Bringing GPS integrated precipitable water as a data stream into GRUAN

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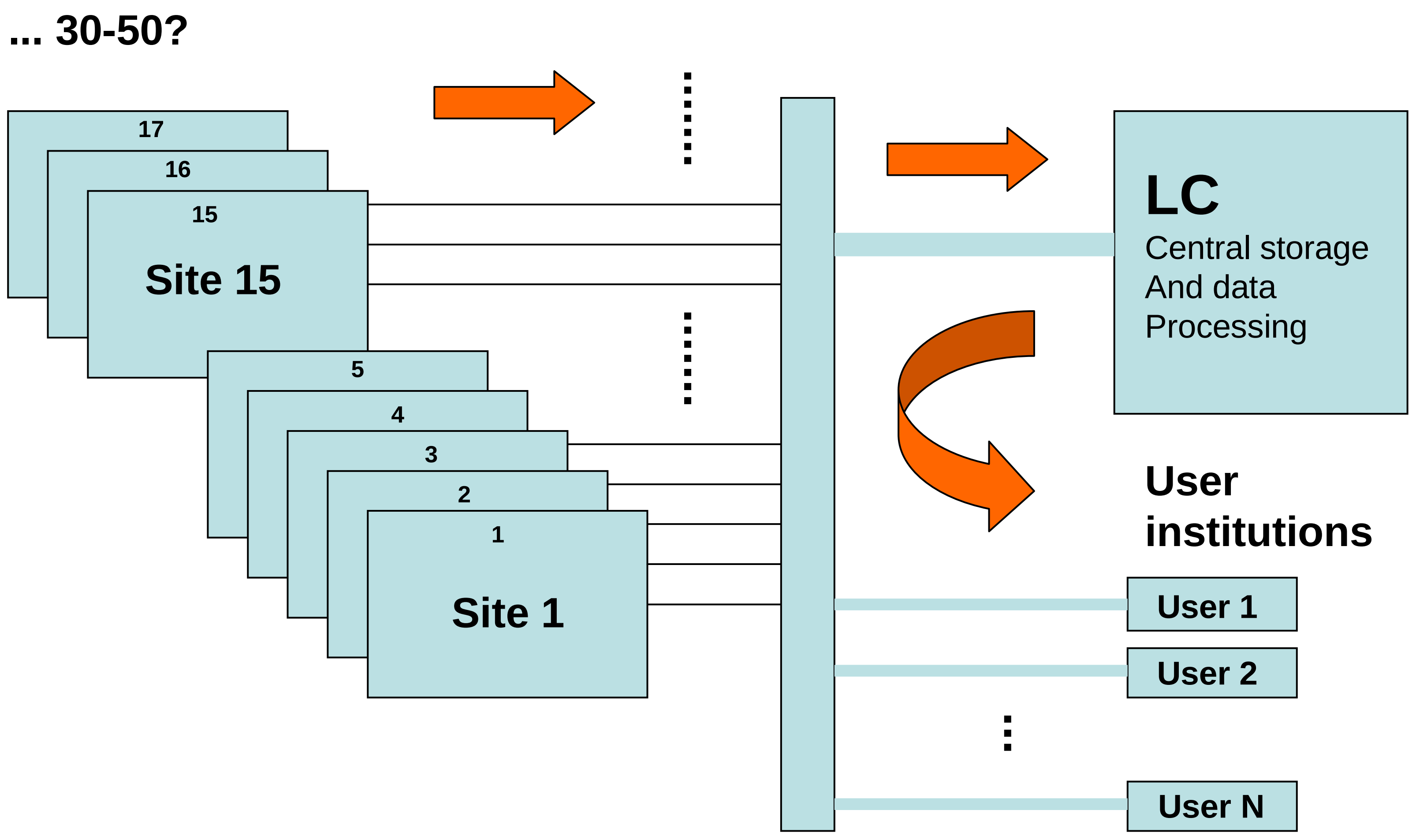
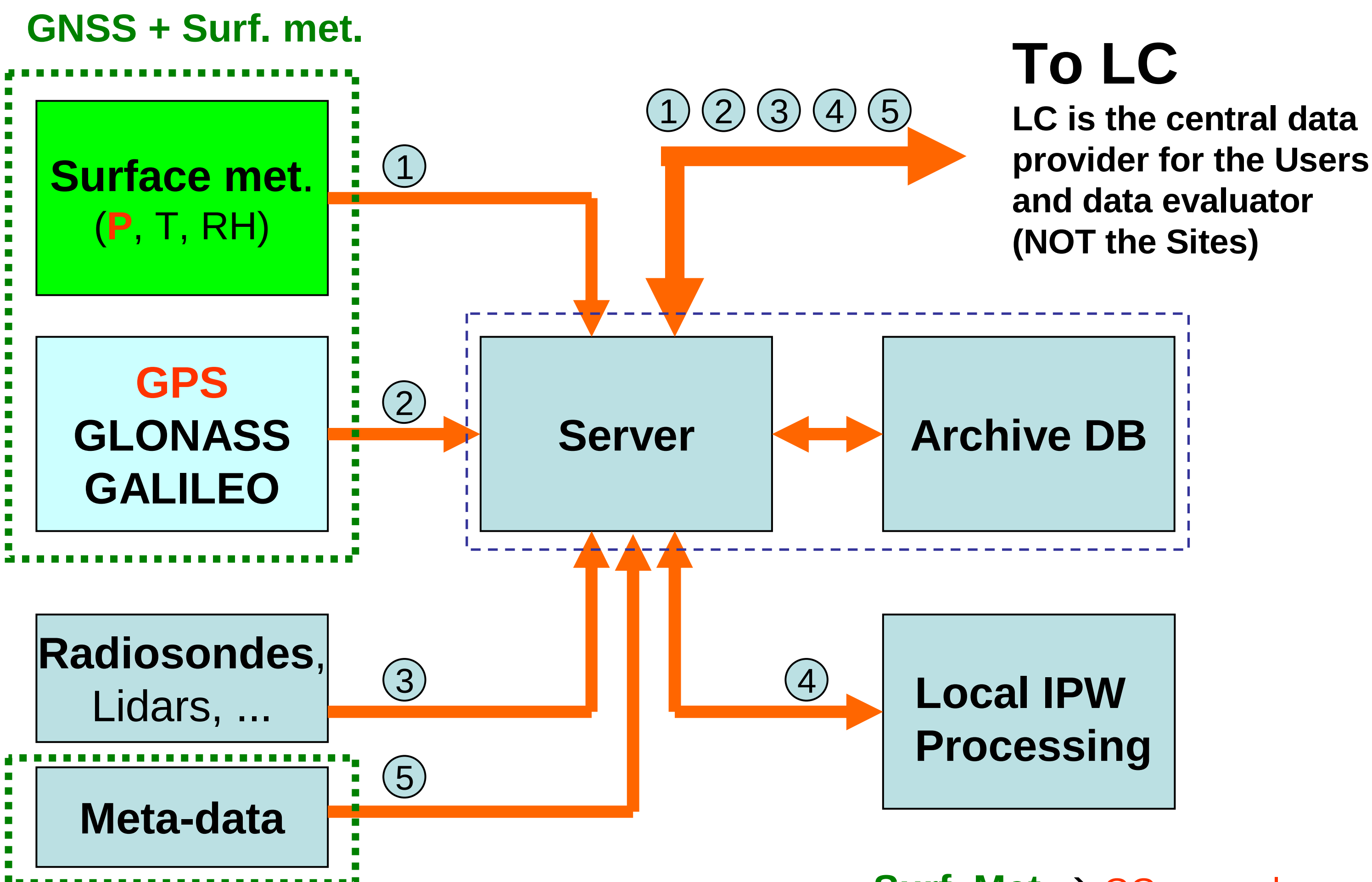
ICM-4, 7th March 2012

