Understanding Tropospheric Influences on the Mesosphere/Thermosphere/Ionosphere Region

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During the extraordinarily quiet recent solar minimum period, the influence of lower altitude forcing on the thermosphere/ionosphere region was clearly observed. Observational evidence implies that the troposphere can couple electrically, dynamically, and chemically to the upper atmospheric regions. Figure 1 shows a sampling of different forcing sources such as volcanic

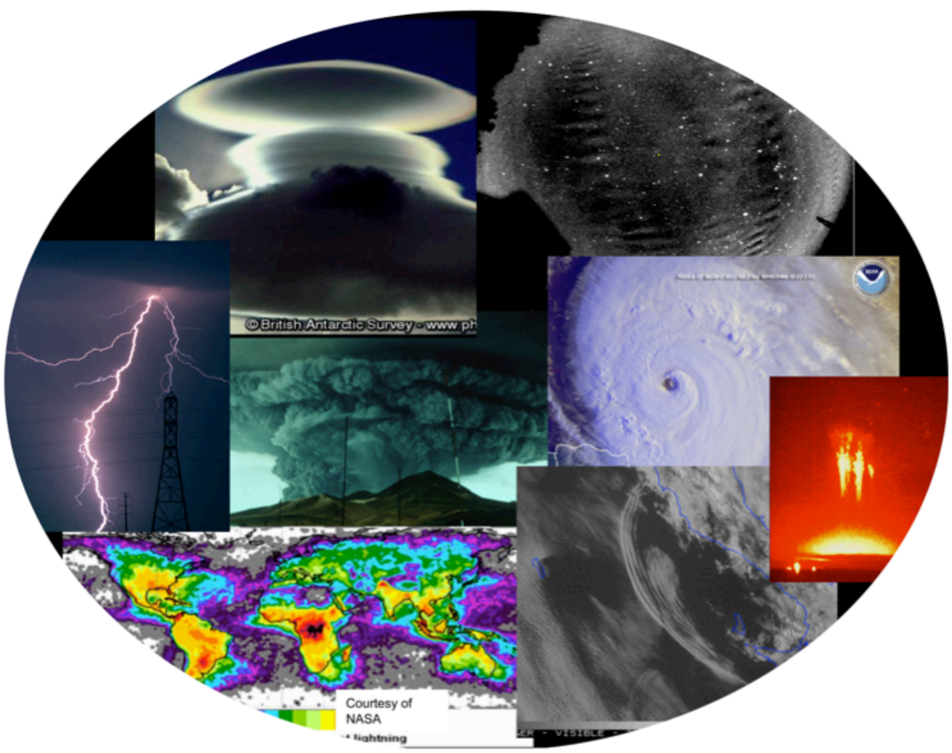

Figure 1. Collage of forcing sources in the troposphere influencing the upper atmospheric regions.

eruptions, atmospheric gravity waves, sprites, lightning, and tropical storms that produce upper atmospheric effects [*Laštovička,* 1998]. Additionally, it has been demonstrated that power lines and other man-made radiation sources can modify the upper atmosphere [*Farell et al.*, 1998].

One potentially strong coupling source between the troposphere and ionosphere/thermosphere is tropical storms, hurricanes, and typhoons. These large storms can potentially couple both electrically and dynamically. Tropical cyclones are prodigious generators of gravity waves and are suspected of affecting the ionosphere though upward propagation of this wave momentum and modification of plasma velocities. Observations have shown that the passage of tropical storms can lead to perturbations in the plasma drift [Bishop et al., 2006] as shown in Figure 2. One of the specific challenges related to tropical storms is determining the electric fields produced above the storm.

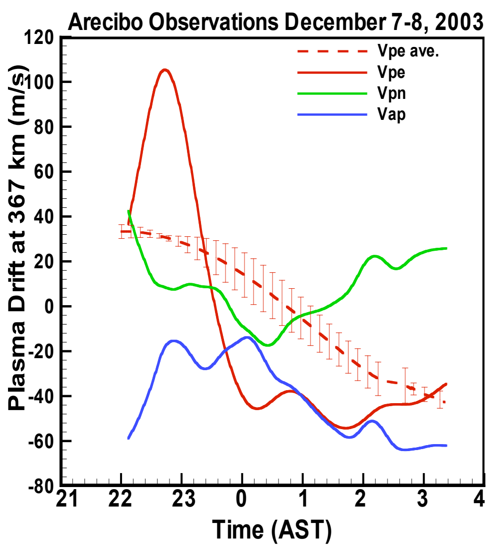

Figure 2. Anomalous plasma drifts observations coincident with passage of Tropical Storm Odette.

