



Satellite Geodesy in Swiss Federal Surveying and related disciplines

wissen wohin
savoir où
sapere dove
knowing where



E. Brockmann



Astronomy + Surveying

NASA image



- Personal background:
 - Studying geodesy in Bonn (1985 – 1991) + >20 years swisstopo (>1999)
 - Phd in astronomy in Bern (1991 – 1996)
- Subject:
 - fundamental astronomy: relation earth and sky
 - Geodesy: measurement the earth; satellite geodesy: stars -> satellites
- Instruments, observations:



Stars as **target**

Optical
Cassegrain telescope,
Zimmerwald 1959



terrestrial **target**

Optical
Theodolite
Reichenbach, 1826



Astronomy + Surveying:

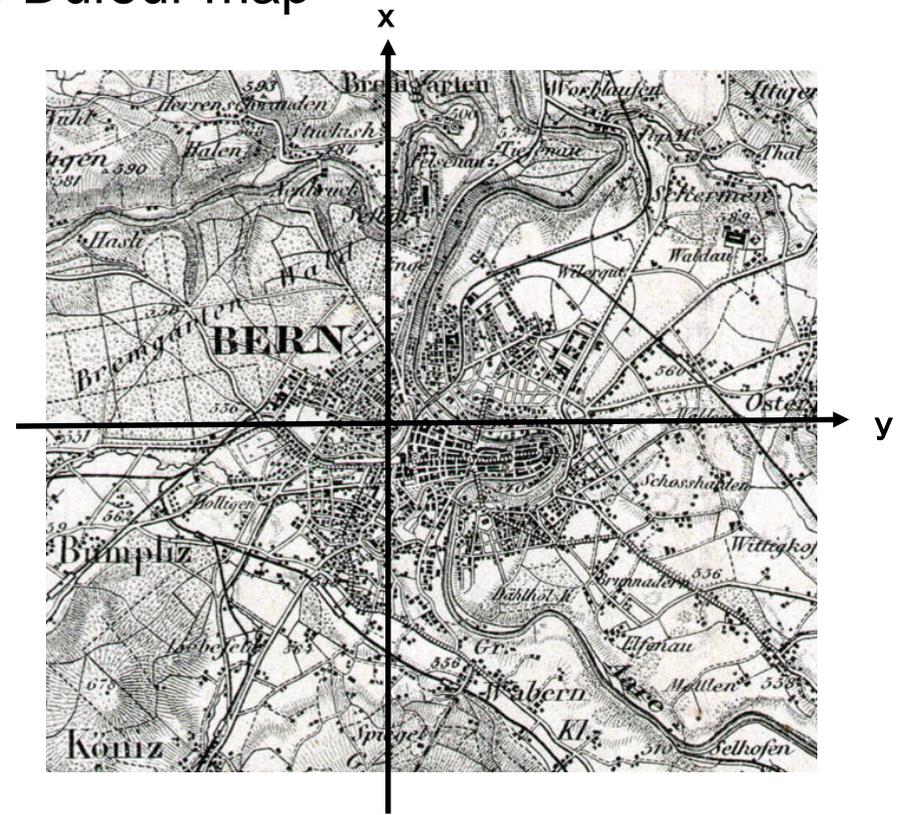
Astronomy “first”

- 1812: observatory «Uraniae»
- 1838: foundation «Bundesamt für Landestopografie»
- Observatory defines the origin in Bern for the Dufour map



λ_0	=	7° 26' 22.50"
ϕ_0	=	46° 57' 08.66"
ξ_0	=	0 (in P_0)
η_0	=	0 (in P_0)

200' 000



600' 000



Old observatory today

PHYSIKALISCHES INSTITUT 1876-1958

INSTITUT FÜR EXACT SCIENCES (1962-1970)

ALTE STERNWARTE

Meridianinstrument 1822-1876 H=572.65

Nullpunkt-Stein 1876-1958 H=564.24

Zentr. Jocky

Fussweg

Koord'ursprung-Stein: 1962-1970 H=559.90

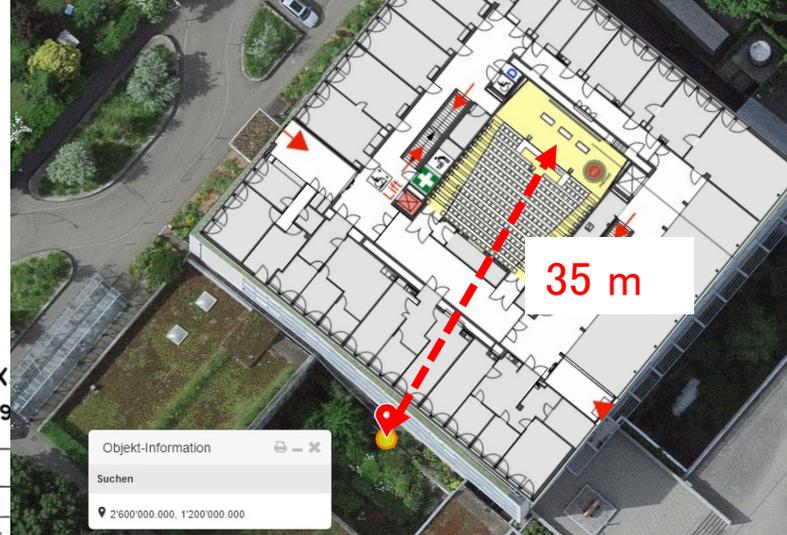
seit 1971 H=556.68

Terrassenbau (1971)

Lichthof I

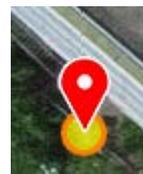
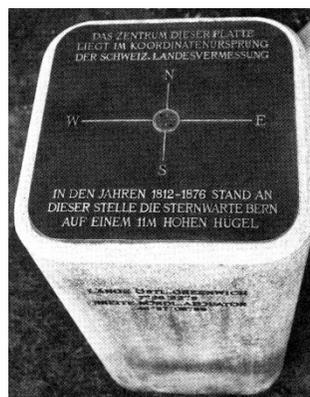
Hochbau (1962)

Untergeschosse



35 m

Objekt-Information
Suchen
2'600'000.000, 1'200'000.000



Memorial stone in atrium of the institute of Exact Sciences

with its coordinates

$y = 600'000 \text{ m}$ $x = 200'000 \text{ m}$ (CH1903)



Content

- Short history of Swiss surveying
- Swiss / international satellite geodesy
 - Geostation Zimmerwald
 - Reference network “LV95”
 - AGNES permanent network
- Quick spot on swisstopo applications
 - Federal Surveying: positioning service swipos
 - GNSS meteorology
 - Tectonic/ Geophysics: Moving reference frames in CH/EU

”powered by” / relations to:
Astronomical institute AIUB



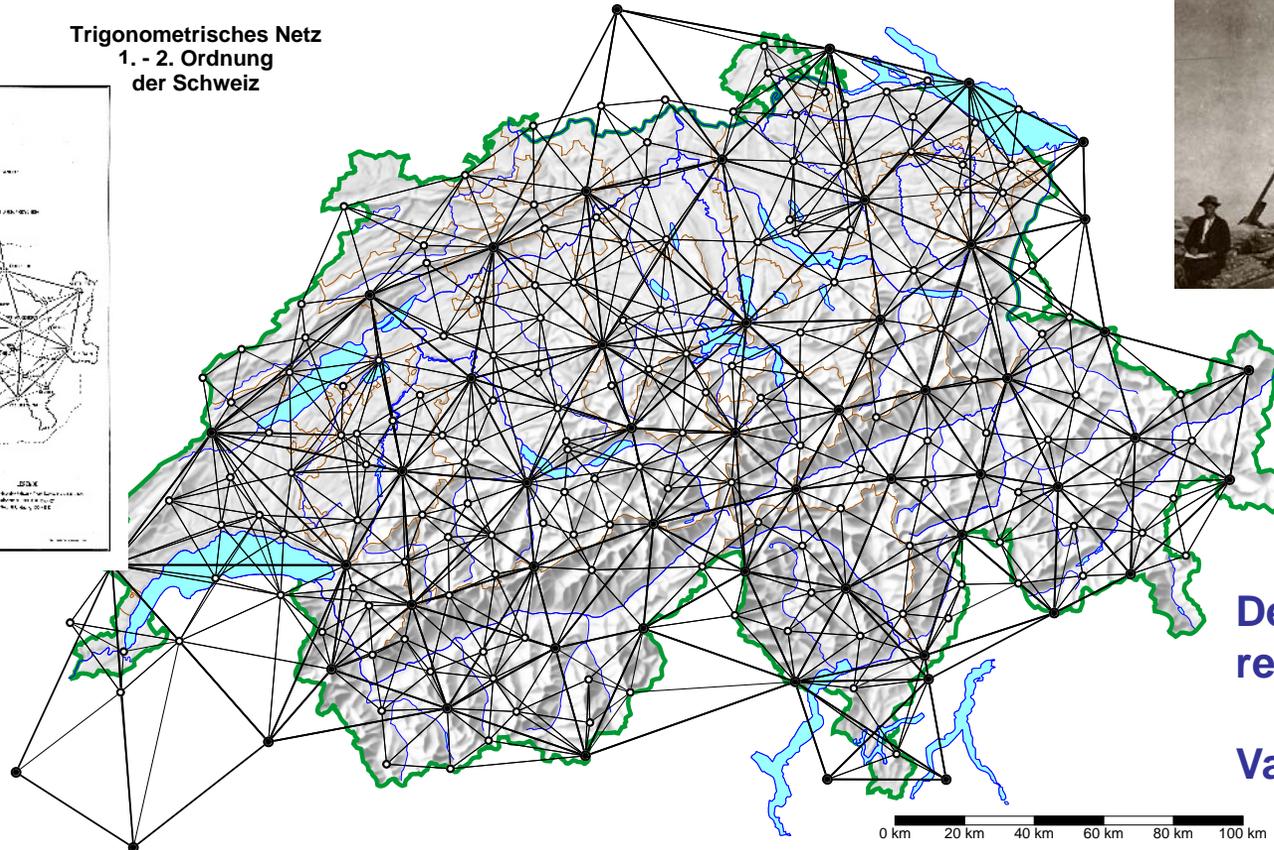
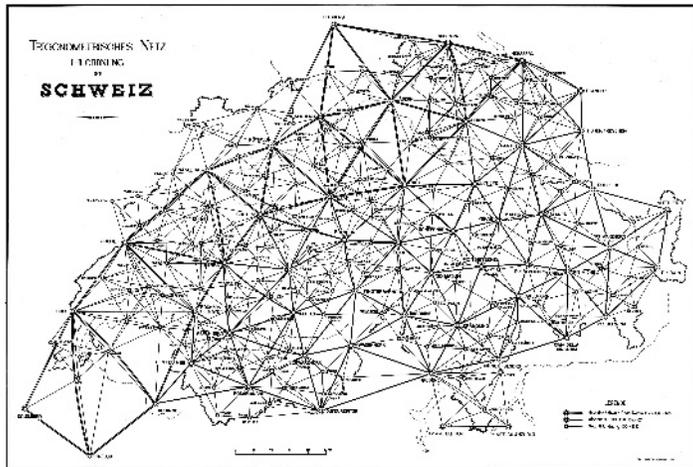
History of Swiss federal surveying



