Development of a regional Maximum Usable Frequency model for Southern Africa

S. Brijraj, M. Kosch, P.J. Cilliers
South African National Space Agency

1. Introduction

One of the important services that the SANSA Space Weather Centre offers is HF propagation predictions for use by airlines, the military and other users of HF radio for long distance communication.

The aim of this project is the validation of Maximum Usable Frequency (MUF) predictions, given by the Ionospheric Communication Enhanced Profile Analysis and Circuit Prediction Program (ICEPAC).

The larger aim is to develop a more suitable and focused prediction model of MUF profiles for Southern Africa, using local conditions.

In order to analyze the validity of the ICEPAC predictions, we compared measured daily variations of the near vertical incidence skywave (NVIS) MUF as measured by means of the ionosonde located at Grahamstown, South Africa, with the values predicted by ICEPAC. The study period considered daily predictions over the period 2010-2019.

2. Method

The RMSE skill score was used as the primary metric to quantify the performance of the prediction model (Fig 1), as dictated by The International Civil Aviation Organization (ICAO). The RMSESS is a modified RMSE value with a maximum of value of 1 showing perfect model-measurement agreement. The Dst and Kp indices were used as indicators of solar storm activity to investigate the storm response of ICEPAC.

To develop our model drivers were selected using how well they are able to be predicted currently, suitability to the Southern Africa region and their correlation coefficient, R, to the measured MUF.

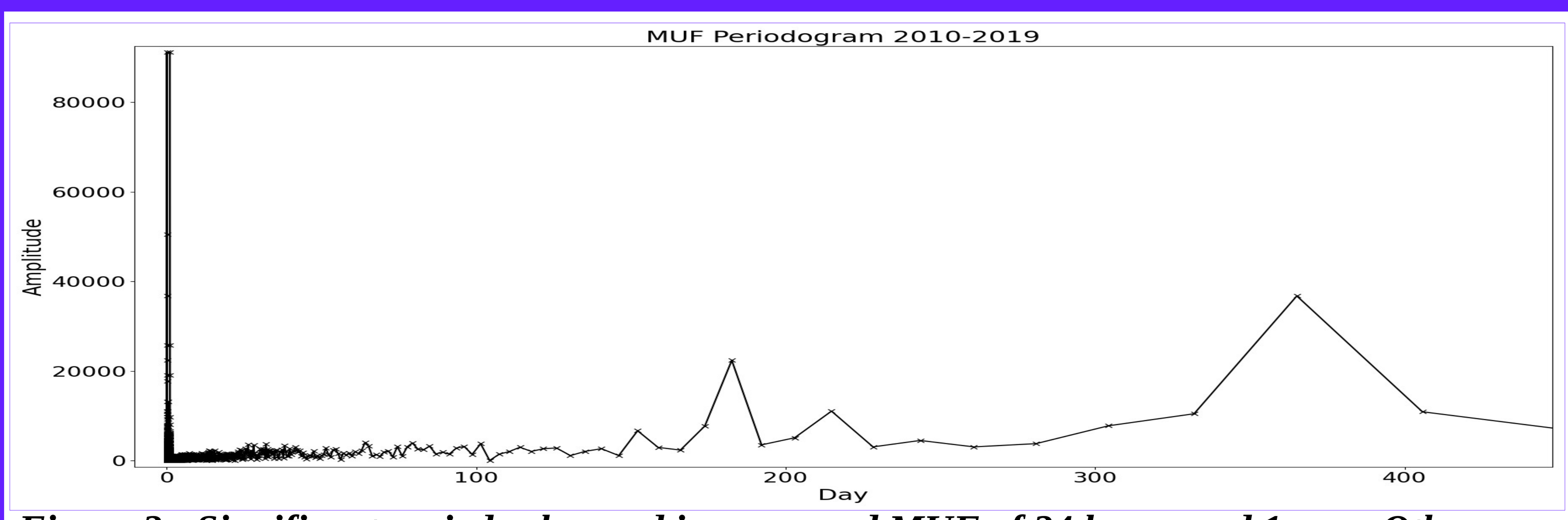

Figure 2: Significant periods observed in measured MUF of 24 hours and 1 year. Other periods of half a year as well hourly are present too.

