GRUAN Lidar Data Stream

Progress Status

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What is Lidar?
Why Lidar in GRUAN?

Lidar (LIght Detection And Ranging) is an active remote sensing technique

1. One or more laser beam(s) sent in the atmosphere
2. Laser light backscattered by atmospheric molecules and particles, collected by telescope
3. Amount of light (raw lidar signal) analyzed as a function of time, i.e., altitude (high temporal and vertical resolution)

Lidar atmospheric composition applications:

1. Vertical profiles of ozone, water vapor, temperature, wind, cloud and aerosol properties (also, CO_2, CH_4, NO_2, and more)
2. Temporal resolution range from seconds to days (e.g., Payerne WV)
3. Vertical resolution range from meters to a few kilometers

Why including Lidars in GRUAN?

1. Good complement to the core GRUAN products (e.g., for water vapor, ozone, temperature)
2. Redundancy, validation purposes, as well as dedicated studies (e.g., 2D variability)
3. Synergy with other networks, measurements already available in some GRUAN sites

Why (and how to) develop a Lidar Product for GRUAN that is not already available elsewhere?

Except for two aerosol networks (EARLINET and MPLNET), there is no such thing as "Centralized Data Processing" for networked lidars

To meet GRUAN requirements and/or recommendations:

1. All sources of **uncertainty** must be comprehensively characterized
2. The full data processing must meet **traceable standards**
3. Data processing sources and methods must be transparent (**no black box**!)
4. Data processing must carefully **manage change with time** over long periods of time! (decades and longer)

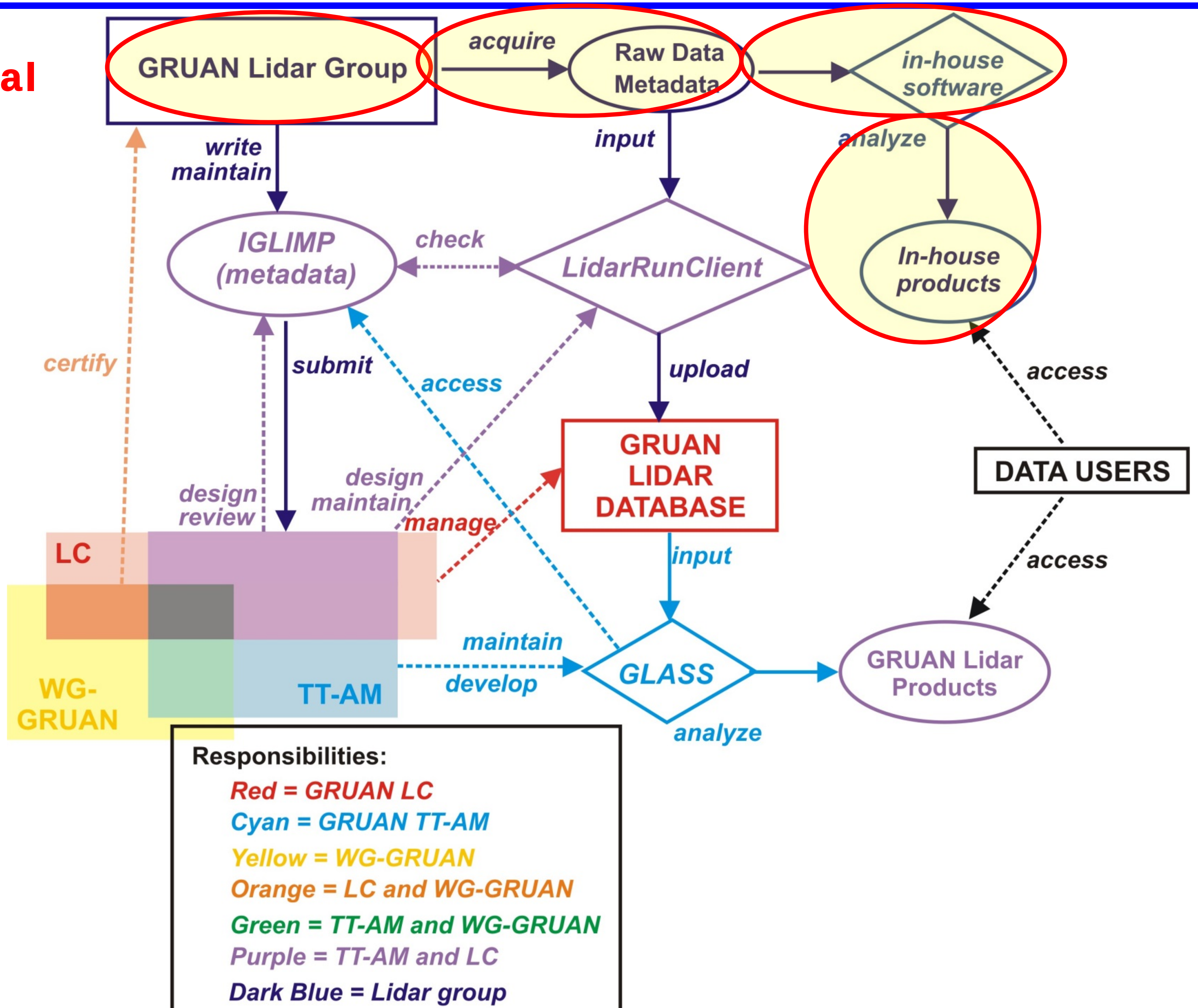
The answer to above points 1-4 is:

1. The development of a "customized" LidarRunClient interface at each GRUAN Lidar site
2. The development of a transparent instrument-dependent and time-dependent Centralized data processing software

   ➔ GLASS (Global Lidar Analysis Software Suite)

