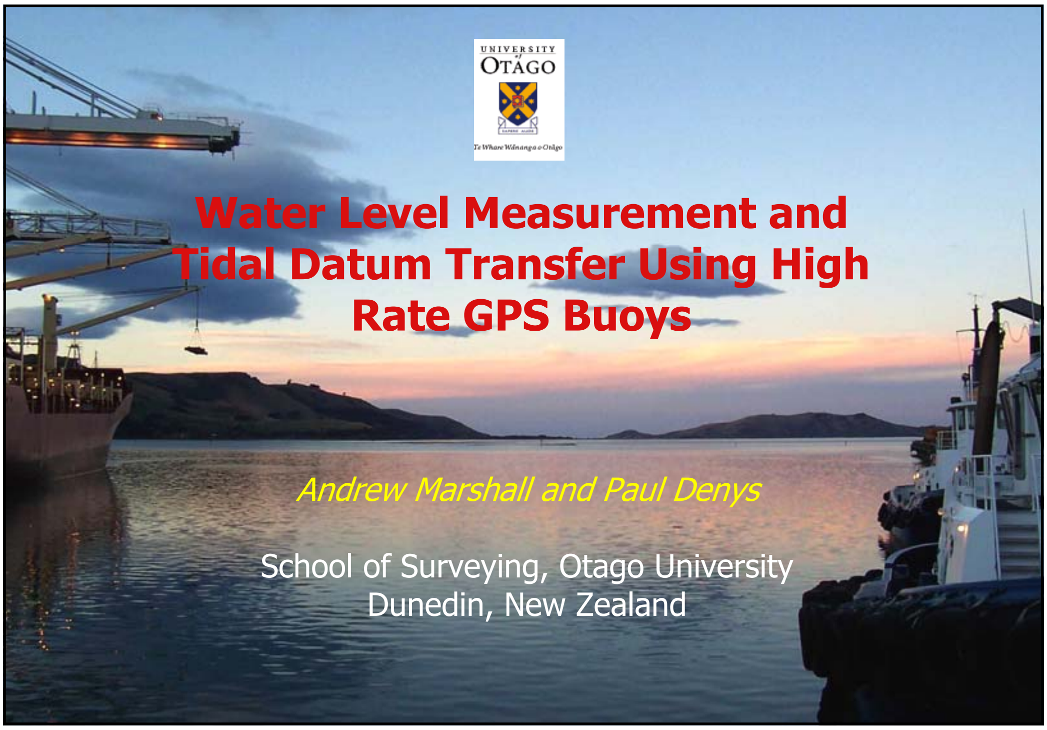

Water Level Measurement and Tidal Datum Transfer Using High Rate GPS Buoys

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Introduction

Importance of Tidal Datums:

- Reference for navigation charts (CD) and
- Height datums (MSL)
- Coastal cadastral boundaries (MHWS and MHW)

Research Problem:

- Traditional tidal datum methods/equipment have limitations:
  Accuracy Efficiency Cost
- Two general methods:
  1. Levelling – Terrestrial/GPS
  2. Tidal Datum Transfer Procedures
- GPS buoy technology offers unproven potential

Objectives

Previous Research

- Ability to measure water levels <1 cm proven
- But – little previous research investigating the viability of using light weight GPS buoys to transfer tidal datums

Research Objectives

– *Primary:* To verify the ability of a high rate GPS buoy to measure sea levels compared to a tide gauge
  - To determine the precision of the GPS buoy measurements relative to the tide gauge
  - To determine the accuracy able to be achieved by examining the bias between these two systems

– *Secondary:* To demonstrate the accuracy that a tidal datum can be transferred using the sea levels estimated from GPS buoys.

Introduction

- Location
  – Existing tide gauges
  – ≈ 11km apart

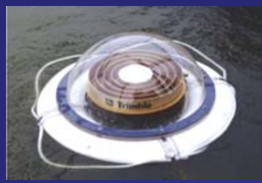
- Tangible Benefits:
  – Easy data collection
  – Coastal cadastral boundaries
    - Increasing pressure on coastal development
    - Rising sea levels
  – Efficient tidal datum transfer

GPS Buoys – Background

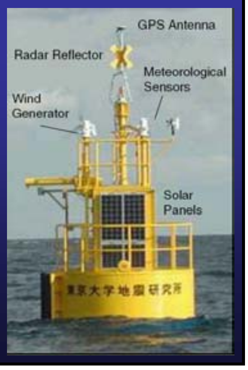
GPS Buoy Designs

- 3 common types:
  1. Lightweight wave rider
     - Antenna only
     - Tethered

