GNSS based Reflectometry Applications

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Introduction – GNSSR

- Experiments with Radar systems started during WWII by various nations and observed an unknown noise in received signal as the results of wind over ocean

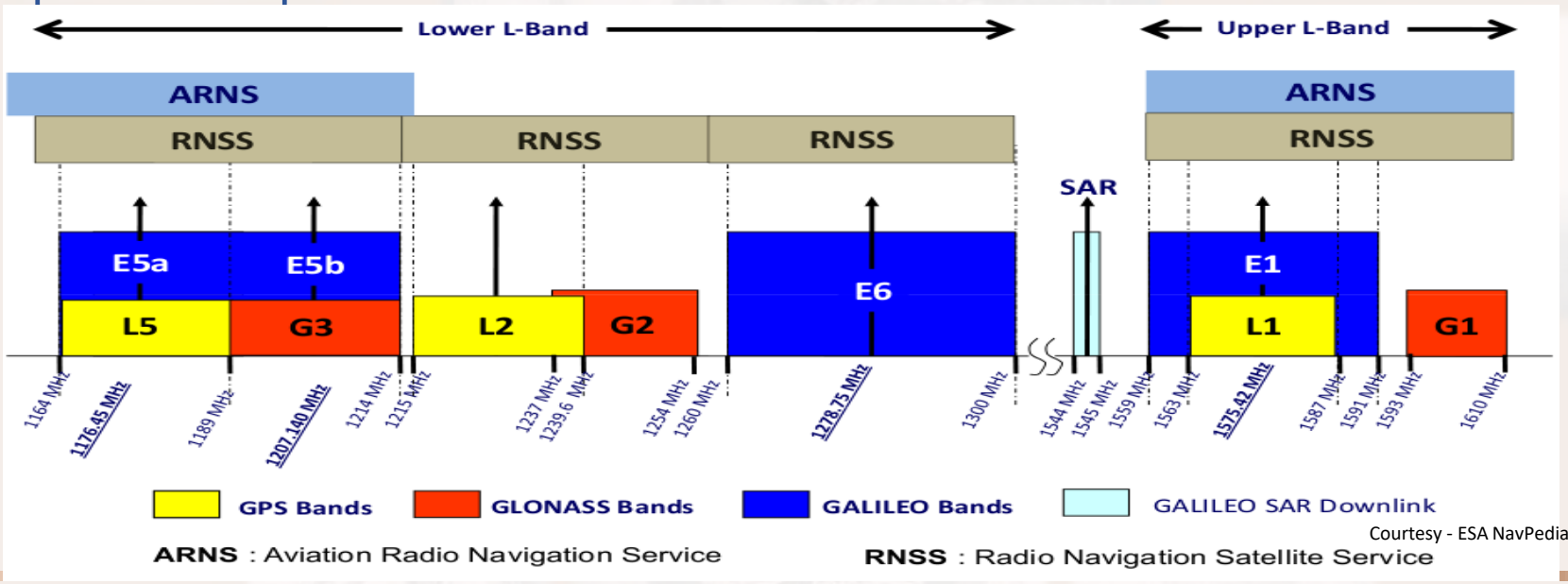
- The finding resulted in the development of a number of radar remote sensing system to study surface wind over oceans

- Despite extensive characterization of meteorological conditions over land, relatively limited observations are available over ocean which covers ~70% of Earth's surface

- **GNSS Reflectometry** – Refers to observing the reflected GNSS signals from the interacting surface and generating scatterometric measurement to study the properties of that surface.

Introduction - GNSS

- Global Navigation Satellite Systems (GNSS) is the general term used for systems that allow users to determine their location based on information from satellites
- More than 100 Satellites are transmitting signals on L Band across the Globe
- More opportunistic signals to derive reflectometry products with good temporal and spatial resolution

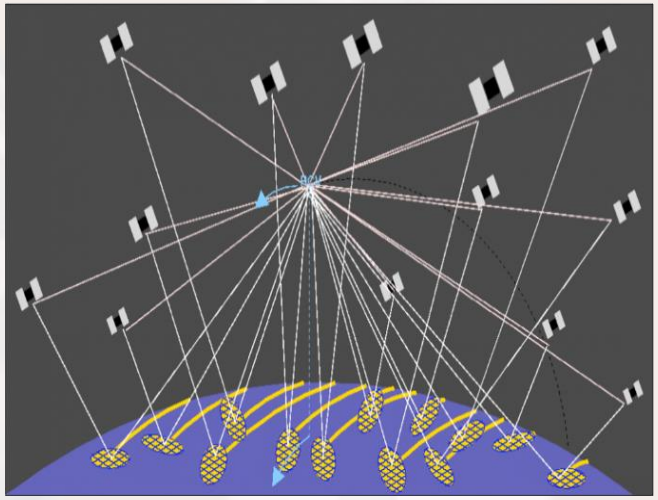


Courtesy - ESA NavPedia

Introduction : GNSS-R Applications

- GNSSR Used because of - continuous availability of GNSS-signals
  - economic viability
- Important applications
  - **Ocean surface study**
  - **Soil moisture detection**

    (L-Band is found to be most sensitive towards soil moisture)



- Other important applications – sea ice detection, land terrain features
- Sensor configuration depends on what is to be sensed

