Characterisation of the Agulhas Current as a Resource for Marine Energy Extraction

Renewable Energy Post-Graduate Symposium

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CENTRE FOR RENEWABLE AND SUSTAINABLE ENERGY STUDIES

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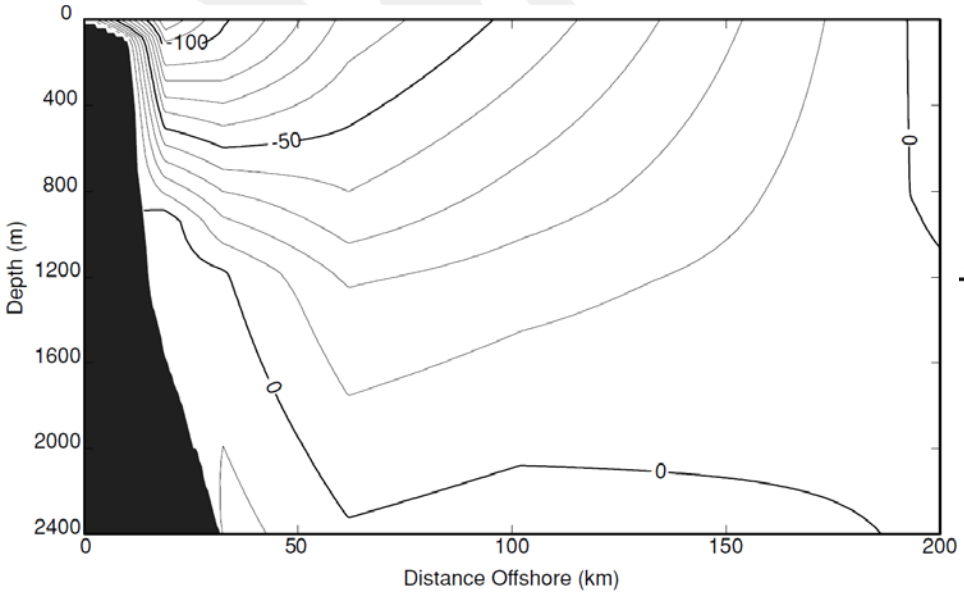
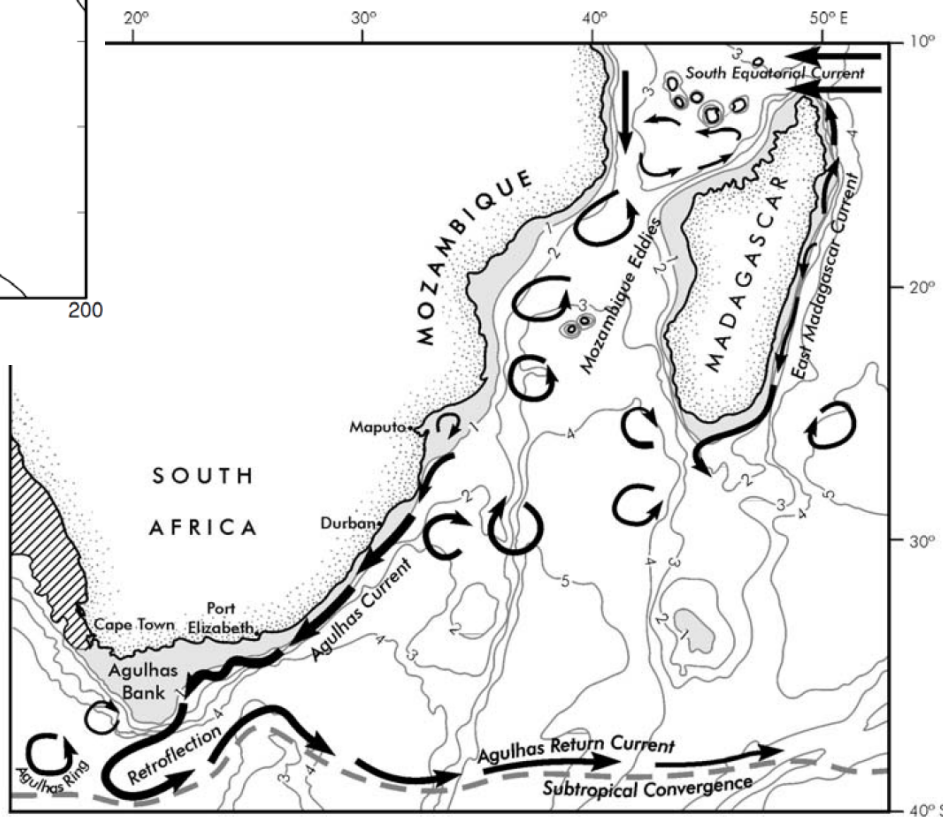
- The Agulhas Current
- Measurements and Assessment Method
- Results
- Technology Readiness
- Capacity Factor
- Conclusion

