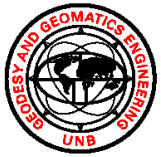

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THE GPS BROADCAST ORBITS: AN ACCURACY ANALYSIS

R.B. Langley[1], H. Jannasch[1], B. Peeters[1,2], and S. Bisnath[1]

[1]Geodetic Research Laboratory
University of New Brunswick
Fredericton, N.B., Canada

[2]Faculty of Aerospace Engineering
Delft University of Technology
Delft, The Netherlands

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Outline

- Motivation
- Goals
- Approach
- Results
- Web Display
- U.S. Space Command Reports
- Anticipated Broadcast Orbit Improvements
- Conclusions and Future Work

Motivation

- Day-to-day accuracy of navigation message ephemerides (broadcast orbits) not readily available
- Independent assessment of ephemeris error in Standard Positioning Service error budget considered useful
- Broadcast orbit accuracies needed to assess errors in future U.S. and Canadian Wide Area Augmentation Systems (WAASs)

Goals

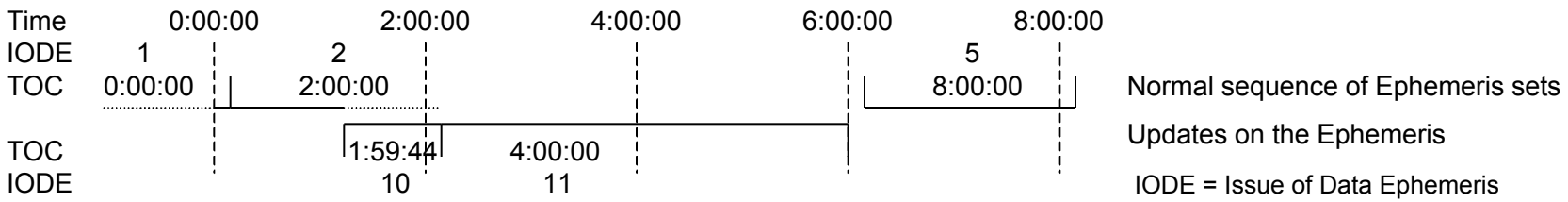
- Develop algorithms and software to automatically compute (once per day) the broadcast orbit errors and meaningful statistics
- Develop algorithms and software to automatically compute (once per day) the WAAS orbit correction errors and meaningful statistics
- Post the analysis results on the World Wide Web

Approach

- Accuracies are assessed through comparisons with orbit products provided by the International GPS Service (IGS)
- Separate assessments carried out with IGS predicted, rapid, and final orbits
- Broadcast orbits obtained from “auto” RINEX navigation files provided by Scripps Orbit and Permanent Array Center (SOPAC) Web site
- IGS orbits obtained from the IGS Central Bureau ftp site

Approach, cont'd.

- Broadcast orbits evaluated according to ICD-GPS-200
- Ephemeris sets are normally updated every 2 hours
- Ephemeris set considered valid from 2 hours before Time of Ephemeris (TOE) until 2 hours after TOE
- But a particular set is first used when it was first transmitted = Transmission Time of Message (TTOM), typically 1:59:42 before TOE



Approach, cont'd.

- Antenna phase centre offset from spacecraft centre of mass:

Block II/IIA*: $x_{pc} = 0.279$, $y_{pc} = 0.000$, $z_{pc} = 1.023$ metres
Block IIR*: $x_{pc} = 0.279$, $y_{pc} = 0.000$, $z_{pc} = 1.023$ metres

- Standard body-fixed frame to WGS 84 conversion applied

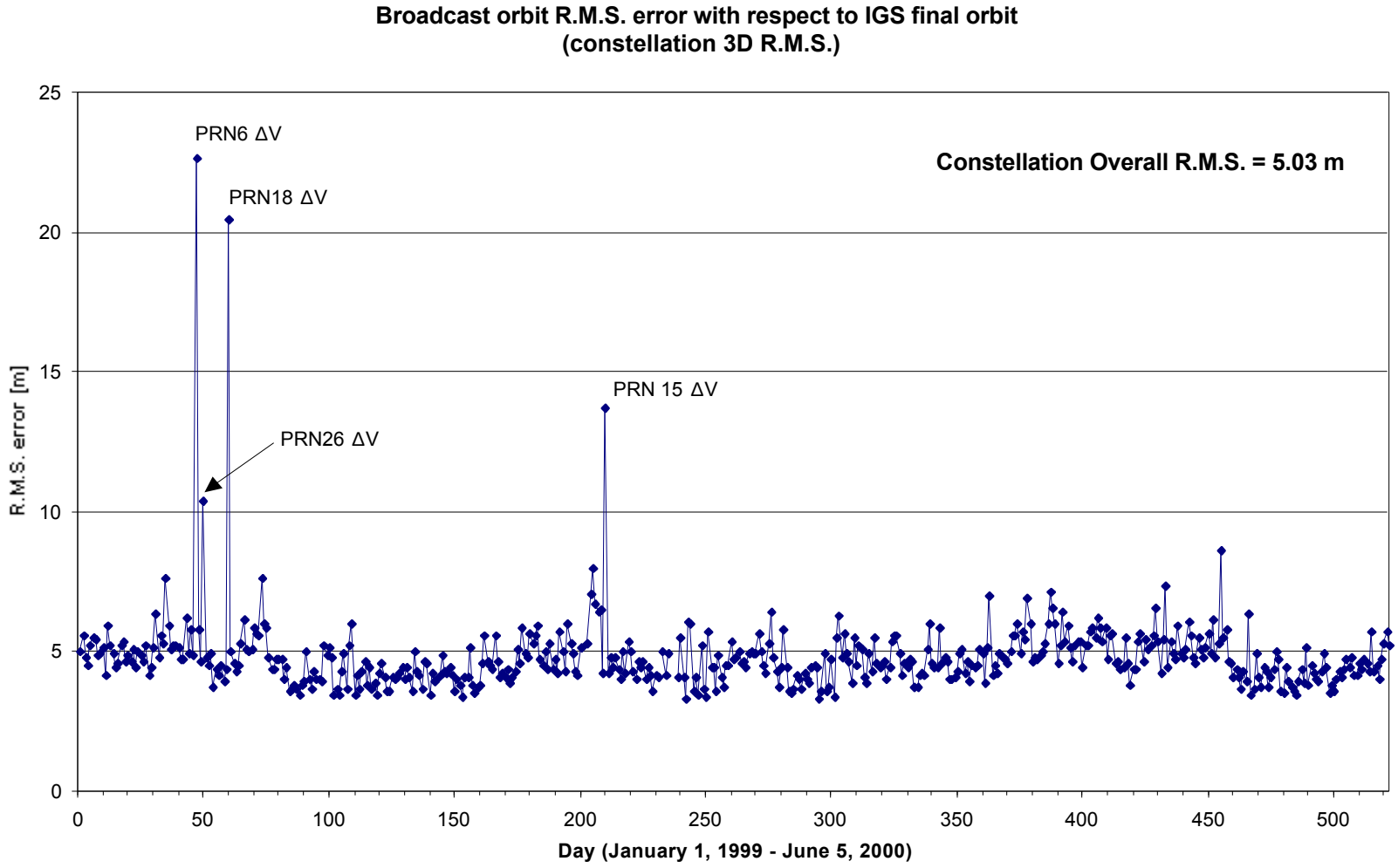
- No datum transformation; WGS 84 assumed consistent with IGS frame (ITRF)

*NIMA uses
Block II/IIA*: $x_{pc} = 0.2794$, $y_{pc} = 0.0000$, $z_{pc} = 0.9519$ metres
Block IIR*: $x_{pc} = 0.0000$, $y_{pc} = 0.0000$, $z_{pc} = 1.1725$ metres

Approach, cont'd.

- Broadcast orbits computed every 15 minutes at the IGS orbit epochs
- Differences between broadcast orbit x, y, z values and IGS values computed = dx, dy, dz
- For each day, the minimum, maximum, and r.m.s. differences, dx, dy, dz for each satellite are computed
- 3D-error: $\sqrt{dx^2 + dy^2 + dz^2}$ also computed
- Results posted to Web

