

# Status/Development of a GRUAN Lidar Data Stream

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## ➡ Definition

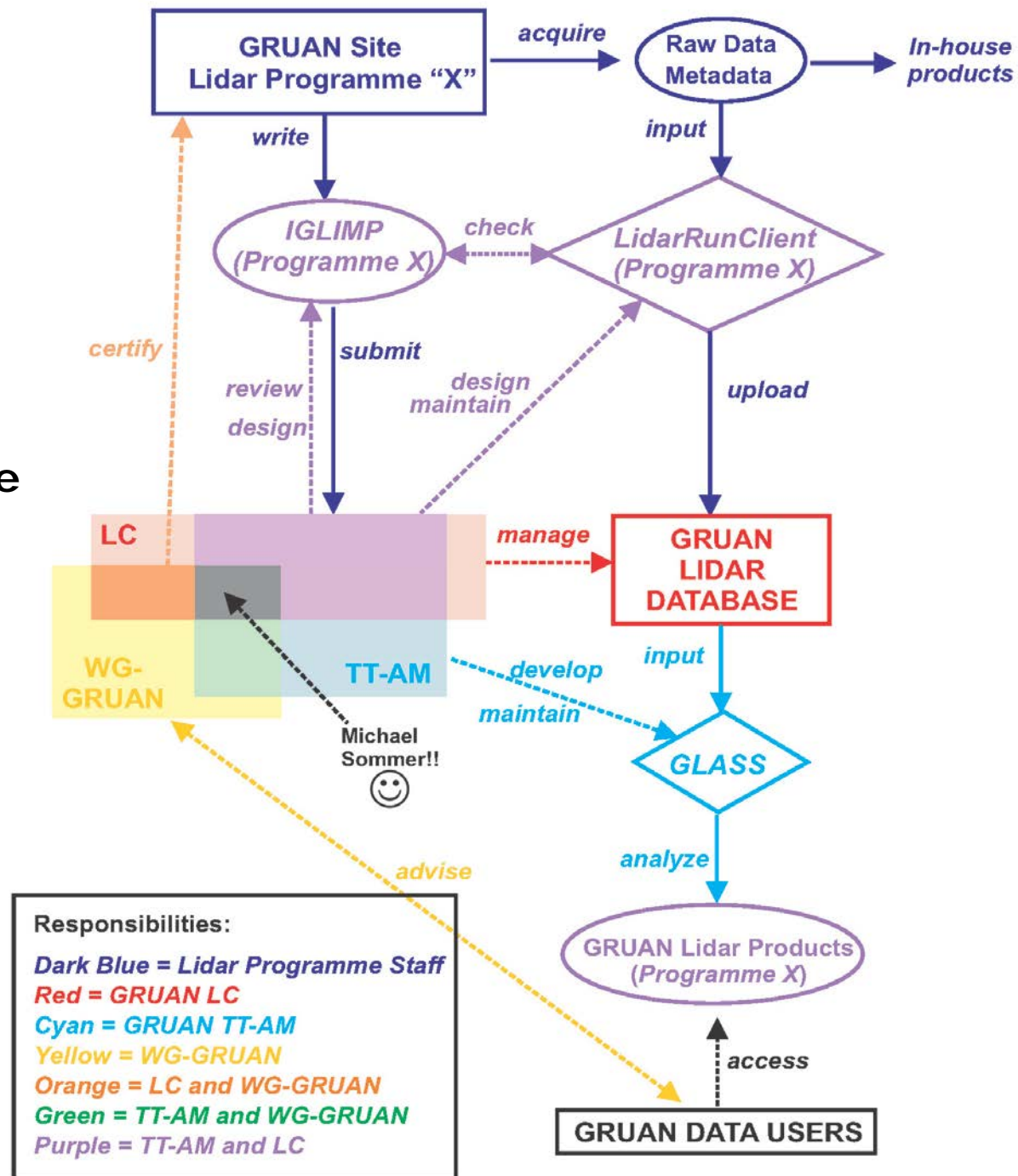
*The overall infrastructure underlying the lidar measurement and the subsequent production of a GRUAN lidar product, from data acquisition to data product management.*

## ➡ 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 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... ☺)*

## ➡ 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*

Info

  
Program: LidarRunClient  
Version: 0.1.5 (2014-03-04)

Navigation

Operational Functions

Start page

List management

Maintenance

General

Show log

Navigation

Exit Program

Start Page

Templates

Please choose a template and create a new measurement event.  
  
If you are an administrator, you can manage the list of templates: create a new one, edit a current one, delete an old one.

Manage 

New...

Edit...

Delete

Choose

Opened Measurement Events

This list includes all opened (started) measurement events, which are not uploaded (completed) till now. Please select one and finish it.

O/C	Code	Date	No.	Version	Setup	
	First test of template v2	2014-03-03 12:00	1	1	TEST-1	PAY

View...

Edit...

Delete...

Additional Information

General Info

Closed Measurements

Archived Measurements

GRUAN Metadata from

2014-02-20 11:25

News

Last use of RsLaunchClient

2014-03-03 13:37

Count of templates

1

Count of opened events

1

Count of closed events

0

Count of archived events

2

Client Mode

Operator Mode

Welcome to GRUAN LidarRunClient

General GRUAN News

In future here you will find current news of GRUAN.

Last Version

In future here you will find news about latest released version of LidarRunClient.


Version History of LidarRunClient

In future here you will find older news about history of LidarRunClient.

Contact

JPL

GRUAN ICM-6, Mar 10-14, 2013, Greenbelt, MD, USA



LidarRunClient v0.1.5 (2014-03-04)

Start Page x LidarRun [1]2014-03-10T12[1] x

**Info**

**GRUAN**

Program: LidarRunClient  
Version: 0.1.5 (2014-03-04)

**Navigation**

Operational Functions

Start page

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Maintenance

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Exit Program

**Steps**

1. Observation
2. Instrumentation
3. Channels
4. Operating procedures
5. Measurement conditions
6. Attach files
7. Upload

**Observation**

GRUAN Station PAY | Payerne

Measuring System PAY-LI-01 | Payerne Raman WV Lidar (RALMO) 1 at Payerne

Please select an observation type for which the new event should be created.

Observation Type Payerne LidarRun (Test 1) (PAY-LI-01)

Please choose the scheduled date and time of LidarRun event and add following details.

Scheduled Date (UT) 2014-03-10 12:00

Measurement No. 1

Version 1

Measurement ID

Main Operator PAY-PUS | Purro, Stéphane

Comments

Experiment ☐ This event is an experimental measurement. (Data will not be published)

Please choose the campaign and add it with a specific code for this event.

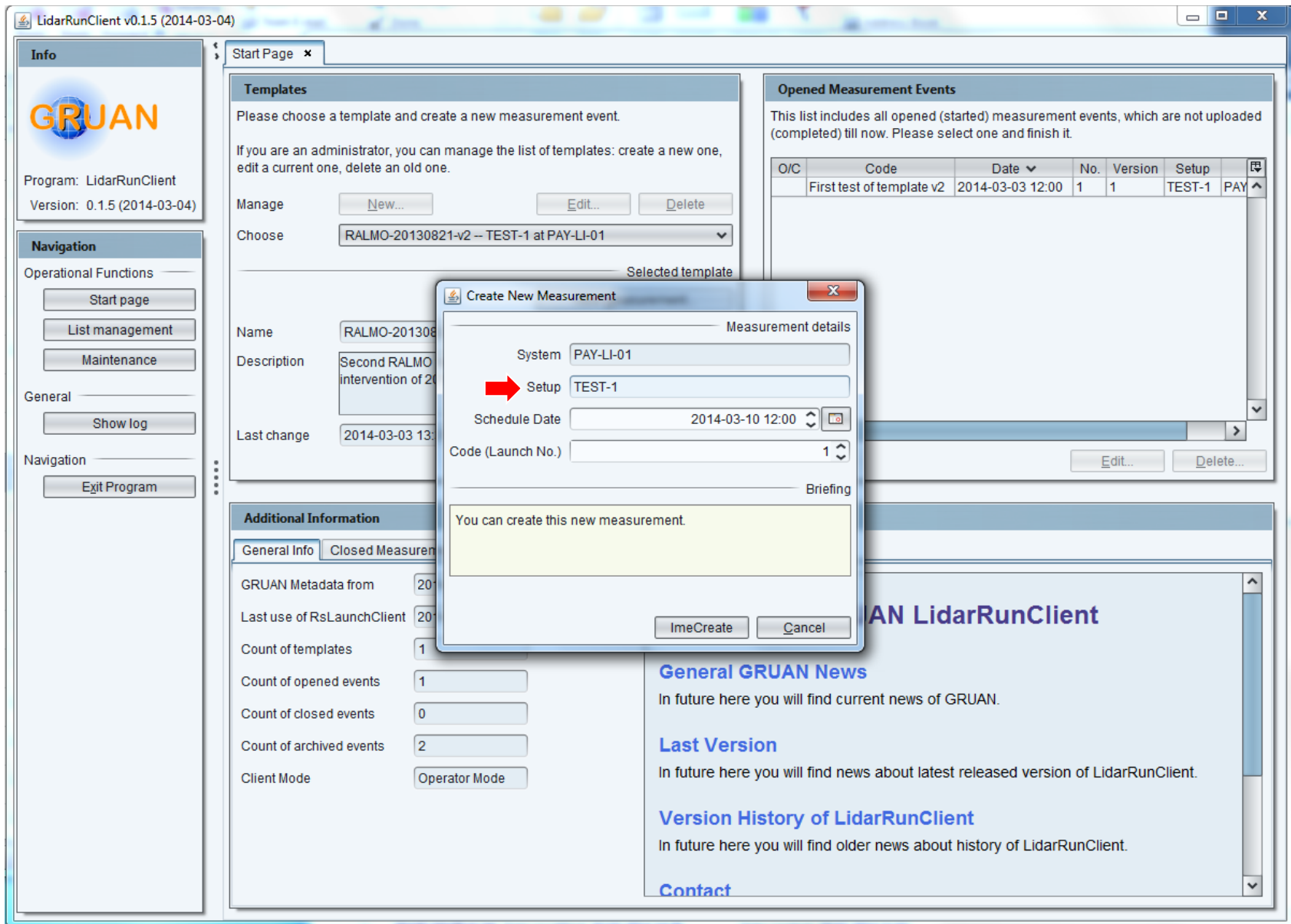
Campaigns

Add...

