Replies to reviewers' comments

Comment to reviewers

Really, the Authors are deeply grateful to thank the third reviewers very much for his/her important comments that helped us to reformat the original manuscript with the final forms that we are really appreciating his/her deep insight, without attention for the final results. Really we appreciate his/her time. We have responded to all comments and have revised the paper in light of them. Details of our responses to each comment are shown below.

Reviewer 3:

Comment (1):

According to the title, article investigate ionosphere over Egypt. Approximately longitude of Egypt is in the range 22-32^{o}N, but the result in the paper are obtained only for the 30-32^{o}N region. It would be better to mark this in the title (e.g. writing "Northern Egypt").

Response:

Considered

Comment (2):

The other problem of the title is that it gives insufficient information about the paper content. Reading the title one can think that the paper describes analysis of models used in IGS from GIM calculation. It is still not clear from the article what do you mean by "IGS-Global Ionosphere Mapping model" mentioned in the title. Please specify it in the text. I think the title should also show that you investigate improvement of precise positioning method based on usage of ZDPID algorithm and TTC 2.7 software.

Response:

The paper is titled by "Evaluation of the IGS-Global Ionospheric Mapping model over Northern Egypt". In the abstract we clarified: "The current paper evaluates the ionospheric correction by Global Ionospheric Maps (GIM), provided in Ionosphere map Exchange (IONEX) files produced by International GNSS Services "IGS". The evaluation is performed based on investigating the effect of a given GIM ionospheric correction on kinematic relative positioning solutions.".

The usage of ZDPID algorithm is to confirm the non feasibility of IGS-IONEX model over the areas that have poor data which is clarified in the paper context.

Comment (3):

Authors do not describe what laboratory GIM data is used in study. Such a description is absolutely necessary because of differences between existing GIMs, especially taking into account the paper conclusion (lines 386-388). It should also be explained why do authors prefer used data to the others.

Response:

The IONEX data files that were used in the current study are the standard IONEX data file, see the header of one of the IONEX data files that published by IGS computing centers. We did not really investigate the different types of IONEX files since we are concerned with their effect on the position solution.

```
     1.0            IONOSPHERE MAPS     MIX                 IONEX VERSION / TYPE
cmpcmb v1.2          GRL/UWM             28-apr-15 16:23     PGM / RUN BY / DATE
ionex file containing IGS COMBINED Ionosphere maps           COMMENT
global ionosphere maps for day 105, 2015                     DESCRIPTION
IONEX file containing the COMBINED IGS TEC MAPS and DCBs     DESCRIPTION
      IONEX files of the following IAACs were combined: cod  DESCRIPTION
                                                        jpl  DESCRIPTION
Contact address: Andrzej Krankowski                          DESCRIPTION
                 Geodynamics Research Laboratory             DESCRIPTION
                 University of Warmia and Mazury (GRL/UWM)   DESCRIPTION
                 Oczapowski St. 1                            DESCRIPTION
                 10-957-Olsztyn, POLAND                      DESCRIPTION
                 e-mail:  kand@uwm.edu.pl                    DESCRIPTION
                                                             DESCRIPTION
  2015     4    15     0     0     0                        EPOCH OF FIRST MAP
  2015     4    16     0     0     0                        EPOCH OF LAST MAP
  7200                                                       INTERVAL
    13                                                       # OF MAPS IN FILE
  COSZ                                                       MAPPING FUNCTION
     0.0                                                     ELEVATION CUTOFF
combined TEC calculated as weighted mean of input TEC valuesOBSERVABLES USED
   323                                                       # OF STATIONS
    31                                                       # OF SATELLITES
  6371.0                                                     BASE RADIUS
     2                                                       MAP DIMENSION
   450.0 450.0   0.0                                       HGT1 / HGT2 / DHGT
    87.5 -87.5  -2.5                                       LAT1 / LAT2 / DLAT
  -180.0 180.0   5.0                                       LON1 / LON2 / DLON
    -1                                                       EXPONENT
TEC values in 0.1 tec units;  9999, if no value available    COMMENT
DCB values in nanoseconds, reference is Sum_of_SatDCBs = 0   COMMENT
```

Comment (4):

One of the most important parts of the study is the algorithm of Zero-differenced phase Ionospheric Delay (ZDPID) calculation. The presented reference cites the paper not published yet. This almost-published article was also cited in the another paper of the authors in IJSER (http://www.ijser.in/archives/v6i4/IJSER172374.pdf). I would recommend to describe the algorithm in the current paper in more details. I also would strongly recommend not to cite articles which are not published.

