Ocean Thermal Energy Conversion (OTEC): Potential for Multiple Applications at Sea and Onshore

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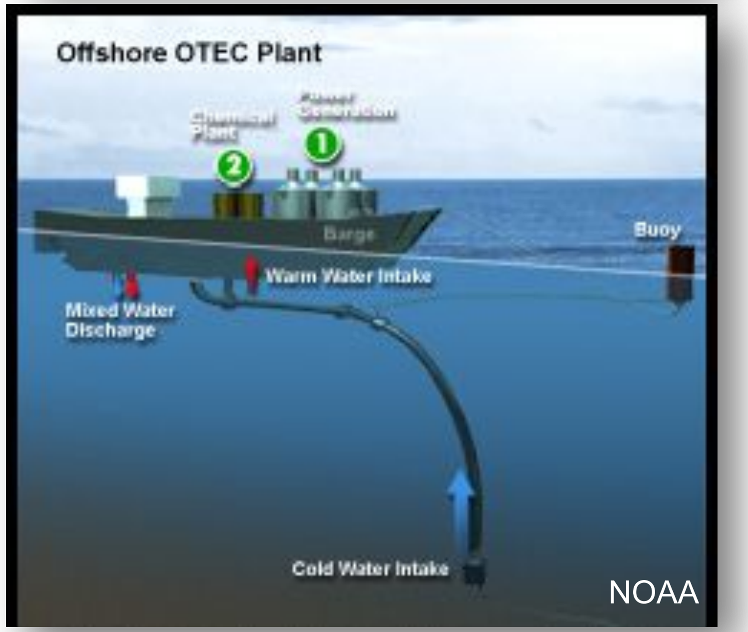
Ocean Thermal Energy Conversion (OTEC)

- Relatively simple technology only viable in tropical regions
- Generates energy from temperature differential between warm surface water and the deep cold water below (~20˚C)
- No large-scale OTEC systems have been successfully deployed, but nearshore and onshore plants are under development
    - Small, onshore systems can supply power, desalinated water, and sea water air conditioning (SWAC)
    - Large, floating offshore plants could provide baseload power
- Potential for additional services and products with OTEC



OTEC in the United States

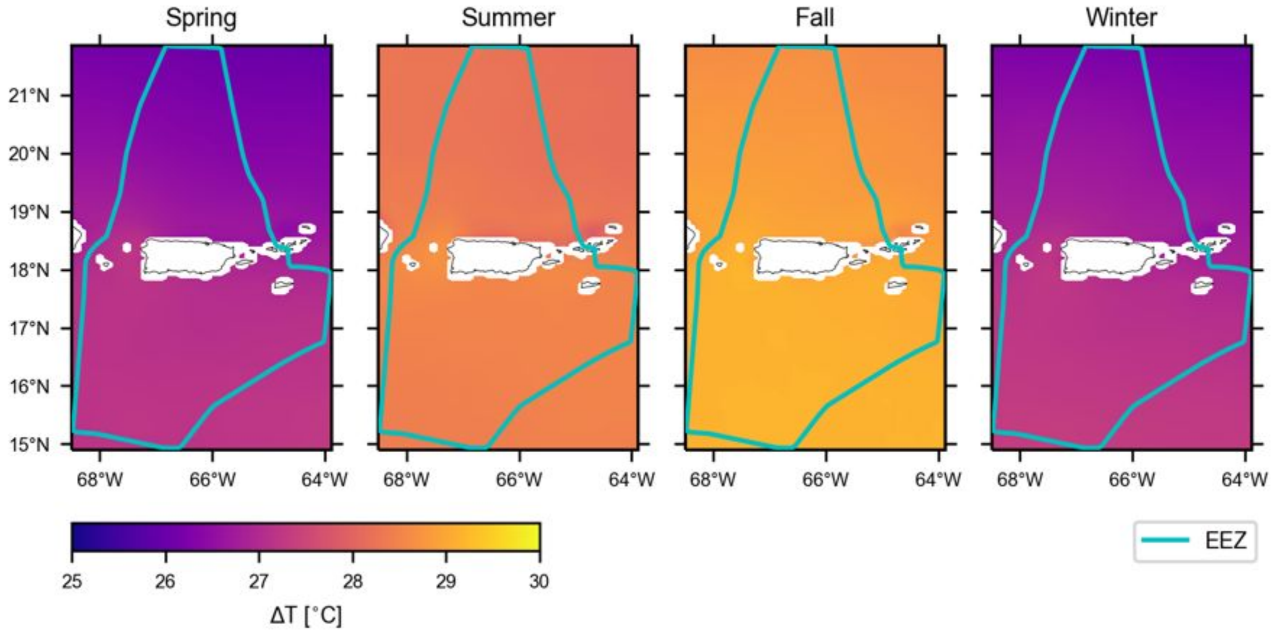
- Little engagement in OTEC development in US for about a decade
  - Renewed focus and legislation in 2020
  - Funding so far has been small:
    - ✔ SBIRs & STTRs
    - ✔ Small projects at US DOE national laboratories

