Relating high ozone, ultrafine particles and new particle formation episodes using cluster analysis

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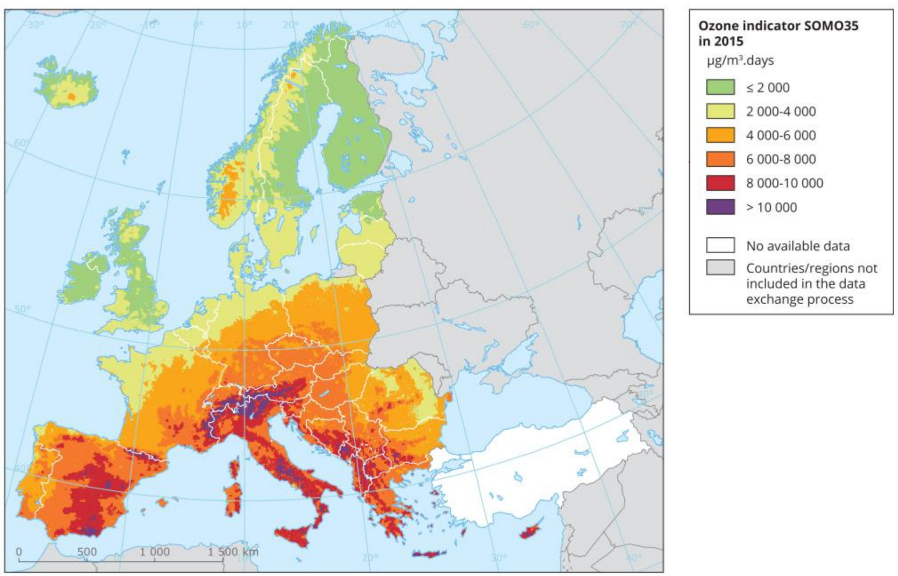
Ozone (O_3)

Table ES.1 Percentage of the urban population in the EU-28 exposed to air pollutant concentrations above certain EU and WHO reference concentrations (minimum and maximum observed between 2014 and 2016)

Pollutant	EU reference value ([a])	Exposure estimate (%)	WHO AQG ([a])	Exposure estimate (%)
$PM_{2.5}$	Year (25)	6-8	Year (10)	74-85
PM_{10}	Day (50)	13-19	Year (20)	42-52
O_3	8-hour (120)	7-30	8-hour (100)	95-98
NO_2	Year (40)	7-8	Year (40)	7-8
BaP	Year (1)	20-24	Year (0.12) RL	85-90
SO_2	Day (125)	< 1	Day (20)	21-38

Source: EEA (2018)

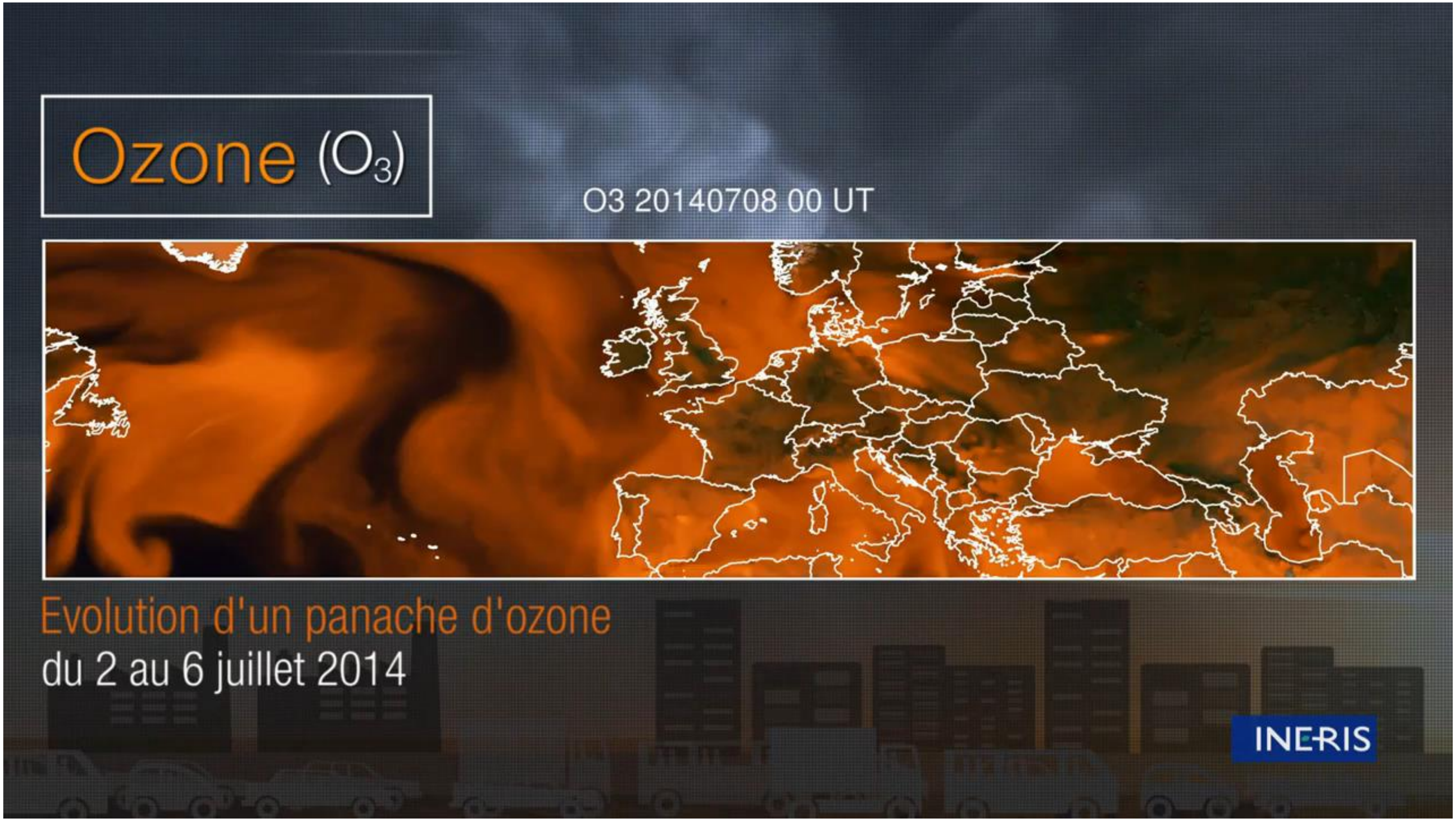


Source: ETC/ACM, 2018b.

	O_3	
Country	SOMO35 ([a])	Premature deaths ([b])
Austria	6 170	380
Belgium	2 790	220
Bulgaria	4 180	350
Croatia	6 240	230
Cyprus	6 390	40
Czechia	5 560	460
Denmark	2 200	90
Estonia	1 780	20
Finland	1 360	50
France	4 250	1 800
Germany	4 300	3 000
Greece	6 910	610
Hungary	5 550	530
Ireland	860	20
Italy	6 860	3 200
Latvia	2 560	50
Lithuania	2 800	90
Luxembourg	3 460	10
Malta	5 790	10
Netherlands	2 680	290
Poland	4 530	1 300
Portugal	3 990	300
Romania	2 950	580
Slovakia	5 460	210
Slovenia	6 650	100
Spain	5 820	1 800
Bosnia and Herzegovina	6 050	170
Former Yugoslav Republic of Macedonia	6 200	90
Iceland	260	< 1
Kosovo under UNSCR 1244/99	6 130	120
Liechtenstein	5 800	< 5
Monaco	8 020	< 5
Montenegro	6 790	30
Norway	1 760	50
San Marino	7 180	< 5
Serbia	5 280	420
Switzerland	6 170	300
EU-28	**4 250**	**16 400**
Total	**4 310**	**17 700**

Source: EEA (2018)

17 700 premature deaths per year in Europe
(excl. Ukraine, Belarus, Moldova, Turkey and Russia)



Source: INERIS (www.ineris.fr/fr/ineris/actualites/qualite-air-racontee-modelisation)

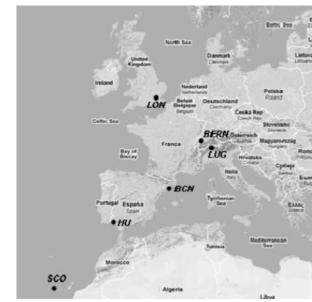
- Maximum concentrations in the southern regions (Mediterranean)
- Local formation and depletion (daily cycles)
- Long-range transport (European and hemispheric)

