Terrestrial data analysis strategies and software; SINEX generation

Pierguido Sarti [1], Detlef Angerman [2]

With contribution of

John Dawson [3] and Patrick Sillard [4,5]

[1] Istituto di Radioastronomia (IRA) – INAF – Bologna – Italy
[2] Deutsches Geodaetisches Forschungsinstitut (DGFI) – Munich – Germany
[3] Geoscience Australia – Camberra – Australia
[4] Institut National de la Statistique et des Etudes Economiques – France
[5] Institut Géographique National – France

Summary

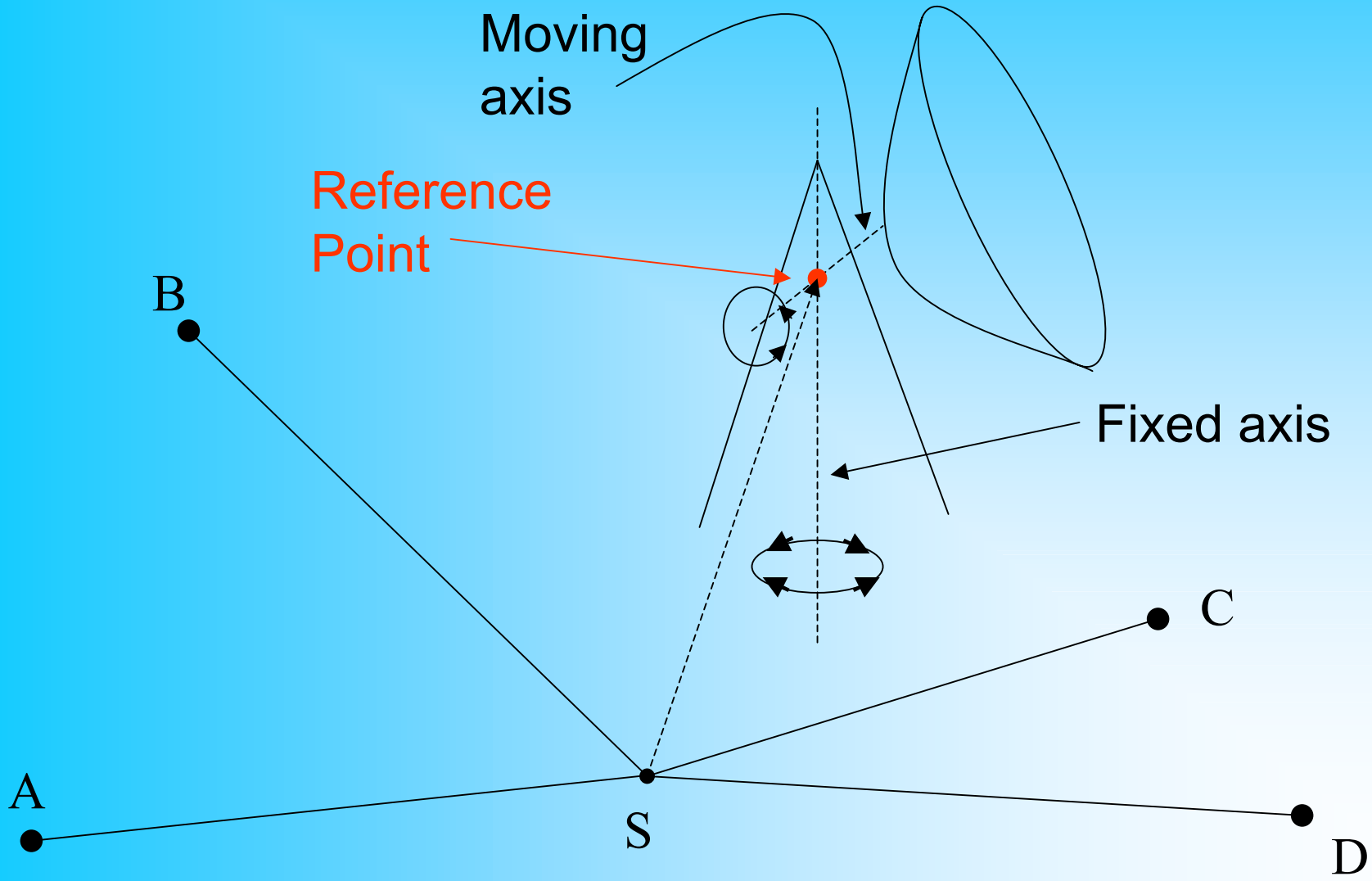
- Aspects related to Reference Point definition
- Ground observations
- Computation
- Documentation

