GRUAN GNSS Precipitable Water (GNSS-PW) Task Team:
Status, Progress and Plan

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Members:

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- *Gunnar Elgered, Chalmers University, Sweden*
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- *Yoshinori Shoji, Meteorological Research Institute, Japan*
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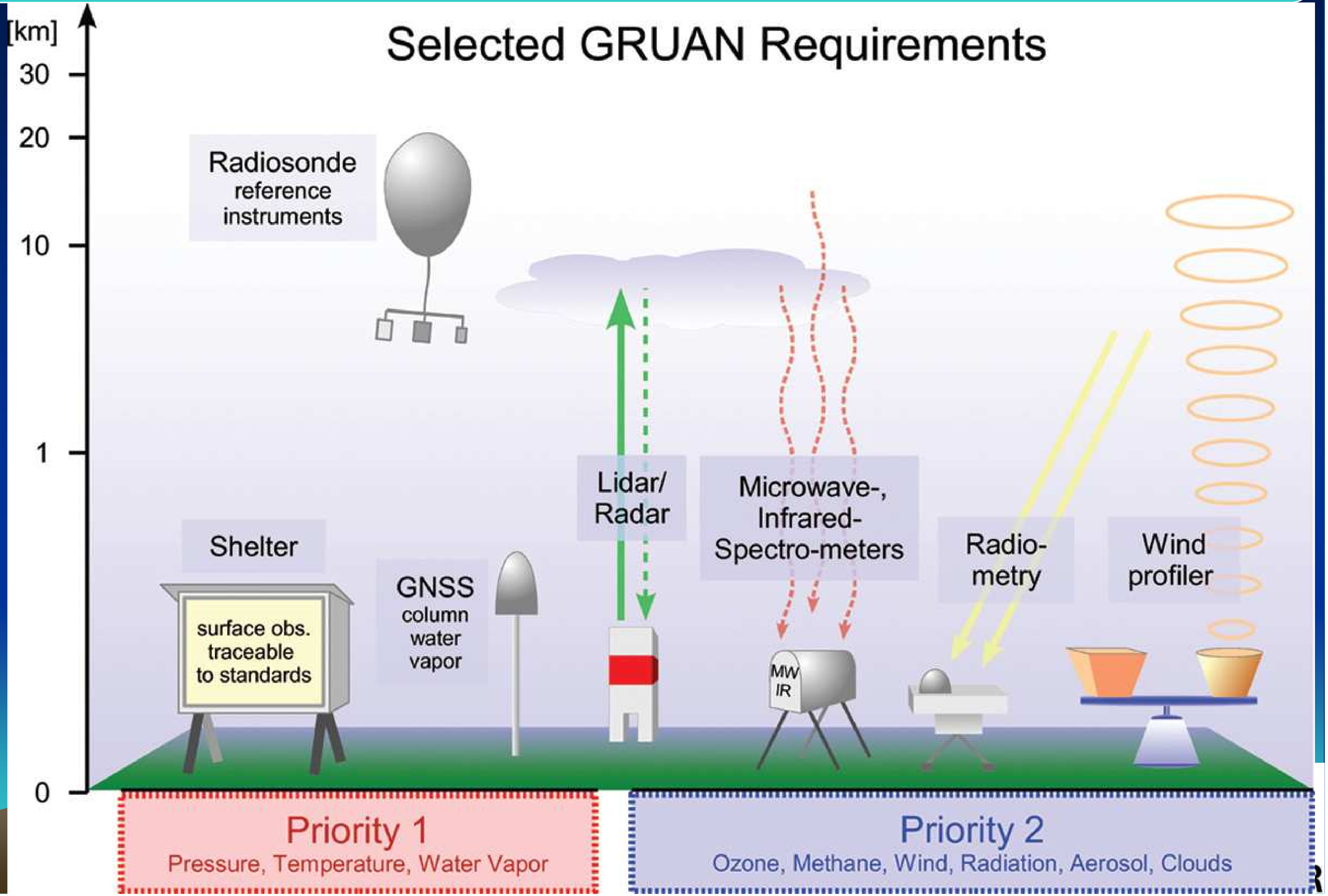
Why GNSS-PW Task Team?



Why GNSS (Global Navigation Satellite Systems)?

