DISCUSSION FOR THE MEAN POLE
IDS 2017

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IERS STANDARDS, POLE AND MEAN POLE

Objective :

response of the earth to the accelerations due to pole changes

<u>Stations positions :</u>

low frequency : postglacial rebound part (linear motion) included in the ITRF
still correct hypothesis ?

response to annual/chandler frequency band, how to compute it correctly ?

<u>Earth gravity field : effects on J2 orientation (C21,S21)</u>

low frequency part : 'mean pole' geometric transformation

annual/Chandler frequency band

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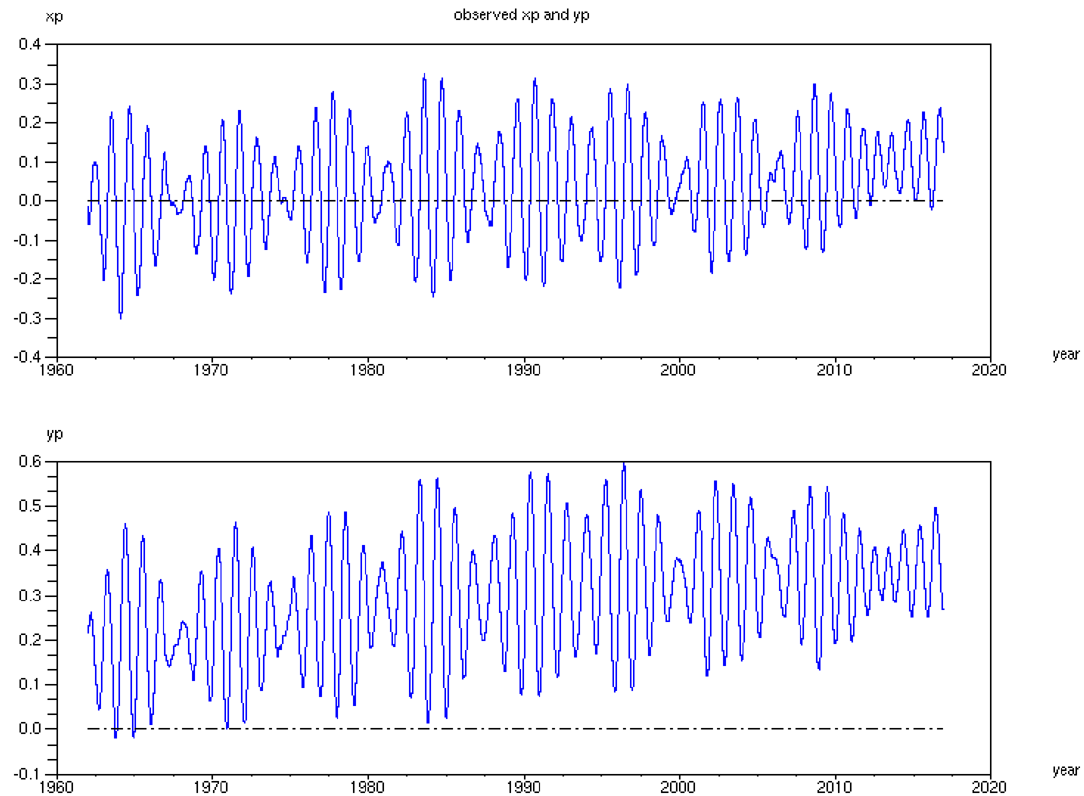
OBSERVED POLAR MOTION



