Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

armasuisse
Bundesamt für Landestopografie swisstopo

20 years of maintaining the Swiss Terrestrial Reference Frame CHTRF

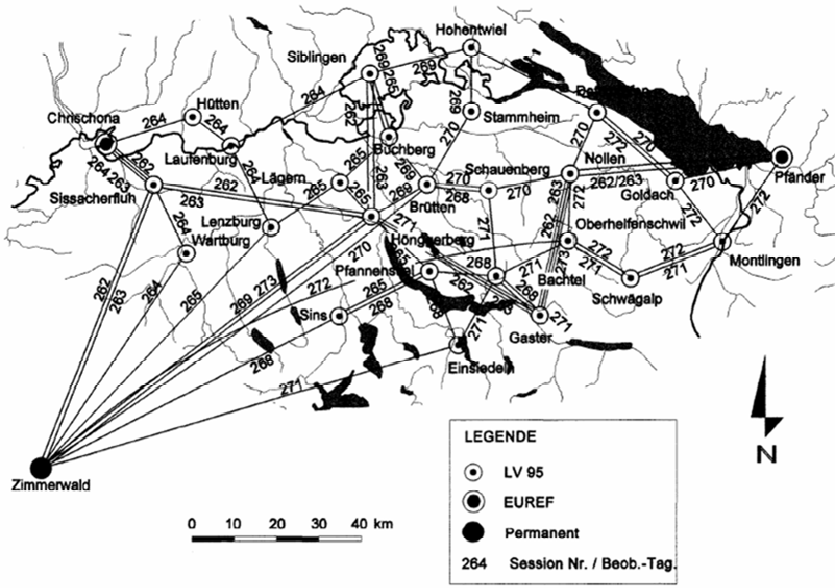
E. Brockmann

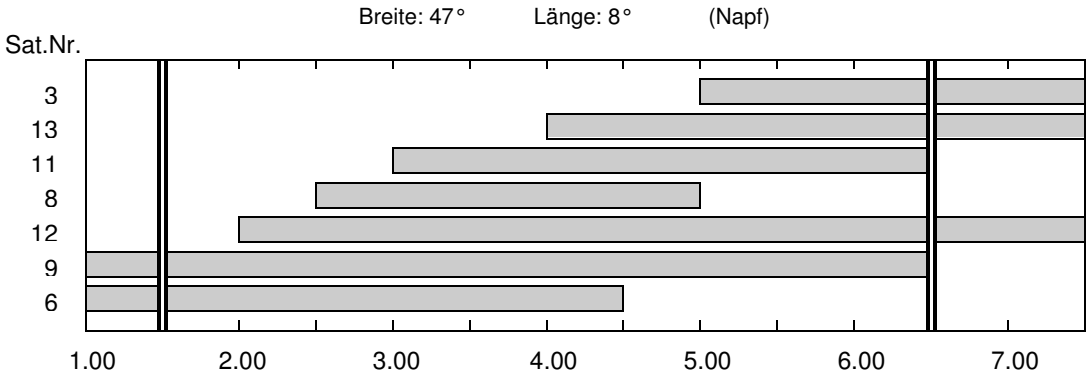
Content

- Maintenance concept
- Campaign 2010
- Combination of Results 1988 – 2010
  - Coordinates (comparison with published coordinates)
  - Velocities (horizontally)
- Conclusion

Simple maintenance concept

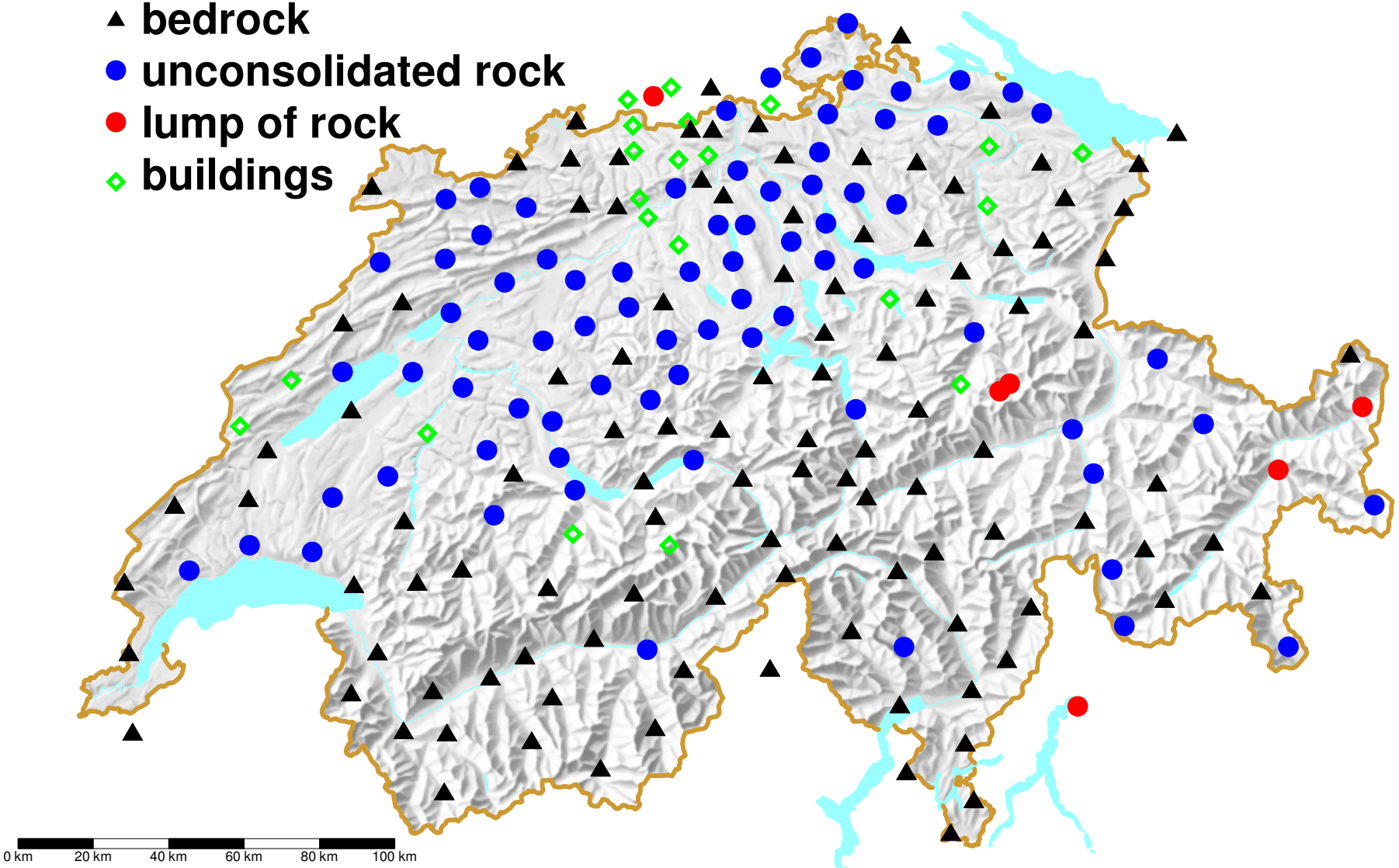
- Original network setup: 1988 – 1995
- Re-observations every 6 years: 1998, 2004, 2010





