A BUFR Template for STD Data

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Data Access for Data Assimilation

1. Selection of observation type
2. Data base access provides BUFR data
3. Read observations
4. Selection of observations
   - Blacklisting/Whitelisting of stations or providers
   - Selection of best provider/product
5. Data thinning (temporal and/or regional)
6. Bias correction
7. ...
8. Processing with observation operator (assimilation or monitoring)

BUFR Requirements

BUFR Requirements

- Information for selective data base access
- Only one observation type per BUFR record
- One BUFR file per observation type
- Unique specification of processing center and product
- BUFR template with all data required for assimilation

Not Required ?

- Detailled information on station, GNSS hardware, processing internals, ...
- Extra observations
- Extra fields for NWP output

BUFR Template – Required Data

ST model:

$$STD = ZHD \cdot m_h + ZWD \cdot m_w + m_g \cdot (G_N \cdot \cos\phi + G_E \cdot \sin\phi) + \delta - \varphi_m$$

STD	Slant Total Delay, final STD
ZHD	Zenith Hydrostatic Delay, ZHD used in STD processing
ZWD	Zenith Wet Delay, ZWD used in STD processing
G_N	N-S gradient
G_W	E-W gradient
δ	residual of least-squares fit
φ_m	phase multipath
m_h	hydrostatic mapping function
m_w	wet mapping function
m_g	gradient mapping function
ϕ	azimuth

DWD BUFR Template

BUFR Section 4 – Data

Data Field	Element Name	Descriptor	Scale	Tab. B Ref.	Tab. B Width	Units	Comments
1	Station or Site Name	0 01 015	0	0	160	CCITT IA5	Station & Processing Centre
2-4	**Date**	**3 01 011**					
2	Year	0 04 001	0	0	12	Year	4-digit year
3	Month	0 04 002	0	0	4	Month	1–12
4	Day	0 04 003	0	0	6	Day	1–31
5-7	**Time**	**3 01 013**					
5	Hour	0 04 004	0	0	5	Hour	0–23
6	Minute	0 04 005	0	0	6	Minute	0-59
7	Second	0 04 006	0	0	6	Second	0-59
8	Latitude (high-accuracy)	3 01 022	5	-9000000	25	Degrees	$\pm 90^{\circ}$ – precision equivalent to approx. 1 m
9	Longitude (high-accuracy)	3 01 022	5	-18000000	26	Degrees	$\pm 180^{\circ}$ – precision equivalent to approx. 1 m
10	Height of Station	3 01 022	0	-400	20	Metres	to 1 cm - geometric height relative to mean sea level
11	Geoid Undulation	0 10 036	2	-15000	15	Metres	Geoid height above WGS-84 ellipsoid, ±150 m to 1 cm

DWD BUFR Template

Data Field	Element Name	Descriptor	Scale	Tab. B Ref.	Tab. B Width	Units	Comments
ZTD Product							
12	Time Significance	0 08 021	0	0	5	Code Table	23=Monitoring Period
13	Time Period	0 04 025	0	-2048	12	Minutes	5–60 mins, nominally 15 mins
14	Pressure	0 10 004	-1	0	14	Pa	to 0.1 hPa – e.g. local AWS ob.
15	Temperature	0 12 001	1	0	12	K	to 0.1 K – .e.g. local AWS ob.
16	Relative Humidity	0 13 003	0	0	7	Percent	to 1% RH – e.g. local AWS ob.
17	ZTD				15	Metres	(ZTD processing) 500-3000 mm to 0.1 mm
18	ZTD Error				10	Metres	0-100 mm to 0.1 mm
19	ZHD				15	Metres	(ZTD processing) 500-3000 mm to 0.1 mm
20	Component of Zenith Path Delay due to Water Vapour	0 15 035	4	0	14	Metres	(ZTD processing) 0–1000 mm to 0.1 mm => ZWD
21	Atmospheric GNSS Gradient, N-S Direction			-10000	15	Metres	(ZTD processing) ±(0-100) mm to 0.01 mm
22	Atmospheric GNSS Gradient, E-W Direction			-10000	15	Metres	(ZTD processing) ±(0-100) mm to 0.01 mm

