NavIC based Adaptive Vegetation Correction Scheme for GNSS-IR derived *Field Scale Soil Moisture* Retrieval

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In-situ measurement techniques

- **Direct measurements (Classical method)**
  - ❑Measure soil moisture directly
  - ❑Example:
    - ❑**Gravimetric measurement**
    - ❑**Volumetric measurement**

- Samples are collected from fields and are oven dried at 125°C for over 24-48 hours (depending on soil texture).
- Bulk density for each sampling point are derived from known volume sample ring and dry soil.

In-situ measurement techniques

Indirect measurements

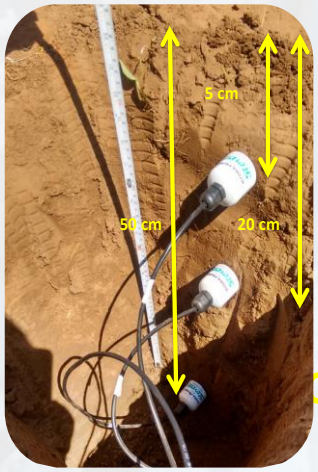
- Measure another soil property and relate to soil moisture content
- Examples:
  - TDR/FDR/Dielectric Methods
  - Neutron Probe (Cosmic Ray based)

Utilization

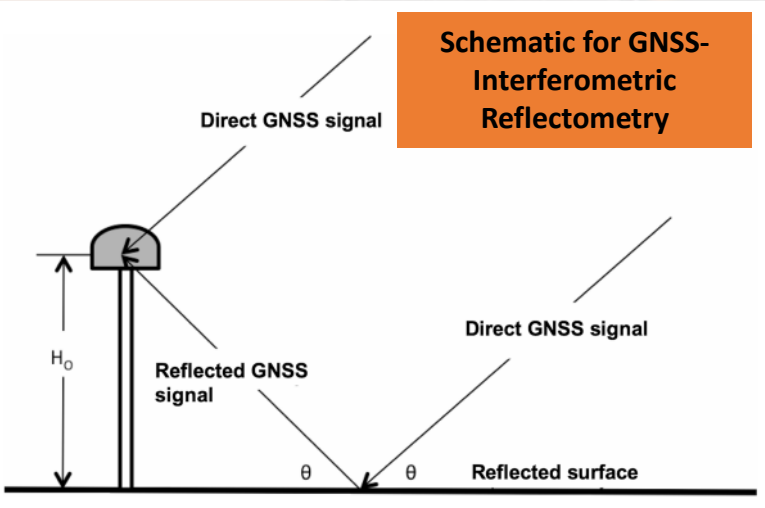
- **Validation of Satellite derived SM**

Limitation

- **Time consuming and Expensive**.
- **Destructive** methods.
- **Point measurements** in space and time of a temporal and spatial highly variable phenomenon.
- Does not account for **spatial and temporal variability of soil moisture**.



Basic Principles of GNSS-IR using NavIC



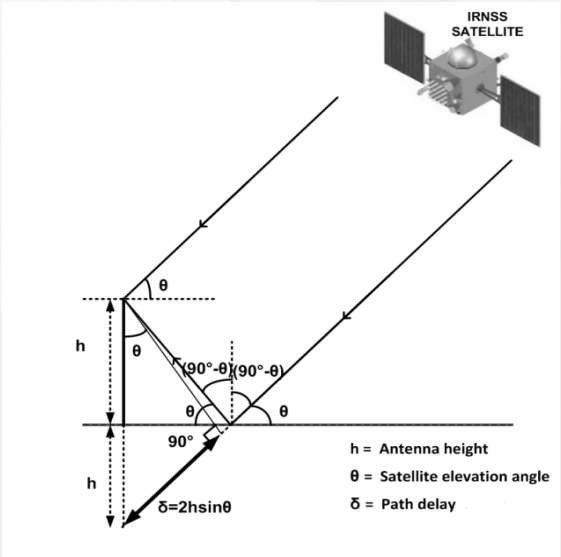
Schematic for GNSS-Interferometric Reflectometry

- Path difference causes interference at receiver.
- Multipath C/N_o is given as.

$$C/N_{\circ\, mpi} = A\cos\left(\frac{4\pi h}{\lambda}\sin\theta + \phi_{mpi}\right)$$

