Comparison of Equatorial Plasma Bubbles and Spread-F Observations Using 2-D GPS ΔTEC Data Maps and Ionosonde Measurements over the South American Sector

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Abstract

We report our cross-validation of equatorial plasma bubble (EPB) observations based on 2-D ΔTEC data maps over the South American sector, against equatorial spread-F (ESF) observations based on digisonde measurements at several locations. The 2-D ΔTEC data maps were derived using a GPS TEC data detrending procedure [Pradipta et al., 2015] that is inherently capable of distinguishing between wavelike fluctuations associated with traveling ionospheric disturbances (TIDs) and deep depletions associated with EPBs. The data detrending was performed for TEC signals along individual ionospheric piercing point (IPP) trajectories from individual stations, before spatially interpolating the ΔTEC values into a fine 0.2 deg x 0.2 deg geographic latitude/longitude grid. We validated the EPB/depletion observations from these 2-D ΔTEC data maps against digisonde observations of ESF occurrences at Jicamarca (JI91J), Cachoeira Paulista (CAJ2M), and Fortaleza (FZA0M) using data recorded in 2011. A general agreement was found between the EPB and ESF occurrences. Over Jicamarca: 55.1% fall within the EPB=YES & ESF=YES category, 20.6% fall within the EPB=NO & EPB=NO category, 24.4% fall within the EPB=NO & ESF=YES category, and 0% fall within the EPB=YES & ESF=NO category. Over Cachoeira Paulista: 48.5% fall within the EPB=YES & ESF=YES category, 37.4% fall within the EPB=NO & EPB=NO category, 13.2% fall within the EPB=NO & ESF=YES category, and 0.8% fall within the EPB=YES & ESF=NO category. Over Fortaleza: 68.8% fall within the EPB=YES & ESF=YES category, 10.4% fall within the EPB=NO & EPB=NO category, 20.2% fall within the EPB=NO & ESF=YES category, and 0.6% fall within the EPB=YES & ESF=NO category. The classification process of EPB/ESF occurrences (+'s) and no-occurrences (-'s) in this validation work also points at the possibility of performing combinatoric pattern analyses on EPB/ESF occurrence likelihood. This type of analysis may be useful in assessing the fundamental limit of EPB/ESF occurrence predictability that can be theoretically achieved.

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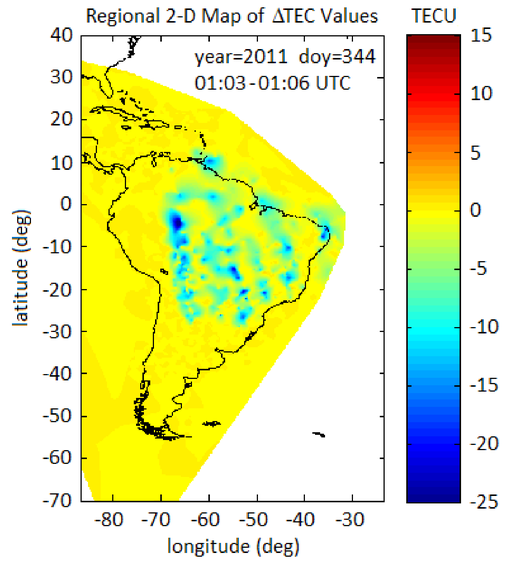
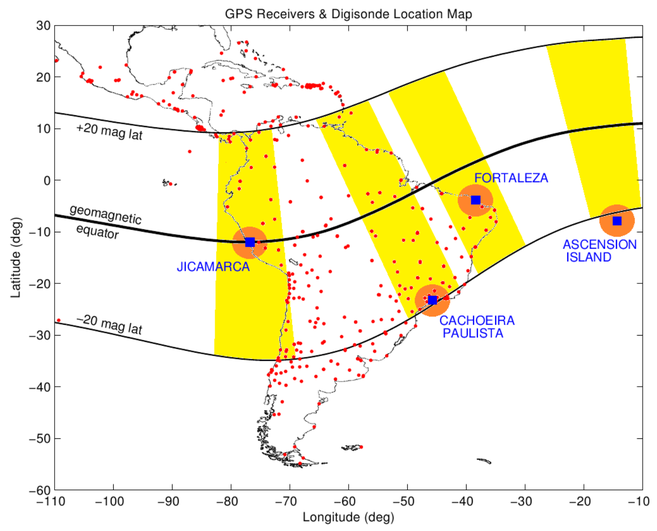
2-D ΔTEC Data Maps and Digisonde Stations in South America



