



UNIVERSITÀ DEGLI STUDI DI NAPOLI  
**FEDERICO II**

**itee** PhD  
information technology  
electrical engineering



**Marianna Franzese**

**Development of Algorithms to Process L-Band SAR Data:  
Focusing on the Detection and Mitigation  
of Ionospheric Effects in  
DinSAR Analysis**

Tutor: Prof. Antonio De Maio  
co-Tutor: Dr. Eng. Claudio De Luca

**itee** PhD  
information technology  
electrical engineering

Cycle: XXXIX

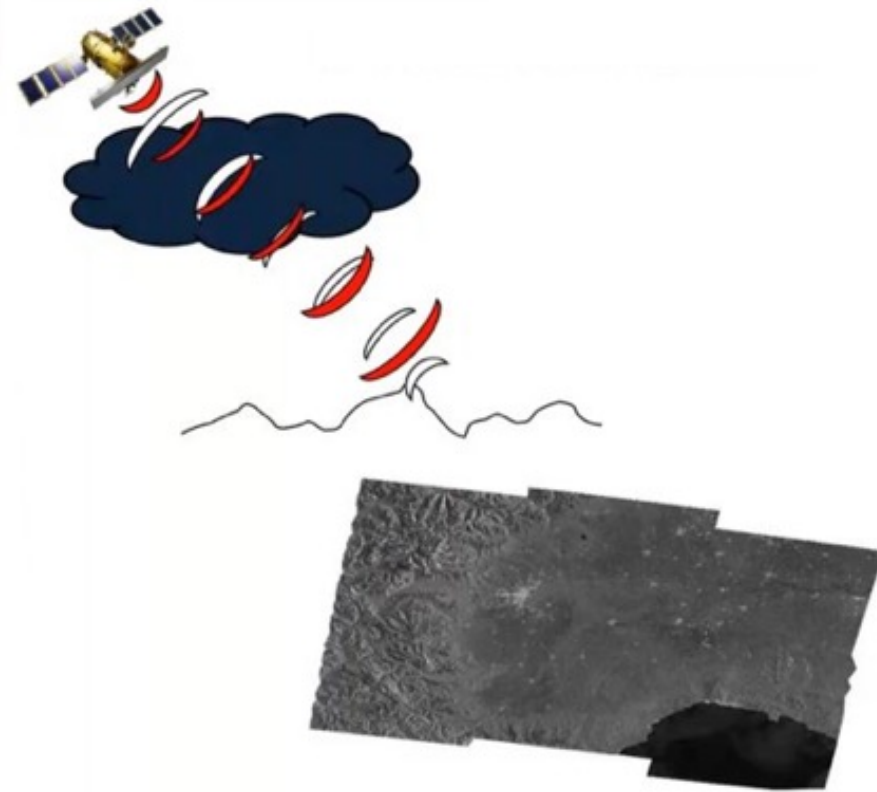
Year: Second

# My Background

- **MSc degree:** Telecommunication Engineering at University of Naples “Federico II”
- **DIETI Research group:** Radar Signal Processing and Electronic Defense Research Group (*RSPRG*)
- **PhD start date:** 01/11/2023
- **Scholarship type:** Istituto per il Rilevamento Elettromagnetico dell’ Ambiente (IREA-CNR)

# Research Field of Interest

## Synthetic-Aperture Radar (SAR)



**Microwave sensor:** ability to “observe” even in the presence of clouds.

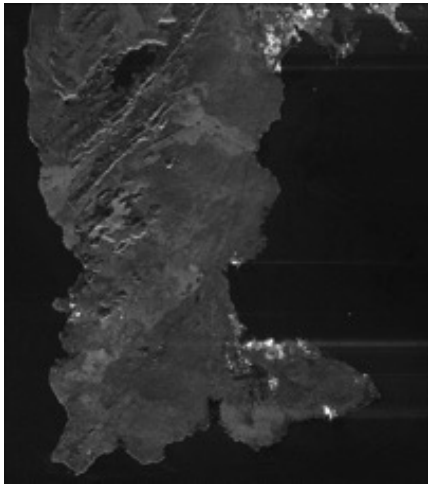
**Active sensor:** ability to “observe” both day and night.

**Coherent sensor:** ability to preserve both amplitude and phase information (**techniques of SAR interferometric**).

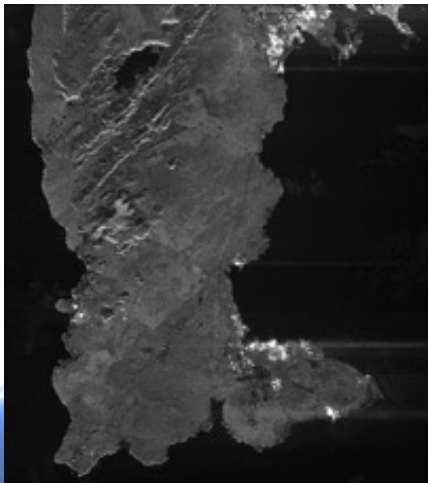
# Research Field of Interest

## Differential Interferometric SAR (DInSAR)

Primary Image

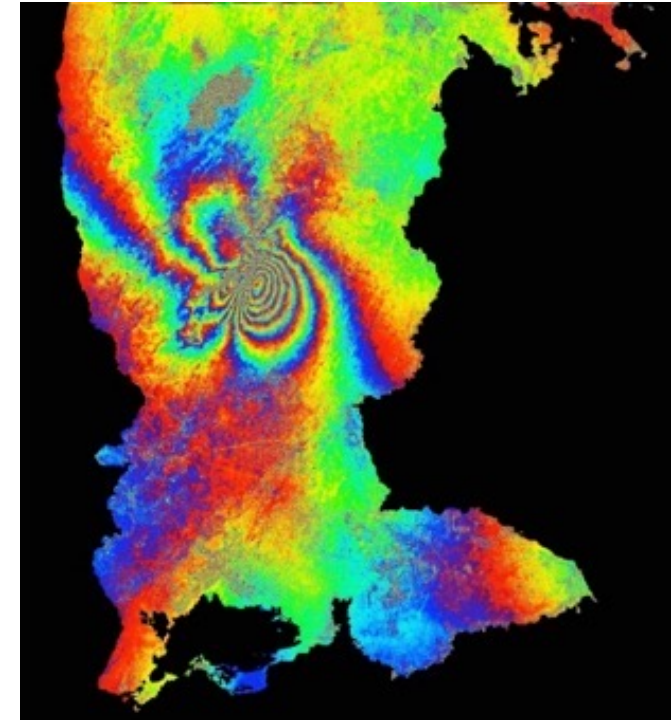


Secondary Image



$$\Delta\phi = \phi_1 - \phi_2$$
$$\Delta\phi \simeq 4\pi \frac{\textit{deformation}}{\lambda}$$

Differential Interferogram



It is possible to detect centimetre-scale deformations!

# Summary of Study Activities

## **Study activities**

- Synthetic Aperture Radar Processing
- Ground Displacement Analysis Methods
- L-band SAR Data
- Ionosphere
- Unmanned Aerial Vehicles (UAVs)
- Radar Cross-Section Estimation

## **Ad hoc PhD courses/schools**

- Cubes & Clouds
- How to boost your PhD
- Matrix Electronic Scan Antennas for Radar Signal Processing Applications
- Cooperative and Non-Cooperative Localization Systems

## **Conferences/events attended**

- IEEE International Workshop on Technologies for Defense and Security 2024, Napoli, Nov. 2024.
- Living Planet Symposium 2025, Vienna, Austria, 23-27 Jun 2025.

# Research Activity: Overview

## 1. TOPIC:

- Development of algorithms to process **L-Band SAR data** for interferometric applications.

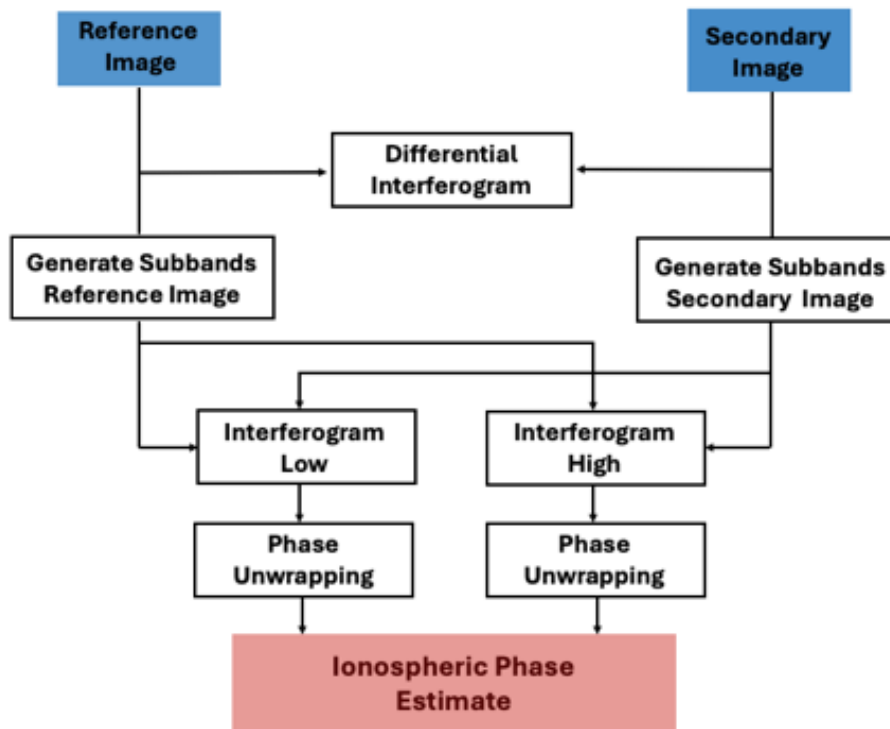
## 2. MOTIVATION:

- Growing number of **L-band missions** (SAOCOM-1, NISAR, PALSAR-3, ROSE-L).
- A major issue at L-band is the **ionospheric disturbance**, which degrades the quality of interferometric products and, consequently, displacement measurements.