GRUAN – network of sites



Data stream at the site



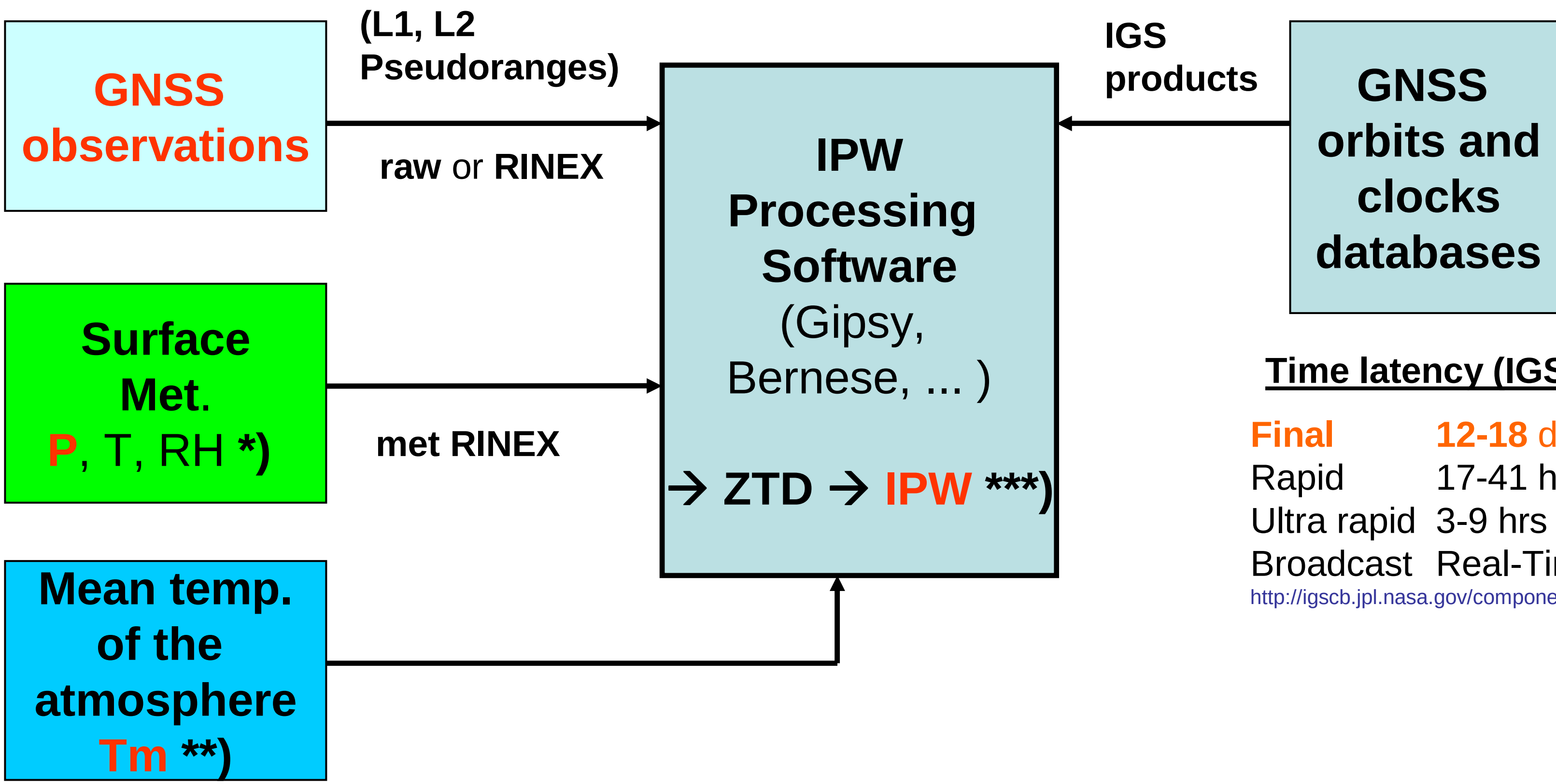
GNSS-rules → inherited from IGS-regulations, adapted to GRUAN needs (ref. GG-manual)

Surf. Met. → GG-manual

Site Meta-data → site log- and history files (GG-manual)

data FORMATS for GRUAN Data Flow (GRUAN-TD-1)

Input variables for IPW calculations



Time latency (IGS):

Final	**12-18** days
Rapid	17-41 hrs
Ultra rapid	3-9 hrs
Broadcast	Real-Time

http://igscb.jpl.nasa.gov/components/prods.html

*) Pressure sensor‘s and GNSS antenna height difference fixed within (<=1m)
If > 1m → pressure corrections calculated

Pressure sensor accuracy: <= +/- 0.5 hPa
Temperature sensor accuracy: <= 0.1 K

**) Tm comes from radiosonde measurements, model or Tm-Ts relationship (specifically for the site). *Ref. Wang et al, 2005, Bevis et al, 1992*

***) Time Latency 1 Month (by a table of requirements)

Uncertainties and the sources of uncertainties for IPW

Theoretical analysis for GNSS IWV: Tong Ning, Gunnar Elgered, Junhong Wang and Liangying Zang, 2012 (+ GNSS-PW TT presentation)

Orbits: Depends on IGS product category (for climate research -- final products, the best we can get).