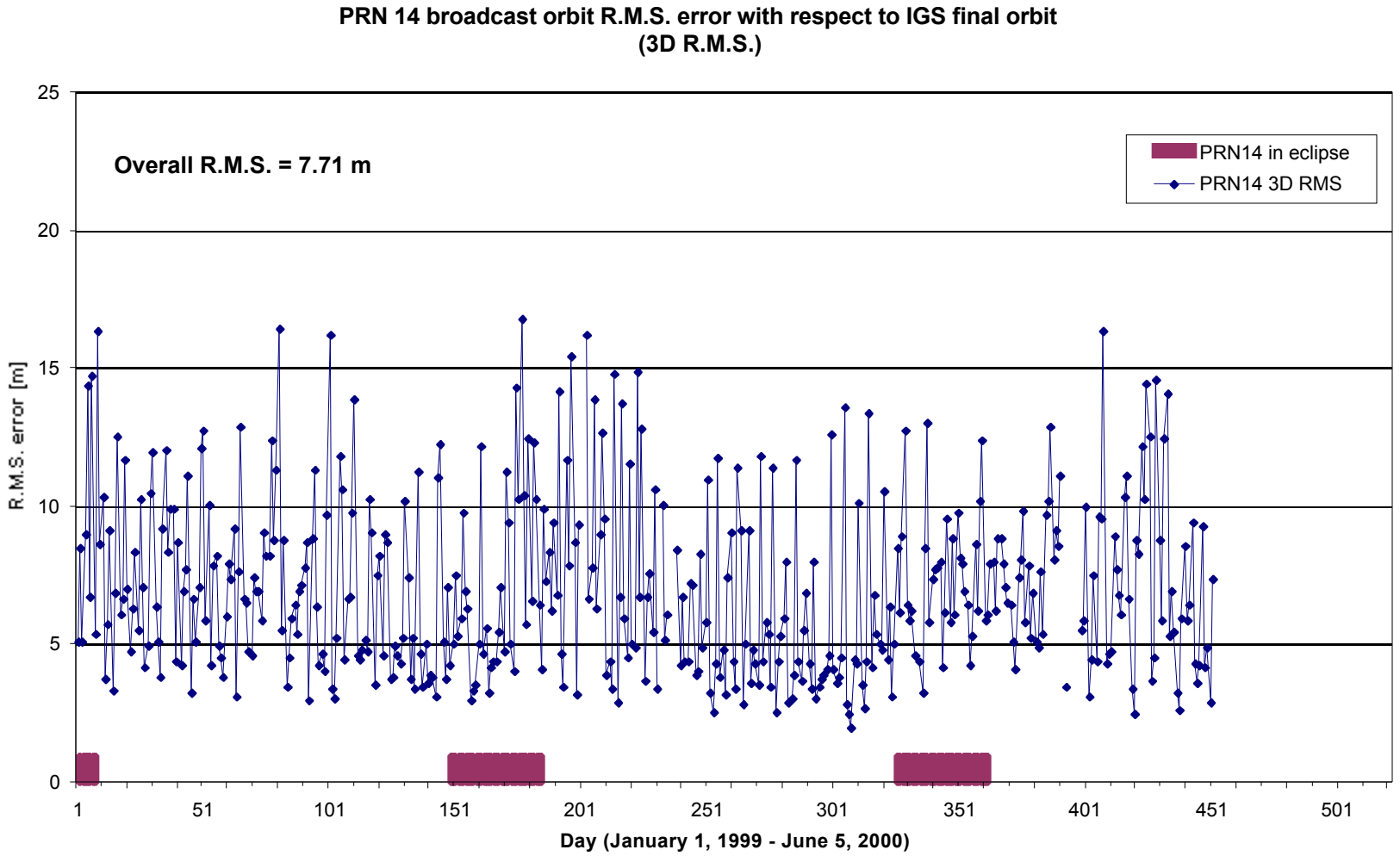
Constellation Daily 3D R.M.S. Error



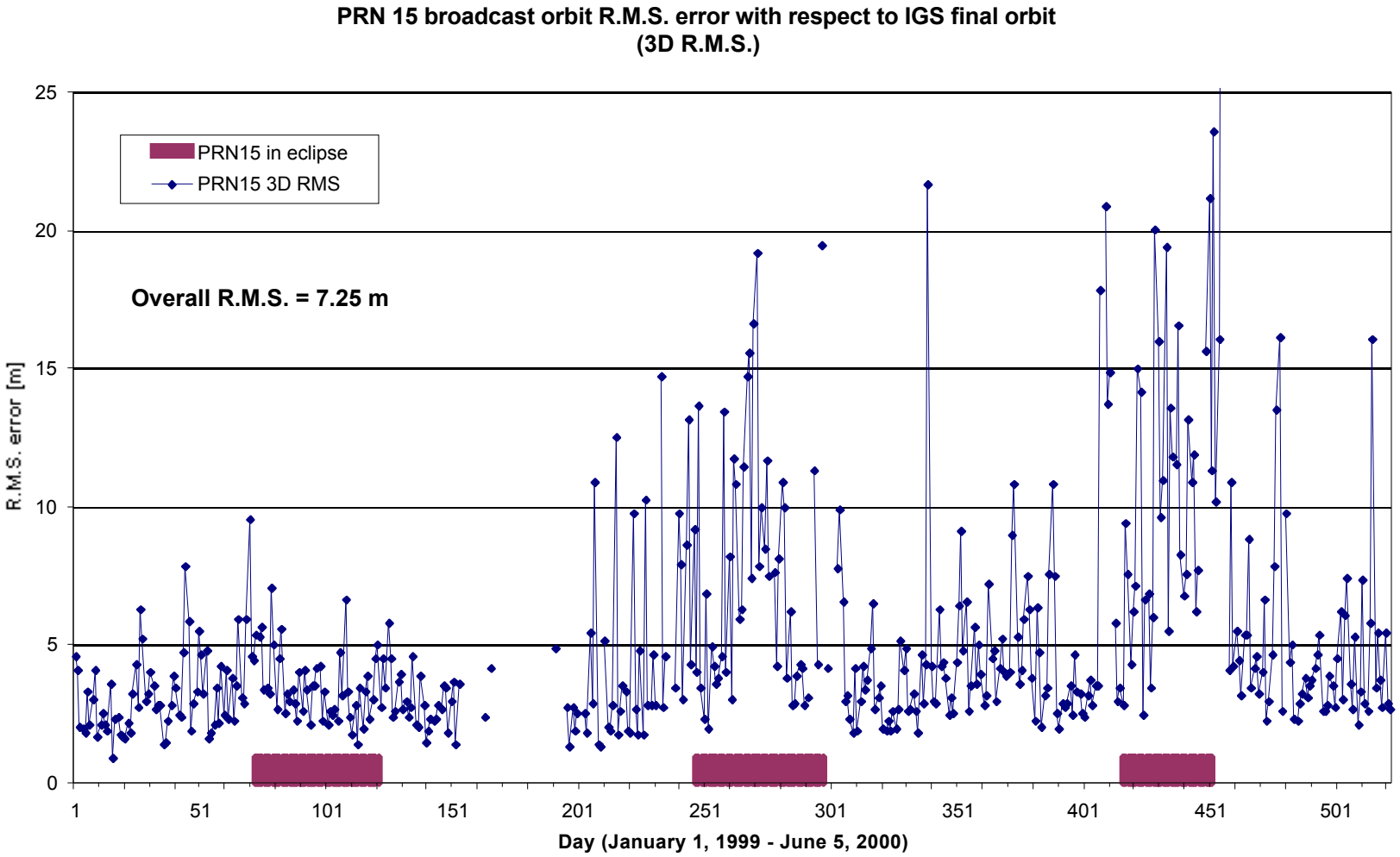
Some Problem Satellites

- PRN02 - possible problems in eclipse
- PRN14 - large ranging errors; retired 14/4/00
- PRN15 - reaction wheel problems in eclipse
- PRN16 - clock problems
- PRN18 - reaction wheel problems in eclipse
- PRN23 - solar array slewing in eclipse