1903 – 1943

Triangulation Network 1. - 3. order (LV03)

Trigonometrisches Netz
1. - 2. Ordnung
der Schweiz



Definition of the «old»
reference system «LV03»

Valid in Switzerland till 2020



Pyramid: Napf (~1920)



**Pyramids: for better
visibility from far away**



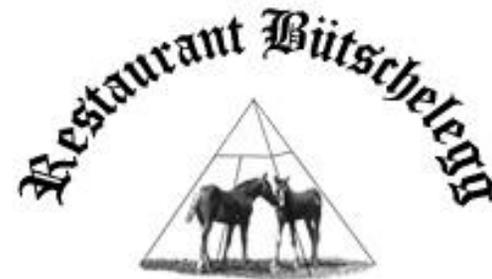
Pyramid as swisstopo logo or touristic attraction

- 1979-1994:



Bundesamt für Landestopographie
Office fédéral de topographie
Ufficio federale di topografia

- now: touristic attraction



Alt. 1607 m **Hôtel
du Chasseron**
Le plus haut des balcons du Jura vaudois





History of Swiss federal surveying



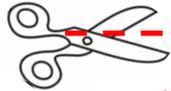
1975 – today

Satellite Laser Ranging (SLR)
in Zimmerwald



1985 – 1995

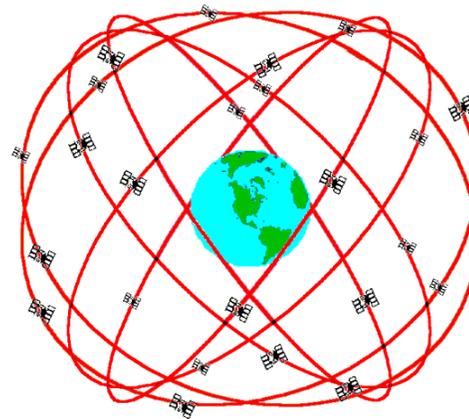
Network adjustment 1./2. order (distortions)



1987 – 1995

GPS technology in federal surveying applications:

- building the reference network LV95
- measuring coordinates and connection to triangulations network LV03



Global Positioning System





Importance of Satellite Geodesy with time perspective of 200 years

“Classical” geodesy



Satellite Geodesy

(last 30 years -> main focus of this presentation)



Reference network LV95 (1988 – 1995)

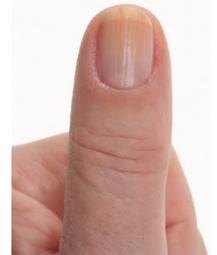
Main reference points

Densification points



200 stable points

accuracy:
1-2 cm horizontally
3 cm vertically



New reference point:
Zimmerwald



Impressions LV95 sites



Männlichen, 2004



Piton (F), 2004

Tie to bed rock and
connected to the geology

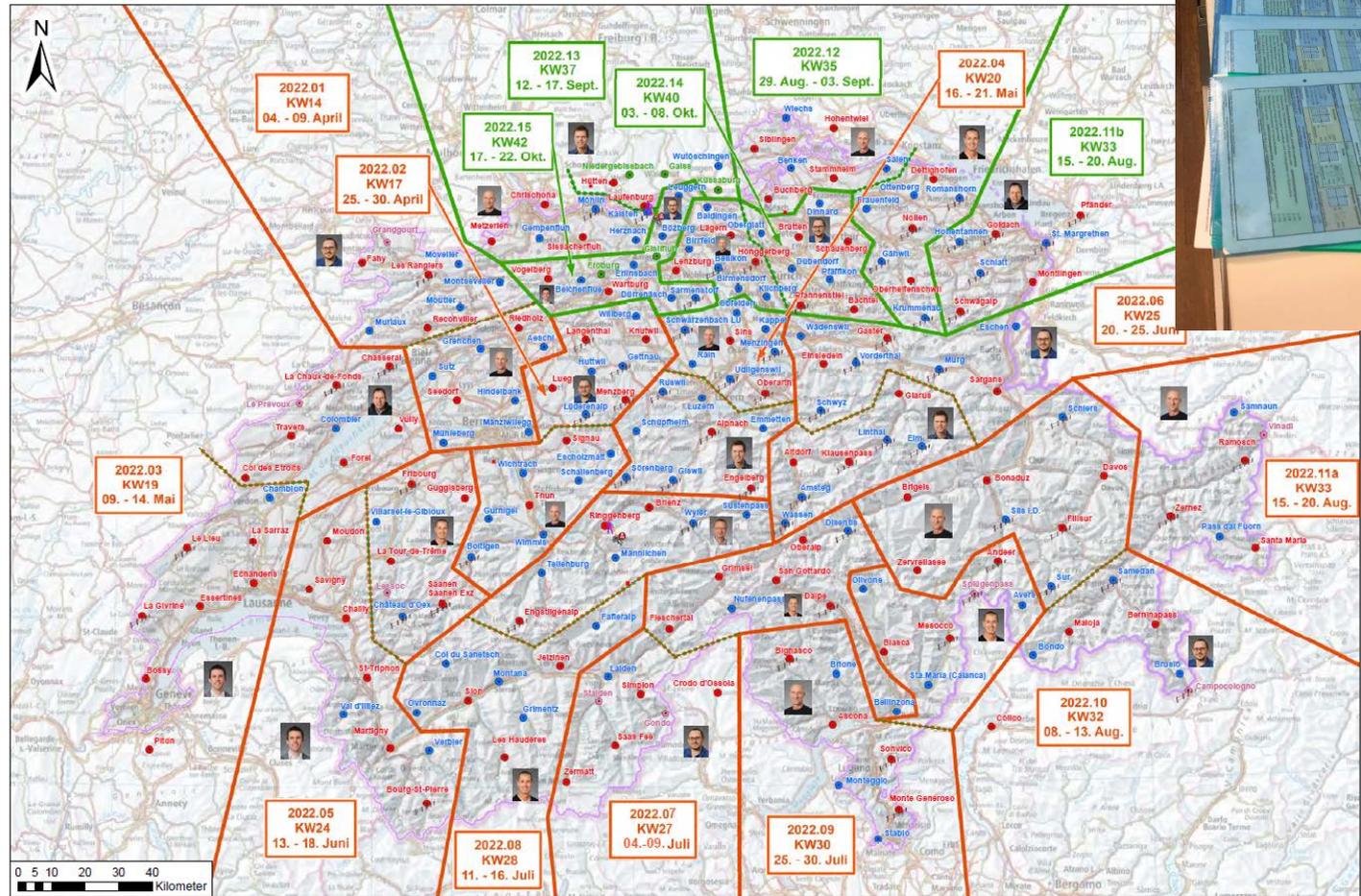
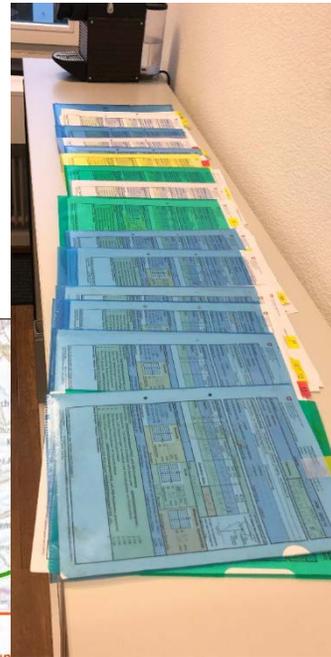
None of the old pyramid
points can be used (no
satellite view)



LV95 today: campaign 2022

- 15 weeks
- 4.4. – 30.10.2022
- 7 observers
- 222 points
- 48h obs. per point

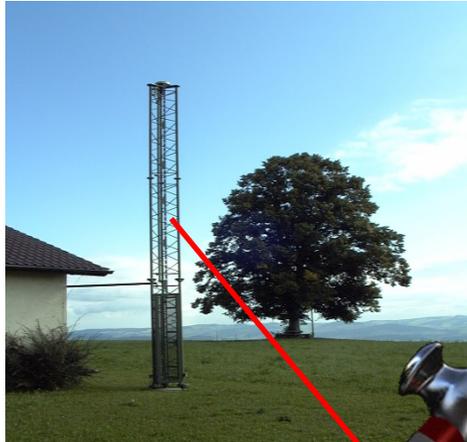
re-observation
every 6 years



Date: 16.03.2022



Geostation Zimmerwald as the new reference for federal surveying in Switzerland



Reference station

GNSS



Satellite

Laser

Ranging

SLR / CCD



- Zimmerwald observatory since 1956 – **again ahead to surveying**
- **AIUB close collaboration with swisstopo**
- International contribution of Switzerland with an important core station