Response:

Considered

Comment (5):

The article mentioned above also contains a part of the results from the current paper. Authors should add corresponding references to all the previously obtained results (especially to figures (see fig. 10)). Both the articles (current and in IJSER) investigate ionosphere during April 15, 2015. Average KP index value during 15.04.2015 reached 5, so the geomagnetic conditions were disturbed. Authors should explain why did they choose

this day. Moreover, the results for a single day are not allow to make solid conclusion about method effectiveness or GIM uselessness. Presenting the same results of GIM modification for other days will make a basis for the conclusion.

Response:

The following part was given in the initial issue of the current paper:

The big differences between the IGS and regional ionospheric values enhanced us to see the magnetic storm conditions during the time of observing data. As it is indicated in figure (5), issued by Laboratory of X-ray astronomy of the Sun, that three magnetic storms were occurred in the 15 of April 2015 started at 9:00 and ended at 21 O'clock. Also, Andrzej Krankowski and Manuel Hernandez-Pajares (2016) confirmed that due to the shortage of GNSS station in North Africa, the first GIM computation stage suffered from the hole existing in the North Africa and Oceans, see figure (6). They deployed an optimum spatial-temporal interpolation technique to cover these holes. Based upon the above discussion, it is easily to find that the derived ionospheric TEC values derived from IONEX GIM products is un-feasible and useless to be used in precise positioning.

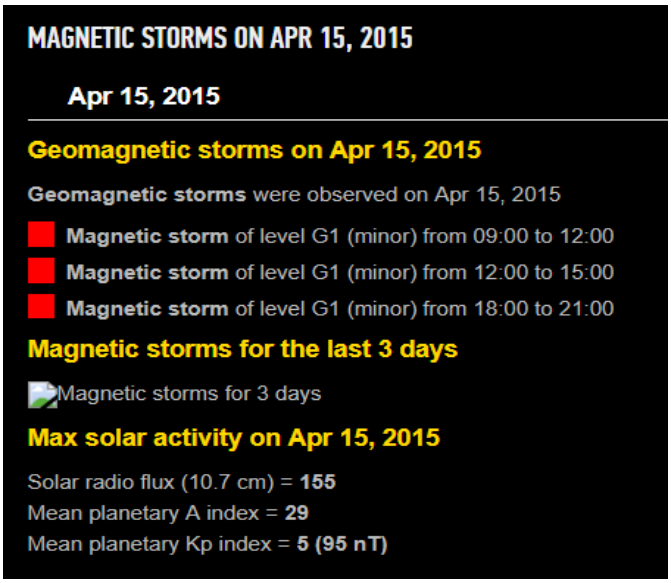

Figure (5): The magnetic storms as observed by Laboratory of X-ray astronomy of the Sun, Lebedev Institute, Russia in April, 15 2015

After discussing the results with the co-author, we agreed that the effect of the magnetic storm should also be reflected more precisely in IGS IONEX values for the used large data and efficient algorithm. So we were convinced that the shortage will be mainly to the used interpolation technique that was employed in the IGS computing centers. Thus we format the paper as that was given.

Comment (6):

Being labeled "Results and discussion" section 4 contains no discussion. The obtained results are important and should be discussed. I think authors should give some explanation of presented dynamics of ZDPID TEC values, dynamics of station position before and after ModIONEX usage and all the statistical quantities they obtained.

Response:

The following part was added to cover the required comment:
"To explain the given results. One should consider that GIMs suffered from the lack of stations at some areas (e.g., over the oceans), e.g. lack of data over the equatorial, North Africa, Atlantic and in-part over equatorial and southern Pacific. This shortage of data, hamper the detection of the equatorial anomalies (Krankowski, 2016). Additionally, GIMs are a combination of TEC derivation from GPS observations, as well as different TEC modeling techniques. This also explains why the TEC derived from GIMs is very smooth over the region. On the other hand, the solution with modified ION obtained by ZDPID reflect the improvement of the temporal and spatial resolution of GIM. Also, ZDPID gives a much more detailed picture of the local ionosphere map and outputs real perception of the local ionosphere map."