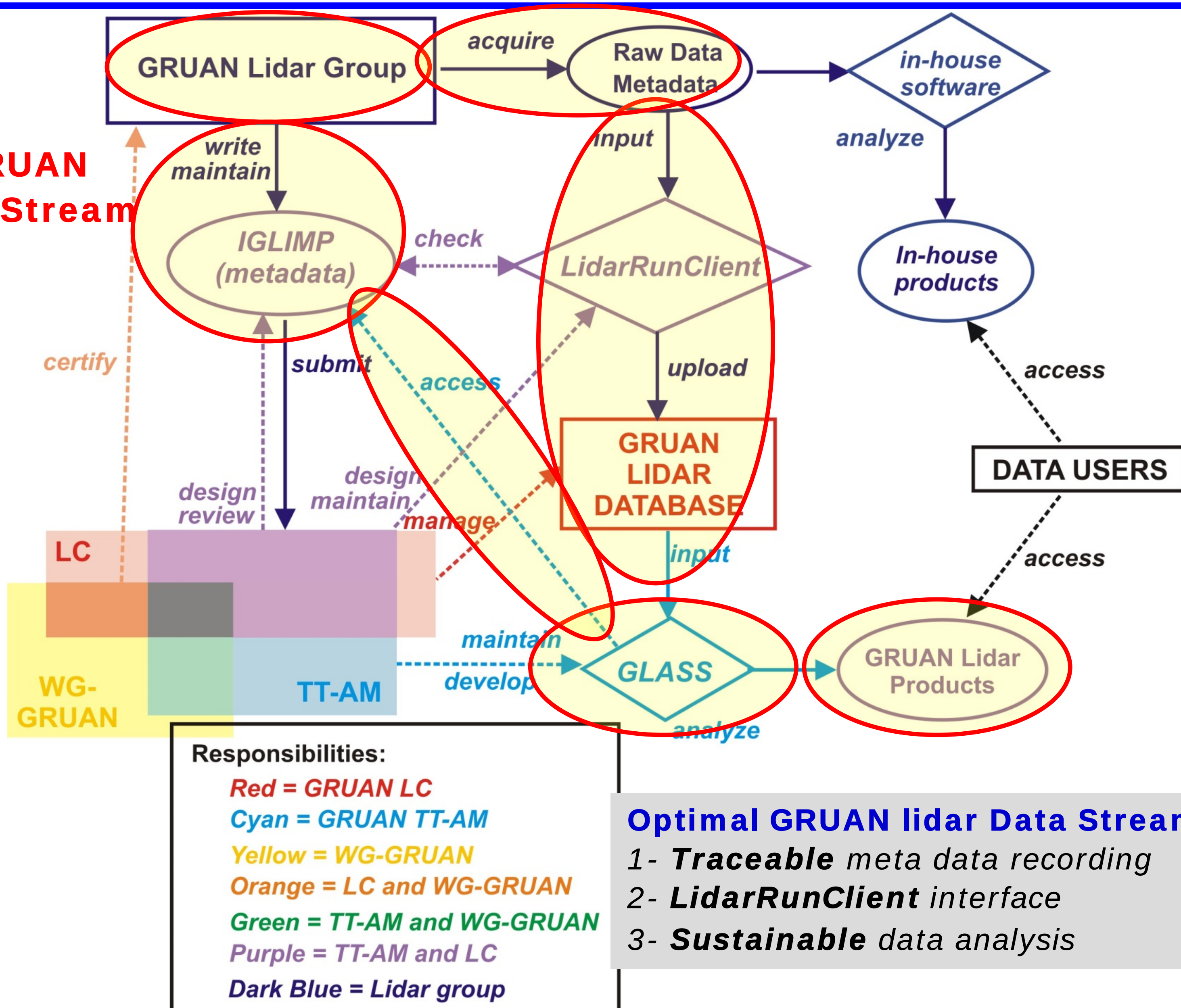
Lidar GRUAN Product vs. In-house Products