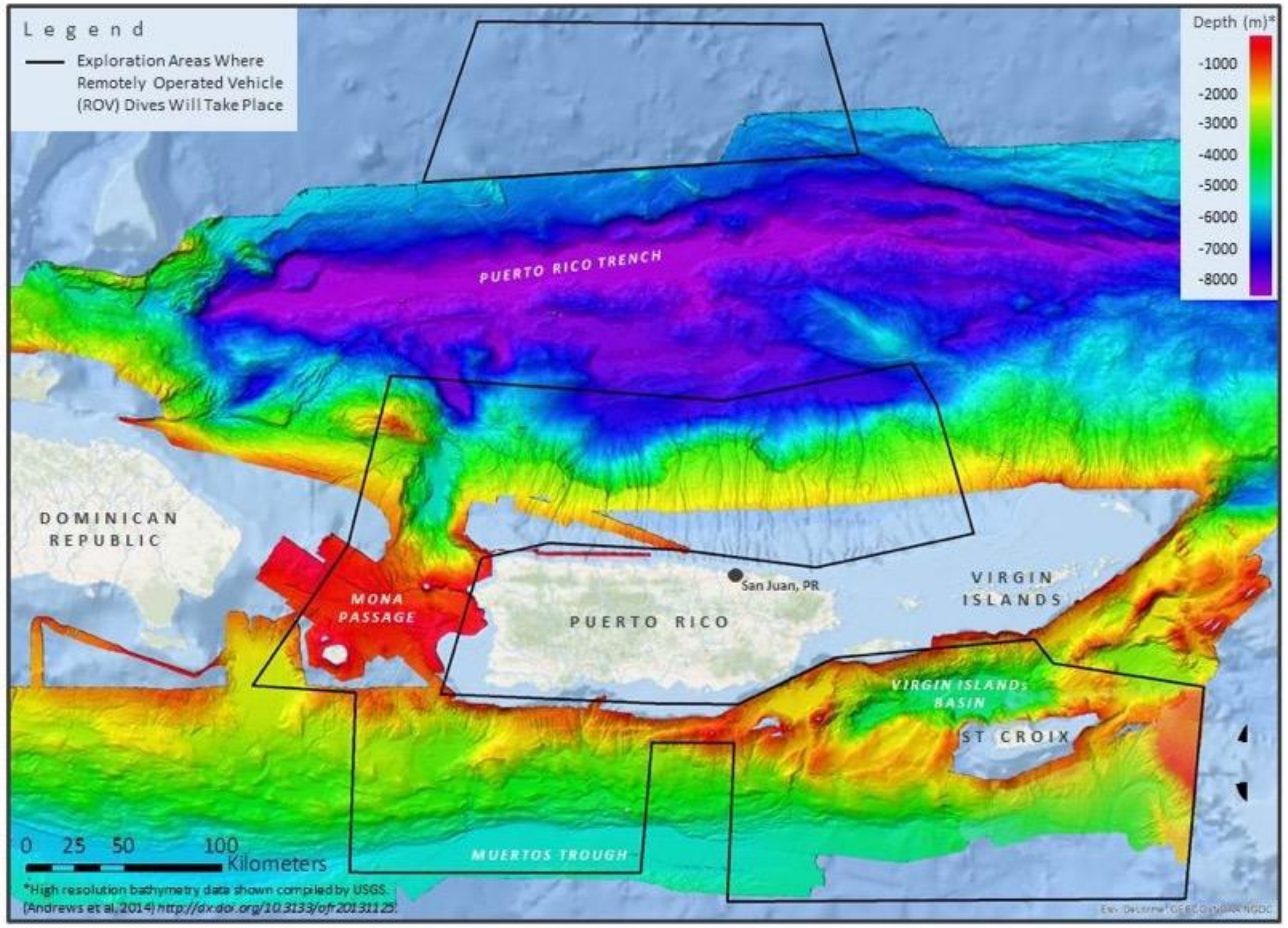
Examining feasibility of OTEC in US waters

- Reaching out to experts around the world
- Examining barriers to development
- Use cases to examine feasibility (Puerto Rico, St. Croix, Hawaii, Guam)
- Resource assessment in Puerto Rico and Hawaii
- Coupled with aquaculture and grid stabilization in Guam
- OTEC end uses: power, disaster recovery, freshwater

Puerto Rico and US Virgin Islands

- Islands in eastern Caribbean Sea
- Close to Puerto Rico trench = deep ocean water close to islands
- Adequate temperature differential year round



