Ann. Geophys. Discuss.,
https://doi.org/10.5194/angeo-2018-97-AC1, 2018

Annales Geophysicae Discussions
Open Access

Interactive comment on "Improvements to Predictions of the Ionospheric Annual Anomaly by the International Reference Ionosphere Model" *by* Steven Brown et al.

Steven Brown et al.

sbrown3@gmu.edu

Received and published: 21 November 2018

The authors would first like to extend their gratitude to referee 1. We appreciate the referee's insight, time and diligence in reviewing this manuscript. What follows is a response to the referee's comments. We tried to break the referee's comments into sections and respond directly. Thank you

---

[referee] This study uses a newly conceived method of calculating hemispheric adjustments to the IRI URSI foF2 maps to investigate the model's capacity to represent the

Printer-friendly version

Discussion paper

Annual Anomaly. ...... increased flexibility in the basis set (i.e. allowing for two indices rather than one) would, by construction......Until the cause of the IRI's original AI underestimation is properly identified, drawing physical interpretations is largely conjecture.

[response] We agree and have changed the text as follows:
We have removed all text concerning physical interpretations from the end of the discussion, including aspects of it in the introduction. This text includes pages 17 lines 33-35 and page 18 lines 1-27.
We have replaced this text with discussion:
"Improvements to the IRI predictions of the annual anomaly are related to three qualities regarding our index, IGNS, which improve upon the other indices.
—the index is computed separately for Northern and Southern hemispheres
—the index is not averaged over 12-months
These first two qualities are the most important. These qualities are consistent with the observed features of the annual anomaly: the anomaly occurs over time scales less than 1 year and causes the ionosphere's climatology over the Northern hemisphere to differ from the Southern hemisphere. Thus observations of the annual anomaly drive the improvements needed to improve IRI's description of the anomaly.
— the index is computed using the URSI-88 foF2 model.
"This addresses the problems associated with model-index incompatibility raised by Brown et al. (2017). Undoubtedly, the reliability of IRI's description of the annual anomaly is related to the original fitting of the CCIR and URSI foF2 maps, which were computed using an uneven hemispherical distribution of observational data with a strong bias towards the Northern hemisphere. Using separate hemispheric indices to drive the CCIR and URSI models helps to overcome some of this hemispheric bias and results in a better description of the annual anomaly."

[referee] Is this considered a potential replacement to the current methodology in the

Printer-friendly version

Discussion paper

IRI? Using a hemispheric adjustment would likely create significant artificial gradients at the boundary between the hemispheres, making this approach unusable for many applications that rely on the IRI, such as trans-equatorial HF propagation modeling.

[response] The reviewer makes a very good point that needs to be addressed by future studies. Most likely a smoothing algorithm in a transition region could help to overcome this problem. This is outside of the scope of this study that primarily wanted to assess the benefit of hemispheric indices in improving IRI's description of the annual anomaly.

[referee] What is the advantage of this method over already available products, such as IRTAM, the real-time IRI? The IRTAM is presumably a far more robust assimilation scheme and is readily available at the moment. Where does your method fit?

[response] Both the standard IRI and IRTAM version of IRI are important ionosphere models, which are needed for a number of applications. Efforts to improve both should continue. The IRI is recognized by the International Standardization Organization (ISO) as the ISO standard for the ionosphere and its full functionality is freely available to the international community. The full functionality of the IRTAM is available at a premium, a limited version is available freely. Our index improves the IRI by reducing foF2 model prediction errors. This is also of benefit to IRTAM, which uses IRI for its initialization. With a more realistic first guess IRTAM will more quickly converge to represent real-time conditions. IRI is also critical to IRTAM as the background ionosphere for regions where no data are available.

To emphasize this point in the text we have added the following to the first paragraph of the INTRODUCTION (page 2 line 4):

"....is widely used for the empirical specification of the ionosphere. Recent efforts have concentrated on assimilating data into IRI to more accurately represent real-time conditions. The IRI Real-Time Assimilative Mapping (IRTAM) is a first step towards this goal assimilating ionosonde data for foF2 and hmF2 into IRI. Both the standard IRI and IRTAM version of IRI are important ionospheric models, which are needed for a number of applications. The IRI is recognized by the International Standardization Organization (ISO) as the ISO standard for the ionosphere and its full functionality is freely available to the international community. Efforts to improve the IRI is of benefit to IRTAM, which uses IRI for its initialization. With a more realistic first guess IRTAM will more quickly converge to represent real-time conditions. IRI is also critical to IRTAM as the background ionosphere for regions where no data are available. Efforts to improve both models should continue. There are other efforts underway as well as described by Bilitza et al. (2011, 2017)."

And will update the bibliography to include the following citations:

Bilitza D., L.-A. McKinnell, B. Reinisch, and T. Fuller-Rowell, The International Reference Ionosphere (IRI) today and in the future, J. Geodesy, 85:909–920, DOI 10.1007/s00190-010-0427-x , 2011

Bilitza, D., D. Altadill, V. Truhlik, V. Shubin, I. Galkin, B. Reinisch, and X. Huang (2017), International Reference Ionosphere 2016: From ionospheric climate to real-time weather predictions, Space Weather, 15, 418–429, doi:10.1002/2016SW001593.

