

USING R TO WORK WITH MARINE SPATIAL DATA

clustered, Fibonacci **Dr. David March**

Postdoctoral Researcher



<https://github.com/dmarch/r-marine>

OUTLINE

```
#### Add sampling area to the map
map <- leaflet() %>%
  addProviderTiles("Esri.OceanBasemap", group="Esri Ocean") %>% # Base map
  setview(lng=2.8, lat=39, zoom=8) %% # Position to center map and zoom level
  addPolygons(data=box, fillColor="transparent") # add bounding box
map # plot map
```

- INTRODUCTION TO MARINE DATA**
- INTRODUCTION TO R**
- n = 100
- type = "random"
- LESSON 1: VIRTUAL ECOLOGIST**
- LESSON 2: BENTHIC TERRAIN MODELING**
- #### Add sampling stations to the map
- map <- leaflet() %>%
 addProviderTiles("Esri.OceanBasemap", group="Esri Ocean") %>% # Base map
 setview(lng=2.8, lat=39, zoom=8) %% # Position to center map and zoom level
 addPolygons(data=box, fillColor="transparent") %>% # add bounding box
 addCircles(data=pts, color = "red") # add sampling stations
map # plot map

```
#### Add sampling area to the map
map <- map %>%
  addPolygons(data=box, fill="white", stroke="black") %>% # add bounding box
  setview(lng=2.8, lat=39, zoom=10) %>% # Position to center map and zoom level
  addCircles(data=pts, color="red", size=10) %>% # add sampling stations
map # plot map
```

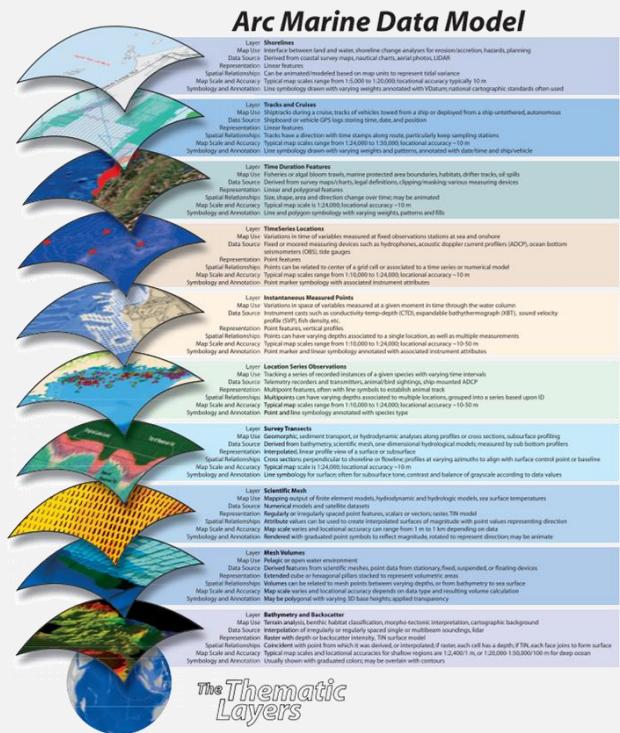
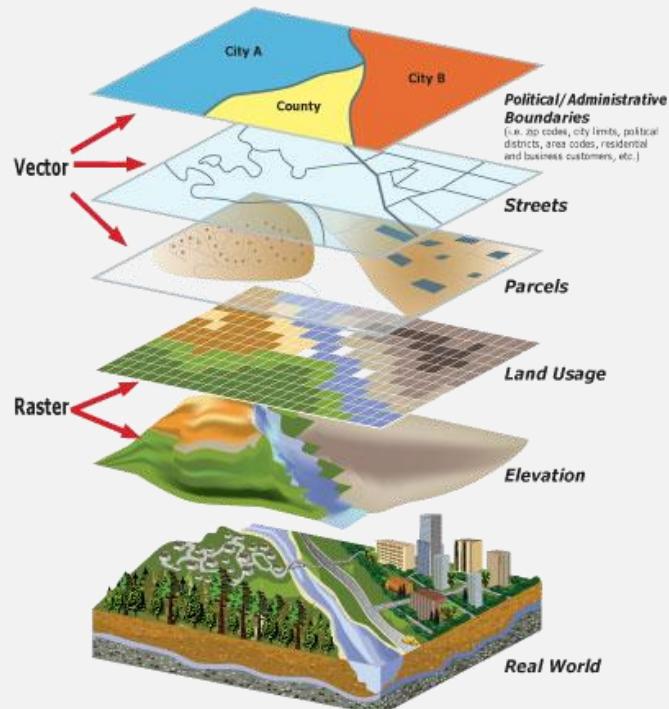


```
## Sampling area
n = 100
type = "hexagonal"
pts <- sample_hexagon(n, type)
```

```
#### Add sampling area to the map
map <- map %>%
  addPolygons(data=box, fill="white", stroke="black") %>% # add bounding box
  setview(lng=2.8, lat=39, zoom=10) %>% # Position to center map and zoom level
  addCircles(data=pts, color="red", size=10) %>% # add sampling stations
map # plot map
```

