Astrometric Analysis
&
ICRF3

AVN School, HartRAO, 21.03.2018

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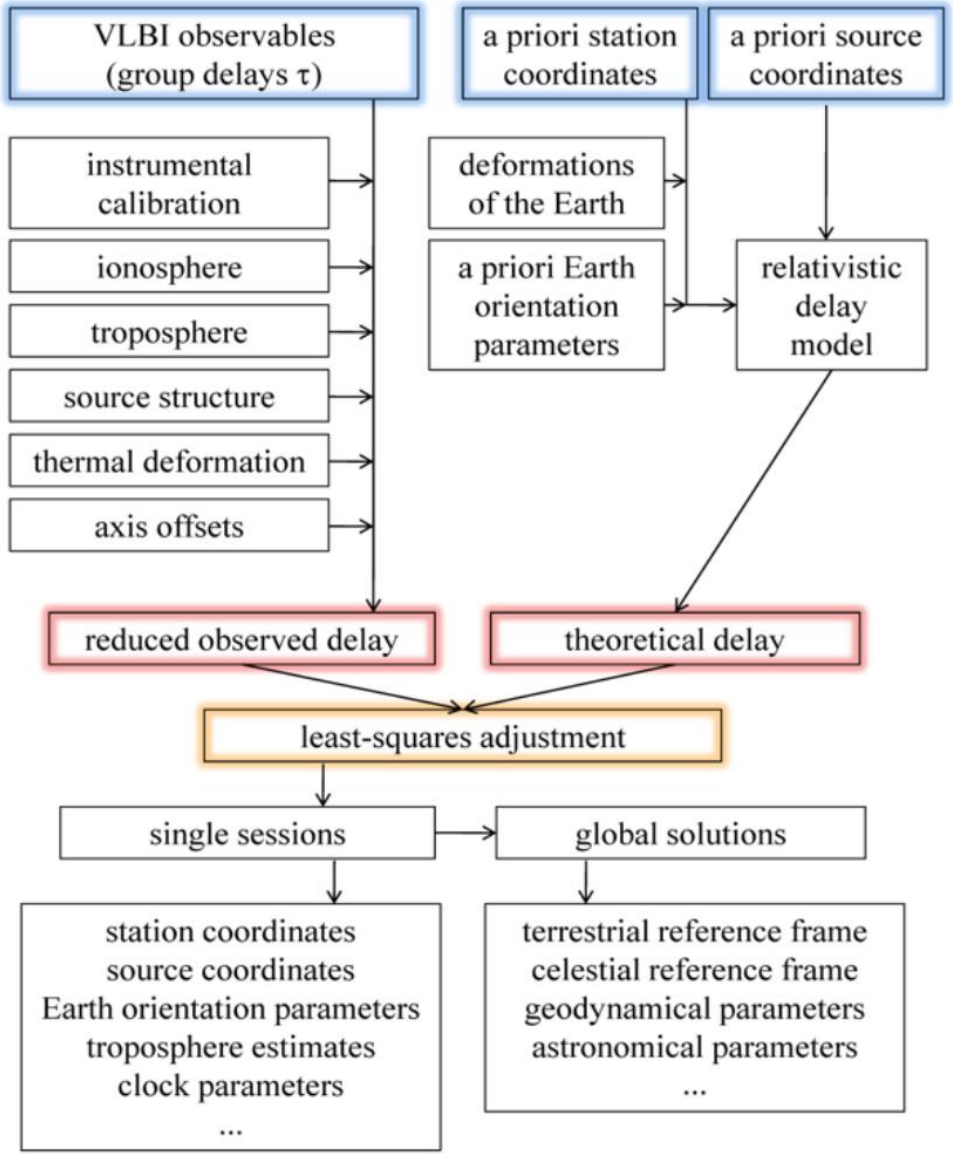
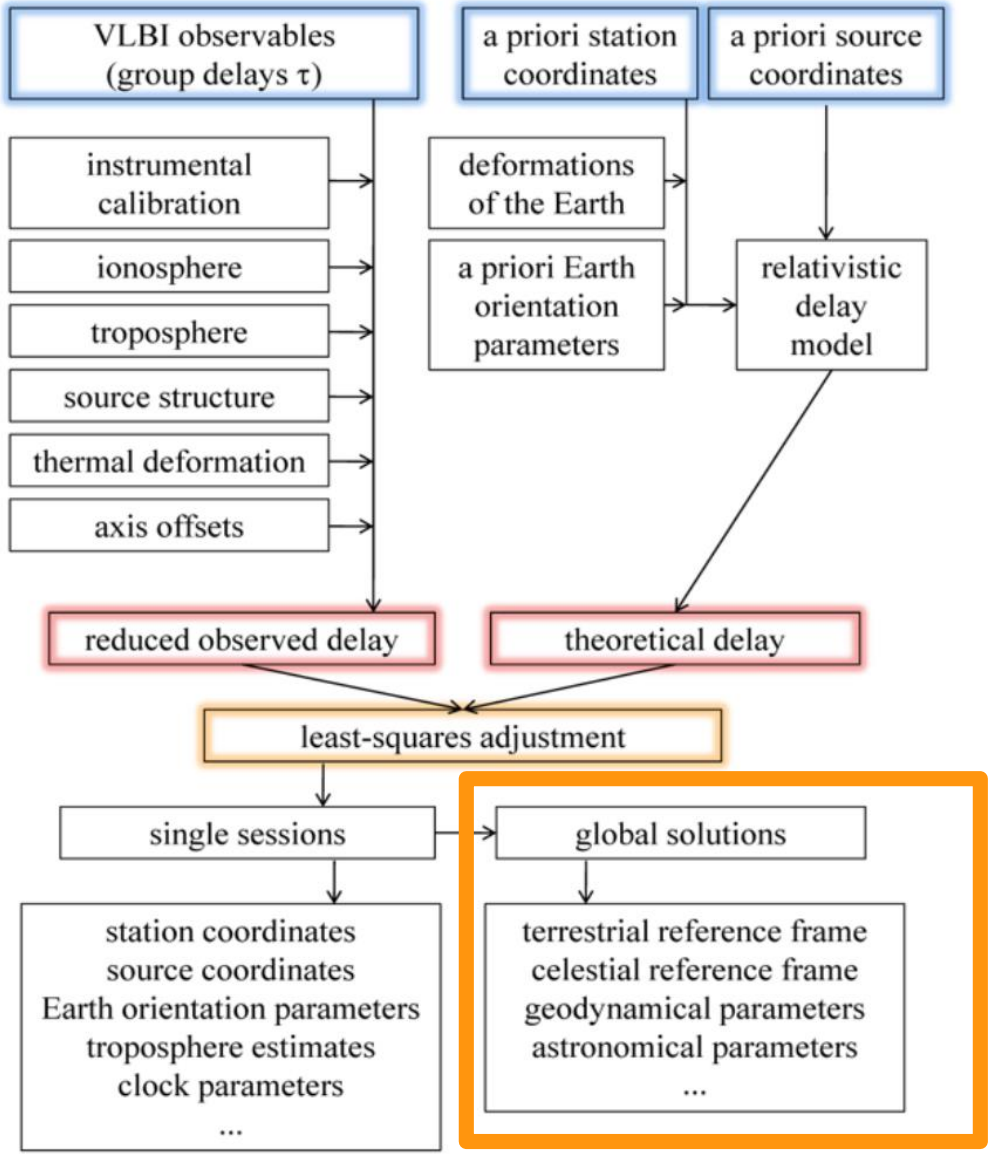
Analysis Background



