Update of the SAA corrective model for Jason1 And a SAA preliminary corrective model for Spot5

Hugues Capdeville, Jean-Michel Lemoine, Petr Štěpánek

SAA corrective model for Jason1

Update of the SAA model following the last orbit change

Since May 4th 2012, the satellite Jason-1 has been moved to a geodetic orbit.

The corrective model for Jason-1 has been updated to take into account the new orbit of Jason-1. The main change is that we can no longer consider the Topex mean ground track (determined over a 7-year period) after the maneuvers performed to move Jason-1 on the geodetic orbit.

For the new orbit, since it is drifting, we had to add another capability in the model. we can use an external orbit in sp3 format.

The new version of software based on sp3 orbit has the following upgrades:
- additional routines to convert orbit to a ground track
(entetesp3.f90, conv_orbsp3_orbgeo.f90, xyzflh.f90, angle.f90, egalite.f90, common_cons.f90)

-4 routines modified (modele.f90, hf_jason_doris_freq.f90, calcul_dfsat.f90 and interpol_datemes.f90)

-a new input file called « orbit_sp3 » in ANNEXE/ORBITE which contains orbit file in sp3 format

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SAA corrective model for Jason1

How to use the new feature ?

When you use sp3 files in input, you have to give one or several sp3 orbit files concatened in the file « orbit_sp3 » (in ANNEXE/ORBITE).
This file must contain the measurements period given by the measurements file ANNEXE/MESURE/Input (in free format or DORIS 2.2 CDDIS format, see technical note)

The software offers now 4 options, two options (3 and 4) added by the new feature:
1) Input file measurement CDDIS (DORIS 2.2)
2) Input file measurement in free format (DATES in TAI)
3) Input file measurement CDDIS (DORIS 2.2) and use sp3 orbit
4) Input file measurement in free format (DATES in TAI) and use sp3 orbit

Before the orbit change, we can use Topex mean ground track or sp3 orbit files (1 to 4), and after change only sp3 files (3 and 4).

Remark

Before the orbit change (May 4th 2012), the file "jason_cycle_dates" has been updated regularly by the Central Bureau. Now, it is no longer necessary to get it, because the final version of this file is delivered with the model.

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 February 20th 2009 and January 6th 2012, ~3 years)

•**Determination of the SAA onboard frequency signal**
  - using the method developed with several satellites Spot2-4 & 5,and Envisat (combination)
  - addition of jason2 and Cryosat2 and loss of Spot2 (since 07/2009) and Spot5 (sensitive to SAA)
  - we processed 3 years of data for each satellite

•**Principle**
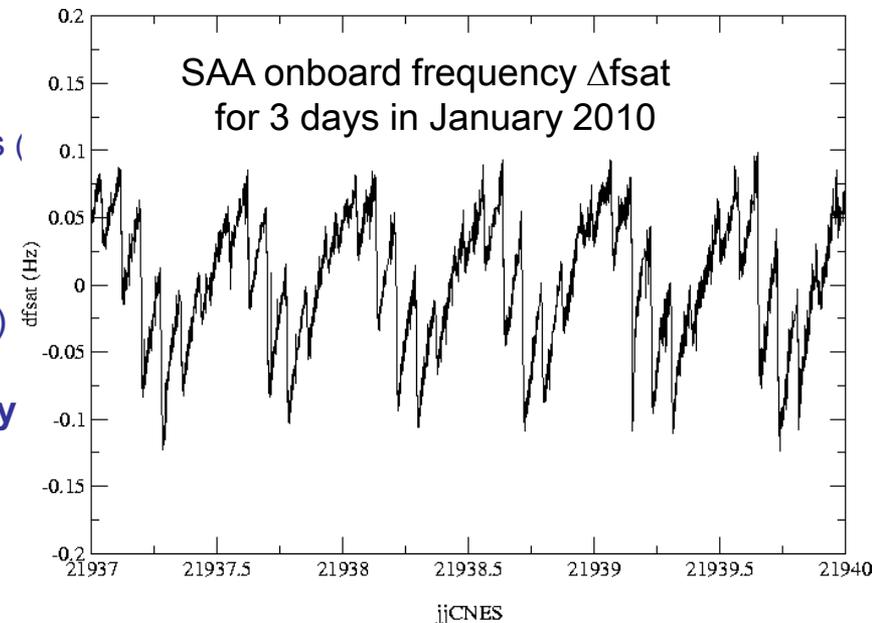**1) Determination of precise orbits of all DORIS satellites**
 combination of all satellites except Jas1→ station parameters (
 Jason1 → orbit dynamical parameters

