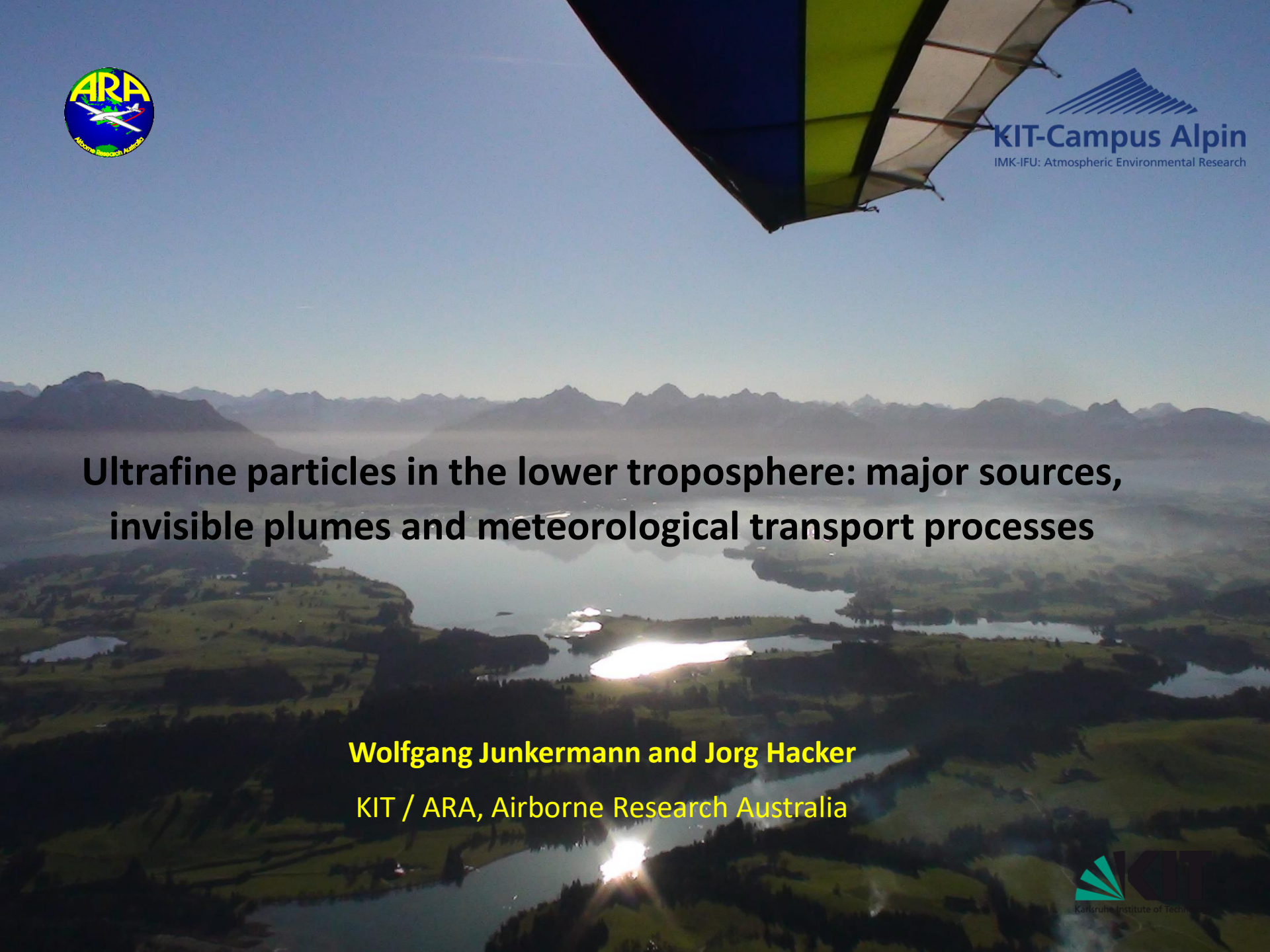


KIT-Campus Alpin
IMK-IFU: Atmospheric Environmental Research

Ultrafine particles in the lower troposphere: major sources, invisible plumes and meteorological transport processes

Wolfgang Junkermann and Jorg Hacker

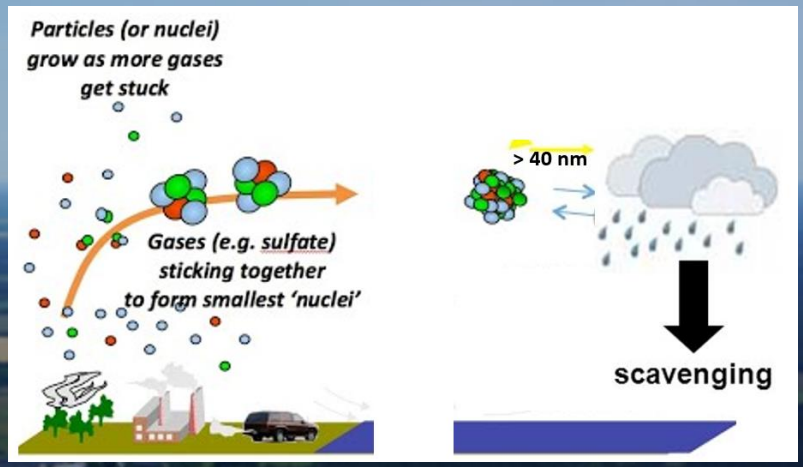
KIT / ARA, Airborne Research Australia

What do we know about UFP

number concentrations
urban, rural, maritime .....300 - 300000

Aitken (1890), Landsberg (1938), Went (1960), Twoomey (1974) .....

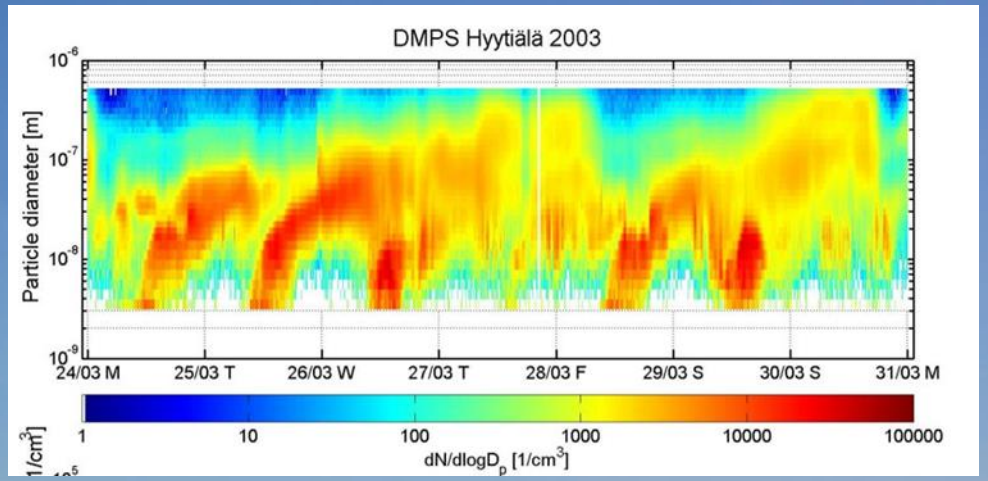
lifecycle
GPC (Mohnen, 1969)

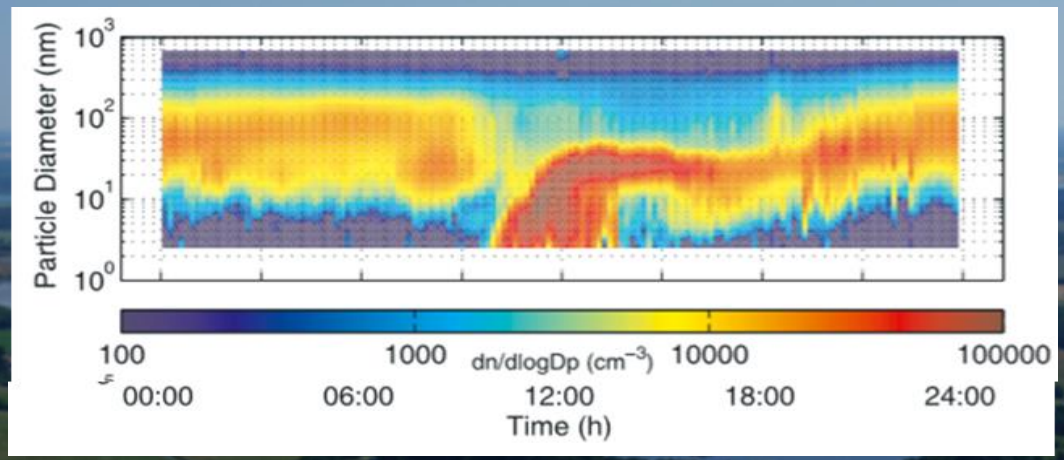


What's new?
Since ~ 1990?

