# DORIS/JASON clock behavior assessment in the South Atlantic Anomaly region

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**Summary:**

Using the Gipsy/Oasis software at JPL, we have processed the first 20 cycles of DORIS data (from January 15, 2002 to July 30, 2002).

Anomalous results can be seen in different types of results:

1. DORIS postfit residuals for Precise Orbit Determination,

2. Apparent estimated displacements of a few ground stations (all located in the South Atlantic Anomaly region),

3. Anomalous estimated clock behaviors for the Toulouse and Kourou DORIS master stations.

The purpose of this poster is to summarize the different problems that we can see in the DORIS data and propose a physical explanation of these computations artifacts

Our explanation is that over the South Atlantic Anomaly region, the JASON clock is affected and shows a very significant acceleration that can explained the anomalous results that we observe.

This explanation is compatible with all the anomalous results that we have seen

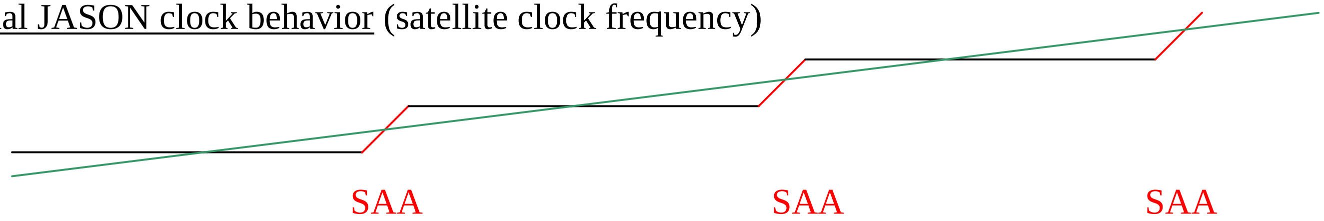
## Our basic hypothesis :

The South Atlantic Anomaly (SAA) is a region close to the West coast of Brazil in which the shielding effect of the magnetosphere is not perfectly spherical and a shows a ‘pot-hole’ as a result of the eccentric displacement of the center f the magnetic field compared with the origin (center of mass). In this region, Low Earth Orbiting satellites should see their clock vary in frequency due to an extended particule flux that they cross on a period basis.
([http://www.ll.mit.edu/ST/sbv/saa.html](http://www.ll.mit.edu/ST/sbv/saa.html))

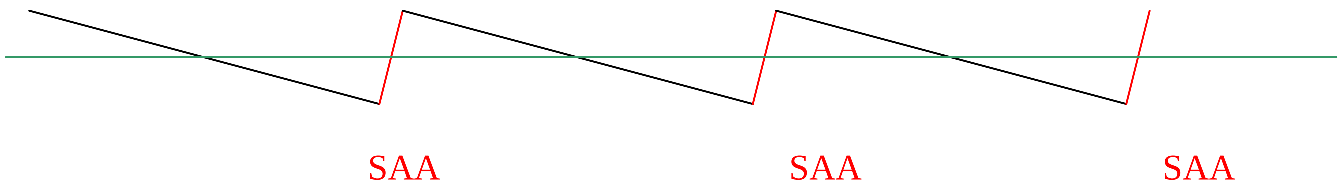
In our model, we will consider that :

- Outside the South Atlantic Anomaly region, the satellite clock frequency is constant (1rst order polynomial)
- inside the South Atlantic Anomaly region, the clock is linearly accelerated (2nd order polynomial)

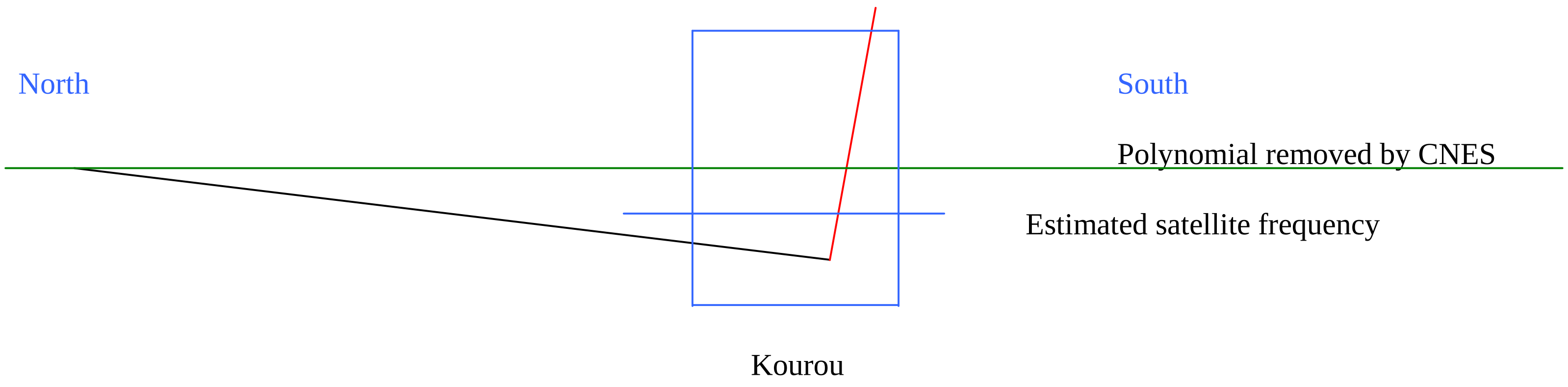
Actual JASON clock behavior (satellite clock frequency)




