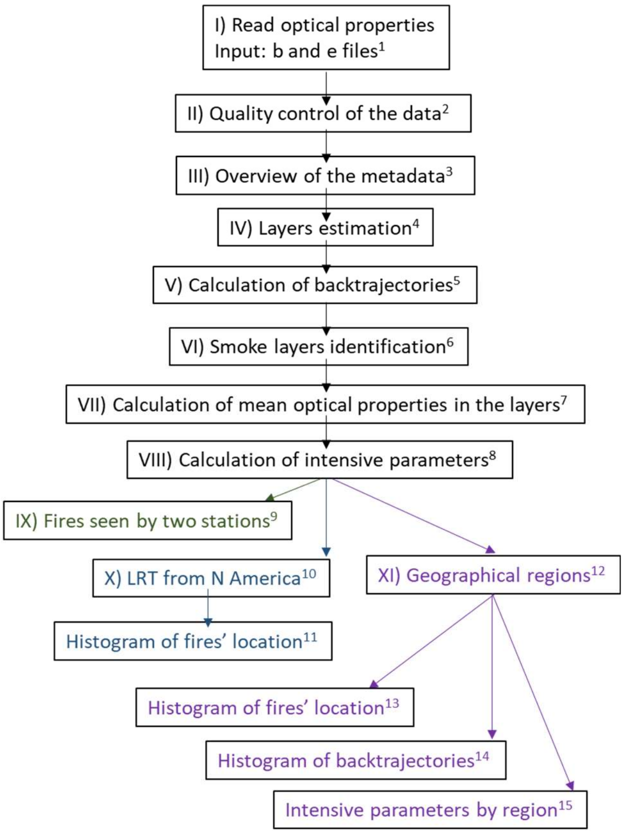
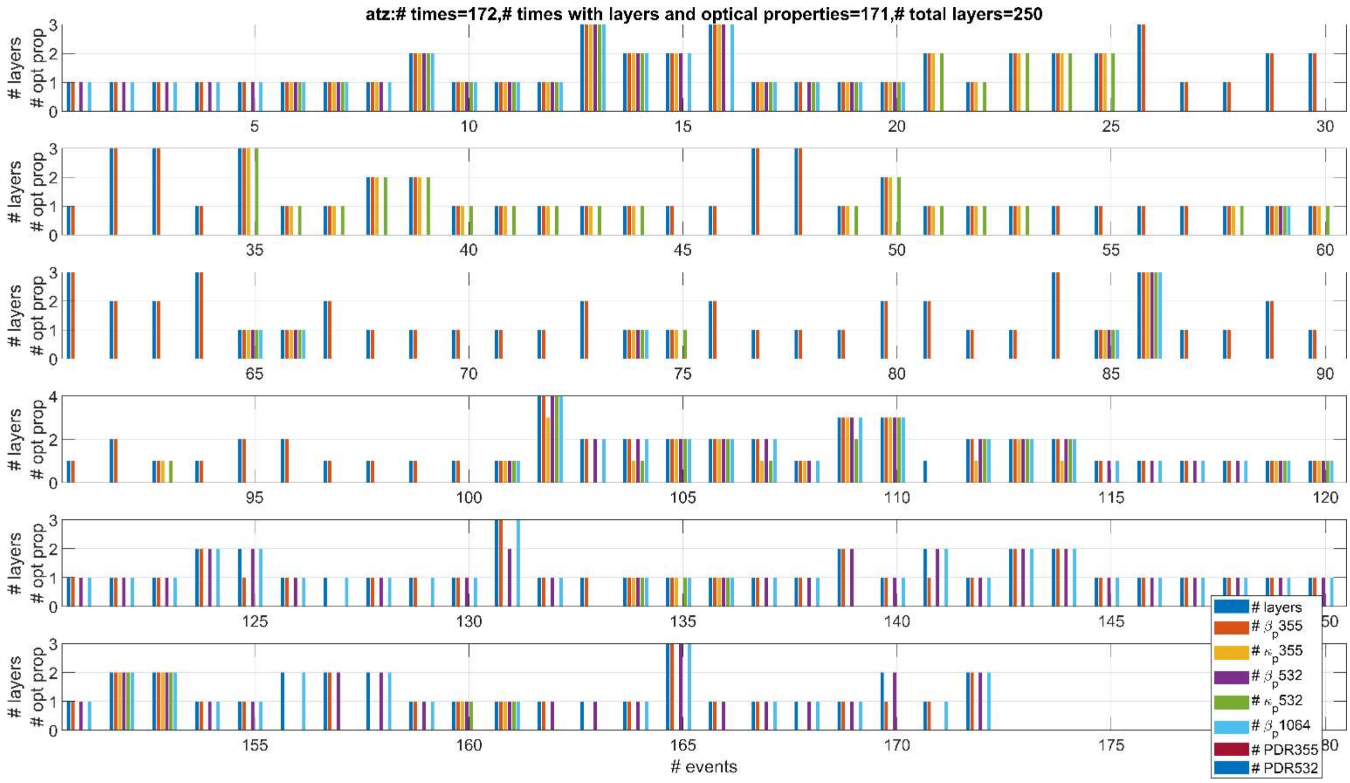
1 Methodology for data analyses

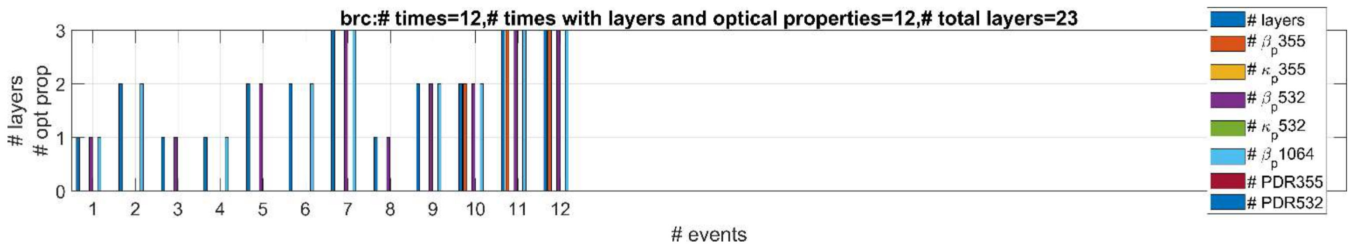


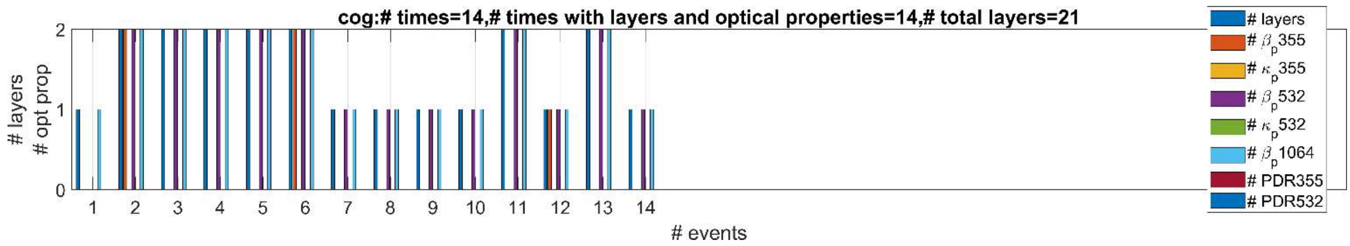
[1] 3589 input files
[2] EARLINET/Forest Fire files checked following EARLINET criteria; additional in-house checks
[3] e.g. detection mode, evaluation method, raw resolution
[4] algorithm developed; non-accurate estimates were manually corrected; 1901 layers calculated for 960 time stamps
[5] run Hysplit, 10 days backwards; use GDAS0.5° (23 cases on GDAS1°)
[6] use Hysplit backtrajectory and fires emissions (FIRMS); 1053 layers for 677 time stamps were considered as having BB origin
[7] the average in the layer is calculated if at least 90% data is available; the averages for which SNR<2 were dismissed; there were 1050 layers for 676 time stamps for which at least one average optical property was calculated. Fig. S3.
[8] Values outside the range of acceptable values are dismissed. Remaining IPs are considered further (795 layers, 526 time stamps). Fig. S5.
[9] based on backtrajectories, the common fires (smoke measured by two stations) were identified; compares IPs; measured smoke can be of "single fire" or "mixed fires". See Figs. 2-3.
[10] based on backtrajectories, the measured smoke can be "pure N America" or "mixed" (N America + local); smoke was measured by single station or several stations; e.g. smoke measured by three stations Fig. 4, Table 2; statistics over LRT from N America (Fig. 5 and Table 3).
[11] by station
[12] region: SE ("atz","ino","pot","the"), NE ("cog","mas","waw"), SW ("brc","evo","gra"), CE ("cbw","lei","hpb")
[13] by station; see Figs. 6-9.
[14] main circulation pattern revealed for some regions.
[15] IPs are classified based on smoke' continental origin (Europe, N America, Asia, Africa or a mixture of them). Mean values and scatter plots are considered. Figs. 10-12, S7, Table 4, S1.

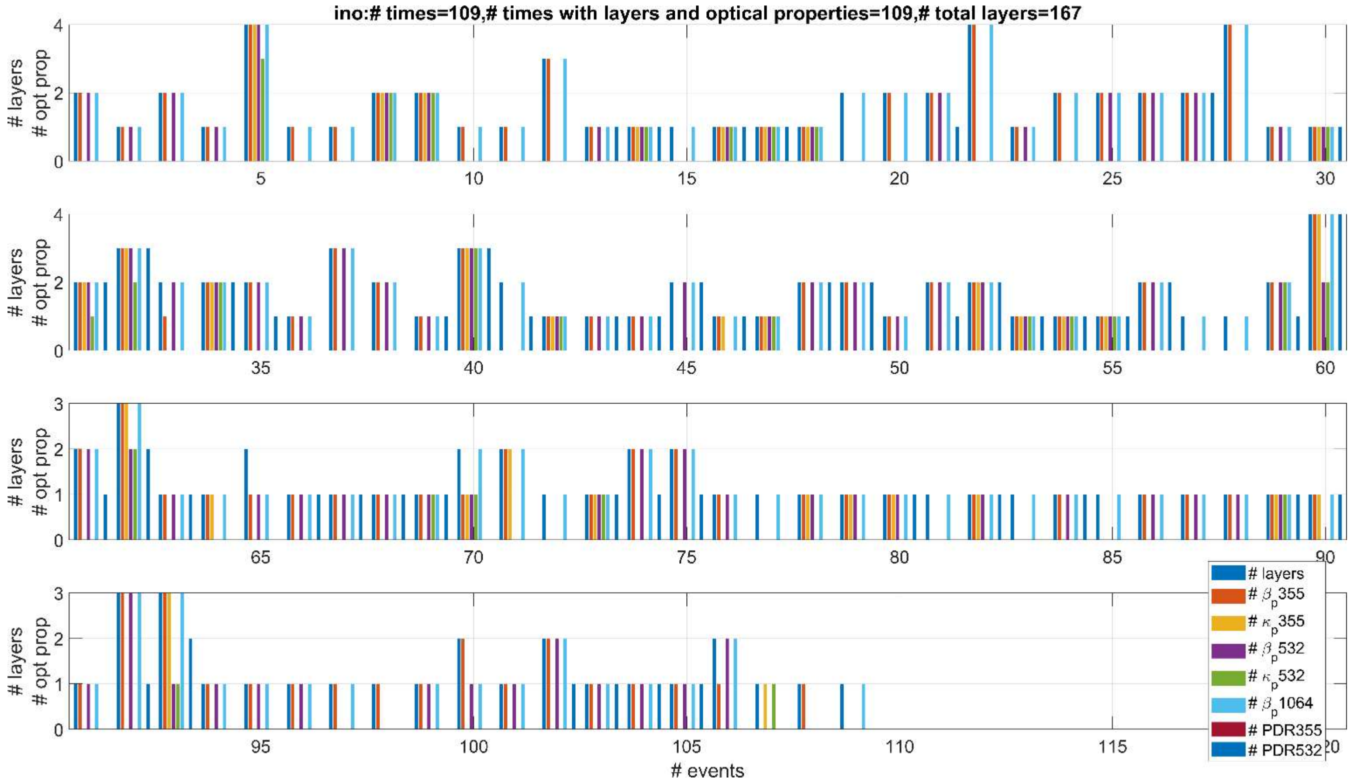
Figure S1. Methodology diagram.

2 Statistics over the number of layers and optical properties





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opt prop
events
layers
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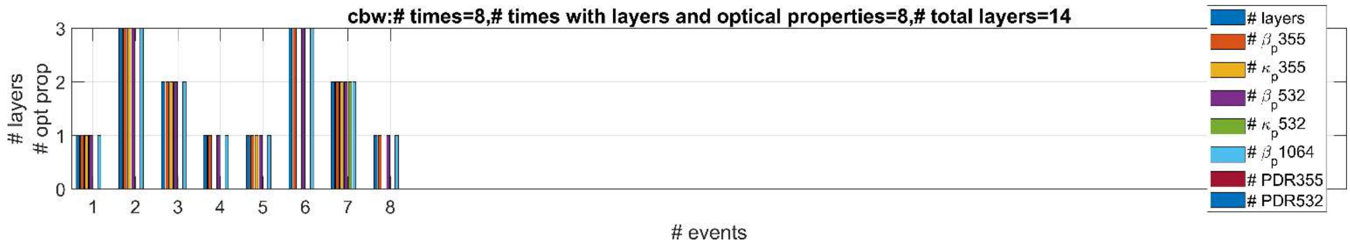
κ_p355
β_p532
κ_p532
β_p1064
PDR355
PDR532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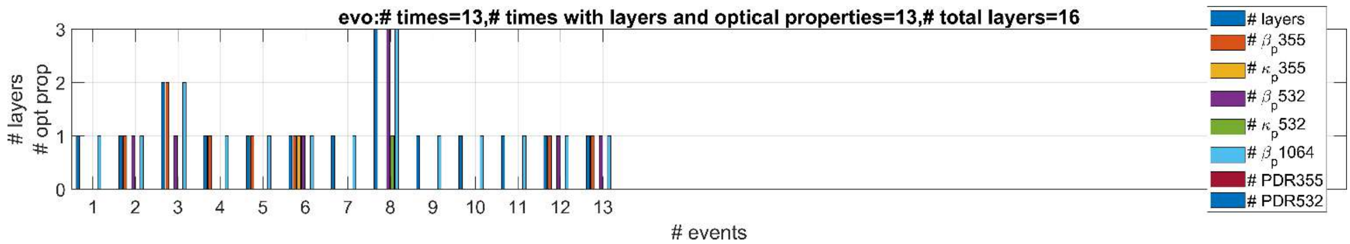
layers
opt prop
events
layers
β_p355
κ_p355
β_p532
κ_p532
β_p1064
PDR355
PDR532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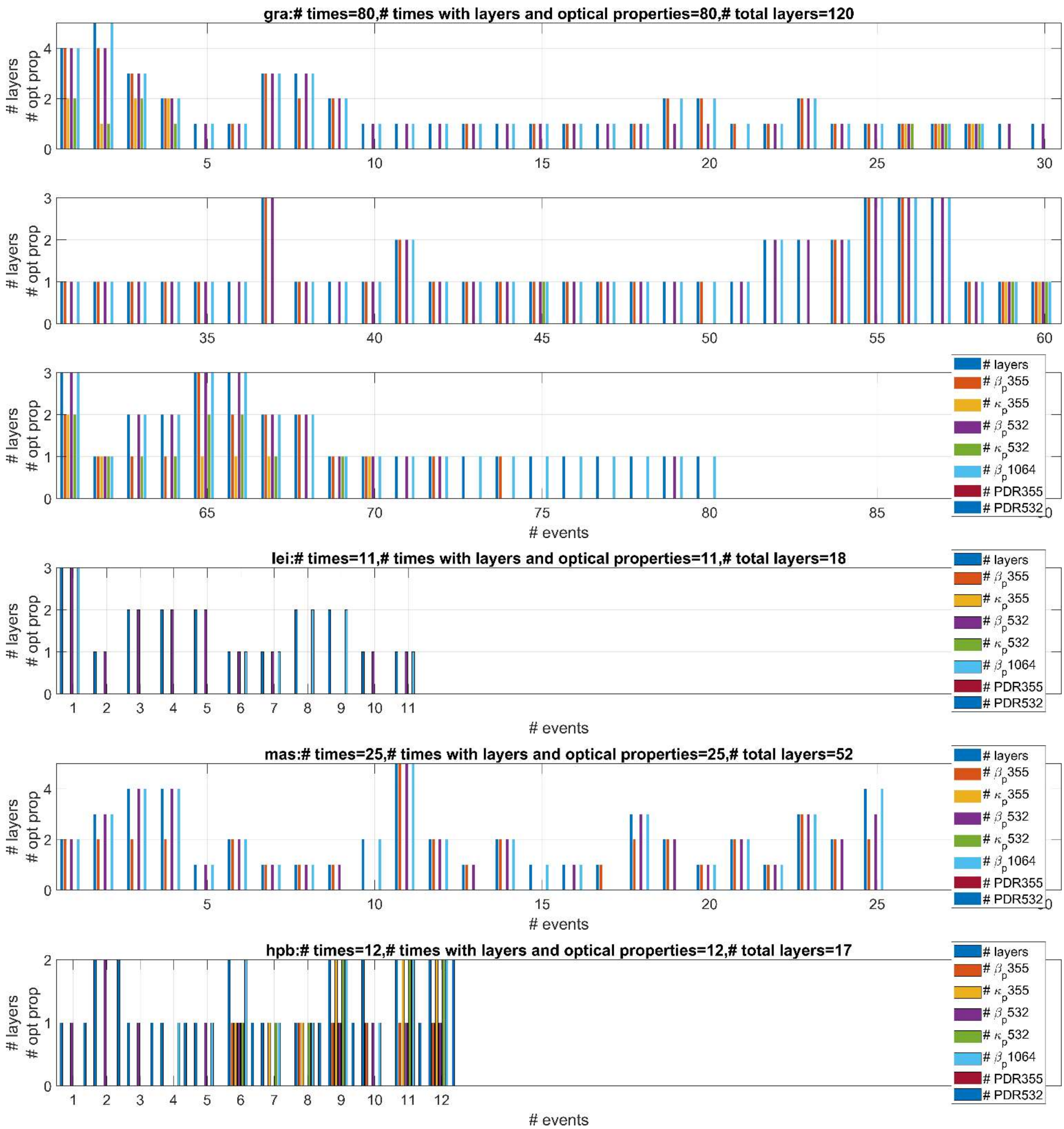
opt prop
events
layers
β_p355
κ_p355
β_p532
κ_p532
β_p1064
PDR355
PDR532



