TECHNISCHE UNIVERSITÄT WIEN
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Introduction to Geodetic VLBI

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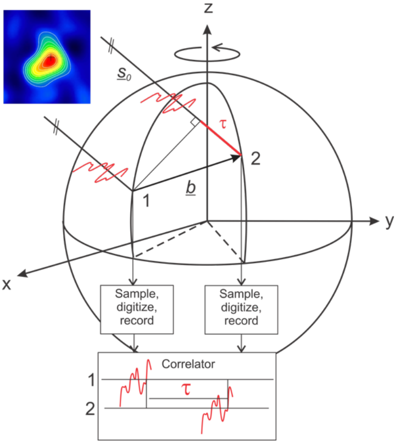
Geodetic, Astrometric and Astronomic VLBI

What's the difference?

- Geodesy uses VLBI to derive earth bound parameters
- Astrometry uses VLBI to measure the position and movement of astronomical objects
- Astronomie uses VLBI to image astronomical objects

Geometric principal



$$\tau = -\frac{\vec{b} \cdot \vec{s}_0}{c} = t_2 - t_1 \qquad (1)$$

- Baseline (station positions) and source position must be in the same reference frame
- τ is what we observe with VLBI
- Normal VLBI session consists of a globally distributed network

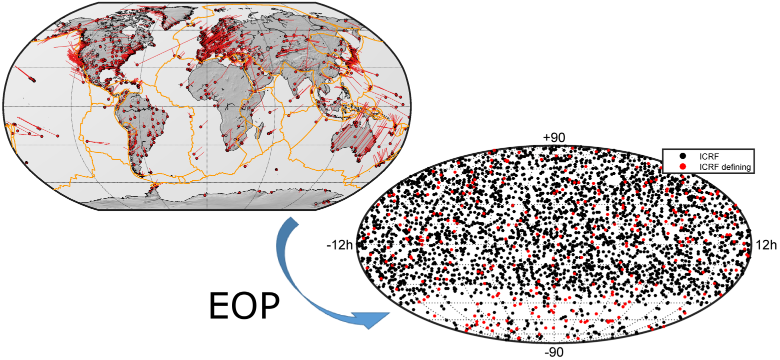
Definitions

scan: a time period during which multiple stations observes the same source simultaneously
Example: 5 stations observe source 0454-234

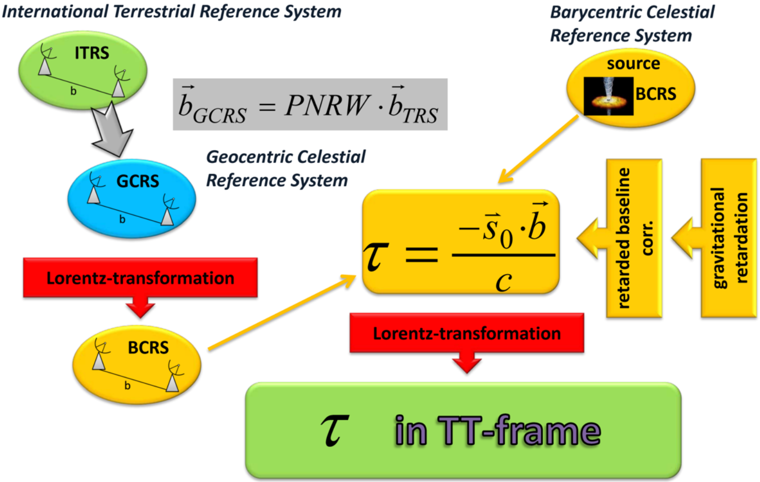
observation: a single baseline during a scan
Number of observations per scan: $n_{obs} = \frac{n_{sta} \cdot (n_{sta} - 1)}{2}$
Example: $n_{sta} = 5 \rightarrow n_{obs} = 10$

Earth orientation

From the International Terrestrial Reference System (ITRS) to the Geocentric Celestial Reference System (GCRS) at the epoch of the observation t