Ocean Current Energy around SA

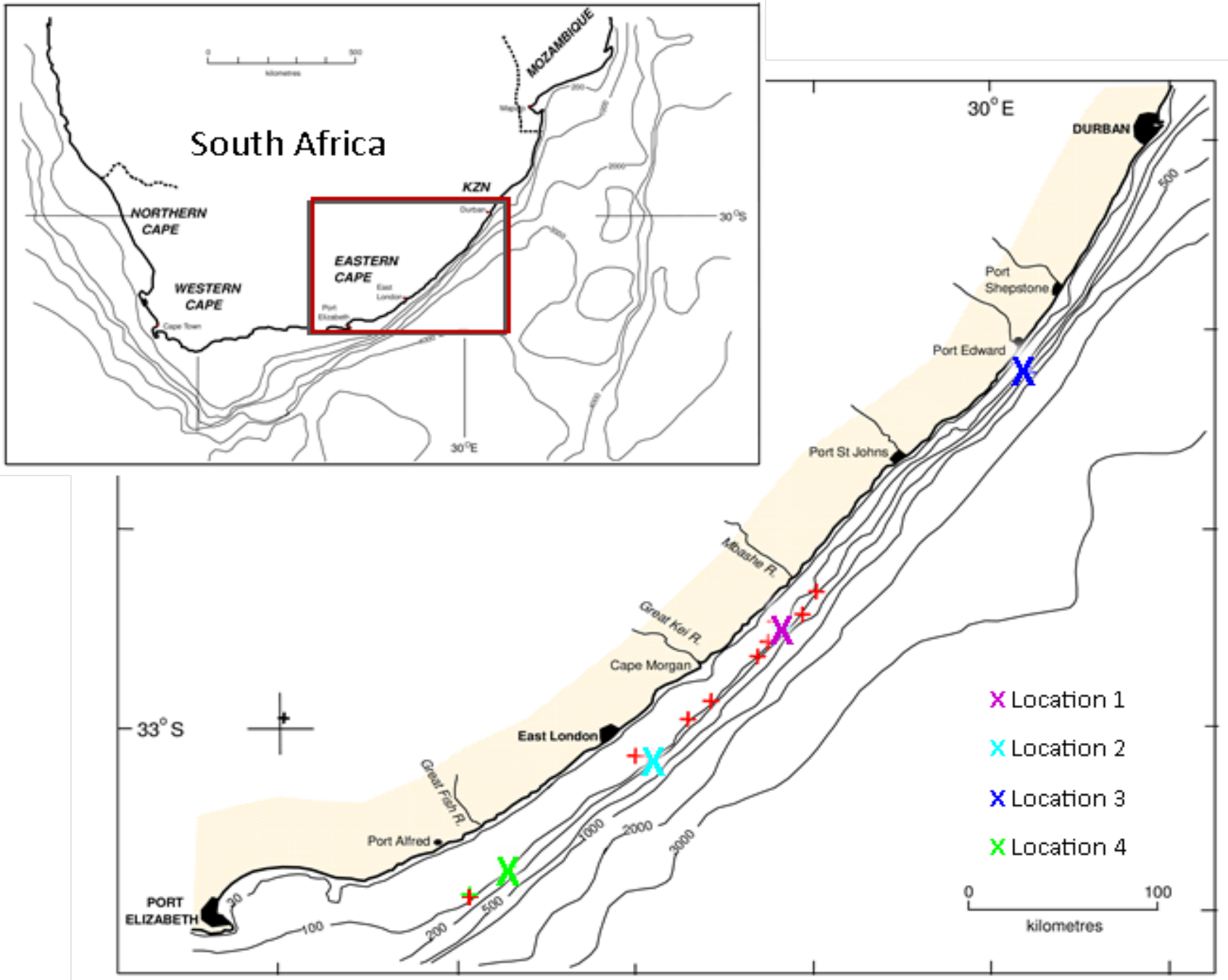


Agulhas Current is the Southern Hemisphere's strongest ocean current

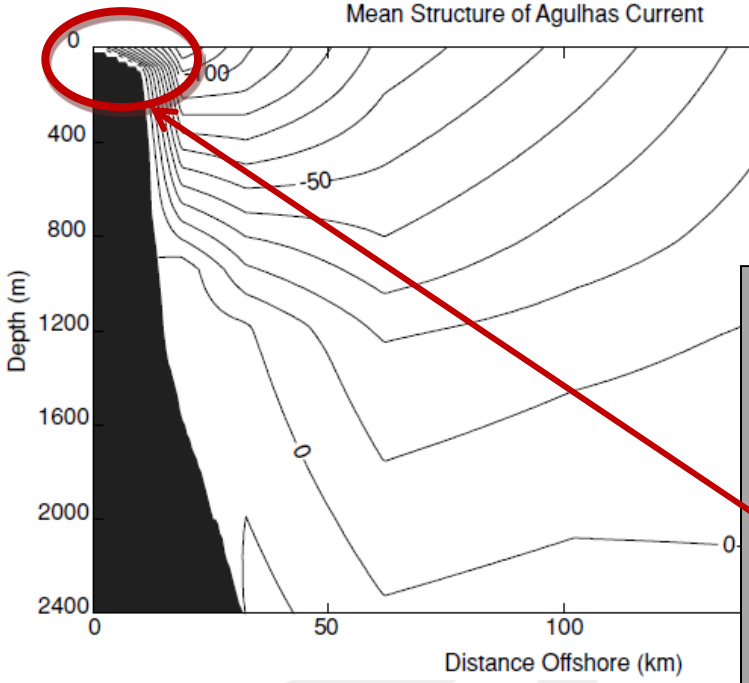


Transport of **-69.7 Sv ± 4.3 Sv** is achieved by the Agulhas Current at 31° S

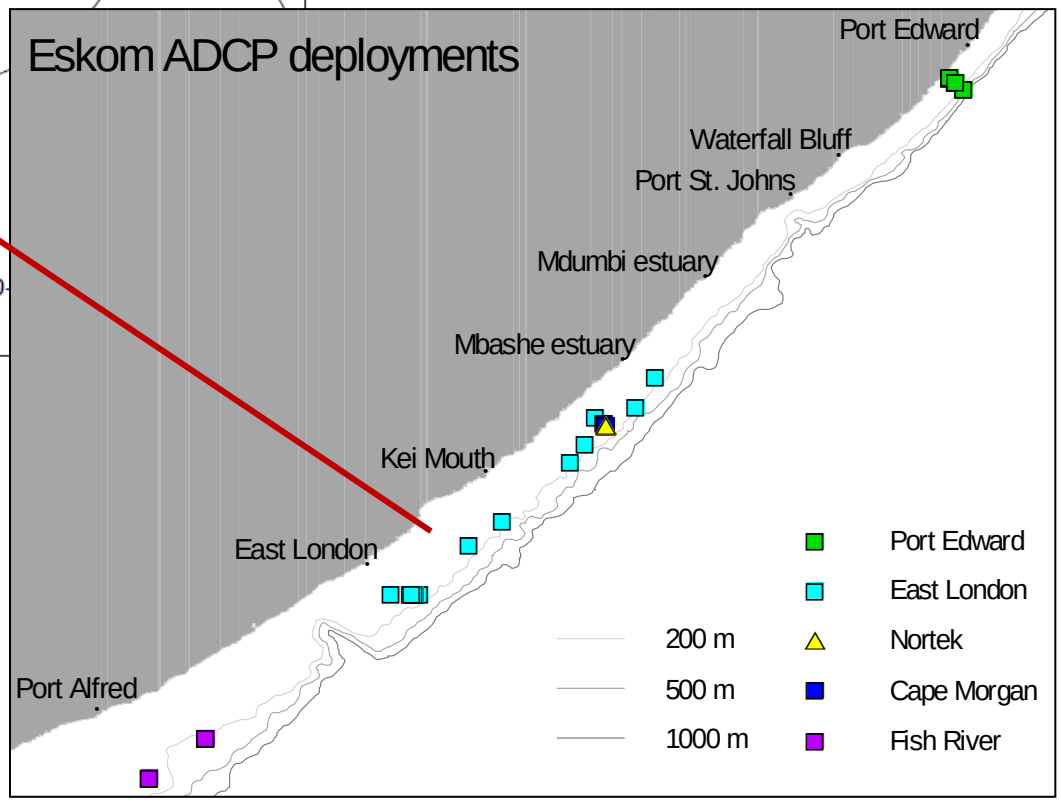
Viability for energy extraction?


South Africa
MOZAMBIQUE
KZN
NORTHERN CAPE
EASTERN CAPE
WESTERN CAPE
Durban
East London
Port Elizabeth
Cape Town
30°S
30°E
