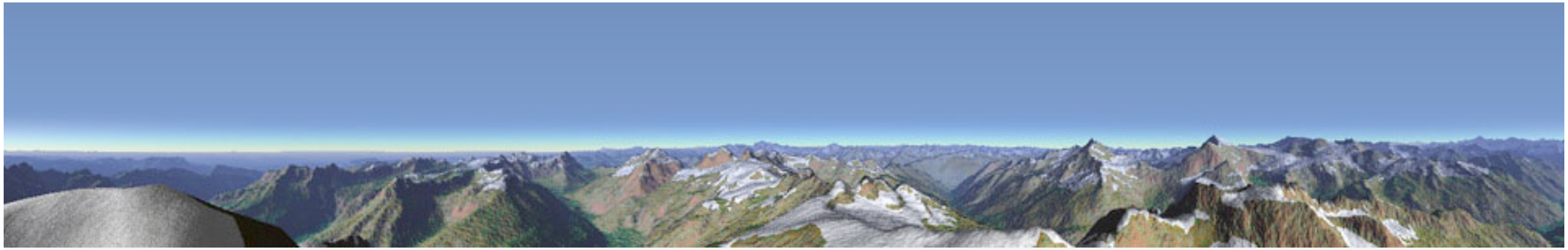

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Determination and Use of GPS Differential Code Bias Values

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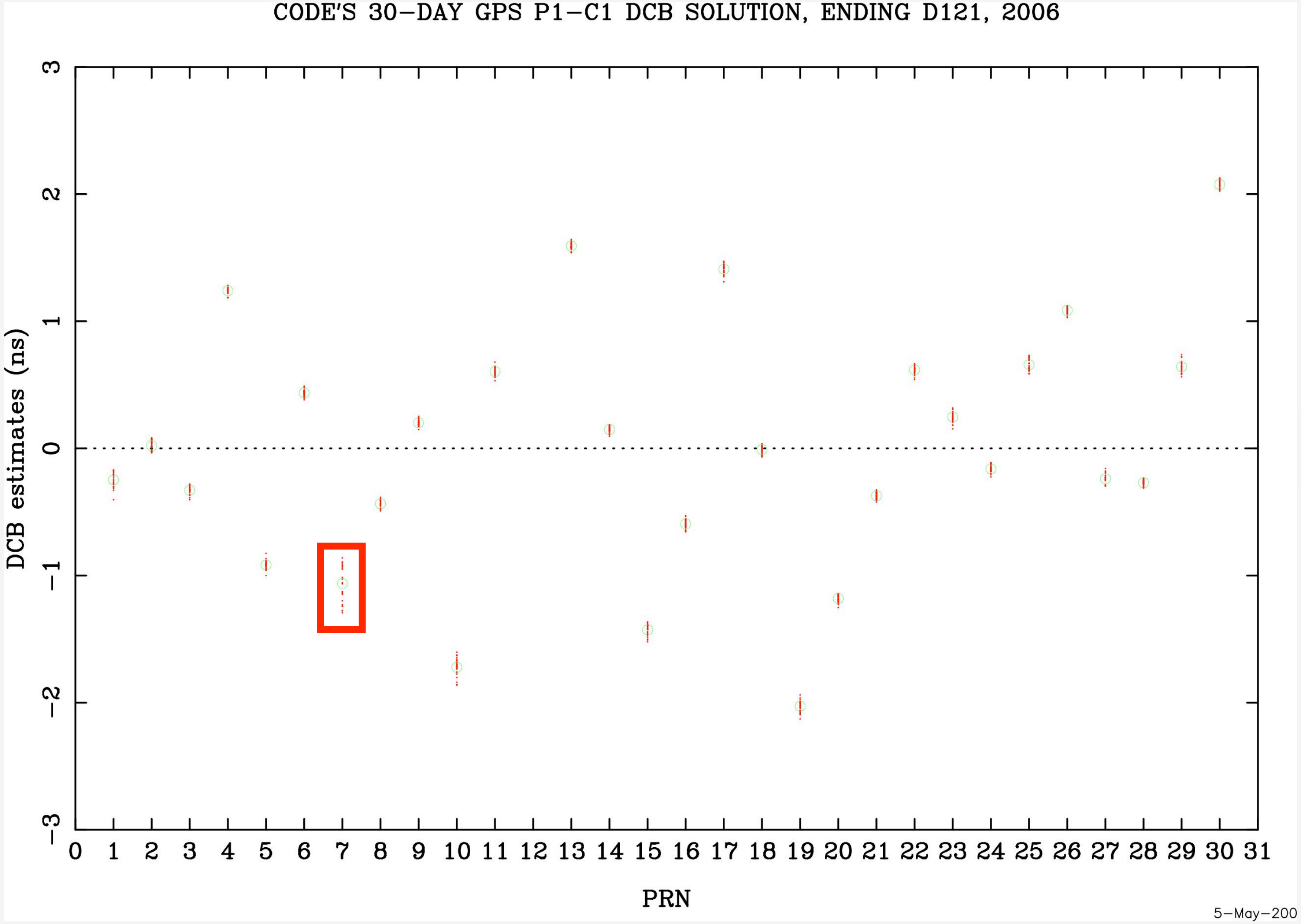
Introduction (1)