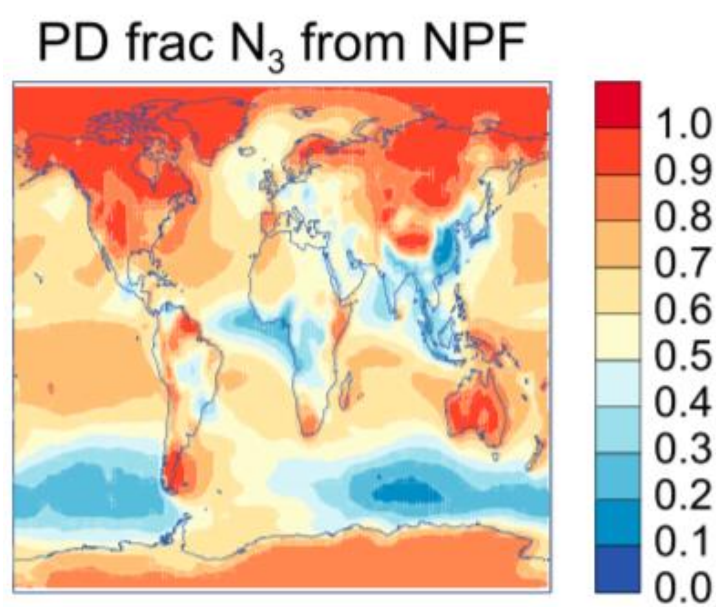
Ultrafine Particles (UFP)

N : Particle number concentration
N1 : Contribution of vehicle exhaust to N
N2 = N – N1 : Contribution of new particle formation or primary particles excluding vehicle exhaust (e.g., biomass burning, biogenic emissions, residential emissions)

(Reche et al., 2011)

%	BCN	LUG	NK	Bern	MR	HU	SCO
N1	46	39	54	45	78	38	47
N2	54	61	46	55	22	62	53
N1 (11:00–14:00 h UTC)	31	41	45	49	91	15	36
N2 (11:00–14:00 h UTC)	69	59	55	51	9	85	64



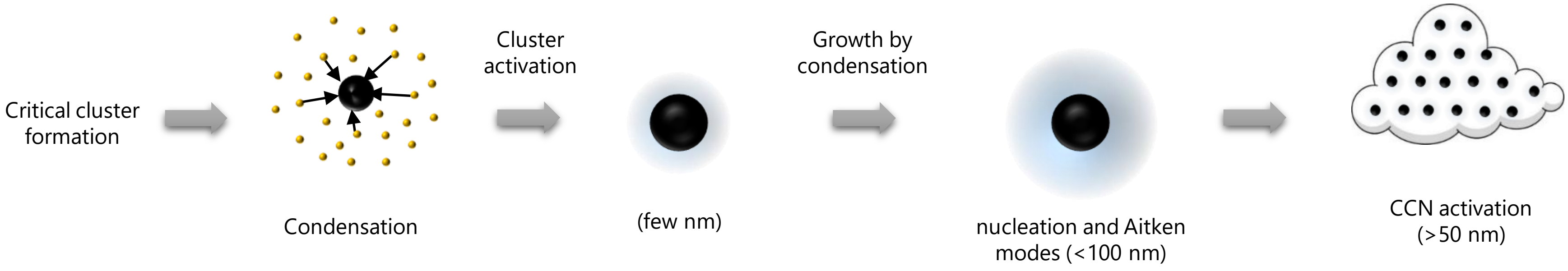


Secondary particles dominate UFP number concentration in the global troposphere

(Gordon et al., 2017)

New Particle Formation (NPF)

Atmospheric new particle formation and growth involves the formation of molecular clusters and their subsequent growth from gaseous precursors to larger sizes, up to sizes at which these particles may act as cloud condensation nuclei (CCN).

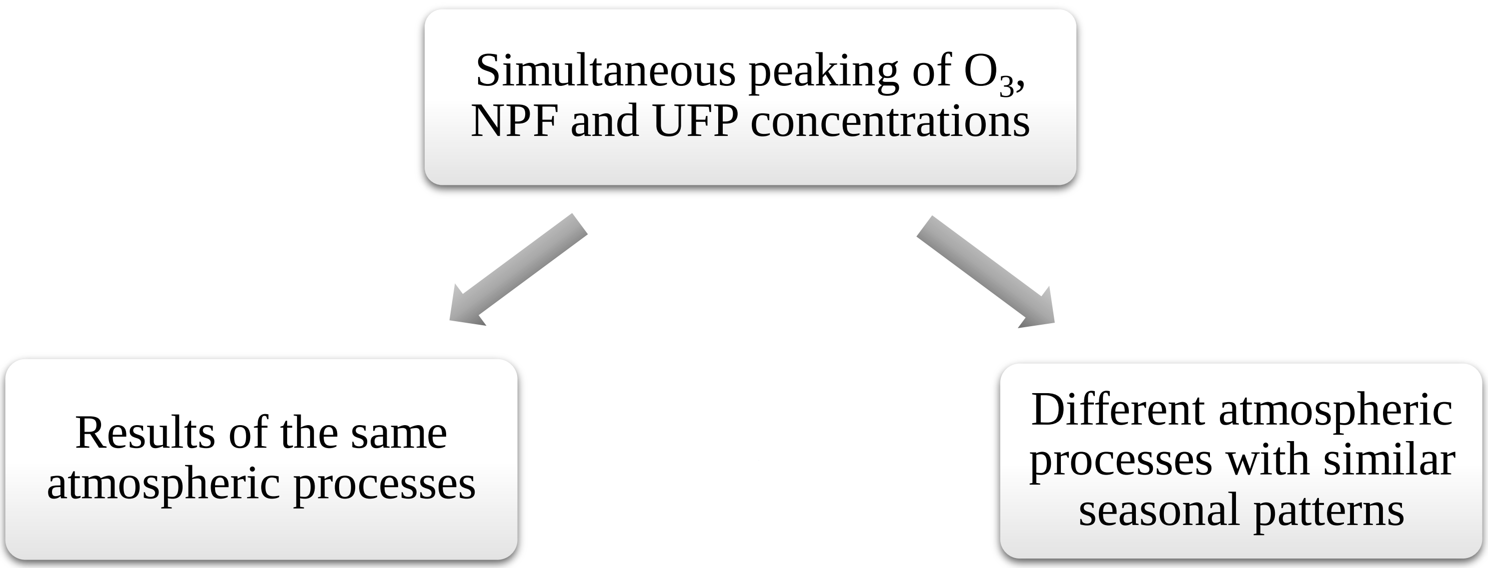


The interest in NPF lies in its potential ability to increase – even dominate – UFP number concentration and CCN concentration.

Simultaneity of O_3, NPF and UFP

Previous studies on particle number size distribution in high insolation urban areas reveal the **frequent simultaneous occurrence of NPF and O_3 episodes in spring and summer**

(e.g., Fernández-Camacho et al., 2010; Minoura and Takekawa, 2005; Park et al., 2008; Pey et al., 2009; Brines et al., 2015; Wonaschütz et al., 2015; Wang et al., 2016)



Area of study

Montseny (MSY; Barcelona, Spain)

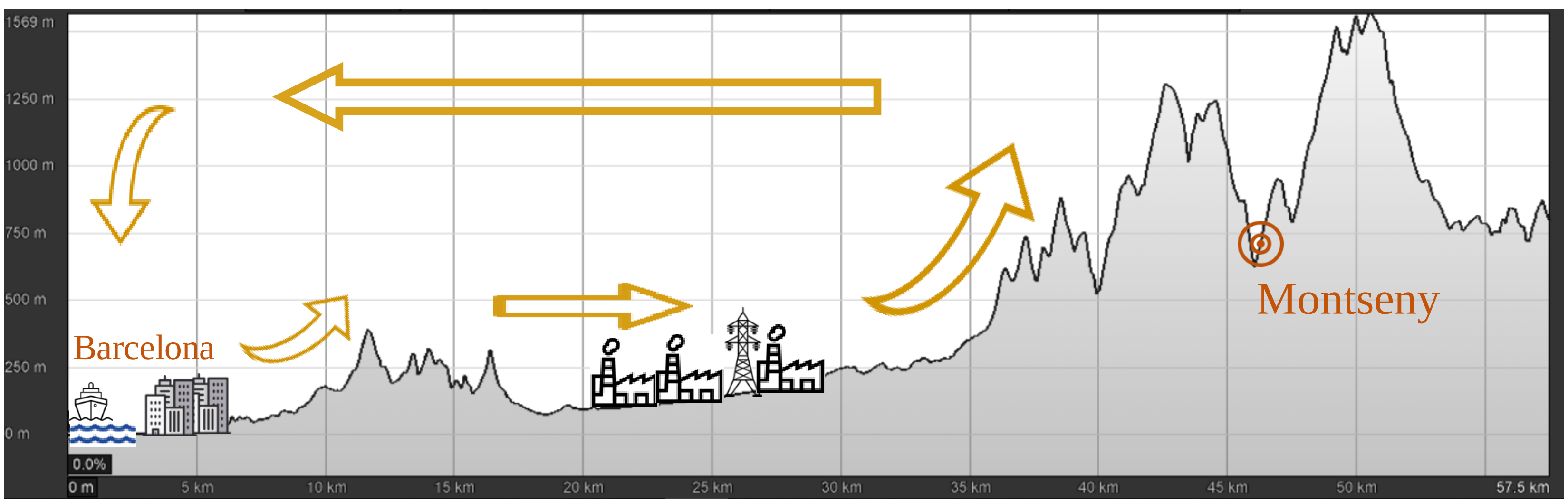
41°46’45.63″N, 02°21’28.92″E

720 m a.s.l.