GNSS-observations: Constellation of GNSS satellites, extreme meteorological conditions (thunderstorms, Sun bursts), multi-path, electromagnetic interference.

Surface met. measurements: thermal drift, data gaps in time series.

Analysis Software and related atmospheric models: Mean temperature of the atmosphere,antenna phase centre offset, mapping functions,...

Changes in hardware or firmware.

What can be done?

Orbits: nothing, just wait for and use the final IGS-products.

GNSS-observations: Constellation of GNSS satellites - nothing, extreme meteorological conditions (thunderstorms, Sun bursts) – for thunderstorms, choose a suitable place for the installation, multi-path – follow the instructions (Guidelines), electromagnetic interference (follow the Guidelines).

Surface met. measurements: thermal drift – regular calibration and validation *), data gaps in time series – regular monitoring and service.

Software and related atmospheric models: Mean temperature of the atmosphere, antenna phase centre offset, mapping functions,... Mostly all software used by geodetic community give good and reliable results. The quality of the final product depends on analyst's experience and initial data quality. (Ref. Gendt et al, 2001)

Changes in hardware or firmware: follow the Guidelines.

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*) actually it seems to be not enough, look at the example for discussions

What can be done? continued...

From theoretical analysis Tong et al. 2012:

The uncertainties from **ZTD** and surface pressure **Ps** dominate over other sources of uncertainty for IPW. The main attention must be pointed to obtaining of these two parameters.

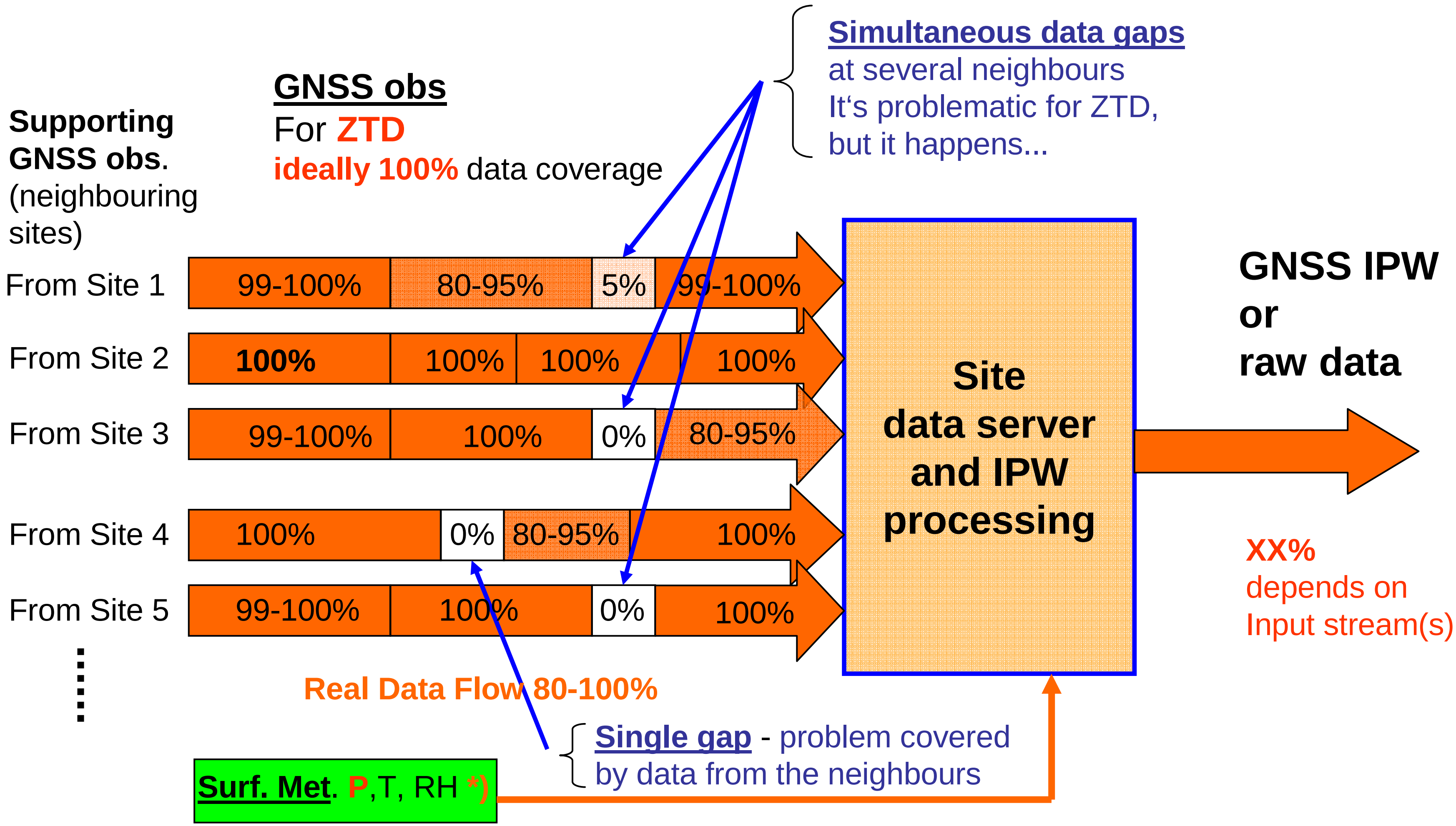
Additional recommendations:
Reducing multi-path at the sites (follow the Guidelines).