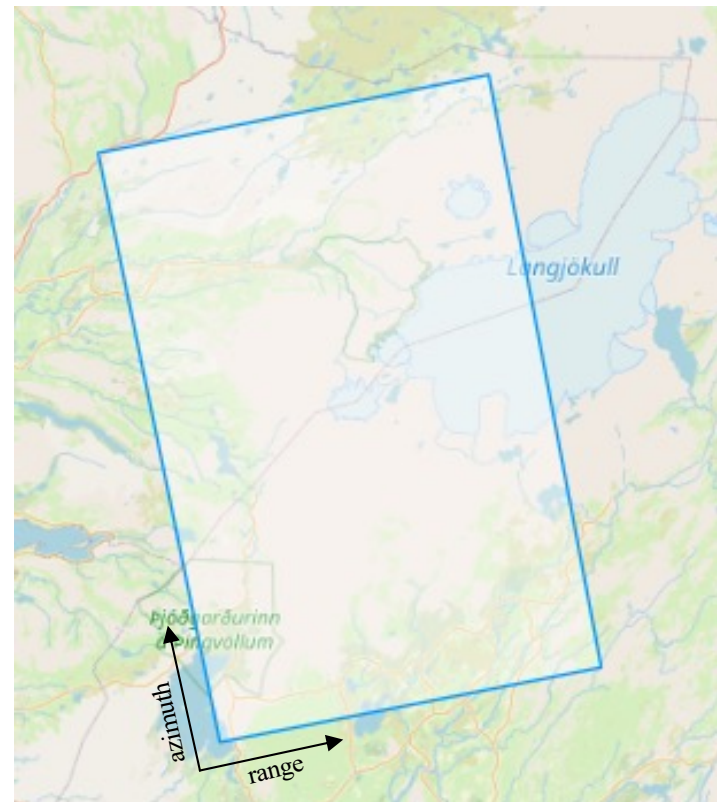
## 3. METHODOLOGY:

- The **Range Split-Spectrum (RSS) method** is one of the most widely used techniques for ionospheric phase estimation.
- However, the **standard RSS method** suffers from intrinsic limitations, mainly due to **noise amplification** and the **need for phase unwrapping**.
- During this year of the PhD activity, an **enhanced iterative implementation of the RSS method** has been developed to overcome the main limitations of the standard approach.

# Standard RSS Method

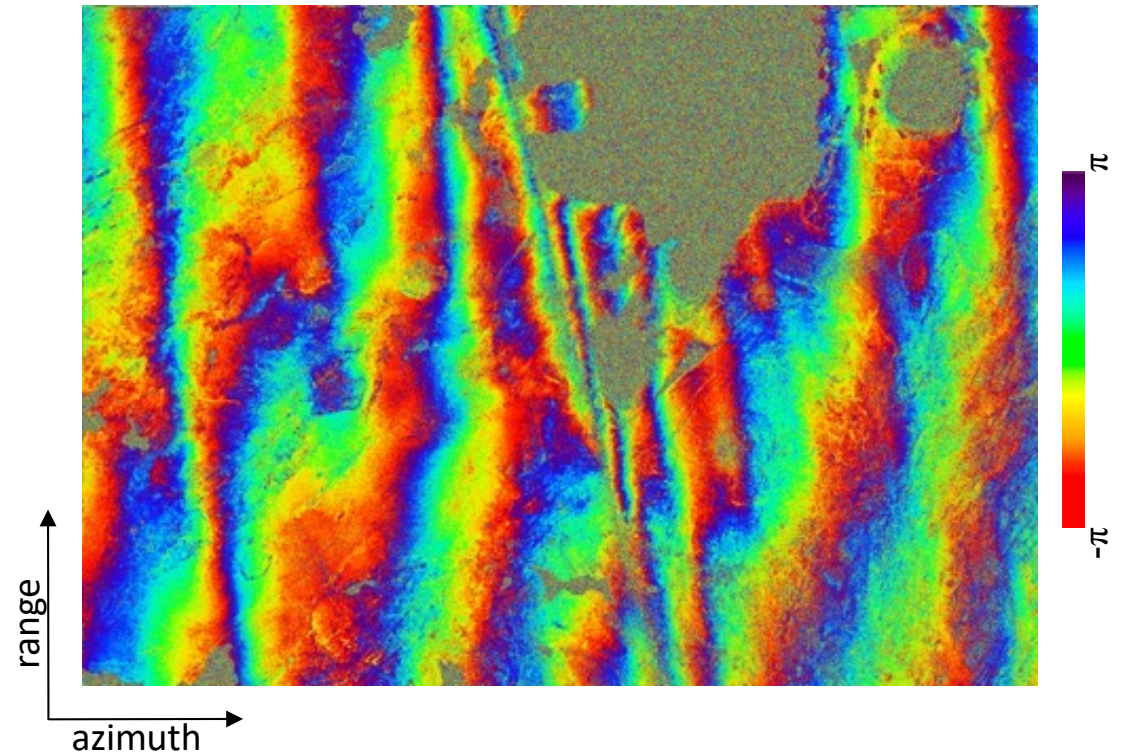
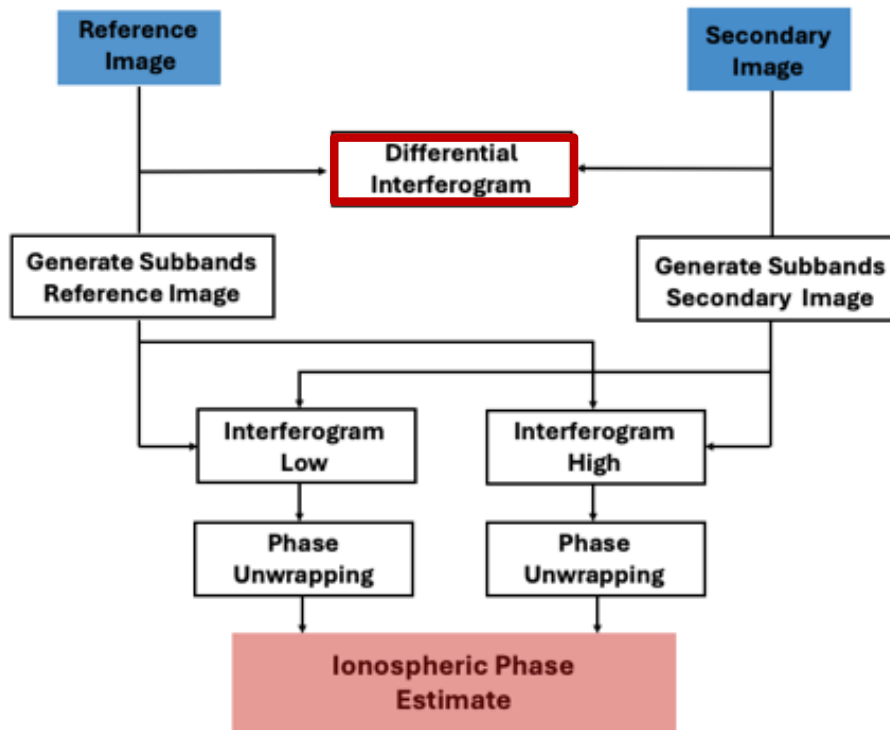


SAOCOM-L1A-ASC-S5



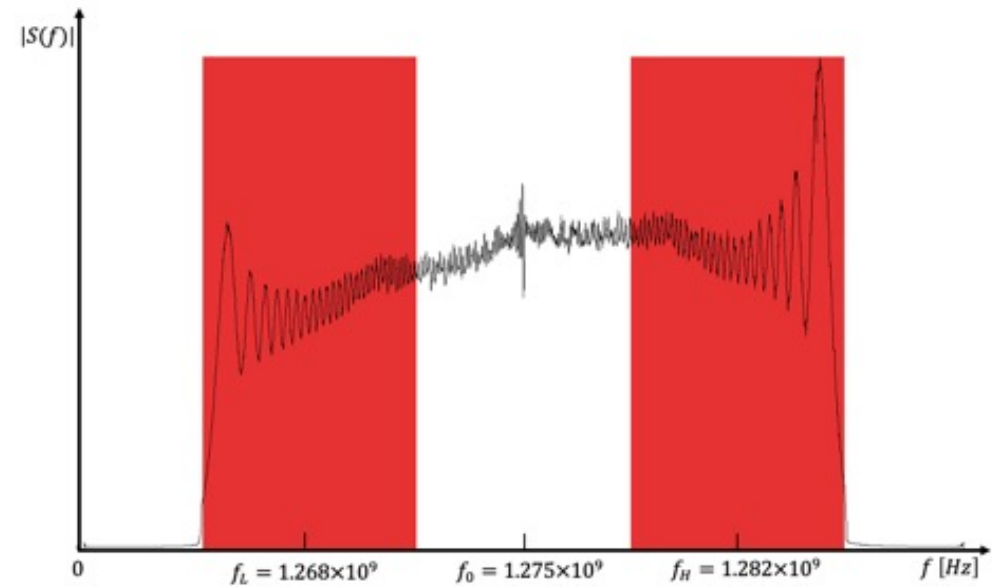
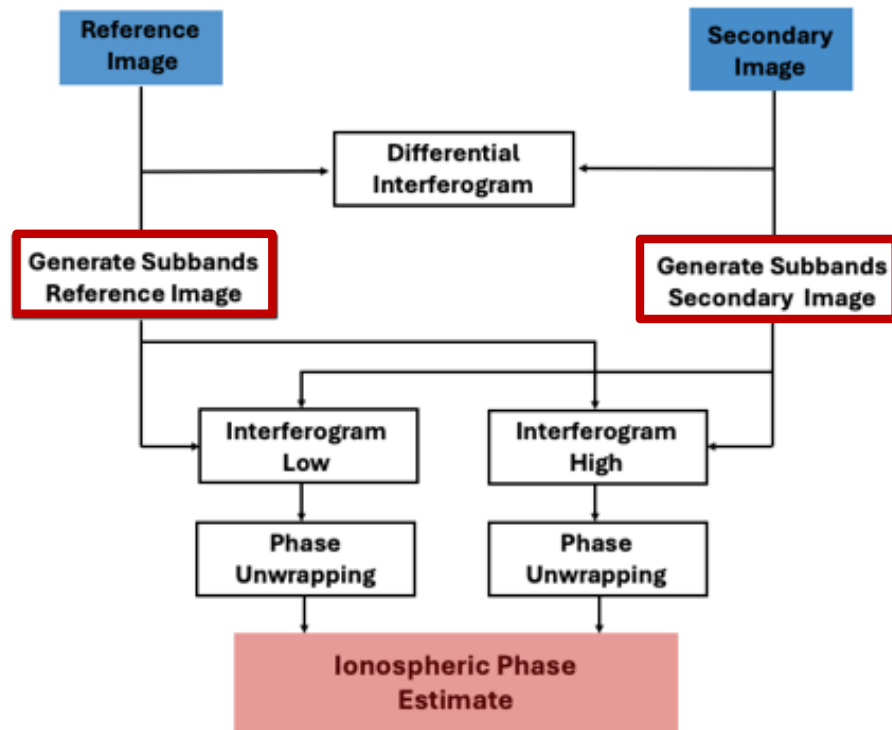
# Standard RSS Method

