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# *Recent developments in wave energy along the coast of southern African*

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**Ocean Energy workshop**

**18 September 2009**

# Contents

RENEWABLE & SUSTAINABLE ENERGY STUDIES

- Introduction
- Industry opportunities & barriers
- Global & local wave energy resource
- Commercial projects in SA
- SWEC
- ShoreSWEC
- Way forward
- Conclusions
- Recommendations

# Introduction

RENEWABLE & SUSTAINABLE ENERGY STUDIES

- Highest energy density of all RE sources
- Free source of non-polluting energy
- Seasonal variability corresponds to demand (in SA)
- Seasonal variability compliments wind & solar energy

# Opportunities for wave energy development in SA

RENEWABLE & SUSTAINABLE ENERGY STUDIES

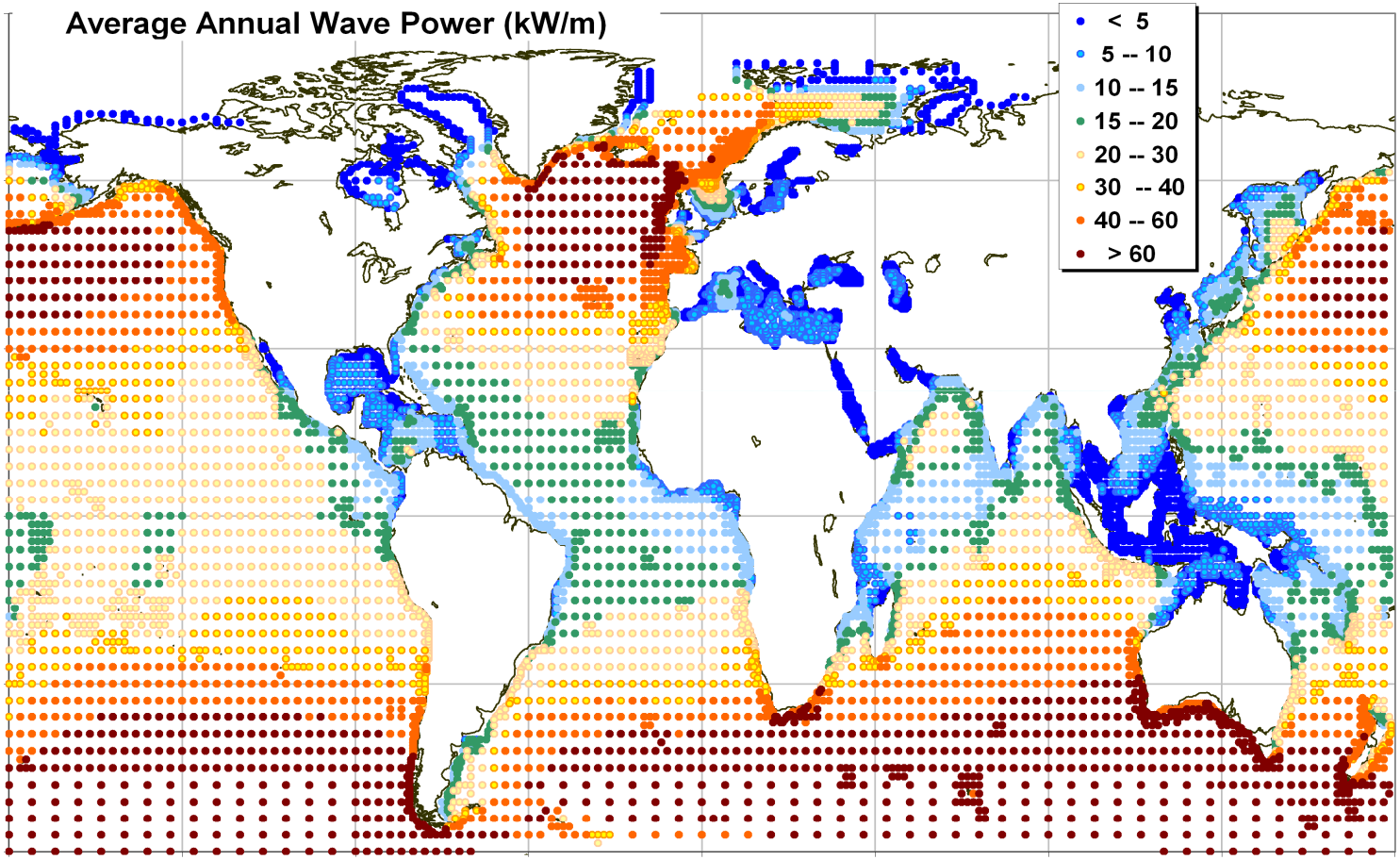
- SA renewable energy target of 10 000 GWh by 2013
- Abundant resource (30 – 50 kW/m)
- Energy security & strengthen weak coastal grid
- Strong research base dating back to the seventies
- Competent community of coastal engineers, naval architects and ship manufacturers
- Job creation

# Industry barriers

- Immature, unproven technology
- Lack of collaboration between various role-players
- “Low” cost of electricity in SA
- No financial incentives
- No clear guidelines for licensing and permit requirements
- Difficult to quantify environmental impacts

