Monitoring and Analysis of Wake-Induced Vessel Motions: An Innovative Case-Study Williamstown, Melbourne

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- Acknowledgements
- Background – Study Area – Relevance
- Monitoring Plan
- Results
- Take Home

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Acknowledgements

- **Williamstown Maritime Precinct - *Wave, Wash and Surge Study***
- Coauthors and Contributors
- Parks Victoria
- Department of Transport
- Ports Victoria (VPCM)
- Port of Melbourne
- Williamstown Precinct Stakeholders – Yacht Clubs, Marinas and Local Stakeholders – BIA

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Background

- *"Severe surges that knock people off their feet whilst on the boat. Damages occurring to yacht decks and fittings due to the pull of mooring lines during surges."*
- *"Boats rocking violently leading to damages as a result of clashing masts."*

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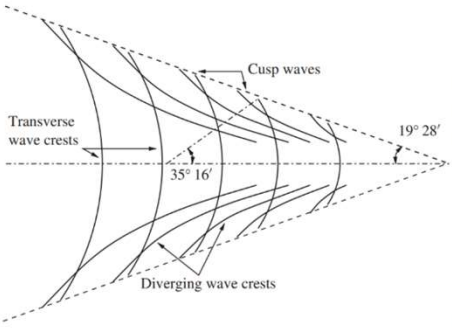
Background

- *Wake waves 101*
- *Torsvik et al., 2015*
- *Aerial view example (Nearmap 2013)*



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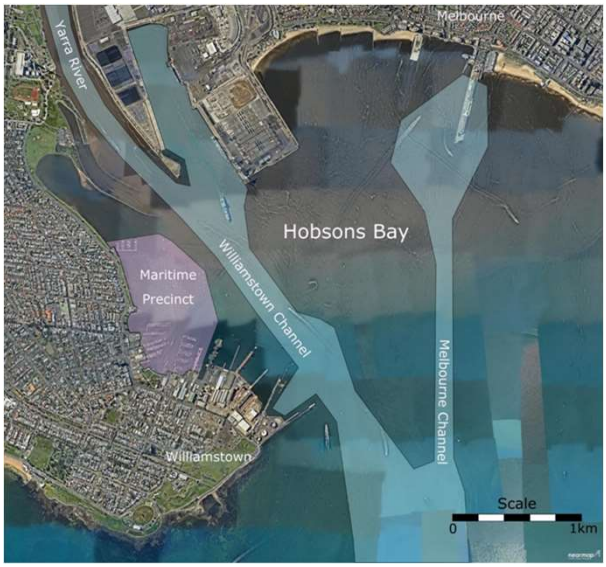
Study Area

- **Williamstown Maritime Precinct**
- Maritime and Boating Activity
- Cultural and Heritage Significance
- Economic and Trade Importance
- Victoria's Busiest Waterway!
- ***Relevance to this Conference…***



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Study Area – Wave Climate

- BMT's *PPB* SWAN model
- Natural conditions: not-conforming with AS-3962:2020
- Further exacerbated / degraded by wake wave propagation

Wave Direction (coming from)			Return Period (year)								
			1	2	5	10	20	50	100	200	500
337.5	22.5	N	0.37	0.39	0.41	0.43	0.45	0.48	0.50	0.52	0.55
22.5	67.5	NE	0.34	0.36	0.39	0.40	0.42	0.45	0.47	0.49	0.51
67.5	112.5	E	0.38	0.44	0.49	0.52	0.54	0.57	0.59	0.61	0.63
112.5	157.5	SE	0.55	0.60	0.65	0.69	0.73	0.78	0.81	0.84	0.89
157.5	202.5	S	0.49	0.54	0.60	0.64	0.68	0.73	0.77	0.80	0.85
202.5	247.5	SW	0.30	0.32	0.34	0.35	0.36	0.38	0.39	0.40	0.41
247.5	292.5	W	0.31	0.33	0.35	0.36	0.37	0.39	0.40	0.41	0.42
292.5	337.5	NW	0.30	0.32	0.34	0.35	0.36	0.38	0.39	0.40	0.41
Omni Direction			0.55	0.60	0.65	0.69	0.73	0.78	0.81	0.84	0.89

Direction and peak period of design harbour wave	Significant wave height H_s	
	Wave event exceeded once in 50 years	Wave event exceeded once a year
Head seas less than 2 s	Conditions not likely to occur during this event	Less than 0.3 m wave height
Head seas greater than 2 s	Less than 0.6 m wave height	Less than 0.3 m wave height
Oblique seas greater than 2 s	Less than 0.4 m	Less than 0.3 m wave height
Beam seas less than 2 s	Conditions not likely to occur during this event	Less than 0.3 m wave height
Beams seas greater than 2 s	Less than 0.25 m wave height	Less than 0.15 m wave height
NOTE For criteria for an "excellent" wave climate multiply wave height by 0.75, and for a "moderate" wave climate multiply wave height by 1.25. For vessels of less than 20 m in length, the most severe wave climate should satisfy moderate conditions. For vessels larger than 20 m in length, the wave climate may be more severe.		

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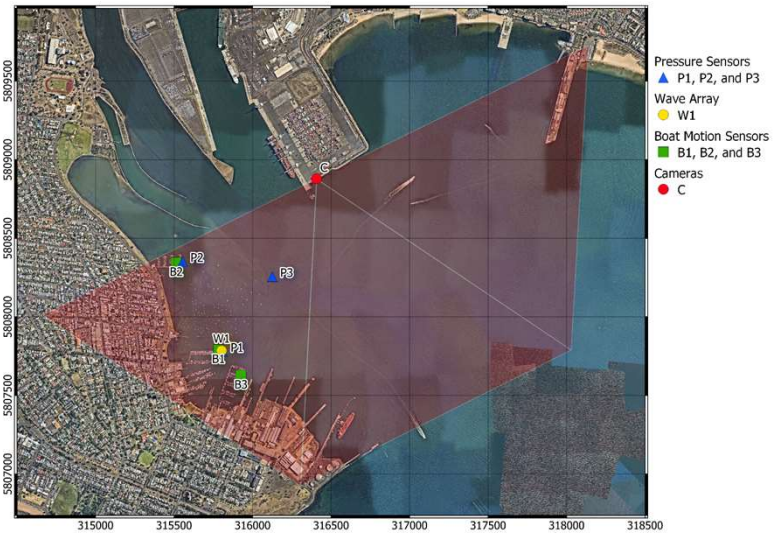
Monitoring Plan

- 3 Boat motion sensors (B)
- 3 Pressure sensors (P)
- 1 Wave sensor array (W)
- 1 Camera system (C)
- AIS and metocean data and Port log (VPCM)
- Data collection period: **December 2020 – April 2021**



(background image: Nearmap)

