Plan for the IDS Contribution to the ITRF 2020

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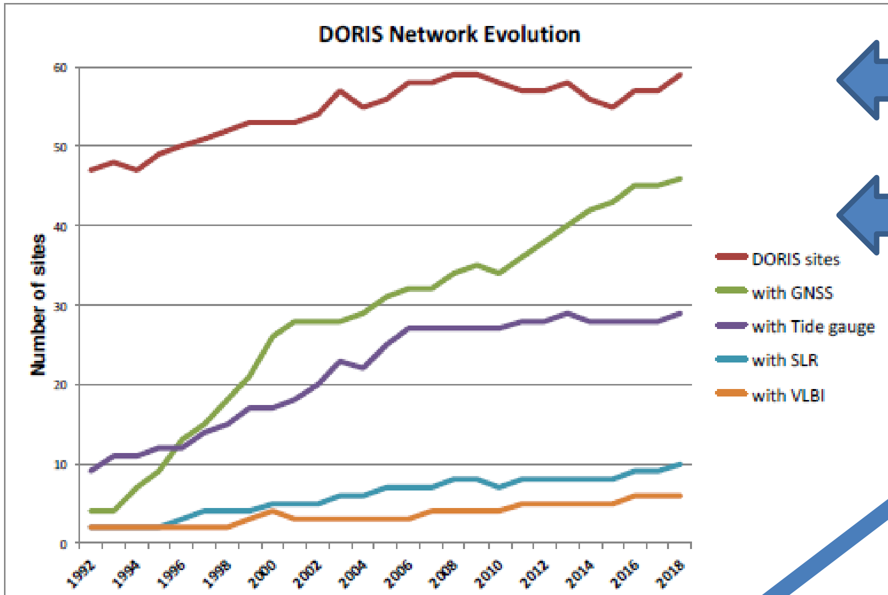
Previous and forthcoming contributions

- ITRF 2005: 2 analysis centers, 6 satellites
- ITRF 2008: 7 analysis centers, 7 satellites
- ITRF 2014: 6 analysis centers, 11 satellites

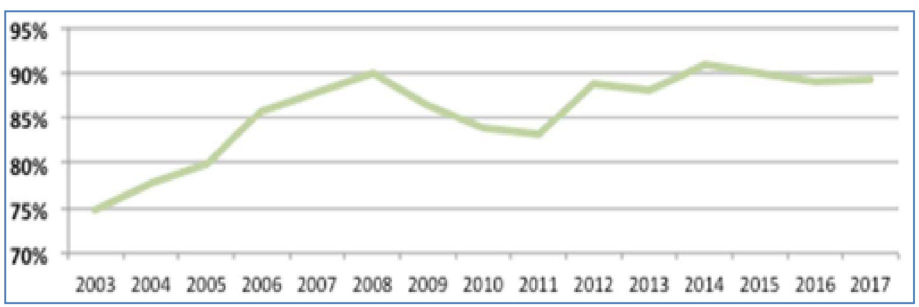
- ITRF 2020 (expected): 6 analysis centers, 14 satellites

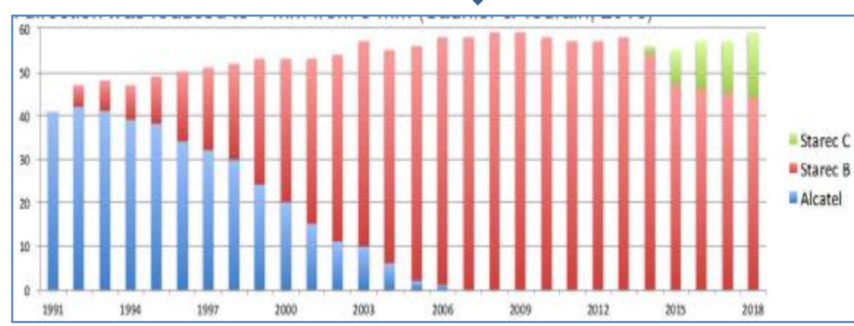
ESA	software: NAPEOS
GOP	software: Bernese
GRG	software: Gins/Dynamo
GSC	software: GEODYN
IGN	software: Gipsy-Oasis
INA	software: Gipsy-Oasis

