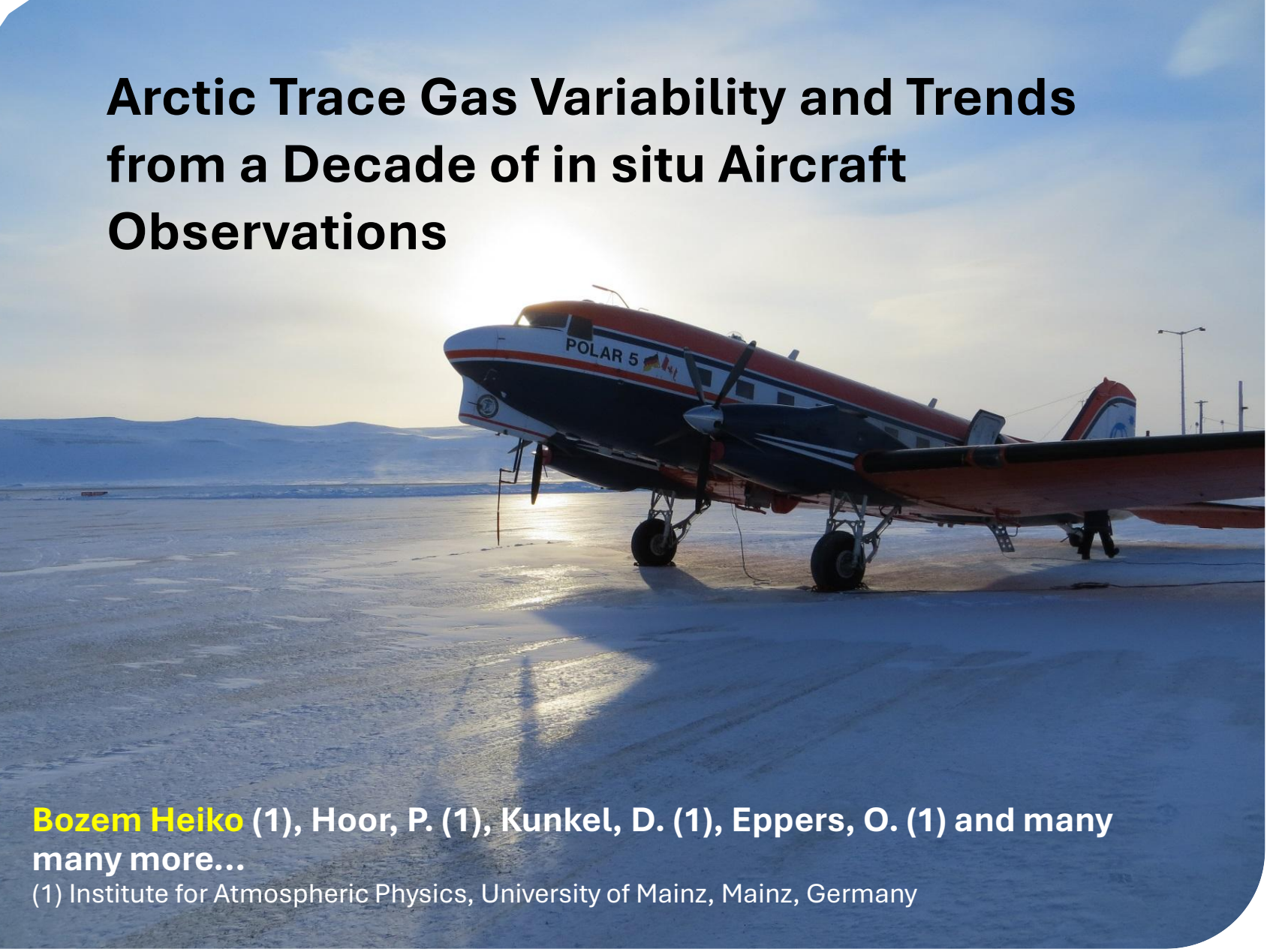
Arctic Trace Gas Variability and Trends from a Decade of in situ Aircraft Observations



Sapporo, 1972

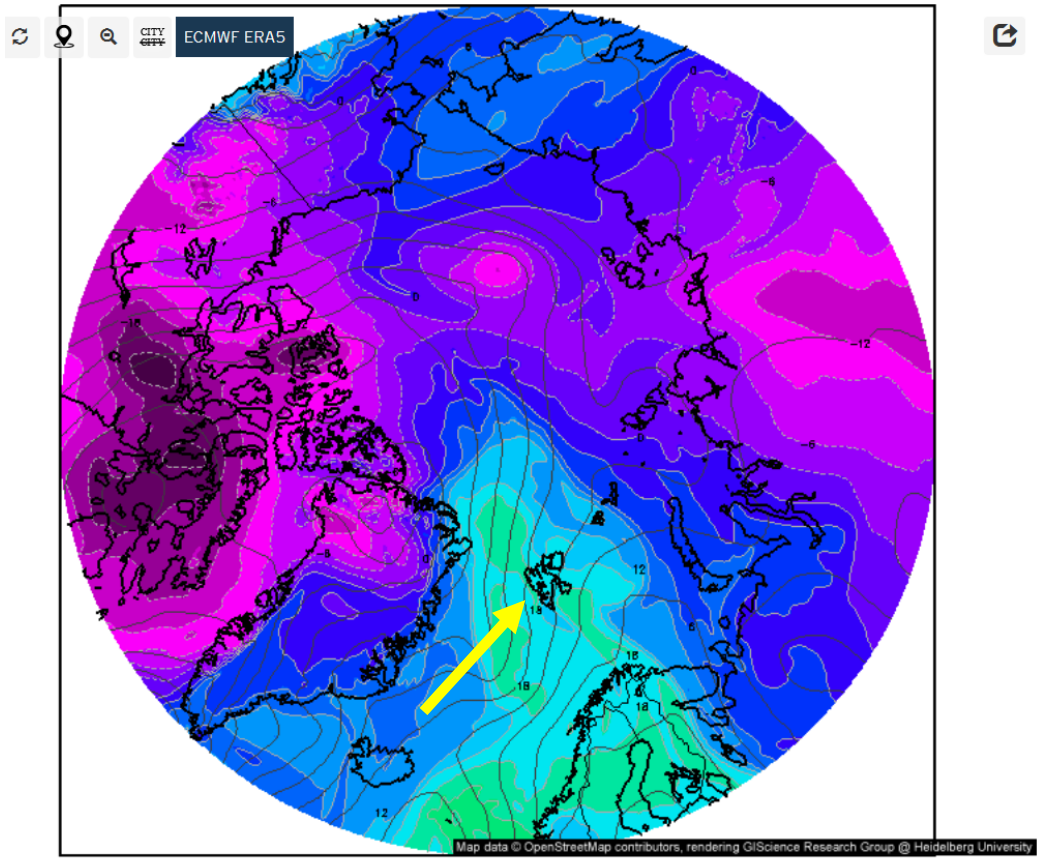
Bozem Heiko (1), Hoor, P. (1), Kunkel, D. (1), Eppers, O. (1) and many many more...
(1) Institute for Atmospheric Physics, University of Mainz, Mainz, Germany

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

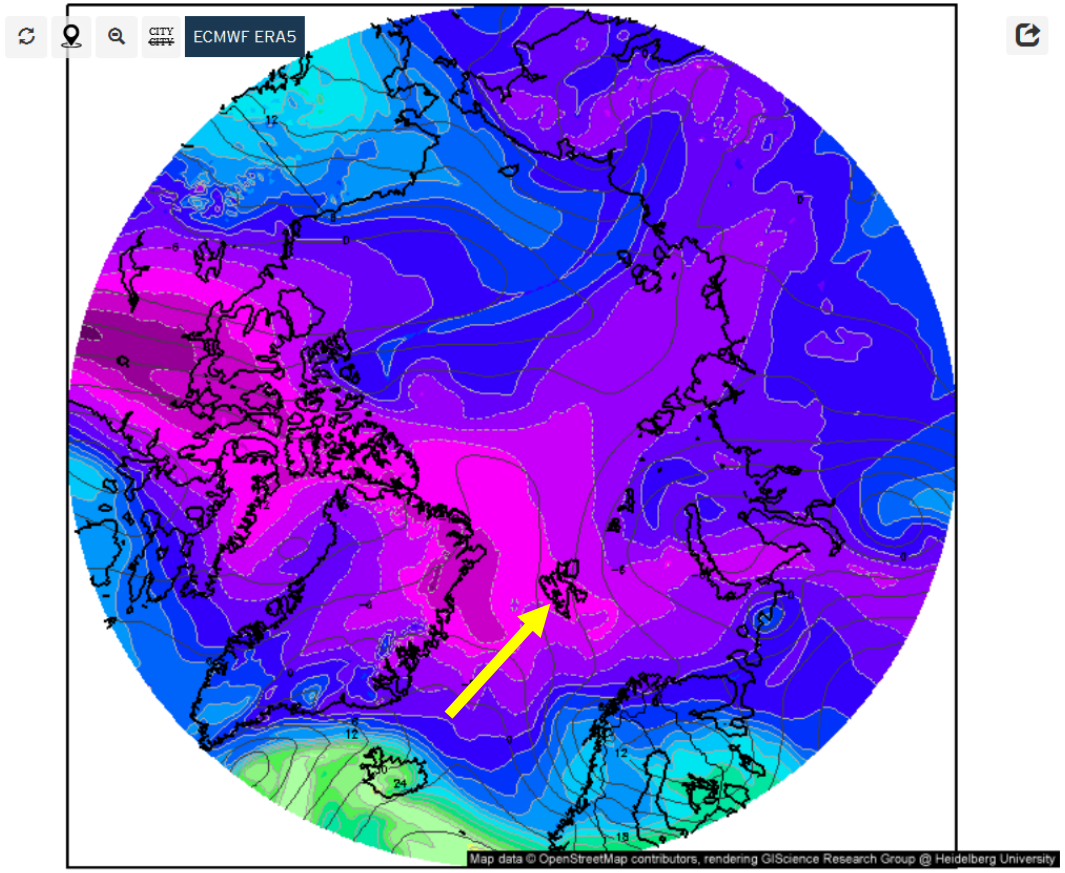
JG|U

Equivalent potential temperature during HALO AC3 at two different times

13.3.2022 - WAI

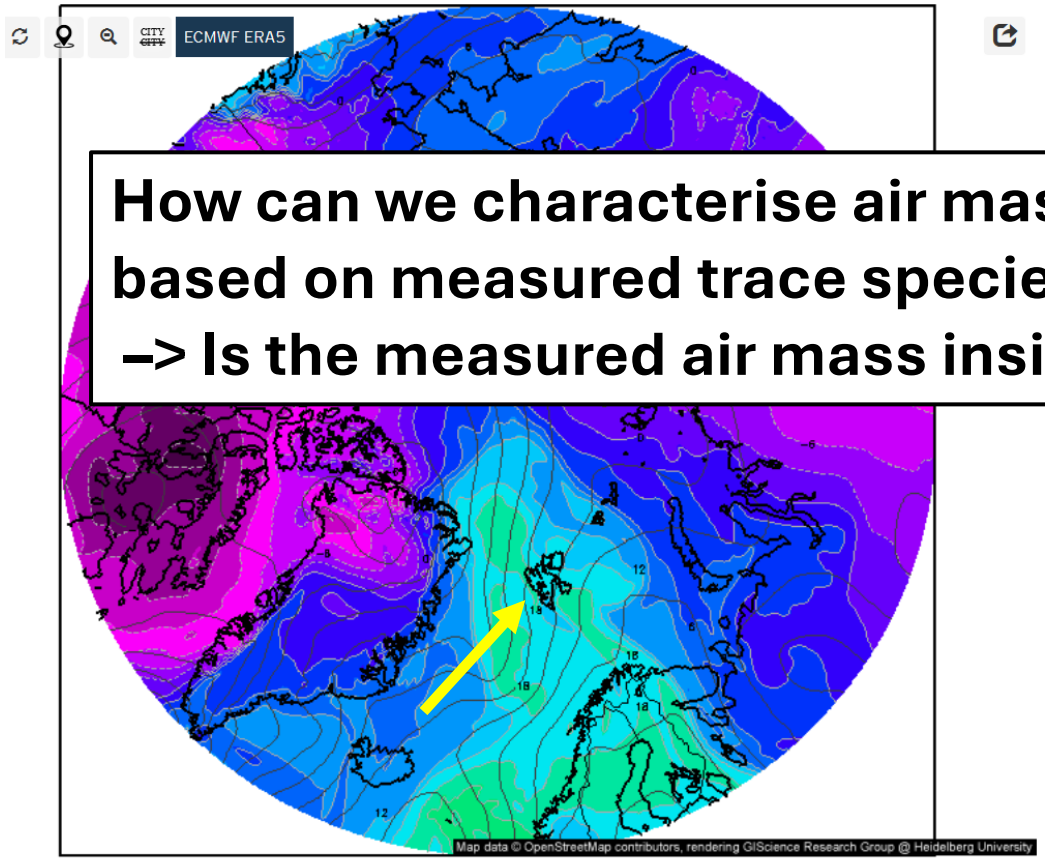


25.3.2022 - CAO

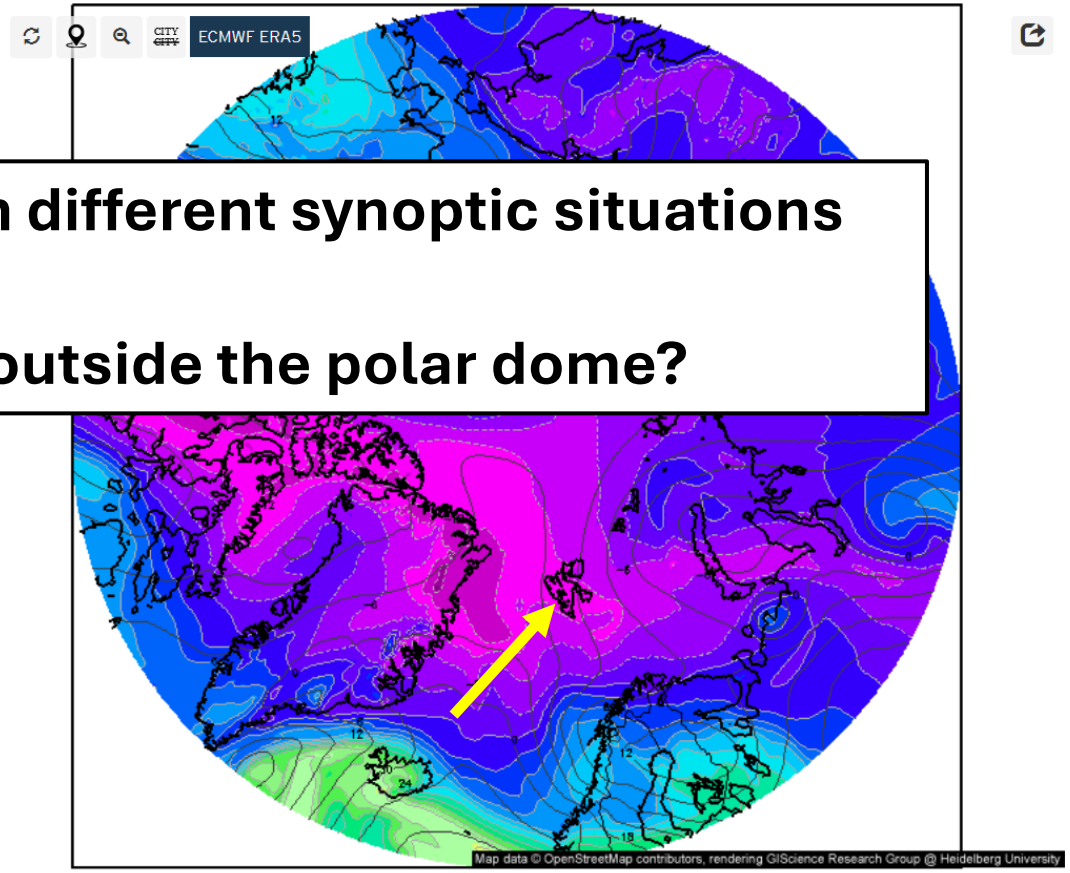


Equivalent potential temperature during HALO AC3 at two different times

13.3.2022 - WAI



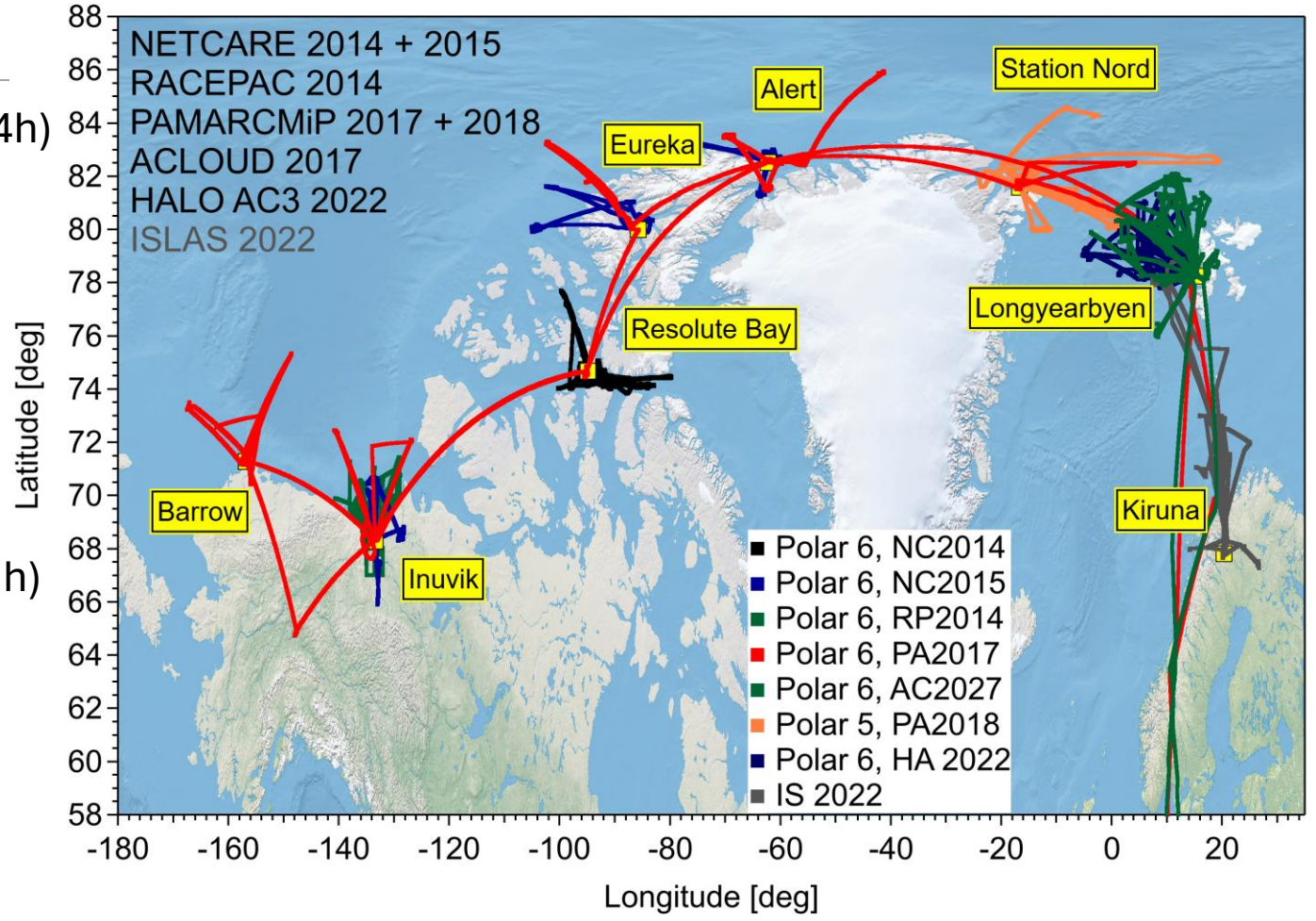
25.3.2022 - CAO



How can we characterise air masses in different synoptic situations based on measured trace species?
–> Is the measured air mass inside or outside the polar dome?

Data base

- **RACEPAC 2014** -> Arctic early summer (16 flights, 44h) 2014/04 – 2014/05
- **NETCARE 2014** -> Arctic summer (11 flights, 45 h) 2014/07
- **NETCARE 2015** -> Arctic spring (14 flights, 48 h) 2015/04
- **PAMARCMIP 2017** -> Arctic spring (26 flights, 98 h) 2017/04
- **ACLOUD 2017** -> Arctic early summer, (19 flights, 81 h) 2017/05 – 2017/06
- **PAMARCMIP 2018** – Arctic spring (14 flights, 75 h) 2018/03 – 2018/04
- **HALO AC3 2022** – Arctic Spring (13 Flights, 64 h) 2022/03 – 2022/04
- **ISLAS 2022** – Arctic Spring (9 Flights, 44 h) 2022/03 – 2022/04



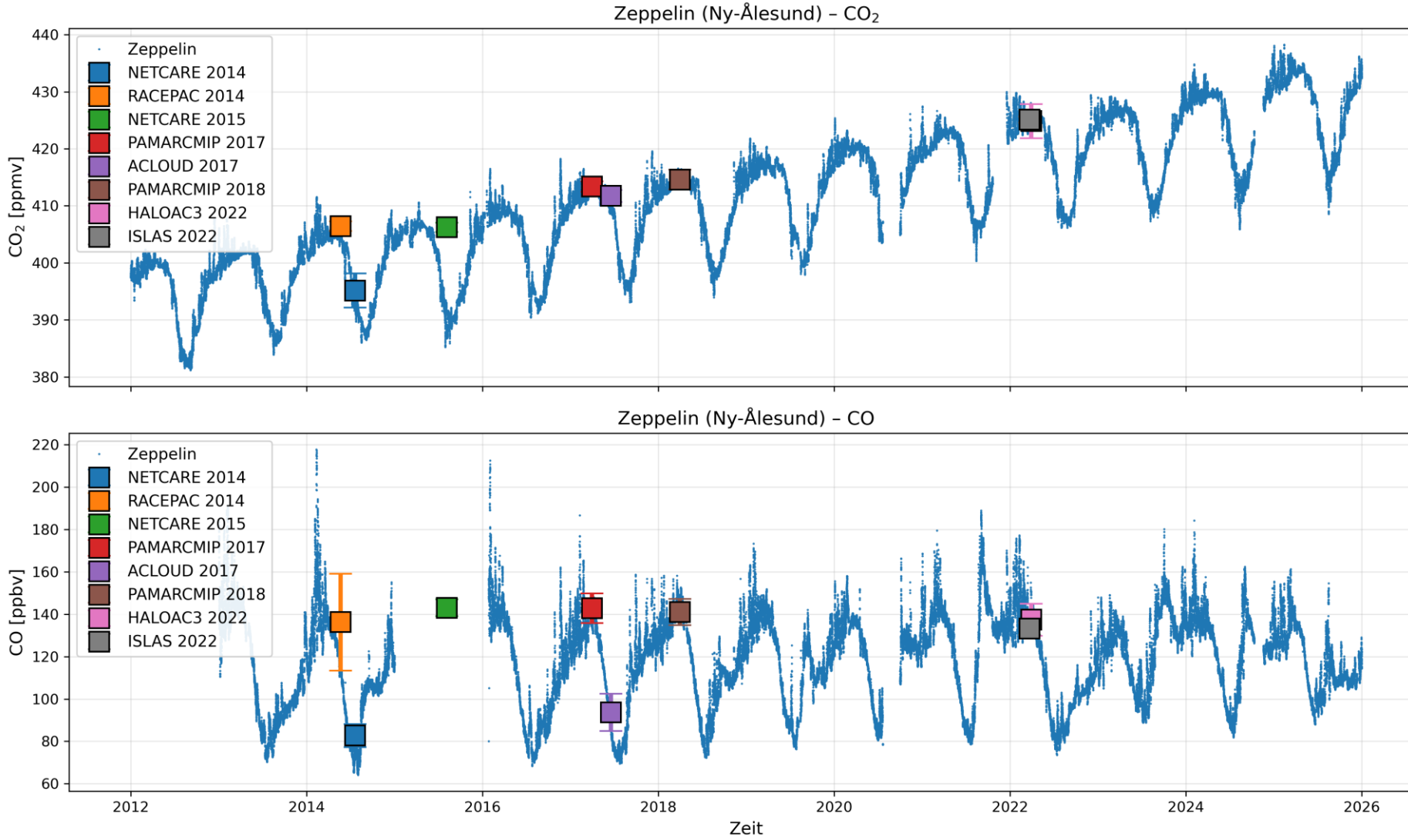
⇒113 flights, 455 flight hours

(almost no instrument failures)

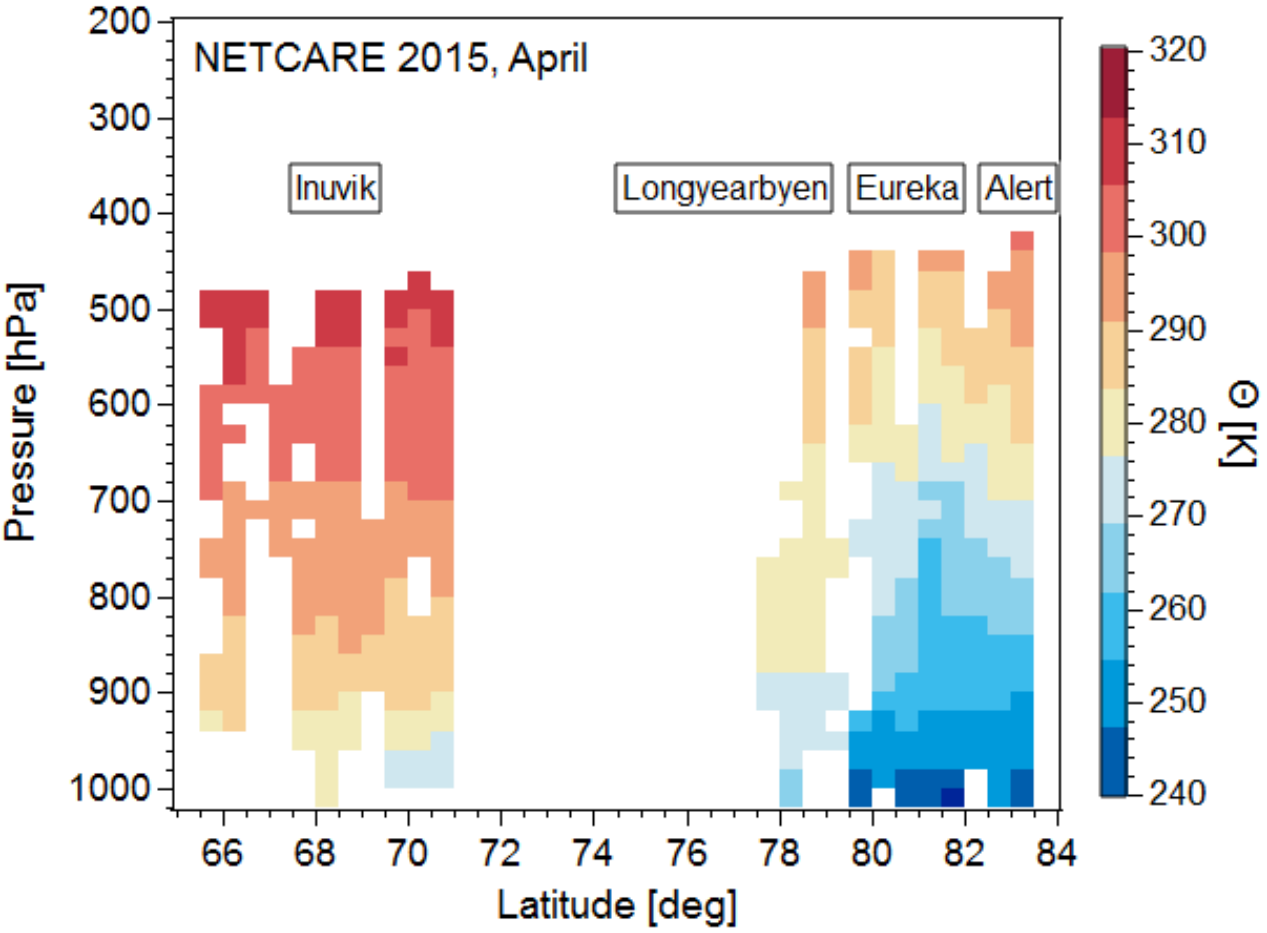
- Instrumentation for aerosol, trace gas and cloud droplet measurements

