EXPLORATION OF PLANETARY ATMOSPHERES AND CLIMATES FROM AN ENERGY PERSPECTIVE. L. Li¹ and X. Jiang², ¹Department of Physics, University of Houston, Houston, TX, 77204 (lli7@central.uh.edu), ²Department of Earth and Atmospheric Sciences, University of Houston, Houston, TX, 77204.

Introduction: From the energy perspective, there are some important processes in the planetary atmospheric systems, which include radiant energy budget, radiative transfer, and energy conversion. The radiant energy budget and its temporal variation influence the thermal structure of these atmospheric systems. Furthermore, the transfer and distribution of radiant energy within these atmospheric systems can generate mechanical energy to drive atmospheric circulation, weather, and climate. For giant planets, the radiant energy budget and the related internal heat can help understand the evolutionary history of planets.

Here we present some recent progresses in exploring the radiant energy budgets and mechanical energy cycles in the atmospheric systems of the gas giant planets (Jupiter and Saturn) and terrestrial bodies (e.g., Earth and Titan) in our solar system.

Planetary Energies: There are different types of energies on planets and moons [1]. We mainly focus on two energies: the radiant energy and the mechanical energy. For planets and moons, the radiant energy includes two components: the absorbed solar energy and the emitted thermal energy. The radiant energy budget sets critical constraints for the total energies of planets and moons. Furthermore, the transfer and distribution of the radiant energy can generate mechanical energy for the atmospheric systems on planets and moons. The mechanical energy is generally described by the Lorenz energy cycle [2] in which the incoming solar radiation generates potential energy that is transferred to kinetic energy and is finally lost to dissipation.

The studies of radiant and mechanical energies have wide interests in the fields of astronomy, planetary sciences, and atmospheric sciences. In this study, we discuss the radiant energy budget and the Lorenz energy cycle, which are the two important processes related to the radiant and mechanical energies.

Previous Studies And Limitations: The radiant energy budgets of planets and moons in our solar system have been explored for a long time. For our home planet-Earth, the absorbed solar energy basically balances the emitted thermal energy at a global scale, even though small energy imbalance exists [3]. Regarding to the giant planets, the emitted thermal energy is generally larger than the absorbed solar energy, and an internal heat is inferred (e.g., [4-5]). The previous studies of the radiant energy budgets of giant planets are based on observations with significant limitations (e.g.,[6-7]). Therefore, the radiant energy budgets of giant planets should be re-examined with more complete observations.

The Lorenz energy cycle [2] is widely used in the studies of the atmospheres of Earth (e.g., [1]) and other planets (e.g., [8-9]). However, studies of the long-term characteristics of the global atmospheric energy cycle are lacking. The satellite-based global data sets in the modern satellite era make it possible to examine the long-term variations of the Lorenz energy cycle of the global atmosphere on our home planet.

Recent Progresses: We have made some progresses in understanding the radiant energy budgets and the Lorenz energy cycles on some planets and moons in our solar system, which are introduced as below.

Jupiter’s radiant energy budget and internal heat. Based on the observations from the Cassini spacecraft, we first measure Jupiter’s emitted thermal power [10]. Then we measure Jupiter’s albedo in the domain of wavelength and phase angle, which is shown in Fig. 1. Jupiter’s albedo is further used to determine Jupiter’s radiant energy budget and internal heat [11]. Our study suggests that Jupiter’s internal heat is $7.485\pm0.160$ W/m², which is significantly larger than $5.444\pm0.425$ W/m² from the previous estimate [12].

Figure 1. Jupiter’s albedo in the domain of phase angle and wavelength (from [11]).

Saturn’s varying emitted power. The Cassini observations are also used to examine the radiant energy budget of Saturn. We first find that Saturn’s emitted power significantly changed from the Voyager epoch to the Cassini epoch [13]. Our study based on the long-term Cassini observations [14] also suggests that the seasonal cycle plays important roles in the temporal variations of Saturn’s emitted power (Fig. 2). Figure 2 also show that the 2010 giant storm significantly modified Saturn’s emitted power especially in the storm latitudes.


Titan’s emitted power decreased by 2.5±0.6% from 2007 to 2013.

Earth’s Lorenz energy cycle. Based on the two best meteorological data sets (NCEP and ECMWF) during the modern satellite era (1979-2013), we update the mean state of the Lorenz energy cycle of the global atmosphere [16], which corrects some components in the classical picture [17]. Then we explore the temporal variations of the Lorenz energy cycle (Fig. 4), which suggests that the efficiency of the global atmosphere as a heat engine increased during the modern satellite era [18].

Future Work: There are still plenty of studies that need to be accomplished for a better understanding of the radiative energy budgets and Lorenz energy cycles of planets and moons. For example, the energy budgets of Saturn and Titan and their temporal variations can be examined with the Cassini long-term observations. In addition, we plan to examine the radiative energy budgets of other astronomical bodies in our solar system (e.g., Uranus, Neptune, Mercury, Venus, Mars, Enceladus, and Europe) and conduct the corresponding comparative studies (Fig. 5).

Figures 2, 3, 5. Comparative studies of planetary energy.

The Lorenz energy cycles of the global atmospheres of Earth and Mars have been studied (e.g., [5] [9]), but the studies of the Loren energy cycles of other planets and moons with significant atmospheric systems (e.g., giant planets, Venus, and Titan) are lacking. It will be interesting to examine the Lorenz energy cycles on these planets and moons with new observations and numerical simulations.


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