

## Introduction

The Global Positioning System (GPS) plays an important role in the combination of space-geodetic techniques which is one of the main goals of the GGOS-D project (Rothacher et al., 2007). GPS provides access to different parameter groups relevant for a rigorous combination, namely geometric parameters (station positions, origin of the tracking network), atmospheric parameters (troposphere zenith delays and gradients) and Earth orientation parameters (polar motion, length of day and nutation rates). This contribution focuses on the GPS tracking network, the processing scheme and the accuracy and consistency of the GPS satellite orbits. Although the orbits are not of interest for the combination, it is worth to have a more detailed look at this parameter type as a precise orbit modeling is a prerequisite for high-quality global GPS solutions.

The Bernese GPS Software (Dach et al., 2007) was used to reprocess global GPS networks starting with the RINEX observation files. Two different solutions based on more than a decade of GPS observations have been computed for the GGOS-D project according to the standards of the first (Steigenberger et al., 2006b) and the second (Steigenberger and Tesmer, 2007) iteration. The output of the GPS processing for the intra- and inter-technique combination are files in SINEX (Solution INdependent EXchange) format.

## Tracking Network

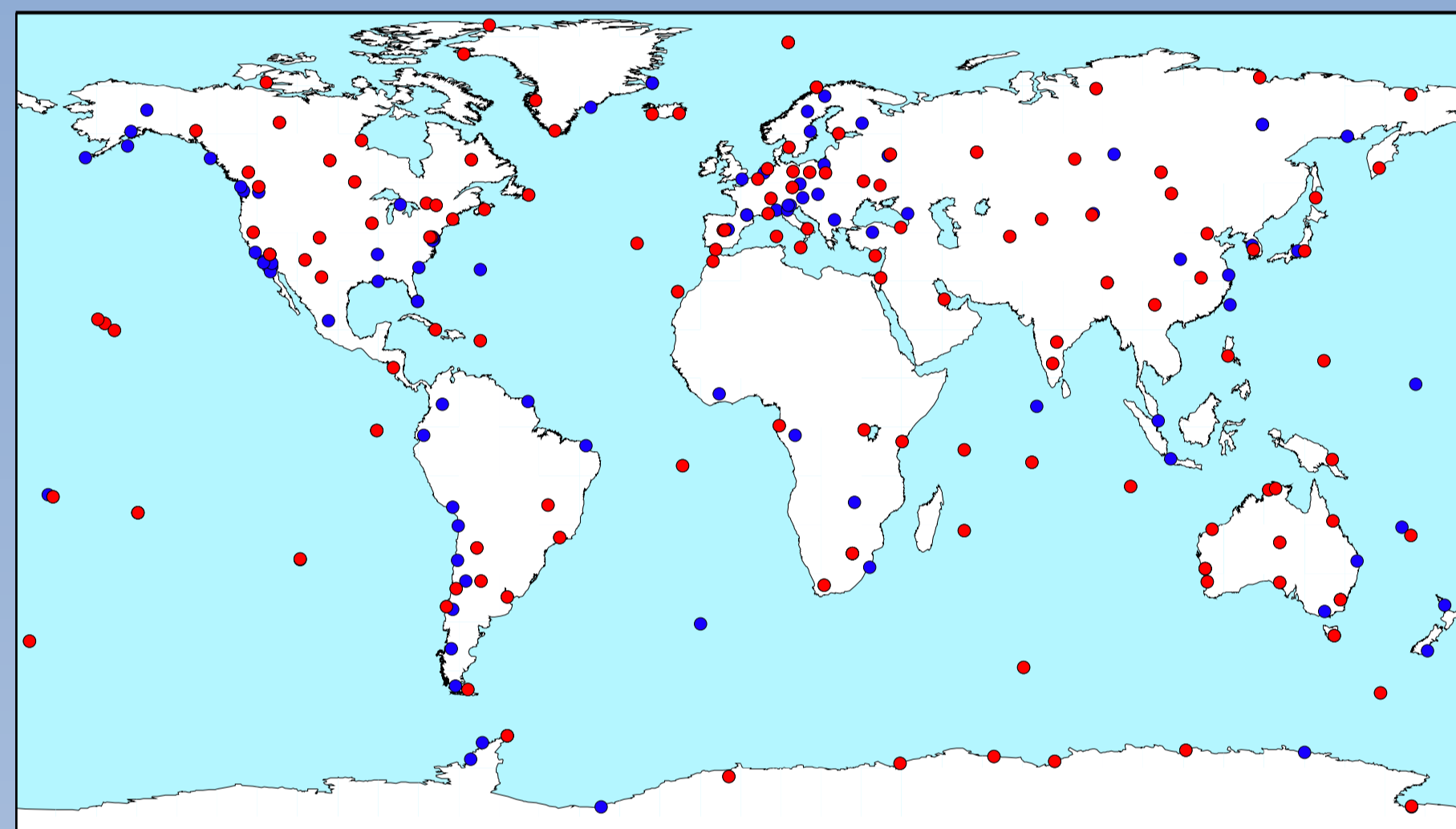


FIGURE 1: GPS tracking network for the second iteration of GGOS-D. Stations that have been used for datum definition are given in red.

The tracking network (Figure 1) mainly consists of IGS stations, but also several stations of the permanent networks EPN (EU-REF Permanent Network) and CORS (Continuously Operating Reference Stations) have been included. In addition, offline observing stations in Antarctica and Greenland contribute to the tracking network. The nominal number of stations is 202 and 241 for the 1st and the 2nd iteration, respectively. However, the number of stations per day is smaller (see Figure 2) due to changes in the station configuration (deactivation and outages of stations).

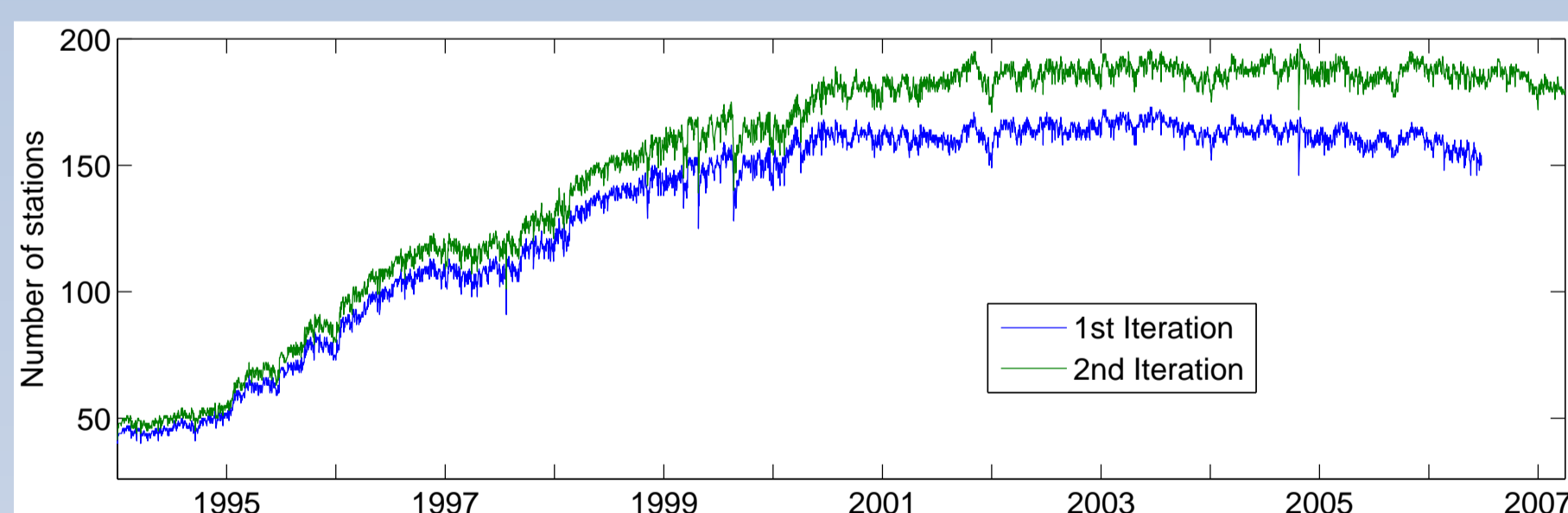


FIGURE 2: Number of GPS tracking stations per day contributing to the GGOS-D solutions of the first and the second iteration.

## GPS Processing

Table 1 gives an overview of the parameters estimated in the 1st iteration of the GPS solution for GGOS-D and their parameter spacing.

