ScuDo

Scuola di Dottorato ~ Doctoral School

WHAT YOU ARE,TAKES YOU FAR

34th Cycle

Theoretical, simulation and experimental results on scintillation detection and mitigation.

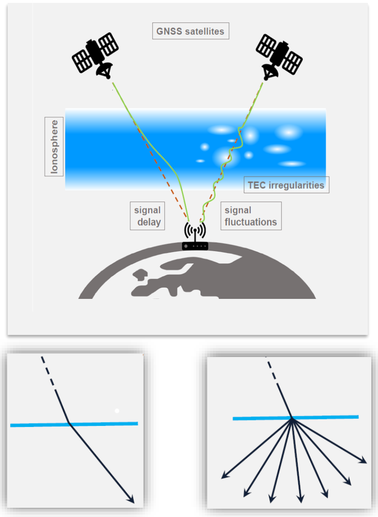
Rayan Imam

Supervisor: Prof. Fabio Dovis

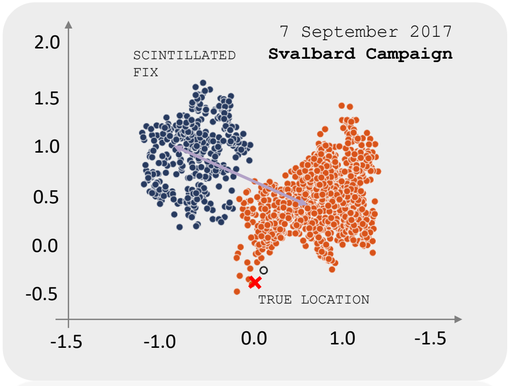
MOTIVATION

- Radio signal Scintillations are rapid fluctuations in the intensity and phase of radio waves, generated when a signal passes through irregularities in electron desnsity in the ionosphere.

- These irregularities cause refractions and difrations to the signal, resulting is unmodelled delays and constructive/destructive signal fluctuations



- Scintillation affects all transionospheric signals:
  - Communications
  - Global Navigation Satellite Systems (GNSS)

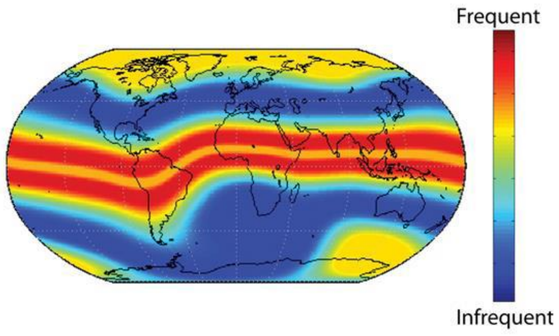


- Navigation Systems affected in different ways:

➢ Unmodelled Errors/delays
➢ Loss of Tracking loops lock
➢ Complete loss of the signal

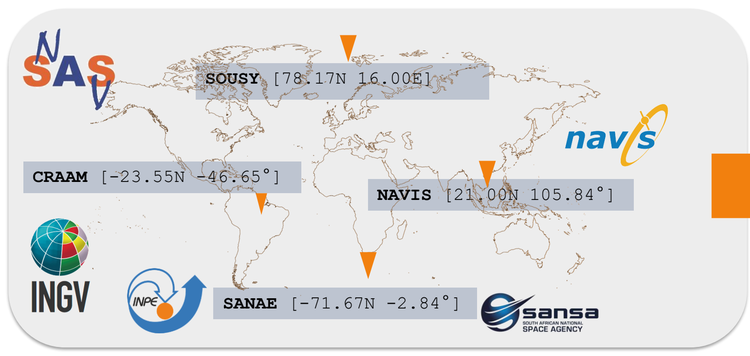
→ **ERROR in POSITION ESTIMATION**

- This is critical for some applications :
  - ✓ Aviation
  - ✓ Surveying
  - ✓ Precise Positioning



- On the other hand, scintillated navigation signals can be considered as **signals of opportunity to monitor the upper layers of the atmosphere**:
  - ➢ **High number** of transmitting **satellites** (more than 100 satellites at the moment)
  - ➢ Being the expected GNSS signal well known and modeled, the measurement of the distortions can be used to infer atmospheric parameters.

Data, Methodology and Results



+3TBs
RAW GNSS SIGNAL SAMPLES

+3YEARS
Continuous data Collection

I am using Machine Learning Techniques to detect scintillation:
- Supervised Learning
- Unsupervised Learning
- Deep learning

- Results of scintillation detection using different supervised ML techniques with different features extracted from GNSS signals:

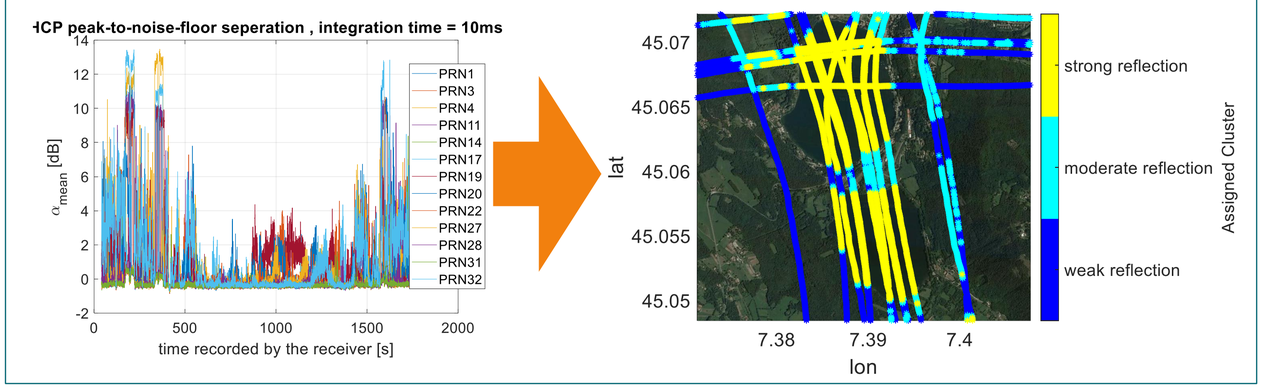
➢ Using raw raw samples

Feature set	Features included							Training Accuaracy %		
	S4	C/N0	EL	<I>	<Q>	<SI>	<SI²>	Trees	SVM	KNN
L1	■	■	■					96.4	95.5	97.0
L2_2				■	■	■	■	89.8	94.9	95.0
L4		■	■			■	■	90.8	60.5	97.0
L5						■	■	90.1	95.4	97.2
L6			■			■	■	90.5	95.9	99.4%
L7		■				■	■	89.2	95.2	95.2

➢ Using Averages over time windows

Set	1 minute		3 minutes		Accuaracy
	covIQ	varSI	covIQ	varSI	KNN
R1	■	■			99.5%
R2		■			99.6%
R3	■				98.0%
R4			■	■	99.7%
R5				■	99.5%
R6			■		98.5%

I also tested machine learning on other types of GNSS data.
- K-means applied to GNSS-R data for detecting water:



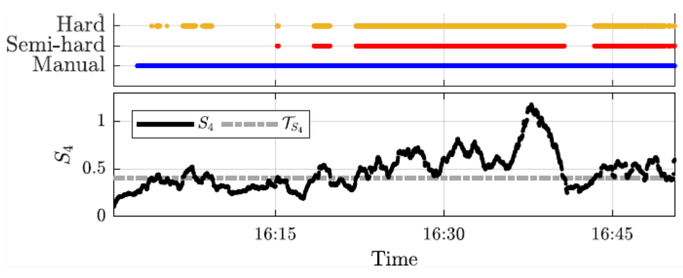
OBJECTIVE

- GNSS based scintillation detection and modelling requires proper estimation techniques able to distinguish the effect from other error sources such as noise and multipath.

- Multipath due to static environment can be identified analysing time series of collected data at same location due to regularity of the constellations.

- The metrics currently in use for detecting scintillation $(S_4 and\ \sigma_\phi)$ have high false alarms as well as high miss rate.
- They do not allow to model fast changes and they model the phenomenon over windows of one minute.

Manual \	Hard Rule: No	Hard Rule: Scint.	Semi-hard: No	Semi-hard: Scint.
No	32.9	15.2	52.1	0
Scint.	18.9	29.0	22.0	25.9



❖ In this research I am investigating machine learning (ML) techniques for scintillation detection, using data only from GNSS signals.
❖ Also, I am investigating ML technigues to model other features of GNSS signals like multipath and GNSS-Reflectometry.

Future work:

❑ Unsupervised ML for scintillation detection.
❑ Distinguishing scintillation from multipath and other receiver errors.
❑ Implementing the detection model on a software radio receiver.

Submitted and published works

- **Imam**, R. , Pini, M. , Marucco, G. , Dominici, F. , Dovis, F. , *"Data from GNSS-Based Passive Radar to Support Flood Monitoring Operations"*, **proceedings** of the 2019 International Conference on Localization and GNSS (ICL-GNSS) , 2019, pp. 1-7
- Cilliers, P., Alfonsi, L., Correia, E., Bergeot, N., Dovis, F., Linty, N., **Imam**, R., Ward, J., "Multi-constellation GNSS observation of ionospheric scintillation at SANAE-IV in Antarctica", Beacon **Symposium** August 2019, Poland.
- Favenza, A., **Imam**, R., Dovis, F., Pini, M., "*Detecting water using UAV-based GNSS-Reflectometry data and Artificial Intelligence*", 2019 IEEE international **workshop** on Metrology for Agriculture and Forestry, October, 2019
- **Imam**, R., Pini, M., Marucco, G., Dominici, F., Dovis, F., "Use of GNSS-based Passive Radar Data to Support Flood Monitoring Operations", Selected Papers from 9th International Conference on Localization and GNSS 2019 (ICL-GNSS 2019) . **Under Review.**

Activities

- The 7th African Space Leadership Congress, November 5-7, 2018, Nigeria
- ESA/JRC International Summerschool on GNSS. July 15 - 26, 2019, Portugal
- ESA Space Weather for the Mediterranean Region workshop. Sept 26, 2019, Turin.

List of attended classes

Code	Title of the course	(Date, credits)
01QRQRV	Compressed sensing: theory and applications	(28/08/2019, **4**)
01QTEIU	Data mining concepts and algorithms	(14/12/2018, **4**)
01RONKG	Python in the Lab	(06/05/2019, **4**)
01TEHRV	Data Science for Networks (didattica di eccellenza)	(15/02/2019, **6**)
01TEVRV	Deep learning (didattica di eccellenza)	(04/06/2019, **6**)
03SGVRV	Entrepreneurship and start-up creation from Uni Research	(09/05/2019, **8**)
01NDLRV	Lingua italiana I livello	(18/06/2019, **3**)

POLITECNICO DI TORINO

PhD program in
Electrical, Electronics and Communications Engineering