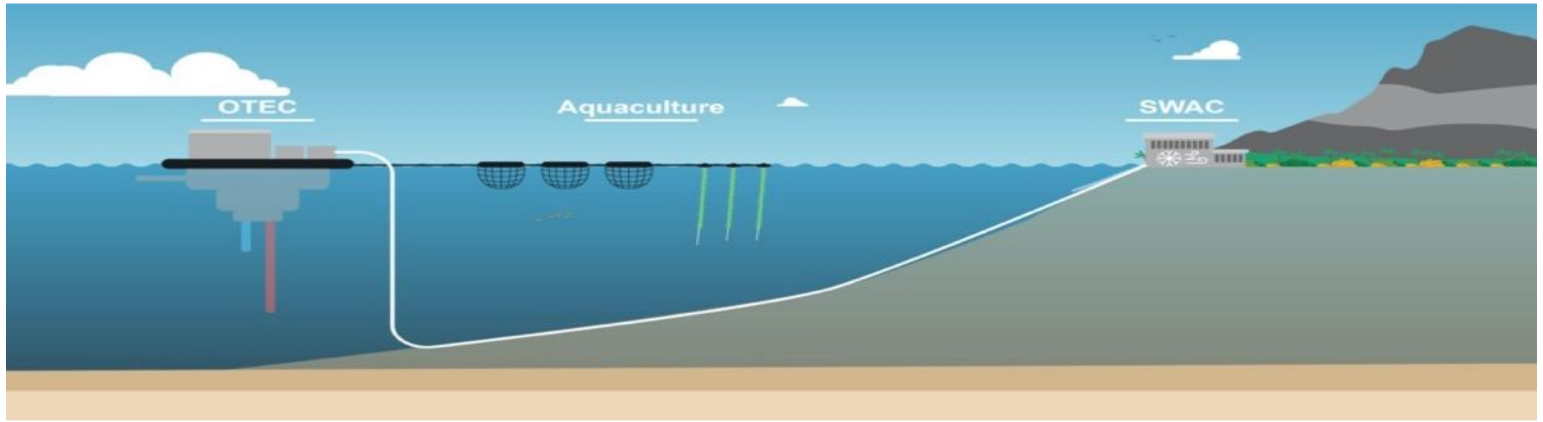


Puerto Rico Case

- 10MW OTEC plant
- Backup power grid, disaster recovery emergency services
- Also aquaculture
- Puerto Yabucoa nearest port
- 4.7km to cold water pipe

Multi-Use OTEC Platform

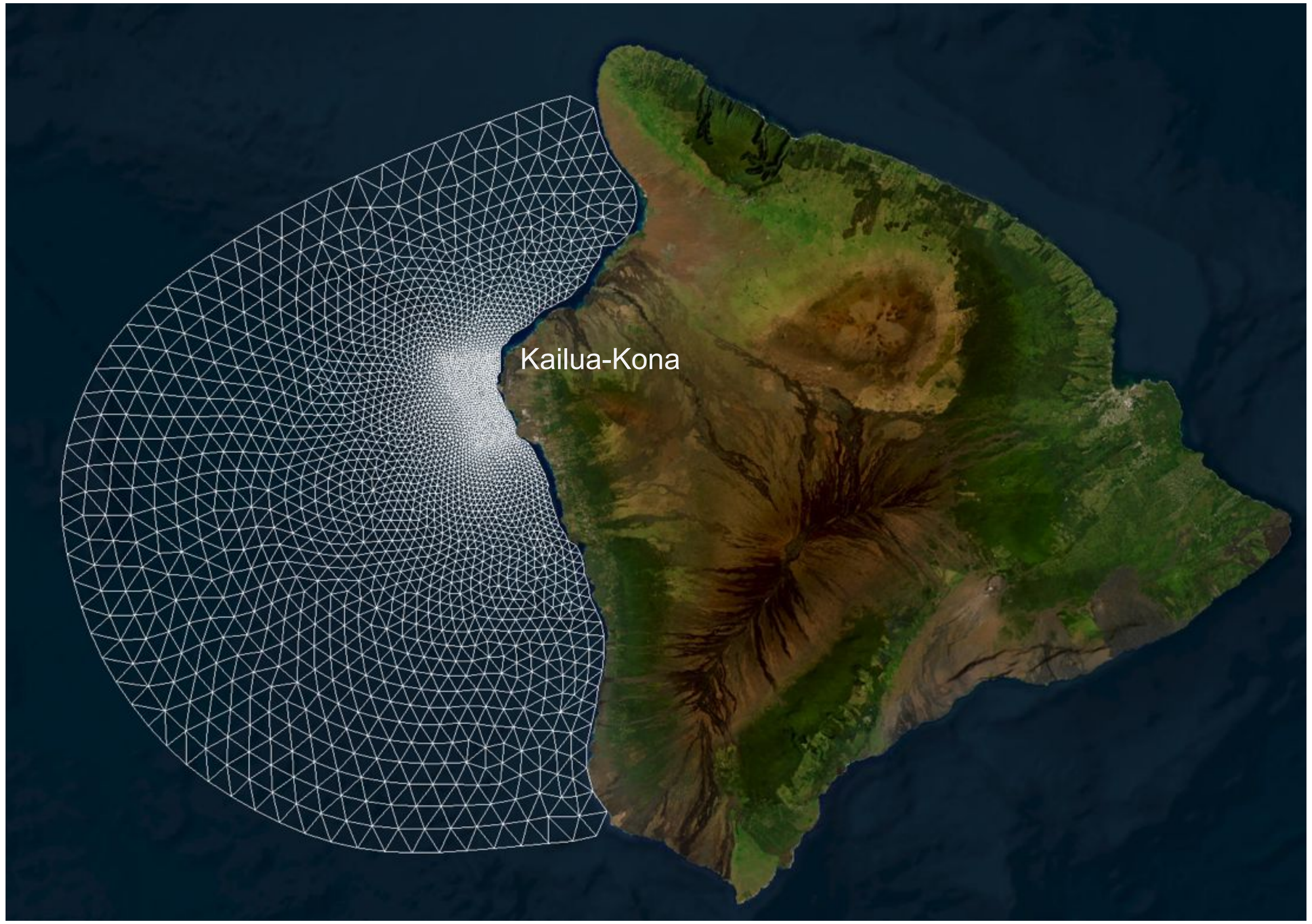
- PNNL, Makai, & Ocean ERA
- Located off Kona, HI at Natural Energy Laboratory of Hawaii Authority (NELHA)
- Technical feasibility of OTEC platform to provide:
  - Power
  - SWAC and district cooling
  - Desalination
  - Deep water for aquaculture
  - Critical mineral extraction
  - Efuels (ammonia/hydrogen)
- Tradeoffs for multiple uses
- Specific environmental effects
  - New plume model
- Community needs/values



