Assessment of Power Potential of Tidal Currents and Impacts of Power Extraction on Flow Conditions in Indonesia

Kadir Orhan, FTZ, University of Kiel
Roberto Mayerle, FTZ, University of Kiel

CC BY

ERE3.2/OS4.8 Marine renewable energy; resource characterisation, interactions and impacts

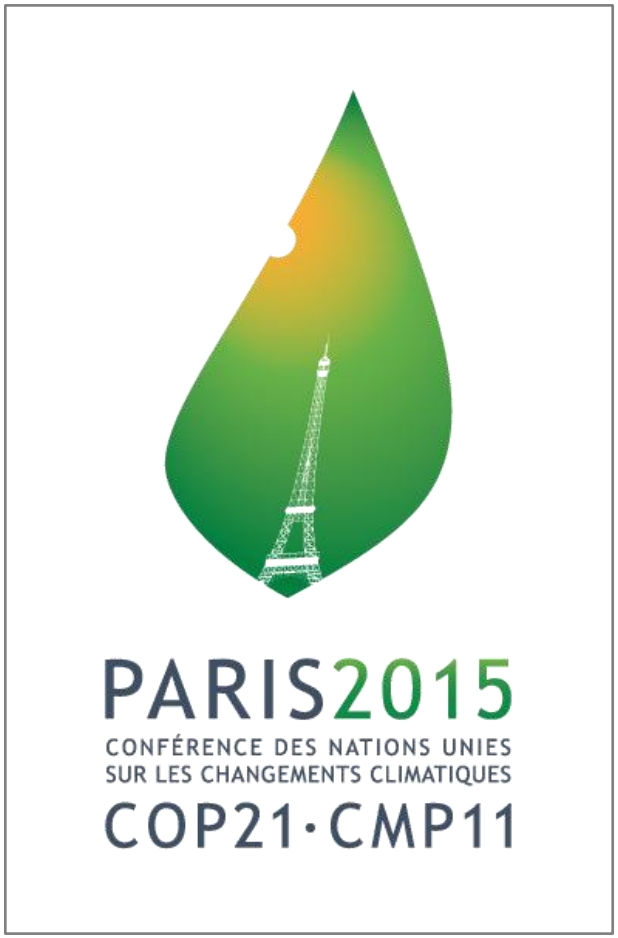
OUTLINE

CC BY

1. Introduction
2. Objectives
3. Methodology
4. Conclusions and Outlook

1. Introduction

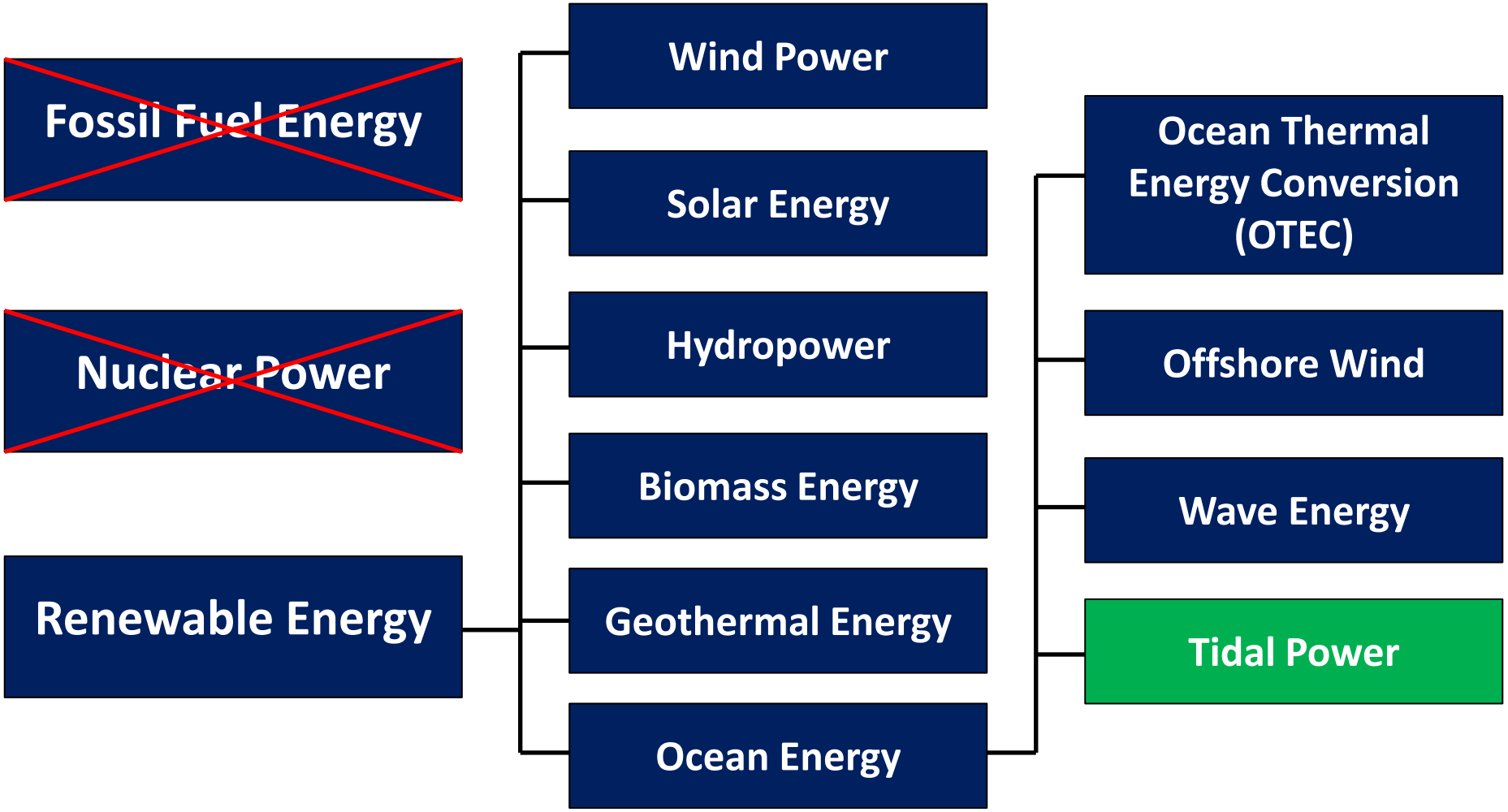
CC BY



«Climate change represents an urgent and potentially irreversible threat to human societies and the planet and thus requires the widest possible cooperation by all countries, and their participation in an effective and appropriate international response, with a view to accelerating the **reduction of global greenhouse gas emissions**.»

