Results of the Ambient Air Experiments during the EUSAAR 2009 Absorption Photometer Workshop

(Aethalometer)

Agnes Filep, Aki Virkkula, Alessandro Dell'Acqua,
Alfred Wiedensohler, Angela Marinoni, Bas Henzing,
Grisa Mocnik, Gerrit Leeuw, Kostas Eleftheriadis,
Linda Rondo, Paulo Fialho and Thomas Müller

Objectives

- Develop methodologies to compensate for apparent absorption caused by scattering due to the use of filter matrix support.

  - Development of an improved compensation technique for the AE's attenuation coefficient, $\sigma_{\mathrm{ANT}\text{-}comp}$.

  - Correlation of the $\sigma_{\mathrm{ANT}\text{-}comp}$, with MAAP's absorption coefficient measurements, σ_{abs}, to evaluate the AE's *C* and *R* corrections for the sampled aerosol.

Instrumentation Setup

- The instruments used in all the experiments sampled simultaneously from a common chamber with continuously refreshed dried ambient air.

  - **Four** High Sensitivity (HS) Aethalometers (AE) (370, 470, 520, 590, 660, 880, 950 nm)
  - **Four** Extended Range (ER) Aethalometers (AE) (370, 470, 520, 590, 660, 880, 950 nm)
  - **Three** Multi Angle Absorption Photometers (MAAP) (635 nm)
  - **One** Particle Soot Absorption Photometer (PSAP) (565 nm)
  - **One** Particle Soot Absorption Photometer (PSAP) (467, 530, 660 nm)
  - **One** Multi Wavelength Photoacoustic system (MuWaPas) (266, 355, 532, 1064 nm)
  - **One** Echotec Aurora Nephelometer (450, 520, 700 nm)
  - **Two** TSI3563 Nephelometer (450, 550, 700 nm)

Instrumental Working Equations

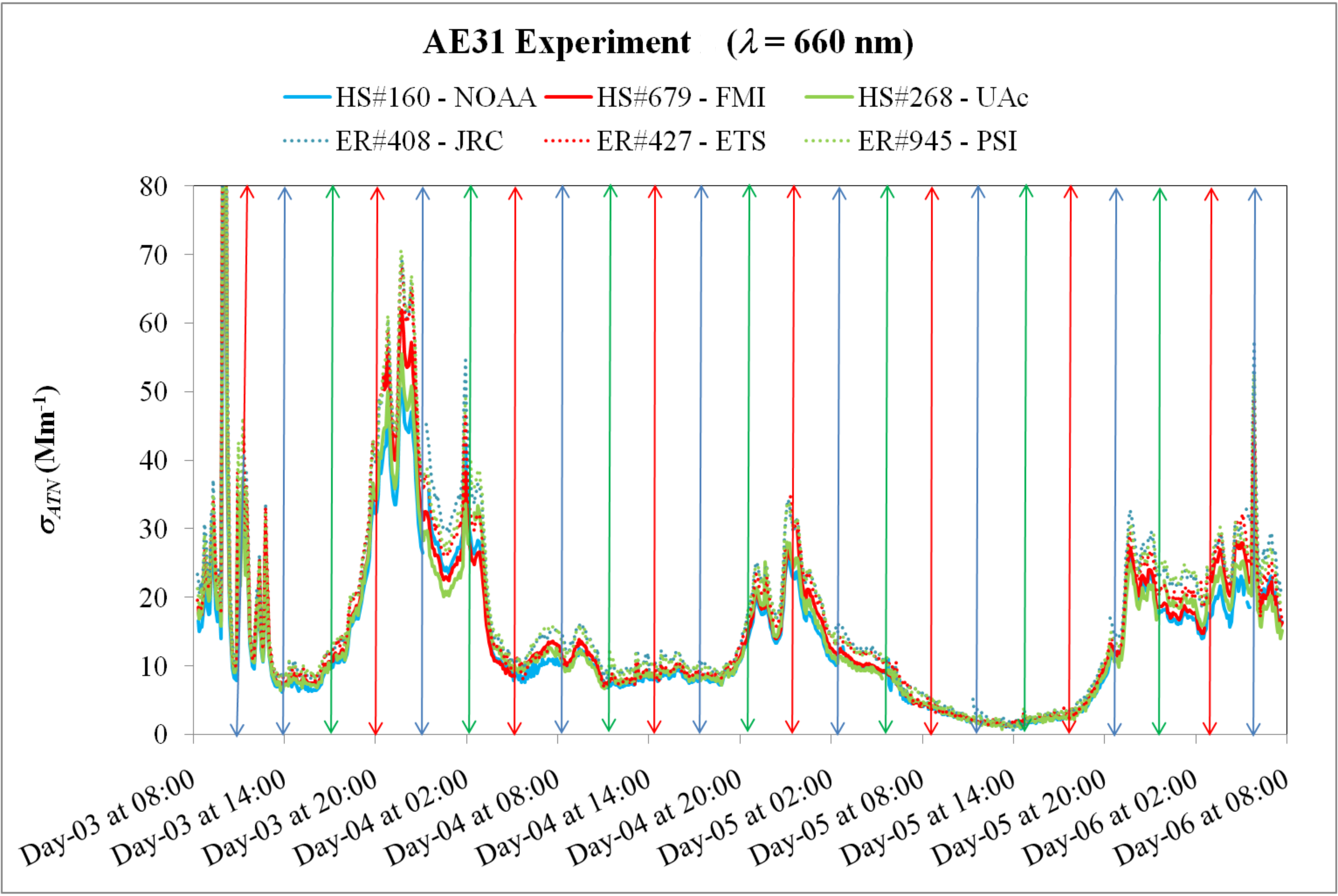
- AE $$\sigma_{ATN}\left(Mm^{-1}\right)=C_{BC}\left(ng.m^{-3}\right)\times\left(\frac{14.625\left(m^{2}g^{-1}\mu m\right)}{\lambda\left(nm\right)}\right)$$
- MAAP $$\sigma_{abs}\left(Mm^{-1}\right)=\frac{C_{BC}\left(ng.m^{-3}\right)\times 6.5\left(m^{2}/g\right)}{1000}$$
- PSAP $$\sigma_{ATN}\left(Mm^{-1}\right)$$
- MuWaPas $$\sigma_{abs}\left(Mm^{-1}\right)$$
- Nephelometer $$\sigma_{sct}\left(Mm^{-1}\right)$$

Experiment (Different Spot Time Loading)

(08:20 03-July to 07:35 06-July-2009)

- The Aethalometers were divided in three different groups sampling with a time difference of 3 hours but with the same flow rate.

  - **AE-31** – 4 dm^3/min
    - HS#160; ER#408
    - HS#679; ER#427
    - HS#268; ER#945
  - **MAAP-5012** – 10 dm^3/min
    - #080; #012; #140
  - **PSAP**
    - **DLR** (3λ) – 0.79 dm^3/min
    - **Vespien** (1λ) – 0.84 dm^3/min



AE31 Experiment (λ = 660 nm)
HS#160 - NOAA
HS#679 - FMI
HS#268 - UAc
ER#408 - JRC
ER#427 - ETS
ER#945 - PSI
σATN (Mm-1)
0
10
20
30
40
50
60
70
80
Day-03 at 08:00
Day-03 at 14:00
Day-03 at 20:00
Day-04 at 02:00
Day-04 at 08:00
Day-04 at 14:00
Day-04 at 20:00
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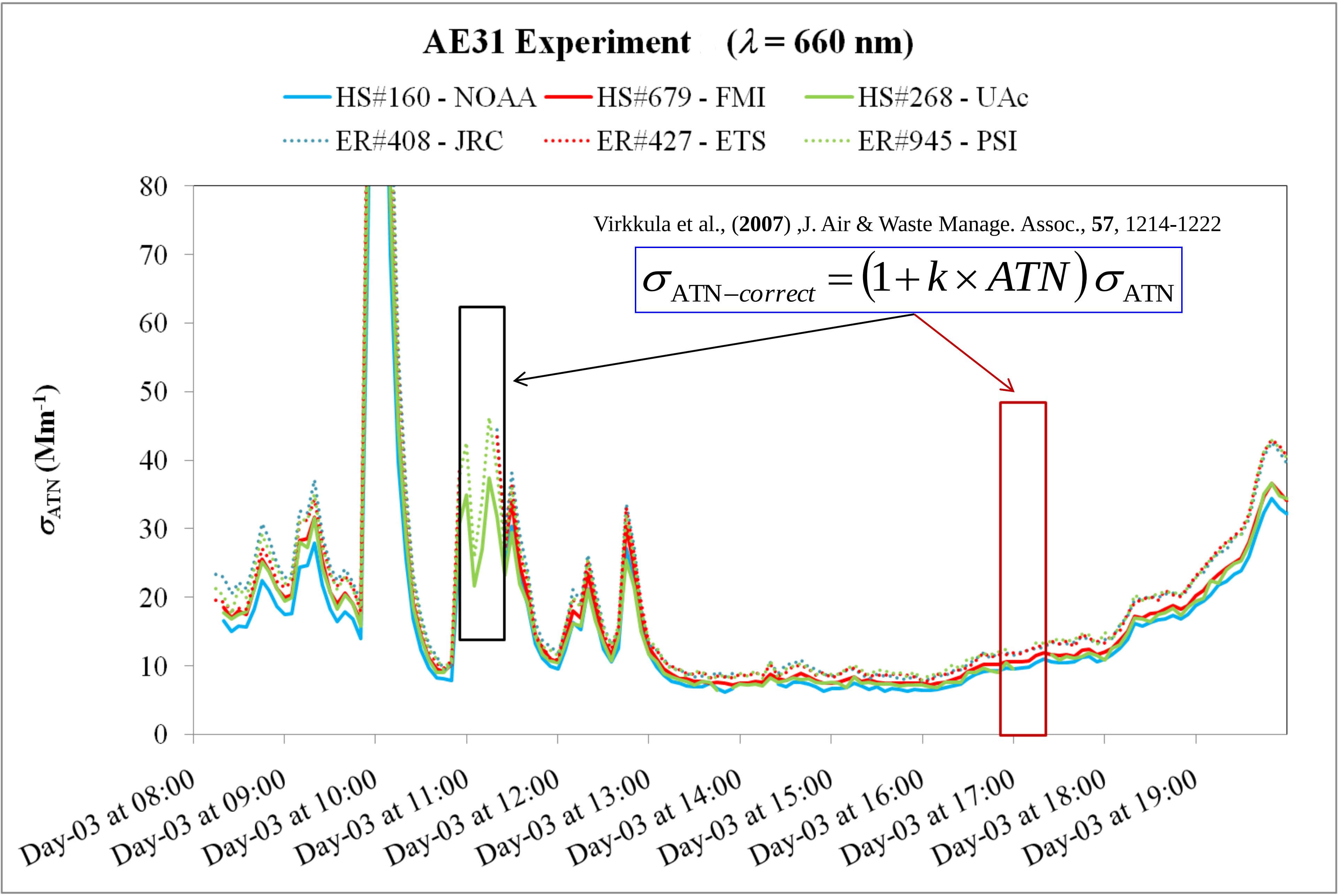
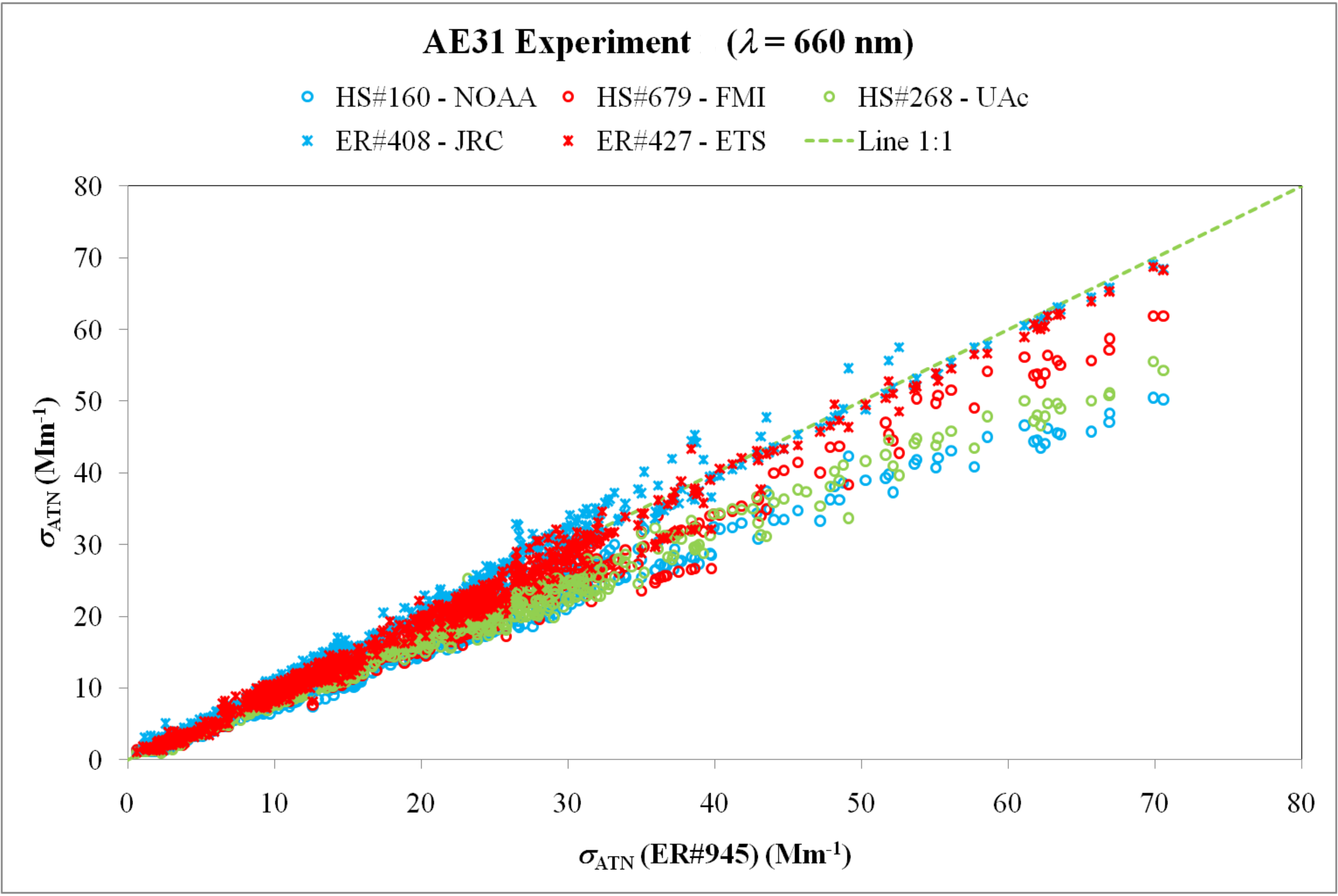
Day-05 at 08:00
Day-05 at 14:00
Day-05 at 20:00
Day-06 at 02:00
Day-06 at 08:00