Remove

< Prev Next > Finish Close

# LidarRunClient "New Measurement" page



The screenshot displays the LidarRunClient v0.1.5 (2014-03-04) interface. The main window is titled "Start Page" and contains several sections:

- Info:** Displays the GRUAN logo, program name (LidarRunClient), and version (0.1.5 (2014-03-04)).
- Navigation:** Includes buttons for "Start page", "List management", "Maintenance", "Show log", and "Exit Program".
- Templates:** A section for creating new measurement events. It includes a "Manage" button, a "Choose" dropdown menu (currently showing "RALMO-20130821-v2 -- TEST-1 at PAY-LI-01"), and a "Selected template" label.
- Opened Measurement Events:** A table listing events. The table has columns: O/C, Code, Date, No., Version, Setup, and PAY. The first row shows "First test of template v2" with a date of "2014-03-03 12:00", No. "1", Version "1", Setup "TEST-1", and PAY "PAY".
- Additional Information:** A section for general information, including "GRUAN Metadata from", "Last use of RsLaunchClient", "Count of templates", "Count of opened events", "Count of closed events", "Count of archived events", and "Client Mode" (currently set to "Operator Mode").

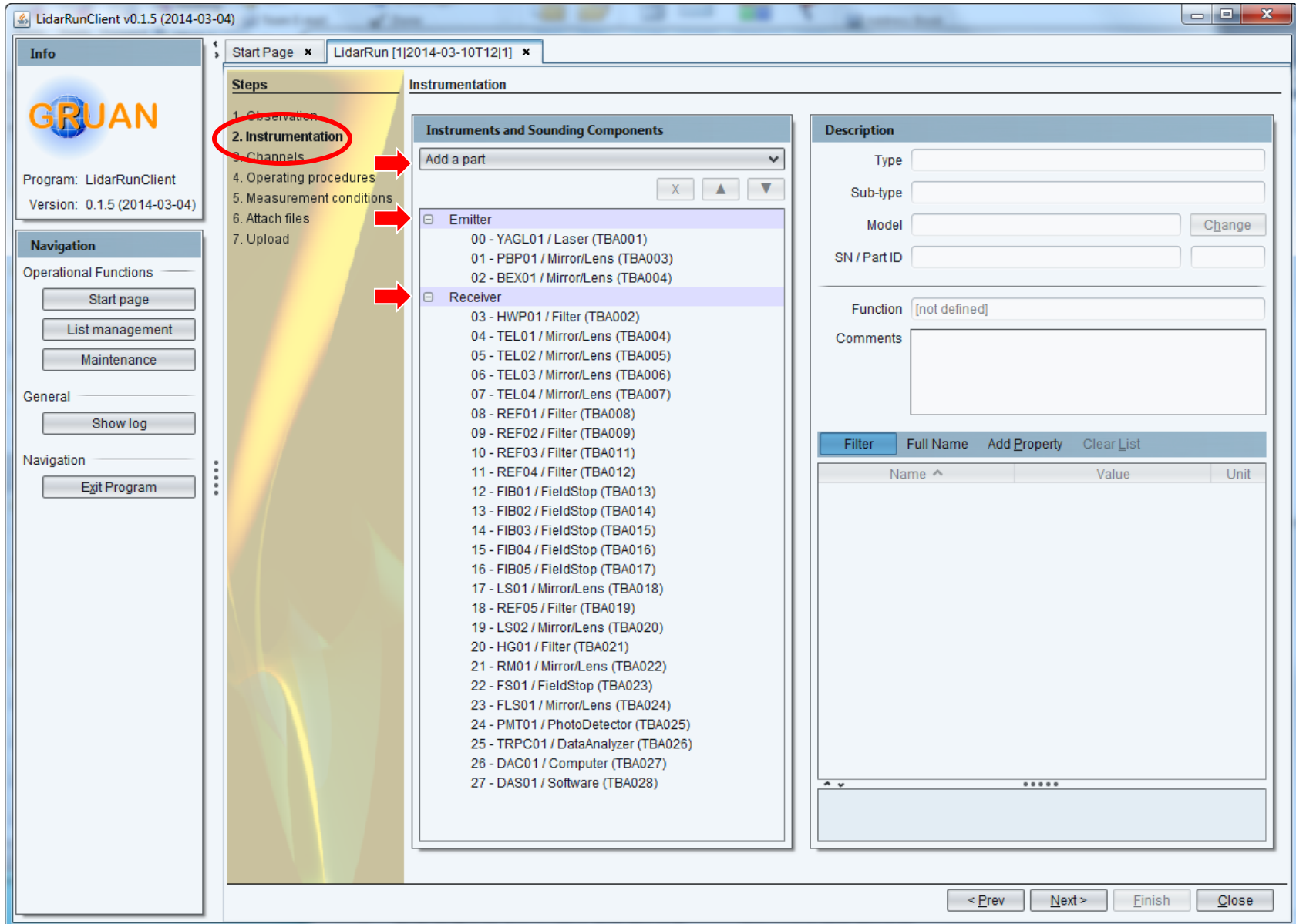
A "Create New Measurement" dialog box is open in the center, showing the following details:

- System:** PAY-LI-01
- Setup:** TEST-1 (indicated by a red arrow)
- Schedule Date:** 2014-03-10 12:00
- Code (Launch No.):** 1
- Briefing:** You can create this new measurement.
- Buttons:** "ImeCreate" and "Cancel".

The bottom right corner of the main window contains a "GRUAN LidarRunClient" section with links for "General GRUAN News", "Last Version", "Version History of LidarRunClient", and "Contact".



# LidarRunClient "Instrumentation" page



**Info**

Program: LidarRunClient  
Version: 0.1.5 (2014-03-04)

**Navigation**

Operational Functions

- Start page
- List management
- Maintenance

General

- Show log

Navigation

- Exit Program

**Steps**

1. Observation
2. Instrumentation
3. Channels
4. Operating procedures
5. Measurement conditions
6. Attach files
7. Upload

**Instrumentation**

**Instruments and Sounding Components**

Add a part

- Emitter
  - 00 - YAGL01 / Laser (TBA001)
  - 01 - PBP01 / Mirror/Lens (TBA003)
  - 02 - BEX01 / Mirror/Lens (TBA004)
- Receiver
  - 03 - HWP01 / Filter (TBA002)
  - 04 - TEL01 / Mirror/Lens (TBA004)
  - 05 - TEL02 / Mirror/Lens (TBA005)
  - 06 - TEL03 / Mirror/Lens (TBA006)
  - 07 - TEL04 / Mirror/Lens (TBA007)
  - 08 - REF01 / Filter (TBA008)
  - 09 - REF02 / Filter (TBA009)
  - 10 - REF03 / Filter (TBA011)
  - 11 - REF04 / Filter (TBA012)
  - 12 - FIB01 / FieldStop (TBA013)
  - 13 - FIB02 / FieldStop (TBA014)
  - 14 - FIB03 / FieldStop (TBA015)
  - 15 - FIB04 / FieldStop (TBA016)
  - 16 - FIB05 / FieldStop (TBA017)
  - 17 - LS01 / Mirror/Lens (TBA018)
  - 18 - REF05 / Filter (TBA019)
  - 19 - LS02 / Mirror/Lens (TBA020)
  - 20 - HG01 / Filter (TBA021)
  - 21 - RM01 / Mirror/Lens (TBA022)
  - 22 - FS01 / FieldStop (TBA023)
  - 23 - FLS01 / Mirror/Lens (TBA024)
  - 24 - PMT01 / PhotoDetector (TBA025)
  - 25 - TRPC01 / DataAnalyzer (TBA026)
  - 26 - DAC01 / Computer (TBA027)
  - 27 - DAS01 / Software (TBA028)

**Description**

Type

Sub-type

Model

SN / Part ID

Function [not defined]

