DORIS: Introduction to Bernese GPS Software

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DORIS, the basic facts

- Based on Doppler effect (frequency shift measured)
- Designed 1982 for POSEIDON mission
- Receivers are on board, Transmitters ground stations
- Two frequencies ~ 2 GHz , 400 MHz
- First used 1990 for SPOT-2
- One of four IERS techniques
- Over 50 Stations, 17 collocations with GPS
- IDS – International Doris Service

Source: IDS web site

CDDIS DORIS Data (1)

Transformation to RANGE RATE (average Doppler velocity) *V*

$$V = (c/fb)\,(fb - fs - D/T)$$

***fb* = beacon frequency**

***fs* = satellite (receiver) frequency**

***D* = number of cycles**

***T* = time interval**

***c* = velocity of light**

Version 1.0: fb,fs nominal

Version 2.0: fb,fs estimated

Version 2.1: fb nominal, fs estimated

CDDIS DORIS Data (2)

Corrections: ionosphere, troposphere, centre of mass

Other data: preprocessing indicator, Atmosphere data

Transformation between on board clock and TAI (for transformation coefficients are used pseudorange observations between satellite and master beacon)

$$T = t + a_0 + a_1(t - t_0) + a_2(t - t_0)^2$$

T = TAI, t = on board time, a_i = estimated coefficients

For satellite frequency estimation

$$f_s = f_{s(nominal)}\,(1 + a_1 + 2a_2\,(t - t_0))$$

***For* version *1.0* CDDIS format used higher polynom degree**

Only 2 GHz frequency observation , 400 MHz observation used only to compute the ionosphere correction

Implementation into Bernese GPS software

Bernese GPS software – developed in AIUB

Input DORIS data: CDDIS

First step: Old 2.0 format data processing, all corrections applied

Second step: format 2.1 data processing, beacon frequency offset and troposphere estimation

Transformation of Range rate to difference between two pseudoranges

$\Delta R = - T V$

GPS – like approach

One DORIS observation is divided into two parts (two pseudoobservations):

Beginning: 100 km new ambiguity flag

End: 100 km + observation

$\Phi_1 = \rho(t_1) + A \equiv 0$

$\Phi_2 = \rho(t_2) + A$

$\Delta\Phi \equiv \Phi_2 - \Phi_1 = \rho(t_2) - \rho(t_1)$

- **Constant 100 km is used to have always a positive value**
- **Ambiguities A are eliminated before NEQ inversion**
- **In principle is possible in the case of new receivers use phase –like processing**

