

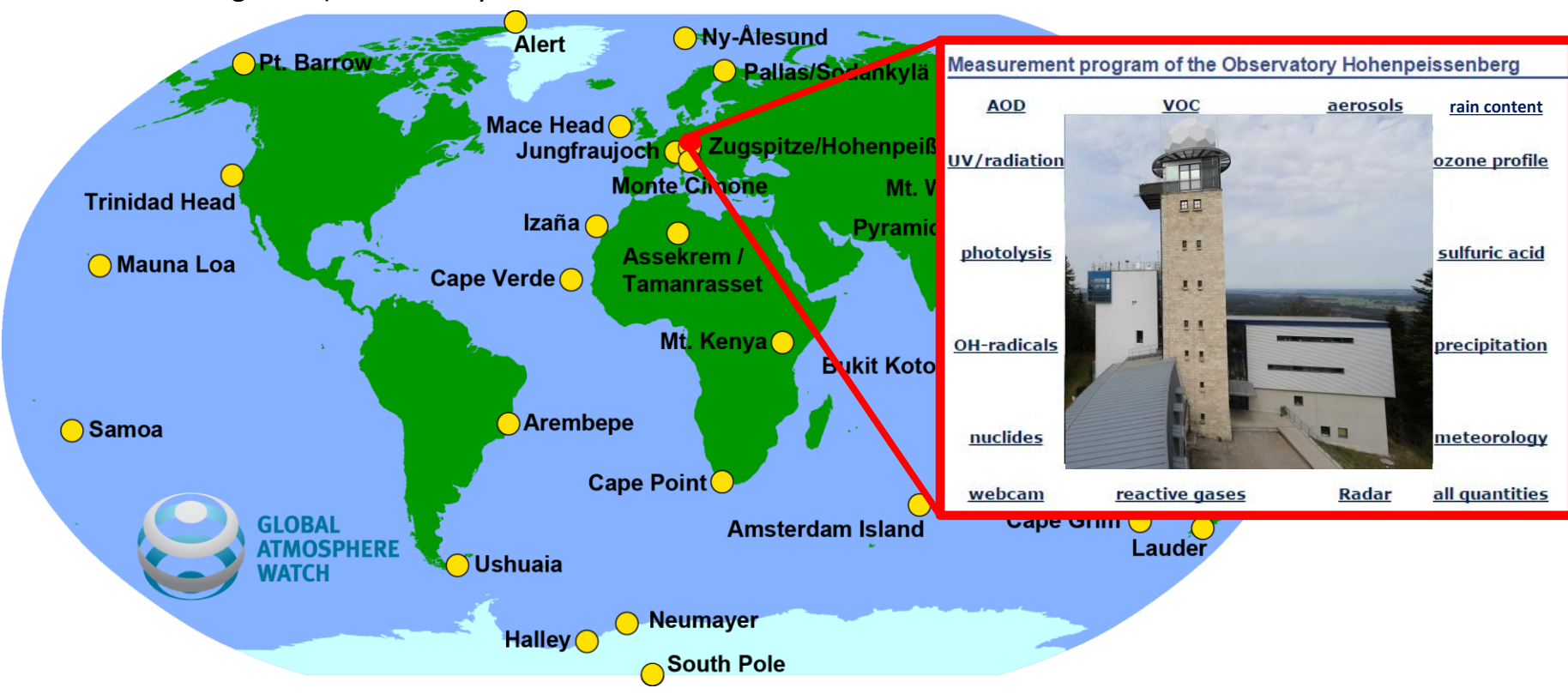


# Validation of Multi-AXis-DOAS NO<sub>2</sub> and aerosols at MOHp





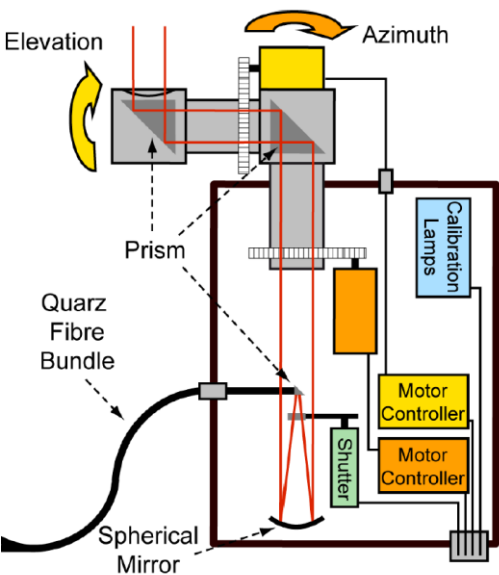
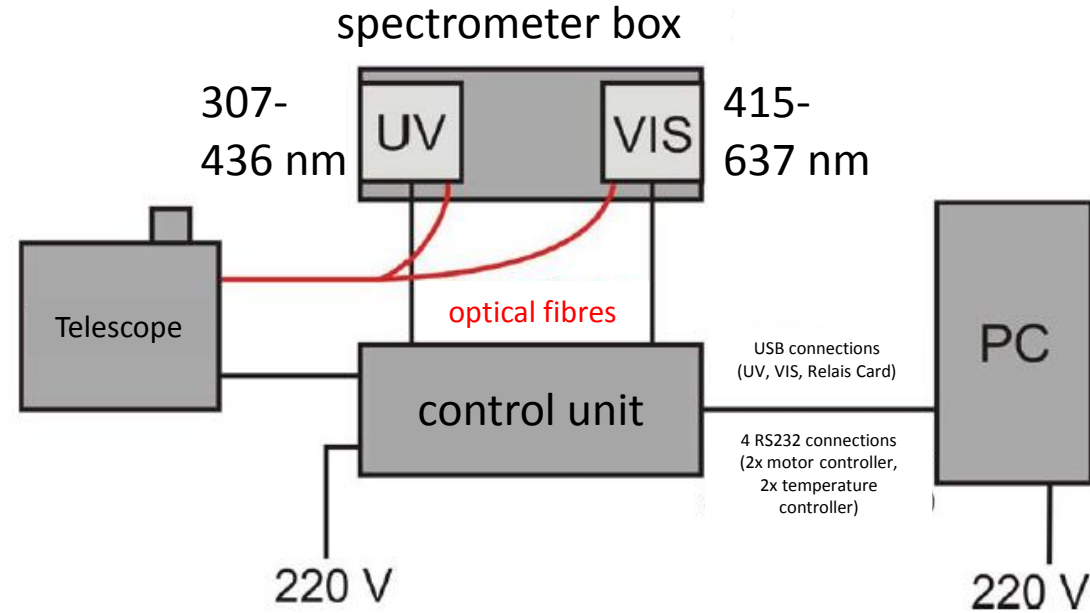
- oldest mountain observatory in the world
- 980 m above sea level, 60 km southwest of Munich, 30 km north of northern rim of the Alps
- long history of weather observations and climate monitoring
- since 1992: besides Schneefernerhaus (Zugspitze) only Global Station in the Global Atmosphere Watch (GAW, WMO-Programm) in Germany



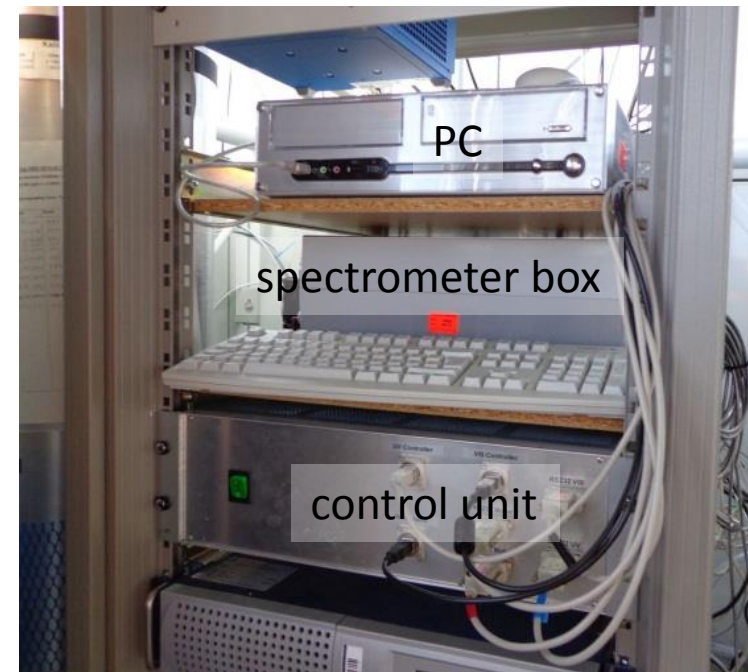




- spectrometer box: thermal stabilization of spectrometers
- control unit: spectrometer controllers, thermal controllers, power supply
- PC: measurement routine (MS-DOAS, Udo Frieß)

