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Realization of ETRS89: Alternatives, future concepts

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ETRS89 Definition

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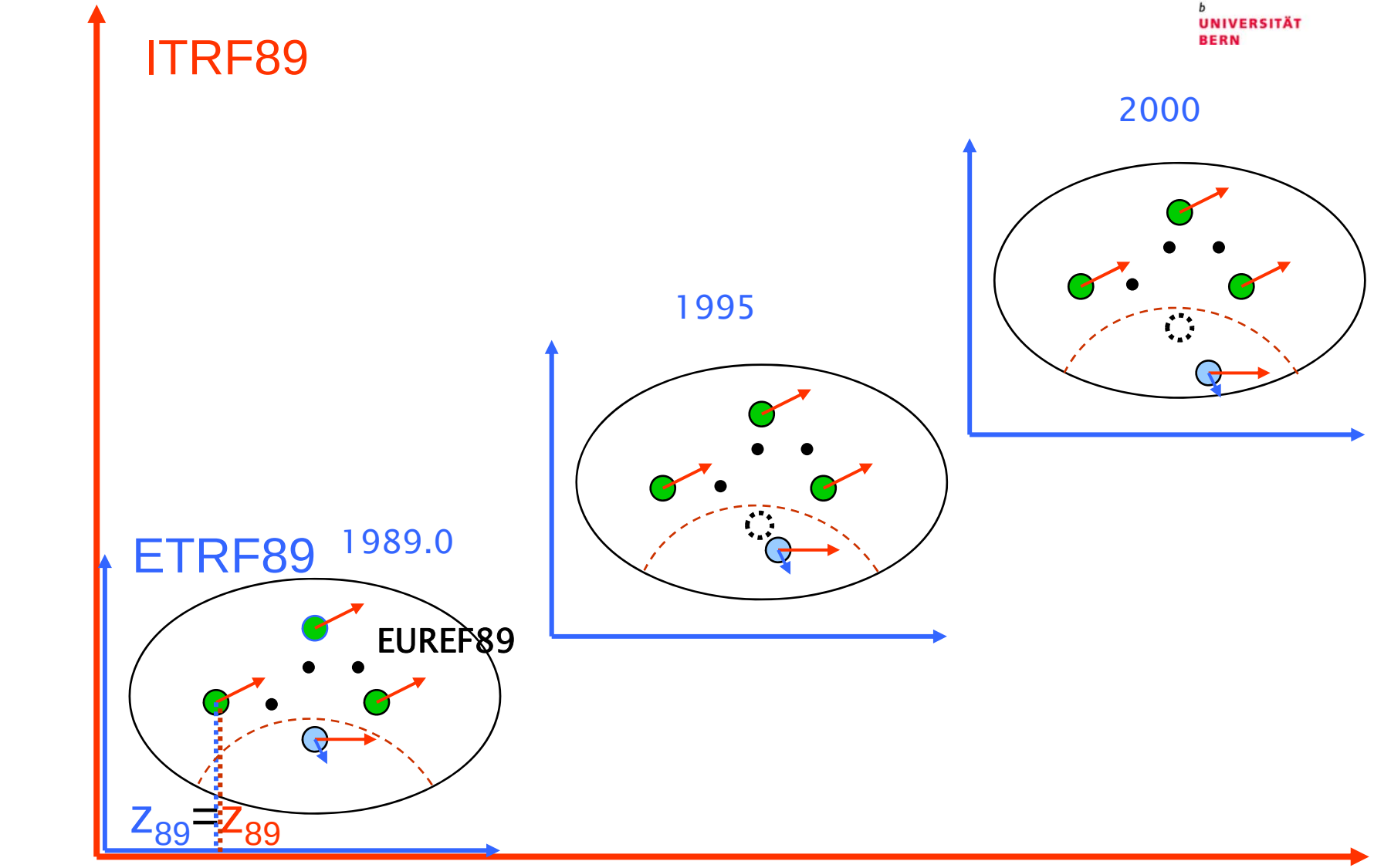
- Resolution No 1, Firenze 1990
  - "recommends that the system to be adopted by EUREF will be *coincident with ITRS* at the epoch 1989.0 and *fixed to the stable part* of the Eurasian Plate and will be known as European Terrestrial Reference System 89 (ETRS89)"
  - "accepts that … for most applications, the coordinates will have no time variation"
- Resolution No 1, Bern 1992
  - "recommends that this solution *(Bernese solution of EUREF GPS 1989 campaign)* be accepted as the current realiastion of the ETRS89 under the name of EUREF89"

