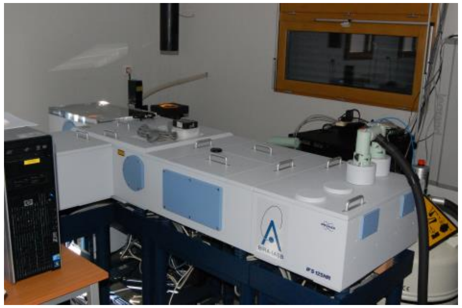
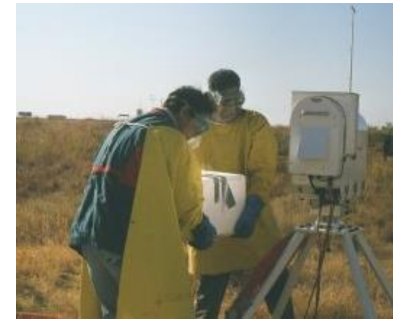


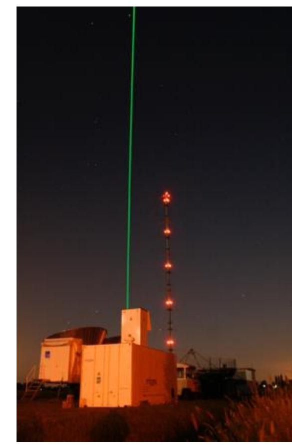
GAIA-CLIM



Work Package 2

Measurement uncertainty quantification

Karin Kreher (BKS) & the WP2 team



GAIA-CLIM GA, ECMWF, Reading (UK), 6-7 February 2017

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 640276.

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Agenda

15:15-16:15 ***Work Package 2.***
Measurement uncertainty quantification (Karin Kreher)

15:15-15:30 Summary of the progress made to date in the 5 subtask 2.1.1 – 2.1.6, Karin Kreher, BKS

15:30 -15:45 Progress report on the development of best practices (task 2.3), Paul Green, NPL

15:45-16:00 Summary of the uncertainty assessment for the measurement capabilities provided to WP5 and discussion of the uncertainty questionnaires, Karin Kreher, BKS

16:00-16:15 Progress report on the uncertainty estimates identified for baseline network capability (task 2.2), Karin Kreher, BKS

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WP2 – Measurement Uncertainty Quantifications

Task 2.1 consists of six sub-tasks which are each instrument/ECV specific. In each case the aim is to either attain **metrologically traceable measurements** or achieve **substantial progress** towards this goal, plus to undertake a **detailed uncertainty quantification.**

- Production of traceability chains (building upon the QA4ECV project approach) plus numbers behind the boxes – every step needs a robust & quantitative assessment
- Documentation as to how to make the measurements, process the data and quantify the uncertainties (for each product to be included into the VO)
- Peer-reviewed publications

Task 2.2 identifying a **defensible set of uncertainty estimates for a subset of ECVs with baseline network capability** as identified by WP1.

Task 2.3 Review of the methodologies and tools for uncertainty quantification created under tasks 2.1 and 2.2 to ensure that the uncertainty traceability and measurement techniques follow best practice

→ **Guide to Uncertainty in Measurement & its Nomenclature**

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Task 2.1 – Development of reference quality measurement capabilities and uncertainty quantification

Structured in 6 “instrument” subtasks based on different measurement techniques (Lidar, MWR, FTIR, UV-Vis, MAX-DOAS, GNSS)

Main activities over the last 12 month:

1. Review of the GAID
2. Improvement of the uncertainty quantification and traceability chains (in close collaboration with NPL, Task 2.3)
3. Contribution to the VO (WP5) via the ROR table and D2.3

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 640276.

GAIA-CLIM WP2, task 2.1, **1. Review of GAID**

1. GAID – the existing gaps have been reviewed with focus on including any new information gained through assembling the traceability chains.

2. One FTIR gap has been retired and 2 new FTIR gaps have been identified by the TCCON community:

   (A) **Lack of FTIR sites with high/low albedo and Carbon emissions hot spot monitoring**
   TCCON sites located in regions with high or low albedo are missing. Since retrievals could be biased by the albedo, observations at such sites would help investigating the existing biases in the satellite retrievals.

   (B) In addition a possible gap relating to "**Higher and faster measurement frequency by automatic measurement and retrieval for FTIR**" was identified and will be included in the next version of the GAID.

3. During last couple of weeks: All existing gaps have been reformatted into the new template, still ongoing for some of the gaps. Another round of reviews would be helpful.

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Task 2.1.2: Temperature and H_2O profiles measured by microwave radiometers

- Contribute to the GAID (5 entries)
  - G2.13: Missing MW standards maintained by Metrological Institute

Technical: NIST

  - G2.14: Missing the uncertainty associated with MW absorption models used in MWR retrievals

Knowledge: GAIA-CLIM

  - G2.15: Lack of unified tools for automated MWR data quality control
  - G2.16: Missing agreement on calibration best practices and instrument error characterization
  - G2.17: Lack of a common effort in homogenization of retrieval methods

Governance: TOPROF

Specific updates to the previously presented chains:

1) **Traceability chain for total column ozone measured with UV-visible spectroscopy (shown in the next slide)**
2) Developments to make the traceability chains more valuable and more attractive to use for the user: e.g. interactive traceability chain boxes which bring up background information when clicked (examples can be downloaded from the GAIA-CLIM webpage).
3) GAIA-CLIM traceability chains and uncertainty quantification study for ozone observations presented at the QOS 2016 in Edinburgh in September, showcasing the traceability chain and processing steps for LIDAR, FTIR and UV-visible spectroscopy
4) No traceability chain yet developed for tropospheric ozone measured by MAX-DOAS but an extensive intercomparison campaign (CINDI-2) was held in the Netherlands in September including more than 30 MAX-DOAS instruments from 24 different groups. The results are expected to provide valuable background material for further development in processing procedures and uncertainty quantification.

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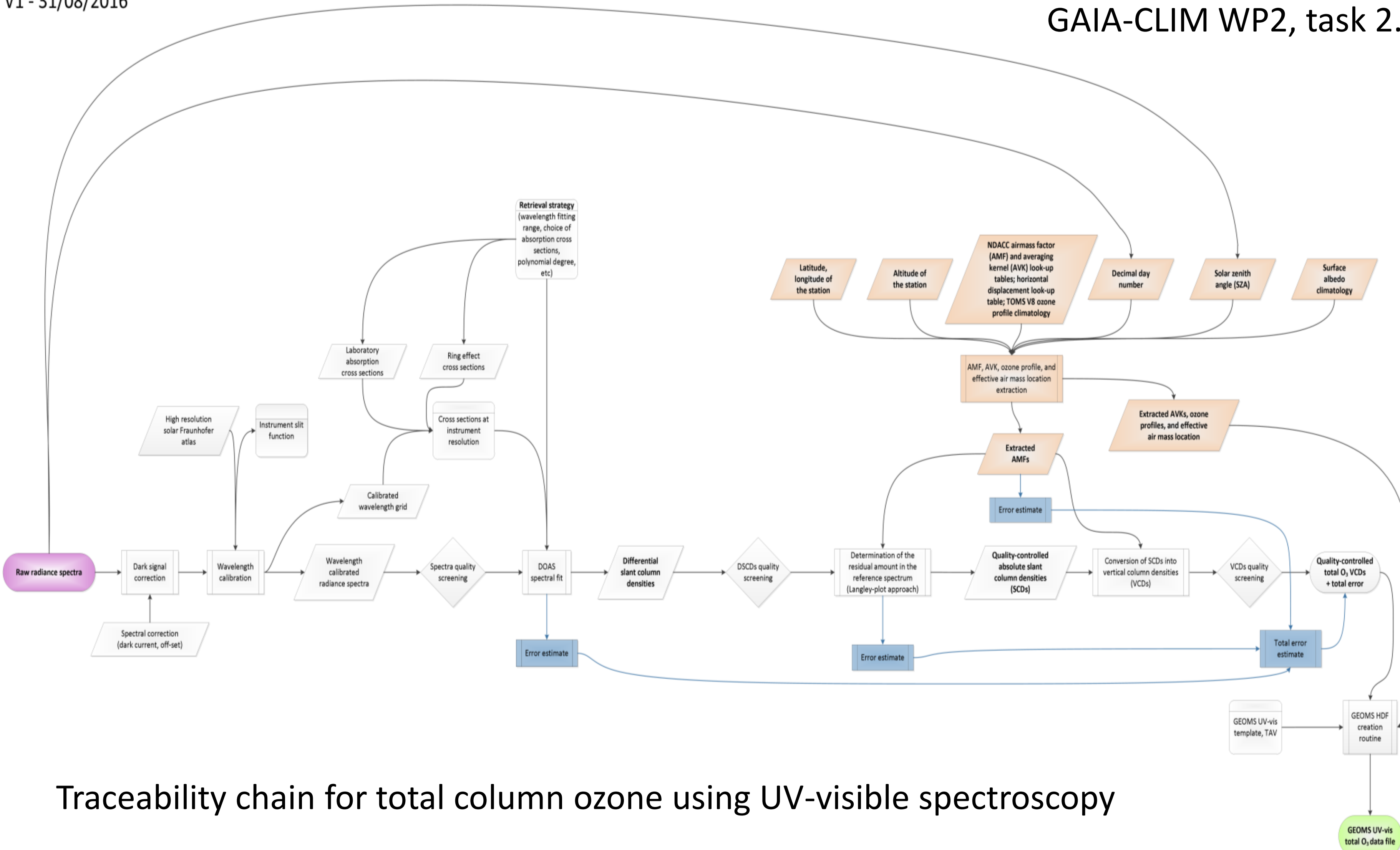

