Blue-Cloud
Piloting innovative services for Marine Research & the Blue Economy

Sara Pittonet Gaiarin, Trust-IT Services,
Blue-Cloud Coordinator

Blue-Cloud has received funding from the European Union's Horizon Programme call BG-07-2019-2020,
topic: [A] 2019 - Blue Cloud services, grant Agreement number 862409.

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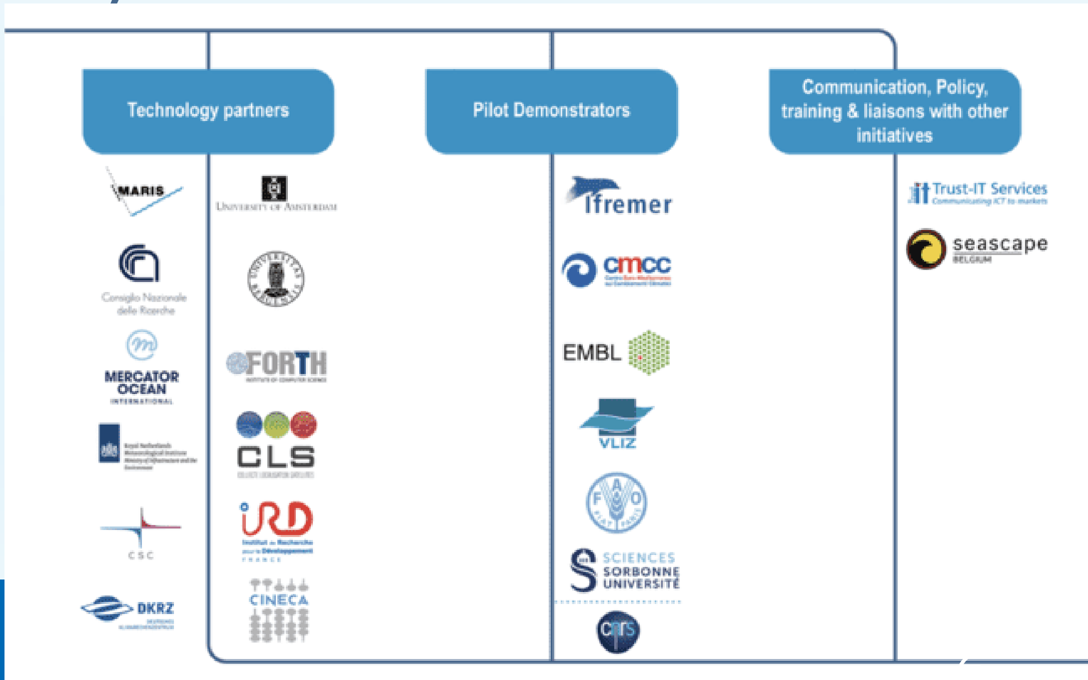
Blue-Cloud in numbers

- **Funding:** H2020: The ‘Future of Seas and Oceans Flagship Initiative’ (BG-07-2019-2020) topic: [A] 2019 - Blue Cloud services
- **Timing:** 36 Months (start October 2019)
- **Budget:** 5.9 Million Euro
- **Partnership:** 20 partners
- **13 Blue federated Infrastructures**



Overarching project objectives

Blue-Cloud aims to become *the* environment for the “Blue community”, offering access to **an unprecedented wealth of multi-disciplinary data resources and added-value services** for the benefit of the future marine research and blue economy landscapes

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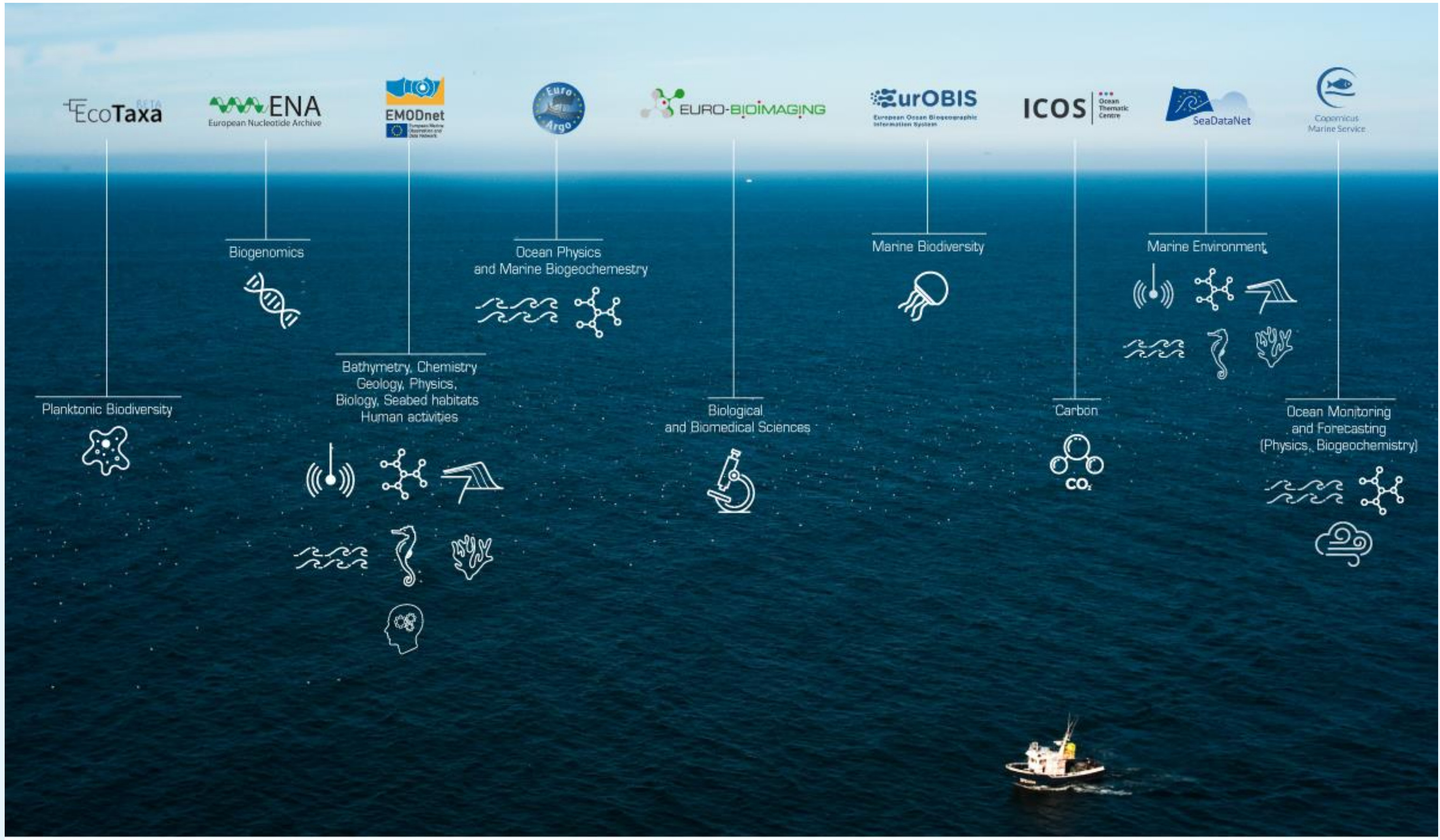
The Blue-Cloud Offer

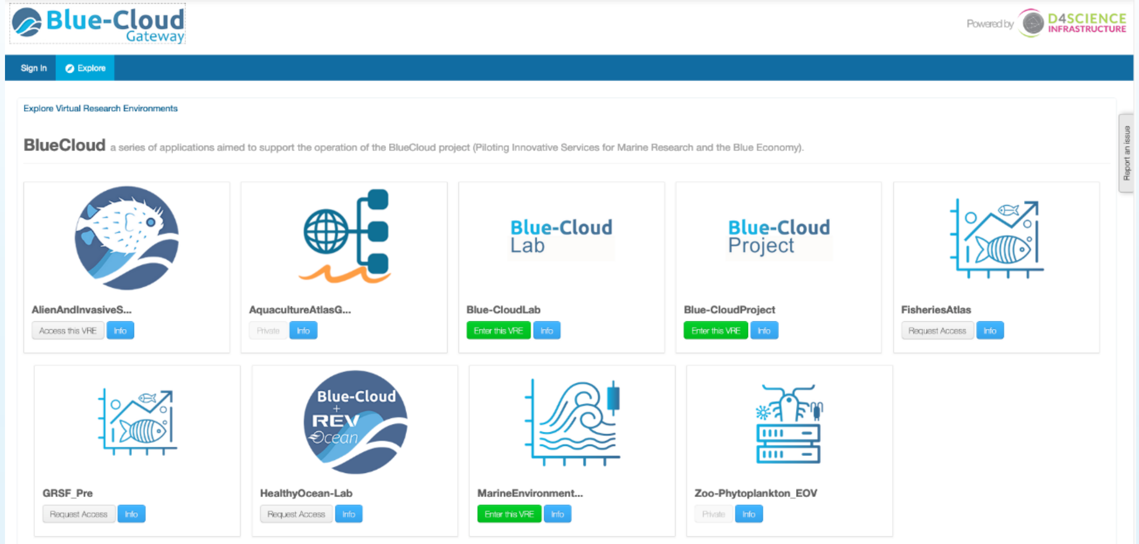
Blue-Cloud aims at federating **leading European marine data management infrastructures** with **horizontal e-infrastructures** to create a trusted virtual space - the *Blue-Cloud Technical Framework* - where scientists can access the **ocean data, tools, services and research outputs** they need to perform research in a more efficient way

https://www.blue-cloud.org/data-infrastructures



Copernicus
Europe's eyes on Earth
WEkEO
D4SCIENCE
INFRASTRUCTURE
EUDAT
Collaborative
Data Infrastructure

Blue-Cloud Virtual Research Environments



https://blue-cloud.d4science.org/

Each Blue-Cloud VRE includes:

- services that facilitate **collaboration** between users
- services supporting the execution of **analytical tasks** embedded in a distributed computing infrastructure
- services enabling the co-creation of new entire **Virtual Laboratories**, aimed at realising open science-friendly working environments.

Five real-life demonstrators

Zoo & Phytoplankton EOV products

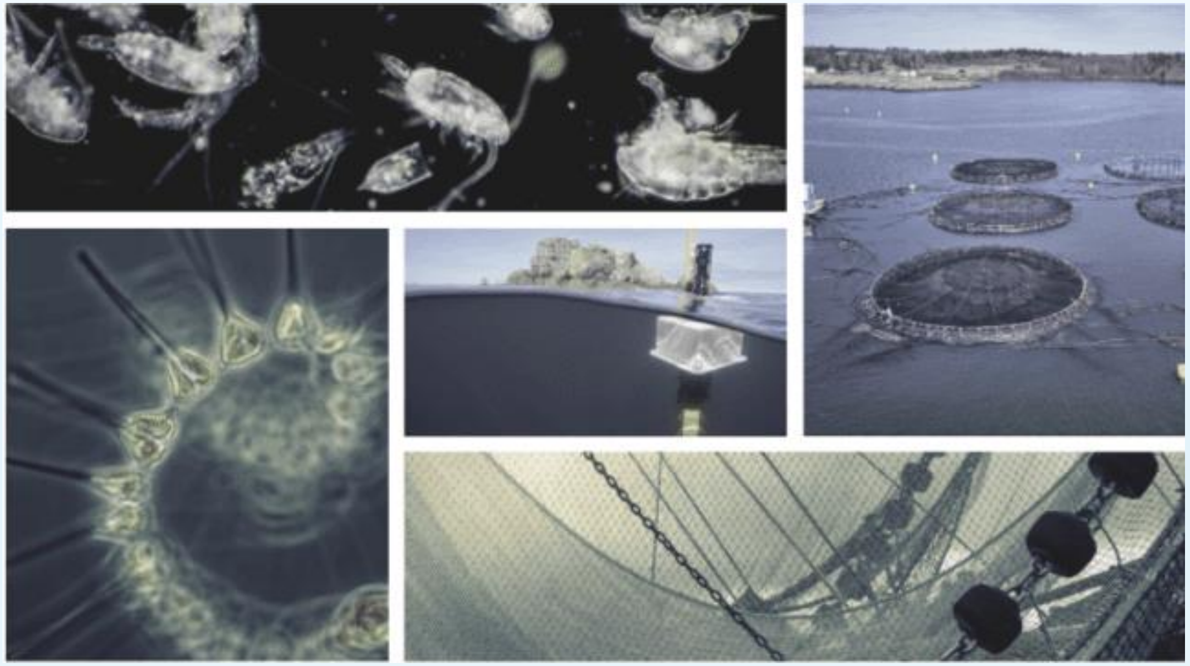
Plankton Genomics

Marine Environmental Indicators

Fish a matter of scales

Aquaculture Monitor

A number of Blue Cloud Demonstrators are being developed and make use of existing, and drive the further development of additional, Blue Cloud services. They've been originally selected for their importance **for marine ecosystems research, conservation, forecasting & innovation in the Blue Economy, not only in Europe but also across the globe**



https://www.blue-cloud.org/demonstrators

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Five real-life demonstrators

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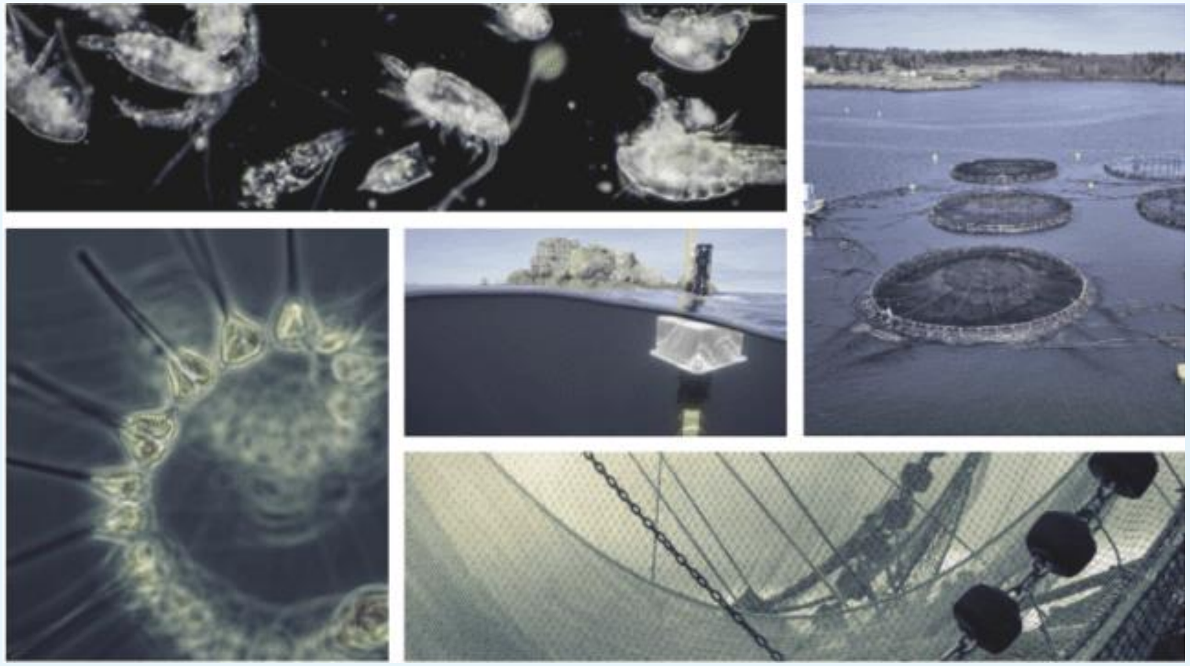
- Zoo & Phytoplankton EOV products
- Plankton Genomics
- Marine Environmental Indicators
- Fish a matter of scales
- Aquaculture Monitor



https://www.blue-cloud.org/demonstrators

Zoo & Phytoplankton EOV Products

Zoo & Phytoplankton EOV products

Processing several data resources available under different European marine networks to produce unique zoo- and phytoplankton EOV products.

