ITINERIS

Optical processing of lidar data

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Ministero dell'Università e della Ricerca

Italiadomani

Agenda

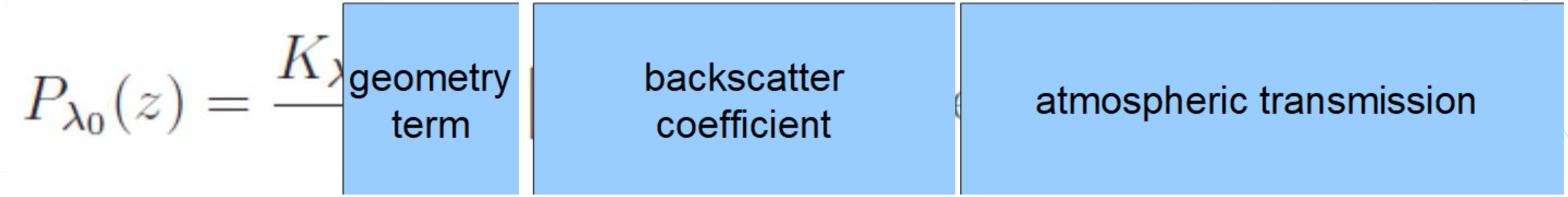
- Basics
  - literature
  - Lidar equation
- The „extinction only“ product
  - General product options
- The „Raman backscatter“ product
  - usecases
  - Calibration options
- The „elastic backscatter“ product
  - Lidar ratio assumption
- The „lidar ratio and extinction“ product
  - Effective vertical resolution
- VLDR and PLDR
- Outlook

Literature

LIDAR --- Range-resolved
Remote Sensing of the Atmosphere
C. Weitkamp Springer Verlag, Heidelberg, 2005

EARLINET single Calculus Chain - technical - Part2:
Calculation of optical products
Mattis et al. AMT 2016

Lidar equation



P P_λ	measured signal
K_λ	lidar constant (instrument performance)

Lidar equation

$$P_{\lambda_0}(z) = \frac{K_{\lambda_0} O(z)}{z^2}$$

backscatter coefficient

atmospheric transmission

P P_λ	measured signal
K_λ	lidar constant (instrument performance)
$O(z)$	overlap function
z	range

Lidar equation

$$P_{\lambda_0}(z) = \frac{K_{\lambda_0} O(z)}{z^2} \left[\beta^{\mathrm{mol}}_{\lambda_0}(z) + \beta^{\mathrm{par}}_{\lambda_0}\right]$$

atmospheric transmission

P P_λ	measured signal
K_λ	lidar constant (instrument performance)
$O(z)$	overlap function
z.	range
$\beta_\lambda(z)$	backscatter coefficient, particles + molecules

Lidar equation

$$P_{\lambda_0}(z) = \frac{K_{\lambda_0} O(z)}{z^2} \left[\beta^{\mathrm{mol}}_{\lambda_0}(z) + \beta^{\mathrm{par}}_{\lambda_0}\right] \exp\left(-2\int_0^z \alpha_{\lambda_0}(\zeta)\mathrm{d}\zeta\right)$$

P P_λ	measured signal
K_λ	lidar constant (instrument performance)
$O(z)$	overlap function
z	range
$\beta_\lambda(z)$	backscatter coefficient, particles + molecules
$\alpha_\lambda(z)$	extinction coefficient, extinction = scattering + absorption

Lidar equation

$$P_{\lambda_0}(z) = \frac{K_{\lambda_0} O(z)}{z^2} \left[\beta^{\mathrm{mol}}_{\lambda_0}(z) + \beta^{\mathrm{par}}_{\lambda_0}\right] \exp\left(-2\int_0^z \alpha_{\lambda_0}(\zeta)\mathrm{d}\zeta\right)$$

P P_λ	measured signal
K_λ	lidar constant (instrument performance)
$O(z)$	overlap function
z	range
$\beta_\lambda(z)$	backscatter coefficient, particles + molecules
$\alpha_\lambda(z)$	extinction coefficient, extinction = scattering + absorption

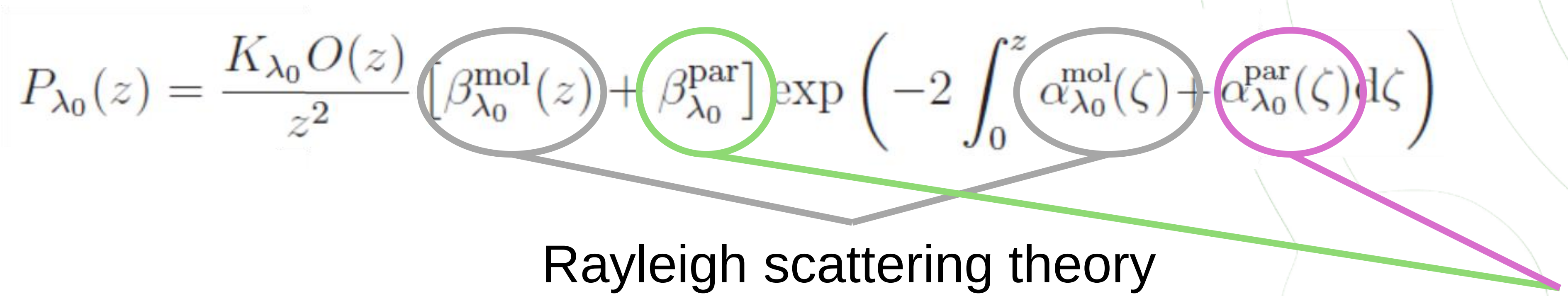
$$\alpha_\lambda(z) = \alpha_\lambda^{\mathrm{s,mol}}(z) + \alpha_\lambda^{\mathrm{s,par}}(z) + \xcancel{\alpha_\lambda^{\mathrm{a,mol}}}(z) + \alpha_\lambda^{\mathrm{a,par}}(z)$$

Elastic and Raman signals

$$P_{\lambda_0}(z) = \frac{K_{\lambda_0} O(z)}{z^2} \left[\beta_{\lambda_0}^{\mathrm{mol}}(z) + \beta_{\lambda_0}^{\mathrm{par}}\right] \exp\left(-2 \int_0^z \alpha_{\lambda_0}^{\mathrm{mol}}(\zeta) + \alpha_{\lambda_0}^{\mathrm{par}}(\zeta) \mathrm{d}\zeta\right)$$

Rayleigh scattering theory
+
air density profile from
radiosonde observations

Elastic and Raman signals

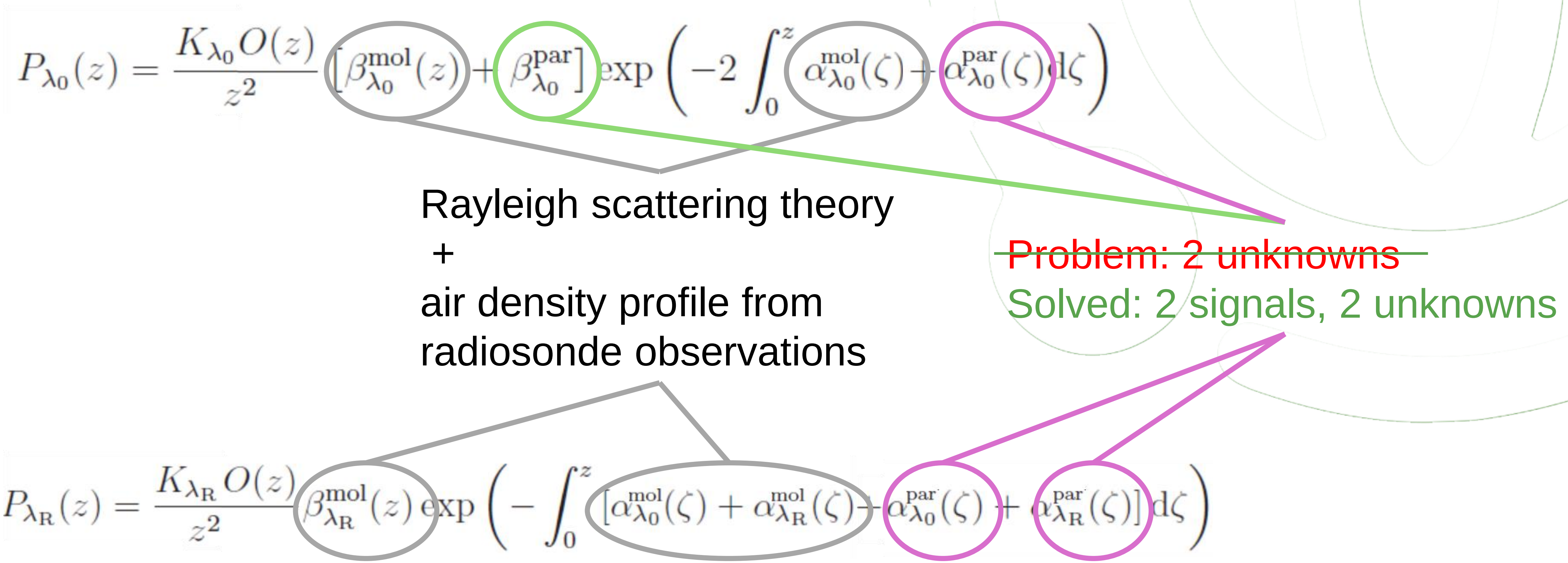


$$P_{\lambda_0}(z) = \frac{K_{\lambda_0}O(z)}{z^2}\left[\beta^{\mathrm{mol}}_{\lambda_0}(z) + \beta^{\mathrm{par}}_{\lambda_0}\right]\exp\left(-2\int_0^z \alpha^{\mathrm{mol}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_0}(\zeta)\mathrm{d}\zeta\right)$$

Rayleigh scattering theory
+
air density profile from
radiosonde observations

Problem: 2 unknowns

Elastic and Raman signals



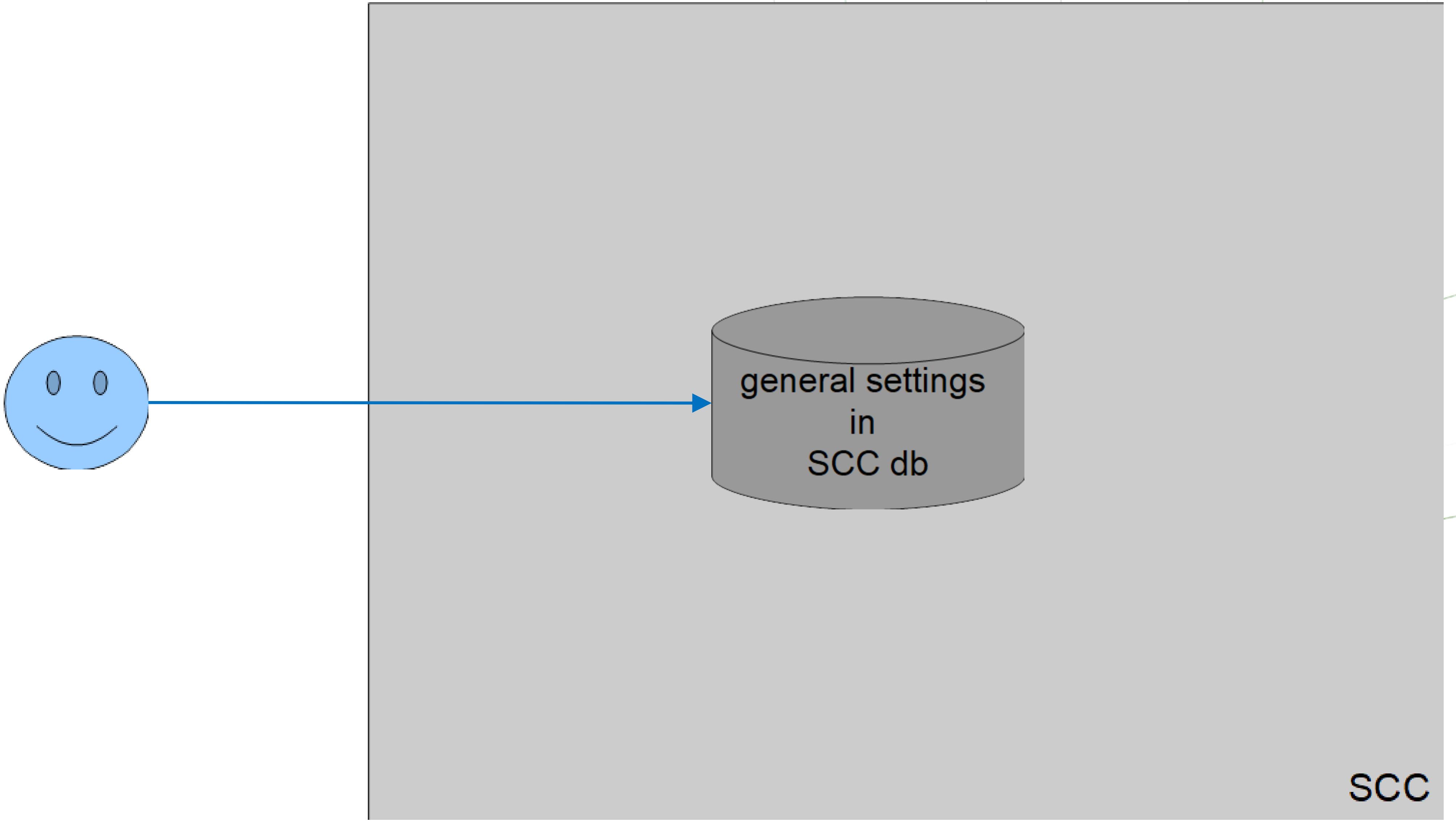
$$P_{\lambda_0}(z) = \frac{K_{\lambda_0} O(z)}{z^2} [\beta^{\mathrm{mol}}_{\lambda_0}(z) + \beta^{\mathrm{par}}_{\lambda_0}] \exp\left(-2\int_0^z \alpha^{\mathrm{mol}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_0}(\zeta) \mathrm{d}\zeta\right)$$

Rayleigh scattering theory
\+
air density profile from
radiosonde observations

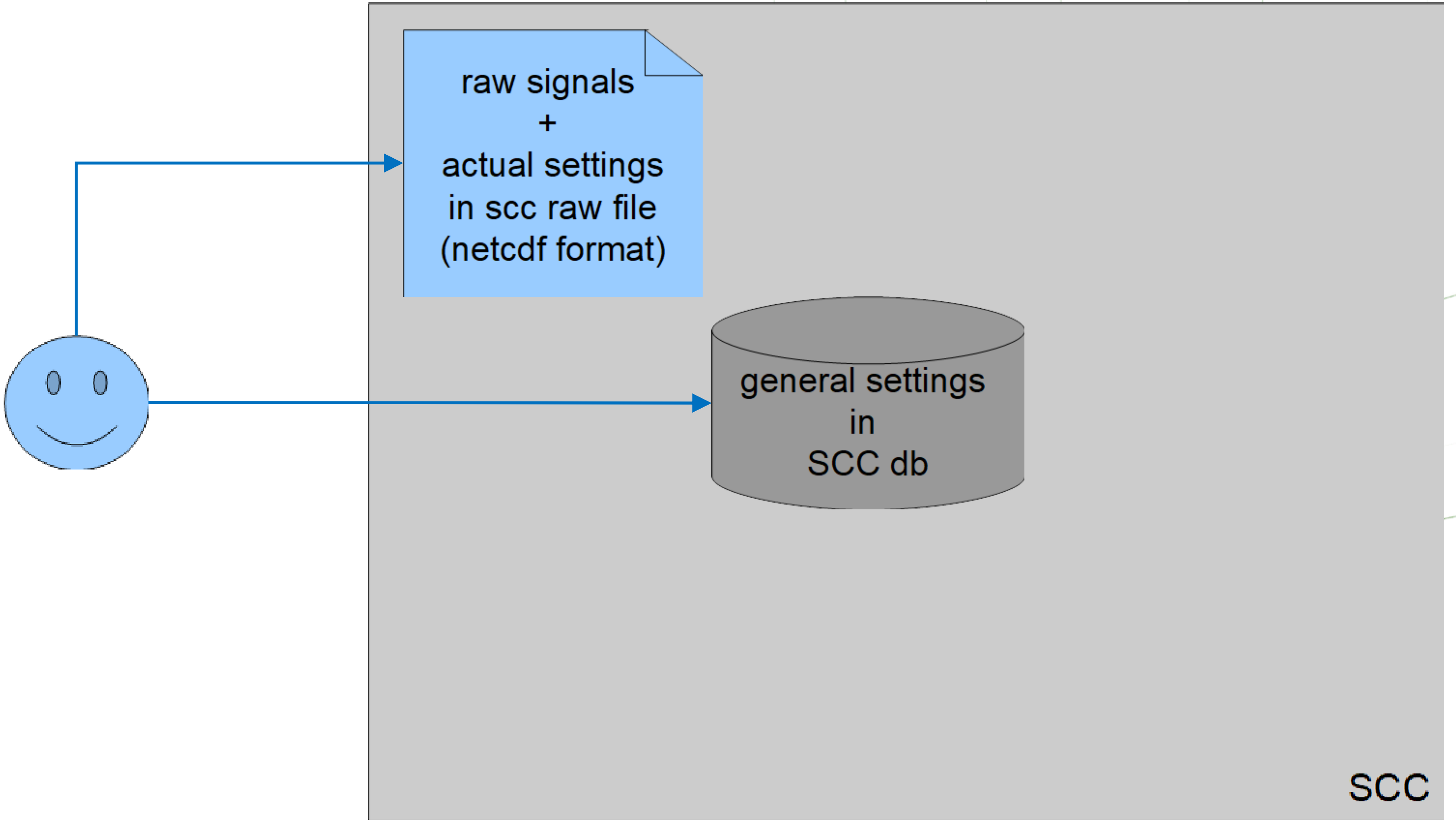
~~Problem: 2 unknowns~~
Solved: 2 signals, 2 unknowns

$$P_{\lambda_\mathrm{R}}(z) = \frac{K_{\lambda_\mathrm{R}} O(z)}{z^2} \beta^{\mathrm{mol}}_{\lambda_\mathrm{R}}(z) \exp\left(-\int_0^z [\alpha^{\mathrm{mol}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{mol}}_{\lambda_\mathrm{R}}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_\mathrm{R}}(\zeta)] \mathrm{d}\zeta\right)$$

Interactions between user and SCC



Interactions between user and SCC

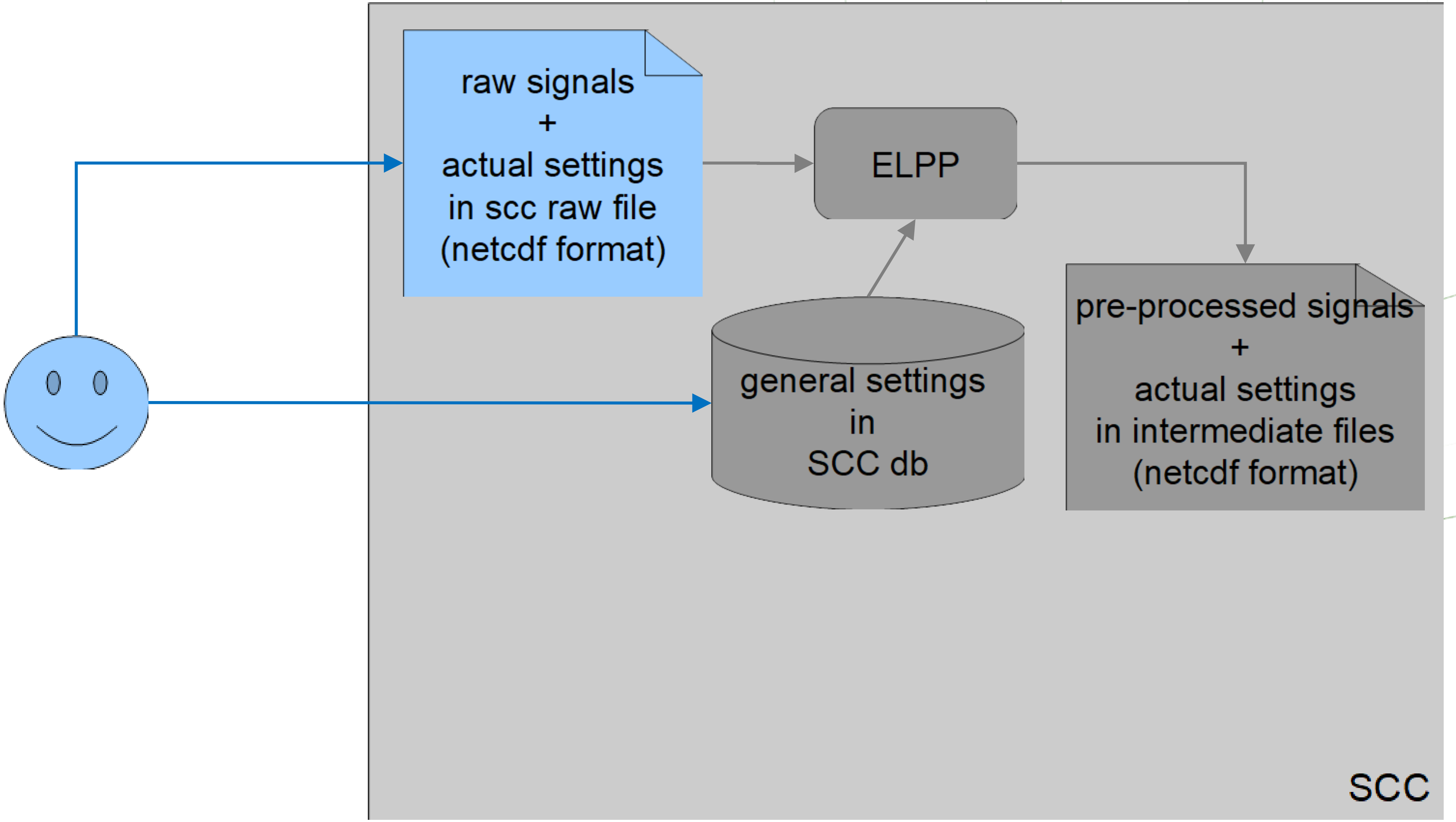


raw signals
+
actual settings
in scc raw file
(netcdf format)

general settings
in
SCC db

SCC

Interactions between user and SCC



raw signals + actual settings in scc raw file (netcdf format)

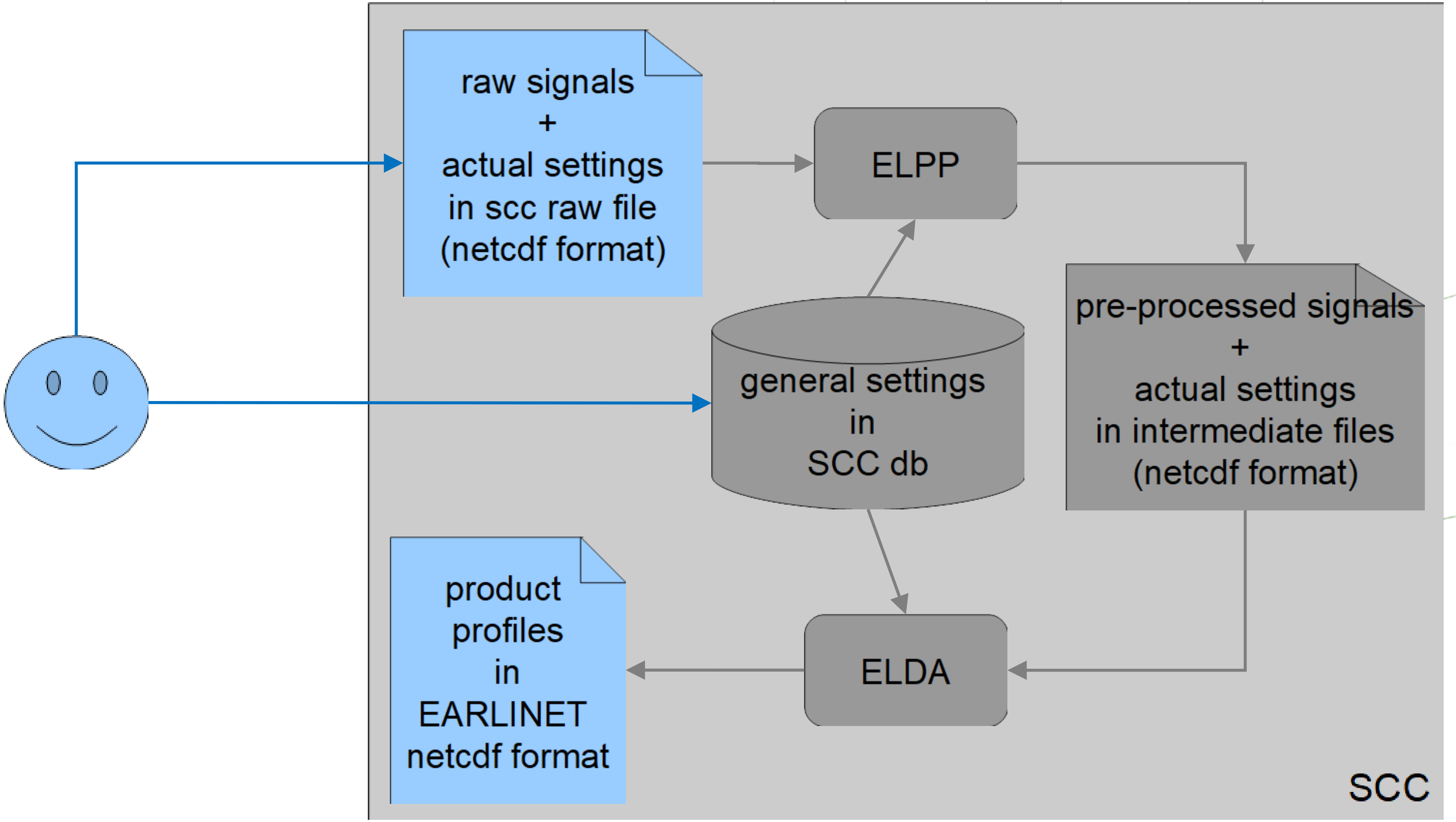
ELPP

general settings in SCC db

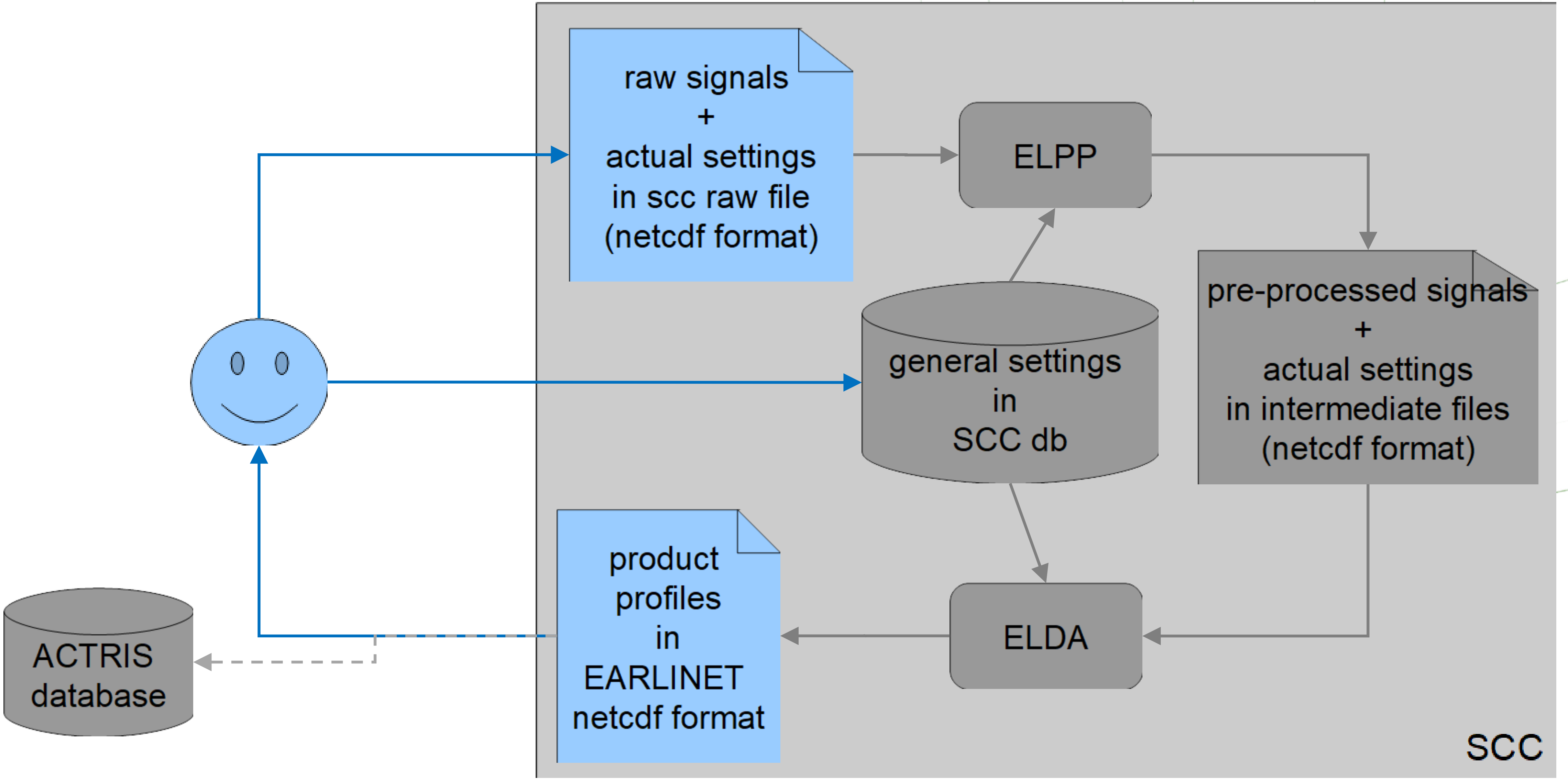
pre-processed signals + actual settings in intermediate files (netcdf format)

SCC

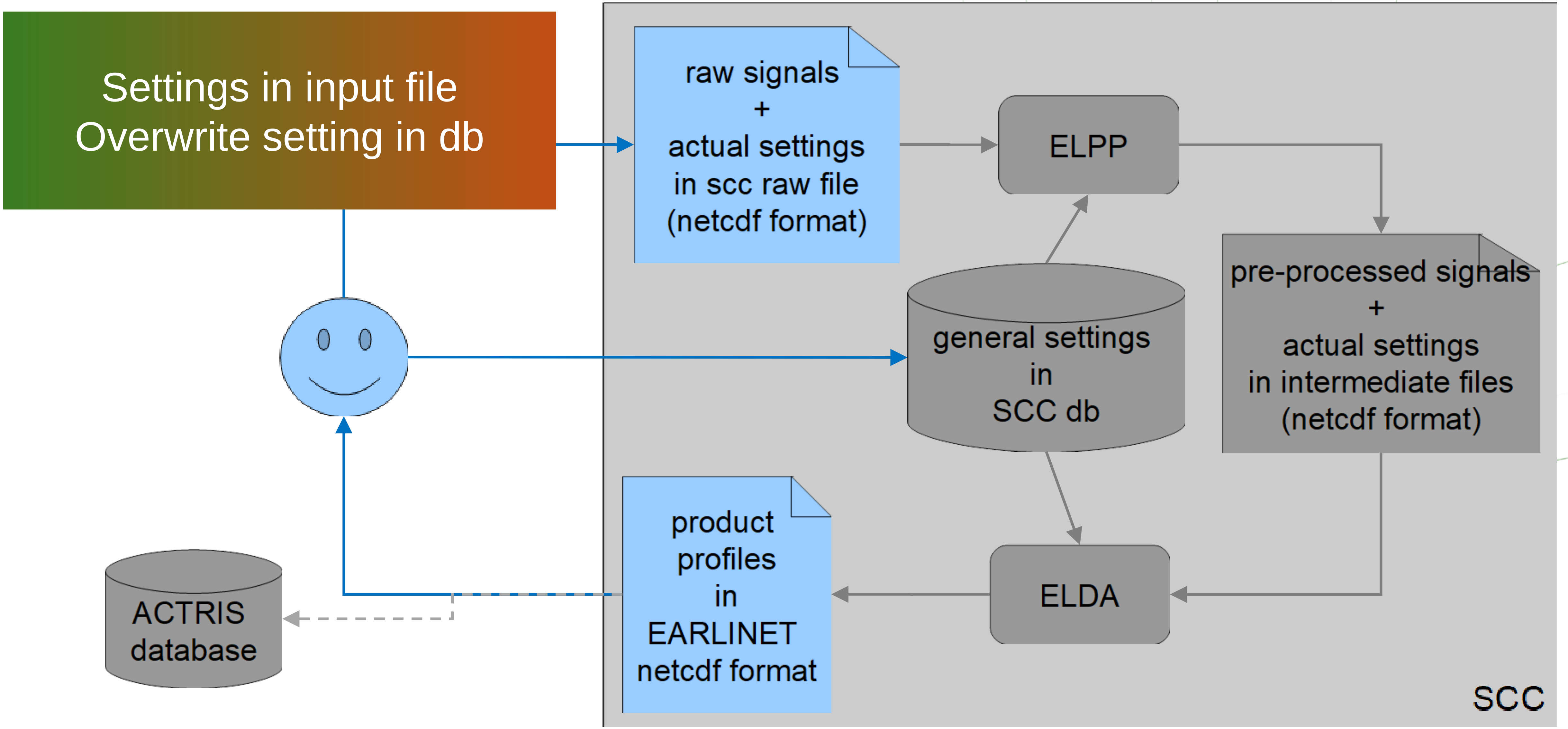
Interactions between user and SCC



Interactions between user and SCC



Interactions between user and SCC



Settings in input file
Overwrite setting in db

raw signals
+
actual settings
in scc raw file
(netcdf format)

ELPP

general settings
in
SCC db

pre-processed signals
+
actual settings
in intermediate files
(netcdf format)

product
profiles
in
EARLINET
netcdf format

ELDA

ACTRIS
database

SCC

- The «extinction only» product
- General product options

Signal corrections before retrievals

$$P_{\lambda_0}(z) = \frac{K_{\lambda_0} O(z)}{z^2} \left[\beta^{\mathrm{mol}}_{\lambda_0}(z) + \beta^{\mathrm{par}}_{\lambda_0}\right] \exp\left(-2 \int_0^z \alpha^{\mathrm{mol}}_{\lambda 0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda 0}(\zeta) \mathrm{d}\zeta\right)$$

$$P_{\lambda_\mathrm{R}}(z) = \frac{K_{\lambda_\mathrm{R}} O(z)}{z^2} \beta^{\mathrm{mol}}_{\lambda_\mathrm{R}}(z) \exp\left(-\int_0^z \left[\alpha^{\mathrm{mol}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{mol}}_{\lambda_\mathrm{R}}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_\mathrm{R}}(\zeta)\right] \mathrm{d}\zeta\right)$$

Signal corrections before retrievals

1) in ELPP

- range² correction
- overlap correction

$$P_{\lambda_0}(z) = \frac{K_{\lambda_0}\xcancel{O(z)}}{\xcancel{z^2}}\left[\beta^{\mathrm{mol}}_{\lambda_0}(z) + \beta^{\mathrm{par}}_{\lambda_0}\right] \exp\left(-2\int_0^z \alpha^{\mathrm{mol}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_0}(\zeta)\,\mathrm{d}\zeta\right)$$

$$P_{\lambda_\mathrm{R}}(z) = \frac{K_{\lambda_\mathrm{R}}\xcancel{O(z)}}{\xcancel{z^2}}\beta^{\mathrm{mol}}_{\lambda_\mathrm{R}}(z) \exp\left(-\int_0^z \left[\alpha^{\mathrm{mol}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{mol}}_{\lambda_\mathrm{R}}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_\mathrm{R}}(\zeta)\right]\mathrm{d}\zeta\right)$$

Signal corrections before retrievals

1) **in ELPP**

- range² correction
- overlap correction

2) **in ELDA**

- correction for atmospheric transmission due to scattering at air molecules

$$P_{\lambda_0}(z) = \frac{K_{\lambda_0}\cancel{O(z)}}{\cancel{z^2}}\left[\beta^{\mathrm{mol}}_{\lambda_0}(z) + \beta^{\mathrm{par}}_{\lambda_0}\right]\exp\left(-2\int_0^z \cancel{\alpha^{\mathrm{mol}}_{\lambda_0}}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_0}(\zeta)\mathrm{d}\zeta\right)$$

$$P_{\lambda_\mathrm{R}}(z) = \frac{K_{\lambda_\mathrm{R}}\cancel{O(z)}}{\cancel{z^2}}\beta^{\mathrm{mol}}_{\lambda_\mathrm{R}}(z)\exp\left(-\int_0^z \left[\cancel{\alpha^{\mathrm{mol}}_{\lambda_0}}(\zeta) + \cancel{\alpha^{\mathrm{mol}}_{\lambda_\mathrm{R}}}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_\mathrm{R}}(\zeta)\right]\mathrm{d}\zeta\right)$$