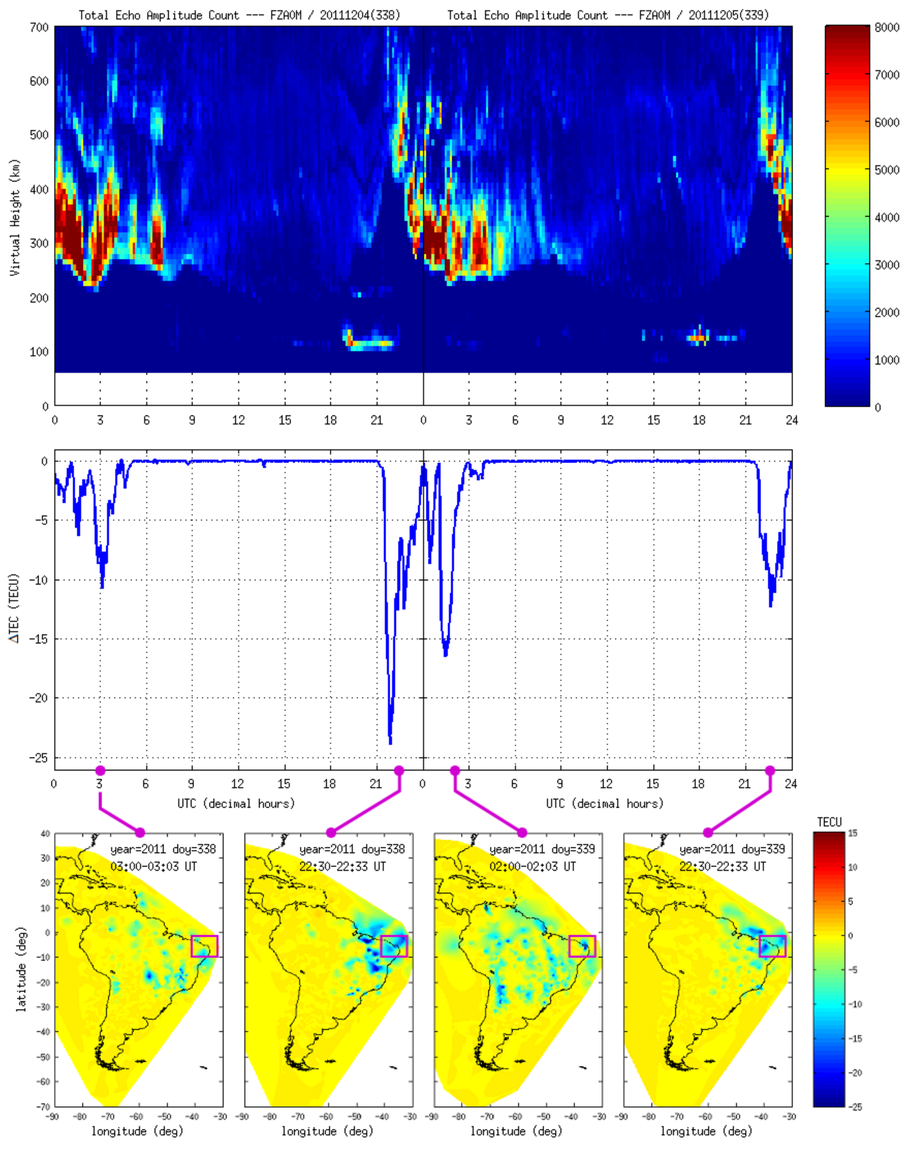


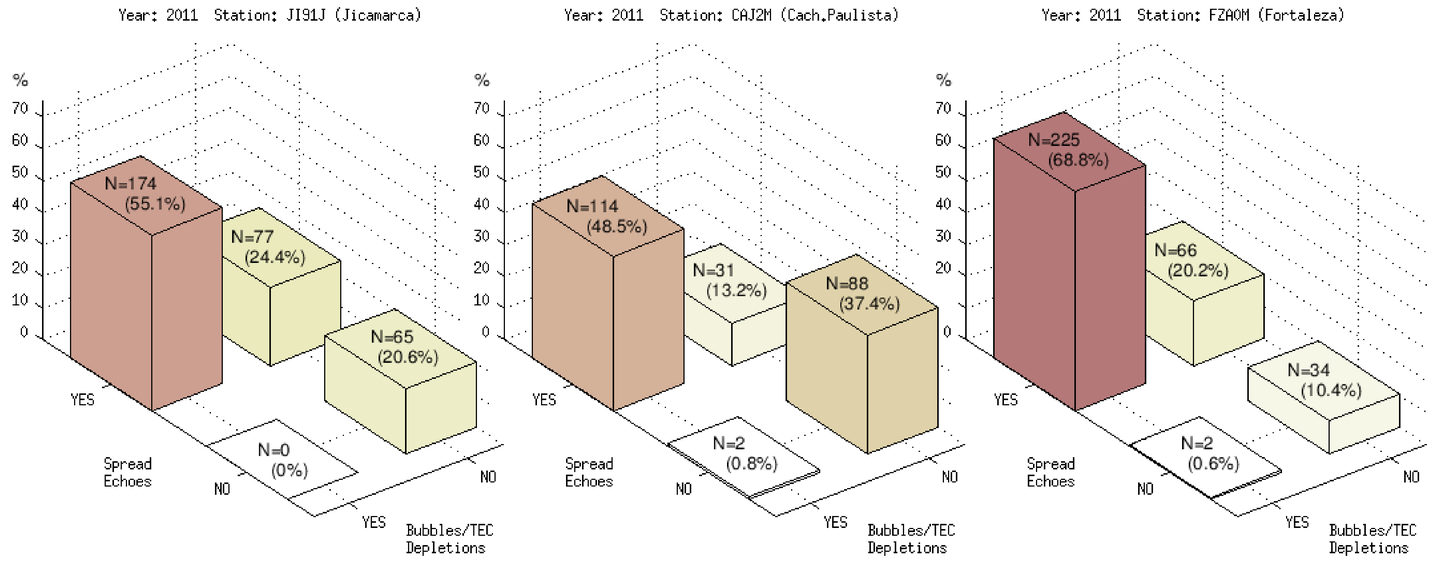
Left: 2-D ΔTEC data map showing EPBs. Right: Map of ground-based GPS receivers and digisonde stations.