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lei:# times=11,# times with layers and optical properties=11,# total layers=18
mas:# times=25,# times with layers and optical properties=25,# total layers=52
hpb:# times=12,# times with layers and optical properties=12,# total layers=17
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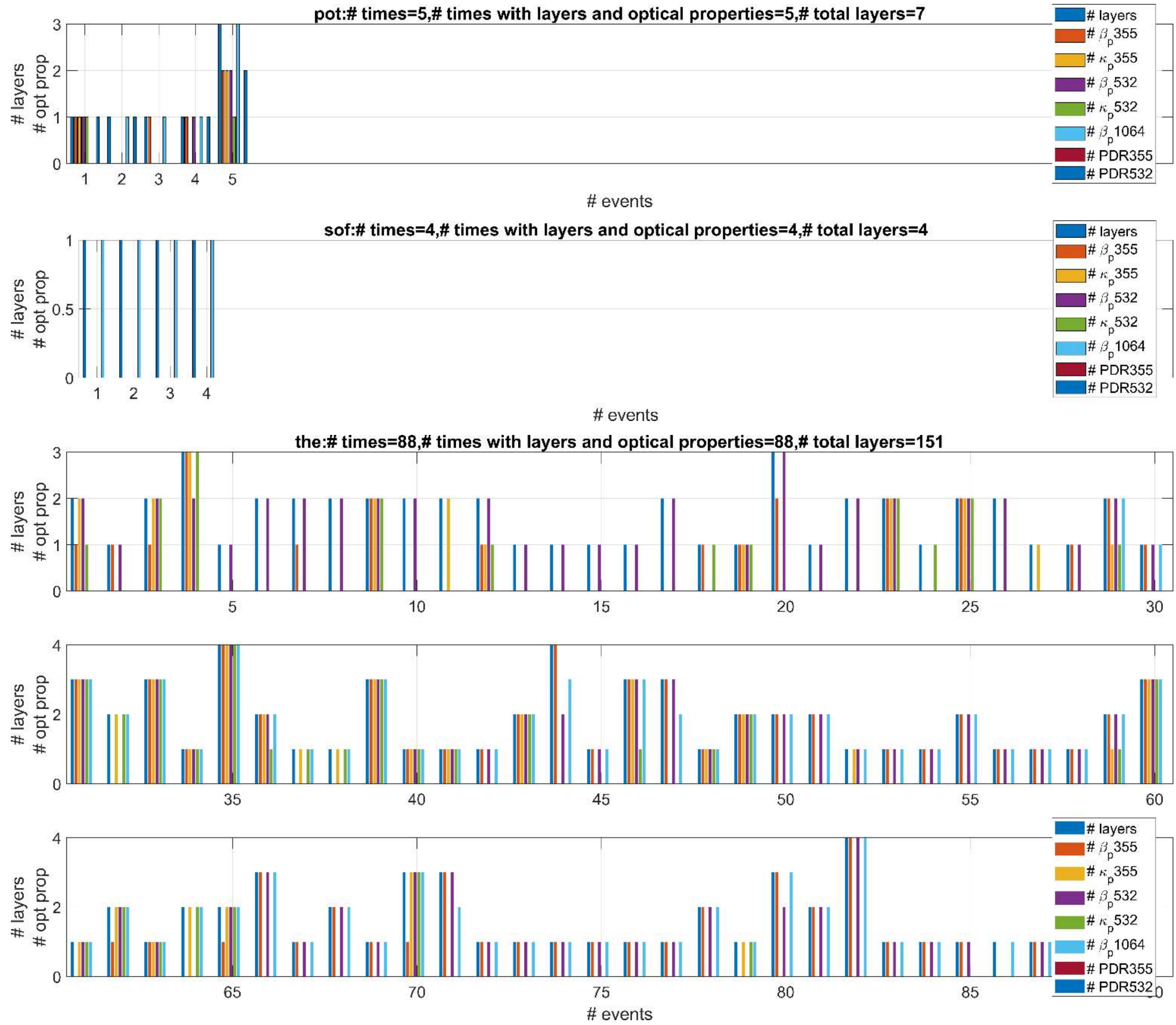
β_p1064
PDR355
PDR532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layers
opt prop
events
layers
βp355
κp355
βp532
κp532
βp1064
PDR355
PDR532
sof:# times=4,# times with layers and optical properties=4,# total layers=4
the:# times=88,# times with layers and optical properties=88,# total layers=151

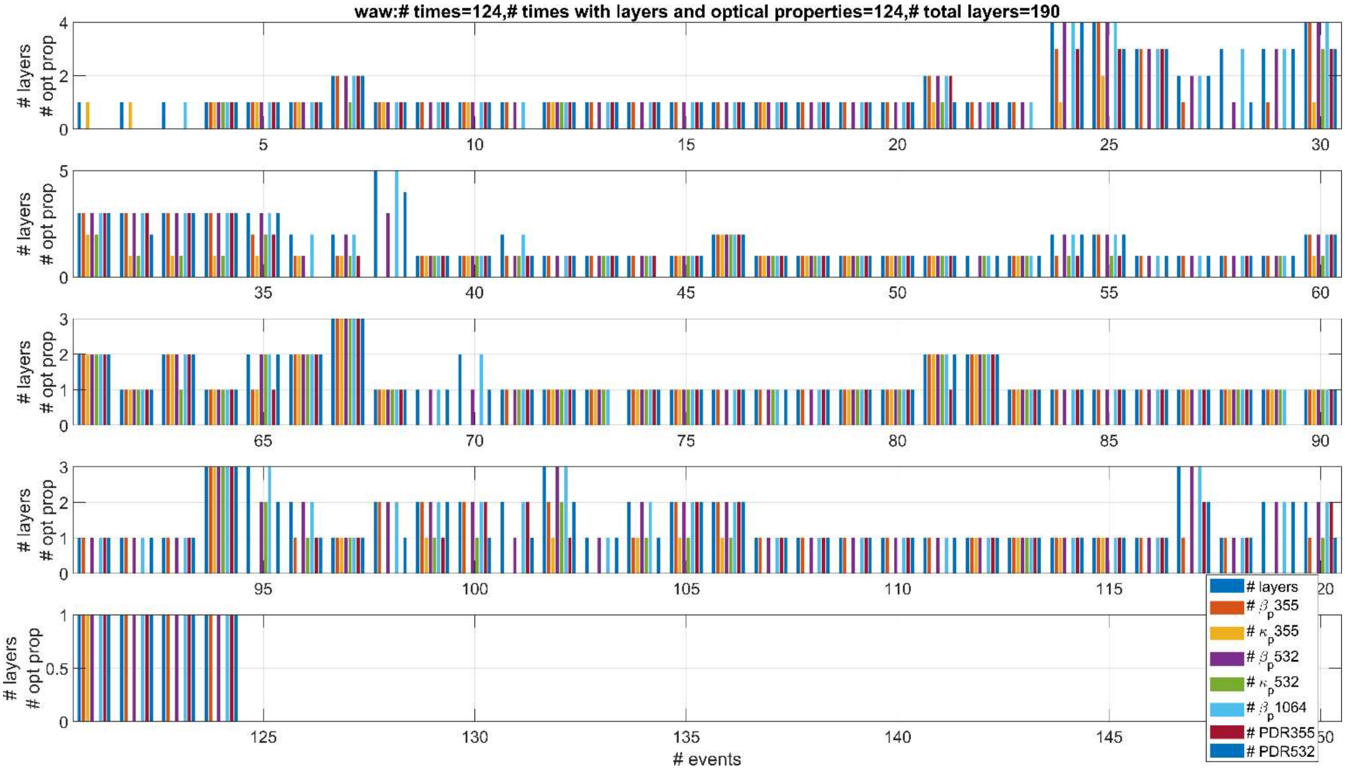
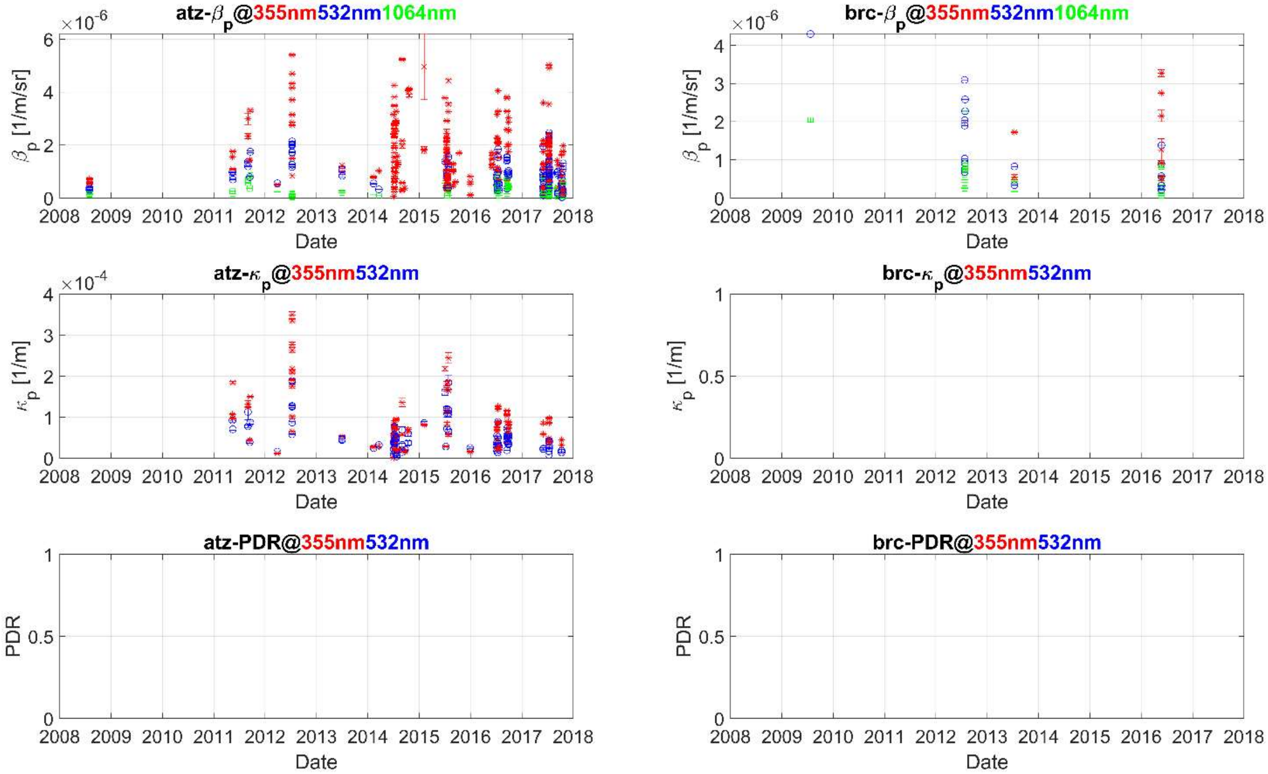
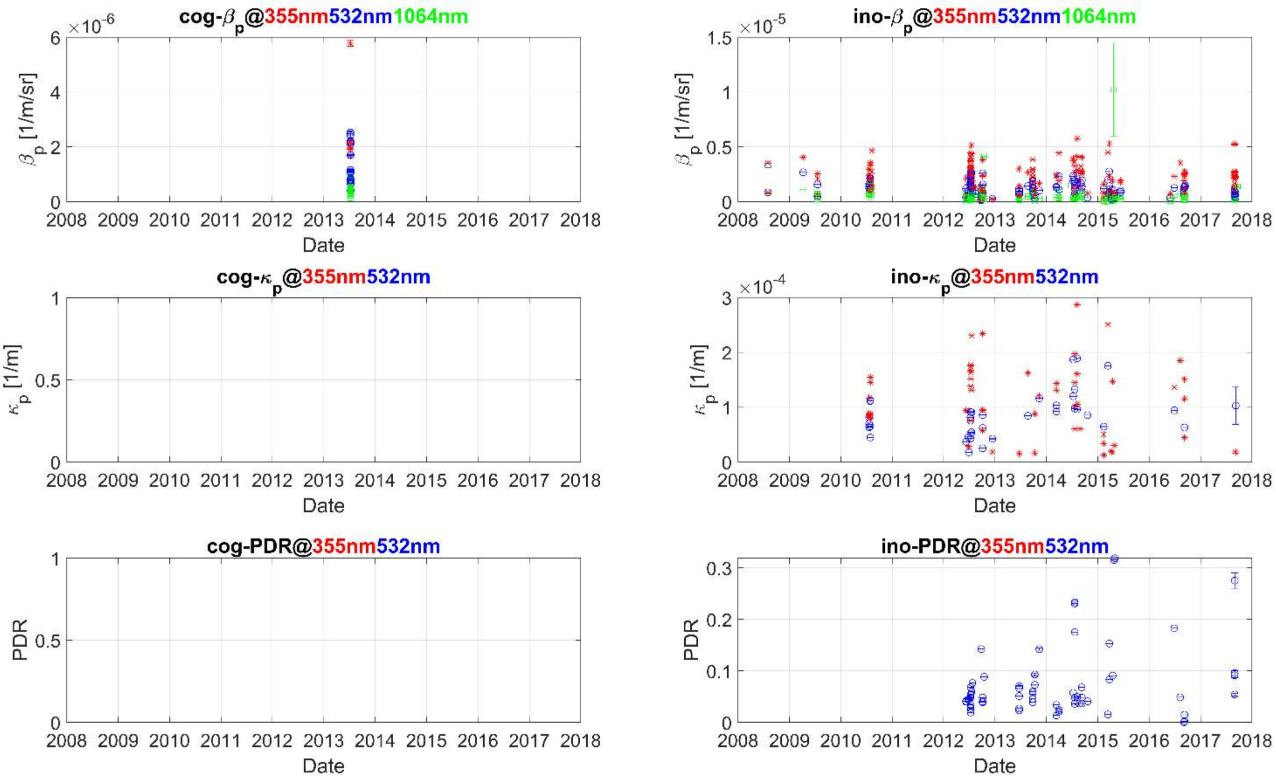


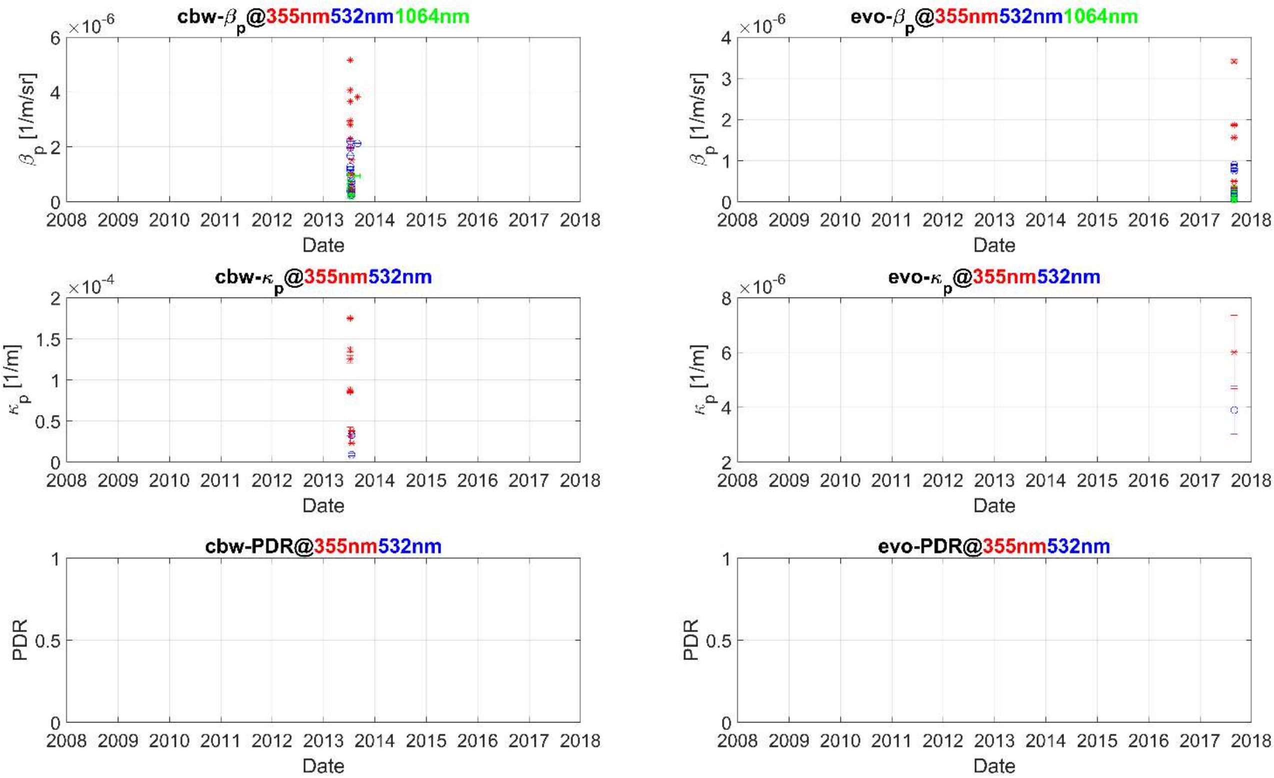
Figure S2. Number of times (# events) with smoke layers and the corresponding number of optical properties available. Station's acronym is in the title. For each event we have the number of layers (first blue bar) and the number of optical properties following the colour code in legend (particle backscatter coefficient β_p at 355 nm shown by dark orange on the second bar, particle extinction coefficient κ_p shown by dark yellow on the third bar etc). PDR stands for particle linear depolarization ratio.

