A HIGH ALTITUDE BALLOON EXPERIMENT TO PROBE STRATOSPHERIC ELECTRIC FIELDS FROM LOW LATITUDES

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Outline of this Talk

- The Earth’s Global Electric Circuit
- Why on a balloon platform and what do we expect to measure?
- Challenges and how do we address them
- BEENS Experiment - Instrument and the limitations
- BEENS - Stratospheric electric fields
- Summary

(TWO GOOD CONDUCTORS (the Earth and the Upper Atmosphere) AND A ‘DIELECTRIC BETWEEN THEM’ (the Lower Atmosphere);

THERE ARE CURRENT GENERATORS DRIVING A GIANT ELECTRIC CIRCUIT LINKING THE TWO)
UT dependence of Carnegie curve obtained during 1920s and the invoking of global thunderstorm activity (classical picture)

(Comparison plot used to prove Wilson’s hypothesis)

Quasi-DC sources of EMF that drive the GEC: (A modern approach)

• Thunderstorms
• Dynamo interaction between the solar wind and the magnetosphere
• Dynamo effect of atmospheric tides in the thermosphere

Transient luminous events reveal electrical activity above thunderclouds

The vertical electric field ~100 V/m on the ground decreases with altitude to become negligible within the ionosphere.
Ground-based measurements of GEC parameters

- Ground based measurements of DC global electric circuit are dependent on the atmospheric columnar resistance.
- Approximately 95% of the atmospheric columnar resistance lies below 10 km altitude.
- Thus, ground based measurements of DC global electric circuit involve local continental effects on the observations made.

- HIGH ALTITUDE BALLOONS provide an excellent platform for monitoring the ionospheric potential of thunderstorm generated vertical electric field and the large scale horizontal electric fields generated in the ionosphere and magnetosphere mapped to the middle atmosphere.
- MAKE USE OF SUCH PLATFORMS TO OBTAIN MEASUREMENTS OF IONOSPHERIC ELECTRIC FIELDS FROM STRATOSPHERIC ALTITUDES
Large-scale ionospheric/magnetospheric electric fields map to stratospheric altitudes with some attenuation (e.g., Park, 1976)

- Large-scale ionospheric electric fields driven by ionospheric and magnetospheric drivers do map down to the lower atmosphere with negligible attenuations.

- Horizontal electric field thus measured at balloon altitudes from low latitudes can be related to the overhead ionospheric electric field.

- Scale lengths of the order of tens of km are strongly attenuated in the equatorial atmosphere compared to the high latitudes.

- Balloon experiments conducted during certain times of the day near the equator can provide useful information on the ionospheric electrodynamics.
Weak electric fields (~ mV/m in the horizontal and ~hundreds of mV/m in the vertical) to be measured

Stratosphere is weakly conducting with high internal impedances ($10^{11}$-$10^{12}$ ohms) and so the input impedances of the electronics should be two orders greater

Leakage currents if the insulation is not proper

Probes to be deployed on long booms so as to be away from the central conducting body (gondola)

Long loadlines so as to be far enough away from the balloon that gets charged quickly, especially during the ascent and descent

Photoemission currents to be minimized or balanced suitably for meaningful measurements
Balloons Experiment to Measure Stratospheric Electric Fields - The Beens Experiment

- Technique Adopted: Langmuir Double Probe

\[ E = \frac{V_1 - V_2}{d} \]

(in the absence of other sources of electric fields including the contact potential differences)

- The electric field is obtained as the potential difference between the appropriate pair of spheres divided by their separation distance.
BEENS Experiment was conducted on 13 December 2013 from Hyderabad (9°N geomagnetic), India

Objectives of the balloon experiment

• To obtain the electrical structure of the stratosphere over low latitudes

• To identify and understand the role of major drivers of the GEC

• To monitor ionospheric electric fields at balloon altitudes and study their local time behaviour in the context of the known physics of equatorial ionospheric phenomena

