Implementation and use of the DORIS RINEX phase measurements in the GINS software

Jean-Michel Lemoine, Richard Biancale, Laurent Soudarin

Introduction

❖ Since the launch of the new generation DGXX DORIS receiver, the DORIS measurements are available in DORIS RINEX format, an extension of RINEX 3.0 format.

❖ The measurement quantities in this format are a precise, but ambiguous, phase measurement as well as a pseudo-range measurement, synchronous on both frequencies, thus similar in many respects to a GNSS measurement.

❖ The DORIS measurements are also still provided in the former Doppler-type DORIS 2.2 format.

❖ Three satellites carry today the DGXX receiver: Jason2, Cryosat2 and HY2A.

❖ We have implemented and tested the new DORIS phase measurement in the GINS software. We compare the use of this new type of measurement with the traditional Doppler measurement in terms of orbital fit residuals and DORIS station network estimation. We have considered 3 cases:

- DORIS 2.2 Doppler measurement ;
- DORIX RINEX phase measurement converted to Doppler by differentiating consecutive measurements ;
- DORIX RINEX ambiguous phase measurement treated as such.

Measurement equations

❖ DORIS 2.2 format

$$N_{OBS} = \left(\left(f_e - f_r \right) - \frac{f_e V_{2.2}}{c} \right) \Delta t$$

$$V_{THEO} = \frac{\rho_1 - \rho_2}{\Delta t} \quad V_{OBS} = \frac{c}{f_e} \left(\frac{N_{OBS}}{\Delta t} + \left(f_r - f_e \right) \right)$$

❖ DORIX RINEX phase measurement converted to Doppler

First we differentiate 2 consecutive phase measurements: $N_{OBS} = L_1(t_1) - L_1(t_2)$

Then we process the cycle count as above.

Only the measurements every 10 seconds are considered.

Parameters: 1 troposphere parameter per pass, 1 station frequency offset per pass.

❖ DORIX RINEX ambiguous phase measurement (see 2010 paper by Mercier et al. in ASR)

$$D_{THEO} = \rho_0 - \rho(t) \quad D_{OBS} = c \frac{L_1(t_0) - L_1(t)}{f_e}$$

Where t_0 is the first epoch of the phase batch

Parameters: 1 ambiguity per phase batch, 1 troposphere parameter per pass, 1 station frequency offset per pass

Some problems in the phase measurements processing

❖ Measurement interruptions

During a pass above a station, the measurements are often interrupted for 2 main reasons:

- Similar Doppler values for different channels (frequency scrambling)
- Small Doppler values and cycle slips.

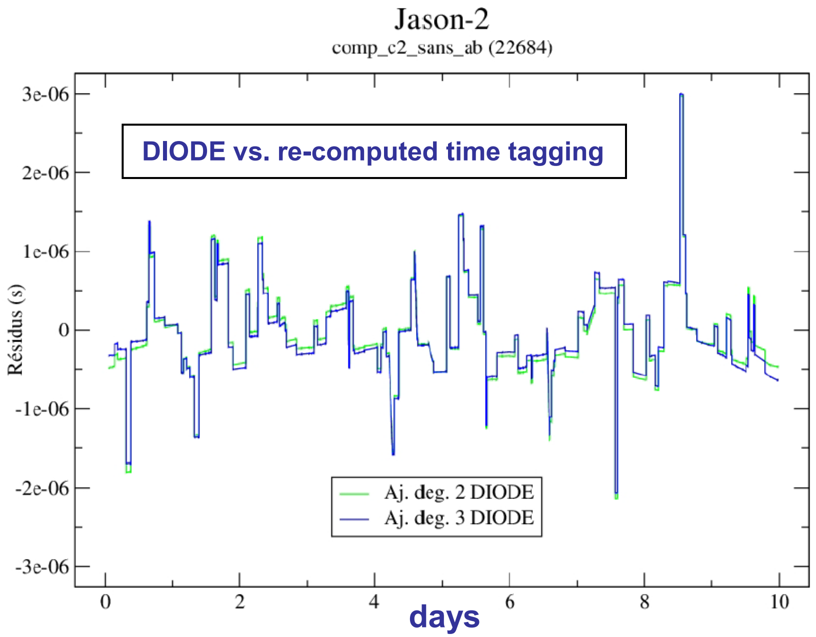
In both cases we do not try to reconstruct the cycle slips in the phase measurement. We break the pass in two parts and start again with a new ambiguity.

