Affordable GNSS PPP Results as Constraints for Pressure Time Series Offshore

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Introduction

- This work shows how we utilized affordable GNSS receivers on an uncrewed surface vehicle (USV) to constrain pressure time series data

- The future goal is tidal datum transfer at offshore locations

Septentrio Mosaic X5 development kit with antenna (<$1300)

SIRIUS RTK GNSS Drotek (<$500)

Introduction

This presentation focuses on:

1. A new tidal-datum transfer technique at offshore locations

2. Water level measurements and accuracy attainable using affordable (< $2000) GNSS PPP as constraints to the pressure time-series

Why we care about tidal datums offshore?

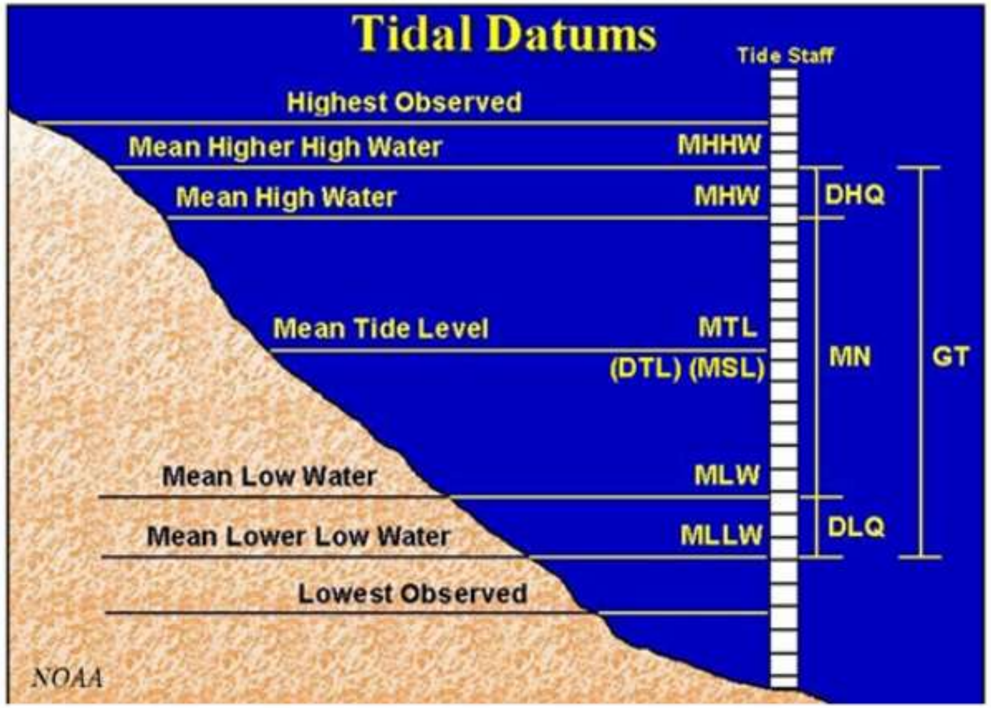
- Chart datum as vertical reference in some offshore applications

Examples:

- Encumbrance to safe navigation
- Engineering installations on seafloor

Ellipsoid

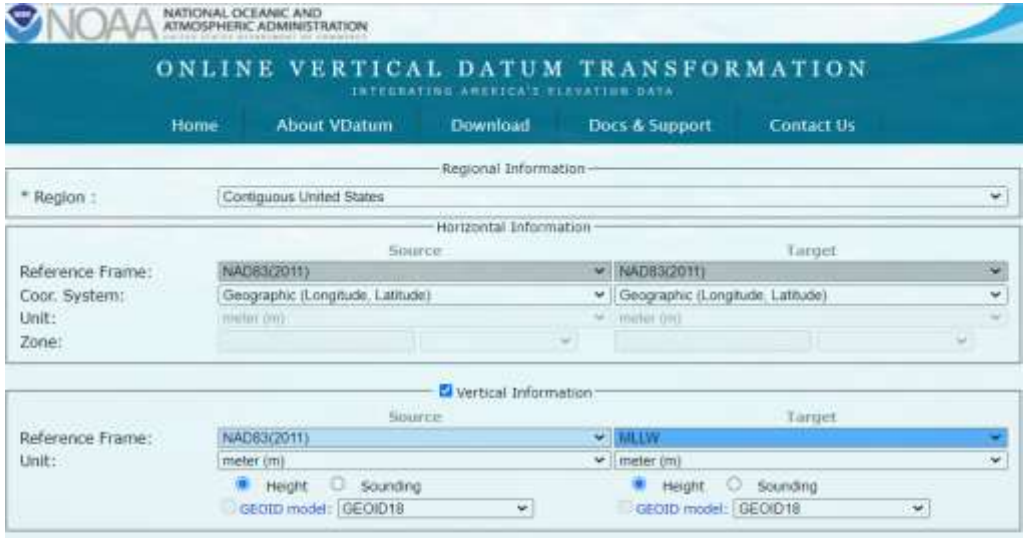
CO-OPS Representation of Tidal Datums



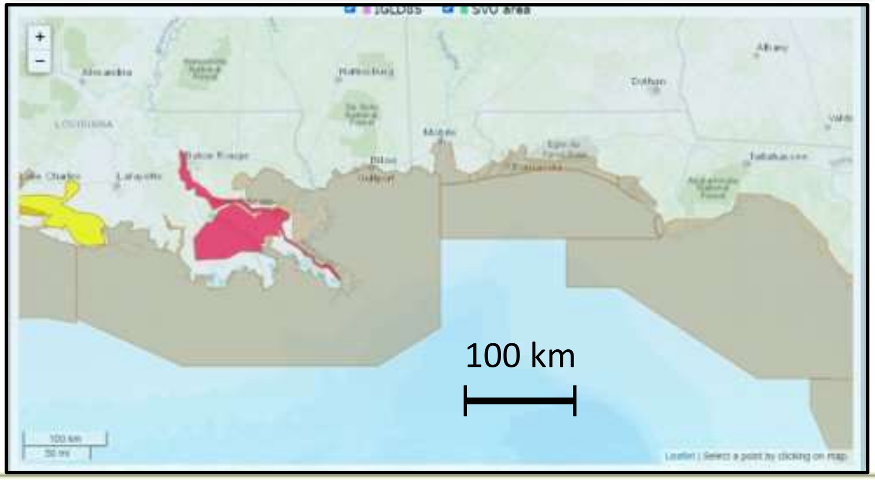
https://tidesandcurrents.noaa.gov/datum_options.html

