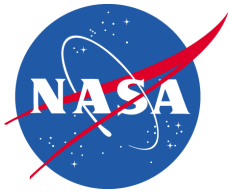


The development of the GSC contribution to ITRF2013

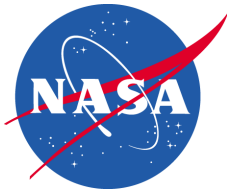
F.G. Lemoine, D.S. Chinn, N.P. Zelensky, J.W. Beall, K. Le Bail
2014 IDS Workshop
Konstanz, Germany
October 27, 2014



Summary of GSC SINEX Series developed since ITRF2008



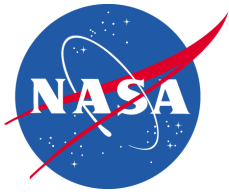
| Series. | Description |
|--|---|
| gscwd12 | Previous operational series (continuation of ITRF2008 series) |
| gscwd13 | Test series in response to IERS call (atmosphere loading) |
| gscwd15 | New time series (1992-2012): updates & data cleanups. |
| gscwd17 | Test of macromodel-related changes only (SPOT-2, SPOT-3, Envisat) |
| gscwd18 | New time series (1992-2012): gscwd17 + implementation of modelling to handle DORIS station frequency changes. |
| gscwd20 | New time series (1992-2013). Implementation of IERS2010. Changes to drag modeling as recommended by AWG (Toulouse, April 2013). |
| gscwd21 | Test implementation of phase law for Starec and Alcatel antennae. |
| gscwd25 ¶ | New time series (1992-2013). Use GSFC-derived TVG solution (weekly smoothed times series). Add Jason-1, HY2A. |
| gscwd26 ¶ | As gscwd25, + Adjust cross-track opr's per arc instead of per day. Along-track OPR parameterization is unchanged. |
| ¶ Final series delivered for ITRF2013. | |



Summary of Changes wrt. ITRF2008 (1)



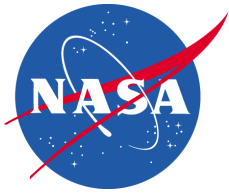
| Change | |
|-------------------------|--|
| Static gravity model | GOCO2s (L > 5) vs. EIGEN-GL04S1 |
| Time-variable gravity | (L<5). GSFC-derived SLR-DORIS time series |
| Troposphere (1) | GMF/Saastmoinen vs. Niell/Hopfield |
| Troposphere (2) | Adjust wet-only vs. Adjust dry+wet. |
| Ocean Tides | GOT4.8 vs. GOT4.7 |
| Ocean pole tide | Applied. |
| Station coordinates | DPOD2008v1.12 |
| New DORIS Data | Envisat (2002-2006) & SPOT-4 (1998-1999) |
| New Satellite Data | Jason-1, Cryosat-2, HY2A (Saral not included per AWG). |
| Non-conservative forces | (1) Macromodel changes S2, S3, S4, Envisat; (2) SPOT-5 solar array pitch; (3) UCL models: Jason-1, Jason-2. (4) Quaternions: J1, J2 & Cryosat-2 & some TP arcs. |
| Pole modeling | IERS2010 standards (<i>Petit and Luzum, 2010; Table 7.7, pp. 115</i>) |



Summary of Changes wrt. ITRF2008 (2)



| Change | |
|---|--|
| Frequency Bias | Account for change from nominal frequency. |
| Phase Law | Verified through tests for Alcatel & Starec Antennae. |
| Data Editing. | Delete stations per week (< 250 observations). Also remove stations with spurious adjustments. |
| Apply DORIS tracking point offset in GEODYN | For ITRF2008, DORIS data-supplied corrections were used. |
| SPOT-5 SAA Corrections | Applied 2006-2013, per AWG. |
| DORIS time bias (TOPEX) | used model derived from SLR-DORIS POD time-bias solutions. |



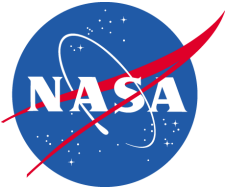
POD RMS of fit Summary

(cm for SLR, mm/s for DORIS)