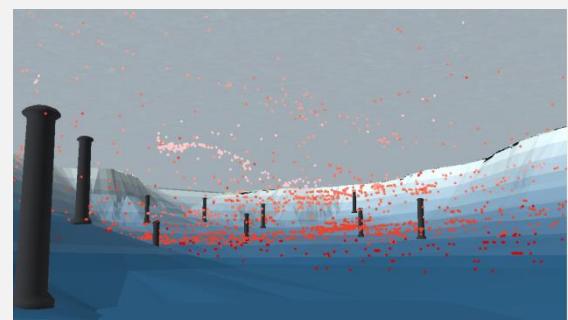
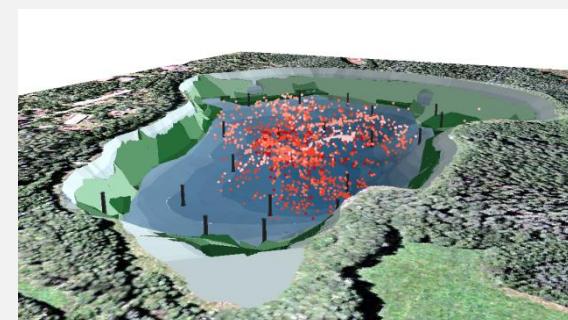
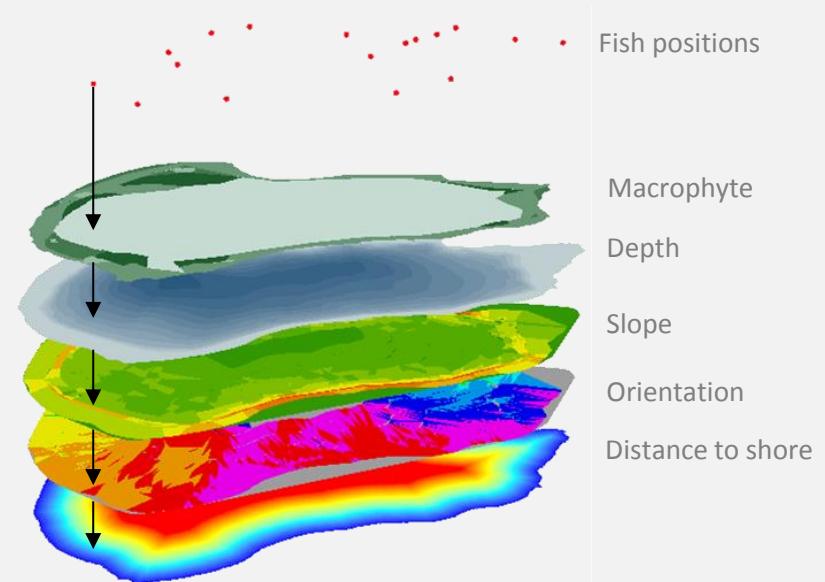
INTRODUCTION TO MARINE DATA

INTRODUCTION TO MARINE DATA - GIS AND MARINE DATA



QUESTION: Which of the two models (raster or vector) fits better your data?