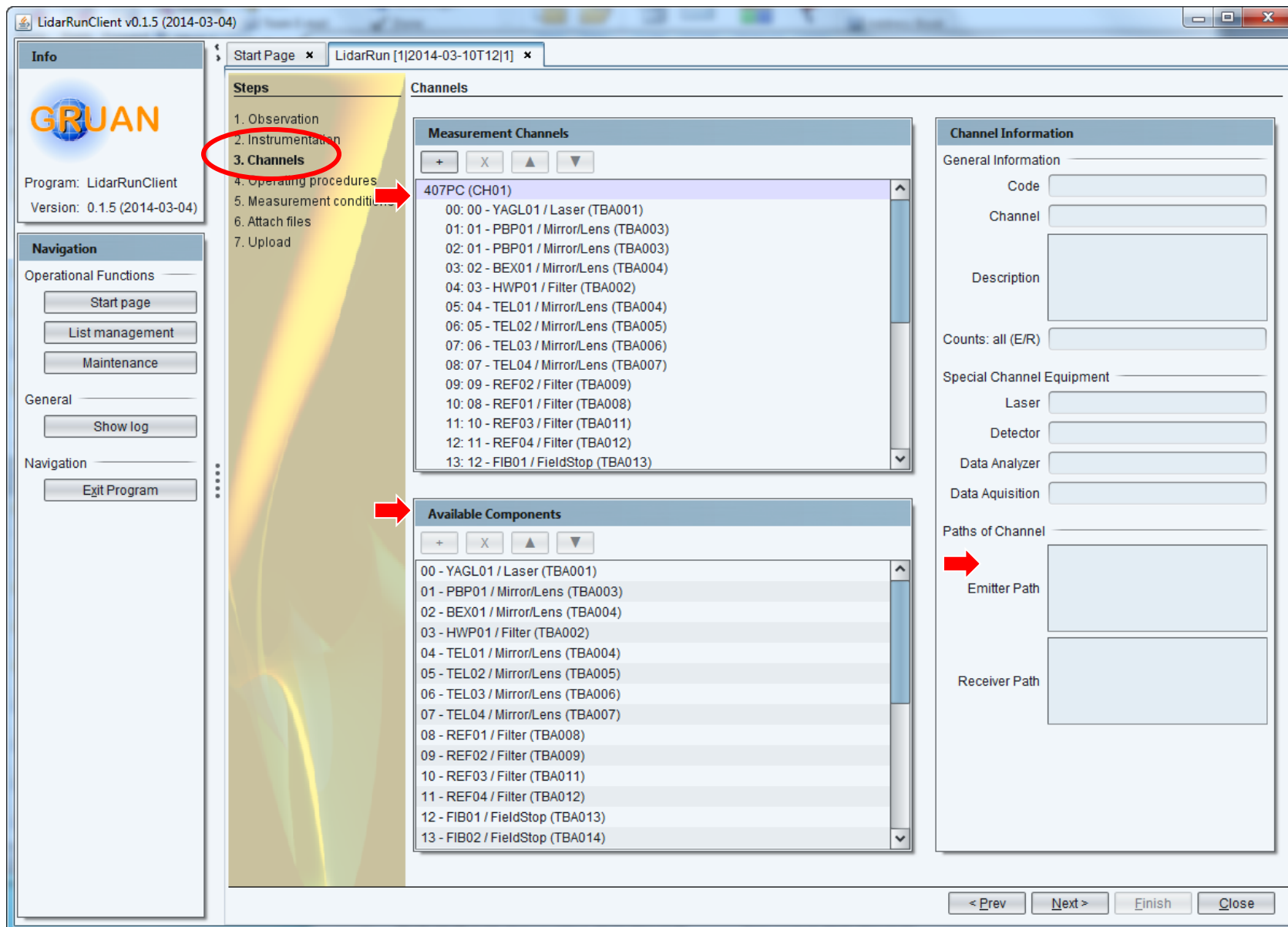
Comments

Filter Full Name Add Property Clear List

Name	Value	Unit
------	-------	------

< Prev Next > Finish Close

# LidarRunClient "Channels" page



LidarRunClient v0.1.5 (2014-03-04)

Start Page x LidarRun [1]2014-03-10T12[1] x

**Info**

**GRUAN**

Program: LidarRunClient  
Version: 0.1.5 (2014-03-04)

**Navigation**

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Start page  
List management  
Maintenance

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**Steps**

1. Observation
2. Instrumentation
- 3. Channels**
4. Operating procedures
5. Measurement conditions
6. Attach files
7. Upload

**Channels**

**Measurement Channels**

+ X ▲ ▼

407PC (CH01)

- 00: 00 - YAGL01 / Laser (TBA001)
- 01: 01 - PBP01 / Mirror/Lens (TBA003)
- 02: 01 - PBP01 / Mirror/Lens (TBA003)
- 03: 02 - BEX01 / Mirror/Lens (TBA004)
- 04: 03 - HWP01 / Filter (TBA002)
- 05: 04 - TEL01 / Mirror/Lens (TBA004)
- 06: 05 - TEL02 / Mirror/Lens (TBA005)
- 07: 06 - TEL03 / Mirror/Lens (TBA006)
- 08: 07 - TEL04 / Mirror/Lens (TBA007)
- 09: 09 - REF02 / Filter (TBA009)
- 10: 08 - REF01 / Filter (TBA008)
- 11: 10 - REF03 / Filter (TBA011)
- 12: 11 - REF04 / Filter (TBA012)
- 13: 12 - FIB01 / FieldStop (TBA013)

**Available Components**

+ X ▲ ▼

- 00 - YAGL01 / Laser (TBA001)
- 01 - PBP01 / Mirror/Lens (TBA003)
- 02 - BEX01 / Mirror/Lens (TBA004)
- 03 - HWP01 / Filter (TBA002)
- 04 - TEL01 / Mirror/Lens (TBA004)
- 05 - TEL02 / Mirror/Lens (TBA005)
- 06 - TEL03 / Mirror/Lens (TBA006)
- 07 - TEL04 / Mirror/Lens (TBA007)
- 08 - REF01 / Filter (TBA008)
- 09 - REF02 / Filter (TBA009)
- 10 - REF03 / Filter (TBA011)
- 11 - REF04 / Filter (TBA012)
- 12 - FIB01 / FieldStop (TBA013)
- 13 - FIB02 / FieldStop (TBA014)

**Channel Information**

General Information

Code

Channel

Description

Counts: all (E/R)

Special Channel Equipment

Laser

Detector

Data Analyzer

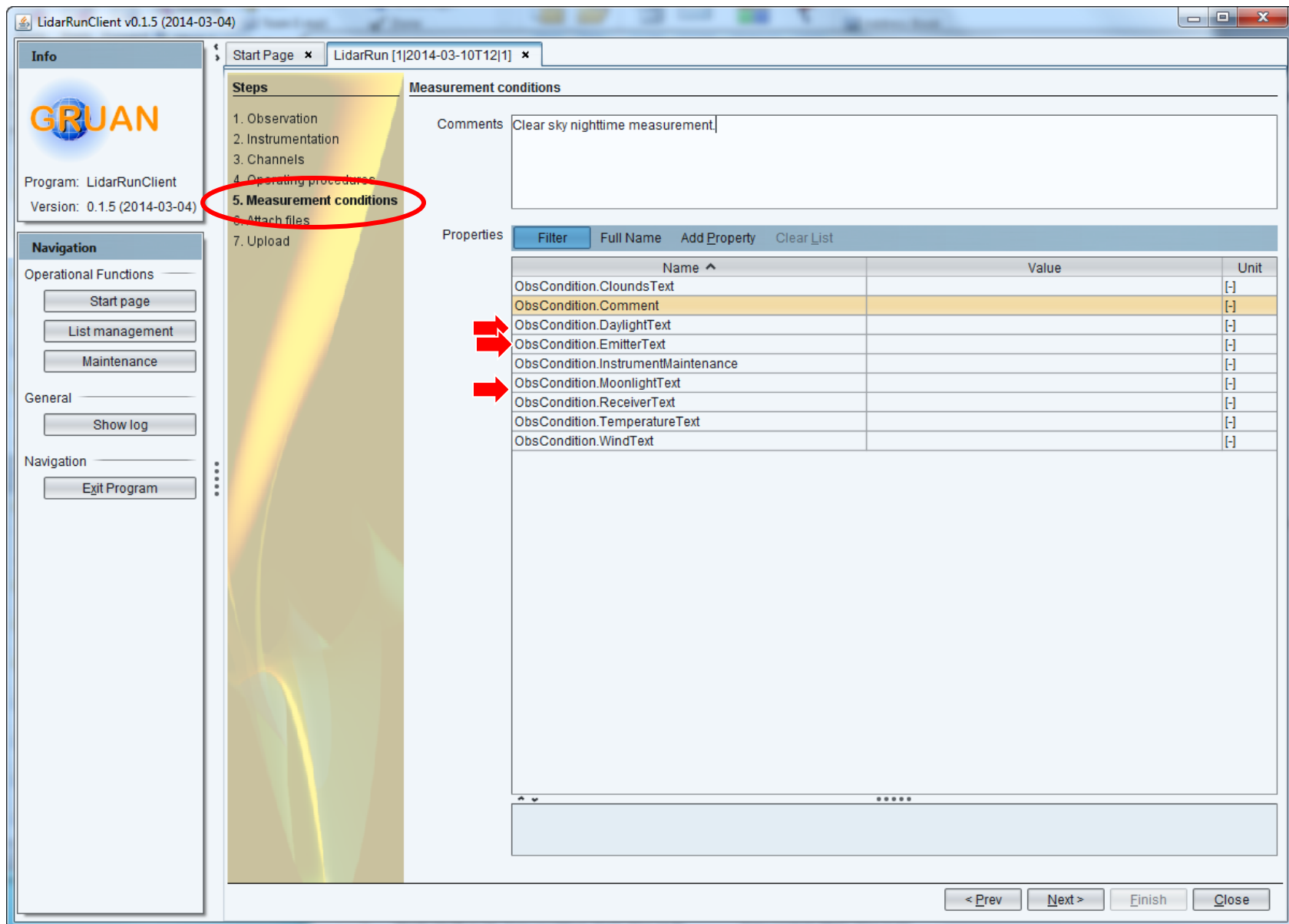
Data Acquisition

Paths of Channel

Emitter Path

Receiver Path

< Prev Next > Finish Close



LidarRunClient v0.1.5 (2014-03-04)

