

Evaluation of the TanDEM-X Digital Elevation Model by PPP GPS -Analysis and Intermediate Results-

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Evaluation of TanDEM-X by PPP GPS

Structure

- **Background and Motivation**
- **Precise Point Positioning**
- **Data Acquisition and Analysis**
- **Conclusions and Outlook**

Motivation

- First Mission using Synthetic Aperture Radar (SAR)
 - First homogeneous global Digital Elevation Model (DEM)
Accuracy: 6 to 10m (resolution 30m)
- New DEM Mission: TandDEM-X
 - **Expected accuracy: 2m relative (resolution 12m)**



**Kinematic evaluation method :
Precise Point Positioning (PPP)**

Precise Point Positioning

- **Characteristics**
 - **One Receiver**
 - **No reference station**
 - **Continuous dual-frequency code and carrier phase observations**
 - **Precise correction models required**

Precise Point Positioning

• Characteristics

Extract from IGS Products (IGS, 2009)

		Accuracy	Latency	Sampling Interval
Broadcast	<i>Orbits</i>	~100cm	<i>Real time</i>	<i>Daily</i>
	<i>Sat. clocks</i>	~2.5ns SDev		
Ultra-Rapid (predicted half)	<i>Orbits</i>	~5cm	Real Time	15 min
	<i>Sat. clocks</i>	1.5ns SDev		
Rapid	<i>Orbits</i>	2.5cm	17 – 41 hours	15 minutes
	<i>Sat. clocks</i>	25ps SDev		5 minutes
Final	<i>Orbits</i>	2.5cm	12 – 18 days	15 minutes
	<i>Sat. clocks</i>	~20ps SDev		30 seconds

Precise Point Positioning

• Processing Procedure

– Raw Data

- 10Hz RINEX files

– Software

- **GIPSY – OASIS (GOA II) from JPL, USA**

GPS-Inferred Positioning System and Orbit Analysis Simulation Software

- Freeware for research and teaching purposes
- Command line based software runs on Fedora 10
- No user manual