Traceability chain for total column ozone using UV-visible spectroscopy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 640276.

GAIA-CLIM WP2, task 2.1, **2. Uncertainty quantification and traceability chains**

Specific updates to the previously presented chains:

1) Traceability chain for total column ozone measured with UV-visible spectroscopy (shown in the next slide)
2) **Developments to make the traceability chains more valuable and more attractive to use for the user: e.g. interactive traceability chain boxes which bring up background information when clicked (examples can be downloaded from the GAIA-CLIM webpage & shown in the following slides).**
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Aerosol extinction coefficient (Raman method)

Receiving Telescope: The portion of the laser radiation backscattered from the atmosphere at different altitude ranges is collected by a telescope. Two or more telescopes with different optical properties can be used to optimize lidar performances in different atmospheric regions (near range, far range).

Detector: The Raman backscattered light is forwarded to the detector, consisting of a photomultiplier tube (PMT) or an avalanche photodiode (APD), where it is converted to an electical signal.

Laser Transmitter λ_L → Receiving Telescope → Spectral filtering/Raman backscattering λ_R → Detector Assembly → Acquisition Assembly

Laser Transmitter: Short light pulses at wavelength λ_L are vertically trasmitted into the atmoshere by a laser transmitter.

Spectral filtering/Raman backscattering: The radiation collected by the telescope is forwarded to an optical system (consisting of lenses, mirrors, beam splitters and interference filters) where it is spectrally filtered, so as only the Raman backscattered light from the atmosphere, at wavelength λ_R, is transmitted to the following receiving system.

Acquisition: A trigger circuit synchronizes the signal acquisition so that it measures the intensity of the backscattered light from the atmosphere at different distances from the transmitter. This is the Raman lidar signal. The acquisition of lidar signals can be performed in analog mode by an Analog to Didital Converter (ADC), or/and in photon counting mode by a counting system (a discriminator plus a

very high count rates, that occurs in the near range.

Raw Raman lidar signals → Pre-proc…

Raw Raman lidar signals: Raman lidar signals are acquired with raw time and vertical resolutions depending on the lidar system and are provided with their absolute standard uncertainty.

Pre-processed lidar signals: the pre-processed Raman lidar signals have time and vertical resolutions depending on temporal averaging and vertical smoothing performed in pre-processing module. They are provided with their absolute standard uncertainty .

Aerosol extinction: the profile of aerosol extinction coefficient at wavelength λ_L has time resolution depending on temporal averaging performed in pre-processing module and effective vertical resolution depending on vertical smoothings performed in pre-processing and processing modules. It is provided with its absolute standard uncertainty .

Standard uncertainty

Uncertaintes due to pre-processing

Standard uncertainty

Calibration uncertaintes

Uncertainty due to multiple scattering

Multiple scattering: the residual error in extinction coefficient without correction for multiple scattering is neglectable in cloud- free atmosphere, 12% and 4% at the base and top of cirrus clouds, 10% and less than 3% at the base and inside cumulus clouds [Ansmann et al., 1992].

Standard uncertainty: Standard deviation of a Poisson distribution of photon counts for lidar signals in photon counting mode, or temporal and vertical moving averages for lidar signals in analog mode.

Uncertaintes due to pre-processing: uncertaintes due to the temporal averaging of signals during varing atmospheric conditions and residual errors due to the overlap correction and the other corrections. The error due to the overlap correction can reach 50% for heights below the full overlap (Wandinger and Ansmann, 2002)

Standard uncertainty: Standard deviation of a Poisson distribution of photon counts for signals in photon counting mode, or standard deviation of the temporal average of lidar signals in analog mode.

Calibration uncertaintes: In the calibration procedure, the retrieval of a molecular density profile needs an estimate of temperature and pressure profiles that differ from the real profiles, in particular from the real temperature. Without temperature inversions, the residual error associated with this estimate is less than 5% and even lower using radiosondes [Ansmann et al., 1992]. On the other hand, the assumption of Angstrom exponent value causes residual errors in the order of 5%, by varing the assumed value of 0.5 [Ansmann et Muller, 2005].

GAIA-CLIM WP2, task 2.1, **2. Uncertainty quantification and traceability chains**

Specific updates to the previously presented chains:

1) Traceability chain for total column ozone measured with UV-visible spectroscopy (shown in the next slide)
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and are expected to be available mid-2017 the peer-reviewed literature.

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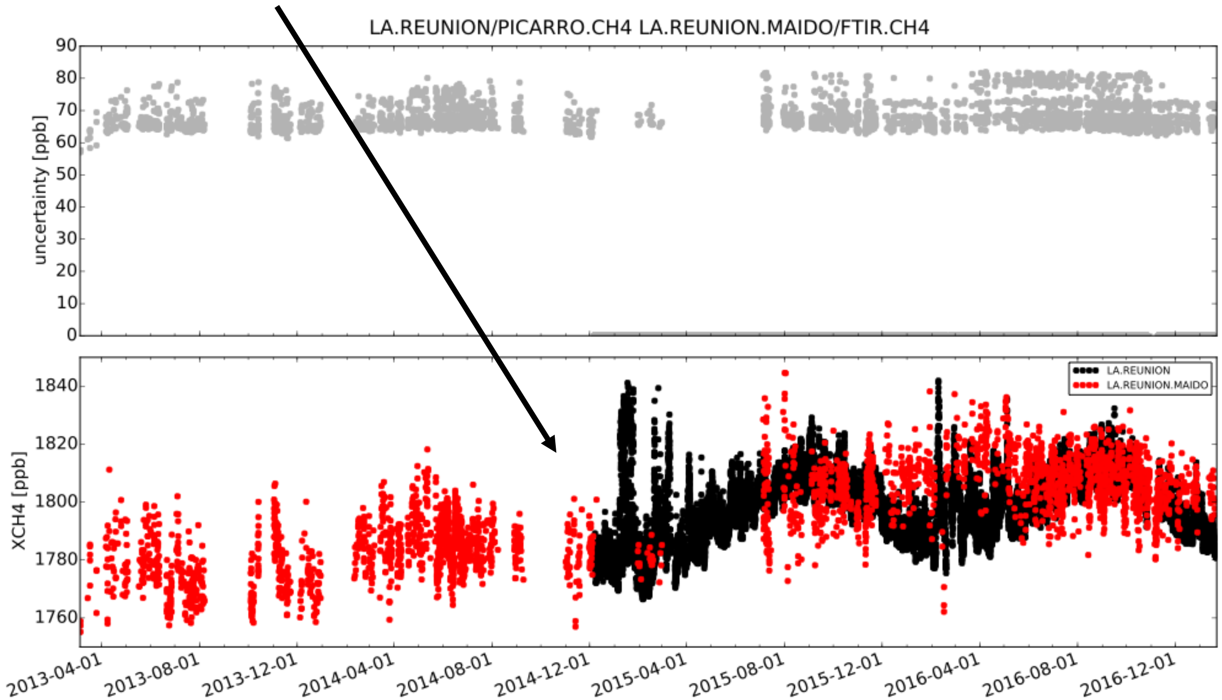
WP 2, Task 2.1.3

