Title of Report: INVESTIGATION OF ESF TRIGGERS USING BALLOON-BASED AND GROUND-BASED DIAGNOSTICS

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At the time of this report, the experiment was getting ready to be flown. The results will be available later through a possible follow on grant

14. ABSTRACT
It is widely believed that gravity waves trigger the occurrence of F-region irregularities. This inference of gravity wave seeding the irregularities was based on the Range-Time-Intensity maps of the incoherent scatter radar echoes. The radar-returned echoes of F-region irregularities are in the form of waves, with periodicities ranging from 60 minutes to 120 minutes. But, till this date no measurements have been carried out before the irregularities are actually triggered to conclusively answer this question of gravity waves as the seeds for ESF onset. As a part of this work, two BU-built optical spectrographs will be flown on board a high-altitude balloon from the National Balloon Launch facility in Hyderabad, India to obtain the wave characteristics before the occurrence of the F-region irregularities. These spectrographs will make measurements of airglow emissions at three wavelengths (280.0nm, 557.7nm and 630.0nm) that originate at different altitudes; namely 85, 100 and 230 km, respectively. The measurements will be carried out in different orientations such that the combined data can be used to obtain two-dimensional daytime maps of these emissions. Such maps will be processed to obtain information on the spatial and temporal characteristics of the wave features. In addition, data from this experiment will be well complemented by both optical and radio diagnostics operating from the ground at various locations in India.

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Investigation of ESF Triggers using Balloon-Based and Ground-Based Diagnostics

Abstract:

It is widely believed that gravity waves trigger the occurrence of F-region irregularities. This inference of gravity wave seeding the irregularities was based on the Range-Time-Intensity maps of the incoherent scatter radar echoes. The radar-returned echoes of F-region irregularities are in the form of waves, with periodicities ranging from 60 minutes to 120 minutes. But, till this date no measurements have been carried out *before* the irregularities are actually triggered to conclusively answer this question of gravity waves as the seeds for ESF onset. As a part of this work, two BU-built optical spectrographs will be flown on board a high-altitude balloon from the National Balloon Launch facility in Hyderabad, India to obtain the wave characteristics before the occurrence of the F-region irregularities. These spectrographs will make measurements of airglow emissions at three wavelengths (280.0nm, 557.7nm and 630.0nm) that originate at different altitudes; namely 85, 100 and 230 km, respectively. The measurements will be carried out in different orientations such that the combined data can be used to obtain two-dimensional daytime maps of these emissions. Such maps will be processed to obtain information on the spatial and temporal characteristics of the wave features. In addition, data from this experiment will be well complemented by both optical and radio diagnostics operating from the ground at various locations in India.

Experiment Plan:

Boston University will provide the experiments to be flown on the balloon. As mentioned earlier, collaborating institutions from India are: Physical Research Laboratory, Space Physics Laboratory, Andhra University, and National Atmospheric Research Laboratory. National Balloon Facility (NBF) of TIFR will provide the Gondola, platform for holding the instruments, launch support, telemetry, range and other services at the launch facility in addition to the recovery of the payloads after their descent.

Emission Wavelength	**Emission Altitude**
MgII 280.0 nm	85 km
OI 557.7 nm	100 km
OI 630.0 nm	230 km

Table 1 Emissions proposed for measurements from the balloon and their altitudes.

Balloon-borne instruments:

We propose to include two imaging optical spectrographs, as part of the balloon-borne payload. One spectrograph will be a spectral imager for making Mg^+ emission measurements at 280.0 nm and the other will be a High Throughput Imaging Echelle Spectrograph (HiTIES) for redline (630.0 nm) and greenline (557.7 nm) measurements. Figure 1 shows the approximate fields-of-view from a 35 km altitude of balloon-borne measurements for these emissions assuming a negligible drift of the balloon. Both these spectrographs will have their own data acquisition systems. These spectrographs will image the atmospheric dynamics along the slit. During the float period of the balloon (which is expected to be about 8 hours), these spectrographs will be repeatedly rotated in 30^o increments with approximately 5 minutes of data acquisition at each position. The spectrographs will return to their normal position after data acquisition at these positions, Pointing accuracy required for the Gondola is very modest (of the order of 0.1^{o}) which will allow us to repeatedly scan the sky in quick successions. As the instruments will have imaging property and due to their cylindrical symmetry, optical emissions measured from such orientations will yield information on the behavior

