

# Azimuthal variability of O<sub>4</sub> and NO<sub>2</sub> measured during MADCAT in summer 2013 in Mainz, Germany



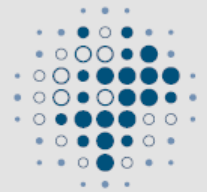
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University Minsk, Belarus  
IISER, Mohali, India  
University Galati, Romania

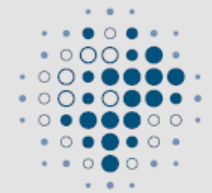
Steffen Beirle, Sebastian Böhnke, Ilya Bruchkousky, Maksym Chirkov, Daniel Constantin, Caroline Fayt, Udo Frieß, Clio Gielen, Matthias Gottschalk, Myojeong Gu, Cagin Güler, Francois Hendrick, Christian Hermans, Martin Horbanski, Jin Junli, Fahim Khokhar, Ted Koenig, Vinod Kumar, Johannes Lampel, Jeongsoon Lee, Ang Li, Yuhan Luo, Jianzhong Ma, Buhalgem Mamtimin, Alexis Merlaud, Franz Meixner, Jan Nasse, Ivan Ortega, Lara Penth, Enno Peters, Gaia Pinardi, Julia Remmers, Andreas Richter, Andre Seyler, Reza Shaiganfar, Vinayak Sinha, Frederik Tack, Michel van Roozendael, Rainer Volkamer, Thomas Wagner, Yang Wang, Folkard Wittrock, Pinhua Xie, Marc Ziegler



# Content

- MAD-CAT campaign
- Azimuthal distribution of  $\text{O}_4$  and  $\text{NO}_2$ 
  - Comparison of the different instruments
  - Comparison to simulations
  - Comparison to Car-DOAS
- Conclusion





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# MAD-CAT: Instruments and Aims

- 16 MAX-DOAS instruments
    - 6 azimuth scanning instruments
  - Car-MAX-DOAS operated by 3 groups
  - NO<sub>2</sub>-CE-DOAS (Heidelberg)
  - Aeronet-Station on the same building
  - ...
- 
- Compare DSCDs of the instruments
  - Investigate azimuth distributions
  - ....



Intensive Phase: June to  
begin of July 2013

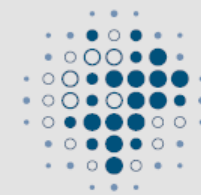
Extended Phase: until mid of  
October 2013



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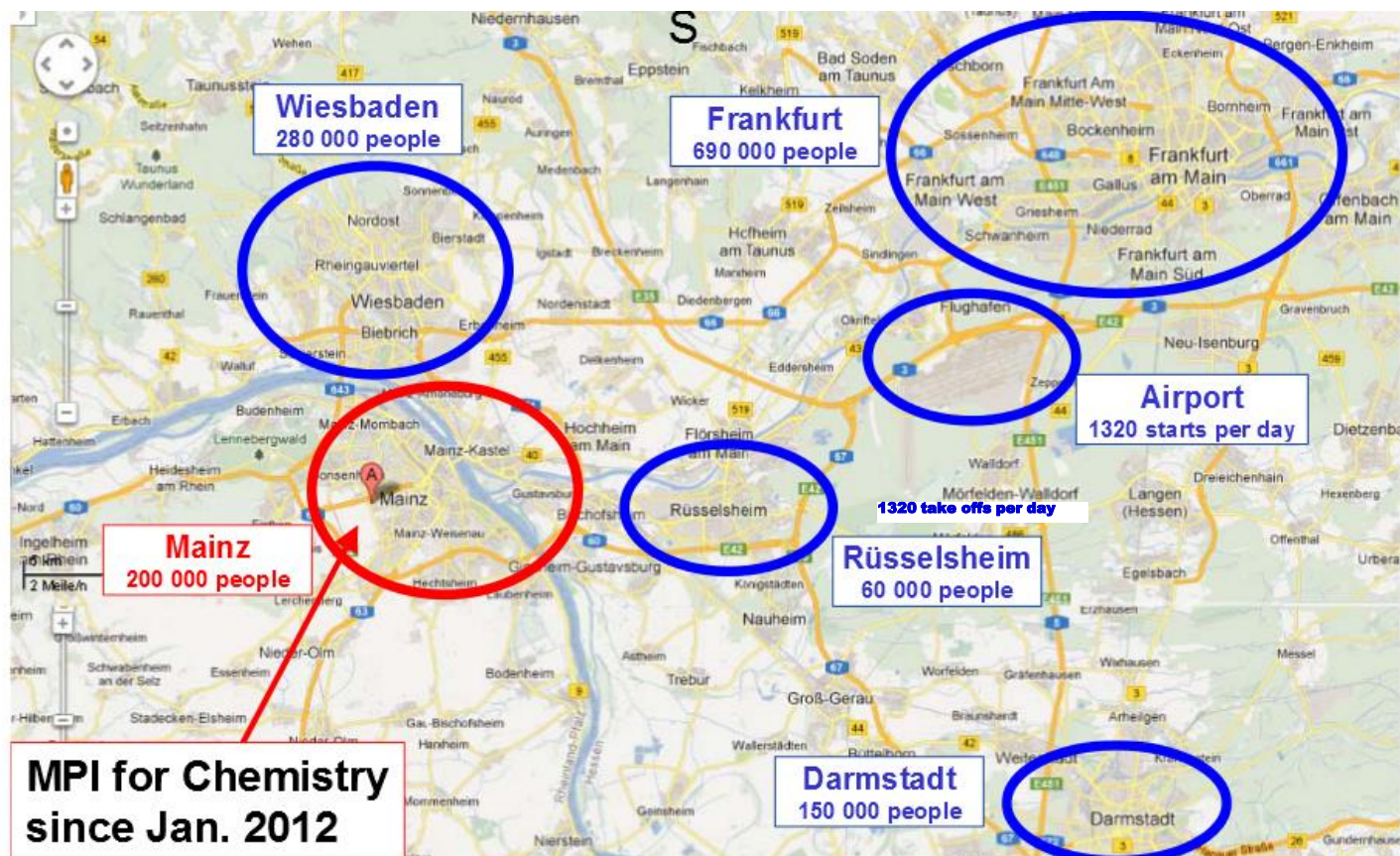


# Multi Axis DOAS – Comparison Campaign for Aerosols and Trace Gases

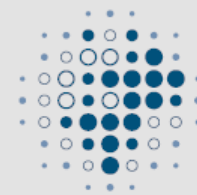


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Standard viewing direction:  
51° (towards Frankfurt)



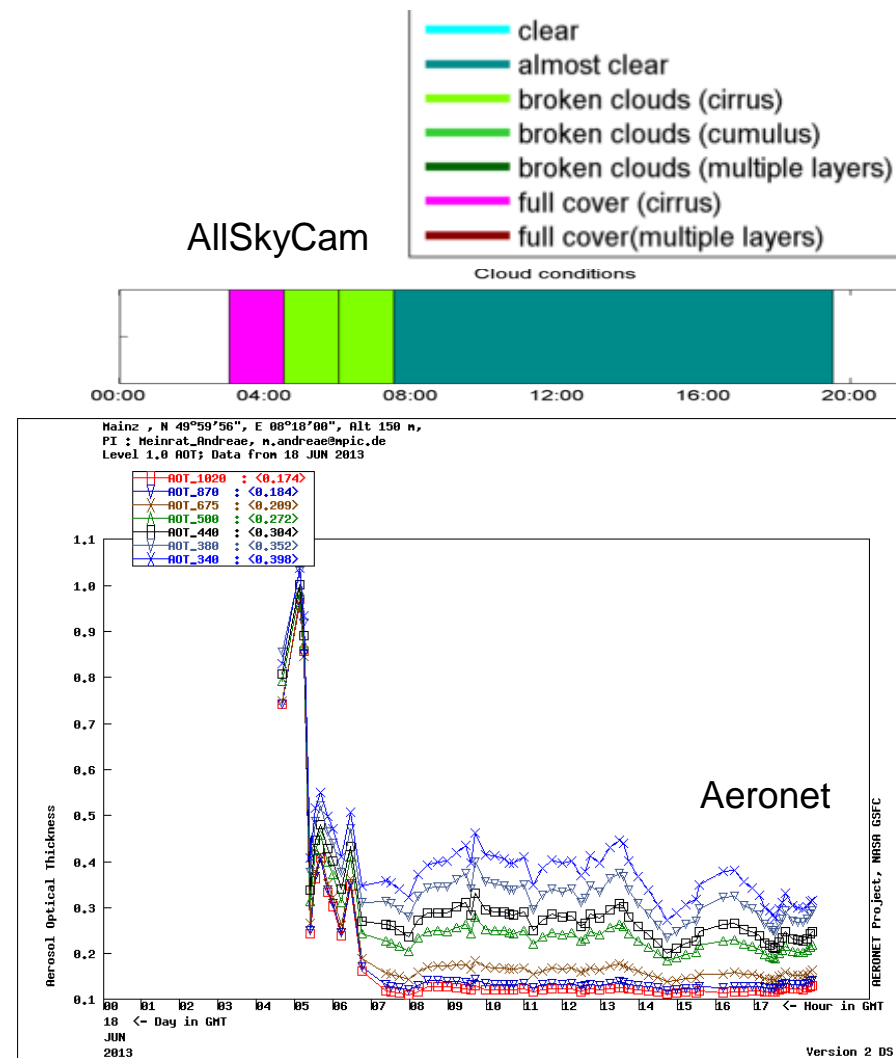
MAX-PLANCK-GESELLSCHAFT

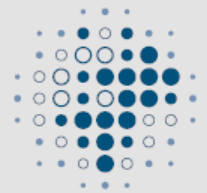


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# Azimuthal Comparisons

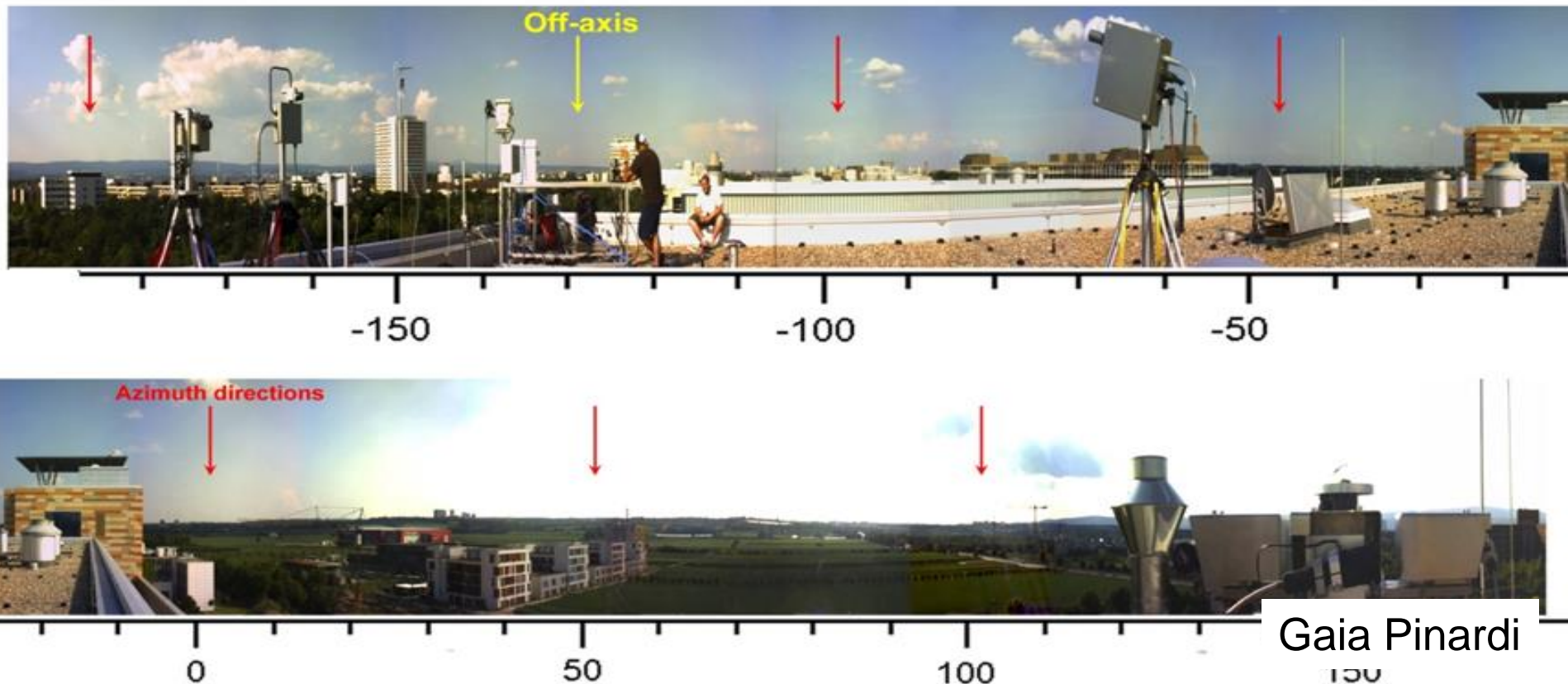
- Focus on 1 day: 18.06.13
- Used as comparison/quality check: Aeronet, AllSky Camera
- 4 Groups: Bremen, Boulder, Heidelberg, Mainz
- NO<sub>2</sub> from vis small analysis setting
- O<sub>4</sub> from UV analysis setting





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## Azimuth scans: round view

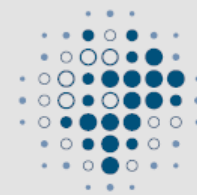


- (minimum) 1 scan every 2 hours → several groups made more measurements
- Elevation:  $2^\circ$
- Daily reference



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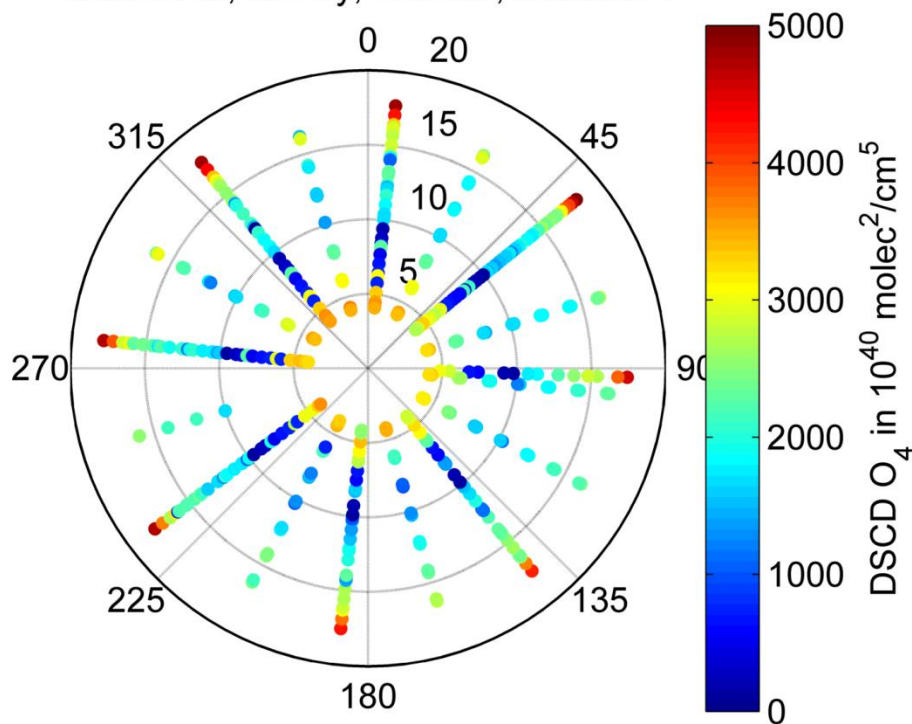


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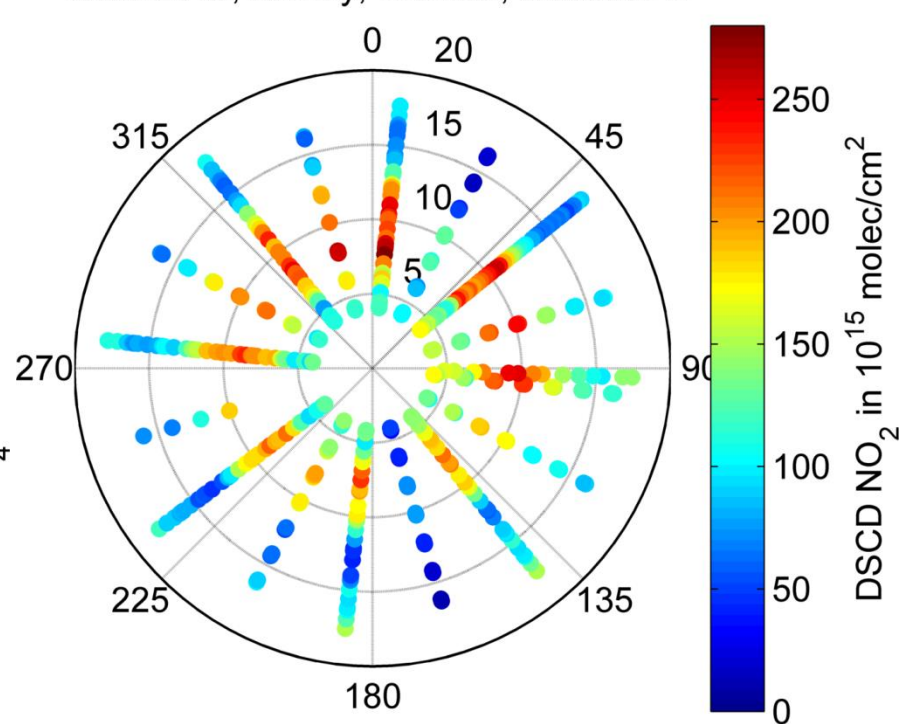
# Bremen – full day



