Investigating the Effect of Revised SIDC SSN Values on VOACAP

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March 2017

Introduction

A key VOACAP input parameter is the Sun Spot Number (SSN), traditionally derived from data published by the National Geophysical Data Center (NGDC) / National Oceanic and Atmospheric Administration (NOAA) (Perkiömäki, 2010). However, at the end of 2016, NOAA discontinued providing predicted data, instead directing users to the SIDC website. The SIDC SSN values were previously very similar to those of the NGDC / NOAA and employed a common smoothing algorithm, designed to reduce the effect of short term perturbations without obscuring the behaviour of the underlying 11-year solar cycle. Unfortunately, this no longer the case and in July 2015 the SIDC dataset underwent a major revision, the most significant component of which was the removal a 0.6 scaling factor. *"This scale change, when combined with the recalibration, leads to a net increase of about 45% (correction variable with time) of the most recent part of the series, after 1947"* (SIDC, 2017).

This survey seeks to investigate the effects of using revised the SSN values with VOACAP by employing the methodology prescribed in ITU-R P.1148-1 to compare performance for three candidate sets of SSN data;

NGDC The original NGDC / NOAA values. Archived copies of these values are available at `https://www.esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/sunspot.dat`.

SIDC The revised SIDC values (i.e. post July 2015). These values are made are available at `http://sidc.oma.be/silso/`.

SIDC_ADJ 'Adjusted' SIDC values. This set applies a 0.7 scaling factor to the published SIDC values in a bid to reduce them to the levels of the original NGDC values. As may be expected, there is a high correlation between the NGDC and SIDC SSN values, confirmed by a Pearson correlation coefficient of 0.996 when comparing the valiues for the period 1964–2016. The Root Mean Square Error (RMSE) between the data sets for the same period is of 32.5. After application of the 0.7 scale factor, this is reduced to 4.0 indicating good fit.

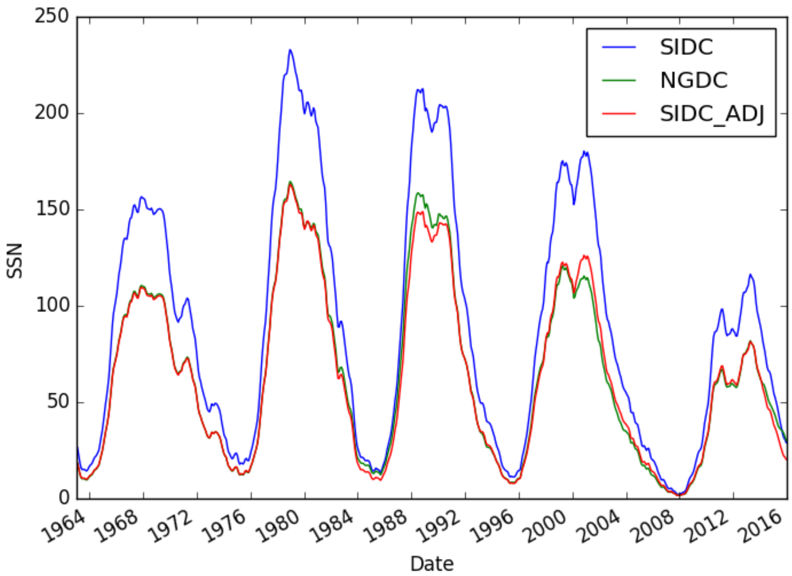

Figure 1: SSN Values for the period 1964–2016

Figure 1 compares the three datasets for the period 1964 (the start of the D1 dataset) to 2016.

The effect of using the revised SSN will be evaluated using both VOACAP's IONCAP and Normal absorption modes, in addition to corrections proposed by Shovkoplyas (Hand, 2012). Selection of the mode and application of the Shovkoplyas' modifications are defined at run time by the version number suffix in the file `itshfbc\database\Version.w32` where;

Identifier	Suffix	Mode
W_*	W	Normal Mode
I_*	I	IONCAP Absorption Model
WA_*	A	Normal Mode / Shovkoplyas' modifications
IA_*	a	IONCAP Mode / Shovkoplyas' modifications