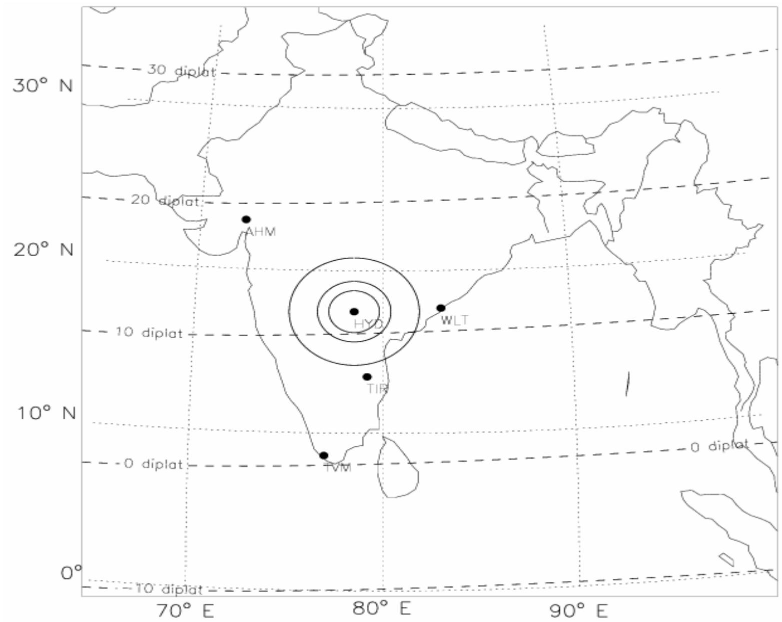

Figure 1 Different sites of observations in Indian longitudes are shown. The fields-of-view (circles) for MgII, OI greenline and OI redline emissions from a floating altitude of 35 km for the balloon over Hyderabad are also shown. The fields-of-view are shown in Table 2.

of the atmospheric dynamics in both latitude and longitude at three different altitudes as shown in Table 1. This information will then be processed to derive the speed and direction of propagation of waves present at each of the emission altitudes.

Complementary Ground-based Measurements:

This experiment has been brought under the umbrella of CAWSES-India Phase II program to enable access to better database of instruments and measurements that are carried out from time to time in India. Comprehensive and coordinated experimental observational campaign is being planned during the launch window of the balloon experiment.

Complementary ground-based observations will be made by optical and radio techniques from various locations. HF Radar, Digisonde, Dayglow photometer both for mesospheric and thermospheric emissions, magnetometer, meteor wind radar, night time photometer, all-sky camera, in addition to running the CRABEX chain of receivers will be carried out from Trivandrum (0.75^{o} N Dip Lat.). Wide-angle optical imagers for making 557.7 630.0 nm and 777.4 nm nightglow emissions will be made from Tirunalveli (TVL) (0.73^{o} N Dip Lat.). The MST Radar will be run in the ionospheric mode from NARL Gadanki, Tirupathi (5.6^{o} N Dip Lat.) to yield information on the scale sizes of the irregularities. Multi-HIRISE observations of OI 557.7, OI 630.0 and OI 777.4 nm dayglow line emissions will be made from Hyderabad (HYD) (9.6^o N dip Latitude), which is located between the Equatorial Ionization anomaly trough and the crest. Additionally, digisonde data and scintillation measurements will be measured from Waltair (9.8^o N Dip Lat.), Ahmedabad (15.1^o N Dip Lat.), Bhopal (15.3^o N Dip Lat.), and Delhi (20.8^o N Dip Lat.) will yield information on the strength of the Appleton anomaly and to assess the latitude extent of the irregularities in the nighttime. Total Electron Content (TEC) measurements will be available from the chain of meridional receivers, set up along a longitudinal chain of India during the passes of NNSS both during nighttime and daytime. Table 2 lists the locations and the experiments that will be carried out from India.