INTRODUCTION TO MARINE DATA – SPATIAL OPERATIONS



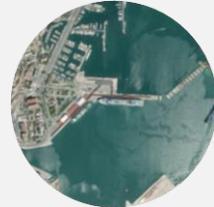
INTRODUCTION TO MARINE DATA – DATA TYPES



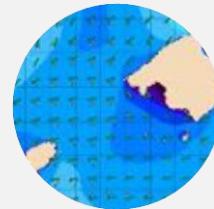
FIXED STATIONS
Eg. Buoys, Tide gauges



MOVING PLATFORMS
Eg. Gliders, Argo, Animals



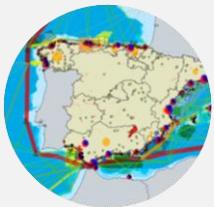
REMOTE SENSING
Eg. Satellite, ROV, Sonar



NUMERICAL MODELS
Ej. Waves, currents



BIODIVERSITY
Eg. Benthic, pelagic



HUMAN ACTIVITIES
Eg. Fisheries, aquaculture



LEGISLATION
Eg. MPA, jurisdictions



HISTORICAL DATA
Eg. documents, maps

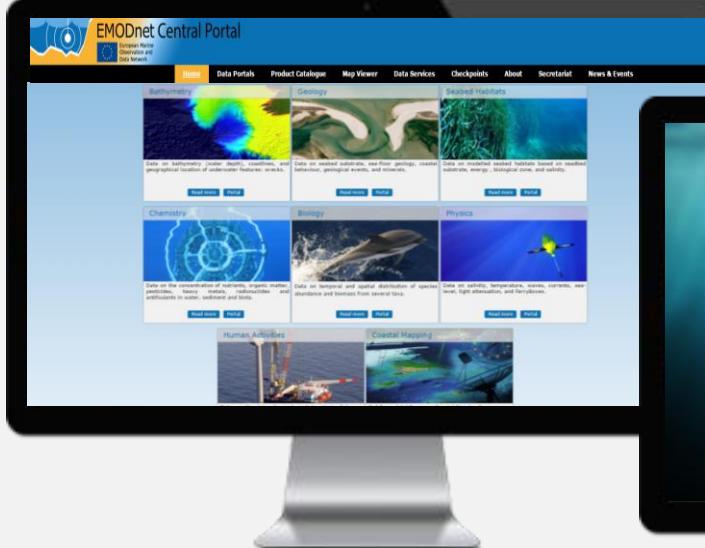
QUESTION: What kind of data are you working with?

INTRODUCTION TO MARINE DATA – DATA ACQUISITION



Coastal and Ocean Observing Systems like SOCIB (www.socib.es) provide data streams in real time

