Update of the SAA JASON-1 corrective model by the use of the maps of energetic particles obtained by the dosimeter CARMEN onboard of JASON-2

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Regular Update of the SAA corrective model for Jason1

Update of the model parameters (regular update)

•Update of the model taking into account the additional DORIS data since the last update
(data between January 2012 and May 2013, >1 year)

•Determination of the SAA onboard frequency signal
- using the method developed with several satellites Spot-4, Envisat, Jason-2, Cryosat-2 and Hy2a (combination)
- we processed more than 1 year of data for each satellite

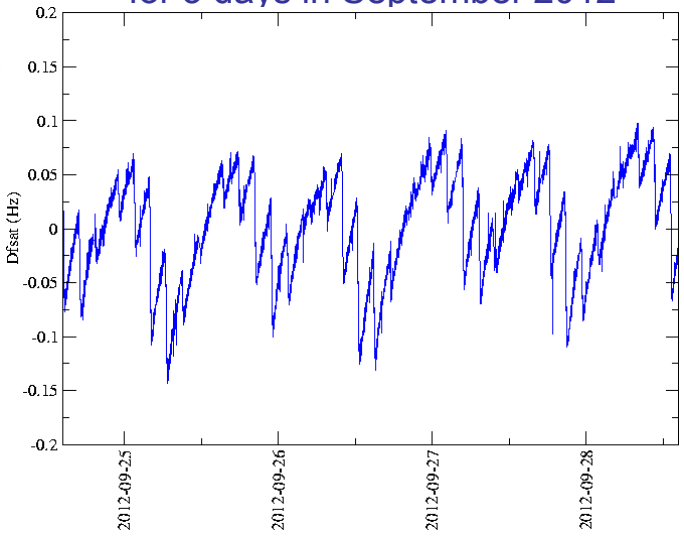
•Principle

1) Determination of precise orbits of all DORIS satellites
combination of all satellites except Jas1→ station parameters (MZB,MFO)
Jason1 → orbit dynamical parameters

2) Determination of measurement residual
we have fixed station parameters and Jason-1 orbit (of step 1)

3) Conversion of measurement residual in offset frequency
Δfsat (*in Hz on 2GHz)*

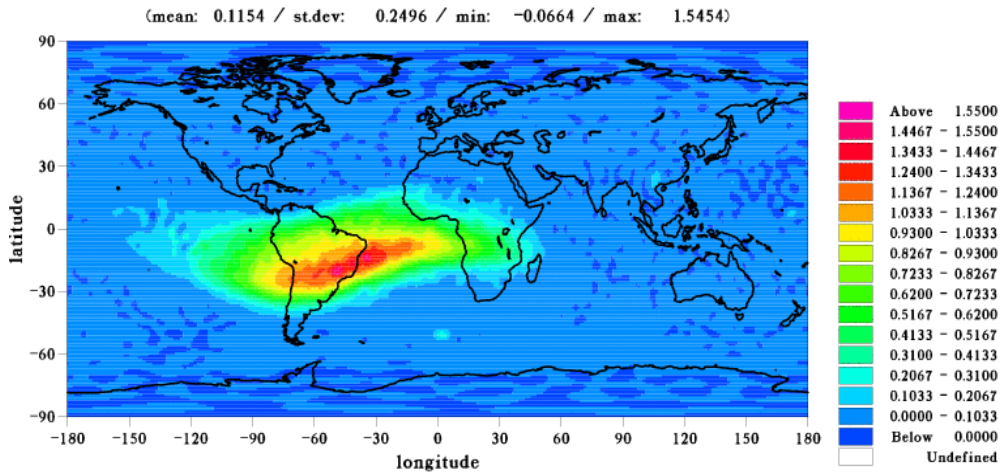
SAA onboard frequency Δfsat
for 3 days in September 2012

