Response to Reviewer #1

Note: Referee comments transcribed; Author reponses in square brackets.

Page 3, line 22: could you provide a reference defining the “evil twin” problem?

[The statement of the "evil twin" problem is presented in the sentence preceding its designation. This paper contains the first published usage of that terminology.]

Page 5, Figure 2: I suggest to explicitly state also in the caption that the depicted geometry represents the maximum latitude for the orbits of both Jason 2 (66°) and GPS (55°). To improve figure readability I suggest to plot a dot at the position of each satellite. The geographic grid could also be plot more lightly, e.g. gray, to make the geometries between satellites more outstanding.

[The beginning of the statement introducing Figure 2 (page 5, line 10) is changed to: "Figure 2 is a north-south cross-section for Jason-2 (latitude 66°) and two GPS satellites (latitude 55°) at their (north) polar extremes, ...". A similar statement in the caption would be unnecessarily redundant.

With the implementation of a lighter grid, the vertices associated with the satellite locations are more evident, and additional markers do not appear to be necessary.]

It is also worth stating in the caption of Figure 2, that the circles are plotted at every integer value of L.

[Labels for "L=2", "L=3", "L=4" are added along the lower vertical radius.]

Page 6, Figure 3; Page 9, Figure 5; Page 14, Figure 9: please add in the caption or on the figure axes that the units are TECU.

[TEC unit designations are added to the appropriate axes for these figures.]

Figure 3: I suggest to explicitly indicate in the graph titles that the data shown are from the polar regions only.

[Additional "polar region" designations are included in the titles.]

Page 8, line 21, and page 17, line 26: note that the Heise et al. work cited from the Earth Observation with CHAMP has been published in 2005. Another article based on the same algorithm was indeed published in 2002: Heise, S., N. Jakowski, A. Wehrenpfennig, C. Reigber, and H. Lühr (2002), Sounding of the topside ionosphere/plasmasphere based on GPS measurements from CHAMP: Initial results, Geophys. Res. Lett., 29(14), 1699, doi:10.1029/2002GL014738.

[This article was noted through the citation by Pedatella and Larson (2010), with the 2002 date, but the discrepancy from the 2005 copyright date of Earth Observation with CHAMP was not noticed. The citation and reference are both changed.]

Page 9, line 12 and Figure 5: I think that it could be useful to explicitly indicate if the formula used to compute LT is LT=UT+longitude/15, with 0 <= longitude <360. With the formula, it is more understandable that the LT varies between 0 an 48. I think it is important to make it clear for the reader that on the figure data at different UT can have the same LT, because Jason 2 satellite was making 12.8 complete orbits during 24 hours, with a very similar local time of the ascending node.

[Revision: "A [0,24] hour limit is not imposed on the LT evaluations, and continuity in LT is maintained for successive GPS samples, except for the (positive East) longitude discontinuity from 360° to 0° in each orbit. Thus, for the combined

Universal Time (UT) and longitude (Lon) progressions (with LT(h) = UT(h) + Lon(deg)/(15 deg-h-1)), the LT values extend over [0,48] hours for the 24 hours of Universal Time."]

Page 10, figure 6: please indicate if the green dot isolines are magnetic latitudes, from which model they have been computed and for which altitude they are displayed.

[Caption addition: "The magnetic latitudes displayed within the plot frame are Magnetic Apex Coordinates (VanZandt et al., 1972), appropriate for the ground station locations."

Reference: VanZandt, T. E., W. L. Clarke, and J. M. Warnok, Magnetic apex coordinates: A magnetic coordinate system for the ionospheric F2 layer, Jour. Geophys. Res., 77, 2406-2411, 1972]

Page 11, line 4: in this sentence the "magnetic local times" are indicated, while Figure 5 was showing "LT". To avoid confusion, I suggest to make it explicit that the two different local times have been considered.

[Revision: "Because of the high inclination (66.04°) of the Jason-2 orbit, the satellite passages over Africa occur primarily for magnetic local times around 11:00 (for southward passes) and 23:00 (for northward passes) for this day, using the ground station magnetic local time selection conventions previously employed by Mazzella et al. (2017)."]

Figure 7: to improve clarity, I suggest to make a visual difference (e.g. a dashed line or a different colour) between PIM with boundary at 1000 km and PIM starting from 1346 km and indicate this visual difference in the legend on top of the figure.

[A different color is implemented for the PIM plasmasphere electron content with a lower boundary altitude of 1346 km, with a modified legend and a revised last sentence in the caption.