- Presentation at ACVE Oct 2016
- Presentation at IRWG on GAIACLIM and QA4ECV CO harmonisation
- Uncertainty harmonisation required updating retrieval scripts: shared between GAIACLIM and QA4ECV
- Now working on GAIACLIM NDACC FTIR targets: CH4 and O_3



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GAIA-CLIM WP2, task 2.1, **2. Uncertainty quantification and traceability chains**

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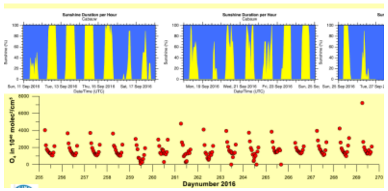
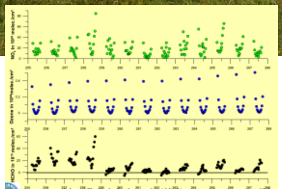
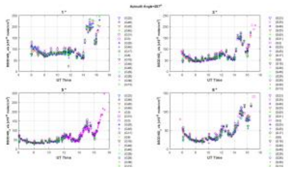
Second Cabauw Intercomparison of Nitrogen Dioxide measuring Instruments

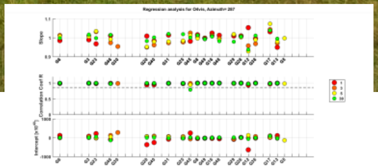
CINDI-2 data products: Ozone, NO_2, Formaldehyde, O_4, aerosol

CINDI-2 Semi-blind Intercomparison
12 - 28 September 2016
Cabauw, The Netherlands









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What do we want to achieve with CINDI-2 in comparison to CINDI

- To follow on from previous intercomparisons by Roscoe et al. (1999), Vandaele et al. (2005) and Roscoe et al. (2010) and to apply recommendations made:
  - synchronisation of measurements (very detailed measurement protocol)
  - exact alignment of the elevation angle (horizon scans & lamp measurements)
  - more groups (24) & more instruments (33)
  - more viewing directions (7 for 2d instruments)
  - profiling techniques

Semi-blind intercomparison protocol (NDACC)

- Measurement from the previous day have to be provided to the campaign referee by 10 am.
- At a daily meeting (4 pm), slant columns measured during the previous day were displayed without assignment to the different instruments.
- The referee notifies instrument representatives if there is an obvious error so that this can be corrected for the rest of the campaign.
- At the end of the formal campaign, plots have instrument names attached, and plots of mean differences from one selected reference instrument or an average of several selected reference instruments are discussed.
- After the end of the formal campaign time, revisions are only accepted where full details of the reasons for changes are supplied.

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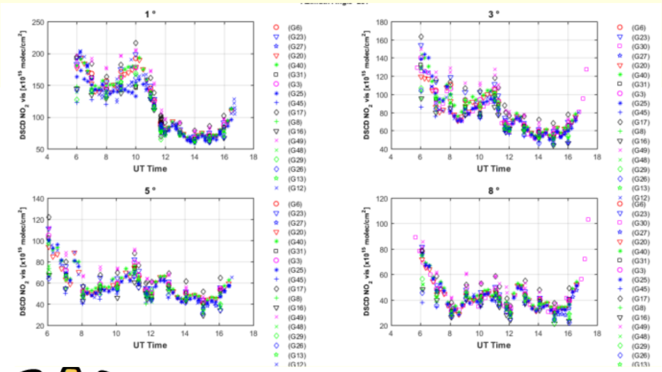
Diagnostics for discussions during the daily meetings

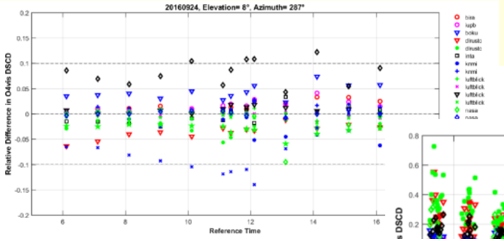
- Daily time series for most of the species
  (2xNO2, 2xO4, 2xO3, HCHO)

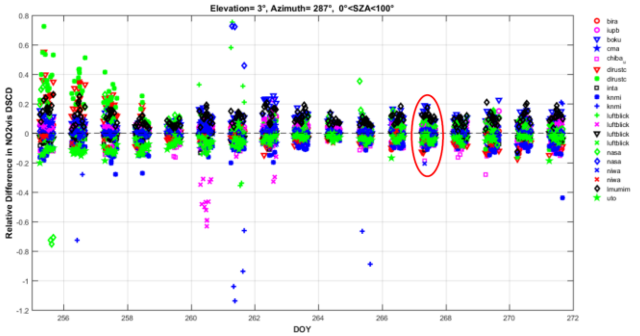
- Relative differences (daily and longer time period)

- Correlation plots

- Plots with summary of regression analysis from correlation plots







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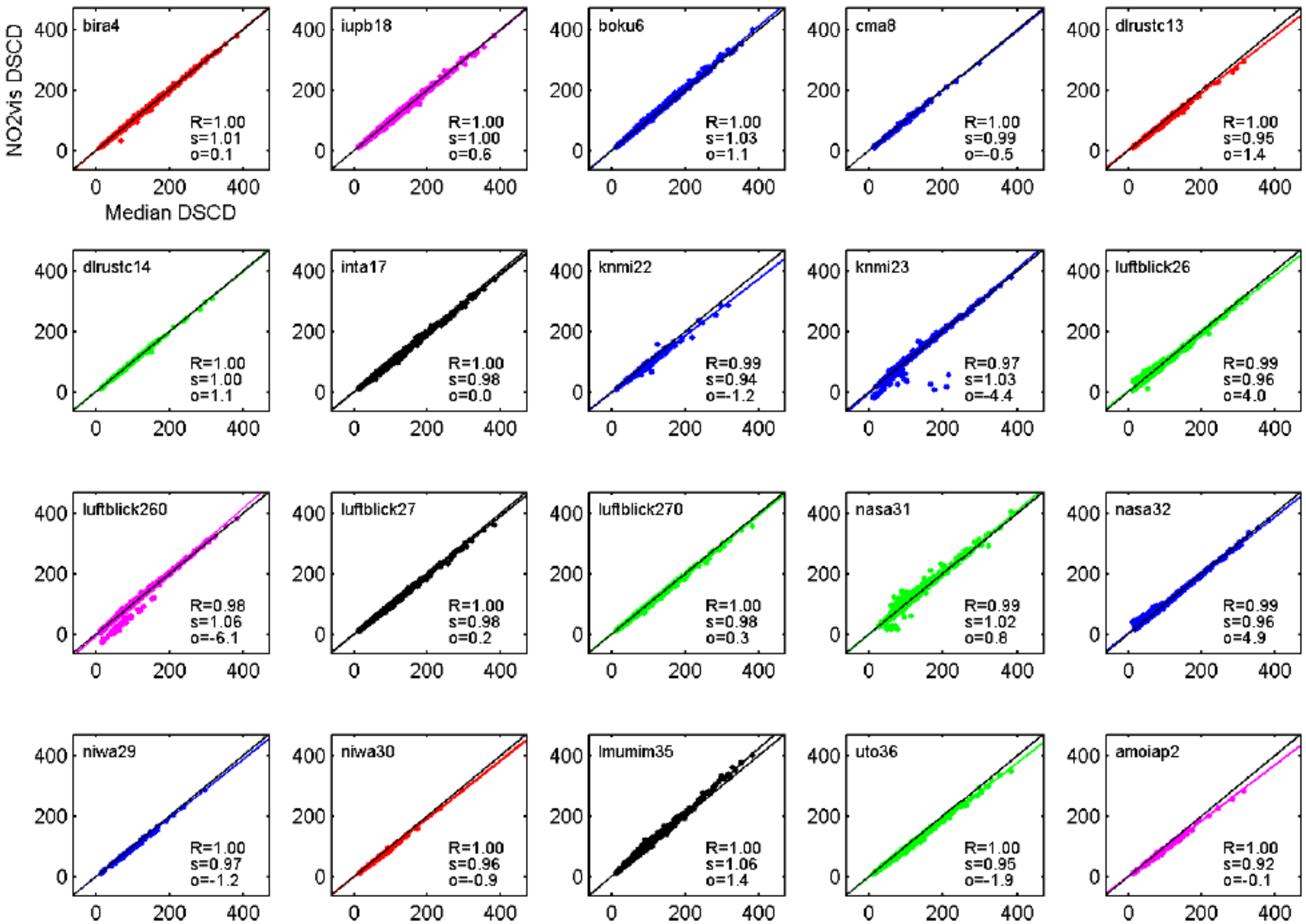
Elevation= 5°, 0°<SZA<100°, All azimuths