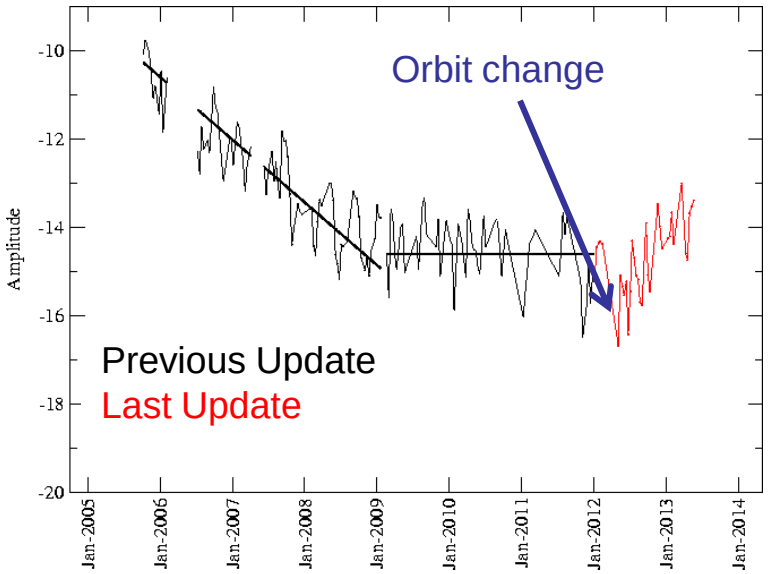


Regular Update of the SAA corrective model for Jason1

Determination of the parameters

-Using the SAA Jason1 map





- **Model parameters**
- **Amplitude (Hz/day)= Map_SAA(lat,lon) x Amplitude (t)**

  Previous update

  - first period: linear regression
  - second period: a constant

  Last Update:

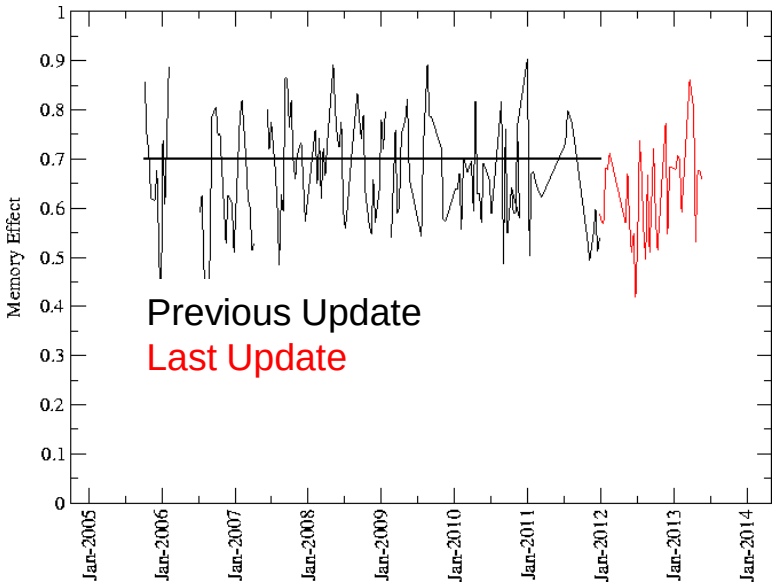
  - linear regression corresponding to the orbit change in 2012