AE31 Experiment (λ = 660 nm)
HS#160 - NOAA
HS#679 - FMI
HS#268 - UAc
ER#408 - JRC
ER#427 - ETS
ER#945 - PSI
Virkkula et al., (2007) ,J. Air & Waste Manage. Assoc., 57, 1214-1222
$\sigma_{\mathrm{ATN}-correct} = (1 + k \times ATN)\,\sigma_{\mathrm{ATN}}$
σATN (Mm-1)
0
10
20
30
40
50
60
70
80
Day-03 at 08:00
Day-03 at 09:00
Day-03 at 10:00
Day-03 at 11:00
Day-03 at 12:00
Day-03 at 13:00
Day-03 at 14:00
Day-03 at 15:00
Day-03 at 16:00
Day-03 at 17:00
Day-03 at 18:00
Day-03 at 19:00



AE31 Experiment (λ = 660 nm)
HS#160 - NOAA
HS#679 - FMI
HS#268 - UAc
ER#408 - JRC
ER#427 - ETS
Line 1:1
σATN (Mm-1)
σATN (ER#945) (Mm-1)
0
10
20
30
40
50
60
70
80

$$\sigma_{\mathrm{ATN}-Comp}(\lambda) = (1 + k(\lambda) \times \mathrm{ATN}(\lambda))\,\sigma_{\mathrm{ATN}}(\lambda)$$

$$\sigma_{\mathrm{ATN}-Comp}(\lambda, \mathrm{Ref.\ AE}) = a_0(\mathrm{AE\#})\,(1 + k(\lambda) \times \mathrm{ATN}(\lambda, \mathrm{AE\#}))\,\sigma_{\mathrm{ATN}}(\lambda, \mathrm{AE\#})$$

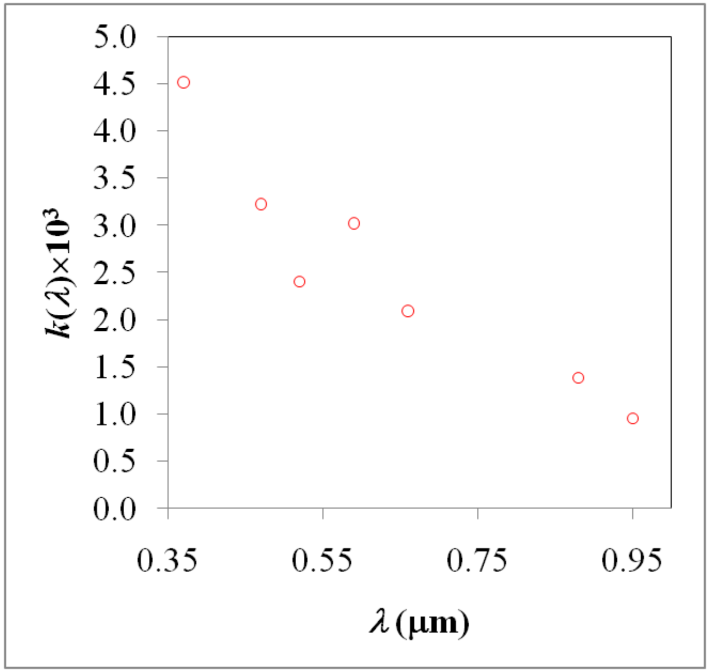
$$\begin{cases}
\sigma_{\mathrm{ATN}-Comp}(\lambda, \mathrm{ER\#945}) = a_0(\mathrm{ER\#945})\,(1 + k(\lambda) \times \mathrm{ATN}(\lambda, \mathrm{ER\#945}))\,\sigma_{\mathrm{ATN}}(\lambda, \mathrm{ER\#945}) \\
\sigma_{\mathrm{ATN}-Comp}(\lambda, \mathrm{ER\#945}) = a_0(\mathrm{HS\#160})\,(1 + k(\lambda) \times \mathrm{ATN}(\lambda, \mathrm{HS\#160}))\,\sigma_{\mathrm{ATN}}(\lambda, \mathrm{HS\#160}) \\
\sigma_{\mathrm{ATN}-Comp}(\lambda, \mathrm{ER\#945}) = a_0(\mathrm{HS\#268})\,(1 + k(\lambda) \times \mathrm{ATN}(\lambda, \mathrm{HS\#268}))\,\sigma_{\mathrm{ATN}}(\lambda, \mathrm{HS\#268}) \\
\sigma_{\mathrm{ATN}-Comp}(\lambda, \mathrm{ER\#945}) = a_0(\mathrm{HS\#679})\,(1 + k(\lambda) \times \mathrm{ATN}(\lambda, \mathrm{HS\#679}))\,\sigma_{\mathrm{ATN}}(\lambda, \mathrm{HS\#679}) \\
\sigma_{\mathrm{ATN}-Comp}(\lambda, \mathrm{ER\#945}) = a_0(\mathrm{ER\#408})\,(1 + k(\lambda) \times \mathrm{ATN}(\lambda, \mathrm{ER\#408}))\,\sigma_{\mathrm{ATN}}(\lambda, \mathrm{ER\#408}) \\
\sigma_{\mathrm{ATN}-Comp}(\lambda, \mathrm{ER\#945}) = a_0(\mathrm{ER\#427})\,(1 + k(\lambda) \times \mathrm{ATN}(\lambda, \mathrm{ER\#427}))\,\sigma_{\mathrm{ATN}}(\lambda, \mathrm{ER\#427})
\end{cases}$$

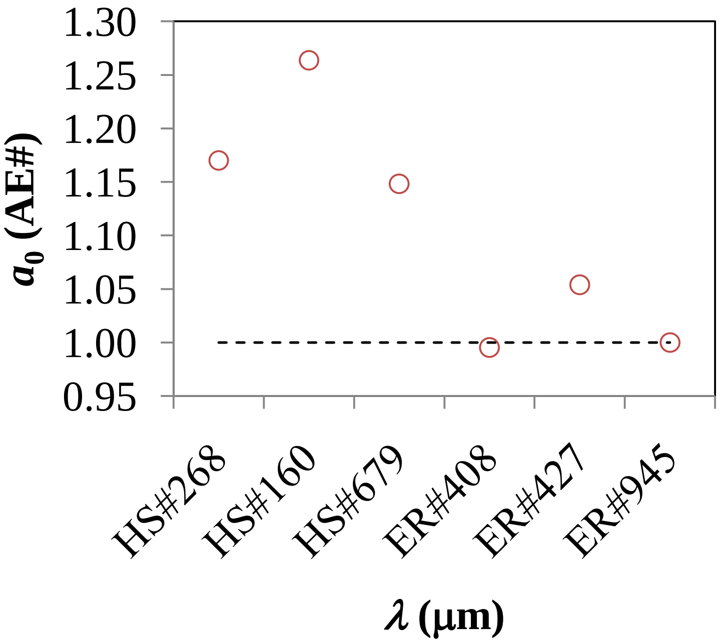
ER#945 was choose as the reference Aethalometer $\Rightarrow a_0(\mathrm{ER\#945}) = 1$

N = 28154
Standard Error = 1.5 Mm^{-1}

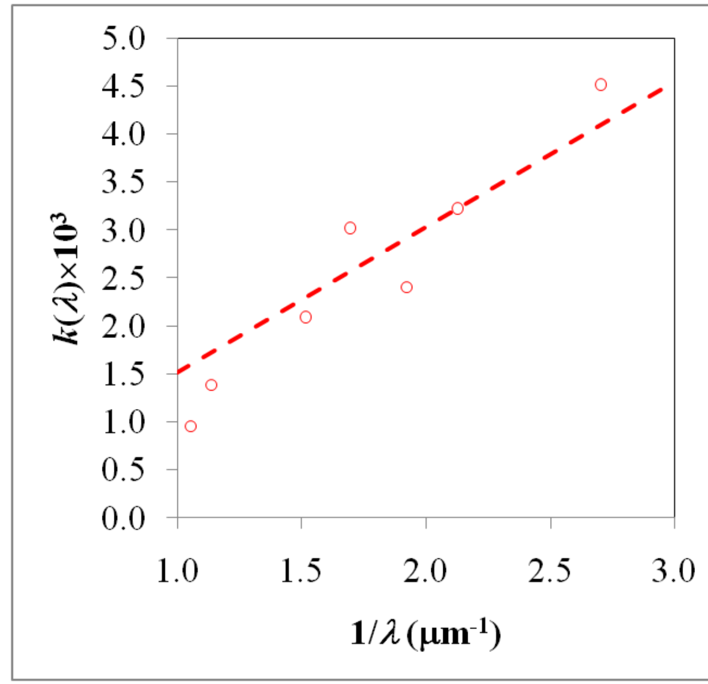
λ (nm)	$k(\lambda) \times 10^3$
370	4.51
470	3.22
520	2.40
590	3.02
660	2.09
880	1.39
950	0.96