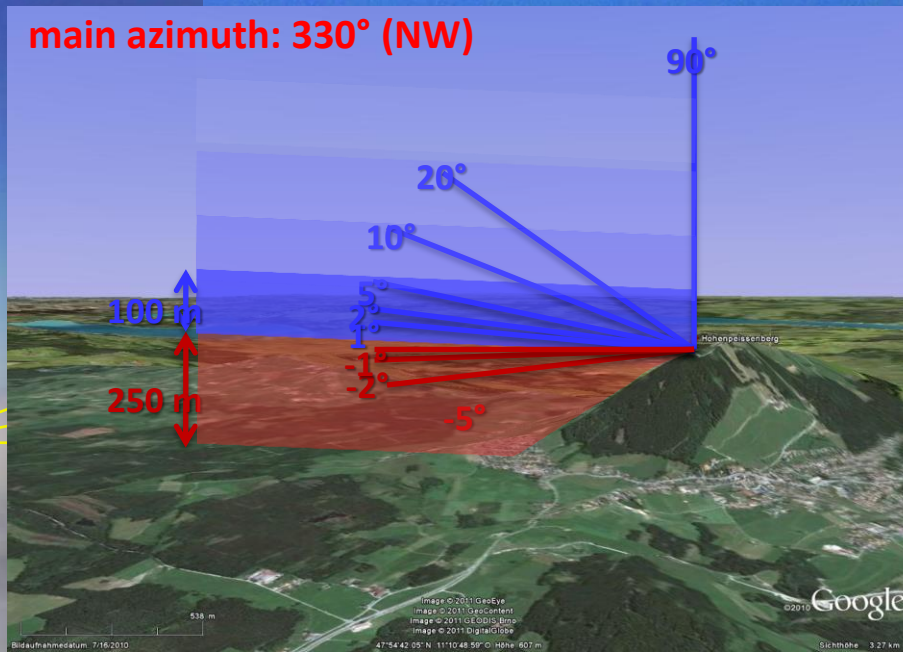


[Yilmaz, 2012]





main azimuth: 330° (NW)

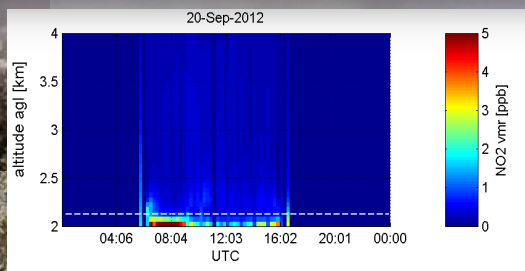
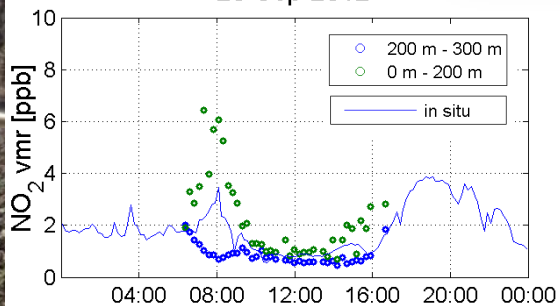


DOAS Analysis:  
Spectra at different elevation  
angles are compared to a  
reference spectrum

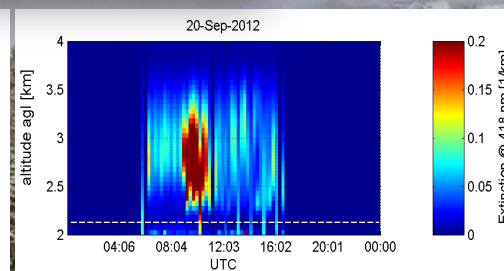
Differential Slant Column  
Densities (dSCD):  
NO<sub>2</sub>, HCHO, HONO, O<sub>3</sub>, ...

Inverse Radiation Transfer  
Modelling (HEIPRO using  
SCIATRAN 2)

20-Sep-2012



Vertical Profiles of Trace  
Gases



Vertical Profiles of Aerosol

## Aims:

- Link between local in-situ measurements and satellite data in the framework of GAW
- Improvement of operational service
- development of automated evaluation routines
- Comparison with other measurement procedures at MOHP (in-situ, sun photometer, PFR)



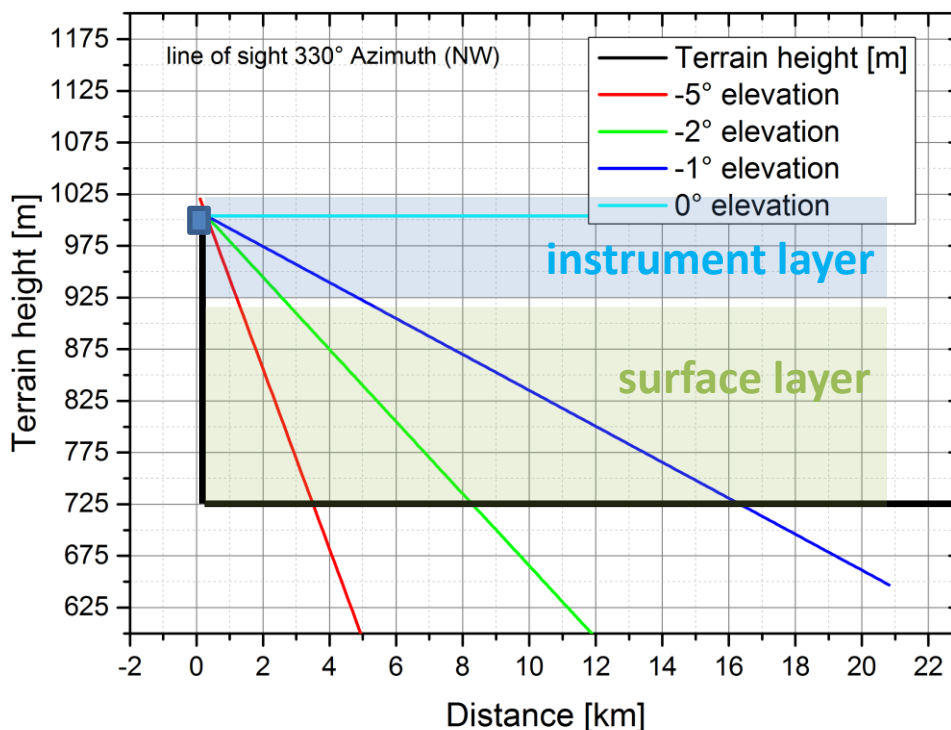
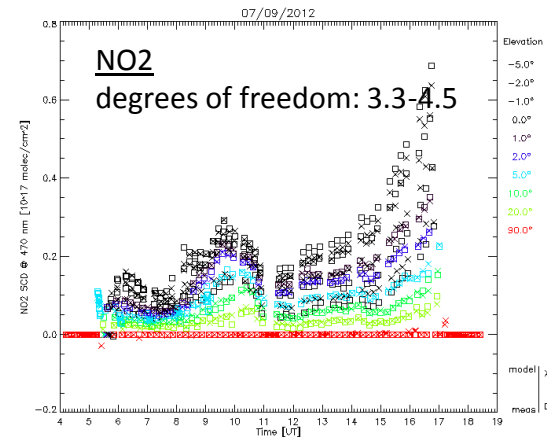
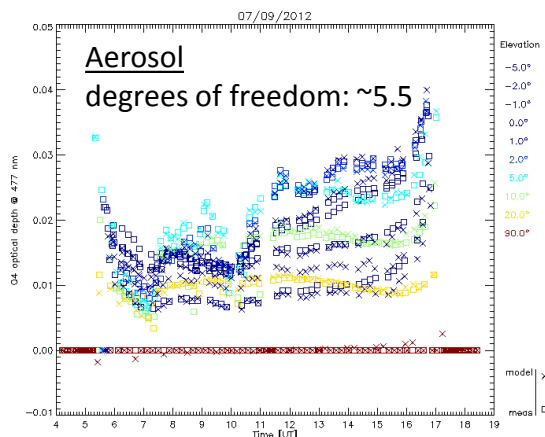
- 0-4 km agl (corresponds 0.75-4.75 asl)
- height grid 100 m
- interval 15 min
- T profile 15°C/0° (summer/winter), linear decreasing
- p profile 910 hPa, barometric height form