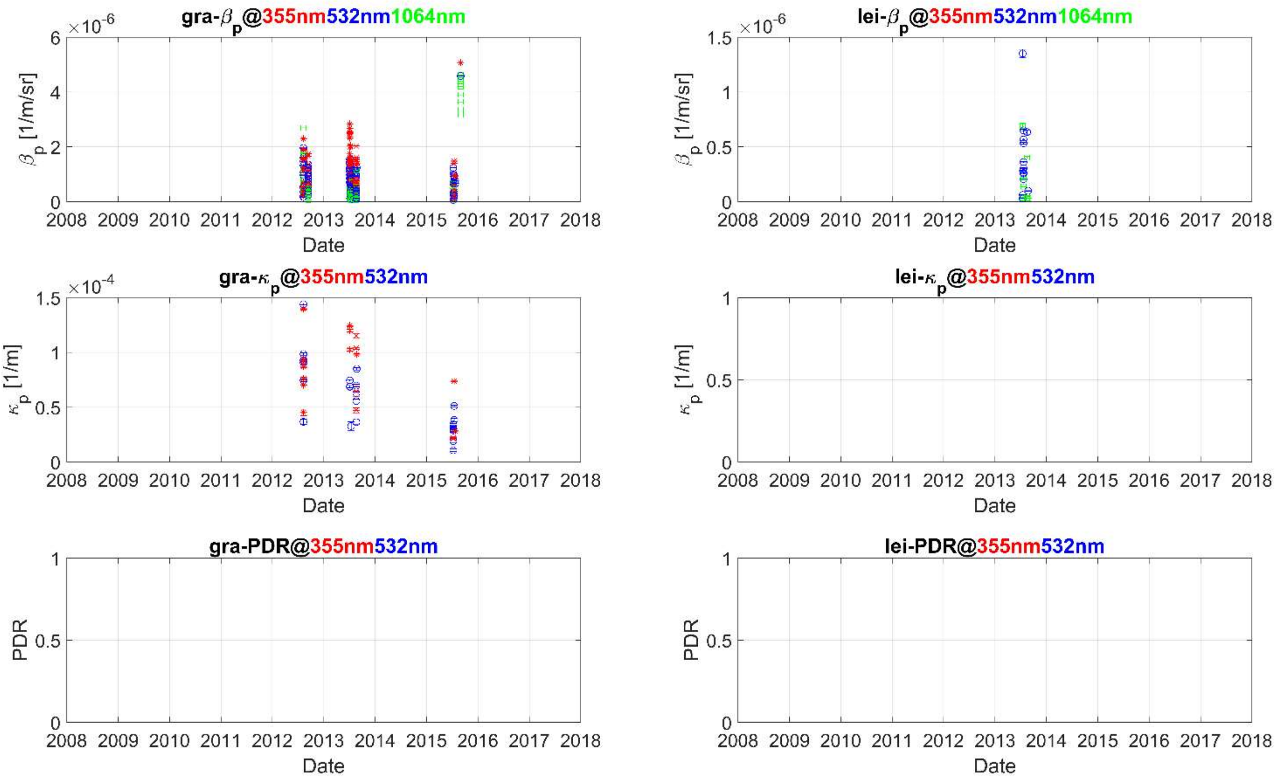
3 Mean optical properties in the layers

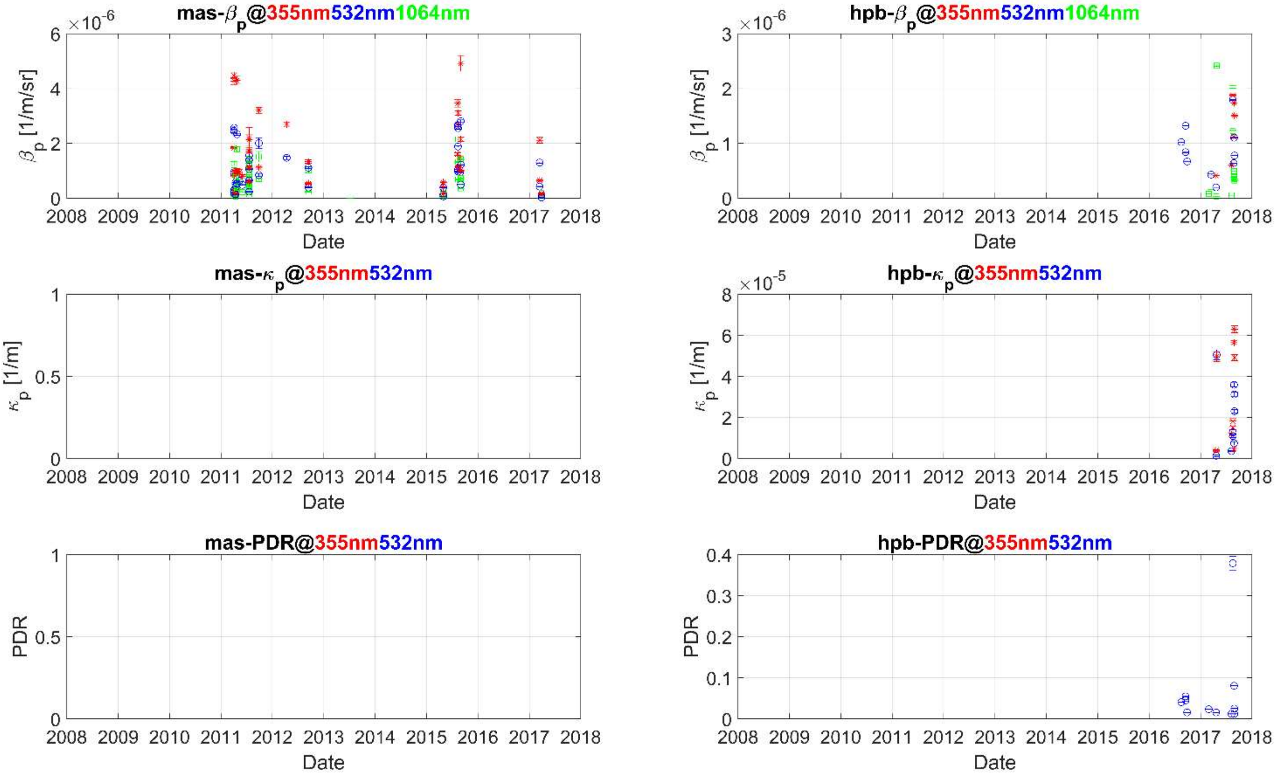


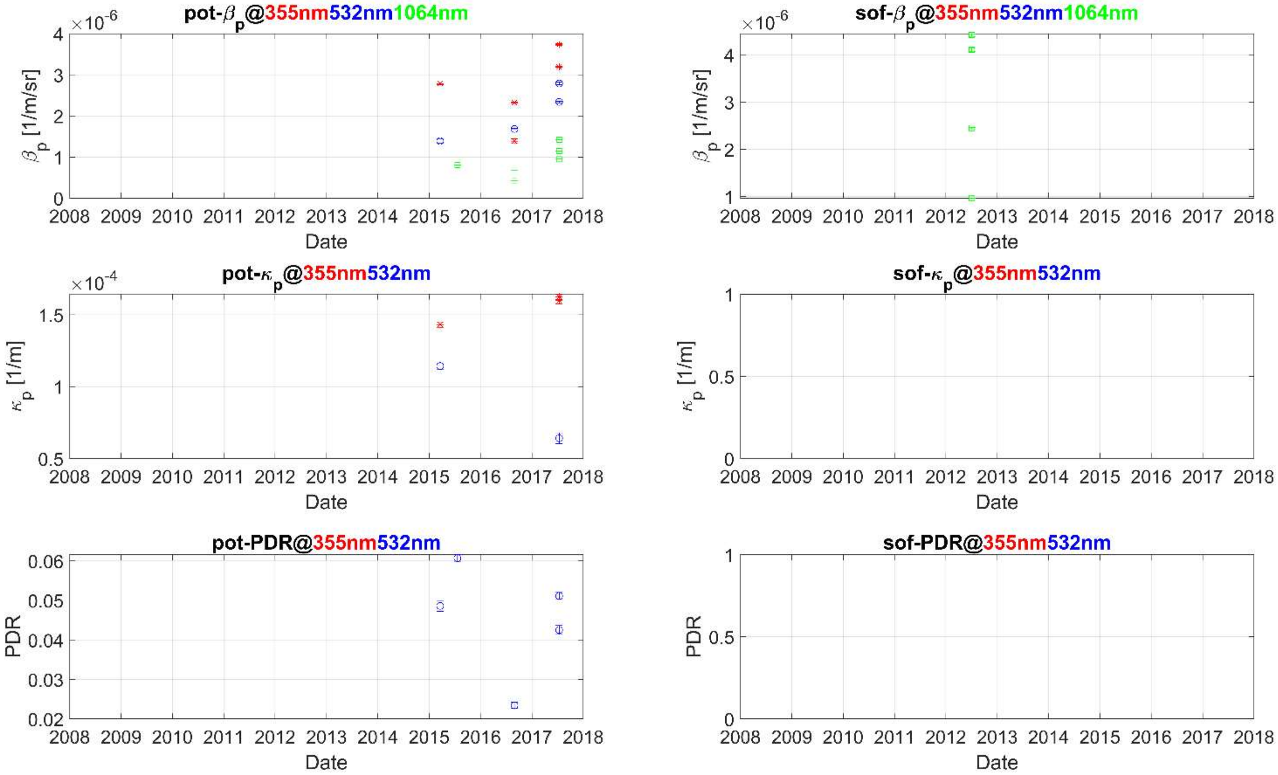


cog-βp@355nm532nm1064nm
ino-βp@355nm532nm1064nm
cog-κp@355nm532nm
ino-κp@355nm532nm
cog-PDR@355nm532nm
ino-PDR@355nm532nm
βp [1/m/sr]
κp [1/m]
PDR
Date


cbw-β_p@355nm532nm1064nm
β_p [1/m/sr]
$\times10^{-6}$
Date
evo-β_p@355nm532nm1064nm
β_p [1/m/sr]
$\times10^{-6}$
Date
cbw-κ_p@355nm532nm
κ_p [1/m]
$\times10^{-4}$
Date
evo-κ_p@355nm532nm
κ_p [1/m]
$\times10^{-6}$
Date
cbw-PDR@355nm532nm
PDR
Date
evo-PDR@355nm532nm
PDR
Date
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018


gra-β_p@355nm532nm1064nm
$\times 10^{-6}$
β_p [1/m/sr]
lei-β_p@355nm532nm1064nm
$\times 10^{-6}$
β_p [1/m/sr]
gra-κ_p@355nm532nm
$\times 10^{-4}$
κ_p [1/m]
lei-κ_p@355nm532nm
κ_p [1/m]
gra-PDR@355nm532nm
PDR
lei-PDR@355nm532nm
PDR
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Date


mas-β_p@355nm532nm1064nm
β_p [1/m/sr]
$\times 10^{-6}$
Date
hpb-β_p@355nm532nm1064nm
$\times 10^{-6}$
mas-κ_p@355nm532nm
κ_p [1/m]
hpb-κ_p@355nm532nm
$\times 10^{-5}$
mas-PDR@355nm532nm
PDR
hpb-PDR@355nm532nm
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018


pot-β_p@355nm532nm1064nm
sof-β_p@355nm532nm1064nm
pot-κ_p@355nm532nm
sof-κ_p@355nm532nm
pot-PDR@355nm532nm
sof-PDR@355nm532nm
β_p [1/m/sr]
κ_p [1/m]
PDR
Date

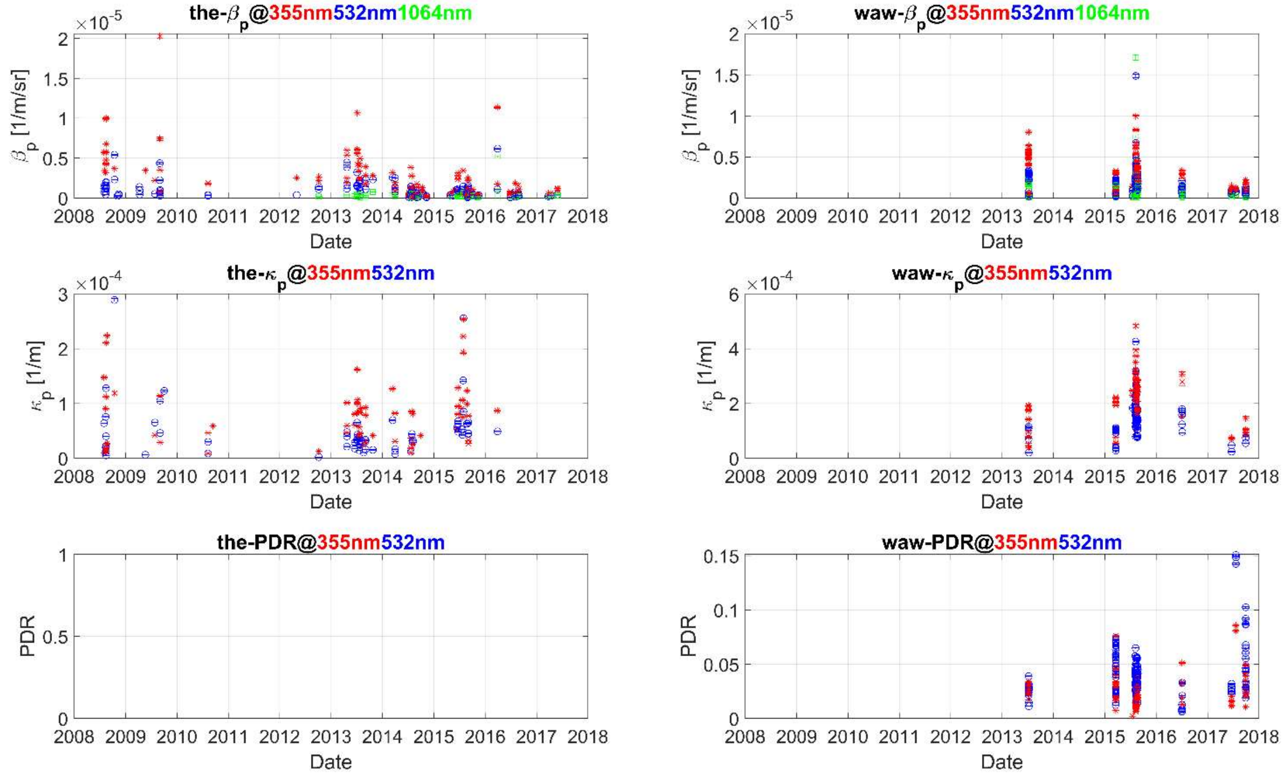
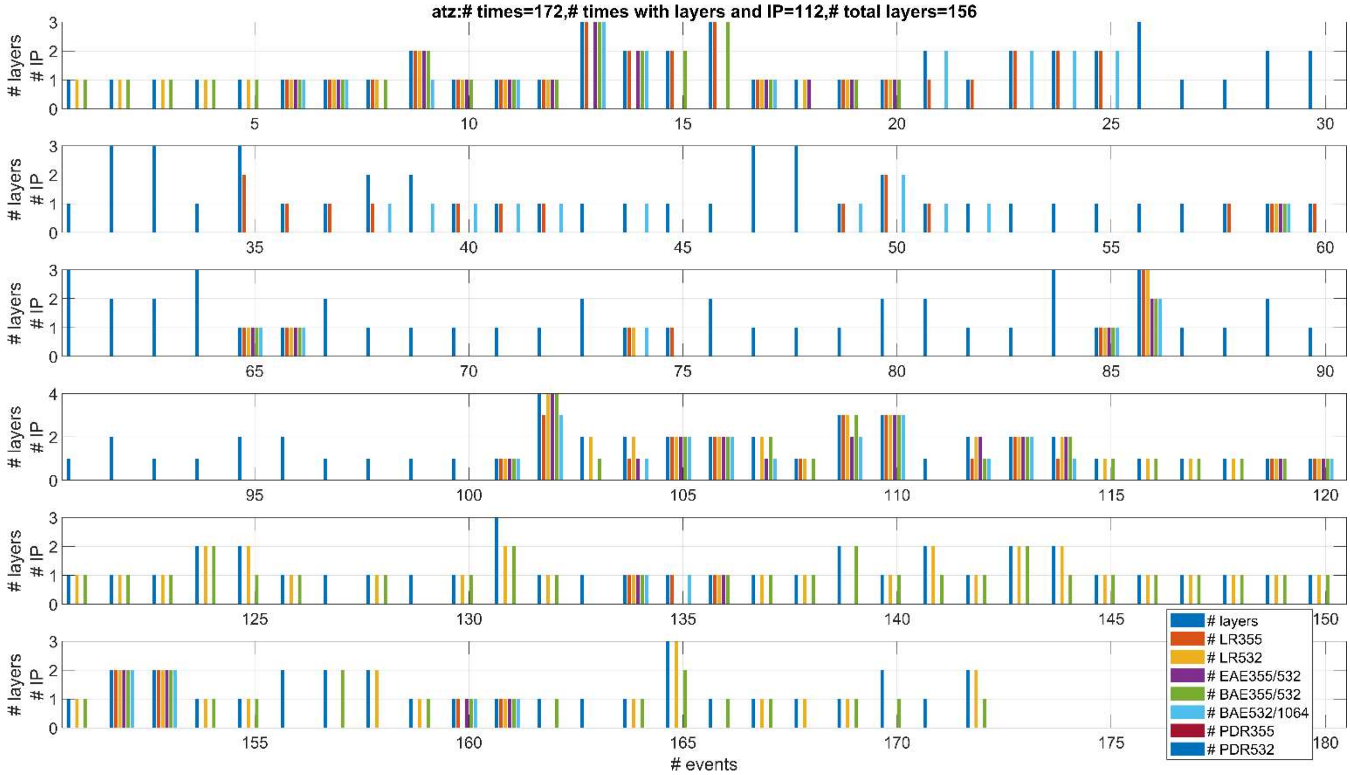
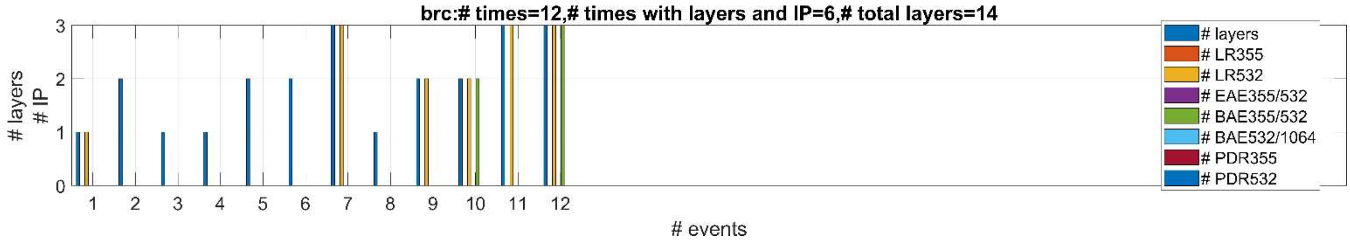
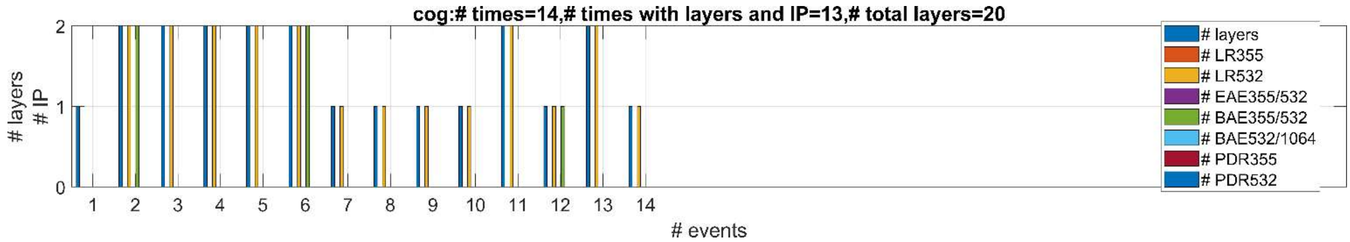


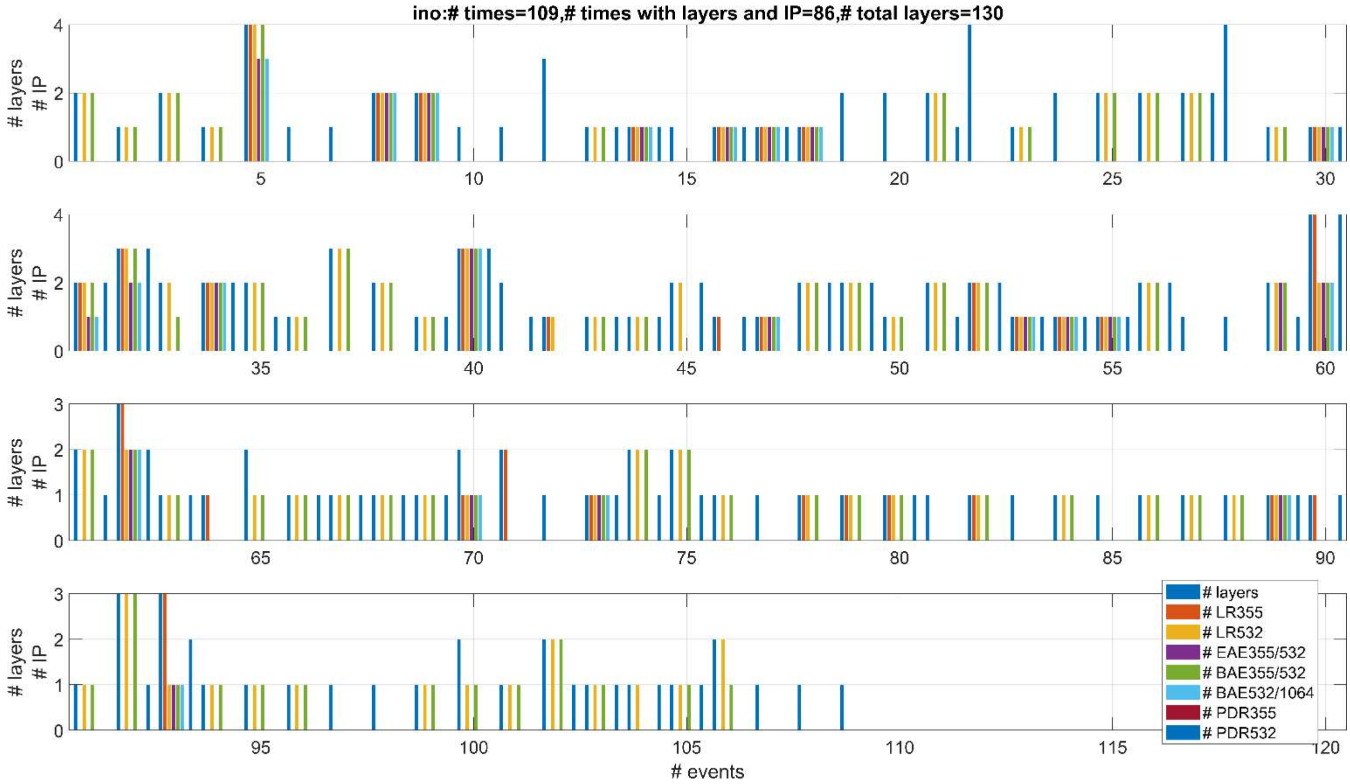
Figure S3. Values of the mean optical properties and associated uncertainties in the smoke layers for each station. Station's acronym is in the title. β_p = particle backscatter coefficient, κ_p = particle extinction coefficient, PDR = linear particle depolarization ratio.