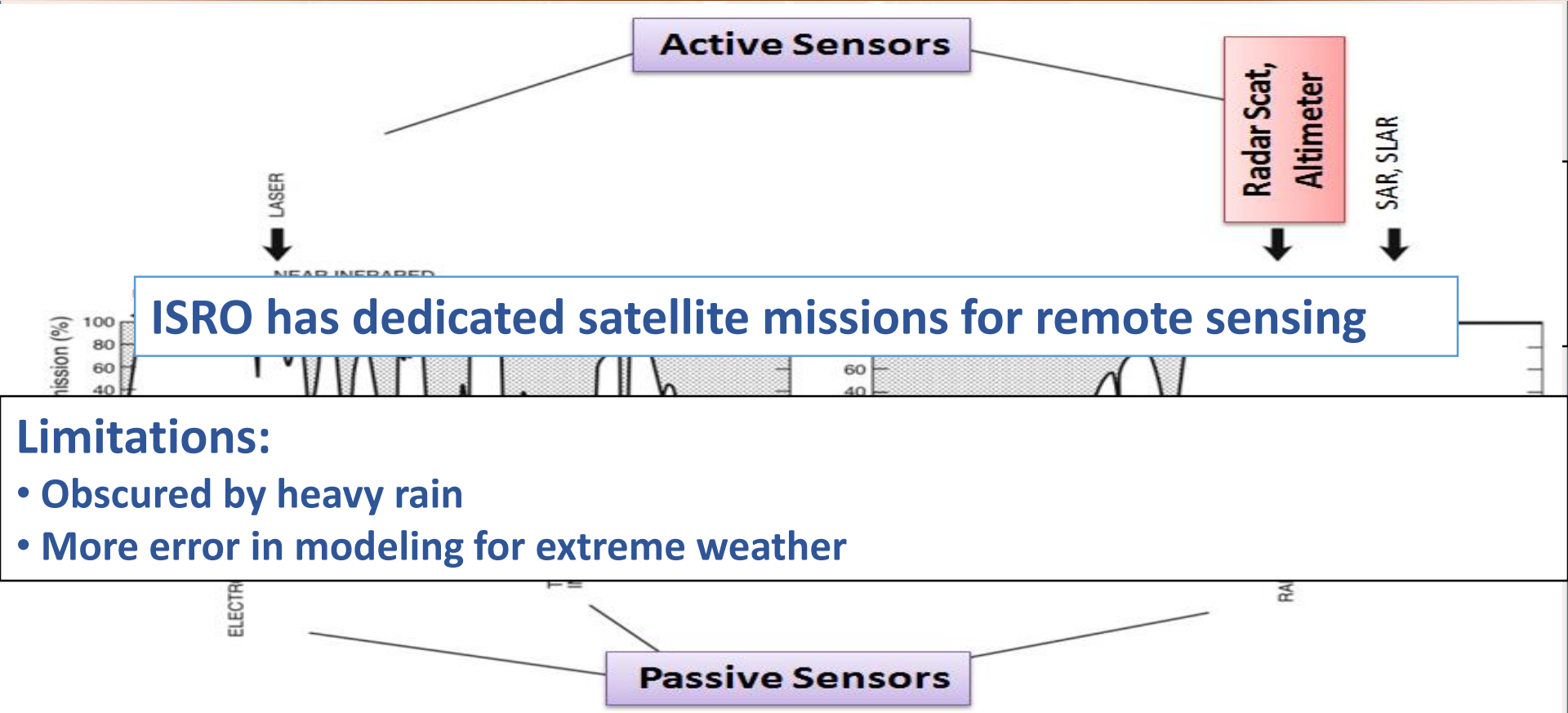
Introduction - NavIC

- NavIC is a regional satellite navigation system broadcasting at L5 and S frequencies with GEO/GSO satellite constellation.
- NavIC Constellation is currently Operational 24x7.
- NavIC receiver is flown in various ISRO Remote Sensing missions.
- Utilization of NavIC receivers is limited to the onboard real time PVT

Carrier Frequencies and Band Width

Signal	Central Frequencies	Bandwidth
SPS–L5	1176.45MHZ	24 MHz (1164.45 -1188.45 MHz)
SPS-S	2492.028MHZ	16.5MHz (2483.50 – 2500.00MHz)