Geostation Zimmerwald once and now



1992

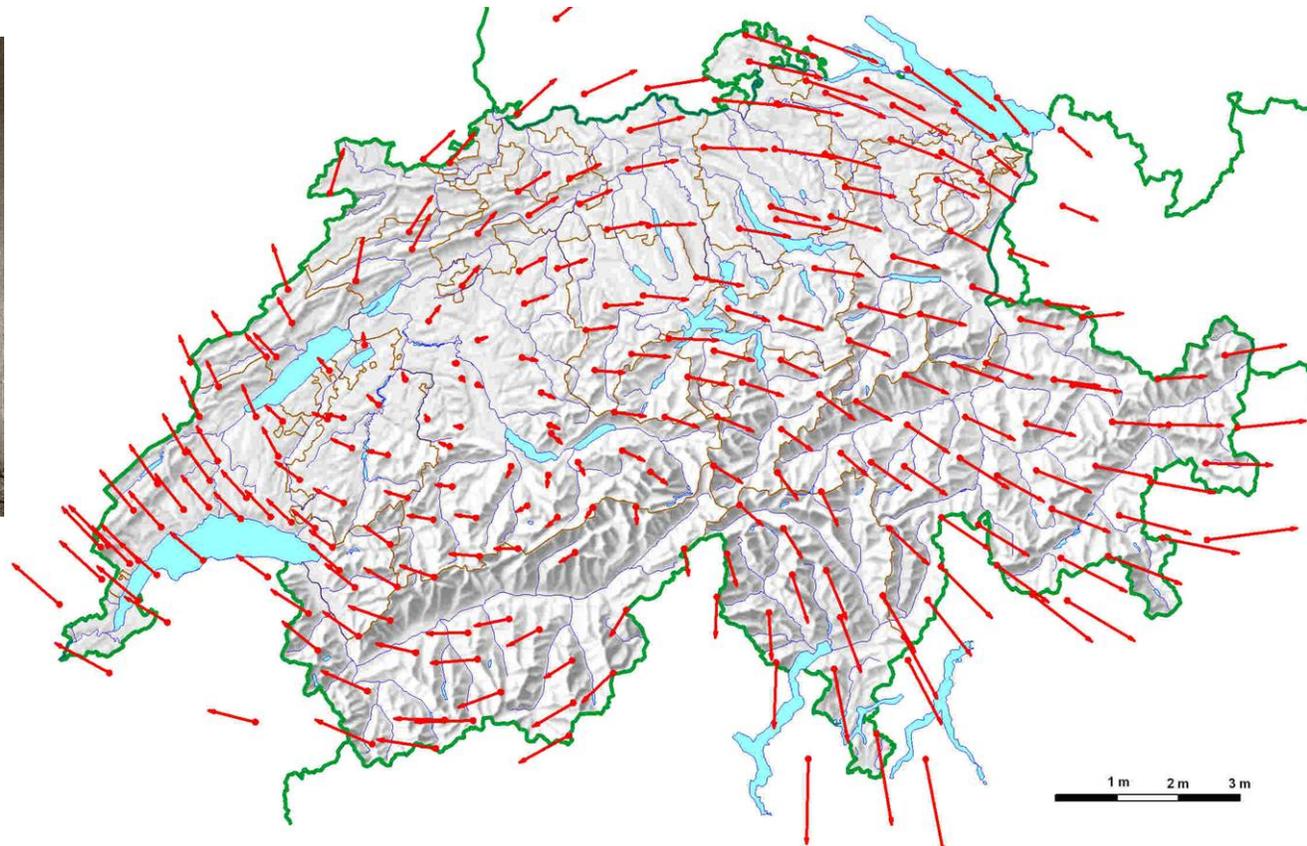


2020



Comparison LV03 - LV95

Switzerland “grew” by 3 meters

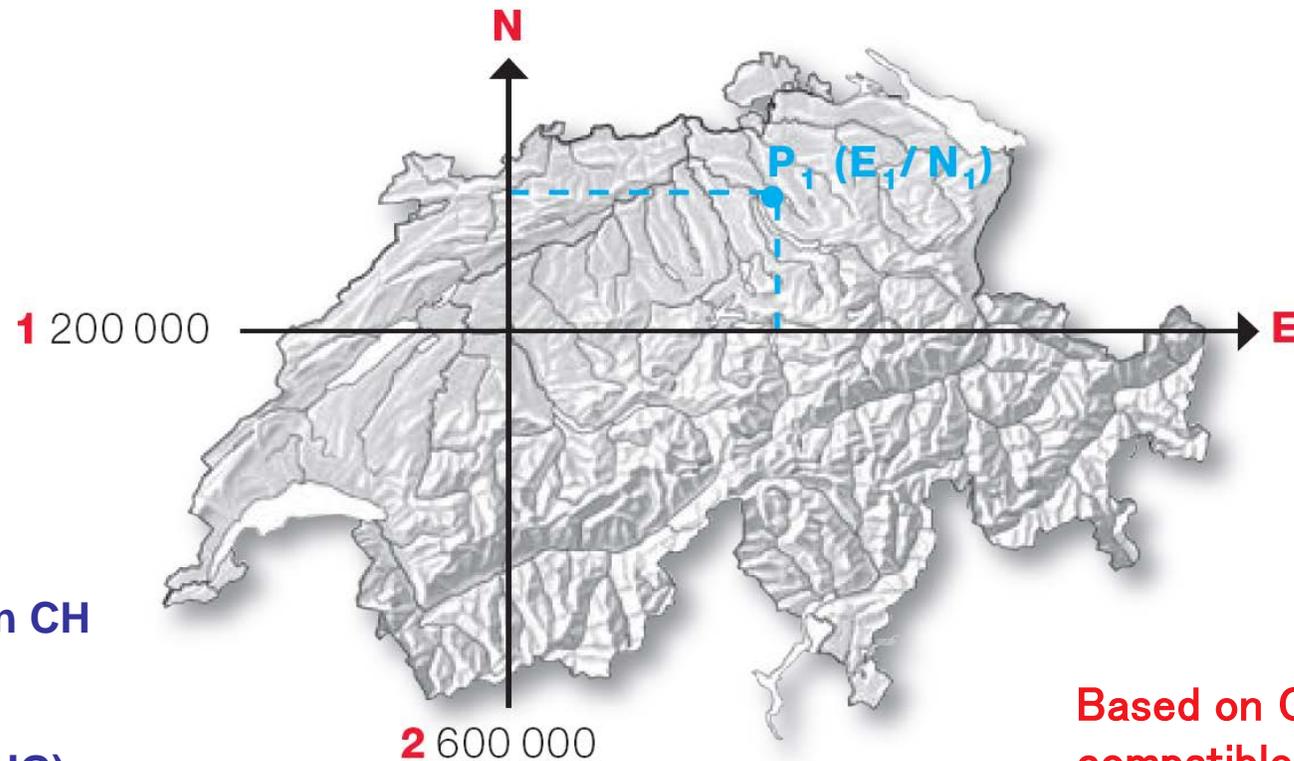




New reference system CH1903+ (frame LV95)

Satellite geodesy requested:

“New coordinates” 1'200'000 / 2'600'000 for all Swiss geodata (and also swisstopo maps)



Official coordinate system in CH
for all geodata (> 2020)

Law of Geoinformation (GeoIG)

Based on CHTRS95 →
compatible with Europe (ETRS)



News of a new coordinate system...

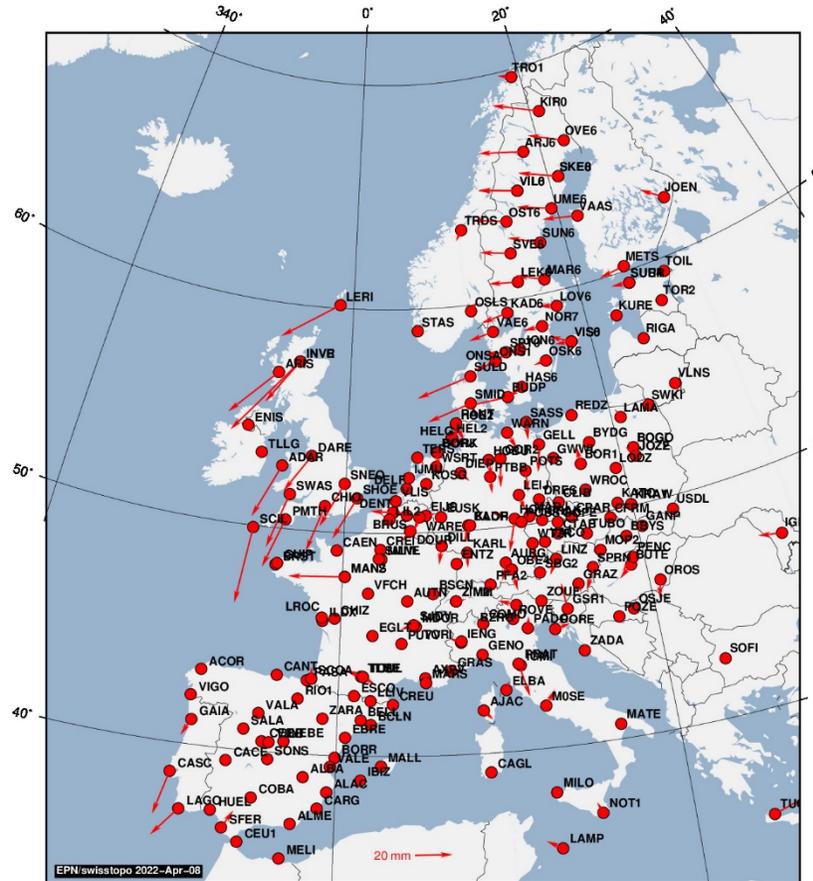


Long **transition phase** from
LV03 to LV95 coordinates:
1995 - 2020

© Carl Calvert (EUREF 2005, Vienna)

Reference frames in Europe

- Success story - high interoperability:
 - All countries aligned to ETRF (with slightly different reference frames and epochs)
 - ~1-2 cm agreement to a current scientific best solution
- AIUB and swisstopo involved in EUREF governing board since 20+ years (clearly over-represented 😊)



Status 2022: official national coordinates w.r.t scientific coordinates



COU	Frame Name
AUT	ETRF00
BEL	ETRF2000
BGR	ETRF2000
CHE	ETRF93
CZE	ETRF2000(R05), ETRF89
DEU	ETRF2000(R05,R08)
DNK	ETRF92
ESP	ETRF2005
EST	ETRF96
FIN	ETRF96
FRA	ETRF93, ETRF2000(R05)
GBR	ETRF97, ETRF2000
GRC	ETRF05
HRV	ETRF2000(R05)
HUN	ETRF00
IRL	ETRF89
ITA	ETRF2000
LTU	ETRF2000
LVA	ETRF2000
MDA	ETRF97
MKD	ETRF2000(R05)
NLD	ETRF2000(R05)
NOR	ETRF97
POL	ETRF2000(R05)
PRT	ETRF97
ROU	ETRF2000
SRB	ETRF2000(R05)
SVK	ETRF2000
SVN	ETRF05
SWE	ETRF97

Status 2016

Most reference frames are “static” with no intra-country movements



Permanent GNSS network AGNES



1998 – today

Automatic GNSS network for Switzerland (AGNES)

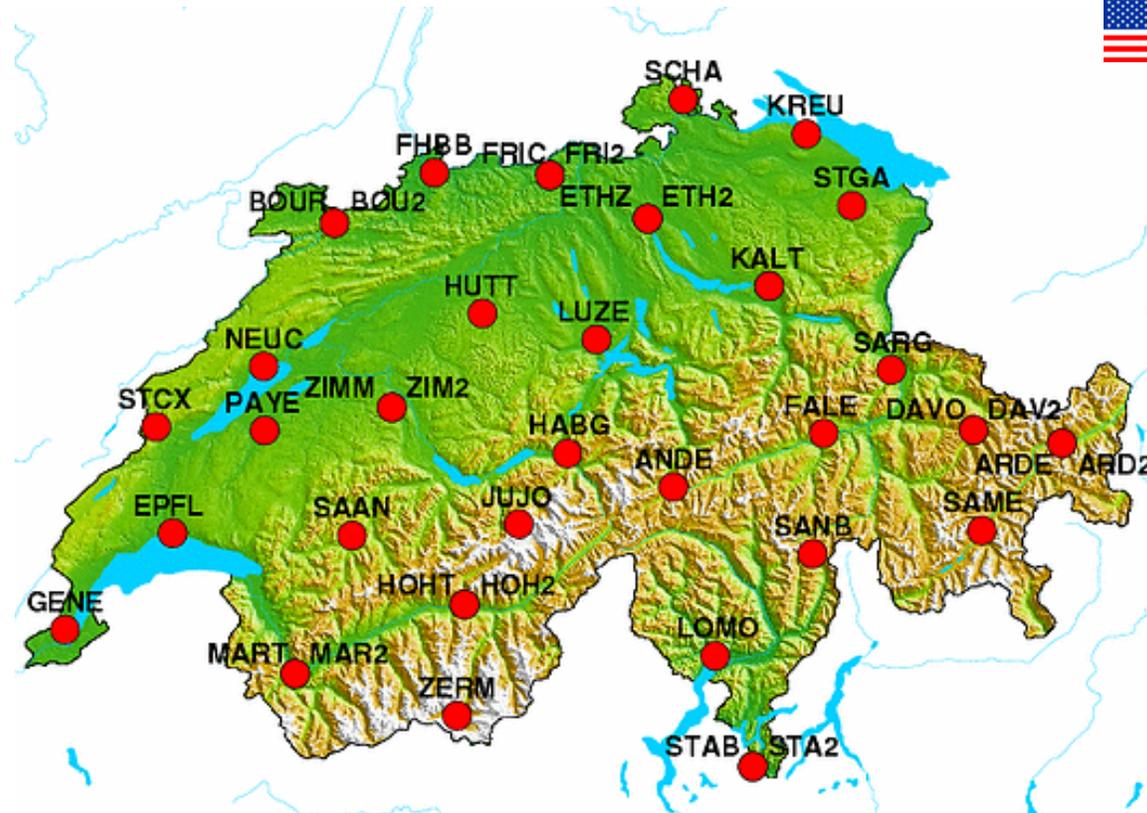
1991: 1 station, 1998: 6 stations, 2001: 30 stations