Comment (7):

Current conclusion gives nothing for understanding the paper results. All the listed statement are not good. First statement is not derived from the paper because the results of GIM-based positioning was not presented. The fact that changed IONEX usage effect on station coordinates show that GIM values play role. It should be shown that there is no difference, but not just claimed. Second statement is just a general description. I think it should present some quantitative values to show that ZDPID algorithm gives good corrections for all the stations. Third statement have no ground. The only place in the article where the listed software is discussed is this part of the conclusion. If authors really obtained such a result they should present how did the do that.

Response:

The conclusion in the paper is completely reformatted and the following conclusion was added:

GIMs suffered from the lack of stations at some areas (e.g., over the oceans), e.g. lack of data over the equatorial, North Africa, Atlantic and in-part over equatorial and southern Pacific. This shortage of data, hamper the detection of the equatorial anomalies. Additionally, GIMs are a combination of TEC derivation from GPS observations, as well as different TEC modeling techniques. This also explains why the TEC derived from GIMs is very smooth over the region. We speculate that this may be occurred due to the global nature of GIM.IGS Analysis centers (ACs) often use TEC representation algorithms, which result in a model resolution comparable with the whole area of the region under investigation. To overcome this shortage over Egypt and similar territories, and to improve the temporal and spatial resolution of GIM, Regional Ionospheric Model, like ZDPID, gives a much more detailed picture of the local ionosphere map and outputs real perception of the local ionosphere map.

The current paper evaluates the ionospheric correction by Global Ionospheric Maps, GIM, provided in (IONEX) files produced by International GNSS Services "IGS". The evaluation is done based on investigating the effect of given GIM ionospheric correction on kinematic relative positioning solution. The evaluation has been performed on several baselines with different lengths in Egypt. The data were processed three times: the first run was performed by using the specified baselines data with normal default processing parameters, i.e. without using GIM. The second run was carried out using modified GIM and the third run was made using static precise point positioning for all 24-hours data of all stations to be used as a threshold reference values for comparison. The CSRS-PPP was deployed to give the required static solution for the specified stations.

The differences between the CRCS-PPP solution and the two TTC positioning solution were computed and depicted. The results show how the computed regional Ionospheric value by ZDPID algorithm, fed into the MOD-IONEX. improve the quality and the quantity of the three positioning components against either the values computed by standard default parameters of the commercial software or the ionospheric values given in the IGS IONEX files

Comment (8):

line 7: Are all the GIMs generated in CODE?

Response:

(**GIM) are generated on a daily basis and provided by several analysis centers using data from about 400 GPS/GLONASS sites of the IGS and other institutions**

Comment (9):

line 8: where did you get the number 400? Description in CODE file (codg1050.15i) reports about 300 stations (268 in header), number of stations in IGS file (igsg1050.15i) is 323.

Response:

According to http://www.igs.org/network there is about 501 IGS Stations

ANTC00CHL	IGS	Los Angeles	Chile	G2	-37.3387028	-71.5320500
AREG00PER	IGS	Arequipa	Peru	CNES	-16.4654233	-71.4929041
AREQ00PER	IGS	Arequipa	Peru	JPL	-16.4655170	-71.4927967
ARHT00ATA	IGS	McMurdo Station	Antarctica	JPL	-77.8294361	166.6636528
ARTU00RUS	IGS	Arti	Russian Federation	RDAAC	56.4298222	58.5604528
ARUC00ARM	IGS	Aruch-Yerevan	Armenia	JPL	40.2857222	44.0855833

Comment (10):

line 10: "to cover these holes" repeats line 12

Response:

Considered: - abstract were modified

Comment (11):

line 33: “2 hours” - since 2015 CODG provide the maps with the resolution of 1 h

Response:

Considered: - introduction were modified

Comment (12):

lines 38-39: difficult to read. Reformulate please.

Response:

Considered: - Reformulated

Comment (13):

line 43: All the GIM maps have this resolution, not only from IGS.