Universal Access to Sustainable Energy

1. Introduction



1. Introduction

CC BY

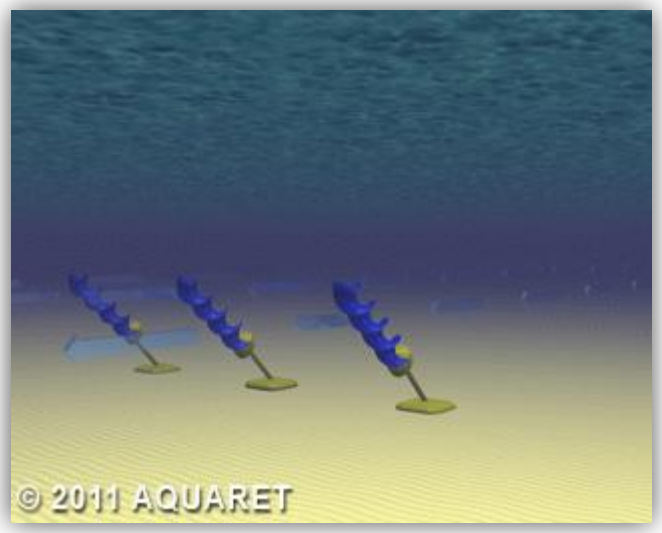
120GW

TOTAL ESTIMATED TIDAL STREAM CAPACITY GLOBALLY

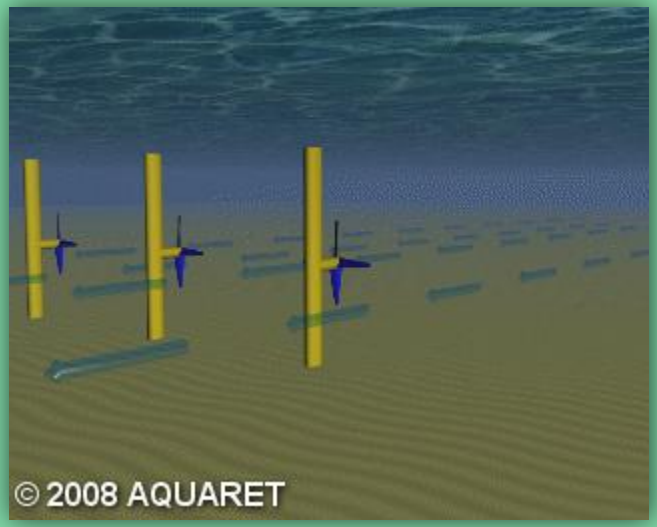
source [Image]: Atlantis Resources

2. Objectives

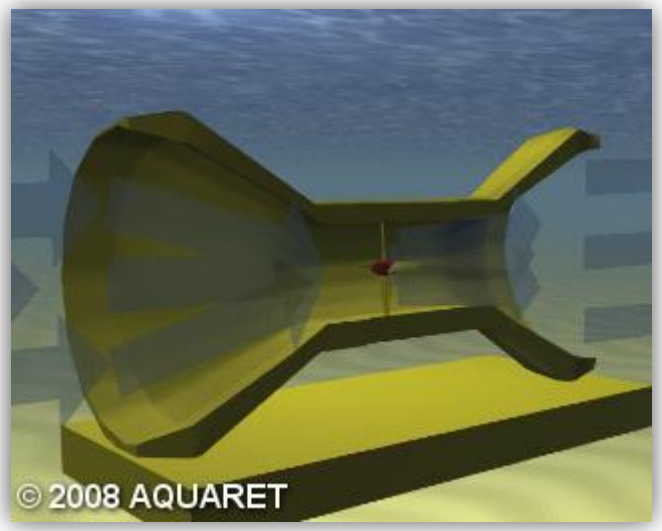
Archimedes screw



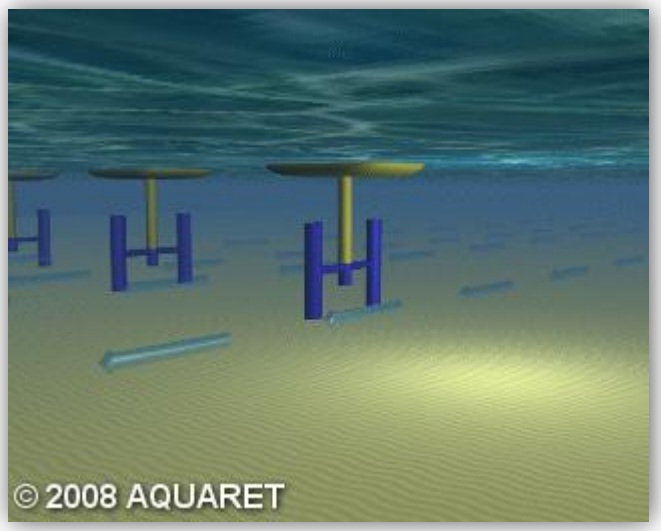
Horizontal axis turbine



Venturi effect device

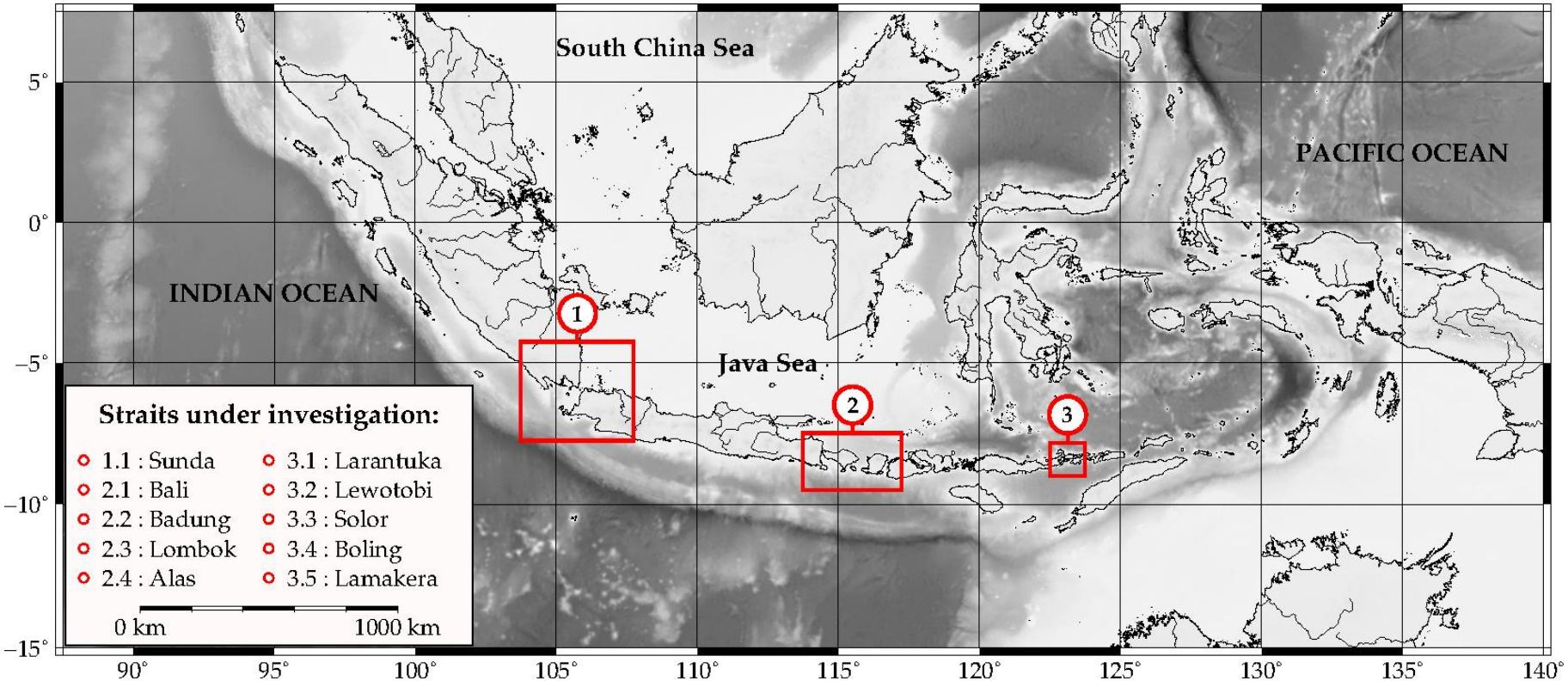


