# Status DORIS RINEX Processing at GSFC


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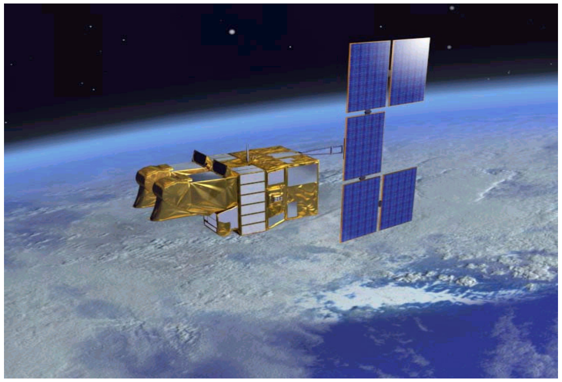
IDS

**OSTST POD**
**Reston, Virginia**
**October 20-23, 2015**



# In preparation for DORIS Rinex processing
# Preliminary test conducted
# (beginning with Jason-3 only Rinex available)

1) Method for converting DORIS Rinex phase data to range-rate (Doppler) data.

2) Compare Jason-2 POD processing with the new reconstructed Rinex range-rate data against traditional V2.2 range-rate data.

3) Compare DORIS stations estimated with V2.2 and Rinex range-rate Jason-2 data

# Range Rate from DORIS Rinex phase and corrections to observed measurement

$$\text{rrate}(T^c) = \lambda_1 (\Phi_1(T_i) - \Phi_1(T_{i-1})) / (T_i - T_{i-1})$$ *(Mercier 2015)*

$$= (D(T^c_i) - D(T^c_{i-1})) / \Delta T \;+\; c(\Delta t_r - \Delta t_e) / \Delta T$$

$$+\; \Delta_{\text{satellite USO frequency}} + \Delta_{\text{ionosphere}} + \Delta_{\text{relativity}}$$

**where**

**$D(T^c)$ : distance between emitter (e) and receiver (r) 2GHz phase centers at coordinate TAI time ($T^c$), and includes refraction effects. $(\Delta t_r - \Delta t_e)/\Delta T$ : satellite-beacon clock frequency offset difference; $\Delta t$ clock offset between i and i-1 times; $\Delta T$ = 10 TAI seconds.**

**and**

**$\Delta_{\text{satellite USO frequency}}$ : Polynomial fit to offset estimates**
**$\Delta_{\text{ionosphere}}$ : 1st order correction** *(Lemoine 2015)*
**$\Delta_{\text{relativity}}$ : Periodic terms**

# DORIS Rinex range rate GEODYN processing (computed or theoretical measurement)

Rinex range rate GEODYN processing:

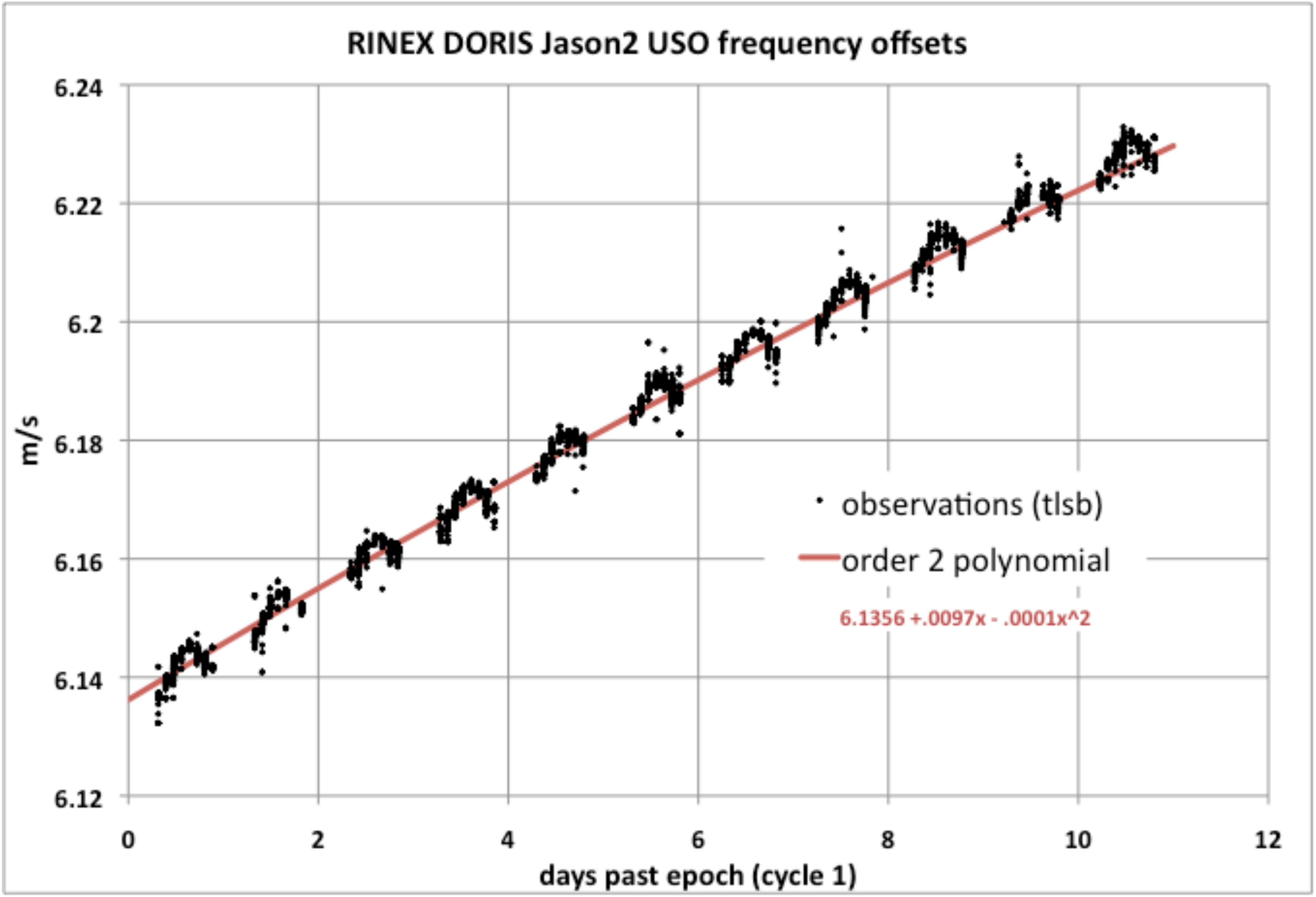
$$\text{range rate} + \text{USO frequency bias (per pass)} + \Delta_{\text{troposphere}} + \Delta_{\text{phase center}}$$

where

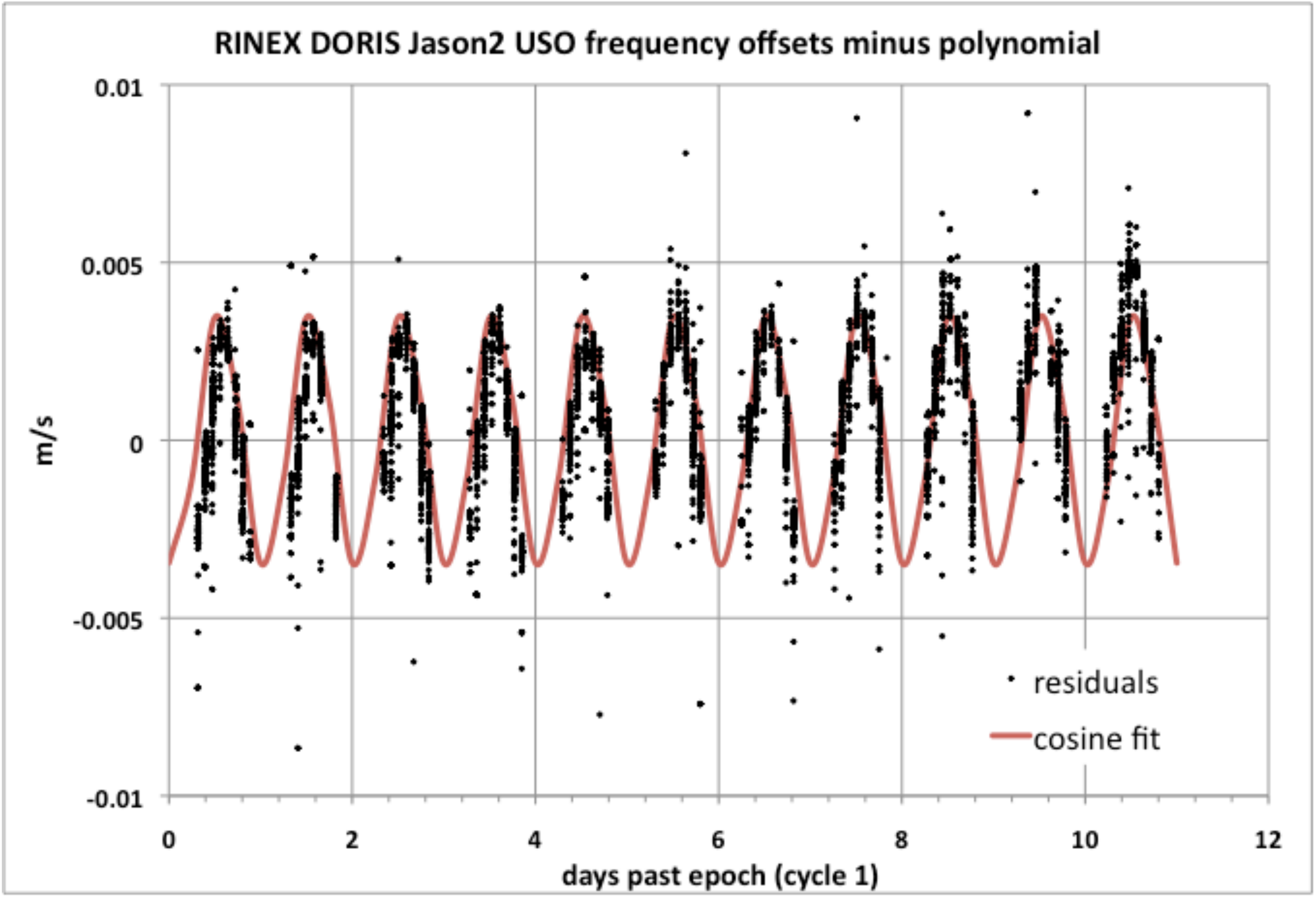
$\Delta_{\text{troposphere}}$ : VMF1 (plus bias/pass)