30° E
DURBAN
Port Shepstone
Port Edward
Port St Johns
Mbashe R.
Great Kei R.
Cape Morgan
East London
33° S
Great Fish R.
Port Alfred
PORT ELIZABETH
20
100
200
500
1000
2000
3000
Location 1
Location 2
Location 3
Location 4
0
100
kilometres

Agulhas Current: Data Analysed



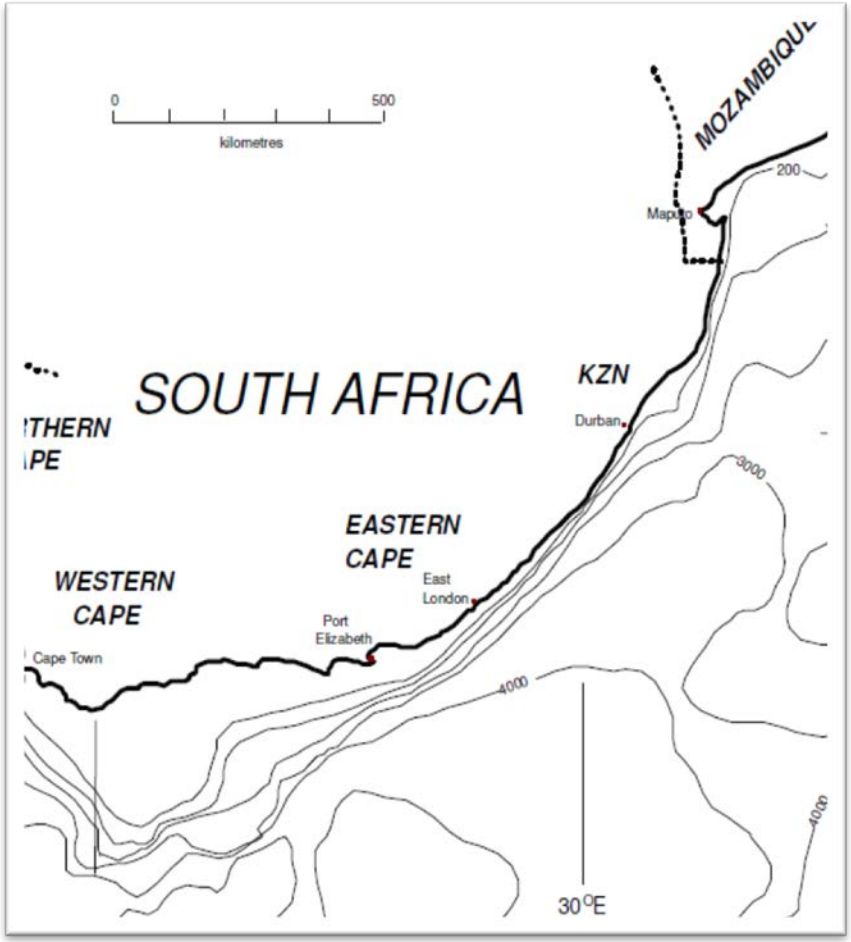
Location of ADCP deployment of data collected



the current is situated 20 km from the coastline (at ~200 m bathymetry line) at the surface and 70 km wide

