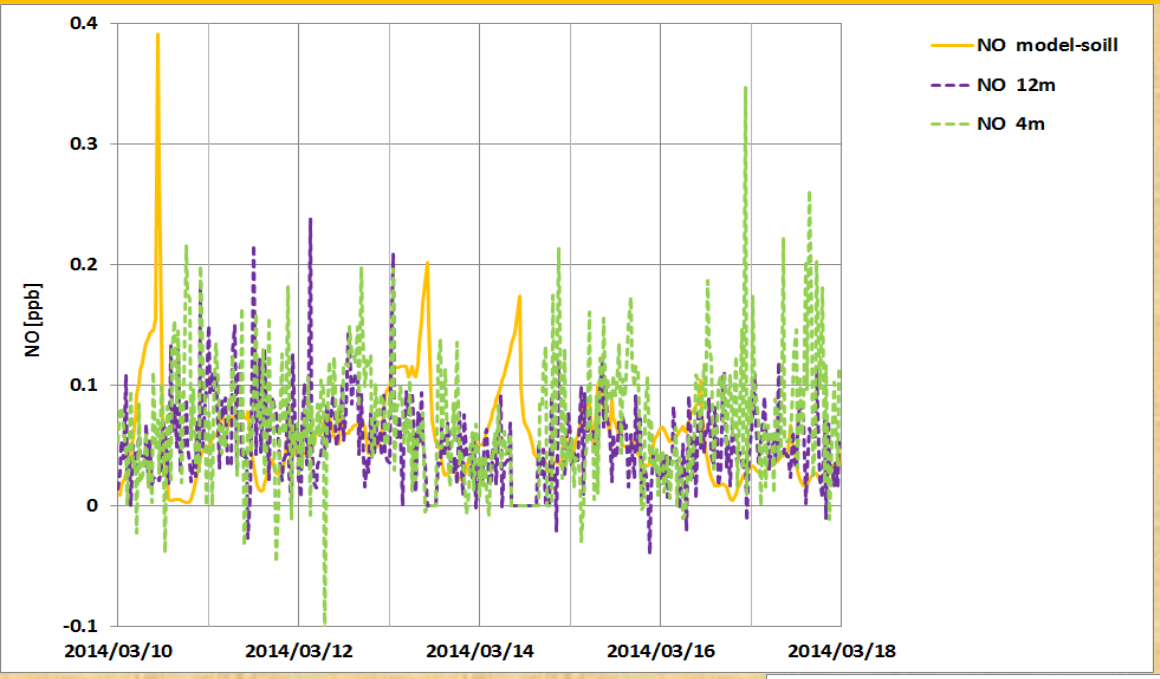
Example for the wet season 2014

NOx gradients – comparison with MLC-Chem-model



Example for the wet season 2014

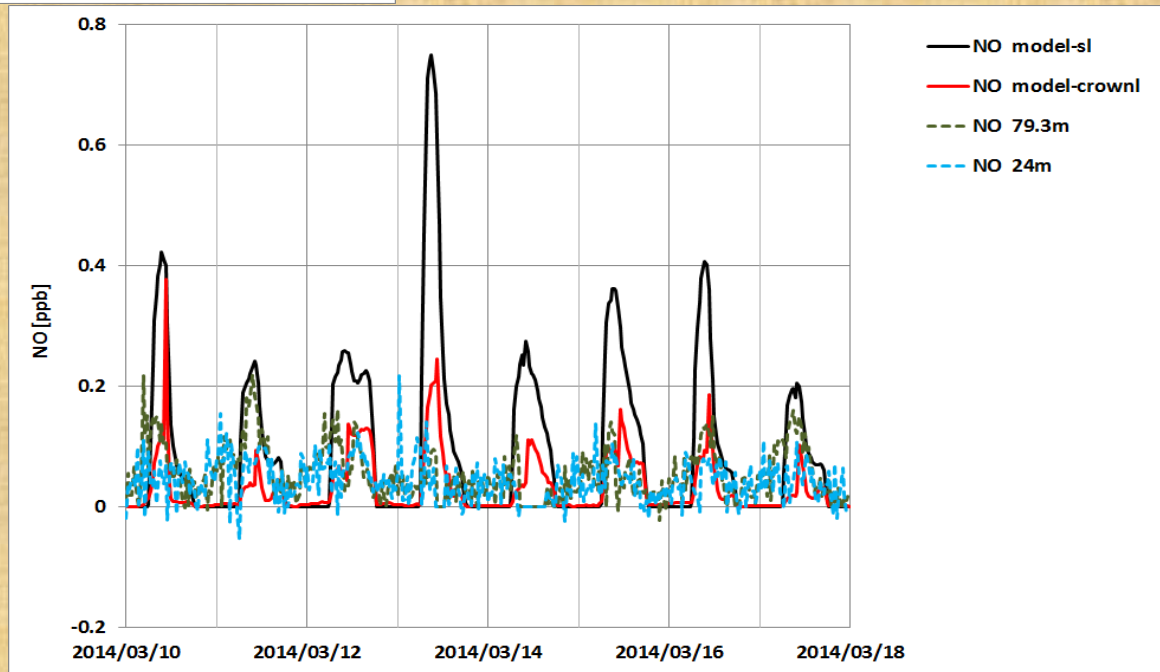
NO gradients – comparison with MLC-Chem-model