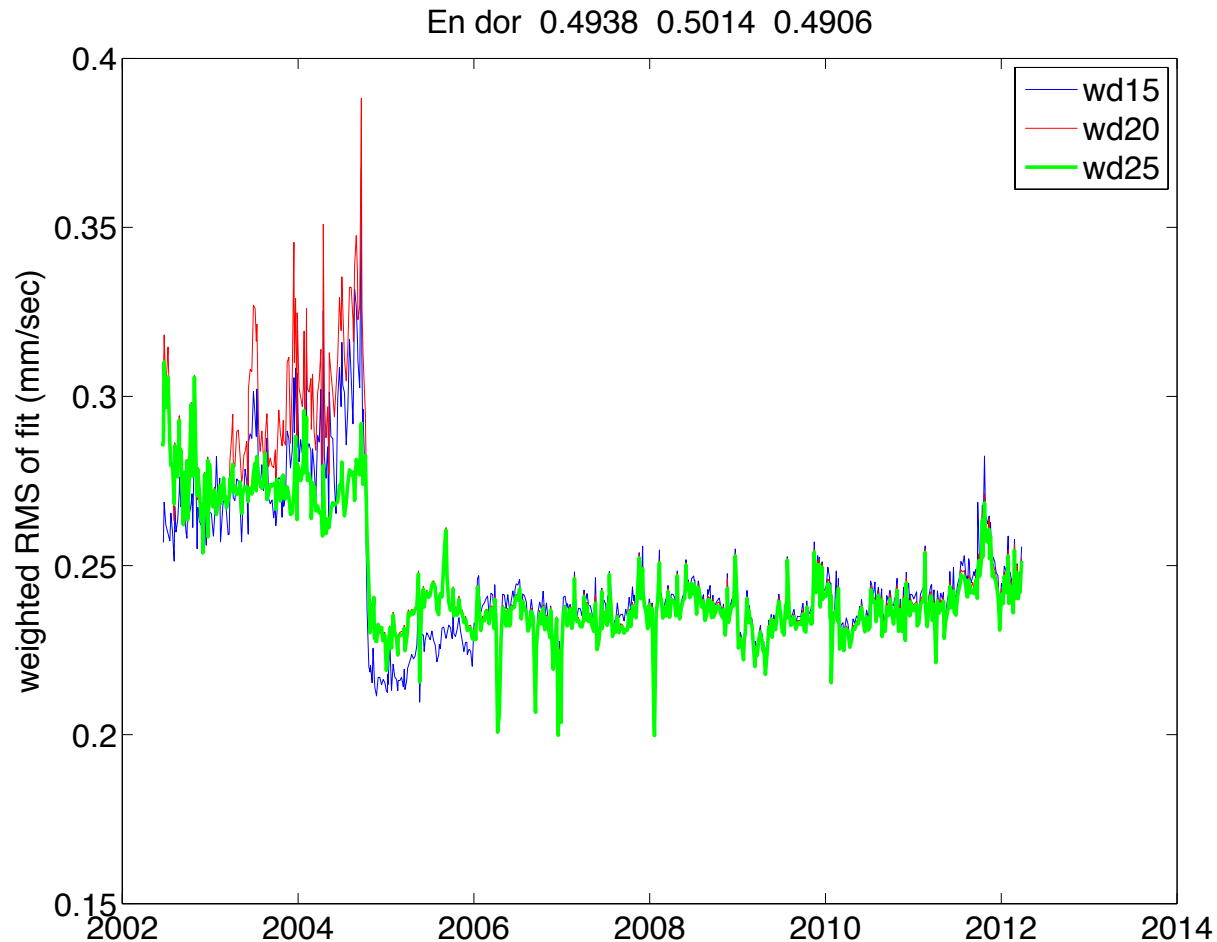


| Satellite & Data | wd12 | wd15 | wd20 | wd25 |
|------------------|-------|-------|-------|-------|
| Lageos-2 | 0.881 | 0.842 | 0.823 | 0.815 |
| Stella | 1.600 | 1.496 | 1.472 | 1.388 |
| Starlette | 1.586 | 1.506 | 1.494 | 1.344 |
| Larets | 1.607 | 1.434 | 1.465 | 1.357 |
| Envisat (SLR) | 1.272 | 1.289 | 1.126 | 1.039 |
| (DORIS) | 0.494 | 0.492 | 0.491 | 0.491 |
| TOPEX (SLR) | 1.701 | 1.679 | 1.668 | 1.701 |
| (DORIS) | 0.513 | 0.514 | 0.513 | 0.512 |
| Jason2 (SLR) | 1.215 | 1.165 | 1.172 | 1.118 |
| (DORIS) | 0.361 | 0.376 | 0.379 | 0.379 |
| Cryosat-2 (SLR) | 2.131 | 1.850 | 1.304 | 1.134 |
| (DORIS) | 0.437 | 0.445 | 0.402 | 0.400 |
| HY-2A (SLR) | ---- | ----- | 1.506 | 1.335 |
| (DORIS) | | | 0.411 | 0.409 |
| ¶ SARAL (SLR) | ---- | ----- | 1.621 | 1.405 |
| (DORIS) | | | 0.399 | 0.392 |

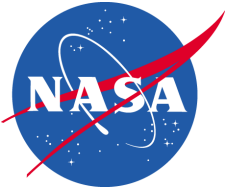
¶ SARAL is independent. Not included in ITRF2013 submission or processing.