4. Statistics over the number of layers and intensive optical parameters





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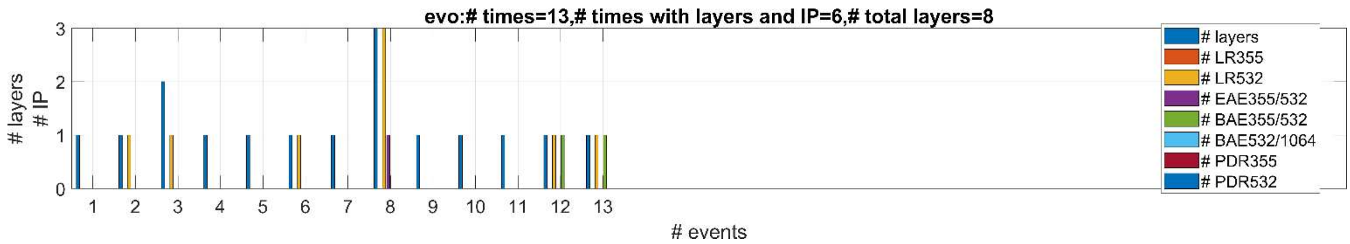
layers
IP
events
layers
LR355
LR532
EAE355/532
BAE355/532
BAE532/1064
PDR355
PDR532


cbw:# times=8,# times with layers and IP=8,# total layers=14
layers
IP
events
layers
LR355
LR532
EAE355/532
BAE355/532
BAE532/1064
PDR355
PDR532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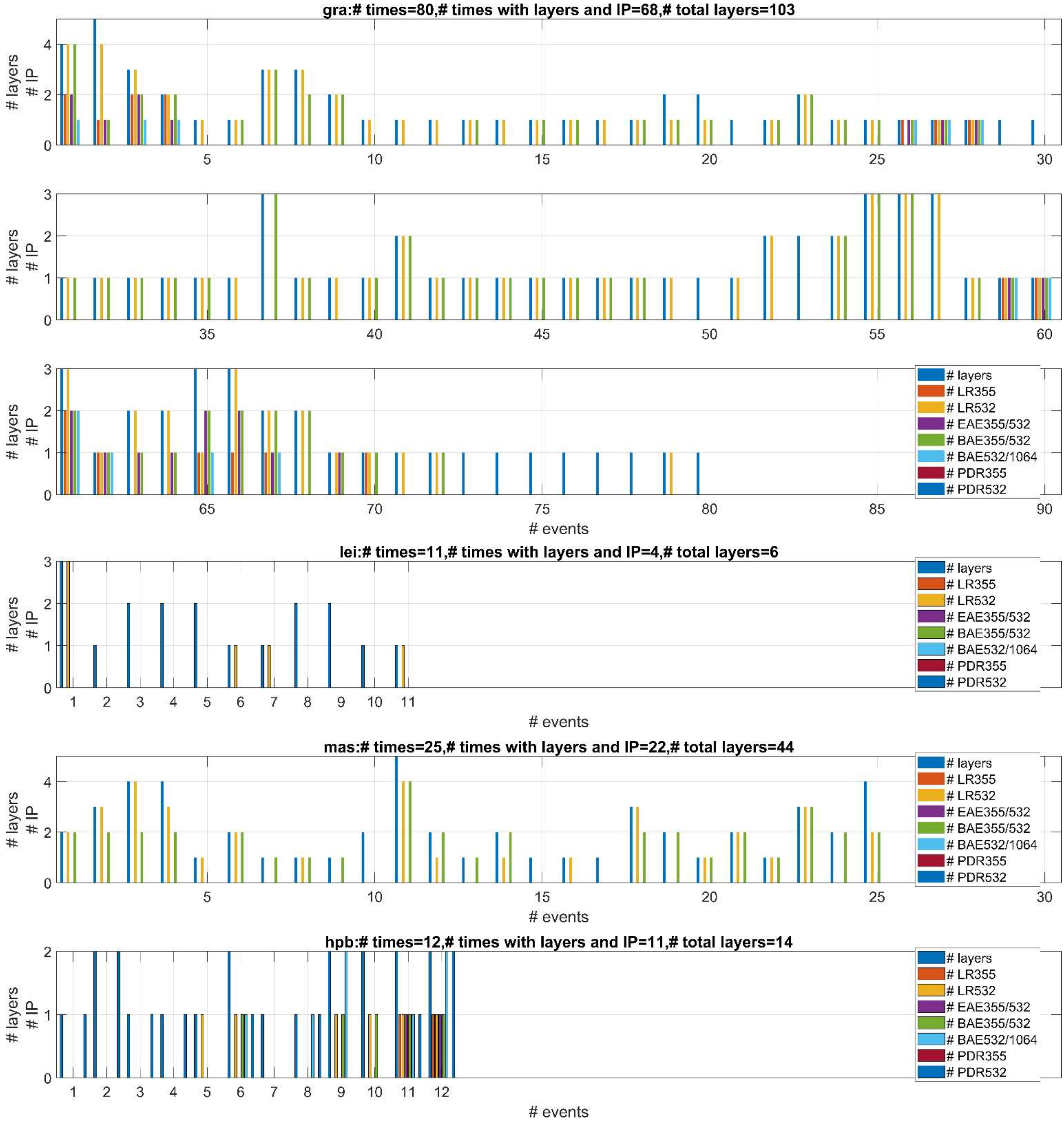
layers
IP
events
layers
LR355
LR532
EAE355/532
BAE355/532
BAE532/1064
PDR355
PDR532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mas:# times=25,# times with layers and IP=22,# total layers=44
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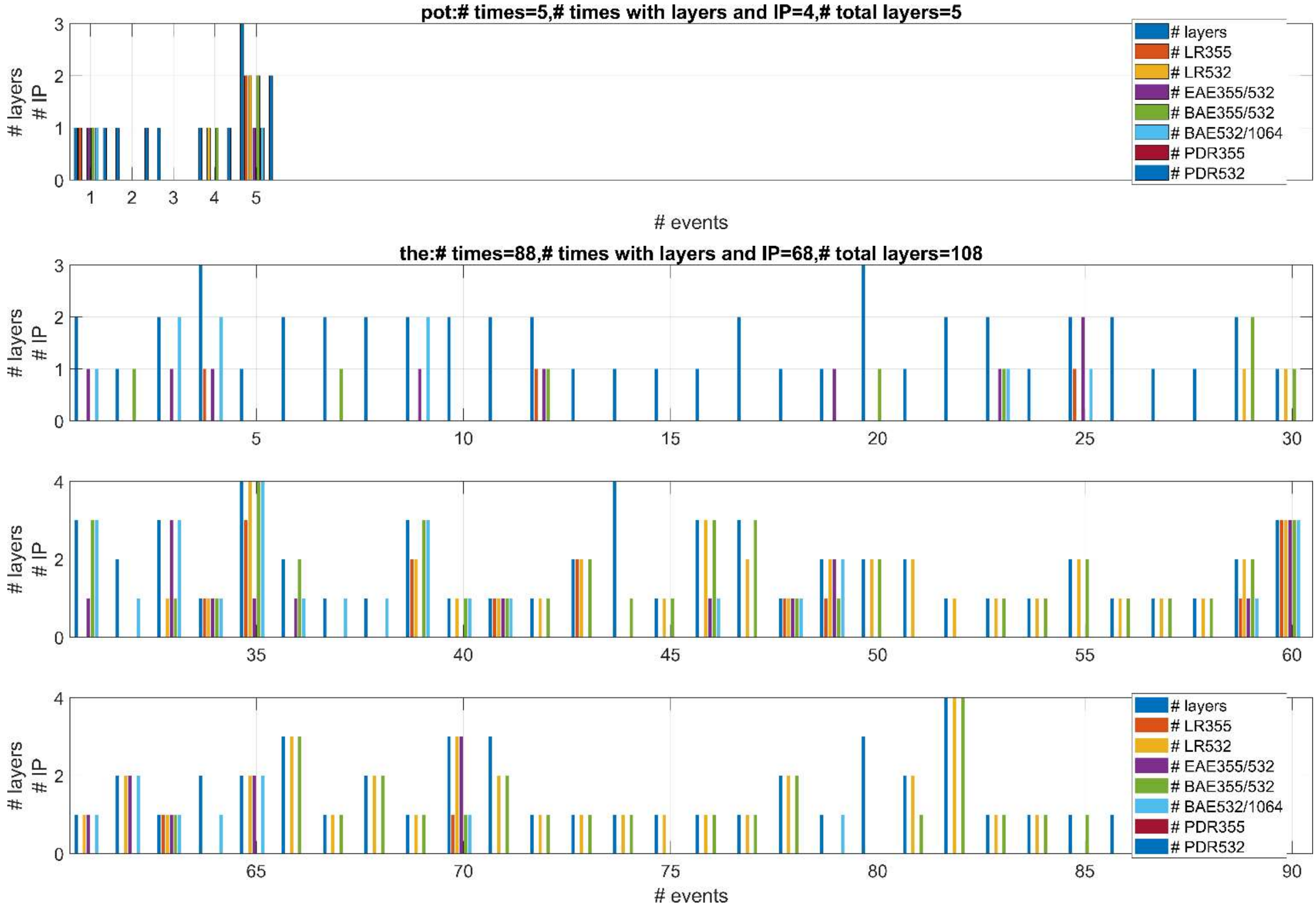
PDR355
PDR532



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IP
events
layers
LR355
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PDR355
PDR532

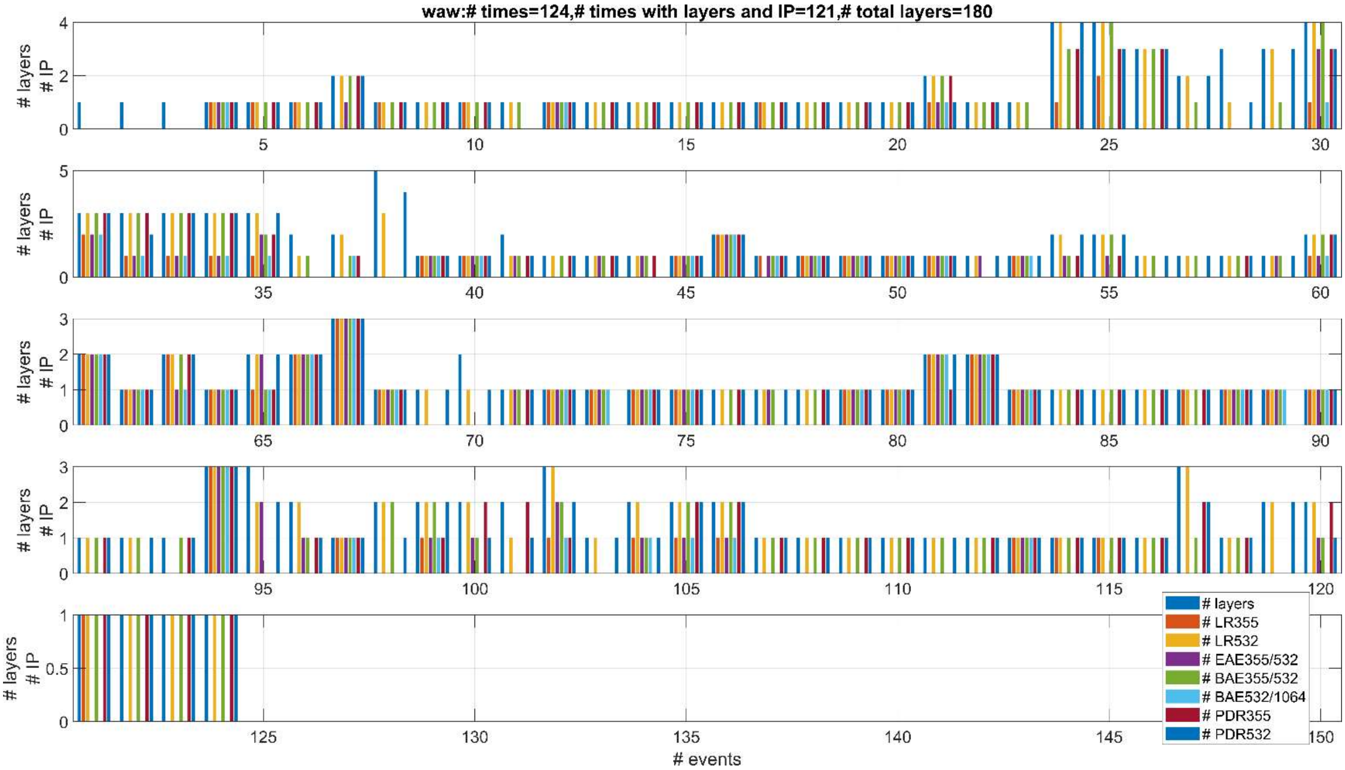
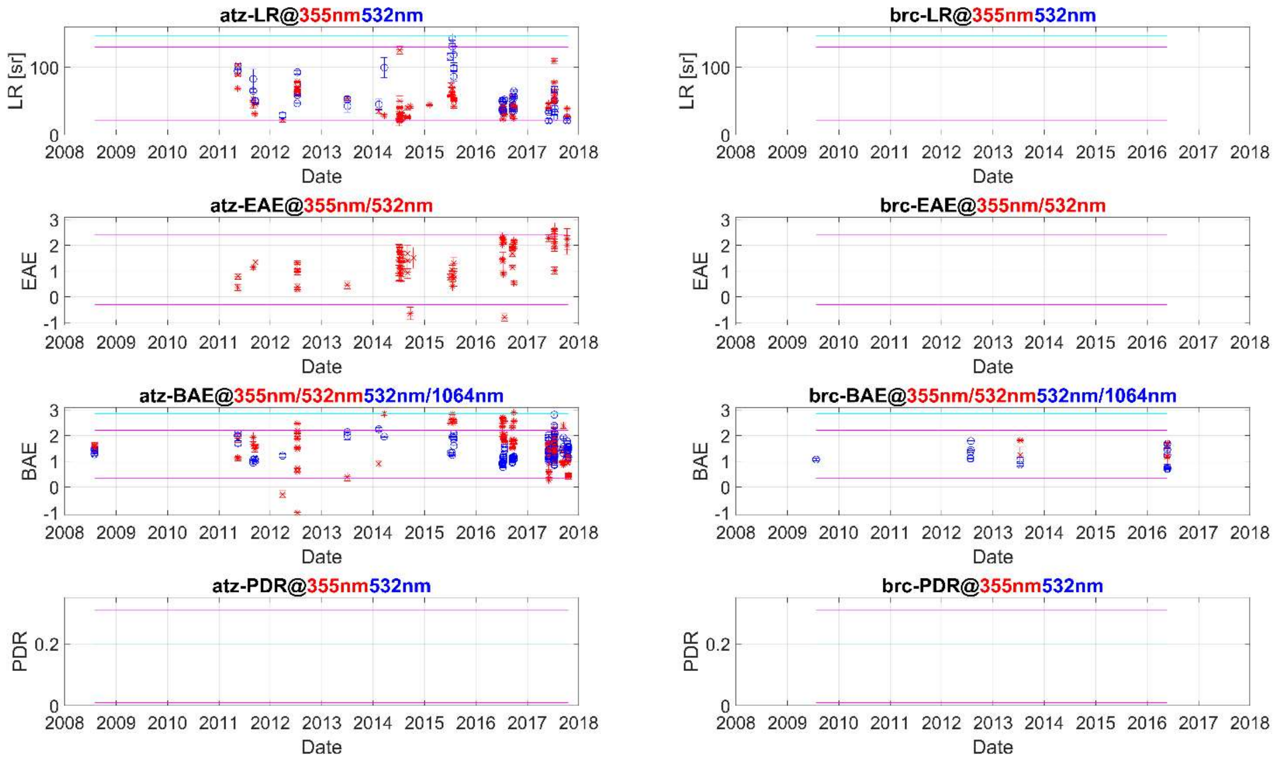
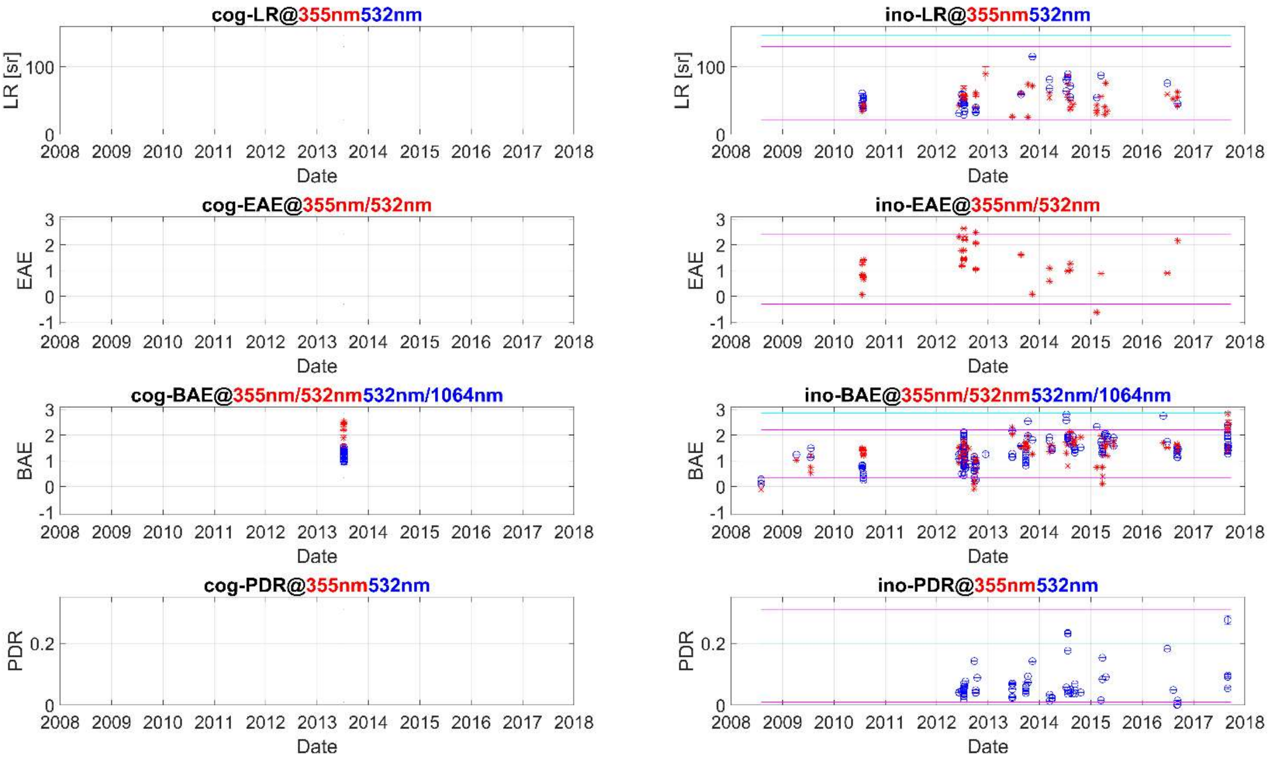
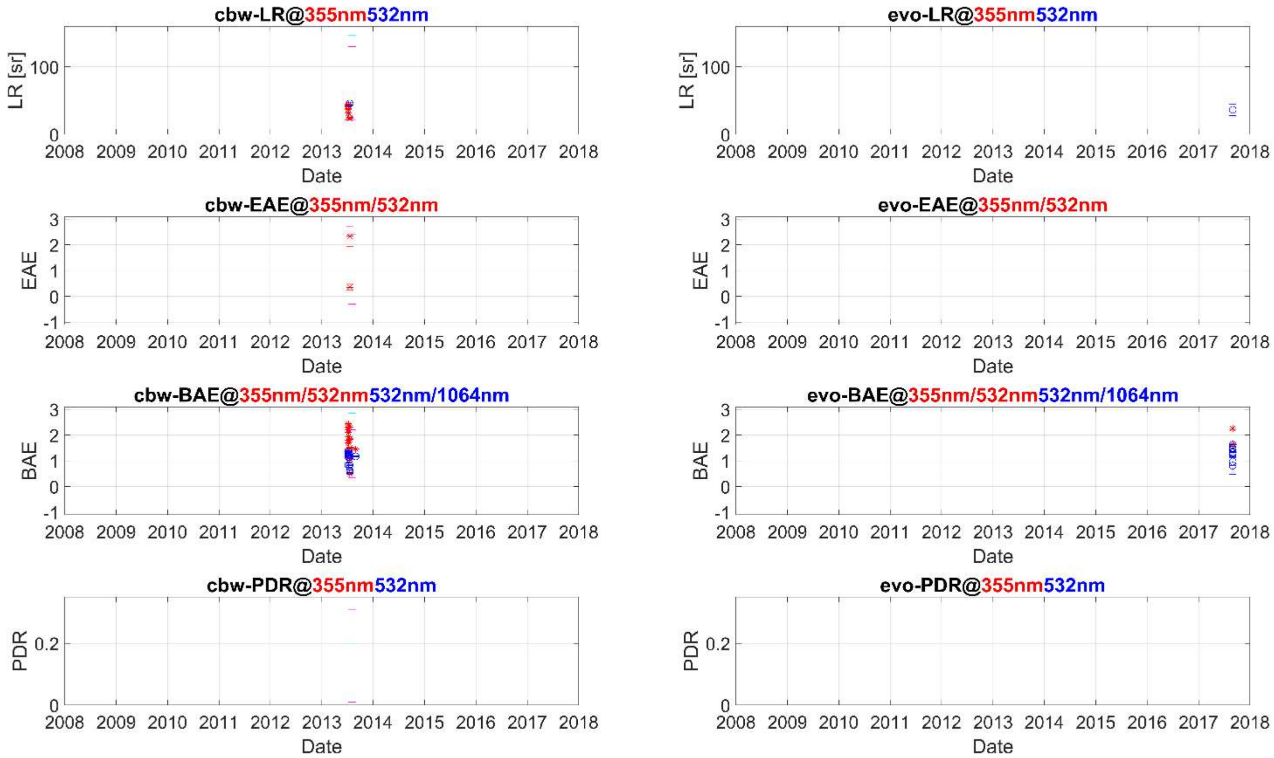