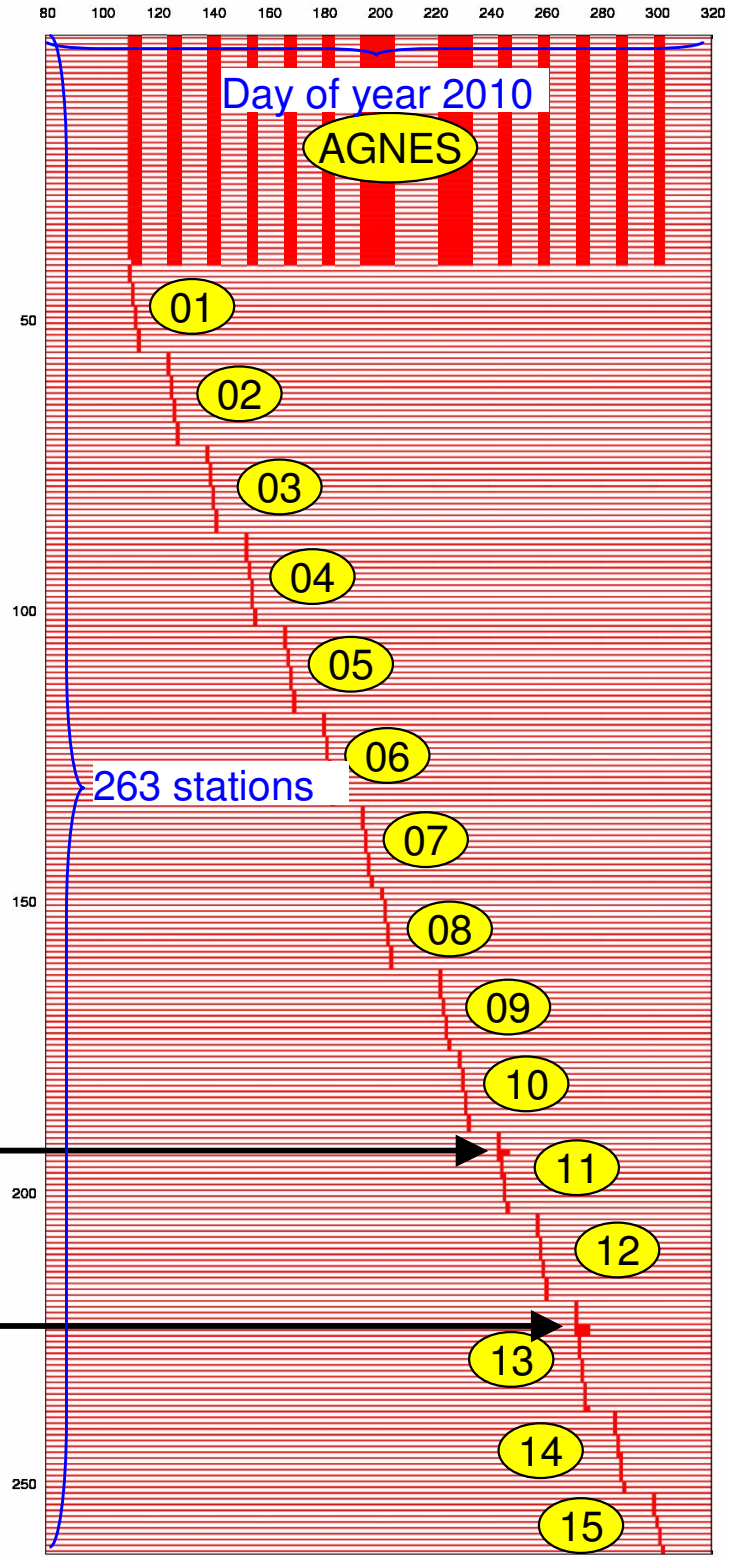
- Changes:
  - big campaigns (persons and receivers) versus 2 persons and permanent networks,
  - satellite constellations, equipment (antennas!), …
  - communication (radio versus mobile phone)

Point monumentations



CHTRF2010: Campaign

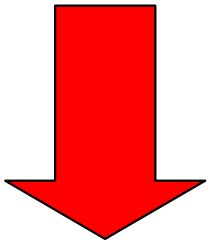
- 219 LV95 points
- ~ 43 h observations/point (CHTRF04: 18 h -> 100% more, but only 20% more personal effort)
- 16 operators
- 15 weeks (April – October 2010; each week 2 operators each with 4 GPS receivers)
- 37‘000 km by car



CHTRF2010: Motto

CHTRF2010: analysis statistics

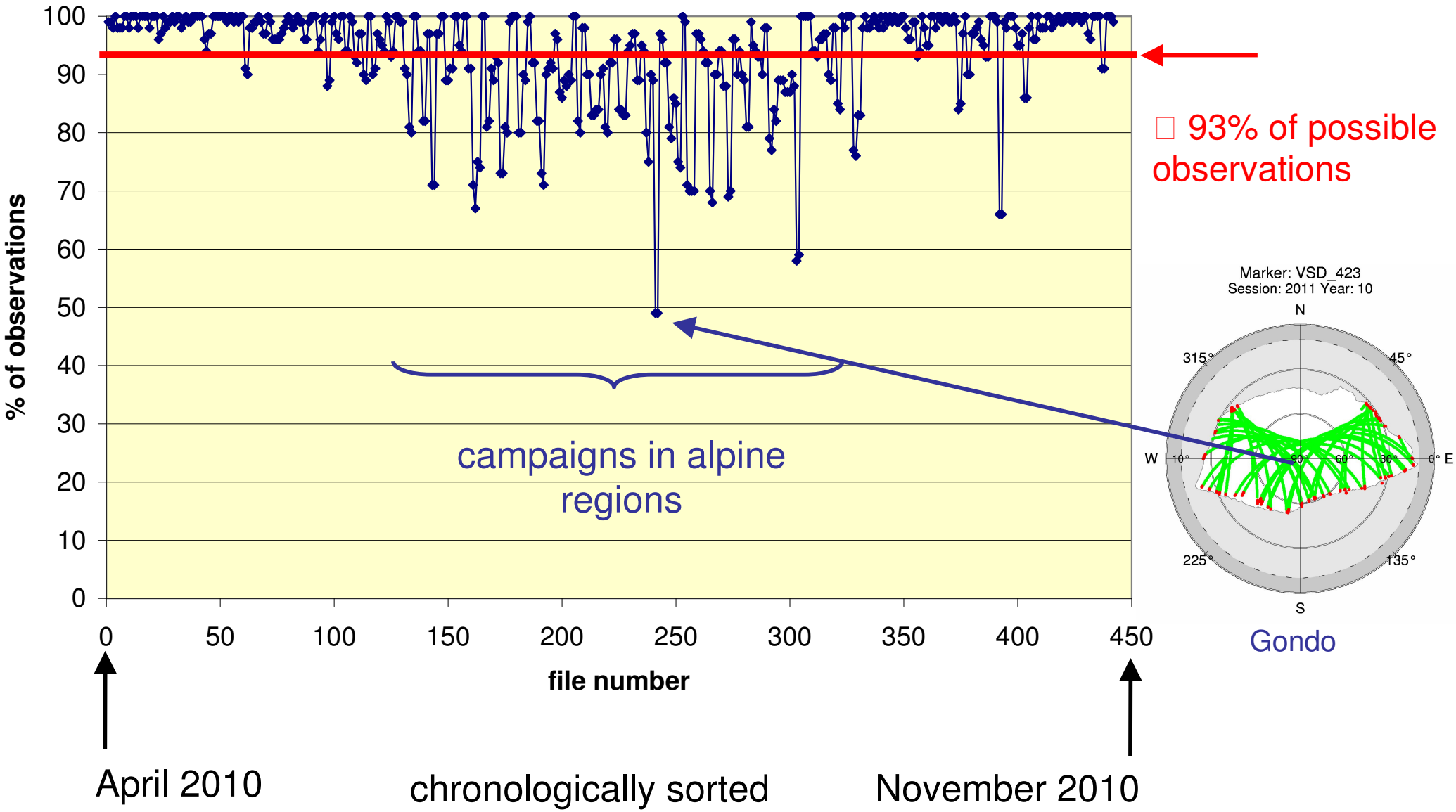
- 15 weeks campaign data, 221 files, □43 hours
- 40 permanent AGNES stations
- 76 sessions, 3397 baselines
- 120 Mio. L3 observations (30 seconds sampling)