Location	Coordinates	Experiment	Parameter measured
Tirunalveli (TVL)	8.4^o N, 77.4^o E; 0.73^o N dip Lat.	OI 630.0nm, OI 557.7nm and OI 777.4 nm nightglow imagers, Meteor Wind Radar	
Trivandrum (TVM)	8.6^o N, 77^o E; 0.75^o N dip Lat.	HF Radar, Digisonde, Dayglow photometer both for mesospheric and thermospheric emissions, magnetometer, meteor wind radar, night time photometer, All sky camera, CRABEX chain	Ne, ESF information, GPS Scintillations, Plasma bubbles, neutral winds at around 90 km altitude, TEC*, etc
Tirupathi (TIR)	13.5° N, 79.2° E; 5.6^o N dip Lat	MST Radar in ionospheric mode	Ne, TEC*
Hyderabad (HYD)	17.5° N, 78.5° E; 9.6^o N dip Lat	Balloon Launch; Multi-HIRISE	2-D maps of: 1) Mg^+ over 1.5^o x 1.5^o in space (lat. x long.), 2) OI green line over 2.5^o x 2.5^o 3) OI redline over 6.0^o x 6.0^o for 1 – 3 are Balloon-borne experiments, and the ground based measurements are: 4) OI 557.7 nm (3.5^o x 0.01^o) 5) OI 630.0mn (8.0^o x 0.01^o) 6) OI 777.4 nm (10.0^o x 0.01^o) 7) TEC*
Waltair (WAL)	17.7° N, 83.3° E; 9.8^o N dip Lat	Digisonde, HF Doppler Radar, L-Band scintillations	Ne, GPS Scintillations, And F-region vertical drifts
Ahmedabad (AHD)	23° N, 72.5° E; 15.1^o N dip Lat	DGP	OI redline emissions
Bhopal (BPL)	23.2° N,77.4° E; 15.3^o N dip Lat	Digisonde	Ne, TEC
Delhi (DEL)	28.7° N, 77.2° E; 20.8^o N dip Lat	Digisonde	Ne, TEC
Total Electron Contents TEC* along the meridian is obtained subject to passes of NNSS			
The data from the Geostationary Earth Orbit Augmented Navigation (GAGAN) i.e., the Indian Space Based Navigational Network data will also be available during the campaign			

Table 2 List of experiments planned from different locations in India.

3) Recent progress and current status:

The Optical spectrograph has been built. Optical alignment is completed. Optical calibration for wavelength classification has been completed. Figure 2 shows the simulation results that predicted the position of spectral lines of interest on the detector. The x-axis in this figure shows the pixel number on the detector. The y-axis is along the slit orientation and has no physical significance in this figure. The vertical lines show the pixel position of a particular spectral line (wavelength given along the vertical line) and the diffraction order (shown in parenthesis). All the wavelengths shown in this figure, except the one at 2800 Å, are spectral lines of Mercury.

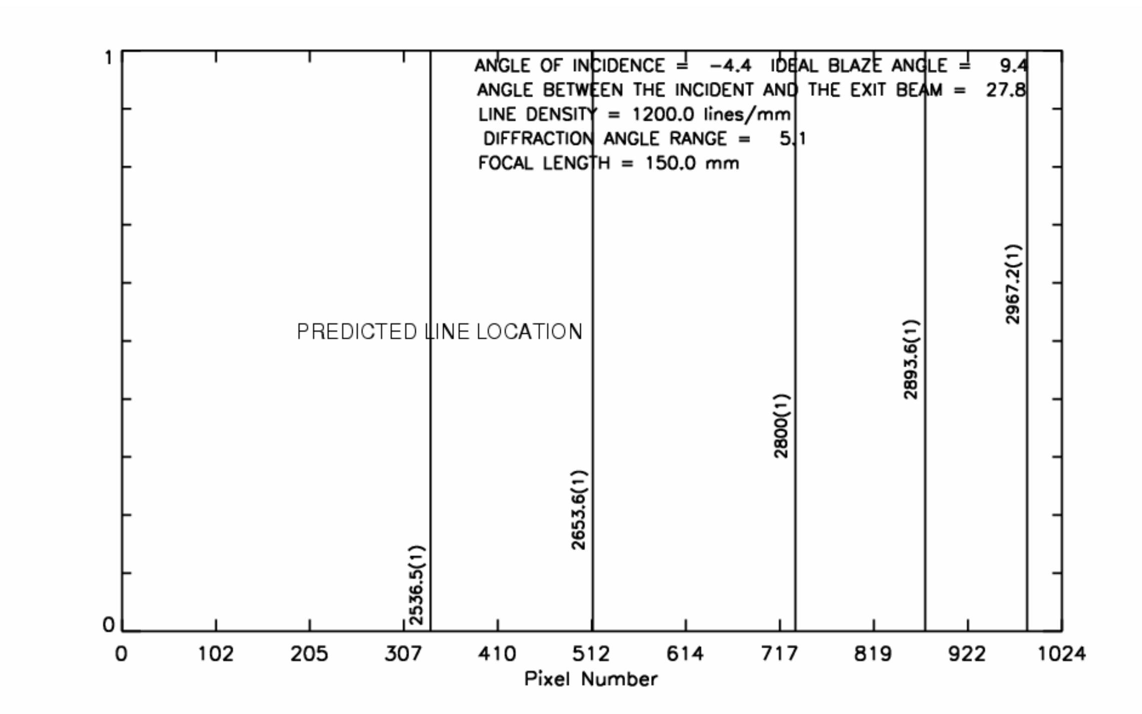

Figure 2 Simulated locations of spectral lines of interest in the near-UV wavelength domain. All the wavelengths shown above except the one at 2800 Å are spectral lines of Mercury.