- The following code (pseudorange) observables are available from GPS: C/A (=C1), P1(Y1), P2(Y2).
- In the presence of *Anti-Spoofing (A/S),* P-codes P1, P2 are encrypted for non-authorized users to Y1, Y2.
- We have to distinguish between three receiver classes (in terms of the code tracking technology):
  - P1/P2: C1, P1, P2
  - C1/X2: C1, X2=C1+(P2-P1)
  - C1/P2: C1, P2
- C1/X2 receiver models are identified as cross-correlation (CC) receivers. Prominent examples are Rogue and Trimble 4000 models.
- The operation of CC receivers depends on the A/S state. It is assumed here that *A/S* is always *on* (!).
- The latest generations of Leica, Novatel, Trimble receivers belong to the C1/P2 receiver class (see IGS Mail 3737).

Introduction (2)

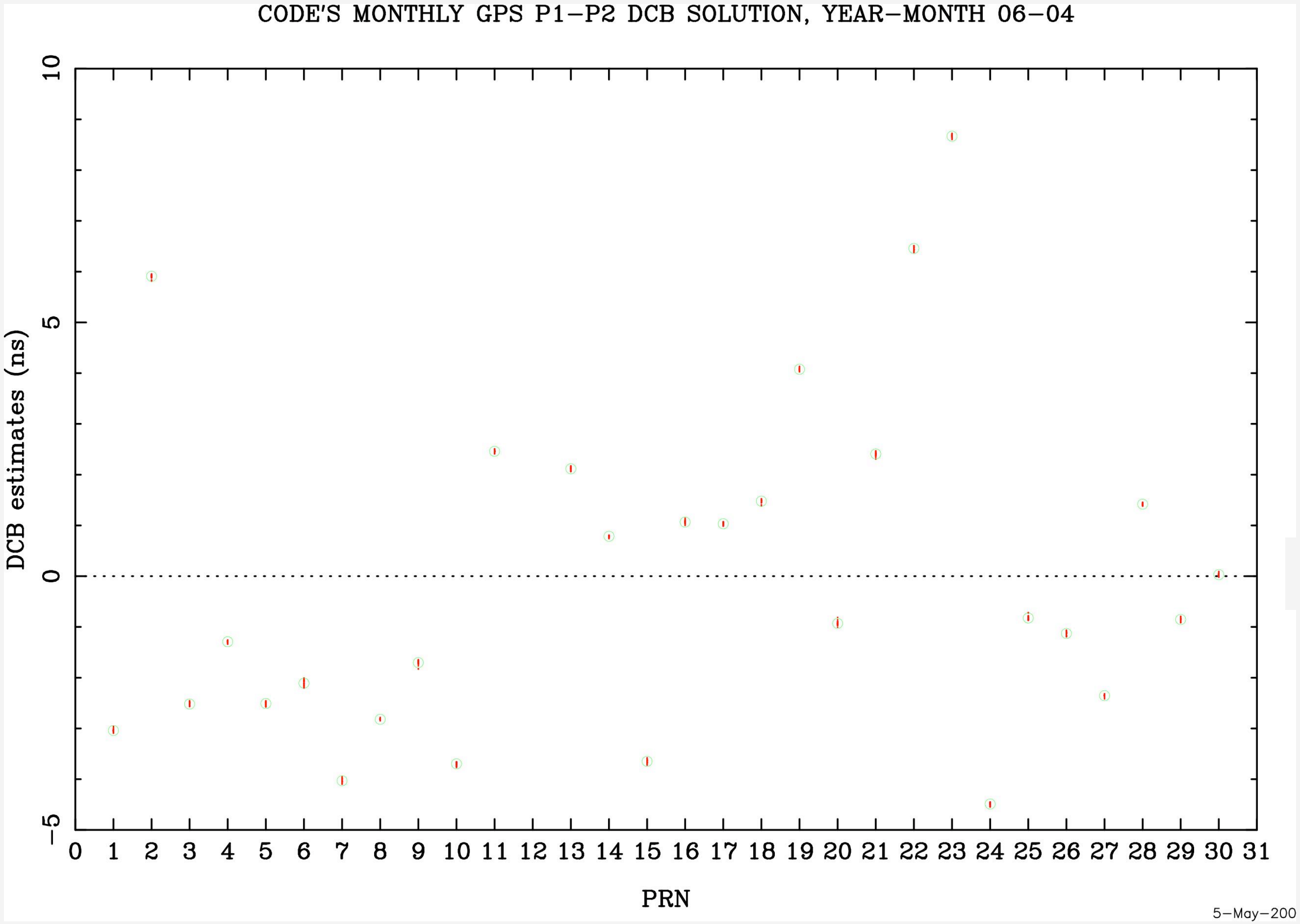
- Instrumental biases, B_{C1}, B_{P1}, B_{P2}, are present with respect to C1, P1, P2. These biases are not accessible (in the absolute sense).
- It is common to address the following differences of code biases:
  - P1-P2 and
  - P1-C1 differential code bias (=DCB).
- By convention, precise satellite clock corrections contain a specific linear combination of P1 and P2 satellite biases, specifically the ionosphere-free LC: $2.55 \cdot B_{P1} - 1.55 \cdot B_{P2} (+B_0)$.
- It is obvious that code tracking data from both the C1/X2 and the C1/P2 receiver class must be corrected in order to achieve full consistency with P1/P2 data, or precise satellite clock information.
- The RINEX conversion utility cc2noncc is an easy-to-use tool to make given code measurements consistent with P1/P2 data by applying satellite-dependent P1-C1 bias corrections (e.g. produced by CODE, see IGS Mail 3212). The cc2noncc program is available at: https://goby.nrl.navy.mil/IGStime/cc2noncc/cc2noncc.f