$\Delta_{\text{phase center}}$ : update satellite antenna Z offset and Starec station Up eccentricity to ionosphere-free positions

# $\Delta_{\text{satellite USO frequency}}$ : 2nd order polynomial fit Rinex frequency offset estimates include satellite clock error and Relativistic bias/drift



# USO frequency correction residuals



# USO frequency correction performance using external ephemeris

| test (SLR/DORIS) 10-day (cycle 001) | DORIS points | DORIS (mm/s) | time bias ($10^{-6}$ sec) |
|---|---|---|---|
| v2.2 | 187402 | 0.3686 | -2.8 |
| rinex; no correction | 190605 | 0.3810 | -1.0 |
| rinex; linear correction | 190565 | 0.3786 | -0.9 |
| rinex; 2$^{nd}$ order polynomial | 190573 | 0.3784 | -1.0 |

**Continue to investigate improving satellite USO frequency correction**

# DORIS range-rate Relativity correction for satellite clock – only periodic terms required

$$\Delta V_{REL} = \frac{1}{c}\left[U_r - U_e + \frac{V_r^2 - V_e^2}{2}\right]$$

*(JM Lemoine et al., 2015)*

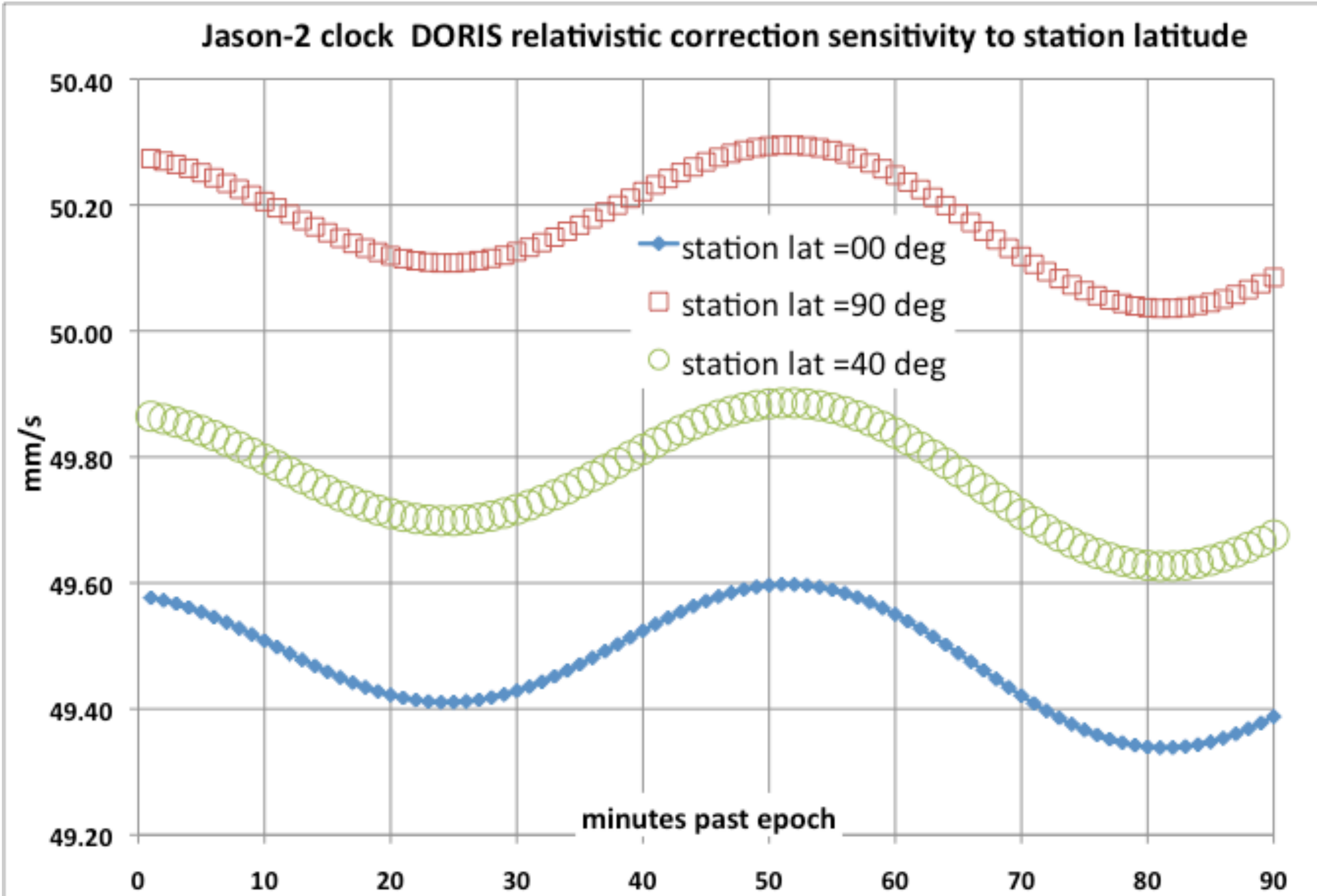
$$U = \frac{GM}{r}\left(1 - \left(\frac{a_e}{r}\right)^2 J_2 \frac{3\sin^2(\varphi) - 1}{2}\right)$$

With $J_2 = 1.0826264\ 10^{-3}$

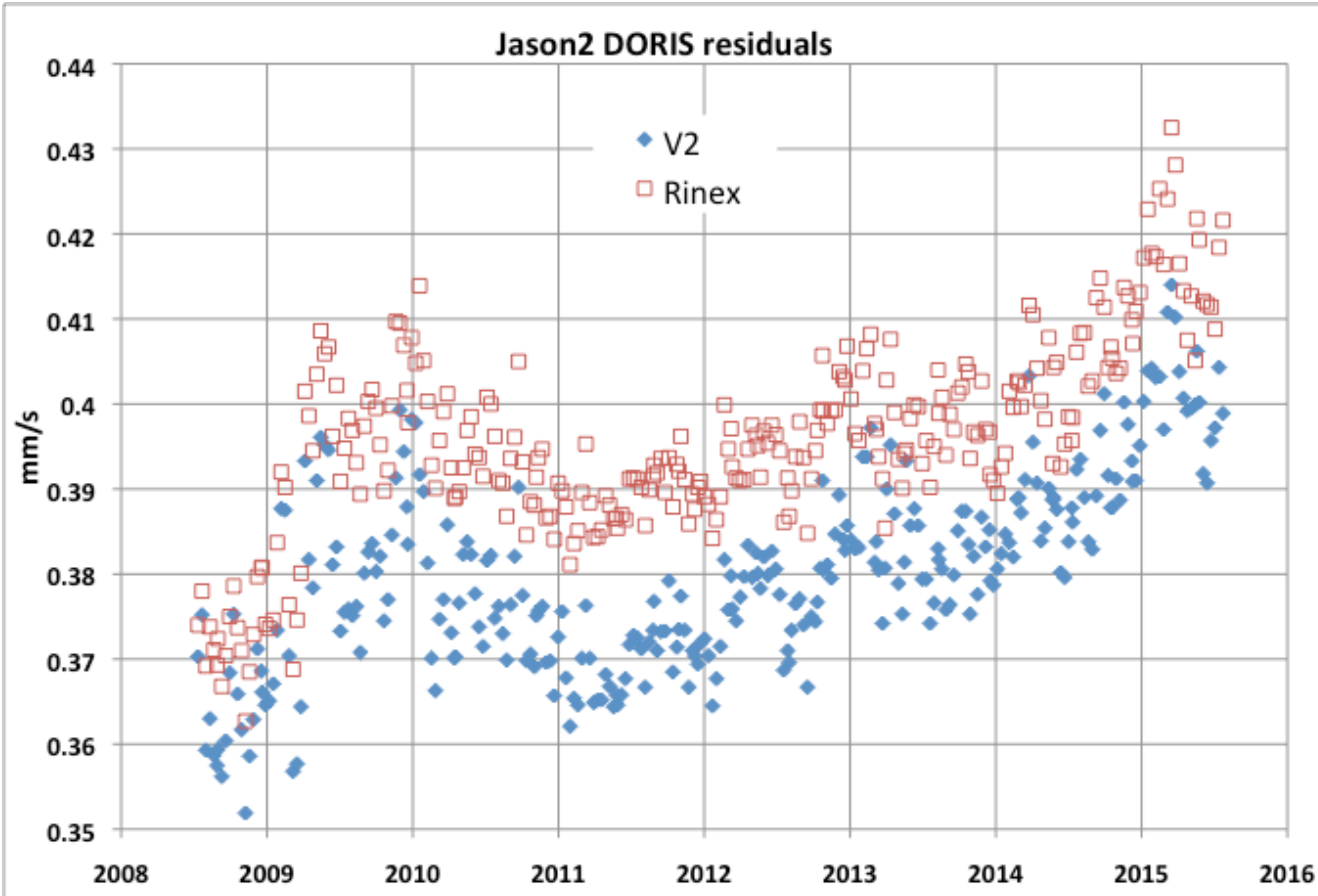
For correction to RINEX data:

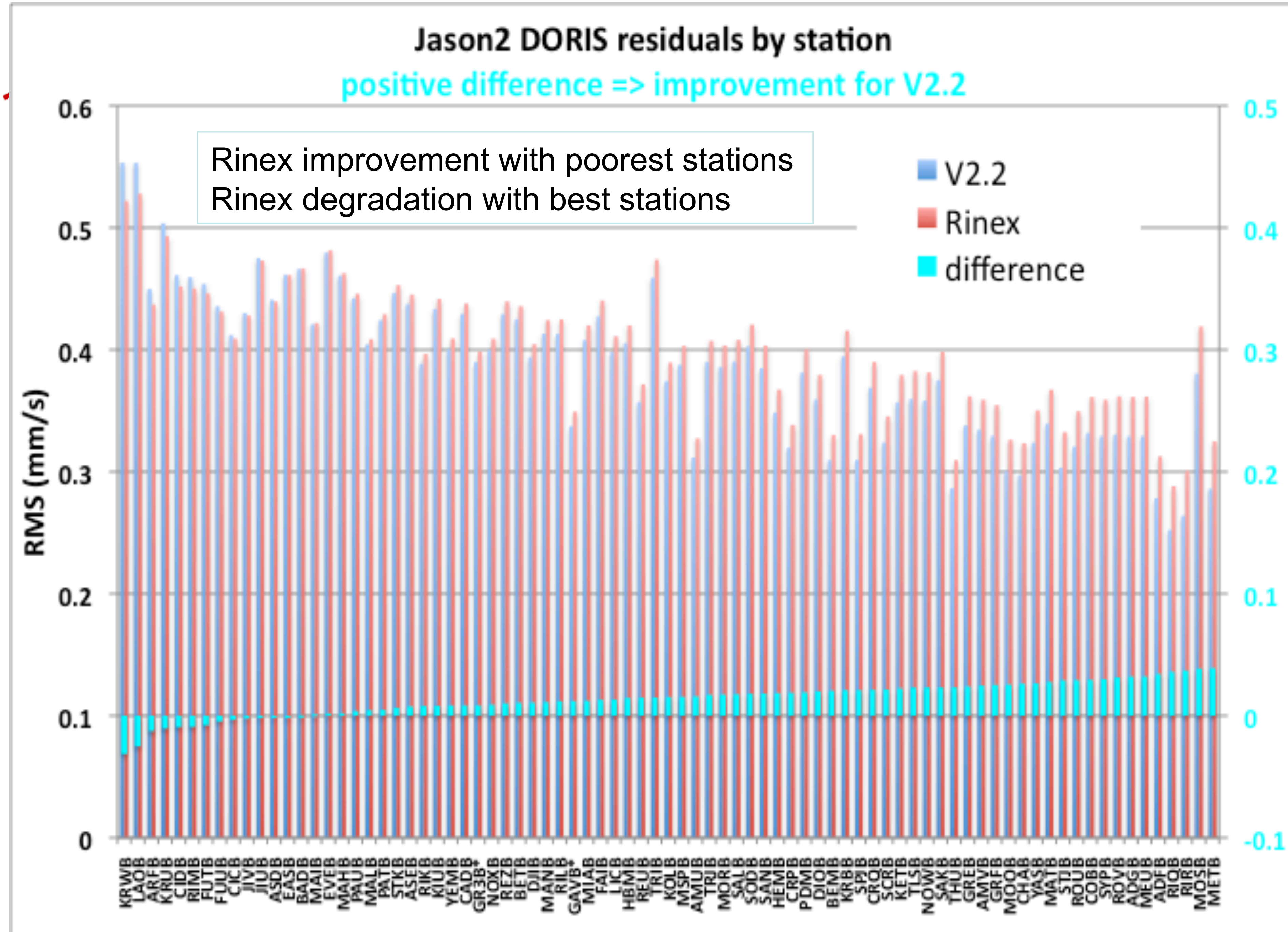
1) use sp3 orbit data to compute $U_r$ and $V_r$ which vary in time.
2) assume a single station position to compute $U_e$ and $V_e$ which do not vary in time.
3) periodic terms obtained upon removing an estimated offset+rate from the total relativity correction.