# Global wave power resource

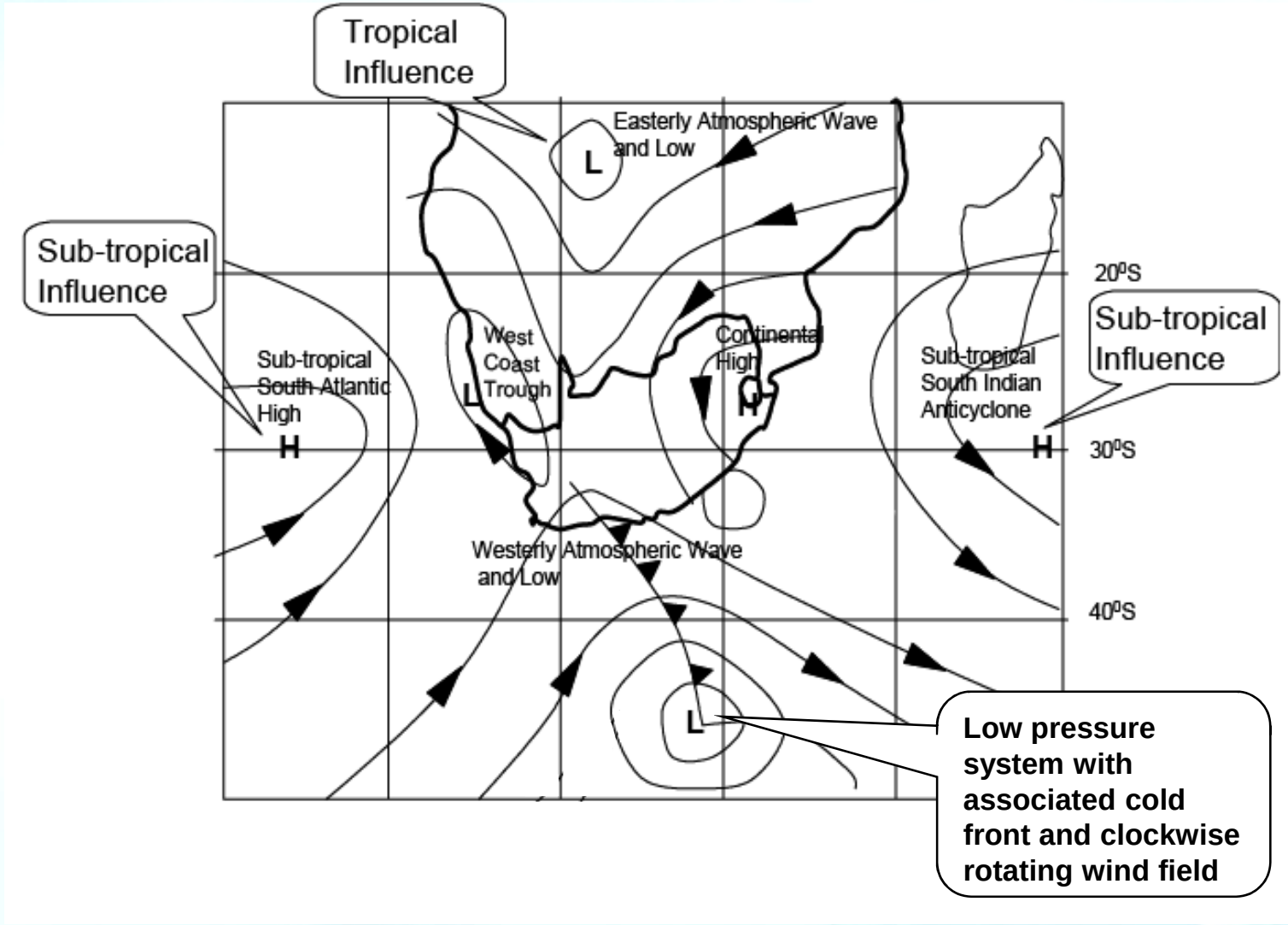
RENEWABLE & SUSTAINABLE ENERGY STUDIES




World Waves data/OCEANOR/ECMWF

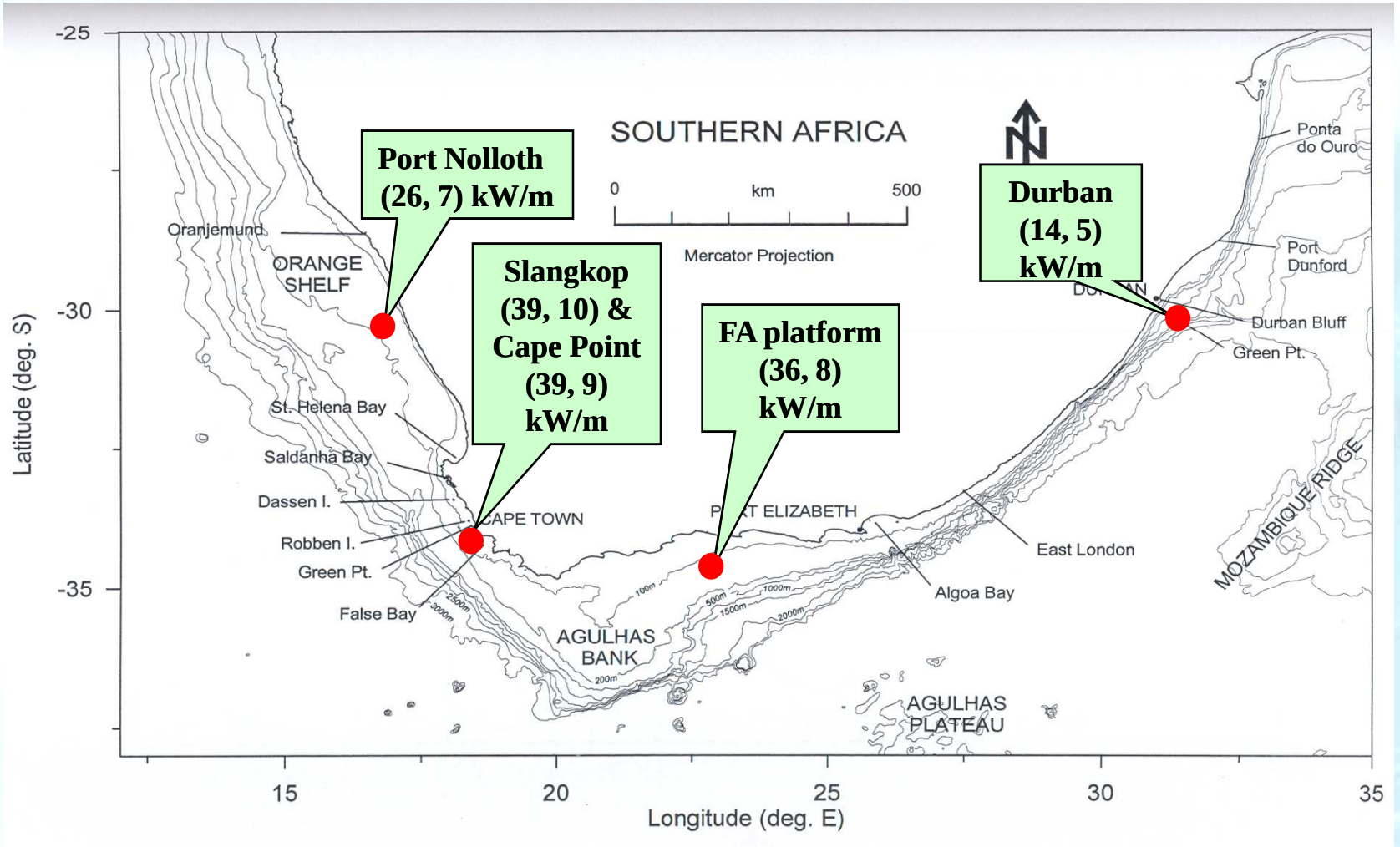
# SA meteorology

RENEWABLE & SUSTAINABLE ENERGY STUDIES



# Measured wave data analysis

RENEWABLE & SUSTAINABLE ENERGY STUDIES



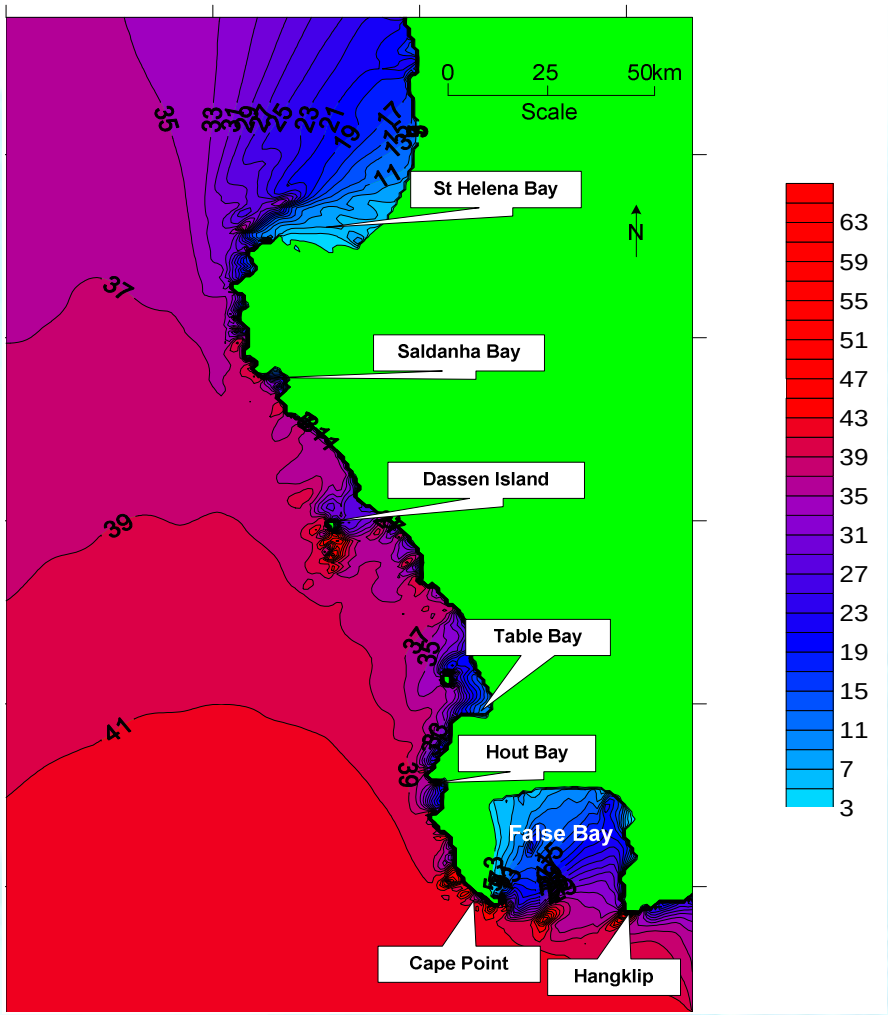
# Modelled wave data analysis

RENEWABLE & SUSTAINABLE ENERGY STUDIES

## Model output

- Mean annual