AE#	a_0 (AE#)
ER#945	1.00
HS#160	1.26
HS#268	1.17
HS#679	1.15
ER#408	1.00
ER#427	1.05





$$k(\lambda) = \frac{k}{\lambda} \quad where \;\; k = 1.49 \pm 0.09 \text{ nm} \quad r = 0.900$$



$$\sigma_{\mathrm{ATN-}Comp}(\lambda) = \left(1 + k \times \frac{\mathrm{ATN}(\lambda)}{\lambda}\right)\sigma_{\mathrm{ATN}}(\lambda) \Rightarrow \sigma_{\mathrm{ATN-}Comp}(\lambda, \mathrm{Ref.\ AE}) = a_0(\mathrm{AE\#})\left(1 + k \times \frac{\mathrm{ATN}(\lambda, \mathrm{AE\#})}{\lambda}\right)\sigma_{\mathrm{ATN}}(\lambda, \mathrm{AE\#})$$

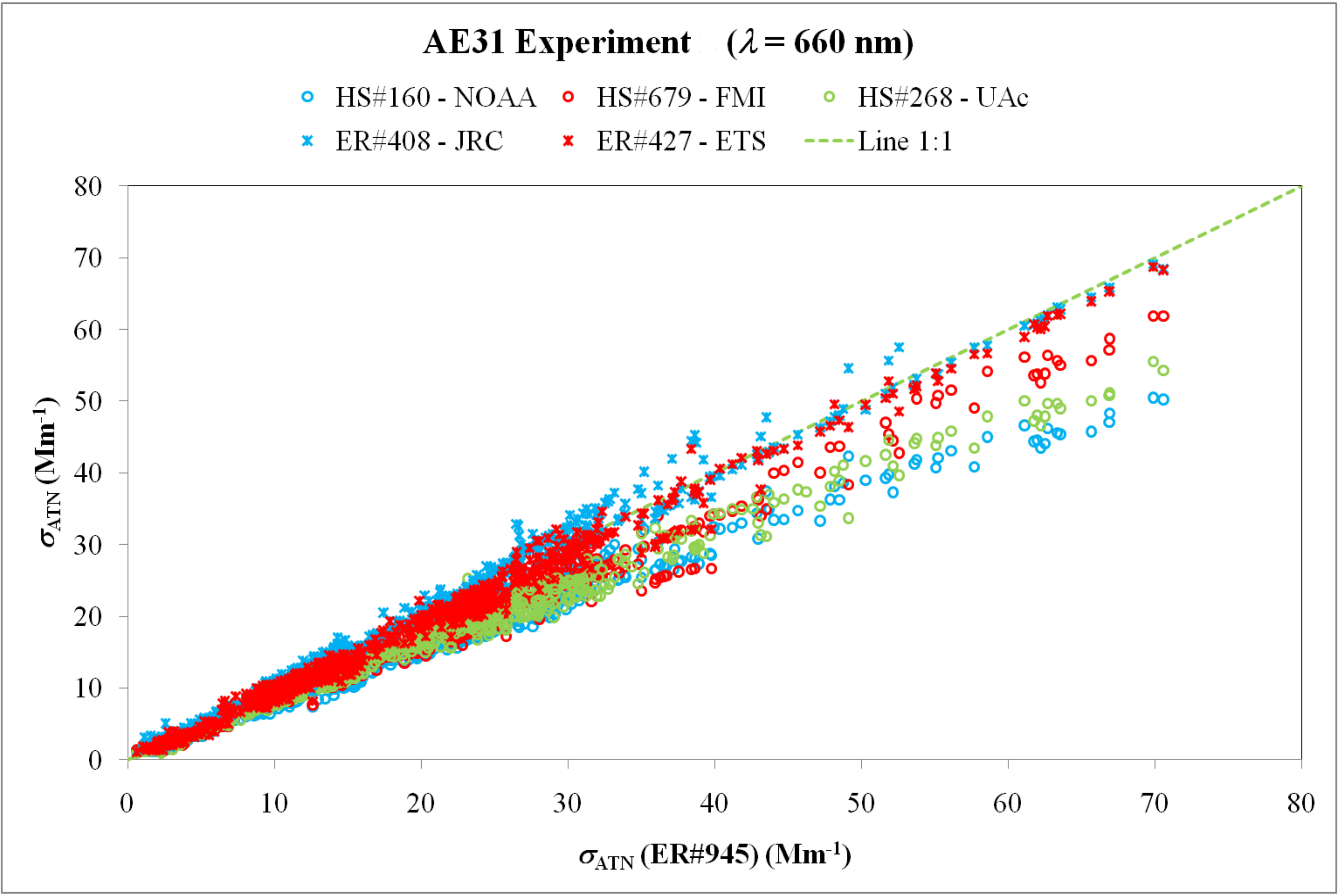
$$\begin{cases} \sigma_{\mathrm{ATN-}Comp}(\lambda, \mathrm{ER\#945}) = a_0(\mathrm{ER\#945})\left(1 + k \times \frac{\mathrm{ATN}(\lambda, \mathrm{ER\#945})}{\lambda}\right)\sigma_{\mathrm{ATN}}(\lambda, \mathrm{ER\#945}) \\ \sigma_{\mathrm{ATN-}Comp}(\lambda, \mathrm{ER\#945}) = a_0(\mathrm{HS\#160})\left(1 + k \times \frac{\mathrm{ATN}(\lambda, \mathrm{HS\#160})}{\lambda}\right)\sigma_{\mathrm{ATN}}(\lambda, \mathrm{HS\#160}) \\ \sigma_{\mathrm{ATN-}Comp}(\lambda, \mathrm{ER\#945}) = a_0(\mathrm{HS\#268})\left(1 + k \times \frac{\mathrm{ATN}(\lambda, \mathrm{HS\#268})}{\lambda}\right)\sigma_{\mathrm{ATN}}(\lambda, \mathrm{HS\#268}) \\ \sigma_{\mathrm{ATN-}Comp}(\lambda, \mathrm{ER\#945}) = a_0(\mathrm{HS\#679})\left(1 + k \times \frac{\mathrm{ATN}(\lambda, \mathrm{HS\#679})}{\lambda}\right)\sigma_{\mathrm{ATN}}(\lambda, \mathrm{HS\#679}) \\ \sigma_{\mathrm{ATN-}Comp}(\lambda, \mathrm{ER\#945}) = a_0(\mathrm{ER\#408})\left(1 + k \times \frac{\mathrm{ATN}(\lambda, \mathrm{ER\#408})}{\lambda}\right)\sigma_{\mathrm{ATN}}(\lambda, \mathrm{ER\#408}) \\ \sigma_{\mathrm{ATN-}Comp}(\lambda, \mathrm{ER\#945}) = a_0(\mathrm{ER\#427})\left(1 + k \times \frac{\mathrm{ATN}(\lambda, \mathrm{ER\#427})}{\lambda}\right)\sigma_{\mathrm{ATN}}(\lambda, \mathrm{ER\#427}) \end{cases}$$