- Recommendations for each topic

1. Different definitions for ITRF tracking points

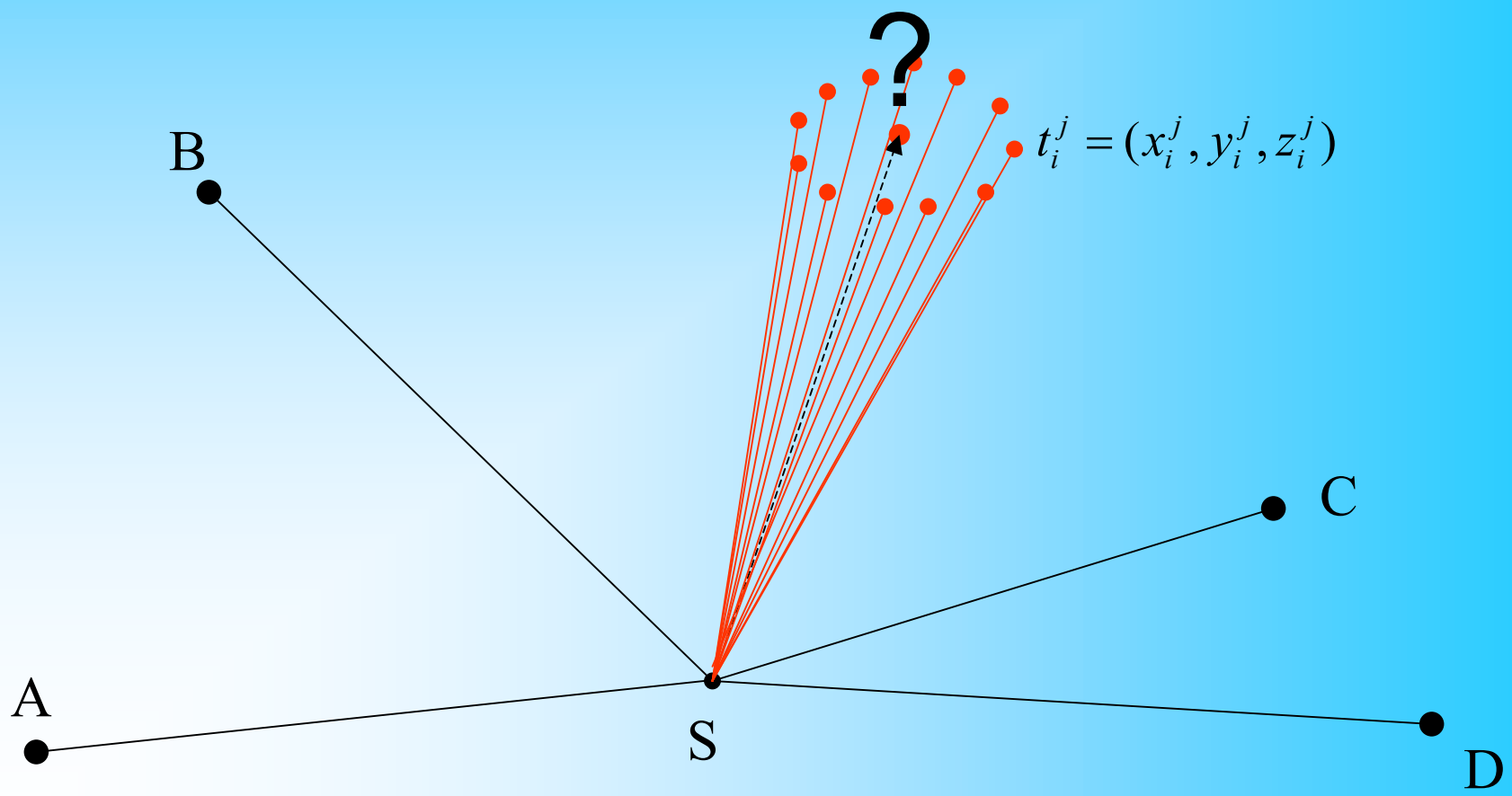
- The tracking point is materialized (e.g.: geodetic marker) => eccentricity with RP
- The RP is not materialized and is located trough geometrical constraints on observed targets