## Aerosol Retrieval

- linear decreasing a priori (smoothed)
  - extinction  $0.1 \text{ km}^{-1}$  at surface
  - not smaller than  $0.0033 \text{ km}^{-1}$
  - error 100%
- surface albedo 0.06 (no days with snow cover)
- Angström 1.36
- SSA 0.93/0.9
- Asymmetry 0.7/0.7

## NO2 Retrieval

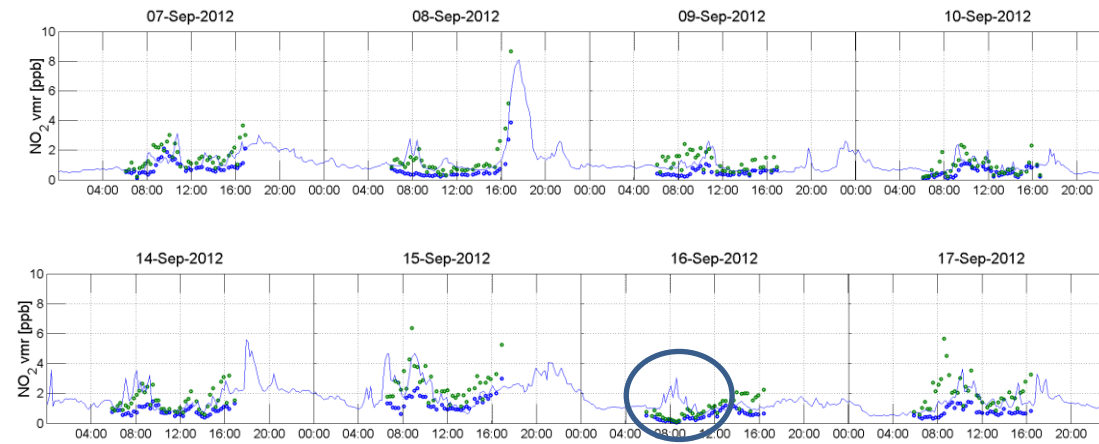
- exponential a priori:
  - surface 2 ppb NO2
  - scale height 2 km



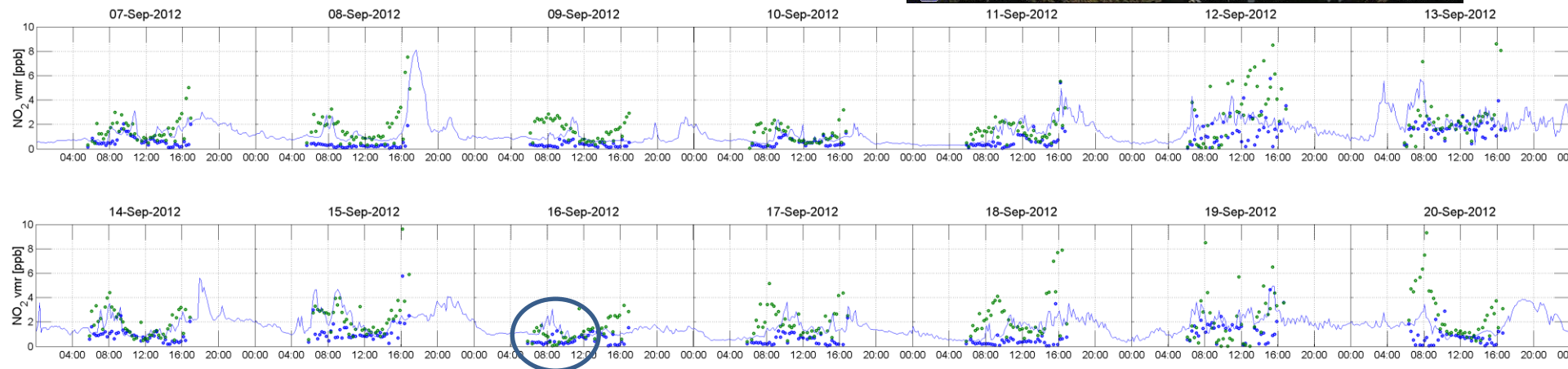




UV



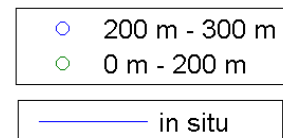
VIS

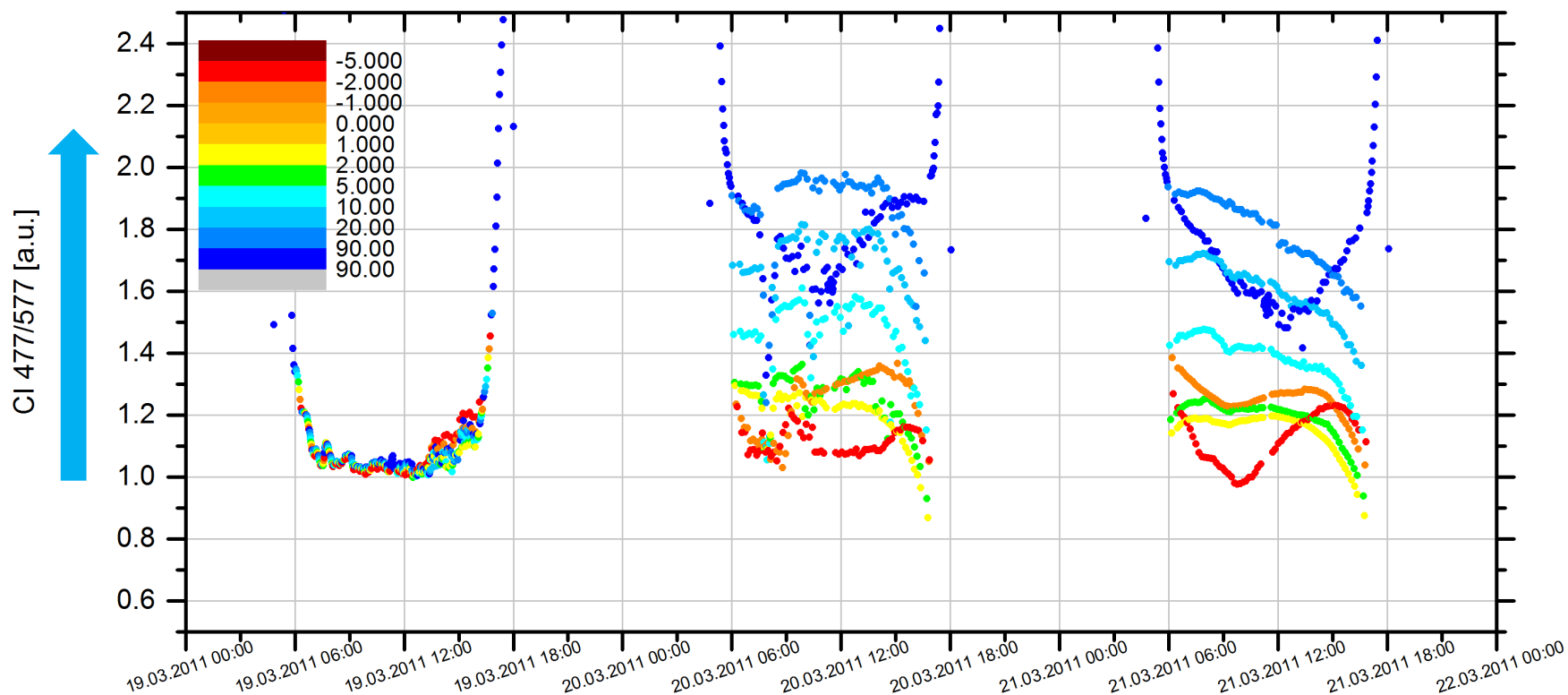


0-200 m: **surface layer** (average of two model layers, 0-100 m and 100-200 m)