2007: 42 stations (GPS+GLO)

2016: Multi-GNSS (GPS+GLO+GAL+BDS)



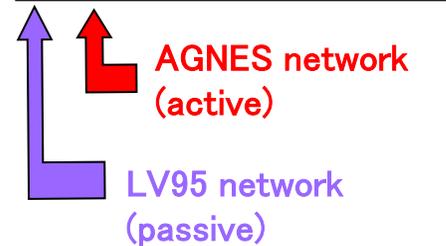
Satellite systems evolves, too



Continuous modernization of AGNES necessary



Backbone of geodetic infrastructure





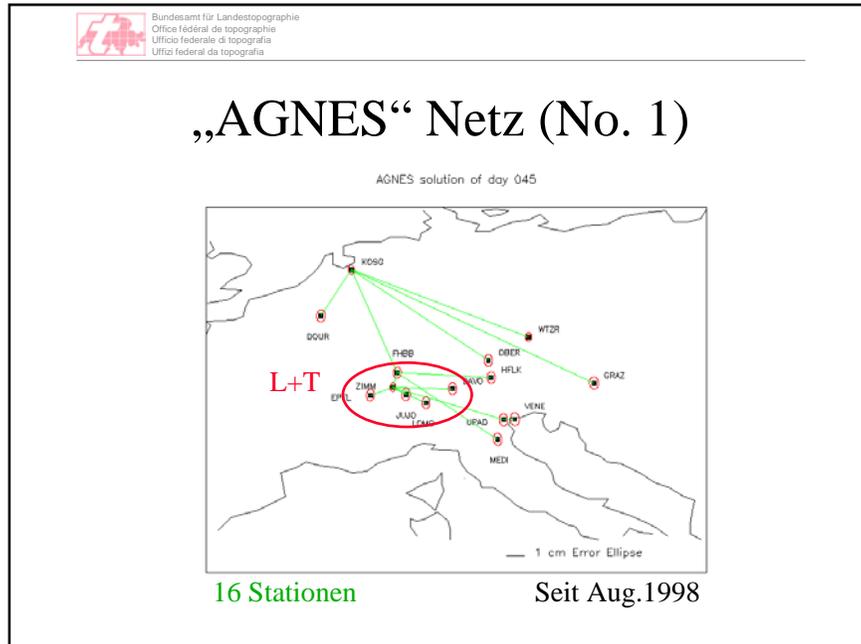
Installing AGNES



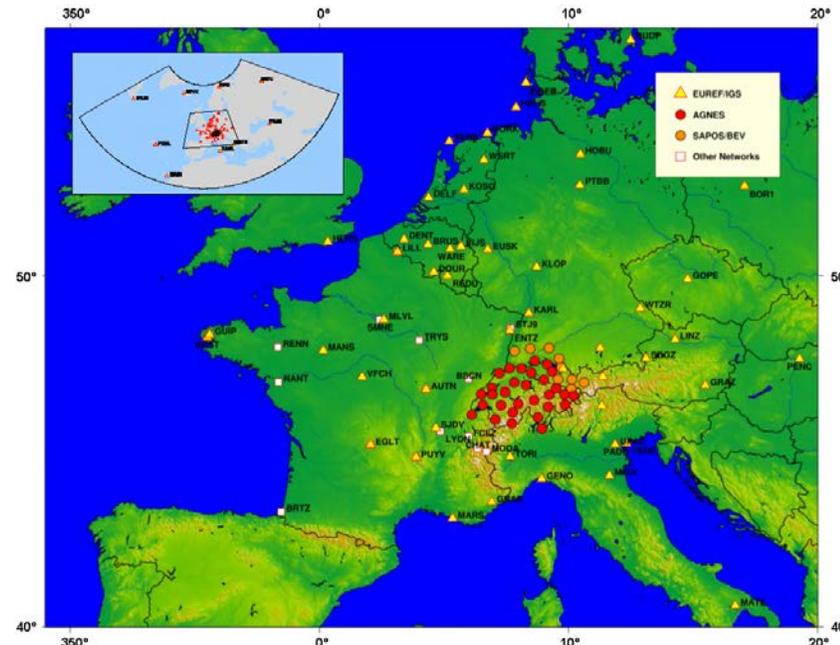


Analyses using Bernese GNSS Software at swisstopo

network (#stations)	availability	comments
EUREF sub-network (>60)	100 % daily	reference frame Europe 
AGNES + sub-network EUREF (>200)	100 % daily	reference frame Switzerland  Schweizerische Eidgenossenschaft Confédération suisse Confederazione Svizzera Confederaziun svizra
AGNES + sub-network EUREF (>200)	98 % hourly	monitoring + numerical weather prediction  Schweizerische Eidgenossenschaft Confédération suisse Confederazione Svizzera Confederaziun svizra 



1998



today



Hierarchical Permanent Networks



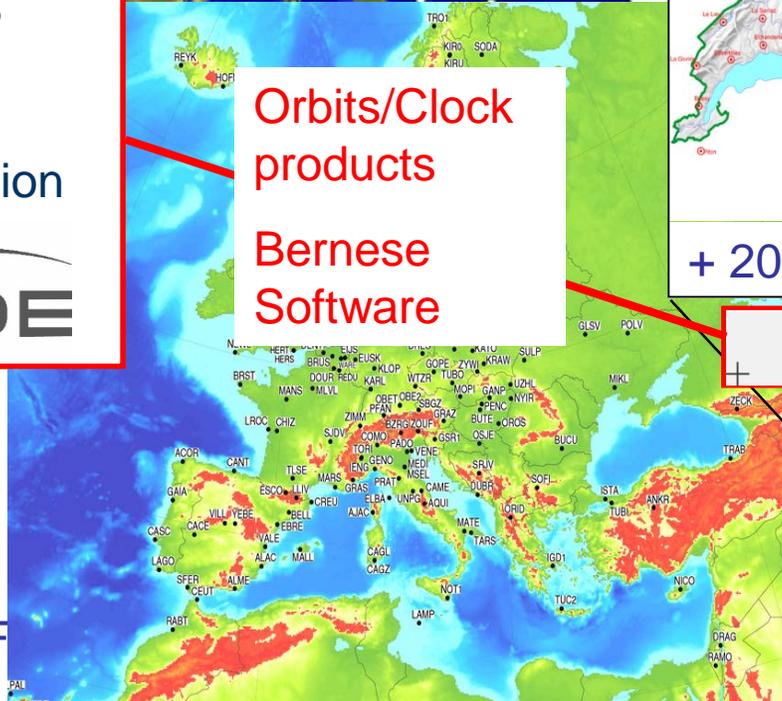
Univ. Berne: AIUB
Center for Orbit
Determination
(CODE): contribution
to IGS



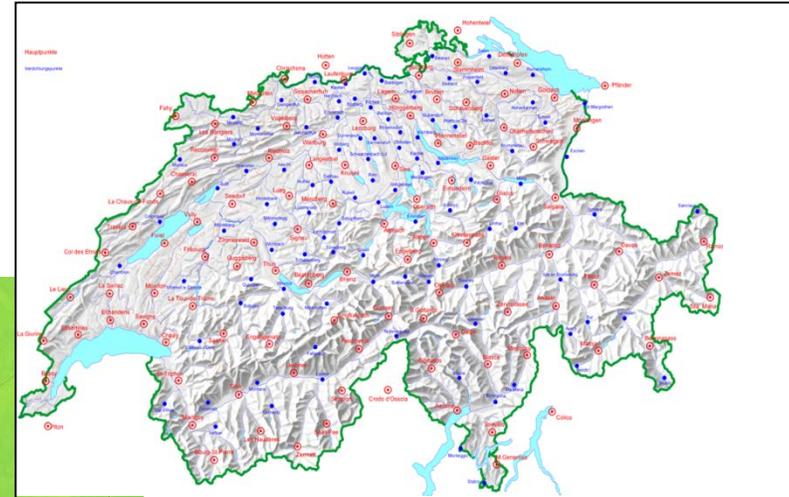
Global: IGS
(500 stations)

Continental: EUREF
(400 stations)

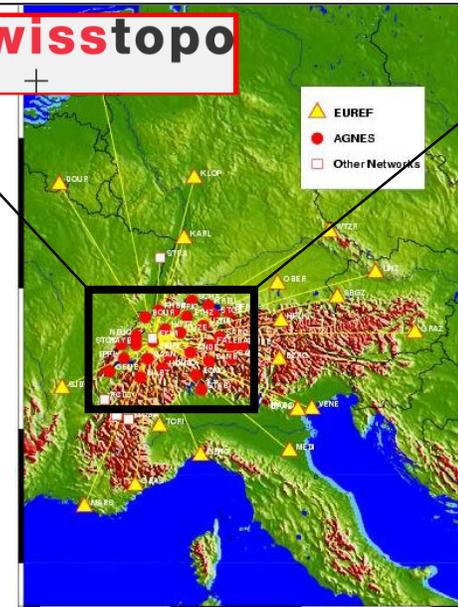
Orbits/Clock
products
Bernese
Software



National: AGNES
(42 stations)



+ 200 LV95 control points; not perm.



