Integration of future clock networks into geodetic reference frames

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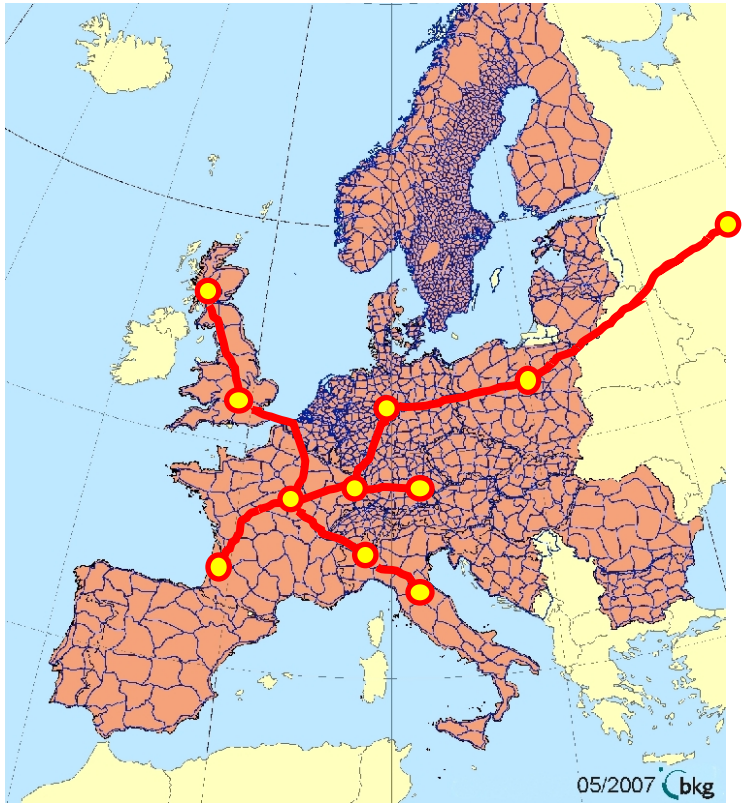
Use of optical clock networks for relativistic geodesy