## Relativity periodic terms are due only to the satellite and will be identical for any ground station

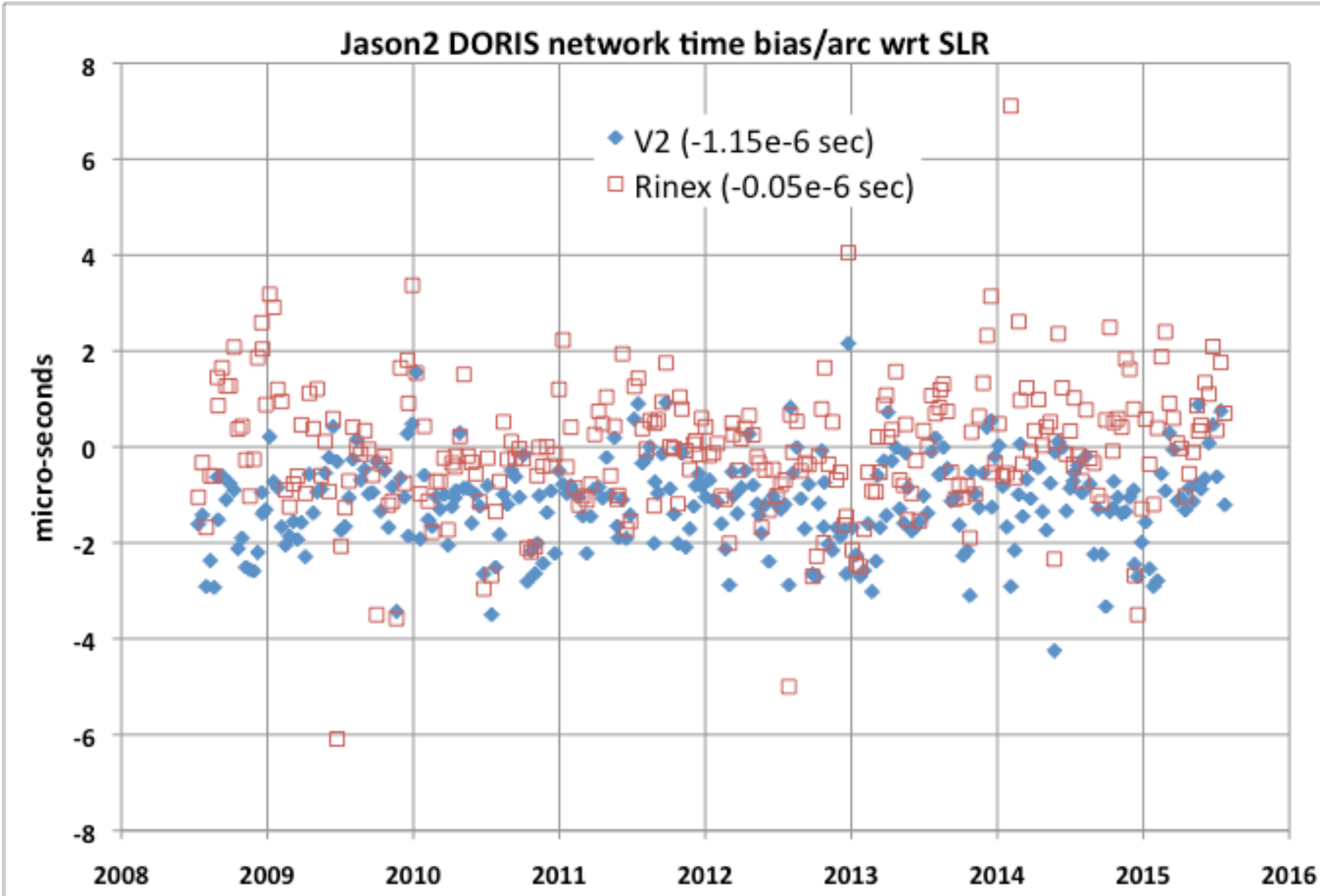


# Jason-2 DORIS Residuals

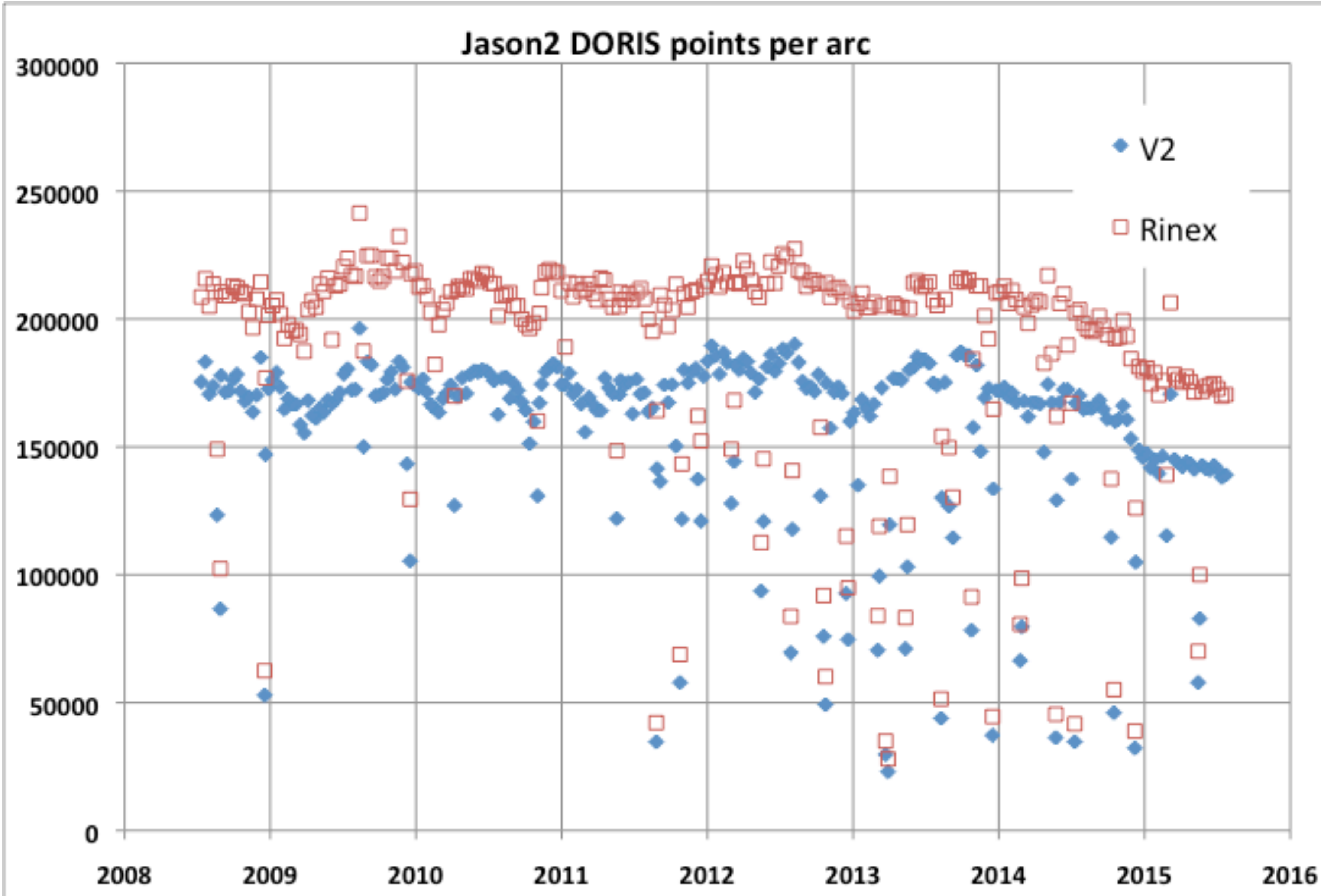



Jason2 DORIS residuals by station
positive difference => improvement for V2.2
Rinex improvement with poorest stations
Rinex degradation with best stations
V2.2
Rinex
difference
RMS (mm/s)
0.6
0.5
0.4
0.3
0.2
0.1
0
0.5
0.4
0.3
0.2
0.1
0
-0.1
KRWB LAOB ARFB KRUB CIDB RIMB FUTB FUUB CICB JIVB JIUB ASDB EASB BADB MAIB EVEB MAHB PAUB MALB PATB STKB ASEB RIKB KIUB YEMB CADB+ GR3B+ NOXB REZB BETB DJIB MANB RILB GAVB+ MIAB FAIB LICB HBMB REUB TRIB KOLB MSPB AMUB TRJB MORB SALB SODB SANB HEMB CRPB PDMB DIOB BEMB KRBB SPJB CRQB SCRB KETB TLSB NOWB SAKB THUB GREB AMVB GRFB MOOB CHAB YASB MATB STJB ROUB COBB SYPB ROVB ADGB MEUB ADFB RIQB RIRB MOSB METB

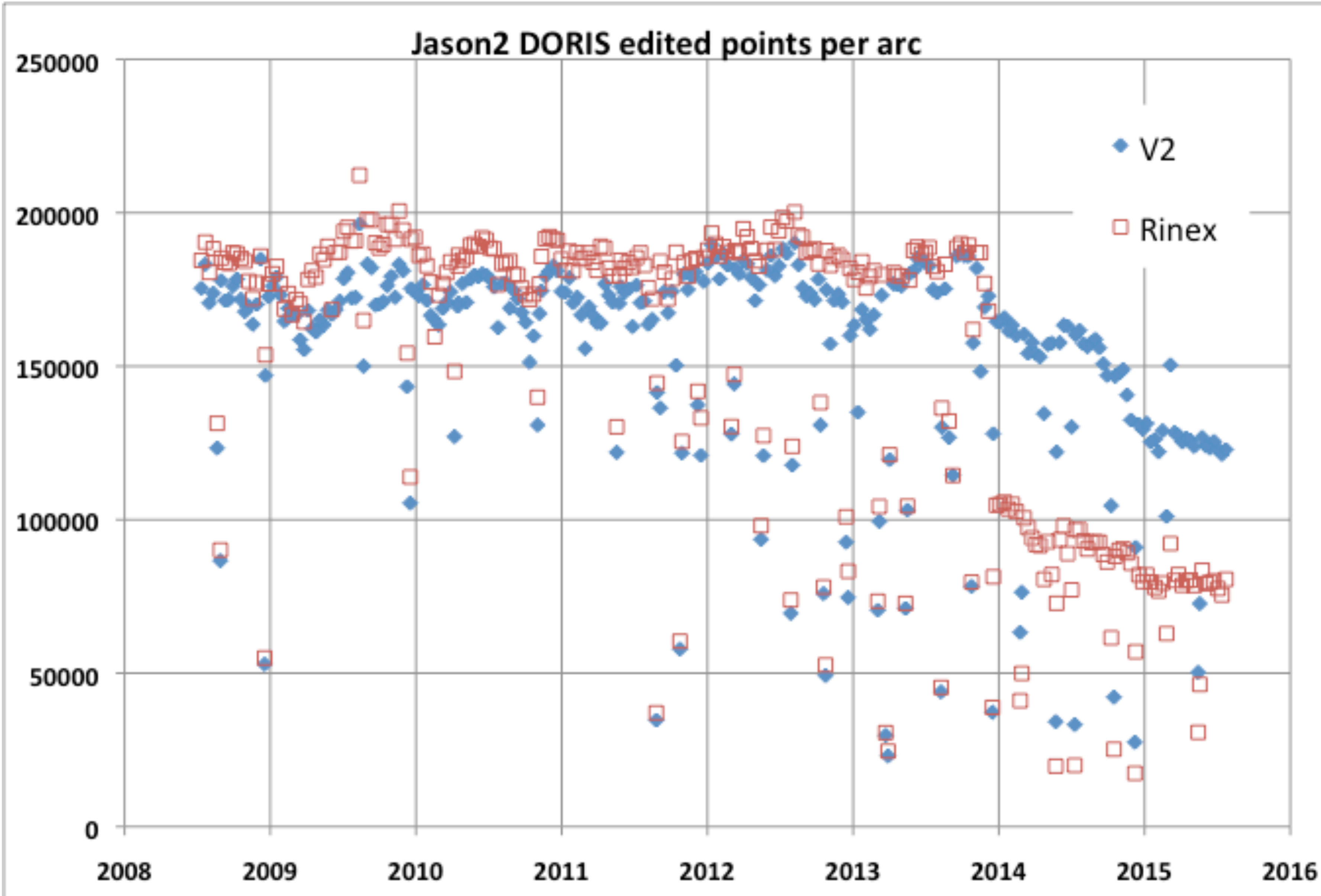
# Jason-2 DORIS time bias / 10-day arc wrt SLR (1.1 micro-sec constant difference in time tags)



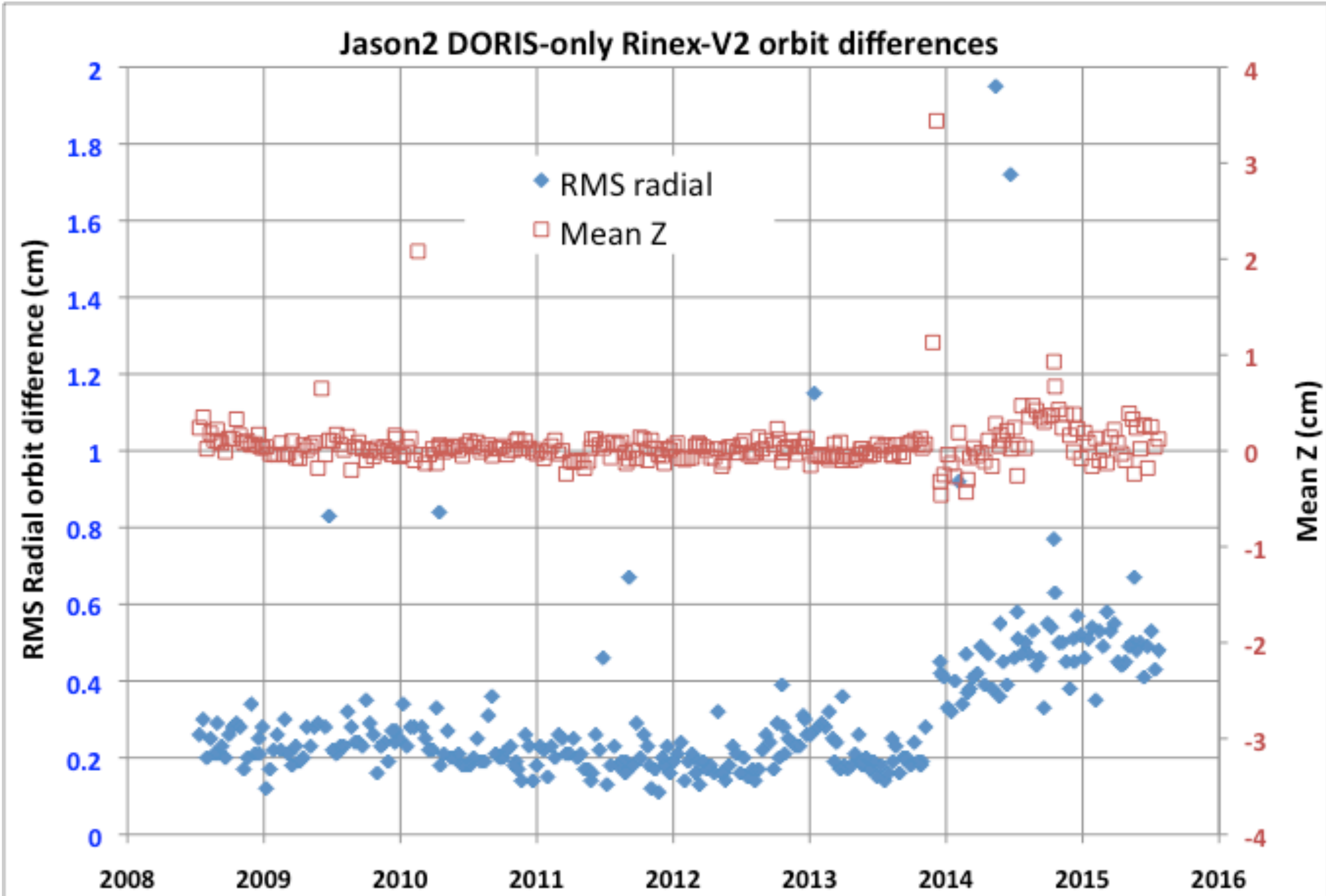
# Jason-2 DORIS data before GEODYN dynamic editing