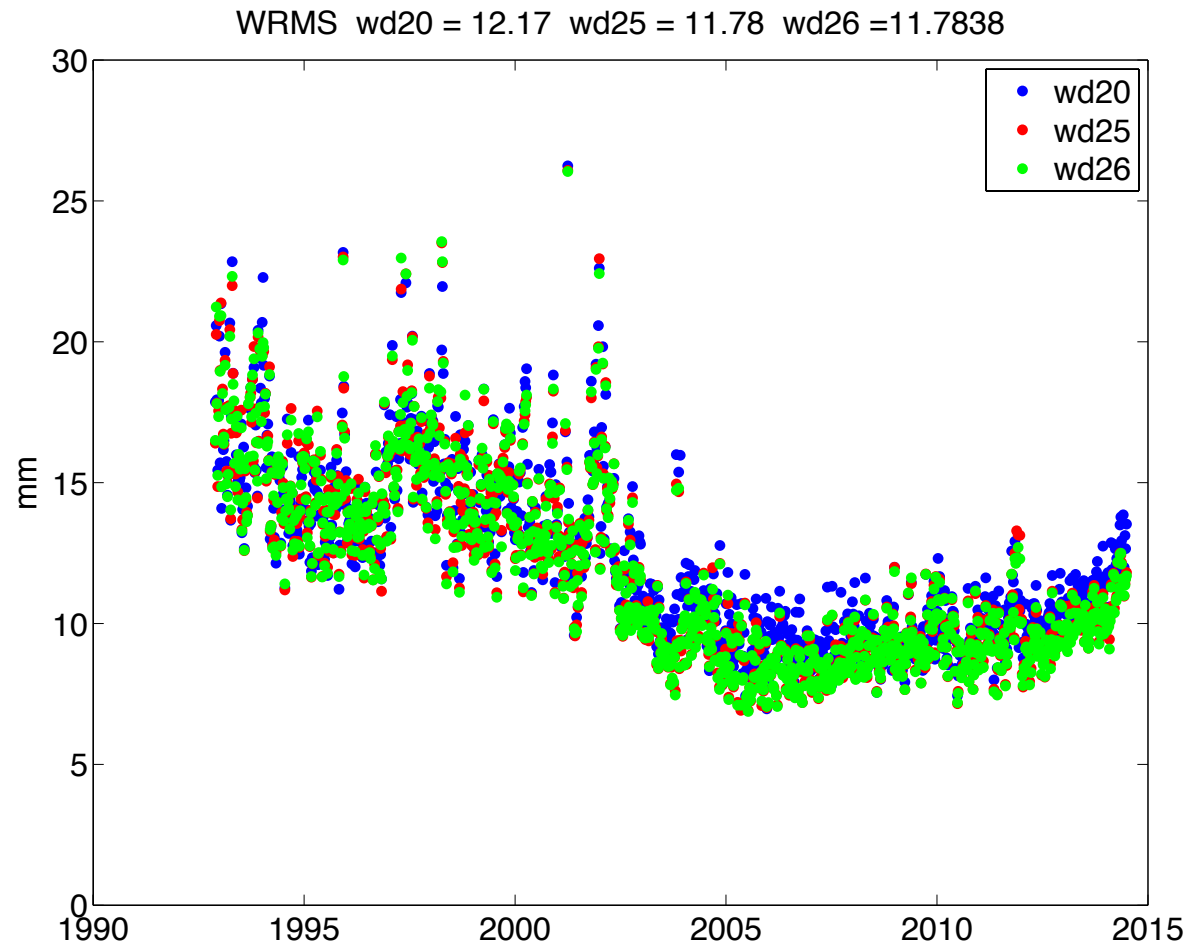
POD RMS Summary: Envisat

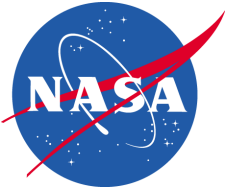


Improvement in Envisat (DORIS) RMS of fit (**2003-2004**) for wd20 to wd25, is due to calculation of measurement offset corrects in GEODYN via an attitude model, rather than using the DORIS-data-supplied corrections.

