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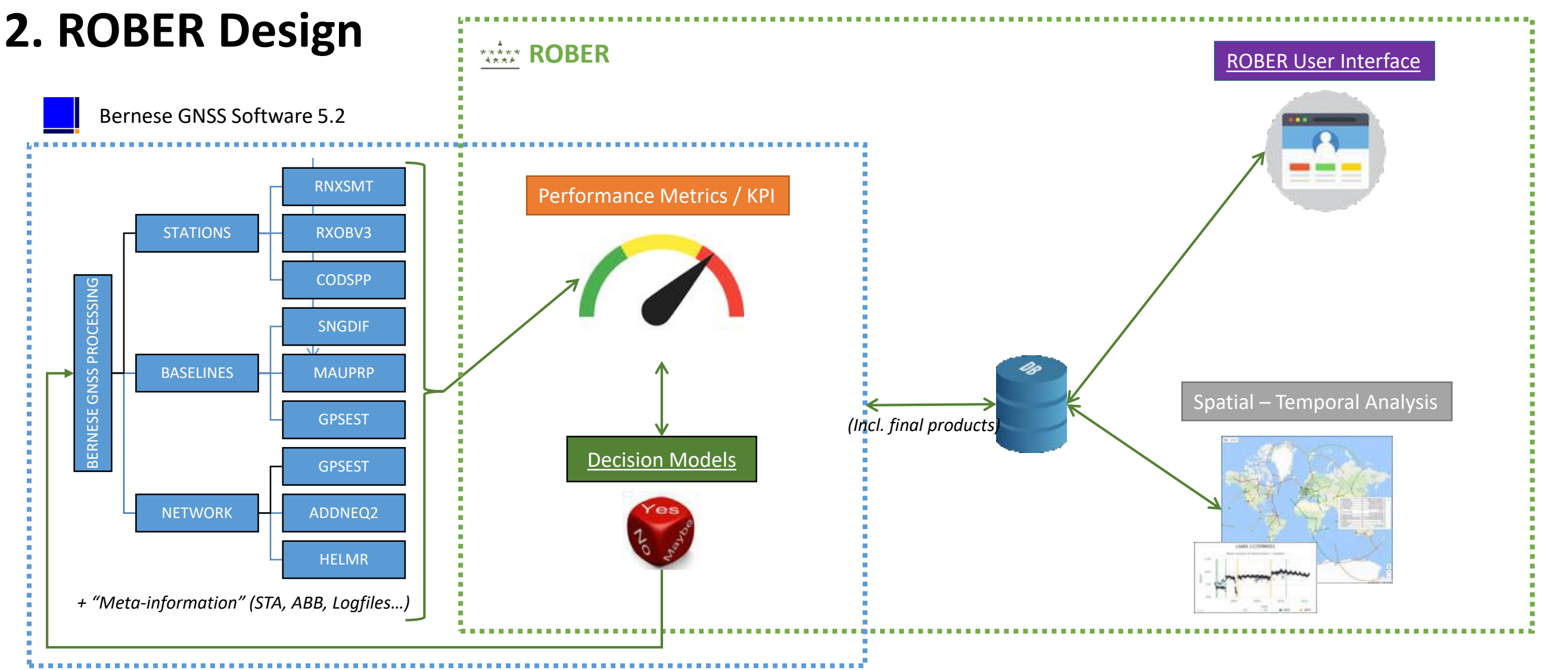
1. Introduction

ROBER is a dynamical tool designed to enhance the reliability and the precision of final products (coordinates, tropospheric parameters...) obtained from a GNSS network solution estimated by the Bernese GNSS software v5.2 for projects like EUREF or E-GVAP. It consists of

- Programs that extract, at each sequential step of the data analysis, performance metrics, analyze their temporal and spatial behaviors, and identify Key Performance Indicators (KPIs).
- Storing this information together with relevant meta-data in MySQL databases.
- Using the defined KPIs and database information to track down the source of performance degradation/problem.
- Decision models to automatically correct for it, as early as possible in the processing, or at least provide the operator with warning messages to request manual inspection.
- A web interface to present and analyze each performance monitoring step (graphs, maps, reports...), allow manual investigation of the origin of performance degradations/problems/inconsistencies, and provide web tools to fix them.

