Monitoring of SA*POS*®sites using tiltmeters

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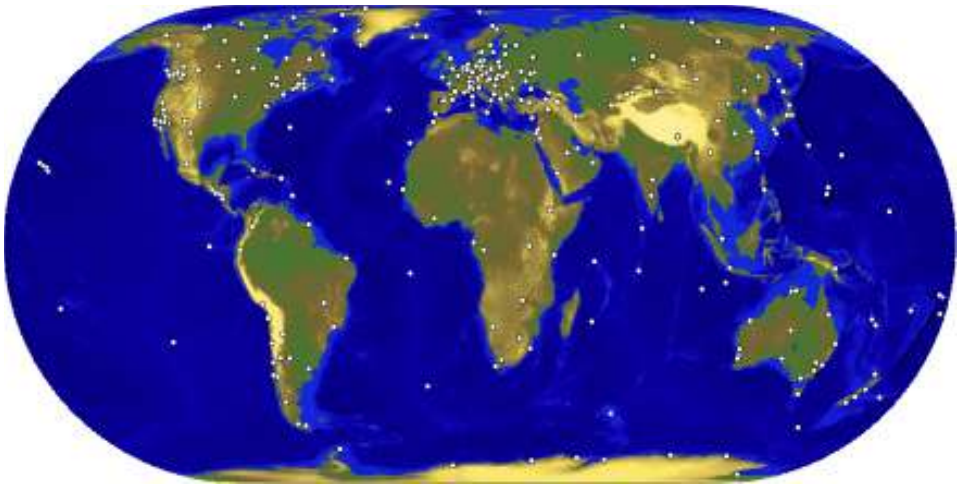
Geodetic Institute
Karlsruhe Institute of Technology

15.08.2008

- GNSS networks
  - IGS
  - EPN
  - SA*POS*®
- GNSS: 3D = 2D + 1D
- Markers: mainly on buildings



[3]

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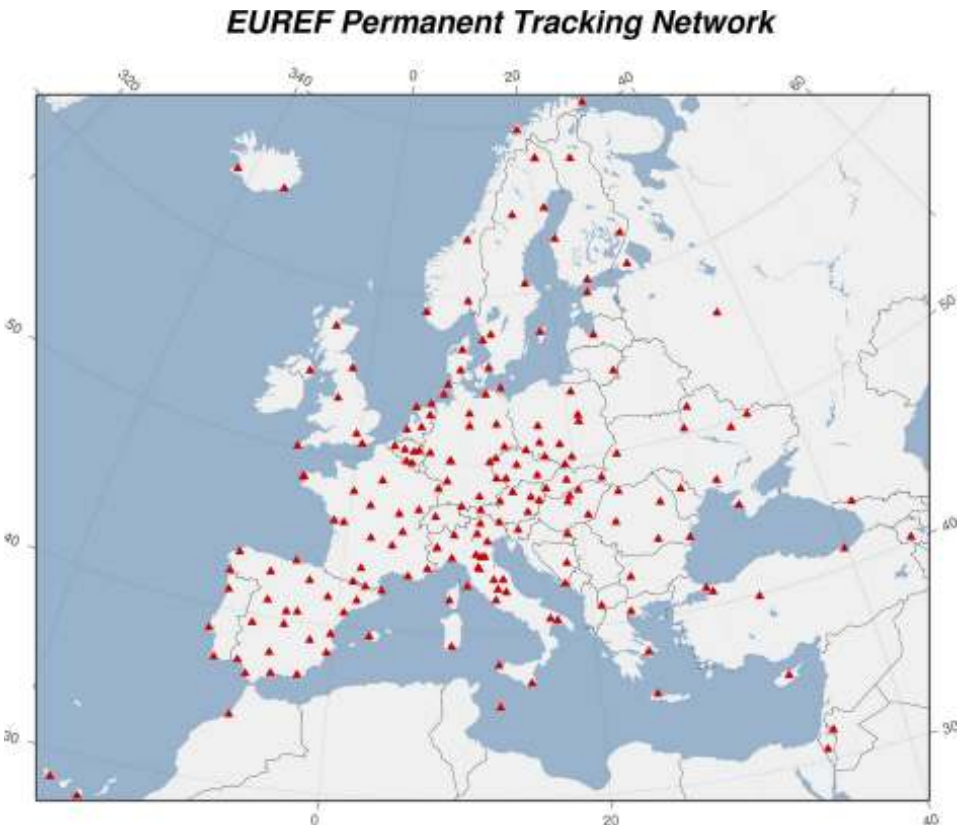

[1]

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[9]

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[9]

Facts

SA*POS*®(Satellite Positioning Service of the German State Survey):

- Provides data to improve the accuracy of positioning (real time and postprocessing)
- Is only based on GNSS
- Primary use: cadastre

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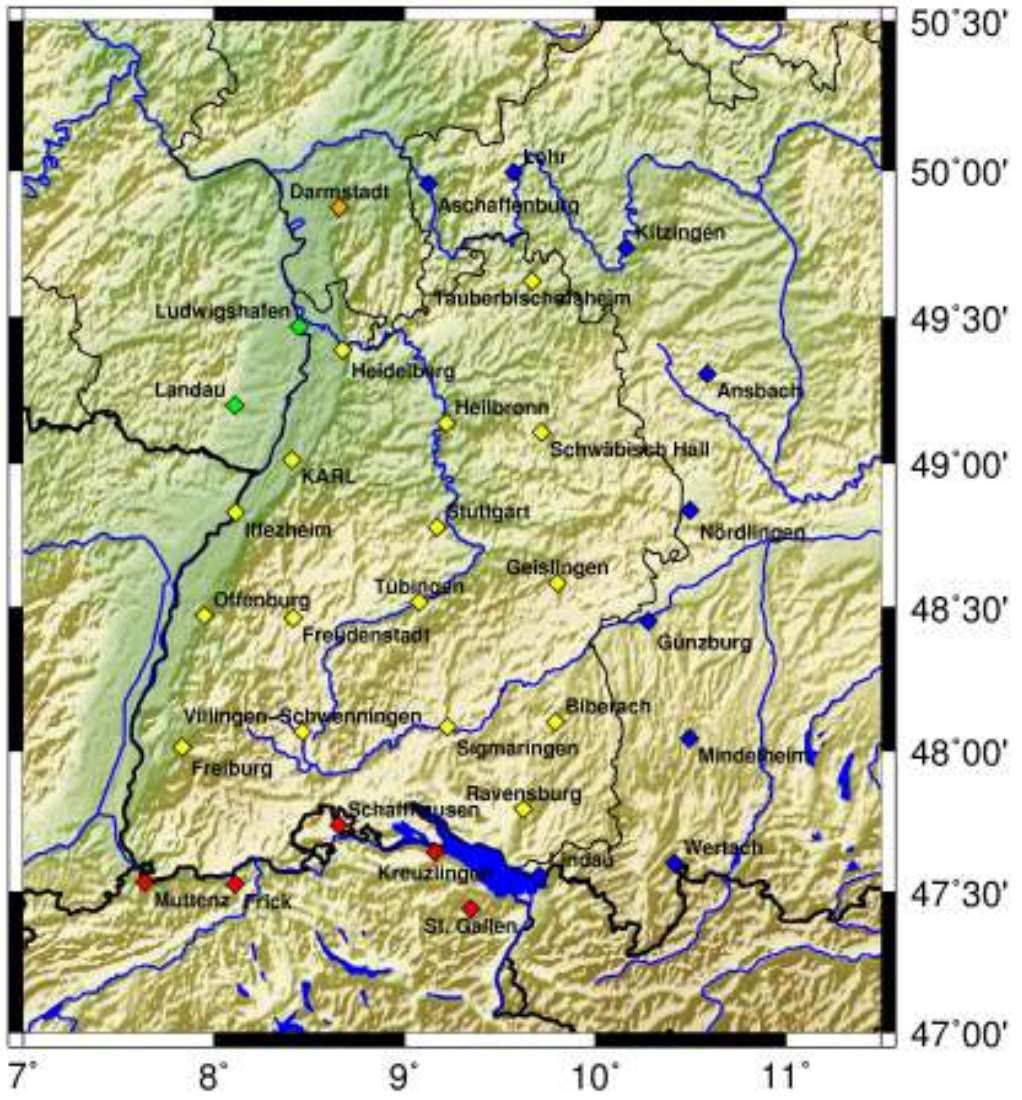
SAPOS® in the state of Baden-Württemberg

SAPOS®in Baden-Württemberg

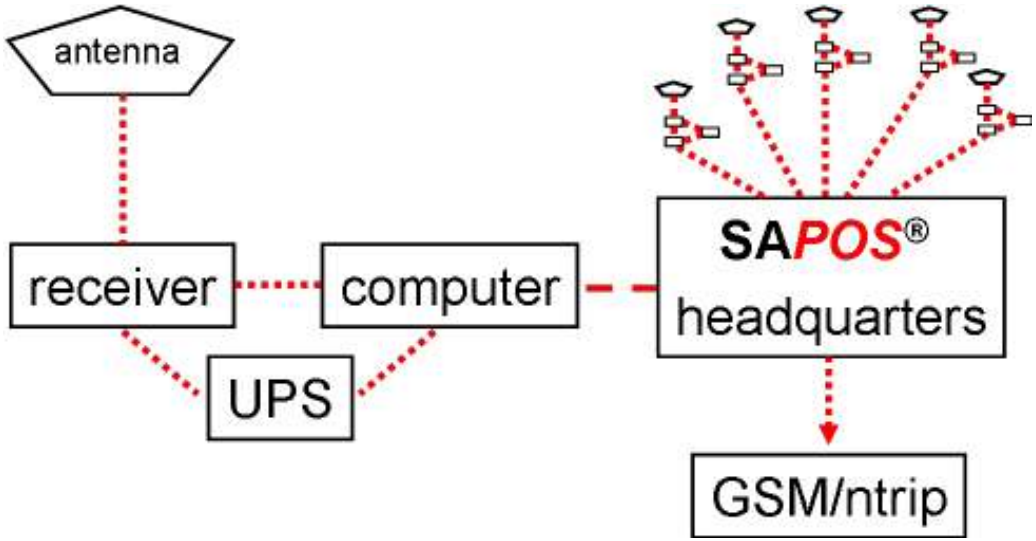
- 16 own sites
- 17 sites of surrounding states
- Headquarters in Karlsruhe
- In full use since February 2003



Scheme

Scheme of SA*POS*®

- Antenna
- Receiver
- Headquarters
- Network



Examples of different SA*POS*® sites in Baden-Württemberg

Karlsruhe

[7]

Examples of different SAPOS® sites in Baden-Württemberg

Stuttgart

[7]

[4]

Examples of different SAPOS® sites in Baden-Württemberg

Freiburg

[4]

[4]

Examples of different SA*POS*® sites in Baden-Württemberg

Freudenstadt

[4]

[4]

Intermediate summary:

- GNSS techniques are used for displacement determination
- SA*POS*® is to be used for detection of geodynamic processes
- Replacement of levelling by means of GNSS techniques
  - Levelling markers near the surface of the earth
  - GNSS-sites mostly on buildings
- Aim: Evaluation of the quality of GNSS sites on buildings

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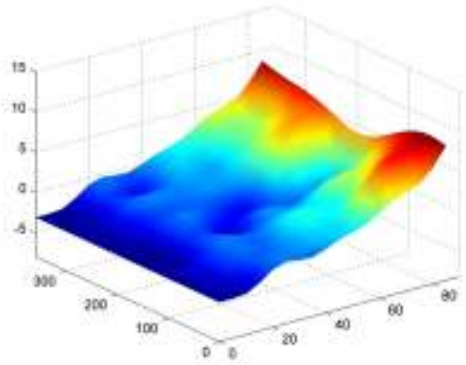
... on GNSS

- Equipment
- Atmosphere
- Antenna environment
  ⇒Multipath
- ...



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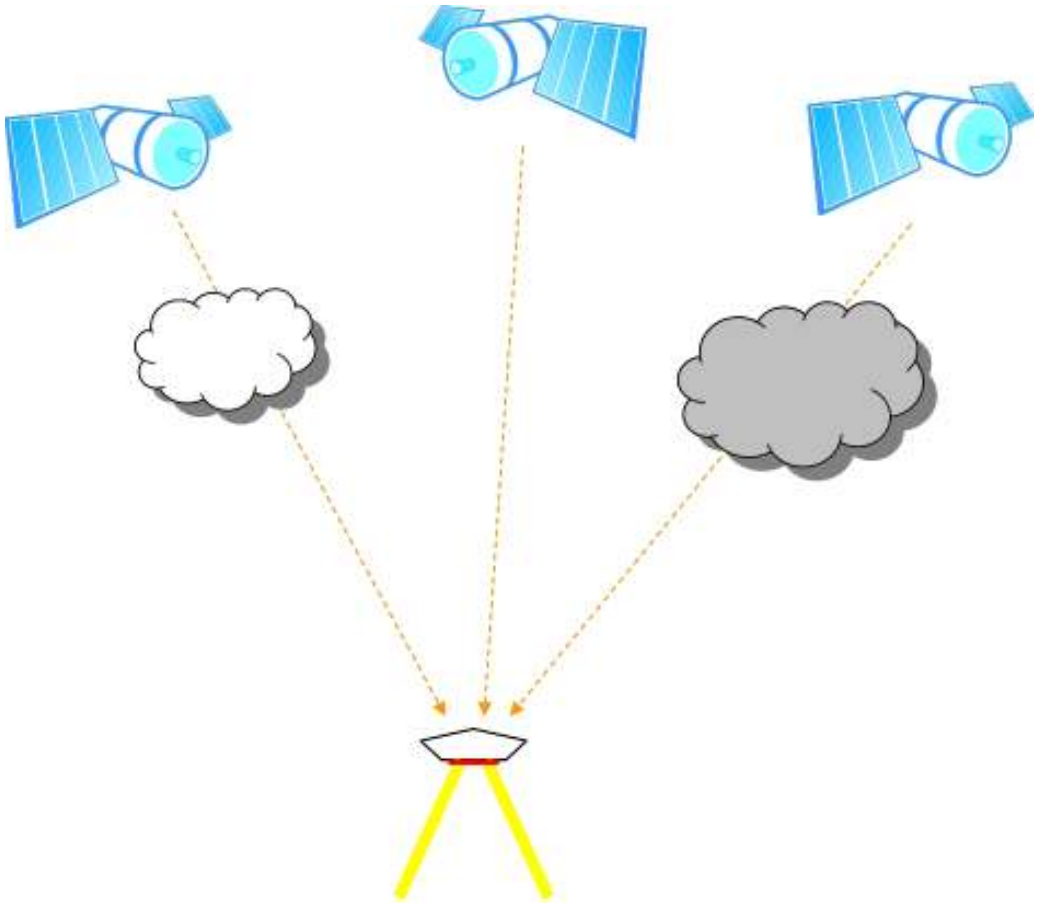

