CALVAL : IMPROVED REAL-TIME DORIS/DIODE ORBITS for JASON-2 OGDR

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CALVAL Abstract

- On February 2010, a new version of the DIODE (DORIS Immediate Orbit on-board Determination) Navigation Software has been uploaded on-board DORIS/Jason-2. This renewed real-time on-board orbit determination software package has been activated on February 18th, following a recommendation of the Seattle OSTST.
- Thanks to a very good coordination between the different agencies, only a few OGDR were impacted by early convergence of the on-board orbit estimation process. In the mean time, TRIODE parameters were modified both at EUMETSAT and at NOAA in order to optimize ground processings.
- Since February 18th, accuracy of on-board DORIS/DIODE orbits has been oscillating between 1 and 5 cm radial RMS as compared to the final Precise Orbit Ephemerides (POE) orbit, allowing valuable NRT use of Jason-2 OGDR products. The presentation details these results through several months of on-board data.
- Future improvements are also discussed for Jason-2 as well as for the next missions. Ground analysis and validation tests show that the DORIS measurement is very precisely and properly modelled in the DIODE navigation software. Consequently, improvement of DIODE accuracy is still possible and should be driven by enhancement of the physical models : forces and perturbations of the satellite movement, Radio/Frequency phenomena perturbing measurements. Of course, parallel improvement of the DORIS station network is a necessity (densification reduction of interferences, suppression of multipath, stability of the antennas, …). In the end, if both models and network keep on being improved, a one-centimeter accuracy is possible with future versions of DIODE.

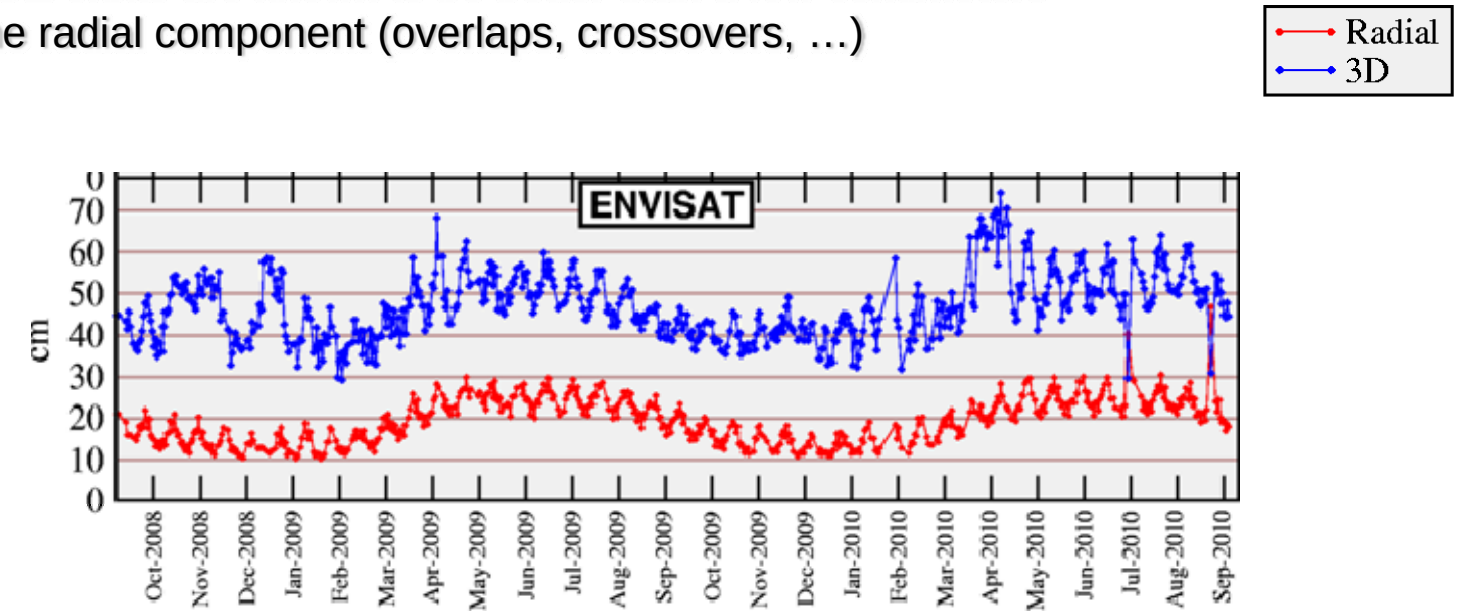
General overview

- Description of the navigation results of :
  - Envisat,
  - Jason-1,
  - and a few recent CryoSat-2 results, …
- Then the presentation will focus on the Jason-2 mission
  - Results of the new DIODE version.

- DIODE (DORIS Immediate Orbit on-board Determination) is a real-time on-board orbit determination software series, embedded in the DORIS receiver.
- Different versions have been flown on-board different satellites, beginning with SPOT4 (1998), Jason-1 (2001), SPOT5 (2002), EnviSat (2002), Jason-2 (2008), and CryoSat-2 (2010).