JASON satellite clock in the DORIS data
(after removal of a long-term polynomial by CNES in their preprocessing = ———— )



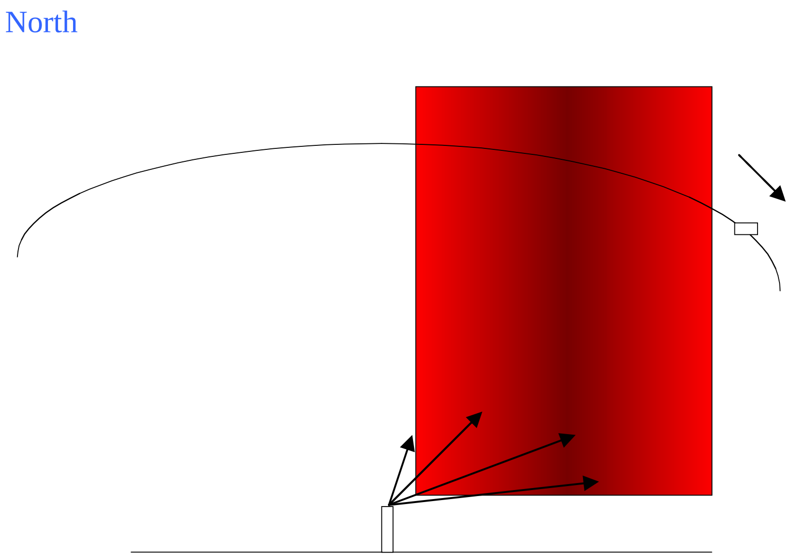

Outside the SAA, the remaining clock possess a small acceleration (we suppose we can neglect it)
Inside the SAA, the remaining clock acceleration is constant and positive. The frequency shift is growing linearly with time.



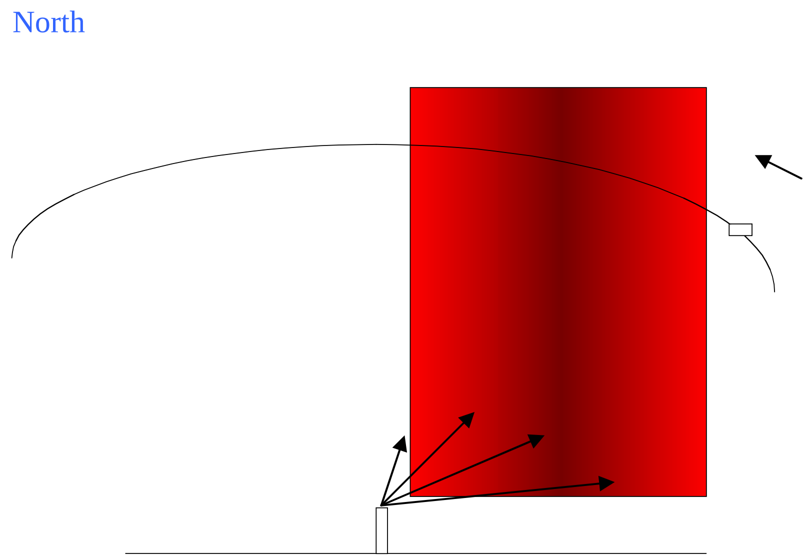

At Kourou, due to the acceleration of the JASON clock in the SAA, the estimated satellite clock should be negative for descending pass and positive for ascending pass. So the estimated station frequency should be higher for descending pass and lower for ascending pass (receiver/transmitter clock have symmetric roles in the physical equations).