Signal corrections before retrievals

1) **in ELPP**

- range² correction
- overlap correction

2) **in ELDA**

- correction for atmospheric transmission due to scattering at air molecules

$$P_{\lambda_0}(z) = \frac{K_{\lambda_0} \cancel{O(z)}}{\cancel{z^2}} \left[\beta^{\mathrm{mol}}_{\lambda_0}(z) + \beta^{\mathrm{par}}_{\lambda_0}\right] \exp\left(-2\int_0^z \cancel{\alpha^{\mathrm{mol}}_{\lambda_0}(\zeta)} + \alpha^{\mathrm{par}}_{\lambda_0}(\zeta)\,\mathrm{d}\zeta\right)$$

$$P_{\lambda_0}(z) \longrightarrow \widehat{P_{\lambda_0}}(z)$$

$$P_{\lambda_R}(z) = \frac{K_{\lambda_R} \cancel{O(z)}}{\cancel{z^2}} \beta^{\mathrm{mol}}_{\lambda_R}(z) \exp\left(-\int_0^z \left[\cancel{\alpha^{\mathrm{mol}}_{\lambda_0}(\zeta)} + \cancel{\alpha^{\mathrm{mol}}_{\lambda_R}(\zeta)} + \alpha^{\mathrm{par}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_R}(\zeta)\right] \mathrm{d}\zeta\right)$$

$$P_{\lambda_R}(z) \longrightarrow \widehat{P_{\lambda_R}}(z)$$

Retrieval of an «extinction only» product

$$\widehat{P_{\lambda_\mathrm{R}}}(z) = K_{\lambda_\mathrm{R}} \beta^\mathrm{mol}_{\lambda_\mathrm{R}}(z) \exp\left(- \int_0^z \left[\alpha^\mathrm{par}_{\lambda_0}(\zeta) + \alpha^\mathrm{par}_{\lambda_\mathrm{R}}(\zeta) \right] \mathrm{d}\zeta \right)$$

↑

$$\beta^\mathrm{mol}_{\lambda_\mathrm{R}} = N^\mathrm{mol}_\mathrm{R}(z)\, \sigma^\mathrm{mol}_{\lambda_0}\ \Phi^\mathrm{mol}_{\lambda_0}(\pi)$$

Retrieval of an «extinction only» product

$$\widehat{P_{\lambda_\mathrm{R}}}(z) = K_{\lambda_\mathrm{R}} \beta^{\mathrm{mol}}_{\lambda_\mathrm{R}}(z) \exp\left(-\int_0^z \left[\alpha^{\mathrm{par}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_\mathrm{R}}(\zeta)\right] \mathrm{d}\zeta \right)$$

$$\beta^{\mathrm{mol}}_{\lambda_\mathrm{R}} = N^{\mathrm{mol}}_{\mathrm{R}}(z)\, \sigma^{\mathrm{mol}}_{\lambda_0}\ \Phi^{\mathrm{mol}}_{\lambda_0}(\pi)$$

$$\alpha^{\mathrm{par}}_{\lambda_0}(z) + \alpha^{\mathrm{par}}_{\lambda_\mathrm{R}}(z) = -\frac{\mathrm{d}}{\mathrm{d}z} \ln \frac{\widehat{P_{\lambda_\mathrm{R}}}(z)}{N^{\mathrm{mol}}_{\mathrm{R}}(z)}$$

$$\frac{\alpha^{\mathrm{par}}_{\lambda_0}}{\alpha^{\mathrm{par}}_{\lambda_\mathrm{R}}} = \left(\frac{\lambda_\mathrm{R}}{\lambda_0}\right)^{\mathring{a}}$$

Retrieval of an «extinction only» product

$$\widehat{P_{\lambda_R}}(z) = K_{\lambda_R}\,\beta^{\mathrm{mol}}_{\lambda_R}(z)\exp\left(-\int_0^z \left[\alpha^{\mathrm{par}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_R}(\zeta)\right]\mathrm{d}\zeta\right)$$

$$\uparrow$$

$$\beta^{\mathrm{mol}}_{\lambda_R} = N^{\mathrm{mol}}_{\mathrm{R}}(z)\,\sigma^{\mathrm{mol}}_{\lambda_0}\;\Phi^{\mathrm{mol}}_{\lambda_0}(\pi)$$

$$\alpha^{\mathrm{par}}_{\lambda_0}(z) + \alpha^{\mathrm{par}}_{\lambda_R}(z) = -\frac{\mathrm{d}}{\mathrm{d}z}\ln\frac{\widehat{P_{\lambda_R}}(z)}{N^{\mathrm{mol}}_{\mathrm{R}}(z)}$$

$$\nwarrow$$

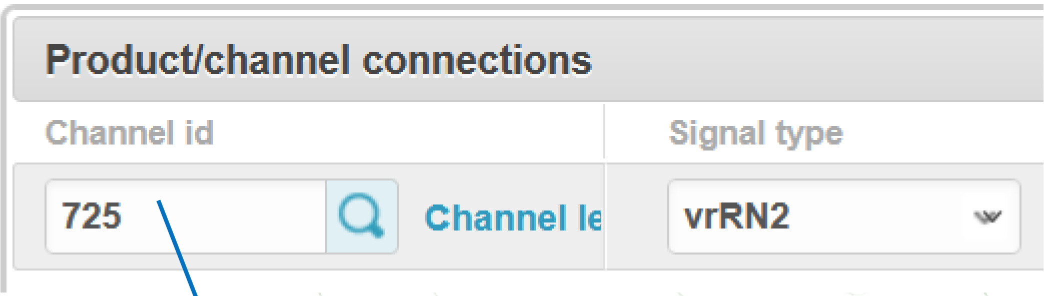
$$\frac{\alpha^{\mathrm{par}}_{\lambda_0}}{\alpha^{\mathrm{par}}_{\lambda_R}} = \left(\frac{\lambda_R}{\lambda_0}\right)^{\mathring{a}}$$

$$\alpha^{\mathrm{par}}_{\lambda_0} = -\frac{\mathrm{d}}{\mathrm{d}z}\ln\frac{\dfrac{\widetilde{P_{\lambda_R}}(z)}{N^{\mathrm{mol}}_{\mathrm{R}}(z)}}{1+\left(\dfrac{\lambda_0}{\lambda_R}\right)^{\mathring{a}}}$$

Ansmann et al., *Opt. Lett.*, 1990
Ansmann et al., *Appl. Phys.B*, 1992
Ansmann et al. *Appl Opt.*, 1992

Parameters of the «extinction only» product

$$\alpha^{\mathrm{par}}_{\lambda_0} = -\frac{\mathrm{d}}{\mathrm{d}z}\ln\frac{\dfrac{\boxed{\widetilde{P_{\lambda_\mathrm{R}}}(z)}}{N^{\mathrm{mol}}_{\mathrm{R}}(z)}}{1+\left(\dfrac{\lambda_0}{\lambda_\mathrm{R}}\right)^{å}}$$

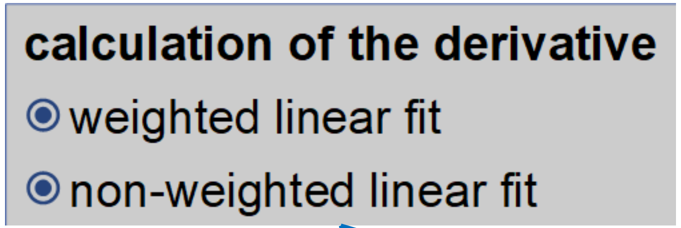


Product/channel connections

Channel id	Signal type
725 Channel le	vrRN2

1 Raman signal of type *vrRN2*

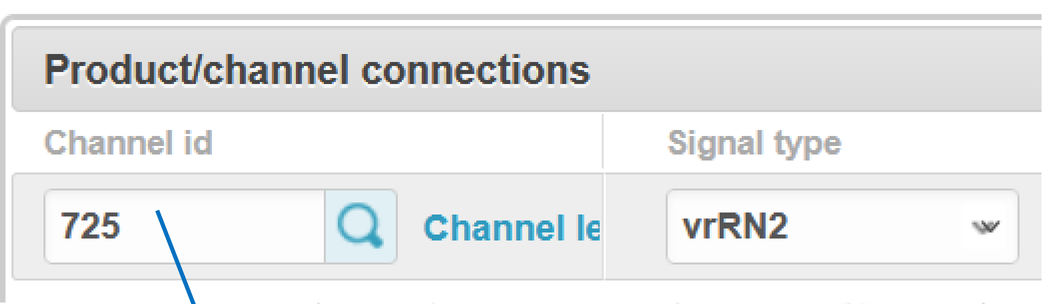
Parameters of the «extinction only» product



calculation of the derivative

- ● weighted linear fit
- ● non-weighted linear fit

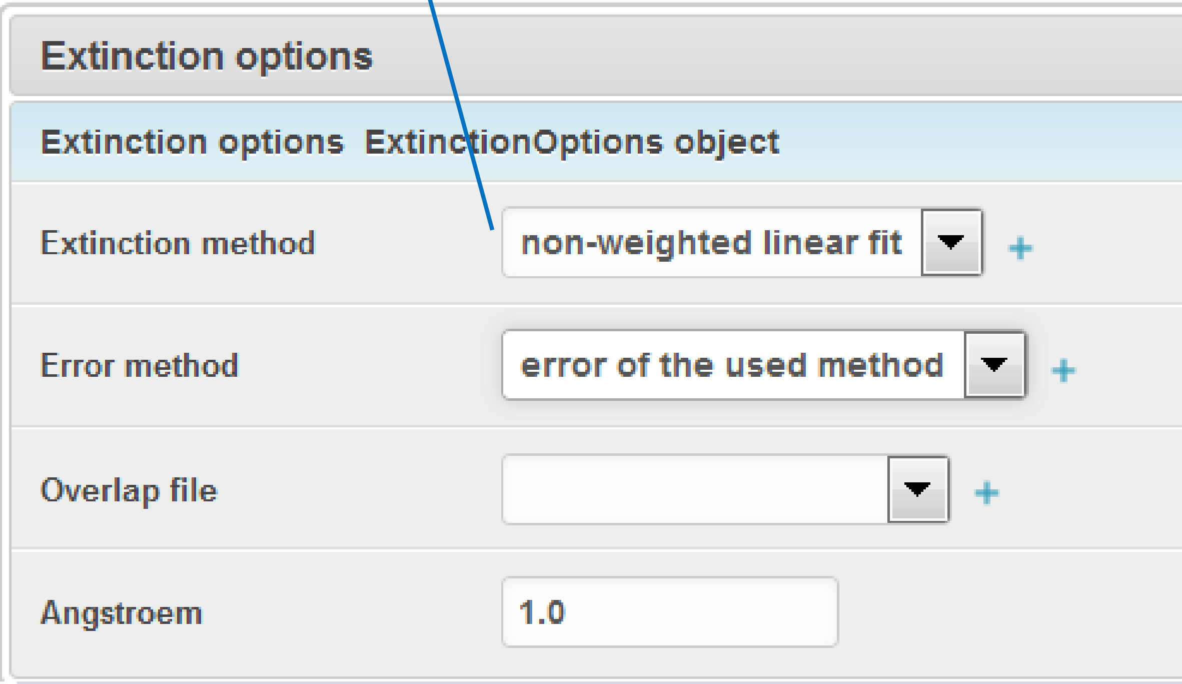
$$\alpha^{\mathrm{par}}_{\lambda_0} = -\boxed{\frac{\mathrm{d}}{\mathrm{d}z}}\ln\frac{\;\frac{\boxed{\widetilde{P_{\lambda_{\mathrm{R}}}(z)}}}{N^{\mathrm{mol}}_{\mathrm{R}}(z)}\;}{1+\left(\frac{\lambda_0}{\lambda_{\mathrm{R}}}\right)^{\mathring{a}}}$$



Product/channel connections

Channel id		Signal type
725	Channel le	vrRN2

1 Raman signal of type *vrRN2*

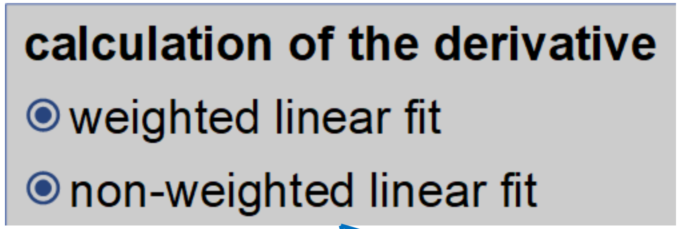


Extinction options

Extinction options ExtinctionOptions object

Extinction method	non-weighted linear fit
Error method	error of the used method
Overlap file	
Angstroem	1.0

Parameters of the «extinction only» product

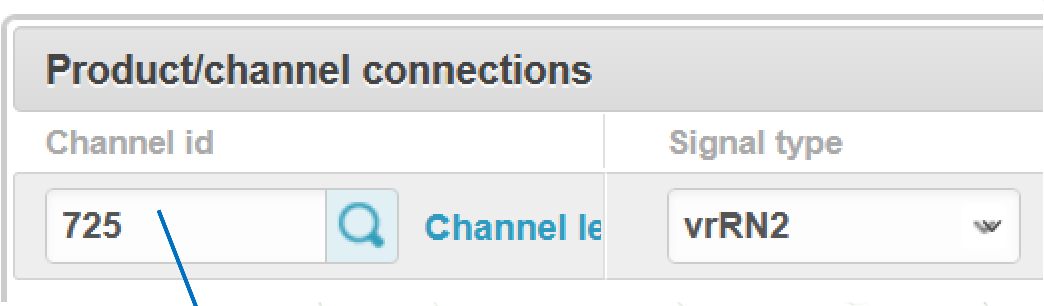


calculation of the derivative

◉ weighted linear fit

◉ non-weighted linear fit

$$\alpha^{\mathrm{par}}_{\lambda_0} = -\boxed{\frac{\mathrm{d}}{\mathrm{d}z}}\ln\frac{\dfrac{\boxed{\widetilde{P_{\lambda_\mathrm{R}}}(z)}}{N^{\mathrm{mol}}_{\mathrm{R}}(z)}}{1+\left(\dfrac{\lambda_0}{\lambda_\mathrm{R}}\right)^{\boxed{å}}}$$



Product/channel connections

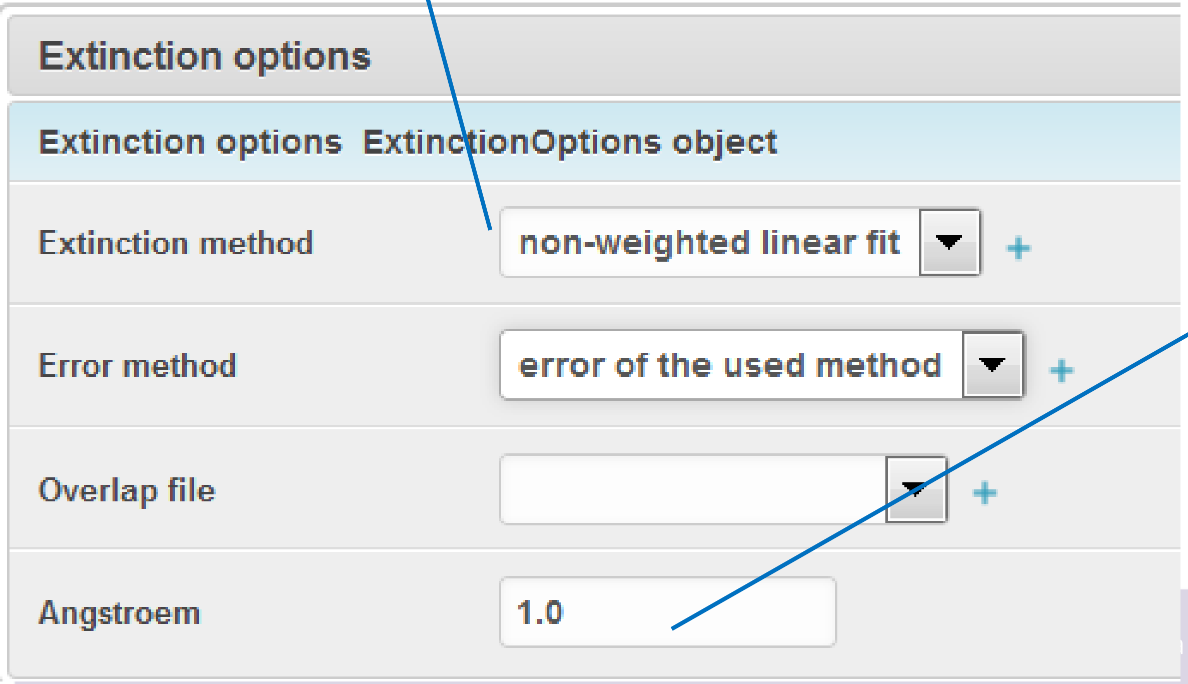
Channel id: 725

Signal type: vrRN2

1 Raman signal of type *vrRN2*

Ångström exponent

- value -1 ... 3
- default = 1



Extinction options

Extinction options ExtinctionOptions object

Extinction method: non-weighted linear fit

Error method: error of the used method

Overlap file:

Angstroem: 1.0

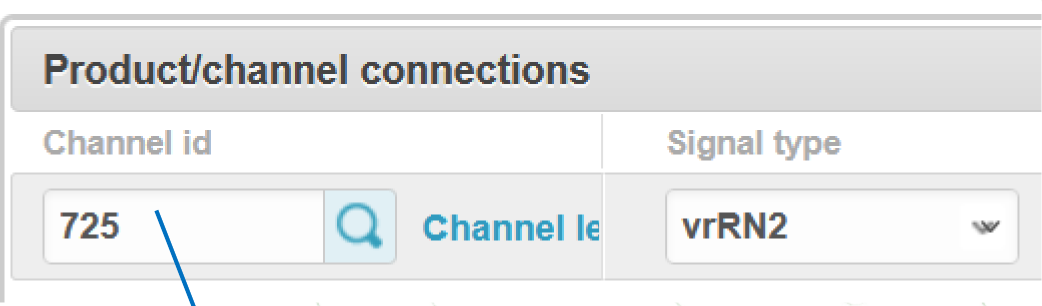
Parameters of the «extinction only» product

calculation of the derivative

● weighted linear fit

● non-weighted linear fit

$$\alpha^{\mathrm{par}}_{\lambda_0} = -\boxed{\frac{\mathrm{d}}{\mathrm{d}z}}\ln\frac{\dfrac{\boxed{\widetilde{P}_{\lambda_\mathrm{R}}(z)}}{N^{\mathrm{mol}}_{\mathrm{R}}(z)}}{1+\left(\dfrac{\lambda_0}{\lambda_\mathrm{R}}\right)^{\boxed{å}}}$$



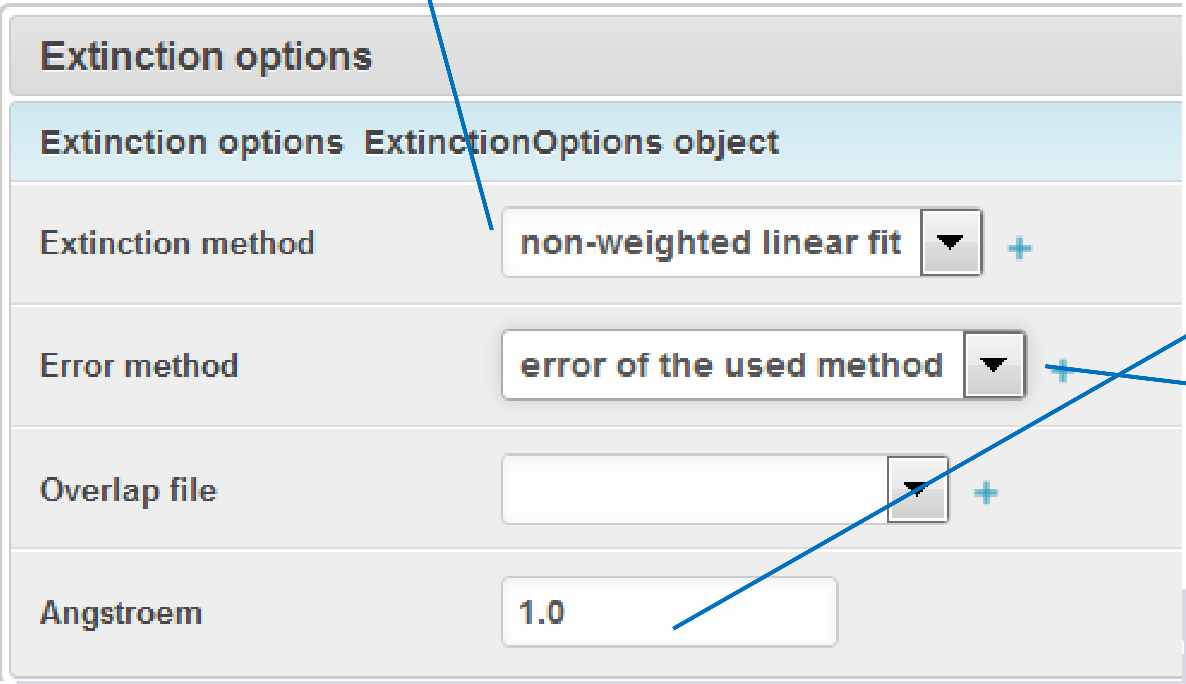
Product/channel connections

Channel id		Signal type
725	Channel le	vrRN2

1 Raman signal of type *vrRN2*

Ångström exponent

- value -1 ... 3
- default = 1



Extinction options

Extinction options ExtinctionOptions object

Extinction method: non-weighted linear fit

Error method: error of the used method

Overlap file:

Angstroem: 1.0

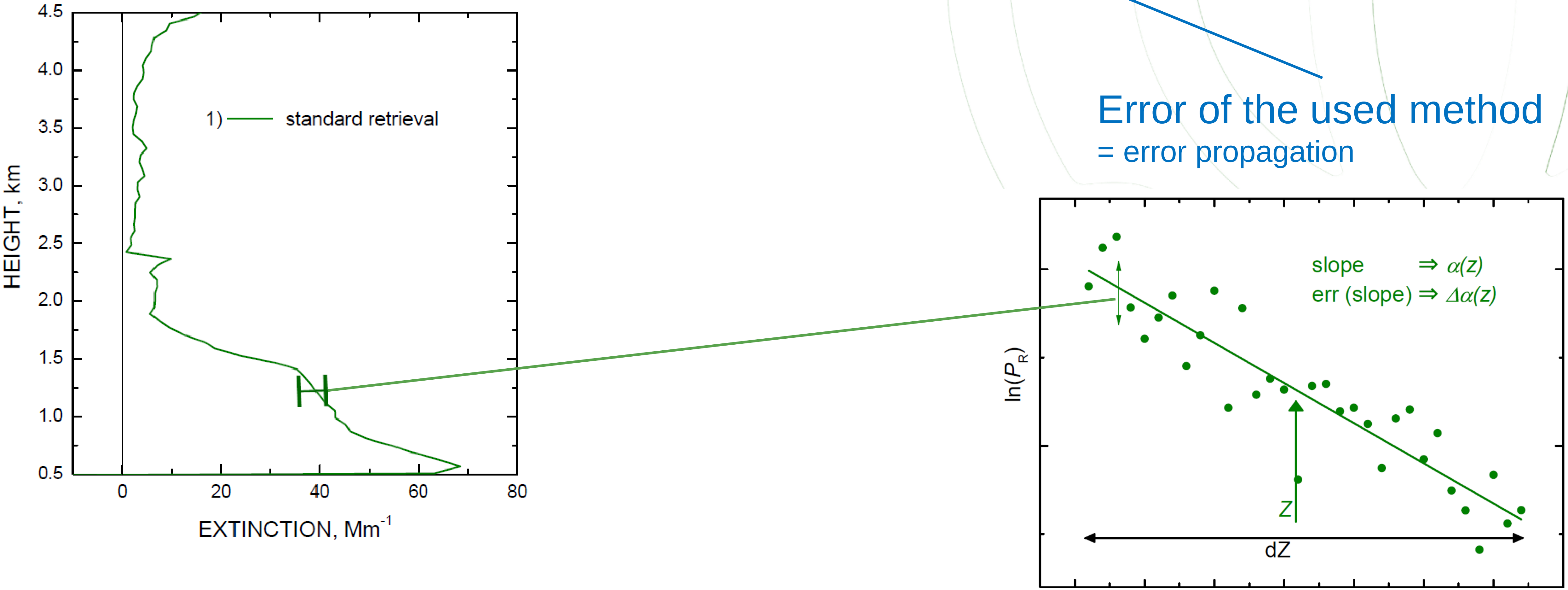
For each product:

Error method

● error of the used method

● Monte Carlo

Error methods

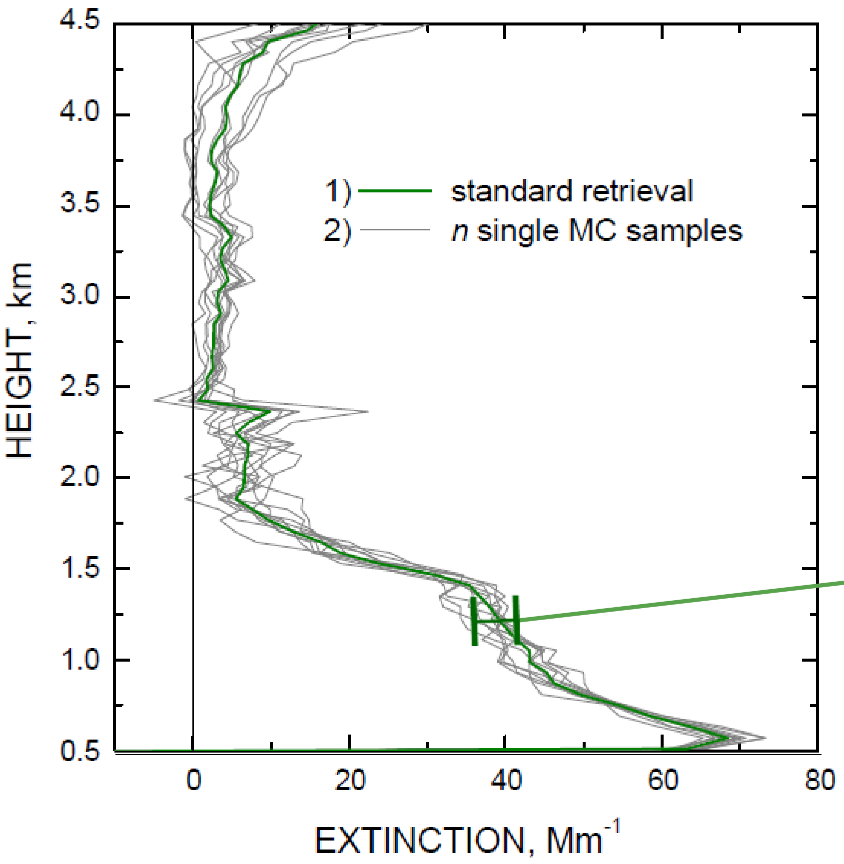


Error of the used method

= error propagation

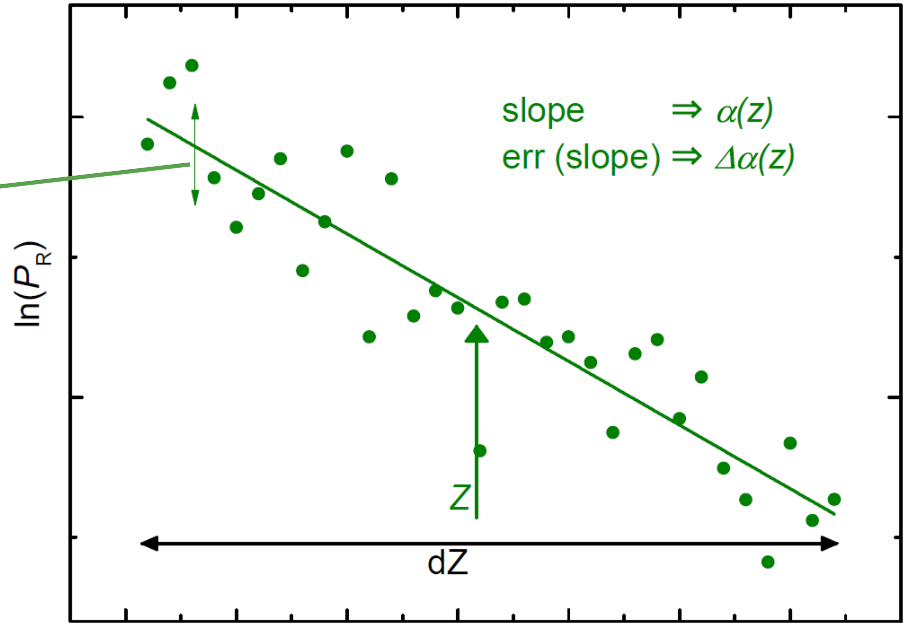
Error methods

Monte-Carlo

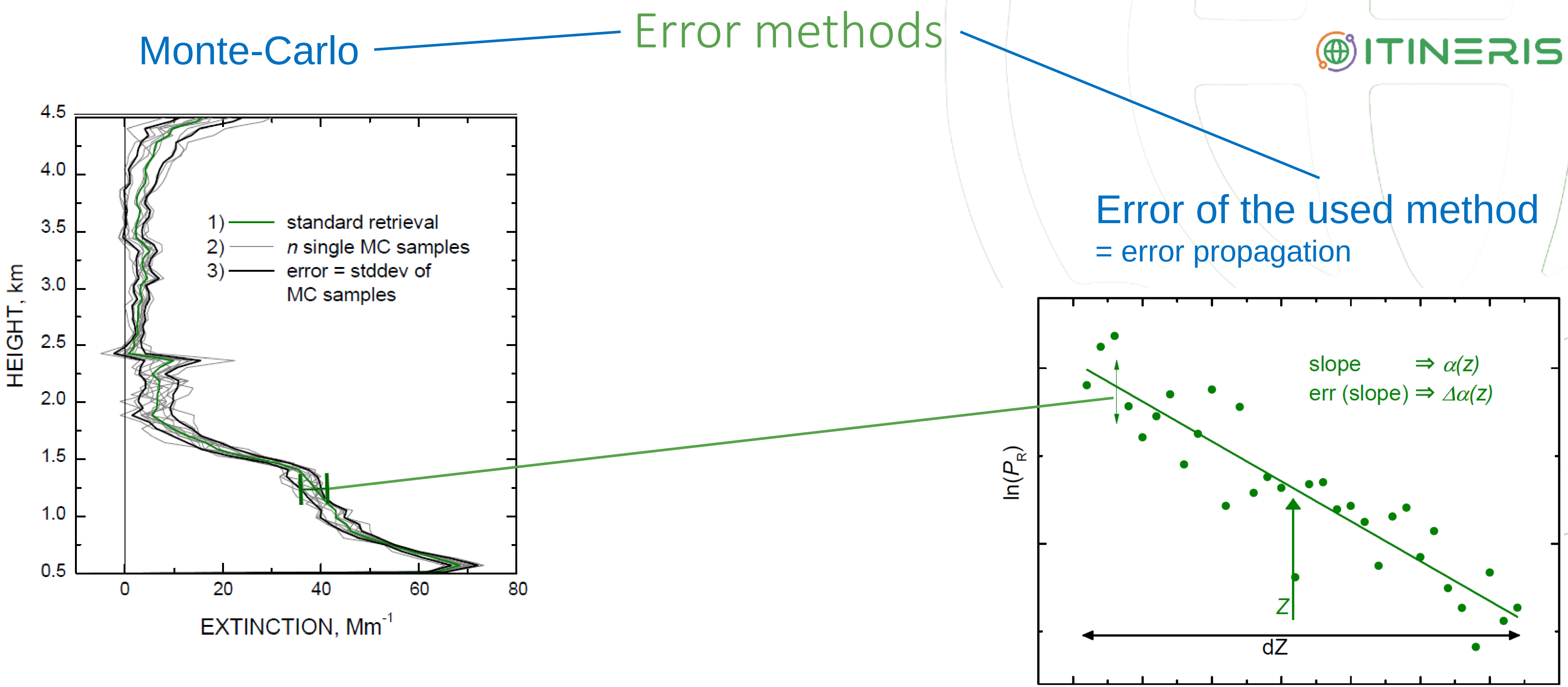


Error of the used method

= error propagation



Error methods



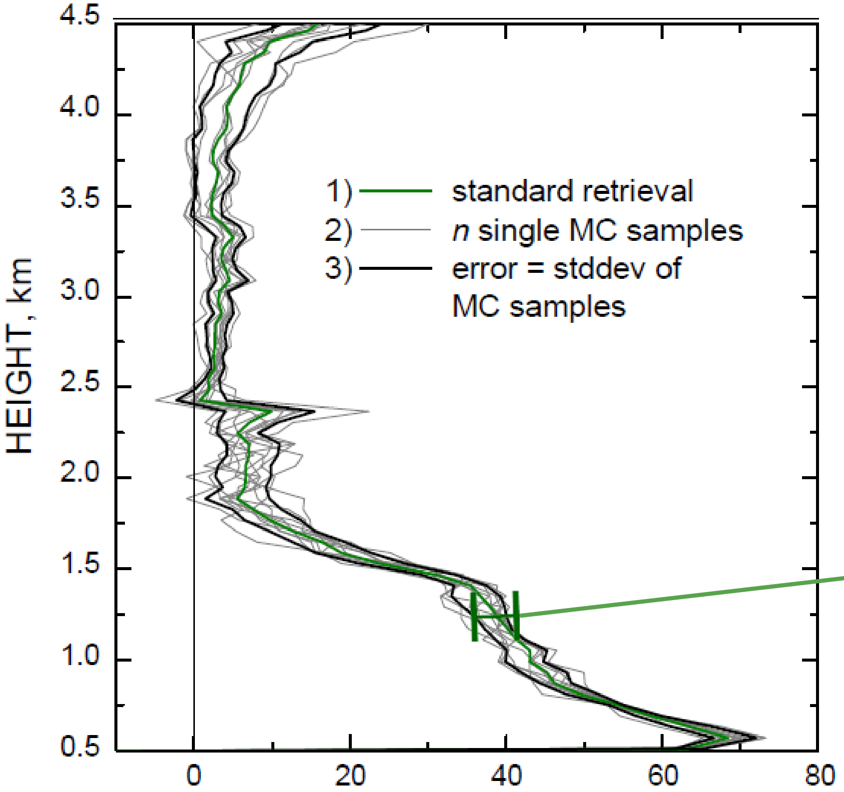
Monte-Carlo

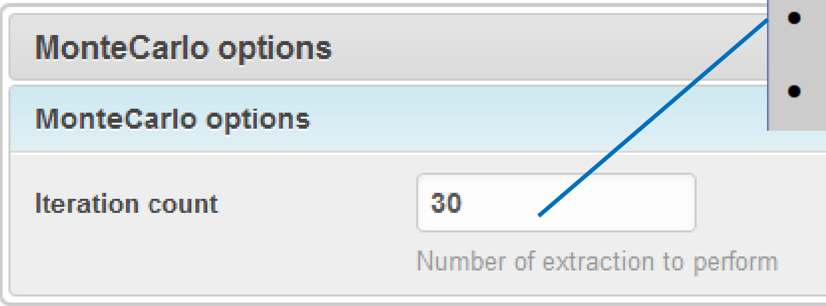
Error of the used method

= error propagation

Error methods

Monte-Carlo





MonteCarlo options

MonteCarlo options

Iteration count: 30

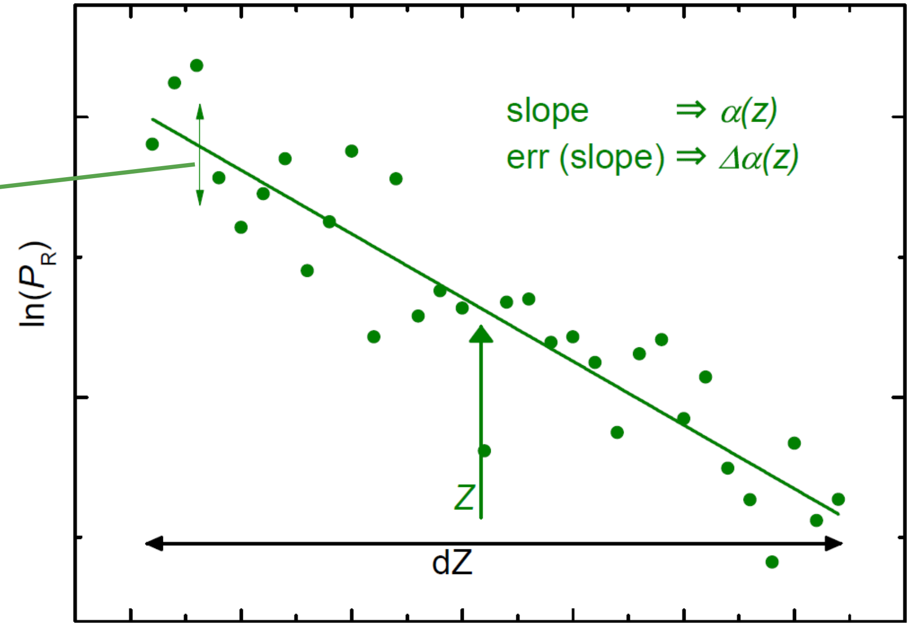
Number of extraction to perform

number of samples

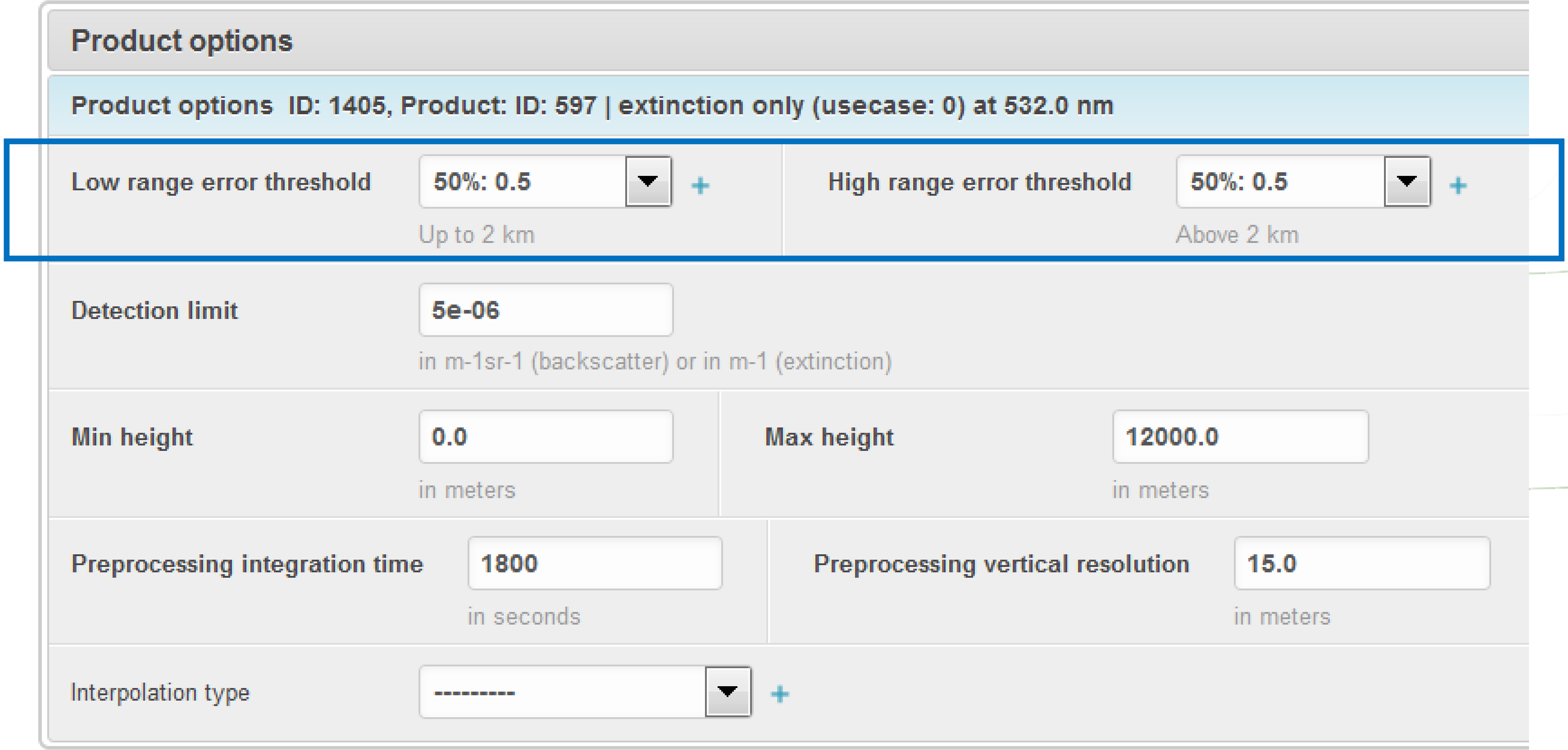
- must be >1
- typical values: 10 ... 30