New issues arised by local ties: surveying immaterialized points

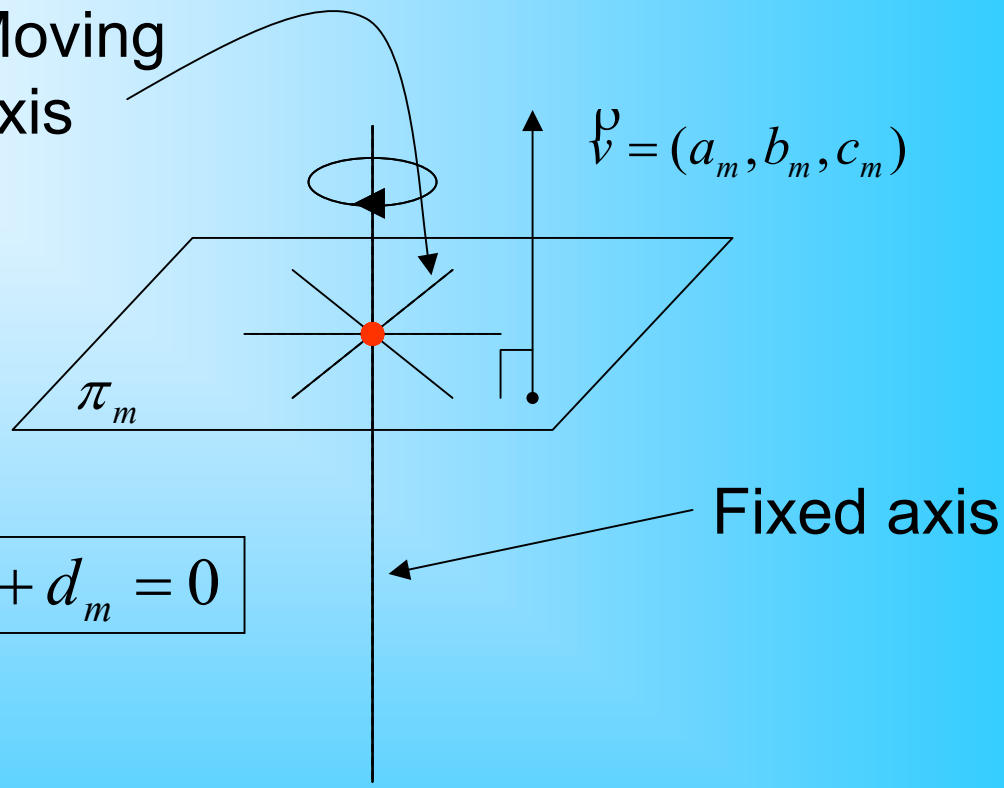


New issues arised by local ties: surveying immaterialized points

$$\forall\, t_i^j = (x_i^j, y_i^j, z_i^j)\, \exists\, g(x_i^j, y_i^j, z_i^j) = 0;\ 1 \le i \le k$$