Offshore tidal datum

- NOAA's Vdatum model extends up to ~200 km offshore
- The model provides seamless transformation between 36 different vertical reference system
    - ellipsoidal, orthometric, tidal, etc.



https://vdatum.noaa.gov/



The problems

- There are large uncertainties (~30 cm) at some locations
- Water level measurement is required at offshore locations to improve the model
- Nearshore tide stations installation types are not ideal offshore
- Vandalization of sea-surface deployments

Requirements for tidal datum transfer

1. A long-term primary gauge (control) with 19-year datums

2. A short-term gauge (subordinate); the location where tidal datums are required

3. Simultaneous observation at the control and subordinate gauges at least for 30 days

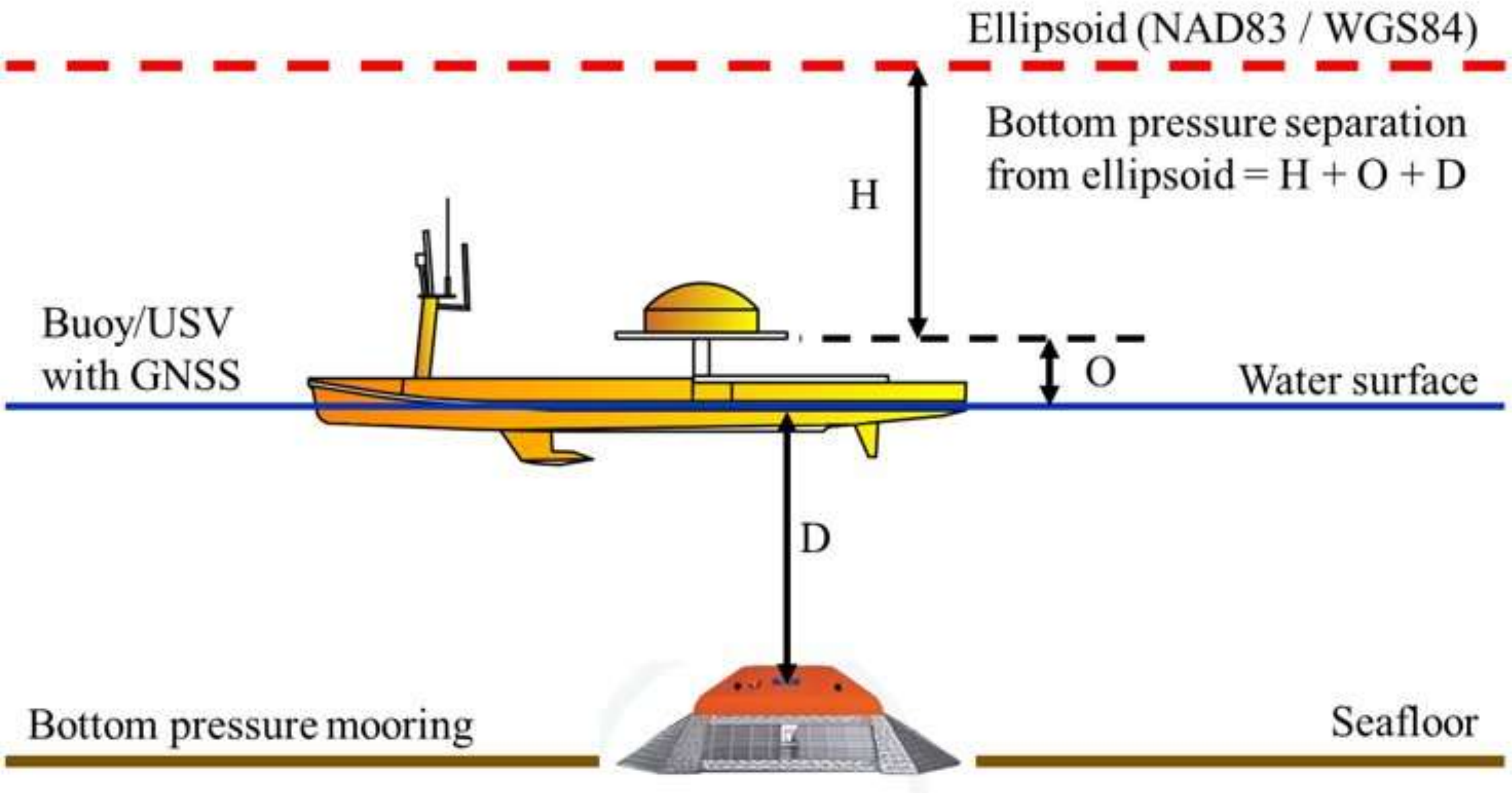
Q1: How do we address the water level requirements offshore?

Q2: What accuracy is possible with affordable GNSS receiver in PPP strategy?

Q3: Do we need a tilt / motion sensor / GNSS+INS for high accuracy ?

The new offshore concept

Collocated sea surface and seafloor observation for > 30 days



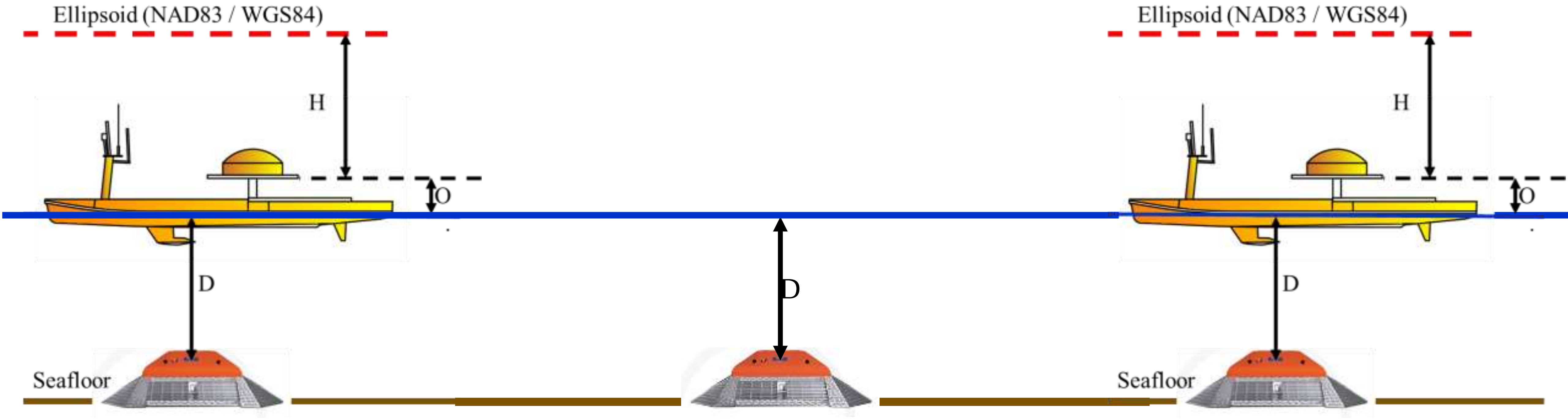
H: ellipsoidal height
O: water surface offset from GNSS antenna
D: seafloor depth