Finland

Italy





worldwide

What we don‘t know about UFP

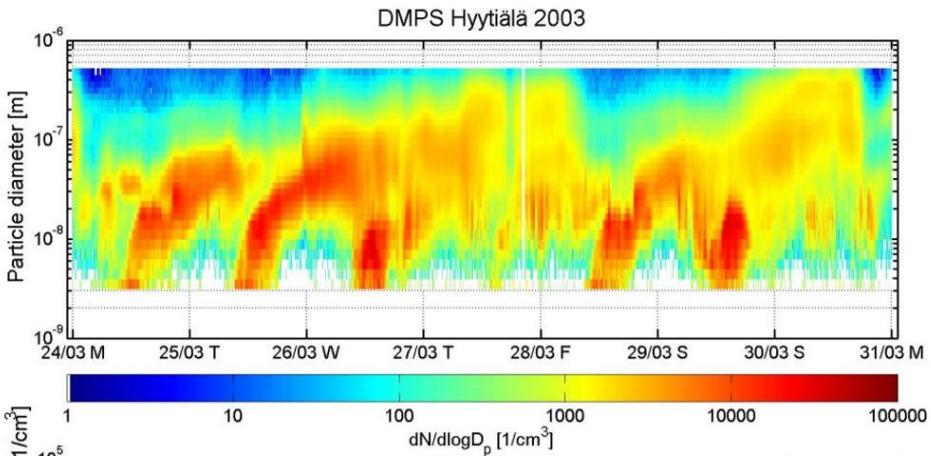
PRIM <-> SEC , contribution to budget

how to quantify ?

50% from GPC ? (Dunne et al, 20

Karlsruhe Institute of Technology

QUEST, ~~Quantification~~ of Aerosol Nucleation in the European Boundary Layer



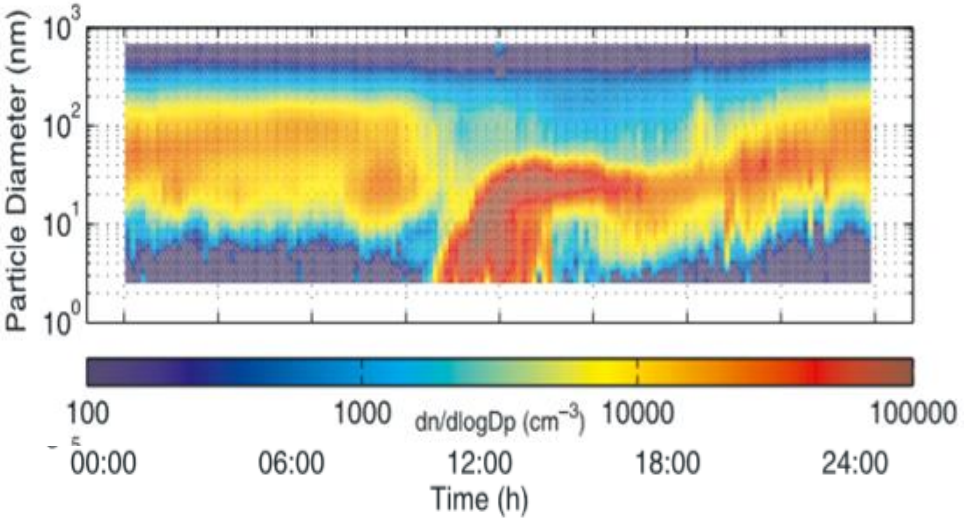
TIMING HYYTIÄLÄ 2003/SPC 2004, VOC?

Airborne measurements of nucleation mode particles II: Boreal forest nucleation events

C. D. O'Dowd, Y. J. Yoon, **W. Junkermann**, P. Aalto, M. Kulmala, H. Lihavainen, and Y. Viisanen, ACP, 2009

Cloud condensation nucleus production from nucleation events at a highly polluted region

Ari Laaksonen, Amar Hamed, Jorma Joutsensaari,Laura Hiltunen, Fabrizia Cavalli, **Wolfgang Junkermann**, Ari Asmi, Sandro Fuzzi, and Maria Cristina Facchini, GRL, 2005



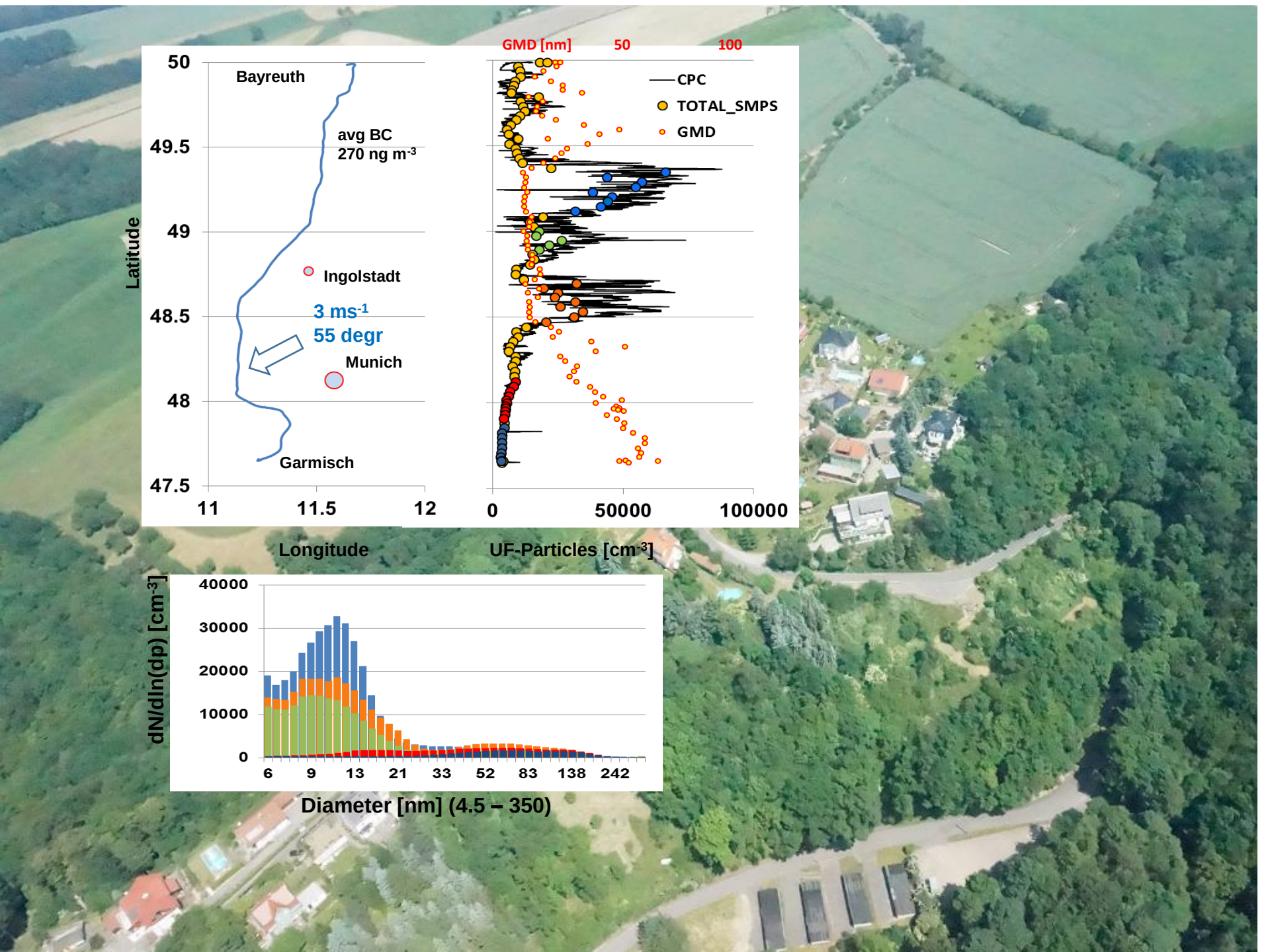
Karlsruhe Institute of Technology

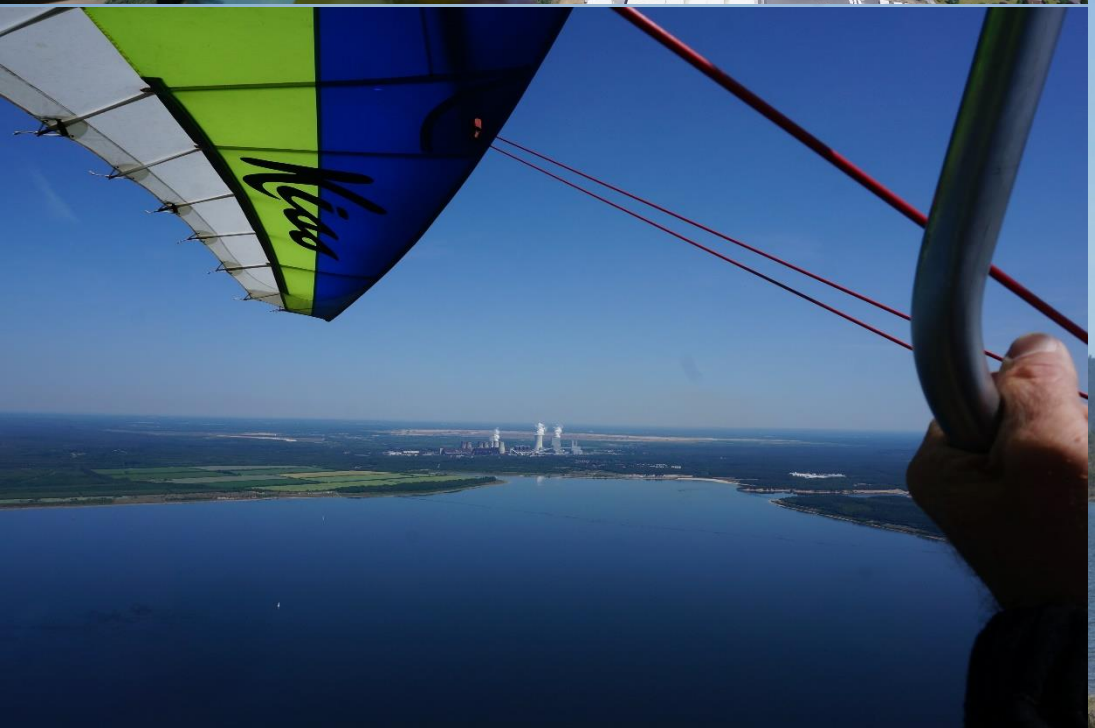
Quantification of individual sources ?

