High precision daytime TEC measurements using the Murchison Widefield Array

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1 *Extended Abstract*

It has long been established that interferometers can be used to measure very accurate differential total electron content (dTEC) often with a precision as high as mTECU at high spatial and temporal resolution. This has led to several interesting discoveries like the direct detection of ionospheric plasma ducts, direct imaging of travelling ionospheric disturbances etc. A downside of the techniques used by intereferometers to arrive at accurate dTEC measurements is that they cannot be used during daytime with ease. This has implied that almost all of such works has been done during night-time.

We used data from the Murchison Widefield Array (MWA) to study the daytime ionosphere when the MWA was pointing towards the sun. This work has been enabled by very high SNR measurements (due to a very bright Sun) and the very accurate calibration achieved by the Automated Imaging Routine for Compact Arrays for Radio Sun (AIRCARS). AIRCARS solves for the phase difference between the rays incident at two antennas which can be inverted to find the dTEC between the corresponding lines-of-sight. We find that this inversion can only be done if there is a dominant compact source on the solar disc. At present, we can measure the dTEC at an accuracy of $\mu TECU$ under suitable conditions (right panel of Fig. 1).

The left panelof Figure 1 shows the mean dTEC over a 1 minute period by converting the mean phase obtained by AIRCARS over the same duration and the middle panel shows the deviation from the mean dTEC for one 0.5 s snapshot. The right panel shows the typical accuracy of dTEC measurements for a 0.5 s snapshot. These panels show that the TEC can change by 72 mTECU over 3 km and demonstrate our ability to detect rapid sub-mTECU fluctuations, respectively. We have calculated the phase structure function and find it to be highly anisotropic, with ionopsheric structures elongated along the local magnetic field. We also find that the power law model traditionally used to describe the phase structure function does not yield a good fit for our observations. The likely reason is that the model assumes the same scale lengths through out the ionosphere, which does not hold true during the day. Our high accuracy dTEC measurements are sensitive to this difference. We believe that such accurate dTEC measurements provide access to previously unexplored phase space and can potentially open new directions of research in ionospheric physics.

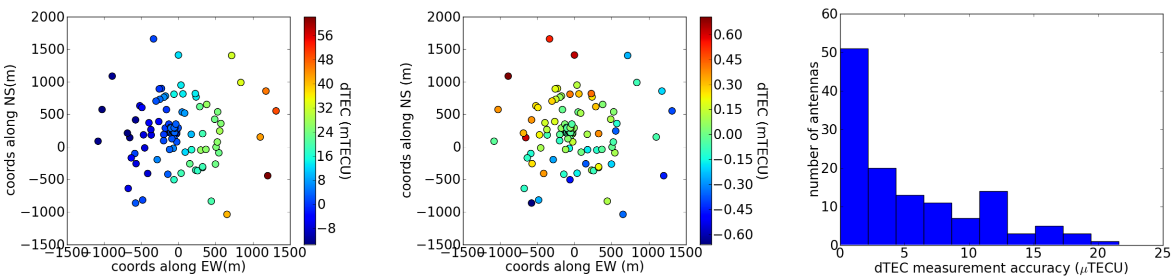

Figure 1. The left panel shows the mean dTEC of the antennas with respect to the line of sight (LOS) of the reference antenna, over a period of 1 minute. This is obtained by converting the phase solved by AIRCARS for each antenna to the dTEC of the corresponding LOS using a linear relation. Over the 3 km extent of the array, the dTEC has changed by 72 mTECU. The middle panel shows the mean subtracted dTEC at a 0.5s snapshot, illustrating the small and fast phase variations over the array. The maximum dTEC variation in this figure is about 0.89 mTECU. The right panel shows the accuracy of the dTEC measurements for a typical 0.5s snapshot.