- Mean seasonal
- Mean monthly

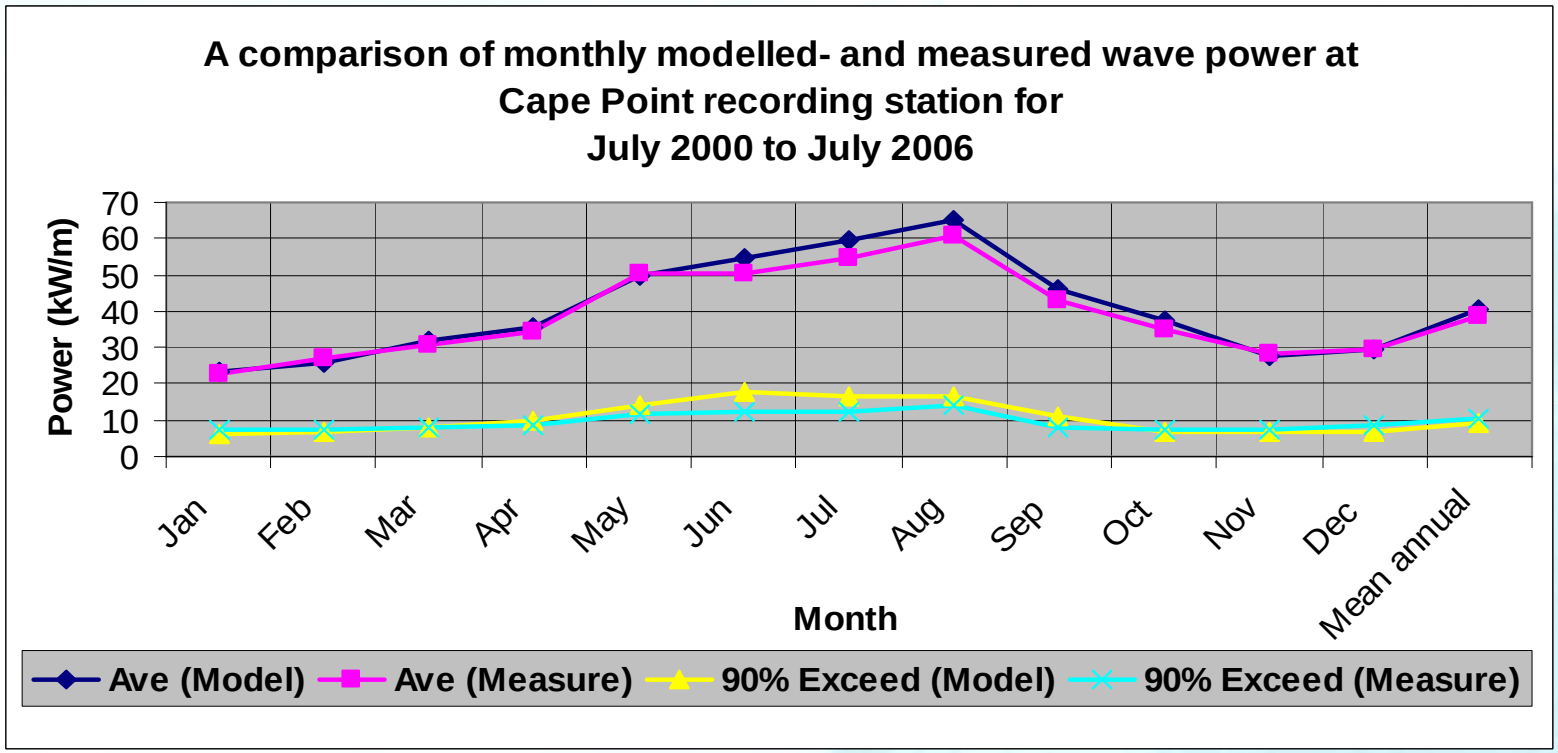
**Mean annual average wave power (kW/m)**



# Modelled wave data analysis

RENEWABLE & SUSTAINABLE ENERGY STUDIES

## Comparison of model hindcast- to measured data



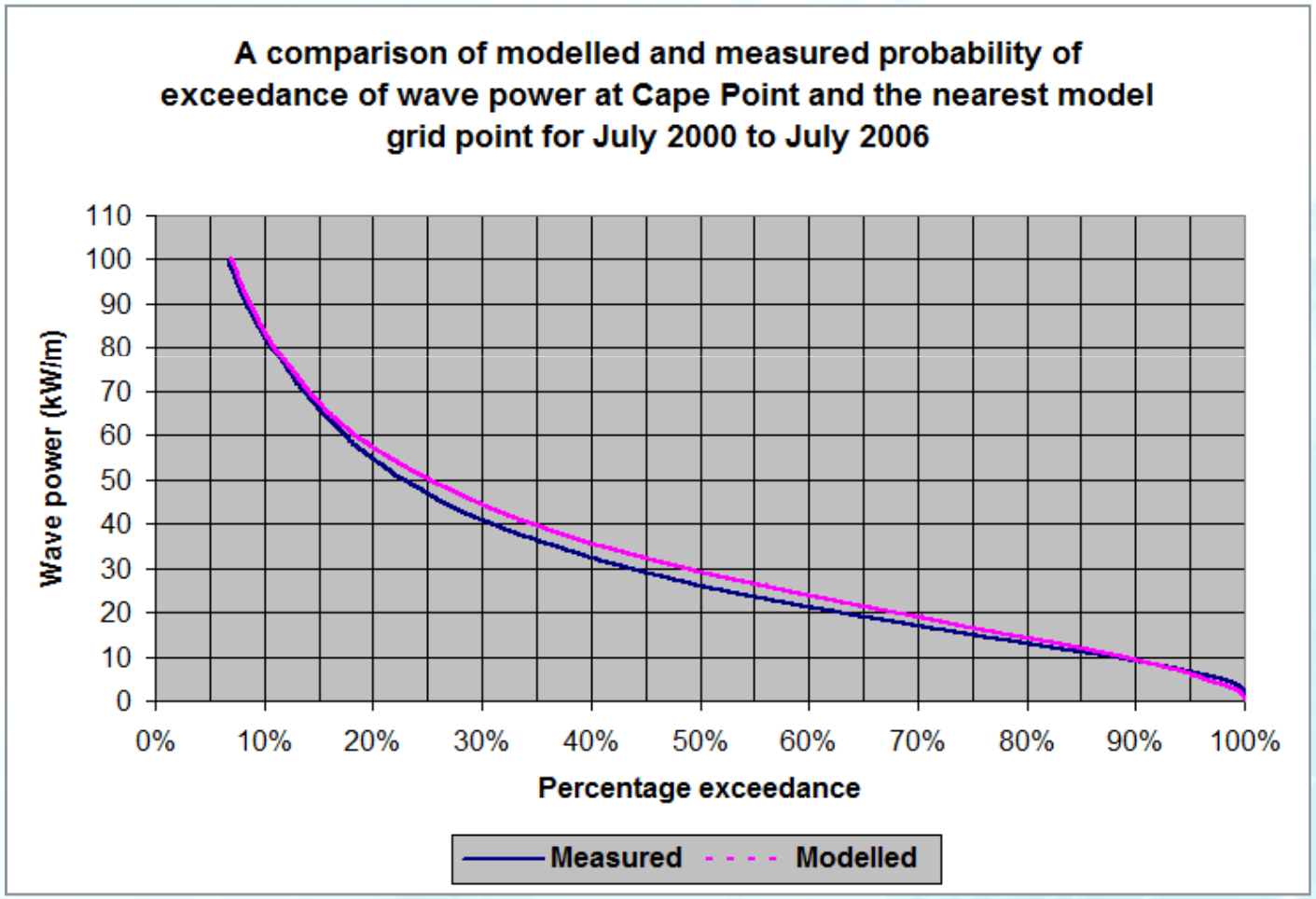

**% Difference between hindcast- and measured wave data**

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4% | -6% | 3% | 4% | -1% | 9% | 9% | 6% | 8% | 7% | -2% | 1% | 5% |