GPS P1-C1 DCB Values, Computed at CODE



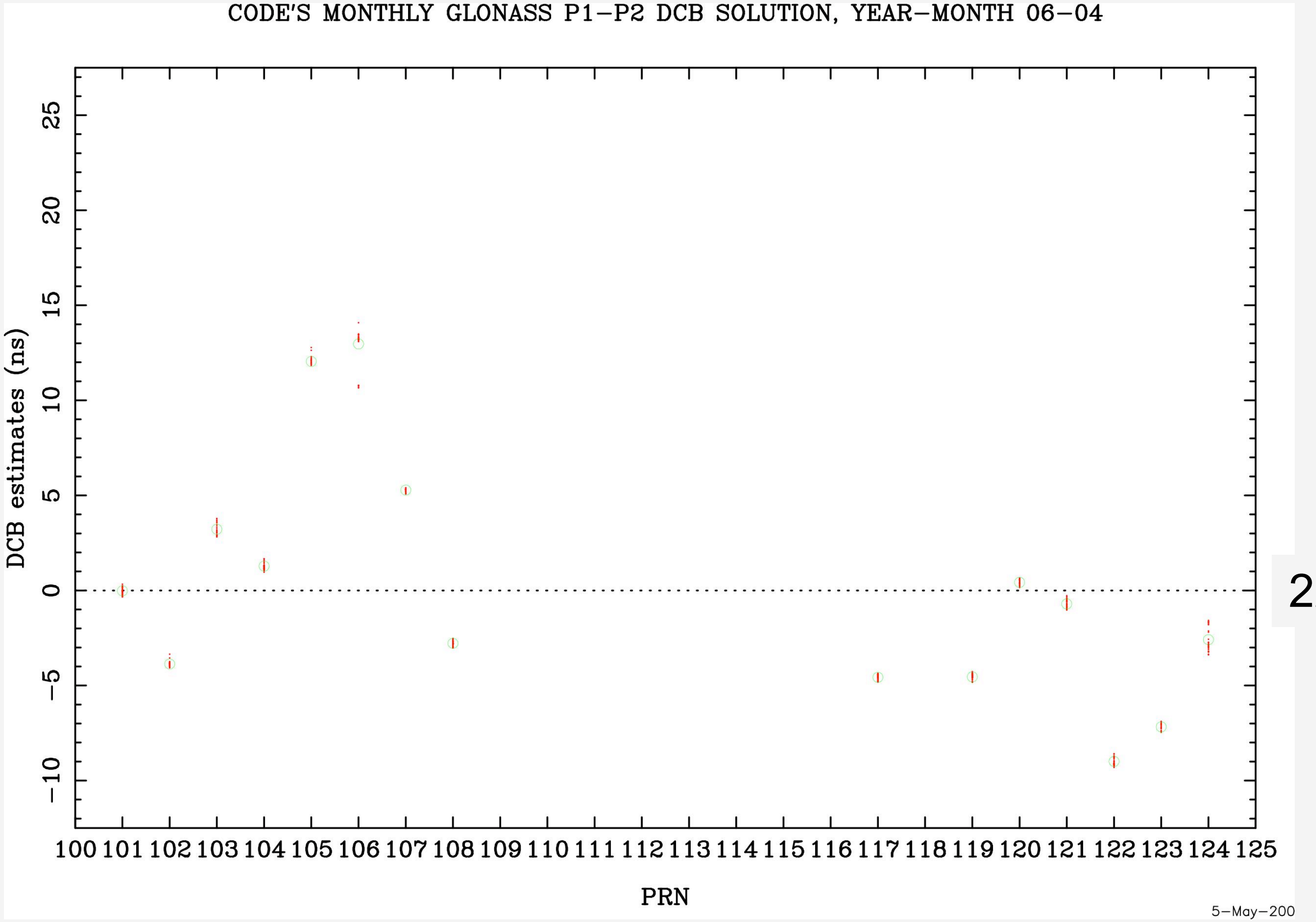
4 ns = 1.2 m

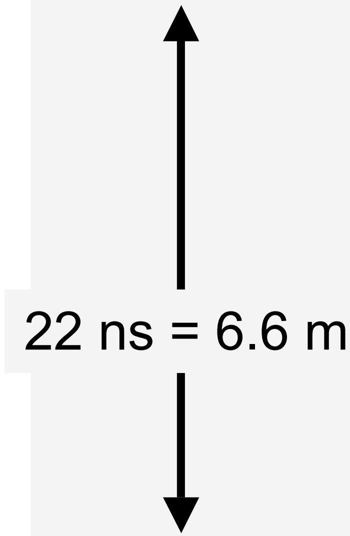
GPS P1-P2 DCB Values, Computed at CODE



13 ns = 3.9 m

GLONASS P1-P2 DCB Values, Computed at CODE





How to Use P1-P2 and P1-C1 Satellite DCB Information

The following table gives the corrections due to satellite-specific P1-P2 and P1-C1 DCB values for the most important linear combinations derived from various combinations of code observable types:

LC	P1/P2	C1/X2=C1+(P2−P1)		C1/P2		
L1	$+1.55 \cdot B_{P1-P2}$	$+1.55 \cdot B_{P1-P2}$	$+B_{P1-C1}$	$+1.55 \cdot B_{P1-P2}$	$+B_{P1-C1}$	← Single-freq.
L2	$+2.55 \cdot B_{P1-P2}$	$+2.55 \cdot B_{P1-P2}$	$+B_{P1-C1}$	$+2.55 \cdot B_{P1-P2}$		
L3 (L_C)	0		$+B_{P1-C1}$		$+2.55 \cdot B_{P1-C1}$	← Clock
