Artificial Upwelling: current efforts and anticipated impacts of intermingling the ocean

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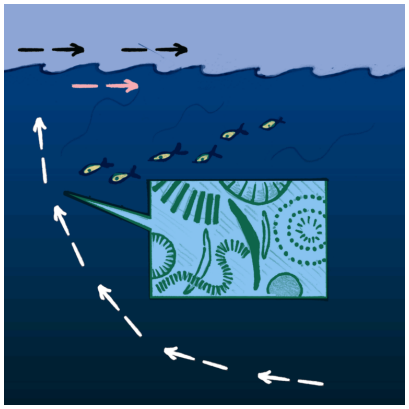

by Anja Chalmin

The US-based
Climate Foundation
revealed plans to intermingle ocean water layers in Australian and Philippine coastal waters with the aim of sequestering atmospheric carbon as well as stimulating the growth of phytoplankton and macroalgae, and enhancing fish production. The foundation says it obtained a permit to supply deep ocean water to a Philippine coastal reef area and announced the launch of a project intermingling surface water with deep ocean water in Storm Bay, Tasmania, for 2020.[i]

Introduction
to the approach

The
process of transporting deep ocean water to the surface is called upwelling. Natural upwelling is caused by winds and the rotation of the earth and intermingles the generally colder water from the deep ocean with water in upper ocean layers. Deep ocean water (DOW) is often rich in nutrients and can therefore increase primary production in sunlit ocean layers, e.g. by enhancing the growth of phytoplankton.

Since
a few decades, researchers have been investigating whether it is possible and reasonable to extend natural upwelling areas artificially. The research has been driven by the following hypotheses:

(1) intermingling
of ocean layers may increase the growth of primary and enhance fish production;

(2) an
accelerated primary production may raise the uptake and sequestration of atmospheric CO_2
by the ocean;

(3) cold DOW
may cool the overlying air and/or coral reefs.[ii]

Technical progress and feasibility

During
the past fifty years, various upwelling technologies have been developed and tested in the open ocean. About twenty outdoor trials aimed mainly at increasing the upwelling efficiency while reducing the energy demand. For example, electrical pumps have turned out to be too expensive, and upwelling processes based on differences in temperature or salinity have been too inefficient. New technical developments being explored include upwelling pumps working with wave power, or air-lift pumps upwelling DOW with compressed air and solar energy. Most research has been carried out and funded by Universities and public research institutions from China, European Union, Japan, Norway, and USA.

Artificial
upwelling requires adding large structures to the ocean. The afore mentioned outdoor trials used pipes to upwell ocean water from depths of up to ~300 m, e.g. with tubes made of PVC, often connected to diving platforms. If installed on larger scale, such structures could cause issues for marine life, shipping and fisheries. Data on the service life of such devices, possible impacts of the components on water quality, concepts of waste avoidance, or maintenance requirements and costs are incomplete or not available.[iii]

Environmental and Socio-political risks

GESAMP[1],
a body advising the United Nations on scientific aspects of marine environmental protection, reviewed various marine geoengineering technologies[2],
among them artificial upwelling. The report concluded that the field studies carried out to date did not submit evidence that artificial

upwelling can sequester carbon on larger scale. In addition, the report names the following environmental and socio-political risks:

Termination effect:
Artificial upwelling of colder DOW increases the absorption of heat in the ocean. As soon the upwelling stops, the absorbed heat would be released into the ambient air, resulting in additional warming of the earth's atmosphere.

Transboundary effects:
Artificial upwelling of colder DOW may affect agricultural production as a result of changes in weather patterns, e.g. rainfall.

Unfavourable composition of dissolved gases:
(1) Additional carbon uptake may further increase ocean acidification. (2) Nutrient-rich DOW is generally also rich in dissolved carbon, upwelling may therefore release additional CO_2 to the atmosphere. (3) Enhanced biological production can deplete oxygen levels in the upper ocean and cause impairments to marine life and local fisheries.[iv]

Current research priorities and developments

Current research activities are mainly being carried out by Chinese, US American, and European actors.

In China, **Zhejiang University** is undertaking various research and modelling studies to improve the energy management for artificial upwelling in coastal areas, while boosting carbon sequestration and primary marine productivity. From November 2018 to May 2019, an outdoor trial was conducted in a coastal kelp farm located in **Aoshan Bay**, Shandong Province. Offshore solar energy has been used as power source for upwelling DOW during the kelp growing season, covering an area of 0,8 ha. Water layers were intermingled by rising air bubbles. In addition, kelp farming combined with artificial upwelling has been modelled for three bays in Shandong Province.

Zhejiang University is

undertaking additional trials in a water tank. The tank was used to further improve an air-lift upwelling device developed by Zhejiang University. Currently the research is focusing on the correlation of chlorophyll concentration and water properties as salinity, temperature and pH. The research carried out by Zhejiang University is funded by public research programmes.