k = 1.51±0.15 **nm**

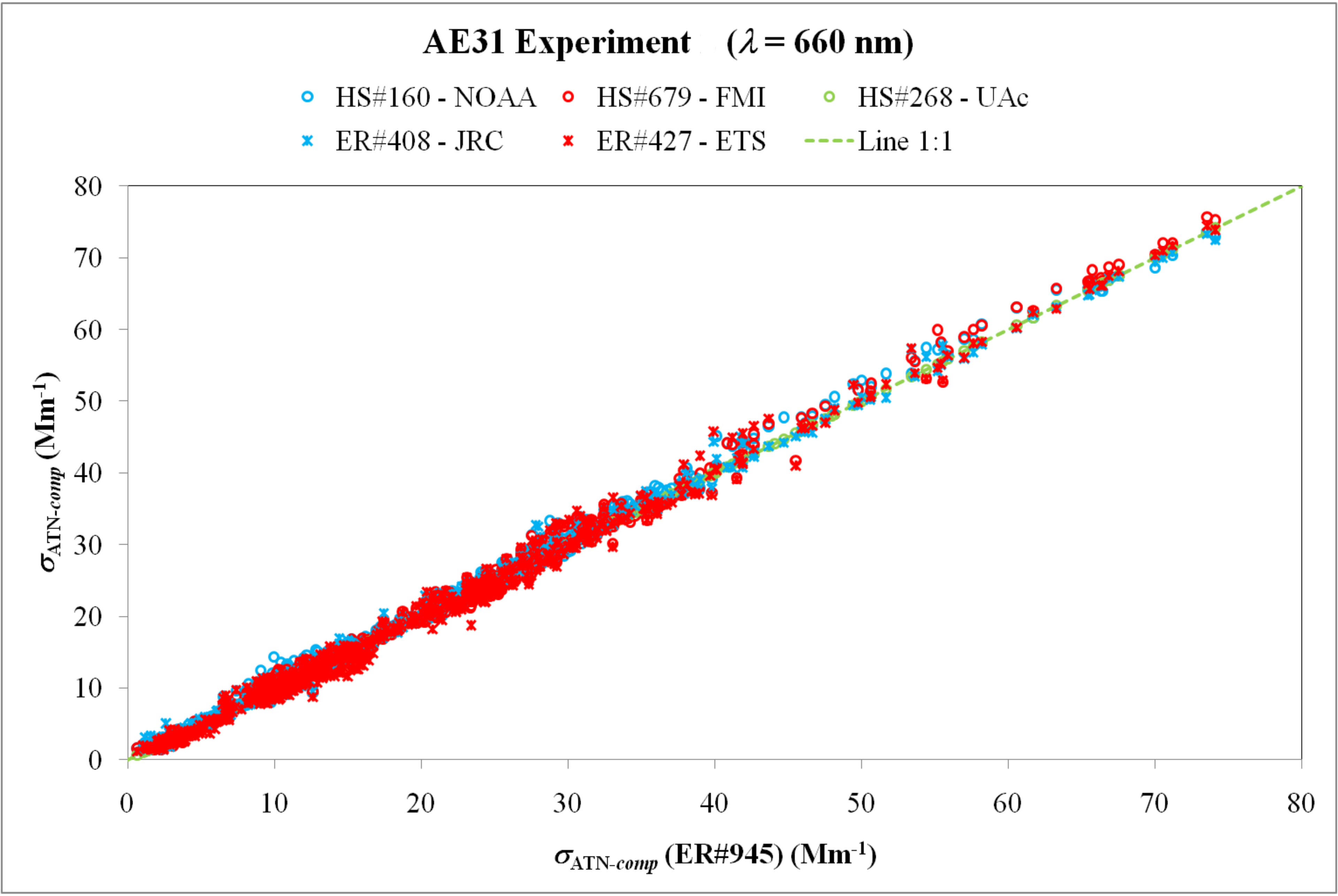
N = 28154

Standard Error = 1.5 **Mm^{-1}**

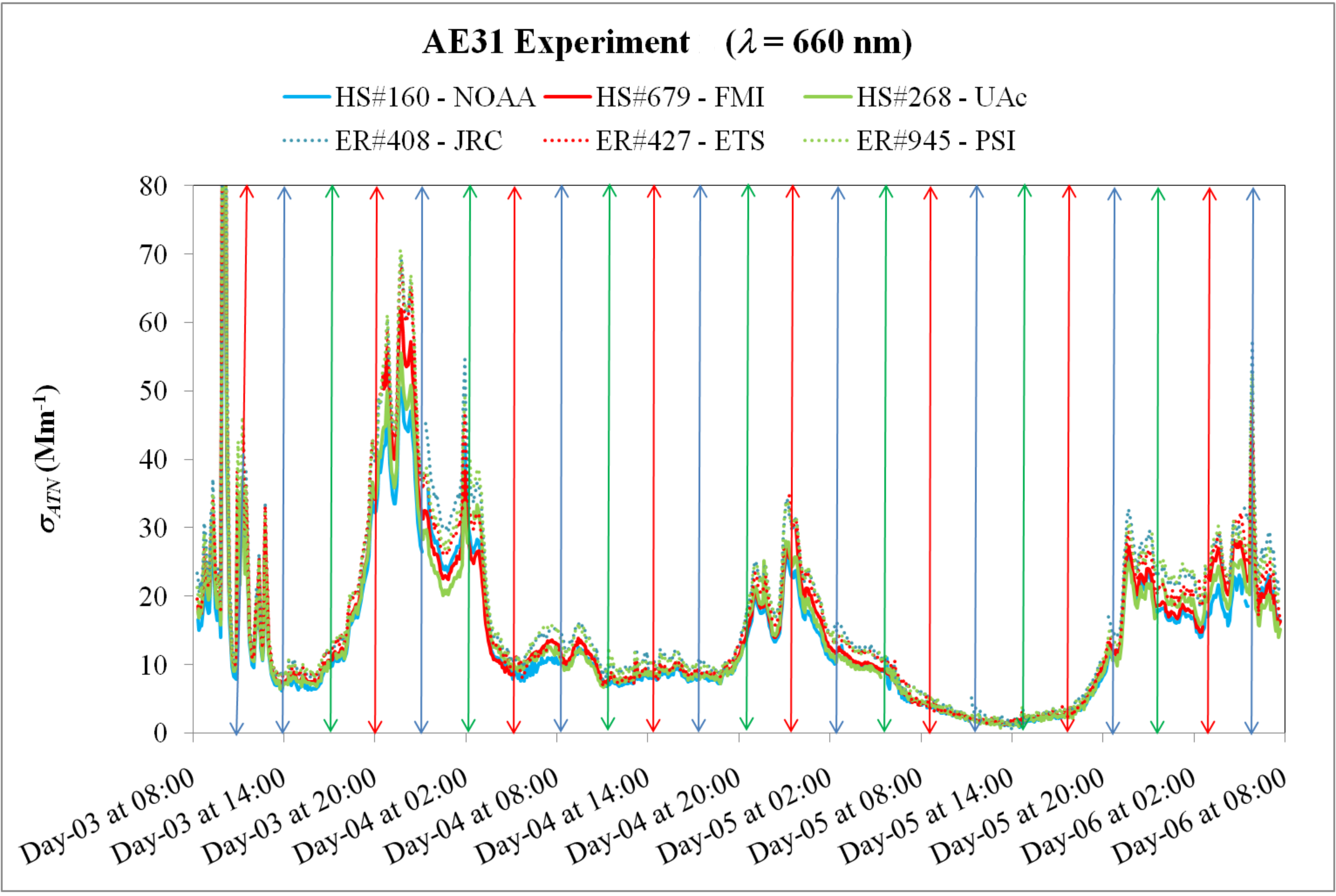
AE#	**a_0 (AE#) ±0.004**
ER#945	1.000
HS#160	1.260
HS#268	1.167
HS#679	1.146
ER#408	0.995
ER#427	1.054

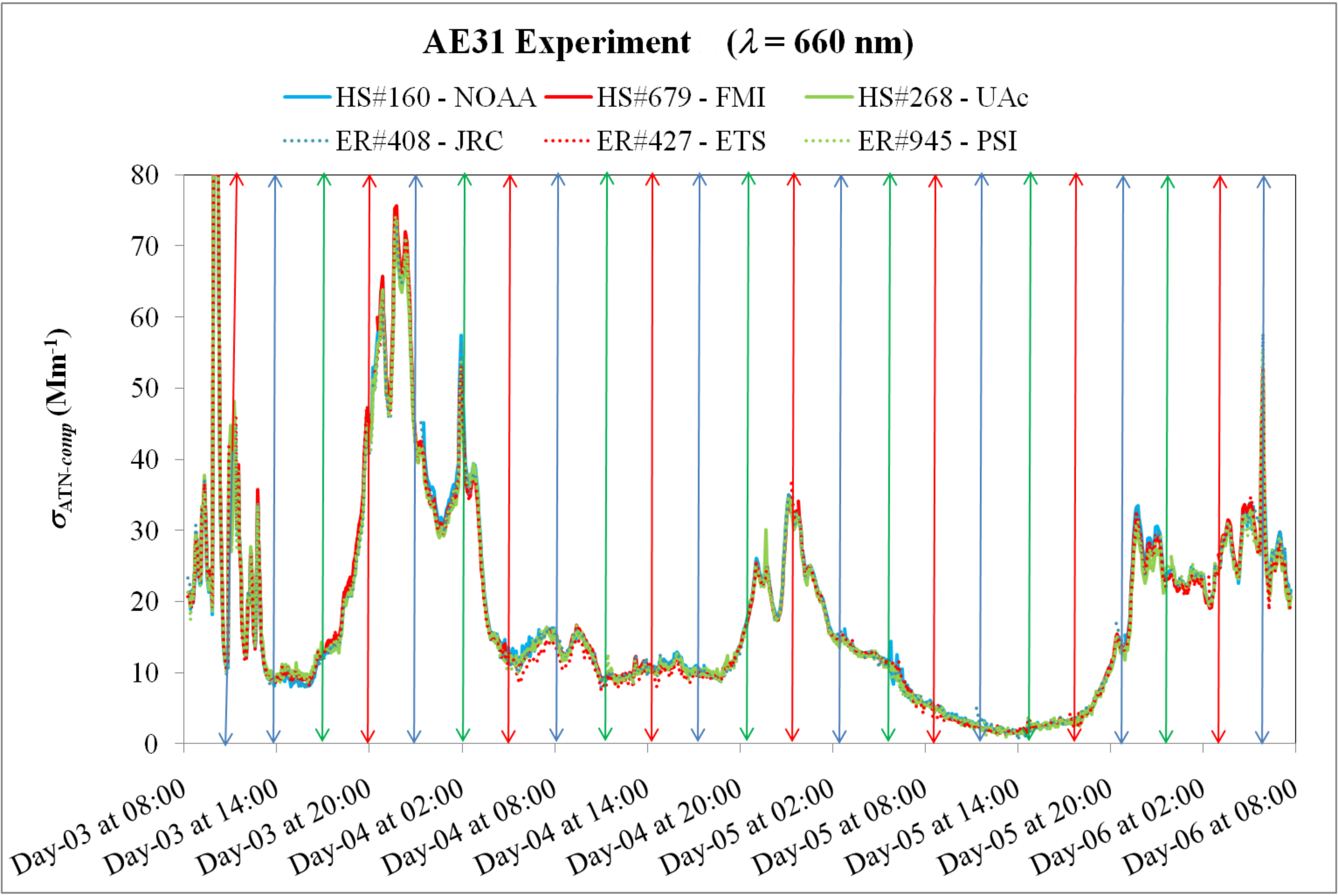


AE31 Experiment (λ = 660 nm)
HS#160 - NOAA
HS#679 - FMI
HS#268 - UAc
ER#408 - JRC
ER#427 - ETS
Line 1:1
σATN (Mm-1)
σATN (ER#945) (Mm-1)
0
10
20
30
40
50
60
70
80