Info

GRUAN

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Version: 0.1.5 (2014-03-04)

Navigation

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Navigation

Exit Program

Steps

1. Observation
2. Instrumentation
3. Channels
4. Operating procedures
- 5. Measurement conditions**
6. Attach files
7. Upload

Measurement conditions

Comments

Clear sky nighttime measurement

Properties

Filter Full Name Add Property Clear List

Name ^	Value	Unit
ObsCondition.CloudsText		[-]
ObsCondition.Comment		[-]
ObsCondition.DaylightText		[-]
ObsCondition.EmitterText		[-]
ObsCondition.InstrumentMaintenance		[-]
ObsCondition.MoonlightText		[-]
ObsCondition.ReceiverText		[-]
ObsCondition.TemperatureText		[-]
ObsCondition.WindText		[-]

< Prev Next > Finish Close

# LidarRunClient "Attach Files" page

LidarRunClient v0.1.5 (2014-03-04)

Info

GRUAN

Program: LidarRunClient  
Version: 0.1.5 (2014-03-04)

Navigation

Operational Functions

Start page  
List management  
Maintenance

General

Show log

Navigation

Exit Program

Steps

1. Observation
2. Instrumentation
3. Channels
4. Operating procedures
5. Measurement conditions
- 6. Attach files**
7. Upload

Attach files

List of files to attach

27 - DAS01 / Software (TBA028)		
ZIP - Packed Lidar Raw Files (*.zip)	MISSING [required]	-
A-RAW - Lidar Raw File (Payerne) (*.*)	[optional]	-

Selected file of LIDAR

Part 27 - DAS01

Linked Instruments

☐ This instrument

Type ZIP - Packed Lidar Raw Files (\*.zip)

Required? [required]

Status Warning

File Name

File Path

Checksum

Size

Choose Local Files

GRUAN

- ☐ a1140500.080811
- ☐ a1140500.091019
- ☐ a1140500.101227
- ☒ RALMO\_20120510\_20120511.dat
- ☐ TMW\_RawData\_Obs\_a1140.070688

RALMO\_20120510\_20120511.dat

All Files

Accept File(s) Cancel

Actions

Add Files

Remove File

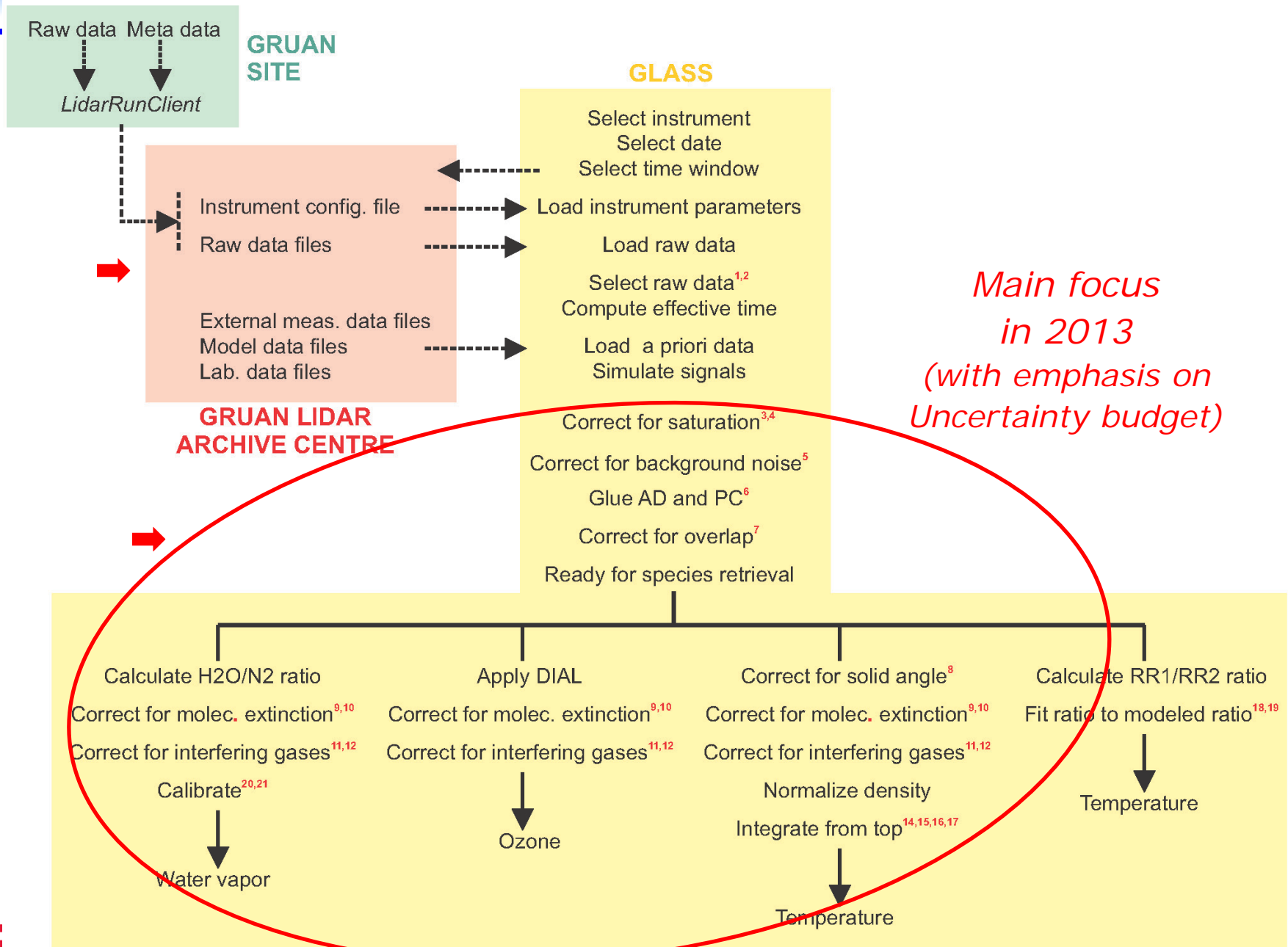
Add File

Check File

View File

Please, add all red marked required data files.

< Prev Next > Finish Close



### 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  $\sigma_x$  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  $x_1, x_2, \dots, x_n$ :

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

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

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

➡ **Addressed by ISSI Team and included in GLASS:**

- ➡ 1. Photon Counting statistical noise
- 2. Saturation (pile-up): dead-time  $\tau$
- 3. Background correction: Fitting coefficients  $b_j$
- 4. Molecular extinction: cross-sections values  $\sigma_{Ray}$
- 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

➔ **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 (H<sub>2</sub>O 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*