ACTRIS

GLOBAL ATMOSPHERE WATCH

Generalitat de Catalunya
Departament de Territori i Sostenibilitat



Instrumentation

2014 – 2018 (April – Sept)

O_3: Photometry-based analyzer (MCV 48AV)

$N_{9\text{-}856\,nm}$: SMPS (TROPOS) + CPC (TSI 3772)

NOx: Chemiluminiscence-based analyzer (Thermo Scientific 42i-TL)

SO_2: UV fluorescence analyzer (Teledyne T100)

BC: MAAP

Meteorological data: Davis Vantage Pro Plus

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12 June – 1 August 2017

UNIVERSITY OF HELSINKI

AIS (Air Ion Spectrometer; Airel Ltd.): ion spectra 0.8 – 40 nm

PSM (Particle Size Magnifier; Airmodus): number size distribution 1.15 – 2.6 nm

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10 – 14 July 2017

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Balloon soundings 0 – 2 km a.g.l.

Resolution: 45 s, ~25 m

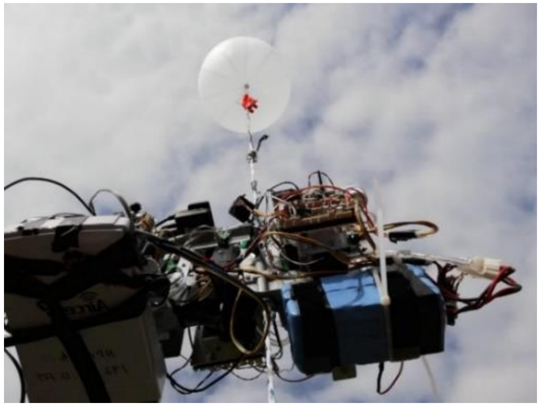
$N_{8\text{-}245\,nm}$: Hy-SMPS

$N_{>3\,nm}$: Hy-CPC

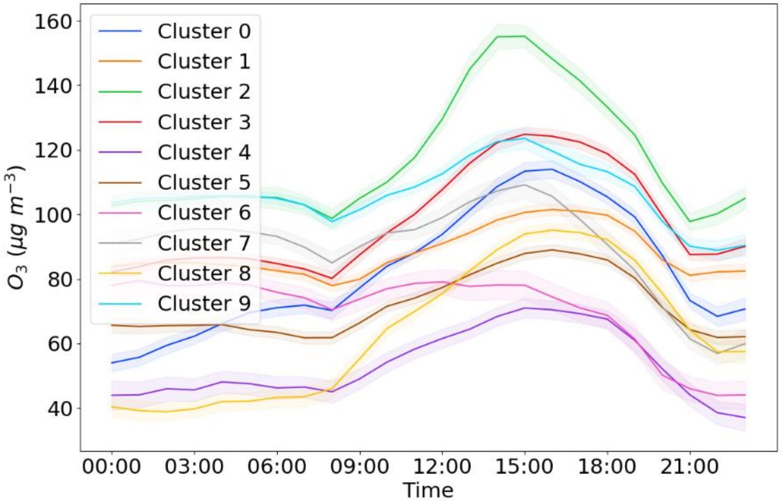
O_3: POM (2B Technologies)

BC: microAethalometer

Meteorological data: T, RH, P, WS, WD

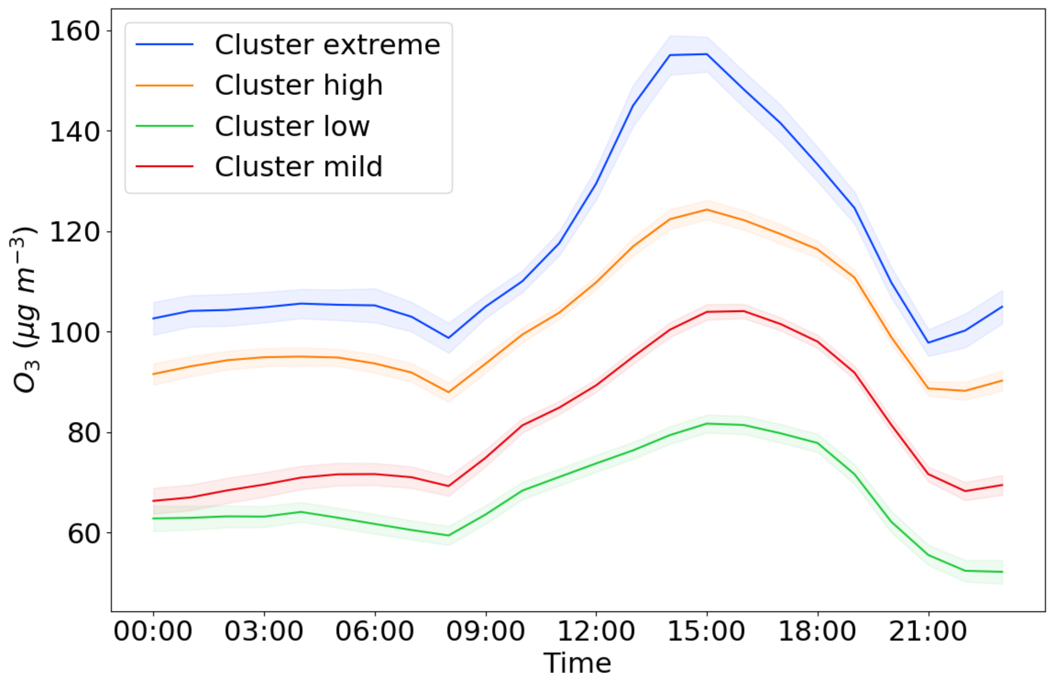


Clustering O_3 daily cycles



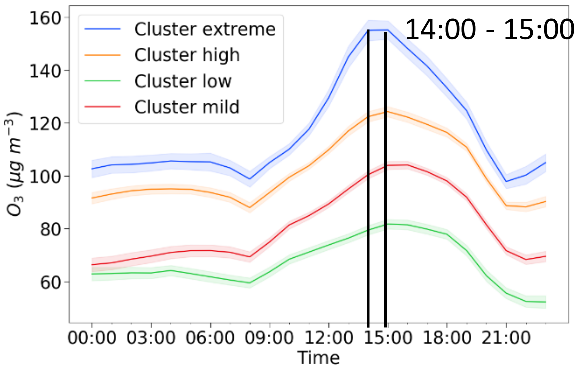
The number of clusters was chosen manually so that only 1 cluster contained exceedances of the EU hourly target value (180 μg m^{-3} h^{-1}), using the minimum number of clusters.

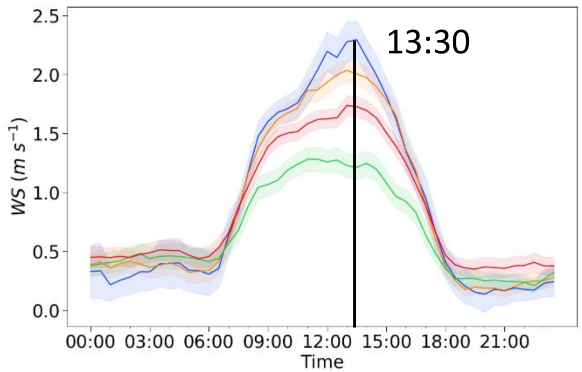
We detected clusters that share similar patterns in all or most of the variables considered and we grouped them into 4 clusters.