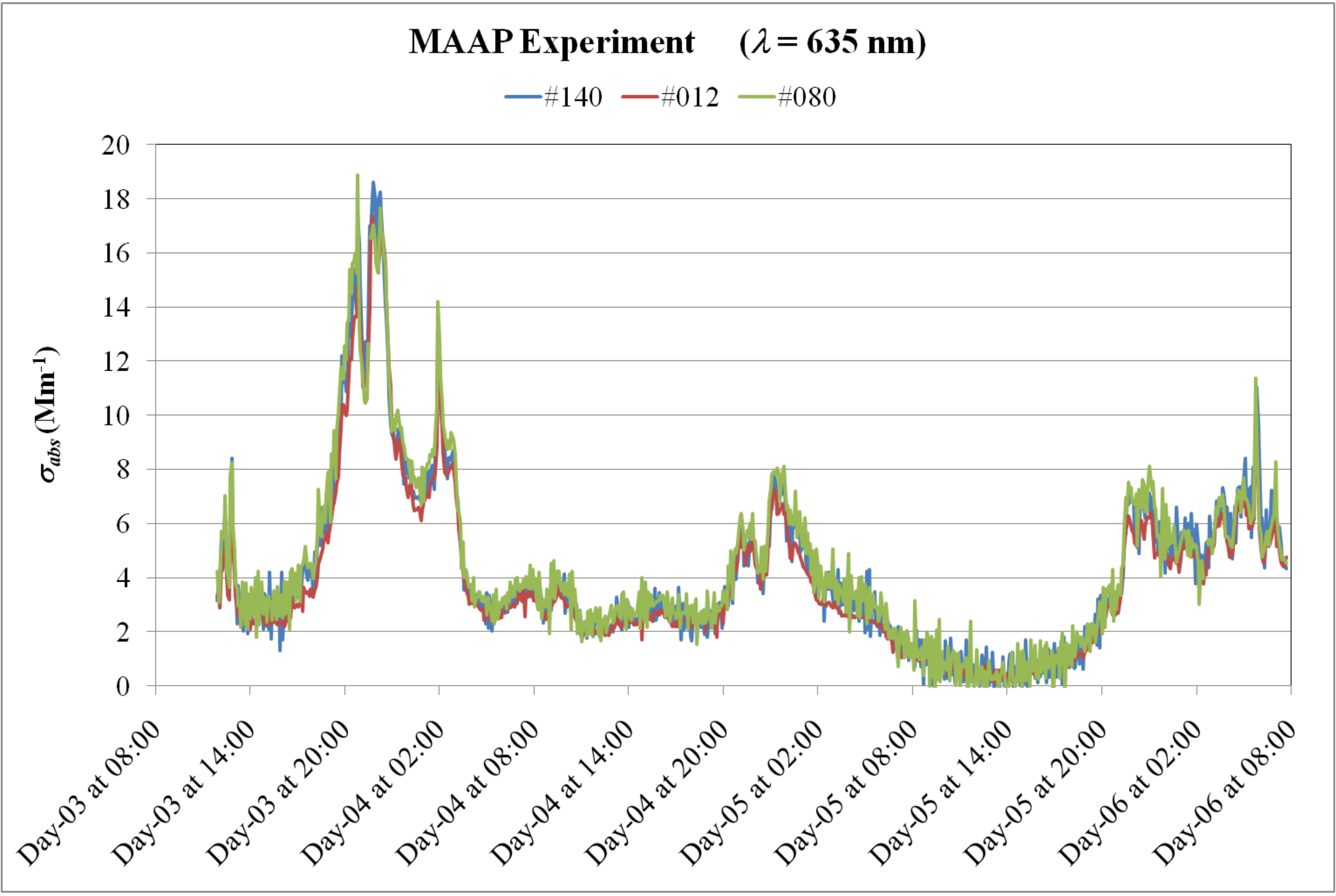


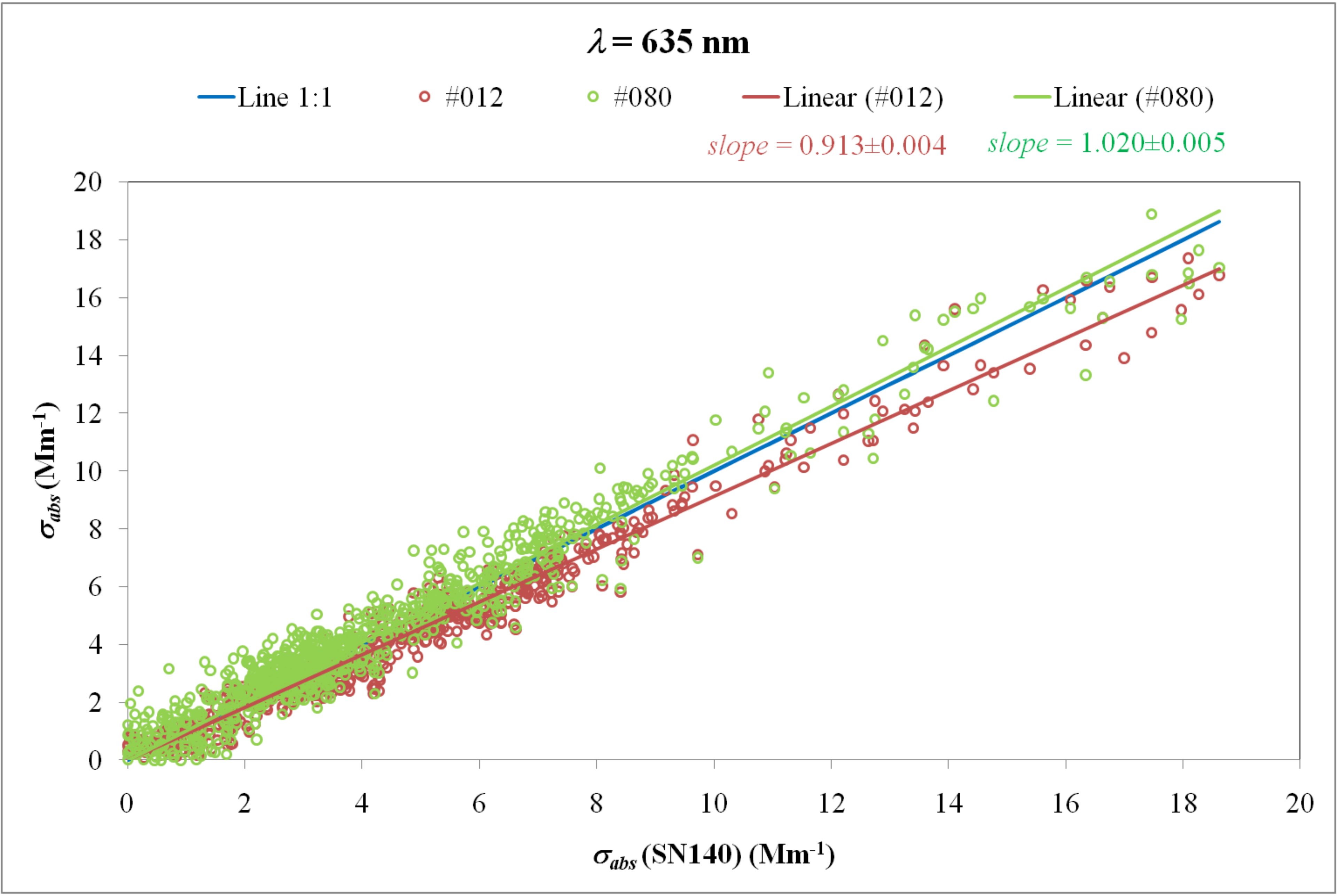
AE31 Experiment (λ = 660 nm)
HS#160 - NOAA
HS#679 - FMI
HS#268 - UAc
ER#408 - JRC
ER#427 - ETS
Line 1:1
$\sigma_{ATN\text{-}comp}$ (Mm^{-1})
$\sigma_{ATN\text{-}comp}$ (ER#945) (Mm^{-1})
0
10
20
30
40
50
60
70
80


AE31 Experiment (λ = 660 nm)
HS#160 - NOAA
HS#679 - FMI
HS#268 - UAc
ER#408 - JRC
ER#427 - ETS
ER#945 - PSI
σATN (Mm-1)
0
10
20
30
40
50
60
70
80
Day-03 at 08:00
Day-03 at 14:00
Day-03 at 20:00
Day-04 at 02:00
Day-04 at 08:00
Day-04 at 14:00
Day-04 at 20:00
Day-05 at 02:00
Day-05 at 08:00
Day-05 at 14:00
Day-05 at 20:00
Day-06 at 02:00
Day-06 at 08:00



AE31 Experiment (λ = 660 nm)
HS#160 - NOAA
HS#679 - FMI
HS#268 - UAc
ER#408 - JRC
ER#427 - ETS
ER#945 - PSI
σATN-comp (Mm-1)
0
10
20
30
40
50
60
70
80
Day-03 at 08:00
Day-03 at 14:00
Day-03 at 20:00
Day-04 at 02:00
Day-04 at 08:00
Day-04 at 14:00
Day-04 at 20:00
Day-05 at 02:00
Day-05 at 08:00
Day-05 at 14:00
Day-05 at 20:00
Day-06 at 02:00
Day-06 at 08:00


MAAP Experiment (λ = 635 nm)
#140
#012
#080
σ_{abs} (Mm^{-1})
20
18
16
14
12
10
8
6
4
2
0
Day-03 at 08:00
Day-03 at 14:00
Day-03 at 20:00
Day-04 at 02:00
Day-04 at 08:00
Day-04 at 14:00
Day-04 at 20:00
Day-05 at 02:00
Day-05 at 08:00
Day-05 at 14:00
Day-05 at 20:00
Day-06 at 02:00
Day-06 at 08:00



λ = 635 nm
Line 1:1
#012
#080
Linear (#012)
Linear (#080)
slope = 0.913±0.004
slope = 1.020±0.005
σabs (Mm-1)
σabs (SN140) (Mm-1)
0
2
4
6
8
10
12
14
16
18
20

Correlating MAAP with AE

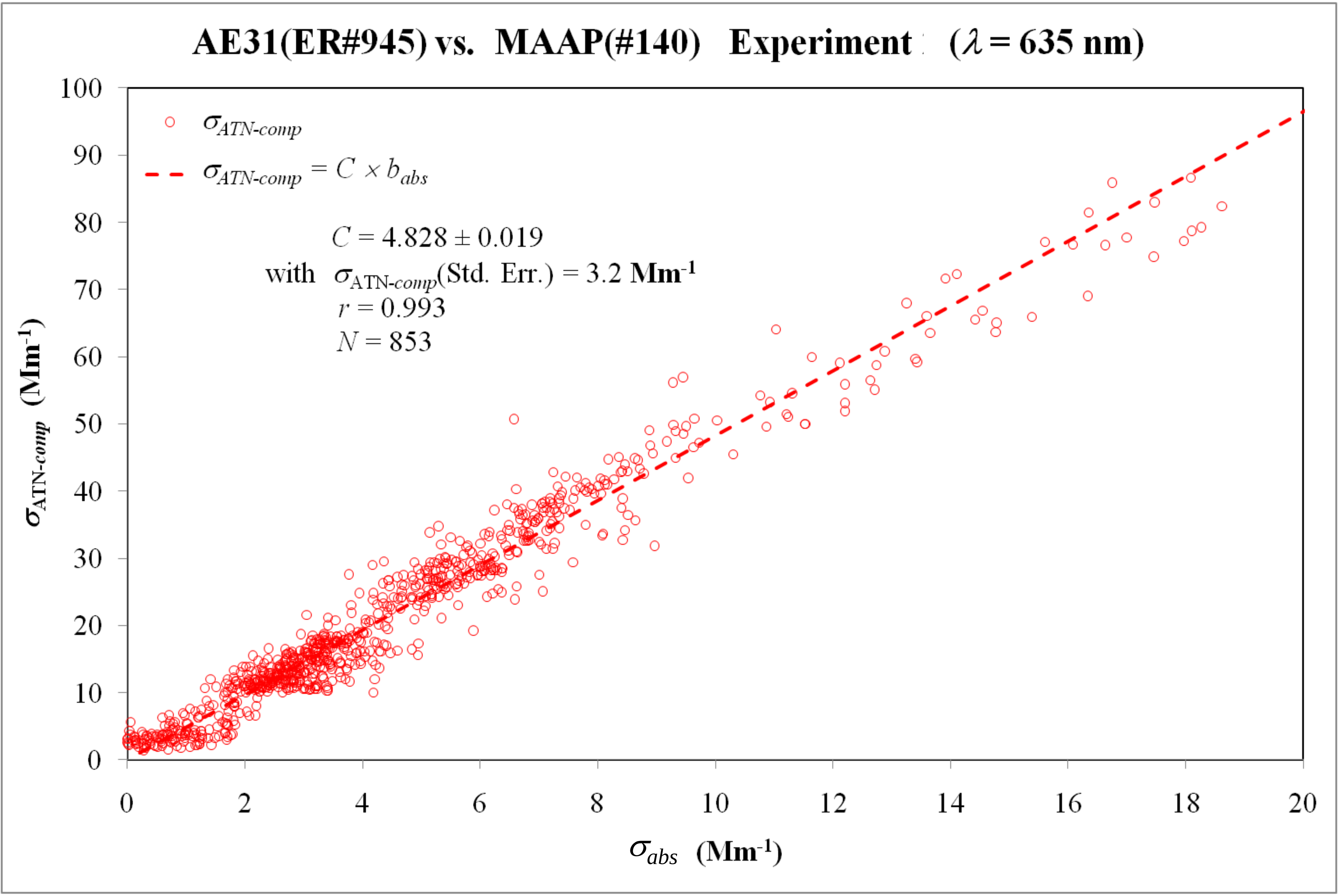
- MAAP #140 data was selected as the reference
  - Data in Standard Pressure (1013.25 mBar) and Temperature (273.15 K)
  - MAAP #080 is too noisy
  - MAAP #012 is slightly different from the other two and have less data then MAAP #140.

- AE31 ER#945 data is used as the reference
  - data was convert to 635 nm by using the relation,

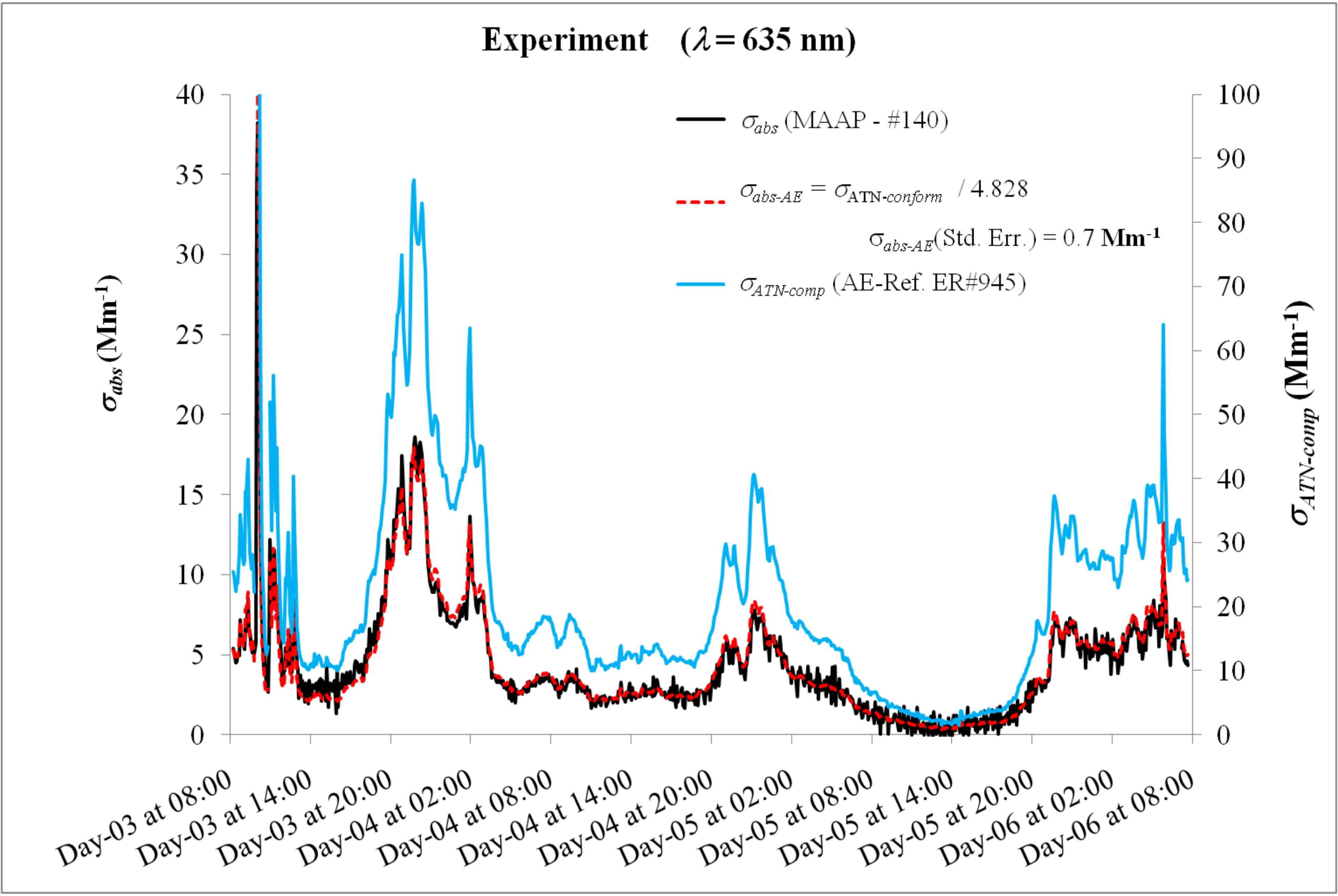
$$\sigma_{\text{ATN-}comp}(635) = \sigma_{\text{ATN-}comp}(660)\left(\frac{660}{635}\right)^{\alpha}$$