18.06.2013, fullDay, Bremen, elevation 2

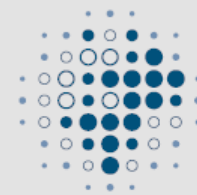


18.06.2013, fullDay, Bremen, elevation 2



Time information on cycles: morning in the middle, evening outside

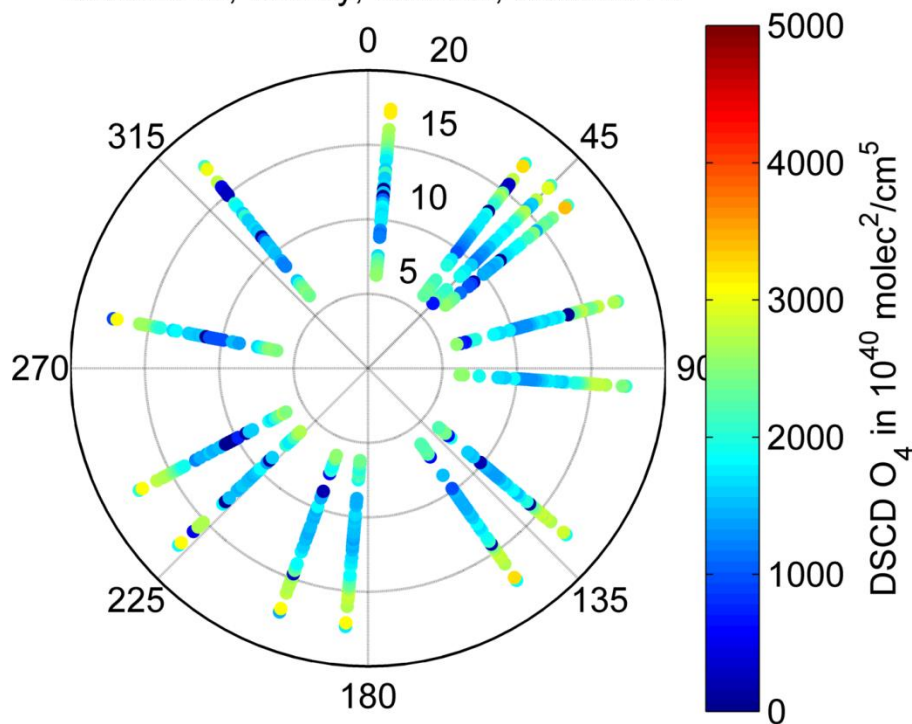




## Boulder – full day

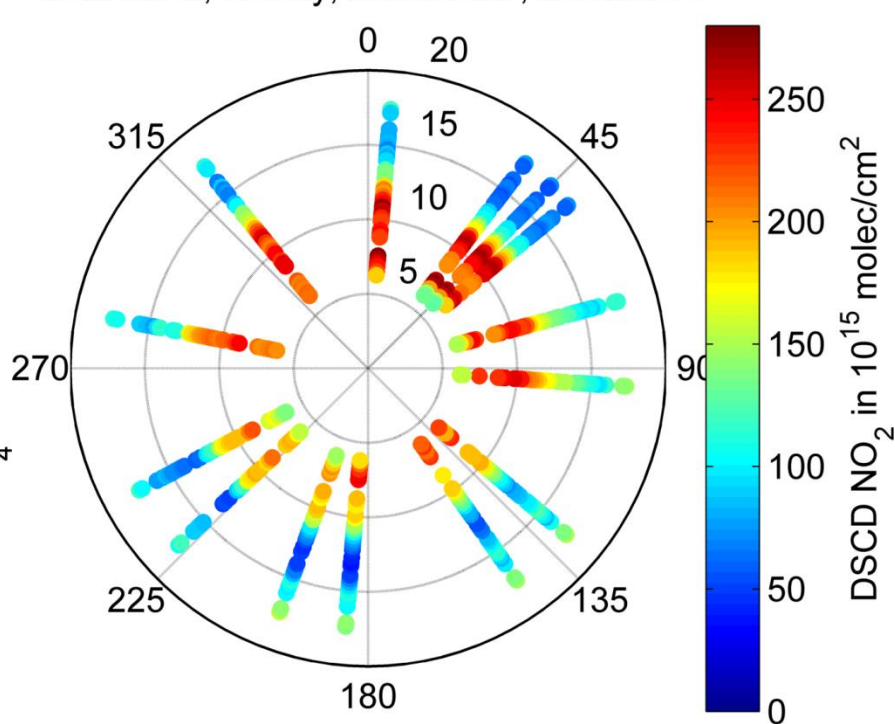
O<sub>4</sub>

18.06.2013, fullDay, Boulder, elevation 2



NO<sub>2</sub>

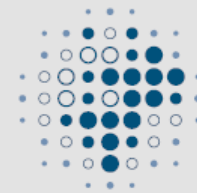
18.06.2013, fullDay, CUBoulder, elevation 2



Time information on cycles: morning in the middle, afternoon outside







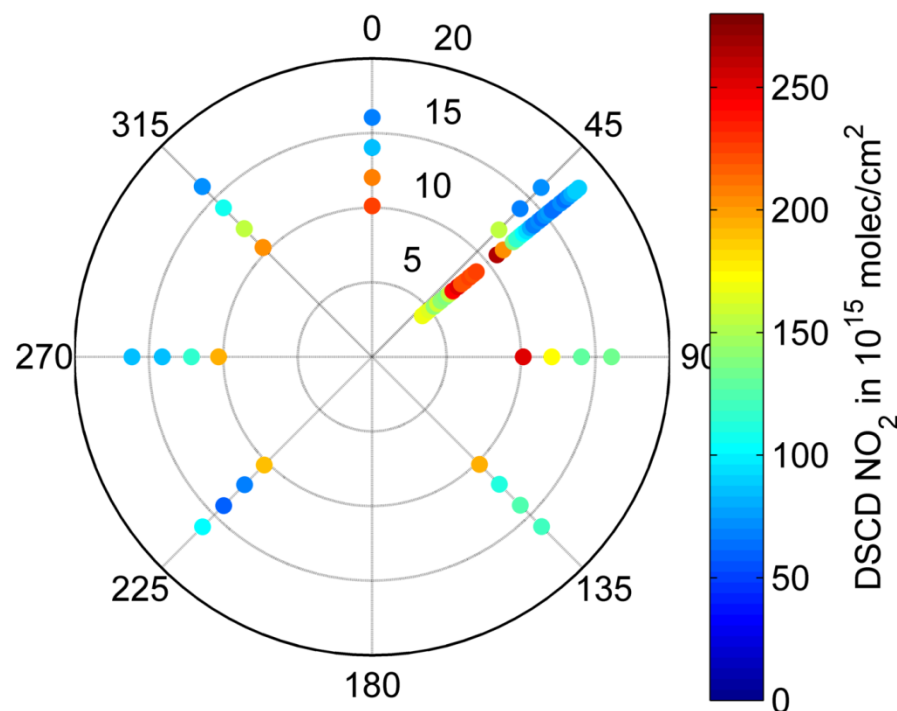
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# Heidelberg— full day

$O_4$

$NO_2$

18.06.2013, fullDay, heidelberg, elevation 2

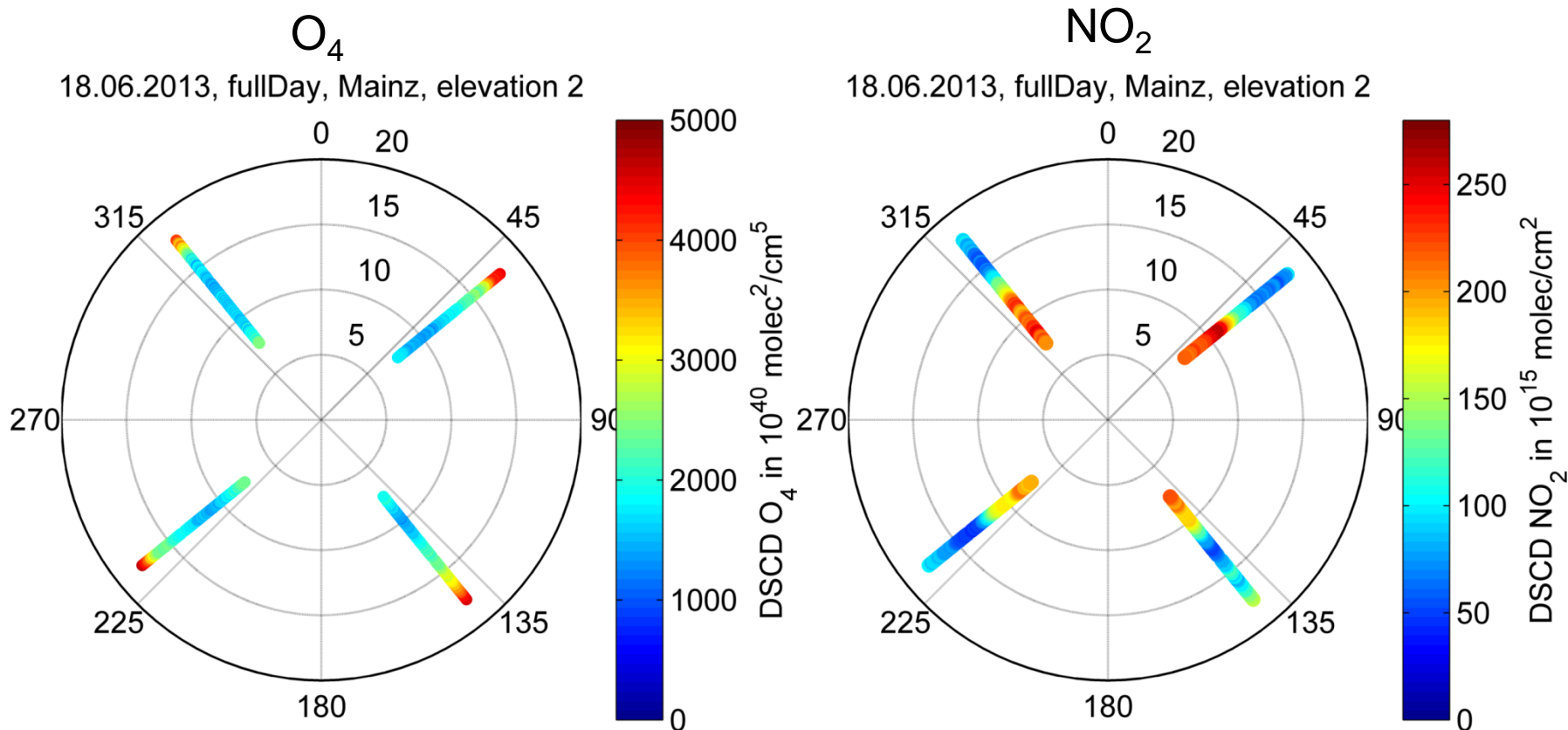


Time information on cycles: morning in the middle, evening outside





# Mainz – full day



Time information on cycles: morning in the middle, afternoon outside

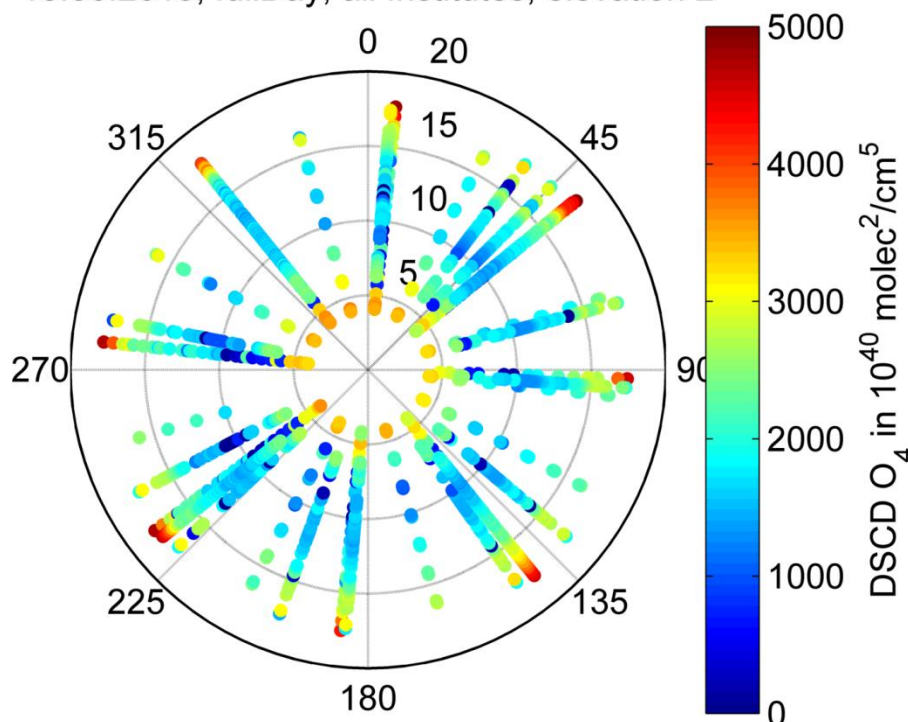


# All Instruments, full Day

○ Bremen  
□ Boulder  
△ Heidelberg  
◇ Mainz

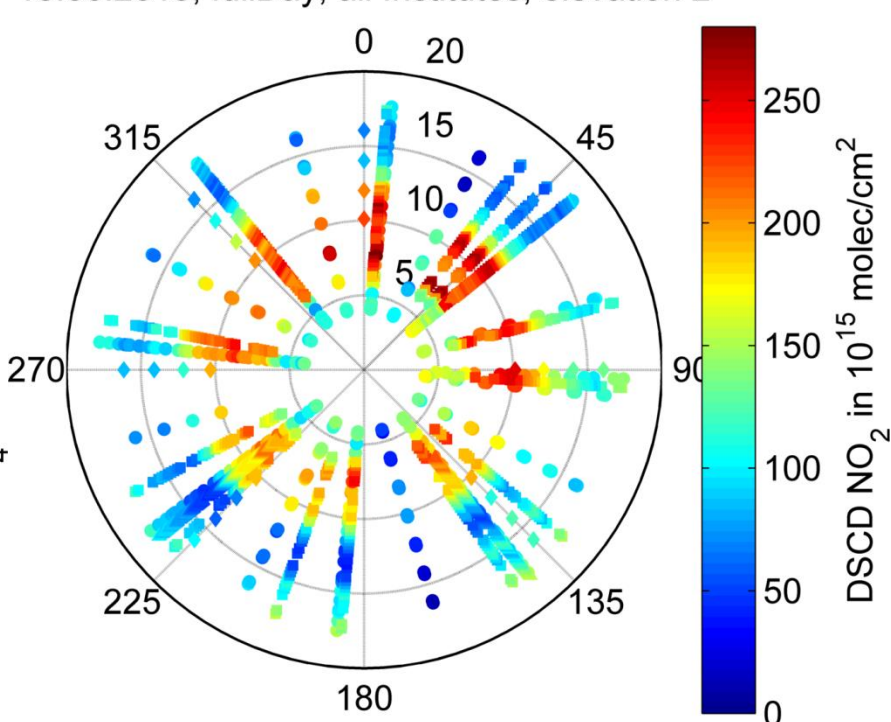
O<sub>4</sub>

18.06.2013, fullDay, all Institutes, elevation 2



NO<sub>2</sub>

18.06.2013, fullDay, all Institutes, elevation 2



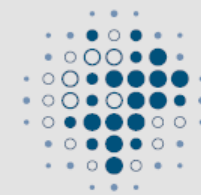
- The results of the different instruments are in good agreement
- Good spatial and temporal resolution





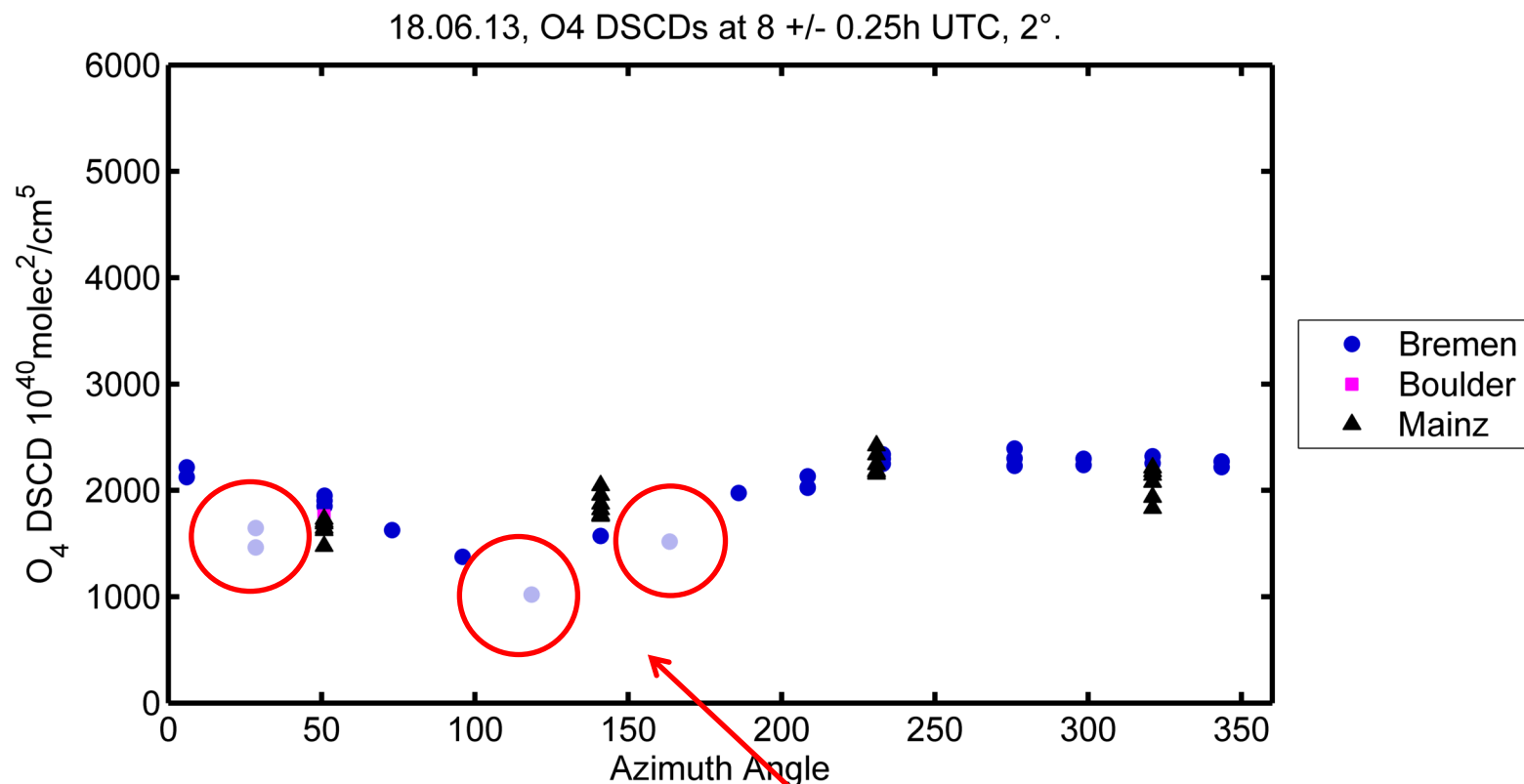
# O<sub>4</sub>:

## All instruments, daily development



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8 UTC (+/-0.25h)