Parameter	Parameter spacing
Station positions	1 day
Origin of the tracking network	1 day
Troposphere zenith delays	2 hours
Troposphere gradients	1 day
Ionosphere parameters	2 hours
Earth rotation parameters	1 hour
Nutation parameters	1 day
Orbital elements	1 day
Radiation pressure parameters	1 day
Pseudo-stochastic pulses	12 hours
Differential Code Biases	1 day
Receiver clocks	5 minutes
Satellite clocks	5 minutes
Ambiguities	—

TABLE 1: Parameters estimated within the GPS contribution for GGOS-D. The parameters are grouped by geometric, atmospheric, Earth orientation, orbital and GPS-specific parameters.

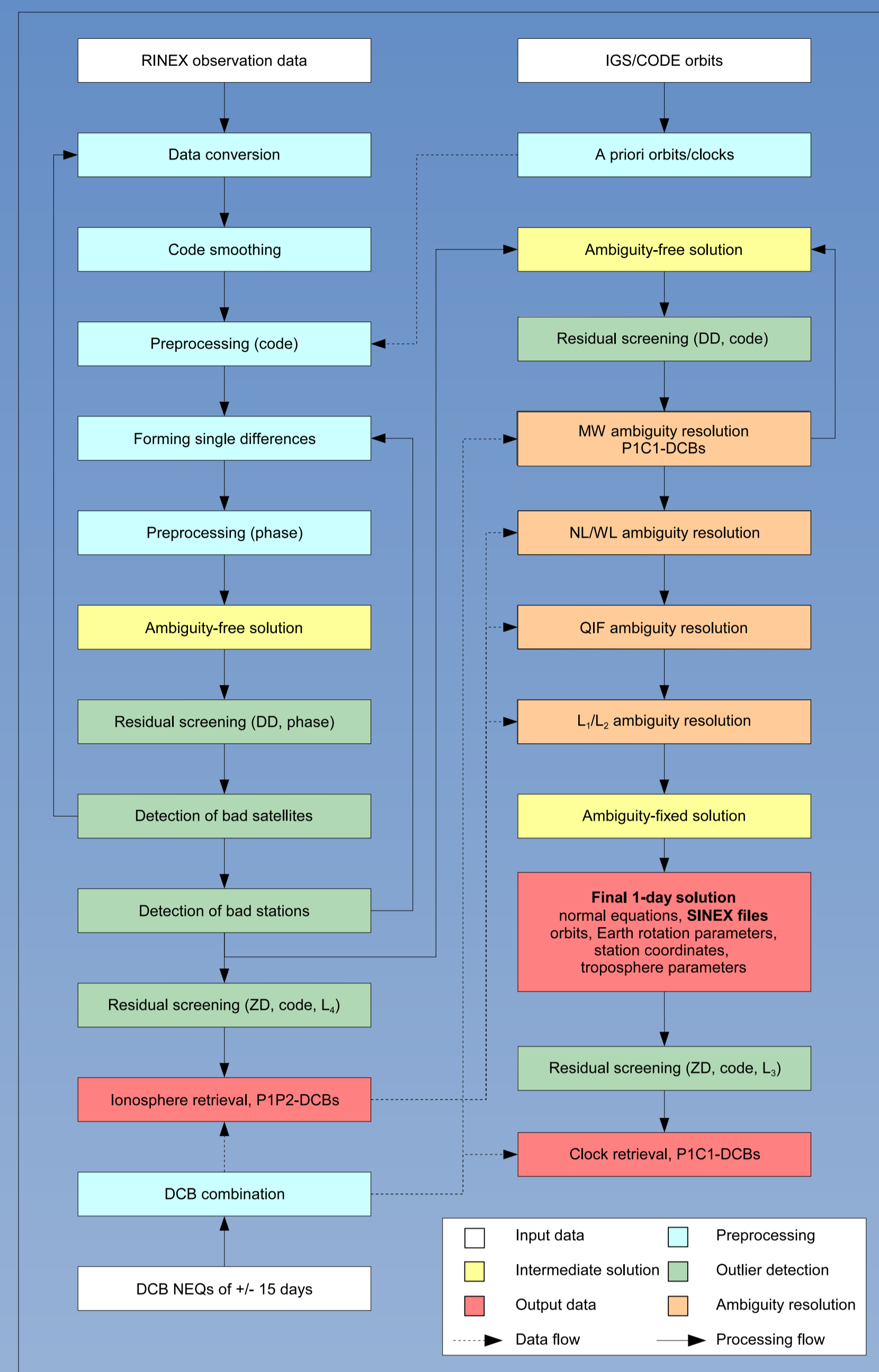


FIGURE 3: Processing flow of the GPS solutions for GGOS-D. Abbreviations: DCBs - Differential Code Biases; DD - Double Difference; MW - Melbourne-Wübbena; NEQ - Normal Equation (System); NL - Narrow Lane; QIF - Quasi-Ionosphere Free; WL - Wide Lane; ZD - Zero Difference.