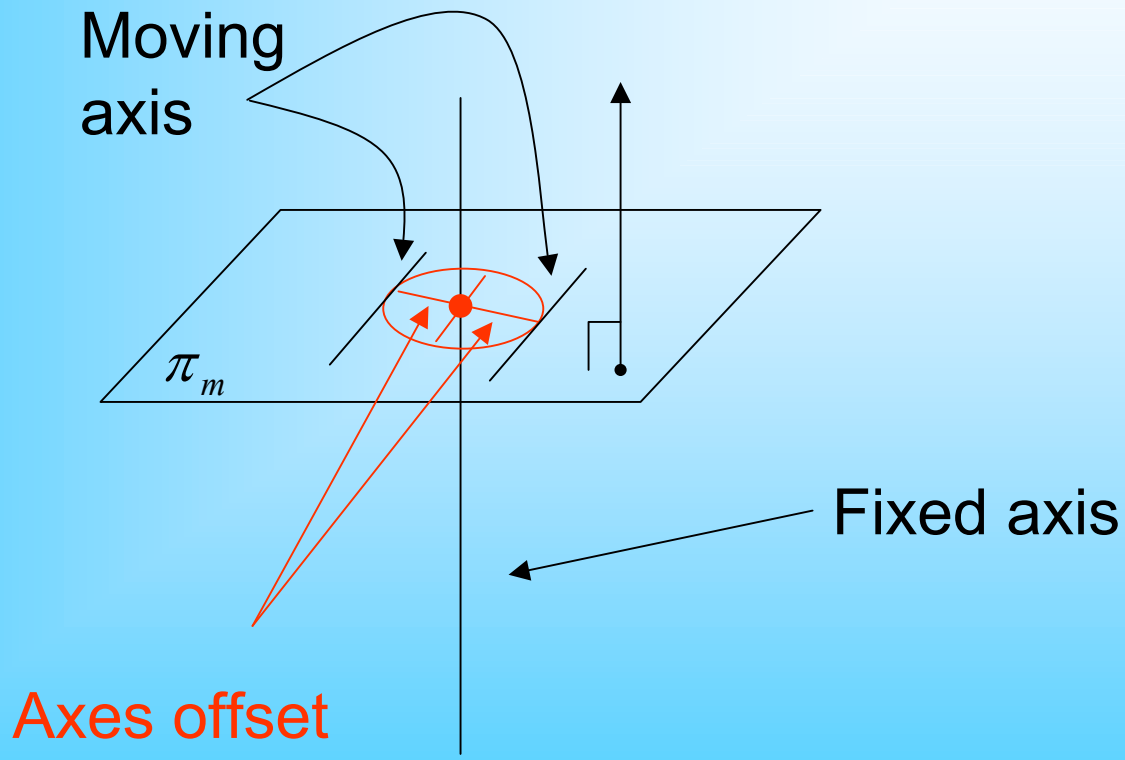


VLBI and SLR Reference Points

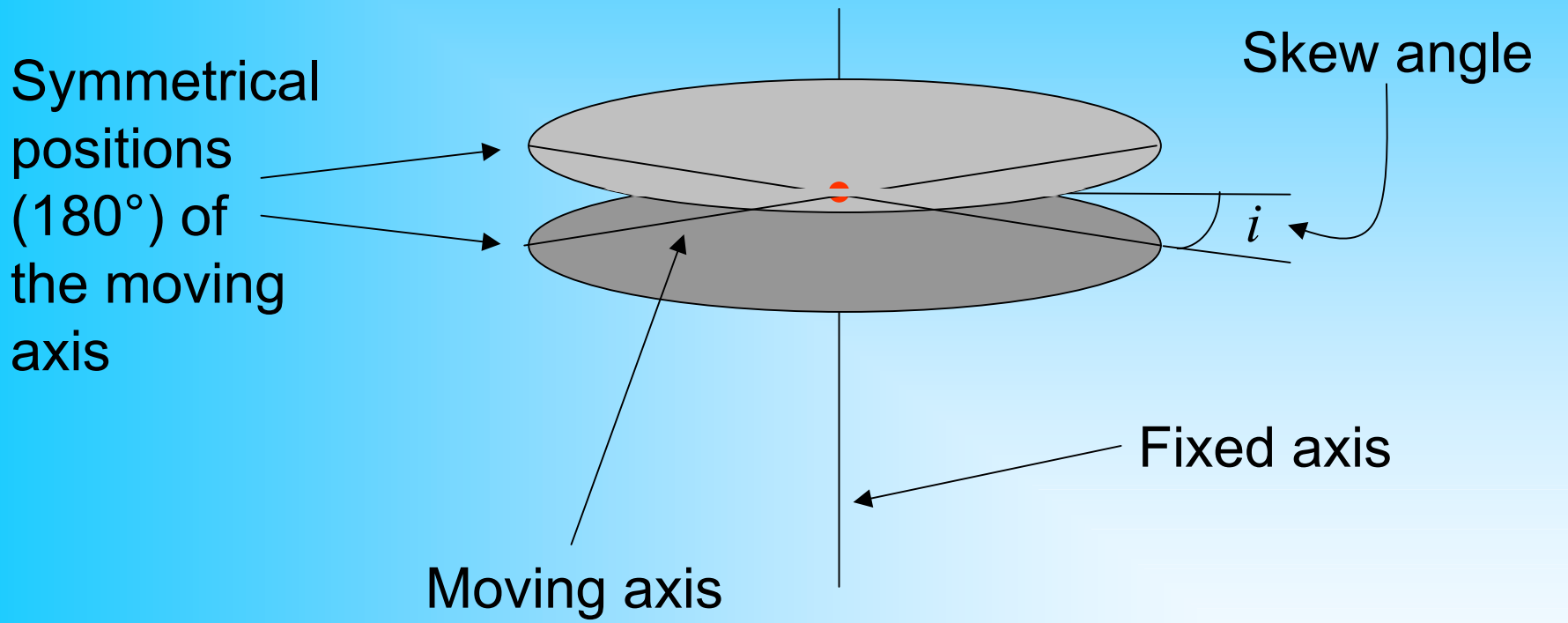


$$\pi_m : a_m x + b_m y + c_m z + d_m = 0$$

VLBI Reference Point with axes offset

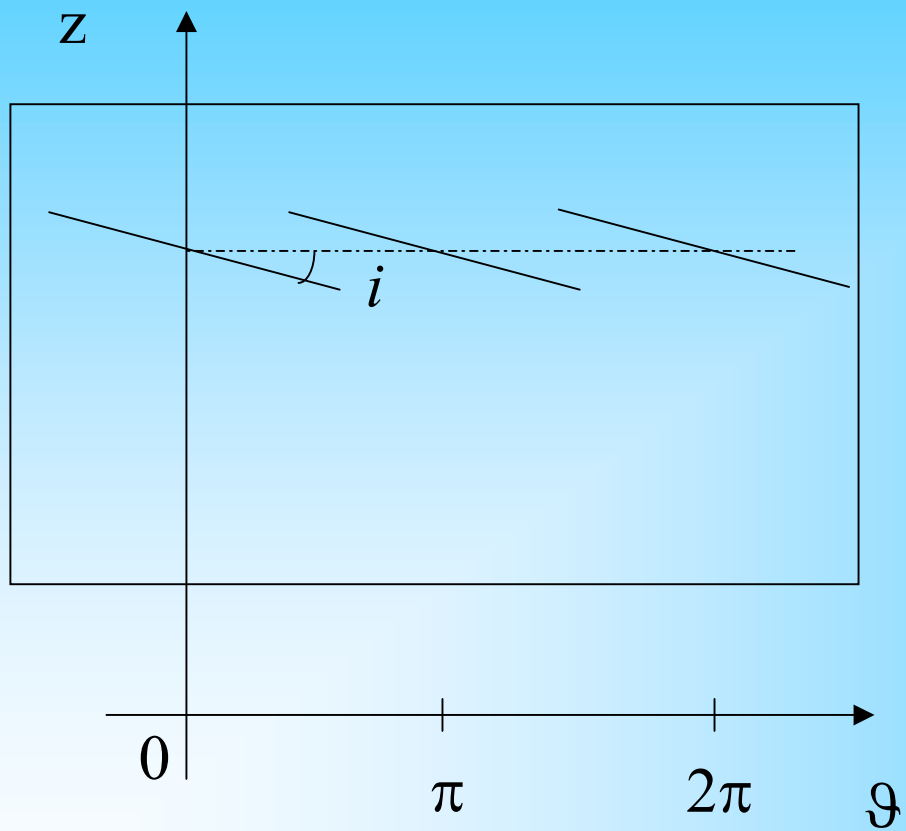


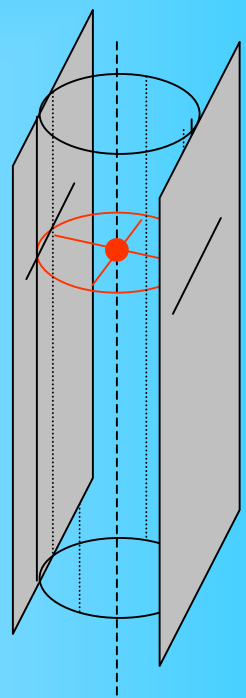
VLBI and SLR Reference Points: lack of orthogonality between the fixed and moving axis (skew error)



π_m does not exist!

VLBI Reference Point with offset AND lack of orthogonality between the axes





Recommendations

1. A clear definition of RPs be developed by the analysis communities for each technique
2. In every cases a geodetic marker is materialized and an accurate eccentricity is re-estimated every time the local tie survey is performed.
3. The Space geodetic analysis and local tie community develop new local tie products for use in analysis (e.g.: skew angle, tilt angle, wobble, structural deformations…)