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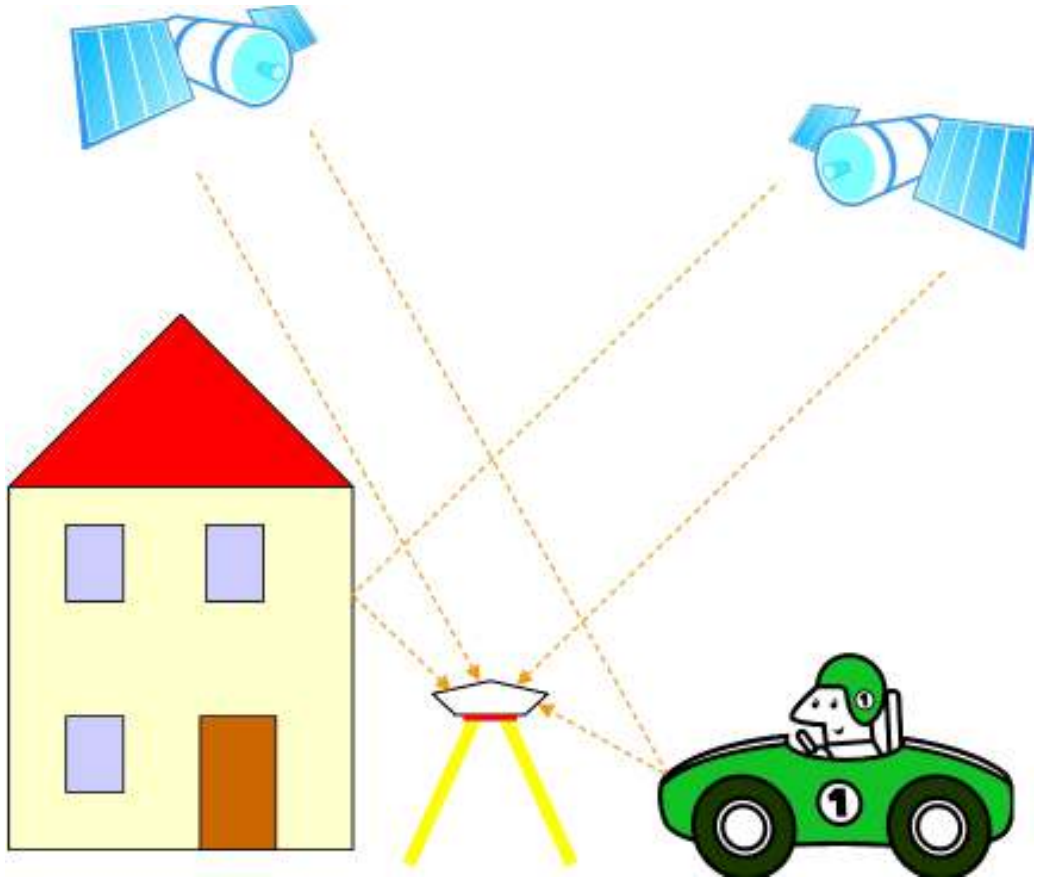
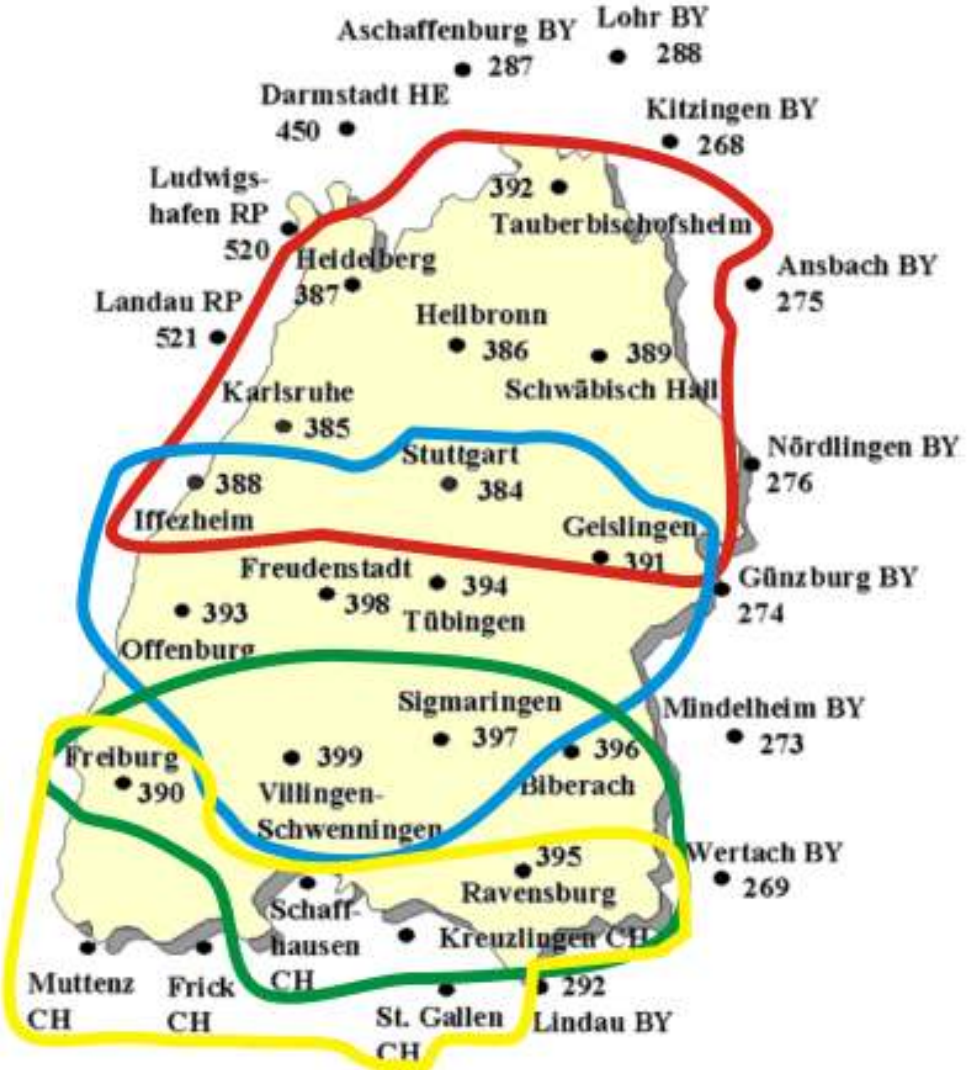
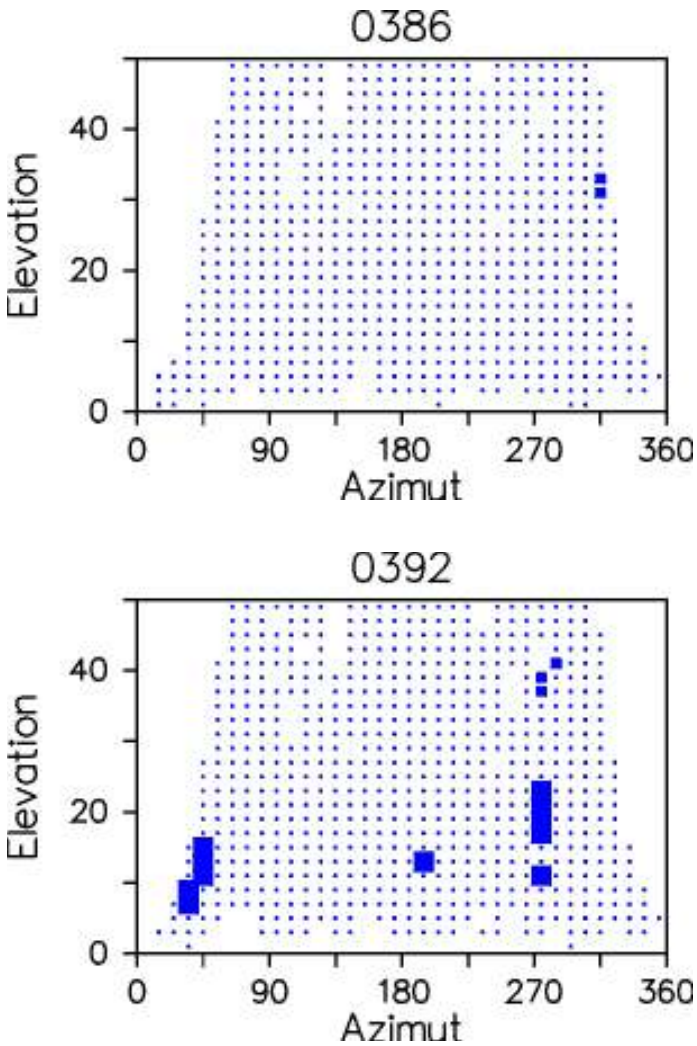


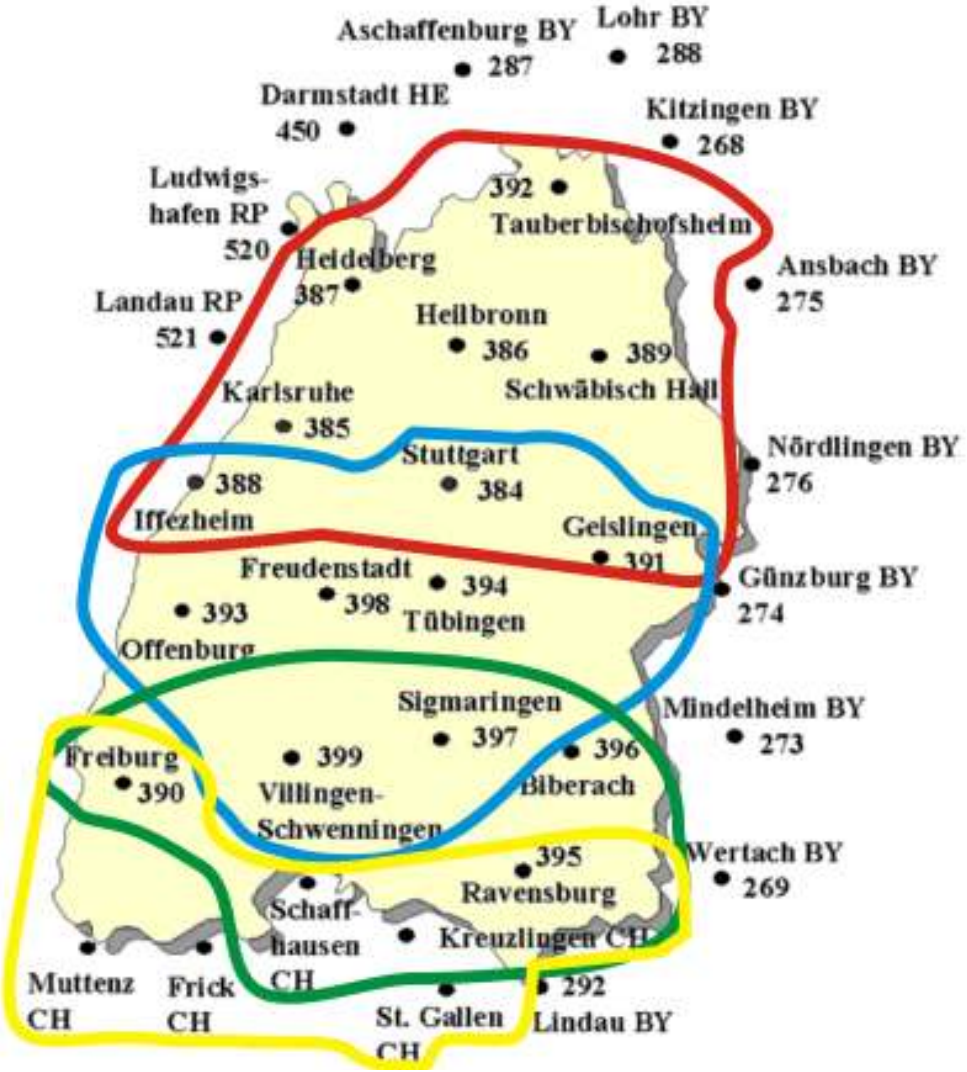
Multipath analysis of SA*POS*®sites in Baden-Württemberg

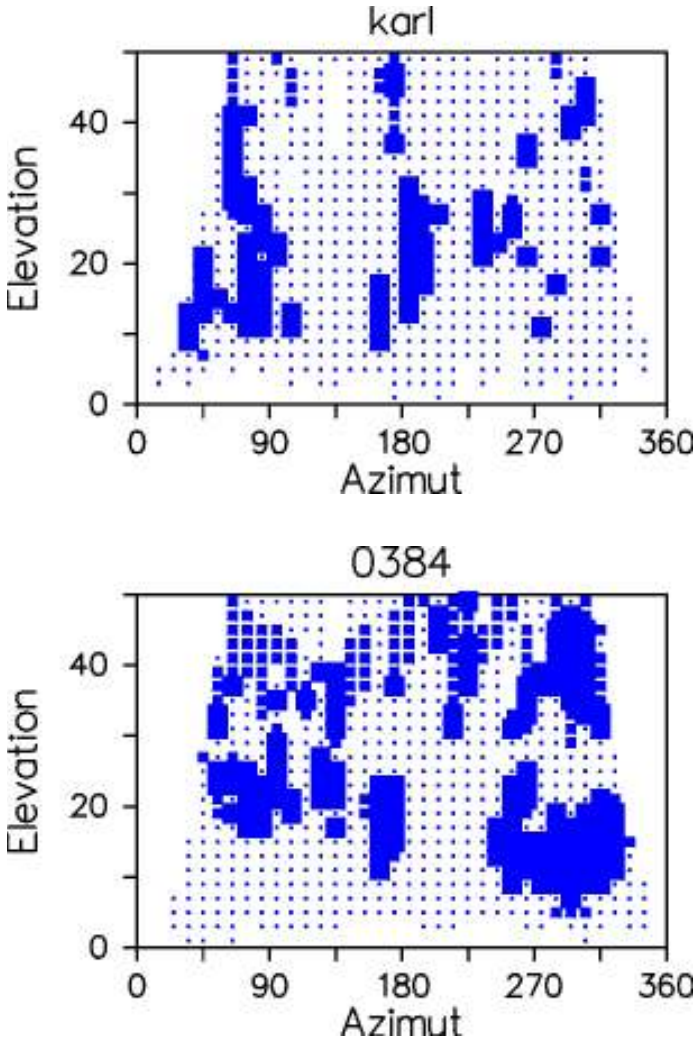




[8]

Multipath analysis of SA*POS*®sites in Baden-Württemberg





[8]

... on GNSS and buildings

Meteorology:

- Temperature
- Air pressure
- Precipitation
- Wind
- Humidity

Hydrology:

- Precipitation
- Ground water

... on GNSS and buildings

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Idea

- Concept
  - Tilt
  - Changes of position/height
- Sensors
  - Tiltmeter Kern Nivel20
  - Tiltmeter Leica Nivel210
- Additional data:
  - Meteorology
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Idea

Specifications of the tiltmeters:

		Kern Nivel20	Leica Nivel210
Range	A	-1.50 .. 1.50 mrad	-1.51 .. 1.51 mrad
	B	-	-2.51 .. 2.51 mrad
	C	-	-3.00 .. 3.00 mrad
Accuracy	A	$\pm$0.002 mrad	$\pm$0.0047 mrad
	B	-	$\pm$0.0141 mrad
	C	-	$\pm$0.0471 mrad
Resolution		0.001 mrad	0.001 mrad
Dimension		90 x 90 x 63 mm^3	95 x 91 x 68 mm^3

Software development

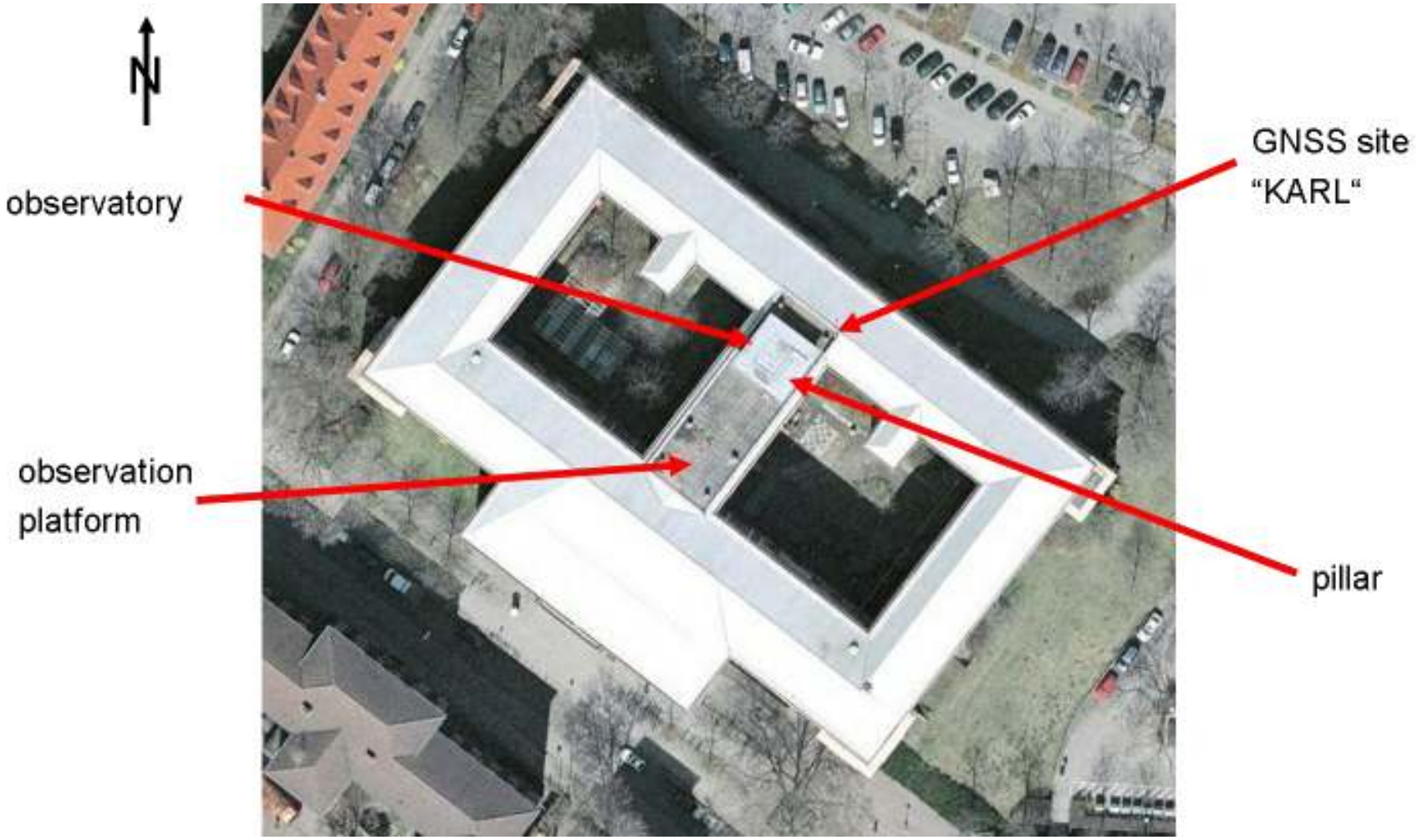
Communication with Nivel20/Nivel210, including automated data storage on laptop

Measurements:

- GIK (Geodetic Institute Karlsruhe)
- BFO (Black Forest Observatory)
- Lock of Iffezheim

GIK: first tests

Top view on the Geodetic Institute

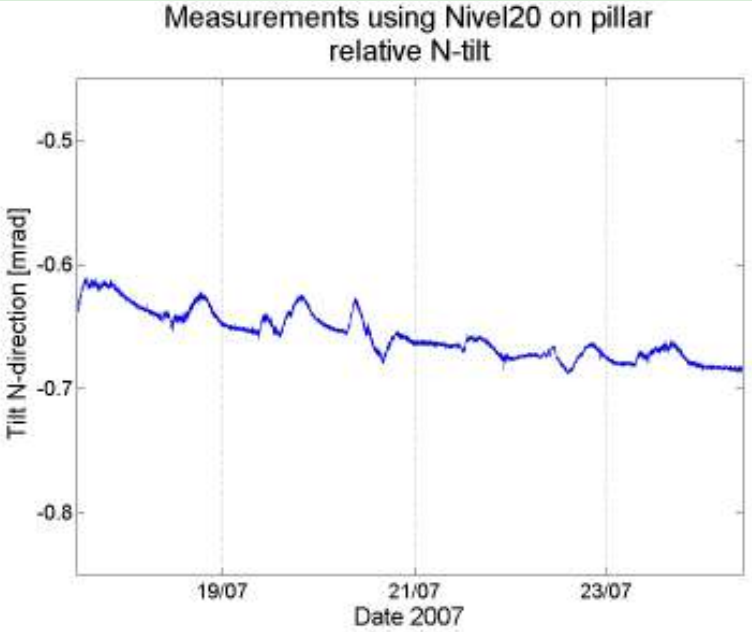


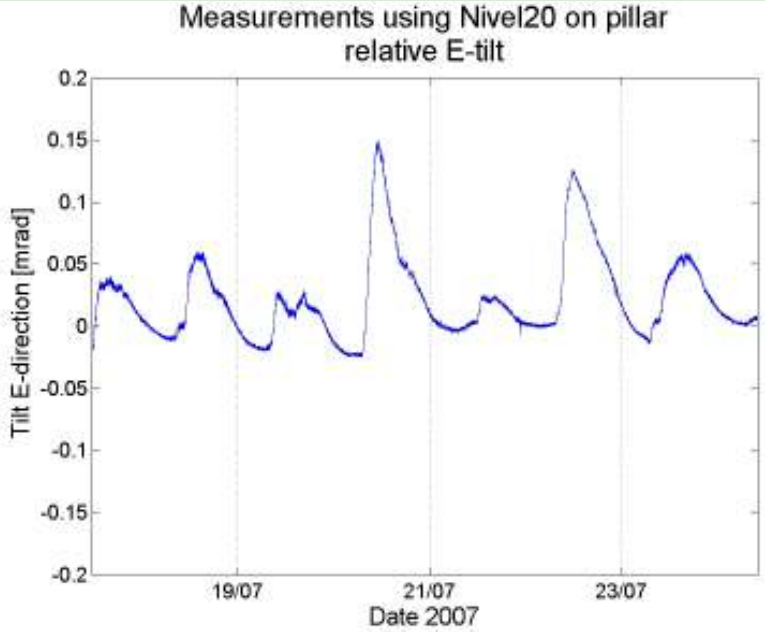
Height of the building: 16 m [6]

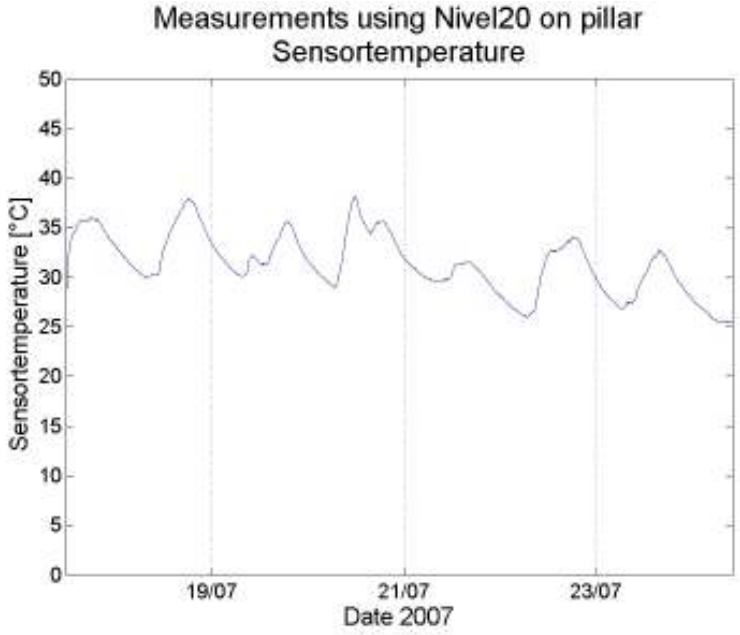
GIK: on a pillar

Setup on pillar

GIK: on a pillar





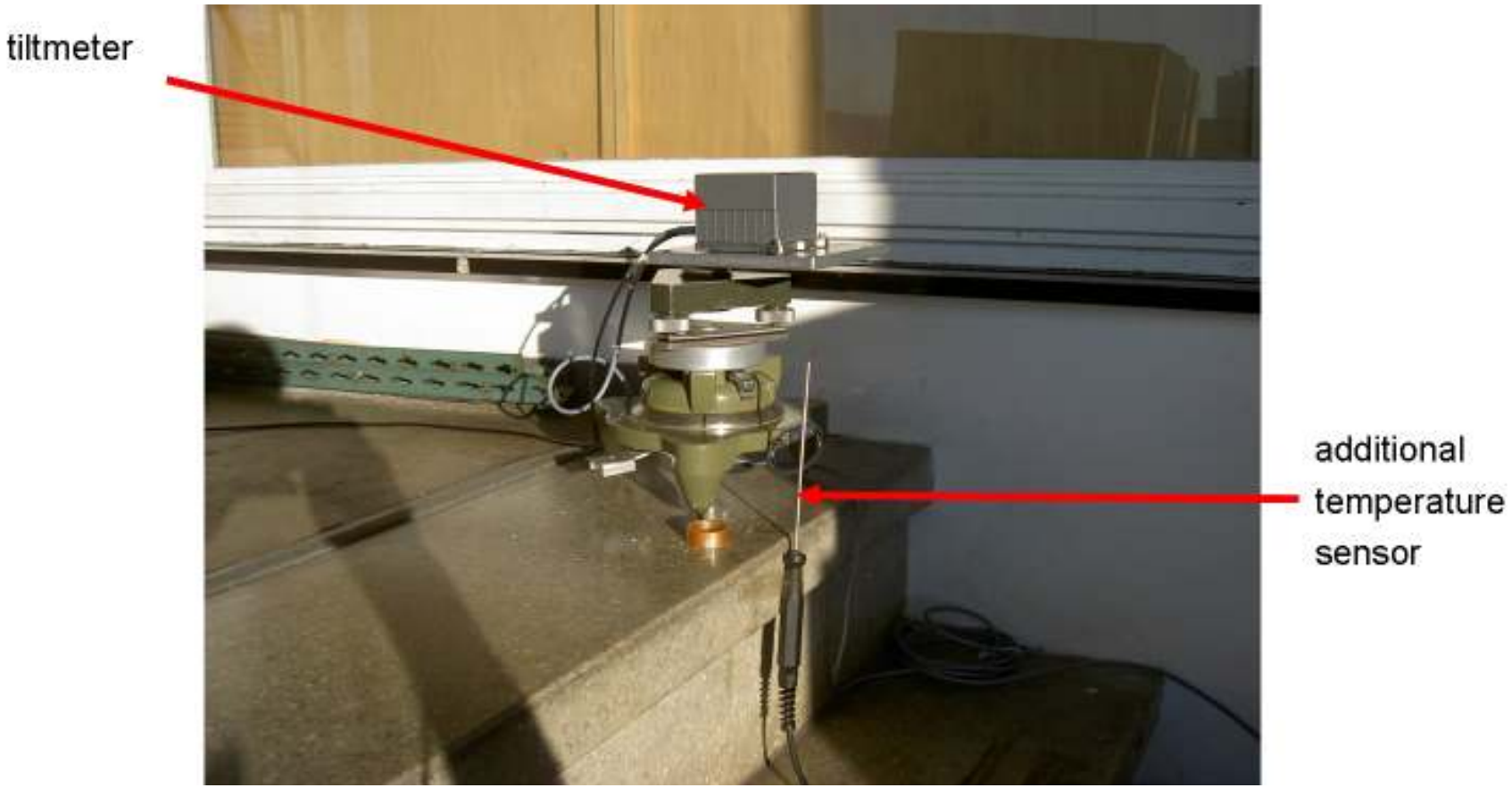


GIK: on a pillar

- Variation during the day
- Correlation: temperature $\Leftrightarrow$ tilt
- Max-Min $\approx$ 0.16 mrad $\widehat{=}$ 2.5 mm (E-W)
- $\Rightarrow$Pillar stable???