Agulhas Current: Characteristics

- Poleward flowing Under Current
- The continental shelf narrows between Durban and Port Elizabeth
  - also helps stabilize the Agulhas Current in this region and no regular wide meanderings are present.
- Destabilizing Region: The Natal Bight
  - This area has a wider continental shelf and the shelf's morphology change destabilizes the current, resulting in infrequent formation of **Natal Pulses**
  - Large cyclic meanders which travel down the coast and can displace the current core by 150-200 km seawards



Some basic findings

	Location 1 CM		Location 2 EL	Location 3 PE	Location 4 FR
Location	-32.507, 28.832		-33.150 28.099	-31.196, 30.175	-33.703, 27.298
Period	2006/05/11 2007/06/05	2009/03/23 2010/09/13	2007/08/18 – 2009/03/22	2005/09/08 – 2006/09/09	2008/04/01 – 2010/03/04
Sea bed depth [m]	84.16	84.16	85.00	61.00	92.20
Mean [m/s]	**1.48**	**1.46**	**1.4**	**0.95**	**0.97**
Median [m/s]	1.59	1.6	1.54	1.03	0.94
Standard Deviation [m/s]	0.53	0.59	0.61	0.42	0.54
Maximum [m/s]	2.7	2.82	2.83	1.92	2.77

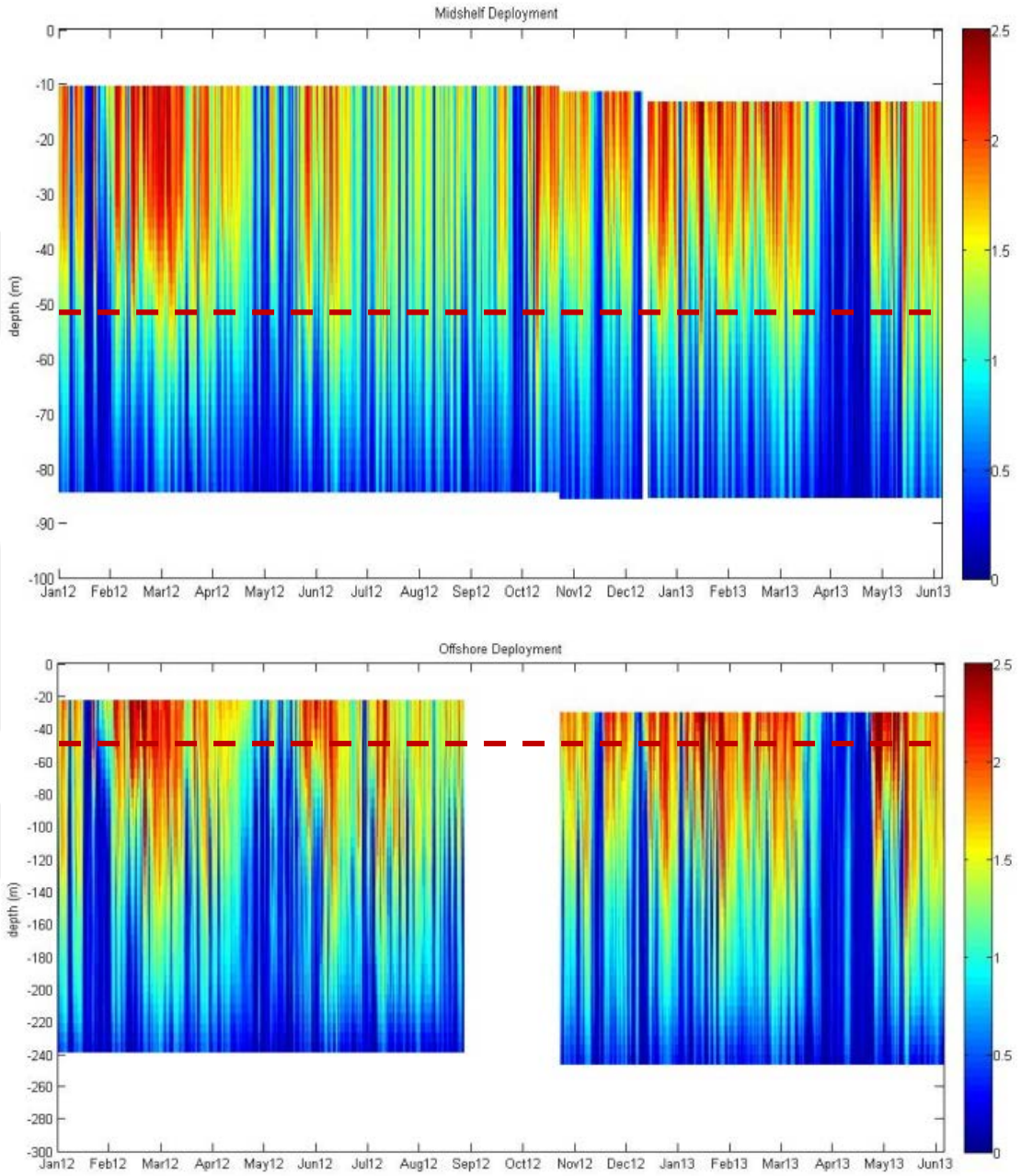
How to Analyse the data?