David & Mathias

Analysis Background



David & Mathias

Analysis Background

Least squares adjustment

$$x = x0 + \Delta x$$

$$A^T P A \cdot \Delta x = A^T P l$$

$$N = A^T P A$$

$$b = A^T P l$$

$$\Delta x = N^{-1} \cdot b$$

A=design matrix
P= weight matrix
l= red. obs. (o-c)
N= normal equation m.
b= right hand side-vector
x0= a-priori
x= unknowns

Analysis Background

Multiple LS

$$A = \begin{pmatrix} A_1 \\ A_2 \end{pmatrix}, \quad P = \begin{pmatrix} P_1 & 0 \\ 0 & P_2 \end{pmatrix}$$

$$(A_1^T P_1 A_1 + A_2^T P_2 A_2) \cdot x = A_1^T P_1 l_1 + A_2^T P_2 l_2$$

$$A_1^T P_1 A_1 \cdot x = A_1^T P_1 \cdot l_1$$

$$A_2^T P_2 A_2 \cdot x = A_2^T P_2 \cdot l_2$$

$$N_1 = A_1^T P_1 A_1, \quad b_1 = A_1^T P_1 \cdot l_1$$

$$N_2 = A_2^T P_2 A_2, \quad b_2 = A_2^T P_2 \cdot l_2$$

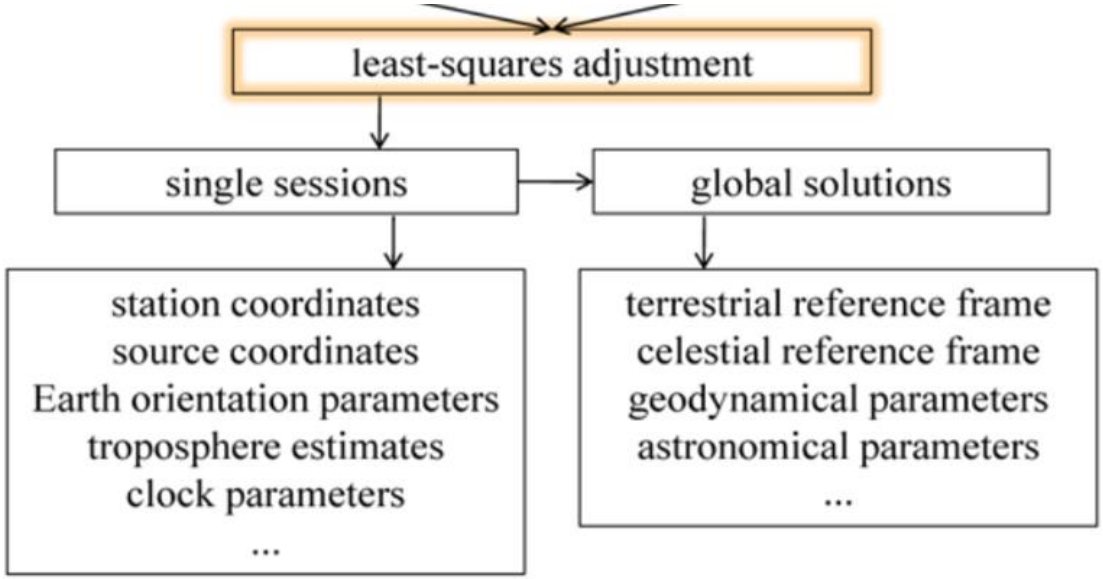
$$(N_1 + N_2) \cdot x = b_1 + b_2$$