L4 (L_I)	$-B_{P1-P2}$	$-B_{P1-P2}$		$-B_{P1-P2}$	$+B_{P1-C1}$	← Iono.
L5 (L_W)	$-1.98 \cdot B_{P1-P2}$	$-1.98 \cdot B_{P1-P2}$	$+B_{P1-C1}$	$-1.98 \cdot B_{P1-P2}$	$+4.53 \cdot B_{P1-C1}$	
L6 (MW)	0		$-B_{P1-C1}$		$-0.56 \cdot B_{P1-C1}$	← Amb. res.

$\nu_2^2/(\nu_1^2 - \nu_2^2) = 1.546$
$\nu_1^2/(\nu_1^2 - \nu_2^2) = 2.546$
$\nu_1\,\nu_2/(\nu_1^2 - \nu_2^2) = 1.984$
$\nu_1/(\nu_1 - \nu_2) = 4.529$
$\nu_1/(\nu_1 + \nu_2) = 0.562$

C1/C2		
$+1.55 \cdot B_{P1-P2}$	$+B_{P1-C1}$	
$+2.55 \cdot B_{P1-P2}$		$+B_{P2-C2}$
	$+2.55 \cdot B_{P1-C1}$	$-1.55 \cdot B_{P2-C2}$
$-B_{P1-P2}$	$+B_{P1-C1}$	$+B_{P2-C2}$
$-1.98 \cdot B_{P1-P2}$	$+4.53 \cdot B_{P1-C1}$	$-3.53 \cdot B_{P2-C2}$
	$-0.56 \cdot B_{P1-C1}$	$-0.44 \cdot B_{P2-C2}$

$\nu_2/(\nu_1 - \nu_2) = 3.529$
$\nu_2/(\nu_1 + \nu_2) = 0.438$

Determination methods:

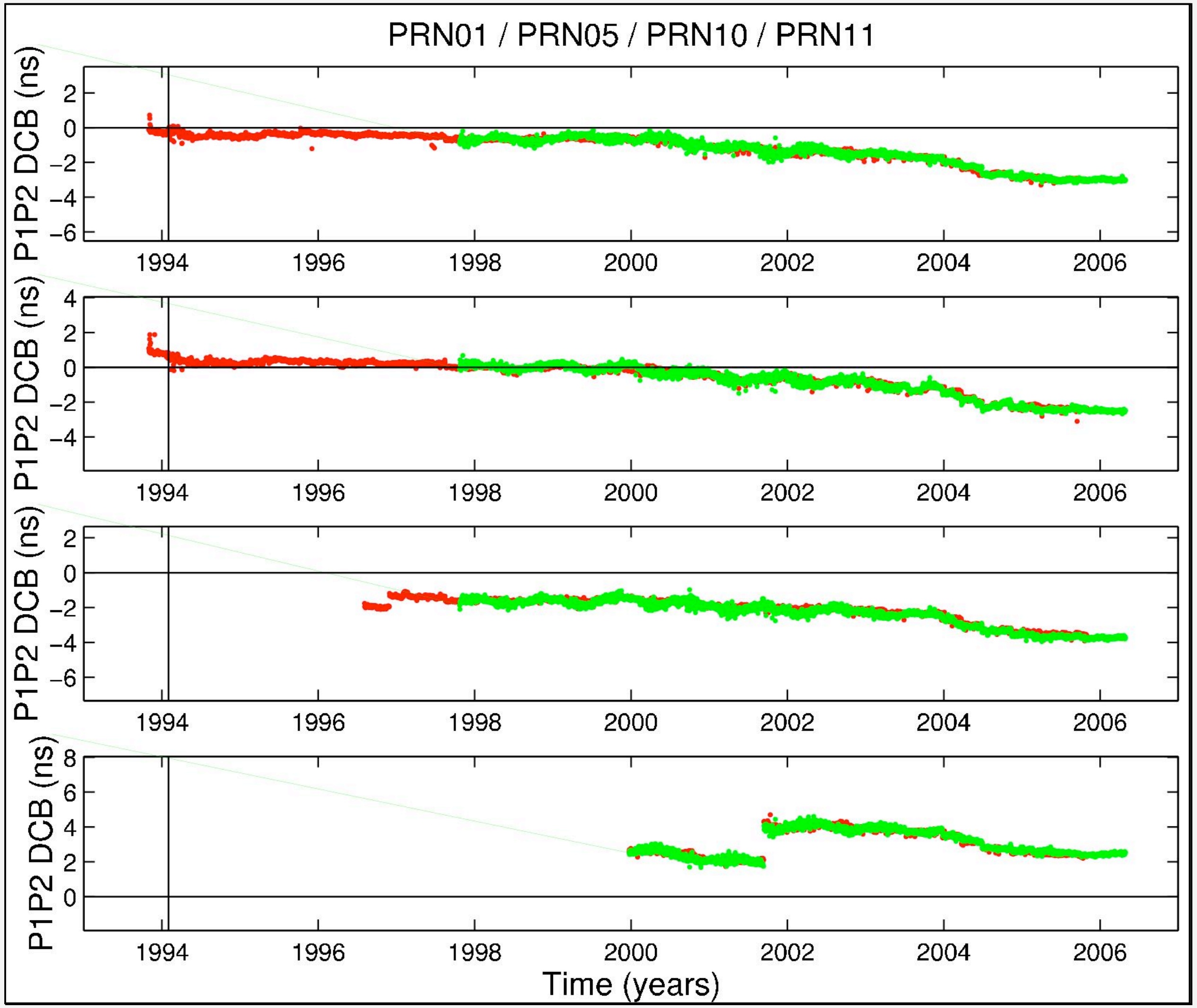
- P1-P2: Iono. / Abs. receiver cal.
- P1-C1: Diff. / Clock / Amb. res.

Verification of Receiver Tracking Technology (Using the Bernese Software Version 5.0)