INTRODUCTION TO MARINE DATA – MARINE OPEN DATA PORTALS



<http://www.emodnet.eu>



<http://socib.es>

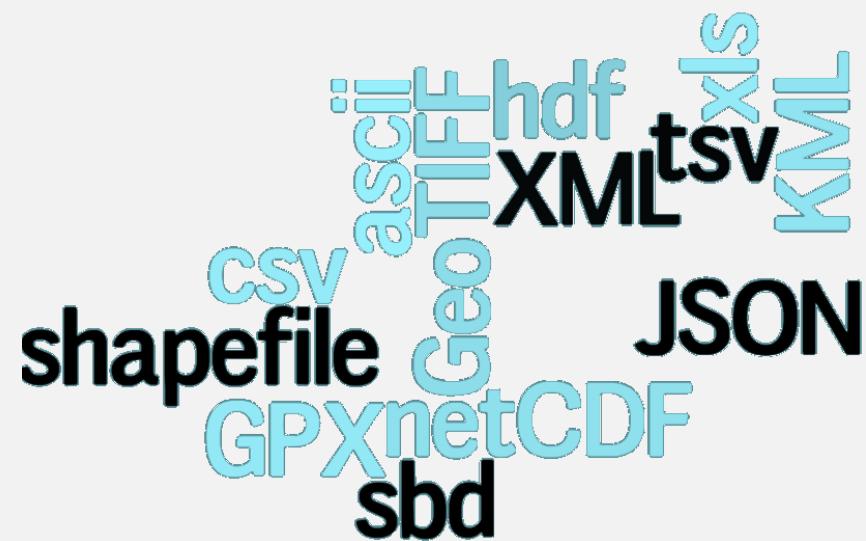


<http://marine.copernicus.eu>

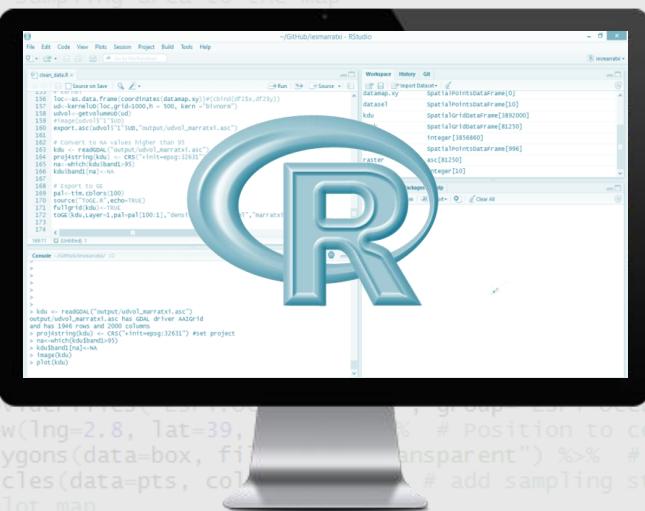
QUESTION: Do you know any web portal where you could download a marine dataset?

EXERCISE: Take a closer look to these 3 data portals and try to download a dataset of your interest

INTRODUCTION TO MARINE DATA – COMMON DATA FORMATS



QUESTION: Which electronic data formats do you know?



```
n") %>% # Base map  
  inter map and zoom level  
  bounding box
```