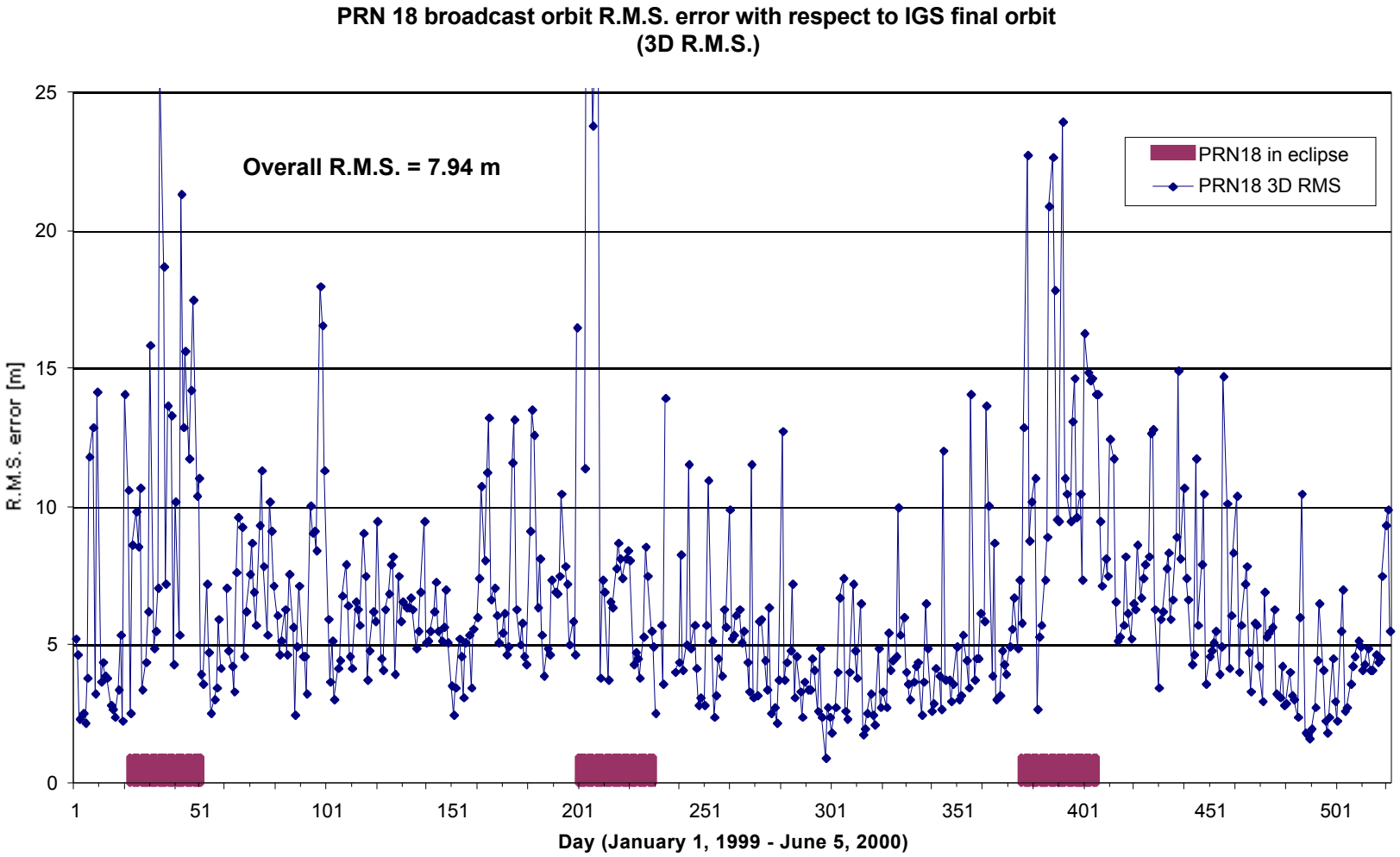
PRN14 Daily 3D R.M.S. Error



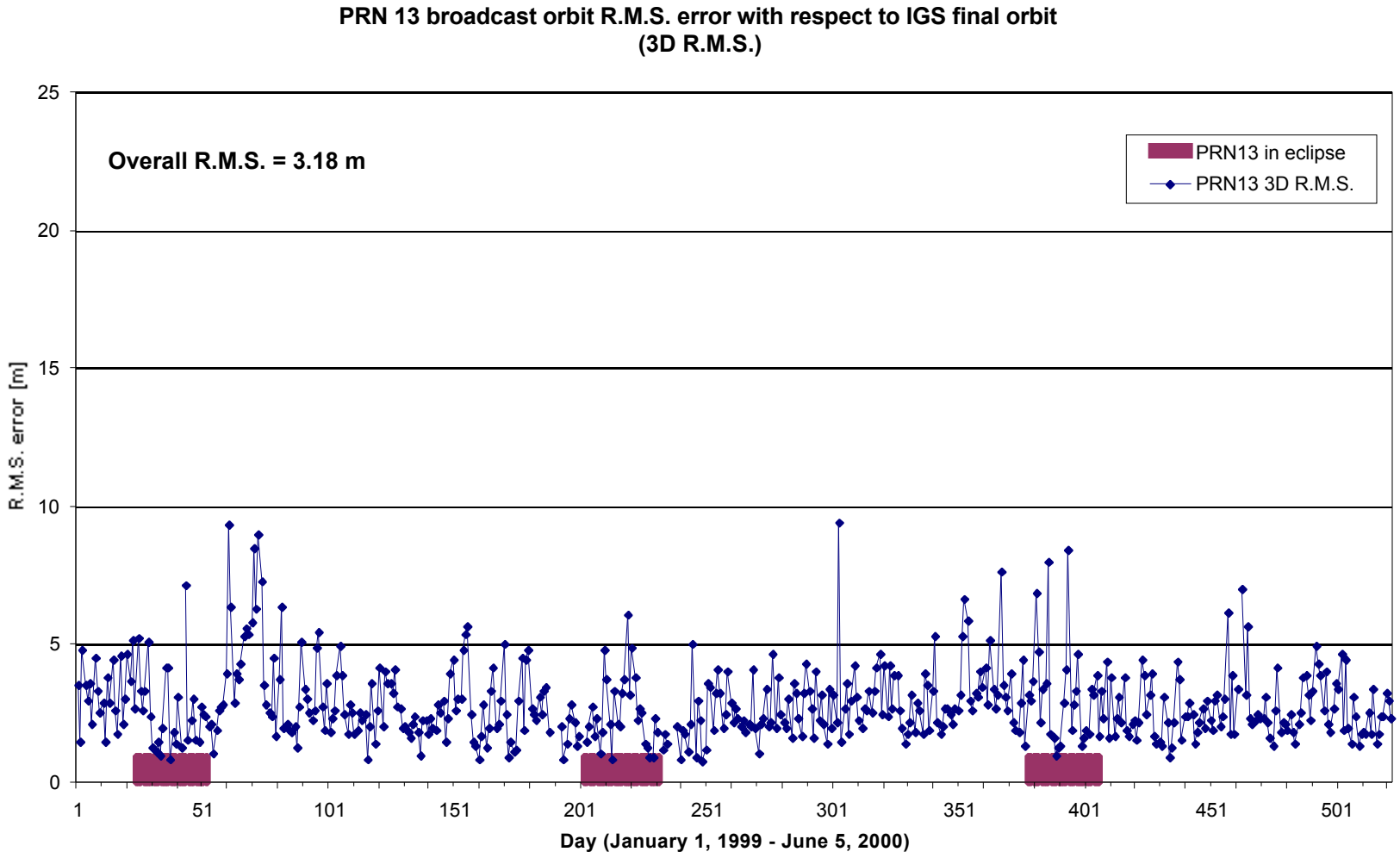
PRN15 Daily 3D R.M.S. Error



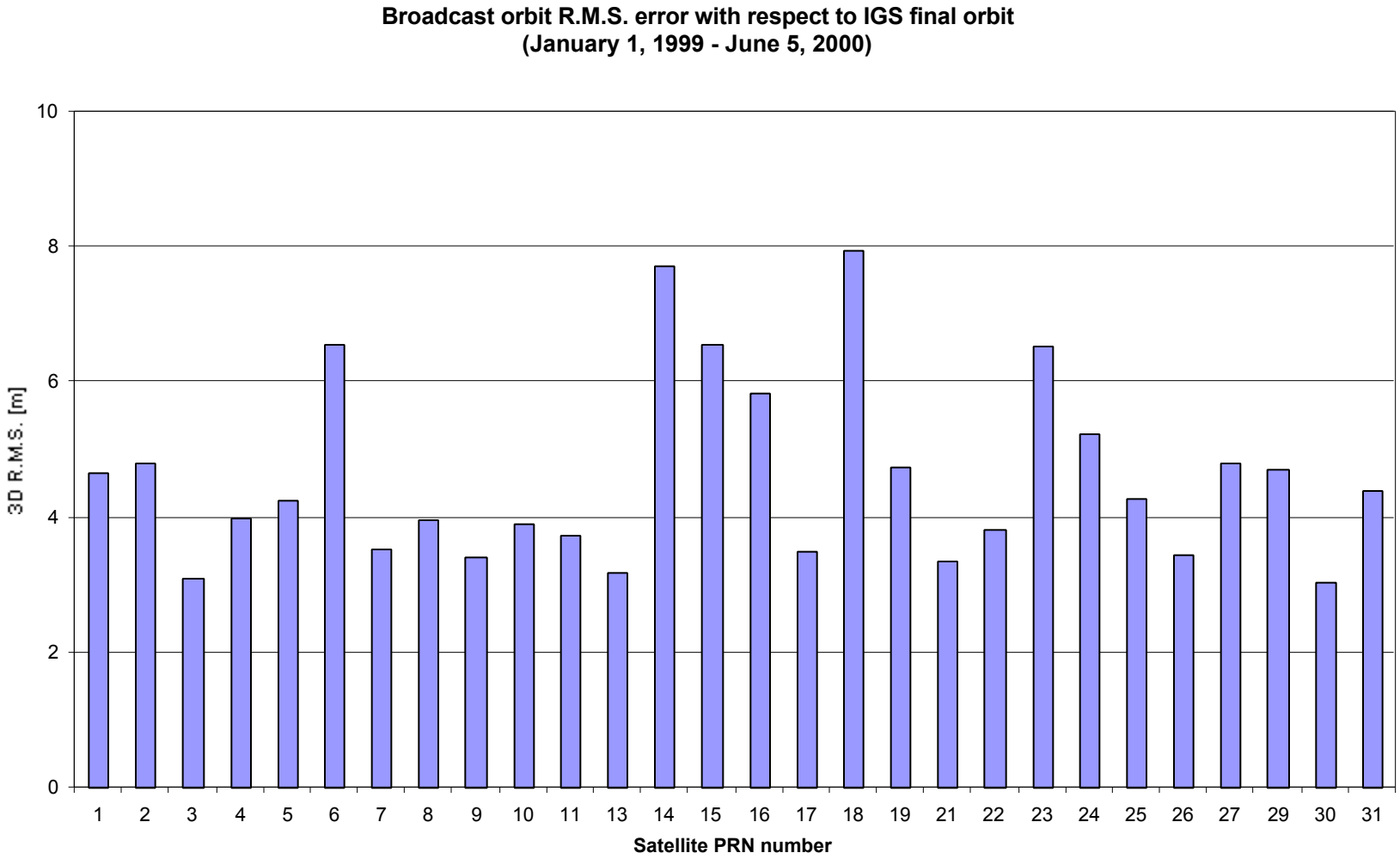
PRN18 Daily 3D R.M.S. Error



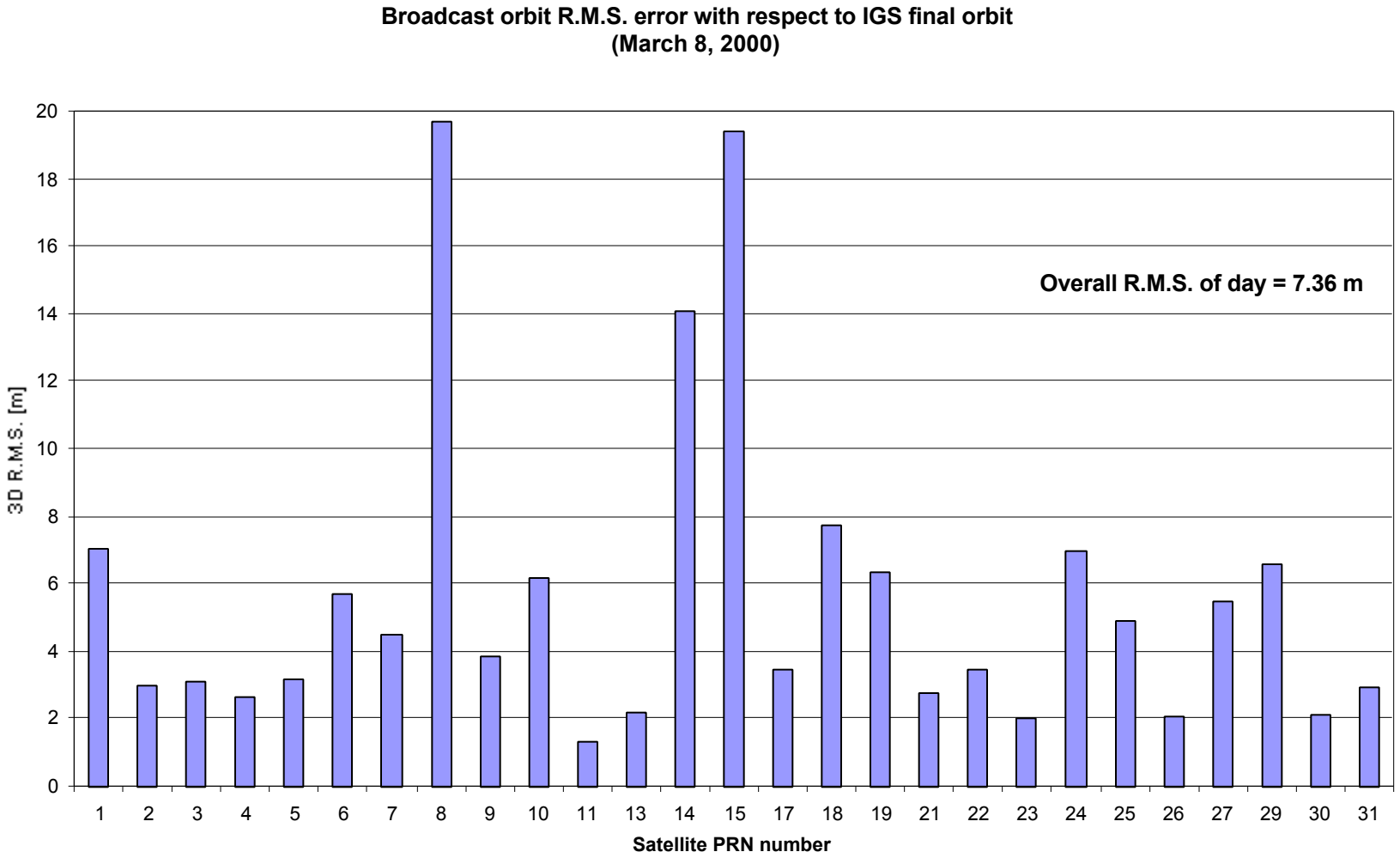
PRN13 Daily 3D R.M.S. Error



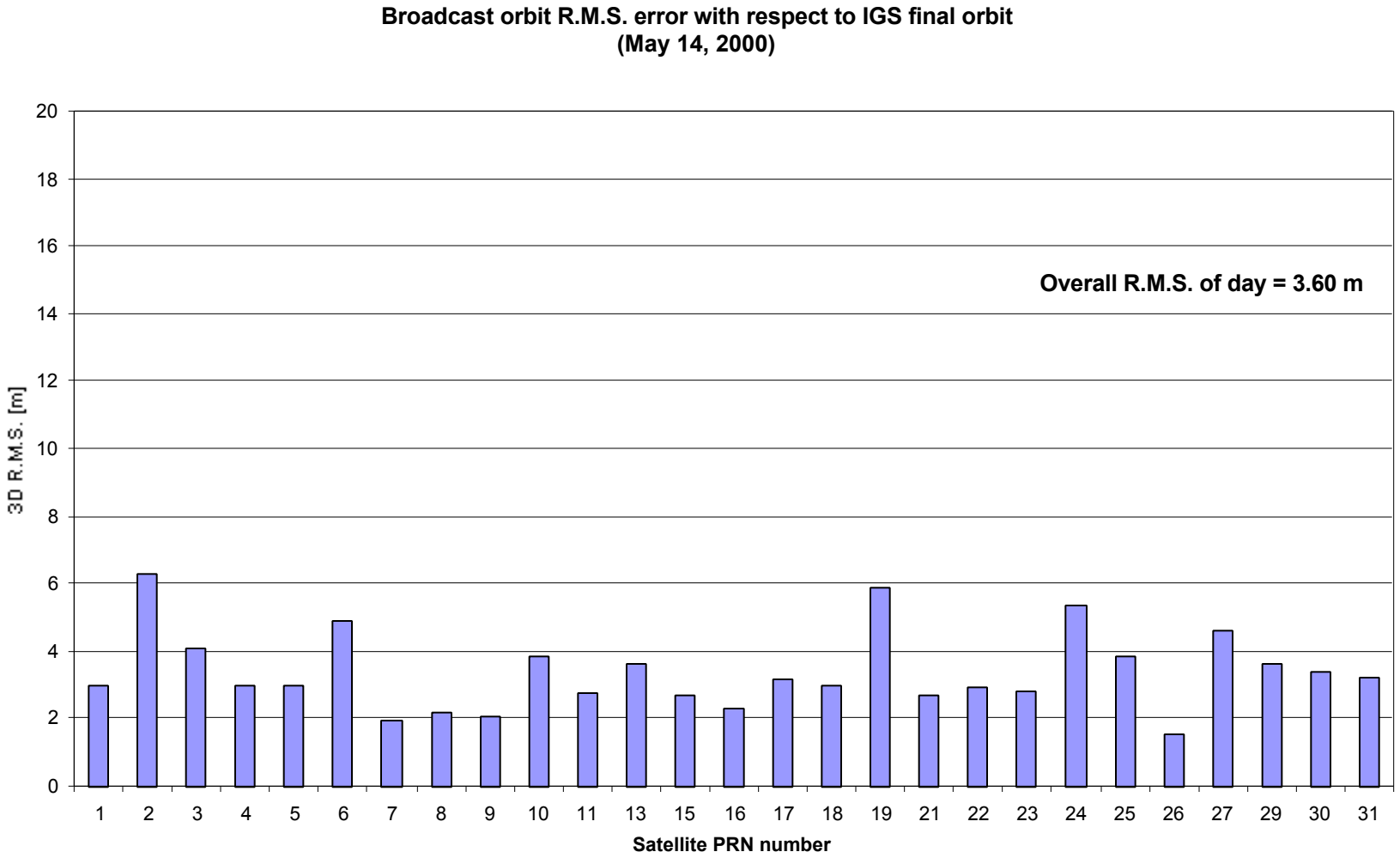
3D R.M.S. Error by Satellite