Table 2 lists important GPS-related differences between the 1st and 2nd iteration (general differences are given in Steigenberger and Tesmer (2007)). The processing scheme was deduced from an earlier GPS reprocessing effort of TU Dresden and TU München (Steigenberger et al., 2006a) and is similar to that of the CODE IGS analysis center (Hugentobler et al., 2005). Figure 3 gives an overview of the processing scheme. Input data are RINEX observation files and C04 05 Earth rotation parameters, merged IGS/CODE orbits and Differential Code Biases (DCBs) from an earlier reprocessing run as a priori information. After the preprocessing, a first ambiguity-free solution is computed. This solution provides the basis for the residual screening and the detection of bad stations and satellites. Global Ionosphere Maps (GIMs) are estimated as input data for the application of 2nd and 3rd order ionospheric corrections (Fritsche et al., 2005) and as a priori values for the ambiguity resolution. Ambiguities are fixed to integer numbers for baselines up to 6000 km with different methods (depending on the baseline length). The final products of the 1-day solution are estimated in an ambiguity-fixed solution. For this final 1-day solution, a no-net-rotation condition w.r.t. IGS05 is applied. The major output for the inter- and intra-technique combination within the GGOS-D project are normal equations in the internal Bernese format and the solution independent exchange (SINEX) format. These daily normal equations include the following parameters:

- Station positions
- Troposphere zenith delays
- Troposphere gradients
- Earth rotation parameters
- Nutation parameters
- Origin of the tracking network

Satellite orbits and troposphere parameters of non-located sites are pre-eliminated as they are not of interest for the combination.

	1st Iteration	2nd Iteration
Number of stations	202	241
Start time	1 January 1994	
End time	24 April 2006	31 March 2007
Number of SINEX files	4496	4838
Reference frame	IGb00 <sup>a</sup>	IGS05
Phase center model	igs05_1365.atx	igs05_1421.atx
A priori RPR model	ROCK <sup>b</sup>	CODE <sup>c</sup>

TABLE 2: Important GPS-related differences between first and second iteration.

<sup>a</sup>Ray et al. (2004)

<sup>b</sup>Fliegel et al. (1992); Fliegel and Gallini (1996)

<sup>c</sup>Springer (2000)

## Satellite Orbits

### Formal Accuracy

An indicator for the formal accuracy of satellite orbits is given in the header of the SP3c orbit files. This so-called SP3c accuracy code  $n$  stands for a formal position accuracy of  $\pm 2^n$  millimeters. The SP3c accuracy codes of the reprocessed 1-day orbits of the second GGOS-D iteration are shown in Figure 4. In 1994 and 1995 the accuracy is worse due to the sparse tracking network, see Figure 2. This fact that is also visible in the internal consistency tests that will be discussed below. Later on, the formal accuracy is in general below one centimeter.