Beginning: 100 km new ambiguity flag

Next: 100 km + observation1

Next: 100 km + observation1 + observation2

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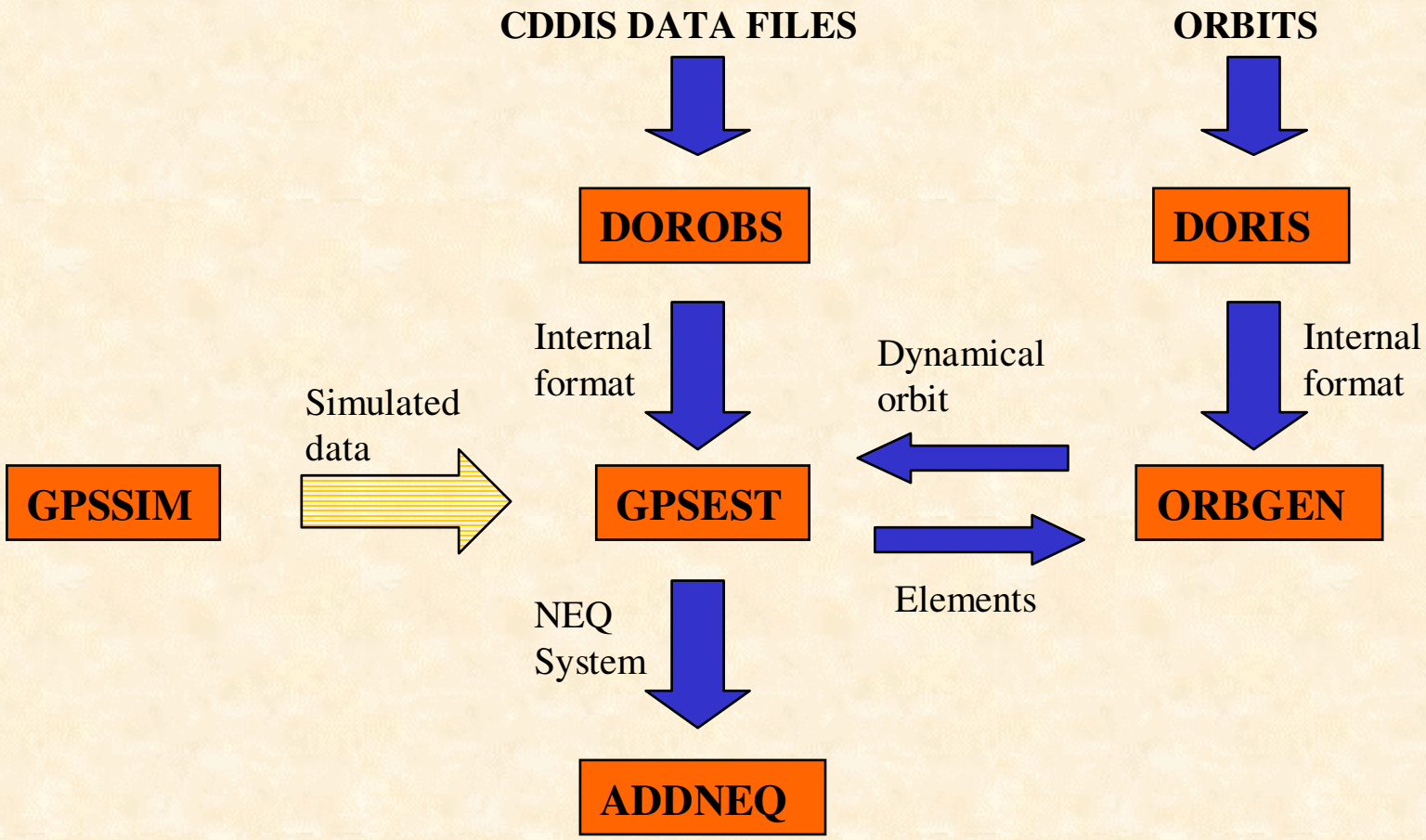
DORIS in Bernese software



Parameter estimation tests

- **Processed data: Jason june 2002, Jason may 2003, Topex may 2003, Spot 2 may 2003**
- **Network and beacon frequency estimation: POE orbit fixed, CDDIS troposphere, Network + Beacon Frequency estimated**
- **Orbit estimation (Topex & Jason): Monthly Network estimates fixed, CDDIS troposphere, GPS Dynamic orbit model, beacon frequency estimated. Some additional estimates with low constrained network.**
- **Troposphere estimation: Orbit fixed or estimated, Beacon frequency fixed or estimated, network fixed, troposphere estimated**

Network Estimation

SOLUTION COMPARISON	Complete Earth surface			´South Atlantic´ area excluded		
	Lat. (cm)	Long.(cm)	Height(cm)	Lat.(cm)	Long. (cm)	Height(cm)
Jmay03 - IGN	18.6	6.5	14.3	11.2	5.7	13.9
Jmay03-Jjun02	10.8	6.9	6.2	4.9	6.2	5.2
Jmay03-Tmay03	15.8	6.2	8.1	4.8	5.2	4.9
Tmay03 - IGN	7.0	3.8	6.9	X	X	X
S2may03 - IGN	8.2	3.2	6.5	X	X	X
Tmay03-S2may03	2.6	4.0	3.1	X	X	X
S2Tmay03- IGN	8.1	2.8	6.2	X	X	X