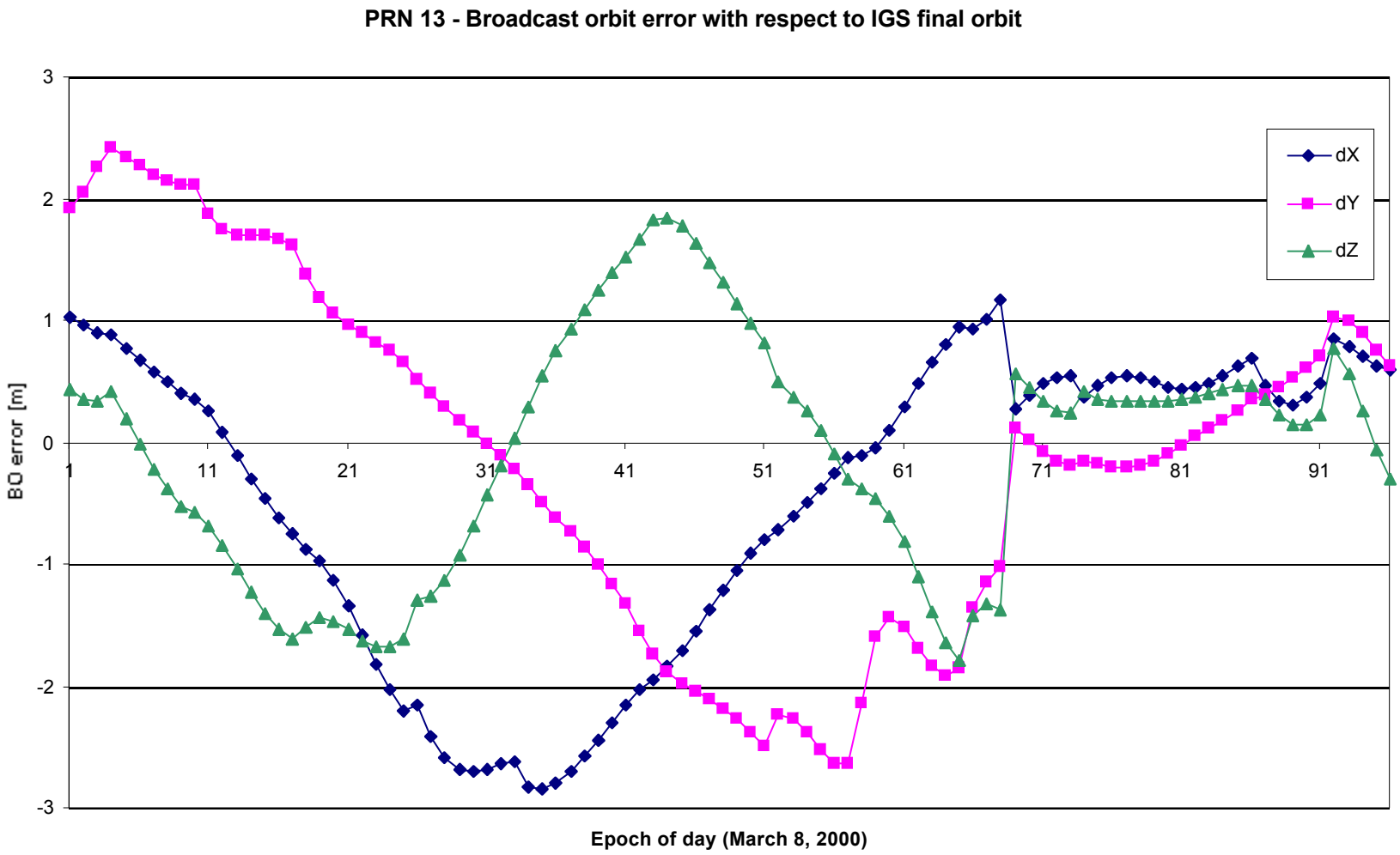
3D R.M.S. Error on March 8, 2000



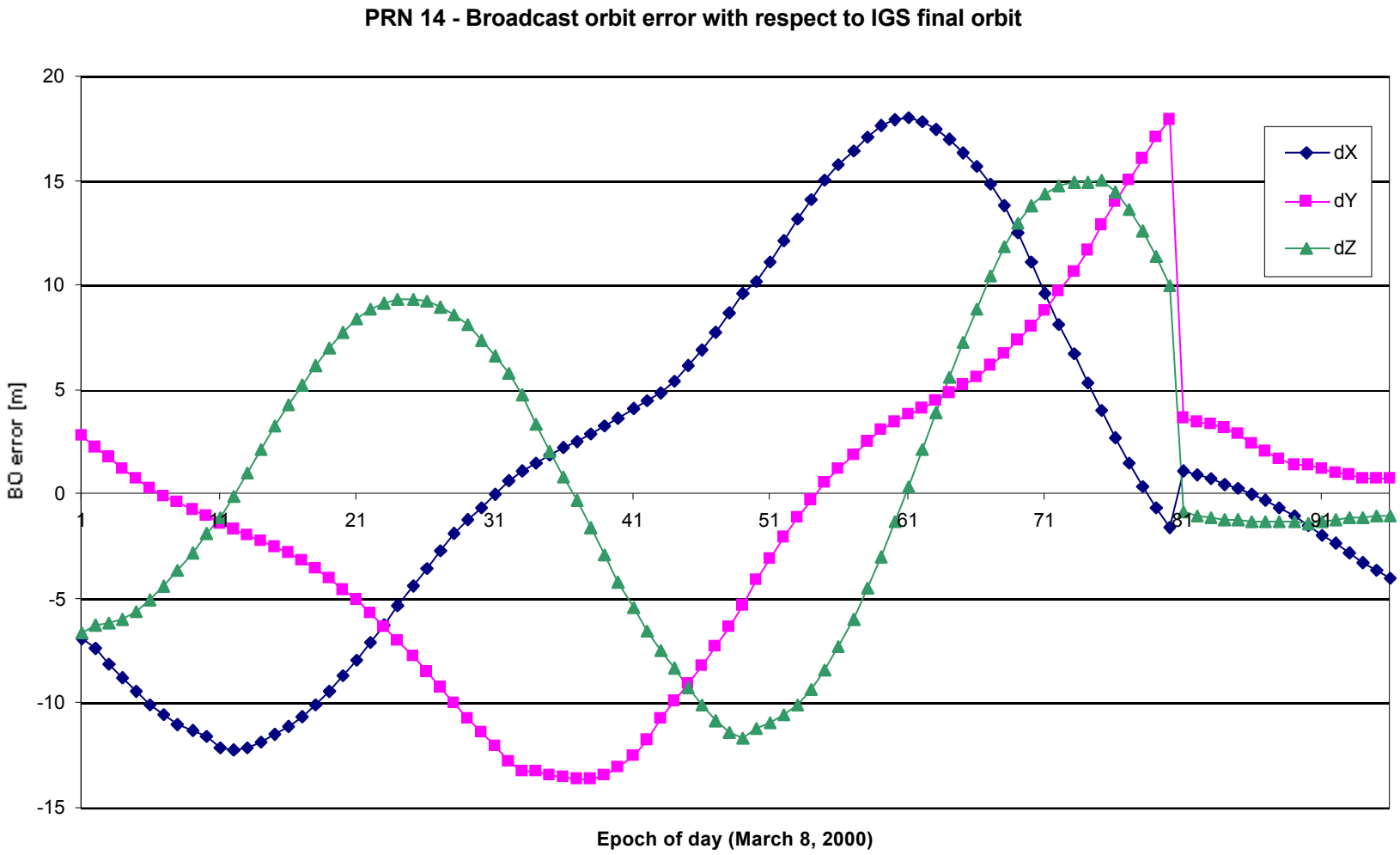
3D R.M.S. Error on May 14, 2000



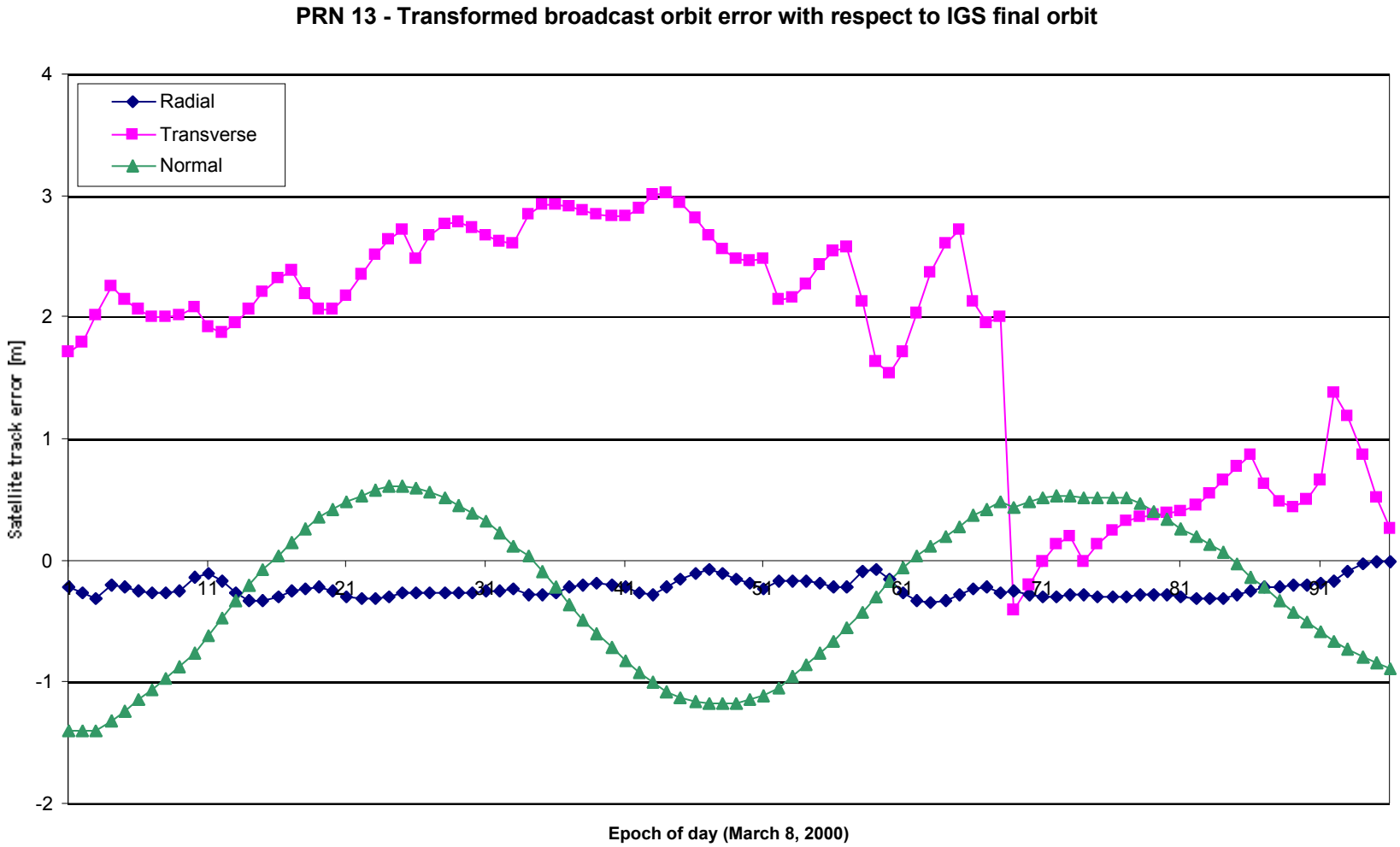
PRN13 XYZ Errors on March 8, 2000



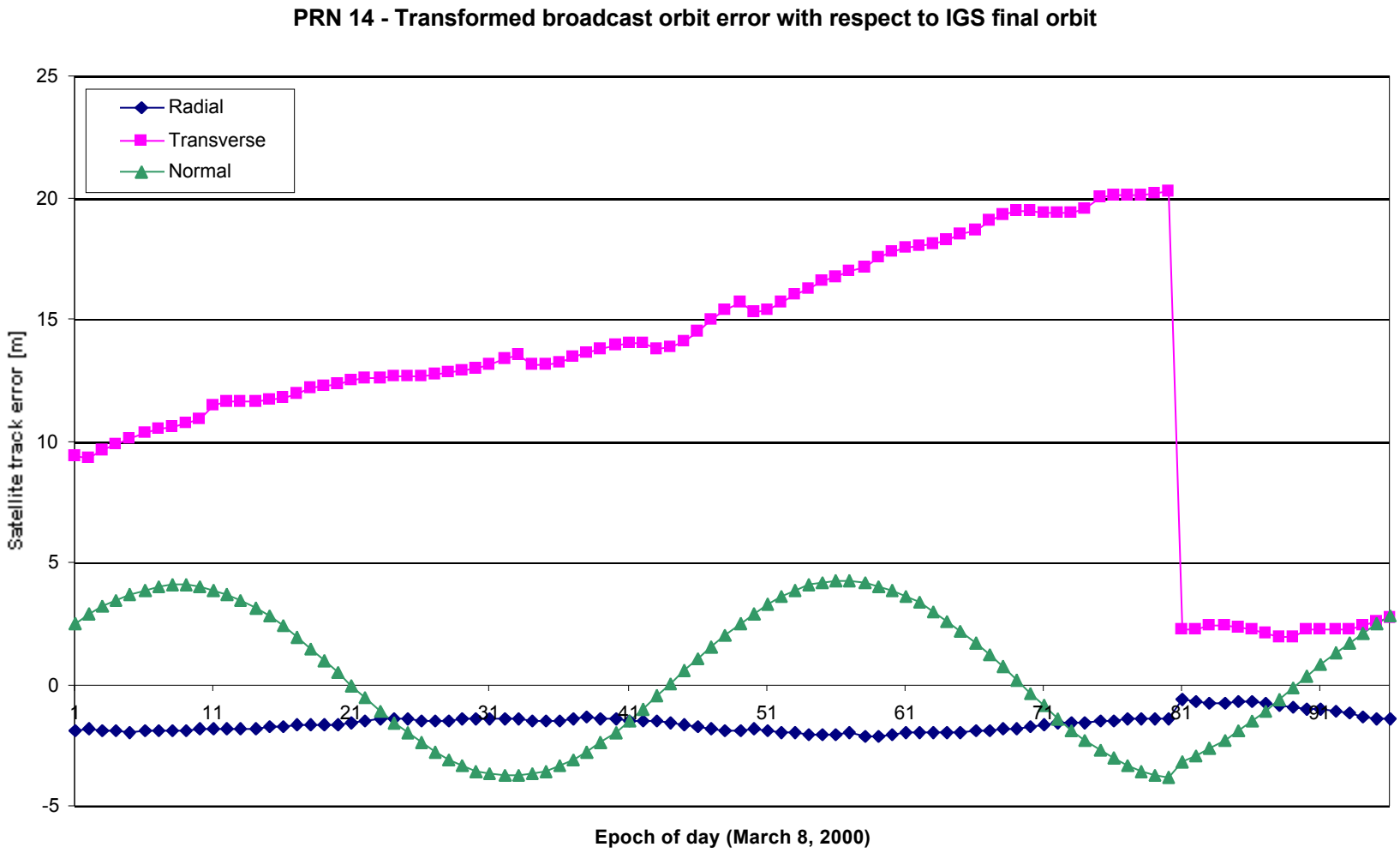
PRN14 XYZ Errors on March 8, 2000



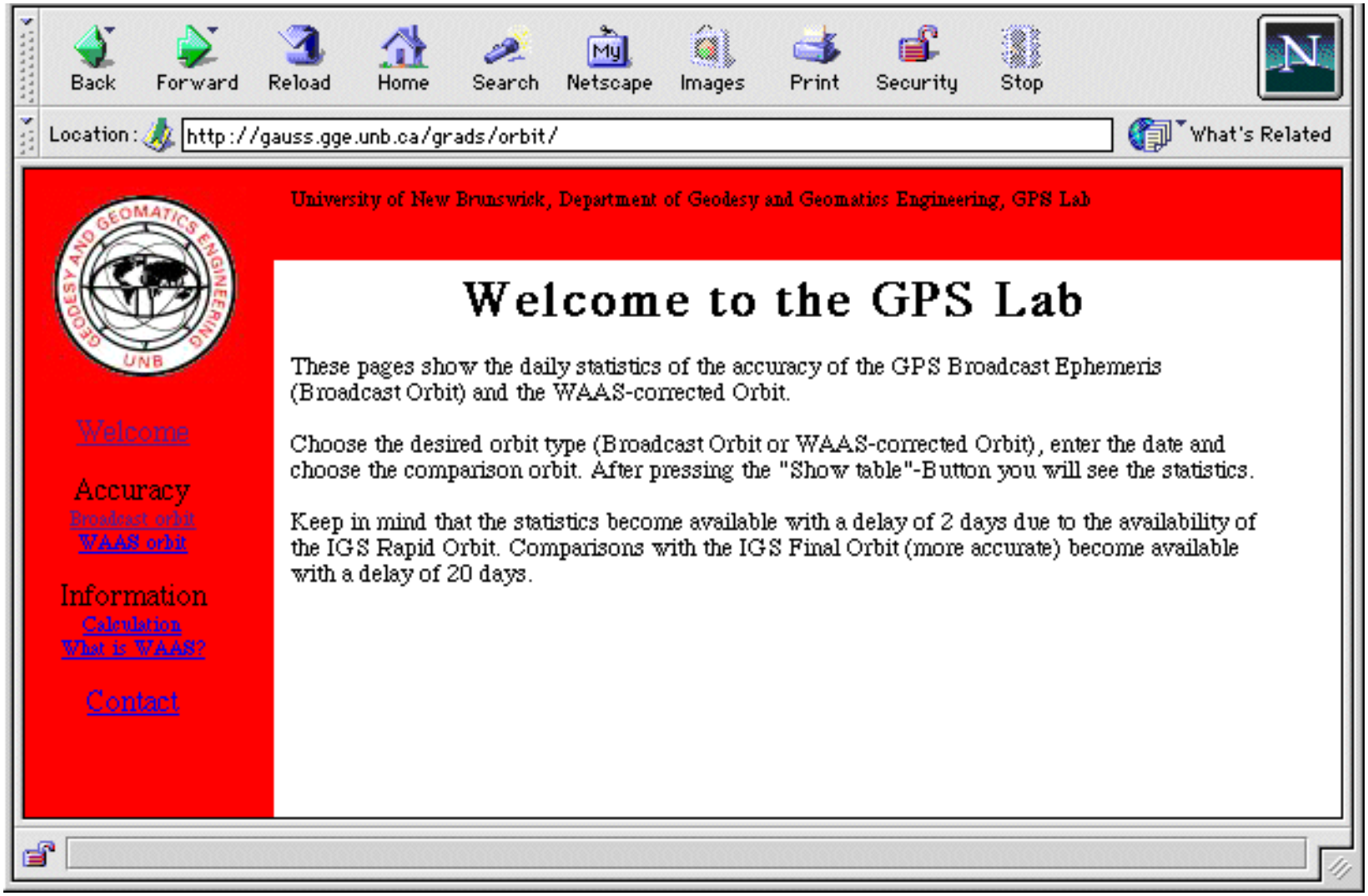