- **Time constant of the relaxation behaviour τ**

  Last update: as berore fixed to 40 mn

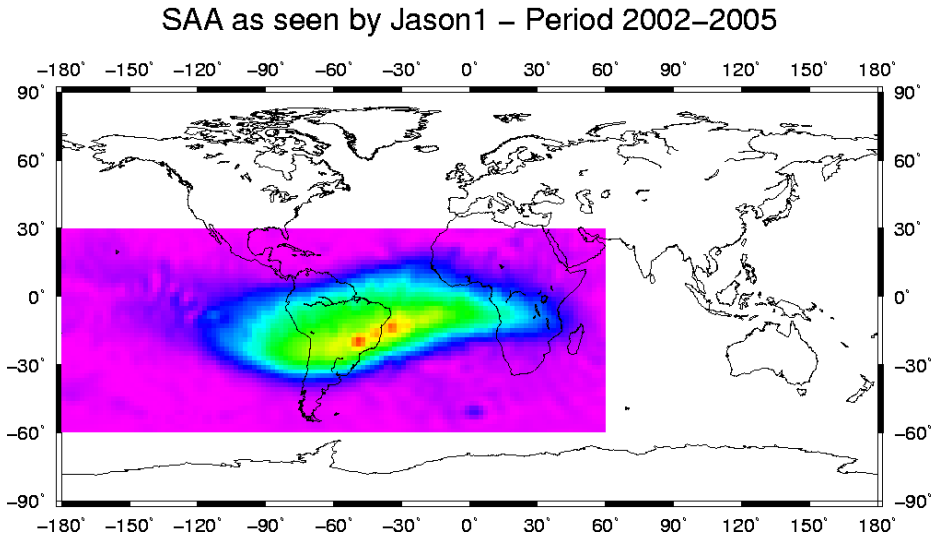
- **Memory effect me**

  →we find again me=0.7



SAA corrective model for Jason-1 by using CARMEN map

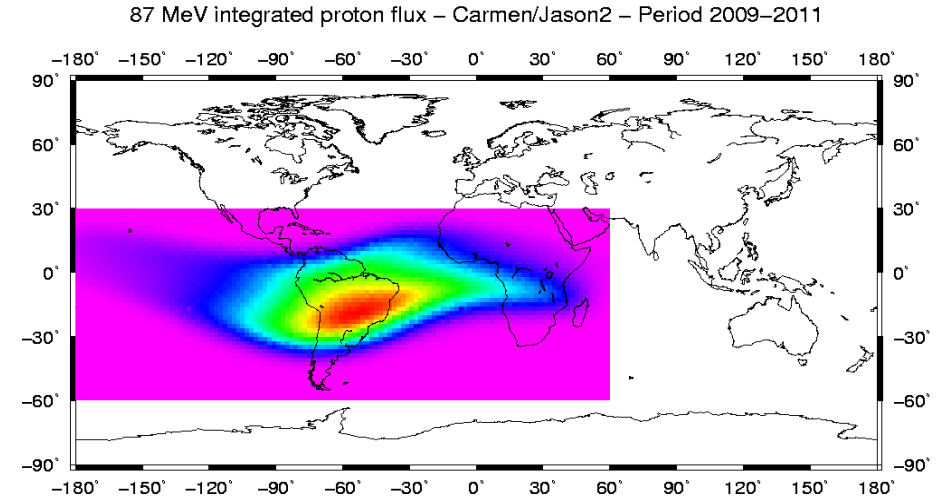
Correlation study of the SAA grid from DORIS data and from CARMEN data



SAA Grid from Jason-1 DORIS data

- 1°x1° grid (2002-2005)

(converted in 2°x2° grid for this study)



SAA Grid from Jason-2 CARMEN data

- 5 energy band tested

63, 76, 87, 97 and 138 MeV

- 4 annual grids (2x2°)

from 2009 to 2012

and a mean grid 2009-2011 (2x2°)

for 87 MeV and 138 Mev

SAA corrective model for Jason-1 by using CARMEN map

Correlation study of the SAA grid from DORIS data and from CARMEN data

Method of comparison

- determination of the correlation coefficients between both grids
- looking for the energy band having the best agreement with Jason-1 map
- determination of the coefficients by adjusting in latitude and longitude per 2° grid step
  looking for the max correlation by taking into account geographical offsets
- adjusting by least square to calculate the scale factor k between both grids
  (Carmen) Grid = k x (Jason-1) Grid