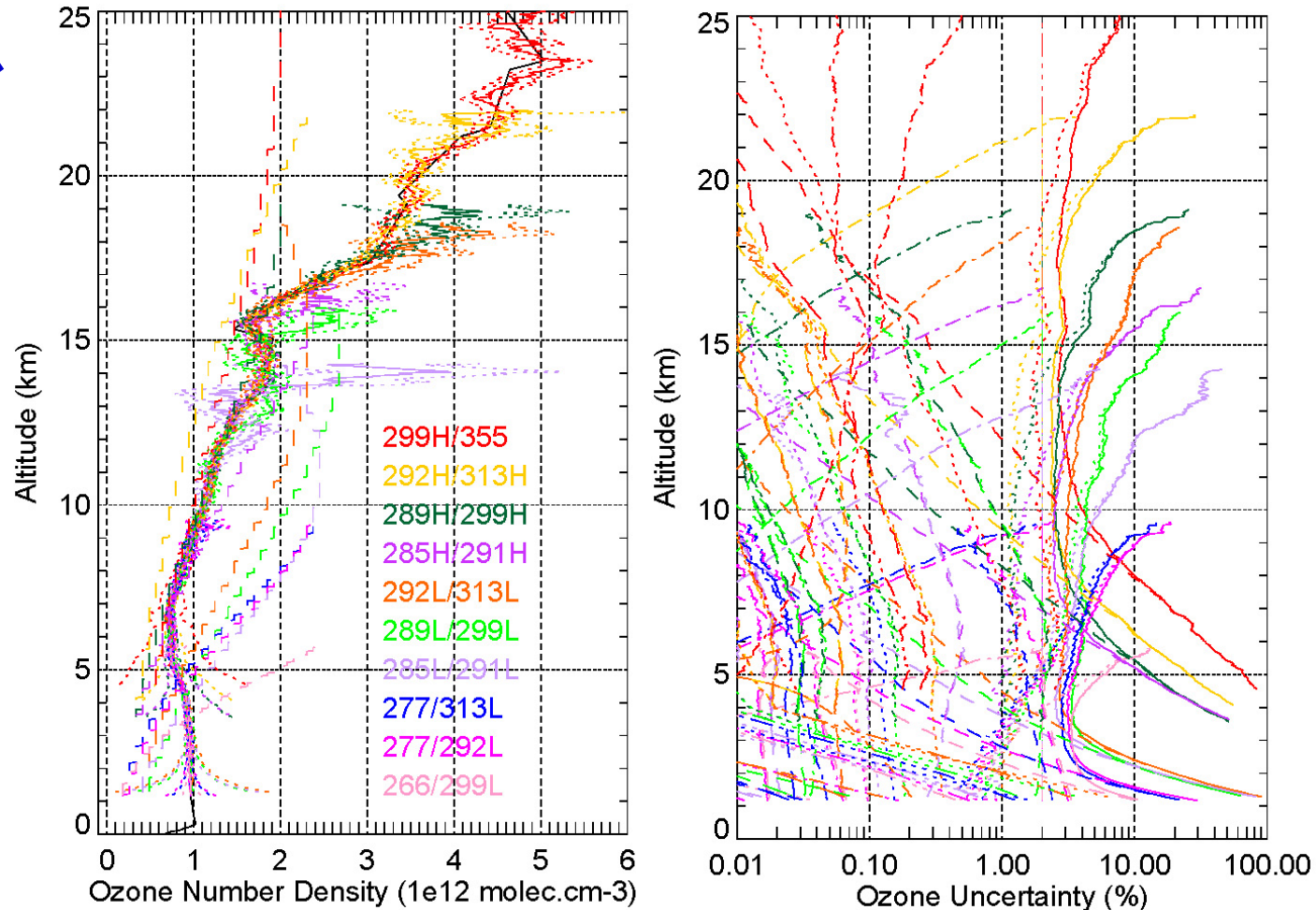
*Reason #2: →*

*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*



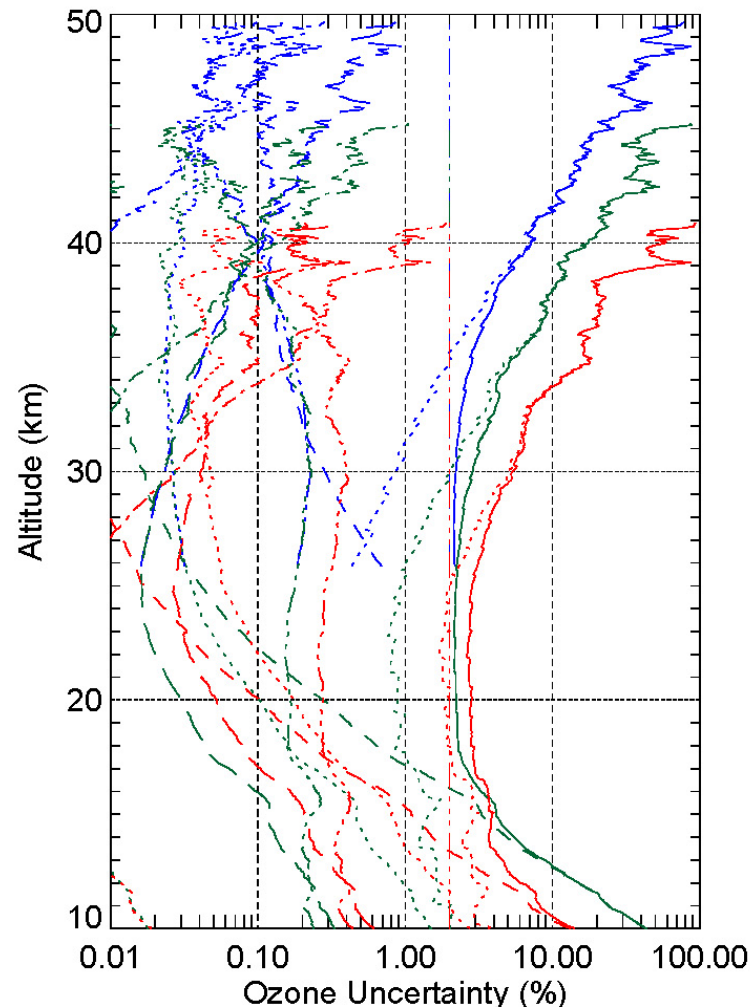
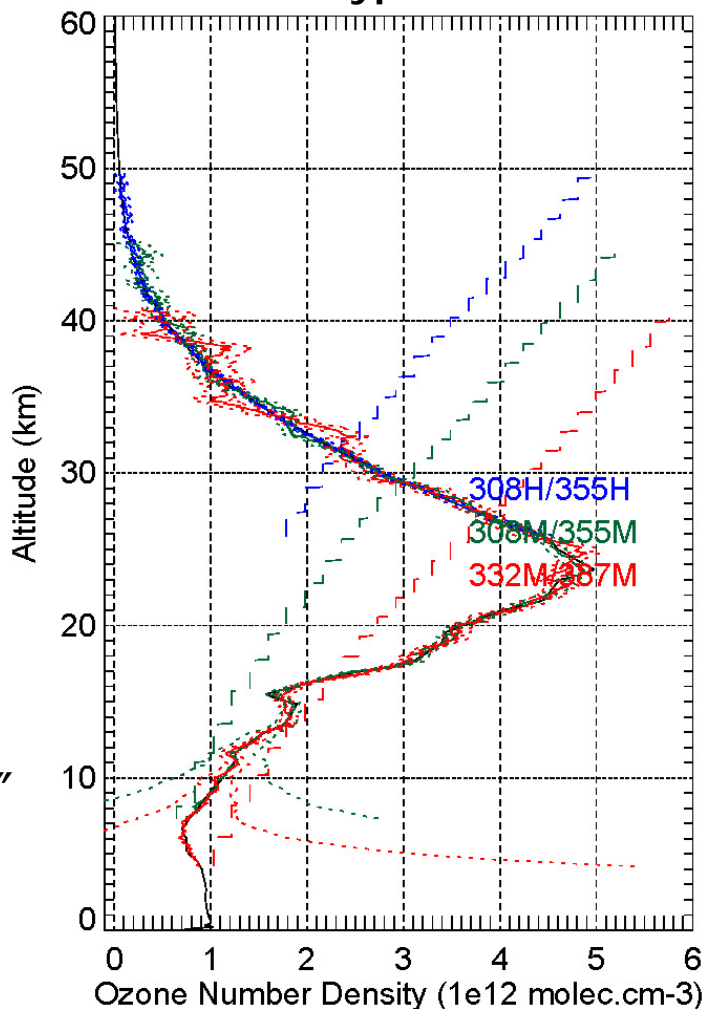
## Typical NDACC stratospheric ozone lidar product

## Reason #3: →

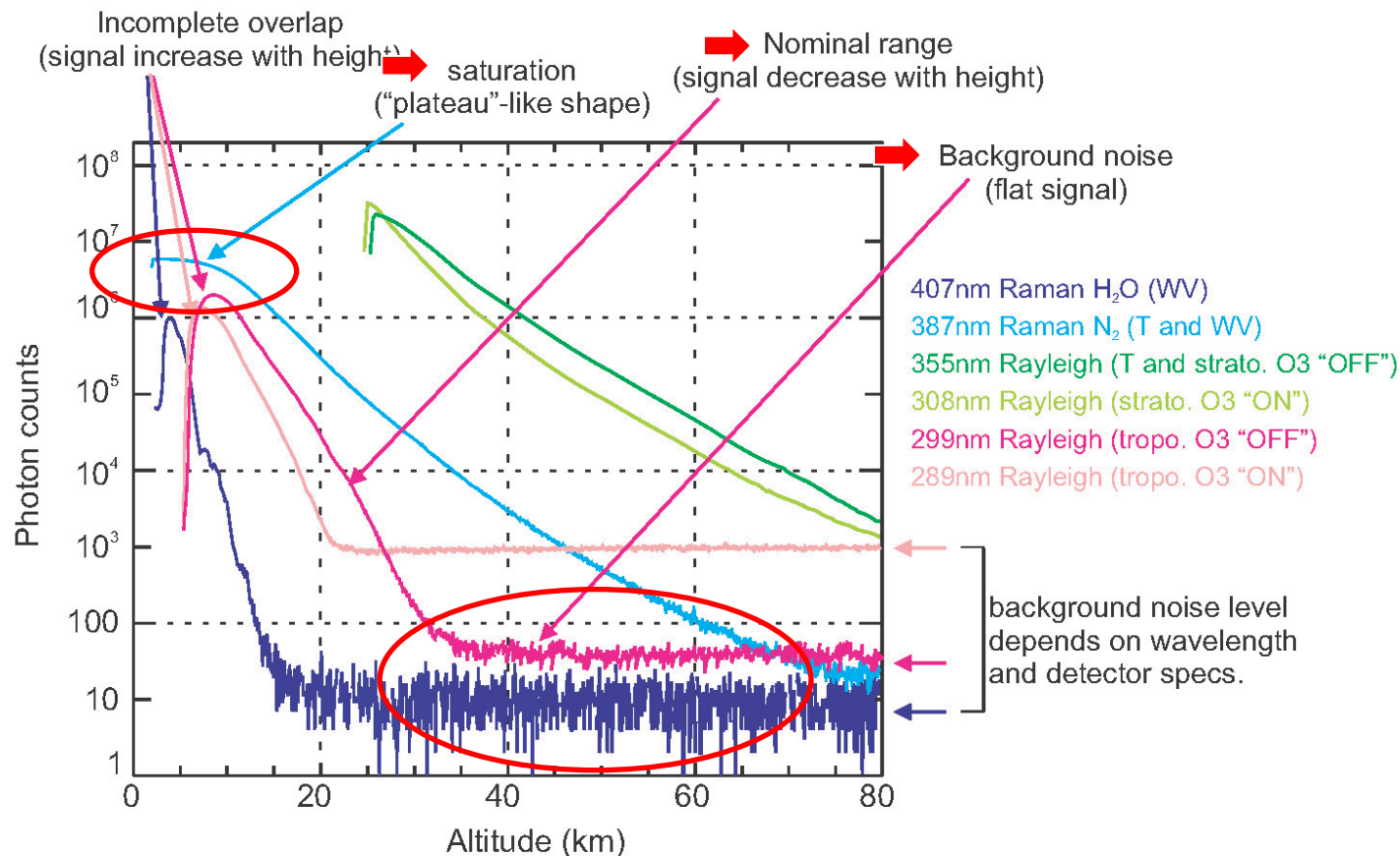
Lidar methods and corrections differ from one species to the other