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

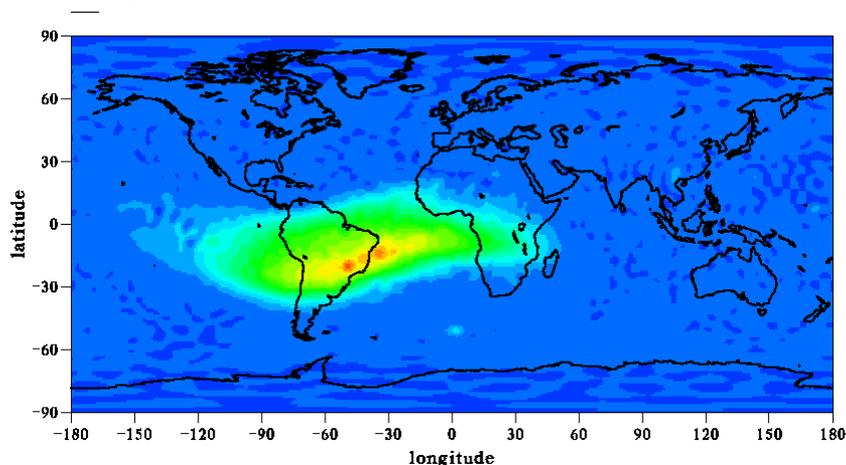**3) Conversion of measurement residual in offset frequency**
Δ**fsat** *(in Hz on 2GHz)*

SAA onboard frequency Δfsat for 3 days in January 2010

SAA corrective model for Jason1

•**Determination of the parameters**

- Using the SAA Jason1 map

- Model parameters
  amplitude in Hz/day
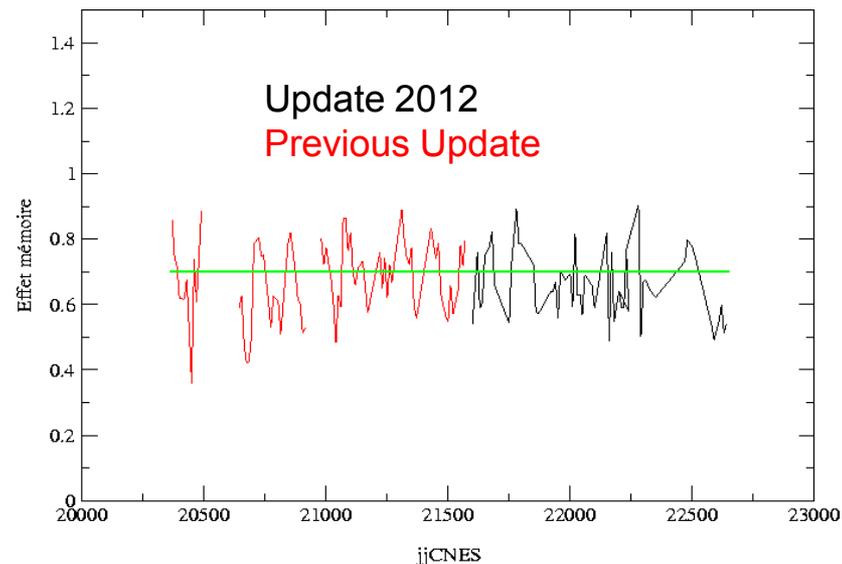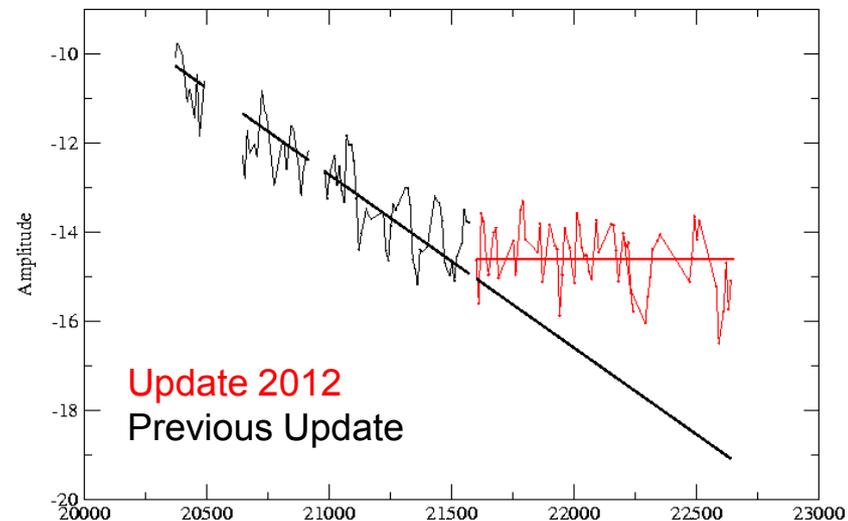 →Map_SAA(lat,lon) x Amplitude (t)
  →Update 2012→ Amplitude=-14.6
  time constant of the relaxation behaviour τ
  →fixed to 40 mn
  memory effect me
  →we find again me=0.7

