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

Dharmendra Kumar Pandey
Indian Space Research Organization (ISRO)

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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.
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

➢ Path difference causes interference at receiver.

➢ Multipath $C/N_0$ is given as.

$$C/N_0_{mpi} = A \cos\left(\frac{4\pi h}{\lambda} \sin \theta + \phi_{mpi}\right)$$

Where $A$ is multipath Amplitude

$\phi_{mpi}$ is the multipath phase

Geometry of Multipath Reception

Schematic for GNSS-Interferometric Reflectometry
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
Field scale VSM inversion scheme with adaptive vegetation correction Scheme
Multipath Signal from NavIC Satellite

(a) Raw multipath signal

(b) Detrended C/No data (V/V)

(c) C/No data (V/V)

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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( R )</th>
<th>Bias ((m^3/m^3))</th>
<th>RMSD ((m^3/m^3))</th>
<th>ubRMSD ((m^3/m^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h &lt; 1 \lambda )</td>
<td>0.39</td>
<td>0.0058</td>
<td>0.0454</td>
<td>0.0451</td>
</tr>
<tr>
<td>( 1 \lambda \leq h &lt; 2 \lambda )</td>
<td>0.82</td>
<td>-0.0592</td>
<td>0.0667</td>
<td>0.0313</td>
</tr>
<tr>
<td>( 2 \lambda \leq h &lt; 3 \lambda )</td>
<td>0.41</td>
<td>-0.0438</td>
<td>0.0751</td>
<td>0.0611</td>
</tr>
<tr>
<td>( h \geq 3 \lambda )</td>
<td>0.74</td>
<td>-0.0198</td>
<td>0.0443</td>
<td>0.0396</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( R )</th>
<th>Bias ((m^3/m^3))</th>
<th>RMSD ((m^3/m^3))</th>
<th>ubRMSD ((m^3/m^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h &lt; 1 \lambda )</td>
<td>0.73</td>
<td>0.0182</td>
<td>0.0369</td>
<td>0.0321</td>
</tr>
<tr>
<td>( 1 \lambda \leq h &lt; 2 \lambda )</td>
<td>0.92</td>
<td>0.0045</td>
<td>0.0272</td>
<td>0.0267</td>
</tr>
<tr>
<td>( 2 \lambda \leq h &lt; 3 \lambda )</td>
<td>0.95</td>
<td>-0.0330</td>
<td>0.0373</td>
<td>0.0174</td>
</tr>
<tr>
<td>( h \geq 3 \lambda )</td>
<td>0.87</td>
<td>-0.0060</td>
<td>0.0126</td>
<td>0.0113</td>
</tr>
</tbody>
</table>
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.).