Conclusions from the definition

- "*fixed to the stable part*" implies that the ETRS is rotating "somehow" with the Eurasian plate
- "*no time variation*" implies the desire to avoid changes in time of the positions of European stations within the *stable part*
- The definition does not say anything about the realizations nor the reference epoch of the realizations

- The first realization (EUREF89) was based on SLR/VLBI-derived "fiducial stations" given in ITRF89 at epoch 1989.0

First realization of ETRS89



Most simple realization *based on a ITRFyy*

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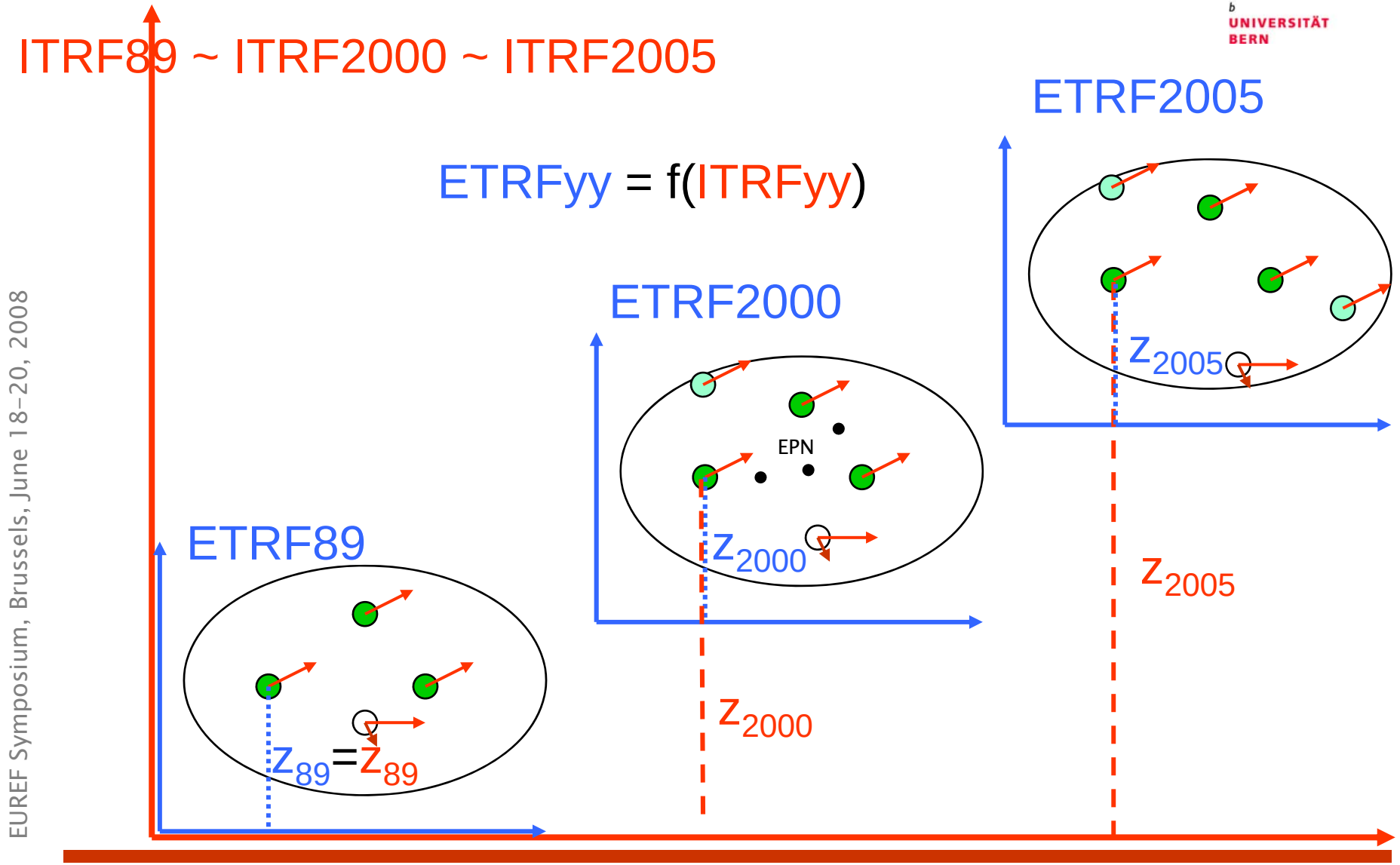
Just fulfilling the requirement "fixed to the stable part":