GIK: on a step

Setup on step



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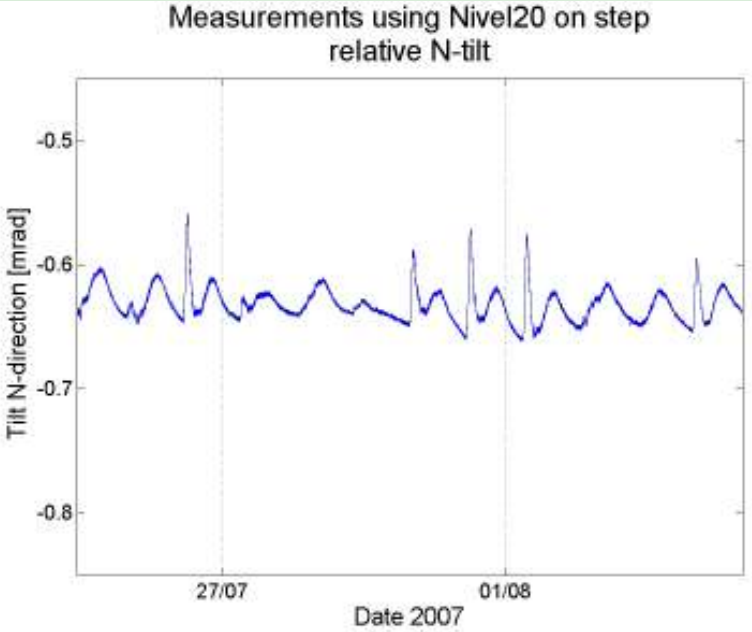
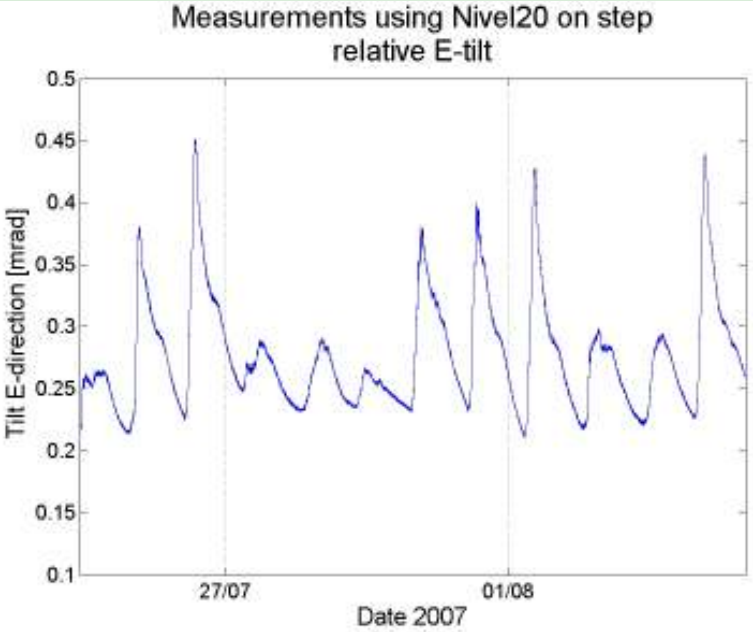
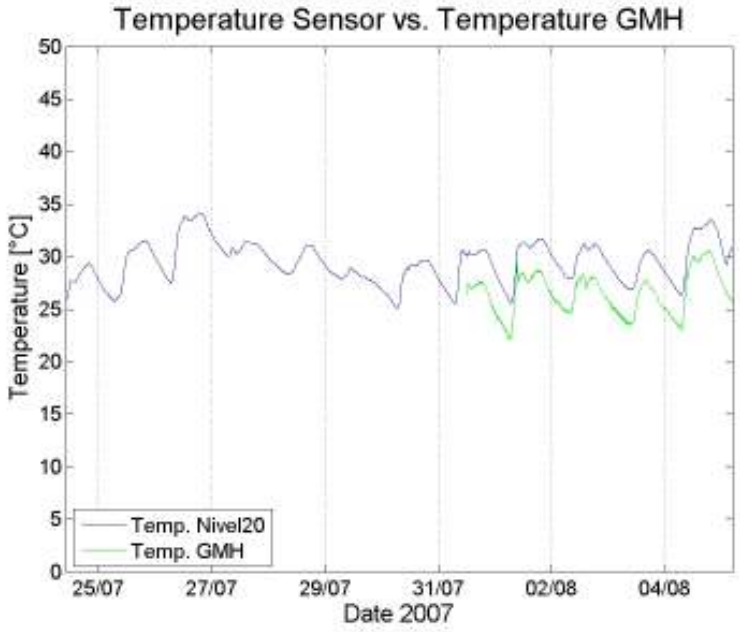

Measurements using Nivel20 on step
relative N-tilt
Tilt N-direction [mrad]
-0.5
-0.6
-0.7
-0.8
27/07
01/08
Date 2007


Measurements using Nivel20 on step
relative E-tilt
Tilt E-direction [mrad]
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
27/07
01/08
Date 2007


Temperature Sensor vs. Temperature GMH
Temperature [°C]
50
45
40
35
30
25
20
15
10
5
0
Temp. Nivel20
Temp. GMH
25/07
27/07
29/07
31/07
02/08
04/08
Date 2007

GIK: on a step

- Variation during the day are obvious
- Correlation: temperature $\Leftrightarrow$ tilt
- Max-Min $\approx$ 0.23 mrad $\widehat{=}$ 3.7 mm (E-W)
- $\Rightarrow$Movement of the building???

GIK: at the bracket of KARL - tripod

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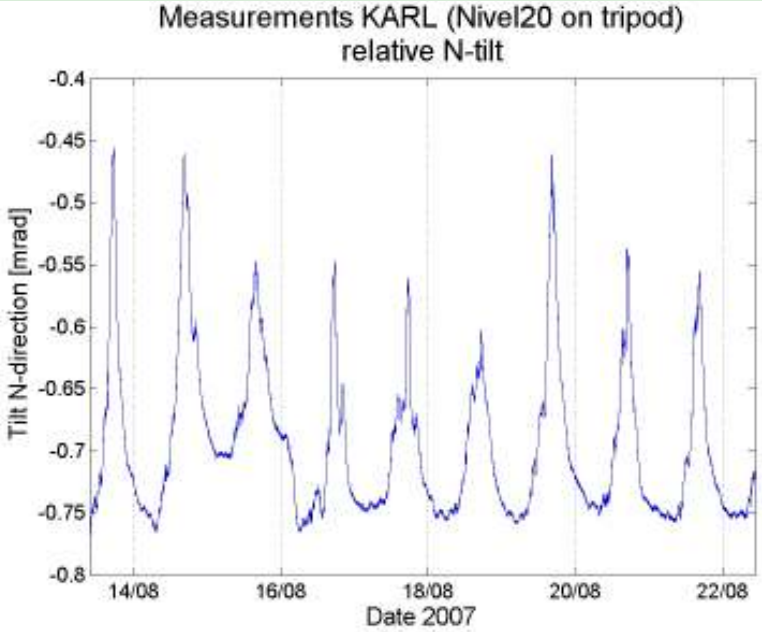

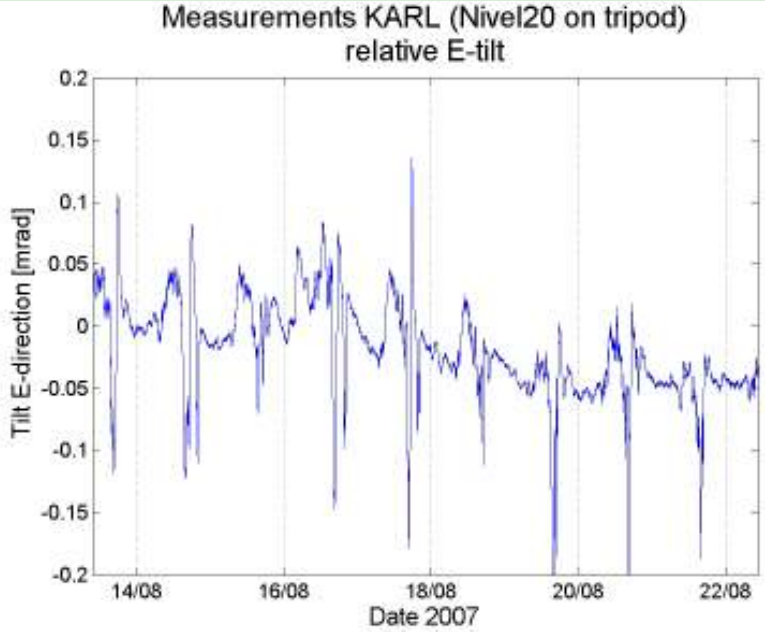

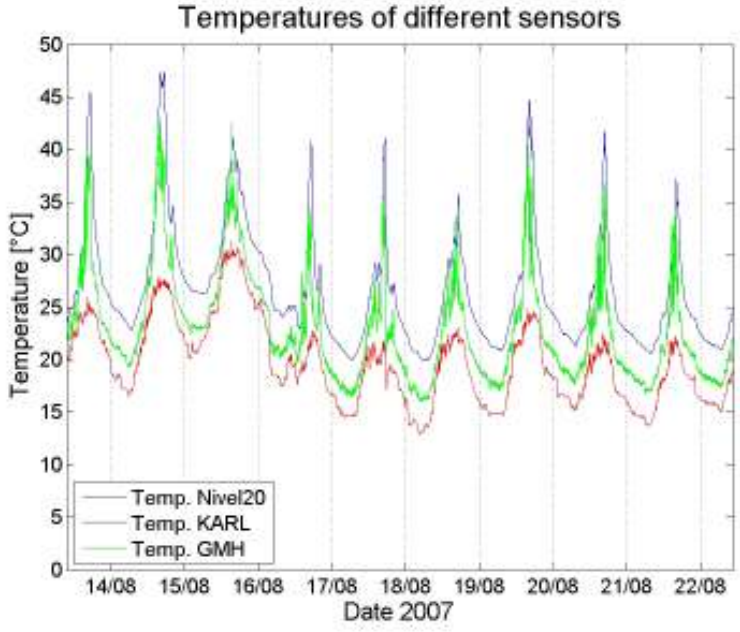

GIK: at the bracket of KARL - tripod

- Variation during the day are obvious
- Correlation: temperature $\Leftrightarrow$ tilt
- Main amplitude in N-S direction
- Max-Min $\approx$ 0.3 mrad $\widehat{=}$ 4.8 mm (N-S)
- What about the peaks in the afternoon???

GIK: at the bracket of KARL - CRC-adapter

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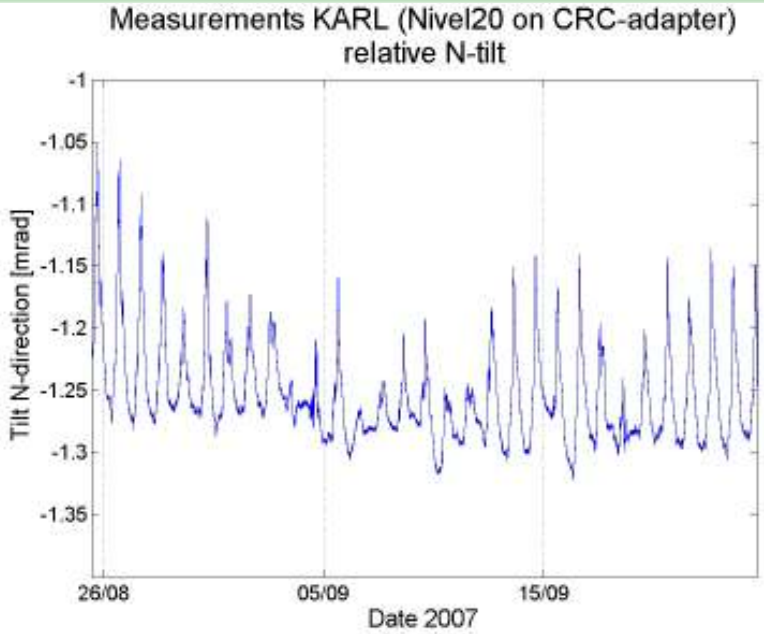
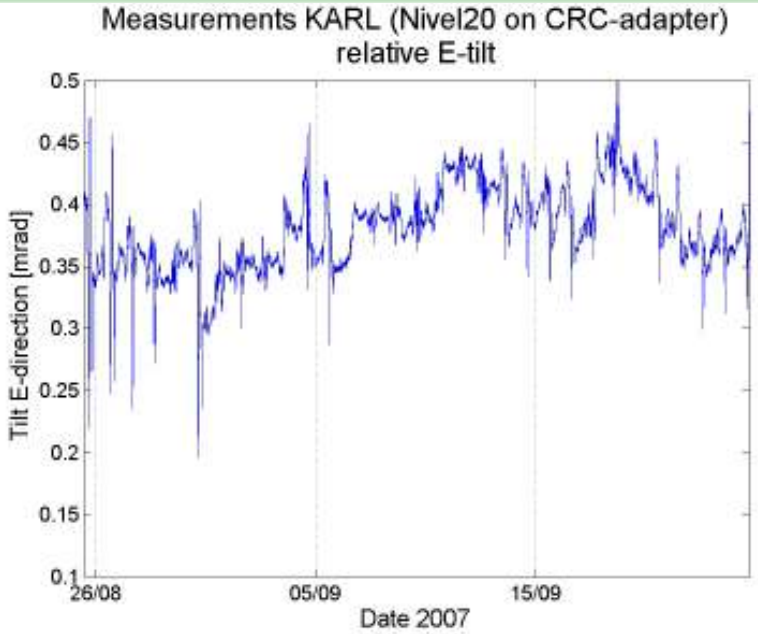
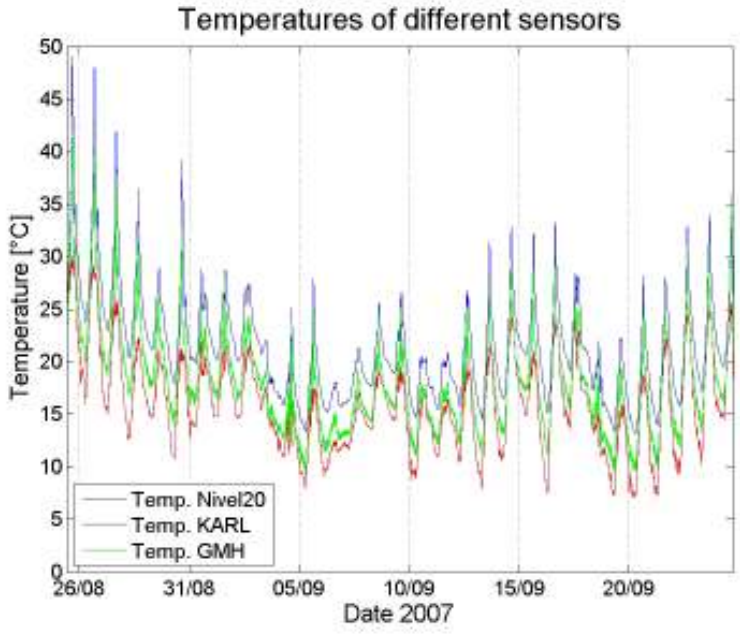


