RT Activities at EUREF LAC GOP

- Present and Outlook

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EUREF-TWG Lisbon, March 5-6, 2007

Present

GOP RT services

NTRIP Server (EUREF-IP)

```
EUREF-IP/VESOG/CZEPOS: GOPE0 RTCM2 1,3,16,18,19,22,31 GPS+GLO
EUREF-IP/VESOG/CZEPOS: TUBO0 RTCM2 1,3,18,19          GPS
         VESOG/CZEPOS: PLZE0 RTCM2 3,18,19,22,31      GPS+GLO
         VESOG/CZEPOS: LYSH0 RTCM2 3,18,19,22,31      GPS+GLO
         VESOG/CZEPOS: VSBO0 RTCM2 3,18,19,22,31      GPS+GLO
         VESOG/TEST  : GOPE1 RTCM2 1,3,16,18,19       GPS
         VESOG/TEST  : GOPG0 RTCM2 3,18,19,22,31      GPS+GLO
```

- already part of EUREF-IP

NTRIP Caster (for VESOG - GNSS permanent station network)

- actually distributes RTK data from the VESOG GNSS stations
- Caster is running on dedicated hosted server and we can provide particular casting also for EUREF-IP in future.

GOP RT usage

NTRIP Clients (EUREF-IP)

- developing the tool for data stream monitoring
- completing BNC (BKG Ntrip Client) to store data batches to feed EUREF Local Data Centre with hourly RINEX files

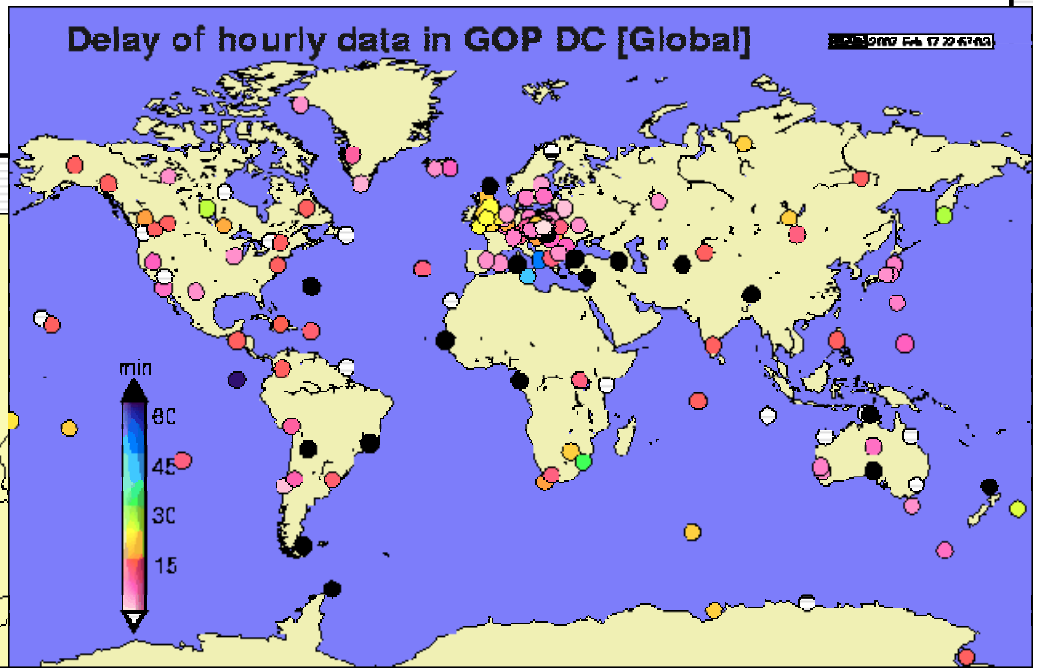
RTIGS Archiver (IGS RTWG)

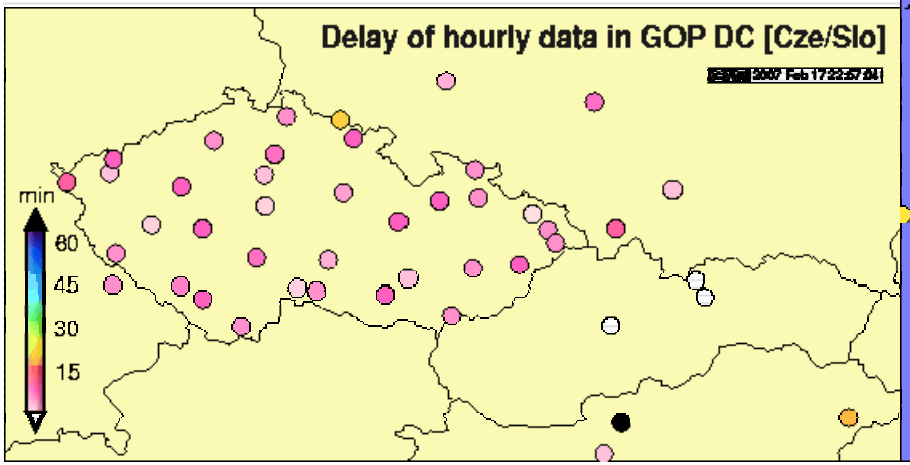
- storing about 18 RTIGS global stations in hourly RINEX files

RT-client usage

Support Data Center and near-real time processing at GOP

- GPS meteorology
- Ultra-rapid orbits





GOP RT support – ultra-rapid orbit determination

Last improvements:

- switched to official Bernese V5.0 (source modified)
- revised network configuration and processing startup
- parallel analysis using clusters (4 CPUs @ 2 PCs)
- handling unhealthy satellites,manoeuvres in analysis
- satellite not excluded from processing(only in product)
- ambiguity fixing (in 6 hour sessions)
- estimated ionosphere model supporting ambig. resol.
- real-time data supported from RT-IGS
- datum definition: fidutial sites iteratively checked
- new IGS standards (since Nov 2006)

GOP orbit determination - basic processing features

pre-processing :
- 6h-data batch

final product :
- by NEQ stacking

product update :
- 6 hours
- hourly rate possible

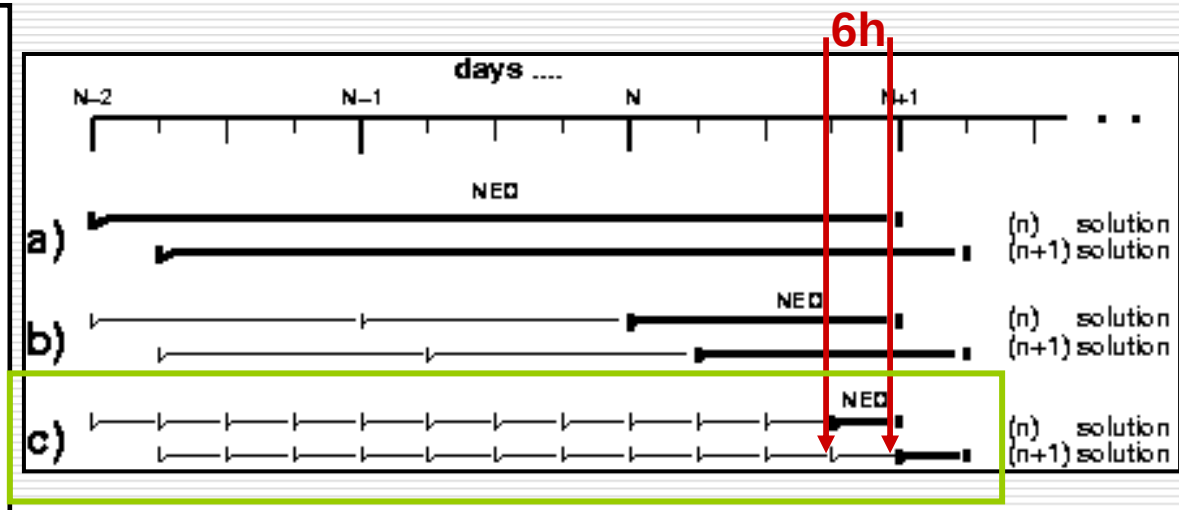
a priori orbits:
- IGS ultra-rapid predictions
- Broadcast orbits