Response:

All GIM maps have same resolution but different temporal resolution

Comment (14):

lines 58-60: I would specify accuracy values to enhance the statement. Anyway it is not clear why do you say it here.

Response:

Computing VTEC from pseudoranges have low accuracy in comparison with carrier phase due to high noise in pseudoranges observations and investigating accuracy of VTEC estimated from pseudoranges and carrier phase is out of scope of this work.

Comment (15):

lines 61-62: Could you list several models?

Response:

Such as spherical harmonic, spherical harmonic cap, USE TIME-DEPENDENT MODEL OF THE GLOBAL IONOSPHERE, COUPLED THERMOSPHERE IONOSPHERE MODEL (CTIM)

Comment (16):

line 62: “low temporal and spatial resolutions”. What do you mean by low resolution. Could you specify it with quantities? The same for “low accuracy” in line 63.

Response:

Because of Most of IGS Analysis Centers (ACs) often use TEC representation algorithms. the spherical harmonics, as a main algorithm in obtaining the TEC values, the results can not reflect the short band of ionospheric change. GIMs are a combination of TEC derivation from GPS observations, as well as different TEC modeling techniques. This also explains why the TEC derived from GIMs is very smooth over the region and result in a low resolution and less accurate compared with regional ionosphere.

Comment (17):

lines 62-63: Do you mean Li-Pi combination by "carrier phase-smoothed pseudorange"? Specify that because in line 72 you are saying that carrier phase gives precise positioning and that is confusing.

Response:

To estimate VTEC from pesudorange we use this combination to mitigate errors in pseudorange and so we use carrier phase to estimate VTEC after fixing ambiguity

Comment (18):

line 65: Choose one: el/m2 or e/m2 (as in line 165)

Response:

Considered

Comment (19):

line 75: El-Hattab et al., 2003 – is it a misprint (in References year is 2001)?

Response:

Considered

Comment (20):

line 83: "As is known" - Can you add a reference to the corresponding paper?

Response:

Considered

Comment (21):

line 86: "correct ionospheric correction" - bad formulation

Response:

Considered

Comment (22):

line 119: What do you mean by "long baseline"? Could you give some range for the value or make a comparison? The same thing for short (line 126) and medium (line 131) baselines.

Response:

Really it is difficult to specify a range of lengths for baselines, but by referring to Rabah, 1998, the short baselines could be for baselines less than 50 km, medium baselines for lengths up to 500 km and long baselines for lengths over 500 km.

Comment (23):

line 131: Satellite elevation angles?

Response:

Considered

Comment (24):

line 142: I would replace “amount” by “value”

Response:

Considered

Comment (25):

lines 147-148: TECU value was defined previously in line 65.

Response:

Considered

Comment (26):

line 157: You define L4(t) and 'GF here, but do not use them below. Do you really need them and what L4(t) should mean? In GNSS studies L usually stands for phase advance but this is the only place where you use it.

Response:

This is used by ZDPID to estimate VTEC

Comment (27):

line 160: add space in “L1frequency”

Response:

Considered

Comment (28):

lines 163 – 165: Is it a definition of Single Layer Model? If so, you should highlight that. It is not obvious now.

Response:

SLM were considered in current study

Comment (29):

line 8: where did you get the number 400? Description in CODE file (codg1050.15i) reports about 300 stations (268 in header), number of stations in IGS file (igsg1050.15i) is 323.

Response:

Considered please see comment 9

Comment (30):

line 174: Add a numeration if it is a subsection, else remove it. Actually, being entitled as “Mapping function model” the subsection gives no information about F(E). It describes a

well-known procedure of IPP coordinates calculation. Why do you give this here? And where is the mapping function model?

Response:

Considered, the mapping function was redefined and the subsection was reformatted, in the highlighted part

Comment (31):

lines 183-184: the same phrase "Ionospheric pierce point (IPP)". Please remove one.

Response:

Considered

Comment (32):

lines 178, 186 and 216: I don't really think it is necessary to define IPP position calculation equations especially citing your own paper. There are plenty of work about it before 2017 (e.g. Klobuchar, J. (1987) Ionospheric Time-Delay Algorithms for Single- Frequency GPS Users. IEEE Transactions on Aerospace and Electronic Systems, AES-23, 325-331. http://dx.doi.org/10.1109/TAES.1987.310829)

Response:

Considered

Comment (33):

line 180: Azimuth is a positively-defined quantity. I would add _/2 to A value.

