GRUAN Lidar Data Stream

ICM-11 Progress Status Update (2019)

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Why aren't there any GRUAN Lidar Products (yet) on the GRUAN Database ???

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… Because it is not just lidar, it is GRUAN Lidar

GRUAN Requirements:

1. **Uncertainty** fully characterized
2. **Traceable standards** for data processing
3. **Transparent** processing methodology (no black box)
4. **Careful management of change** with time

GRUAN Solutions:

1. LidarRunClient interface at each GRUAN Lidar site
2. Centralized, yet instrument-dependent and time-dependent data processing software

➔ **GLASS (Global Lidar Analysis Software Suite)**

GRUAN Caveats:

1. Lack of adequate resources for what we want to do
2. Lack of efficient follow-up by principal investigators (including myself)

➔ **Delayed, delayed, and delay again……**

GLASS version 1.1 (2019)
Comprehensive meta data ingestion

Meta data ingested to GLASS using 3 meta data files:

1. **Instrumentation** hardware and software configuration
2. **Signals analysis options ("pre-processing")**
3. **Product options** (species-specific retrieval)

The meta data imported into data processor are instrument-dependent AND time-dependent

Instrument meta data file is unique for a given lidar instrument
It includes history of the instrument's hardware and raw data acquisition configuration

Signal pre-processing and species retrieval meta data files do not have to be unique
They depend on time and science application

Each meta data read in the meta data files can be overridden at GLASS execution time, by use of 100+ optional keywords

Advantages of 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.)

Data processing uses a single call line (IDL), building batch files is easy:

- **Example 1:**

```
GLASS,'TMTOL','2018/03/01',anlmode='NDACC'
```

The above IDL command line will launch GLASS for the analysis of the TMF tropospheric ozone lidar (TMTOL) data taken on March 1, 2018, with the option of producing a profile tailored for the NDACC archive center

- **Example 2:**

```
GLASS,'TMTOL','2018/03/01',anlmode='TROPOMI',o3filtnam='SGBlackman'
```

The above IDL command line will do the same thing, but will use specific parameters adapted for the validaiton of the TROPOMI satellite instrument, and also will override the default filter used to vertically smooth the profile
(next slide shows which meta data file 3 keyword is replaced)

Example of instrument meta data file

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

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 instrument meta data file (continued)

...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

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

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...

Example of signal pre-processing meta data file

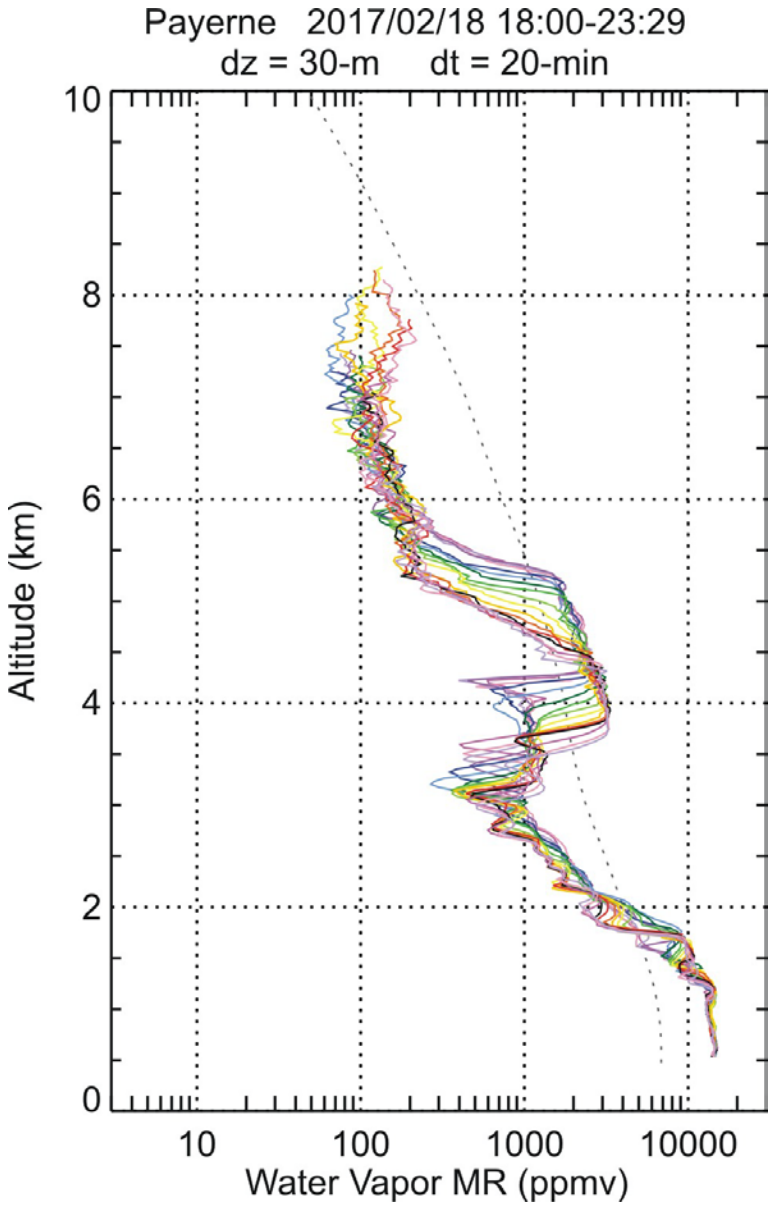
```
ANALYSIS OPTIONS HISTORY
1999/11/23 00:00:00 > 2002/08/02 23:59:59 ; spec=1 ; strm=1 ; except=1 ; dset=1 ; zbin=1 ; tbin=1 ; sgnl=1 ; xtrn=1 ; bkg=1...
2002/09/17 00:00:00 > 2009/07/31 23:59:59 ; spec=1 ; strm=2 ; except=1 ; dset=1 ; zbin=1 ; tbin=1 ; sgnl=1 ; xtrn=1 ; bkg=1...
2009/08/01 00:00:00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

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

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
```