Where A is multipath Amplitude

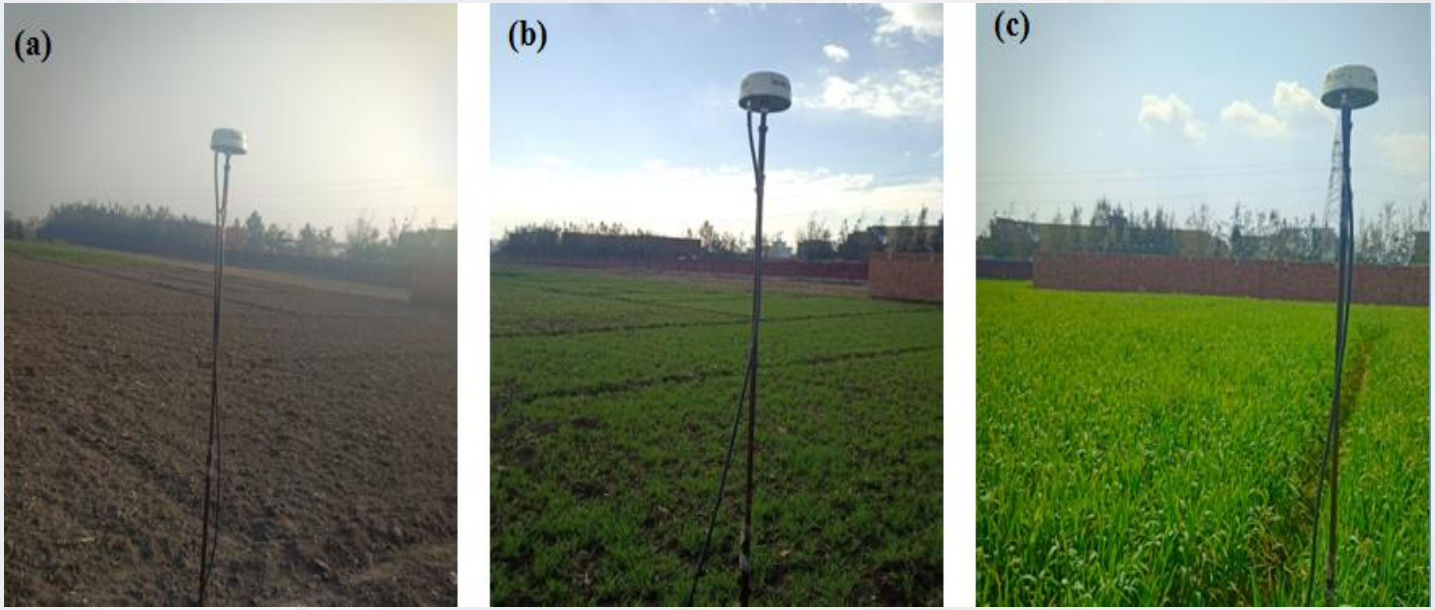
ϕ_{mpi} **is the multipath phase**



Geometry of Multipath Reception

Study Area and Data Used for Field Experiments

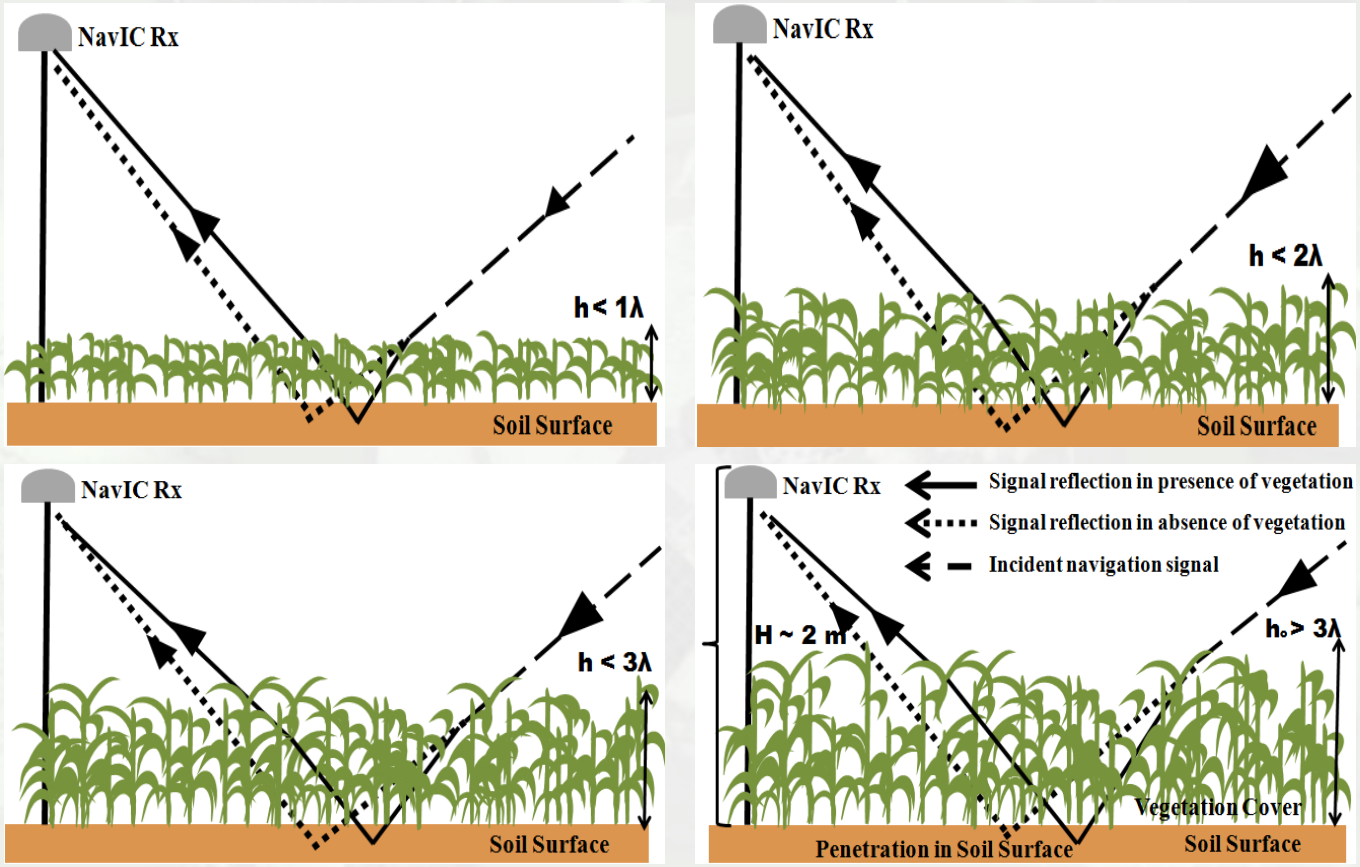
- NavIC L5 band data utilized for Field experiments.
- Observations were carried out at Dehradun, Uttarakhand, India:



Field Photographs of NavIC Receiver deployment

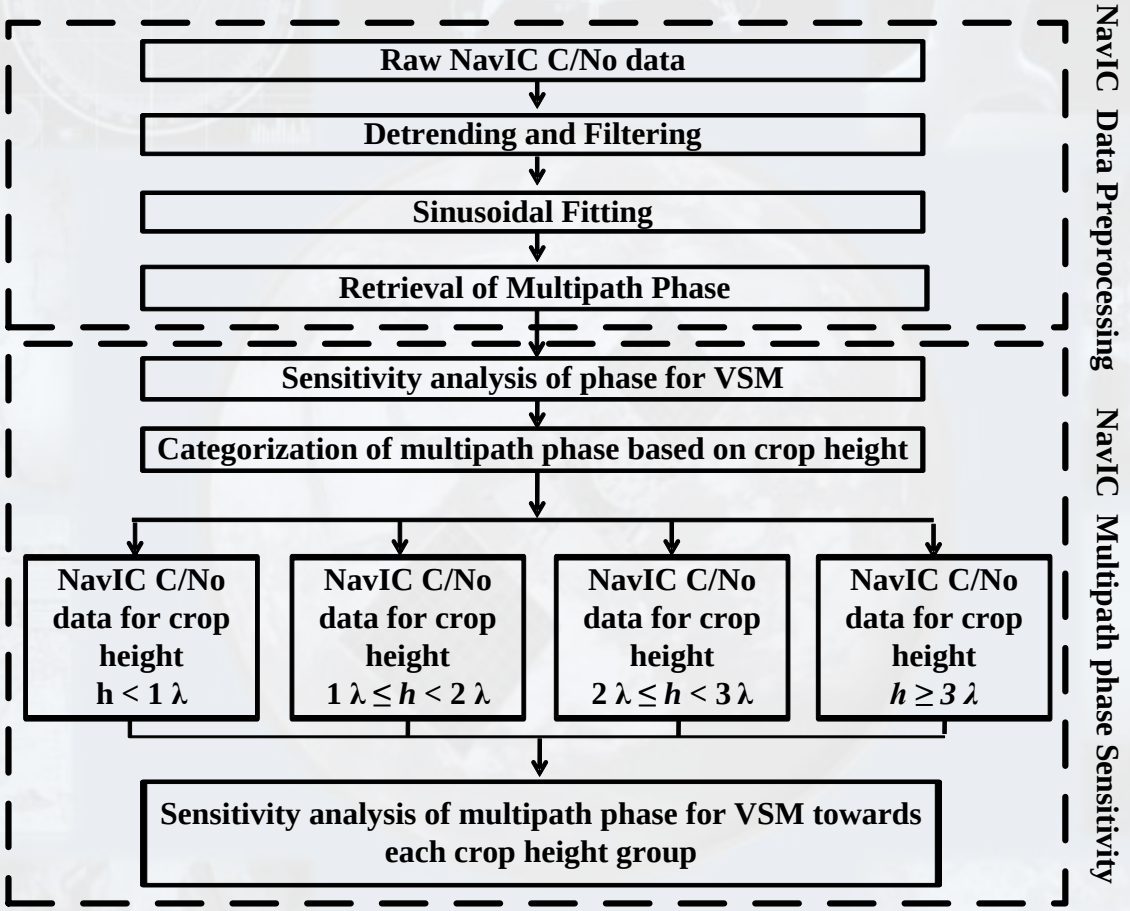
- **The in situ soil moisture was collected three times a day and reported soil moisture value is average of 20 samples.**