# Modelled wave data analysis

RENEWABLE & SUSTAINABLE ENERGY STUDIES

## Comparison of model hindcast- to measured data



# Commercial developments in southern Africa

RENEWABLE & SUSTAINABLE ENERGY STUDIES

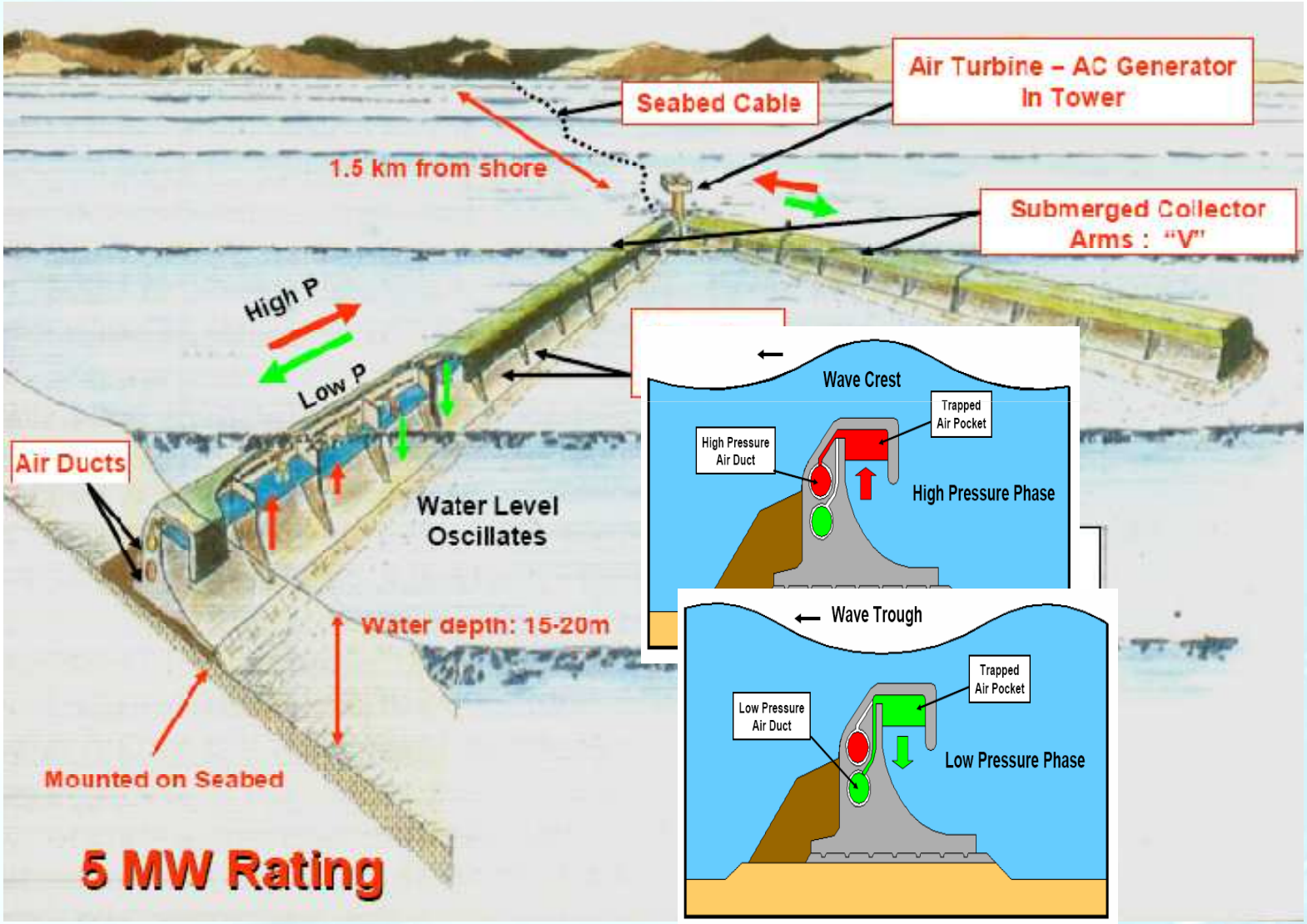
Oceanlinx: Namibia

Pelamis: Southern Cape coast


Finavera's Aquabuoy: Southwest coast

# Stellenbosch Wave Energy Converter(SWEC)

RENEWABLE & SUSTAINABLE ENERGY STUDIES



# SWEC (cont)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

## Barriers for full scale deployment

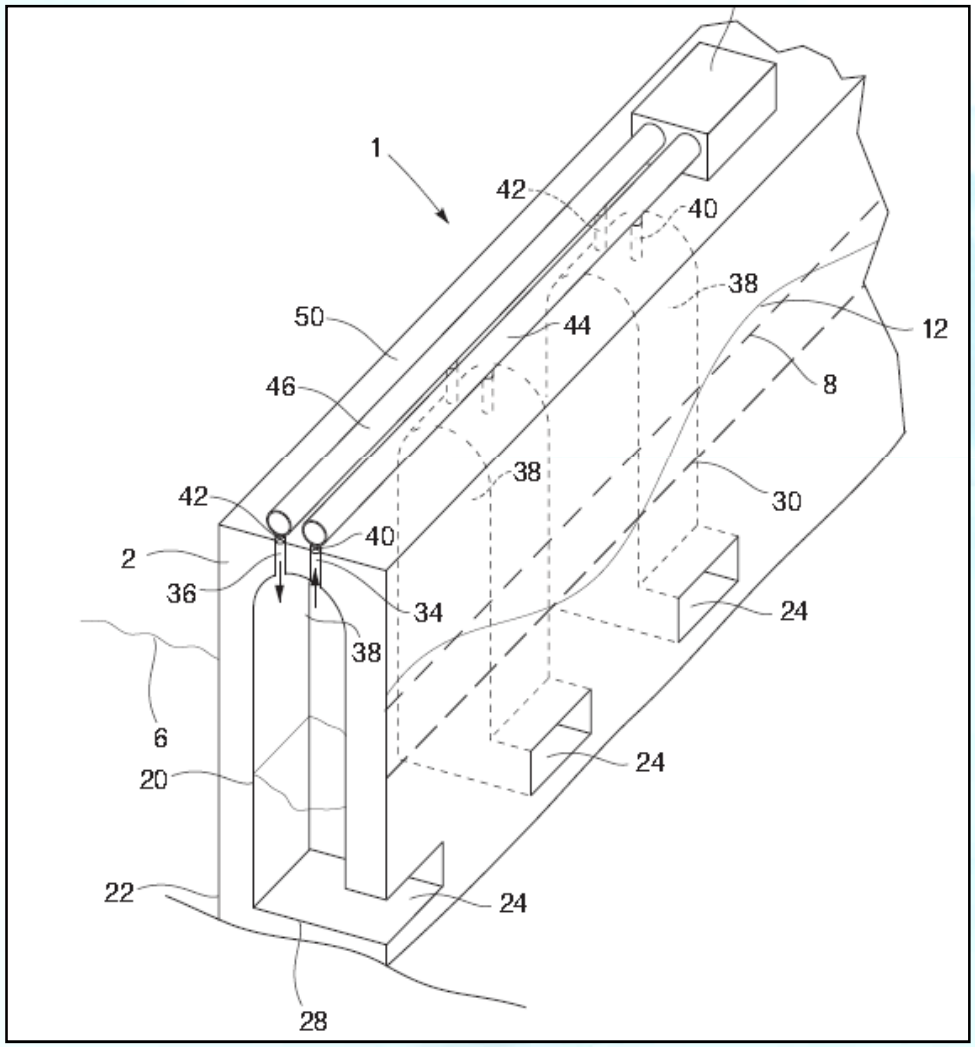
- Oil price stabilised
- High capital cost
- Complex licensing & permit requirements

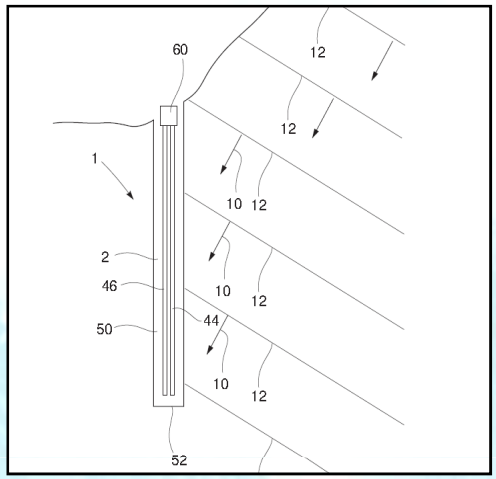
**Incorporate SWEC principle into breakwater structure for existing/new port development**

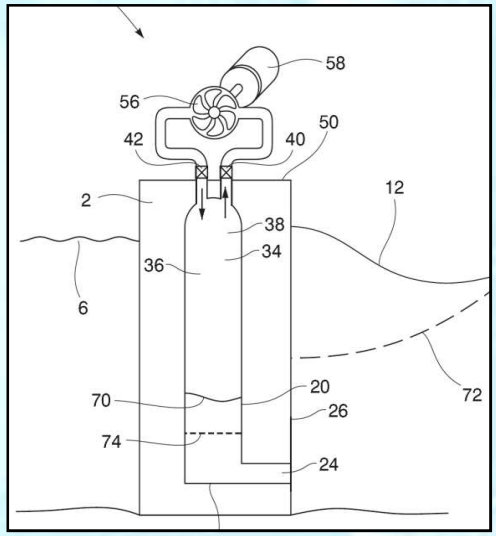
- Cost sharing between breakwater & WEC
- Reduced loadings on breakwater
- Simplifies EIA
- Supply clean, free energy to development