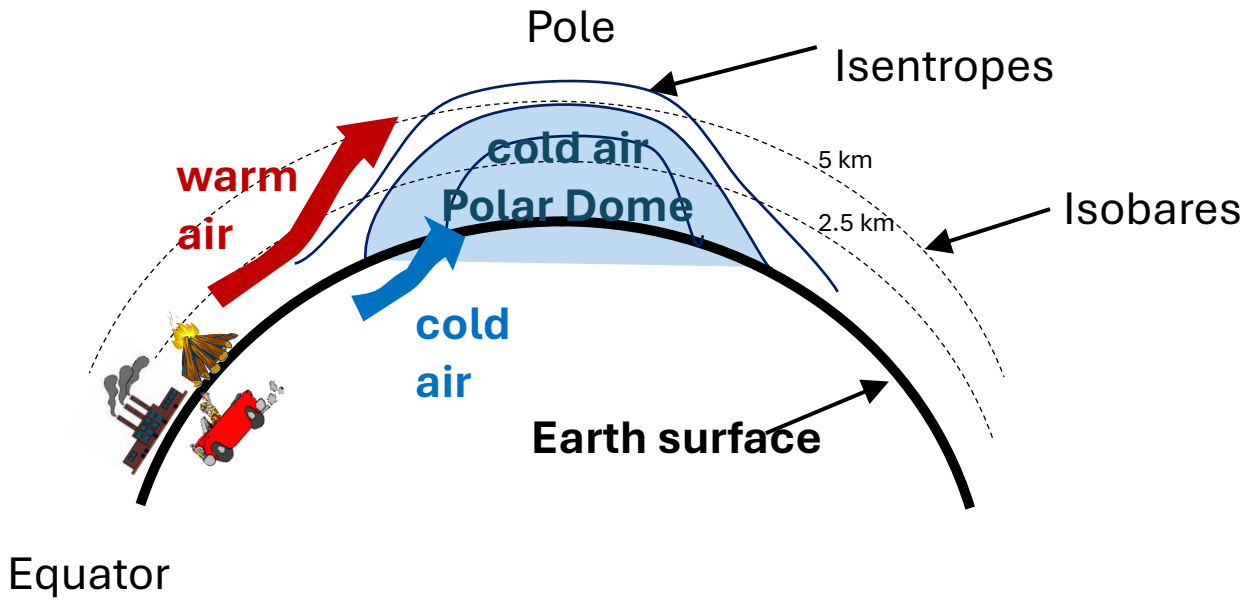
Comparison to ground based measurements (Zeppelin mountain)

- Zeppelin shows a seasonal cycle for both species, CO and CO_2
- Measurements of the lowest 500 m of the airborne data compare very well to the ground station data

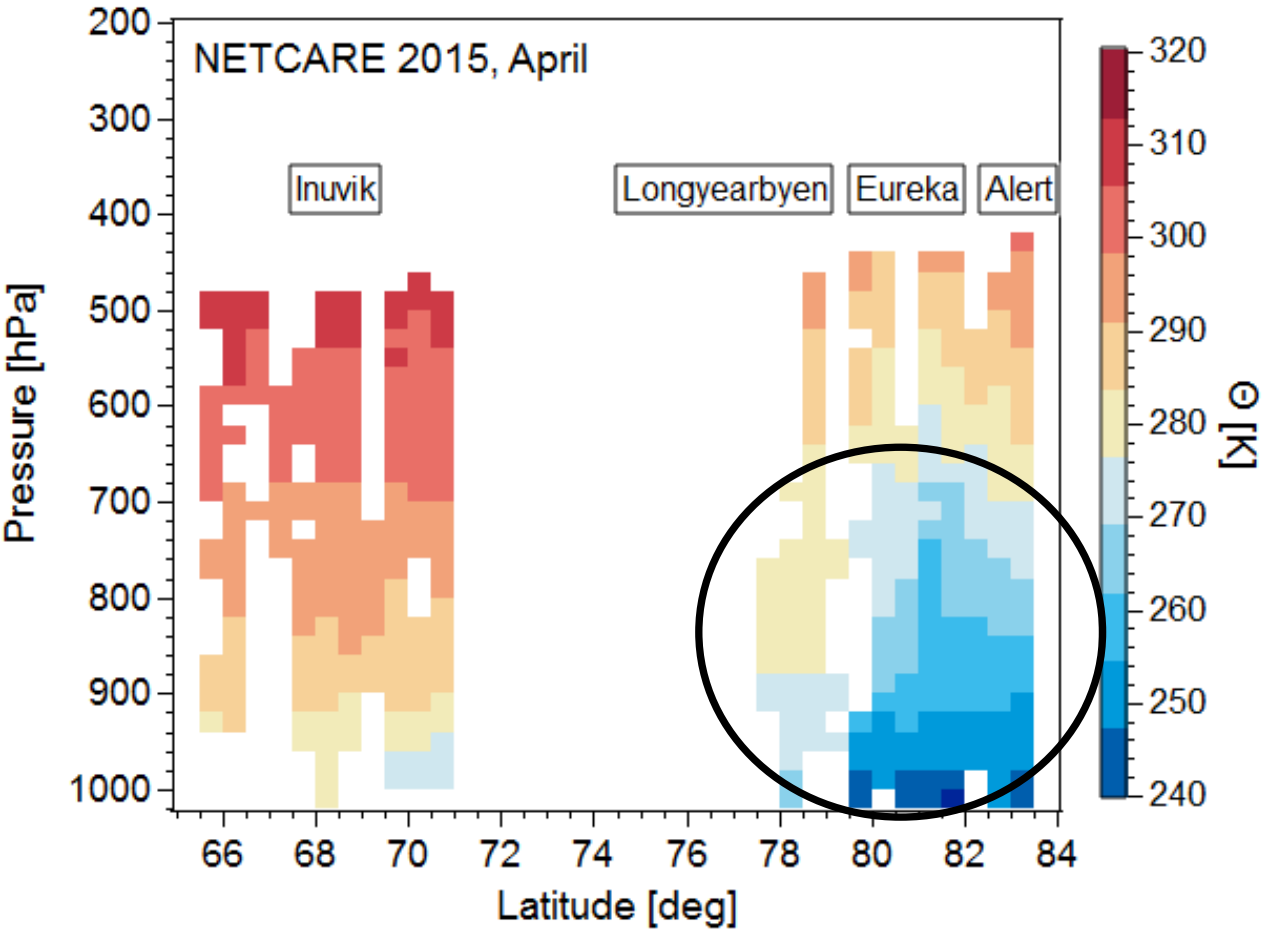


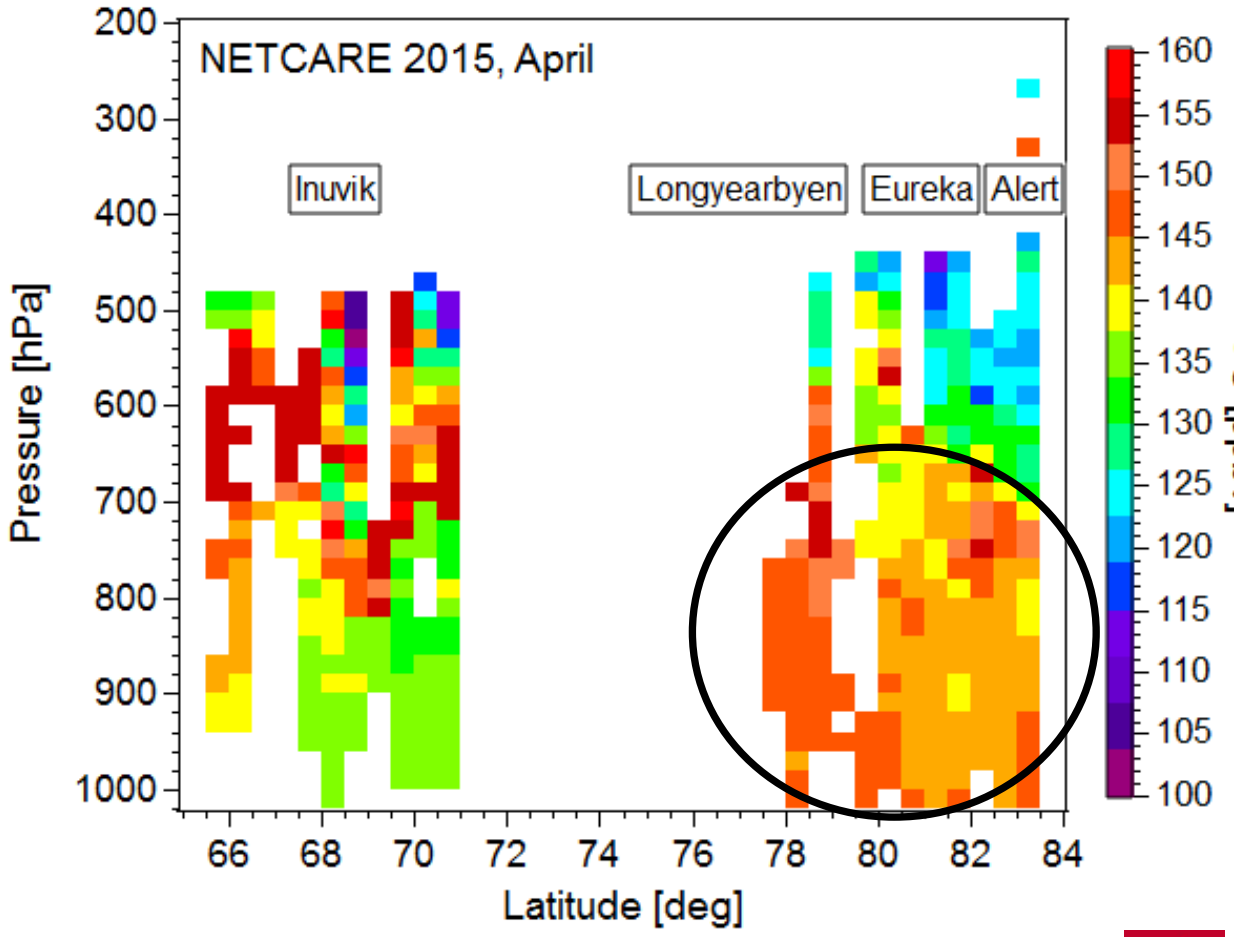
Potential temperature and CO distribution for NETCARE 2015





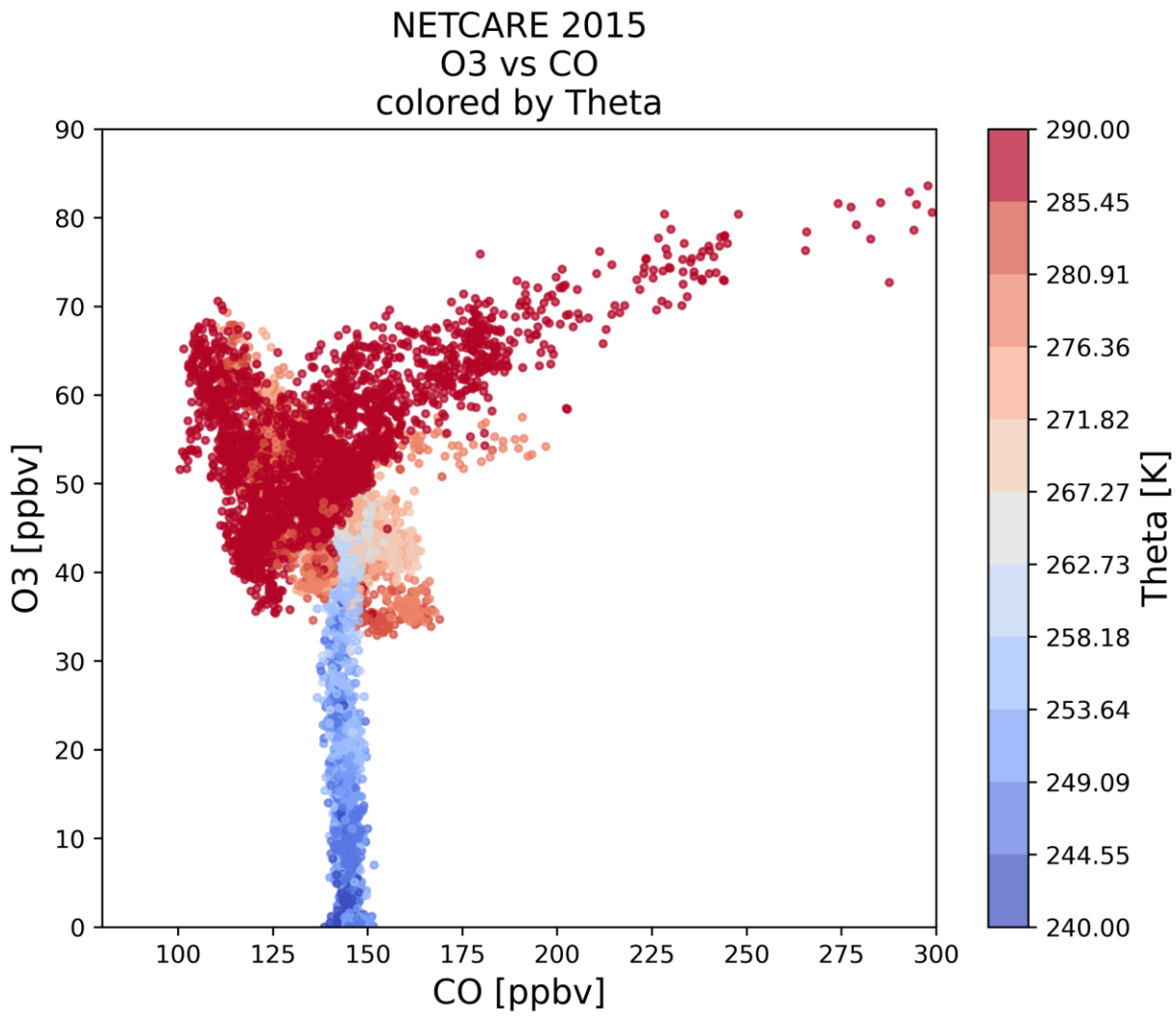
Potential temperature and CO distribution for NETCARE 2015





Correlation analysis

O_3-CO-correlation – The figure skating plot



Correlation analysis

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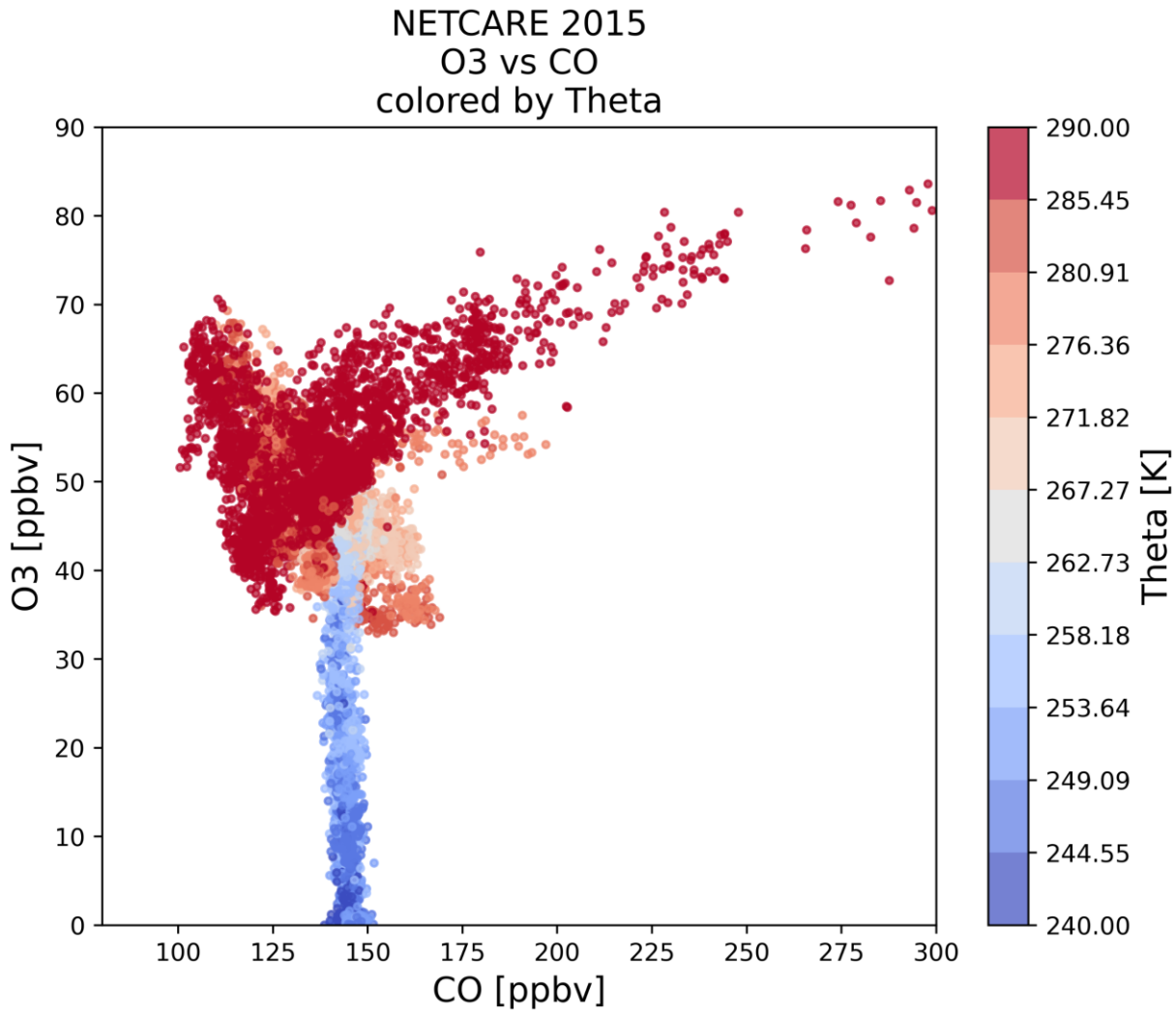
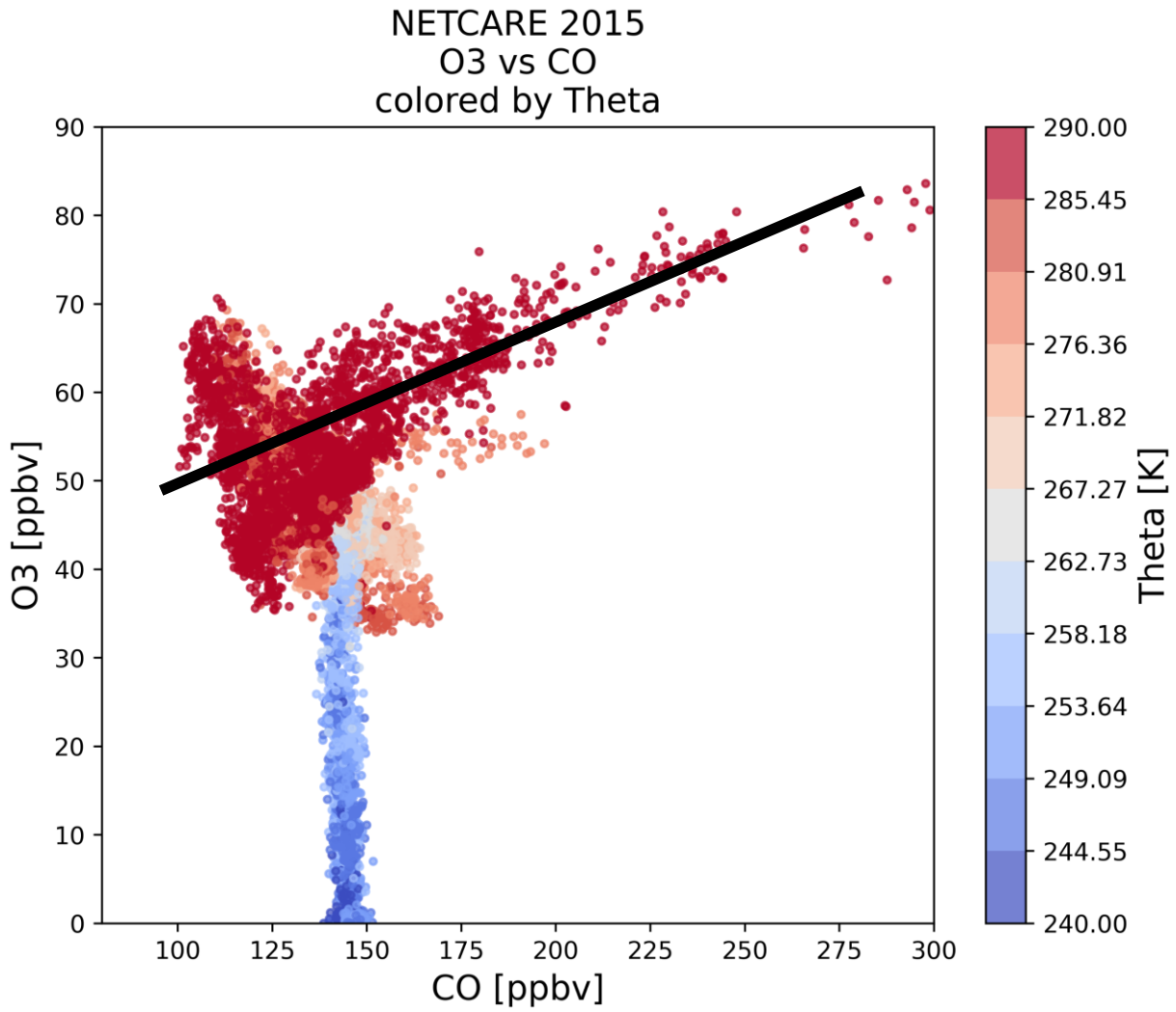
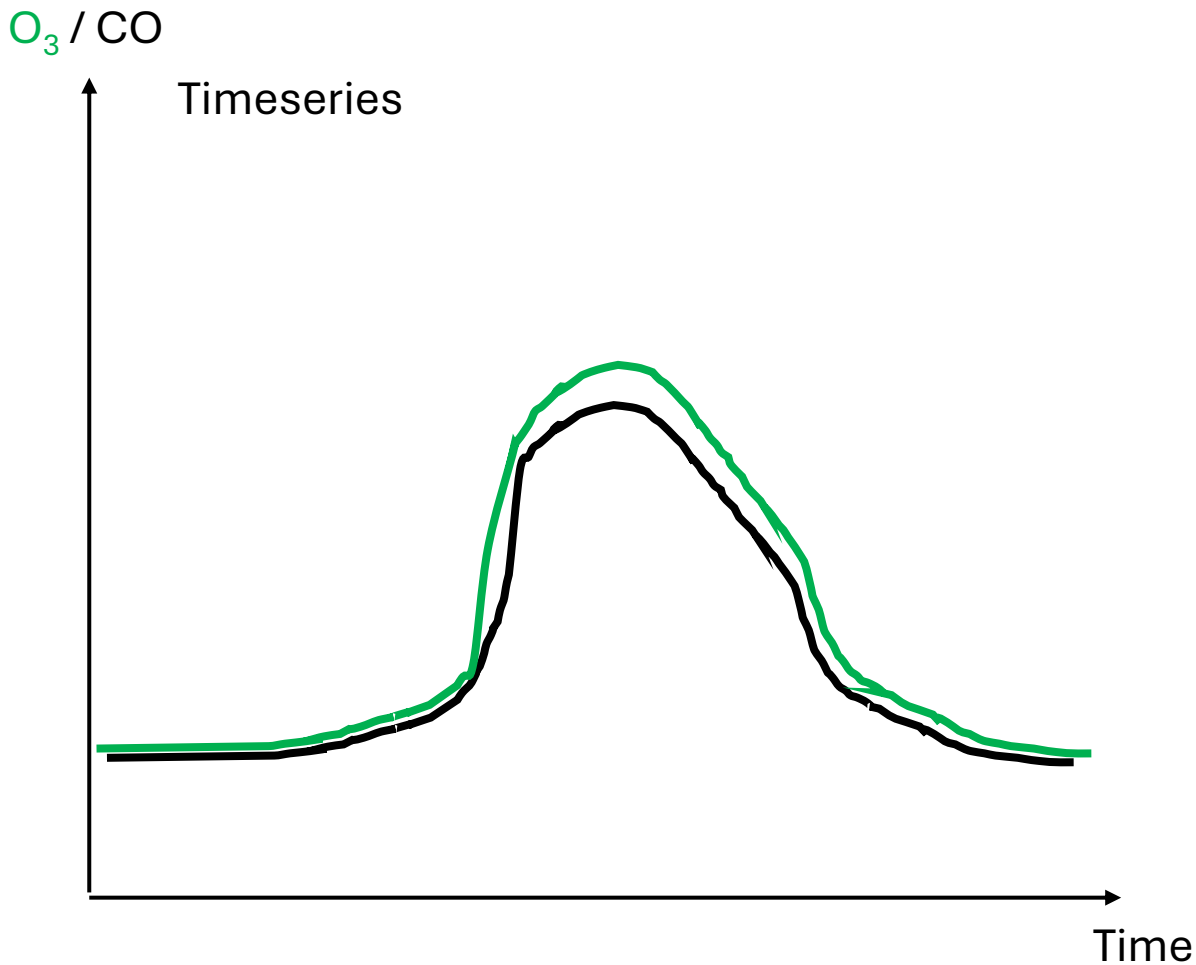


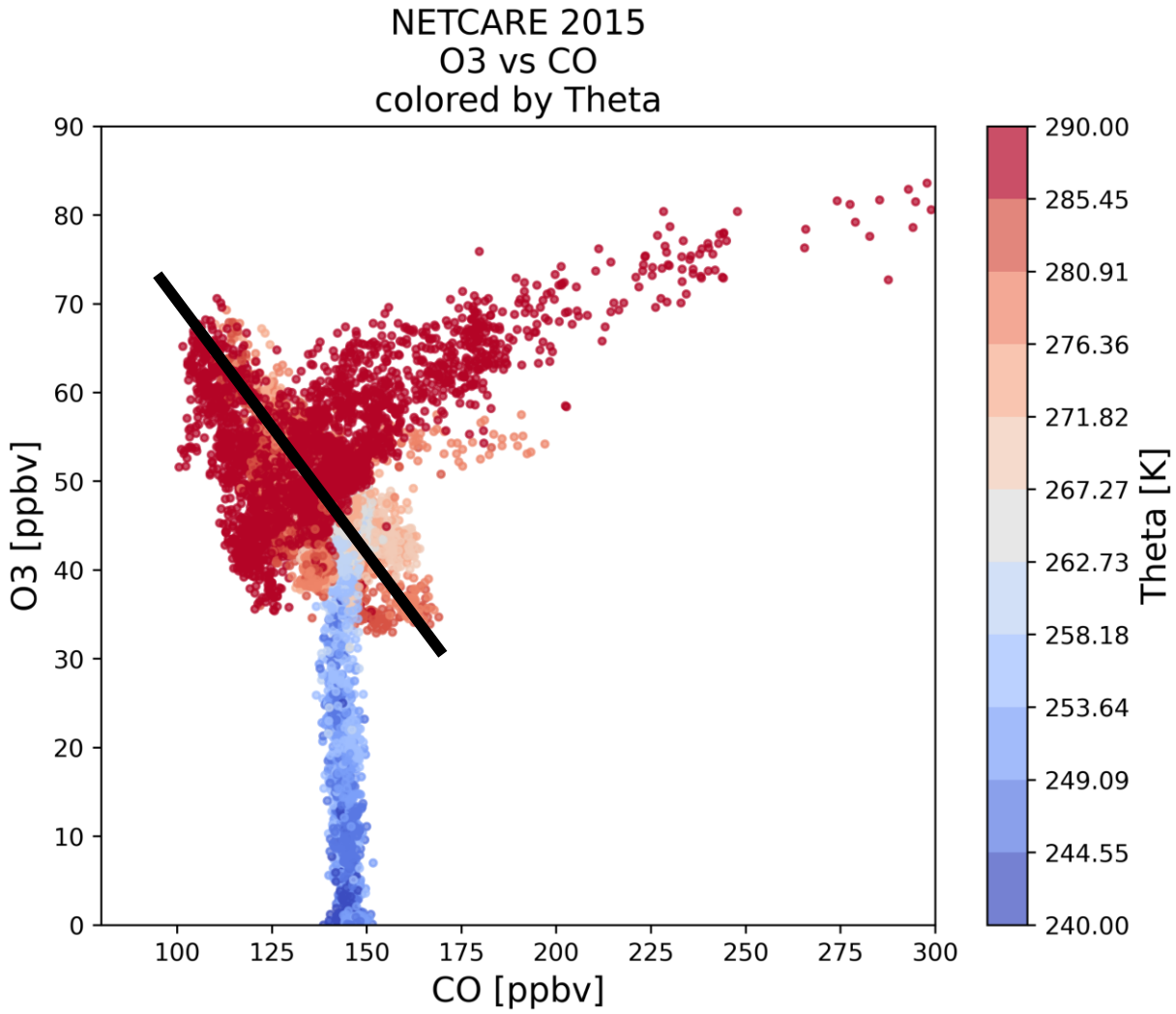
O_3-CO-correlation – photochemical production in photochemically active periode