Traditional in-house



Lidar GRUAN Product vs. In-house Products

Optimal GRUAN Lidar Data Stream



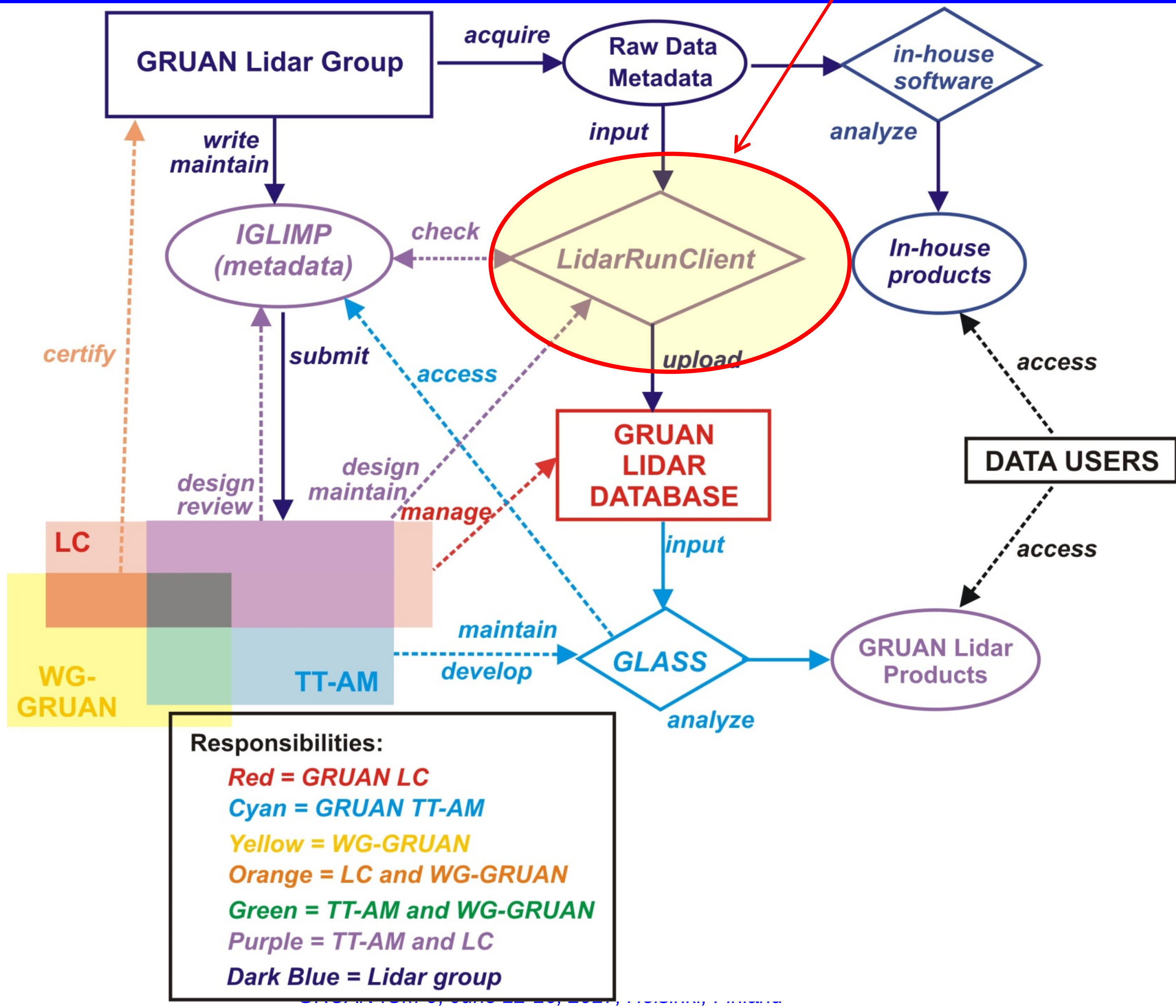
Optimal GRUAN lidar Data Stream:

1- ***Traceable*** *meta data recording*

2- ***LidarRunClient*** *interface*

3- ***Sustainable*** *data analysis*

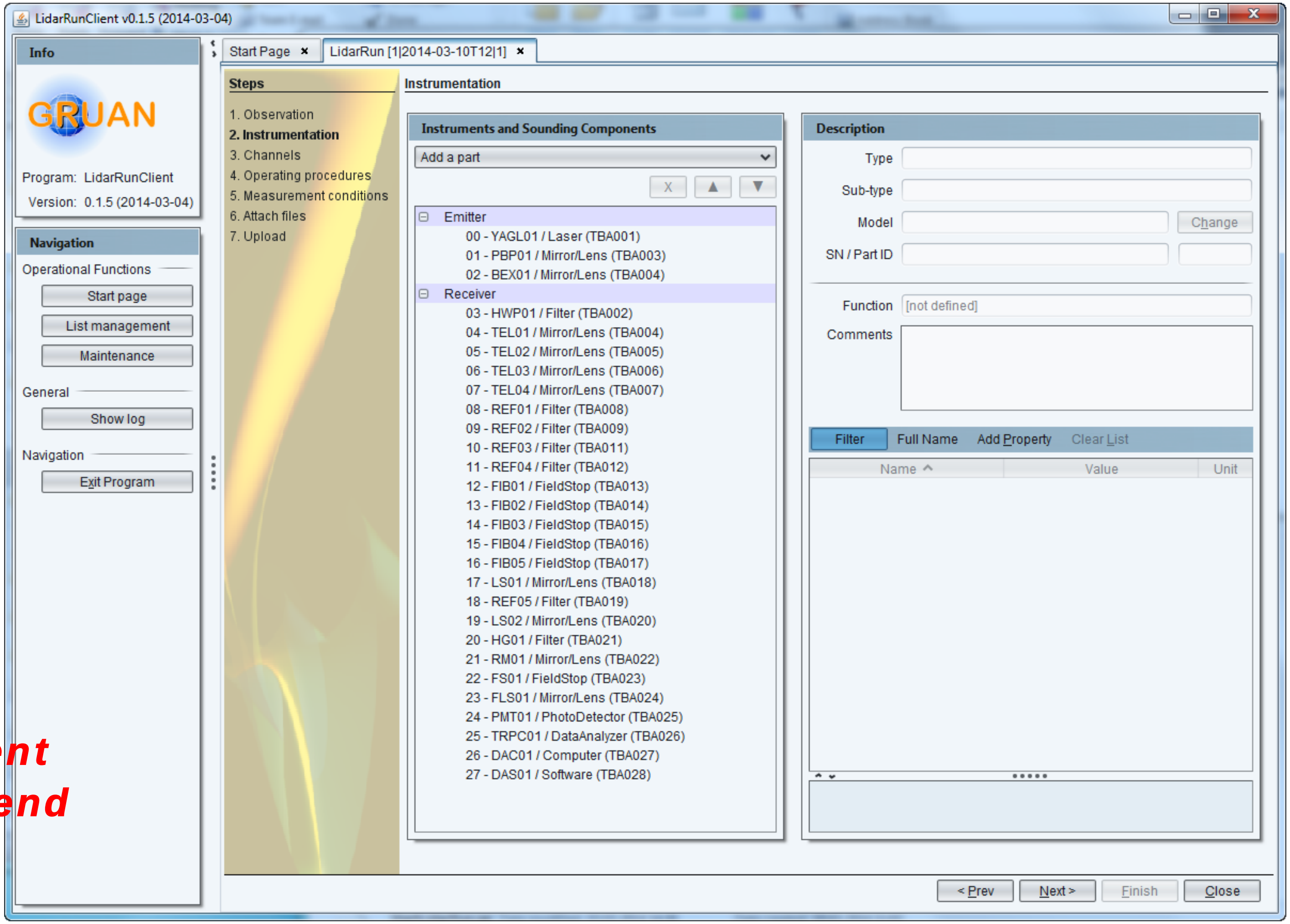
LidarRunCLient



LidarRunClient Status

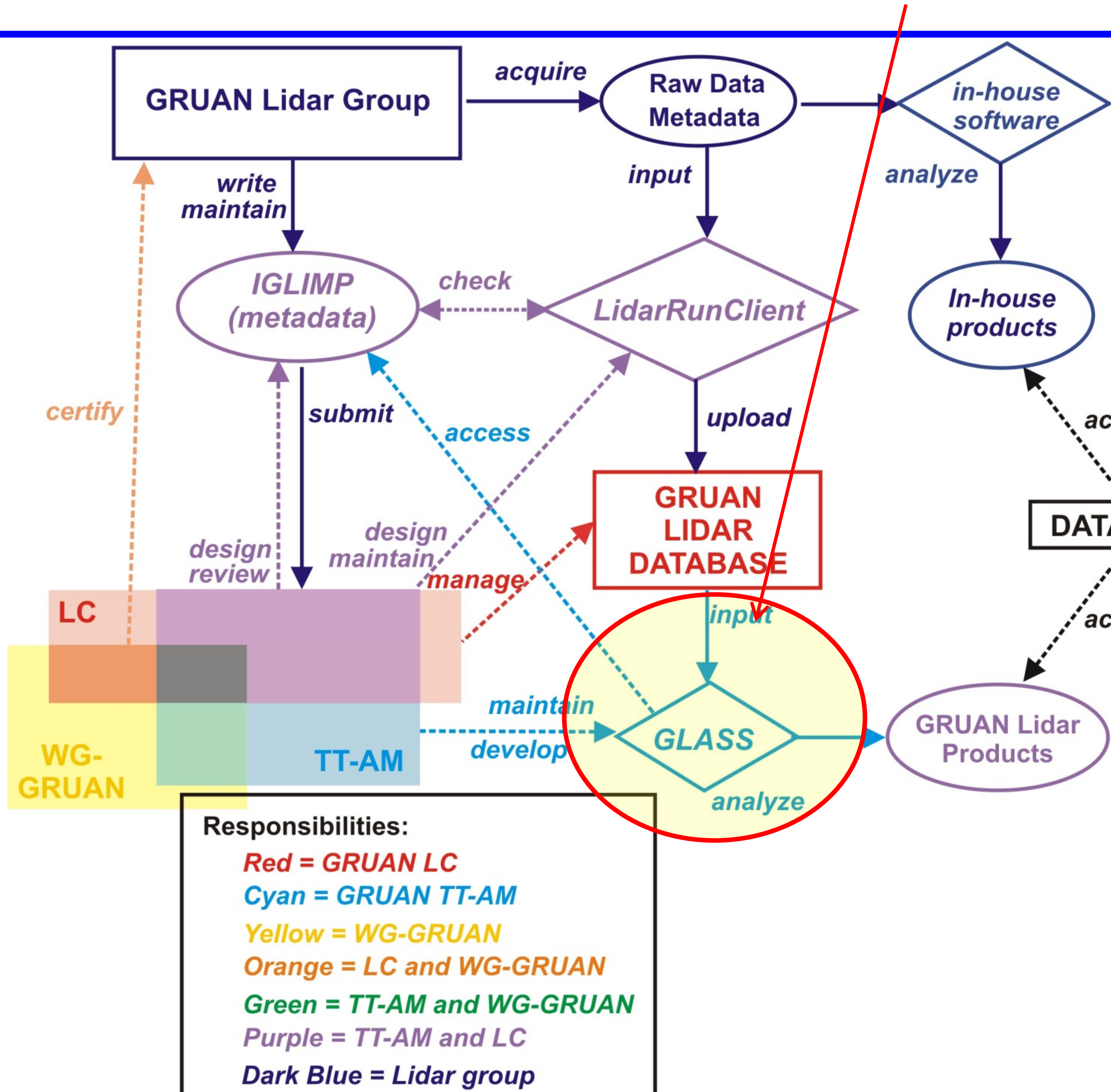
Development still (!!) ongoing

Initiated 2015, refined 2016, to be continued next week! ☺



M. Sommer and T. Leblanc agreed on firm commitment to finalize before end of 2017

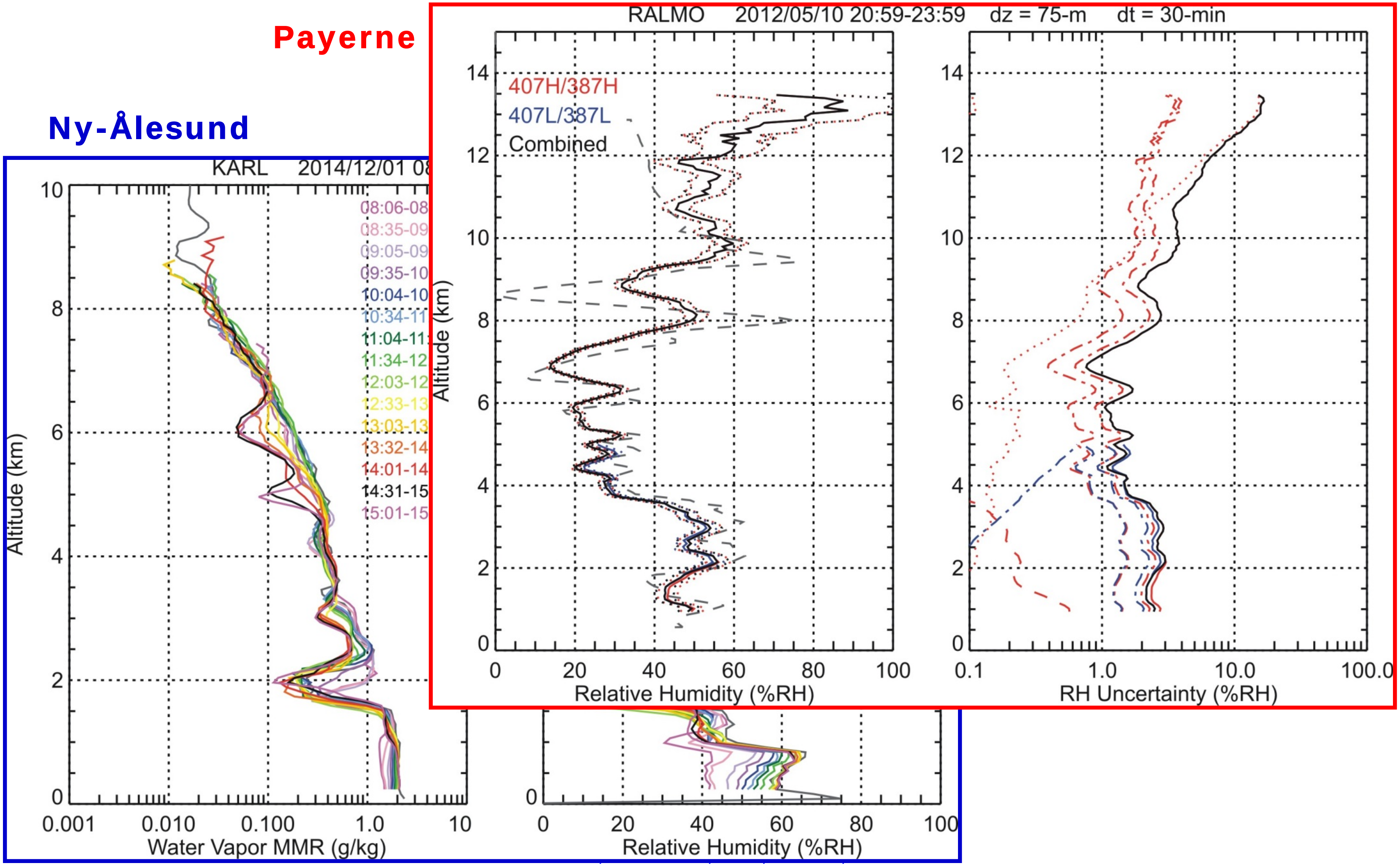
GLASS (Data processing)



GLASS beta-version (2015-2016) presented to previous ICM

Payerne

Ny-Ålesund



2016/2017: GLASS v1 with Comprehensive meta data ingestion

For each lidar instrument, the meta data are imported into GLASS v1 by accessing 3 meta data files:

1. Instrumentation hardware and software configuration
2. Raw lidar signals analysis option
3. Species-specific retrieval options

Imported meta data are <u>instrument-dependent AND time-dependent</u>

There is only one "instrument meta data file" per lidar instrument
(the file includes the entire history of the instrument's hardware and software configuration)

For each instrument, we can set several "signal analysis configurations", and several "species retrieval configurations"
(based on either time, or science application, or both)

The meta data structure is designed in such a way that each meta datum imported to GLASS is "independent" from all the others (on a data processing point of view)

Content of meta data file 1 (instrumentation)

Section 1: Deployment History (geolocation)

Section 2: Raw Data Stream Configuration History (lidar channels)

GLASS uses Section 2 to fetch the proper instrument setup, which is fully described by five sub-sections (Section 3):

Section 3: Setup details Lists

- Emitter setup list
- Optical Receiver setup list
- Data Recorder setup list
- Laser and data recorder trigger setup list
- Data Acquisition Software setup list

GLASS finally uses Section 3 to associate the (only) setup found to the hardware involved in that setup (Section4):

Section 4: Full list of hardware and software components

- Hardware names, types, function, and any numerical parameter relevant to the data processing