Response:

It is already considered in the written code

Comment (34):

line 187: As far as I understand, according to the fig (2): angle = E' - E. In your article (Sedeek et al. 2017) it was defined this way.

Response:

Considered

Comment (35):

line 192: Why do you take ionosphere height to be 450 km? Usual value is about 300-350 km in accordance with altitude of F2 maximum.

Response:

Height ranges from 350 – 450 km and we choose 450 km because high density of electron content .

Comment (36):

line 198: what do you mean by “enhance ambiguity resolution”?

Response:

As it is known that the ionospheric delay is considered as one of the mean errors that hinder the ambiguity resolution of baselines. So by incorporating a values of the ionospheric delay into solution, without any doubt will enhance the chances of the ambiguity resolution.

Comment (37):

line 200: Misprinted IONEX

Response:

Considered

Comment (37):

line 200: Misprinted IONEX

Response:

Considered

Comment (38):

line 202: misprint “different lengths”

Response:

Considered

Comment (39):

line 202: What do you mean by “ion TEC”? What is the difference with TEC and how do you get it?

Response:

Considered

Comment (40):

lines 229-230: “Processing” was used trice. Please reformulate

Response:

Considered

Comment (41):

lines 240 and 254-255: This table is not necessary. You are not using its data at all. I recommend to remove it.

Response:

Considered

Comment (42):

lines 245-247: You claim this with no evidence. This statement should be proven.

Response:

There was no effect in positioning using ionex data

Comment (43):

line 248: Again, what do you mean by “Ion TEC”?

Response:

The paper was recently published in a local non web journal as :
Tawfeek, H., A. Sedeek, M. Rabah, and G. El-Fiky (2018). "Regional Ionosphere Mapping Using Zero Difference GPS Carrier Phase", Scientific Bulletin, Faculty of Engineering, Azhar Univerisity, vol.40(1), pp. 379–397.

See attached externally a pdf version of the paper.

Comment (44):

lines 257-258: The algorithm should be described in more details. I strongly recommend not to cite articles not published yet.

Response:

Considered

Comment (45):

line 258: describe the GPS phase ambiguity resolution model in more details.

Response:

The GPS phase ambiguity resolution model by using Sequential Least Square Adjustment was described in full details in the attached paper

Comment (46):

line 261: “for the aforementioned stations”: you mentioned 7 stations, but according to table 2 and figure (4) data for only 5 of them was used. If so, I would recommend to remove unused stations from both figure (3) and description in lines 217-221.

Response:

Considered

Comment (47):

line 264: Values from which GIM map and what node of it do you use here? Table (3) allow me to consider that the node is located at (32.5_N, 30_E). Even in case of values from (30_N, 30_E) most stations are quite far from the node. Don’t you think the approximated values should be used here?

Response:

Considered Because of the used stations were located between longitude 29 & 32 and latitude 30 & 32. We of course we agree to use approximate values of the

GIM, but should be considered by the used software that was developed by Trimble, we show only the given values of GIMs. But for the developed software we adopted the values to be approximated to the used node to be involved by the Trimble software. We are really in developing a MATLAB code to allow the resulted values.

Comment (48):

lines 263-264: Differences between ZDPID TEC from stations are more dramatical than between ones and GIM values. Station ALEX being located between SAID and MNSR gives huge TEC. Could it be connected with another receiver in ALEX? The figure (4) should be discussed in much more details.

Response:

In this figure, the Alex station has a different receiver that may be the receiver code bias is not correctly fit and/or may be the ambiguity initialization for this station is not fixed correctly. So If you feel that removing it will harmonise the results we can do it. However, all the given baseline results used the nearest station, namely BORG, just 50 km from it.

Comment (49):

lines 273-274: “derived” used twice; “useless for use” is a bad formulation

Response:

Considered

Comment (50):

line 347: It is better to replace second “Figures 7,8,9 and 10” by “The figures”

Response:

Considered

Comment (51):

lines 352-356: This sentence ought to split and reformulate.