Error of the used method

= error propagation



General product options: Error thresholds



Product options

Product options ID: 1405, Product: ID: 597 | extinction only (usecase: 0) at 532.0 nm

Low range error threshold: 50%: 0.5
Up to 2 km

High range error threshold: 50%: 0.5
Above 2 km

Detection limit: 5e-06
in m-1sr-1 (backscatter) or in m-1 (extinction)

Min height: 0.0
in meters

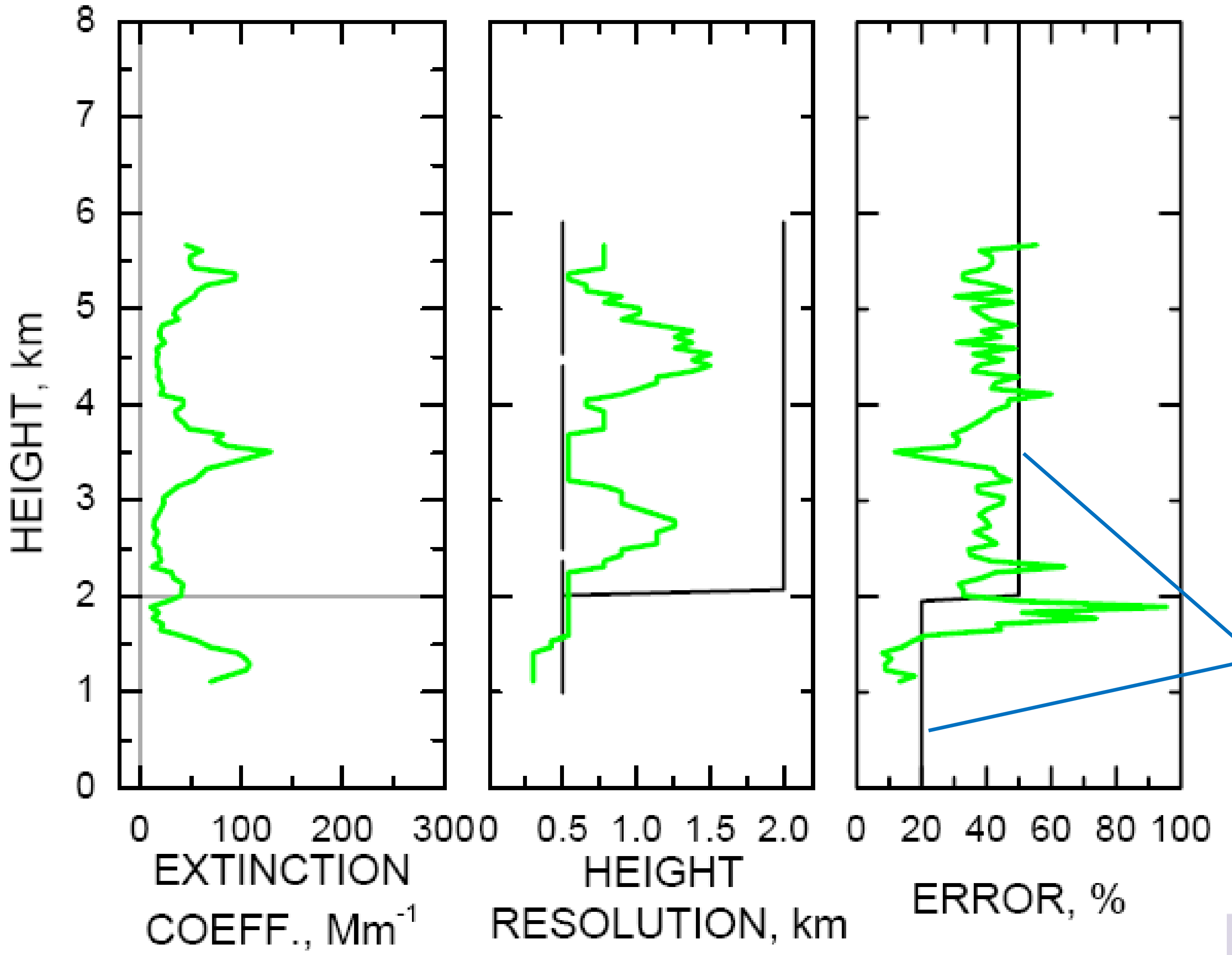
Max height: 12000.0
in meters

Preprocessing integration time: 1800
in seconds

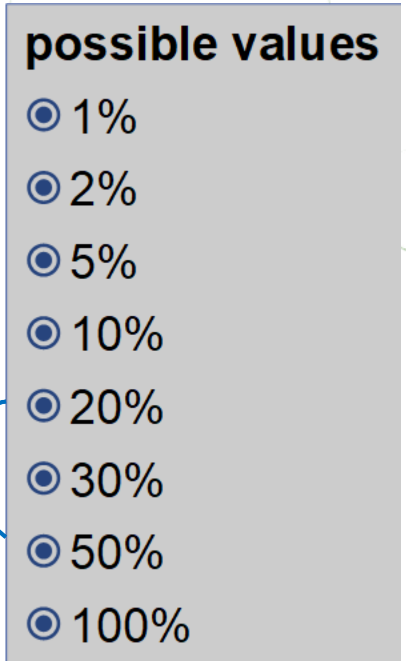
Preprocessing vertical resolution: 15.0
in meters

Interpolation type: ---------

General product options: Error thresholds



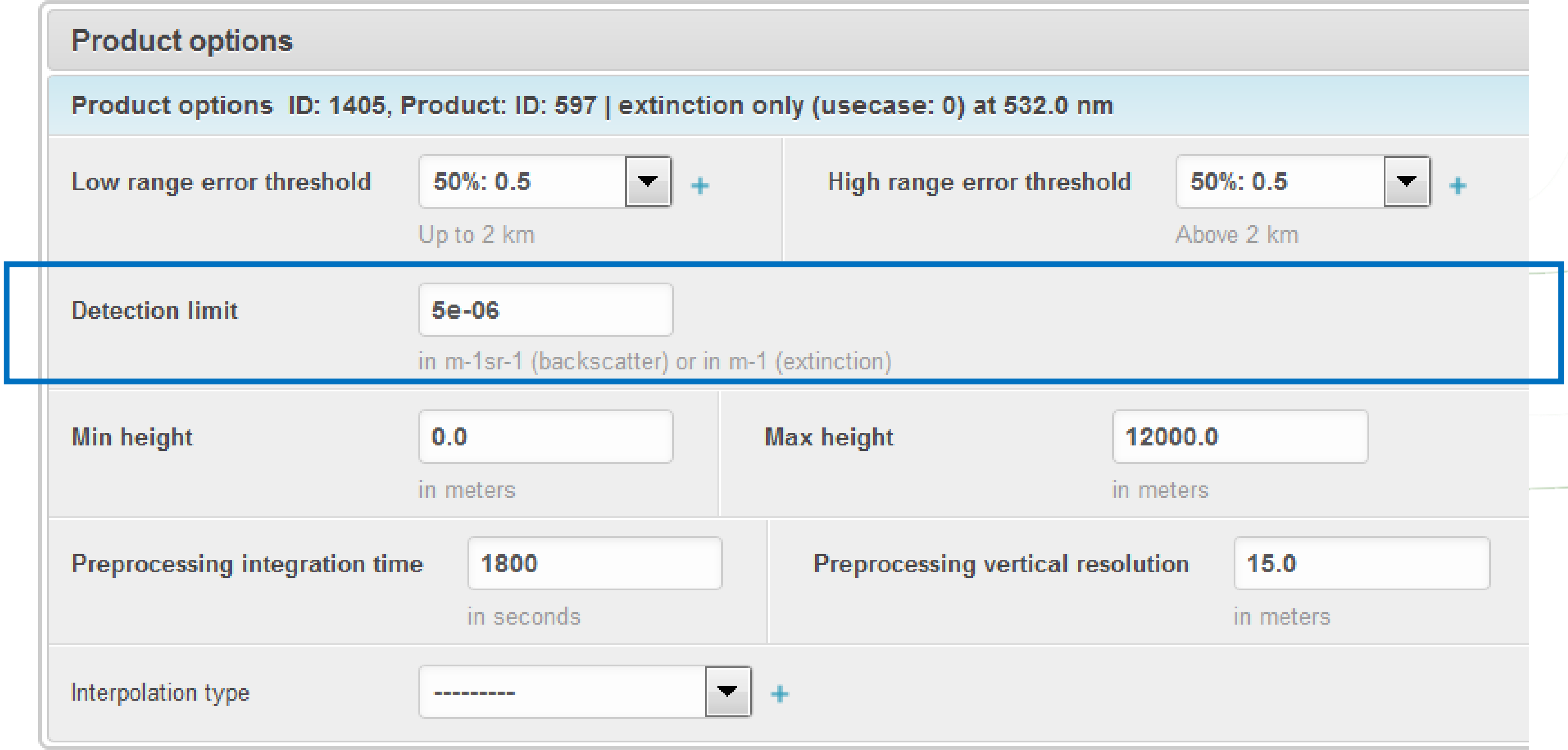
- needed for automated smoothing and averaging
- can be different below and above 2km



possible values

◉ 1%
◉ 2%
◉ 5%
◉ 10%
◉ 20%
◉ 30%
◉ 50%
◉ 100%

General product options: Detection limit



Product options

Product options ID: 1405, Product: ID: 597 | extinction only (usecase: 0) at 532.0 nm

Low range error threshold 50%: 0.5 — Up to 2 km

High range error threshold 50%: 0.5 — Above 2 km

Detection limit 5e-06 — in m-1sr-1 (backscatter) or in m-1 (extinction)

Min height 0.0 — in meters

Max height 12000.0 — in meters

Preprocessing integration time 1800 — in seconds

Preprocessing vertical resolution 15.0 — in meters

Interpolation type ----------

General product options: Detection limit

- needed for automated smoothing and averaging
- used for quality control in case of very small data values
- example: error threshold = 10%, detection limit = 5 Mm^{-1}

General product options: Detection limit

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- example: error threshold = 10%, detection limit = 5 Mm^{-1}
    - $\alpha = 50\ \mathrm{Mm}^{-1} \pm 3\ \mathrm{Mm}^{-1} \rightarrow \boxed{\Delta\alpha = 6\% < 10\%,}$ $\boxed{\Delta\alpha < 5\ \mathrm{Mm}^{-1}}$ ✓

General product options: Detection limit

- needed for automated smoothing and averaging
- used for quality control in case of very small data values
- example: error threshold = 10%, detection limit = $5\ \mathrm{Mm}^{-1}$
  - $\alpha = 50\ \mathrm{Mm}^{-1} \pm 3\ \mathrm{Mm}^{-1} \rightarrow \boxed{\Delta\alpha = 6\% < 10\%,}$ $\boxed{\Delta\alpha < 5\ \mathrm{Mm}^{-1}}$ ✓
  - $\alpha = 50\ \mathrm{Mm}^{-1} \pm 6\ \mathrm{Mm}^{-1} \rightarrow \boxed{\Delta\alpha = 12\% > 10\%,}$ $\boxed{\Delta\alpha > 5\ \mathrm{Mm}^{-1}}$ ✗

General product options: Detection limit

- needed for automated smoothing and averaging
- used for quality control in case of very small data values
- example: error threshold = 10%, detection limit = 5 Mm^{-1}
  - $\alpha = 50\ \mathrm{Mm}^{-1} \pm 3\ \mathrm{Mm}^{-1} \rightarrow \Delta\alpha = 6\% < 10\%$, $\Delta\alpha < 5\ \mathrm{Mm}^{-1}$ ✓
  - $\alpha = 50\ \mathrm{Mm}^{-1} \pm 6\ \mathrm{Mm}^{-1} \rightarrow \Delta\alpha = 12\% > 10\%$, $\Delta\alpha > 5\ \mathrm{Mm}^{-1}$ ✗
  - $\alpha = 10\ \mathrm{Mm}^{-1} \pm 3\ \mathrm{Mm}^{-1} \rightarrow \Delta\alpha = 30\% > 10\%$, $\Delta\alpha < 5\ \mathrm{Mm}^{-1}$ ✓

General product options: Detection limit

- needed for automated smoothing and averaging
- used for quality control in case of very small data values
- example: error threshold = 10%, detection limit = $5\ \mathrm{Mm}^{-1}$
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  - $\alpha = 50\ \mathrm{Mm}^{-1} \pm 6\ \mathrm{Mm}^{-1} \rightarrow \Delta\alpha = 12\% > 10\%,\quad \Delta\alpha > 5\ \mathrm{Mm}^{-1}$ ✗
  - $\alpha = 10\ \mathrm{Mm}^{-1} \pm 3\ \mathrm{Mm}^{-1} \rightarrow \Delta\alpha = 30\% > 10\%,\quad \Delta\alpha < 5\ \mathrm{Mm}^{-1}$ ✓
  - $\alpha = 10\ \mathrm{Mm}^{-1} \pm 6\ \mathrm{Mm}^{-1} \rightarrow \Delta\alpha = 60\% > 10\%,\quad \Delta\alpha > 5\ \mathrm{Mm}^{-1}$ ✗

General product options: Detection limit

- needed for automated smoothing and averaging
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- example: error threshold = 10%, detection limit = 5 Mm^{-1}
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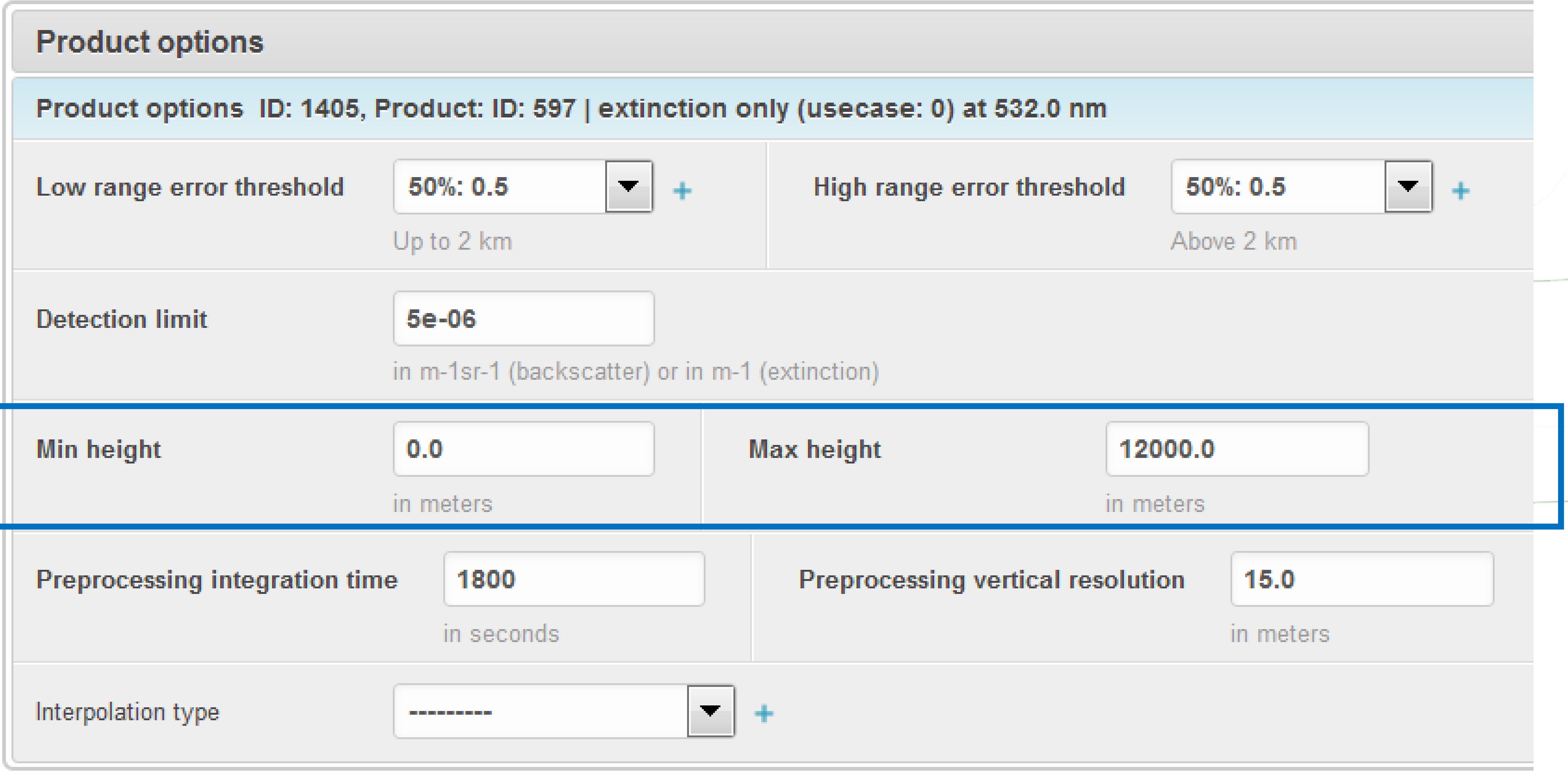
  - $\alpha = 10\ \mathrm{Mm}^{-1} \pm 3\ \mathrm{Mm}^{-1} \rightarrow \Delta\alpha = 30\% > 10\%,$ $\Delta\alpha < 5\ \mathrm{Mm}^{-1}$ ✓
  - $\alpha = 10\ \mathrm{Mm}^{-1} \pm 6\ \mathrm{Mm}^{-1} \rightarrow \Delta\alpha = 60\% > 10\%,$ $\Delta\alpha > 5\ \mathrm{Mm}^{-1}$ ✗
- typical values:
  - extinction: 5 Mm^{-1}
  - lidar ratio and extinction: 5 Mm^{-1}
  - backscatter: 0.1 $\mathrm{Mm}^{-1}\mathrm{sr}^{-1}$
  - backscatter + depolarization: 0.1 $\mathrm{Mm}^{-1}\mathrm{sr}^{-1}$

General product options: valid altitude range



Product options

Product options ID: 1405, Product: ID: 597 | extinction only (usecase: 0) at 532.0 nm

Low range error threshold 50%: 0.5 (Up to 2 km)

High range error threshold 50%: 0.5 (Above 2 km)

Detection limit 5e-06 (in m-1sr-1 (backscatter) or in m-1 (extinction))

Min height 0.0 (in meters)

Max height 12000.0 (in meters)

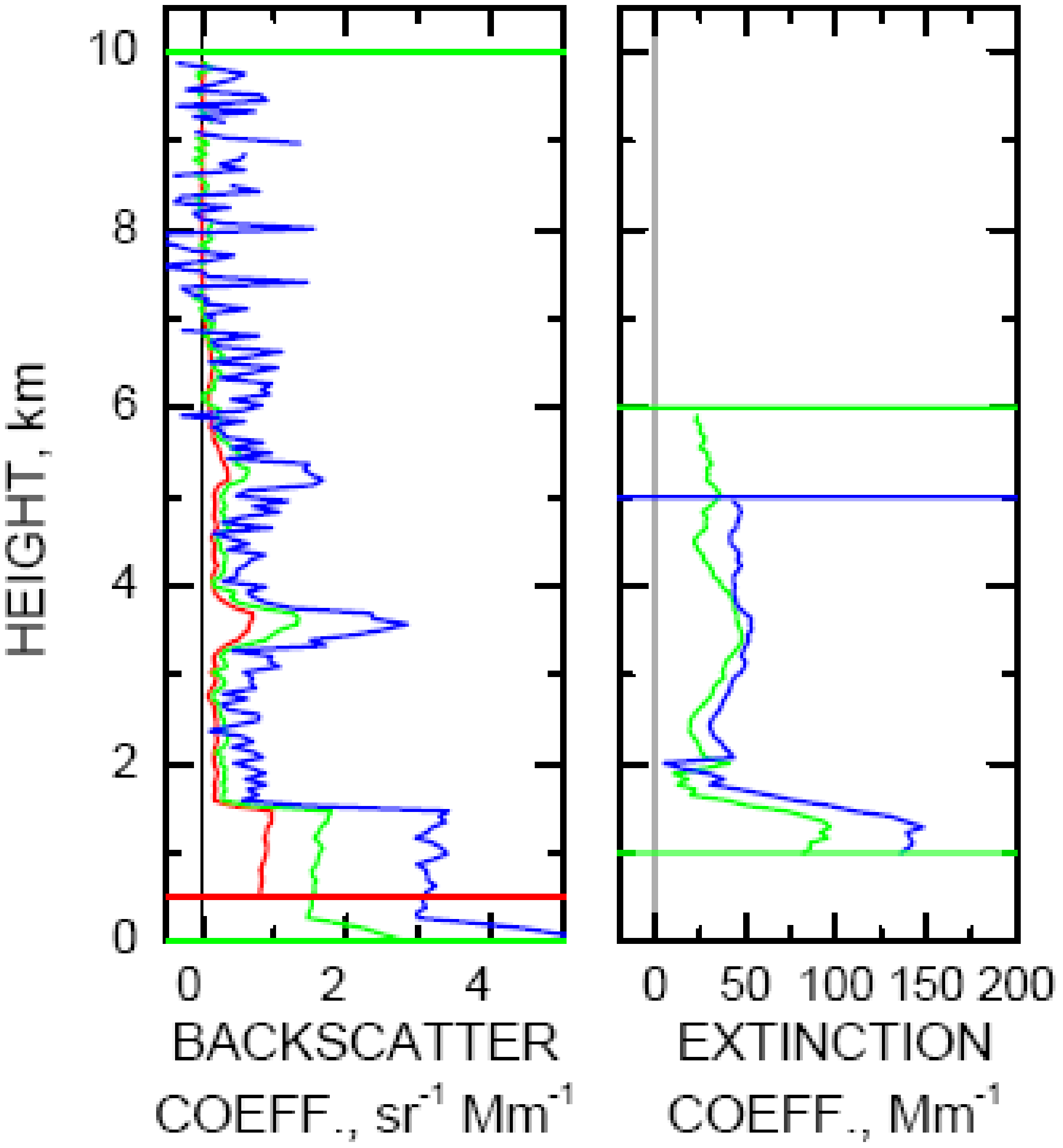
Preprocessing integration time 1800 (in seconds)

Preprocessing vertical resolution 15.0 (in meters)

Interpolation type ----------

General product options: valid altitude range

- Can be / should be different for different products
- You provide the limits of your hardware
- ELDA then determines the actual limits (depending on current weather situation)



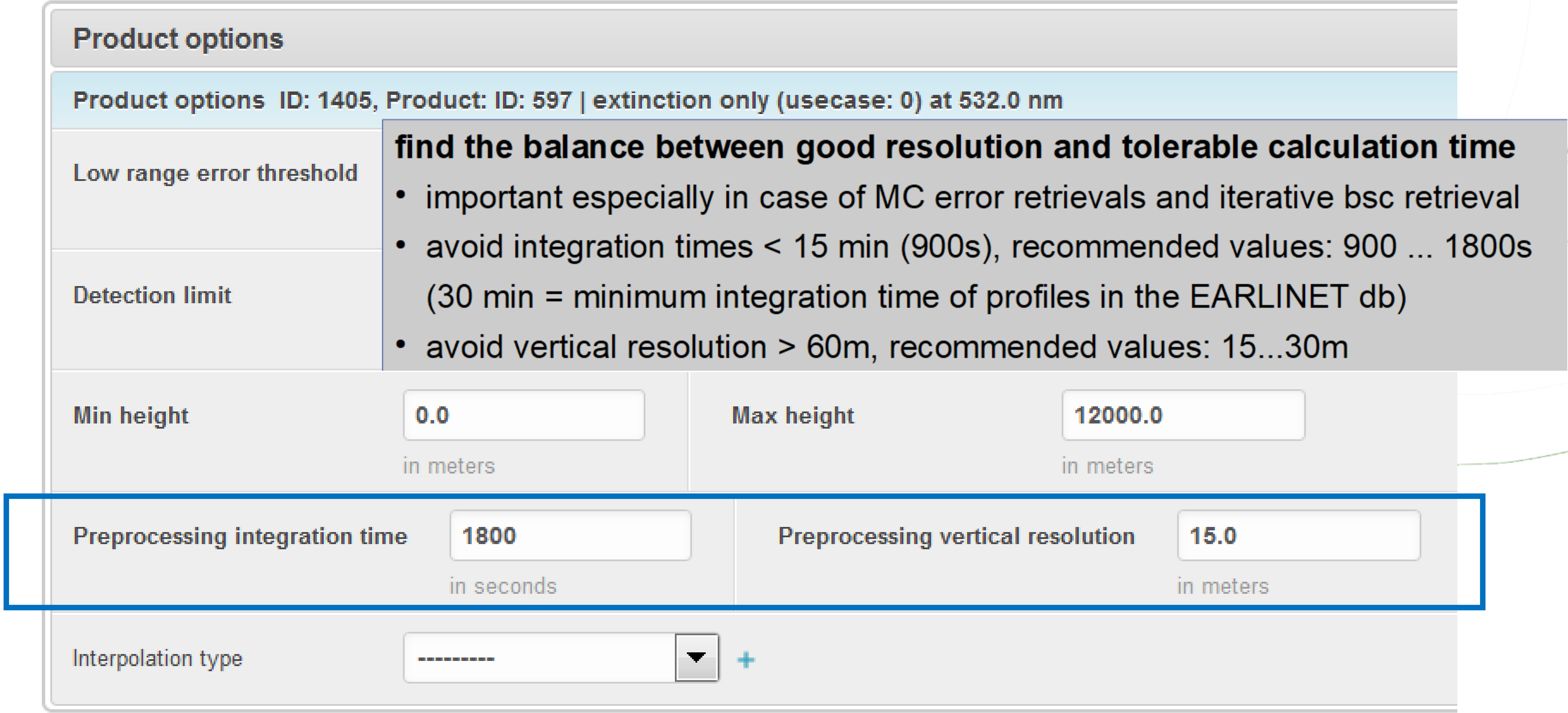
Zmax

- Determined by signal artifacts (from ATLAS) or snr in optimum conditions
- Must include calibration interval of bsc products

Zmin

- Ext: $z_{min} \approx z_{ovl}$ + smooth length
- Elast bsc: $z_{min} \approx z_{ovl}$
- Raman bsc: $z_{min} \approx$ where $ovl(P_0) = ovl(P_R)$

General product options: preprocessing resolution



Product options

Product options ID: 1405, Product: ID: 597 | extinction only (usecase: 0) at 532.0 nm

Low range error threshold

Detection limit

Min height: 0.0 (in meters)

Max height: 12000.0 (in meters)

Preprocessing integration time: 1800 (in seconds)

Preprocessing vertical resolution: 15.0 (in meters)

Interpolation type: ---------- ▼ +

find the balance between good resolution and tolerable calculation time

- important especially in case of MC error retrievals and iterative bsc retrieval
- avoid integration times < 15 min (900s), recommended values: 900 ... 1800s (30 min = minimum integration time of profiles in the EARLINET db)
- avoid vertical resolution > 60m, recommended values: 15...30m

- The «Raman backscatter» product
- usecases
- Backscatter calibration options

Retrieval of «Raman backscatter» product (via backscatter ratio)

ITINERIS

Ferrare et al.,
J. Geophys. Res., 1998

$$R_{\beta}(z) = \frac{\left[\beta^{\mathrm{par}}(z) + \beta^{\mathrm{mol}}(z)\right]}{\beta^{\mathrm{mol}}(z)}$$

$$\beta^{\mathrm{par}}(z) = \beta^{\mathrm{mol}}_{\lambda_0}(z)\left(R_{\beta}(z) - 1\right)$$

$$R_{\beta}(z) = F^{\beta}\,\frac{\widehat{P_{\lambda_0}}(z)}{\widehat{P_{\lambda_{\mathrm{R}}}}(z)}\,\frac{O_{\lambda_{\mathrm{R}}}(z)}{O_{\lambda_0}(z)}\,\exp\left[\left(1 - \left(\frac{\lambda_0}{\lambda_{\mathrm{R}}}\right)^{å}\right)\int_0^z \alpha^{\mathrm{par}}_{\lambda_0}(\zeta)\mathrm{d}\zeta\right]$$

Retrieval of «Raman backscatter» product (via backscatter ratio)

Ferrare et al.,
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$$\beta^{\mathrm{par}}(z) = \beta^{\mathrm{mol}}_{\lambda_0}(z)\,(R_\beta(z) - 1)$$

$$R_\beta(z) = F^\beta \frac{\widehat{P_{\lambda_0}}(z)}{\widehat{P_{\lambda_R}}(z)} \cancel{\frac{O_{\lambda_R}(z)}{O_{\lambda_0}(z)}} \boxed{\exp\left[\left(1 - \left(\frac{\lambda_0}{\lambda_R}\right)^{\mathring{a}}\right) \int_0^z \alpha^{\mathrm{par}}_{\lambda_0}(\zeta)\mathrm{d}\zeta\right]}$$

calibration factor

signal ratio

differential overlap

$$O_{\lambda_R}(z) \cong O_{\lambda_0}(z)$$

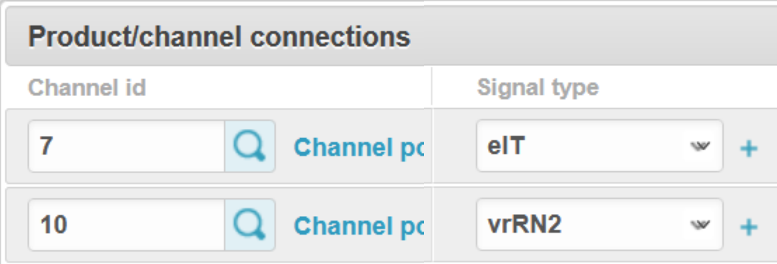
differential atmospheric transmission

≤ 7 %

Parameters of «Raman backscatter» product

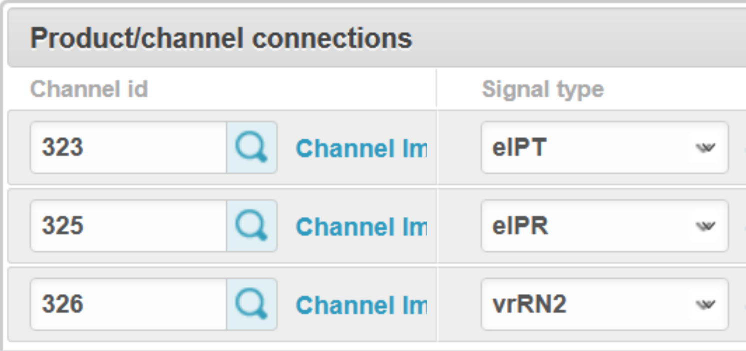
$$R_\beta(z) = F^\beta \boxed{\frac{\widehat{P_{\lambda_0}(z)}}{\widehat{P_{\lambda_\mathrm{R}}(z)}}} \frac{O_{\lambda_\mathrm{R}}(z)}{O_{\lambda_0}(z)} \exp\left[\left(1-\left(\frac{\lambda_0}{\lambda_\mathrm{R}}\right)^{å}\right)\int_0^z \alpha_{\lambda_0}^{\mathrm{par}}(\zeta)\mathrm{d}\zeta\right]$$

- 2 elastic signals of types *elPT* + *elPR* *or* 1 elastic signal of type *elT*
- 1 Raman signal of type *vrRN2*



Product/channel connections

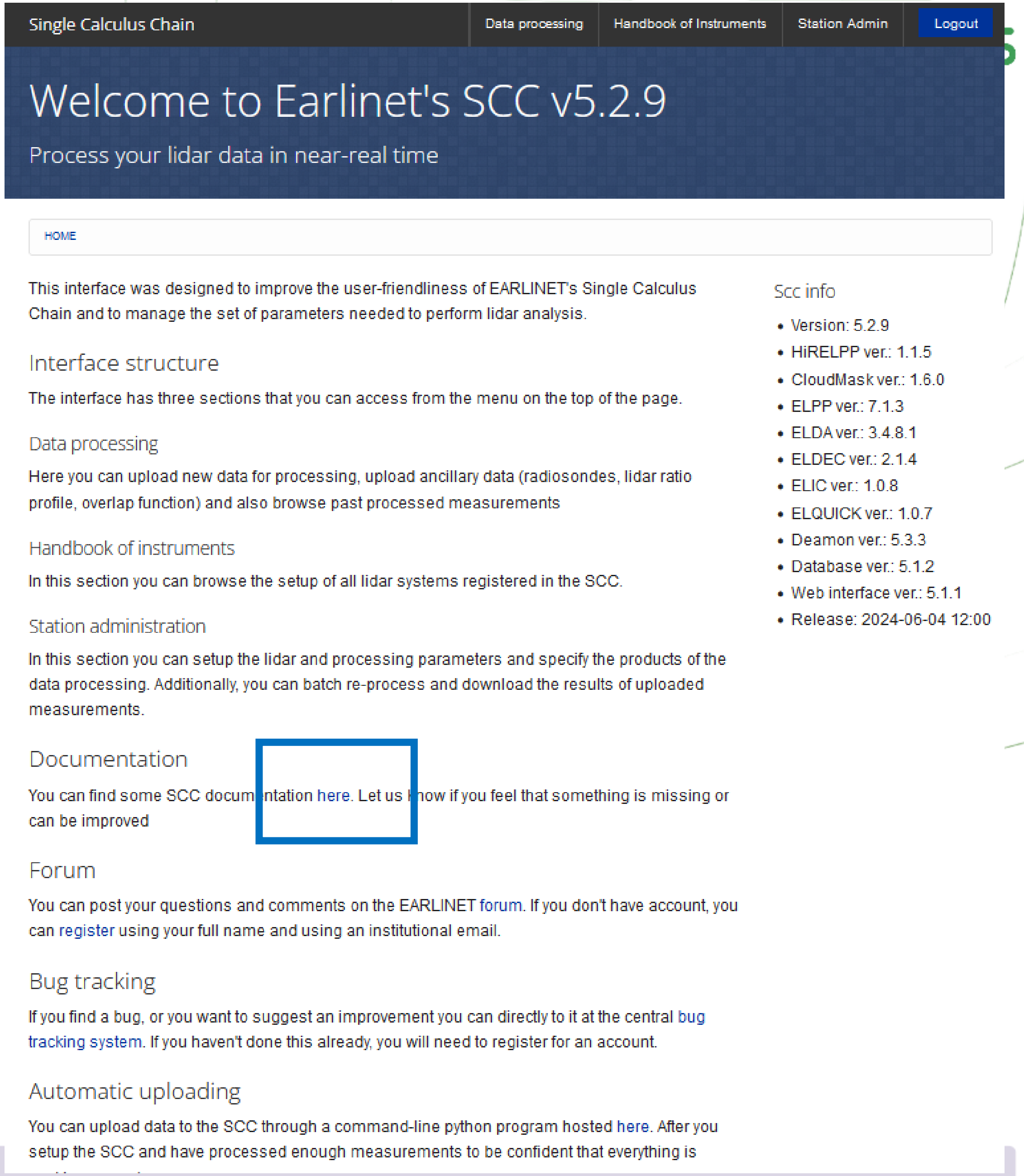
Channel id		Signal type
7	Channel pc	elT
10	Channel pc	vrRN2



Product/channel connections

Channel id		Signal type
323	Channel Im	elPT
325	Channel Im	elPR
326	Channel Im	vrRN2

usecases



Welcome to Earlinet's SCC v5.2.9

Process your lidar data in near-real time

This interface was designed to improve the user-friendliness of EARLINET's Single Calculus Chain and to manage the set of parameters needed to perform lidar analysis.