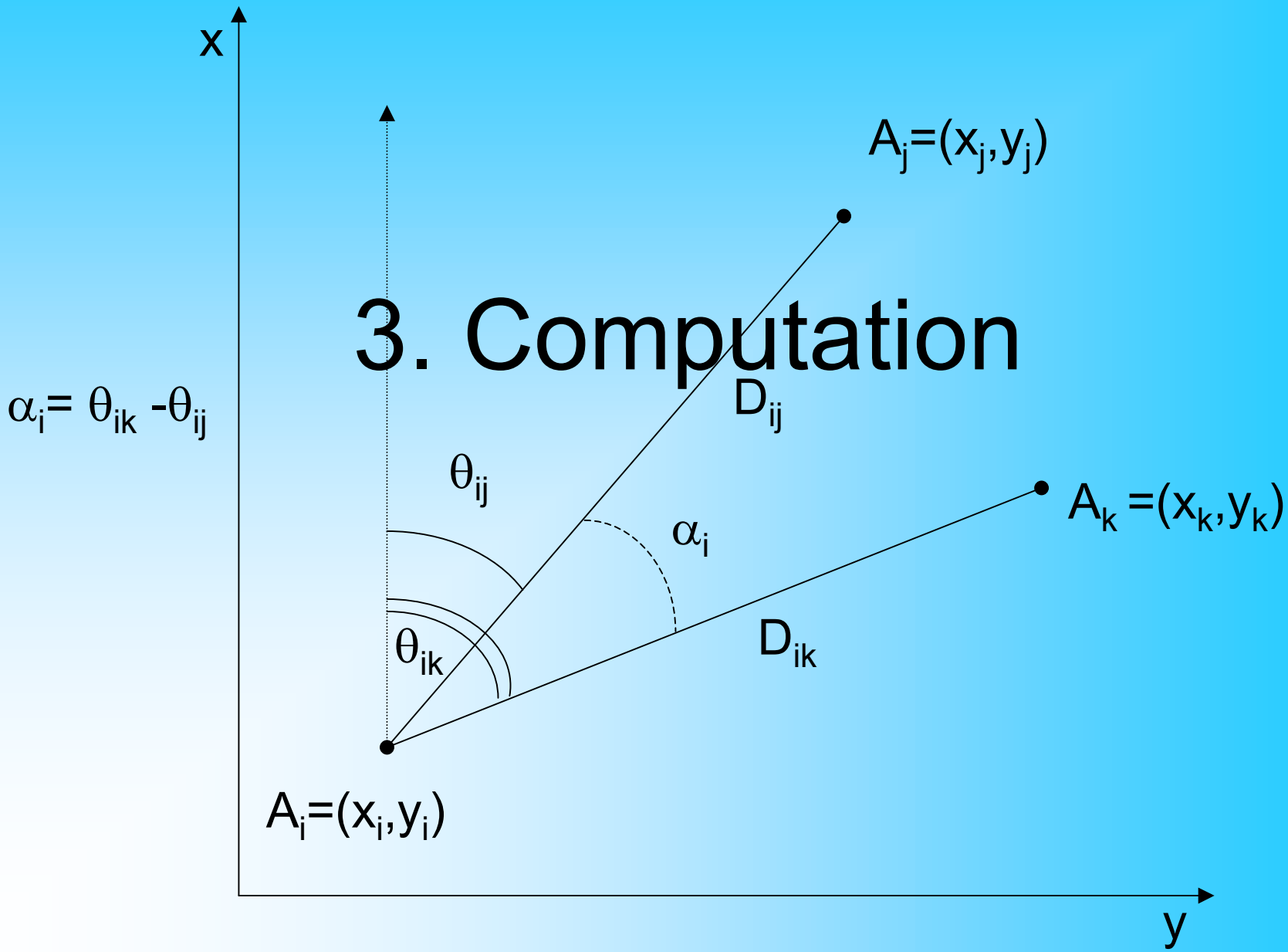
2. Ground Observations

- Final accuracy deeply influences the survey planning
- Design of the network has an impact on the variance-covariance matrix
- Relevant parameters for measurements corrections must be taken into account when processing (e.g.: refraction, geoid undulation)

Recommendations

4. Standardized campaign procedures for homogeneous and accurate results should be adopted
5. A priori simulation of terrestrial observations should be undertaken so as to asses the impact of the survey design

2-D sketch of triangulation and trilateration



3. Computation

Linearization: angles (1)

$$\theta_{ij} = \bar{\theta}_{ij} + \delta y_j \frac{\cos^2 \bar{\theta}_{ij}}{\bar{x}_j - \bar{x}_i} - \delta y_i \frac{\cos^2 \bar{\theta}_{ij}}{\bar{x}_j - \bar{x}_i} - \delta x_j \frac{\cos^2 \bar{\theta}_{ij} (\bar{y}_j - \bar{y}_i)}{(\bar{x}_j - \bar{x}_i)^2} +$$

$$+ \delta x_i \frac{\cos^2 \bar{\theta}_{ij} (\bar{y}_j - \bar{y}_i)}{(\bar{x}_j - \bar{x}_i)^2} \qquad \bar{D}_{ij} = \frac{(\bar{x}_j - \bar{x}_i)}{\cos \bar{\theta}_{ij}} = \frac{(\bar{y}_j - \bar{y}_i)}{\sin \bar{\theta}_{ij}}$$

$$\theta_{ij} = \bar{\theta}_{ij} + \delta y_j \frac{\cos \bar{\theta}_{ij}}{\bar{D}_{ij}} - \delta y_i \frac{\cos \bar{\theta}_{ij}}{\bar{D}_{ij}} - \delta x_j \frac{\sin \bar{\theta}_{ij}}{\bar{D}_{ij}} + \delta x_i \frac{\sin \bar{\theta}_{ij}}{\bar{D}_{ij}}$$

$$\theta_{ij} = \bar{\theta}_{ij} + a_{ij} (\delta x_j - \delta x_i) + b_{ij} (\delta y_j - \delta y_i)$$