Vertical axis turbine

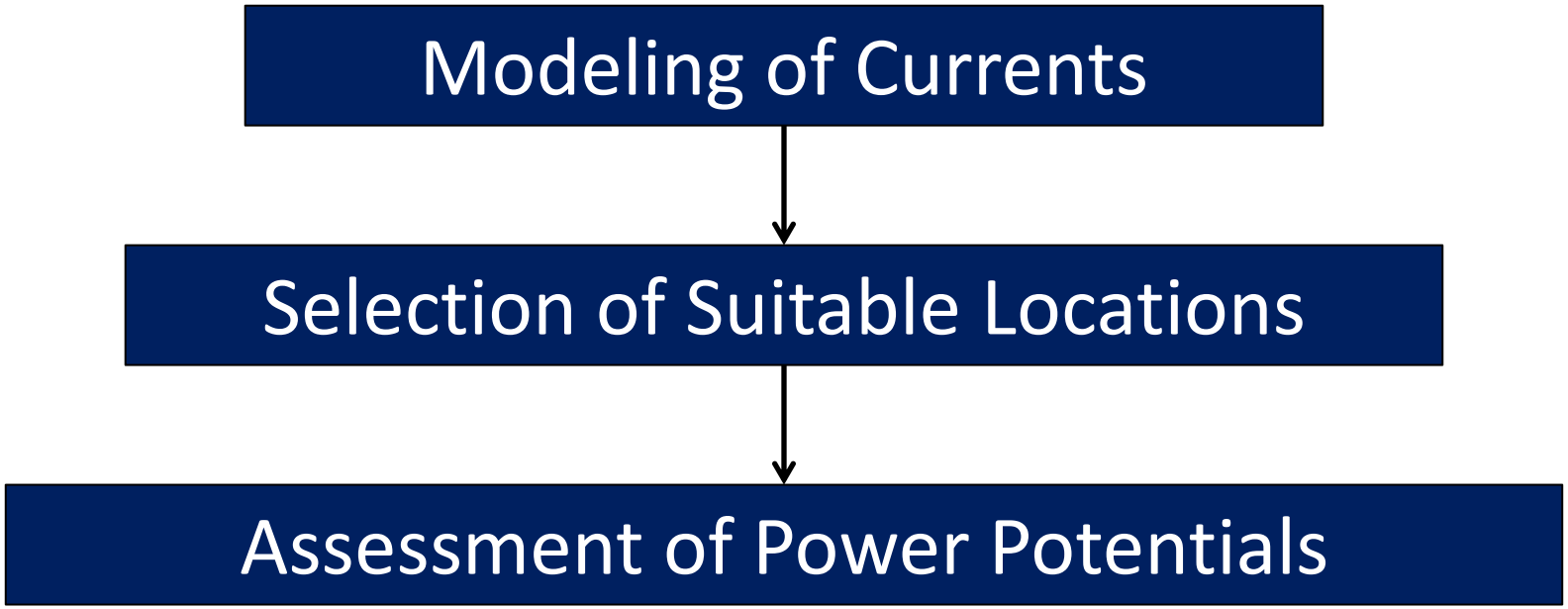


2. Objectives

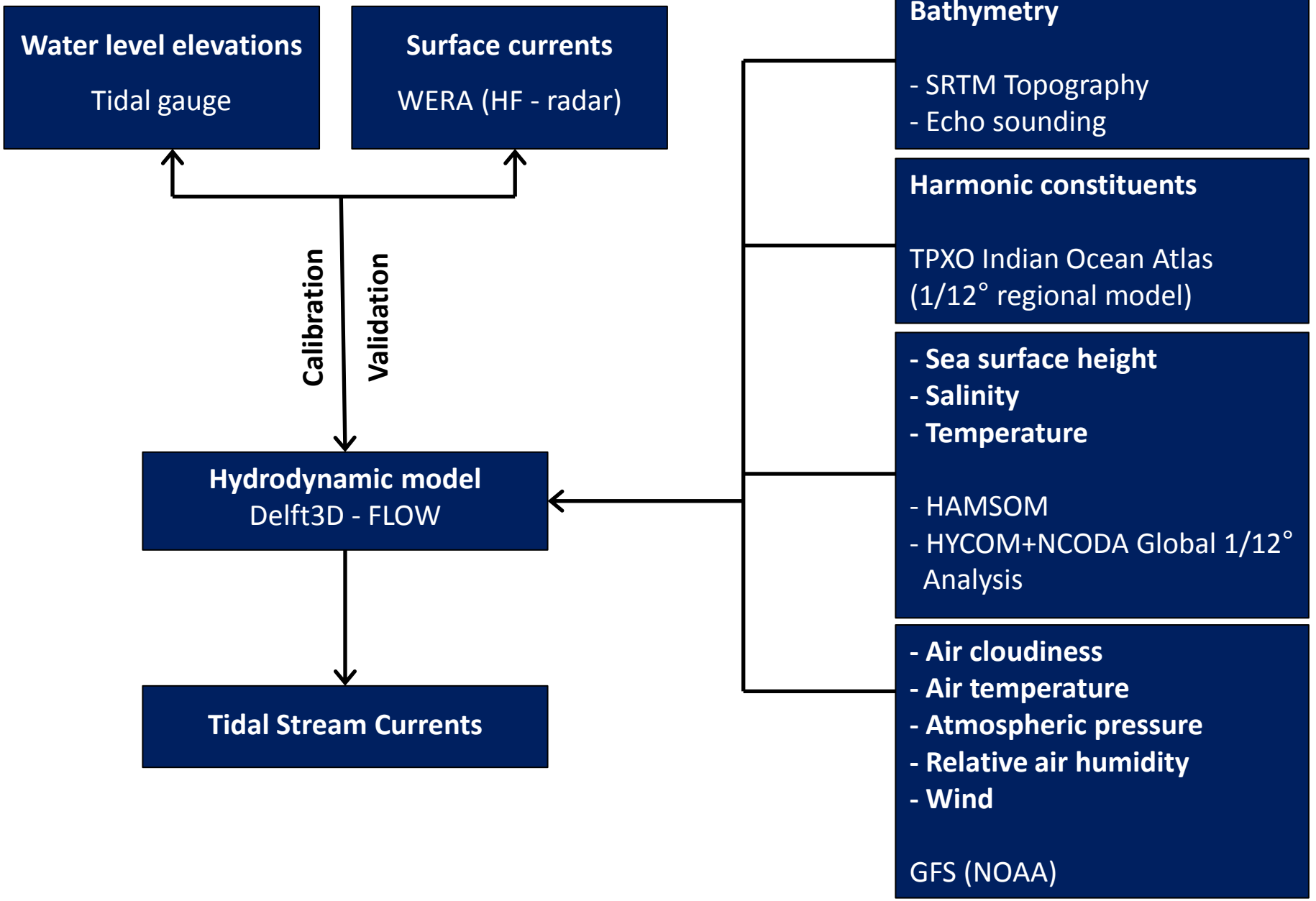
Straits in Indonesia being investigated

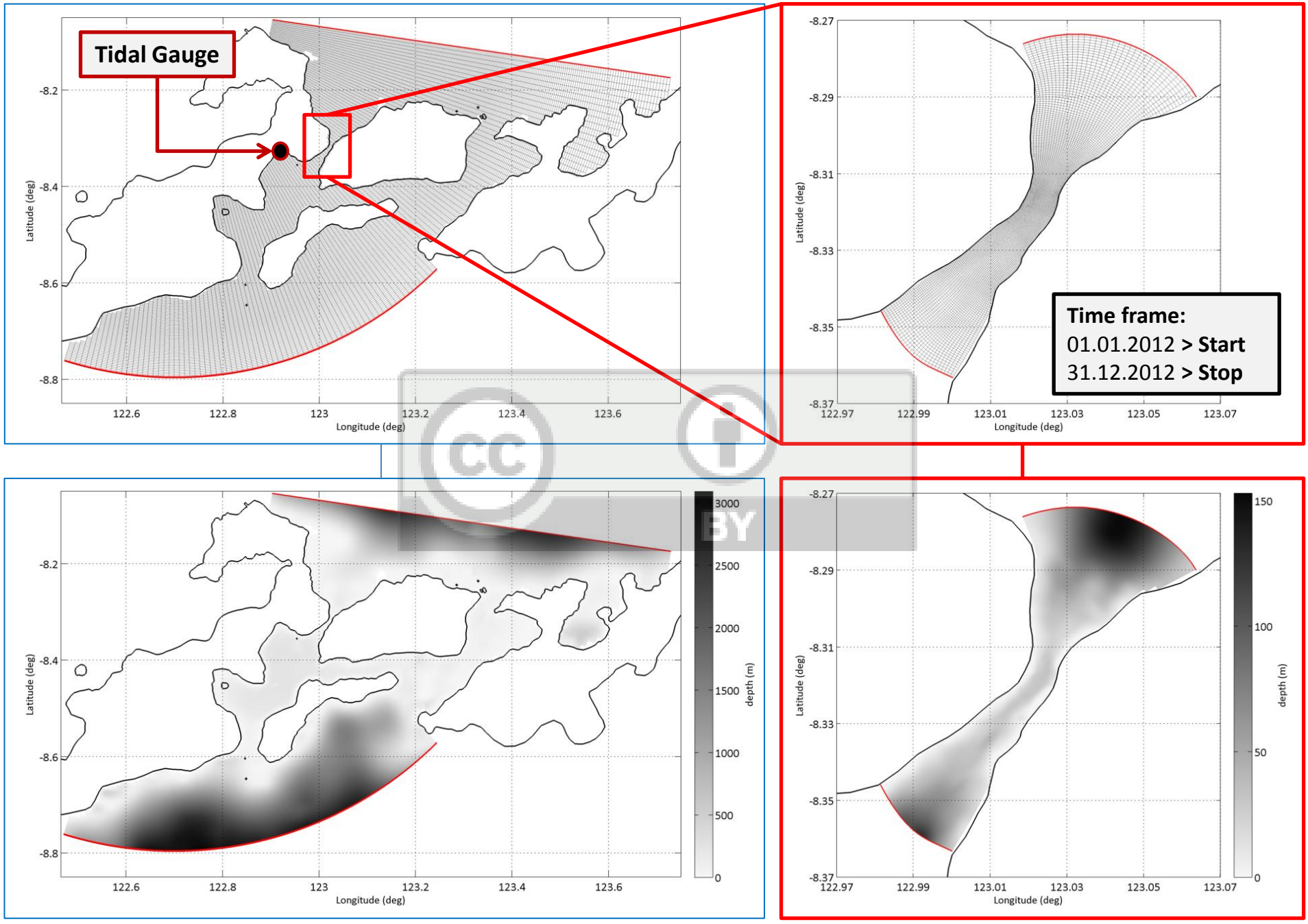


3. Methodology



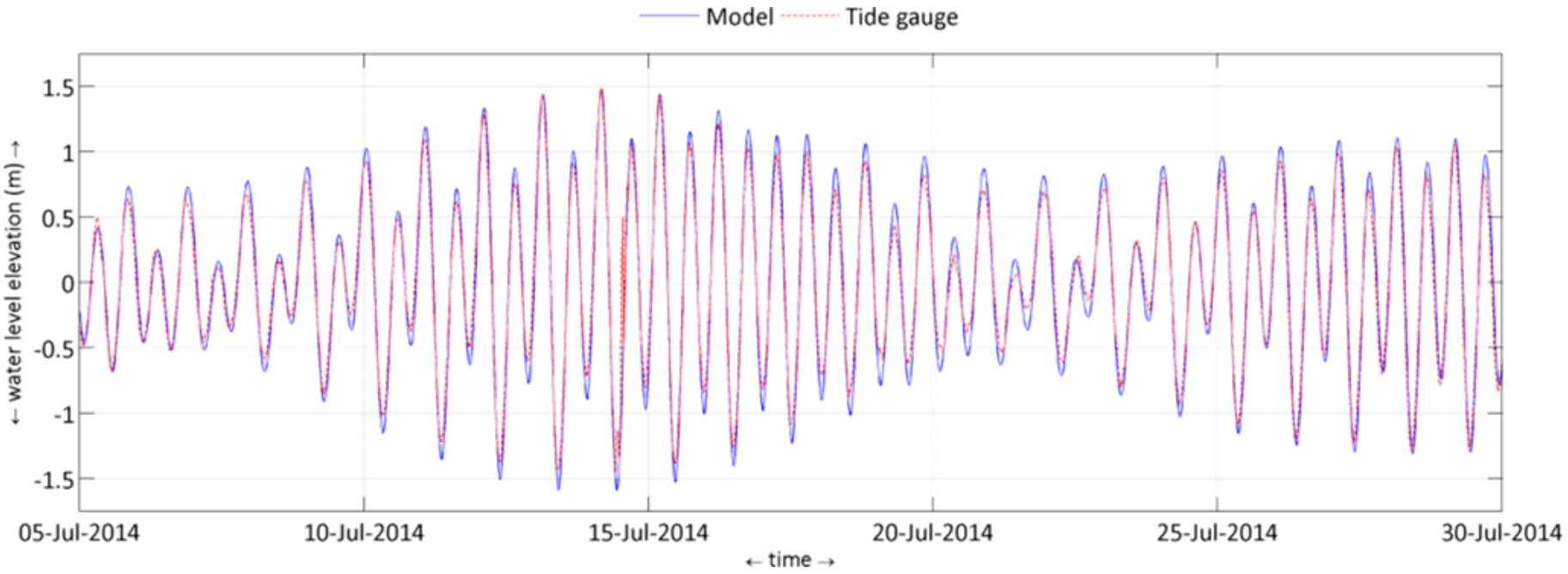
3.1. Modeling of Currents




Tidal Gauge
Latitude (deg)
Longitude (deg)
-8.2
-8.4
-8.6
-8.8
122.6
122.8
123
123.2
123.4
123.6
-8.27
-8.29
-8.31
-8.33
-8.35
