Status / Development of a GRUAN Lidar Data Stream

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GRUAN Lidar Programme

Definition

The overall infrastructure underlying the lidar measurement and the subsequent production of a GRUAN lidar product, from data acquisition to data product management.

Domains of application

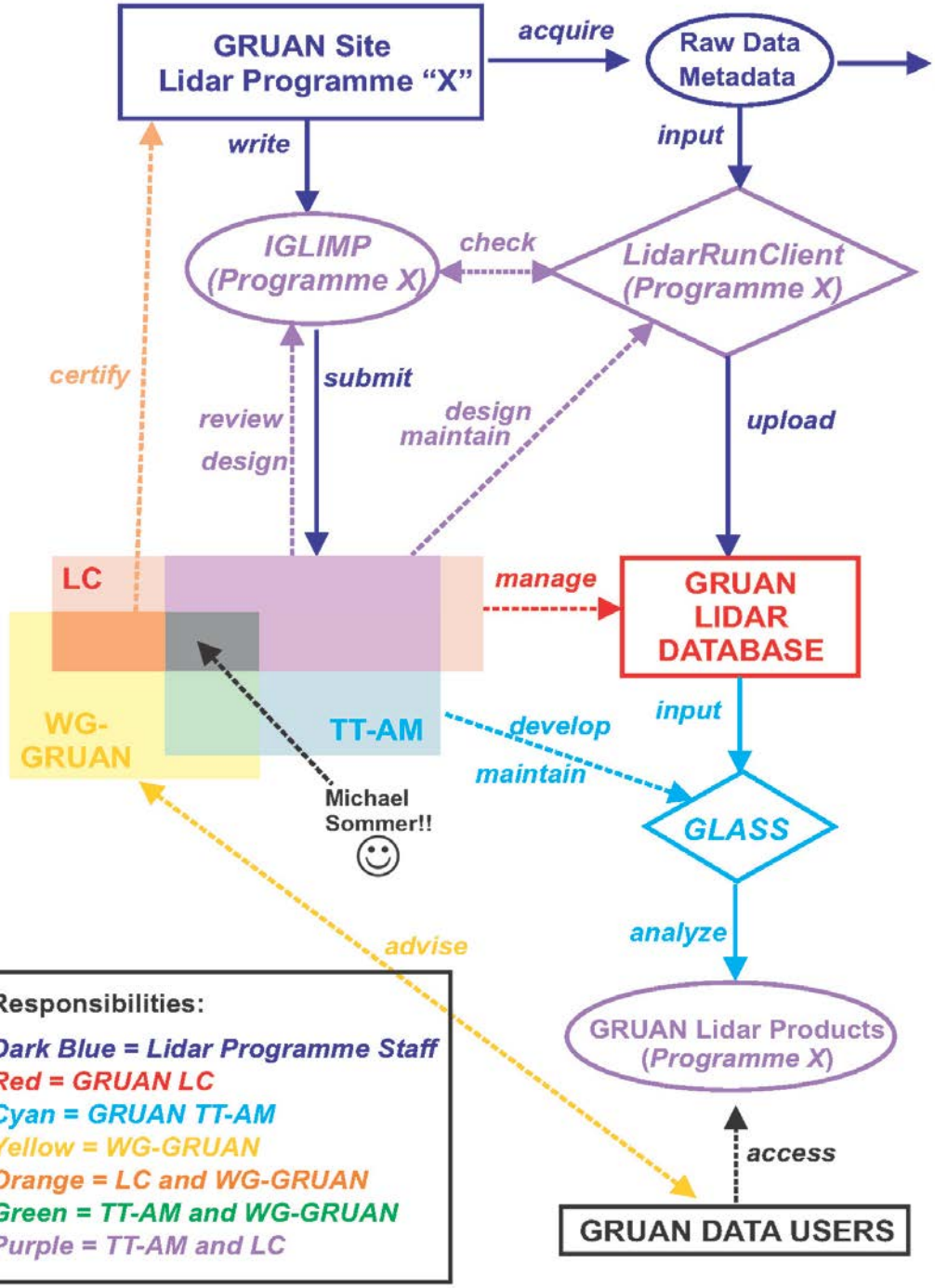
Setup, modification and maintenance of the instrumentation, the standard operating procedures for the acquisition of the raw data and the lidar calibration, and the complete and homogenized upload of the raw data and meta-data onto the GRUAN lidar data handling center for subsequent centralized processing

Mandatory components

- *The **GRUAN Lidar Guide** defining the complete framework of the Programme, from instrumentation to retrieval* ☺
- *A lidar instrument* ☺
- *Dedicated and motivated staff* ☺
- *An Individual GRUAN Lidar Instrumentation and Measurement Protocol (**IGLIMP**)*
- *The **LidarRunClient** utility for traceable data and meta data recording and upload*
- *The centralized GRUAN Lidar Analysis Software Suite (**GLASS**) for consistent data processing*

GRUAN

Lidar Programme Modus Operandi



Progress Summary on Required Components

GRUAN Lidar Guide

***0 % of this presentation**: No progress in 2013.*
Progress to resume mid-2014 with anticipated finalization late 2014

Lidar Instrument

***0 % of this presentation**: Potential GRUAN lidar sites are well-known*

IGLIMP

***0 % of this presentation**: No progress in 2013.*
Will be finalized based upon completion of all other components of the Programme

LidarRunClient Utility

***20 % of this presentation**: Overview of the first version of the GRUAN LidarRunClient*

GRUAN Lidar Analysis Software Suite (GLASS)

75 % of this presentation: Uncertainty Budget
Large heritage from the results of the ISSI Team on NDACC Lidar Algorithms,
In this presentation: reviewing selected material which is currently being compiled in 3 AMT papers (under preparation) and a 90 pp Report (under revision)

5 % of this presentation: The first-ever GRUAN Lidar Product
from Payerne! (for your eyes only… ☺)

LidarRunClient

Concept

Concept and design similar to that of RsLaunchClient, w/ additional functionality adapted to multiple lidar channels

Essential for Raw data and Meta Data Uploading / Archiving

PRD upload onto GRUAN data archive center must be performed using LidarRunClient

No PRD shall be accepted if not uploaded through LidarRunClient

Uploading frequency

Non-continuously-operated lidars: immediately after each measurement period

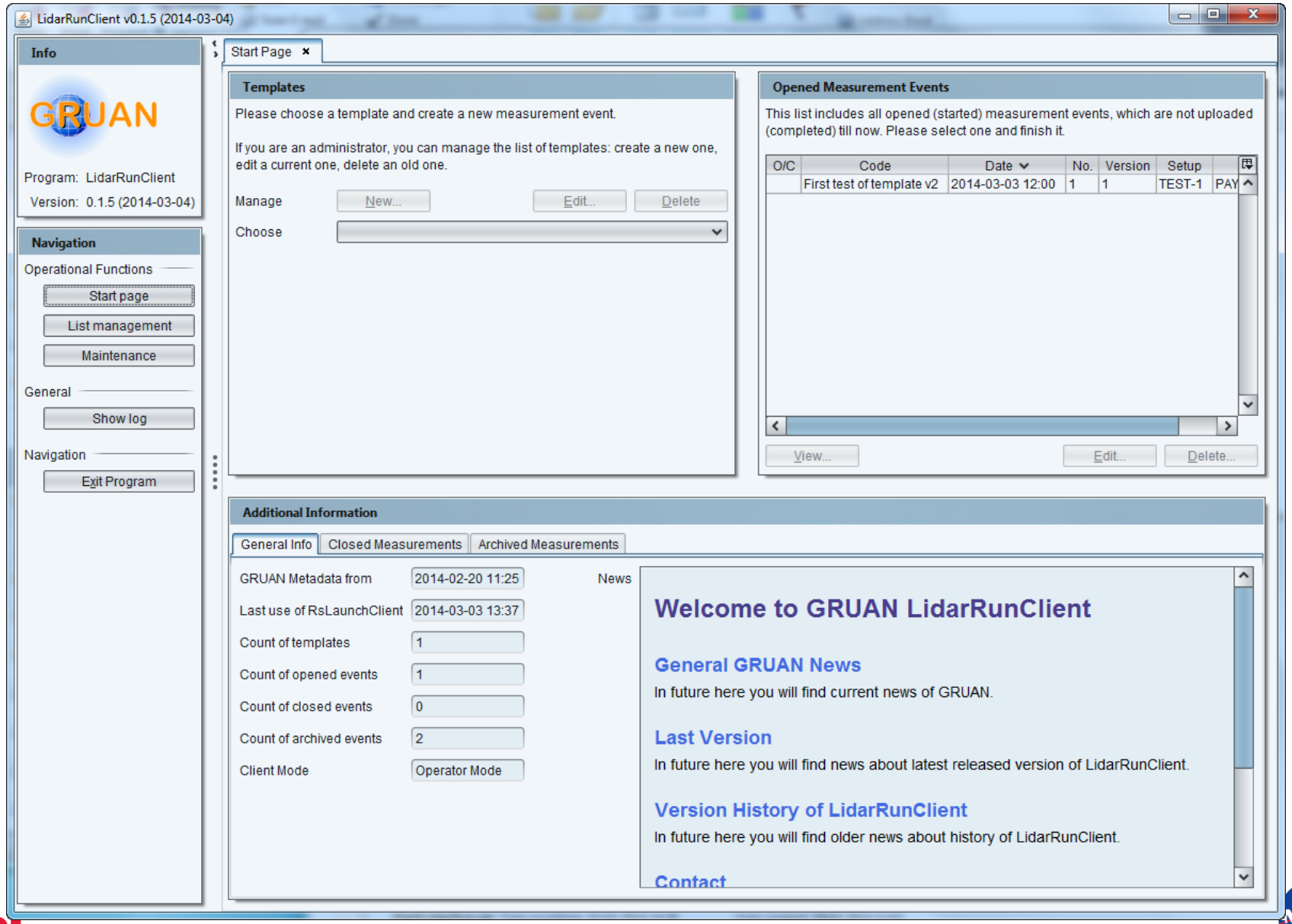
For 24/7-operated lidars: Once a day, uploading all data from the same UT date

