ESTIMATION OF THE ATMOSPHERIC REFRACTIVITY FROM WEATHER RADAR DATA

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Motivation of the work

Knowledge of the **refractivity variations** in the lower part of the atmosphere with enough **temporal** and **spatial** resolution in order to:

- Forecast convective initiation and boundary layer processes [1].

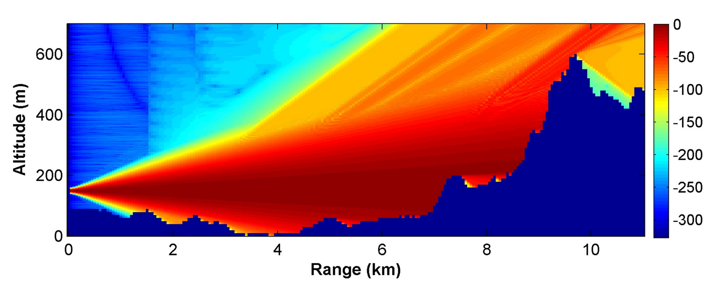
$\mathbf{N} = 77.6\frac{p}{T} + 37.3 \times 10^5 \frac{e}{T^2}$

e: water vapor pressure (hPa) -> moisture

T: temperature (K)

P: atmospheric pressure (hPa)

- Model the radio wave propagation using the parabolic equation [2].



$$\frac{\partial^2\varphi}{\partial x^2} + \frac{\partial^2\varphi}{\partial z^2} + k^2\mathbf{n}^2\varphi = 0$$

$\mathbf{n}$: refractive index, $\mathbf{N} = 10^6(\mathbf{n}-1)$

Thesis objective

Recently, it has been shown that refractivity can be obtained from radar phase measurements using stationary target returns with a high spatial and temporal resolution about flat terrain and zero vertical gradient [3, 4]:

$$\phi(\mathbf{r},\mathbf{t}) = \frac{4\pi f}{c} r\, n(t)$$

Remaining challenges are:

- Estimate the refractivity about **complex terrain** taking into account **height variations** between radar and targets, **vertical gradient variations** and the **Earth's curvature** [5]:

$$\phi(\mathbf{r},\mathbf{t}) = 2\pi f t = \frac{4\pi f}{c}\int_0^{\mathbf{R(t)}} \mathbf{n}(\mathbf{r},\mathbf{t})dr$$

  - In the lower part of the atmosphere, a **linear decrease of the refractive index** with the height can be assumed:

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

  - It will be necessary to characterize the length of the ray path **R(t)** and its height **h(r,t)** above the Earth's surface using the equivalent Earth's model.

- 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:

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

Nex Year Planning

Current works are focused on:

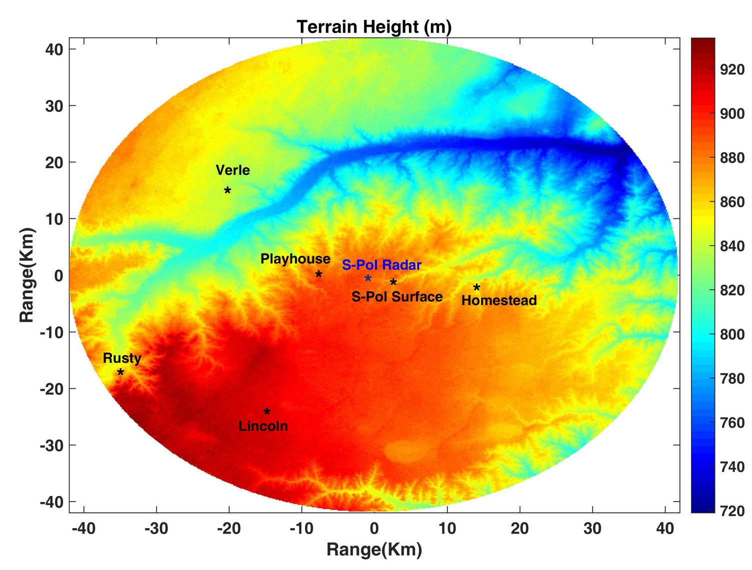
- Publications in peer-reviewed journals of the results obtained from different measurement campaigns.
- Production and defense of the dissertation.