GNSS-IR under different crop growth stages



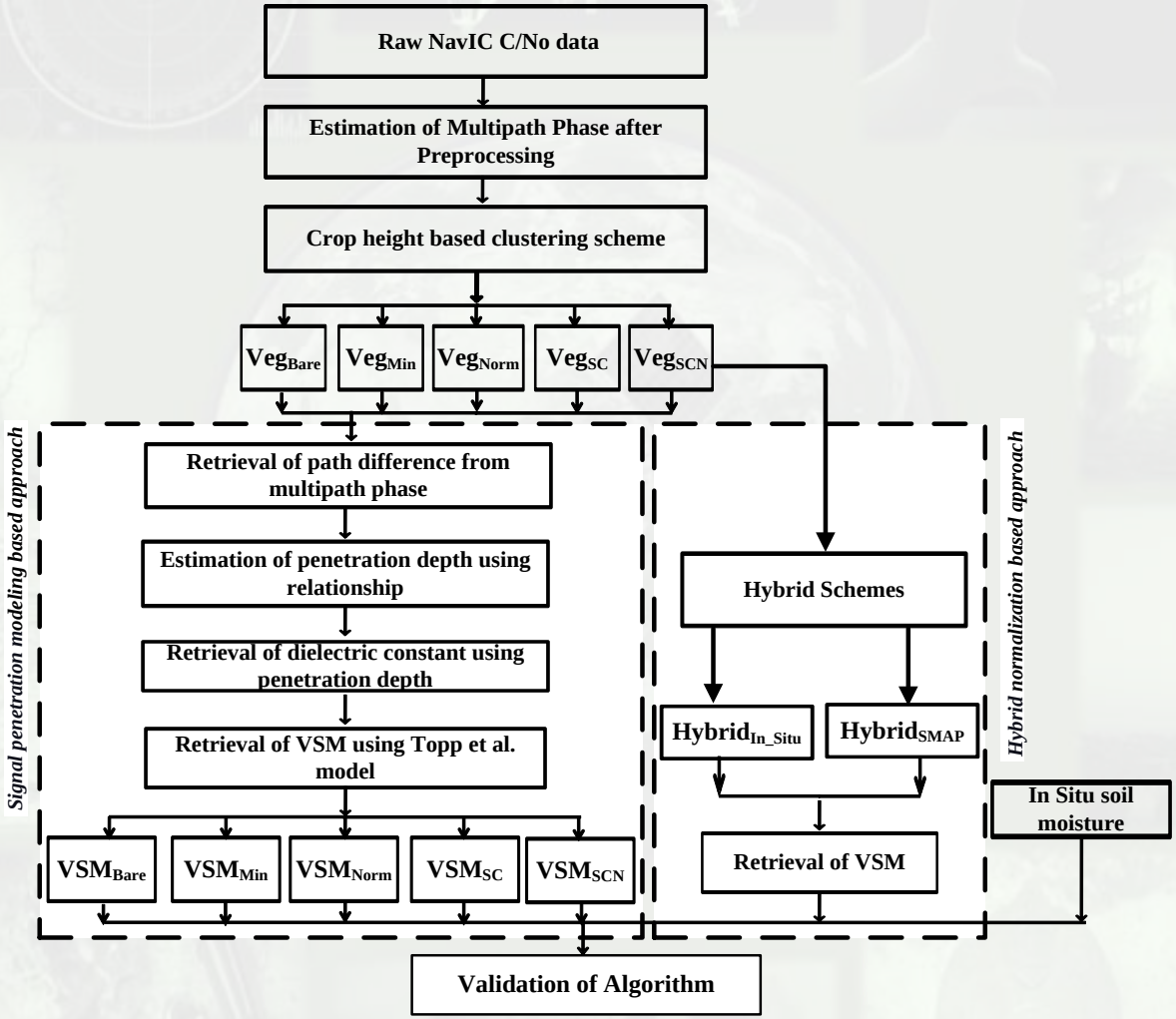
Schematic diagram showing the additional path travelled by the NavIC multipath signal in presence of vegetation at different crop height scenario