Uploading before and after a change event

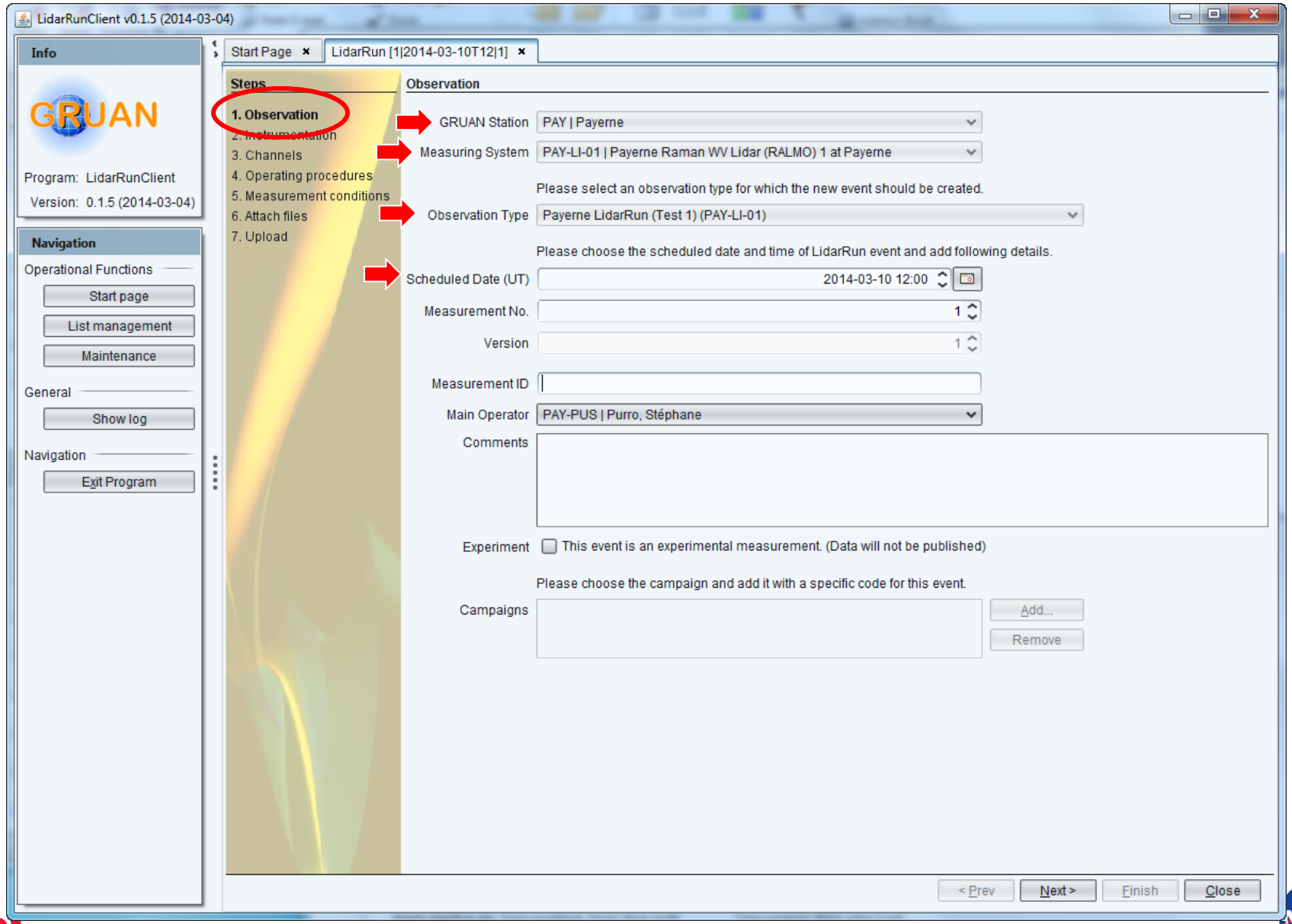
If one or several changes of instrumentation or operating procedure occurred during a given 24 hours cycle, the PRD must be uploaded separately for each of the multiple, uninterrupted data acquisition periods