-8.37
122.97
122.99
123.01
123.03
123.05
123.07
Time frame:
01.01.2012 > Start
31.12.2012 > Stop
depth (m)
3000
2500
2000
1500
1000
500
0
150
100
50
0

3.1. Modeling of Currents

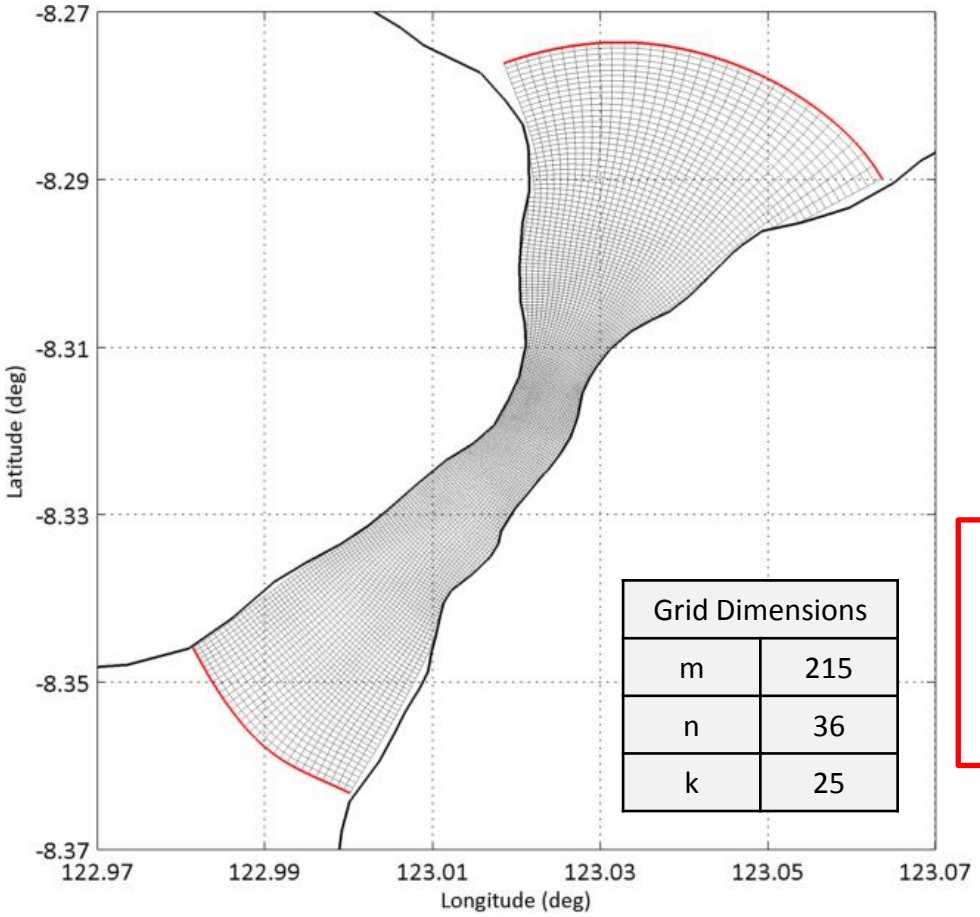
Comparison between modeled water level elevations and tidal gauge measurement for the Strait of Larantuka



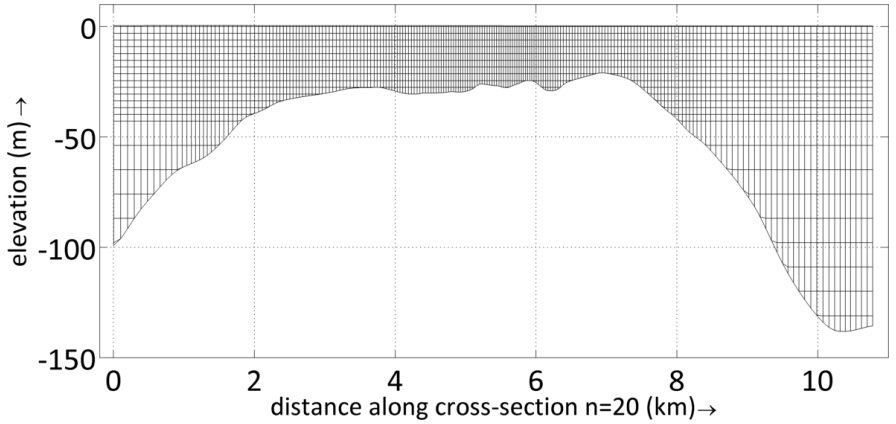
Pearson correlation coefficient (r)	0.98
Root-mean-square error (RMSE)	0.11