Research plan

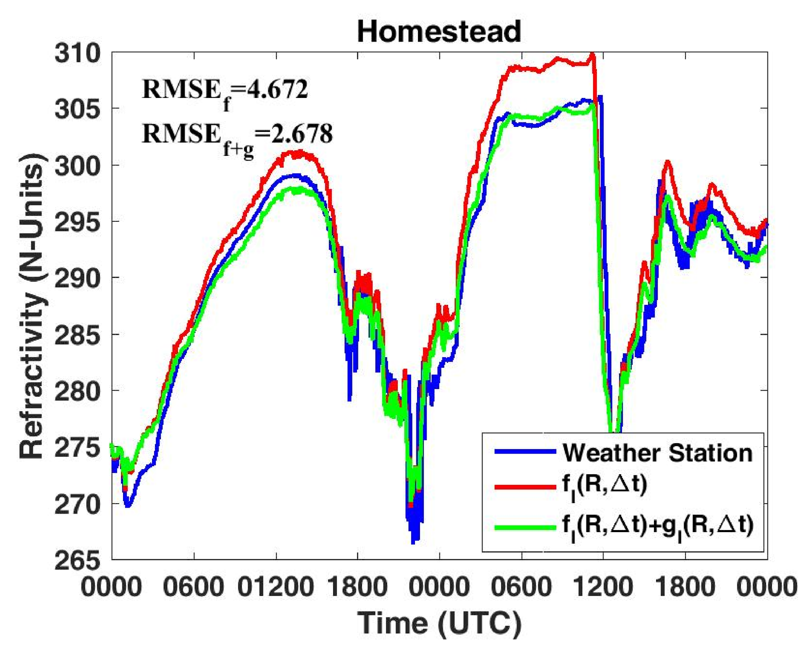
	2013	2014				2015				2016				2017		
	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3
Bibliographical review																
Analysis and improvement of wave propagation models																
Evaluation of resources																
Measurement campaigns																
Implementation of algorithm																
Analysis of algorithm and comparison with others																
Dissemination of results																

Results: Radar-Target Path

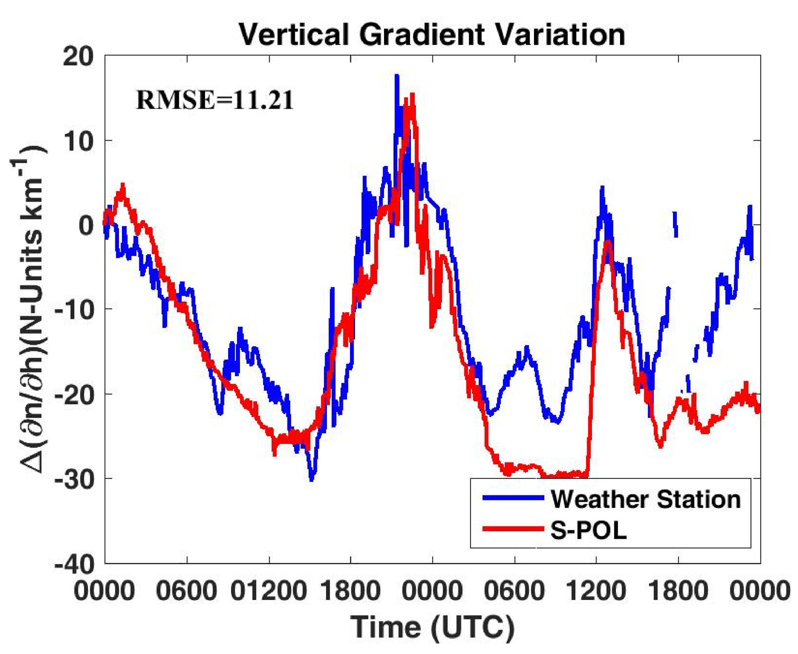
- Digital elevation model of the terrain:



- Refractivity variations along the path between the radar and the targets (**R(t)**) show an excellent agreement with refractivity derived from weather stations.



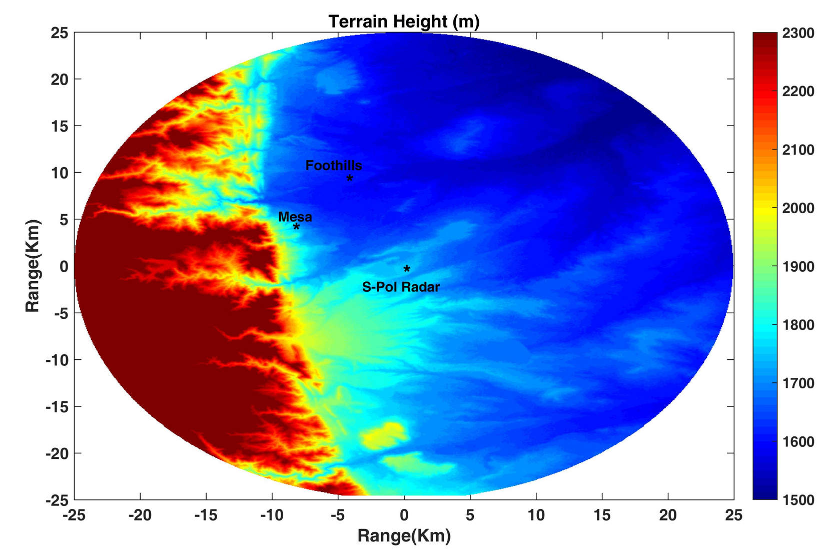
- Vertical gradient variations show a good agreement with gradient derived from AERIBAGO interferometer.