- Take a realization of ITRS → ITRFyy
- Determine "somehow" rotation pole and rotation rate dr/dt of the Eurasian plate from this solution
- Select a reference epoch for the realization
- Move all European reference stations into the reference epoch by their ITRFyy-velocities
- Rotate them by the rotation angle

  $$r = dr/dt * (t_{ref} - 1989.0)$$

  into the ETRS89 → ETRFyy

Later Realizations of ETRS89



Remarks to the *Most simple realization*

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- Each realization is completely independent from earlier realizations (unless the ITRFyy datum depends on earlier datums)
- In the early days the applied rotation was based on plate motion models
- Changes/uncertainties in the applied rotation *rate* will become more disturbing with time
- Changes/uncertainties related to the datum realizations of subsequent ITRFyy may also lead to significant variations of positions in the ETRFyy counterpart

Improvements (1)

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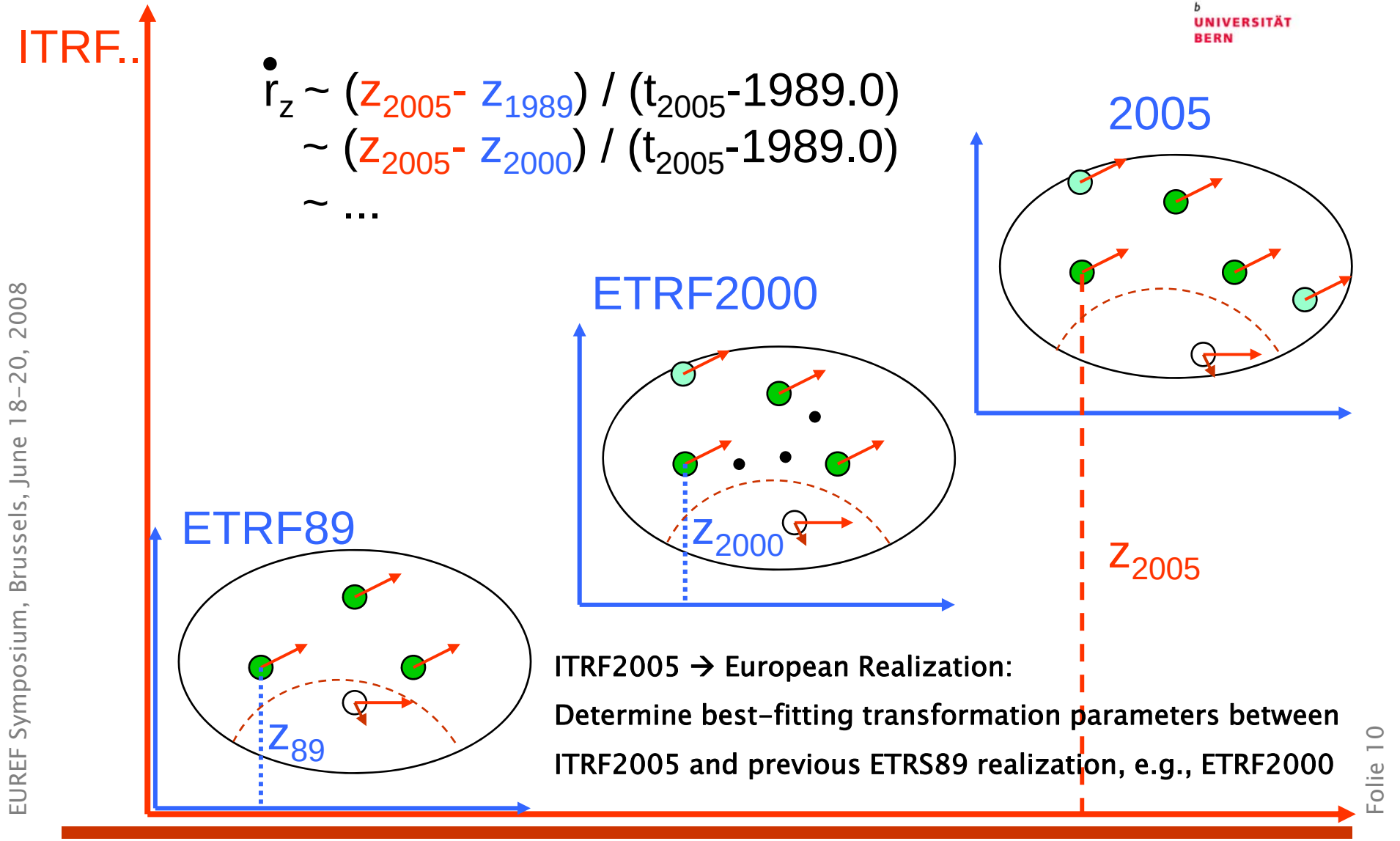
- Include additional parameters into the transformation ITRFyy→ETRFyy
  - E.g., to attenuate effects from changes in the datum
  - Mainly translations, Zuheir also includes translation rates
- Various ways how to determine such additional parameters
  - Proposal by Zuheir to base these additional parameters on the values determined in the "memo", i.e. based on global analysis