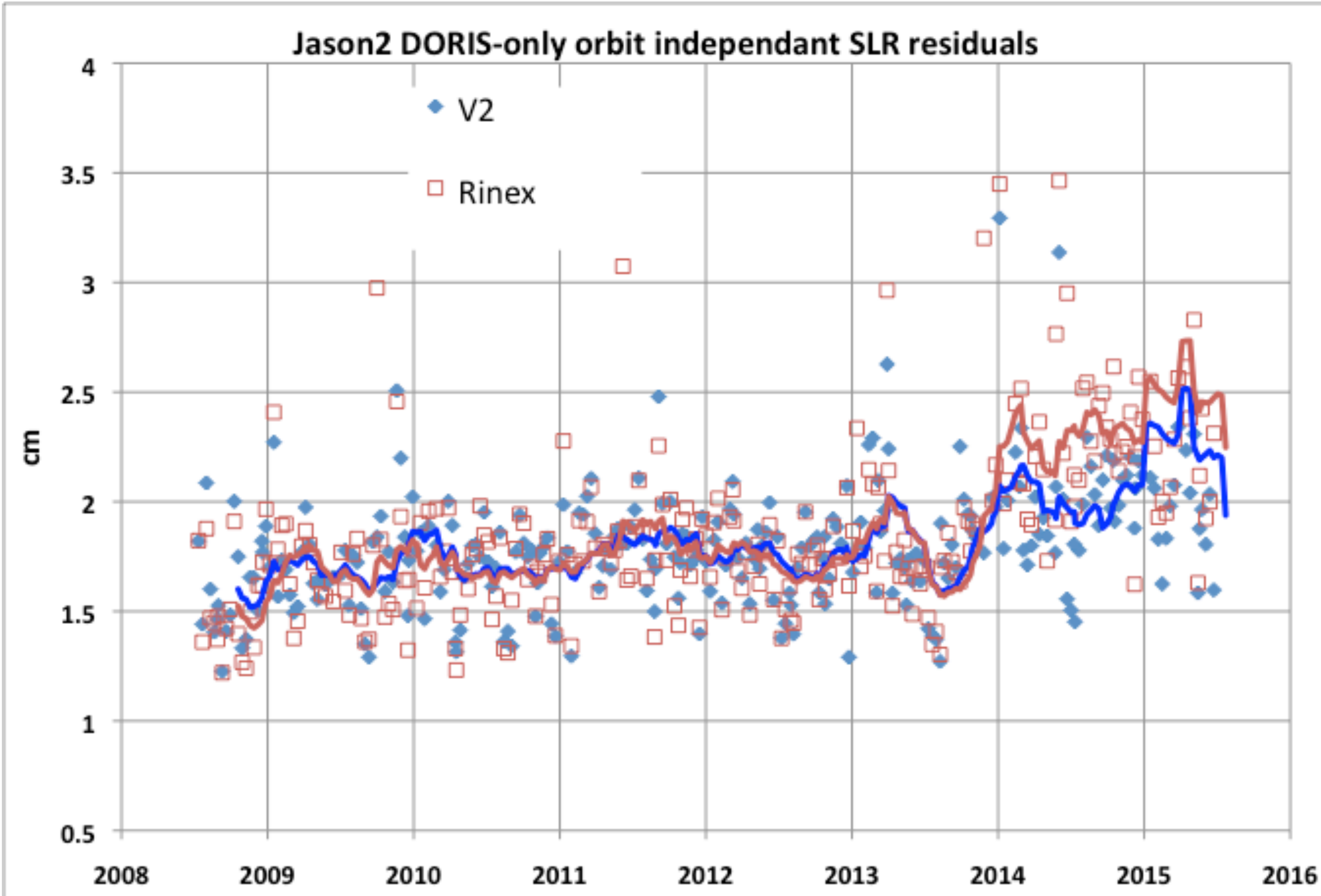
# Jason-2 DORIS data after GEODYN dynamic editing