# ShoreSWEC

RENEWABLE & SUSTAINABLE ENERGY STUDIES



# Site selection

RENEWABLE & SUSTAINABLE ENERGY STUDIES

## Criteria

- Existing and/or new breakwater structure with suitable orientation
- Wave energy resource characteristics
- Impact on the surrounding environment and regulatory requirements
- Potential power purchaser
- Service vessels and waterfront infrastructure for system deployment, retrieval and servicing
- Proximity to device fabrication, assembly facilities and expertise
- Proximity to onshore grid interconnection points

# Site selection (cont)

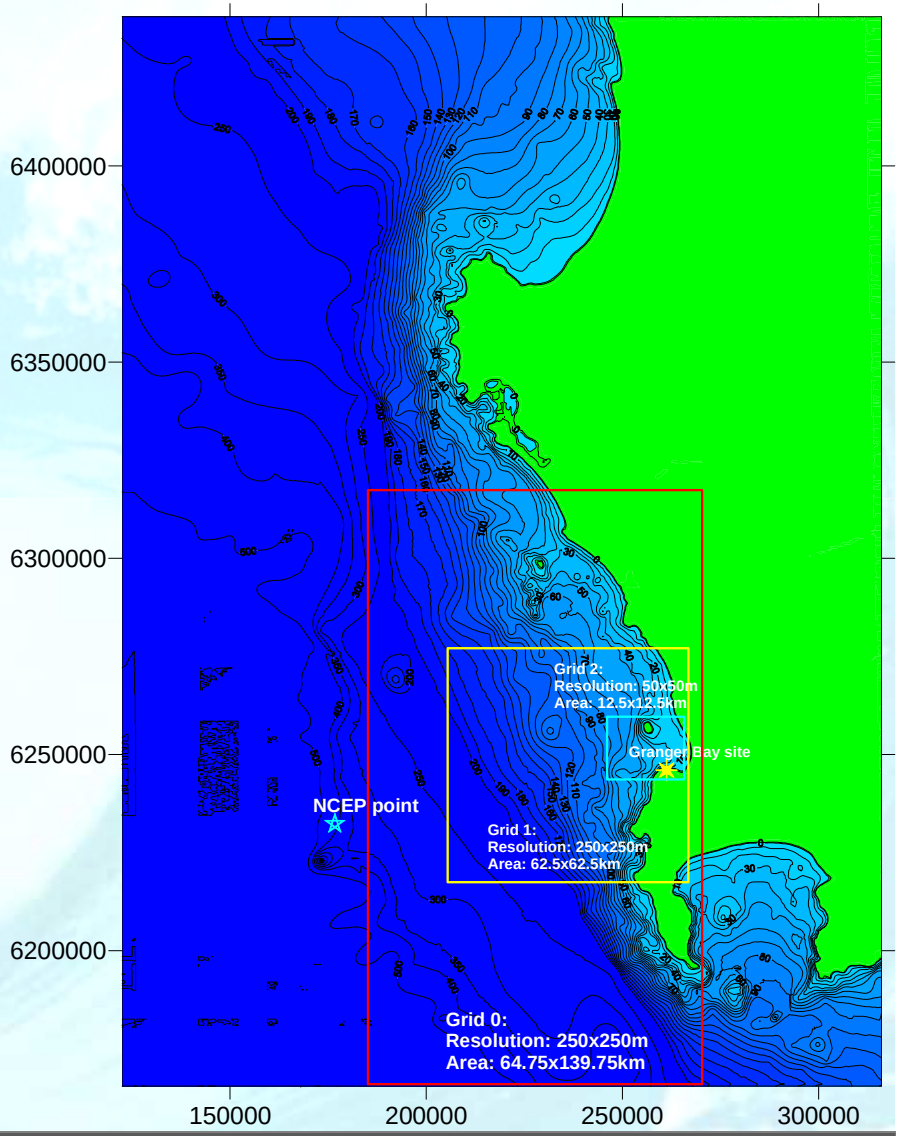
RENEWABLE & SUSTAINABLE ENERGY STUDIES

## Granger Bay

# Table Bay wave energy resource

RENEWABLE & SUSTAINABLE ENERGY STUDIES

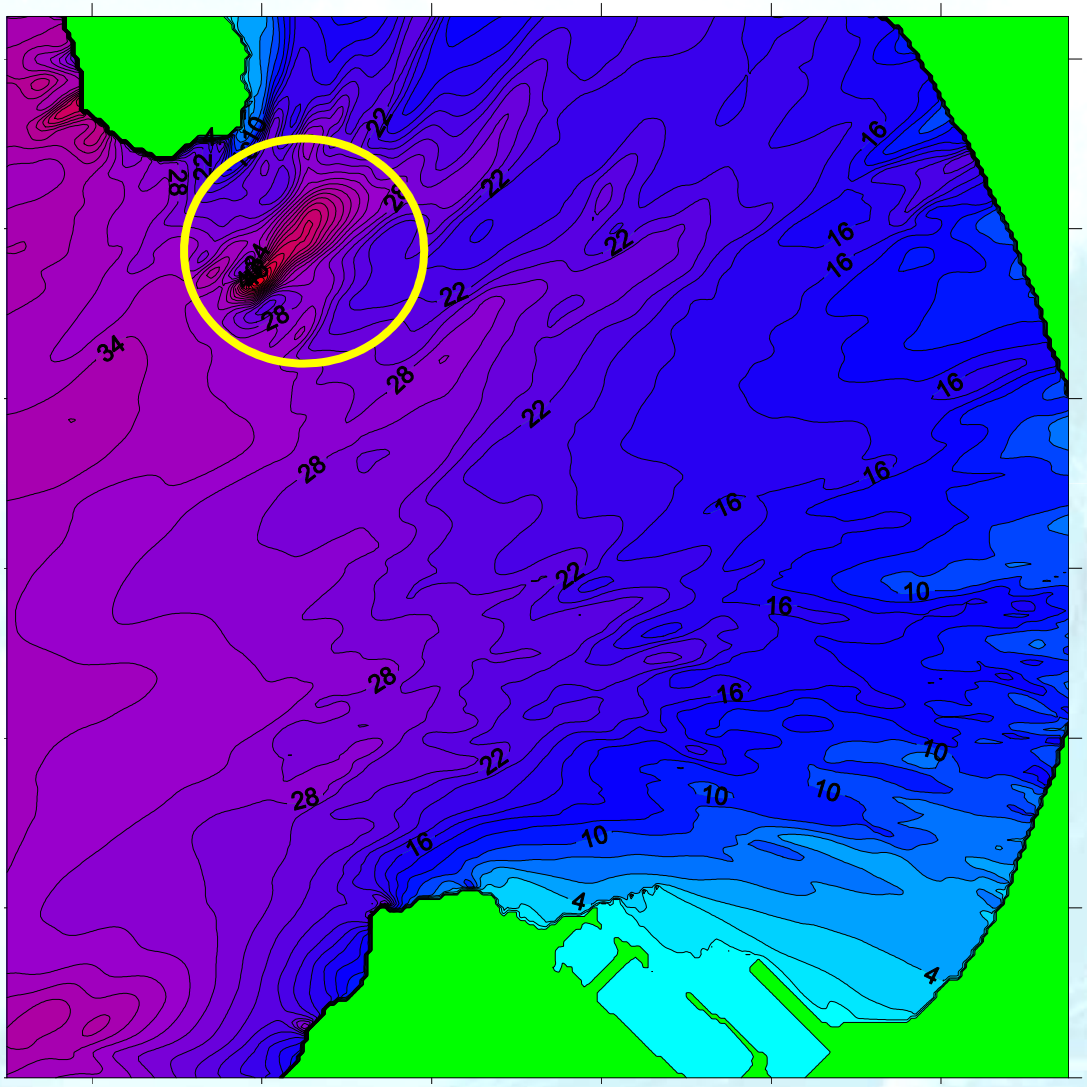
- NCEP hindcast wave data
- SWAN wave model



# Table Bay wave energy resource (cont)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

Mean annual average wave power distribution of Table Bay based on 10 years of hindcast wave data