Thanks to the Blue-Cloud interface, the demonstrator will implement a workflow to apply **big data analysis and machine learning** (e.g. neural networks) methods on multi-source data sets. The framework will include a ground truth model using near real-time data from LifeWatch data. The **resulting workflow will be published as a Blue-Cloud Virtual Lab**, and results will be exploited through dissemination in the policy advisory process.

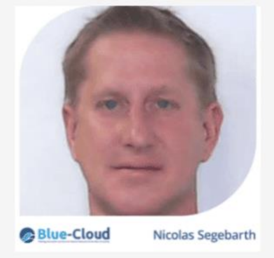
- https://youtu.be/9WwvKT1Gid0
- **Beta release in October 2020**
- **Webinar in February 2021**

- More info: https://www.blue-cloud.org/news/plankton-climate-change-demonstrator

External Stakeholders Experts Board

14 ESEB Members joined Blue-Cloud

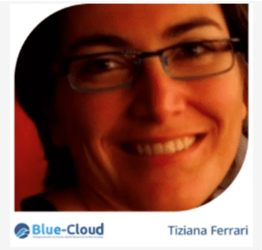
https://www.blue-cloud.org/eseb



Policy Officer at European Commission

Water and Marine group at European Environment Agency

Scientific Officer at European Commission Joint Research Centre



Managing Director at EGI Foundation

Executive Director European Marine Board and Professor at UHI

Marine Geologist at MARUM at the University Bremen

Head of IT Services at EMBL

Director of IMARDIS

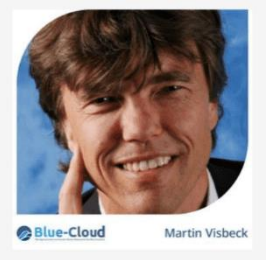
General Secretary of EATiP

Cos4Cloud Coordinator & Chair of the WG "Data, Tools and Technologies" at ECSA

Head of the IOC Project Office for IODE

Managing Partner at Premotec, President of EuroFIR AISBL & member of IMEKO

Chemical oceanographer at GEOMAR



Professor at GEOMAR

The Blue-Cloud Roadmap to 2030

- A co-created, community **Vision** for the development of the **Blue-Cloud** beyond project-end and into the future (2030)
- A **Strategic Plan** towards successfully achieving the **Blue-Cloud Vision**
- 1st release by **March 2021** · 2nd (final) release by **July 2022**

What do we want the Blue-Cloud to achieve?

For whom? By when?

How do we get there?

Value Proposition
Added value to users

Core Assets
Services & applications

Community
Key actors

Technical Framework
Technical architecture & interface with EOSC

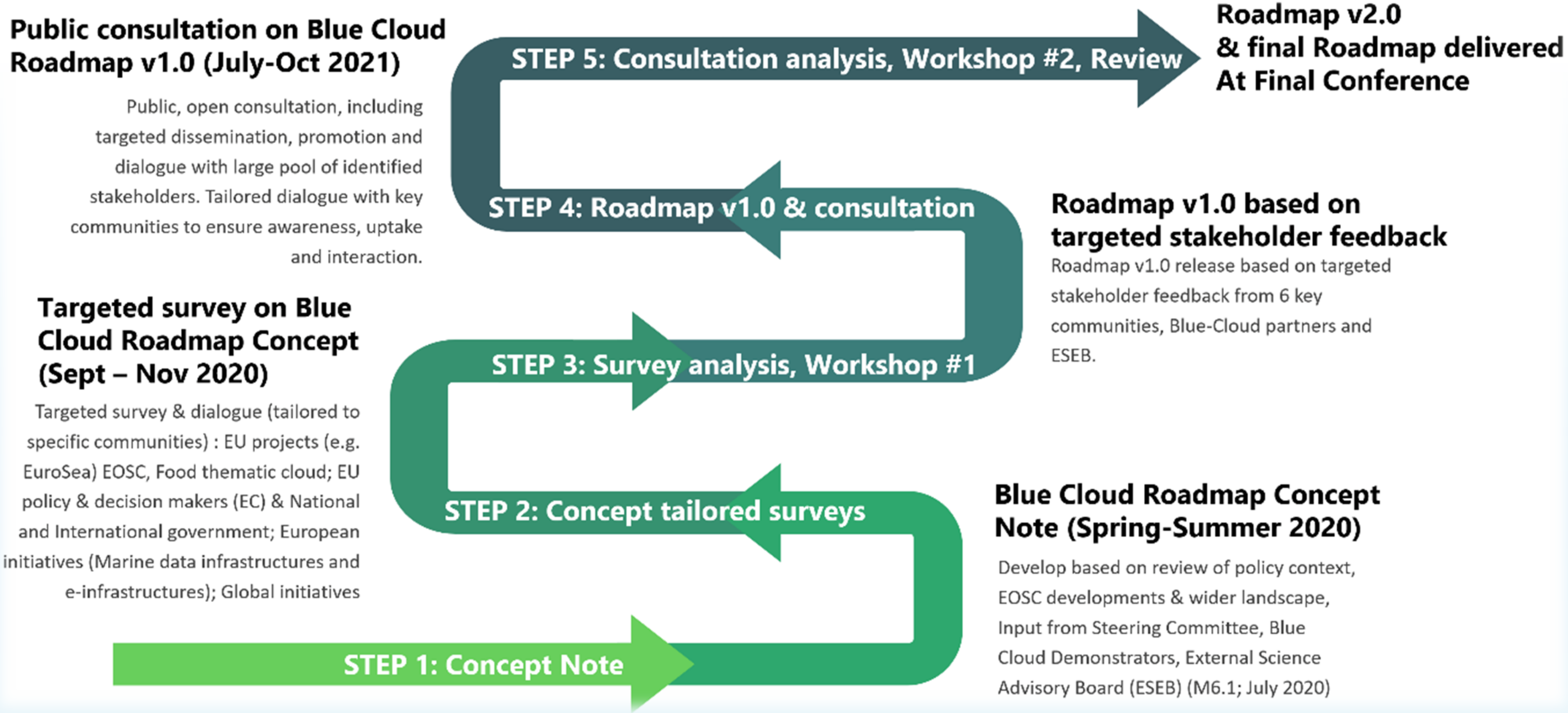
Exploitation & Sustainability
Service Exploitation & Sustainability Plan

Action Plan
2022 - 2025
Strategic Objectives & Recommendations
2030

Policy & Societal Context

ROADMAP

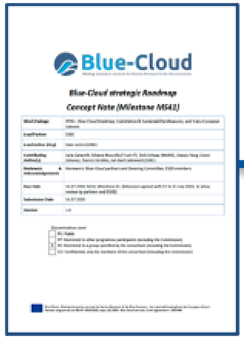
The Blue-Cloud Roadmap: Process



Engaging & consulting the B-C community
Phase 1: July-December 2020

Blue-Cloud

BLUE-CLOUD ROADMAP CONSULTATION PROCESS SO FAR


Blue-Cloud

Blue-Cloud strategic Roadmap

Concept Note (Milestone MS41)

ESEB Workshop July 2020	Online Survey Oct – Nov 2020	Policy Dialogue Nov 2020	ESEB Workshop Dec 2020
Feedback collection about technical concept and demonstrators	Collection of inputs from the marine community, to be used in the development of the "Roadmap to 2030"	Start a dialogue on the Blue-Cloud can meet EU policy priorities in marine research, environment, economy, policy making, and decisioning, to feed into the Blue-Cloud Roadmap 2030	Collect inputs for the initial blueprint for the Blue-Cloud Roadmap to 2030,built on results from consultation

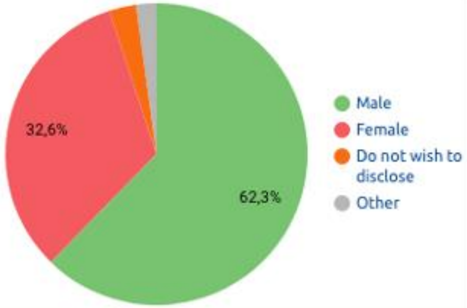
Engaging & consulting the B-C community

Online survey Blue-Cloud Roadmap

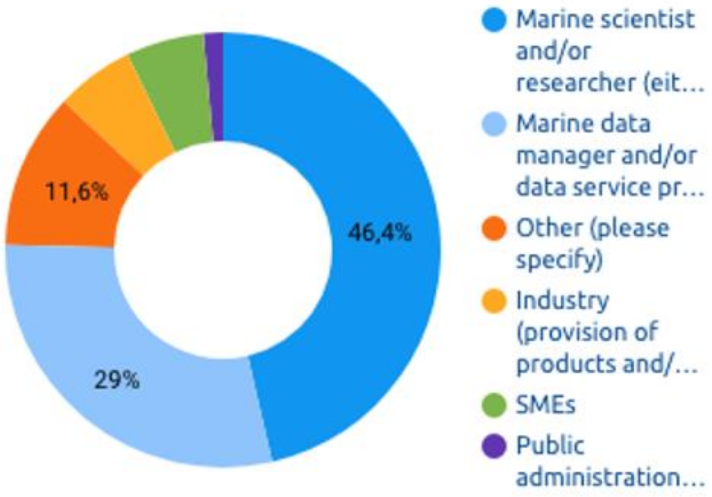
October - November 2020

Blue-Cloud

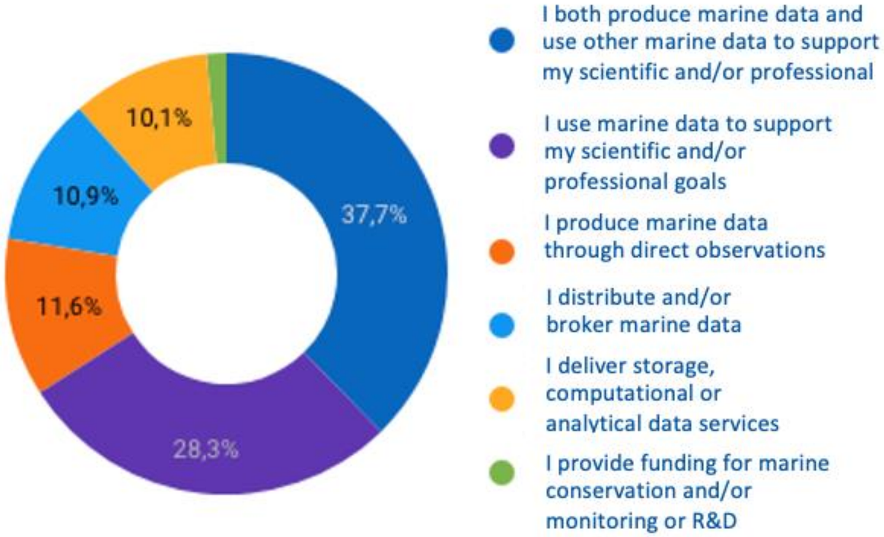
Profile of respondents



Respondent types



Connection with marine data



Sectors

(please note this was a multiple-choice question)

+ Sector	Quantity
Academia	51
Blue economy	8
Business	12
Government	27
Non-governmental organisation	17
Other	11

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Blue-Cloud has built synergies with European and international stakeholders

BUILDING AN ALL ATLANTIC OCEAN COMMUNITY
Implementing the Belém Statement

AORA
ATLANTIC OCEAN RESEARCH ALLIANCE

AtlantOS

Examples of concrete synergies

BeOpen is contributing to the exploitation of data from their observatory (maritime and water transports) into the Blue-Cloud demonstrator on marine environmental indicators, thus interlinking different sets of data for several thematic clouds.

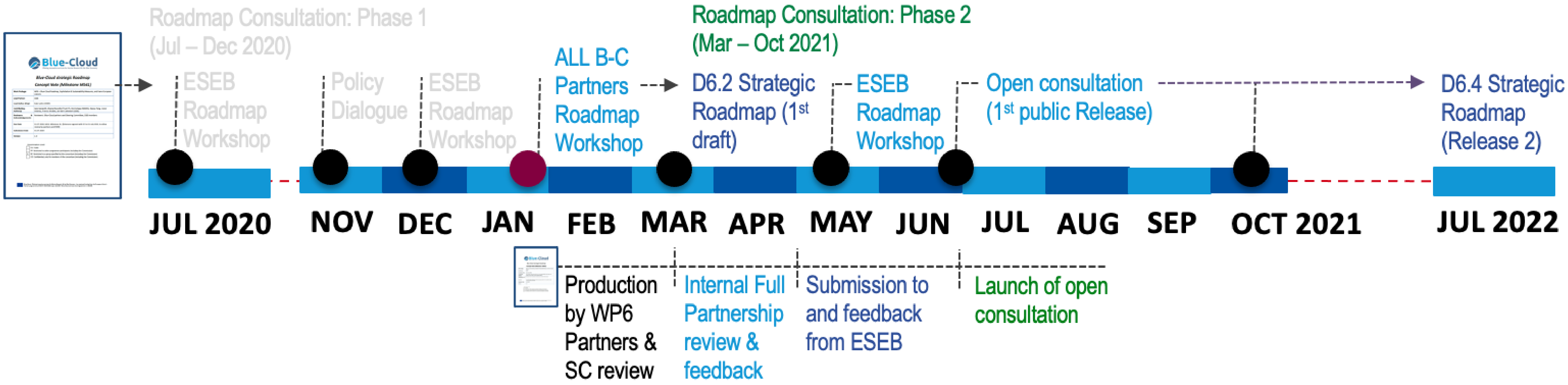
EuroSea is interested in the Blue-Cloud demonstrators on Biodiversity (Plankton Genomics), Fisheries and Aquaculture to further exploit FAIR data efforts on the network level for forecasts and observations using data from Copernicus, EOSS and GOOS.