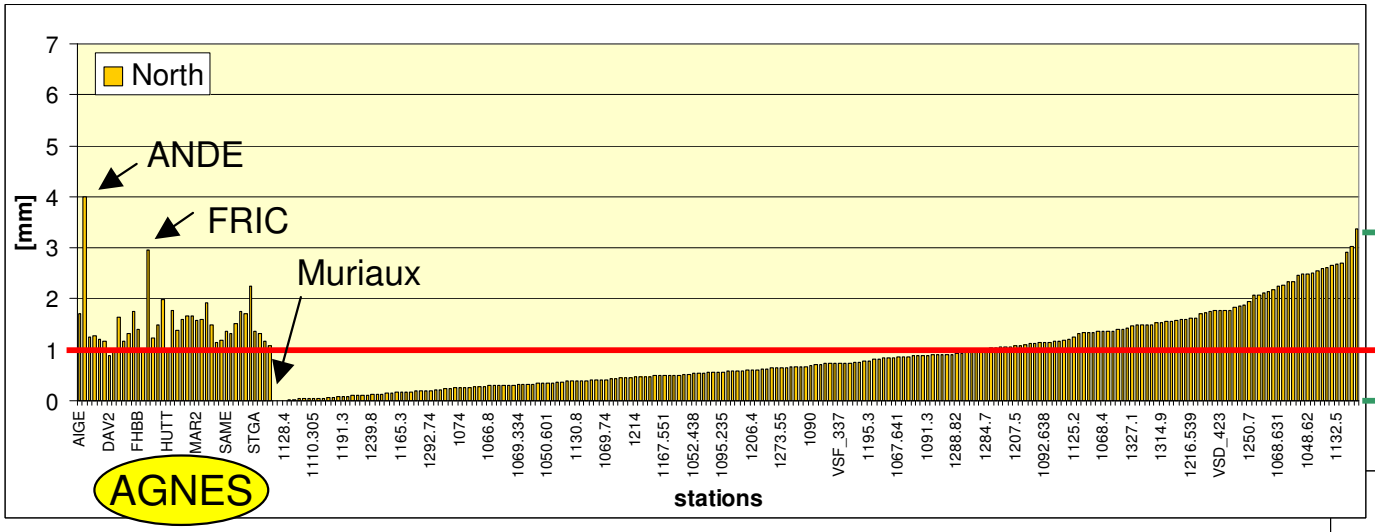
Semi-automatic data processing
Bernese 5.0+ (CPU time: ca. 5 days on a LINUX, 8 CPU, 32GB RAM)

- 263 * 3 coordinates
- 120‘000 other parameters (ambiguities, troposphere)

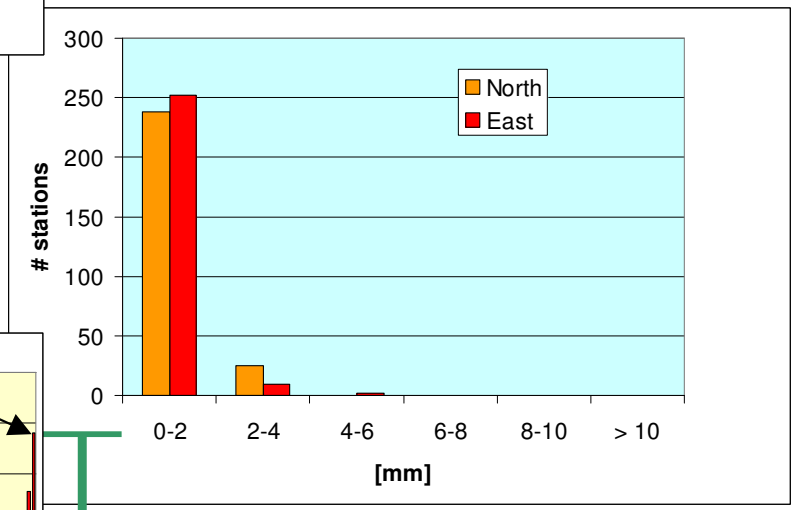
CHTRF2010: observation statistics

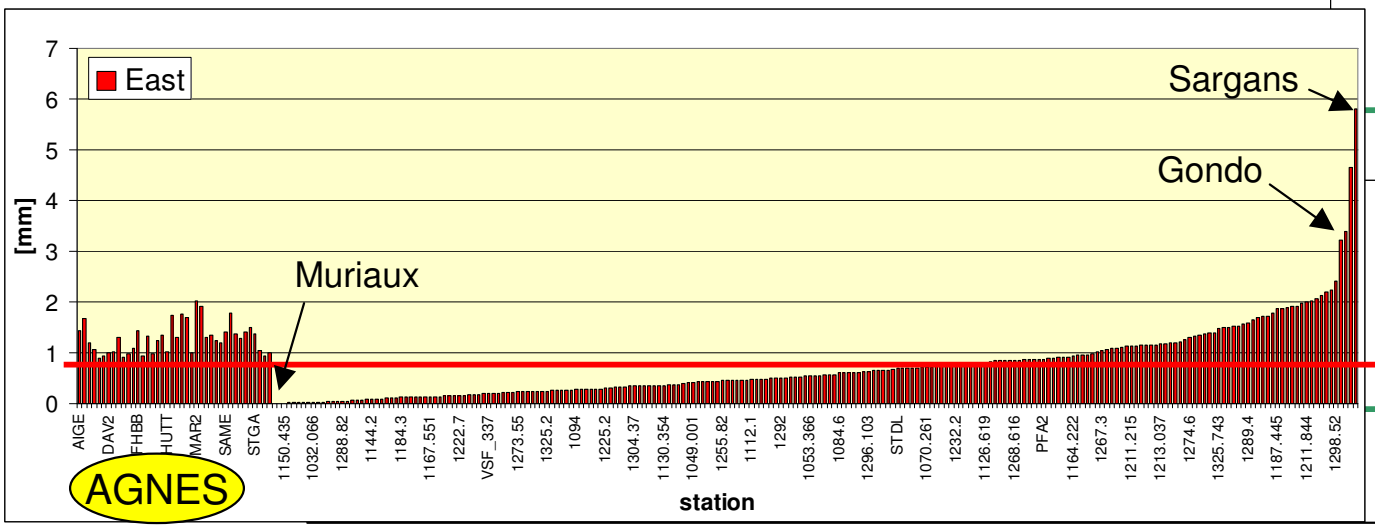


Repeatability - horizontally (2 session)

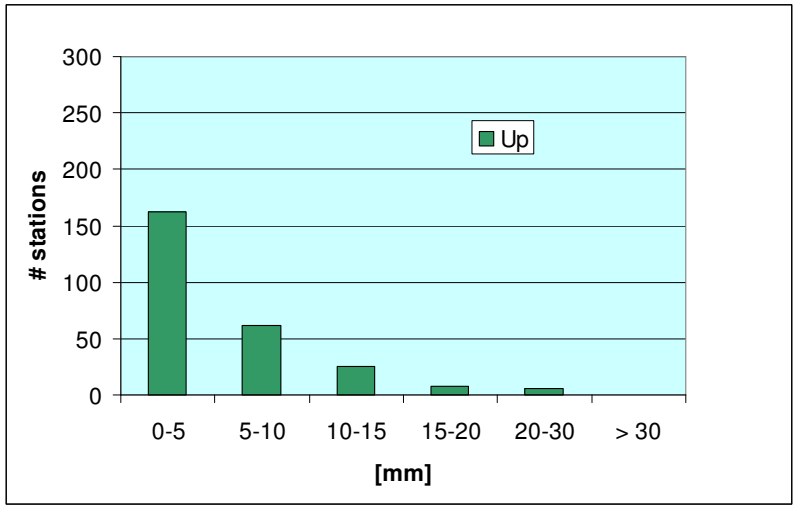


- North std 1.0 mm $\bullet\sqrt{2}$ -> diff. 1.4 mm
- East std 0.8 mm $\bullet\sqrt{2}$ -> diff. 1.1 mm