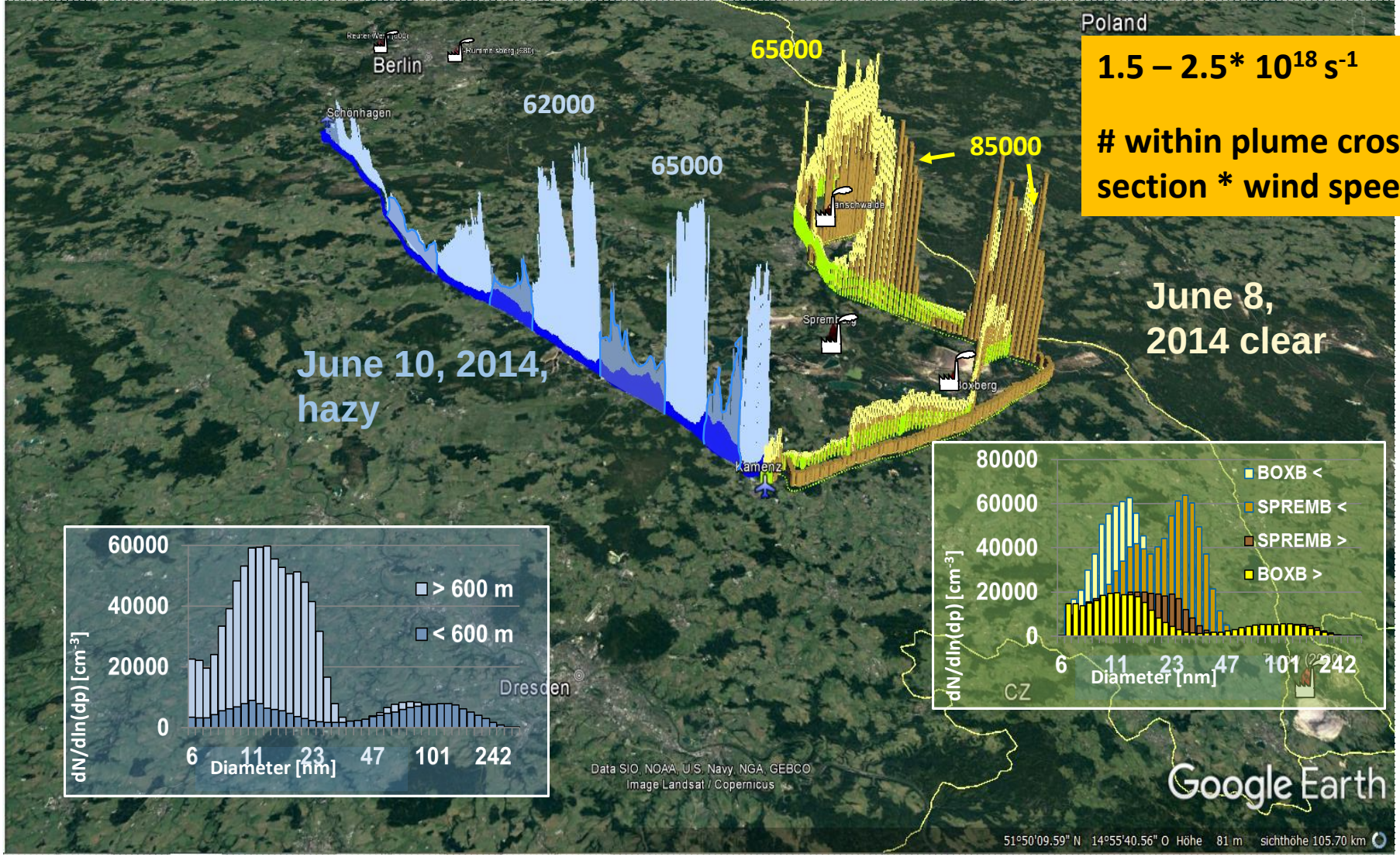
順路
THIS WAY

Let‘s get into the air to search for particles

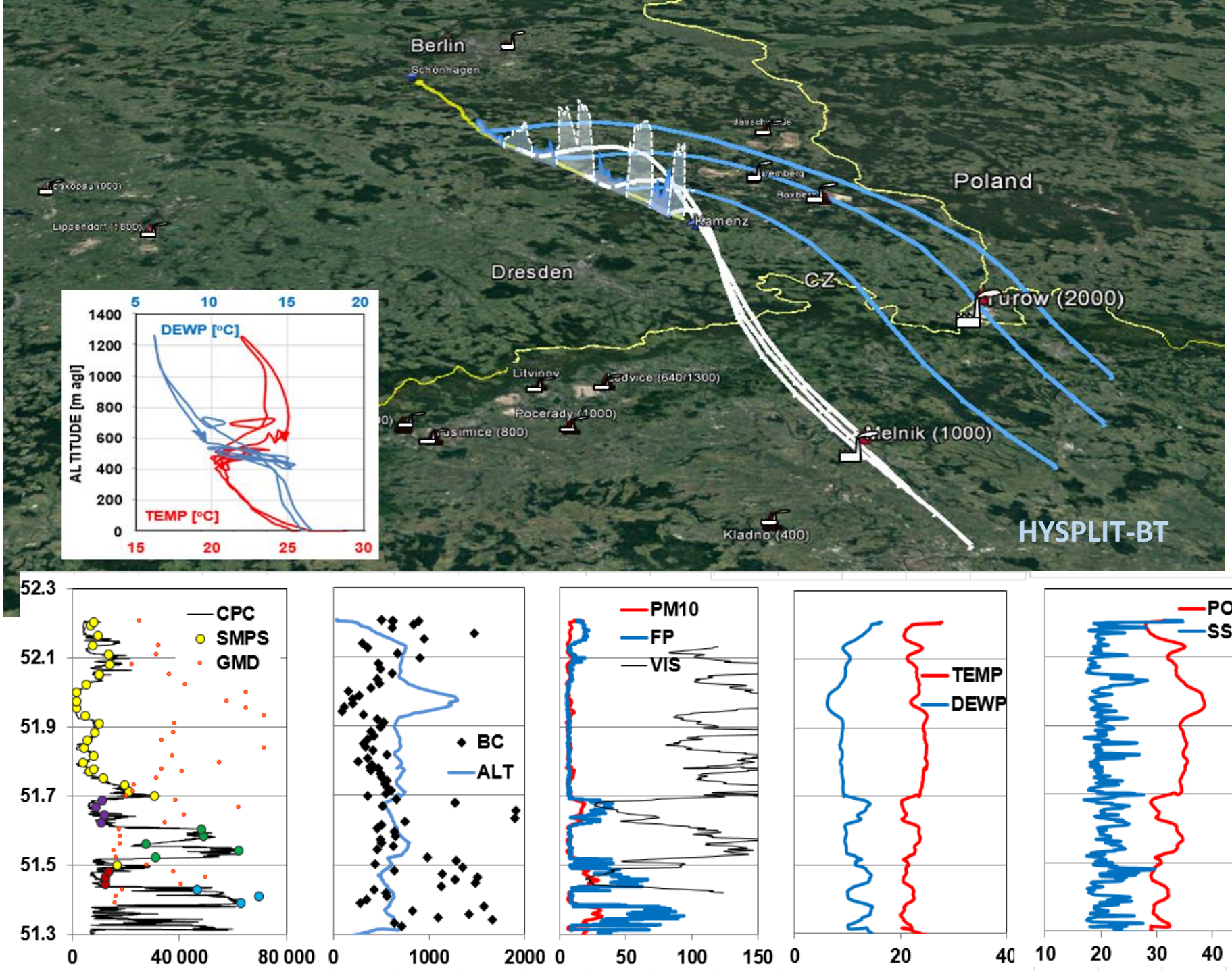
Karlsruhe Institute of Technology


GMD [nm]
50
100
CPC
TOTAL_SMPS
GMD
Bayreuth
avg BC
270 ng m-3
Ingolstadt
3 ms-1
55 degr
Munich
Garmisch
Latitude
50
49.5
49
48.5
48
47.5
11
11.5
12
Longitude
0
50000
100000
UF-Particles [cm-3]
dN/dln(dp) [cm-3]
40000
30000
20000
10000
0
6
9
13
21
33
52
83
138
242
Diameter [nm] (4.5 – 350)