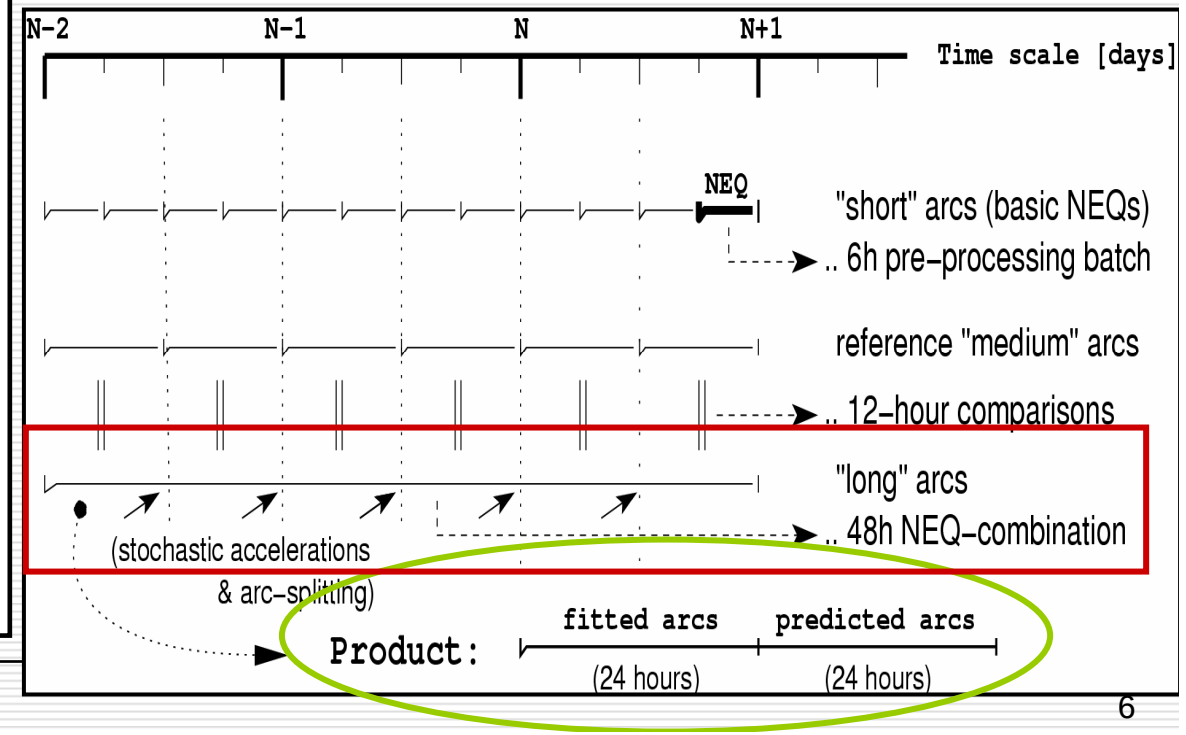
iteratively improved orbits:
- 1 day

final orbits :
- 3 days

 # sites: 56

 # clusters : 5



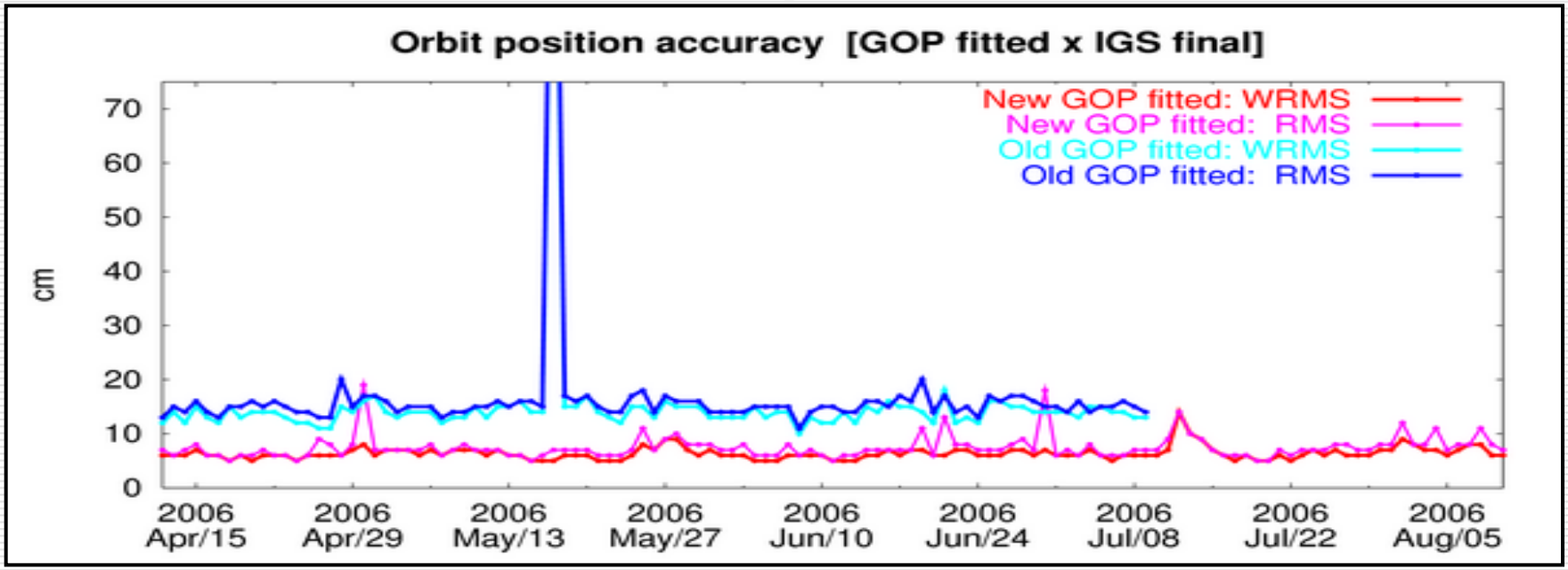


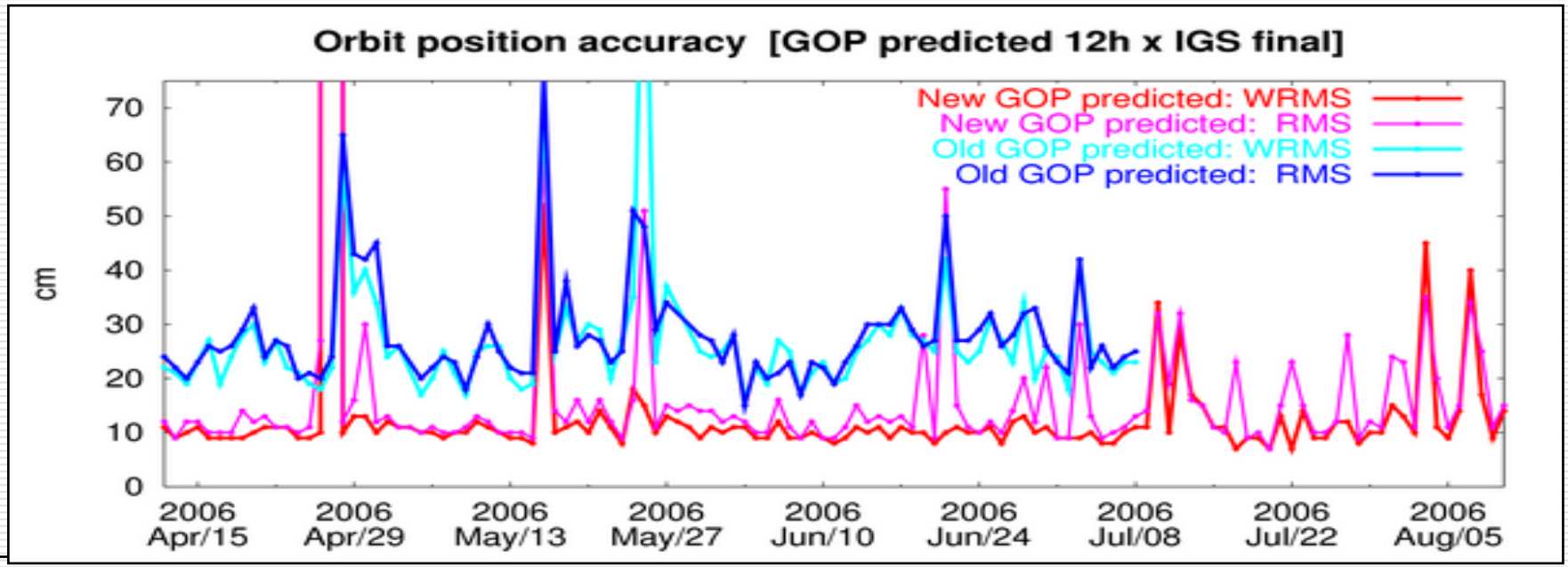
Processing optimizations

- processing approach (procedure, sessions)
- Bernese programs and strategies (input, setup)
- network clustering optimization (size of sub-networks)
- source code efficiency (repeating tasks, I/O operations)

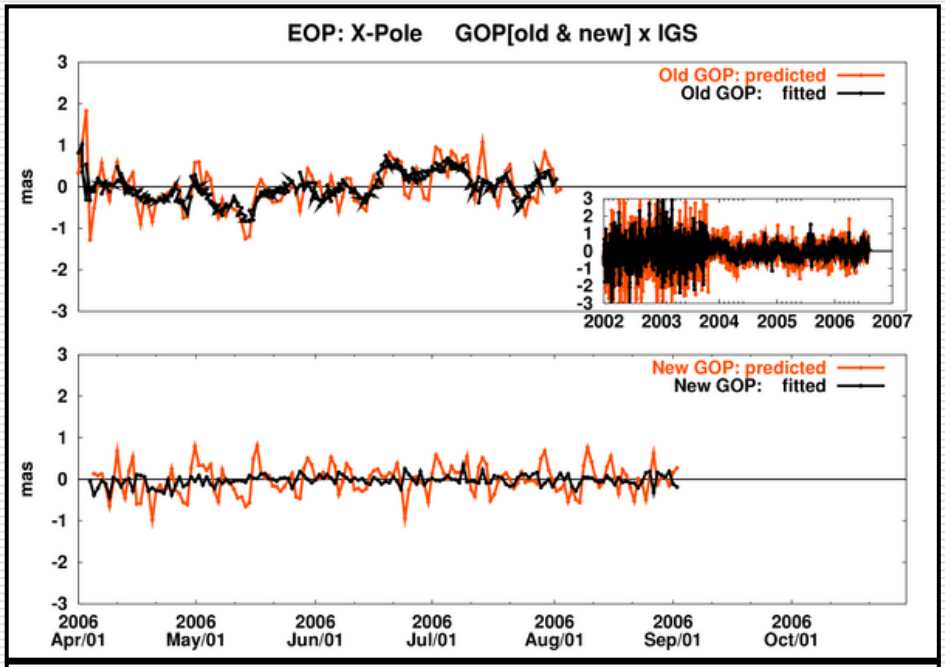
1 session	run-time	disk usage	comments
24 h (1)	54 min	40 MB	clusters optimized
12 h (1)	36 min	30 MB	clusters optimized
6 h (0)	33 min	24 MB	no optimized
6 h (1)	30 min	24 MB	cluster optimized
6 h (2)	24 min	24 MB	cluster and source-code optimized