200-300 m: **instrument layer**

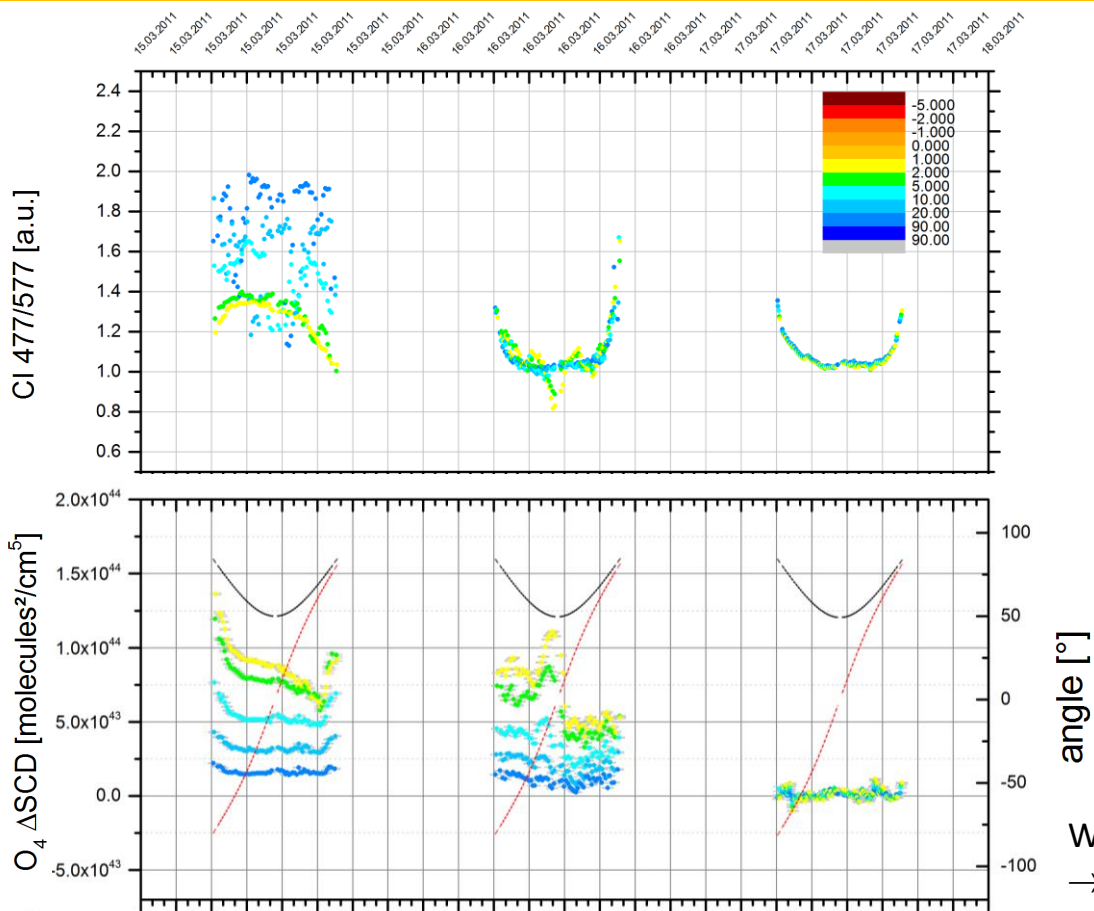
in situ [Stefan Gilge]: inlet ~10 m below MAX-DOAS



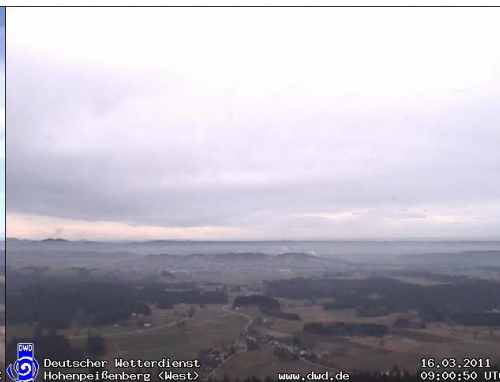




# Cloud Detection



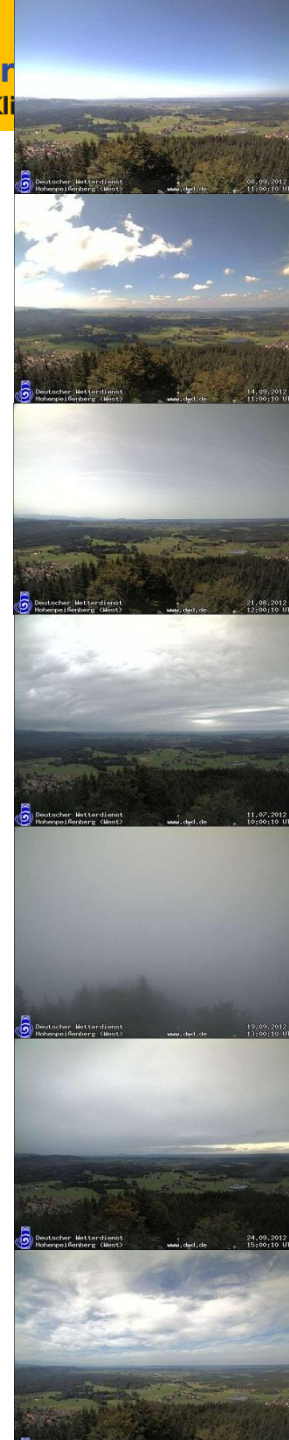
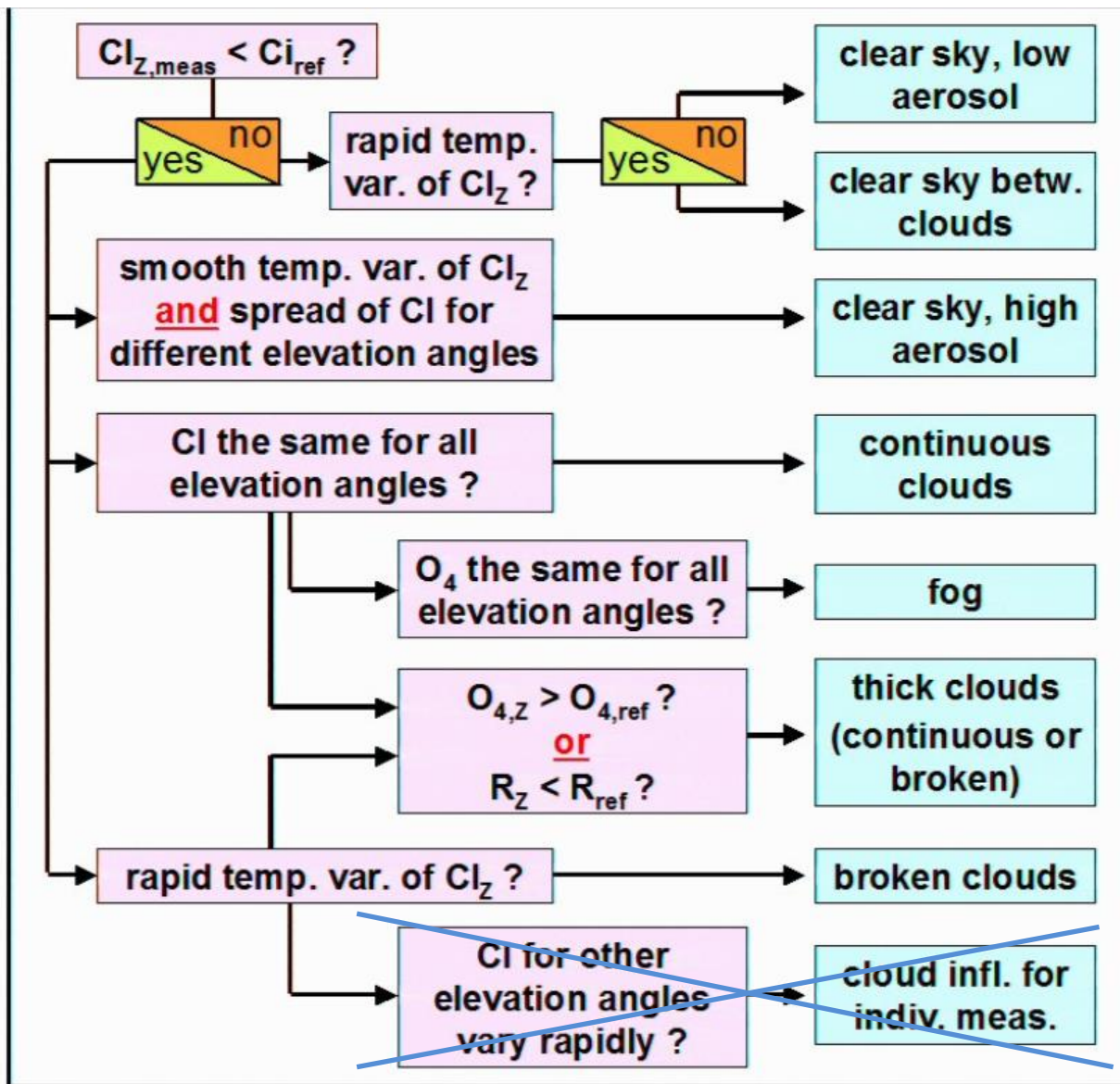
Wagner et al., 2013:  
→ cloud detection via CI and  $O_4$