Table 1: VOACAP Absorption Models

Methodology

ITU-R P.1148-1 evaluates the performance of HF Prediction Models by comparing predicted values with measured data in the D1 Databank. The Databank comprises some 16268 samples derived from 181 HF circuits during the period 1964–1985 (ITU, 2014). The paths have been chosen to represent a variety of HF paths in terms of SSN, location and time of year. Candidate prediction algorithms generate retrospective 'predictions' which are compared with measured data and the results presented in a standardised format to facilitate comparison between models. ITU-R P.1148-1 prescribes the use of the mean and standard deviation (SD) of the residuals[1] calculated for all available data (i.e. where both measured and predicted data is available) as a comparison metric. Values are calculated for the complete dataset; the standard does not permit discarding outlier data. However, additional groupings based on criteria defining the circuit (e.g. frequency, geographic attributes, SSN values etc.) are suggested to facilitate a deeper insight to the model's behaviour. These sub-groups are of primary interest to the model's developers and are not intended, nor should be used, as a basis for selecting models on a path-by-path basis (ITU, 1997).

Although ITU-R P.1148-1 is clear in stating that the *"most important parameter for assessing the accuracy of the monthly median signal intensities given by a particular prediction method is the standard deviation"*, this survey will also consider comparison using the RMSE, a generalised measure and widely used to compare predicted and measured data (Bruce and Bruce, 2016).

Predictions have been generated using a suite of automated scripts using the latest version of Windows VOACAP (16.1207) available at the time of writing (`http://www.greg-hand.com/hfwin32.html`). Dedicated Python scripts were then used to analyse the data using the Pandas Toolkit and Matplotlib for graphical data presentation.

Results

The results of the twelve model / SSN Data combinations are presented in Table 2, arranged in order of ascending standard deviation as per the recommendations of ITU-R P.1148-1. Models are identified by the identifiers provided in Table 1 concatenated with the SSN identifiers corresponding to the three candidate sources of SSN data identified above.

Model	Mean	SD	RMSE
IA_NGDC	-5.71	18.36	19.23
IA_SIDC_ADJ	-5.81	18.38	19.28
I_NGDC	-5.51	18.39	19.20
I_SIDC_ADJ	-5.62	18.41	19.28
IA_SIDC	-5.70	18.83	19.67
I_SIDC	-5.52	18.92	19.71
WA_NGDC	-7.03	19.09	20.34
WA_SIDC_ADJ	-7.13	19.09	20.38
W_NGDC	-6.83	19.10	20.28
W_SIDC_ADJ	-6.94	19.11	20.33
WA_SIDC	-6.93	19.50	20.69
W_SIDC	-6.74	19.57	20.70

Table 2: Results

From 1 it can be seen that the IONCAP absorption model provides superior

[1]The difference between the predicted and measured monthly median sky-wave signal intensities (i.e. predicted minus measured)

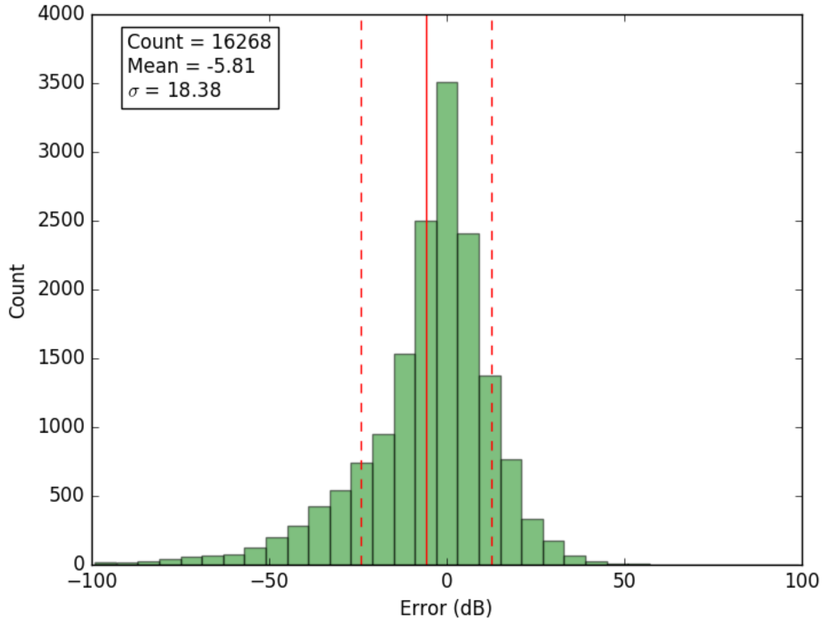

Figure 2: Predicted vs. Measured Field Strength

results in every case when compared to the Normal model. The differences in SD between rows are small yet it is interesting to note the consistency in the ordering within the IONCAP and Normal subsets. As might be expected, both the IONCAP and Normal models favour the original NGDC SSN data employed during the application's development. Furthermore, when using SD as a metric for comparison both IONCAP and the Normal models benefit from the application of the corrections proposed by Shovkoplyas.