Interface structure

The interface has three sections that you can access from the menu on the top of the page.

Data processing

Here you can upload new data for processing, upload ancillary data (radiosondes, lidar ratio profile, overlap function) and also browse past processed measurements

Handbook of instruments

In this section you can browse the setup of all lidar systems registered in the SCC.

Station administration

In this section you can setup the lidar and processing parameters and specify the products of the data processing. Additionally, you can batch re-process and download the results of uploaded measurements.

Documentation

You can find some SCC docum ntation here. Let us now if you feel that something is missing or can be improved

Forum

You can post your questions and comments on the EARLINET forum. If you don't have account, you can register using your full name and using an institutional email.

Bug tracking

If you find a bug, or you want to suggest an improvement you can directly to it at the central bug tracking system. If you haven't done this already, you will need to register for an account.

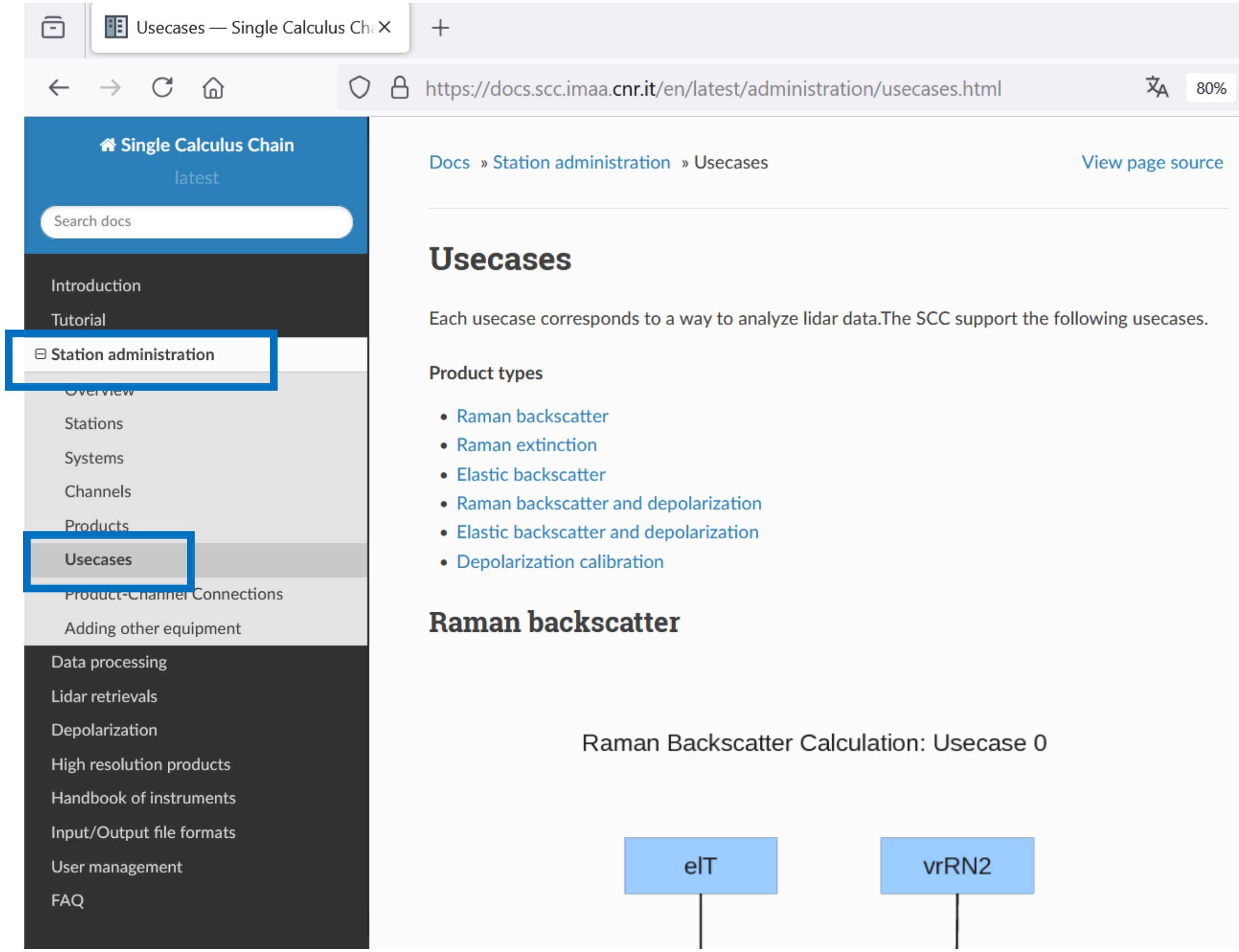
Automatic uploading

You can upload data to the SCC through a command-line python program hosted here. After you setup the SCC and have processed enough measurements to be confident that everything is

Scc info

- Version: 5.2.9
- HiRELPP ver.: 1.1.5
- CloudMask ver.: 1.6.0
- ELPP ver.: 7.1.3
- ELDA ver.: 3.4.8.1
- ELDEC ver.: 2.1.4
- ELIC ver.: 1.0.8
- ELQUICK ver.: 1.0.7
- Deamon ver.: 5.3.3
- Database ver.: 5.1.2
- Web interface ver.: 5.1.1
- Release: 2024-06-04 12:00

usecases



Usecases

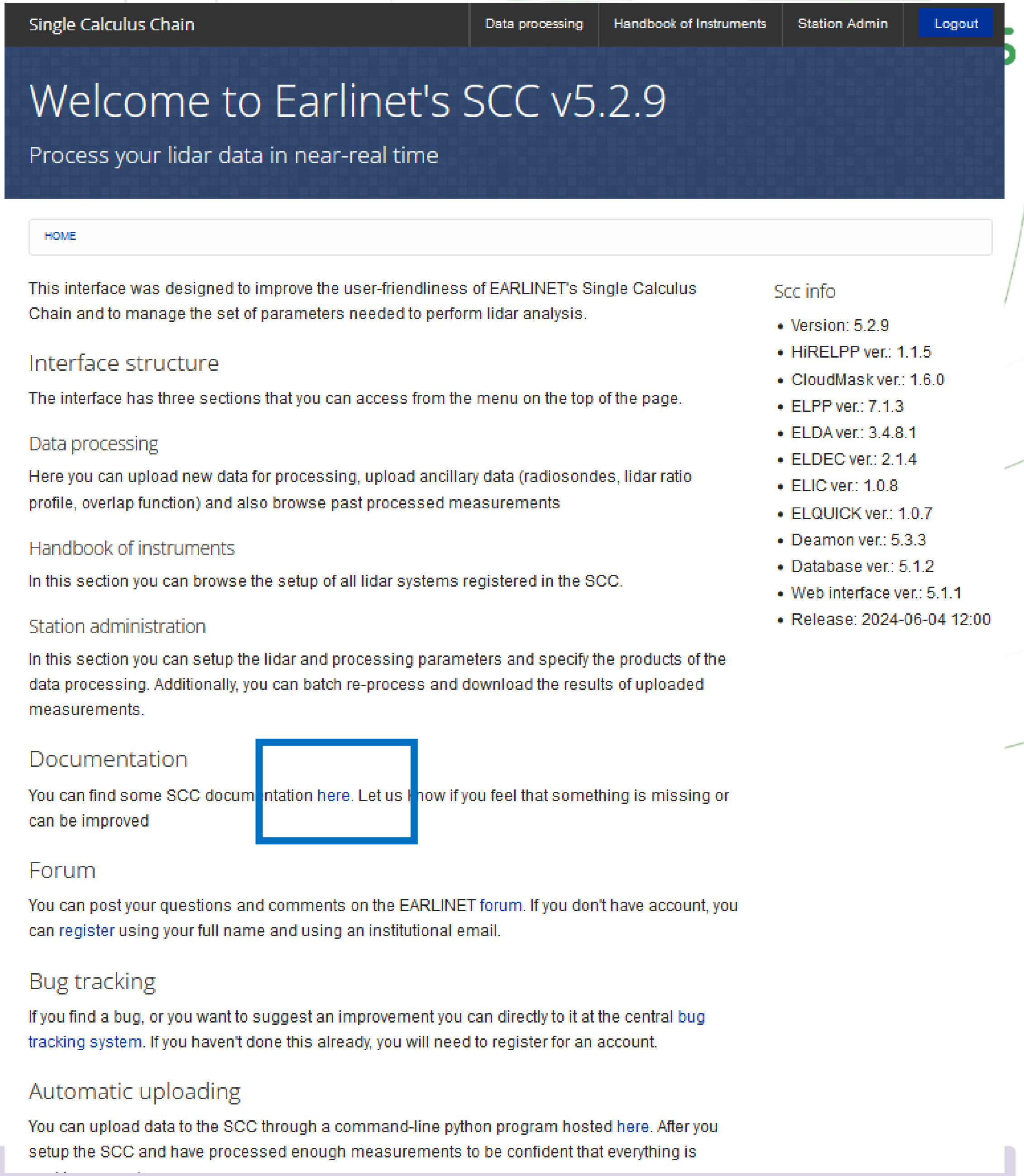
Each usecase corresponds to a way to analyze lidar data.The SCC support the following usecases.

Product types

- Raman backscatter
- Raman extinction
- Elastic backscatter
- Raman backscatter and depolarization
- Elastic backscatter and depolarization
- Depolarization calibration

Raman backscatter

Raman Backscatter Calculation: Usecase 0



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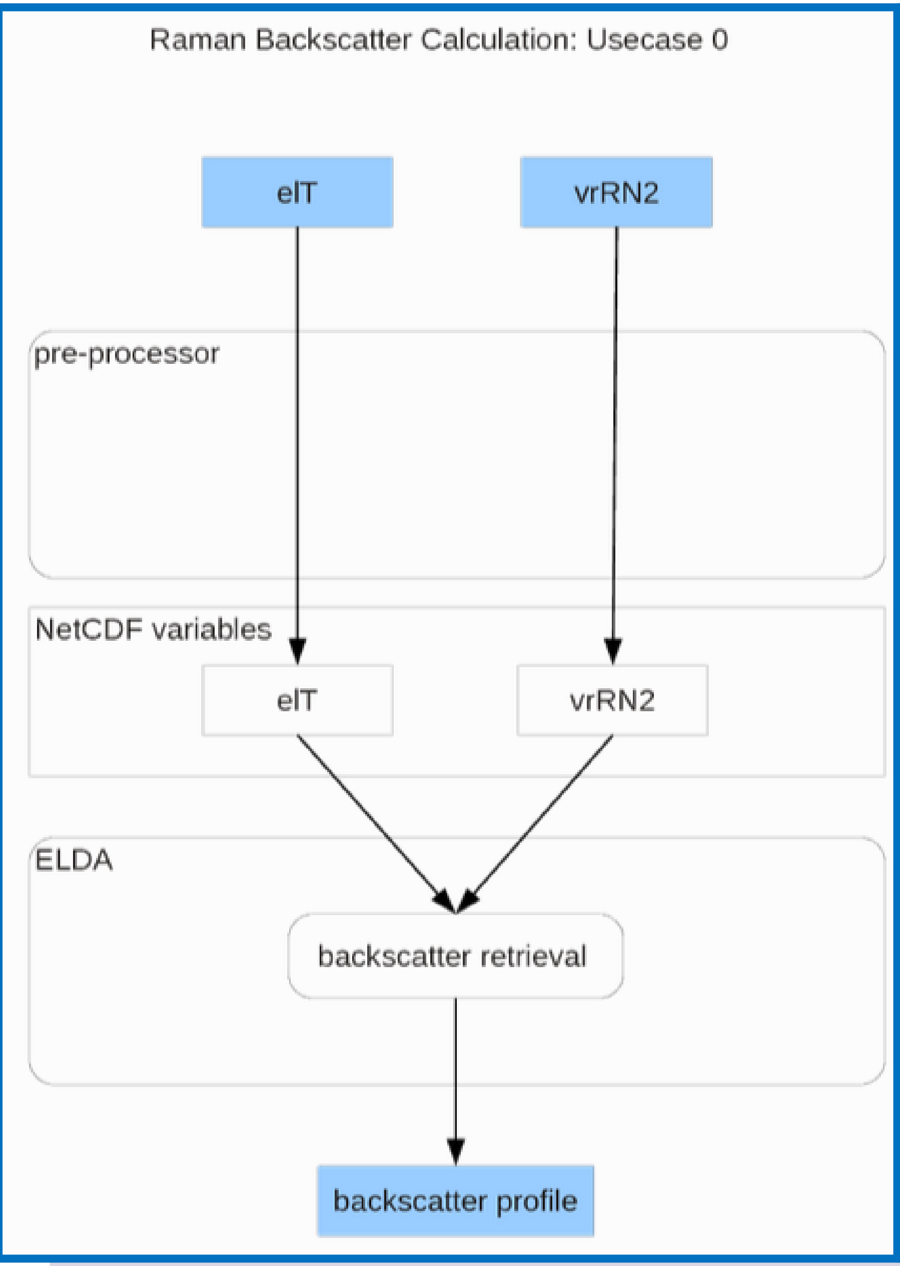
usecases



Raman Backscatter Calculation: Usecase 0

elT

vrRN2

pre-processor

NetCDF variables

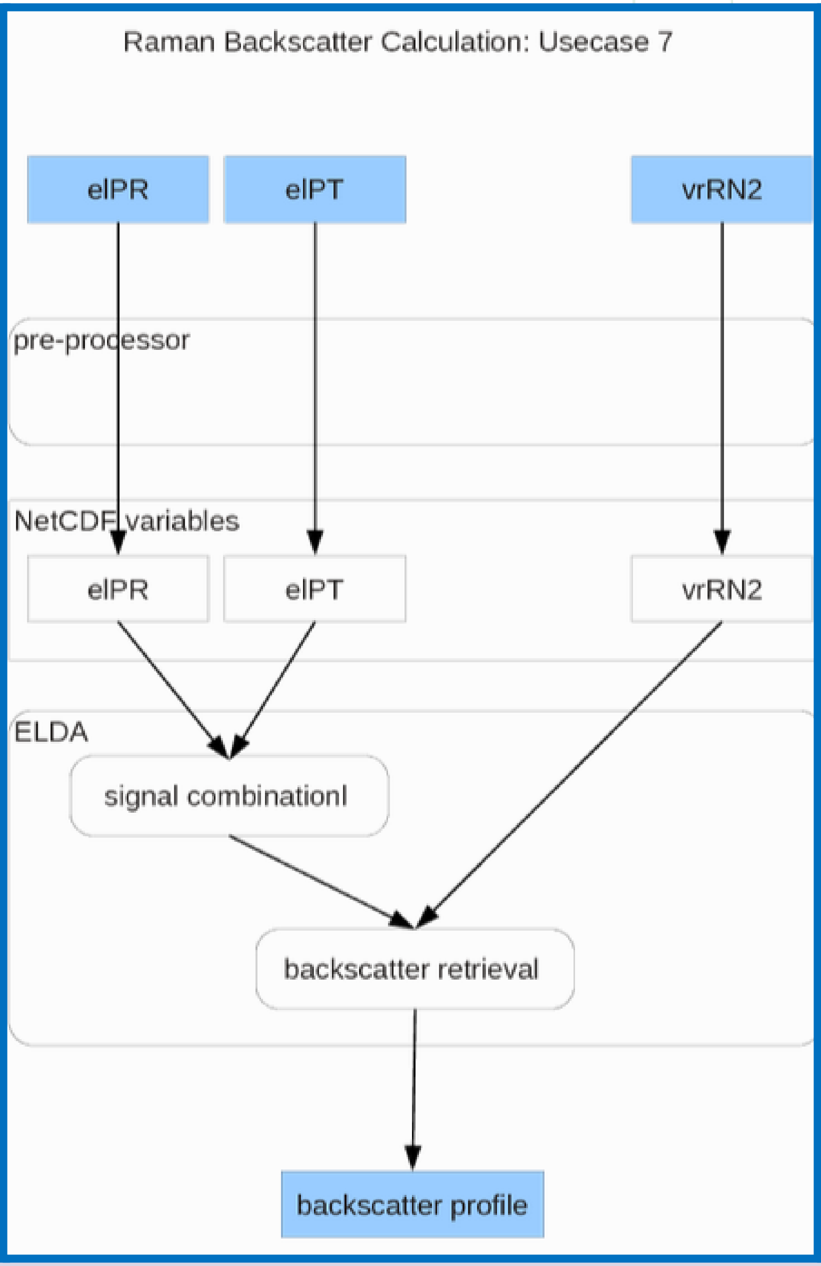
elT

vrRN2

ELDA

backscatter retrieval

backscatter profile



Raman Backscatter Calculation: Usecase 7

elPR

elPT

vrRN2

pre-processor

NetCDF variables

elPR

elPT

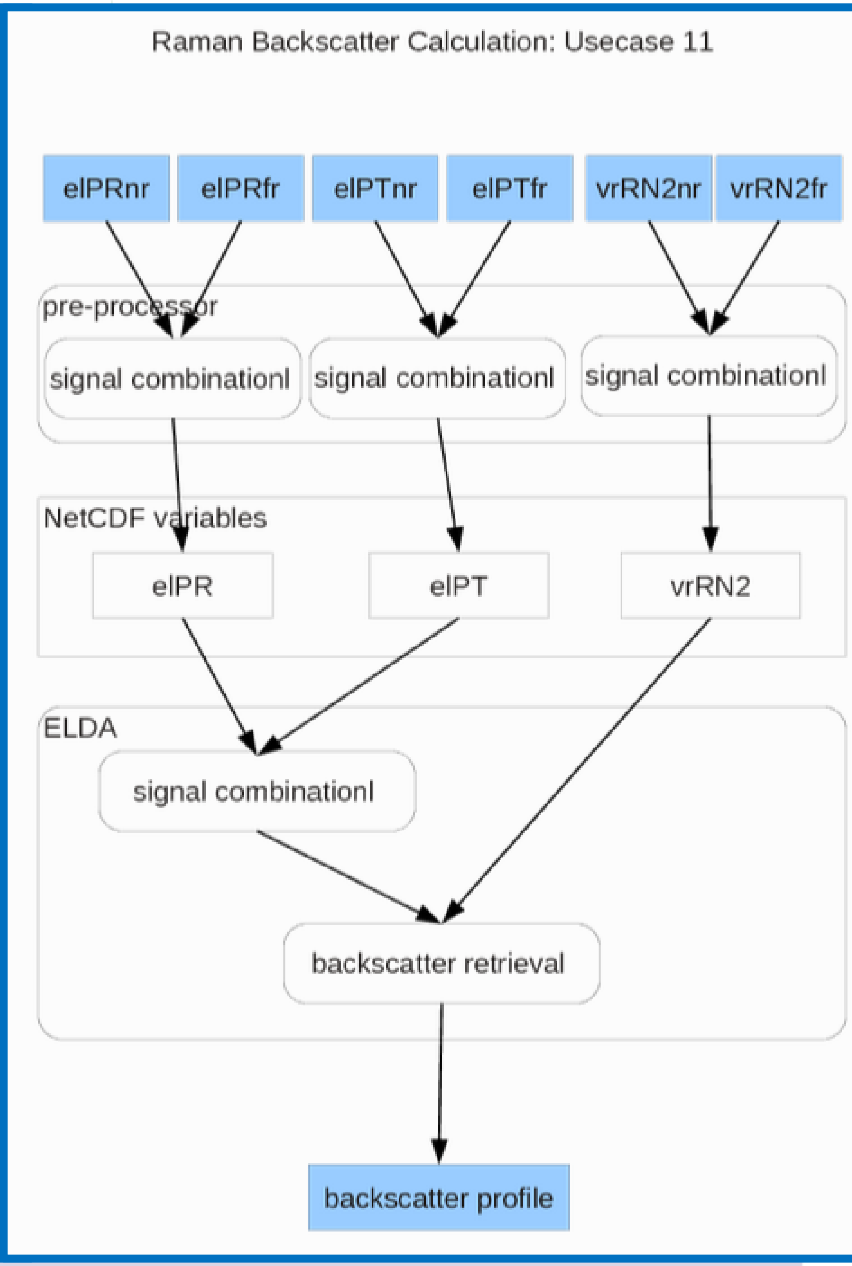
vrRN2

ELDA

signal combinationl

backscatter retrieval

backscatter profile



Raman Backscatter Calculation: Usecase 11

elPRnr

elPRfr

elPTnr

elPTfr

vrRN2nr

vrRN2fr

pre-processor

signal combinationl

signal combinationl

signal combinationl

NetCDF variables

elPR

elPT

vrRN2

ELDA

signal combinationl

backscatter retrieval

backscatter profile

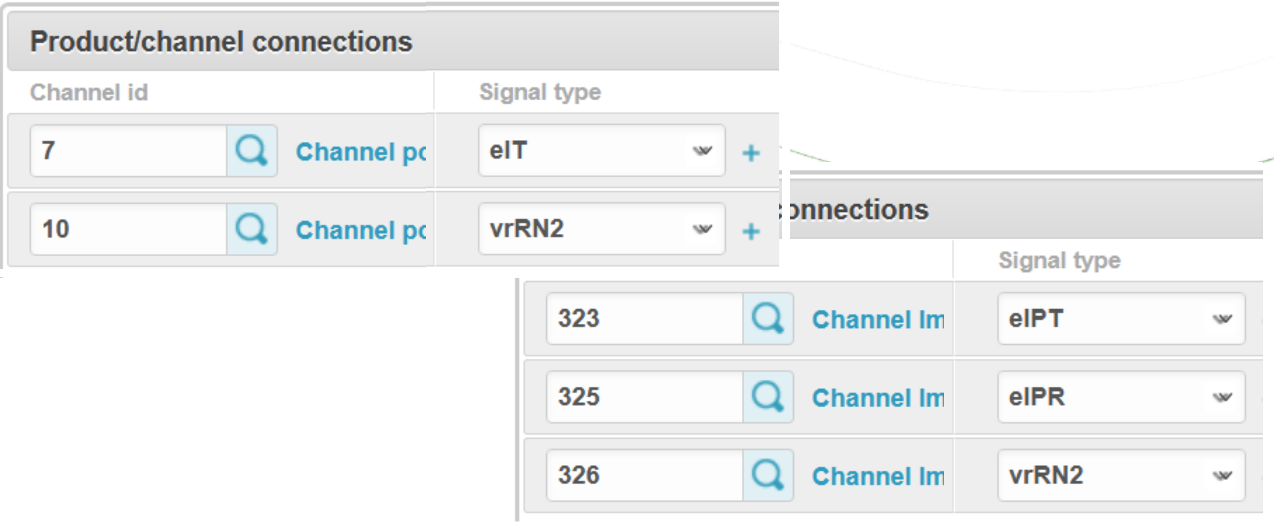
Parameters of «Raman backscatter» product

differential overlap - caution:

if overlap is provided for Raman signal (for extinction)
→ overlap is needed also for elastic signal

$$R_\beta(z) = F^\beta \boxed{\frac{\widehat{P_{\lambda_0}}(z)}{\widehat{P_{\lambda_R}}(z)}} \boxed{\cancel{\frac{O_{\lambda_R}(z)}{O_{\lambda_0}(z)}}} \exp\left[\left(1-\left(\frac{\lambda_0}{\lambda_R}\right)^{å}\right)\int_0^z \alpha^{\mathrm{par}}_{\lambda_0}(\zeta)\mathrm{d}\zeta\right]$$

- 2 elastic signals of types *elPT* + *elPR* *or* 1 elastic signal of type *elT*
- 1 Raman signal of type *vrRN2*



Product/channel connections

Channel id		Signal type
7	Channel pc	elT
10	Channel pc	vrRN2

onnections

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Parameters of «Raman backscatter» product

differential overlap - caution:

if overlap is provided for Raman signal (for extinction)
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$$R_\beta(z) = \boxed{F^\beta} \boxed{\frac{\widehat{P_{\lambda_0}}(z)}{\widehat{P_{\lambda_R}}(z)}} \boxed{\cancel{\frac{O_{\lambda_R}(z)}{O_{\lambda_0}(z)}}} \exp\left[\left(1-\left(\frac{\lambda_0}{\lambda_R}\right)^{å}\right)\int_0^z \alpha_{\lambda_0}^{\text{par}}(\zeta)\mathrm{d}\zeta\right]$$

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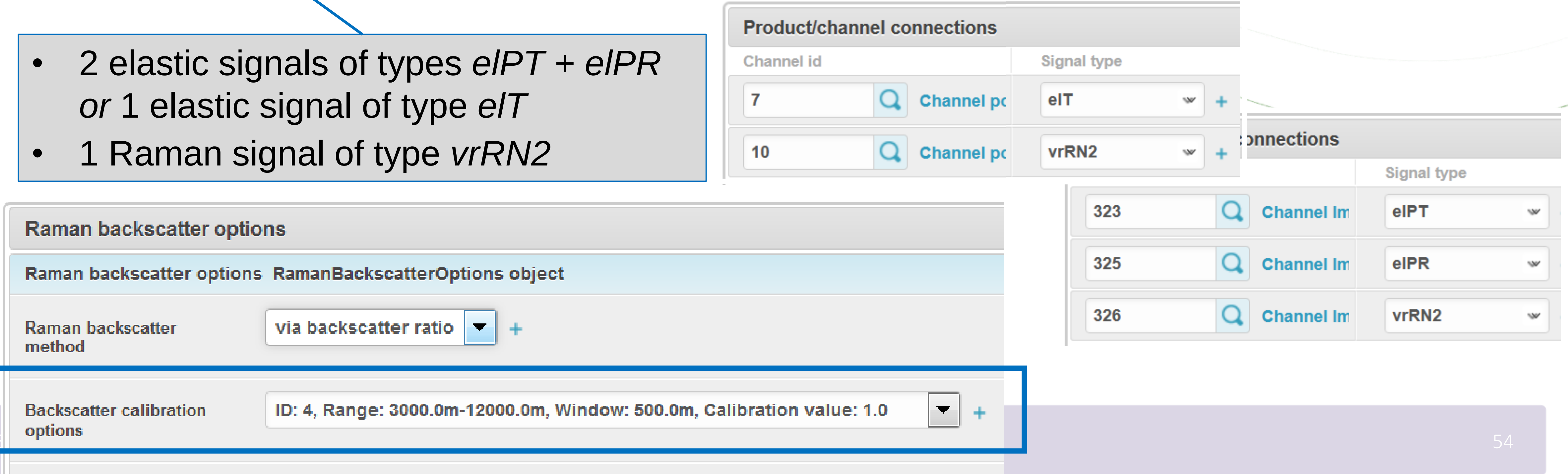

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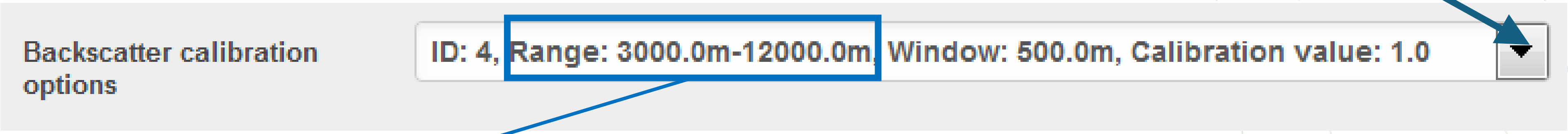
Raman backscatter options

Raman backscatter options RamanBackscatterOptions object

Raman backscatter method: via backscatter ratio

Backscatter calibration options: ID: 4, Range: 3000.0m-12000.0m, Window: 500.0m, Calibration value: 1.0

«Backscatter calibration options» → pick one !

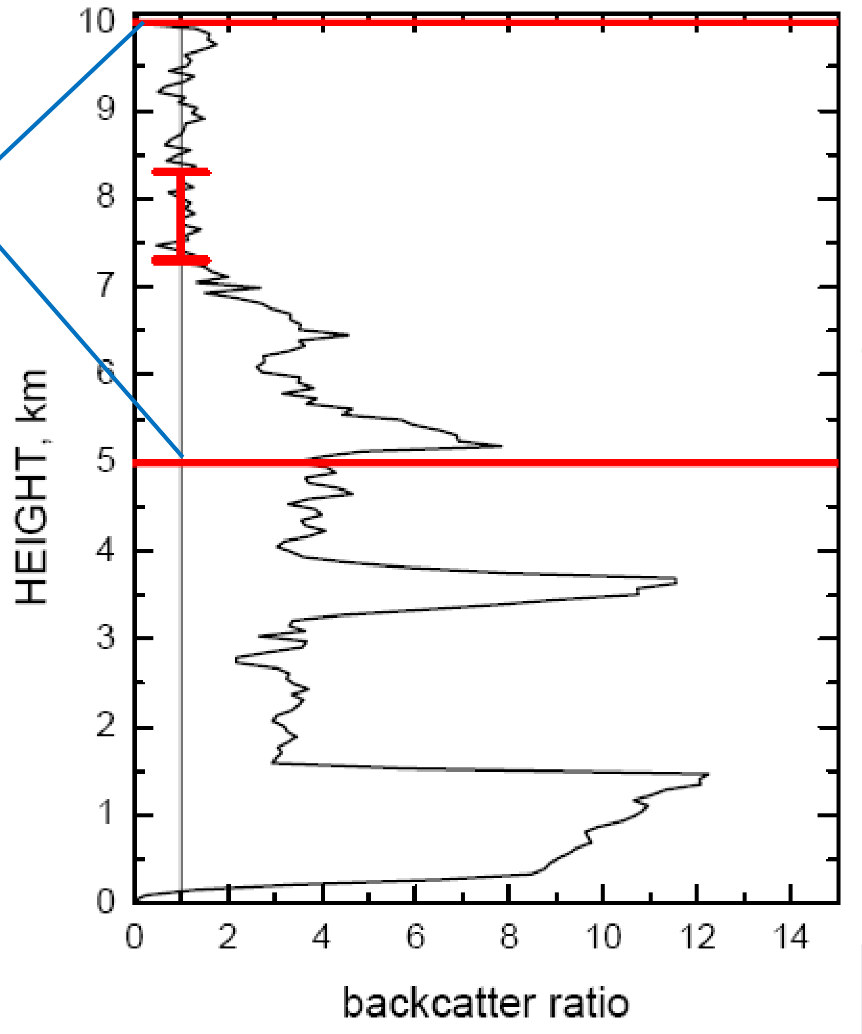


Backscatter calibration options

ID: 4, Range: 3000.0m-12000.0m, Window: 500.0m, Calibration value: 1.0

calibration interval

- e.g. 5-10km
- or 3-12km
- must be inside valid altitude range!



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Backscatter calibration options

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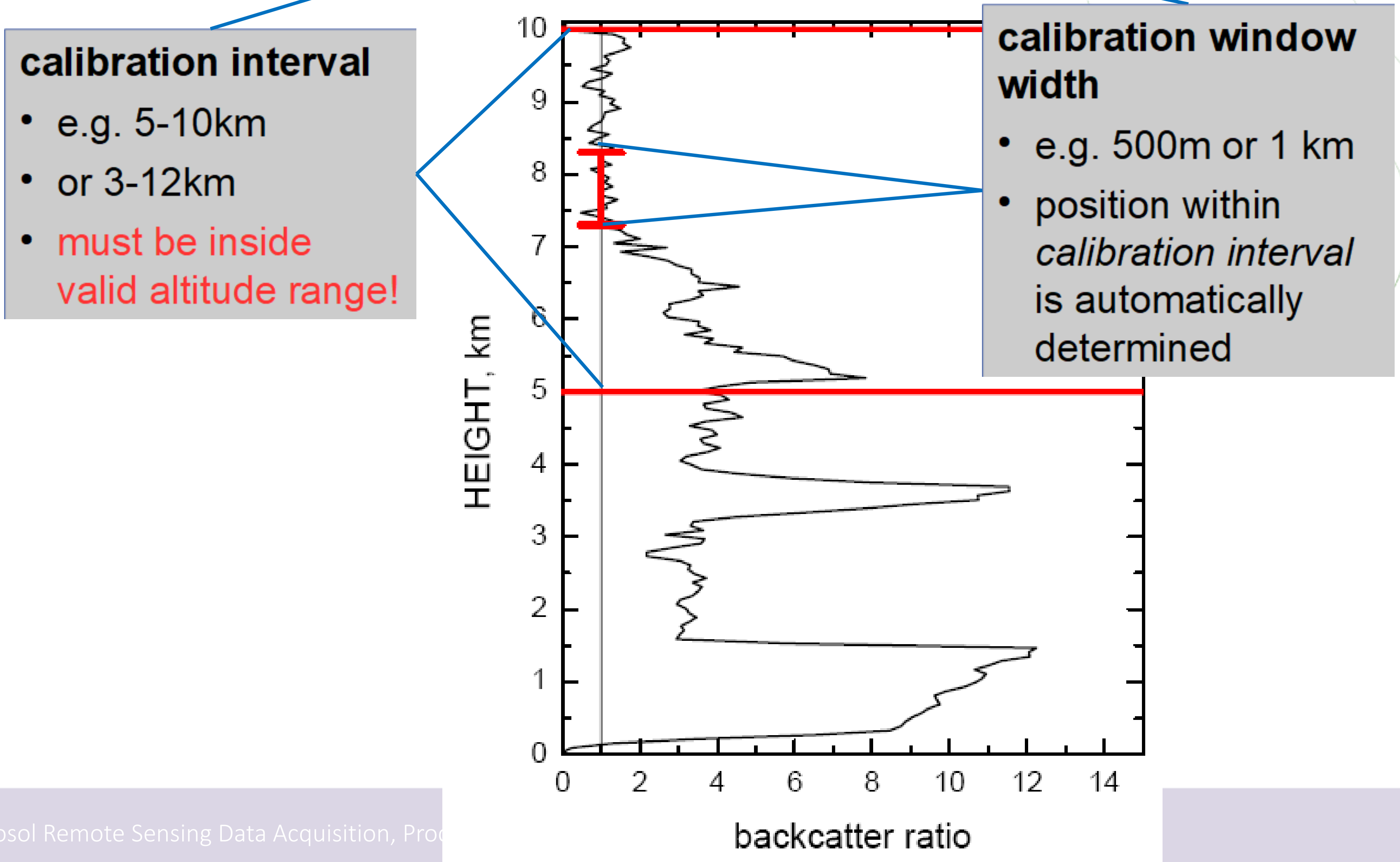

calibration interval

- e.g. 5-10km
- or 3-12km
- must be inside valid altitude range!

calibration window width

- e.g. 500m or 1 km
- position within *calibration interval* is automatically determined

«Backscatter calibration options» → pick one !