Location

- Existing plant at NELHA on Hawaii
- Power for nearby installations, SWAC
- Port of Kawaihae 37 km north

Resource Characterization Model Domain



- Grid
  - 360 m ~ 4.5 km horizontal resolution
  - 2 ~ 48 vertical layers
- Bathymetry
  - ETOPO 2022
- Target period
  - Aug 1 2015 to Dec 31 2019 – 1825 days
- Forcing
  - CFS V2
- Initial and boundary conditions
  - CMEMS & FES 2014
- Computational resources
  - 2 node / 72 cores (Eagle)

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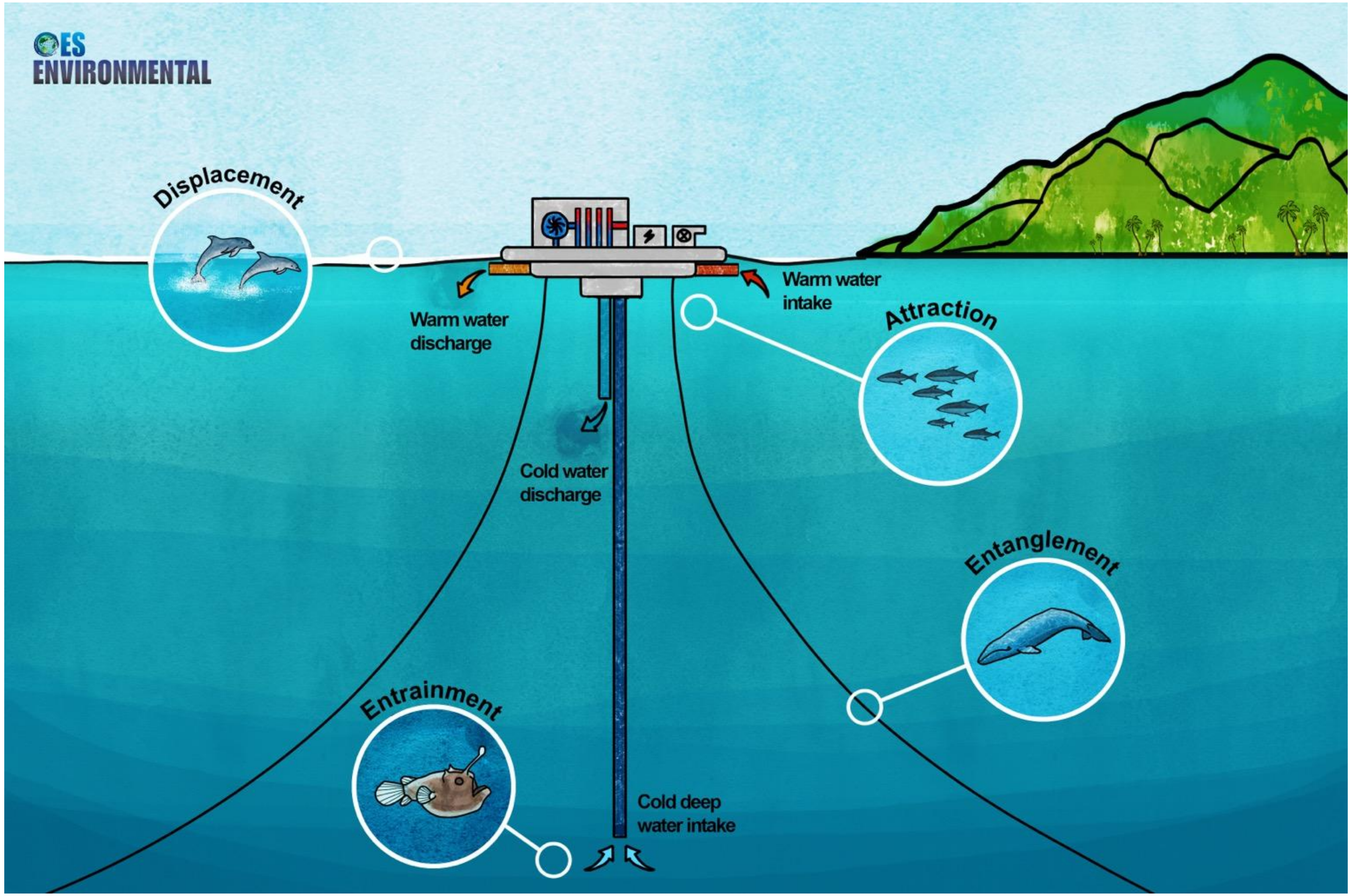
Potential environmental effects