Envisat

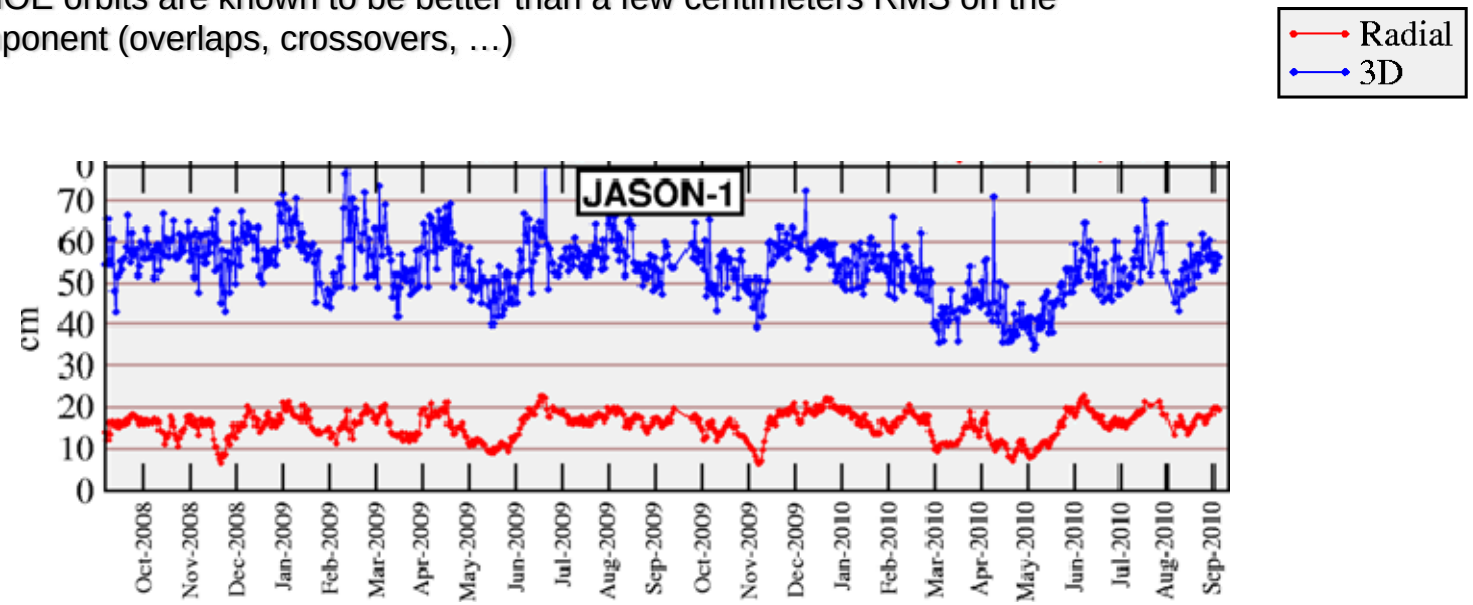
- Differences between on-board Diode and MOE orbits
- One RMS each day (except in case of manoeuver)
- Envisat MOE orbits are known to be better than a few centimeters RMS on the radial component (overlaps, crossovers, …)



- One-year oscillations probably due to Moon&Sun attraction
- A shorter period (week) has not been investicated
- Rather old issue of the Diode software (GEN2 v3_00, 2003)
- An enhanced version has been designed, but not uploaded (risk of memory failure)
- OLD PROCESSOR (31750) would not accept a modern issue of DIODE

Jason-1

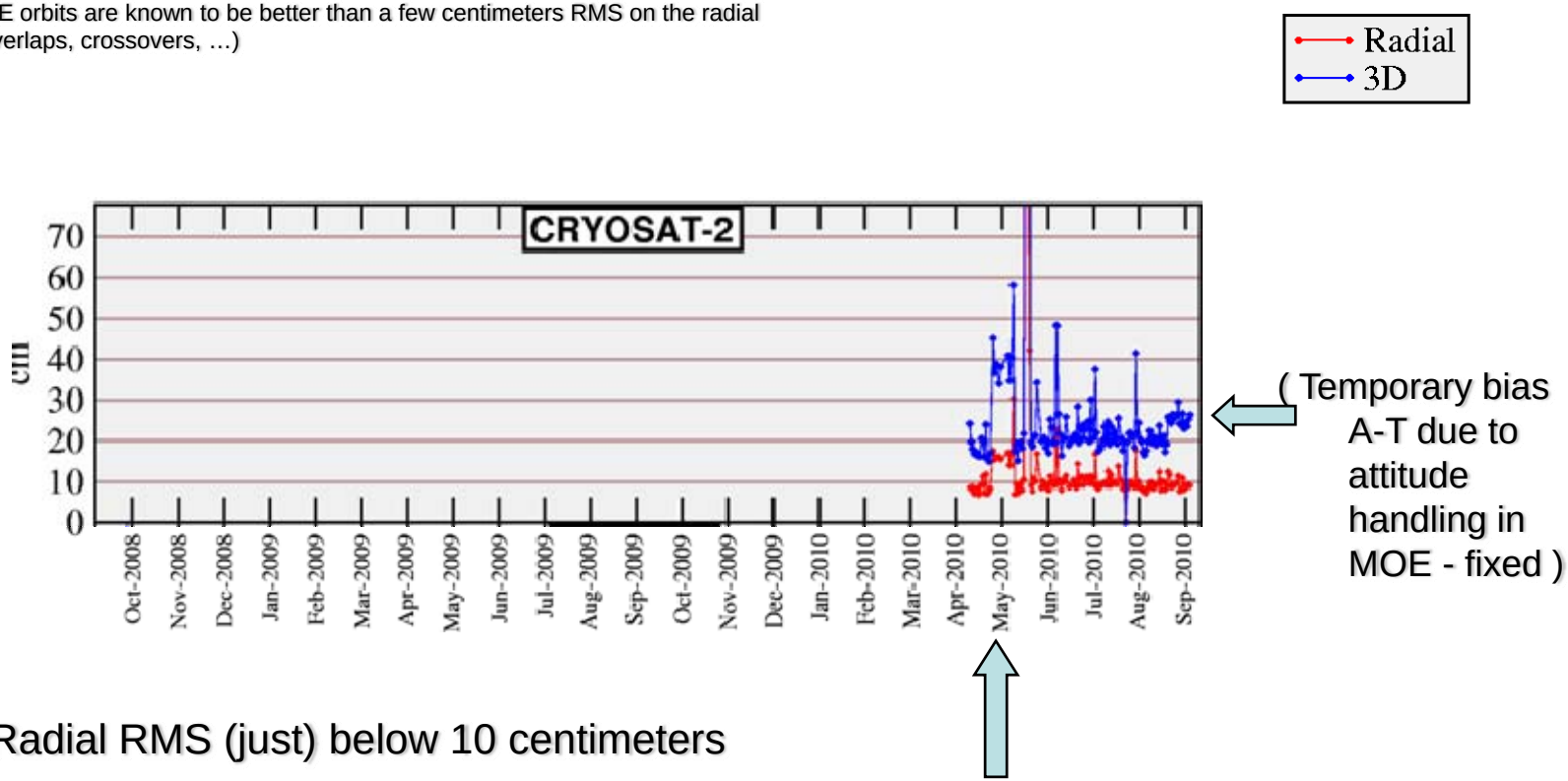
- Differences between on-board Diode and MOE orbits
- One RMS each day (except in case of manoeuver)
- Jason-1 MOE orbits are known to be better than a few centimeters RMS on the radial component (overlaps, crossovers, …)