were, α = 1.11±0.15

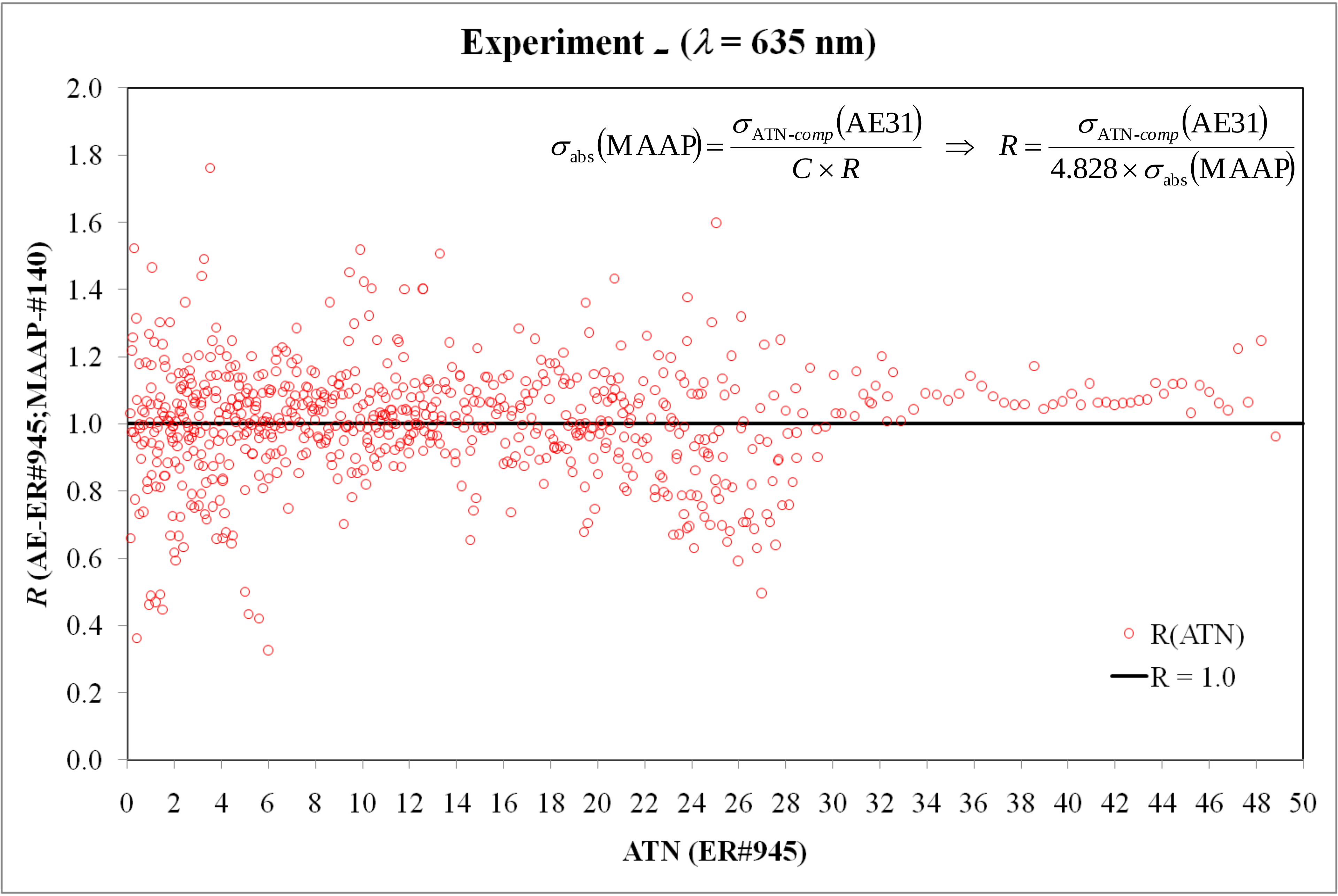
  - scaled to Standard Pressure and Temperature by using the ambient aerosol temperature and pressure taken from the Nephelometer inlet sensors.



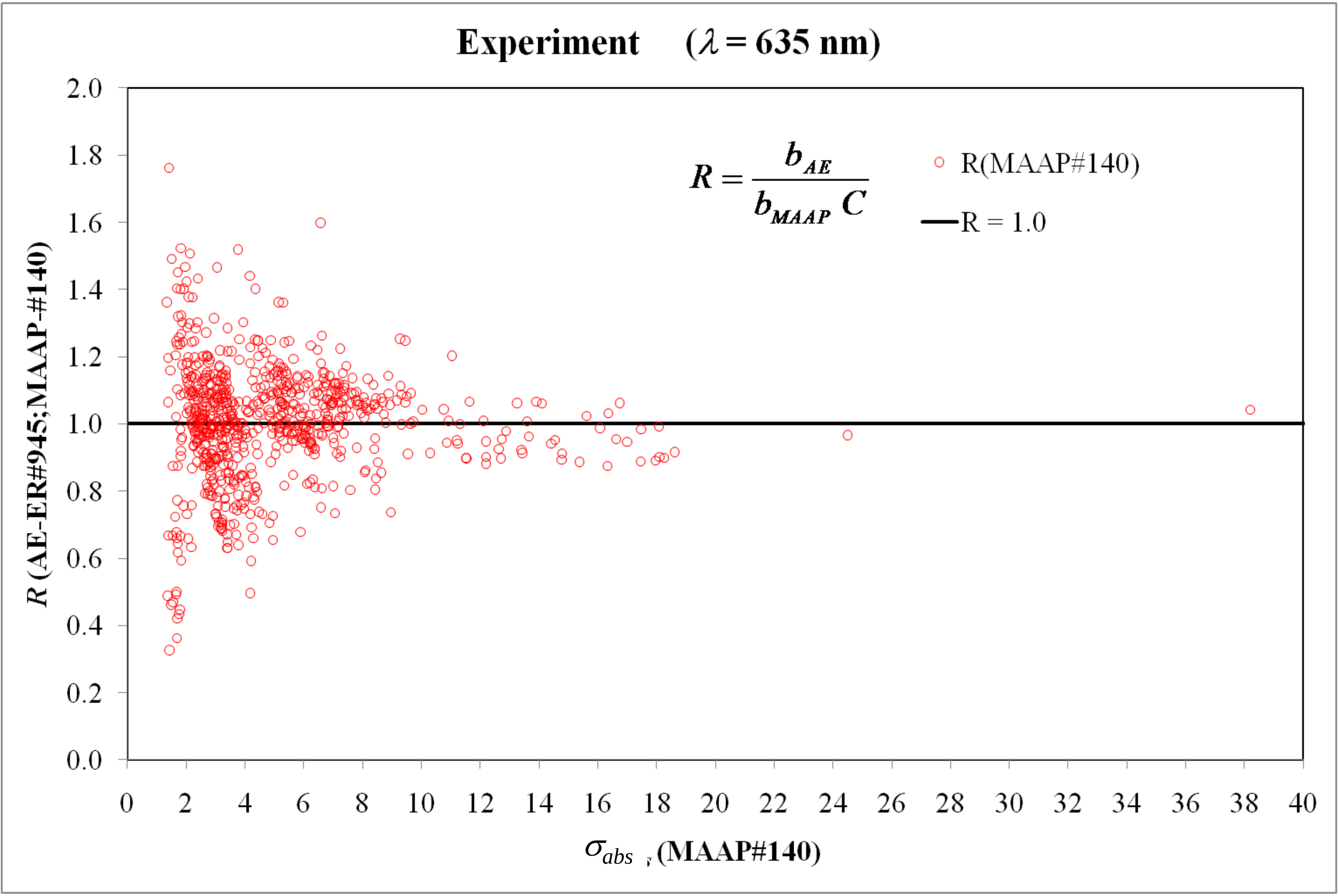
AE31(ER#945) vs. MAAP(#140) Experiment (λ = 635 nm)
σ_ATN-comp
σ_ATN-comp = C × b_abs
C = 4.828 ± 0.019
with σ_ATN-comp(Std. Err.) = 3.2 Mm-1
r = 0.993
N = 853
σ_ATN-comp (Mm-1)
σ_abs (Mm-1)



Experiment (λ = 635 nm)
σabs (Mm-1)
σATN-comp (Mm-1)
σabs (MAAP - #140)
σabs-AE = σATN-conform / 4.828
σabs-AE(Std. Err.) = 0.7 Mm-1
σATN-comp (AE-Ref. ER#945)
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
70
80
90
100
Day-03 at 08:00
Day-03 at 14:00
Day-03 at 20:00
Day-04 at 02:00
Day-04 at 08:00
Day-04 at 14:00
Day-04 at 20:00
Day-05 at 02:00
Day-05 at 08:00
Day-05 at 14:00
Day-05 at 20:00
Day-06 at 02:00
Day-06 at 08:00



Experiment ‗ (λ = 635 nm)
σabs(MAAP) = σATN-comp(AE31) / (C × R) ⇒ R = σATN-comp(AE31) / (4.828 × σabs(MAAP))
R (AE-ER#945;MAAP-#140)
ATN (ER#945)
R(ATN)
R = 1.0
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50



Experiment (λ = 635 nm)
R = b_AE / (b_MAAP C)
R(MAAP#140)
R = 1.0
R (AE-ER#945;MAAP-#140)
σ_abs (MAAP#140)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

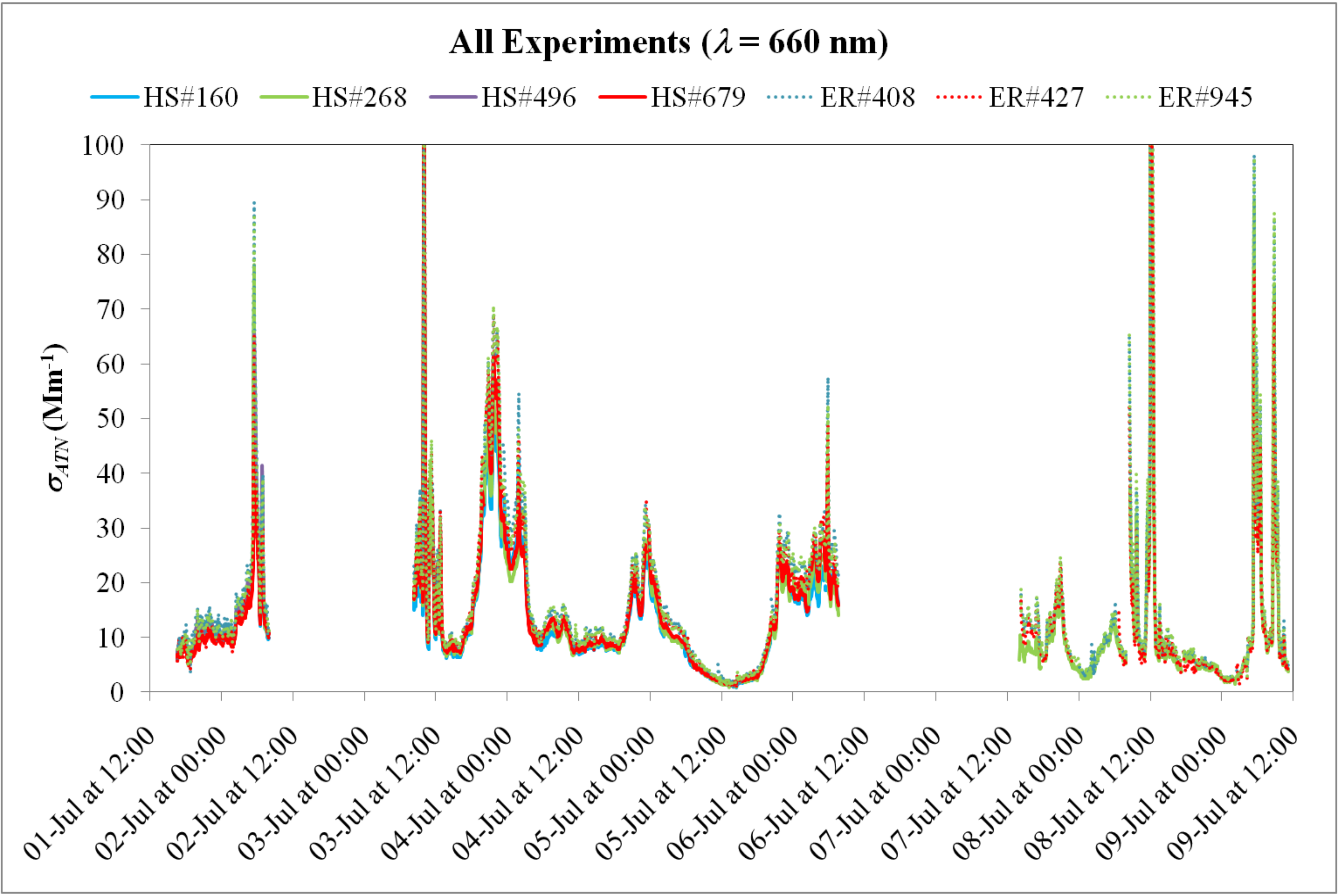
Summary Information

$$\sigma_{\text{ATN}-comp}(\lambda) = \sigma_{\text{ATN}}(\lambda) \times \left(1 + k \times \frac{\text{ATN}(\lambda)}{\lambda}\right)$$