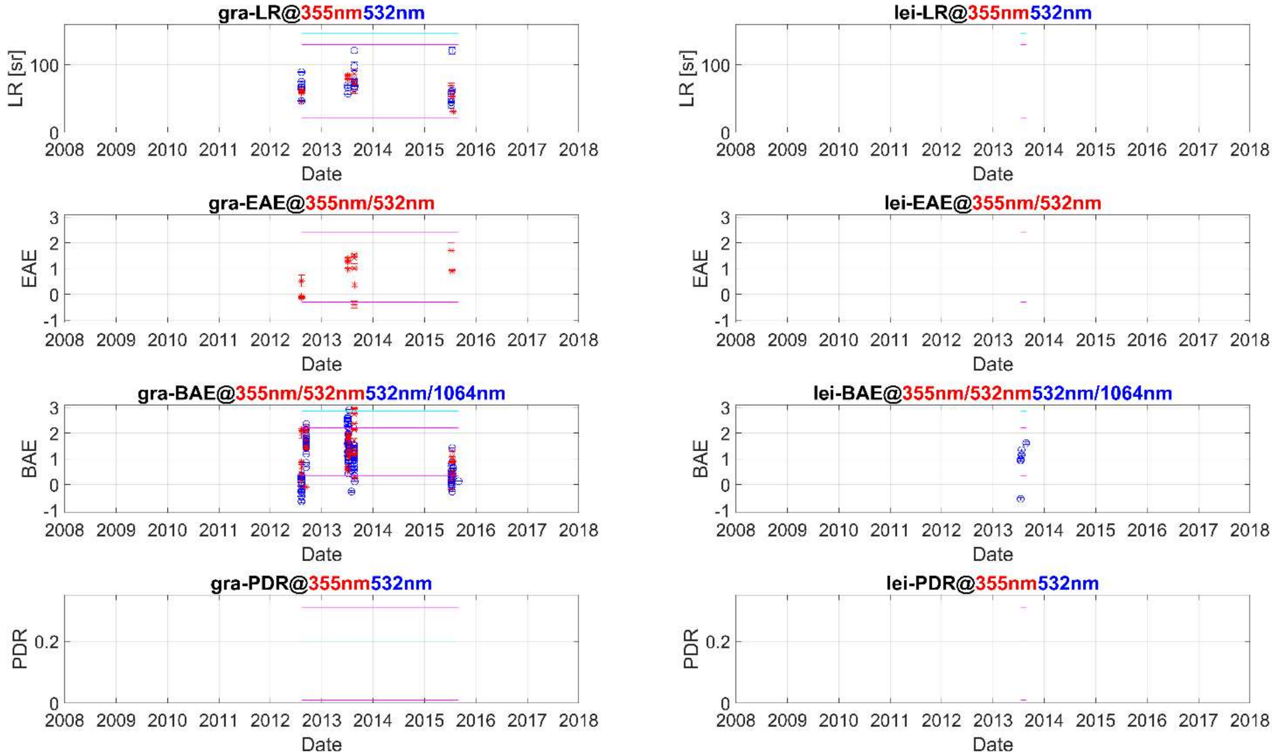
Figure S4. Number of times (# events) with smoke layers and the corresponding number of intensive parameters retrieved. Station's acronym is in the title. For each event we have the number of layers (first blue bar) and the number of intensive parameters following the colour code in legend (LR at 355 nm shown by dark orange on the second bar, LR at 532 nm shown by dark yellow on the third bar etc). LR = lidar ratio, EAE = extinction Ångström exponent, BAE=backscatter Ångström exponent and PDR = particle linear depolarization ratio. No intensive parameter was available for Sofia station.

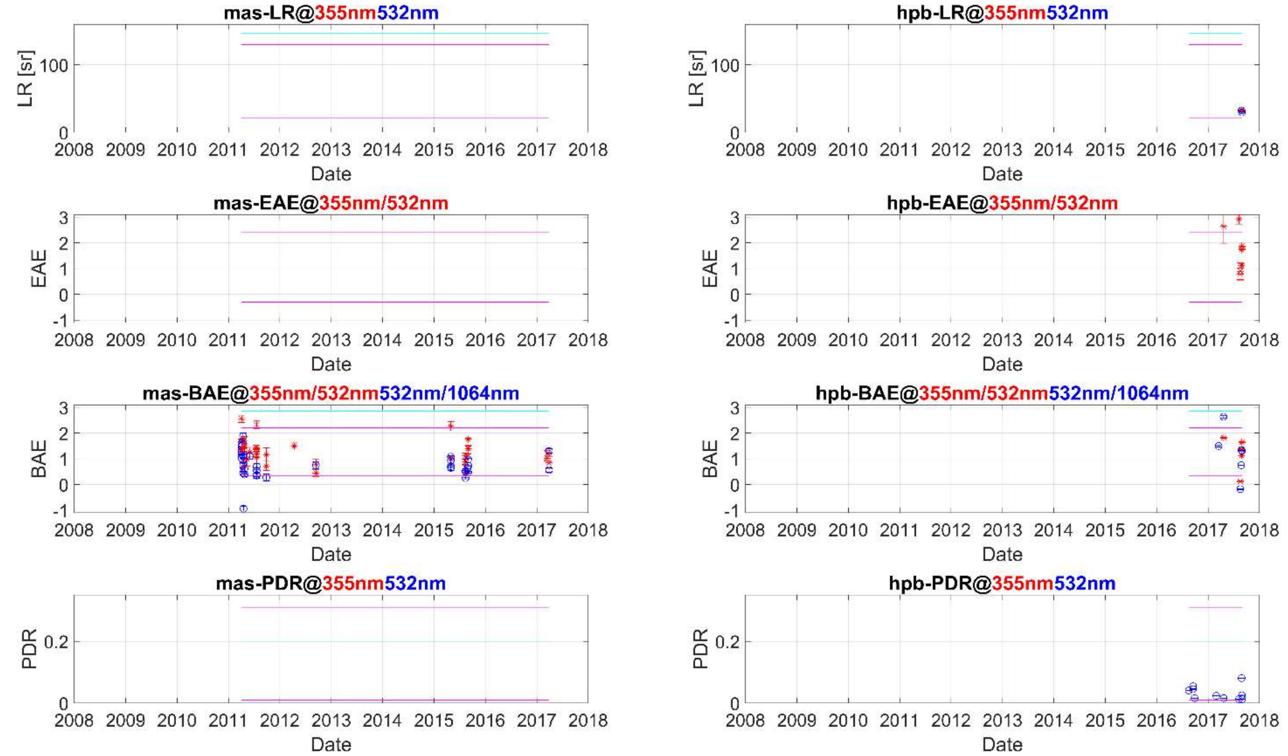
5 Mean intensive optical parameters in the layers




cog-LR@355nm532nm
LR [sr]
Date
ino-LR@355nm532nm
cog-EAE@355nm/532nm
EAE
ino-EAE@355nm/532nm
cog-BAE@355nm/532nm532nm/1064nm
BAE
ino-BAE@355nm/532nm532nm/1064nm
cog-PDR@355nm532nm
PDR
ino-PDR@355nm532nm


cbw-LR@355nm532nm
evo-LR@355nm532nm
cbw-EAE@355nm/532nm
evo-EAE@355nm/532nm
cbw-BAE@355nm/532nm532nm/1064nm
evo-BAE@355nm/532nm532nm/1064nm
cbw-PDR@355nm532nm
evo-PDR@355nm532nm
LR [sr]
EAE
BAE
PDR
Date
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018


gra-LR@355nm532nm
LR [sr]
Date
lei-LR@355nm532nm
gra-EAE@355nm/532nm
EAE
lei-EAE@355nm/532nm
gra-BAE@355nm/532nm532nm/1064nm
BAE
lei-BAE@355nm/532nm532nm/1064nm
gra-PDR@355nm532nm
PDR
lei-PDR@355nm532nm


mas-LR@355nm532nm
LR [sr]
Date
hpb-LR@355nm532nm
mas-EAE@355nm/532nm
EAE
hpb-EAE@355nm/532nm
mas-BAE@355nm/532nm532nm/1064nm
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hpb-BAE@355nm/532nm532nm/1064nm
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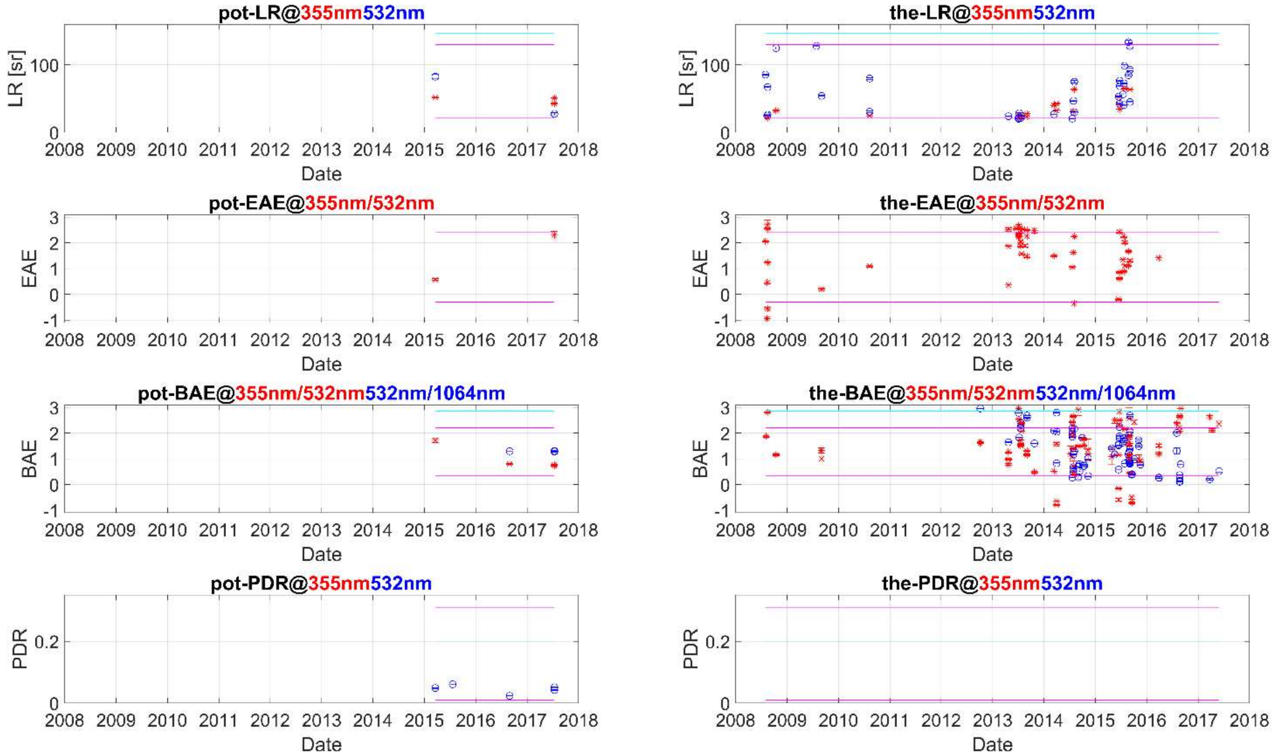
PDR
hpb-PDR@355nm532nm


pot-LR@355nm532nm
the-LR@355nm532nm
LR [sr]
pot-EAE@355nm/532nm
the-EAE@355nm/532nm
EAE
pot-BAE@355nm/532nm532nm/1064nm
the-BAE@355nm/532nm532nm/1064nm
BAE
pot-PDR@355nm532nm
the-PDR@355nm532nm
PDR
Date
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

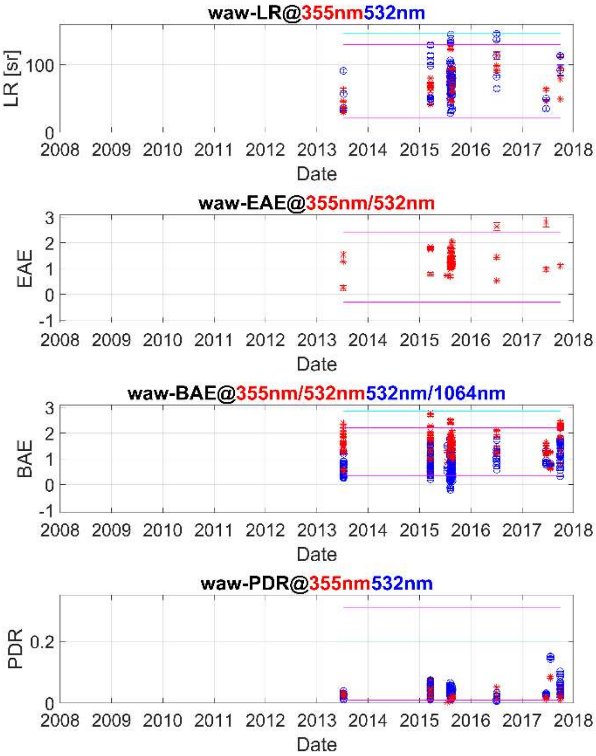
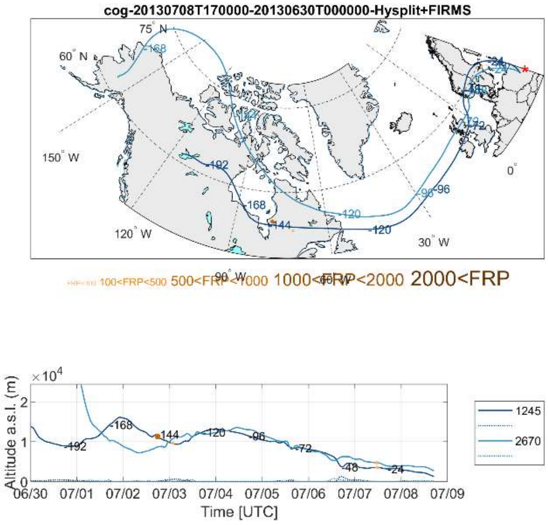
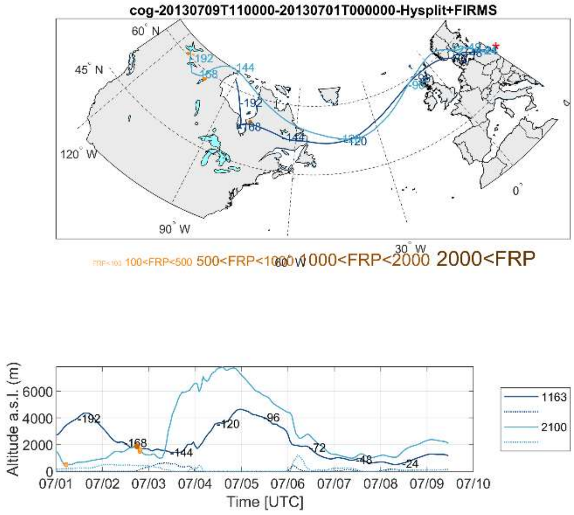
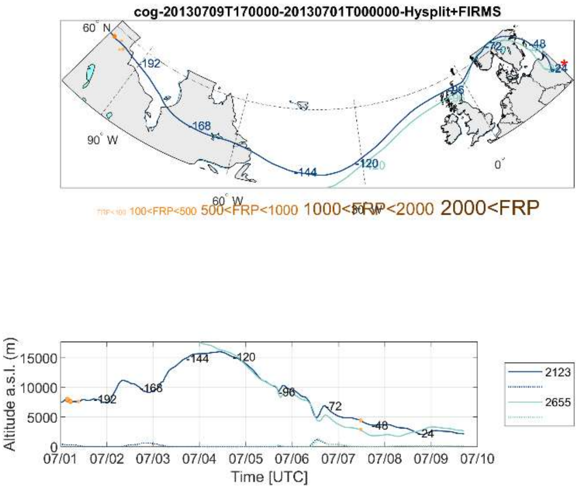


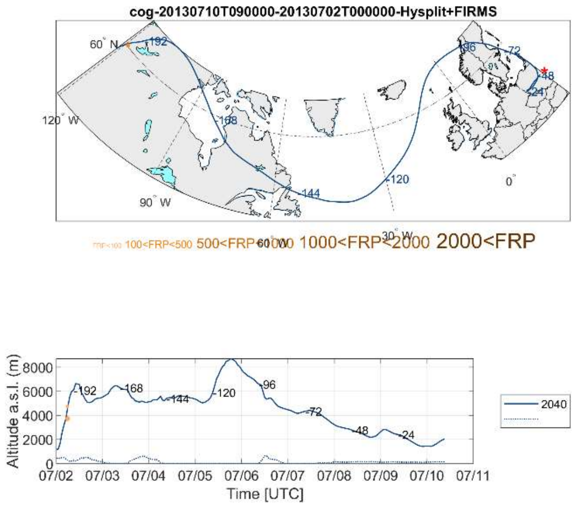
Figure S5. Intensive parameters for each station. Station's acronym is in the title. The lines represent the extreme values found in literature. The lines in magenta show the limits for the intensive parameters shown in red while the cyan lines show the limits for the intensive parameters shown in blue.