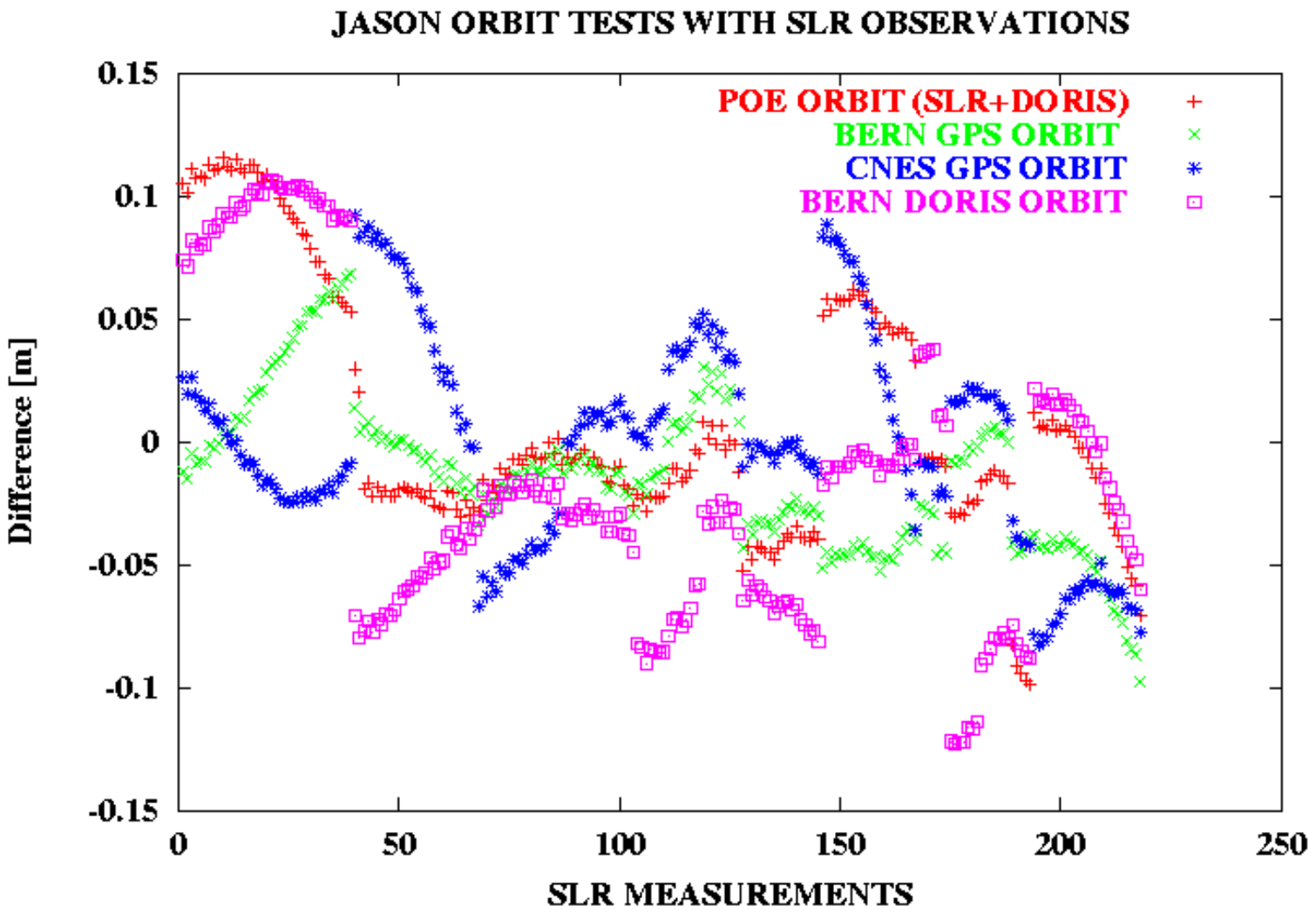
Repeatability of individual weakly solutions ~ 4-5 cm in 3D position