INTRODUCTION TO R

INTRODUCTION TO R - TOOLBOX



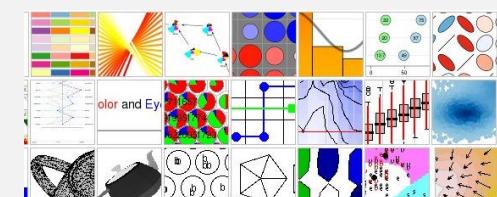
IMPORT / EXPORT

Eg. GDAL/OGR, Rcurl, RPostgreSQL



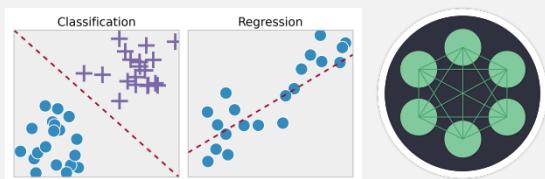
PROCESSING

Eg. Geotools, Proj4, raster



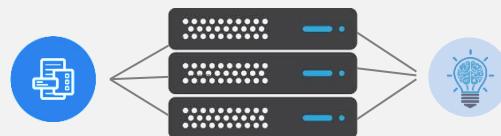
VISUALIZATION

Eg. maptools, plot, igraph



DATA ANALYSIS

Eg. GLM, GAM, MCMC, Boosted Regression Trees, Network Analysis, Simulation, SSM,



PARALLEL COMPUTING

Eg. parallel on Xeon X5687 (3.60 GHz quad-core) 64GB RAM



REPORTS & NOTIFICATIONS

Eg. Markdown

INTRODUCTION TO R – SOME TIPS TO BETTER UNDERSTAND

```
#### Add sampling area to the map
map <- leaflet() %>%
  addProviderTiles("Esri.OceanBasemap", group="Esri Ocean") %>% # Base map
  setview(lng=-2.8, lat=39, zoom=8) %% # Position to center map and zoom level
  addPolygons(data=box, fillColor="transparent") # add bounding box
map # plot map

#### Spatial Sampling
n = 100
type = "random" # options: regular, random, stratified, nonaligned, hexagonal, clustered, fibonacci
pts <- spsample(box, n, type)

#### Add sampling stations to the map
map <- leaflet() %>%
  addProviderTiles("Esri.OceanBasemap", group="Esri Ocean") %>% # Base map
  setview(lng=-2.8, lat=39, zoom=8) %>% # Position to center map and zoom level
  addPolygons(data=box, fillColor="transparent") %>% # add bounding box
  addCircles(data=pts, color = "red") # add sampling stations
map # plot map
```

#

?

class()

data.frame

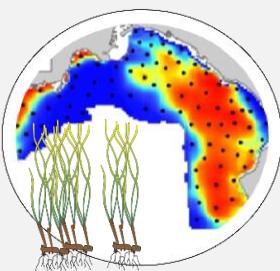
comment

ask

inspect

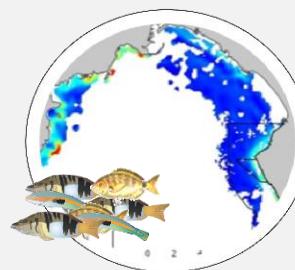
your best friend

INTRODUCTION TO R – PRACTICAL APPLICATIONS



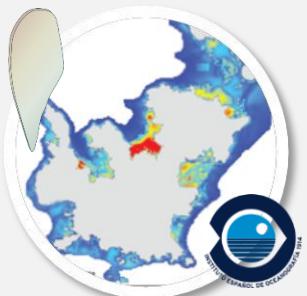
BENTHIC ECOSYSTEMS

Bayesian models
March et al. 2013



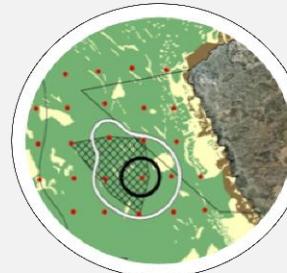
FISHERIES

Generalized linear mixed model
March et al. 2014



BIODIVERSITY

Regression kriging
Vázquez et al. 2014



ANIMAL TELEMETRY

Home range, wavelets
March et al. 2010, 2011

```
#### Add sampling area to the map
map <- l
  addPro
  setview
  addPo
map #>
  n") %>% # Base map
  nter map and zoom level
  bounding box

#### Sp
n = 100
type =
pts <- s

#### Ad
map <-
  addPro
  setview(lng=2.8, lat=39,
  addPolygons(data=box, fi
  addCircles(data=pts, col
map # plot map
```



LESSON 1

VIRTUAL ECOLOGIST

- ✓ Create your first map
- ✓ Sampling design
- ✓ Simulate simple distributions
- ✓ Import/export vectorial data