Backscatter calibration options

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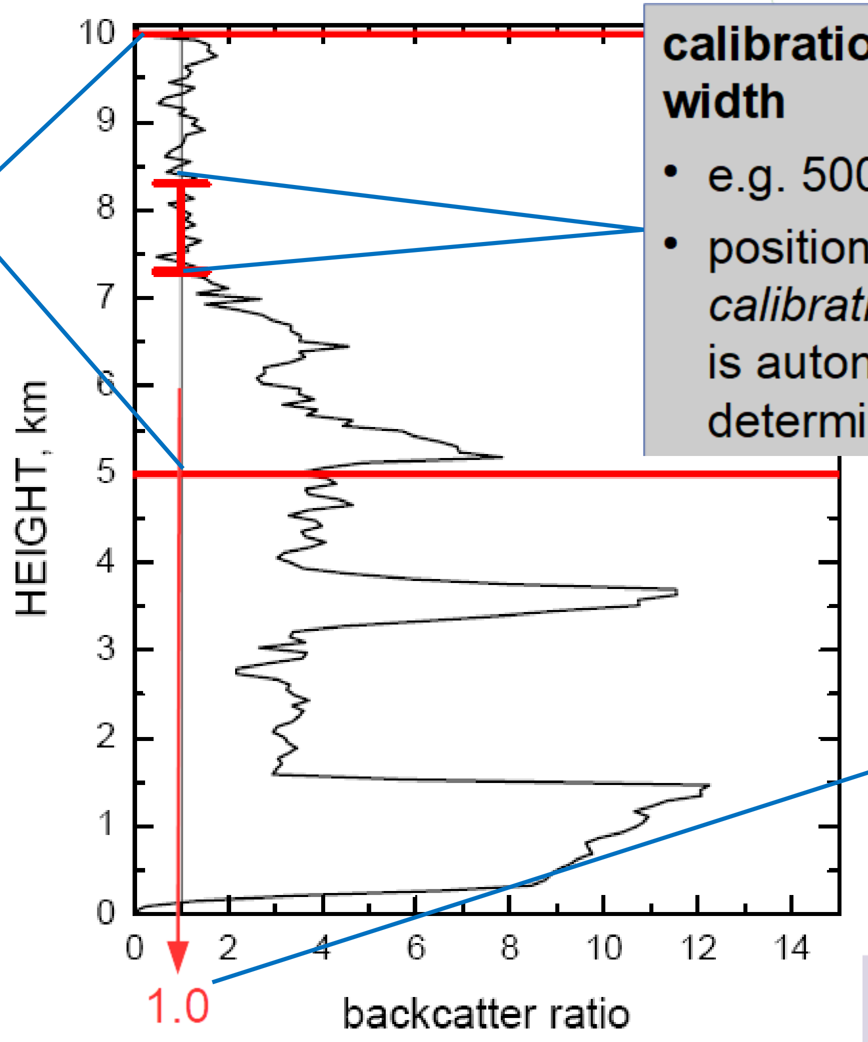


calibration window width
- e.g. 500m or 1 km
- position within *calibration interval* is automatically determined

calibration value
- as bsc ratio
- no aerosol → 1.0
- 10% aerosol → 1.1

«Backscatter calibration options» → pick one !

Backscatter calibration options

ID: 4, Range: 3000.0m-12000.0m, Window: 500.0m, Calibration value: 1.0

calibration interval

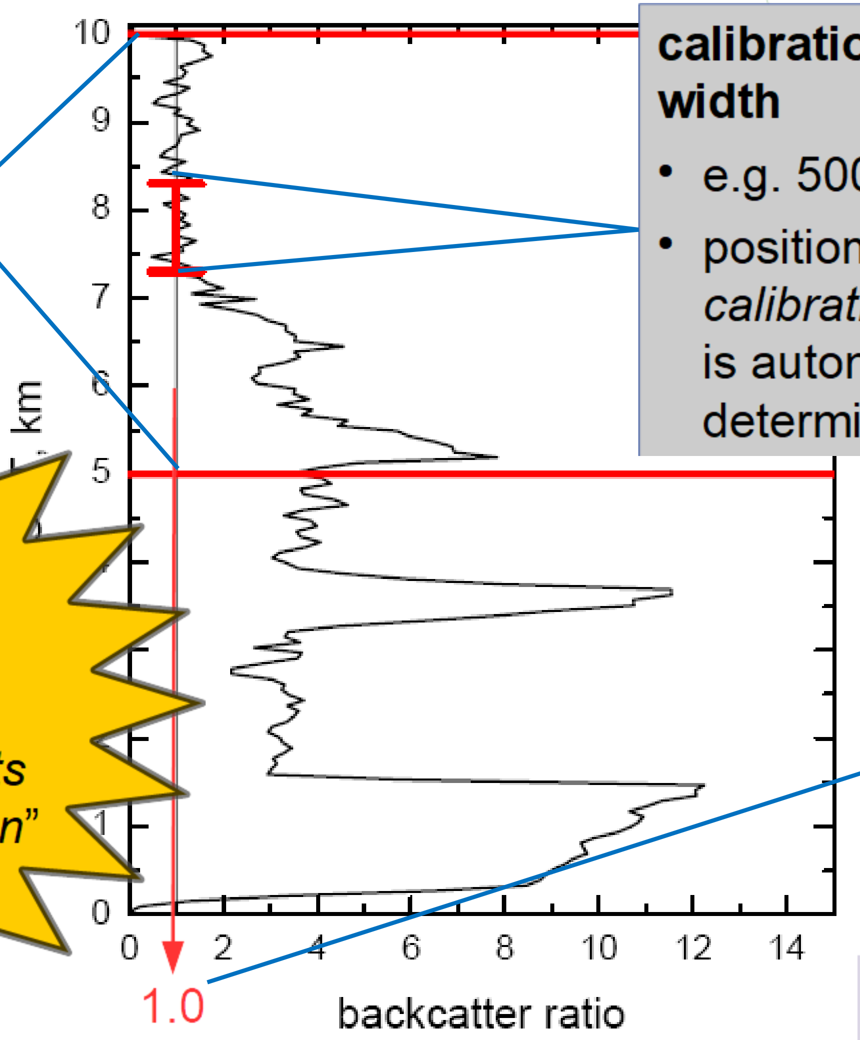
- e.g. 5-10km
- or 3-12km
- must be inside valid altitude range!

calibration window width

- e.g. 500m or 1 km
- position within *calibration interval* is automatically determined

calibration value

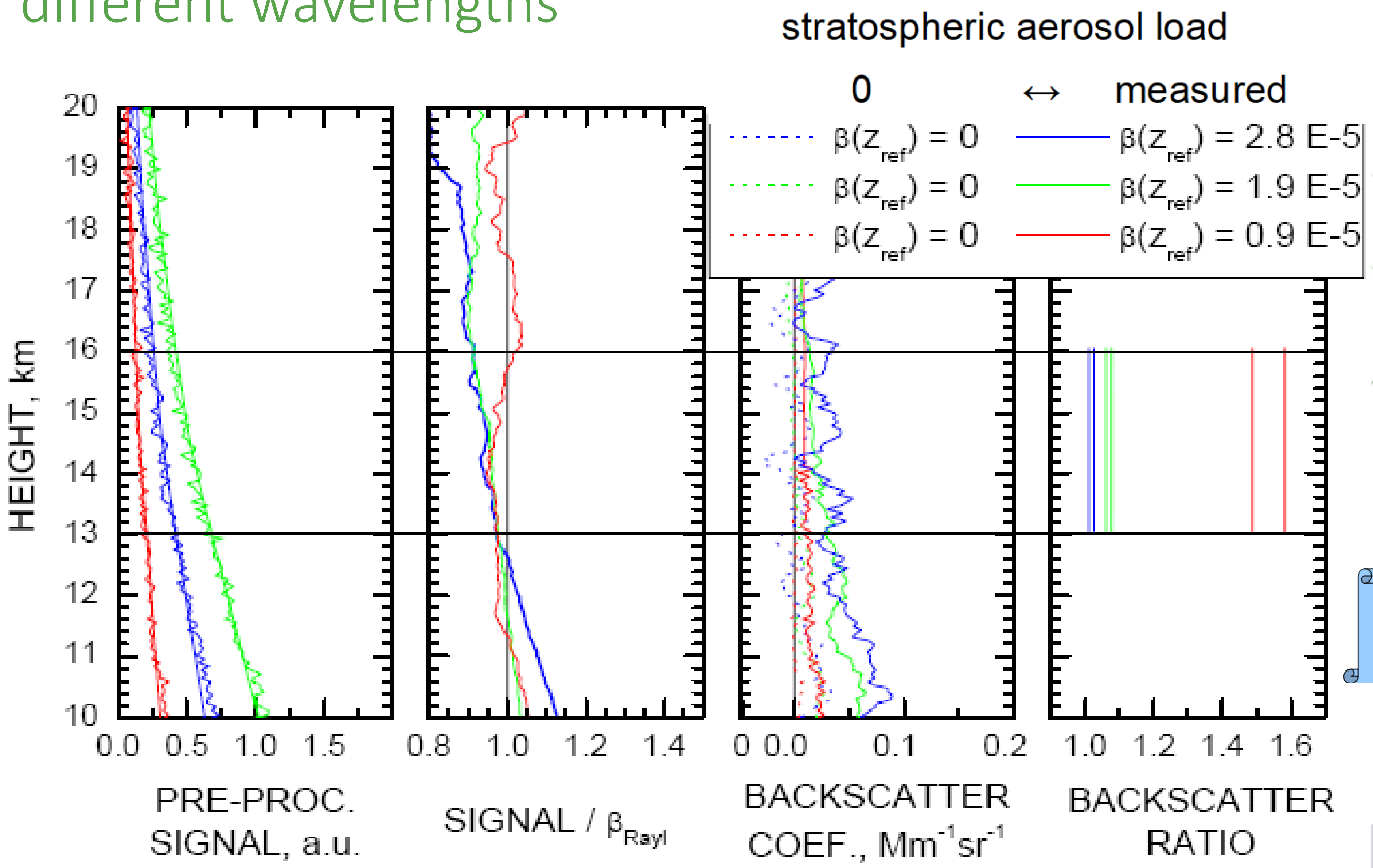
- as bsc ratio
- no aerosol → 1.0
- 10% aerosol → 1.1



Frequent error: if no window with sem* < max error can be found →*"No valid data points for calibration"*

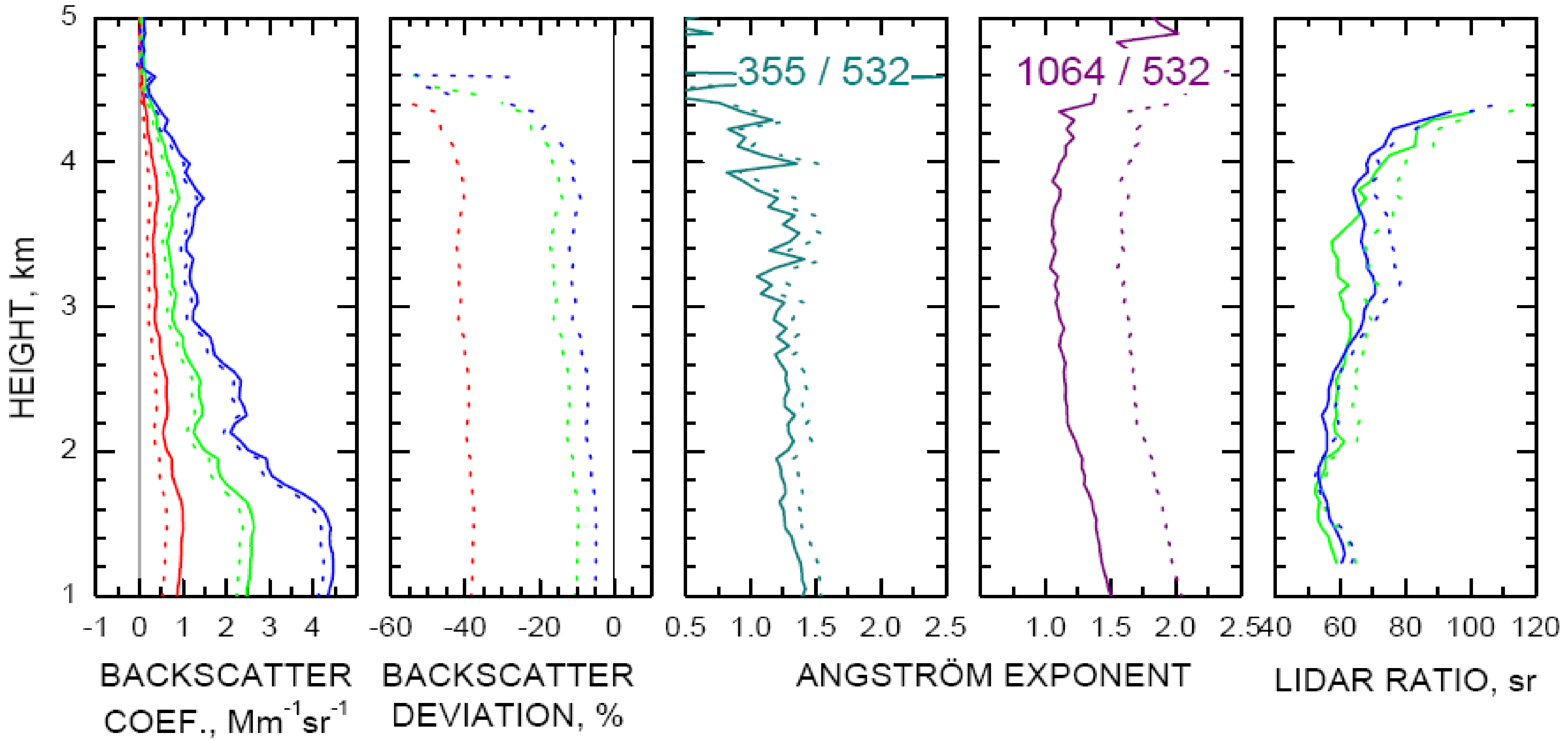
*standard error of mean

Influence of calibration on backscatter profiles at different wavelengths

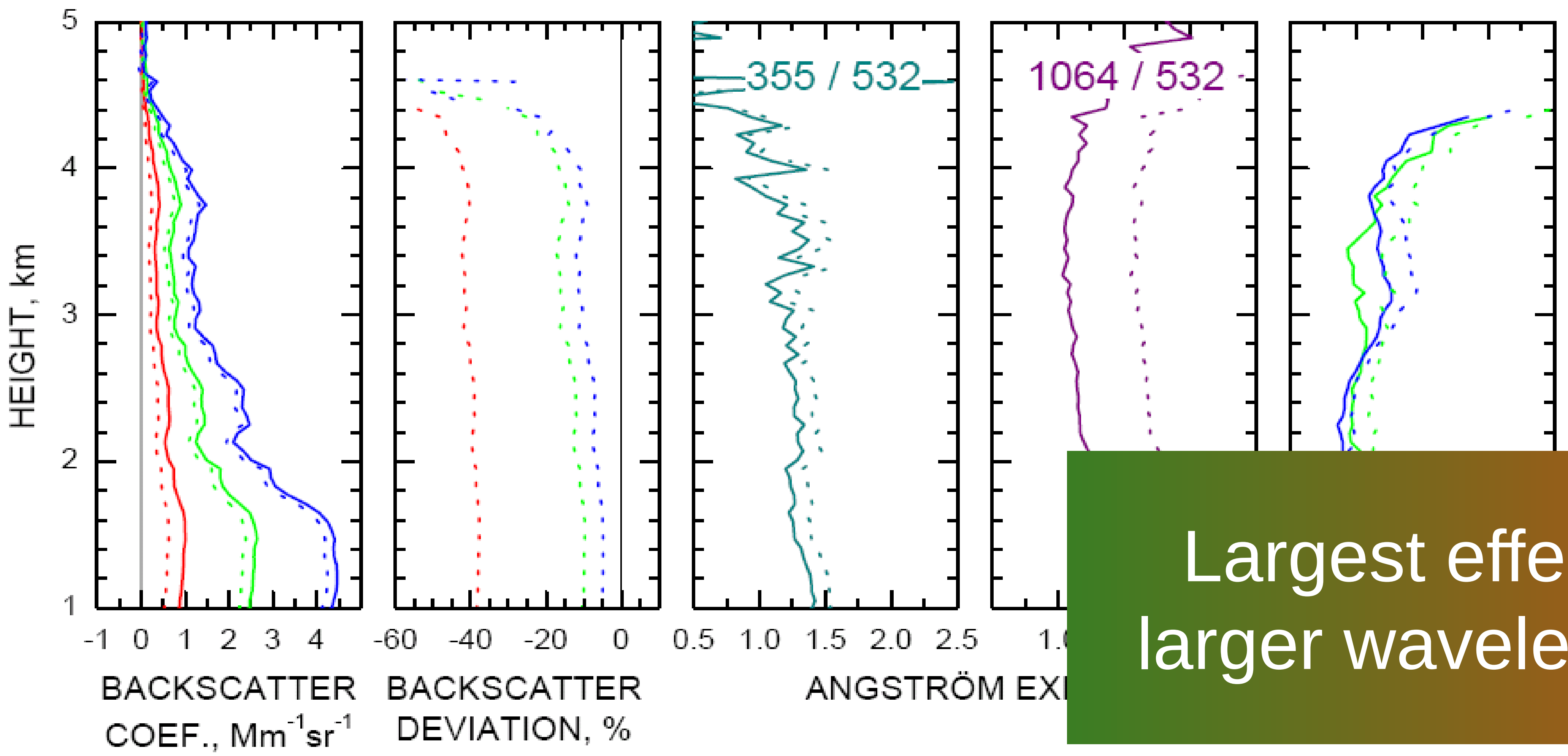


Deshler et al. JGR 2006

Influence of calibration on backscatter profiles at different wavelengths



Influence of calibration on backscatter profiles at different wavelengths



Largest effect at larger wavelengths

- The «elastic backscatter» product
- How to provide lidar ratio assumption

Retrieval of «elastic backscatter» product

$$\widehat{P_{\lambda_0}}(z) = [\beta^{\mathrm{mol}}_{\lambda_0}(z) + \beta^{\mathrm{par}}_{\lambda_0}] \exp\left(-2\int_0^z \alpha^{\mathrm{mol}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_0}(\zeta)\mathrm{d}\zeta\right)$$

Retrieval of «elastic backscatter» product

$$\widehat{P_{\lambda_0}}(z) = \left[\beta^{\mathrm{mol}}_{\lambda_0}(z) + \beta^{\mathrm{par}}_{\lambda_0}\right] \exp\left(-2 \int_0^z \alpha^{\mathrm{mol}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_0}(\zeta) \mathrm{d}\zeta\right)$$

- 1 equation ↔ 2 unknowns

  → lidar ratio assumption:

$$S^{\mathrm{par}}_{\lambda_0}(z) = \frac{\alpha^{\mathrm{par}}_{\lambda_0}(z)}{\beta^{\mathrm{par}}_{\lambda_0}(z)}$$

Retrieval of «elastic backscatter» product

$$\widehat{P_{\lambda_0}}(z) = \left[\beta^{\mathrm{mol}}_{\lambda_0}(z) + \beta^{\mathrm{par}}_{\lambda_0}\right] \exp\left(-2\int_0^z \alpha^{\mathrm{mol}}_{\lambda_0}(\zeta) + \alpha^{\mathrm{par}}_{\lambda_0}(\zeta)\,\mathrm{d}\zeta\right)$$

- 1 equation ↔ 2 unknowns
  → lidar ratio assumption:

$$S^{\mathrm{par}}_{\lambda_0}(z) = \frac{\alpha^{\mathrm{par}}_{\lambda_0}(z)}{\beta^{\mathrm{par}}_{\lambda_0}(z)}$$

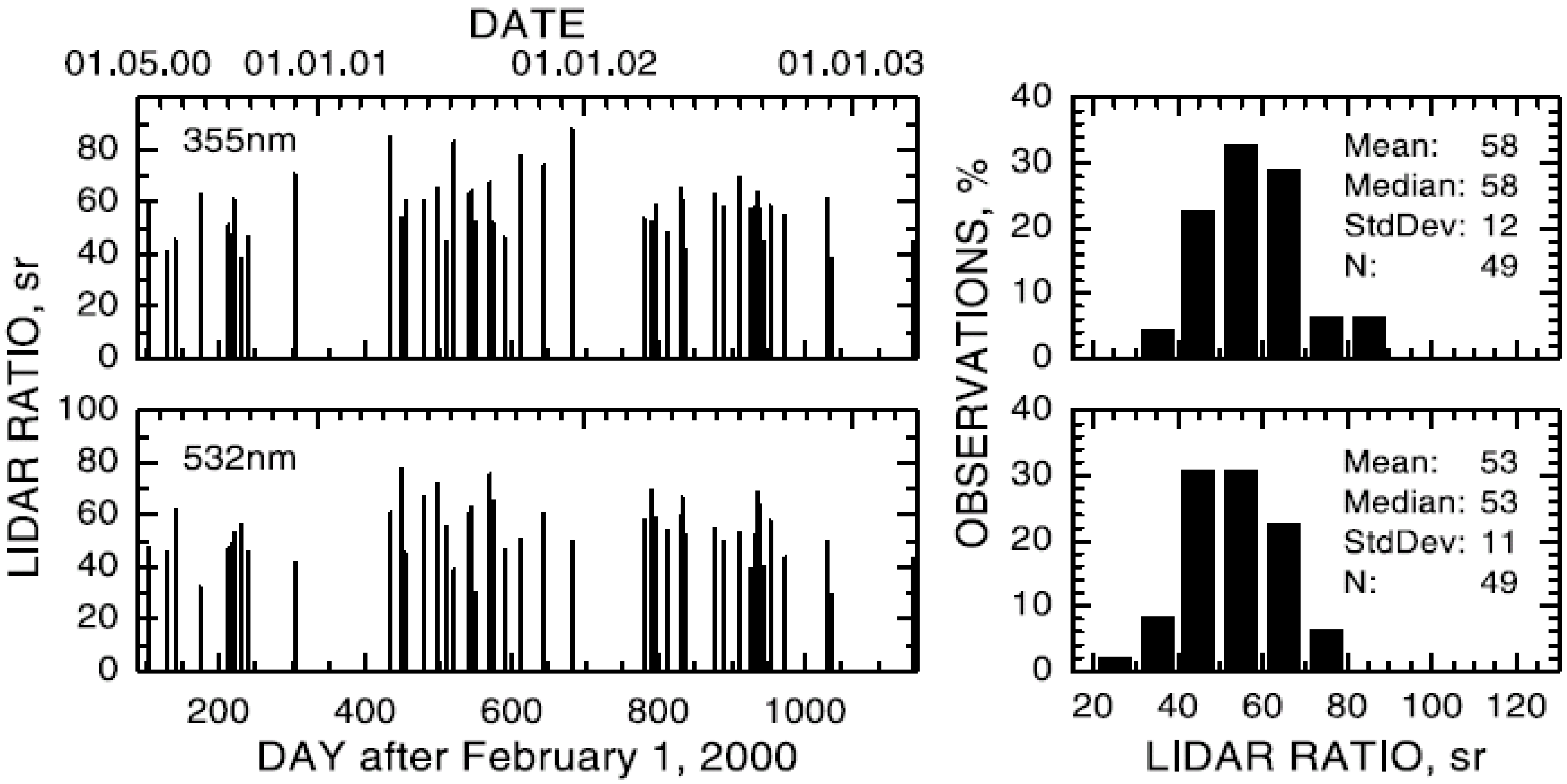
- 2 methods to solve the equation:
  - Klett-Fernald
  - Iterative method

Klett, *Appl. Opt.*, 1981
Fernald, *Appl. Opt.*, 1984

Di Girolamo et al., *Appl. Opt.*, 1999
Masci, *Annali di Geofisica*, 1999

Influence of the lidar ratio assumption

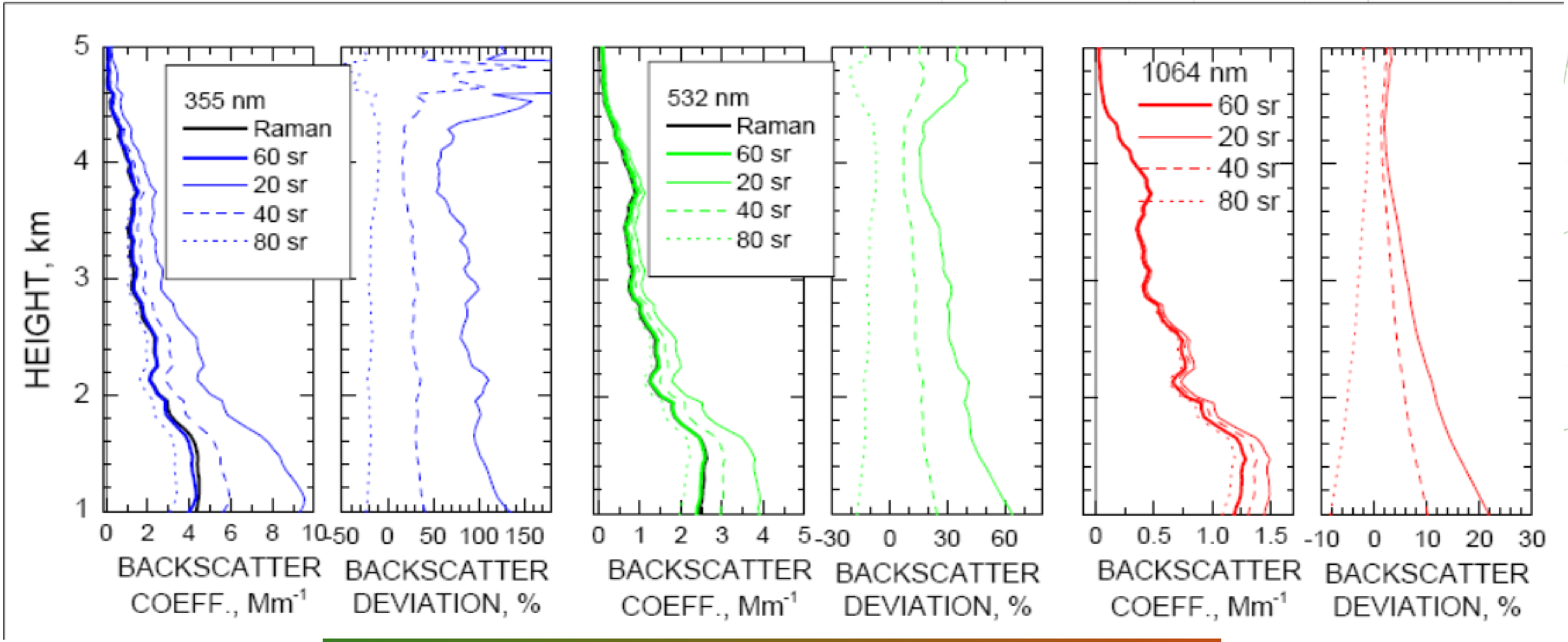
MATTIS ET AL.: MULTIYEAR AEROSOL PROFILING IN EUROPE D13203



Measured lidar ratios are highly variable, also within one aerosol type (e.g., urban industrial)

Figure 7. Mean particle lidar ratios measured in the upper part of the boundary layer at 355 and 532 nm and corresponding frequencies of occurrence, mean and median values, one standard deviations, and numbers of observations. Only cases with simultaneous observations at both wavelengths are shown.

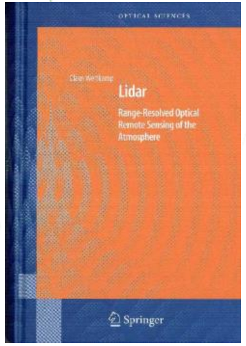
Influence of lidar ratio assumption on KF retrievals



Largest effect at smaller wavelengths

Klett-Fernald method

$$\begin{aligned}
\beta^{\mathrm{par}}_{\lambda_0} &= -\beta^{\mathrm{mol}}_{\lambda_0}(z) + \frac{A(z, z_{\mathrm{ref}})}{B(z_{\mathrm{ref}}) + 2\int_z^{z_{\mathrm{ref}}} S^{\mathrm{par}}_{\lambda_0}(\zeta)A(\zeta, z_{\mathrm{ref}})\mathrm{d}\zeta},\\
\text{with}\\
A(x, z_{\mathrm{ref}}) &= P_{\lambda_0}(x)x^2 \exp\left(2\int_x^{z_{\mathrm{ref}}} \left[S^{\mathrm{par}}_{\lambda_0}(\xi) - S^{\mathrm{mol}}\right]\beta^{\mathrm{mol}}_{\lambda_0}(\xi)\mathrm{d}\xi\right), \quad x = z,\ \zeta\\
\text{and}\\
B(z_{\mathrm{ref}}) &= \frac{P_{\lambda_0}(z_{\mathrm{ref}})z^2_{\mathrm{ref}}}{\beta^{\mathrm{par}}_{\lambda_0}(z_{\mathrm{ref}}) + \beta^{\mathrm{mol}}_{\lambda_0}(z_{\mathrm{ref}})}.
\end{aligned}$$



Lidar

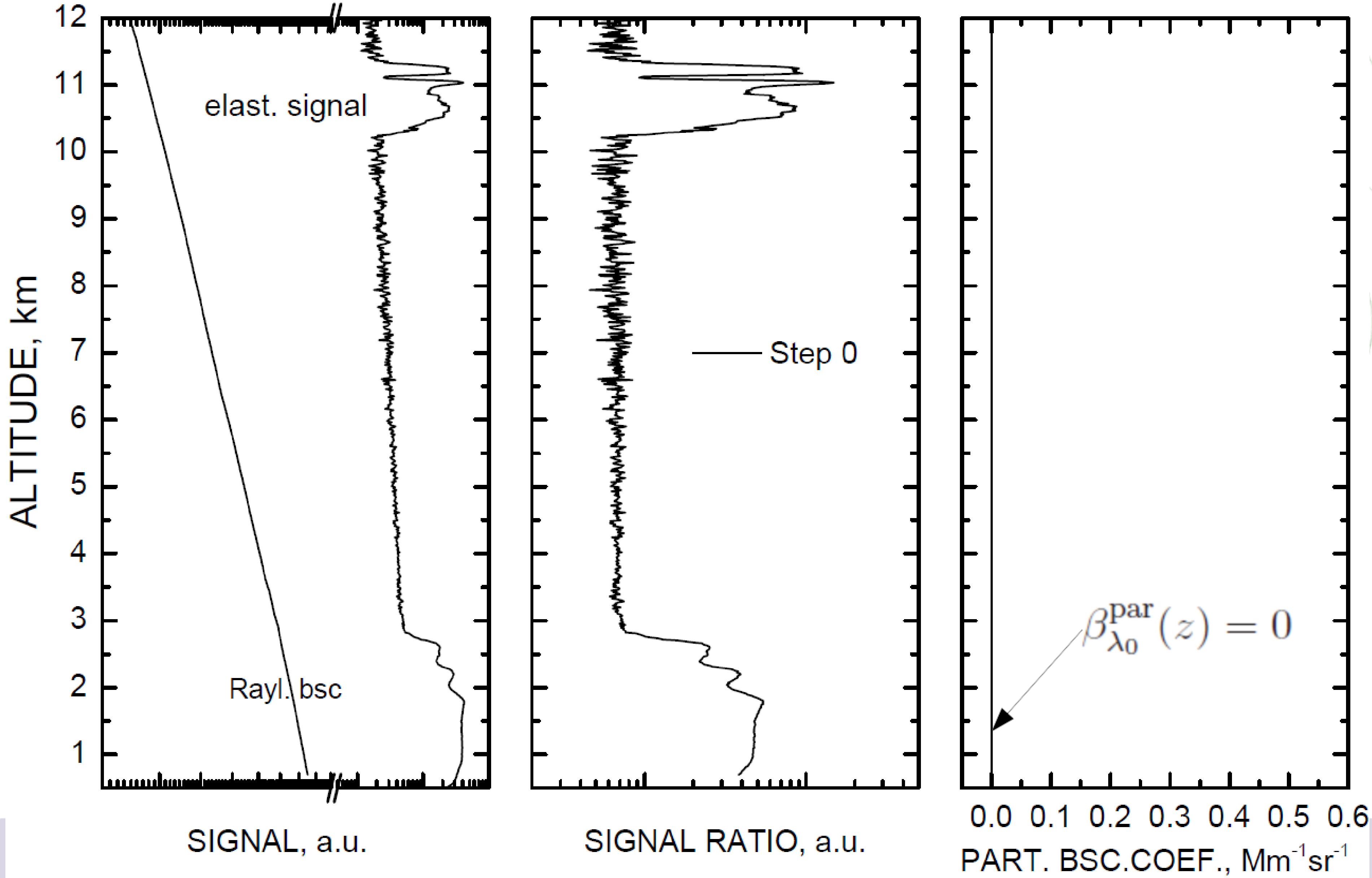
Range-Resolved Optical Remote Sensing of the Atmosphere

Springer

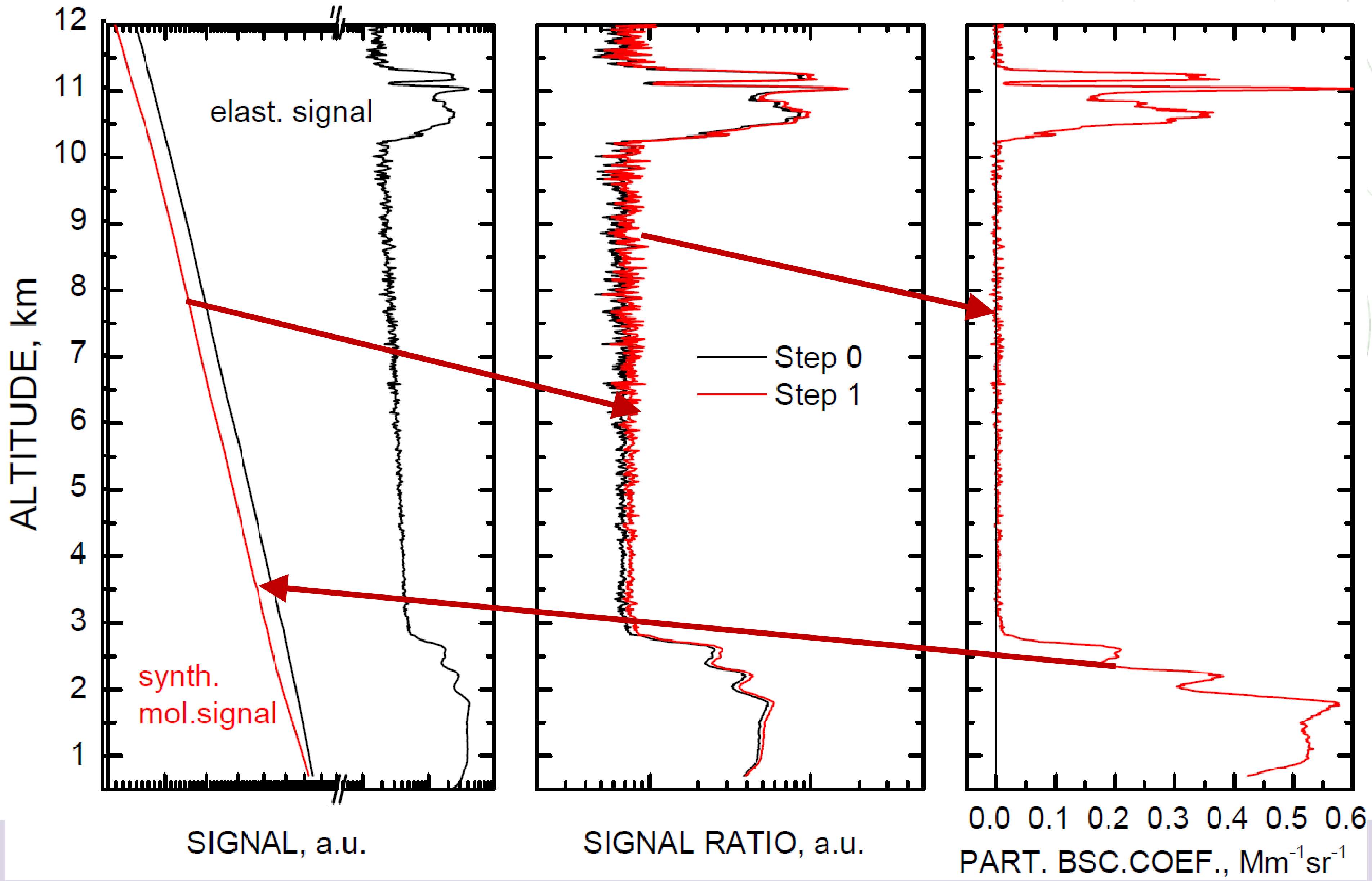
- KF equations can be solved
    - forward integration: from ground to top (z >zref)
    - backward integration: from top down to ground (z <zref)
    - only backward integration implemented in SCC
- complicated equation
    - no error propagation implemented in SCC
    - error retrieval only with MC method