- Strong correlation with the attitude mode : Jason-1 solar radiation pressure model is not very well fitted
- Long-term evolution : no upload to correct the mass value on-board, … and ageing of thermo-optical coefficients
- Rather old issue of the Diode software (MINI v2_08, 2002)
- OLD PROCESSOR (31750) would not accept a modern issue of DIODE

CryoSat-2

- Differences between on-board Diode and MOE orbits
- One RMS each day (except in case of manoeuver)
- CryoSat-2 MOE orbits are known to be better than a few centimeters RMS on the radial component (overlaps, crossovers, …)

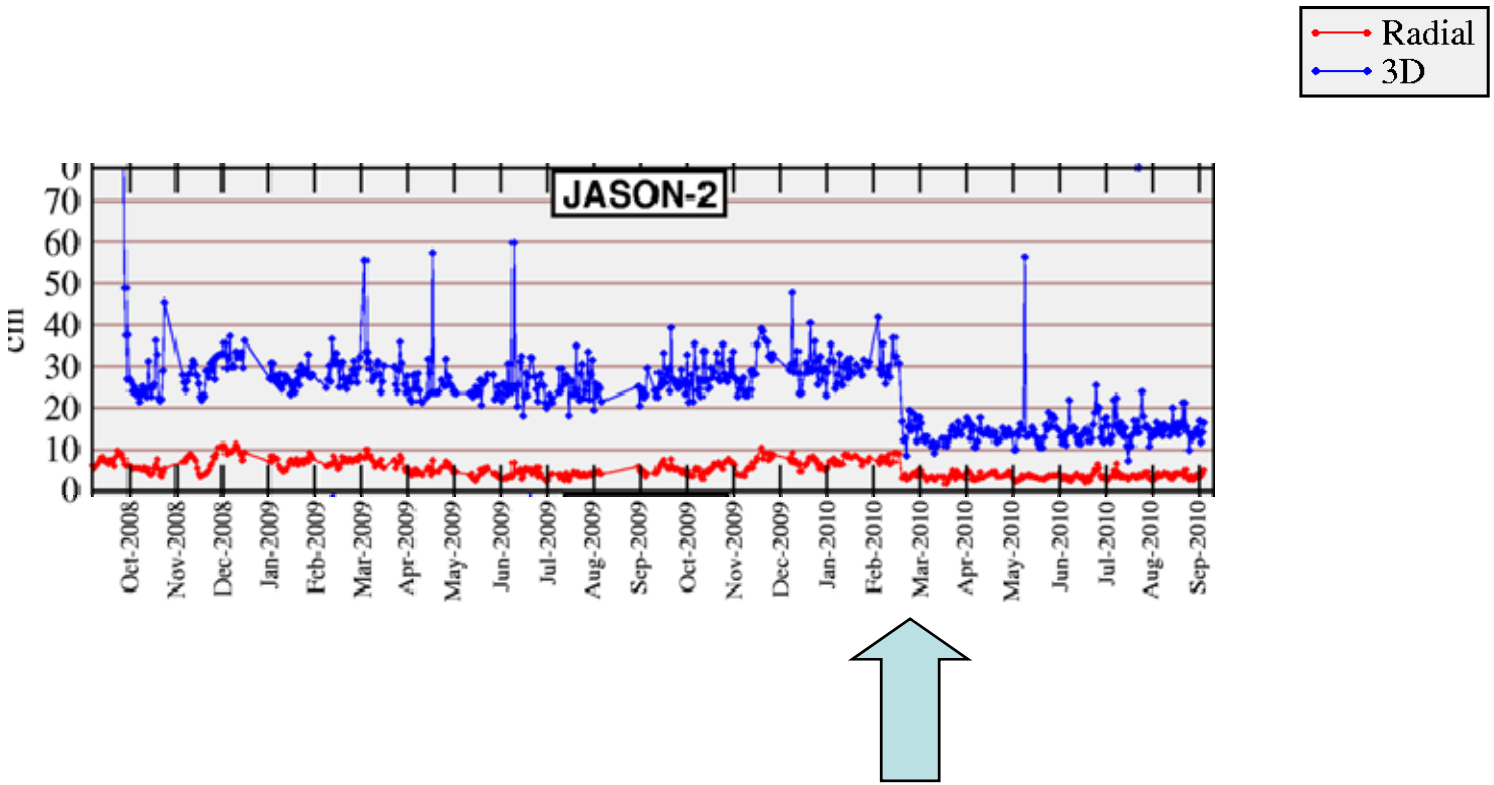


(Temporary bias A-T due to attitude handling in MOE - fixed)

- Radial RMS (just) below 10 centimeters
- Main perturbation on the graph is tied to 180° rotation of the satellite (center of phase, radiation pressure acceleration)
- Rather recent issue of the Diode software (DGXX v7_00, Feb. 2009)
- A better version exists (in-flight on-board Jason-2, see next view) and could be uploaded, probably leading to a few centimeters improvement

Jason-2

- Differences between on-board Diode and MOE orbits
- One RMS each day (except in case of manoeuver)
- Jason-1 MOE orbits are known to be better than a few centimeters RMS on the radial component (overlaps, crossovers, …)