TEC Data Detrending Method Reference:

Pradipta, R., C. E. Valladares, and P. H. Doherty, (2015), An effective TEC data detrending method for the study of equatorial plasma bubbles and traveling ionospheric disturbances, *J. Geophys. Res. Space Physics*, 120, 11,048-11,055, doi:10.1002/2015JA021723.

Cross-Validation Results of EPB vs ESF Observations in South America

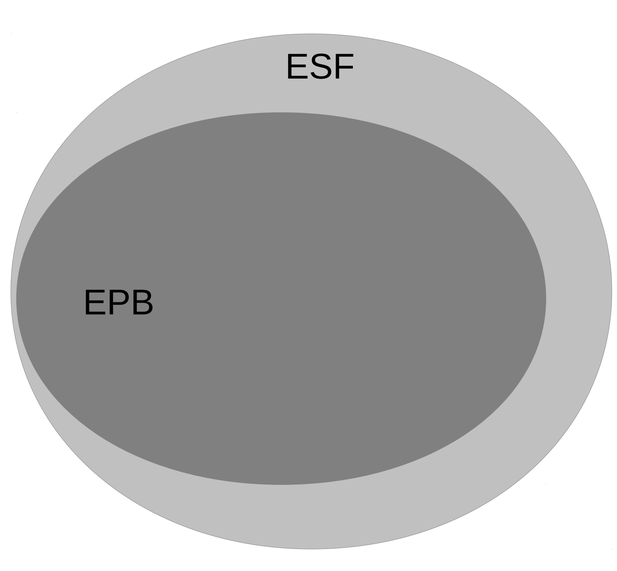




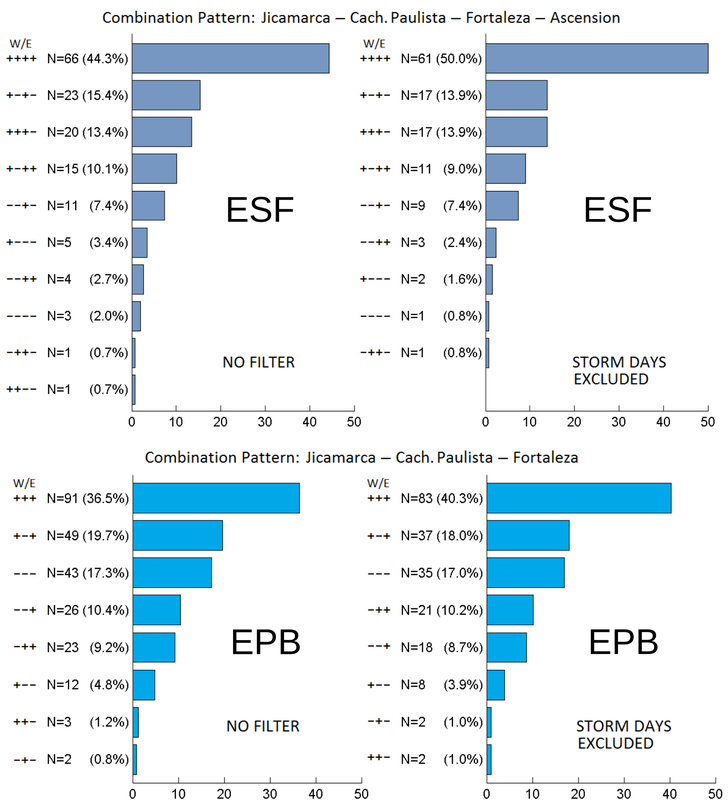
Left: Sample sequence of range-time-intensity (RTI) plots of ionogram echo count from Fortaleza (FZA0M) digisonde station, time series plot of GPS-derived ΔTEC values within region-of-interest (ROI) around Fortaleza, and several snapshots of the 2-D ΔTEC data maps at certain epochs – on 4/5 December 2011. Higher echo count in the RTI plot indicates equatorial spread-F (ESF). Depletions (negatives) in the ΔTEC time series and 2-D maps indicate equatorial plasma bubbles (EPB).