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SAA corrective model for Jason1

Where can you find the model ?
- the corrective model for Jason-1 DORIS Doppler data designed by CNES is available on the CB ftp site under:
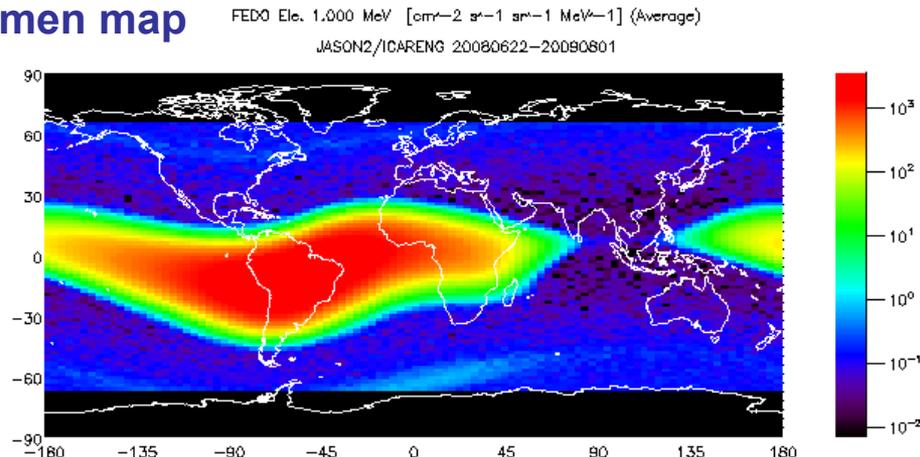 ftp://ftp.ids-doris.org/pub/ids/satellites/CORRECTIVE_MODEL_JASON1

- you can get this model and the technical note which gives the principle of the model and allows its implementation and its use

Conclusions and perspectives
- the SAA corrective model for Jason-1 has been updated to take into account the last orbit change
- the model parameters have been updated taking into account 3 years additional DORIS data
- we could use the maps of energetic particles obtained by the dosimeter CARMEN onboard of Jason2 (to improve the model and to update the model regularly)

Example of a Carmen map

FEDO Ele. 1.000 MeV [cm^−2 s^−1 sr^−1 MeV^−1] (Average)
JASON2/ICARENG 20080622−20090801