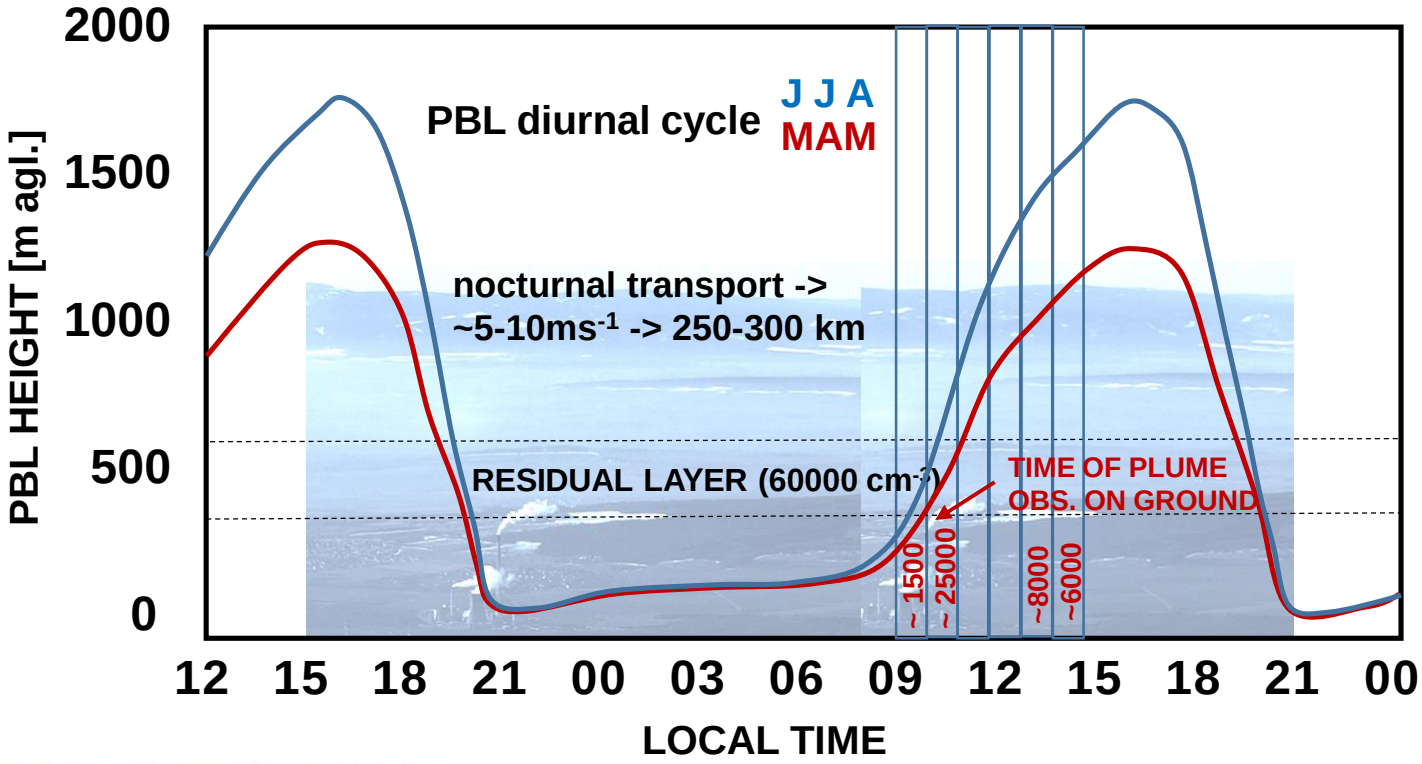


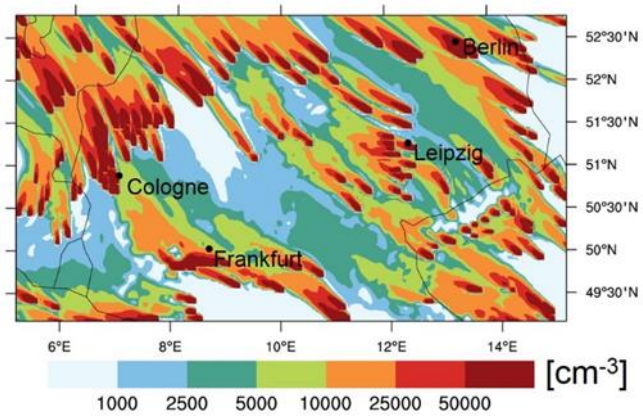


HIGH 3D VARIABILITY


Berlin
Schönhagen
Poland
Kamenz
Dresden
CZ
Turow (2000)
Litvinov
Pocerady (1000)
Kladno (400)
HYSPLIT-BT
DEWP [°C]
TEMP [°C]
ALTITUDE [m agl]
CPC
SMPS
GMD
BC
ALT
PM10
FP
VIS
TEMP
DEWP
POTT
SST

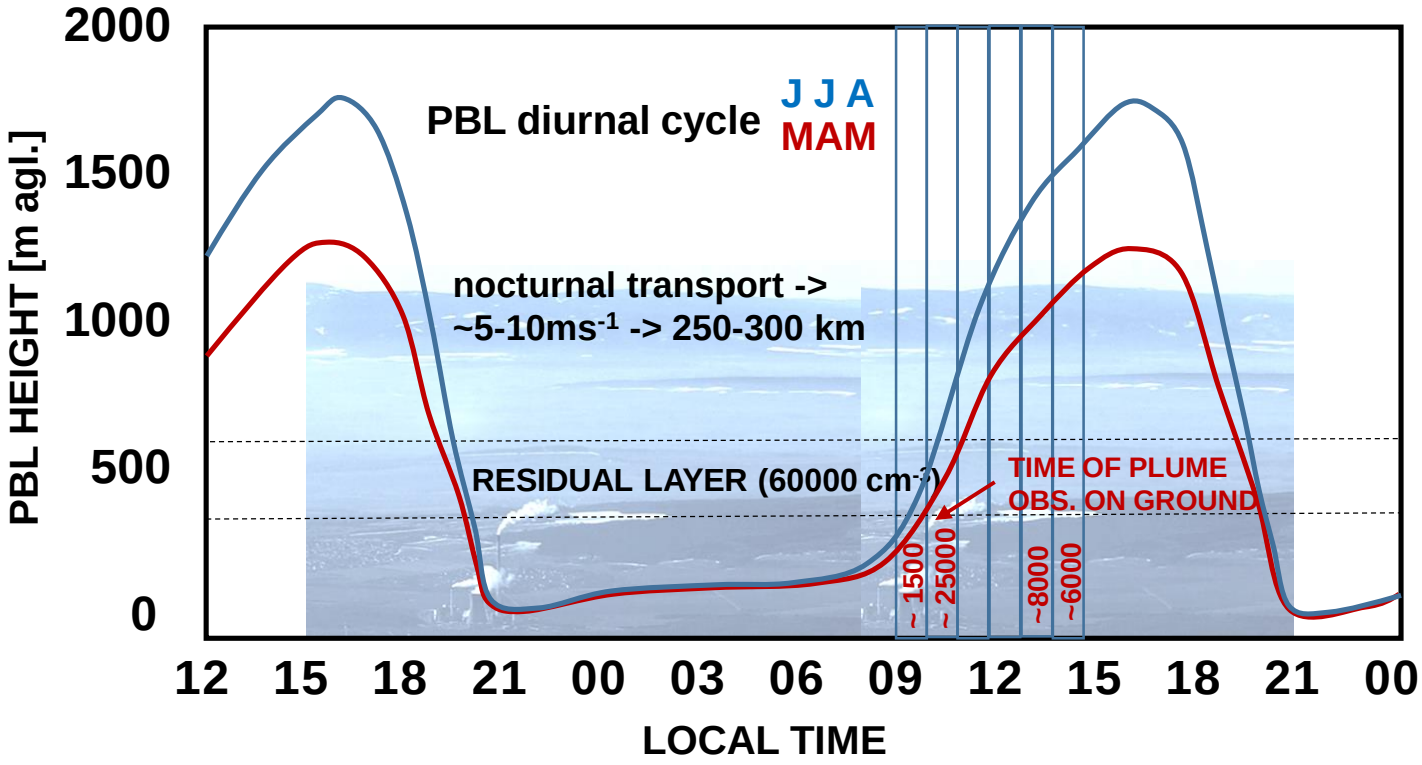
Diurnal PBL-Cycle (SGP) and elevated emission