Error method monte carlo

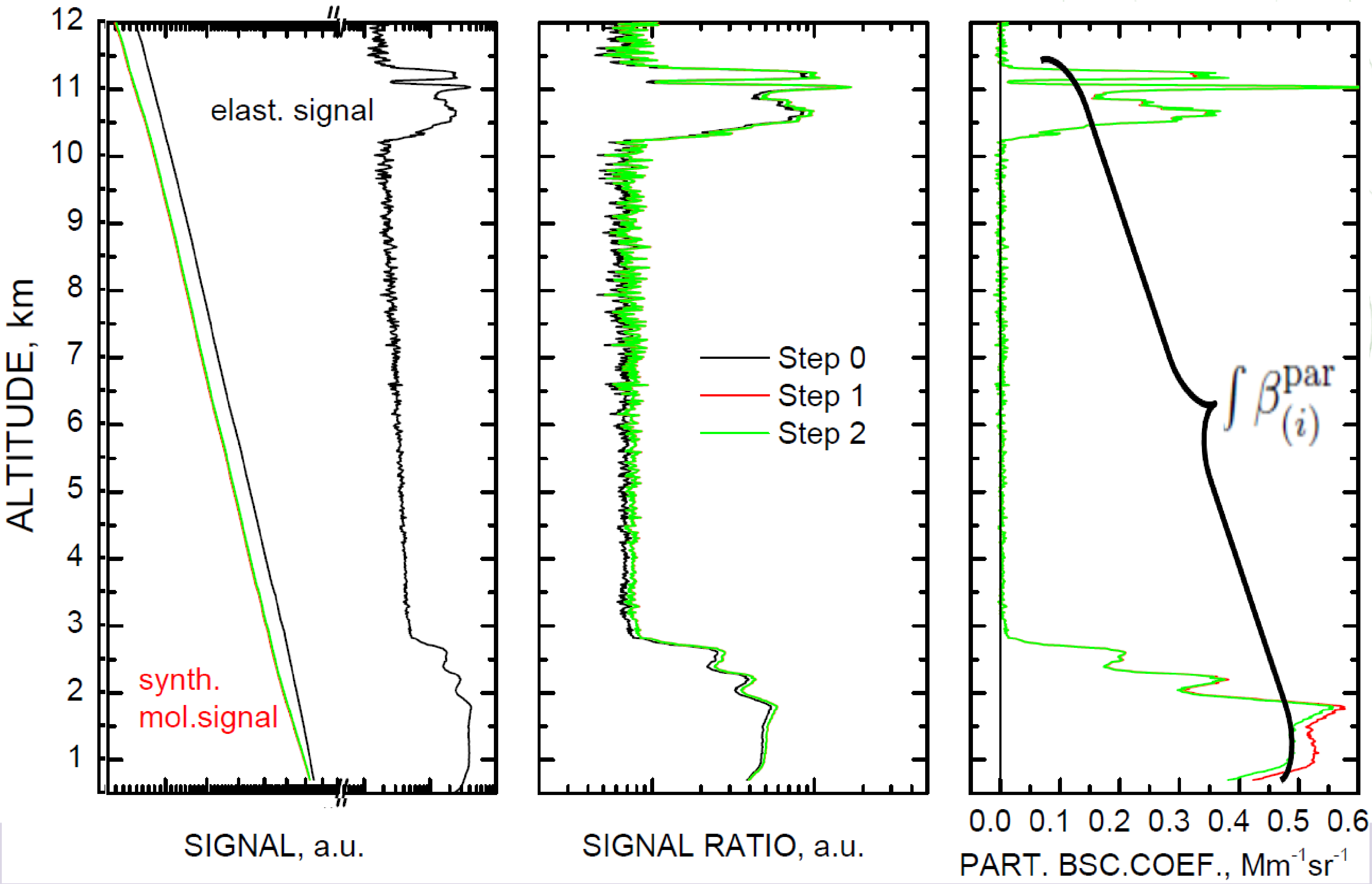
Iterative method



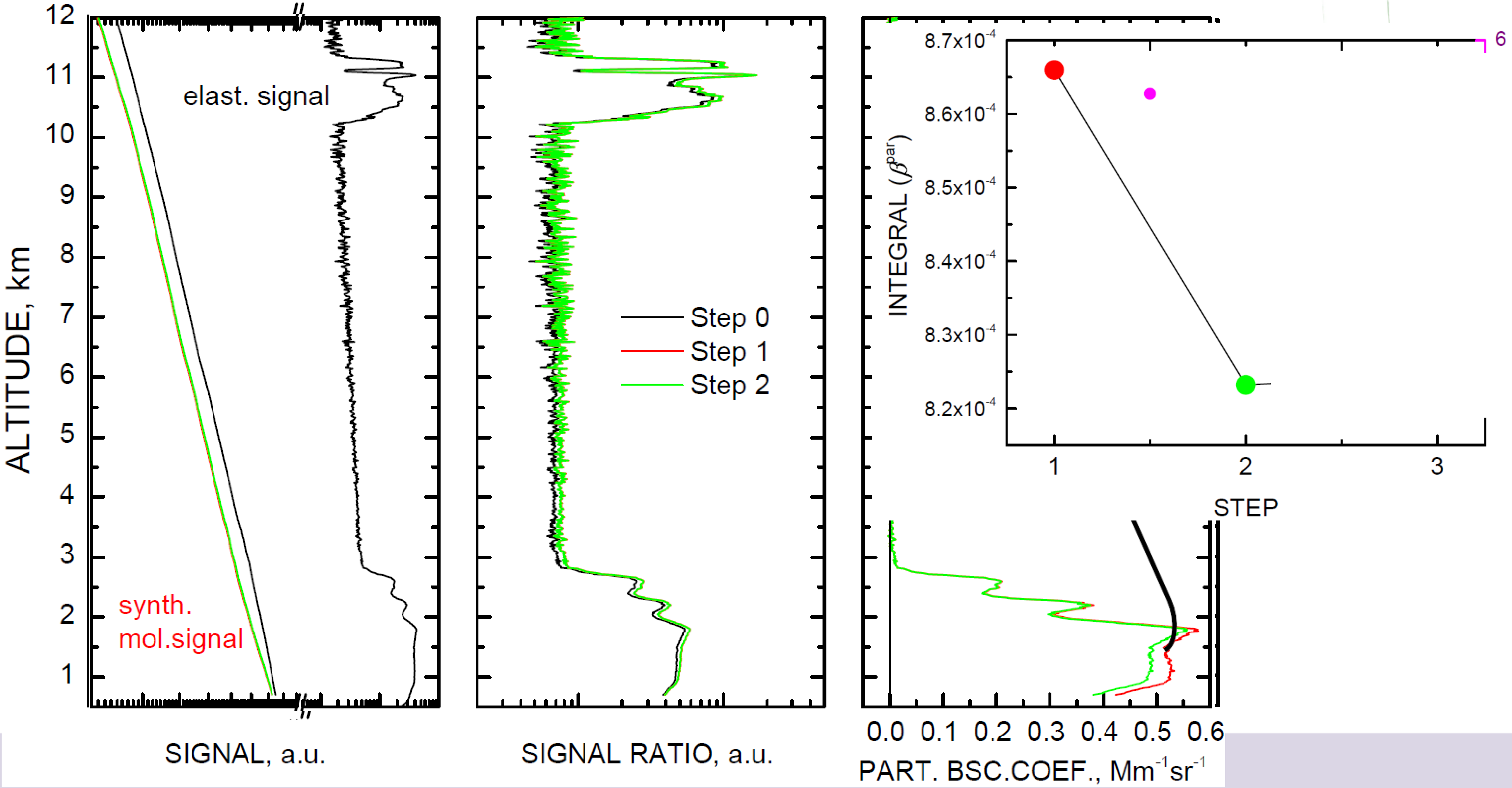
Iterative method



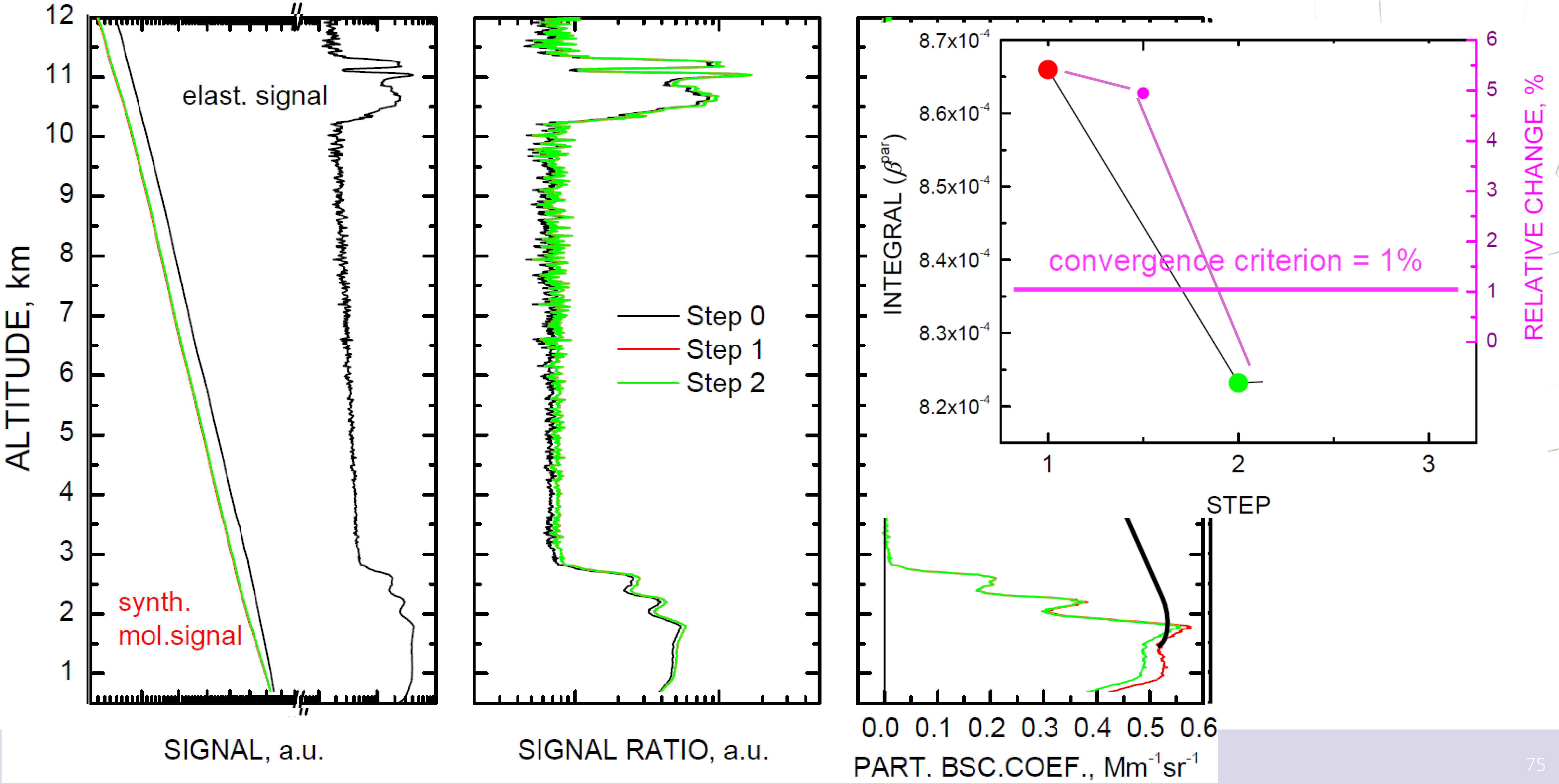
Iterative method



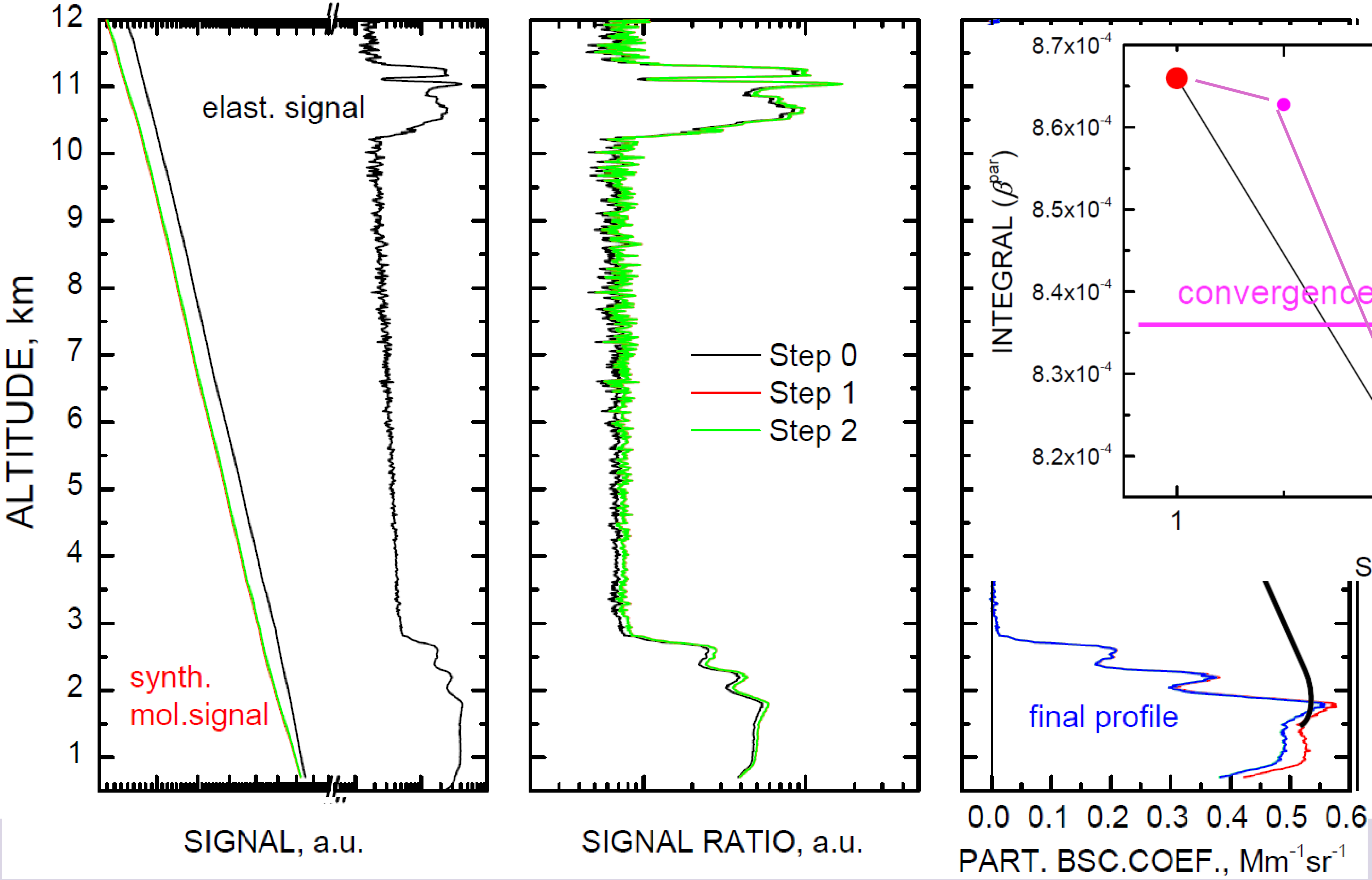
Iterative method



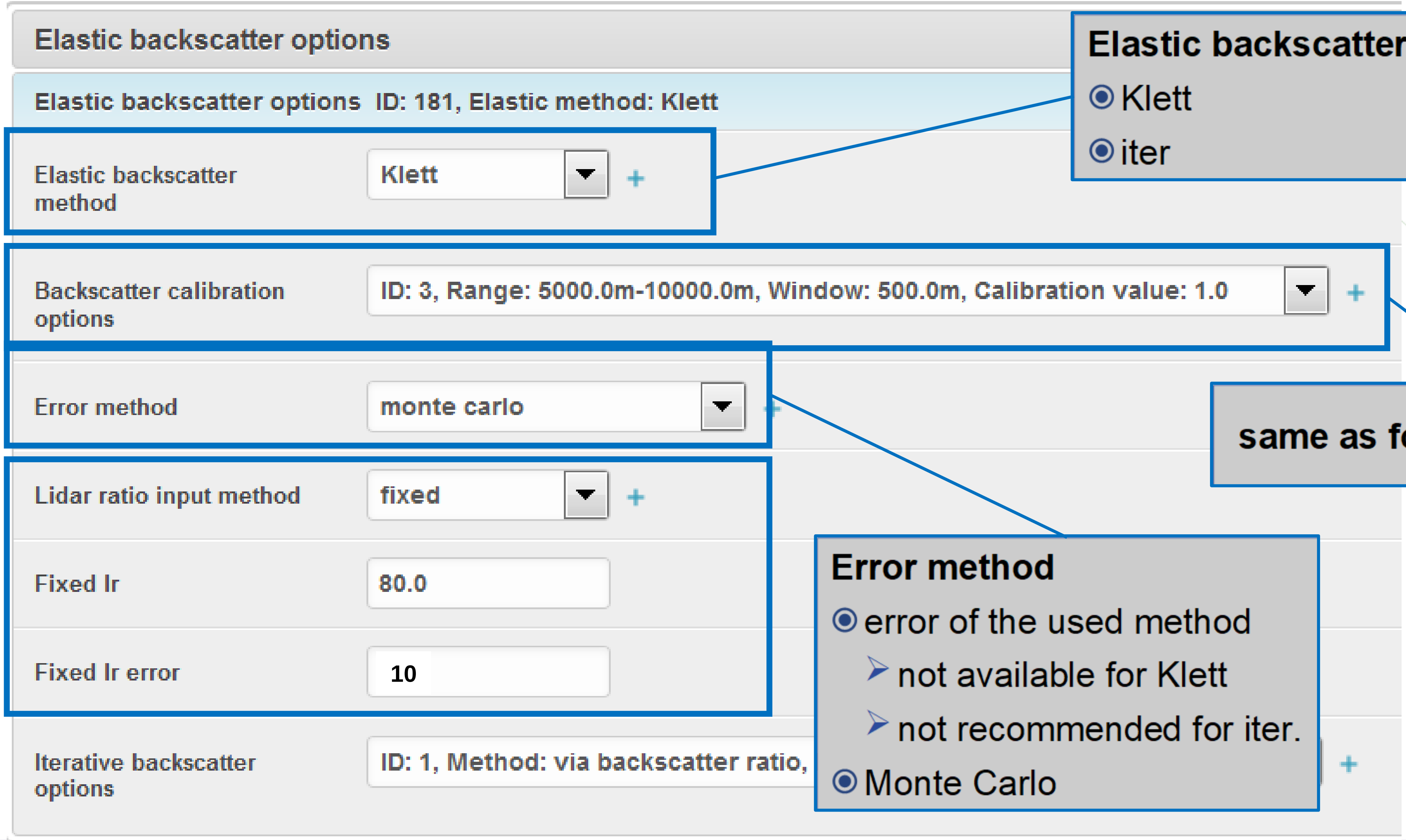
Iterative method



Iterative method



Parameters of “Elast. backscatter” product



Elastic backscatter options

Elastic backscatter options ID: 181, Elastic method: Klett

Elastic backscatter method: Klett

Backscatter calibration options: ID: 3, Range: 5000.0m-10000.0m, Window: 500.0m, Calibration value: 1.0

Error method: monte carlo

Lidar ratio input method: fixed

Fixed lr: 80.0

Fixed lr error: 10

Iterative backscatter options: ID: 1, Method: via backscatter ratio,

Elastic backscatter method

● Klett

● iter

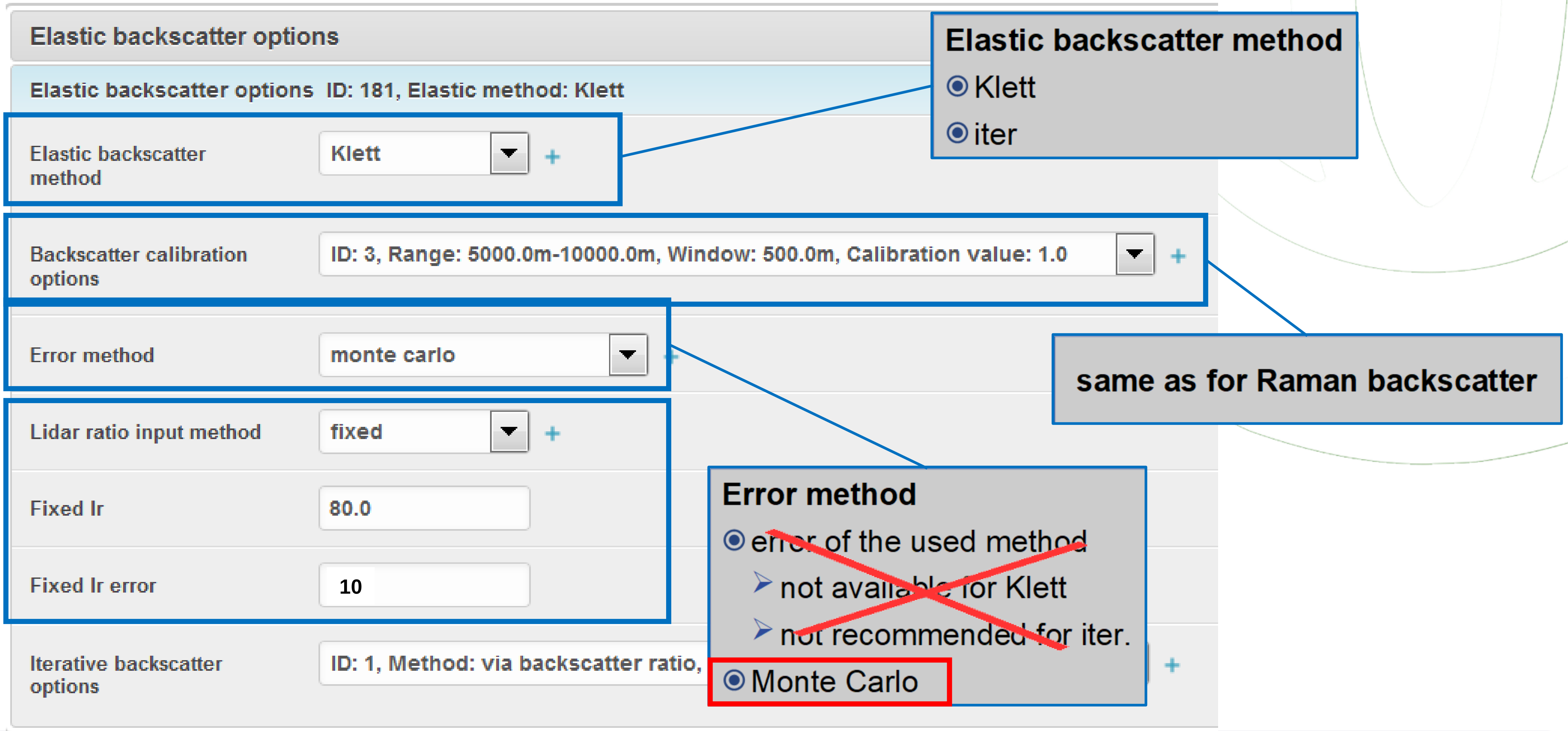
same as for Raman backscatter

Error method

● error of the used method
  - not available for Klett
  - not recommended for iter.

● Monte Carlo

Parameters of “Elast. backscatter” product



Elastic backscatter options

Elastic backscatter options ID: 181, Elastic method: Klett

Elastic backscatter method	Klett
Backscatter calibration options	ID: 3, Range: 5000.0m-10000.0m, Window: 500.0m, Calibration value: 1.0
Error method	monte carlo
Lidar ratio input method	fixed
Fixed lr	80.0
Fixed lr error	10
Iterative backscatter options	ID: 1, Method: via backscatter ratio,

Elastic backscatter method

● Klett

● iter

same as for Raman backscatter

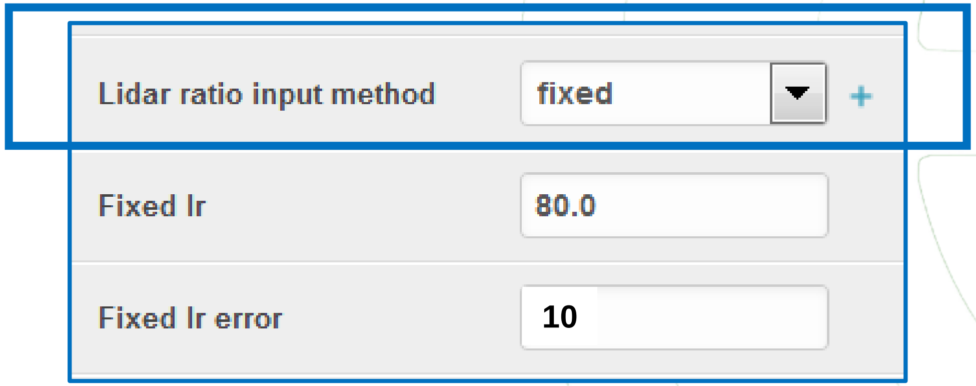
Error method

● ~~error of the used method~~

- ~~not available for Klett~~
- ~~not recommended for iter.~~

● Monte Carlo

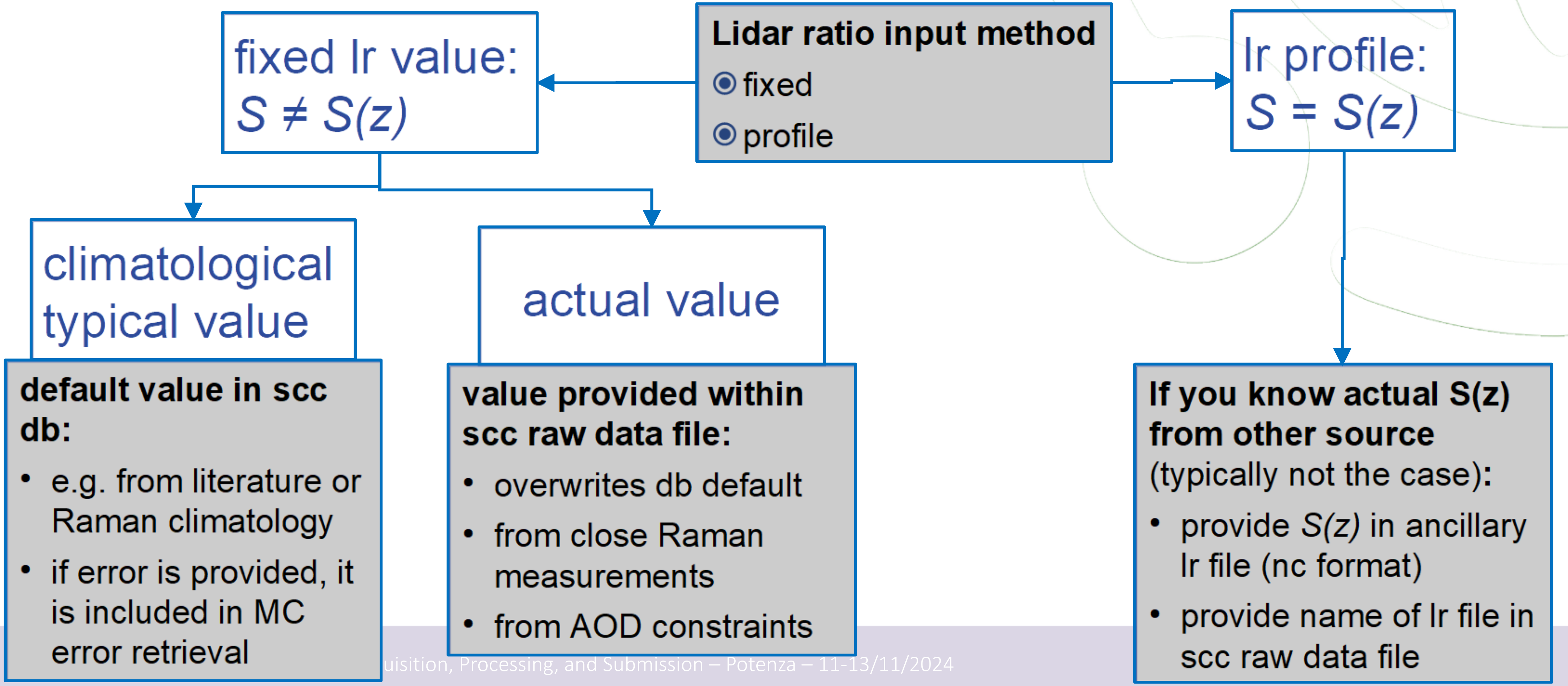
Lidar ratio assumption



Lidar ratio input method: fixed

Fixed lr: 80.0

Fixed lr error: 10



Lidar ratio input method

◉ fixed

◉ profile

fixed lr value:
$S \neq S(z)$

climatological typical value

default value in scc db:

- e.g. from literature or Raman climatology
- if error is provided, it is included in MC error retrieval

actual value

value provided within scc raw data file:

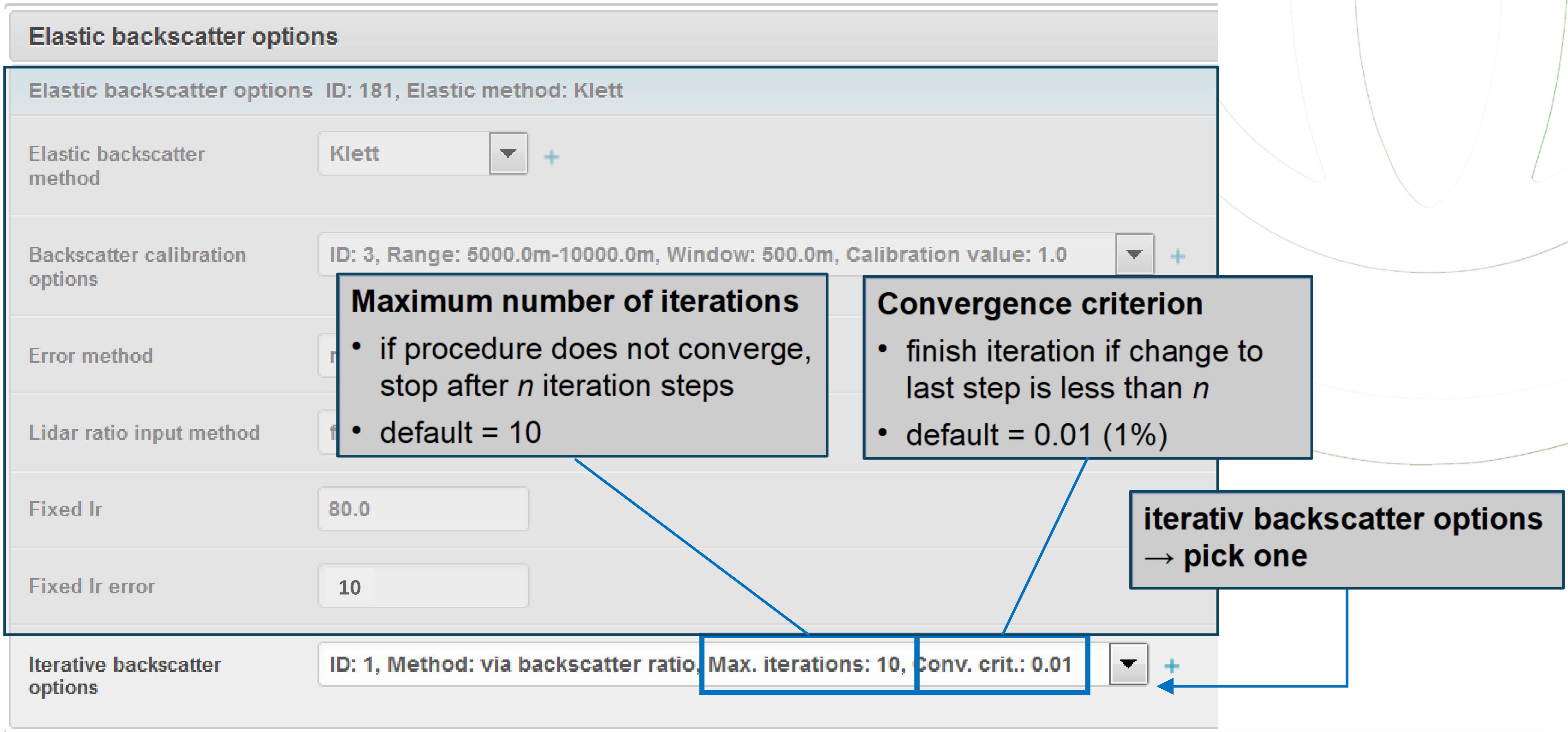
- overwrites db default
- from close Raman measurements
- from AOD constraints

lr profile:
$S = S(z)$

If you know actual S(z) from other source (typically not the case)**:**

- provide *S(z)* in ancillary lr file (nc format)
- provide name of lr file in scc raw data file

Parameters of “Elast. backscatter” product



Elastic backscatter options

Elastic backscatter options ID: 181, Elastic method: Klett

Elastic backscatter method: Klett

Backscatter calibration options: ID: 3, Range: 5000.0m-10000.0m, Window: 500.0m, Calibration value: 1.0

Error method: r

Lidar ratio input method: f

Fixed lr: 80.0

Fixed lr error: 10

Iterative backscatter options: ID: 1, Method: via backscatter ratio, Max. iterations: 10, Conv. crit.: 0.01

Maximum number of iterations

- if procedure does not converge, stop after *n* iteration steps
- default = 10

Convergence criterion

- finish iteration if change to last step is less than *n*
- default = 0.01 (1%)

iterativ backscatter options → pick one

- The «lidar ratio and extinction» product
- Effective vertical resolution

Retrieval of lidar ratio product

$$S_{\lambda_0}^{\mathrm{par}}(z) = \frac{\alpha_{\lambda_0}^{\mathrm{par}}(z)}{\beta_{\lambda_0}^{\mathrm{par}}(z)}$$

Retrieval of lidar ratio product

$$S^{\text{par}}_{\lambda_0}(z) = \frac{\alpha^{\text{par}}_{\lambda_0}(z)}{\beta^{\text{par}}_{\lambda_0}(z)}$$

→ “*extinction only*” product

→ “*Raman backscatter*” product

- Problem $\beta^{\text{par}}_{\lambda_0}(z)$ usually has much higher vertical resolution than $\alpha^{\text{par}}_{\lambda_0}(z)$

