The International GNSS Service (IGS, Dow et al., 2009) aims to provide accurate and autonomous GPS & GLONASS orbit products. Each Analysis Center (AC) contributes with their own orbit products, which are then combined in the Center for Orbit Analysis Coordinator (CACC) into the IGS combined solution. Precise orbit determination (POD) is undertaken using various strategies within each AC. The Center for GNSS Operations in Europe (CODE) and the European Space Operations Center (ESOC), which both provide fully autonomous GPS & GLONASS orbit products, are following the strategies described in their respective AC report 3.5: Combined processing strategy summary (AC/3.5). Some of the significant features extracted from the respective AC/N are shown in Table 1.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>The IGS should take into account the station network selection, which affects the orbit accuracy, in a potential multi-GNSS combination orbit scheme.</td>
</tr>
<tr>
<td>5</td>
<td>A common reference scenario was implemented in both software, in order to understand the impact of the different processing scheme settings on the orbit solution. It was detected that both softwares showed a similar sensitivity to the station network selection.</td>
</tr>
<tr>
<td>6</td>
<td>When looking into the orbit solutions, we can see that for the CODE solutions comparisons, for both, GPS and GLONASS, the RMS from SNW 1 vs SNW 2 shows a lower consistency with respect to SNW 2 and SNW 3 solutions (Fig. 5). In CODE, the solutions computed with SNW 3 show a better consistency with respect to CODE solutions.</td>
</tr>
<tr>
<td>7</td>
<td>It can be observed in Fig. 5 that for the CODE solutions comparisons, for both, GPS and GLONASS, the RMS from SNW 1 vs SNW 2 shows a lower consistency with respect to CODE solutions. In CODE, the solutions computed with SNW 3 show a better consistency with respect to CODE solutions.</td>
</tr>
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Influence of station distribution on GNSS satellite orbits

3. Station network configurations

In order to understand the magnitude and behavior of the station network impact in the orbit solutions, three different station network (SNW) distributions were selected. The station networks were to be referred to as: SNW1, SNW2 and SNW3. All of the configurations are a subset of the IGS available network. The description and details from each SNW are as follows:

- SNW1 is deployed in Fig. 1. It is based on the SNW1 from the IGS final processing scheme used in CODE AC. 
- SNW2 is deployed in Fig. 2. It is a subset of SNW1, with the additional of three stations to enhance global coverage, especially in the Oceanic Pacific area, where SNW1 has a better GPS coverage. 
- SNW3 was designed based on the available IGS network, selecting an equally distributed set of stations. The orien- tation for selection was such that, the high variation of ground track coverage observed in Fig. 4 and Fig. 5, for instance in the Northern and Southern parts, was lowered as much as possible. As a result, it can be observed in Fig. 6, that the SNW3 has a considerably lower ground track coverage variation than that in SNW1 and SNW2.

In Table 2, the number of stations for each SNW are listed.

<table>
<thead>
<tr>
<th>Station Network</th>
<th>Number of Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNW1</td>
<td>212</td>
</tr>
<tr>
<td>SNW2</td>
<td>163</td>
</tr>
<tr>
<td>SNW3</td>
<td>123</td>
</tr>
</tbody>
</table>

Figures 1-5 show the station networks configurations and the network ground track coverages. The network ground track coverages are shown in Fig. 4, 5, and 6. A SNW summary from the three different configurations is shown in Table 2.

4. Results

The data processed covers the time period of one month (DOY071 to 2015 to DOY071 2015). The precise orbit solutions computed will follow the geodetic nomenclature: the orbit estimates SNW will be referred to as: SNW1(SNW1), SNW2(SNW2), SNW3(SNW3); on the other hand, the solutions computed using the default processing scheme: SWN1(CODE), SWN2(CODE), SWN3(CODE). The comparisons were done by 1-day arc solutions in the radial (R), along-track (T), and cross-track (N) directions in a 90 min time interval spacing. Given two orbit solutions, seven different transformation parameter: 3 translations, 3 rotations and scale- were calculated, to compensate for differences in the realization of the datum definition due to the station selection.

In the case of GLONASS, when looking into the comparisons between SNW1(CODE) vs SNW2(CODE) (Fig. 7), the most typical max/min residual values range in the interval [-10,10] m. Nevertheless, a significant amount of ~15% of the max/min values are in the range [-10,10] and [10,15]. For the comparison SWN2(CODE) vs SWN3(CODE) in Fig. 8, in the previous comparison, an amount of around 15% of the max/min residuals are in the intervals [-15,10] and [10,15].

In the case of GPS, the first comparison (see Fig. 7) shows that the most typical values gather around ±3 cm, whereas ~20% of the max/min are within [-10,10] and [-5,5]. Figure 8, which shows the max/min residual values histogram for SWN1(CODE) vs SWN2(CODE) has an amount of around 10% of residual values within [-10,5] and [5,10]. In the overall, the radial component suffers less variation from one station configuration to the other when estimating the orbits with ESOC IGS final processing scheme. GPS orbits, on the other hand, show a big percentage of max/min around a higher residual value in the case of SWN1(CODE) vs SWN2(CODE) than that in SWN1(CODE) vs SWN3(CODE). It can be con- cluded that GLONASS is affected about 2 to 3 times more than GPS. SNW 1 and SNW 2 GLONASS solutions comparison have a very similar consistency wrt. regions with less stations with a negative impact on the orbit. On the other hand, the ESOC solutions comparisons, for both, GPS and GLONASS, have a similar consistency for both software solutions. In the overall, the station network impact can be observed in both processing scheme solutions. Nevertheless, the visibility in the orbit components is different depending on the orbit and the processing model used.

It can be observed in Fig. 9 that for the CODE solutions comparisons, for both, GPS and GLONASS, the RMS from SNW 1 vs SNW 2 shows a lower value than SNW 1 and SNW 3 when using CODE processing scheme. Nevertheless, the solutions computed with SNW 2 and SNW 3 show a similar consistency to that computed with CODE and SNW 3. When performing POD with CODE processing scheme, the solutions from SNW 2 and SNW 3 appear to have worse consistency than the ones computed with SNW 1 and SNW 3 as well as SNW 3 and 1. It can be concluded that the station network selection has a different impact depending on the constellation and the processing scheme. Furthermore, even though there is a bigger reduction in the number of stations tracking GPS from SNW1 (221) to SNW3 (66) than for GLONASS (from 163 to 66), the RMS is not affected accordingly, meaning that the IGS from SNW1 (CODE) vs SNW3(CODE) and CODE vs CODE) for GPS is not bigger than that for GLONASS. Therefore, there is still a better agreement between SNW1 and SNW3 for GPS than for GLONASS.

When looking into the ground track residual plots, it can be observed that the SNW impact is a geometry dependent effect. Figures 10 and 11 show R0R ground track residual (R component) plots for SNW1 vs SNW2. The highest residual (according to the color scale bar) are, in both cases, reached in the indicated region. Figures 4 and 5 reveal that both areas have a worst coverage with respect to other areas and the effect is so in most of the GLONASS satellites.

5. Conclusions

The station network selection has a bigger impact on the POD than the expected. The POD solutions computed with different software and processing schemes, but with the same SNW selection, show the same tendency behavior; which implies it is a systematic effect. The cross-check between the software solutions has been further investigated, this will give a better understanding of the data quality and impact on ambiguity resolution in the orbit solutions. On the other hand, the other aspects, such as the observation quality, need to be considered, as well when performing POD.

6. Outlook

The IGS should take into account the station network selection, which affects the orbit accuracy, in a potential multi-GNSS combination orbit scheme. A weighting scheme would be suggested to address the issue.

References


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