Example of species retrieval meta data file

```
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

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

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\
```

Examples of results: Payerne

5 hours time span,
20 minutes integration
for process studies or
satellite validation



The GLASS Output files

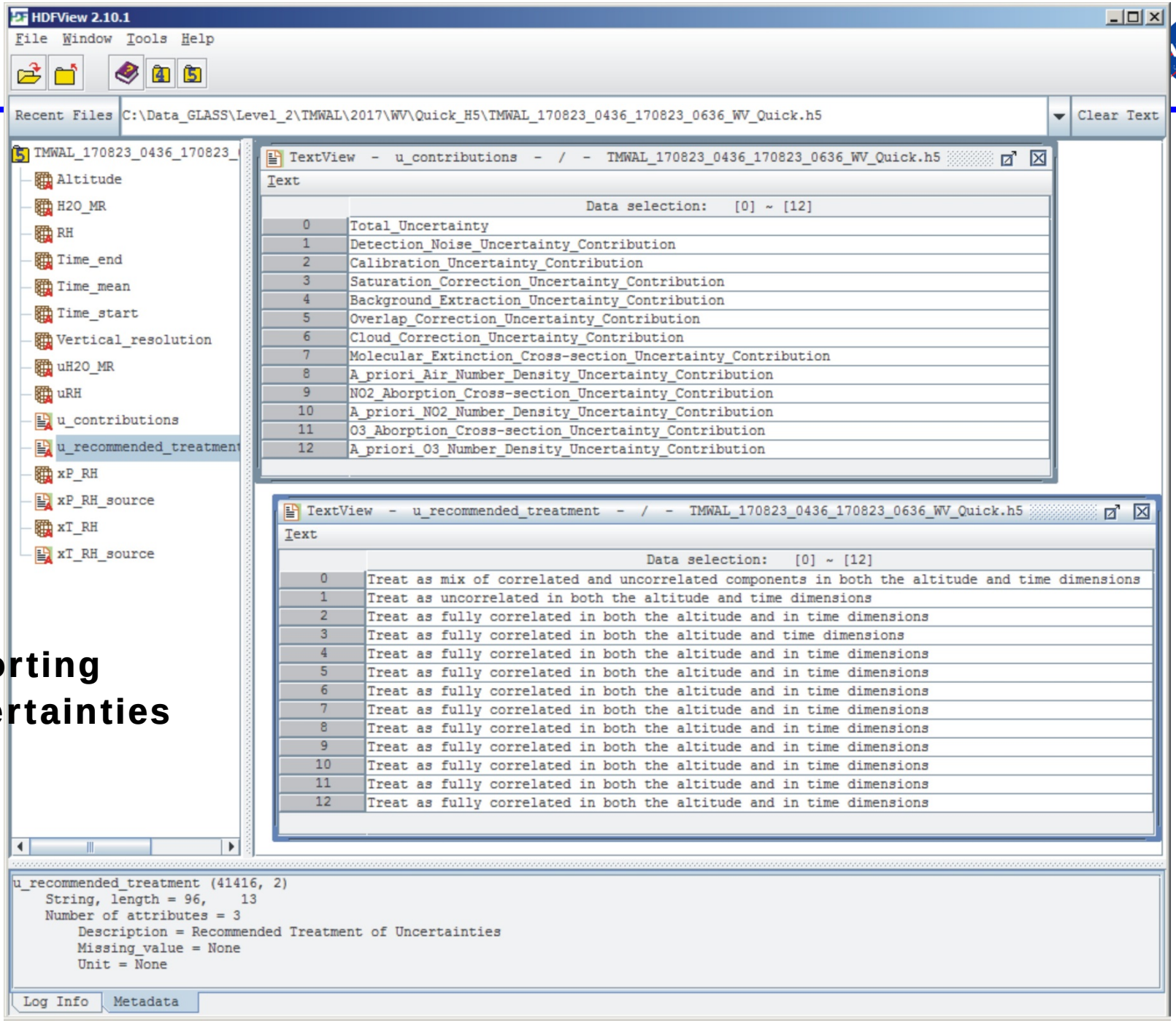
Each call to GLASS leads to the analysis of one or multiple profiles measured during a consistent or continuous, lidar measurement sequence