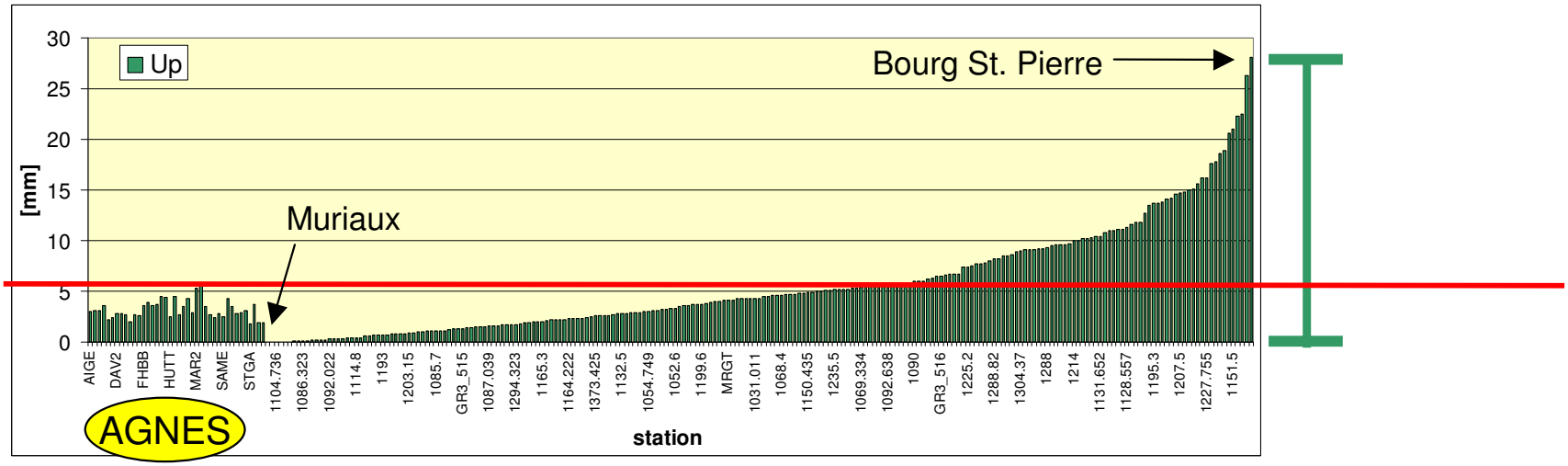




Repeatability - vertically (2 sessions)



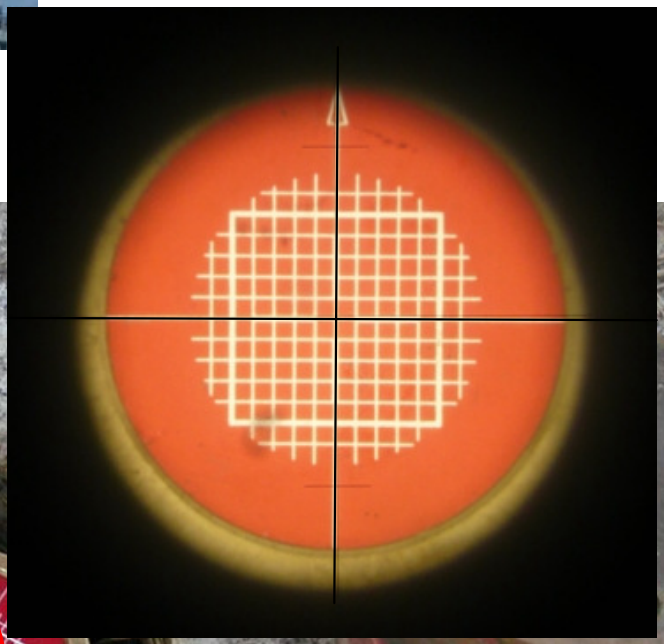
- $\bullet\sqrt{2}$
- Up std : 5.3 mm -> diff 7.4 mm

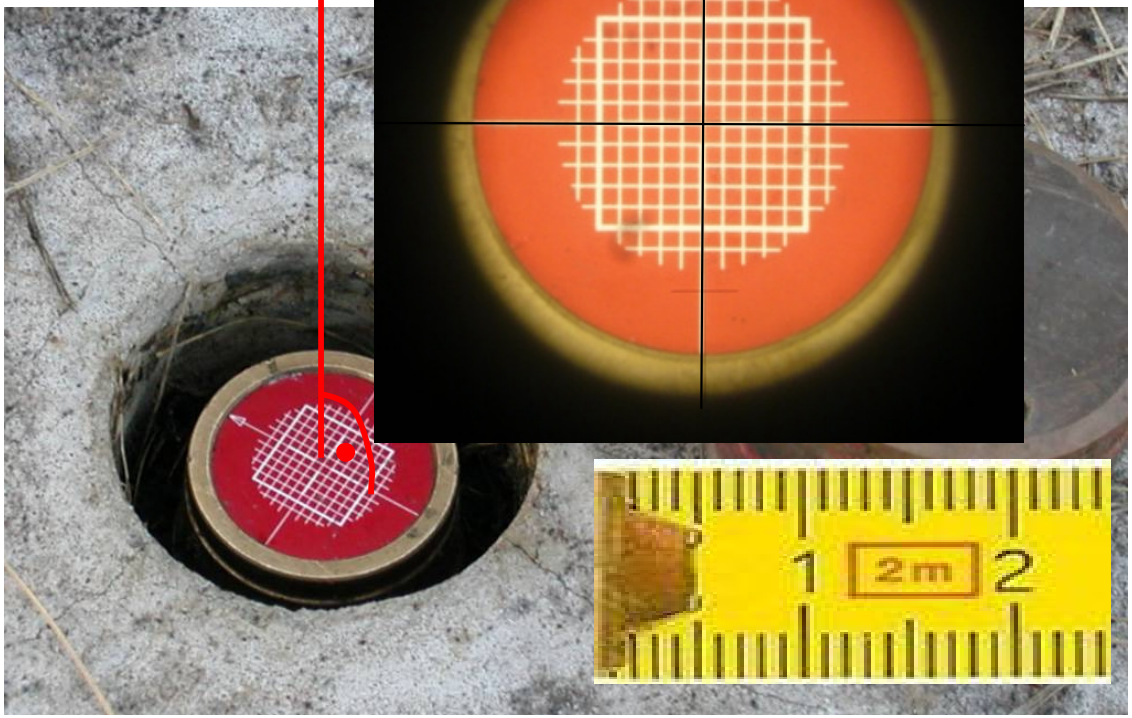


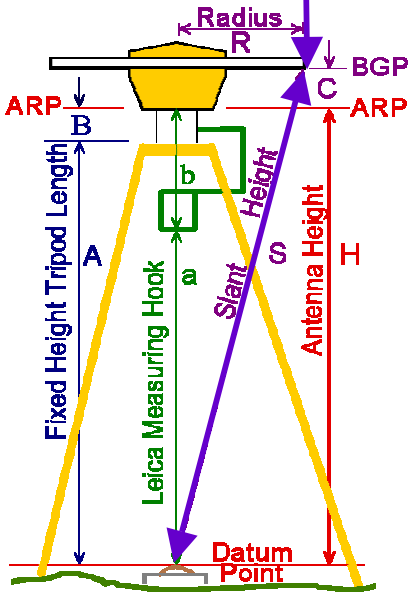
… eccentricity checks …

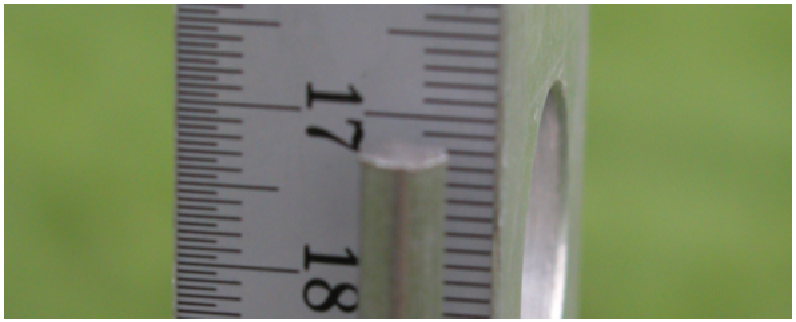
plane (± 2/10 mm)

height (± 0.5 mm + check)