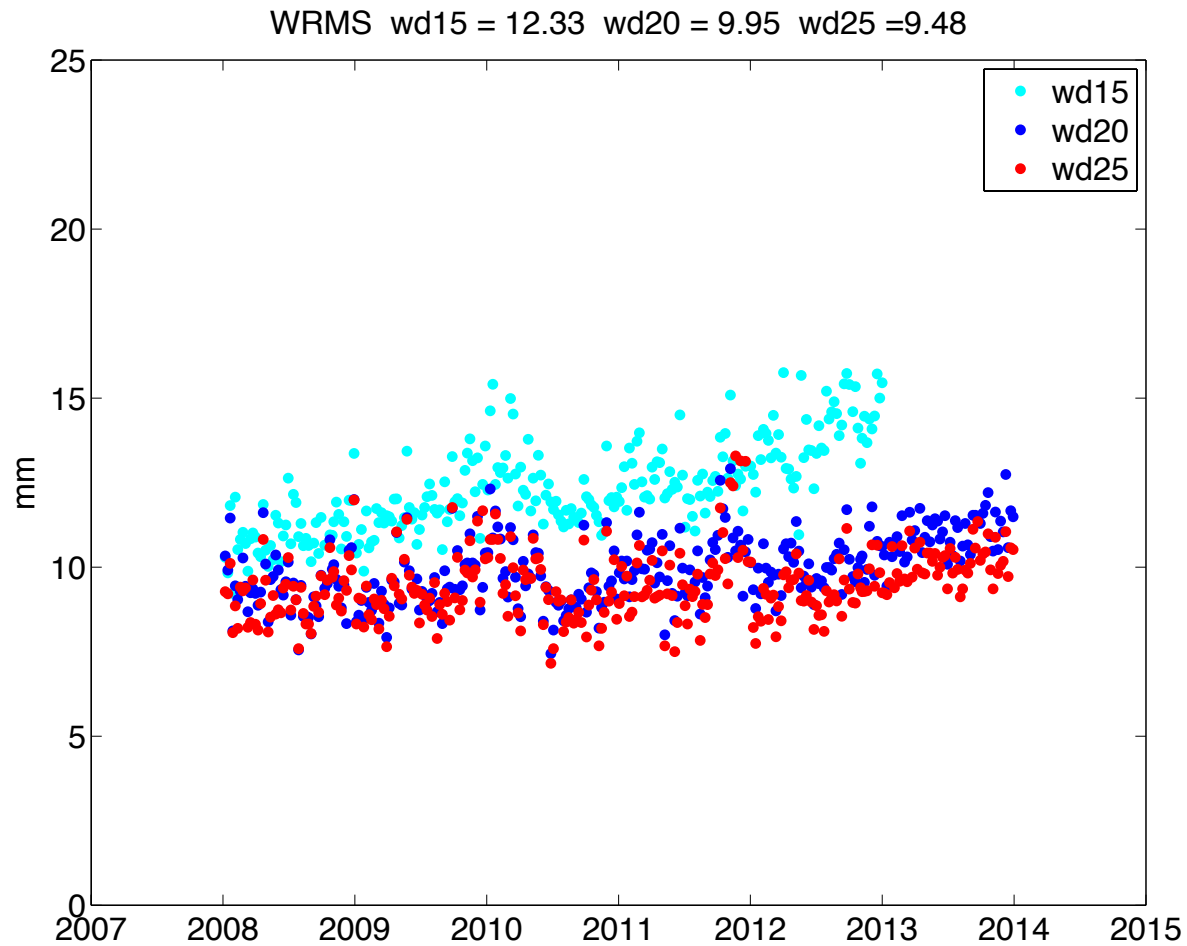


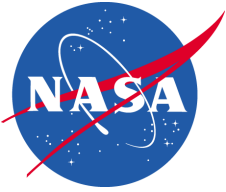
WRMS Comparison



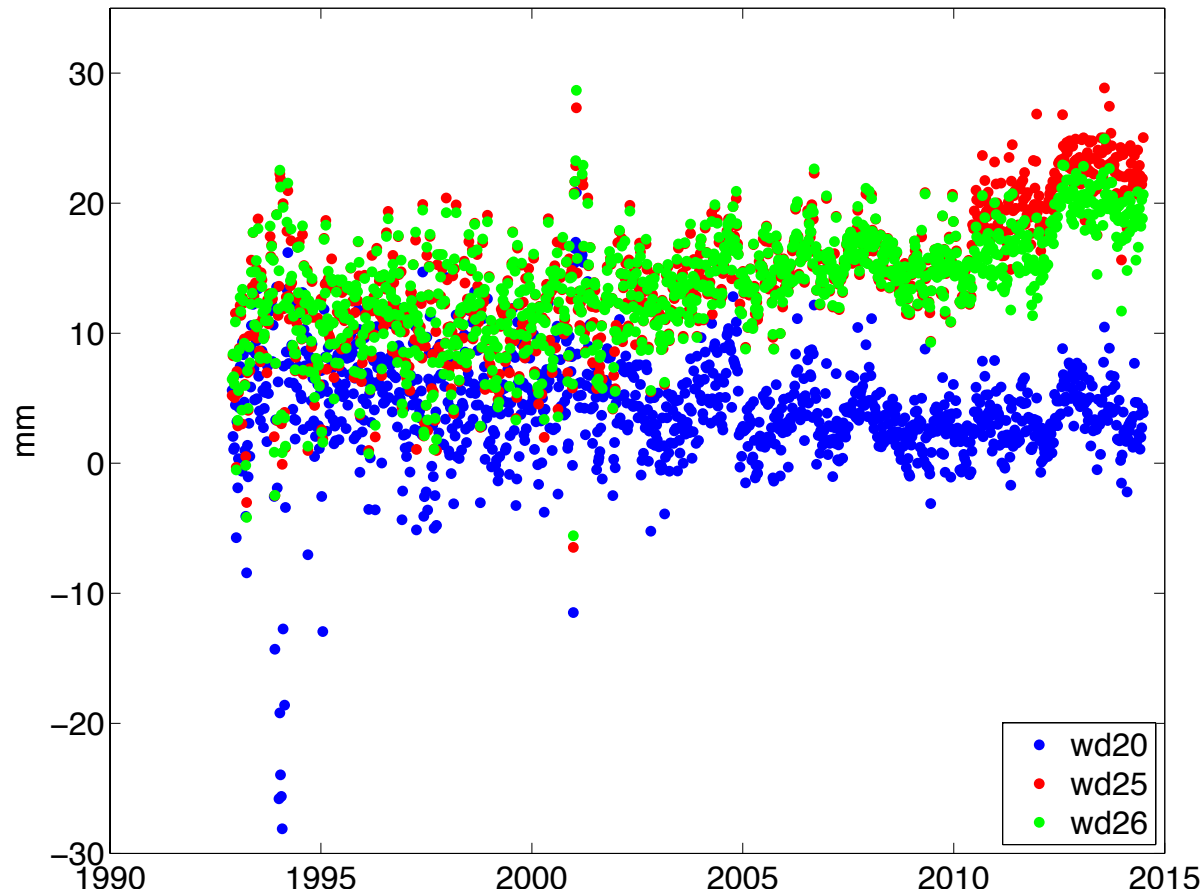


WRMS Comparison (2008-2014)