ITU-R P.1148-1 also suggests graphical presentation of the results, employing a histogram of predicted versus measured field strength as shown in Figure 2 which presents the distribution of residuals for the AI_SIDC_ADJ model. From this plot, which resembles a skewed-normal distribution, it can be seen that VOACAP generally tends to favour pessimism and has a higher probability of under rather than over predicting.

A box plot (Figure 3) corresponding to the AI_SIDC_ADJ model presented in Figure 2 yields further insight, indicating that while VOACAP tends to favour pessimistic results overall, VOACAP actually has a strong tendency to over estimate field strength at the lower range of measured results where the greatest residuals are observed.

It is of interest to note that if RMSE is used as the basis for comparison, the Shovkoplyas modifications may be viewed as degrading performance.

In all cases, the use of unmodified SIDC SSN values yields inferior performance.

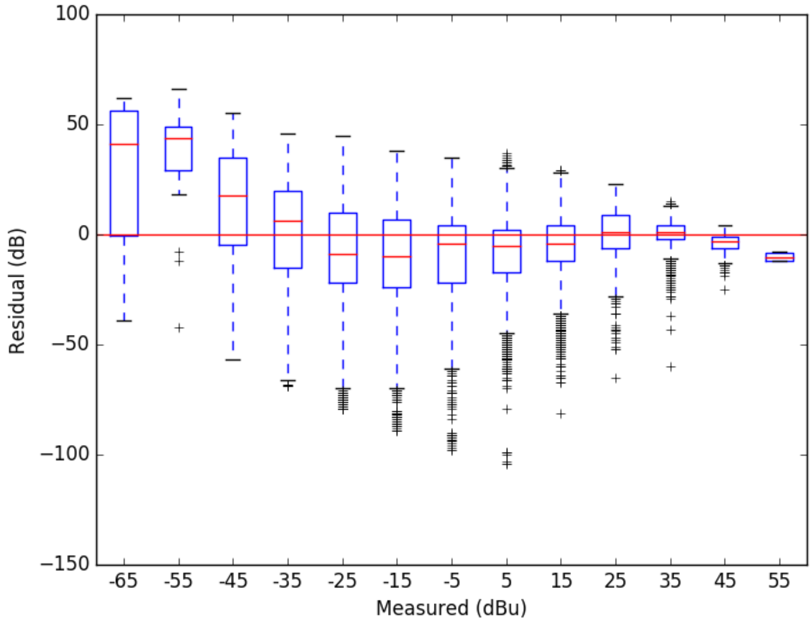

Figure 3: Residual Distribution vs. Measured Field Strength

Conclusions

From the results it can been seen that the difference in SD for a particular absorption model is the order of 0.5dB, suggesting that the source of SSN values is not a major factor for day to day use. However, users looking for the greatest precision in future predictions for which NGDC / NOAA results are no longer available would be best served by using a modified set of the SSN values. Such an approach requires revalidation with each upgrade of VOACAP to ensure that future changes to the application do not account for the use of revised SSN values.

Furthermore, evaluation of results in accordance with ITU-R P.1148-1 supports the case for the application of the modifications proposed by Shovkoplyas.

The above two factors suggest that for the current version of VOACAP, the suffix of the `Version.w32` file should therefore be set to 'a' (e.g. 'Version 16.1207a'), selecting the IONCAP absorption model and the Shovkoplyas corrections.

Acknowledgements

I am indebted to Chris Behm and Bill Ingram for permission to use a suite of scripts automating the the build and running of the test files. This software provided a valuable insight into approaching this type of application.

I would also like to thank Jari Perkiömäki, maintainer of the http://www.voacap.com website for the informative and engaging exchanges that we've shared over the years which have pushed me keep learning.

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