Densification: most
consistent
processing required



Bernese Software at European Analysis Centres

- 14/16 analysis centres are using **Bernese Software BSW**
- current version update 5.2 -> 5.4 (after 10 years) showed clearly that ACs are waiting for that update
- Update also to the most recent product lines, now!
- → AIUB/CODE is a critical infrastructure for mapping agencies in Europe

	Analysis Centre Description	Software	GNSS
	ASI Centro di Geodesia Spaziale G. Colombo, Italy	GipsyX 1.6	GRE
	BEK Bavarian Academy of Sciences & Humanities, Germany	BSW 5.2	GRE
	BEV Federal Office of Metrology and Surveying, Austria	BSW 5.2	GRE
	BKG Bundesamt für Kartographie und Geodäsie, Germany	BSW 5.2	GRE
	COE Center for Orbit Determination in Europe, Switzerland	BSW 5.3	GR
	IGE Instituto Geografico Nacional, Spain	BSW 5.2	GRE
	IGN Institut Géographique National de L'information Geographique et Forestière, France	BSW 5.2	GR
	LPT Federal Office of Topography swisstopo, Switzerland	BSW 5.3	GRE
	MUT Military University of Technology, Poland	GG 10.71	GE
	NKG Nordic Geodetic Commission, Lantmateriet, Sweden	BSW 5.2	GRE
	RGA Republic Geodetic Authority, Serbia	BSW 5.2	GRE
	ROB Royal Observatory of Belgium, Belgium	BSW 5.2	GRE
	SGO Lechner Knowledge Center, Hungary	BSW 5.2	GRE
	SUT Slovak University of Technology, Slovakia	BSW 5.2	GRE
	UPA University of Padova, Italy	BSW 5.2	GRE
	WUT Warsaw University of Technology, Poland	BSW 5.2	GRE

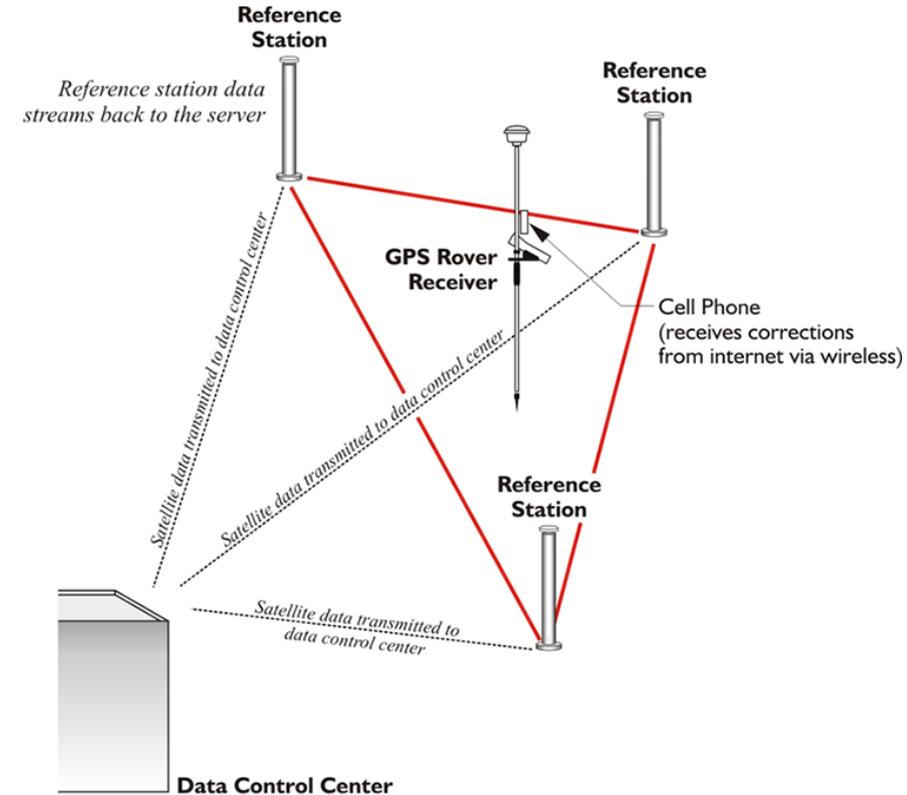
Status 2020



AGNES in real-time via mobile phone

Positioning service **swipos** (since 2001)

- accuracy: ca. 2-3 cm hor., 4-5 cm vertically
- 3600 paid licenses (2021)
- Applications in surveying, geoinformation, agriculture, ...



Source: *GPS for Land Surveyors*

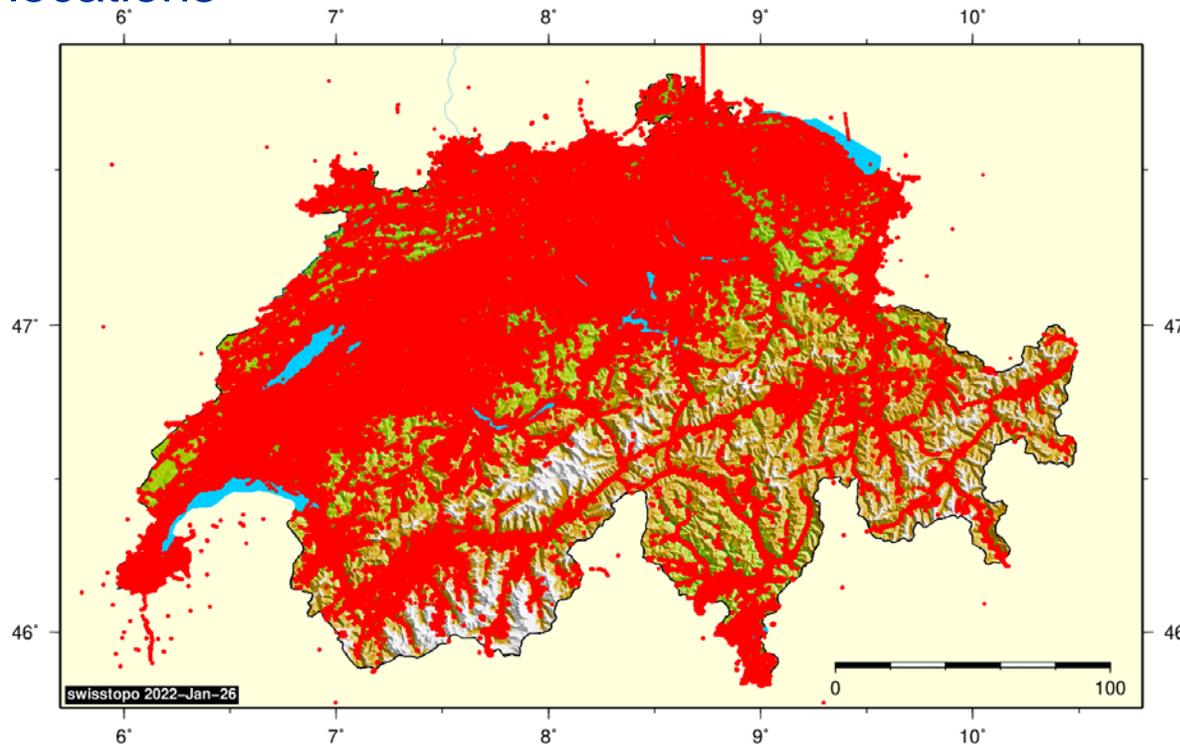


swipos user statistic 2021

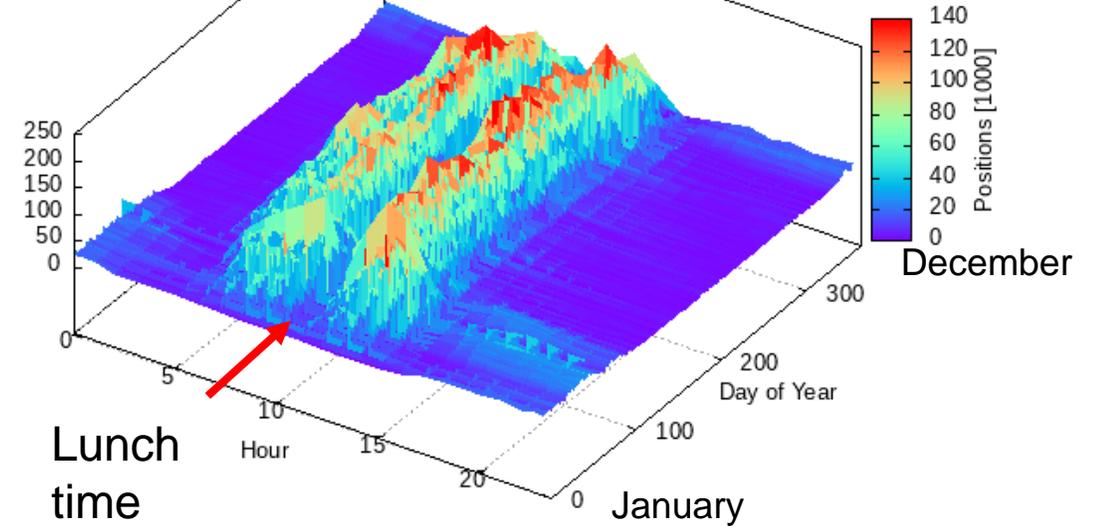
- 222'000'000 positions

- Corona lock-down not visible
- Wednesday is most productive day of the week
- Lunch time break