Caption revision: "The corresponding PIM profiles are displayed, for a 1000 km boundary for the ionosphere only (bottom panel) and as the upper PIM profile ("PIM (>1000 km)") for the plasmasphere, while the lower PIM plasmasphere profile ("PIMA (>1346 km)") corresponds to an alternative boundary altitude of 1346 km, for comparison to the Jason-2 values.]

How the error bars have been computed for this figure?

[Addition to text, after "The Jason-2 equivalent vertical PEC (EqVPEC) and ground-station plasmasphere vertical electron content (VPEC) derived by the SCORPION method are displayed in Fig. 7 (top panels) as latitudinal profiles, together with the ionosphere vertical electron content (bottom panels) and composite ionosphere and plasmasphere vertical electron content (middle panels) derived by SCORPION." (p.11, l. 8-11):

"The error bars in Fig. 7 for the ground-based TEC measurements are calculated in the manner described by Mazzella et al. (2017), while the Jason-2 TEC error bars are derived from the analysis for Figure 4, based on the Gaussian "noise" (0.75 TEC units) required to reproduce the cumulative distribution for the Jason-2 TEC data."]

Page 13, line 20 and Figure 8: please add the PRN number of the common GPS satellite shown in this example.

[Text revision (p. 13, l. 16-22): "An example of alignments for the ground station ARMI is displayed in Fig. 8, indicating the lines-of-sight from the station to Jason-2 (red) and the common GPS satellite (PRN 14) (purple), plus the lines-of-sight (blue) from Jason-2 to that GPS satellite."

Caption revision: "Aligned lines-of-sight from the ground station ARMI to Jason-2 (red) and to the common GPS satellite (PRN 14) observed (purple), plus the lines-of-sight (blue) from Jason-2 to that GPS satellite, with nominal plasmasphere penetration points for the Jason-2 lines-of-sight (black dots), based on the median cumulative slant TEC calculated from

PIM."

Related change, after "For comparison, an offset linear fit (Y=A+X) to the data samples, with an intercept of 0.168±0.924 TEC units, is displayed in blue, and a first-order fit (Y=A+B*X), with a slope of 0.921 and an intercept of 0.311±0.920 TEC units, is displayed in red." (p. 13, l. 31-33):

"A tabulation of all the SPEC comparisons and associated parameters is provided in the Supplement, as the data for Fig. 9."]

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Response to Reviewer #2

Note: Referee comments transcribed; Author reponses in square brackets.

Very sorry for the slow and late review on this. This study essentially serves as a validation of the SCORPION plasmaspheric TEC estimation method but also establishes a methodology for validating plasmaspheric TEC determination methods. The results are compelling and the authors have largely considered most caveats that such a study would run into. A few minor comments and references that could be useful:

1) Given that this study mainly concerns a validation of the SCORPION results, it would be very useful to include a brief overview of the SCORPION method in this study. The interpretation of the outcomes of this paper depend heavily on an understanding of the SCORPION method and it's assumptions, so a brief overview is likely very important for most readers.
[There is some description of the SCORPION method at p. 2: l. 32 - p. 3: l. 16, but from the unusual perspective of focusing on the plasmasphere baseline. This description contains material corresponding to that in the brief description by Mazzella (2009) and the summary description by Mazzella et al. (2007). An extended description is presented by Mazzella (2012) (Section 2), also in the context of the plasmasphere baseline determination. The most extensive description is by Mazzella et al. (2002), cited within the plasmasphere baseline discussion for the article being reviewed, although the formulation of the weight function and the plasmasphere representation were changed significantly between 2002 and 2007.]

2) Page 3 Lines 18-23: This is also explained in Themens et al., (2015), which might be a valuable reference here for illustration purposes, and to show that others have also reached this conclusion about plasmaspheric TEC contributions to TEC calibration methods.
https://doi.org/10.1002/2015JA021639
[This part of the introductory discussion was intended to present the concept of the "plasmasphere baseline", which was the rationale for the methodology of the comparative ground-based study, and also as a prelude to the concluding discussion associated with Figure 9 (p. 15: lines 4-13). The suggested reference would have been more appropriate for the associated Africa ground-based study (Mazzella et al., 2017), but does not distinguish between the bias errors induced by the spatially varying plasmasphere electron content and the ambiguity in the bias determination produced by the plasmasphere baseline. These were illustrated by Mazzella (2012) (Table 2 and Figure 12).]