- **CSRS-PPP from National Resources Canada**

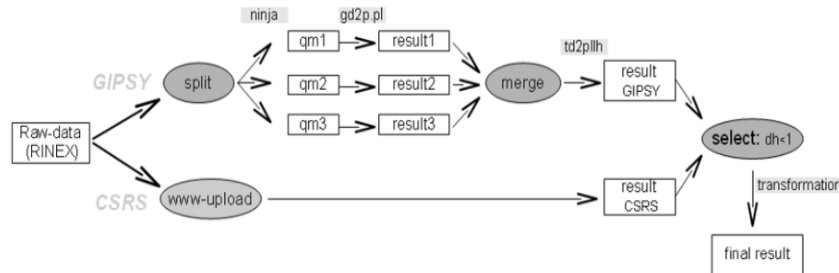
Canadian Spatial Reference System

- Web - Interface

Precise Point Positioning

• Processing Procedure

➤ Parallel Processing

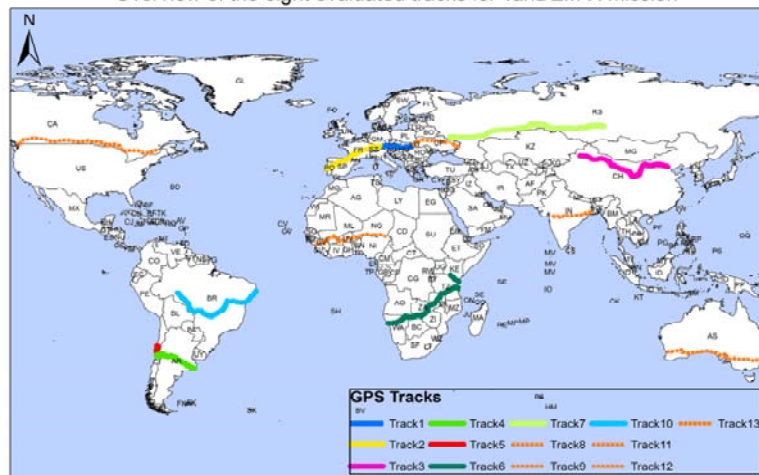


➤ Averaging of positions with $dh < 1m$

➤ Results compared with PDGPS

Data Acquisition and Analysis

Overview of the eight evaluated tracks for TanDEM-X mission



Data Acquisition and Analysis

• Current Status of Data Acquisition

Track	Position	Direction	Start	End	Length [km]	Receiver
1	Munich - Ukraine	Forward	05/13/08	05/15/08	997	Leica GX1230
		Backward	05/15/08	05/17/08	1004	Leica GX1230
2	Munich - Sao Martinho	Forward	06/09/08	06/13/08	2343	Leica GX1230
		Backward	06/15/08	06/28/08	2573	Leica GX1230
3	Beijing - Gauquan	Forward	10/04/08	10/11/08	3903	Leica GX1230
4	Laguna Verde - Punta De Choros	Forward	11/21/08	11/23/08	622	Leica GX1230
		Backward	11/23/08	11/24/08	556	Leica GX1230
5	Vina Del Mar - Mar Del Plata	Forward	11/24/08	11/28/08	1715	Leica GX1230
		Backward	12/01/08	12/09/08	1811	Leica GX1230
6	Nairobi - Outjo	Forward	06/14/09	06/24/09	4584	TPS HIPER_GGD
7	Krasnojarsk - Belgorod	Forward	07/20/09	07/31/09	4657	Leica GX1230
10	Recife - Porto Veiho	Forward	07/31/09	08/07/09	4984	TPS HIPER_LITE

Total length = 29749 km

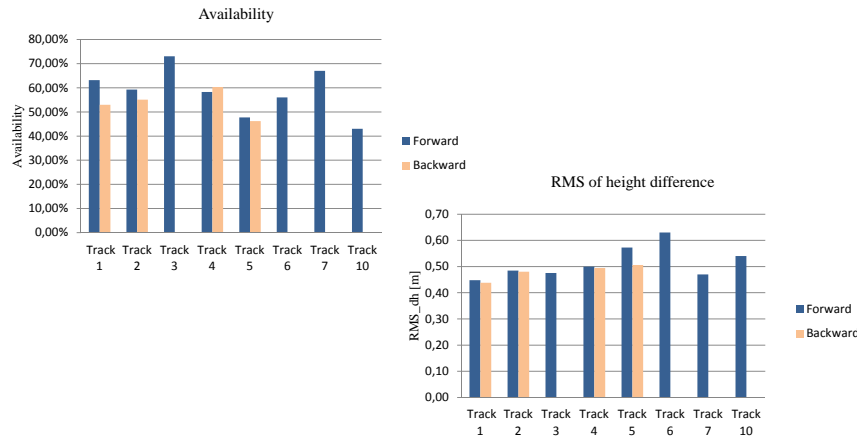
Data Acquisition and Analysis

• Results of Post-Processing

Track	Position	Direction	Epochs	Duration [Hour]	Avail.	RMS_dh [m]	Point density [1/km]
1	Munich - Ukraine	Forward	375046	16.5	65.0%	0.45	376
		Backward	350577	18.4	57.0%	0.44	349
2	Munich - Sao Martinho	Forward	772685	36.2	60.0%	0.48	330
		Backward	774775	39.1	58.0%	0.48	301
3	Beijing - Gauquan	Forward	1788140	68.0	71.0%	0.48	458
4	Laguna Verde - Punta De Choros	Forward	288296	13.8	59.0%	0.50	464
		Backward	260881	12.0	58.0%	0.49	469
5	Vina Del Mar - Mar Del Plata	Forward	497312	28.9	46.0%	0.57	290
		Backward	519377	31.2	47.0%	0.51	287
6	Nairobi - Outjo	Forward	1656912	85.6	56.0%	0.63	361
7	Krasnojarsk - Belgorod	Forward	2079222	88.0	67.0%	0.47	446
10	Recife - Porto Veiho	Forward	1254412	86.5	43.0%	0.54	251
Weighted mean					59.2%	0.52	

