DORIS measurement for ionosphere studies

C. Tourain, C. Jayles, A. Auriol (CNES, Toulouse, France),
F. Didelot (CLS, France)

DORIS Ionosphere capacities

Doris system is based on the process of a dual frequency signal 401.25MHz and 2036.25MHz. This design was chosen to permit the construction of a iono-free 2GHz measurement.

Considering the first order dev of phase path P *(1)* , a iono-free phase path can be determined *(2)* :

$$P_{2GHz} = L_0 + \frac{aN_T}{f_{2GHz}^{\ 2}\sin\varphi} \qquad P_{400MHz} = L_0 + \frac{aN_T}{f_{400MHz}^{\ 2}\sin\varphi} \quad (1) \Rightarrow L_0 = \frac{\alpha^2 P_{2GHz} - P_{400MHz}}{\alpha^2 - 1} \quad (2)$$

$$\alpha = \frac{f_{2GHz}}{f_{400MHz}} > 1$$

Measurements can also be exploited to determine the ionospoheric delay *(3)*:

$$P_{2GHz} - L_0 = \frac{P_{400MHz} - P_{2GHz}}{\alpha^2 - 1} \quad (3)$$

This simplified theory shows DORIS measurements are a potential information source for ionosphere applications (TEC determination, ionosphere observation…)

Observation on Jason2 DORIS instrument

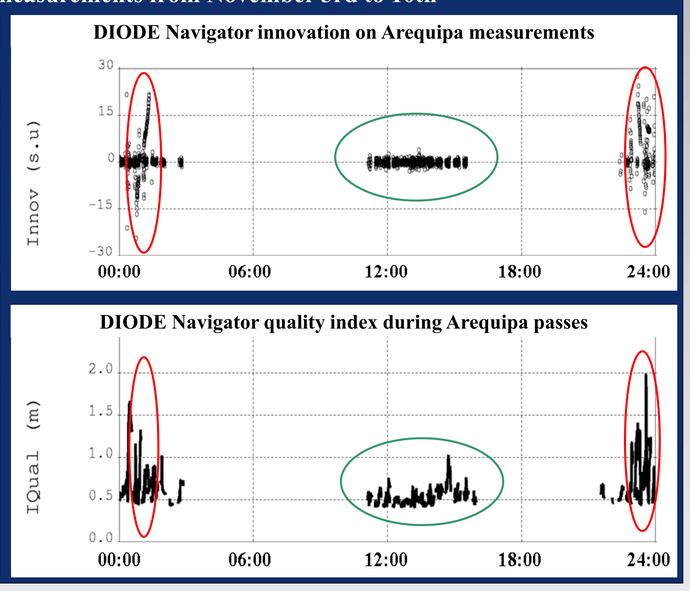
Currently, 3 DGXX DORIS instruments (latest issue) are flying : on Jason 2, Cryosat 2 and HY2-A. Soon a fourth instrument will fly on Saral/Altika. Those instruments deliver 2 sets of 2GHz and 400MHz phase measurements every 10 seconds.

On board Jason 2, those measurements are processed by the DIODE navigator to give a real time orbit. During some period in the year and over certain beacons, the real time orbit processing (Kalman filter) is disturbed :

- **The quality index given by the navigator takes higher values,**
- **The innovation of the tilter for the measurements processed is also higher.**

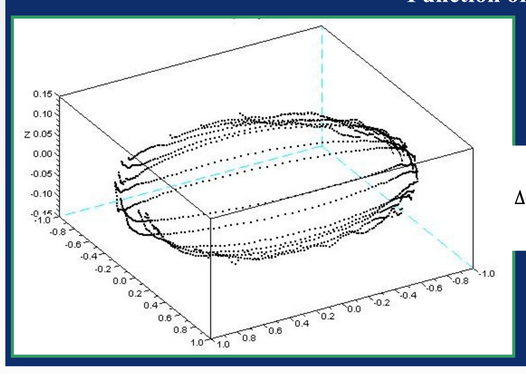
Those disturbances are observed for specific local time slots.