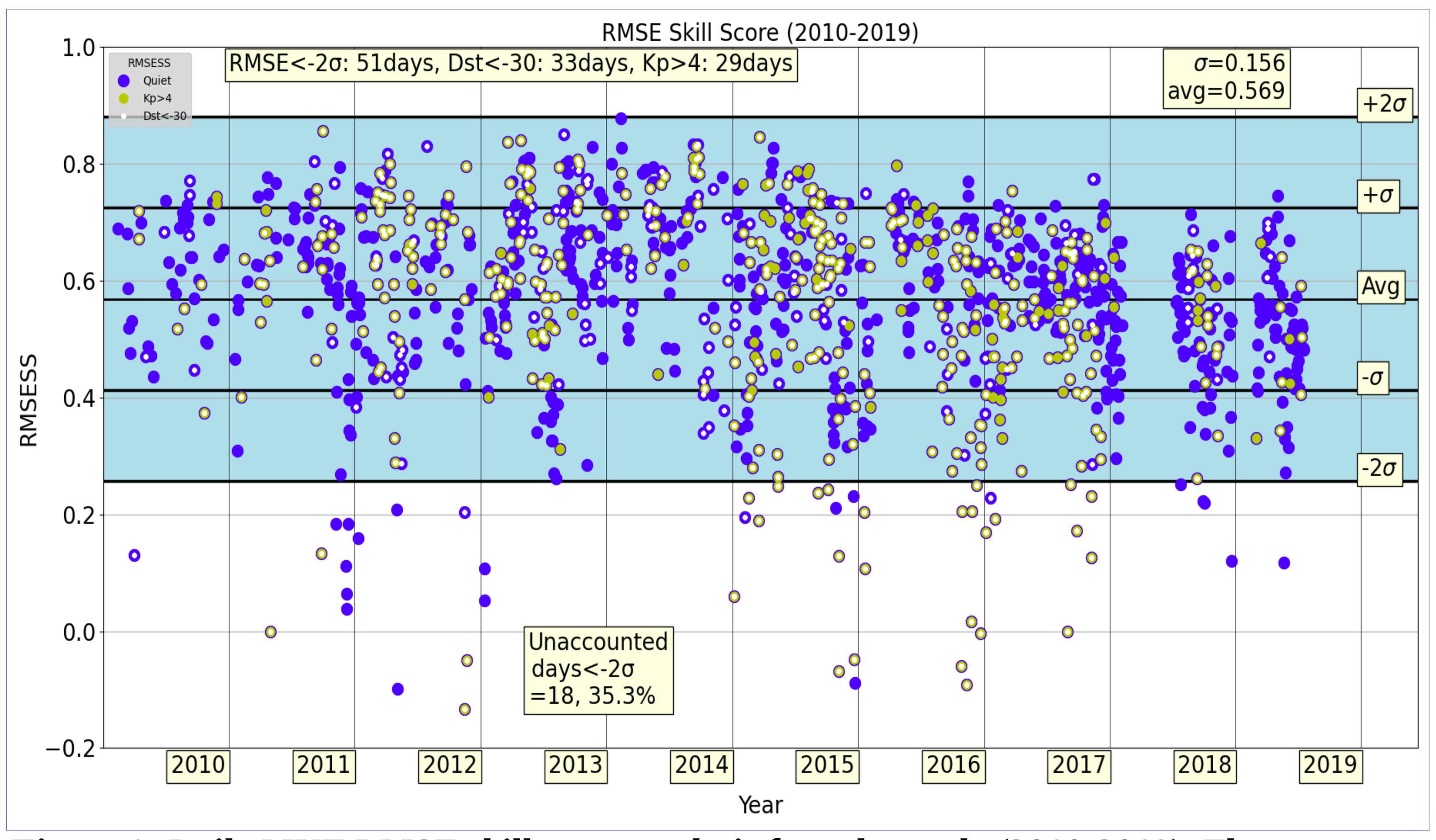

Figure 1: Daily MUF RMSE skill score analysis for solar cycle (2010-2019). The average daily value is 0.569 out of a maximum of 1. Out of 1231 total days, 51 have a RMSESS below -2σ with 18 of those days currently unconnected to a corresponding geomagnetic disturbance (Kp>4 and Dst< -30nT).

3. Results

The results of this study provide a methodology and baseline to evaluate the accuracy of HF propagation predictions. The average daily skill score was found to be 0.57, with a standard deviation of 0.16. This average can be explained as ICEPAC consistently overpredicts MUF[1]. The daily skill scores for the majority of the days were within two standard deviations of the average. However, 35% of all daily skill scores that fell below 2 standard deviations could not be reasonably connected to solar storm activity, as indicated by Kp>4 and Dst<-30nT. Since on average we can only achieve 57% of an ideal prediction-measurement match, the need for the development of an updated model is necessitated.

For the new model, frequency analysis of the MUF over a decade yielded significant periodicities of 1 year and 24 hours (Fig 2). Solar Zenith Angle helps reproduce the 24 hour diurnal variation well, yielding R>0.71 against the MUF. F10.7cm (R>0.32) helps to contribute the low frequency annual variation of the MUF over a decade. We found that using solar zenith angle, 10.7 cm solar radio flux and the Kp index as drivers we could predict daily MUF values that matched the measured values with R>0.82 (Fig 3).