	Location	Bin Resolution	Distance from Shore	Time Period	Sounding Depth
1	Mid-shelf	2 m	14 km	2012/01/24 2013/06/30	91 m
2	Edge of shelf (off-shore)	6 m	19 km	2012/01/24 2013/06/30	255 m

Parameters of Interest	
Velocity magnitude	Probability of Exceedance
Current Direction	Directional Roses
Percentage Current Reversals	$\frac{\sum_{i=1}^{N}\lvert\theta_i - \bar{\theta}\rvert > \frac{\pi}{2}}{N}$
Power Density	$P_d = \frac{1}{2}\rho {v_{ins}}^3$
Capacity Factor	$C_f = \frac{\sum_{i=1}^{N} Power\ produced}{\sum_{i=1}^{N} Turbine\ rated\ power}$

Results: Current Magnitude

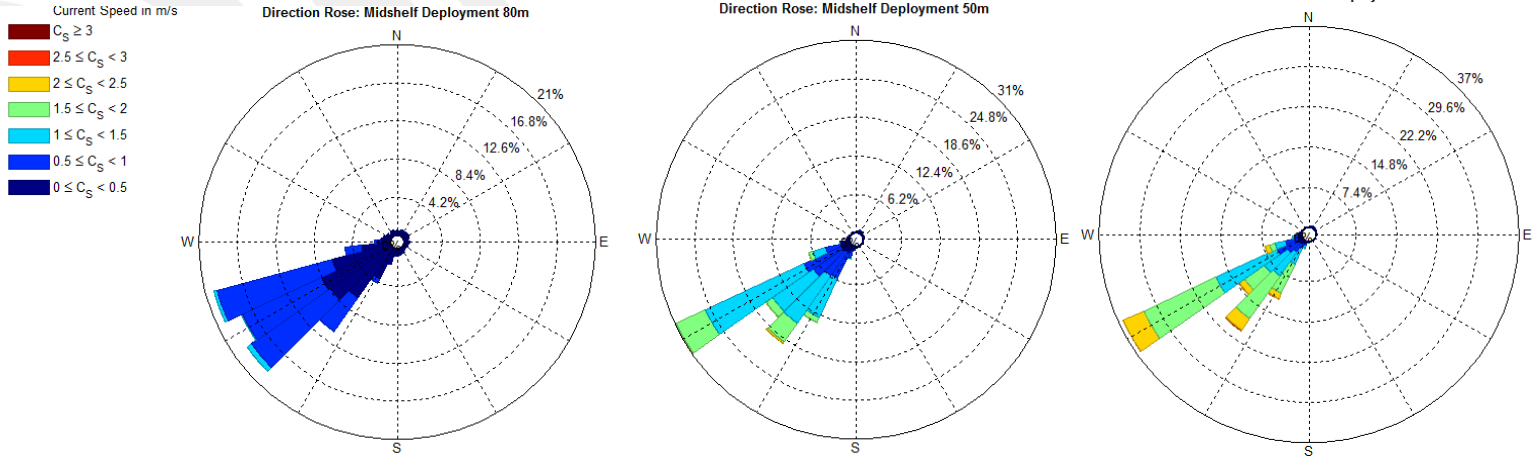
- Notice the presence of Natal Pulses
- The affects of this phenomenon on the extractable power will be significant