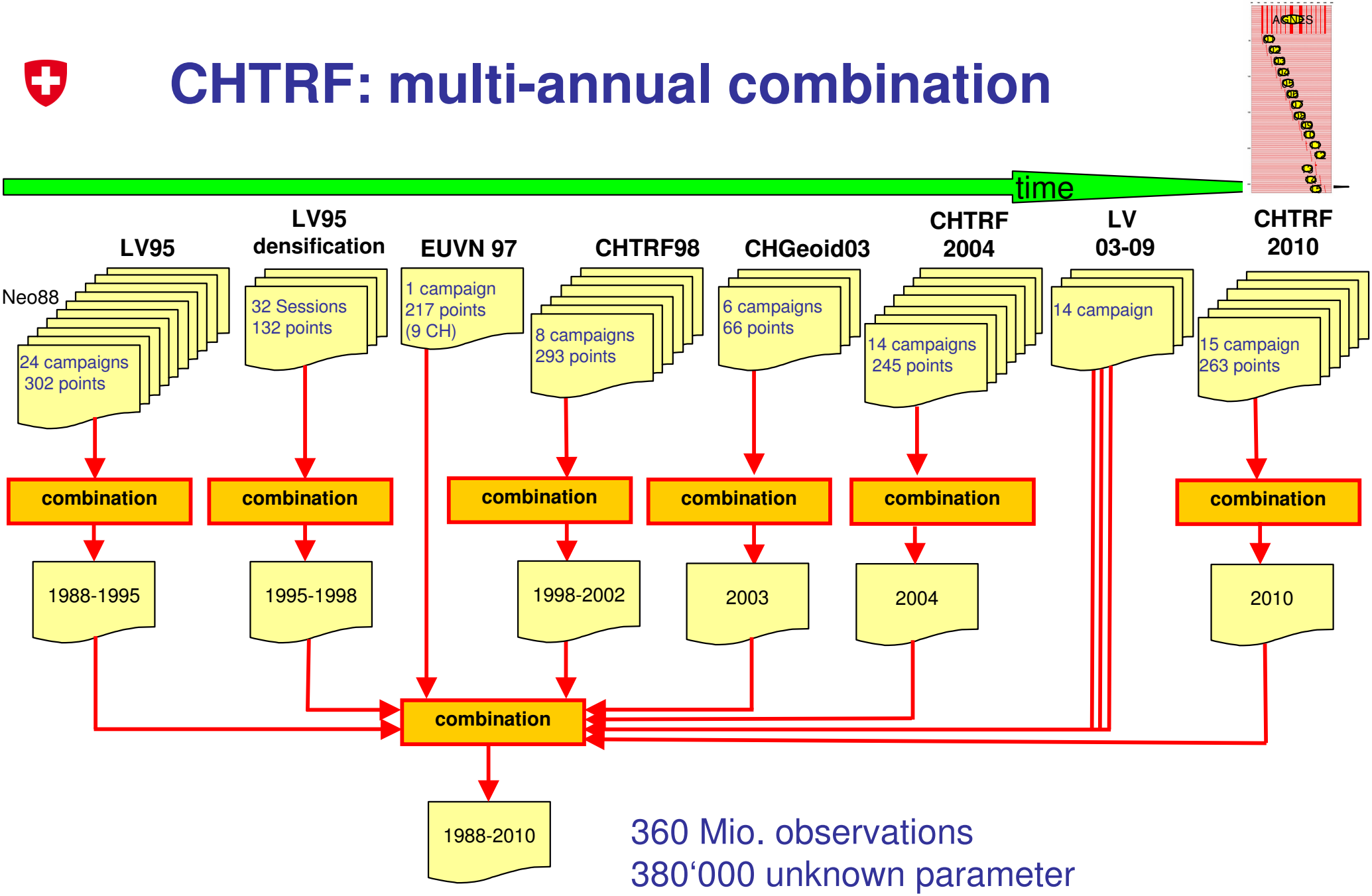






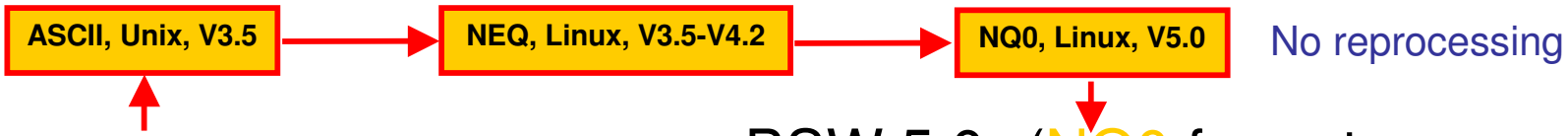


CHTRF: multi-annual combination



360 Mio. observations
380‘000 unknown parameter
687 *3 point coordinates

Reproduction of results 2004



No reprocessing

BSW 4.2 (NEQ format)

BSW 5.0+ (NQ0 format, new program + input files)

```
   1   Q:/LV95.CMB/OUT/LV95SNXWGT.NEQ
   2   Q:/LV95P/OUT/LV95PSNX.NEQ
   3   Q:/EUVN/OUT/EUVN_ITR.NEQ
   4   Q:/CHTRFCMB/OUT/CH98P_S.NEQ
   5   Q:/CHTRFCMB/OUT/CH03_S.NEQ
   6   Q:/CHTRFCMB/OUT/CH04_S.NEQ
   7   Q:/CHTRFCMB/OUT/MULTI_A.NEQ

STATISTIC OF SOLVED FOR PARAMETERS                  #PARAMETERS
 STATION COORDINATES                                   1881
#PRE-ELIMINATED                                         627


 SHORT SOLUTION STATISTIC
 ------------------------
 TOTAL NUMBER OF PARAMETERS                  :    2769227
 TOTAL NUMBER OF OBSERVATIONS                :  359627322
 NUMBER OF SINGLE DIFF. FILES                :       5569
 ------------------------------------------------

 A POSTERIORI SIGMA OF UNIT WEIGHT  :    0.0014
```

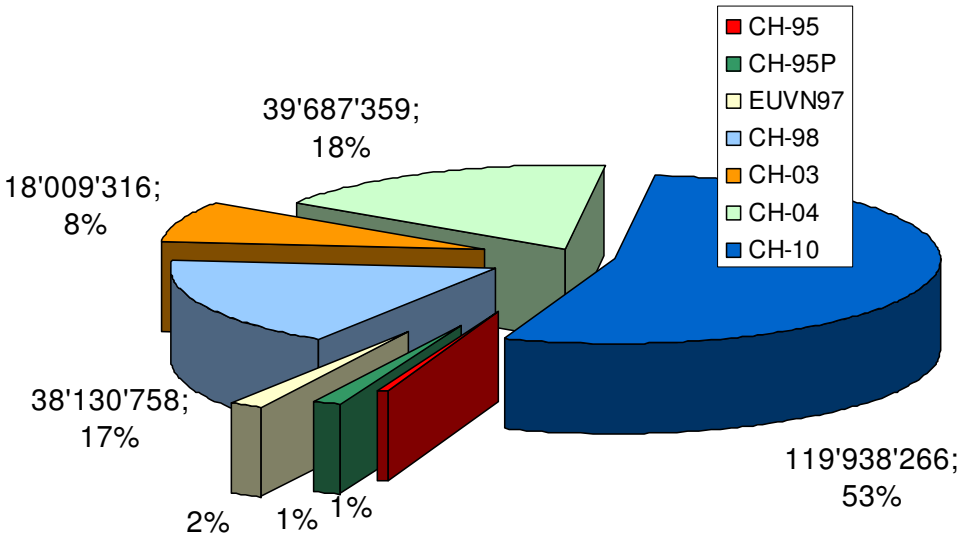
```
   1  ${P}/CH_CMB/SOL/LV95SNXWGT.NQ0
   2  ${P}/CH_CMB/SOL/LV95PSNX.NQ0
   3  ${P}/CH_CMB/SOL/EUVN_ITR.NQ0
   4  ${P}/CH_CMB/SOL/CH98P_S.NQ0
   5  ${P}/CH_CMB/SOL/MULTI_A.NQ0
   6  ${P}/CH_CMB/SOL/CH03_S.NQ0
   7  ${P}/CH_CMB/SOL/CH04_S.NQ0


Statistics:
----------

Total number of explicit parameters          1881
Total number of implicit parameters       2767346

Total number of adjusted parameters       2769227
Total number of observations            356637881
Degree of freedom (DOF)                 353868654


A posteriori RMS of unit weight           0.00136 m
```