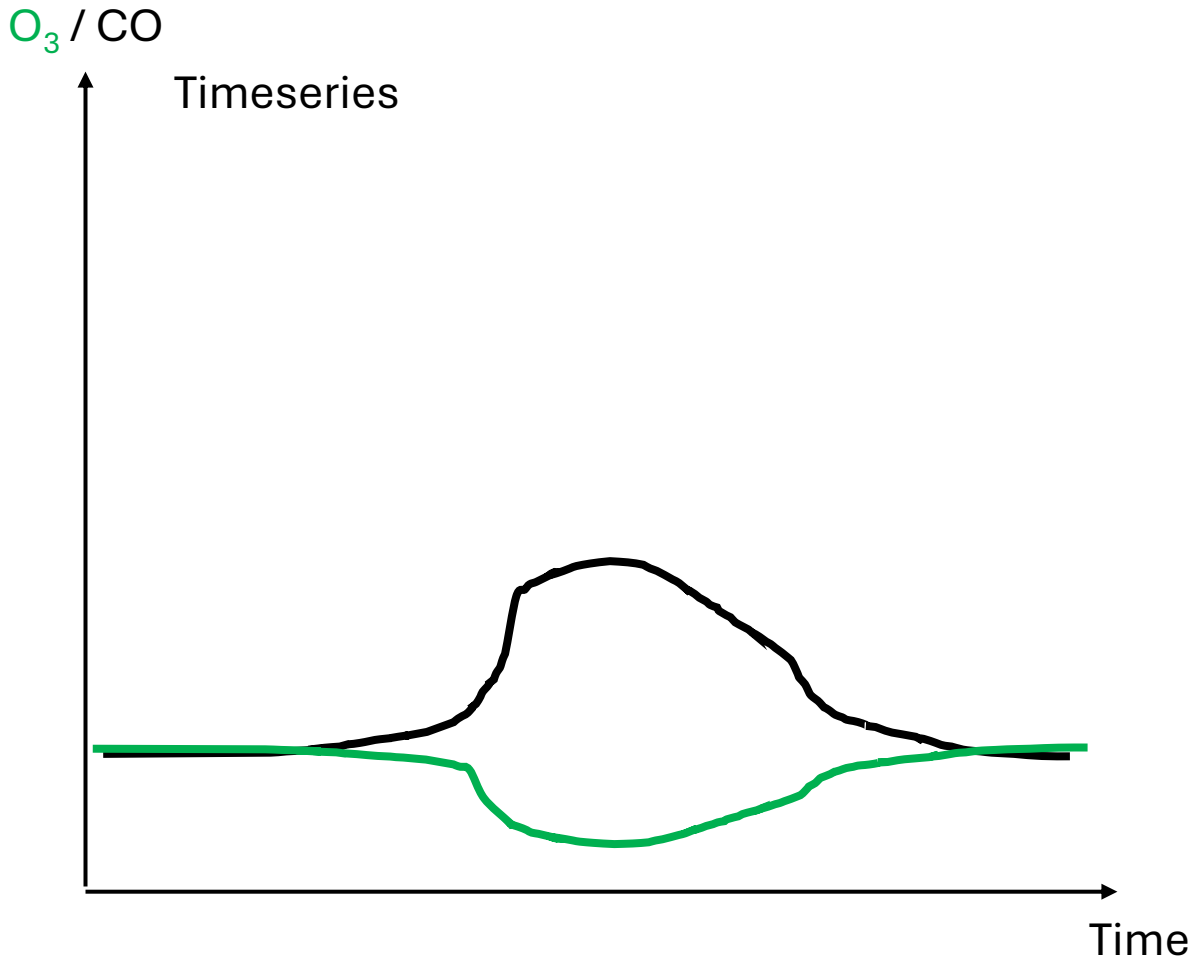




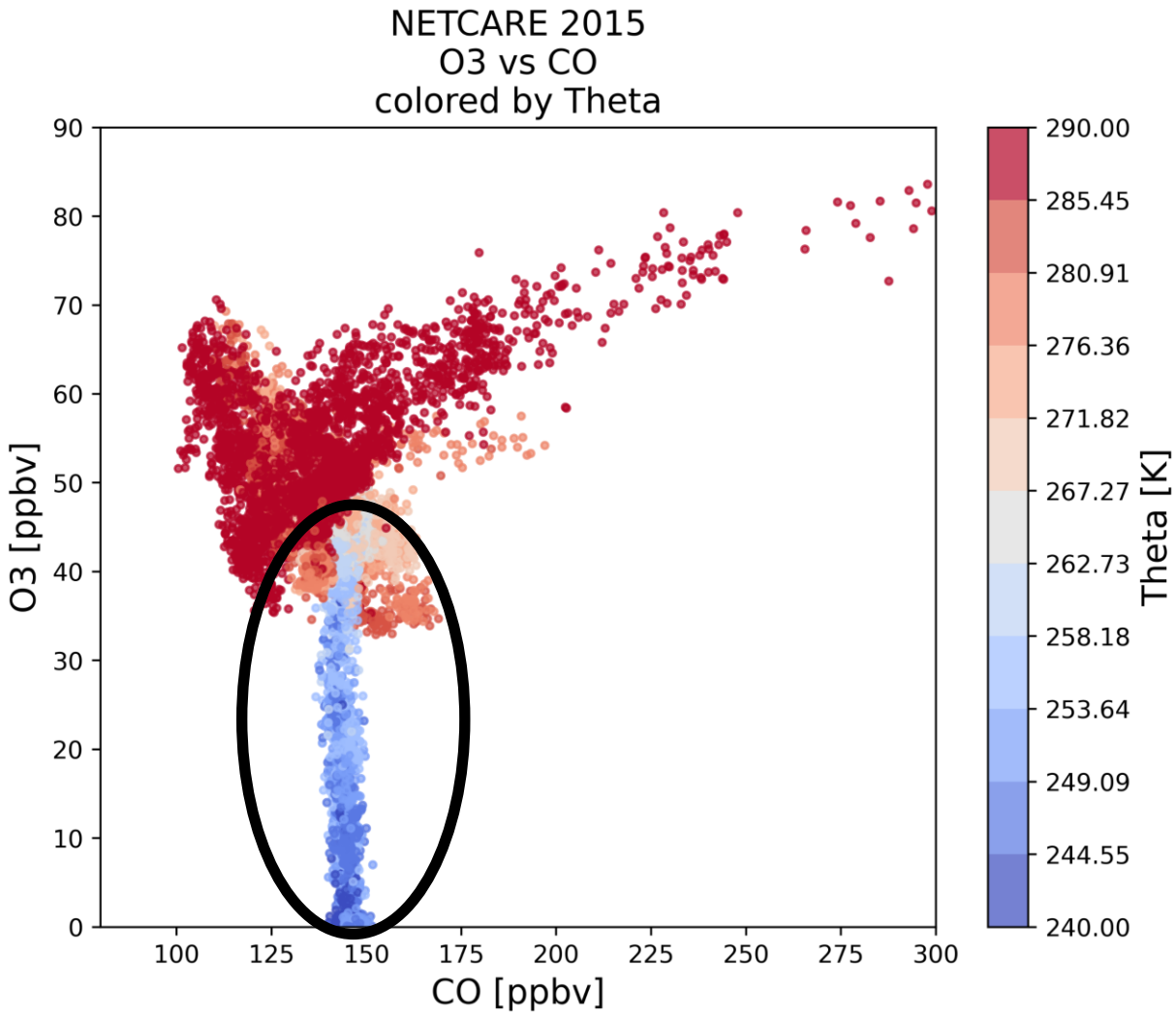
Correlation analysis

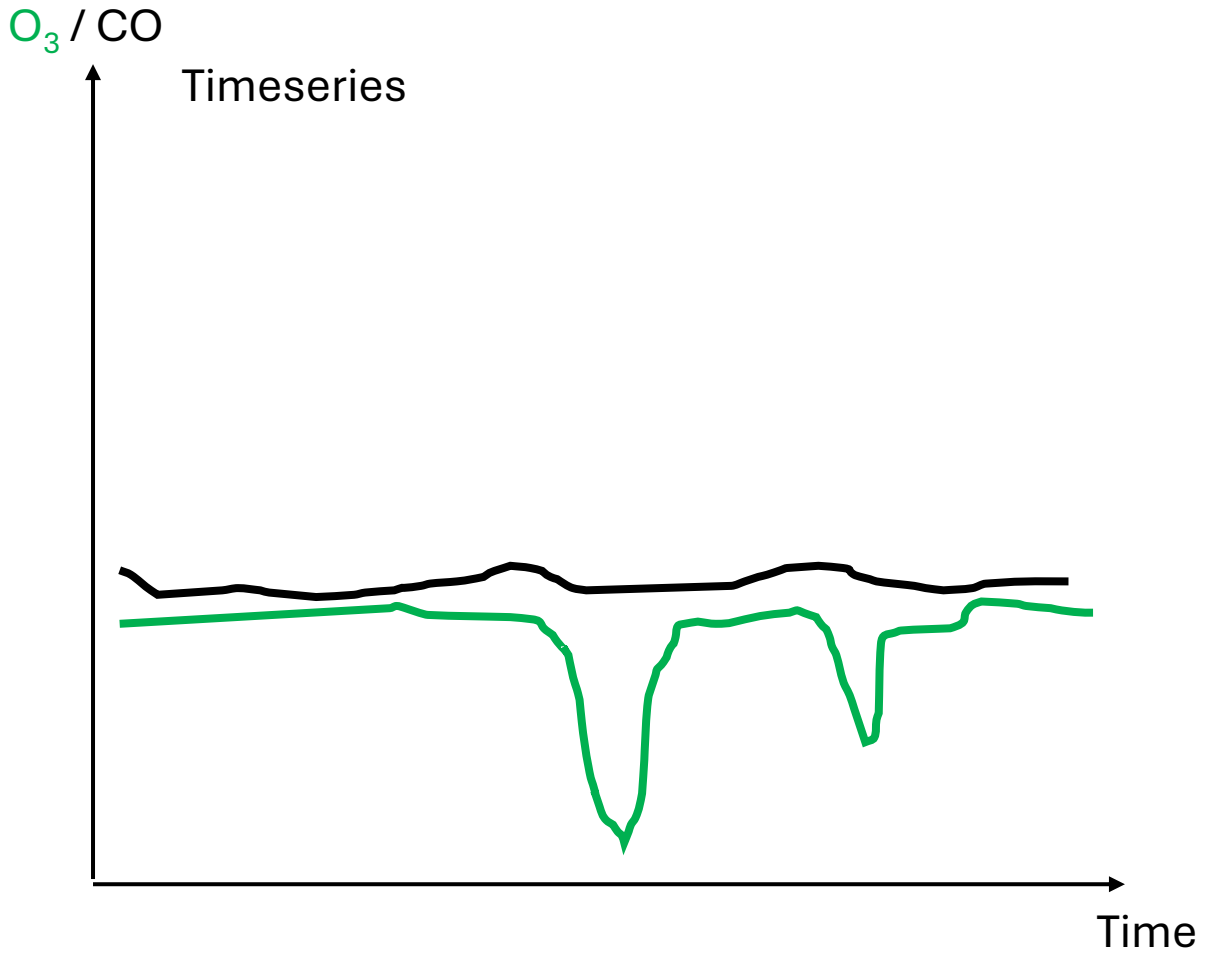
O_3-CO-correlation – removal of ozone by reaction with anthropogenic pollution in photochemically not active periode





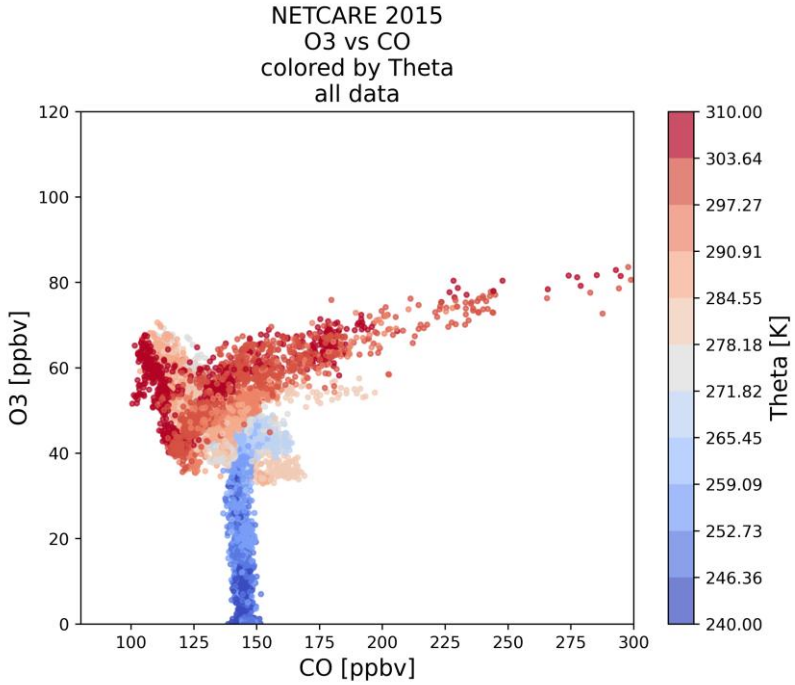
O_3-CO-correlation – ozone depletion events