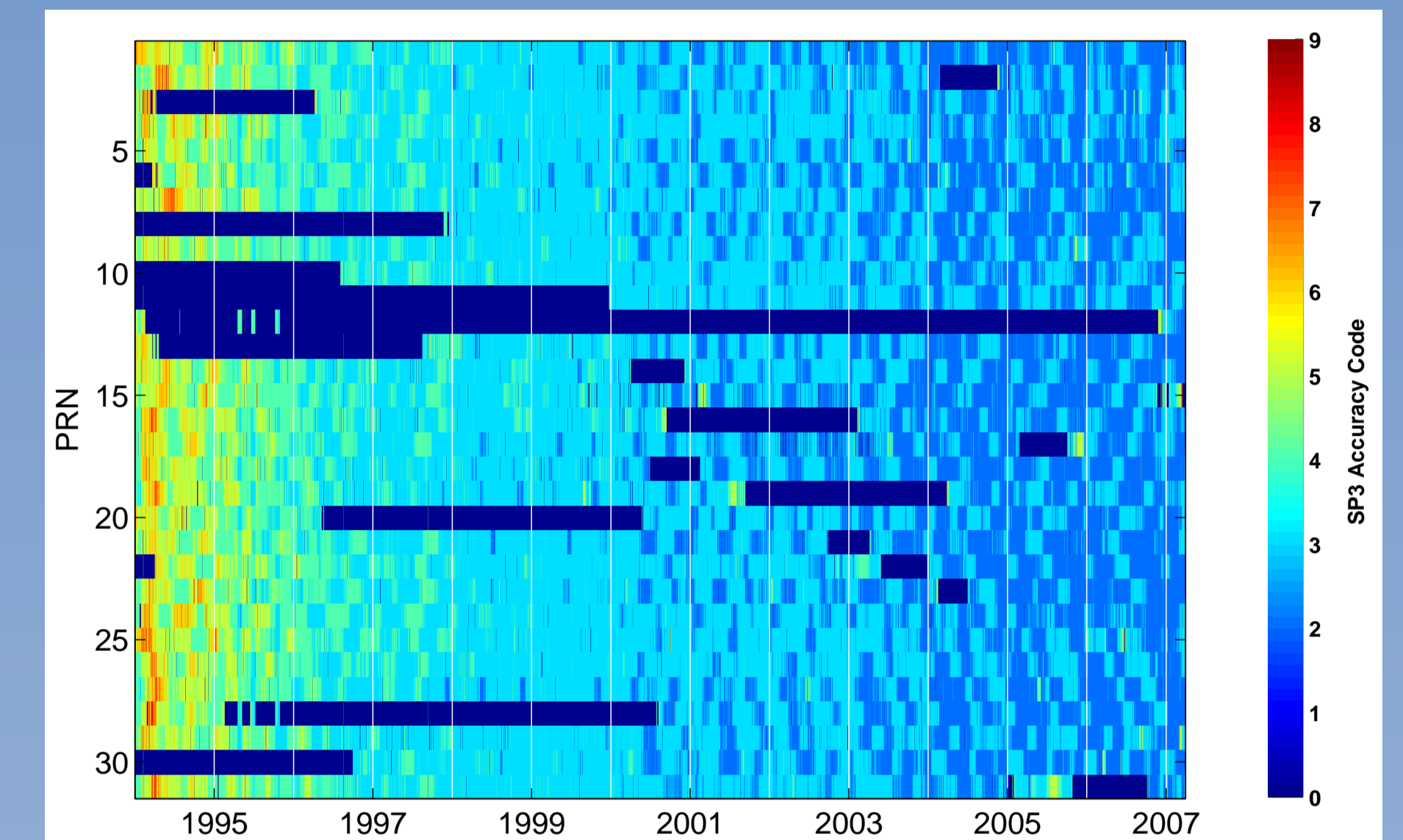


FIGURE 4: Formal accuracy of the GPS satellite orbits (SP3c accuracy codes). PRNs not occupied are given in dark blue.

### Internal Consistency

To quantify the internal consistency of the satellite orbits, 3-day orbit arcs were fitted through 3 consecutive 1-day orbits. The mean RMS of the 3-day arc w.r.t. the three 1-day arcs serves as quality indicator. As an example, Figure 5 shows the RMS time series for PRN27/SVN27. Like for the formal accuracy, a degraded orbit consistency is visible in the first two years due to small number of stations at the beginning.