FNS-Cloud and Blue-Cloud are addressing the engagement with users from the Blue-Cloud Fisheries Demonstrator for integrating datasets from different disciplines, such as nutrition.

Odyssea and Blue-Cloud are developing synergies for feeding each other's demonstrators with relevant data, especially for the demonstrators on environmental indicators, fisheries and aquaculture.

The synergy is aiming to integrate citizen science data and observations of COS4CLOUD into the Blue-Cloud through the Biodiversity and Environmental indicators demonstrators.
Contribution of COS4CLOUD to the Blue-Cloud 2030 Roadmap.

Next steps



- Blue-Cloud Open Workshop (March 2021)
- Blue-Cloud Roadmap Workshop (June 2021)

Thank you! Questions?

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Zoo & Phytoplankton
EOV products

Big data and machine learning methods to enhance biodiversity data

Renosh PR, Sorbonne Université (SU) – CNRS/Laboratoire d'Océanographie de Villefranche (LOV)
Alexander Barth, University of Liege – GHER
Gert Everaert & Patricia Cabrera, Flanders Marine Institute (VLIZ)

Blue-Cloud has received funding from the European Union's Horizon Programme call BG-07-2019-2020, topic: [A] 2019 - Blue Cloud services, grant Agreement number 862409.

Agenda

10:00: Introduction, Blue-Cloud Vision and Mission, by Sarah Pittonet, Trust-IT Services

10:05: Zoo-Phytoplankton EOV demonstrator insights, by Patricia Cabrera, VLIZ

10:10: Deriving global ocean 3D Chlorophyll-a concentrations using machine learning techniques, by Renosh Pannimpullath Remanan, LOV

10:20: Deriving gridded data products for zooplankton distribution using variational analysis and neural networks, by Alex Barth, ULiège

10:30: Modelling zoo- and phytoplankton interactions, by Gert Everaert, VLIZ

10:40: Next steps, by Patricia Cabrera, VLIZ

10:45: Q&A, moderated by Sarah Pittonet, Trust-IT Services

Demonstrator insights

Zoo & Phytoplankton EOV products

Objective

Machine learning approach to derive zoo and phytoplankton biomass and diversity products

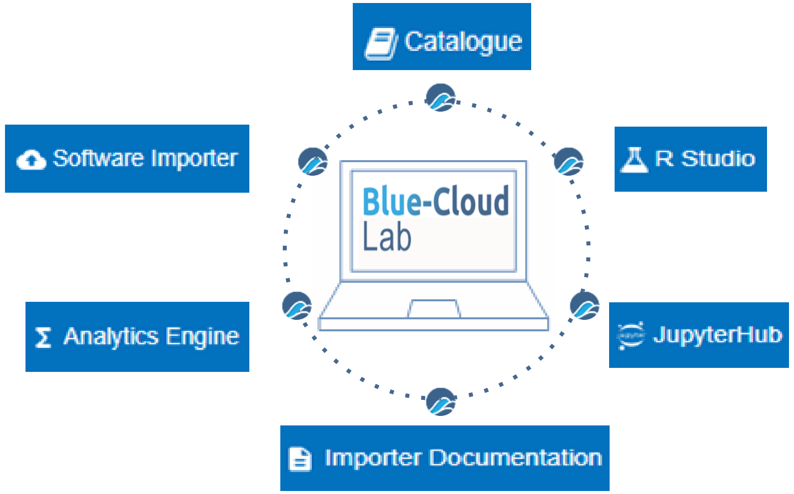
Methodology

Data compilation & processing

Ground truth modelling using NRT data

Big data & Machine learning

Tool



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Demonstrator workflow

Data inputs

EurOBIS
European Ocean Biogeographic Information System

SeaDataNet

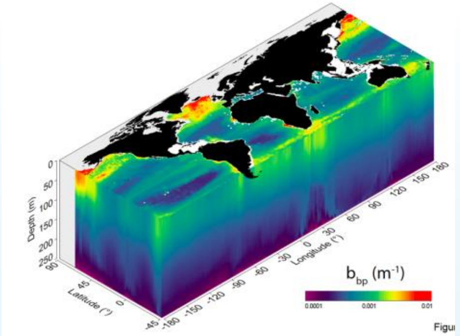
Copernicus
Europe's eyes on Earth

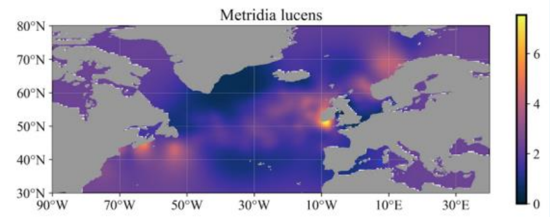
EMODnet

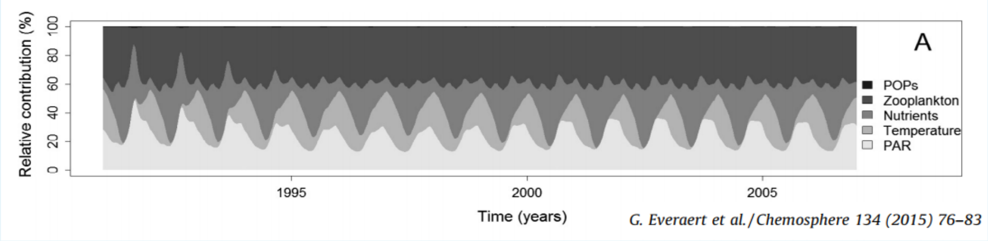
LifeWatch
BELGIUM

NEURAL NETWORK MODEL

Data outputs







Scientific validation

Phytoplankton EOV products

Deriving global ocean 3D Chlorophyll-a concentrations using machine learning techniques

Renosh P. Remanan, renosh.pr@obs-vlfr.fr
Raphaëlle Sauzède, raphaelle.sauzede@imev-mer.fr
Julia Uitz, julia.uitz@imev-mer.fr
Hervé Claustre, claustre@obs-vlfr.fr

Outline

- Introduction
- Objectives
- Methodology
- Data
- Validation
- How to use the demonstrator?
- Conclusions and perspectives

Introduction

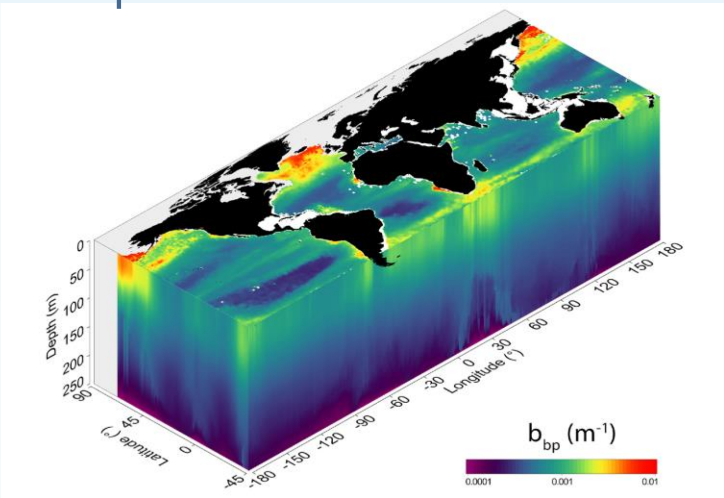
- Through their photosynthetic capacity, **phytoplankton organisms form the basis of the marine food web** on which all life in the ocean depends.
- These microalgae are also key to the biological carbon pump, by which the oceans sequester carbon and hence **mitigate the impact of climate change** induced by CO2 anthropogenic emissions.
- **Chlorophyll-a (Chla)** is the key pigment associated with phytoplankton photosynthesis and is thus widely used as a **proxy for the phytoplankton biomass in the ocean.**
- Knowledge of global ocean 3D Chla will contribute to improve the proficiency and vastly reduce the uncertainty regarding the **present state of marine ecosystems and their response to ongoing and future climate change.**

Objectives

- Generate global ocean 3D fields of Chlorophyll-a & Phytoplankton size classes using a machine learning-based method, following the approach of ***Sauzède et al. (2016).***

- This approach takes advantage of both the fine vertical resolution of Argo T/S profiling floats and the synoptic coverage of ocean color satellite imagery in order to extend a surface biogeochemical variable to depth and create a 3D product.

- The beta version of the Phytoplankton-EOV generates 3D fields of monthly average Chla for the year 2018.



Methodology

Multi Layer Perceptron (MLP) model training

Satellite data

BGC- Argo data

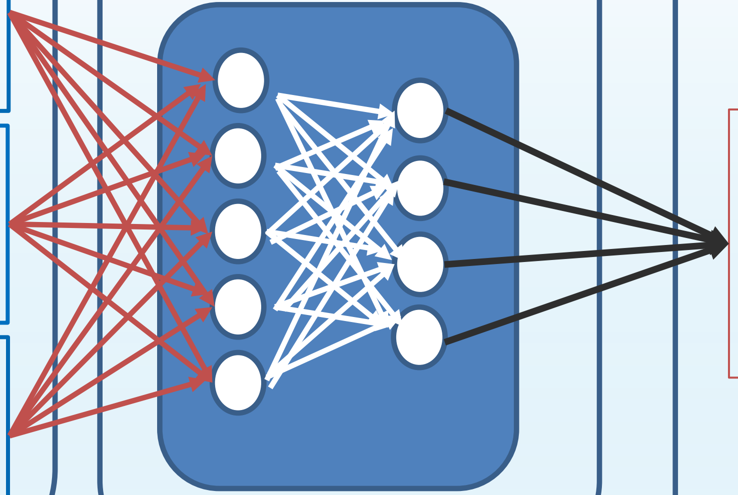
Input layer

Surface parameters
- Remote sensing reflectance (412, 443, 490, 555, and 670 nm)
- Sea level anomaly
- Photosynthetically available radiation

Vertical parameters
- Temperature (PCA transformed)
- Salinity (PCA transformed)
- Spiciness (PCA transformed)
- Mixed Layer Depth

Space time components
- Day of the year (in cycle transformation)
- Longitude/Latitude (In cartesian transformation)

Hidden layers



Output layer

PCA of Chla values in 19 depths

[0, 10, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, and 1000 m]

BGC- Argo data

How to derive global 3D Chla ?

Monthly mean global satellite data (CMEMS & Globcolor)

Monthly mean global Physical data (CMEMS)

Input

Surface parameters
- ❖ Remote sensing reflectance (412, 443, 490, 555, and 670 nm)
- ❖ Sea level anomaly
- ❖ Photosynthetically available radiation

Vertical parameters
- ❖ Temperature (PCA transformed)
- ❖ Salinity (PCA transformed)
- ❖ Spiciness (PCA transformed)
- ❖ Mixed Layer Depth

Space time components
- ❖ Day of the year (in cycle transformation)
- ❖ Longitude/Latitude (In cartesian transformation)

MLP model

Global 3D monthly mean Chla fields (19 depths)

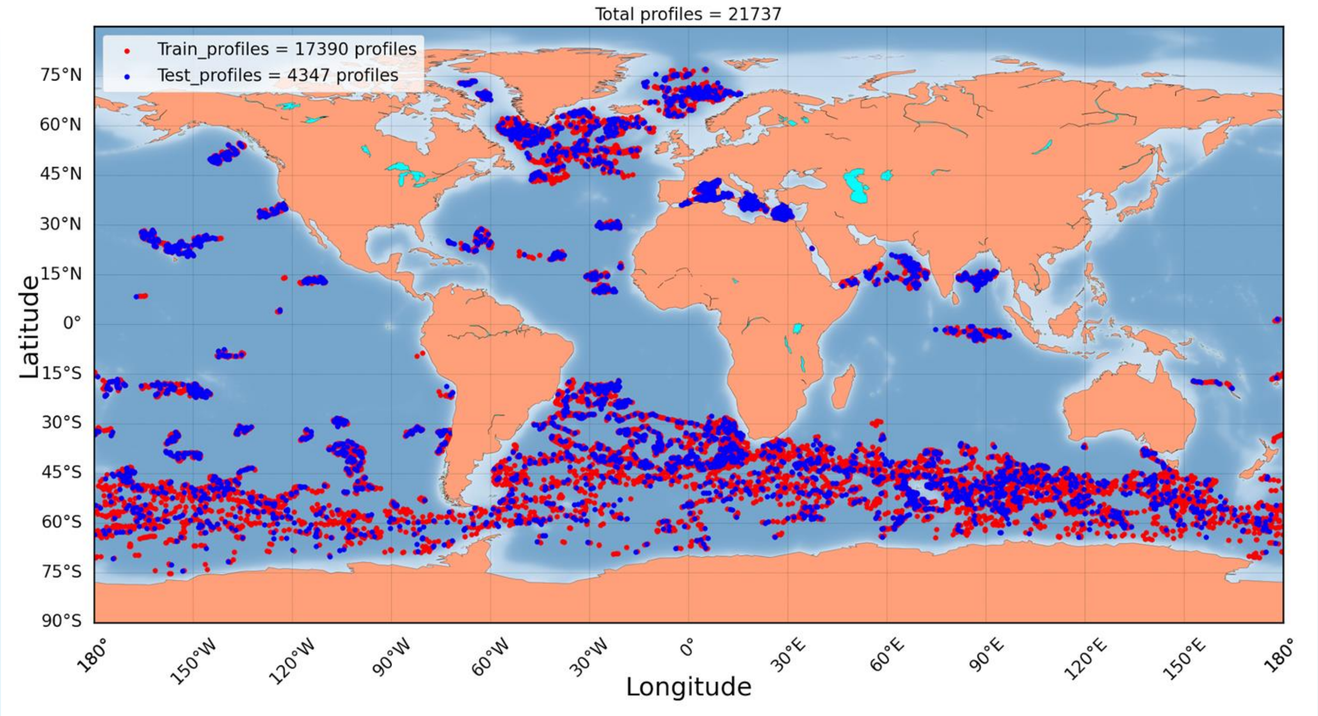
[0, 10, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, and 1000 m]