NO mixing ratios

near ground, inside and above the canopy

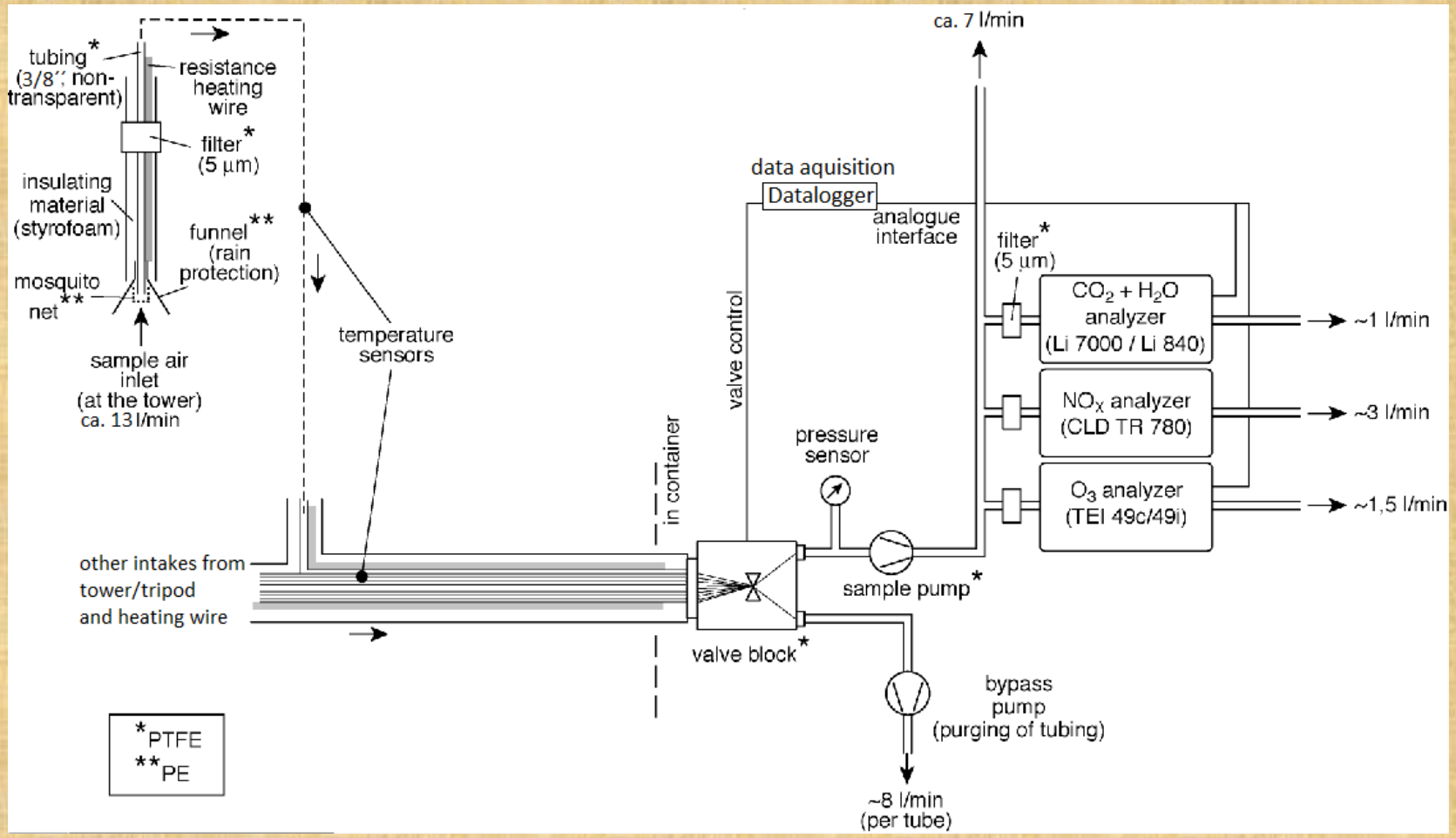
Example for the wet season 2014




Thank you very much
for your attention !!!

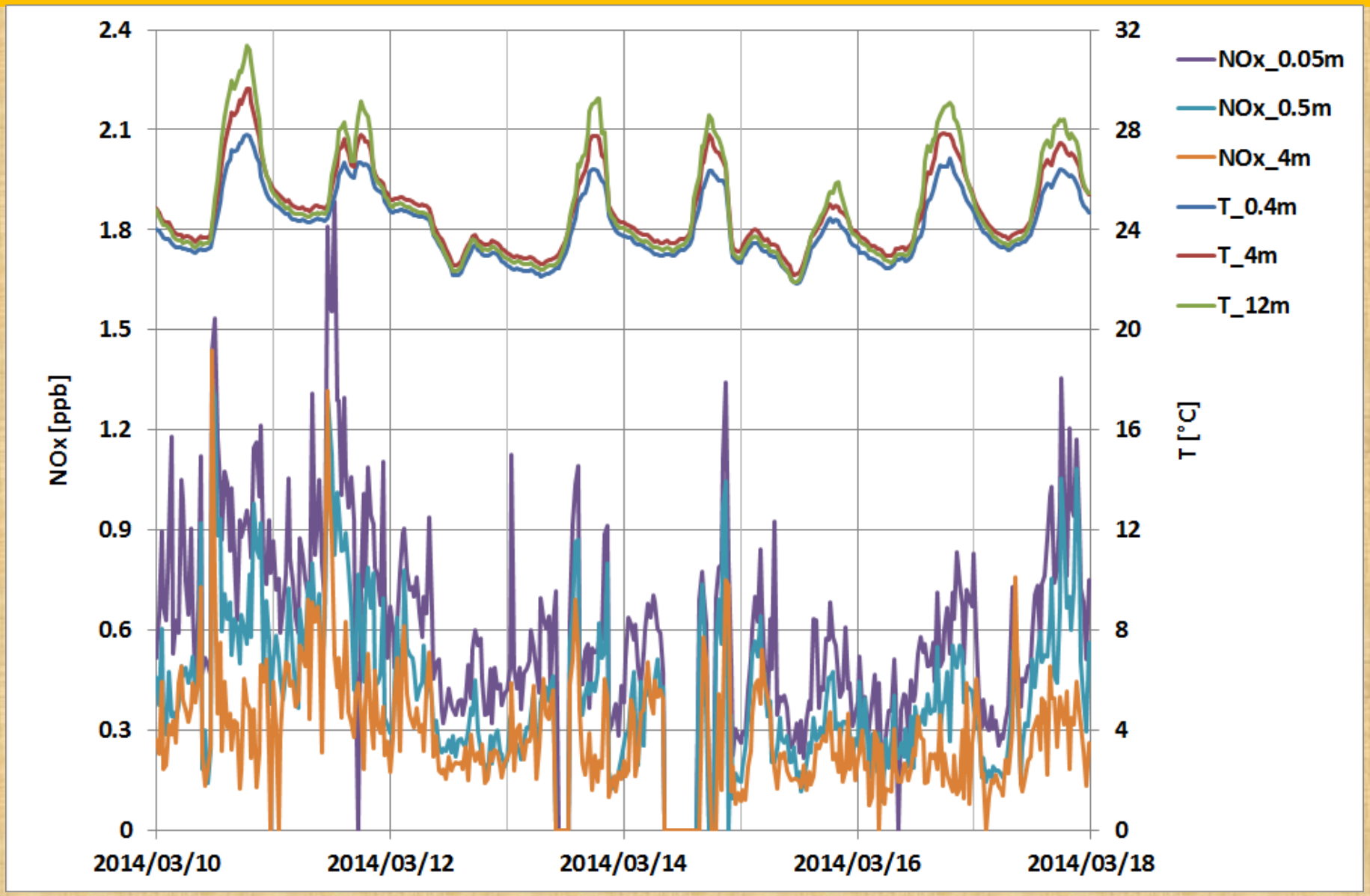
Measurements

The profile system



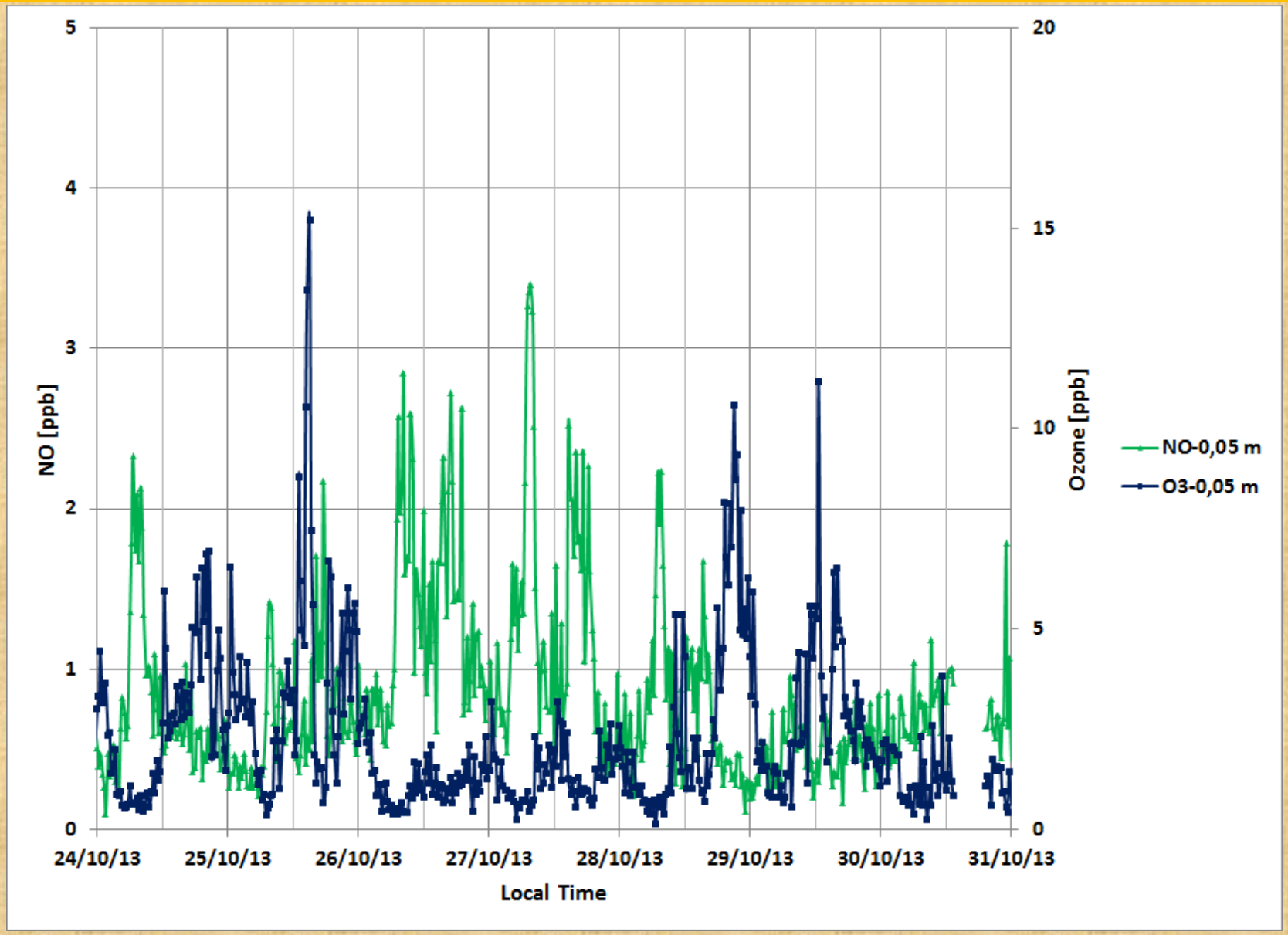
The gradient system with inlets and analyzers *[by courtesy of A. Moravek]*