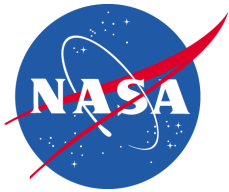




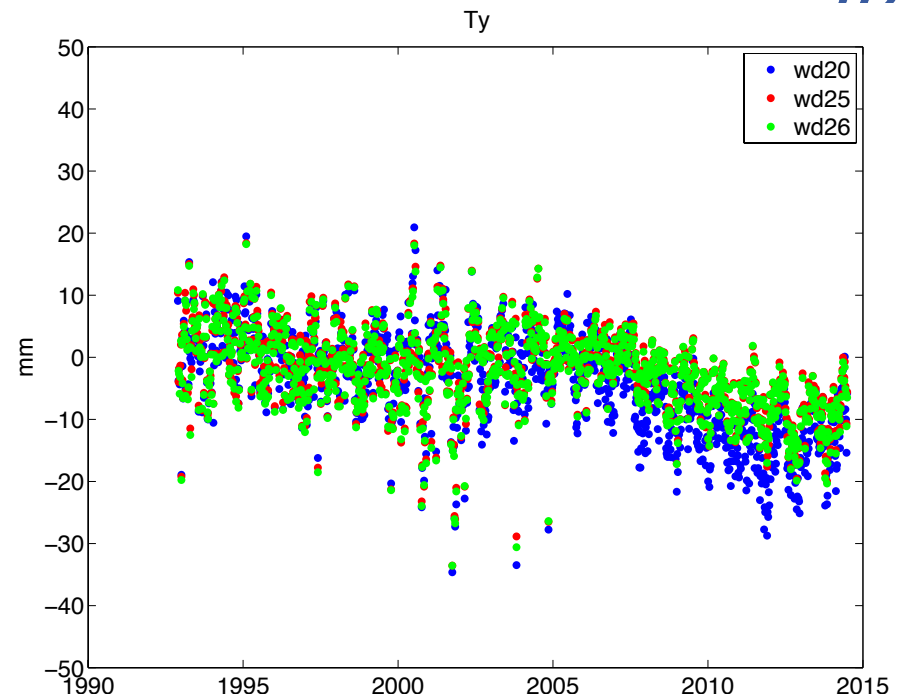
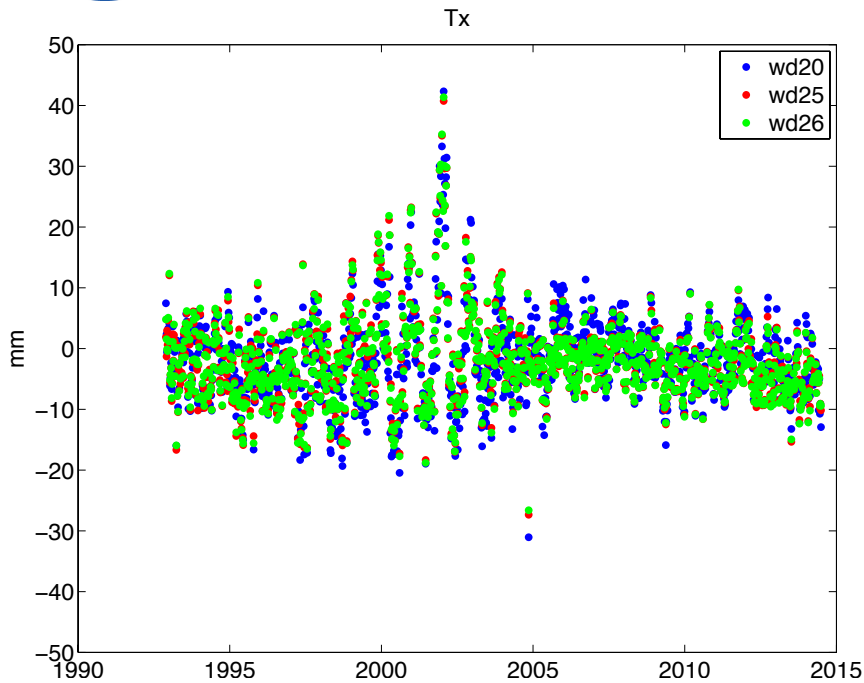
Scale Comparison