## Differential Interferogram

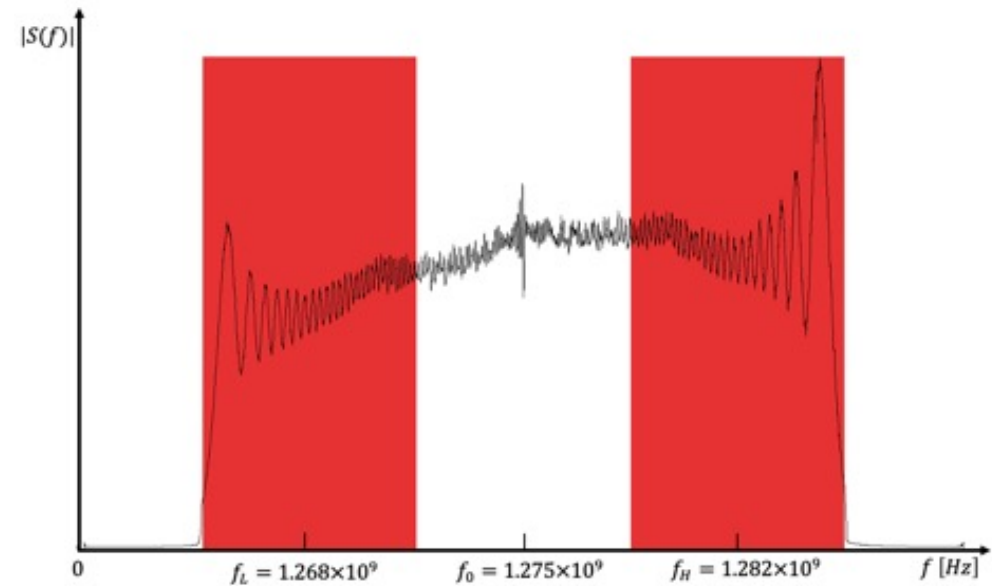
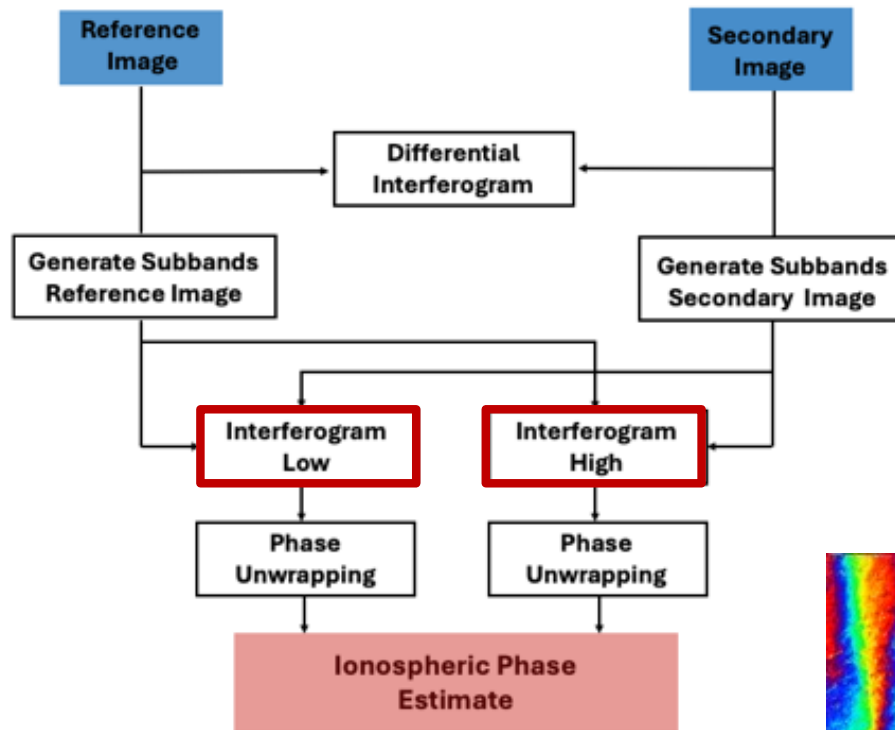


$$\Delta\phi = \Delta\phi_{non-disp} + \Delta\phi_{iono}$$

# Standard RSS Method

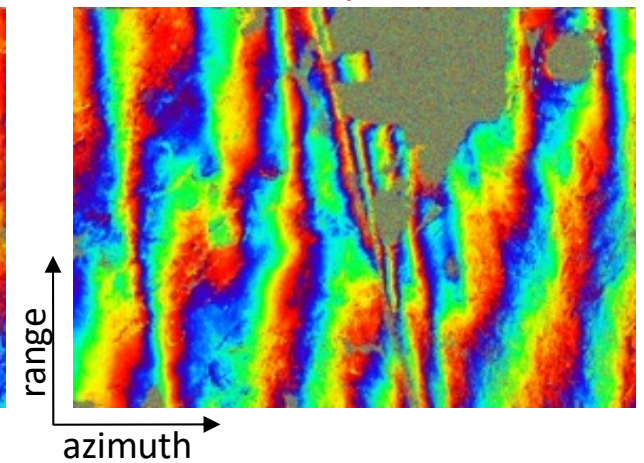
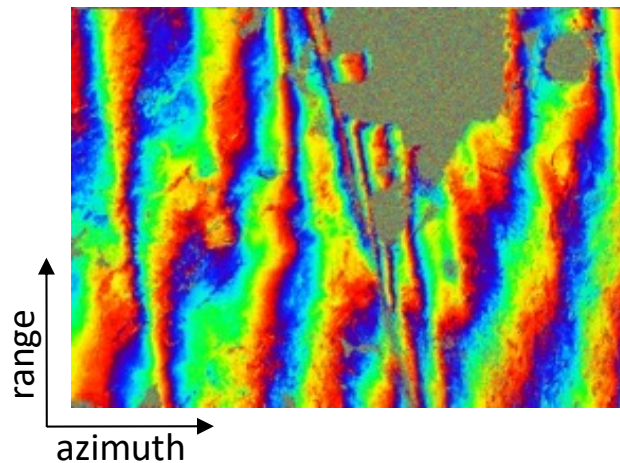