DWD BUFR Template

Data Field	Element Name	Descriptor	Scale	Tab. B Ref.	Tab. B Width	Units	Comments
ZTD Product							
	Change bit width	2 01 131					Set bit width to 10
	Change scale	2 02 129					Set scale to 1
23	Precipitable Water	0 13 016	0	0	7	Kg m^{-2}	0–100 Kg m^{-2} to 0.1 Kg m^{-2}
	Change scale	2 02 000					Re-set to Table B value
	Change bit width	2 01 000					Re-set to Table B value
24	Log_{10} of Vertically Integrated Electron Density	0 15 011	3	14000	13	log(m^{-2})	14–22 to 0.001 – TEC=10^{value}
25	Quality Flags for ground-based GNSS data	0 33 038	0	0	10	Flag Table	Bit flags – see Table 6
26	Total Number	0 08 022	0	0	16	Numeric	No. of GNSS satellites in solution

Extra element for IWV??

Total number per GNSS: N_{GPS}, N_{GLO}, N_{BeiDou}, N_{Gal}, ... ??

DWD BUFR Template

Data Field	Element Name	Descriptor	Scale	Tab. B Ref.	Tab. B Width	Units	Comments
			STD Product				
27	Time Significance	0 08 021	0	0	5	Code Table	30=Time of occurence ?? => observation time
28	Quality Flags for ground-based GNSS data	0 33 038	0	0	10	Flag Table	Bit flags – see Table 6
	Replication	1 06 025					Replicate next 22 descriptors 70 times
r1	Satellite Classification	0 02 020	0	0	9	Code Table	GNSS series – see Table 7
r2	Platform Transmitter ID	0 01 050	0	0	17	Numeric	GNSS PRN (1-40)
	Change Table B scale	2 02 127					Subtract 1 from scale
r3–r5	Location of Platform	3 04 030					GNSS (ECF coordinate system) to 10cm
r3	Distance from Earth's centre in direction 0° longitude	0 27 031	2	-1073741824	31	Metres	(X)
r4	Distance from Earth's centre in direction 90° East longitude	0 28 031	2	-1073741824	31	Metres	(Y)
r5	Distance from Earth's centre in direction of North Pole	0 10 031	2	-1073741824	31	Metres	(Z)
	Change Table B scale	2 02 000					

DWD BUFR Template

Data Field	Element Name	Descriptor	Scale	Tab. B Ref.	Tab. B Width	Units	Comments
r6	Azimuth	0 05 021	2	0	16	Degrees	to 0.01° – clockwise from True North
r7	Elevation	0 07 021	2	-9000	15	Degrees	to 0.01° – above horizontal
r8	Atmospheric Path Delay in satellite Signal	0 15 031	4	5000	20	Metres	500–90000 mm to 0.1 mm => STD
r9	Estimated Error in Atmospheric Path Delay	0 15 032	4	0	14	Metres	0–1000 mm to 0.1 mm => STD error
r10	SHD				20	Metres	500–90000 mm to 0.1 mm
r11	SWD				18	Metres	0-10500 mm to 0.1 mm
r12	SIWV				16	Kg m^{-2}	0-4440 Kg m^{-2} to 0.1 Kg m^{-2}
r13	ZHD				15	Metres	(STD processing) 500-3000 mm to 0.1 mm
r14	Component of Zenith Path Delay due to Water Vapour	0 15 035	4	0	14	Metres	(STD processing) 0–1000 mm to 0.1 mm => ZWD
r15	Atmospheric GNSS Gradient, N-S Direction			-10000	15	Metres	(STD processing) ±(0-100) mm to 0.01 mm
r16	Atmospheric GNSS Gradient, E-W Direction			-10000	15	Metres	(ZTD processing) ±(0-100) mm to 0.01 mm
r17	Residual				14	Metres	post-fit residual
r18	Pmulti				14	Metres	phase multipath