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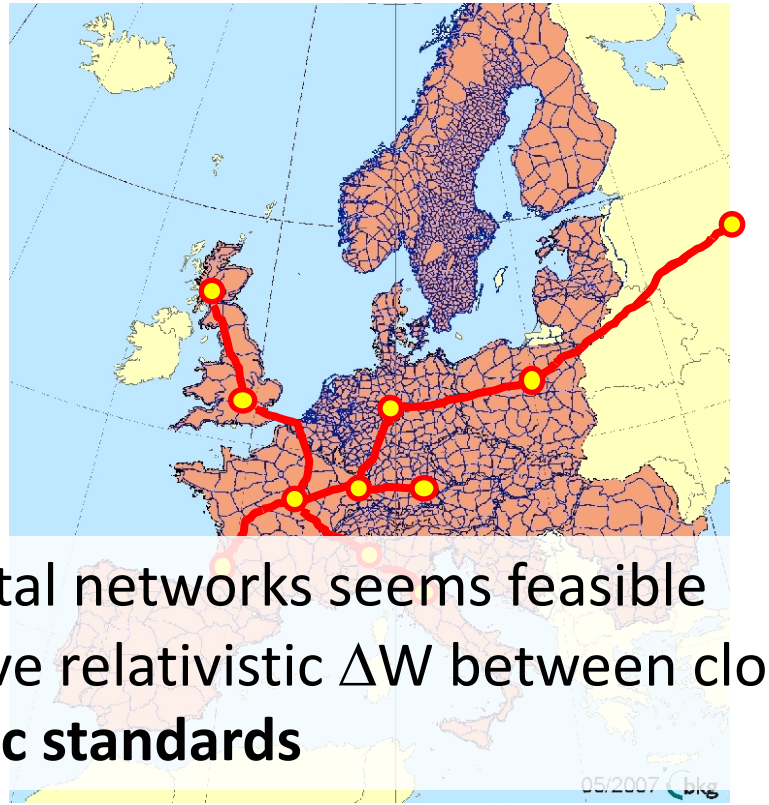
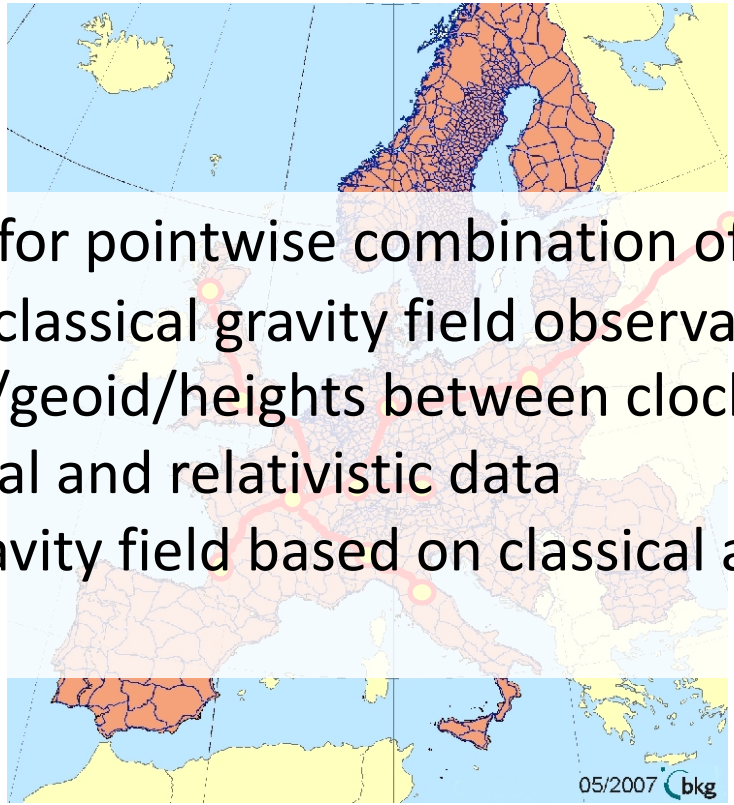


- continental networks seems feasible
- would give relativistic ΔW between clock sites based on **atomic standards**

Challenges for geodetic modeling



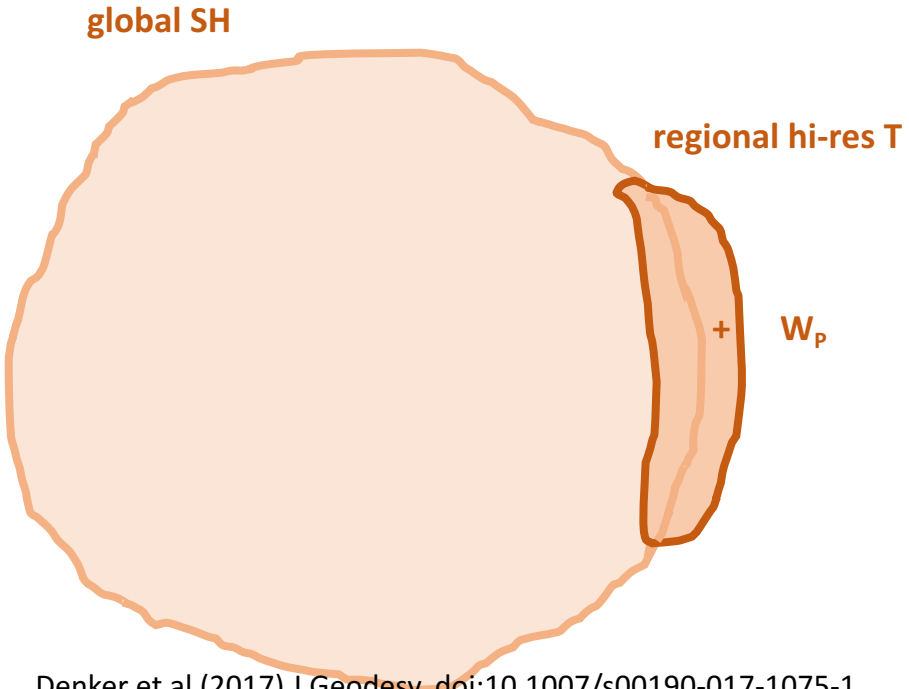
- methods for pointwise combination of relativistic ΔW with classical gravity field observations
- potential/geoid/heights between clock sites based on classical and relativistic data
- full 3d gravity field based on classical and relativistic data