# Standard RSS Method



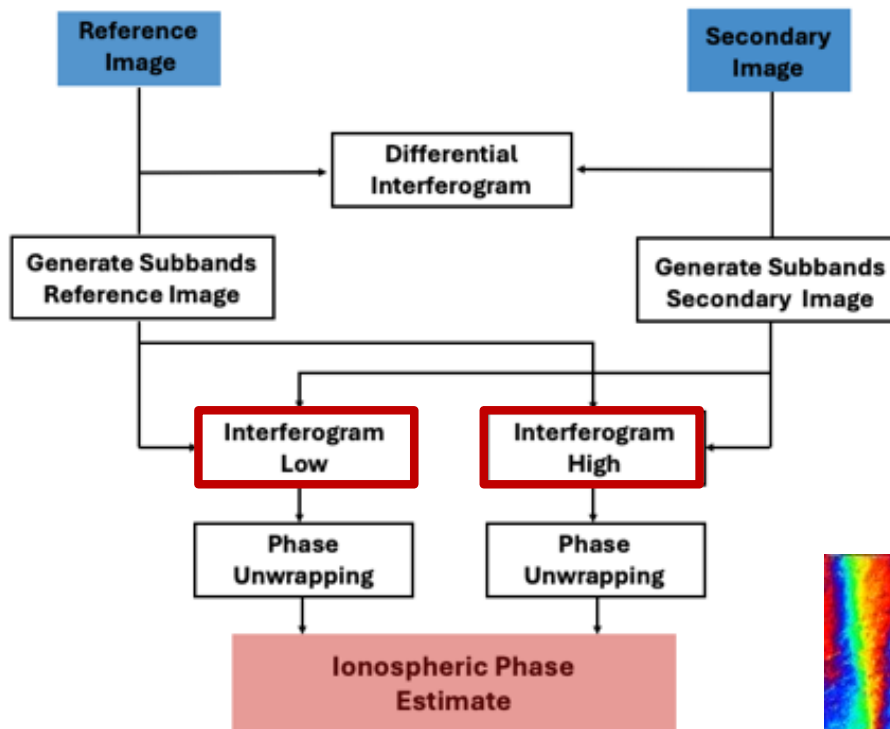
$\Delta\phi_L$

$\Delta\phi_H$



# Standard RSS Method

## System of Equations:

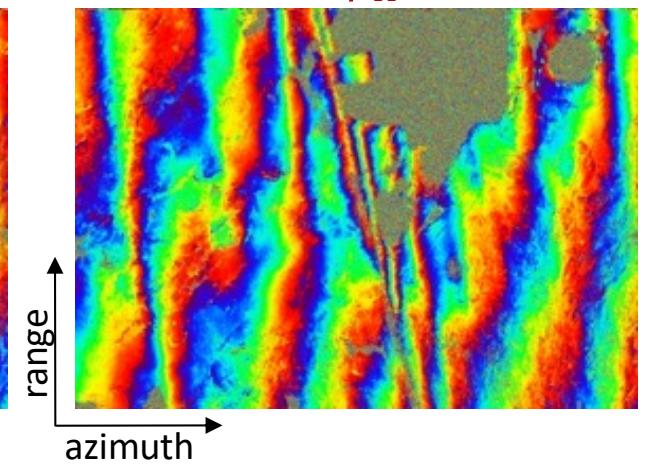
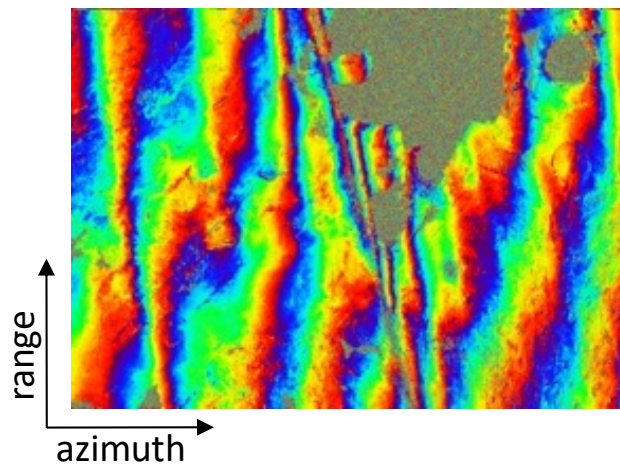


$$\Delta\phi_L = \Delta\phi_{non-disp} \frac{\lambda_0}{\lambda_L} + \Delta\phi_{iono} \frac{\lambda_L}{\lambda_0}$$

$$\Delta\phi_H = \Delta\phi_{non-disp} \frac{\lambda_0}{\lambda_H} + \Delta\phi_{iono} \frac{\lambda_H}{\lambda_0}$$

$\Delta\phi_L$

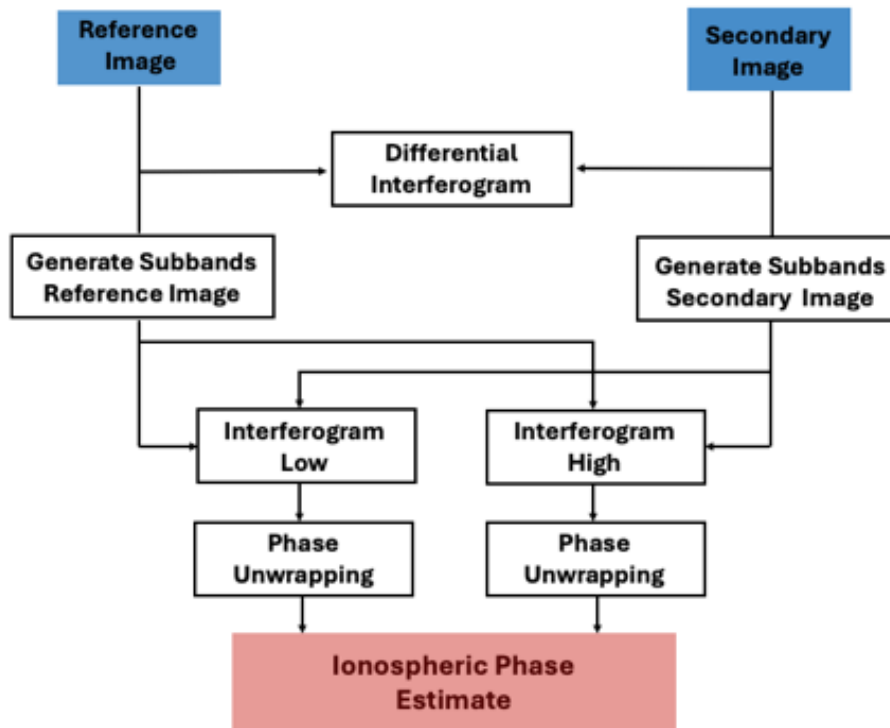
$\Delta\phi_H$



# Standard RSS Method

## Ionospheric Phase Estimate:

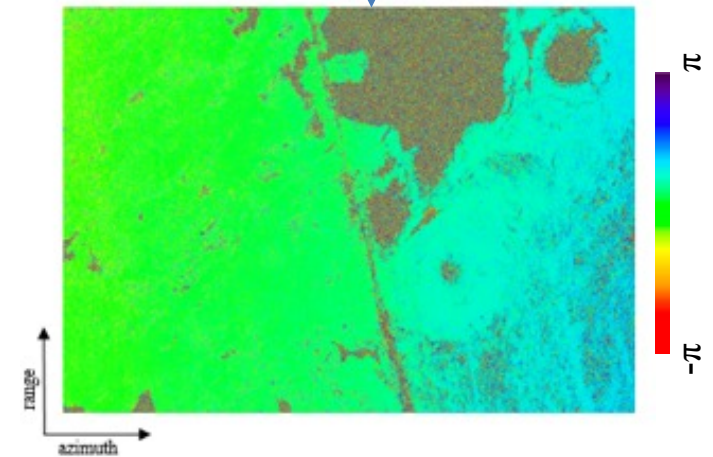
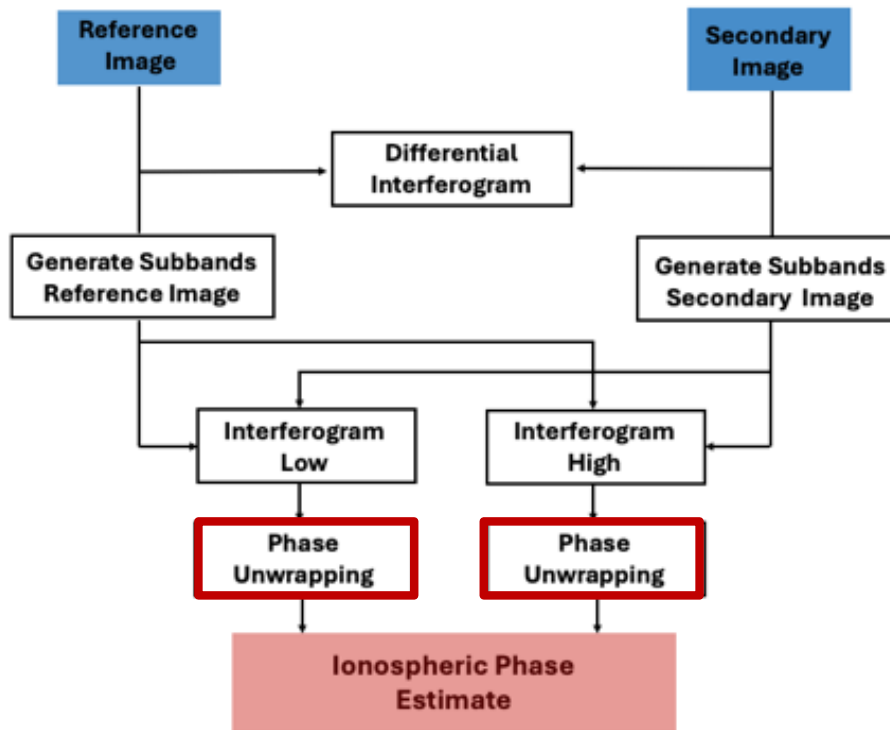
$$\Delta\hat{\phi}_{iono} = \frac{\lambda_0\lambda_H}{\lambda_H^2 - \lambda_L^2} \left( \Delta\phi_H - \frac{\lambda_L}{\lambda_H} \Delta\phi_L \right)$$



# Standard RSS Method

## Ionospheric Phase Estimate:

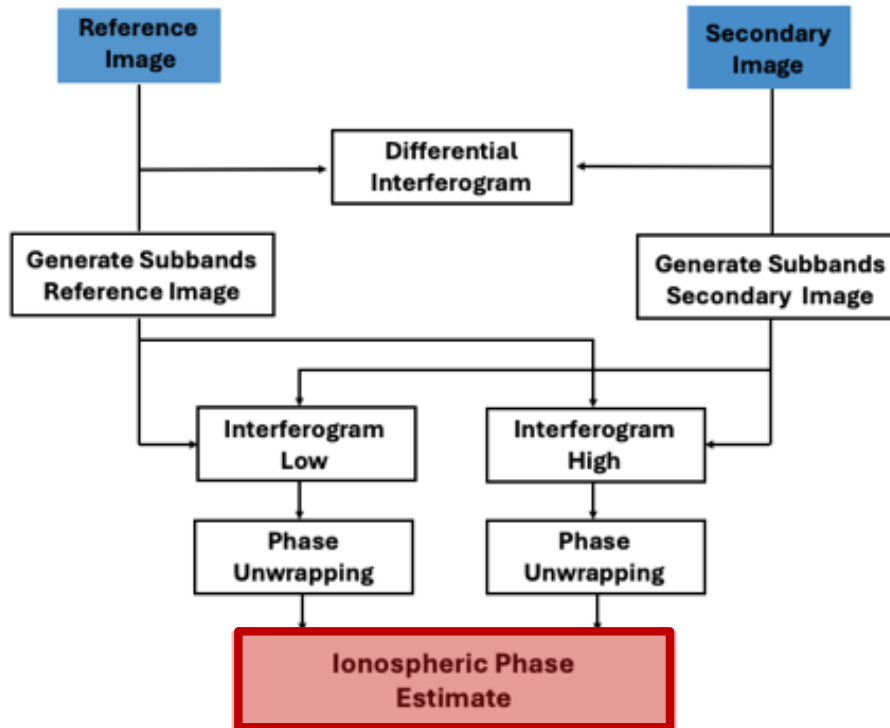
$$\Delta\hat{\phi}_{iono} = \frac{\lambda_0\lambda_H}{\lambda_H^2 - \lambda_L^2} \left( \Delta\phi_H - \frac{\lambda_L}{\lambda_H} \Delta\phi_L \right)$$



