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# Estimation of period and $Q$ of the Chandler wobble

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## SUMMARY

The period $P$ and $Q$-value of the Chandler wobble are two fundamental functionals of the Earth's internal physical properties and global geodynamics. We revisit the problem of the estimation of $P$ and $Q$, using 10.8 yr of modern polar motion as well as contemporary atmospheric angular momentum (AAM) data. We make full use of the knowledge that AAM is a major broad-band excitation source for the polar motion. We devise two optimization criteria under the assumption that, after removal of coherent seasonal and long-period signals, the non-AAM excitation is uncorrelated with the AAM. The procedures lead to optimal estimates for $P$ and $Q$. Our best estimates, judging from comprehensive sets of Monte Carlo simulations, are $P = 433.7 \pm 1.8$ ($1\sigma$) days, $Q = 49$ with a $1\sigma$ range of (35, 100). In the process we also obtain (as a by-product) an estimate of roughly 0.8 for a 'mixing ratio' of the inverted-barometer (IB) effect in the AAM pressure term, indicating that the ocean behaves nearly as IB in polar motion excitation on temporal scales from months to years

**Key words:** atmospheric angular momentum, Chandler wobble, period, polar motion, $Q$-factor.

## 1 INTRODUCTION

The free Eulerian motion in the Earth's rotation, known as the Chandler wobble, was discovered in astrometric data by S. Chandler over 100 years ago. It has a period $P$ of about 14 months as viewed from the terrestrial reference frame, and a finite quality factor $Q$ due to inevitable energy dissipation. Chandler $P$ and $Q$ are two of the fundamental functionals for global geodynamics. Observations of their values are useful constraints in the inference of physical properties of the Earth's interior (e.g. Smith & Dahlen 1981; Okubo 1982; Zschau 1986): $P$ depends sensitively on the mantle elasticity and anelasticity structure, the extent to which the fluid core is decoupled from the mantle, and how close the pole tide is to equilibrium, whereas $Q$ contains information about the budget and processes of kinetic energy dissipation by the oceans, mantle anelasticity, and core–mantle coupling.

The International Latitude Service (ILS) began routine monitoring of the Earth's polar motion around 1900. Estimates of Chandler $P$ and $Q$ were made, once reasonably accurate data had been accumulated. Observationally, the Chandler wobble is a major component in the polar motion, along with the annual wobble and a polar drift. It has continued to exist since its discovery, and has exhibited a complex behaviour. Its amplitude varied slowly with an apparent 40 year modulation from a few tens to a few hundreds of milliarcseconds (mas). The spectrum exhibited multiple-component fine structure and a phase reversal around 1930. As its exact nature and excitation sources remain far from fully understood, this complex behaviour has posed great challenges to attempts to estimate Chandler $P$ and $Q$.

Table 1 includes past estimates of $P$ and $Q$ using ILS data, by Jeffreys (1940, 1968), Ooe (1978), Wilson & Haubrich (1976), and Wilson & Vicente (1980, 1990). Two approaches were taken. The approach devised by Jeffreys (and later followed by Wilson & Haubrich 1976 and Wilson & Vicente 1990) seeks minimum variance for the excitation in a maximum-likelihood scheme. The approach used by Ooe (1978) and Wilson & Vicente (1980) adopts autoregressive–moving-average modelling for the observed polar motion. Both approaches assume Gaussian random excitations. This assumption, however, is hardly realistic. Physically, under the conservation of angular momentum, the excitation of Chandler wobble requires geophysical processes that involve mass movement in or on the Earth (e.g. Munk & MacDonald 1960). All geophysical processes are characterized by certain statistical properties. There is no *a priori* reason to expect randomness or 'Gaussian-ness'; the 'systematic' behaviour in the ILS observations described above attests to that fact.

To identify the Chandler excitation sources has remained an outstanding geophysical problem for decades. Only recently has the search been partially successful, as the variation of the atmospheric angular momentum (AAM) was found to be responsible for a major portion of the polar motion excitation,