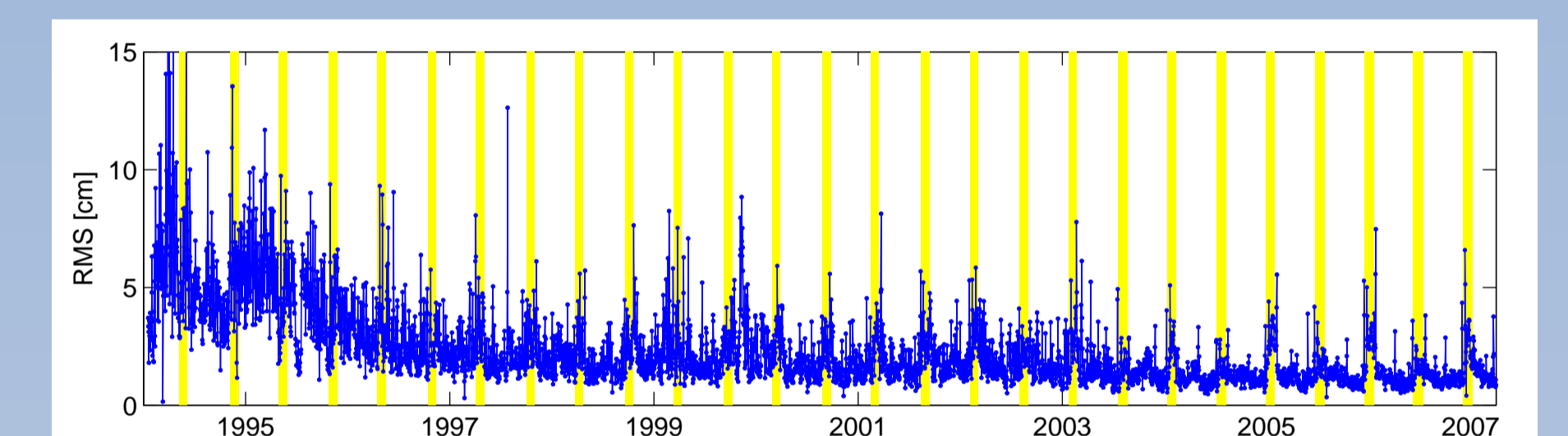


FIGURE 5: Internal orbit consistency of PRN27/SVN27. 3-day orbit arcs were fitted through 3 consecutive 1-day orbits. The mean RMS of the 3-day arc w.r.t. the three 1-day arcs serves as quality indicator. Eclipse periods introducing modeling problems resulting in higher RMS values are given in yellow.

Mean RMS values for the whole time period of the second iteration (January 1994 – March 2007) are shown in Figure 6 for each satellite. Outliers exceeding 0.5 m have been excluded for the averaging. The huge RMS value of PRN 23 is related to problems with the solar panels. In general, the order of the RMS values is on the level of 2–3 centimeters.

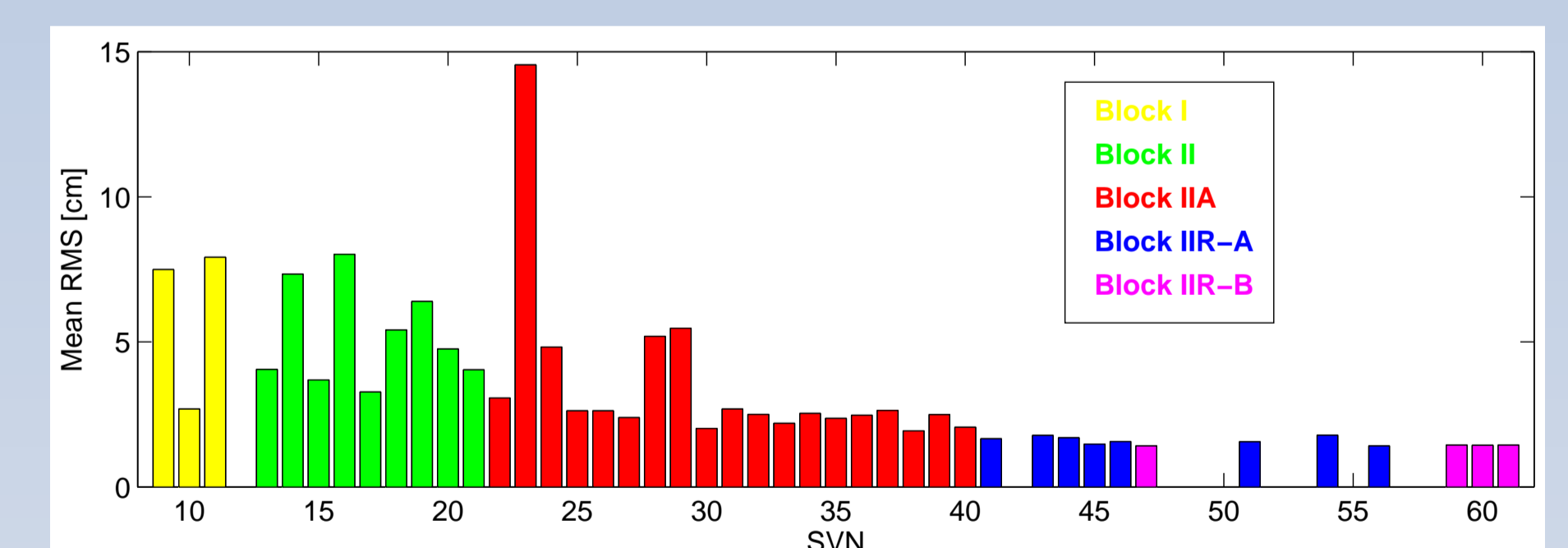


FIGURE 6: Mean internal consistency of all GPS satellites for the time period January 1994 – March 2007.

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