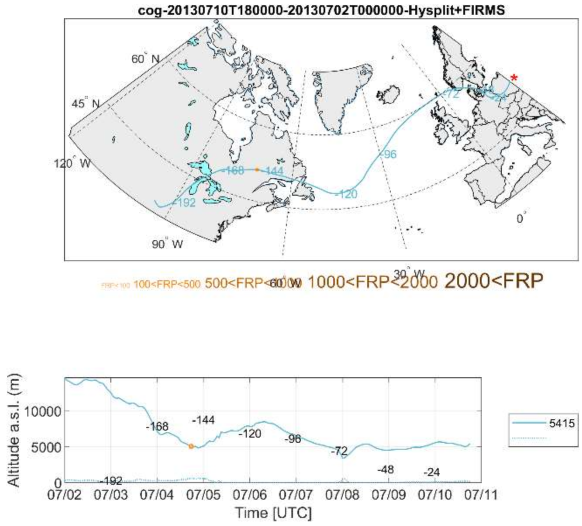
6 Backtrajectories for event 20130708-20130710 in Belsk (“cog”), Cabauw (“cbw”), and Warsaw (“waw”) stations

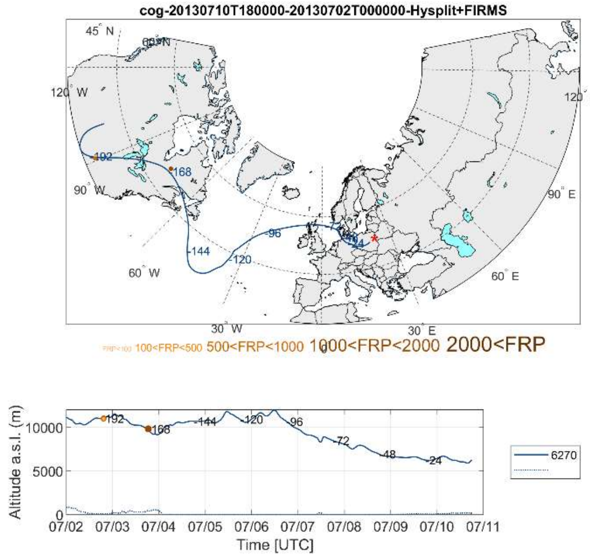









cog-20130710T180000-20130702T000000-Hysplit+FIRMS
100<FRP<500 500<FRP<1000 1000<FRP<2000 2000<FRP
Altitude a.s.l. (m)
Time [UTC]
5415


cog-20130710T180000-20130702T000000-Hysplit+FIRMS
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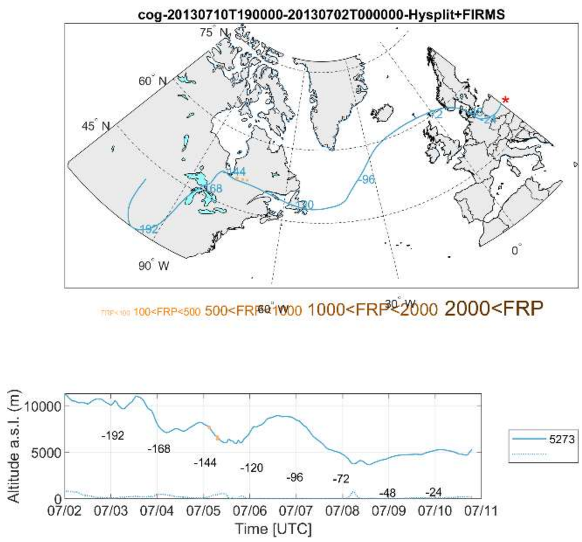
Altitude a.s.l. (m)
Time [UTC]
6270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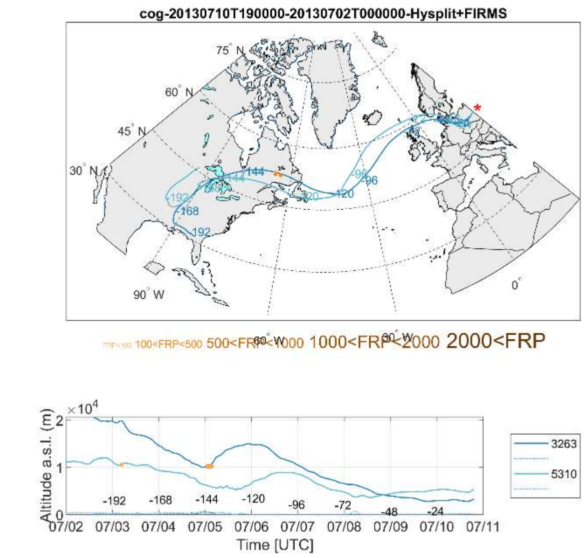
100<FRP<500 500<FRP<1000 1000<FRP<2000 2000<FRP
Altitude a.s.l. (m)
Time [UTC]
5273


cog-20130710T190000-20130702T000000-Hysplit+FIRMS
100<FRP<500 500<FRP<1000 1000<FRP<2000 2000<FRP
Altitude a.s.l. (m)
Time [UTC]
3263
5310

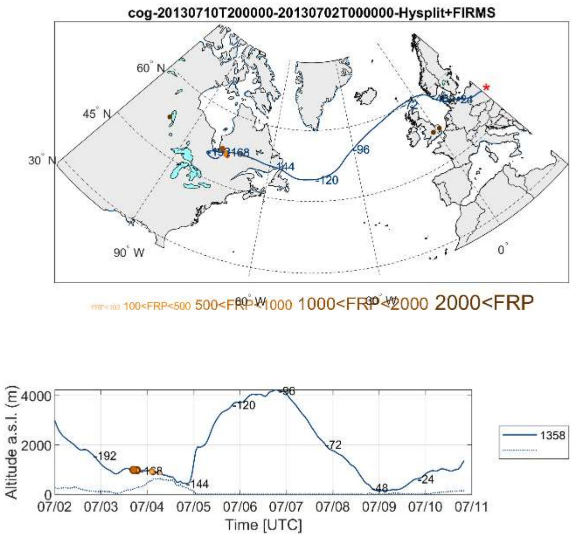
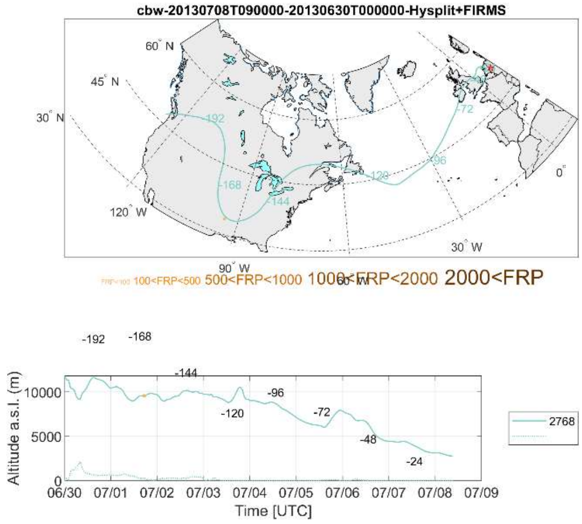
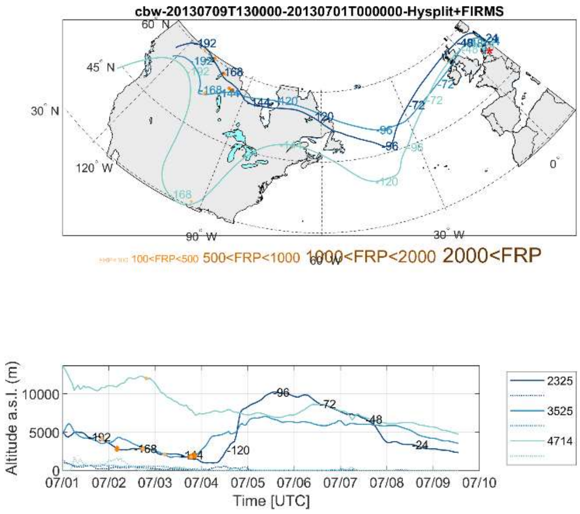


Figure S6.1. Hysplit backtrajectories and location of the fires (according to FIRMS) along backtrajectories within 100 km and +/- 1h for Belsk ("cog") station for the period 8-10 July 2013. Lower plots show the altitude (a.s.l.) of the backtrajectories versus time. Fires' occurrence time is shown as well. Date and time (start and end for backtrajectory) for each measurement is mentioned in the title of each plot.


cbw-20130708T090000-20130630T000000-Hysplit+FIRMS
100<FRP<500 500<FRP<1000 1000<FRP<2000 2000<FRP
Altitude a.s.l. (m)
Time [UTC]
2768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Time [UTC]
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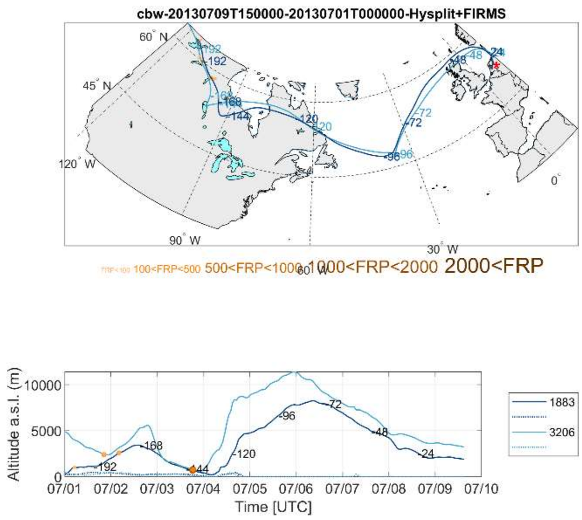
3525
4714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Time [UTC]
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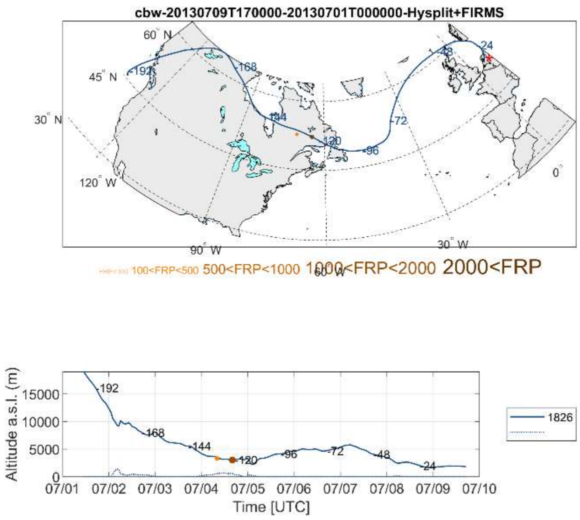
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Time [UTC]
1826

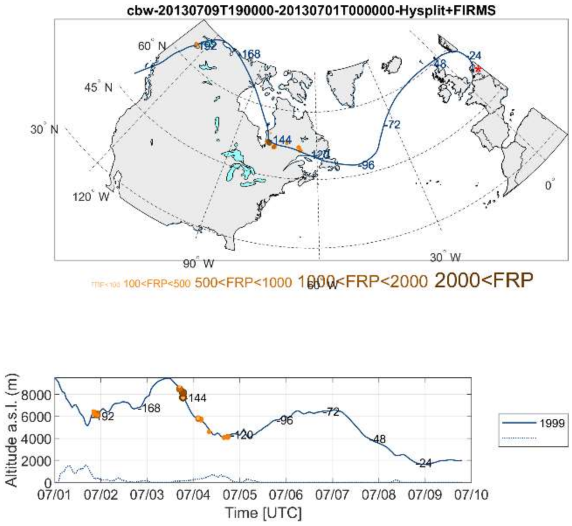
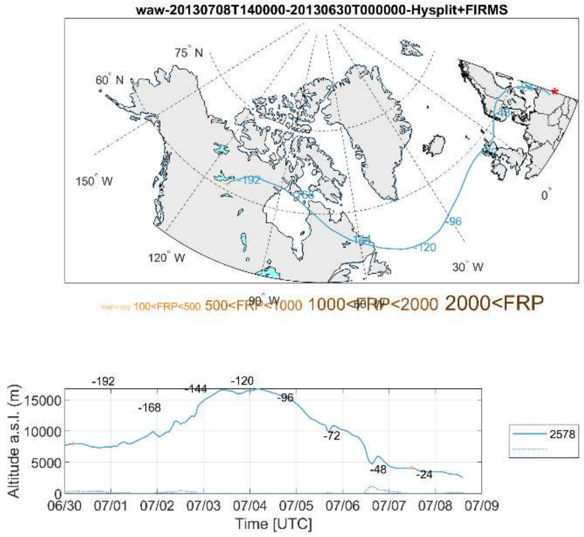


Figure S6.2. Same as Fig. S6.1 for Cabauw ("cbw") station.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Time [UTC]
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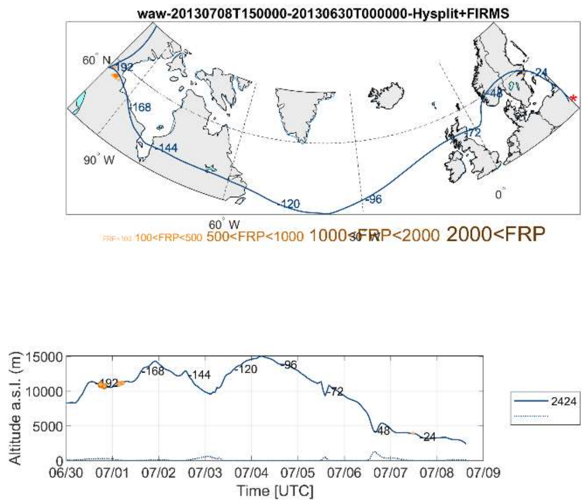
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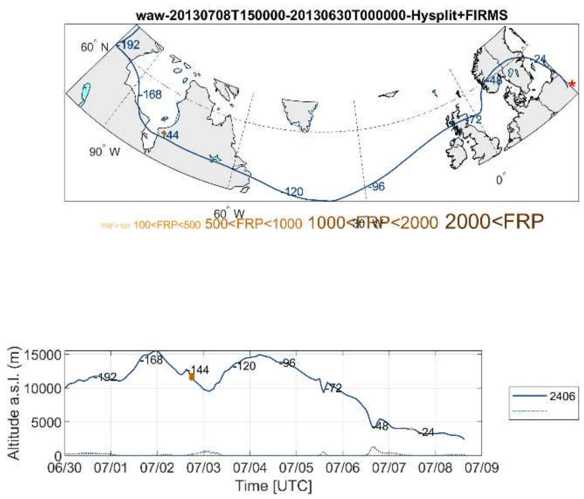
Time [UTC]
2424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Time [UTC]
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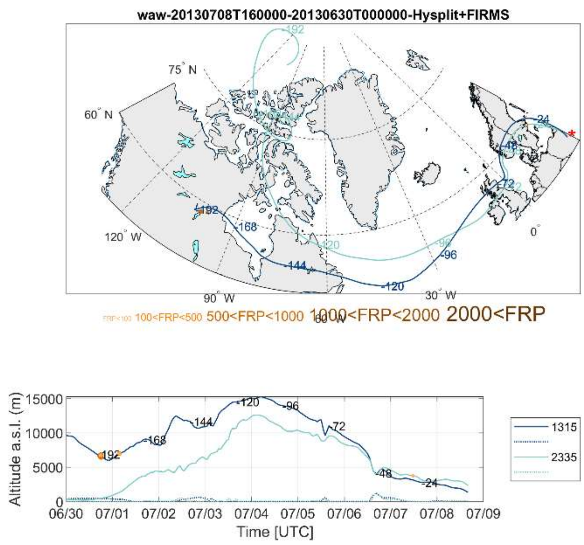
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Time [UTC]
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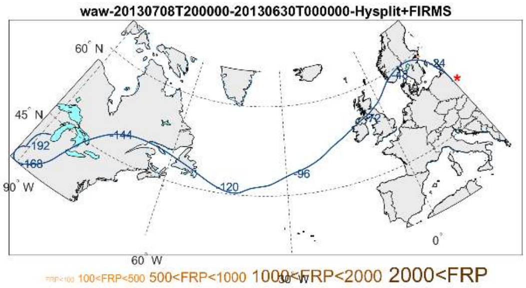
2335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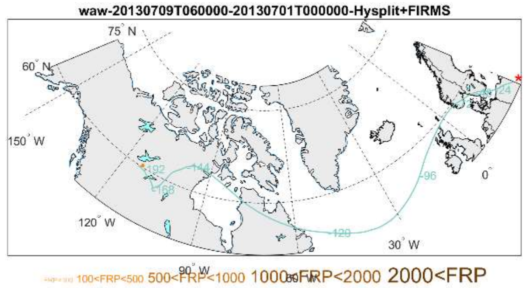
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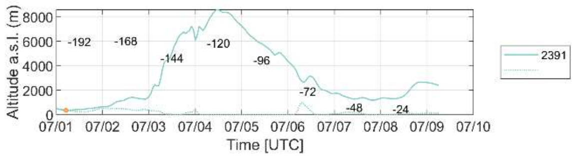
Altitude a.s.l. (m)
Time [UTC]
1999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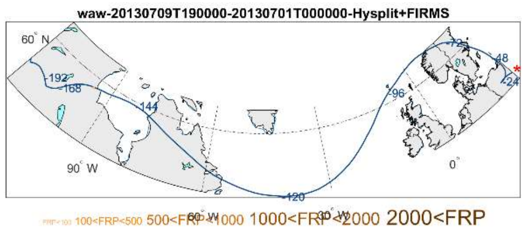
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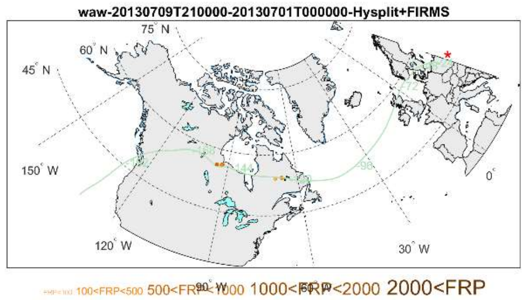
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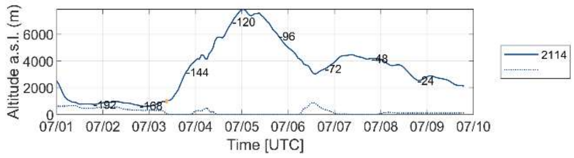
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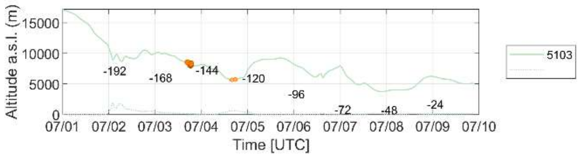
Time [UTC]
2114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Time [UTC]
5103

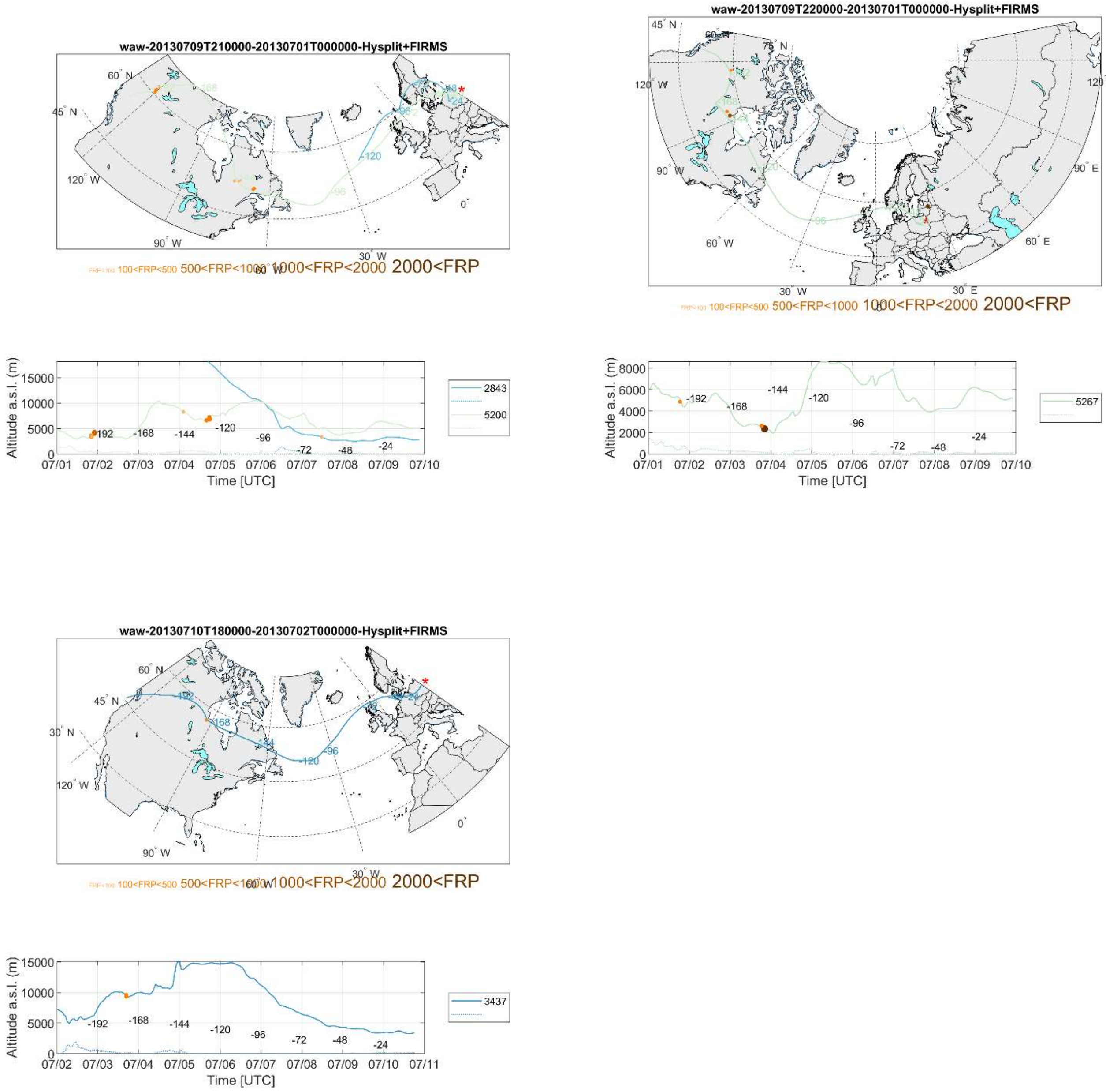
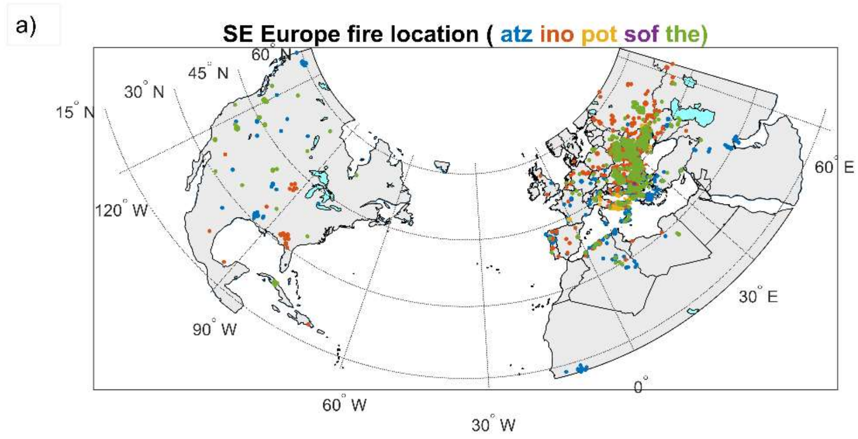


Figure S6.3. Same as Fig. S6.1 for Warsaw ("waw") station.