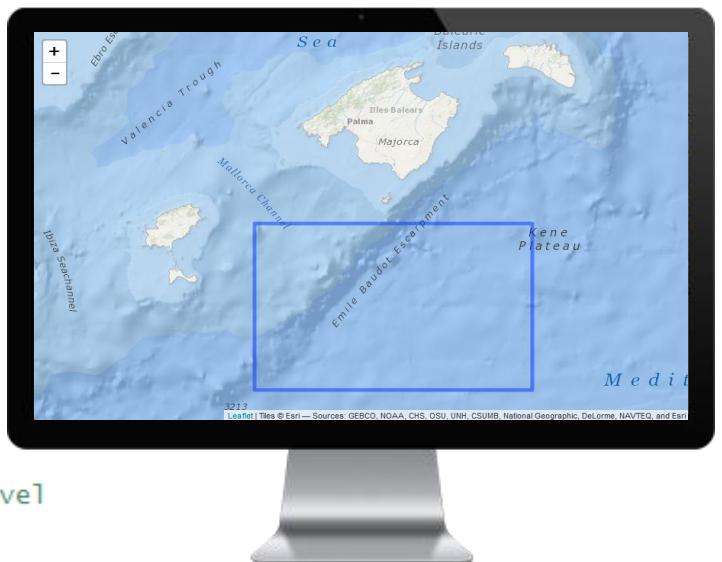
LESSON 1 – DEFINE YOUR STUDY AREA



You could use a software like Google Earth to get longitude and latitude information about your sampling area

LESSON 1 - CREATE YOUR FIRST MAP

```
26 #-
27 # Part 1: Create your sampling area
28 #-
29 # Define your sampling area using a bounding box (x: longitude, y: latitude)
30 # Note: you can use Google Earth to explore your area, get latitude and longitude,
31 # and define your own
32 xmin = 2
33 xmax = 4
34 ymin = 38
35 ymax = 39
36 e <- extent(c(xmin, xmax, ymin, ymax)) # create extent
37 box <- as(e, "SpatialPolygons") # coerce to a SpatialPolygons object
38 plot (box) # now the plot is not meaningful... we need some base maps
39 #-
40
41
42 #-
43 # Part 2: Create your first map using leaflet
44 #-
45 ##### Add sampling area to the map
46 map <- leaflet() %>%
47   addProviderTiles("Esri.OceanBasemap", group="Esri Ocean") %>% # Base map
48   setView(lng=2.8, lat=39, zoom=8) %>% # Position to center map and zoom level
49   addPolygons(data=box, fillcolor="transparent") # add bounding box
50 map # plot map
51 #-
```

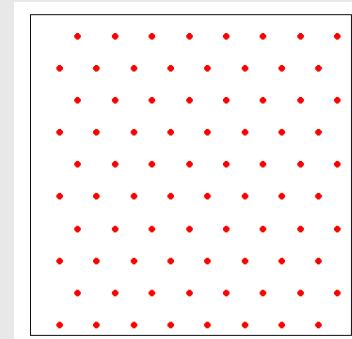
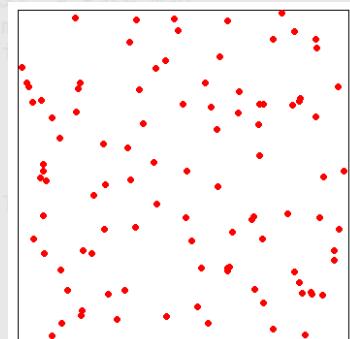
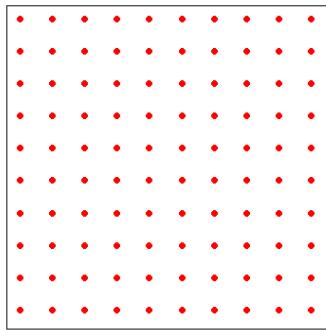