Retrieval of lidar ratio product

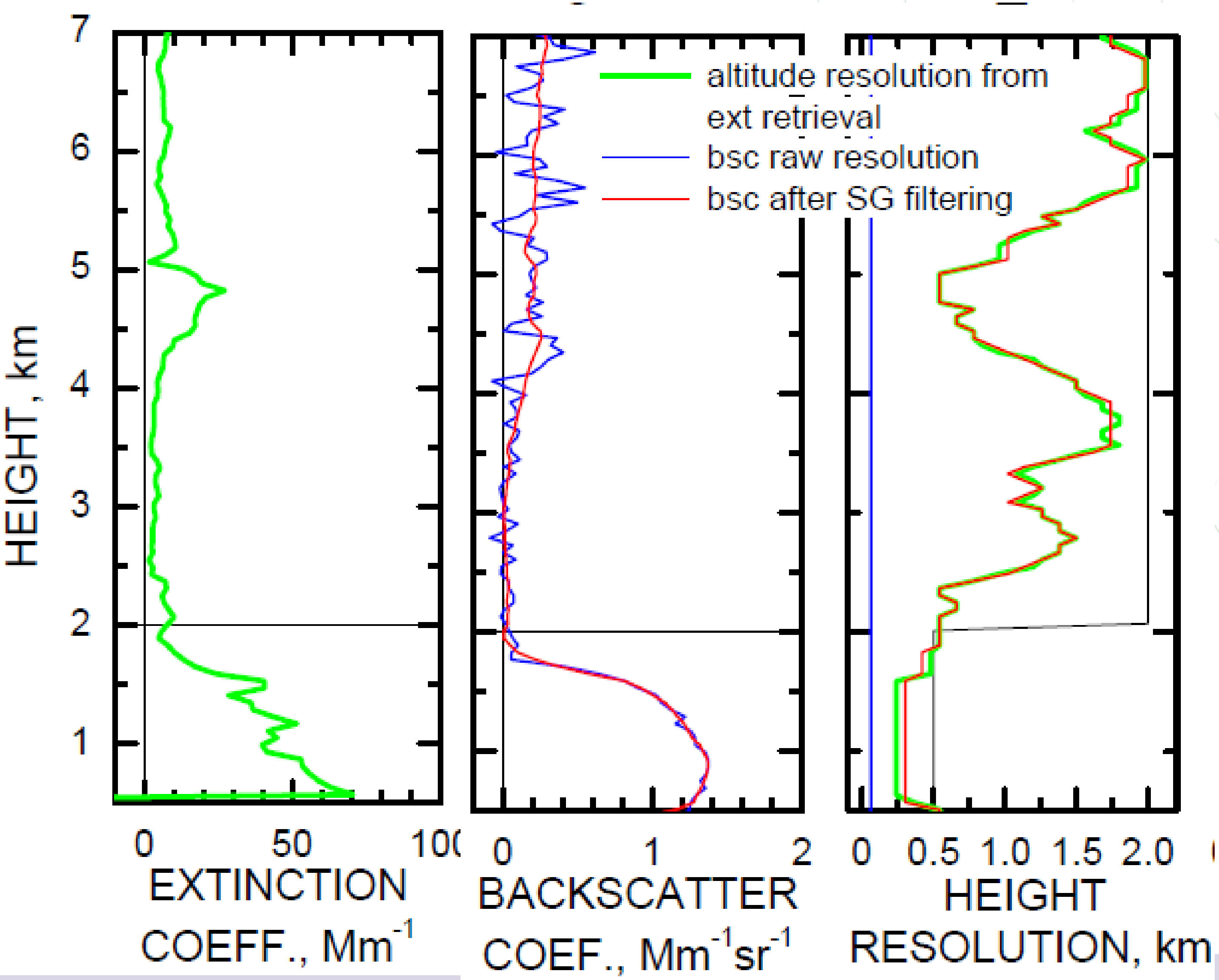
$$S^{\mathrm{par}}_{\lambda_0}(z) = \frac{\boxed{\alpha^{\mathrm{par}}_{\lambda_0}(z)}}{\boxed{\beta^{\mathrm{par}}_{\lambda_0}(z)}}$$

$\alpha^{\mathrm{par}}_{\lambda_0}(z)$ → “*extinction only*” product

$\beta^{\mathrm{par}}_{\lambda_0}(z)$ → “*Raman backscatter*” product

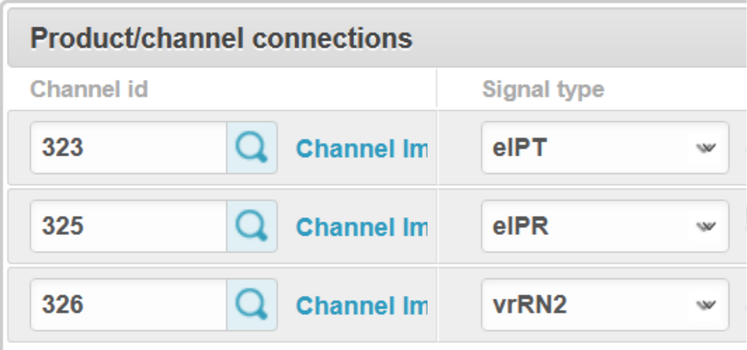
- ➔ Problem $\beta^{\mathrm{par}}_{\lambda_0}(z)$ usually has much higher vertical resolution than $\alpha^{\mathrm{par}}_{\lambda_0}(z)$
- ➔ solution: smooth $\beta^{\mathrm{par}}_{\lambda_0}(z)$ before calculating the ratio
  - 1) determine effective vertical resolution of
  - 2) smooth $\beta^{\mathrm{par}}_{\lambda_0}(z)$ with Savitzky-Golay filter to obtain the same effective vertical resolution

Effective vertical resolution



Parameter of «lidar ratio» product

- 2 elastic signals of types *elPT* + *elPR or* 1 elastic signal of type *elT*
- 1 Raman signal of type *vrRN2*
- Same as for corresponding Rbsc product



Product/channel connections

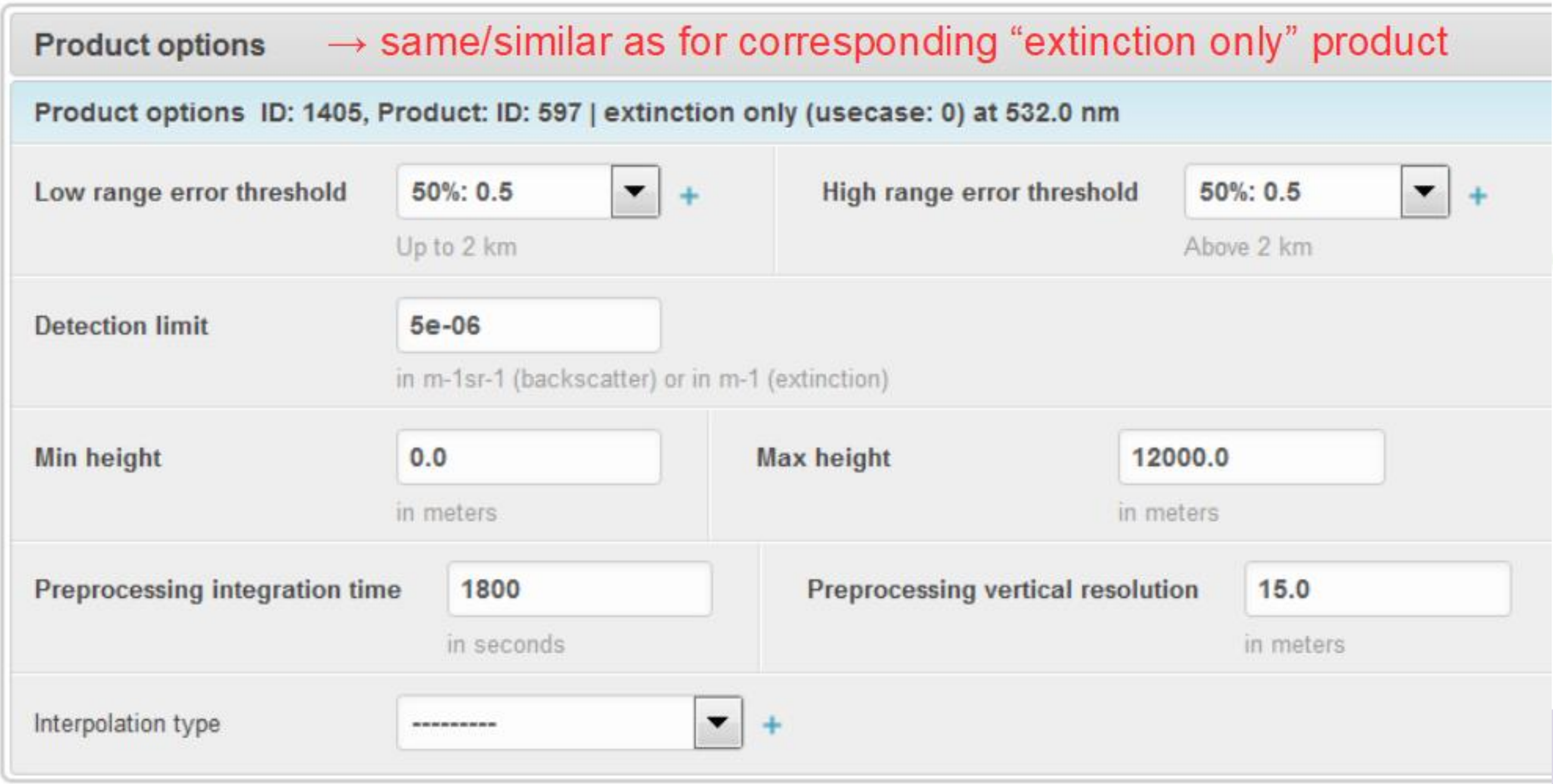
Channel id		Signal type
323	Channel Im	elPT
325	Channel Im	elPR
326	Channel Im	vrRN2

Parameter of «lidar ratio» product

- 2 elastic signals of types *elPT* + *elPR or* 1 elastic signal of type *elT*
- 1 Raman signal of type *vrRN2*
- Same as for corresponding Rbsc product

Product/channel connections

Channel id		Signal type
323	Channel Im	elPT
325	Channel Im	elPR
326	Channel Im	vrRN2



Product options → same/similar as for corresponding “extinction only” product

Product options ID: 1405, Product: ID: 597 | extinction only (usecase: 0) at 532.0 nm

Low range error threshold: 50%: 0.5 (Up to 2 km)

High range error threshold: 50%: 0.5 (Above 2 km)

Detection limit: 5e-06 (in m-1sr-1 (backscatter) or in m-1 (extinction))

Min height: 0.0 (in meters)

Max height: 12000.0 (in meters)

Preprocessing integration time: 1800 (in seconds)

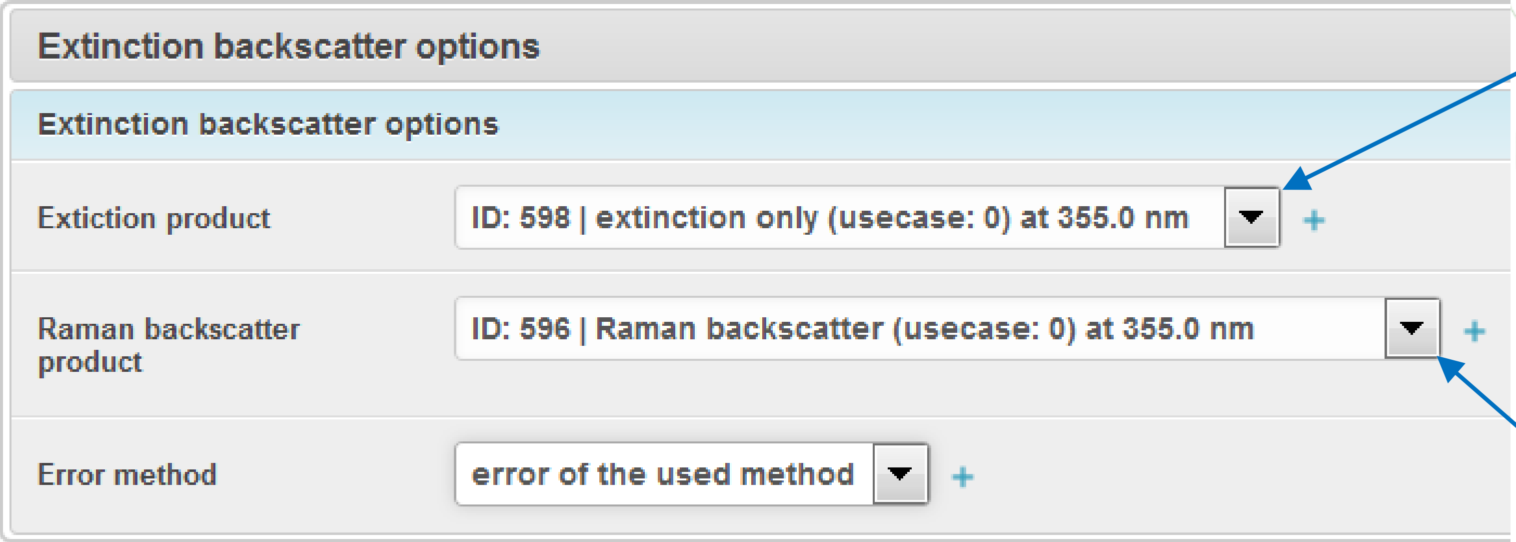
Preprocessing vertical resolution: 15.0 (in meters)

Interpolation type: ----------

Paramater of «lidar ratio» product

select a link

- previously defined “extinction only” product
- extinction parameters (e.g. method) of this product are used
- same wavelength!



Extinction backscatter options

Extinction backscatter options

Extiction product: ID: 598 | extinction only (usecase: 0) at 355.0 nm

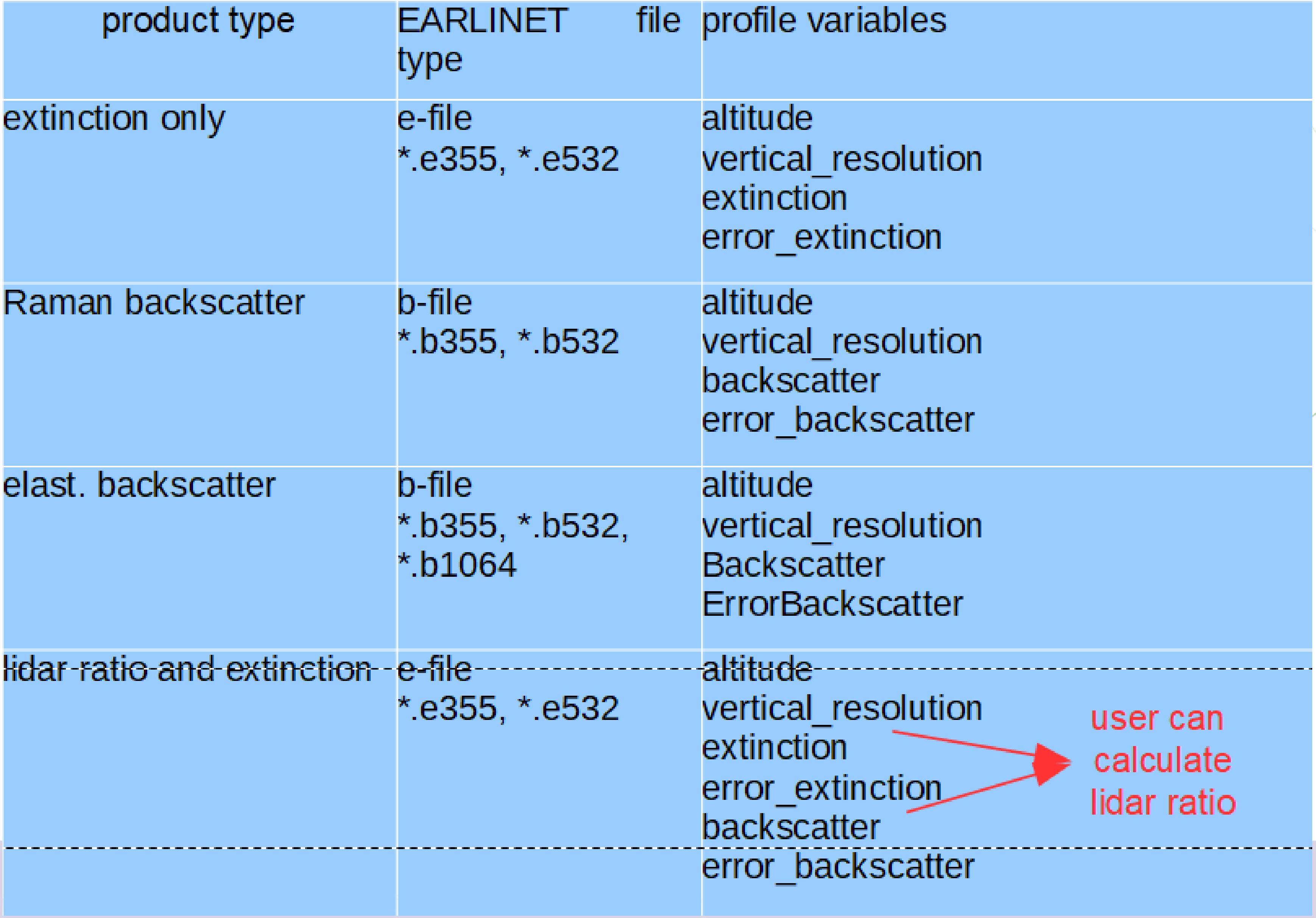
Raman backscatter product: ID: 596 | Raman backscatter (usecase: 0) at 355.0 nm

Error method: error of the used method

select a link

- previously defined “Raman backscatter” product
- Raman bsc parameters (e.g. calibration) of this product are used
- same wavelength!

Output of different product types (netCDF files in EARLINET format)



product type	EARLINET file type	profile variables
extinction only	e-file *.e355, *.e532	altitude vertical_resolution extinction error_extinction
Raman backscatter	b-file *.b355, *.b532	altitude vertical_resolution backscatter error_backscatter
elast. backscatter	b-file *.b355, *.b532, *.b1064	altitude vertical_resolution Backscatter ErrorBackscatter
lidar ratio and extinction	e-file *.e355, *.e532	altitude vertical_resolution extinction error_extinction backscatter error_backscatter

user can calculate lidar ratio

Which product types shall I use?

There are product types:

- “extinction only”
- “lidar ratio and extinction”
- “Raman backscatter”

Isn’t it enough to use the “lidar ratio” product?
Because it contains extinction and backscatter?
→ *NO!*

Which product types shall I use?

There are product types:

- ~~“extinction only”~~ → needed only if elast. signal not available
- “lidar ratio and extinction”
- “Raman backscatter”

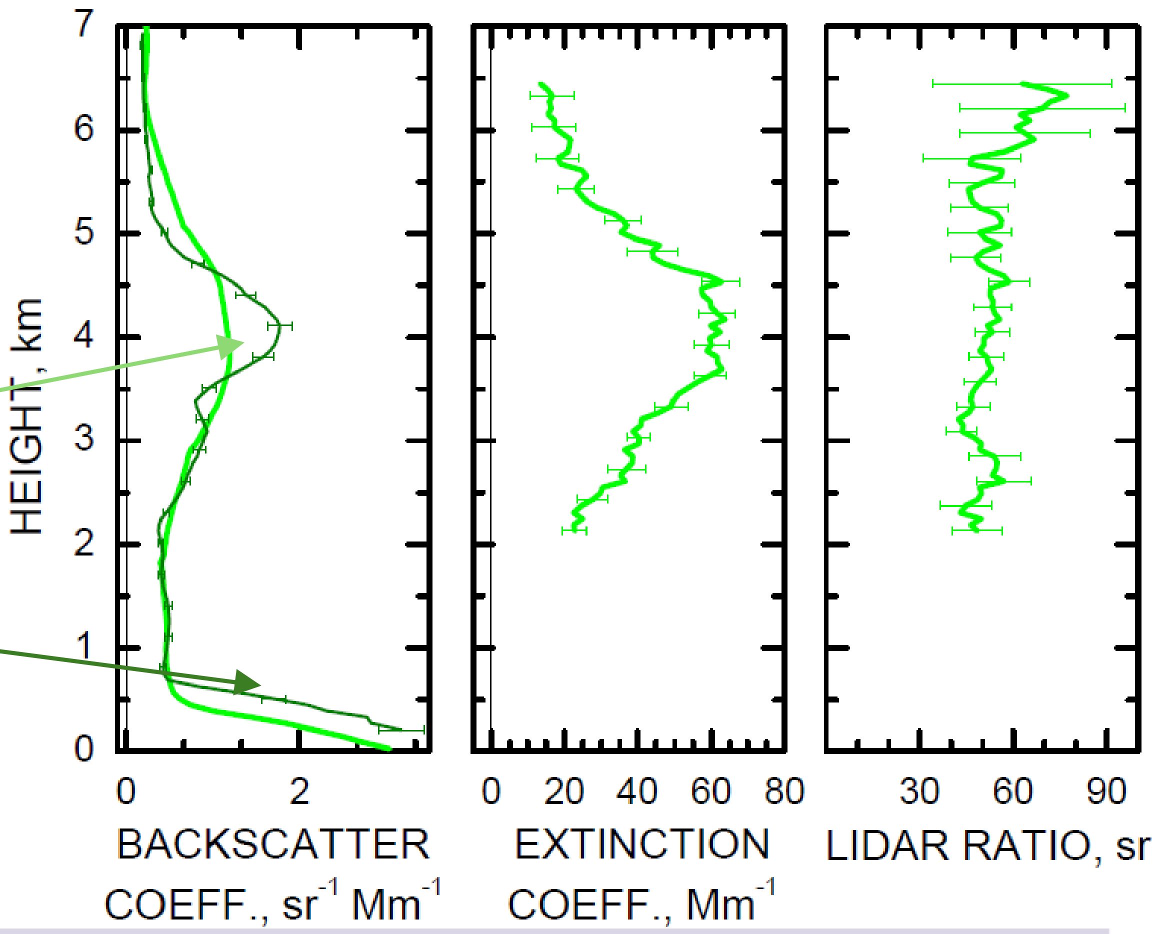
Isn’t it enough to use the “lidar ratio” product?
Because it contains extinction and backscatter?
→ *NO!*

Which product types shall I use?

There are product types:

- ~~“extinction only”~~ → needed only if elast. signal not available
- “lidar ratio and extinction” → ext + bsc **profile with low resolution**
- “Raman backscatter” → bsc profile **with high resolution**

Isn’t it enough to use the “lidar ratio” product?
Because it contains extinction and backscatter?
→ *NO!*



β-smooth in e-file
for *S*, *å*, etc.

β-high-res in b-file
e.g., for layer detection

- «Raman backscatter and depolarization» product
- «Elastic backscatter and depolarization» product

Equations

- Volume linear depolarization ratio (VLDR)

$$\delta=\frac{\delta^{*}(G_T+H_T)-(G_R+H_R)}{(G_R-H_R)-\delta^{*}(G_T-H_T)}$$

with

apparent VLDR

calibr. factor correction

$$\delta^{*}=\frac{K}{\eta^{*}}\frac{I_R}{I_T}$$

reflected signal

transmitted signal

apparent calibration factor

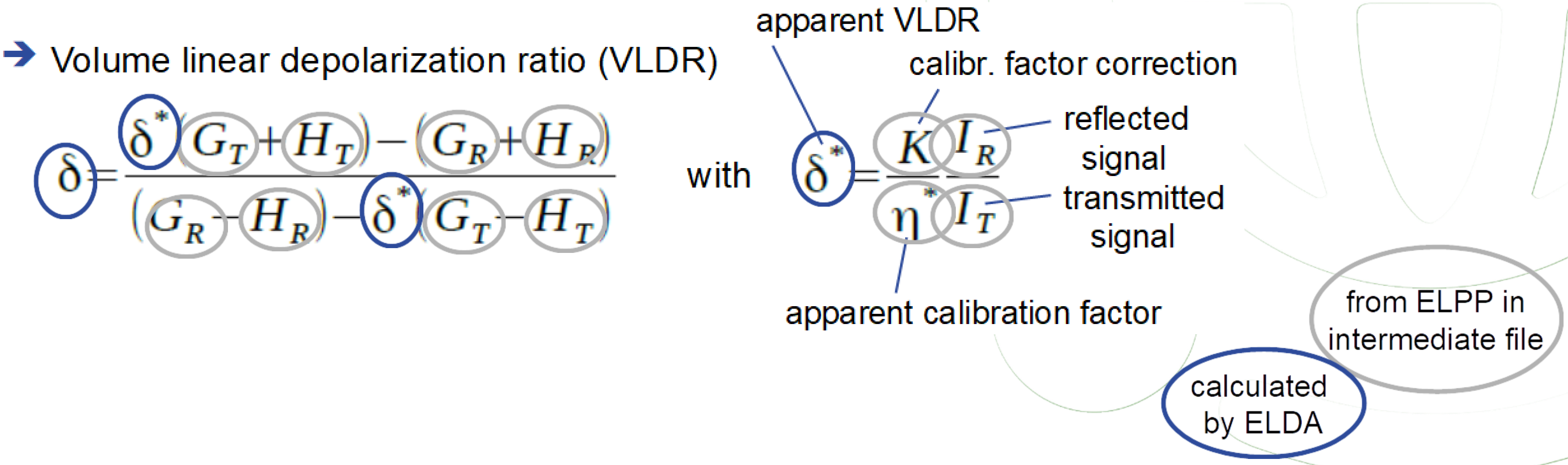
Equations

- Volume linear depolarization ratio (VLDR)

$$\delta = \frac{\delta^{*}(G_T + H_T) - (G_R + H_R)}{(G_R - H_R) - \delta^{*}(G_T - H_T)}$$

with

$$\delta^{*} = \frac{K}{\eta^{*}} \frac{I_R}{I_T}$$



apparent VLDR

calibr. factor correction

reflected signal

transmitted signal

apparent calibration factor

from ELPP in intermediate file

calculated by ELDA

Equations

- ➔ Volume linear depolarization ratio (VLDR)

$$\delta = \frac{\delta^{*}(G_T + H_T) - (G_R + H_R)}{(G_R - H_R) - \delta^{*}(G_T - H_T)}$$

with

apparent VLDR

calibr. factor correction

$$\delta^{*} = \frac{K}{\eta^{*}} \frac{I_R}{I_T}$$

reflected signal

transmitted signal

apparent calibration factor

from ELPP in intermediate file

calculated by ELDA

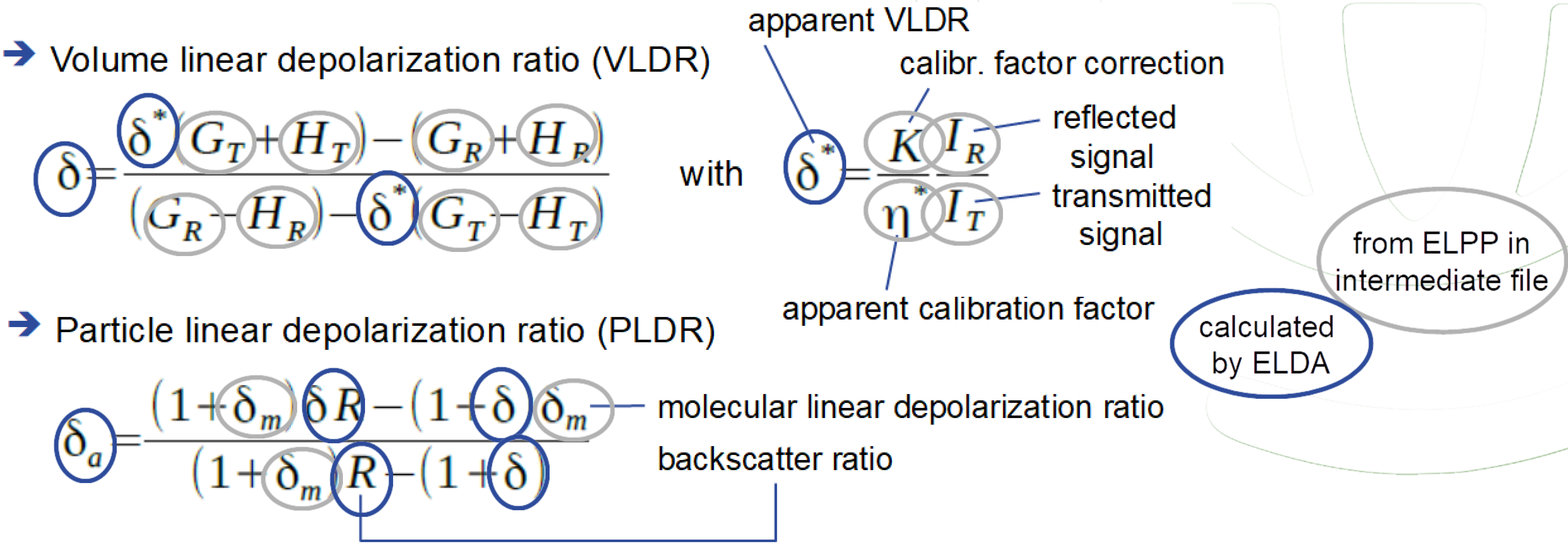
- ➔ Particle linear depolarization ratio (PLDR)

$$\delta_a = \frac{(1+\delta_m)\,\delta R - (1+\delta)\,\delta_m}{(1+\delta_m)\,R - (1+\delta)}$$

molecular linear depolarization ratio

backscatter ratio

Equations



- Volume linear depolarization ratio (VLDR)

$$\delta = \frac{\delta^*(G_T + H_T) - (G_R + H_R)}{(G_R - H_R) - \delta^*(G_T - H_T)}$$

with

$$\delta^* = \frac{K}{\eta^*}\frac{I_R}{I_T}$$

apparent VLDR

calibr. factor correction

reflected signal

transmitted signal

apparent calibration factor

from ELPP in intermediate file

calculated by ELDA

- Particle linear depolarization ratio (PLDR)

$$\delta_a = \frac{(1+\delta_m)\delta R - (1+\delta)\delta_m}{(1+\delta_m)R - (1+\delta)}$$

molecular linear depolarization ratio

backscatter ratio

Equations

- Volume linear depolarization ratio (VLDR)

$$\delta = \frac{\delta^*(G_T + H_T) - (G_R + H_R)}{(G_R - H_R) - \delta^*(G_T - H_T)}$$

with

$$\delta^* = \frac{K}{\eta^*}\frac{I_R}{I_T}$$

apparent VLDR

calibr. factor correction

reflected signal

transmitted signal

apparent calibration factor

from ELPP in intermediate file

calculated by ELDA

- Particle linear depolarization ratio (PLDR)

$$\delta_a = \frac{(1+\delta_m)\delta R - (1+\delta)\delta_m}{(1+\delta_m)R - (1+\delta)}$$

molecular linear depolarization ratio

backscatter ratio

- Total signal

$$I_{total} \propto \frac{\frac{\eta^*}{K} H_R I_T - H_T I_R}{H_R G_T - H_T G_R}$$

Equations

ITINERIS

- Volume linear depolarization ratio (VLDR)

$$\delta = \frac{\delta^*(G_T + H_T) - (G_R + H_R)}{(G_R - H_R) - \delta^*(G_T - H_T)}$$

with

apparent VLDR

calibr. factor correction

$$\delta^* = \frac{K}{\eta^*}\frac{I_R}{I_T}$$

reflected signal

transmitted signal

apparent calibration factor

- Particle linear depolarization ratio (PLDR)

$$\delta_a = \frac{(1+\delta_m)\delta R - (1+\delta)\delta_m}{(1+\delta_m)R - (1+\delta)}$$

molecular linear depolarization ratio

backscatter ratio

from ELPP in intermediate file

calculated by ELDA

- Total signal

$$I_{total} \propto \frac{\frac{\eta^*}{K} H_R I_T - H_T I_R}{H_R G_T - H_T G_R}$$

Freudenthaler et al., *AMT*, 2016

D'Amico, "Implementation of particle linear depolarization ratio calculation in the SCC"

Retrieval of VLDR and PLDR

1) if no total signal is measured:

    calculate total signal from I_T and I_R

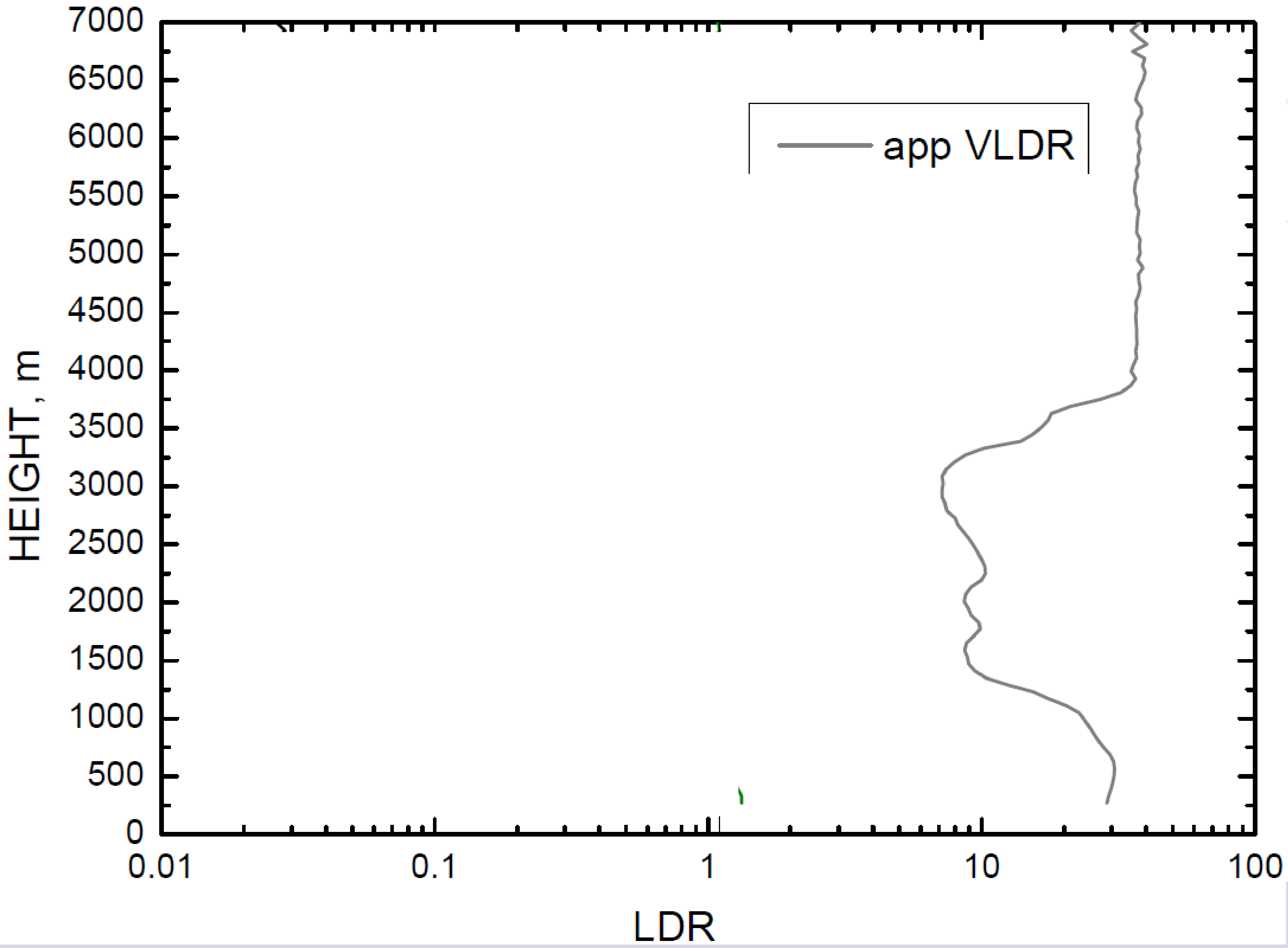
   else:

    use total signal for backscatter retrieval

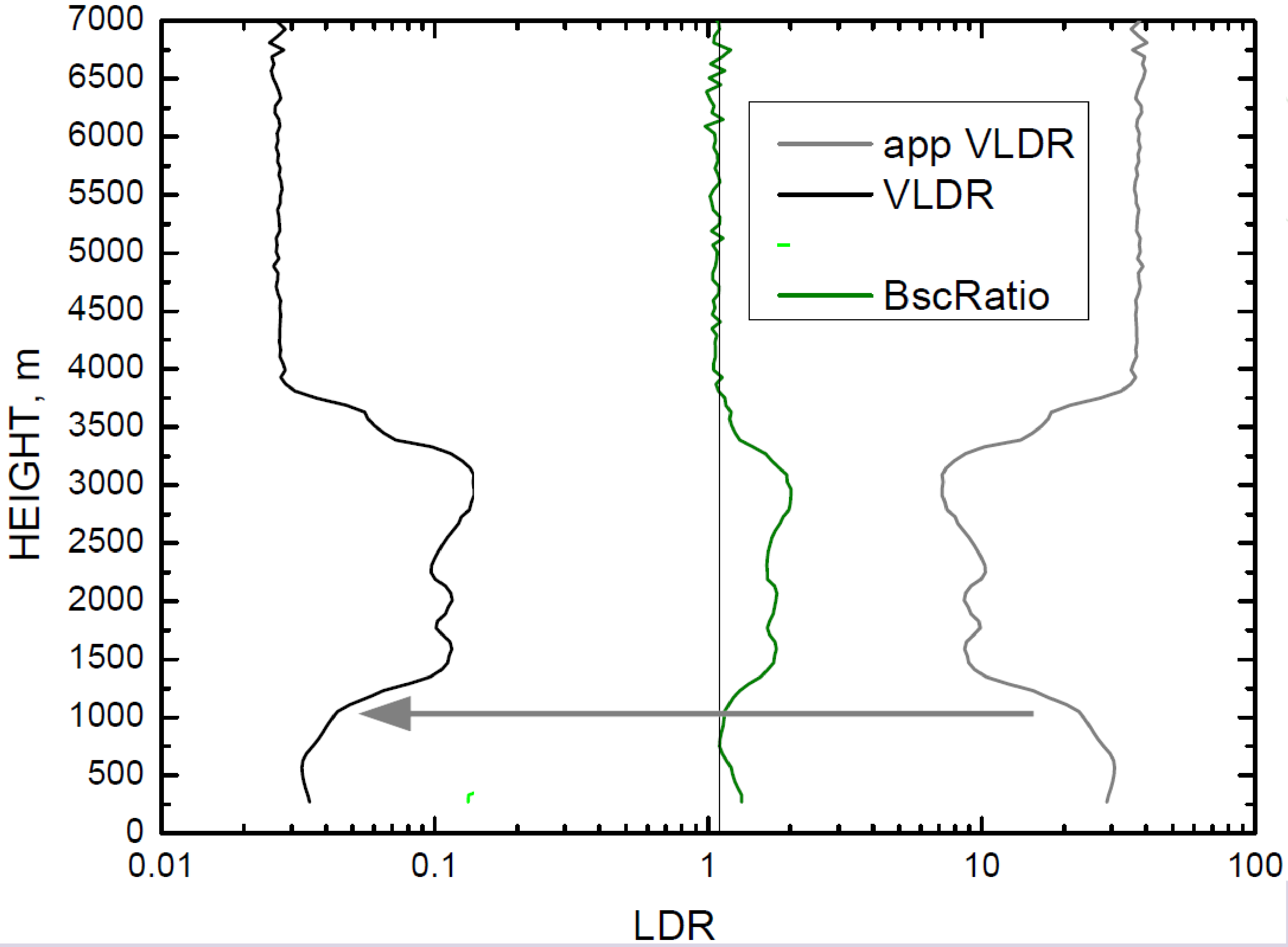
2) calculate VLDR, particle backscatter coefficient, and backscatter ratio *R* with same vertical resolution