JASON ORBIT ESTIMATION, FIXED NETWORK

DIFFERENCE BETWEEN	After Helmert transformation			Before Helmert transformation		
	Radial (cm)	Along (cm)	Out (cm)	Radial (cm)	Along (cm)	Out (cm)
10. 5. 2003	2.1	5.2	3.7	4.3	5.2	9.3
15. 5. 2003	3.1	7.3	9.7	3.2	7.6	13.3
20. 5. 2003	3.0	7.6	4.9	3.7	7.7	8.2
25. 5. 2003	2.1	5.3	5.8	3.3	5.6	9.4
30. 5. 2003	2.2	6.4	4.4	3.7	6.7	8.6
average	2.5	6.4	5.7	3.6	6.6	9.8

TOPEX ORBIT ESTIMATION, FIXED NETWORK

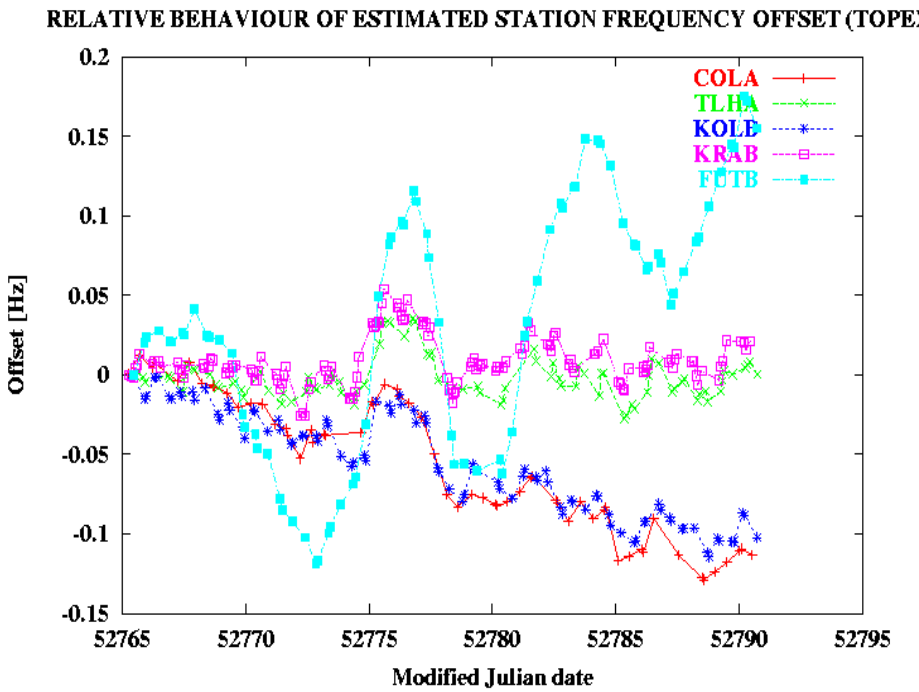
DIFFERENCE BETWEEN	After Helmert transformation			Before Helmert transformation		
	Radial (cm)	Along (cm)	Out (cm)	Radial (cm)	Along (cm)	Out (cm)
10. 5. 2003	2.2	5.5	4.3	4.3	5.6	12.2
15. 5. 2003	3.2	7.9	7.6	4.3	8.0	9.5
20. 5. 2003	3.1	7.9	6.2	4.1	8.3	12.1
25. 5. 2003	2.1	4.8	5.7	2.6	5.9	6.1
30. 5. 2003	2.6	6.2	4.8	4.4	7.5	12.2
average	2.6	6.5	5.7	3.9	7.1	10.4