Data

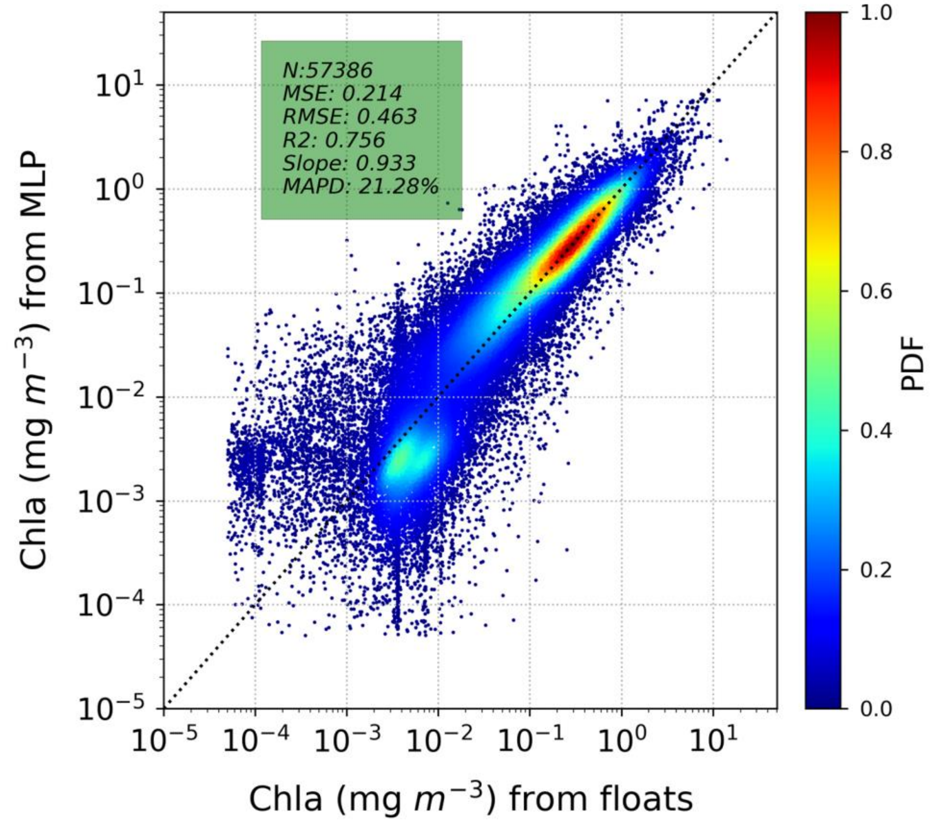
Variable	Data used for	Source	Data type	Data measured from
BGC-Argo data of Chlorophyll-a, Temperature and Salinity	MLP training & Validation	Agro-GDAC (Coriolis data center)	Freely accessible	Depth-resolved
Satellite derived Remote sensing reflectance (Rrs)	MLP training and generation of output 3D Chla product	CMEMS	Freely accessible	Surface
Sea Level Anomaly (SLA)		CMEMS (DUACS)	Freely accessible	Surface
Satellite derived Photosynthetically Available Radiation (PAR)		CMEMS / Globcolour	Freely accessible	Surface
Physical data (Salinity and Temperature)	Generation of ouput 3D Chla product	CMEMS (ARMOR3D)	Freely accessible	Depth-resolved
HPLC pigment database	Validation	LOV	Accessible upon request	Depth-resolved

Validation

Distribution of the Argo Chla

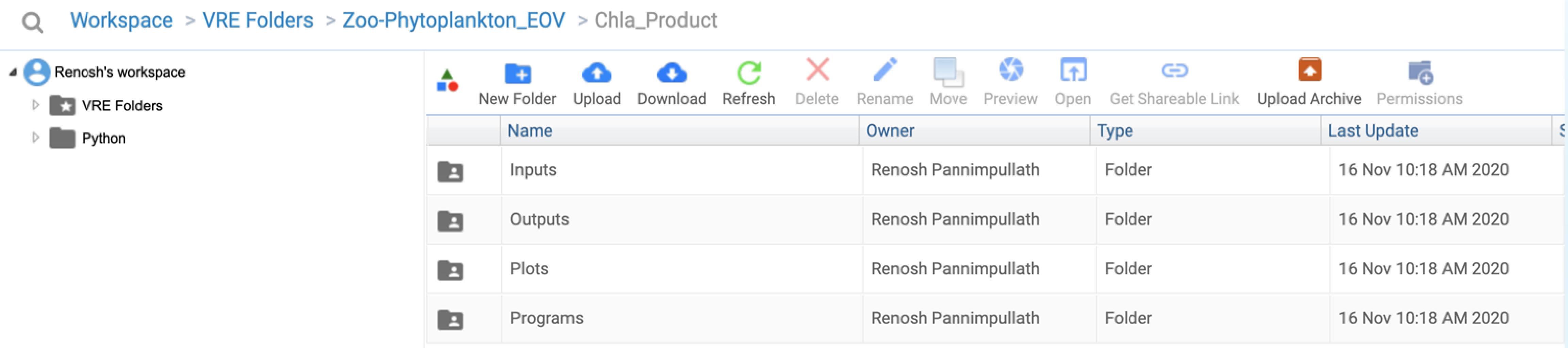


MLP model validation



How to use the Demonstrator?

zoo-phytoplankton_eov → Chla_Product



Name	Owner	Type	Last Update
Inputs	Renosh Pannimpullath	Folder	16 Nov 10:18 AM 2020
Outputs	Renosh Pannimpullath	Folder	16 Nov 10:18 AM 2020
Plots	Renosh Pannimpullath	Folder	16 Nov 10:18 AM 2020
Programs	Renosh Pannimpullath	Folder	16 Nov 10:18 AM 2020

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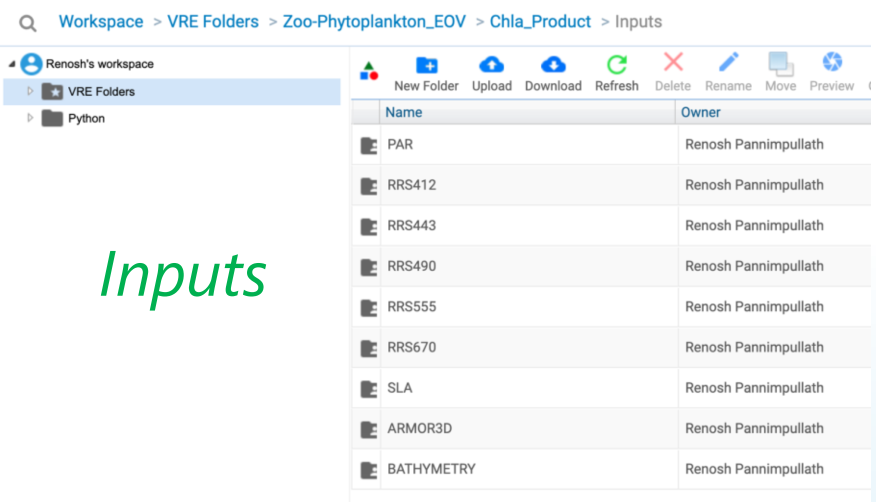
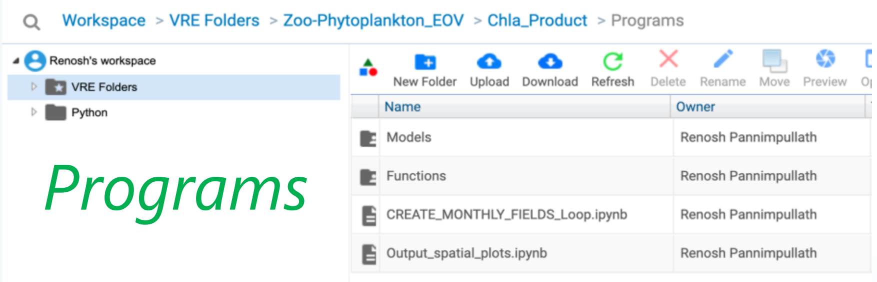
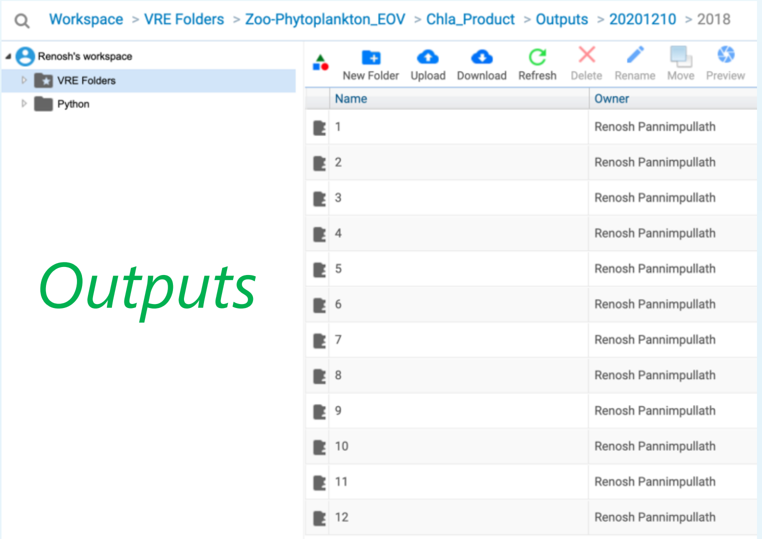
Inputs



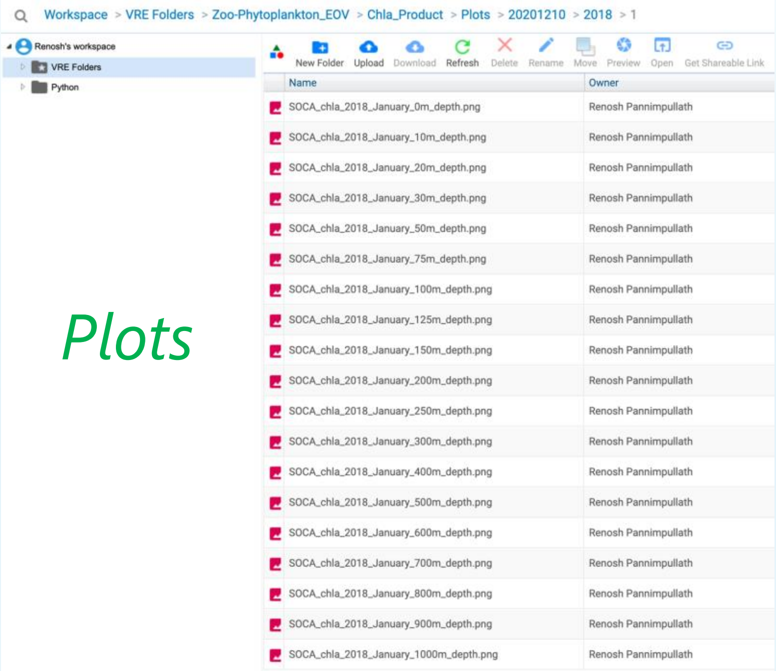
Programs



Outputs



Plots



2 Jupyter notebooks

Making output files (netcdf)

Location
Chla_Product -> Programs

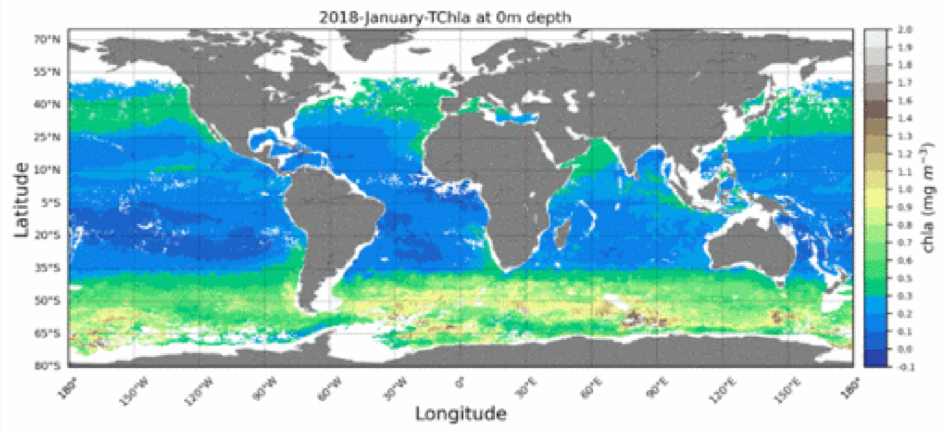
Name of the Notebook
CREATE_MONTHLY_FIELDS_Loop.ipynb

Plotting the output (.png files)

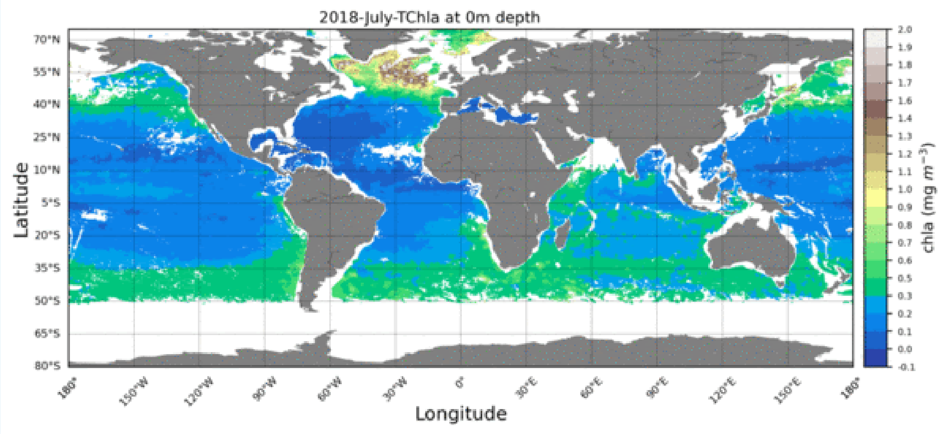
Location
Chla_Product -> Programs

Name of the Notebook
Output_spatial_plots.ipynb

Winter



Summer



Conclusions and perspectives

- Users can generate the global 3D monthly mean Chla concentrations for the year 2018 and corresponding plots, using the 2 jupyter-notebooks provided in the "Programs" folder.
- The output ".nc" files will be stored in the "Output" folder and corresponding plots (.png) will be stored in the "Plots" folder.
- If users wish to save these data and plots in different folders, they can edit the path in the notebook.
- In the short term, the MLP model will be refined in order to improve the quality of the retrieved products.
- The Chla concentrations derived using the MLP model will be validated against HPLC reference pigment data.