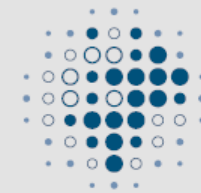
Pointing towards obstacles



MAX-PLANCK-GESELLSCHAFT

# O<sub>4</sub>:

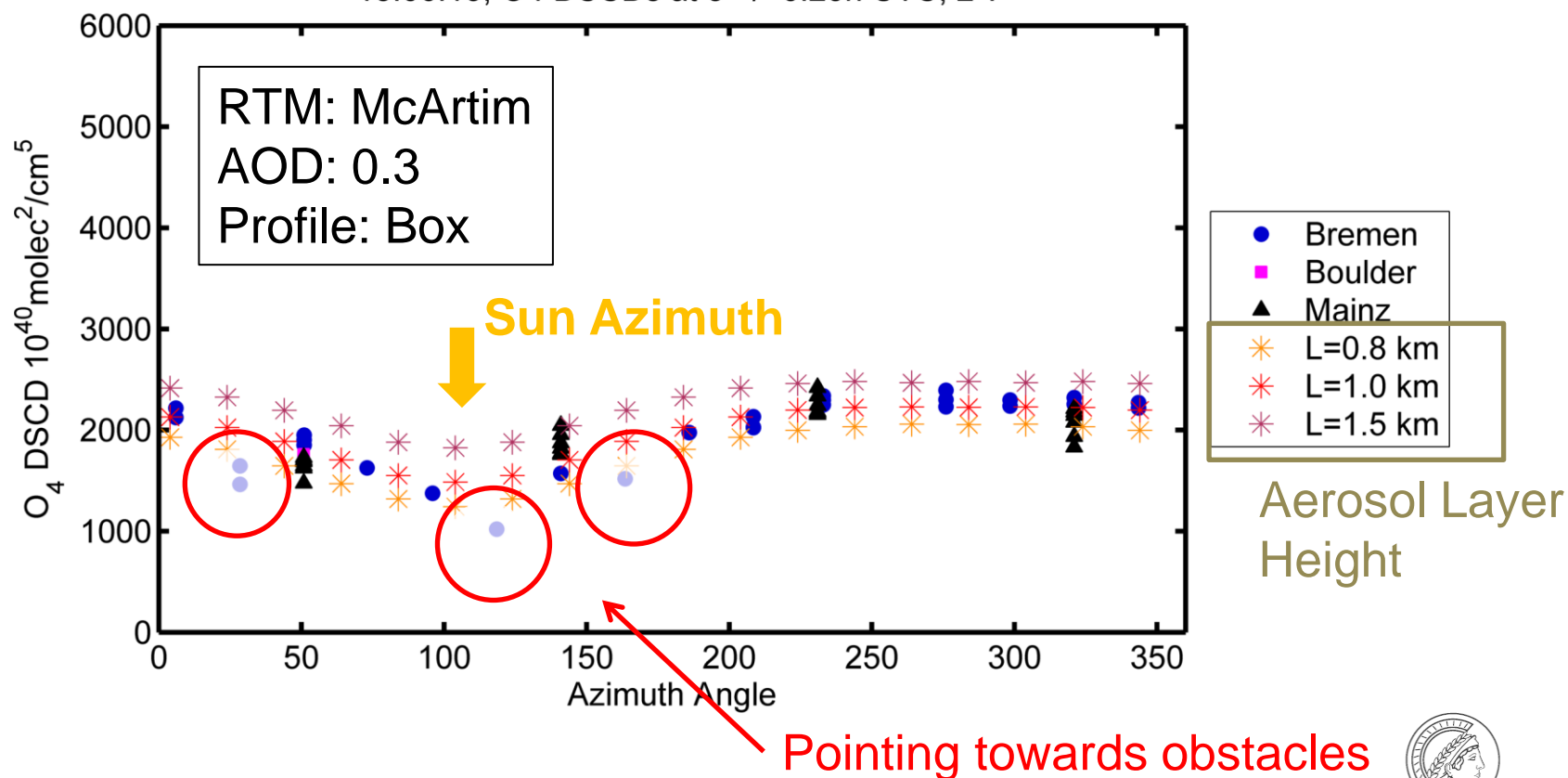
## All instruments, daily development



MAX-PLANCK-INSTITUT  
FÜR CHEMIE

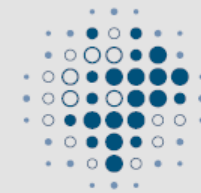
8 UTC (+/-0.25h)

18.06.13, O<sub>4</sub> DSCDs at 8 +/- 0.25h UTC, 2°.



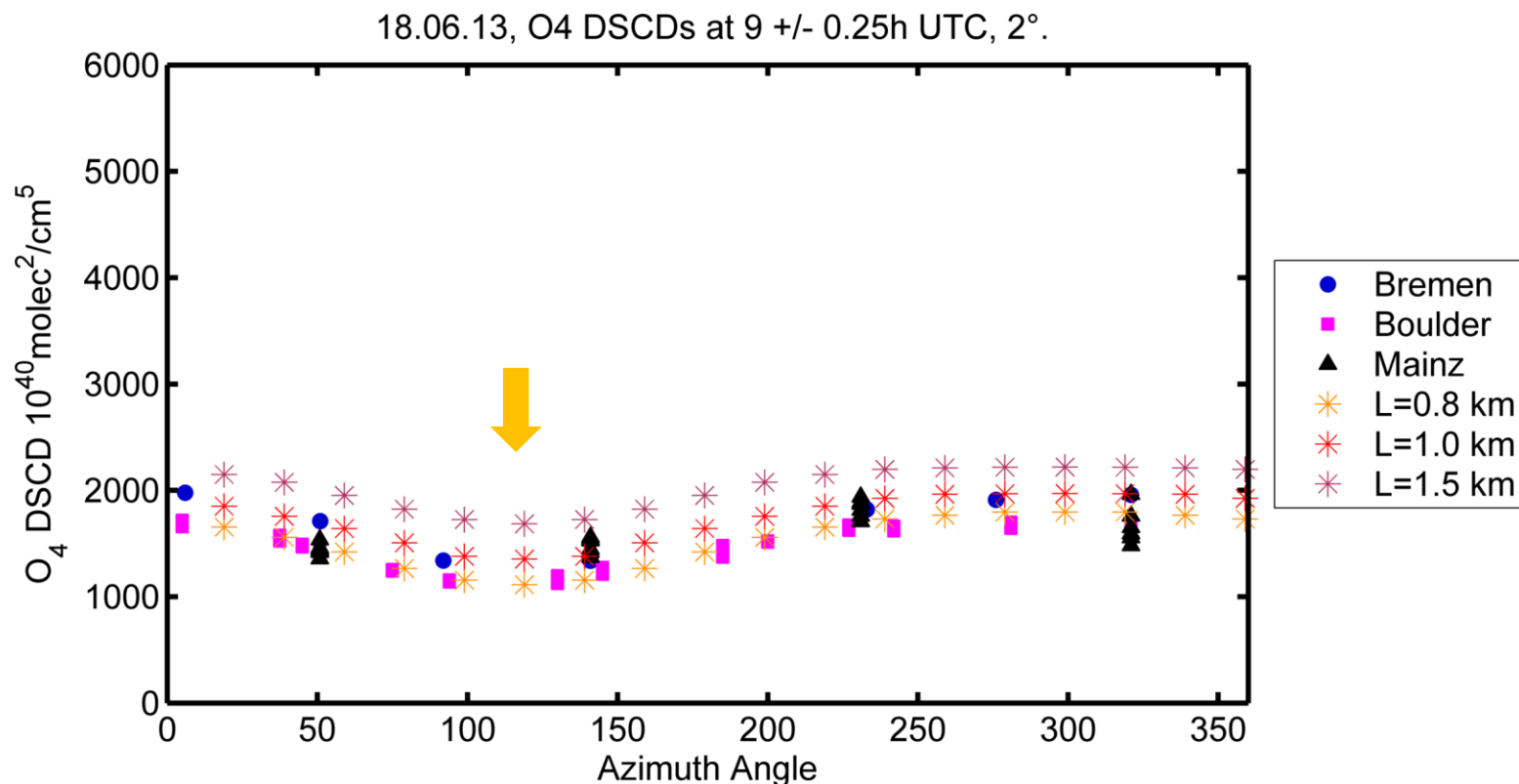
# O<sub>4</sub>:

## All instruments, daily development



MAX-PLANCK-INSTITUT  
FÜR CHEMIE

9 UTC (+/-0.25h)

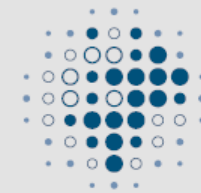


MAX-PLANCK-GESELLSCHAFT



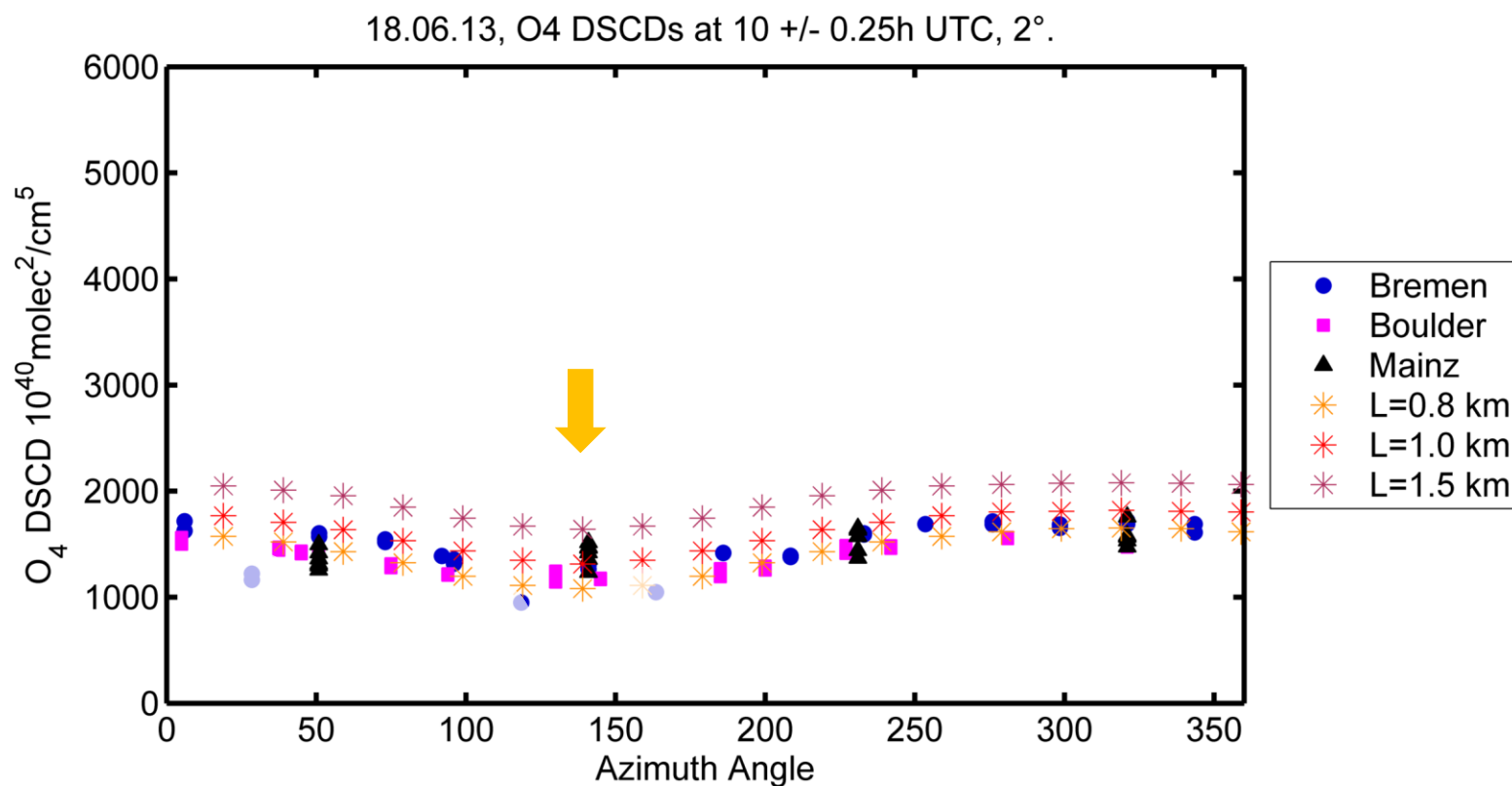
# O<sub>4</sub>:

## All instruments, daily development



MAX-PLANCK-INSTITUT  
FÜR CHEMIE

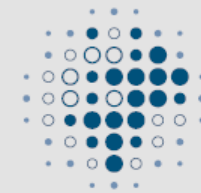
10 UTC (+/-0.25h)



MAX-PLANCK-GESELLSCHAFT

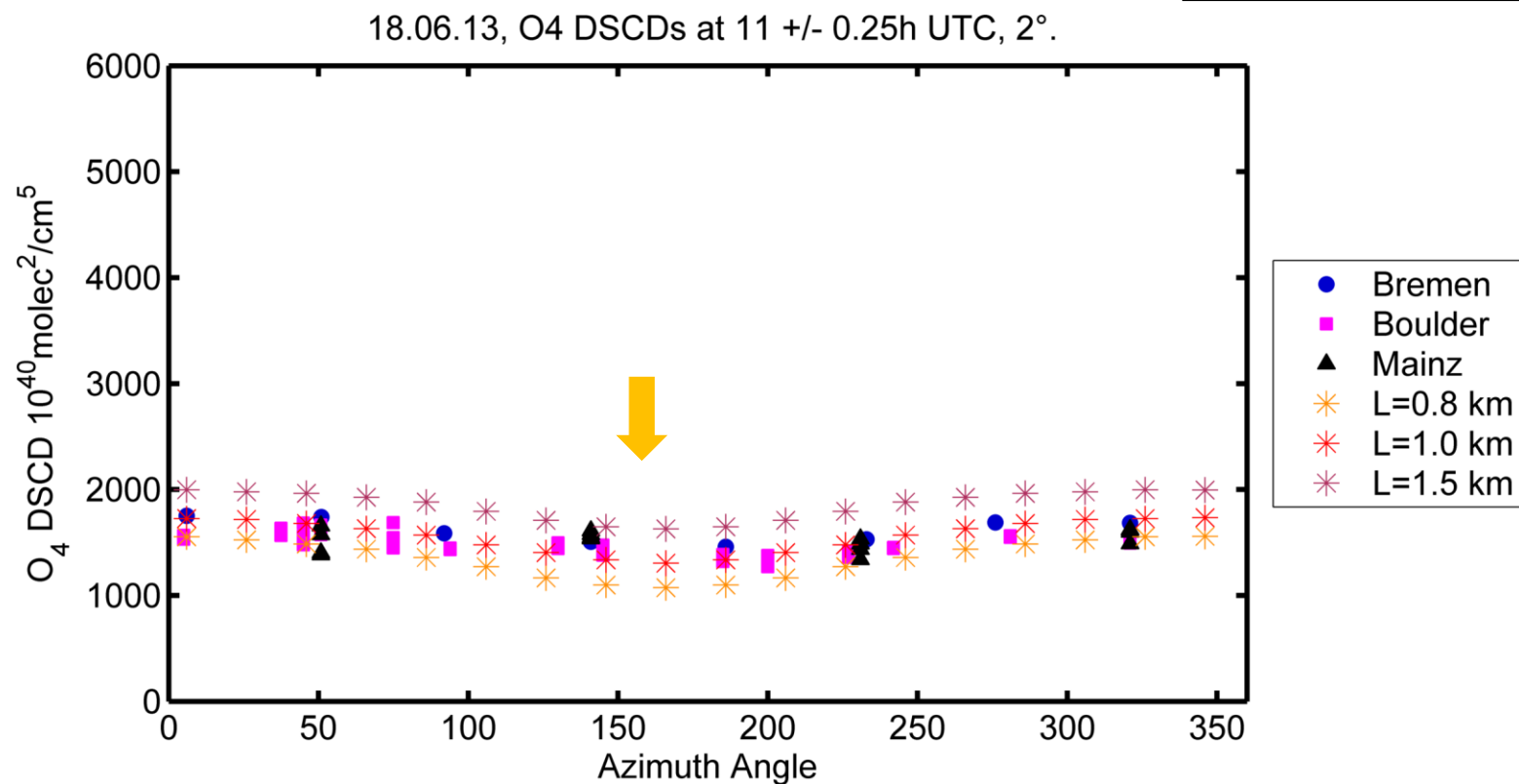
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## All instruments, daily development



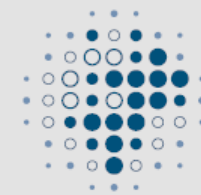
MAX-PLANCK-INSTITUT  
FÜR CHEMIE

11 UTC (+/-0.25h)



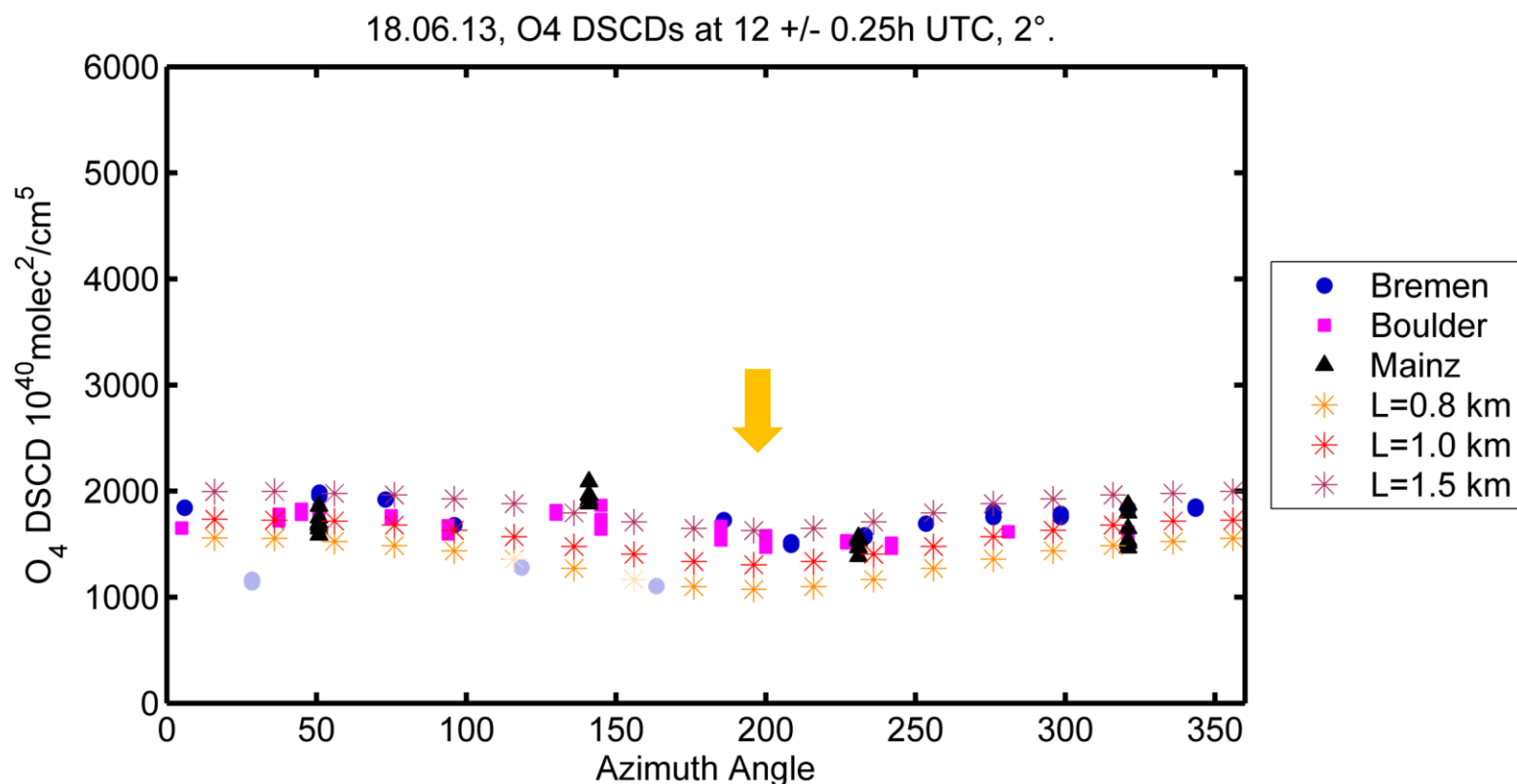
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## All instruments, daily development