[referee] One of the features of the current IG12 index is its stability to be forecasted. How would you implement this methodology in the IRI to retain the forecast capability?

[response] The reviewer makes a very good point. A monthly index provides better results when used for retrospective modelling, e.g., creating a re-analysis data set combining existing data with model inputs. To retain the forecast capability, we commend to use a, a 12-month averaged IGNS index.

[referee] 1) Figure 1 – Do you have copyright approval to reproduce this figure? If so, please state so and list the publisher.

[response]We do not have the copyright approval. This figure was removed from the body of the manuscript.

[referee] 2) Figure 2 – There are significant holes in the station distribution. Perhaps comment on how this may affect your results.

[response] The reviewer makes a good point. We will include the following text in the methodology:
(page 7 line 6) “The station distribution will not have an effect on our results regarding the annual anomaly because we always use station paired with one from the Northern hemisphere and one from a magnetically conjugate location in the Southern Hemisphere.“

(page 7 line 13) “Because there are more stations in the Northern hemisphere than in the Southern hemisphere our results for the Solstitial variation are more statistically significant for the Northern hemisphere.“

[referee] 3) Table 4 – Do you have statistical error information for the values in this table? Are these statistically significant?

[response] We do not have a meaningful statistic for the station pair AI. All literature concerning the AI index calculation also does not present a statistic for the AI. Perhaps due to the small number of data points required for a single AI calculation.

We have begun to investigate this further. At present, we are considering to include an RMS

[referee] 4) Figure 4 – Can you comment on the differences between your top left figure here and that from Rishbeth and Muller-Wodarg (2006)? There appear to be differences in the ionosonde-derived AI values for the same pairs. Were you unable to acquire the same ionosonde data or are there processing differences between your study and theirs? This would also somewhat highlight the need to have some sort of error measure associated with AI values.

[response] We agree, we will add the following text to the first paragraph of section 3.1.1:
(page 12 line 1): "Data are presented for the Wallops–Hobart (green), Wakkanai–Port Stanley (blue), and Kodaikanal–Huancayo (red) station pairs for the years 1970-1990, a subset of our full data record. This subset of our data record is presented in order to recreate Figures 3 and 4 from Risbeth and Muller-Wodarg (2006) and perform a direct comparison with their work. We emphasize three contributing factors which will cause deviations of the charts presented in this work and those presented by Rishbeth and Muller-Woodarg. First, we were unable to find sufficient data for their fourth example, the Slough–Kerguellen station pair, and thus, it was replaced by an additional station pair, Poiters–Christchurch (black). Second, the charts presented in this work use monthly median observations in the range of 10LT to 14LT. Rishbeth and Woodarg (2006) indicated using observational data from 12LT. And thirdly, our data were obtained from both SPIDR and GIRO data repositories, Rishbeth and Muller-Wodarg did

not use data from the GIRO repositories. We do not expect these contributing factors to significantly affect our results. "

[referee] 5) Regarding the incompatibility between the IG from CCIR and using it for the URSI maps – Why would you not just recalculate a monthly IG index for the URSI maps, as you have done for the IGNS index? This way you would be able to definitively define where the errors are coming from.

[response] This manuscript emphasizes a comparison of IRI predictions using our new index, IGNS, with predictions using the official (CCIR-based) IG and IG12 indices. Currently IRI uses the CCIR-based IG indices with the CCIR maps as well as the URSI maps. So the use of an URSI-based IG index as proposed and studied by Brown et al. (2017) will result in additional improvements of IRI predictions. We point out that this model-index incompatibility was problematic for low solar cycle conditions. Our index demonstrated improvements for all solar cycle levels.

[referee] Minor Comments:

Page 2, Line 15 – Please cite your previous paper regarding the method of determining the IGNS here.
Page 5, Line 1 – "utilized" -> "using" or "utilizing"
Page 6, Last Line – AP -> Are you referring to Ap, the daily arithmetic mean of the three hourly ap index, or are you referring to the three hour ap index itself. A bit semantic being a capitalization difference, but these two indices are often confused.
Table 8 – Low SA -> move to right.
Page 18, Line 10-12 -> Perhaps mention the differential behaviour of the north and

south PC indices here as well?
Page 19, Line 16 – GRO -> GIRO

[response] We have addressed the listed minor points.
We used the daily arithmetic mean of the Ap. This is now clarified in the text. We have included the following additional text (page 2, line 15) “These adjustments improve the predictions of temporal and spatial variations in foF2 that are made by the IRI model. Please refer to Brown et al. (2017) for a full description of the calculation of IGNS.”

Interactive comment on Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2018-97, 2018.

Table 4.8: Average S_{foF2} Separated by Hemisphere

Average S_{foF2}	High SA NH	High SA SH	Low SA NH	Low SA SH
Ionosonde	3.74	-1.99	0.89	-0.56
IRI[IG_{12}]	2.74	-1.48	0.39	-0.1
IRI[IG]	3.54	-1.89	0.11	-0.09
IRI[IG^{NS}]	3.52	-1.92	0.56	-0.52

Fig. 1. Revised Table 4.8

Printer-friendly version

Discussion paper