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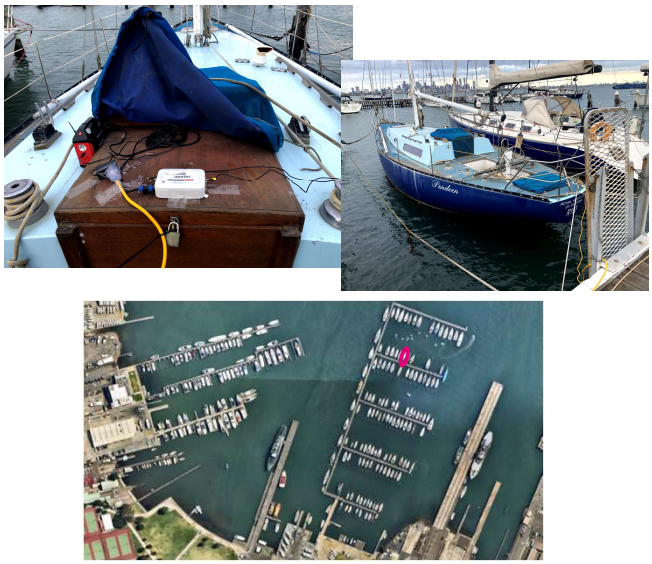
Boat Motion Sensors

- "Marine Link Sense"
- Connected to mains power + backup battery 12V
- 'Pendeen' (B3)
- Berthed near the northwest corner of the Royal Yacht Club of Victoria (RYCV)
- Sensor was deployed on the companion way hatch, roughly along the centreline of the boat
- Boat orientation of approximately 7° from N
- Images show:
  - the motion sensor in situ
  - the yacht
  - the yacht mooring location



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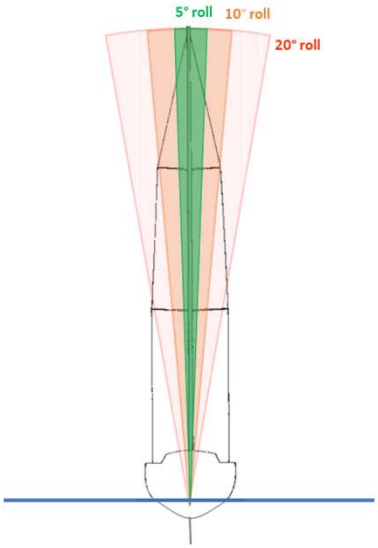
Boat Motion Measurements

- **Roll**: 'tilting' rotation of a vessel about its longitudinal/X (front-back or bow-stern) axis
- Pitch: 'up/down' rotation of a vessel about its transverse/Y (side-to-side or port-starboard) axis
- Yaw: 'circling' rotation of a vessel about its vertical/Z (mast) axis
- **Amplitude:** is the <u>total angle either side</u> of 0 measured in degrees



(base yacht image: Sun Odyssey 40 Manual.pdf, www.jeanneau-owners.com)

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Boat Motion Measurements

- Sway: ‘side-to-side’ movement of a vessel along its transverse/Y (side-to-side or port-starboard) axis
- **Surge**: ‘back/forth’ movement of a vessel along its longitudinal/X (front-back or bow-stern) axis
- Heave: ‘up/down’ movement of a vessel along its vertical/Z (mast) axis
- **Acceleration**: The rate of change in vessel’s velocity over time with velocity being the rate at which the vessel changes its position

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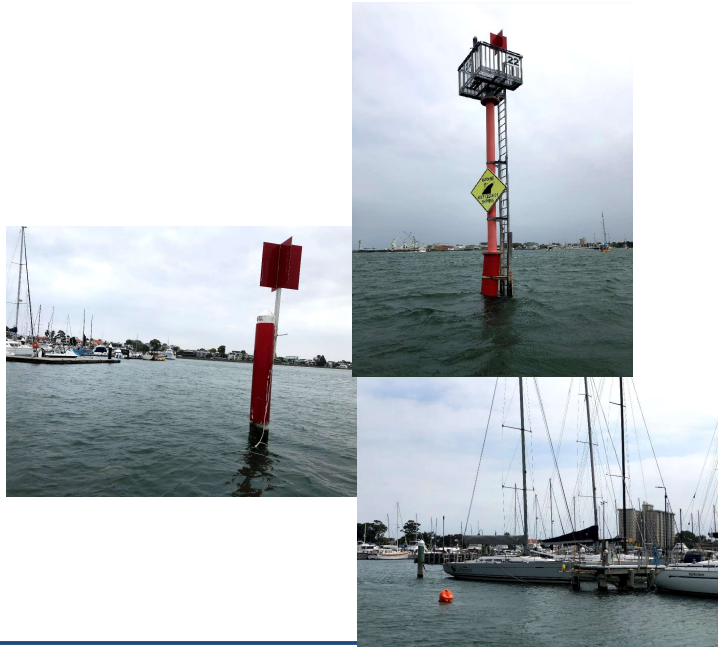
Wave Conditions Measurements – Pressure Sensors

- RBR “Solo” D (wave 16)
- Sampling rate of 4Hz (240 samples per min)
- Battery life ~6-8 weeks (required service)
- Deployed using a simple mooring design
- Images show:
  - Locations of deployments



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Wave Conditions Measurements – ”Wave Array” – Acoustic Range Sensor

- Array made of a 3 Senix ToughSonic30 sensors
- Ultrasonic pulses reflecting on the water surface
- (similar to a downward looking ADCP)
- Sampling rate of 4Hz (240 samples per min)
- Connected to mains power + backup battery 12V
- Deployed from HBYC jetty using a wooden frame
- Navigational hazard – Notice to Mariners

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Camera System

- Set 3 outdoor bullet network cameras (Vivotek IB9391-EHT)
- Network Video Recorder (NVR - Vivotek ND9541P)
- Deployed on Webb Dock
- Covering ~180deg view
- 3840x2160 resolution
- Sampling rate of 1 frame per second
- Connected to mains power + backup battery 12V

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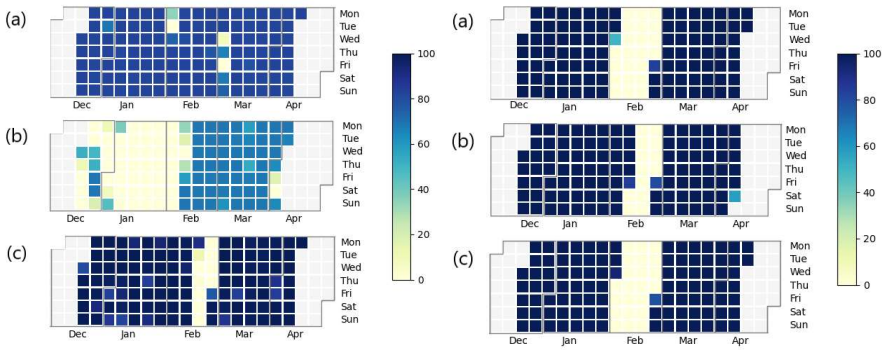
Results