Combined determination of gravity potential

classical (Denker et al 2017): $W_P = U_P + T_P$

- global spherical harmonic potential model
  - bandlimited (l_{max})
  - Lageos, GRACE, GOCE, GRACE FO
- regional hi-res model of disturbing potential T, height anomaly ζ
  - gravity anomaly grid (gravimetry, few km)
  - topographic mass model (DEM)
  - independent of mass density (to first order, Molodensky approach or similar)
  - Europe: EGG2015 model
- GNSS position

accuracy at clock sites: 0.1 ... 1 m^2/s^2 (1 ... 10 cm); biases?

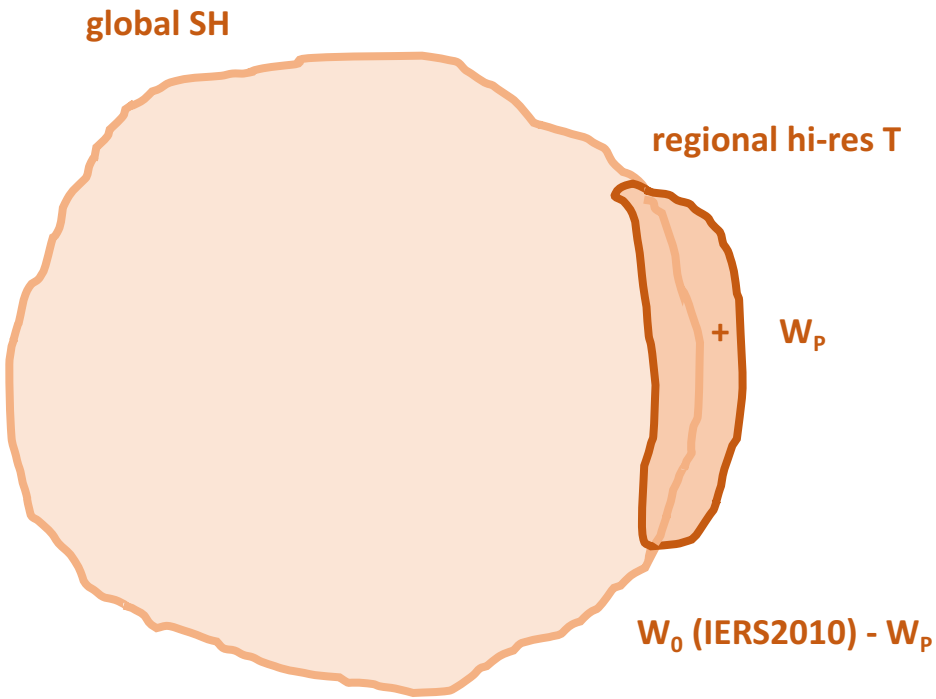


Denker et al (2017) J Geodesy, doi:10.1007/s00190-017-1075-1
Klees et al (2018) J Geodesy, doi:10.1007/s00190-017-1076-0
Pavlis & Weiss (2017) Metrologia, doi:10.1088/1681-7575/aa765c