Linearization: angles (2)

$$\theta_{ij} = \bar{\theta}_{ij} + a_{ij}(\delta x_j - \delta x_i) + b_{ij}(\delta y_j - \delta y_i)$$

$$\theta_{ik} = \bar{\theta}_{ik} + a_{ik}(\delta x_k - \delta x_i) + b_{ik}(\delta y_k - \delta y_i)$$

$$\bar{\theta}_{ik} + a_{ik}(\delta x_k - \delta x_i) + b_{ik}(\delta y_k - \delta y_i) +$$

$$-\bar{\theta}_{ij} - a_{ij}(\delta x_j - \delta x_i) - b_{ij}(\delta y_j - \delta y_i) - \alpha_i^* = \nu_i$$

$$(a_{ij} - a_{ik})\delta x_i + (b_{ij} - b_{ik})\delta y_i - a_{ij}\delta x_j - b_{ij}\delta y_j +$$

$$+ a_{ik}\delta x_k + b_{ik}\delta y_k + l_i = \nu_i$$

Linearization: distances

$$D_{ij} - D_{ij}^{*} = \nu_{ij}$$

$$D_{ij} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2}$$

$$D_{ij} = \sqrt{(\bar{x}_j + \delta x_j - \bar{x}_i - \delta x_i)^2 + (\bar{y}_j + \delta y_j - \bar{y}_i - \delta y_i)^2} =$$

$$= \bar{D}_{ij} + \delta x_j \frac{\bar{x}_j - \bar{x}_i}{\bar{D}_{ij}} - \delta x_i \frac{\bar{x}_j - \bar{x}_i}{\bar{D}_{ij}} + \delta y_j \frac{\bar{y}_j - \bar{y}_i}{\bar{D}_{ij}} - \delta y_i \frac{\bar{y}_j - \bar{y}_i}{\bar{D}_{ij}}$$

$$\boxed{-c_{ij}\delta x_i + c_{ij}\delta x_j - d_{ij}\delta y_i + d_{ij}\delta y_j + l_{ij} = \nu_{ij}}$$

Computation

- Wide variety of software for terrestrial data adjustment
- A sufficiently sophisticated modelling of relevant effects must be ensured
- Normal equations must be available for further processing, depending on RP measuring approach

Approaches to VLBI/SLR RP estimate

- **Direct:** observation of a physical target representing the RP
- **Hybrid:** observations of targets representing a materialization of the moving axis of the telescope
- **Indirect:** observation of targets on the structure of the telescope (also applicable in GPS/DORIS antenna)

Direct approach

- Rarely applicable (never in SLR)
- No connection with the physics of observations: difficult representation of the RP
- No information on the orientation and deformation of the telescope
- It is estimated straightforwardly in terrestrial data adjustment

Hybrid approach

- Observations of a rotational sequence of the targets representing the elevation axis
- No information on the axis orientation is recovered
- No information on the antenna deformation can be recovered
- The composition of tilt and skew angles will be indistinguishable
- Geometrical constraints are needed

Indirect approach

- Geometrical considerations are needed
- Heavely affected by gravitational deformations of the structure (VLBI)
- Aims at realizing the physical definition of the RP
- Tilt, skew and other relevant parameters can be estimated
- A better link with Space Geodesy structure modelling can be realized

Recommendations

6. The direct, hybrid and indirect approaches to RP determination must be compared
7. Different indirect methodologies and software must be evaluated
8. A pilot project should be set up: ad hoc survey at a representative co-location site

4. Documentation

- Datasets of terrestrial observations are of great importance for promoting software comparison
- Different groups should process the same observations
- Local network pillars survey are useful for local deformations
- SINEX files are the final result of complete local survey

Recommendations

9. Standards on raw terrestrial data archiving and sharing must be developed
10. Agreement on type and number of stations to be included in SINEX
11. Agreement on reference frame in which local ties are expressed in SINEX and how they are mapped
12. Agreement on the generation of SINEX files (e.g.: which blocks are mandatory and which constraints are applied)