Improvements (2)

- Refer all subsequent realizations ETRFyy to a reference realization, e.g., ETRF2000, i.e. extract and combine parameters from the memo in a way that they take into account the datum differences to ETRF2000 (actually between ITRFyy and ITRF2000)

Remark: The "memo values" are results from the global analysis, they are not specifically optimized for Europe

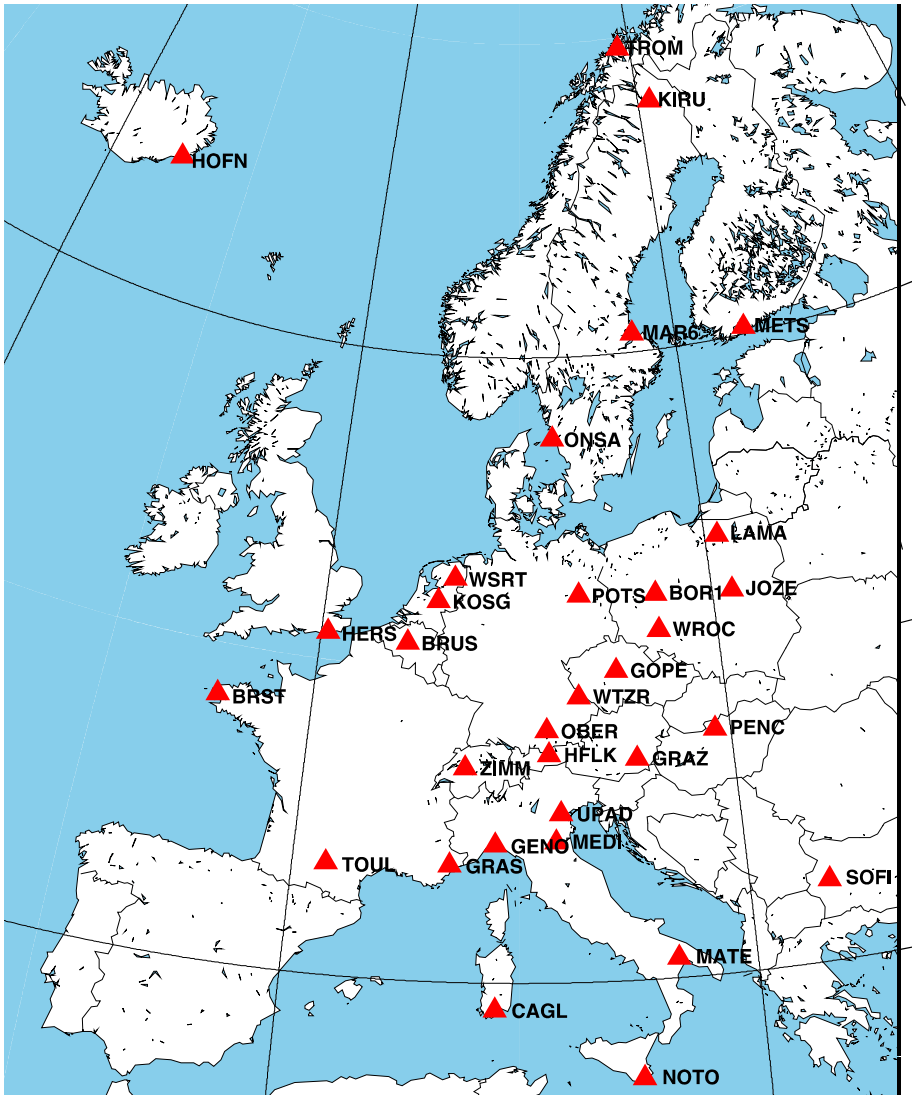
Alternative Realization of ETRS89



Rigorous Solution

- Select a reference realization ETRF00, e.g., ETRF2000
- Select max number of European stations that
  - are present in both ETRF2000 and ITRFyy with sufficiently long history