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Zooplankton EOV products

Deriving gridded data products for zooplankton distribution using variational analysis & neural networks

LIÈGE université GHER

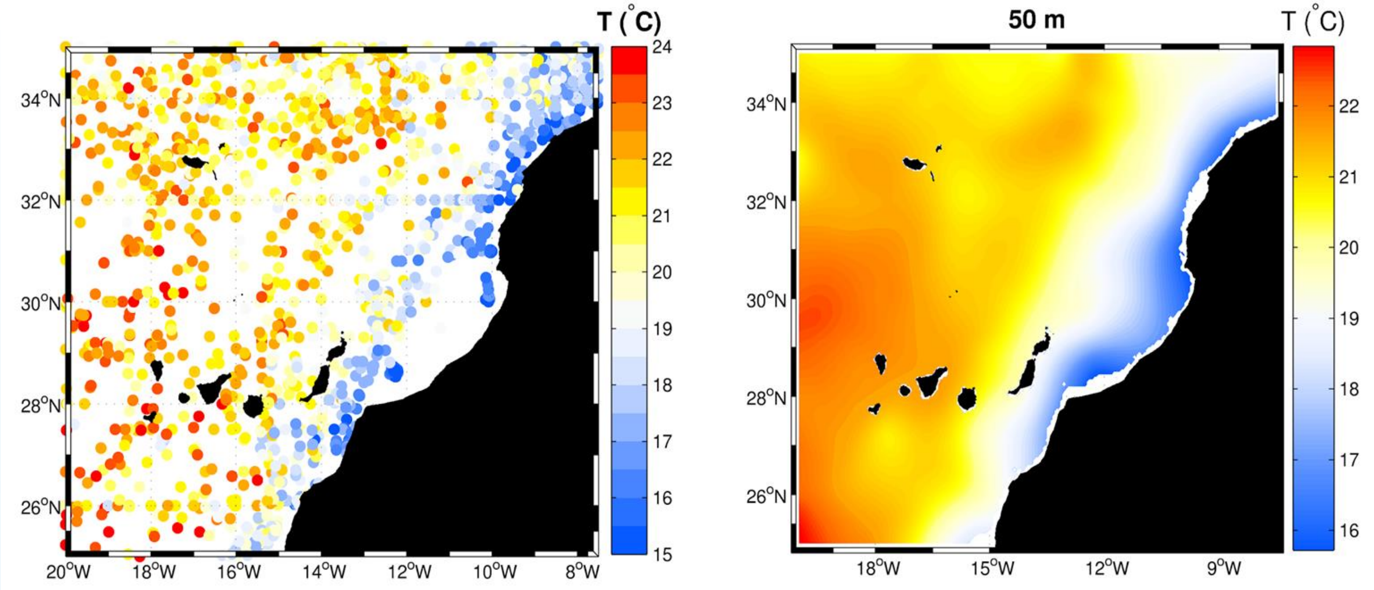
Alexander Barth, a.barth@uliege.be
Charles Troupin, ctroupin@uliege.be

Interpolation and data analysis

Difficulties in oceanography:

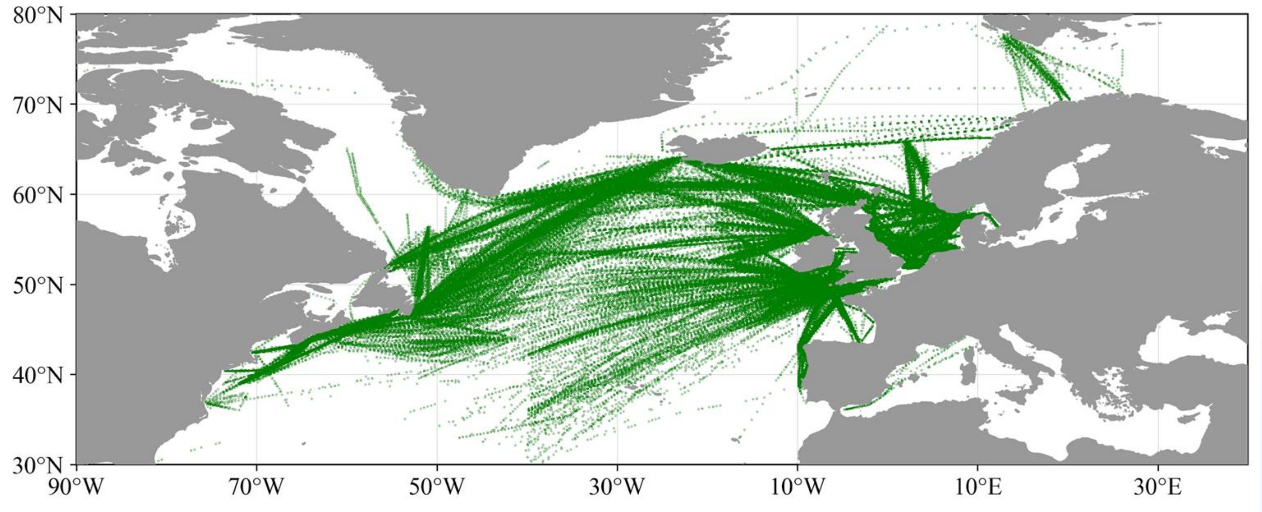
- Data distribution/scarcity
- Confidence in measurements
- Representativity error

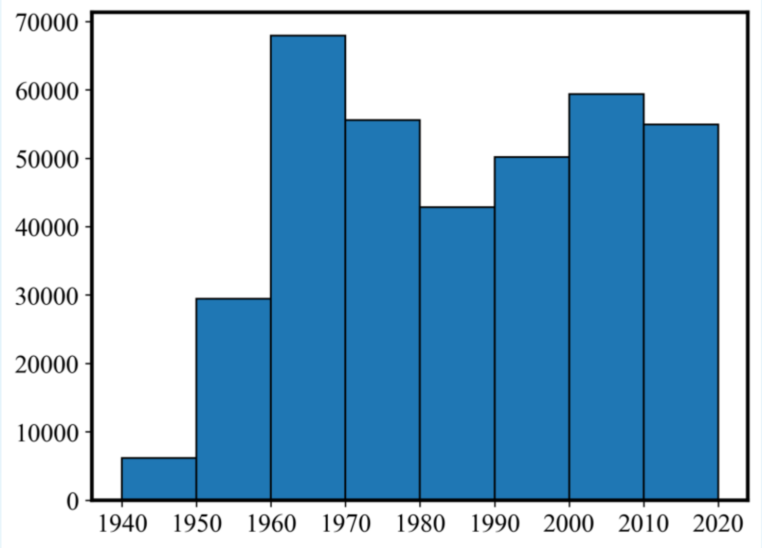
Possible usage: climatologies, reference state, model validation



The dataset

- Data from the continuous plankton recorderoperated by the Marine Biological Association, UK
- Heterogeneous distribution
- Data since 1940
- Data | position | number of ind/m^3





The method

DIVAnd: Data Interpolating Variational Analysis in n dimensions

https://github.com/gher-ulg/DIVAnd.jl

Code written in Julia (https://julialang.org/)

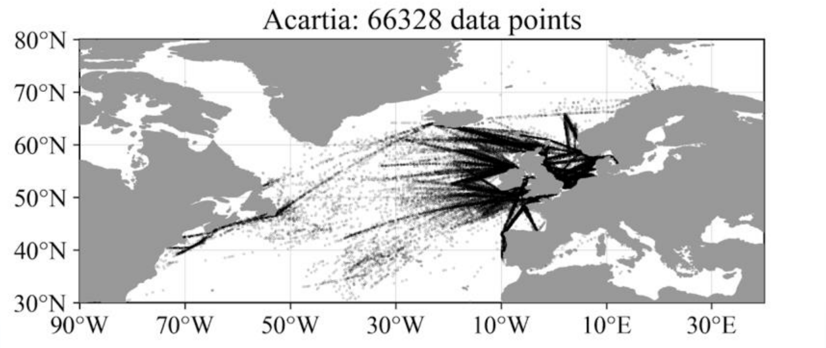
DIVAnd

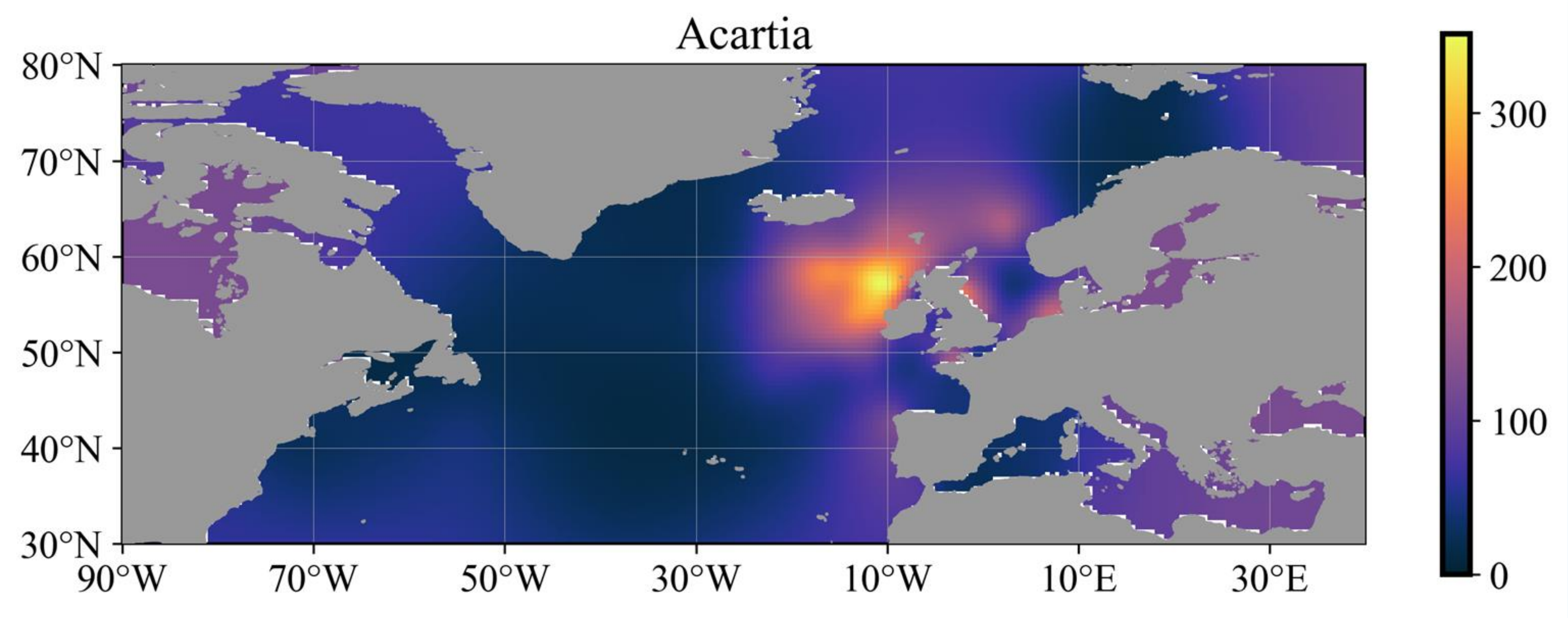
CI passing | codecov 80% | docs stable | docs latest | DOI 10.5281/zenodo.4400206

`DIVAnd` (Data-Interpolating Variational Analysis in n dimensions) performs an n-dimensional variational analysis/gridding of arbitrarily located observations. Observations will be interpolated/analyzed on a curvilinear grid in 1, 2, 3 or more dimensions. In this sense it is a generalization of the original two-dimensional DIVA version (still available here https://github.com/gher-ulg/DIVA but not further developed anymore).

DIVAnd Application

Spatial interpolation

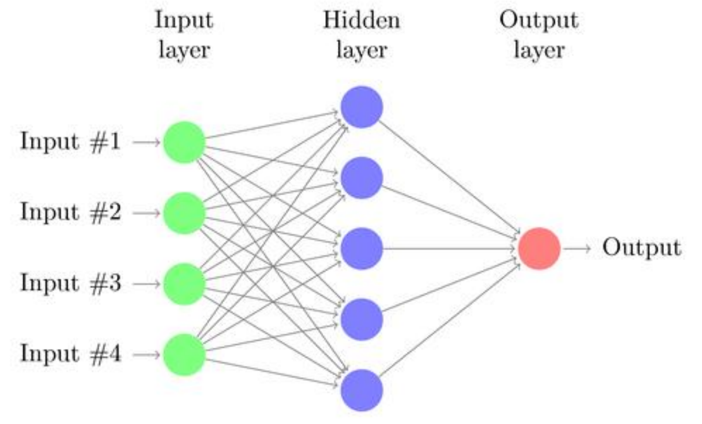




DIVAnd with a Neural Network

$$g(x) \;=\; f\,(v_1, v_2, \ldots v_n) \;+\; x'$$

- The beta version of the Phytoplankton-EOV generates 3D fields of monthly average Chla for the year 2018.
- v_1, v_2, … v_n are environmental variables related to the probability
- $f\,(v_1, v_2, \ldots v_n)$ is a neural network
- x' is a residue varying of a specified length-scale (DIVAnd)
- Also applicable to occurrence probability with a slightly different formulation



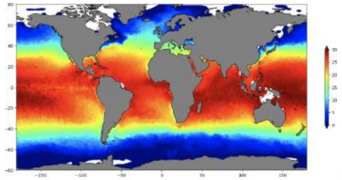
Neural network
(Multilayer perceptron)

Neural network technique

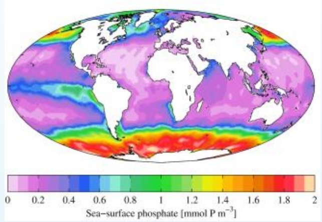
Using other sources of information to improve the interpolation. Used “Co-variables”:

- Sea water temperature (SeaDataCloud)
- Salinity (SeaDataCloud)
- Distance from coast (NASA Goddard Space Flight Center)
- Bathymetry (GEBCO)
- Nitrate, Silicate and Phosphate (World Ocean Atlas 2018)