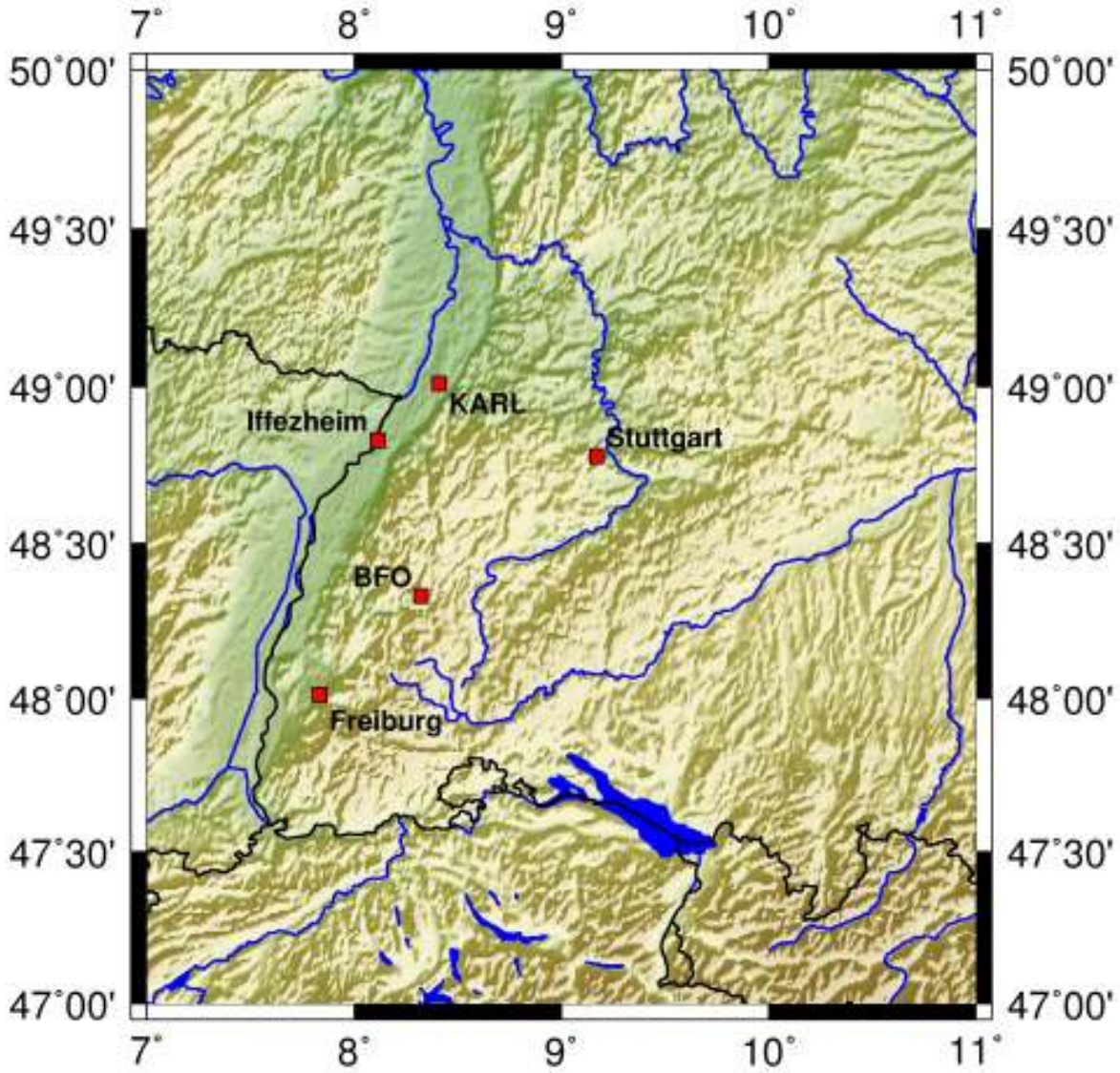




GIK: at the bracket of KARL - CRC-adapter

- Variations during the day are obvious
- Correlation: temperature $\Leftrightarrow$ tilt
- Main amplitude in N-S direction
- Max-Min $\approx$ 0.22 mrad $\widehat{=}$ 3.5 mm (N-S)
- Peaks in the afternoon remain despite changed setup

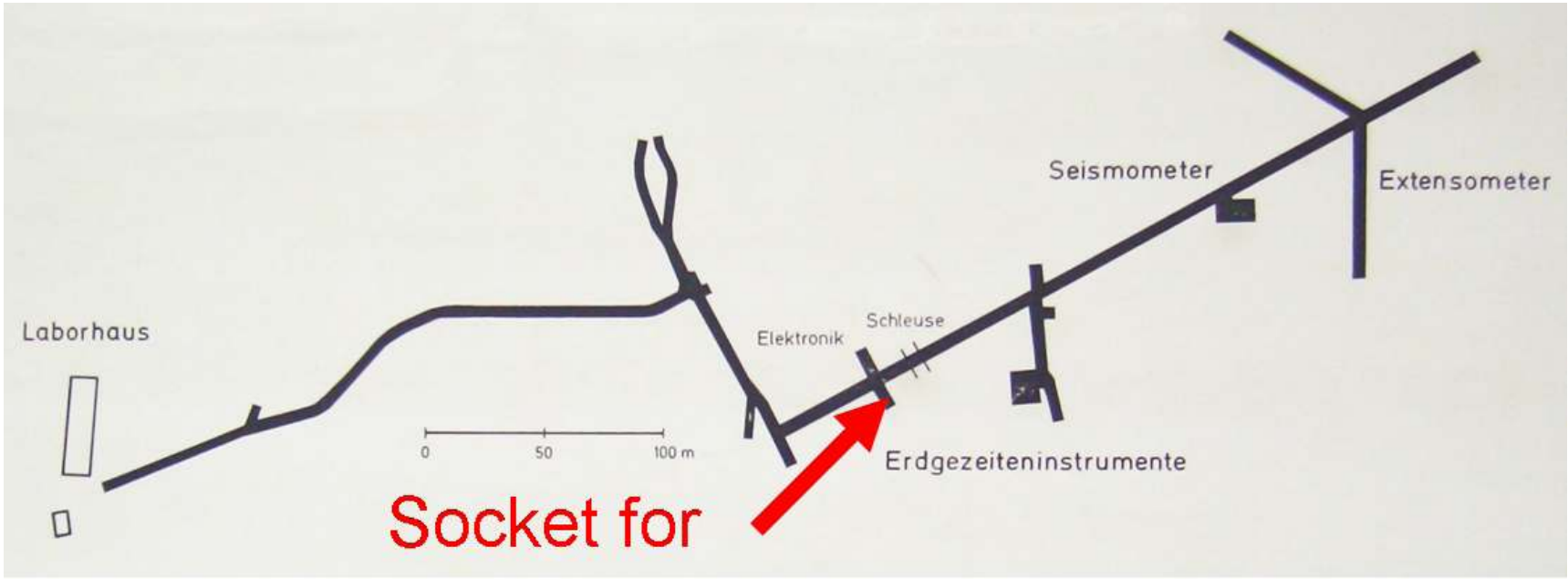
Location of the BFO



Location of the BFO

Location of the BFO

Tunnel of the BFO



BFO: setup

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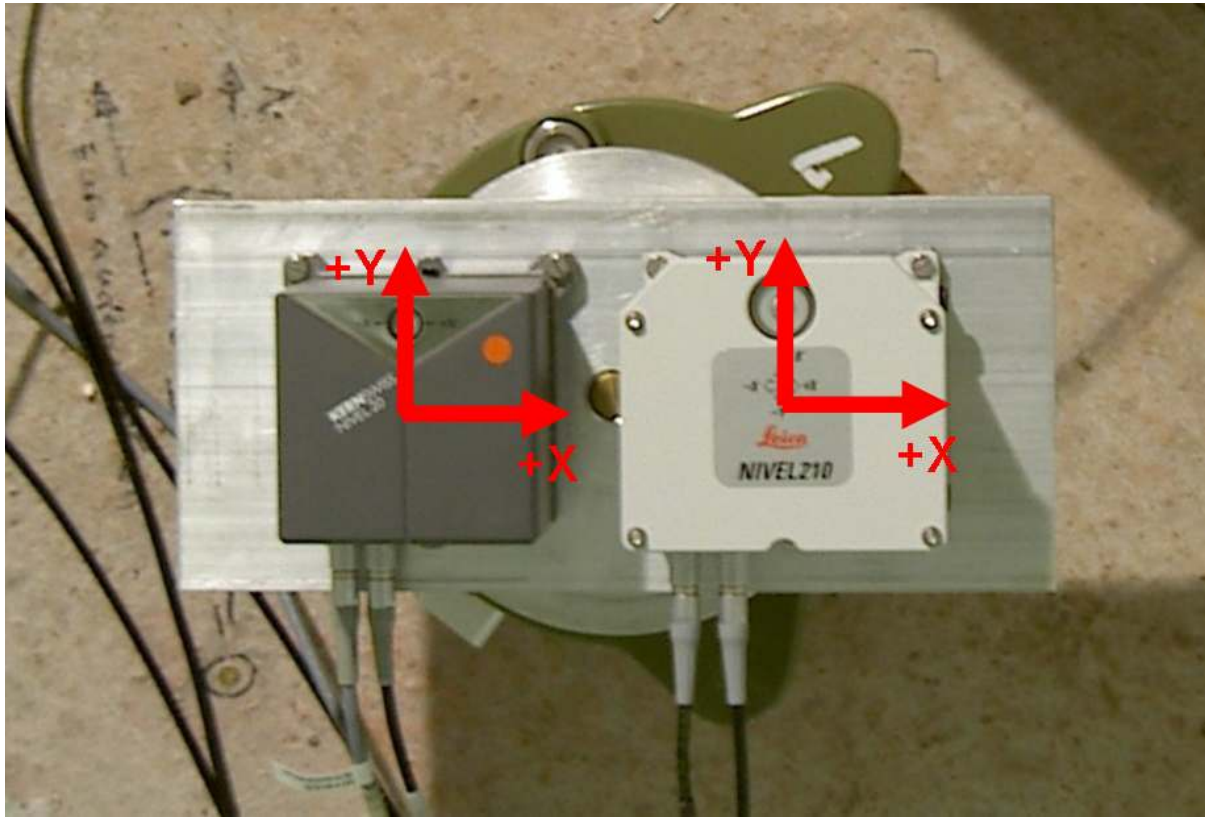
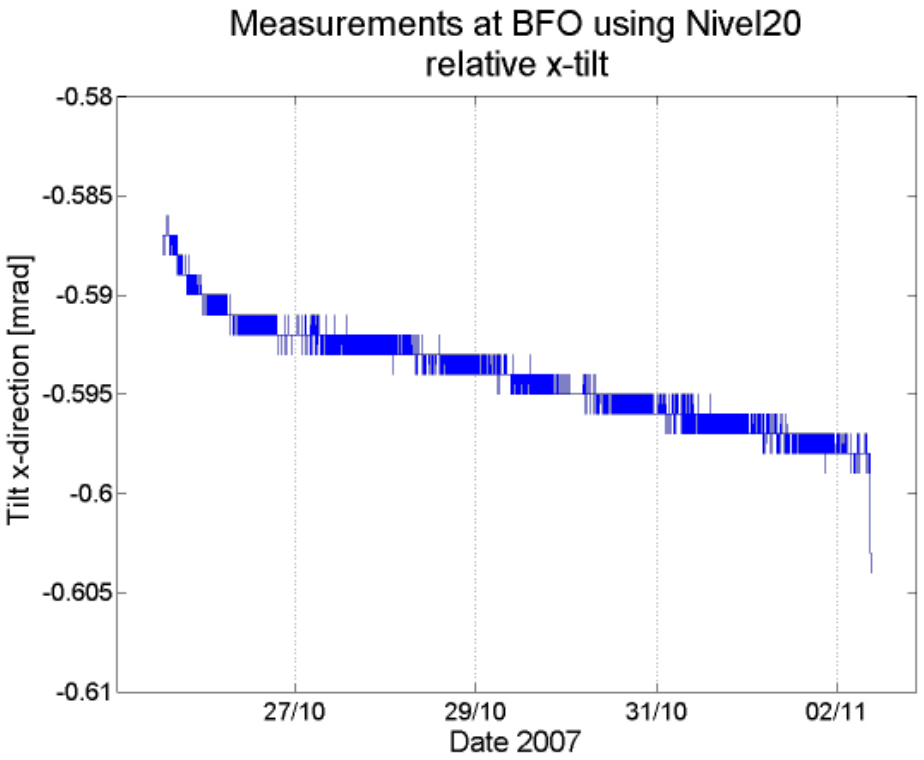
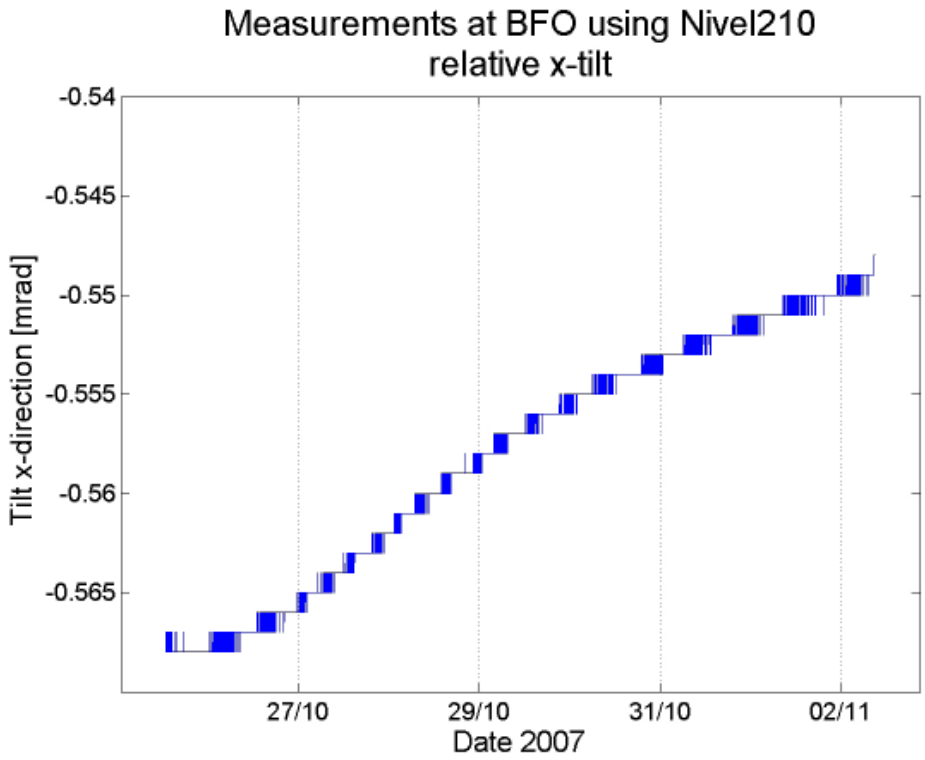
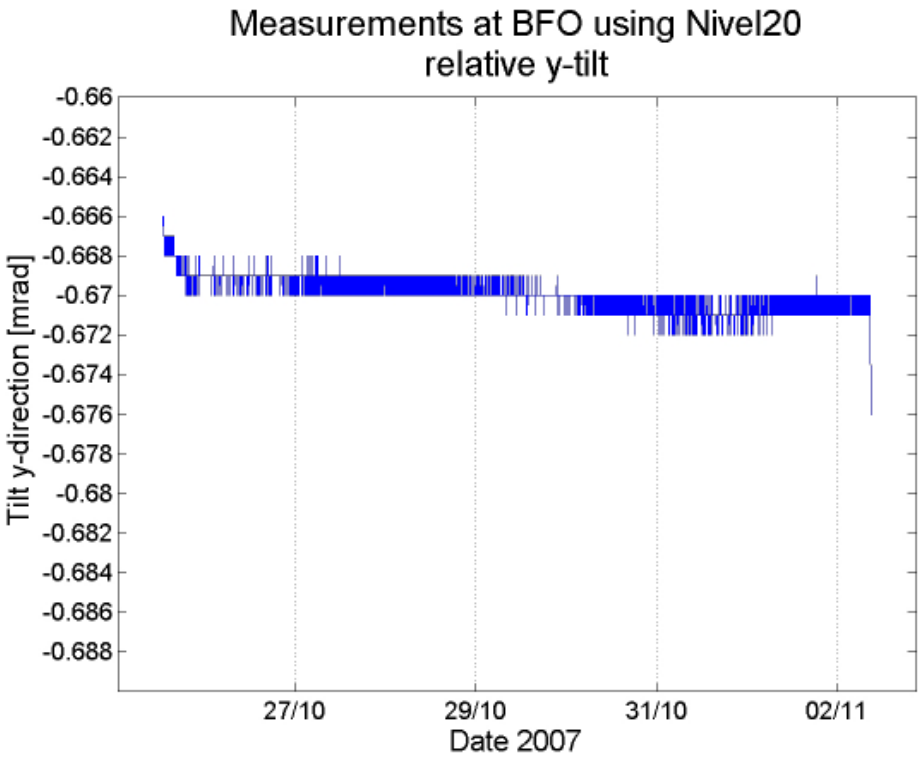