Remote Sensing



ISRO has dedicated satellite missions for remote sensing

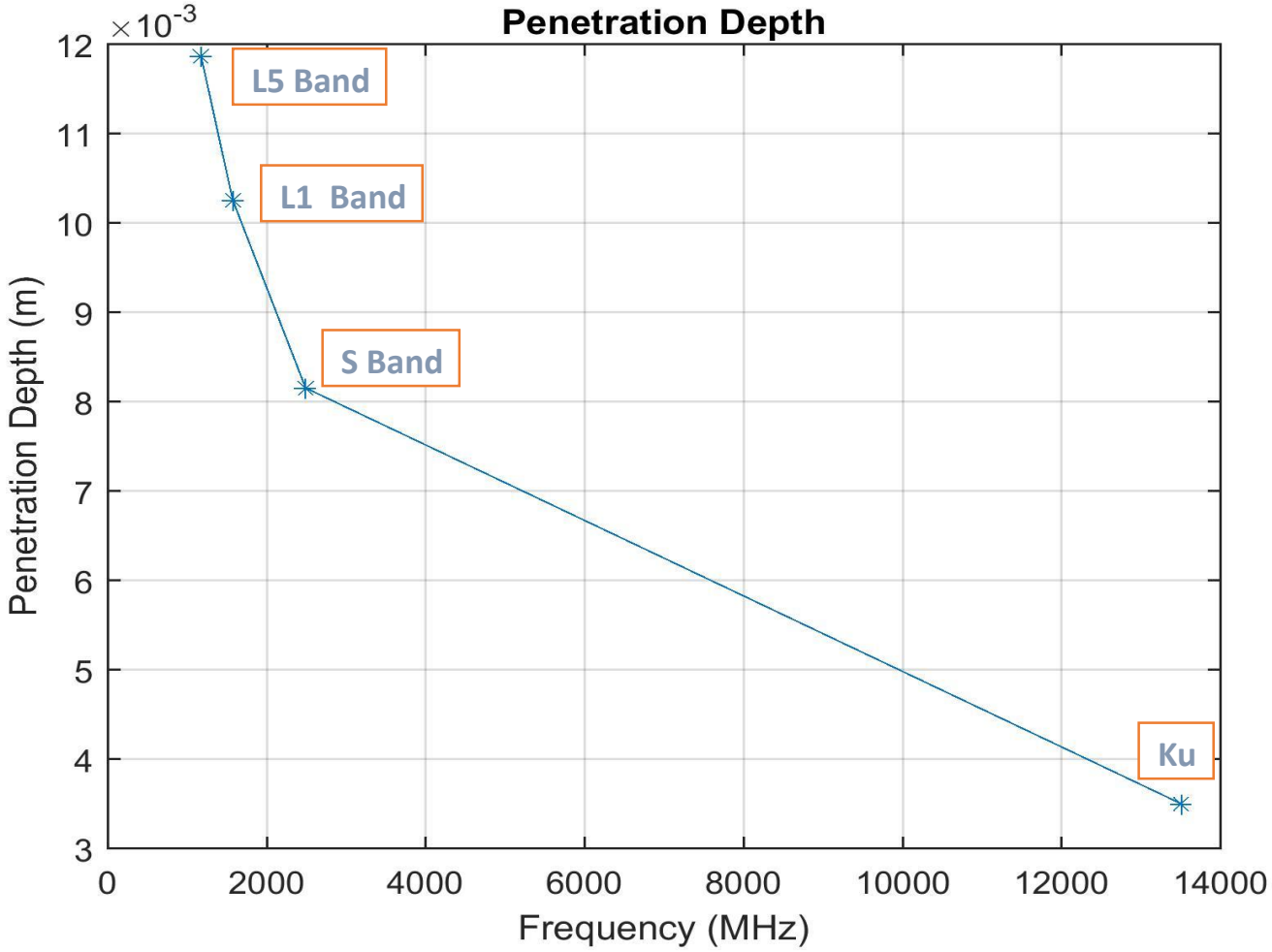
Limitations:

- Obscured by heavy rain
- More error in modeling for extreme weather

Reflectrometry with NavIC

- NavIC transmits Civil signals on two widely separated frequencies i.e. L5 and S
- Offers enormous opportunities for the research on reflectometry using L5 and S as earlier studies are on L1 alone
- L5 band penetration depth is highest among GNSS signals
- S band has least penetration depth among GNSS signals
- S Band is less susceptible to Ionospheric effect among all GNSS signals