Combined determination of gravity potential

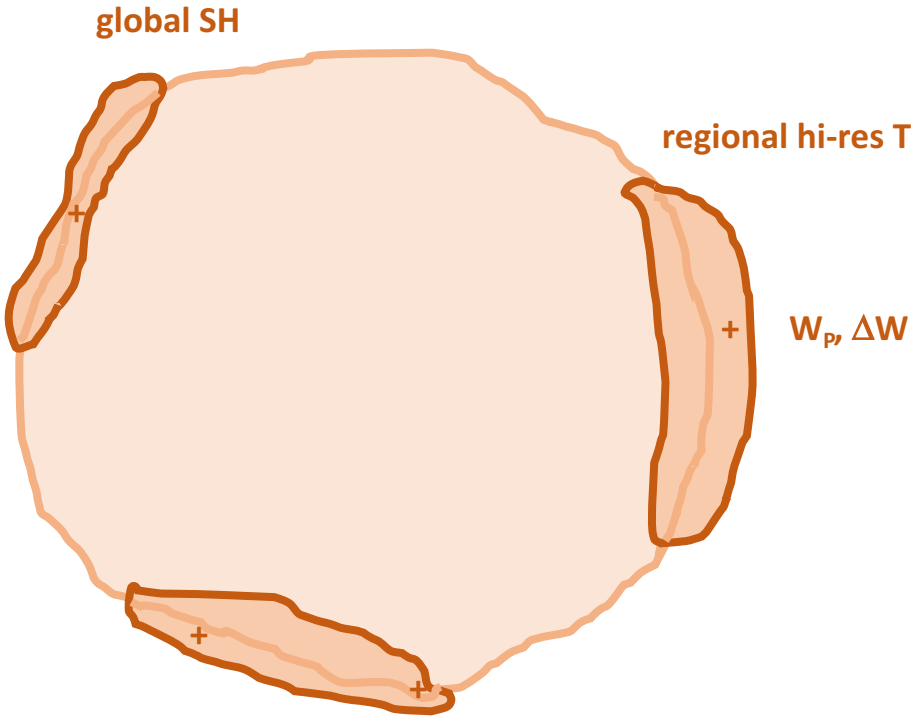
Denker et al (2017):

- reference to W_0
- $W_0^{(i)}$ can be dealt with
  - IAU / IERS2010, IHRS, others
  - if close to Mean Sea Level



Combined determination of gravity potential

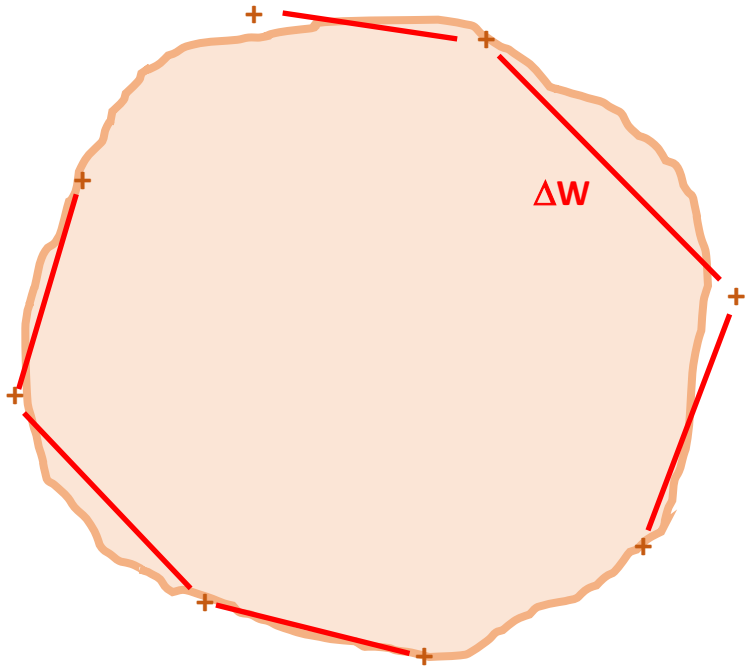
- perspective: network of W_p stations based on classical approaches
- with evolving quality
  - new data (sats, terrestrial)
  - modeling refinements
  - ...
  - as in all geodetic reference frames