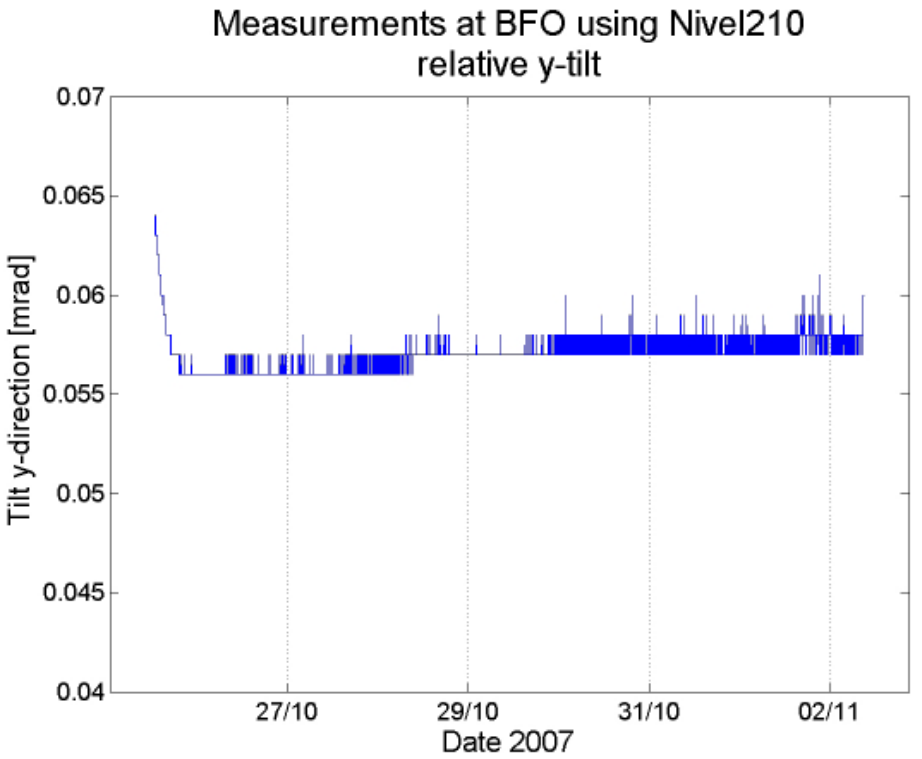
BFO: results


Measurements at BFO using Nivel20
relative x-tilt
Tilt x-direction [mrad]
-0.58
-0.585
-0.59
-0.595
-0.6
-0.605
-0.61
27/10
29/10
31/10
02/11
Date 2007

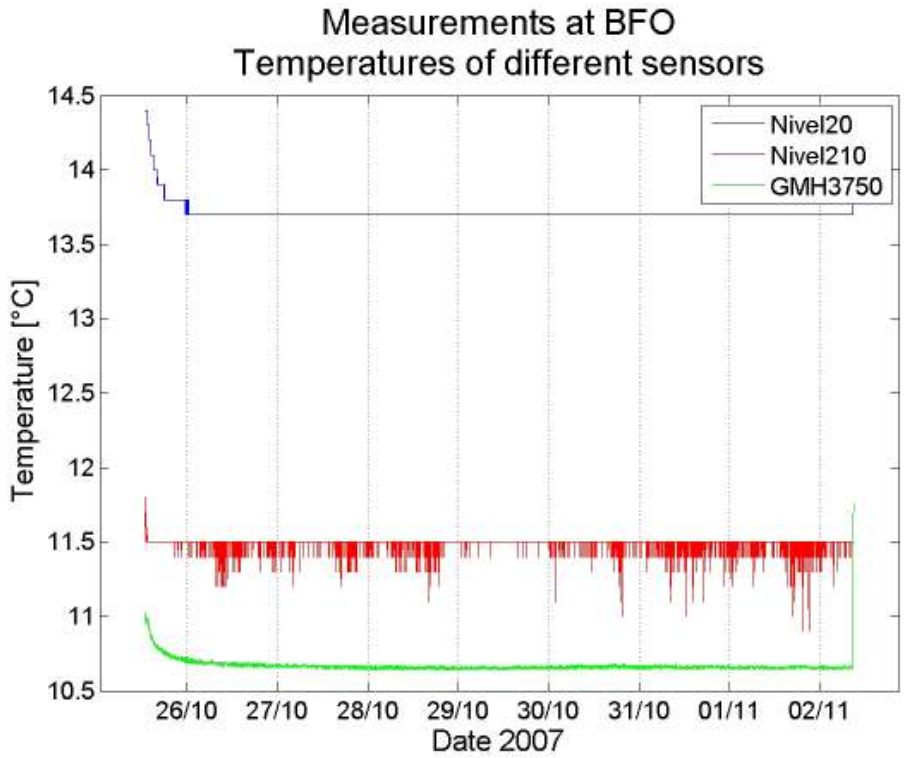

Measurements at BFO using Nivel210
relative x-tilt
Tilt x-direction [mrad]
-0.54
-0.545
-0.55
-0.555
-0.56
-0.565
27/10
29/10
31/10
02/11
Date 2007

BFO: results


Measurements at BFO using Nivel20
relative y-tilt
Tilt y-direction [mrad]
-0.66
-0.662
-0.664
-0.666
-0.668
-0.67
-0.672
-0.674
-0.676
-0.678
-0.68
-0.682
-0.684
-0.686
-0.688
27/10
29/10
31/10
02/11
Date 2007


Measurements at BFO using Nivel210
relative y-tilt
Tilt y-direction [mrad]
0.07
0.065
0.06
0.055
0.05
0.045
0.04
27/10
29/10
31/10
02/11
Date 2007

BFO: results


Measurements at BFO
Temperatures of different sensors
Nivel20
Nivel210
GMH3750
Temperature [°C]
14.5
14
13.5
13
12.5
12
11.5
11
10.5
26/10
27/10
28/10
29/10
30/10
31/10
01/11
02/11
Date 2007

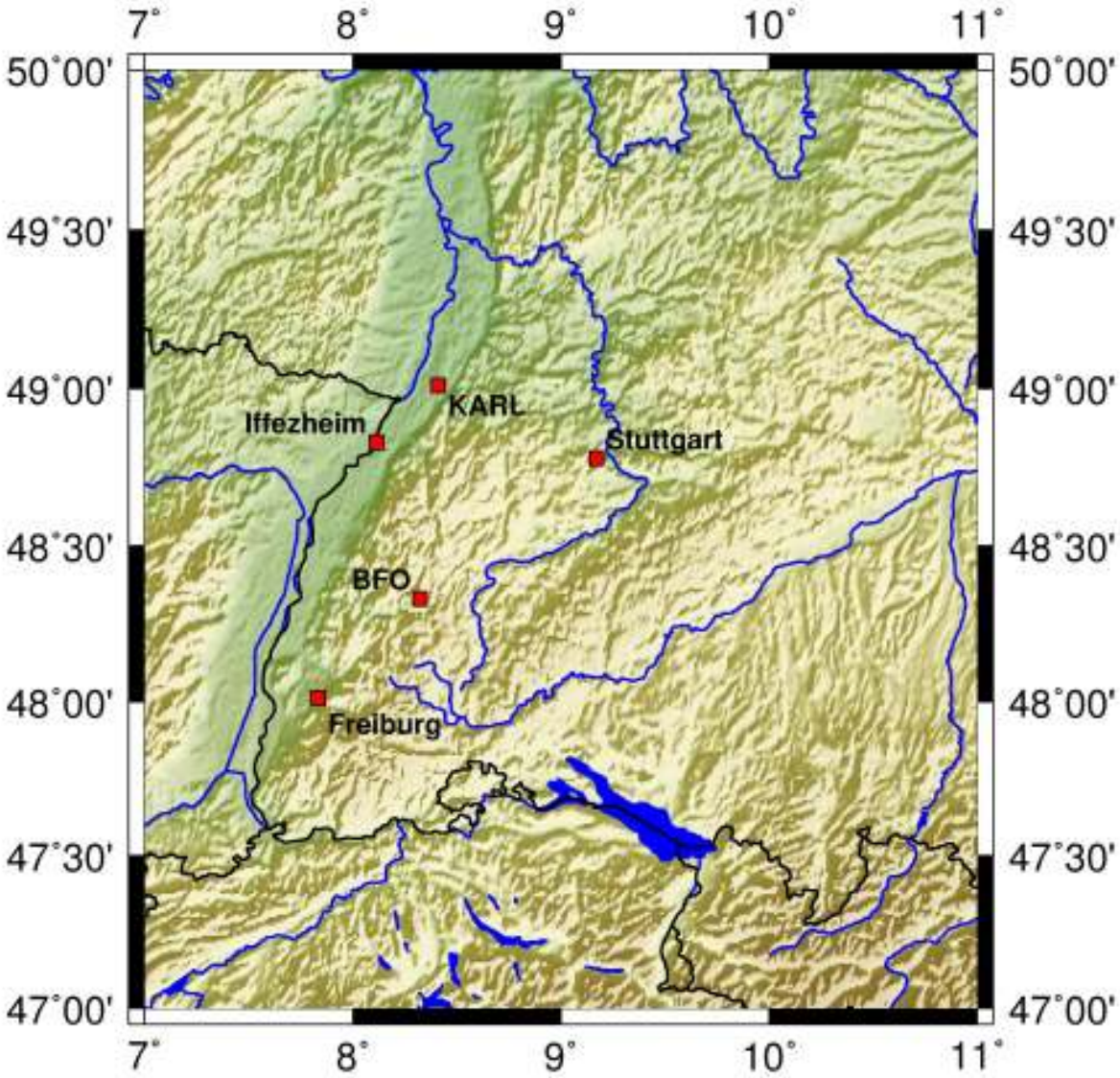
BFO: results

- Adaption period 1/2 day
- Opponent drift in x-direction
- y-direction very stable
- Temperature in tunnel very constant

Aim

Evaluation of the sensor noise in a very calm environment

Location of the lock in Iffezheim



Location of the lock in Iffezheim

[10]

Location of the lock in Iffezheim

[10]

[4]

Iffezheim: preliminary work

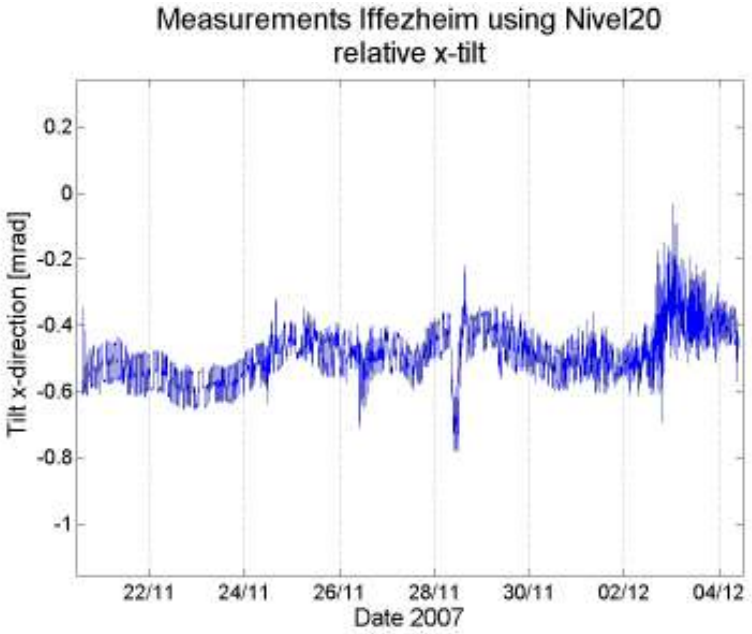
- Remote control desired
- No dedicated line available
- Vodafone UMTS card available
- Modification of the Nivel software
- Planned Tasks

