ESTIMATION OF THE ATMOSPHERIC REFRACTIVITY FROM WEATHER RADAR DATA

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(*Doc_TIC*)

Motivation of the work

Estimation of the atmospheric refractivity variations in the lower part of the atmosphere from radar phase measurements of stationary targets returns with enough temporal and spatial resolution.

Recently it has been shown that refractivity can be obtained from radar phase measurements with a high spatial and temporal resolution about flat terrain [1, 2]:

$$\phi(r,t) = 2\pi f t = \frac{4\pi f}{c}\int_0^R n(r',t)dr' \qquad (1)$$

In particular, it can be obtained from measurements of phase variation between responses from stationary targets at different time instants:

$$\Delta(\Delta\phi(\Delta_r,\Delta_t)) = \frac{4\pi f \Delta_r}{c}\Delta n(\Delta_r,\Delta_t) \qquad (2)$$

Remaining challenges are to estimate the refractivity about complex terrain taking into account height variations between radar and targets, vertical gradient variations and the Earth's curvature [3].

It is of importance in numerous fields, such as:

- Meteorology where it is used to derive temperature and humidity which is important because the convergence of moisture at low-levels is related to the initiation of severe storms and deep convections [4].
- Electromagnetic wave propagation coverage prediction, where in this case, it is important to reduce interference between nearby stations and to ensure the required signal level within the whole coverage area (dynamic management of the spectrum) [5].

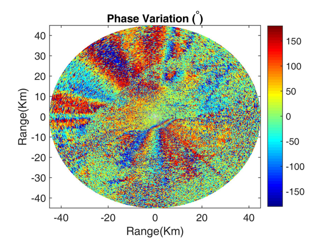

Figure 1: Initiation of deep convection.

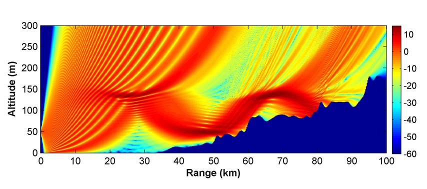

Figure 2: Path Loss using two-way parabolic equation.

Thesis objective

The objective of this thesis is to improve the actual algorithms for estimating refractivity by means of weather radar data. With this purpose the work lines considered will be:

- A search method of stationary targets independent of the atmospheric conditions. For this purpose, a variability index based on dual polarization measurements, which depends only on the movement of the targets, was defined as:

$$SI = \frac{1}{(S-1)M}\left|\sum_{l=1}^{S-1}\sum_{k=1}^{M} e^{j[\{\phi_{l,k}^{HV}\}-\{\phi_{l-L,k}^{HV}\}]}\right| \qquad (3)$$

- A more accurate description of the phenomena involved to reduce uncertainties improving the existing algorithms to estimate the refractivity taking into account the height variation between the selected targets and the radar, the vertical variation of the atmospheric refractivity and the height ray above the surface of the ground. In the lower part of the atmosphere, a linear decrease of the refractive index can be assumed so

$$n(r,t) = n(r,h_R,t) + (h(r,t)-h_R)\frac{\partial n(h_R,t)}{\partial h} \qquad (4)$$

Nex Year Planning

- Current works are focused on including height variations, whenever the radar and the ground clutter are not at the same height, and refractivity vertical gradient in the algorithms.
- Next year work will focus on the publication of results and the production and defense of the dissertation.

Research plan

In order to achieve the objectives proposed the following research plan is considered. This plan is reviewed after each task in view of the results obtained.

	2013	2014				2015				2016				2017
	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1
Bibliographical review														
Analysis and improvement of wave propagation models														
Evaluation of technological resources														
Planning of measurements campaign														
Implementation of the algorithm														
Analysis of the algorithm and comparison with others														
Dissermination of the results (Thesis)														

Characterization of the path

In order to resolve the integral equation, it is necessary to characterize the length and the height of the ray path above the Earth's surface using the equivalent Earth's model (Fig. 1-2).

- Length of the ray path

$$R(t) = -(\frac{\partial n(r,t)}{\partial h})^{-1}\cdot \arccos\left(1+\frac{L^2}{2\cdot(\frac{\partial n(r,t)}{\partial h})^{-2}}\right) \qquad (5)$$

where

$$L^2 = (E_r+h_R)^2+(E_r+h_T)^2-2(E_r+h_R)(E_r+h_T)\cos(\frac{S}{E_r}) \qquad (6)$$

- Heigth of the ray path

$$h(r,t) = h_R + \frac{(h_T-h_R)}{R}r + \frac{1}{2a_e}\frac{R^2-(h_T-h_R)^2}{R}(\frac{r^2}{R}-r) \qquad (7)$$

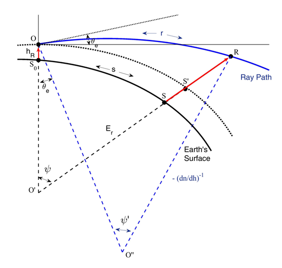

Figure 3: Curved path of the ray along the earth's surface.

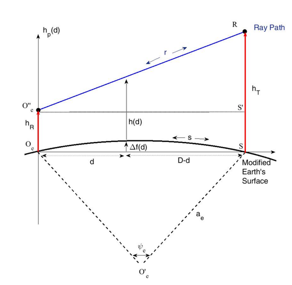

Figure 4: Straight path of the ray along the modified earth's surface.

Constraints

The time between two consecutive scans should be set to the height of the targets over the Earth's surface and the distance between them and radar in order to:

- avoid that the phase wraps 2π rad between two consecutive scans.
- neglect the contribution due to Earth's curvature with regards to the horizontal and vertical contributions.

