Geodesy and Geodynamics xxx (2017) 1–6

Contents lists available at ScienceDirect

Geodesy and Geodynamics

journal homepages: www.keaipublishing.com/en/journals/geog; http://www.jgg09.com/jweb_ddcl_en/EN/volumn/home.shtml

Atmospheric acceleration and Earth-expansion deceleration of the Earth rotation

Wenbin Shen [a, *], Sung-Ho Na [b, **]

[a] Department of Geophysics, School of Geodesy and Geomatics, Key Laboratory of Geospace Environment and Geodesy of Ministry of Education, Wuhan University, Wuhan 430079, China
[b] Korea Space Geodetic Observation Center, 276-71 Wolsangongdan-ro, Sejong 30060, Republic of Korea

A R T I C L E I N F O

Article history:
Received 29 August 2016
Received in revised form
23 January 2017
Accepted 10 February 2017
Available online xxx

Keywords:
Atmosphere
Tides
Earth expansion
Earth rotation change

A B S T R A C T

Previous studies suggest that tidal friction gives rise to the secular deceleration of the Earth rotation by a quantity of about 2.25 ms/cy. Here we just consider additional contributions to the secular Earth rotation deceleration. Atmospheric solar semi-diurnal tide has a small amplitude and certain amount of phase lead. This periodic global air-mass excess distribution exerts a quasi-constant torque to accelerate the Earth's spin rotation. Using an updated atmospheric tide model, we re-estimate the amounts of this atmospheric acceleration torque and corresponding energy input, of which the associated change rate in length of day (LOD) is −0.1 ms/cy. In another aspect, evidences from space-geodesy and sea level rise observations suggest that Earth expands at a rate of 0.35 mm/yr in recent decades, which gives rise to the increase of LOD at rate of 1.0 ms/cy. Hence, if the previous estimate due to the tidal friction is correct, the secular Earth rotation deceleration due to tidal friction and Earth expansion should be 3.15 ms/cy.

1. Introduction

One global phenomenon associated with the atmosphere is that local atmospheric pressure records maximum at around 10 am in the morning and minimum at around 4 pm in most places with another pair of maximum and minimum at 10 pm and 4 am as well. This periodic variation can be interpreted as S2 atmospheric tide and is most prominent in the tropic areas (Fig. 1). Since the maximum atmospheric pressure appears about 2 h earlier than 12 h noon and 24 h midnight, the S2 atmospheric tide results in accelerating torque [1].

As shown in the left hand side of Fig. 2, the Earth's tidal bulge due to the moon is slightly asymmetrical and gives rise to an opposite torque to the Earth rotation with energy dissipation, decelerating the Earth's spin rotation, increasing the lunar orbital radius slowly and retarding its position on the celestial sphere. This phenomenon has been first analyzed by G. Darwin and later by other following investigators [1,2] and references therein]. Earth's deceleration has been confirmed either by Paleozoic fossils showing their growth rhythm or by historical solar eclipse records. Comparison with the estimates from occultation also confirms the secular variation of LOD [3]. The increase of the distance between the Earth and the moon has been directly confirmed by recent Lunar Laser Ranging [3]. One set of updated estimates of these tidal decelerating torque and tidal energy dissipation are respectively 4.83×10^{16} Nm and 3.42×10^{12} Watt [4]. The right hand side of Fig. 2 describes the S2 atmospheric tide, which results in accelerating torque to the Earth. Smaller its effect than ocean/body tidal deceleration, the atmospheric acceleration is often overlooked. However, its existence is real and incessant so that it surely exerts considerable amount of torque and keeps on adding spin rotational energy to the planet Earth.

Ray reported their model of the Earth's atmospheric S1 and S2 tides [5,6], and which has been widely accepted afterwards. In this

* Corresponding author.
** Corresponding author.
E-mail addresses: wbshen@sgg.whu.edu.cn (W. Shen), sunghona@ajou.ac.kr (S.-H. Na).

Peer review under responsibility of Institute of Seismology, China Earthquake Administration.

Production and Hosting by Elsevier on behalf of KeAi

http://dx.doi.org/10.1016/j.geog.2017.02.002

Please cite this article in press as: W. Shen, S.-H. Na, Atmospheric acceleration and Earth-expansion deceleration of the Earth rotation, Geodesy and Geodynamics (2017), http://dx.doi.org/10.1016/j.geog.2017.02.002