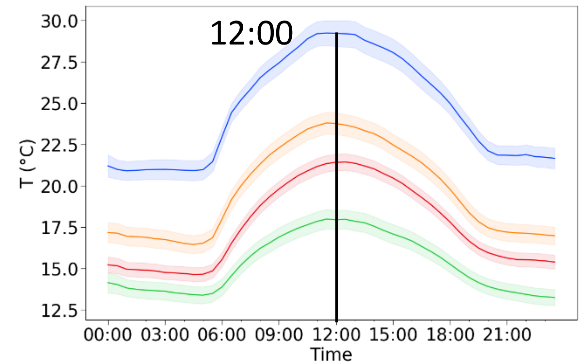


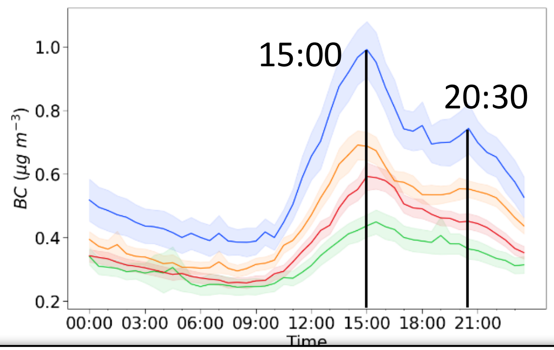
* Shaded areas show 95% confidence intervals

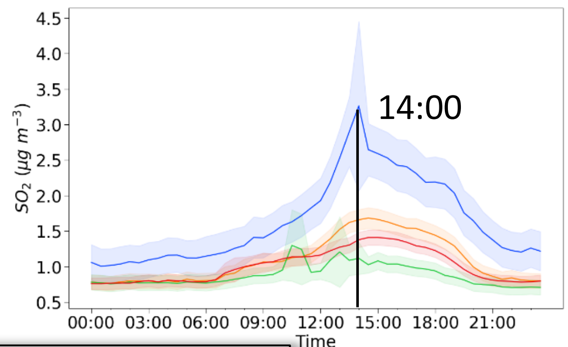
Average daily cycles

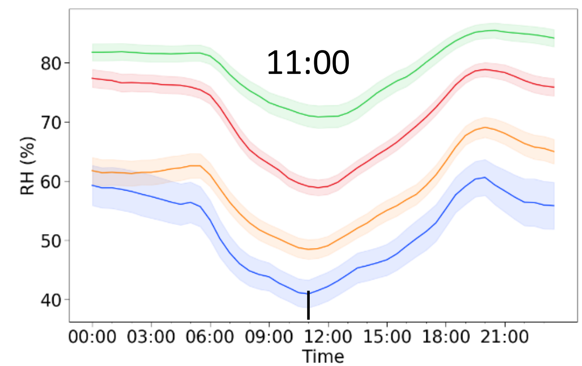




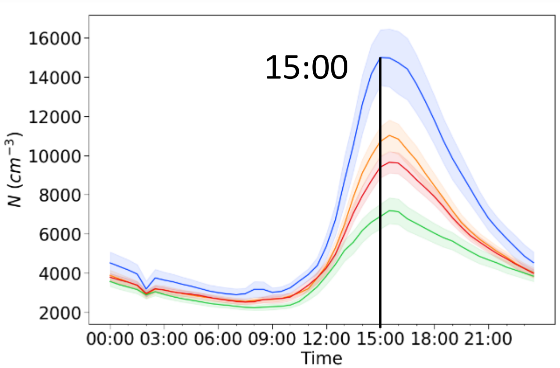


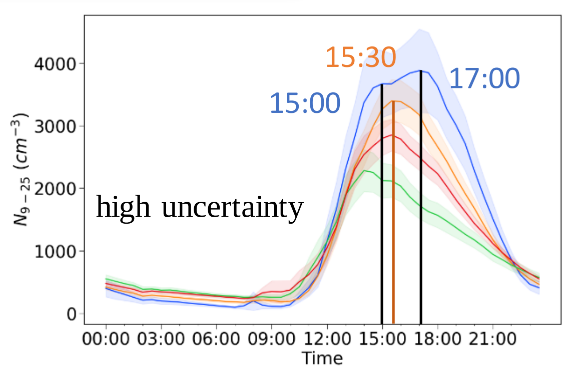


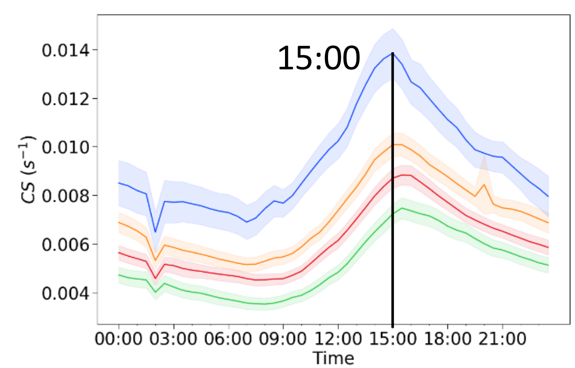




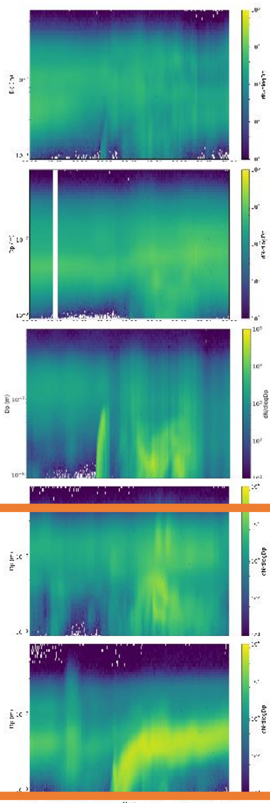
BC and N peak simultaneously → Peak in N <u>not</u> related to NPF







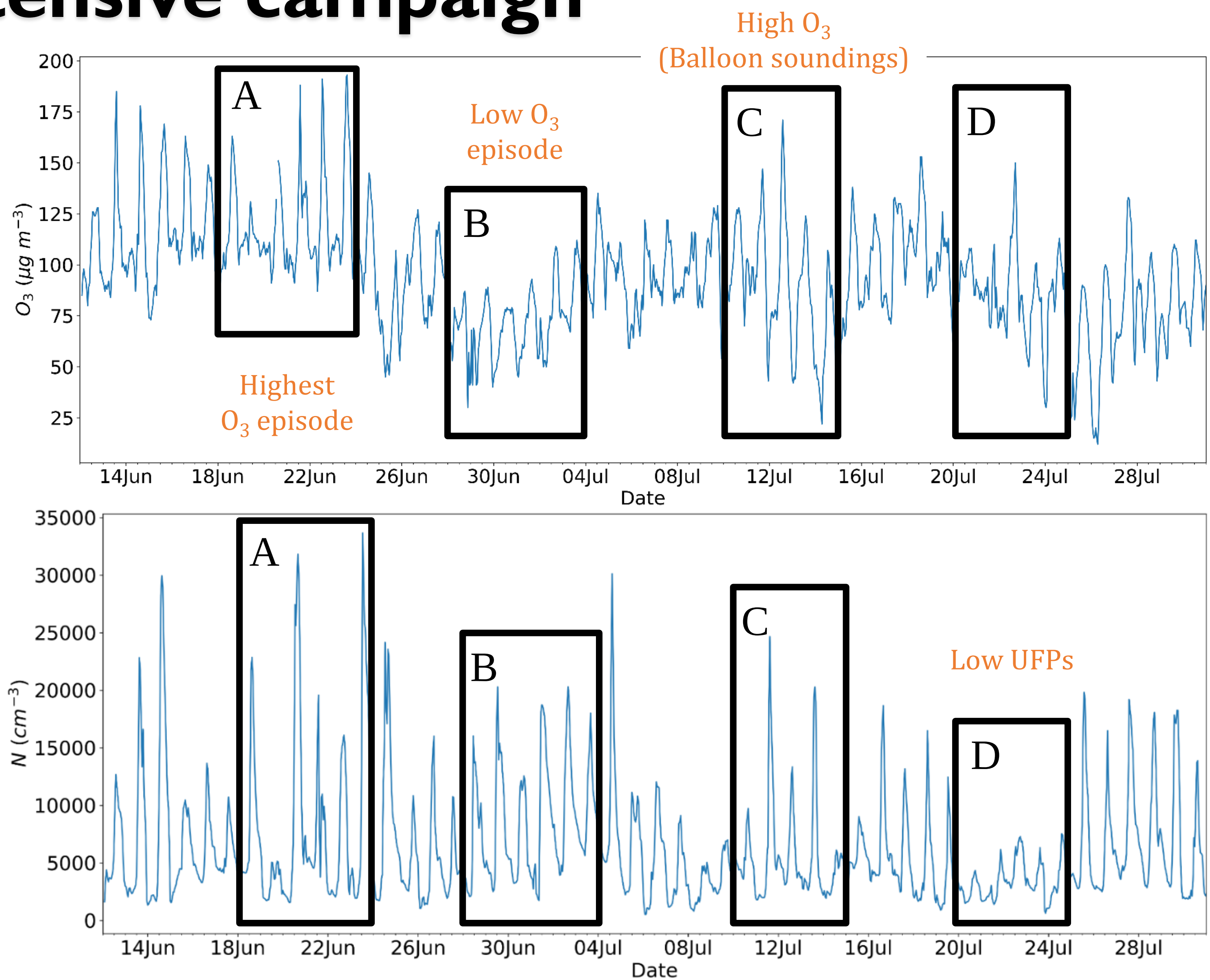
O_3 and New Particle Formation



NPF category	Extreme O_3	High O_3	Mild O_3	Low O_3
No data	11.9%	14.2%	16.2%	21.8%
Non-event	72.9%	66.1%	60.8%	56.4%
Undefined	3.4%	[illegible]	[illegible]	1.3%
Bursts	10.2%	10.1%	8.8%	8.5%
Class II event	1.7 %	3.2 %	2.8 %	3.4 %
Class I event	0.0 %	3.7 %	8.5 %	8.6 %