Coordinate comparison:

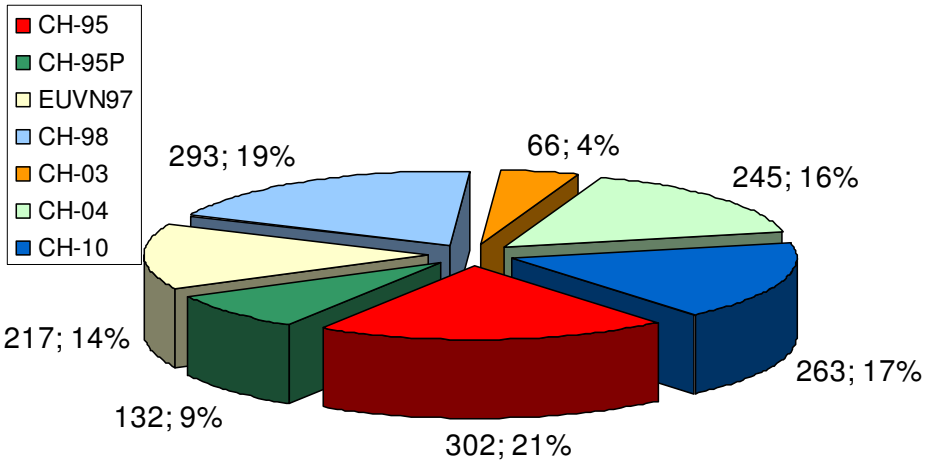
```
-------------------------------------------------------------------------
|     | RMS / COMPONENT  |     |        0.0       0.0       0.0 |    |
-------------------------------------------------------------------------
NUMBER OF PARAMETERS  :     3
NUMBER OF COORDINATES :  1881
RMS OF TRANSFORMATION :     0.0 MM
```

Statistics

observations



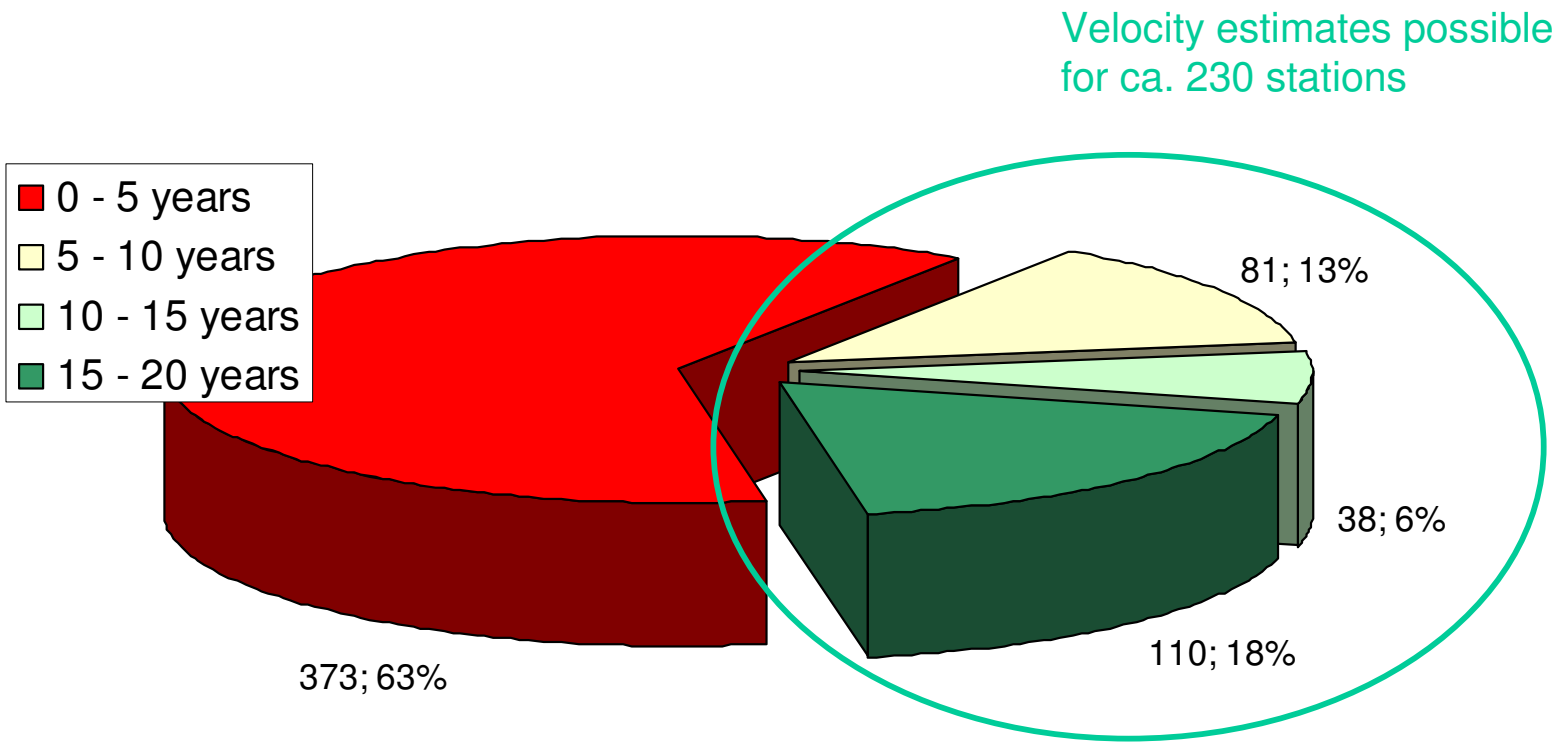
stations



Permanent stations are responsible for the big amount auf data in 2010

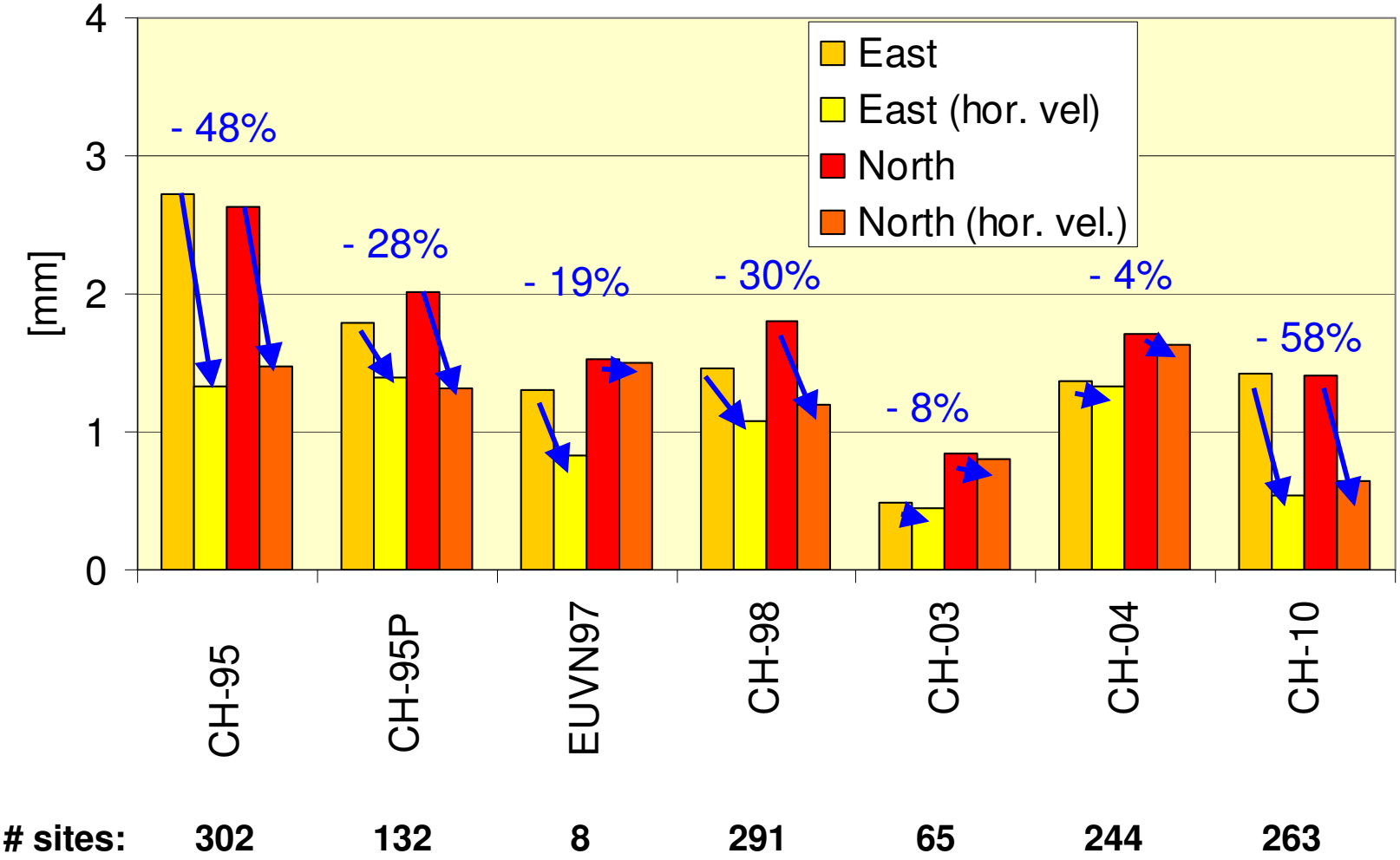
Statistics (2)