Combined determination of gravity potential

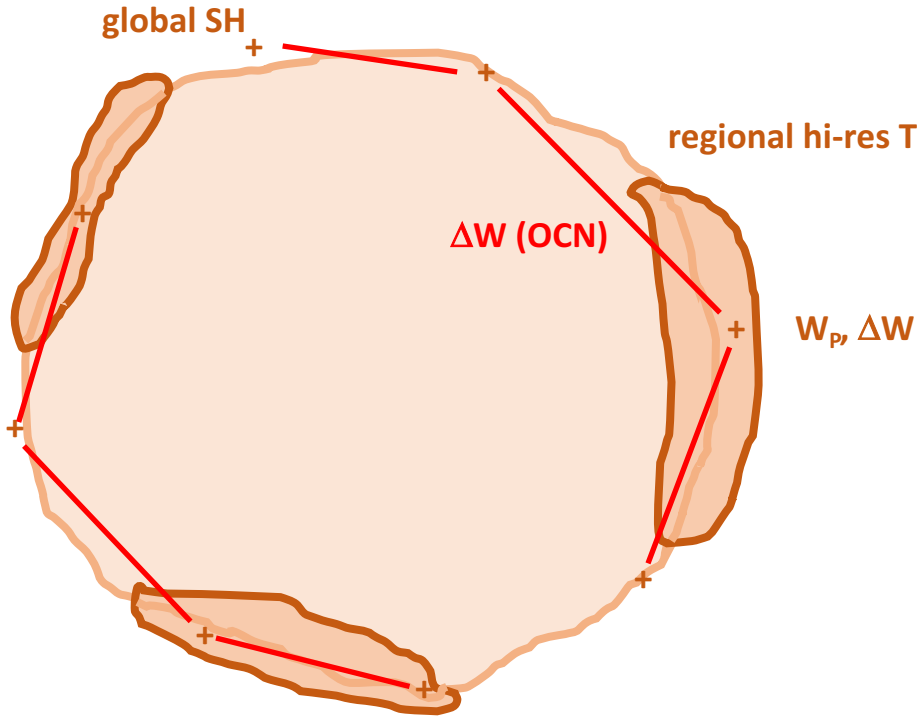
relativistic:

- in optical clock networks
- gravity potential differences
- on continental scale



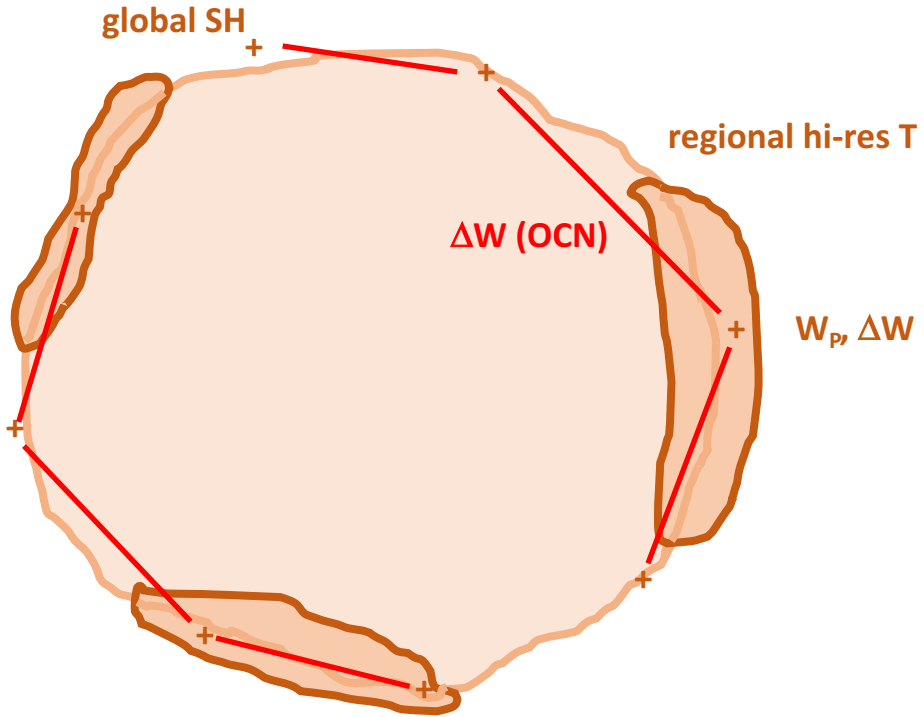
Combination of “techniques”