Each of these periods shall be considered as a separate GRUAN lidar observation

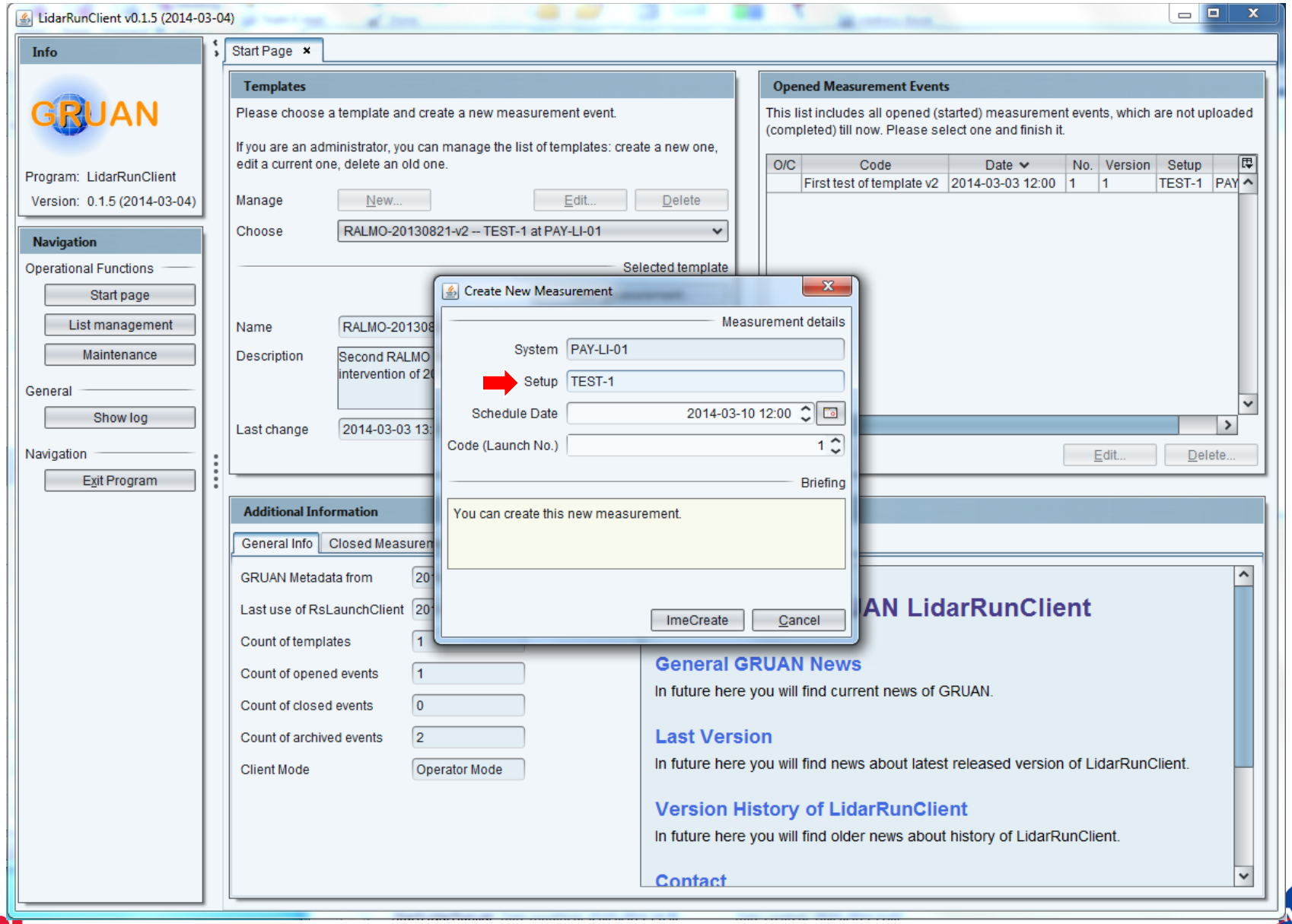
LidarRunClient Start Page



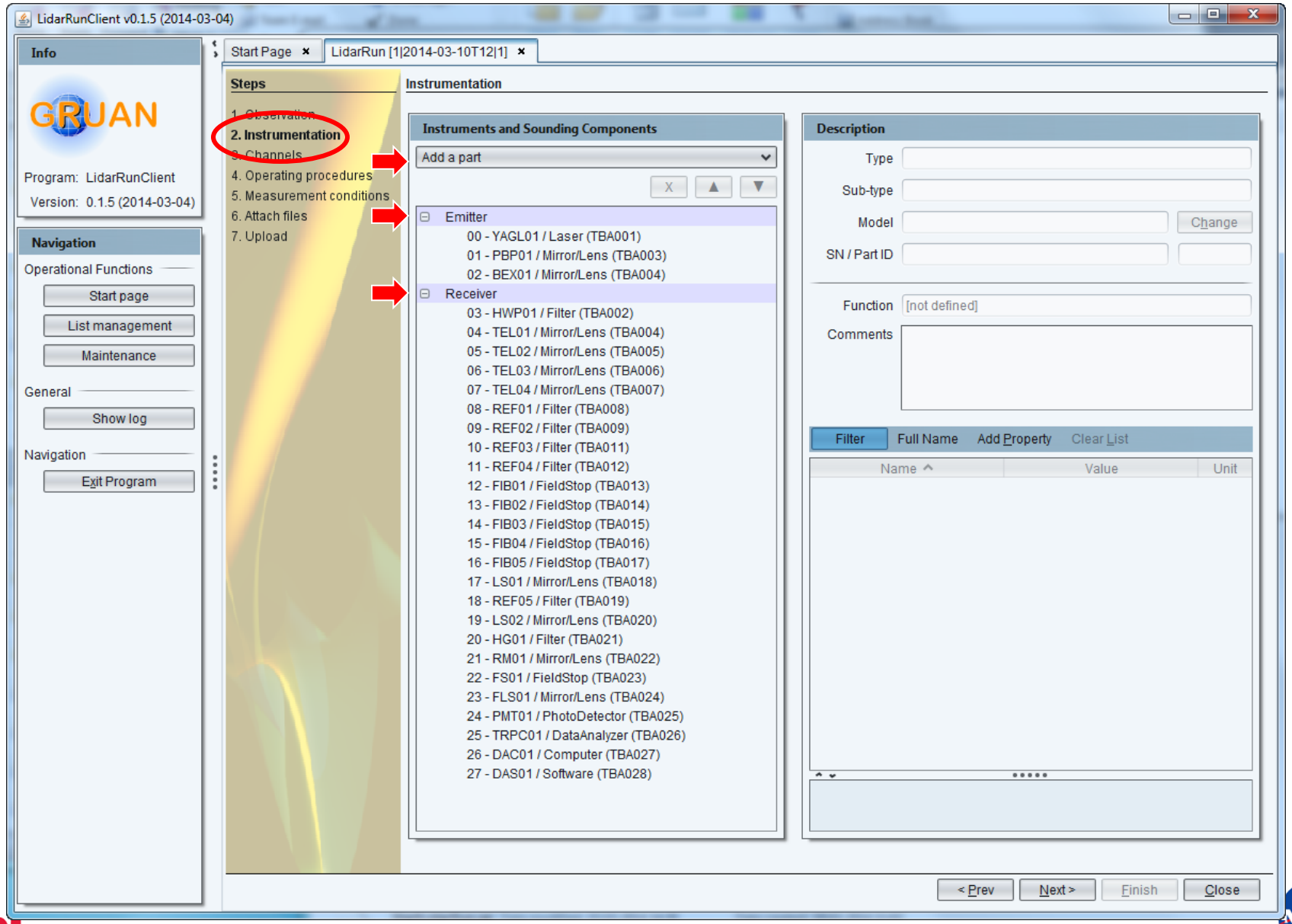
LidarRunClient “Observation” page



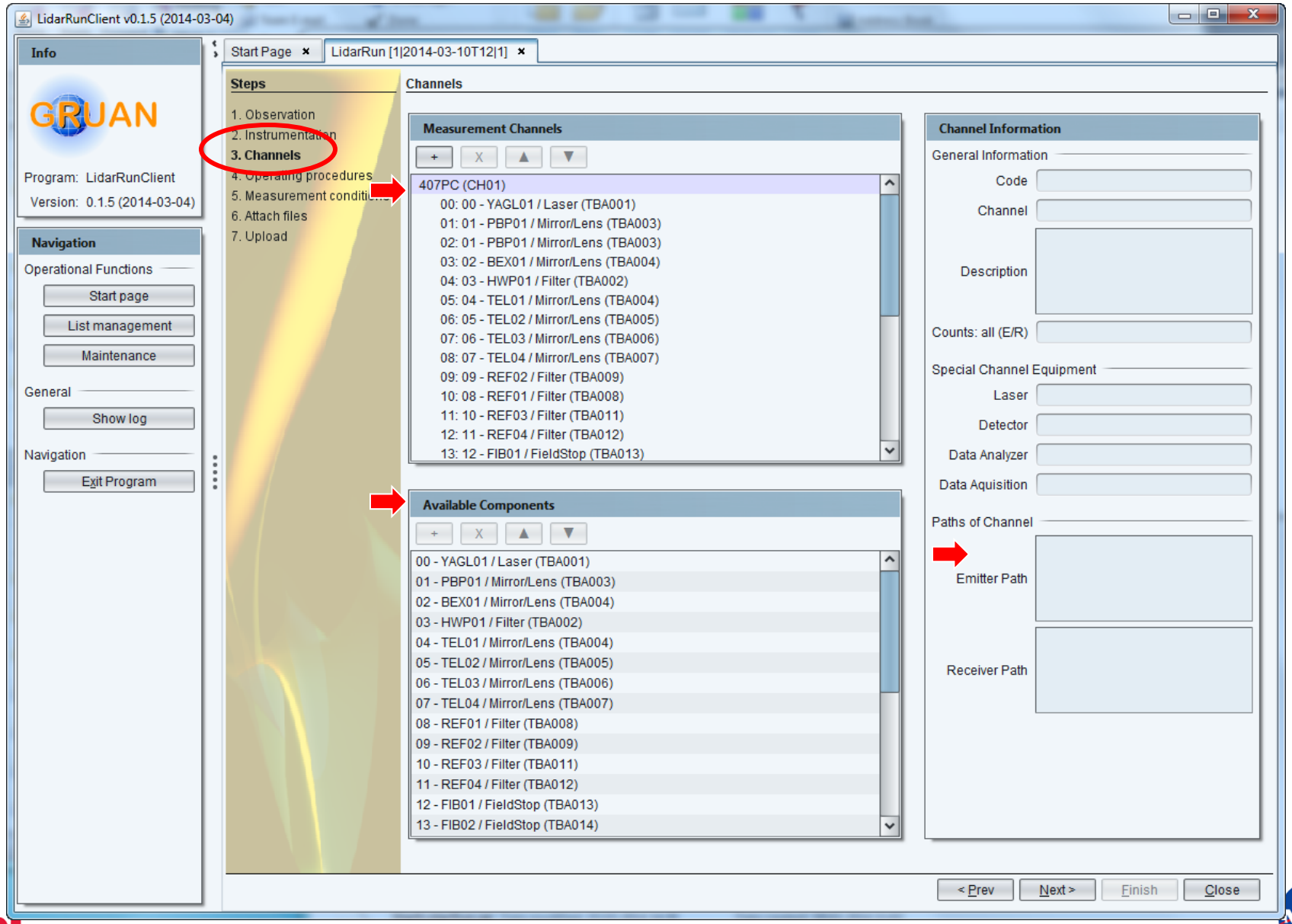
LidarRunClient “New Measurement” page



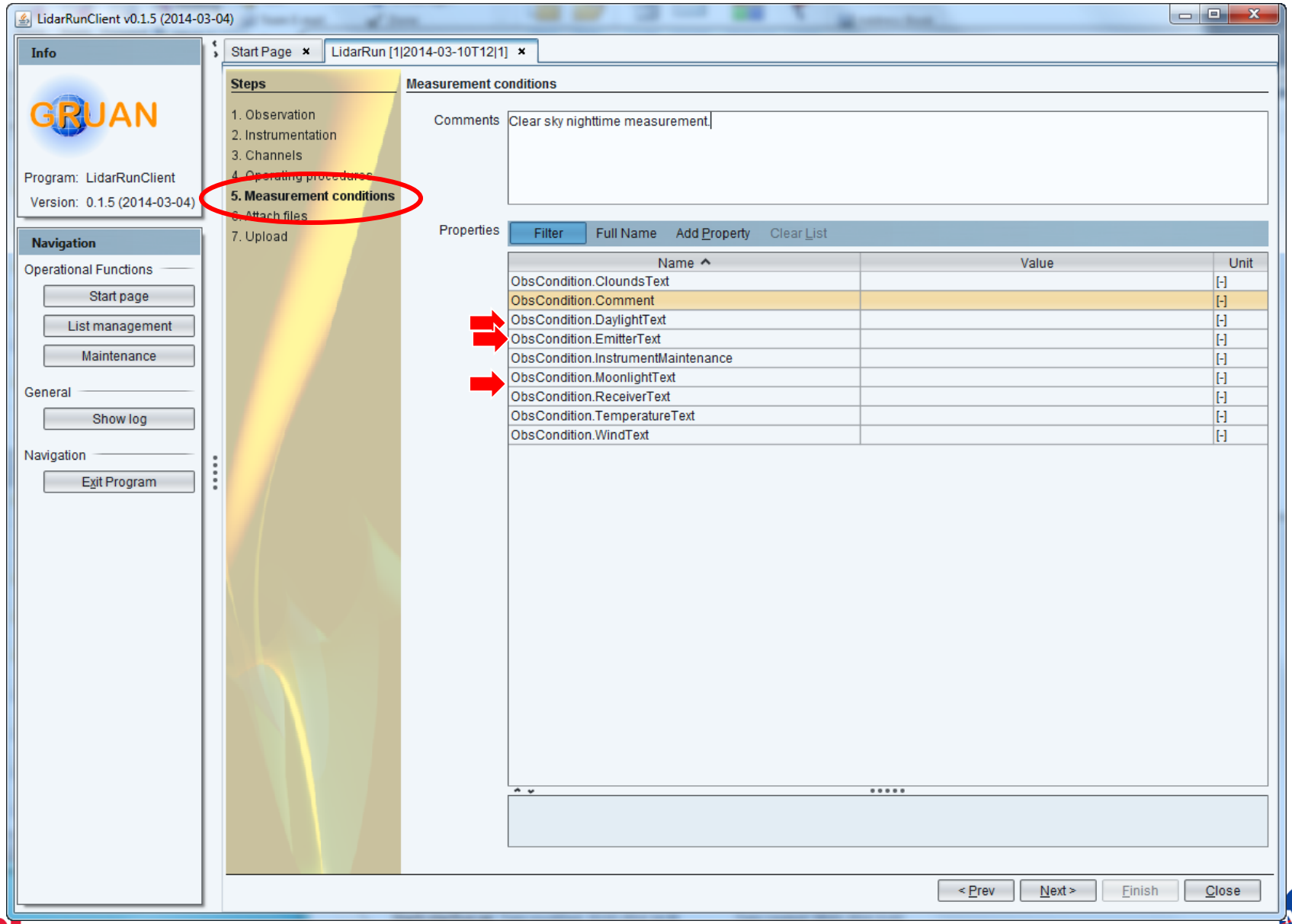
LidarRunClient “Instrumentation” page



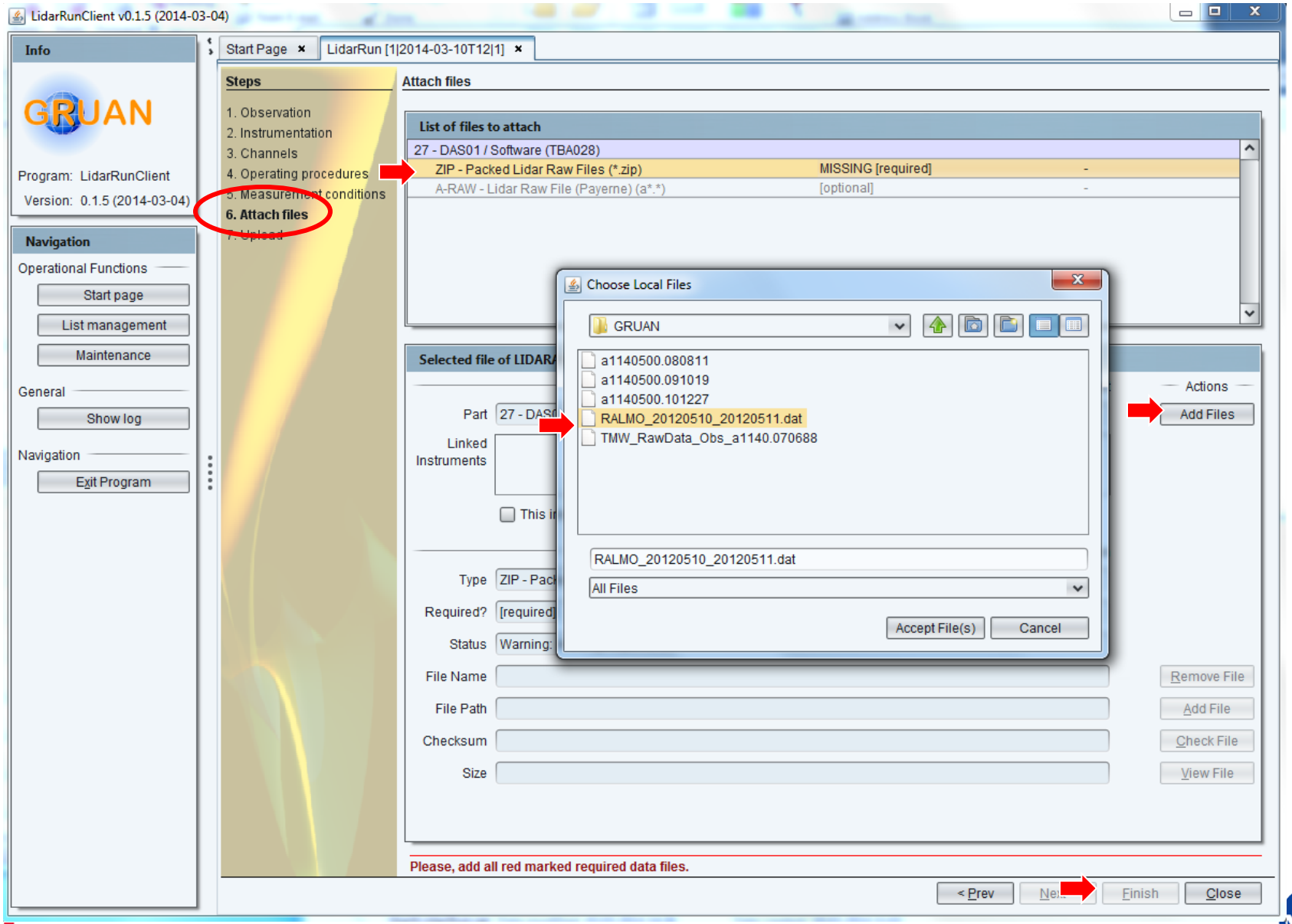
LidarRunClient “Channels” page



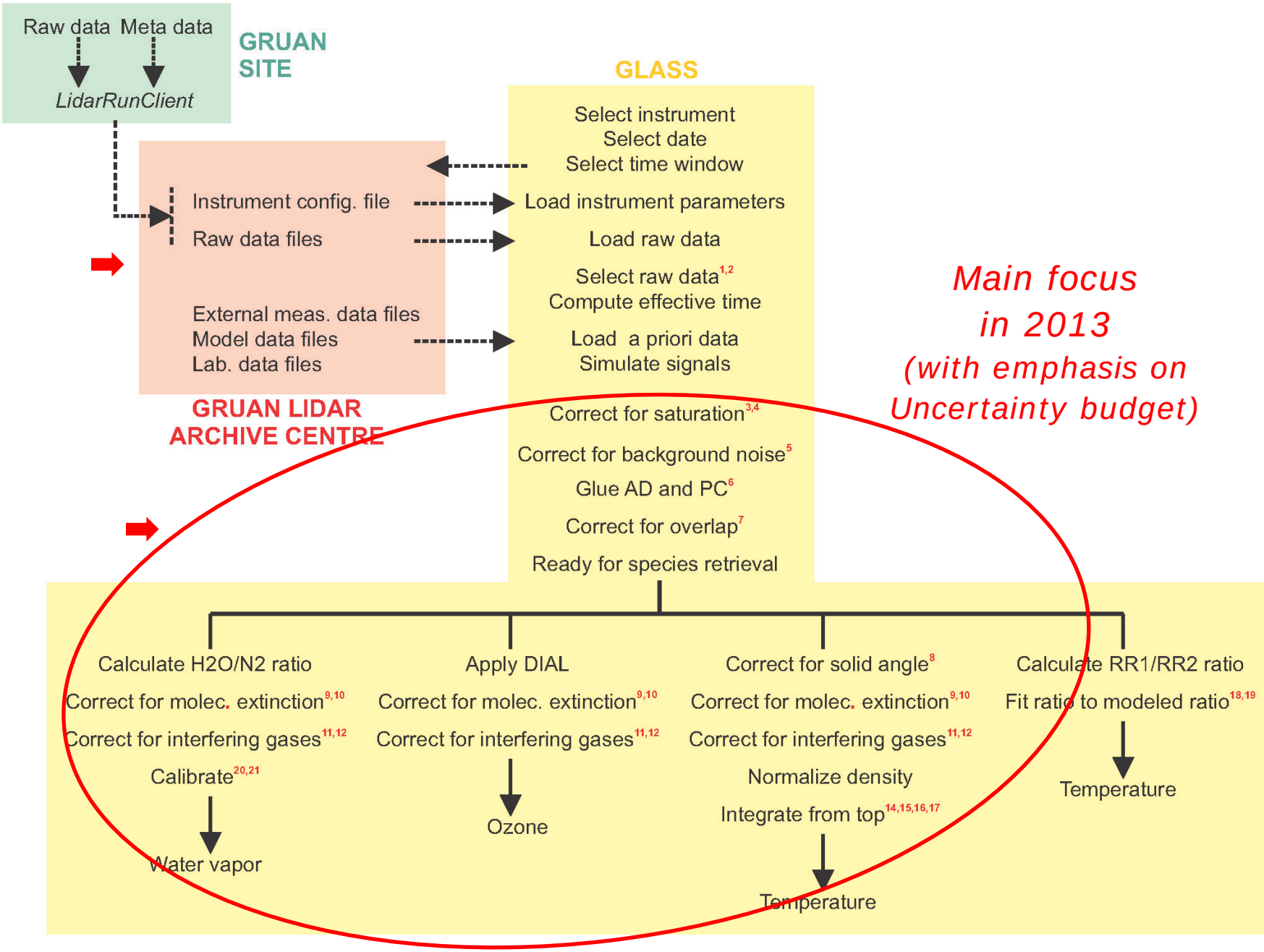
LidarRunClient “Measurement Conditions” page



LidarRunClient “Attach Files” page



The GRUAN Lidar Analysis Software Suite (GLASS)



Main focus in 2013 (with emphasis on Uncertainty budget)

Terminology and general approach

Terminology Agreed by ISSI Team on NDACC Lidar Algorithms:

1. *The NDACC-lidar-standardized uncertainty is the **combined standard uncertainty** u as defined by the **BIPM** technical documents **JCGM-100** (2008) and **JCGM-200** (2008)*
2. *u must be obtained from known, **traceable** standard uncertainty components u_x associated with multiple sources of uncertainty x*
3. *If no traceable standard uncertainty is available for x, u_x must be taken as the standard deviation σ_x of the normally distributed probability function describing x*
4. *The contribution of multiple standard uncertainty components u_x to the combined standard uncertainty u must follow the fundamental law of variance propagation, i.e.:*