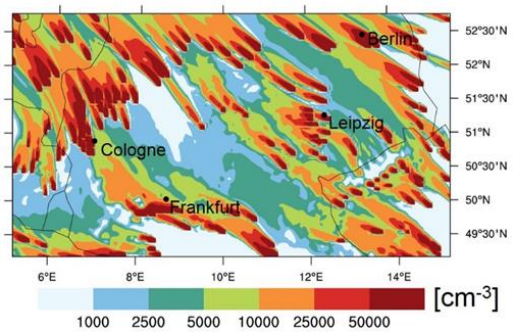


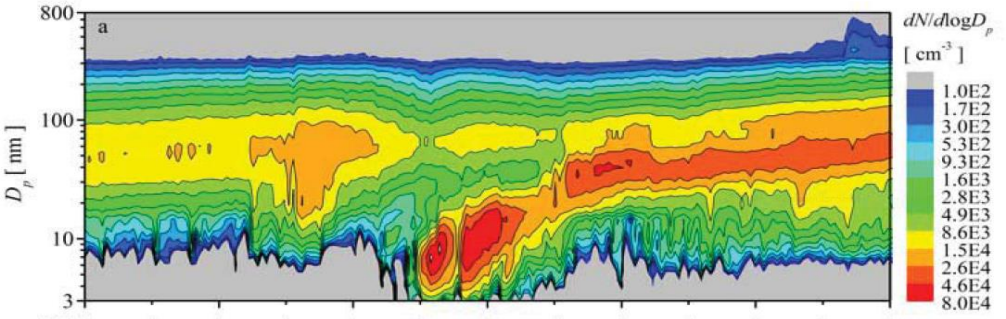


Junkermann et al, 2011

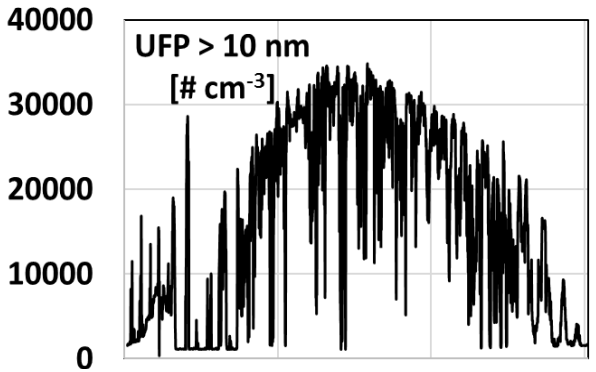
Karlsruhe Institute of Technology

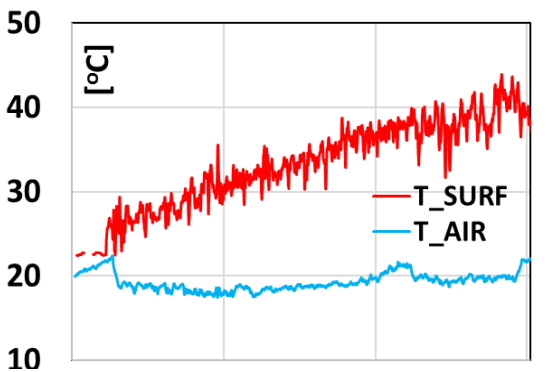

PBL diurnal cycle
J J A
MAM
nocturnal transport ->
~5-10ms-1 -> 250-300 km
RESIDUAL LAYER (60000 cm-3)
TIME OF PLUME
OBS. ON GROUND
~ 1500
~ 25000
~8000
~6000
PBL HEIGHT [m agl.]
2000
1500
1000
500
0
12 15 18 21 00 03 06 09 12 15 18 21 00
LOCAL TIME

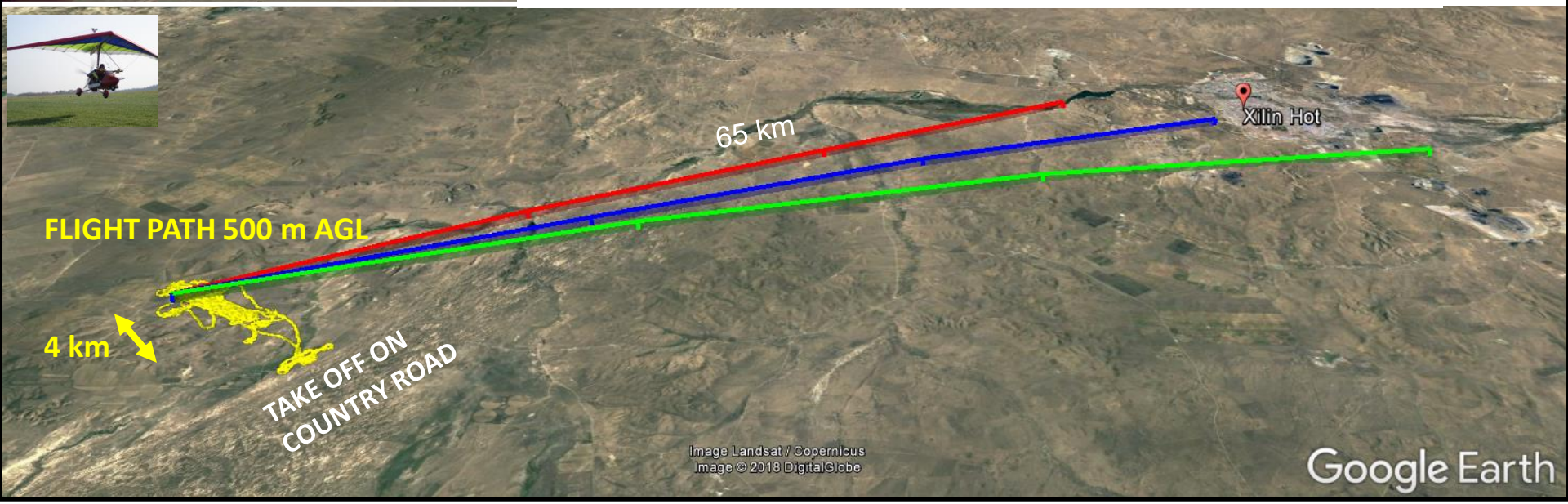

Berlin
Leipzig
Cologne
Frankfurt
52°30'N
52°N
51°30'N
51°N
50°30'N
50°N
49°30'N
6°E
8°E
10°E
12°E
14°E
[cm-3]
1000 2500 5000 10000 25000 50000


a
800
100
10
3
Dp [nm]
dN/dlogDp
[cm-3]
1.0E2
1.7E2
3.0E2
5.3E2
9.3E2
1.6E3
2.8E3
4.9E3
8.6E3
1.5E4
2.6E4
4.6E4
8.0E4

UFP event due to veering plume, well mixed PBL, INNER MONGOLIA, 3.7.2009

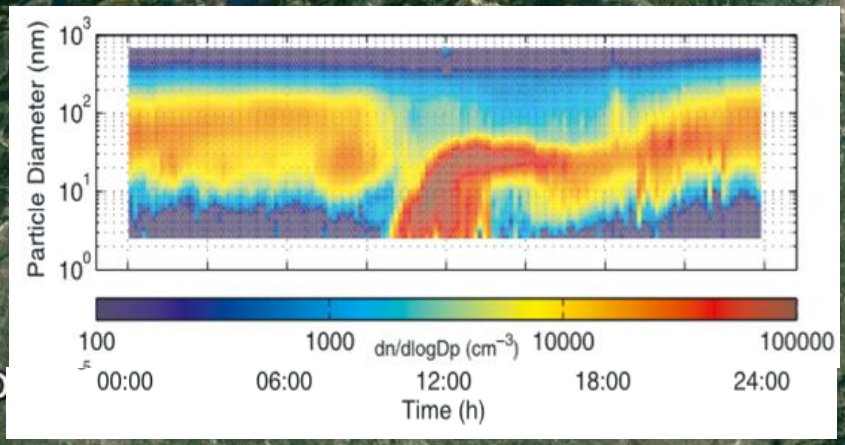






6 h backtrajectories 2 hourly intervals

surface particle event SPC



Marghera(750)
Venezia (1280)
Porto_Tolle (2640)

6 h trajectories
2 h intervals

San Pietro Capofiume
Ravenna (750)

Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Cloud condensation nucleus production from nucleation events at a highly polluted region

Ari Laaksonen, Amar Hamed, Jorma Joutsensaari,Laura Hiltunen, Fabrizia Cavalli, Wolfgang Junkermann, Ari Asmi, Sandro Fuzzi, and Maria Cristina Facchini, GRL, 2005

Melpitz

JÄNSCHWALDE 120 km
BUSCHHAUS 140 km
SCHKOPAU 70 km
LEUNA 70 km
LIPPENDORF 55 km
SPREMBERG 110 km
BOXBERG 110 km
.....

