Newsletter 3 of the subgroup T5 of the IAU WG ICRS

Towards a new definition of the CEP

(N. Capitaine, 31 January 2000)

The present Newsletter of the subgroup T5 is devoted to the preliminary conclusions concerning the discussion on the future of the Celestial Ephemeris Pole. The individual answers or comments to the questions of the Newsletter 2 are given in an Annex to this Newsletter.

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This Newsletter includes the following sections :

1. The possible options for an extended definition
2. Summary of the answers and comments to the Newsletter 2
3. Considerations on the main issues
4. Preliminary proposals
5. New questions to the subgroup T5

1 The possible options for an extended definition (c.f. Newsletter 2)

The extended definition of the CEP must take into account the high frequency components both in polar motion and nutation at the microarcsecond level and must be not dependent on the techniques and strategy of observations.

Definition

The separation between the terrestrial and the celestial parts of the motion as considered for the current definition of the CEP cannot be extended to the high frequency domain, as there is, in such a domain, an overlapping between the motions in the CRS and the TRS. An other kind of separation has therefore to be proposed for extending the definition in such a frequency domain. The definition must clearly specify which part of the motion is considered in the CRS or the TRS on the basis on clear theoretical considerations. Two different approaches have been considered in order to achieve this goal :

A) a *deterministic approach* (previously called *dynamical*), separating the motions according to their physical cause,

B) a *frequency approach* separating the motions according to their frequency domain.

Following the deterministic approach, the *predictable* sub-diurnal terms can be included (options A1, A2) or not (A3) in the nutation model and the *predictable high frequency* motion in the TRS can be included (A2) or not (A3) in the model for the polar motion

Following the frequency approach, Mathews (1999 a) has proposed a definition (B1) of the CEP which keeps the symmetry in the frequency band between terrestrial motion and celestial motion by extending the definition outside the current frequency interval.

An other option (B2) is to separate the motions according to the known frequencies of the predictable motions in the CRS and TRS. This option corresponds rather to a deterministic approach.

Realization

The procedure (C1) proposed by Mathews for realizing the definition B1 is to estimate simultaneously, in processing the observations, the current celestial pole offsets and current polar motion and the high frequency signal. The estimated high frequency components are diurnal and semi-diurnal retrograde periodic terms in the celestial motion and diurnal and semi-diurnal prograde periodic terms in the terrestrial motion. Such a procedure realizes a definition of the CEP which extends the current one on a symmetric way in the frequency domain (see Brzeziński 1999 for an extensive discussion on the use of these high frequency parameters in polar motion and nutation). However, the estimated high frequency motions do not correspond to the predictable ones, which are prograde within the CRS and both prograde and retrograde in the TRS.

An other proposed procedure (C3) is similar to the previous one but estimating only the current celestial pole offsets in the CRS and the whole predictable high frequency signal (prograde and retrograde diurnal components as well as prograde and retrograde semi-diurnal ones) in the TRS. This corresponds to a deterministic approach .

Other possible realizations are based upon a global analysis (C2) of the current estimates of the EOP (or only the pole coordinates) over a long period in order to extract the high frequency signal.

2 Summary of the answers and comments to the Newsletter 2

Definition

- it is necessary to abandon the IAU 1980 conceptual definition which specifies that "this pole has no nearly-diurnal motion...",
- the reference pole has not to be defined by its realization but by a clear concept not dependent on further improvements in the model,
- this pole must be realizable by a model as accurately as possible,
- the change from the CEP to the new definition has to be as less as possible in its practical realization,
- a change of name could be considered as the "Celestial Reference Pole" (CRP), or the "Celestial Intermediate Pole" (CIP),

- the deterministic approach seems to be preferable, as it appears to be more easily realizable and A3 is the preferred option,

A much debated question is to include or not the diurnal and semi-diurnal terms of nutation in the CRS. Perhaps it should be necessary to define a "Mean CRP" (MCRP) including only the long periodic part of the motion both in the TRS and the CRS, and then a "true CRP" as obtained by adding the high frequency components to the polar motion of the MCRP.

Realization

- the pole of reference must no more be realized by the IAU 1980 theory of nutation,

- the reference pole must not be defined by a model, but must be realizable by a model as accurately as possible,

- precession and nutation must be specified by a conventional model, including or not the high frequency nutations according to the chosen option for the conceptual definition,

- the preferred option for realizing the pole is to extract the high frequency signal (or corrections to an empirical model for this signal) from the pole coordinates only (C3),

A much debated question is if the high frequency signal in polar motion must be estimated together with the long periodic motion in the software for processing the data or must rather be estimated in a second step from the currently estimated coordinates of the pole.

3 Considerations on the main issues

The main issues (see Capitaine 1999 for more details) concern the predictable high frequency motions in nutation (Bretagnon *et al.* 1997) and polar motion (Herring & Dong 1994) and the new strategy of observations in which the part of sub-daily observations will increase in a near future.

1) The recent models, at a microarsecond accuracy, include :

- prograde diurnal nutations (in $\Delta\psi \sin\varepsilon_0$ and $\Delta\varepsilon$) with amplitudes of the order of 15 microarseconds,

- prograde semi-diurnal nutations with amplitudes of the order of 15 microarseconds.