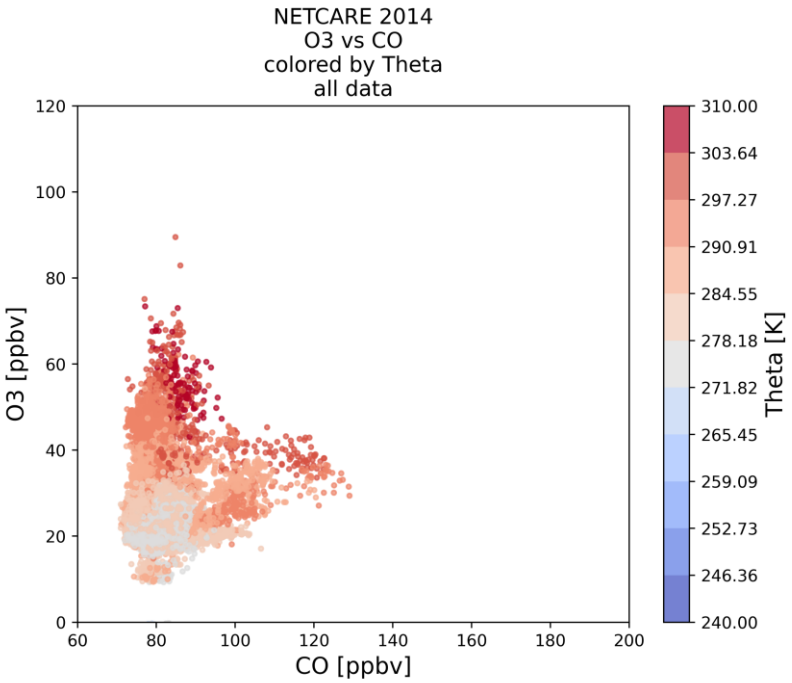




Correlation analysis

Different campaigns




NETCARE 2014
O3 vs CO
colored by Theta
all data
O3 [ppbv]
CO [ppbv]
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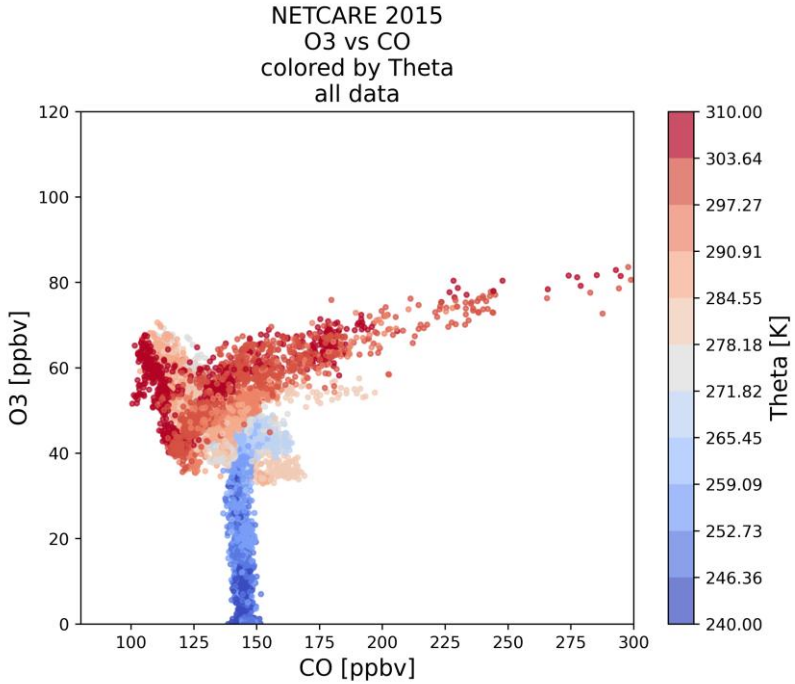
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all data
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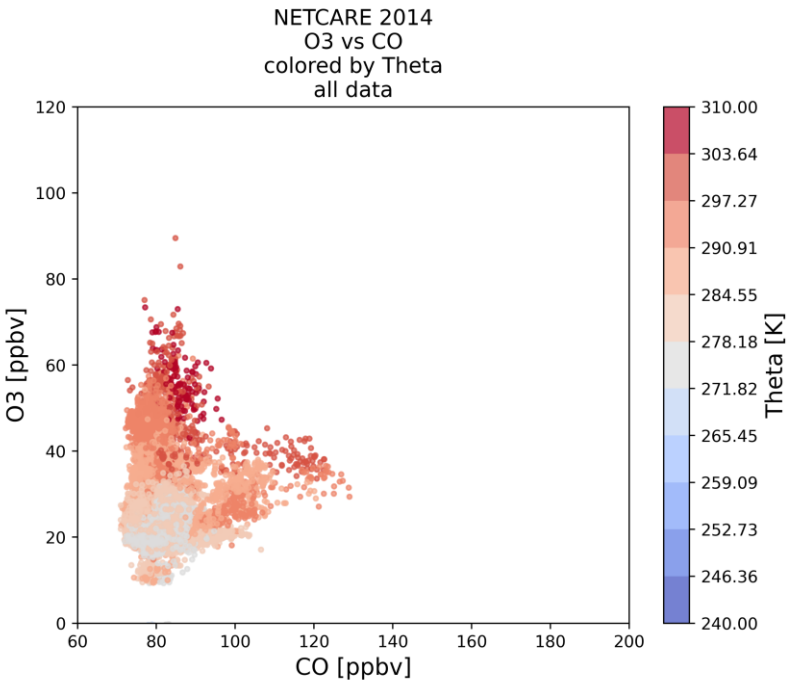
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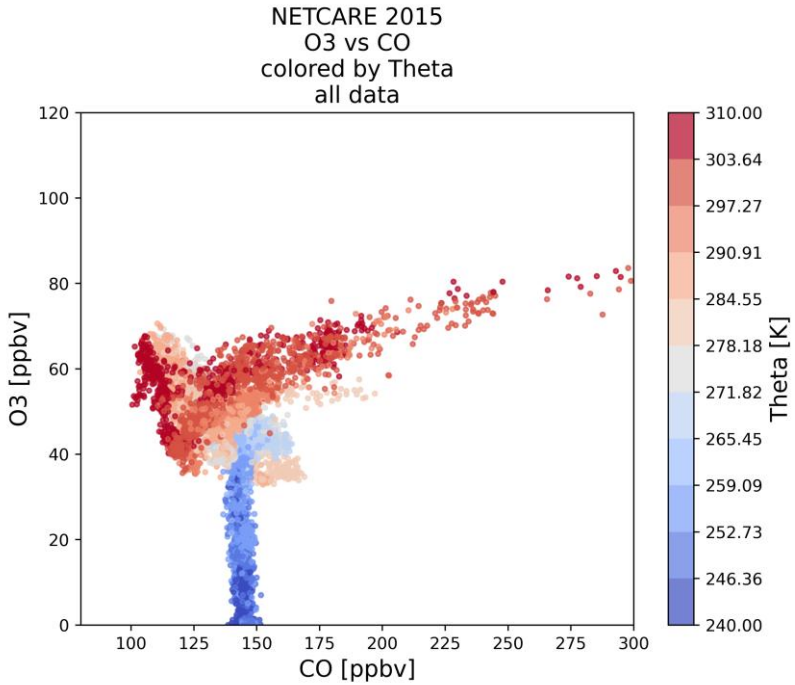
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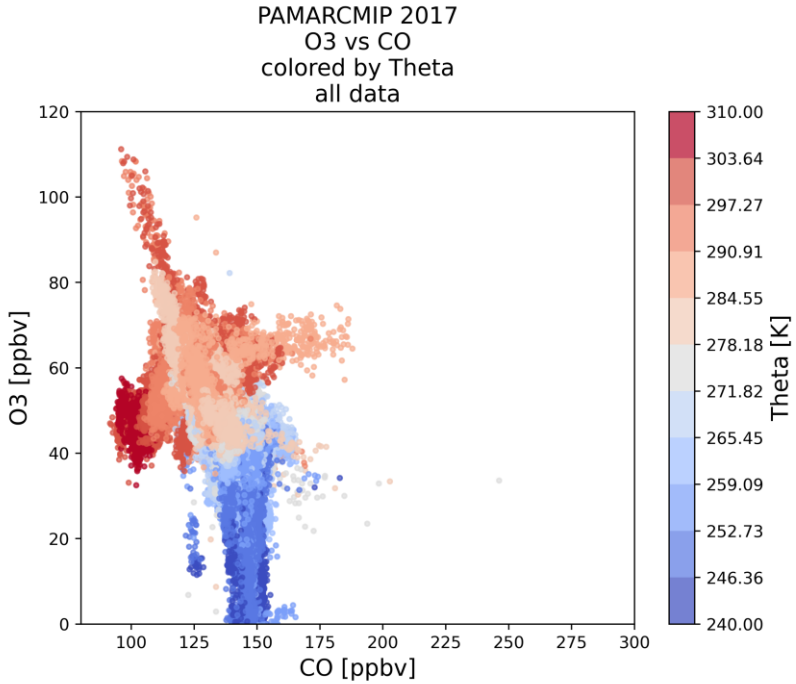
PAMARCMIP 2017
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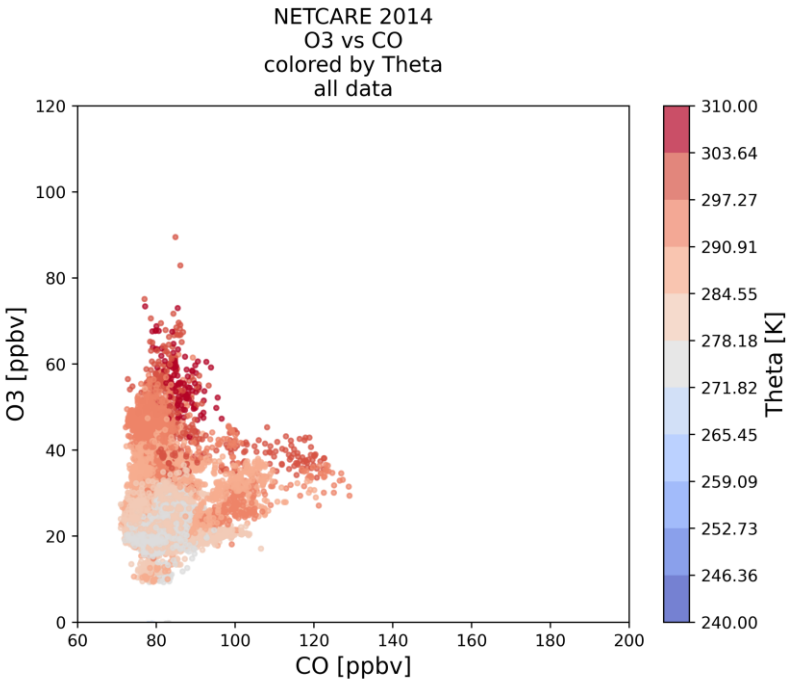
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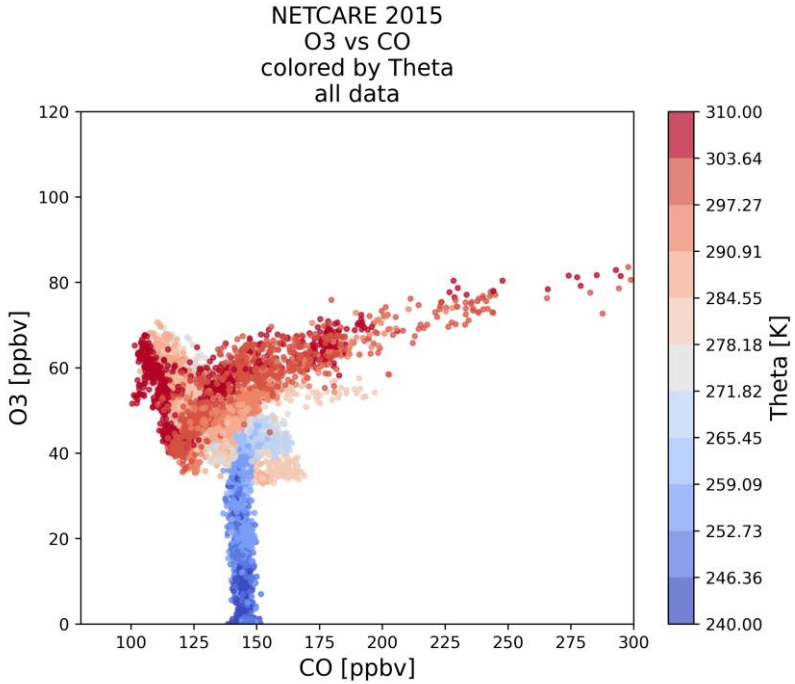
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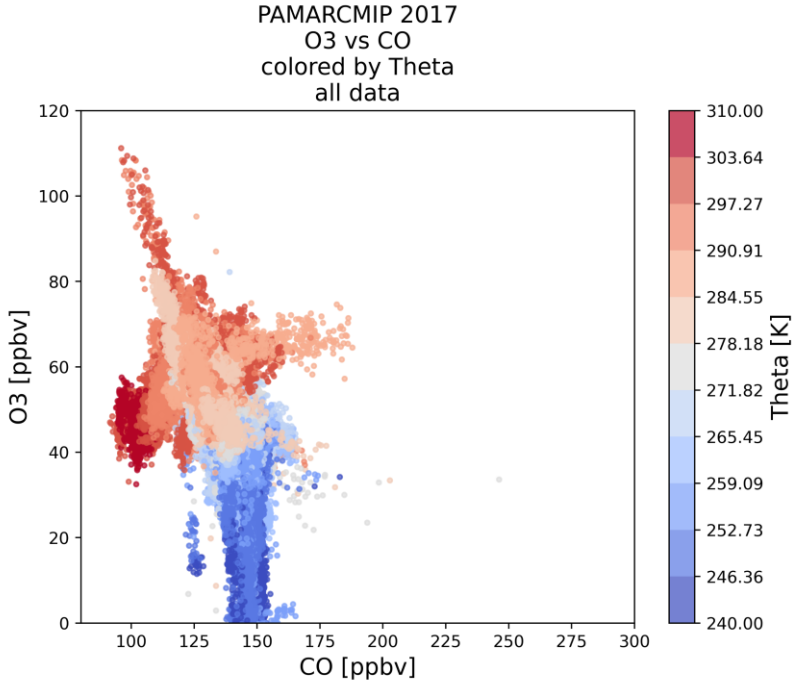
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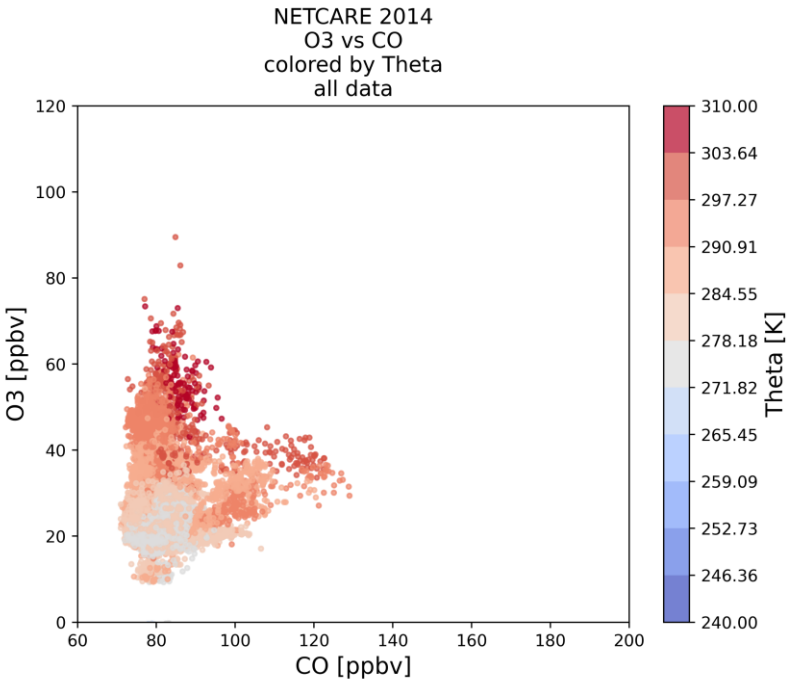
Milano 2026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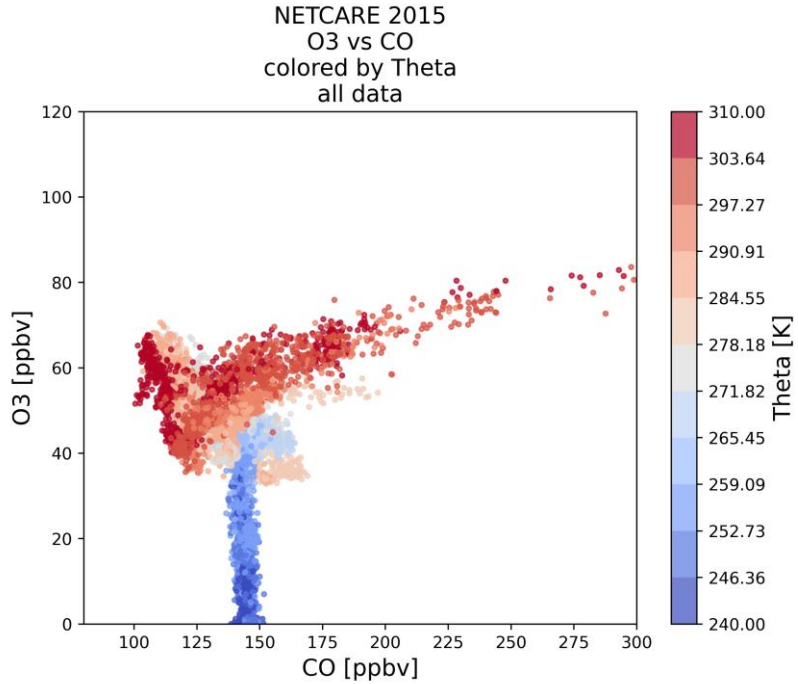
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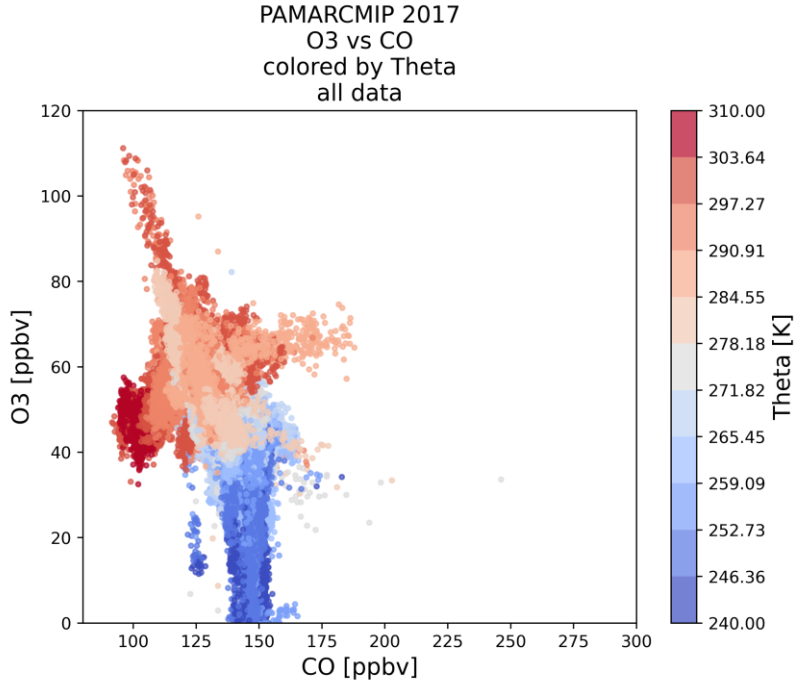
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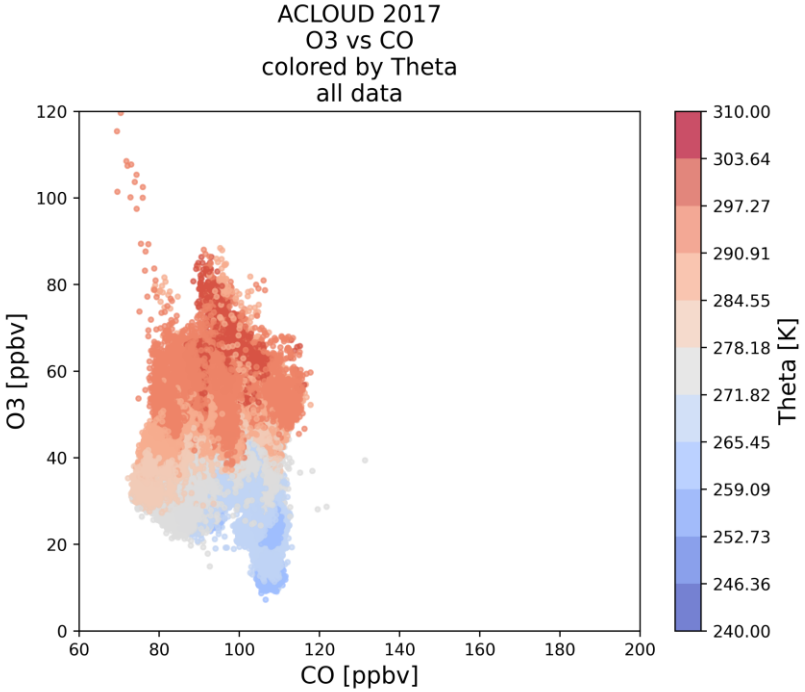
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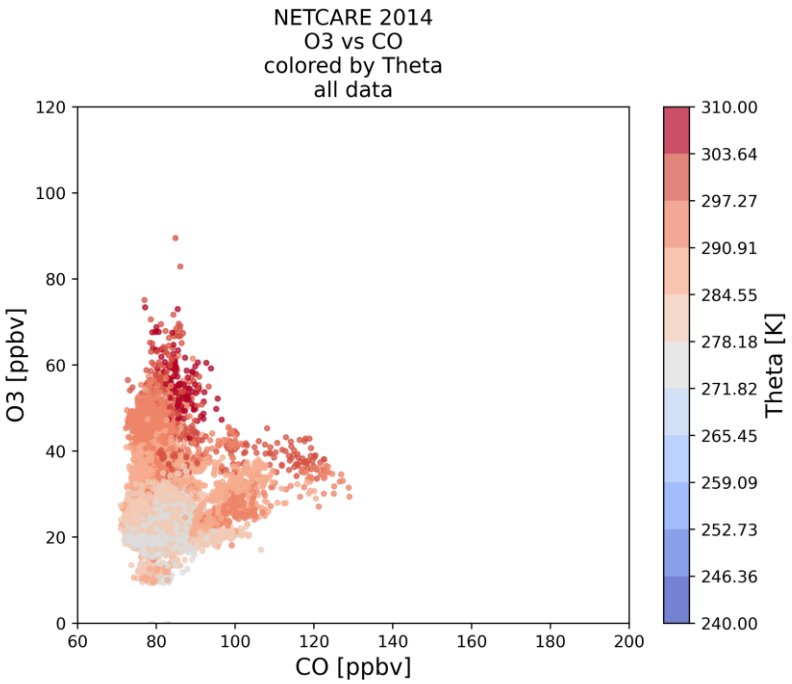
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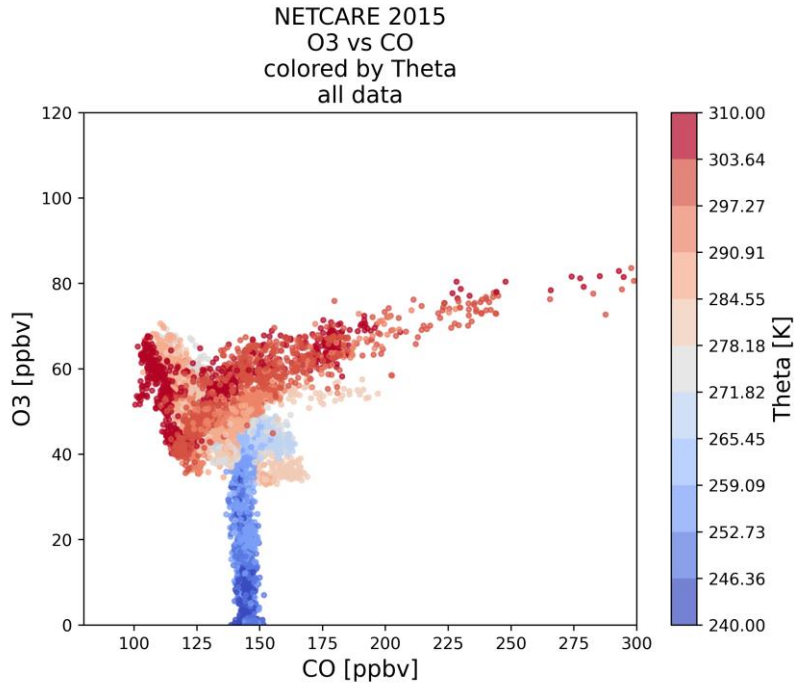
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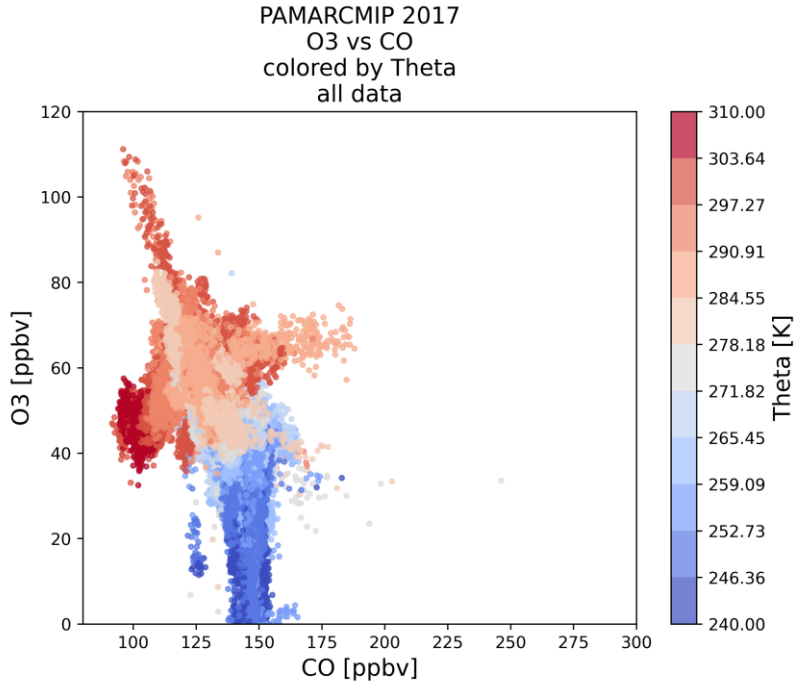
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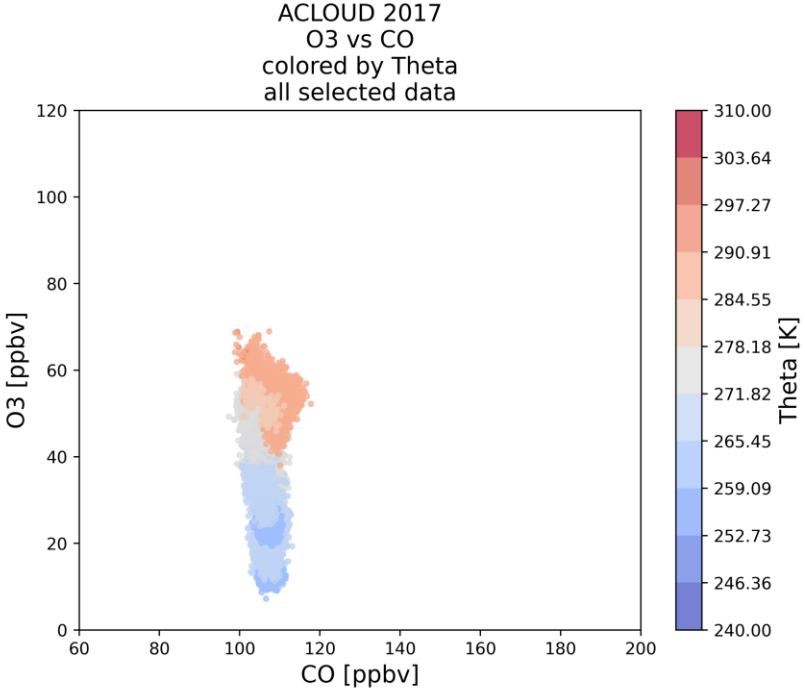
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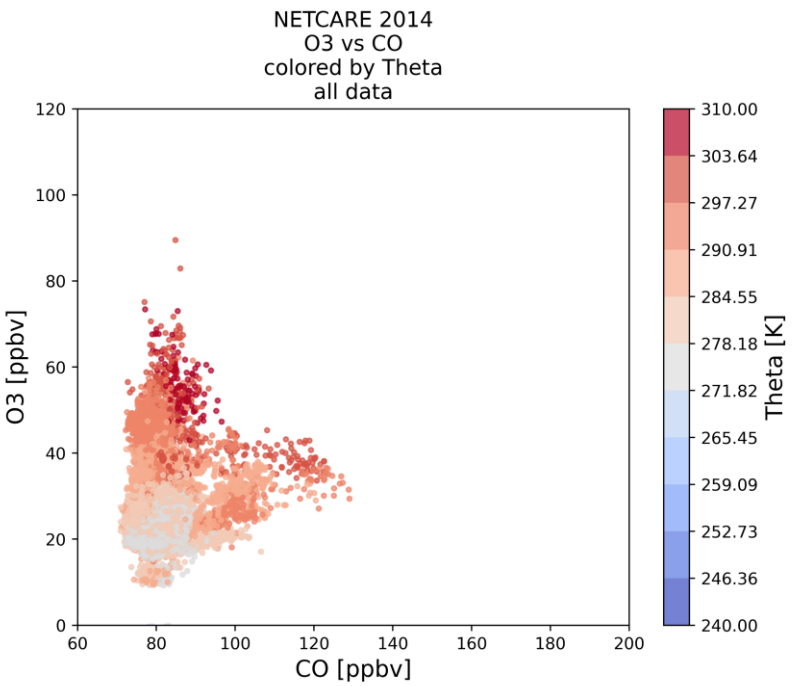
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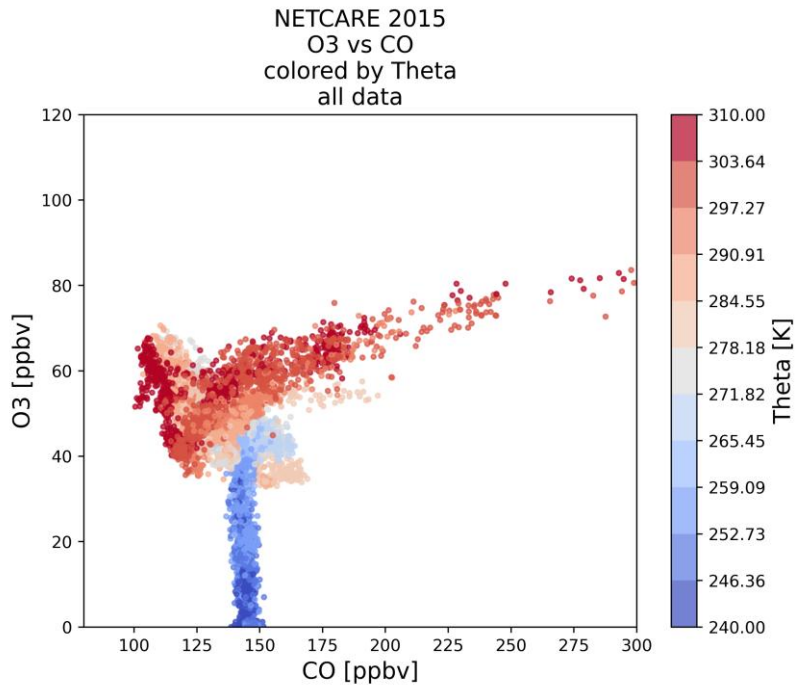
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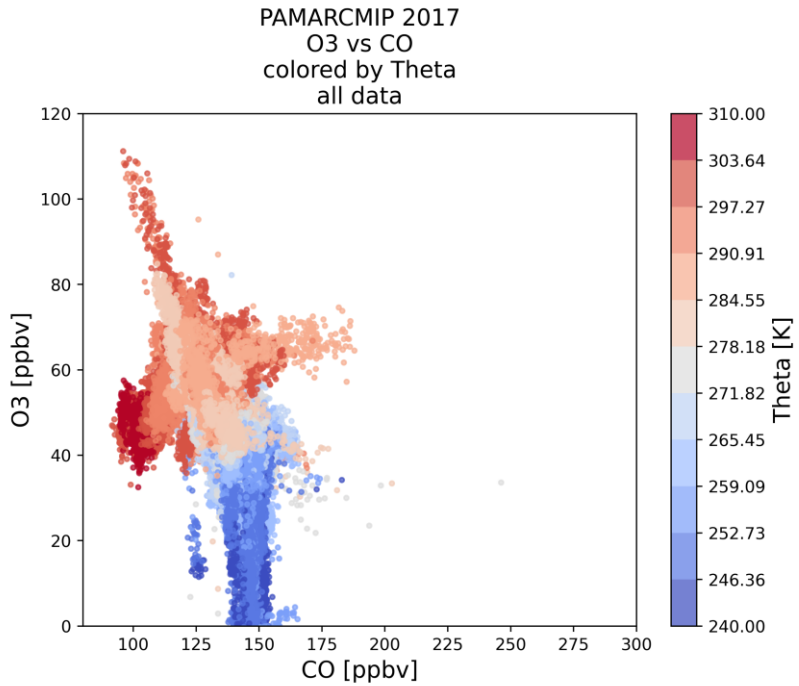
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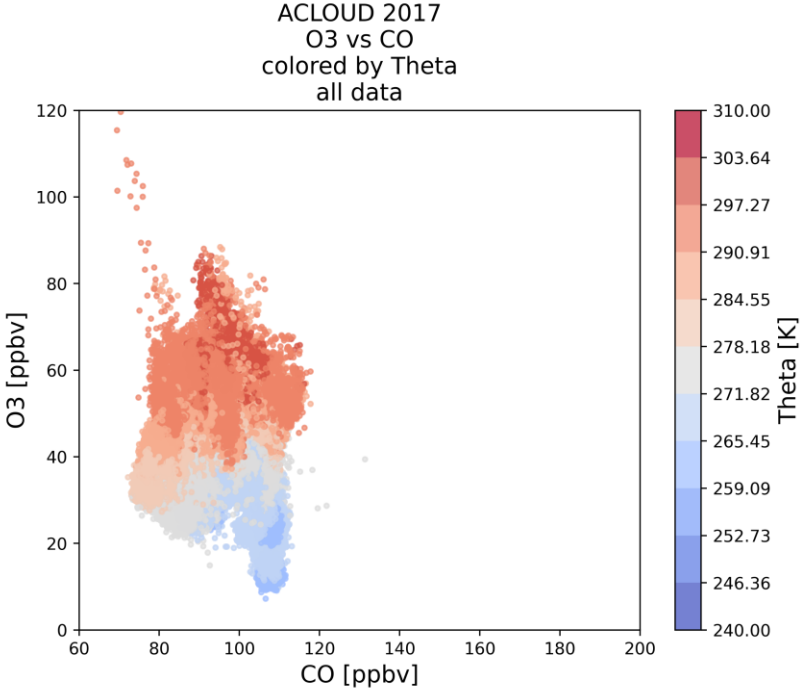
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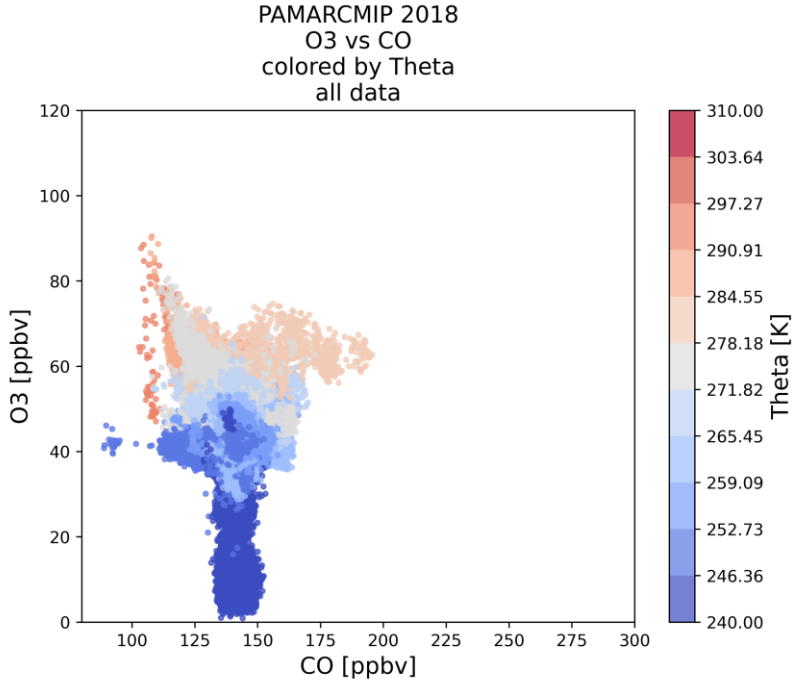
PAMARCMIP 2018
O3 vs CO
colored by Theta
all data
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CO [ppbv]
Theta [K]
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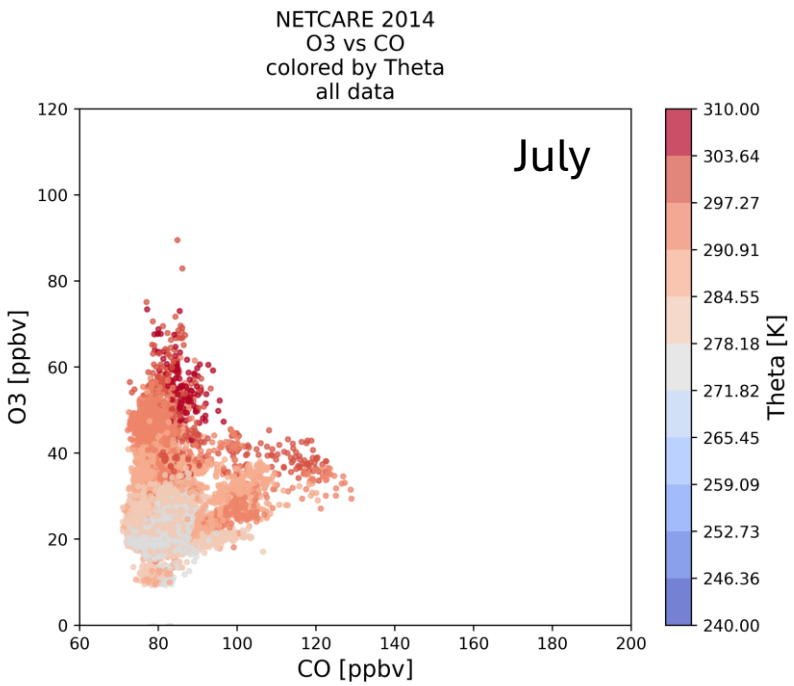
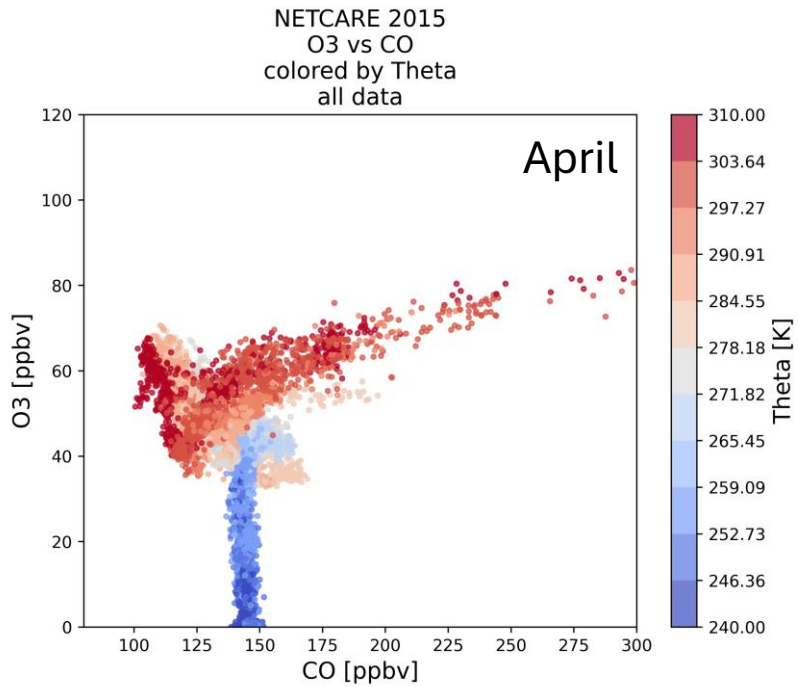
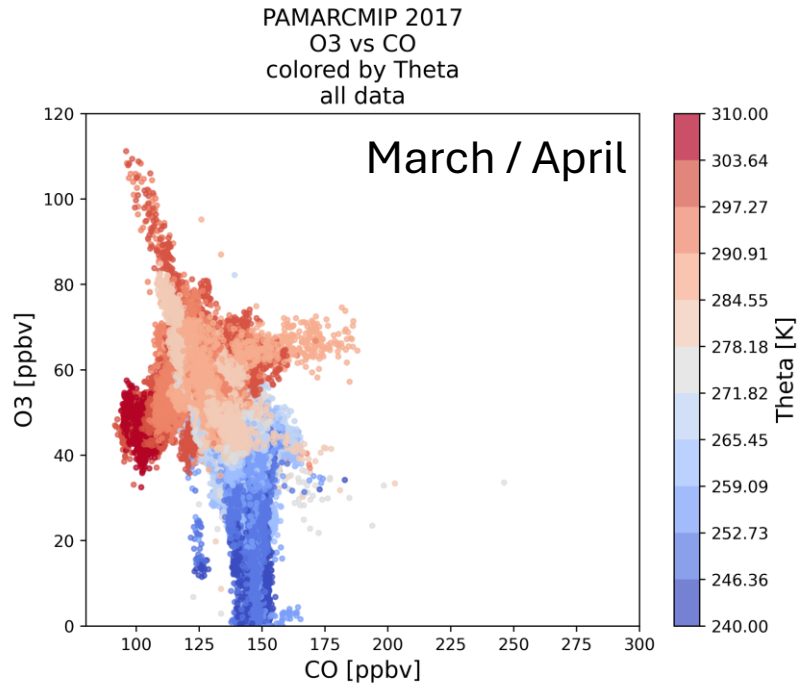
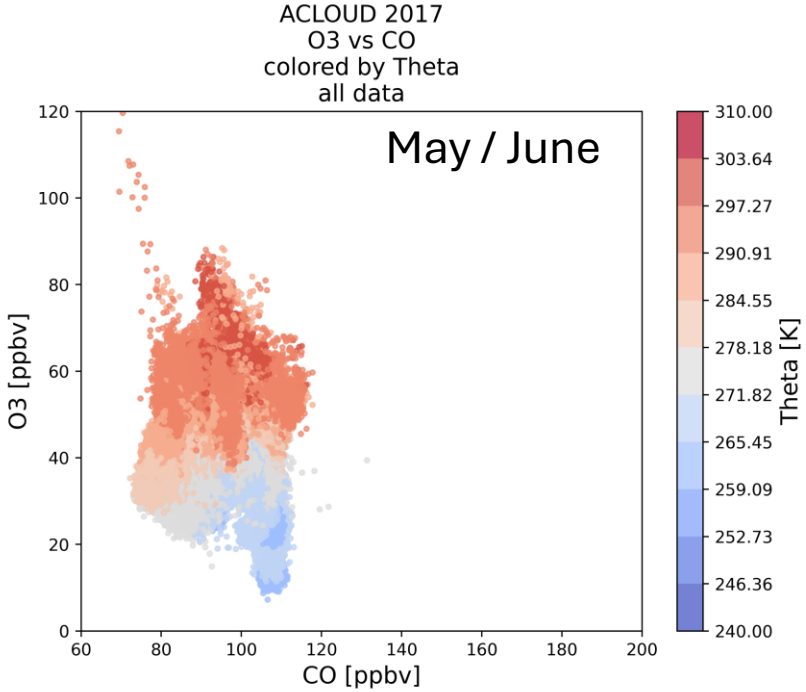
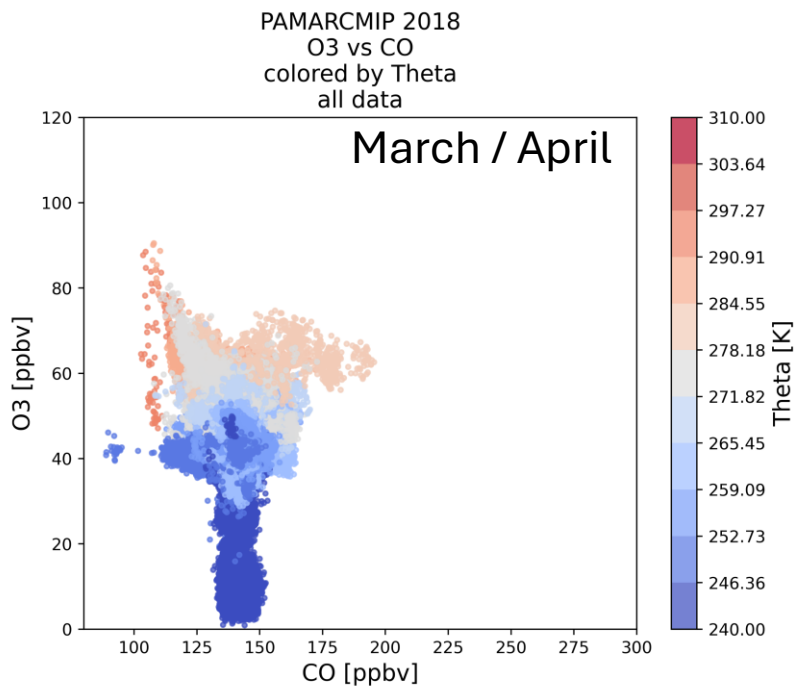
297.27
290.91
284.55
278.18
271.82
265.45
259.09
252.73
246.36
240.00

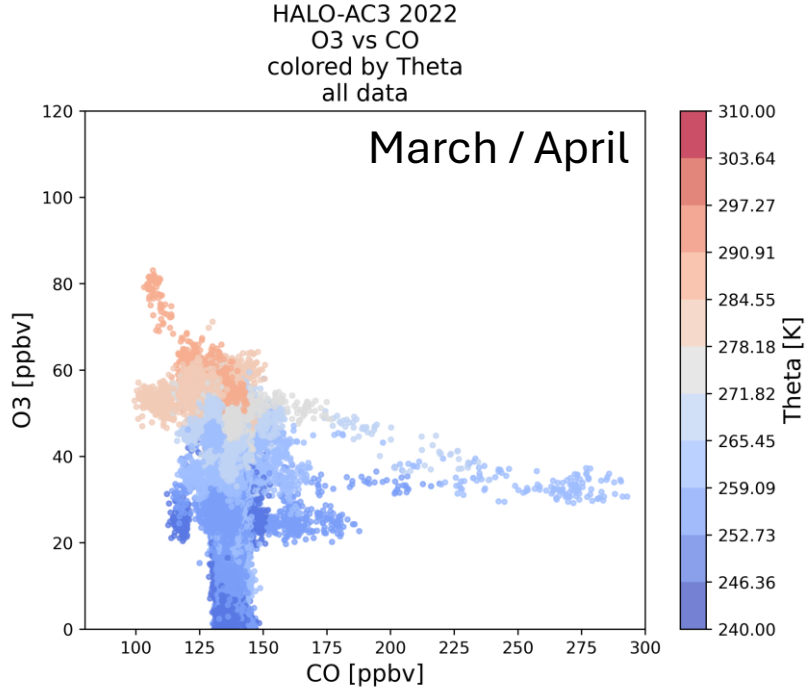

NETCARE 2014
O3 vs CO
colored by Theta
all data
July
O3 [ppbv]
CO [ppbv]
Theta [K]
310.00
303.64
297.27
290.91
284.55
278.18
271.82
265.45
259.09
252.73
246.36
240.00