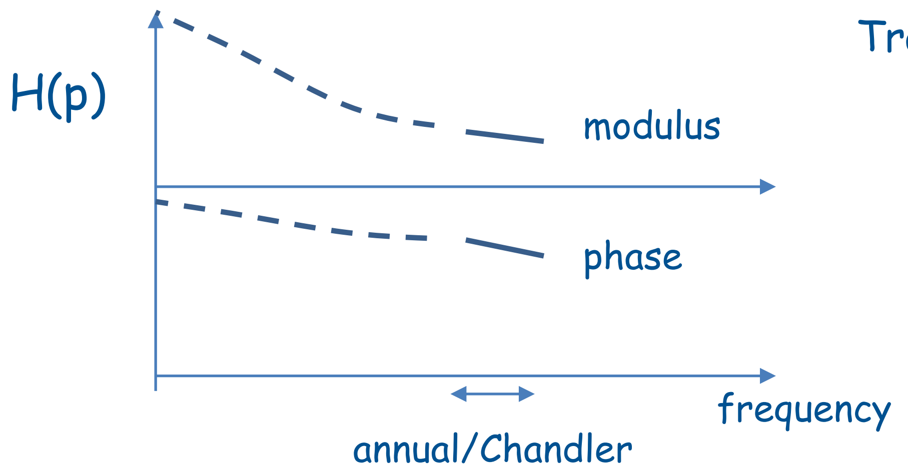
Main frequency content

- annual (~ 365.25 days)
- Chandler (~ 435 days)
- low frequency
  assumed linear motion up to ~1990
  pluriannual content observed on the complete interval

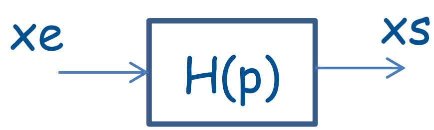
How to estimate the earth response to the complete excitation defined as a function of time ?

Remark : the low frequency part of the response may depend on past effects, not known

DYNAMIC SYSTEM TRANSFER FUNCTION



Transfer function known in the annual/Chandler frequency band



$$\begin{aligned} \dot{x}_s + a_0 x_s &= a_1 x_e \quad \text{with } a_0 > 0 \\ \dot{y}_s + a_0 y_s &= a_1 y_e \end{aligned}$$

Annual frequency band only :

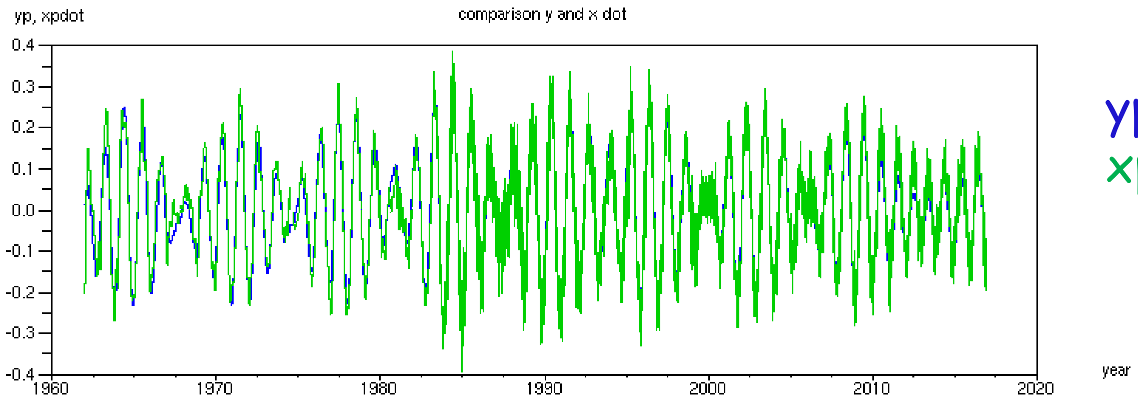
$$x_e = a\cos(\omega t + \phi) \longrightarrow \begin{aligned} (i\omega + a_0)x_s &= a_1 x_e \\ (i\omega + a_0)y_s &= a_1 y_e \end{aligned}$$

Transformed, for a prograde (clockwise) motion for xe,ye ($\begin{matrix} \dot{x}_e & \leftrightarrow & \omega y_e \\ \dot{y}_e & \leftrightarrow & -\omega x_e \end{matrix}$):