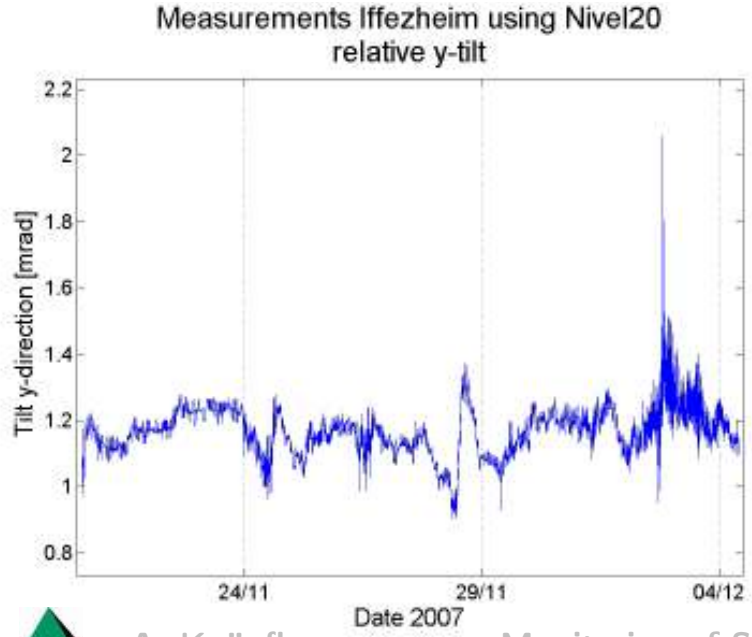
Iffezheim: setup

Iffezheim: setup

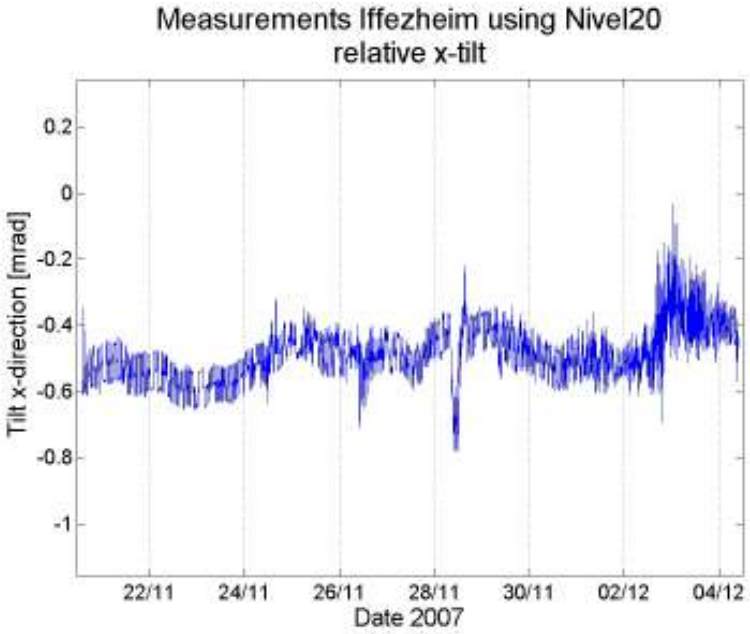
Iffezheim: setup

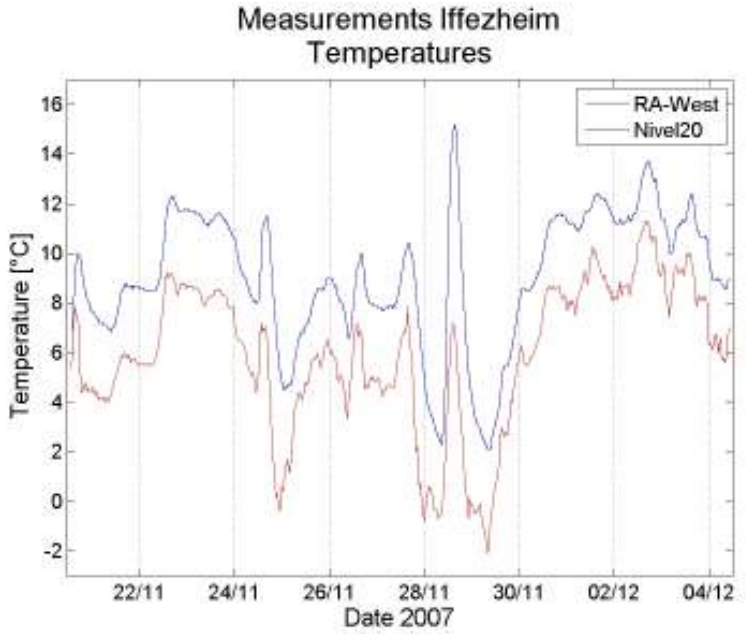
Iffezheim: results

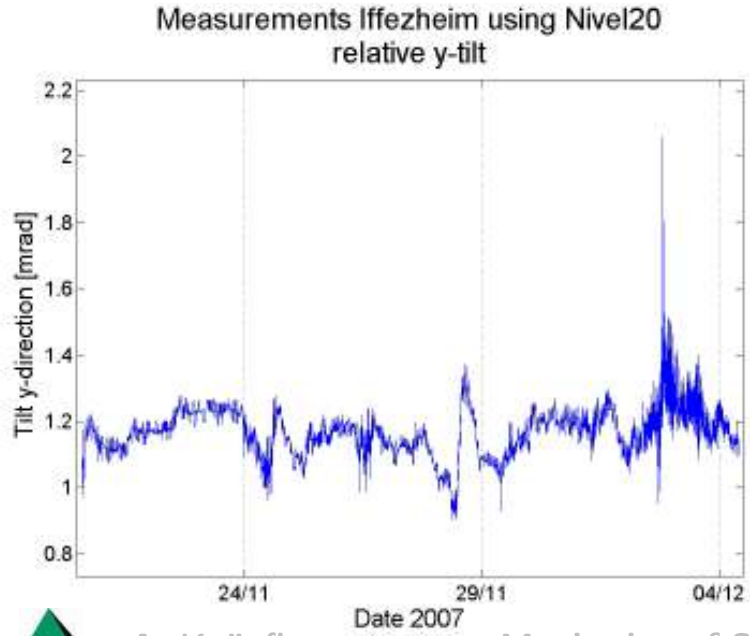


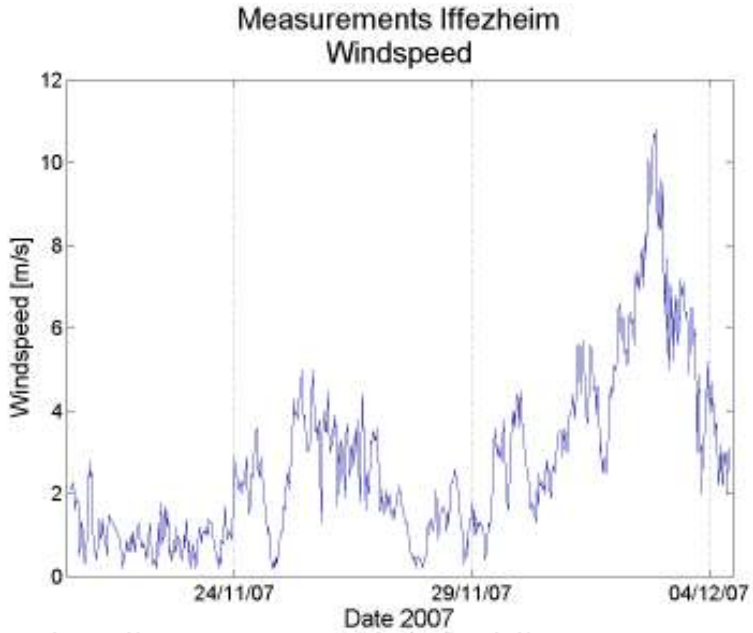


Iffezheim: results









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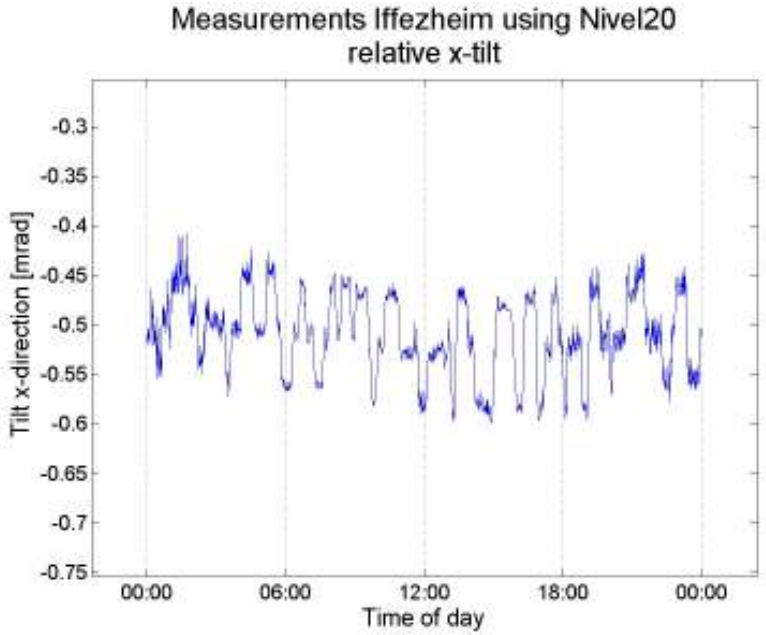

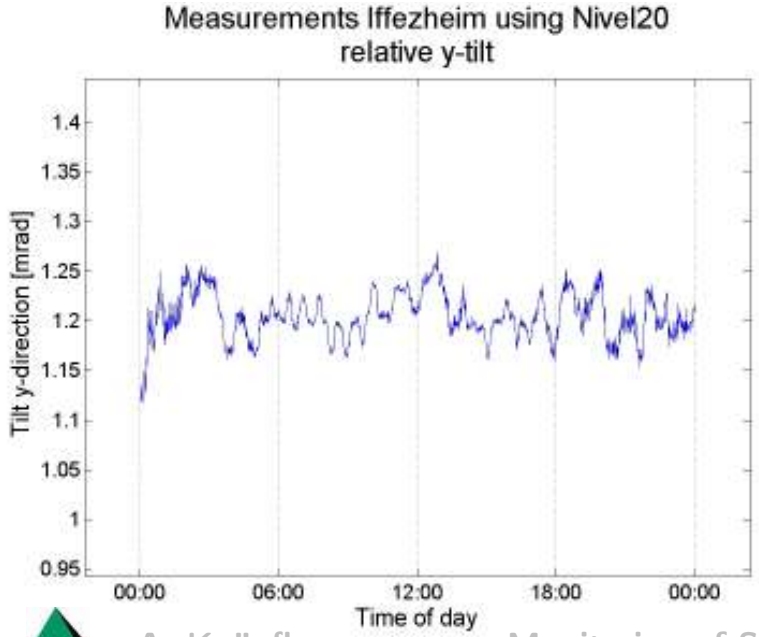

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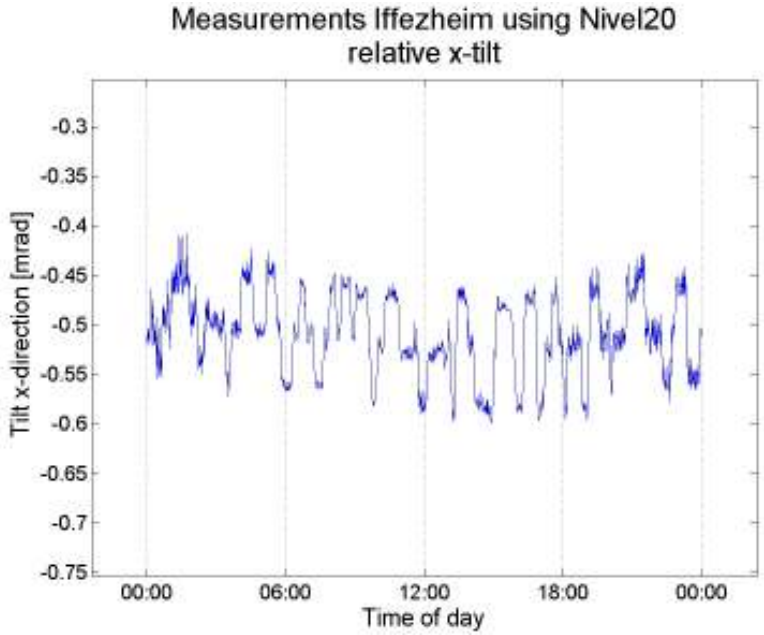
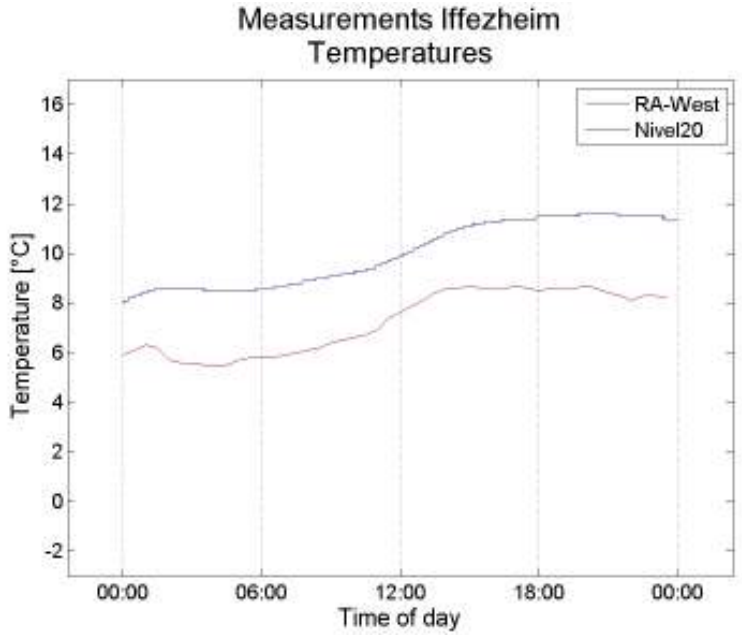
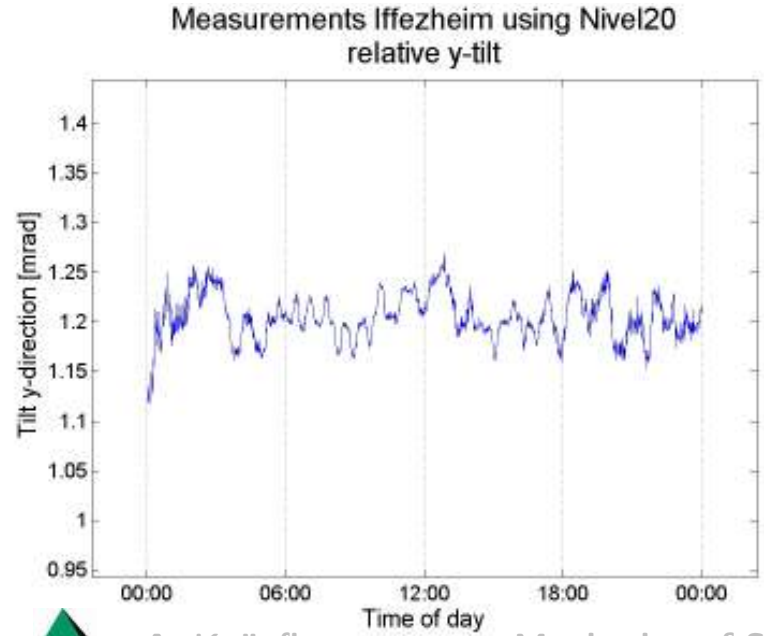
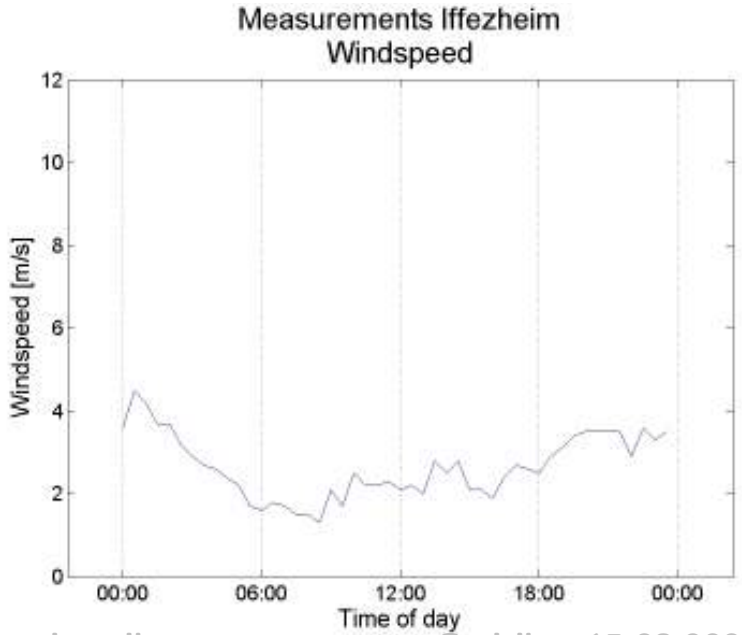
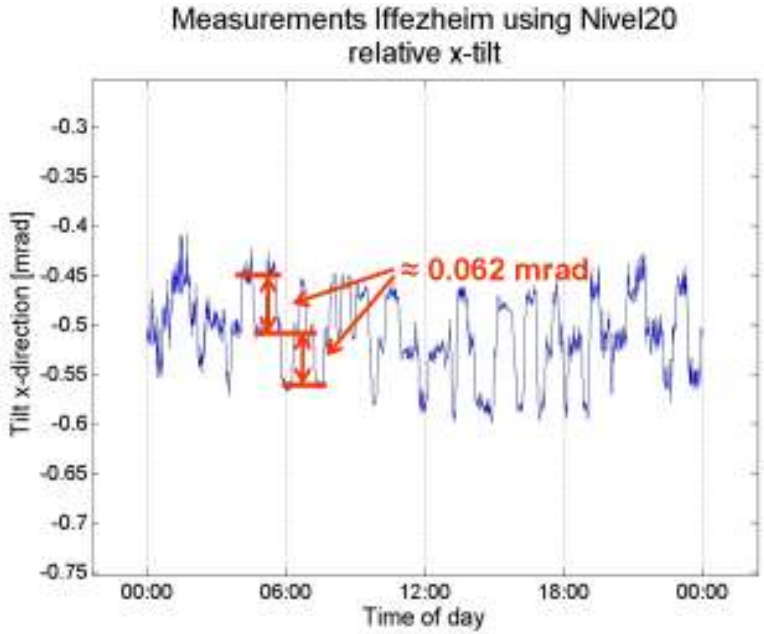