- Overview
- A few “characteristic event” examples
- **Statistical results**



Data return (%): Left – Boat Motion Sensors | Right – Pressure Sensors

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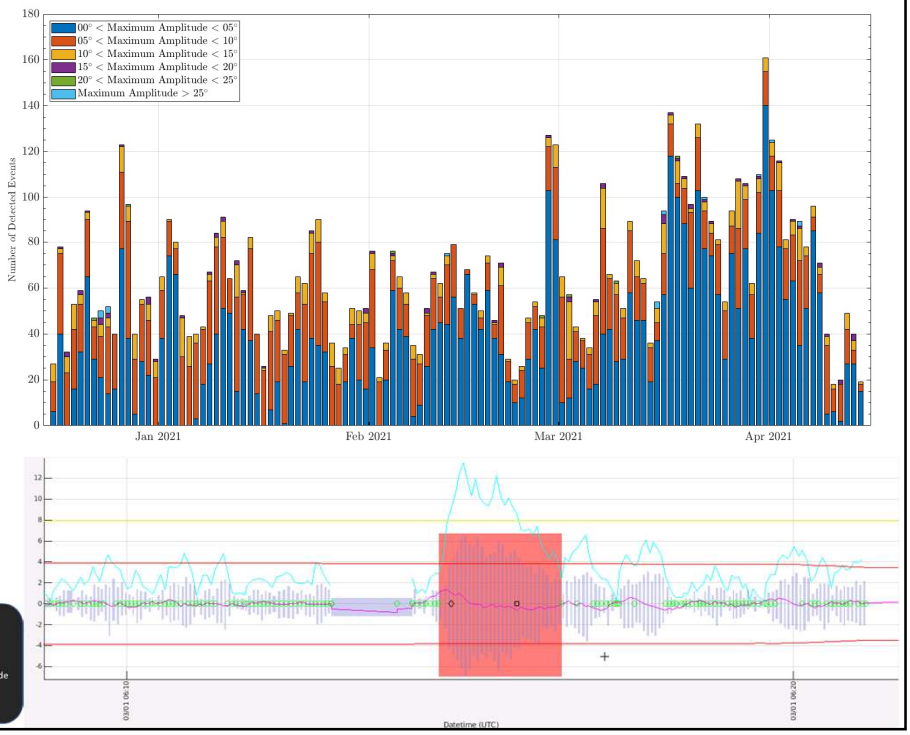
Event Detections

- Data collection period: Dec 2020 – April 2021
- Events occurring every day of the collection period
- Over 8,378 detections (over 60 detections per day)
  - Each sensor counted
  - Not all working/berthed entire collection period
  - Algorithm (dynamic)



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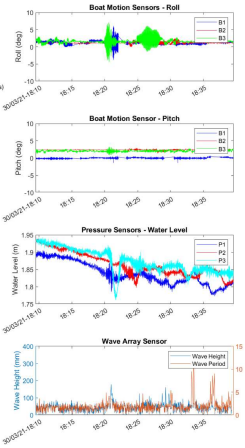
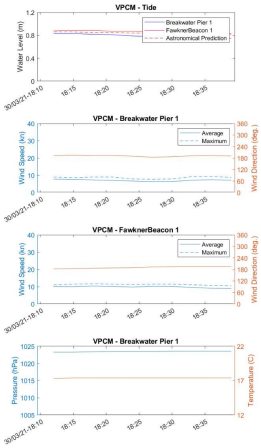
Example event – Tug and Large Ship (Container)
30 Mar 2021 18:24





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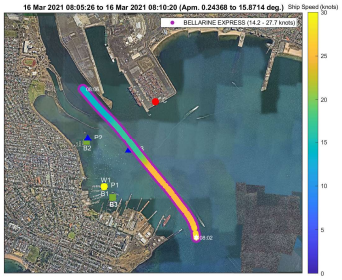
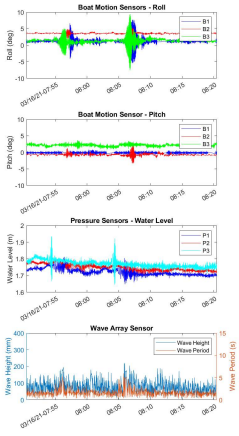
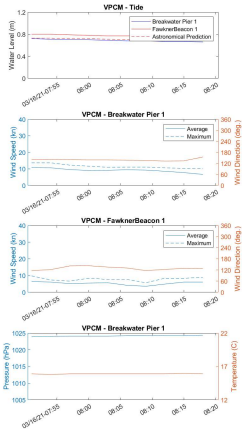
Example event – Fast Ferry (only AIS vessel)
16 Mar 2021 08:05







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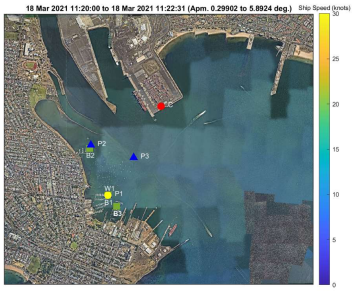
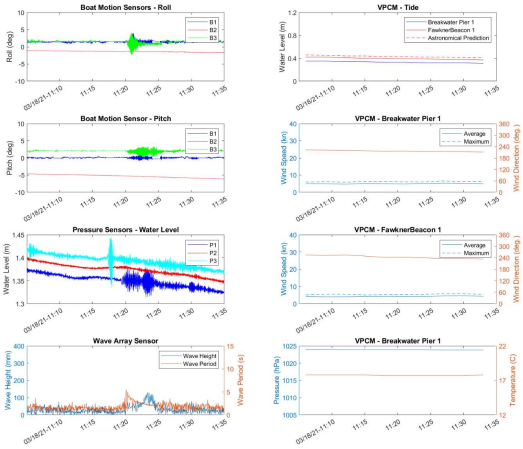
Example event – No associated AIS vessel
18 Mar 2021 11:20 (reported event #21)





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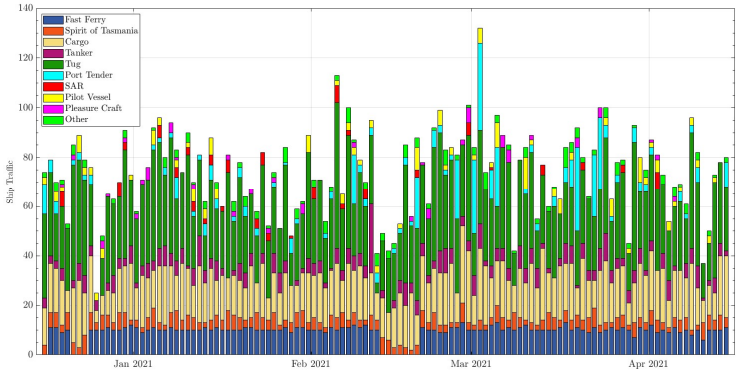
Marine Traffic – During Collection Period

- VPCM Watch Keeper Log
  ~3,000 vessel movements

- AIS (Automated Identification System)
- Not all vessels have/transmit AIS
- Data includes
  - MMSI number, Vessel name
  - Vessel type
  - Vessel length, width
  - Time (UTC)
  - Vessel position
  - Vessel speed
- Plotted as 'vessel passage' (>5 knots)