  - lie in the "stable part" of Europe
- Move the stations into common reference epoch using respective velocities (ETRF2000 and ITRFyy)
- Determine Helmert transformation parameters between the two sets of coordinates (least squares adjustment)
- Introduce the smallest possible number of parameters, e.g., 3 translations, 3 rotations and r.rates and
- Include additional derivatives, if necessary

Least-squares estimation of transformation parametes



31 defining points used for the estimation of transformation parameters between ITRF and ETRF

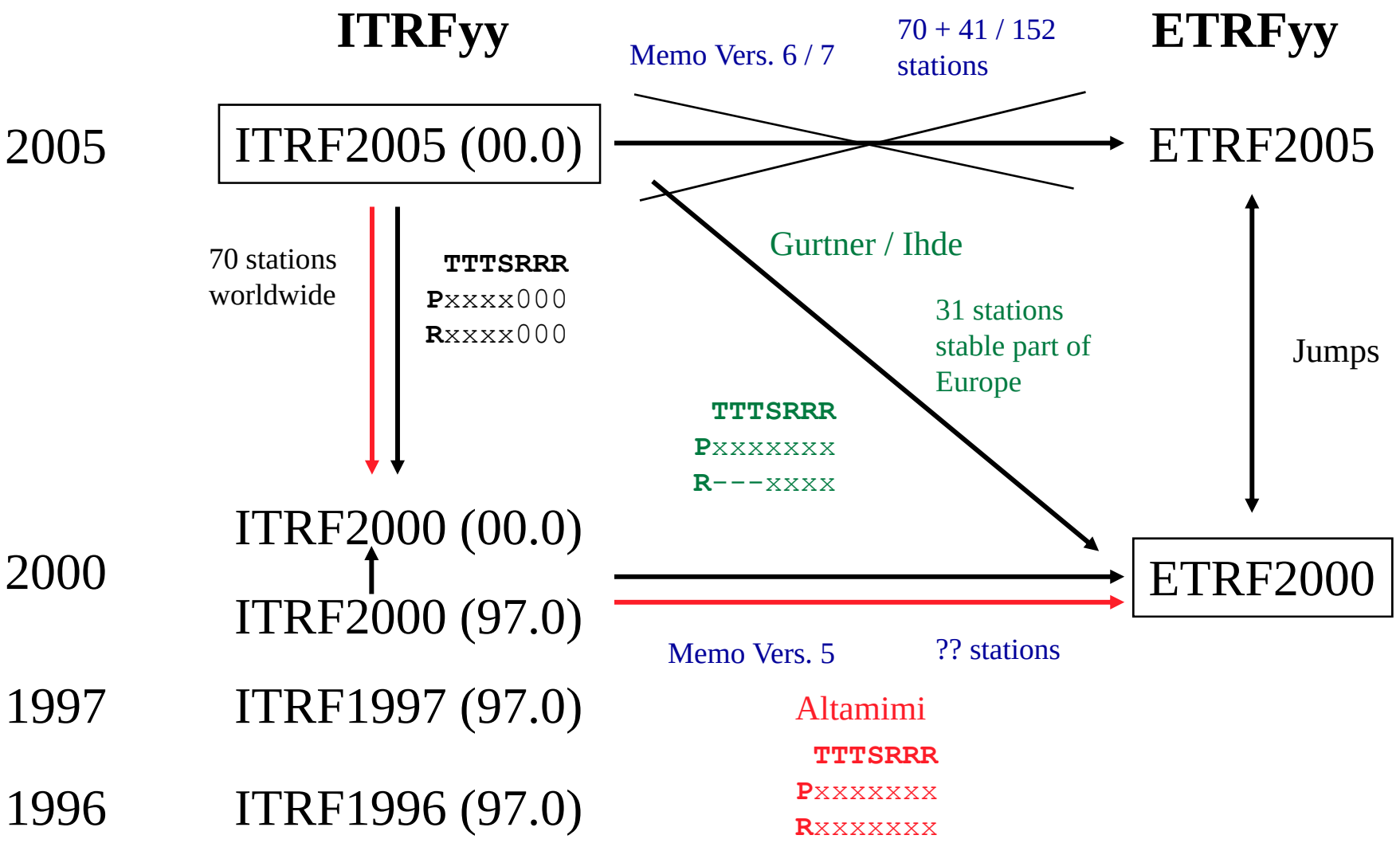
i.e . without
HOFN on Island
KELY and THU1 on Greenland
NYAL on Spitsbergen