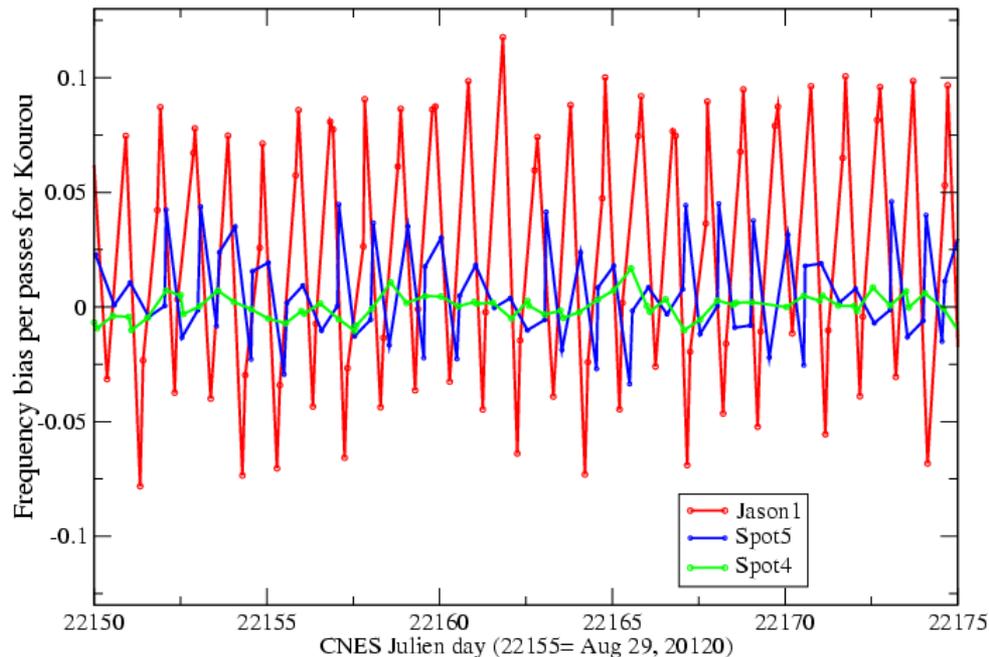# *SAA corrective model for Spot5*

Effect of the SAA on Spot5

SPOT-5 oscillator is affected by SAA, shown first by Petr Štěpánek and confirmed by many tests
- size of the effect is lower than for Jason-1 (about one order of magnitude?)
- the effect is far from being negligible
- the observations of 3 stations are strongly affected: Brazil (CADB),Peru (ARFB) and Chile (SANB)
- in extreme case CADB has a decimeter offset of station height for single satellite solution

Example of Results showing the problem:

Frequency bias adjusted per pass for Kourou

SAA corrective model for Spot5

Determination of the SAA onboard frequency signal obtained from measurements DORIS