$$\Delta x = N^{-1} \cdot b$$

Analysis Background

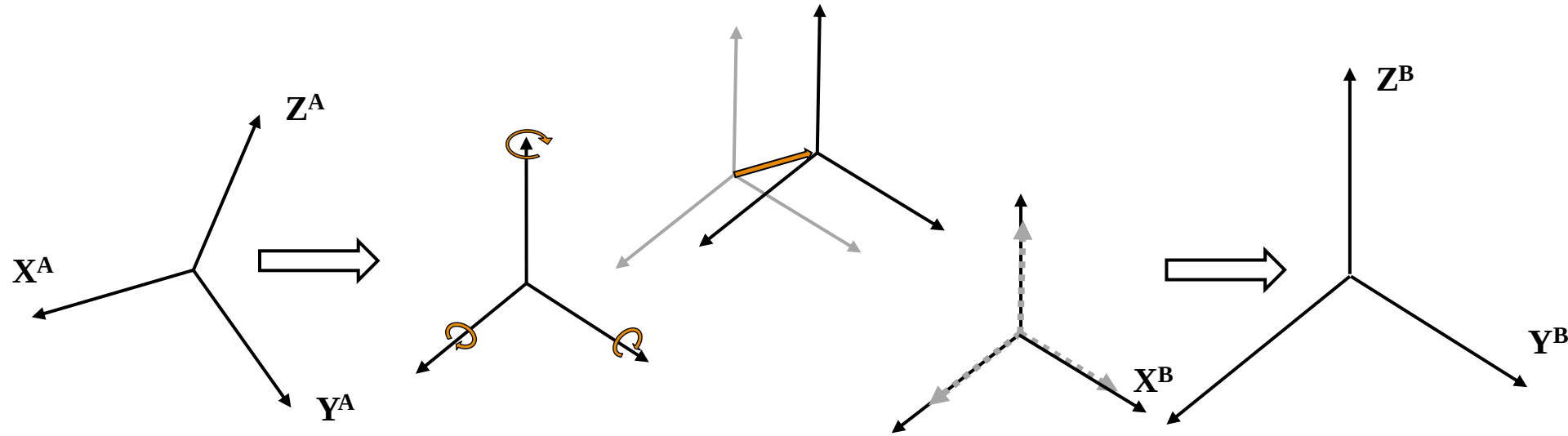
Stacking

- Datum free
  - Each session has its own individual datum
    - dispose of the datum
  - VLBI software packages can do that



Datum (TRF)

- VLBI is a relative technique
  - to obtain absolute locations of the antennas network conditions have to be introduced
- Similarity / Helmert transformation
  - between the a priori and the new adjusted reference frame



Datum (TRF)

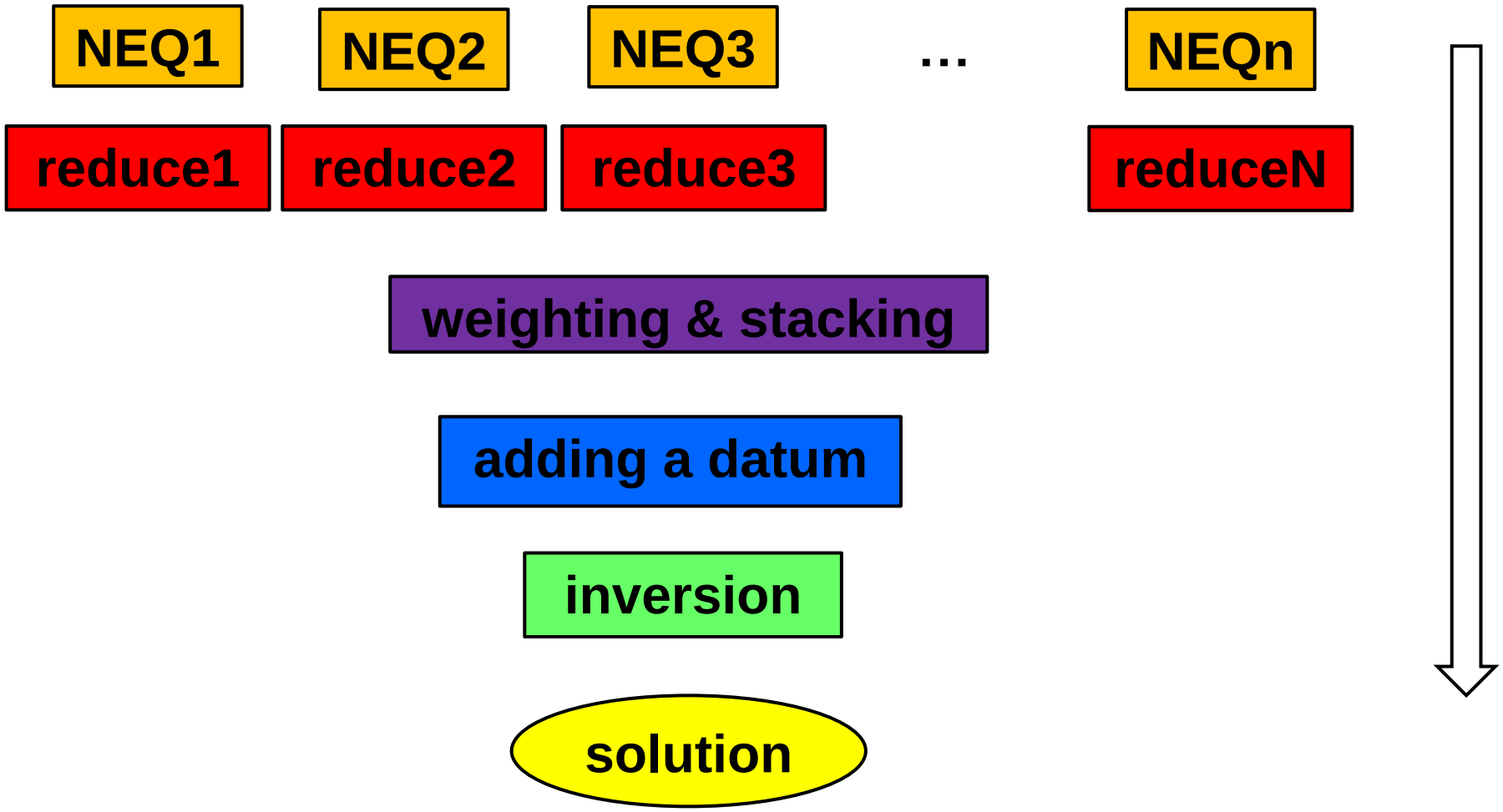
- VLBI is a relative technique
  - to obtain absolute locations of the antennas network conditions have to be introduced
- Similarity / Helmert transformation
  - between the a priori and the new adjusted reference frame
  - 7 degrees of freedom -> 7 parameter transformation
- Definition of the relationship between the a-priori network and the estimated one.