Methodology: Part-A



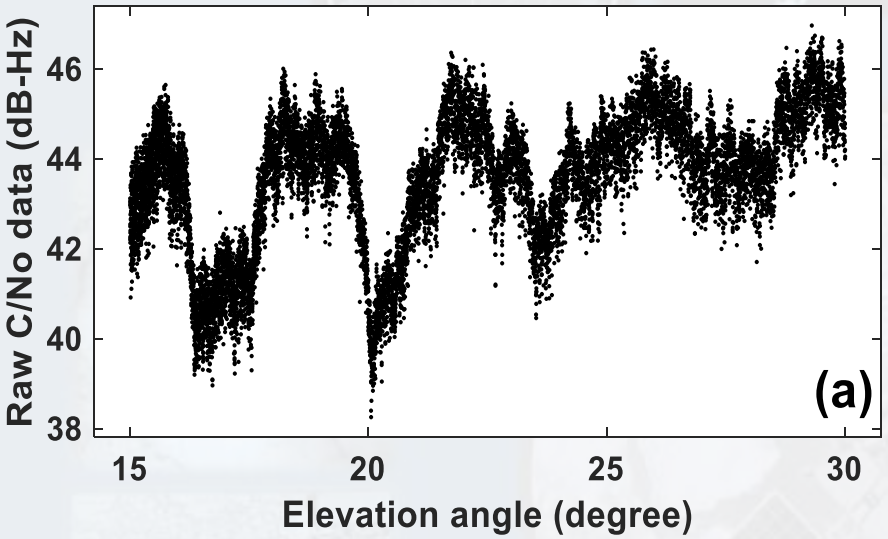
Flowchart for NavIC data preprocessing and sensitivity analysis of NavIC-IR multipath phase in presence of vegetation