A similar problem should also be seen in Toulouse (other DORIS master station)

# Station at the boundary of the SAA region




DESCENDING PASS AT KOUROU

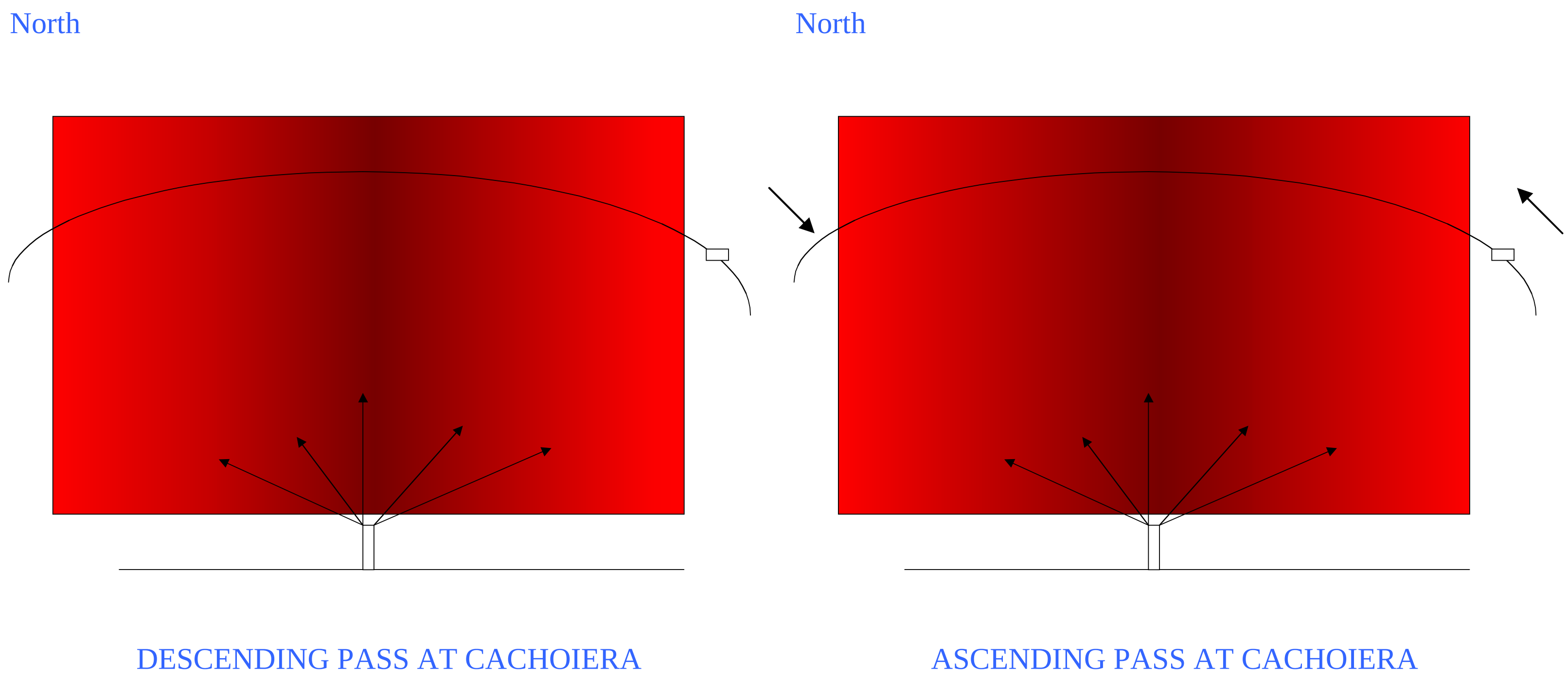



ASCENDING PASS AT KOUROU

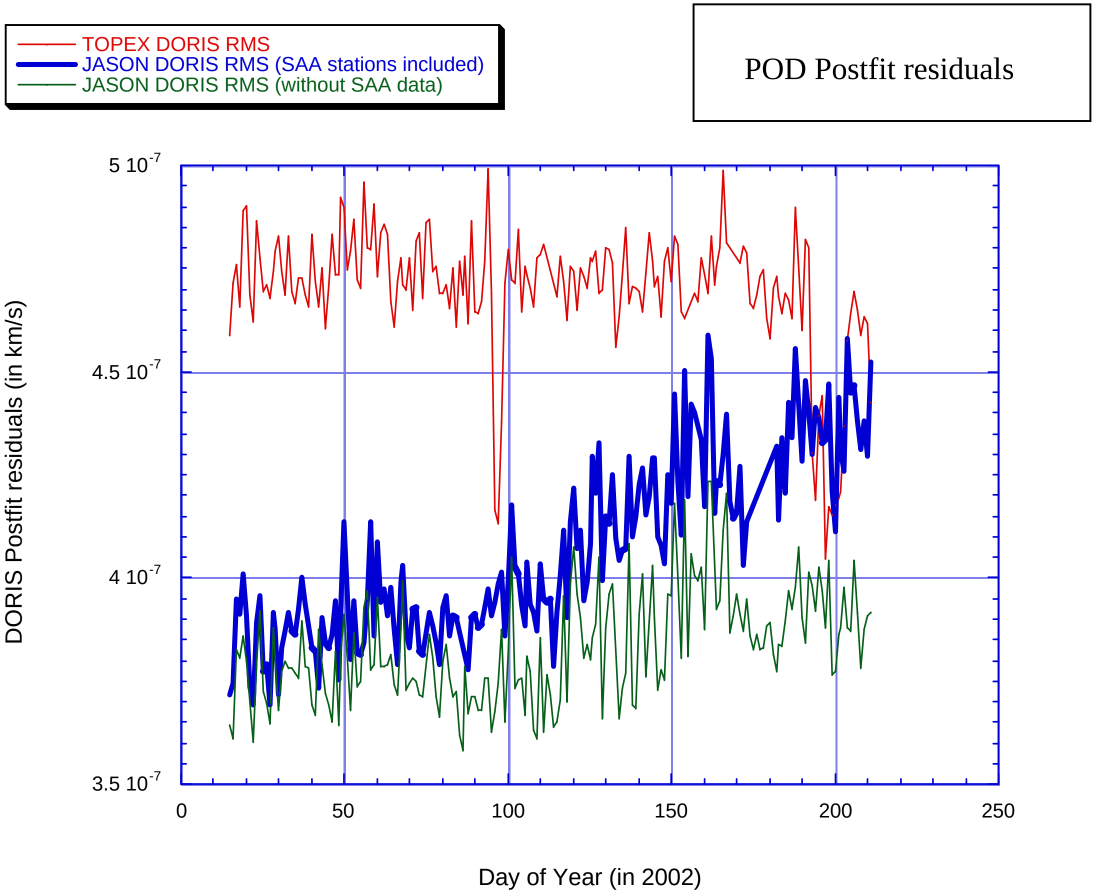
Stations that are at the boundary of the SAA region see the satellite in the SAA region differently between ascending and descending passes

Stations North of the SAA should have an apparent South velocity in latitude as well as positive altitude velocity
Station South of the SAA should have an apparent North velocityas well as positive altitude velocity