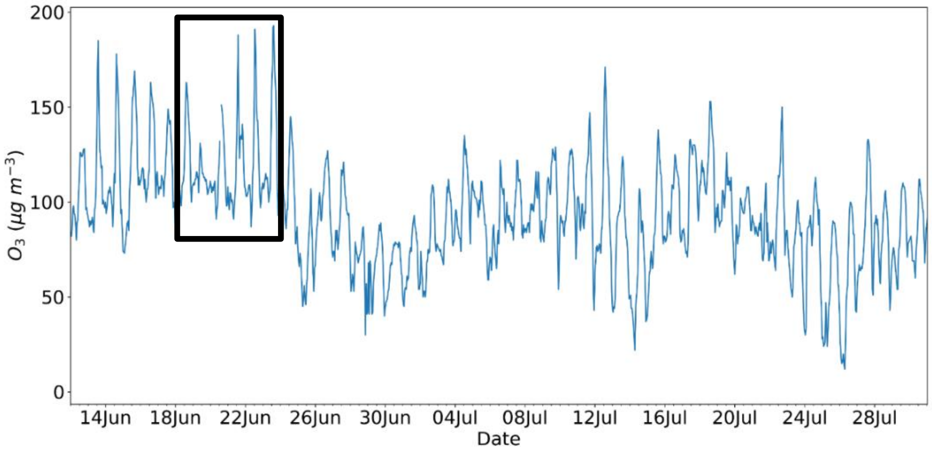
NPF is less frequent the higher the O_3

Intensive campaign

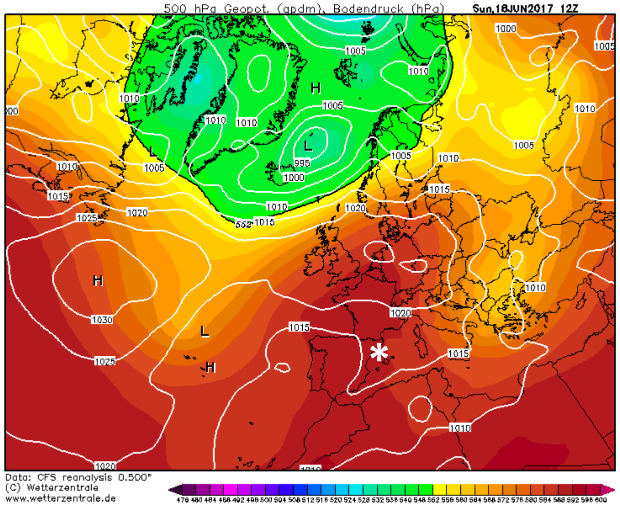


Case A: Highest O_3 episode

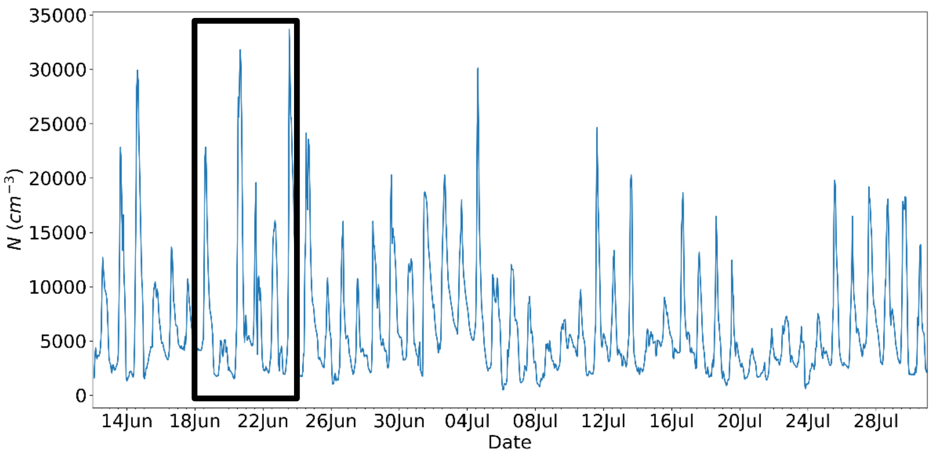
Highest O_3



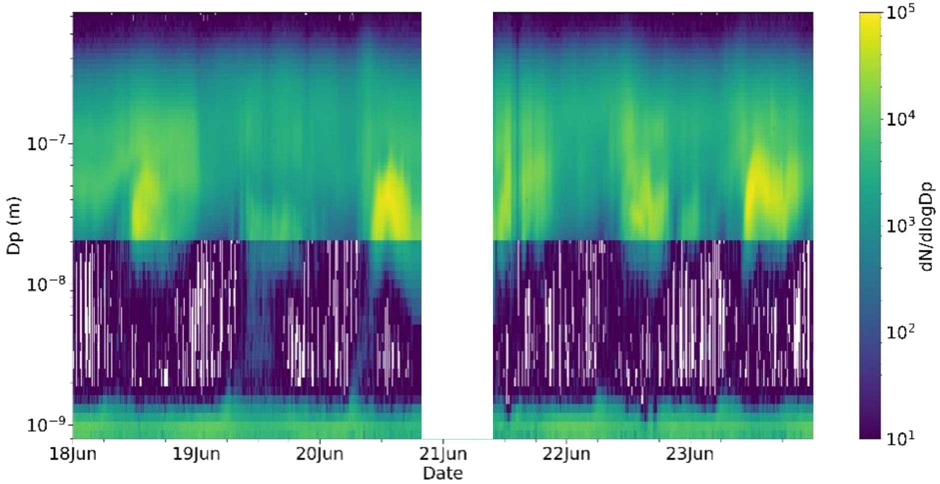
Heat wave, stagnation



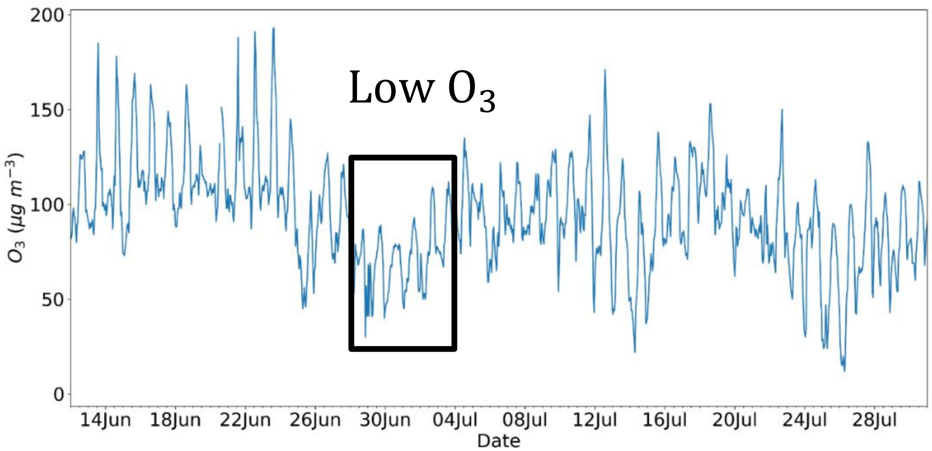
Highest UFP conc



