MESOSPHERE AND LOWER THERMOSPHERE (MLT): DYNAMICS AND COUPLING

Anybody who travels frequently will know that weather can change dramatically from one place to another. If this travel is done vertically, into the sky, then this change is all the more spectacular. It changes from a realm of dense molecular setting to an almost empty space. The change in temperature can also drastically rise, though one may not feel the heat, since there are few molecules zipping past by you.

Unlike the earth, the atmosphere is not etched in ‘stone’. The atmosphere is made of many atmospheres that seem to merge into, or separate out, from each other seemingly all at once. There is a constant give and take between different compositions making up these ‘diverse’ atmospheres. The oxygen and nitrogen molecules that predominate in them are sometimes of ‘standard’ and ‘non-standard’ form. The standard form refers to molecules of no electrical charge, while the latter are the broken up and ionized variants. The intense energy emanating from sun is responsible for the ‘breakdown’ of normal molecules.

The coexistence, and intermingling of standard and non-standard atmospheres leads to a diverse set of natural processes. These are brought about by the searing radiative, dynamical and electromagnetic forces. The geomagnetic field throws out its field lines that blanket the whole planet protecting it from many potential harmful effects unleashed by sun. The structure of these field lines plays an important role in the redistribution of non-standard or ‘ionized’ particles over the space encompassing the tropical latitudes. The kind of geomagnetic field line configuration present over the low and mid-latitude regions triggers a host of phenomena that are unique to this region only. These processes have the potential to interfere with global radio communication network that can have dire economic consequences.

The understanding that a system of currents exist in the atmosphere has been doing the rounds for over a century. For the present article, however, it is better to confine ourselves to the atmosphere at a height of 100 to 120 km from the surface of the earth. This is the ionosphere where the currents flow in an anticlockwise direction during day and in clockwise direction during night in the northern hemisphere. In the southern hemisphere the currents flow in opposite direction to that of the northern hemisphere during day and night. This pushing around, providing ‘direction’ to the currents, is due to the action of tidal winds.

The flow of tidal winds is not dependent on just one factor. A whole lot of parameters are involved in its making. The fundamental understanding of how the tidal winds blow from place to place and the genesis of how currents migrate, maneuvered by magnetic field lines, is solely understood through simulation. It is very difficult to keep a track of it *in situ*. Currently, direct observation at such height is logistically impractical.

But one cannot throw in the towel. There is a need to pursue an eclectic approach, because only then can we better understand the upper atmosphere. This is the region where different natural forces compete with one another to generate a host of new ‘forces’. These forces include gravity waves, infrared-, ultraviolet radiation and other perturbations, alongwith high-altitude winds that blow ions (charged atoms) across the earth's magnetic field by creating a dynamo. All these forces cause collisions between neutral and charged particles enabling them to exchange charge, to transfer energy and momentum amongst them. These processes are active even when the sun is ‘inactive’ or quiet. But there is a crescendo of events when there is a solar ‘storm’. The cataclysmic burst of charged particles and radiation completely rearranges global thermospheric circulation in a matter of hours.

When looked at these factors more closely one can understand that they can vary in space and time. The upper atmosphere filters out the shortest wavelengths of ultraviolet energy from the sun before it reaches the surface of earth. It is estimated that the total solar radiative output can vary by about 0.1% over an 11-year solar cycle; ultraviolet by few percent; extreme ultraviolet and X-rays by factors of 10 to 100 on even much shorter timescales.

The genesis of tidal wind system operational during the solar quiet time is very complex and believed to originate in the realm of lower atmosphere. Recent studies, through satellite observations and simulation, have strongly indicated the dominant role of lower atmospheric forcing in driving ionospheric weather during solar quiet times.

The region between 80 and 120 km, according to many geophysicists, is a realm so difficult to observe and study that they have christened it as "ignorosphere." It is formally called the mesosphere and lower thermosphere (MLT). For scientists studying this ignorosphere the most fascinating phenomenon of this region is the atmospheric tides. These are global-scale variations in wind, temperature, and pressure tied to solar input. They occur throughout the atmosphere on a regular basis and are seen once or twice daily (diurnally and semidiurnally), with smaller tides at more frequent intervals. The tides move westward with the sun, driven by solar radiation and its absorption and reemission at various heights.

The presence of atmospheric tides has been known for a long time. The clue to it was found in long-documented trend in surface air pressures near the equator, which revealed a small but distinct rise and fall every 12 hours. Thus, winds and waves are responsible for the coupling of lower and upper layers of our atmosphere. The gaseous components, when they rise up in the atmosphere, lose their density rapidly, creating atmospheric waves that grow in amplitude. This they do to conserve their kinetic energy density.

The atmospheric waves generated in the 80 to 120 km region can be efficiently monitored by the atmospheric radars. These are also called as the MLT radars and they have been providing a wealth of information on atmospheric waves of various spatial and temporal scales. The global and large scale ones are tides and planetary waves, while the gravity waves are of smaller scales. Both of them carry significant amount of energy and momentum from their source region which lies in the lower atmosphere. Both the large- and small scale waves are responsible for the dynamical coupling between the lower and upper atmosphere.

The best way to study these processes will be to be in the thick of things. This is not possible as of now. The next best thing would be to decipher those changes by observing them from the safe confines of a laboratory.

IIG is doing just that. It has its eyes trained on the atmosphere by way of medium frequency (MF) radars. These radars collect information on the horizontal wind field changes occurring in the region situated at an altitude from 80 to 98 km. Two MF radars have been placed at Tirunelveli and Kolhapur. The former is in the equatorial region and the latter is in the mid-latitude region. Both are separated by a distance of almost eight latitudinal degrees.

MF observational data spans for over 18 years from Tirunelveli and has unraveled a wealth of information on understanding the time-mean zonal flow, planetary-scale waves, tides, and small-scale gravity waves. These studies have found a lot of weather-induced variability, inferred to cause considerable variability in the winds, temperature, and composition of the ionosphere. It is also believed that this weather-induced variability may be interacting with solar and auroral-induced variability, making it an important key to understanding solar-terrestrial coupling.

Tirunelveli MF radar data has hinted at the teleconnection between El Nino and upper atmospheric tides, and also to the interrelationship between the equatorial counter electrojet and semidiurnal tide in the MLT region. The latter is more prominently noticed during sudden stratospheric warming events.

Some of the ongoing studies at the two locations have combined satellite observations of global scale tides with radar observations to understand sources of tidal variabilities. This data is analyzed against the backdrop of, and as a diagnostic tool, that provides information on low latitude electric fields and currents.

IIG has procured high performance computing, and with the amassing of ground- and satellite-based data, the equatorial aeronomy community here is better poised to understand the role of atmospheric forcing from below in driving ionospheric winds, electric fields, currents, irregularities and such other features in day-to-day timescales.

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