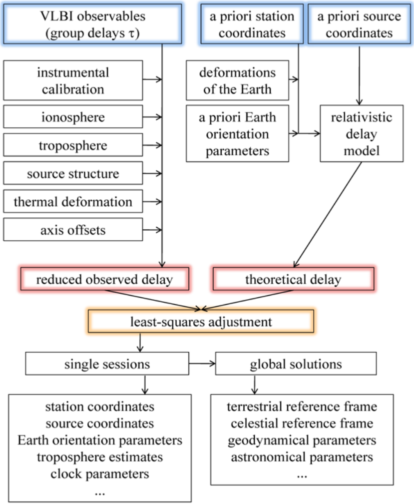
Earth orientation



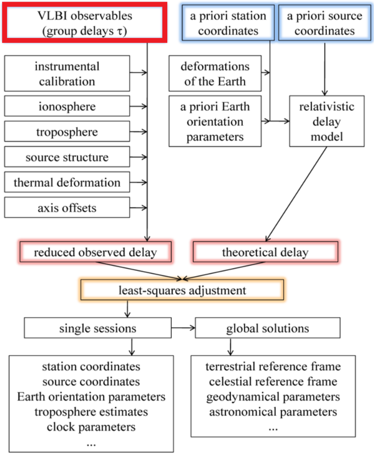
Least Squares Method

Understanding LSM is necessary to understand results and requirements for geodetic VLBI
$\rightarrow$ short introduction (unfortunately with some math)

VLBI analysis flowchart



Observation corrections



Observations are provided by correlator

- NGS format (ASCII)
- VGOS-DB (netCDF files)

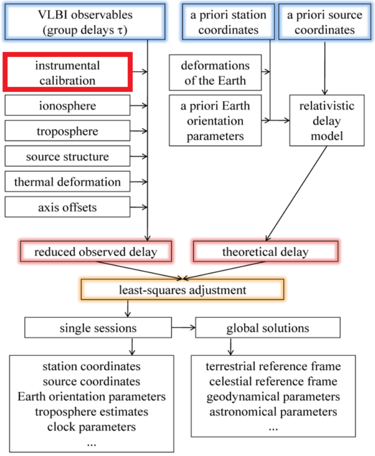
Observation corrections NGS format

- baseline
- time
- source
- observation τ (formal error)
- cable calibration correction
- meteorological observations
- ionospheric corrections

```
TSUKUB32  WETTZELL  0059+581 2014 06 17 17 02  57.0000000000
    6179107.24911047    .00202   825648.6829278118    .00613
    .00623     .00000     .00000     .00000     .735289988539280
       .00    .0         .00    .0         .00    .0         .00    .0
   -.00577    -.00206     .00000     .00000     .00000     .00000
    21.005     17.000   1002.500    946.800     96.000     63.400
       -3.2154615660    .00258        -.0002886440    .00525
    6179107.24911047    .03704   825648.6829278118    .22030
```

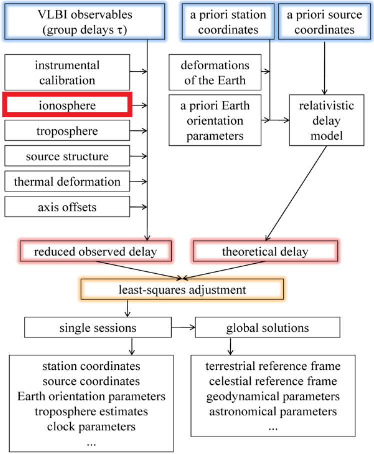
Observation corrections

instrumental calibration



stretching of cables introduces an additional delay

Observation corrections ionosphere



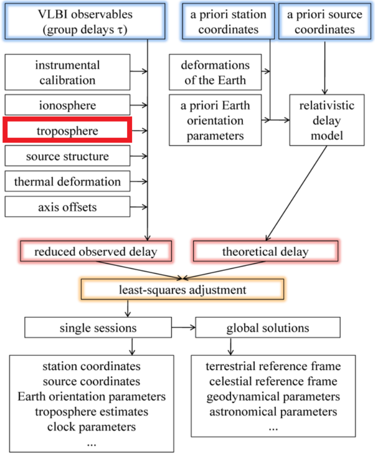
Ionosphere is dispersive (changes with frequency) for radio waves
Observing two frequencies (X- and S-band) at the same time lets you calculate the ionospheric correction