MAX-PLANCK-INSTITUT  
FÜR CHEMIE

12 UTC (+/-0.25h)

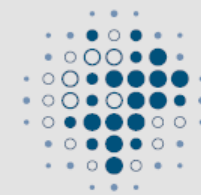


MAX-PLANCK-GESELLSCHAFT



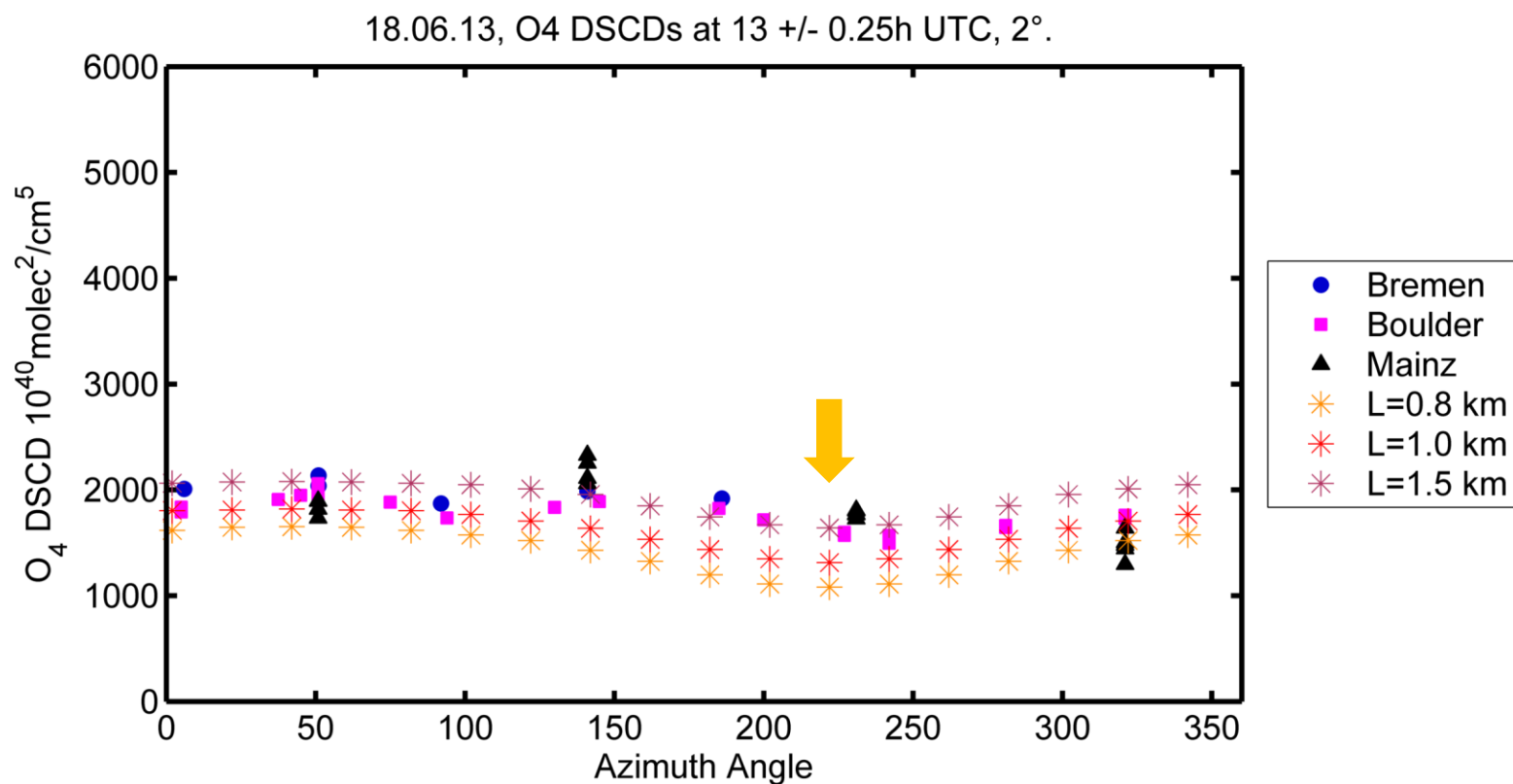
# O<sub>4</sub>:

## All instruments, daily development



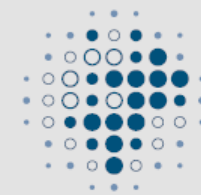
MAX-PLANCK-INSTITUT  
FÜR CHEMIE

13 UTC (+/-0.25h)



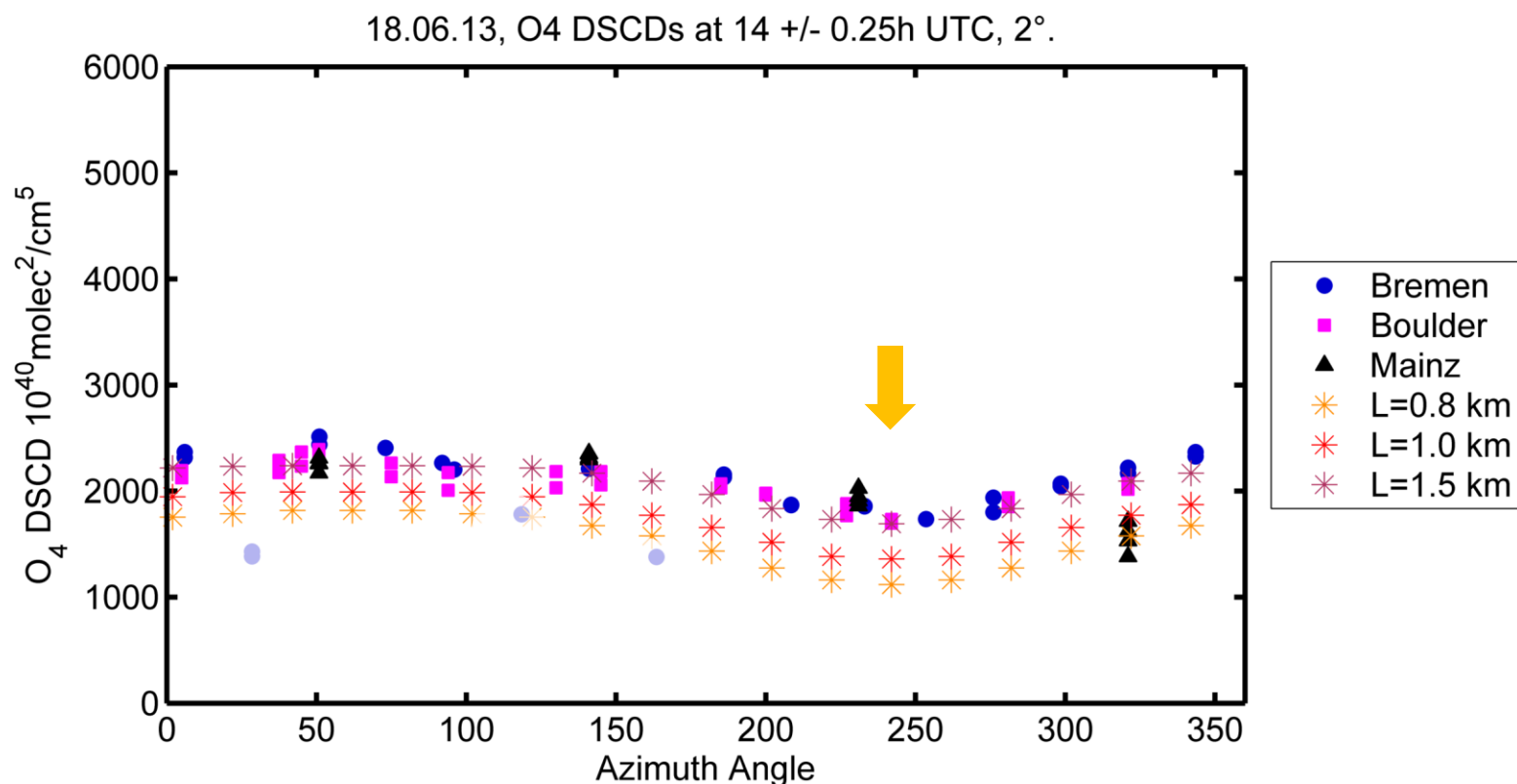
# O<sub>4</sub>:

## All instruments, daily development



MAX-PLANCK-INSTITUT  
FÜR CHEMIE

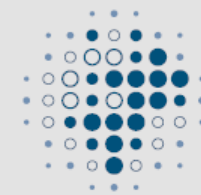
14 UTC (+/-0.25h)



MAX-PLANCK-GESELLSCHAFT

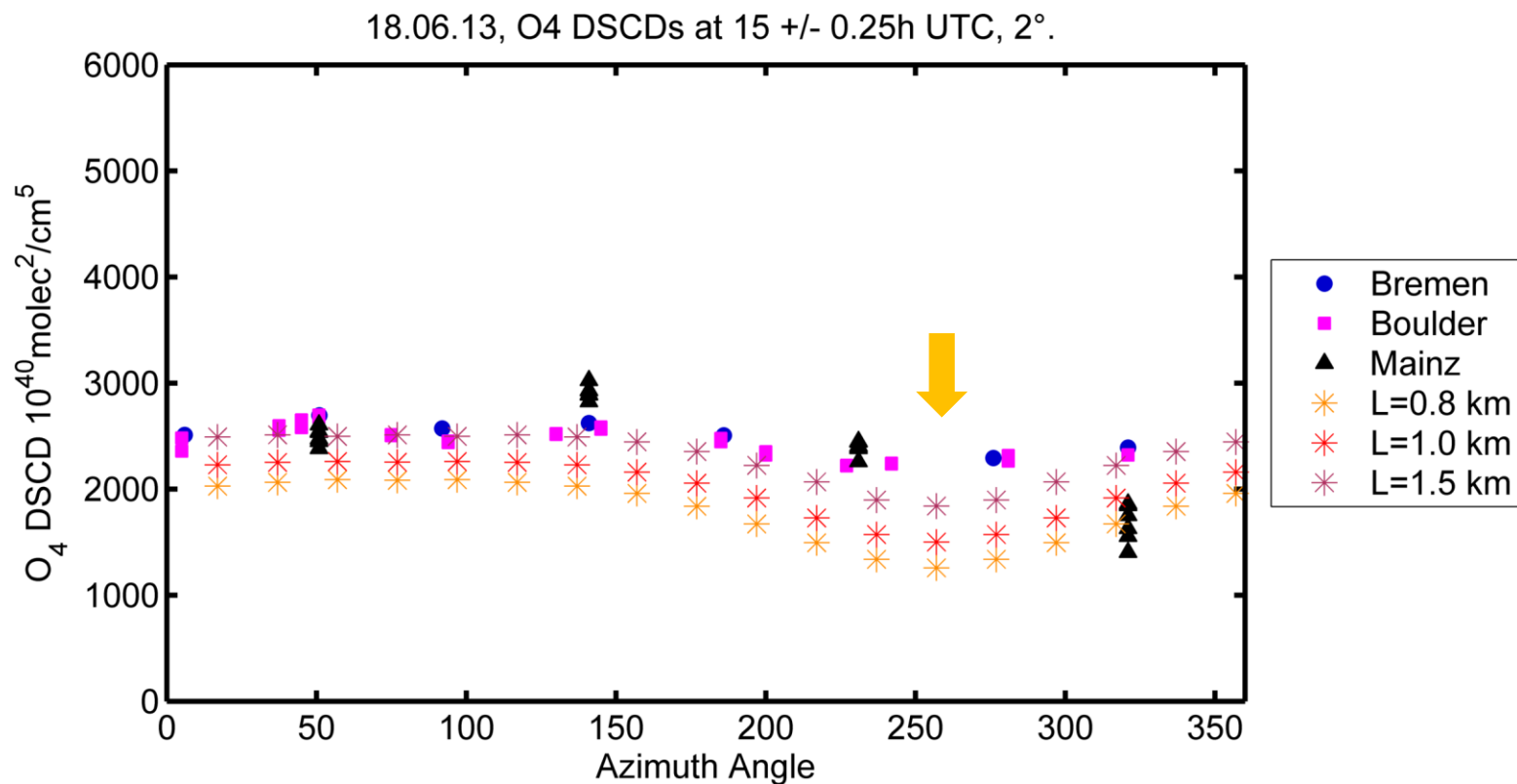
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## All instruments, daily development



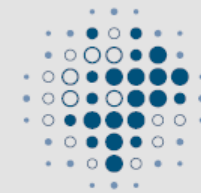
MAX-PLANCK-INSTITUT  
FÜR CHEMIE

15 UTC (+/-0.25h)



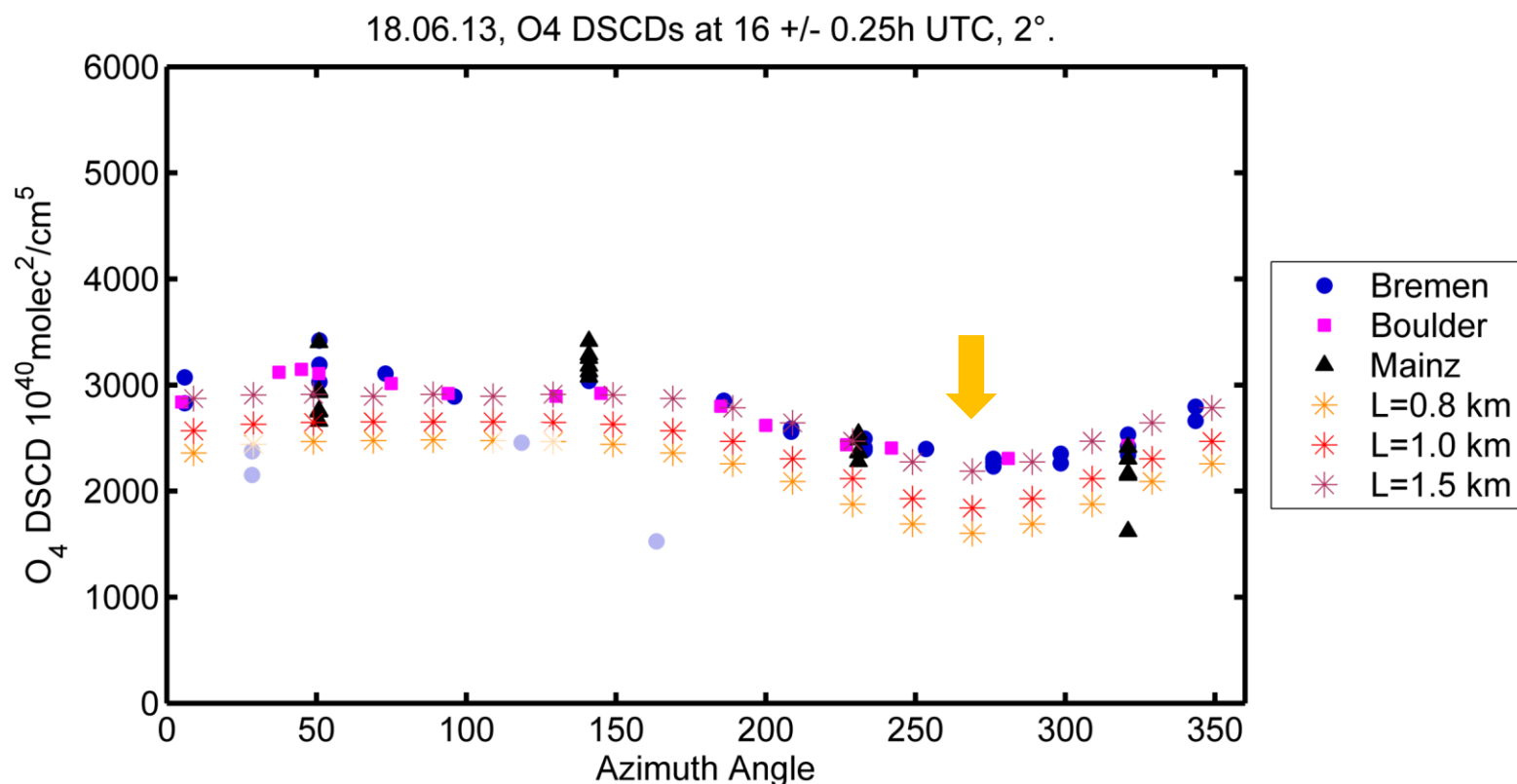
# O<sub>4</sub>:

## All instruments, daily development



MAX-PLANCK-INSTITUT  
FÜR CHEMIE

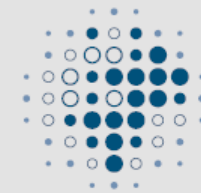
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MAX-PLANCK-GESELLSCHAFT