  2. Autonomous lightweight wave rider
     – Houses receiver, antenna, battery

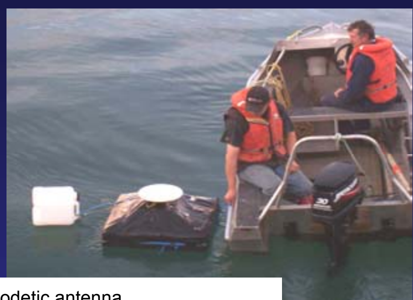


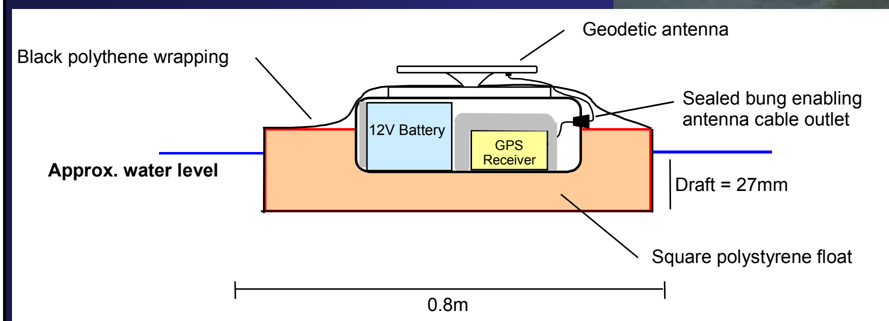
  3. Autonomous, large scale
     – E.g. Tsunami monitoring



GPS Buoy Construction

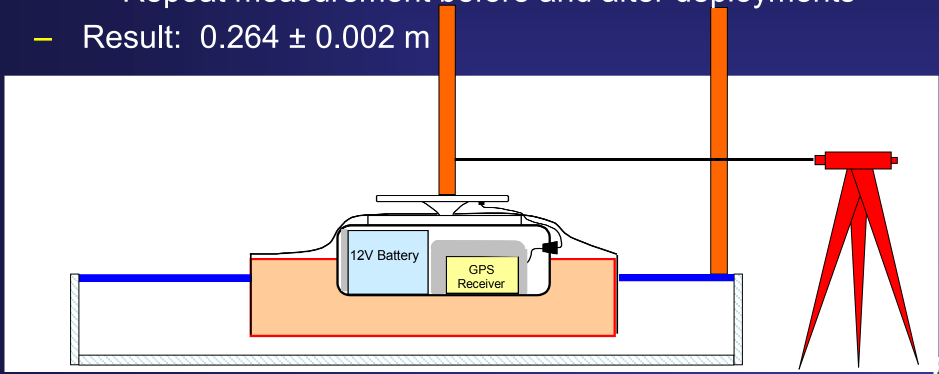
- Considerations
  – Water proof
  – Antenna height above water
  – Tethering





Antenna Height Offset

– Tank filled with fresh water
– Spirit levelling with lightweight measuring rod
– Measurement between
  • Top of Antenna + Water Level BM
  • Repeat measurement before and after deployments
– Result: 0.264 ± 0.002 m



GPS Buoy Deployments

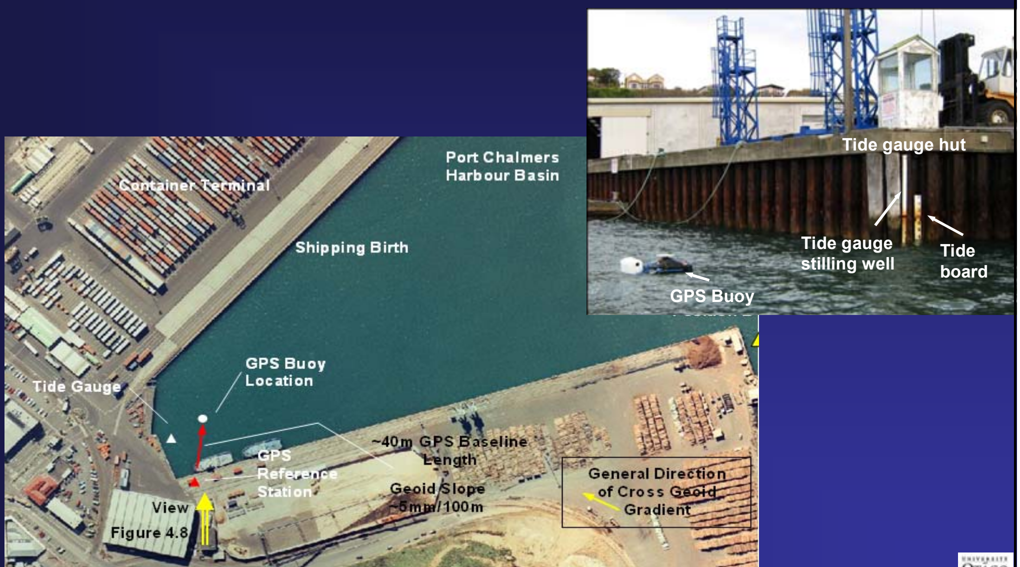
• Simultaneous locations
  – Port Chalmers + Dunedin Wharf
  – Existing tide gauges
  – ≈ 11km apart