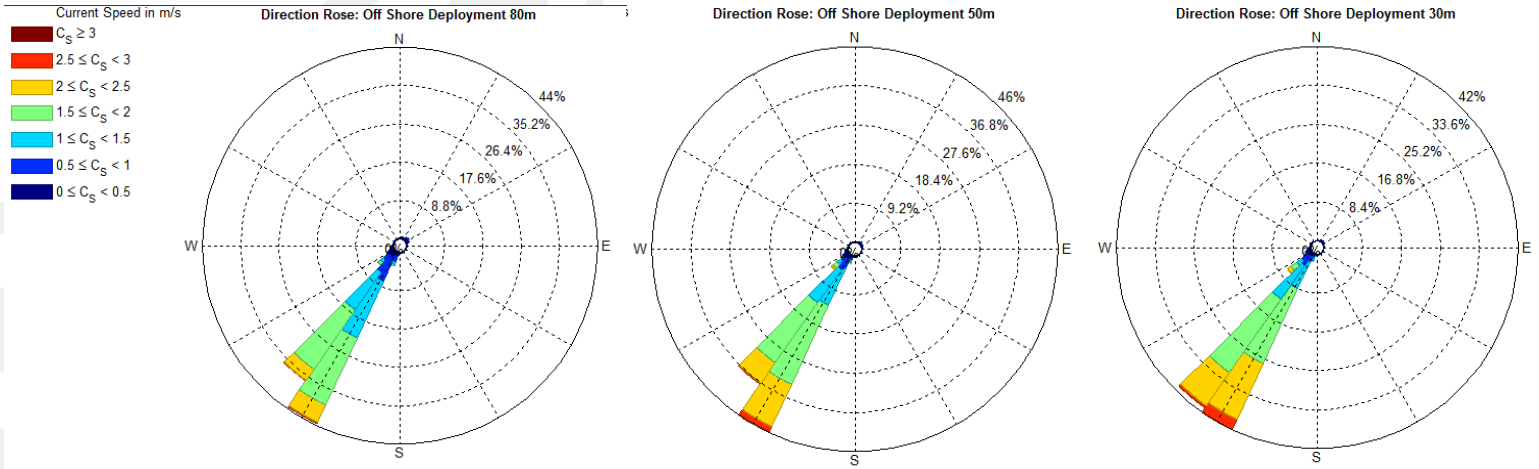
Mid-shelf

Off-shore

Results: Current Direction

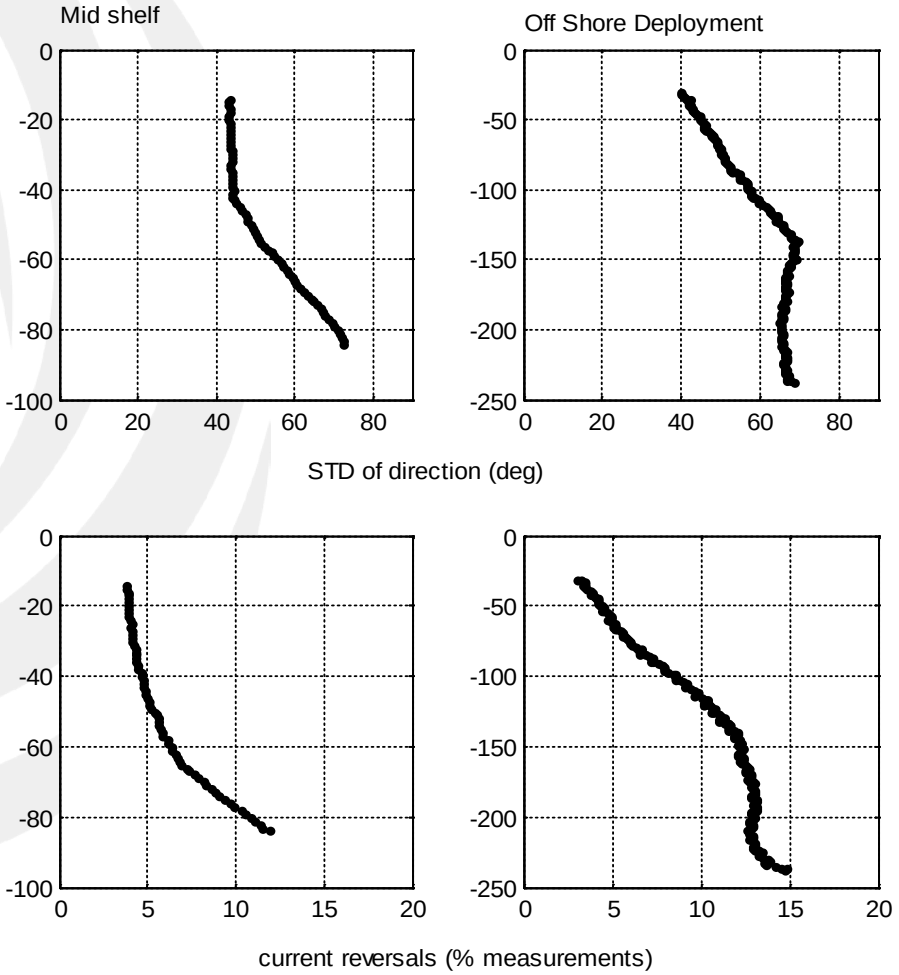


Mid-shelf

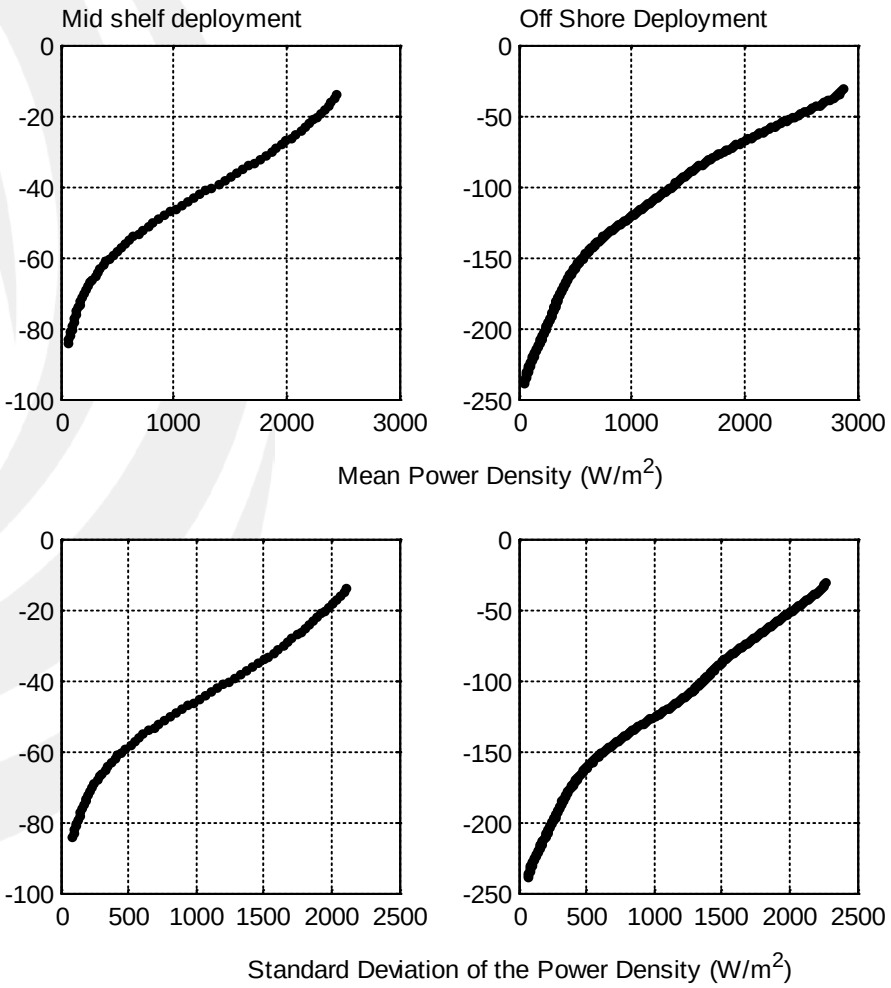


Off-shore

Results: Percentage Current Reversals



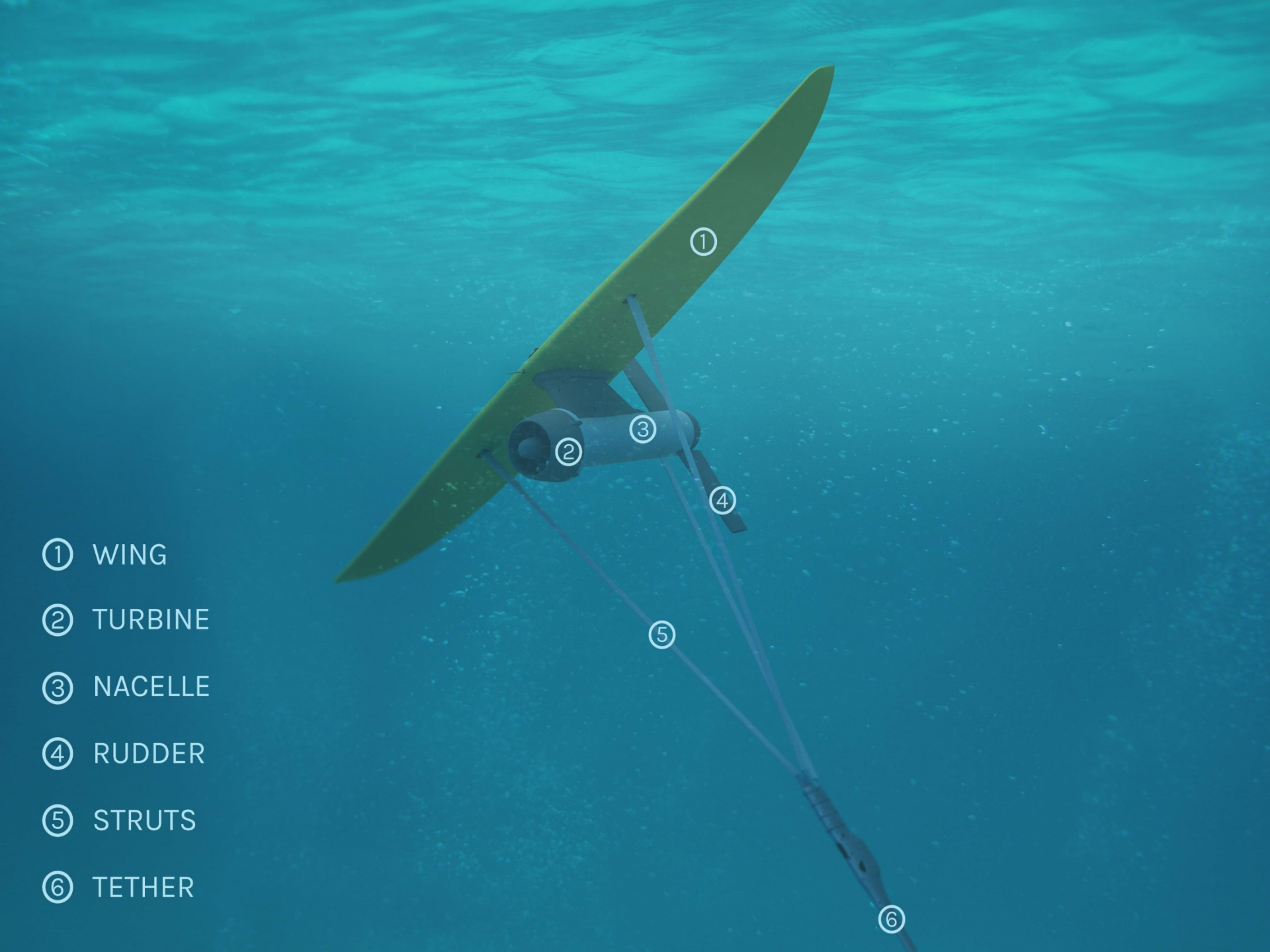
Results: Power density



Technically Extractable Power

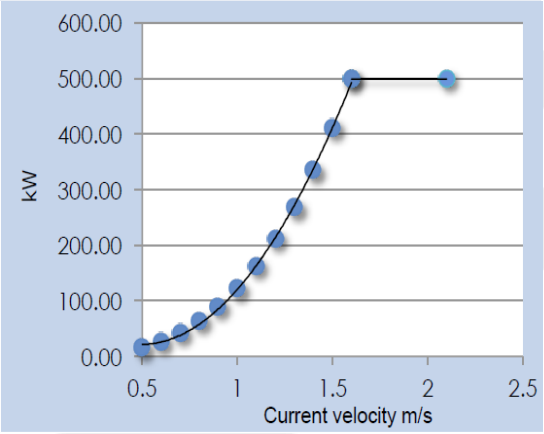
- Capacity factor depends on the available technology
- Ocean current technology very immature
- Can transfer lessons learnt and some technology development from the tidal industry