- **Using the Jason1 approach**
- **1) Determination of precise orbits of all DORIS satellites**
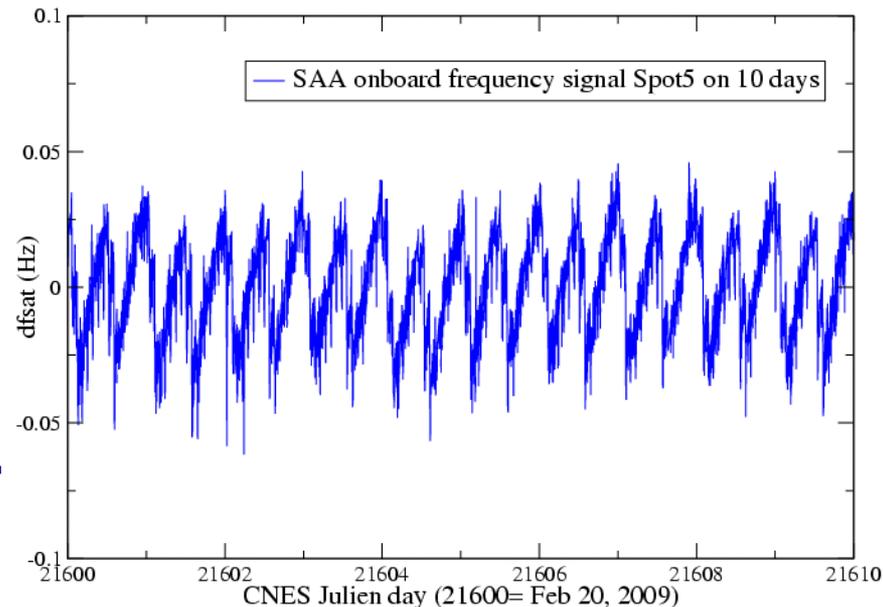 combination of all satellites except Spot5 → station parameters (MZB,MFO)
  Spot5 → orbit dynamical parameters
- **2) Determination of measurement residual**
  we have fixed station parameters (from combination) and Spot5 orbit (of step1)
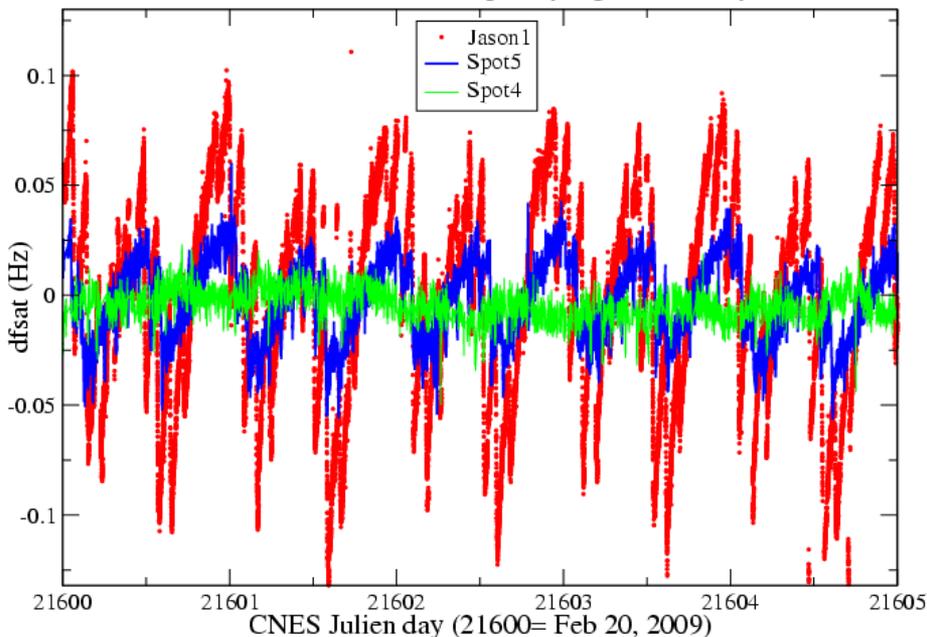- **3) Conversion of measurement residual in offset frequency Δfsat** (*in Hz on 2GHz*)

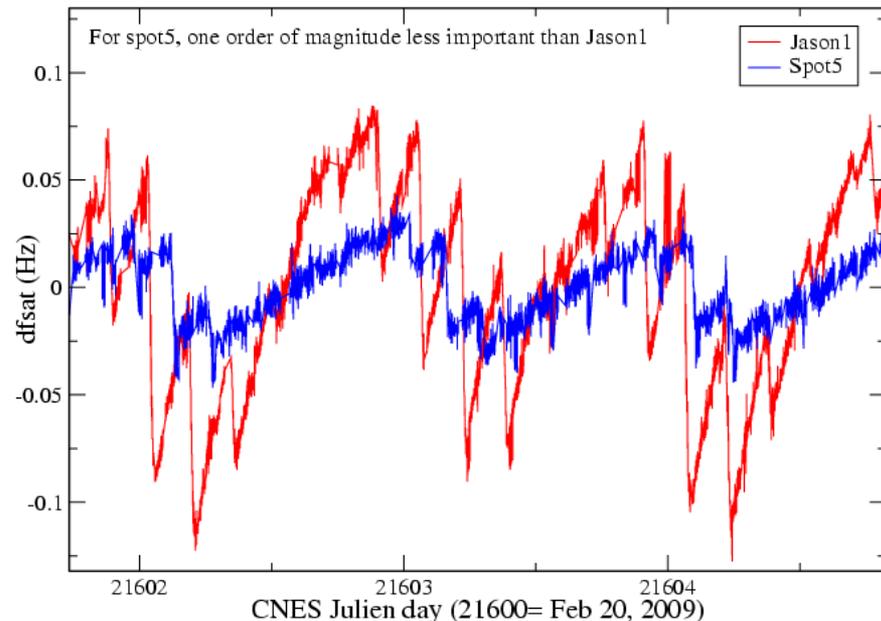- **SAA onboard frequency obtained from ~3 years of data** (20/02/2009 to 27/12/2011)