Since 2017, the US Department of Energy is implementing the **MARINER** (Macroalgae Research Inspiring Novel Energy Resources) program. The program seeks to develop the scale and efficiency of marine biomass production and supports eighteen research projects. Among them is a project called "Kampachi Farm – Single Point Mooring Array for Macroalgae". Kampachi Farm is a Hawaii-based mariculture company. The project team at the farm is designing technologies to enable large-scale macroalgae cultivation without the addition of fertilizer. Upwelling of nutrients for the purpose of enhancing growth of macroalgae is among the proposed solutions.

In 2019, Kampachi Farms and Makai Ocean Engineering have partnered for the **Blue Field Demonstration Project**. This pilot-scale offshore project aims to supply macroalgae with nutrients by upwelling DOW. The upwelling devices include a 40 m² swimming platform and wave-powered pumps with pipes extending to a depth of up to 300 m. The proposed site is about 3 km offshore of West Hawaii. The project is presently awaiting the necessary state and federal permits for deployment. The pilot is designed for a period of three years, and the intended start time is October 2019.

The Climate Foundation (TCF), a US-based NGO, founded in 2007 and directed by Brian von Herzen, published plans for artificial upwelling activities along the coasts of Australia, Africa, America and Asia. In 2008, TCF developed wave-powered upwelling technology and tested the device in the open ocean, about 100 km north of **Hawaii**.
In 2016, the foundation was among the ten winners of the Australian "Blue Economy Challenge", an initiative led by the Australian Department of Foreign Affairs and Trade. TCF announced that the grant money will be used to establish its wave-powered upwelling technology along the coastline of **Zanzibar**, aiming to restore productivity of seaweed production for 10.000 seaweed farmers. The implementation was announced for 2017, but there is little to suggest that the project has been realized. Since 2018, TCF has staff based in the **Philippines,** and plans to establish an upwelling system on Bohol, an island located in the Visayas archipelago. According to the TCF website, a permit has been obtained to operate in a coastal reef area. The project's goal is restoring productivity of red seaweed production

for 2,000 seaweed farmers. Another project has been announced for 2020, in the Tasmanian **Storm Bay, Australia**, where TCF aims to restore kelp forests and store carbon by providing its wave-powered upwelling technology. According to TCF the project is carried out in cooperation with the University of Tasmania and the INTREPID Foundation. In addition, TCF advertises its technology for the cooling of reef water, e.g. for the growth and survival of the Great Barrier Reef. TCF's activities are being sponsored by foundations, private donations, government grants and industry contracts.

The research project **Ocean artUp** is funded by the European Commissions' Horizon 2020 Framework Programme. Coordinated by the German GEOMAR Helmholtz Centre for Ocean Research, it aims to study the feasibility, effectiveness, and associated risks of artificial upwelling as well as its potential for increasing ocean productivity, raising fish production, and enhancing oceanic CO_2 sequestration.
The studies include field experiments in the subtropical North Atlantic, and investigation of natural upwelling events south of the Canary Islands is also planned. Artificial upwelling trials are taking place in Gran Canarias' Taliarte harbour in so-called mesocosms. Mesocosms can be described as large test tubes, used to simulate a continuous upwelling situation. This year's "test tubes" are 2m in diameter, 4m in length, and each with a volume of $8m^3$. In 2018, the mesocosms were used to test different upwelling intensities. This year's field trials started in September 2019 and study the effects of different nutrient ratios on plankton.[v]

Outlook

Ongoing research continues studying artificial upwelling as a potential mean for CO_2 removal.
Due to costs, and for implementation reasons, the research focus is shifting to coastal areas and to a combination of artificial upwelling with mariculture activities, e.g. seaweed farming. If mariculture is combined with artificial upwelling and adopted on larger scale, the above mentioned risks for marine life, shipping and fisheries as well as the environmental and socio-political questions and risks would intensify.

Further information on artificial upwelling:

Artificial Upwelling – Technology Factsheet:

https://www.geoengineeringmonitor.org/2018/06/artificial-upwelling/

Interactive
Geoengineering Map: https://map.geoengineeringmonitor.org/ – contains more details and references for the above mentioned (**highlighted in bold characters**)
and further artificial upwelling projects

[1]
Joint Group of
Experts on the Scientific Aspects of Marine Environmental Protection

[2]
Definition of geoengineering:
https://www.geoengineeringmonitor.org/what-is-geoengineering/

[i]
Geoengineering Map (https://www.geoengineeringmonitor.org/resources/)

[ii]
GESAMP (2019):
High level review of a wide range of proposed marine geoengineering techniques. Edited by P.W. Boyd and C.M.G. Vivian. GESAMP Report No. 98. (Link: http://www.gesamp.org/publications/high-level-review-of-a-wide-range-of-proposed-marine-geoengineering-techniques)

[iii]
Geoengineering Map (https://www.geoengineeringmonitor.org/resources/)

[iv]
GESAMP (2019):
High level review of a wide range of proposed marine geoengineering techniques. Edited by P.W. Boyd and C.M.G. Vivian. GESAMP Report No. 98. (Link: http://www.gesamp.org/publications/high-level-review-of-a-wide-range-of-proposed-marine-geoengineering-techniques)

IPCC (2019):
IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. (Link: https://www.ipcc.ch/srocc/home/)

[v]
Geoengineering Map

(https://www.geoengineeringmonitor.org/resources/)