3.1. Modeling of Currents

Model set-up: Strait of Larantuka



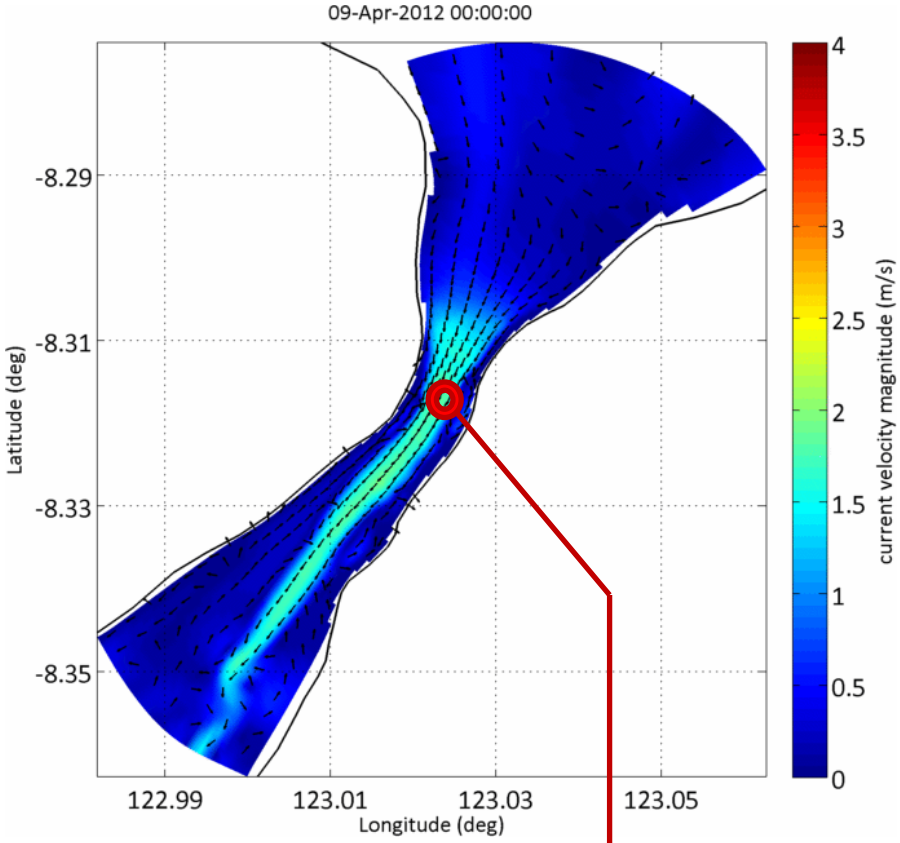
Grid Dimensions	
m	215
n	36
k	25

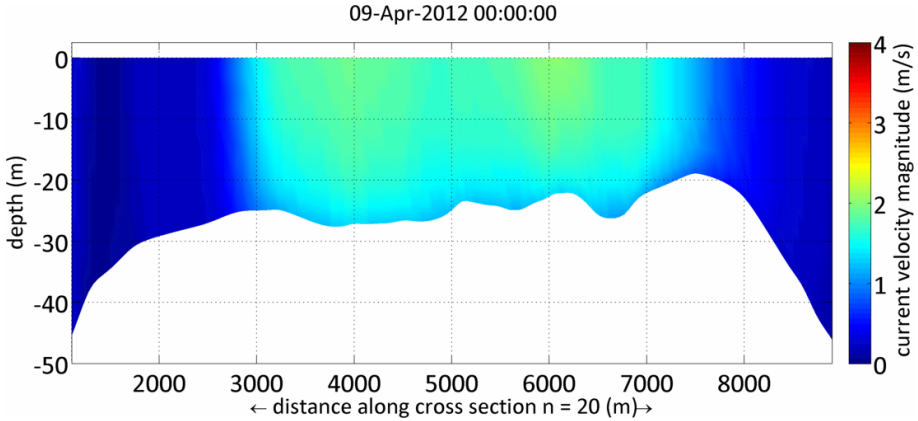


3D models with fixed layers in the depth-wise direction

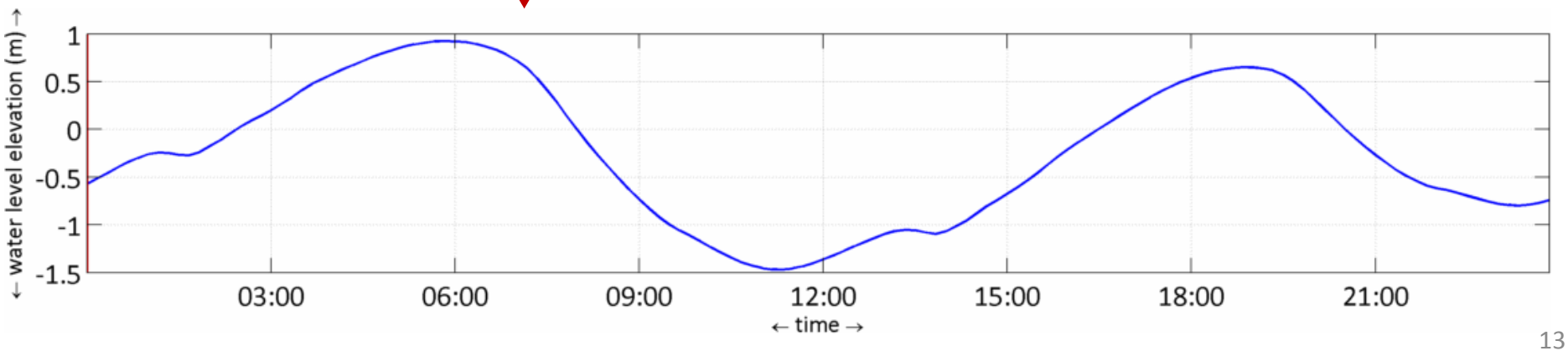
Accuracy of the vertical distribution of temperature and salinity

Current Velocity Magnitudes

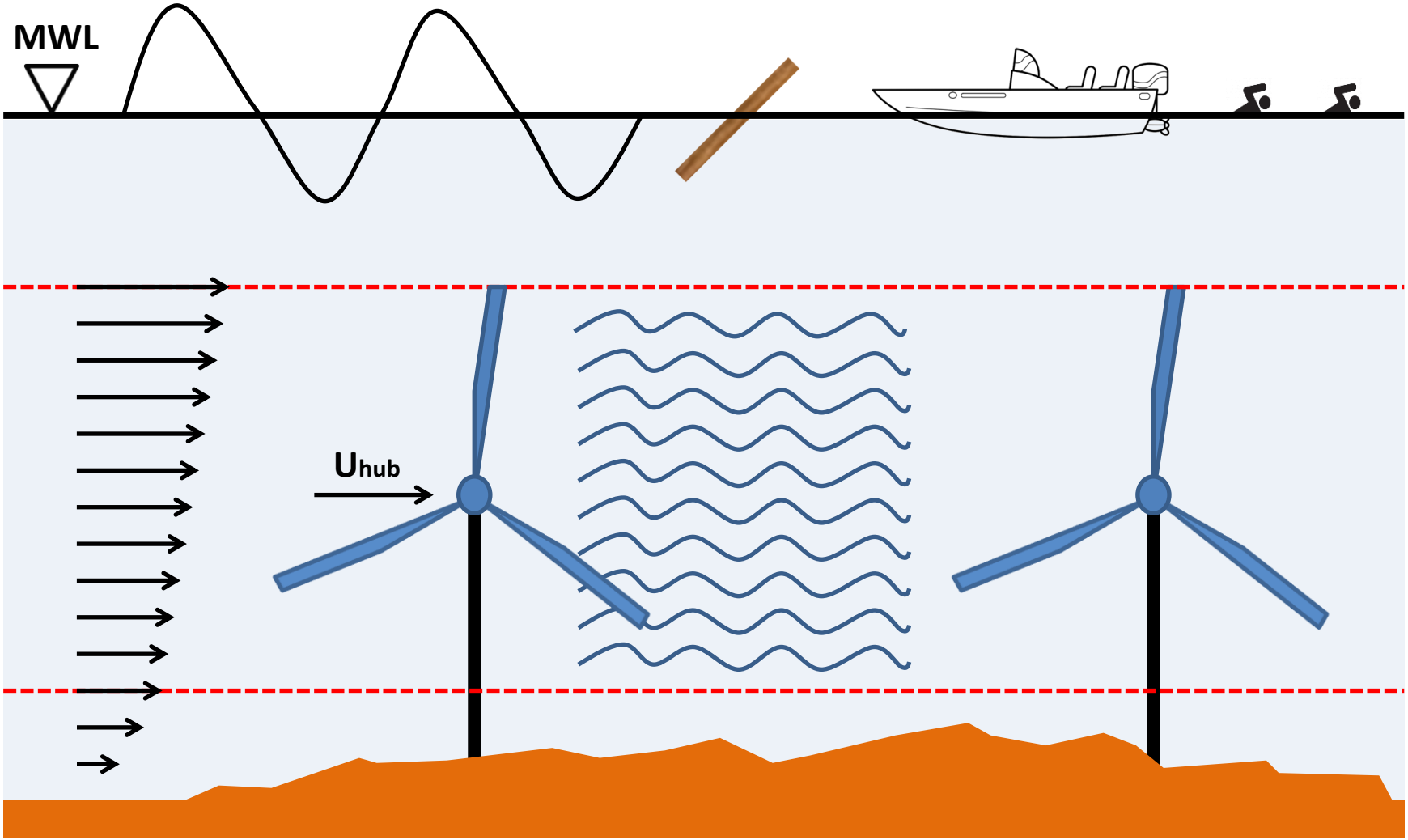




$$P = \frac{1}{2} \cdot \rho \cdot U^3$$



3.2. Selection of Suitable Locations



$$P_{electric} = A_{turbine} \cdot \frac{1}{2} \cdot \rho \cdot U_{hub}{}^{3} \cdot \eta_{turbine} \cdot \eta_{ptake-off}$$