If y is defined as a function of the independent variables x_1, x_2,.., x_n :

$$y = f(x_1, x_2, ..., x_N) = y_0 + \sum_{n=1}^{N} \frac{\partial y}{\partial x_n} x_n$$

And if $u_n = u(x_n)$ is the standard uncertainty for the source x_n, then the combined uncertainty for y is:

$$\Rightarrow \quad u_y = \sqrt{\sum_{n=1}^{N} \left| \frac{\partial y}{\partial x_n} \right|^2 u_n^2 + \sum_{m=1}^{N} \left(\sum_{n=1(n \neq m)}^{N} \frac{\partial y}{\partial x_n} \frac{\partial y}{\partial x_m} \mathrm{cov}(x_n, x_m) \right)}$$

Sources of Measurement and Retrieval Uncertainty

Addressed by ISSI Team and included in GLASS:

1. Photon Counting statistical noise
2. Saturation (pile-up): dead-time τ
3. Background correction: Fitting coefficients b_j
4. Molecular extinction: cross-sections values σ_{Ray}
5. A priori air density $N_a(z)$ for molecular extinction correction
6. Absorption cross-sections $\sigma_A(T(z))$ for O3, NO2, O2, SO2
7. A priori Number Density of interfering gases $N_{IG}(z)$ for O3, NO2, O2, SO2
8. Gravity g(z,lat) for temperature integration
9. A priori (tie-on) air density or pressure $T_a(z)$, $N_a(z)$, $p_a(z)$
10. Raman backscatter cross-section temperature dependence $\sigma_{Ram}(T(z))$
11. Water Vapor Calibration (including uncertainty in a priori source)

Each of the above sources is considered uncorrelated with the others, BUT…

… sources 2 and 3 require covariance computation when processing requires use of multiple altitude bins

Sources of Measurement and Retrieval Uncertainty (cont.)