Example of meta data file 1 (instrumentation)

```
-------------------------------------------------------------------------------------------------------------

DEPLOYMENT HISTORY
1999/11/01 00:00:00 > 2099/12/31 23:59:59 ; SiteID=TMF ; SiteLong=-117.68 ; SiteLat=+34.43 ; SiteElev=2285 ; SiteName=Tble-Mntn

DATA STREAMS HISTORY
2002/09/17 00:00:00 > 2012/01/26 23:59:59 ; NStreams=2 ; Emit=1,2     ; Recv=1,2     ; Recd=1,2     ; Trig=1,1     ; Acqu=1,1
2012/01/27 00:00:00 > 2012/12/18 23:59:59 ; NStreams=4 ; Emit=1,2,1,2 ; Recv=1,2,3,4 ; Recd=3,4,5,6 ; Trig=1,1,1,1 ; Acqu=2,2,2,2
2012/12/22 00:00:00 > 2013/01/25 23:59:59 ; NStreams=4 ; Emit=1,2,1,2 ; Recv=1,2,5,6 ; Recd=3,4,5,6 ; Trig=2,2,2,2 ; Acqu=3,3,3,3

-------------------------------------------------------------------------------------------------------------

EMITTER HARDWARE SETUP LIST
Emit=1 ; Path=YAG01/1-RAMCEL01-BEX01-TRMIR01 ; Trig=DG01-DG02-YAG01
Emit=2 ; Path=YAG01/2-RAMCEL02-BEX02-TRMIR02 ; Trig=DG01-DG02-YAG01

RECEIVER HARDWARE SETUP LIST
Recv=1 ; Path=TEL01-FIB01/1-CHOP01-DBS01/1-IF01-PMT01
Recv=2 ; Path=TEL01-FIB01/2-CHOP01-DBS02/1-IF02-PMT02
Recv=3 ; Path=TEL02-FIB02-CHOP01-DBS03/1-IF03-PMT03
Recv=4 ; Path=TEL03-FIB03-CHOP01-DBS04/1-IF04-PMT04
Recv=5 ; Path=TEL04-IF05-PMT05
Recv=6 ; Path=TEL05-IF06-PMT06

DATA RECORDER SETUP LIST
Recd=1  ; Path=LICEL01-TR01/2-COMP01 ; Trig=DG01-DG02-TR01
Recd=2  ; Path=LICEL01-TR01/4-COMP01 ; Trig=DG01-DG02-TR01
Recd=3  ; Path=LICEL01-TR02/2-COMP01 ; Trig=DG01-DG02-TR02
Recd=4  ; Path=LICEL01-TR02/4-COMP01 ; Trig=DG01-DG02-TR02
Recd=5  ; Path=LICEL01-TR03/2-COMP01 ; Trig=DG01-DG02-TR03
Recd=6  ; Path=LICEL01-TR03/4-COMP01 ; Trig=DG01-DG02-TR03
```

FILE CONTENT CONTINUES ON NEXT SLIDE....

Example of meta data file 1 (instrumentation)

…CONTINUED FROM PREVIOUS SLIDE:

```
TRIGGER SETTINGS LIST
Trig=1 ; BinRange0=1
Trig=2 ; BinRange0=2

DATA ACQUISITION SETTINGS LIST
Acqu=1 ; NSamples=1024  ; SampleTime=0.4e-6 ; SoftwName=LAcquire  ; Discrim=12 ; VRange=20e-3
Acqu=2 ; NSamples=819   ; SampleTime=0.5e-6 ; SoftwName=LAcquire  ; Discrim=12 ; VRange=20e-3
Acqu=3 ; NSamples=8192  ; SampleTime=50e-9  ; SoftwName=LAcquire  ; Discrim=12 ; VRange=20e-3
Acqu=4 ; NSamples=16380 ; SampleTime=50e-9  ; SoftwName=LicelMain ; Discrim=12

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HARDWARE LIST
HardwID=BEX01     ; Type=BeamExpander
HardwID=BEX02     ; Type=BeamExpander
HardwID=COMP01    ; Type=Computer
HardwID=DBS01/1   ; Type=Beamsplitter
HardwID=DBS02/1   ; Type=Beamsplitter
HardwID=FIB02     ; Type=Fiber
HardwID=FIB03     ; Type=Fiber
HardwID=IF01      ; Type=Filter ; BandPass=288.95e-9 ; FWHM=1.2e-9
HardwID=IF02      ; Type=Filter ; BandPass=299.10e-9 ; FWHM=1.2e-9
HardwID=IF03      ; Type=Filter ; BandPass=288.95e-9 ; FWHM=1.2e-9
HardwID=RAMCEL01 ; Type=RamanCell ; RamGas=D2 ; RamShift=2986.0e2
HardwID=RAMCEL02 ; Type=RamanCell ; RamGas=H2 ; RamShift=4160.0e2
HardwID=TEL01     ; Type=Telescope
HardwID=TEL02     ; Type=Telescope
HardwID=TR01/1    ; Type=DataRecorder ; Memory=A ; DetectMode=AD ; NBits=12      ; SamplesOffPC=10
HardwID=TR01/2    ; Type=DataRecorder ; Memory=A ; DetectMode=PC ; DeadTime=4e-9 ; DeadTimeUncert=4e-10 ; SaturType=NonParalyz
HardwID=TR01/3    ; Type=DataRecorder ; Memory=B ; DetectMode=AD ; NBits=12      ; SamplesOffPC=10
HardwID=TRMIR02  ; Type=Mirror
HardwID=YAG01/1  ; Type=Laser  ; Wavelength=266.00e-9 ; RepRate=30
HardwID=YAG01/2  ; Type=Laser  ; Wavelength=266.00e-9 ; RepRate=30
```

Etc…

Content of meta data file 2 (signal processing options)

Section 1: Raw Lidar Signals Analysis Options (time-dependent)

GLASS uses Section 1 to fetch the proper analysis configuration, which is fully described by ten sub-sections (Section 2):

Section 2: Signal analysis configuration details lists

- Species retrieval options
- Stream selection options list
- Exceptions list
- Dataset selection options list
- Vertical binning options list
- Temporal binning options list
- Signal-quality-related options list
- Ancillary data options list
- Saturation correction options list
- Background correction options list

