GNSS Meteorology Workshop 2019
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WROCŁAW UNIVERSITY OF ENVIRONMENTAL AND LIFE SCIENCES

University of Stuttgart

LOW-COST RECEIVERS FOR GNSS METEOROLOGY

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Multi-GNSS constellation

Operational satellites (>100):

GPS	**31 (+2)**
GLONASS	**22**
Galileo	**22 + 2**
BeiDou 2/3	**15 + 18**

Final products:

- CODE MGEX
- experimental
- GPS >> other GNSS

Real-time products:

- GPS official, GLO unofficial
- all GNSS in CLK93 (CNES AC)

Permanent stations

www.igs.org www.epncb.oma.be www.asg-eupos.pl

- >30 satellites tracked @ a mGNSS station;
- ZTD = *f* (*T*, *P*, *e*) ➔ GNSS meteorology;
- remote sensing: accuracy + all-weather & high resolution;
- insufficient to monitor water vapour content in some cases?
- low(er)-cost receivers & antennas on the market

Post-Processing DD solution

Piksi Multi

GNSS Characteristics

GNSS Signal Tracking

GPS L1/L2, GLONASS G1/G2,
BeiDou B1/B2, Galileo E1/E5b
SBAS[1]

GNSS Data Rates

Measurements (Raw Data)	Up to 10 Hz
Standard Position Outputs	Up to 10 Hz
RTK Position Outputs	Up to 10 Hz[2]
Swift Binary Protocol (SBP) and NMEA-0183	

Maximum Operating Limits[3]

Velocity	515 m/s

PIKSI MULTI GNSS MODULE

Technical Specifications

Antenna Specification	
Frequency Range	GPS L1/L2 GLONASS L1/L2 BeiDou B1/B2/ B3
Impedance	50 ohm
Polarization	RHCP
Axial Ratio	≤ 3 dB
Azimuth Coverage	360°
Output VSWR	≤ 2.0
Peak Gain	5.5 dBi
Phase Center Error	± 2 mm
LNA Specification	
LNA Gain	40 ± 2 dB
Noise Figure	≤ 2.0 dB
Output VSWR	≤ 2.0
Operation Voltage	3.3 ~ 12V DC
Operation Current	≤ 45 mA
Group Delay	≤ 5 ns
Mechanical Specification	
Dimension	φ 152*62.2 mm
Connector	TNC Female
Weight	435 g
Environment Specification	
Storage Temp	-55° C to +85° C
Operating Temp	-45 °C to +85° C
Humidity	95% No-condensing

Post-Processing DD solution (PI02)

Post-Processing DD solution (PI05)

What about the bias?

Bias vs Denivelation

- remaining bias < 2mm

Low-cost GNSS-Meteo station

Experiment

Single-frequency receiver

15.03 – 18.04.2019 (33 days)

Dual-frequency receiver

30.04 – 10.05.2019 (11 days)

L1: Network NRT solution

15.03 – 18.04.2019
(33 days)

NRT vs. Final (USNO)

	[mm]
RMSE	5
Mean	0
StdDev	5
Median	0

L1/L2: Network NRT solution

30.04 – 10.05.2019
(11 days)

NRT vs. Final (USNO)

	[mm]
RMSE	7
Mean	5
StdDev	6
Median	5

L1/L2: Real-time PPP solution (G-only)

RMS = 14 mm
Mean = 10 mm
S.Dev. = 9 mm
Max = 36 mm
R2 = 0.84
Avail.: 65%

L1/L2: Real-time PPP solution (G+R+E)

RMS = 14 mm
Mean = 10 mm
S.Dev. = 9 mm
Max = 36 mm
R2 = 0.84
Avail.: 65%

RMS = 7 mm
Mean = -1.0 mm
S.Dev. = 7 mm
Max = 28 mm
R2 = 0.91
Avail.: 97%

Summary & conclusions

Time	Mode	GNSS:	Receiv.	Freq:	StdDev
Final	DD	GR	Piksi M.	L1/L2	2 – 10 mm
NRT	DD	GR	M8P	L1	5 mm
NRT	DD	GR	F9P	L1/L2	6 mm
Real-time	PPP	G	F9P	L1/L2	9 mm
Real-time	PPP	GRE	F9P	L1/L2	7 mm

ZTD accuracy depends on:

- receiver / antenna ($$ > $)
- time regime (Final =~ NRT > RT)
- strategy (PPP =? DD)
- #SV (GNSS > GPS only)

StdDev <10mm (~2kg/m^2 IWV)

ACCEPTED for meteorology!

Quiz

25k EUR

+

= 100 ×

+

L1/L2

#Stat=103

Avg. Dist: 40 km

#Stat=1000

Avg. Dist: 12 km

#Stat=5000

Avg. Dist: 5 km

#Stat=10000

Avg. Dist: 3 km

A) ? = 10

B) ? = 50

C) ? = 100

Low-cost receivers
for GNSS meteorology

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Thank you!

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