- Discharge of cold water at surface
- Entrainment of water with biota
- Discharge of chemicals
- Interference with migration routes
- Entanglement in mooring lines
- Reef effect on fish
- Settling of benthic organisms, potential non-native species introduction
- Changes in nearshore waters due to temperature, circulation changes

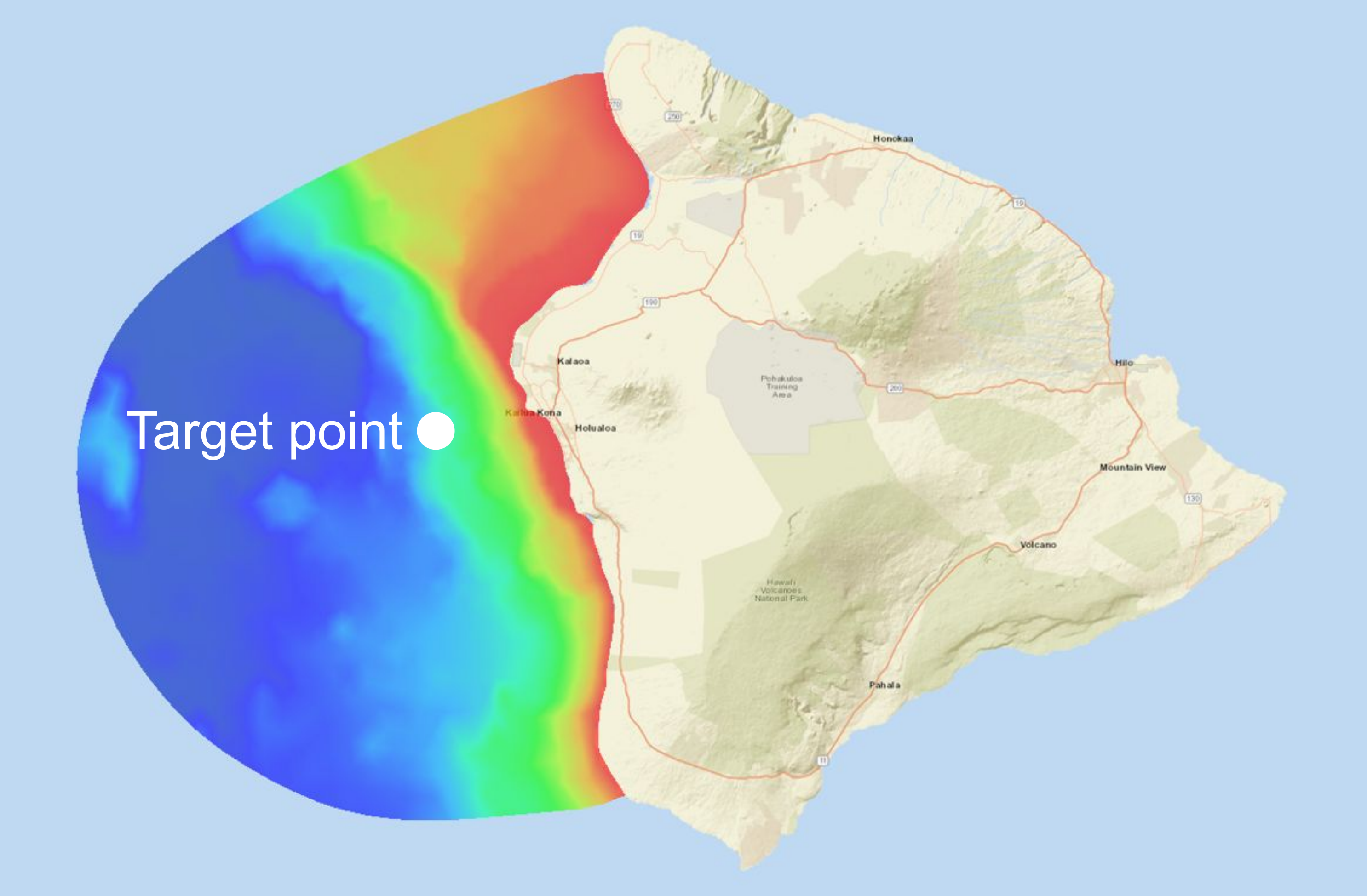
Each effect will depend on the scale and location of the OTEC plant