Methodology: Part-B

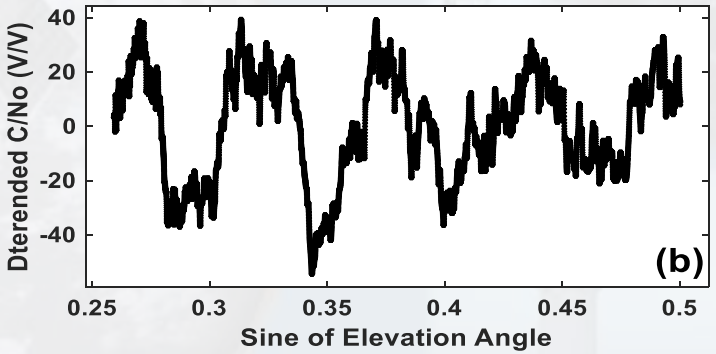


Field scale VSM inversion scheme with adaptive vegetation correction Scheme

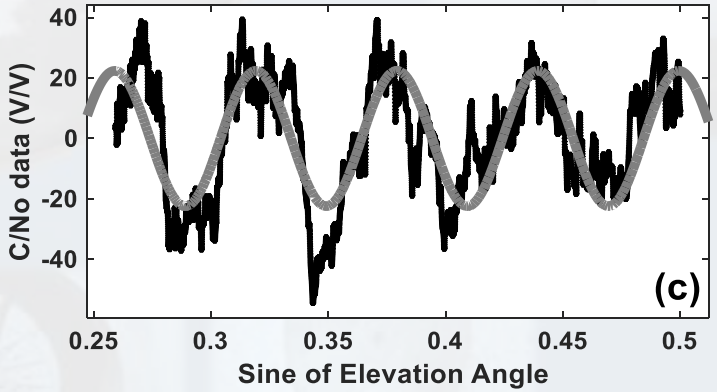
Multipath Signal from NavIC Satellite



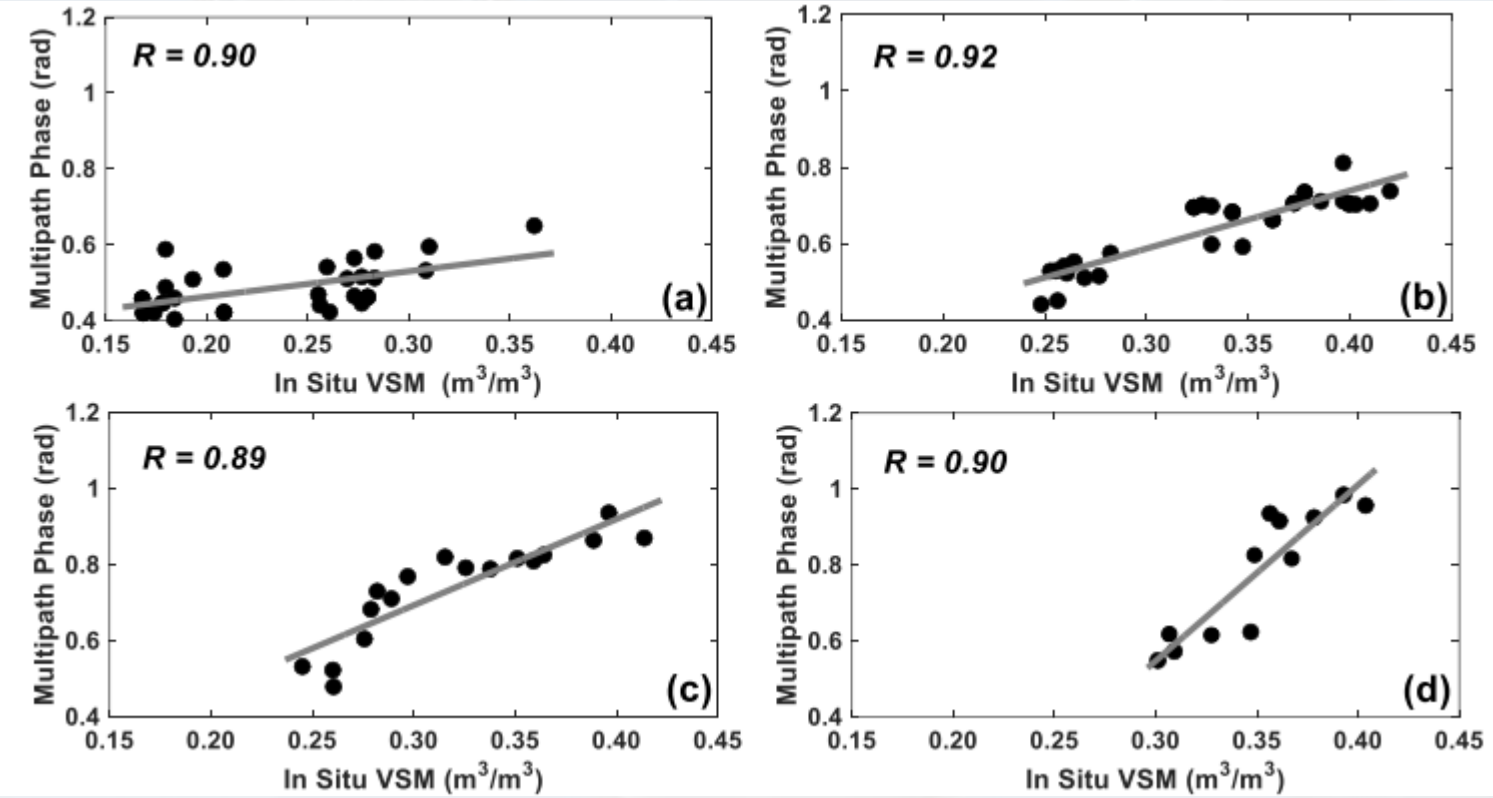
Raw multipath signal



Detrended and noise removed signal

