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Author: Dr. Onur Çelik
Delft University of Technology, The Netherlands

Prof. Colin R. McInnes
University of Glasgow, United Kingdom

AN INVESTIGATION INTO A COMBINED SERVICE OF SPACE-BASED SOLAR ENERGY AND CLIMATE ENGINEERING VIA ORBITING SOLAR REFLECTORS

Abstract

The concept of orbiting solar reflectors (OSRs) has been proposed to enhance solar energy generation by illuminating large terrestrial solar power farms (SPFs) before sunrise and after sunset. Large, flat and ultralightweight reflectors intercept incoming solar energy in orbit and reflect an image of the solar disk onto SPFs with tracking. The concept aims at enhancing clean energy generation; however, it introduces additional heat into the Earth's climate system, approximately equal to 80 GWh per pass by a representative system of 1 km diameter reflector in a 1000 km orbit [Çelik and McInnes, 2022]. It can be shown that the long-term integrated climate forcing due to fossil fuel use is orders of magnitude greater than the heat generated by their combustion [Zhang and Caldeira, 2015]. Therefore, displacing fossil fuel use through additional energy from space still has a significant climate benefit. However, it may also be possible to use OSRs for climate cooling, in addition to delivering clean energy to displace fossil fuels, thus delivering a net climate service. It can then be envisaged that SPFs could be illuminated on the nightside of the Earth to generate clean electricity, while partially blocking incoming sunlight on the dayside to minimise heat input to the climate system. This can be enabled by near-equatorial elliptical orbits with a long dwell time on the dayside whose Sun-synchronicity, i.e., the precession of the argument of periapsis (AoP), is achieved via a combination of the Earth's oblateness perturbation and solar radiation pressure, in heliotropic configuration [Colombo and McInnes, 2012]. This paper investigates these families of non-Keplerian heliotropic orbits for such a combined space-based energy and climate engineering application. First, families of (quasi-)frozen heliotropic orbits are identified in the phase space of eccentricity and the AoP measured from the sunline, for a given semi-major axis and reflector area-to-mass ratio. This is achieved by using the Hamiltonian of the perturbed two-body dynamics, where stable equilibria can be found for apoapsis on the sunline. A control law is then developed to track SPFs. A range of suitable orbits are then identified in both planar and three-dimensional cases, for which the energy input and the reduction of solar insolation are calculated with the objective to minimise the net energy input to the Earth's climate system. It will be shown that blocking sunlight is possible in a latitude band in the equatorial region while terrestrial solar energy is enhanced by OSRs.