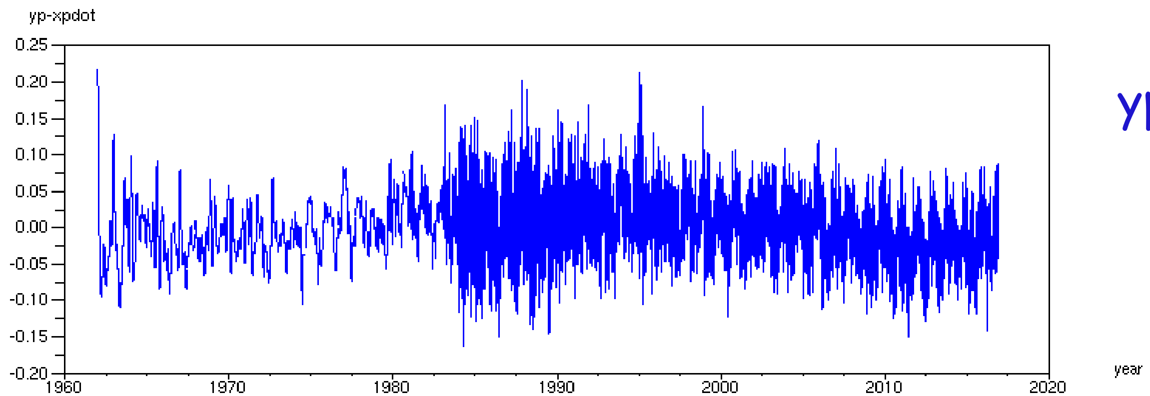
$$\begin{aligned} x_s &= x_e - 0.0115 y_e \\ y_s &= y_e + 0.0115 x_e \end{aligned}$$

The formula is valid only in the annual frequency band and for prograde xe,ye

XPDOT AND YP



yp
xpdot

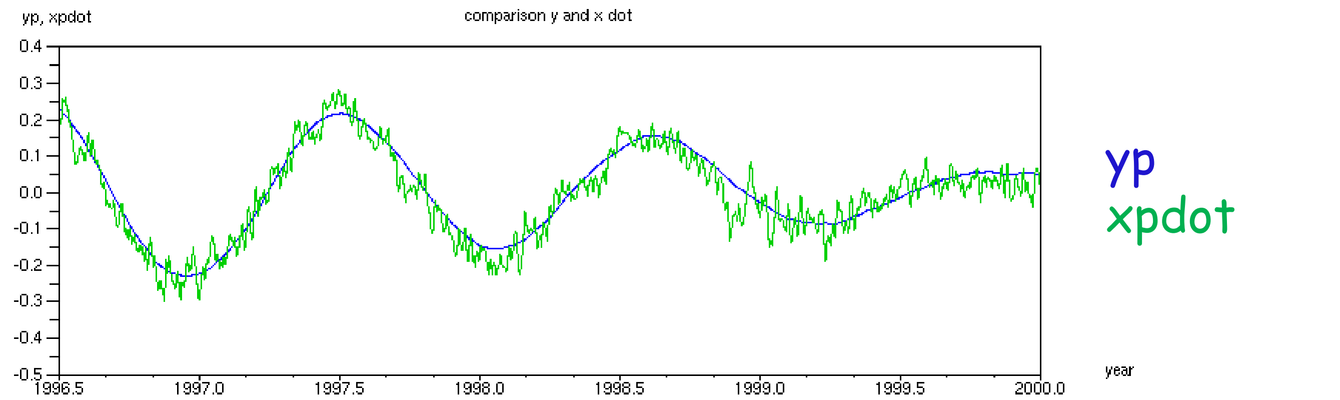


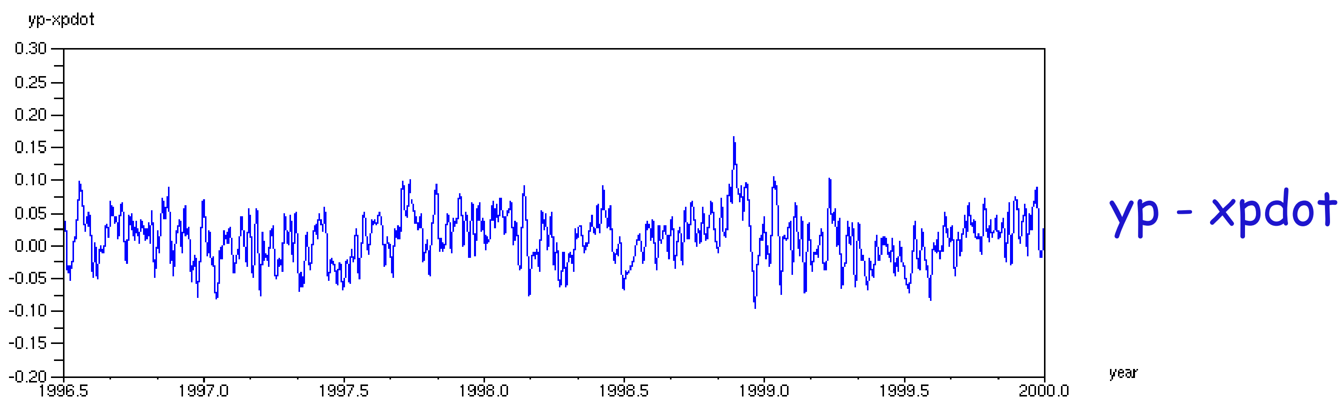
yp - xpdot

High frequency content due to xpdot estimation method (finite differences)

