Mapping Inland Surface Water and Soil inundation Using Spire GNSS Reflection Data

IROWG-10
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1. Background

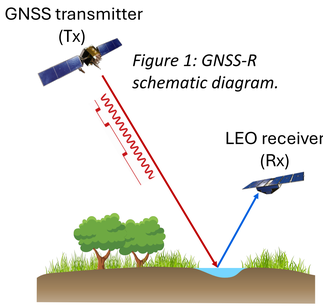


Figure 1: GNSS-R schematic diagram.

GNSS reflectometry (GNSS-R):

- Using GNSS transmissions as a illumination source for **passive bistatic radar**
- All-weather and day-night capability
- Penetrating relatively dense vegetation
- Cost-effective for building a constellation of micro/nano-satellites
- Potential for a short revisit time (e.g., several hours to a few days) and a hm/km-level footprint size

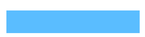
Conceptual diagrams of how soil and water surface affect reflectivity:

- Vegetation
- Soil surface roughness
- lower dielectric constant compared to water

Rough water surface

- No vegetation effect
- Water surface roughness
- Higher dielectric constant

Calm water surface



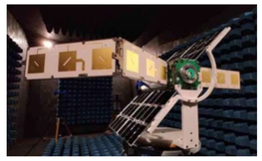
- No vegetation effect
- No surface roughness
- Higher dielectric constant

Higher reflectivity

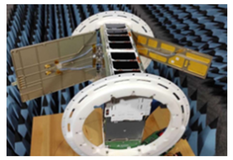
2. Spire GNSS-R CubeSats and reflectivity observations

FM110, Dec 2019

FM146 & 147, Jan 2021



FM172, Apr 2023



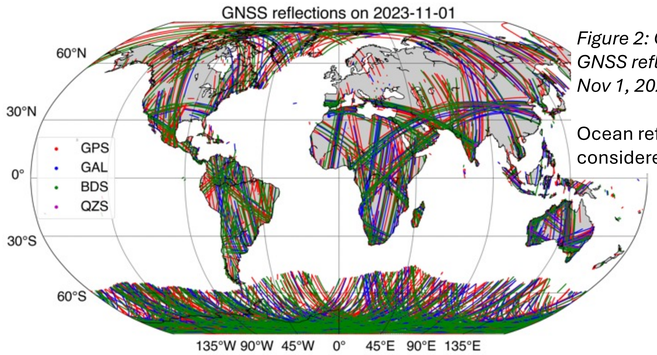


Figure 2: Ground tracks of GNSS reflection data on Nov 1, 2023.

Ocean reflection data not considered.

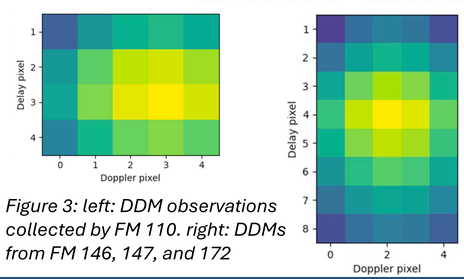


Figure 3: left: DDM observations collected by FM 110. right: DDMs from FM 146, 147, and 172

Basic info of observations:

- 2 Hz calibrated reflectivity observations
- Observations over land and polar regions
- Multiple GNSS
- Legacy and modern navigation signals