$$\Delta\tau_X^{ion} = (\tau_X - \tau_S) \cdot \frac{f_S^2}{f_X^2 - f_S^2}$$

$$f_S = 2.3GHz$$

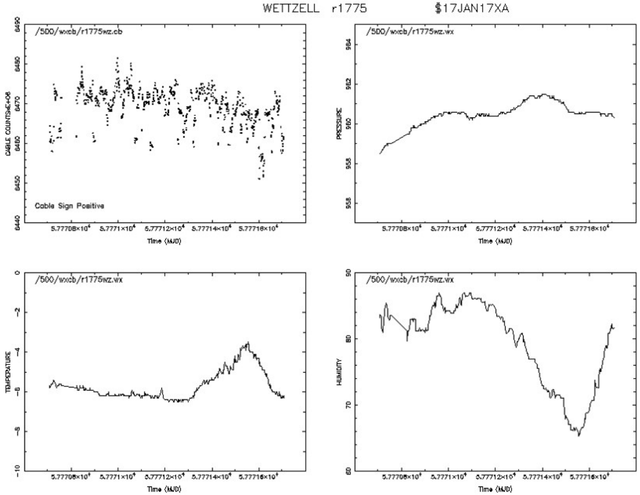
$$f_X = 8.4GHz$$

Observation corrections troposphere



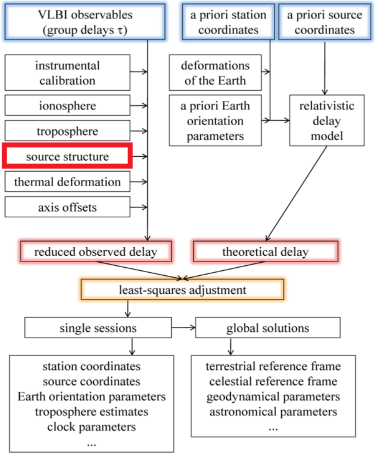
Measuring tropospheric parameters (e.g. pressure) on site

Observation corrections troposphere



Observation corrections

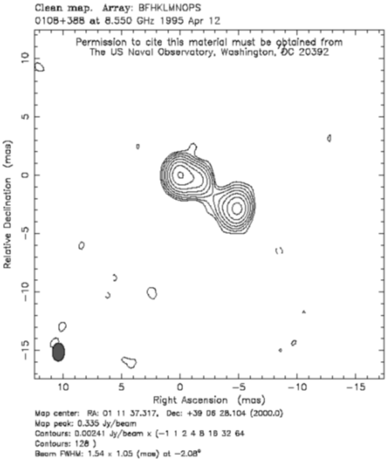
source structure



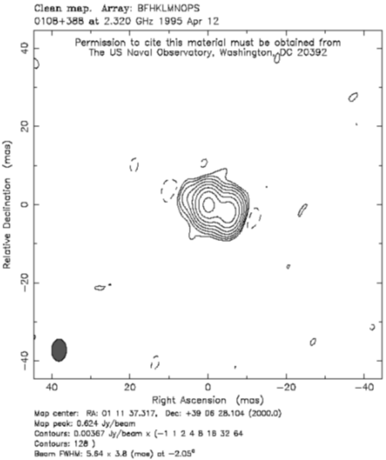
- Source is not always point-like
- Structure can change with frequency

Observation corrections troposphere

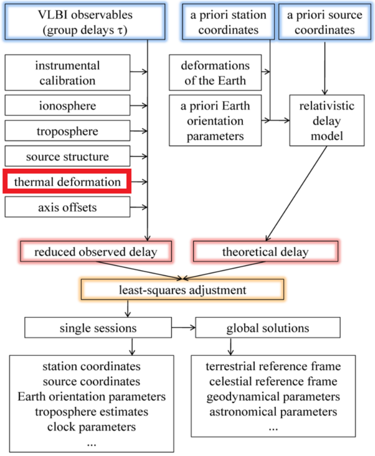
X-Band



S-Band



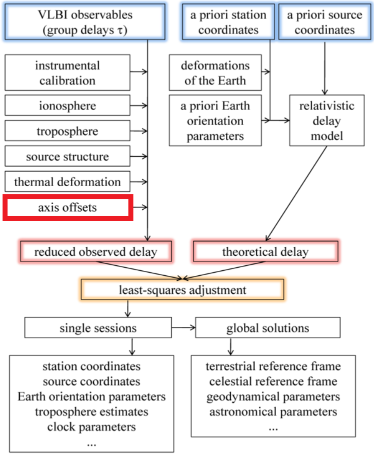
Observation corrections thermal deformation