PRN13 RTN Errors on March 8, 2000



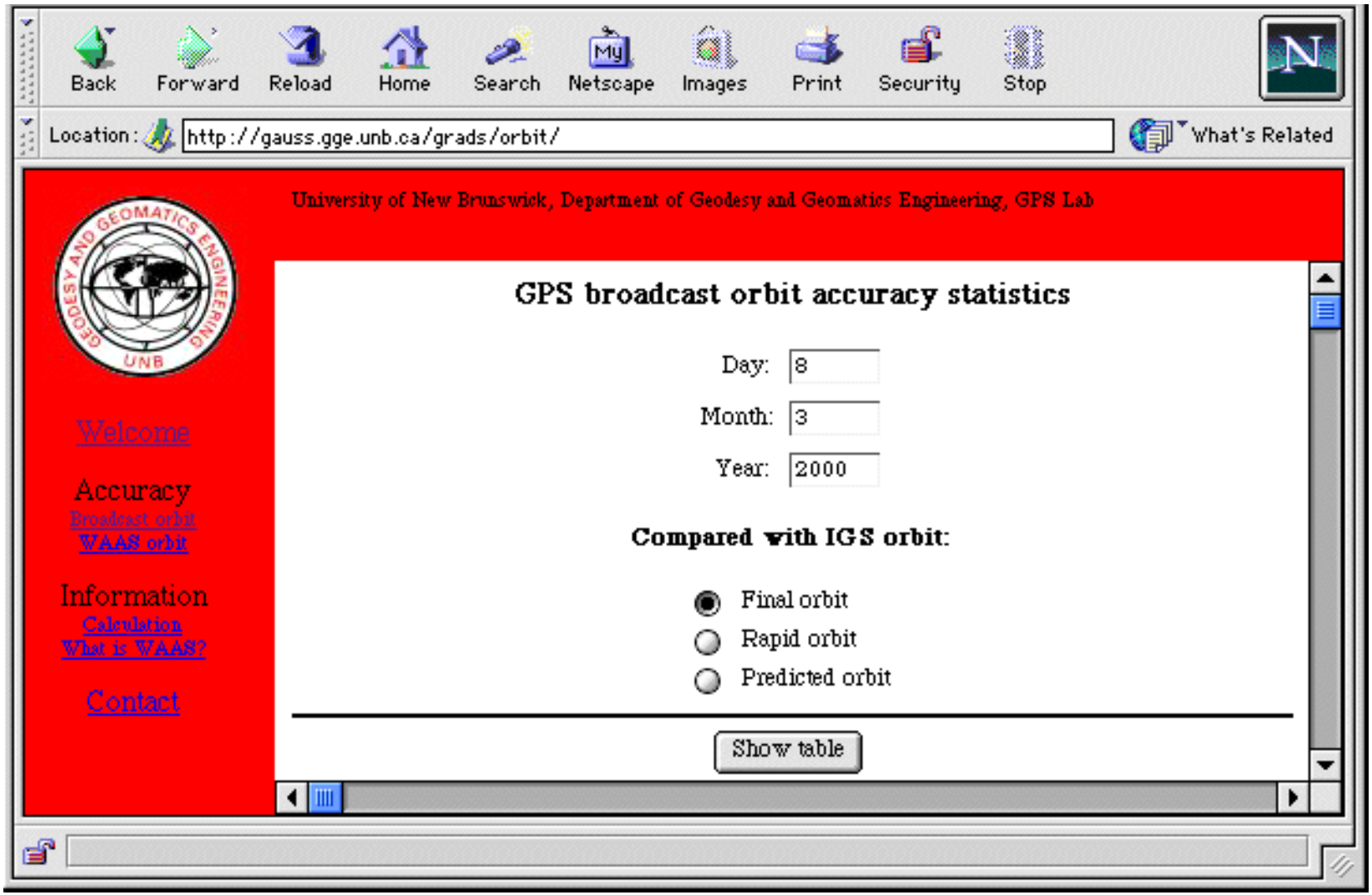
PRN14 RTN Errors on March 8, 2000



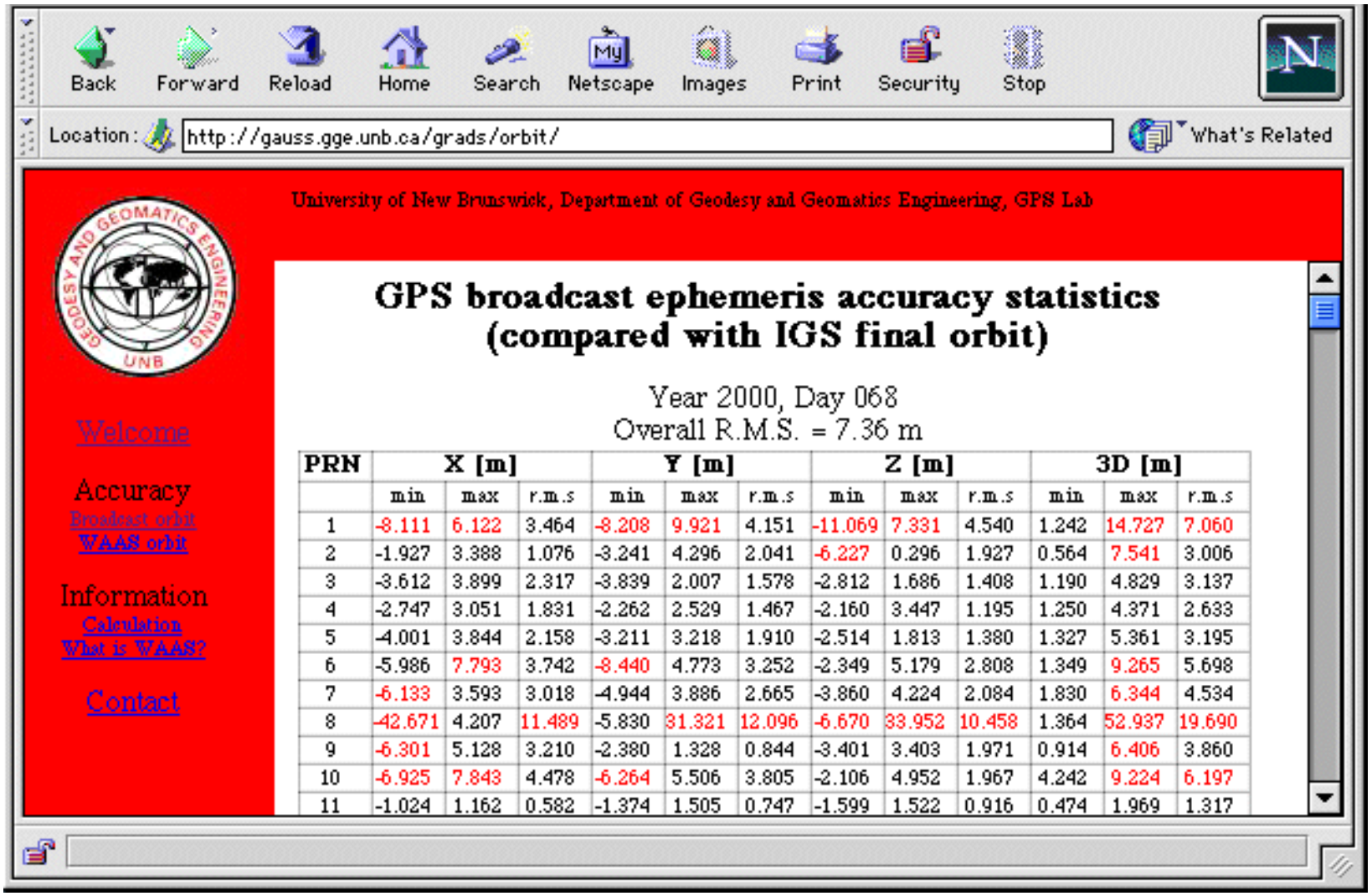
Web Display


Back
Forward
Reload
Home
Search
Netscape
Images
Print
Security
Stop
Location :
http://gauss.gge.unb.ca/grads/orbit/
What's Related
University of New Brunswick, Department of Geodesy and Geomatics Engineering, GPS Lab
Welcome to the GPS Lab
These pages show the daily statistics of the accuracy of the GPS Broadcast Ephemeris (Broadcast Orbit) and the WAAS-corrected Orbit.
Choose the desired orbit type (Broadcast Orbit or WAAS-corrected Orbit), enter the date and choose the comparison orbit. After pressing the "Show table"-Button you will see the statistics.
Keep in mind that the statistics become available with a delay of 2 days due to the availability of the IGS Rapid Orbit. Comparisons with the IGS Final Orbit (more accurate) become available with a delay of 20 days.
Welcome
Accuracy
Broadcast orbit
WAAS orbit
Information
Calculation
What is WAAS?
Contact

Web Display cont'd.