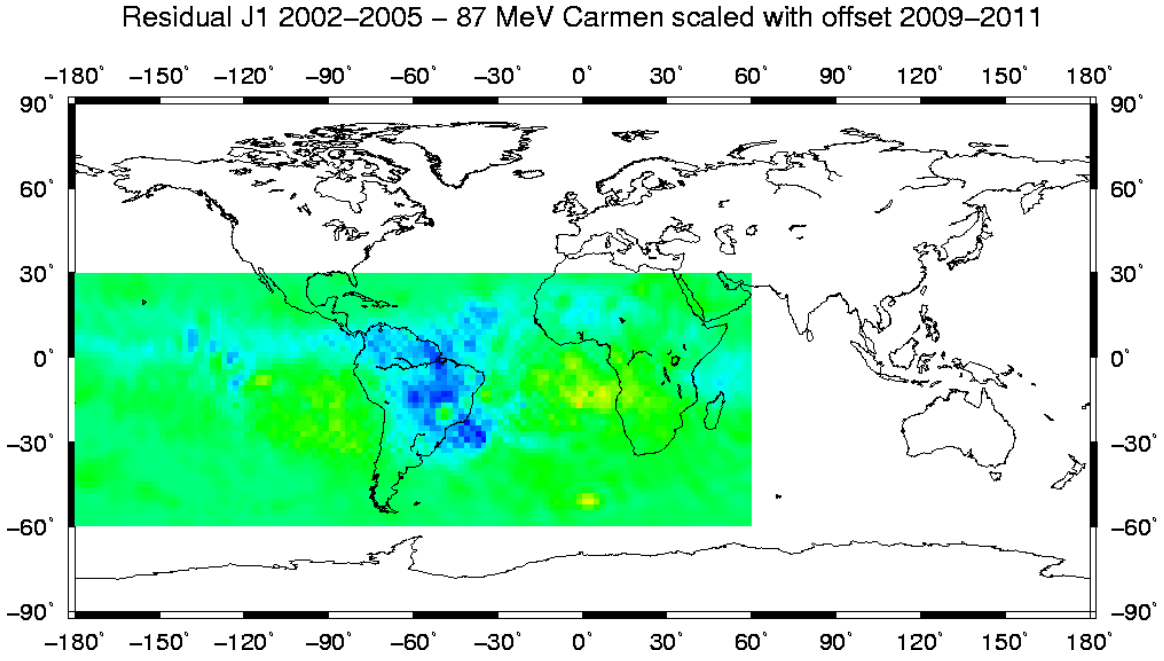
Carmen Grids (MeV)		Jason-1 Grid (2002-2005)			
		Offset longitude	Offset latitude	Correlation coeficient	Scale factor K
Mean 2009-2011	**87**	**0**	**6**	**98.58**	**631.54**
	138	-2	8	98.05	385.42
Year 2011	63	0	6	98.35	827.09
	76	0	6	98.45	730.46
	87	0	6	98.56	632.78
	97	-2	4	98.25	566.15
	138	-2	8	98.04	386.96

SAA corrective model for Jason-1 by using CARMEN map

Correlation study of the SAA grid from DORIS data and from CARMEN data

Residual map between Jason-1 map and the mean 87Mev CARMEN map with 6° latitude offset

Residual = (Jason-1) Grid – 1/k (Carmen) Grid



- Residuals are homogeneous on the SAA area
- SAA maximum slightly higher on the Jason-1 grid