## Cloud classification scheme





- NO<sub>2</sub>: by now July 2012 – December 2012
- in total 72 days between July 2012 and December 2012, 44 without fog
- NO<sub>2</sub> UV and VIS:  $\text{vmr}(0-200 \text{ m}), \text{vmr}(200-300 \text{ m}), \text{average} = \frac{\text{vmr}(0-200 \text{ m}) + \text{vmr}(200-300 \text{ m})}{2}$

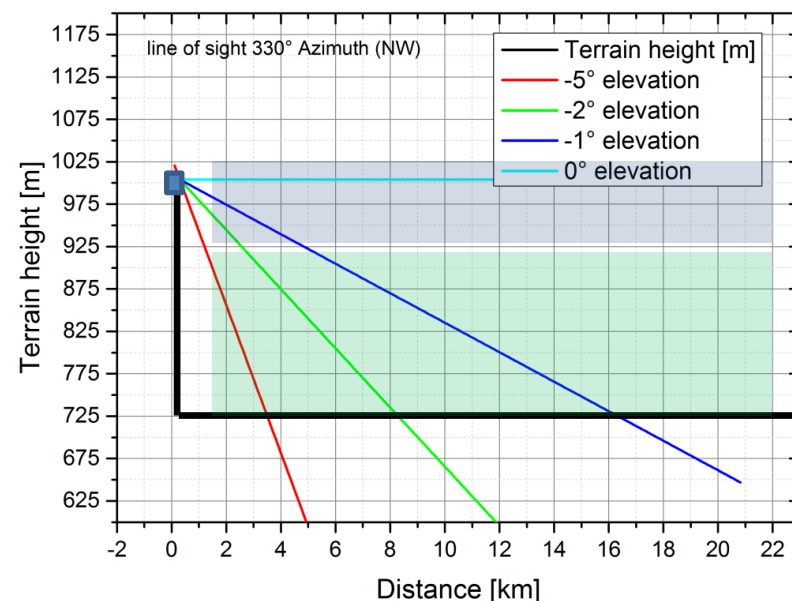
classification	Correlation UV				Correlation VIS			
	average	0-200 m	200-300 m	N	average	0-200 m	200-300 m	N
clear sky, low aerosol	0.69	0.66	0.68	568	0.64	0.58	0.44	568
clear sky between clouds	0.53	0.5	0.44	522	0.49	0.46	0.28	495
clear sky, high aerosol	-	-	-	0	0.55	0.62	-0.1	100
continous clouds	0.84	0.79	0.79	126	0.7	0.63	0.48	124
fog	0.13	0.09	0.16	1027	0.19	0.17	0.15	982
thick clouds (continous or broken)	0.69	0.68	0.62	322	0.45	0.41	0.33	317
broken clouds	0.62	0.68	0.57	289	0.59	0.56	0.42	

→ best correlation with average vmr

→ clear and cloudy conditions similar

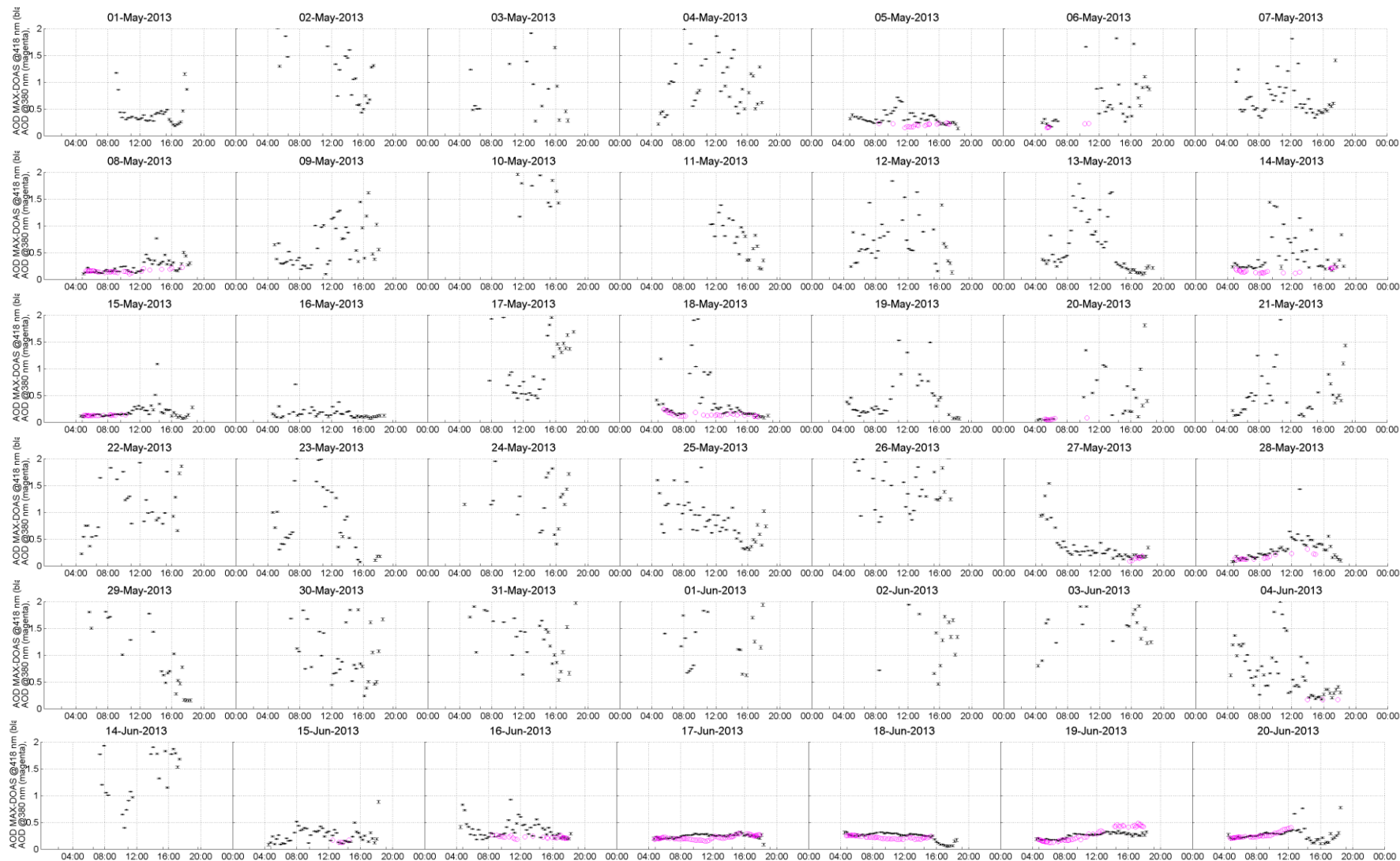
→ in general better correlation in UV

- Averaging Kernel
- Quality Filter (degrees of freedom, goodness of fit)