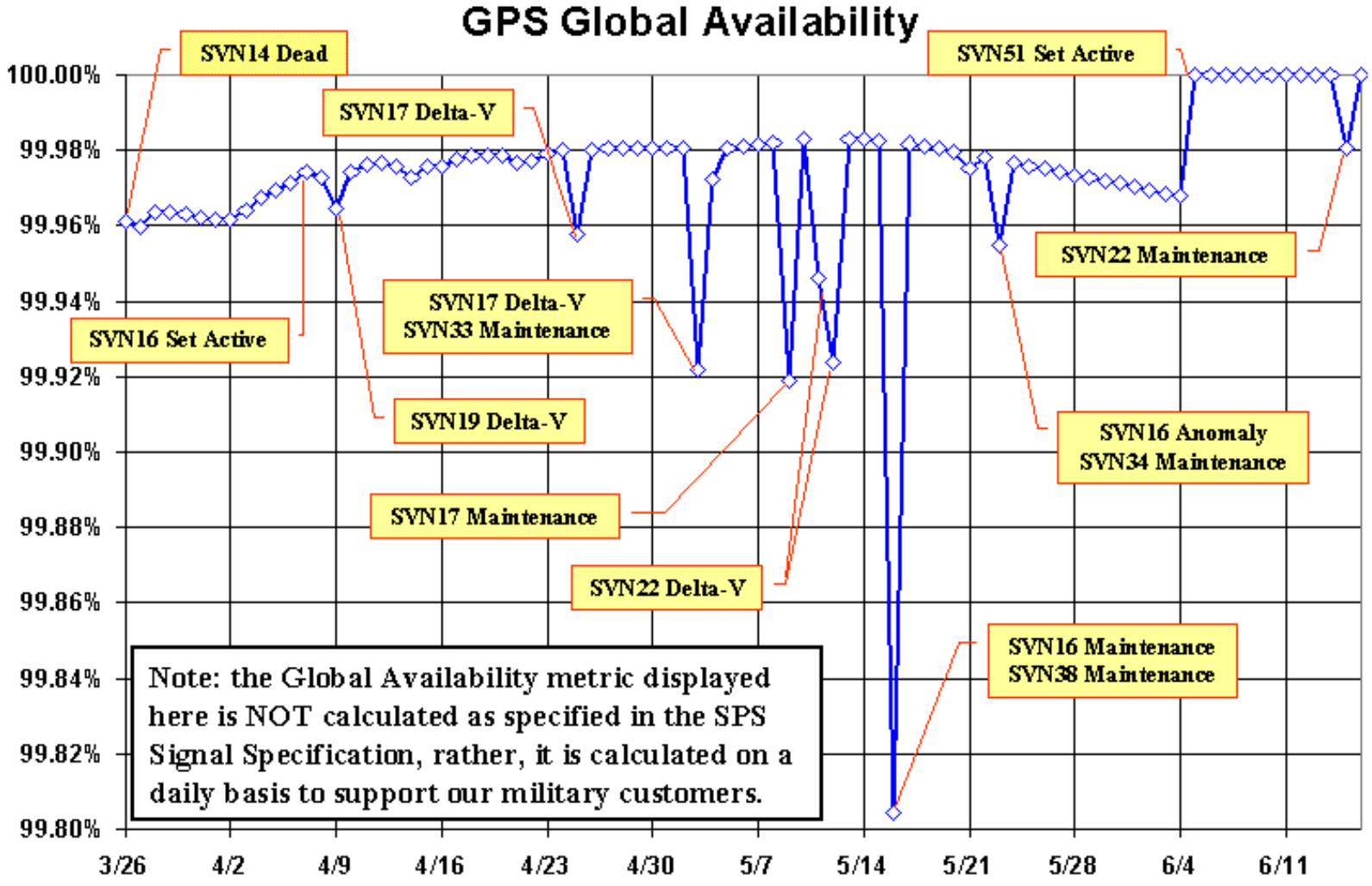


Web Display cont'd.



PRN	X [m]			Y [m]			Z [m]			3D [m]		
	min	max	r.m.s	min	max	r.m.s	min	max	r.m.s	min	max	r.m.s
1	-8.111	6.122	3.464	-8.208	9.921	4.151	-11.069	7.331	4.540	1.242	14.727	7.060
2	-1.927	3.388	1.076	-3.241	4.296	2.041	-6.227	0.296	1.927	0.564	7.541	3.006
3	-3.612	3.899	2.317	-3.839	2.007	1.578	-2.812	1.686	1.408	1.190	4.829	3.137
4	-2.747	3.051	1.831	-2.262	2.529	1.467	-2.160	3.447	1.195	1.250	4.371	2.633
5	-4.001	3.844	2.158	-3.211	3.218	1.910	-2.514	1.813	1.380	1.327	5.361	3.195
6	-5.986	7.793	3.742	-8.440	4.773	3.252	-2.349	5.179	2.808	1.349	9.265	5.698
7	-6.133	3.593	3.018	-4.944	3.886	2.665	-3.860	4.224	2.084	1.830	6.344	4.534
8	-42.671	4.207	11.489	-5.830	31.321	12.096	-6.670	33.952	10.458	1.364	52.937	19.690
9	-6.301	5.128	3.210	-2.380	1.328	0.844	-3.401	3.403	1.971	0.914	6.406	3.860
10	-6.925	7.843	4.478	-6.264	5.506	3.805	-2.106	4.952	1.967	4.242	9.224	6.197
11	-1.024	1.162	0.582	-1.374	1.505	0.747	-1.599	1.522	0.916	0.474	1.969	1.317

Satellite Incidents



Signal-in-Space Range Error

- Computed by GPS Control Segment
- Clock and ephemeris errors:

$$\mathrm{SISRE} = \sqrt{(\mathrm{R} - \mathrm{CLK})^2 + \frac{1}{49}\left(\mathrm{A}^2 + \mathrm{C}^2\right)}$$

where
R = radial ephemeris error
A = along-track ephemeris error
C = cross-track ephemeris error
CLK = clock error

Signal-in-Space Range Error Estimates

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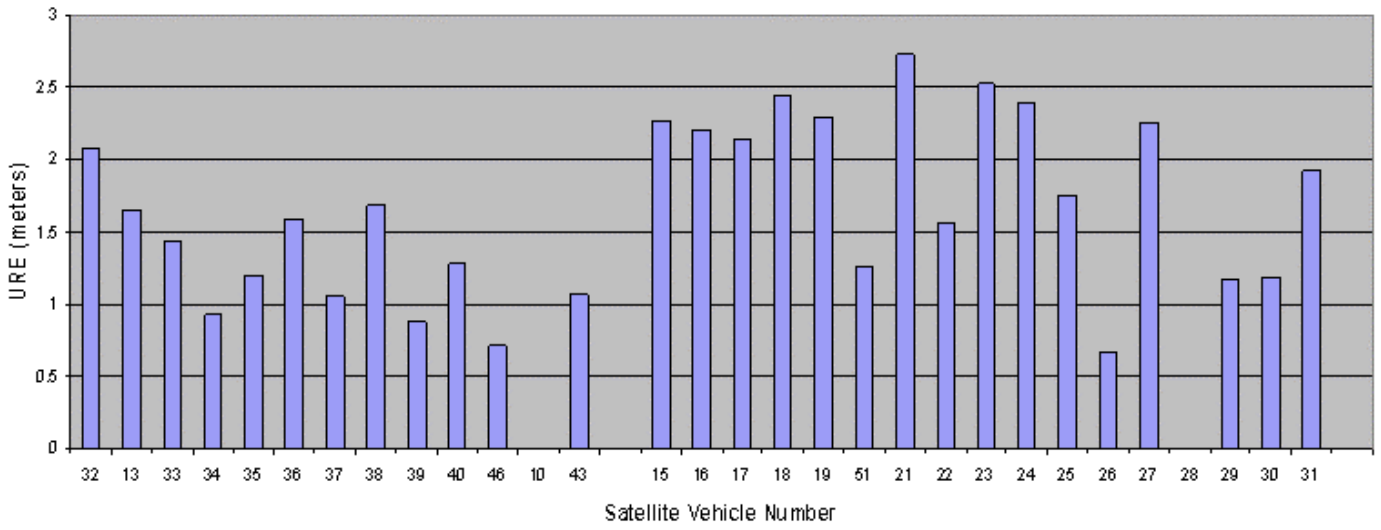
User Range Error Assessments

Signal in Space User Range Error (URE)



20 June, 2000

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Anticipated Broadcast Orbit Improvements

- Broadcast orbits should improve due to the GPS Accuracy Improvement Initiative (AII) and other efforts:
  - augment tracking network with NIMA stations
  - improve Master Control Station Kalman filter
  - more frequent uploads
  - expected r.m.s. SISRE after AII = 1.3 metres
  - further enhancements from clock replacements at monitor stations, multipath mitigation, improved tropospheric delay modelling, more satellites with rubidium clocks

Conclusions and Future Work

- Daily broadcast orbit error automatically computed and posted to the Web
- Database available for detailed study
- Constellation 3D r.m.s. error over past 18 months about 5 metres;some satellites as good as 3 metres
- RTN error components to be computed and compared to MCS SISRE estimates
- Comparison with NIMA precise ephemeris
- WAAS orbit correction errors to be assessed