NOx-T-comparison



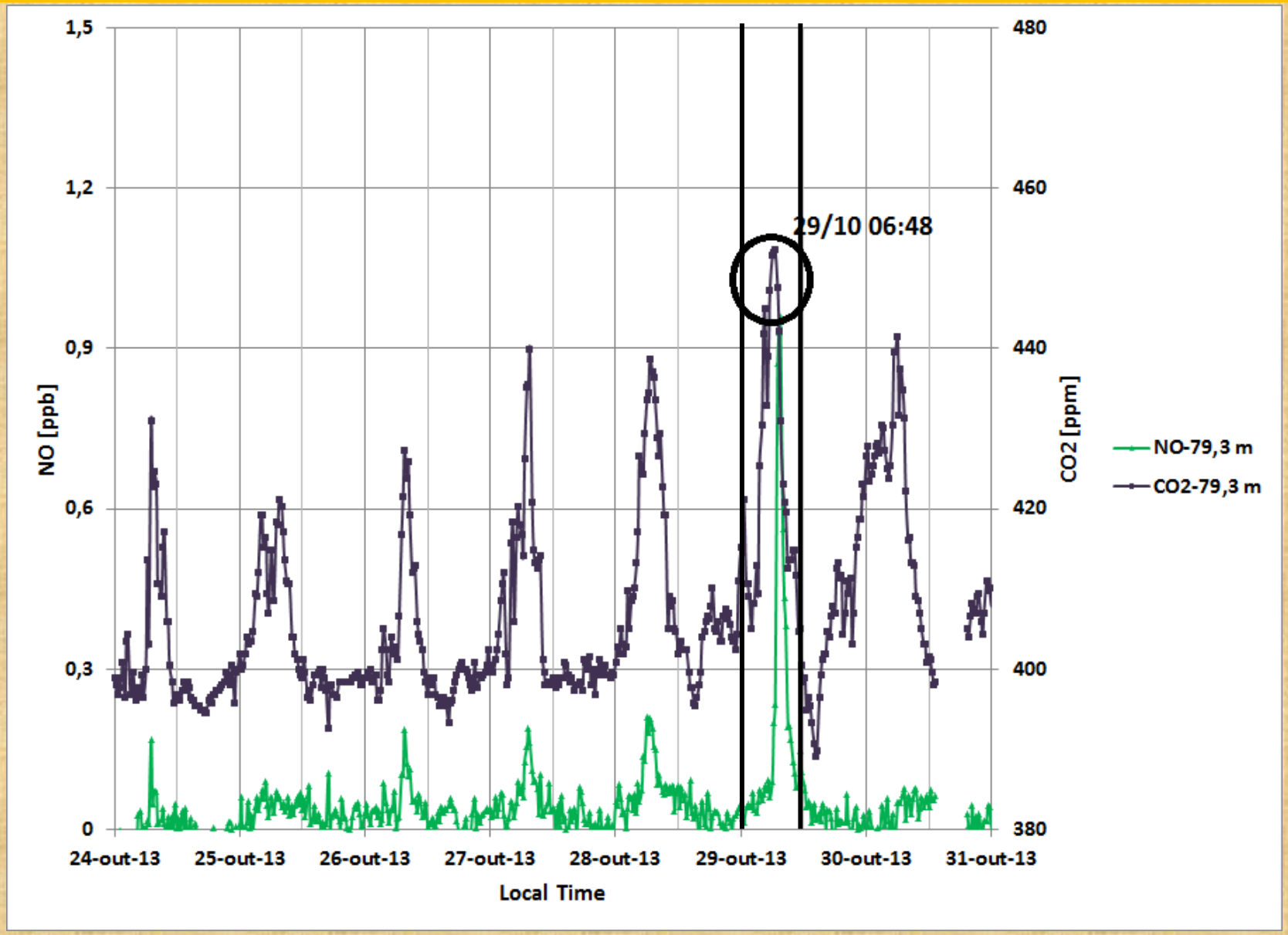
Example for wet season 2014

Venting of canopy



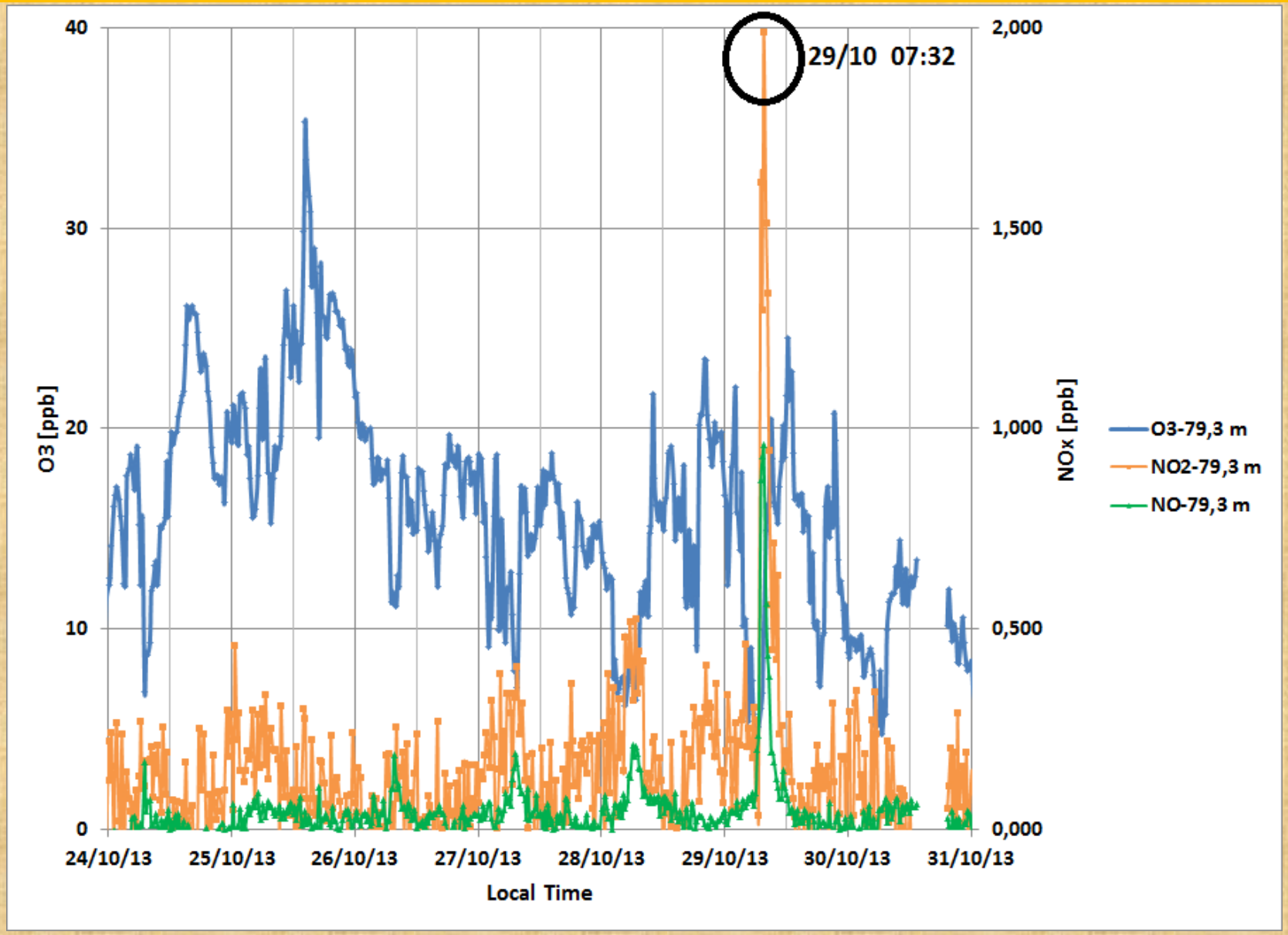
NO*-and O_3-*profile at the ATTO site between 24/10/13 and 30/10/13