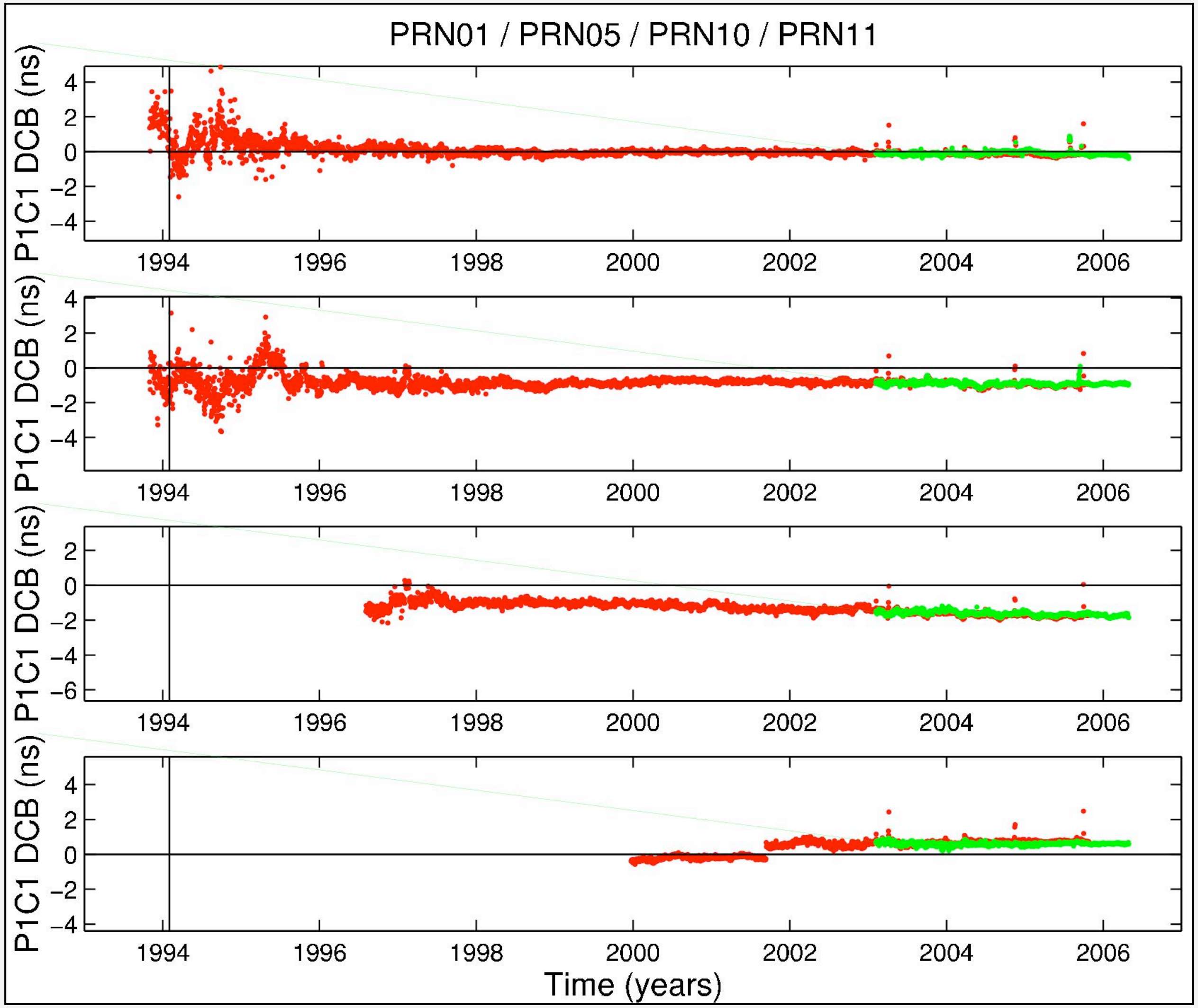
Excerpt of a PPP BPE processing summary file (PPP03139.PRC):

```
================================================================================
PART 6: VERIFICATION OF RECEIVER TRACKING TECHNOLOGY
================================================================================

 STATION NAME           MULTIPLIER   RMS ERROR    SUGGESTED RECEIVER TYPE    GIVEN RECEIVER NAME / TYPE     MATCH
 ---------------------------------------------------------------------------------------------------------------

 BRUS 13101M004   -G       -0.224        0.043    P1/P2    5.242   28.666     ASHTECH Z-XII3T       P1/P2     OK
 FFMJ 14279M001   -G       -0.105        0.051    P1/P2    2.045   21.578     JPS LEGACY            P1/P2     OK
 MATE 12734M008   -G        0.874        0.048    C1/X2    2.637   18.312     TRIMBLE 4000SSI       C1/X2     OK
 ONSA 10402M004   -G       -0.104        0.041    P1/P2    2.536   26.943     ASHTECH Z-XII3        P1/P2     OK
 PTBB 14234M001   -G       -0.124        0.048    P1/P2    2.579   23.352     ASHTECH Z-XII3T       P1/P2     OK
 VILL 13406M001   -G       -0.062        0.044    P1/P2    1.404   24.048     ASHTECH Z-XII3        P1/P2     OK
 ZIMJ 14001M006   -G        0.057        0.048    P1/P2    1.195   19.598     JPS LEGACY            P1/P2     OK
 ZIMM 14001M004   -G        1.131        0.047    C1/X2    2.788   24.083     TRIMBLE 4000SSI       C1/X2     OK
```

