# Project Details

**ROSES ID:** NNH20ZDA001N
**Selection Year:** 2020
**Program Element:** Focused Science Topic

**Topic:** Modeling and Validation of Ionospheric Irregularities and Scintillations

**Project Title:**
Global Modeling of Equatorial Spread F

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**Summary:**
Science Goals and Objectives:
Post-sunset ionospheric irregularities in the equatorial F region were first observed by Booker and Wells in 1938 using ionosondes. This phenomenon eventually became known as equatorial spread F (ESF). It is now known that during ESF the equatorial ionosphere becomes unstable because of a Rayleigh-Taylor-like instability: large scale (10s km) electron density `bubbles' can develop and rise to high altitudes (1000 km or greater at times). Given the complexity and non-linear development of equatorial plasma bubbles, computational models are needed to tackle this problem. We propose a 4 year program to investigate the causes and nonlinear consequences of equatorial spread F. The objectives of the proposed research program are to (1) identify the causes of day-to-day and longitudinal variability associated with equatorial spread F, (2) investigate the nonlinear evolution of equatorial plasma bubbles, and (3) calculate the linear growth rate of the instability to help identify the underlying driving mechanism(s).

Methodology:
We will use the first-principles whole atmosphere model WACCM-X and the ionosphere model SAMI3 to investigate the onset and evolution of equatorial spread F on a global scale. These models provide a unique capability to address this problem. The WACCM-X model not only provides the large-scale variations of the neutral densities, temperature, and winds as inputs to SAMI3, but also self-consistently generated atmospheric gravity waves that can act as seeds to trigger equatorial spread F. The SAMI3 model, using WACCM-X inputs, is capable of resolving the onset and evolution of equatorial plasma bubbles. Moreover, SAMI3 use a high-order flux-correction transport scheme that reduces numerical diffusion and allows steep density gradients to develop that is necessary to model ESF. To our knowledge this is the only global model with this capability. We will compare and validate our simulation studies to available data such as TEC, radio occultation, radar, and ionosonde experiments. An emphasis will be on coordinating and comparing model results to GOLD and ICON observations. Working with rest of our LWS team, we will seek additional collaborative opportunities to analyze relevant data and further validate our results.

Proposed Contributions to Focused Science Team Effort:
The proposed program is directly relevant to this focused science topic. Two of the goals of the program are (1) to ``identify the mechanisms and structures that are responsible for ionospheric irregularities and scintillations at various latitudes (low, mid, and high latitudes) and longitudes'' and (2) to ``determine the growth rates, spectral characteristics, the nonlinear evolution associated with specific generation mechanisms and their role in scintillations.'' The milestones are to (1) perform simulation studies of equatorial spread F under different geophysical conditions, (2) identify the causes of day-to-day and longitudinal variability, and (3) calculate the linear growth rate of the instability to help identify the underlying driving mechanism(s). The proposed effort also directly addresses a key objective of the LWS program SSA-4 (Physics-based Total Electron Content (TEC) Forecasting Capability) as well as goals set forth in the Decadal Survey regarding plasma-neutral coupling.

# Publication References:

**Summary:** Blah

**Reference:** Huba, J.D., Generalized Rayleigh-Taylor Instability: Ion Inertia, Acceleration Forces, and E Region Drivers, J. Geophys. Res: Space Phys., 127, e2022JA030474, https://doi.org/10.1029/2022JA030474, 2022.

- **Investigation Type:** Other Investigations
- Blah

**Summary:**

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