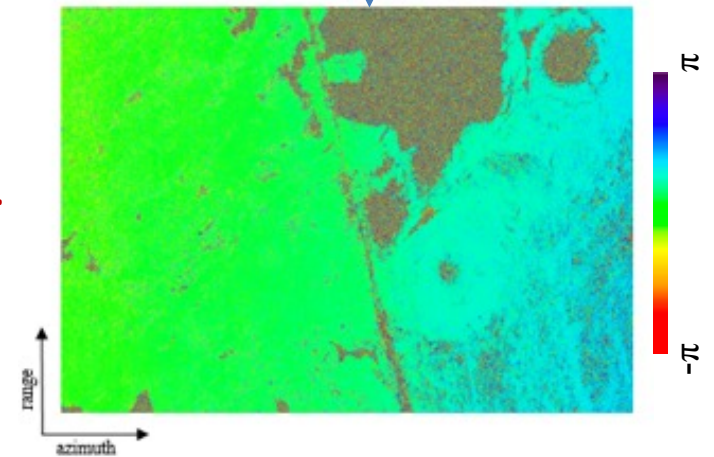
# Standard RSS Method

## Ionospheric Phase Estimate:

$$\Delta\hat{\phi}_{iono} = \frac{\lambda_0\lambda_H}{\lambda_H^2 - \lambda_L^2} \left( \Delta\phi_H - \frac{\lambda_L}{\lambda_H} \Delta\phi_L \right)$$



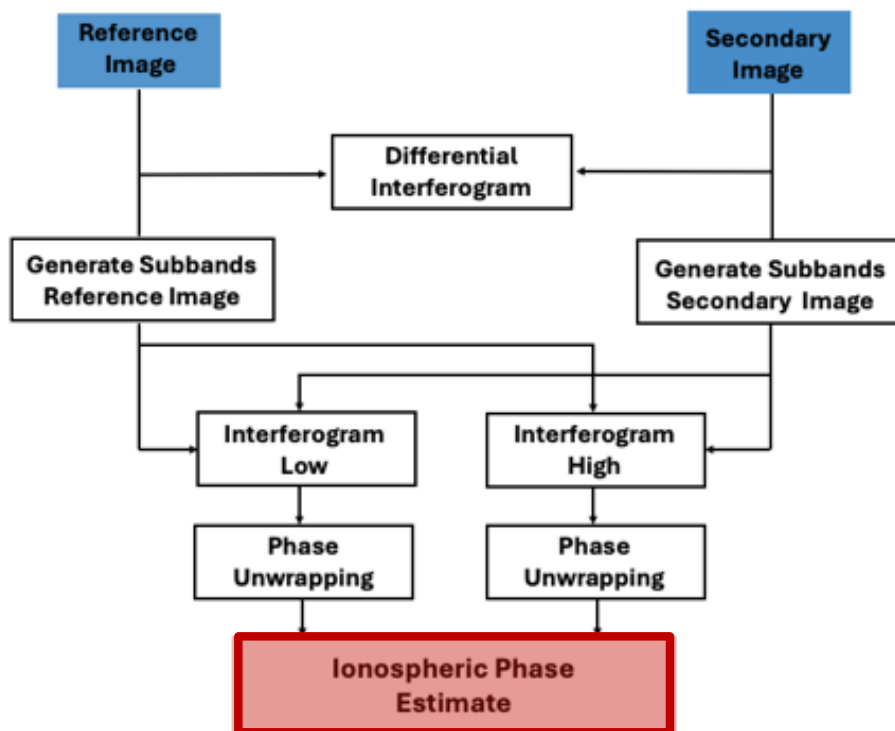
$$\frac{\lambda_0\lambda_H}{\lambda_H^2 - \lambda_L^2}$$



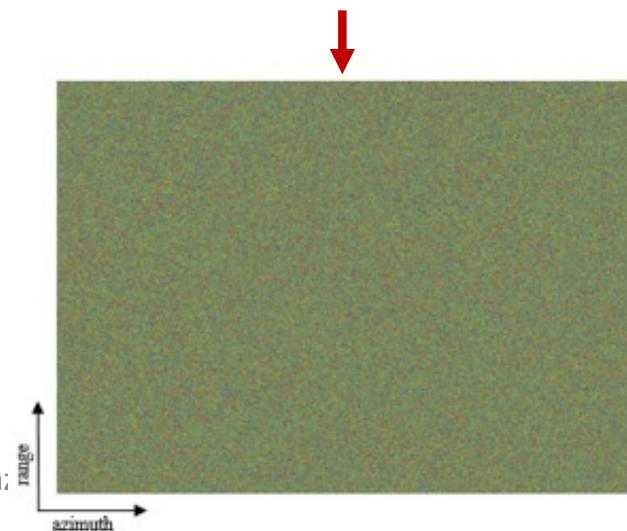
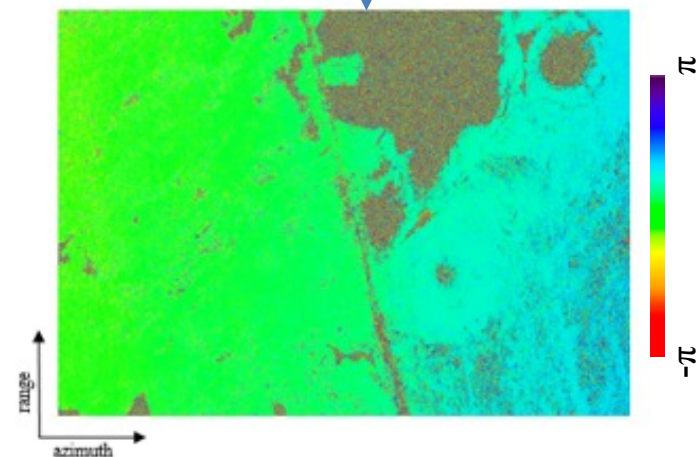
# Standard RSS Method

## Ionospheric Phase Estimate:

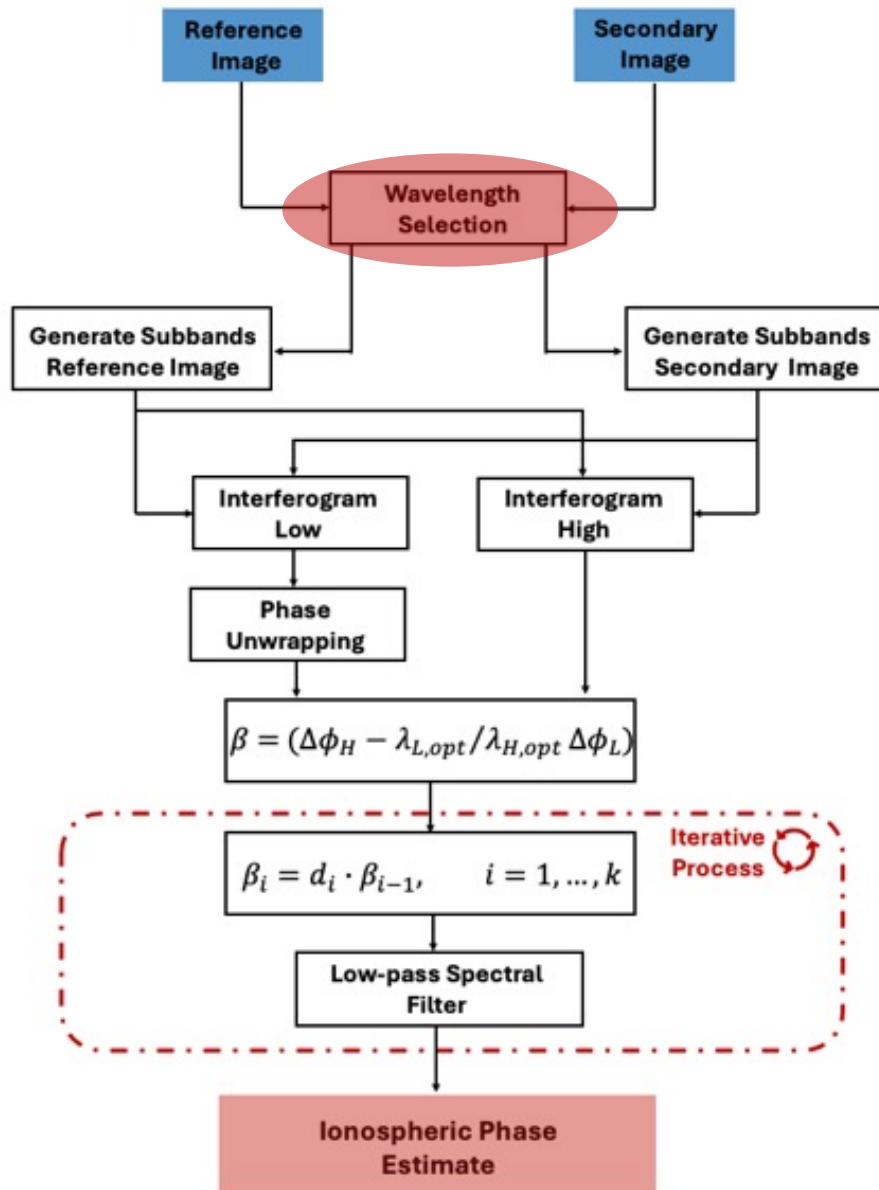
$$\Delta\hat{\phi}_{iono} = \frac{\lambda_0\lambda_H}{\lambda_H^2 - \lambda_L^2} \left( \Delta\phi_H - \frac{\lambda_L}{\lambda_H} \Delta\phi_L \right)$$