➡ ***Currently not yet finished to be addressed, or not addressed at all by ISSI Team:***

1. *Analog Detection (AD) noise (quantization)*
2. *PC and AD gluing: gluing (fitting) coefficients w_j*
3. *Particulate backscatter and extinction (affects all species)*
4. *Calibration curve and spectral stability of the RR lines (RR Temperature only)*
5. *Overlap and shutter correction: O(z), fitting coefficients o_j (all species)*
6. *Fluorescence contamination (H2O only)*

➡ ***Sources 1, 2** anticipated to be included soon in a more advanced version of GLASS (2014)*

➡ ***Source 3** often requires questionable assumptions on the state of atmospheric particulate matter (composition, size, etc.)*
➔ will be included in GLASS eventually, but requires careful consideration first

➡ ***Source 4** specific to RR temperature lidar. To be addressed in concert with RR temperature experts when (if) GRUAN ready for GRUAN RR Temperature Product*

➡ ***Sources 5 and 6** can be minimize/removed by instrument re-design or optimization They are instrument-dependent and often time-dependent within the same instrument*

Did it feel somewhat long to get to this point?

Reason #1: 2013 = (too) busy year , not enough time dedication available

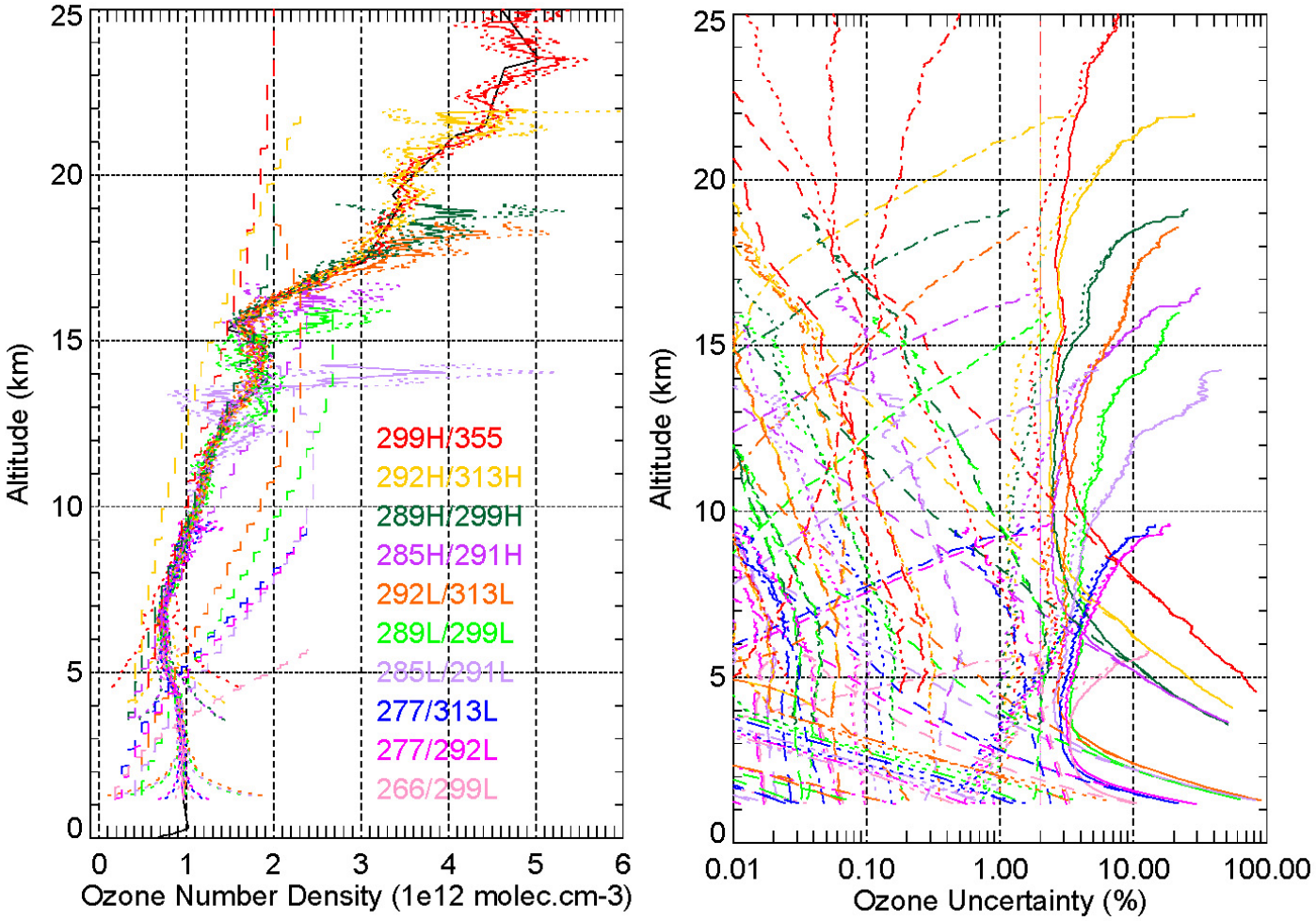
Reason #2: ➔

Each lidar has its own characteristics

➔ Huge quantity of work to compile

"There is one RS92 for many sites but as many lidars as there are sites!"

Typical NDACC tropospheric ozone lidar product



Did it feel somewhat long to get to this point? (cont.)

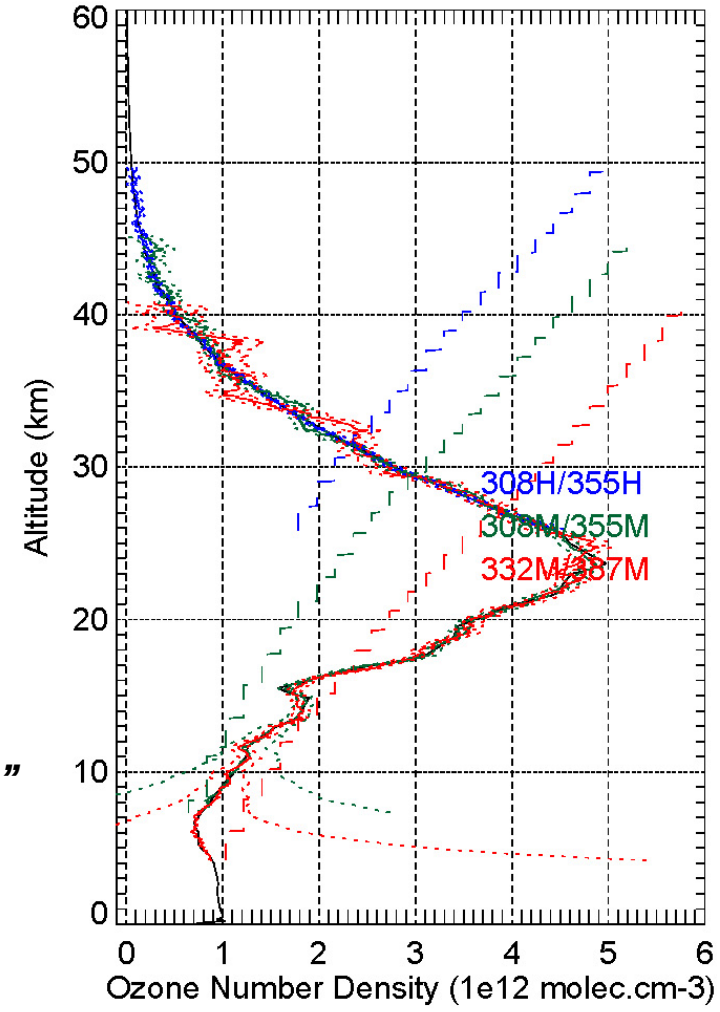
Reason #3: ➔

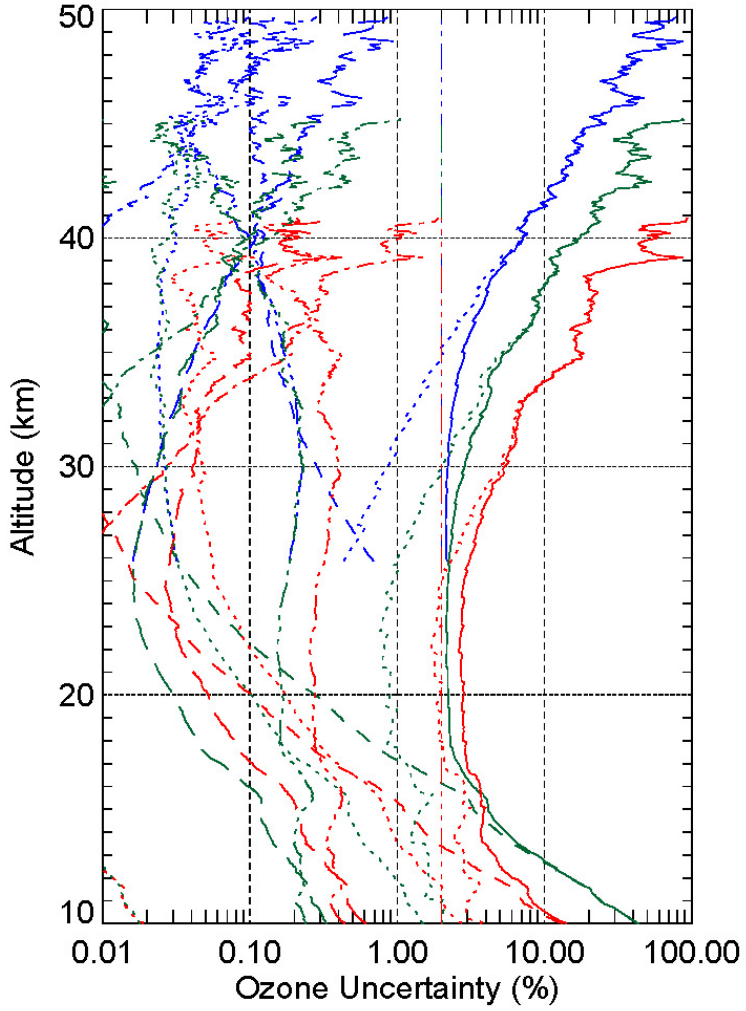
Lidar methods and corrections differ from one species to the other