Top: Summary percentage histograms of EPB and ESF occurrence comparisons at Jicamarca, Cachoeira Paulista, and Fortaleza coordinates. EPB occurrences were based on the 2-D ΔTEC data maps evaluated around the digisonde station, and ESF occurrences were based on the ionograms recorded by the digisondes.

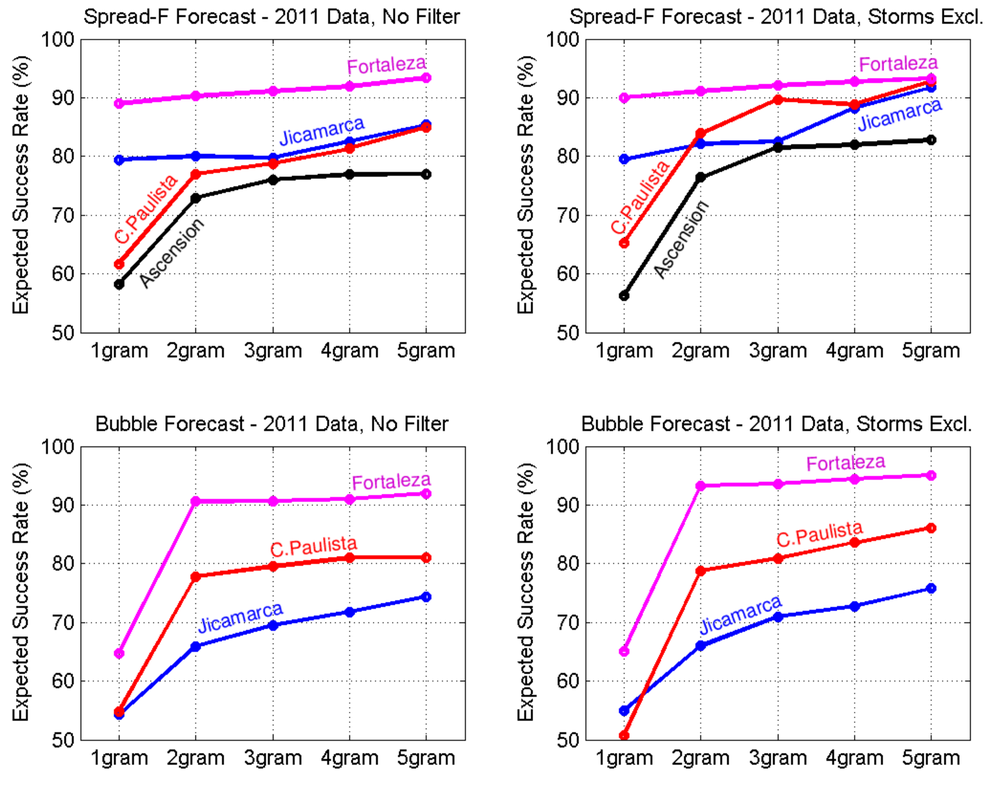
Right: A Venn diagram illustrating the relational inclusiveness between EPB and ESF occurrences in general. There are cases of ESF without EPB, but cases of EPB without ESF are rather implausible.



Spatial Combinatorics of ESF & EPB Occurrences



Temporal Combinatorics (Day-to-day Patterns) of ESF & EPB Occurrences



Based on the tabulated ESF and EPB occurrences for various calendar dates in 2011, a *mock-forecast* was retroactively conducted as a side product of this ΔTEC data validation research work.

The *mock-forecast* exercise was performed based on empirical day-to-day combinatorics of the tabulated occurrence (+) and no-occurrence (−) of ESF and EPB at the designated locations.

Different day-to-day combinatorial lengths were considered for this *mock-forecast* exercise; from 1gram (+ vs −), 2gram (++ vs +− vs −+ vs −−), 3gram (+++ vs ++− vs +−+ vs … vs −−+ vs −−−), all the way up to 5gram (+++++ vs … vs −−−−−).

The results of this *mock-forecast* exercise show that reasonable levels of ESF/EPB forecast success rate may be theoretically expected from the utilization of combinatorics analysis on historical day-to-day occurrences of ESF and EPB over certain location.