DORIS system evolution - network



- Rising number of stations (aprox. till 2008)
- Rising number of inter-technique co-locations
- Network availability around 90%
- Antenna replacement with types of lower antenna phase center uncertainty





For more detail information see Saunier, 2018

DORIS system evolution – space segment

Satellite	from	to	max. tracking stations	Used for ITRF 2014
SPOT-2	1992	2008	1	Yes
T/P	1992	2005	1	Yes
SPOT-3	1994	1996	1	Yes
SPOT-4	1998	2013	1	Yes
Jason-1	2002	2013	2	Some ACs
Envisat	2002	2012	2	Yes
SPOT-5	2002	2015	2	Yes
Jason-2	2008	2020 (?)	7	Yes
Cryosat-2	2010	2020*	7	Yes
Hy-2A	2011	2020*	7	Yes
Saral	2013	2020*	7	Some ACs
Jason-3	2016	2020*	7	No
Sentinel-3A	2016	2020*	7	No
Sentinel-3B	2018	2020*	7	No

* expected

DORIS data to be used for ITRF 2020 reprocessing

- 3 new satellites

Doppler vs. RINEX observations

- In previous IDS deliveries for ITRF, only Doppler data were processed
- Now also RINEX data (Phase and pseudorange) are processed
- Most analysis centers transform Phase to Doppler
- Only pseudoranges for time-reference beacons are processed to estimate onboard polynomial clock model
- Advantage of RINEX – closer to raw measurements
- Both formats are not available for all the satellites

Type Obs.	Ionosphere	Onboard clock	Phase center offset
Doppler	Corrections from data file	Corrections from data file	Corrections from data file or measured/calculated attitude + nominal offset
RINEX	Measurement on both frequencies	Calculated from pseudorange measurements	Measured/calculated attitude + nominal offset