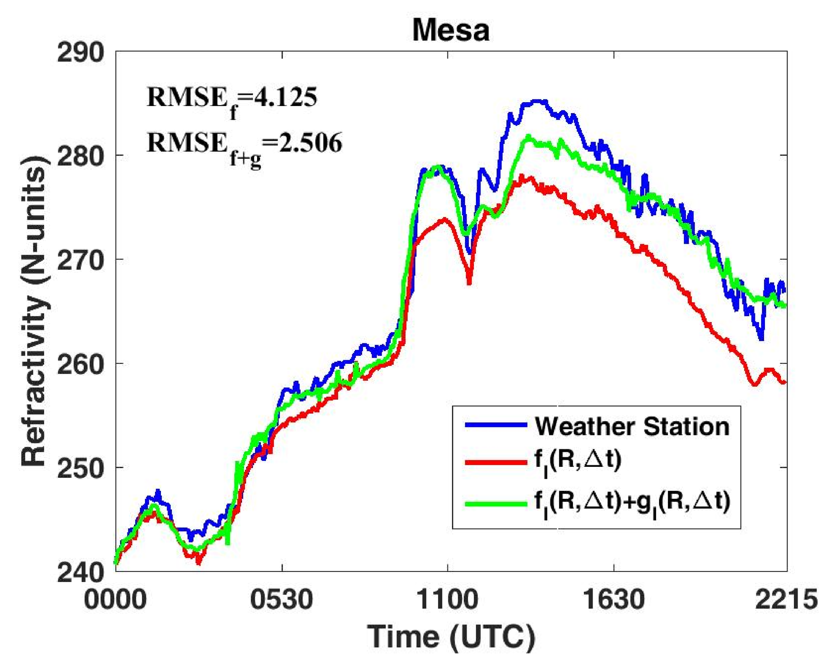
- R. Nocelo and V. Santalla. "Horizontal and vertical gradient refractivity variations from radar phase measurements". In the 2017 IEEE International Radar Conference, Seattle, USA, May 2017.
- R. Nocelo and V. Santalla. "Joint estimation of the horizontal refractivity and the vertical gradient variations from radar phase measurements". Submitted to Quarterly Journal of the Royal Meteorological Society, May 2017.

Results: Target-Target Path

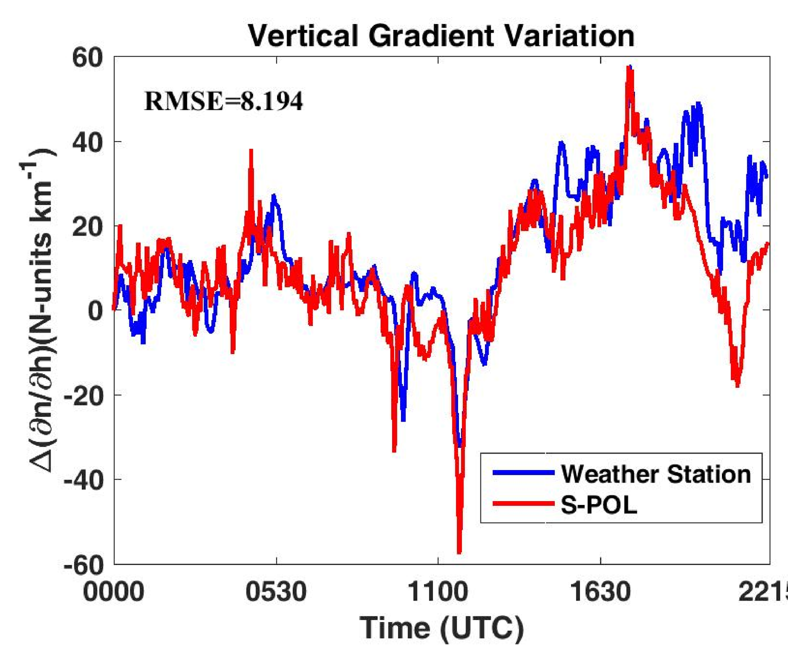
- Digital elevation model over hilly terrain.



- High-Resolution refractivity variations between targets (Δ**R(t)**) show a good agreement with refractivity from weather stations:



- Vertical gradient variations show a good performance with vertical gradient variations derived from two weather stations.



- A trade-off between spatial resolution and accuracy of the results should be achieved.
- R. Nocelo and V. Santalla. "High-Resolution refractivity retrieval from radar phase measurements over hilly terrain". Submitted to Remote Sensing Journal, June 2017.

References

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

[2] Y. Selen and J. Kronander. "Optimizing power limits for white spaces devices under a probability constraint on aggregated interference". In *IEEE Inter. Symp. on Dynamic Spectrum Access Networks, June 2012.*

[3] 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.*

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

[5] 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.*