Use fixed GNSS antenna cut-off angles and the same software for analysis over a longer time-span.

Regularly collect and update station meta-data.

GNSS-PW TT is currently working on the issues.

IPW data stream from the site



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*) Usually fully automated data stream from 1 sensor only may have gaps and jumps. Secure by some additional ref. points (data sources)?

Surface met. data stream and data quality verification

In practice 2 possibilities to handle Surf.met. data stream together with GNSS obs:

1) Weather station connected to the GNSS receiver (and all together to the server).
2) Meteodata stream from the nearest automated weather station, converted to daily met-RINEX (coming from the most reliable sensor).

What about the quality?

Case „1“ – invisible dataflow, if just uploaded, nobody will check (example).

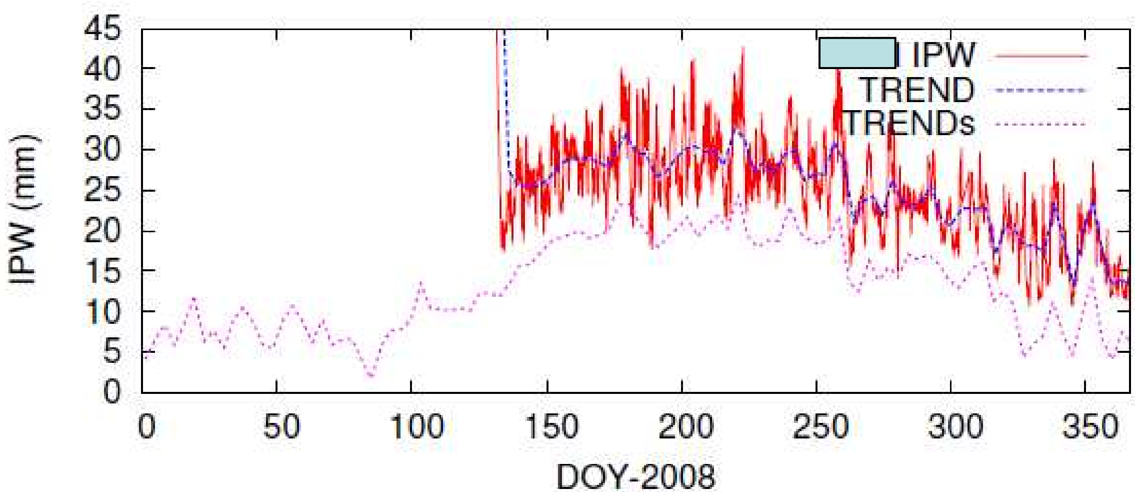
Case „2“ - before uploading the operator decides by looking at the data (big errors easily discovered), small errors not noticed.

Common practice to guarantee the data quality:
Regular calibrations/validations by a certified validator and well-scheduled technical service. Meanwhile it is believed that everything is OK. Usually it is...
... but look at the example (next slide).

In fact, each meteorological observatory has usually several pressure and temperature sensors at the site – why not to use them for routine check of the output of the „main“ sensor?

Automation, supporting the data stream – good and/or bad (example)?