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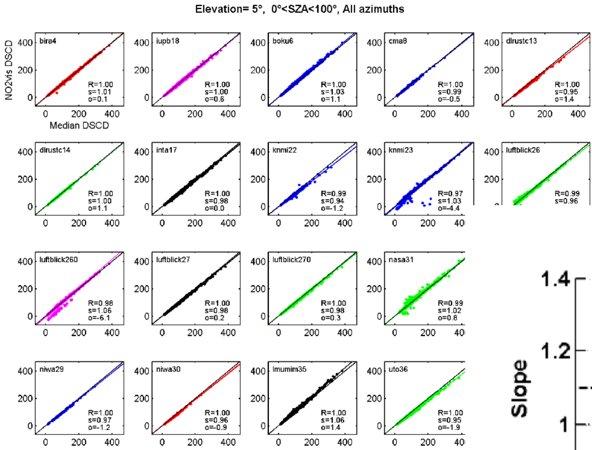

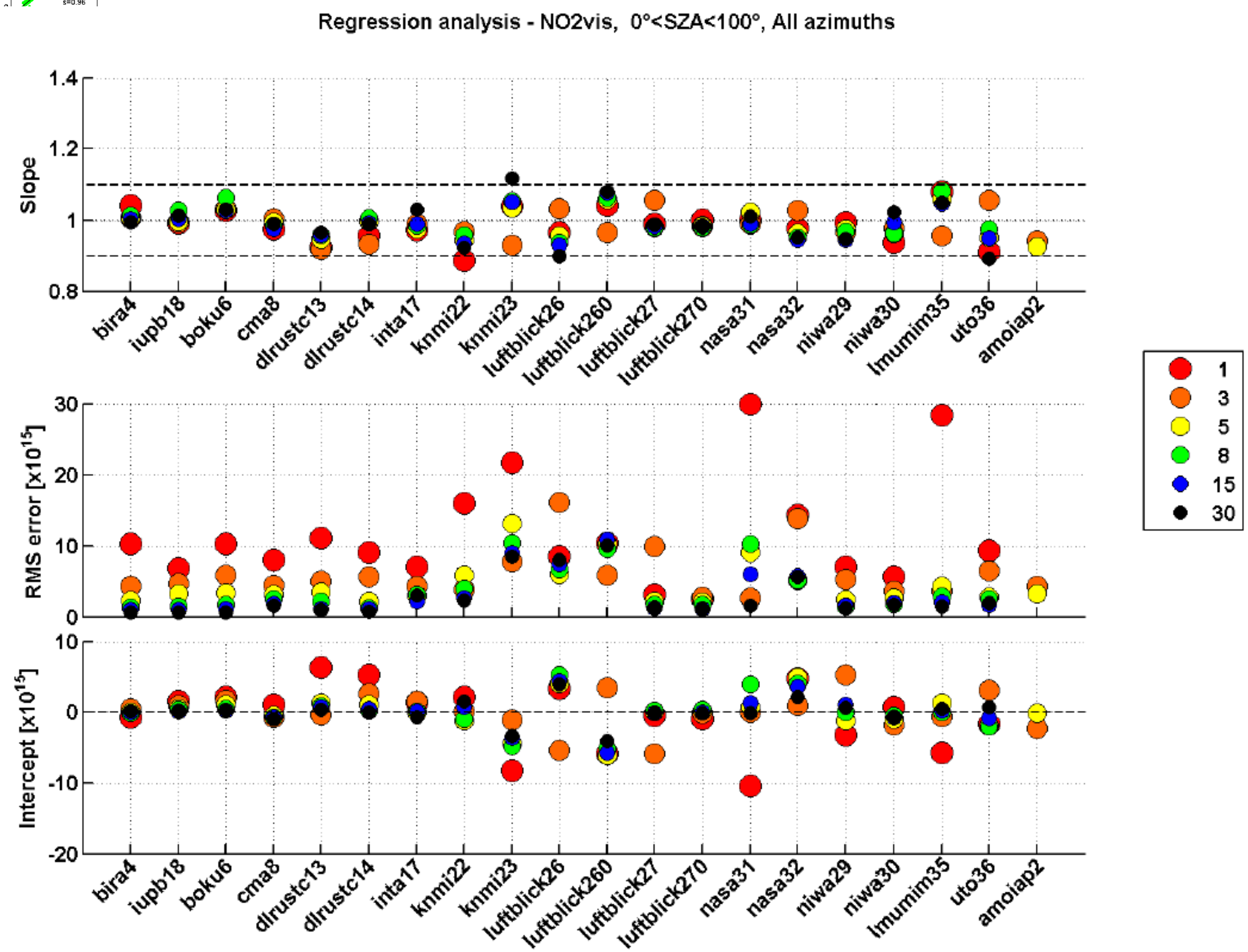

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	NO2vis			NO2visSmall			NO2uv			O4vis			O4uv			HCHO			O3uv			O3vis		
	slope	offset	RMS	slope	offset	RMS	slope	offset	RMS	slope	offset	RMS	slope	offset	RMS	slope	offset	RMS	slope	offset	RMS	slope	offset	RMS
bira4	1.02	-0.61	4.79	1.03	-0.52	4.46	1.02	0.43	3.09	1	0.3	1.58	1.01	0	0.74	0.97	7.25	5.01	1.01	0	0.13	1.01	0.46	0.57
auth3	--	--	--	0.96	1.03	5.45	1.01	-2.07	6.25	--	--	--	1.04	-0.71	2.69	1.17	2.68	18	1.01	0.01	0.23	--	--	--
aiofm1	--	--	--	--	--	--	0.81	3.83	28.58	--	--	--	0.93	-0.17	2.37	0.82	13.55	19.12	1.67	-0.1	3.48	--	--	--
iuph19	--	--	--	0.95	0.57	4.76	0.98	0.09	12.54	--	--	--	0.95	0.91	1.89	0.94	-2.47	15.05	0.96	-0.02	0.26	1.07	3.4	3.87
iupb18	1	0.74	4.15	1.02	0.51	3.76	1.02	0.83	2.74	0.99	0.33	1.38	0.96	0.85	1.39	1.06	3.08	5.2	1	0.01	0.35	1.01	0.05	0.33
boku6	1.04	0.71	5.61	--	--	--	--	--	--	1	0.63	1.74	--	--	--	--	--	--	--	--	--	1.02	-0.36	0.63
cma7	--	--	--	0.96	2.09	10.6	0.96	1.87	7.34	--	--	--	1.03	-0.63	2.07	0.81	1.1	12.73	0.95	-0.04	0.29	--	--	--
cma8	0.99	-0.76	4.2	--	--	--	--	--	--	1	0.14	3.17	--	--	--	--	--	--	--	--	--	1.11	9.3	23.08
chiba_u9	0.92	0.09	5.46	0.94	-1.32	5.31	0.92	-0.23	3.66	0.94	2.97	2.8	0.93	1.56	1.14	0.8	8.33	8.15	0.82	0.08	0.15	--	--	--
csic10	--	--	--	--	--	--	0.83	-8.56	26.45	--	--	--	0.89	-8.09	23.48	1.22	-29.91	59.66	0.83	-0.32	2.36	--	--	--
cu-boulder11	--	--	--	0.73	10.3	17.07	1.00	-3.20	9.04	--	--	--	1.03	-1.35	2.29	1.01	-3.26	10.39	--	--	--	0.99	-0.58	0.89
cu-boulder12	--	--	--	0.99	-3.18	18.18	0.99	-3.04	12.34	--	--	--	0.87	1.79	7.13	0.33	27.27	23.89	0.88	0.35	1.38	--	--	--
dlrustc13	0.94	1.99	5.53	0.96	1.13	4.38	0.97	-0.29	2.98	0.95	0.47	2.12	1.01	-0.02	1.14	1.09	-6.81	6.6	1	0.66	0.74	1.03	0.84	1.01
dlrustc14	0.98	1.46	4.31	1	1.16	3.64	1.01	0.31	2.38	0.97	0.47	1.57	1.01	0.33	0.87	1.23	-12.38	9.24	0.98	0.7	0.72	0.97	-0.46	0.61
iiserm16	--	--	--	1.06	-0.18	5.26	1.02	0.97	4.80	--	--	--	1.07	0.7	1.81	0.77	-20.06	20.51	0.81	-0.04	0.31	--	--	--
inta17	0.97	0.44	3.93	--	--	--	--	--	--	0.99	0.25	2.07	--	--	--	--	--	--	--	--	--	1	0.48	0.81
knmi21	--	--	--	--	--	--	0.98	-2.18	3.62	--	--	--	1.02	0.32	1.43	0.84	-7.48	15.01	--	--	--	--	--	--
knmi22	0.91	1.46	8.2	--	--	--	--	--	--	0.98	0.4	2.67	--	--	--	--	--	--	--	--	--	--	--	--
knmi23	1.03	-3.51	14.47	1.03	-0.86	10.92	1.01	-1.18	40.30	1.11	-9.29	15.4	1.04	-1.1	12.53	1.02	-2.79	23.04	1.04	-0.11	1.64	1.03	-2.32	10.6
luftblick26	0.96	3.37	6.82	1.03	-6.39	11.93	1.01	-0.30	2.77	0.99	4.39	13.12	1.02	-0.49	1.32	1.06	-2.95	11.14	1.01	0.02	0.23	1	2.16	7.42
luftblick260	1.05	-4.92	10.28	0.97	9.48	12.84	--	--	--	1.05	-6.29	13	--	--	--	--	--	--	--	--	--	1.06	-3.99	9.09
luftblick27	0.99	-0.24	2.33	1	-0.43	2.03	0.99	0.09	2.63	1.01	-0.19	1.03	1	-0.3	1.15	1.01	-0.58	9.48	0.98	-0.01	0.19	0.98	-0.19	0.36
luftblick270	0.99	-0.4	2.22	1.01	-0.07	2.08	--	--	--	1	-0.17	0.9	--	--	--	--	--	--	--	--	--	1	0.53	0.51