Example of meta data file 2 (raw signals analysis)

```
ANALYSIS OPTIONS HISTORY
1999/11/23 00:00:00 > 2002/08/02 23:59:59 ; spec=1 ; strm=1 ; except=1 ; dset=1 ; zbin=1 ; tbin=1 ; sgnl=1 ; xtrn=1 ; bkg=1...
2002/09/17 00:00:00 > 2009/07/31 23:59:59 ; spec=1 ; strm=2 ; except=1 ; dset=1 ; zbin=1 ; tbin=1 ; sgnl=1 ; xtrn=1 ; bkg=1...
2009/08/01 00:00:00 > 2012/01/26 23:59:59 ; spec=1 ; strm=2 ; except=2 ; dset=1 ; zbin=2 ; tbin=1 ; sgnl=1 ; xtrn=1 ; bkg=1...

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SPECIES RETRIEVAL OPTIONS LIST
spec=1 ; ozone=1

STREAM SELECTION OPTIONS LIST
strm=1 ; NChans=4 ; Stream=1,3,5,7   ; StreamName=289H,299H,289L,299L
strm=2 ; NChans=4 ; Stream=1,2,3,4   ; StreamName=289H,299H,289L,299L

EXCEPTIONS LIST
except=1 ; Default=1
except=2 ; Exception=1,2

DATASET SELECTION OPTIONS LIST
dset=1 ; Default=1
dset=2 ; includ=2,3,4,8,10
dset=3 ; exclud=2,5

VERTICAL BINNING OPTIONS LIST
zbin=1 ; Default=1
zbin=2 ; dz=15 ; when=Before

TIME BINNING OPTIONS LIST
tbin=1 ; dt=-1 ; when=Before
tbin=2 ; dt=10 ; when=After

SIGNAL PROCESSING OPTIONS LIST
sgnl=1 ; znom=10000,12000,5000,5000

ANCILLARY DATA OPTIONS LIST
xtrn=1 ; xtsce=NCEP-NDACC ; xpsce=RS ; xo3sce=EnvCan
xtrn=2 ; sigray=Eberhard ; sigo3=SG ; signo2=BOGUMIL ; sigso2=BOGUMIL ; sigo2=IASB ; betaray=IASB ; betaram=IASB

BACKGROUND CORRECTION OPTIONS LIST
bkg=1 ; fitfct=CST,CST,CST,CST ; fitbot=30000,30000,40000,40000 ; fittop=60000,60000,60000,60000
bkg=2 ; fitfct=NONE
```

Content of meta data file 3 (species retrieval options)

Section 1: Species retrieval configurations (time-dependent)

GLASS uses Section 1 to fetch the proper species retrieval configuration, which is fully described by six sub-sections (Section 2):

Section 2: Species retrieval configuration details lists

- Species-specific stream selection options
- Vertical filtering (vertical resolution) options list
- Profile merging options list
- Profile cut-off options list
- Ancillary data options list (e.g., use of T/p for RH)
- Write out product options list (e.g., data format, location, etc.)

Example of meta data file 3 (species retrieval)

```
ANALYSIS OPTIONS
1999/11/23 00:00:00 > 2009/07/31 23:59:59 ; o3=1 ; o3filt=1 ; o3merge=1 ; o3cut=1 ; o3xtrn=1 ; o3out=1
2009/08/01 00:00:00 > 2012/12/18 23:59:59 ; o3=2 ; o3filt=4 ; o3merge=2 ; o3cut=3 ; o3xtrn=1 ; o3out=1
2012/12/22 00:00:00 > 2017/01/23 23:59:59 ; o3=1 ; o3filt=1 ; o3merge=1 ; o3cut=2 ; o3xtrn=1 ; o3out=1
2017/01/24 00:00:00 > 2099/12/31 23:59:59 ; o3=1 ; o3filt=1 ; o3merge=1 ; o3cut=2 ; o3xtrn=1 ; o3out=1

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OZONE PROCESSING OPTIONS LIST
o3=1 ; No3Range=2 ; o3on=3,1    ; o3off=4,2
o3=2 ; No3Range=3 ; o3on=3,1,2  ; o3off=4,2,5

O3 VERTICAL FILTERING OPTIONS LIST
o3filt=1 ; FiltName=SavGol ; FiltDeg=2 ; FiltOrd=1 ; Constrain=VR ; Template=2,1   ; MaxVal=3000,3000
o3filt=2 ; FiltName=SavGol ; FiltDeg=2 ; FiltOrd=1 ; Constrain=VR ; Template=2,1,1 ; MaxVal=3000,3000,3000
o3filt=3 ; FiltName=SavGol ; FiltDeg=2 ; FiltOrd=1 ; Constrain=DN ; CstVal=8,8
o3filt=4 ; FiltName=SavGol ; FiltDeg=2 ; FiltOrd=1 ; Constrain=DN ; CstVal=8,8,5

O3 RANGE MERGING OPTIONS LIST
o3merge=1 ; No3Merge=2 ; o3rge=1,2   ; Constrain=ALT ; o3dzmerge=1000      ; o3zmerge=12000
o3merge=2 ; No3Merge=3 ; o3rge=1,2,3 ; Constrain=ALT ; o3dzmerge=1000,1000 ; o3zmerge=12000,16000

O3 PROFILE CUT-OFF OPTIONS LIST
o3cut=1 ; Constrain=ALT ; o3zcutbot=2200,2200      ; o3zcuttop=35000,35000       ; o3czcutbot=2200 ; o3czcuttop=35000
o3cut=2 ; Constrain=UNC ; o3zcutbot=80,80          ; o3zcuttop=60,40             ; o3czcutbot=80   ; o3czcuttop=40
o3cut=3 ; Constrain=ALT ; o3zcutbot=2200,7000,9000 ; o3zcuttop=18000,18000,28000 ; o3czcutbot=2200 ; o3czcuttop=28000
o3cut=4 ; Constrain=UNC ; o3zcutbot=80,80,80       ; o3zcuttop=40,40,40          ; o3czcutbot=80   ; o3czcuttop=40
o3cut=5 ; Constrain=VAL ; o3zcutbot=3e18,3e18,3e18 ; o3zcuttop=8e18,8e18,8e18    ; o3czcutbot=3e18 ; o3czcuttop=8e18

O3 ANCILLARY DATA OPTIONS LIST
o3xtrn=1 ; xnvmrsce=NCEP-NDACC

O3 PROFILE WRITE-OUT OPTIONS LIST
o3out=1 ; Format=HDF4/GEOMS ; Template=004 ; ArchivePath=C:\Temp\
```

Advantages of present meta data ingestion approach

Main advantage: Mass processing and re-processing are made easy!