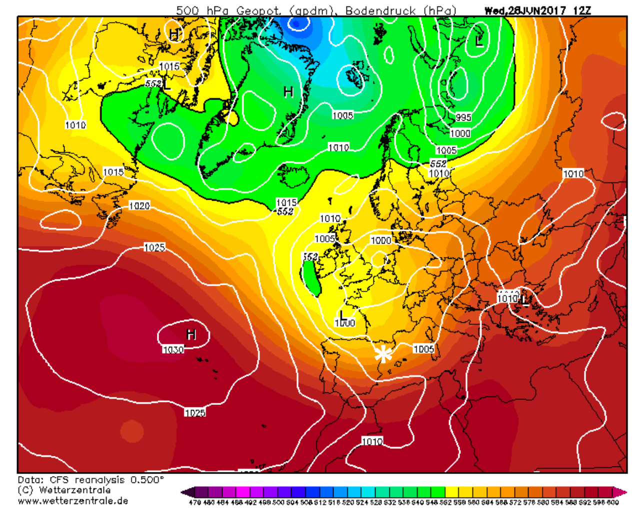
NPF not favoured

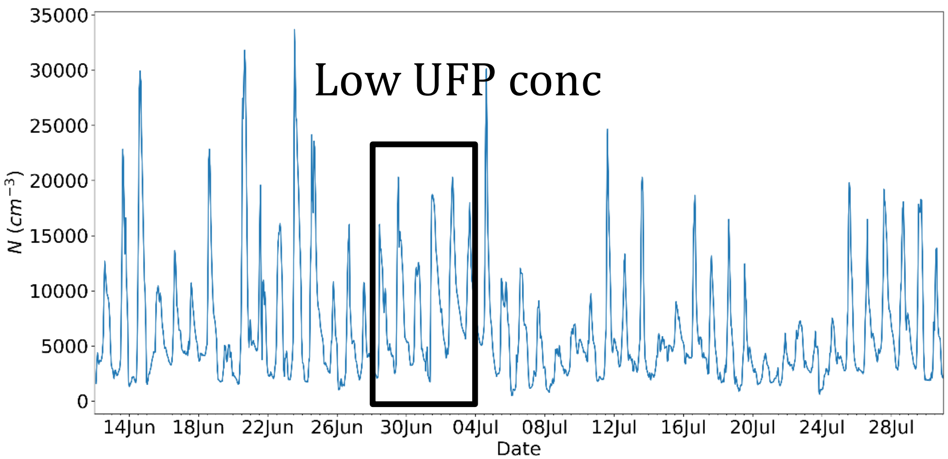


Case B: Low O_3 episode

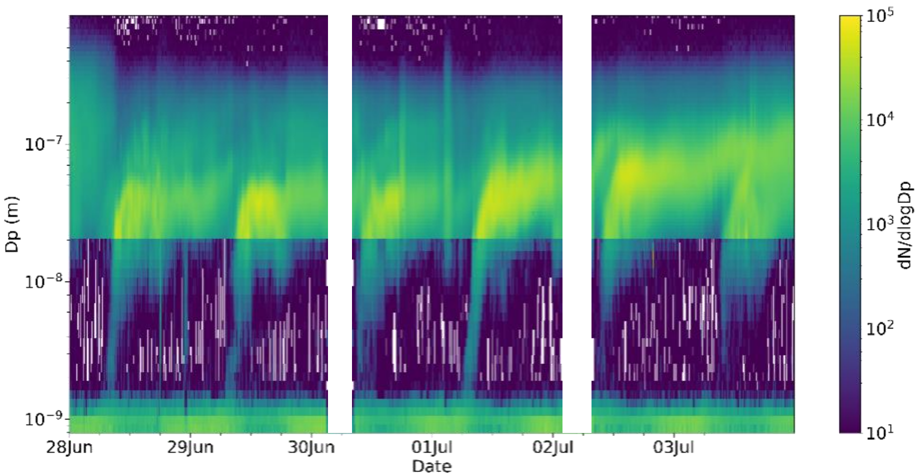


Front

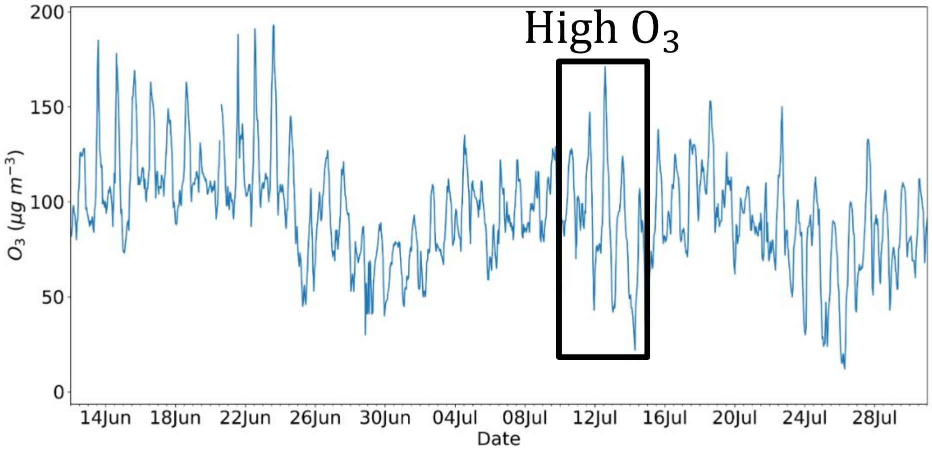




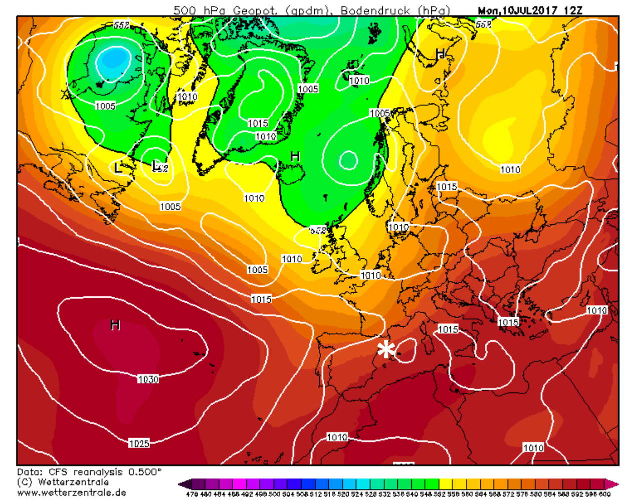
Regional NPF

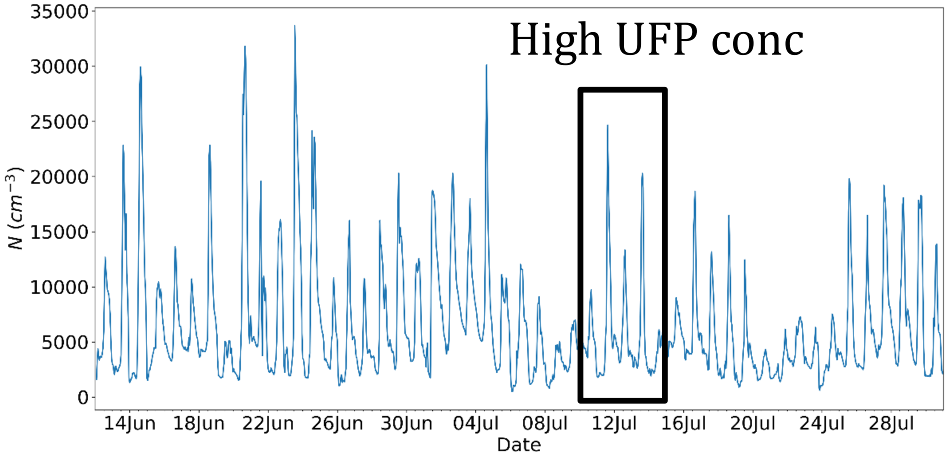


Case C: High O_3 (Balloon soundings)