3) Page 15, Lines 27-28: This link does not work. You may want to put the code in a separate repository, or if it is proprietary, please state so. Would the Gallagher model versions below be at all analogous to what you have used in this study?
https://plasmasphere.nasa.gov/models/
[It was noted that the PIM source link was not currently active, and an alternative source reference does not exist. The license for the software has restrictions regarding redistribution.
Some GPS TEC simulations were generated during this study and the one for the Africa stations, for various models, with separate calculations for the ionosphere and plasmasphere contributions, displayed in the format of Figure 3 by Mazzella et al. (2017). The Global Core Plasmasphere Model (GCPM) associated with plasmasphere.nasa.gov/models

has ionosphere and plasmasphere profiles distinctly different from those for PIM. Additionally, GCPM displays TEC discontinuities for both the ionosphere and plasmasphere, while no such discontinuities were displayed by PIM.]

4) Page 16, Line 6: They have moved to http://ftp.aiub.unibe.ch/CODE/
[Thank you for the reference.]

5) Regarding POD bias estimation methods: Watson et al. (2018) assessed these methods using POD data from a highly elliptical polar orbiting satellite (CASSIOPE ePOP), showing that the zero-TEC assumption is generally valid for satellites at altitudes at or above ~1000km, which might provide some further support for your assertion here. https://doi.org/10.1002/2017RS006453 They also validate the other methods you have references, such as the minimizations of standard deviations method.
[It is not clear whether a general or specific assertion is being referenced by the reviewer's comment. Although Watson et al. (2018) briefly discuss the Zero-TEC method, their discussions and displays are primarily for the minimization of standard deviations (MSD) technique, with only a general comparison of the Zero-TEC results to the MSD results, and for a significantly large receiver altitude range [1200 km, 1500 km], with associated TEC variations. The range of TEC values discussed is significantly larger than the median value shift applied to the Jason-2 TEC measurements, so the corroboration of the Jason-2 analysis would be weak.]

Just some other random thoughts:
1) One way to check the self-consistency of the results would be to compare your results to the Jason-2 altimeter TEC data and compare that to your vertical ionospheric TEC. Jason-2 has had its error behaviour very well characterized in the past, so it may be another independent validation source for you.
[As noted by Mazzella et al. (2017): "Comparisons of IEC, using the JASON-2 altimeter data, are considerably restricted for the chain of stations used in the current study, because of their inland locations." The required Jason-2 tracks would need to be over water, but Figure 6 shows that there are very few occurrences (red tracks) for this. The only possible comparisons are for Grahamstown (GRHM), and both passes transition between sea and land, reducing the available extent of data. A similar circumstance occurred for a comparison of Jason-1 altimeter TEC data in the vicinity of Alaska (Mazzella, 2012), and the limitation on Jason-1 TEC data available for averaging also presented problems for the comparison to GPS TEC.]

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Response to Topical Editor

Topical Editor decision: Publish subject to minor revisions (review by editor)
by Dalia Buresova
Public justification (visible to the public if the article is accepted and published):
Dear Dr. Mazzella, dear Dr. Yizengaw,

Thank you for choosing Annales Geophysicae for publishing interesting results of the comparative analysis you carried out.

I am very pleased to say that the article has received favourable reviews and that the current status of your article requires a minor modification. From my side, I am inclined to the recommendation of one of the opponents to add to the text (for example, in the Introduction) a brief description of the used SCORPION method, including the already mentioned references in your answer and the decoding of the abbreviated name SCORPION in the first place where it was mentioned.

If you are prepared to undertake the improvements required, please send us a modified version of the manuscript with an indication of the modifications made.

I am willing to read the manuscript once again.

Kindest regards

Yours cordially
Dalia Buresova

Response:

Dear Dalia Buresova:

A short description of the SCORPION method has been added in the Introduction, discussing the GPS bias determination method used by its predecessor SCORE and how that method was augmented to accommodate the presence of plasmasphere electron content. The augmented method permits determinations of the separate plasmasphere and ionosphere contributions to total electron content, prompting the modification of the SCORE acronym to SCORPION.

Additional references are cited regarding the background for SCORPION, and further citations of previously included references are provided in that description.

Modifications have also been incorporated regarding comments by the referees, as noted in the individual responses to the referees.

With gratitude,
Andrew Mazzella

Other changes in the manuscript:

Figure/box sizes were adjusted, to accommodate caption changes and relocations with respect to the main text.
Numerous suspect hyphens were replaced by "en dashes", except for Internet addresses and "doi" designations.
The Mazzella et al.(2017) reference was augmented by a "doi" specification.
The columns for Table 1 were slightly adjusted.
The text associated with mention of SCORE was revised, for addition of the SCORPION description, to avoid redundancy.
A statement of gratitude to referees and Topical Editor was added, in the Acknowledgments.
The Web source reference for relative GPS satellite biases was changed to that noted by the referee, with an access date.