<u>**Calculating IPW**</u>: GNSS observations have been OK, uploaded T and RH also, but the <u>surface pressure</u> has a <u>huge bias before DOY 140</u>, and stays just a bit less biased after DOY150 (data was downloaded and processed in 2010, but it is still there -- last checked 22 Feb. 2012).
It makes also the IPW-solution after DOY150 biased compared to the standard atmospheric model used for TRENDs (violet). 3 hPa error in Ps → 1 mm error in PW



The bias example above comes from „blind automation“, however it could have been avoided by automated check before uploading. The BIG ERROR (before DOY140) can be easily detected even visually, but how to detect the SMALL ERRORS? The only solution – automated check by comparing data from independent sources at the site.

For user comfort

Three counterparts: Sites, LC, Users
Data to/from GRUAN (To LC/central_DB and From Central_DB)

How the User gets satisfied – an important aspect is to offer easily understandable and easy-to-process information WHAT WE HAVE and FROM WHICH TIME, adequate description on changes.
The Sites: well-regulated procedures and formats (and tools) to deliver the data and to verify the initial data quality, updating the changes.
LC: well-regulated procedures and formats (and tools) to deliver the data (to Users) and to get initial data from the Sites.

For GNSS it means offering good information about site history and logfiles (created and developed under IGS regulations). Rather old approach, but works well (for a qualified user). (examples with numerous changes – not so easy to follow, if the number of stations gets over 10) GNSS TT tasks #5 and #7.

Cannot we offer/plan something complementary to „conventional logfiles“? Or sharing some unified tools for logfile- and site history analysis, data availability tables, etc?

Supporting experiments (additional research) to improve the GRUAN GNSS-PW data products quality and reliability?

According to GNSS-PW TT task #8: Encouraging and recommending experiments and research for resolving the tasks mentioned in the subtopics 1-7 ...

-**For best practices**, how to configure the GNSS-receivers, comparing data analysis by different software and methods/models for **GNSS-data analysis. Several** aspects like multipath caracteristics, GNSS satellites' constellation dependence on latitude, etc are **site-specific. Analysis** of these effects and certain optimisation of GNSS-PW data processing for a site **can be left for the sites**, at least partly (and supervised by LC and TTs).

-**To keep the stations active and motivated** with a possibility to show initiative and keep the „belonging to GRUAN" important for holding organisation's administration (national contributions to GRUAN).