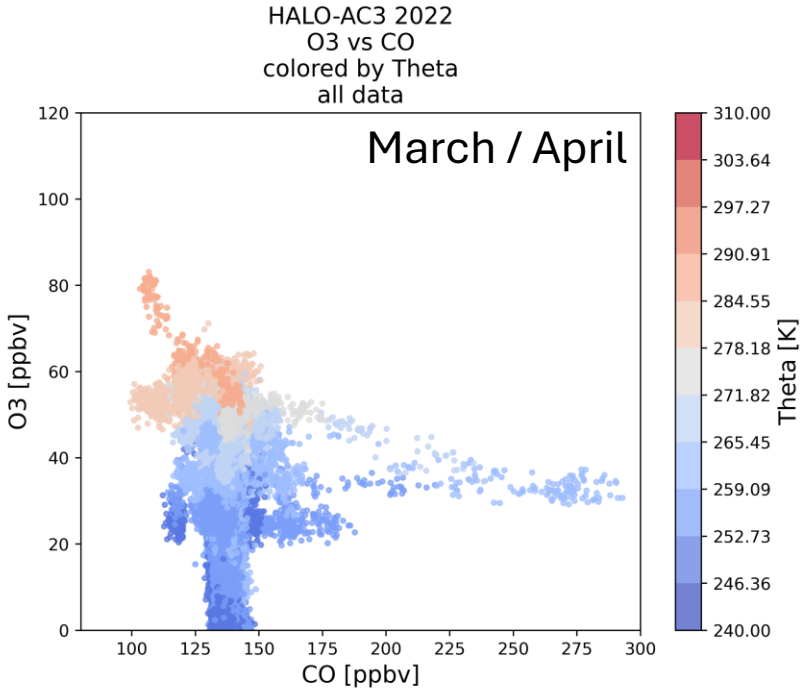

NETCARE 2015
O3 vs CO
colored by Theta
all data
April
O3 [ppbv]
CO [ppbv]
Theta [K]
310.00
303.64
297.27
290.91
284.55
278.18
271.82
265.45
259.09
252.73
246.36
240.00

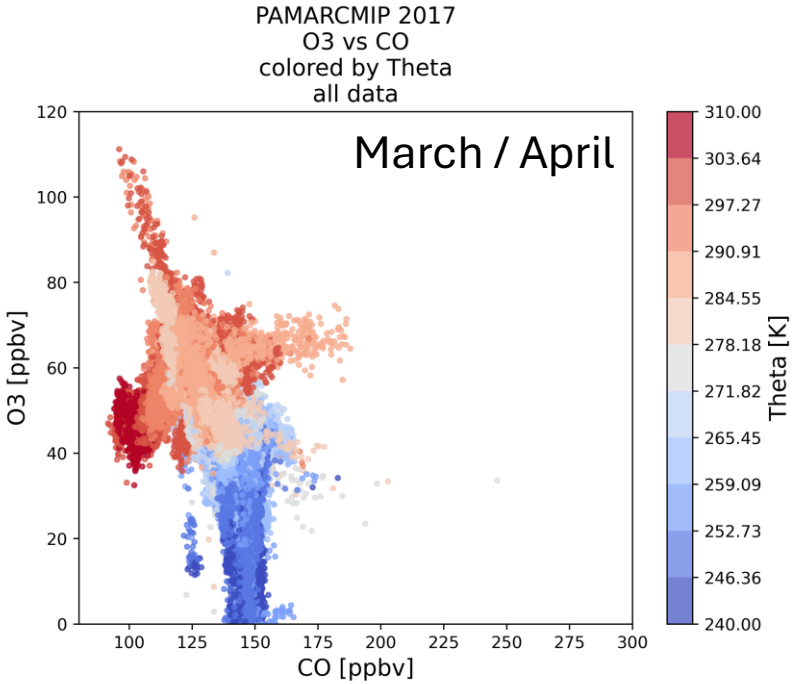

PAMARCMIP 2017
O3 vs CO
colored by Theta
all data
March / April
O3 [ppbv]
CO [ppbv]
Theta [K]
310.00
303.64
297.27
290.91
284.55
278.18
271.82
265.45
259.09
252.73
246.36
240.00

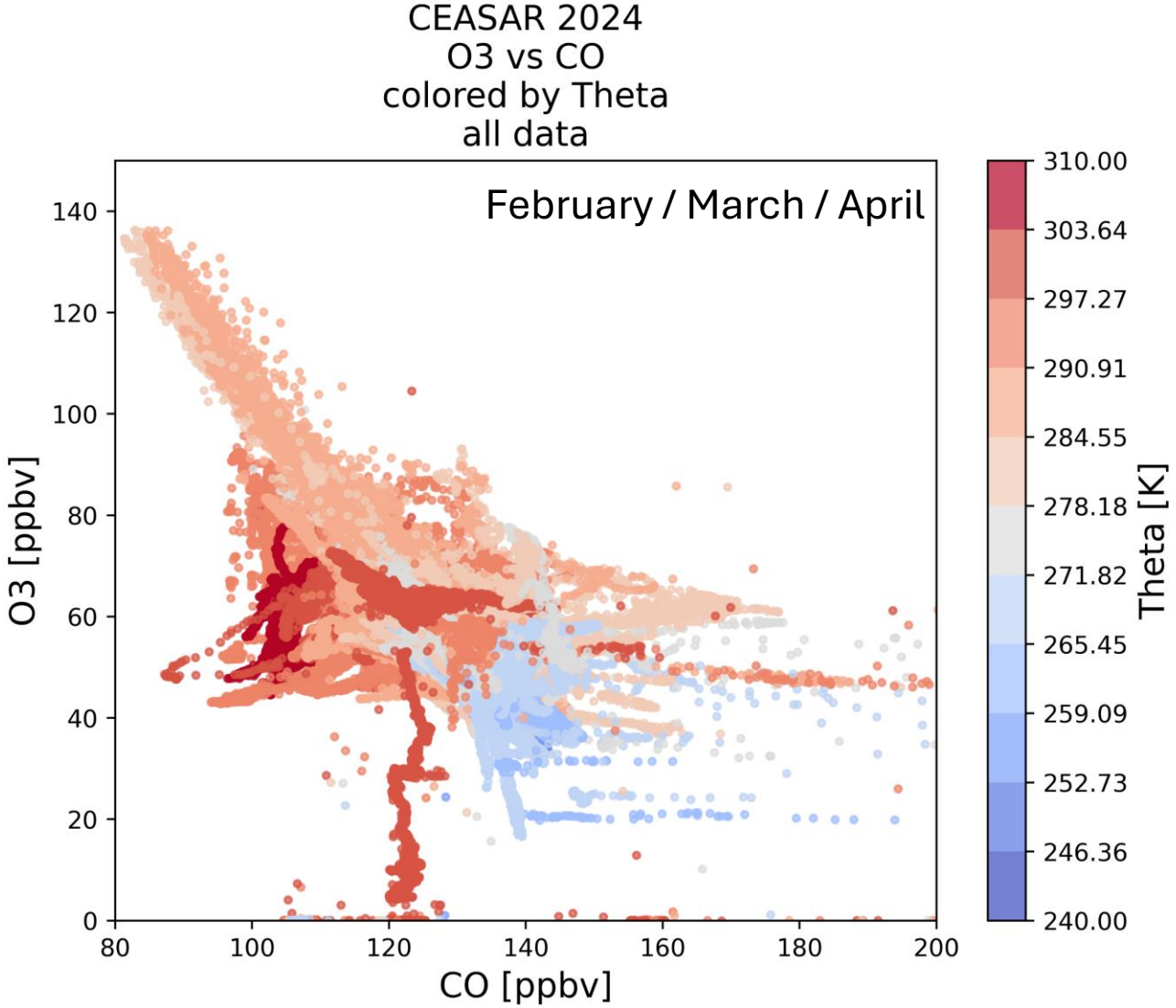

ACLOUD 2017
O3 vs CO
colored by Theta
all data
May / June
O3 [ppbv]
CO [ppbv]
Theta [K]
310.00
303.64
297.27
290.91
284.55
278.18
271.82
265.45
259.09
252.73
246.36
240.00


PAMARCMIP 2018
O3 vs CO
colored by Theta
all data
March / April
O3 [ppbv]
CO [ppbv]
Theta [K]
310.00
303.64
297.27
290.91
284.55
278.18
271.82
265.45
259.09
252.73
246.36
240.00

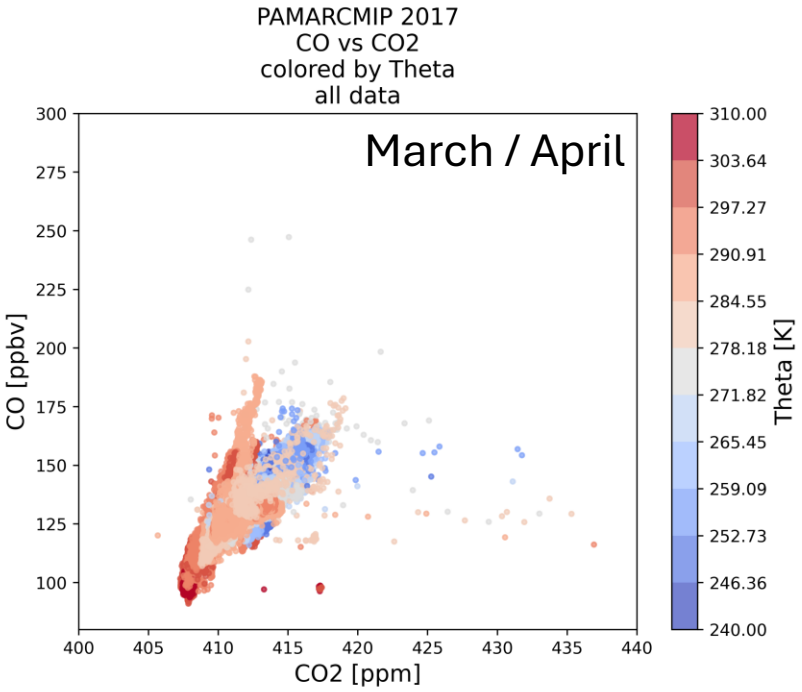

HALO-AC3 2022
O3 vs CO
colored by Theta
all data
March / April
O3 [ppbv]
CO [ppbv]
Theta [K]
310.00
303.64
297.27
290.91
284.55
278.18
271.82
265.45
259.09
252.73
246.36
240.00

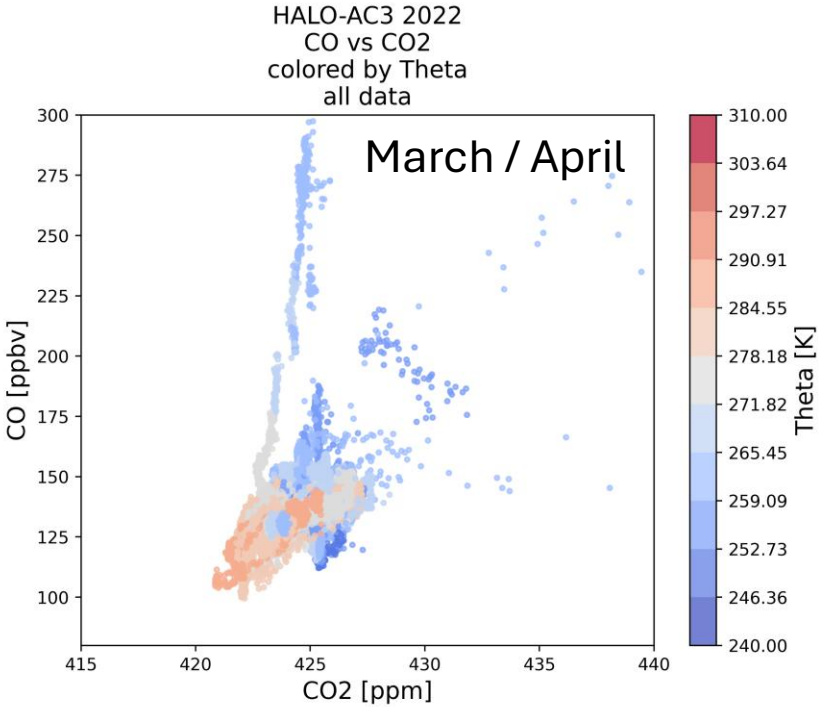


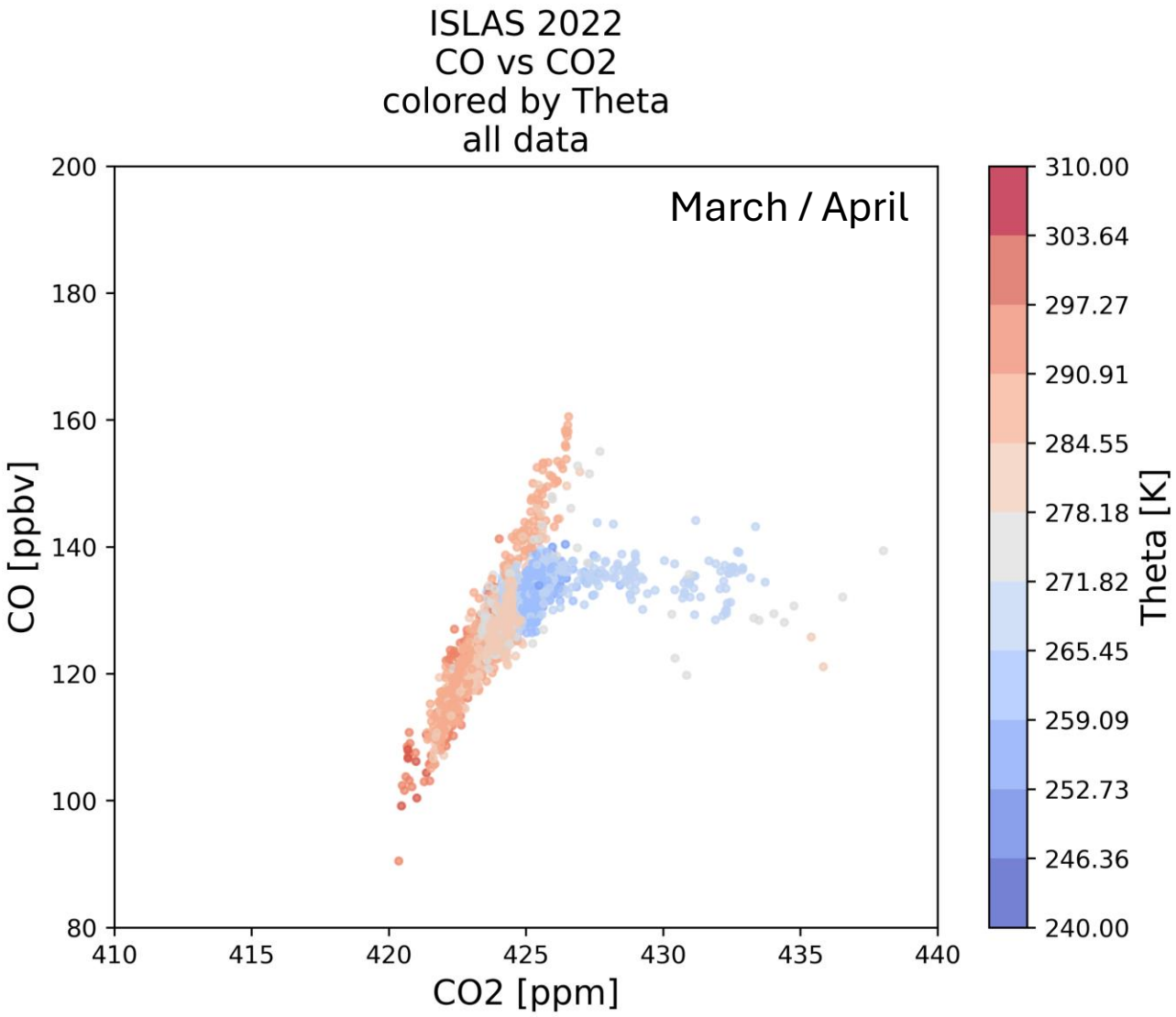




Data provided by NCAR EOL under the sponsorship of the National Science Foundation. https://data.eol.ucar.edu/