Transformation parameters from ITRF2005 Ep. 2000.0 to ETRF2000 Ep. 2000.0

T_x mm	T_y mm	T_z mm	D 10^{-9}	R_x mas	R_y mas	R_z mas	sigma0 mm
43 ±3	46 ±6	-46 ±3	1.0 ±0.5	0.7 ±0.2	5.8 ±0.1	-8.8 ±0.1	2.5

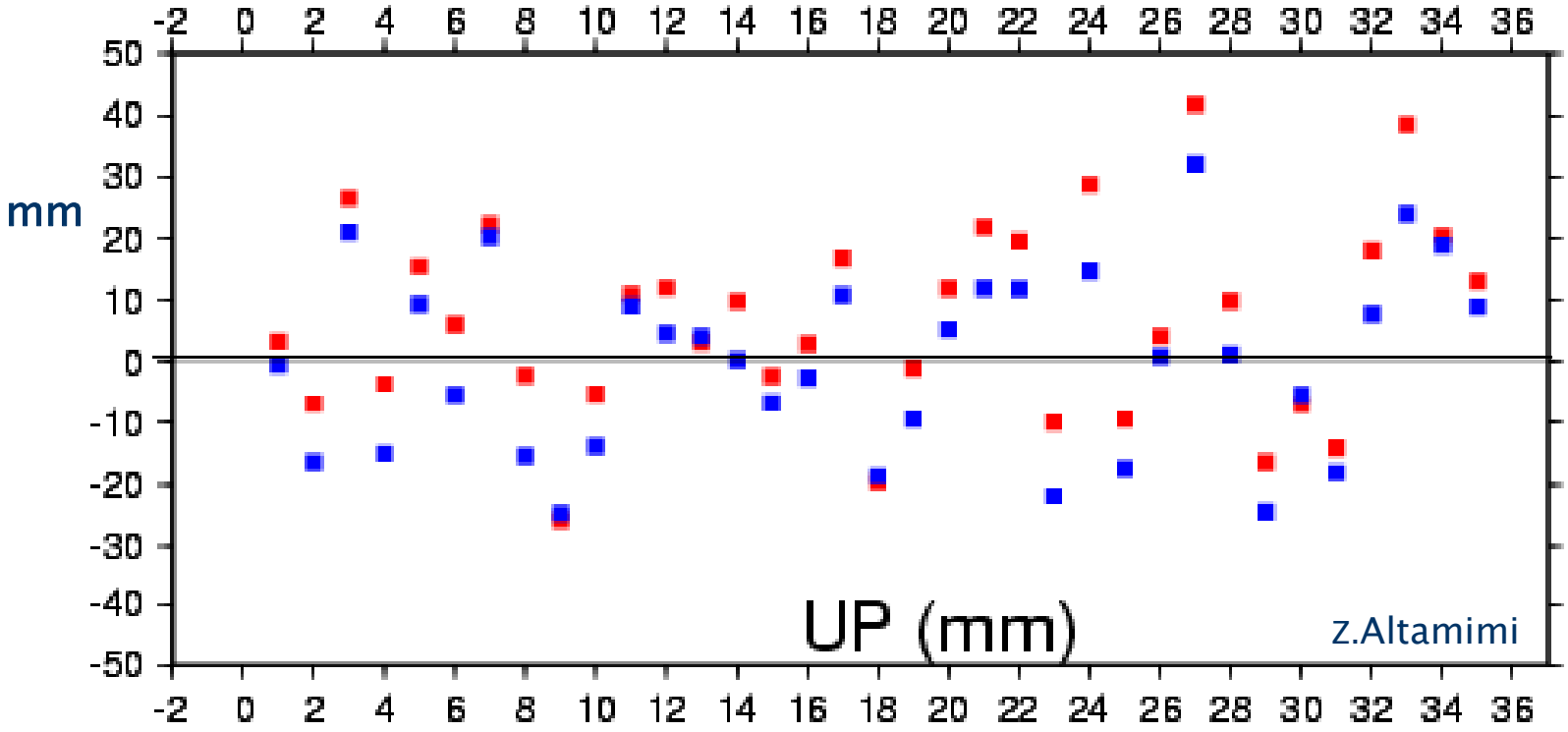
δT_x mm/y	δT_z mm/y	δT_z mm/y	δD 10^{-9}/y	δR_x mas/y	δR_y mas/y	δR_z mas/y	sigma0 mm/y
			-0.28 ±0.03	+0.05 ±0.02	+0.52 ±0.01	-0.80 ±0.03	0.93