DWD BUFR Template

Data Field	Element Name	Descriptor	Scale	Tab. B Ref.	Tab. B Width	Units	Comments
r19	MapH				16		hydrostatic mapping function
r20	MapW				16		wet mapping function
r21	MapG				16		gradient mapping function
r22	Log_{10} of Slant Integrated Electron Density				13	$log(m^{-2}$	14–22 to 0.001 – TEC=10^{value}
(166)	(end replication)						
167	Sample Scanning Mode Significance	0 08 060	0	0	4	Code Table	=5 (Nth/Sth) – see Table 8
168	Difference in Path Delays for Limb Views at Extremes of Scan	0 15 033	5	-10000	15	Metres	±(0–100 mm) to 0.01 mm
169	Estimated Error in Path Delay Difference	0 15 034	5	0	14	Metres	0–100 mm to 0.01 mm
170	Sample Scanning Mode Significance	0 08 060	0	0	4	Code Table	=6 (East/West) – see Table 8
171	Difference in Path Delays for Limb Views at Extremes of Scan	0 15 033	5	-10000	15	Metres	±(0–100 mm) to 0.01 mm
172	Estimated Error in Path Delay Difference	0 15 034	5	0	14	Metres	0–100 mm to 0.01 mm

Questions

- One BUFR format for ZTD and STD data?
- ZTD and STD data in the same file/ same BUFR record ?
- Keep the old (slightly modified) ZTD BUFR ?
- For each station there are several products from several providers. How to specify product and provider in a consistent and unique way? (Currently extended station name)
- Error estimates: Which data will be provided with (reliable) error estimates? $\rightarrow$ additional BUFR entries
- Could GNSS processing centers provide a short documentation for each product?

Data Flow

Operational data flow:
GNSS processing → COST/SINEX-TRO → BUFR → database

Data flow for experimental or campaign data ?

- Local simulation of operational data flow
- Requires COST/SINEX-TRO decoder
- Requires BUFR encoder

Data exchange between users ?
How to exchange extra observations (WVR), NWP model output (ZTD,STD, ...), results of validation studies, ... between users?

- Easy to read/write exchange format with encoder/decoder
- netCDF/HDF5 converter ?

SINEX-TRO – Questions/Comments

1. Same sampling rate for **all** tropospheric estimates?
   - Each product needs to have it's own "natural" sampling rate → best estimate
   - Interpolated data should not be provided as an trop estimate as it's not obvious what data and how many data to assimilate!

   30 s STDs and 1 h ZTDs - how to encode? How to distinguish interpolated data from one center and true data from another center?
2. TROP/SOLUTION and SLANT/SOLUTION
   Currently ZHD, ZWD and gradients from TROP/SOLUTION are used for the STD estimate.
   → TROP/SOLUTION and SLANT/SOLUTION should be independent.
   → All parameters used to estimate the STD should be given in the SLANT/SOLUTION section, at least all parameters entering equ. 4 (p. 7).
   → No problem with different sampling rates of ZTDs/STDs.

SINEX-TRO – Questions/Comments

3. Satellite positions missing
   STD assimilation requires satellite positions. To estimate the satellite position form azimuth/elevation leads to large errors (km) in the satellite positions!
4. STD mapped to zenith missing
   The SLANT/SOLUTION should provide the corresponding ZTD for each STD.
   What is the correct way to map the STD to zenith? All mapping functions = 1? What about residual and multipath effect?
5. EPOCH – observation time format?
   EPOCH in solutions - not defined!
   If EPOCH is year:doy:sec this is very inconvenient for almost all users. Couldn't one provide a more usual date format? (YMDhms, MJD, ...).

SINEX-TRO – Questions/Comments

6. TROP/SLANT/SOLUTION – data in different tables?
   Will all data from all tables appear in the SOLUTION block?
   Only a subset? Only data from TROP/DESCRIPTION?
7. Errors
   What error information will be available? One extra column for each parameter? For some parameters? How do decode?
   Errors are not mentioned in the TROP/DESCRIPTION!
8. No format for .../SOLUTION
   To be defined in TROP_SOLUTION_WIDTH?
   Real/Integer/Character? How to specify?
   Minimum precision for real numbers?

SINEX-TRO – Questions/Comments

9 Encoding of many stations?
How to write SINEX-TRO files with hundreds of stations?
Sorting of observations? By station, by time, not specified?

Current STD processing at GFZ:
$\sim$ 500 stations, $\sim$ 120000 STDs per hour (GPS only), $\sim$ 5 MB
$>$ 350000 rows for STDs, $>$ 25 columns
$\rightarrow \sim$ 45 MB hourly SINEX-TRO files with multi GNSS

Reprocessing, daily files:
$3.5 \cdot 10^6$ STDs, $\sim$ 200 MB)
$\rightarrow >$ 1 GB hourly SINEX-TRO files with multi GNSS

Not really human readable, slow processing $\rightarrow$ binary format?