Data Acquisition and Analysis

• Results of Post-Processing



Data Acquisition and Analysis

• Results of Post-Processing

➤ Results of PDGPS

Track	Ref. Station	Num. of comparisons	MEAN_dh [m]	RMS_dh [m]
1	LINZ	7	0.21	0.26
	OBE3	3	-0.51	0.53
2	OBE3	29	0.21	0.5
	SALA	35	0.18	0.37
3	URUM	99	-0.03	0.39
4	No ref. Station			
5	Sant	97	0.37	0.79
6	No ref. Station			
7	NVSK	41	0.39	0.15
10	BRAZ	88	-0.16	0.24

Data Acquisition and Analysis

• Analysis of Accuracy-Height Difference Correlation

Height difference of each epoch: dh

Position accuracy for each epoch: s_{3D}

Average s_{3D} : $MEAN_{s_{3D}}$

Standard deviation of s_{3D} : $stdv_{s_{3D}}$



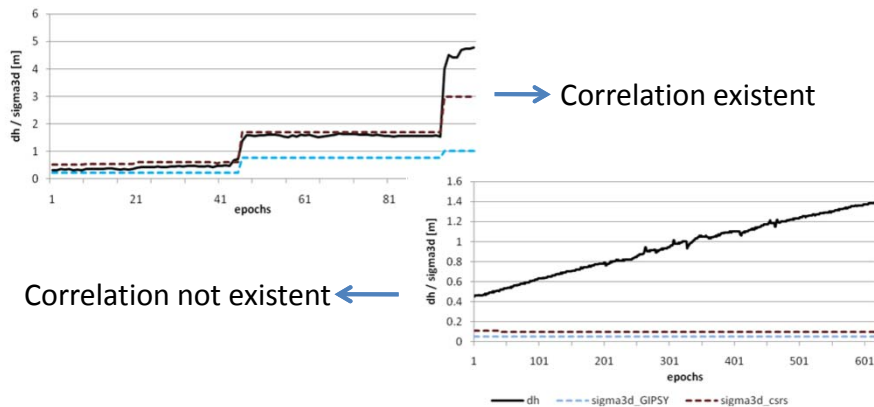
Data Acquisition and Analysis

• Analysis of Accuracy-Height Difference Correlation

<i>in cm</i>		GIPSY filtered		GIPSY rejected		CSRS filtered		CSRS rejected		
track	subtrack	MEAN <small>s3D</small>	Stdv <small>s3D</small>	MEAN <small>s3D</small>	Stdv <small>s3D</small>	MEAN <small>s3D</small>	Stdv <small>s3D</small>	MEAN <small>s3D</small>	Stdv <small>s3D</small>	avail.
3	01	13	6	19	28	10	5	13	20	71%
	02	10	4	11	5	8	3	10	6	84%
	03	12	7	27	40	21	17	46	70	69%
	04	8	4	11	10	6	4	7	5	55%
	05	4	1	5	5	6	1	7	3	65%
	06	6	3	28	24	11	8	108	50	80%
2	01	19	10	148	130	25	13	55	43	45%
	02	24	12	28	25	81	75	258	270	48%
	03	23	13	31	29	43	34	95	109	53%
	04	21	12	29	32	36	29	105	204	74%
	05	14	13	27	47	20	50	54	246	70%
	06	21	12	41	45	33	20	73	83	57%

Data Acquisition and Analysis

• Analysis of Accuracy-Height Difference Correlation



Conclusions and Outlook

- **Evaluation of TanDEM-X by PPP processing of the first 8 tracks**
- **Average height RMS: 0.52m**
- **Average availability: 59%**
- **The correlation between height difference and internal accuracies is obvious, but not stringent for all data.**
- **Further tracks in Ukraine, Canada, West Africa, Australia and India are available and will be analyzed soon**

Thanks for your attention !

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