- Suitable for networks
- Suitable for large (long-term) data sets
- Suitable for transparency and traceability (all meta data used are recorded)
- Suitable for multi-applications (process study? climatology? Pick your pref.)

Additional functionality of GLASS v1 (compared to GLASS beta):

- You can override every meta data option imported from the meta data files by using corresponding keywords at the IDL command prompt when launching the analysis

- **Example 1:**

```
GLASS,'TMTOL','2009/11/18',anlmode='NDACC'
```

The above IDL command line will launch GLASS for the analysis of the TMF tropospheric ozone lidar (TMTOL) data taken on Nov 11, 2009, with the option of producing a profile tailored for the NDACC archive center (i.e., specific meta data file #2)

- **Example 2:**

```
GLASS,'TMTOL','2009/11/18',anlmode='NDACC',o3filtnam='SGBlackman'
```

The above IDL command line will do the same thing, but will override the default filter used to vertically smooth the profile (filter used instead: “SGBlackman”) (next slide shows which meta data file 3 keyword is replaced)

Previous slide example: Keyword meta data from file 3

```
ANALYSIS OPTIONS
1999/11/23 00:00:00 > 2009/07/31 23:59:59 ; o3=1 ; o3filt=1 ; o3merge=1 ; o3cut=1 ; o3xtrn=1 ; o3out=1
2009/08/01 00:00:00 > 2012/12/18 23:59:59 ; o3=2 ; o3filt=4 ; o3merge=2 ; o3cut=3 ; o3xtrn=1 ; o3out=1
2012/12/22 00:00:00 > 2017/01/23 23:59:59 ; o3=1 ; o3filt=1 ; o3merge=1 ; o3cut=2 ; o3xtrn=1 ; o3out=1
2017/01/24 00:00:00 > 2099/12/31 23:59:59 ; o3=1 ; o3filt=1 ; o3merge=1 ; o3cut=2 ; o3xtrn=1 ; o3out=1

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OZONE PROCESSING OPTIONS LIST
o3=1 ; No3Range=2 ; o3on=3,1    ; o3off=4,2
o3=2 ; No3Range=3 ; o3on=3,1,2  ; o3off=4,2,5

O3 VERTICAL FILTERING OPTIONS LIST
o3filt=1 ; FiltName=SavGol ; FiltDeg=2 ; FiltOrd=1 ; Constrain=VR ; Template=2,1   ; MaxVal=3000,3000
o3filt=2 ; FiltName=SavGol ; FiltDeg=2 ; FiltOrd=1 ; Constrain=VR ; Template=2,1,1 ; MaxVal=3000,3000,3000
o3filt=3 ; FiltName=SavGol ; FiltDeg=2 ; FiltOrd=1 ; Constrain=DN ; CstVal=8,8
o3filt=4 ; FiltName=SavGol ; FiltDeg=2 ; FiltOrd=1 ; Constrain=DN ; CstVal=8,8,5

O3 RANGE MERGING OPTIONS LIST
o3merge=1 ; No3Merge=2 ; o3rge=1,2   ; Constrain=ALT ; o3dzmerge=1000      ; o3zmerge=12000
o3merge=2 ; No3Merge=3 ; o3rge=1,2,3 ; Constrain=ALT ; o3dzmerge=1000,1000 ; o3zmerge=12000,16000

O3 PROFILE CUT-OFF OPTIONS LIST
o3cut=1 ; Constrain=ALT ; o3zcutbot=2200,2200      ; o3zcuttop=35000,35000       ; o3czcutbot=2200 ; o3czcuttop=35000
o3cut=2 ; Constrain=UNC ; o3zcutbot=80,80          ; o3zcuttop=60,40             ; o3czcutbot=80   ; o3czcuttop=40
o3cut=3 ; Constrain=ALT ; o3zcutbot=2200,7000,9000 ; o3zcuttop=18000,18000,28000 ; o3czcutbot=2200 ; o3czcuttop=28000
o3cut=4 ; Constrain=UNC ; o3zcutbot=80,80,80       ; o3zcuttop=40,40,40          ; o3czcutbot=80   ; o3czcuttop=40
o3cut=5 ; Constrain=VAL ; o3zcutbot=3e18,3e18,3e18 ; o3zcuttop=8e18,8e18,8e18    ; o3czcutbot=3e18 ; o3czcuttop=8e18

O3 ANCILLARY DATA OPTIONS LIST
o3xtrn=1 ; xnvmrsce=NCEP-NDACC

O3 PROFILE WRITE-OUT OPTIONS LIST
o3out=1 ; Format=HDF4/GEOMS ; Template=004 ; ArchivePath=C:\Temp\
```

What's Next?

Same old song!... Combine the puzzle pieces together:

- ➔ Meta data exported by LidarRunClient have to be linked to the new GLASS meta data files
- ➔ A GRUAN lidar data stream IT environment need to be built-up: Location TBD
- ➔ Meta data files for several candidate GRUAN lidars must be built-up
- ➔ Full documentation need to be written
- ➔ After all of the above is completed:
    - ➔ GLASS can produce and archive first version of GRUAN Lidar Products
    - ➔ GLASS package will be ready for distribution

TAKE HOME MESSAGE:

Progress is slow, as usual, but we are converging!

Hoping for first release late 2017 (Oct-Dec)

THANK YOU