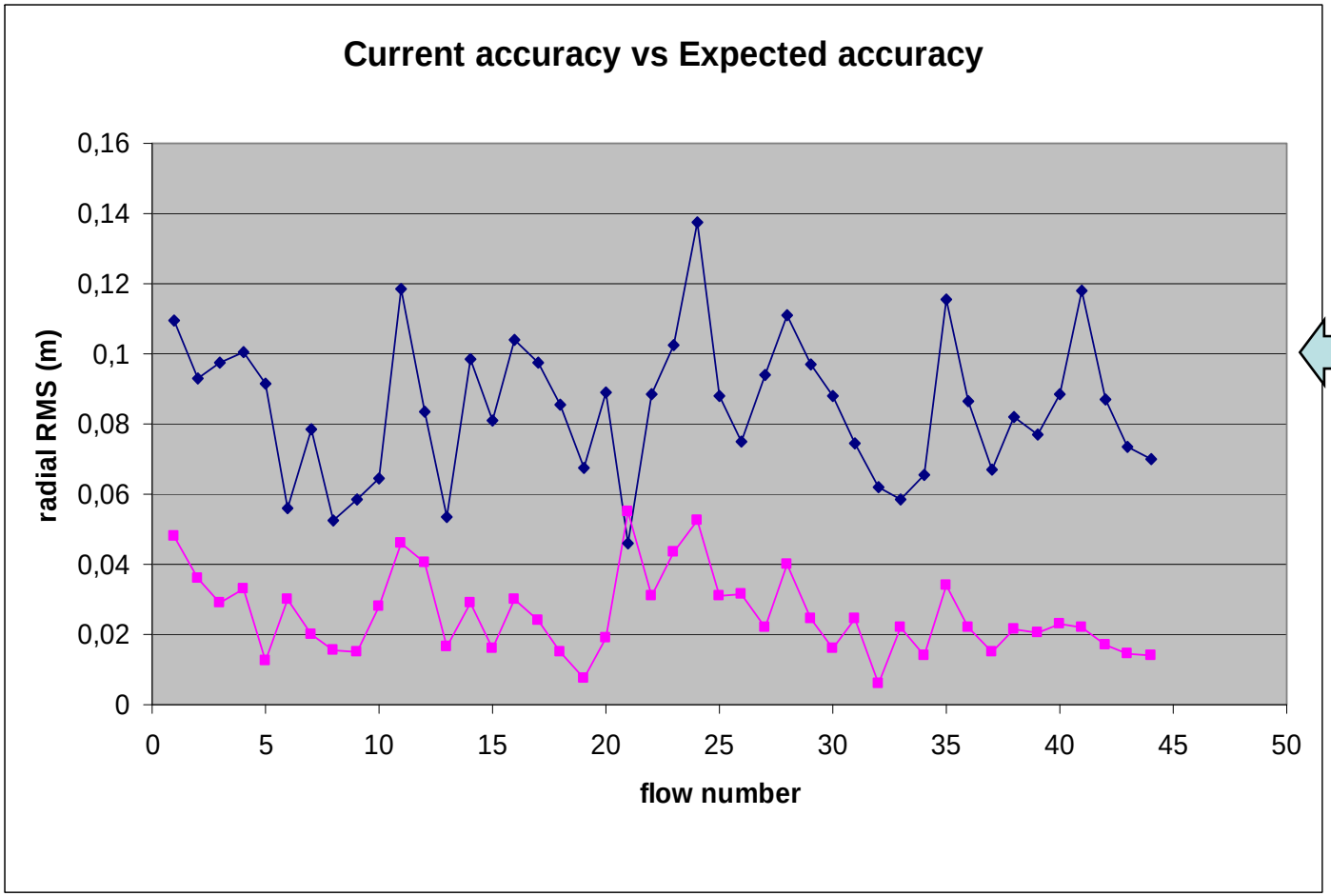
- Feb. 2010 improvement is due to upload of the new DGXX v8_00 flight software (including Diode v4.02 version) … as recommanded by the Seattle OSTST

- Radial RMS now most of the time below 5 cm

(before flight) ground tests of the new DGXX v8_00 issue :

what was foreseen for OGDR final accuracy (DIODE + TRIODE)

Reference = POE; radial **RMS** value of each flow



In blue :

early V4_00 configuration,

(Specification = 10 cm)

V8_00 version results are much better and well inside the specifications

Jason-2 new DORIS upload

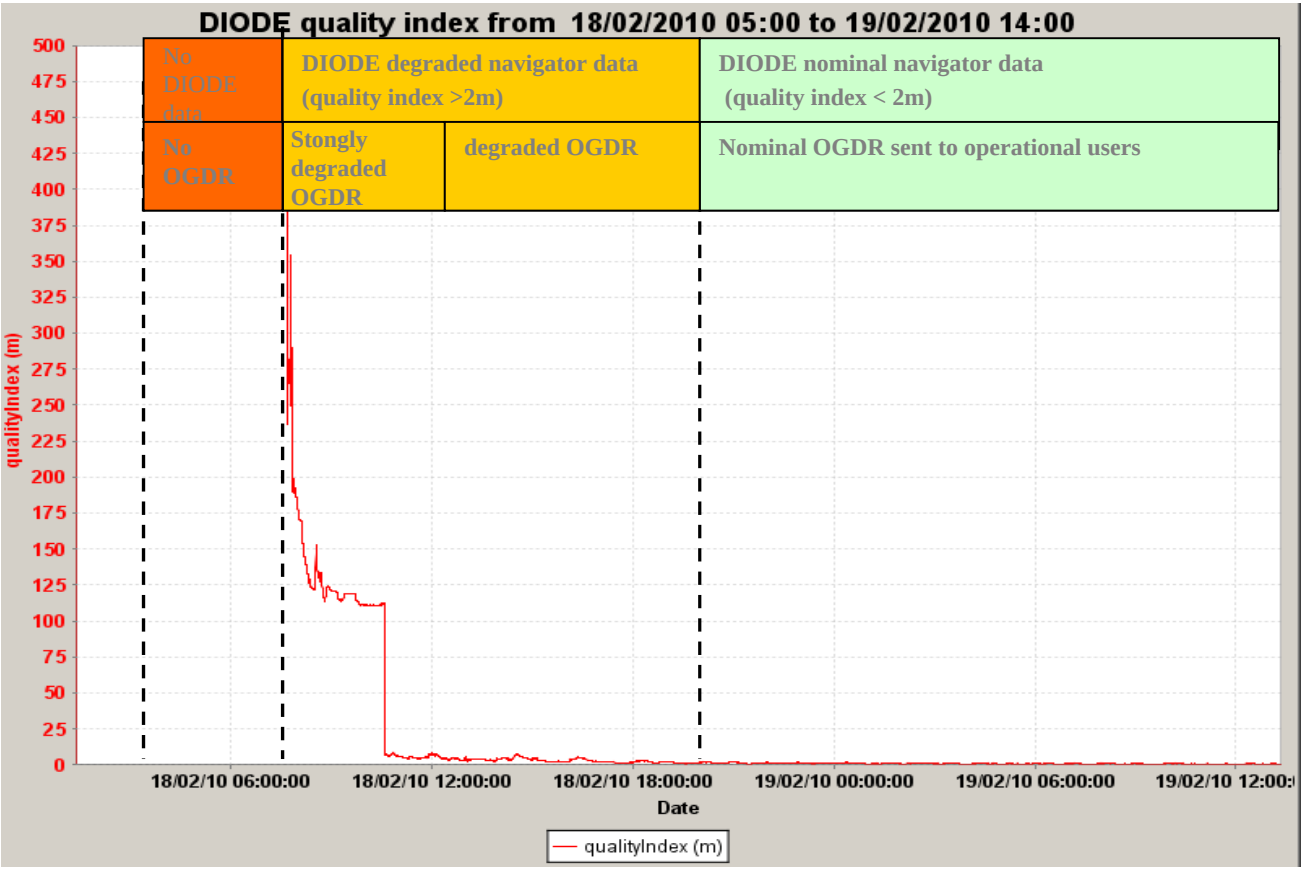
- **Upload was done on configuration DORIS B memory plan, while DORIS A was still operating**
- *On February 15th an 16th, the DORIS OBFS was uploaded thanks to 118 TC groups. The end of upload was sent on Usingen pass from 13h29 to 13h50 on the 16th of February. As foreseen, this upload implied no impact on DORIS instrument processing.*