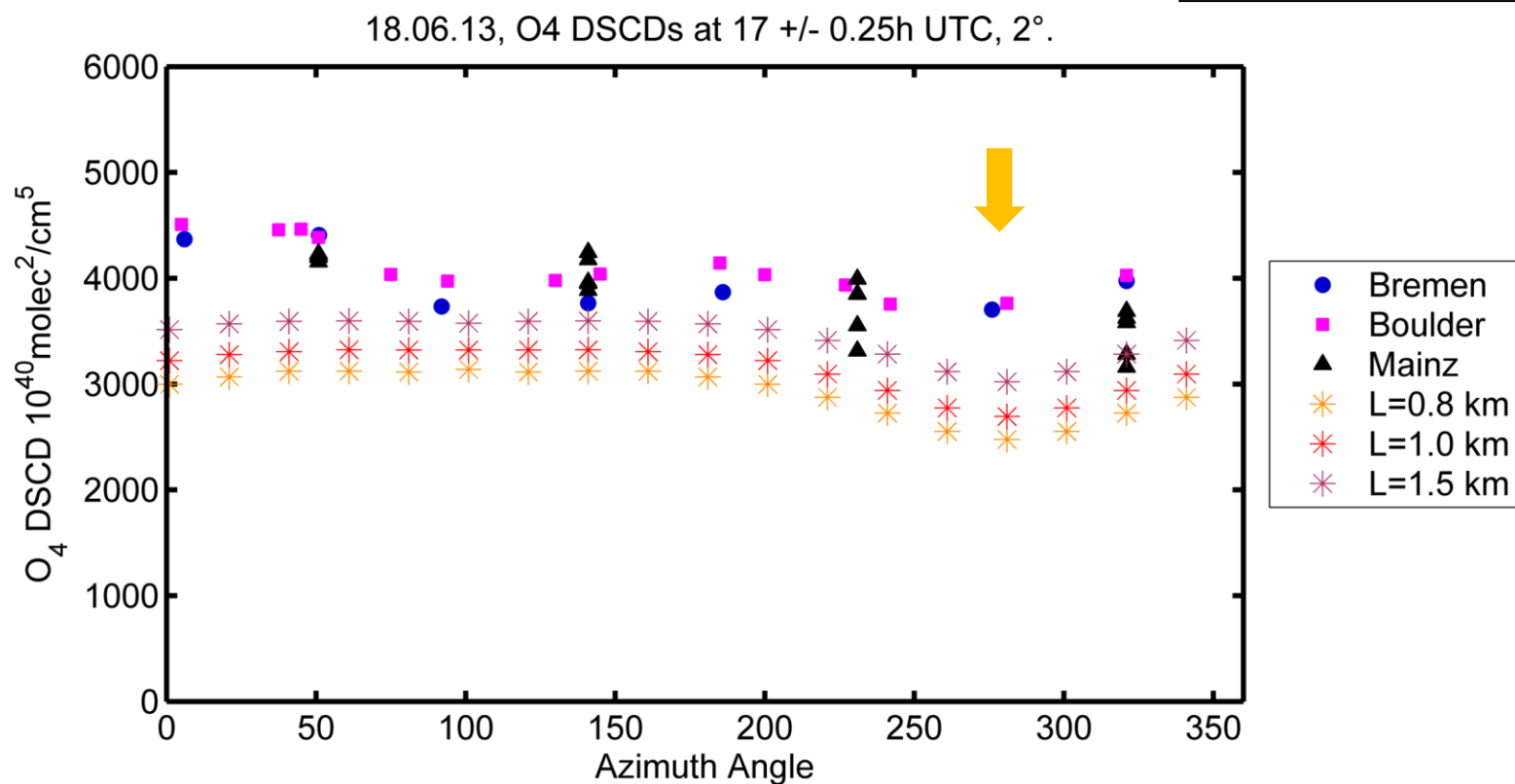
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## All instruments, daily development



MAX-PLANCK-INSTITUT  
FÜR CHEMIE

17 UTC (+/-0.25h)

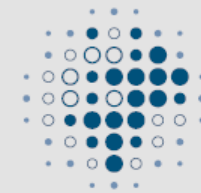


MAX-PLANCK-GESELLSCHAFT



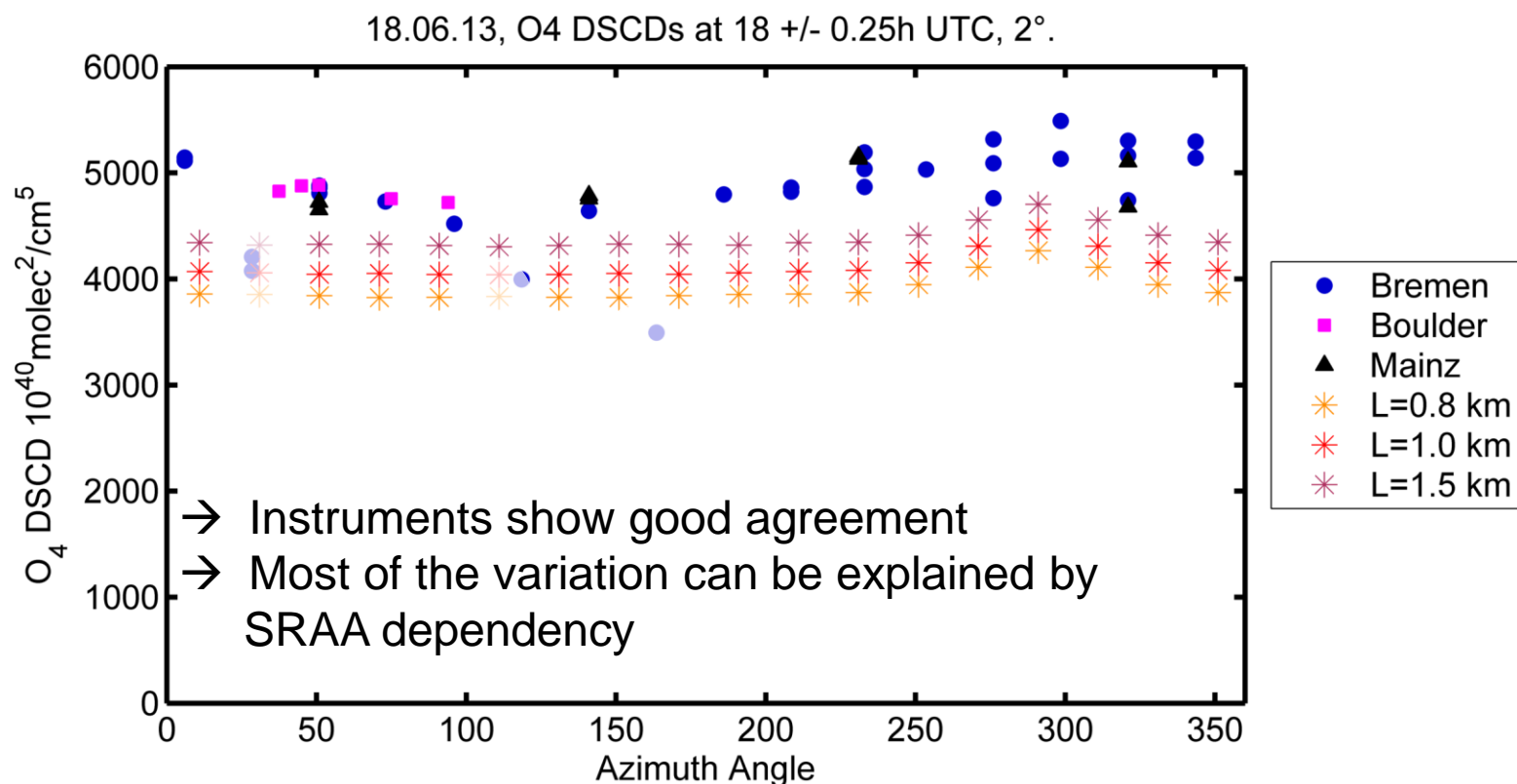
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MAX-PLANCK-INSTITUT  
FÜR CHEMIE

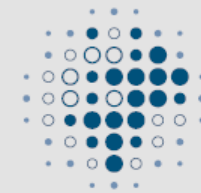
18 UTC (+/-0.25h)



MAX-PLANCK-GESELLSCHAFT

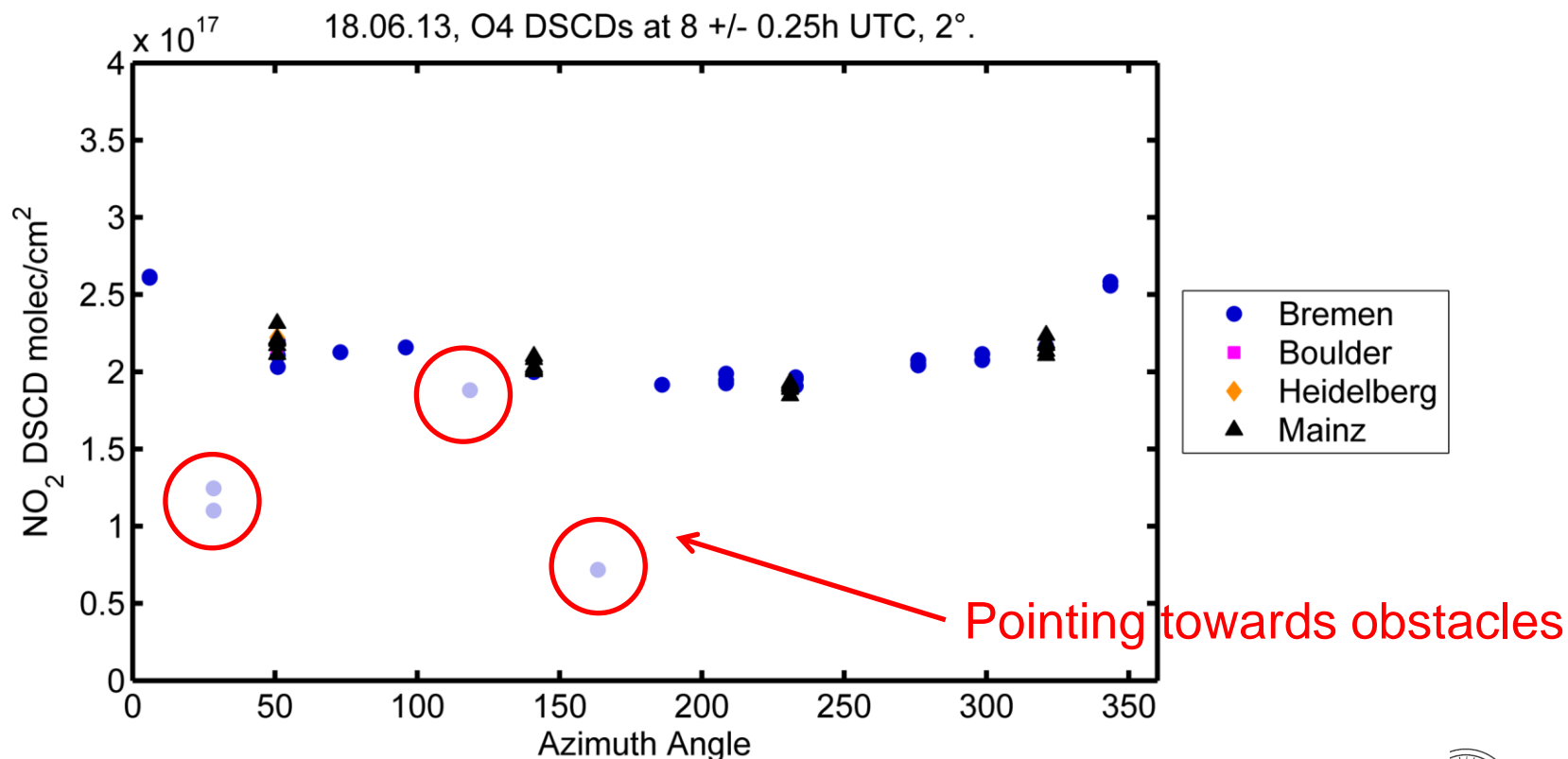
# NO<sub>2</sub>:

## All instruments, daily development



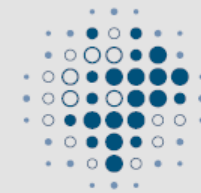
MAX-PLANCK-INSTITUT  
FÜR CHEMIE

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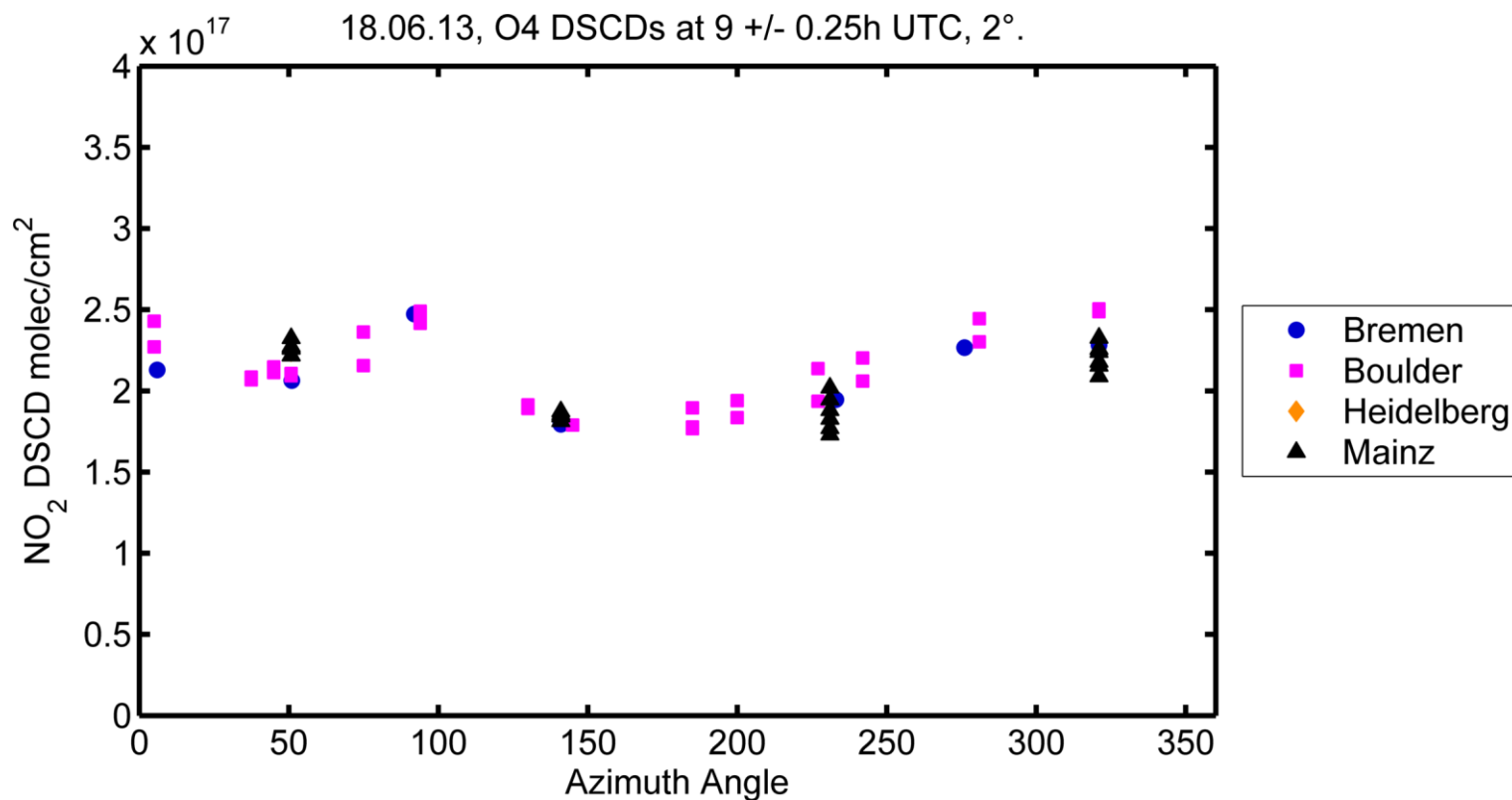
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## All instruments, daily development



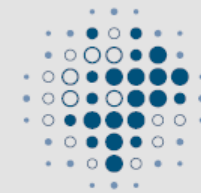
MAX-PLANCK-INSTITUT  
FÜR CHEMIE

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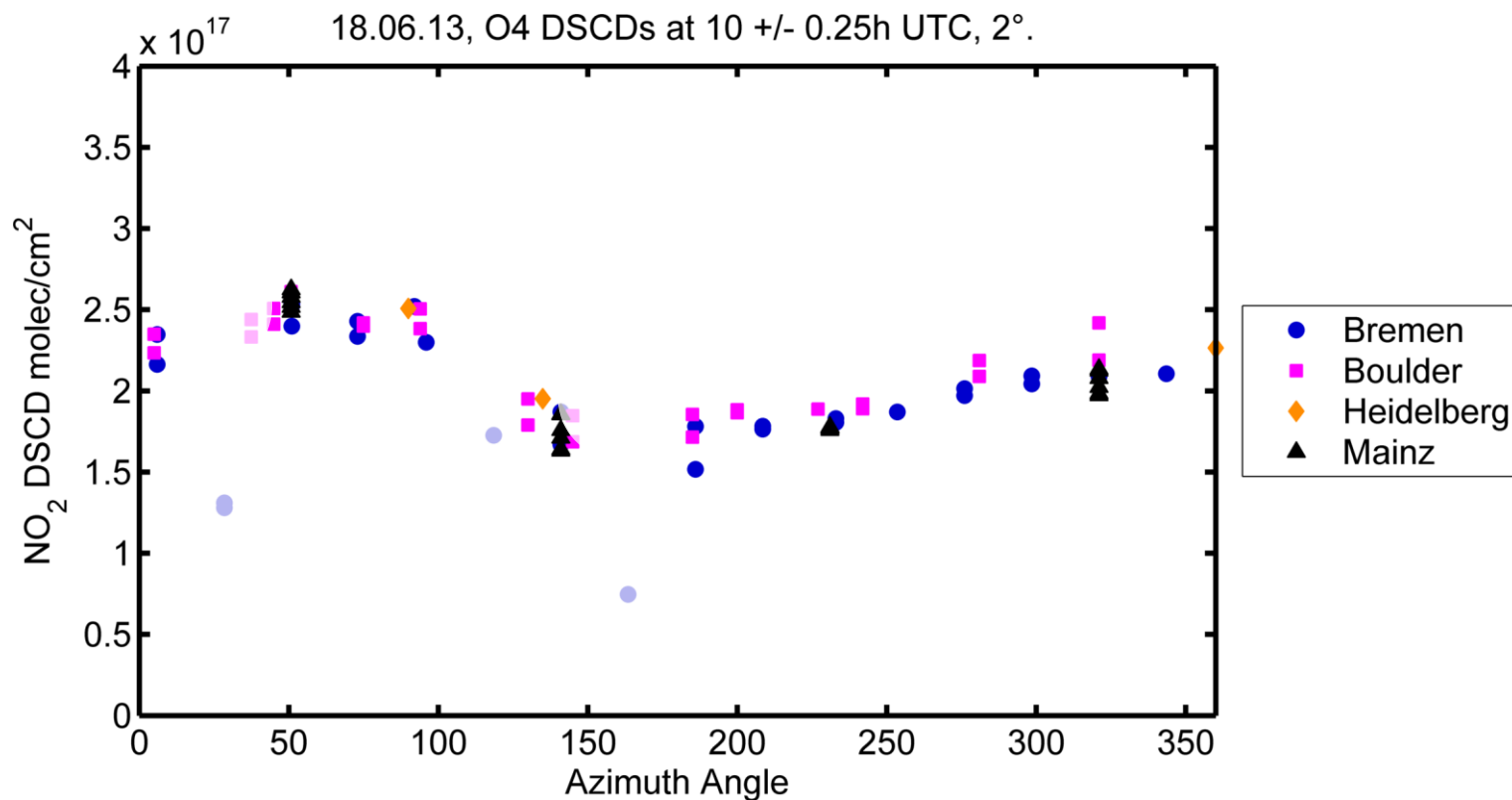
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## All instruments, daily development