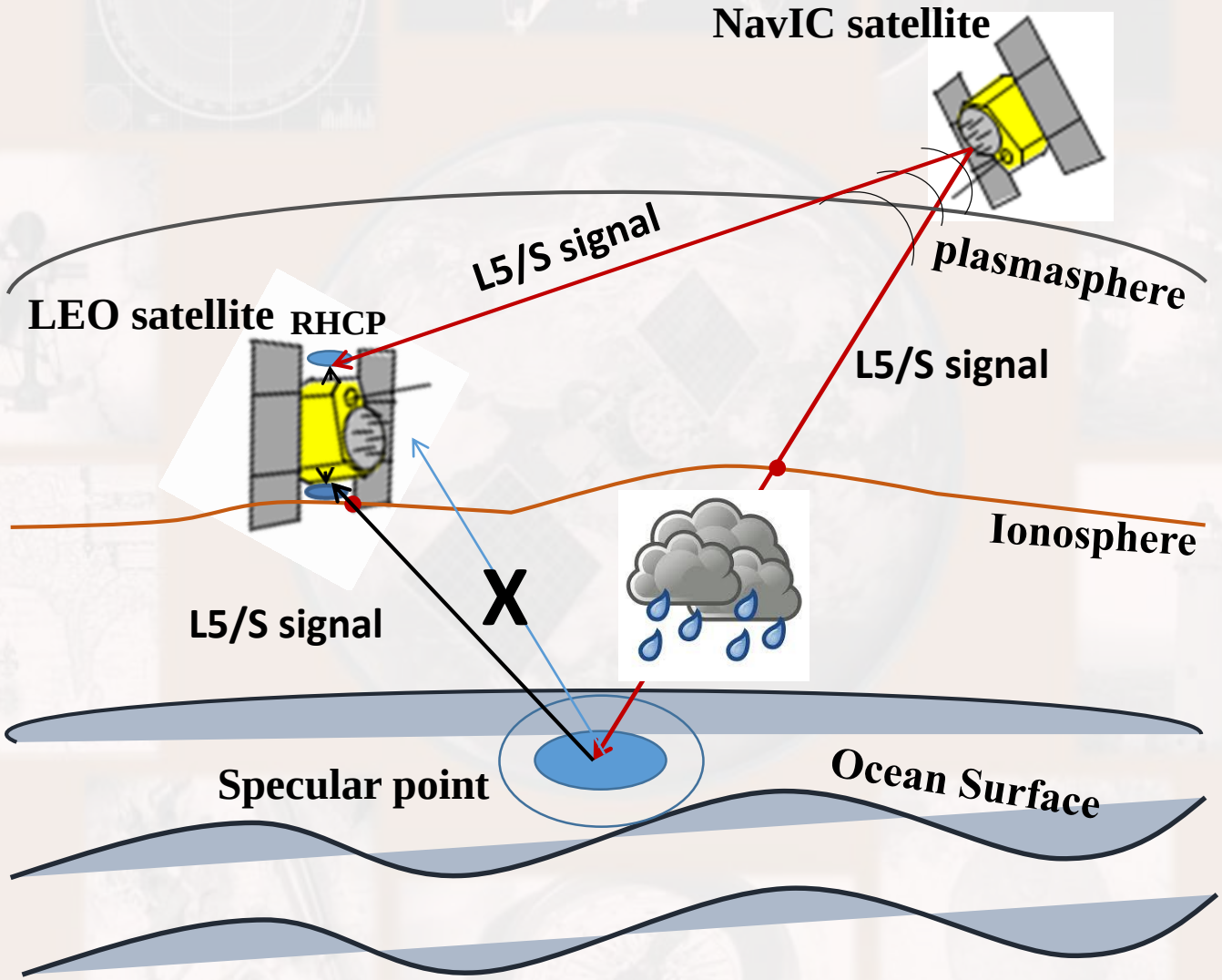
Reflectometry With NavIC



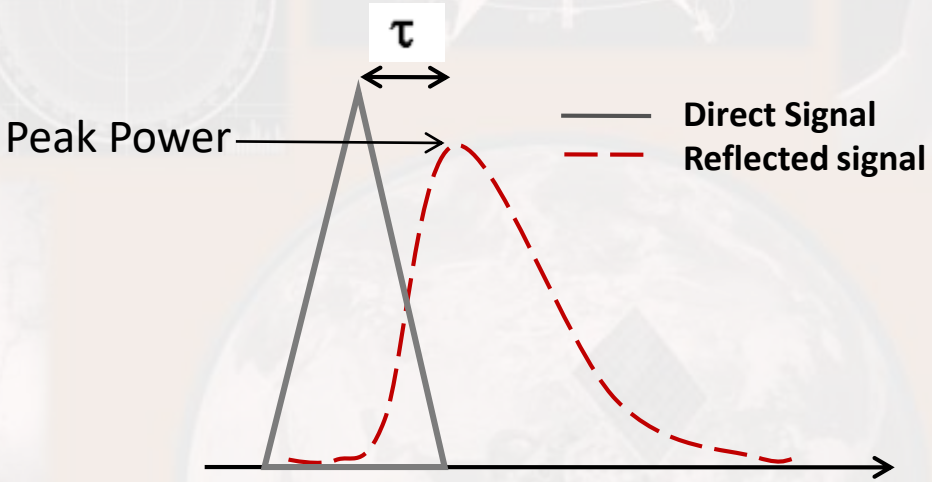
Advantages of NavIC signal

- S Band offers Better surface characterization
- S Band is less susceptible to Ionospheric effects

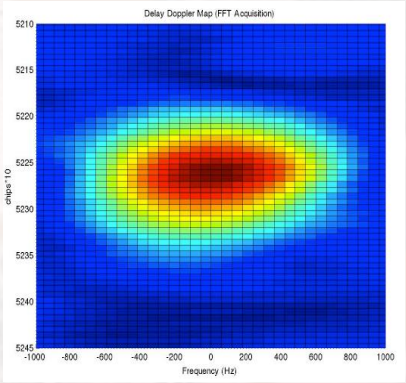
Ocean Surface Roughness Study



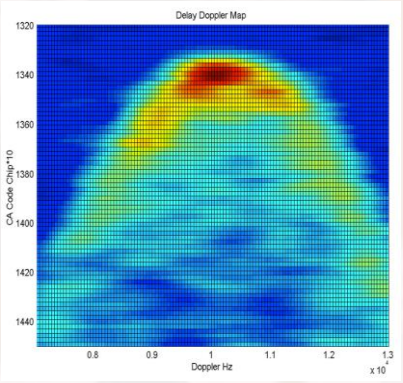
Ocean Surface Roughness Study



Delay Doppler Map (DDM)