7. Histograms of fires location by region



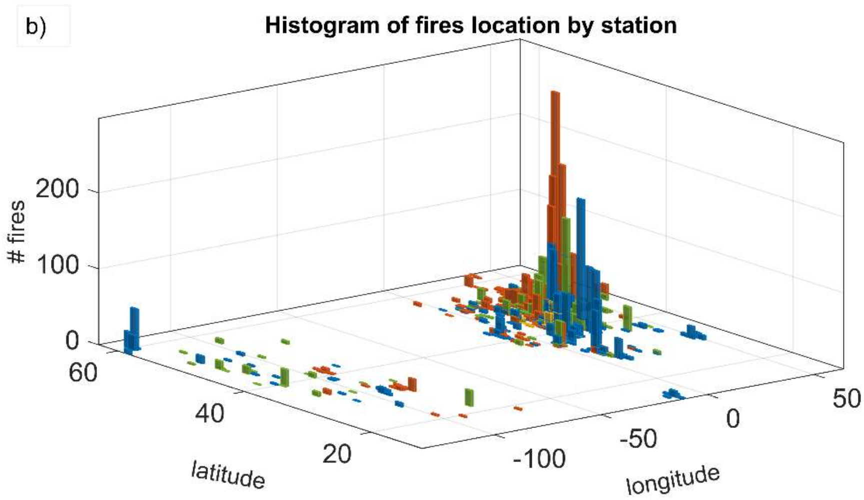
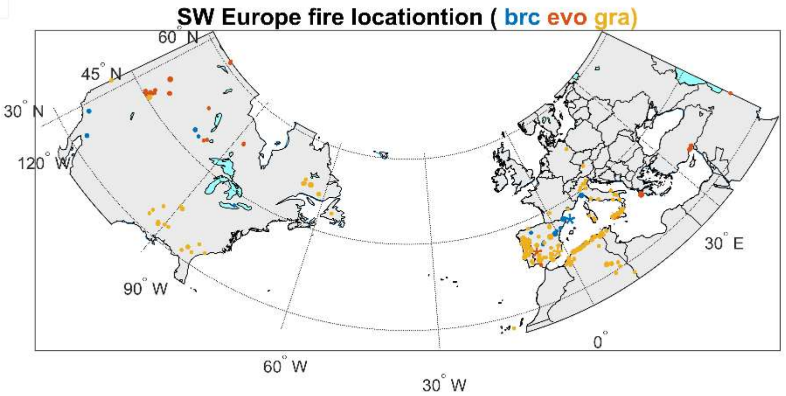


Figure S7.1. SE Europe region formed by stations Athens ("atz"), Bucharest ("ino"), Potenza ("pot"), Sofia ("sof") and Thessaloniki ("the"). a) location of the fires detected by each station. Note that due to overlap some fires are hidden. b) histogram of the fires detected by each station.

a)



b)

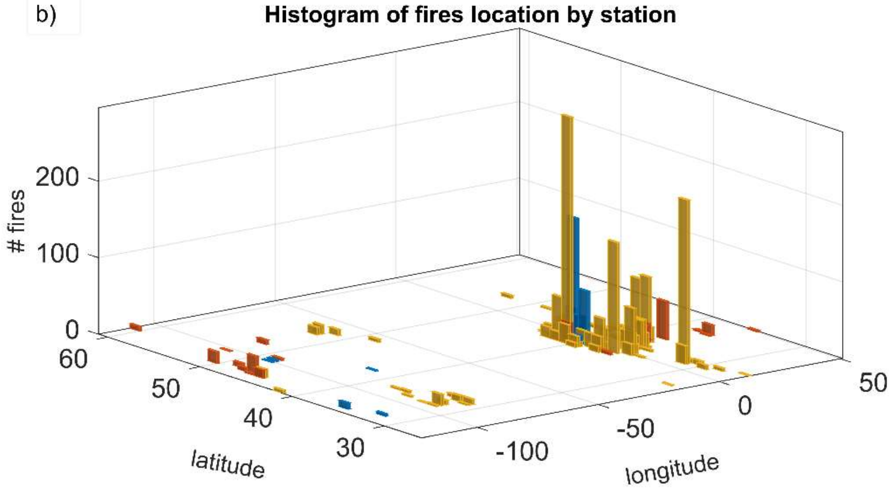
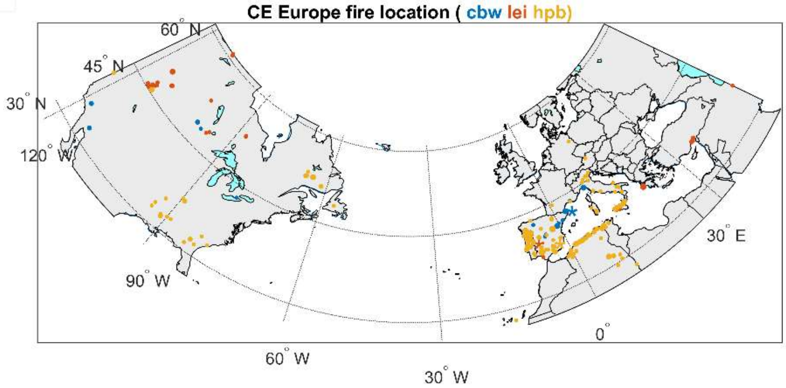


Figure S7.2. SW Europe region formed by stations Barcelona ("brc"), Evora ("evo") and Granada ("gra"). a) location of the fires detected by each station. Note that due to overlap some fires are hidden. b) histogram of the fires detected by each station.

a)



b)

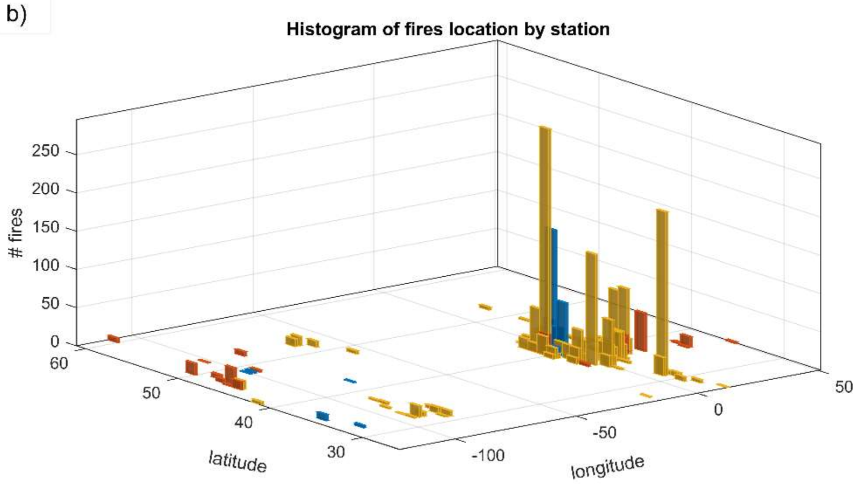
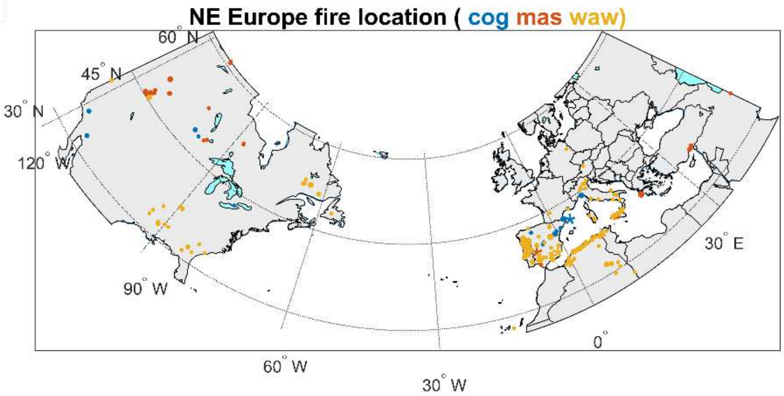


Figure S7.3. Central Europe region formed by stations Cabauw ("cbw"), Leipzig ("lei") and Hohenpeißenberg ("hpb"). a) location of the fires detected by each station. Note that due to overlap some fires are hidden. b) histogram of the fires detected by each station.

a)



b)

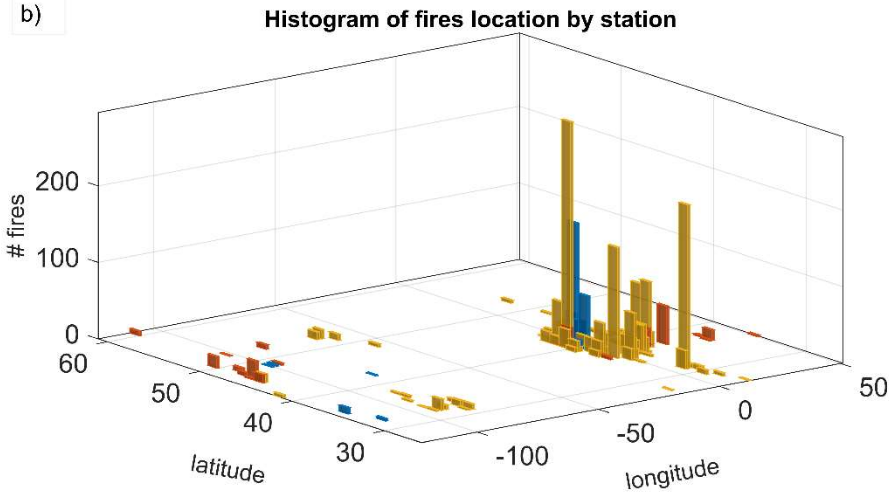
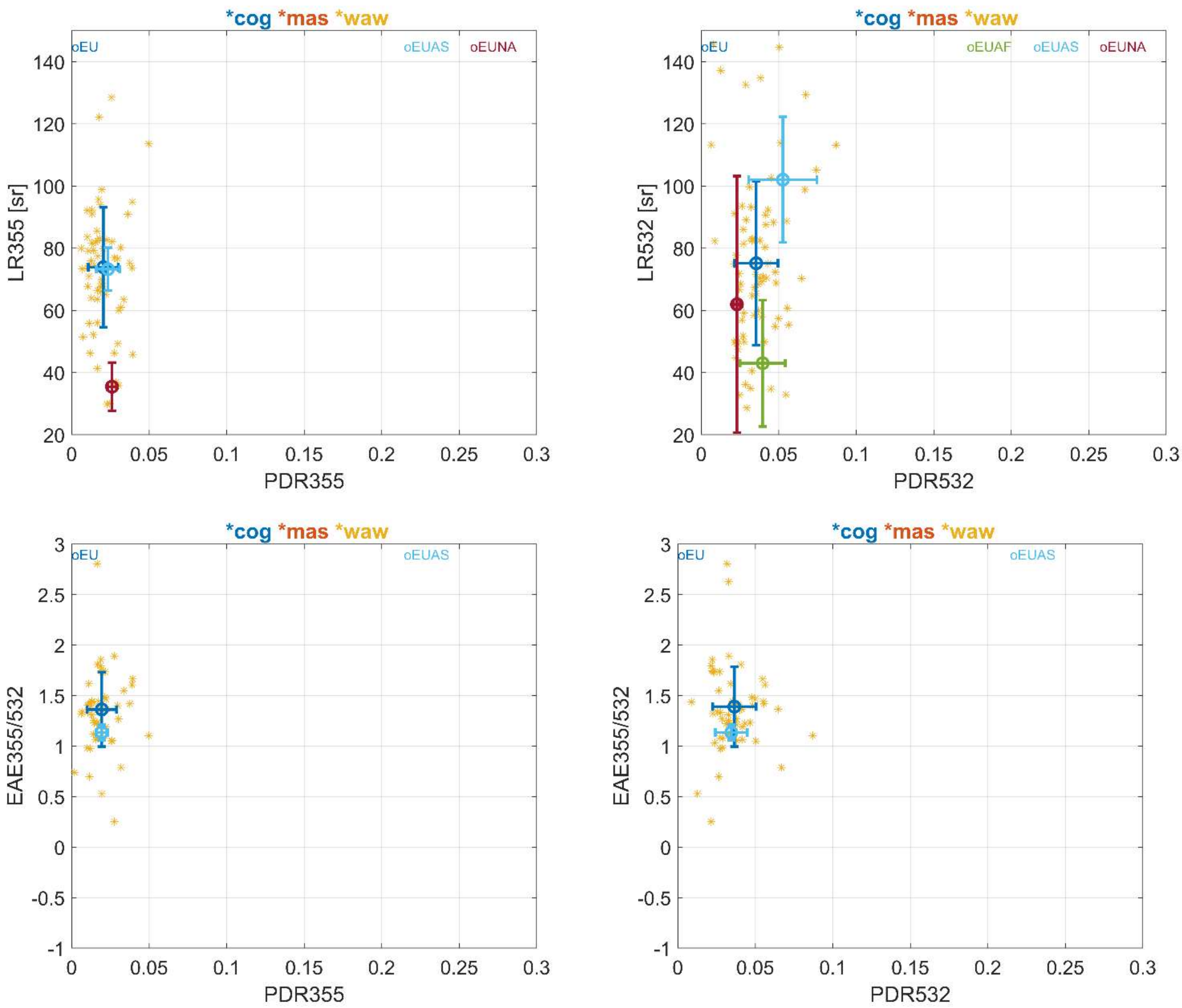


Figure S7.4. NE Europe region formed by stations Belsk ("cog"), Minsk ("mas") and Warsaw ("waw"). a) location of the fires detected by each station. Note that due to overlap some fires are hidden. b) histogram of the fires detected by each station.

8. Scatter plots intensive parameters for NE region



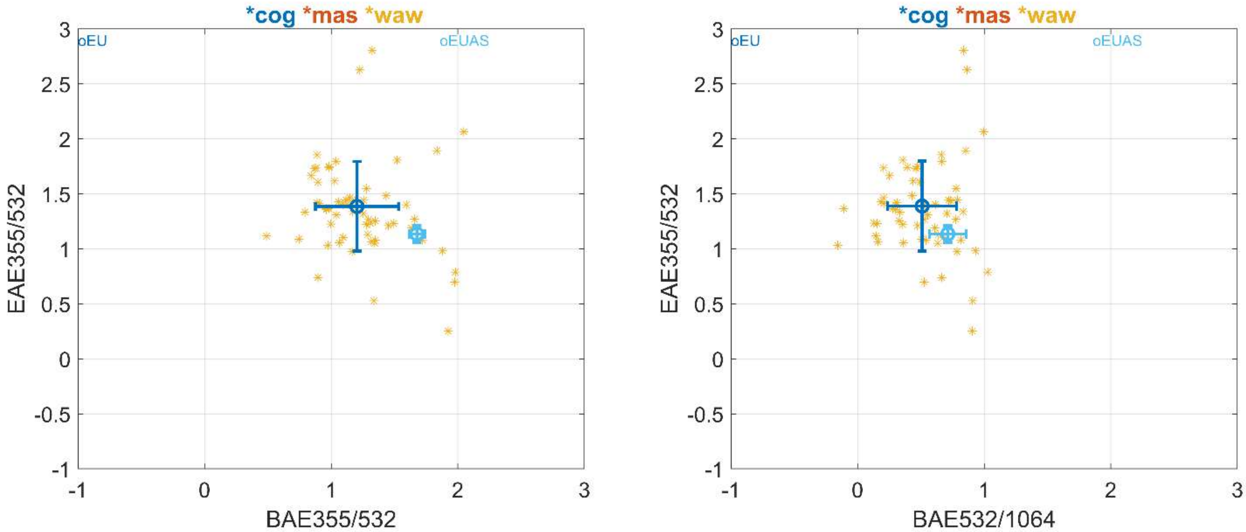
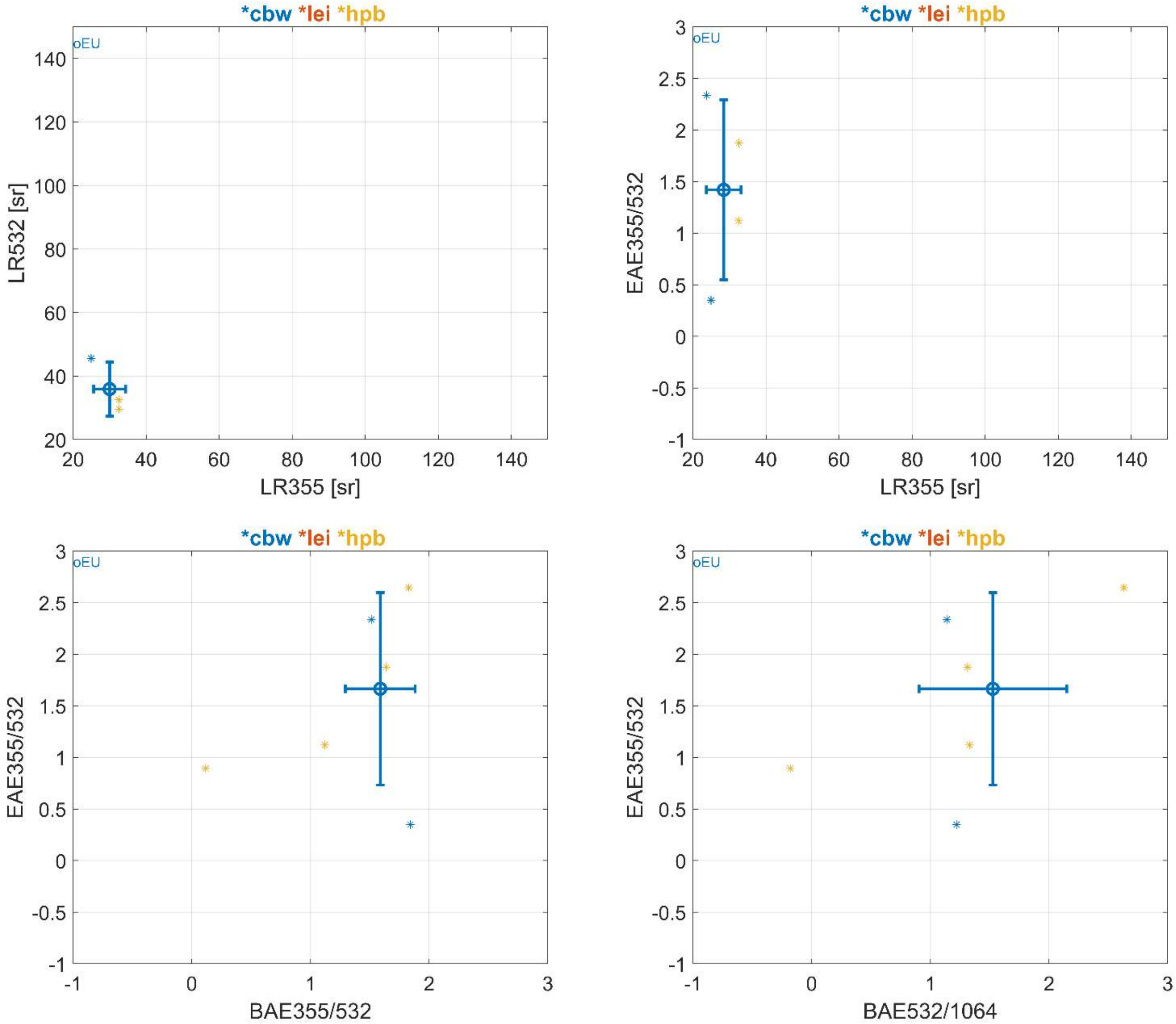


Figure S8. Scatter plots between various IPs except those shown in Fig. 6 for NE region. The colour code of the asterisks is station related (as labelled in the title). The colour code for the mean (circle) and STD values is related with the source origin (stated as text on the plots).

