GPS Precise Point Positioning as a Method to Evaluate Global TanDEM-X Digital Elevation Model

7th FIG Regional Conference

TS 1C
Advances in GNSS Positioning and Applications I

Volker Schwieger[1], Jürgen Schweitzer[1], Detlev Kosmann[2]

[1]*Institute for Applications of Geodesy to Engineering, University Stuttgart*
[2]*German Aerospace Centre, German Remote Sensing Data Centre, Wessling*
Germany

Hanoi, Vietnam, October 19th, 2009

University of Stuttgart

Institute for Applications of Geodesy to Engineering

Structure

- Motivation
- The TanDEM-X Satellite Mission
- Kinematic GPS Tracks for Evaluation
- Precise Point Positioning – PPP
  - General Characteristics
  - Processing Procedure
- First Results
- Conclusions and Outlook

University of Stuttgart
Institute for Applications of Geodesy to Engineering

Motivation

- **Shuttle Radar Topography Mission (SRTM) delivered first homogeneous global Digital Elevation Model (DEM)**
- **SRTM accuracy: 6 to 10 m (resolution 30 m)**
- **New DEM Mission: TanDEM-X**
- **Expected accuracy: 2 m relative (resolution 12 m)**

Need for global evaluation method for the DEM !

Cooperation of

German Aerospace Centre (DLR)

and FIG Commission 5

to find data acquisiteurs for GPS PPP

International Federation of Surveyors
Commission 5 - Positioning and Measurement
www.fig.net/figtree/commission5

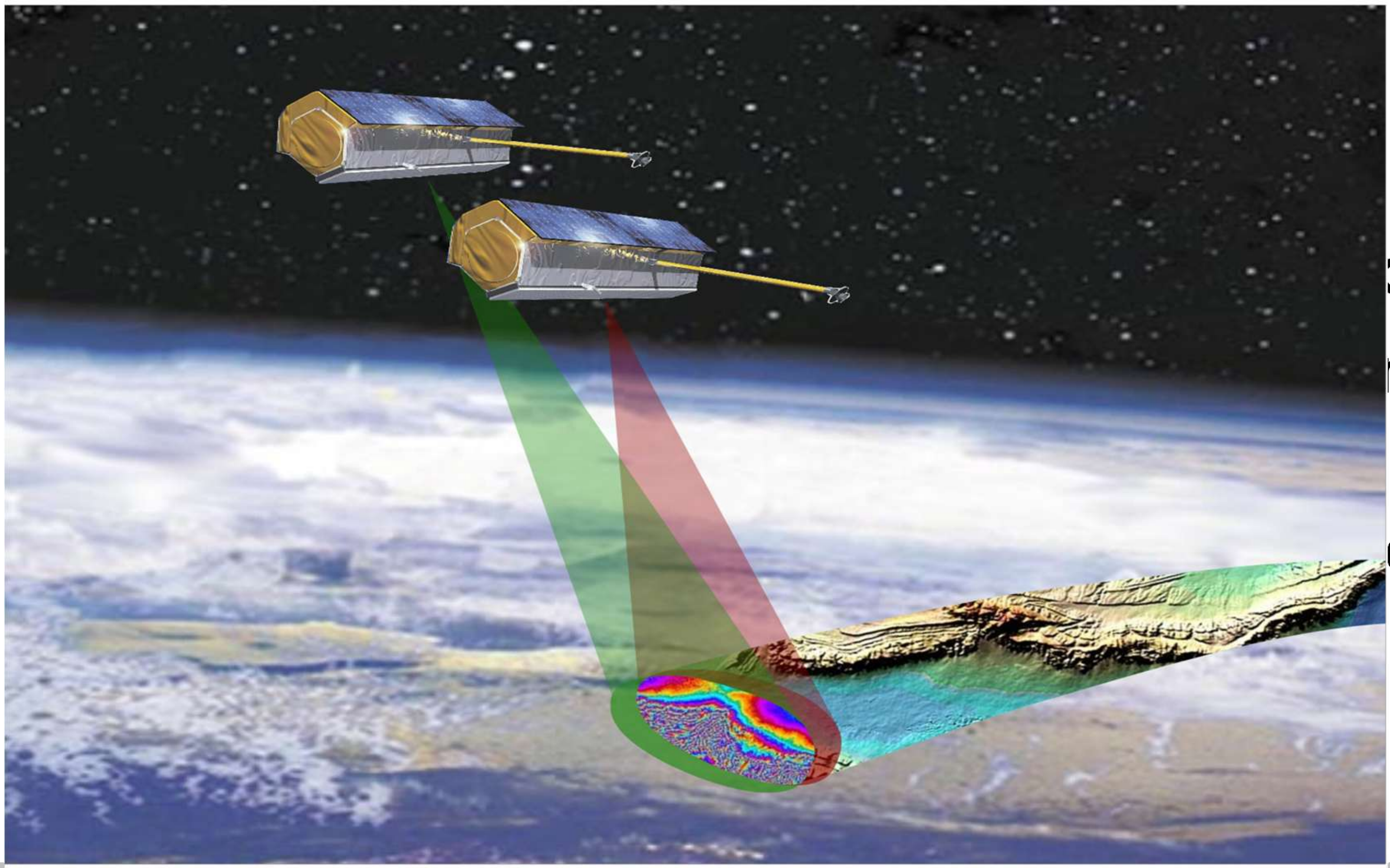
German Aerospace Center
German Remote Sensing Data Center (DFD)
http://www.dlr.de/