Datum (TRF)

- Fixing stations
  - Problematic if stations do something funny
- Free datum conditions
  - Set the translation parameters to zero: No-Net-Translation
  - Set the rotation parameters to zero: No-Net-Rotation
  - datum stations
- CRF
  - NNR on datum sources

Analysis Background

Stacking

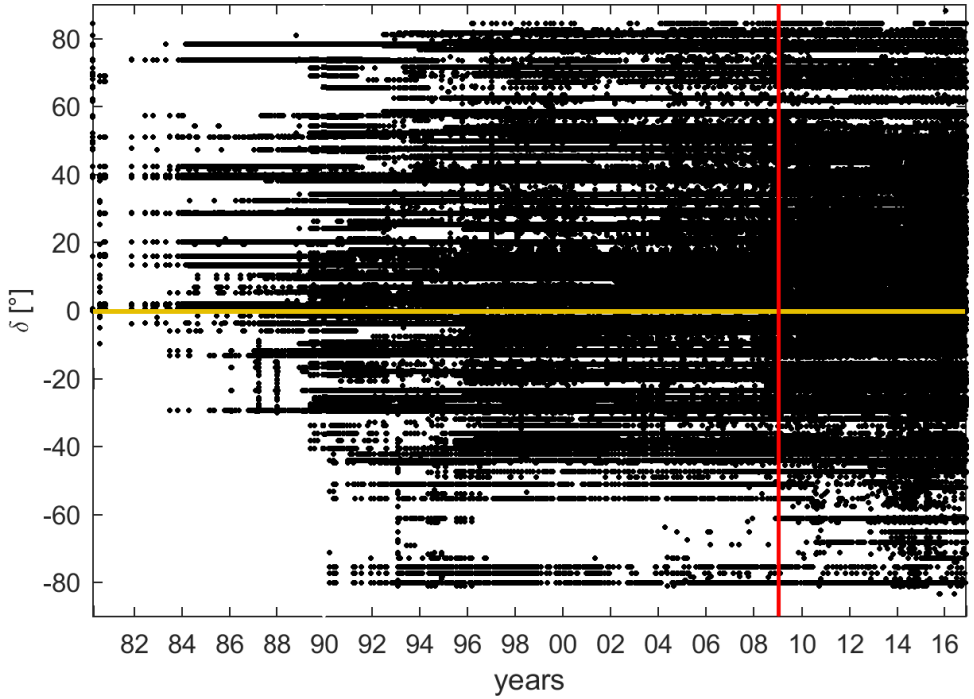


Stacking

- **Stacking allows to accumulate observations**
  - Avoid singularities with <3 observations
  - Use all available observations to source
- **Global gives „average“ at mean epoch**
  - Problem special handling sources
- **Datum definition**
  - No-net-rotation
    - No global rotation relative to the defining sources
    - Realized though transforming onto existing reference
  - Need of boring sources: defining sources

Motivation

- new sources are observed
- new stations enter network
- longer observing time spans could reveal unstable sources



(Plank et al. 2016)

Who? Working Groups

- **International Astronomical Union**
  - **Division A - Fundamental Astronomy**
    - Third Realization of the International Celestial Reference Frame
      - To oversee the generation, validation and utility of the third generation ICRF in the radio domain by 2018
      - formed in 2012
      - 20 members, 8 institutions
- **International VLBI Service for Geodesy and Astrometry**
  - **IVS Working Group on Galactic Aberration**
    - formulate a recommendation to the ICRF3 working group
    - 15 members, 9 institutions

Action items

- **Session list**
- **Estimation settings**
  - Parameterization + models
  - Estimated, reduced & fixed parameter
  - Datum definition
- **List of non-AGN sources**
  - Super novae
  - Lenses
  - Radio stars
  - Pulsars
- **List for special handling sources**
  - Only ‚boring‘ sources enter global solution
- **List of datum sources**
  - Define the no-net-rotation constraint
- **List of linking sources**
  - Assure the alignment with the previous cataloged
- **Evaluation of the final catalog**
  - Comparison with ICRF2
  - Comparison within the different submissions
- **Formulation of the resolution**
- **Publishing of the catalog**

Getting it done!