System	Country	Coding	Orbital height & period	Number of satellites	Frequency	Launch date	Status
GPS	United States	CDMA	20,200 km, 12.0h	≥ 24	1.57542 GHz (L1 signal) 1.2276 GHz (L2 signal)	Operation: 1978 Global available: 1994	operational
GLONASS	Russia	FDMA/CDMA	19,100 km, 11.3h	24 (30 when CDMA signal launches)	Around 1.602 GHz (SP) Around 1.246 GHz (SP)	Start: 1982 Full national coverage: 2010	operational with restrictions, CDMA in preparation
Galileo	European Union	CDMA	23,222 km, 14.1h	2 test bed satellites in orbit 22 operational satellites budgeted	1.164-1.215 GHz (E5a and E5b) 1.215-1.300 GHz (E6) 1.559-1.592 GHz (E2-L1-E11)	First four: 2011 Full Operation: 2020	in preparation
COMPASS	China	CDMA	21,150 km, 12.6h	35[8]	B1: 1,561098 GHz B1-2: 1.589742 GHz B2: 1.207.14 GHz B3: 1.26852 GHz	2012/2020	5 satellites operational, additional 30 satellites planned

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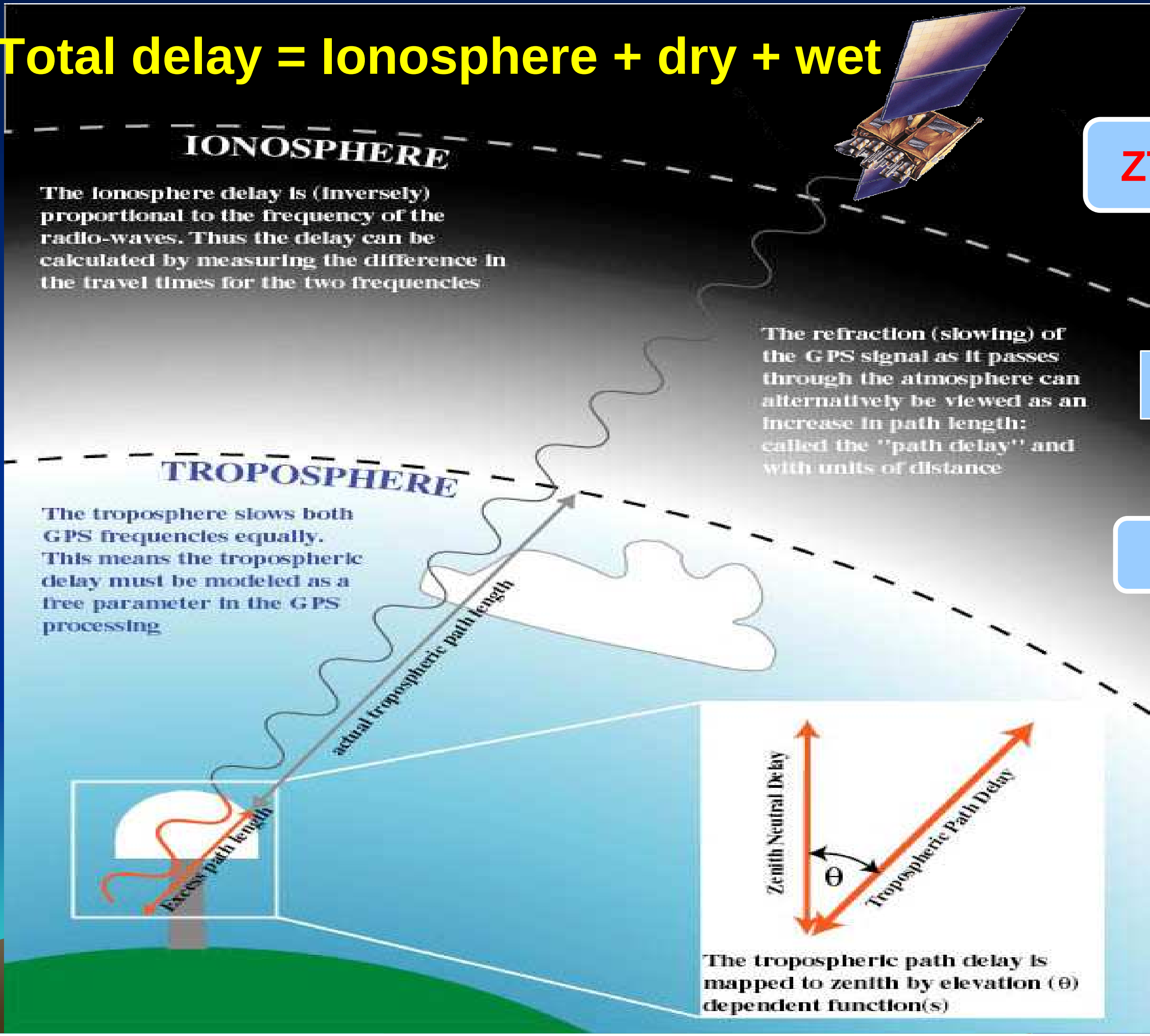
How does GNSS estimate precipitable water?