- **After completing the upload, there was necessity of :**
  - **Turn OFF the « old » issue,**
  - **Turn ON the new issue,**
  - **Let it converge.**

On Thursday 18th February, the DORIS Instrument was restarted at 05:01 am UTC thanks to a time tagged TC. Then, the DORIS instrument has entered an initialisation phase:

Date and time	*Status*
2010-02-18 from 05:01 to 07:39 am (UTC)	*DIODE is totally unavailable.*
2010-02-18 from 07:39 to 10:35 am (UTC)	*DIODE navigator data are available but with degraded quality.*
2010-02-18 from 10:35 to 19:30 (UTC)	*DIODE precise convergence process is in progress, the quality of navigator data is not considered as nominal.*
2010-02-18, 19:30 (UTC)	*End of initialisation, DIODE reaches its nominal quality*

Minimize upload (negative) impact

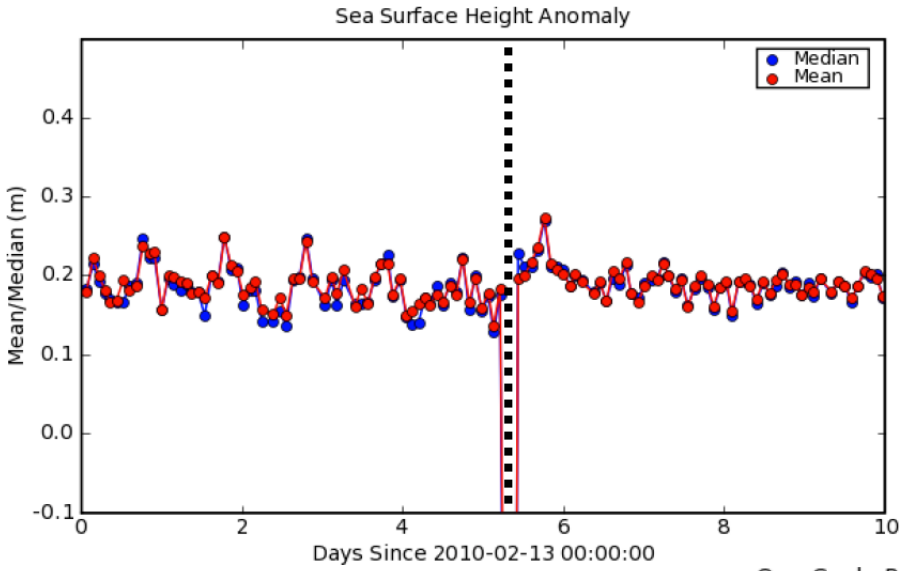


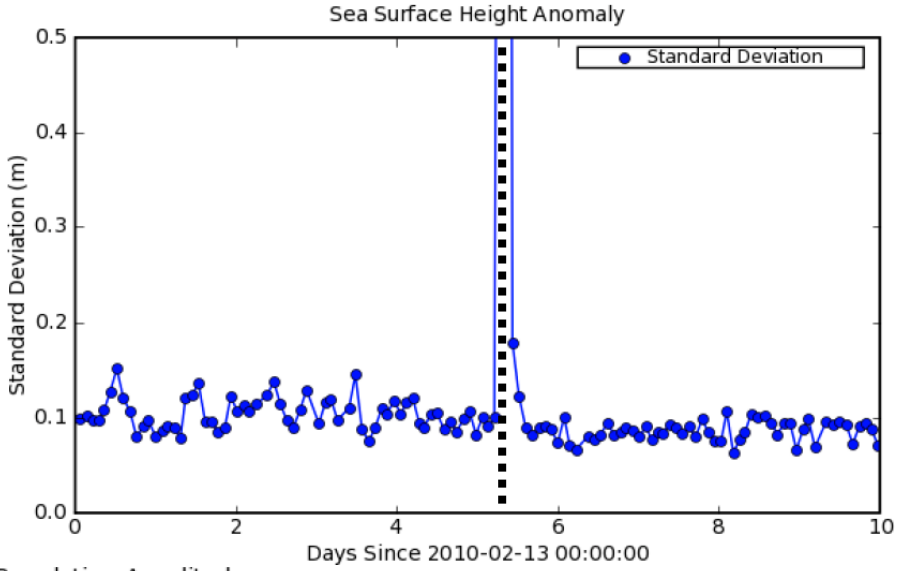
- mission break : only 5H30 thanks to a great preparation and to a good collaboration between ops teams.

DORIS upload impact : only 15 hours of lacking or degraded OGDR products (8 OGDR files).

No impact on other products (DORIS measurements, ground orbits, …)