Schkopau (900)

Ref_Leuna

Lippendorf (1800)

Image Landsat / Copernicus

Junkermann et al, 2011

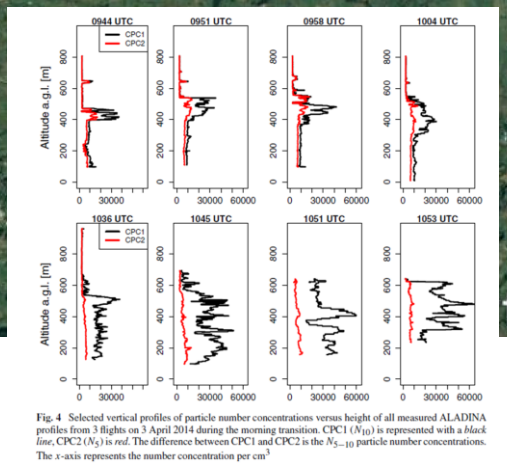
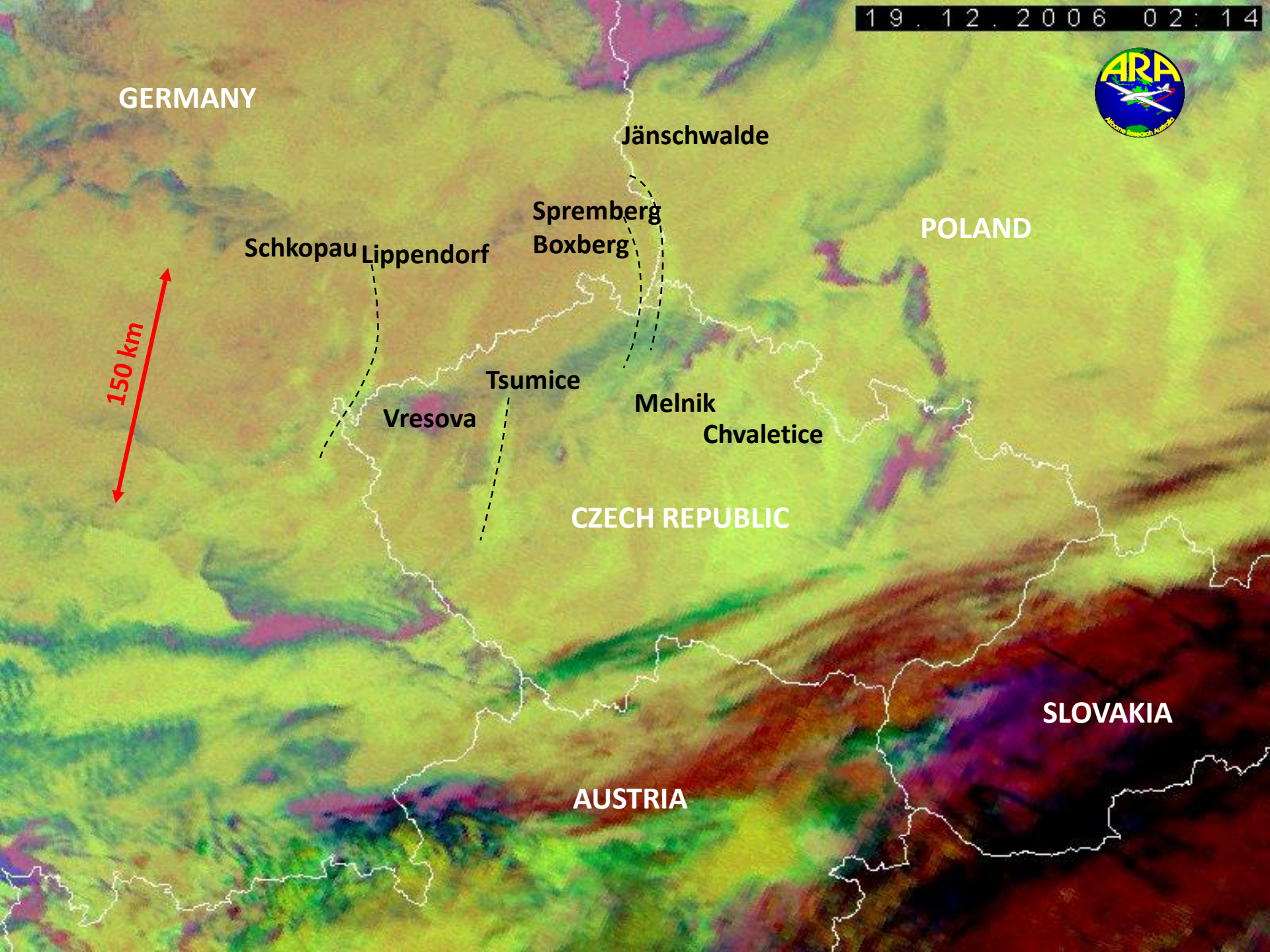
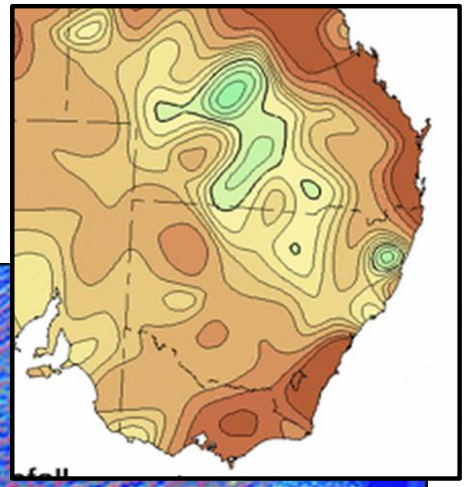


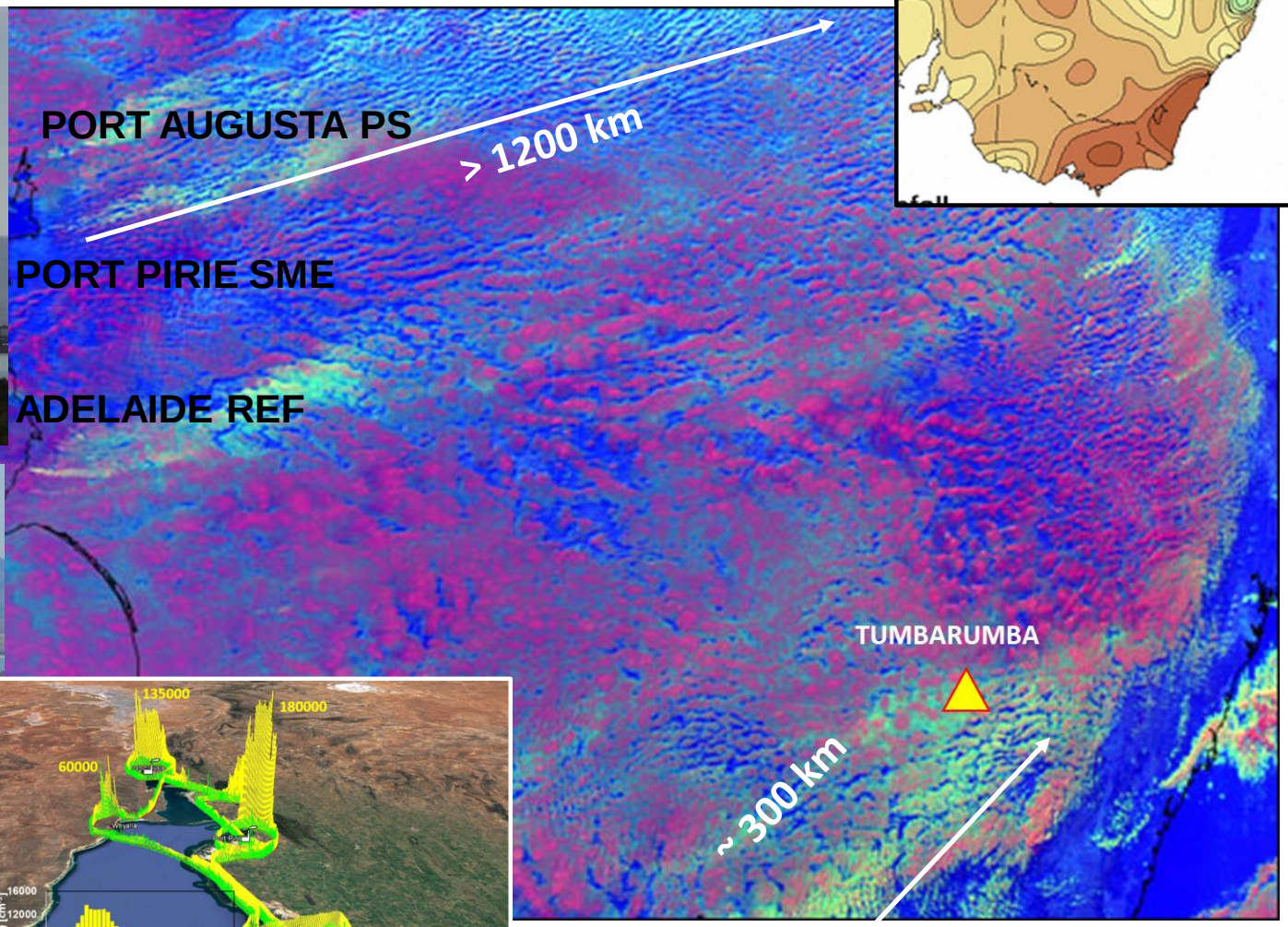
Fig. 4 Selected vertical profiles of particle number concentrations versus height of all measured ALADINA profiles from 3 flights on 3 April 2014 during the morning transition. CPC1 (N_{10}) is represented with a *black line*, CPC2 (N_5) is *red*. The difference between CPC1 and CPC2 is the N_{5-10} particle number concentrations. The *x*-axis represents the number concentration per cm^3