3. Qinghai Lake

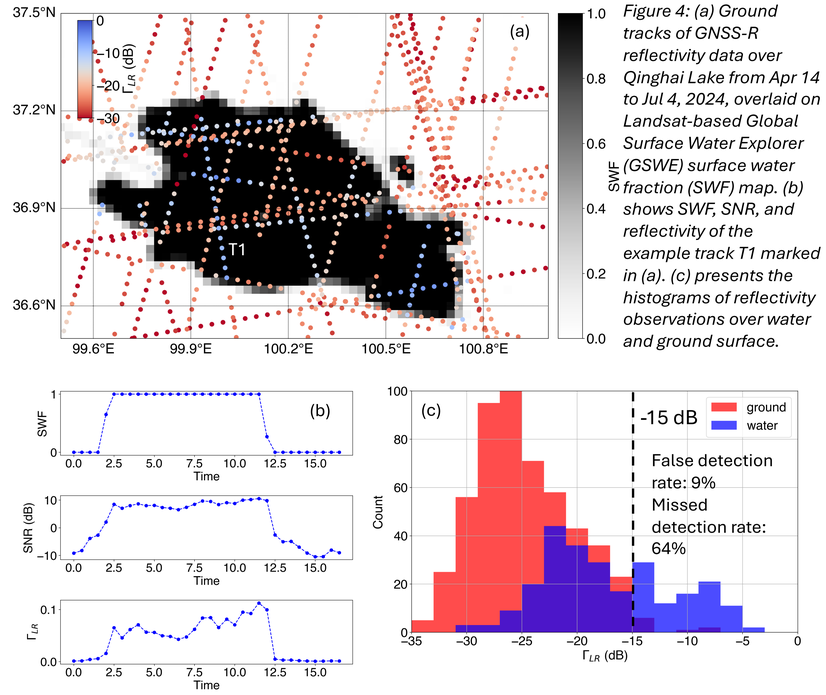


Figure 4: (a) Ground tracks of GNSS-R reflectivity data over Qinghai Lake from Apr 14 to Jul 4, 2024, overlaid on Landsat-based Global Surface Water Explorer (GSWE) surface water fraction (SWF) map. (b) shows SWF, SNR, and reflectivity of the example track T1 marked in (a). (c) presents the histograms of reflectivity observations over water and ground surface.

T1 shows a good agreement of reflectivity observations to SWF. Reflectivity observations over water surface are not always higher than those over ground surface due to water waves.

4. East Africa

East Africa has been experiencing more frequent and severe flooding, mainly due to heavy rainfalls and insufficient floodwater regulation infrastructures.