Venting of canopy



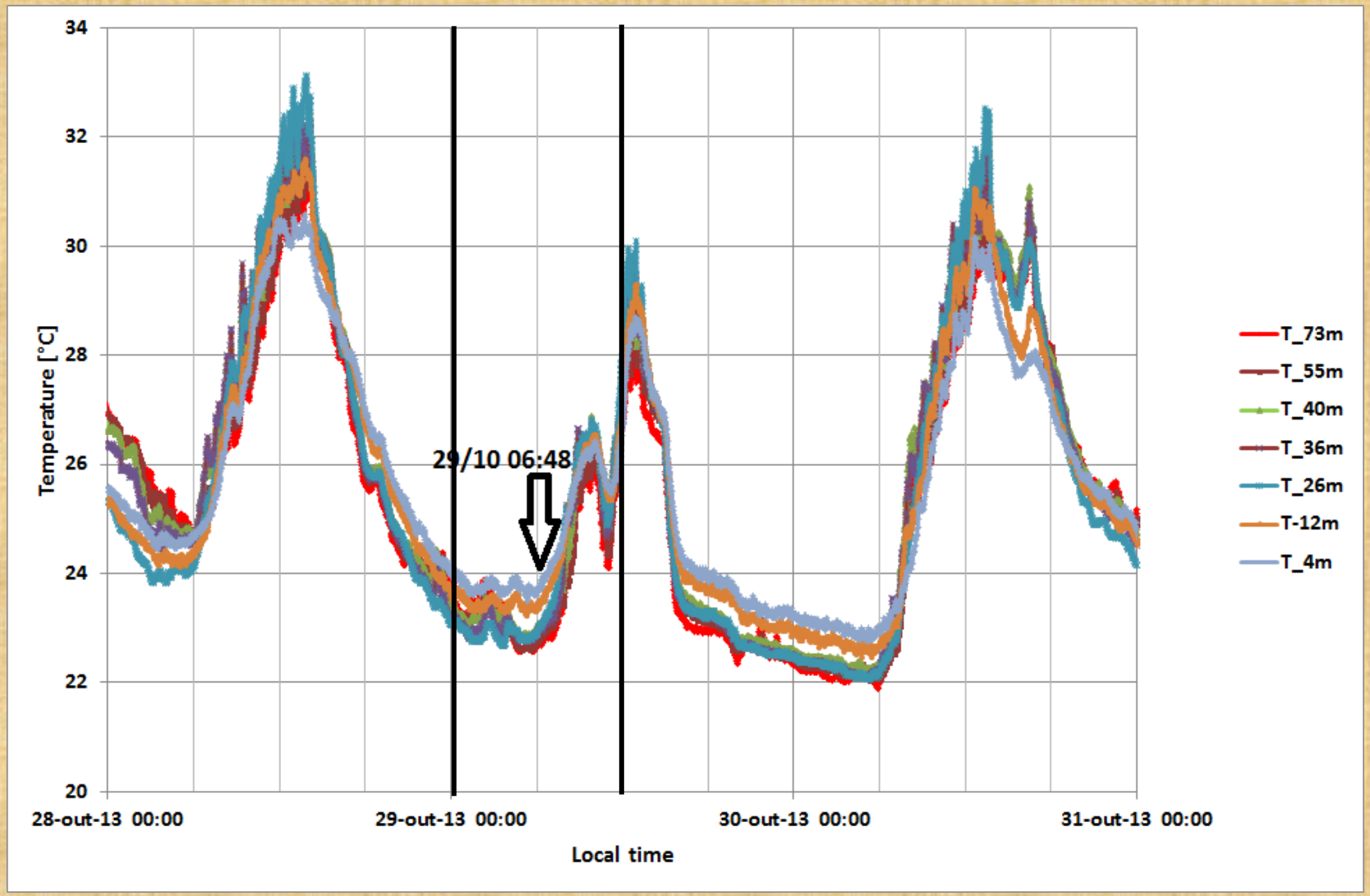
NO*-and CO_2–*profile at the ATTO site between 24/10/13 and 30/10/13