$$\frac{\lambda_0\lambda_H}{\lambda_H^2 - \lambda_L^2}$$



# Enhanced RSS Method



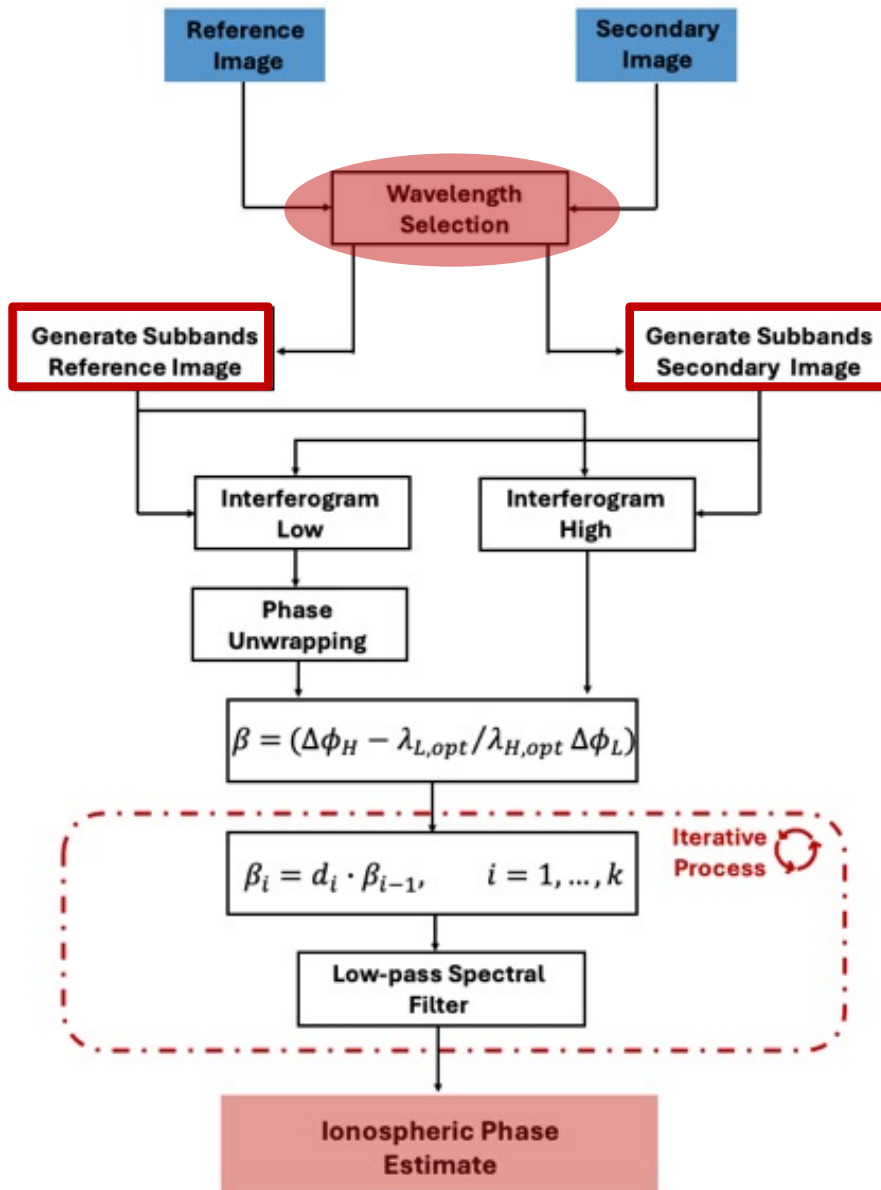
## Ionospheric Phase Estimate:

$$\Delta\hat{\phi}_{iono} = \frac{\lambda_0 \lambda_H}{\lambda_H^2 - \lambda_L^2} \left( \Delta\phi_H - \frac{\lambda_L}{\lambda_H} \Delta\phi_L \right)$$



- Integer value
- Factorizable into multiple divisors

# Enhanced RSS Method

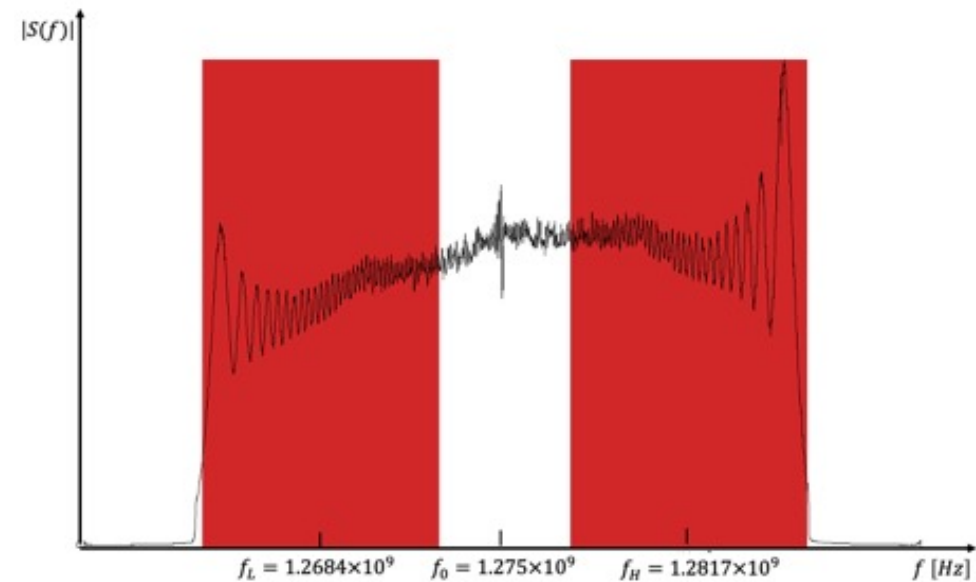


## Ionospheric Phase Estimate:

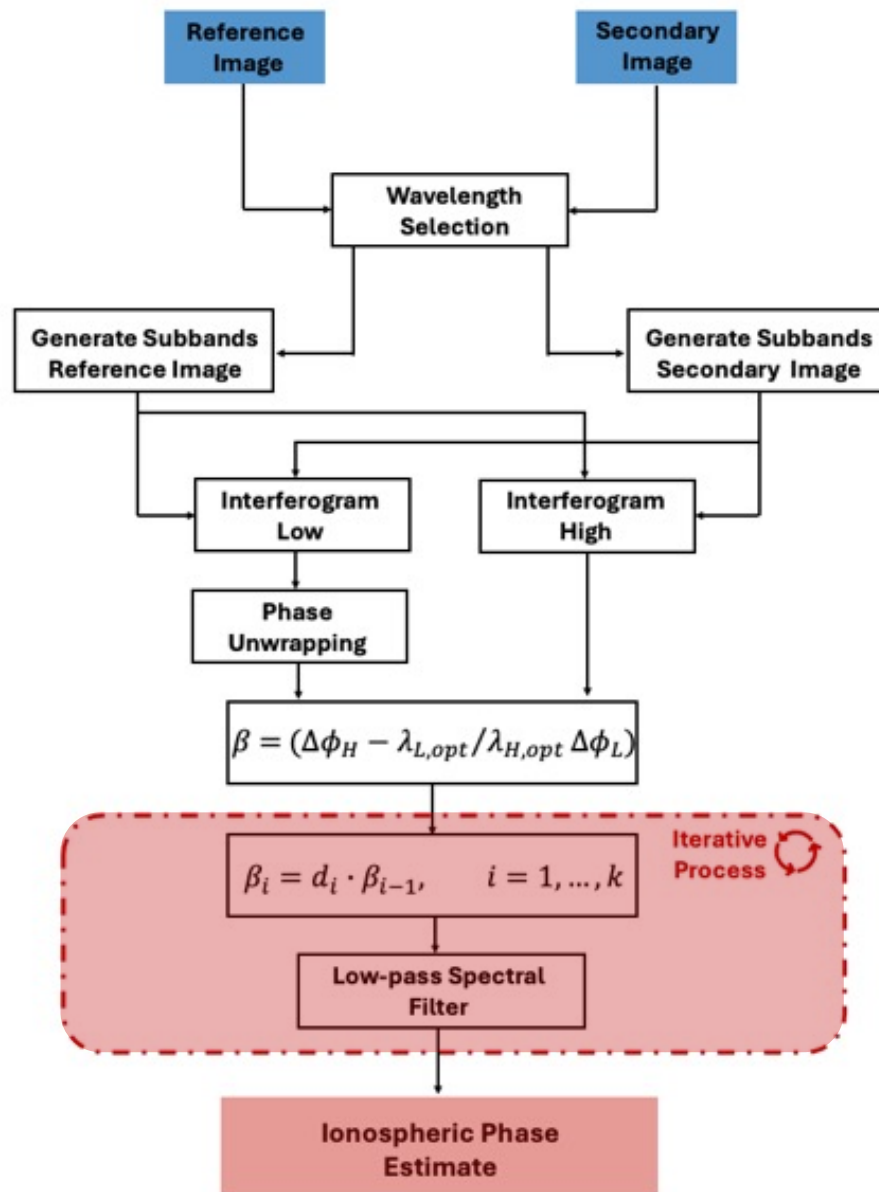
$$\Delta\hat{\phi}_{iono} = \frac{\lambda_0 \lambda_H}{\lambda_H^2 - \lambda_L^2} \left( \Delta\phi_H - \frac{\lambda_L}{\lambda_H} \Delta\phi_L \right)$$