University of Stuttgart

Institute for Applications of Geodesy to Engineering

TanDEM-X Satellite Mission

- TerraSAR-X add-on for Digital Elevation Measurements



coherence

nes

o the earth,

TanDEM-X Digital Elevation Model

Generated by Cluster of Applied Remote Sensing, DLR:

- RawDEM generation, mosaicing of stripes and calibration,
- bundle block adjustment for conversion into final DEM
  (40 000 unknowns and 2 000 000 observations for a continent)
- provision of a height error map (HEM); **to be evaluated !**

Parameter	Error	Remark
absolute vertical accuracy	10 m	90% linear error
horizontal accuracy	10 m	90 % circular error
relative vertical accuracy	**2 m** (slope < 20%) 4 m (slope > 20%)	90% linear error
spatial sampling / resolution	0.4" (~12m)	independent pixels

Expected DEM Accuracy

University of Stuttgart
Institute for Applications of Geodesy to Engineering

Kinematic GPS Tracks – Requirements I

Conversion to evaluation standard deviations

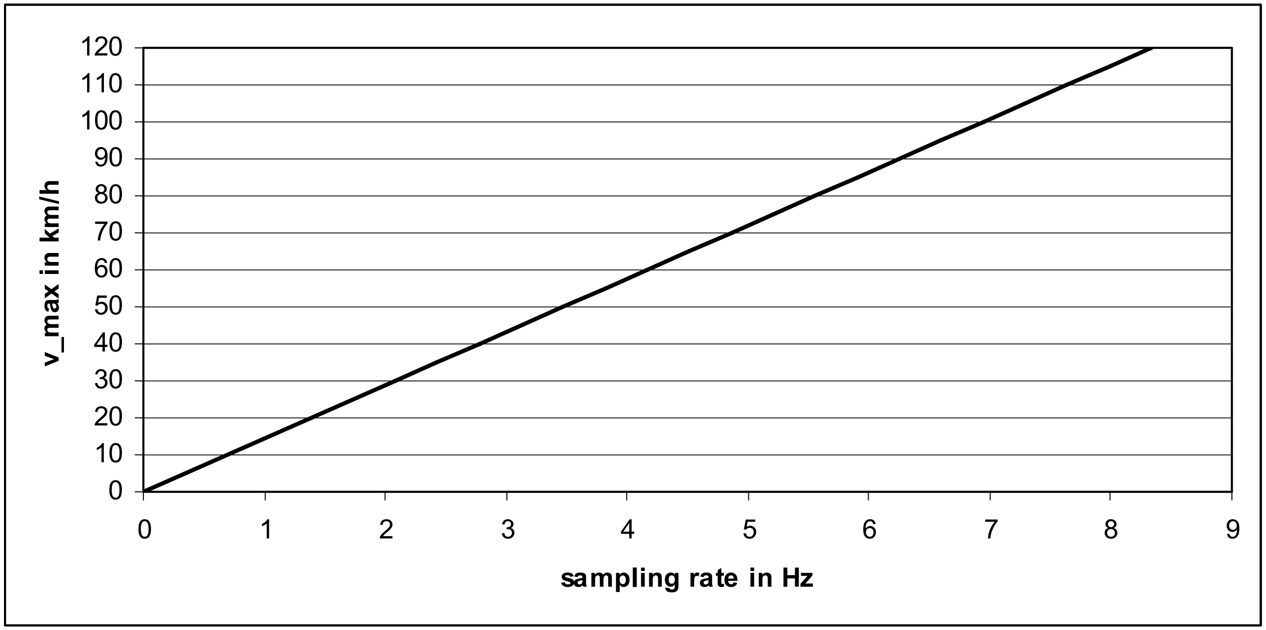
Accuracy	TanDEM-X specification		Requirements for reference trajectories		
	HRTI-3	Std.dev.	Std.dev. factor 3	Std.dev. factor 5	Std.dev. factor 10
Abs. vertic.	10 m	6.10 m	2.03 m	1.22 m	0.61 m
Rel. vertic.	2 m (slope < 20 %)	0.86 m	0.29 m	0.17 m	0.09 m
Horizontal	10 m	4.65 m	1.55 m	0.93 m	0.47 m

Two defined accuracy levels and different acquisition methods

	Required Standard Deviation	Differential GPS	Precise Point Positioning
level 1	1 m (factor 5)	smoothed DGPS	Code PPP
level 2	0.3 m (factor 3)	PDGPS (phase)	Phase PPP

Kinematic GPS Tracks – Requirements II

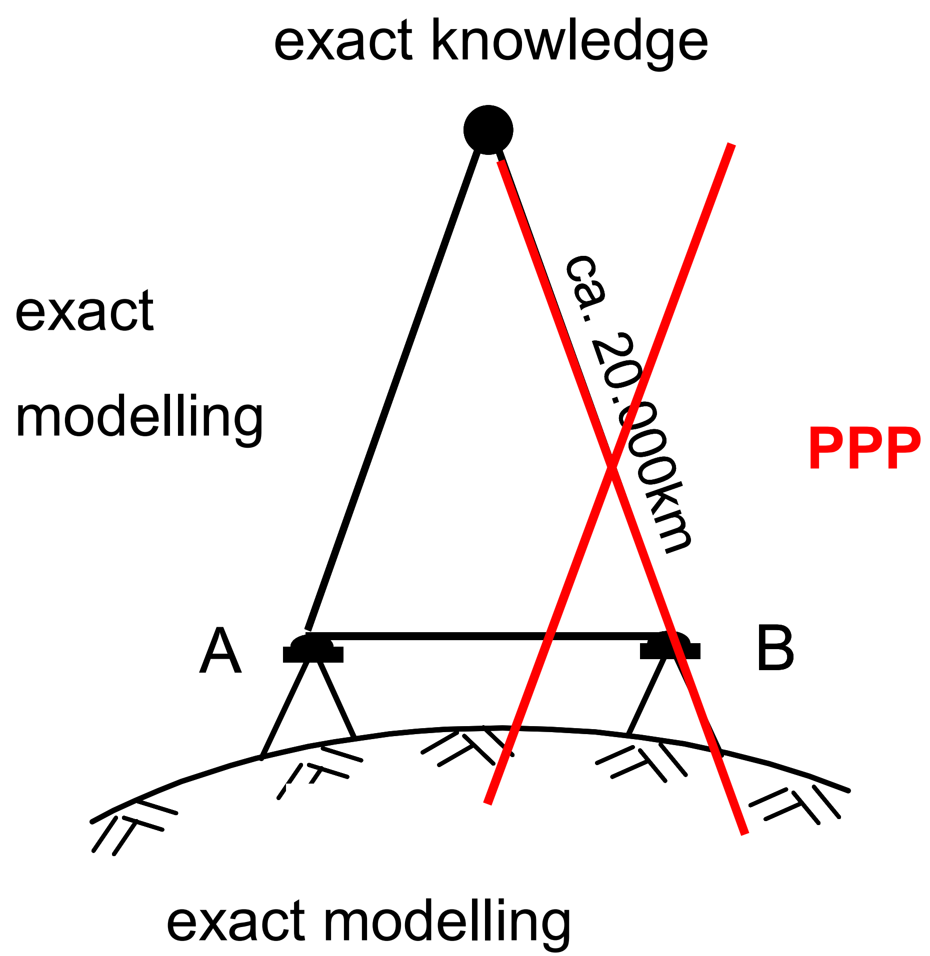
- Resolution: 12 m x 12 m
- For reliable evaluation: al least 3 positions within one pixel
- Relation to velocity and sampling rate
- Sampling rate of 10 Hz allows up to120 km/h,
  2 Hz usable for 30 km/h maximum only