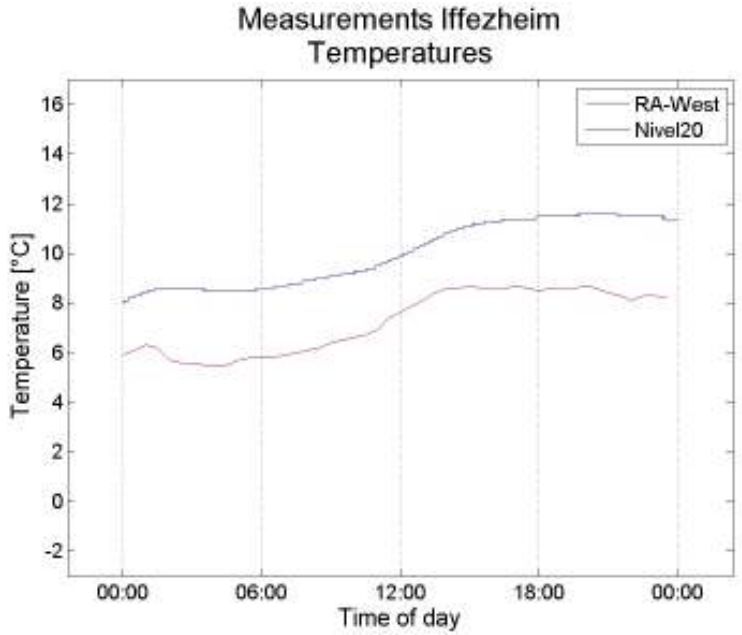


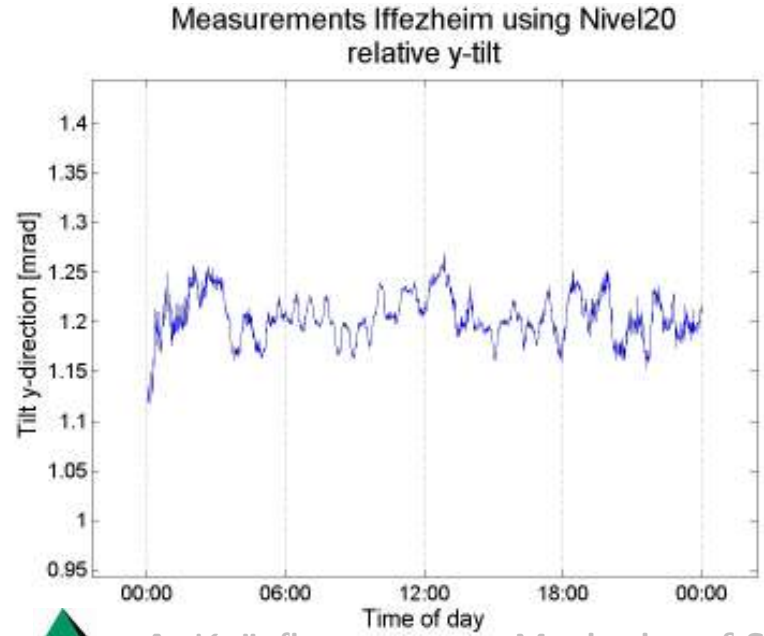


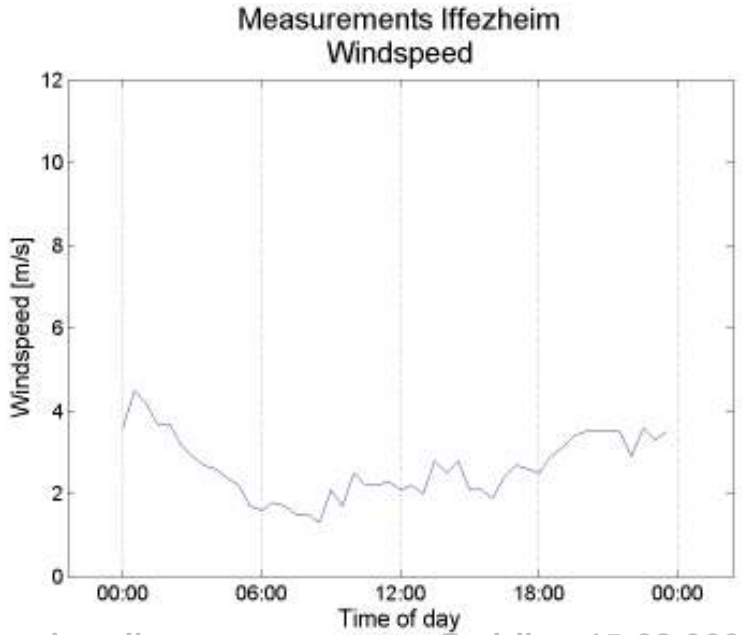


Iffezheim: results









Iffezheim: results

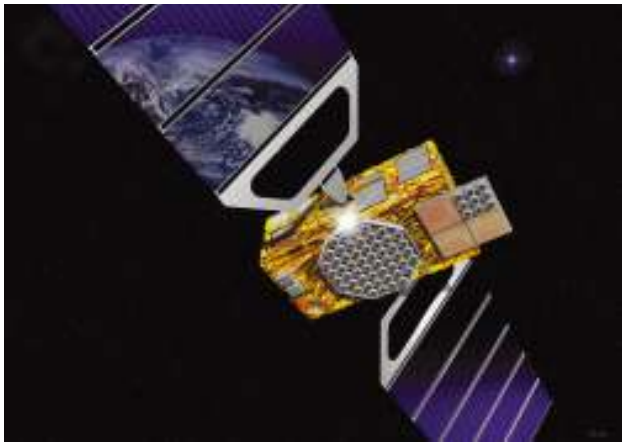
- Operation of the lock obvious
- Amplitude based on assumptions $\pm$ 1.8 mm
- Strong storm ($2^{th}/3^{th}$ December 2007) visible

Conclusions:

- Monitoring of SA*POS*®-sites using tiltmeters is possible
- Daily variation can be detected
- Uplift can't be detected
- Topic rather difficult for GNSS researchers
- Gained experiences
- Other sensors?

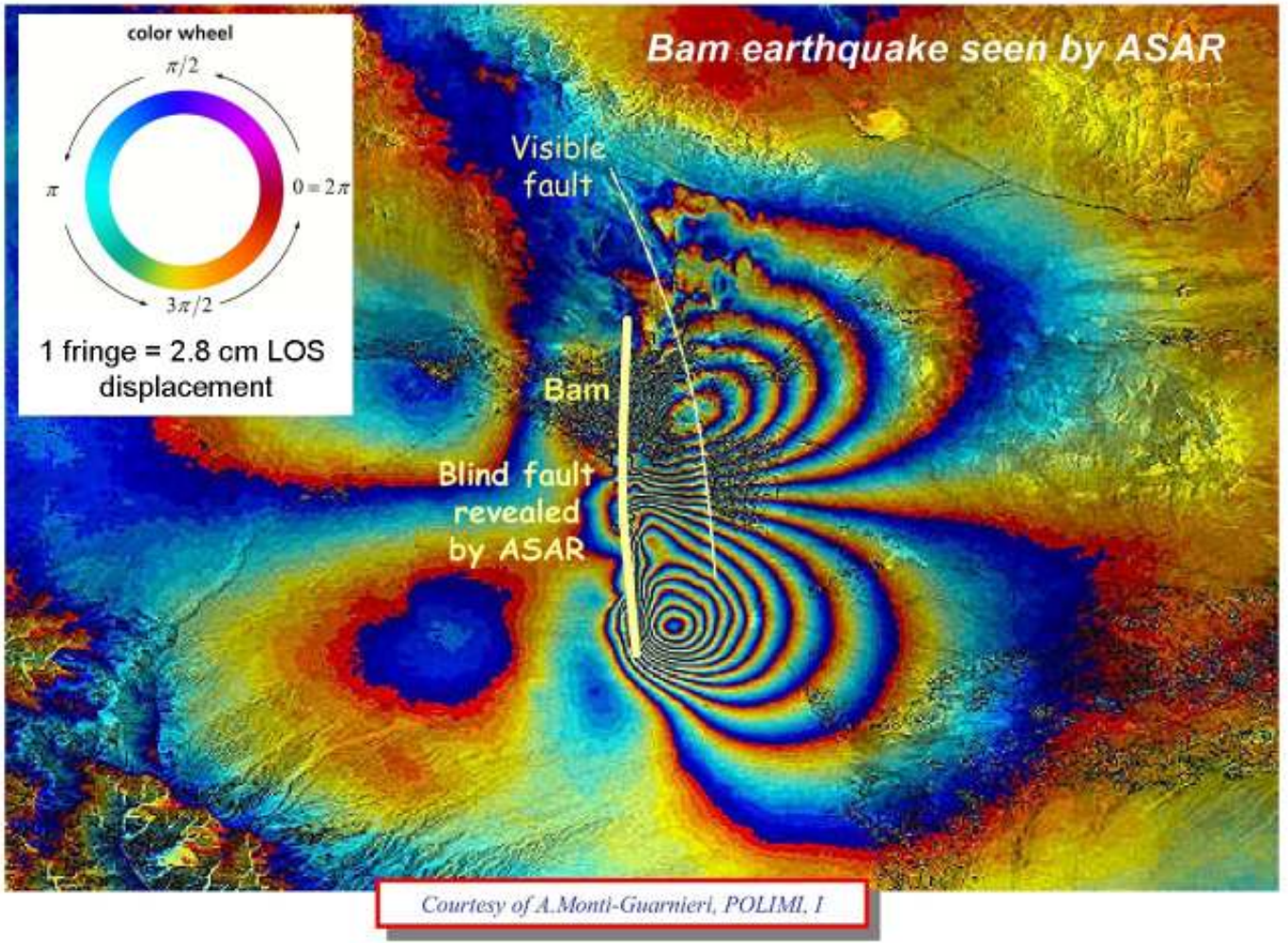
- GNSS
- InSAR
- PS-InSAR

GPS satellite Block III
[5]

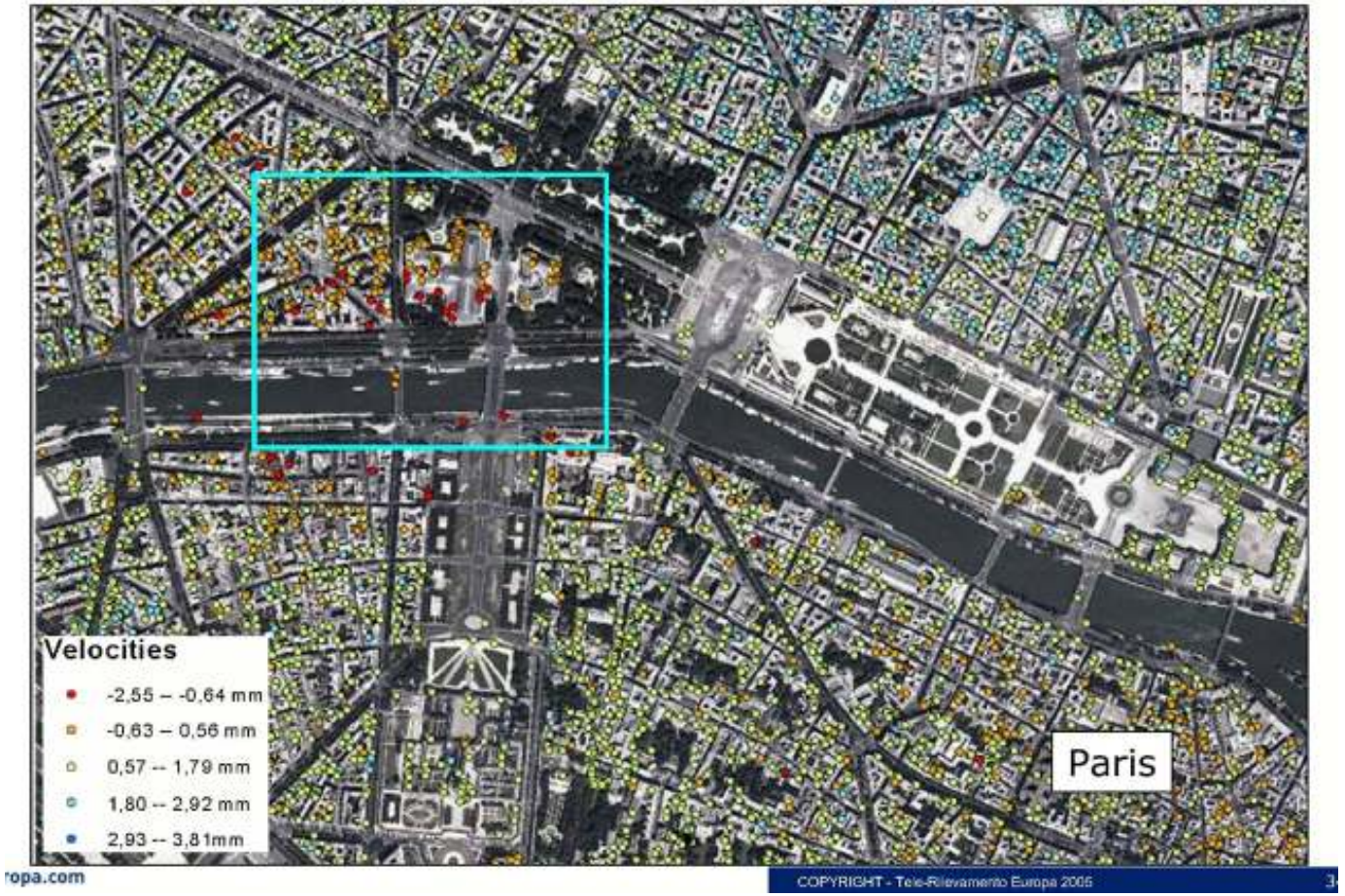


Galileo satellite
[2]

- GNSS
- InSAR
- PS-InSAR



- GNSS
- InSAR
- PS-InSAR



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Thankyou for your attention!