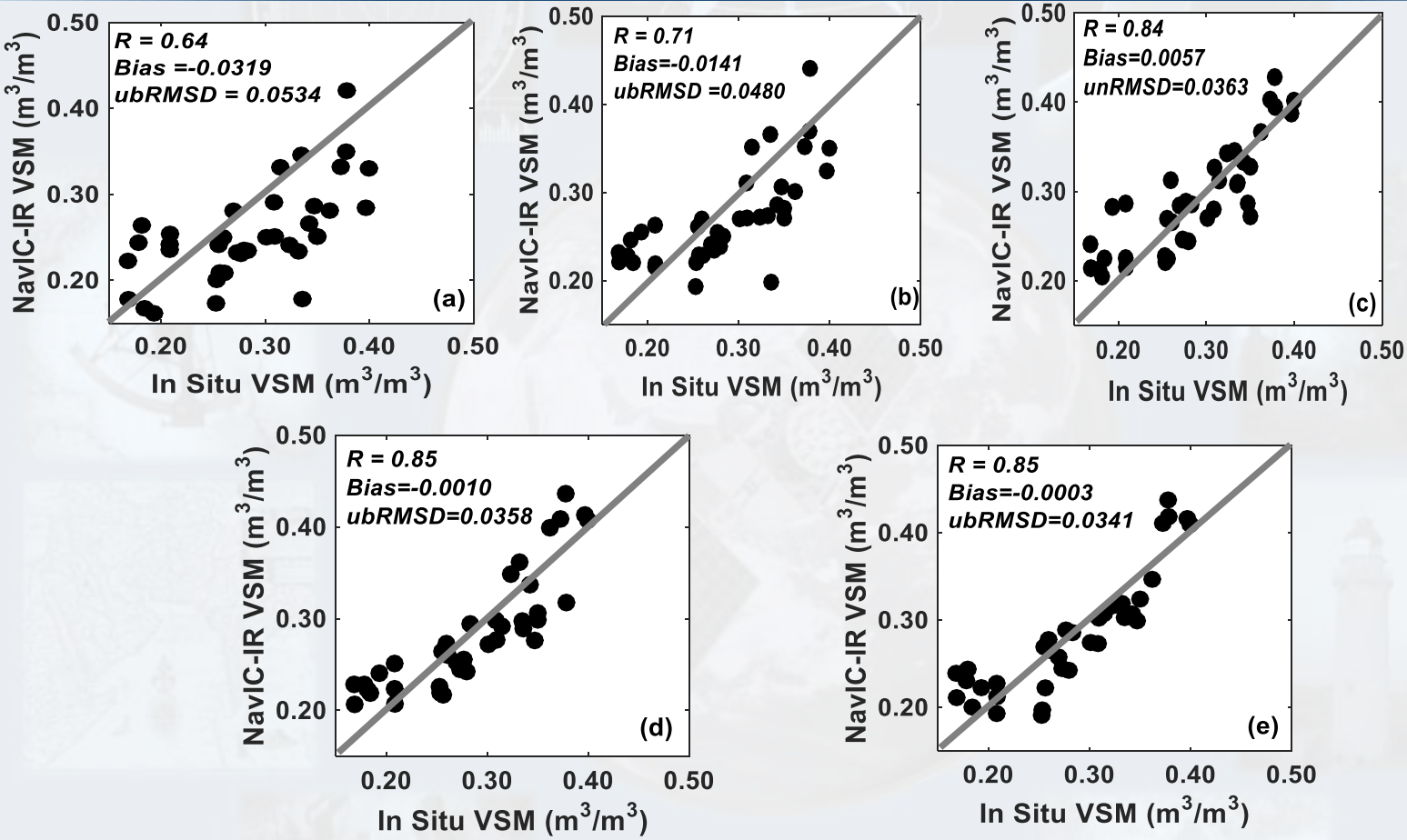


Sensitivity of Multipath Phase towards soil moisture over different crop growth stages



Scatter plot between multipath phase and *in-situ* VSM (a) when $h < 1\ \lambda$, (b) when $1\lambda \leq h < 2\lambda$, (c) when $2\ \lambda \leq h < 3\lambda$, (d) when $h \geq 3\lambda$.