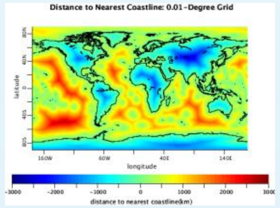
SeaDataCloud T/S climatology



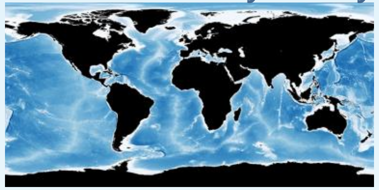
World Ocean Atlas



Distance from coast

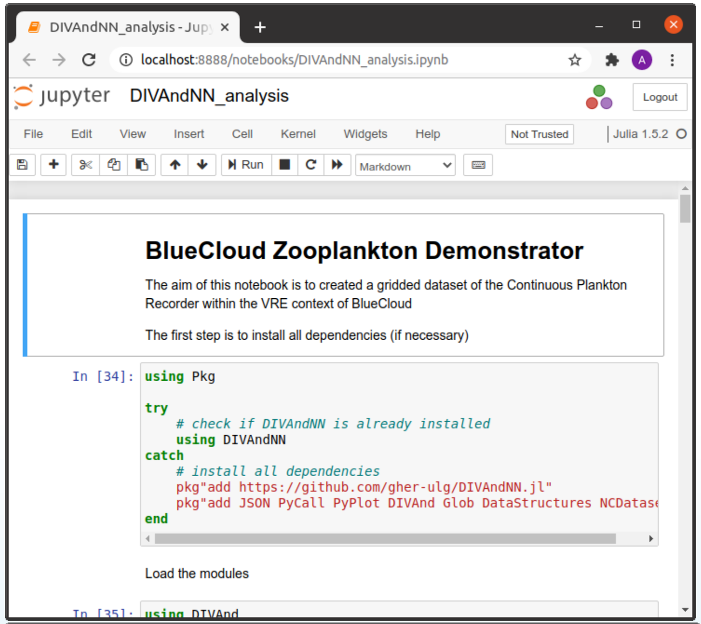


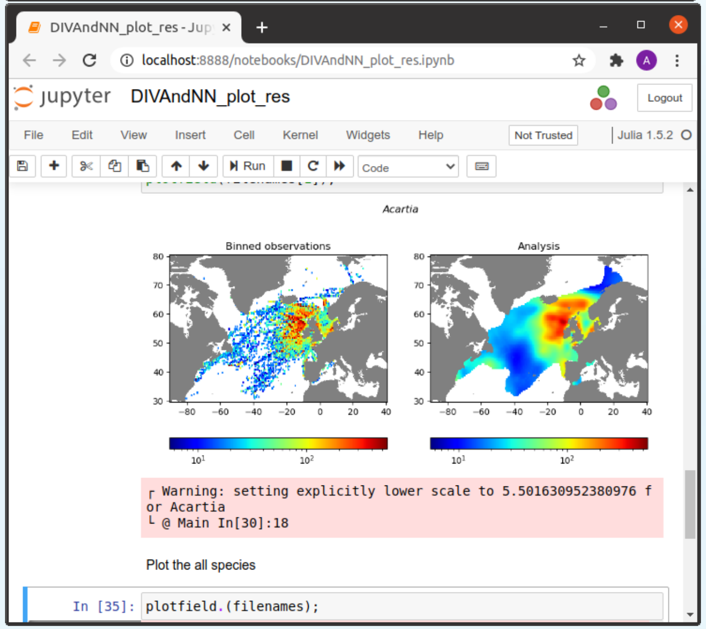
GEBCO Bathymetry



Approach

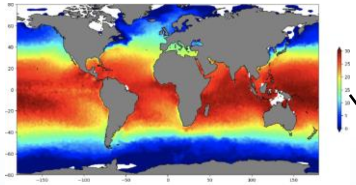
- Reproducible approach:
  - **Version control** using GitLab (at ULiège).
  - **Continuous integration** (testing that the code still runs after every pushed commit).
  - Declare all necessary **direct software dependencies.**
  - **Full snapshot of the dependency tree** (direct and indirect dependencies).
  - Projects can be easily **instantiated** (i.e. the exact Julia environment can be replicated with a single command).
- Using two Jupyter notebooks
  - **Analysis**
    - Preparation of covariables.
    - Split data into training and validation dataset.
    - DIVAnd + neural network analysis.
  - **Visualization of the results.**



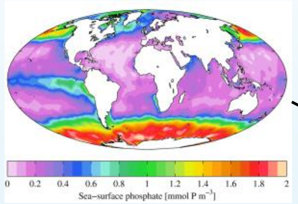


Overview

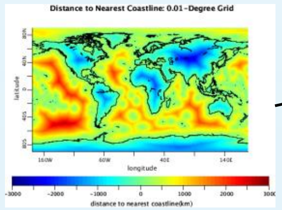
SeaDataCloud T/S climatology



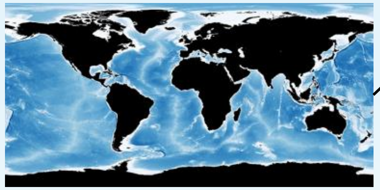
World Ocean Atlas (nutrients)

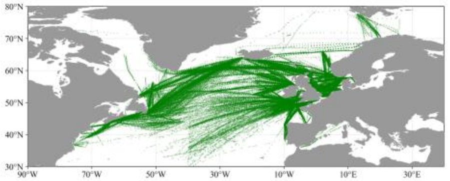


Distance from coast



GEBCO Bathymetry

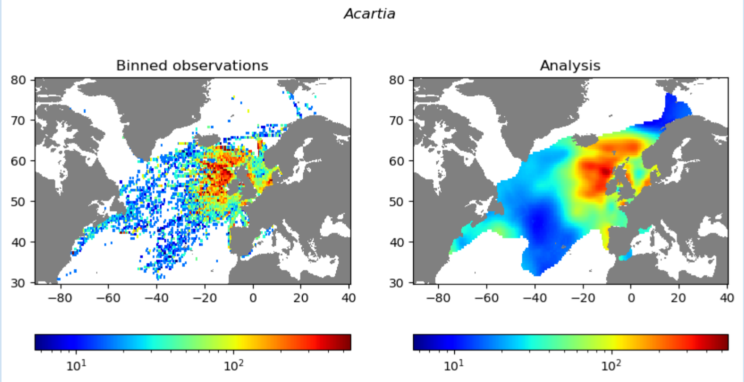




CPR data

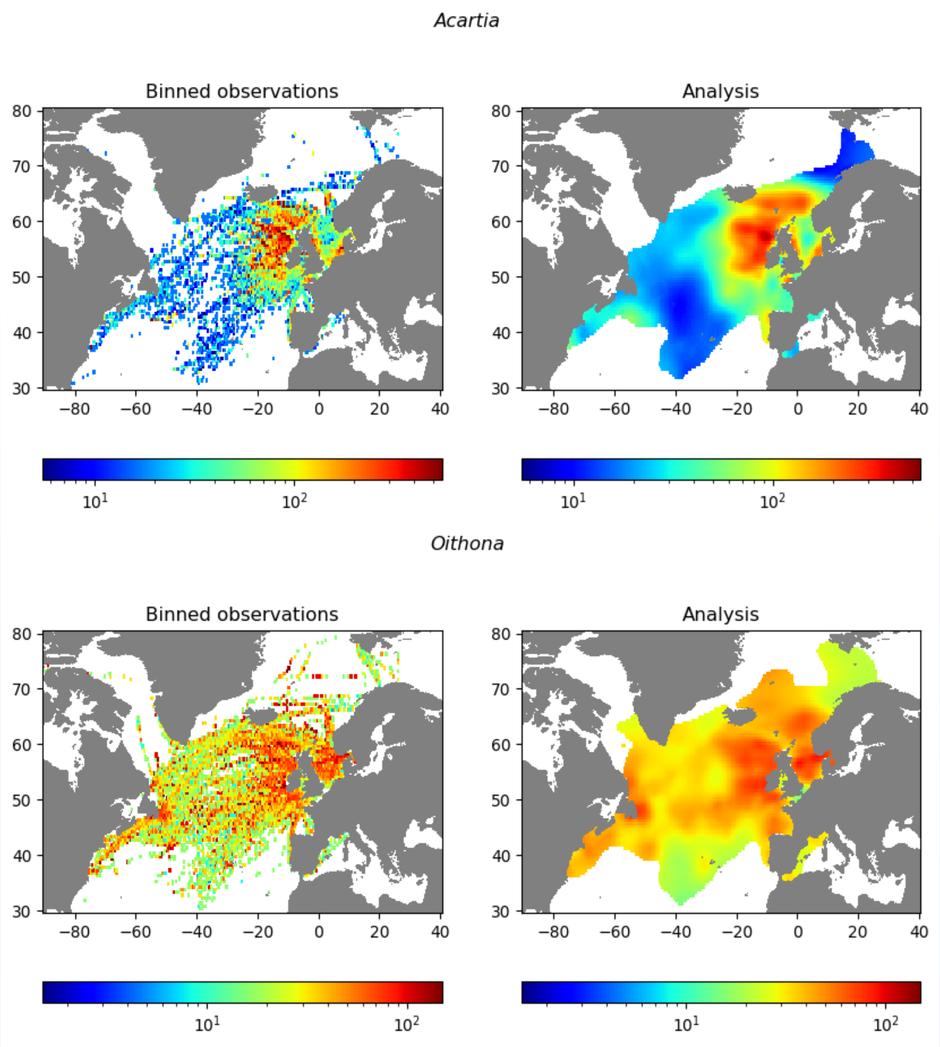
jupyter

julia DIVAnd + Neural network



Blue-Cloud Gateway

Some example results



- Inhomogeneous sampling -> inhomogeneous error spatially
- A relative error map is derived allowing to mask the value far away from the observations

Conclusions

- Collaborative virtual research environment have a large potential to boost scientific productivity
- Capture the relationship between specie distribution and environment parameters using a neural network
- Spatial (and temporal) coherence: constraints used in variational inverse methods
- Possibility to use irregularly sampled observations
- Perspective: explore the potential of convolutional networks (e.g. DINCAE, Data INterpolating Convolutional Auto-Encoder)

Scientific validation

Modelling zoo- &
phytoplankton interactions

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Viviana Otero, viviana.otero@vliz.be

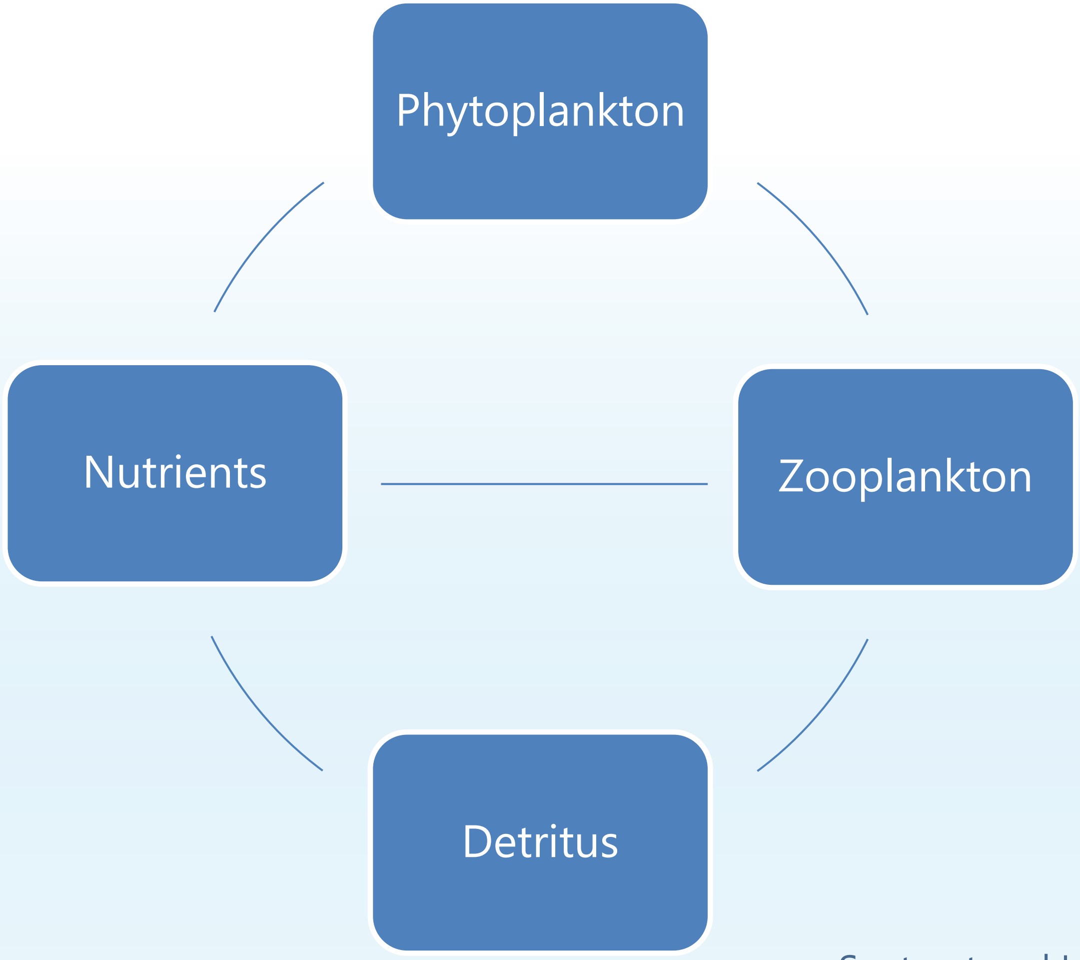
Plankton in marine ecosystems

- Marine phytoplankton fuels marine food webs
- Drivers that limit phytoplankton abundance:
  - Temperature
  - Nutrients
  - Light
  - Zooplankton grazing
- Changes in space and time