# Station in the middle of the SAA region



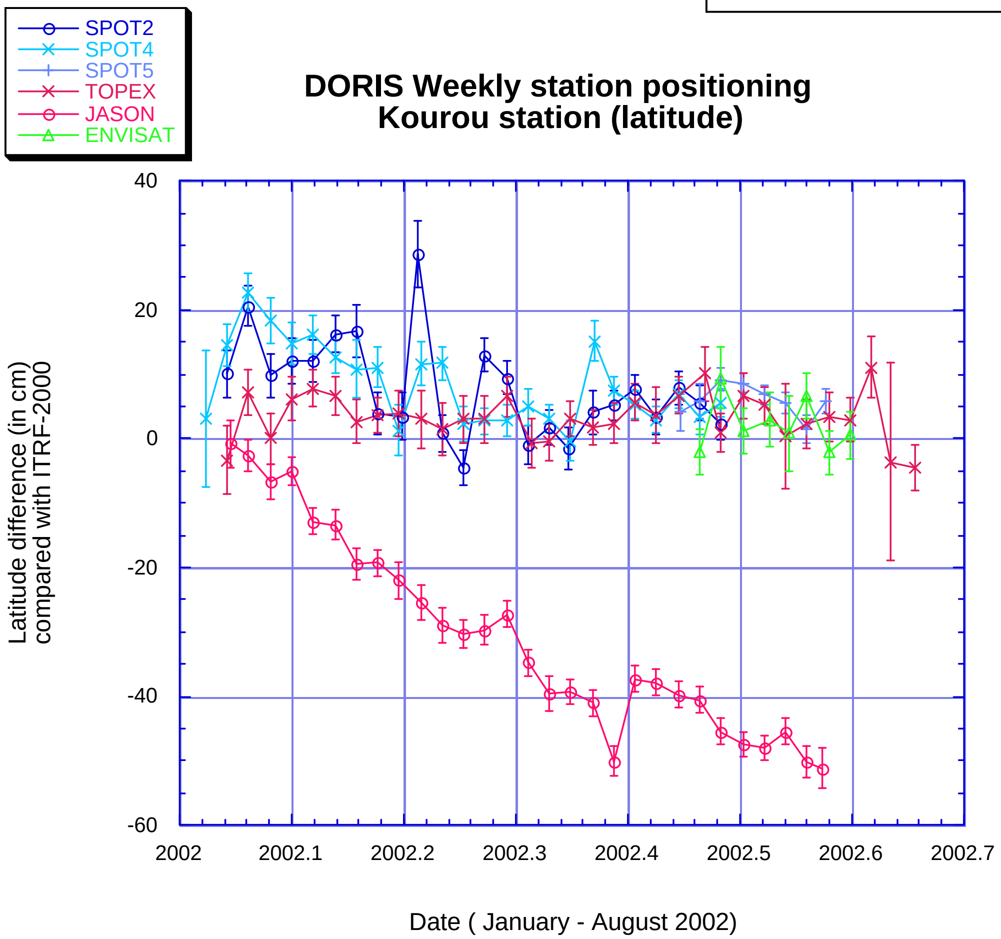

Stations in the middle of the SAA, due to the symmetry of the passes will have a large apparent velocity in height
If the un-modelled satellite clock acceleration in the SAA is positive, the apparent station altitude should be positive.




Without using the DORIS data from stations in the South Atlantic Anomaly region, as expected, JASON/DORIS residuals are smaller (0.38 mm/s) than TOPEX/DORIS residuals (0.48 mm/s). JASON has a new generation of DORIS receiver.
When using all DORIS data, the JASON residuals grow with time, showing that our models degrade with time.

All stations coordinates were fixed to ITRF-2000. For the newest stations, coordinates provided by J. Ries were adopted.