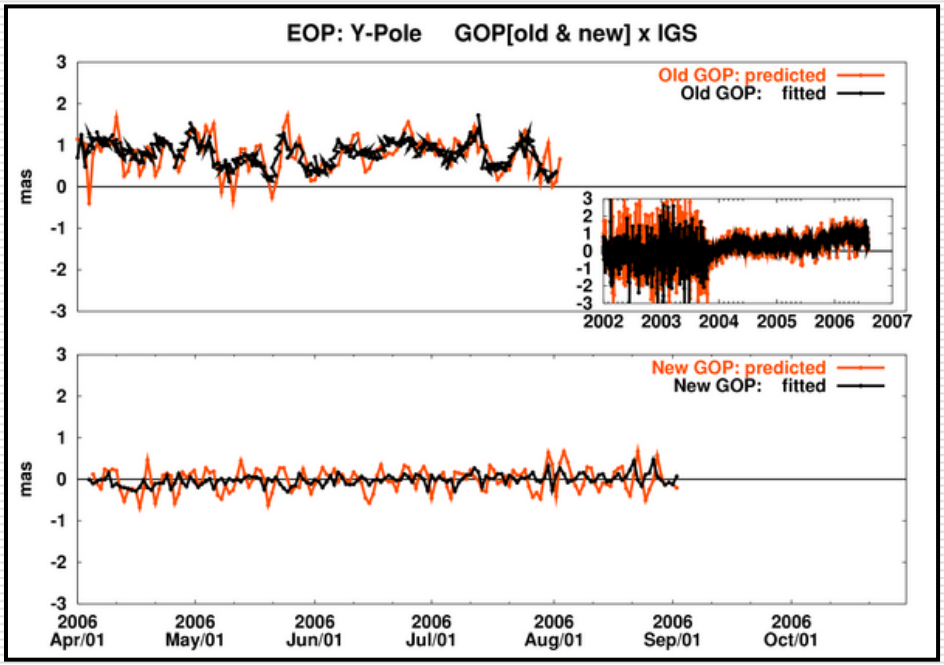
GOP new and old product: GPS orbits

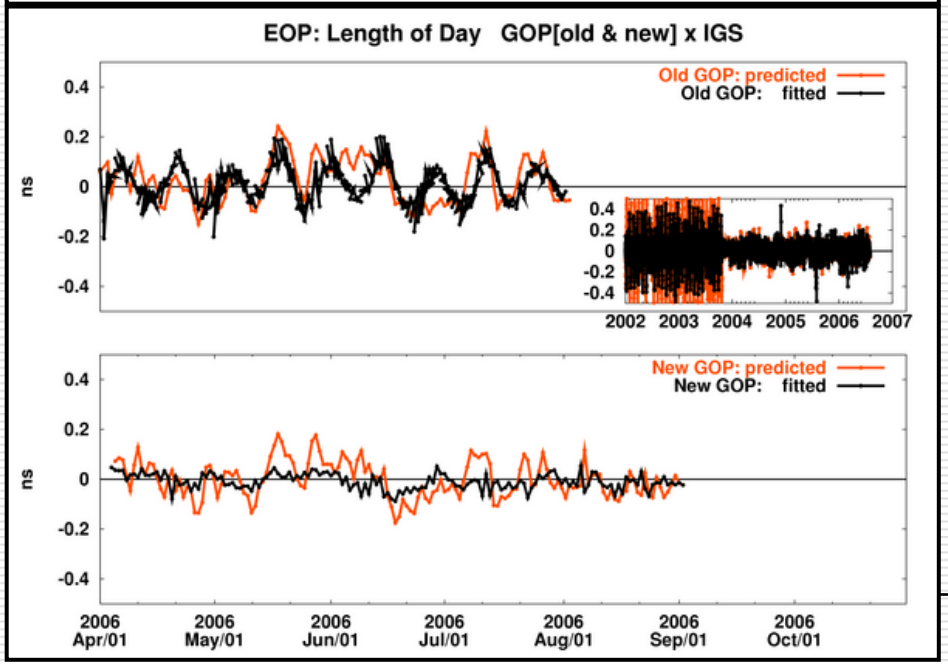


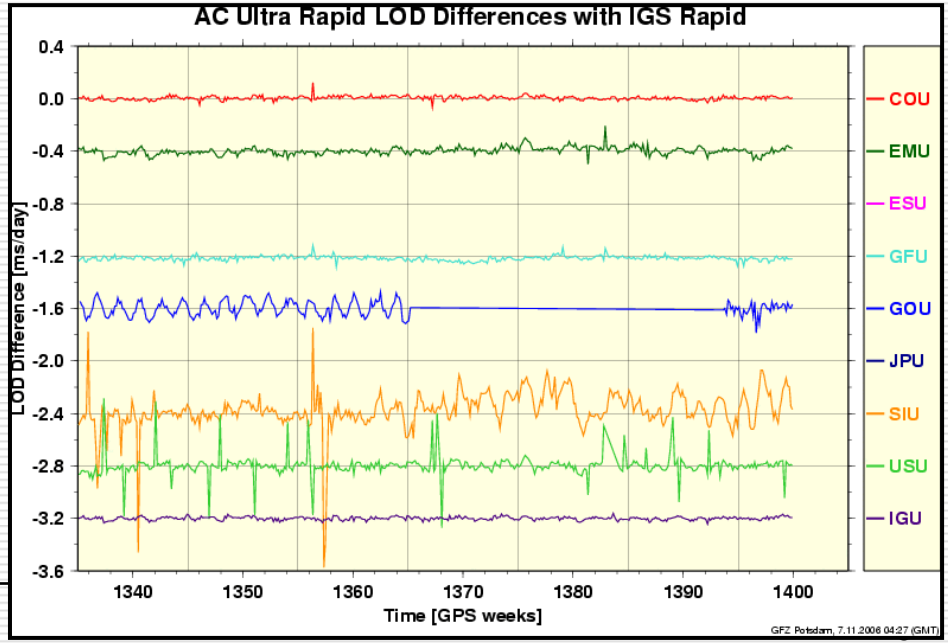


GOP new and old products: X,Y-Pole, LOD

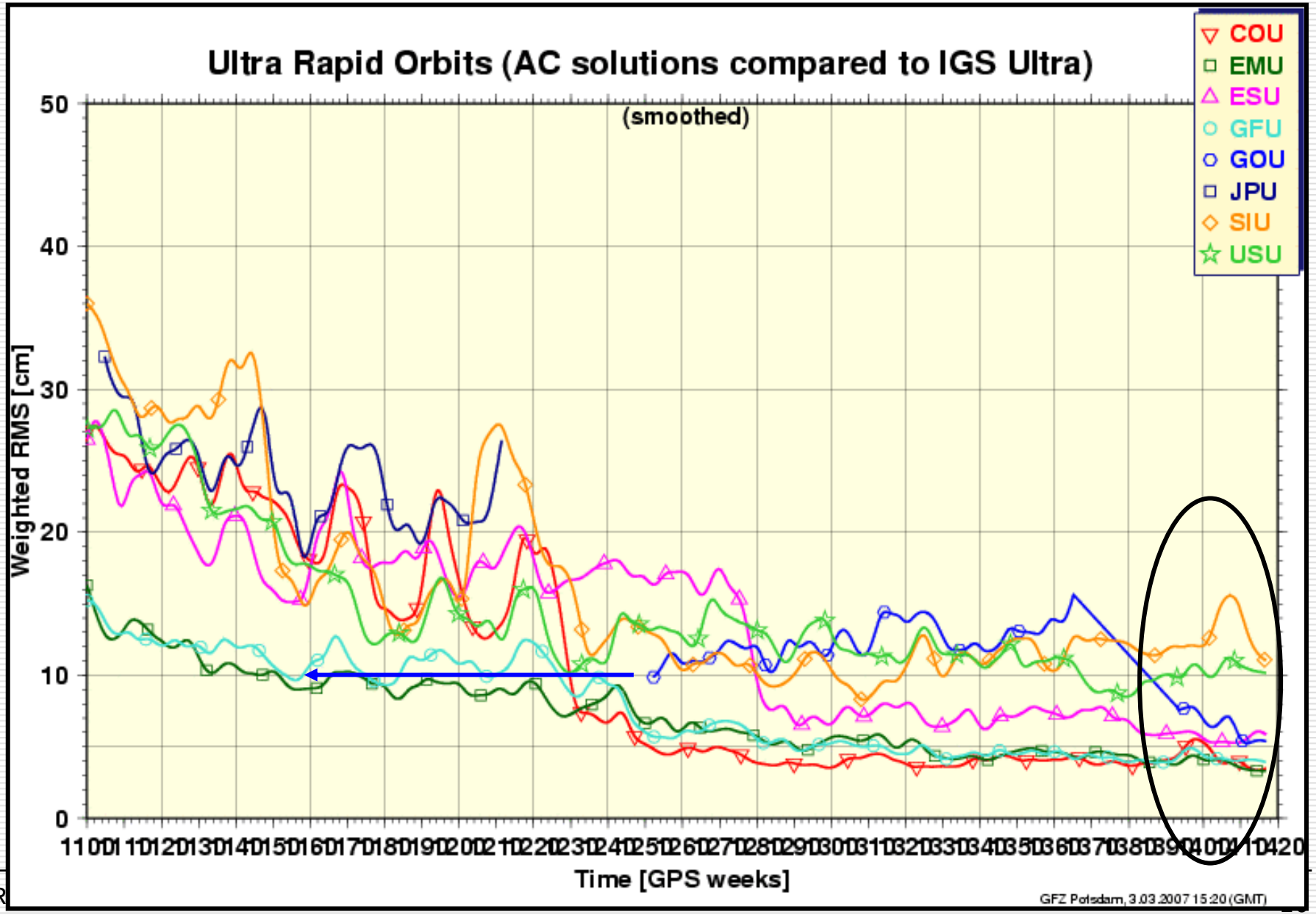








IGS combination (from IGS ACC monitoring)



GOP product summary table

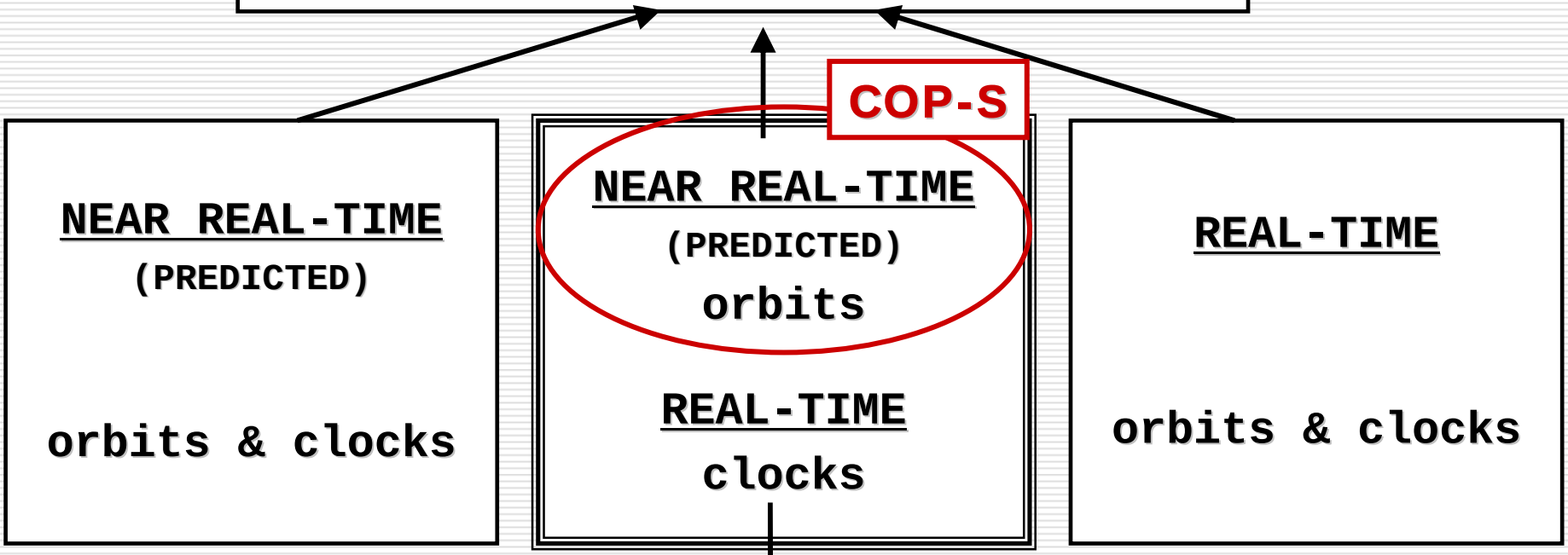
fitted predicted	Orbits [cm]	Clocks [ns]	X-pole [mas]	Y-pole [mas]	Xp rate [mas/day]	Yp rate [mas/day]	LOD [ns]
GOU_old 2006	12 24	-	0.3 0.5	0.9 0.9	0.1 0.1	0.4 0.4	0.07 0.09
GOU_new 2006	6 12	-	0.1 0.3	0.1 0.3	0.4 0.4	0.2 0.4	0.03 0.07
IGU	<5 10	0.2 5	0.1 0.3	0.1 0.3	0.3 0.5	0.3 0.5	0.03 0.06

Next Priority: 1) support of GLONASS ultra-rapids
2) support of precise clocks
+ higher update rate possible

Outlook

Motivation

The aim: **Real-Time Precise Point Positioning**



possible models | **model + rt product** | real-time products

Two streams with different distribution scheme ?

Not necessarily, but useful.