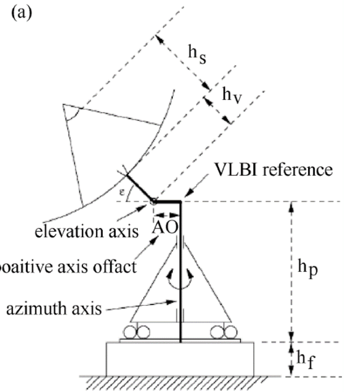
Modeling thermal expansion of telescopes

Observation corrections

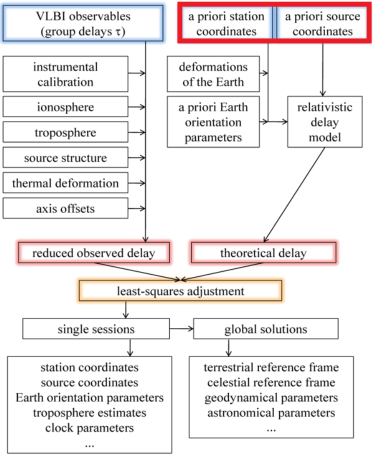
axis offsets



Axes of telescopes usually don't intersect



The theoretical delay a priori coordinates

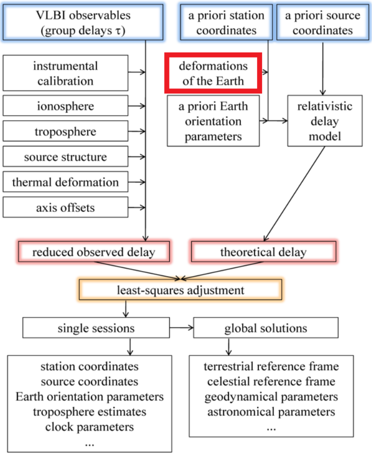


From TRS and CRS realisations

- ITRF2014
- ICRF2

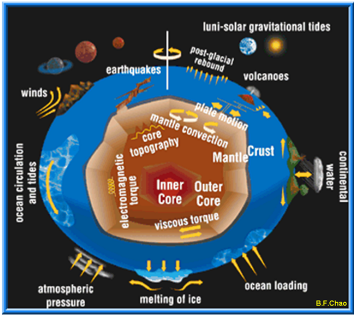
The theoretical delay

deformations of the earth



Various models need to be applied

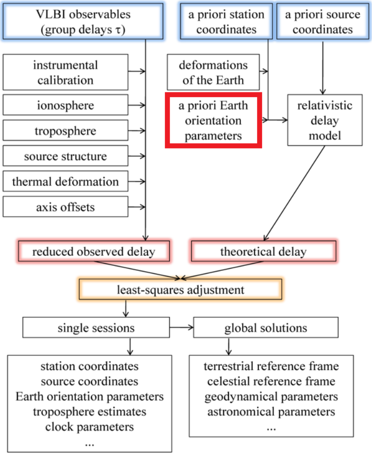
- IERS Conventions



http://geodesy.agu.org

The theoretical delay

a priori Earth orientation parameters

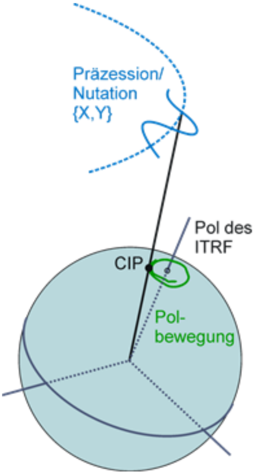


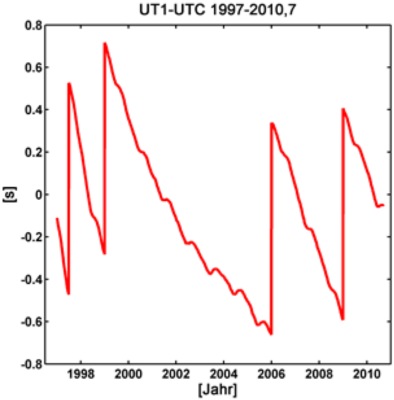
A priori time series (e.g. C04) from the International Earth Rotation and Reference Systems Service (IERS)

Five Earth Orientation parameters (EOPs):