SAA dynamical evolution

West: secular variation of the magnetic field ~0.3°/year

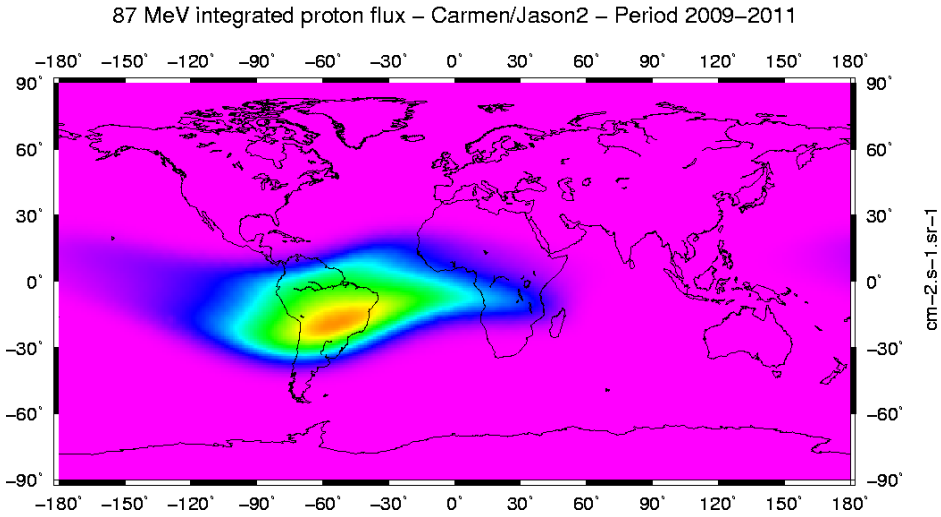
Since 2011 year SAA diminution : beginning of the solar cycle 24

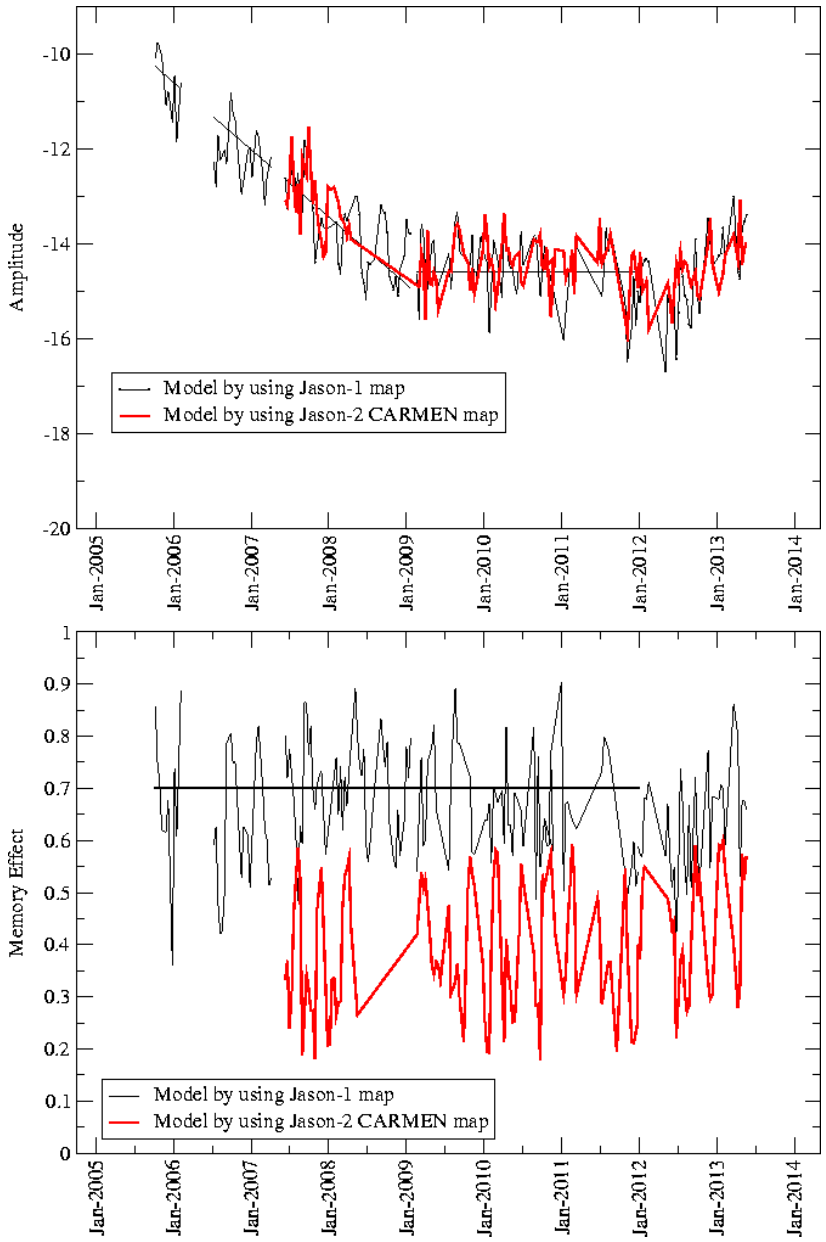
SAA corrective model for Jason-1 by using CARMEN map