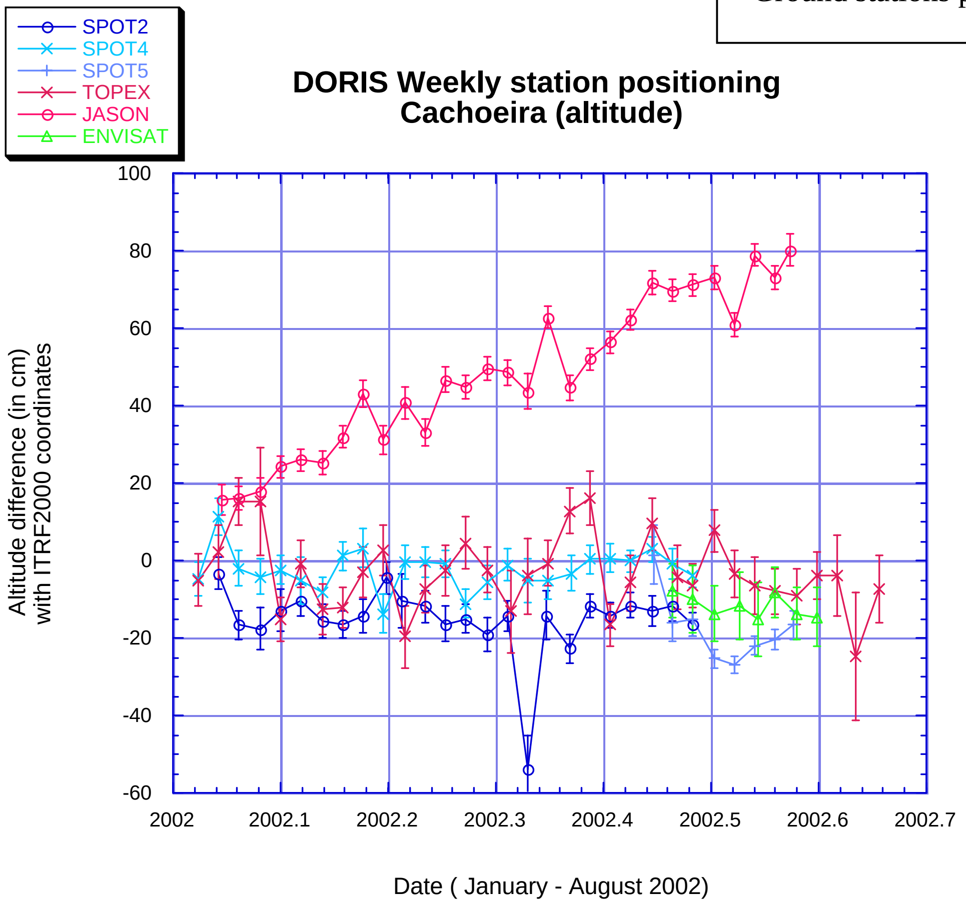
Ground stations positioning



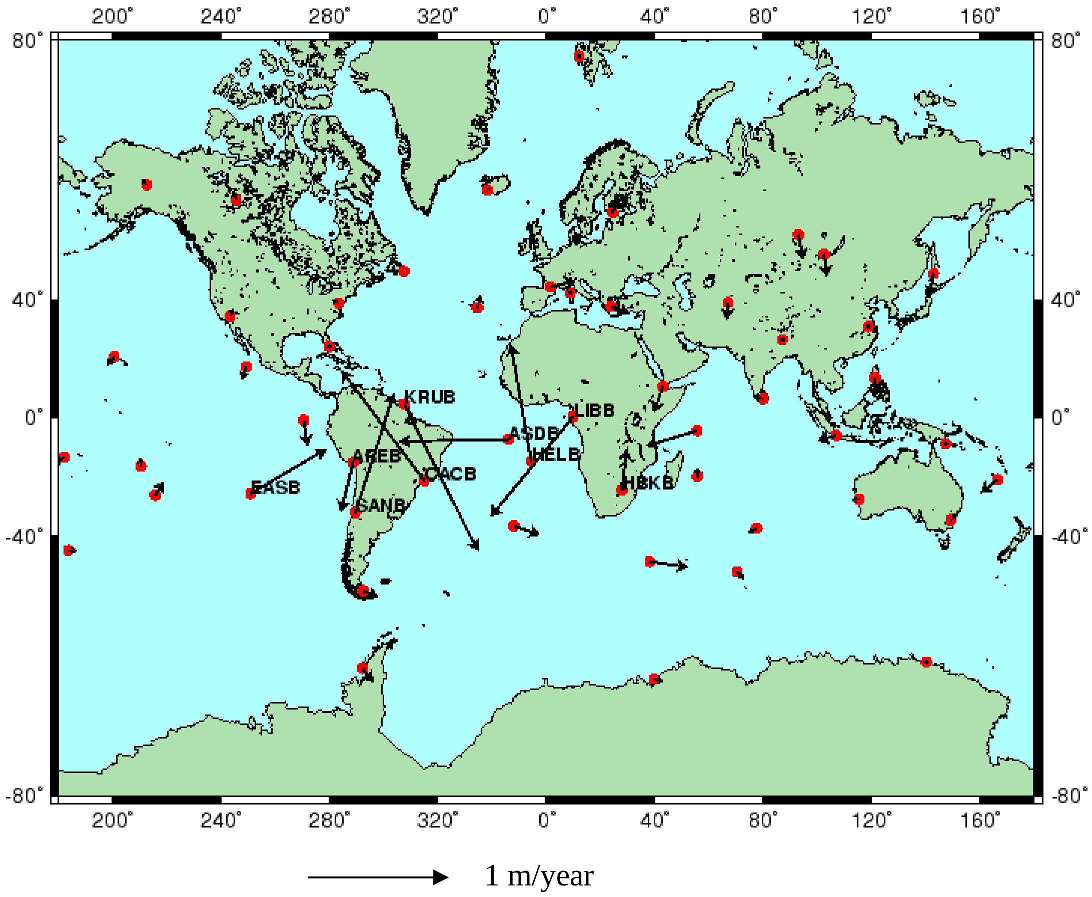

When doing free-network solutions (ground stations coordinates are estimated as well as satellites orbits), some stations, like Kourou (in latitude on this plot) seem to have an anomalous velocity than is only visible from the JASON/DORIS satellite. All other DORIS satellites give solutions that are compatible with ITRF-2000 velocities.

The JASON-determined latitude for Kourou seems to present a very large negative trend (-1 m/year!!!)