➔ *Huger quantity of work to compile*

"There is one FTIR for many species, but there are many lidars for one species"

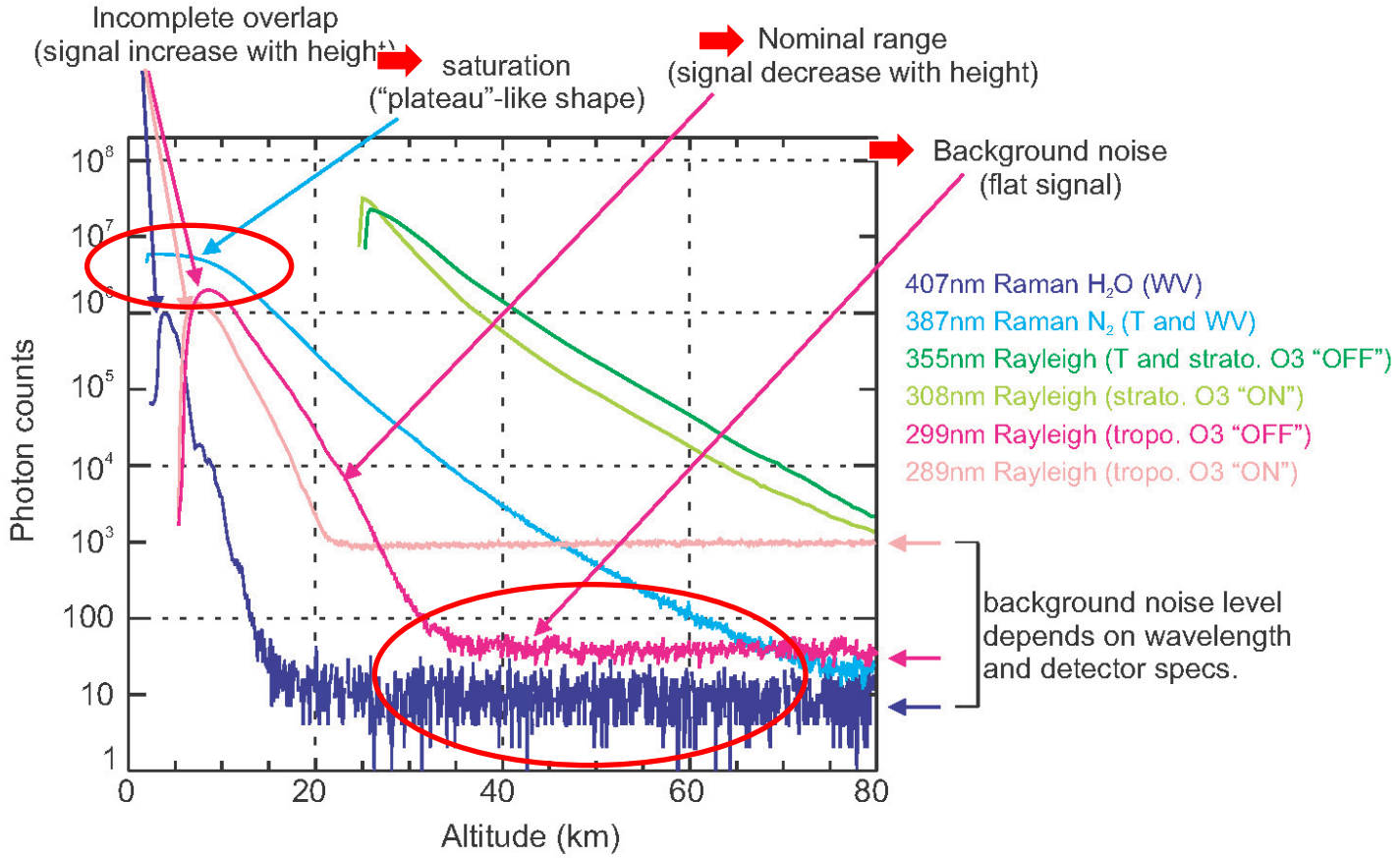
Typical NDACC stratospheric ozone lidar product





Propagating Uncertainty with Correlated Terms

Uncertainty owed to background noise and saturation corrections cannot be propagated assuming the corrected signals are uncorrelated in altitude!



➔ ***Monte Carlo Simulations are required to compute covariance matrix and estimate the resulting impact of correlated terms on uncertainty***

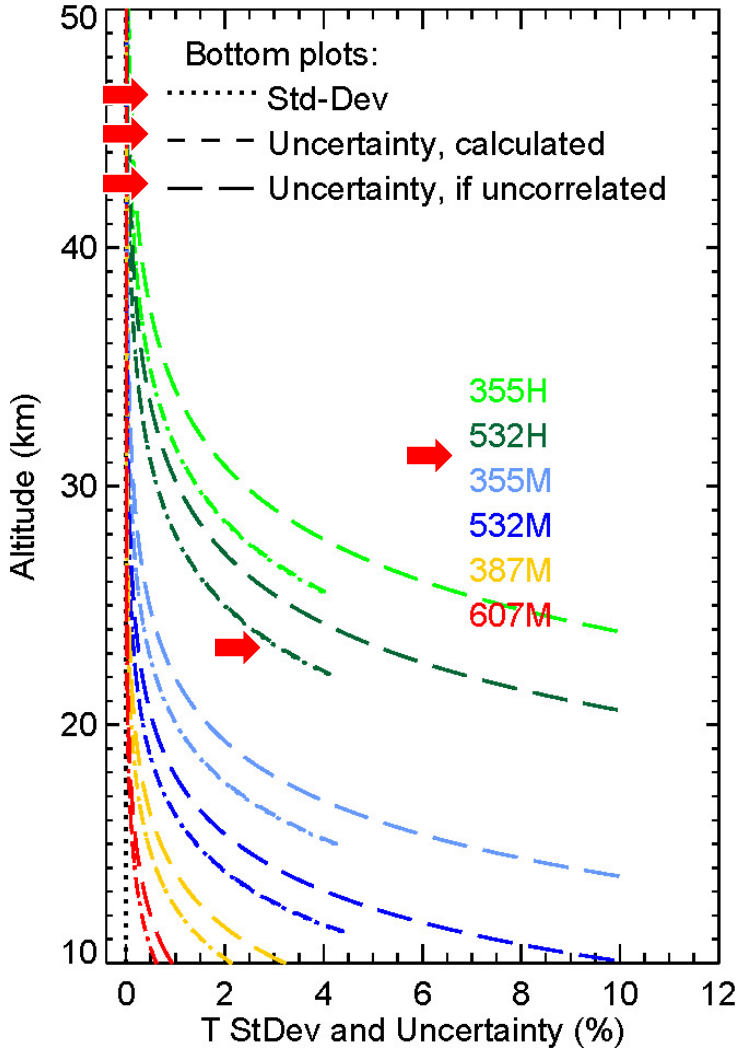
Estimating the Impact of Correlated Terms

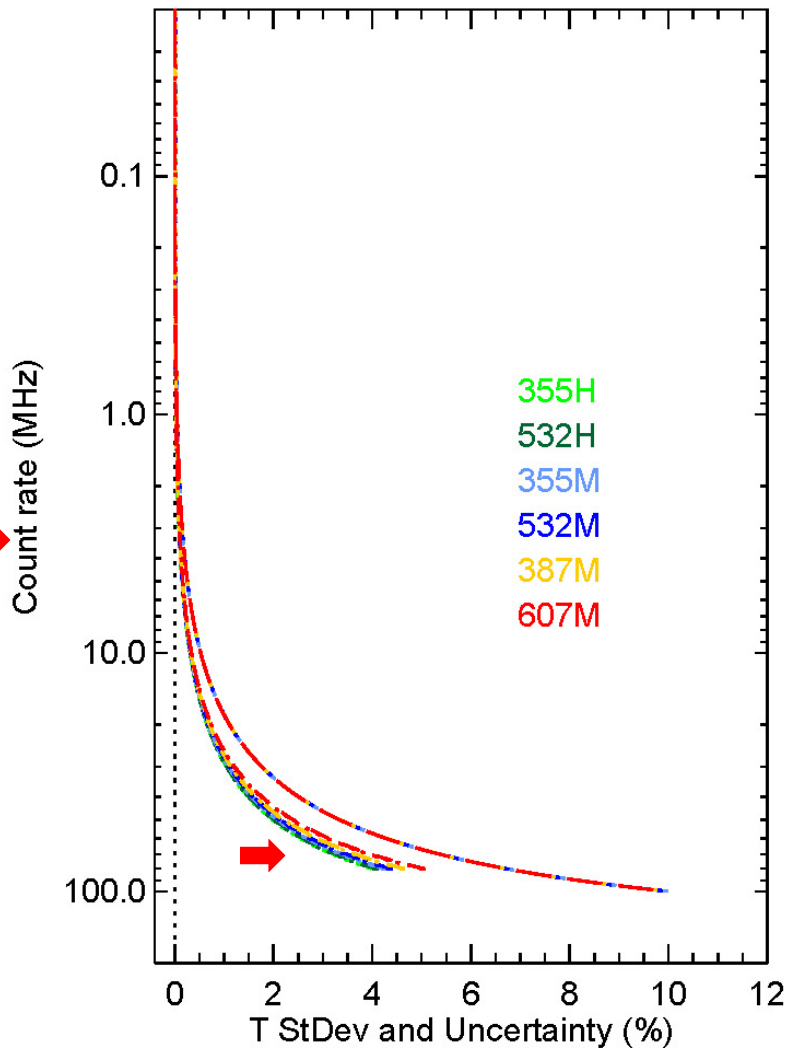
By use of Lidar Signal Simulations and Monte Carlo Runs…