Time Series of Daily GPS P1-P2 DCB Values From TUM/TUD Reprocessing



Time Series of Daily GPS P1-C1 DCB Values From TUM/TUD Reprocessing

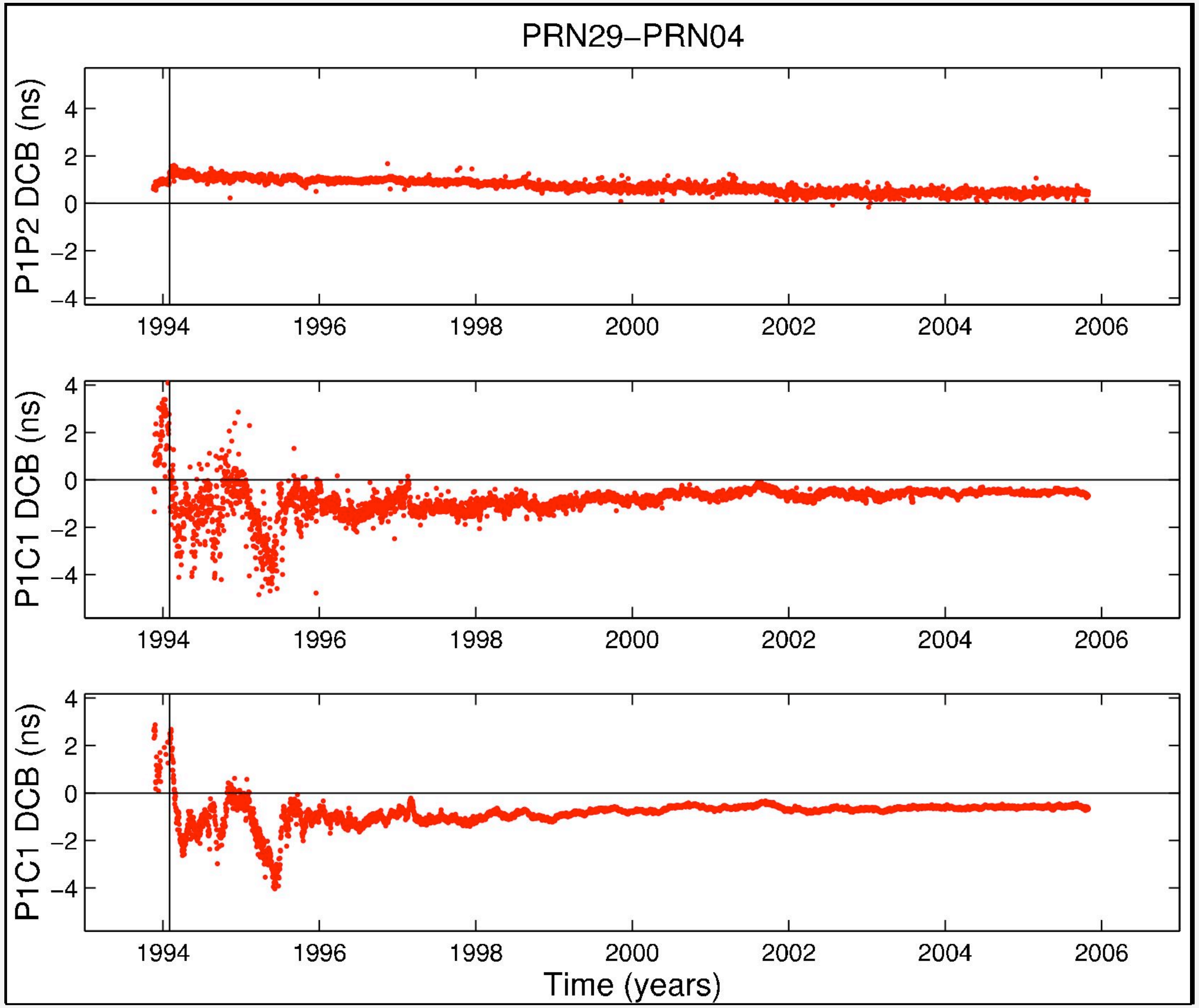


Time Series of Inter-Satellite Differences of P1-P2 and P1-C1 DCB Values From TUM/TUD Reprocessing

P1-P2:

P1-C1:

P1-C1:

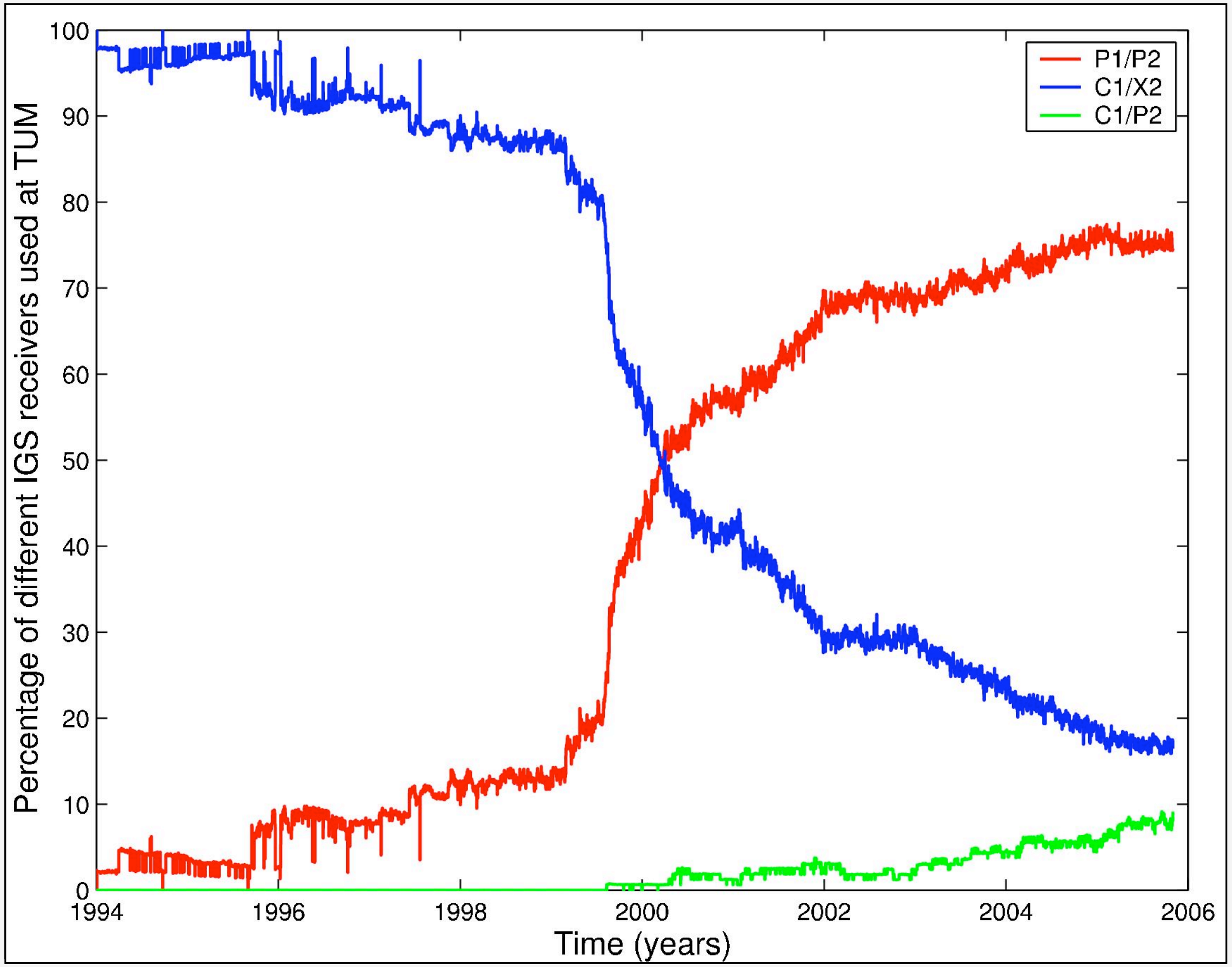


Iono.

Clock

Amb. res. (amb-fixed)

Number of P1/P2, C1/X2, C1/P2 IGS Receivers Used in TUM/TUD Reprocessing



Summary, Conclusions, Questions (1)

- The knowledge of P1-C1 biases is a must for successful ambiguity resolution (on long baselines) and for precise clock estimation when relying on a mixed receiver network.
- We introduced methods for retrieval of satellite (and receiver) DCB values, specifically with regard to P1-C1.
- We validated GPS P1-P2 and P1-C1 DCB results coming from the reprocessing effort made at TU Munich and TU Dresden.
- Reprocessing results show
  - commonly very stable satellite DCBs, specifically for P1-P2,
  - a considerably increased scattering of P1-C1 DCB estimates as long as the number of P1/P2 receivers is small (close to 1),
  - only few jump discontinuities (for the GPS constellation),
  - serious problems concerning A/S (see model assumption!).
- A/S is generally on as of January 31, 1994.

Summary, Conclusions, Questions (2)

- A/S-off state is obviously possible in some cases. The RINEX A/S bit should be considered. It would be convenient to have all (remaining) CC receivers generally operating in A/S-on tracking mode.
- Problems related to datum definition, detection of jump discontinuities, drifts, outliers, anomalies are very similar to those of other time series, such as GNSS station coordinates, antenna offsets/patterns, clocks, RPR model coefficients, etc.
- How should a DCB model look like? Monthly averages or a set of mean values?
- Combination on the basis of corresponding daily NEQ files (using ADDNEQ2) would be desirable.
- Maintenance of the list of C1/P2 receivers (in cc2noncc).
- Further issues: GPS L2C (C2), GLONASS, Galileo, etc.
- Reprocessing of data collected before January 31, 1994 is definitely for masochists …