Figure 3 shows the actual image obtained by the UV spectrograph when illuminated with mercury lamp spectral source. Y-axis is the slit orientation/spatial extent and x-axis shows wavelength. The strong mercury spectral lines as predicted (shown in Figure 2) can be seen in the observations of this figure. The positions of various spectral lines in the predicted and observed plots seem to be in good agreement. The predicted dispersion is 0.66 Å pix^{-1} in comparison with the observed value of 0.71 Å pix^{-1}.

Software for programmed mode of operation has been developed and tested. Through this software we can now operate both the CCDs simultaneously without compromising with the independent modes of operation (i.e., different exposure times and spatial binnings, etc., being different for both the cameras).

The software to interface with the telemetry system provided by the balloon facility is completed. We have tested, simulated, and confirmed using the existing DIO board that the data that is transferred (bit-by-bit) is received properly and the image thus regenerated matches exactly with the original image. This crucial test ensures that we will be able to receive the data transmitted by the balloon computer on the ground. The information contained in the image thus received in the actual experiment will be used to take corrective measures, if required through telecommand. The testing of telecommand operations through software is currently in progress. Further, hardware is also being developed to have an option to turn-on and turn-off the hardware (CCD cameras, onboard computer, etc.), if required.

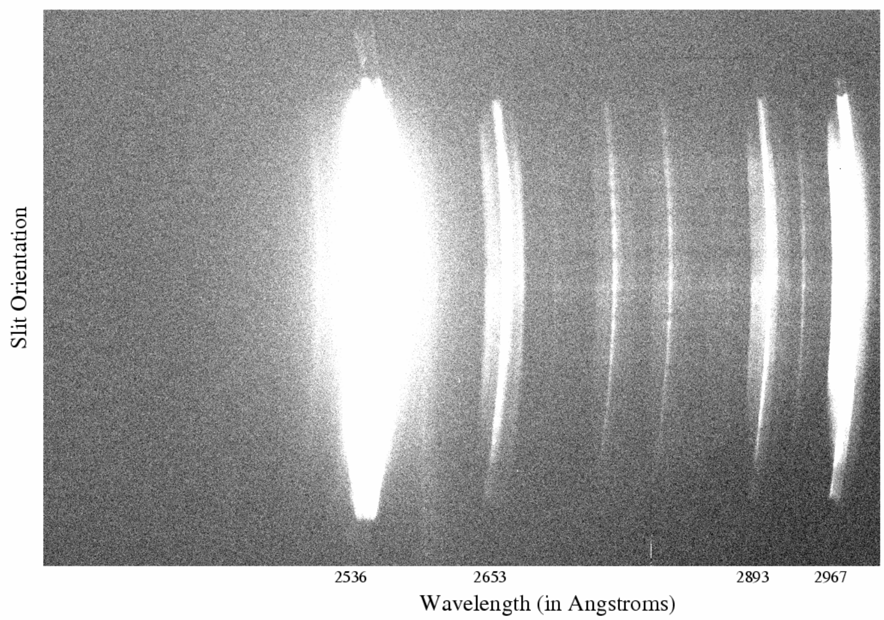

Figure 4 Actual image obtained by the UV spectrograph when illuminated with a mercury lamp spectral source. Y-axis is the slit orientation/spatial extent and x-axis shows wavelength. The strong mercury spectral lines as predicted (shown in Figure 2) can be seen in the observations of this figure.

Thermal and Vacuum tests are being planned currently. These tests and the evaluations thereafter are expected to be completed before the end of October. These tests will specifically simulate the balloon ascent conditions and other requirements as laid out by the Balloon facility.

The platform for fixing the spectrographs onto the Gondola will be prepared by the Balloon facility once the spectrographs arrive at that place, which it is expected will happen in November. The aim is to launch the experiment in this year. Once the launch window is finalized, an announcement will be sent out in advance to ensure operations of the ground network of data. Physical Research Laboratory (PRL) and Andhra University (AU) will coordinate a campaign mode of operations in India to ensure operation of various instruments in India. The data obtained will be analyzed to specifically investigate the existence of wave features.