Observations on Arequipa measurements from November 3rd to 10th



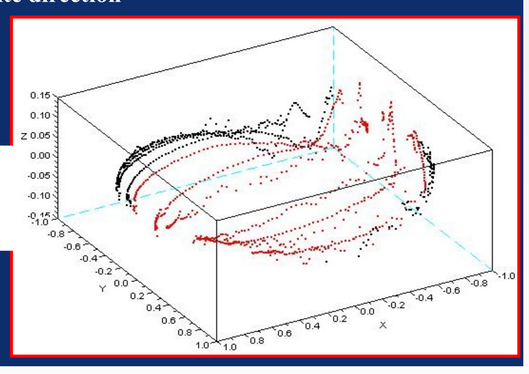
If we determine the Ionosphere effect on the phase difference between the beginning and the end the 10s DORIS sequence *(1)*. We observe values highly disturbed during those passes with respect to normal passes.

Ionosphere effect on ΔPhase measurements for Arequipa from November 3rd to 10th
Function of the station to satellite direction



(1)

$$\Delta(P_{2GHz} - L_0) = \frac{\Delta P_{400MHz} - \Delta P_{2GHz}}{\alpha^2 - 1}$$



Those observations can be correlated with ionosphere scintillations effect.

It seems that through those data, and so, through DORIS instrument measurements, we have information about ionosphere effect.

Ionosphere projects using DORIS signal

The Doris signal is free, and there is no limitation on the number of onboard receivers.

Several projects for ionosphere application using DORIS signal already exist, at different phases:

- **CITRIS instrument on STPSat1 (NRL):**
  From March 2007 to October 2009, the CITRIS receiver archived TEC and radio scintillation data from the DORIS beacons (and LEO CERTO beacons).
  They were processed to determine the fluctuations in ionospheric TEC and radio scintillations associated with equatorial irregularities.
  Presentation : Ionospheric Radio Scintillations and TEC Using the CITRIS Reception of DORIS Transmissions (P. Bernhardt (NRL))

- **DORIS signal receiver on IRIDIUM-NEXT**
  Objective : directly image global ionosphere dynamics in near real time.
  Presentation : DORIS Observations from Future LEO Constellations Space Geodesy Project (D. Rainwater (ARL:UT))

- **DORIS signal tracking on COSMIC-2 (NASA) :**
  Tracking DORIS signals on planned COSMIC-2 satellites to measure the ionosphere could be implemented. The reflection is on going.

All those applications use the DORIS signal with specific processes and formats, nevertheless, those data would be welcome on the IDS data centers. For future projects, it would be interesting to have a common format, such as the RINEX.

DORIS Phase measurements are available

DGXX DORIS instruments' measurements are available in RINEX format (3.0).

Depending on the area seen by the satellite, up to 7 (mean 3) different measurements are registered with their precise time tagging. Every ten seconds, 2 sets of measurements are performed :

- **1st set : at the beginning of the sequence,**
- **2nd set : 3 seconds after the beginning of the sequence.**

The data given are (among others):

- **Pseudo range : low accuracy : ~1km at 400MHz and ~5km at 2GHz**
- **Phase measurement : few mm accuracy.**

Those files are distributed and archived on IDS Data Centers for all DORIS instruments.

This could be an amount of complementary data for ionosphere study.

One advantage is the altitude of satellites (between 700 and 1400 km), this would bring an information about intermediary electronic content.

Electronic Content data could be calculated from those measurements, but the process is to be defined.

Discussions with the CDPP (Centre de Données de Physique des Plasmas) showed that there is an interest to exploit information contained in the RINEX files for near real time 'space weather' application.

Future space radars at P-band (435 MHz) like ESA's BIOMASS candidate mission, need specific ionospheric effects correction. A good comprehension of ionosphere propagation at 435 MHz is needed to ensure good quality images. DORIS ionospheric products could be used to provide models adapted to this frequency band.

At CNES, DORIS teams haven't sufficient skills and resources to process those data.

A promotion work is on going to contact any potential teams interested in processing RINEX data, in order to extract ionospheric information.