Results presented hereafter have been obtained from the analysis of the Bernese software output for a reprocessing campaign for regional climate model validation (CORDEX.be), and covers the period 1995-2016.

2. ROBER Design



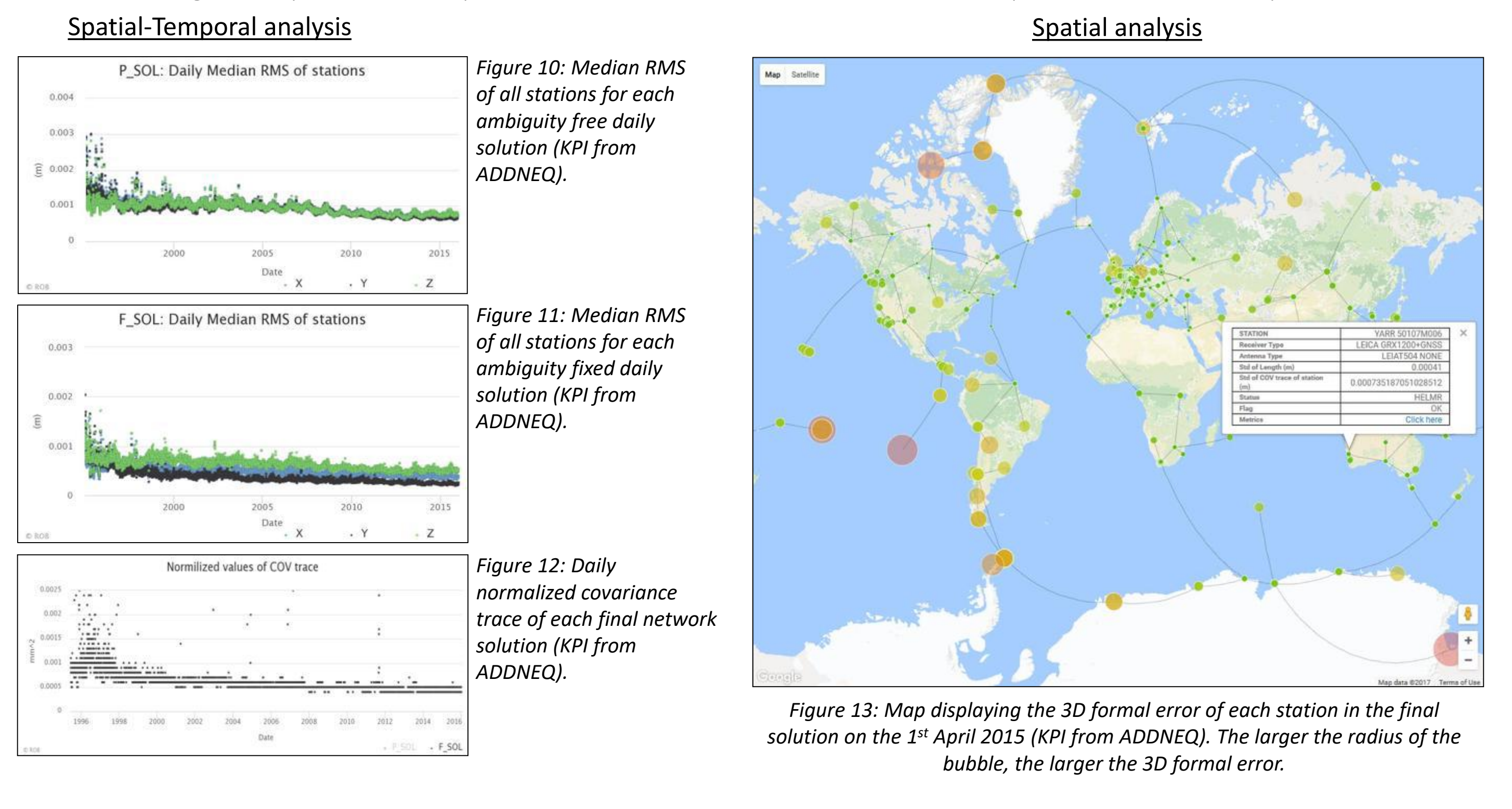
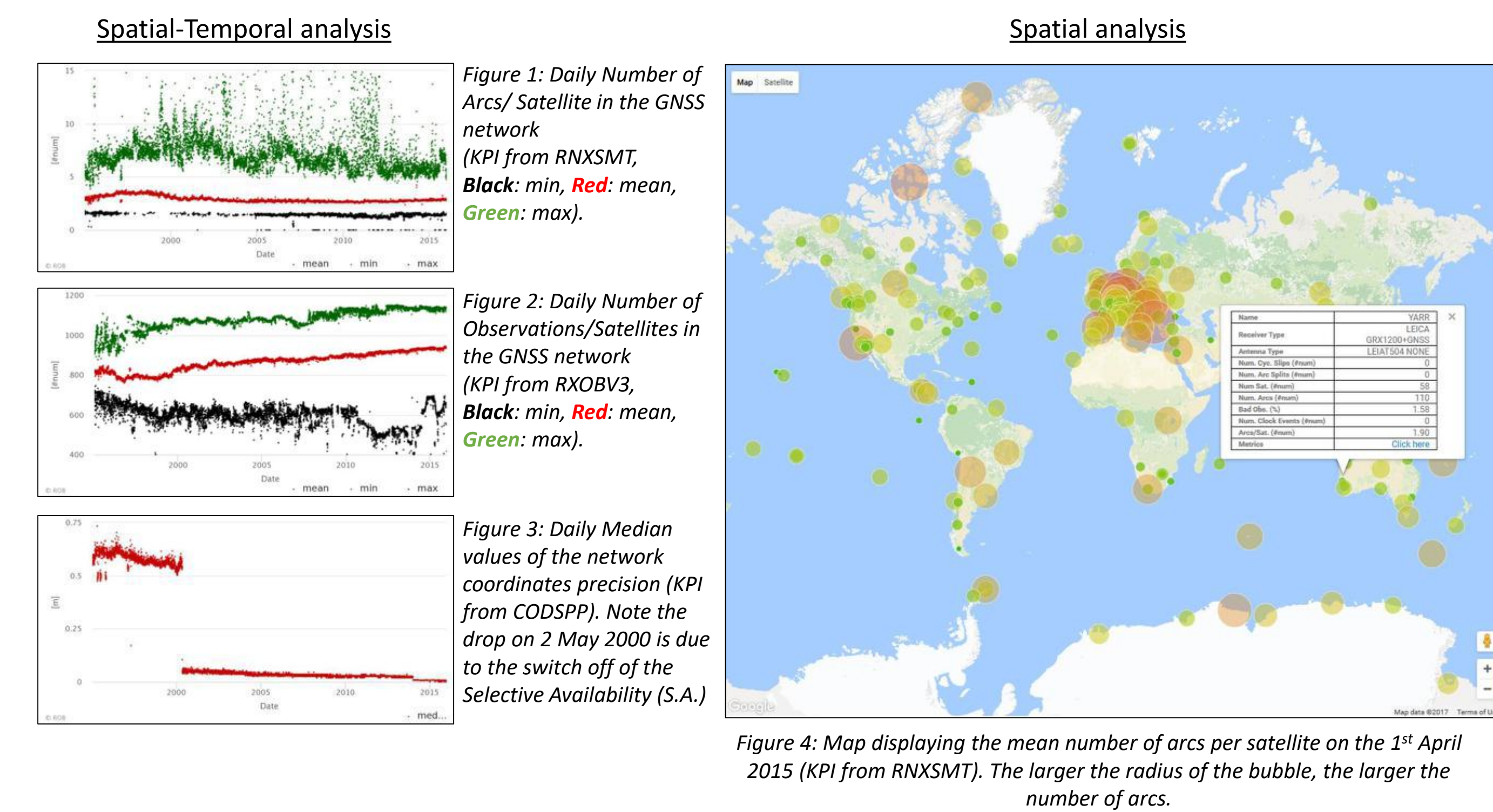
3. Metrics Extraction, Spatial-Temporal Analysis, and Web-based Monitoring of Network Solutions