3.2. Selection of Suitable Locations

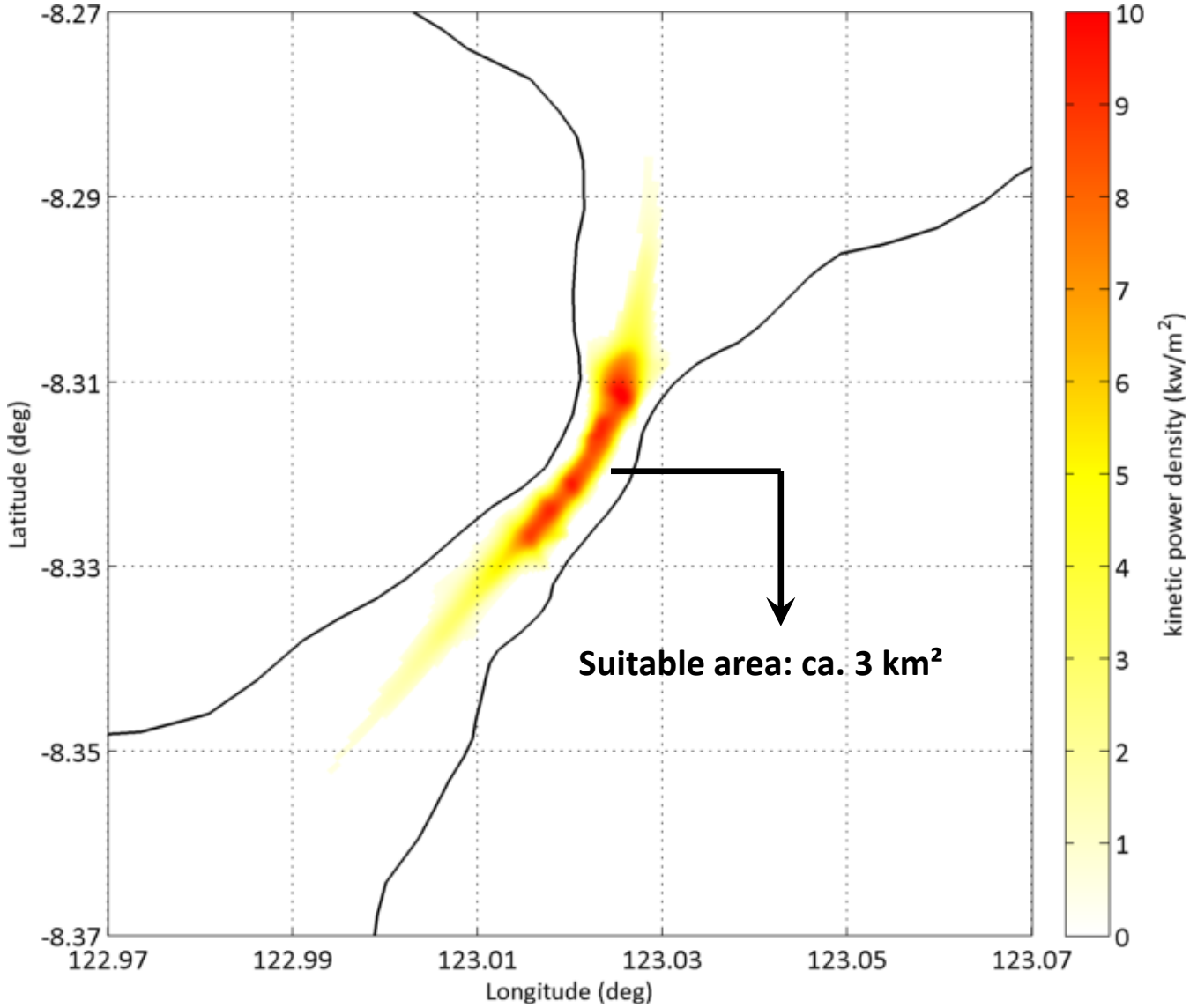
CC BY

- Horizontal axis tidal turbines, which can harness a strongly bi-directional flow with rotor diameters ranging between 1.5m and 20m are considered
- The near free surface upper 5m is eliminated
- The turbines are located above the low-speed benthic boundary layer

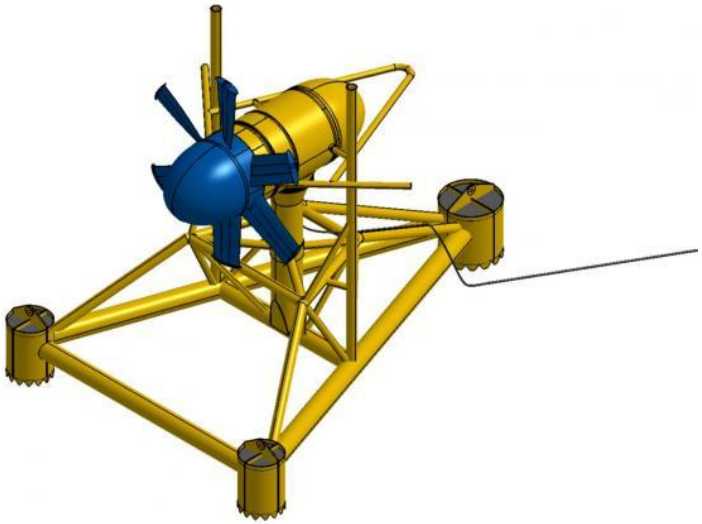
→
- **Minimum depth is defined as 7.5m**
- **The minimum for the power density is selected as 0.5 kW/m^2**
- **The minimum for the surface area is selected as 0.5km^2**

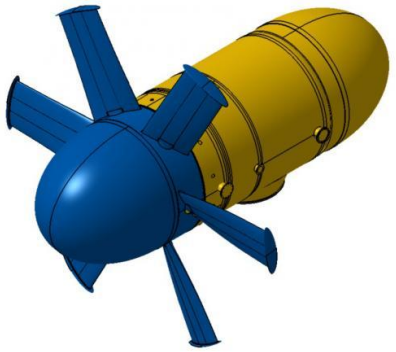
3.2. Selection of Suitable Locations

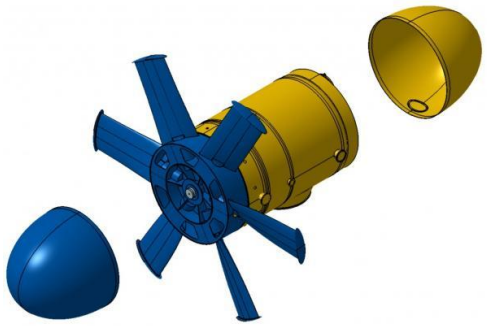
- Kinetic Power Density: Strait of Larantuka

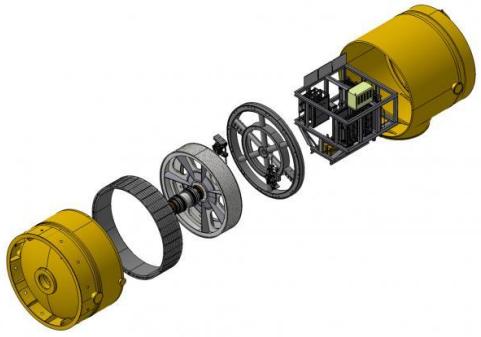


3.3. Assessment of Power Potentials









$$P_{electric} = A_{turbine} \cdot \frac{1}{2} \cdot \rho \cdot U_{hub}{}^{3} \cdot \eta_{turbine} \cdot \eta_{ptake-off}$$

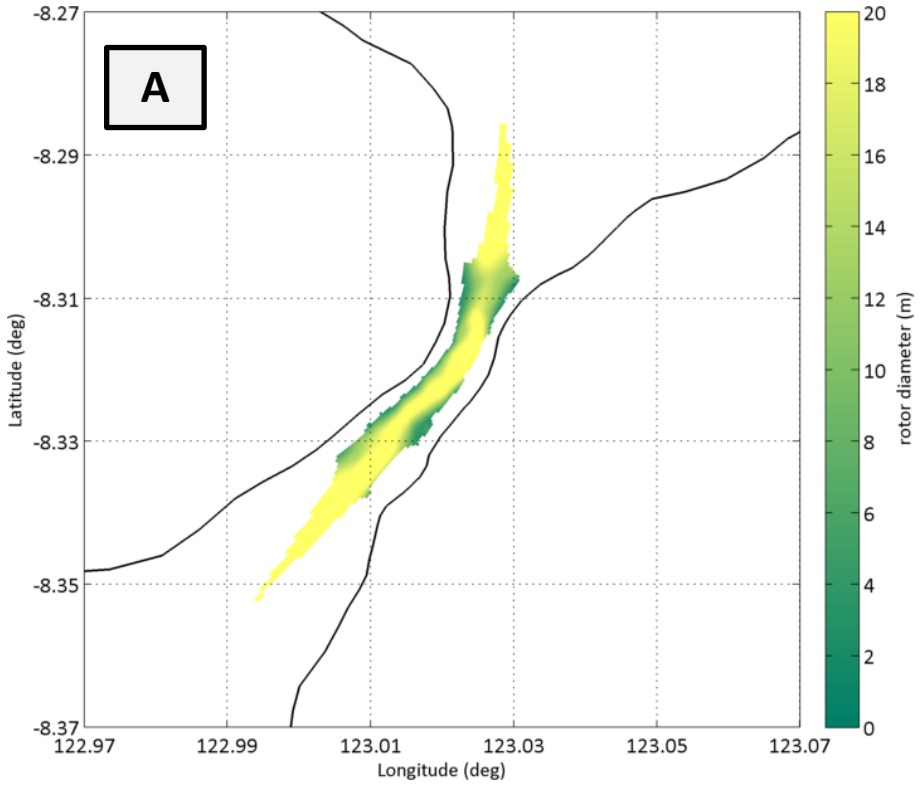
$$\eta_{ptake-off} = \eta_{drivetrain} \cdot \eta_{generator} \cdot \eta_{pcon}$$