Low frequency content is from yp (comparison with the complete yp signal)

XPDOT AND YP





High frequency content due to xpdot estimation (finite differences)

xpdot can be efficiently estimated using yp information at annual frequency (same property for ypdot and -xp)

IERS STANDARDS FORMULAS

The formula can be used only in the annual/Chandler frequency band :

in this case, using functions $\hat{x}_e, \hat{y}_e$ containing all the low frequency content of each signal xe,ye we have :

$$
\begin{aligned}
x_s &= (x_e - \hat{x}_e) - 0.0115(y_e - \hat{y}_e) \\
y_s &= (y_e - \hat{y}_e) + 0.0115(x_e - \hat{x}_e)
\end{aligned}
$$

$\hat{x}_e, \hat{y}_e$ contain all the contribution outside the frequency band of interest

in the external potential, which is equivalent to changes in the geopotential coefficients C_{21} and S_{21}. Using for k_2 the value $0.3077 + 0.0036\,i$ appropriate to the polar tide yields

$$
\begin{aligned}
\Delta\bar{C}_{21} &= -1.333 \times 10^{-9}(m_1 + 0.0115 m_2), \\
\Delta\bar{S}_{21} &= -1.333 \times 10^{-9}(m_2 - 0.0115 m_1),
\end{aligned}
$$

where m_1 and m_2 are in seconds of arc. (IERS standards 2010)

m1 and m2 should contain only information in the annual/Chandler frequency band

$$(m_1 = x_p - \bar{x}_p, \qquad m_2 = -(y_p - \bar{y}_p))$$

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IERS STANDARDS FORMULAS

Same remark holds for the stations coordinates :

$$S_r = -33 \sin 2\theta\,(m_1 \cos\lambda + m_2 \sin\lambda)\ \text{inmm},$$

$$S_\theta = -9 \cos 2\theta\,(m_1 \cos\lambda + m_2 \sin\lambda)\ \text{inmm},$$

$$S_\lambda = 9 \cos\theta\,(m_1 \sin\lambda - m_2 \cos\lambda)\ \text{inmm},$$

(IERS standards 2010)

The 'mean pole' to be used in m1 and m2 in these formulas is a filtering correction not a geophysical model mean pole

Remark : from Wahr 2015, comparison with standards 2010

$$\begin{aligned}
k_2^r &= 0.3077 \\
k_2^i &= 0.0036 \\
a_e &= 6378136.6\ \text{m} \\
g_e &= 9.7803278\ \text{ms}^{-2} \\
\Omega &= 2\pi\ 1.002737811911/86400
\end{aligned}$$

$$\begin{aligned}
C_{21} &= -\frac{a_e\Omega^2}{g_e\sqrt{15}}(k_2^r m_1 + k_2^i m_2) \\
&= -1.336\ 10^{-9}(m_1 + 0.0117 m_2)
\end{aligned}$$