Determination of the parameters

-Using the SAA CARMEN Jason-2 map

with scale factor and longitude shift of 6°





- Model parameters

- **Amplitude (Hz/day)= Map_SAA(lat,lon) x Amplitude (t)**
  the amplitude parameter is similar for both grids

- **Time constant of the relaxation behaviour τ**
  with Jason-1 map τ is fixed to 40 mn
  with CARMEN map τ is fixed to 60 mn

- **Memory effect me**
  with Jason-1 map me=0.7
  with CARMEN map me=0.4

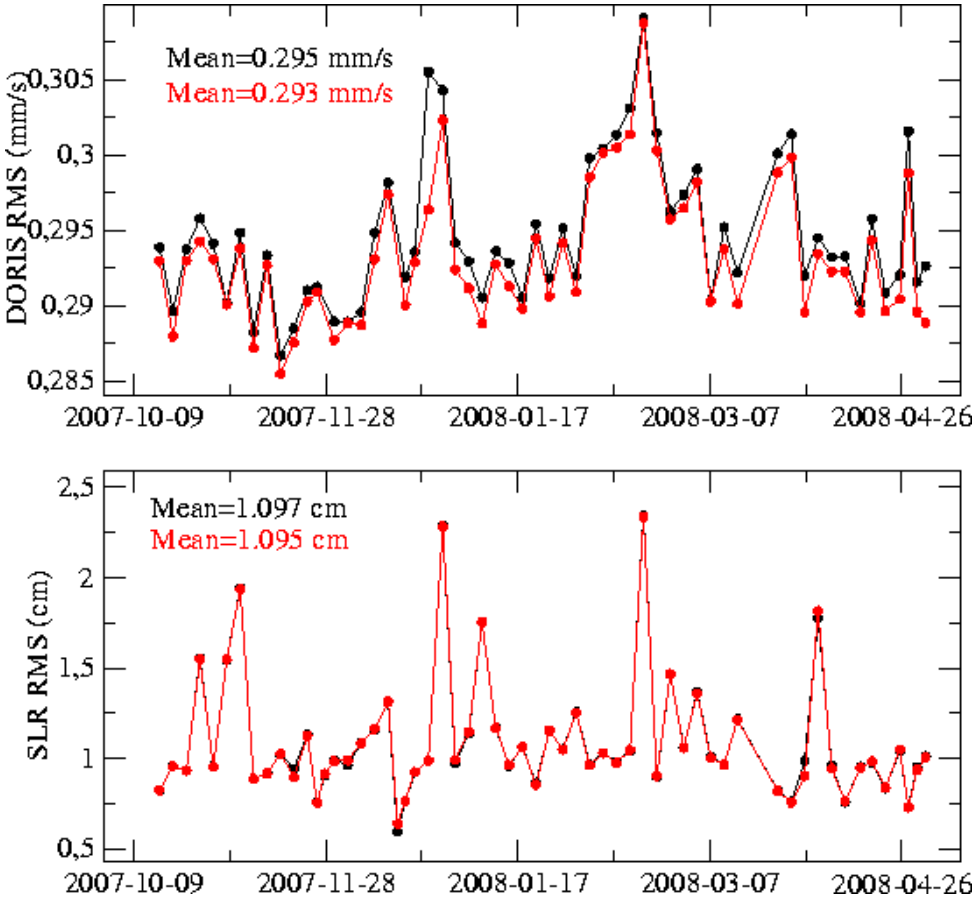
SAA corrective model for Jason-1 by using CARMEN map