We have developed a new stream providing precise continuous orbits in efficient format for real-time distribution: „COP-S“

Towards real-time continuous orbit product

Status:

- IGS ultra-rapid product in batches(4x/day), discrete epochs (15min), GPS only

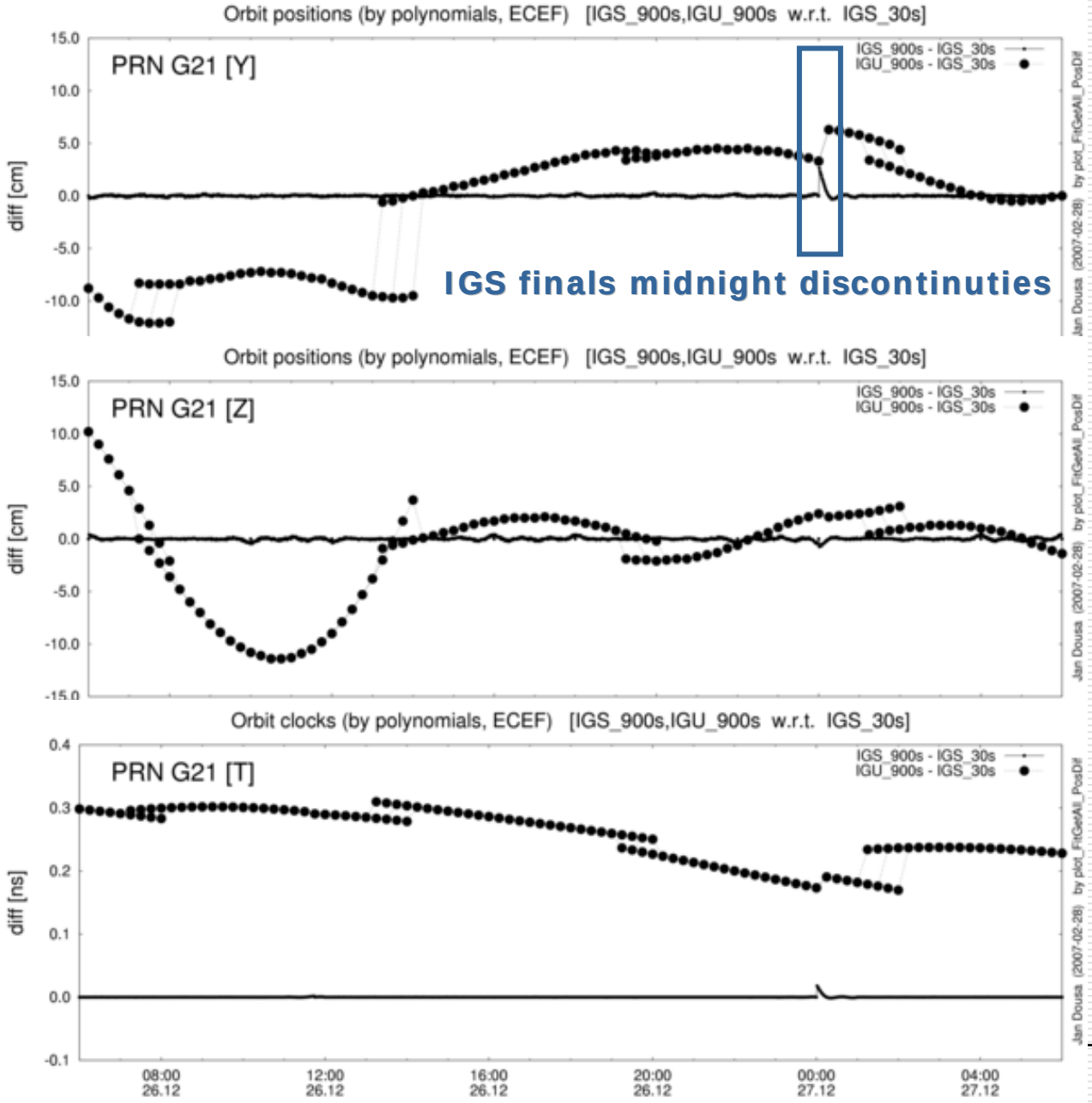
Requests:

- unique(!), efficient and continual representation of precise GNSS orbits to support consistent real-time clock estimations
- distribution via real-time stream
- clients should apply any sampling rates in RT, NRT

Proposition: Continuous Orbit Polynomials Stream (COP-S)

- distribution of the polynomial coefficients representing the individual satellite orbit positions (in ECEF)
- polynomials validity interval: 1 hour (HR:00-HR:60)
- reference epoch: middle of the interval (HR:30)
- method: fitting the polynomials connected to the previous set, minimizing the orbit predictions and getting RMS as the discontinuity meassure
- continuity upto the first derivative (velocity, ddTime)
- COP-S format specified

IGS ultra-rapids (RT) / IGS finals



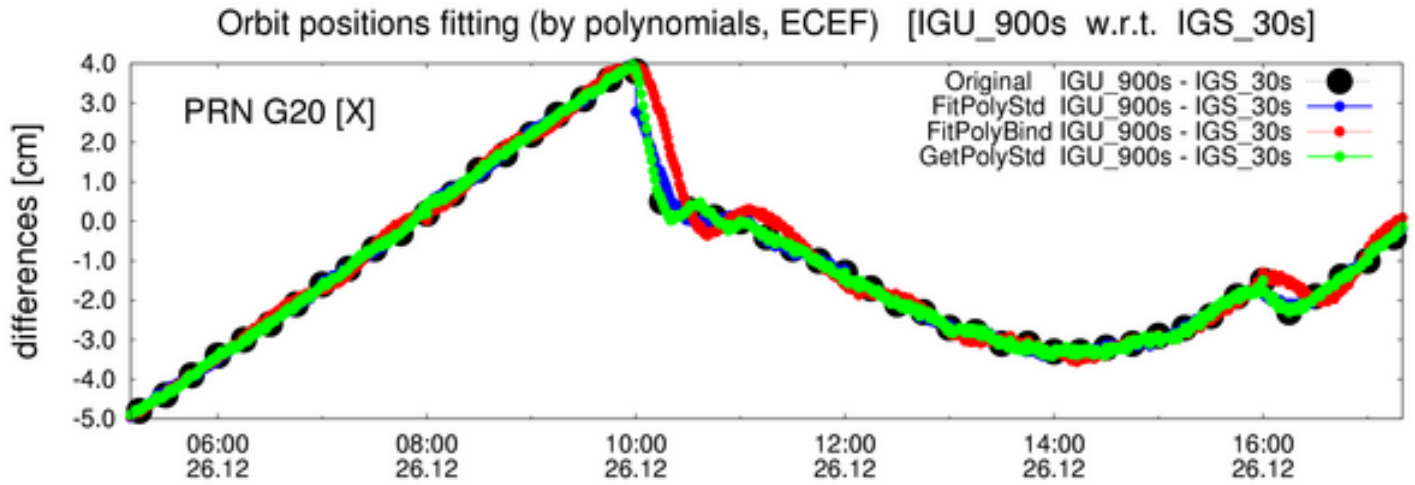
IGU-00: @ 03h UTC
used: 04-10h
IGU-06: @ 09h UTC
used: 10-16h
IGU-12: @ 15h UTC
used: 16-22h
IGU-18: @ 21h UTC
used: 22-04h

Real predictions: 4-10h

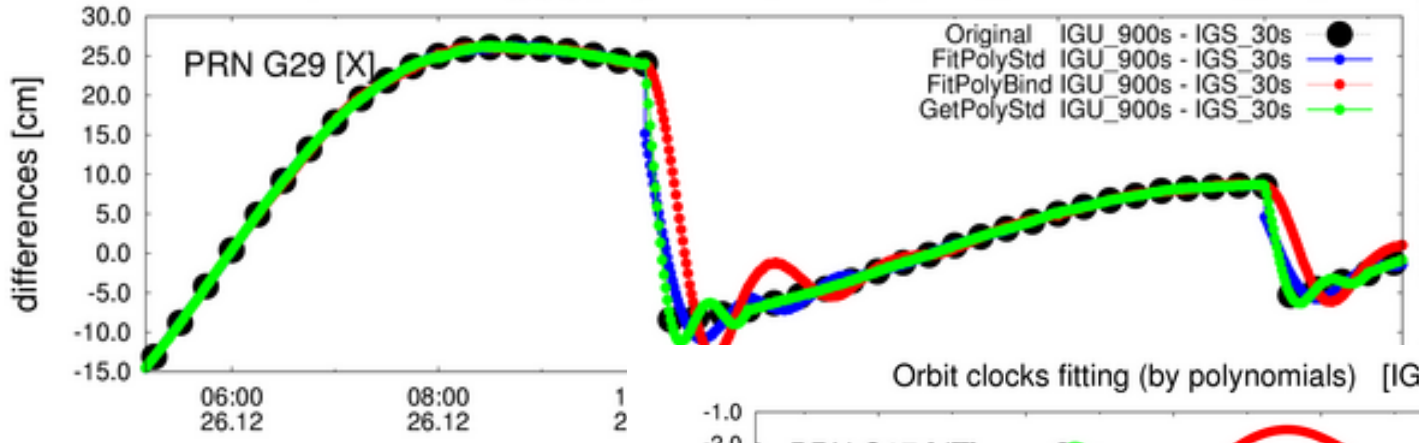
Comparisons:

IGS finals & ultra-rapids in 15min SP3 std files
×
IGS finals in 30sec SP3 modelled in inertial system