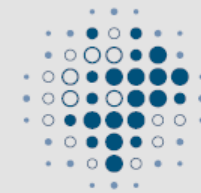
MAX-PLANCK-INSTITUT  
FÜR CHEMIE

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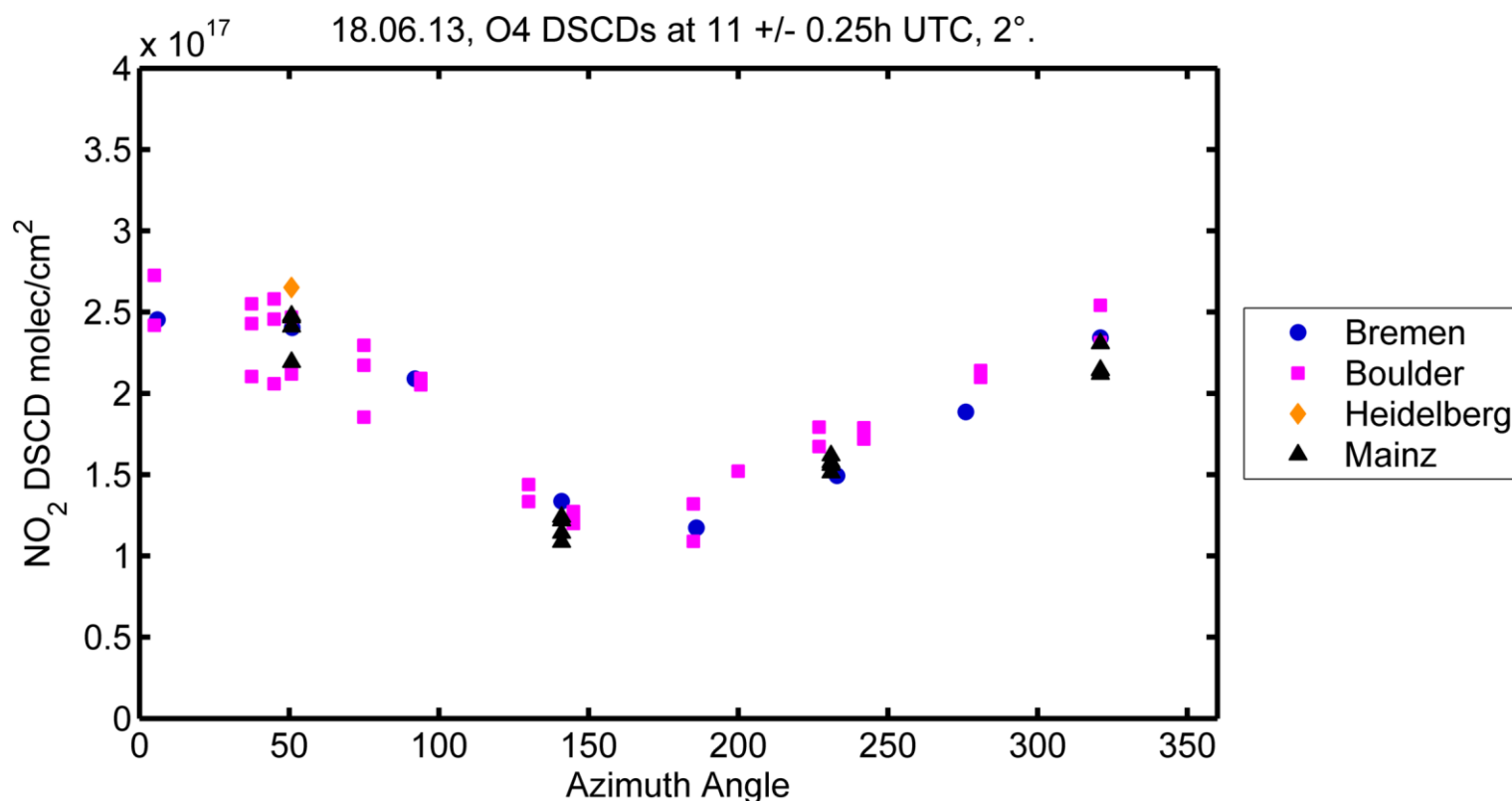
NO<sub>2</sub>:

All instruments, daily development



MAX-PLANCK-INSTITUT  
FÜR CHEMIE

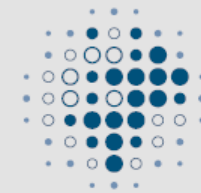
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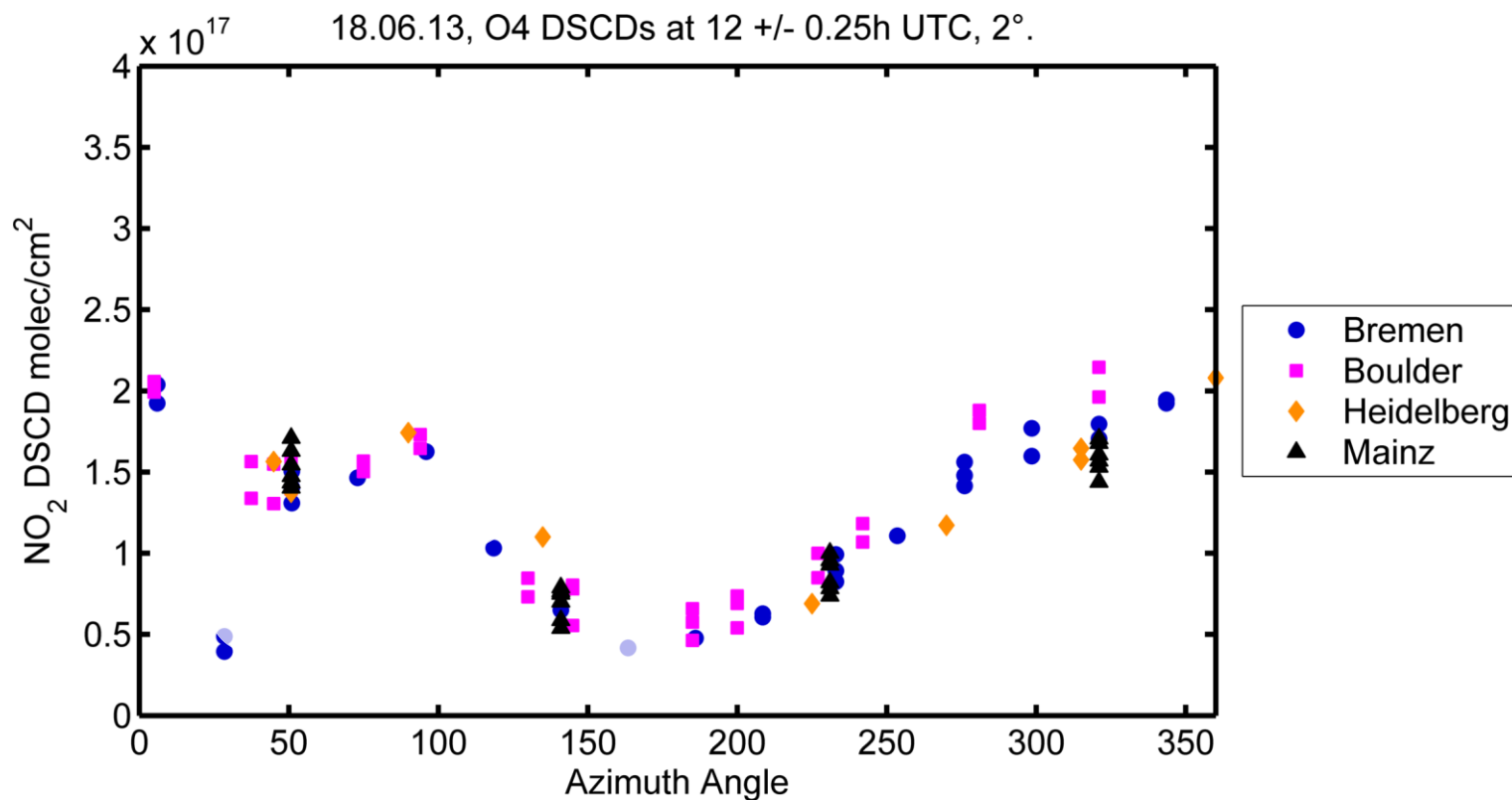
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## All instruments, daily development



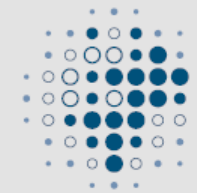
MAX-PLANCK-INSTITUT  
FÜR CHEMIE

12 UTC (+/-0.25h)



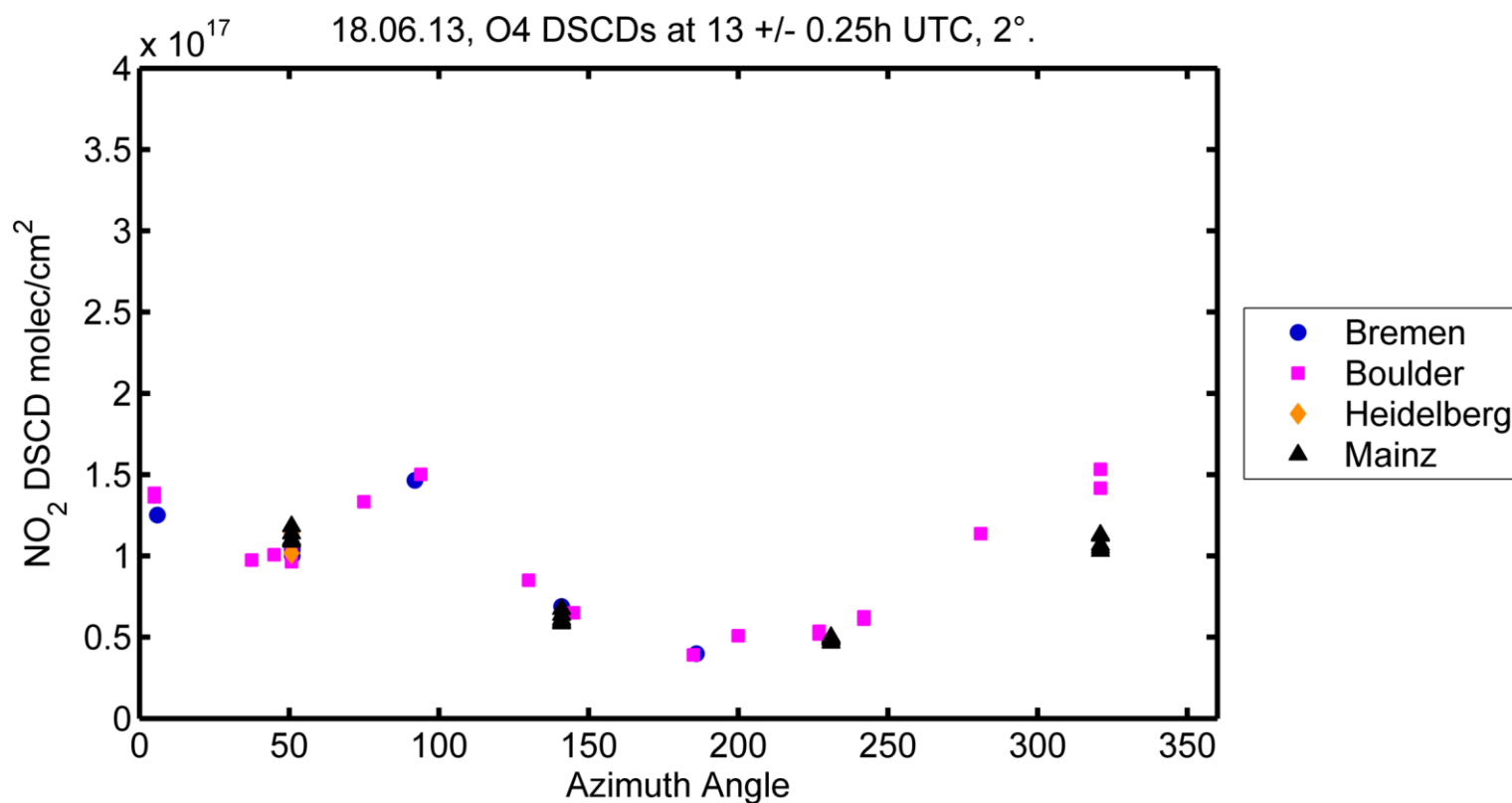
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## All instruments, daily development



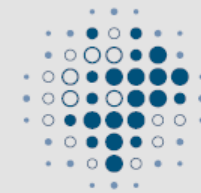
MAX-PLANCK-INSTITUT  
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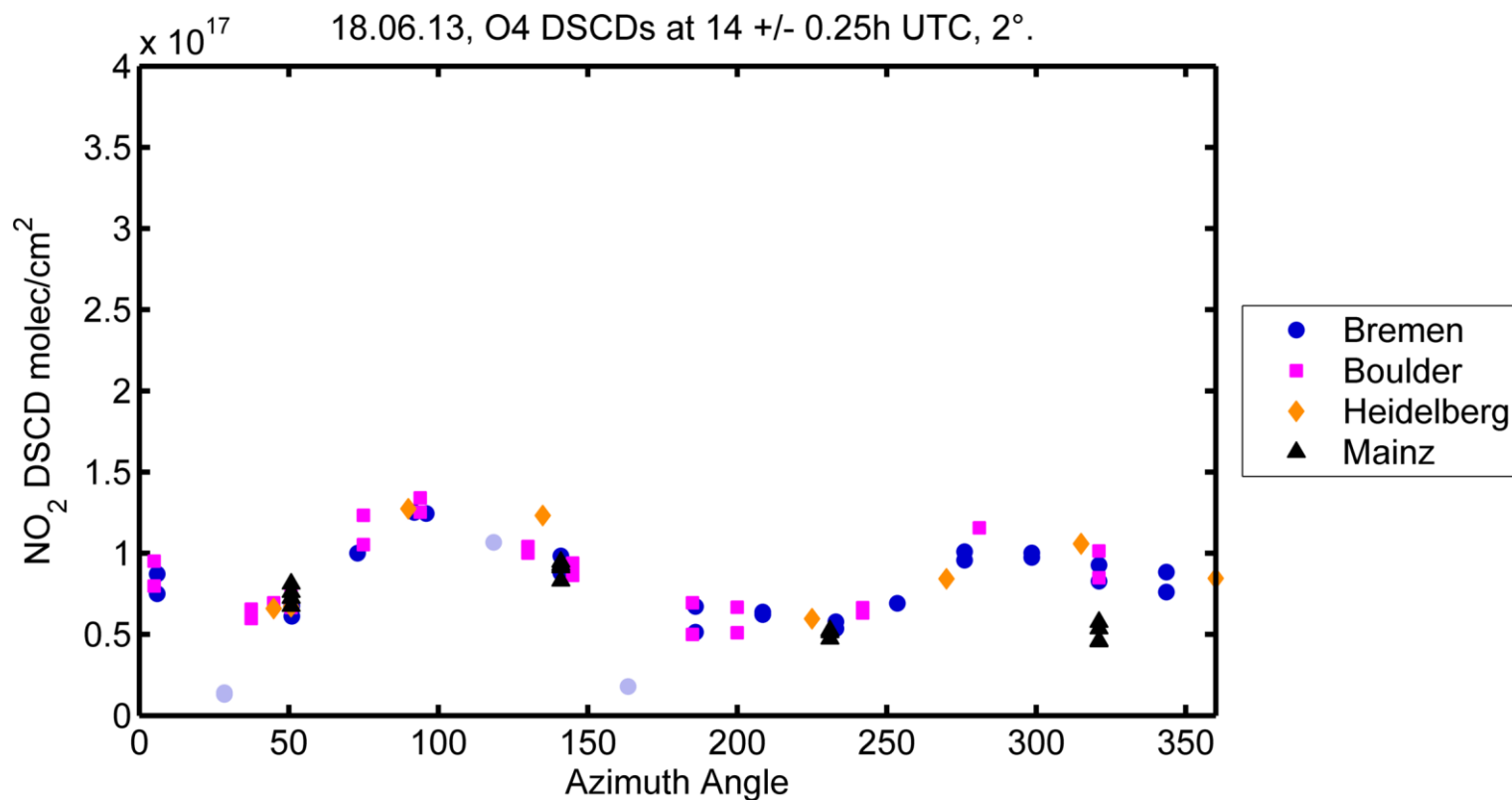
# NO<sub>2</sub>:

## All instruments, daily development



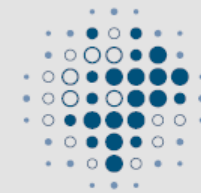
MAX-PLANCK-INSTITUT  
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14 UTC (+/-0.25h)