Impact on the orbit: DORIS and SLR orbit residuals

In the past we showed that the SAA model leads to decrease significantly the RMS of orbit residuals (5%) and to increase the validated measurements

Results with SAA data corrective model using Jason-1 map

Results with SAA data corrective model using CARMEN Jason-2 map



The orbit residuals are systemically lower with CAMEN map but the differences are small

SAA corrective model for Jason-1 by using CARMEN map

Impact on the positioning

Jason-1 weekly solutions obtained with SAA data corrective model using Jason-1 map and CARMEN (Jason-2) map

Comparison to DPOD2008 (values are calculated after the application of the Helmert transformation parameters)
RMS3D and RMS and STD by component
(Mean values on 26 weeks, from July 2007 to May 2008)

Solutions	RMS3D (mm)	RMS Lat (mm)	RMS Lon (mm)	RMS Up (mm)	Std Lat (mm)	Std Lon (mm)	Std Up (mm)
with Jason-1 map	52.5	46.5	57.7	52.2	46.4	57.7	52.2
with Jason- 2 map	50.1	42.3	52.3	52.1	42.1	52.3	52.1

- The RMS3D, RMS by component and STD by component are lower when we use model with CARMEN map

- But as on the orbit residuals the differences are small

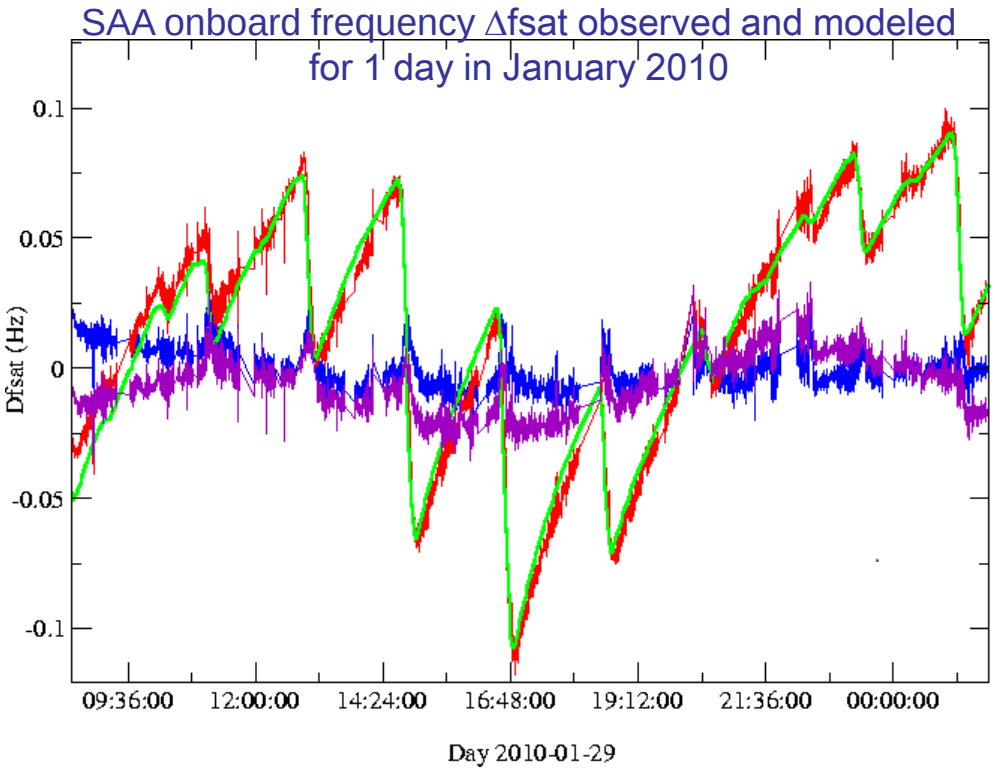
-These results show that the Jason-1 map determined from DORIS data was good

New possible improvement of the SAA corrective model

Residuals after correction by the SAA model

1) SAA onboard frequency signal → red curve
2) Signal obtained by the SAA model → green curve
3) Differences between 1) and 2) → blue curve
4) Determination of the SAA onboard frequency signal after correction of the DORIS Jason-1 data by the SAA model