Ecosystem model

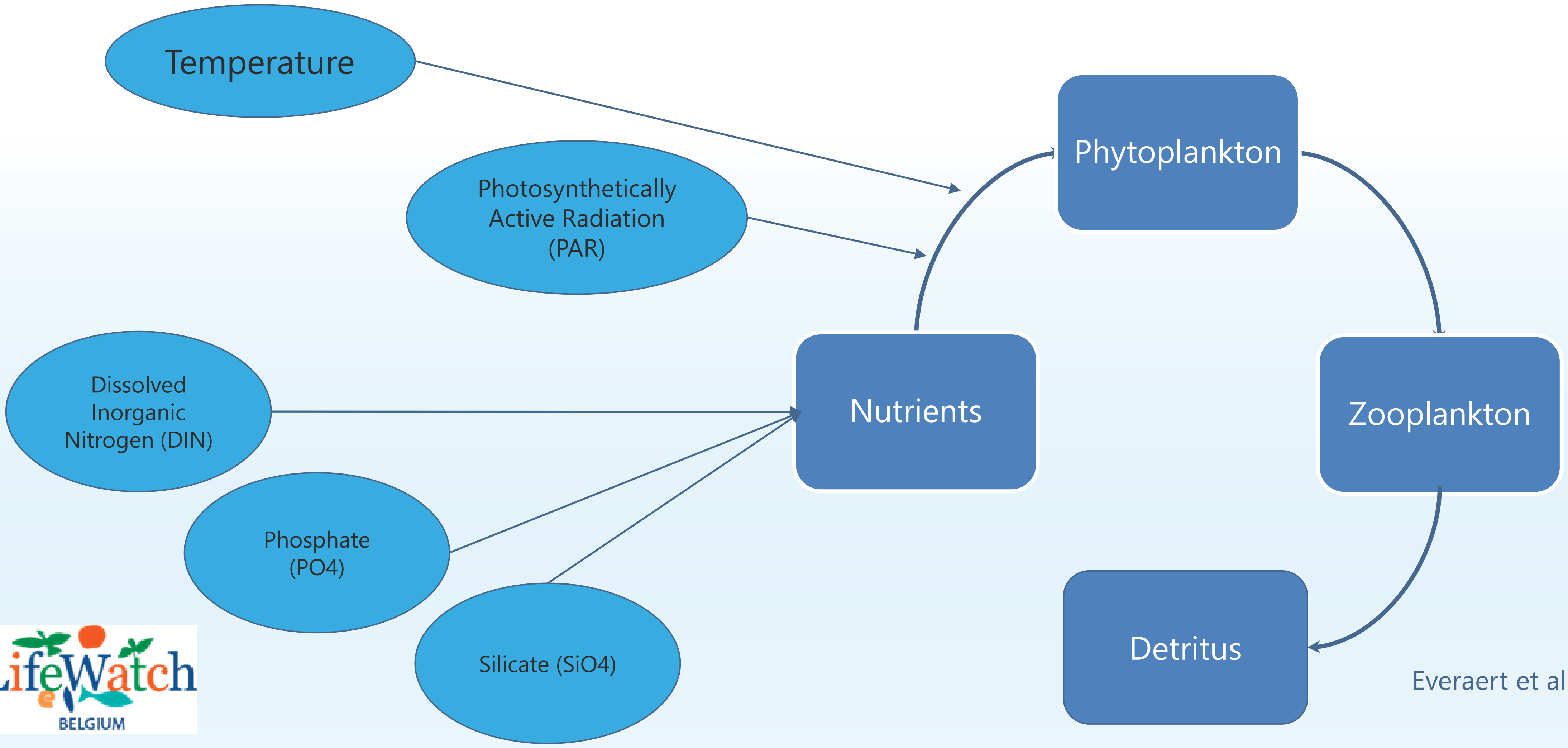
Nutrients, Phytoplankton, Zooplankton and Detritus model for aquatic environments

NPZD Model



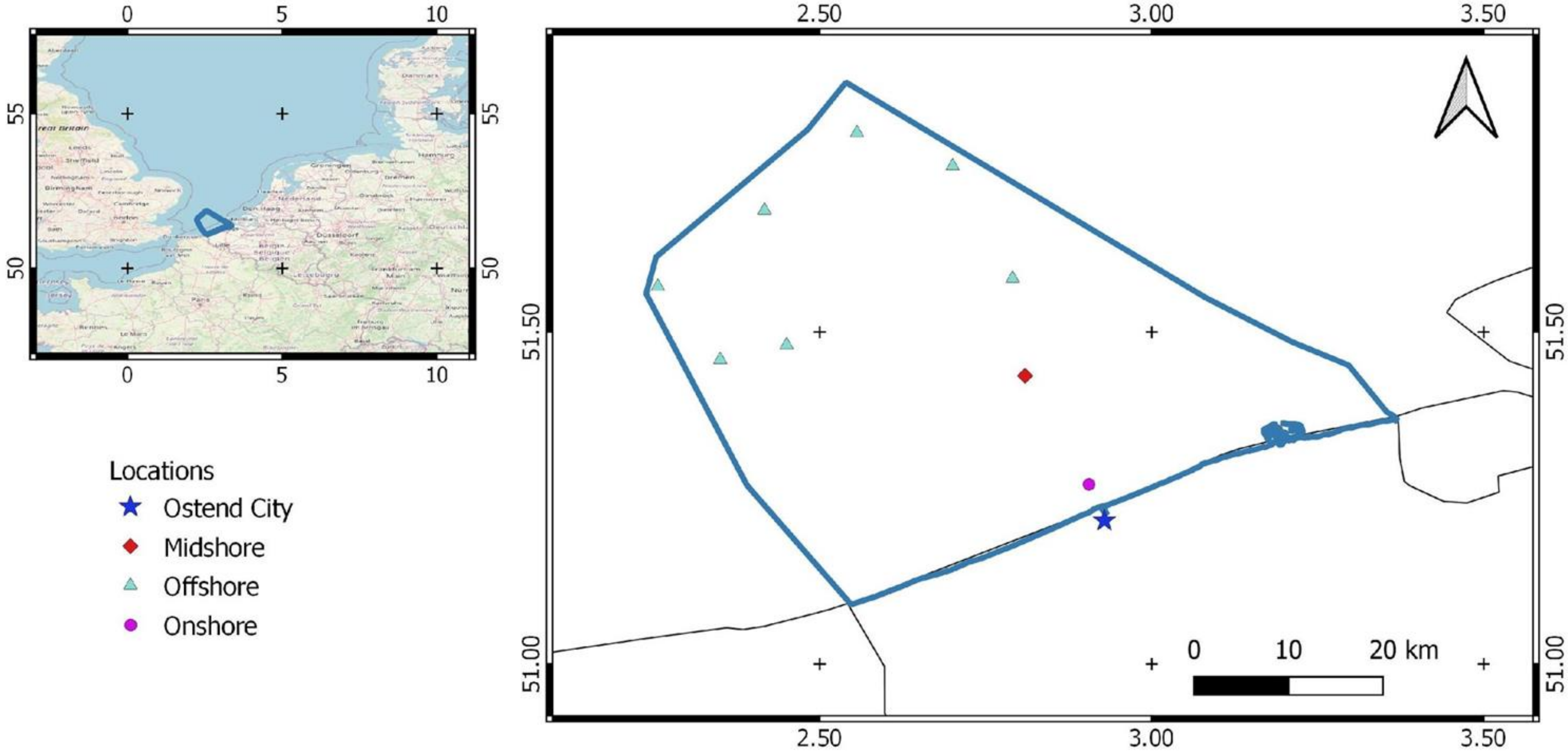
Soetaert and Herman (2009)

NPZD in the Belgian Part of the North Sea



Everaert et al. (2015)

Study area


0
5
10
55
50
Locations
Ostend City
Midshore
Offshore
Onshore
2.50
3.00
3.50
51.50
51.00
0
10
20 km

Model calibration and validation

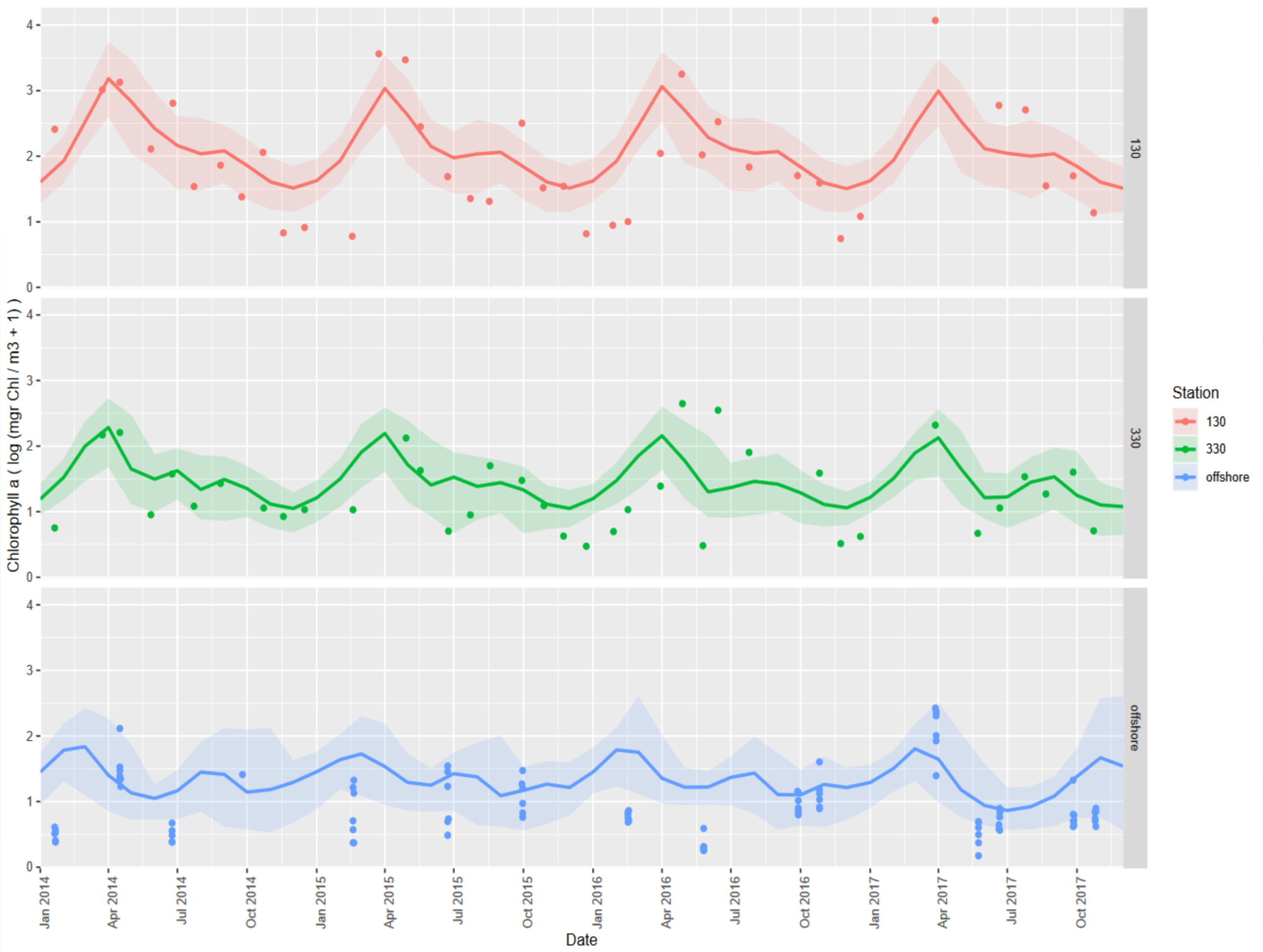
Phase 1
Select parameters

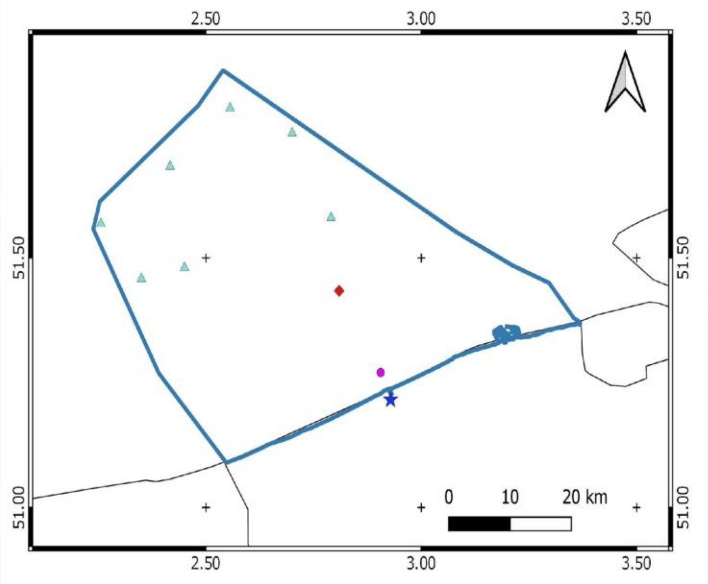
Phase 2
Perform simulations with NPZD model