mpic28	--	--	--	1.01	2.04	5.91	1.03	1.78	4.01	--	--	--	1.02	-0.07	0.92	0.93	6.67	5.04	1.02	0.01	0.15	--	--	--
nasa31	1	1.48	15.24	1	1.11	13.99	1.01	0.86	10.35	0.98	0.34	5.14	0.96	0.4	5.52	0.94	-3.01	22.37	1.01	-0.02	0.48	0.98	0.01	2.13
nasa32	0.98	3.27	7.31	1.02	-2.91	8.24	1.01	-0.13	5.10	0.95	4.65	10	1.02	0.33	3.12	1.08	-6.07	17.98	1	0.05	0.35	0.98	1.09	6.08
niwa29	0.98	-0.68	3.58	0.99	-0.73	2.98	1.01	-0.09	1.95	0.96	-0.98	2.4	0.98	0.92	1.03	0.75	5.63	7.09	1	-0.01	0.1	1.04	-1.55	1.46
niwa30	0.95	0.38	3.46	--	--	--	0.87	3.02	7.54	0.97	0.13	1.7	0.93	-0.05	2.68	0.99	-0.52	6.85	--	--	--	--	--	--
nust33	--	--	--	0.88	-0.17	13.38	0.91	-0.72	12.50	--	--	--	0.76	-0.42	3.61	1.73	-8.97	38.22	--	--	--	--	--	--
lmumim35	1.06	0.58	11.33	0.91	2.82	8.41	0.91	0.79	5.52	1.02	1.36	3.78	0.94	0.87	1.71	0.82	-3.81	8.2	0.82	-0.25	1.37	1.04	-1.79	5.21
uto36	0.92	-0.16	4.98	0.94	0.24	4.38	--	--	--	0.96	-0.16	1.68	--	--	--	--	--	--	--	--	--	0.93	-0.41	0.83
amoiap2	0.92	-0.13	3.33	0.91	0.34	2.91	0.97	-0.96	4.56	1.06	-2.48	3.69	0.93	-1.01	2.13	1.04	-10.71	14.66	--	--	--	--	--	--
latmos24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
latmos25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
bsu5	--	--	--	--	--	--	0.92	0.88	4.08	--	--	--	0.99	-1.37	0.9	0.96	15.66	20.53	0.88	-0.19	0.3	--	--	--
P10	0.94	-2.18	2.93	0.94	-3.21	2.83	0.93	-2.41	2.64	0.95	-3.77	1.24	0.93	-1.12	0.9	0.78	-12.62	5.34	0.9	-0.34	0.14	0.95	-2.51	0.42
P25	0.97	-0.96	3.84	0.97	-0.88	4.07	0.95	-0.91	3.09	0.98	-0.34	1.65	0.95	-0.67	1.14	0.88	-6.22	8.15	0.93	-0.04	0.22	0.97	-0.66	0.62
Median	1	0	4.98	1	0	5.38	1.00	0.00	4.95	1	0	2.4	1	0	1.85	1	0	13.69	1	0	0.31	1	0	1.01
P75	1.03	0.96	7.54	1.03	0.88	11.43	1.05	0.91	10.35	1.02	0.34	4.12	1.05	0.67	2.69	1.12	6.22	20.51	1.07	0.04	0.9	1.03	0.66	5.86
P90	1.06	2.18	12.59	1.06	3.21	14.3	1.07	2.41	25.06	1.05	3.77	13.05	1.07	1.12	6.97	1.22	12.62	23.8	1.1	0.34	1.93	1.05	2.51	9.99

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GAIA-CLIM WP2, task 2.1, **3. Contribution to the VO (WP5) via the ROR table**

- **ROR (Reference Observations Readiness) table entries developed together with WP5 and WP3;**

  internal tool to help us coordinate our efforts between WP2, WP3 and WP5 for data product input into the VO.
- This activity was followed by an **Uncertainty assessment for the measurement capabilities provided to WP5** (D2.3)
- **Aim:** To provide the necessary information to allow the development of user support tools by the WP5 VO team.

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Task	Technique	ECV	Traceability chains	Uncertainty budget behind the chain steps	Available literature	GAIA-CLIM documentation
T 2.1.1	Lidar	Aerosol, T, O3, H2O	✓			
T 2.1.2	MWR	H2O, T	✓			
T 2.1.3	FTIR	CH4, CO2, H2O, O3	✓			
T 2.1.4	UV-Vis	O3	✓			
T 2.1.5	MAX-DOAS	Trop. O3	X			
T 2.1.6	GNSS	H2O	✓			

Overview Table, also for task 2.1 meeting on Thursday

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Questions?