This is a less refined approach than the one of Mercier et al. who manage to reconstruct the cycle slips and therefore not break the pass at small Doppler values.

Receiver clock offset re-determination (improvement of the measurements time tagging)

❖ DORIS measurements are provided in TAI time scale through a conversion from receiver time to TAI time. For the DGXX instruments, this conversion is done on-board by the DIODE autonomous navigator, using a Kalman filter. This conversion can be improved by increasing, from one pass to 10 days, the time span over which the adjustment is done.

❖ In the DORIX RINEX format, the pseudo-range measurements relative to the time reference stations allow for a re-determination of the receiver clock offset with respect to TAI.

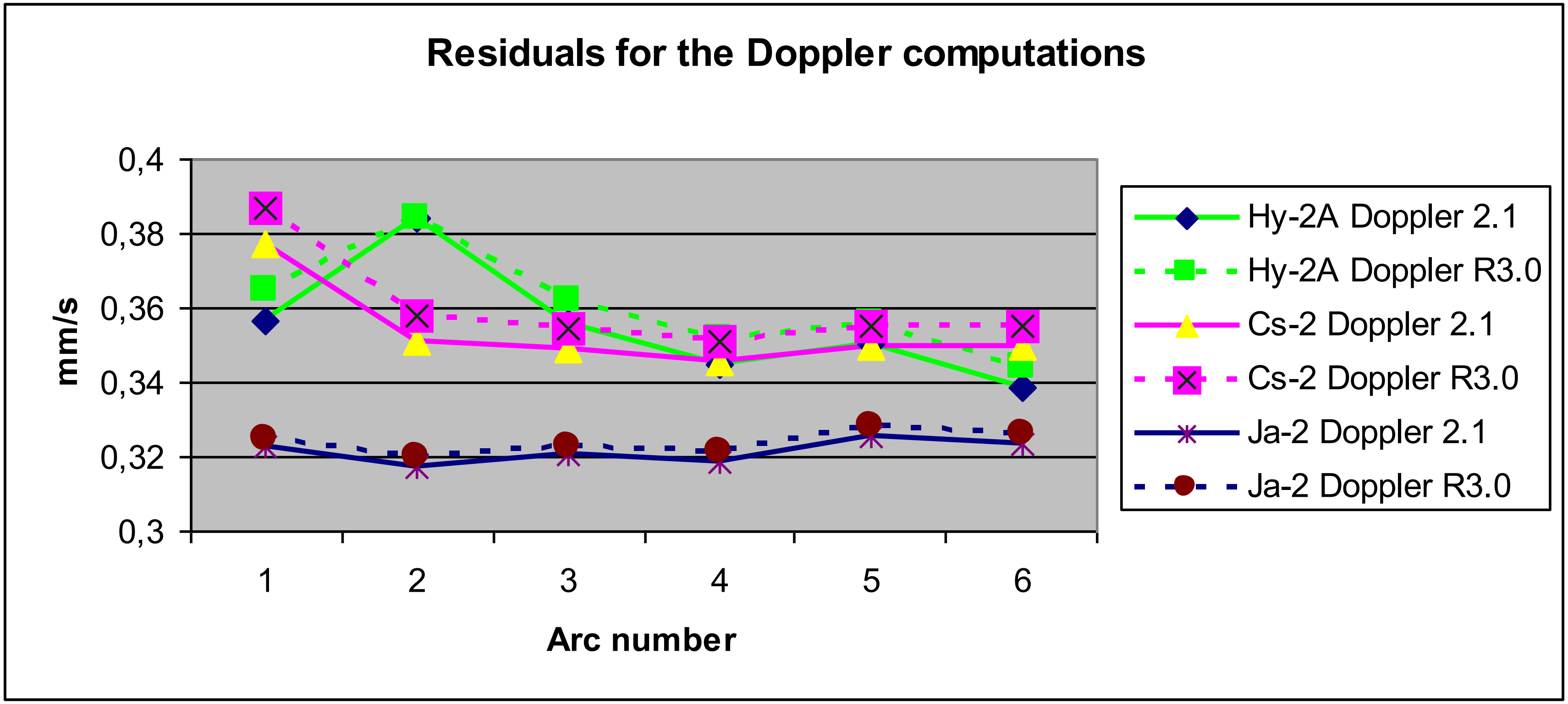