3.1. Station-based Metrics and Analysis

- To check the pre-processing at the observation level (RINEX), ROBER extract metrics⁽¹⁾ for each station and for each processed session (see 2. ROBER Design). Then, ROBER carries out a spatial⁽²⁾ and a temporal⁽³⁾ analysis of these metrics (number of observations, satellites, arcs, standard deviation of coordinates) and identifies the relevant KPI.
- Figures 1-4 below show the spatial-temporal behavior of some network KPIs. The mean number of arcs/satellite varies from 2.3 until 3.8, and the mean number of observations/satellite varies from 750 until 950. The precision of the estimated coordinates at the CODSP step improved from 630 mm (1995, with S.A.⁴ on) to 6 mm (2014).

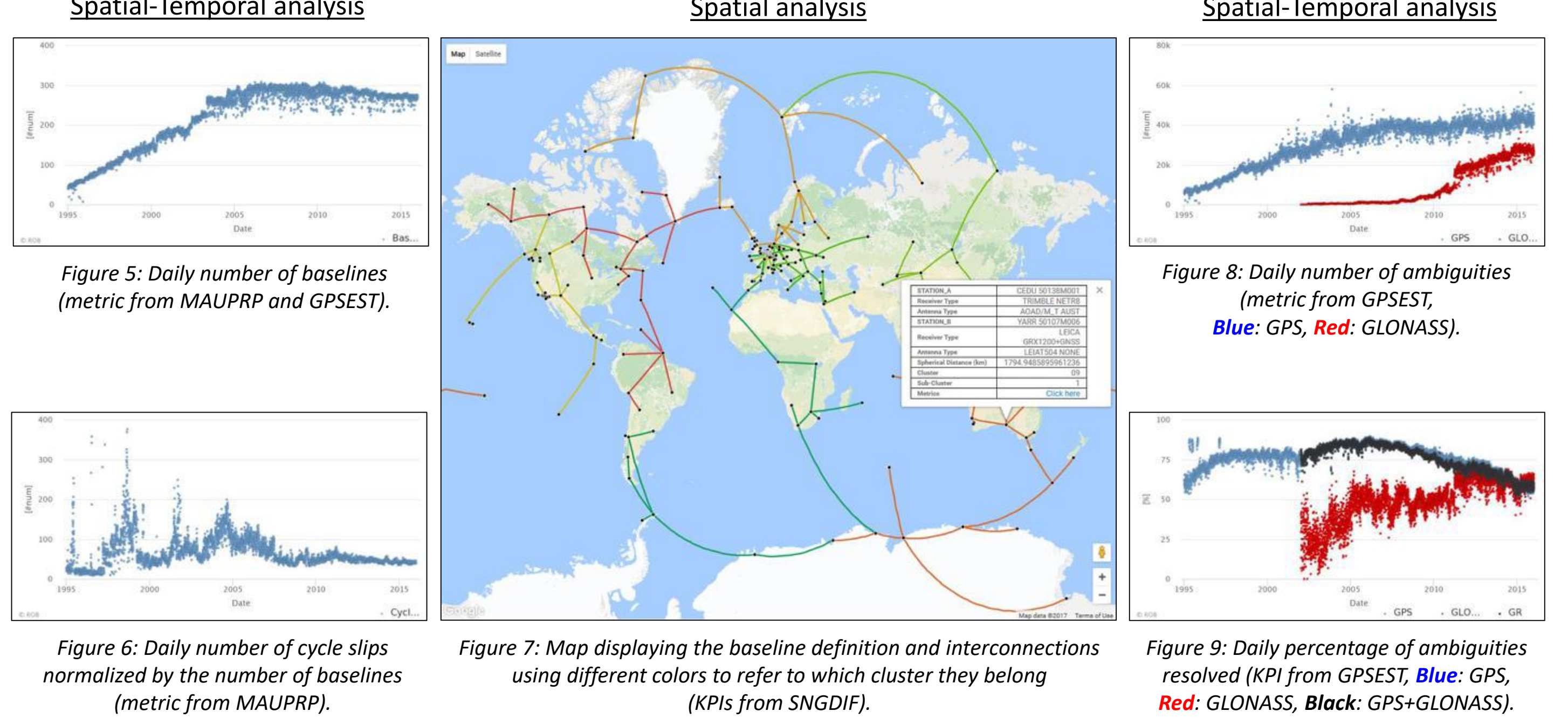
3.3. Network-based Metrics and Analysis

At the final processing steps, ROBER extracts global metrics of the performance of the network solution in addition to station and baseline-driven metrics. Again, the metrics of each processing session undergo a spatial and temporal analysis. Figures 10 and 11 show the time evolution of the median of the 3-D formal error of all estimated coordinates at the ambiguity-free and ambiguity-fixed step respectively. These figures show clear annual variations of the estimated coordinates precision which vary in time from 3 mm (1995) to 0.6 mm (2016) at the ambiguity free step and from 1.7 mm to 0.2 mm at the final step. Figure 12 depicts the daily covariance trace normalized by the number of stations. Figure 13 presents the spatial behavior of the estimated coordinates precision on the 1st April 2015.



3.2. Baseline-driven Metrics and Analysis

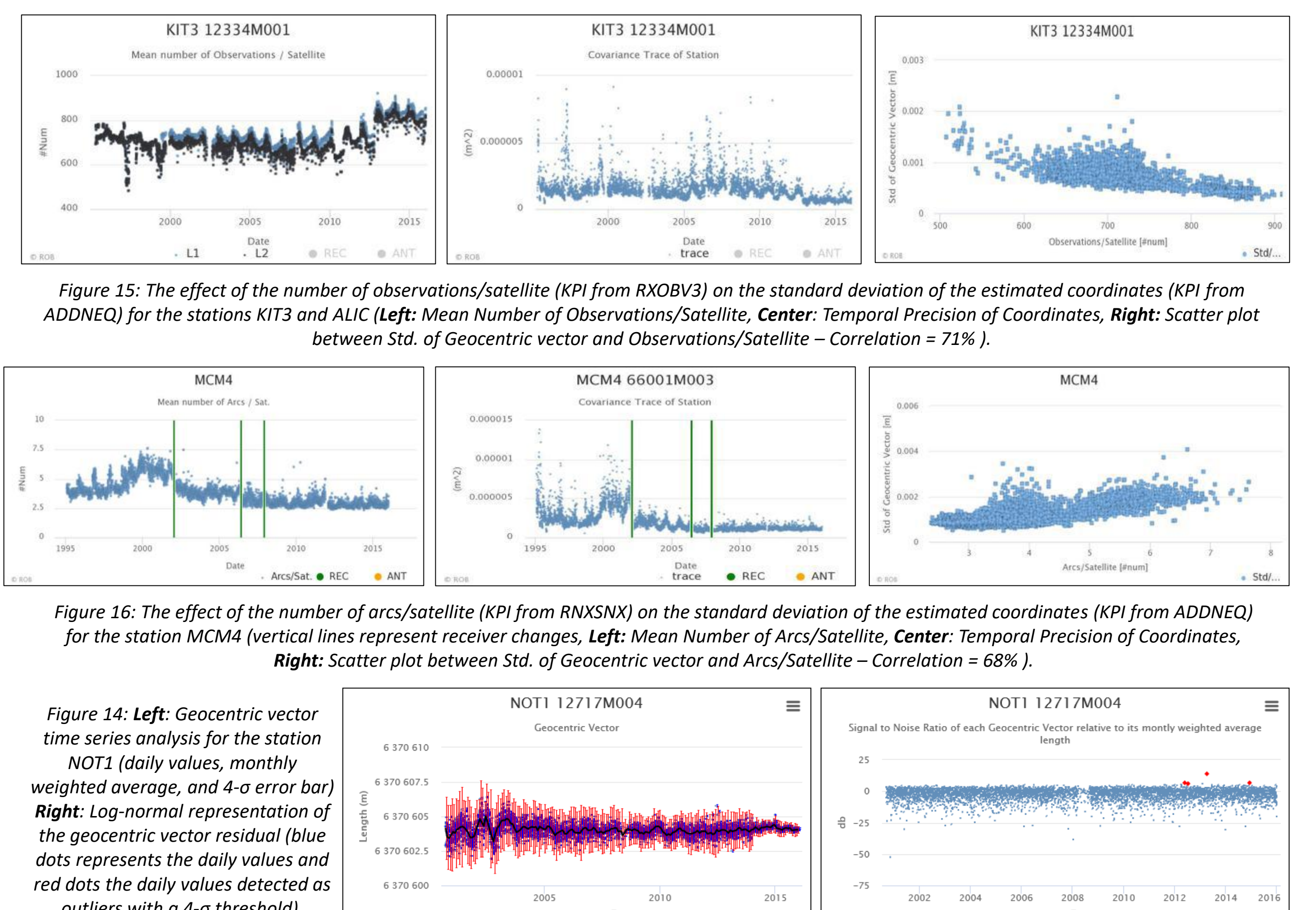
- ROBER analyzes the baseline creation and monitors the (pre-)processing at the baseline level (cycle-slips, outlier screening, ambiguity resolution...), then carries out a spatial and a temporal analysis of these baseline-driven metrics/KPIs. Examples are shown on the right:
 - Figure 6 shows the daily normalized number of cycle-slips. Even if for some sessions, the number of cycle-slips is dramatically high, the processing handles it good, keeping the RMS of the triple-differences at a \pm nominal level.
 - Figure 7 shows how baselines are interconnected (and clustered), allowing to track down the propagation of a performance degradation from one baseline to the connected baselines.
 - Figures 8-9 show the number of ambiguities and the percentage of ambiguities resolved (each per constellation), which varies from 88 % (in 2005) until 49 % (in 2015). Figure 9 also shows the clear decrease in the percentage of resolved ambiguities (starting end 2005).