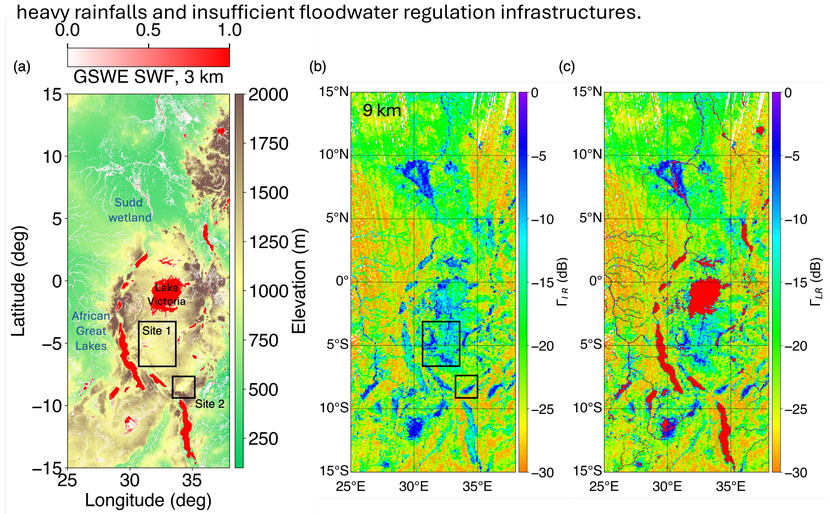
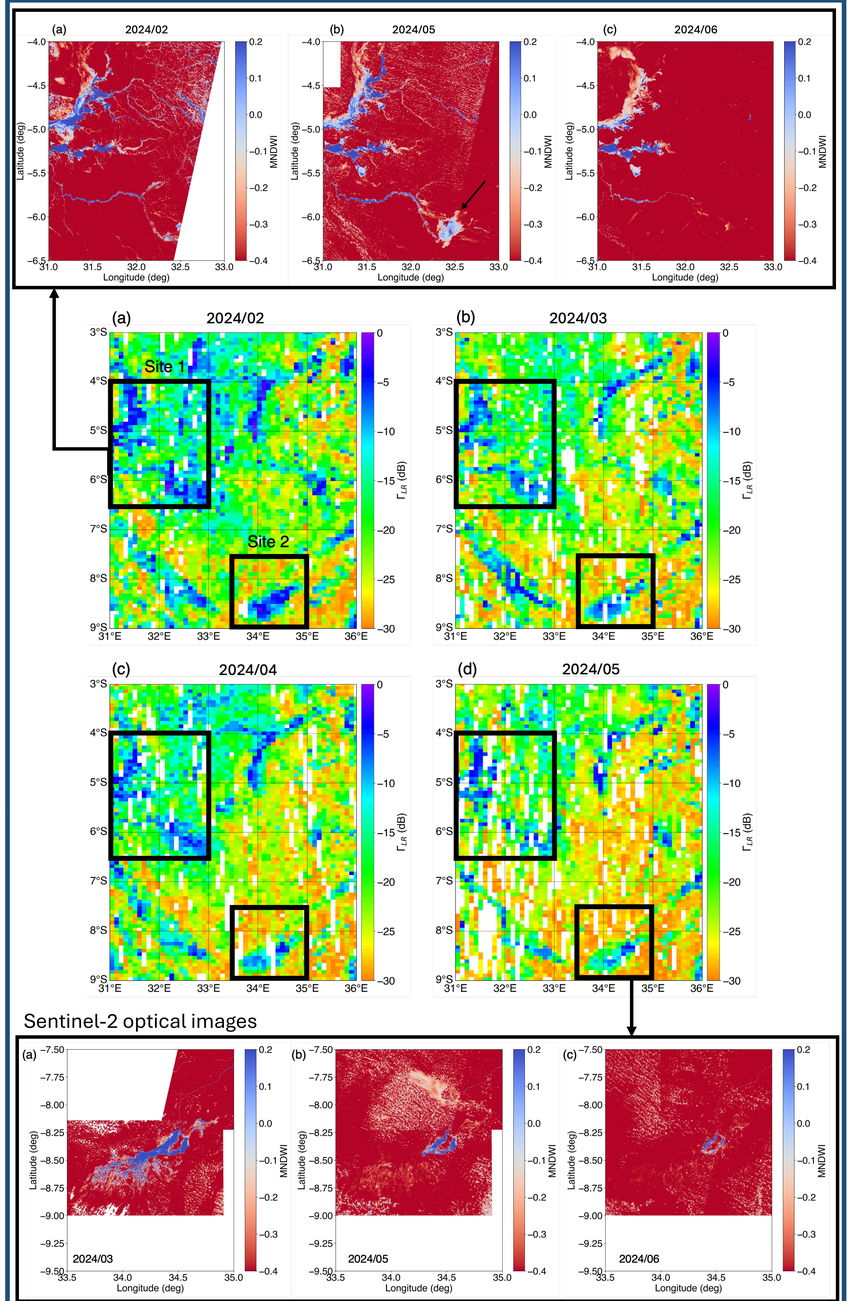


Figure 5: (a) shows the GSWE SWF map in East Africa superimposed on digital elevation map. Black boxes mark the study areas with soil inundation recession from Feb to May 2024. (b) presents the reflectivity observations that have been sorted to ensure the higher values are on top of the lower ones. (c) is similar to (b) but with SWF map.

4. East Africa: soil inundation drainage



Sentinel-2 optical images

Fig 6: temporal evolution of soil inundation drainage at study site 1 and 2.

Summary:

- Spire reflectivity observations are promising for mapping surface water extents and their temporal evolutions.
- A heuristic threshold of -15 dB can be determined to classify water from ground.

Acknowledgement:
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