- Average precision of one pseudo-range measurement: 1000 m (3.10^{-6} s) - slightly better for 400 MHz than for 2 GHz
- Number of pseudo-range measurements over time reference stations per 10 days: ~1000
- Precision of time tagging reached over 10 days, adjusting a degree-3 polynomial: ~ 1.10^{-7} s (0.7 mm along-track)
- Precision of DIODE time tagging ~ 1.10^{-6} s rms (7 mm along-track)
- Maximum error of DIODE time tagging +/- 3.10^{-6} s (+/- 2 cm along-track)

Measurement residuals

Three weeks (six 3.5 day arcs) have been processed for each of the three satellites.

❖ Doppler processing (DORIS 2.2 and DORIS RINEX)



➢ **Arcs 1 of Cryosat-2 and 2 of HY-2A have a problem, they should be disregarded.**

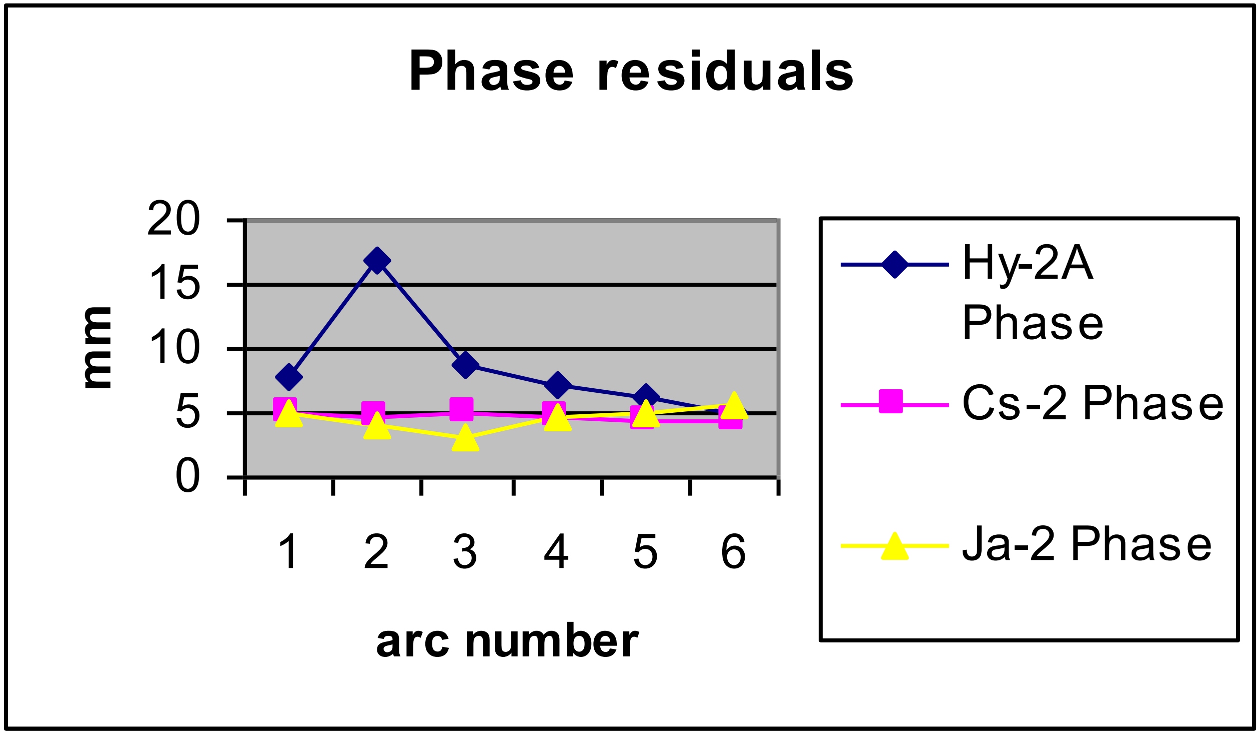
➢ **The Doppler residuals obtained from the DORIS RINEX files are similar to the ones obtained from the DORIS 2.2 files.**