A USV (uncrewed surface vehicle) / a buoy platform equipped with GNSS receiver tracking data at 1 Hz

Hardware	Description
Applanix POS-MV	GNSS+INS
Septentrio Mosaic	GNSS receiver
RBRconcerto	CTD
RBRquartzQ	Paroscientific DigiQuartz pressure sensor 55 dbar
ADCP	Teledyne/RDI

The new offshore concept

Collocated sea surface (≤ 1 day) and seafloor observation (≥30 days)

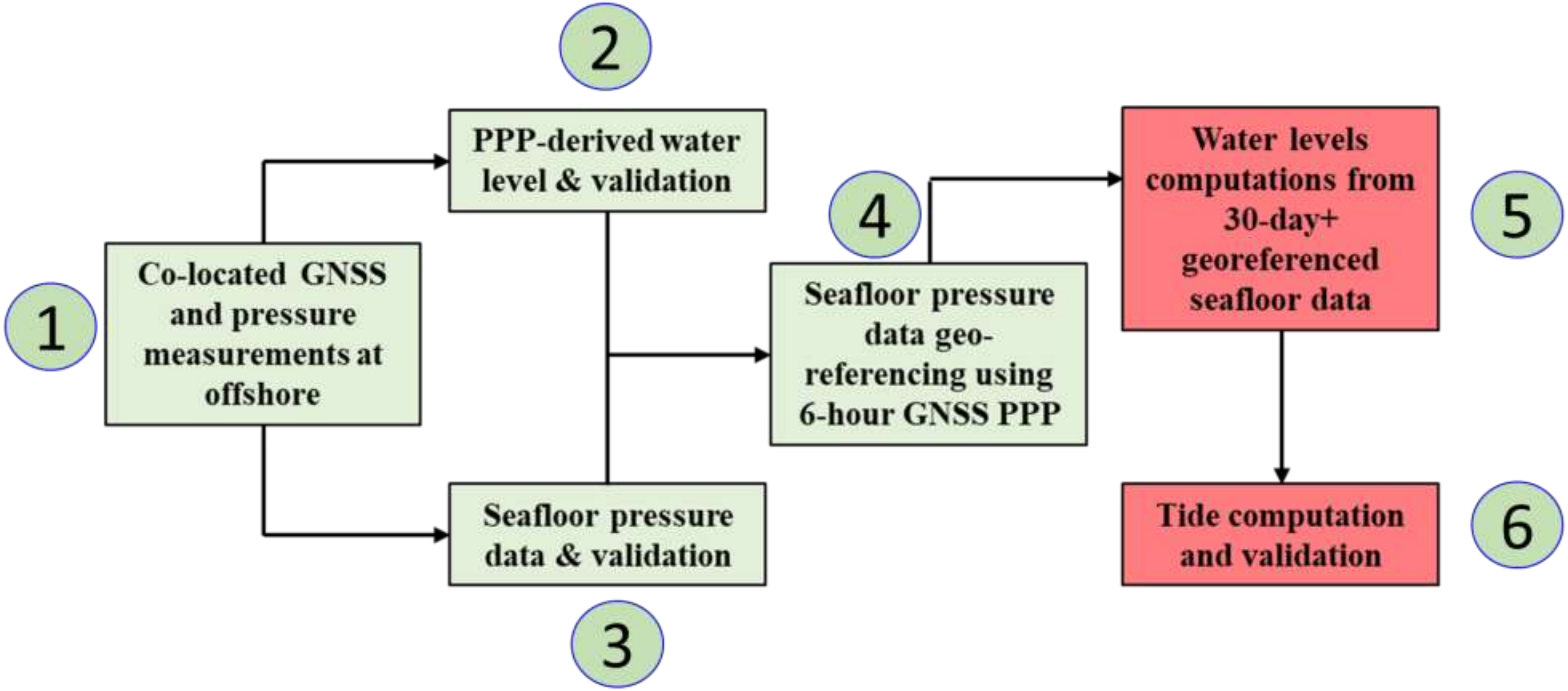


Start :
collocated observations: (≤ 1 day)

Seafloor observations (≤ 30 days)