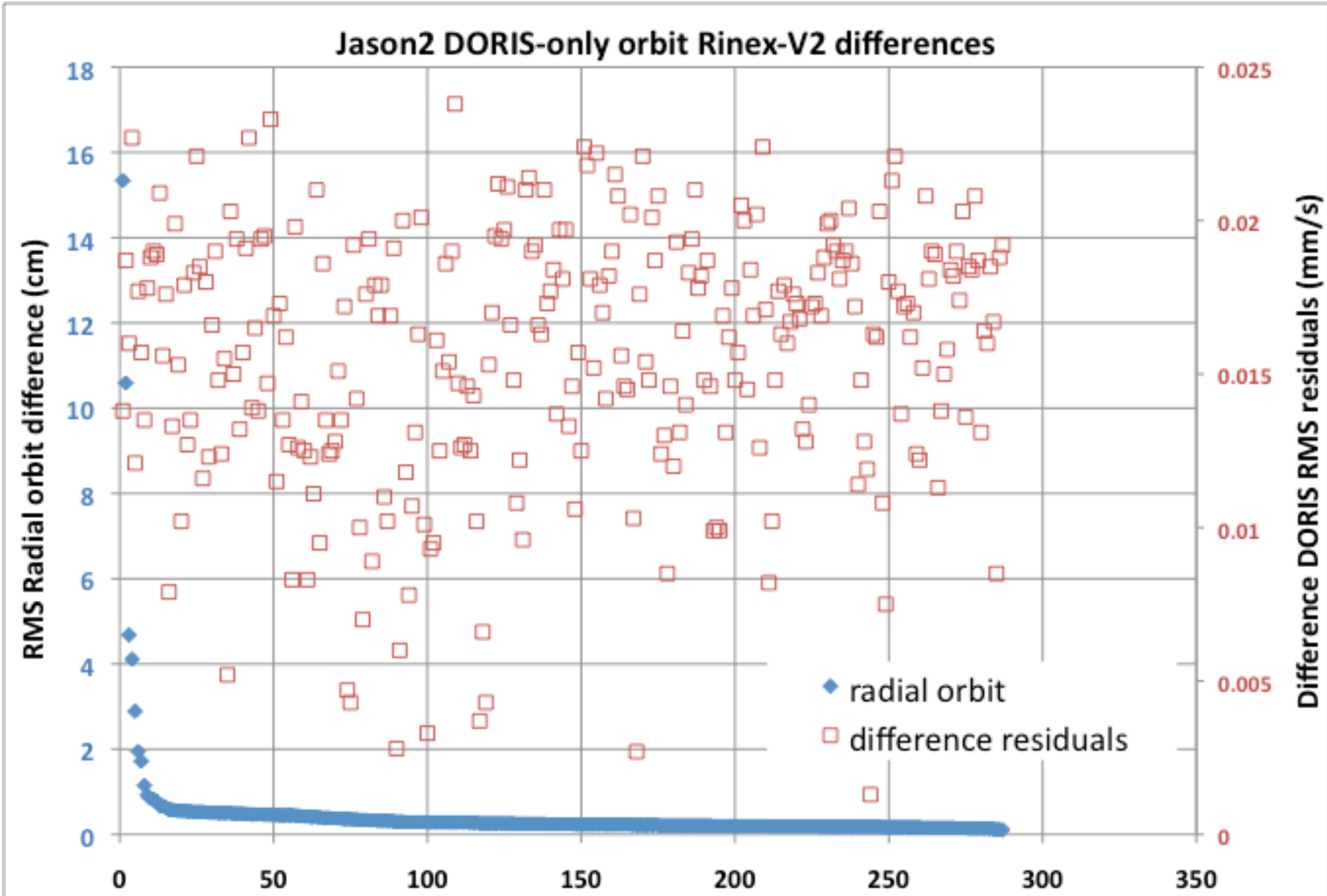
# Jason-2 DORIS-only orbit differences



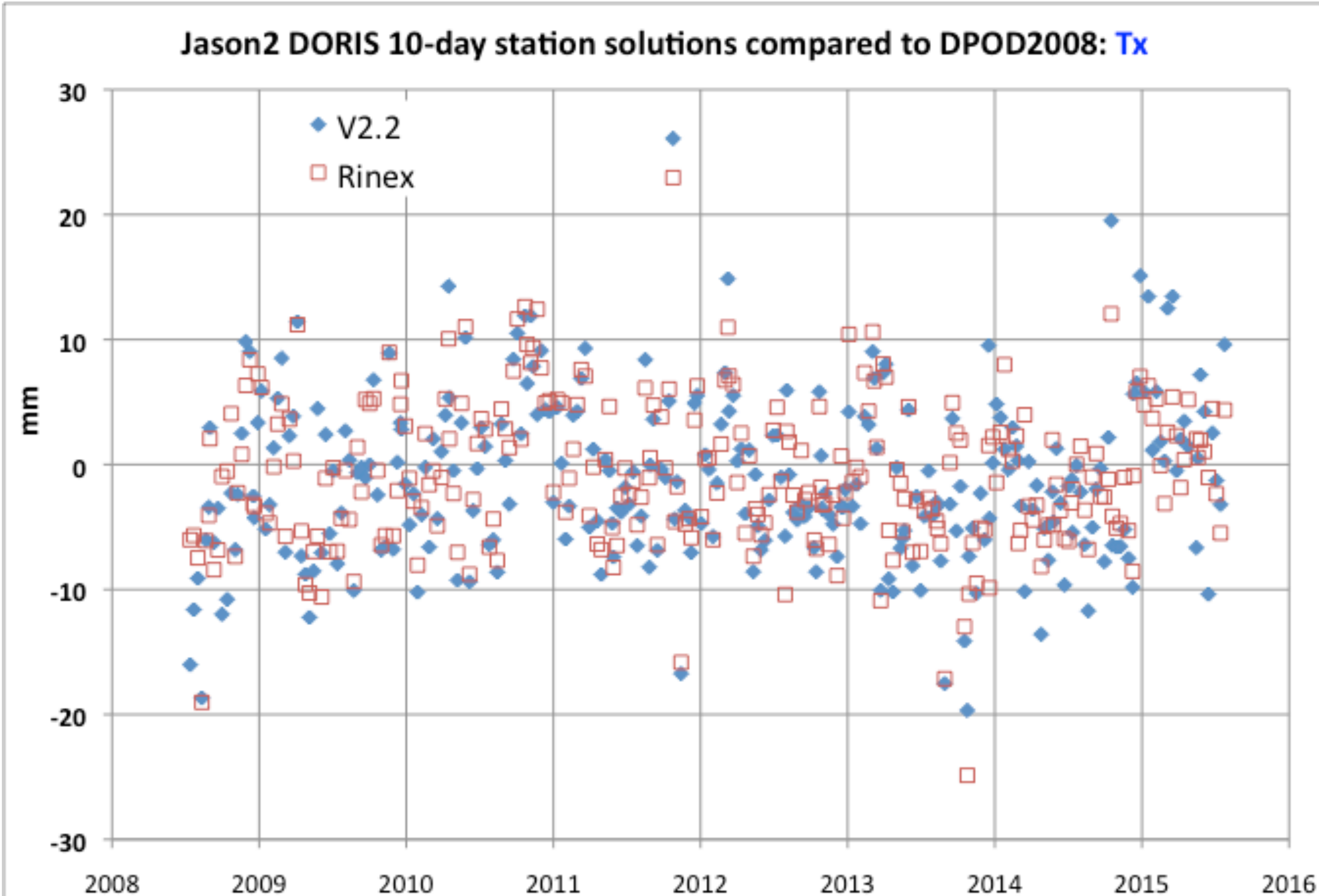
# Independent SLR residuals show DORIS orbits of comparable accuracy up to 2014



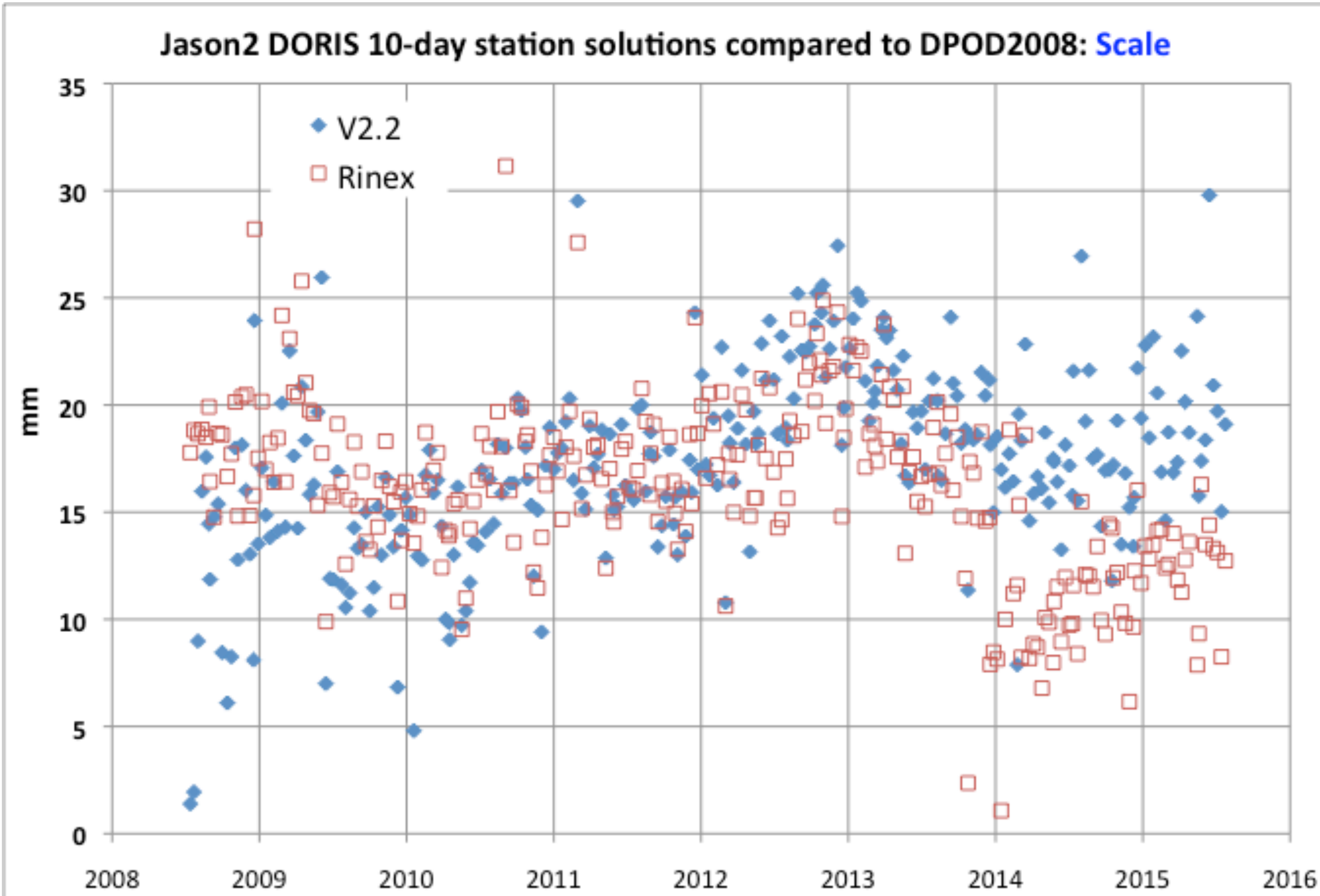
# A few cases where Rinex DORIS converges to degraded orbits



# Jason-2 DORIS station solution Helmert Tx, Ty, Tz are similar for V2.2 and Rinex data



# Jason-2 DORIS station solution Helmert Scale



# Summary

1) Jason2 Rinex DORIS converted to range-rate and compared to V2.2 data processing over cycles 1-260.

2) Overall V2.2 /Rinex data POD processing compares as follows:

| DORIS data | average points used | rms residuals mm/s | radial cm | cross-trk cm | along-trk cm |
|---|---|---|---|---|---|
| V2.2 | 152883 | 0.3803 | --- | --- | --- |
| Rinex | 149142 | 0.3959 | 0.43 | 1.88 | 2.39 |

3) However there are two major problems:

   1) Isolated Rinex arcs can converge to degraded orbit solutions yet show normal DORIS residuals

