# Intra-Session WG2 - Sensor performance & GNSS-IR notes

## GLOSS Group of Experts 2025, Panama

Link to sensors evaluation webpage by UHSLC: <https://uhslc.soest.hawaii.edu/foo/tech_analysis/landing.html>

Brief summary:

1. ~20 participants. Quick survey to have an idea of the level of knowledge. It turned out that one participant has direct experience with processing GNSS-IR data. There may be a need to seek expertise outside the GE (actually, this is how I joined the GE in 2001, for my expertise in GNSS data analysis for vertical land motion). Note that there exists an IAG WG on GNSS-R but dealing with a broader spectrum of applications.
2. The group then moved to discuss results reported from the literature & from the experiences reported by Argentina, Denmark and Norway. Questions were raised about the range or spectrum of phenomena that can be observed and the limitations, for instance, regarding the equipment (low-cost), antenna installation and its environment, sea-state conditions and data analysis methods. Overall, the discussions confirmed the interest expressed during the GE17 meeting. The GE should keep up with advances in this area and set up a WG or Task Force on GNSS-IR.
3. The discussion developed into the broad issue of sensor evaluation, in which GNSS-IR fits in, obviously. This issue appears to be a core “raison d’être” of the GE, similar to the OST/ST group on Satellite Altimetry that meets yearly to review technical evolutions in the observation of the sea surface from space. There is definitely a need to continuously review the technical advances in the area of in situ observation of sea level and share experiences.
4. The group did not address the question of the structure of the proposed WG and SubGroups or Task Force Teams, nor the Terms of Reference, but a possible approach is that Phil and myself draft a proposal and this circulates within the Steering Group, then across the whole GE. [Action Item]
   1. Three possible sub-working groups within an overarching “Instrumentation and Technology” working group:
      1. GNSS-IR
      2. Low-cost sensors
      3. Sensor comparison best practices

General expertise - a few people have tried in, several have awareness and are planning to look at it, some don’t know yet but are interested.

Two questions:

* Can GNSS-IR supplement other techniques for measuring sea level? Can it be used in places where other techniques are not feasible?
* Are the GLOSS data centres ready to include measurements from this technique? And what level? MSL? “Instantaneous” (e.g. hourly)? Real-time?
* How do we validate GNSS-IR data to assess its suitability?

Key links:

* <https://psmsl.org/data/gnssir/>
* Also <https://gnss-reflections.org/>

Guy Woppelmann provided a brief history of the technique.

Importance of Van de Casteele diagrams for quickly assessing the performance of a technique and finding is there’s biases at any particular point in the tidal cycle.

Two approaches to GNSS-iR

1. Spectral approach - the PSMSL approach
2. Using a least squares / Kalman approach - example given from A.Pira at AGU24

Fernando Oriero - results are never going to be exactly the same due to the specifics of the technique. This is an alternative, not a replacement. It’s not ready to replace traditional tide gauges, but has valuable uses, and there should ideally be a GNSS at the site anyway.

Guy Woppelmann - even with traditional gauges it’s important to know when sensors change.

Phil Thompson - experiences need to be documented. How does it handle wavey conditions, or perform if there’s a gradient in water level during a storm surge - will moving reflections measure the moving peak in water level? It’d be good to do extreme statistics on long term measurements, as there’s where there’s likely to be discrepancies.

Sergio - example of GNSS with good view of ocean but doesnt work for reflections as it’s too low. Fernando - yes, if its too low you dont have time to measure changes. With GNSS-IR you dont have the same frequency, you need to balance between better reflections for a higher gauge with rate of change. Guy - yes, you need ~20 minutes to measure changes.

Fernando calculates frequencies over a rolling 20 minute period, with recalculation every minute, so you do get a regular series

Kristine Larsson’s webpage lets you try out the technique by loading RINEX files, and you can get the code to do it yourself.

Oda - there’s gaps in the record where they’ve experimented - is it just the sites are too far north (Norway?). Perhaps it would work for MSL / tidal analysis, but not extremes

Glenn - Larsson 2013 had 80 fixes per day, is it better now? PSMSL page has fixes per day for each site. Guy - you’ve got to orient the antenna correctly - there’s a need for resources.

What’s available on PSMSL - high frequency and daily means. Fernando suggests for hourly means / higher you can have a running means - we need to experiment with different processing procedures. There’s regularly papers published with new procedures and we need to keep up with them.

Per - need to come up with ways of interpolating gaps, especially in locations like Greenland.

Guy - worth pointing out not all GNSS sites record the signal-to-noise ratio so you can’t do GNSS-IR there - please record it!

There’s still unknown biases that need investigation - e.g. Oda, relating to equipment. Perhaps set up a test site with lots of different sensors to investigate?

Different atmospheric conditions can cause different biases - antenna phase centers can also be different. Need to investigate how bias changes with time. Fernando has found fitted constituents can vary in phase, so we need to be very careful.

Phil - an example of sensor comparison at Makai Pier, nothing too sophisticated but an example approach. It’d be good to come up with a common set of approaches to testing new sensors in different environments. It’s a test to see if a radar inside a stilling well is fine or does it bounce off the sides? (Vega C23 narrow beam)

Method - remove the time means to roughly line up datums, do a tide prediction on the median height at each timestep to get residuals.

* Do a lag correlation between the test sensor and other sensors
* Choose a reference sensor (one of the pressures, so no surface issues) - plot difference between each sensor and the reference one. Scatter gets larger when there’s more waves. Shows there’s less variance in the stilling well. Can also see how internal averaging of radar can affect extremes - distinct clipping of extreme values.
* Also histograms of sensor - reference. You can see it’s symmetric vs the one in the stilling well, but those outside the stilling well are skewed.
* Also look at hourly and daily averages. Surprisingly there’s differences, only ~1cm, so not large, but not negligible.

Glenn - has the alliance for coastal technologies got any similar methods? Should we work with them?

Fernando - IHO has similar interests. Risk involving manufacturers is that you might be approving a subset of manufacturers but not others - could be commercial implications.

How can we share our experiences without necessarily making recommendations? Just state facts / results and let people draw their own conclusions?

Guatemala has a project to compare sensors - just radar vs acoustic due to restricted budgets. It would be very helpful if other organisations can share information about other sensor types.

No reason why GNSS-IR sensors / algorithms should be treated any differently, we can use the same kind of approaches.

Phil’s happy to share the examples he’s shown. Question - are they a clean signal in deep water or are there influences from shallow water / coral reefs? Sensors are at the end of a pier - there is a bit of a blockage from swells by a berm, but it’s quite wavy, and quite well exposed to deep water.

Come up with a set of recommendations for comparing sensors. Is this a best practice? Also could include ways of testing individual sites (e.g. firing radars off a steel plate to check measurement point?)

**Action item - sign up google document for people who are interested in this exercice**

**GNSS-IR might be a subgroup to help people try it out?**

**Perhaps low cost sensors subgroup too?**

Is there also scope for low cost GNSS alternatives too? (e.g. NOC alternatives, Argentina mobile phone examples)