Total delay = Ionosphere + dry + wet



ZTD = ZHD + ZWD

$ZHD = f(P_s)$

ZWD = ZTD - ZHD

PW = ∏ * ZWD
∏ = f (Tm)

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Status

- ***7/2010: Establishment of the TT***
- ***10/2010: Completion and approval of the ToR***
- ***10/2010-2/2011: Focus on the first three tasks and divide into three sub-teams***

Goal:

To develop explicit guidance on hardware, software and data management practices to obtain GNSS PW measurements of consistent quality at all GRUAN sites.

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Term of Reference: Duties

1. *To define GRUAN requirements for GNSS-PW observations that are missing in the requirement tables in GCOS (2007).*
2. *To document and review current status of GNSS instruments and associated data processing methods used at GRUAN sites.*
3. *To define GRUAN requirements for a state-of-the-art GNSS station.*
4. To develop guidance on the type, amount, format, temporal resolution and latency of data and associated metadata needed to be stored from the ground-based GNSS measurements and other auxiliary data sources, and data archive and dissemination methods.
5. To identify best practices in making and verifying GNSS observations for GRUAN and other climate applications defined in Task 1.
6. To follow the guidance on reference quality upper-air measurements outlined in Immler et al. (2010) and provide guidelines for GNSS-PW uncertainty analysis.
7. To address the question of how to better manage changes applied to ground-based GNSS measurements.
8. Encouraging and recommending experiments and research for resolving the tasks mentioned in the subtopics 1-7.

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1. To define GRUAN requirements for GNSS-PW observations that are missing in the requirement tables in GCOS (2007). (*Gunnar Elgered & June Wang*)

GRUAN requirements for water vapor (mixing ratio) profile (GCOS-112)

Measurement Range	Vertical range	Vertical resolution	Precision	Accuracy	Long-Term Stability
0.1 to 90000 ppmv	0-30 km	0.05/0.1 km (< 5 / > 5 km)	2%/5% in TR/ST	2%	1% (0.3%/decade)

1. **Requirements on absolute value (in kg/m2 or mm)**
2. **Requirements for ZTD, Ps and Tm are needed too.**
3. **Scientific (not performance) requirements**

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Table 1. Requirements for ZTD, PW, Ps and Tm

("E-GVAP-II: Product Requirements Document")

Variable	ZTD	IW V	P_s	T_m
Measurement range				
Repeatability				
Accuracy	4 mm	1 kgm^{-2}	0.5 hPa	
Long-term stability		0.02-0.06 kgm^2/decade		
Temporal resolution	1h	1h	1h	1h
Data latency	1 months	1 months	1 months	1 months

Issues:

1. **IWV (kg/m2) v.s. PW (mm)**
2. **Fill the blank spaces?**
3. **Should we add a uncertainty column?**

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2. To document and review current status of GNSS instruments and associated data processing methods used at GRUAN sites. *(Kalev Rannat, Galina Dick, Jens Wickert)*

Survey table:

1. Response (Y/N)
2. Station name/Country
3. Contact: Name/Email
4. GPS contact: Name/Email
5. GPS site name
6. GPS position: lat/lon/alt
7. Receiver type
8. Antenna type
9. Sfc met sensors
10. Source of clock & orbit
11. Methods for ZTD
12. Source of Tm
13. Raw data (where & format)
14. Derived data (ZTD/PW) data format
15. Connect with other networks
16. Other

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GCOS Reference Upper-Air Network

No GPS receiver: Lauder

2. To document and review current status of GNSS instruments and associated data processing methods used at GRUAN sites. *(Kalev Rannat, Galina Dick, Jens Wickert)*

1. All sites, without exceptions, use GNSS-instrumentation known from geodetic survey, mostly produced by TRIMBLE, ASHTECH, LEICA, JAVAD.
2. The antenna configurations fit for geodetic needs.
3. All sites use well known geodetic data processing software (Bernese, GIPSY OASIS or Gamit/Globk) running in network or PPP mode.
4. Lindenberg data is additionally processed by GFZ EPOS PPP solution: LDB2 - GFZ EPOS PPP solution/BKG Bernese network solution and LDB0 - GFZ EPOS PPP solution.
5. More differences can be noticed in surface meteorological instruments, but all of them are used and accepted by national meteorological services.
6. Raw data availability - the sites have given the databases and most sites offer both instrument-specific binary and RINEX.
7. Derived data (ZTD/PW), is presented in ASCII and NetCDF (Boulder offers both).
8. For the GNSS-Survey Table one additional column for GNSS-receiver antenna and ground surface pressure sensor height difference is added.
9. Data is missing for ARM GPS-stations and from Xilin Hot (China).
10. Additional needs are documented in "GRUAN guidelines based on IGS standards" (ed. by Y. Shoji)