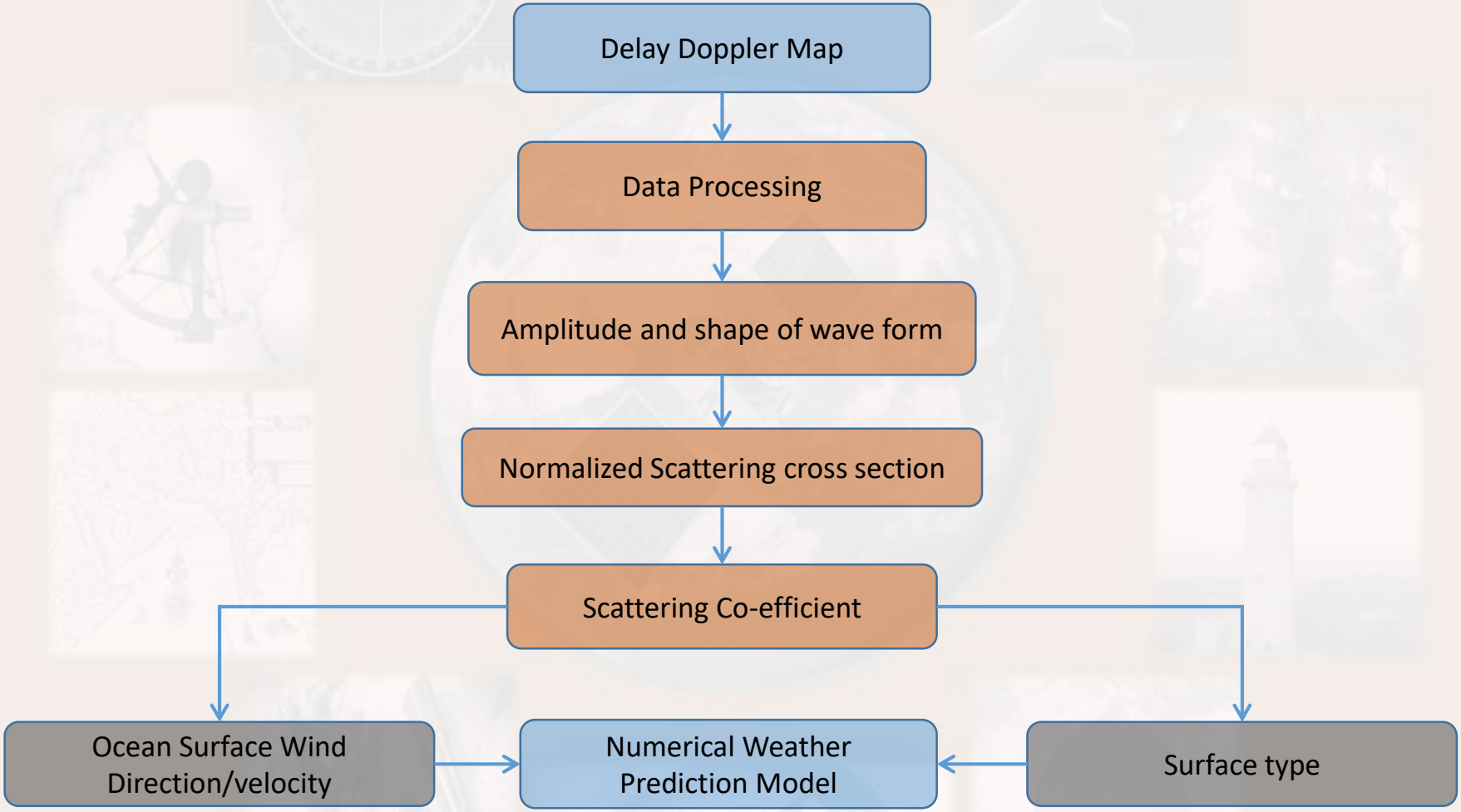


Direct Signal



Reflected Signal

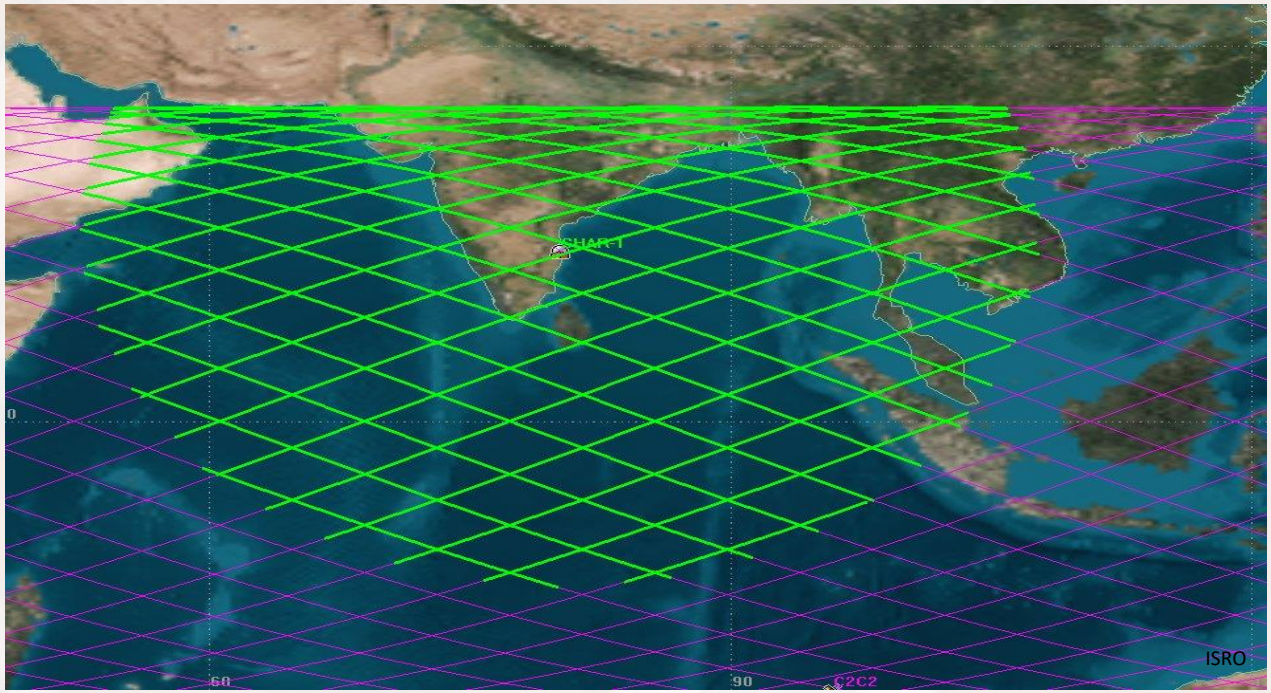
Parameter Retrieval



Tropical Cyclone Study - Indian Oceanic Region

- Constellation of LEO satellites with GNSS Reflecto-Receiver to tropical cyclone Around India