Phase 3
Calculate RMSE based on observed plankton data

Phase 4
Select best simulations based on RMSE

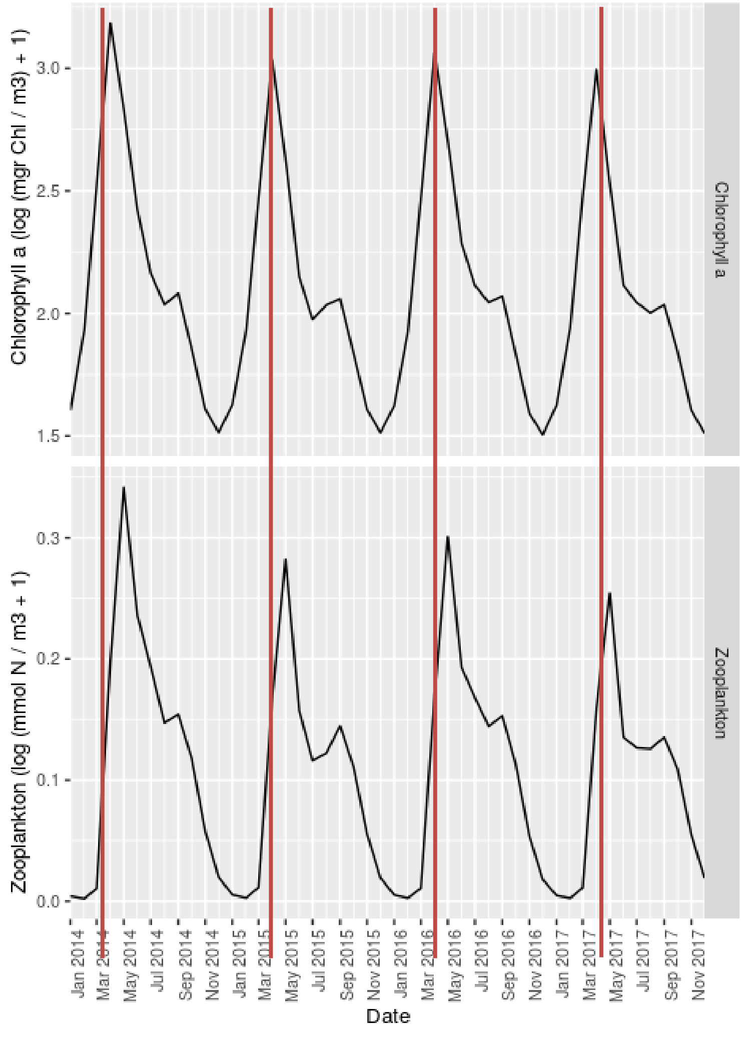
Phytoplankton abundances





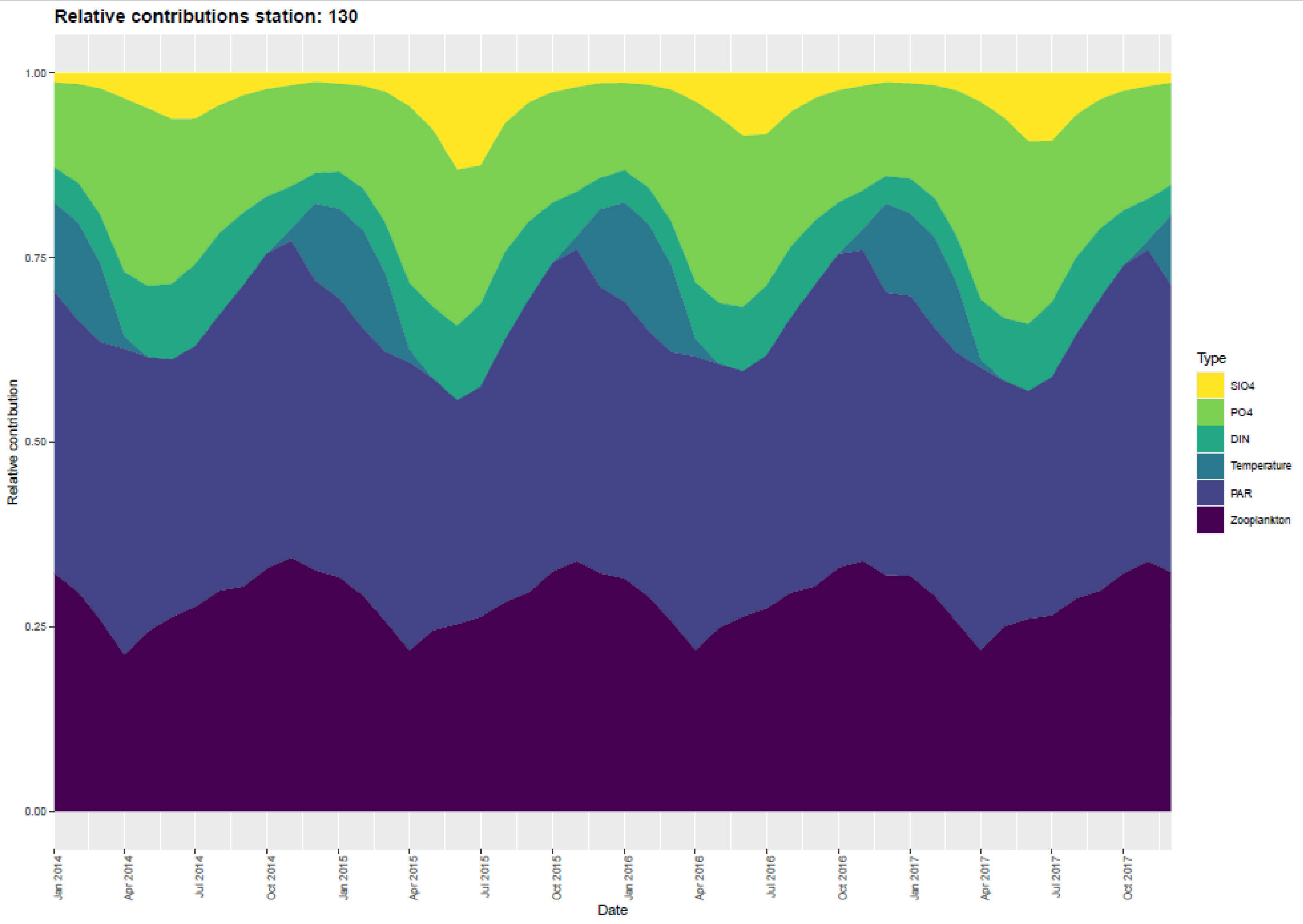
Otero *et al.*, in prep.

Phyto and zooplankton interactions



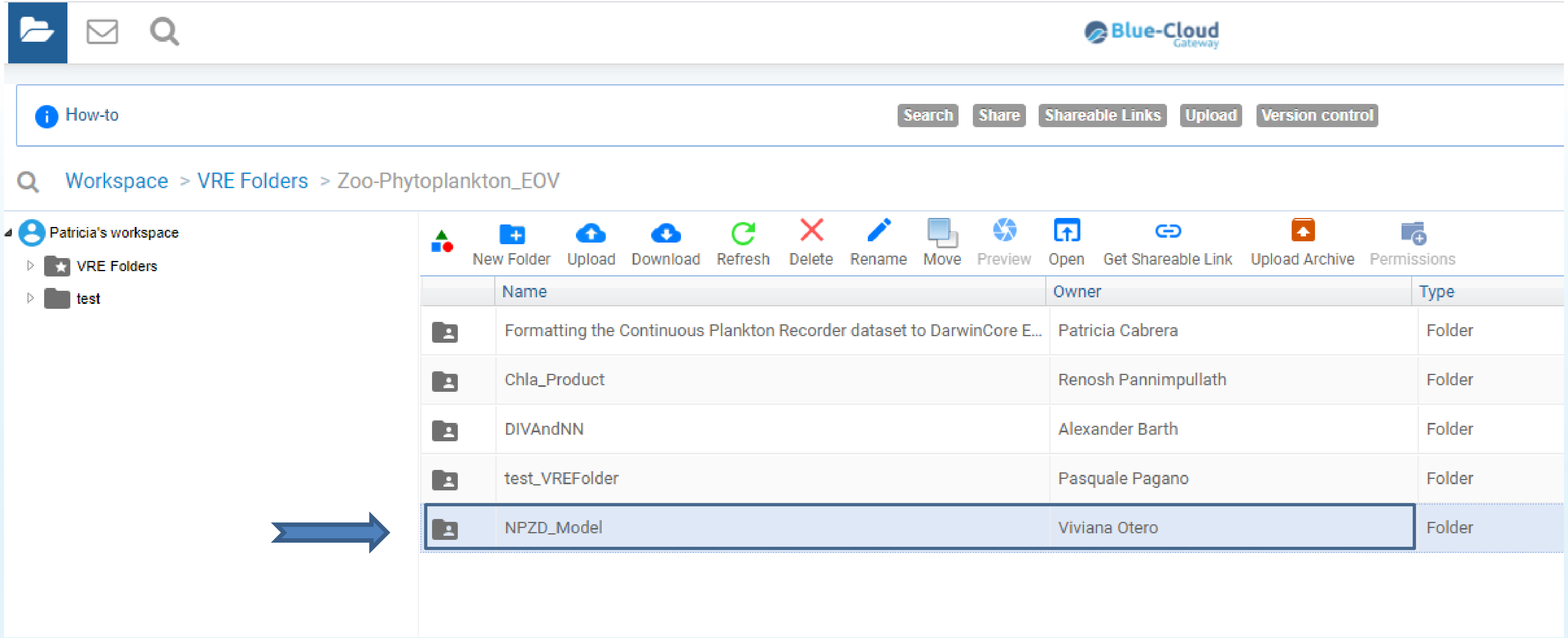
Otero *et al.*, in prep.

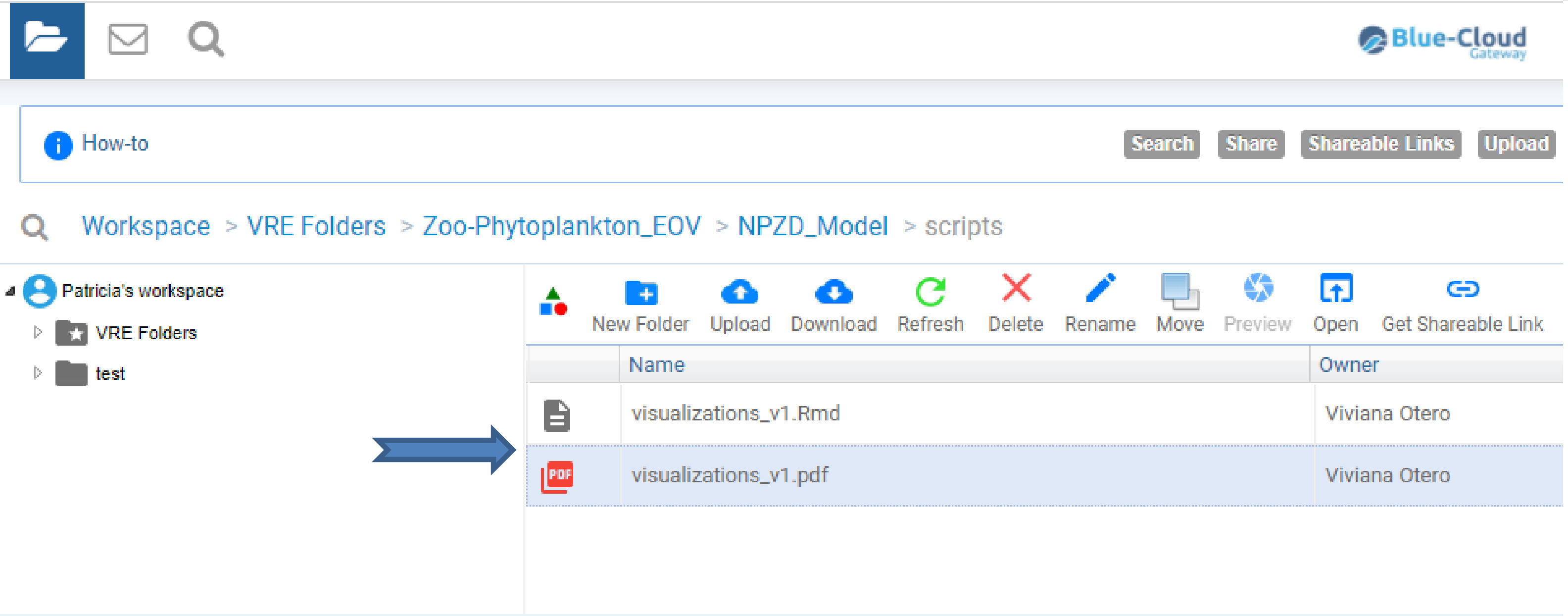
Drivers of phytoplankton abundances

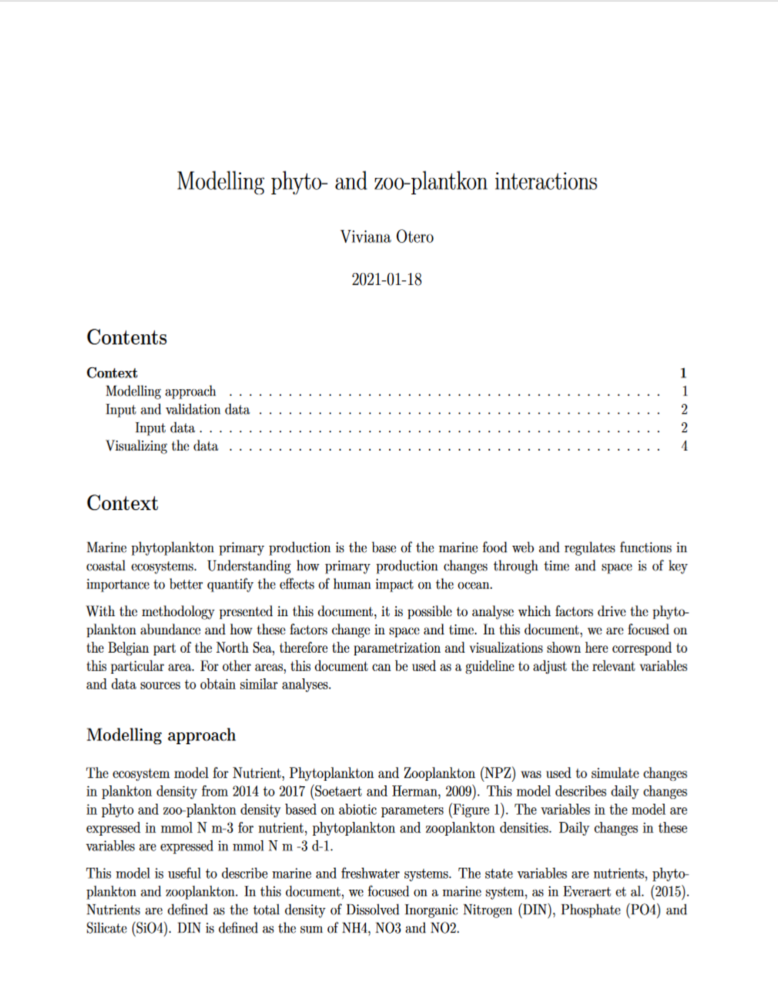


Otero *et al.*, in prep.

How to use the Demonstrator?







Modelling phyto- and zoo-plantkon interactions

Viviana Otero

2021-01-18

Contents

Context

Marine phytoplankton primary production is the base of the marine food web and regulates functions in coastal ecosystems. Understanding how primary production changes through time and space is of key importance to better quantify the effects of human impact on the ocean.

With the methodology presented in this document, it is possible to analyse which factors drive the phytoplankton abundance and how these factors change in space and time. In this document, we are focused on the Belgian part of the North Sea, therefore the parametrization and visualizations shown here correspond to this particular area. For other areas, this document can be used as a guideline to adjust the relevant variables and data sources to obtain similar analyses.

Modelling approach

The ecosystem model for Nutrient, Phytoplankton and Zooplankton (NPZ) was used to simulate changes in plankton density from 2014 to 2017 (Soetaert and Herman, 2009). This model describes daily changes in phyto and zoo-plankton density based on abiotic parameters (Figure 1). The variables in the model are expressed in mmol N m-3 for nutrient, phytoplankton and zooplankton densities. Daily changes in these variables are expressed in mmol N m -3 d-1.

This model is useful to describe marine and freshwater systems. The state variables are nutrients, phytoplankton and zooplankton. In this document, we focused on a marine system, as in Everaert et al. (2015). Nutrients are defined as the total density of Dissolved Inorganic Nitrogen (DIN), Phosphate (PO4) and Silicate (SiO4). DIN is defined as the sum of NH4, NO3 and NO2.

Conclusions

- Integration of different EOV variables, not only to see data-driven trend, but also to understand interactions in a mechanistic way.
- The myriad of inputs are streamlined stepwise towards one common denominator.
- Data and scripts are available and annotated in a RMarkdown document.
- Marine systems are under multiple pressures, but which one is most important and how do these change over time and in space?
- The novelty relates to the quantification of the relative importance of each driver, and this is of interest for the Blue Community.

NEXT STEPS

Phytoplankton EOV

- Refinement of Chla product
- Development of global 3D phytoplankton community product

Zooplankton EOV

- Final test on Blue-Cloud VRE of DIVAnd + Neural Network

Scientific modelling

- Application of the model at other regional seas
- Validation of the model with zoo and phytoplankton products

Survey

Zoo & Phytoplankton EOV products

Thank you

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