- polar motion (x_p, y_p)
- precession, nutation (X, Y)
- UT1-UTC ($dUT1$)

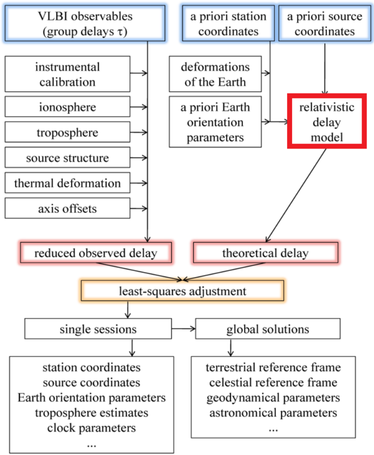
The theoretical delay
a priori Earth orientation parameters





The theoretical delay

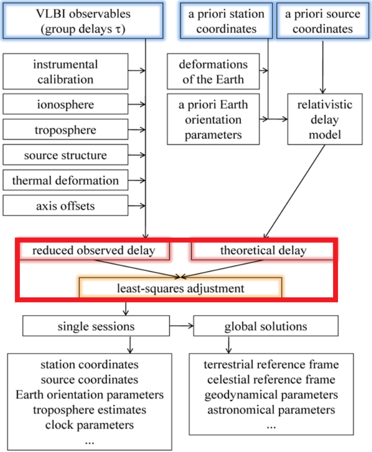
relativistic delay model



Relativistic corrections:

- Retarded baseline correction
- Gravitational retardation

Least Squares Adjustment

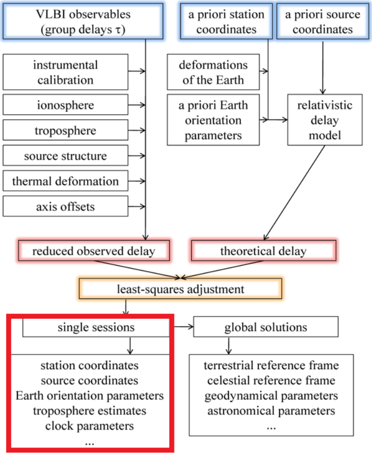


Now we have our reduced observed delay and our theoretical delay

→ we can build the observed minus computed vector $o - c$ and make a least squares adjustment

The results are the estimated parameters

Results single session



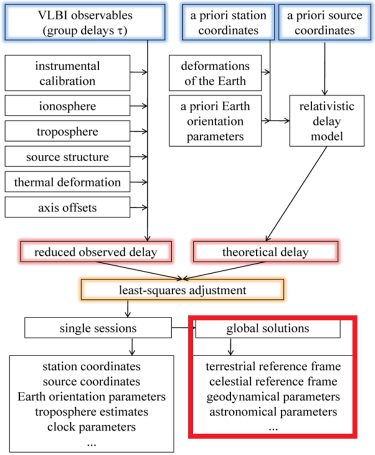
Primary parameters:

- station position
- source position
- EOPs

Secondary parameters (can not be modelled, and therefore have to be estimated)

- troposphere
- clock

Results global solution



Combination of single sessions into one global adjustment.
Session specific parameters, such as troposphere and clock are reduced
Usual parameters:

- TRF
- CRF
- EOP

Special parameters

- axis offsets
- seasonal harmonics of station positions

Results

Polar motion x_p, y_p	Accuracy	50-80 μas
	Product delivery	8-10 days
	Resolution	1 day
	Frequency of solution	$\sim$ 3 days/week
UT1-UTC	Accuracy	3-5 μs
	Product delivery	8-10 day
	Resolution	1 day
	Frequency of solution	$\sim$ 3 days/week
UT1-UTC (Intensives)	Accuracy	15-20 μas
	Product delivery	1 day
	Resolution	1 day
	Frequency of solution	7 days/week
Celestial pole dX, dY	Accuracy	50 μas
	Product delivery	8-10 days
	Resolution	1 day
	Frequency of solution	$\sim$ 3 days/week
TRF (x, y, z)	Accuracy	5 mm
CRF (α, δ)	Accuracy	40-250 μas
	Frequency of solution	1 year
	Product delivery	3 months

Status 2010 of IVS main products (Schlüter and Behrend 2007)

Lecture Introduction to Geodetic VLBI

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