   2) Rinex data from 2014 shows degraded POD

# BACKUP

# K shifted frequency beacons

**frequency K:**

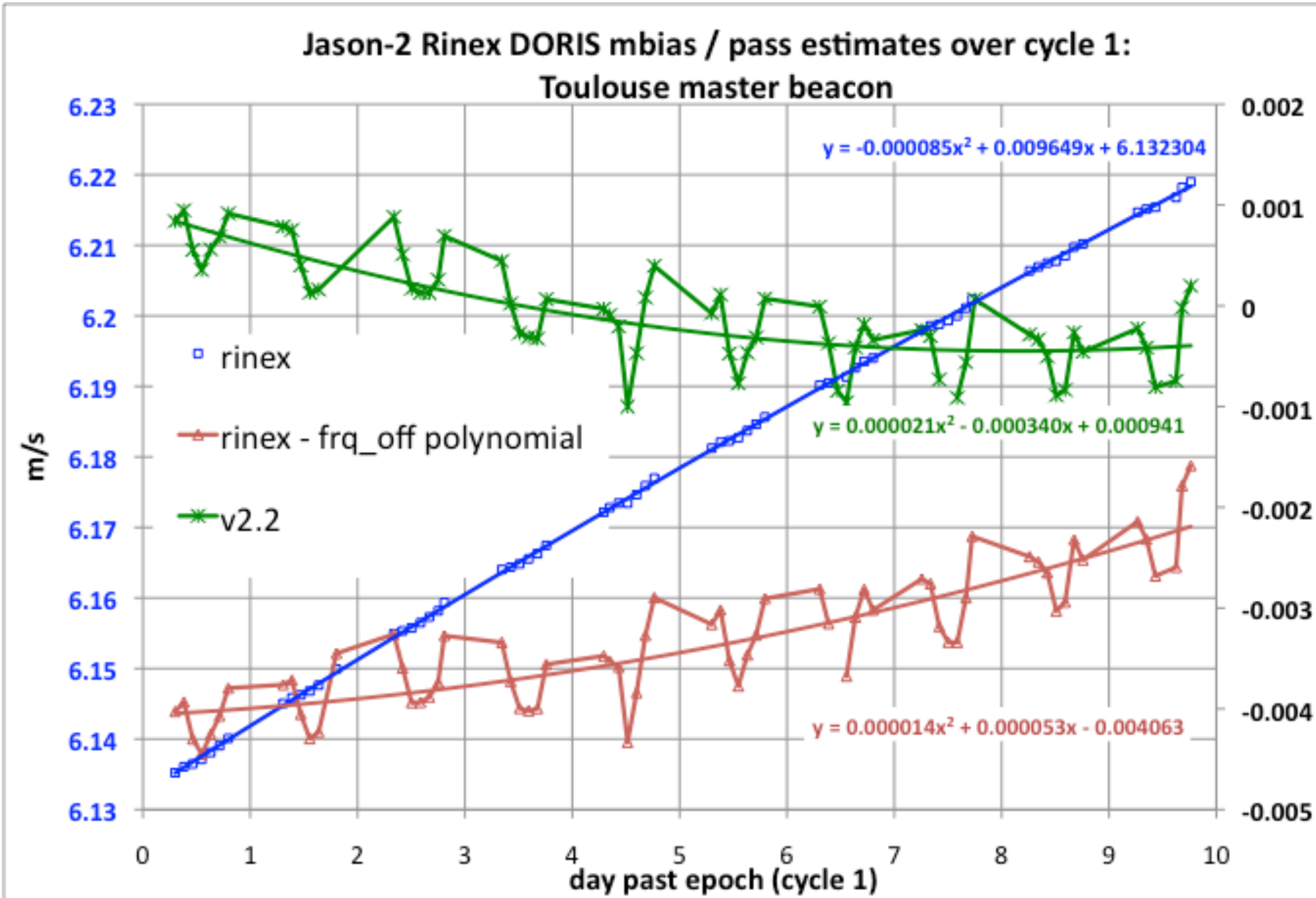
$$f_K = (1 + \alpha_K)\, f_{2GHz}$$

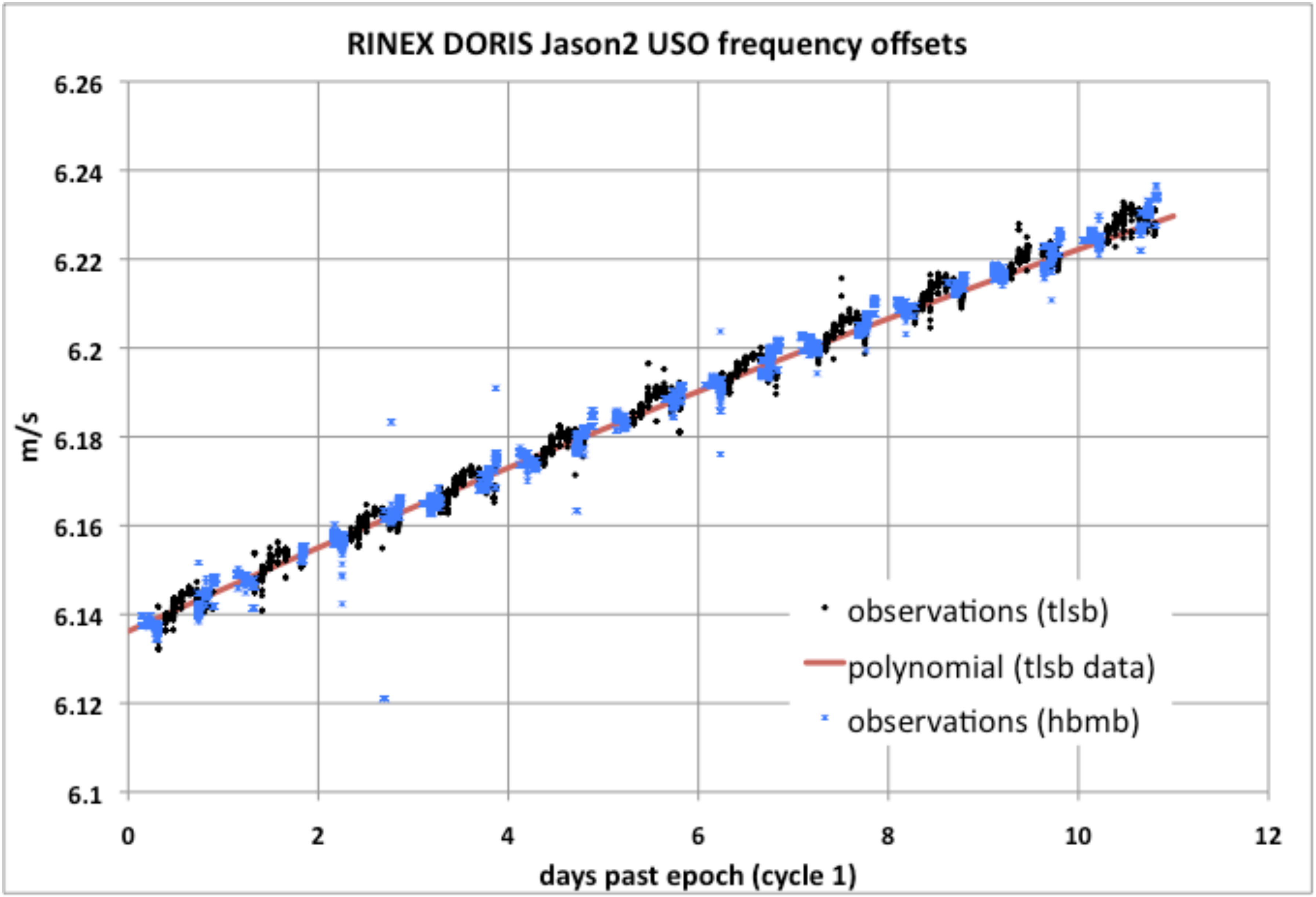
**and**

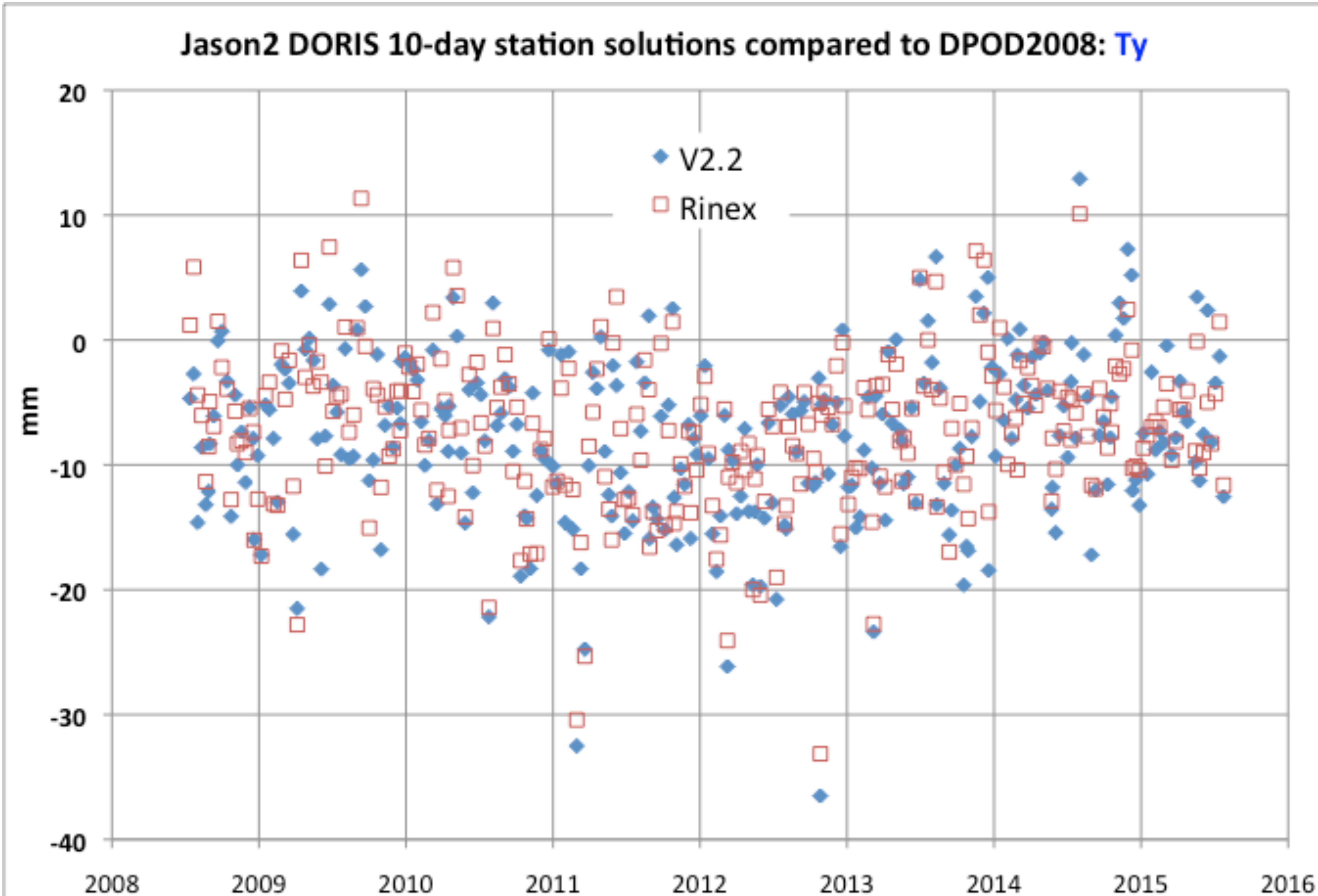
$$Q_{corr}(t_1) = \lambda_K\,(\Phi_{2GHz}) + c * t_1 * \alpha_K /(1 + \alpha_K)$$

