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Introduction

The Earth's thermosphere (~90–800 km) is primarily heated by solar far and extreme ultraviolet (FUV and EUV) irradiance, and the primary cooling mechanism is downward conduction to the lower thermosphere and subsequent radiative cooling by CO_2, NO, and other species [*Roble*, 1995]. Increasing CO_2 concentrations are therefore expected to result in enhanced cooling and consequent contraction of the thermosphere. *Roble and Dickinson* [1989] predicted that a doubling of CO_2 would result in a 40% reduction in mass density at a height of 400 km. An overview of theoretical and empirical studies of mesospheric and thermospheric climate change is given by *Laštovička et al.* [2008].

Model studies [*Qian et al.*, 2008] and satellite measurements [*Emmert et al.*, 2008] suggest that the density trend in the upper thermosphere depends on solar activity and is larger for solar maximum conditions than for solar minimum conditions. One important mechanism of this dependency is that CO_2 cooling is dominant during solar minimum, whereas NO cooling becomes relatively more important during solar [*Mlynczak et al.*, 2010]. Another mechanism is that density scale heights are smaller during cooler solar minimum conditions, so that further contraction of the thermosphere has a larger relative effect on density at a fixed height.

Figure 1 shows measured density trends at 400 km, as a function of the $F_{10.7}$ solar activity index, derived by *Keating et al.* [2000], *Marcos et al.* [2005], and *Emmert et al.* [2008], along with corresponding trends from theoretical simulations by *Akmaev* [2006] and *Qian et al.* [2006]. There is fairly good quantitative agreement among the empirical results. The theoretical trends from *Qian et al.* [2006] agree well with the observed trends in the interval 120 < $F_{10.7}$ < 160, but the predicted trends at solar minimum are considerably smaller than the observed trends. Other mechanisms besides enhanced CO_2 cooling may therefore be contributing to the observed solar minimum trends. The theoretical trend at 200 km computed by *Akmaev et al.* [2006], which represents moderate solar activity and includes the non-negligible effects of middle atmosphere ozone and water vapor trends, is much stronger than the observed trends under similar solar EUV conditions.

Given the solar-cycle dependence of thermospheric long-term trends, it is reasonable to expect that the ionospheric long-term trends will also depend on solar activity. *Qian et al.* [2008, 2009] simulated the effects on the ionosphere of predicted CO_2 increases from 2000 to 2100, under solar minimum and solar maximum conditions. The effect on *F* region parameters was larger under solar minimum conditions, similar to the solar-cycle dependence of secular change in the thermosphere. The solar cycle dependence of the response of *E* region parameters was less pronounced. To date, there has been no comprehensive assessment of the effect of the solar cycle on observed ionospheric trends.

The goal of this CAWSES-II project is to understand how the response of the thermosphere/ionosphere to anthropogenic forcing differs between solar minimum and other phases of the solar cycle.

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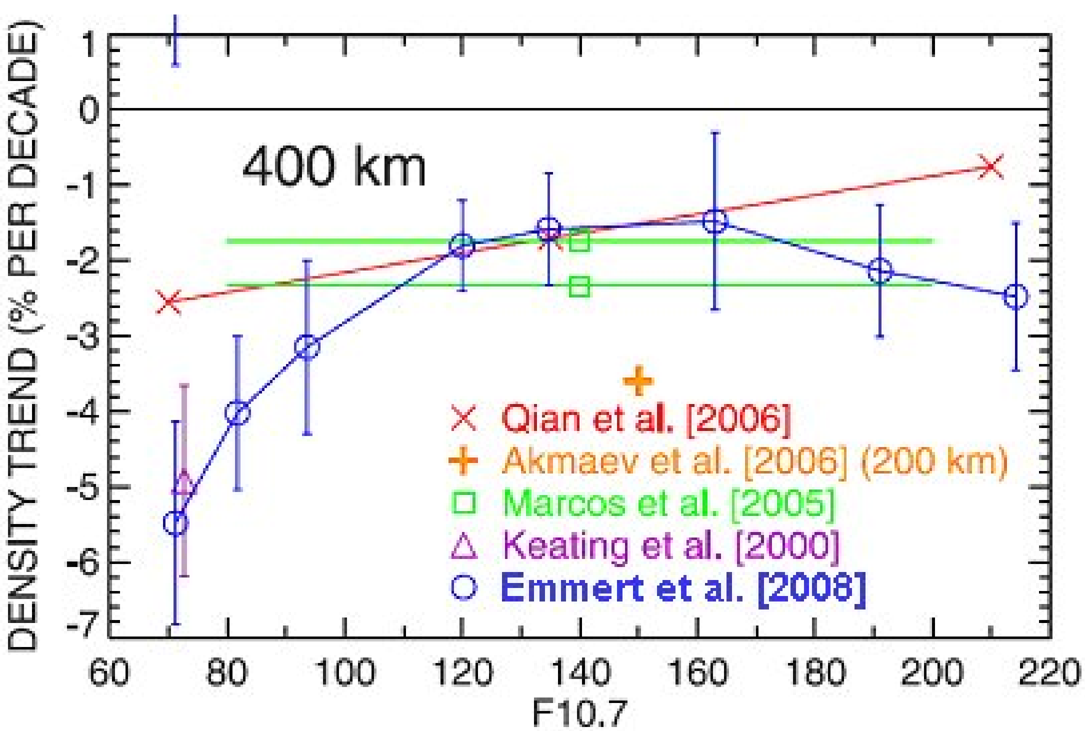

Figure 1. Summary of observed and simulated thermospheric density trends at a height of 400 km, as a function of the $F_{10.7}$ solar activity index. From *Emmert et al.* [2008].