• To monitor and study ELF/VLF waves generated by various sources and their propagation characteristics from a balloon platform

• Test-bed for a future satellite experiment
Experimental setup - Probe Electronics implemented for BEENS Experiment

- Very high input impedance (>10^{14} \, \Omega) electronics to overcome the shorting effect of the atmosphere (impedances of ~10^{11} \, \text{ohms at 30 km})
- 2 orthogonal pairs of conducting spheres for horizontal field and one orthogonal probe, all mounted on insulating booms
- Probe diameters were ~15 cm (to collect large enough charge to drive the electronics)
- Probes must be far enough from the central body to minimize the field perturbations caused by the gondola structure (boom lengths achieved were ~3 m)
- External probe surfaces as well as the ground plates and other external payload surface coated with aquadag
- Experiment conducted during nighttime
- External probe surfaces as well as the ground plates and other external payload surface to be coated with aquadag.
- Signal ground is a star-point ground connected to a set of isolated ground planes surrounding the central payload.
- Entire payload rotated a few times per minute to eliminate DC offsets caused by residual work function differences, non-zero opamp offsets, etc.
- Electric field determined by subtracting the voltages of two opposite spheres.
- A constant horizontal electric field appears as a sine wave (at a rotation rate) in the output voltage.
BEENS before launch – undergoing trials

Rotation of the gondola achieved (1-2 rpm) with a DC torque motor
- BEENS payload reached an altitude of ~35 km.
- Float duration of ~4 hours achieved.

- Gondola rotation rate increased during the ascent.
- Stable rotation achieved for a 90 min duration after the float altitude was reached.
- Data sampling interval was of ~72 ms.
Sample clip of a movie (viewing the gondola) taken from a camera located on the loadline
Measurements of vertical electric field

- Large DC offsets
- Ez severely underestimated due to the nature of the boom material used and also due to coupling between the
Instrument limitations

- 5-probe configuration and coupling between Ex and Ez electrometer inputs
- Inclined boom supporting Ez probe is not entirely non-conducting (polystyrene or fibreglass rods) and so there was a ‘shorting’ effect noticed in the Ez output.
- Ey probes are expected to be ‘clean’ during the times when the gondola rotation was stable
- Noise due to 1 kHz low pass filter (25 pt running means used in the analysis)
- Torque motor driving the gondola to rotate contributed to ‘noise’.
- The motor was switched off for ~3 min. We considered the data set for this period as ‘clean’ and used them to scale the electric field amplitudes for the rest of the period.
- Only Ey probe outputs are considered for analysis and for further discussion.
Sample electric field data at ~35 km

- 05:25-05:27
- 04:37-04:39
- 03:37-03:39

Sample electric field data at different times
What could be the sources for these electric fields?
Equipotential lines from large-scale electric field source due to the Ionospheric dynamo (from Volland, 1982)

- Small horizontal electric fields of ionospheric origin expected at balloon altitudes!
- With 6000 V potential difference over a region encompassing three hours, we would have a horizontal electric field of $\sim 1.2$ mV/m
Data from ELBBO flight, Hu and Holzworth (1997) (ELBBO: Extended Life Balloon-Borne Observatories)
Summary

- An electric field experiment (Balloon Experiment on the Electrodynamics of Near Space (BEENS)) was conducted from the low latitude station, Hyderabad (9°N geomag. lat.) on a clear fairweather night (December 13, 2013).

- Double Langmuir probe technique adopted for the BEENS experiment.

- A float altitude of ~35 km was reached and a float duration of ~4 hrs. obtained.

- A few shortcomings were noticed during this first experiment – interdependence of x and z channels, larger gondola dimension (1 x 1 x 1.1 m).

- Future planned experiments will use a smaller gondola, independent probe pairs and smaller balloons (~30,000 cu. m and accordingly lower float altitude).

- Horizontal electric fields of ~5 mV/m do not seem to be influenced by the instrument parameters – their sources are yet to be ascertained.