Validation of developed VSM retrieved schemes



Scatter plot between NavIC-IR VSM and *in-situ* VSM using (a) VSM_{Bare} (b) VSM_{Min} (c) VSM_{Norm} (d) VSM_{SC} (e) VSM_{SCN}

Evaluation of vegetation correction scheme with Bare soil scheme

Table 1: Performance metrics of VSM_{Bare} scheme at different crop height categories for NavIC-IR based VSM retrieval.

Parameter / VSM_{Bare}	R	Bias (m^3/m^3)	RMSD (m^3/m^3)	ubRMSD (m^3/m^3)
$h < 1\ \lambda$	0.39	0.0058	0.0454	0.0451
$1\ \lambda \leq h < 2\ \lambda$	0.82	-0.0592	0.0667	0.0313
$2\ \lambda \leq h < 3\ \lambda$	0.41	-0.0438	0.0751	0.0611
$h \geq 3\ \lambda$	0.74	-0.0198	0.0443	0.0396

Table 2: Performance metrics of VSM_{SCN} scheme at different crop height categories for NavIC-IR based VSM retrieval.

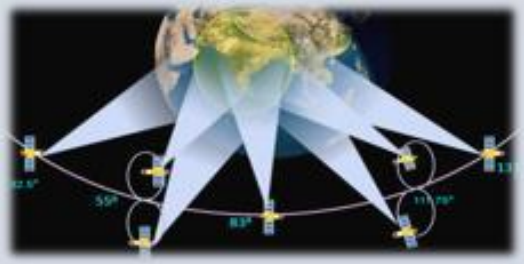
Parameter / VSM_{SCN}	R	Bias (m^3/m^3)	RMSD (m^3/m^3)	ubRMSD (m^3/m^3)
$h < 1\ \lambda$	0.73	0.0182	0.0369	0.0321
$1\ \lambda \leq h < 2\ \lambda$	0.92	0.0045	0.0272	0.0267
$2\ \lambda \leq h < 3\ \lambda$	0.95	-0.0330	0.0373	0.0174
$h \geq 3\ \lambda$	0.87	-0.0060	0.0126	0.0113

Conclusions & Future Scope

- Developed novel **multipath phase based vegetation correction scheme for improved field-scale soil moisture retrieval** using L-band data from **NavIC (Navigation with Indian Constellations) based on GNSS-IR technique**.
- The proposed vegetation correction scheme categorized the crop in different height groups based on crop incident wavelength for sensitivity analysis of NavIC derived multipath phase as GNSS-IR observable towards soil moisture over different crop growth stages and compensate vegetation effect for soil moisture retrievals.
- It need **only multipath phase data for vegetation correction and soil moisture retrieval**.
- The validation results show a significantly improvements in Pearson correlation coefficient (from 0.73 to 0.95), Bias (from -0.033 m^3/m^3 to 0.0045 m^3/m^3), RMSD (from 0.0126 m^3/m^3 to 0.0373 m^3/m^3) and ubRMSD (from 0.0113 m^3/m^3 to 0.0321 m^3/m^3) for all crop height categories during full crop growth cycle for winter wheat crop (sowing to harvesting stages).
- The proposed scheme has **the potential to be directly applied to different crops** as not dependent on any crop specific parameters.
- Overall, proposed scheme has **a good potential for VSM retrievals over crop-covered soil using other GNSS constellations (GPS, GLONASS, Galileo and BeiDou etc.).**

Publication

Sushant Shekhar, Rishi Prakash, Dharmendra Kumar Pandey, Anurag Vidyarthi, , Prashant K. Srivastava, Deepak Putrevu and A. Misra (2022), *"Development Multipath Phase based Adaptive Vegetation Correction Scheme for Improved Field-Scale Soil Moisture Retrieval over Agricultural Cropland Using L-band GNSS-Interferometric Reflectometry Technique"*, IEEE Transaction of Geoscience and Remote Sensing *(Under review)*








Thank You