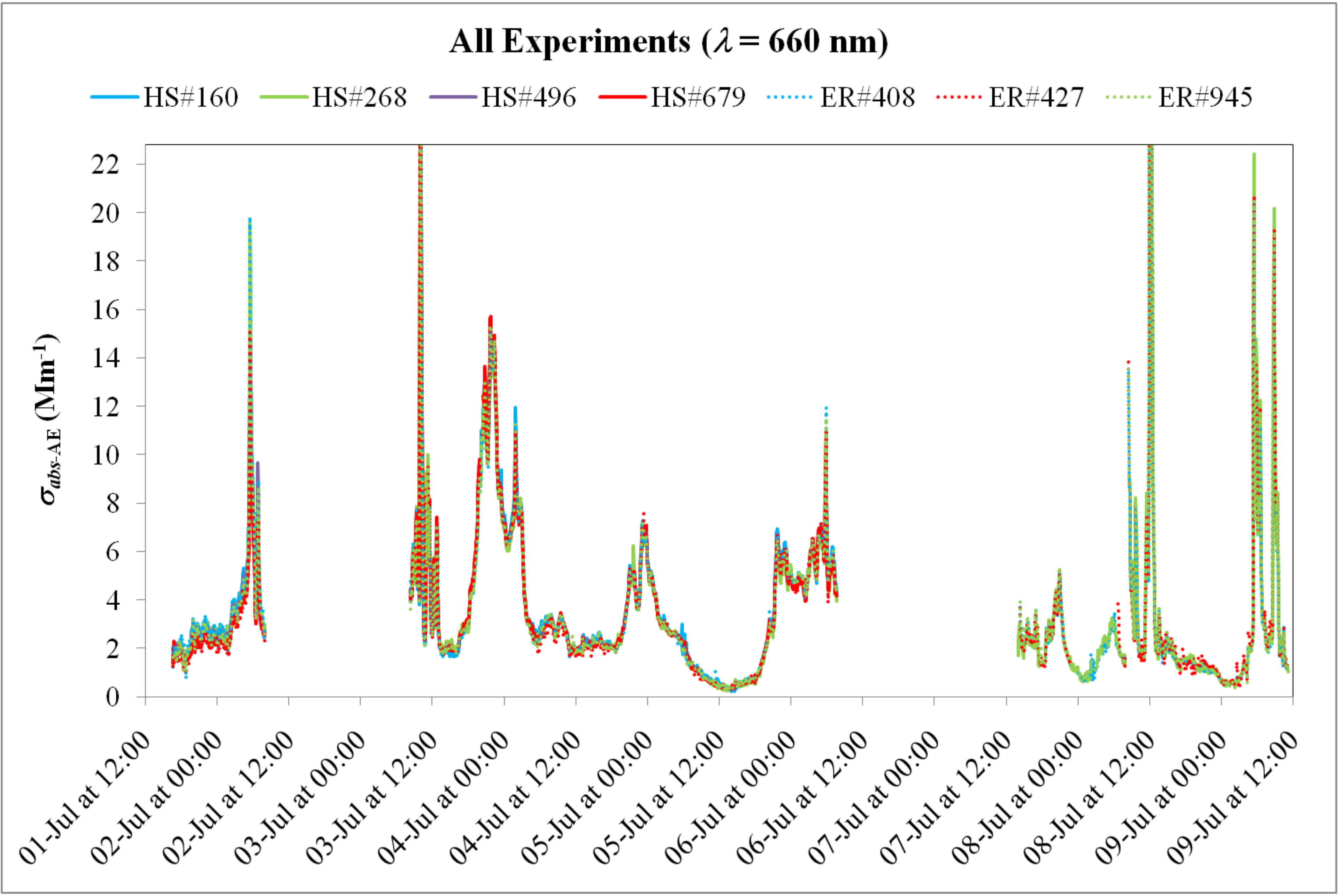
$$k = 1.51 \pm 0.15 \text{ nm}$$

$$\sigma_{abs-\text{AE}} = \frac{\sigma_{\text{ATN}-comp}}{C}$$

Aethalometer	***C***
HS#160	3.821±0.019
HS#268	4.126±0.021
HS#496	4.477±0.023
HS#679	4.205±0.021
ER#408	4.851±0.026
ER#427	4.581±0.024
ER#945	4.828±0.026
Average	4.41±0.38 (9%)



All Experiments (λ = 660 nm)
HS#160
HS#268
HS#496
HS#679
ER#408
ER#427
ER#945
σATN (Mm-1)
100
90
80
70
60
50
40
30
20
10
0
01-Jul at 12:00
02-Jul at 00:00
02-Jul at 12:00
03-Jul at 00:00
03-Jul at 12:00
04-Jul at 00:00
04-Jul at 12:00
05-Jul at 00:00
05-Jul at 12:00
06-Jul at 00:00
06-Jul at 12:00
07-Jul at 00:00
07-Jul at 12:00
08-Jul at 00:00
08-Jul at 12:00
09-Jul at 00:00
09-Jul at 12:00