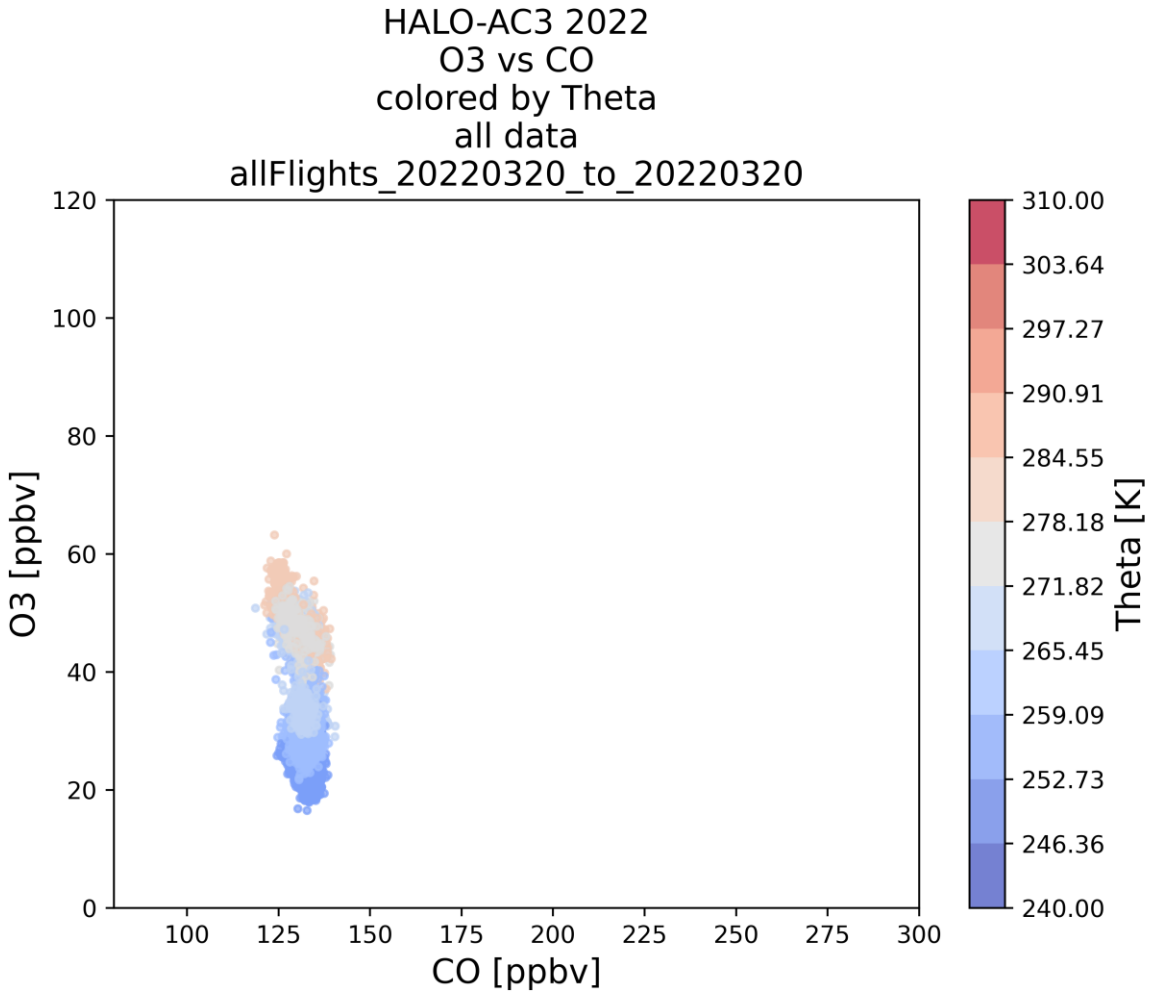


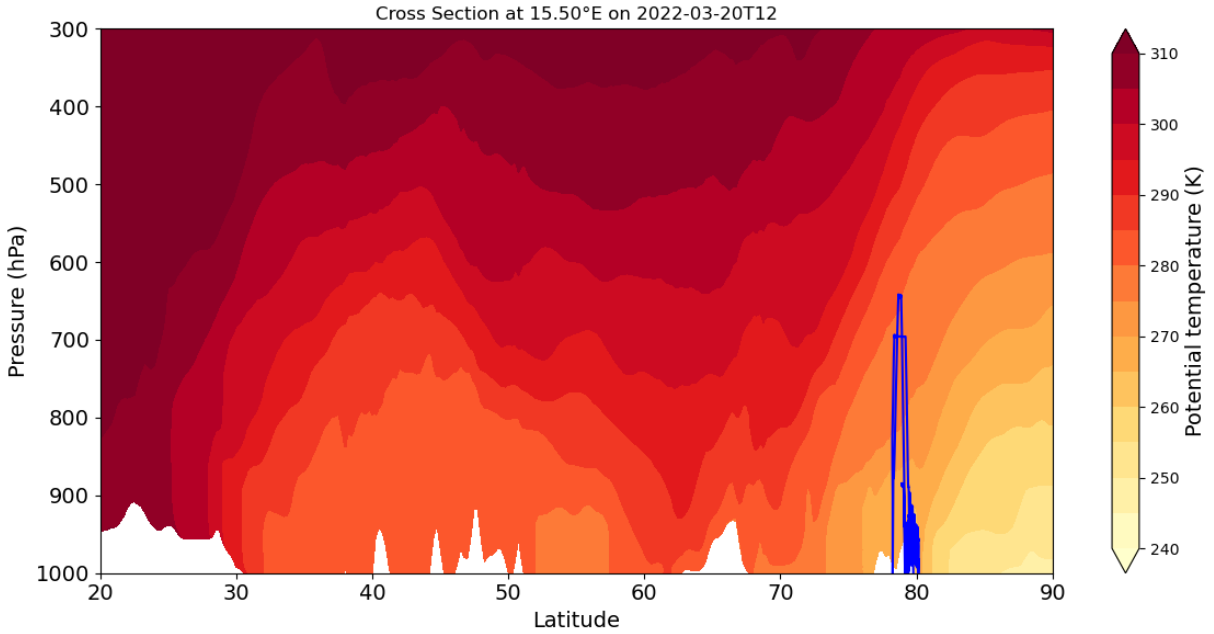


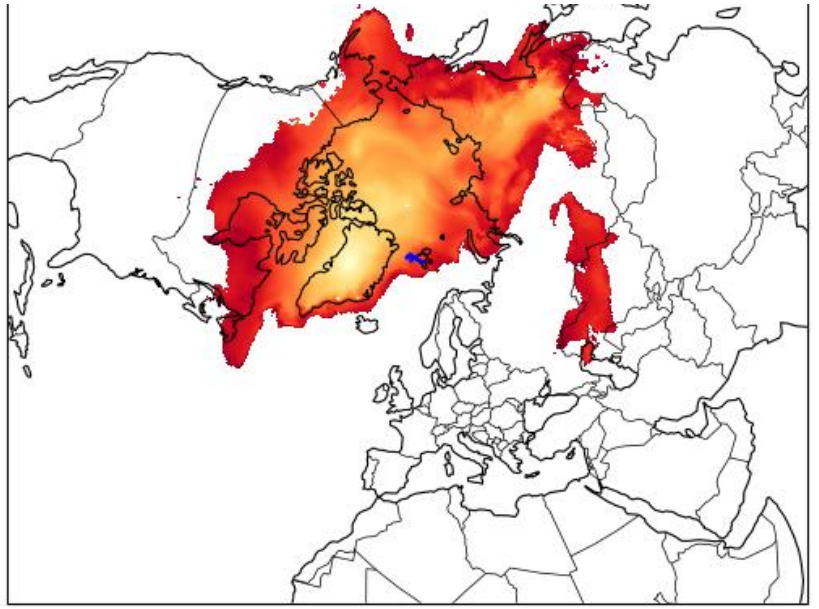
Data courtesy of H. Sodemann

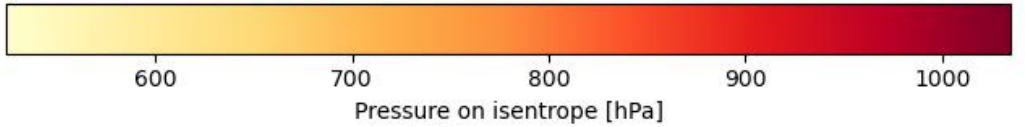
Correlation analysis

Individual flight



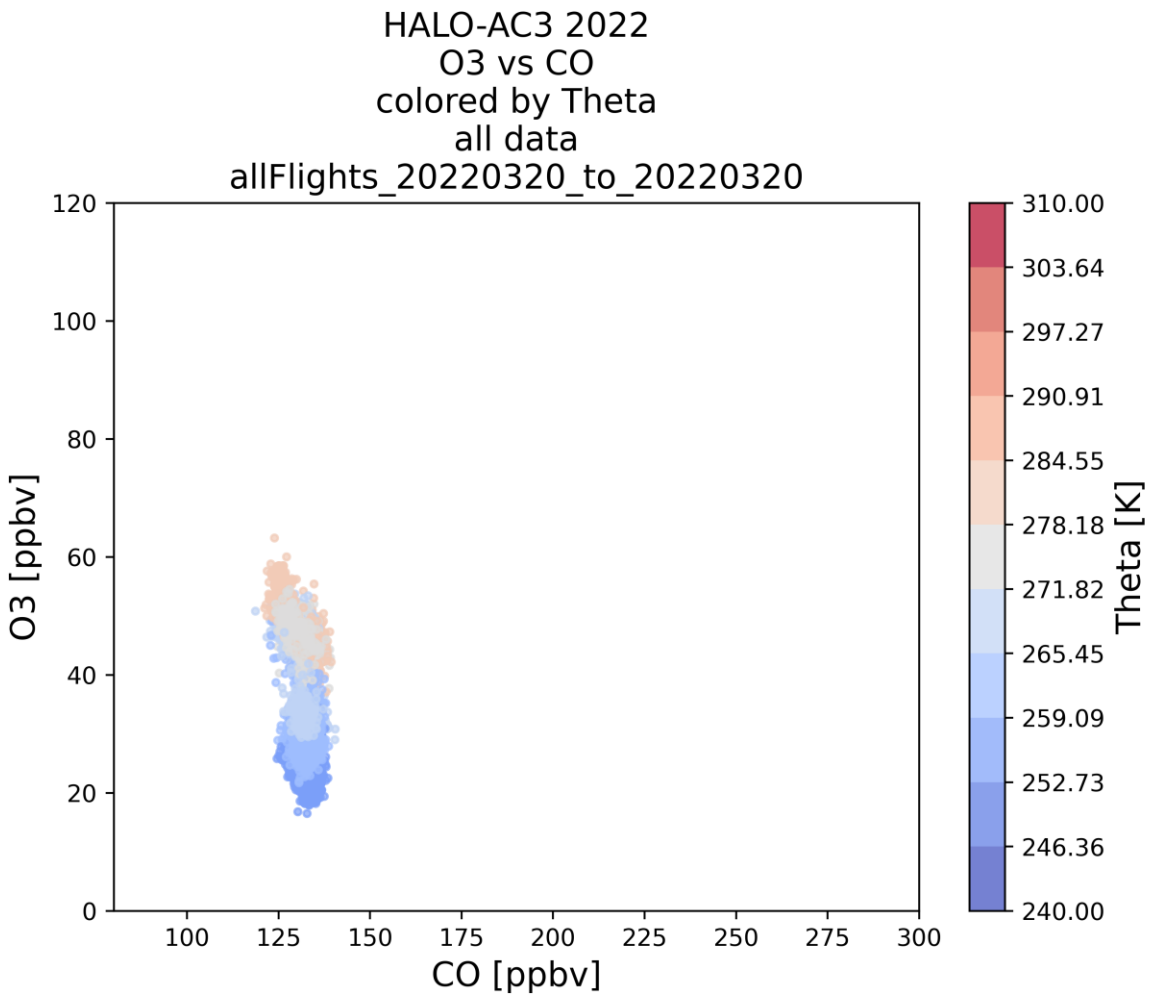


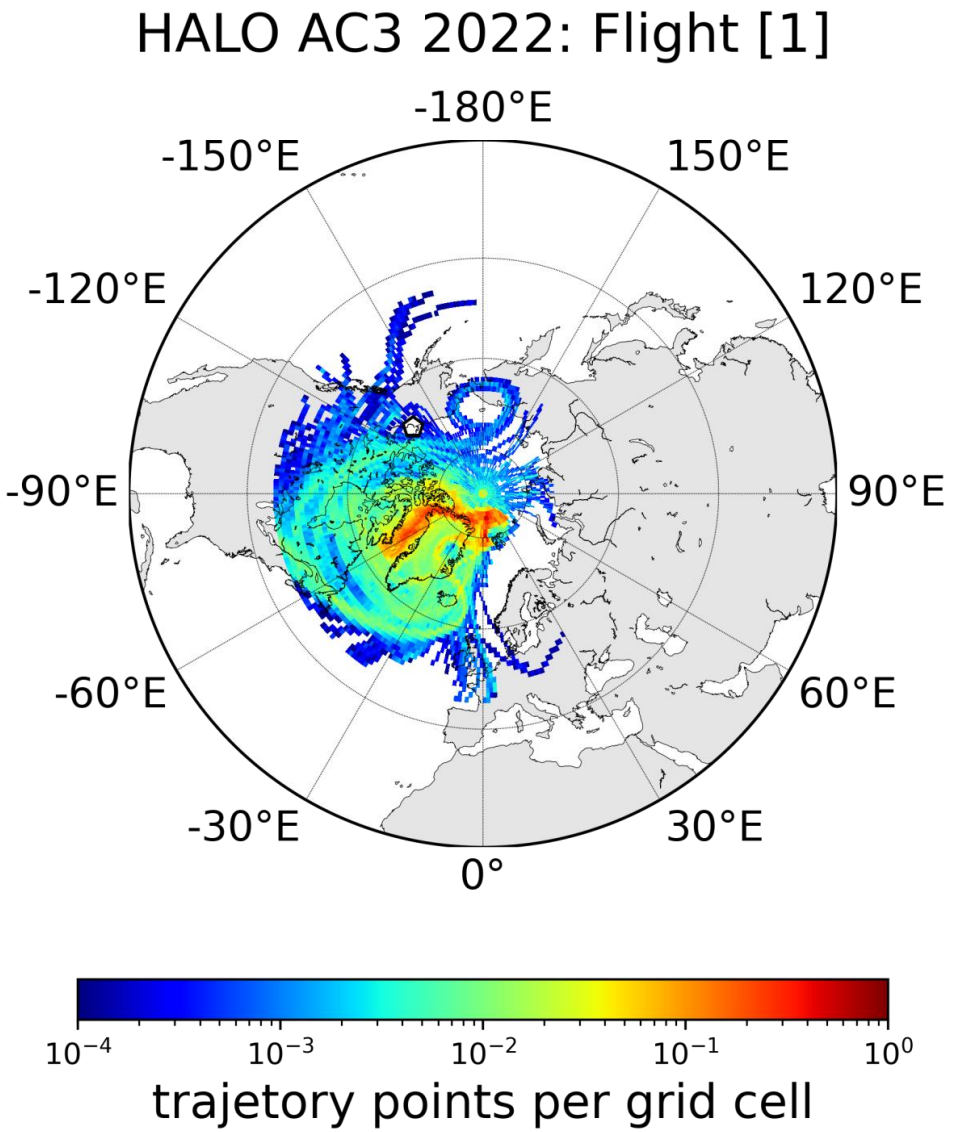




Correlation analysis

Individual flight



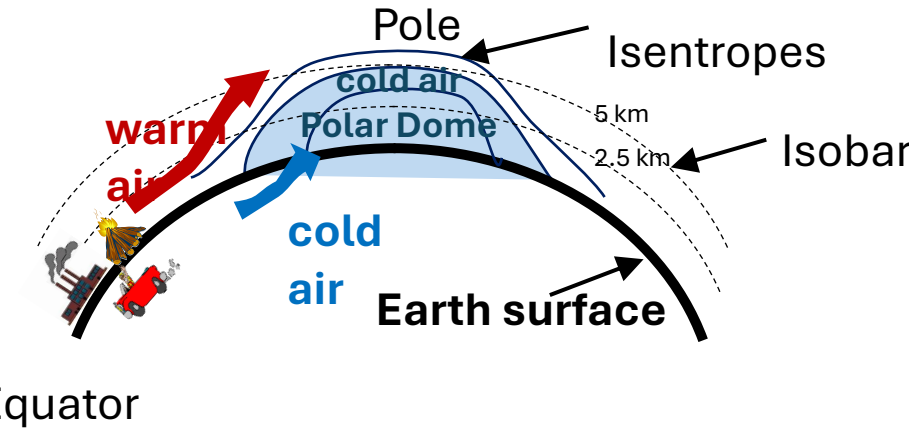


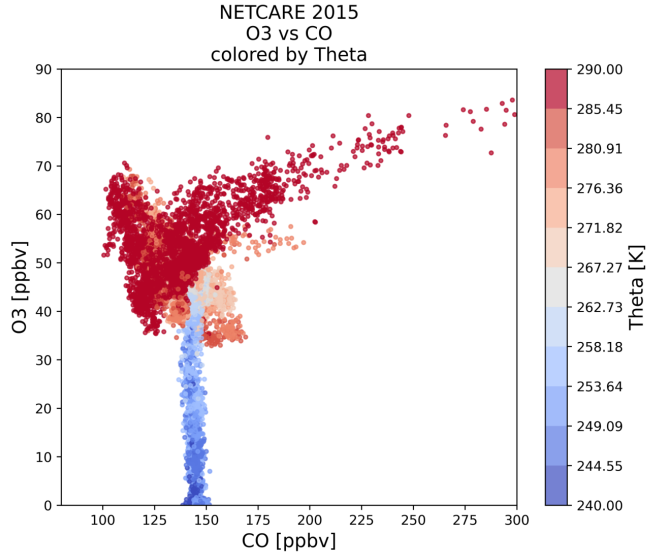
Conclusion…and the way forward

- Identification of the polar dome based on trace gas data succesfull -> dome air masses identified in tracer-tracer correlations

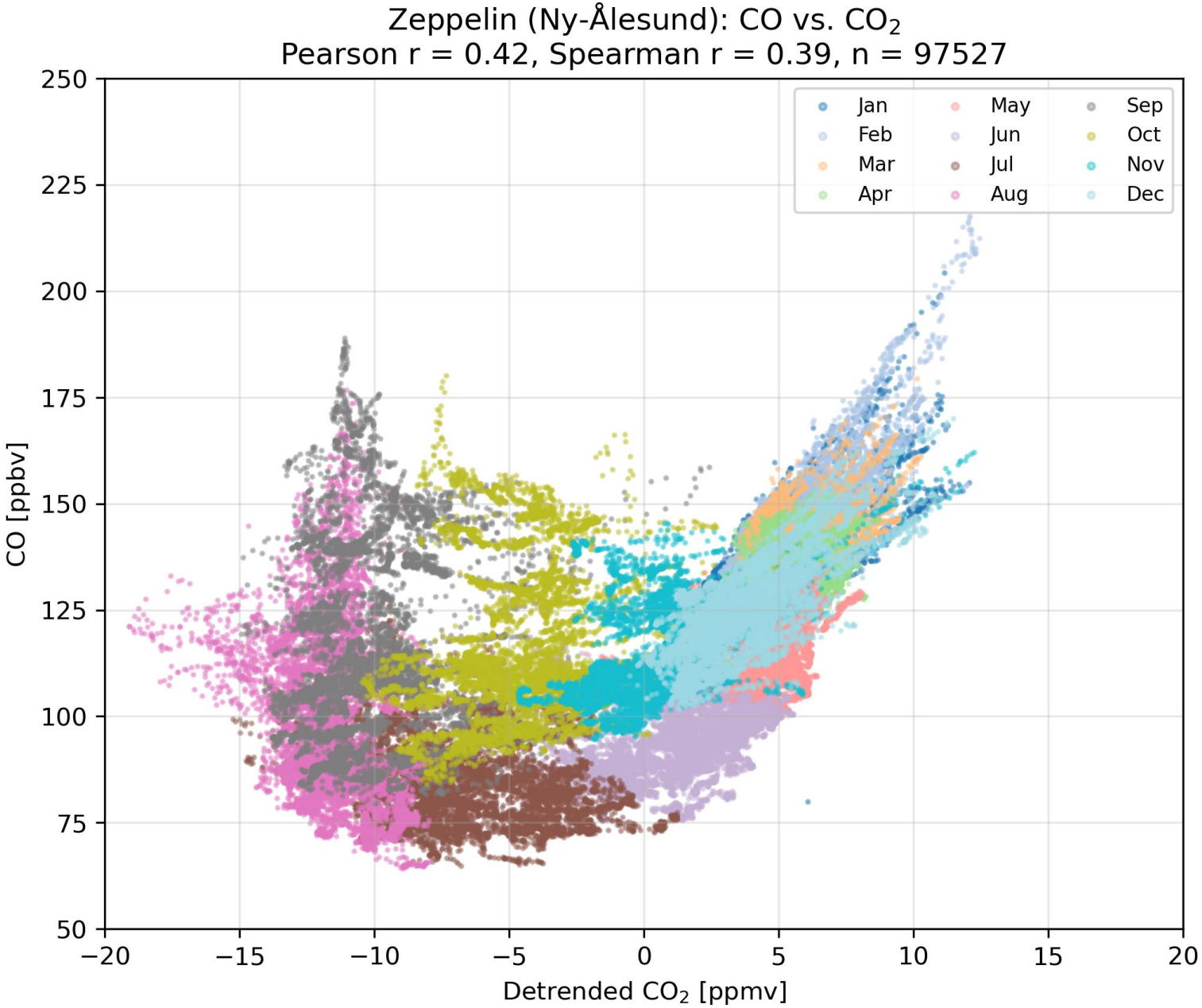
- Correlation analysis reveal similar patterns that allow for characterizing a campaign / a flight / a campaign phase with respect to synoptic regime of the measurements

- Further steps:
  - Connection to ground data
  - trend analysis of airborne data with respect to different synoptic regimes

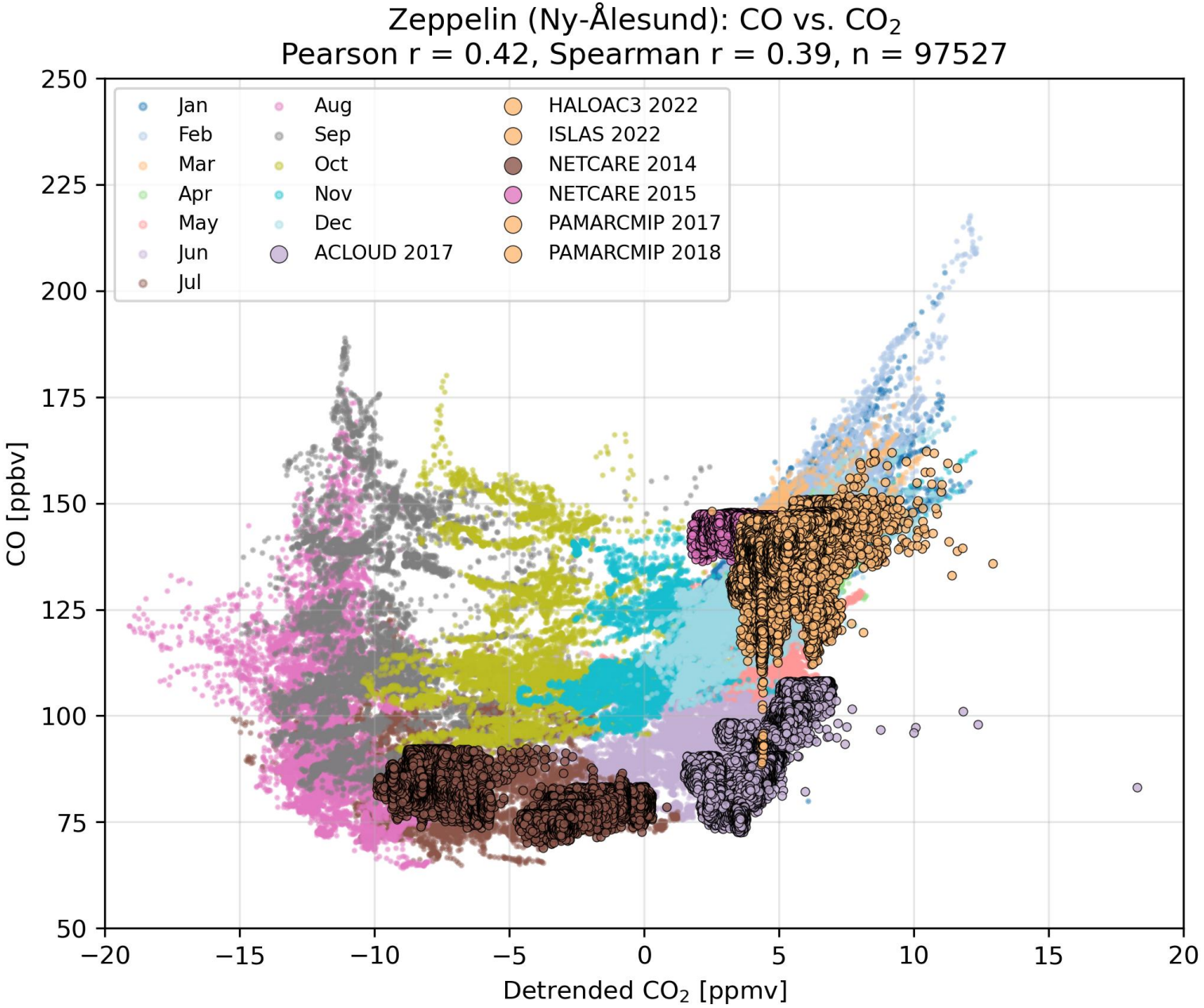




Conclusion...and the way forward



Conclusion...and the way forward



Conclusion…and the way forward

- Identification of the polar dome based on trace gas data succesfull -> dome air masses identified in tracer-tracer correlations

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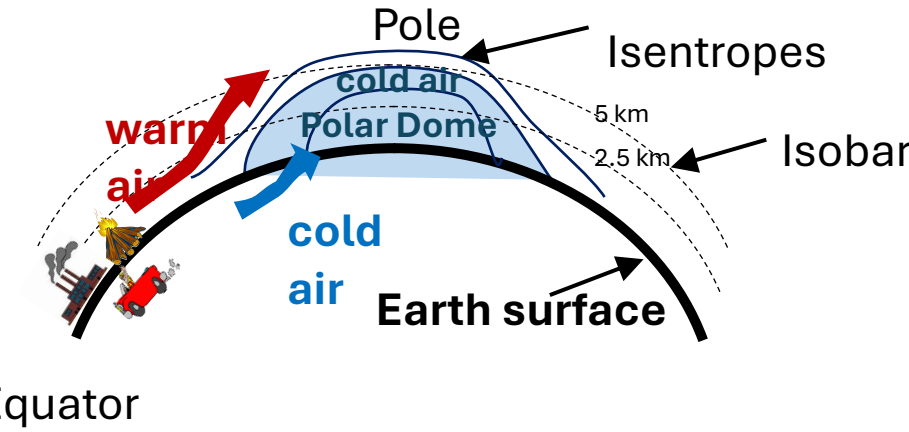
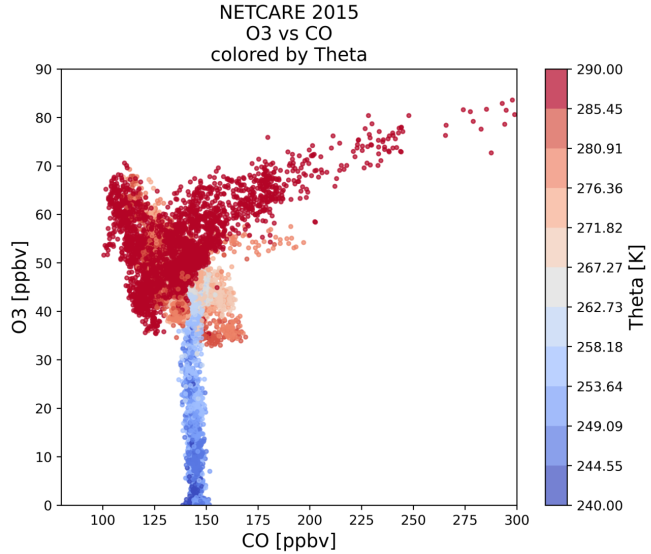
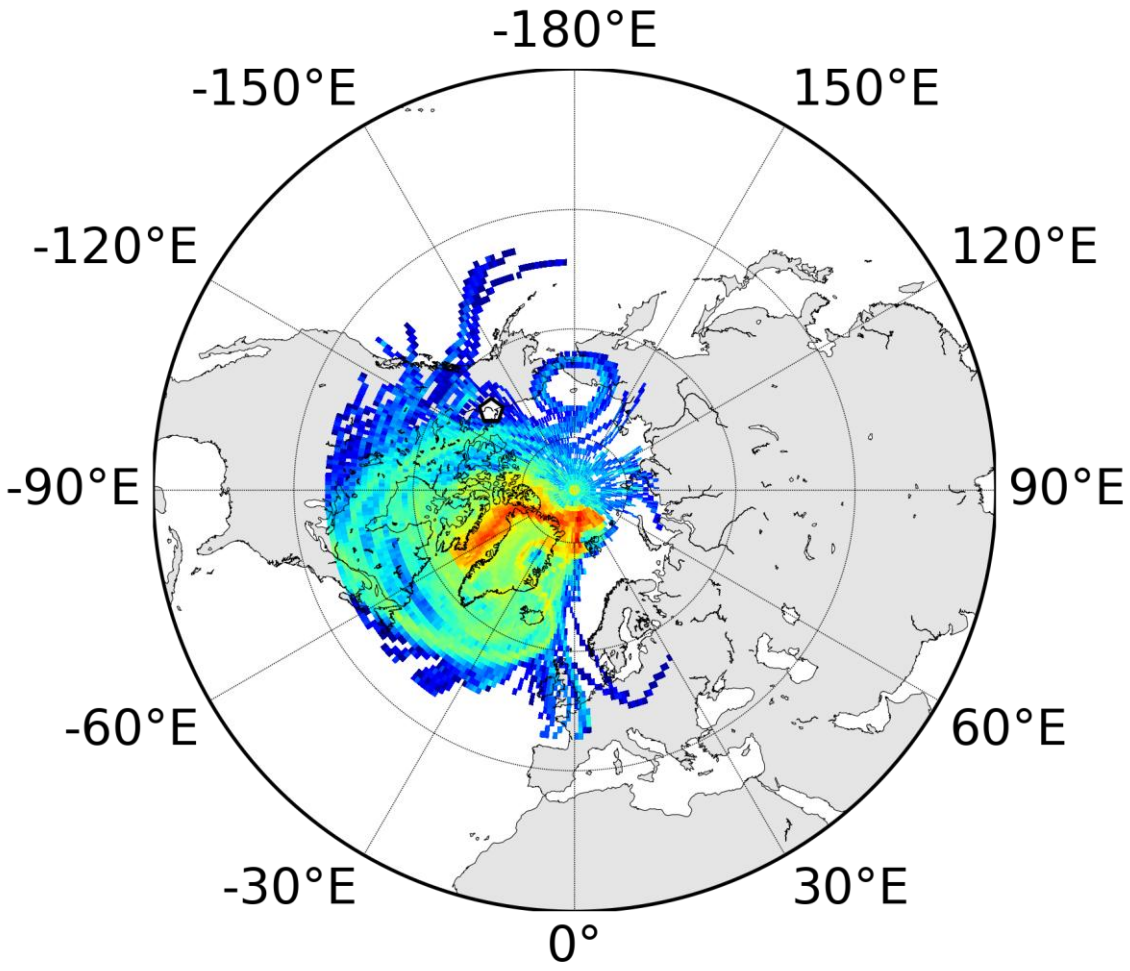
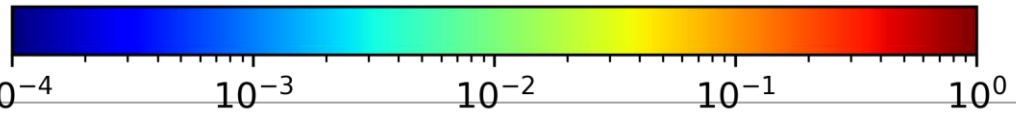
- Further steps:
  - Connection to ground data
  - trend analysis of airborne data with respect to different regimes

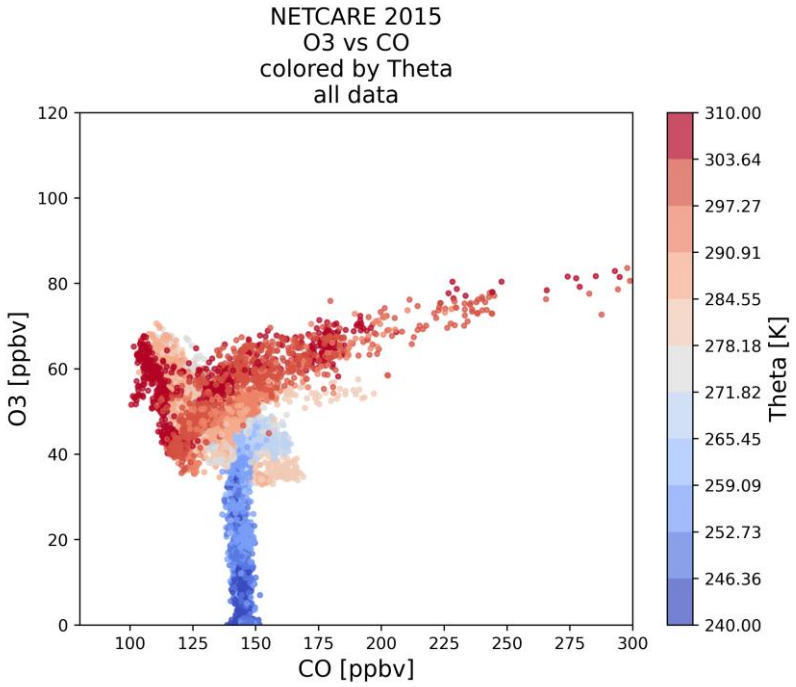


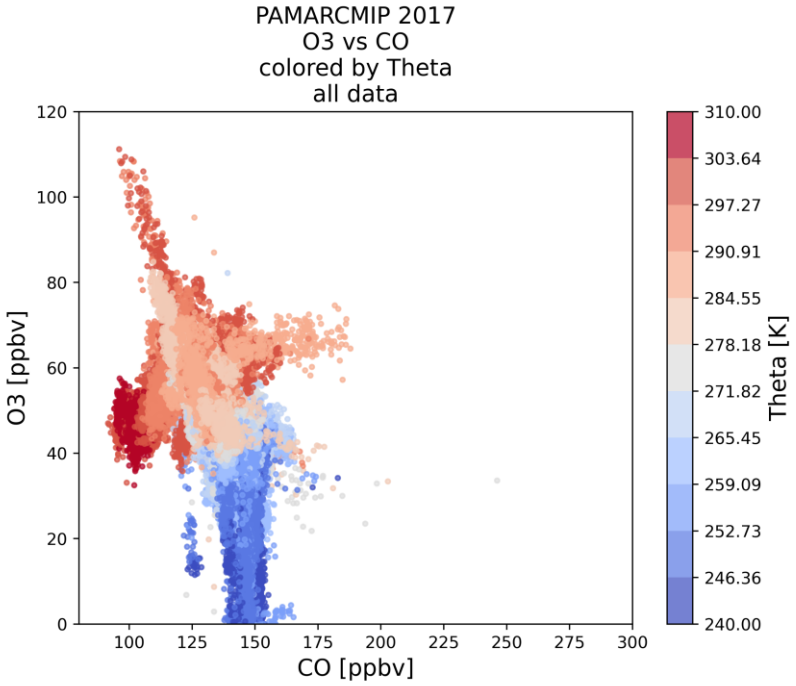


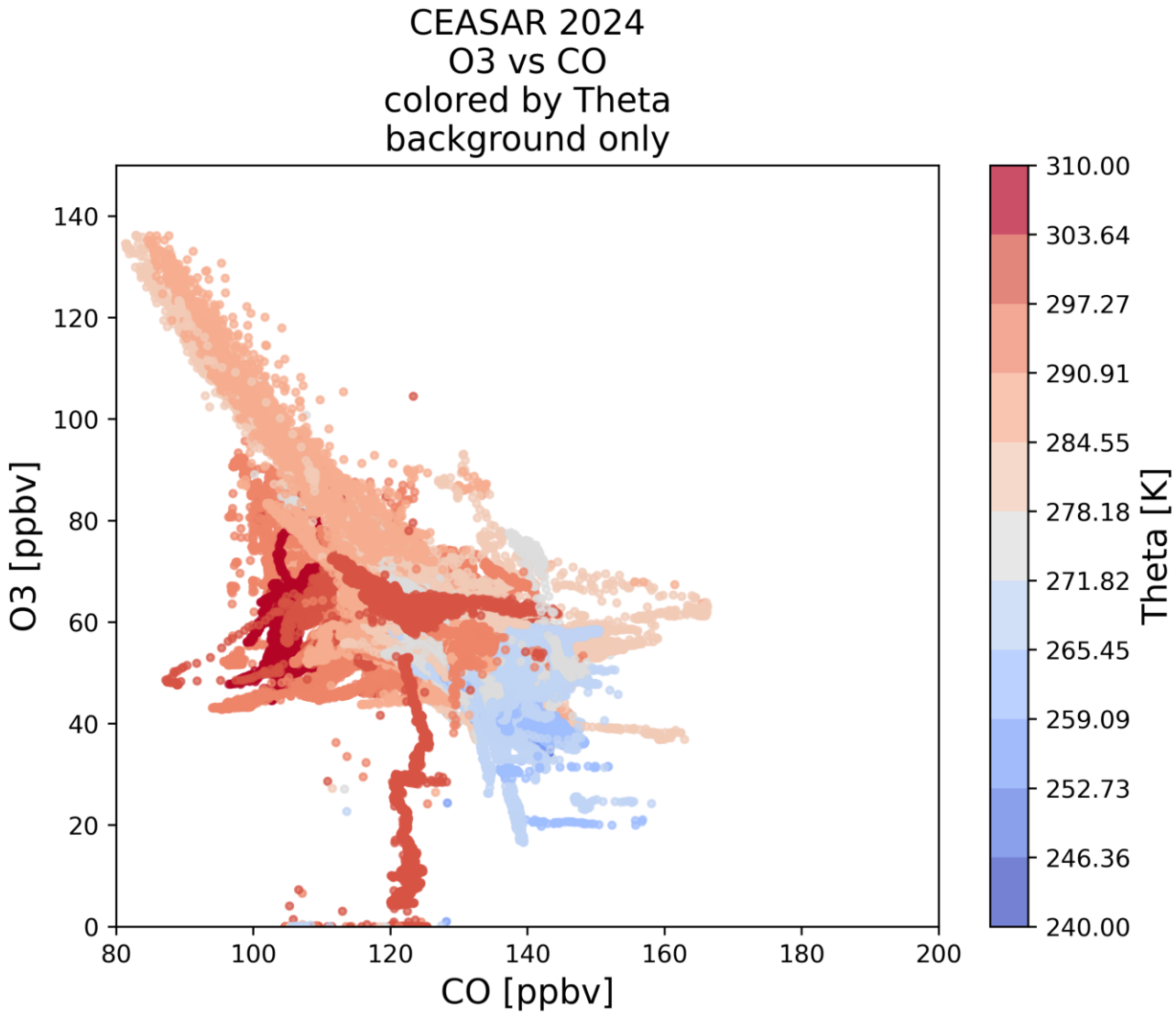
HALO AC3 2022: Flight [1]



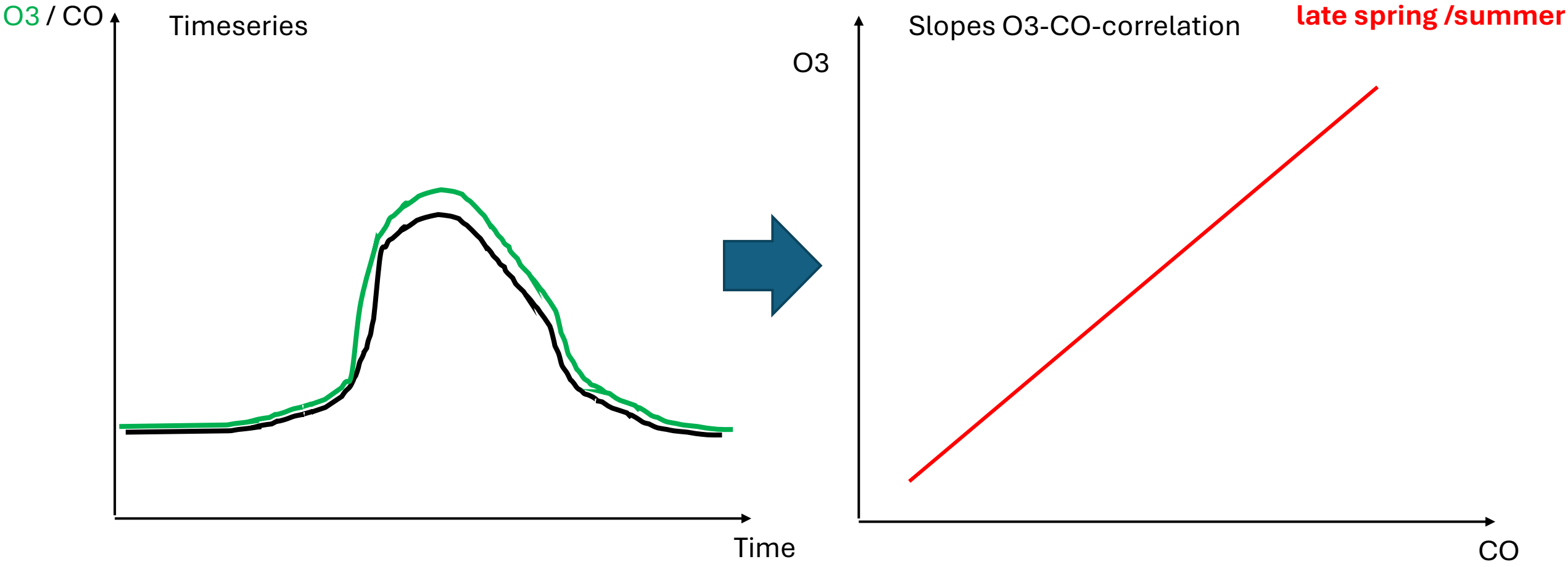



NETCARE 2015
O3 vs CO
colored by Theta
all data
O3 [ppbv]
CO [ppbv]
Theta [K]
310.00
303.64
297.27
290.91
284.55
278.18
271.82
265.45
259.09
252.73
246.36
240.00