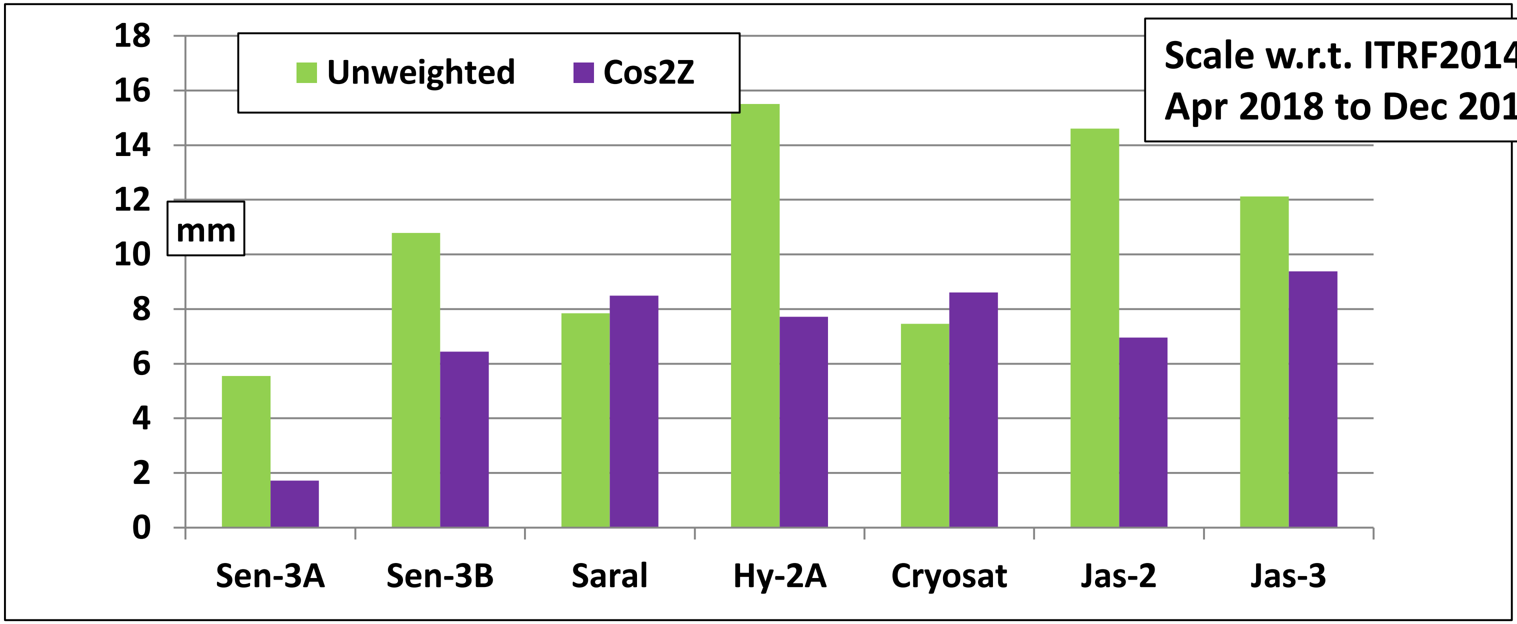
Scale

- Scale inconsistency in IDS solution for ITRF 2014 (in 2012). Another increment in IDS operational solutions in 2015.
- Study Štěpánek and Filler, 2018 shows the impact of data elevation weighting, preprocessing and phase center offset application (correction from data file/own calculation of attitude)
- Correction in HY-2A phase center offset from Satellite provider

Obs. weight Elevation cut off 10 deg	preprocessing indicators from data file	PCO correction from data file	Hy-2A corrected PCO	Scale w.r.t. ITRF 2014 (mm) in 2011.0-2017.0
1	Yes	Yes	-	22.1±10.7
Sin^2 E	Yes	Yes	-	15.5±5.1
Sin^2 E	No	Yes	No	14.2±3.3
Sin^2 E	No	No	No	12.7±2.3
Sin^2 E	No	No	Yes	10.5±2.0

Scale (2) *Why the scale bias is dependent on elevation observation weighting?*

- Elevation dependent systematic effect (elevation weighting and cut off)
- Single-satellite solution experiment – effect is satellite-specific (including sign)
- Scale from single-satellite solutions is more consistent when elevation-dependent weighting is applied (except for Sentinel-3A). Hypothesis: systematic effects of different elevation observations better compensate each other.
- Missing satellite PCV model (For stations elevation-dependent PCV model is applied)
- Multipath? See recent study Ait-Lakbir et al. 2019



Scale w.r.t. ITRF2014 from Apr 2018 to Dec 2018

Scale (Summary)

Improvements w.r.t. ITRF 2014 strategy

- Preprocessing indicators and PCO corrections associated with Doppler observations are not consistent for long time series. Avoiding use of this supplemental information improves scale stability and reduces bias w.r.t. ITRF 2014.
- Elevation dependent weighting significantly increases the stability of the scale and reduces the scale bias w.r.t ITRF 2014.
- Corrected HY-2A PCO reduces the scale bias w.r.t. ITRF2014

Still open issues

- We need a better understanding of the scale bias between individual analysis centers solutions and optimization of elevation weighting and cut off angle.
- Clarification of elevation-dependent systematic effects

South Atlantic Anomaly

- USO instability due to the radiation trapped in Van Allen belts
- Jason-1 (stong effect), Jason-3, SPOT-5 (moderate effect), Jason-2
- Data corretive models for SPOT-5 and Jason-1 (Capdeville et al. 2016)
- USO models for Jason-2, -3 based on Results from T2L2 (Exertier et al. 2010) under testing
- Strategy to rename stations in SINEX for affected satellites
- Strategy to estimate frequency offset as linear instead of constant per satellite pass.