Platis et al, 2015


19.12.2006 02:14
GERMANY
Jänschwalde
Spremberg
Boxberg
POLAND
Schkopau
Lippendorf
150 km
Tsumice
Vresova
Melnik
Chvaletice
CZECH REPUBLIC
SLOVAKIA
AUSTRIA

Daniel Rosenfeld
Science **287**, 1793 (2000)





La Trobe Valley

SIGNIFICANCE FOR THE BUDGET?

present day szenarios

	TG/a	Mode-R [um]	Eff R [um]	Radius	Eff R
				Number of Particles	
Anthropogenic					
Wildfire	42.0	0.040	0.095	9.0	
Biofuel Dom	11.0	0.040	0.095	2.	
Biofuel Dom	9.6	0.015	0.036	3.	
Fossil Fuel surface	6.4	0.015	0.036	2	
Roads /off roads	3.5	0.015	0.036	1	
Ships	7.8	0.500	1.660	7	
Industry (300m)	39.2	0.500	1.660	4	
Power-Pl (300m)	48.2	0.500	1.660		
Natural					
Dust	1678.0	0.650	2.100		5
sea salt	7925.0	0.740	2.500		5
DMS	18.2	0.040	0.095		7
Volcanic	2.0	0.040	0.059		27
Volcanic contin.	12.6	0.040	0.059		27
SOA	19.1	0.040	0.095		27
Anthropogenic				8.9E+29	6.5E+28
Natural				7.3E+28	1.3E+28

PRIM. AEROSOL EMISSIONS /a FOR Y 2000 FOR GLOBAL AEROSOL MODELS ANTR. <> NAT.

NUMBERS CALCULATED FROM SIZE AND MASS

DENTENER ET AL, ACP, 2006

	TG/a	Mode-R [um]	Eff R [um]	Radius	Eff R
				Number of Particles	
Anthropogenic					
Wildfire	42.0	0.040	0.095	9.0E+28	6.7E+27
Biofuel Dom	11.0	0.040	0.095	2.3E+28	1.8E+27
Biofuel Dom	9.6	0.015	0.036	3.9E+29	2.8E+28
Fossil Fuel surface	6.4	0.015	0.036	2.5E+29	1.8E+28
Roads /off roads	3.5	0.015	0.036	1.4E+29	9.9E+27
Ships	7.8	0.500	1.660	7.4E+24	2.0E+23
Industry (300m)	39.2	0.500	1.660	4.3E+25	1.2E+24
Power-Pl (300m)	48.2	0.500	1.660	5.3E+25	1.4E+24
Natural					
Dust	1678.0	0.650	2.100	8.3E+26	2.5E+25
sea salt	7925.0	0.740	2.500	2.7E+27	6.9E+25
DMS	18.2	0.040	0.095	3.9E+28	2.9E+27
Volcanic	2.0	0.040	0.059	4.3E+27	1.3E+27
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Anthropogenic				8.9E+29	6.5E+28
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PRIM. AEROSOL EMISSIONS /a FOR Y 2000 FOR GLOBAL AEROSOL MODELS

ANTR. <> NAT.

NUMBERS CALCULATED FROM SIZE AND MASS

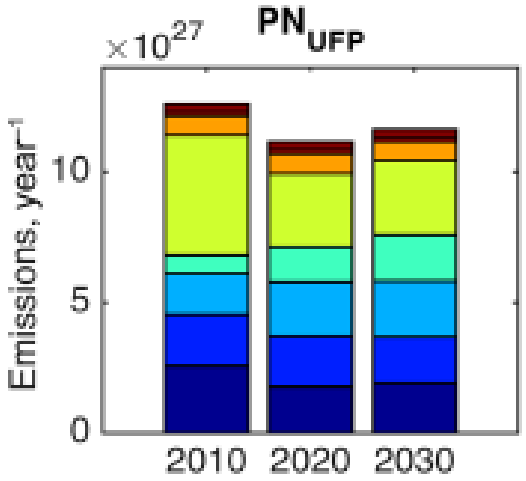
DENTENER ET AL, ACP, 2006

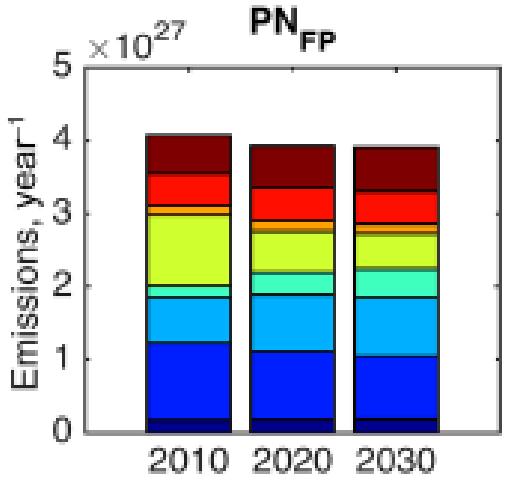
	Tg/a	Mode-R [um]	Eff R [um]	Radius	Eff R
				Number c…	…cles
Anthropogenic					
Wildfire	42.0	0.040	0.095	…+28	6.7E+27
Biofuel Dom	11.0	0.040	0…	2.3E+28	1.8E+27
Biofuel Dom	9.6	0.015	…36	3.9E+29	2.8E+28
Fossil Fuel surface	6.4	0…	0.036	2.5E+29	1.8E+28
Roads /off roads	3.5	0…15	0.036	1.4E+29	9.9E+27
Ships	7.8	0.500	1.660	7.4E+24	2.0E+23
Industry (300 m)	39.2	0.500	1.660	4.3E+25	1.2E+24
Power-St (300 m)	48.2	0.500	1.660	5.3E+25	1.4E+24
Anthropogenic emission				8.9E+29	6.5E+28
GAINS global anthr. cont. Paasonen, 2016				1.3 E+28	

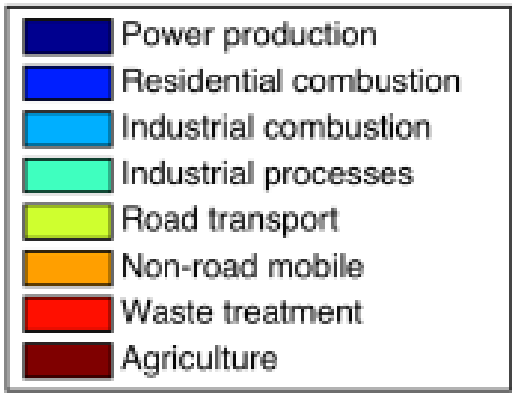
ANY CHANGE SINCE 1990 / 2000 ?

NUMBERS CALCULATED FROM SIZE AND MASS

DENTENER ET AL. ACP, 2006 (Y 2000)







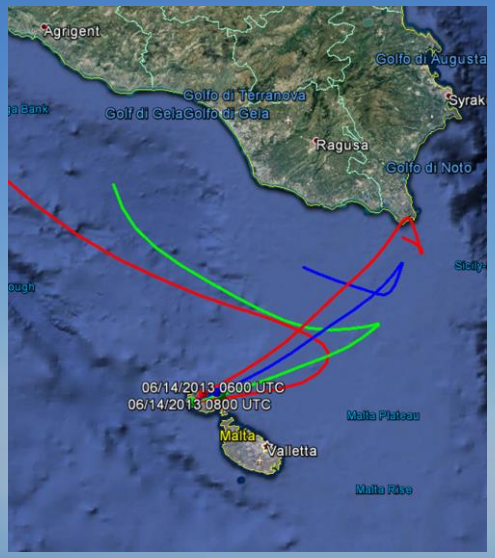
	Tg/a	Mode-R [um]	Eff R [um]	Radius	Eff R
				Number of P	
Anthropogenic					
Wildfire	42.0	0.040	0.095		6.7E+27
Biofuel Dom	11.0	0.040	0.09	E+28	1.8E+27
Biofuel Dom	9.6	0.015		3.9E+29	2.8E+28
Fossil Fuel surface	6.4	0.01	036	2.5E+29	1.8E+28
Roads /off roads	3.5	0.0	0.036	1.4E+29	9.9E+27
Ships	7.8	0.500	1.660	7.4E+24	2.0E+23
Industry (300 m)	39.2	0.500	1.660	4.3E+25	1.2E+24
Power-St (300 m)	48.2	0.500	1.660	5.3E+25	1.4E+24
Anthropogenic emission				8.9E+29	6.5E+28
GAINS				1.3 E+28	
Power-St (300 m)	48.2	0.008 / 0.01		1.3E+31 / 1.9E+30	
8000 units coal		0.008		4.5E+29	
+ > oil power stations, refineries, smelters, Mt.Isa....				..	

ANY CHANGE SINCE 1990 / 2000 ?