Kinematic GPS Tracks - Decision

- (P)DGPS requires second receiver or world-wide available dense CORS network, since baseline lengths should be shorter than 20 km
- PPP can be carried through without these restrictions providing lower but sufficient accuracy
- Level 1 (code data) and level 2 (phase data) is acquired at the same time, if geodetic 2-frequency receivers are used;
  only more accurate level 2 is evaluated
- 10 Hz Kinematic phase PPP solution is optimal

(P)DGPS versus PPP



Precise Point Positioning - Fundamentals

- **Need for one receiver only; no reference station**
- **Special correction models required; especially precise orbits and clocks**

		Accuracy	Latency	Sample Interval
Broadcast	*Orbits*	*~100 cm*	*Real time*	*Daily*
	Sat. clocks	*~2.5ns SDev*		
Ultra-Rapid (predicted half)	Orbits	~5cm	Real Time	15 min
	Sat. Clocks	1.5ns SDev		
Rapid	Orbits	2.5cm	17-41 hours	15 min
	Sat. & Stn clocks	25ps SDev		5min
Final	**Orbits**	**2.5 cm**	**12 – 18 days**	**15 min**
	Sat. & Stn clocks	**~20ps SDev**		**Sat. 30s Stn.:5min**

Orbits and clocks products of IGS (source: IGS 2009)

PPP – Correction Models

	Description	Correction	Impact on positioning
1. Satellite antenna offsets (satellite attitude effect)	Difference between the satellite center of mass and the phase center of its antenna	Correction of satellite coordinates	height: up to 10 cm position: several cm
2. Phase wind-Up (satellite attitude effect)	Rotation of satellite antenna around its bore axis will change the carrier phase	Correction of carrier phase observation	height: several mm
3. Solid earth tides (site displacement effect)	Deformation of the earth caused by gravity of the sun and the moon	Correction of station coordinates	height: several dm position: several cm
4. Ocean Loading (site displacement effect)	Deformation of the earth caused by ocean loading	Correction of stations near the coasts	height: several cm
5. Earth rotation parameters (ERP) (site displacement effect)	Shift of the axis of the earth to the earth's crust: - pole position - time correction dUT1	Correction of Station coordinates (Not necessary, if ITRF is used)	height: several cm position: several cm