→ purple curve



The blue and purple curves are very close in the short term
So like the Jason-1 mission is finished a predictive model is no longer necessary
To improve the SAA correction we will try to correct the DORIS data directly from the SAA onboard frequency signal observed (a filtering will be necessary)

CONCLUSION AND PERSPECTIVE

CONCLUSION

Regular update is done

since the orbit change (beginning of 2012) the amplitude parameter increases

Updating the SAA model by using CARMEN maps showed:

- the SAA Jason-1 map calculated from DORIS data was good
- even using the CARMEN map the correction is not complete

PERSPECTIVE

- **to continue work on the SAA data corrective model using the CARMEN maps** (new tests)
-**to improve the SAA correction by correcting the DORIS data directly from the SAA onboard frequency signal observed**
(a filtering will be necessary)
- **to submit to DORIS Special Issue (Adv. Space Res) a paper on SAA models**
"*Update of the corrective model for Jason-1 DORIS data in relation to the South Atlantic Anomaly and a corrective model for Spot-5*"

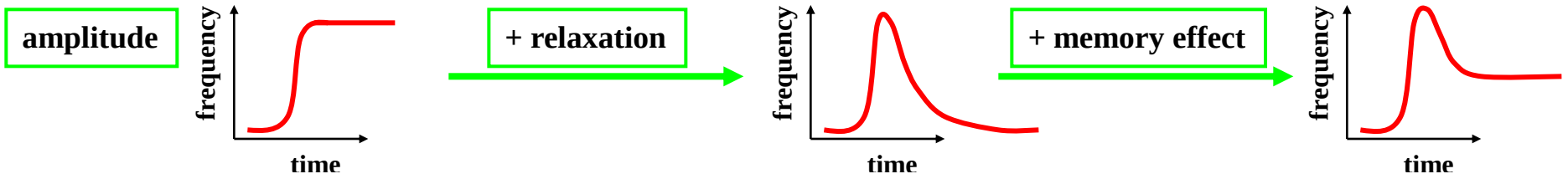
BACK SLIDES

Definition of the model

The model involves, on the one hand, the physical source of the perturbations of the DORIS oscillator, in the form of a 1◦ × 1◦ map of the SAA at the altitude of Jason-1 (1,300 km), and on the other hand, it involves the response of the oscillator to this excitation, through a set of parameters that can vary with time

Basically, under exposure to high-energy protons, a quartz oscillator will react by a frequency drift (positive or negative), proportional through an amplitude factor to the level of exposure (the "dose exposure"); by an exponential relaxation behaviour once the exposure is stopped; and by a "memory effect" corresponding to the fact that the frequency does not come back to its initial level, even a long time after the exposure has been stopped. The following set of parameters has therefore been defined:

- *A: amplitude factor relating the dose received by the* quartz oscillator to the dose exposure
- *τ : time constant of the relaxation behaviour*
- *μ: memory effect coefficient*
- dose_exposure: in its present state, a 1◦×1◦ geographical map of the mean SAA intensity at the altitude of Jason-1



South Atlantic Anomaly

The sensitivity of the ultra stable oscillator (USO) of DORIS/Jason-1 to the high energy protons trapped in the Van Allen belts was first pointed out by Willis et al. (2003, 2004). This sensitivity causes a fluctuation of the frequency when the satellite crosses the area of the South-Atlantic Anomaly (SAA).

The South Atlantic Anomaly is a phenomena that takes place in the ionosphere, at the magnetic equator, where the Van Allen radiation belt (particles emited by the Sun and trapped by the Earth magnetic field into a belt following the magnetic equator) is closest to Earth. This "anomaly" causes among other things errors on the measurement of the Doris instrument onboard *Jason*-1, since the orbit of this satellite is especially exposed. Using the Doris instrument onboard the other satellites, it is possible to study and measure this phenomena, in order to better correct from it.