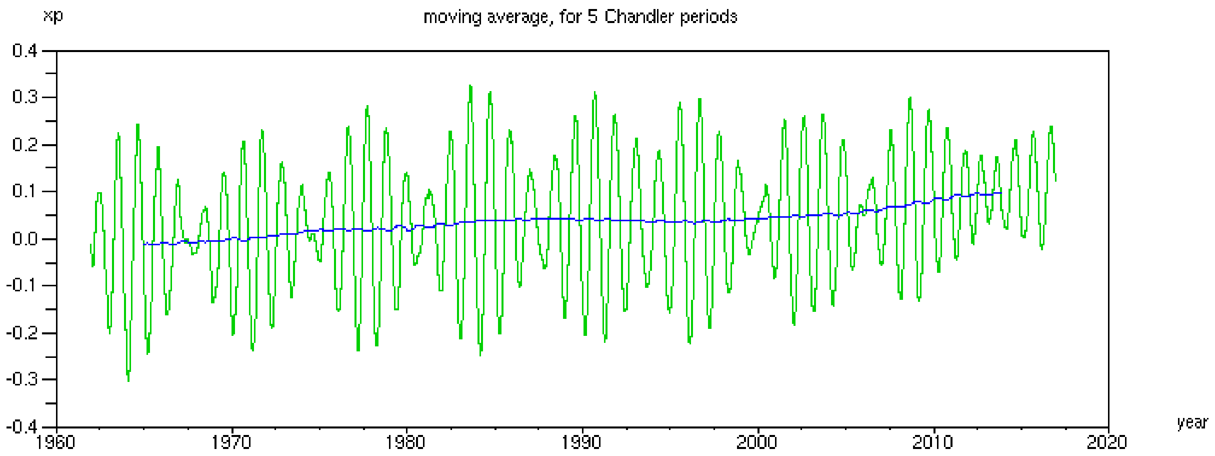
$$\begin{aligned}
S_{21} &= -\frac{a_e\Omega^2}{g_e\sqrt{15}}(k_2^r m_2 - k_2^i m_1) \\
&= -1.336\ 10^{-9}(m_2 - 0.0117 m_1)
\end{aligned}$$

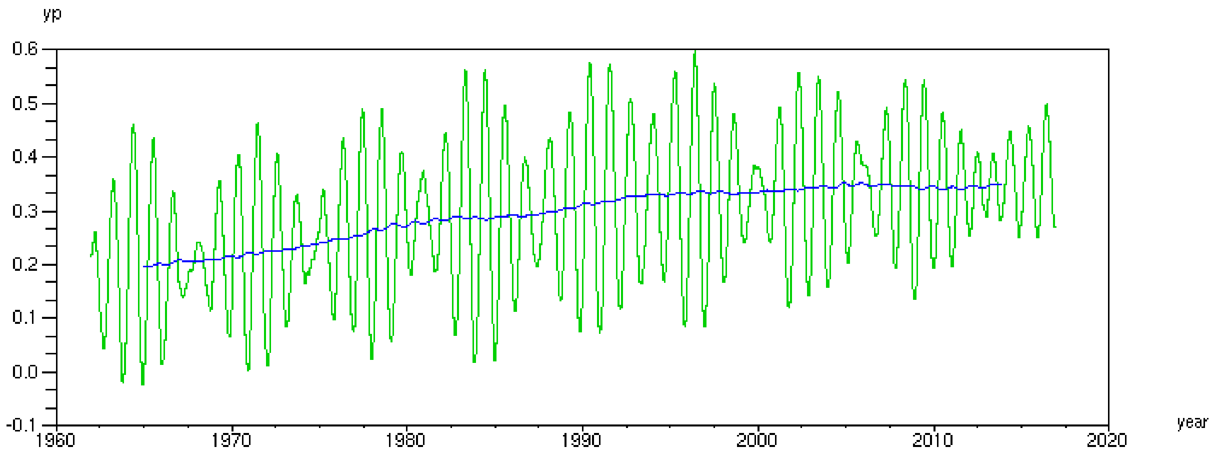
Small diffrences

0.0117 and 0.0115 (standards)

1.336 and 1.333 (standards)