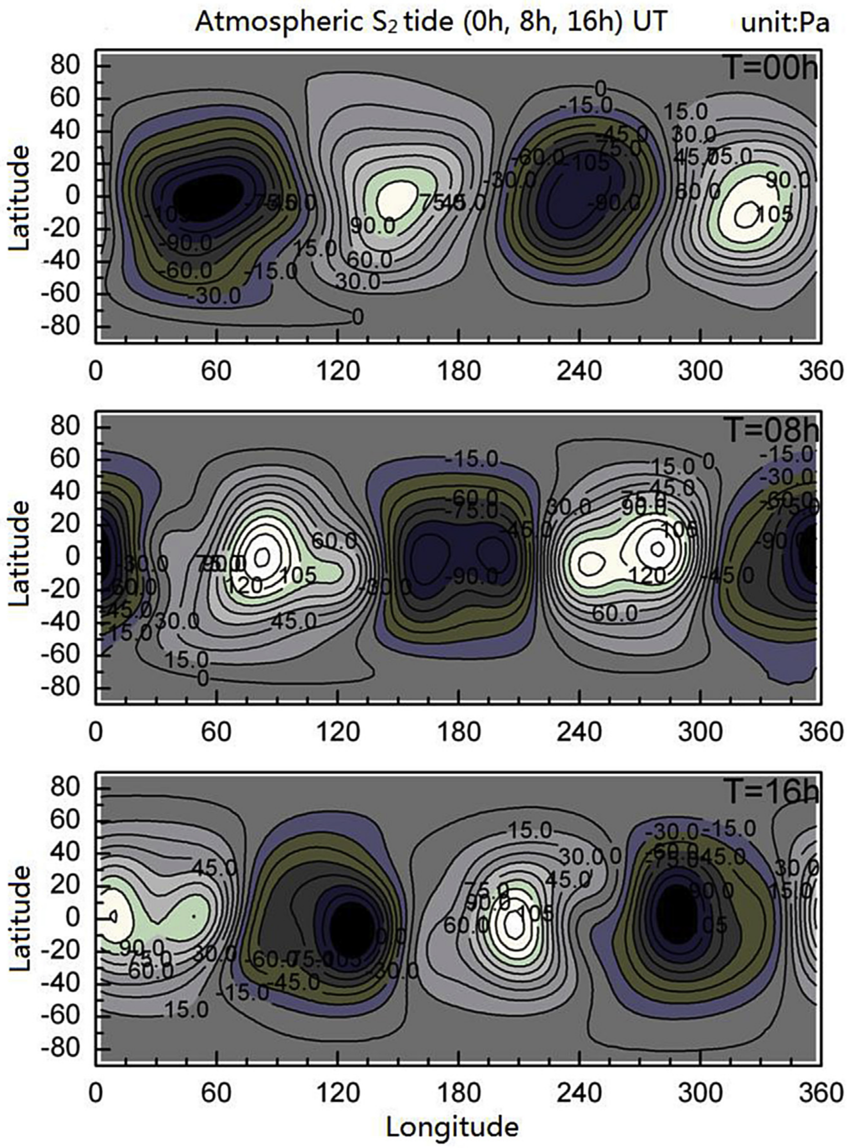

Fig. 1. Global pressure distribution of atmospheric S2 solar semi-diurnal tide at 0 h, 8 h, and 16 h UT (after Ray and Ponte 2003 [8]).

study, we re-estimate the amounts of the atmospheric tidal torque and the corresponding Earth spin rotational energy increase with other values related. Since the previously estimated dissipation value of 3.42×10^{12} Watt was obtained without considering the atmospheric acceleration torque [4], we can infer that the true energy dissipation must be slightly larger by that amount of energy input through the atmospheric tidal interaction.

Concerning the Earth rotation deceleration, the Earth expansion is also a key factor. Whether the Earth expands is an interesting problem in science. After Wilson [8] declared that the Earth is expanding, Creer [9] concluded that the Earth's radius (RE) was around $0.55R$ at the early Precambrian, where $R = 6371$ km is the average radius of the Earth at present, and Dearnley (1965) [10] suggested that RE was around 6000 km before 6.5 Myr, with average radius increase of 0.6 mm/yr. Carey [11,12] concluded that the Earth is expanding within the ocean-floor expansion framework, and Chen [13] concluded that the Earth started to expand around 4300 Myr ago with an increase rate around 0.4 mm/yr comparing with the radius increase at a rate around 0.1 mm/yr at present. Scalera [14–17] supported the Earth expansion hypothesis and concluded that the expansion contributes partly to the observed secular decreasing gravity harmonics J2 (dynamic flattening) and the increasing length of day (LOD). Based on geodetic observations, Shen et al. [18,19] concluded that the Earth expands at a rate of about 0.2 mm/yr. Based on the geodetic observations over land and ocean, further studies [20–22] demonstrate that the Earth expands at a rate of about 0.35 mm/yr in recent decades.

Suppose the Earth expands, it will bring significant influences to different research branches. Here in this study, we focus its influence on the Earth rotation.

2. Method

Based on the model of Schindelegger [23] which has outgrown former works including Ray and Ponte [7], the global pressure distribution of the Earth's atmospheric S2 is expressed as

$$\Delta P = 58.1\overline{P}_{22}(\cos\theta)\cos(2\lambda + 67.9^{\circ})(\mathrm{Pa}) \quad (1)$$

Please cite this article in press as: W. Shen, S.-H. Na, Atmospheric acceleration and Earth-expansion deceleration of the Earth rotation, Geodesy and Geodynamics (2017), http://dx.doi.org/10.1016/j.geog.2017.02.002