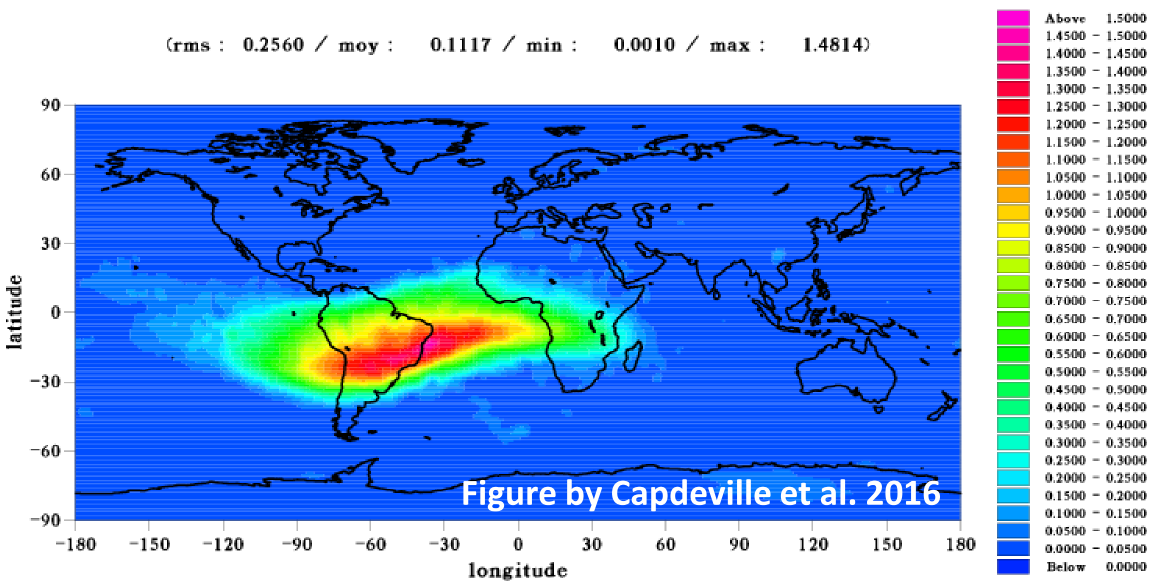


Figure by Capdeville et al. 2016

Non-conservative force modeling

- DORIS satellites are LEOs, with various macromodels, attitude and orbit characteristics
- imperfection results to the signal in translation Xt, Yt, Zt and ERP series
- Draconitic signal of 118 days (T/P and Jason satellites)
  - reduced when applying measured attitude for Jason satellites instead of nominal model
  - For T/P no measured attitude is available, need of proper modeling changes in attitude modes and solar array panel pitch biases and orientations
- Revision and comparison of non-conservative modeling planned for analysis centers before start of ITRF reprocessing
  - SRP coefficient fixed or adjusted?
  - frequency of drag coefficient estimation
  - comparison of OPR amplitudes

New combination strategy (1)

Evaluation of the IDS contribution to ITRF2014 (ids 09) wrt the IDS contribution to ITRF2008 (ids 03) revealed

- **Worse performance in terms of station position residuals wrt ITRF2008 in the East direction mainly from 1993.0 to 2002.4.**
- **A degradation of the X and Y pole differences wrt IERS C04 series from 1993.0 to 2002.4.**

➔ Origin of the degradation?

Table 9
Main statistics of WRMS of the station residuals from IDS 03 (ITRF2008) and IDS 09 (ITRF2014) series. Unit is mm.

Series id.	Time span	East		North		Up	
		Mean	Std	Mean	Std	Mean	Std
IDS 03	1993.0–2002.4	19.41	2.73	15.09	2.50	18.08	2.56
IDS 03	2002.4–2008.5	12.97	1.89	10.25	1.94	12.81	1.96
IDS 03	2008.5–2009.0	16.39	2.24	13.26	1.40	14.82	1.85
IDS 09	1993.0–2002.4	25.19	4.78	15.78	3.23	19.95	3.86
IDS 09	2002.4–2008.5	11.97	2.14	8.73	1.51	10.09	1.92
IDS 09	2008.5–2015.0	9.14	1.23	7.18	1.17	8.05	1.19