Fit / Get polynomial coefficients

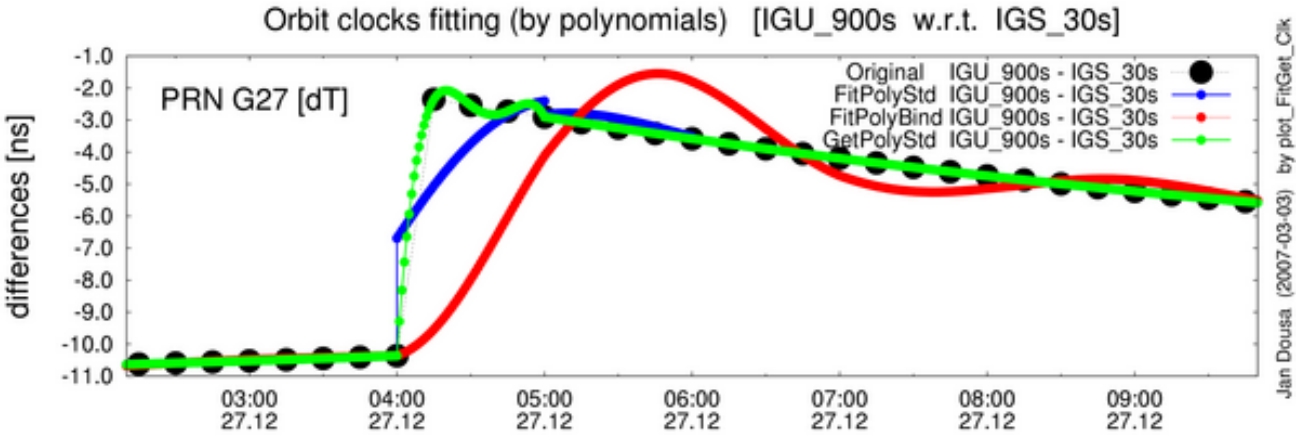


Position - fine

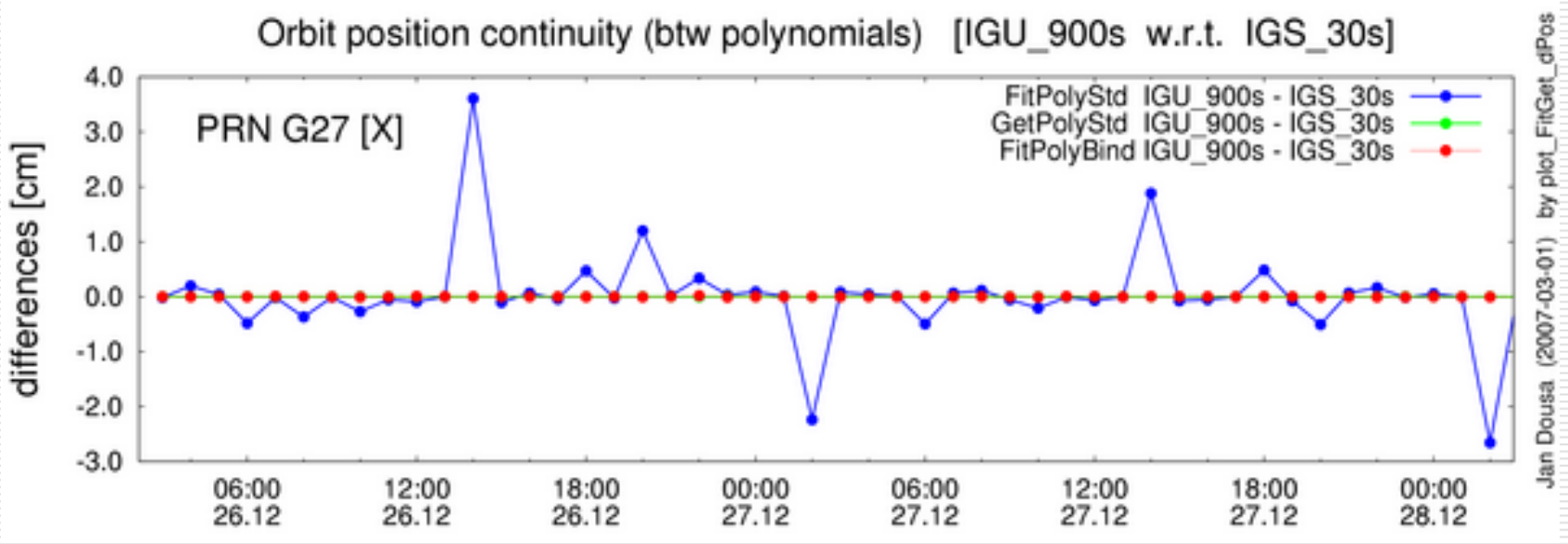


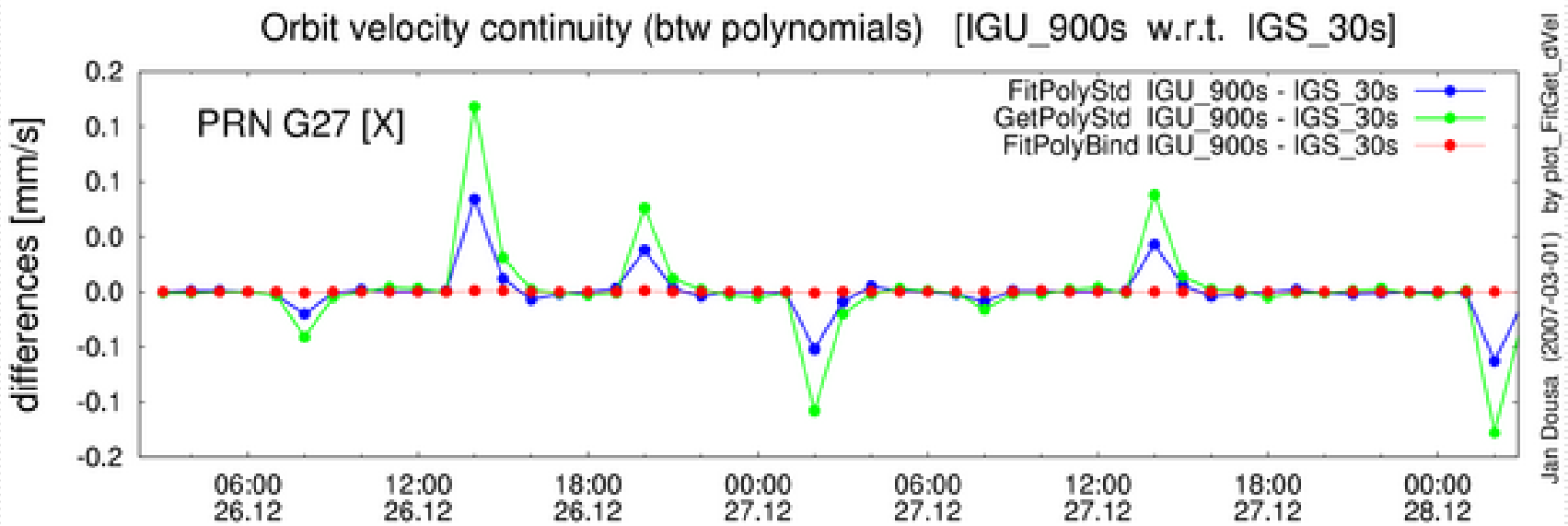
Position - worst

clocks:



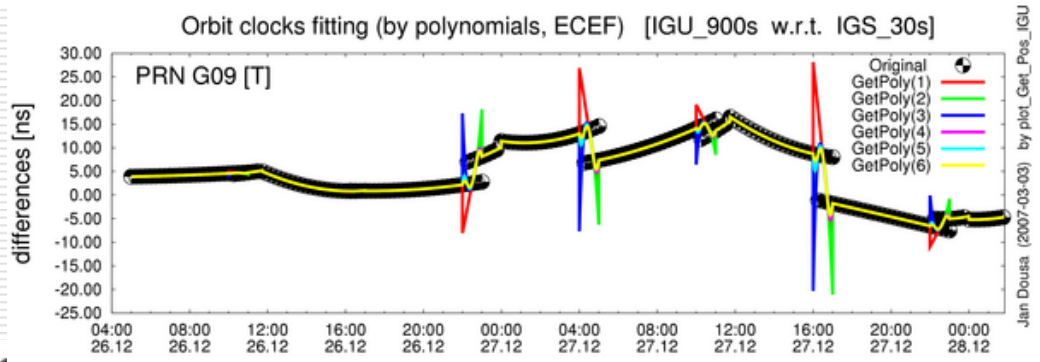
Discontinuities: position/velocity

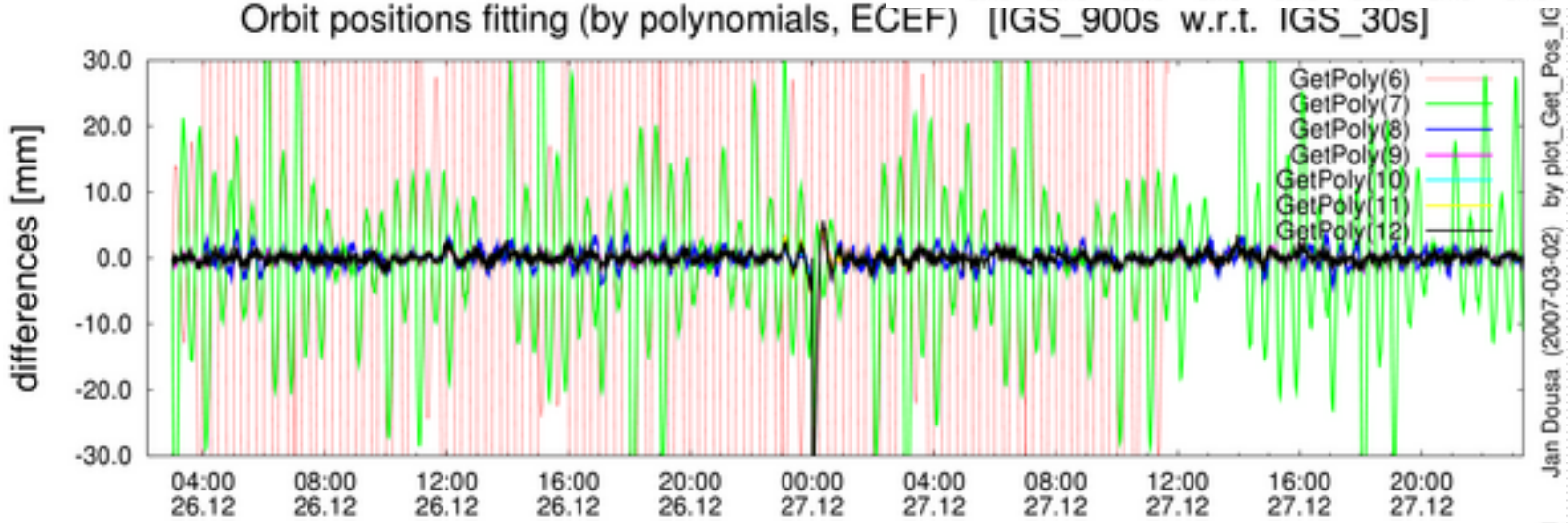




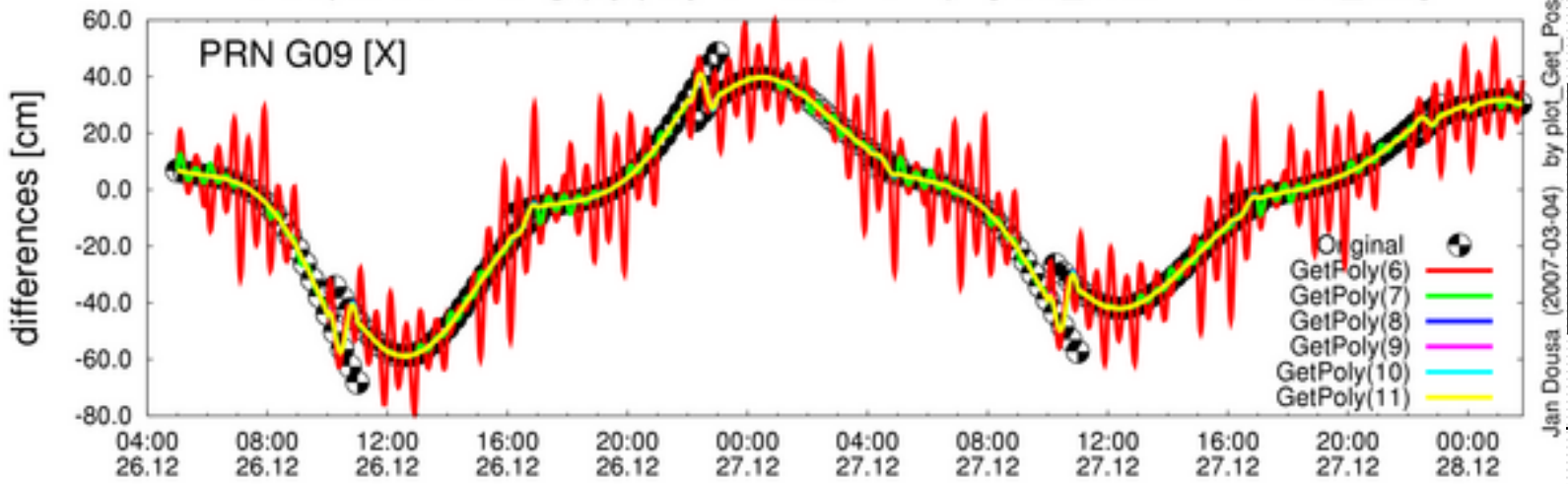
Polynomial degree

Position: 10 deg (12 deg)
Clocks: 4 deg (6 deg)





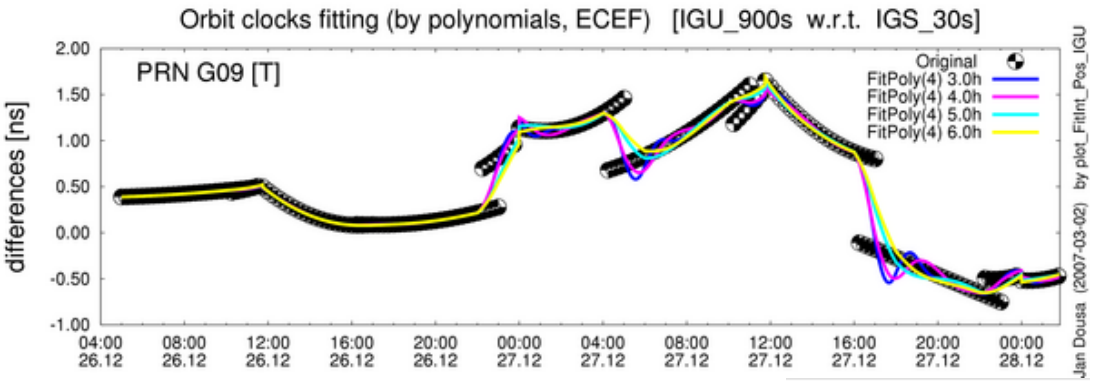
IGS_15min
x
IGS_30sec
[mm] !!