# Table Bay wave energy resource (cont)

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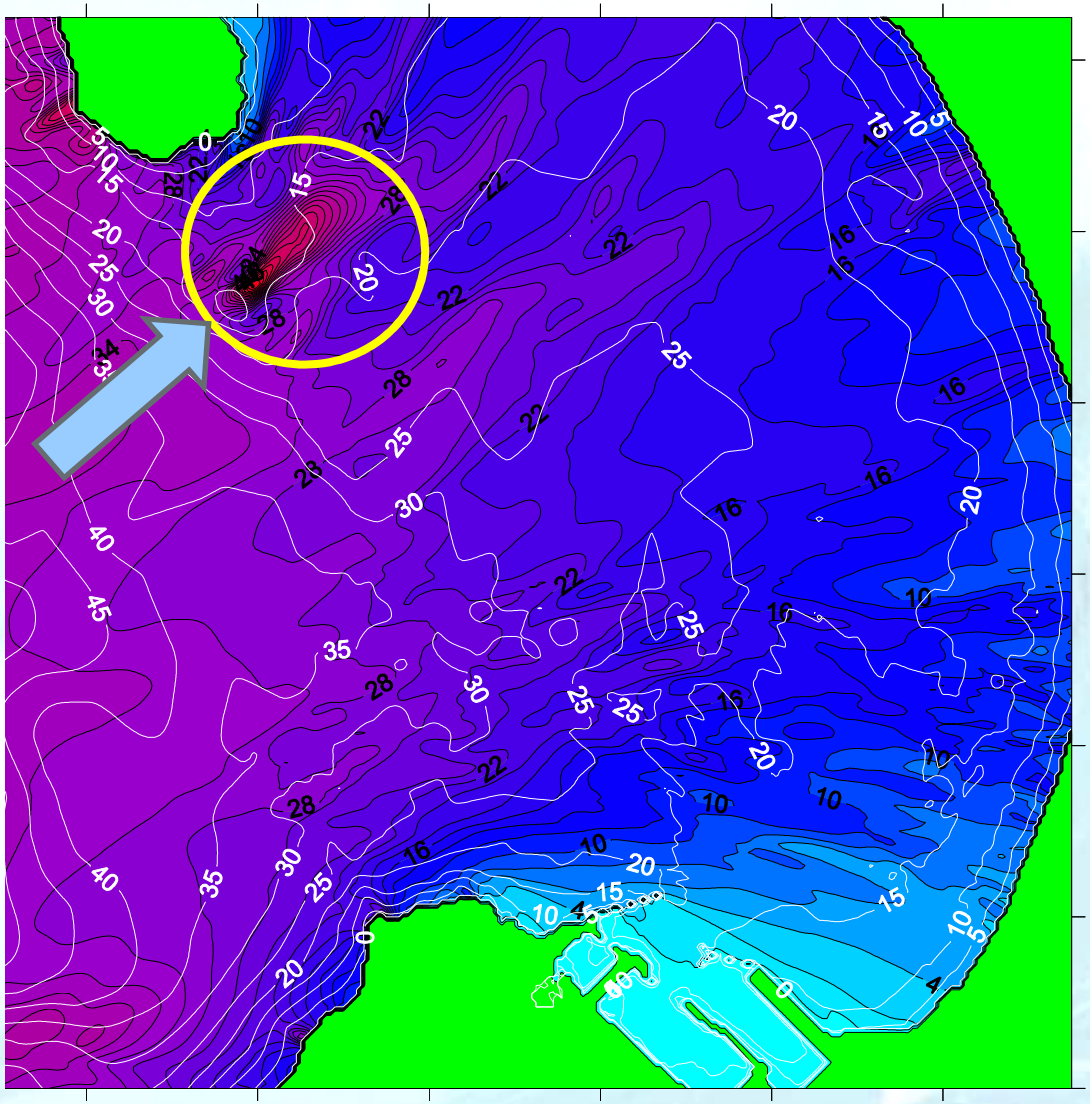
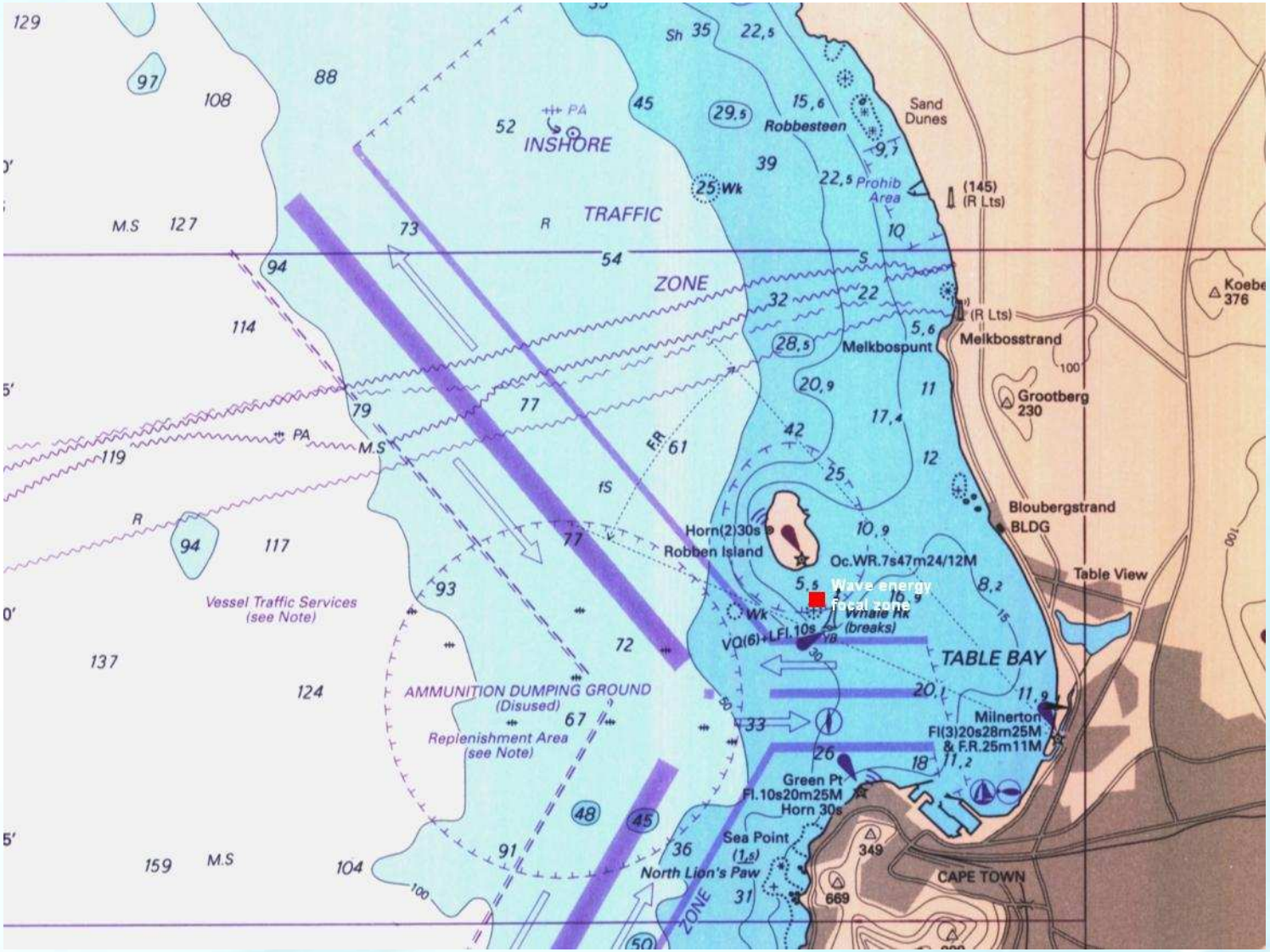
Mean annual average wave power distribution of Table Bay based on 10 years of hindcast wave data

