Future Lidars for Cutting-Edge Science in the ITM Physics and Space-Atmosphere Coupling. X. Chu[1], [1]University of Colorado Boulder (216 UCB, CIRES, Boulder, CO 80309, Email: xinzhao.chu@colorado.edu).

Introduction: In the last 15 years, lidar observations have evolved from being limited to relatively narrow altitude ranges (~80–105 km and the lower mesosphere and stratosphere) to the significantly extended altitude ranges of neutral profiling from near the ground up to ~200 km and ion detection up to ~300 km in altitudes. These recent results demonstrate the huge potentials that lidars and their future generations will bring to the ionosphere-thermosphere-mesosphere (ITM) physics, thus a proper topic for the "solar and space physics decadal survey" white papers. This paper will focus on the future of ground-based lidar studies in enabling cutting-edge sciences in the ITM physics and the coupling between the plasma space and the neutral atmosphere.

Current States: The discovery of thermosphere-ionosphere metal layers made by lidar observations in Antarctica in 2011 [1] and then follow-up discoveries globally have extended lidar profiling upper limit from the lower thermosphere (~105 or 110 km) to nearly 200 km [2-5]. Not only can these metal layers be used as tracers to profile the neutral temperatures and winds in the fast transition E and F regions (especially 100-200 km), but also are the metal layers themselves a unique natural laboratory enabling "experiments" of plasma-neutral coupling processes.

Recent lidar observations at midlatitudes (Boulder and Beijing) have revealed even stunning results – the regular occurrence of thermosphere-ionosphere Na (sodium) layers before dawn up to ~170 km [6], and the first detection of Ca^+ calcium ions to ~300 km [7].

The detection of these tenuous metal layers was enabled by decades of lidar technology development and innovations that have led to very capable lidars with very high detection sensitivities and resolutions [8]. The advanced lidar technologies have also enabled the tracing of various atmospheric waves from near the ground to the thermosphere. In particular, lidar observations has begun to cover the full spectrum of gravity waves in the polar regions, enabling unprecedented studies of wave dynamics and their roles in the global transport of constituents, energy, and momentum over the Earth. New lidar observations in the last decades have inspired the development of new theories on wave generation and coupling, and an example is the so-called multistep vertical coupling of gravity waves from the surface to deep in the thermosphere and ionosphere [9], possibly affecting the space weather research and forecast.

Future Potentials: With significant and on-going advances in lasers, photonics, photo-detectors, optical fibers, telescopes, and data acquisition technologies, there are huge potentials to push the lidar technologies and instrumentation to an entirely new level, which will contribute significantly to the ITM physics and the space-atmosphere coupling science. Several directions for future lidars include, but are not limited to, 1) extension of routine profiling of neutral temperatures and winds to 200 or even 300 km altitudes with larger apertures (telescopes), more powerful lasers, and higher quantum efficiency photodetectors; 2) profiles of neutral and ion species densities, temperature, and their transport from the D-E regions to the F layer peak (~300 km) and higher with modern lidar technologies; 3) enhanced full diurnal coverage of temperature and wind measurements in larger altitude ranges with the high-sensitivity lidar technologies plus robust daytime filters; and 4) development of more autonomous and user friendly lidar systems for more data coverage.

Strategies of Implementation: Many technologies are ready to be implemented into lidar systems, although there is still quite some development of laser technologies needed. It is not realistic to accomplish all the directions mentioned above once, but it is wise to strategically plan the implementation with multiple steps. For example, pushing the detection range to higher and higher altitudes, lidars with large powerful lasers are required, which may not be ready to be autonomous and full-diurnal coverage. However, such lidars will lead to the cutting-edge science in heliophysics physics, opening new windows for new science discoveries. In the meantime, some moderate lidars can be developed into full-diurnal coverage and autonomous operations. A strategy on the future lidar development will be proper for the decadal survey white papers.

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