- **analyze sessions**
  - Parameterization / models
  - Datum free normal equations
- **Stack NEQ**
  - Reduce session-based parameters (clocks, EOP,…)
  - Reduce special handling sources
- **Add datum**
  - Select datum stations in TRF
  - Datum sources are given in CRF
- **Final inversion**
- **Upload to server**

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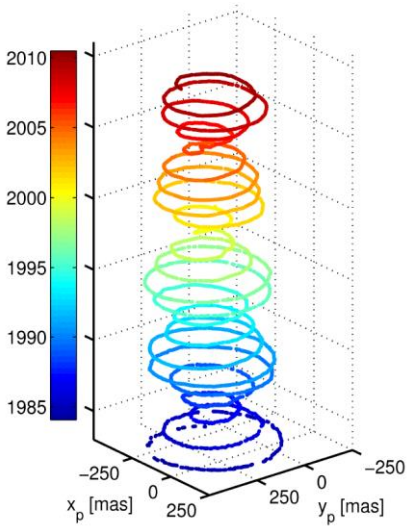
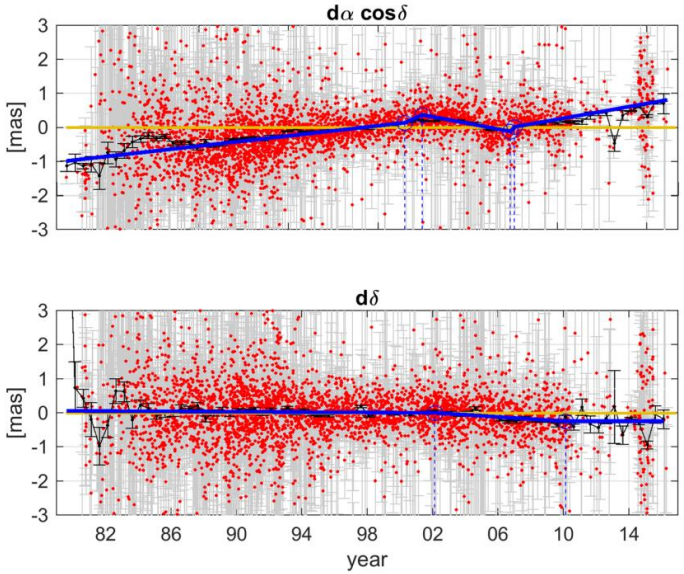
Reduction of parameters

- **Estimated per session**
  - clock
  - zenith wet delay
  - troposphere gradients
  - EOP
  - Special handling sources





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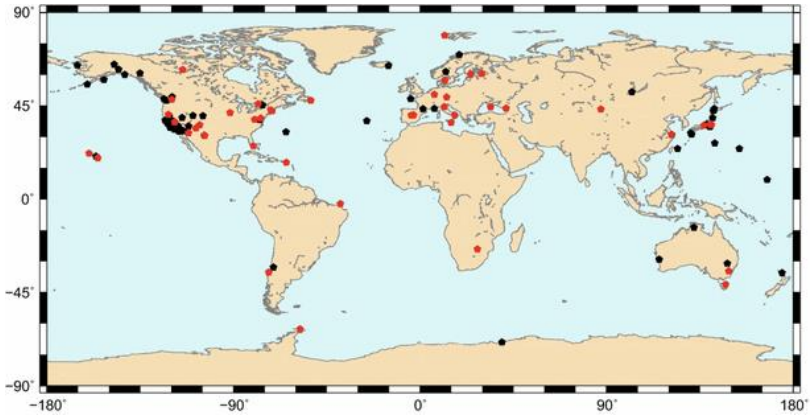
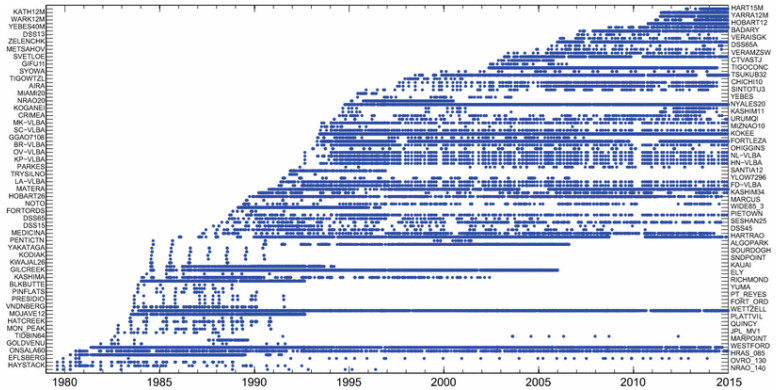
Terrestrial Reference Frame



- **datum stations**
  - stable stations with long observing history
  - good distribution
- **reduce stations**
  - short observing history
  - known problems
- **constant velocities at stations with breaks**
  - e.g. bearing replacement does not change the **velocity of site**
- **velocity ties between stations at same site**
- **discontinuities (earthquake, repairs, etc.)**



(Bachmann et al.,2016)