## UV+VIS



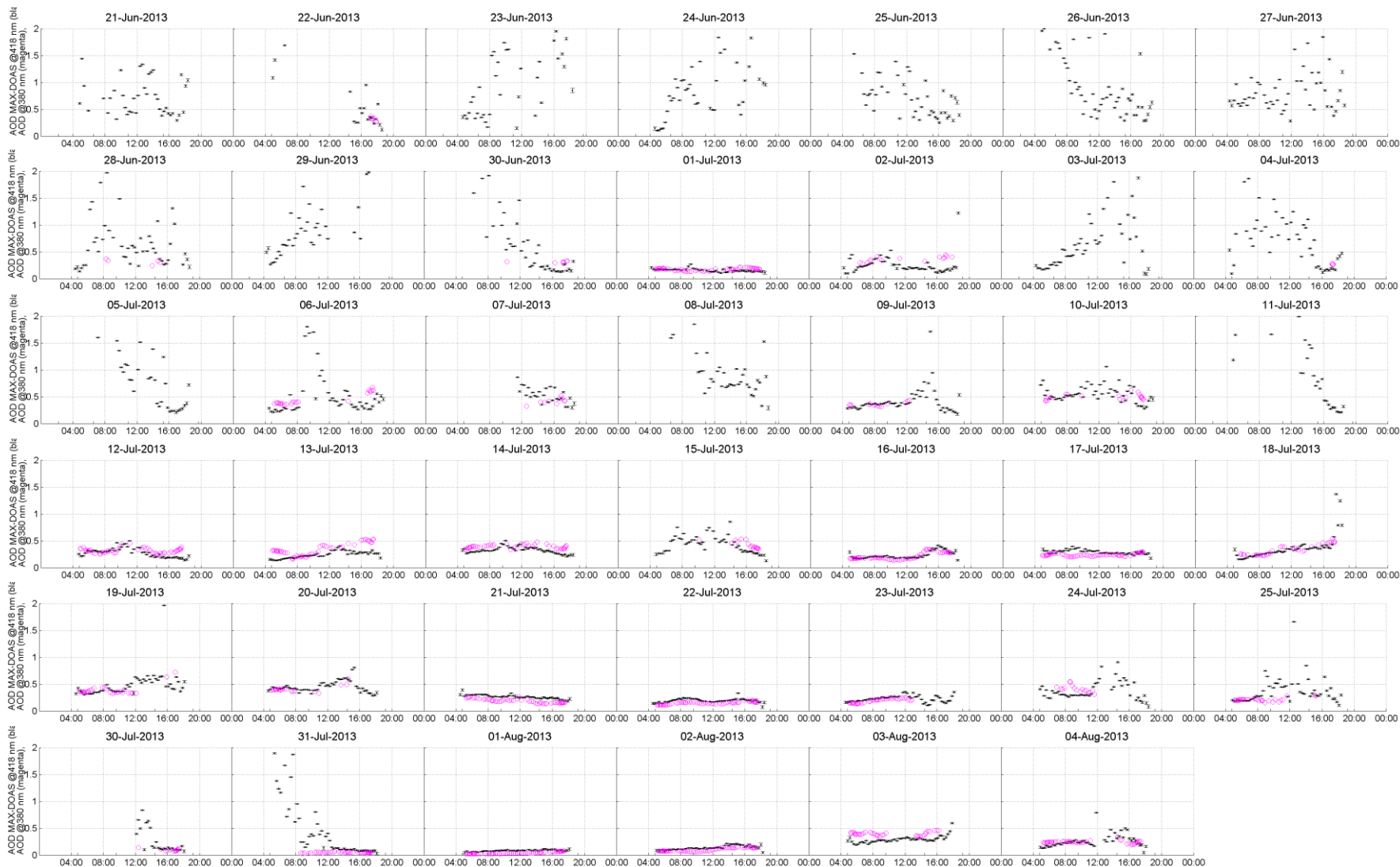
MAX-DOAS AOD @418 nm, degree of freedom > 2

