PhD DGA-CNRS @ IPGP

Deadline 12 May 2016

Title: *3D Ionospheric Tomography for local and global scale with multi-parametric data-set (OTH, GPS, Occultation, SuperDarn): a new adapted vision to study the ionospheric dynamics.*

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General Introduction: *Ionosphere is a variable medium with an active dynamics. Most recent methods in ionospheric tomography are based on the inversion of the total electron content measured by ground-based GPS receivers. As a consequence of the high frequency of the GPS signal and the absence of horizontal ray-paths, the electron density structure is mainly reconstructed in the F2 region (300 km), where the ionosphere reaches the maximum of ionization, and is not sensitive to the lower ionospheric structure. We explored recently a new tomographic method of the lower ionosphere, based on the full inversion of over-the-horizon (OTH) radar data (Roy, Occhipinti et al. 2014). Previous studies using OTH radar for ionospheric tomography inverted only the leading edge echo curve of backscatter ionograms. The major advantage of our methodology is taking into account, numerically and jointly, the effect that the electron density perturbations induce not only in the speed of electromagnetic waves but also on the ray-path geometry. This last point is extremely critical for OTH radar inversions as the emitted signal propagates through the ionosphere between a fixed starting point (the radar) and an unknown end point on the Earth surface where the signal is backscattered. We proved the necessity to take into account both effects simultaneously, and we applied our method to real data realizing an ionospheric tomography of the entirety of Europe with an OTH radar. Today, we wish to entirely pass from several 2D grids to a full 3D grid in order to apply our method to a multi parametric dataset including several ionospheric sounding techniques as GPS ground stations, GPS occultations, OTH radars and the more ambitious SuperDarn network that cover the entire polar region where the ionosphere is not well constrained. We highlight that the backscattered data from SuperDarn are identical to OTH radar, consequently the developed method is perfectly adapted to treat SuperDarn.*

This allows to creating a real 3D ionospheric inverse method for regional and global tomography.

The fellowship strictly requires EU or Swiss nationality.

Detailed Schedule & Tasks: *The PhD schedule and evolution can be organized in 3 main tasks with different goals that can be reached during the three years of the PhD.*

i) The first goal of the PhD, mainly during the fist year, is to improve numerically the developed method to be applied to general 3D grids, instead of 2D grids in a 3D space (as in figure 1, from Roy, Occhipinti et al., 2014). The "2D in a 3D space" approximation is useful for OTH radar measurements, as each measurement could be approximated all in a single azimuth. As a consequence of the radical variation of the ray-paths of the GPS station-satellite geometry, this approximation couldn't be applied and need the over-mentioned 3D grid improvement in order to include in our ionospheric tomography the Total Electron Content measured by GPS. Consequently the entire first year will be dedicated to the include GPS data in the methodology in order to finalize a joint inversion of OTH radar and GPS data, together. This approach can be sensitive at the low ionospheric structures (E region), as well as the maximum of ionization (F region).

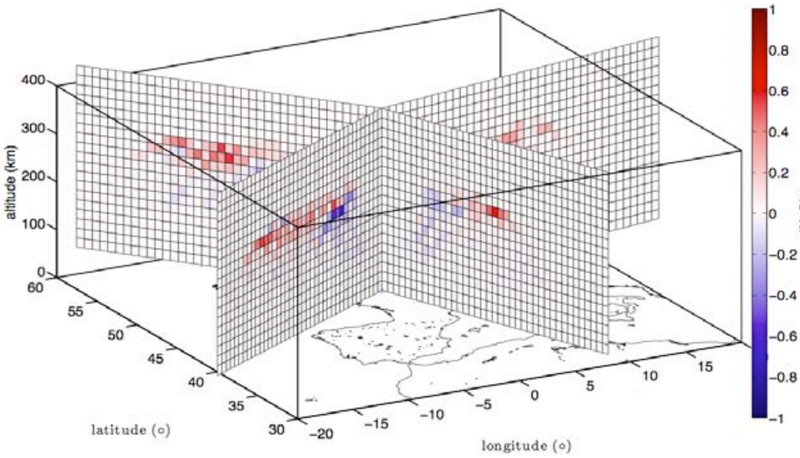

Figure 1: Electron density perturbation obtained by real data inversion measured by the OTH radar Nostradamus the 14 March 2006, at 18:55 UT in four azimuth directions, nominally 67∘, 157∘, 247∘, and 337∘. (from Roy, Occhipinti et al., 2014)

ii) The second objective of the project is to integrate additional data, mainly GPS occultations and SuperDarn radar.

As a consequence of the horizontal geometry of the GPS occultation, the presence of TEC measured on horizontal ray-paths stabilize the solution and will introduce an additional sensitivity to vertical variations, as well as an additional sensitivity to the top ionosphere. We wish to highlight that collaboration with the NASA Jet Propulsion Laboratory could be easily included into the project in order to analyze COSMIC data. Attila Komjathy (JPL), one of the Co-I involved in the COSMIC mission, is a closer collaborator of Giovanni Occhipinti.

The SuperDarn radar mainly works as a OTH radar but its coverage is strongly ambitious in the polar region (figure 2). Super Dual Auroral Radar

Network (SuperDARN) is a network of more than 30 HF radars that look in the upper atmosphere of the Earth from middle latitudes to the polar regions. The radars operate continuously sending a signal that is reflected on the ionosphere and the ground, which is back-scattered to the radar, exactly like OTH radars. Consequently, is could be easily included in our ionospheric tomography method and could be open a terrific improvement of the polar ionosphere knowledge. Indeed, in our knowledge, the SuperDarn data was never used for ionospheric tomography. With a recent participation to a SuperDarn workshop, Giovanni Occhipinti introduces to the community, the idea to use the back-scattered SuperDarn data (normally trashed) for ionospheric tomography based in his results tested on OTH radar. The idea was accepted and welcomed with a great enthusiasm.

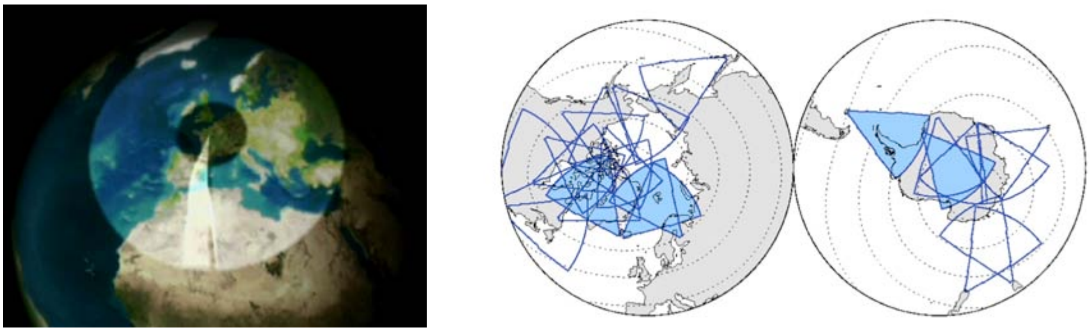

Figure1: The coverage of the OTH Nostradamus (left) and the coverage of the SuperDarn network in the north and South pole (right).

iii) The last goal of the PhD is to pass from a static 3D grid to an adaptive 3D grid (local or global) in order to solve the ionospheric structures with a resolution strongly depending of the density of the data. Indeed, the pole-regions, covered by SuperDarn, or regions where is possible to access to dense GPS network (as Japan with the GEONET data, more than 1000 stations) can be solved with a really high space-time resolution.

Selected References *(students are underlined)*

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