Ground stations positioning

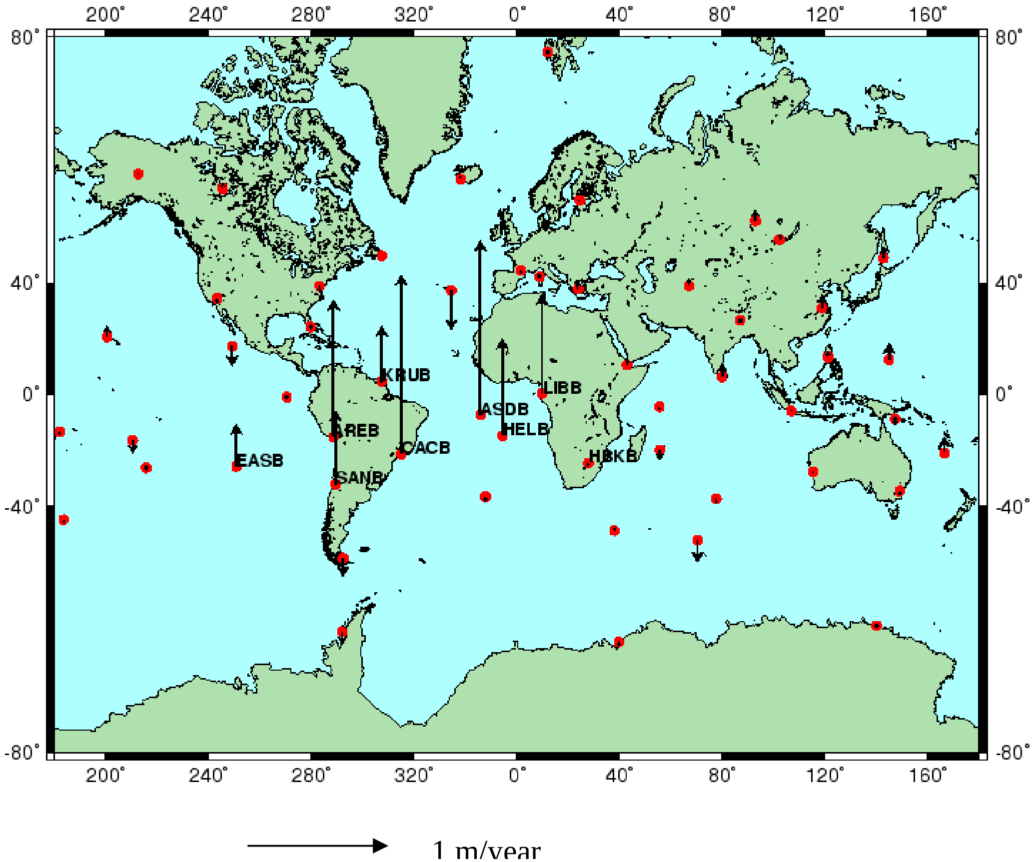



A similar problem can be seen for Cachoeira station in altitude (positive trend of 1.2 m/year)




This map summarizes for all stations the difference between the JASON-derived <u>horizontal apparent displacements</u> of the station compared with the ITRF-2000 velocity.

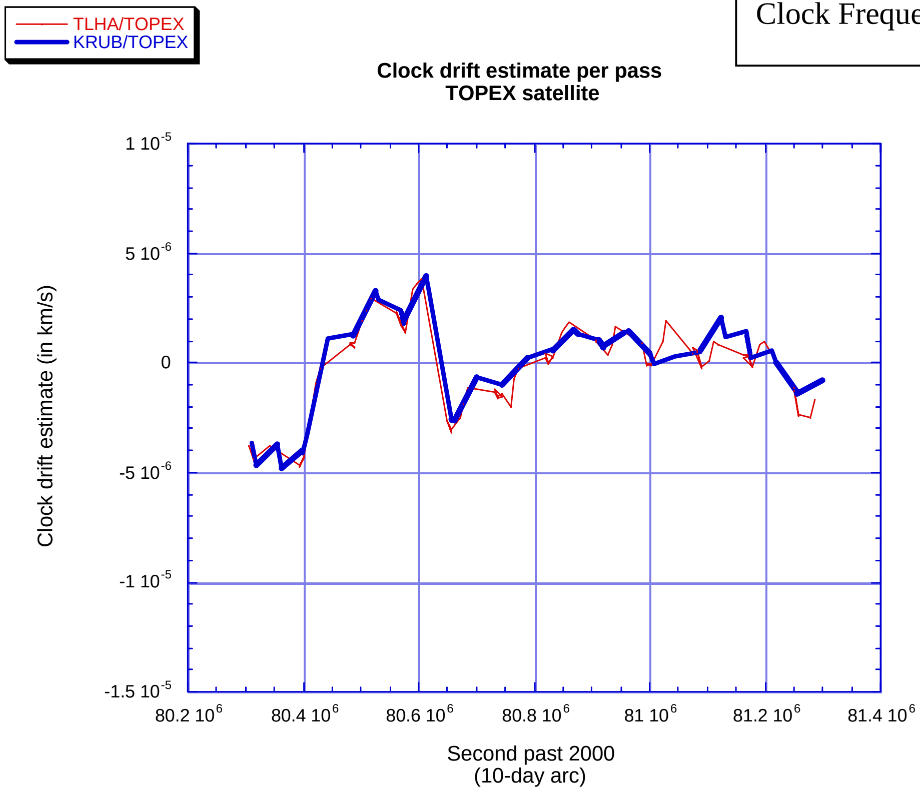
Larger effects can be found at the boundary of the SAA region.




This map summarizes for all stations the difference between the JASON-derived <u>vertical apparent displacement</u> of the station compared with the ITRF-2000 velocity.

Large effect can be seen in the South Atlantic Anomaly region. Larger effect can be seen in the middle of the SAA region. All stations in this region have large positive velocities.