- pointwise combination is expected to be feasible
- absolute W from classical techniques
- ΔW from (weighted) combination, weights of OCN expected to increase
- can start with few network stations



Combination of “techniques”

- details of mathematical model tbc
  - hierarchical adjustment
  - least squares collocation
  - other?



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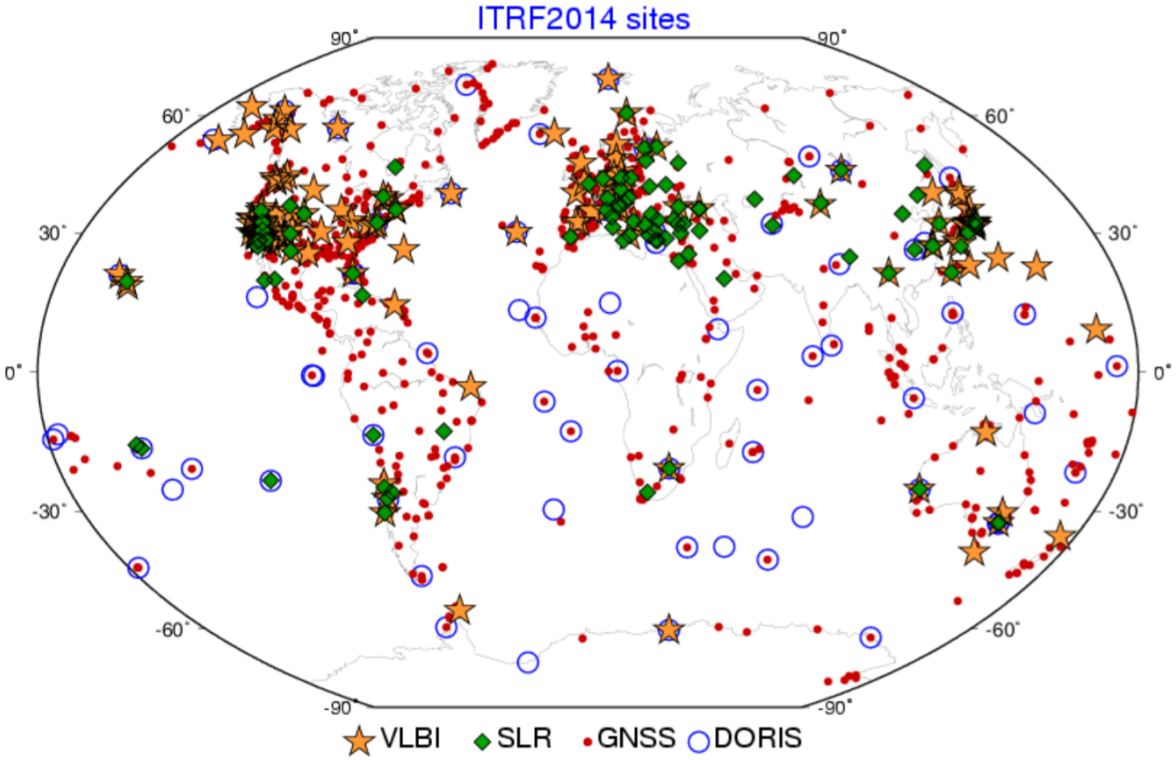
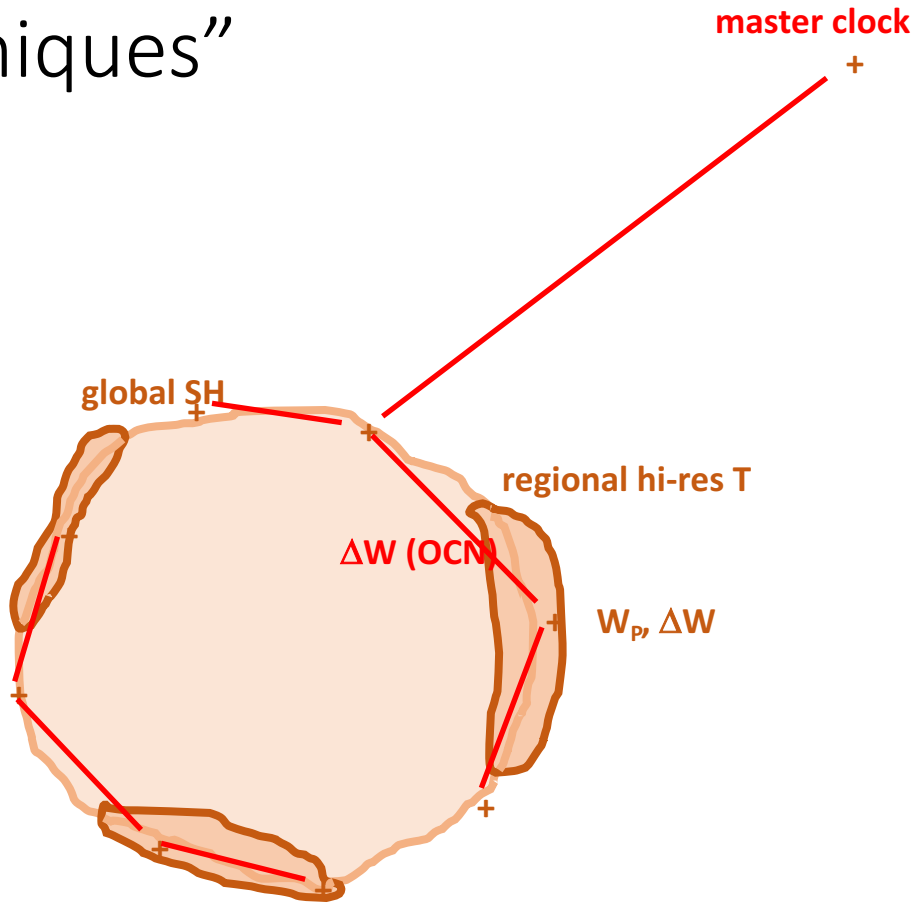