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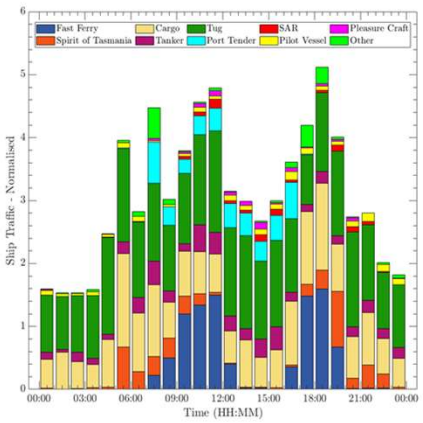
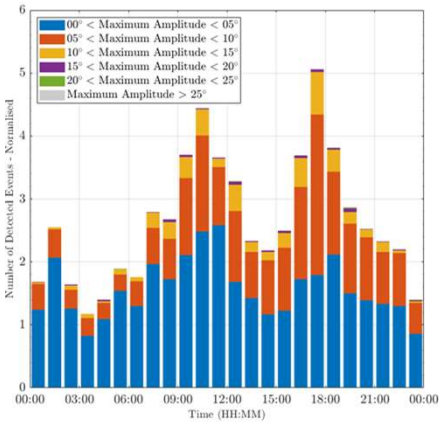
Marine Traffic – During Collection Period – Daily Traffic Pattern

- From AIS
- Daily traffic pattern
  - Vessel speed
  - Vessel type
  - ……
- Event detections also show daily patter…





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Summary Statistics

- 4 main vessel type groups:
  - No AIS vessels – 45%
  - Fast Ferries – 21%
  - Port activities – 30%
  - Other – 2%
  - Multiple vessels – 2%

	Vessel Type Category	Max Amplitude of Roll Detected at any of 3 Boat Motion Sensors						
		0-5°	5-10°	10-15°	15-20°	20-25°	>25°	Total (%)
1	No AIS Vessel Observed	30.46	12.77	1.74	0.29	0.01	0.01	45.29
2	Fast Ferry (only)	5.03	4.68	1.67	0.13	0.02	0.02	11.55
3	Fast Ferry + other	4.34	3.62	1.50	0.04	0.00	0.00	9.50
4	Tug (only)	3.17	0.94	0.14	0.02	0.00	0.00	4.29
5	Tug + large ship (cargo / tanker)	7.57	3.84	1.09	0.16	0.04	0.00	12.69
6	Cargo (only)	3.22	1.99	0.41	0.04	0.01	0.00	5.67
7	Tanker (only)	1.29	0.67	0.11	0.02	0.00	0.00	2.09
8	Spirit of Tasmania (only)	0.85	0.67	0.12	0.02	0.00	0.00	1.66
9	Port Tender (only)	1.31	0.44	0.07	0.01	0.01	0.00	1.85
10	Search And Rescue (SAR) boat (	0.49	0.25	0.06	0.01	0.00	0.00	0.81
11	Pilot Vessel (only)	0.84	0.29	0.10	0.04	0.00	0.00	1.25
12	Pleasure Craft (only)	0.19	0.08	0.05	0.02	0.00	0.00	0.35
13	Other Vessel Type (only)	0.57	0.29	0.04	0.00	0.00	0.00	0.90
14	Multiple vessels (no ferry)	1.35	0.58	0.17	0.01	0.00	0.00	2.11
15	Total (%)	60.68	31.12	7.26	0.81	0.10	0.04	100.00

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Mitigation Strategies Options (at High-Level)

1. Relocating the marinas and yacht clubs away from the area of influence of the events
2. Relocating the Port of Melbourne
3. **Reducing the generation of wake as the main cause of the events, i.e., operational options, such as managing vessel transit and speed limits**
4. Attenuating incident waves (including wake waves) that otherwise propagate into the Williamstown Maritime Precinct, i.e., structural options, such as wave attenuators and breakwaters
5. **Reducing the effect of the incident waves (including wake waves) on the boats and infrastructure, e.g., spacing/reorientation of boats within marinas, local wave attenuation**
6. Do nothing, accepting the current situation and risk of ongoing events

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Take Homes…

- A relatively simple set of instruments and monitoring plan – affordable!
- Designed fit-for-purpose to achieve robust data collection
- Leveraging from other data sources, e.g. AIS and metocean – available to most ports
- Customised analyses, looking at “event” specific characteristics and statistical population
- Generate insight to inform management
- Application now transferable to look at range of issues from marine traffic associated wash and wake…

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Thank you

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- Questions & Answers

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Additional Slides…

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- Mitigation Measures Assessment (at High-level)

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Mitigation Strategies (High-Level) – 3 & 5 – To be further analysed in Stage 3

1. ~~Relocating the marinas and yacht clubs away from the area of influence of the events~~
2. ~~Relocating the Port of Melbourne~~
3. Reducing the generation of wake as the main cause of the events, i.e., operational options, such as managing vessel transit and speed limits
4. ~~Attenuating incident waves (including wake waves) that otherwise propagate into the Williamstown Maritime Precinct, i.e., structural options, such as wave attenuators and breakwaters~~
5. Reducing the effect of the incident waves (including wake waves) on the boats and infrastructure, e.g., spacing/reorientation of boats within marinas and yacht clubs, improve fendering systems and joints
6. ~~Do nothing, accepting the current situation and risk of ongoing events~~

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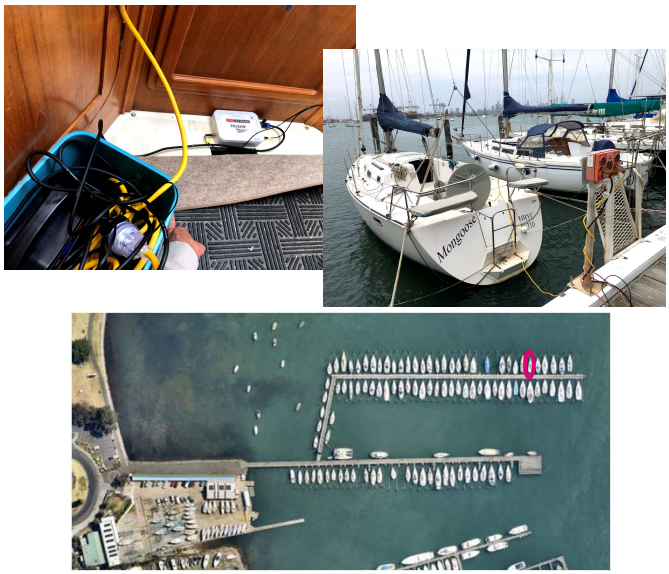
Boat Motion Sensor – B1

- 'Mongoose'
- Berthed near the northeast end of Hobsons Bay Yacht Club (HBYC)
- Sensor was deployed in the cabin (under ladder) roughly along the centreline of the boat
- Boat orientation of approximately 356° from N
- Images show:
  - the motion sensor in situ
  - the yacht
  - the yacht mooring location



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Boat Motion Sensor – B2

- ‘Footloose’
- 40ft sailing yacht
- Berthed near the northeast end of Anchorage Marina
- Sensor was deployed roughly along the centreline of the boat
- Boat orientation of approximately 273° from N
- Images show:
  - the motion sensor in situ
  - the yacht
  - the yacht mooring location

