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STUDIES OF IONOSPHERIC PLASMA ELECTRODYNAMICS

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Final Report

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During the course of this contract we researched a wide variety of topics principally concerning the transport of ionospheric plasma and the role of that transport in the generation and evolution of plasma irregularities.Support from this contract has yielded a wealth of information related to the behavior of the ionosphere and its characteristics that are relevant to total electron content and the appearance of plasma structures.

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During the course of this contract we researched a wide variety of topics principally concerning the transport of ionospheric plasma and the role of that transport in the generation and evolution of plasma irregularities.

Our first task was to design and implement a plasma packet tracing algorithm for determining the convective history of plasma packets subjected to motion at high latitudes due to ExB drifts. Using a convection pattern specified by the electrostatic potential distribution at high latitudes we successfully designed and implemented this algorithm that was subsequently implemented in codes run at AFRL to specify the state of the ionosphere at high latitudes.

Ultimately a time dependence was introduced into the tracing algorithm allowing the effects of spatial and temporal re-orientations of the convection pattern to determined. Pioneering work in the formation of plasma patches from such time variations was conducted in collaboration with AFRL scientists.

The high latitude convection pattern results from contributions due to magnetic merging across the magnetopause and due to viscous interaction in the boundary layers just inside the magnetopause. Examination of extensive data sets allowed us to construct a model containing both these convection sources. The relative strength of these sources can be changed to reproduce specific observations. This model, included in ionospheric models, achieved significant success in reproducing certain ionospheric features responsible for large scale spatial gradients in the plasma.

This theoretical work was conducted in parallel with an extensive analysis of satellite observations to detect plasma patches and their associated plasma irregularities. It was found that ionization patches in the northern polar cap appear, as expected, in a universal time zone corresponding to the time when the cusp is in sunlight. At this time variations in the ionospheric convection geometry, as modeled will structure the high density plasma into large scale patches. In the southern hemisphere, the most sunward extension of the cusp leads the entire polar cap to be in sunlight and thus no contrasting density levels that constitute patches are seen. However, when the cusp crosses the terminator near dawn and dusk, conditions again become favorable for patch formation.

In studying the smaller scale plasma structures associated with patches we find that in most cases a patch is uniformly structured throughout. Patch edges have the largest magnitudes structures but these are distributed almost uniformly around thepatch with almost no dependence on the direction of the plasma flow. Comparison of the appearance of plasma structures with the simultaneous appearance of structure in the convective flow suggests that plasma structuring may be caused primarily by stirring across the large scale gradient produced in the patch generation process. Finally we note that the large scintillation levels associated with ionization patches are due to the relatively high number density in the patch rather than enhanced levels of structure. Indeed we find that the level of structure defined by $\Delta N/N$ is about the same throughout the nighttime polar cap. Further work was identified to pursue under the study of scintillation and patch formation. This work related to the size distribution of patches and the shape of patches was not completed due restricted funding of the contract.

Our final area of investigation supported by this contract was in the behavior of the topside equatorial and mid-latitude ionosphere. Here we used the extensive data base from the DMSP satellites to examine the relative constituent number densities of $O+$, $H+$, and $He+$, which are dramatically dependent on solar activity and the dynamics of the F-region. We find that latitude asymmetries at the fixed DMSP altitude show quite clearly the effects of F-region neutral winds and interhemispheric plasma transport along the magnetic field lines. At solar maximum the topside ionosphere is dominated by $O+$ ions and the latitudinal asymmetries in the $O+$ concentration are minimized by the effects of interhemispheric transport. At the same time asymmetries in the $H+$ concentrations are a maximum. In contrast, at solar minimum H+ dominates the topside ionosphere and latitudinal asymmetries in the H+ concentration are minimized while O+ latitude asymmetries are a maximum. This work shows the dramatic influence of dynamics on the distribution of topside ionospheric species and there are associated changes in the plasma temperature and total number density. Further investigation of these behaviors and the model calculations required to confirm the physical pictures that we have constructed was not accomplished due to funding restrictions.

In summary support from this contract has yielded a wealth of information related to the behavior of the ionosphere and its characteristics that are relevant to total electron content and the appearance of plasma structures. There is certainly more work to do, but this effort yielded over 20 published manuscripts and supported three Ph.D dissertations of three students who have since secured employment in research institutions.