- Challenges? Mooring depth, lower velocity current

Rated speeds
~2 to 2.5 m/s

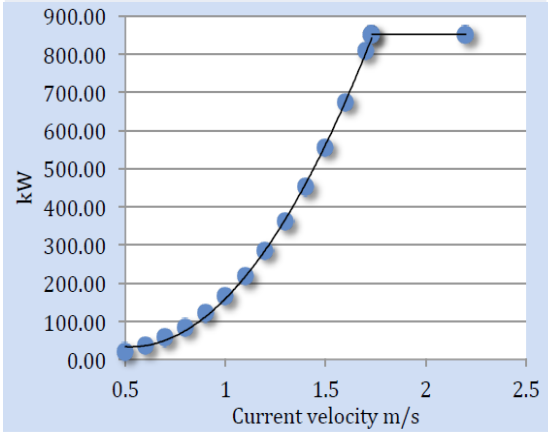

① WING
② TURBINE
③ NACELLE
④ RUDDER
⑤ STRUTS
⑥ TETHER

Results: Capacity Factor

DG-12
Rated: 500 kW
Cut-in speed: 0.4 m/s
Rated speed: 1.6 m/s



DG-14
Rated: 850 kW
Cut-in speed: 0.4 m/s
Rated speed: 1.73 m/s



The price of energy availability coupled with the price per kWh of generated electricity must also be examined when selecting the rated power size of the turbine