Venting of canopy



***NOx**-and O_3-profile at the ATTO site between 24/10/13 and 30/10/13*

Venting of canopy



***T**–profile at the ATTO site between 28/10/13 and 30/10/13*

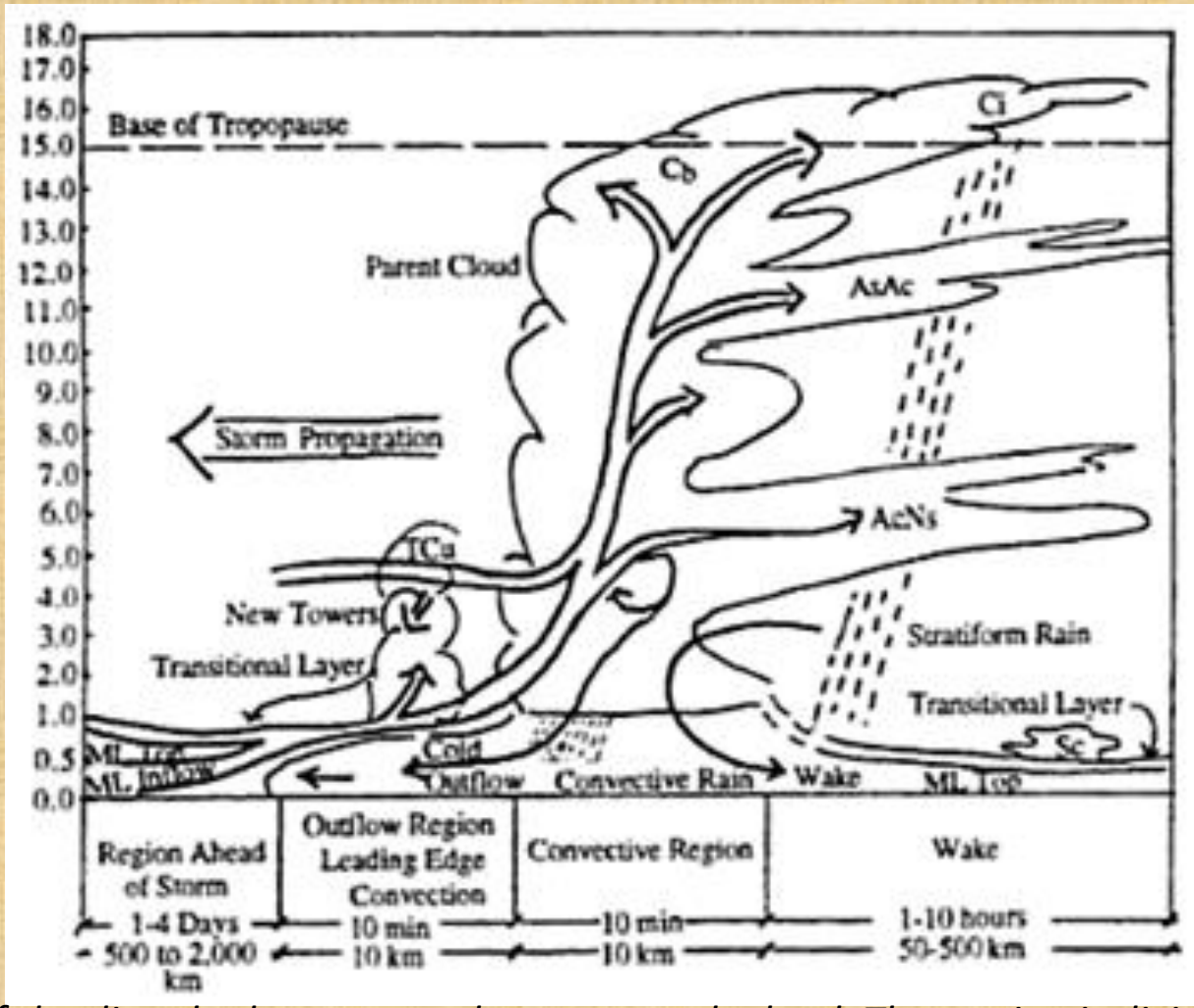
Conclusions and Outlook

- Nocturnal downdrafts in Central Amazonia occur in the rainy and the dryer season
- Forest-Atmosphere-coupling – Extreme weather events, incoming radiation,...
- Emission plumes in the early morning – Change of coupling regimes
- Upcoming IOP in Aug/Sept 2014

Thank you very much for your attention !!!

Downdrafts

The disturbed state



Schematic of the disturbed state over the ocean or the land. The section is divided into the region ahead of the storm, the outflow region, the convective region and the wake of the storm [Garstang & Fitzjarrald, 1999]

Downdrafts

Downdrafts

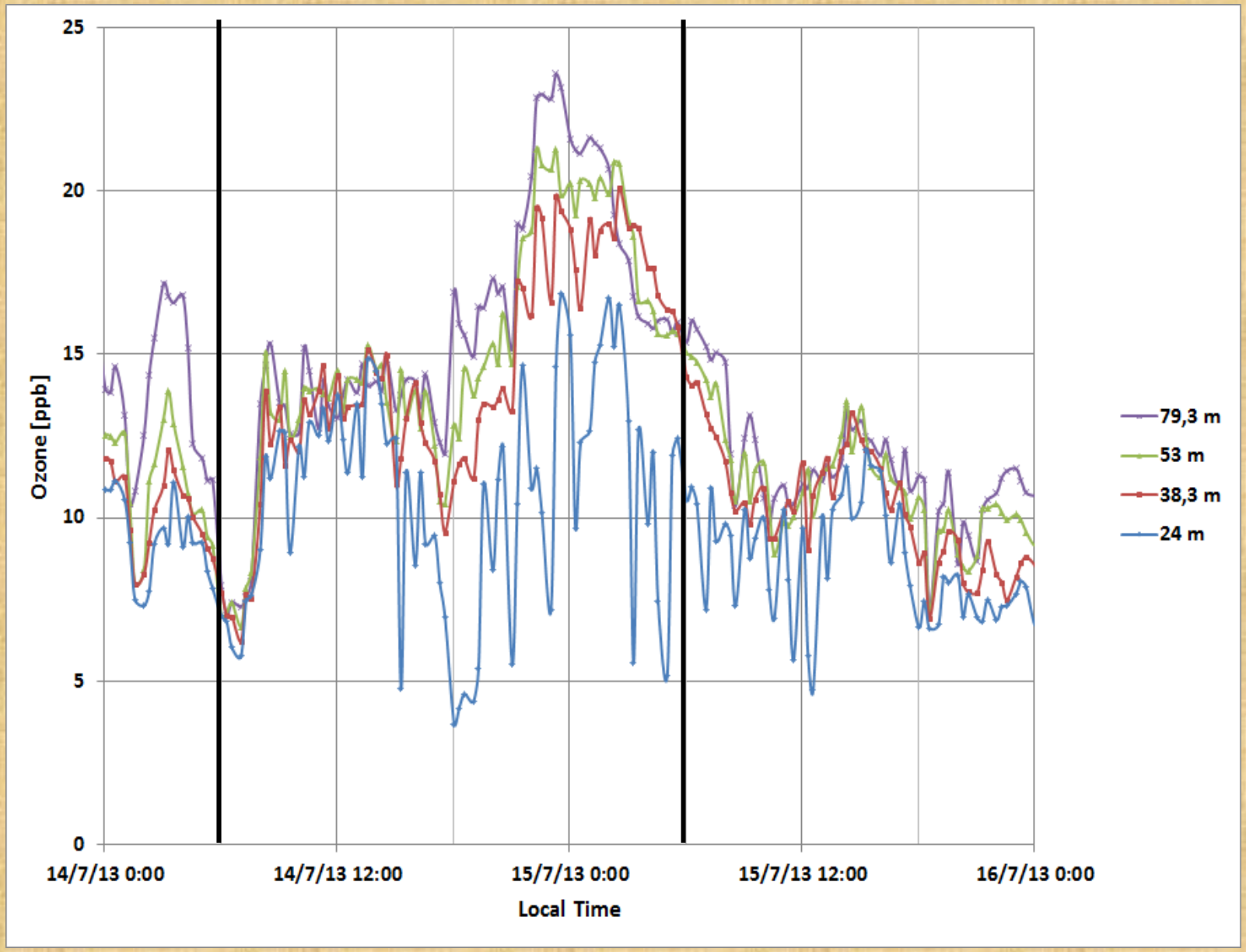
The equivalent potential temperature

$$\boldsymbol{\theta_e} = T_e\left(\frac{p_0}{p}\right)^{\frac{R_d}{c_p}} = \left(\boldsymbol{T} + \frac{L_v}{c_p}\boldsymbol{r}\right)\left(\frac{p_0}{\boldsymbol{p}}\right)^{\frac{R_d}{c_p}}$$