NUMBERS CALCULATED FROM SIZE AND MASS

DENTENER ET AL. ACP, 2006 (Y 2000)

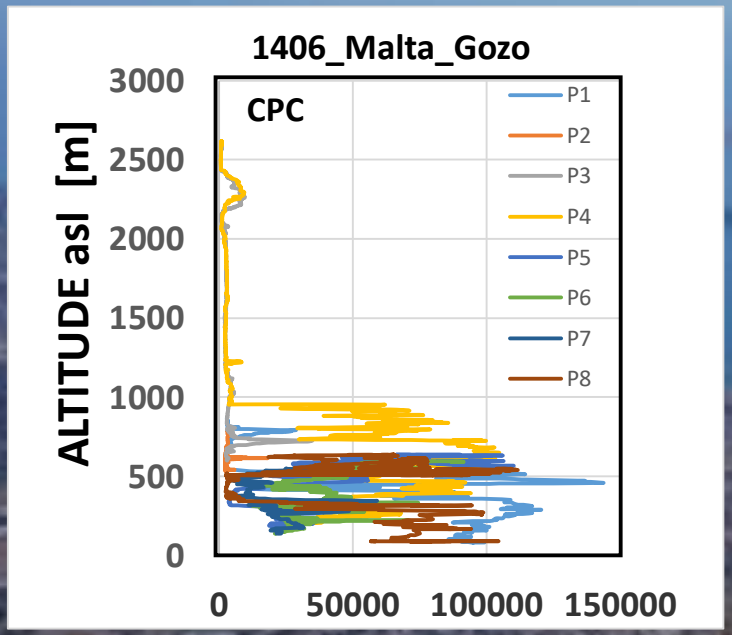
Mode-Radius based on measurements: 2010-2016

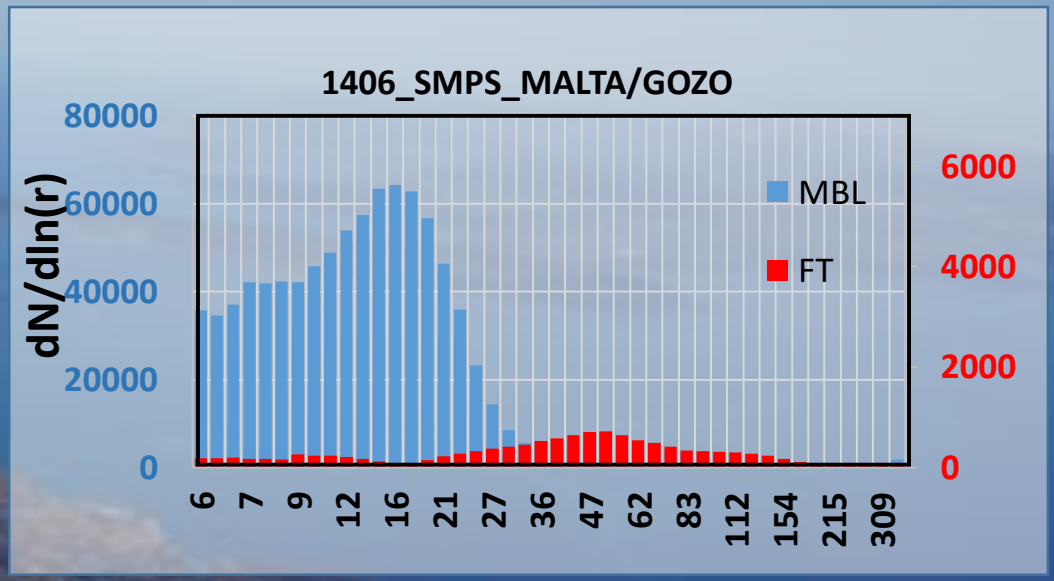


MALTA 2013

$EF_{(n)} > 1.6 \times 10^{16}\ s^{-1}\ km^{-1}$

MBL, AVG # conc, wind





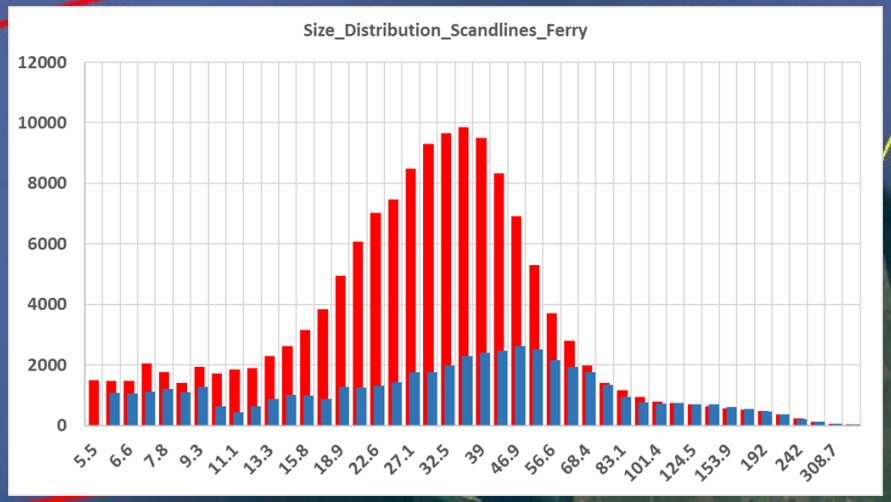
1500 km -> Sicily / Gibraltar ~$2.4 \times 10^{19}\ s^{-1}$

THE WORLDS CLEANEST HYBRID FERRY OCT. 2017

S-Content 0.1 %
17 MW 60%
EF(n) 3.2×10^{15} s^{-1} MW^{-1}

Fehmarnbelt
Holeby
Rødby Sogn
Rødbyhavn
Errindlev Sogn
5 km
downwind

Continental EF(n) 2.9×10^{15} s^{-1} MW^{-1}



Hybrid Ferry

	Tg/a	Mode-R [um]	Eff R [um]	Radius	Eff R
				Number	icles
Anthropogenic					
Wildfire	42.0	0.040	0.095	E+28	6.7E+27
Biofuel Dom	11.0	0.040	0	2.3E+28	1.8E+27
Biofuel Dom	9.6	0.015	36	3.9E+29	2.8E+28
Fossil Fuel surface	6.4	0.01	0.036	2.5E+29	1.8E+28
Roads /off roads	3.5	0.015	0.036	1.4E+29	9.9E+27
Ships	7.8	0.500	1.660	7.4E+24	2.0E+23
Industry (300 m)	39.2	0.500	1.6 0	4.3E+25	1.2E+24
Power-St (300 m)	48.2	0.500	1. 60	5.3E+25	1.4E+24
Anthropogenic emission				8.9E+29	6.5E+28
Power-St (300 m)	48.2	0.008 / 0.015		1.3E+31 /	1.9E+30
8000 units coal		0.008		4.5E+29	
+ oil power stations, refineries, smelters, Mt.Isa....				..	
Ships (2015)	7.8(15.6)	0.015		5.5E+29	

CHANGE SINCE 1990 / 2000 ?

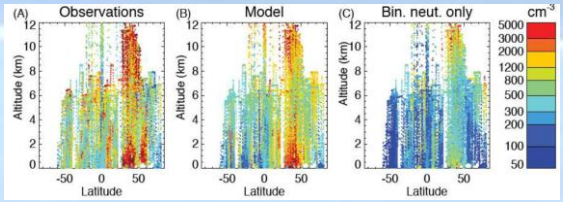
NUMBERS CALCULATED FROM SIZE AND MASS

DENTENER ET AL. ACP, 2006 (Y 2000)

*2 from 2000-2015
Further doubling for 2030 expected

Fanourgakis et al, ACPD 2019
Evaluation of global simulations of aerosol particle number and cloud condensation nuclei, and implications for cloud droplet formation

Models tend to **underestimate** the observed aerosol particle and CCN number concentrations, with average normalized mean bias (NMB) of all models and for all stations, where data are available, of **-24%** and **-35%** for particles with dry diameters >50nm and >120 nm and **-36%** and **-34%** for CCN

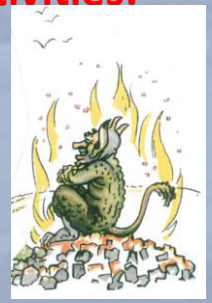


Fuzzi et al, 2016, ACP
Particulate matter, air quality and climate: lessons learned and future needs

The sources of SO_2 and NO_x are relatively well known, i.e. combustion of sulfur-containing fuel and fossil fuel combustion. The ability of the HNO_3 produced by NO_x to form secondary aerosol depends on the **availability of NH_3 in the gas phase** to form ammonium nitrate. **Ammonia is mainly emitted by agricultural activities.**

SCR or SNCR Chemistry

Bai et al 1992, Ind.Eng.Chem.Res.



SUMMARY

SOURCES

PRIMARY <-> SEC (GPC)

METEOROLOGY

CHEMISTRY

Obs: EU, AUS, CN, *US, Amazon, Indian Ocean, Ant(artic) ….*

BUDGETS

EMISSION SZENARIO‘S (PRESENT DAY EMISSIONS……FUTURE).


Thank you for your attention