SAA corrective model for Spot5

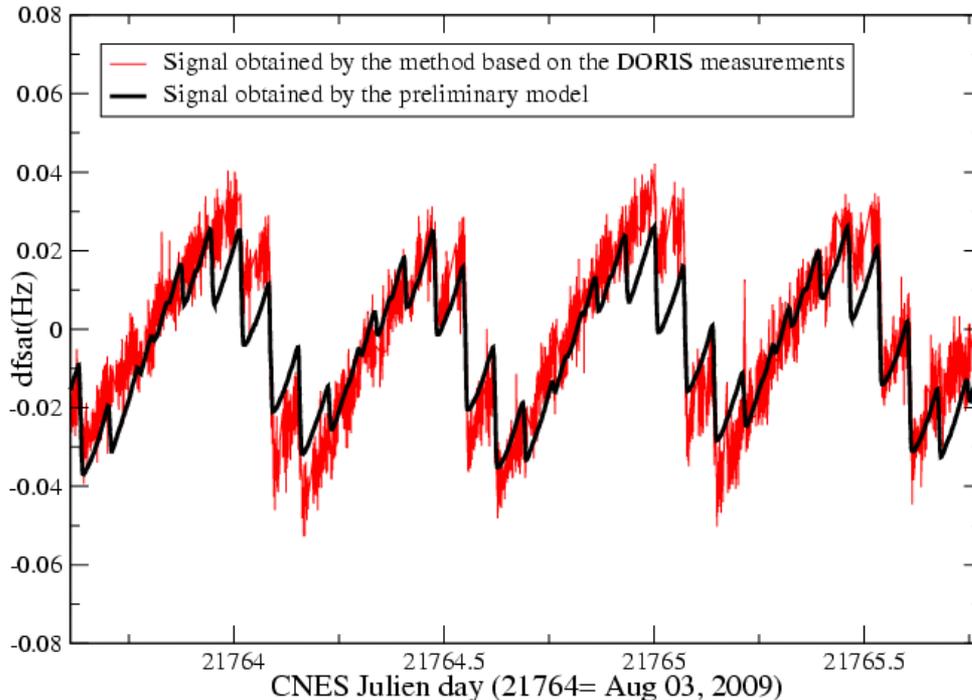• **Comparison of the Spot5 signal with that of Spot4 and Jason1**

- no SAA effect on Spot4
- size of the effect on Spot5 is lower than for Jason-1 (about one order of magnitude)
- behaviour close to the signal of Jason1 chain 1
- when the satellite crosses SAA area: negative amplitude
(τ being very high, difficult to decorrelate τ and me)
- fewer passes in the SAA area for Spot5 than for Jason1 (~5 against 8 per day)

SAA corrective model for Spot5

Preliminary model for Spot5

- **Determination of the model parameters using the Jason1 SAA map**
  model parameters adjusted over a period of 3 years

- **Comparison between the signal from measurements and the signal from model**

SAA onboard frequency signal on 2 days

Legend:
— Signal obtained by the method based on the **DORIS** measurements
— Signal obtained by the preliminary model

- **First results of the orbits residuals**
  - one arc of 8 days
  - w SAA model: stations corrected by the SAA model are CADB, SANB, KRVB and ARFB

wo SAA model		w SAA model	
RMS	Nb Meas	RMS	Nb Meas
0.3426	61775	0.3415	61832

with the SAA model:
- RMS is lower
- the number of measurements is higher

- The signals modeled and measured are very close but the model can be improved

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SAA corrective model for Spot5