Observation interval (total 602 stations)



Comparison with combination (horizontally)

Velocities: min. 3 times + min. 4 years → 233 stations (56 more as before)



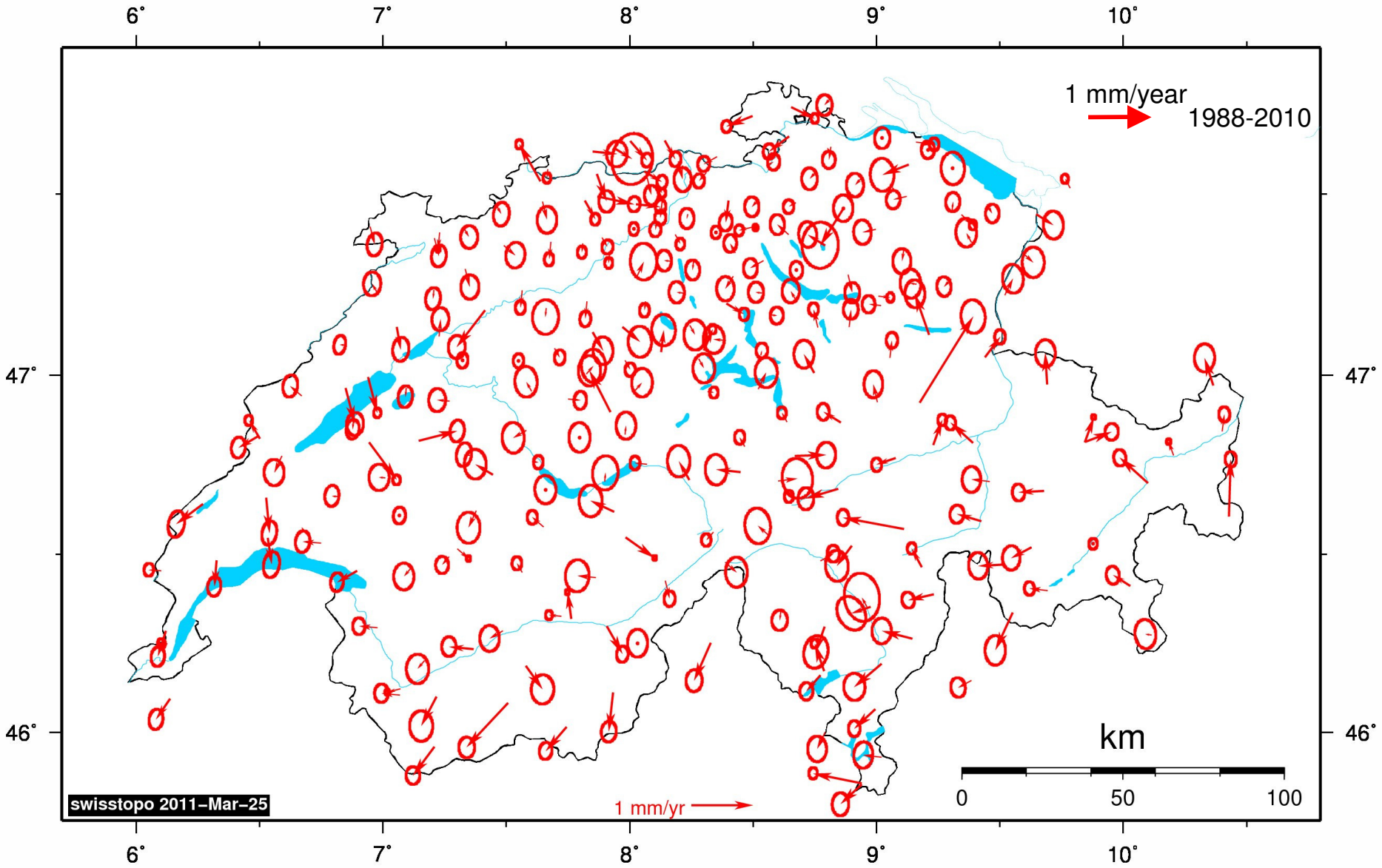
# sites:	302	132	8	291	65	244	263

Campaigns at begin and end important! ~30% kleinere Residuen

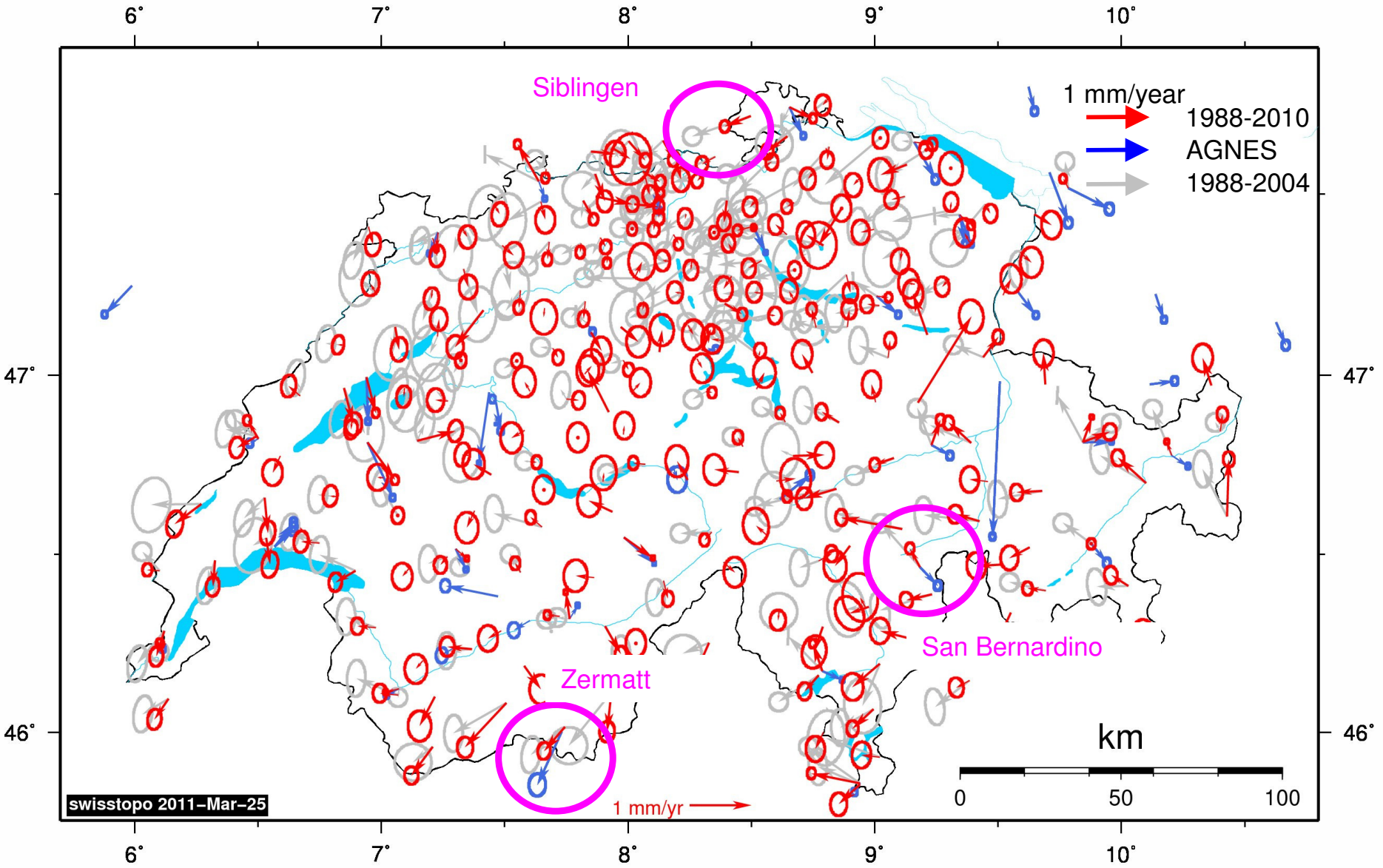
Horizontal CHRF velocities

Rescaling factor: 15

ZIMM and vertical velocities constrained



Horizontal CHRF velocities (2)



Statistics of velocity fields (std)

- 1988-2010: 233 stations move
  E: -0.06±0.23 N: -0.05±0.27 mm/year

- 1988-2004: 172 stations move
  E: -0.40±0.32 N: -0.12±0.36 mm/year

- AGNES: 22 stations (from permanent network) move
  E: 0.14±0.18 N: -0.25±0.21 mm/year

Movements (horizontally) per component:
< 0.2 mm/year (1 sigma)
< 0.6 mm/year (3 sigma) – 6 mm in 10 years
only small number of locally instable sites (LV95 network + AGNES)

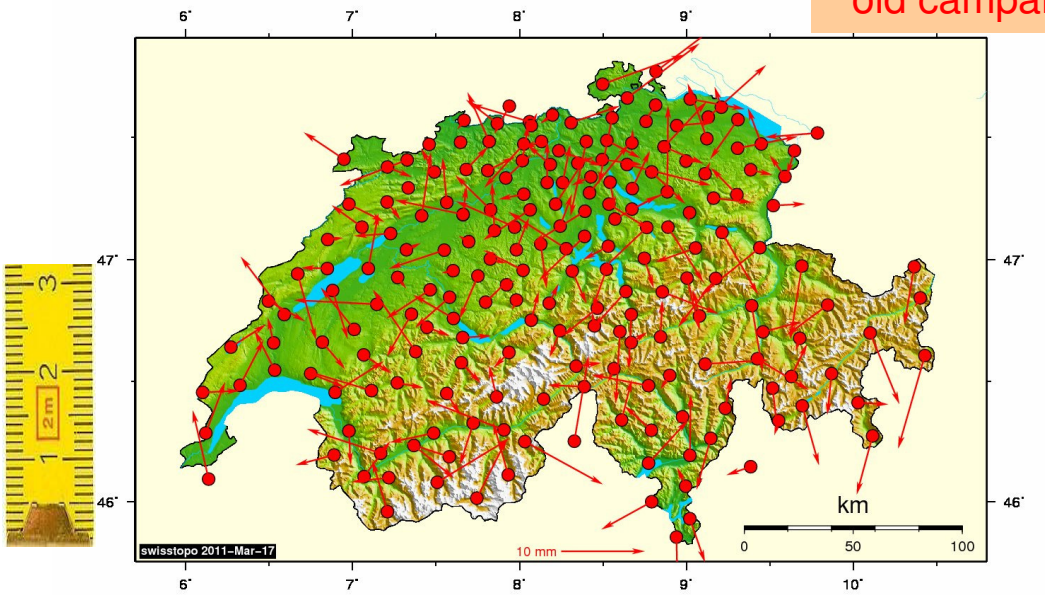
Coordinates: differences to published coordinates

Datum: aligned to published AGNES coordinates

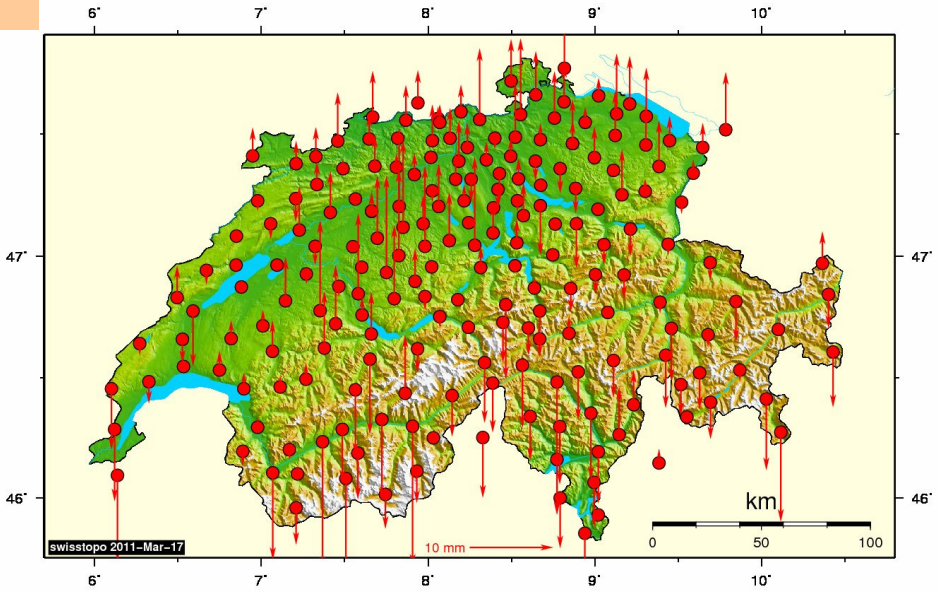
3-D Helmert Translation

N: 1.1 mm, E: 5.7 mm

antenna model