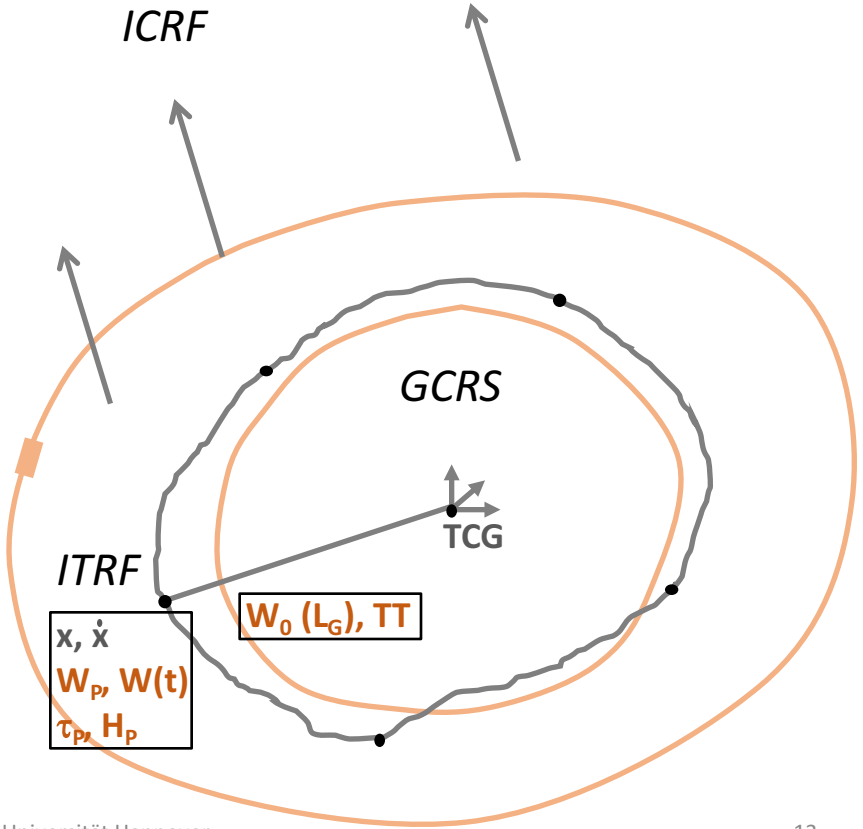
Combination of “techniques”