- Delta-scale (wd20 \rightarrow wd25) is due to the DORIS antenna phase law, the addition of HY2A, and the use of GEODYN-computed offset corrections.
- Change in cross-track OPR parameterization (wd26 vs. wd25) mitigates the scale jump observed in 2010-2014.

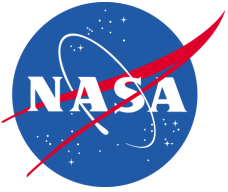


Tx and Ty Comparison

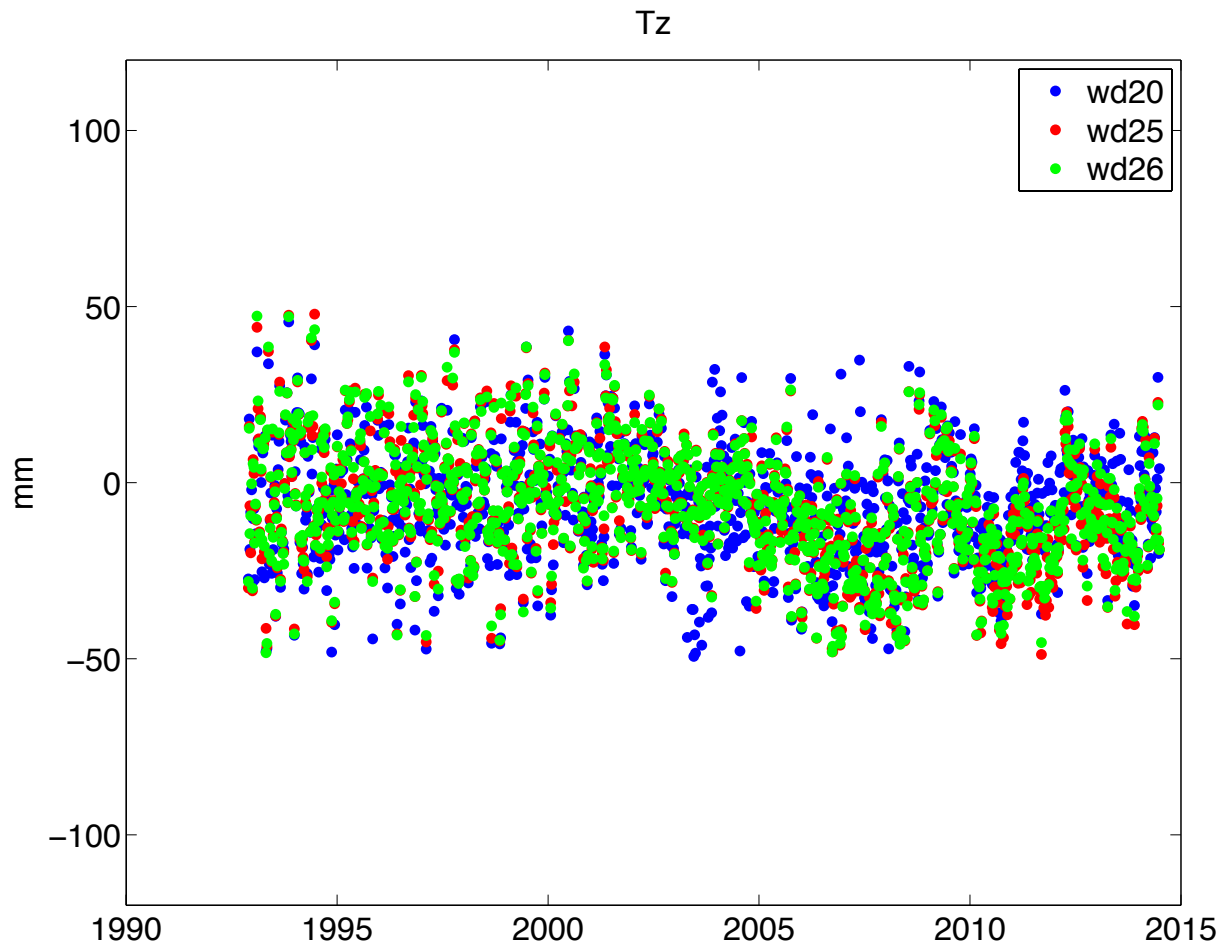


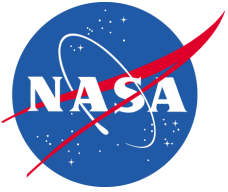
| Tx parameter fit (Jan 1, 2005 – Jan 1, 2014) | | |
|---|--------------|--------------|
| | wd20 | wd25 |
| Slope | -0.546 mm/yr | -0.423 mm/yr |
| Annual | 3.16 mm | 1.70 mm |
| Phase (°) | 322.6 | 319.5 |

| Ty parameter fit (Jan 1, 2005 – Jan 1, 2014) | | |
|---|--------------|--------------|
| | wd20 | wd25 |
| Slope | -2.018 mm/yr | -1.510 mm/yr |
| Annual | 4.13 mm | 2.74 mm |
| Phase (°) | 132.2 | 132.1 |