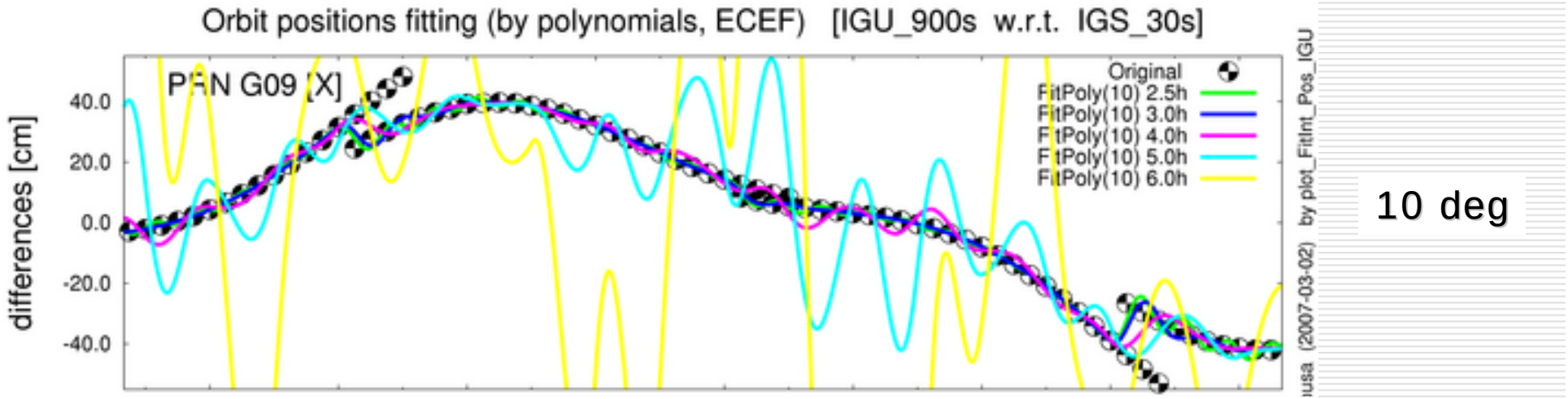


IGU_15min
x
IGS_30sec
[cm]

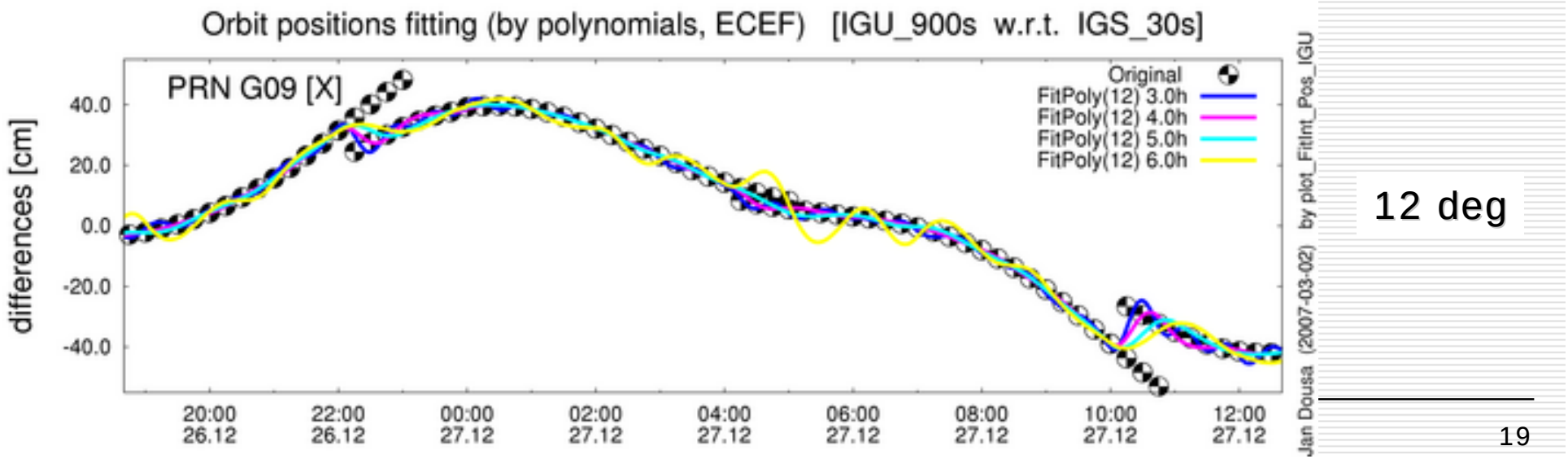
Fitted interval

Position: 3 hours (10 deg)
Position: 4 hours (12 deg)
Clocks: 1 hour (4 deg)