AERONET AOD level 2 data @380 nm





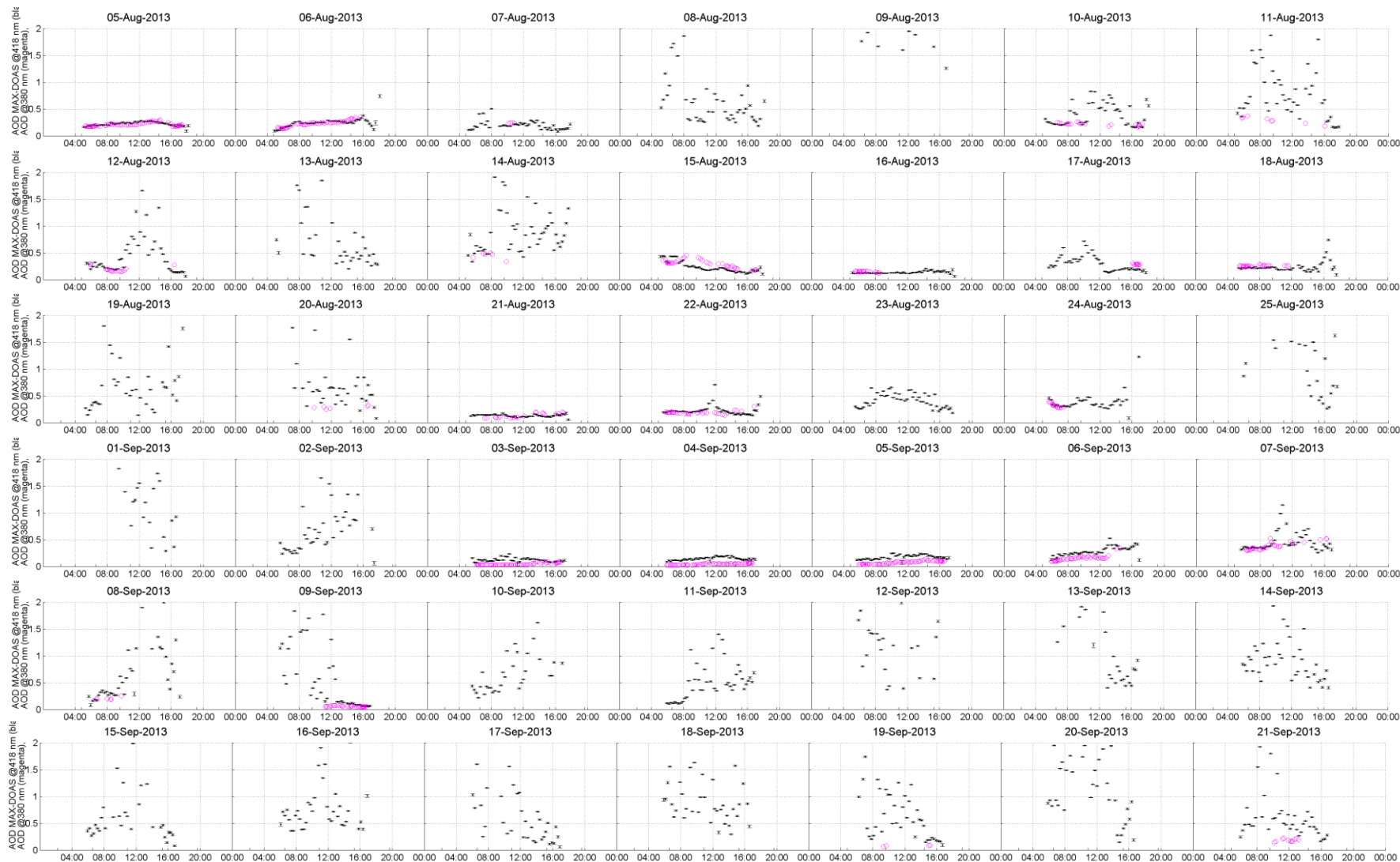
## UV+VIS



MAX-DOAS AOD @418 nm, degree of freedom > 2  
AERONET AOD level 2 data @380 nm



## UV+VIS

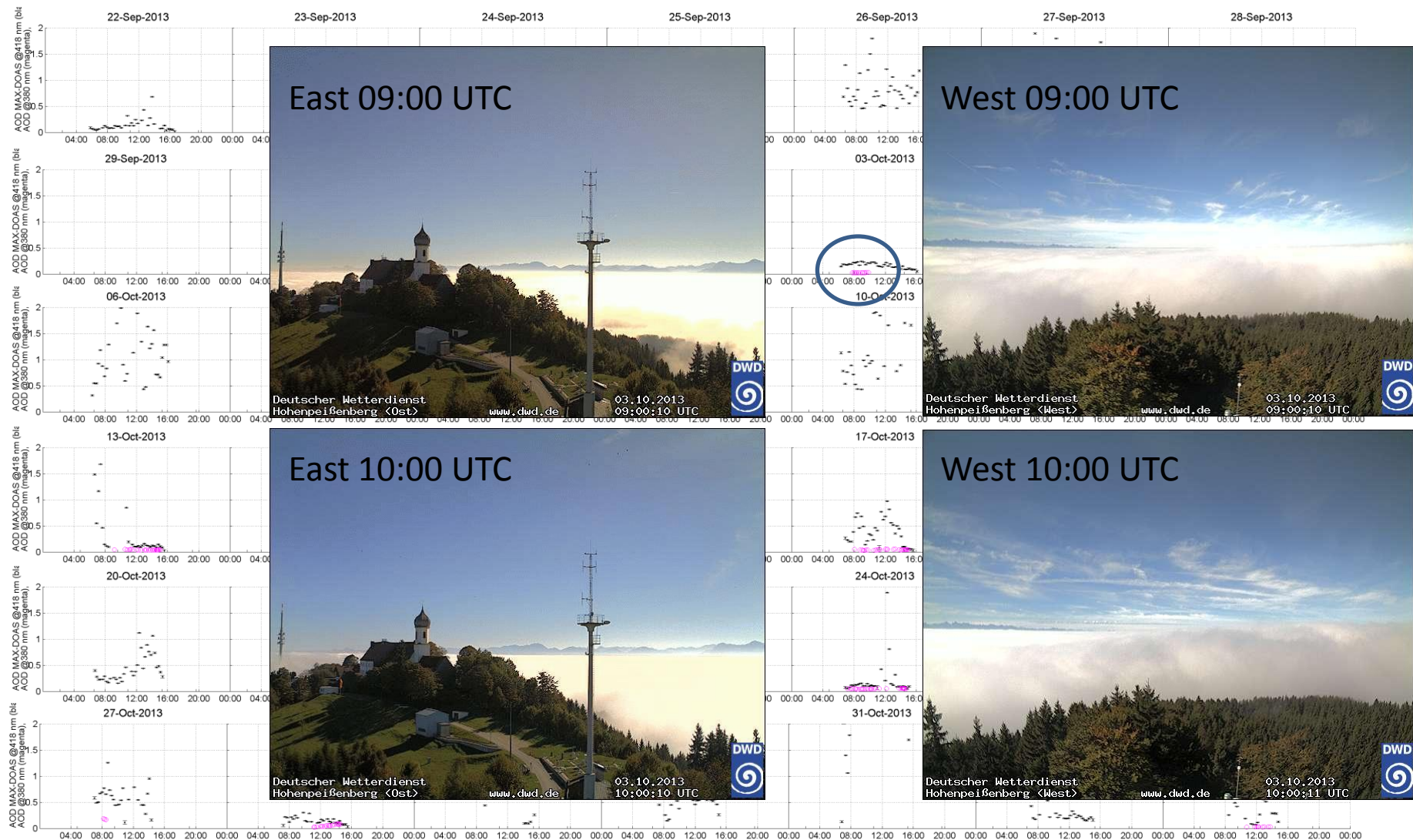


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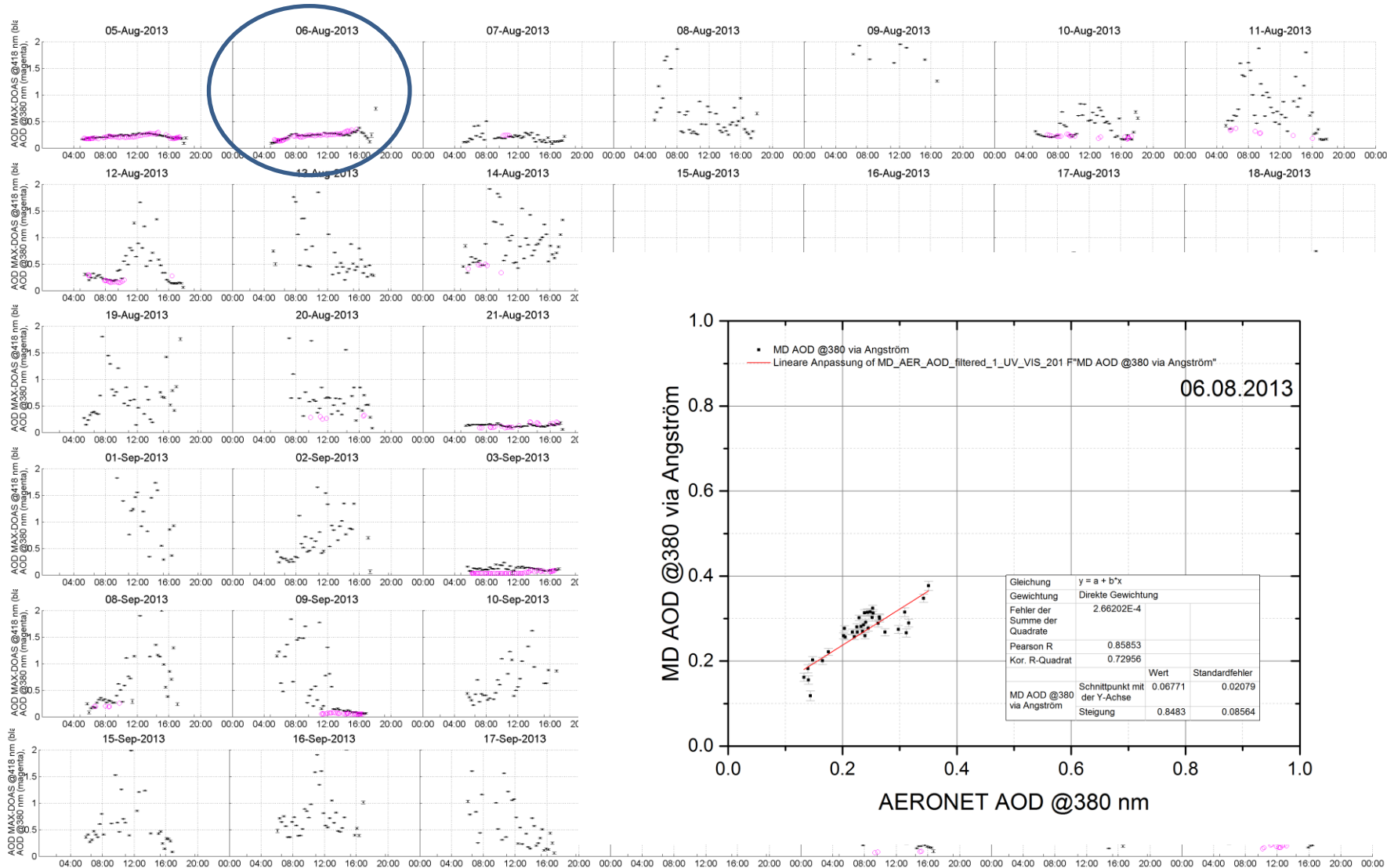
## UV+VIS