old campaigns



U: -3.5 mm



std: N: ±4.2 mm E: ± 4.0 mm
ZIMM: N: -2.3 mm E: 0.4 mm

published coordinates (cm-rounded)

std: U: ± 5.3 mm
ZIMM: U: -4.2 mm

published heights (mm-rounded in 2004)

tilt in height – satellite orbits in a different system
North +7 mm, South -7 mm

Conclusions

2010 campaign	☺	Successfull campaign 2010 for maintaining the Swiss reference frame
	☺	Longer measurement intervals enables quality checks: 1 mm hor. and 5.3 mm vert. (std) per point.
1988-2010 combi	☺	Repeatability of the coordinates 1988-2010: 1.7 mm hor. (1.2 mm with velocities) and 6.8 mm vert. (std) per point.
	☺	Hor. velocities: < 0.6 mm/year (3 sigma per component) – again much smaller than estimated with data till 2004. (no vertical velocities from campaign data).

Conclusions (2)

published coordinates

☺	No modification necessary (limits: hor. 2 cm, vert. 3 cm). A static reference frame is still suffucient. Almost no locally instable points.
😐	Small systematic biases between published coordinates and AGNES/CHTRF: • 6 mm East (partly due to old antenna models) • ±7 mm north/south tilt (satellite reference)

Planning …

Thanks for your attention