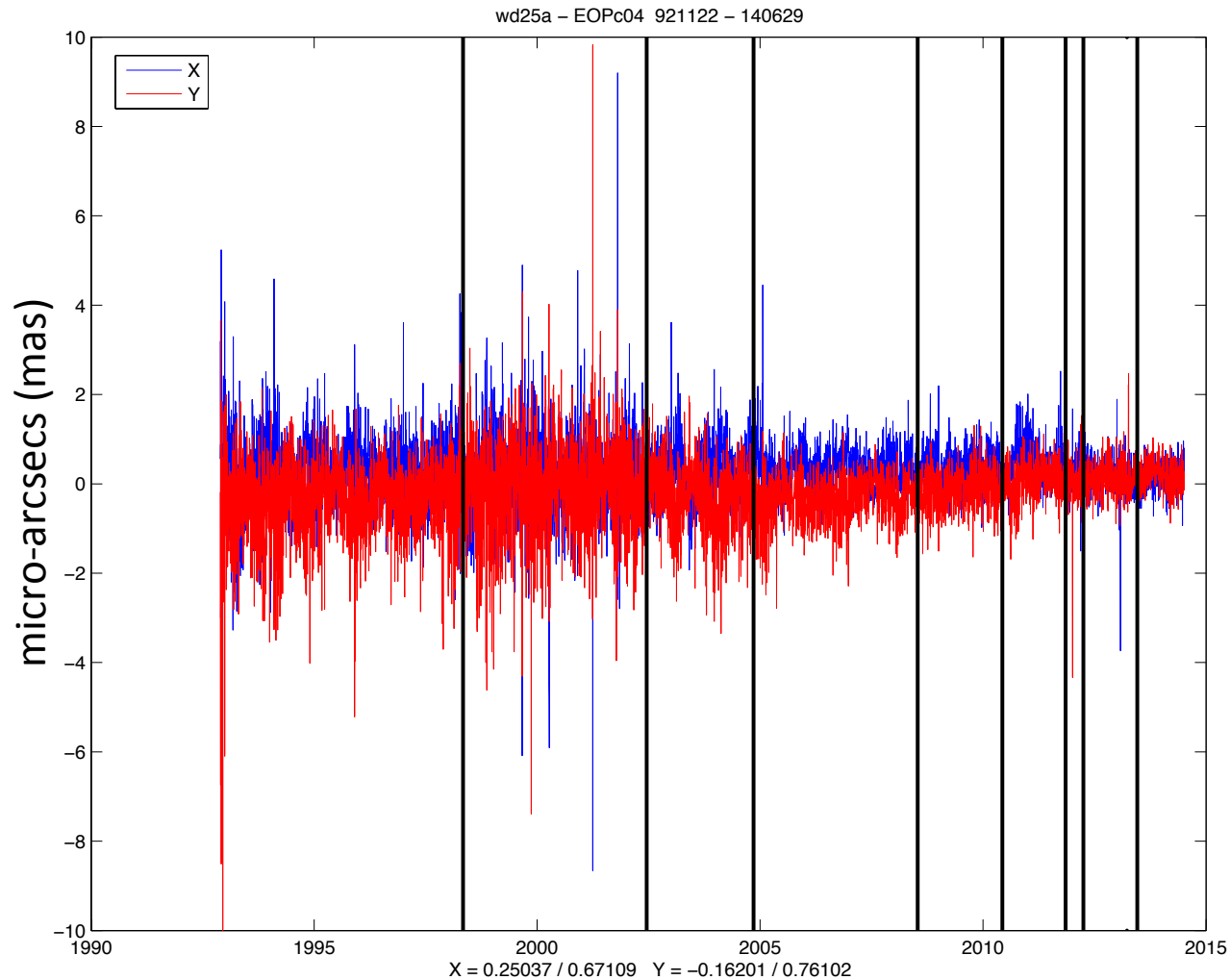


Tz Comparison

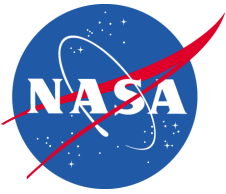




EOP (Px, Py) wd25a Differences w. IERSC04



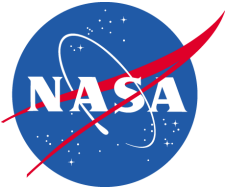
Black vertical lines indicate the dates of changes in the DORIS satellite constellation.



EOP (Px, Py): Summary (wd25a vs. IERSC04)



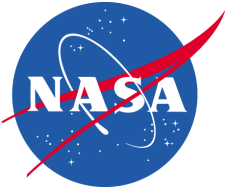
| Time Period | Px Diffs (μ -arcsec) (mean/st dev) | Py Diffs (μ -arcsec) (mean/st dev) | Npts | Nsats | Dates |
|-------------|---|---|------|-------|-----------------|
| All | 0.250/ 0.671 | 0.162/ 0.761 | 7896 | 2-7 | 921122 - 140629 |
| TP #0 | 0.195/ 0.876 | -0.231/ 0.976 | 3483 | 2-3 | 921122 - 980428 |
| TP #1 | 0.149/ 0.969 | -0.070/ 1.068 | 1496 | 3 | 980503 - 020609 |
| TP #2 | 0.291/ 0.581 | -0.230/ 0.697 | 874 | 5 | 020616 - 041031 |
| J1 | 0.302/ 0.412 | -0.261/ 0.436 | 1147 | 5 | 041107 - 080706 |
| J2 | 0.321/ 0.400 | -0.112/ 0.427 | 693 | 5 | 080713 - 100530 |
| C2 | 0.447/ 0.415 | 0.106/ 0.396 | 519 | 6 | 100606 - 111031 |
| HY | 0.338/ 0.349 | -0.023/ 0.294 | 63 | 7 | 111107 - 120324 |
| HY – Env | 0.181/ 0.293 | 0.129/ 0.313 | 260 | 6 | 120401 - 130317 |
| Sa | 0.087/ 0.276 | 0.168/ 0.258 | 67 | 7 | 130324 - 130609 |
| Sa – S4 | 0.142/ 0.299 | 0.203/ 0.304 | 385 | 6 | 130616 - 140629 |



EOP (Px, Py): Conclusions (wd25a vs. IERSC04)

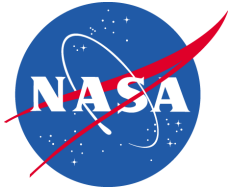