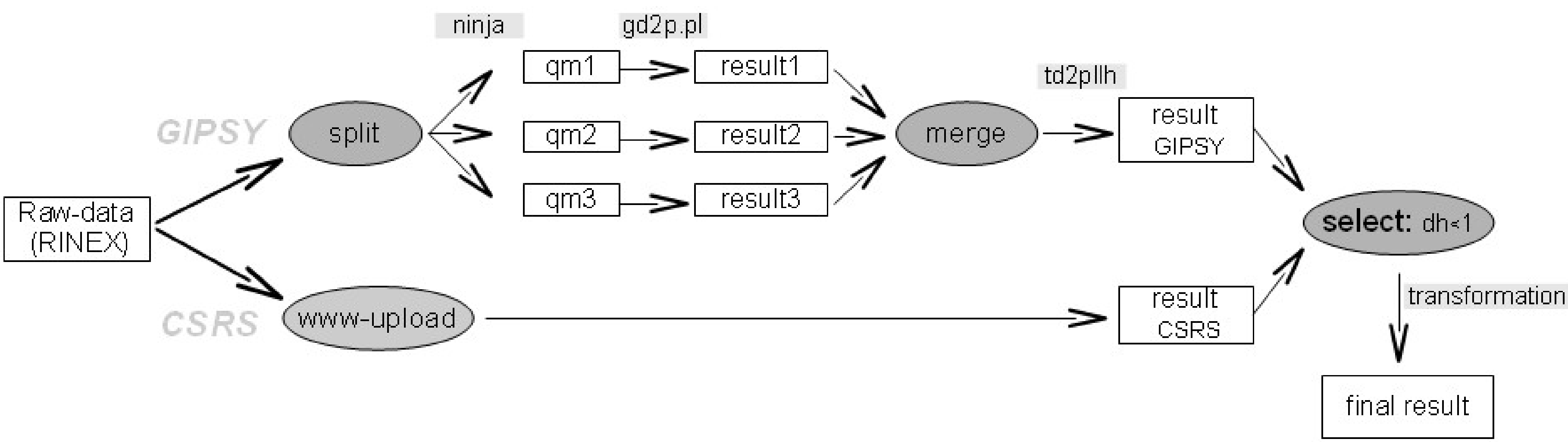
PPP correction models (source: Heßelbarth 2009)

some cm RMS in static mode resp. sub-dm RMS in kinematic mode after approx. 30 minutes (convergence time)