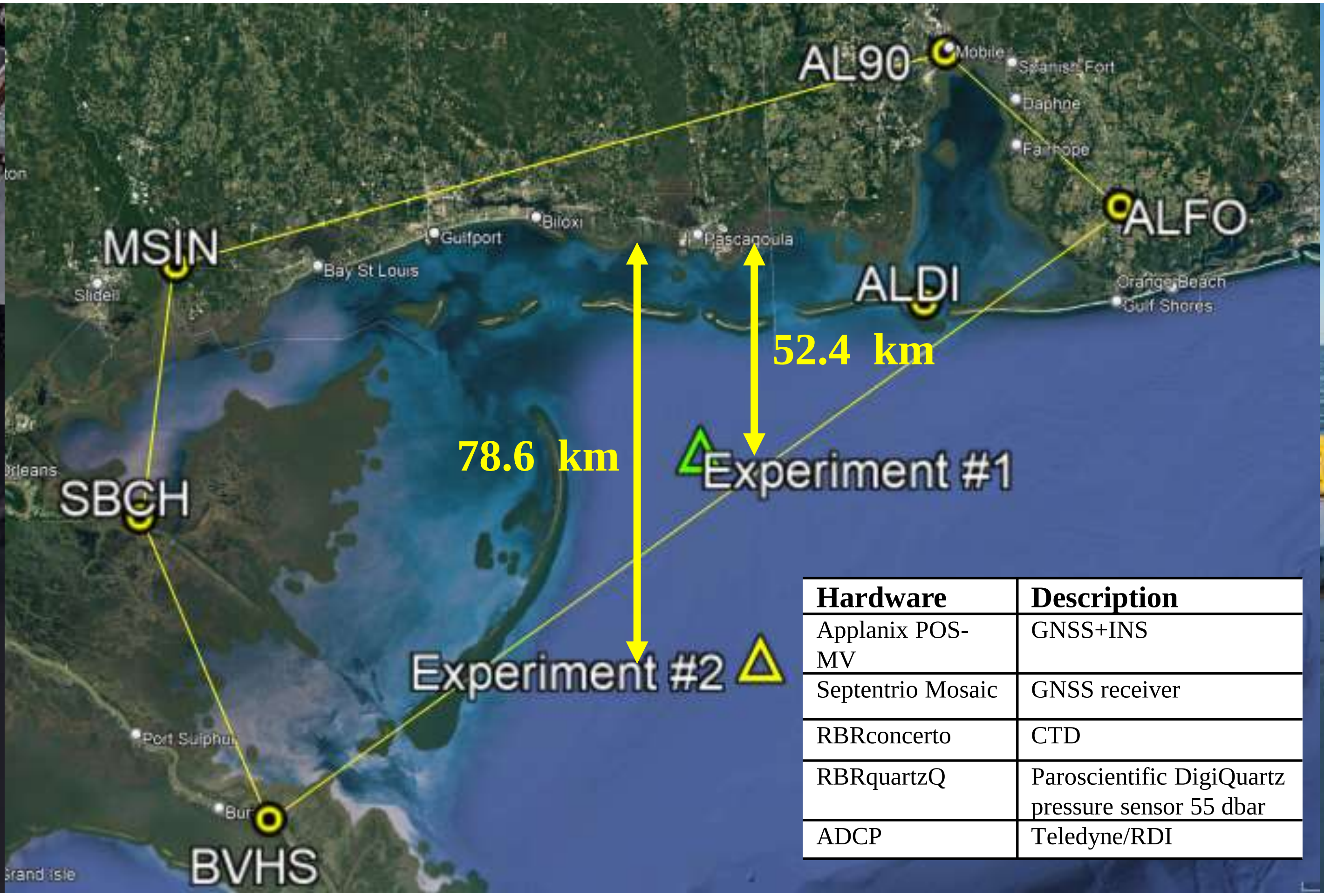
End:
collocated observations: (≤ 1 day)

Experiment design



Tasks highlighted in red will be covered in a future publication

Experiment design



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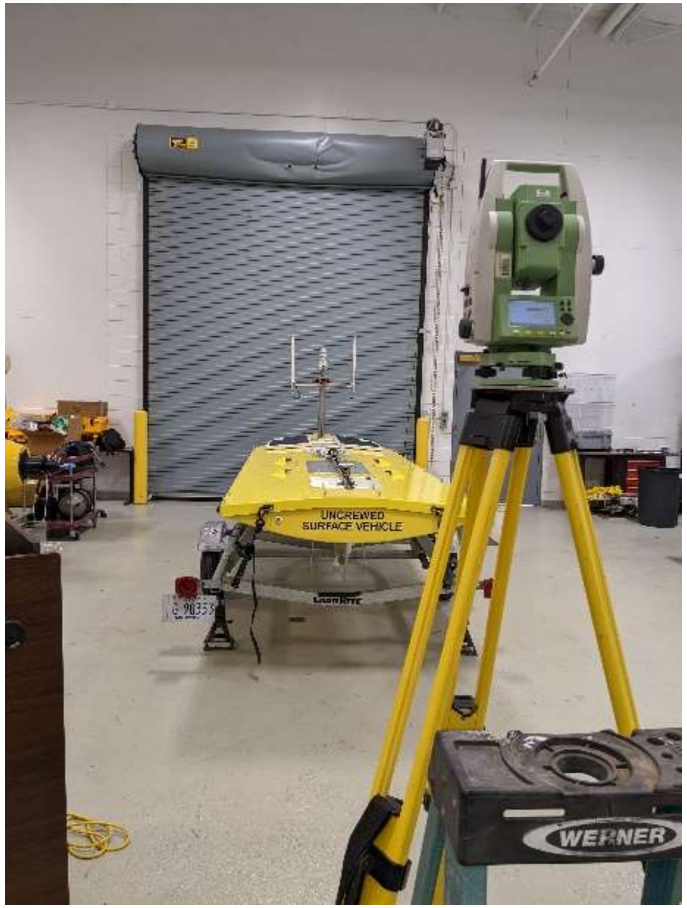
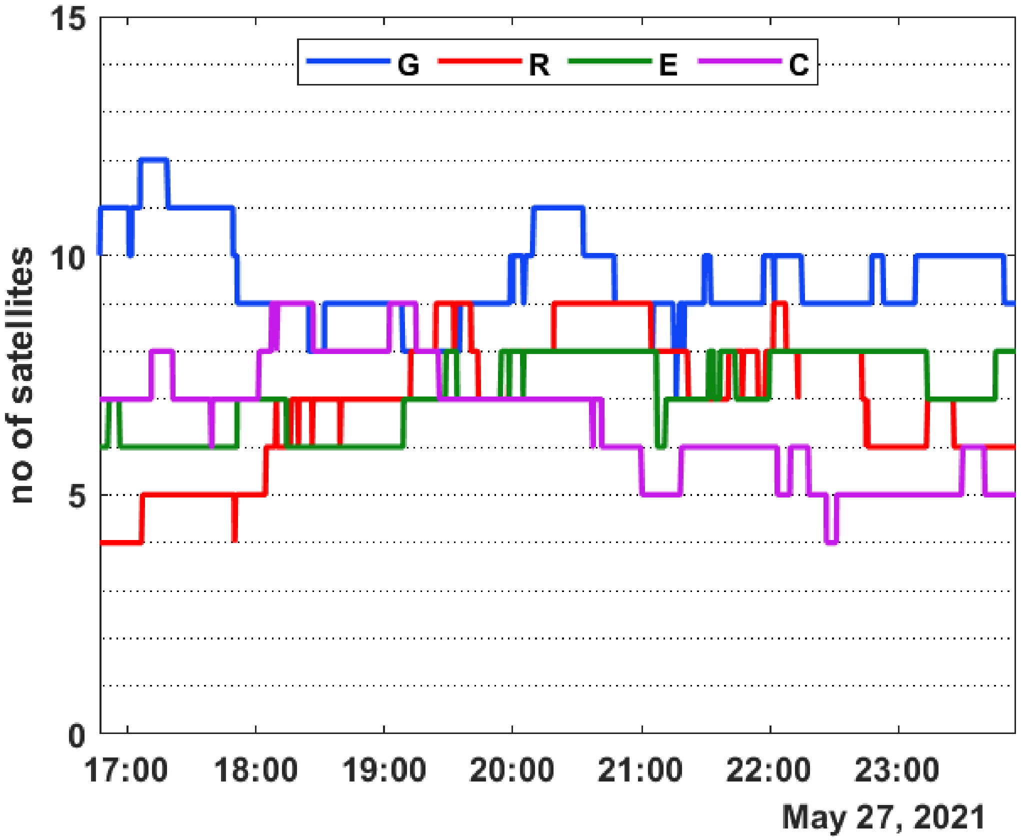
Experiment design