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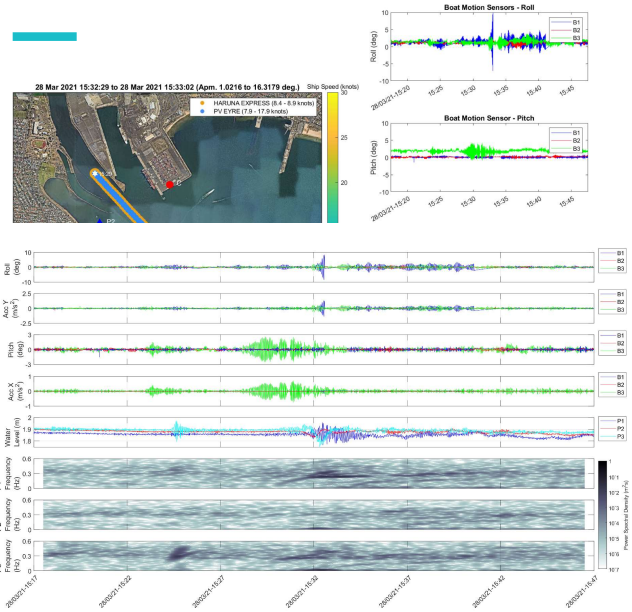
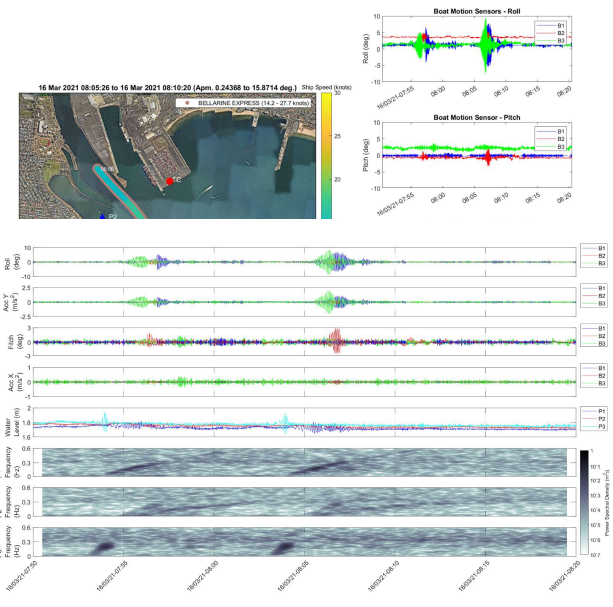
Characterisation of Wake Patterns





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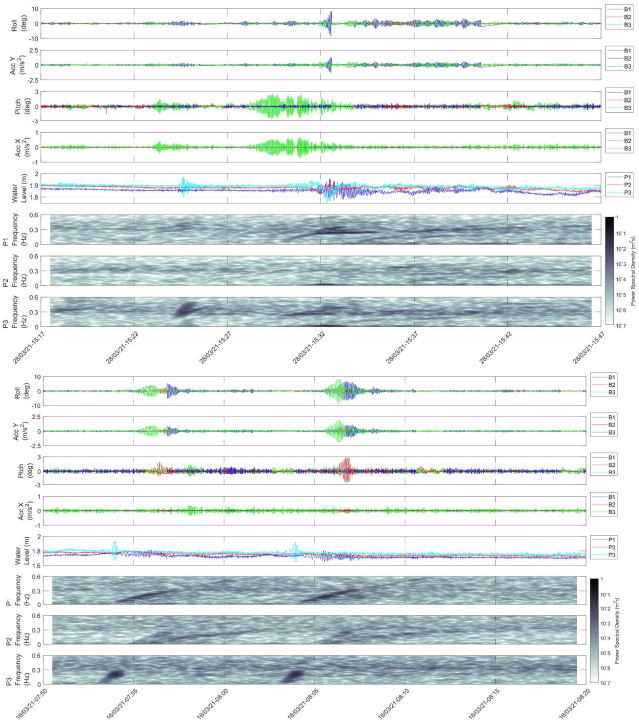
Characterisation of Wake Patterns

- Distinctive wake “signature” of different vessels
- But as wake waves diverge and propagate similar effect on marinas



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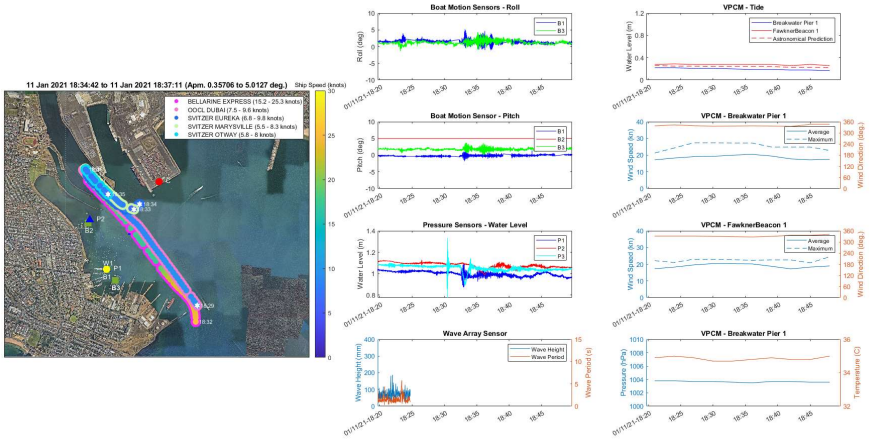
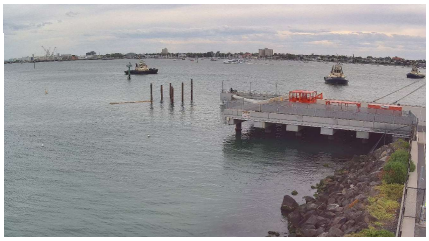
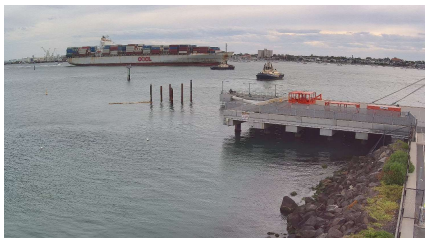
Example event – Fast Ferry & multiple vessels 11 Jan 2021 18:34 (reported event #4)