All Experiments (λ = 660 nm)
HS#160
HS#268
HS#496
HS#679
ER#408
ER#427
ER#945
$\sigma_{abs\text{-AE}}$ (Mm^{-1})
0
2
4
6
8
10
12
14
16
18
20
22
01-Jul at 12:00
02-Jul at 00:00
02-Jul at 12:00
03-Jul at 00:00
03-Jul at 12:00
04-Jul at 00:00
04-Jul at 12:00
05-Jul at 00:00
05-Jul at 12:00
06-Jul at 00:00
06-Jul at 12:00
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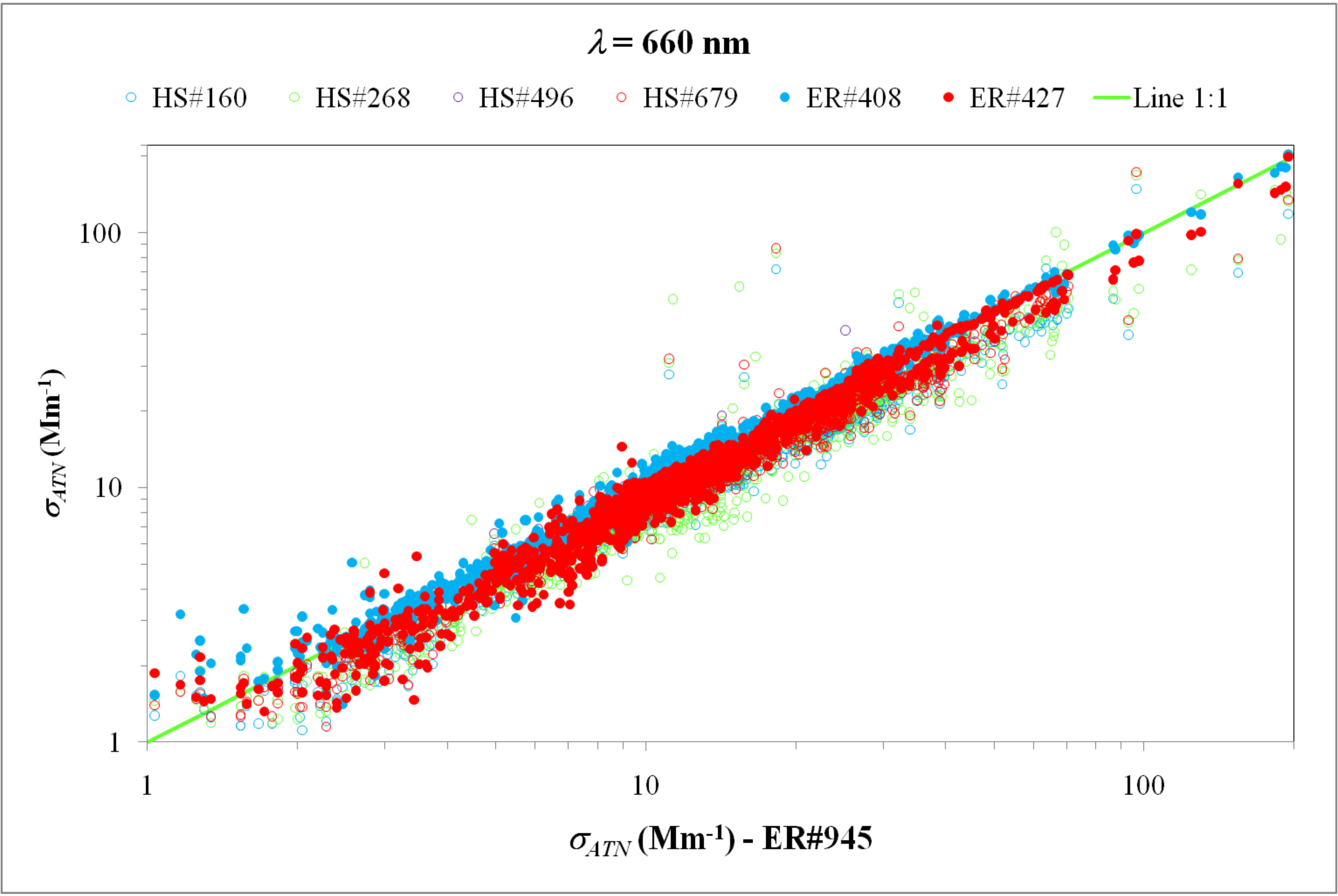
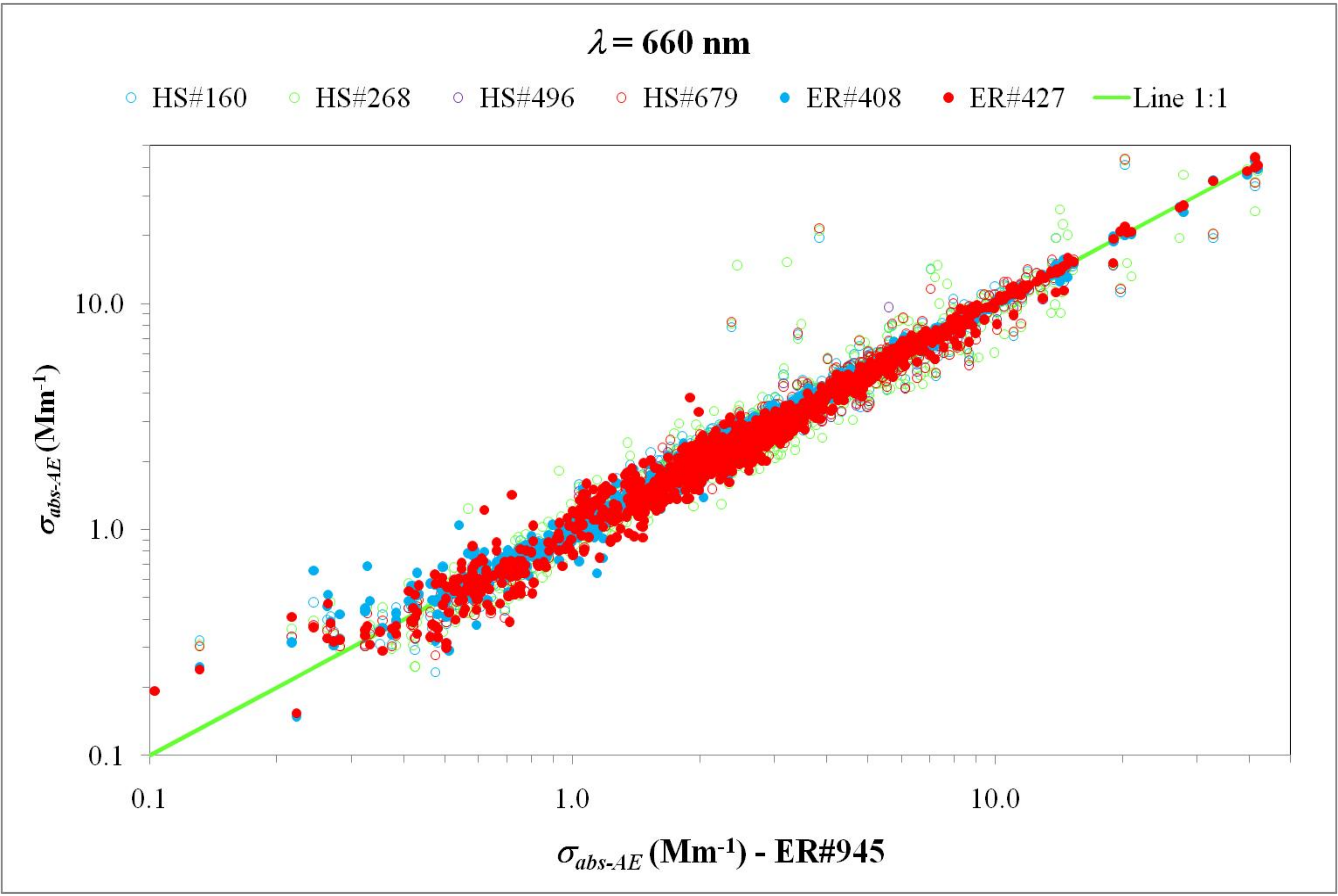
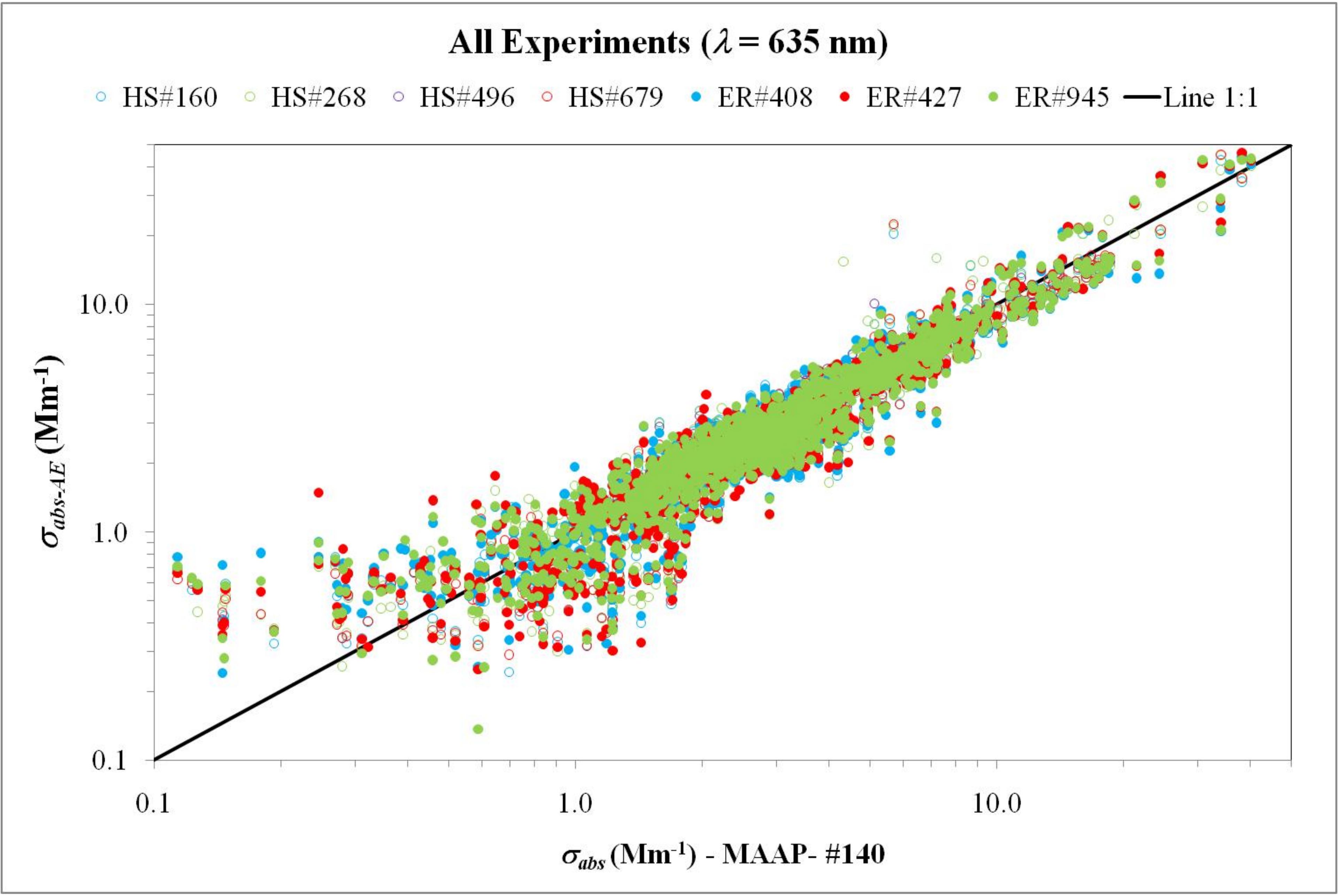
08-Jul at 12:00
09-Jul at 00:00
09-Jul at 12:00

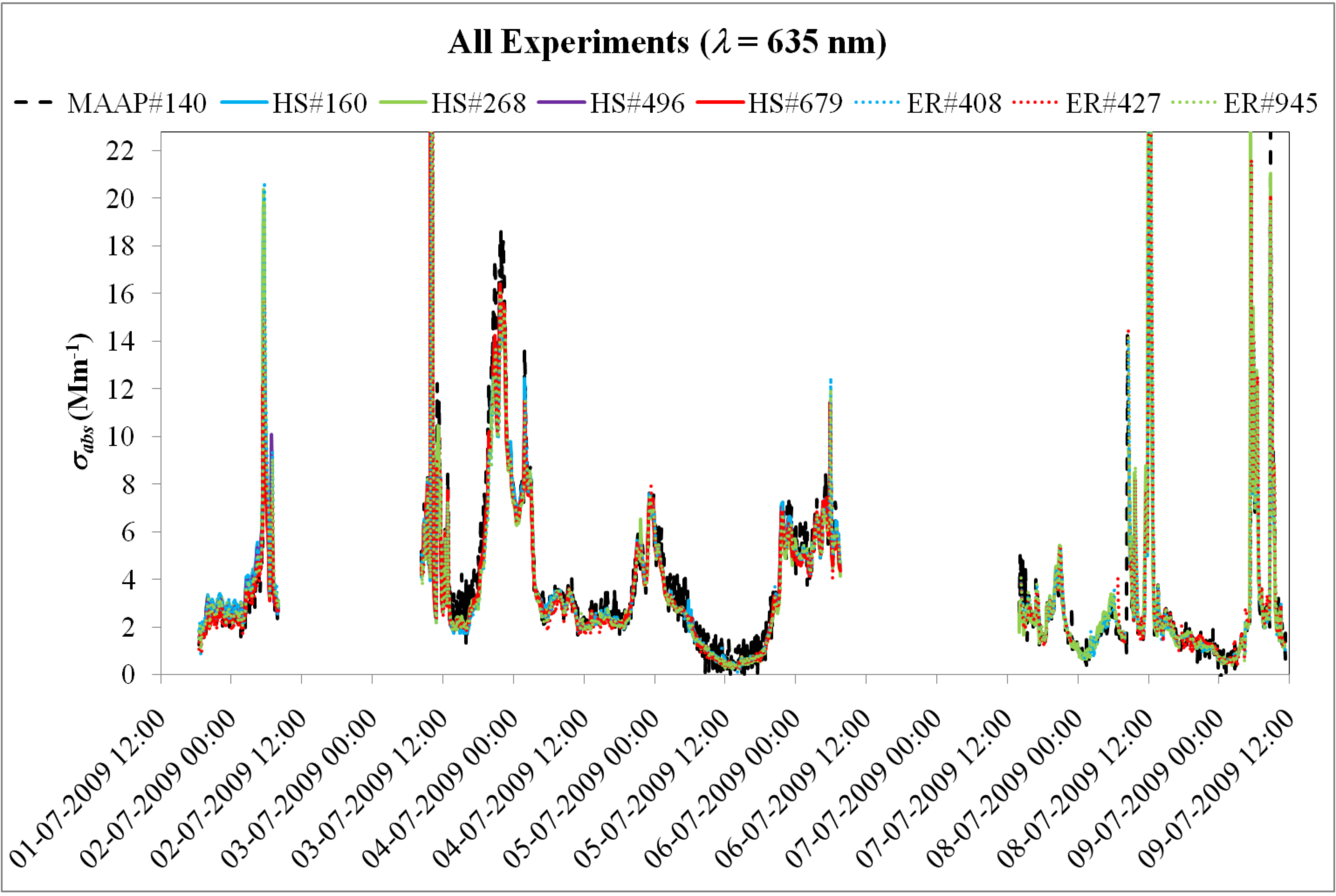


$\lambda = 660$ nm
HS#160
HS#268
HS#496
HS#679
ER#408
ER#427
Line 1:1
σ_{ATN} (Mm^{-1})
100
10
1
1
10
100
σ_{ATN} (Mm^{-1}) - ER#945



$\lambda = 660$ nm
HS#160
HS#268
HS#496
HS#679
ER#408
ER#427
Line 1:1
10.0
1.0
0.1
0.1
1.0
10.0
$\sigma_{abs\text{-}AE}$ (Mm^{-1})
$\sigma_{abs\text{-}AE}$ (Mm^{-1}) - ER#945


All Experiments (λ = 635 nm)
HS#160
HS#268
HS#496
HS#679
ER#408
ER#427
ER#945
Line 1:1
$\sigma_{abs\text{-}AE}$ (Mm^{-1})
10.0
1.0
0.1
0.1
1.0
10.0
σ_{abs} (Mm^{-1}) - MAAP- #140


All Experiments (λ = 635 nm)
MAAP#140
HS#160
HS#268
HS#496
HS#679
ER#408
ER#427
ER#945
σ_{abs} (Mm^{-1})
0
2
4
6
8
10
12
14
16
18
20
22
01-07-2009 12:00
02-07-2009 00:00
02-07-2009 12:00
03-07-2009 00:00
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09-07-2009 12:00

Thank You for Your Attention

- **Involved Institutions**
  - Aerosol d.o.o., Kamniska 41, SI-1000, Ljubljana, Slovenia
  - Department of Optics and Quantum Electronics, University of Szeged, H-6701 Szeged, Hungary
  - Environmental Radioactivity Laboratory, Institute of Nuclear Technology - Radiation Protection N.C.S.R. "Demokritos", 15310 Ag. Paraskevi Attiki, Greece
  - Finnish Meteorological Institute, Climate Change Unit, Helsinki, Finland
  - ISAC - CNR, Via Gobetti 101, 40129 Bologna, Italy
  - JRC, Ispra site, via E. Fermi, 1, I - 21020 Ispra, Italy
  - Leibniz Institute for Tropospheric Research, Leipzig, Germany
  - Netherlands Organisation for Applied Scientific Research, TNO, 80015 Utrecht, The Netherlands
  - University of Azores, P9701-851 Terra Cha, Portugal
  - University of Helsinki, Dept of Physics, Helsinki, Finland

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