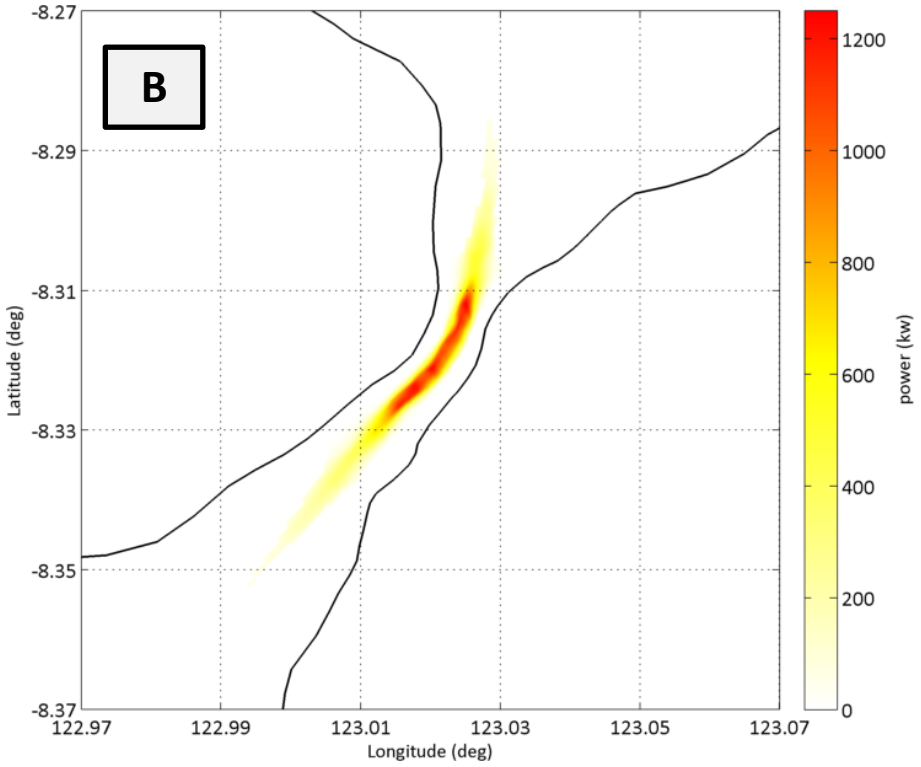
$\eta_{turbine}$	0.45
$\eta_{drivetrain}$	0.96
$\eta_{generator}$	0.95
η_{pcon}	0.98

source [Image]: SABELLA SAS

3.3. Assessment of Power Potentials

Spatial variation of applicable tidal stream turbine rotor diameters (**A**) and average exploitable power density with the tidal stream turbines (**B**)





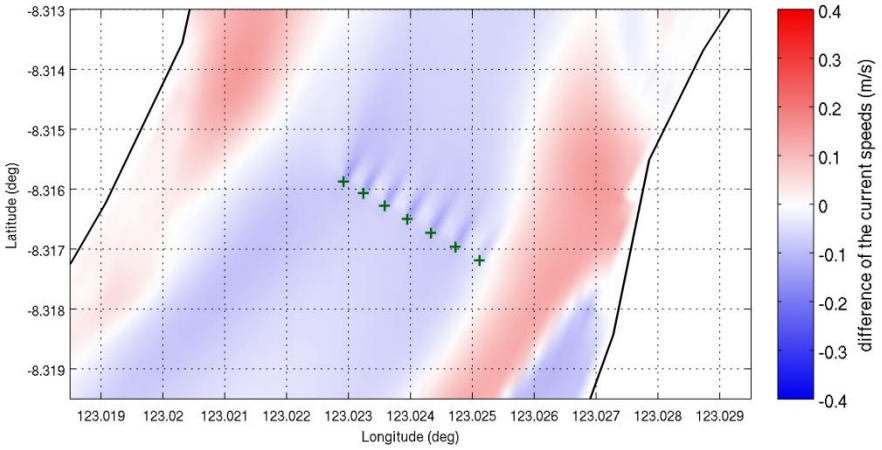
3.3. Assessment of Power Potentials

Summary of the resource mapping of investigated domains

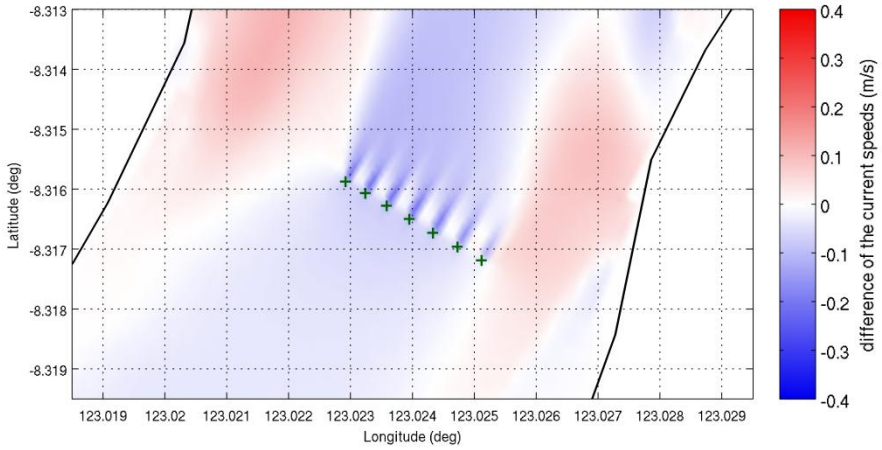
			Cut-in speed = 1.0 (m/s)		Cut-in speed = 0.5 (m/s)	
Strait	Max. kinetic power density (kW/m²)	Max. extractable power by one turbine (kW)	Suitable area (km²)	Total extractable power (MW)	Suitable area (km²)	Total extractable power (MW)
Bali	14.75	1,459	23	462	104	1,045
Larantuka	10.20	1,250	3	199	6	299
Boling	3.49	430	36	593	106	736
Alas	3.07	396	104	1,261	403	2,258
Lombok	2.36	236	53	754	114	865
Sunda	1.56	165	11	107	145	335
Badung	1.52	161	28	238	162	551
			SUM	3,614	SUM	6,089

3.4. Impact on flow conditions

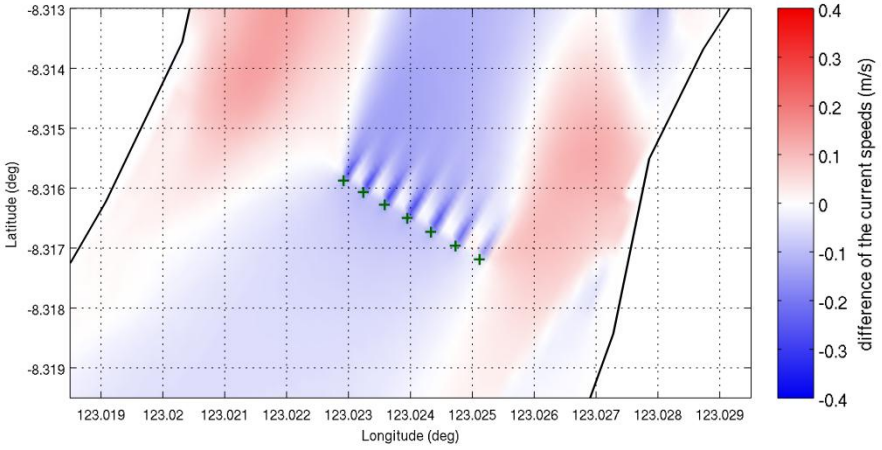
20% dissipation:

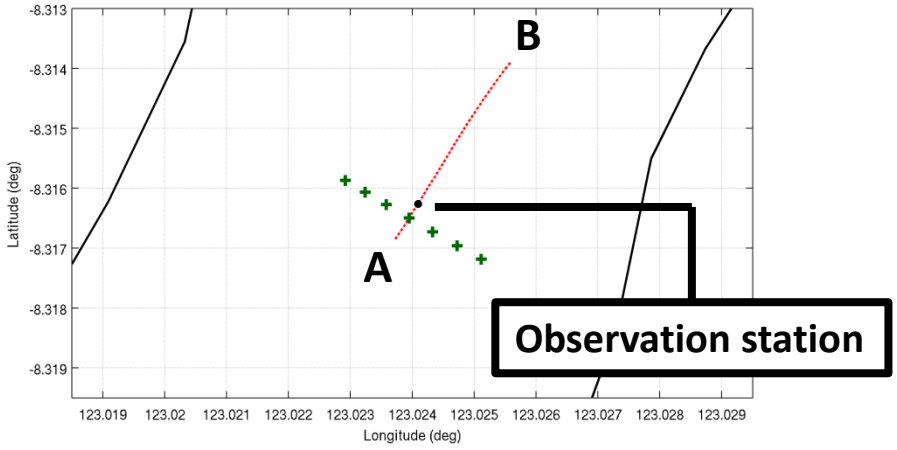


40% dissipation:



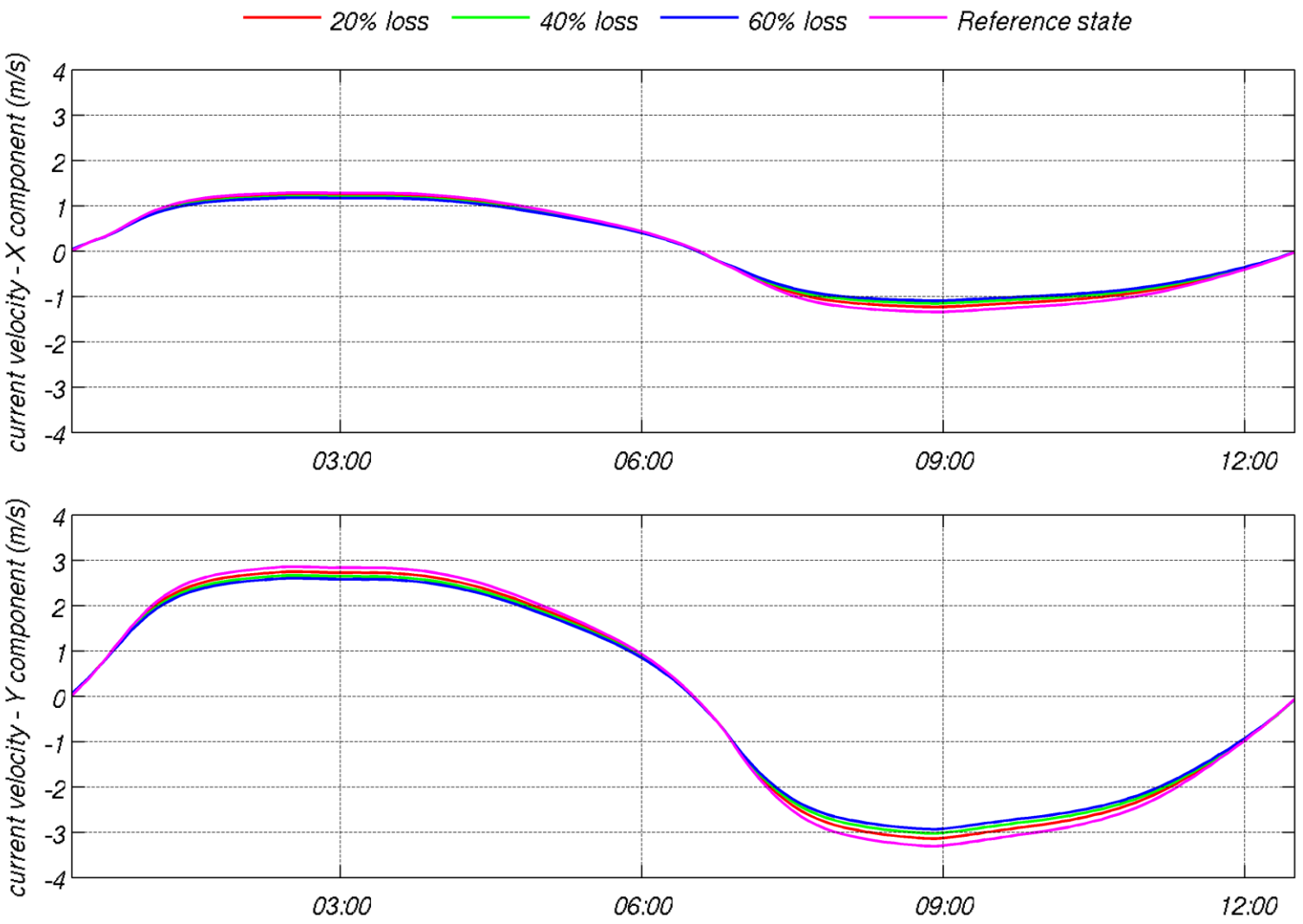
60% dissipation:





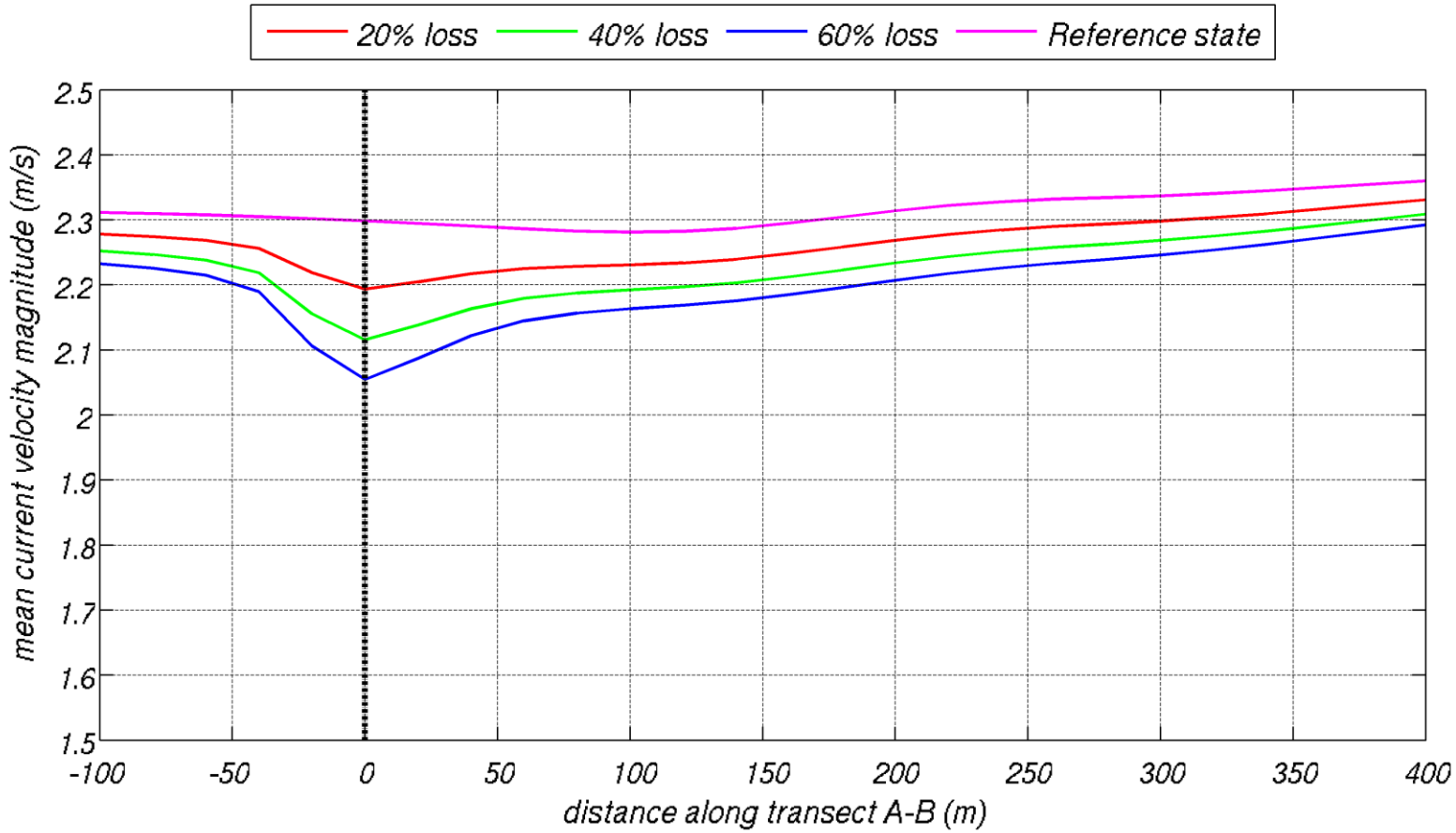
3.4. Impact on flow conditions

Current velocities at the observation station considering 20%, 40% and 60% dissipation of the pre-existing kinetic power and the reference state



3.4. Impact on flow conditions

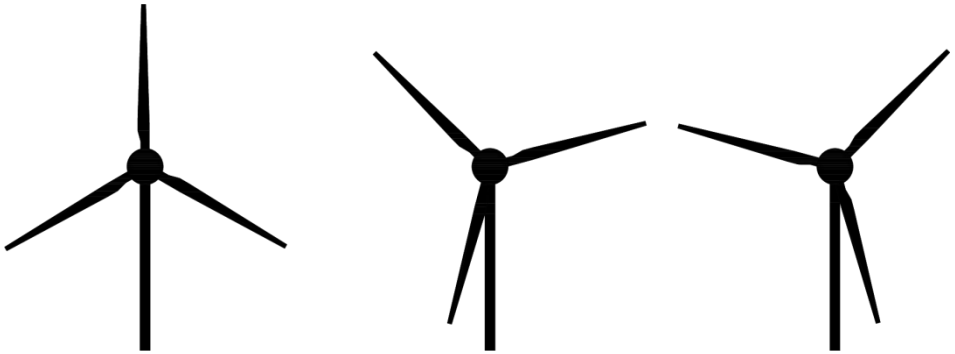
Mean current velocity magnitudes along the transect A-B considering 20%, 40% and 60% dissipation of the pre-existing kinetic power and the reference state



4. Conclusions and Outlook

- A "*decision support system*" for the assessment of tidal stream resources has been successfully developed
- Main difficulties: lack of accurate data for bathymetry and current velocities at the straits
- Total tidal stream power production is likely to exceed 5,000 MW
- Impacts of power extraction have been captured reasonably well with low computational cost
- Future research: coupling of *FLOW* and *CFD* models

Thank you for your attention!



CC BY

Contact: korhan@corelab.uni-kiel.de