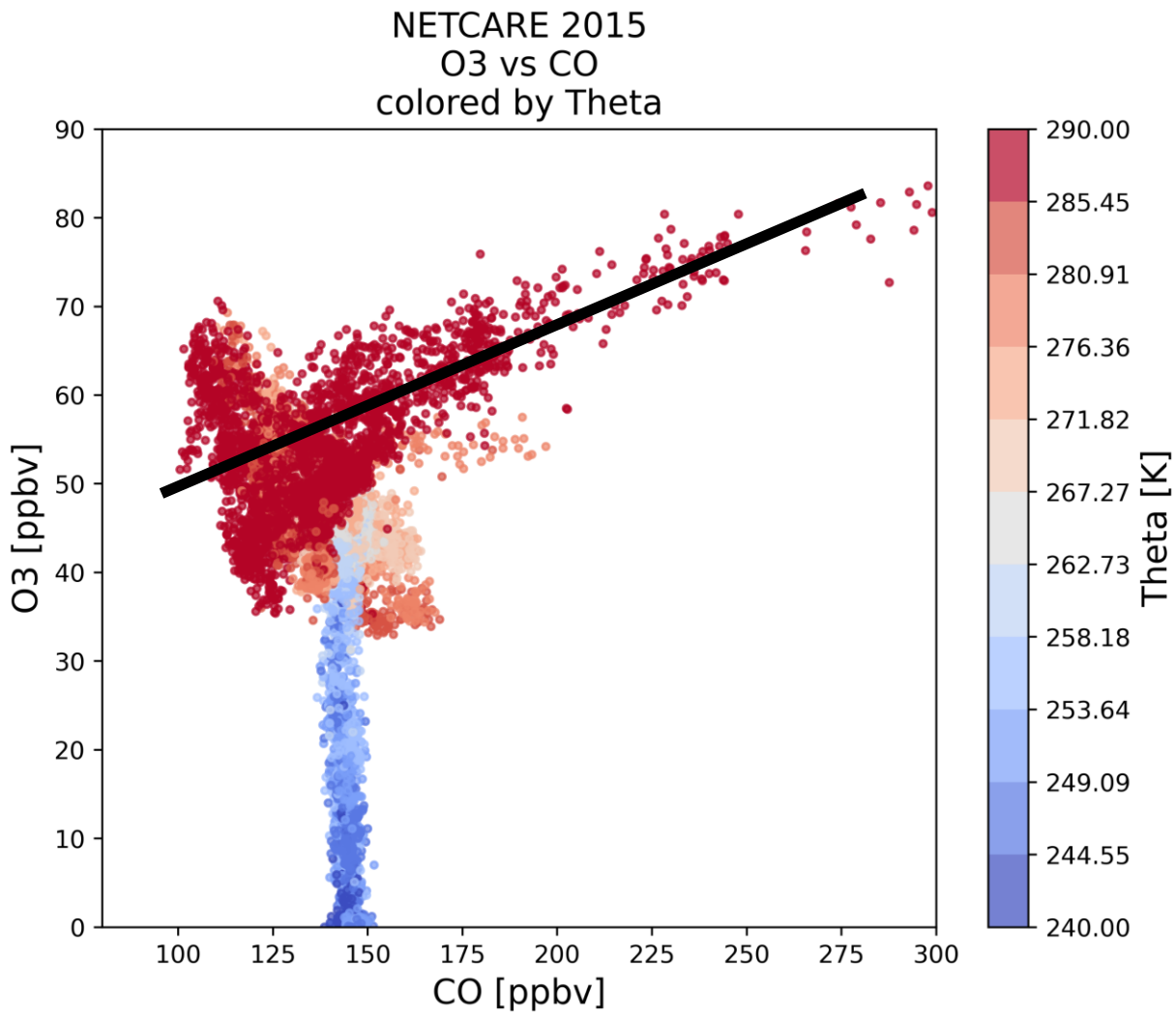

PAMARCMIP 2017
O3 vs CO
colored by Theta
all data
O3 [ppbv]
CO [ppbv]
Theta [K]
310.00
303.64
297.27
290.91
284.55
278.18
271.82
265.45
259.09
252.73
246.36
240.00

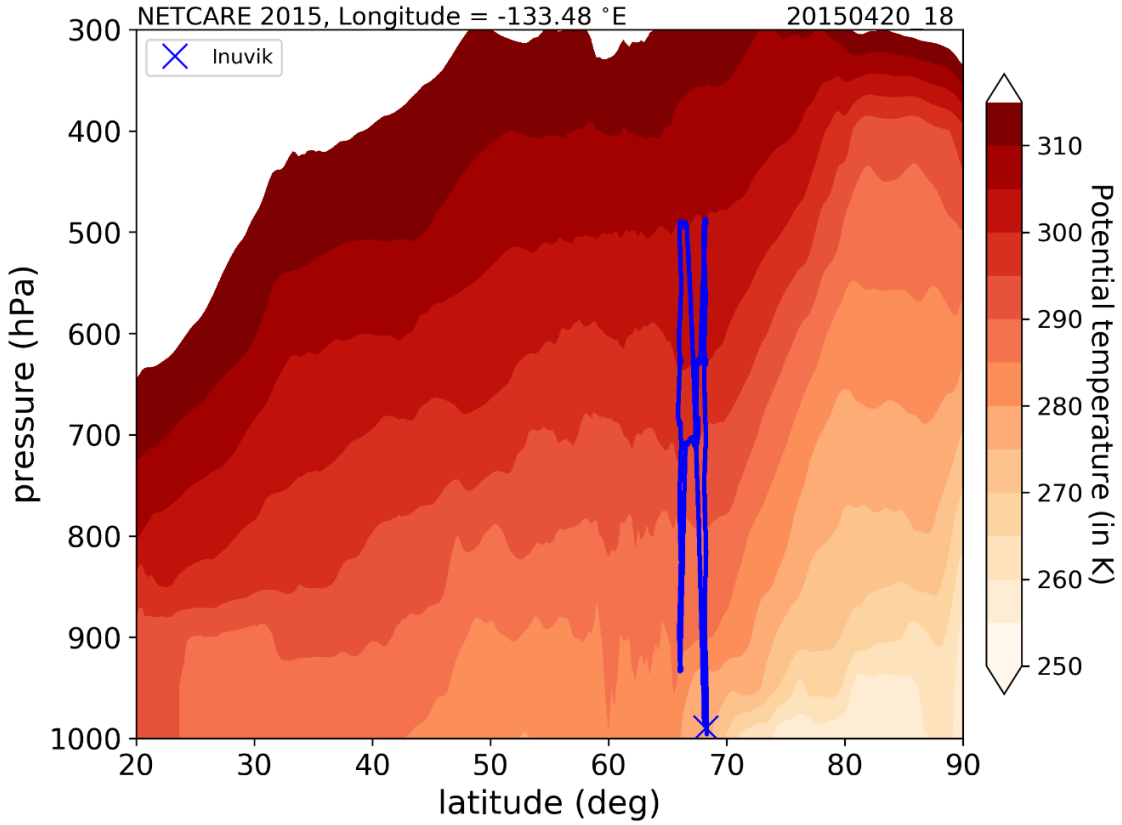

CEASAR 2024
O3 vs CO
colored by Theta
background only
O3 [ppbv]
CO [ppbv]
Theta [K]
310.00
303.64
297.27
290.91
284.55
278.18
271.82
265.45
259.09
252.73
246.36
240.00

O_3-CO-correlation – photochemical production in photochemically active periode



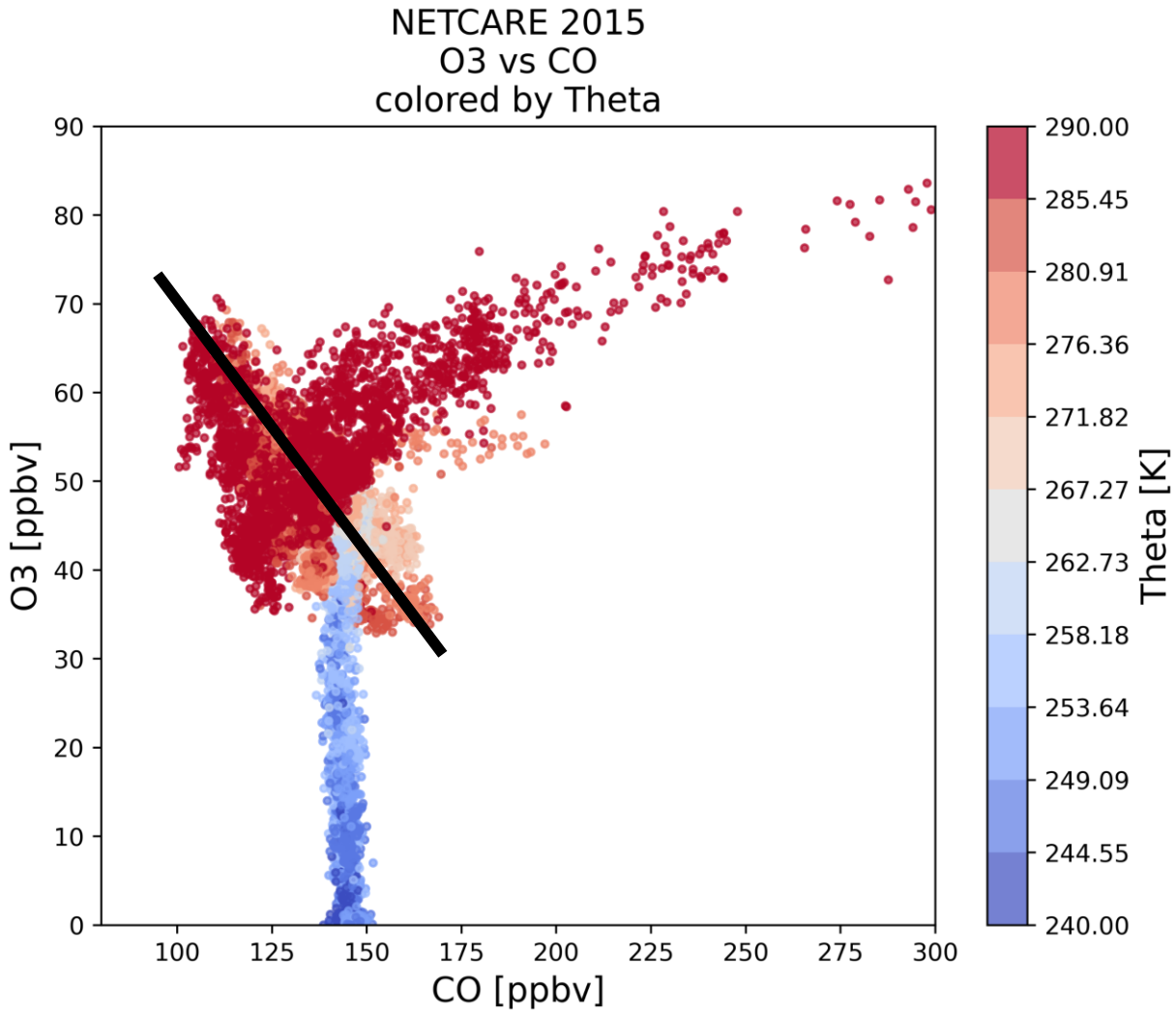
O3-CO-correlation – photochemical production in photochemically active periode

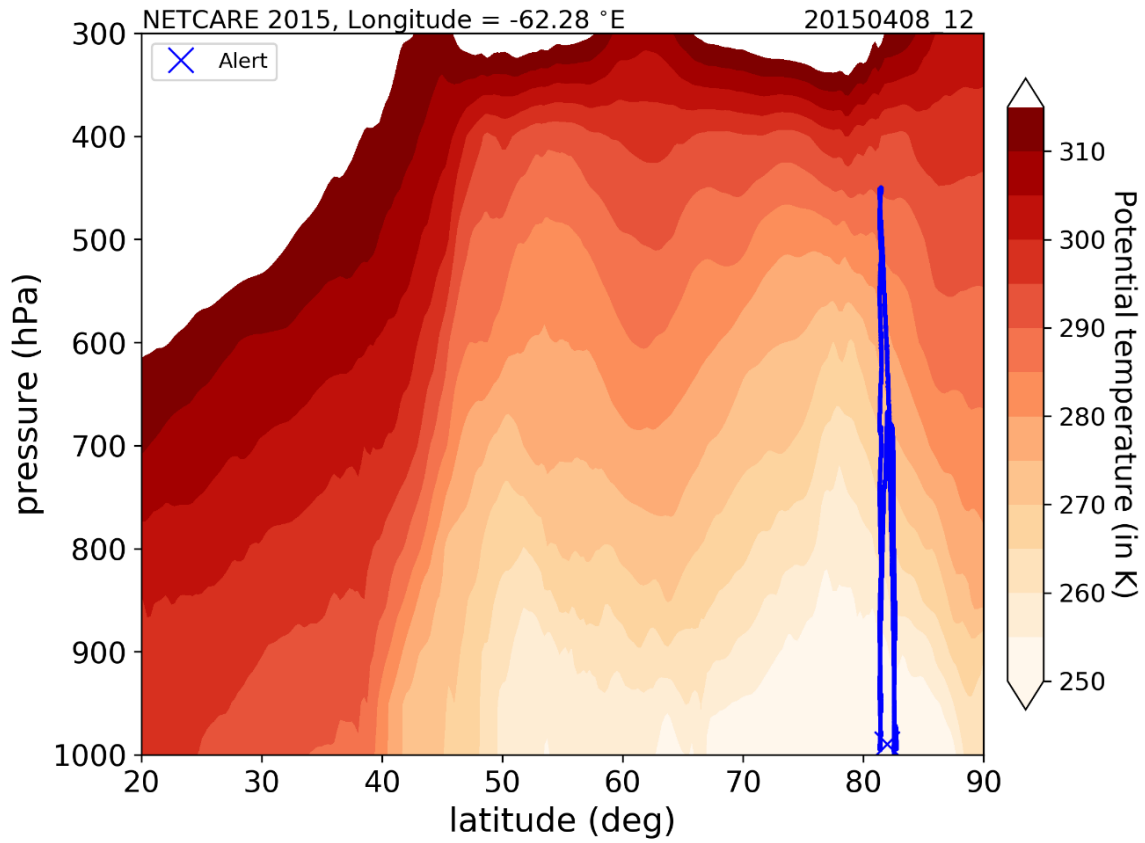




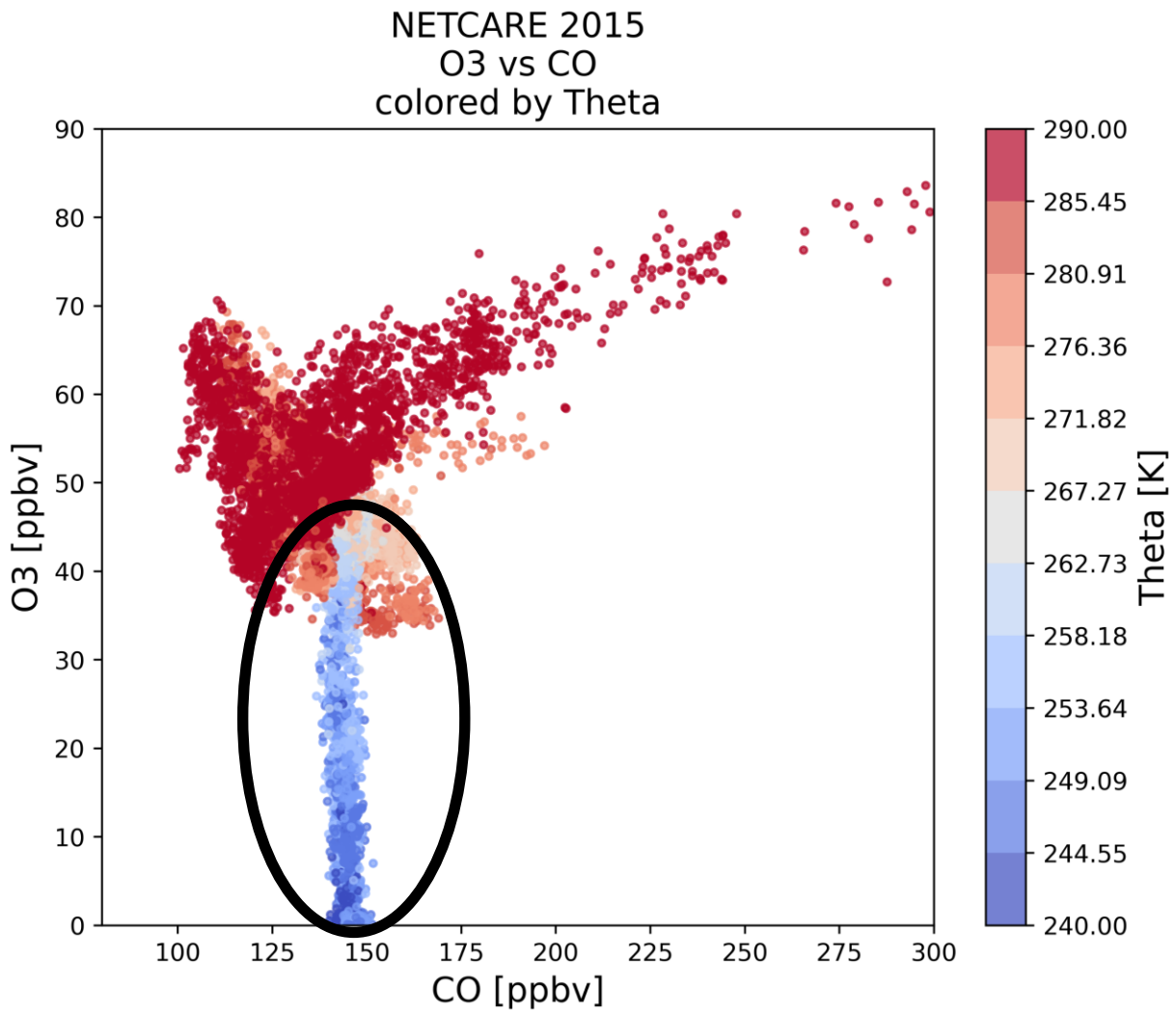
Correlation analysis

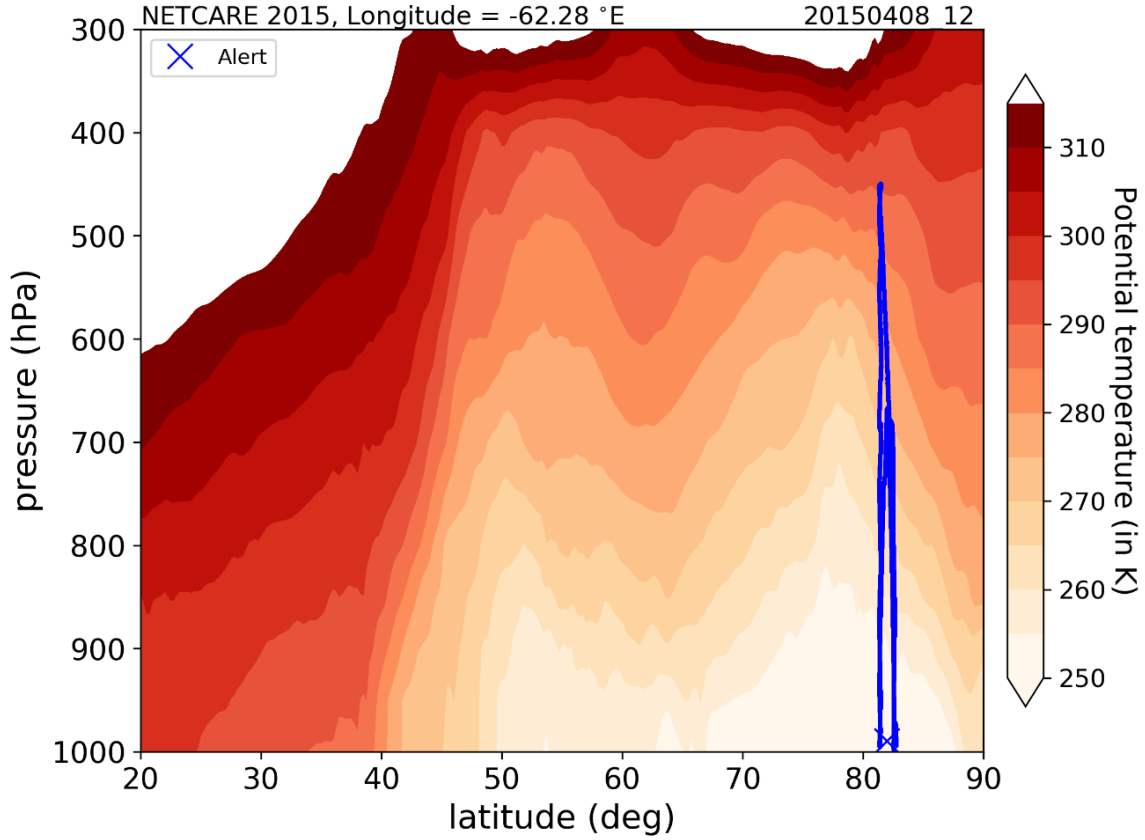
O3-CO-correlation – removal of ozone by reaction with anthropogenic pollution in photochemically not active periode



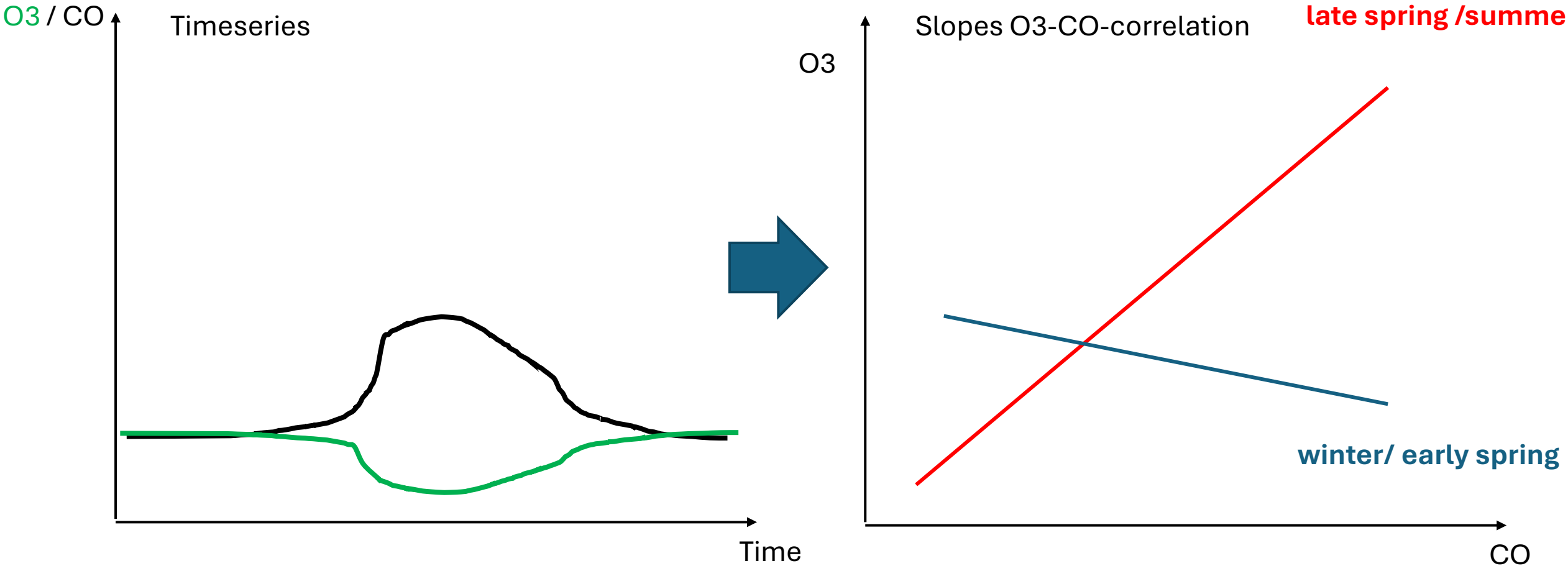


O3-CO-correlation – ozone depletion events

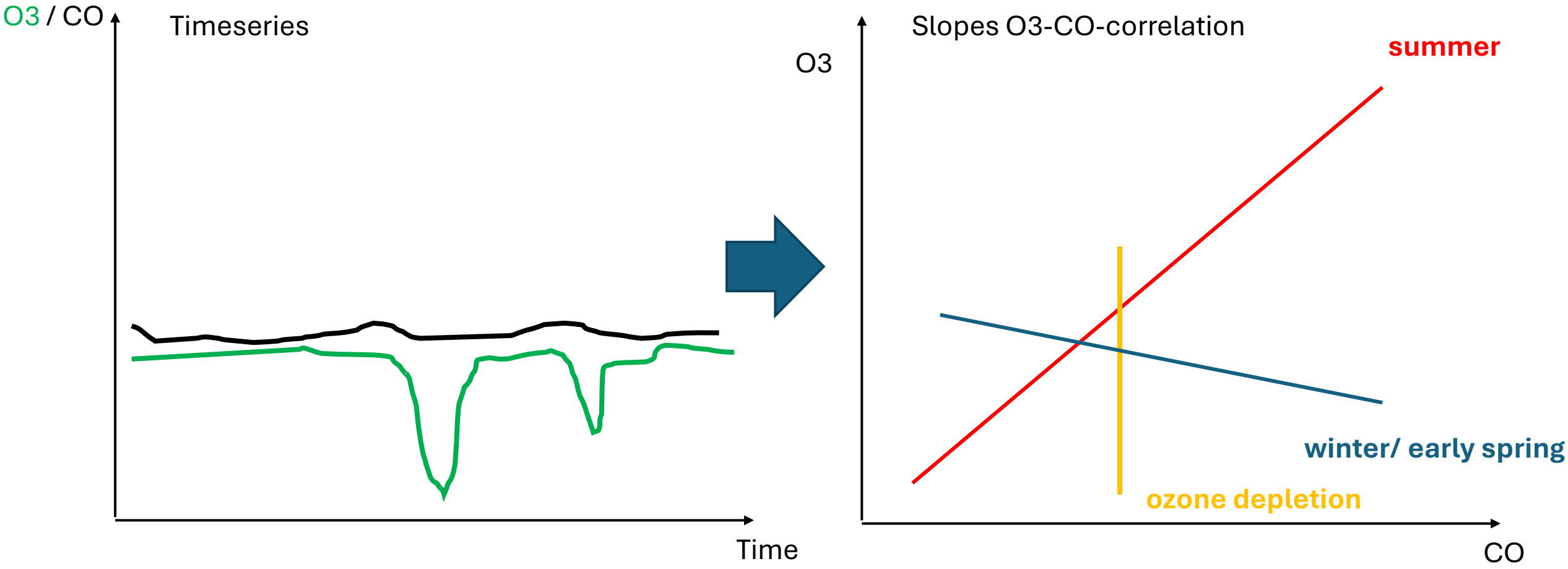




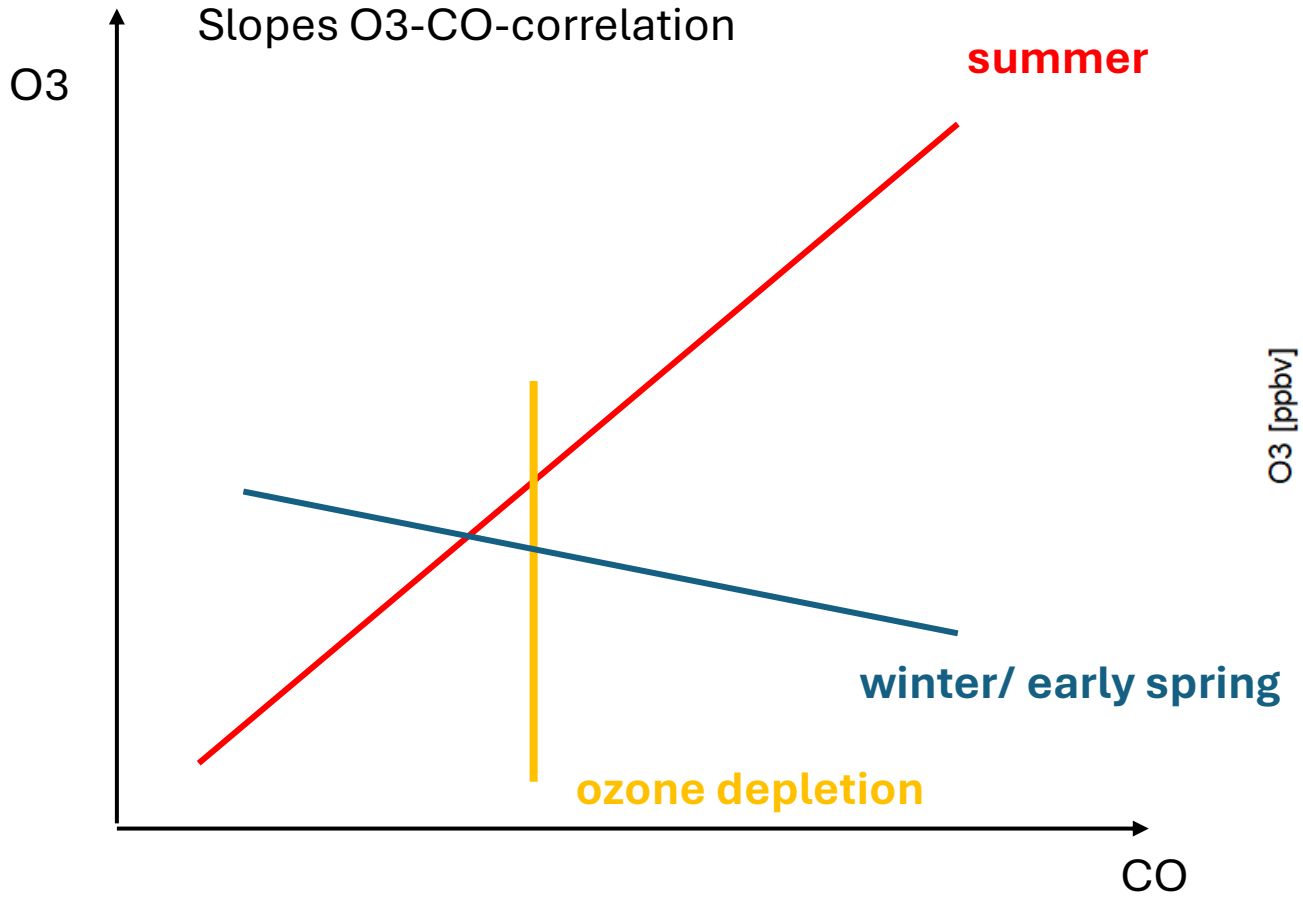
O3-CO-correlation – removal of ozone by reaction with anthropogenic pollution in photochemically not active periode