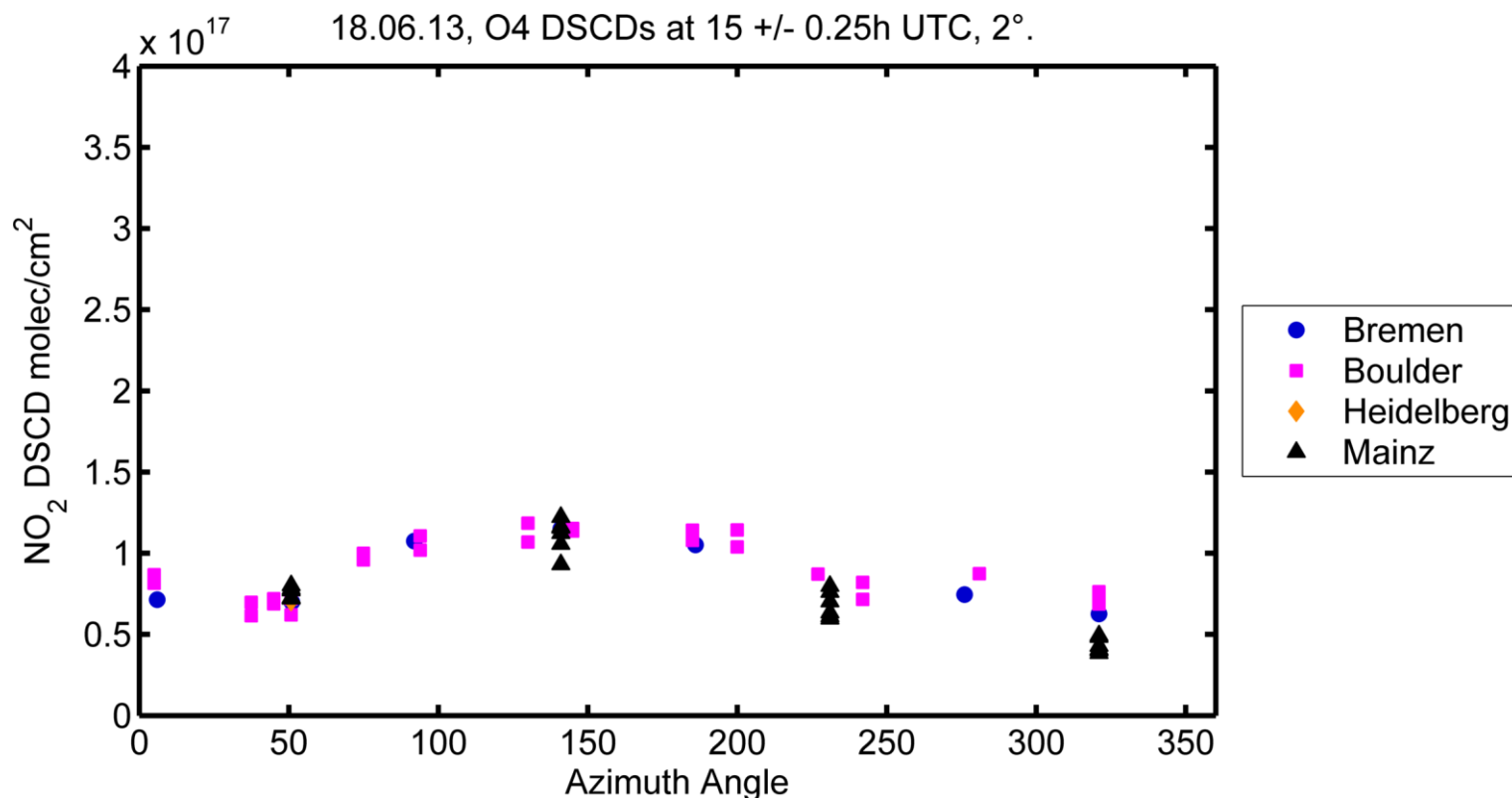
# NO<sub>2</sub>:

## All instruments, daily development



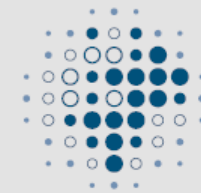
MAX-PLANCK-INSTITUT  
FÜR CHEMIE

15 UTC (+/-0.25h)



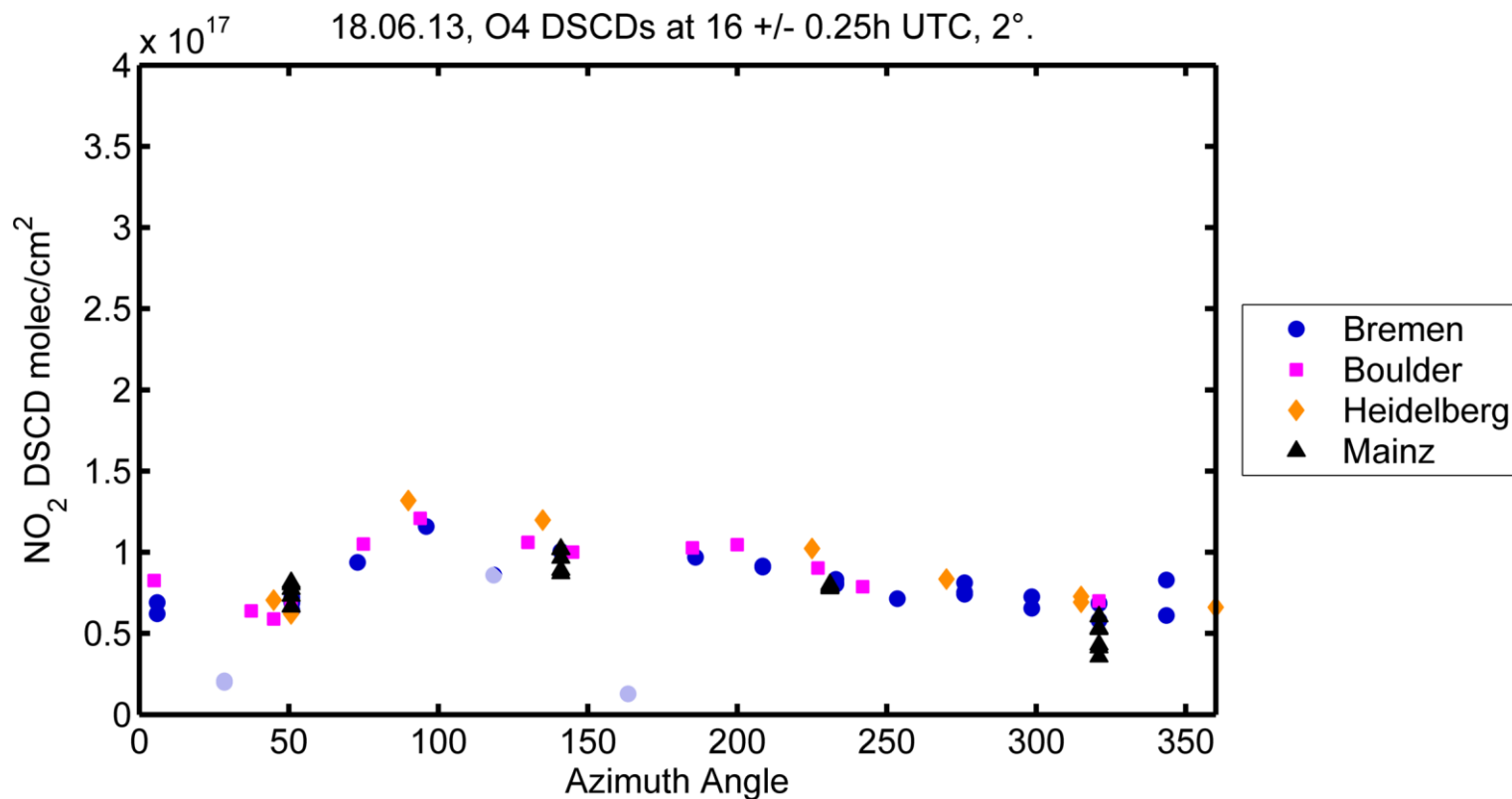
# NO<sub>2</sub>:

## All instruments, daily development



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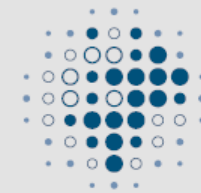
16 UTC (+/-0.25h)





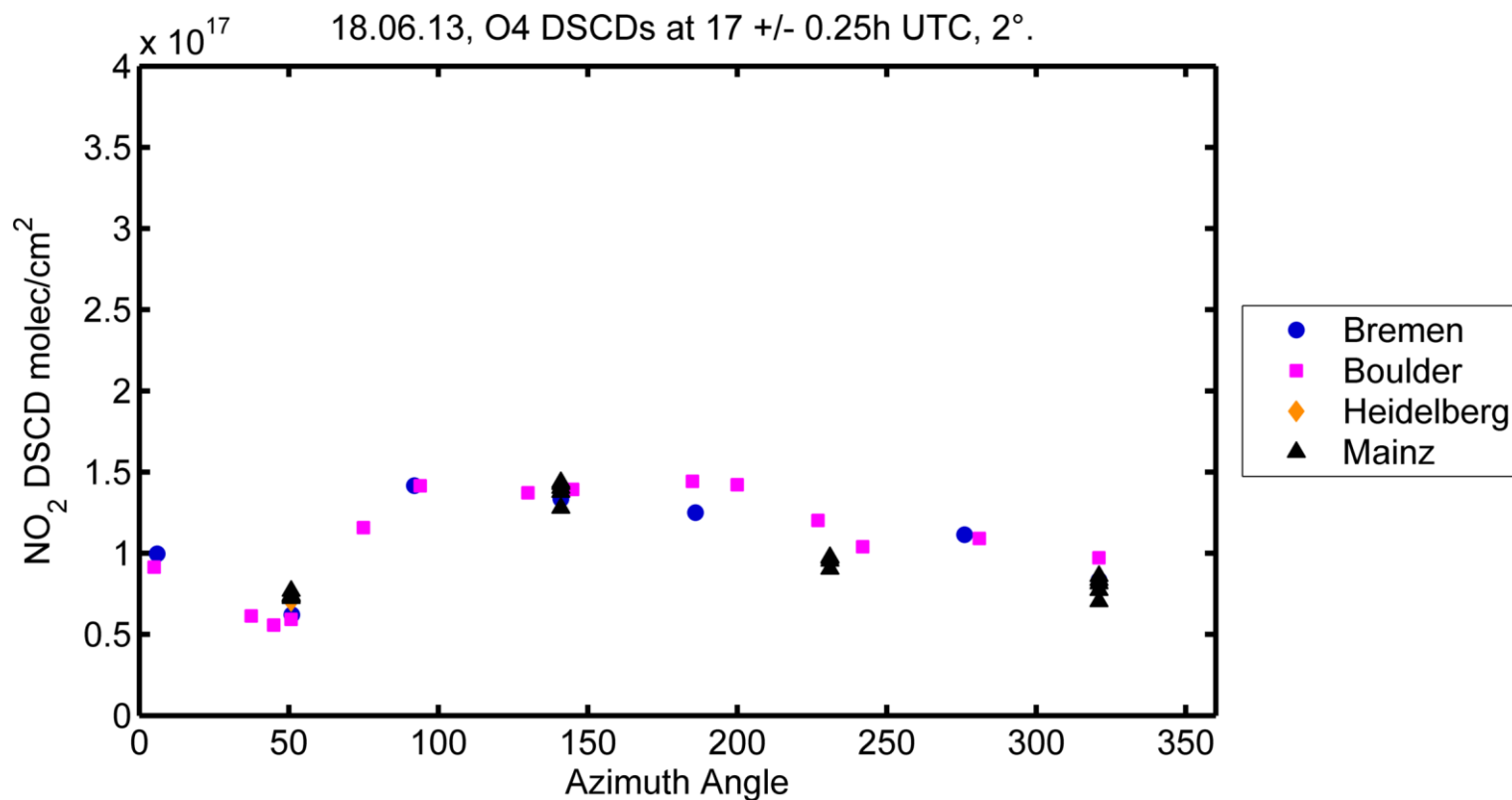
# NO<sub>2</sub>:

## All instruments, daily development



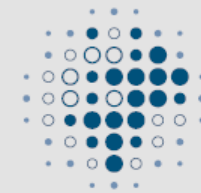
MAX-PLANCK-INSTITUT  
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17 UTC (+/-0.25h)



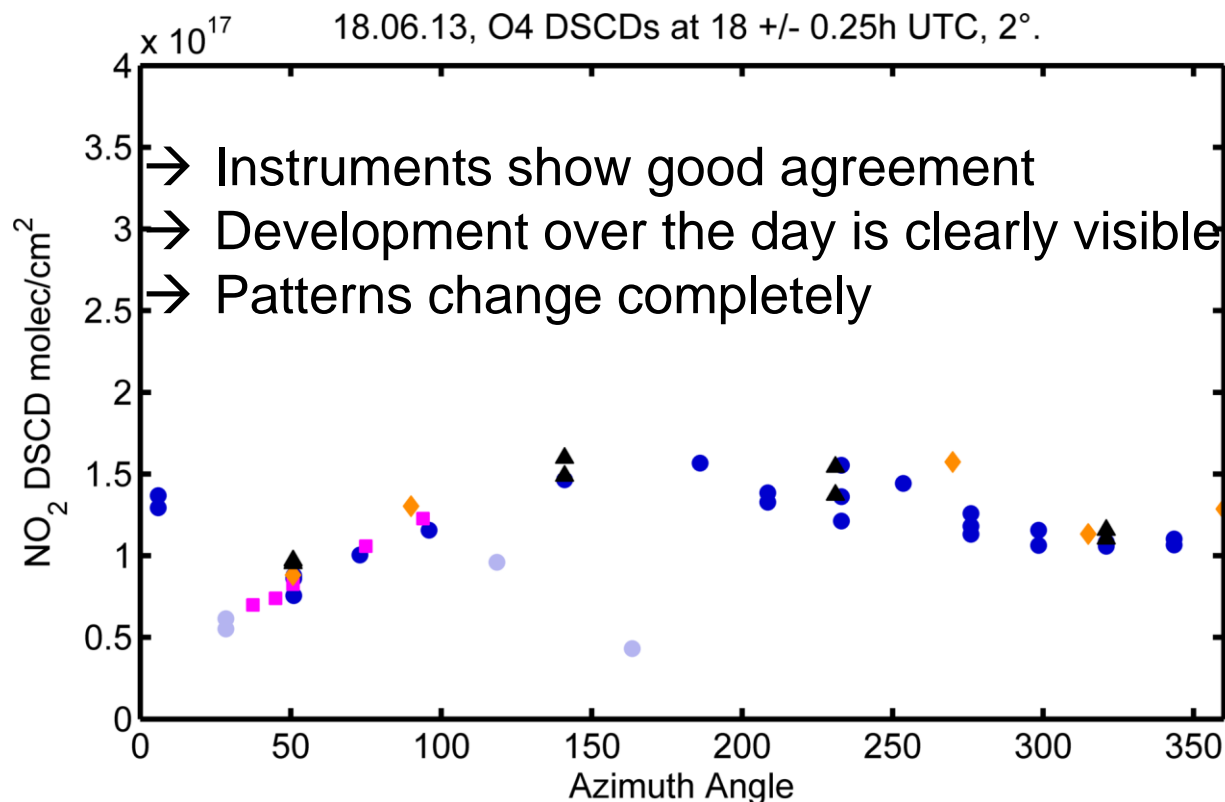
# NO<sub>2</sub>:

## All instruments, daily development



MAX-PLANCK-INSTITUT  
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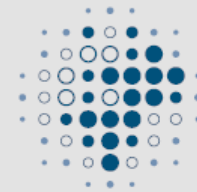
18 UTC (+/-0.25h)



MAX-PLANCK-GESELLSCHAFT

# NO<sub>2</sub>:

## Comparison to Model



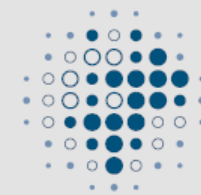
MAX-PLANCK-INSTITUT  
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- Possible causes for the variation:
  - SZA/SRAA dependence
  - Aerosols
  - Variations in NO<sub>2</sub> distribution
- RTM:
  - Aerosol layer height: 1km
  - AOD: 0.3 (mean found by Aeronet)
  - Aerosol shape: box profile
  - Trace gas shape: box profile
  - Use geometrical mean NO<sub>2</sub> VCD to convert DAMF to DSCD (AMF=SCD/VCD)

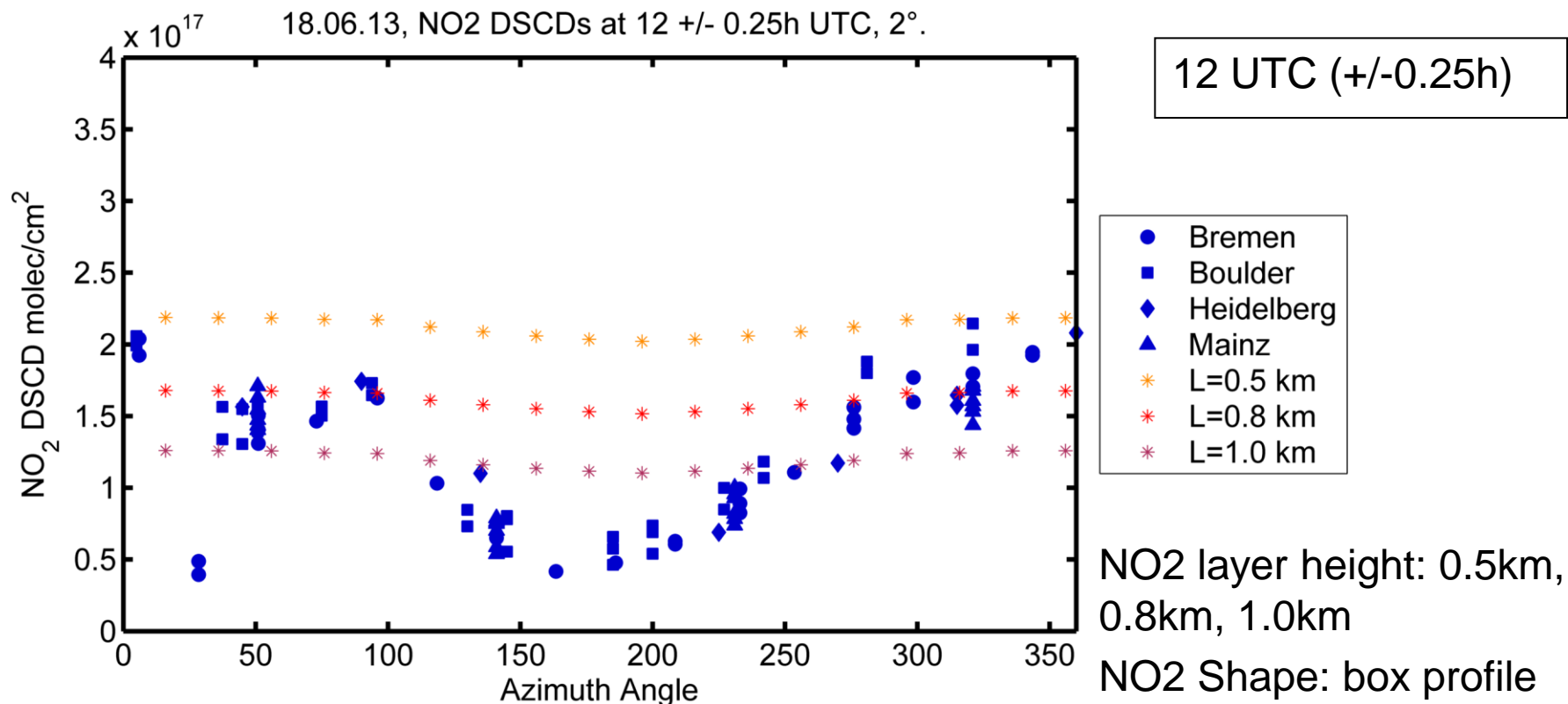


MAX-PLANCK-GESELLSCHAFT

# NO<sub>2</sub>: Comparison to Model



MAX-PLANCK-INSTITUT  
FÜR CHEMIE

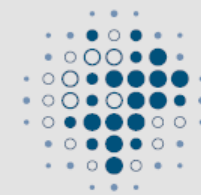


→ Variation is larger than the variation induced by differences in SZA/SRAA



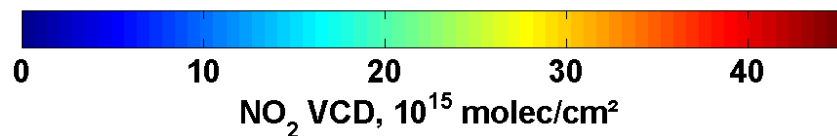
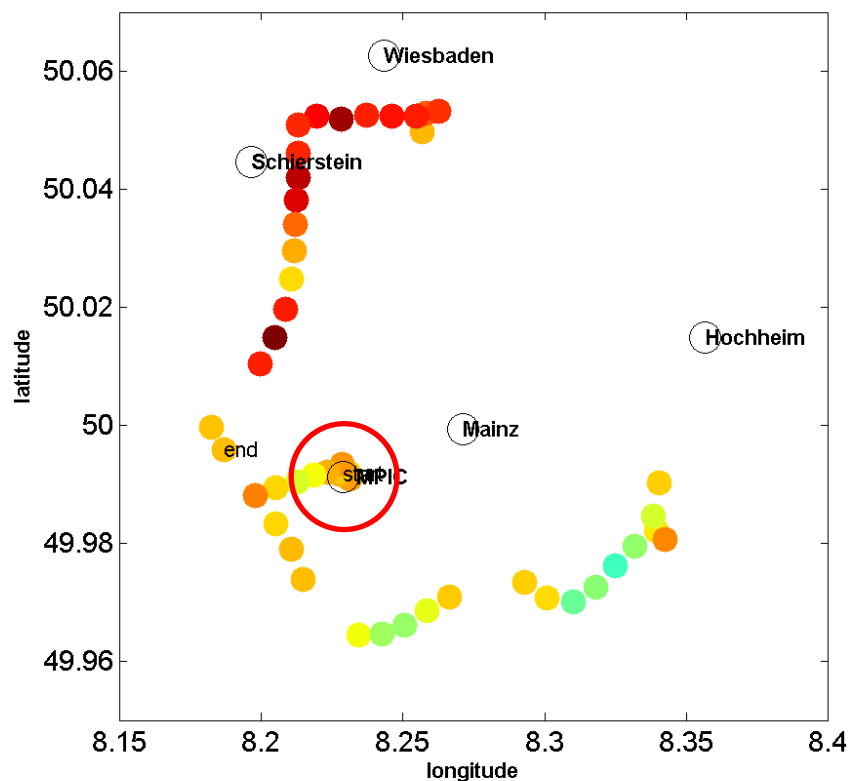
MAX-PLANCK-GESELLSCHAFT