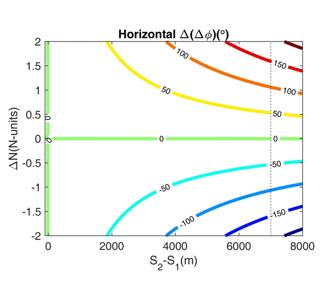

Figure 5: Horizontal term.

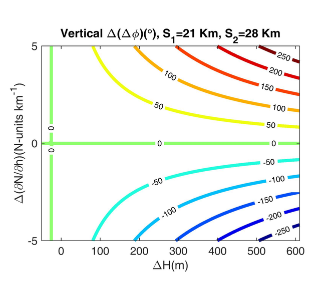

Figure 6: Vertical term.

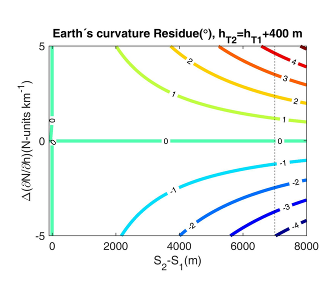

Figure 7: Eath's curvature term.

Results & Discussions

- Data processing from returns: (I,Q) data.

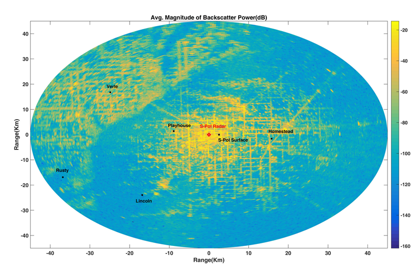

Figure 8: Power of returns.

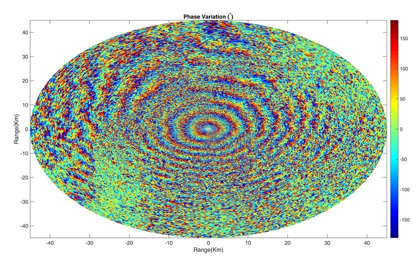

Figure 9: Phase of returns.

- Characterization of the variability of the targets from the measured phase removing the atmospheric variations: stationarity index (SI).

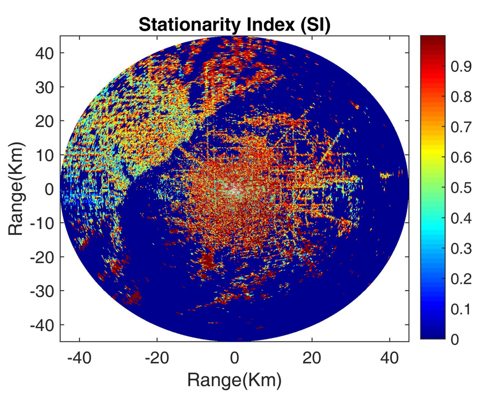

Figure 10: Variability of the ground target returns.

- Estimation of refractivity about flat terrain: comparison with a surface station shows excellent agreement.

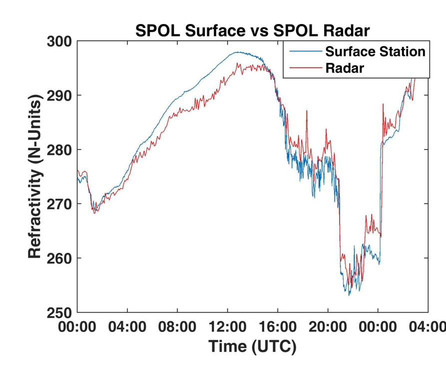

Figure 11: Radar Refractivity vs. Surface Weather Station.

- Estimation of horizontal and vertical gradient refractivity about complex terrain. As the algorithm has two unknowns, variations between target triples are used.

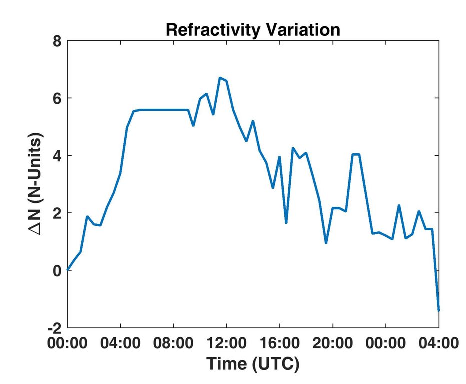

Figure 12: Variation of the horizontal refractivity.

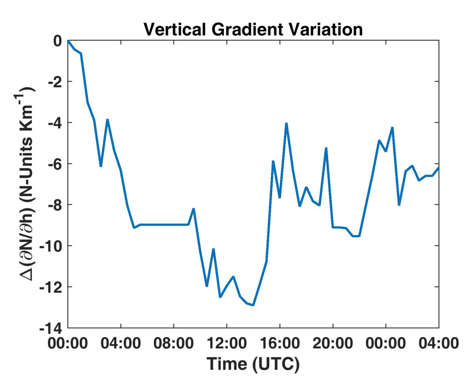

Figure 13: Variation of the vertical gradient.

References

[1] F. Fabry, C. Frush, I. Zawadzki and A. Kilambi. "On the extraction of near-surface index of refraction using radar phase measurements from ground targets". In *Journal Atmospheric and Oceanic Technology, vol. 14, pp. 978-987, August 1997.*

[2] F. Fabry. "Meteorological Value of Ground Target Measurement by Radar". In *Journal Atmospheric and Oceanic Technology, Vol. 21, pp. 560-573, September 2003.*

[3] S. Park and F. Fabry. "Simulation and interpretation of the phase data used by radar refractivity retrieval algorithm". In *Journal Atmospheric and Oceanic Technology, vol. 27, pp. 1286-1301, August 2010.*

[4] C. Ziegler, T. Lee and R. Pielke. "Convective initiation at the dryline: A modeling study". In *Mon. Weather Rev., Vol. 125, June 1997.*

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