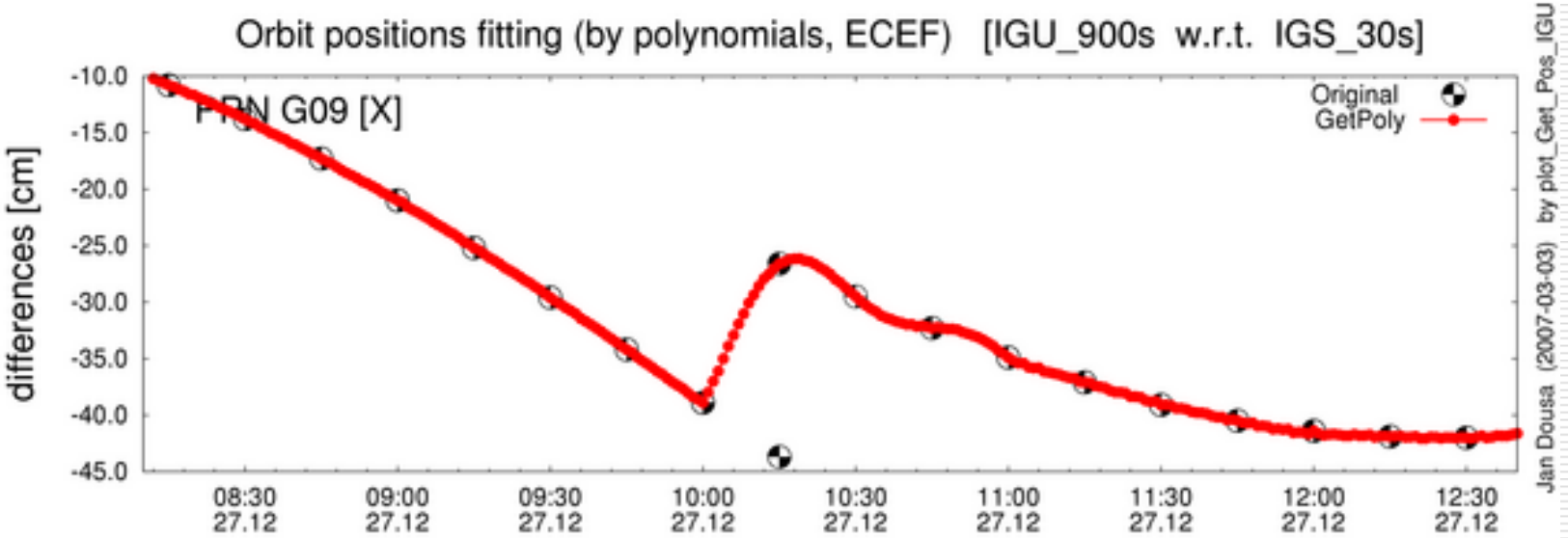


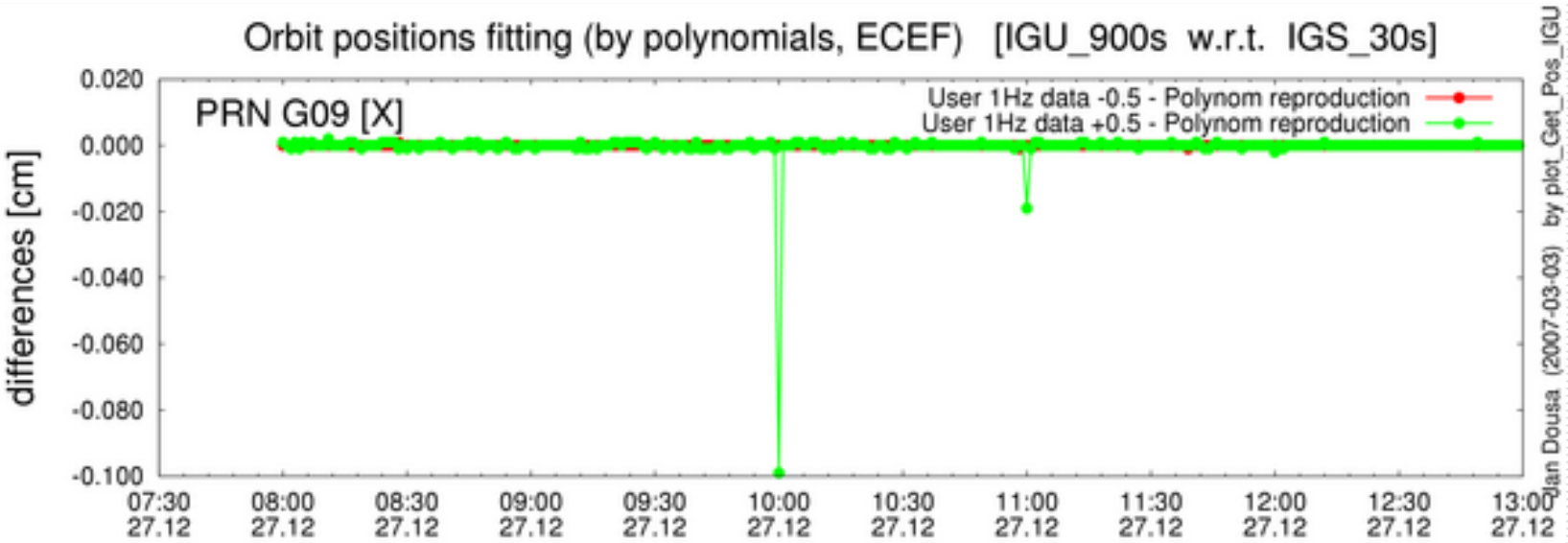
10 deg



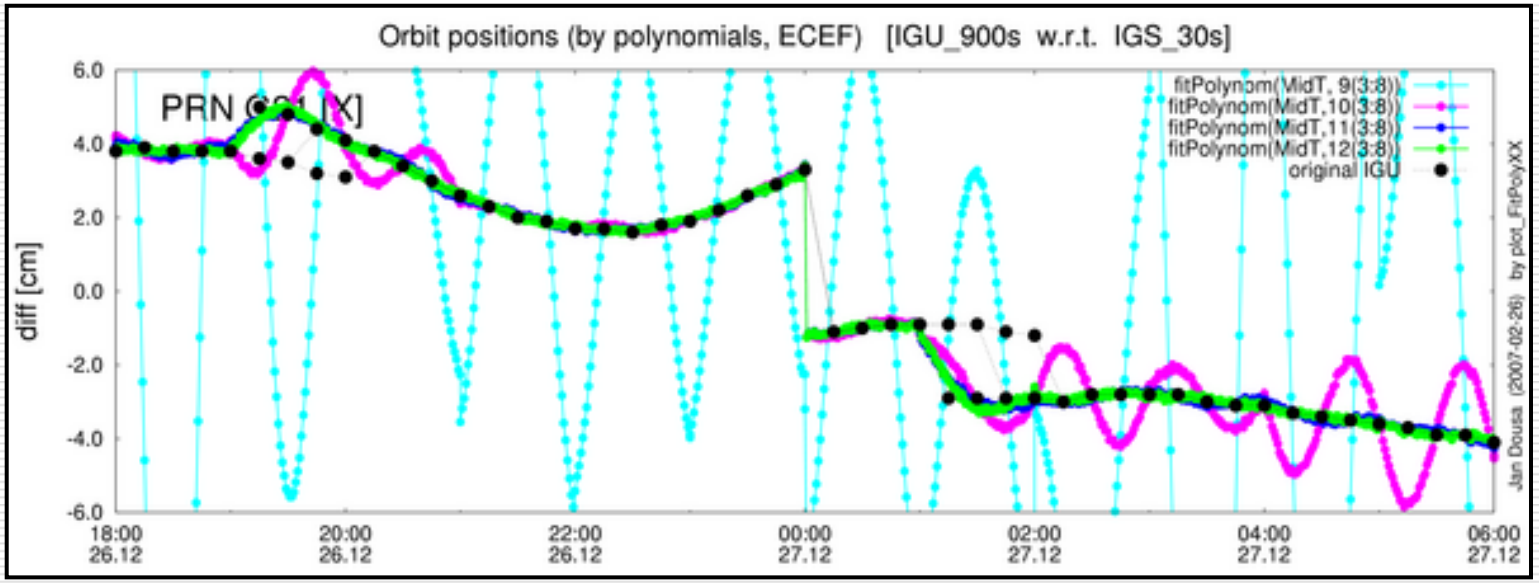
12 deg

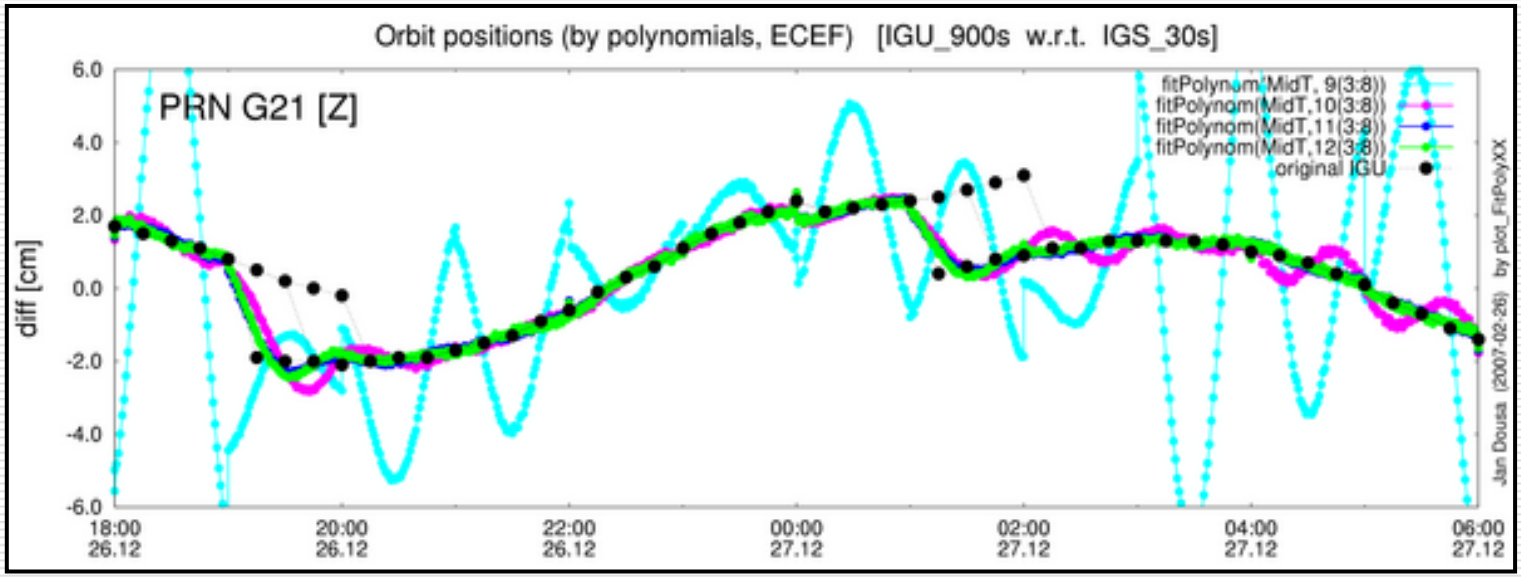
Polynomials reproductibility from 1Hz positions



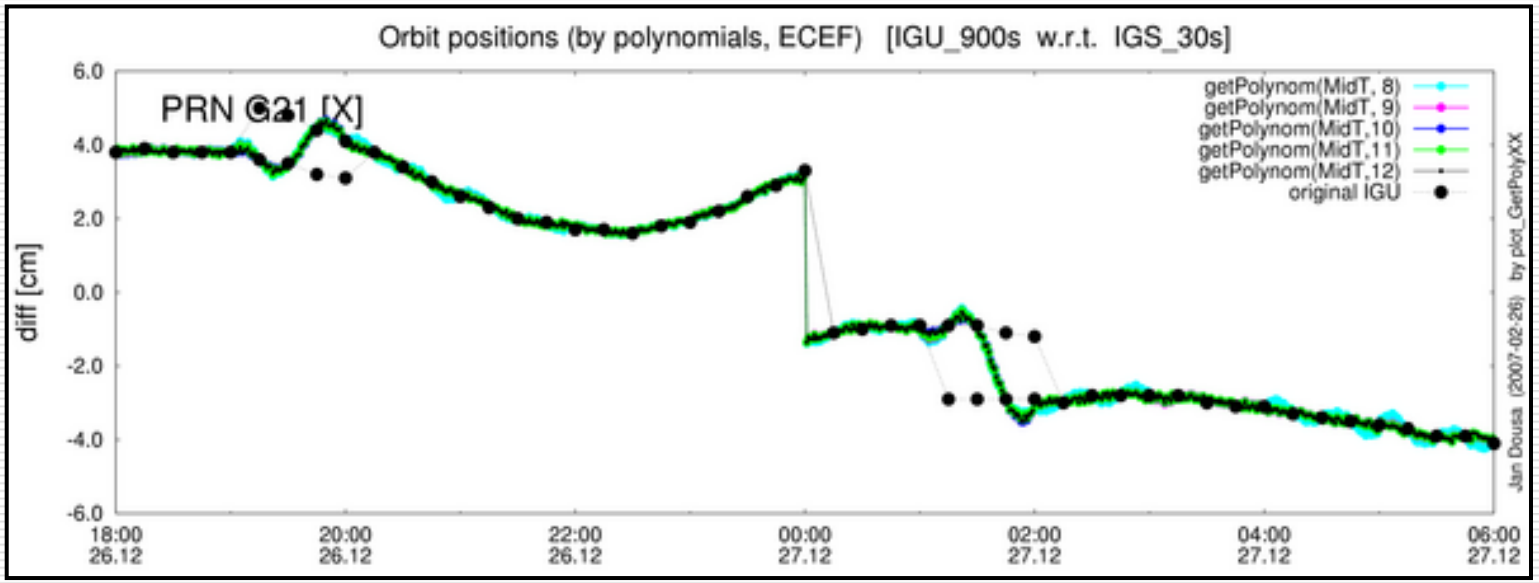


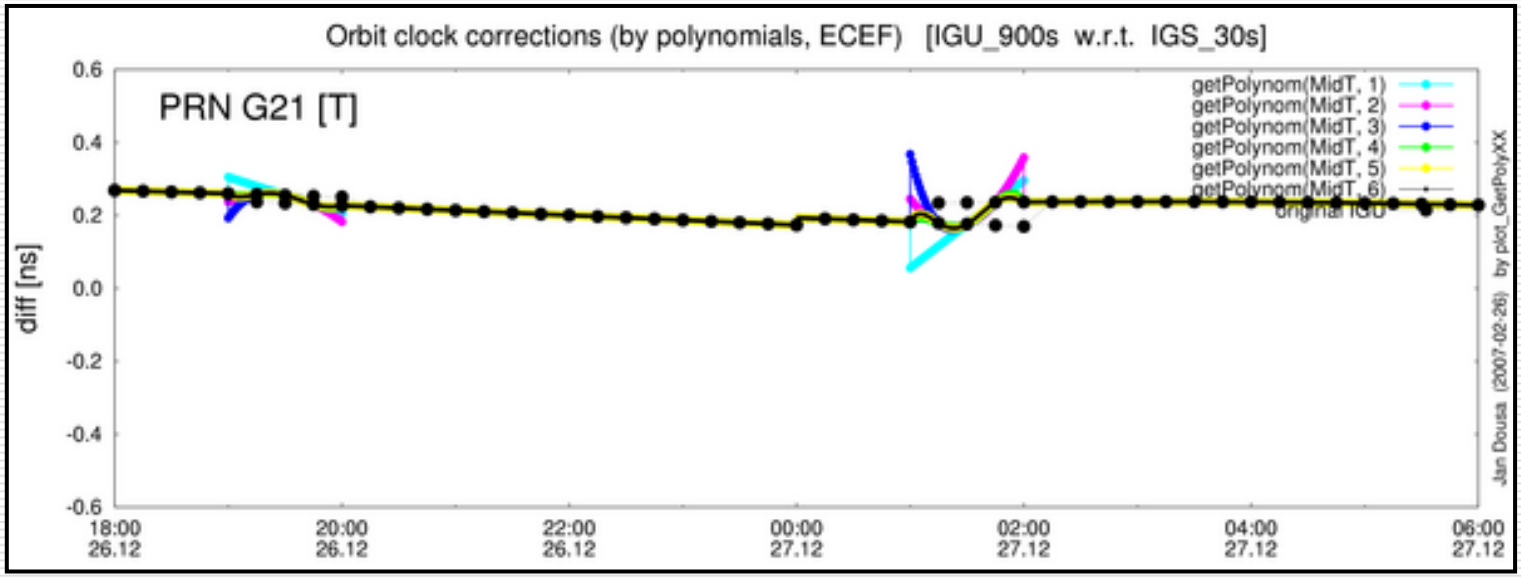
Evaluation: Fitting Polynomials (X, Z)





Evaluation: Getting Polynomials (X, T)