Capacity Factor

Depth	Minesto 850 kW Deep Green rated speed of 1.73 m/s	
	Mid-Shelf Location	Off-Shore Location
30 m	48.5%	71.0%
50 m	28.6%	65.1%

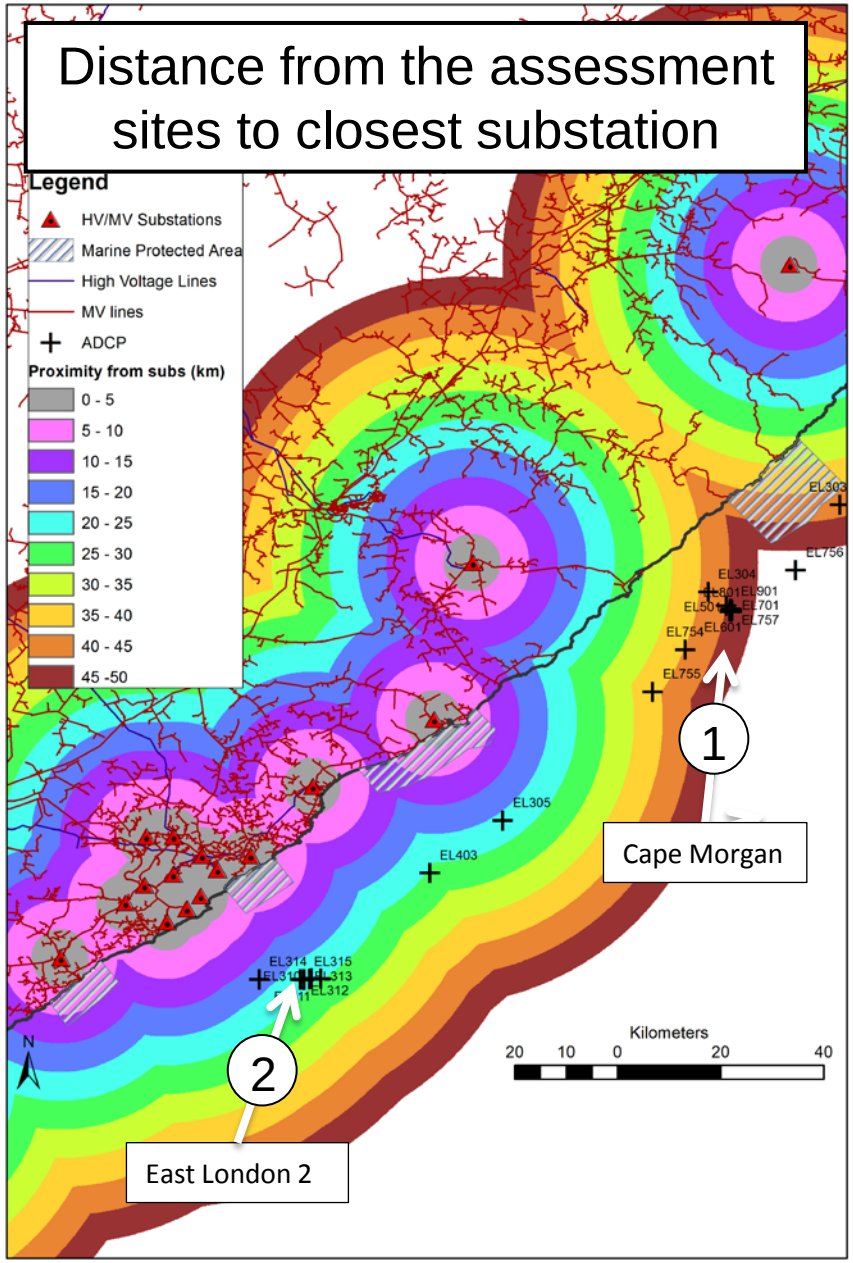
Depth	Minesto 500 kW Deep Green rated speed of 1.6 m/s	
	Mid-Shelf Location	Off-Shore Location
30 m	54.4%	75.6%
50 m	33.8%	70.3%

Other Renewable Energy Capacity Factors	
Tidal	20-30%
Wave	15-22%
Wind	30-45%

Although the capacity factor of the off-shore site is higher than that of the mid-shelf location, the economics of the longer sea cable and increased mooring challenges must be taken into consideration when deciding on an optimal deployment location.

Other contributing factors

- Geotechnical and Mooring Concerns
- Shipping Routes
- Commercial fishing activities
- Existing infrastructure that can consume the generated energy
- Environmental concerns



Conclusion

- The found estimated capacity factors compare well to other renewable energy resources
- Although promising capacity factors can be achieved with the Minesto Deep Green turbines, there is great uncertainty surrounding the survivability and mooring challenges of this technology.

Further Research

- It is recommended that **further technology development** be carried out with specific focus on suitable technology for ocean current applications.
- It is recommended that a **detailed economic assessment** be carried out to determine whether the increased mooring challenges and longer length of undersea cabling is justified by the increased power output at the off-shore site.

It has been shown that this current holds potential to make a significant contribution to the South African electricity grid.


Questions?
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