Improvement rapidly seen by users

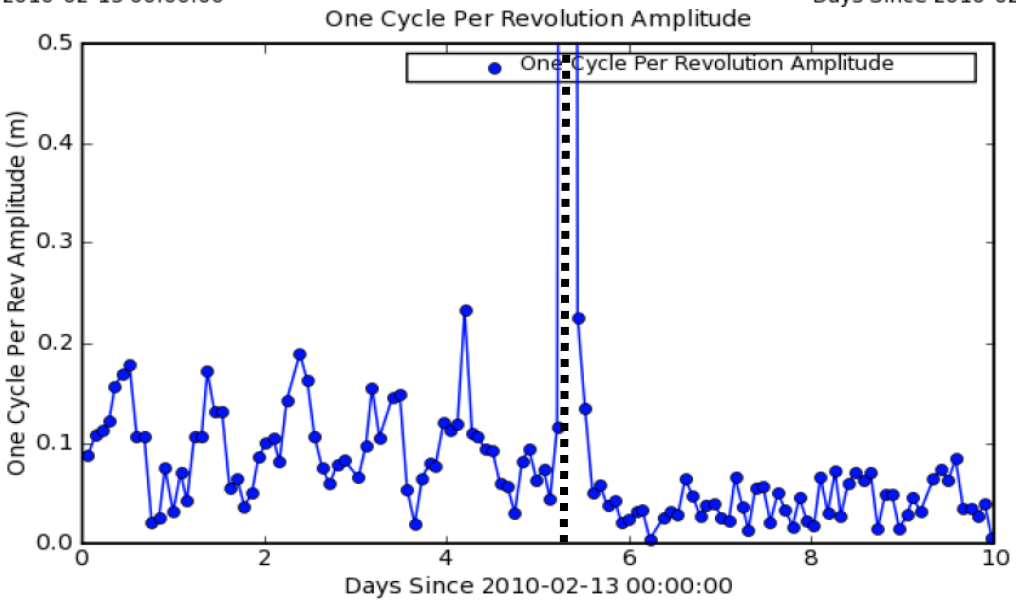


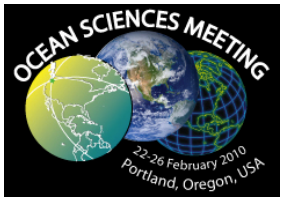


Hi Christian,

Indeed I do! I presented the following figure in my talk in Portland last week, at the Ocean Sciences meeting. We see improvements in the stability of the mean, a slight reduction in RMS, and a significant improvement in the 1-cpr radial orbit error. It's almost always < 10 cm now, and hovers around the 5 cm level. Realizing that this is over basically one rev (~ 2 hour dump to the ground station) this is extremely good performance. A cyclic or longer average would be at the 2-3 cm level I would guess. We are very pleased, as I'm sure all of you are as well! Thanks for developing these improvements, both on-board and in the TM-NRT Triode software. Your hard work has definitely paid off.