University of Stuttgart
Institute for Applications of Geodesy to Engineering

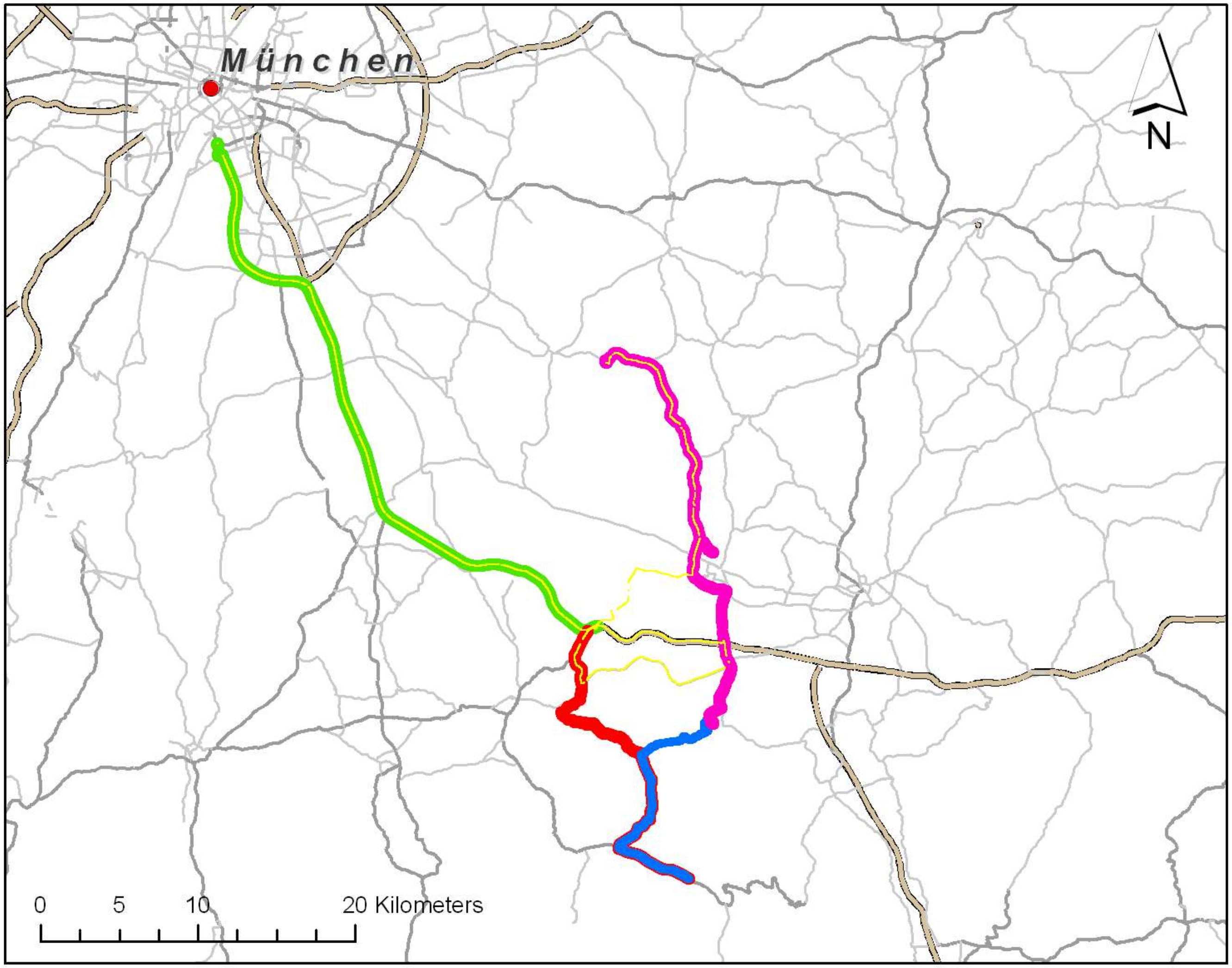
Processing Procedure

- **10 Hz RINEX files are acquired and edited**
- **Parallel Processing**
  - GIPSY-OASIS 5.0 from JPL, USA
  (freeware for research and teaching)
  - CSRS-PPP Online; National Resources of Canada