- Integer value
- Factorizable into multiple divisors



# Enhanced RSS Method



## Ionospheric Phase Estimate:

$$\Delta\hat{\phi}_{iono} = \frac{\lambda_0 \lambda_H}{\lambda_H^2 - \lambda_L^2} \left( \Delta\phi_H - \frac{\lambda_L}{\lambda_H} \Delta\phi_L \right)$$



- Integer value
- Factorizable into multiple divisors

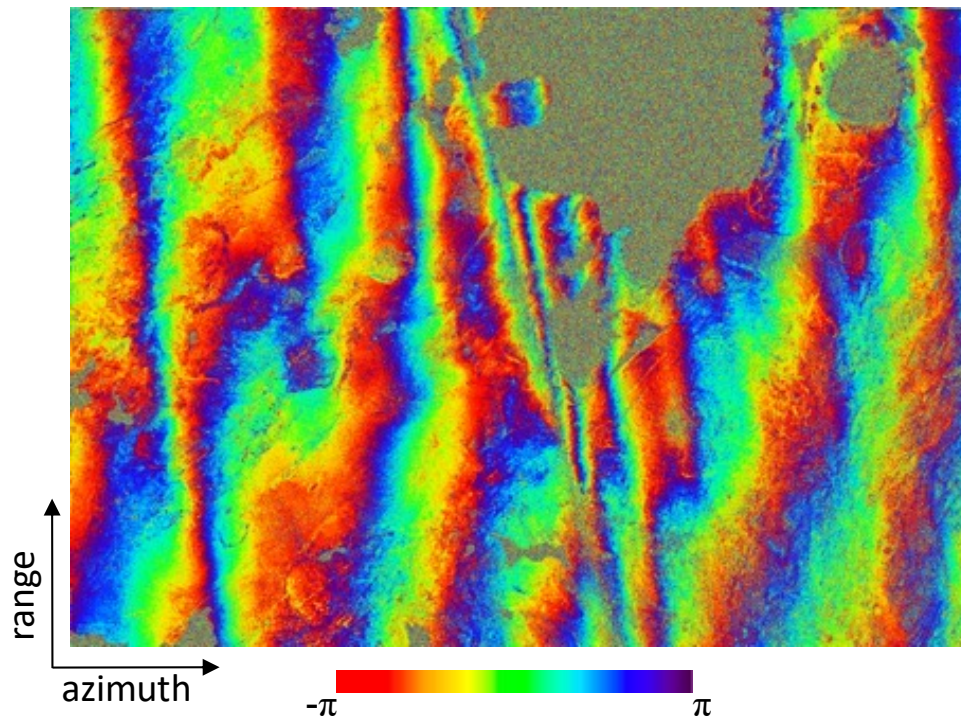
$$N = 48 = 2^3 \times 3 \rightarrow \overset{4}{\text{ITERATION}}$$

## Iterative Process:

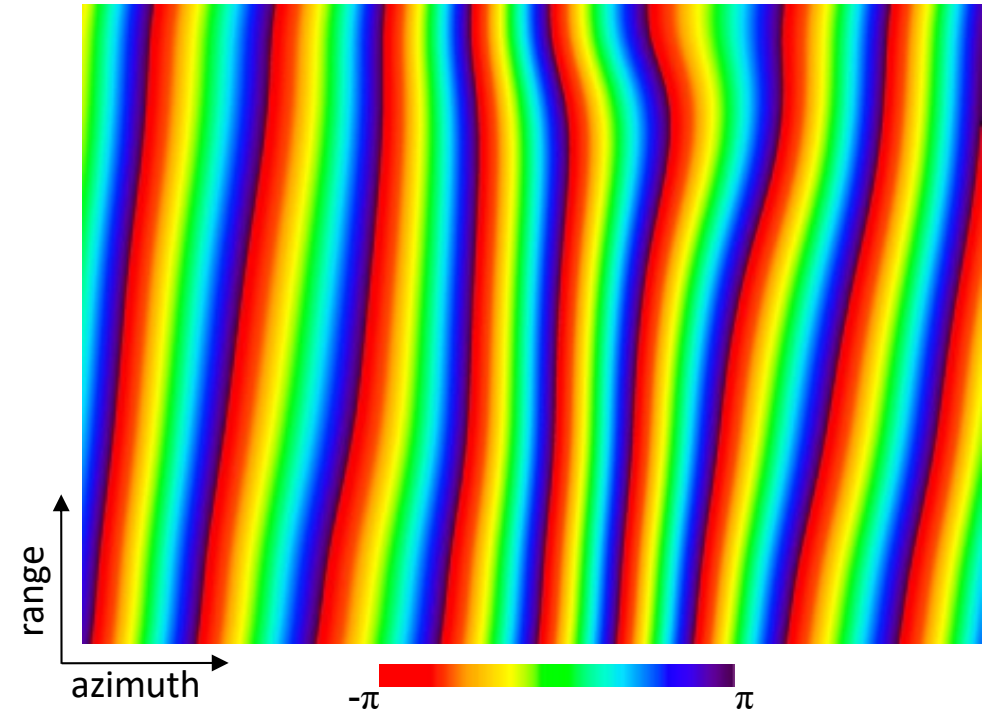
- At each step, one of the **prime numbers** composing the factorization of the integer extraction factor is applied as **multiplicative term**.
- At each step, **spectral low-pass filtering** step is applied to suppress **high-frequency noise**, while preserving **low-frequency ionospheric variations**.