Evolution and improvement of the Spot5 model

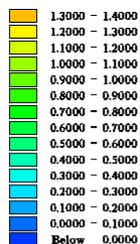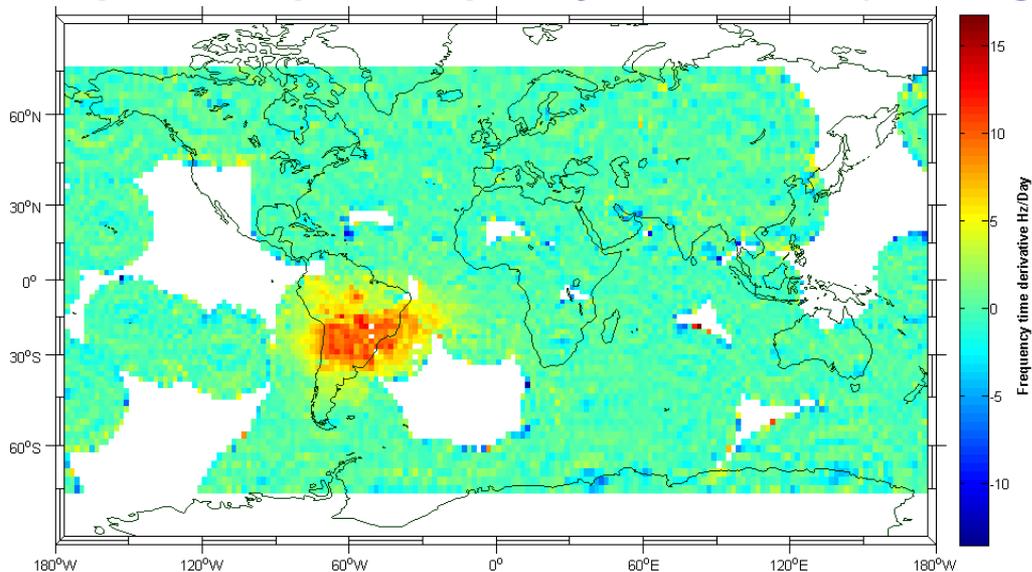- **use a map created for Spot5 (at the altitude of Spot5)**
  - test the map determined by Petr Štěpánek from one year of data

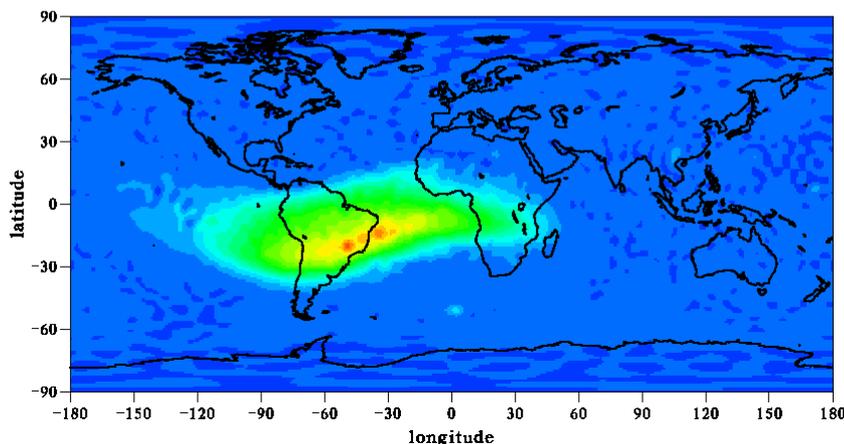there are some differences between SAA map for Spot5 and Jason1: the SAA area is larger for Jason1
  - create a map using 3 years of data
  - use these maps to see the impact on orbit and on positioning (particularly for SAA stations)

Map of the Spot5 frequency drift of Petr (2X2 deg)
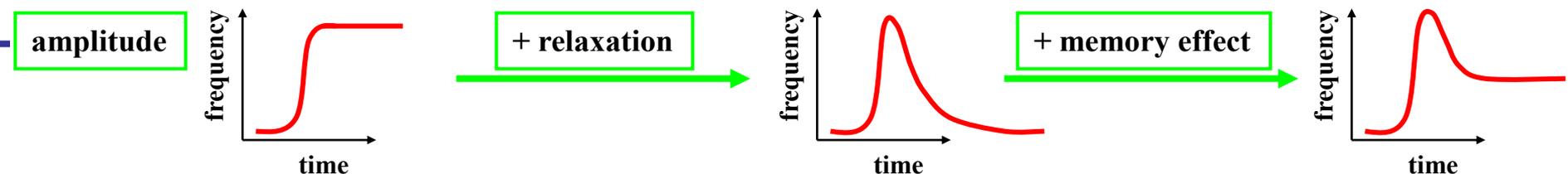

SAA Jason1 map (1X1 deg)

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.