Satellites	3
Altitude	750kms
Orbital Plane	1
Inclination	25°
Phasing	30mins



Advantages

- Oceanic Region around India has L1/L2/L5/S signals and more GNSS signals than any other region

- Study of the relation between the dynamics within the Tropical Cyclone and its intensity at Landfall

- India Being tropical region and lying at lower latitude, a constellation of Reflecto-receiver at LEO with lower inclination provides better revisit time around India and better estimate of land fall intensity

- Measures Wind speed at the inner structure of the storm

- Not only storm intensity, even the track and structure shall be studied

Soil Moisture Detection

Why Soil Moisture (SM) ??

- Soil Moisture (SM) - a vital parameter in Climate Modelling & Agricultural applications
- Earth Observation satellites used to study SM.
  (past missions : *NASA-SMAP*, *ESA-SMOS*)

No global in-situ SM database available to validate these Sat. values

- ***Developed a SM Retrieval algorithm using NavIC L5 signals which can more accurately give the SM at a place*** which can help in building the global *in-situ* SM database

Soil Moisture Detection
GNSS-R Observable used for SM : SNR

- Without multipath, SNR $\longleftrightarrow$ Related to direct received signal

- In presence of multipath, SNR $\longrightarrow$ $f(A_d, A_m, \psi)$

  where A_d : Direct amplitude, A_m : Multipath amplitude and

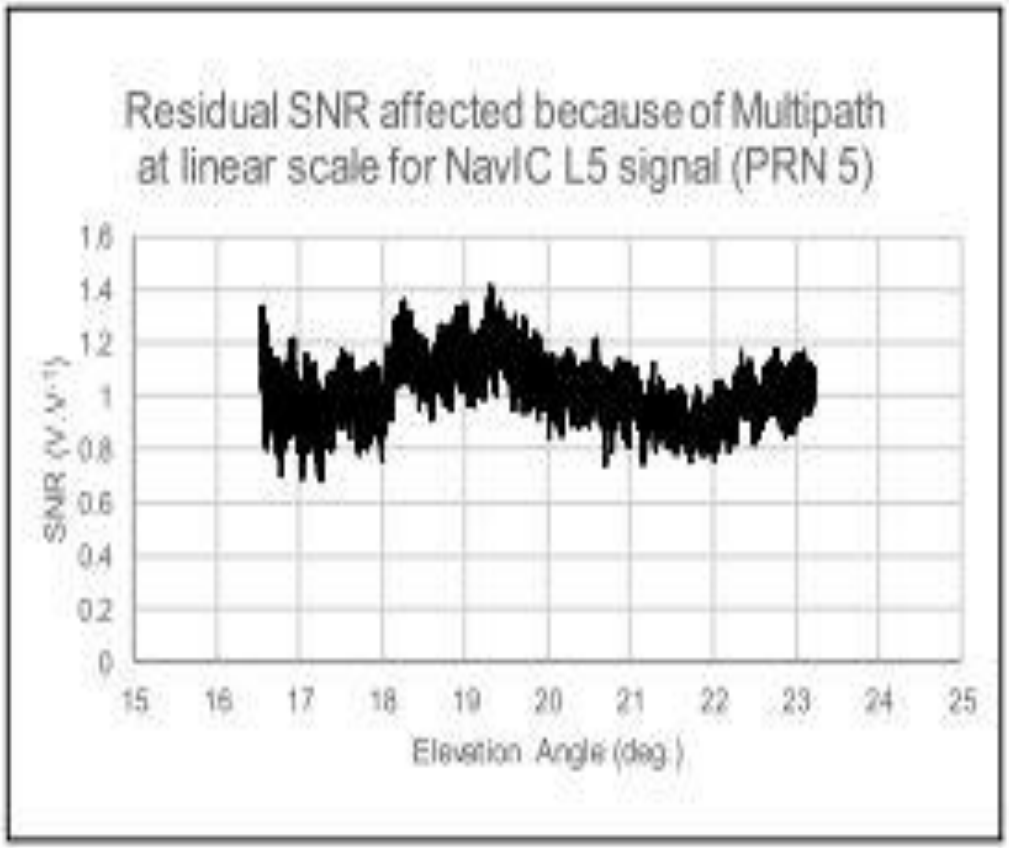
  ψ : Multipath relative phase

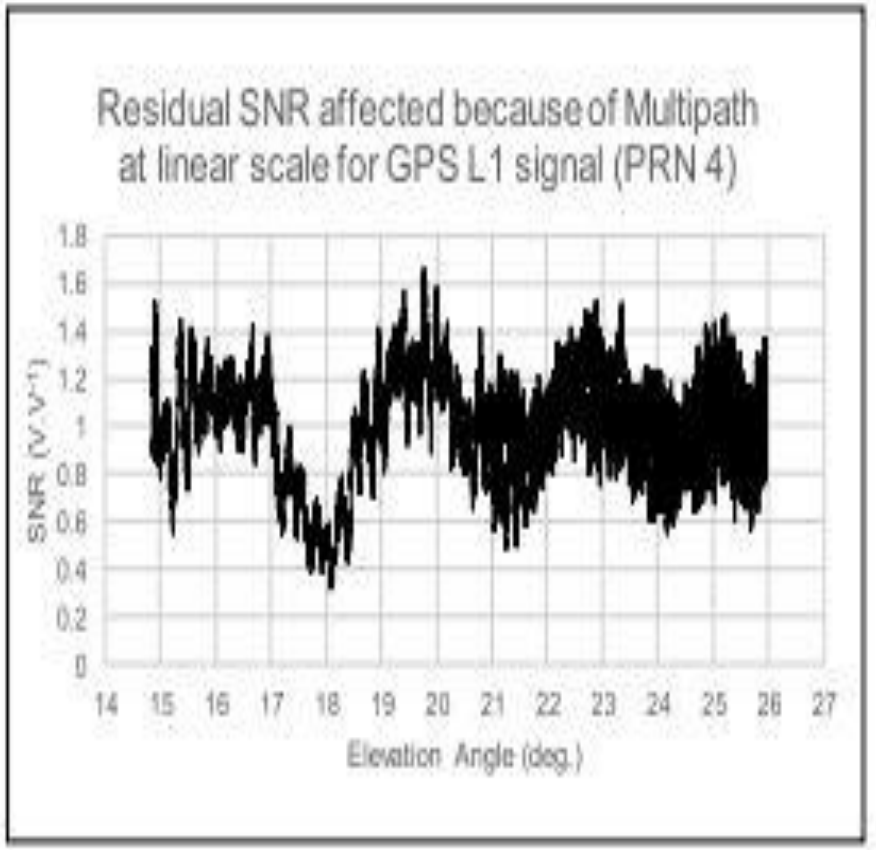
$$SNR^2 = A_d + A_m + 2 A_d A_m \cos\psi \quad \& \quad \frac{d\psi}{dt} = \frac{2\pi}{2\lambda} 2h\cos\phi \frac{d\phi}{dt}$$

- In this, $\psi \longrightarrow f$ (ϕ : Satellite Elevation angle, h : Antenna height above ground , λ : Signal wavelength)

Soil Moisture Detection

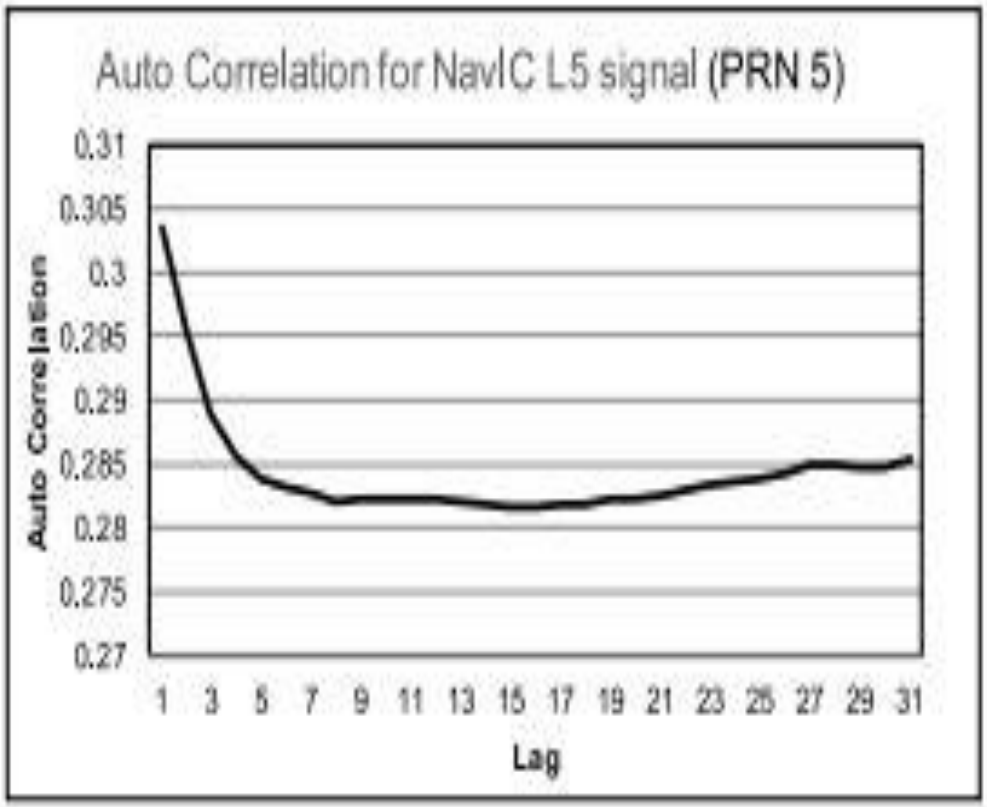
Suitability of NavIC L5 Signals for Multipath





Soil Moisture Detection

Suitability of NGS (NavIC-GPS-SBAS) Receiver for SM Estimation



- **<u>Indigenously developed</u>** NGS Receiver used

- SNR measurements <u>using NavIC L5 Signal</u> using NGS Rx sensitive to multipath & hence <u>suitable for GNSS-R applications</u>