with

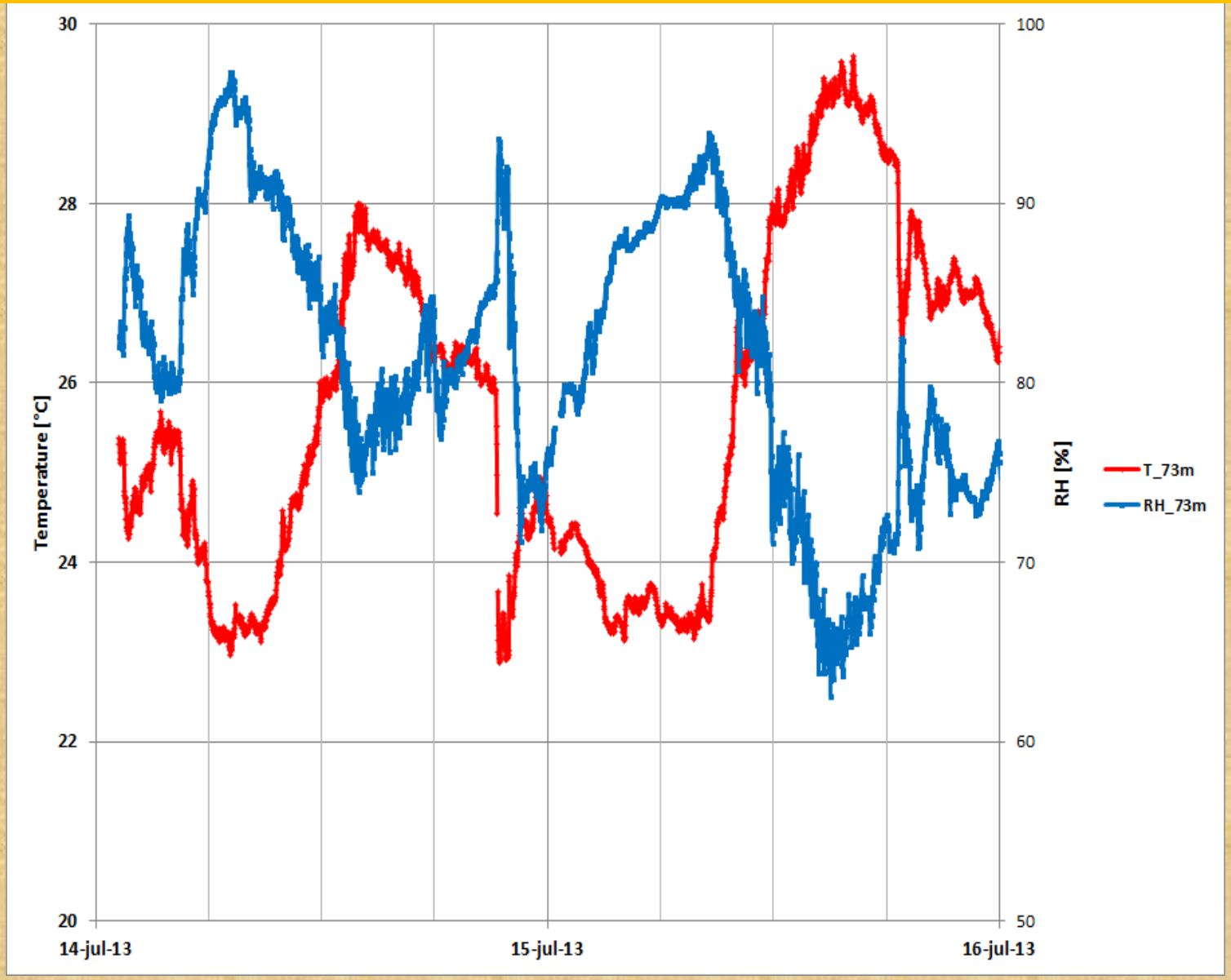
T_e	=	Equivalent temperature
T	=	Temperature of air at pressure p
p	=	Pressure at the point
p_0	=	Standard reference pressure (1000 hPa)
R_d	=	Specific gas constant for air (287 J/(kg·K))
c_p	=	Specific heat or dry air at constant pressure (1004 J/(kg·K))
L_v	=	Latent heat of evaporation (2400 kJ/kg {at 25°C} to 2600 kJ/kg {at 40°C})
r	=	Mixing ratio of water vapor mass per mass of dry air (g/kg)

Downdrafts



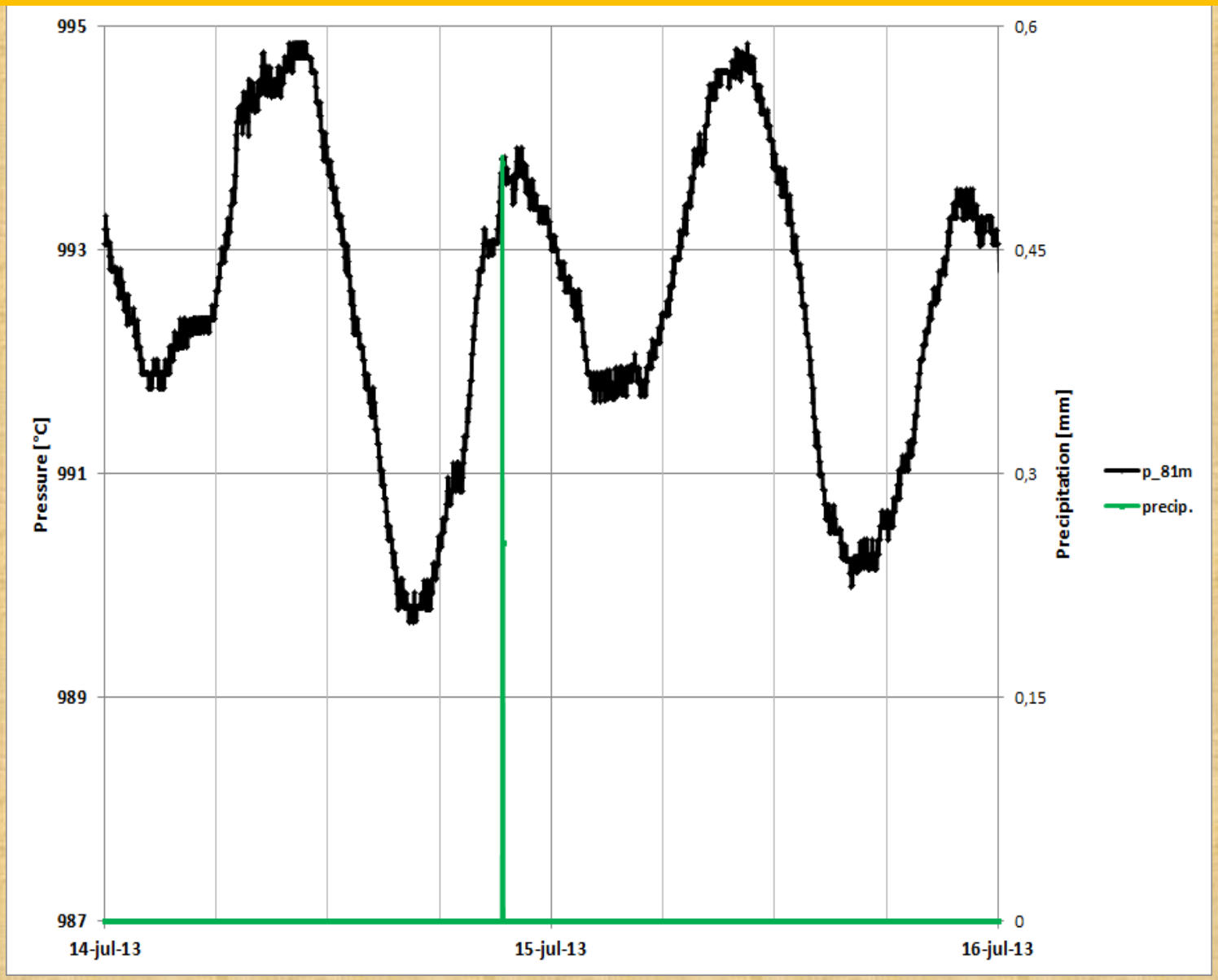
***Ozone**-profile at the ATTO site between 14/07/13 and 16/07/13*