Modus operandi:

- *1. Start from assumed atmospheric state [T(z), p(z), O3(z), H2O(z)] ("true" profiles)*
- *2. Simulate lidar signals using typical real lidar system parameters (forward model)*
- *3. Analyze simulated signals with GLASS*
- *4. Ensure consistency between GLASS and forward model (i.e., ensure retrieved = "truth")*
- *5. For each source of uncertainty, run Monte Carlo simulations by:*
  - *5a. Setting ALL uncertainty sources to 0, except the one to be addressed*
  - *5b. Turning "OFF" all corrections except the one for which uncertainty is to be addressed*
  - *5c. Creating a set of (1000) random, normally distributed values of the parameter(s) used to perform the correction*
  - *5d. Setting the 1-standard uncertainty of the source being addressed to the value of the standard-deviation used to produce the random distribution*
  - *5e. Produce the corresponding set of (1000) retrieved profiles*
- *6. Compute standard deviation of the retrieved profiles and compare to calculated uncertainty*
- *7. Repeat steps 5-6 for each uncertainty source separately, then for all sources together*

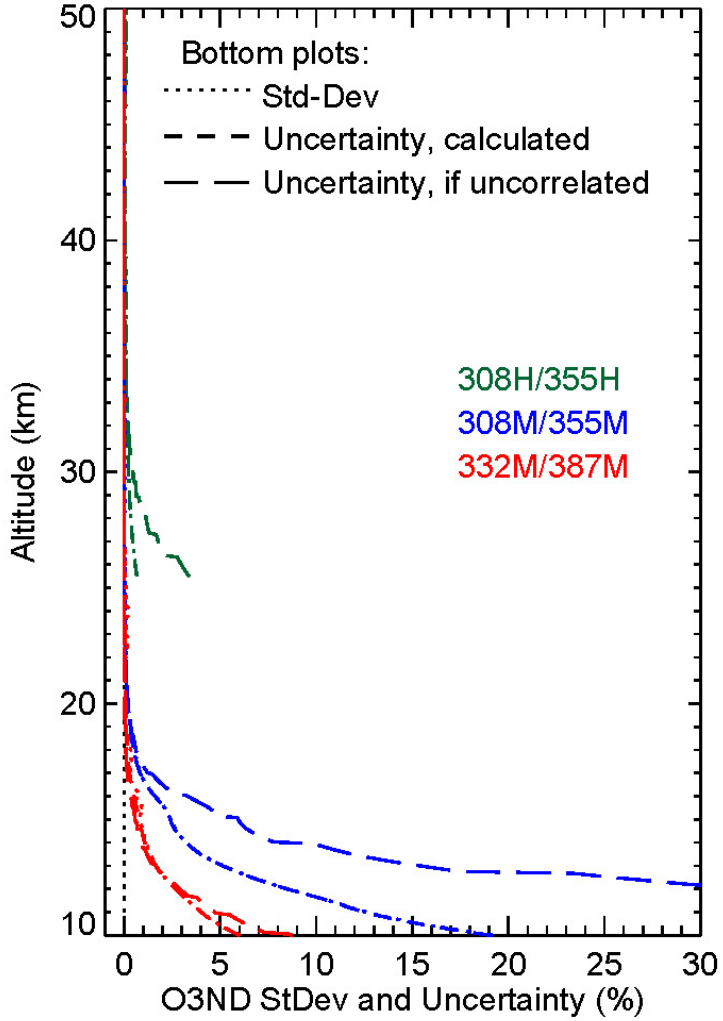
Quantifying saturation correction uncertainty on Temperature

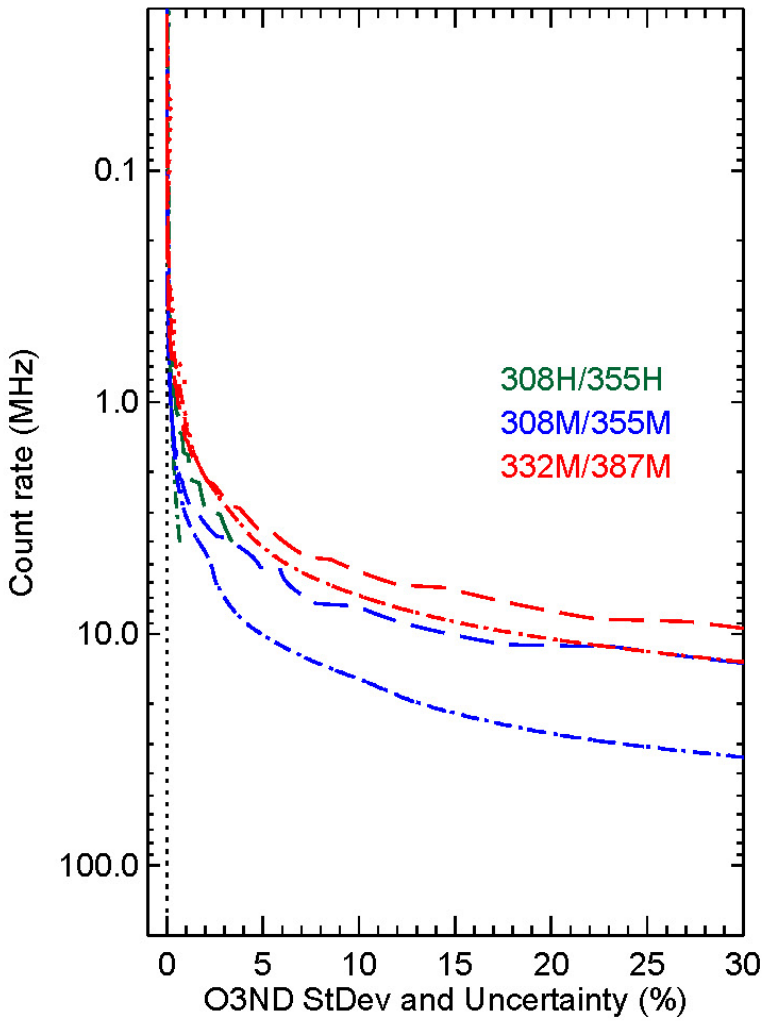




➡ ***Uncertainty due to saturation overestimated if assumed uncorrelated***

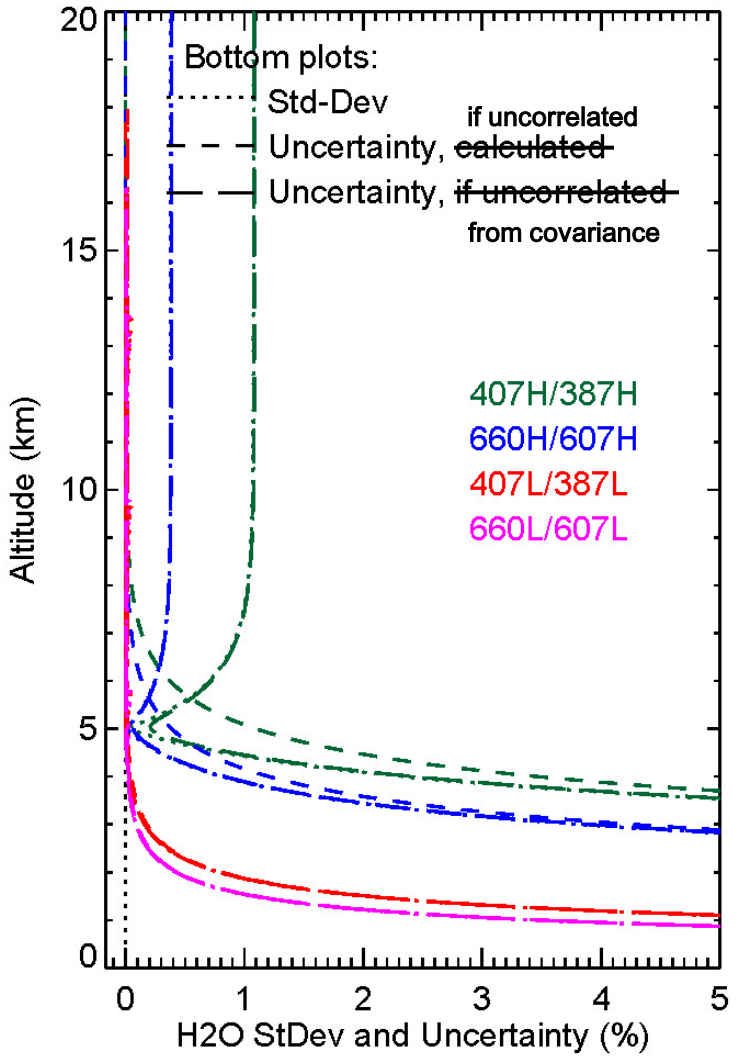
Quantifying saturation correction uncertainty on ozone