Experiment #1: Offsets/lever-arm measurement with tape

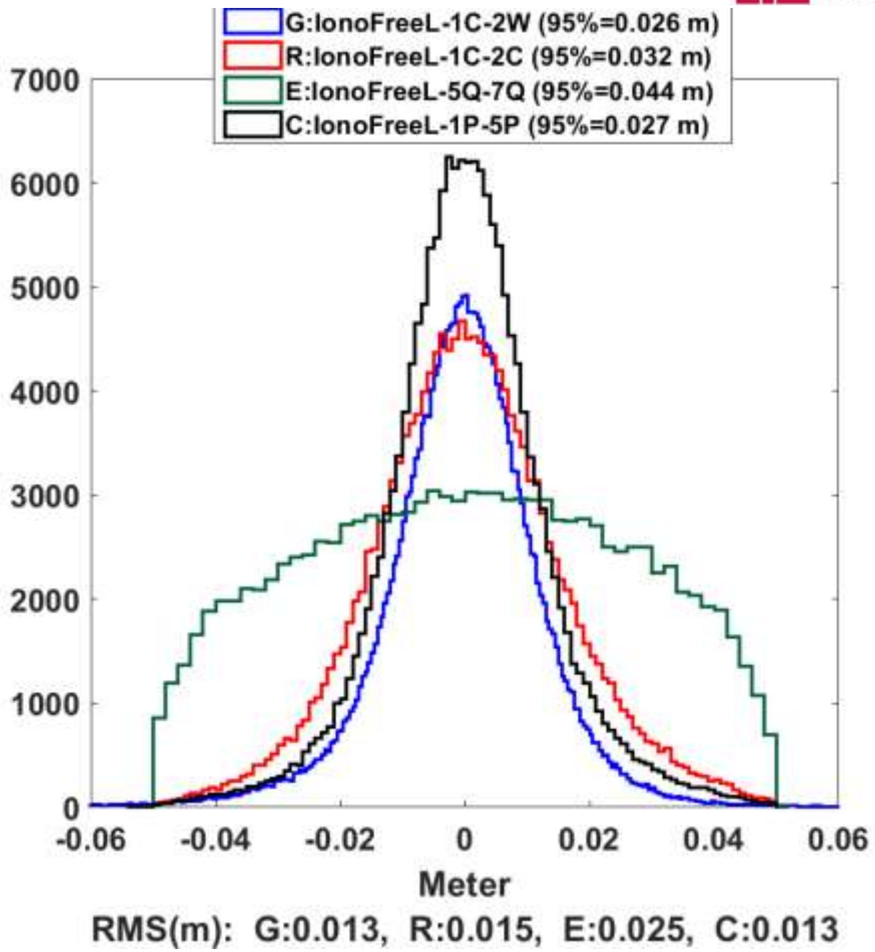


Experiment #2: Offsets/ lever-arms measurement with total station

PPP solution quality



Number of satellites included in GipsyX PPP solution



Carrier-phase residuals uncertainty