The output files include:

- One “compact” HDF-5 results file with one profile (the average of the sequence)
- One “extended” HDF-5 result files with one or multiple profiles covering the sequence including full uncertainty budget and ancillary information
- One “NDACC/GEOMS Compliant HDF-4 result file with one or multiple profiles
- One “quick-look” postscript file with MR and RH profile and their uncertainty
- One postscript file with detail plots of various critical analysis steps
- One postscript file showing all ancillary profiles (e.g., radiosonde) used for the analysis
- One postscript file showing all raw data sets for cloud QA/QC
- One meta data file with all instrument parameters used
- One meta data file with all signal pre-processing parameters used
- One meta data file with all species retrieval parameters used

Specifically tailored to GRUAN requirements

Reporting Uncertainties



Example of GLASS output

Quick-look plot (Table Mountain)

GLASS analysis options

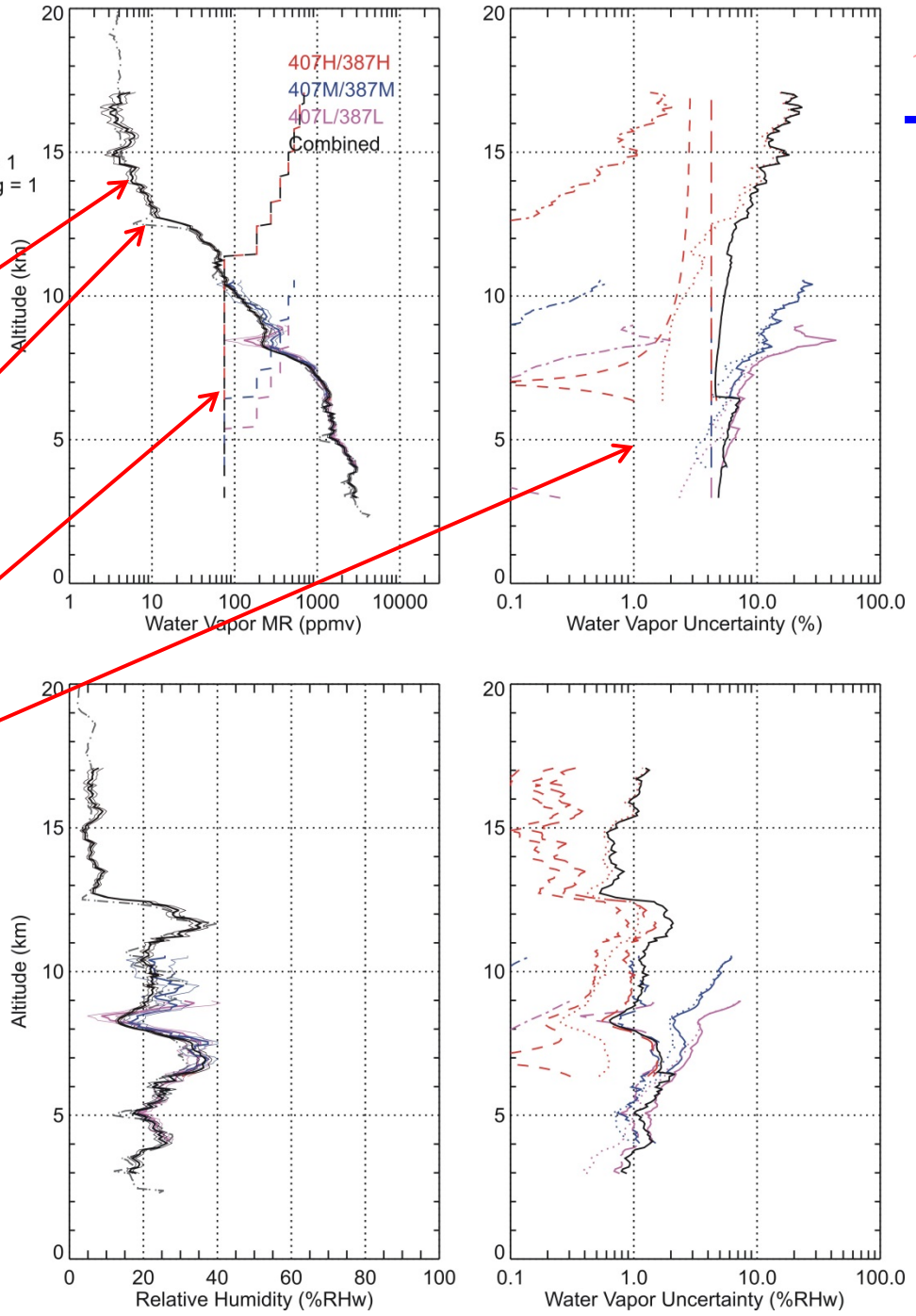
VMR Profile

Critical ancillary information
(here: RS41 for calibration)

Vertical resolution
(NDACC standardized definition)

Full uncertainty budget
(NDACC standardized definition)

Same as VMR but for
Relative Humidity



Summary of GLASS products ready to be validated

GRUAN GRUAN+NDACC NDACC NDACC+TOLNET TOLNET

CAELI (Cabauw):
- Species: WV, T
- Network: GRUAN
- Time span: 2012-present

KARL(Ny-Alesund):
- Species: WV
- Network: GRUAN, NDACC
- Time span: 2010-present

RALMO (Payerne):
- Species: WV, T
- Network: GRUAN, NDACC
- Time span: 2003-present

TMWAL (Table Mountain):
- Species: WV, T
- Network: NDACC
- Time span: 2006-present

LAUSOL (Lauder):