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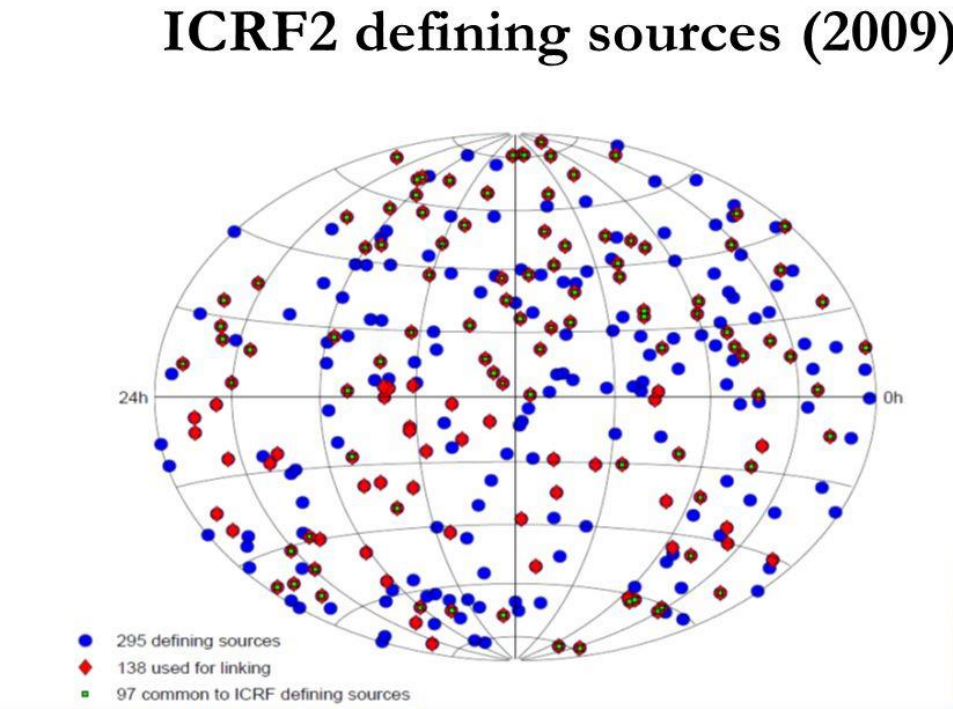
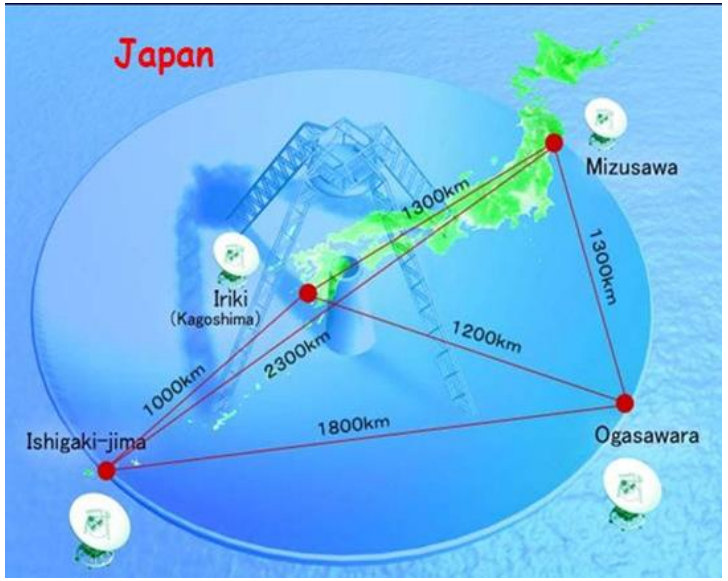
CRF

- **datum sources**
  - known stable sources with many observations
  - good distribution
  - defining sources are used to connect **catalogs**
- **Reduce sources**
  - Special handling sources
  - Sources with to little observations
- **(Fix sources)**



Special issues

- **single baseline sessions**
  - EOP from these sessions can not be estimated and have to be fixed in the global adjustment
- **Small regional networks**
  - Japanese domestic (JADE) sessions



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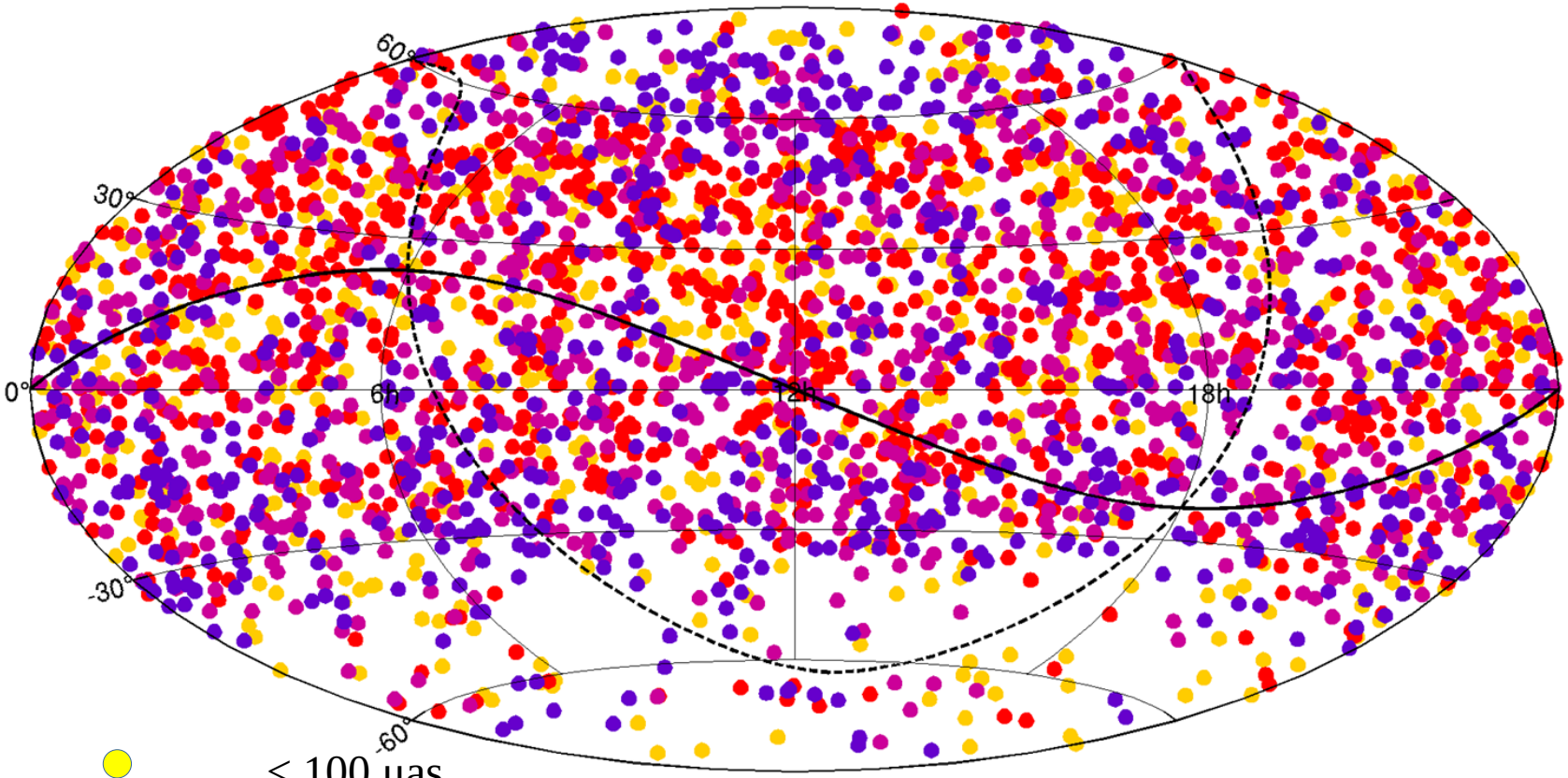
ICRF3