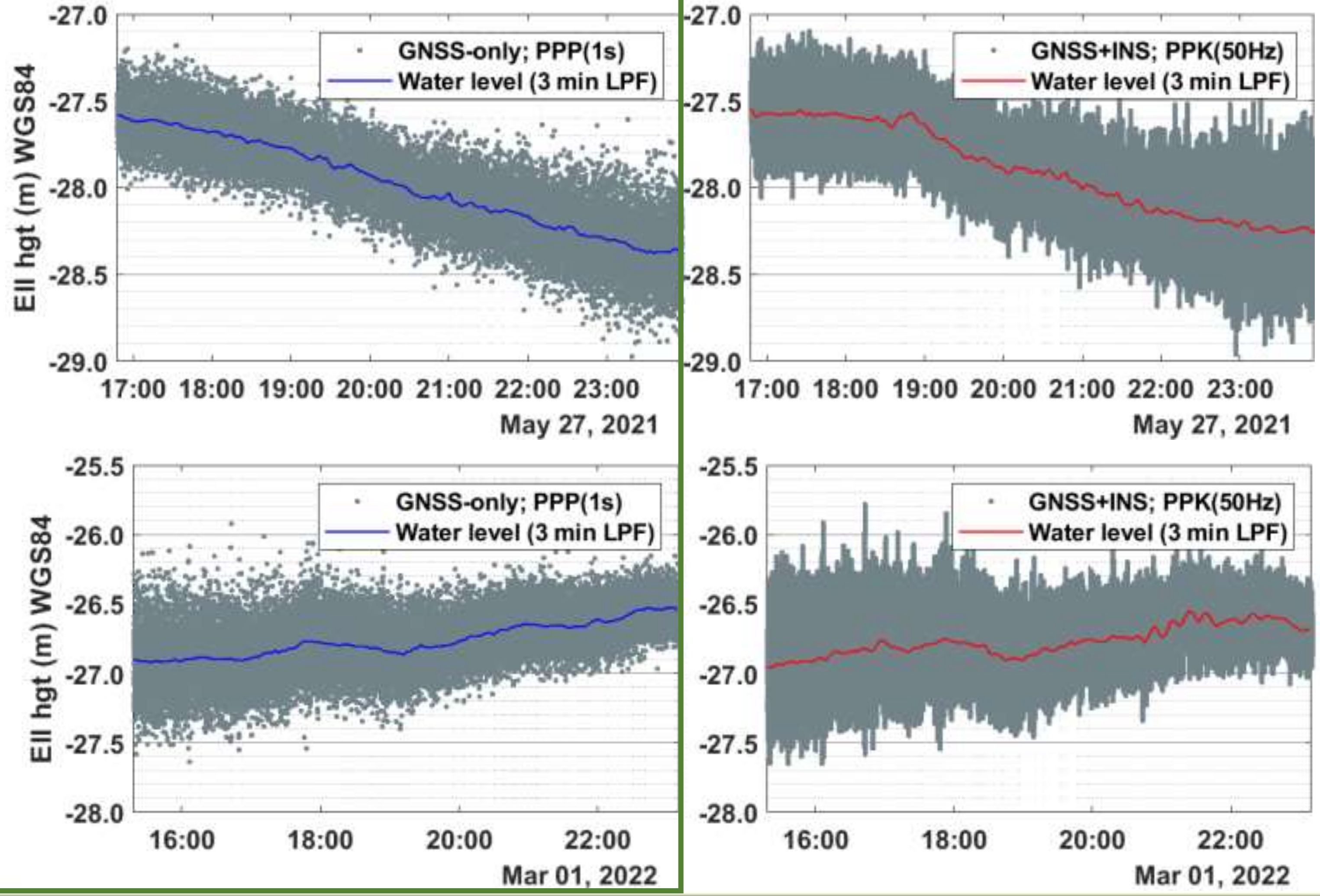
Affordable versus survey-grade GNSS+INS

FIG Orlando Working Week 2023

Affordable GNSS | Survey-grade GNSS+INS

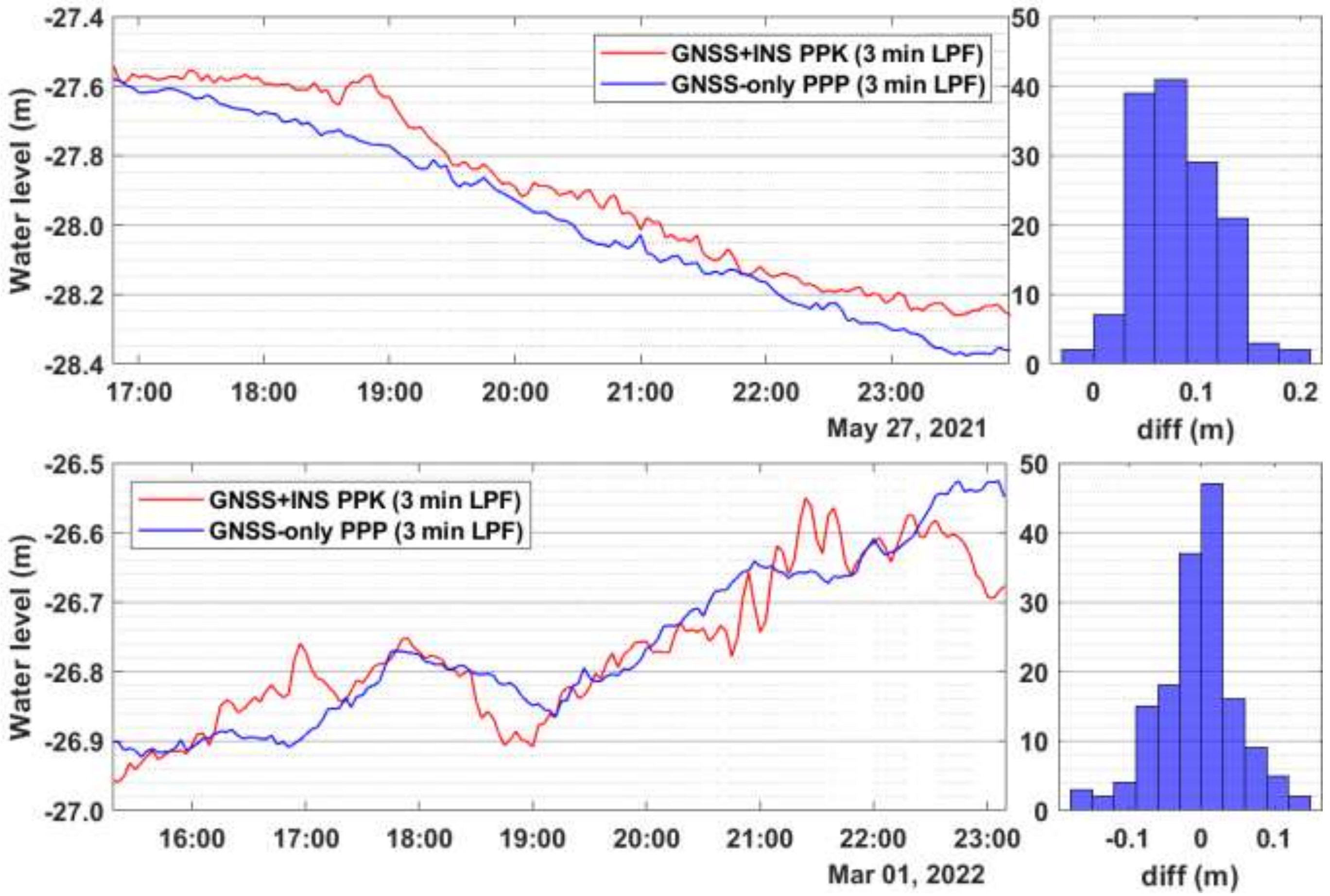
Location 1

Location 2

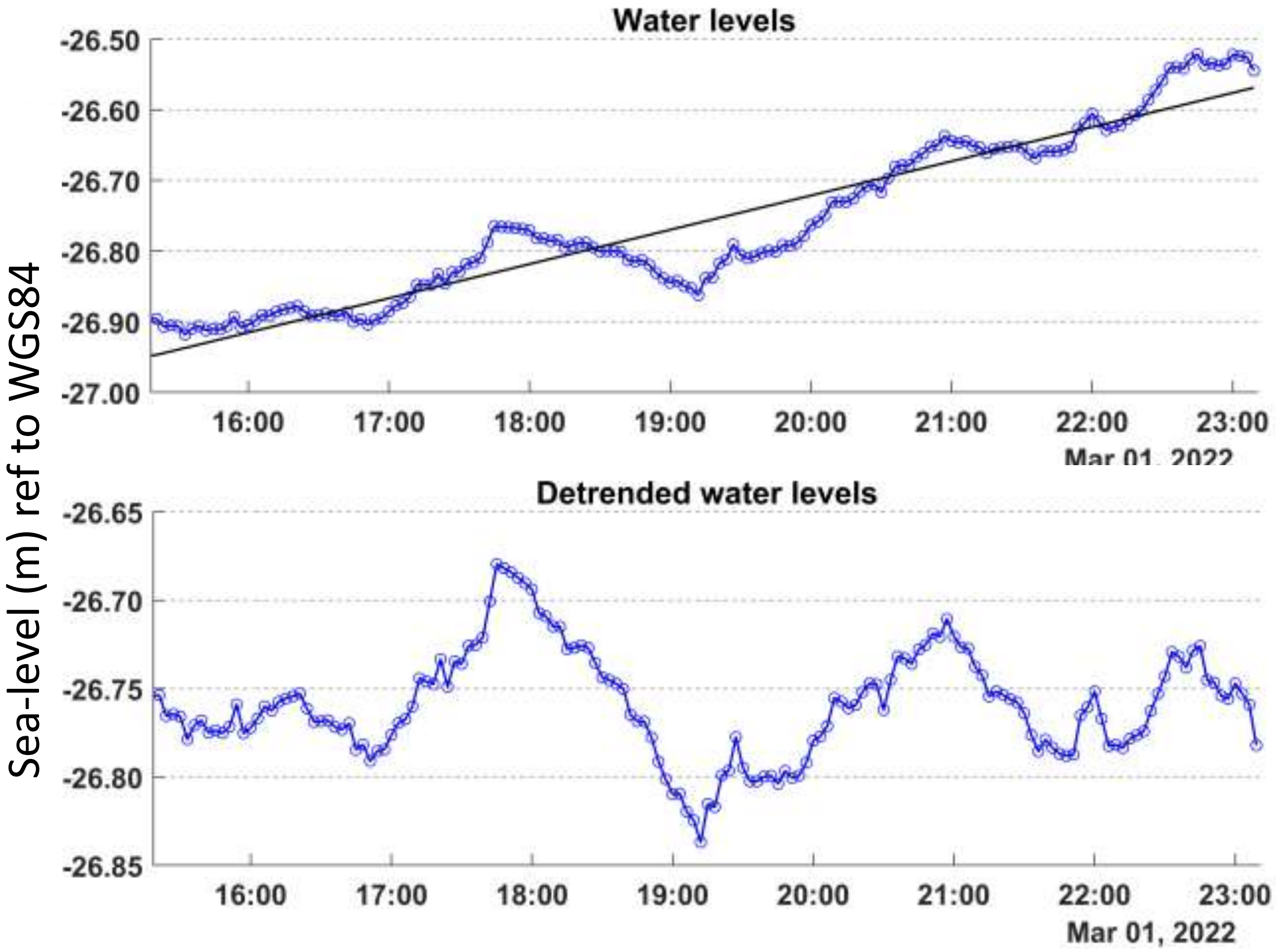


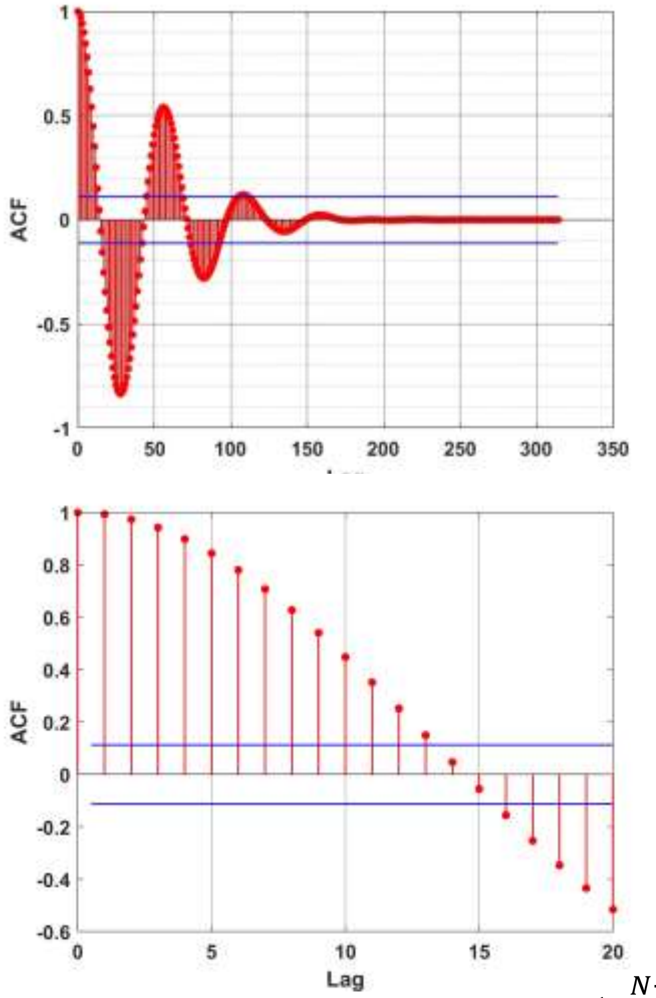
Affordable versus survey-grade GNSS+INS

	GNSS-only PPP versus GNSS+INS PPK (m)			GNSS-only PPP (induced heave applied) versus GNSS+INS PPK		
	mean	1-sigma	95%	mean	std	95%
Exp #1	0.079	0.039	0.141	0.079	0.039	0.142
Exp #2	–0.005	0.054	0.120	–0.010	0.054	0.114