- similarly, clocks in space could be included



Role of W in geodetic reference frames
- a generalistic view -

- elements of geodetic reference frames:
  - origin (geocenter)
  - orientation (EOP)
  - station coordinates, velocities
  - W, W(t), τ_P
  - height reference
- distinction celestial reference frames - dynamic reference frames
- elements connecting the celestial and dynamic frames



GCRS: Geocentric Celestial Reference System; ICRF: International Celestial Reference Frame; ITRF: International Terrestrial Reference Frame

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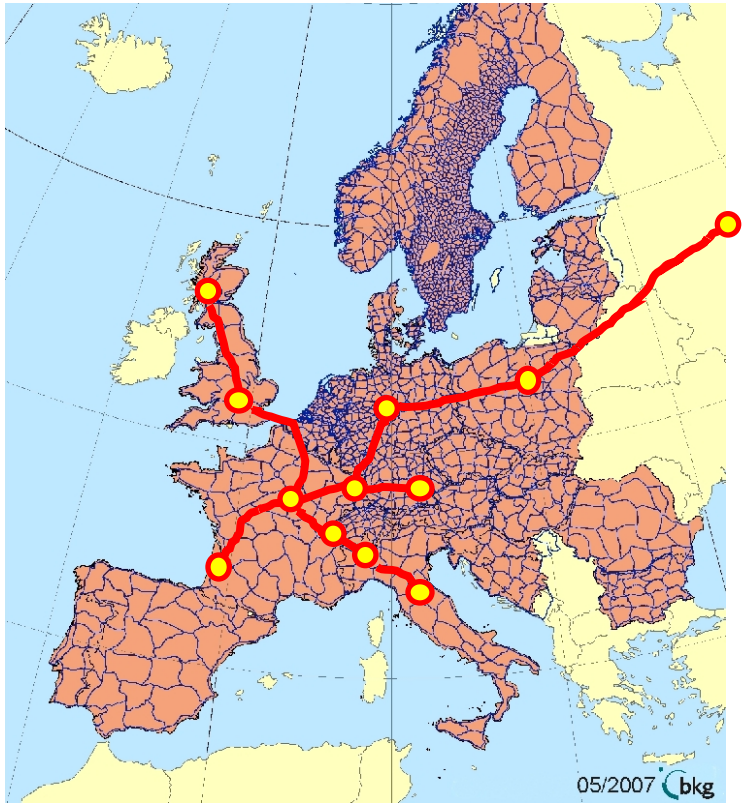

Conclusions

- optical long-distance frequency comparisons open straightforward way for establishing gravity potential and height reference frames
- observing the static and time variable gravity field
- strengthening GNSS/geoid approach

Where should we have clock observations?

- As soon as long-distance frequency comparison in the (low) 10^{-18} regime can be achieved, continental campaigns and networks should be proposed and realized
- Support of geospatial/mapping agencies should be secured
- Integration into IHRS expected