# NO<sub>2</sub>: Comparison to Car-DOAS



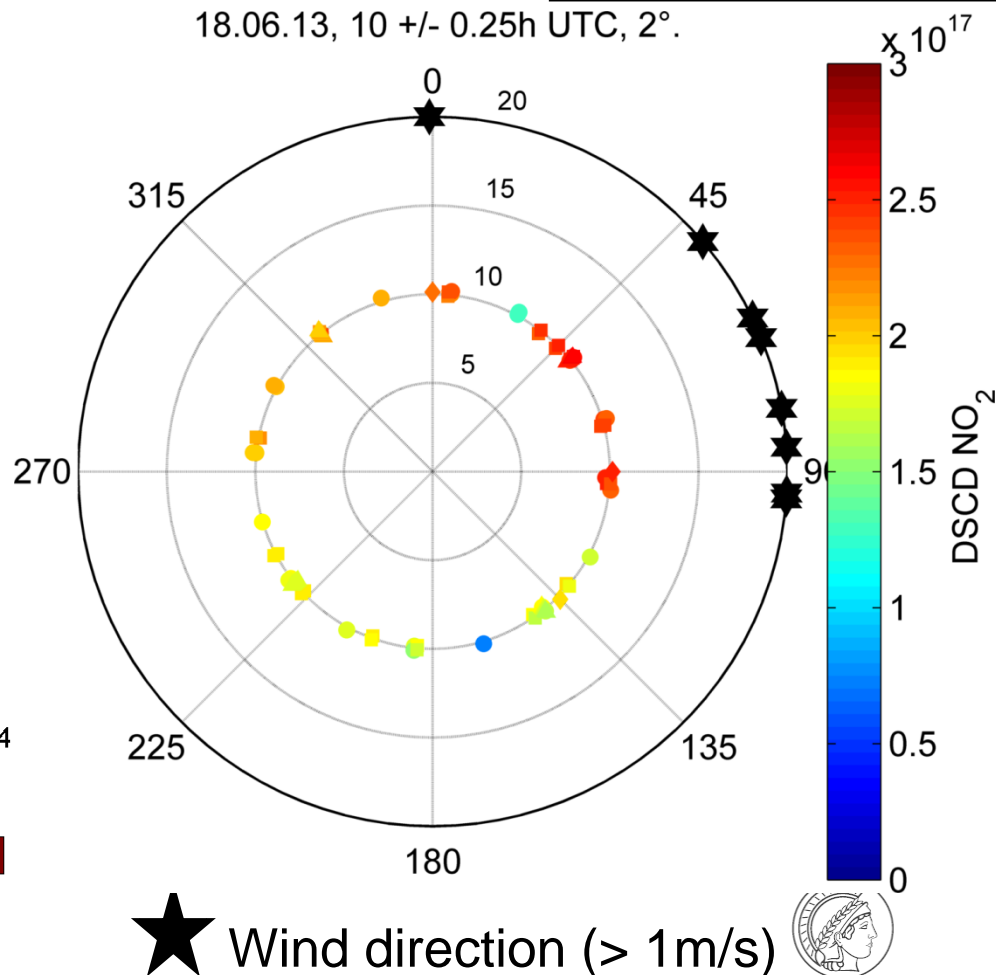
MAX-PLANCK-INSTITUT  
FÜR CHEMIE

2013.6.18 - 9:59-10:36



10 UTC (+/-0.25h)

18.06.13, 10 +/- 0.25h UTC, 2°.



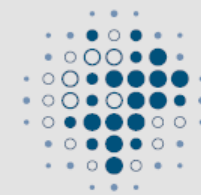
Wind direction (> 1m/s)



MAX-PLANCK-GESELLSCHAFT

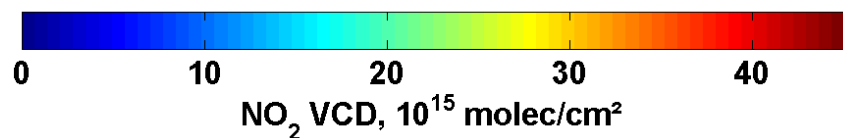
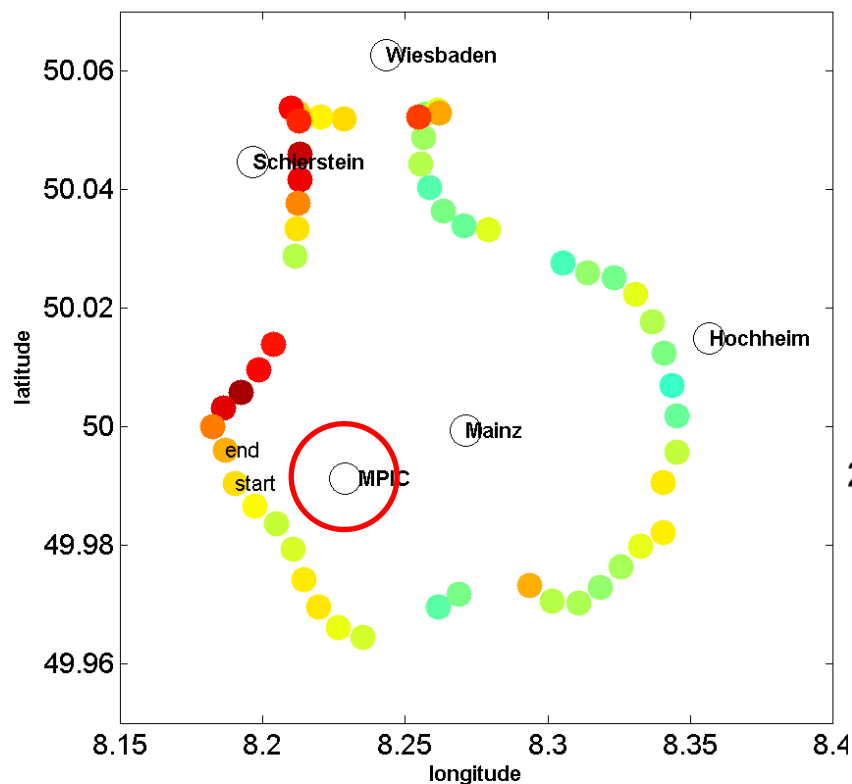


# NO<sub>2</sub>: Comparison to Car-DOAS



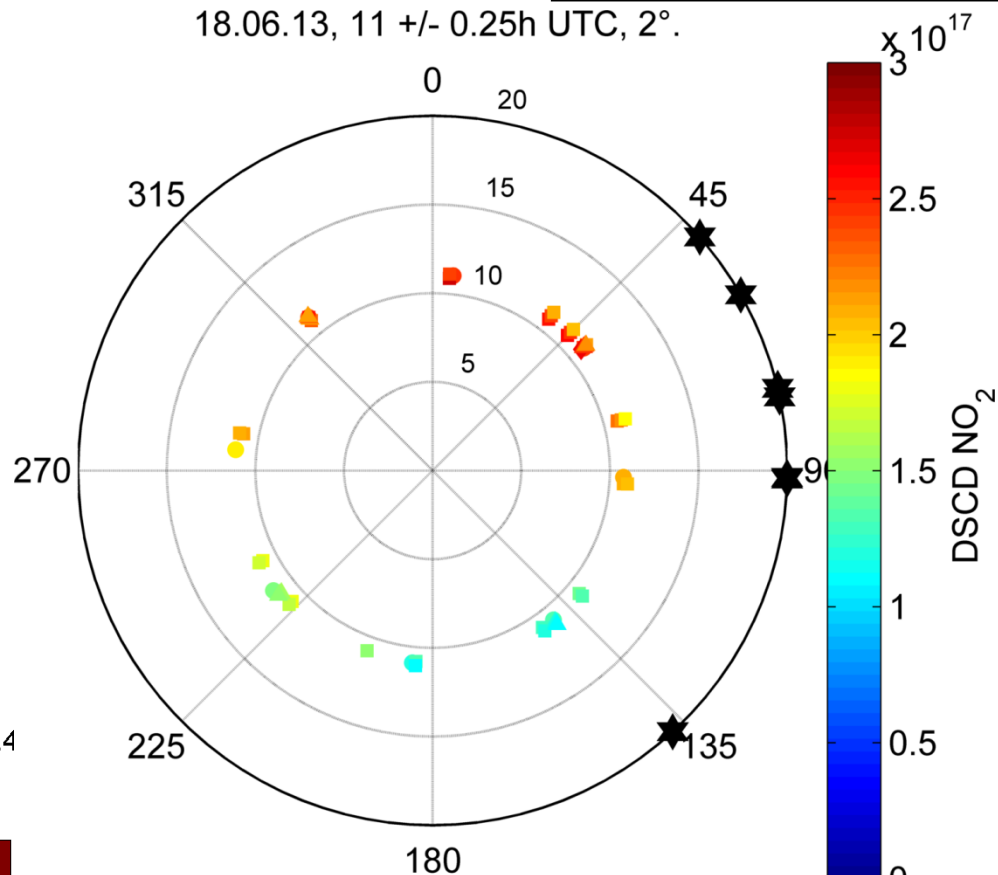
MAX-PLANCK-INSTITUT  
FÜR CHEMIE

2013.6.18 - 10:37-11:06



11 UTC (+/-0.25h)

18.06.13, 11 +/- 0.25h UTC, 2°.

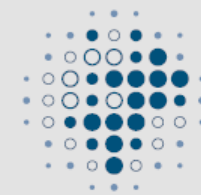


★ Wind direction (> 1m/s)



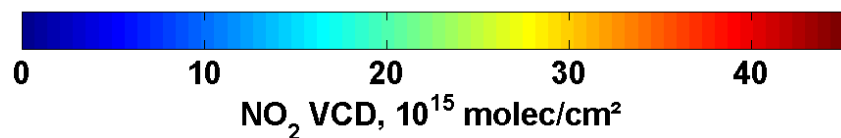
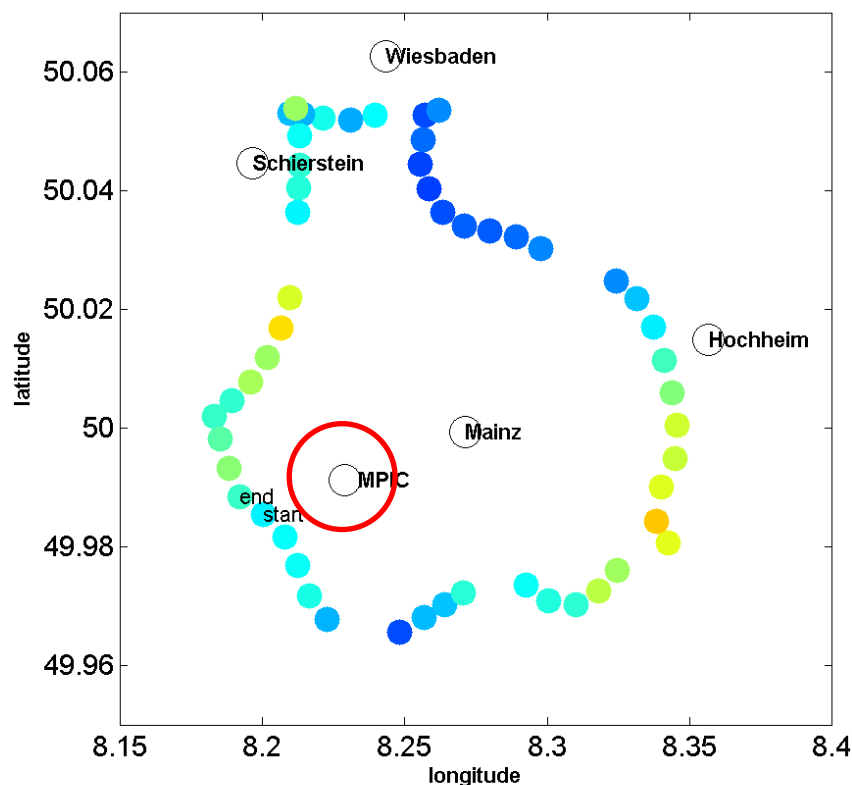
MAX-PLANCK-GESELLSCHAFT

# NO<sub>2</sub>: Comparison to Car-DOAS



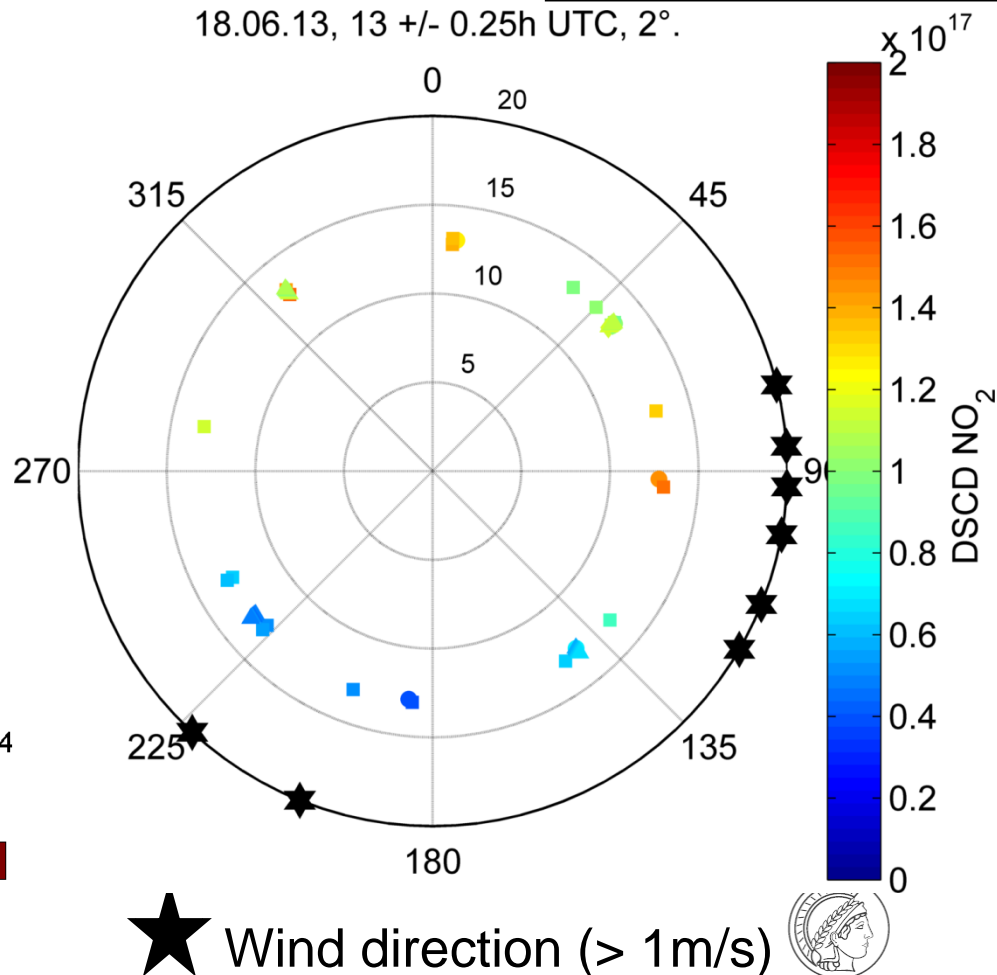
MAX-PLANCK-INSTITUT  
FÜR CHEMIE

2013.6.18 - 13:06-13:35



13 UTC (+/-0.25h)

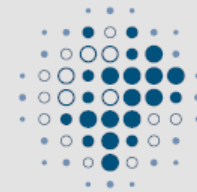
18.06.13, 13 +/- 0.25h UTC, 2°.



Wind direction (> 1m/s)



MAX-PLANCK-GESELLSCHAFT



## Conclusion & Outlook

- Good agreement between the instruments for  $O_4$  and  $NO_2$  DSCDs
- The variation in the DSCDs of  $O_4$  are mostly caused by dependence on SZA and SRAA
- The variation in the DSCDs of  $NO_2$  are much larger than the variation induced by variation in SRAA
- First comparisons to Car-DOAS show good agreements
- Compare the whole data set
- Include other groups
- Do profile inversions



A photograph of a sunset over a city skyline. The sun is a bright, glowing orb in the center of the frame, casting a warm orange and yellow light across the sky. The sky is filled with wispy clouds, some of which are illuminated by the sun's light. In the foreground, the silhouettes of city buildings and a construction crane are visible against the darkening sky. The overall mood is peaceful and contemplative.

Thank you!

Thanks to all MAD-CAT participants!