Potential Environmental Effects of OTEC



(Stephanie King, PNNL)

Cold-water plume model



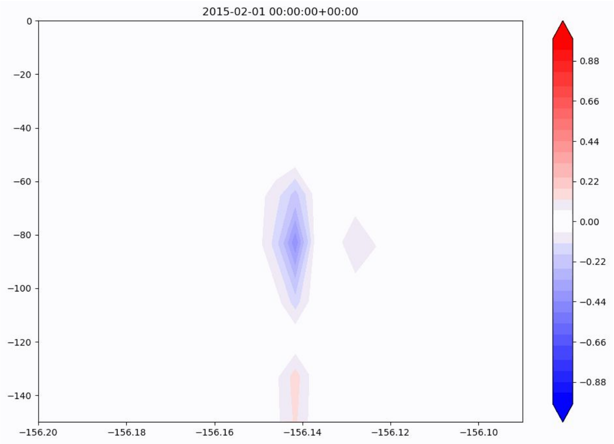
- Discharge location
  - Longitude: -156.1415423
  - Latitude: 19.735094
- Discharge depth
  - 70m
- Discharge temperature
  - 10°C
- Discharge rate
  - Exp.1: 400 m^3/s
  - Exp.2: 800 m^3/s
  - Exp.3: 1600 m^3/s
  - Exp.4: 3200 m^3/s
- Target period
  - Jan 2015 to Jan 2016 (one year)

Cold water plume model at different discharge rates

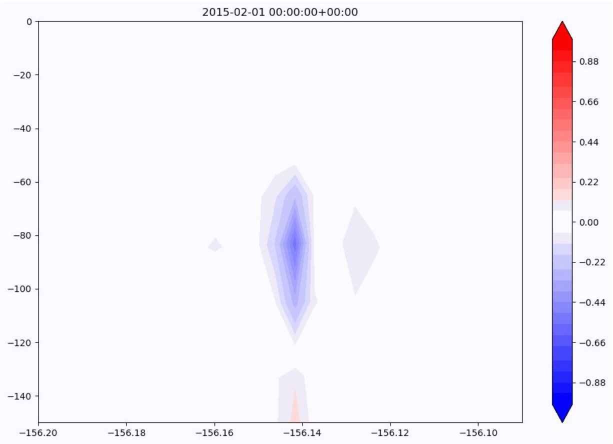
Discharge rate: 400 m^3/s | Discharge rate: 800 m^3/s | Discharge rate: 1600 m^3/s | Discharge rate: 3200 m^3/s

C°

Water depth (m)



Longitude (deg)



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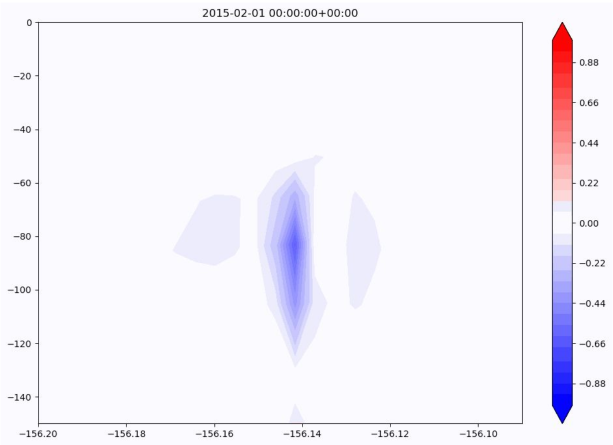
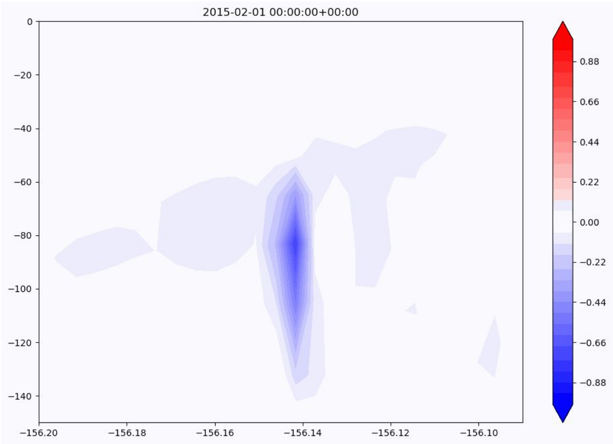