# Research Results

## Differential Interferogram

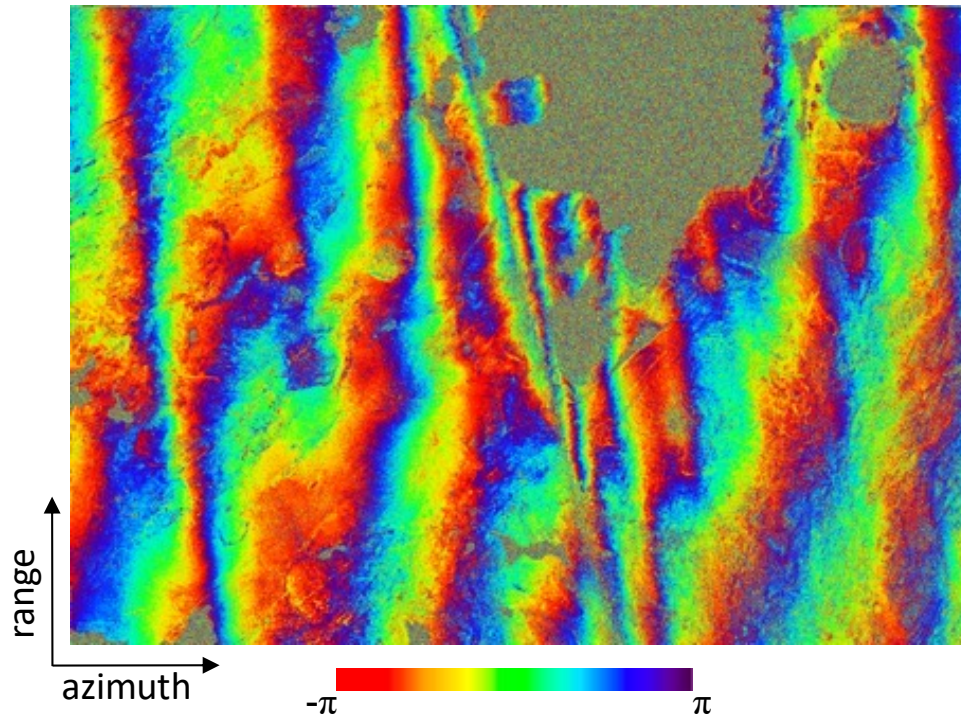


## Ionospheric Component

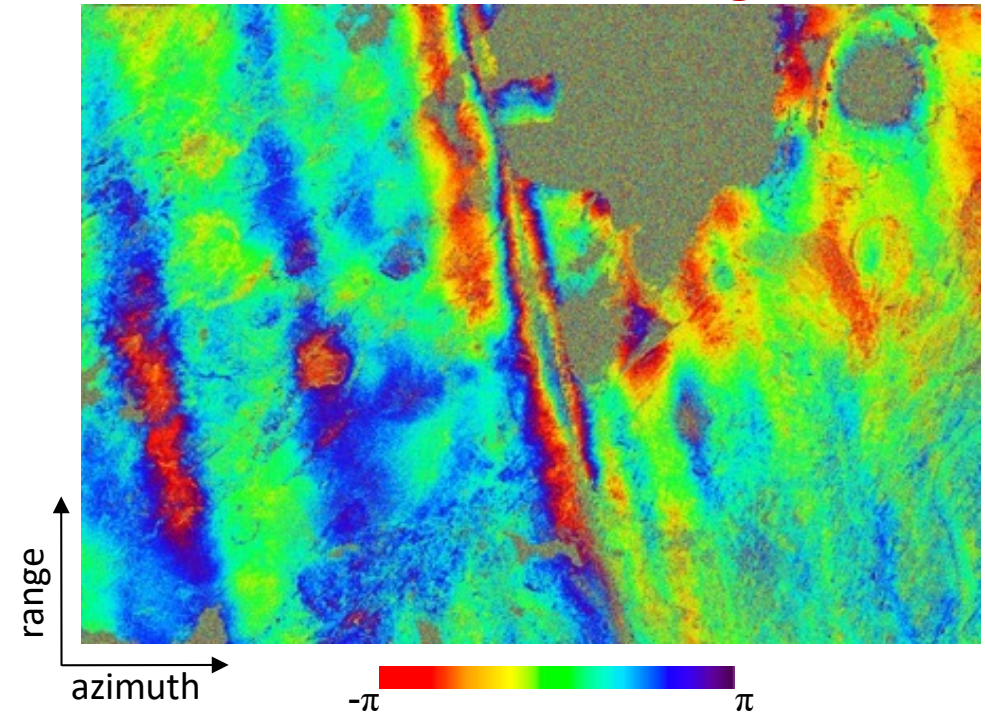


# Research Results

## Differential Interferogram

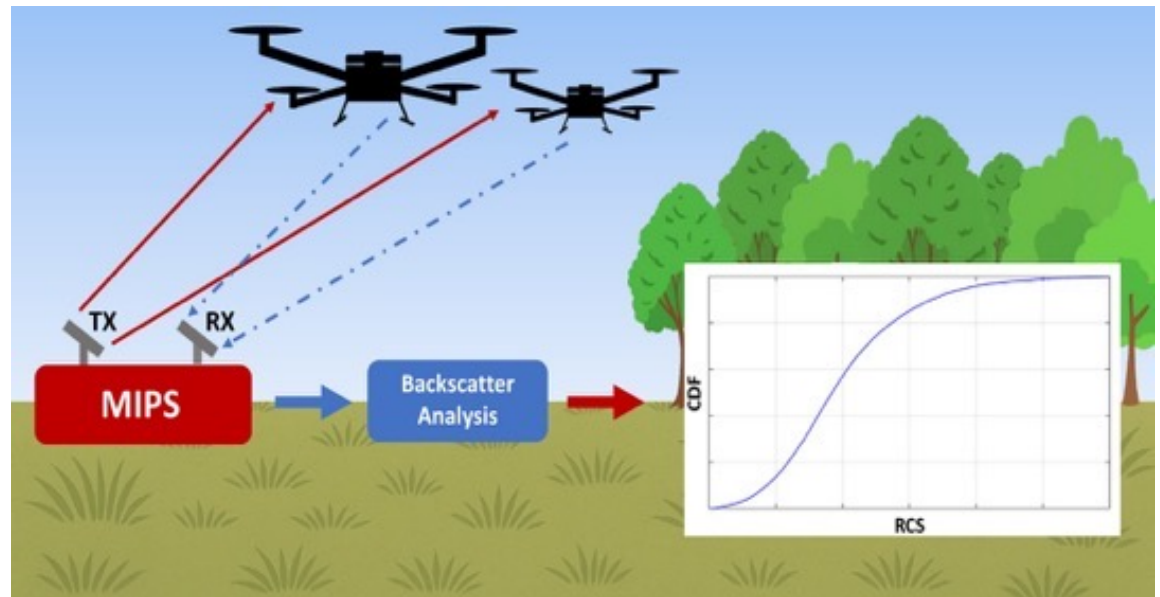


## Ionospheric filtered Differential Interferogram



# Radar Cross-Section Estimation

- The use of **Unmanned Aerial Vehicles (UAVs)** is growing rapidly in both **civil** and **military sectors**, with applications including infrastructure monitoring, precision agriculture, search and rescue.
- The objective is to assess how the statistical behavior of the **Radar Cross-Section (RCS)** depends on **radar frequency**, **polarization configuration**, and **drone type**.
- The study is based on measurements collected with a **Frequency-Modulated Continuous-Wave (FMCW)** radar in a rural area during the simultaneous flight of a commercial and a professional grade drone.



M. Franzese, V. Carotenuto, F. Mattei, C. Conte, G. Rufino, D. Accardo, P. Berardino, A. Di Vincenzo, C. Esposito, A. Natale, G. Palmese, S. Perna, R. Lanari and A. De Maio "In-Flight UAVs Polarimetric Radar Cross-Section Measurement and Statistical Analysis at X- and L- Bands", *IEEE Sensors Journal*.

# Research Products

[C1]	<b>M. Franzese</b> , A. De Maio, R. Lanari, A. Aubry, P. Noli, G. Onorato, Y. Roa, P. Striano, and C. De Luca “ <i>Addressing ionospheric impairments in the azimuth ground displacements retrieved by using SAOCOM-1 L-band SAR data</i> ”, IEEE TechDefense 2024.
[C2]	<b>M. Franzese</b> , V. Carotenuto, F. Mattei, C. Conte, G. Rufino, D. Accardo, C. De Luca, P. Berardino, A. Di Vincenzo, C. Esposito, A. Natale, G. Palmese, S. Perna, R. Lanari and A. De Maio “ <i>Radar Cross-Section Analysis of In-Flight UAVs in X- and L-Band</i> ”, IEEE International Workshop on Metrology for Aereospace 2025.
[C3]	<b>M. Franzese</b> , C. De Luca, Y. Roa, M. Bonano, F. Casu, P. Euillades, L. Euillades, M. Manunta, M. Yasir, G. Onorato, P. Striano L. Dini, D. Tapete and R. Lanari “ <i>Enhancing the P-SBAS Processing Chain for L-Band DInSAR Time Series Retrieval: Insights from the SAOCOM-1 Constellation</i> ”, Living Planet Symposium 2025.
[C4]	Y. Roa, C. De Luca, M. Bonano, V. Bruno, F. Casu, P. De Martino, <b>M. Franzese</b> , S. Gandolfi, E. Giorgin, M. Manunta, M. Mattia, P. Noli, G. Onorato and R. Lanari “ <i>Quantitative assessment of the retrieved SAOCOM-1 L-band DInSAR Time Series accuracy in volcanic and tectonic scenarios of the Italian territory</i> ”, IEEE International Geoscience and Remote Sensing Symposium (IGARSS) 2025.
[C5]	F. Casu, M. Bonano, S. Buonanno, C. De Luca, P. De Martino, F. Di Traglia, M. Di Vito, <b>M. Franzese</b> , A. Fusco, F. Giudicepietro, R. Lanari, G. Macedonio, M. Manunta, F. Monterroso, P. Noli, G. Onorato, Y. Roa, P. Striano, M. Yasir, G. Zeni and I. Zinno “ <i>Evolution analysis of the Campi Flegrei caldera geodetic anomaly ground displacements through the exploitation of spaceborne multi-frequency DInSAR measurements</i> ”, IEEE International Geoscience and Remote Sensing Symposium (IGARSS) 2025.

# Research Products

[C6]	F. Casu, P. Berardino, M. Bonano, S. Buonanno, F. Casamento, F. Cotugno, C. De Luca, A. Di Vincenzo, C. Esposito, <b>M. Franzese</b> , A. Fusco, R. Lanari, M. Manunta, F. Monterroso, A. Natale, P. Noli, G. Onorato, S. Perna, Y. Roa, P. Striano, M. Yasir, G. Zeni and I. Zinno “ <i>Multidisciplinary exploitation of spaceborne DInSAR data for investigating volcanoes and seismic areas</i> ”, EGU General Assembly 2025.
[C7]	F. Monterroso, M. Bonano, S. Buonanno, F. Casamento, F. Cotugno, C. De Luca, <b>M. Franzese</b> , A. Fusco, M. Manunta, G. Onorato, Y. Roa, P. Striano, M. Yasir, G. Zeni, I. Zinno, R. Lanari and F. Casu “ <i>Generation and analysis of spaceborne DInSAR products to support Civil Protection activities in volcanic and seismic regions</i> ”, XII° AIT International Conference (Smart Earth Observation for a Sustainable Future).
[C8]	P. Noli, M. Bonano, S. Buonanno, F. Casamento, F. Casu, F. Cotugno, C. De Luca, <b>M. Franzese</b> , A. Fusco, M. Manunta, F. Monterroso, G. Onorato, Y. Roa, P. Striano, M. Yasir, G. Zeni, I. Zinno and R. Lanari “ <i>DInSAR time-series automatic generation of the Italian territory by exploiting Sentinel-1 SAR data archives through the P-SBAS approach</i> ”, XII° AIT International Conference (Smart Earth Observation for a Sustainable Future).
[C9]	P. Striano, M. Bonano, S. Buonanno, F. Casamento, F. Casu, F. Cotugno, C. De Luca, <b>M. Franzese</b> , A. Fusco, M. Manunta, F. Monterroso, P. Noli, G. Onorato, Y. Roa, M. Yasir, G. Zeni, I. Zinno and R. Lanari “ <i>Extensive Full Resolution P-SBAS analysis for monitoring critical displacements related to the built-up environment over the Italian territory</i> ”, XII° AIT International Conference (Smart Earth Observation for a Sustainable Future).
[J1]	<b>M. Franzese</b> , V. Carotenuto, F. Mattei, C. Conte, G. Rufino, D. Accardo, P. Berardino, A. DiVincenzo, C. Esposito, A. Natale, G. Palmese, S. Perna, R. Lanari and A. De Maio “ <i>In-Flight UAVs Polarimetric Radar Cross-Section Measurement and Statistical Analysis at X- and L-Bands</i> ”, IEEE Sensors Journal.

# Next Year

- ✈️ Development of a new approach to estimate the ionospheric impact on the **Doppler history** of each Single-Look Complex (SLC), aimed at improving **azimuth focusing** and reducing **geometric distortions**.
- 🛰️ **Expected outcomes:** correct the ionospheric contribution within individual **SLC**, enabling a further improvement in the quality of the filtered **differential interferogram** once the range-related ionospheric effects have been mitigated.

From February to July 2026, research activities will continue at the **German Aerospace Center (DLR)**, Oberpfaffenhofen.