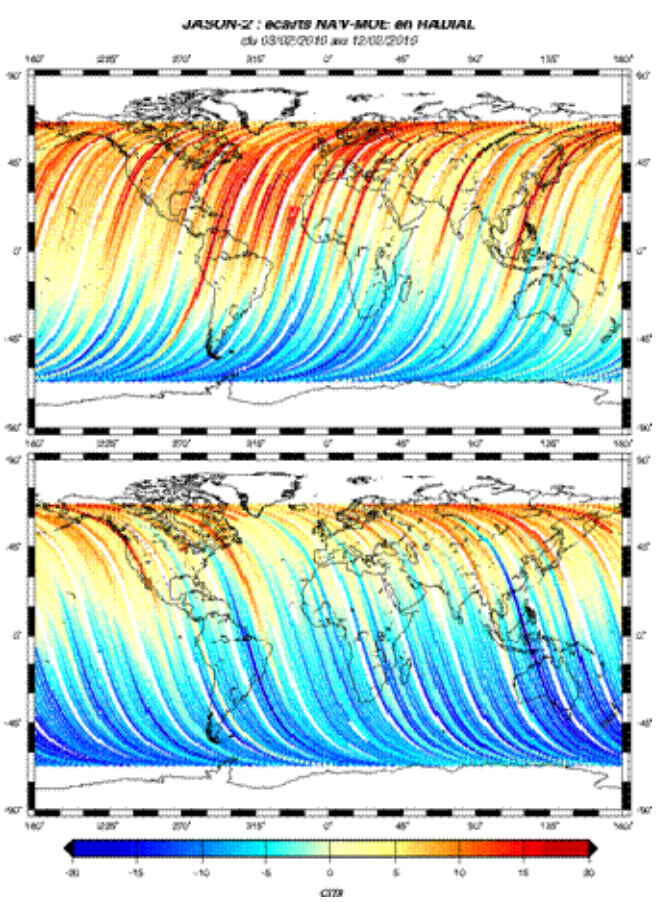
Cheers! John

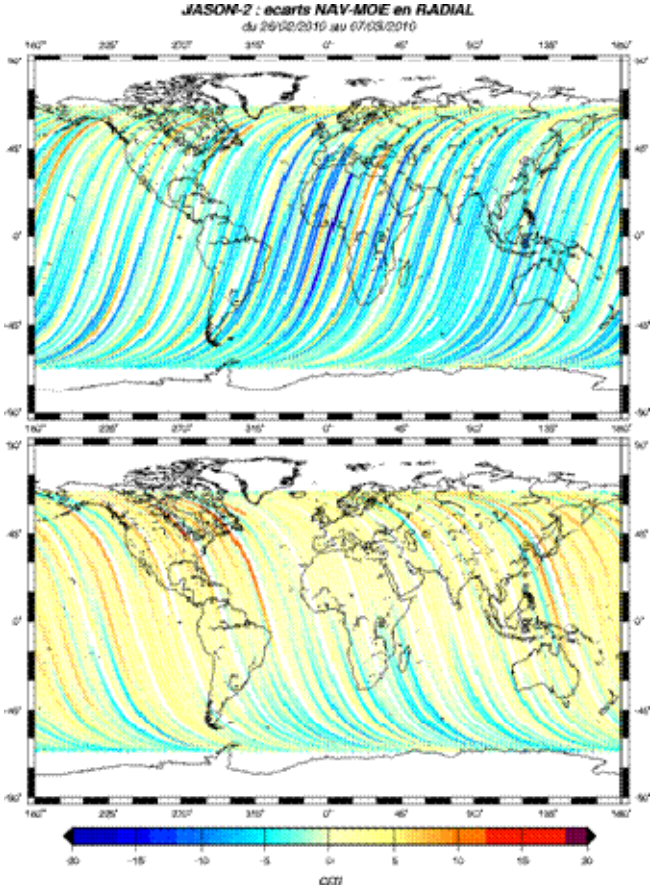




Geographic point of view

- **Previous DIODE** **New DIODE**





DIODE navigator / MOE, radial component

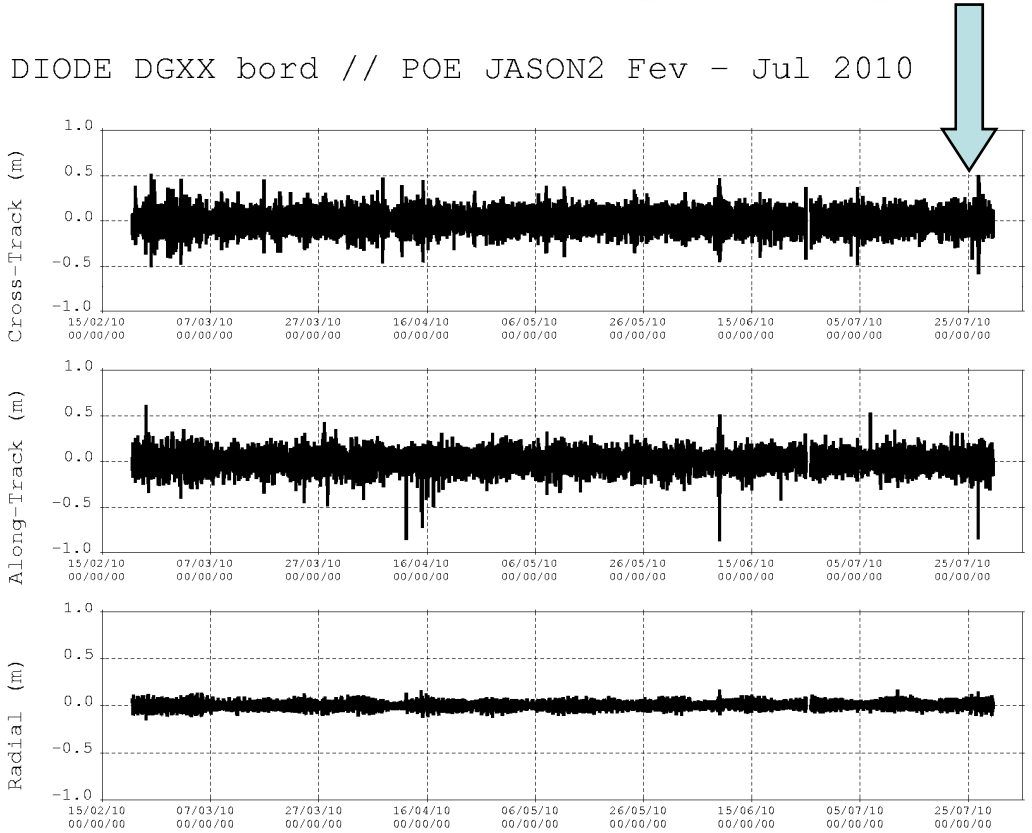
Long-run flight software results

(Diode-POE)

Units = meters

Period = 5.5 months

- *Start Maneuver Burn* *2010-206T22:02:27 076 005*
- *Inhibition during one revolution (6000 sec)*



A few spikes are under investigation

- *Start Maneuver Burn* *2010-105T15:37:56 065 205*
- *Inhibition during one revolution (6000 sec)*

(almost) six-months statistics

	MINIMUM	MAXIMUM	MEAN	SIGMA	RMS
	**********	**********	**********	**********	**********
Radial (m)	**-0.154606**	**0.171139**	**0.004423**	**0.032885**	**0.033181**
Along-Track (m)	-0.868162	0.622008	0.005303	0.077753	0.077933
Cross-Track (m)	-0.583300	0.519838	-0.000761	0.091745	0.091748
3D (m)	0.001000	0.958843	0.109804	0.059459	0.124869
Radial speed (m/s)	-0.000532	0.000762	-0.000005	0.000064	0.000065
A-T speed (m/s)	-0.001113	0.000126	-0.000017	0.000033	0.000036
C-T speed (m/s)	-0.000660	0.000468	0.000003	0.000095	0.000095
Norm (m/s)	0.000001	0.001127	0.000106	0.000058	0.000121

- (comparison done over **227536 points)**

=> error has been divided by more than a factor 2 w.r.t. Diode early version (7.8 cm)

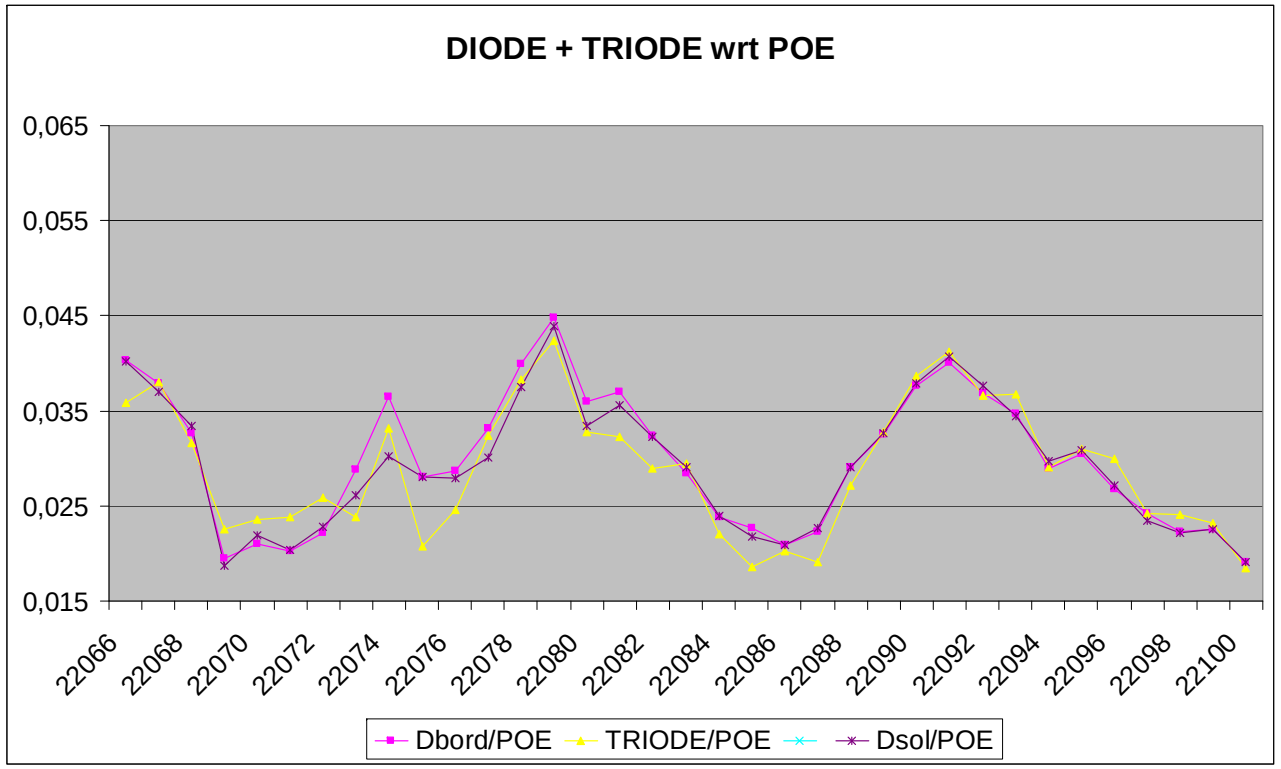
- We are confident for Jason-3 : specification = 5 cm radial RMS