→ Huger quantity of work to compile

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



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



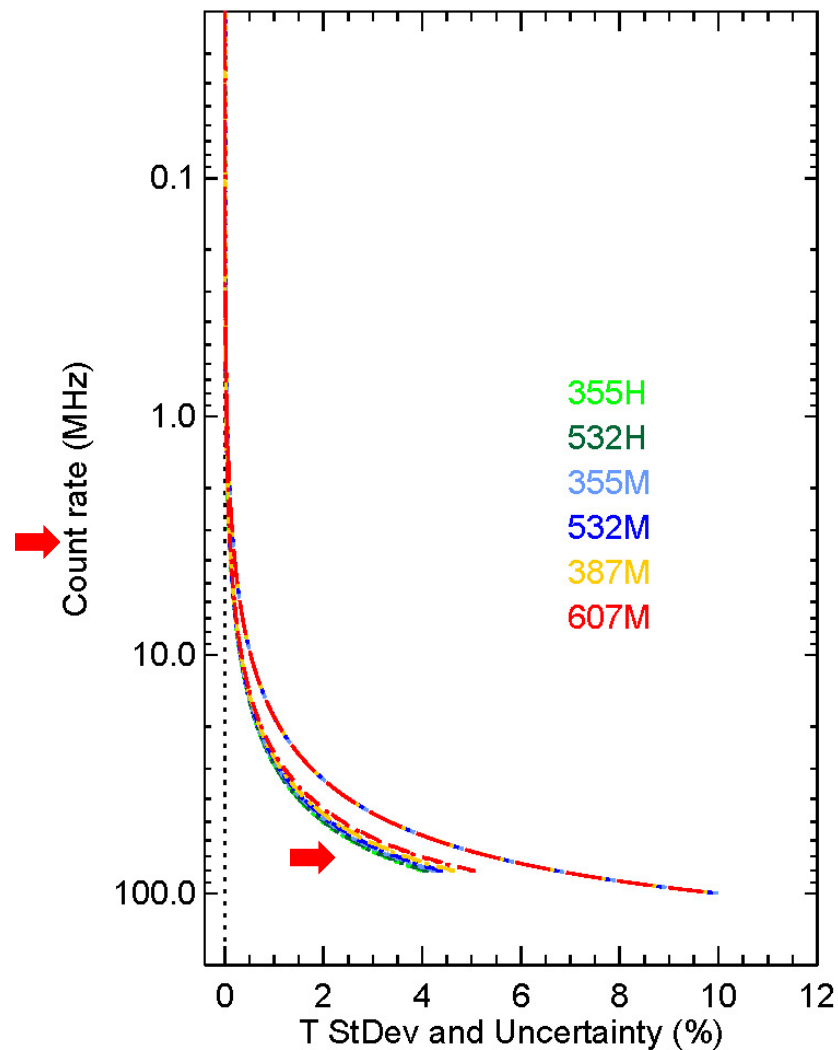
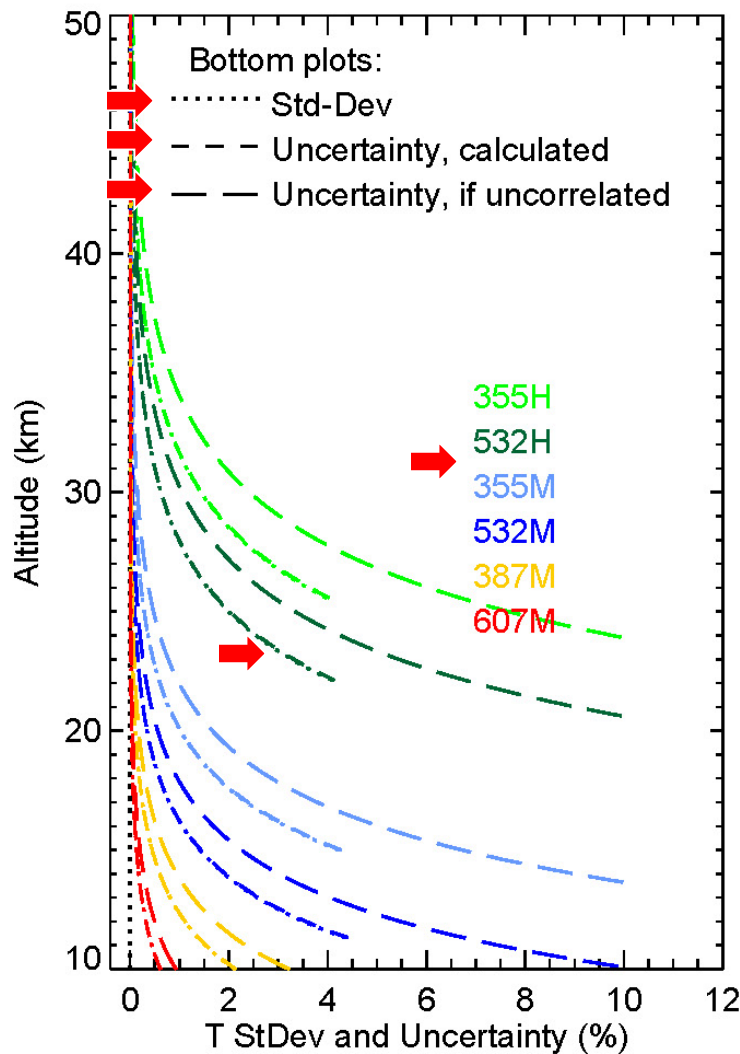
**→ Monte Carlo Simulations are required to compute covariance matrix and estimate the resulting impact of correlated terms on uncertainty**

## By use of Lidar Signal Simulations and Monte Carlo Runs...

### *Modus operandi:*

- ➡ 1. Start from assumed atmospheric state  $[T(z), p(z), O_3(z), H_2O(z)]$  ("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