**where**

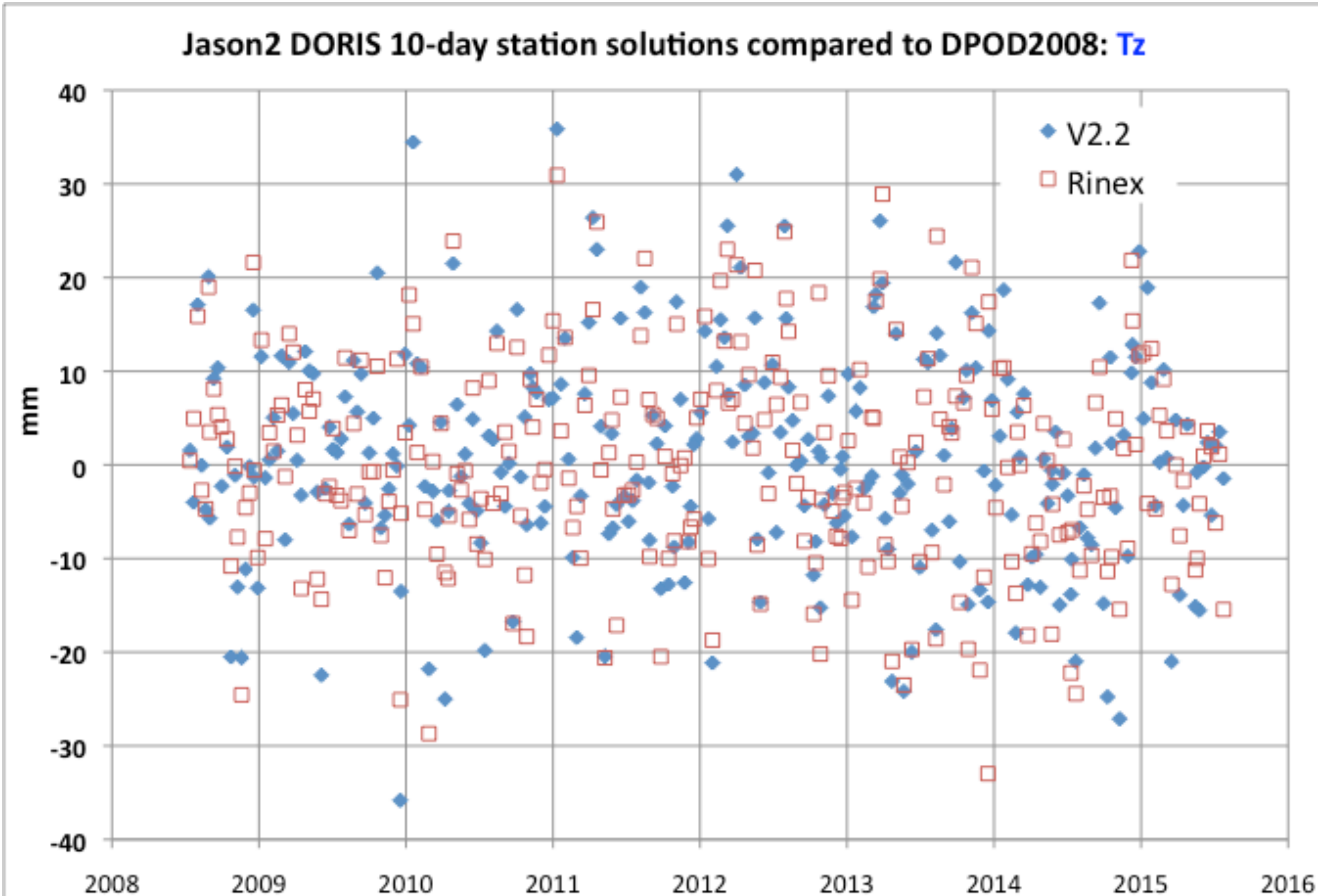
$$\alpha_K = K * (3/4 * 87) / (5 * 2^{26})$$


Jason-2 Rinex DORIS mbias / pass estimates over cycle 1:
Toulouse master beacon
y = -0.000085x² + 0.009649x + 6.132304
y = 0.000021x² - 0.000340x + 0.000941
y = 0.000014x² + 0.000053x - 0.004063
rinex
rinex - frq_off polynomial
v2.2
m/s
day past epoch (cycle 1)
6.23
6.22
6.21
6.2
6.19
6.18
6.17
6.16
6.15
6.14
6.13
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
0
1
2
3
4
5
6
7
8
9
10

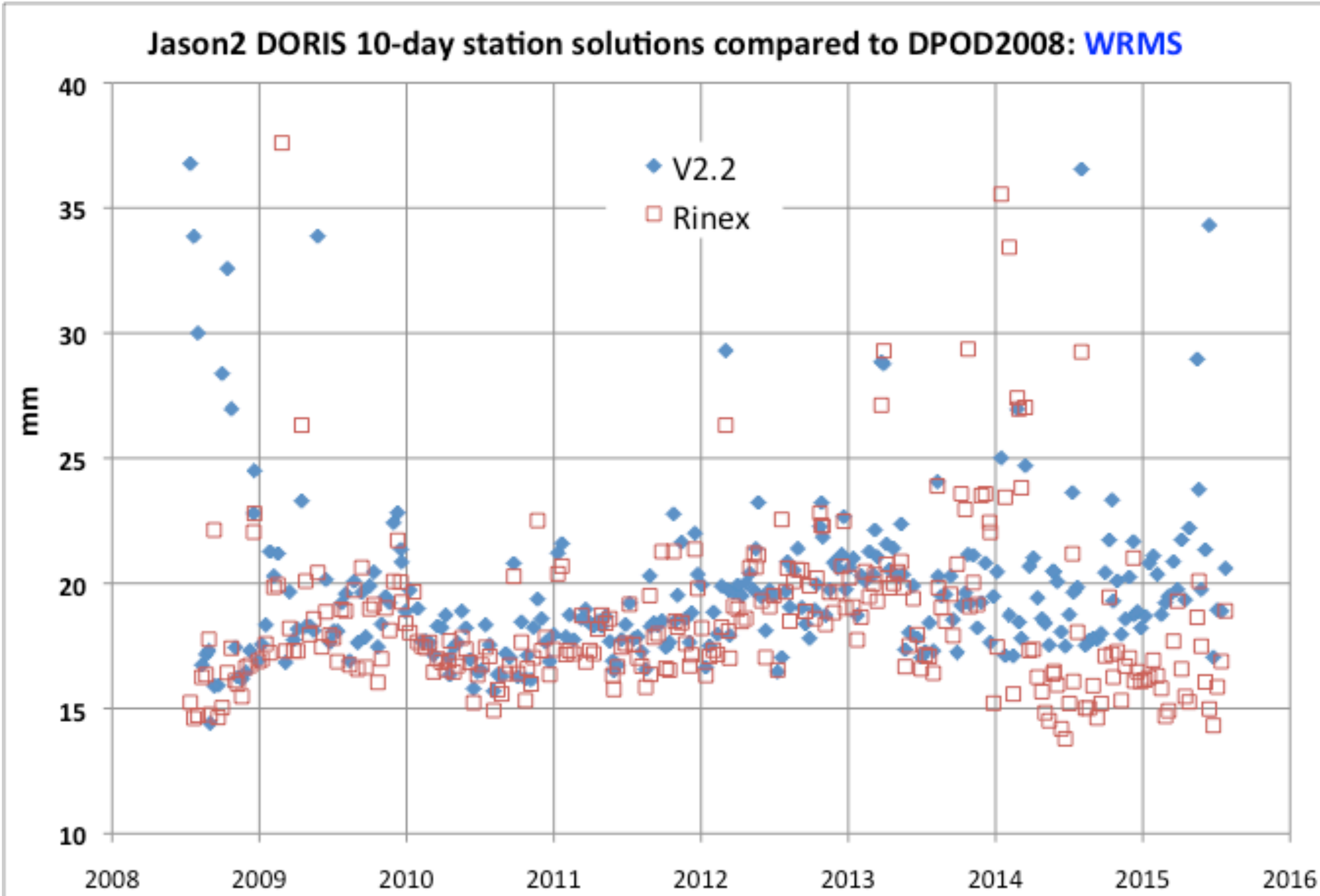

RINEX DORIS Jason2 USO frequency offsets
6.26
6.24
6.22
6.2
6.18
6.16
6.14
6.12
6.1
m/s
0
2
4
6
8
10
12
days past epoch (cycle 1)
observations (tlsb)
polynomial (tlsb data)
observations (hbmb)



Jason2 DORIS 10-day station solutions compared to DPOD2008: Ty
V2.2
Rinex
mm
20
10
0
-10
-20
-30
-40
2008
2009
2010
2011
2012
2013
2014
2015
2016



Jason2 DORIS 10-day station solutions compared to DPOD2008: Tz
V2.2
Rinex
mm
40
30
20
10
0
-10
-20
-30
-40
2008
2009
2010
2011
2012
2013
2014
2015
2016



Jason2 DORIS 10-day station solutions compared to DPOD2008: WRMS
V2.2
Rinex
mm
40
35
30
25
20
15
10
2008
2009
2010
2011
2012
2013
2014
2015
2016