4. Key Performance Indicators (KPIs) and Decision Models (DMs)

At this stage, we already identified four KPI categories that enable the application of decision models:

1. As can be expected, the number of observations has an impact on the final precision of the estimated products of the network solution. We found that there is a significant correlation between three KPIs (number of observations/satellite, number of arcs/satellite, and number of satellites/epoch) and the standard deviation of the estimated coordinates (Figures 15 and 16). The more these numbers decrease/increase the more the magnitude of the correlation increases. Thus, ROBER monitors closely these KPIs to decide if a station should be eliminated from the processing or not, from the very beginning to not contaminate results at other stations.
2. The next important KPI is the connectivity among the clusters/baselines (Figure 7). ROBER monitors the shape of the network, and identifies if there is a cluster or baseline that it is not connected to the remaining of the network. In that case, it causes problems in the creation of the proper covariance matrix of the double differences (block-matrix), hence no unified adjustment over all stations. This emphasizes that the correct inter-connection between all baselines has a great impact on the precision of the final products.
3. Regarding the baselines, we also found strong correlations between the number of the double-difference observations and the precision of the final products. Moreover, the RMS of the post-fit residuals of the triple-differences during the cycle slips correction step and of the double-differences after the ambiguity resolution reveal possible degradation in the baseline processing. This has a significant impact on the precision of the final network products.
4. The last criteria refers to the network solution before and after the ambiguity resolution. Three KPIs are checked in order to identify performance degradations of the network solution. The first is the daily median precision of all estimated coordinates relative to the median precision of the whole time-period (see Figures 10-12 in 3.3). In addition, the standard deviation of each station coordinate (Figure 13) is compared to the daily median precision (Figures 10 and 11), and the last KPI comes from the temporal analysis of the coordinate time series of each station (Figure 14).



Acknowledgments

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