9. Scatter plots intensive parameters for CE and SW regions



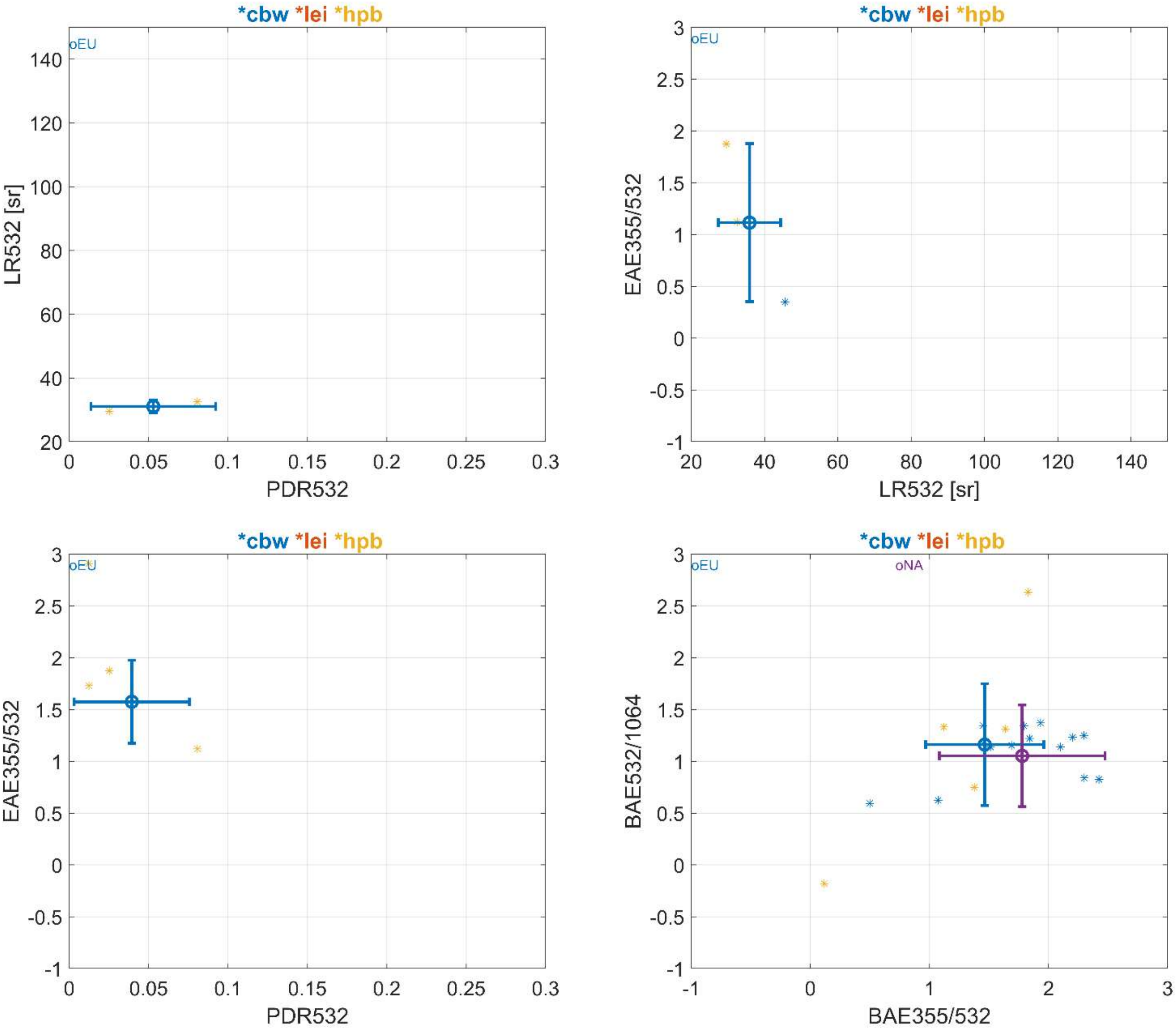
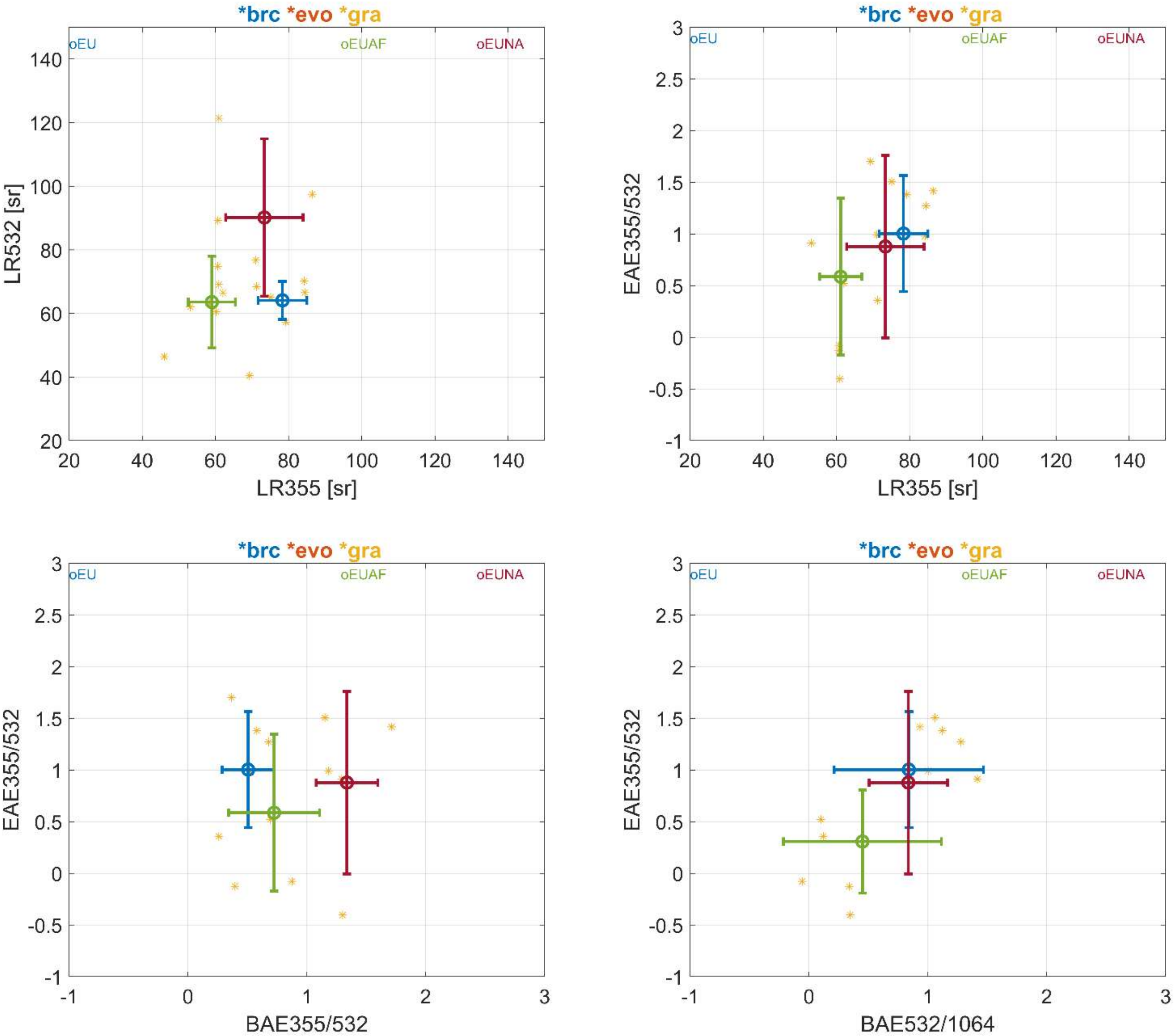


Figure S9.1. Scatter plots between various two intensive parameters for CE region. The colour code of the asterisks is station related (as labelled in the title). The colour code for the mean (circle) and STD values is related with the source origin (stated as text on the plots).



*brc *evo *gra
oEU
oEUAF
oEUNA
LR532 [sr]
LR355 [sr]
EAE355/532
LR355 [sr]
EAE355/532
BAE355/532
EAE355/532
BAE532/1064

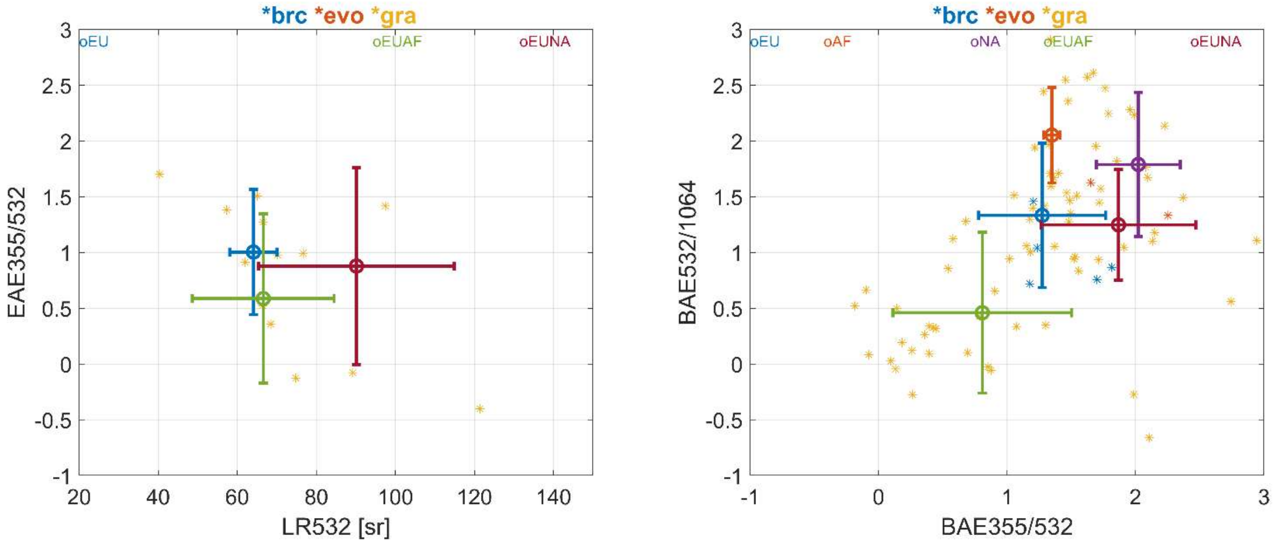


Figure S9.2. Scatter plots between various two intensive parameters for SW region. The colour code of the asterisks is station related (as labelled in the title). The colour code for the mean (circle) and STD values is related with the source origin (stated as text on the plots).

Table S1. Mean values and their STD for IPs and CRs for each region (SE, SW, CE, NE) and each continental source region (EU, AF, NA, EUAF, EUAS, EUNA). The first columns refer to scatter plot in Fig. 7d) (EAE versus CR_{LR}), the middle columns refer to scatter plot in Fig. 7e) (CR_{LR} versus CR_{BAE}) and the last columns refer to scatter plot in Fig. 7f) (EAE versus CR_{BAE}). n represents the number of events available for each scatter plot.

SE	CR_{LR}	LR532	LR355	EAE	n	CR_{LR}	LR532	LR355	CR_{BAE}	BAE2	BAE1	n	EAE	CR_{BAE}	BAE2	BAE1	n
EU	1.2±0.6	57±26	48±14	1.4±0.7	81	1.2±0.5	55±27	48±13	0.7±1.5	1.3±0.5	1.6±0.6	76	1.5±0.8	0.9±1.4	1.4±0.6	1.6±0.6	80
AF						1.6±0	50±0	31±0	0.7±0	1.1±0	1.5±0	1					
NA						2.4±1.6	72±38	32±5	1.6±1.3	2.1±0.2	1.9±1.4	2					
EUAF	1.0±0.1	64±15	61±10	0.4±0.05	2	1.0±0	53±0	54±0	5.4±0	2.1±0	0.4±0	1	0.8±0.4	3.1±3.1	2.0±0.2	1.2±1.1	2
EUAS	1.1±0.2	55±35	47±22	1.5±1	3	1.1±0.2	55±35	47±22	1.0±0.6	1.7±0.5	1.8±0.7	3	1.5±1	1.0±0.6	1.7±0.5	1.8±0.7	3
EUNA	0.9±0.2	50±17	54±5	1.9±0.8	3	0.9±0.2	50±17	54±5	1.2±0.3	1.8±0.3	1.6±0.2	3	1.9±0.8	1.2±0.3	1.8±0.3	1.6±0.2	3

SW	CR_{LR}	LR532	LR355	EAE		CR_{LR}	LR532	LR355	CR_{BAE}	BAE2	BAE1		EAE	CR_{BAE}	BAE2	BAE1	
EU	0.8±0.1	64±6	78±7	1.0±0.6	3	0.8±0.1	64±6	78±7	1.4±0.8	0.8±0.6	0.5±0.2	3	1.0±0.6	1.4±0.8	0.8±0.6	0.5±0.2	3
AF	0.8±0	70±0	84±0	1.0±0	1												
NA																	
EUAF	1.1±0.3	67±18	61±6	0.6±0.8	5	1.1±0.2	67±12	58±5	0.4±0.7	0.3±0.5	0.5±0.4	8	0.3±0.5	0.5±0.6	0.4±0.7	0.8±0.4	4
EUAS																	
EUNA	1.3±0.5	90±25	73±11	0.9±0.9	4	1.3±0.5	90±25	73±11	0.6±0.3	0.8±0.3	1.3±0.3	4	0.9±0.9	0.6±0.3	0.8±0.3	1.3±0.3	4

CE	CR_{LR}	LR532	LR355	EAE		CR_{LR}	LR532	LR355	CR_{BAE}	BAE2	BAE1		EAE	CR_{BAE}	BAE2	BAE1	
EU	1.2±0.5	36±9	30±4	1.1±0.8	3	1.2±0.5	36±9	30±4	0.9±0.3	1.3±0.1	1.5±0.4	3	1.7±0.9	1.0±0.3	1.5±0.6	1.6±0.3	5
AF																	
NA													0.9±0	-1.6±0	-0.2±0	0.1±0	1
EUAF																	
EUAS																	
EUNA																	

NE	CR_{LR}	LR532	LR355	EAE		CR_{LR}	LR532	LR355	CR_{BAE}	BAE2	BAE1		EAE	CR_{BAE}	BAE2	BAE1	
EU	0.9±0.2	74±27	78±19	1.4±0.4	54	1.0±0.2	74±27	78±19	0.4±0.2	0.5±0.3	1.2±0.3	53	1.4±0.4	0.4±0.2	0.5±0.3	1.2±0.3	54
AF																	
NA																	
EUAF	0.9±0	57±0	65±0	1.5±0	1	0.9±0	57±0	65±0	0.2±0	0.2±0	1.1±0	1	1.5±0	0.2±0	0.2±0	1.1±0	1
EUAS	1.2±0.1	87±1	70±5	1.1±0.1	2	1.2±0.1	87±1	70±5	0.4±0.1	0.7±0.1	1.7±0.1	2	1.1±0.1	0.4±0.1	0.7±0.1	1.7±0.1	2
EUNA	2.0±0	91±0	46±0	0.3±0	1	2.0±0	91±0	46±0	0.5±0	0.9±0	1.9±0	1	0.3±0	0.5±0	0.9±0	1.9±0	1

10 List of acronyms

Table S2. List of acronyms

Nomenclature	Definition
ACTRIS	Aerosol Cloud and Trace Gases Research Infrastructure
a.g.l.	Above ground level
a.s.l.	Above sea level
"atz", "brc", "cog", "ino", "cbw", "evo", "gra", "lei", "mas", "hpb", "pot", "sof", "the", "waw"	Athens, Barcelona, Belsk, Bucharest, Cabauw, Evora, Granada, Leipzig, Minsk, Observatory Hohenpeißenberg, Potenza, Sofia, Thessaloniki and Warsaw (lidar stations considered in this study).
BAE	Backscatter Ångström exponent. BAE@355/532=-log(βp355/βp532)/log(355/532), BAE@355/532=-log(βp532/βp1064)/log(532/1064)
BB	Biomass burning
β_p	Particle backscatter coefficient [1/m/sr]
CR(s)	Colour ratio(s). CR_{LR}=LR@532/LR@355, CR_{BAE}=BAE@532/1064/BAE@355/532, CR_{PDR}=PDR@532/PDR@355
EAE	Extinction Ångström exponent. EAE@355/532=-log(κp355/κp532)/log(355/532)
EARLINET	European Aerosol Research Lidar Network
EU, AF, NA, AS	Europe, Africa, North America, Asia continental source regions
EUAF, EUNA, EUAS	Europe + Africa, Europe + North America, Europe + Asia continental source regions
FIRMS	Fire Information for Resource Management System
FRP	Fire radiative power
GDAS	Global Data Assimilation System
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory model
IP(s)	Intensive parameter(s)
κ_p	Particle extinction coefficient [1/m]
LR	Lidar ratio [sr]. LR@355=κp355/βp355, LR@532=κp532/βp532
LRT	Long range transport
MODIS	Moderate Resolution Imaging Spectroradiometer
PDR	Linear particle depolarization ratio
QC	Quality control
SE, SW, CE and NE	Southeast, Southwest, Central and Northeast Europe (geographical measurement regions)
SNR	Signal to noise ratio
STD	Standard deviation
UTLS	Upper Troposphere Lower Stratosphere