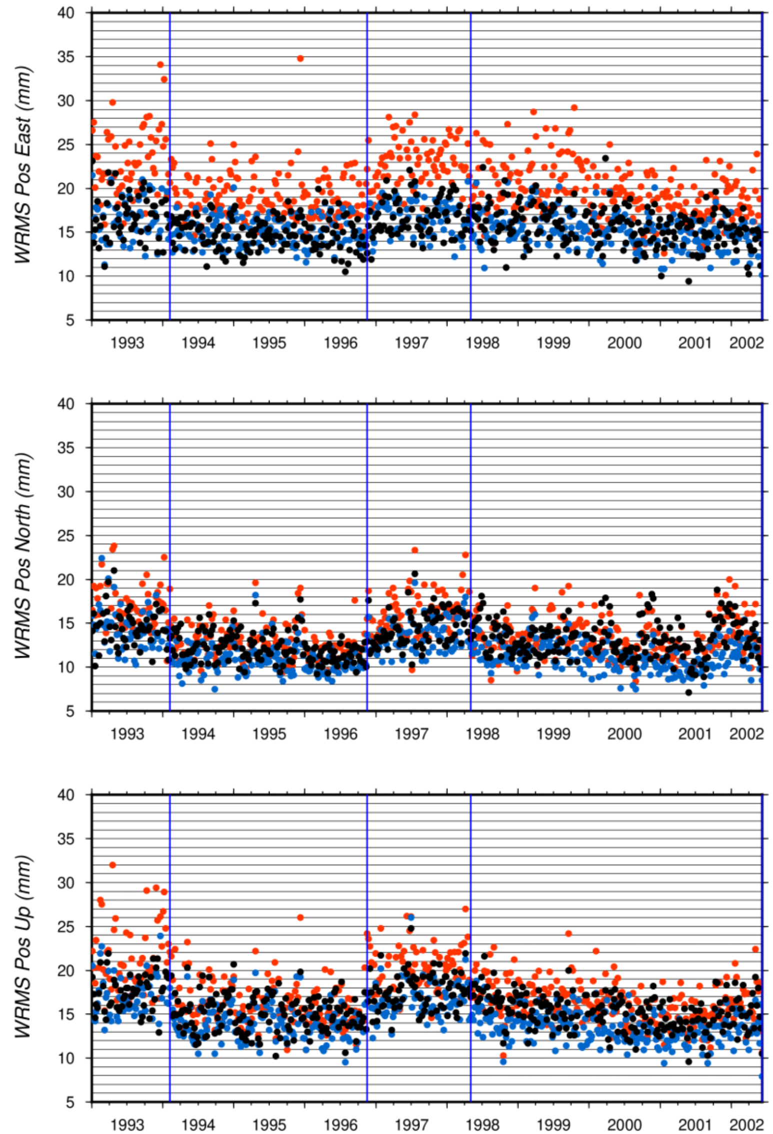
Source: Moreaux et al. (2016).

New combination strategy (2)

ids03 = ITRF2008
ids09 = ITRF2014
idsXX = NEW for ITRF2020

- **For all the time periods, IDS XX performs even better than IDS 03.**

Time Period	Series	North [mm]	East [mm]	Up [mm]
1993.0-1994.1	ids 03	14.5 ± 2.1	16.8 ± 2.6	17.5 ± 2.0
	ids 09	16.9 ± 2.6	23.2 ± 3.8	21.3 ± 3.9
	ids XX	14.3 ± 2.4	16.4 ± 2.4	17.2 ± 2.4
1994.1-1996.9	ids 03	12.1 ± 1.6	14.8 ± 1.8	15.0 ± 2.1
	ids 09	12.7 ± 1.9	19.0 ± 2.7	16.1 ± 2.5
	ids XX	10.9 ± 1.5	15.1 ± 1.6	14.0 ± 1.9
1996.9-1998.3	ids 03	14.4 ± 2.0	16.8 ± 2.1	17.6 ± 2.1
	ids 09	16.0 ± 2.6	23.0 ± 2.7	20.3 ± 2.6
	ids XX	13.6 ± 1.8	16.8 ± 1.9	16.7 ± 2.1
1998.3-2002.3	ids 03	13.1 ± 2.1	15.7 ± 2.2	15.2 ± 2.0
	ids 09	13.3 ± 2.2	19.6 ± 3.1	16.3 ± 2.3
	ids XX	11.2 ± 1.6	15.1 ± 1.9	13.5 ± 1.7



Summary

1) In the new DORIS series, we introduce several strategies to mitigate known errors in the previous realization (ITRF2014)
2) Extending the series with recent data, we profit from improvements in the network and from new satellite missions
3) We reached the long-term stable combined DORIS scale
4) For satellites launched after 2008 , RINEX/DORIS format enables to process data closer to the raw measurement.

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