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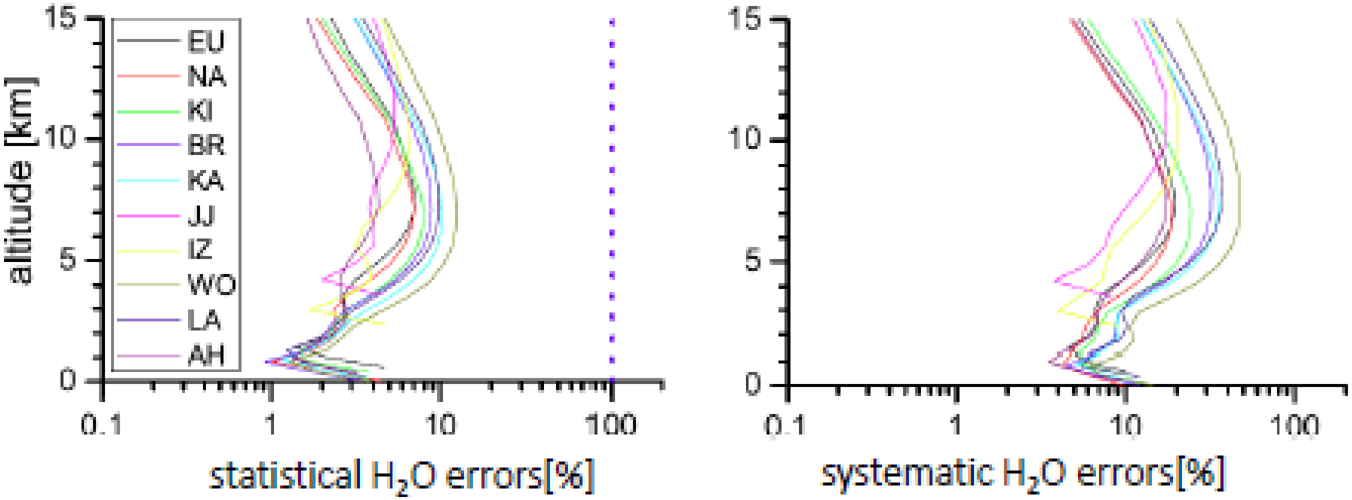
GAIA-Clim related work of the project MUSICA (2011-2016)

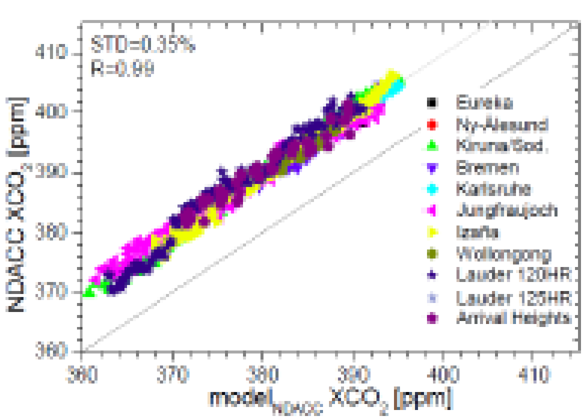
Consistent H_2O product error assessment for many globally distributed NDACC/FTIR sites:

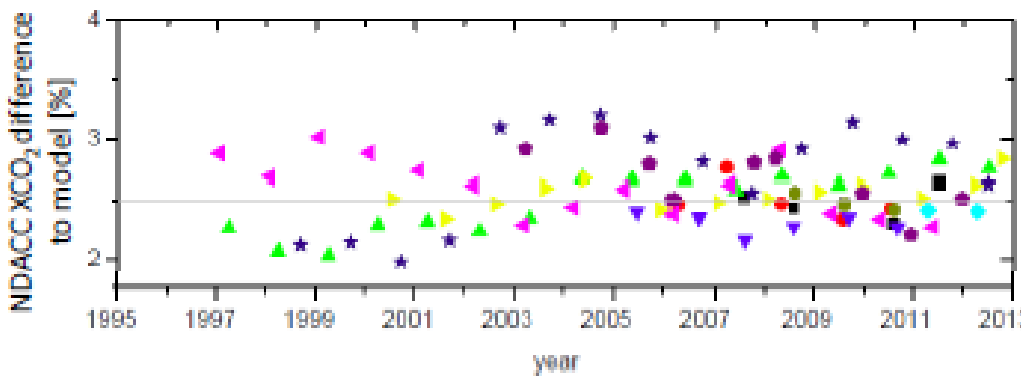


[adopted from Schneider et al., AMT 2012; data availability see Barthlott et al., ESSD 2017]

Site (acronym)	Location and altitude
Eureka (EU)	80.1° N, 86.4° W 610 m a.s.l.
Ny Ålesund (NA)	78.9° N, 11.9° W 15 m a.s.l.
Kiruna (KI)	67.8° N, 20.4° E 419 m a.s.l.
Bremen (BR)	53.1° N, 8.9° E 27 m a.s.l.
Karlsruhe (KA)	49.1° N, 8.4° E 111 m a.s.l.
Jungfraujoch (JJ)	46.6° N, 8.0° E 3580 m a.s.l.
Izaña (IZ)	28.3° N, 16.5° E 2367 m a.s.l.
Wollongong (WO)	34.4° S, 150.9° E 30 m a.s.l.
Lauder (LA)	45.1° S, 169.7° E 370 m a.s.l.
Arrival Heights (AH)	77.8° S, 166.7° E 250 m a.s.l.

Network-wide consistency documentation by using atmospheric CO_2 as standard metric:





[adopted from Barthlott et al., AMT 2015]

Aerosol extinction coefficient (Raman method)

Calibration: The processing requires the assumption of:

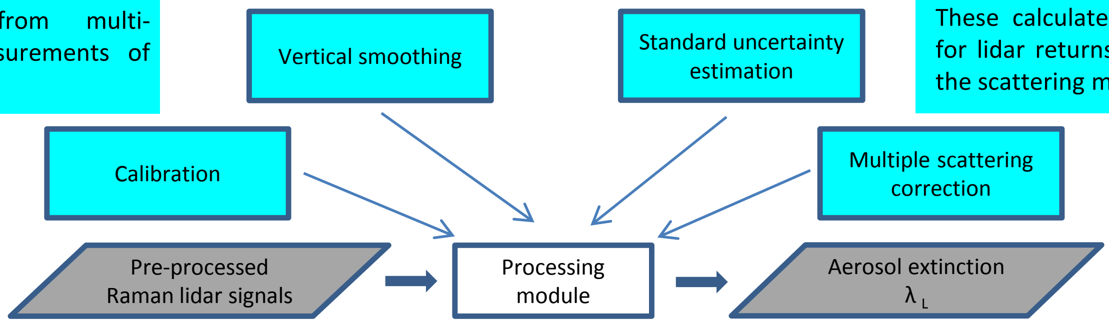
1) Molecular profiles of backscattering coefficient at Raman wavelength λ_R, and of extinction coefficients at laser and Raman wavelengths λ_L and λ_R. These profiles are calculated from models of molecular scattering cross section and a molecular number density profile, retrieved from Standard Atmosphere, radiosondes or mesoscale models;

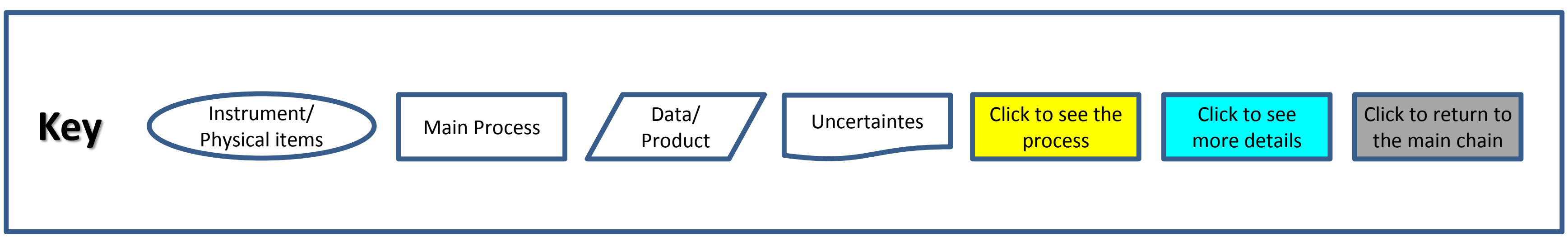
2)Angstrom exponent, describing the wavelength dependence of aerosol extinction coefficients at wavelengths λ_L, and λ_R. Fixed values (0 for cirrus clouds and 1, 1.5 or user-defined values, variable according to actual meteorological conditions) are usually used. Alternatively, values measured with sun photometers or derived from multi-wavelength simultaneous measurements of extinction coefficient are used.