• Observation Parameters:
  – Sampling Frequency
    • 5 second epochs
  – Period – approx 4 days
  – Weather – Extremes

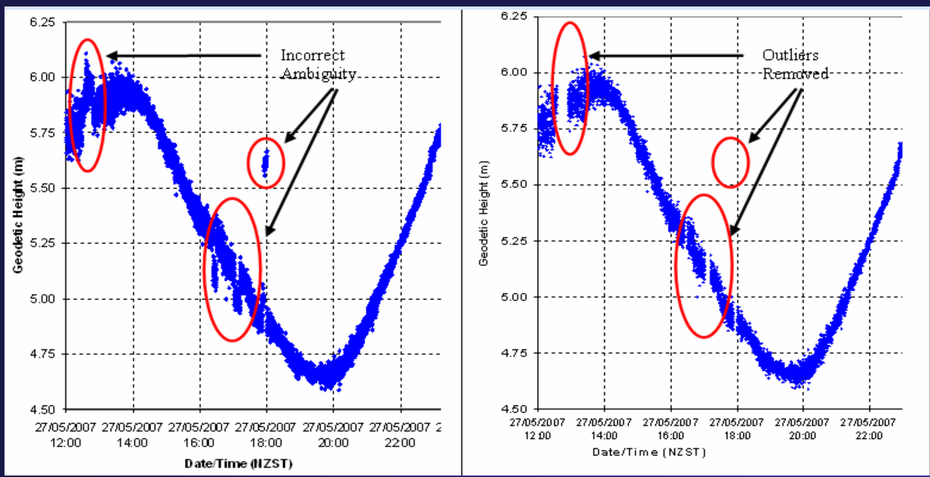
• GPS Processing
  – Outlier Removal

Port of Dunedin

Port Chalmers



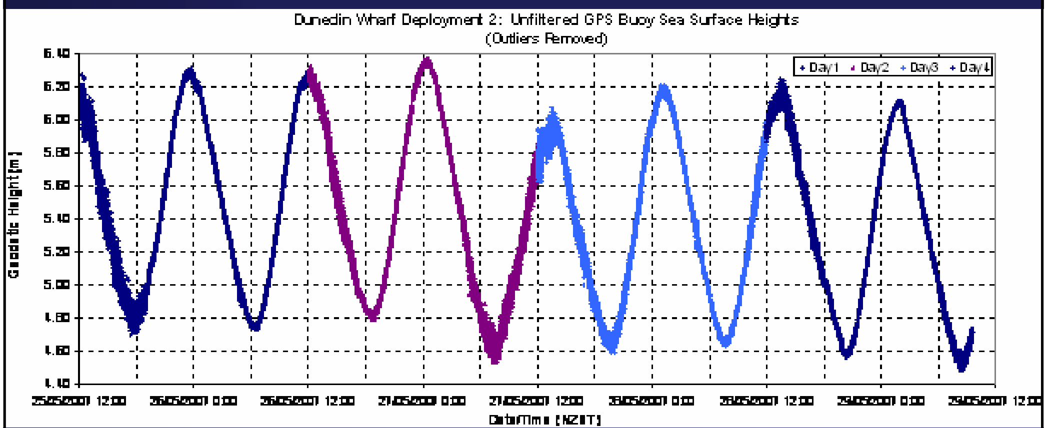
GPS Buoy Sea Surface Heights



With Outliers | Outliers Removed

GPS Buoy Sea Surface Heights

- Unfiltered time series

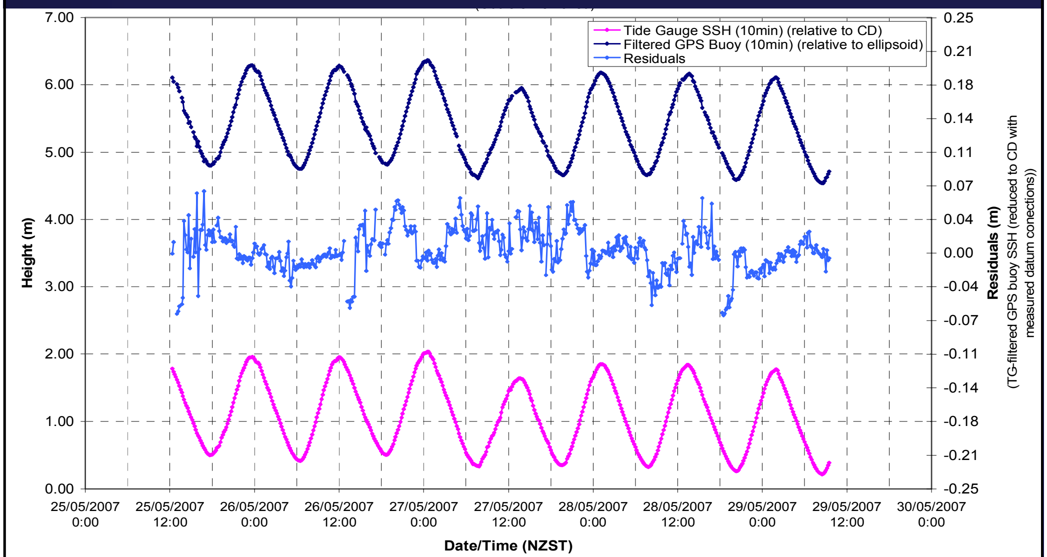


Data Analysis

Verification of the GPS buoy sea surface heights

- Clean Data
- Filtering 10 minute filter length
- $Difference_{TG-GPSBuoy} = TG_{SSH} - GPSBuoy_{FilteredSSH}$
- Results :
  - Height Precision
  - Bias

Tide Gauge – GPS Buoy Comparison



GPS Buoy – Tide Gauge Precision

Deployment	Sampling Rate	Observation Period	rms 1 σ (mm)	rms 95% (mm)
Dunedin Wharf 1	1 sec	~ 24 hours	±17	±33
Dunedin Wharf 2	5 sec	~ 4 days	±23	±43
Port Chalmers 2	5 sec	~ 3.75 days	±24	±47

- *Measurement precision:* *~ ±2 cm level*
- *Comparison to Previous Research:*
  - *~ ±1 cm higher*
  - *Reason unknown, but could be due to a rough sea state*

Geodetic to Chart Datum Offsets

	Deployment:	Dunedin Wharf 1	Dunedin Wharf 2	Port Chalmers 2
	Sampling rate:	(1 sec)	(5 sec)	(5 sec)
Chart datum to ellipsoid offset	Known Datum Offsets (m)	4.322	4.322	4.450
	Measured Datum Offsets (m)	4.309	4.319	4.443
Bias: (Reduced to chart datum)	**Difference (m)**	**+0.013**	**+0.003**	**+0.007**

Data Analysis

<u>Tidal Datum Transfer</u>

- Range Ratio Method used
  - *"Ratio between the known, long-term tidal range and the observed tidal range is the same at both the control and subordinate stations"*
- $Ratio : \frac{MWHS}{mhws} = \frac{MR}{mr}$
- High/Low point determination:
  - Polynomial curves fitted to unfiltered GPS heights
- Observation Period: 3 days

MHWS datum

- *Comparison of the MHWS datum transferred to nearby BM*

Control to Subordinate Stations	Dunedin to Port Chalmers	Port Chalmers to Dunedin
MHWS datum transferred (m above CD)	2.153	2.170
Long-term MHWS datum (m above CD) (LINZ, 2007)	2.144	2.184
Difference:	**-0.009**	**+0.006**

- Comparison to datum transfer study using these tide gauges:
  - Mean difference: 10 ± 21 mm
  - Similar level of accuracy

Implication of Results

- Use in Determining Coastal Cadastral Boundaries
  - Particular estuarine areas with high value land
- Perceived Advantages:
  - **Efficient datum connections** between the GPS buoy and benchmark
    - Eliminates the need for levelling to the tide gauge/staff
  - **Efficiency and time saved in data collection**
    - No manual observations required.
  - **Existing GPS equipment** as owned by a typical surveying firm can be used in combination with **cheap readily available materials** for buoy construction.
  - **Potential for increased accuracy** in the datum transferred because of higher frequency observations
    - (maximised by deploying a GPS buoy at both control and subordinate locations)

Conclusion

Objectives

- *Primary:* Verification of a high rate GPS buoy to measure sea levels
  - Precision: **± 2 cm level**
  - Bias: **< 1 cm**
- *Secondary:* Demonstration of tidal datum accuracy
  - Residuals: **@ 1cm level**

Overall Conclusion

- Only one factor in the tidal datum transfer process BUT:

  GPS buoys can be used successfully to transfer tidal datums and provide a good estimate of the datum relative to a control tide gauge site

Thanks