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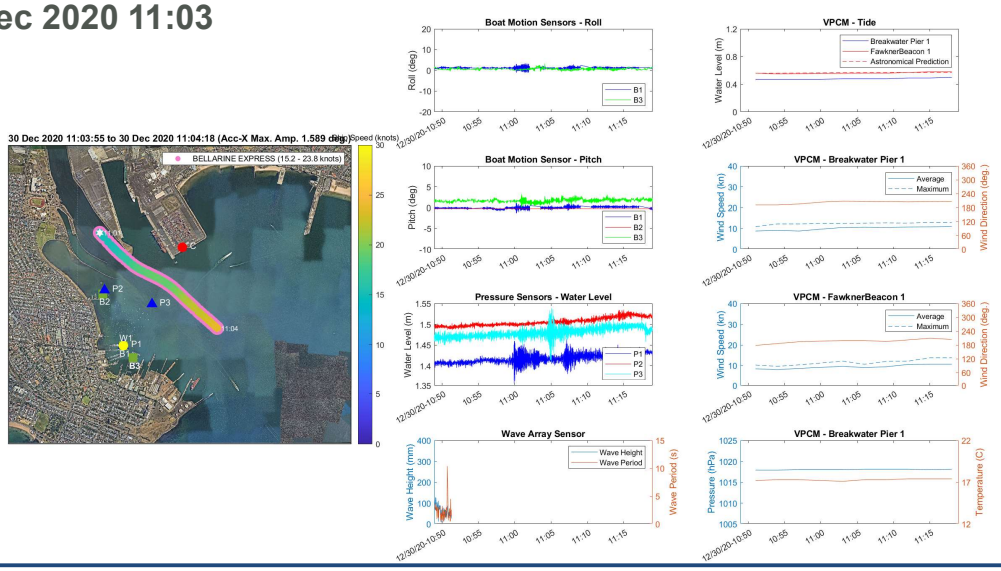
Example event (surge) – Fast Ferry (only AIS vessel)
30 Dec 2020 11:03



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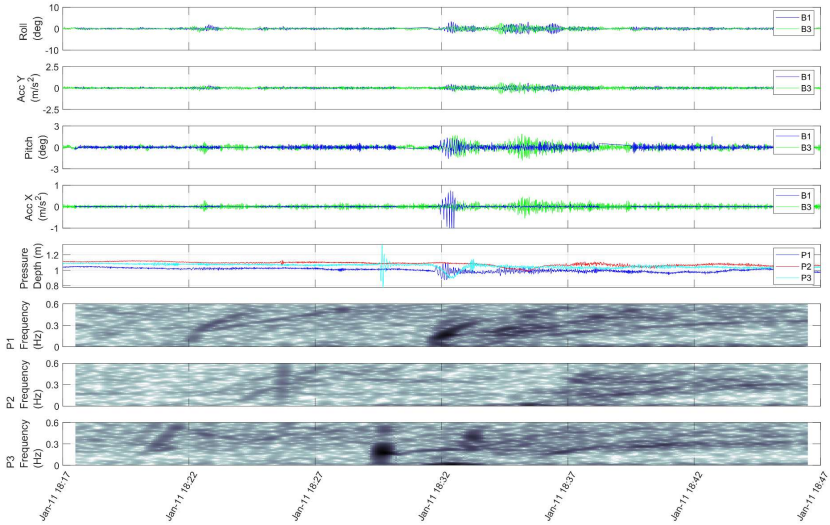
Example event (surge) – Multi vessels
11 Jan 2021 18:34



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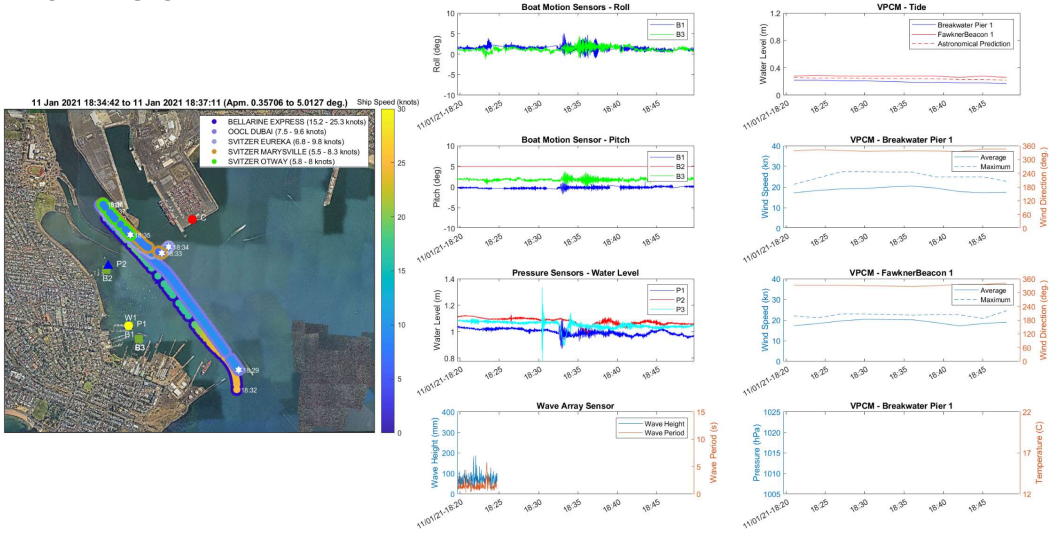
Example event (surge) – Multi vessels
11 Jan 2021 18:34



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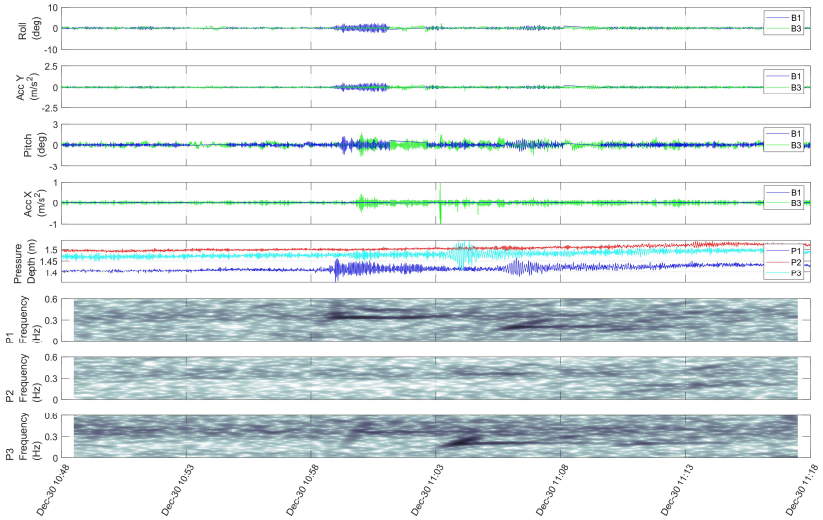
Example event (surge) – Fast Ferry (only AIS vessel)
30 Dec 2020 11:03- Spectrogram