Vertical smoothing: The processing requires the calculation of the derivative of the logarithm of the pre-processed Raman signals. There are several methods to calculate the derivative. The most common methods use linear fit or digital filters, such as Savitzky-Golay filter. The calculation of the derivative implies a vertical smoothing of aerosol extinction coefficient profile and a reduction of its vertical resolution and statistical uncertainty with respect to the pre-processed Raman signals.

Standard uncertainty: The standard uncertainty of aerosol extinction coefficient profile can be estimated with the Monte Carlo method or analytically, by means of error propagation theory.

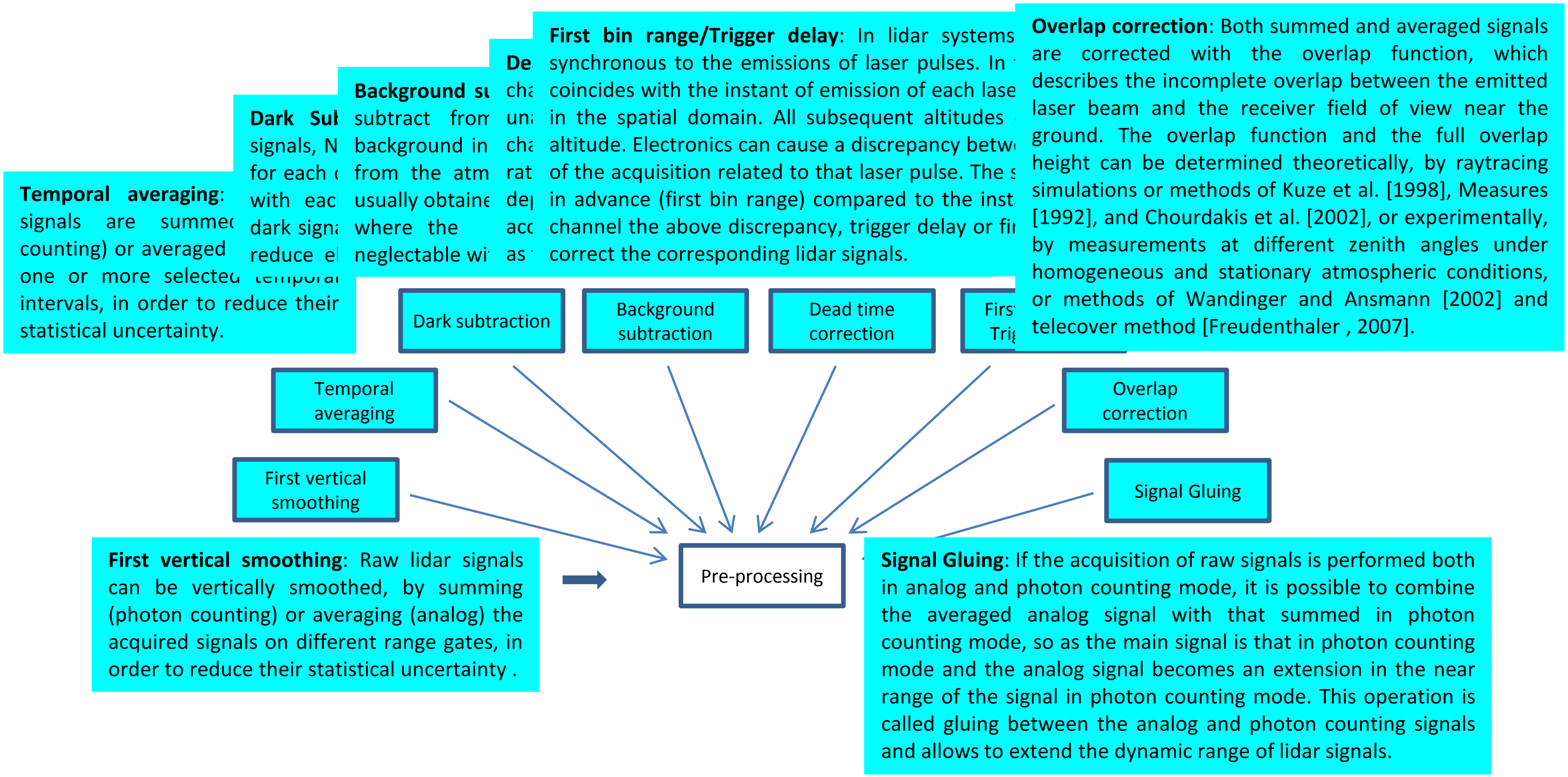
Multiple scattering correction: the profile of aerosol extinction coefficient can be corrected for multiple scattering. This affects the extinction coefficient retrieval in an optically dense medium, as fog and clouds. When the laser beam goes through this medium, not only the singly backscattered photons, but also photons undergoing multiple scattering processes remain in the lidar receiver field of view and are forwarded to the receiving system. In these conditions, lidar equations and algorithms, valid only in single scattering approximation, lose their validity. The multiple scattering makes lidar signals higher and extinction coefficient lower than those measured in single scattering conditions. The correction is performed by introducing in lidar equations correction factors, estimated from multiple scattering models (e.g. Eloranta, 1998). These calculate multiple scattering intensities for lidar returns, considering the properties of the scattering medium and of the lidar system.

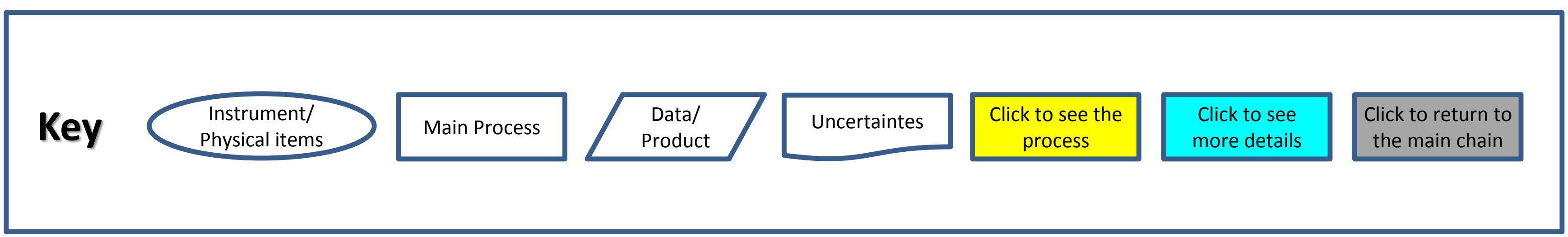




M. Rosoldi and F. Madonna (CNR-IMAA)

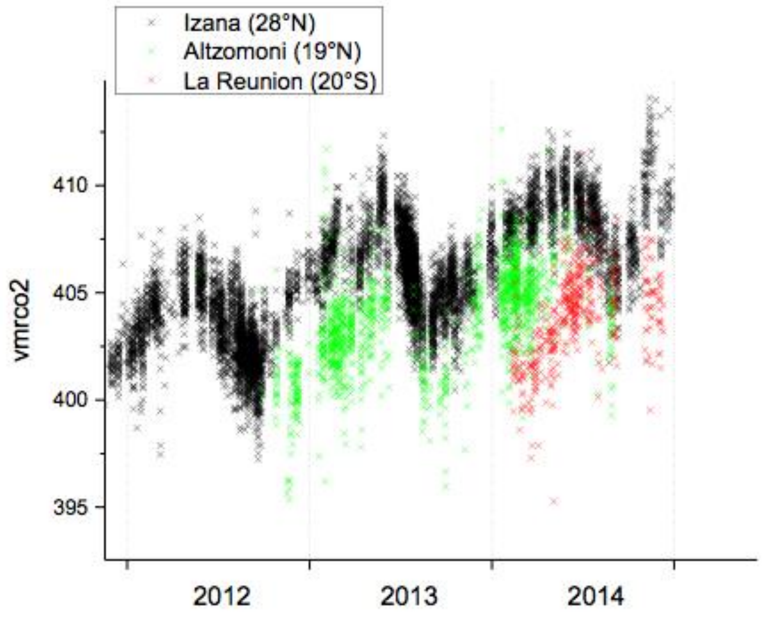
Aerosol extinction coefficient (Raman method)





M. Rosoldi and F. Madonna (CNR-IMAA)

- Rigel Kivi: ongoing work on new Aircore measurements
- Matthias Schneider: ongoing work in MUSICA, uncertainty harmonisation



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Task 2.1.6: Total Column Water Vapour measured by GNSS

K. Rannat (TUT), J. Jones (MO)

Aim: Analyse the **uncertainties for total column water vapour** measured by GNSS and **improve traceability** of the GNSS measurements.