Downdrafts



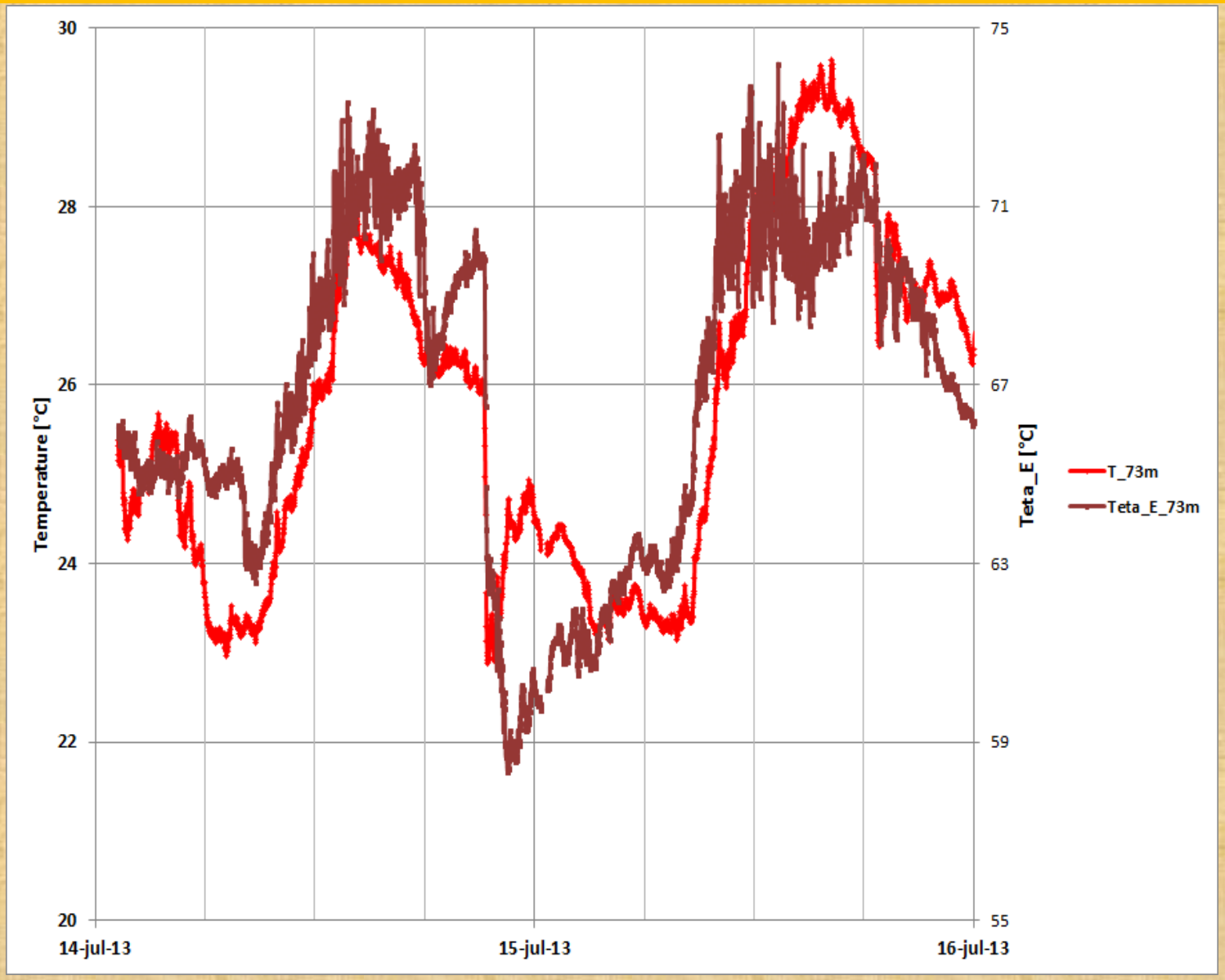
***T**-and **RH**-profile at the ATTO site between 14/07/13 and 16/07/13*

Downdrafts



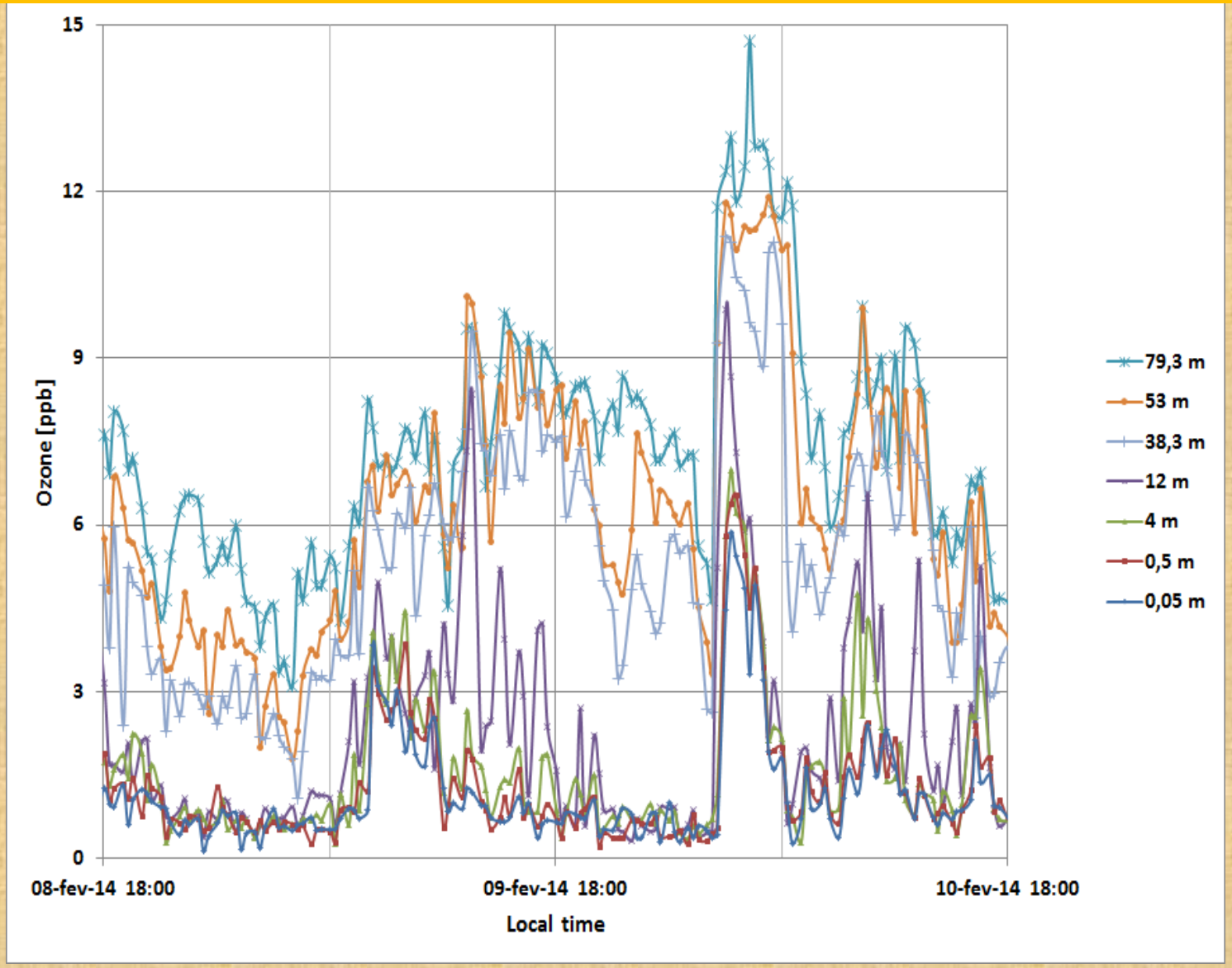
***p**-and **precipitation**-profile at the ATTO site between 14/07/13 and 16/07/13*