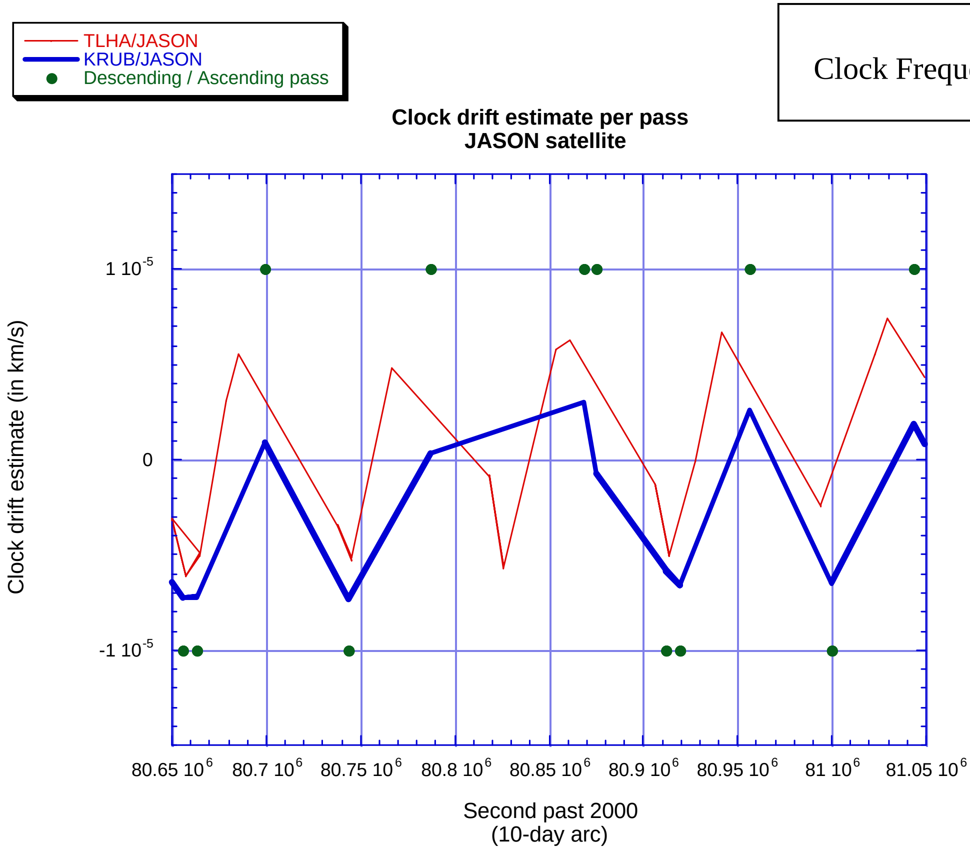
# Clock Frequency estimation




When doing Precise Orbit Determination for TOPEX (all stations coordinates fixed), the 2 DORIS master stations Kourou and Toulouse show a common pattern that corresponds to the remaining short-term satellite clock frequency behavior (after removal of long-term polynomial by CNES).

The amplitude of the remaining frequency is small (typically around 2-3 mm/s)

# Clock Frequency estimation




When doing Precise Orbit Determination for JASON (all stations coordinates fixed), the 2 DORIS master stations Kourou and Toulouse show a very different pattern.
The amplitude of the remaining frequency is much larger (typically around5 mm/s)
The estimation station clock frequency is lower for ascending pass and higher for descending passes

# **Additional comments and questions/answers :**

1. -Why do we see this phenomena on JASON and not on TOPEX ?

The JASON satellite being much smaller than all the other DORIS satellites, including TOPEX, the DORIS clock may be less protected to radiations

2. Would it be possible to remove this effect by estimating an additional DORIS parameter per pass?

No because, the phenomena is not related to the ground station clock but the satellite clock, so the clock acceleration is only constant when the satellite is in the SAA region and not when the satellite passes over a specific station (see plots for the disymetry of effect between ascending and descending passes over Kourou)

3. Why is the phenomena growing with time?

The satellite clock acceleration seems to grow linearly in time. This could be linked to a saturation of the resistance of the JASON clock to radiation. The number of passes of the orbit through the SAA is almost very constant in time, so the total time over the SAA region grows linearly. The effects seems to be proportional to the quantity of radiation received by the satellite of the clock since the launch.

4. Is there a way to get rid of this problem for JASON/DORIS data processing

The rigorous way would be to estimate the JASON clock as a linear model outside the SAA and as a quadratic model inside the SAA. However, the start and end time for crossing the SAA region are not very well defined. Furthermore, it has not yet been totally proven that the satellite clock behavior is quadratic for every pass in this region.

In any case, that current CNES preprocessing should not include Kourou’s DORIS pseudoranges to to the time-tagging of the measurements, as we now know that the satellite clock over Kourou does not have quadratic trend (inside and outside SAA present different clock behavior)