31 stations used



Memo: Boucher / Altamimi, Specification for reference frame fixing in the analysis of EUREF GPS campaign

Residuals ???2005-ETRF2000



Least squares transformation

Proposal by Altamimi

Remarks to *Rigorous Solution*

- Rotation angles divided by (reference epoch – 1989.0) → approximate rotation rate of Euroasian plate
- They also contain contributions of systematic errors
- All the parameters soak up systematic errors of datum realizations and errors of regional nature

- Parameters are mathematical transformation parameters and don't have to be physically interpreted → Formal errors are unimportant.

- Maintains full internal accuracy of the original ITRFyy solution
- Yields the smallest possible residuals/jumps w/r to the reference solution (v^tPv = min) → closest to the users' needs

- Could be further improved by using densified reference network

Current situation

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- So far ETRS89 realizations are fully based on ITRFyy solutions
- Contribution by EUREF:
  - European IGS stations and SLR/VLBI being part of ITRFyy
  - 2000: Inclusion of EPN into ITRF2000 solution
- So far, ETRS89 realizations have not been optimized for maximum consistency between subsequent realizations

Further improvements, future concepts

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- European Permanent Network:
  - 200 permanent stations available
  - Time series of weekly solutions
  - Accumulated solutions
- Use EPN for the maintenance of the ETRS89
  - Excellent internal accuracy
  - Time resolution, spatial density
  - Velocity field
- EPN processing based on ITRF/IGSyy (→ orbits, ERPs,..., SLR,...)
- ETRS89 realizations „independent“ from ITRFyy:
  - Density
  - Frequency
  - ...
- Optimized for long-term consistency between subsequent realizations
- ITRFyy ←→ ETRFyy: Availability of positions/velocities of reference stations and of transformation parameters

Open questions (1)

- How to make use of EPN? In detail?
- How often will there be updates to the parameters and reference coordinates?
- Based on which solutions? Based on which reference?
- How do the mathematical models of the optimization function and the transformations look like? What to do with “scale” differences?
- What to do with annual (or other) variations of ITRFyy/IGSyy-based positions?
  - EPN positions
  - Campaign-based positions
- How to refer user results to the respective realization (naming, traceability, citation, uniqueness)?

→ New special working group proposed

Open questions (2)

- Do we need to modify the definition of ETRS89?

  I don't think so!
  - Definition is simple
  - Sufficiently vague

- Need to modify/extend specifications for the realization/maintenance of ETRS89

  e.g., quantification of the “stable part”