user locations
2021



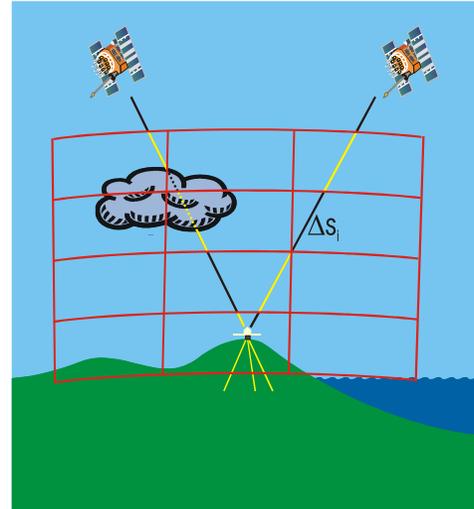
Day-time
use 2021



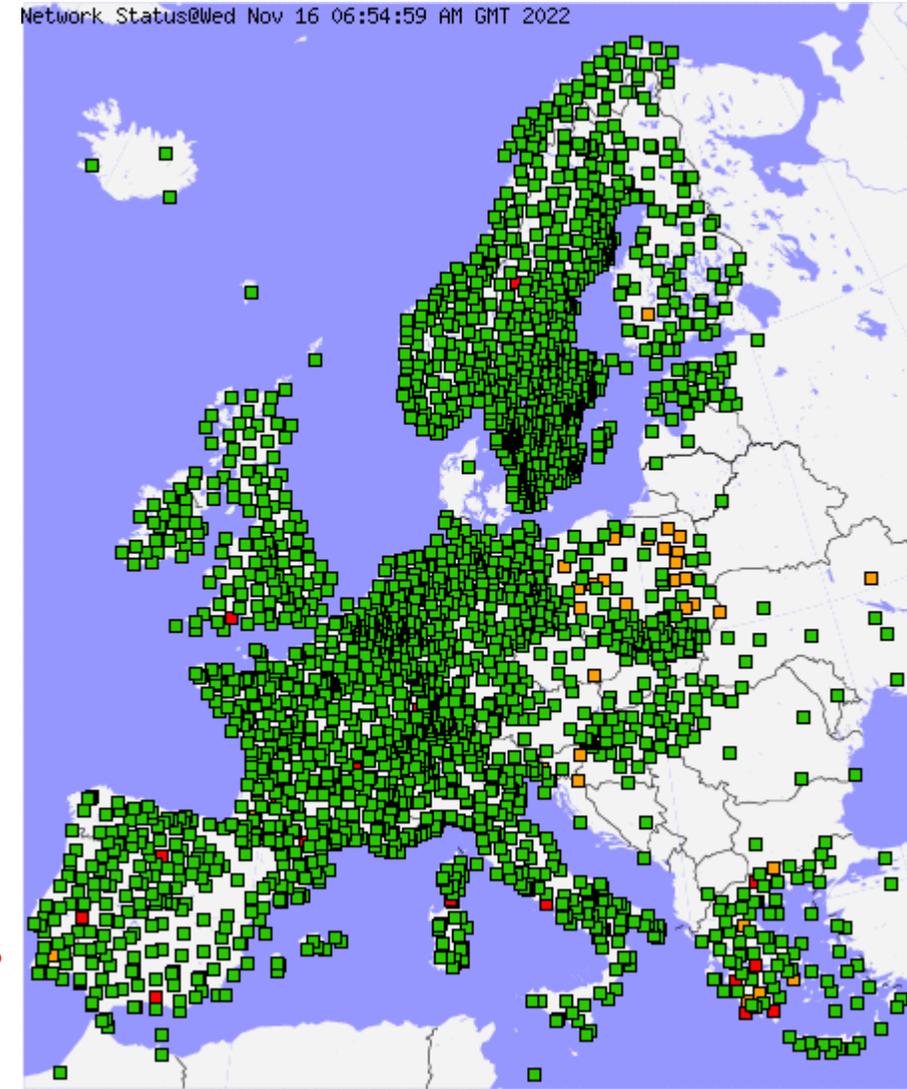


GNSS-Meteorology

- Humidity information extracted from GNSS analyses is sent to EU meteo data bases and to MeteoSwiss **every hour**
- Additional source for **numerical weather prediction**
- > 15 Analysis centres,
> 4000 GNSS stations
> 20 years
> 10 meteo institutions as user
- **powered by AIUB with software + CODE ultra rapid products**



Network Status@Wed Nov 16 06:54:59 AM GMT 2022



ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

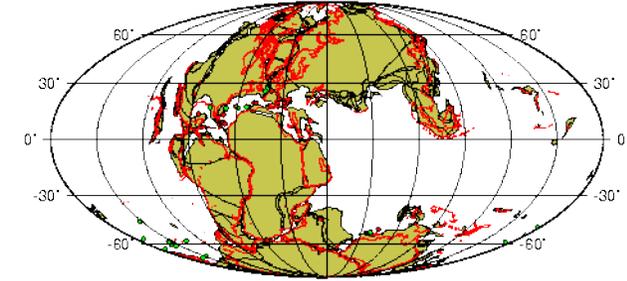


 Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation

 **EUMETNET**
The Network of European Meteorological Services



“Moving” Reference - nothing is fix



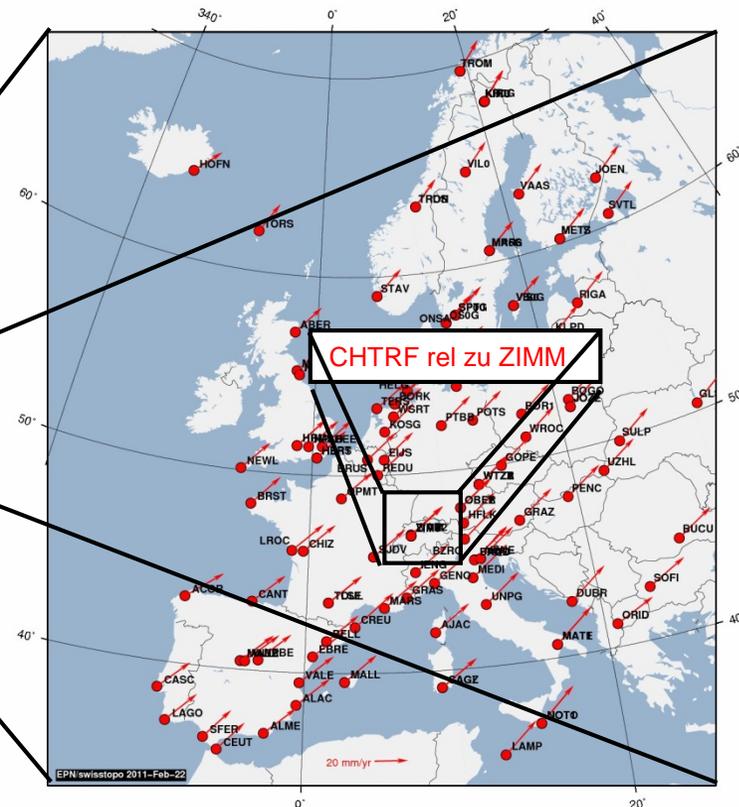
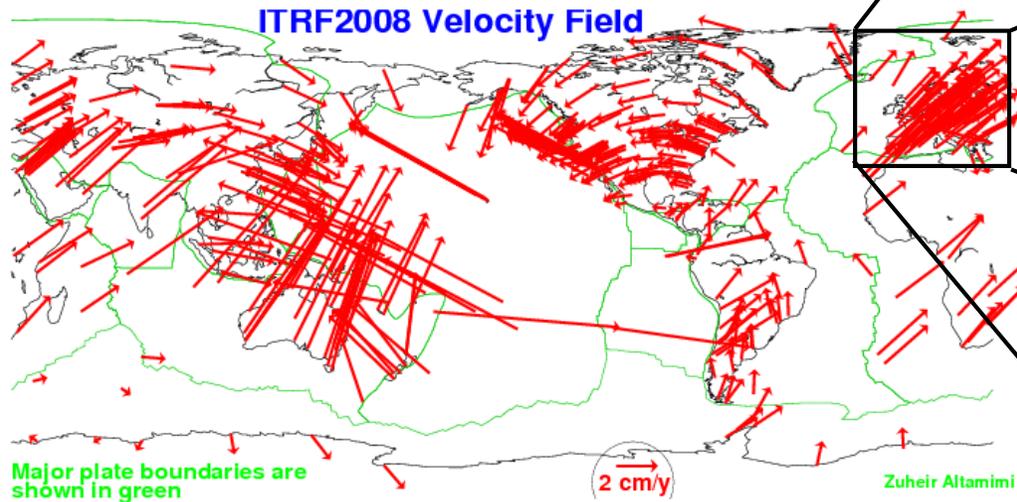
150 My Reconstruction ODSN, Geomar

International

European

CH-Swiss

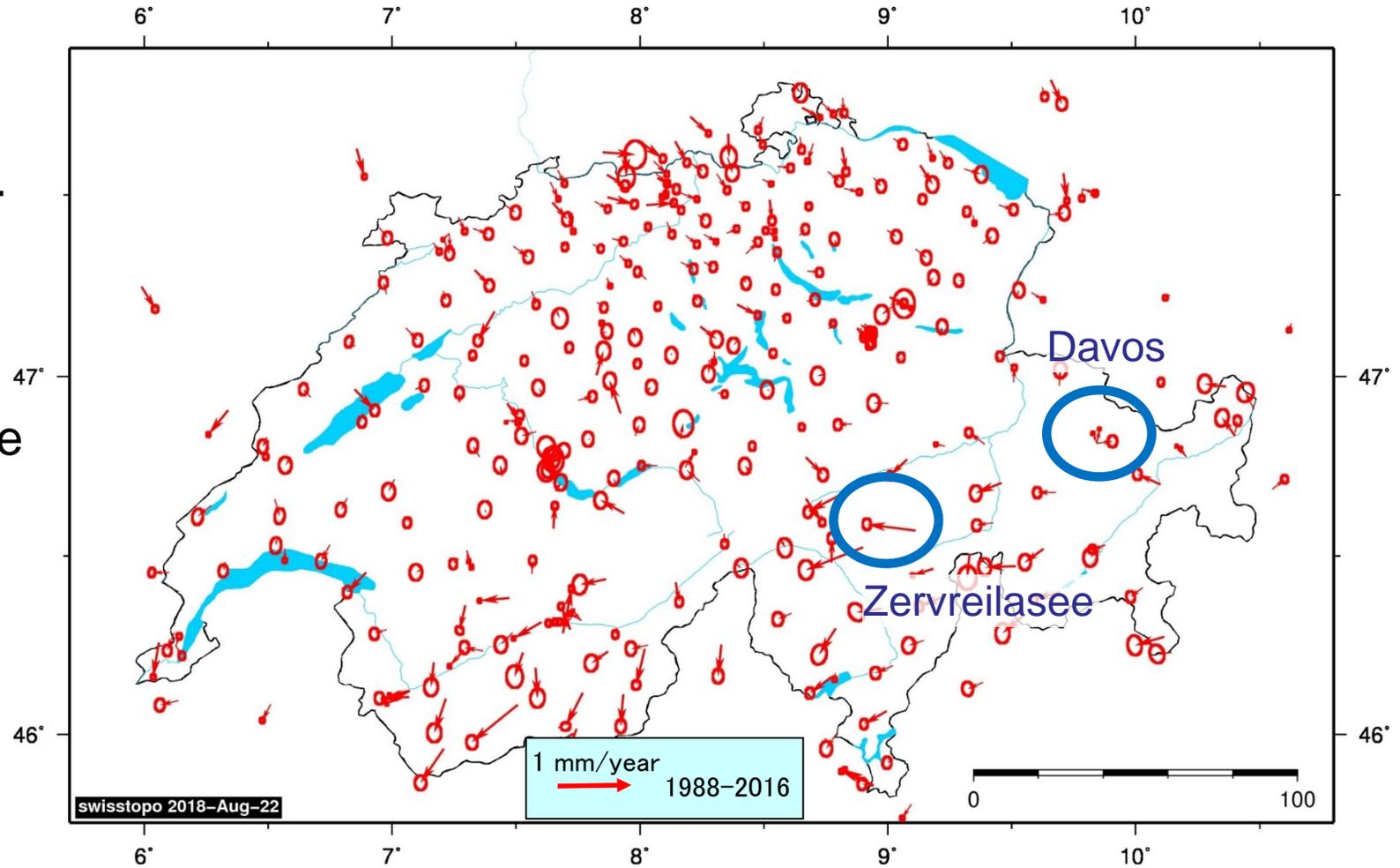
- Europe: 2.5 cm / year towards north-east (ITRS)
- ETRS89 defined as **no longer moving**
- CHTRS95 linked to ETRS89 via Zimmerwald