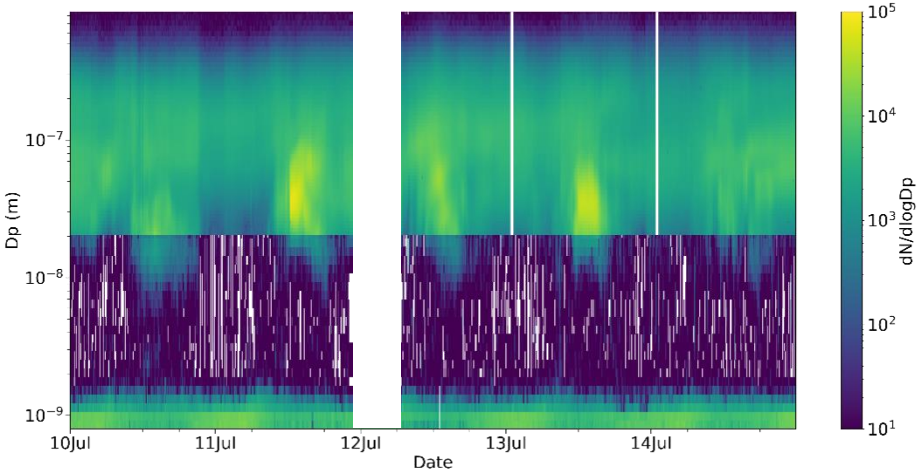


Stagnation starting

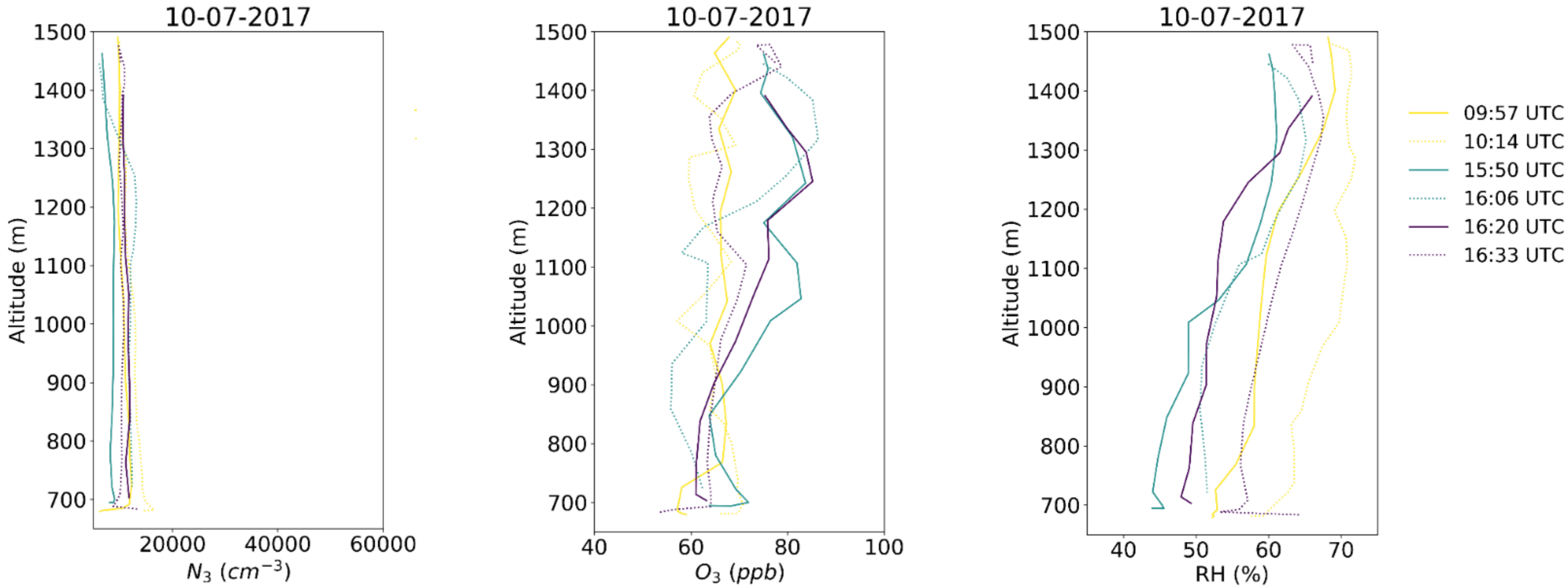




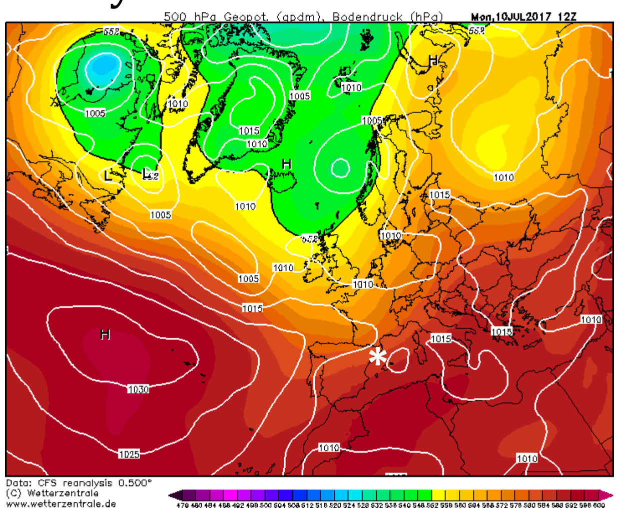
No NPF



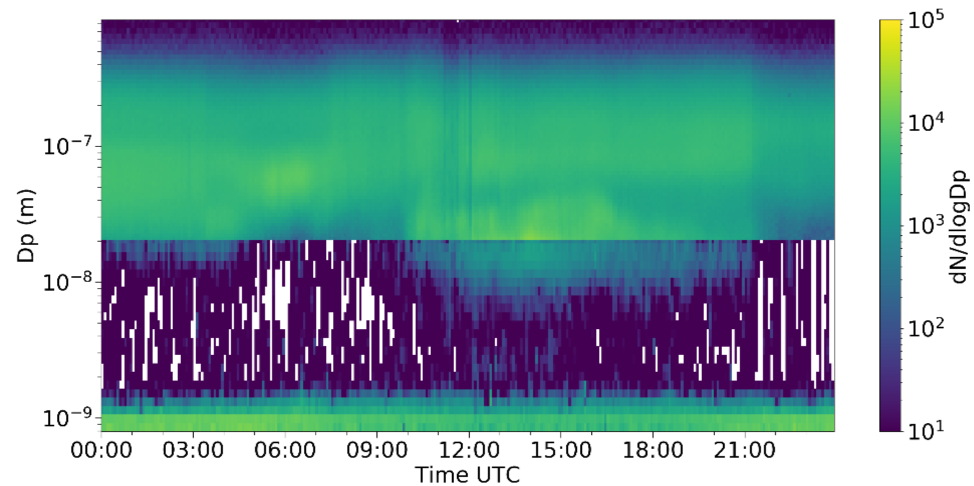
Case C: Balloon soundings



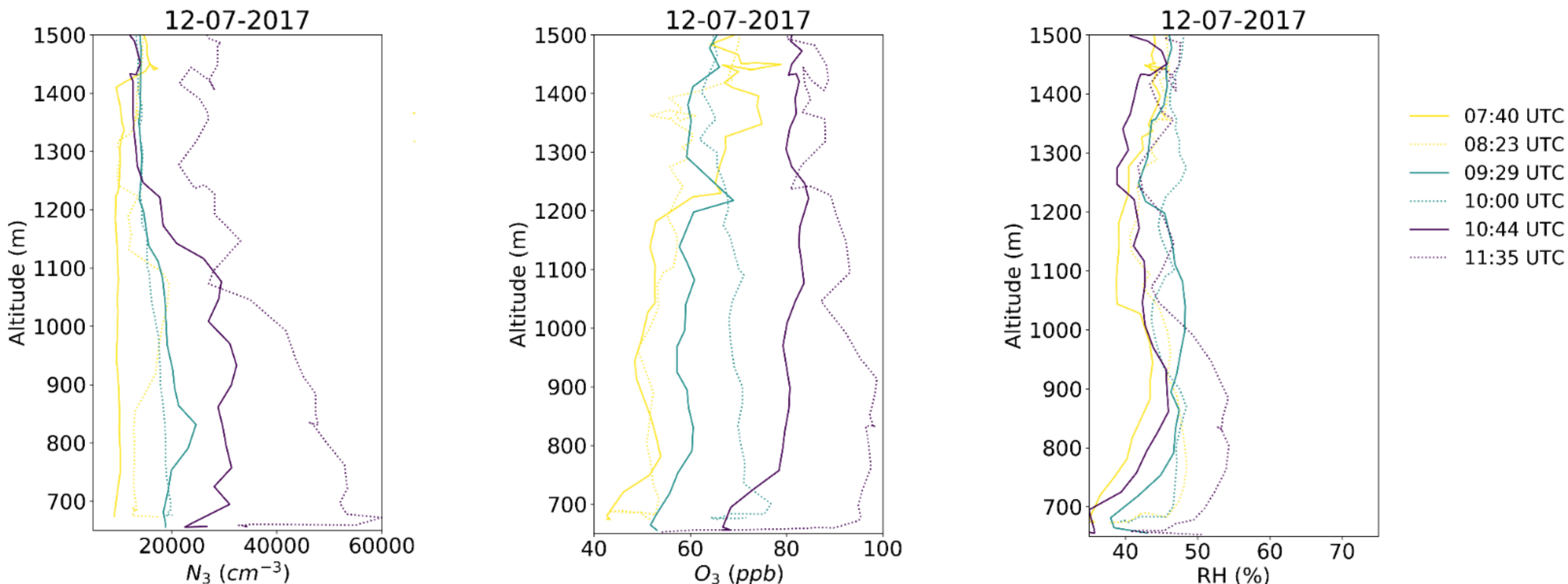
Instability



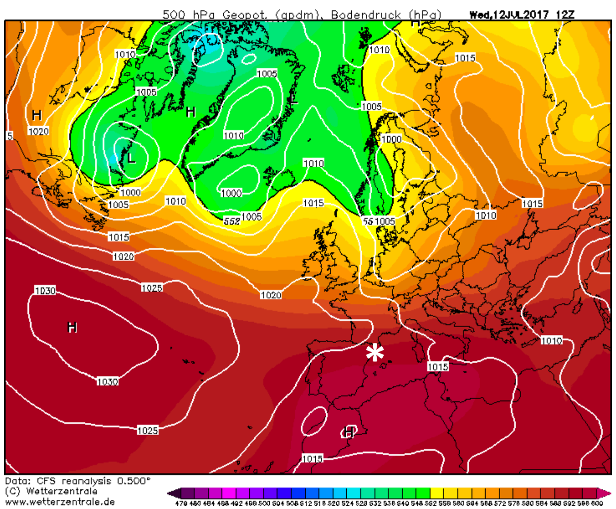
No NPF



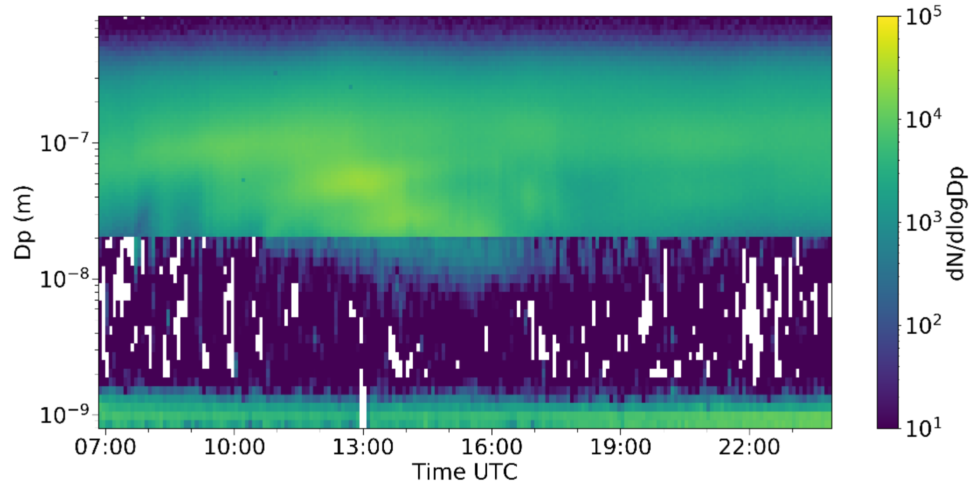
Case C: Balloon soundings



Stagnation



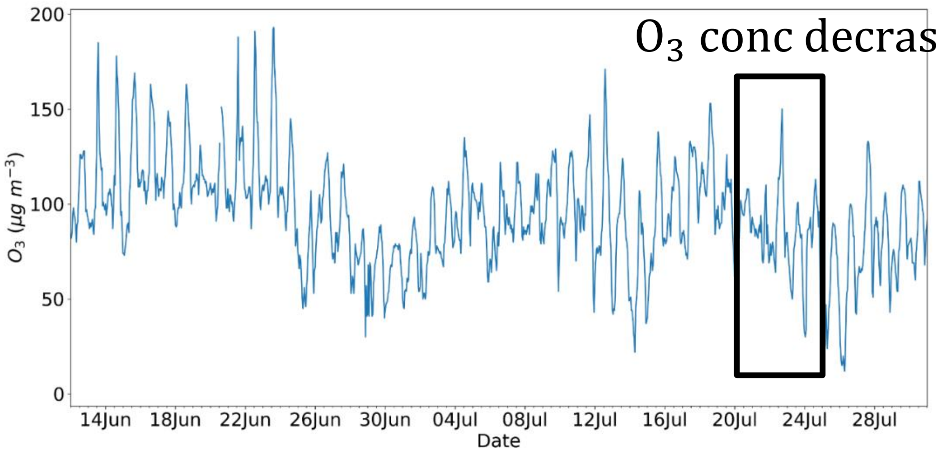
No NPF

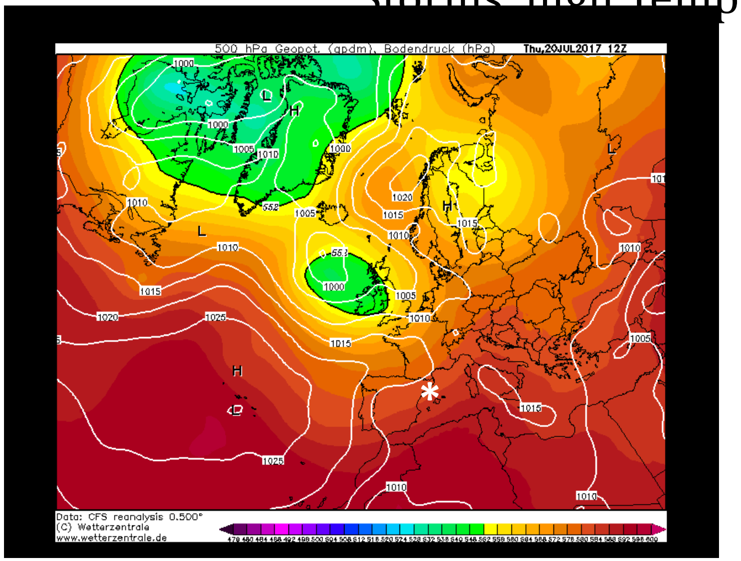


Case D: Low UFPs episode

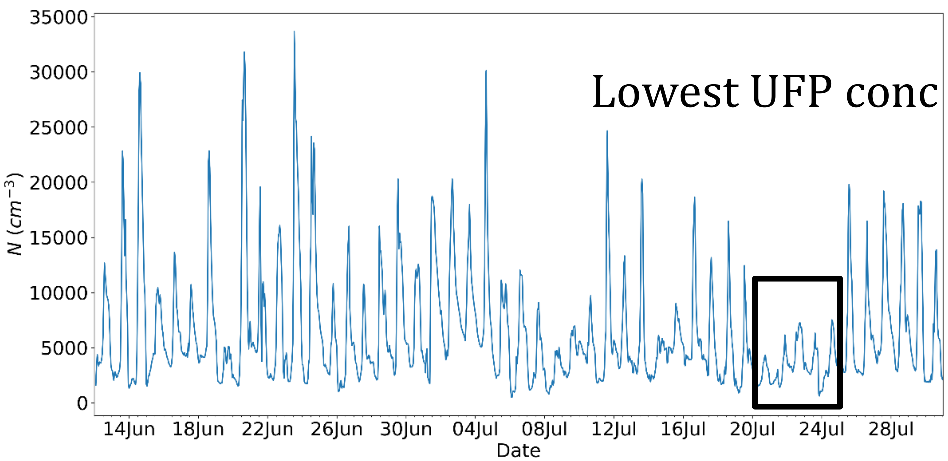
Storms, high Temp.

O_3 conc decrasing

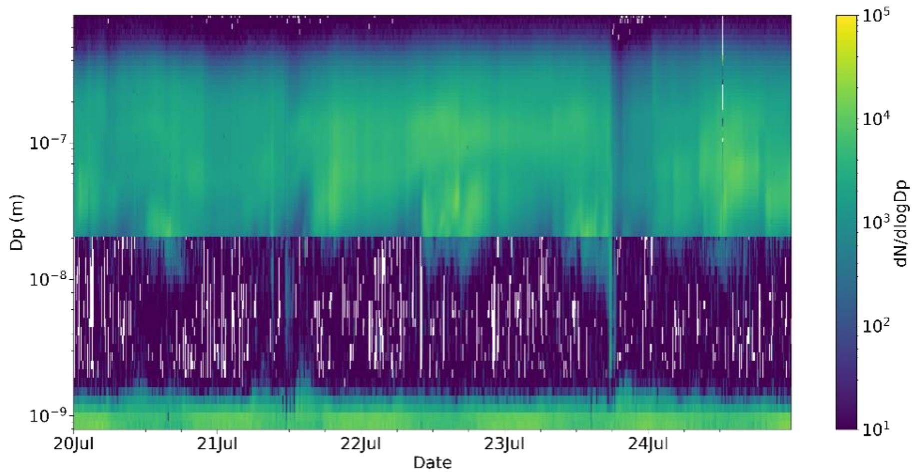




Lowest UFP conc



No NPF



Conclusions

* During vertical **recirculation of air masses** in the W Mediterranean – the main cause of regional O_3 episodes – **high levels of UFP are recorded in parallel with high O_3 concentrations**. This causes the increase of the condensation sink to the point that **NPF is inhibited**.

* **In the absence of recirculation** and during its initial stages, humid air masses with NPF precursors are transported inland and diluted into dryer and warmer rural air masses, enriched with biogenic VOCs and NH_3. This is an **optimal scenario for NPF** in air masses with relatively **low O_3 background concentrations**.

* It might also be the case that, when the atmosphere is too clean, e.g. during the passage of a cold front, the concentrations of NPF precursors is too low, and **NPF is not detected**. In this case **O_3 levels can still be relatively high** because of typically high background levels in summer, but **UFP concentrations are low**.

* The fact that the highest O_3 episodes were recorded together with the highest UFPs **may enhance the health impact of the episodes**. During the lowest O_3 episodes, the contribution of primary UFPs is very low; UFPs are mainly secondary resulting from NPF, and the total number of particles is the lowest. The health impact of UFPs in these two types of episodes is probably different.

house.

HIGH OZONE, ULTRAFINE PARTICLES AND SECONDARY ORGANIC AEROSOLS
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THANK YOU

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idæa

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UPC Universitat Politècnica de Catalunya BarcelonaTech

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