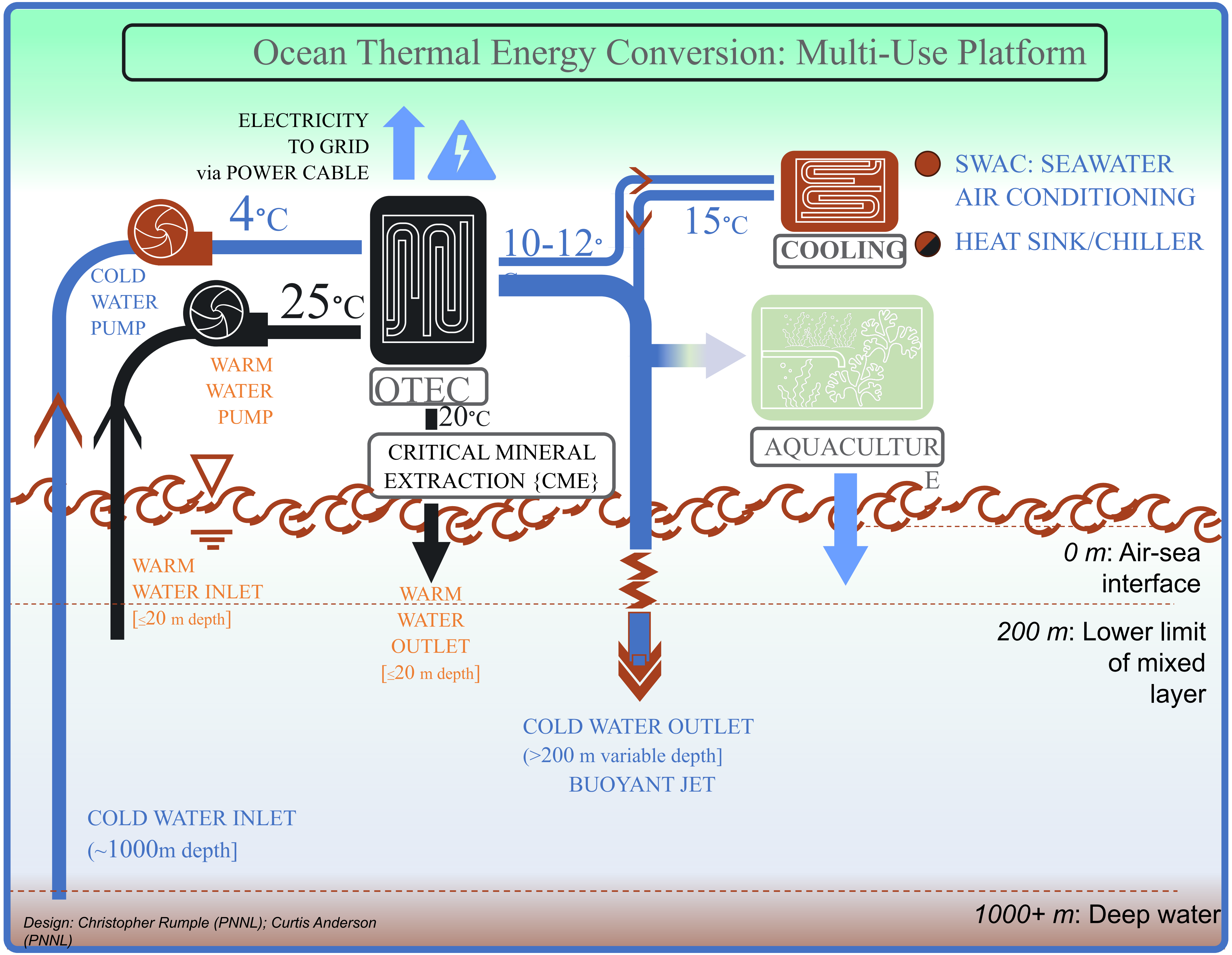
Longitude (deg)