MSL estimation



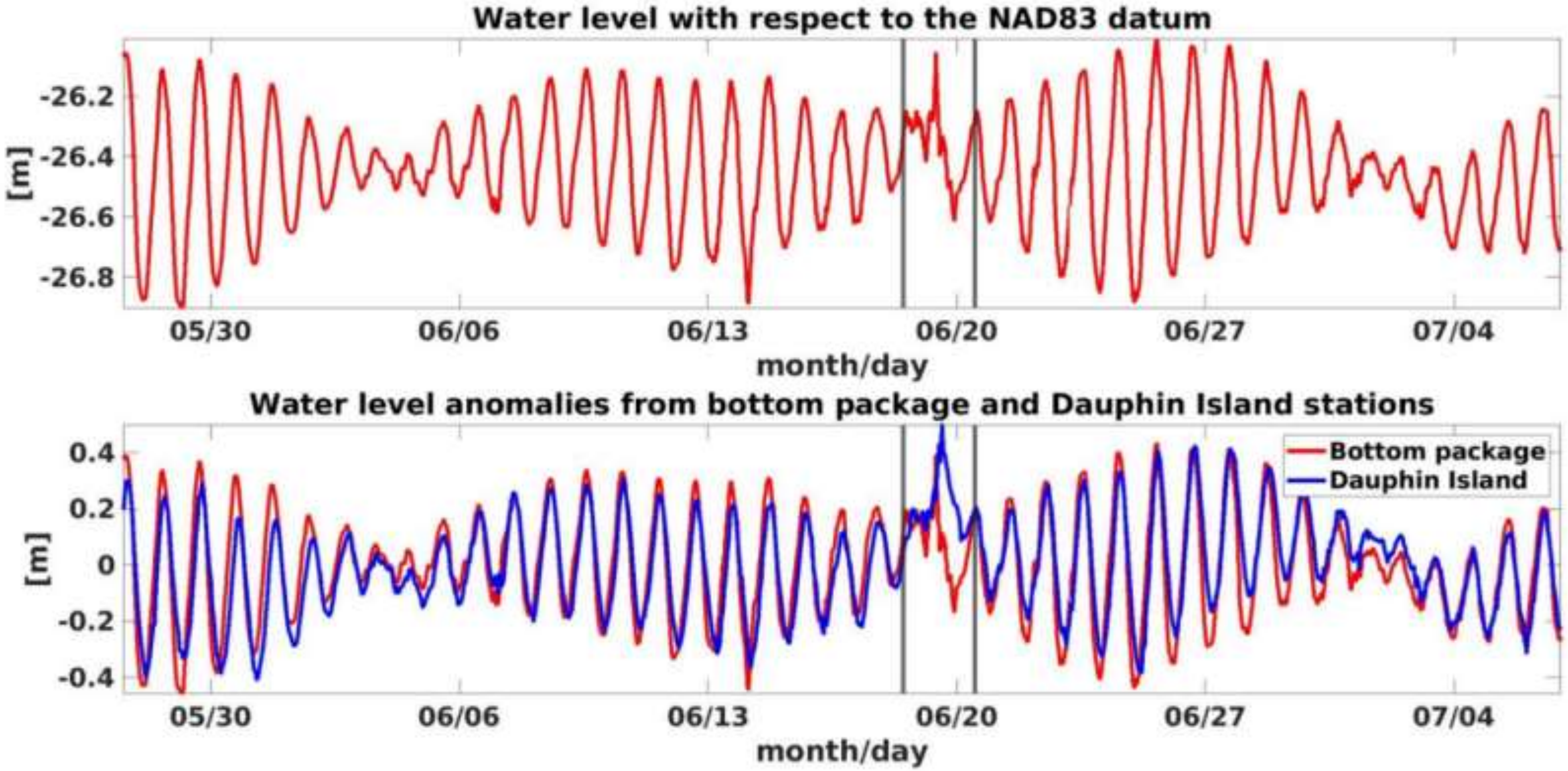


$$r_k = \hat{\rho}_k = \frac{c_k}{c_0} = \frac{autocovariance}{variance}$$

$$c_k = \hat{\gamma}_k = \frac{1}{\text{N}} \sum_{t-1}^{N-k} (z_t - \bar{z})(z_{t+k} - \bar{z})$$

Water level time series

NAD83



Dauphin Island tide station

WGS84

	Induced heave corrected			Induced heave uncorrected		
	MSL (m)	1-sigma	95%	MSL (m)	1-sigma	SEM
Experiment #1	–27.979	0.021	0.006	–27.979	0.021	0.006
Experiment #2	–26.759	0.030	0.009	–26.764	0.030	0.009

Established: Mar 30, 1966
Present installation: Aug 08, 1985

*SEM: standard error of mean

Summary

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Q1: How do we address the water level measurements offshore?

- Deploy sea-surface GNSS hardware and seafloor pressure sensors

Q2: What accuracy is possible with affordable GNSS receiver in PPP strategy

- 5-cm uncertainty (1 σ), provided PPP processing follows best practices

Q3: Do we need a tilt / motion sensor for high accuracy

- It is unnecessary, provided the antenna lever arm is less than 0.5 m

Future work

- Detail analysis of seafloor dataset
- Water level computations using the GNSS-constrained seafloor dataset
- Datum extension computation and validation

*SEM: standard error of mean

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Affordable GNSS PPP Results as Constraints for Pressure Time Series Offshore

Johnson OGUNTUASE, Uchenna NWANKWO, Stephan HOWDEN, USA

Keywords: affordable GNSS, GNSS buoy, PPP, RTK, Vdatum, water level, GNSS buoy

SUMMARY

This paper discusses offshore water level measurements and the accuracies possible using affordable GNSS receivers (<$2000). The goal is to develop an affordable and straightforward technique capable of continuous and accurate water level measurements at remote locations towards addressing the uncertainties inherent in the tidal datum transformation model offered by NOAA's Vdatum. This technique can be used either directly for tidal datum transfer when 30 plus days of GNSS data acquisition is possible or in short-term simultaneous observations with a seafloor-mounted pressure gauge to reference the longer term (30+ days) pressure time series to the ellipsoid before tidal datum transfer is performed. We applied precise point positioning (PPP) results from an affordable GNSS receiver to constrain pressure sensor measurements to the ellipsoid. Limiting Vdatum uncertainties below 10 cm at a 95 % confidence level would require that GNSS height uncertainties be less than 5 cm in the error budget. It is then desirable to investigate the order of PPP vertical positioning accuracies possible with such a receiver on a dynamic platform at sea. We conducted two experiments at different locations offshore using GNSS+INS sensors to validate the affordable PPP vertical positioning results. The GNSS+INS sensors in the post-processed kinematic (PPK) strategy validate the affordable PPP vertical position results. We note that the second experiment's results are more consistent than the first following accurate lever-arms measurements for the GNSS antennas installed on an Echo boat (small uncrewed surface vehicle). Comparing water level moving averages between the two processing strategies shows a mean difference of 4 cm. That result compares instantaneous GNSS heights from the affordable receiver without accounting for induced heave, suggesting that attitude measurements at sea for short lever arms are negligible. Briefly discussed is the preliminary validation of the tidal datum determination offshore using the affordable vertical positions as the constraint.

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Thank you!

Questions?