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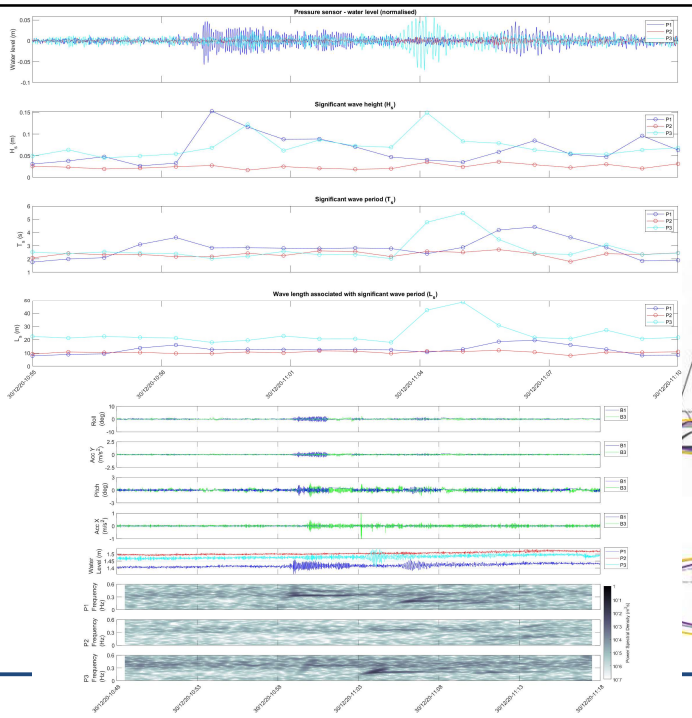
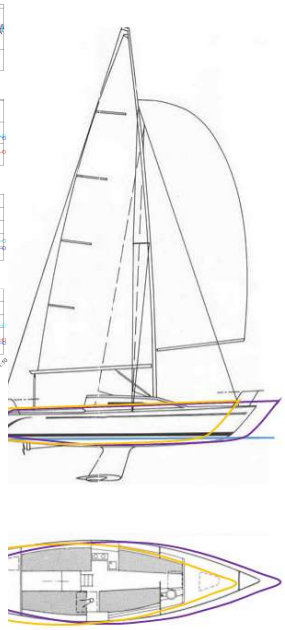
Surge Events

- From analysing the measurements, we now understand better the physics of these
- Surge motions occur “collocated” with roll motions
- Surge motions are initiated by the faster, larger wavelength waves that lead the diverging wake wave “pack”





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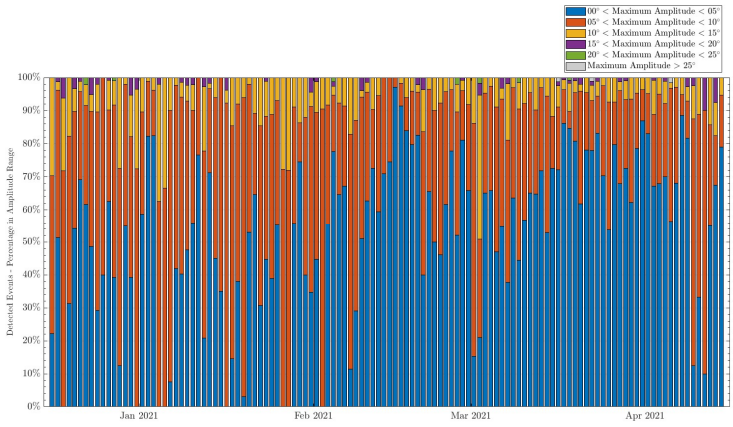
Event Detections by Amplitude

- Amplitude of events as a percentage of detections per day
- Largest proportion <5° (~61%)



BMT

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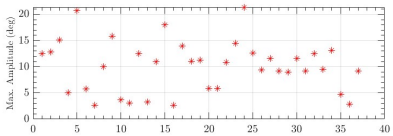
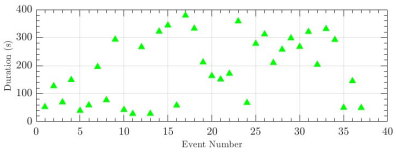
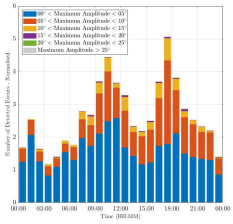
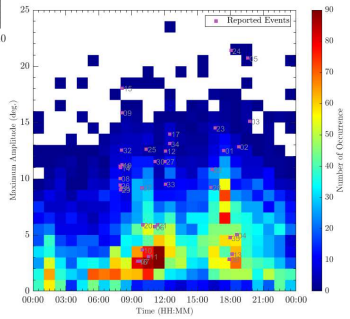
Stakeholder Reported Events - Summary

- 37 reported events during collection period
- Reported events measured amplitude (roll) varied 3 – 22 degrees
- Intensity (or magnitude) of event reported by observers is subjective
- Vessels associated
  - 27 have a Fast Ferry passing
  - 5 have other vessels associated
  - 5 have no associated AIS traffic
    - 3 have small – medium motor boats seen in the video footage
    - 2 inconclusive
  - No clear association with direction of passage









BMT

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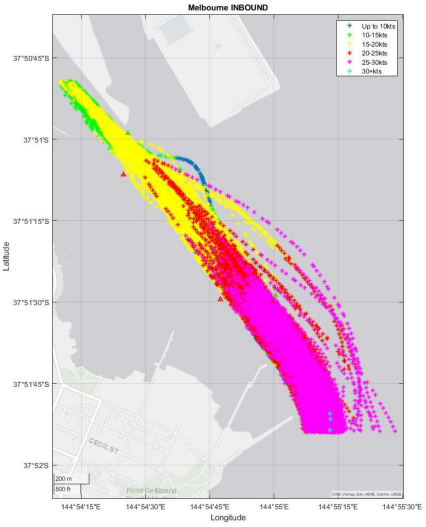
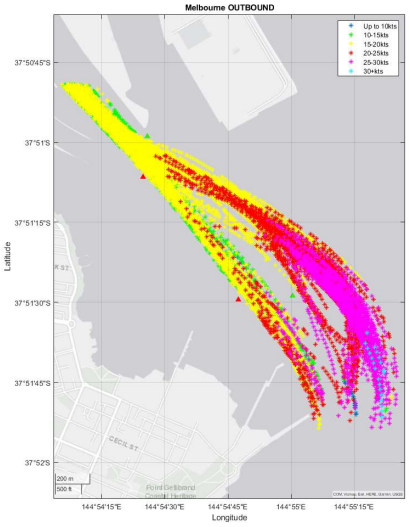
Ferry speeds for detected events associated with a Fast Ferry passage





BMT

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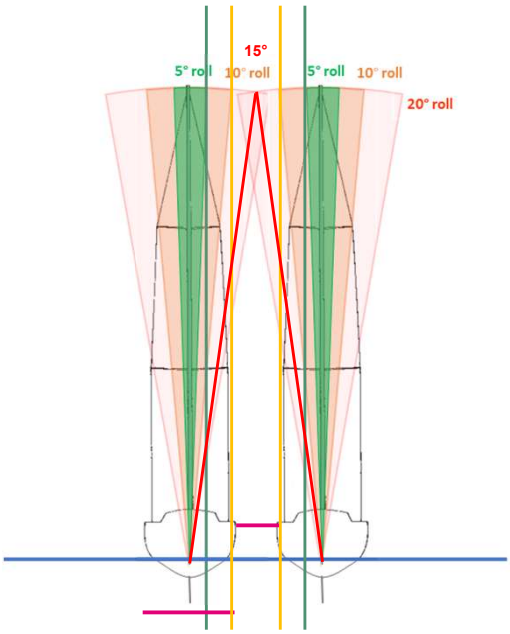
Boat Motion Measurements - Amplitude