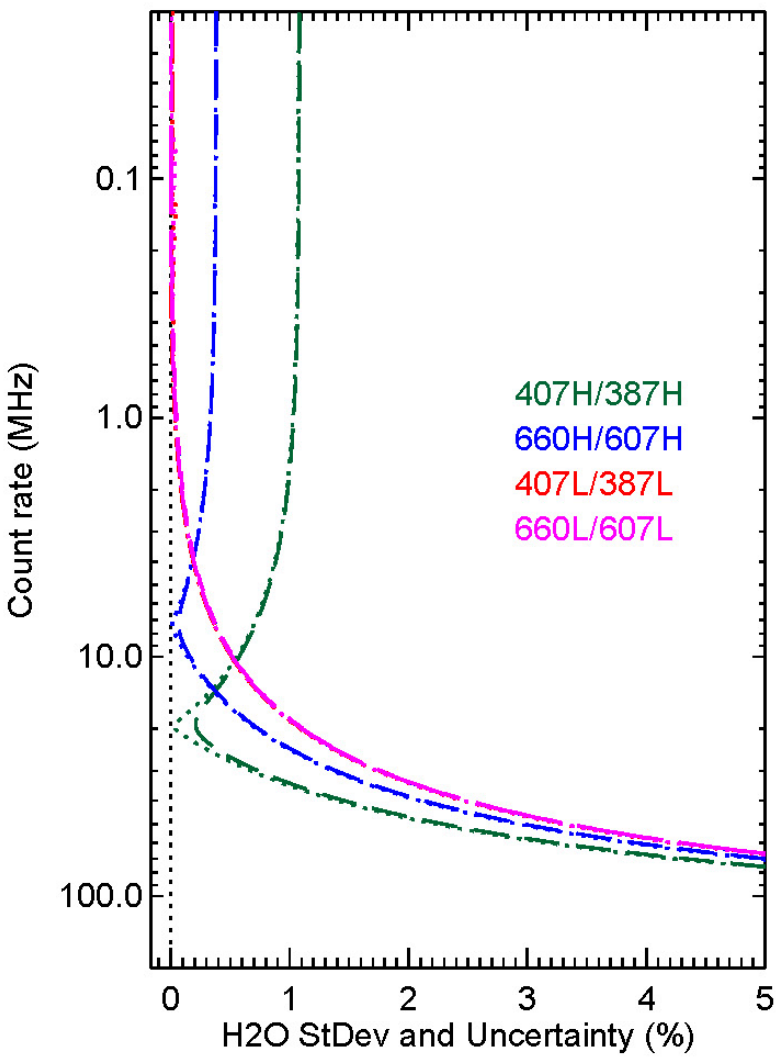




Uncertainty due to saturation overestimated if assumed uncorrelated

Quantifying saturation correction uncertainty on water vapor



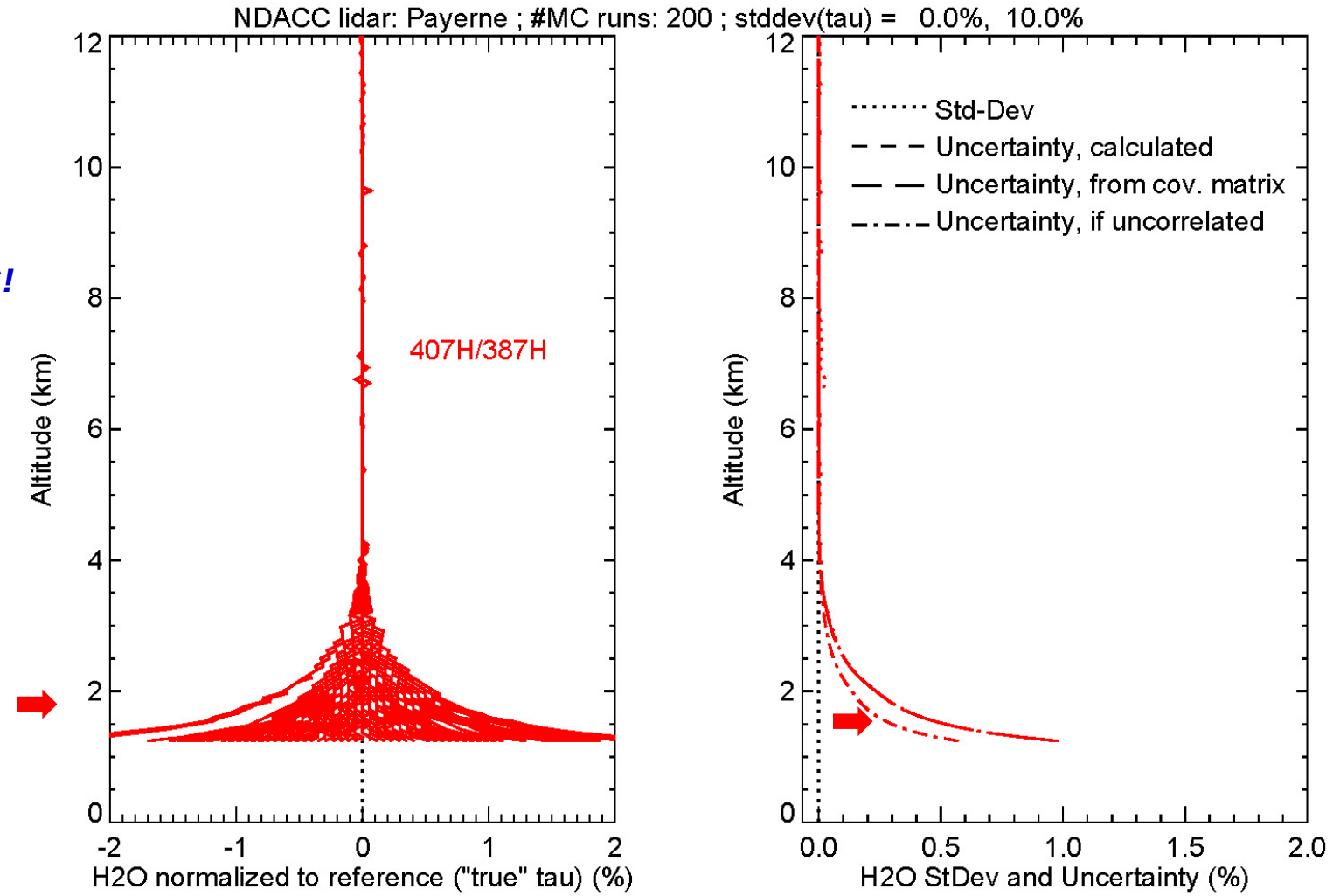


Uncertainty due to saturation is either overestimated or underestimated if assumed uncorrelated!

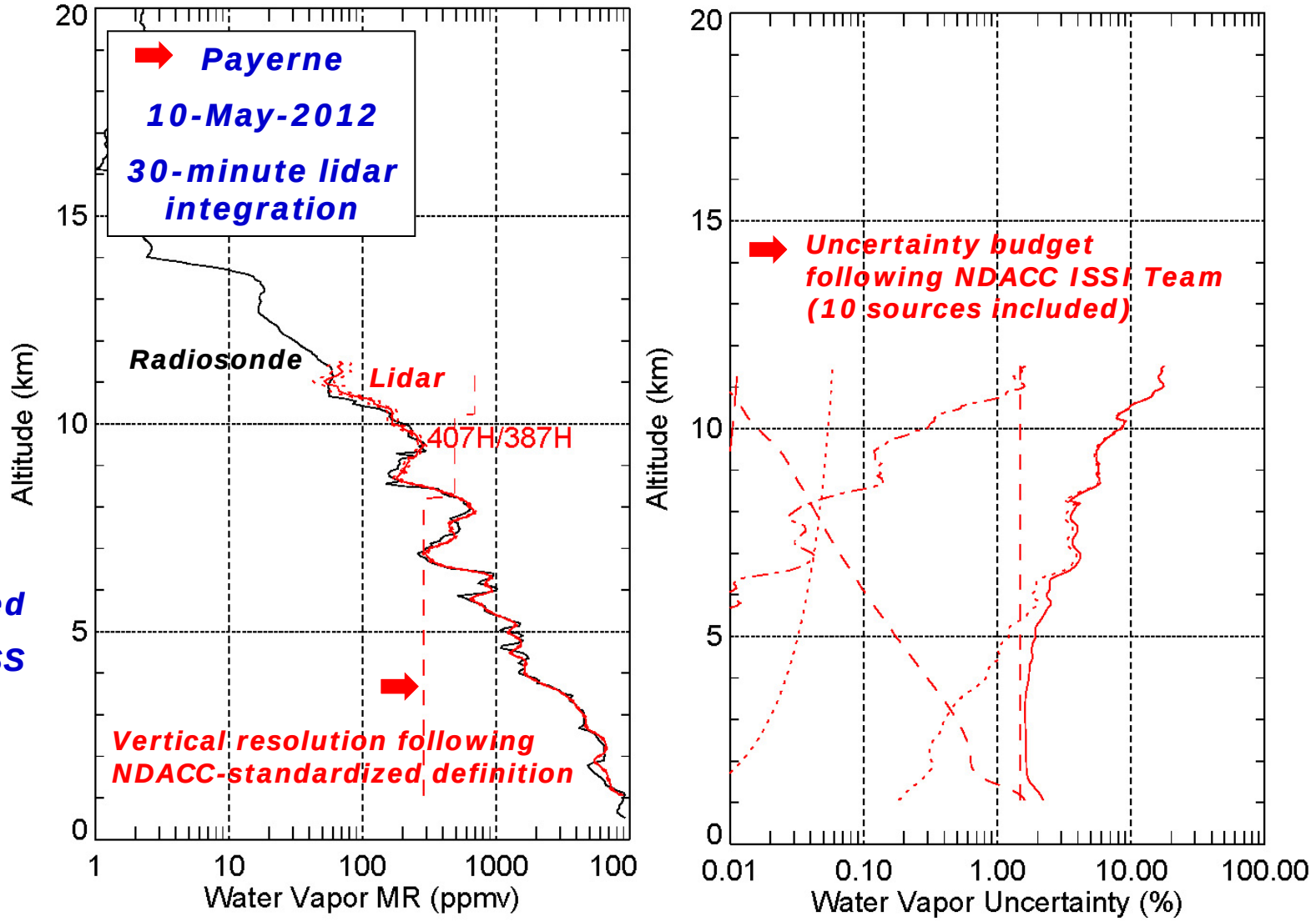
Now Getting Closer to the Real World of GRUAN…

➡ Simulation using actual lidar parameters of Payerne

Retrieved by the GLASS!



Last but not Least… First GRUAN Lidar Product?…



As retrieved by the GLASS

CONCLUSION

➔ *GRUAN Lidar Product development is ongoing*

➔ *2013 progress slower than expected*

➔ *2014 progress expected to be faster:*

- *Lidar Guide should be completed by the end of the year*
- *An anticipated LidarRunClient advanced version should lead to operational mode*
- *GLASS should see significant development (data selection, portability, etc.)*

➔ *Hoping for a GRUAN Lidar "operational" Product in 2015*