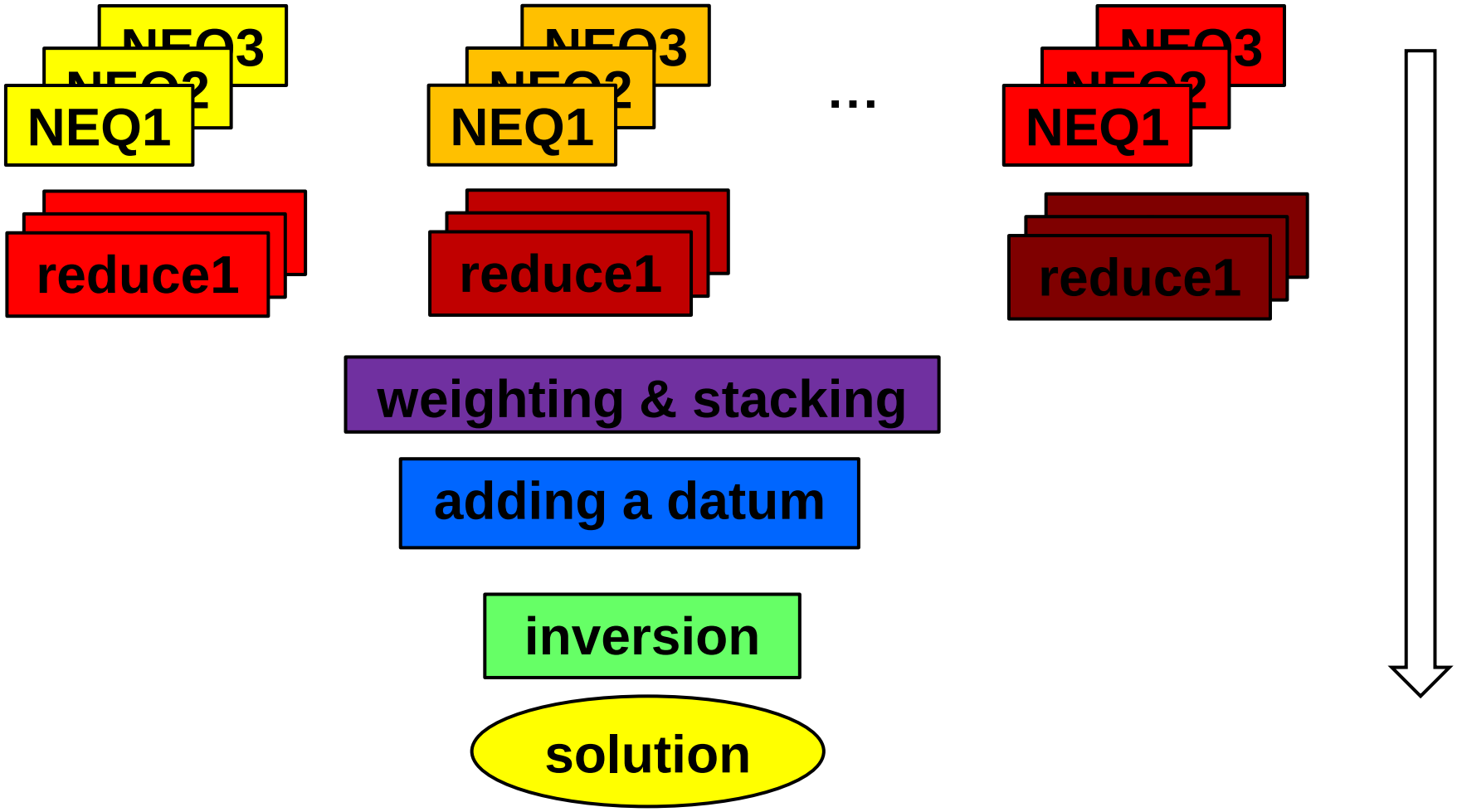
		< 100 μas
100 <		< 200
200 <		< 300
300 <		< 500
500 <		< 1000
1000 <		

Timeline

- **September 2016: 1st prototype solution**
  - Sessions: 5830 (August 1979 - April 2016)
  - Sources: ~4130
- **June 2017: 2nd prototype solution**
  - 6018 (August 1979 - April 2017)
  - Sources: ~4250
- **January 2018: 3rd & final**
  - Sessions: 6030 (August 1979 - November 2017)
  - Sources: ~4350
- **Testing & comparisons (ongoing)**
  - Completeness
  - Accuracy
- **Resolution published August 2018 at the XXXth IAU general assembly in Vienna**
- **01. January 2019: ICRF3 replaces ICF2**

ICRF4 ?