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Software-dependent differences in GNSS-PW uncertainty budget

Practical experiments with “as close as possible” experimental set-ups for different software with identical observational information.

Doing what:
Processing GNSS-data (next slide), obtaining ZTD (and ZTD uncertainties), deriving GNSS-PW, calculating GNSS-PW uncertainties according to T.Ning etal 2016, analysing the differences and the main factors introducing these differences.

Later comparing with PPP-solution from GIPSY.

Choosing COST BENCHMARK sites (ref. Slide 4) – allows to compare with results obtained from independent ACs involved in COST-action.

Some software development (TUT):
Tools for extracting site meteodata from MO-meteodata format → site metRINEX (for GAMIT)
Tools for ZTD → IPW + GRUAN-like uncertainties

Tools for driving experiments with GIPSY and comparing/analysing the results

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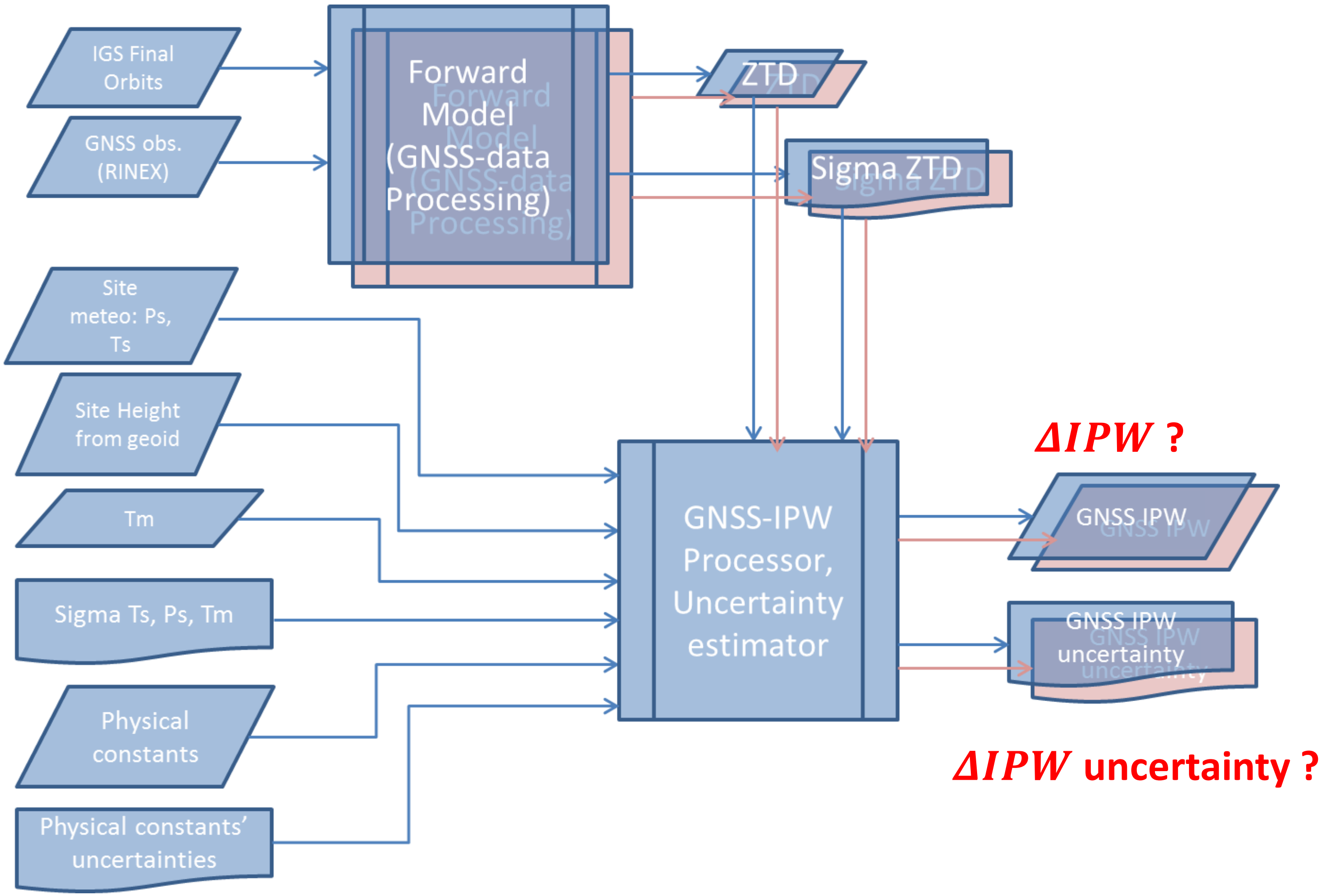
GNSS IPW: The same Metrological Model Chain with different software ?



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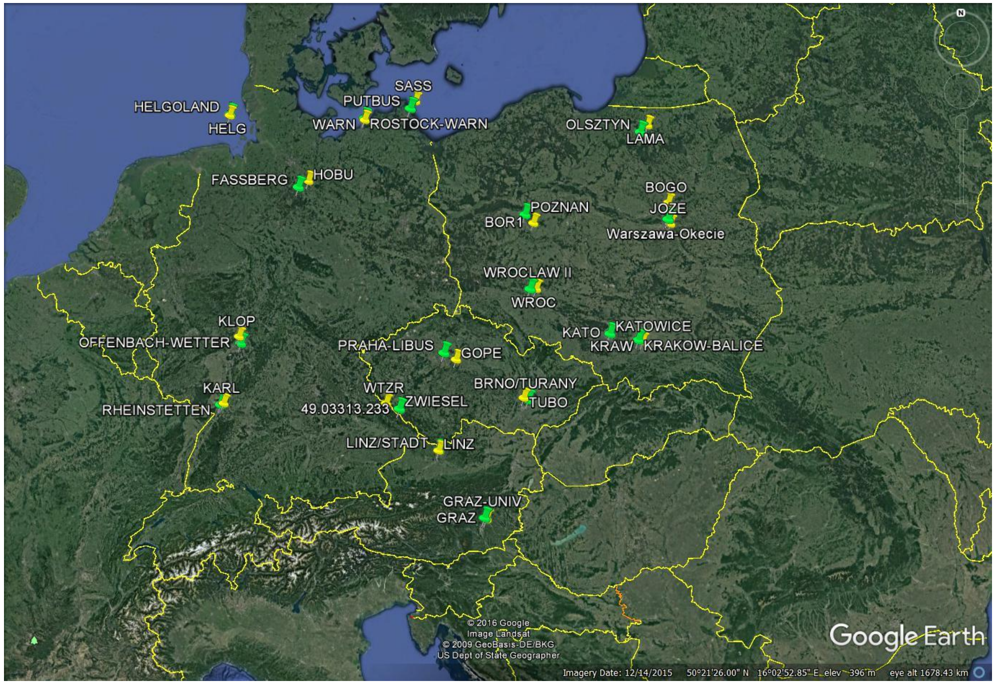
Experimental sites from COST BENCHMARK campaign



«Yellow» – GNSS-sites
«Green» – co-located meteorological stations

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