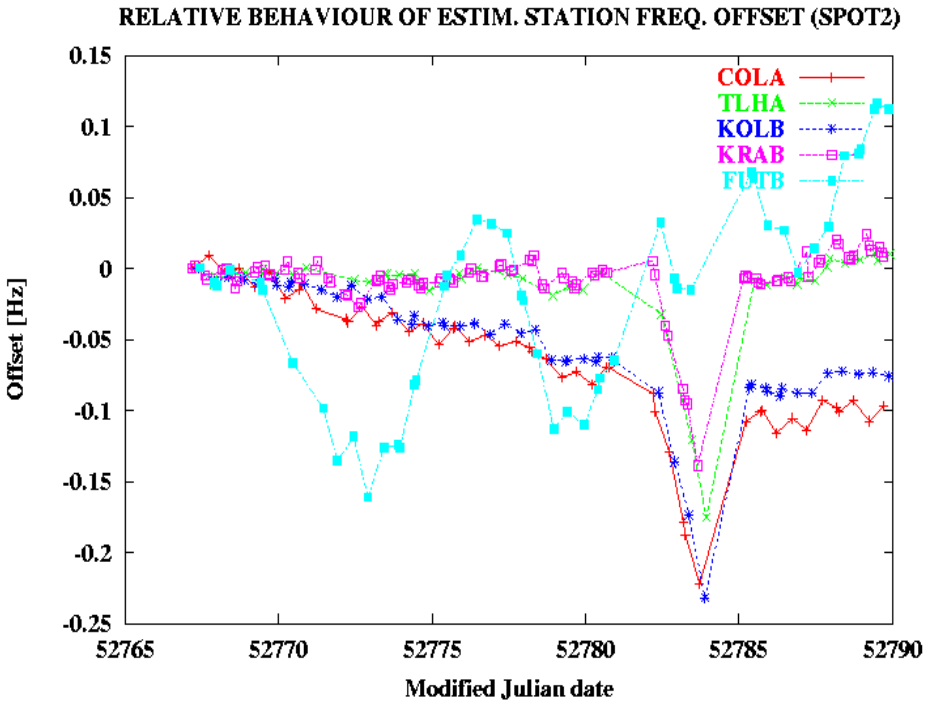


Type of orbit	RMS (cm)
Bern GPS	3.3
CNES GPS	4.2
POE	5.0
Bern DORIS	6.3

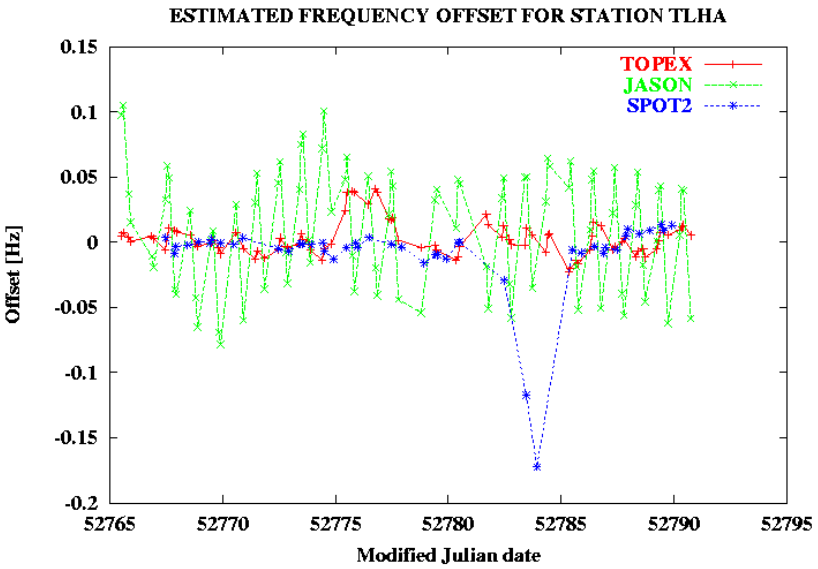
Beacon frequency offset estimation

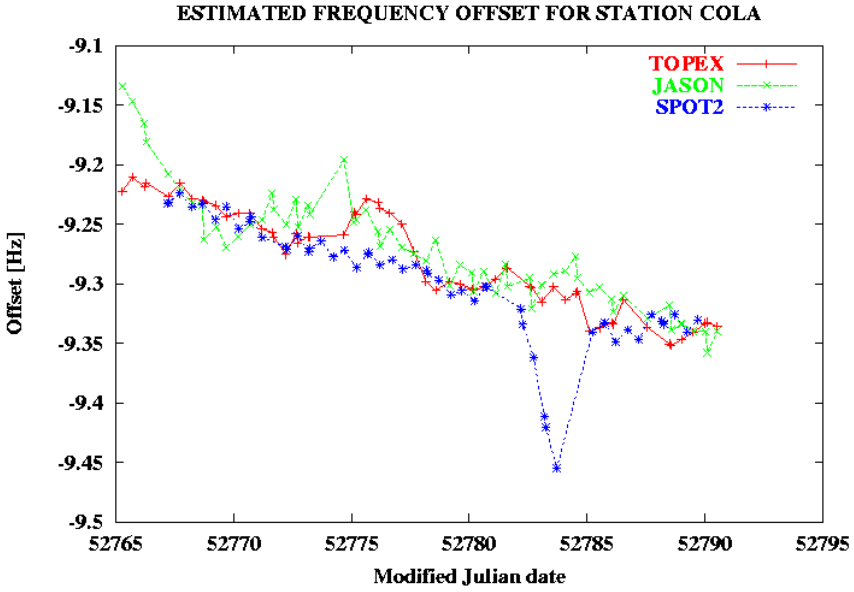
Topex and Spot 2 solutions for chosen stations

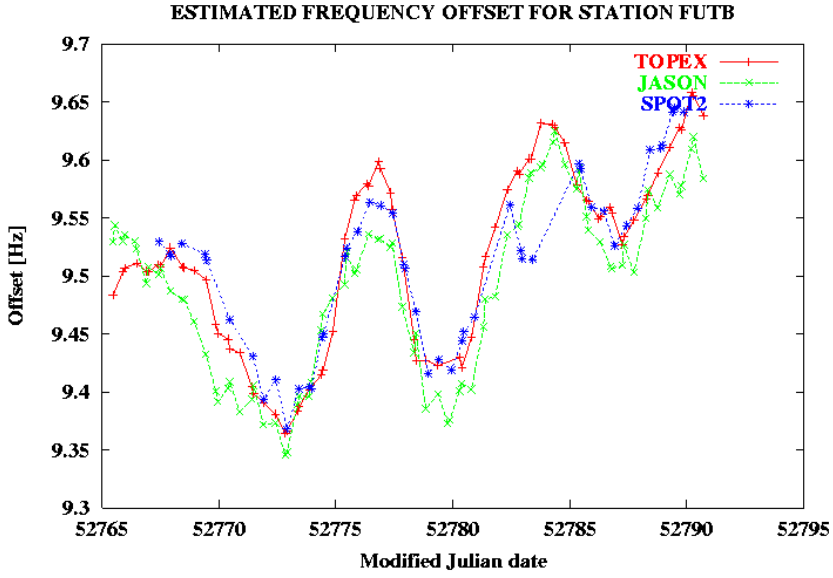




Topex, Spot 2 and Jason solutions comparison







Troposphere estimation

- **APRIORI MODEL: Saastamoinen with dry Niel mapping funkcion**
- **ESTIMATED: wet Niel mapping function, Constant behaviour during the path**
- **RMS of Troposphere Zenith delay ~ 1 cm**
- **Relative difference from CDDIS correction ~ 1%**

Orbit estimated with different troposphere