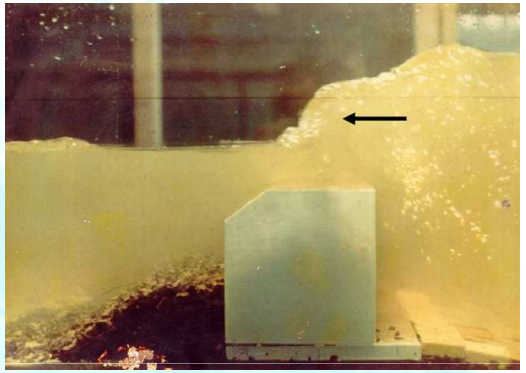


# Table Bay wave energy resource (cont)

RENEWABLE & SUSTAINABLE ENERGY STUDIES



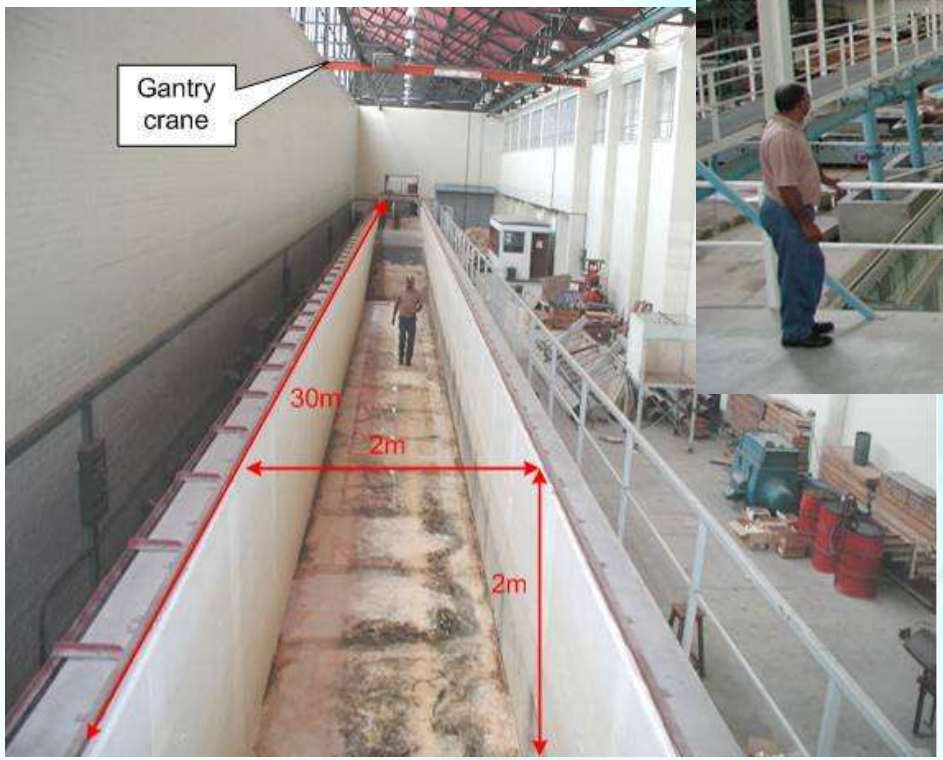
- Determine generation capacity of ShoreSWEC at Granger Bay
- Develop numerical model
- Physical model tests



# Way forward (cont)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

## Upgrading wavemaker facilities in US hydraulic laboratory

# Conclusions

RENEWABLE & SUSTAINABLE ENERGY STUDIES

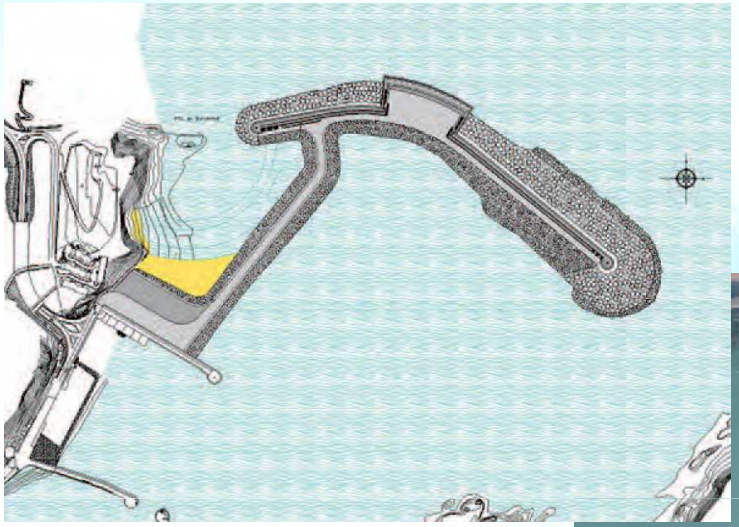
- Great opportunities for wave energy development in SA, but also barriers
- SA has a world class wave energy resource
- SA has an indigenous WEC designed for local conditions
- Opportunity to demonstrate SWEC conversion principle in port development
- Wave power focal zone exist in Table Bay

# Recommendations

- Adapt a culture of collaboration & knowledge sharing
- Support technology conceived locally instead of international developers exploiting our abundant resource
- Promote ideal of wave energy conversion in new port developments
- Increased government support

# Mutriku

RENEWABLE & SUSTAINABLE ENERGY STUDIES



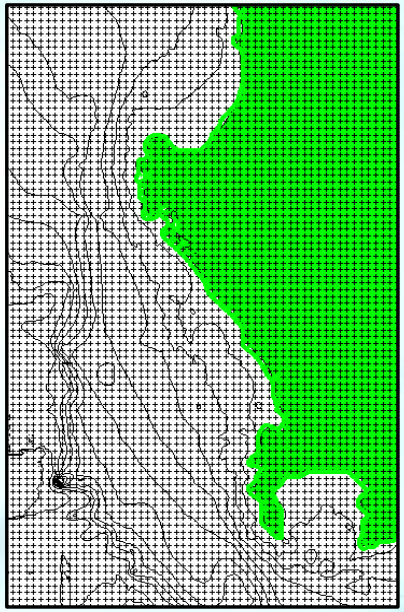

Thank you
for your attention

# SWAN input requirements

## Computational grid

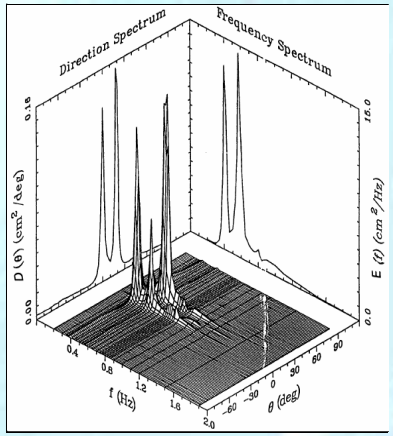
Area: 166 x 272 $km^2$
Resolution: 1 x 1 $km^2$
Gridpoints: 45 591

## Bathymetry grid



## Boundary conditions

Wave height
Wave period
Peak direction



# Modelled wave data analysis

RENEWABLE & SUSTAINABLE ENERGY STUDIES

## SWAN methodology

**Objective**

Transfer 10 years of deep sea hindcast wave data from deep sea to shore of focus area

**Methodology 1**

Simulate entire NCEP data set

- Impractical due to time required

**Methodology 2**

**Assume Hs variation independent of input Hs**

- Determine Hs variation over focus area from unity (Hs = 1m) at Base
- Consider Tp and Dp ranges encompassing entire Base data set

**Hs dependent dissipation processes in SWAN**

- White-capping
- Depth-induced breaking
- Bottom friction

**SWAN simulations**

- Simulate Tp values up to 30s in 2s intervals & Dp range = 0 to 360° in 22.5° intervals
- Total of 256 simulations
- **Output:** Hs variation in terms of $H/H_{BASE}$ for each combination of Tp and Dp in Base data