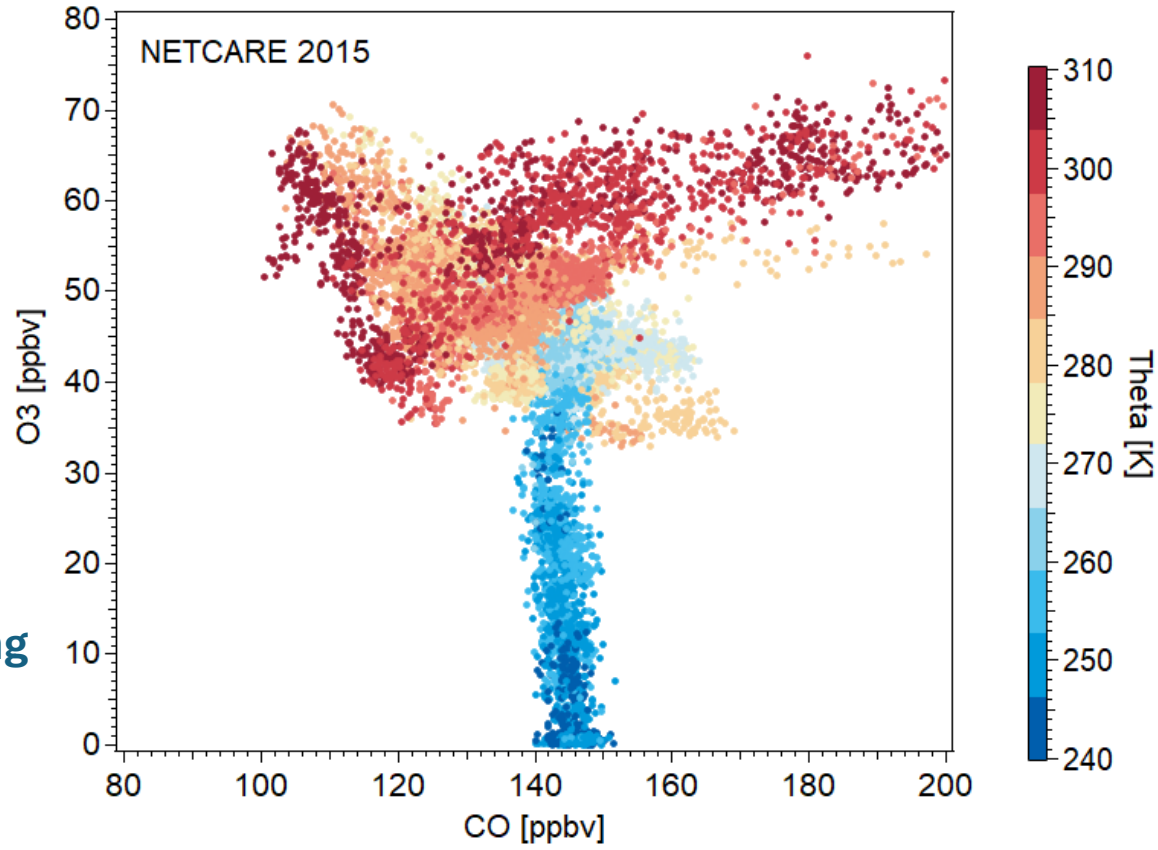


O3-CO-correlation – ozone depletion events

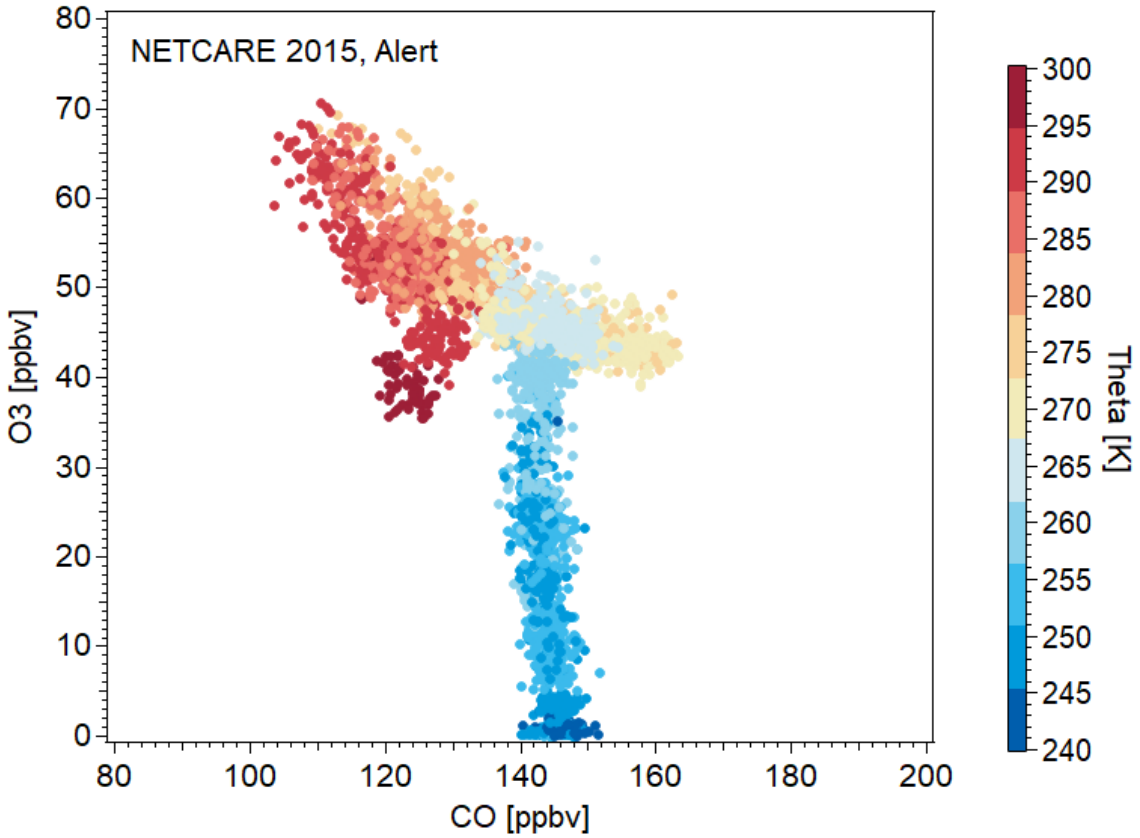


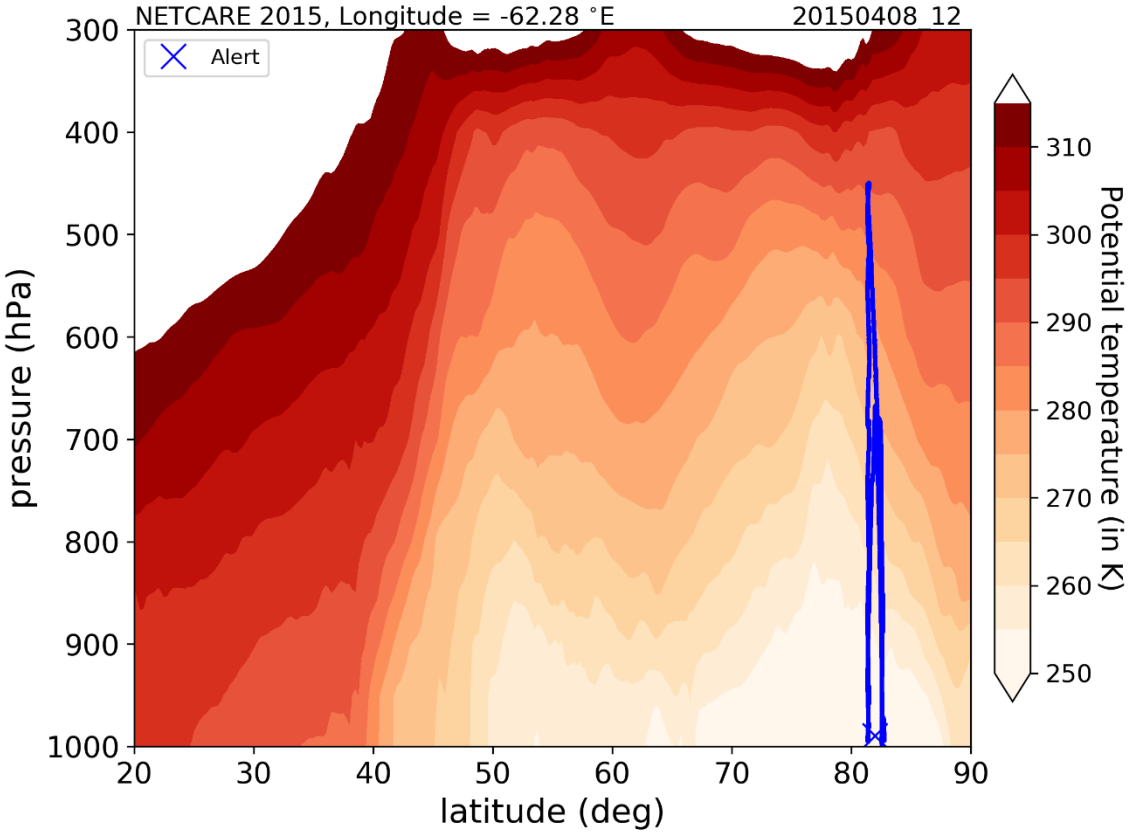
O3-CO-correlation – from the schematic to real data



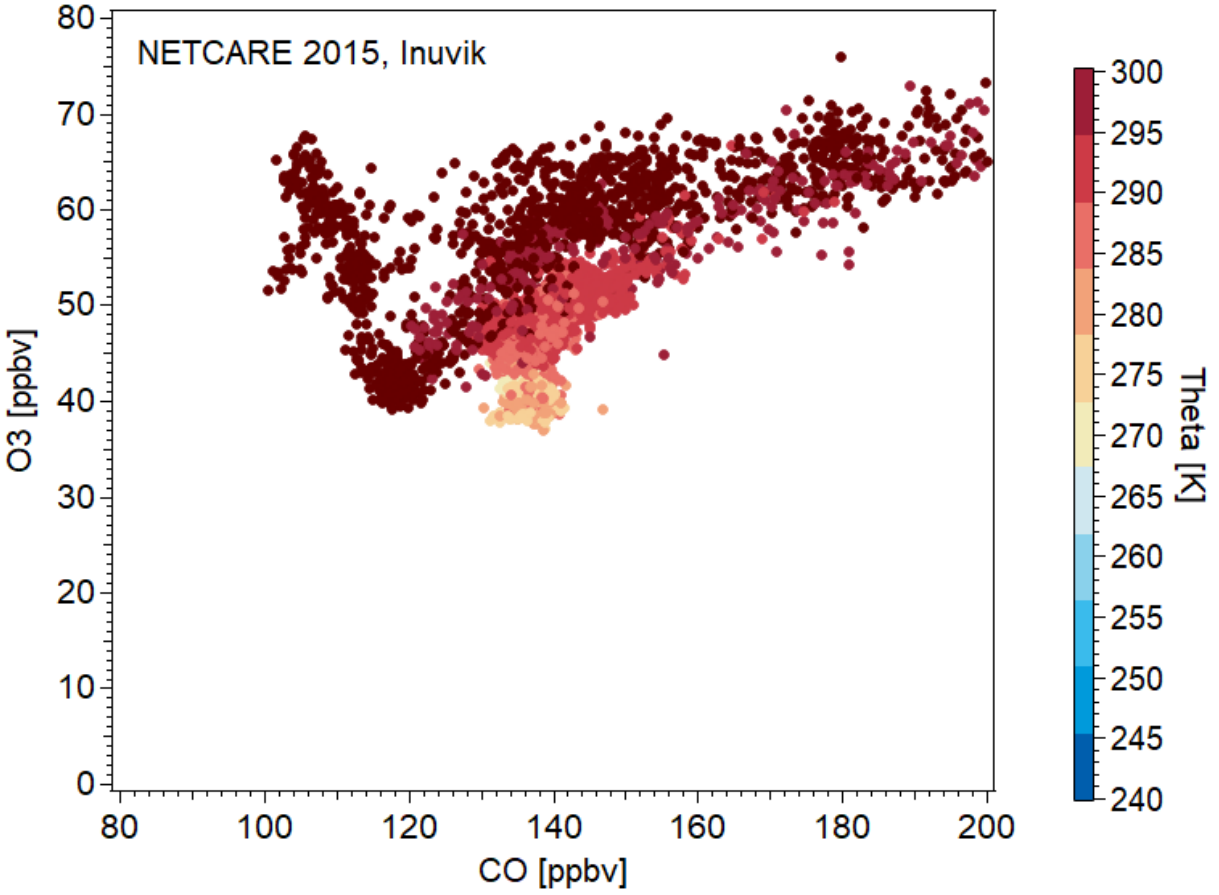


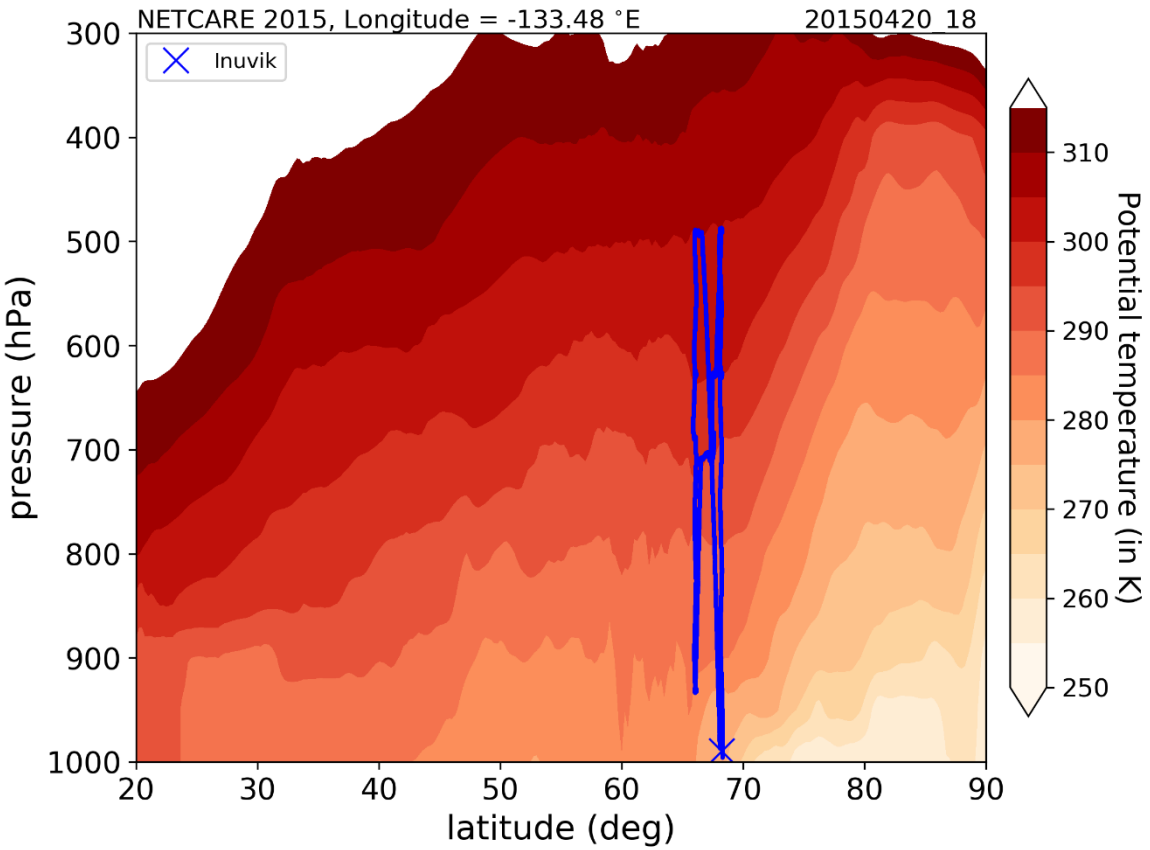
O3-CO-correlation – airborne in-situ data



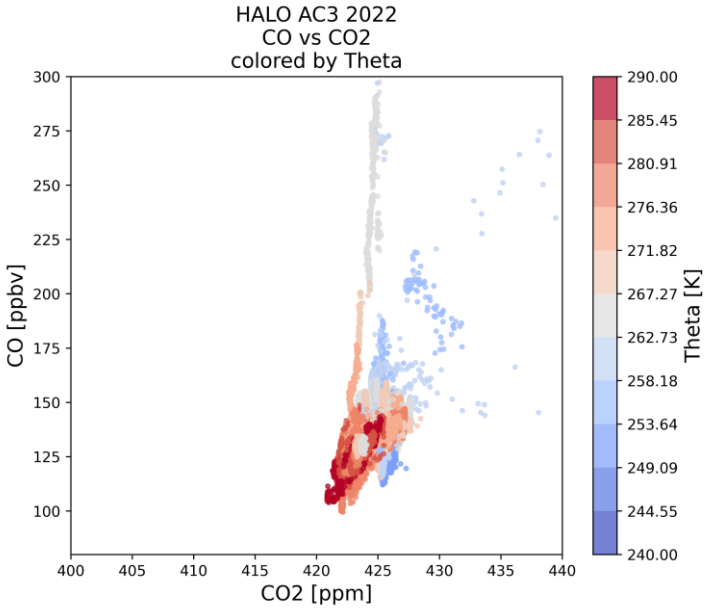


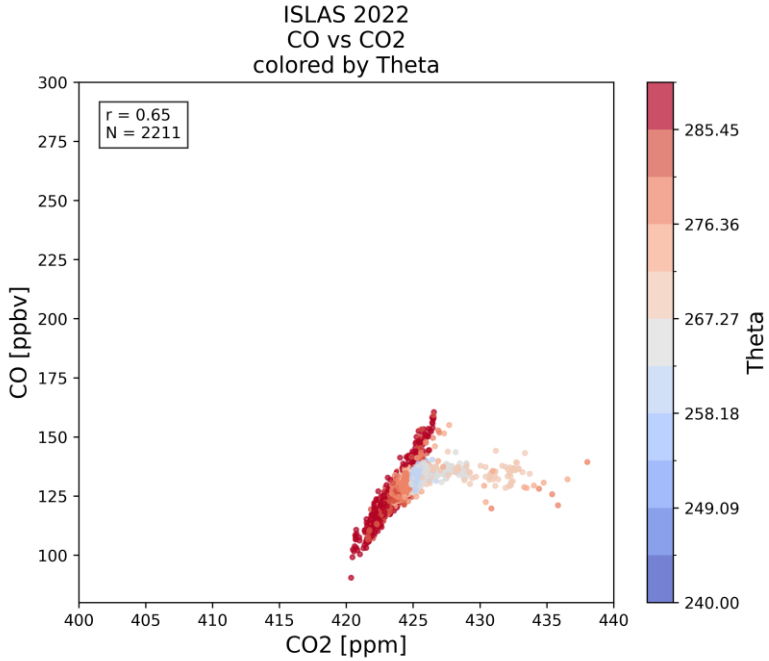
O3-CO-correlation – airborne in-situ data

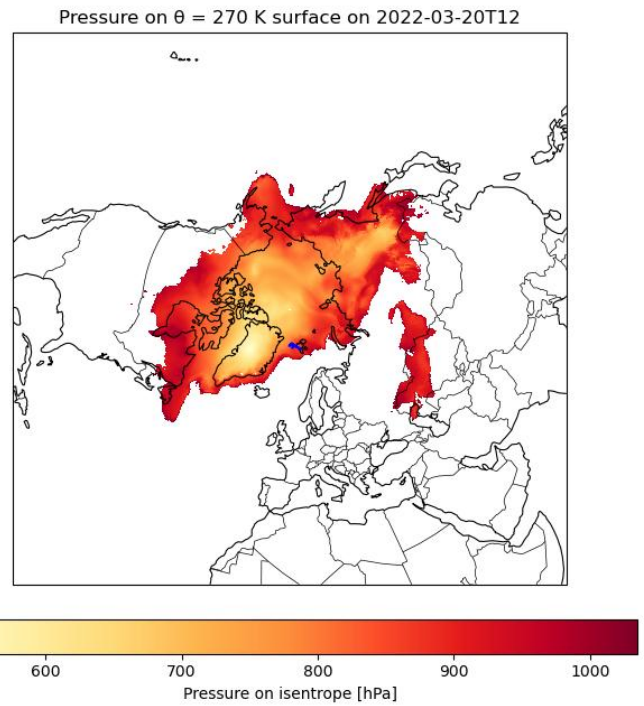


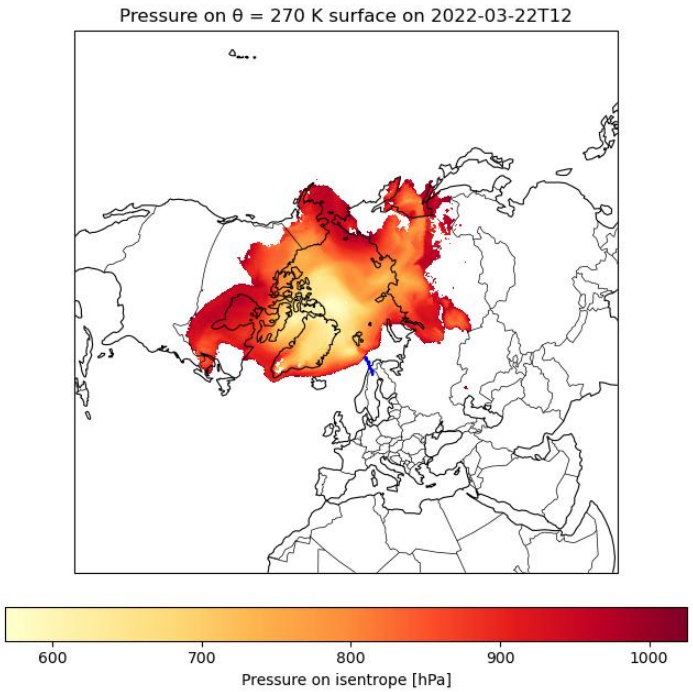


20.3.-10.4.2022

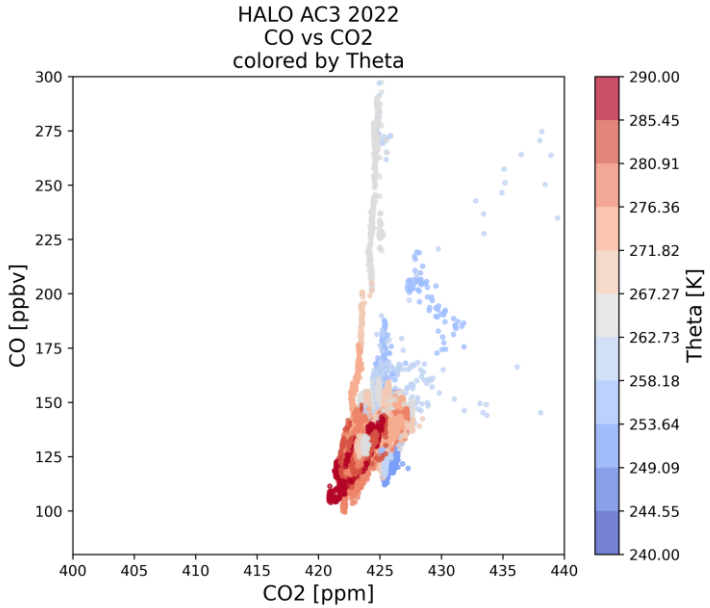

HALO AC3 2022
CO vs CO2
colored by Theta
CO [ppbv]
CO2 [ppm]
Theta [K]
290.00
285.45
280.91
276.36
271.82
267.27
262.73
258.18
253.64
249.09
244.55
240.00

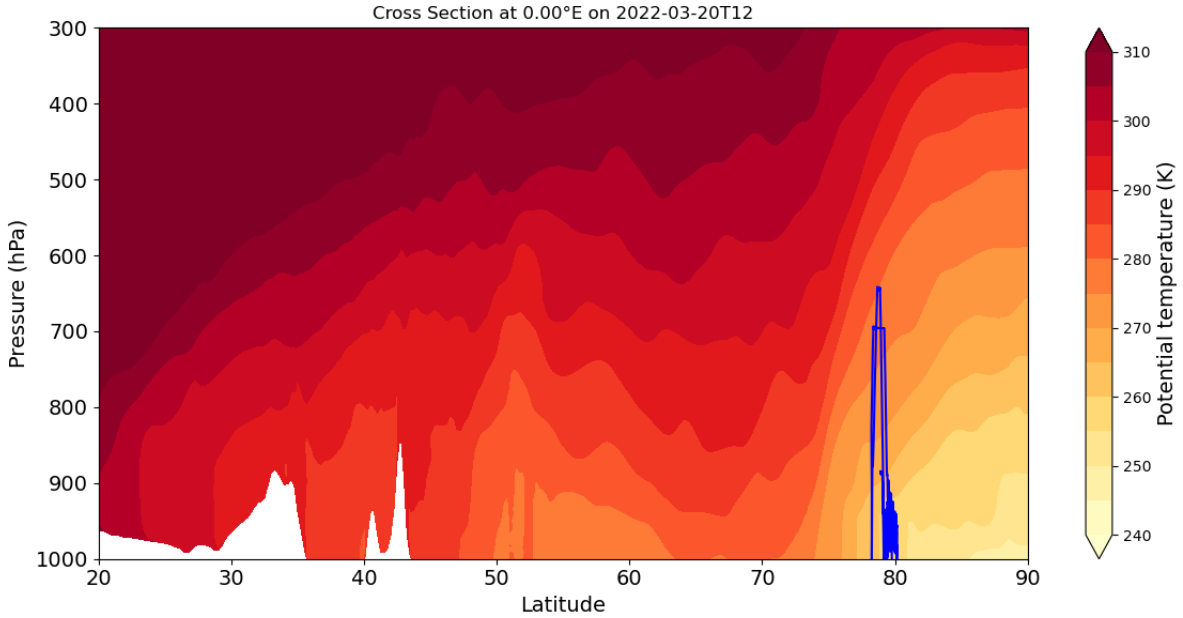

ISLAS 2022
CO vs CO2
colored by Theta
r = 0.65
N = 2211
CO [ppbv]
CO2 [ppm]
Theta
285.45
276.36
267.27
258.18
249.09
240.00

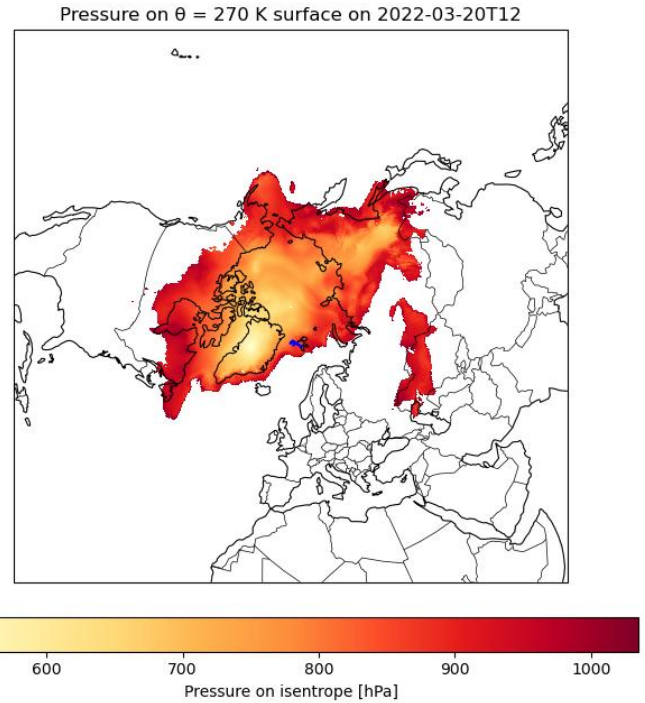

Pressure on θ = 270 K surface on 2022-03-20T12
600
700
800
900
1000
Pressure on isentrope [hPa]


Pressure on θ = 270 K surface on 2022-03-22T12
600
700
800
900
1000
Pressure on isentrope [hPa]

20.3.-10.4.2022


HALO AC3 2022
CO vs CO2
colored by Theta
CO [ppbv]
CO2 [ppm]
Theta [K]
300
275
250
225
200
175
150
125
100
400
405
410
415
420
425
430
435
440
290.00
285.45
280.91
276.36
271.82
267.27
262.73
258.18
253.64
249.09
244.55
240.00


Cross Section at 0.00°E on 2022-03-20T12
Pressure (hPa)
Latitude
Potential temperature (K)
300
400
500
600
700
800
900
1000
20
30
40
50
60
70
80
90
310
300
290
280
270
260
250
240


Pressure on θ = 270 K surface on 2022-03-20T12
600
700
800
900
1000
Pressure on isentrope [hPa]