- 1. Confirms what we have observed previously – Positioning & EOP determination improves with addition of more DORIS satellites.**
- 2. Noticeable degradation near solar maximum (1998-2002)**
(notwithstanding extra Cd parameterization on S4, S5, Envisat)
- 3. Performance with J1, J2 is comparable.**
- 4. Both HY-2A and Saral (Saral not part of ITRF2013 submission) improve EOP determination.**
- 5. Statistics may change as we edit outliers more rigorously.**

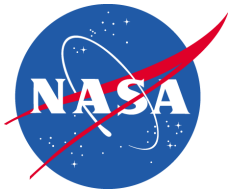


Future work

- Prepare paper(s) for DORIS special issue to document contributions to ITRF2013.
- Add Saral to operational processing.
- Decide how to continue operational series, wrt. TVG modeling and funding.
- DORIS RINEX processing will be the next big challenge.



Backups



Summary

(mean & standard deviation)

| Time Interval | Solution | WRMS (mm) | Tz (mm) | Scale (mm) |
|---------------|----------|-----------|--------------------------|------------------------|
| 2002 - 2008 | wd15 | 11.62 | -7.49 / 20.43 | -1.32 / 3.62 |
| | wd20 | 10.22 | -9.49 / 15.81 | 4.10 / 2.89 |
| | wd25 | 9.48 | -9.64 / 14.45 | 14.49 / 2.67 |
| 2008 - 2014 | wd15 | 12.33 | -4.63 / 17.89 | -3.21 / 2.83 |
| | wd20 | 9.95 | -8.44 / 13.94 | 3.20 / 2.18 |
| | wd25 | 9.48 | -15.40 / 14.58 | 18.61 / 3.86 |

2002-2008. Delta Scale is due to DORIS Antenna Phase Law (+10.39 mm)
2008-2014. Delta Scale is due to DORIS Antenna Phase Law + HY2A (+15.41 mm)