- Species: O3, T
- Network: GRUAN, NDACC
- Time span: 1995-present

TMSOL (Table Mountain):
- Species: O3, T, Aer
- Network: NDACC
- Time span: 1988-present

EURL (Eureka):
- Species: O3, T
- Network: NDACC
- Time span: 2016-present

MLSOL(Mauna Loa):
- Species: O3, T, Aer
- Network: NDACC
- Time span: 1994-present

TROPOZ (Beltsville):
- Species: O3
- Network: NDACC, TOLNet
- Time span: 2016-present

TMTOL (Table Mountain):
- Species: O3
- Network: NDACC, TOLNet
- Time span: 1999-present

LMOL(LaRC):
- Species: O3
- Network: TOLNet
- Time span: 2016-present

AMOLITE (Env. Canada):
- Species: O3
- Network: TOLNet
- Time span: 2016-present

Where do we go from here?

1. GRUAN Lidar Data Product version 1 Validation

Feedback needed by GRUAN WG and Community

"GRUAN Science coordinator" team offered to step in

Fabio Madonna, Xavier Calbet, Tom Gardiner to lead/coordinate efforts with T. Leblanc

Comparisons with sondes, dedicated process studies, etc.

Independent (blind) investigations strongly advised

2. Need to set up systematic / automated raw lidar data and GRUAN data products flow from / to processing center, LC, and NCDC

3. Need to set up final version of LidarRunClient for Cabauw, Payerne, Ny-Alesund, etc.

4. Last but not least: Write out TD with all aspects of GRUAN Lidar Data Stream included

THANK YOU

Backup slides

Role and content of instrument meta data file

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 5 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

Content of signal processing meta data file

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

Content of species retrieval meta data file

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.)