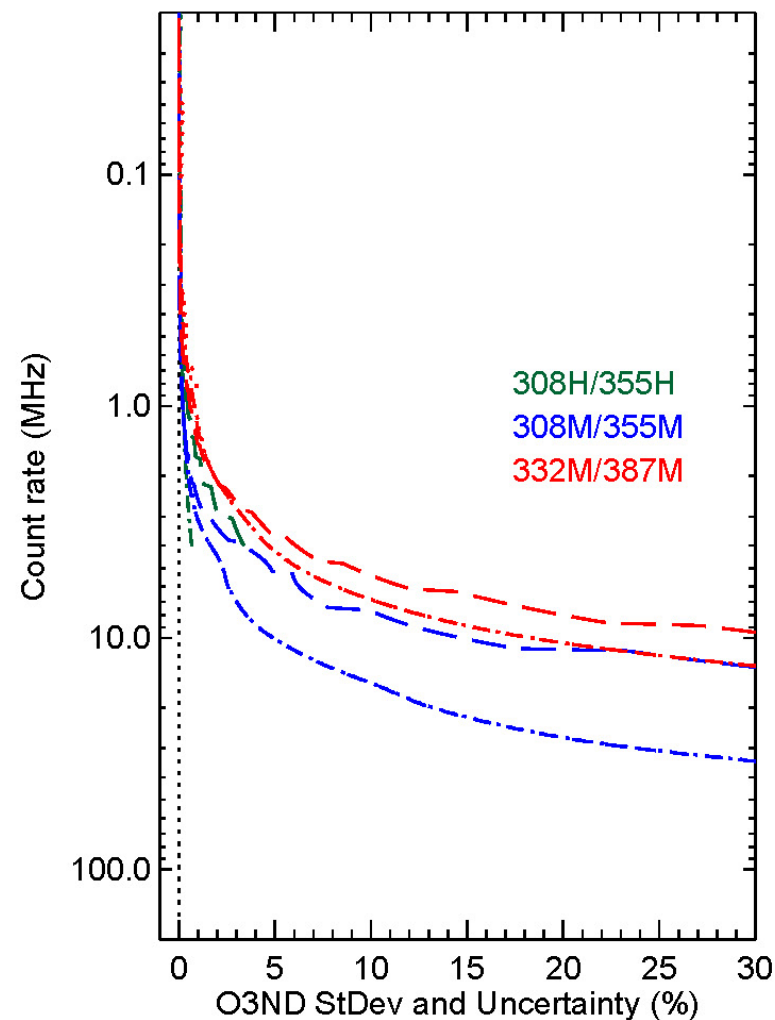
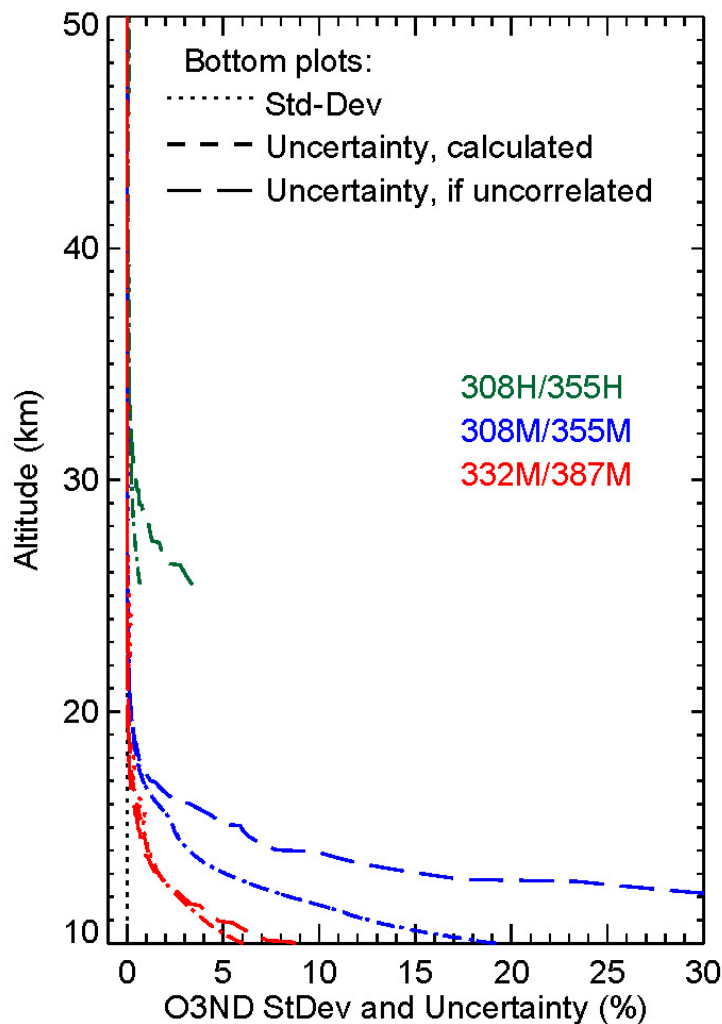
# Quantifying saturation correction uncertainty on Temperature



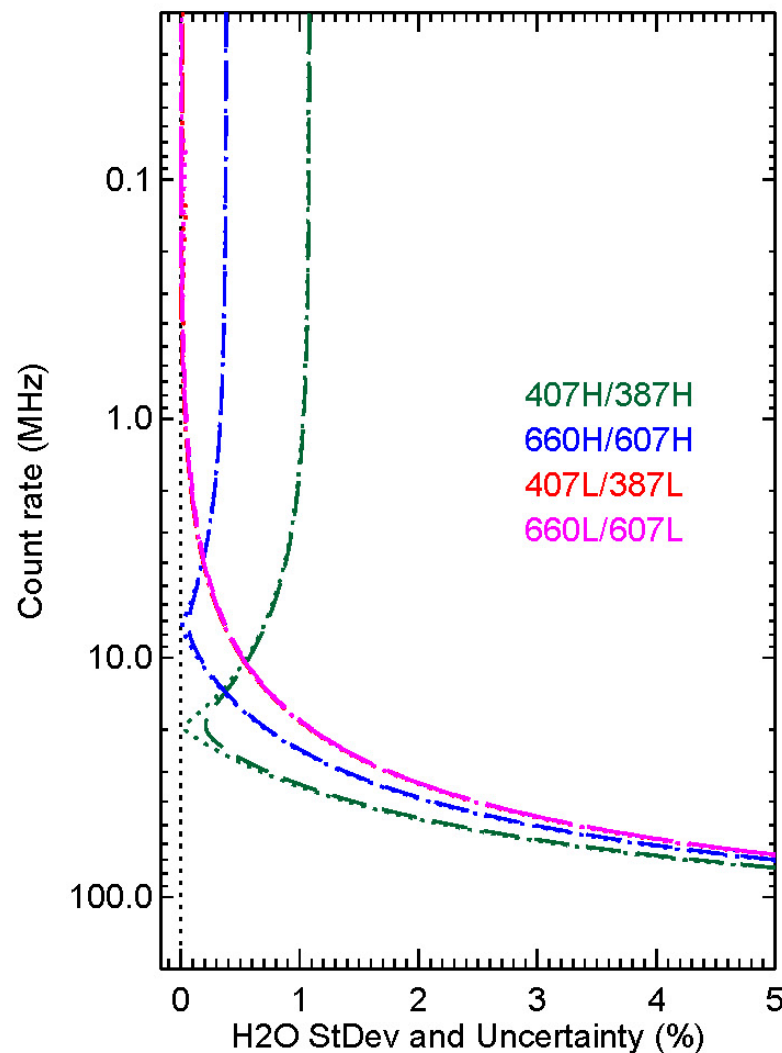
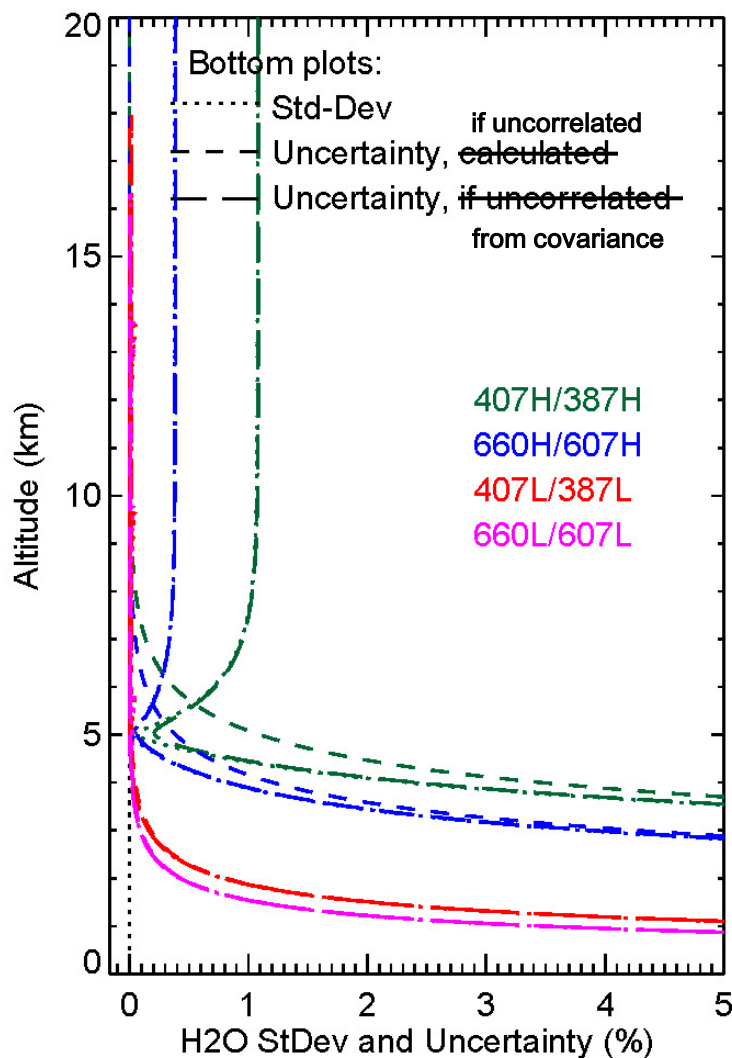
➡ **Uncertainty due to saturation overestimated if assumed uncorrelated**