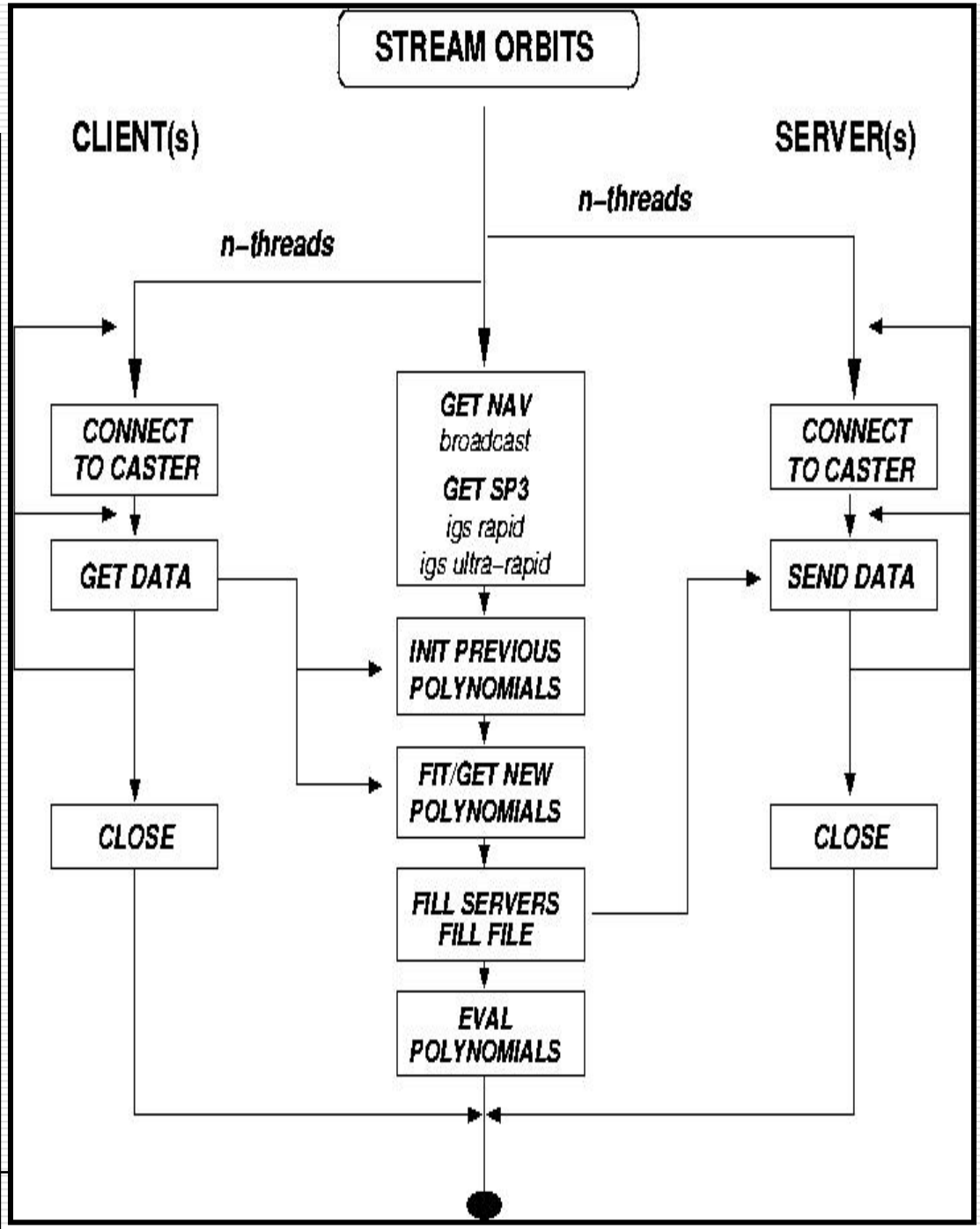




Our implementation

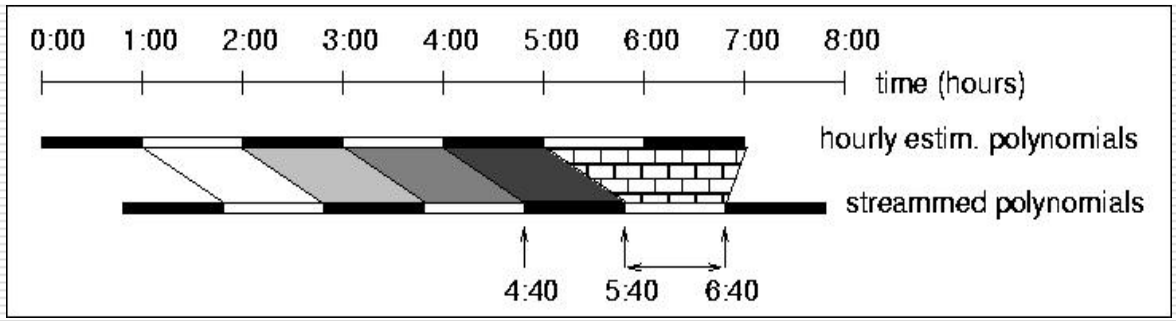
Main features:

- StreamOrbits sw (SO)
- C++ OOP design
- GPSTk used
  (SGLab, Univ.of Texas)
- SO NTRIP servers and clients started at individual threads
- Method: Fit or Get Polynomials
- Hourly reading SP3 products and global navigation message
- Real-time or post-processing mode
- Monitoring will be enabled via both server and client



```
Beg: 2007-02-27 22:00:00
End: 2007-02-27 23:00:00
Ref: 2007-02-27 22:30:00
X 13   4     3.20
+1.311127557190E+07
+2.484722481319E+02
-9.403479788688E-02
+7.156659561677E-06
+2.800645379139E-10
-1.878917158834E-14
-4.387493074794E-19
+1.935407653259E-23
+3.908150292104E-28
-8.876490827089E-33
-2.107005150801E-37
+1.083457989067E-43
-1.299932526312E-47
Y 13   4     2.87
-2.330698459203E+07
+1.056447955393E+02
+1.627371259474E-01
+4.497168684681E-06
-4.639347473885E-10
-1.228586064054E-14
+6.624061151557E-19
+1.450844076686E-23
-4.575124959213E-28
-1.007538543630E-32
+8.590728618908E-38
+4.328259348756E-42
+2.002789462125E-46
Z 13   4     3.29
+4.392944529435E+05
-3.144652604648E+03
-4.576774340250E-03
+1.091913544033E-05
+2.123040342439E-11
-1.072160005340E-14
-4.973822688140E-20
+3.723688787705E-24
+6.596731796337E-29
+8.120488250408E-34
-9.098869184632E-38
-1.860474879109E-42
+3.460040110136E-46
T  7 10     1.28
+8.103883328808E+01
:
```

COP Stream structure



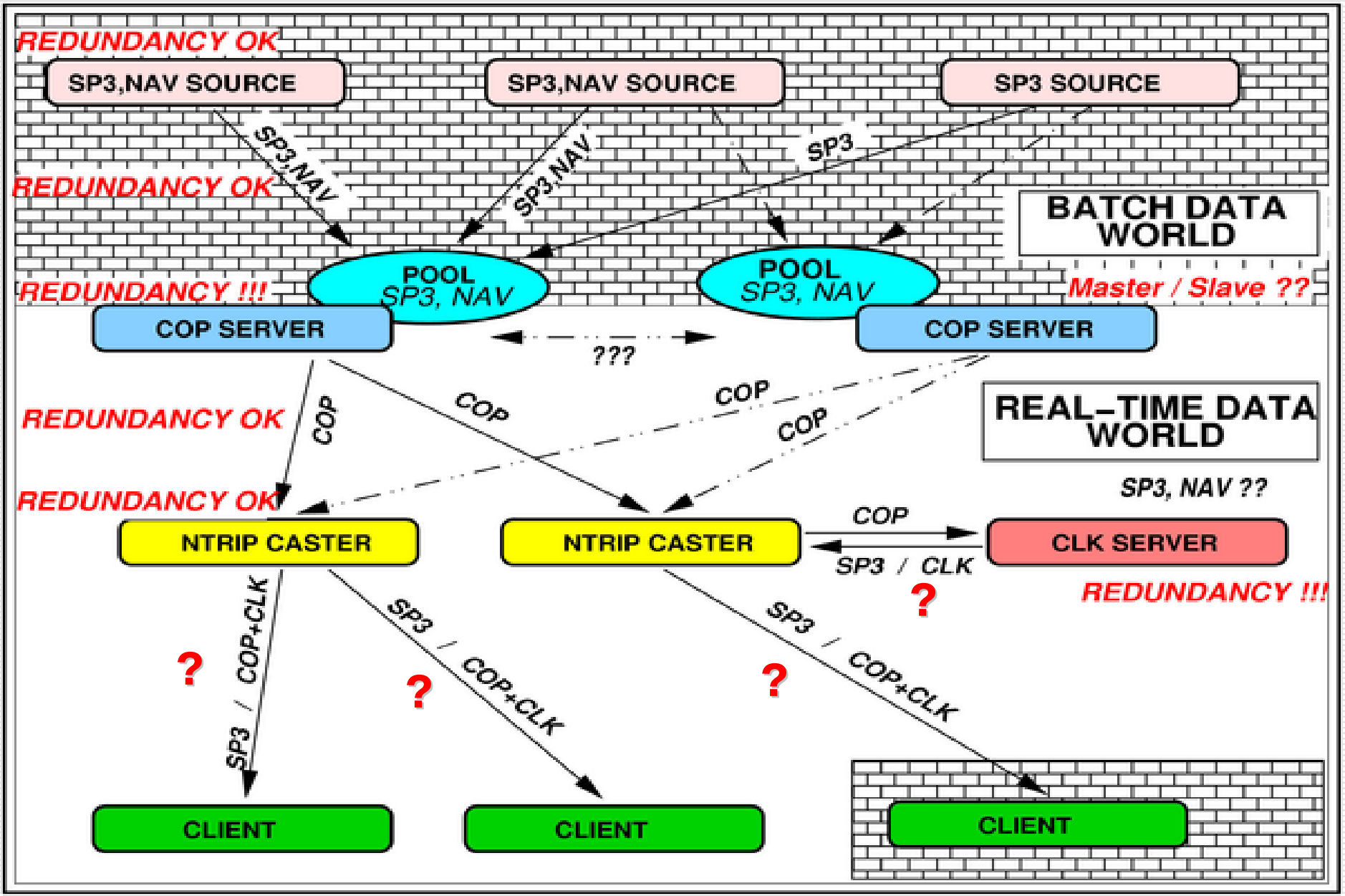
Two blocks of the polynomial coefficient set

- previous/present OR present/future
- each prefixed by '#Time-Mark' comment
- **Each block of the polynomials contains subframes for all satellites**

Satellites' subframes consist of:

- initial comment line
- PRN id, Accuracy Code, Healthy Code
- Beg, End time of the polynomials validity
- Reference time for the polynomials
- blocks of polynomial coeff. (each component)
  - component id: 'X', 'Y', 'Z', 'T'
  - number of coefficients for the component
  - deg of freedom from fitting polynomials
  - RMS from fiting polynomials
  - coefficients

Distribution scheme, redundancy



Further requirements

- **COP Stream should be robust stable**
  - ✓ data source redundancy - ok
  - ✓ caster duplicity enabled
  - ➢ server duplicity (not implemented yet)
- **COP Stream content should be monitored and backward evaluated**
  - ✓ with respect to IGS rapids (24-48h backward)
  - ✓ - orbit positions
  - ✓ - orbit position continuities betw. polynomials
  - ➢ archive in database
  - ➢ web-intergace
- **CLK Stream to support RT/NRT-PPP**

EPN products

Real-time clock generators exist as well as data streams

→ 'COP+CLK' or 'SP3' like stream could be provided

The (near) real-time PPP client software should be prepared.

The client package could be provided to all/most of the EPN operational centers (site operators), who can individually support the RT (or NRT) EUREF future products:

- **station behavior monitoring**
- **GPS meteorology for NWP**
- **earthquake hazard monitoring**
- **...**

COP+CLK or SP3 1Hz stream ? other ?

COP stream: **1sat(3pos) = 33 values/hour**

- + no header
- + satell. accuracy and healthy codes, fitting RMS
- +/- continuous data valid over interval (one hour)
- + transport efficiency when using temporary connections
  aprox. 30s to get a full data set valid for at least 1 hour
  - slower initialization
- + orbit positions continuity provided
- + no gaps when storing SP3 files for NRT batch analysis

CLK stream: **1sat(clk) = 3600 values/hour**

- + e.g. 1Hz clock corrections
- - possible clock gaps when saving for NRT

SP3 1Hz stream: **1sat(3pos+clk) = 10800+3600 values/hour**

- + standardized format (but for batch)
- +/- epoch-wise oriented data for the interpolations
  + fast initialization
- - discrete data, but 1Hz fine for the reproduction [mm]
- - header
- - possible pos+clk gaps when saving for NRT