Response:

Considered

Comment (52):

Figure (2). What is marked by A? It should not be azimuth, but you do not discuss this in text. Either define it, or remove from the figure. Height H can not be defined as you shown, it should radial. Aspect ratio is distorted. Please remake the figure.

Response:

This is the azimuth angle of satellites

Comment (53):

Figure (3). Increase the figure resolution. It would be useful to mark here GIM node position which was used to obtain TEC data. Most eastern point in figure is named Port Saeed, whereas in text its name is Port Said. Chose one name and use it.

Response:

Considered and the figure was reproduced

Comment (54):

Figure (5). The text should be removed from the figure to text. The only useful part of the figure is upper right, so remove all the others.

Response:

Considered

Comment (55):

Figure (6). All the flow char is made roughly, blocks are placed uneven. Text in block "Compute..." is partially hidden. Block with electrons per meter to TECU calculation looks quite useless. Right column blocks contains a lot of empty space.

Response:

Considered

Comment (56):

Table (3). The table consists of there identical blocks with the single number changed. Taking into account that all the values are presented in figure (4) this table could be removed at all.

Response:

Firstly, you should consider that the values that are presented in figure (4) is represented by TECU and the values considered in the tables are 0.1 TECU as defined in the header of the IONEX file as seen in the screen shot

```
   450.0 450.0   0.0                                                HGT1 / HGT2 / DHGT
    87.5 -87.5  -2.5                                                LAT1 / LAT2 / DLAT
  -180.0 180.0   5.0                                                LON1 / LON2 / DLON
    -1                                                              EXPONENT
TEC values in 0.1 tec units;  9999, if no value available         COMMENT
DCB values in nanoseconds, reference is Sum_of_SatDCBs = 0        COMMENT
DIFFERENTIAL CODE BIASES                                          START OF AUX DATA
```

So, the comparison of the given values in the table with the figure should consider the given table for the same day

time	helwan	borg	Said	Mnsr	IGS
0	44.91502	13.81087	13.5404	14.12133	21.5
2	20.01178	9.943241	10.29503	9.107713	20
4	21.62205	15.61603	14.79785	14.75304	21.7
6	15.73853	28.29082	28.32333	28.33345	28.6
8	34.32263	42.69916	41.68518	33.86268	43.1
10	47.74553	47.91415	45.74642	52.46667	55.2

12	55.79223	43.47851	42.12001	54.82788	51.4
14	56.25644	39.41153	39.13251	30.02803	48.2
16	**44.91502**	**29.68096**	**29.78569**	**14.12133**	**44.4**
18	20.01178	14.42673	18.39721	9.107713	25.3
20	21.62205	21.30672	21.16946	14.75304	18
22	15.73853	20.29952	20.35806	28.33345	17.9

Comment (57):

Quality of figs. 7-10 is unacceptable. Obviously, the figures are resized with aspect ration distortion. Labels and legends are difficult to read. The data presented in the figures are not discussed and the only useful part here is in the tables. I recommend remove plots and use numbers from tables to make good visual picture of the dynamics of max, min, max and RMS values before and after ModIONEX usage. It should be noted, that some data is already published in IJSER.

Response:

Considered and really we appreciate

Comment (58):

All the formulas should be the same style and in a good resolution. Now forms (1-4), (5) and others (lines 168 – 169 and 180-194) have absolutely different format. The numeration should be added everywhere (as for 1-4) or removed from all the formulas (as in lines 180-194).

Response:

Considered

Comment (59):

Used before or with no introduction: IGS(8), GNSS(11), IONEX (15), TEC(38), CODE(7), JPL(39), TECU(42), ESA (46), UPC (46), NRCan(46), STEC (53), IPP (165), ECEF (176), CSRS (338)

Response:

Considered

Comment (60):

Reintroduced: GIM(7, 14, 29, 41, 387), SHE(9, 32, 47, 66), TECU (65, 148), IPP (183, 184), TTC(201, 229), ZDPID (257, 390)

Response:

Considered

Comment (61):

Introduced, but not used: MSLM(38), AC(45), SLM(69, 167), TECP and TEC'(151)

Response:

Considered