Movements in CH: Velocity Field CHTRF2016

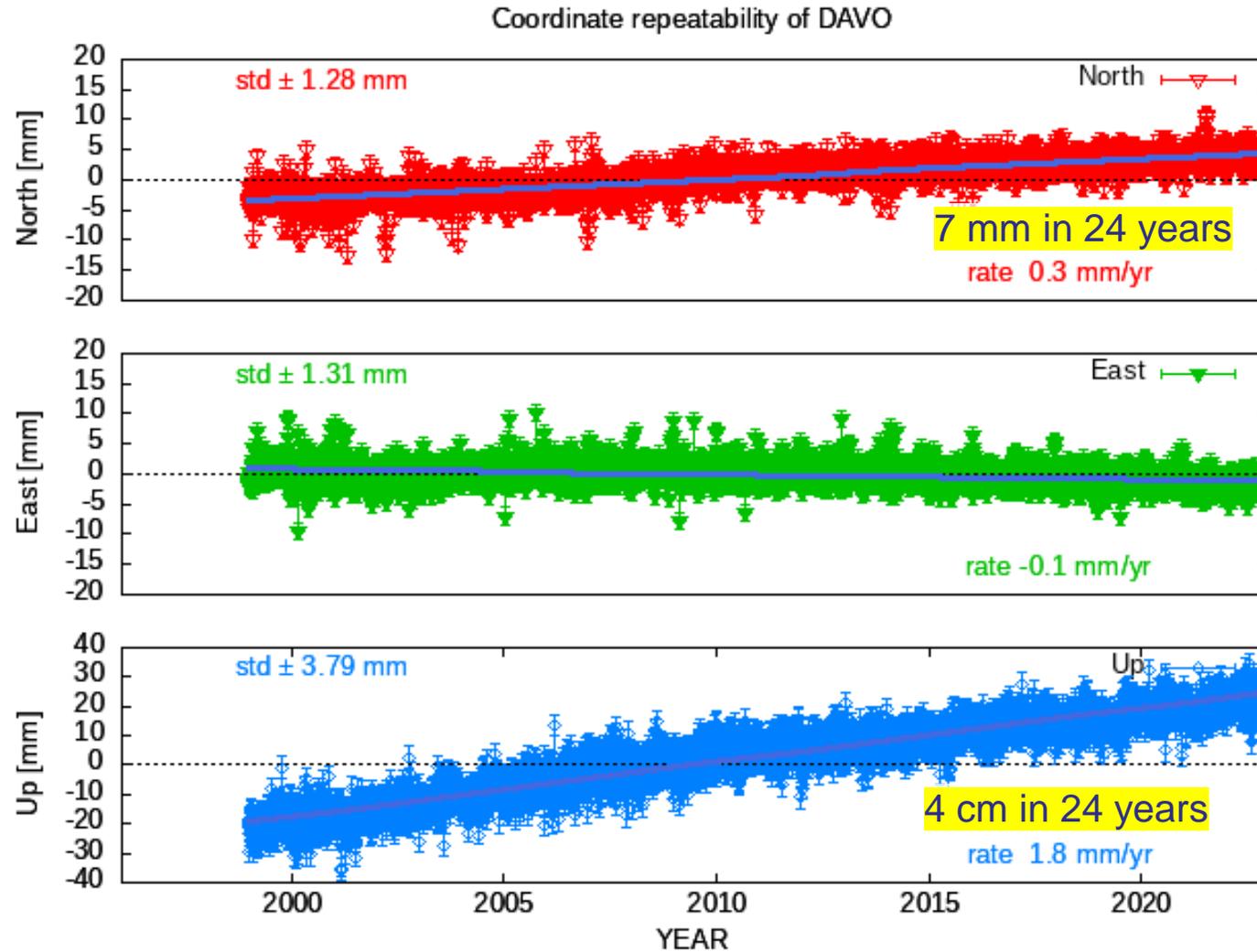
- **Nothing is fix also in CH...**
- We measure too precise...
- We have timeseries ~ 30 yrs...
- 1-2 cm accuracy level of LV95 exceeded after certain time...
(1 mm/yr: 3 cm in 30 years)
- Changing coordinates with time not convenient for geo-reference...
- ... but very interesting for geology and tectonics
- **Challenge for reference frame maintenance in future**



with respect to Zimmerwald



Repeatabilities: Example Davos

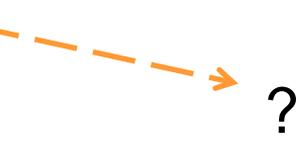
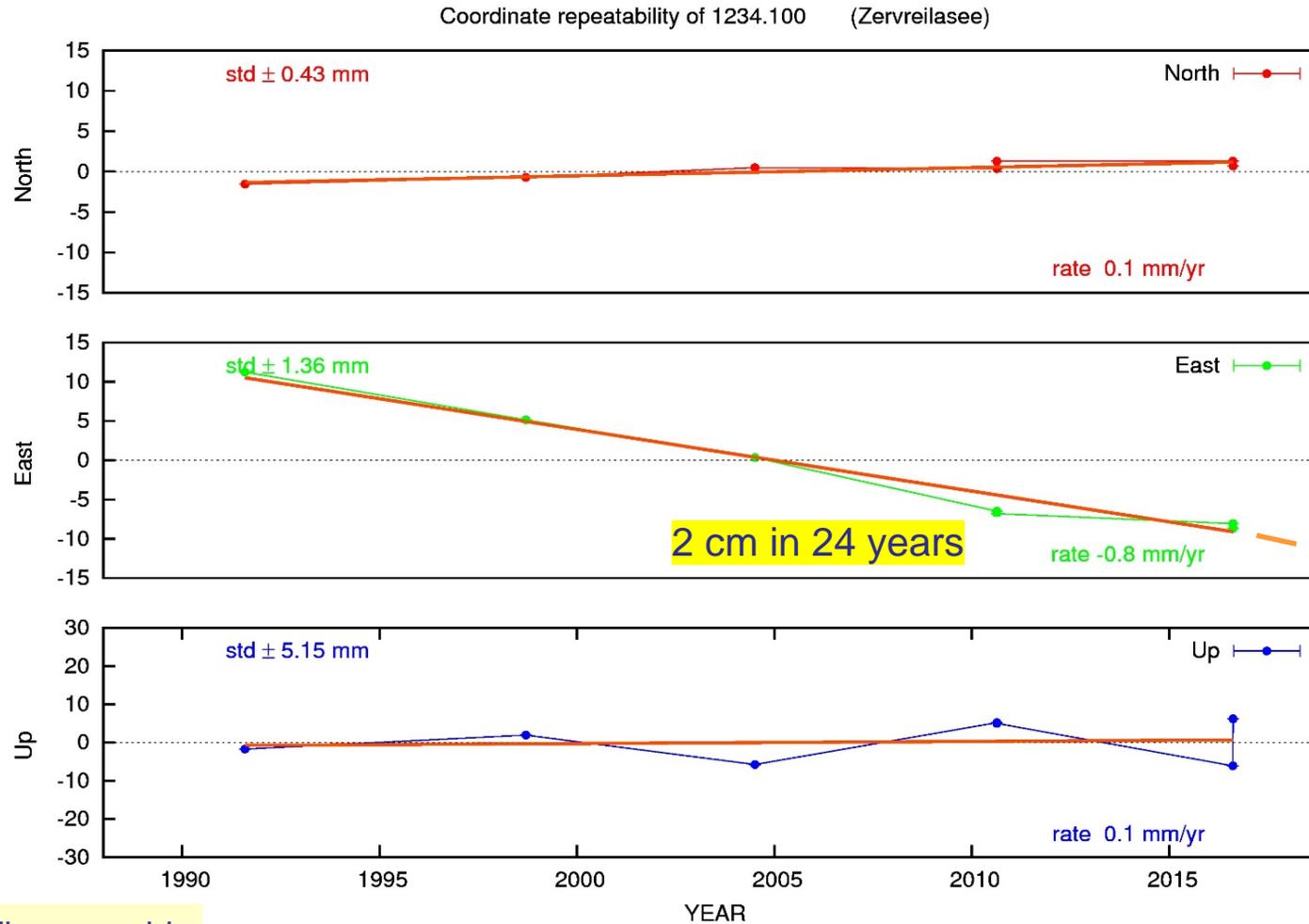


Alpine Uplift 1.8 mm/yr w.r.t Europe
(w.r.t ZIMM 0.7 mm/yr)

16/11/22 04:45



Repeatabilities: Example Zervreilasee



with respect to Zimmerwald

Results in working progress



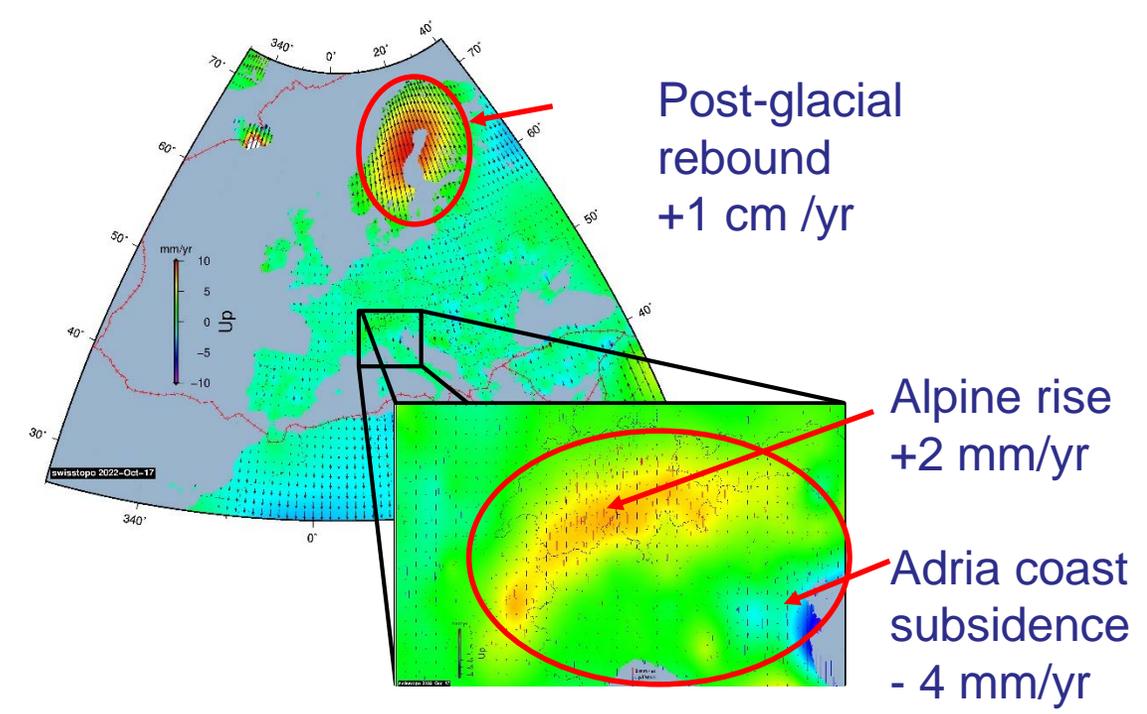
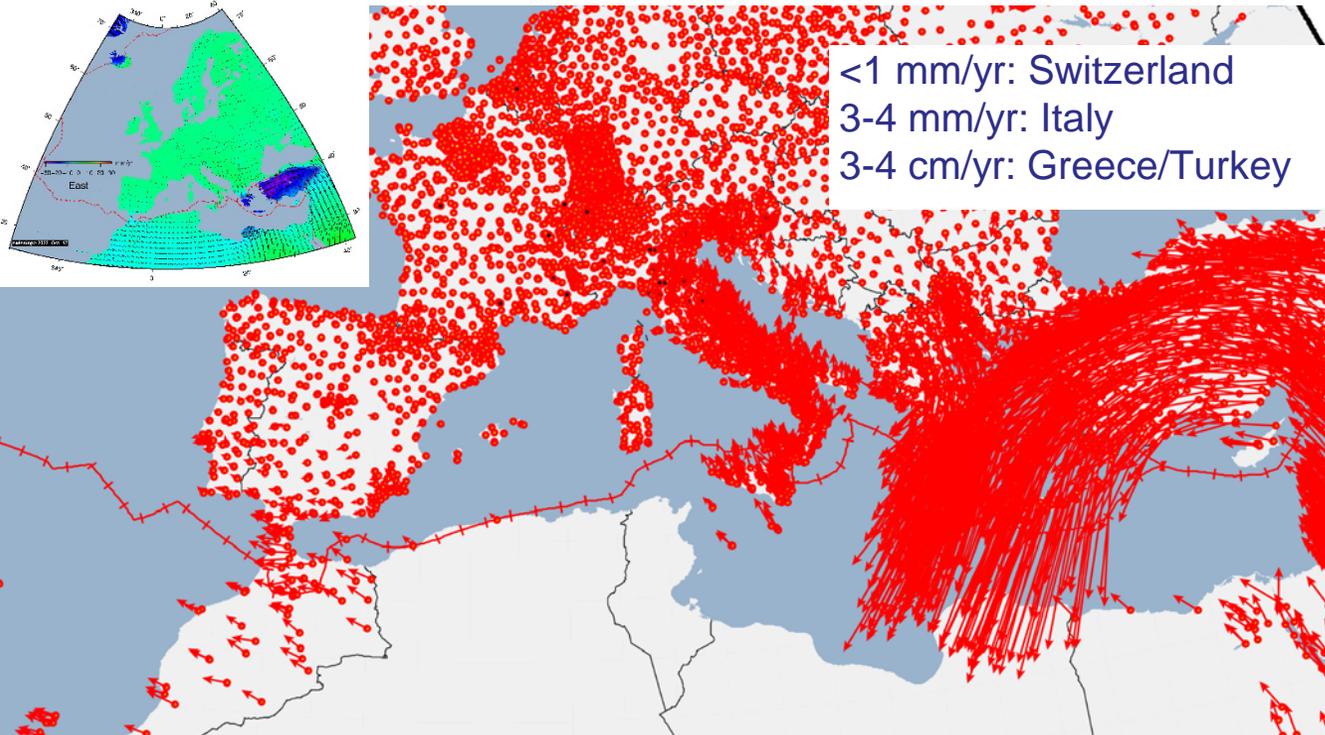
Movements in Europe