We will focus on a combination of these input parameters as there are established models to forecast these parameters with a lead time of at least one day. Other inputs such as sunspot number, Dst and Ap indices have been used for vTEC and foF2 prediction model developments, which could be incorporated too[1,2].

Currently the model is being calculated based on a linear combination of selected input drives. We will be exploring using neural networks in the future.

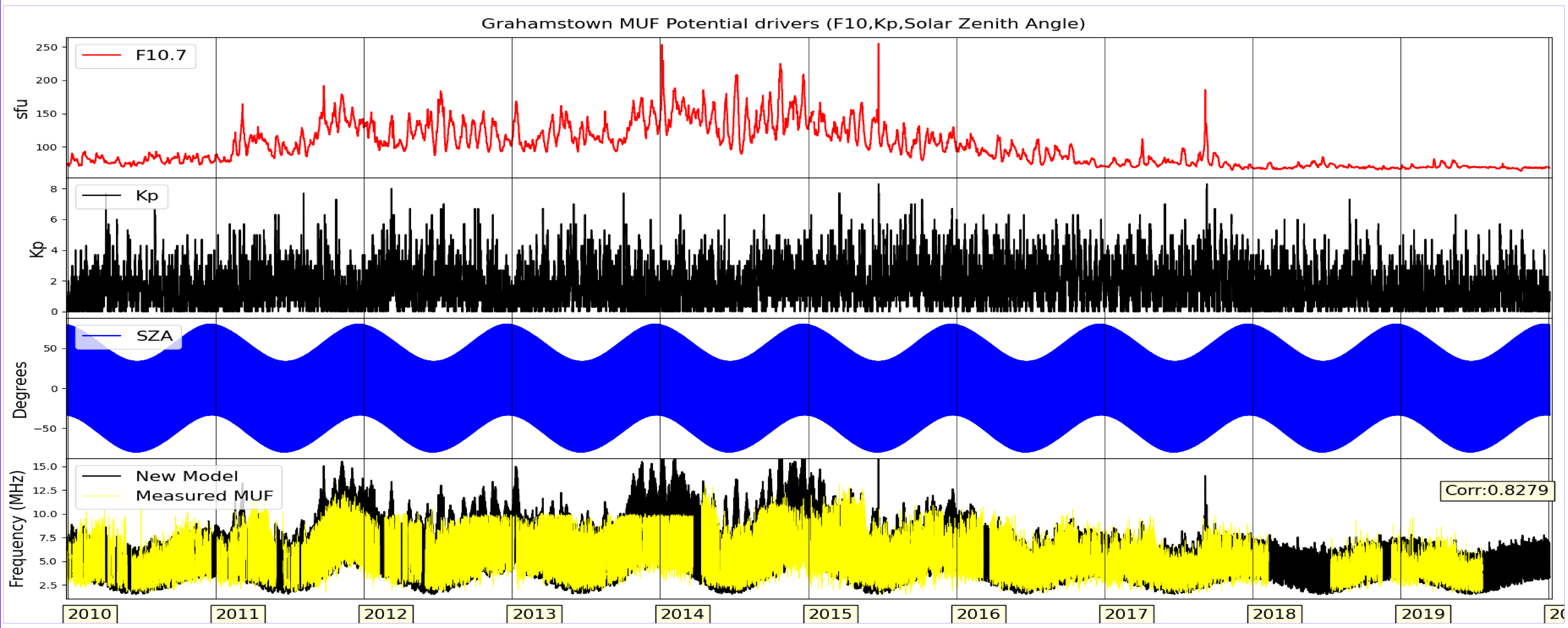

Figure 3: Selected driver inputs (F10.7, Kp and Solar zenith angle) for the developing MUF model (bottom panel). Current best correlation coefficient, R=0.8279

4.Future Work: A combination of F10.7, Solar Zenith Angle and Kp seem to be very promising in producing a model that gives a good correlation with the measured MUF profile to build a new regional prediction model. To create a truly regional model we will use the local K index instead of Kp.

5. References:
1.Athieno, R. et al. (2015), Comparison of observed and predicted MUF(3000)F2 in the Polar cap region, Radio Sci., 50,509–517, doi:10.1002/2015RS005725.
2.D Okoh et al. (2016) A regional GNSS-VTEC model over Nigeria using neural networks: A novel approach, Geodesy and Geodynamics, 7:1, 19-31,ISSN 1674-9847, https://doi.org/10.1016/j.geog.2016.03.003
2. D. Zheng, W. Hu & P. Li (2016) Predicting ionospheric critical frequency of the F2 layer over Lycksele using the neural network improved by error compensation technology, Survey Review, 48:347, 130-139, DOI: 10.1179/1752270615Y.0000000015

SOUTH AFRICAN NATIONAL SPACE AGENCY