Space Weather

Bruce T. Tsurutani,

Jet Propulsion Laboratory, California Institute of Technology

We will give a broad overview of space weather. We will show how solar flares affect the upper ionosphere and how GPS information can identify details of these features. During solar maximum coronal mass ejections (CMEs) are typically released during solar flares (one per flare). The various parts of a CME will be shown both in coronagraph images taken when the CME is near the Sun and in interplanetary space near Earth using plasma and magnetic field data. The geoeffective parts of the CME, its upstream sheath and shock will be discussed. We will show how shocks can produce new magnetospheric radiation belts and dayside auroras, the latter of which "propagate" from local noon towards dawn and dusk. The southward component of the magnetic field within the CME (called a "magnetic cloud") causes storm main phases through the process of magnetic reconnection. The southward fields also cause "prompt penetration" electric fields that propagate to the dayside ionospheric equator, displacing and elevating the equatorial ionospheric anomalies (EIAs). For exceptionally large storms, this uplift can seriously degrade low altitude satellite orbits. In the declining phase of the solar cycle, high speed streams (HSSs) emanating from coronal holes become dominant for space weather effects. The HSSs run into slower speed streams creating compressed regions called "Corotating Interaction Regions" or CIRs. The southward magnetic fields within these interplanetary structures can cause magnetic storms, but generally weaker in intensity than those caused by ICMEs. We will explain why this is. The HSSs following the CIRs have embedded nonlinear Alfvén waves whose southward components can create geomagnetic activity that can last for days to weeks. These are called HILDCAA events which involve the sporadic injection of ~10 to 100 keV electrons and protons into the nightside magnetosphere. The precipitation of the ~10-100 keV electrons into the ionosphere can lead to the destruction of the ozone layer in the near polar regions, under certain conditions. HILDCAAs can also lead to the generation of electromagnetic whistler mode waves known as chorus and the acceleration of relativistic electrons. Relativistic "killer" electrons are another hazard to Earth-orbiting spacecraft. HSSs can cause external forcing to the ionospheric and atmosphere. Results taken from GPS and SABER/TIMED data will be shown. The last solar minimum was highly unusual. 2009 was a period of historical lows: the lowest ap geomagnetic index ever recorded. The causes of this will be explained. Finally we will end with a discussion of extremely large magnetic storms, and how they cause power outages and fires on Earth. Can such extreme storms be predicted? Like earthquakes, not yet. Can meaningful quantitative probabilities of their occurrence in the next 10, 50 and 100 years be calculated? Our answer is no and we will discuss why not.