# Quantifying saturation correction uncertainty on ozone



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

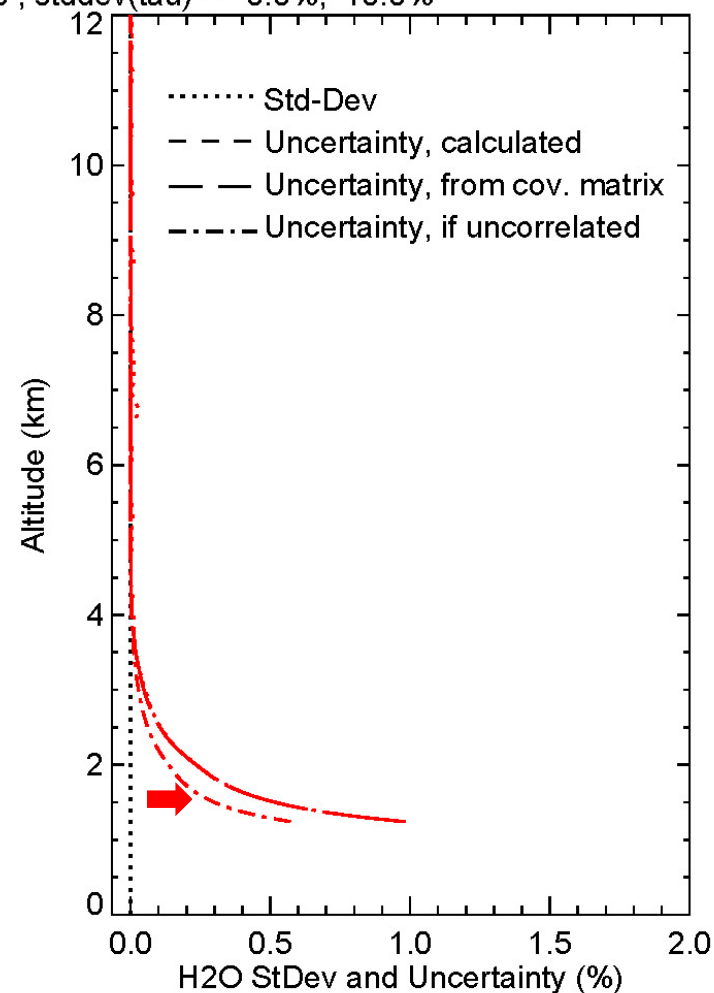
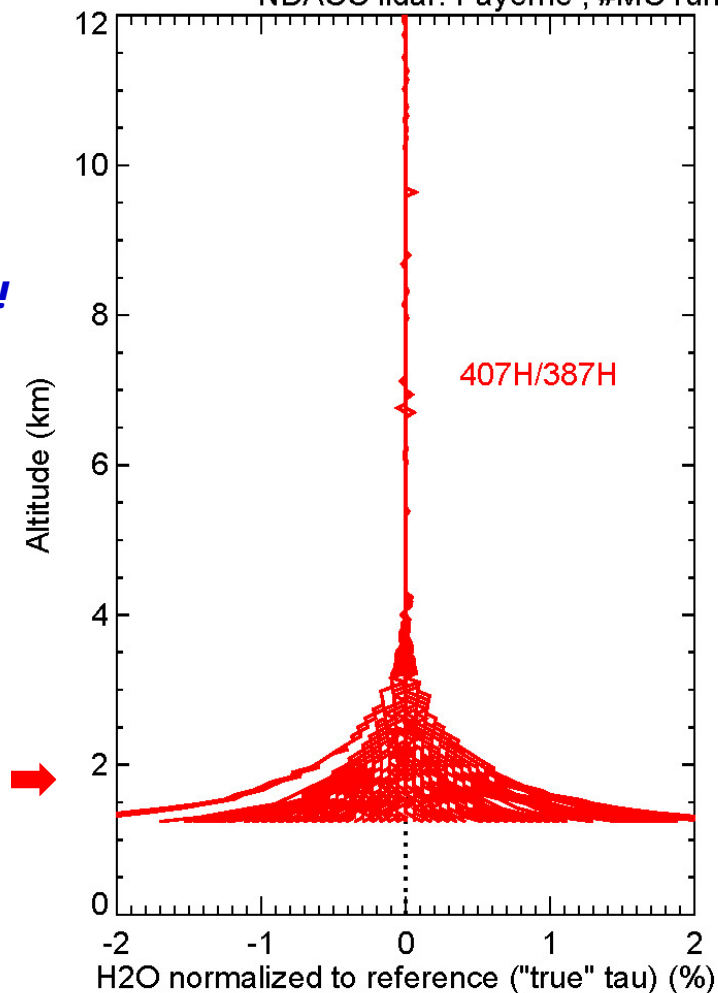


***Uncertainty due to saturation is either overestimated  
or underestimated if assumed uncorrelated!***

➔ Simulation using actual lidar parameters of Payerne

NDACC lidar: Payerne ; #MC runs: 200 ; stddev(tau) = 0.0%, 10.0%

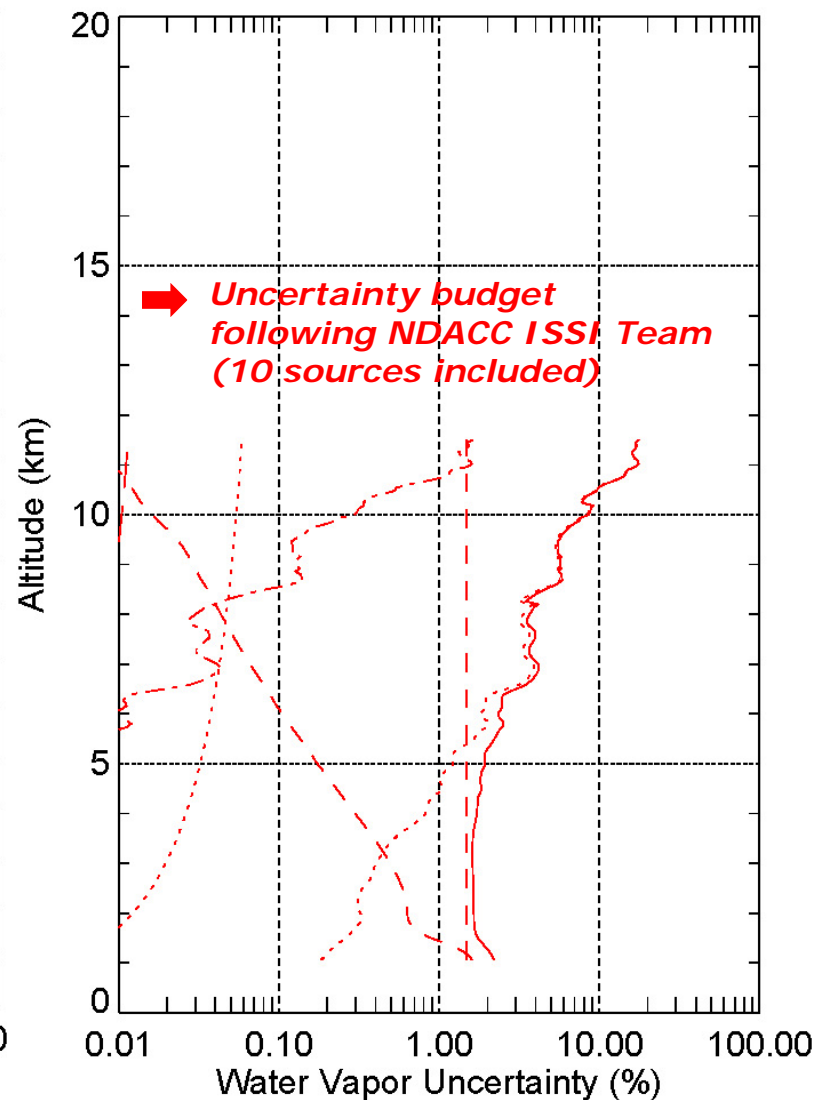
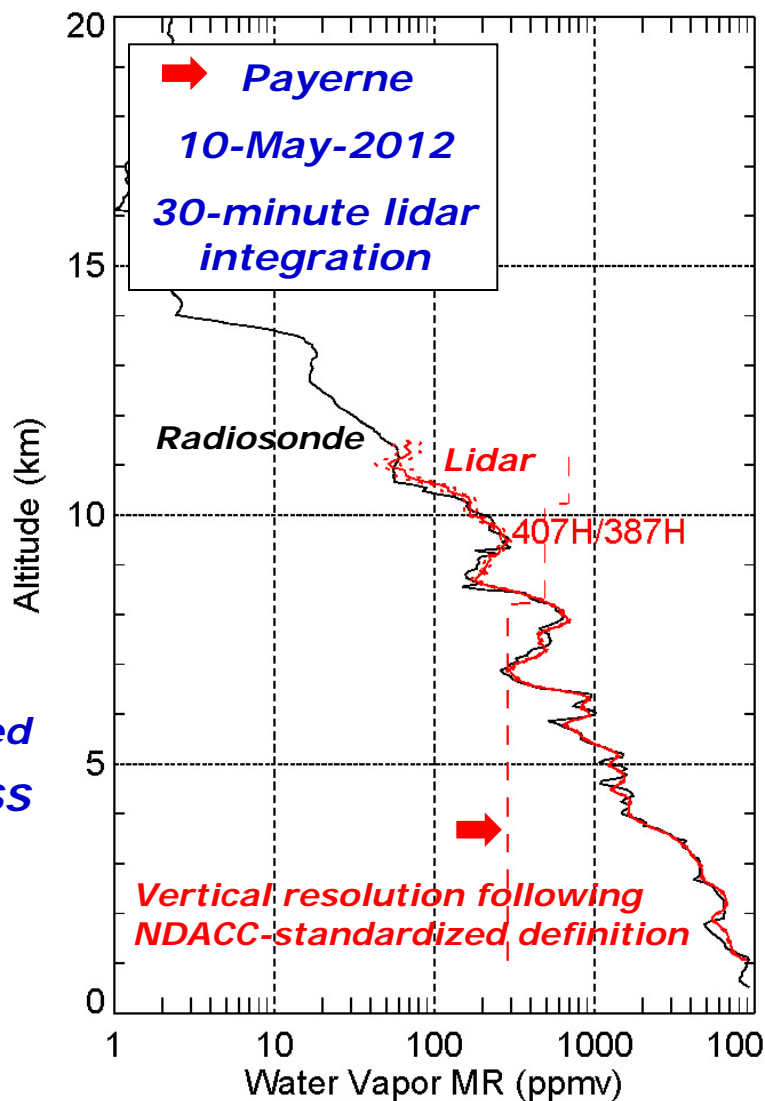
*Retrieved  
by the GLASS!*







*As retrieved  
by the GLASS*



- ➔ *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*