- prograde diurnal variations in polar motion with amplitudes of the order of 150 microarseconds,

- prograde semi-diurnal variations in polar motion with amplitudes of the order of 100 microarseconds,

- retrograde diurnal variations in polar motion with amplitudes of the order of the order of 800 microarseconds,

- retrograde semi-diurnal variations in polar motion with amplitudes of the order of 300 microarseconds.

The overlapping between these different motions is such that :

- the prograde diurnal nutations in space appear in the Earth (Bizouard *et al.* 1999) as long periodic prograde and retrograde variations in polar motion,

⇒ it seems therefore appropriate to extend the definition of the CEP such that this motion be rather considered as a part of the motion of the pole in the TRS (which can be given by a model),

- the semi-diurnal prograde nutations in space appear as prograde diurnal variations in polar motion and it is necessary to choose where to consider more logically this motion, (it must be noted that such prograde diurnal variations in polar motion have in fact already been computed, for a non-rigid Earth, by Chao *et al* (1991) as resulting from the "polar libration" and are thus included in their model for diurnal polar motion).

⇒ such a motion being dependent on the Earth model, it seems more appropriate to consider it in the TRS (which can be given by a model).

- the retrograde diurnal terms in the tidal polar motion variations are in fact included in the most recent models of nutation for a non-rigid Earth,

⇒ such terms must therefore be excluded of the model of polar motion,

- the effect of the purely diurnal oceanic tide K1 must be considered to be included in the constant part of the celestial pole offsets,

⇒ such a term must therefore be excluded of the model of polar motion.

2) For sub-daily observations, the two frequency intervals of polar motion and nutation are no more disjoined and the frequency domain decomposition

into polar motion and nutation becomes unclear. This prevents to estimate simultaneously polar motion and nutation as it is the case in the current VLBI daily estimates.

The major part of the polar motion being not a predictable motion, which has therefore to be estimated by the observations, it seems reasonable, in this case, to specify the precession-nutation by a model and to estimate only the terrestrial part.

References

Bizouard, C., Folgeira, M., Souchay, J., 1999 a, in the Proceedings of the IAU Colloquium 178.

Bretagnon, P., Rocher, P., and Simon, J.-L., 1997, *Astron. Astrophys.***319**, pp 305-317.

Brzeziński,A., 1999, to be published in the Proceedings of the IAU Symposium 178.

Capitaine, N., 1999, to be published in the Proceedings of the IAU Symposium 178.

Chao, B.F., Dong, D.N., Herring, T.A., 1991,*Geophys. Research Letters* **18**, 11, 2007-2010.

Herring, T.A. and D. Dong, 1994, *J. Geophys. Res.* **99**, pp. 18051-18071

Mathews, P.M., 1999 a, in the Proceedings of the *Journes Systmes de Rfrence Spatio-Temporels* 1998, N. Capitaine ed, Observatoire de Paris, pp 161-163.

4 Preliminary proposals

The answers and comments to the Newsletter 2 as well as the considerations above lead to the preliminary proposals :

1) The IAU 1980 conceptual and conventional definition of the CEP must be abandoned,

2) the reference pole has not to be defined by its realization but by a clear concept not dependent on further improvements in the model,

3) this pole must be defined such that it can be realizable by a model as accurately as possible,

4) the change from the CEP to the new definition has to be as less as possible in its practical realization,

5) a change of name could be considered as the "Celestial Reference Pole" (CRP), or the "Celestial Intermediate Pole" (CIP),

6) concerning the motion with respect to the CRS, the choice should be to specify this motion by a model including only the components with periods longer than 2 days (such a model will automatically include all the geophysical perturbations such as the retrograde diurnal motion due to ocean tides),

7) a tentative conceptual definition is "the Pole of the intermediate equator of which motion with respect to the CRS is produced by the luni-solar and planetary torque" (or ... "by the external gravitational forces acting on the Earth"),

as the high frequency motion is not considered in the nutation model, it may be possible to add to the conceptual definition that "the motion of the equator with respect to the CRS is considered for an Earth with an equatorial symmetry", or that "the motion is considered after filtering out terms of period shorter than 2 days",

8) the prograde diurnal terms in nutation should be considered as long periodic terms of the polar motion and the prograde semi-diurnal terms in nutation should be considered as prograde diurnal terms of the polar motion,

9) concerning the motion with respect to the TRS, the choice should be to sharpen the definition of the pole of reference by taking into account the prograde diurnal variations as well as the prograde and retrograde semi-diurnal variations as a predictable part of the polar motion which can be realized by a model,

10) the processing of the observations should include the estimation of the celestial pole offsets wrt the model for precession-nutation as well as the corrections to an empirical model for polar motion,

11) a "Mean CRP" (MCRP) could be defined including only the long periodic part of the motion both in the TRS and the CRS, and then a "true CRP" as obtained by adding the high frequency components to the polar motion of the MCRP.

12) a conventional procedure must be given for estimating the high frequency components in polar motion in order to provide the best realization of the pole in the processing of observations : C3 is proposed when possible or C2 in the more general case.

5 New questions to the subgroup T5

These preliminary proposals for a new definition of the pole of reference are submitted to the subgroup T5 through the following questions :

1. Do you support the proposals above (which ones from 1 to 12) ?

2. Which complementary comments do you consider as necessary ?

3. If you do not support one or several proposals, which alternative proposals are preferable ?