## UV+VIS

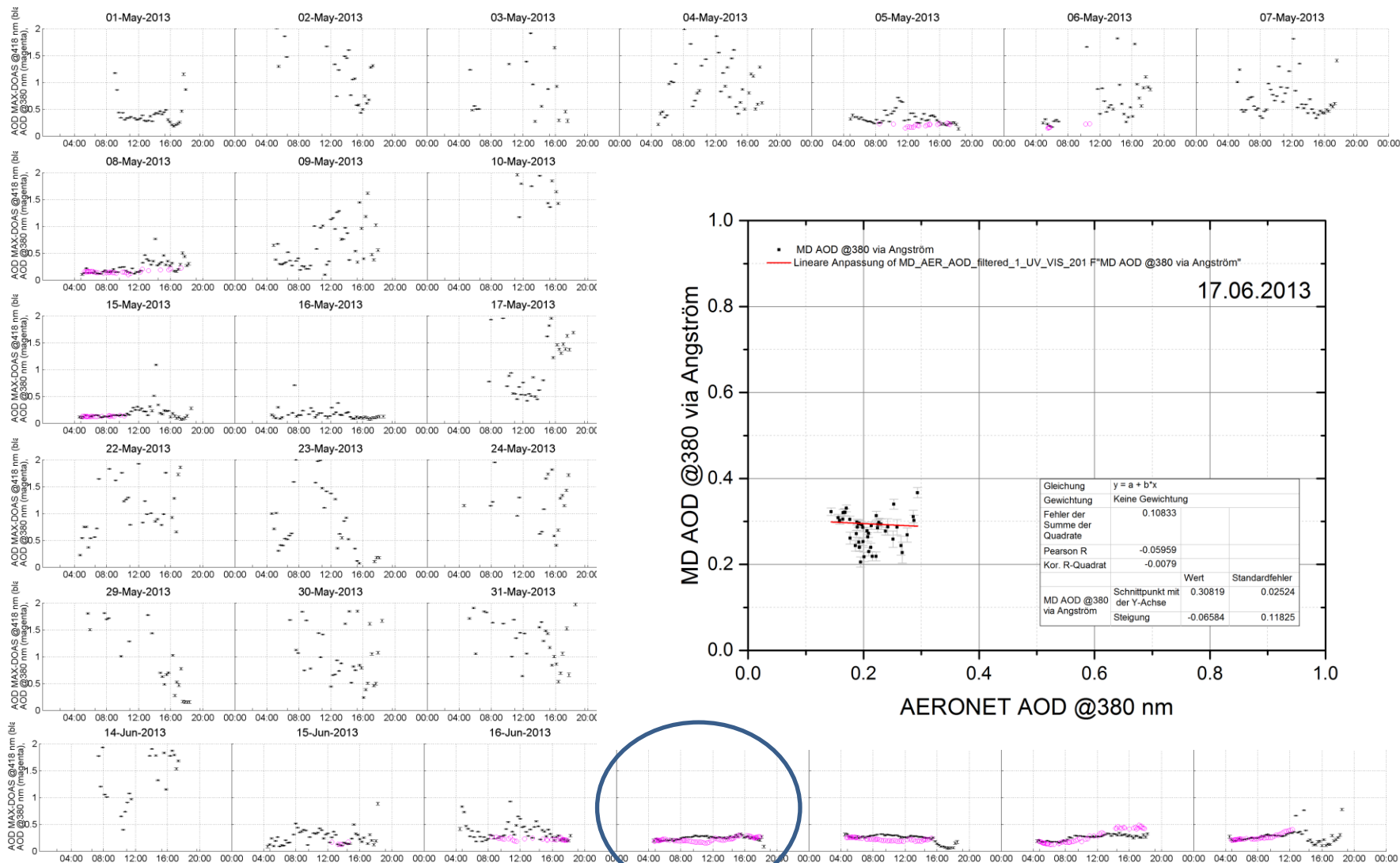


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## UV+VIS



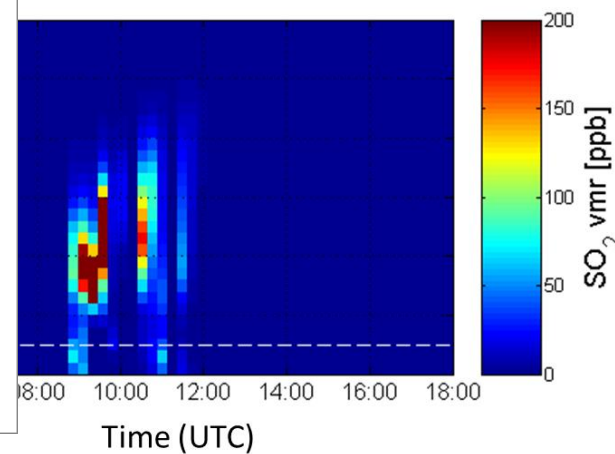
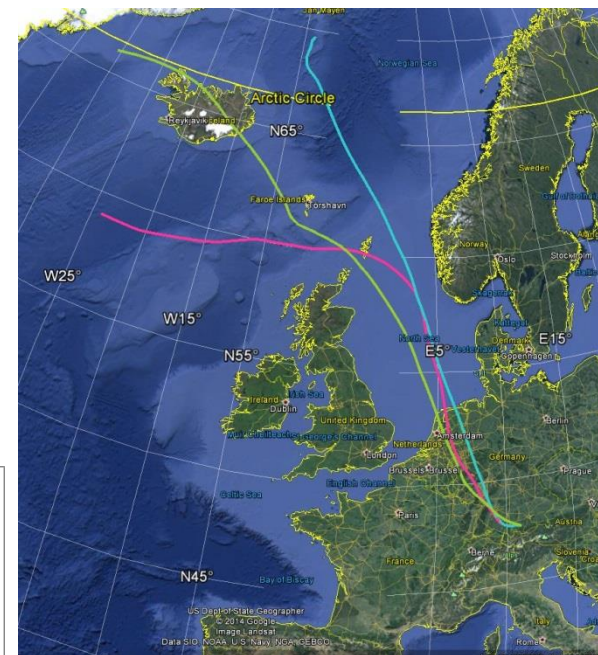
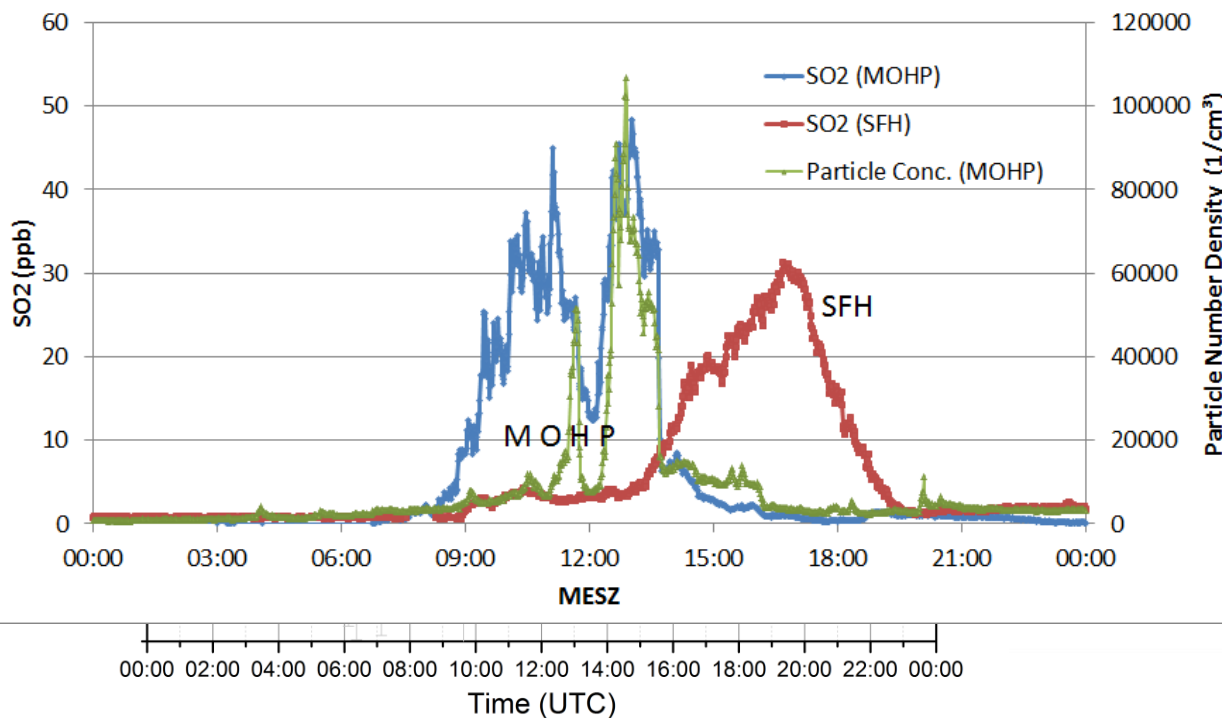
MAX-DOAS AOD @418 nm

AERONET AOD level 2 data @380 nm



- 22.09.2014: SO<sub>2</sub> plume originating from icelandic volcano Bardabunga
- highest SO<sub>2</sub> concentrations since record began, up to 47 ppb at MOHp
- up to 18 DU (Brewer [Ulf Köhler] and MAX-DOAS)

SO<sub>2</sub> and Particle Emissions Bardabunga, 22.09.2014







## Conclusion

- time series of 7 years, comparison of
  - in-situ  $\text{NO}_2$ ,  $\text{H}_2\text{O}$
  - sun photometer, PFR, Ceilometer
- $\text{NO}_2$  retrievals during cloudy conditions seem to be of similar quality as retrievals during clear sky conditions excluding clear sky between clouds, broken clouds
- UV  $\text{NO}_2$  closer to in-situ  $\text{NO}_2$  than VIS
- Meteorology limits correlations (inversions or cloud shielding)
- AOD: diurnal variations of MAX-DOAS and AERONET agree well, discrepancies by different viewing directions can be identified

## Outlook

- more comparison with  $\text{NO}_2$  in-situ measurements at the foot of Hohenpeißenberg
- expand statistics,  $\text{NO}_2$  correlation in 2013
- further improvement by quality filter (criteria: degrees of freedom, chi square, ... ?)
- automation incl. cloud detection
- automatic (optional) adaption of aerosol properties from other instruments



# Thank you!