  (but it depends on quality of RP model)

- (on Jason-2 these statistics also suffer from telemetry LSB : 1 cm) => evolution on Jason-3

TRIODE impact on results

Reference = POE; radial **RMS** value of each flow



Accuracy is more or less the same with TRIODE => OGDR users

Further improvements

- Ground analysis and validation tests show that the DORIS measurement is very precisely and properly modelled in the DIODE navigation software.

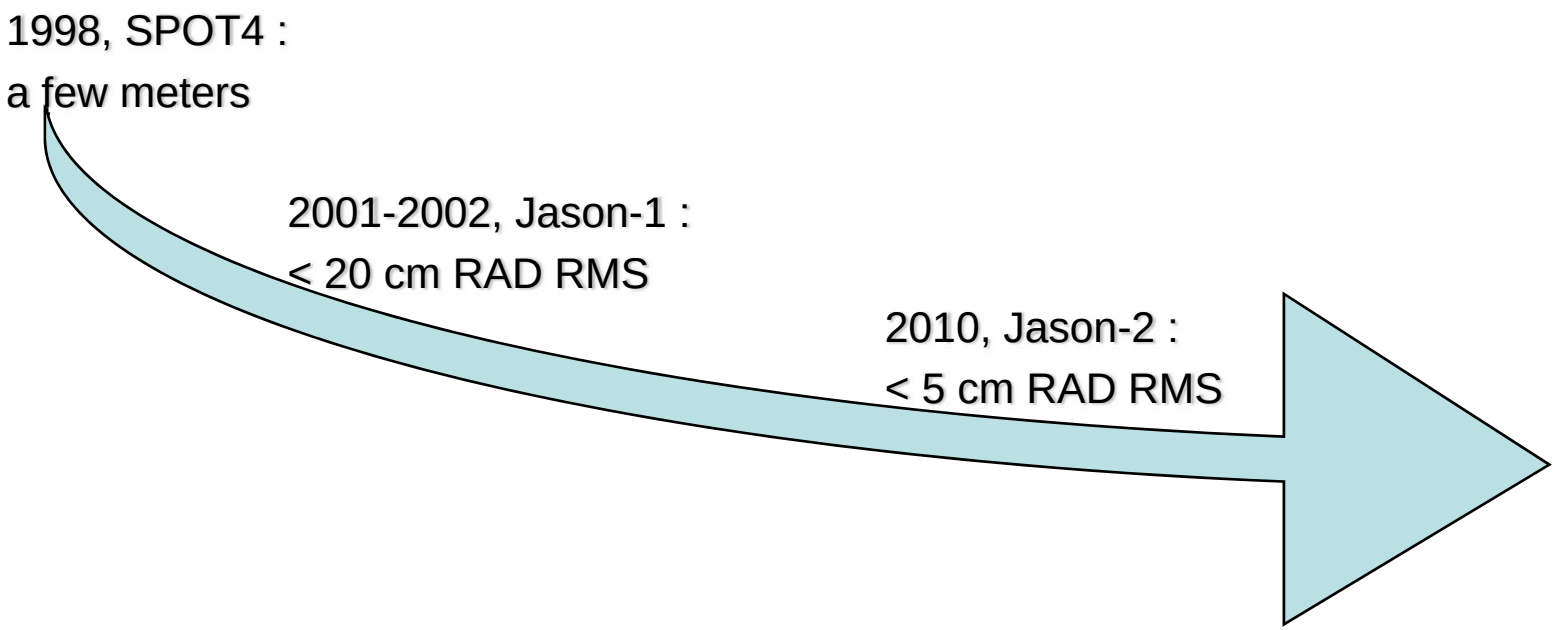
DORIS/Jason-2: Better than 10 cm on-board orbits available for Near-Real-Time Altimetry
(Adv. In Space Research, in press)

- Consequently, improvement of DIODE accuracy is still possible and should be driven by enhancement of the physical models :
  - forces and perturbations of the satellite movement,
  - Radio/Frequency phenomena perturbing measurements.

- Of course, parallel improvement of the DORIS network is a necessity :
  - add new beacons in non-covered zones,
  - reduce masks and interferences,
  - suppress multipath,
  - improve stability of the antennas,
  - Keep on being very active w.r.t. signal integrity

- If all this keep on being improved, …

DIODE accuracy vs time



- **… if both models and network keep on being improved, a one-centimeter consistency with POE could be the target of future versions of DORIS/DIODE.**

POD : DORIS/JASON-2 : LESS THAN 5 CM ON-BOARD ORBITS IN REAL-TIME

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POD Abstract

- DIODE (DORIS Immediate Orbit on-board Determination) is a real-time on-board orbit determination software series, embedded in the DORIS receiver. Different versions have been flown on-board different satellites, beginning with SPOT4 (1998), SPOT5, Jason-1, Jason-2, EnviSat, and the recently launched CryoSat-2. After a description of the DORIS system and its recent evolutions, and a few recent CryoSat-2 results, the presentation will concentrate on the Jason-2 mission.
- On February 2010, a new version of the Navigation Software has been uploaded on EEPROM, without interrupting the RT orbit determination process. After 1.5 year of correct results, the original version has been deactivated and the new version has been started, following a recommendation of the Seattle OSTST.
- This new version improves several technical points observed on the initial version (especially in quaternion processing) and implements enhanced algorithms, Since February, the accuracy of the on-board DORIS/DIODE orbits has been oscillating between 1 and 5 cm radial RMS as compared to the final Precise Orbit Ephemerides (POE) orbit, allowing valuable NRT use of Jason-2 OGDR products. The paper details these results through several months of on-board data.
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