Solar influences on lower atmosphere - nagging uncertainities*

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Our star, the Sun, produces 3.8 X 10^{26} watts of energy per second in the electromagnetic (EM) spectrum, expending a mass of 4.2 X 10^{9} kilograms per second through fusion processes. In fact, this energy pouring out in one second is enough to take care of all our energy requirements for a million years! Though the Sun is characterized by a huge spectrum of violent explosions, the energy we receive is practically constant and is dubbed as the solar constant and is about 1368 Watts/per square meter. Satellite missions (SMM) have shown conclusively that there is no more than a 0.1 percent (one part in 1000) variation in the solar constant. The other form of energy coming from the Sun is through particles, known as the solar wind (4 X 10^{20} W) which can vary violently during events as well as in the course of a solar cycle. Though this energy is insignificant compared to the energy in the EM spectrum (mainly near-UV, visible and IR), we should remember that the solar wind is intercepted by the magnetosphere which is 10 to 20 times larger in radius, and hence 100 to 400 times bigger in cross sectional area. Yet, the amount of this solar wind energy that can penetrate into the terrestrial system being but a very small fraction of the solar energy in the EM spectrum, it has been difficult from energetics point of view to link up our climate with solar variability. Some valiant efforts have been made by invoking dynamic mechanisms such as planetary waves, radiation mechanisms such as the temperature imbalance in the middle atmosphere or the modulation of the Global Electric Circuit. The latter mechanism (Global Electric Circuit) seems to show some promise as it is well established that the galactic cosmic ray entry into our atmosphere is controlled by the degree of invasion of solar wind into the interplanetary space. This galactic cosmic ray reach into the troposphere will influence the local electric conductivity and hence our weather and climate.

While the extreme profligacy shown by humans in recent decades in fossil fuel consumption is suspected to be a prime factor in climate change, a significant contribution from varying solar parameters cannot be ruled out. As the debate linking global warming to fossil fuel burning continues, uncertainties abound. In this case, a clear culprit such as the chlorine atom in the case of ozone depletion, is not yet established. Apprehensive of the down turn in their national economies consequent to a CO_2 cut-back, many countries are reluctant to practice a strict regimen in reducing carbon emissions. Hence, it is essential that sources of global warming/climate change are unambiguously identified. Our solar-terrestrial community should focus on this effort and help the atmospheric scientists in solving this problem of great human interest.

However, it is not difficult to understand the very prominent and sometimes very catastrophic effects imposed on the upper atmosphere, on the ionosphere and on the magnetosphere by these insignificant (compared to solar spectral irradiance) fractions of energy in EUV, X-rays and in solar wind, all of which undergo wild changes during a solar cycle or in a solar event. The tenuous atmosphere above 100 km does not require lot of energy to be modified. But, it is difficult to predict and even more difficult to avoid these problems known as space weather effects. One class of space weather disturbances are caused by energetic ions in the inner belt, and also by ions during solar proton events. Even high energy (~MeV) electrons from magnetosphere as well as cosmic rays can cause severe problems including SEUs. As the space agencies from various countries are planning ambitious space missions, it is imperative that we develop know-how to predict and develop technology to take evasive actions and also to build systems that are robust enough.

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*Keynote address

The last decade has seen the launch of several satellites with sophisticated instruments to study the solar wind much closer to the Sun and the data can give a good lead time for useful predictions. The ULYSSES mission launched in 1990 made history by completing a first orbit around the Sun in January 1998 at 80^o inclination to the solar equator and gave the first results of polar coronal mass ejections (CMEs). This single spacecraft revolutionized our understanding of CMEs and their progression in the heliosphere. I am sure that we will hear many more such success stories during this workshop.

There is also evidence that certain solar features may be undergoing medium-term changes. For example, recent data from the Wilcox and Mount Wilson Observatories show that the solar polar fields have remained weak during the 2000-2005 time frame compared to their build-up from solar maximum to solar minimum in the last several decades!

Apparently the only planet in our solar system hosting life as we know it, Earth boasts of an atmosphere that is unusual and very oxidizing. It is interesting to learn how the evolving bio-systems in the oceans bubbled out oxygen to make it comfortable for life systems that flourished later. But it will be ironical if the congenial atmosphere created by the primitive life systems is ruined by the more sophisticated humans. It will be a sad day to see all the fossil fuel deposits built by photosynthesis over a billion years, converted back to carbon dioxide in a couple of centuries.

We are beginning to understand several complex problems thanks to some excellent data generated by satellite missions. High-resolution measurements of radio and hard x-ray emissions indicate that particle acceleration in a flare is probably the result of acceleration by low frequency MHD waves. Dynamic 3-D MHD modelling of CMEs has thrown light on white-light structures (SOHO) and dimming in X-rays. It has also emerged clearly that the fast solar wind is merely due to heating in open field regions while the slow and dense wind is because of heating in closed magnetic structures at a higher gas pressure. I can see many exciting scientific sessions slated here this week with the assembly of a galaxy of renowned pundits in Solar-Terrestrial Sciences. I hope this workshop will clearly chart a roadmap for future missions including for analytical and modelling programs.