➢ **DORIS RINEX residuals are slightly greater than DORIS 2.2's, but this has to do with the scale factor, as will be shown later.**

Measurement residuals

❖ RINEX phase processing

Residuals of the order of 5 mm, second arc of HY-2A has a problem.



Station network estimation

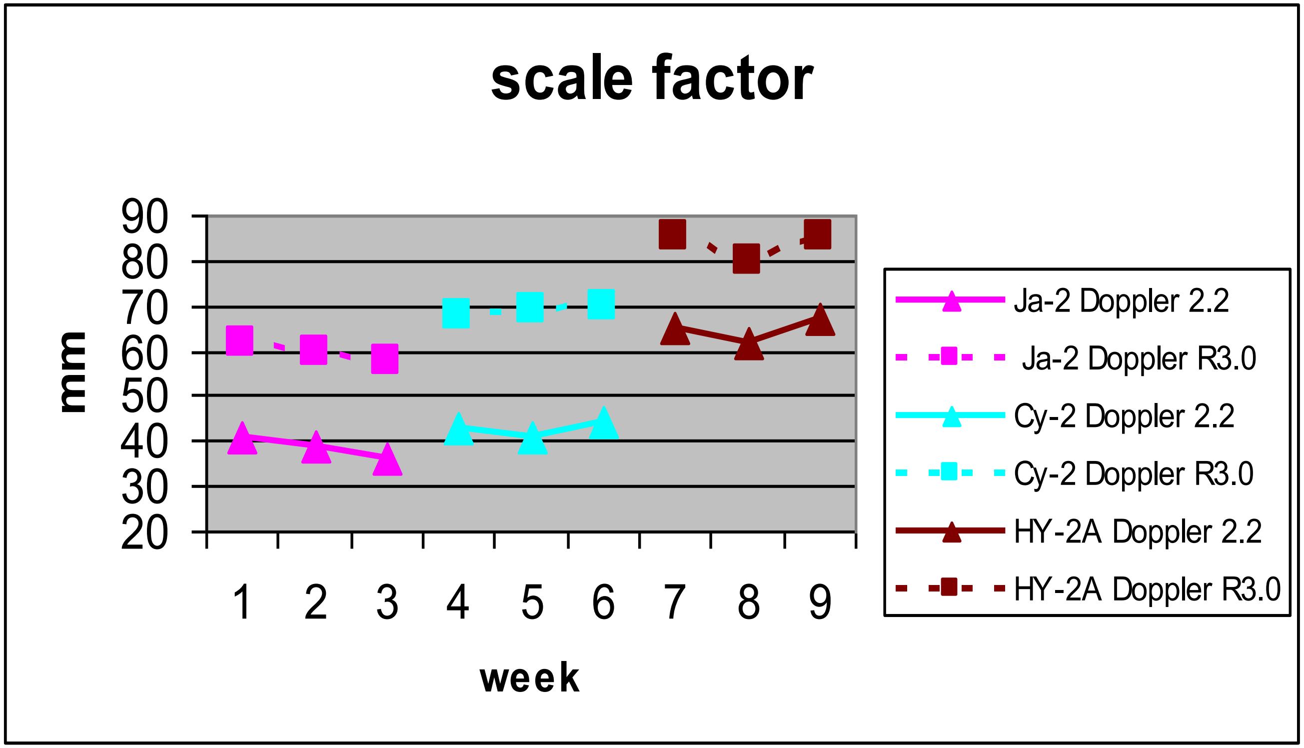
Estimation of the DORIS network using all 3 satellites for 3 weeks.