Downdrafts



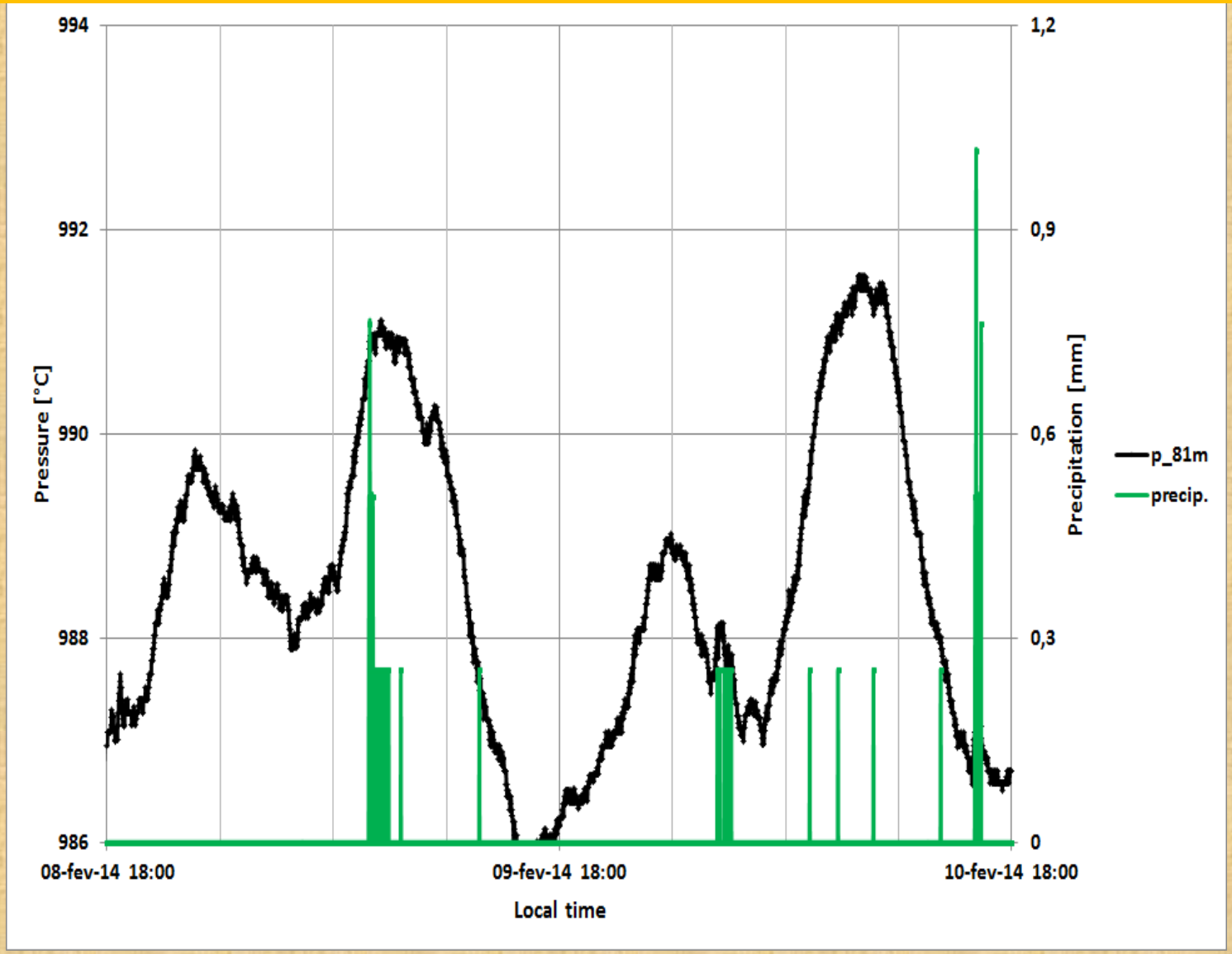
$\boldsymbol{T}$-and $\boldsymbol{\theta_e}$–profile at the ATTO site between 14/07/13 and 16/07/13

Downdrafts



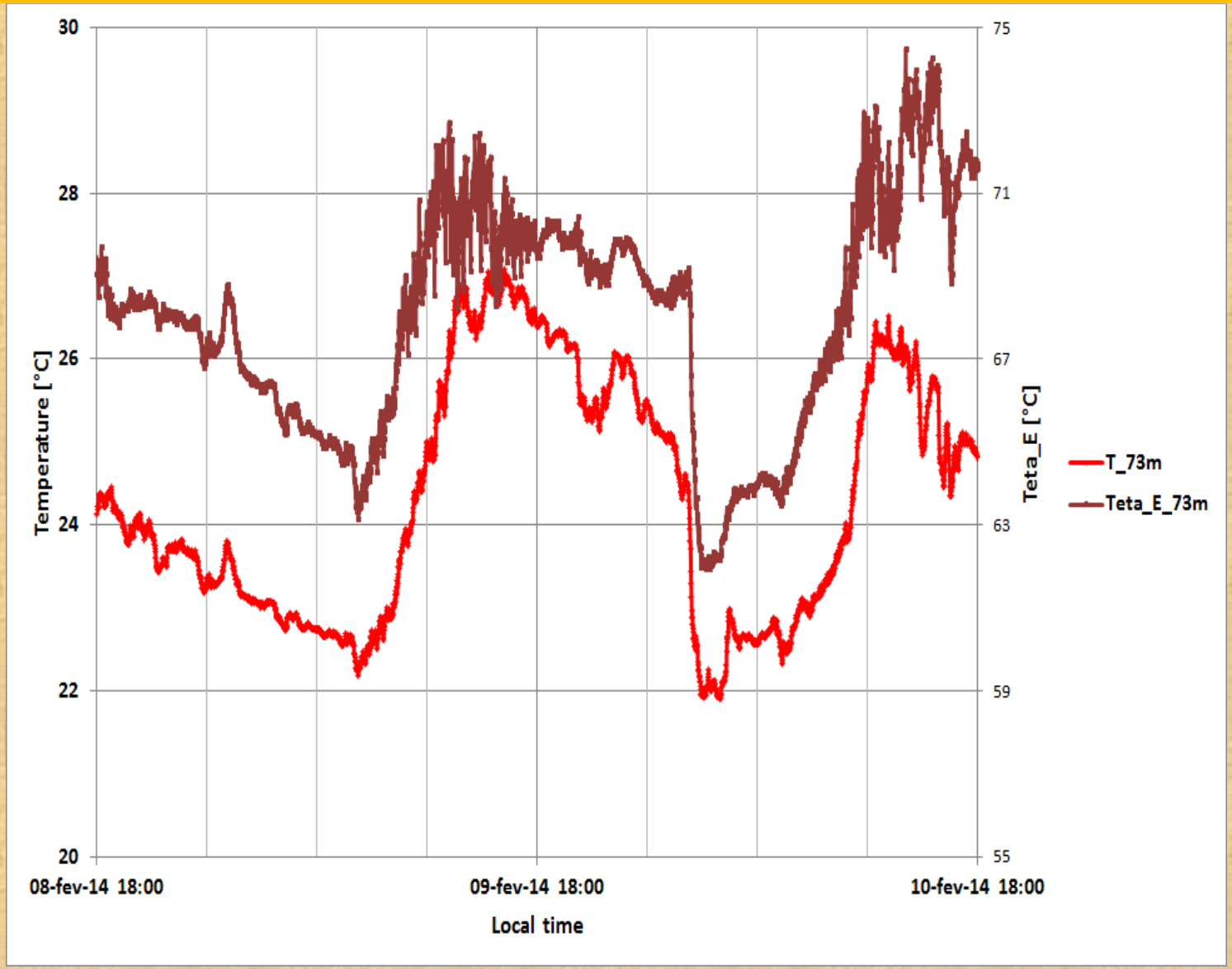
***Ozone**-profile at the ATTO site between 18/02/14 and 10/02/14*

Downdrafts



***p**-and **precipitation**-profile at the ATTO site between 14/07/13 and 16/07/13*

Downdrafts



$\boldsymbol{T}$-and $\boldsymbol{\theta_e}$–profile at the ATTO site between 08/02/14 and 10/02/14