Algorithm for Soil Moisture Estimation

1. GNSS Observables (SNR in dB-Hz)

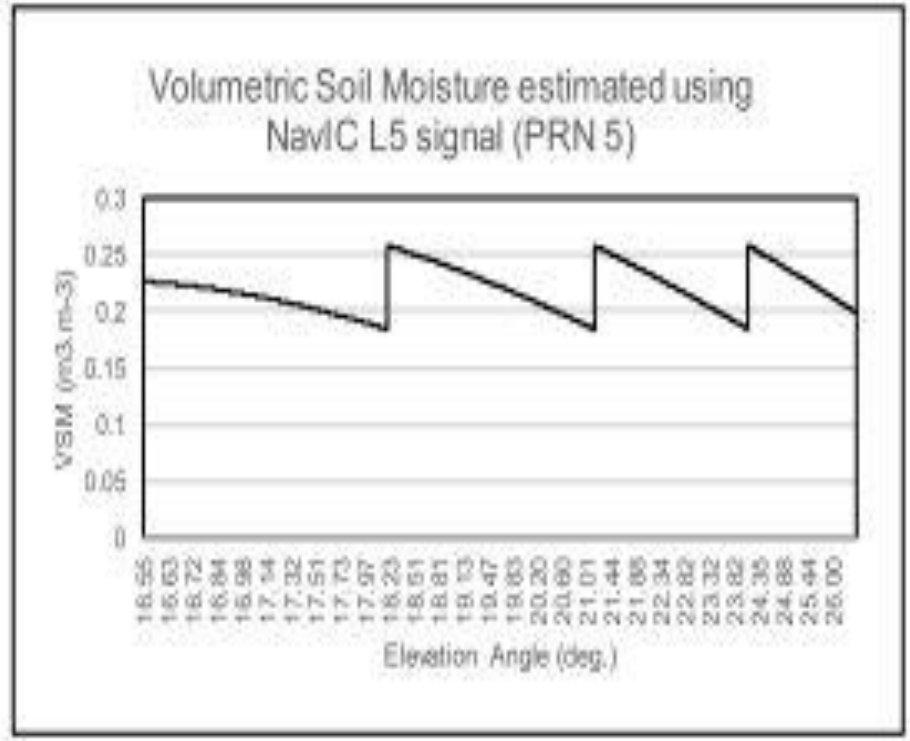
2. Retrieval of multipath signal from direct signal

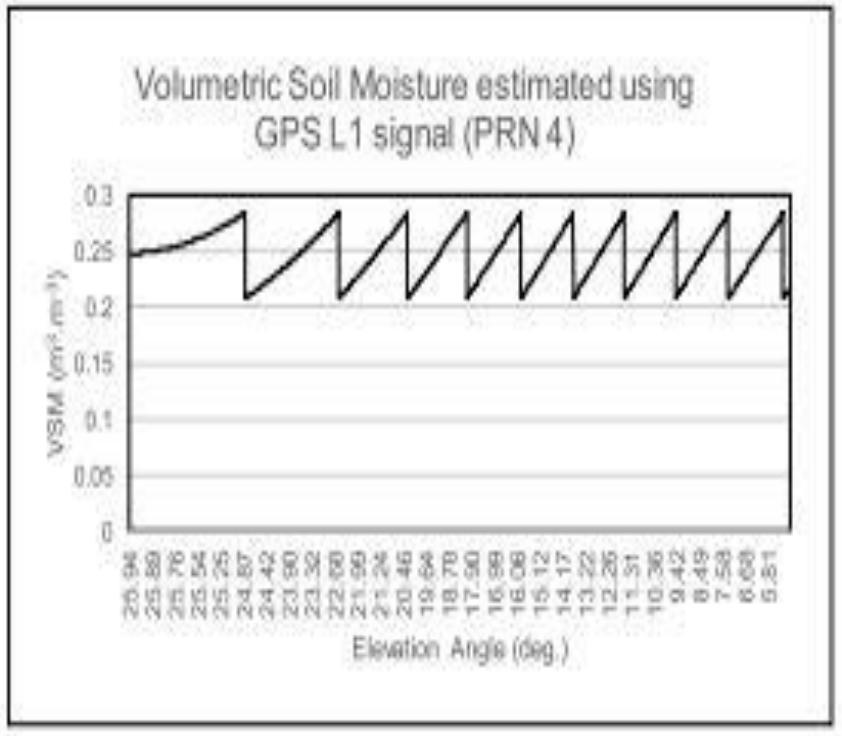
3. Retrieval of modulation pattern & conversion to linear scale

4. Estimation of Multipath Amplitude & Phase

5. Soil Moisture estimation using multipath phase using NavIC L5 signals

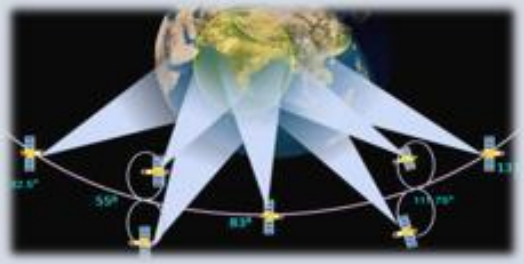
Estimated SM : NavIC L5 *vs* GPS L1





Findings and Future Scope

- Potential of NavIC L5 signal was established to estimate geophysical parameters viz. Soil Moisture.
- The capability of indigenously developed NGS Receiver was established for retrieval of geophysical parameters.
- This work can be further extended to study soil moisture under different environmental conditions which can be further used to generate the *in-situ* database of soil moisture.
- This study also encourages retrieval of other geophysical parameters, such as water level and ice thickness.



Thank You