Another example of coupling is the signature of gravity waves in ionospheric velocity and density measurements. The DE-2 satellite observed suspected gravity waves in neutral and ion measurements at 260 km at night consistent with upward propagation from below [Earle et al., 2008].

In another study, Lieberman *et al.* [2007] showed significant reduction of non-migrating diurnal tides, and a concurrent enhancement in the migrating diurnal mode during the strong 1998 ENSO event.

Although not as strong or consistent, anthropogenic effects may also modify the lower ionosphere. For example, urban areas could be an intense source of ULF emissions that are strongly attenuated and/or absorbed by the lower ionosphere locally, thereby creating a highly localized region of heating [*Farerell et al.*, 1998].

The primary difficulty to studying coupling between the lower and upper regions, is our ability to perform a continuity of observations from the low to high altitudes. From the examples presented, it can be noted that the evidence for coupling between the regions involves observing ionospheric/thermospheric perturbations and noting their correlation to low altitude phenomena while eliminating other possible forcing sources. To begin to tackle this complex system problem coordinated and detailed investigations need to be undertaken that links low altitude observations through the middle atmosphere to the observations in the thermosphere and ionosphere. Specific objectives for improving our understanding of the coupling include:

- Determine the extent and significance that tropical storms in the troposphere play in producing localized electric fields and neutral gas motions in the ionosphere.
    - Measurements are needed of the electric fields at altitudes directly above large tropical storms (currently missing).
- Understand how large-scale neutral winds, gravity waves, and ion drifts are coupled in the low latitude upper atmosphere and how they respond to solar variations and to variable influences from the lower and middle atmosphere.
    - Perform low altitude observations of neutral winds and gravity waves with simultaneous observations of the mesosphere and lower thermosphere wind fields.
- Understand the surface-to-space energy pathway for ULF emissions.
- Discover the cause of planetary-scale plasma upwellings at low latitudes and investigate the effect of unstable flux tubes on inner plasmasphere dynamics.
- Determine the effect on mesosphere and lower thermosphere chemistry due to volcanic discharge, ionization due to sprites and jets, mixing due to gravity wave breaking and turbulence.
- Explain the chaotic and explosive transfer of energy between irregularity scale lengths ranging from 1000 km to 1 cm that occur in the low latitude ionosphere at night.

<u>Recommendations:</u>

Ground-Based Observations:

- Position permanent TIDBIT radars along with ground-based GPS receivers, CCD cameras (as appropriate) and ionosondes at locations likely to experience significant weather disturbances or gravity wave generation such as: East of the Rocky Mountains, among the Caribbean Islands, west of the Andes, and among the Indonesian Islands.
- Utilize low latitude ISRs to study affects from nearby storms

Space-Based Investigations:

- Dedicate a tropical satellite mission dedicated to exploring the tropospheric/ionospheric/thermospheric connection (see white paper on Tropical Coupler).
- Extend C/NOFS satellite operations to allow continued investigation of low latitude ionospheric irregularities that can then be combined with low altitude observations.
- Utilize the ISS for remote sensing experiments focused on the mesosphere and lower thermosphere to observe gravity waves and composition. The ISS is ideally located to observe the low latitudes that are most likely to see large tropical storms.
- Provide international collaboration to the ASIM (Atmosphere-Space Interactions Monitor) European Mission to be launched in 2013. ASIM is an instrument suite focused on the study of severe thunderstorms and their effects on the atmosphere and ionosphere both electrically and chemically.
- Utilize high altitude aircraft and balloons to determine electric fields above storms, and ULF emissions from urban areas.

Coordinated Campaigns:

- Utilize ionosonde, ISR, and Global Lightning Network with appropriate space-based observations.

Modeling Efforts:

- Continue efforts to extend models ionospheric/thermospheric models such as TIEGCM to include lower altitude forcing.
- Extend low altitude tropospheric models into the upper atmosphere.
- Include low altitude forcing in other assimilative models such as SAMI2, GAIM, IDA4D by using low-altitude model output as lower boundary conditions.

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