  (via Web-Intreface)
- **Averaging of positions with dh < 1 m**



Institute for Applications of Geodesy to Engineering
University of Stuttgart

First Results – Test Tracks near Munich



- Gipsy 4.04 / CSRS
- Leica 2-Frequency receivers
- **Availability:**

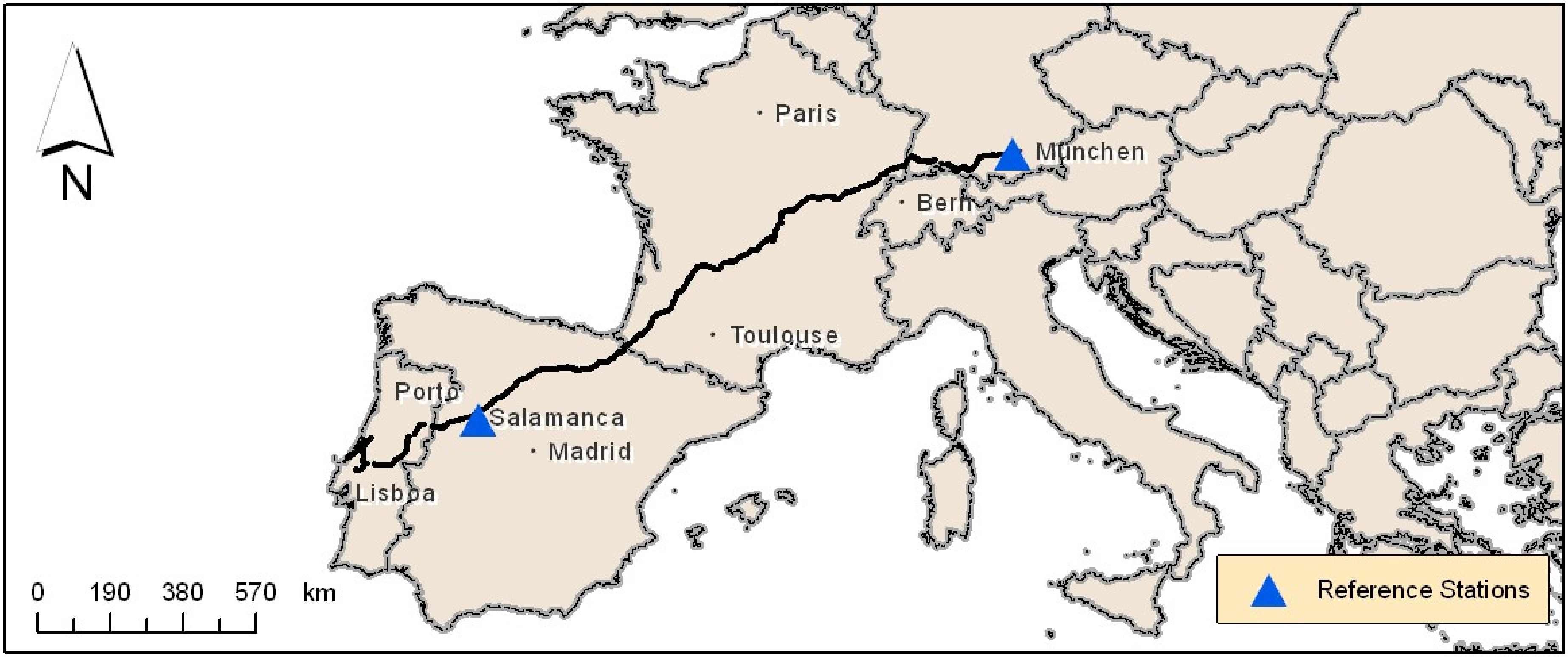
- 70.7 % PDGPS
- 74.4 % PDGPS with VRS
- 90.5 % PPP