LESSON 1 – SPATIAL SAMPLING DESIGN

```
#### Add sampling area to the map
map <- leaflet() %>%
  addProviderTiles("Esri.OceanBasemap", group="Esri Ocean") %>% # Base map
  setview(lng=-2.8, lat=39, zoom=8) %>% # Position to center map and zoom level
  addPolygons(data=box, fill="white", stroke="black", color="black", fillOpacity=0.5) %>% # add bounding box
  map # plot map

#### Spatial sampling
n = 100
type = "random" # random, stratified, nonaligned, fibonacci
pts <- spsample(box, n, type)

#### Add sampling stations to the map
map <- leaflet() %>%
  addProviderTiles("Esri.OceanBasemap", group="Esri Ocean") %>% # Base map
  setview(lng=-2.8, lat=39, zoom=8) %>% # Position to center map and zoom level
  addPolygons(data=box, fill="white", stroke="black", color="black", fillOpacity=0.5) %>% # add bounding box
  addCircles(data=pts, color="red") # add sampling stations
  map # plot map
```



regular random

hexagonal



Use `spsample()` to generate different sampling designs

EXERCISE: change "n" and "type" and plot the results

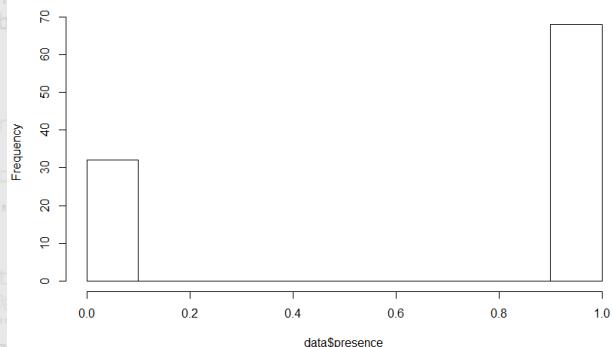
LESSON 1 – SIMULATE DISTRIBUTIONS

```
#### Add sampling area to the map
map <- leaflet() %>%
  addProviderTiles("OpenStreetMap")
setview(lng=2.8, lat=41.3, zoom=12)
addPolygons(data=box, fillcolor="transparent") %>% # add bounding box
map # plot map

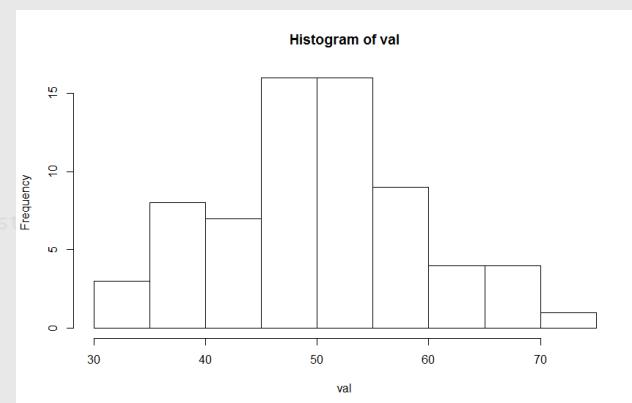
#### Spatial sampling
n = 100
type = "random" # choose random or hexagonal
pts <- spsample(box, n, type)

#### Add sampling stations
map <- leaflet() %>%
  addProviderTiles("OpenStreetMap")
setview(lng=2.8, lat=41.3, zoom=12)
addPolygons(data=box, fillcolor="transparent") %>% # add bounding box
addCircles(data=pts, color = "red") # add sampling stations
map # plot map
```