Comparison to ITRF2008:

	Bias (mm)			RMS (mm)		
	X	Y	Z	X	Y	Z
Doppler 2.2	-5.8	-9.7	0.4	24	15	14
Doppler RINEX	-3.8	-10.7	2.4	28	19	16
Phase RINEX	-0.9	-0.5	0.2	2.7	2.0	1.4

- **The X, Y and Z biases are rather coherent with the statistics of the LCA contribution to ITRF2008.**
- **The Phase results seem too optimistic (hidden constraint ? Error on partial derivative ?)**

Station network estimation

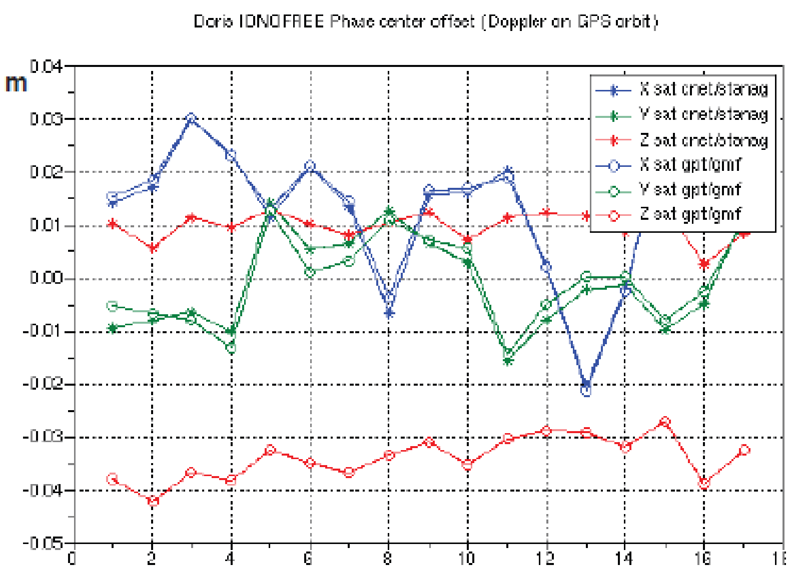


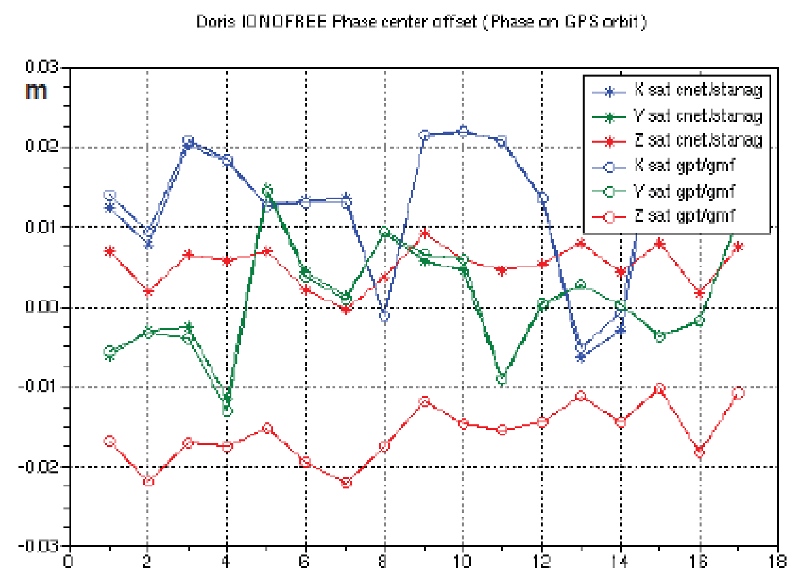
Average difference in scale factor between Doppler 2.2 and Doppler RINEX measurements:

- **Jason-2: 21 mm**
- **Cryosat-2: 26 mm**
- **HY-2A: 19 mm**

Results 1/2

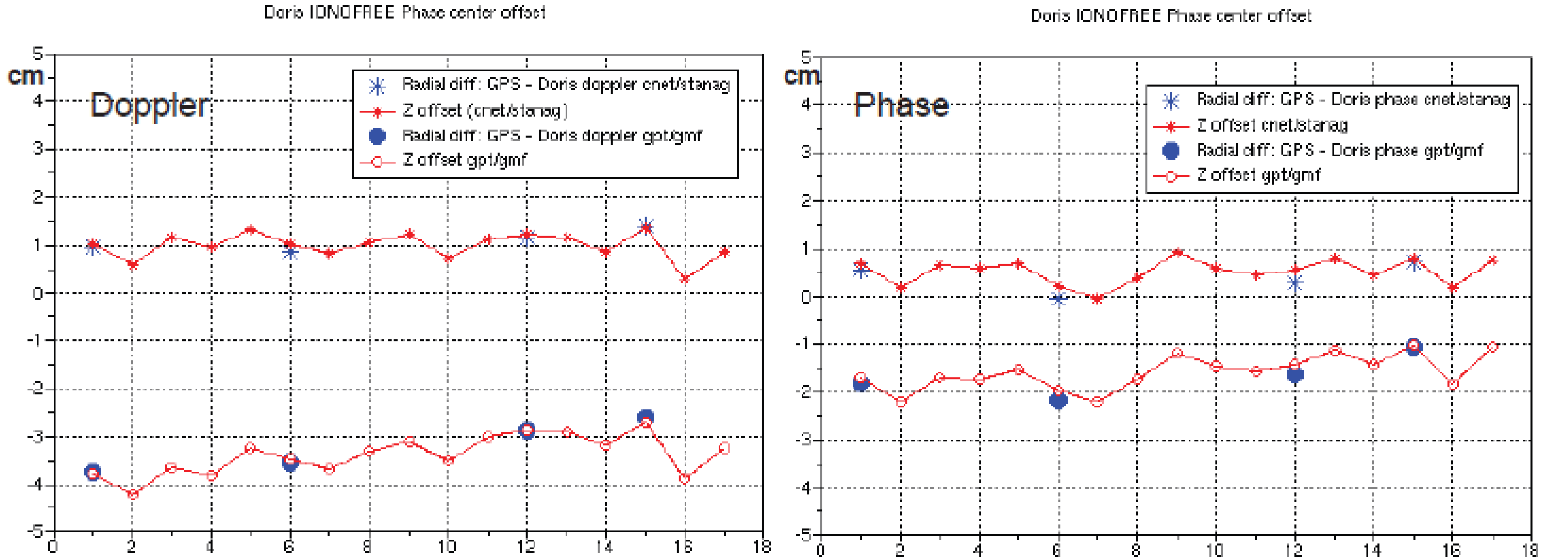
- **Direct estimation of DORIS offset with either Doppler or Phase measurements**





Results 2/2

- For cycles 001,006,012,015 estimation of a radial acceleration that compensates for the offset
  - The resulting orbit is compared to an independent GPS orbit (blue dots in plot below)
  - … obtaining the same result as previous plot



Conclusion

❖ Our results with the DORIS phase measurement seem too good to be true. We need to check our software and make some robustness tests.

❖ When the DORIS RINEX measurements are processed as Doppler measurements, the results are similar to those of the DORIS 2.2 measurements, except for the radial estimation of the network (or satellite antenna).

❖ Is this connected with the problem detected on the DORIS antenna phase center and phase law ?