SIGNAL CHARACTERISTICS OUTSIDE THE ANNUAL BAND



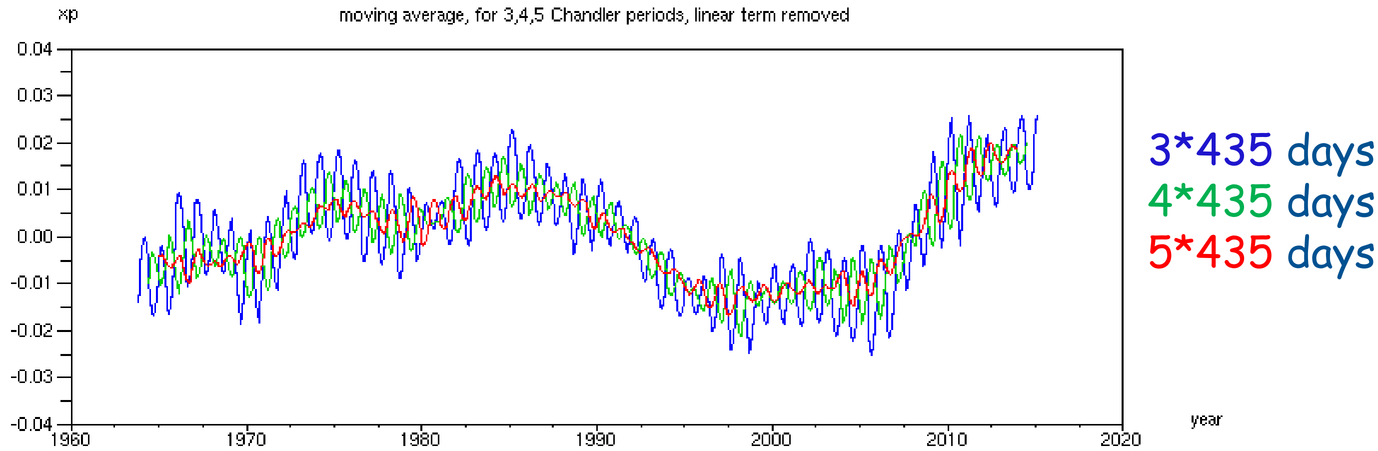


Moving average, 5 Chandler periods : good extraction of the frequency band

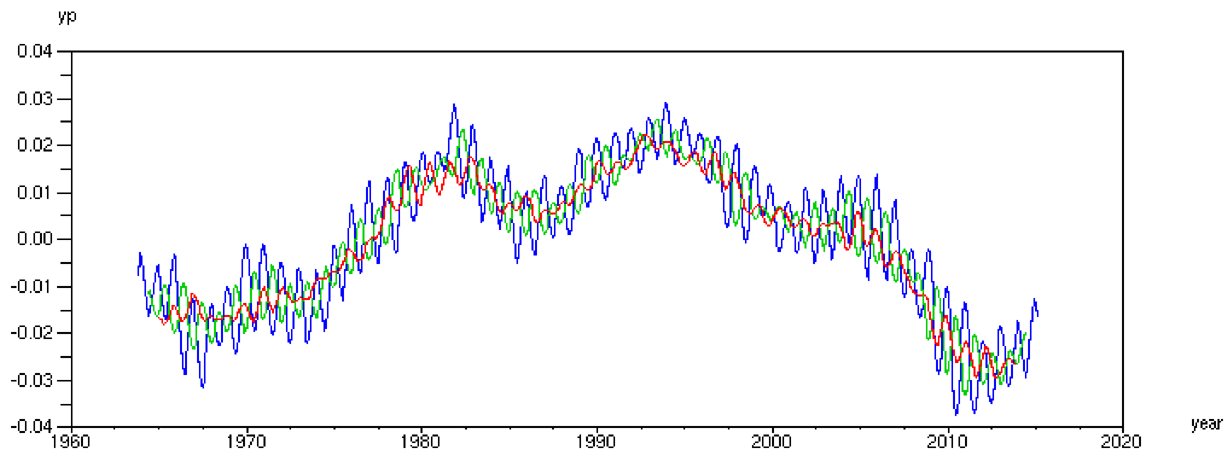
Some pluriannual variations

PRECISION OF THE ESTIMATED LOW FREQUENCY SIGNAL

1 mm effect
on station positioning
at annual/Chandler



1 mm effect
on station positioning
at annual/Chandler



All filtering methods are convenient for a millimetric performance
The remaining frequencies participating below the annual/Chandler signals have negligible effects
Using a linear function as filtering reference with produce several millimeters errors

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CONCLUSION

Annual/Chandler perturbations

m1 and m2 for annual/Chandler formulas in the standards must be computed using a filtered mean pole value for full precision

Filtering with a moving average is sufficient for station positioning
- submillimetric precision for station positioning at annual/Chandler
- linear reference can produce several millimeters errors

→ at least, the current standards approach must be used

Low frequency perturbations

there are pluriannual terms with 0.02, 0.04 arcsec variations

- the response of the earth system at these frequencies is not detailed (use of a 'static' transformation, as in the standards ?)

- are such variations observable in the stations coordinates time series ?

- for the earth potential, the use of a variable gravity field removes the problem (but consistent conventions for the mean pole shall be used)