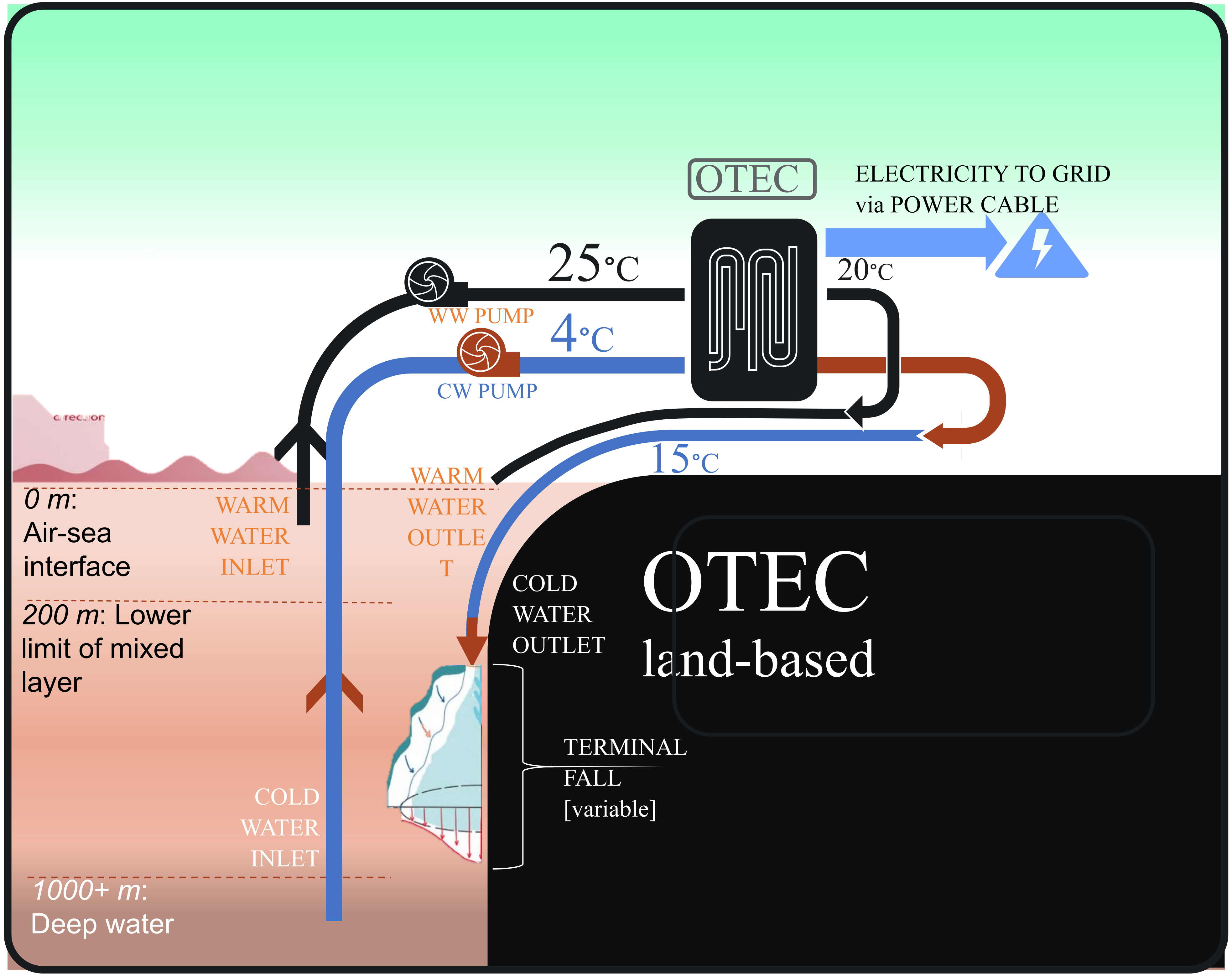
Longitude (deg)

Increased cold-water plumes (e.g., blue area) with the higher discharge rates

2015-02-01



Ocean Thermal Energy Conversion: Multi-Use Platform
ELECTRICITY
TO GRID
via POWER CABLE
4°C
COLD
WATER
PUMP
25°C
WARM
WATER
PUMP
OTEC
10-12°
15°C
COOLING
SWAC: SEAWATER
AIR CONDITIONING
HEAT SINK/CHILLER
AQUACULTUR
E
20°C
CRITICAL MINERAL
EXTRACTION {CME}
WARM
WATER INLET
[≤20 m depth]
WARM
WATER
OUTLET
[≤20 m depth]
COLD WATER OUTLET
(>200 m variable depth]
BUOYANT JET
0 m: Air-sea
interface
200 m: Lower limit
of mixed
layer
COLD WATER INLET
(~1000m depth]
1000+ m: Deep water
Design: Christopher Rumple (PNNL); Curtis Anderson
(PNNL)


OTEC
ELECTRICITY TO GRID
via POWER CABLE
25°C
20°C
WW PUMP
4°C
CW PUMP
15°C
WARM
WATER
OUTLE
T
0 m:
Air-sea
interface
WARM
WATER
INLET
200 m: Lower
limit of mixed
layer
COLD
WATER
OUTLET
OTEC
land-based
TERMINAL
FALL
[variable]
COLD
WATER
INLET
1000+ m:
Deep water

OTEC Feasibility

- Technology is well tested, baseload power
- Optimization continues for efficiency, survivability
  - Heat exchangers
  - New materials and designs for pipes
  - Hardening for typhoon/hurricane resistance
- Capital costs very high (100s millions USD)
- O&M costs expected to be low (compared to other offshore renewables)
- Potential environmental effects understood, can be mitigated
  - Cold water return
  - Entrainment (minimal)
  - Land-based footprint
- Training community members as operators

Thank You!

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