3) calculate PLDR from VLDR and BscRatio

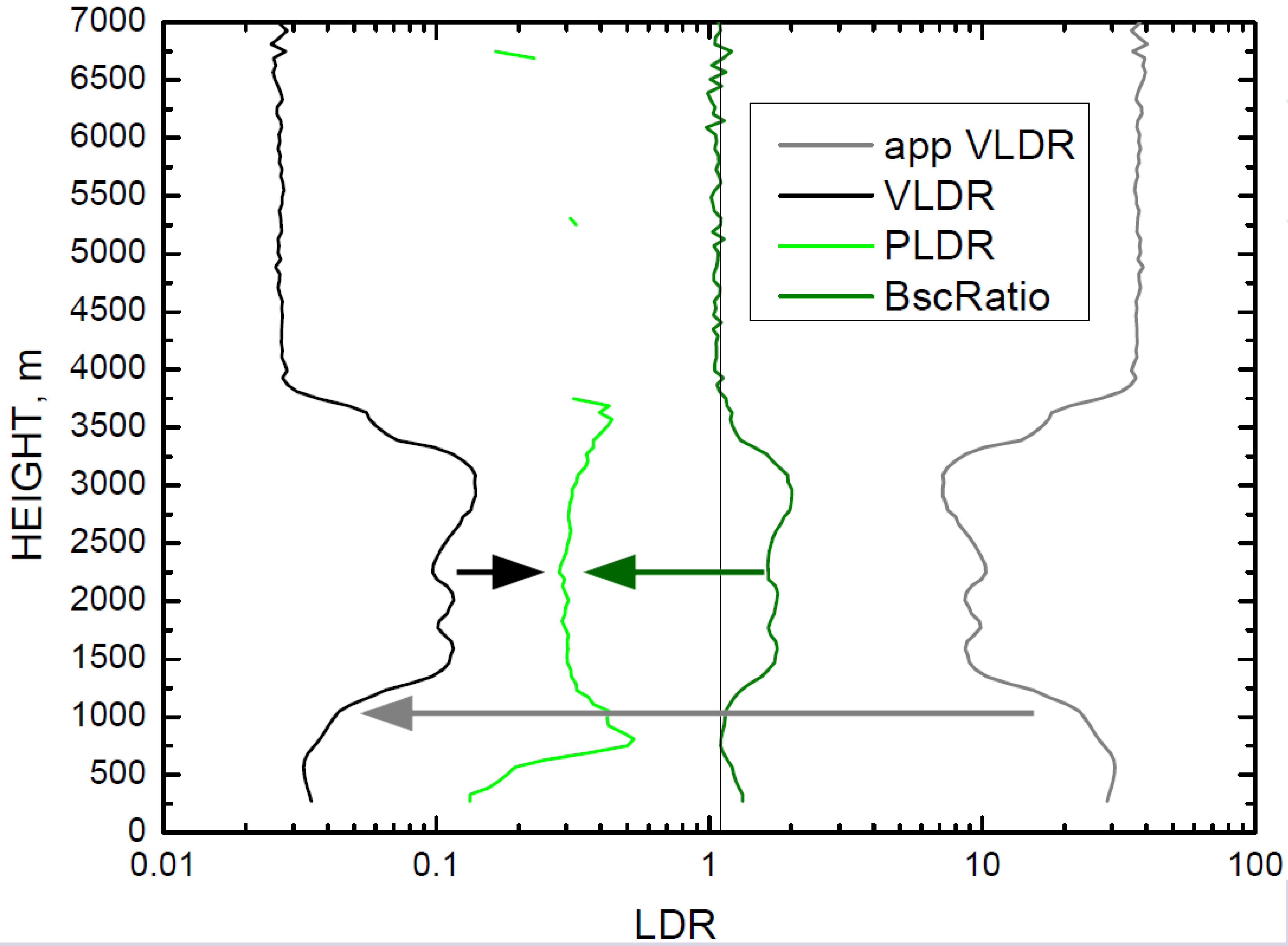
Retrieval of VLDR and PLDR



Retrieval of VLDR and PLDR



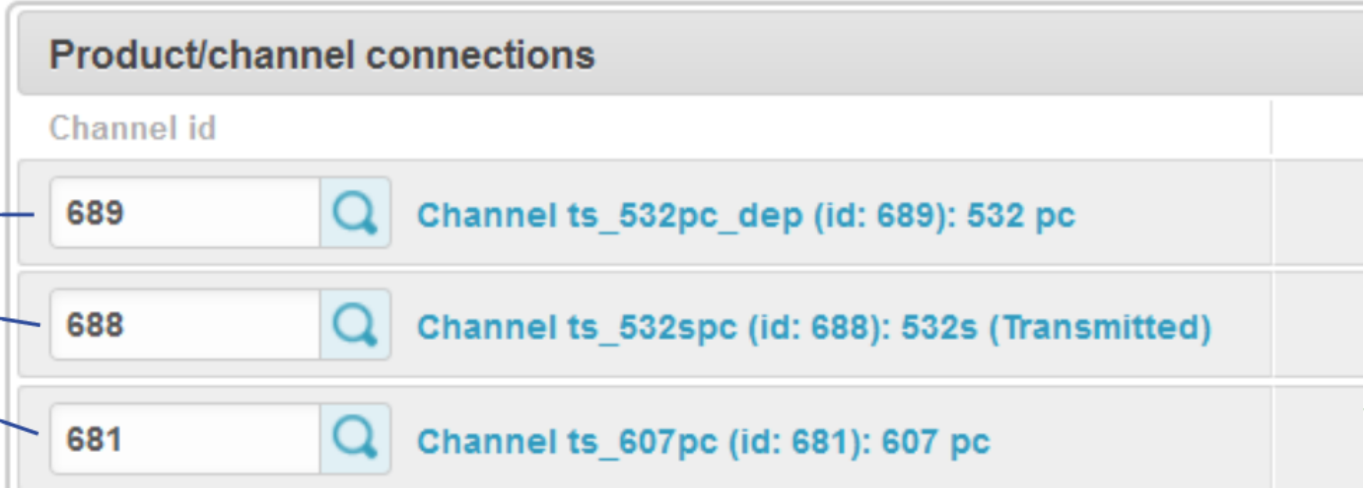
Retrieval of VLDR and PLDR



Parameters of VLDR and PLDR

Channels

- reflected elPR
- transmitted elPT
- (Raman vrRN2)



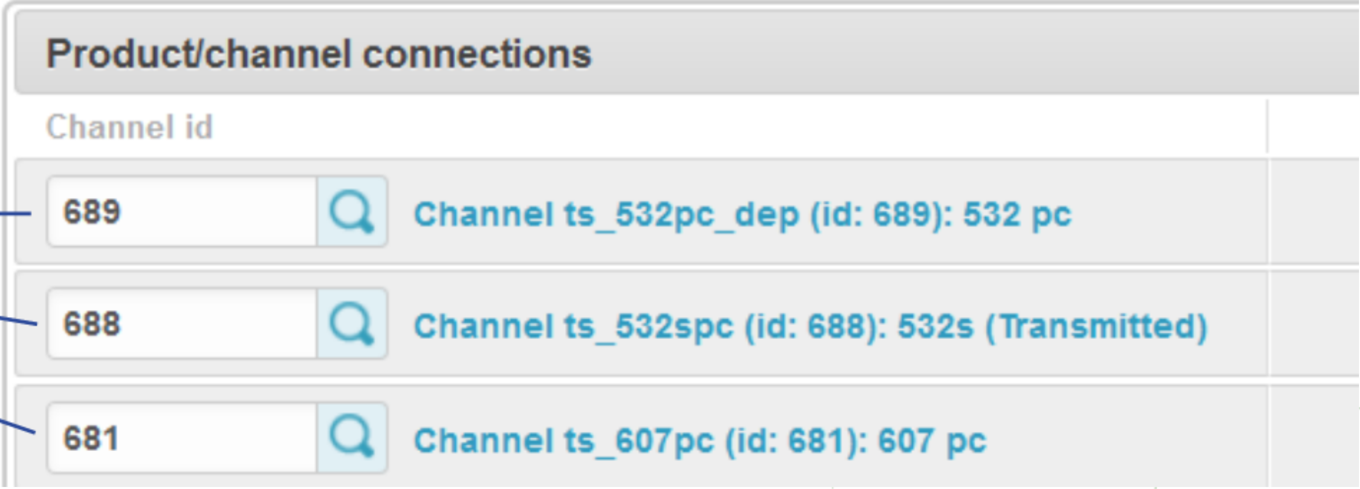
Product/channel connections

Channel id	
689	Channel ts_532pc_dep (id: 689): 532 pc
688	Channel ts_532spc (id: 688): 532s (Transmitted)
681	Channel ts_607pc (id: 681): 607 pc

Parameters of VLDR and PLDR

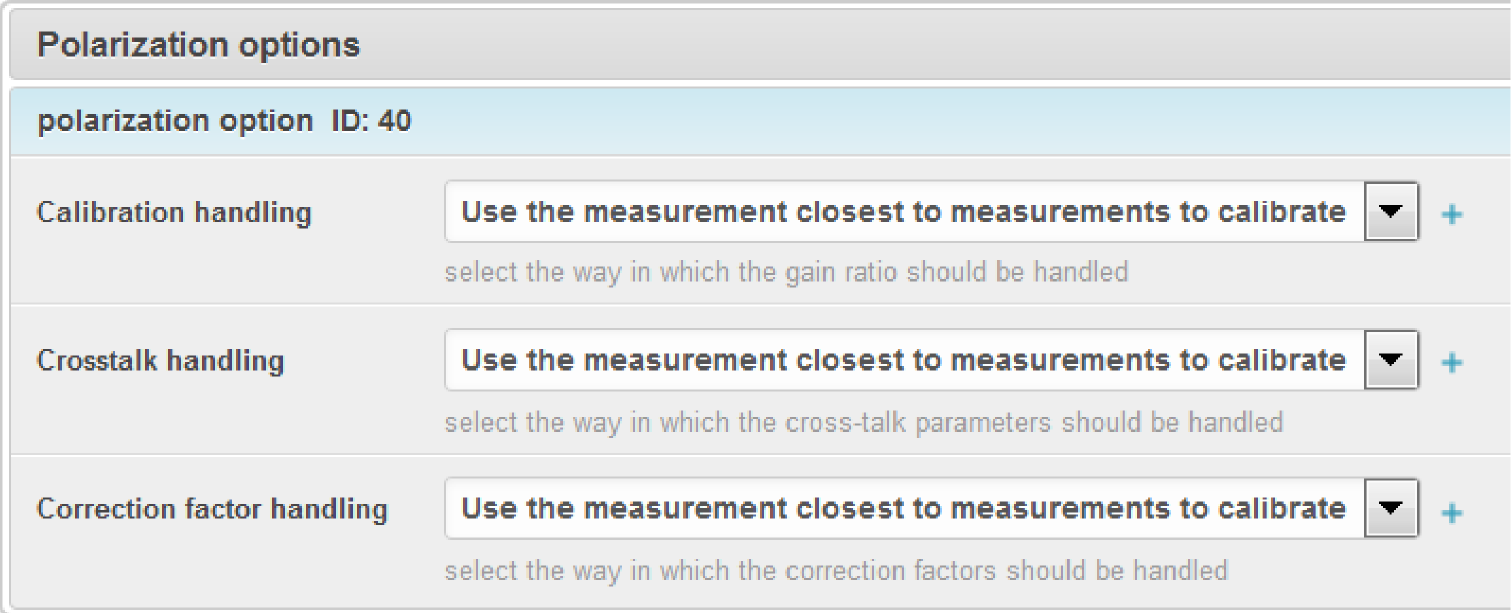
Channels

- reflected elPR
- transmitted elPT
- (Raman vrRN2)



Product/channel connections

Channel id	
689	Channel ts_532pc_dep (id: 689): 532 pc
688	Channel ts_532spc (id: 688): 532s (Transmitted)
681	Channel ts_607pc (id: 681): 607 pc



Polarization options

polarization option ID: 40

Calibration handling: Use the measurement closest to measurements to calibrate
select the way in which the gain ratio should be handled

Crosstalk handling: Use the measurement closest to measurements to calibrate
select the way in which the cross-talk parameters should be handled

Correction factor handling: Use the measurement closest to measurements to calibrate
select the way in which the correction factors should be handled

How to derive polarization parameters from all available measurements?

● use most recent measurement

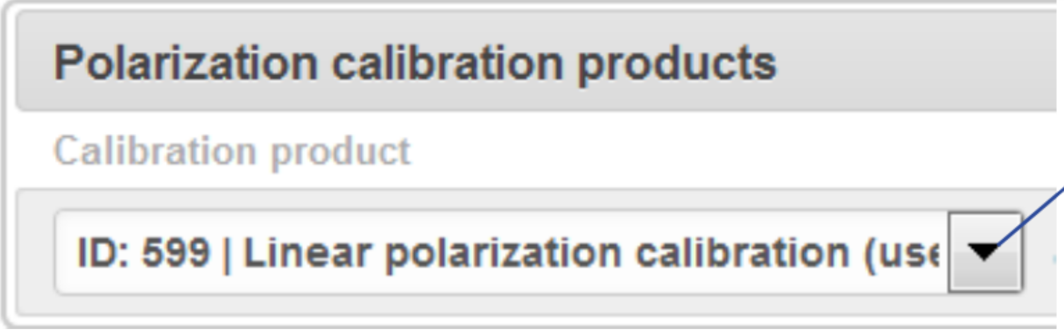
● use the calibration closest to the measurement (default)

● use an average of all measurements

Parameters of VLDR and PLDR

select a link

- previously defined “depolarization calibration” product



Polarization calibration products

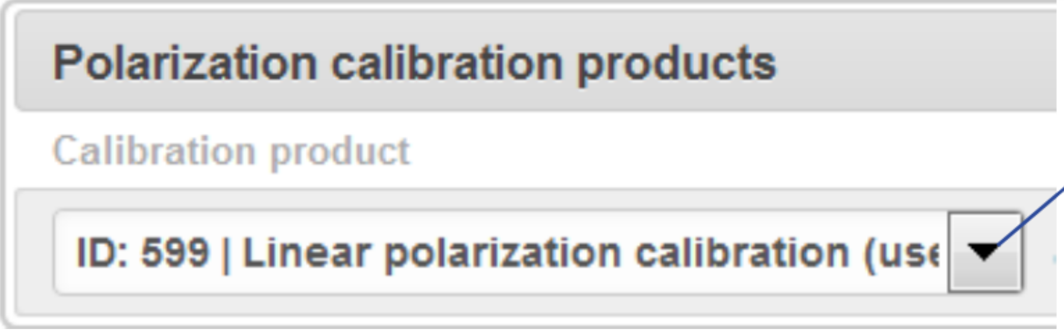
Calibration product

ID: 599 | Linear polarization calibration (use

Parameters of VLDR and PLDR

select a link

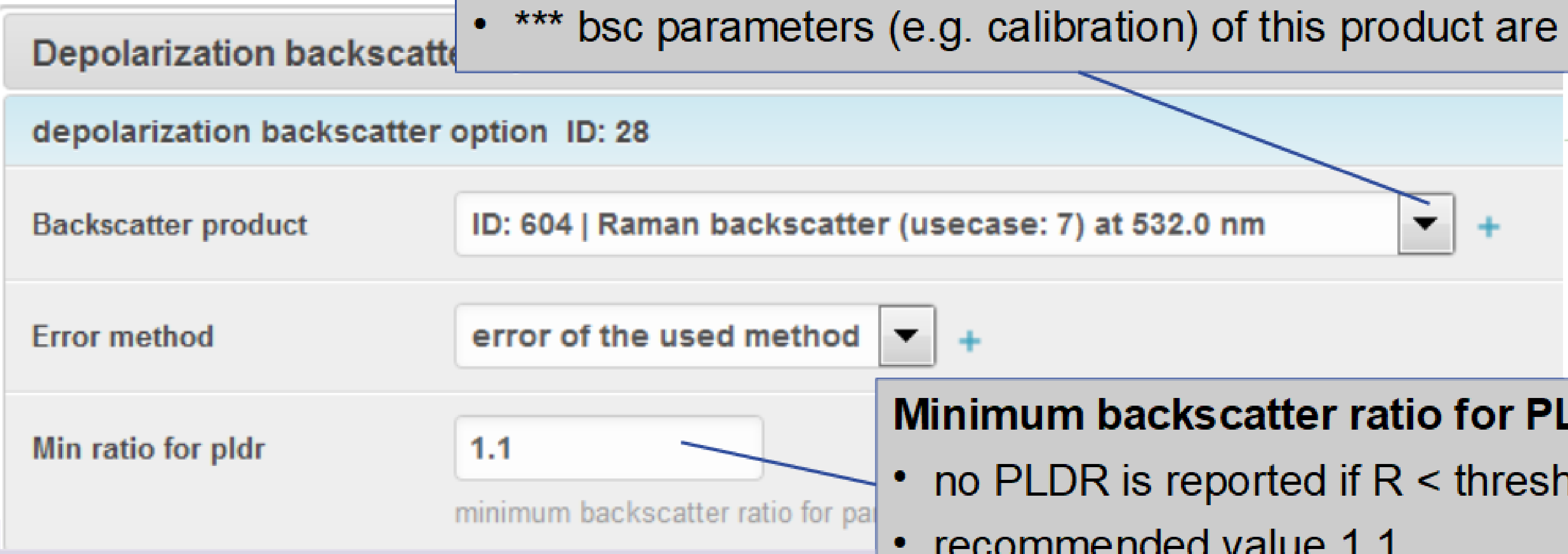
- previously defined “depolarization calibration” product



Polarization calibration products

Calibration product

ID: 599 | Linear polarization calibration (use



Depolarization backscatte

depolarization backscatter option ID: 28

Backscatter product: ID: 604 | Raman backscatter (usecase: 7) at 532.0 nm

Error method: error of the used method

Min ratio for pldr: 1.1

minimum backscatter ratio for pa

select a link

- previously defined “ *** backscatter” product
- *** bsc parameters (e.g. calibration) of this product are used

Minimum backscatter ratio for PLDR

- no PLDR is reported if R < threshold
- recommended value 1.1

Min backscatter ratio for PLDR

$$\delta_a = \frac{(1+\delta_m)\delta R - (1+\delta)\delta_m}{(1+\delta_m)R - (1+\delta)}$$

layers with low aerosol content

- $\beta_p << \beta_m$
- $R \approx 1$
- $\delta \approx \delta_m$

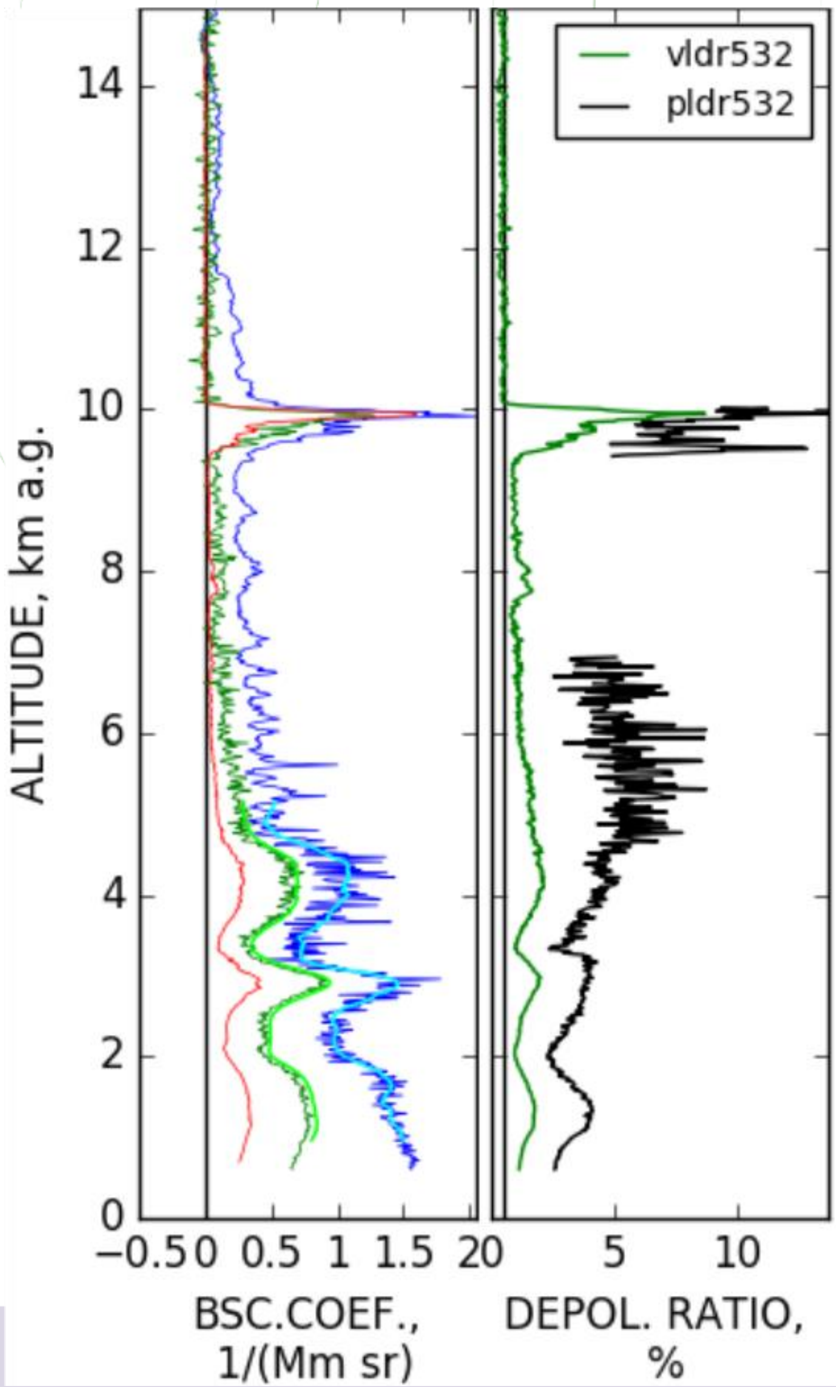
Min backscatter ratio for PLDR

$$\delta_a = \frac{(1+\delta_m)\delta R - (1+\delta)\delta_m}{(1+\delta_m)R - (1+\delta)} = \boxed{\frac{\approx 0}{\approx 0}}$$

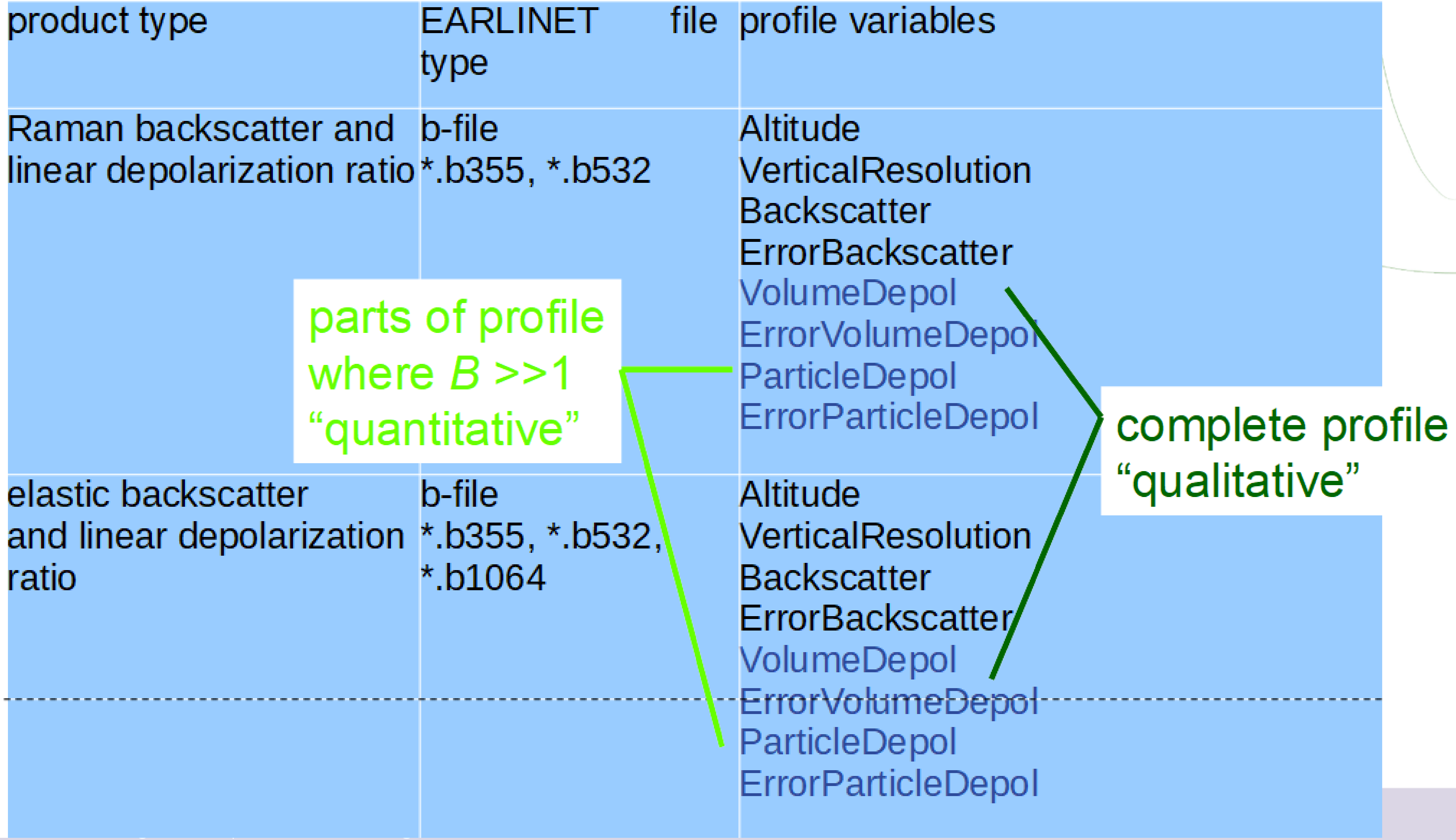
layers with low aerosol content

- $\beta_p << \beta_m$
- $R \approx 1$
- $\delta \approx \delta_m$

➡ *Skip those parts of the profile*



Output of different product types (netCDF files in EARLINET format)

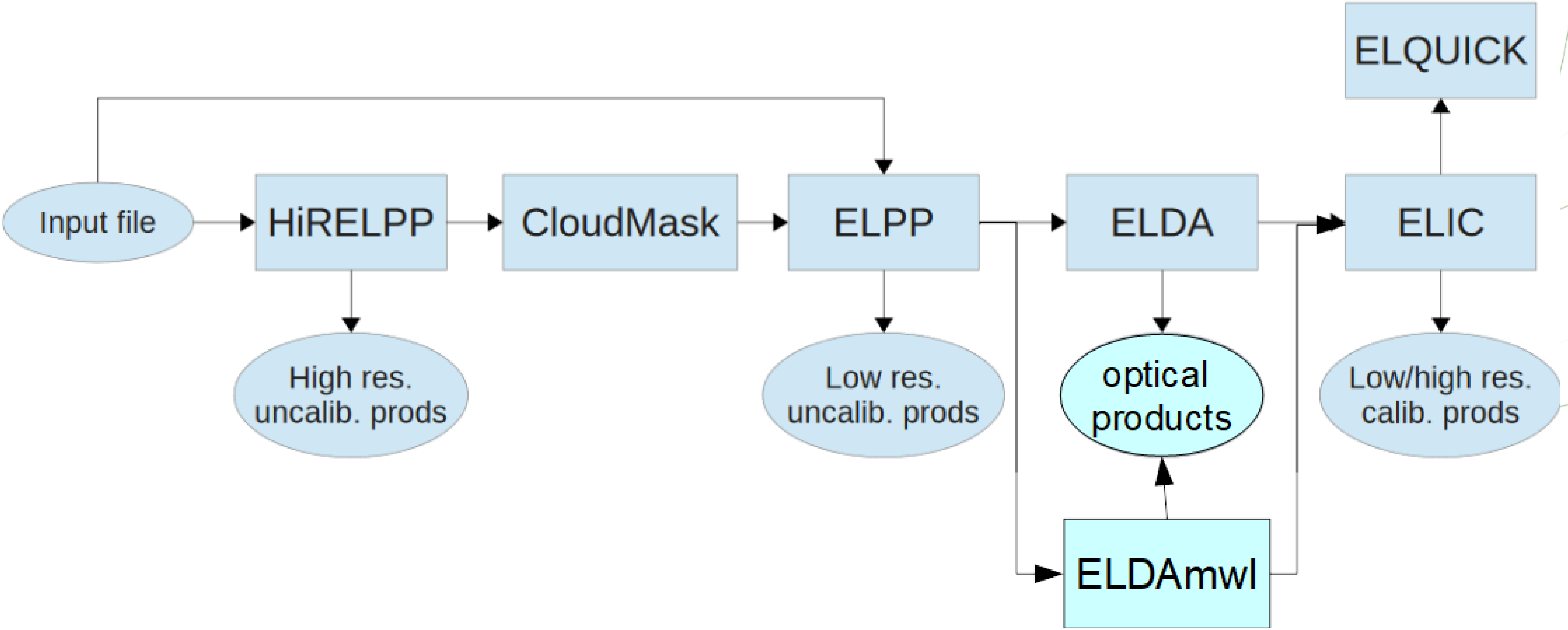


product type	EARLINET file type	profile variables
Raman backscatter and linear depolarization ratio	b-file *.b355, *.b532	Altitude VerticalResolution Backscatter ErrorBackscatter VolumeDepol ErrorVolumeDepol ParticleDepol ErrorParticleDepol
elastic backscatter and linear depolarization ratio	b-file *.b355, *.b532, *.b1064	Altitude VerticalResolution Backscatter ErrorBackscatter VolumeDepol ErrorVolumeDepol ParticleDepol ErrorParticleDepol

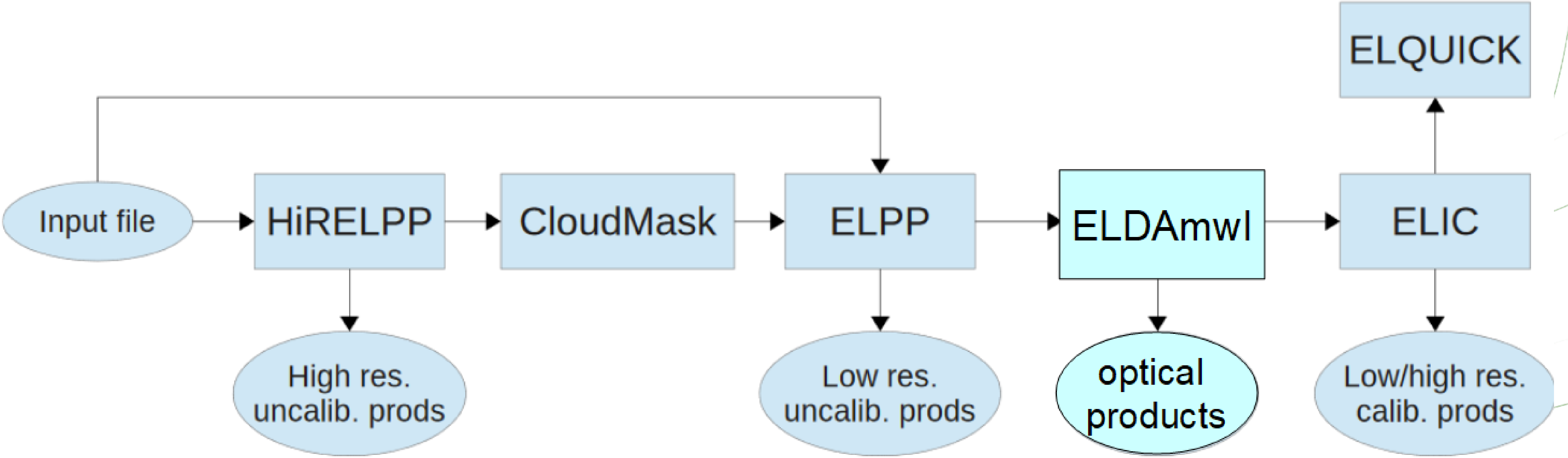
parts of profile
where B >>1
“quantitative”

complete profile
“qualitative”

Outlook


ELQUICK
Input file
HiRELPP
CloudMask
ELPP
ELDA
ELIC
High res.
uncalib. prods
Low res.
uncalib. prods
optical
products
Low/high res.
calib. prods
ELDAmwl

Outlook



Input file

HiRELPP

CloudMask

ELPP

ELDAmwl

ELIC

ELQUICK

High res.
uncalib. prods

Low res.
uncalib. prods

optical
products

Low/high res.
calib. prods

Outlook - ELDAmwl

To provide optical data at several wavelengths on fixed grids

- **Improvements compared to ELDA:**
  - All products on fixed grids
  - mwl backscatter calibration with Rayleigh fit by V. Freudenthaler
  - New, improved algorithm for lidar constants
  - mwl quality control
    - Skip un-physical data
    - Skip noisy data
    - …
    - Attach flags
  - Output file with
    - All basic products (backscatter, extinction, VLDR)
    - All derived products (lidar ratio, PLDR, …)
    - Meta data (for expert use)

Outlook - ELDAmwl

- **Sustainability:**
  - Use Python (widely used, many tools and packages)
  - Support from IT experts for code design
  - Automatic test procedures
  - Automatic documentation
  - Easy installation / updates with virtual environment & package management (poetry)
  - Training for Pilar as second developer (2023)

https://github.com/actris-scc/ELDAmwl

ITINERIS

THANKS!

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Ministero dell'Università e della Ricerca

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