# Modelled wave data analysis

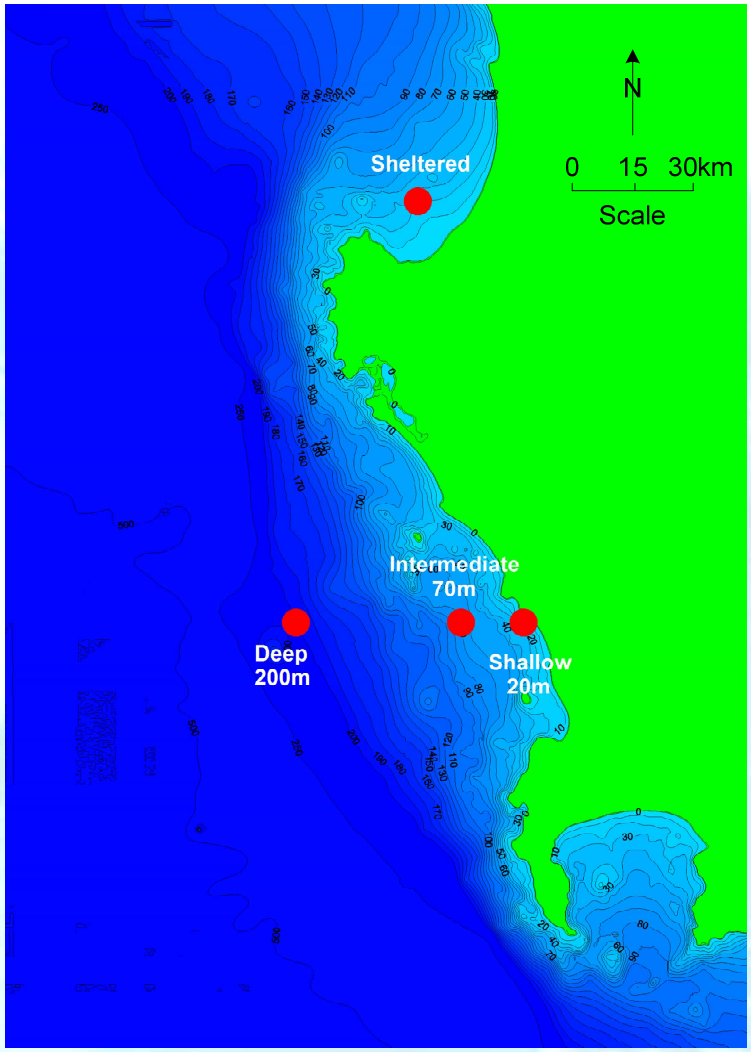
RENEWABLE & SUSTAINABLE ENERGY STUDIES

## Sensitivity analysis of SWAN methodology

Simulate dominant wave conditions

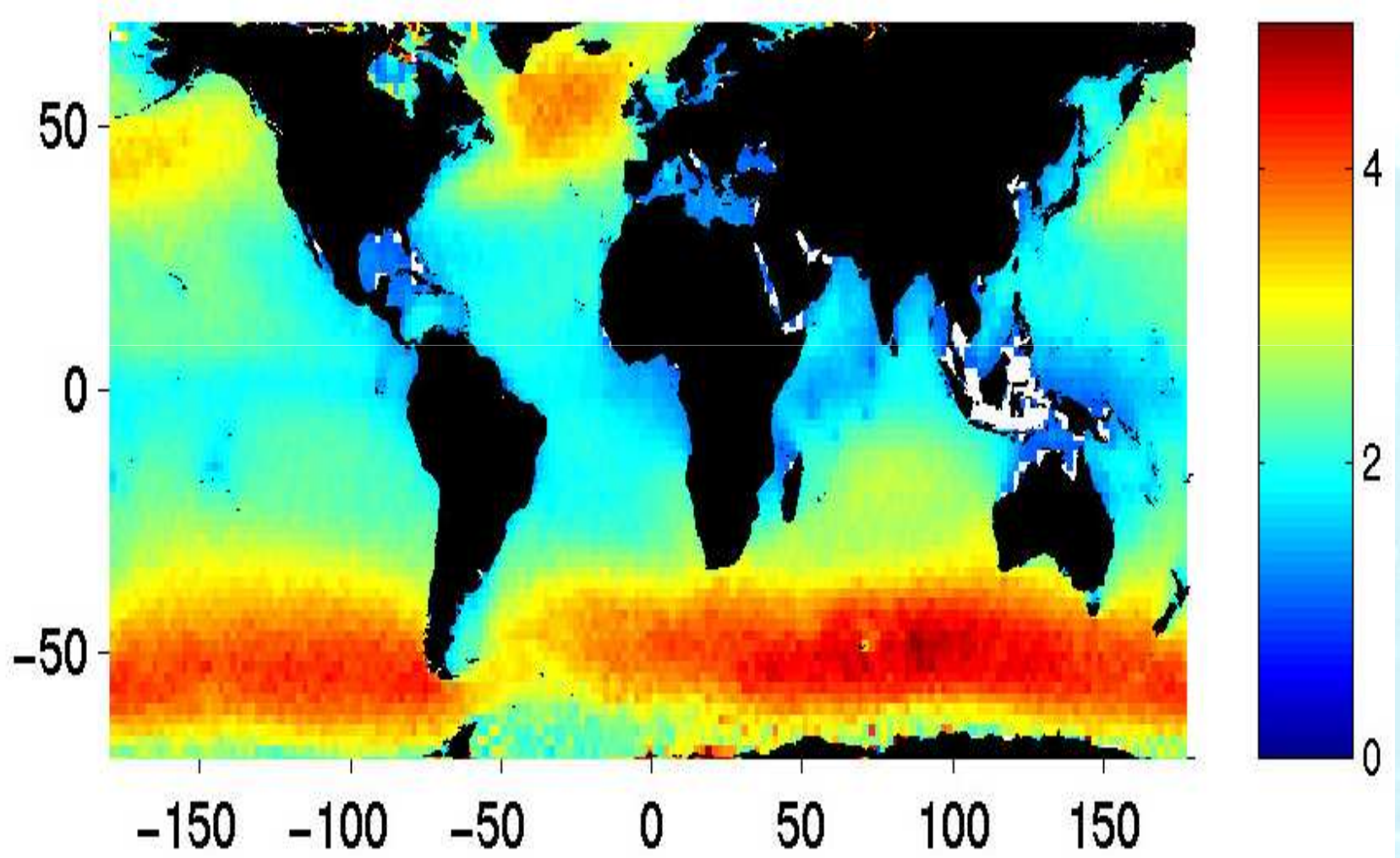
| % Difference between values obtained through model methodology and direct method | | | | |
|---|---|---|---|---|
| | Hs = 2.6m | | | |
| | Deep | Inter | Shallow | Shelter |
| SW-Tp10 | 5% | 8% | 9% | 5% |
| SW-Tp12 | 1% | 2% | 2% | 1% |
| SW-Tp14 | 0% | 0% | 1% | 1% |
| WSW-Tp10 | 4% | 7% | 9% | 6% |
| WSW-Tp12 | 1% | 2% | 2% | 2% |
| WSW-Tp14 | 0% | 0% | 0% | 1% |

CONCLUSION: Model output sufficiently accurate in near-shore applications



# Global wave height distribution

RENEWABLE & SUSTAINABLE ENERGY STUDIES



# Wave energy conversion (WEC) technology

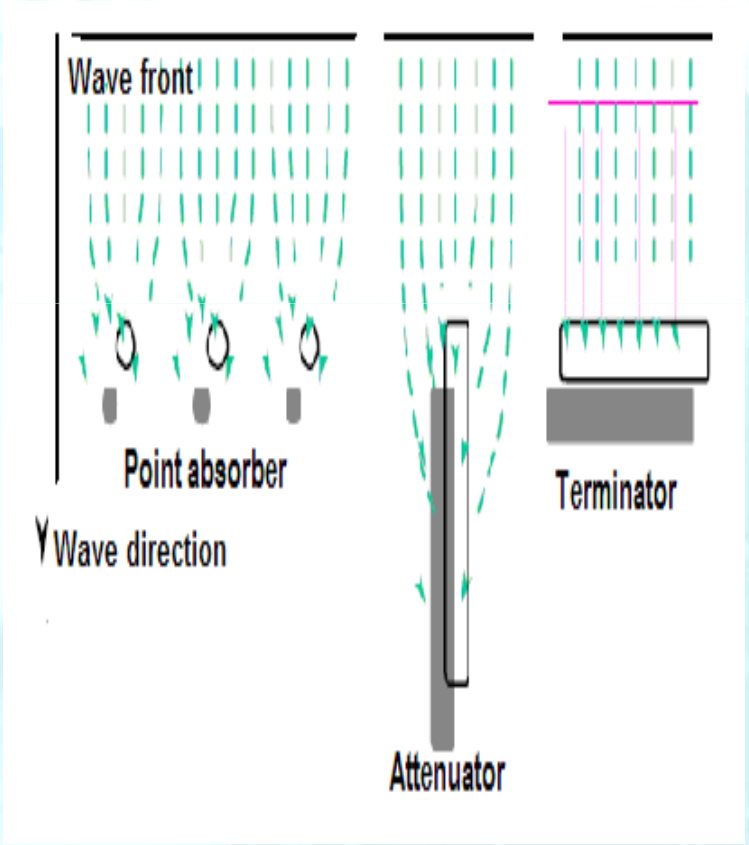
Point absorber

Attenuator

- Perpendicular to wave front

Terminator

- Parallel to wave front




(Falnes, 2005)

# Modelled wave data analysis

RENEWABLE & SUSTAINABLE ENERGY STUDIES

## SWAN computational theory

Spectral action balance equation

$$\frac{\partial}{\partial t}N+\frac{\partial}{\partial x}c_x N+\frac{\partial}{\partial y}c_y N+\frac{\partial}{\partial \sigma}c_\sigma N+\frac{\partial}{\partial \theta}c_\theta N=\frac{S}{\sigma}$$

Generation and dissipation source term (S)

Generation

- Wind input

Dissipation

- White-capping
- Depth induced-wave breaking
- Bottom friction

Non linear wave-wave interaction

- Quadruplets and triads