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3. To define GRUAN requirements for a state-of-the-art GNSS station. (Yoshinori Shoji, John Braun, Seth Gutman)

1. "GRUAN Ground-based GNSS Site Guidelines": Sites, meteorological data and receivers

2. "Instructions for filling out GRUAN GNSS site logs":

3. "GRUAN GNSS New Site Checklist":

- Where is the station located?
- Is the station currently operating, or planned? If planned, when is the projected date it will become operational?
- What agencies are responsible for installing, managing, operating, and maintaining the station?
- What is the expected operational lifetime of the station? How secure is the funding?
- …

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Gruan guidelines based on IGS standards

- IGS (International GNSS Service) – www.igs.org
- IGS is an volunteer federation of more than 200 international agencies in support of the earth science community. Includes raw data (ground tracking network) and derived data products (satellite orbits, earth orientation information, station coordinates, troposphere products,etc).
- Part of the GGOS (Global Geodetic Observing System).

Essential GPS Equipment

GPS Receiver/Antenna	Geodetic quality dual frequency carrier phase observations are needed for any GRUAN site.
Surface Observations (pressure and temp.)	Pressure accurate to <0.5 hPa to remove hydrostatic delay. A 0.5 hPa error in surface pressure ~0.2 mm error in PW.
Internet	Data need to be provided to analysis center(s) in timely manner to ensure that are included in routine processing.
Station Monumentation	GPS antenna should be installed in a manner that conforms to IGS standards.
Cost of Station	A research quality site can be installed for approximately $10K US.

GRUAN Instrument Guidelines

Characteristics	Comment	
GNSS receiver	Survey Grade	Carrier phase quality - dual frequency (L1, L2, required; L5 and other future signals preferred).
GNSS Antenna	Survey Grade	Antenna calibrated within IGS community
Antenna Radome (cover)	Prefer to avoid radome	Hemispherical cover, if any. Use IGS accepted covers
Surface Meteorology Station	Simple surface station (pressure, temp, RH, etc)	Surface pressure is mandatory to remove hydrostatic delay
Reliable Power		

GRUAN Station Guidelines

Characteristics	Comments	
Continuously Operating	24/7 data collection	30 second data sampling interval (minimum)
Permanent Station	Antenna is in a fixed location, geodetic quality is preferred.	See next slides
Sky Visibility	Need whole sky visibility > 10°.	Instrument tracking to at least 3° is preferred.
Data Format	Raw data in native and RINEX format is needed.	
Site Metadata	Collected and updated in site logs	IGS has standard template
Reliable power and communications	Should not be real concern for GRUAN	
Collocated surface meteorology	Surface pressure accurate to 0.5 hPa, routinely calibrated.	Perferrable to integrate with GNSS data stream (for simplicity).
Proximity to Radiosonde site	~10km?	Not well defined now. Collocated is preferable.

Good top surface of pillar narrower than antenna problem no orienting & leveling device

Good orienting & leveling devices

Good rooftop with orienting & leveling device

Examples of good and bad sites (courtesy of NGS – Giovanni Sella)

Site Examples

http://facility.unavco.org/kb/questions/104/UNAVCO+Resources%3A+GNSS+Station+Monumentation

Installing a Short Drill Braced Monument (SDBM)

Plan

- ***5/2011: Complete the first three tasks***
- ***6-12/2011: Work on Task #4-6***
- ***1/2012-12/2012: Finish Task #7-8, prepare a guidance documentation for GRUAN, and prepare possible journal paper(s).***
- ***For any task, first approve the guidelines from TT and WG, publish them as GRUAN technical documents, then publish them as peer-reviewed articles.***

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Challenges and Issues

1. GNSS instruments at Launder (resources, expertise, …)
2. Some tasks require extra amount of time (such as uncertainty analysis)?
3. Who would be responsible for keeping the guidelines up-to-date?
4. Possible future face-to-face meeting for the TT?
5. Collaborations with others on sfc measurements?
6. Who would develop consistent data processing for GNSS PW?
7. ???

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