- **Roll**: 'tilting' rotation of a vessel about its longitudinal/X (front-back or bow-stern) axis
- **Amplitude:** is the total angle either side of 0 measured in degrees



(base yacht image: Sun Odyssey 40 Manual.pdf, www.jeanneau-owners.com)

BMT

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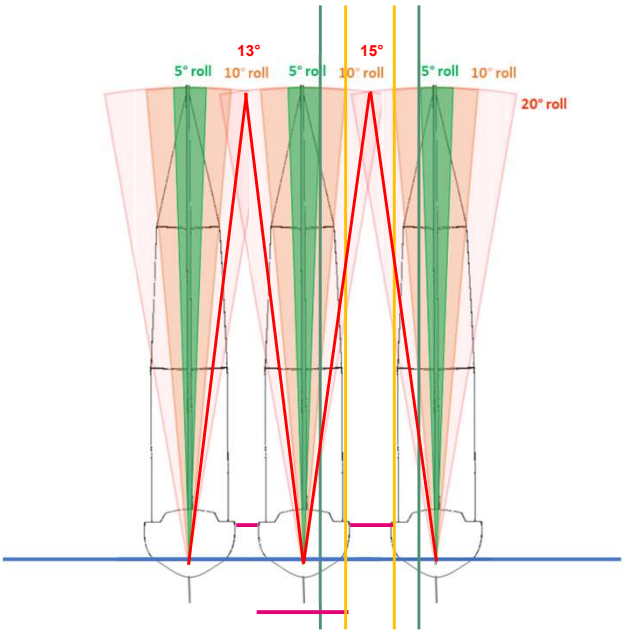
Boat Motion Measurements - Amplitude

- **Roll**: 'tilting' rotation of a vessel about its longitudinal/X (front-back or bow-stern) axis
- **Amplitude:** is the total angle either side of 0 measured in degrees



(base yacht image: Sun Odyssey 40 Manual.pdf, www.jeanneau-owners.com)

BMT

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Summary Statistics

- 4 main vessel type groups:
  - No AIS vessels – 45%/33%
  - Fast Ferries – 21%/23%
  - Port activities – 30%/39%
  - Other – 2% /4%
  - Multiple vessels – 1% /1%

Acceptable? ? ? Unacceptable?

Vessel Type Category		Max Amplitude of Roll Detected at any of 3 Boat Motion Sensors						
		0-5°	5-10°	10-15°	15-20°	20-25°	>25°	Total (#)
1	No AIS Vessel Observed	2552	1070	146	24	1	1	3794
2	Fast Ferry (only)	421	392	140	11	2	2	968
3	Fast Ferry + other	364	303	126	3	0	0	796
4	Tug (only)	266	79	12	2	0	0	359
5	Tug + large ship (cargo / tanker)	634	322	91	13	3	0	1063
6	Cargo (only)	270	167	34	3	1	0	475
7	Tanker (only)	108	56	9	2	0	0	175
8	Spirit of Tasmania (only)	71	56	10	2	0	0	139
9	Port Tender (only)	110	37	6	1	1	0	155
10	SAR (only)	41	21	5	1	0	0	68
11	Pilot Vessel (only)	70	24	8	3	0	0	105
12	Pleasure Craft (only)	16	7	4	2	0	0	29
13	Other (only)	48	24	3	0	0	0	75
14	Multiple vessels (no ferry)	113	49	14	1	0	0	177
15	**Total**	5084	2607	608	68	8	3	8378

BMT

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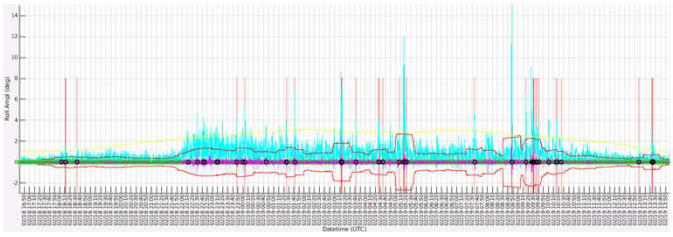
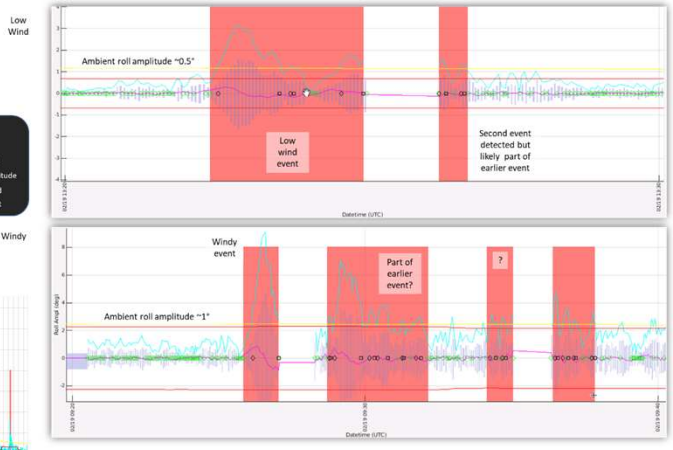
Detection Algorithm

- Algorithm to determine an 'event'
- Dynamic threshold





BMT

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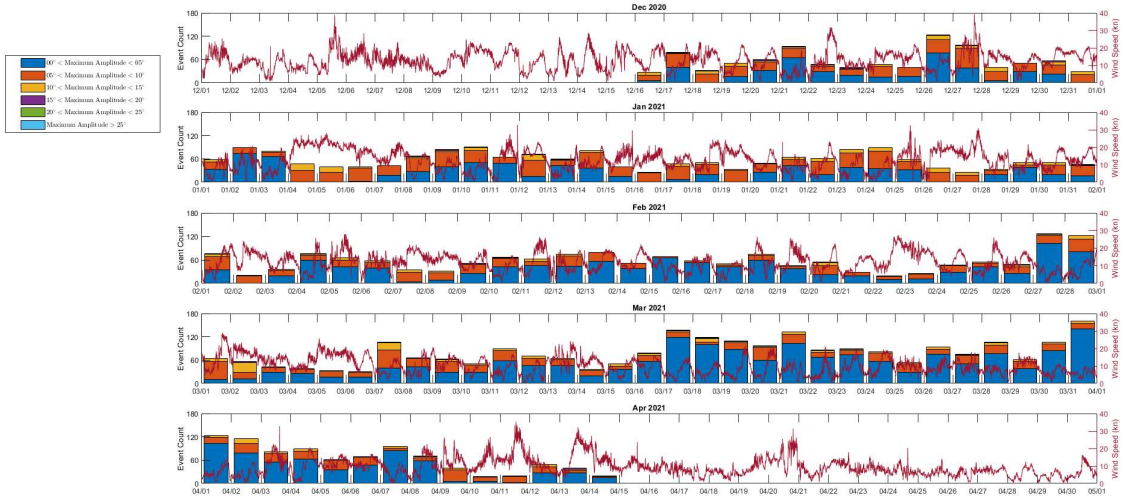
Natural Variability Events (only a small percentage of detections)



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