- EUREF working group

>30 contributors, since 2017
~8000 station velocities
~0.2-0.3 mm/yr hor. standard deviation
~0.4-0.7 mm/yr up std

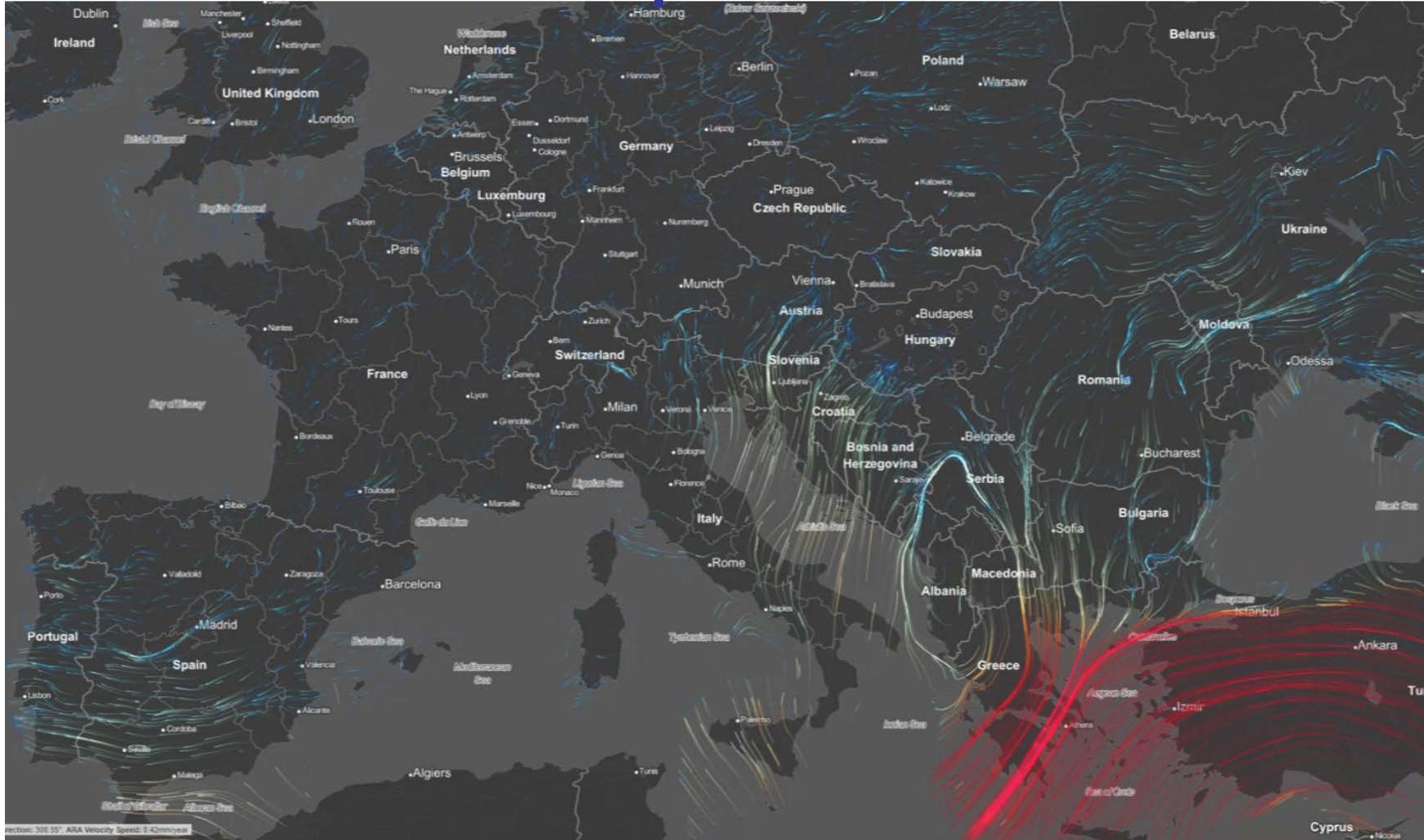
horizontally

vertically





Movements in Europe as wind field animation





AIUB – swisstopo: conclusions

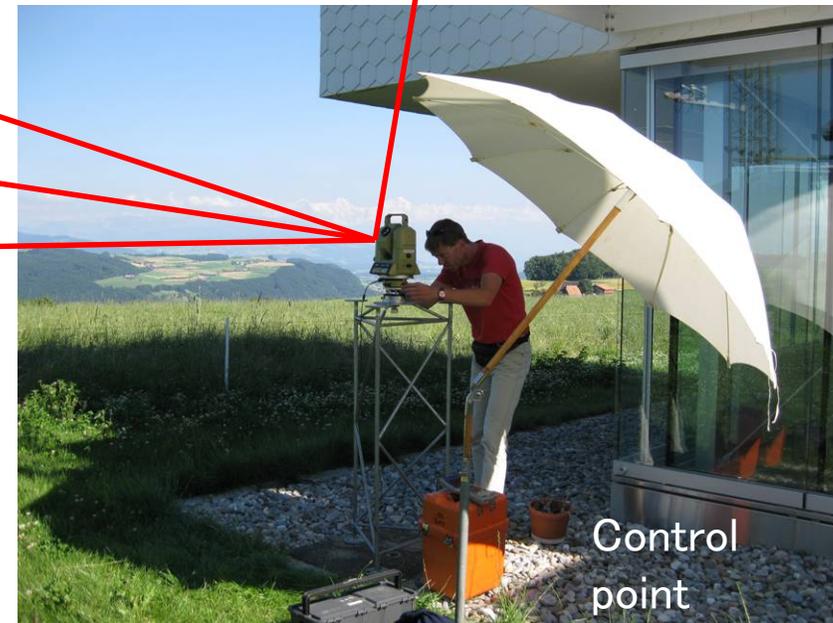
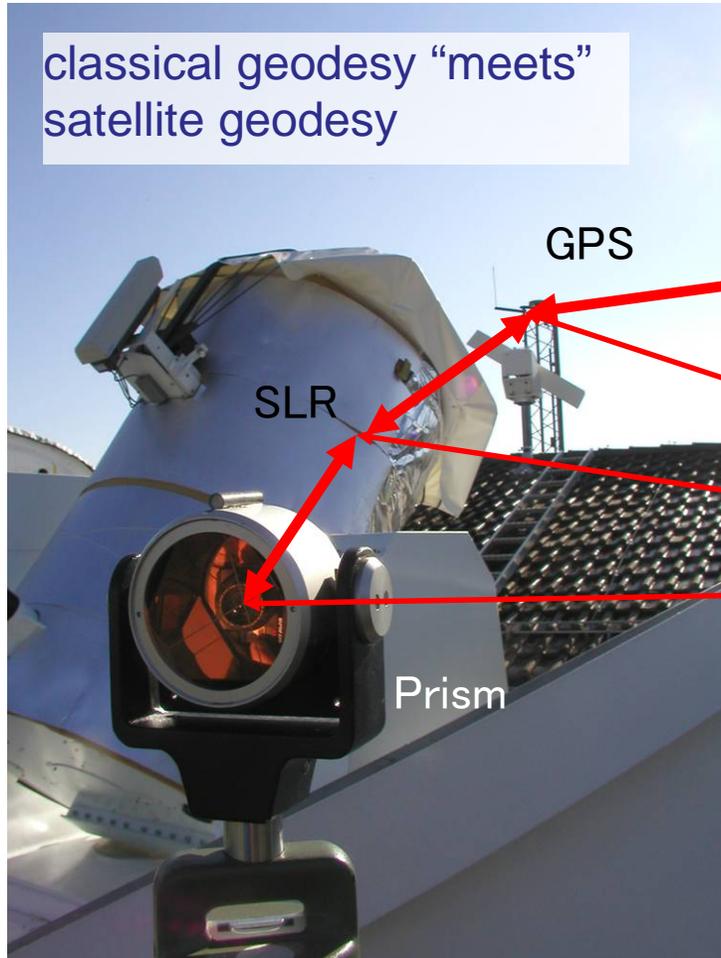
- astronomy was always “first”
- wide common basis + sharing synergies, individual applications on top
- getting the maximum with optimal usage of resources
- close appreciated personal relations

- AIUB:
 - perfectly in shape for a 100-year anniversary
 - contributions highly acknowledged and know-how internationally outstanding
 - leading organization in various fields of satellite geodesy since decades and thanks to the many collaborators in all these years
 - **products and software evolved to critical infrastructure in the area of reference frame maintenance**





Thanks for your attention



Local tie measurements each 6 years