Thank you for your attention

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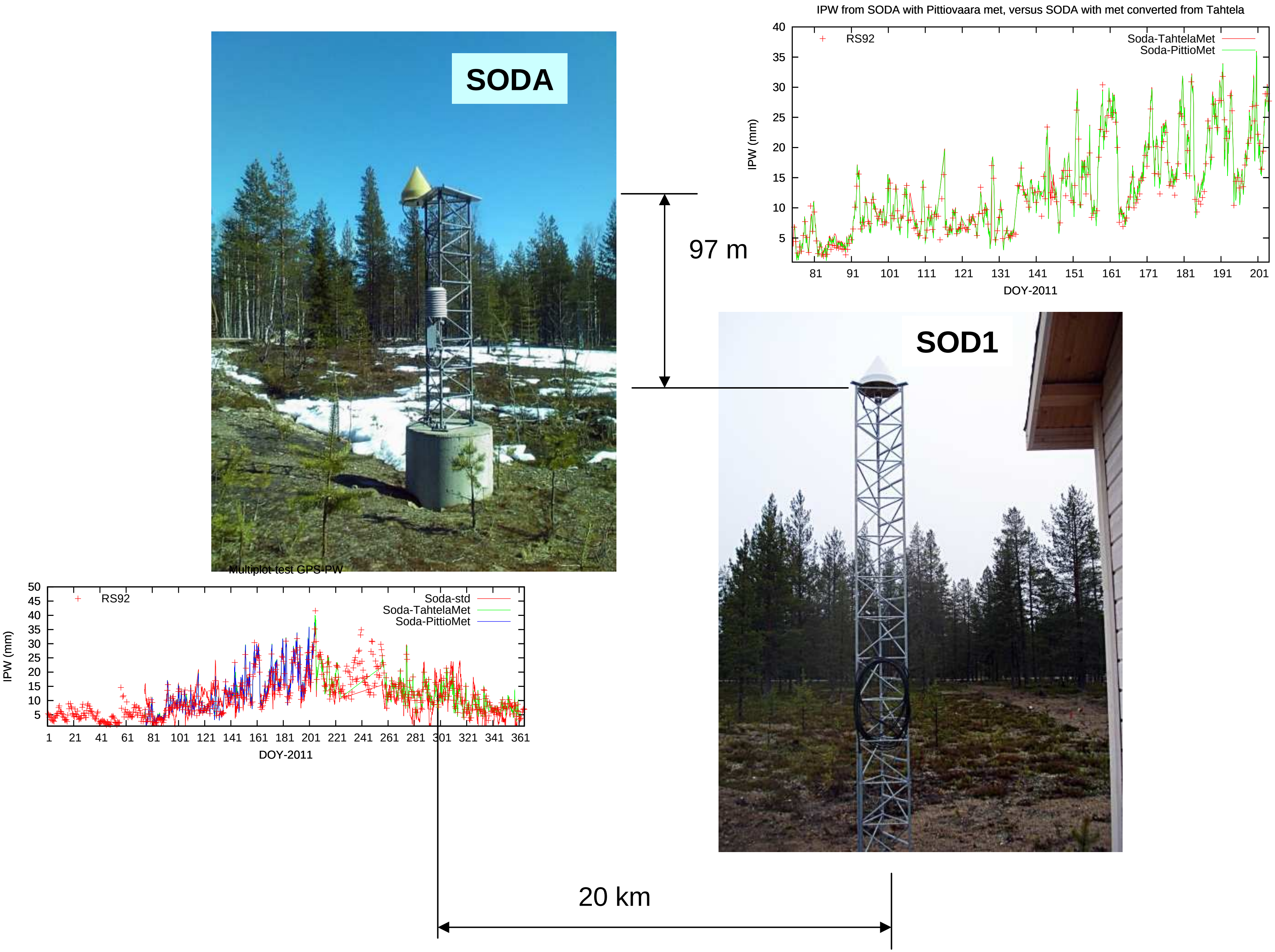
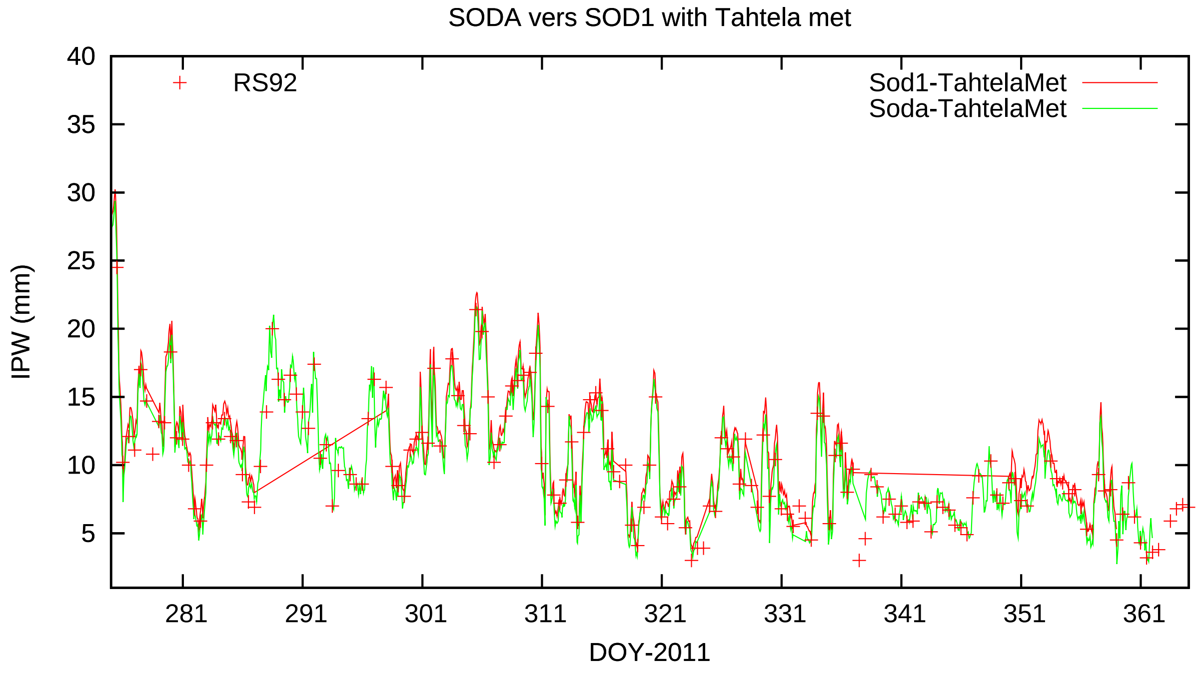
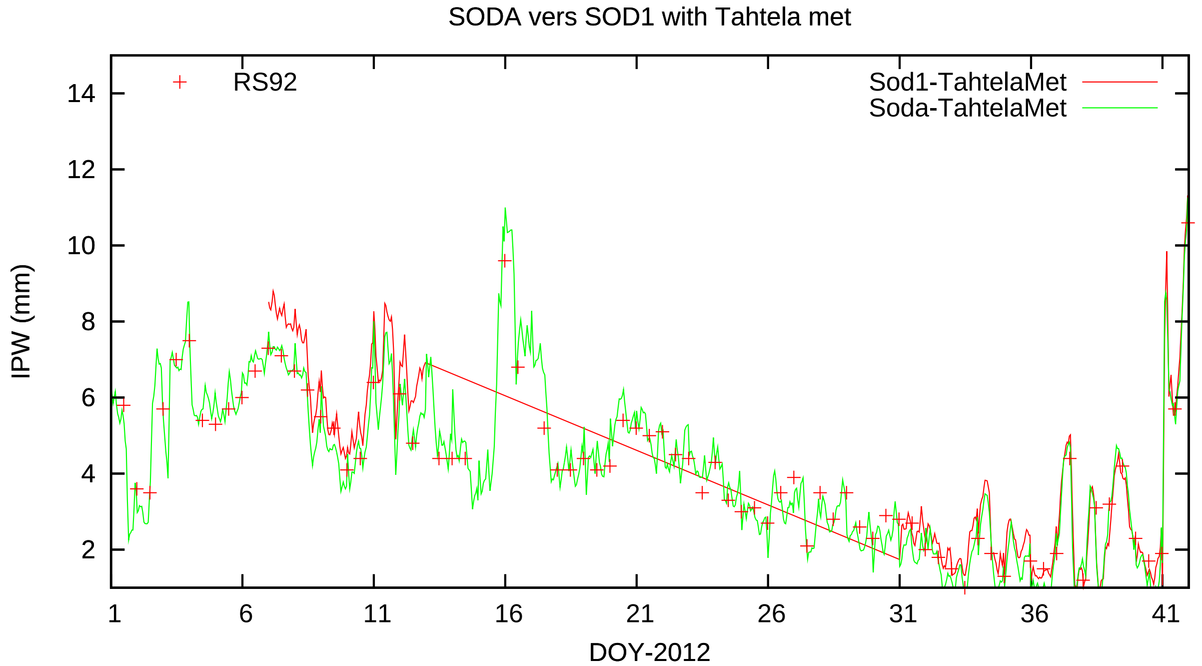
References:
1. GG Guidelines
2. Wang, J., L. Zhang, and A. Dai (2005), Global estimates of water-vapor-weighted mean temperature of the atmosphere for GPS applications, J. Geophys. Res., 110, D21101, doi:10.1029/2005JD006215.
3. Bevis, M., S. Businger, T. A. Herring, C. Rocken, R. A. Anthes, and R. H. Ware (1992), GPS meteorology: Remote sensing of atmospheric water-vapor using the Global Positioning System, J. Geophys. Res., 97(D14),15,787–15,801.
4. GRUAN-TD-1, Manual for the Data Management in GRUAN
5. Gendt, G., Dick, G., Rius, A., et al., Comparison of software and techniques for water vapor estimation using German near real-time GPS data. Phys. Chem. Earth A 26 (6-8), 417-420, 2001


SODA
SOD1
97 m
20 km
IPW from SODA with Pittiovaara met, versus SODA with met converted from Tahtela
RS92
Soda-TahtelaMet
Soda-PittioMet
IPW (mm)
DOY-2011
Multiplot-test GPS-PW
RS92
Soda-std
Soda-TahtelaMet
Soda-PittioMet
IPW (mm)
DOY-2011


SODA vers SOD1 with Tahtela met
RS92
Sod1-TahtelaMet
Soda-TahtelaMet
IPW (mm)
40
35
30
25
20
15
10
5
281
291
301
311
321
331
341
351
361
DOY-2011


SODA vers SOD1 with Tahtela met
RS92
Sod1-TahtelaMet
Soda-TahtelaMet
IPW (mm)
14
12
10
8
6
4
2
1
6
11
16
21
26
31
36
41
DOY-2012