Combination



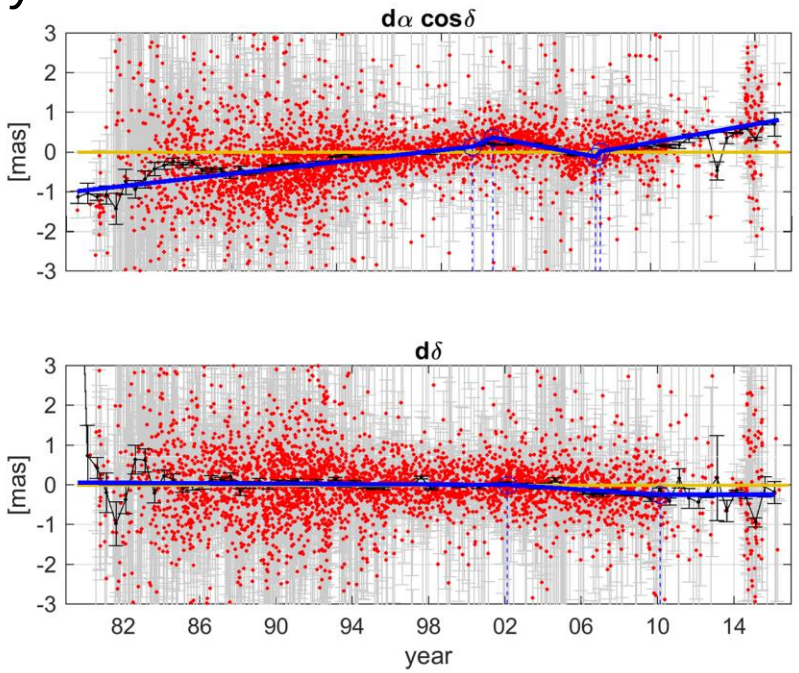
Combination

- **NEQ form different analysis centers**
- **NEQ from different frequencies**

- **Combine space geodetic techniques**
  - Consistency between TRF and CRF

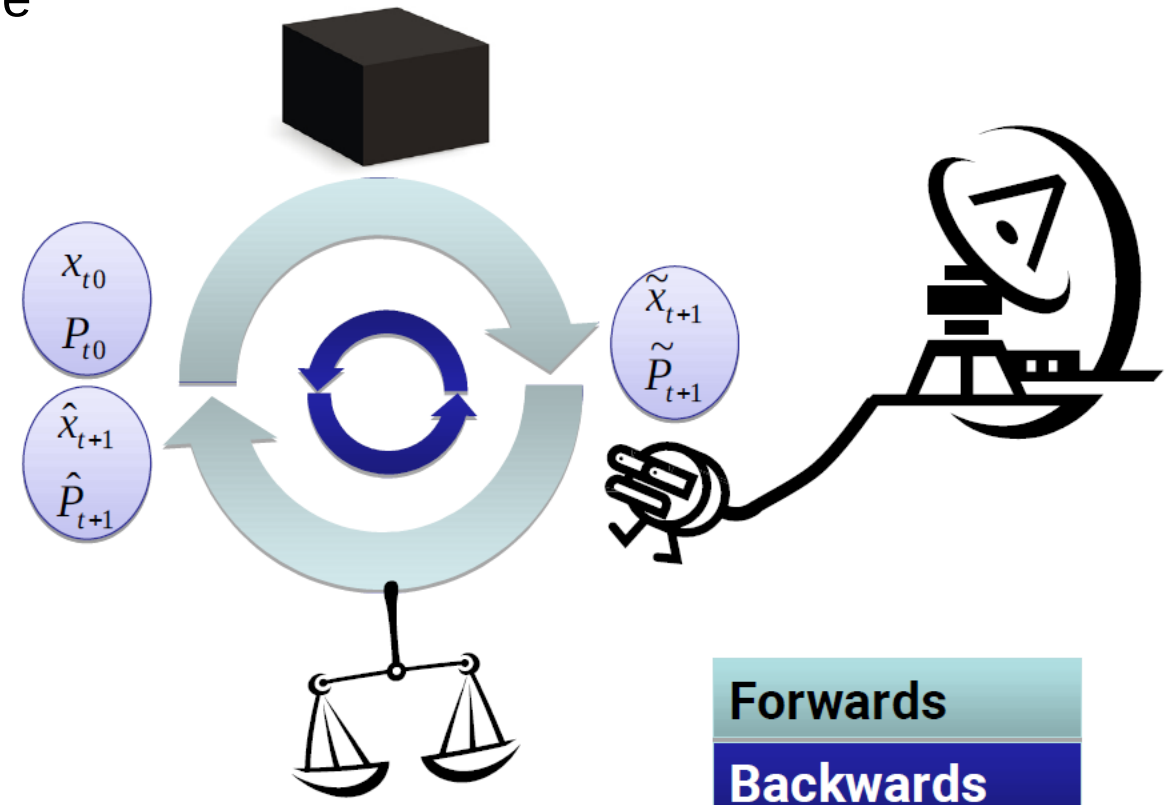
Parameterization

- **Advantages**
  - All sources can be potential datum sources
- **Disadvantages**
  - Spline cannot be generated on the fly
  - Post-processing method



Kalman filter

- **Advantages**
  - Parameterization can be replaced physics
- **Disadvantages**
  - Time varying reference frame



~..a priori
^..a posteriori

The End