- **Accuracy:** 0.68 m RMS

Western Europe Track

- Munich, Germany to Sao Martinho, Portugal
- 9th to 28th June 2008
- Leica GX 1230 (dual frequency), 10 Hz data rate
- 2400 km one way, dedided into 22 separated tracks per direction for processing with GIPSY
- appr. 1.3 million positions
- PDGPS for evaluation:
  - Oberpfaffenhofen near Munich, Germany
  - Salamanca not far from Madrid, Spain

Analysis of Western Europe Track



direction	epochs	availability	RMS_{dh} [m]	length [km]	point density [1/km]
forward	772685	60 %	0.48	2343	330
backward	774775	58 %	0.48	2570	301

Analysis of Western Europe Track

Reference station	Num. of comparisions	$MEAN_{ds}$ [m]	$MEAN_{dh}$ [m]	RMS_{dh} [m]
OBE3	29	0.3	0.21	**0.50**
SALA	35	0.38	0.18	**0.37**

PDGPS evaluation, data rate 30 s only

Conclusions and Outlook

- Evaluation of new TanDEM-X DEM by PPP processing of world-wide kinematic GPS tracks
- Height RMS: 0.5 m
  does not reach the requirements, but sufficient to evaluate DEM
- Availablity: 60 % for first „real track“
- Further tracks in Europe, Asia, Africa and South-America are already acquired
- Tracks in North America, Australia, India are planned
- New status report(s) will follow on FIG Congress in Sydney, Australia, next year in April

Thank you very much for your attention !

CONTACTS

Dr.-Ing. habil. Volker Schwieger / Dipl.-Ing. Jürgen Schweitzer

Institute for Applications of Geodesy to Engineering, University Stuttgart
Geschwister-Scholl-Str. 24 D
70174 Stuttgart
Germany

Phone: ++49-711-685-84064 / -84065
Fax: ++49-711-685-84044
E-mail: volker.schwieger@iagb.uni-stuttgart.de
juergen.schweitzer@iagb.uni-stuttgart.de

Dipl.-Ing. Detlev Kosmann

German Remote Sensing Data Centre,
German Aerospace Centre
Münchnerstr. 20
82234 Wessling
Germany

Phone: ++49-8153-28-1376
Fax: ++49-8153-28-1445
E-mail: detlev.kosmann@dlr.de