Histogram of data\$presence



Histogram of val

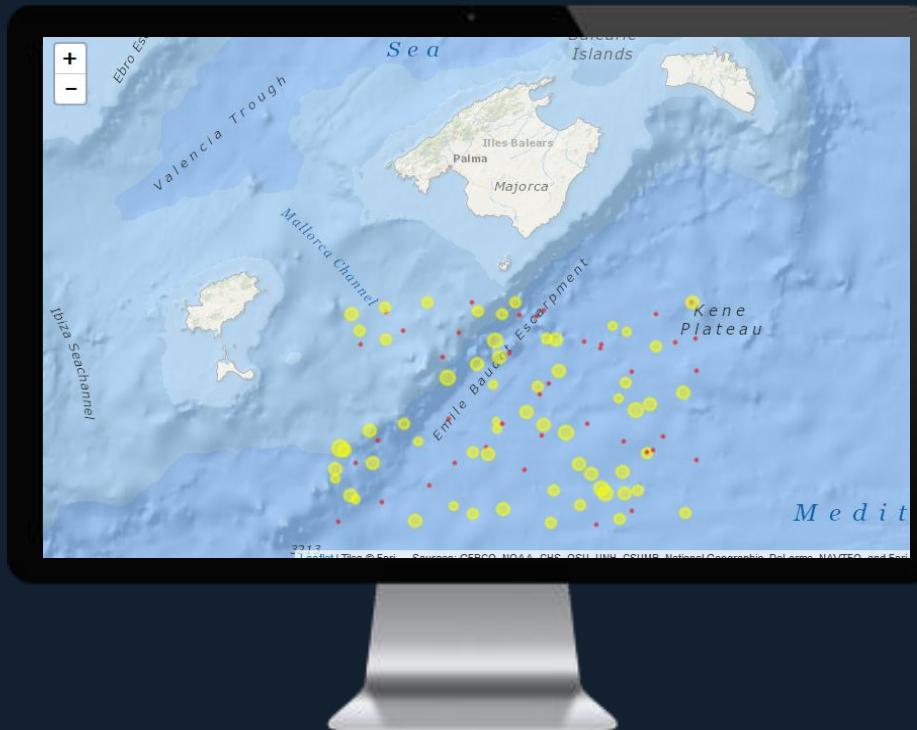


Gaussian



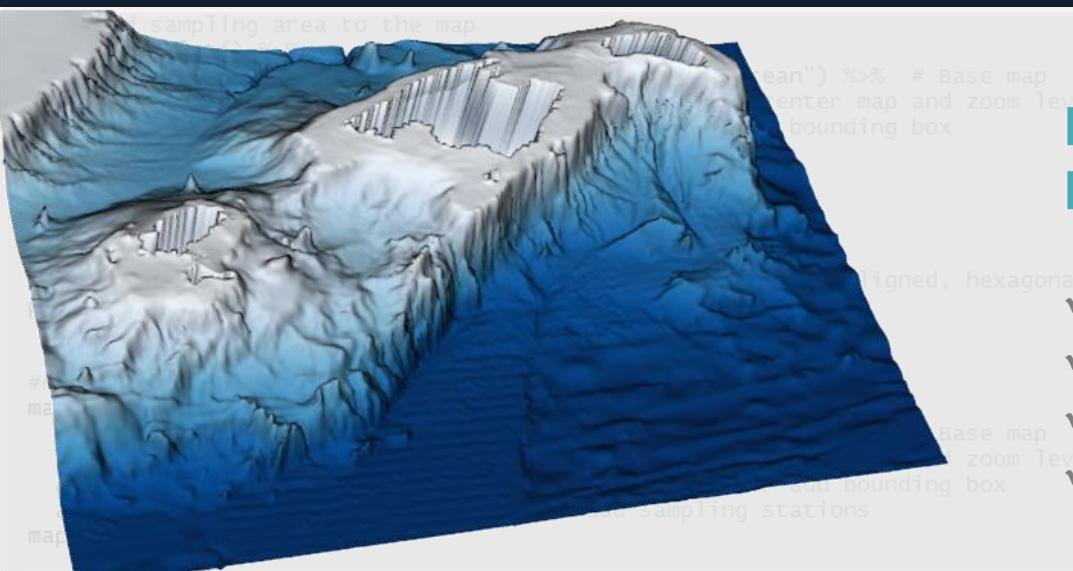
Use `rbinom()` and `rnorm()` to generate random numbers of binomial and Gaussian distributions, respectively

LESSON 1 – MAP YOUR DATA AND EXPORT DIFFERENT FORMATS



EXERCISE: Create a pop-up to display information associated to each sampling station

BONUS: Save your final map as a webpage

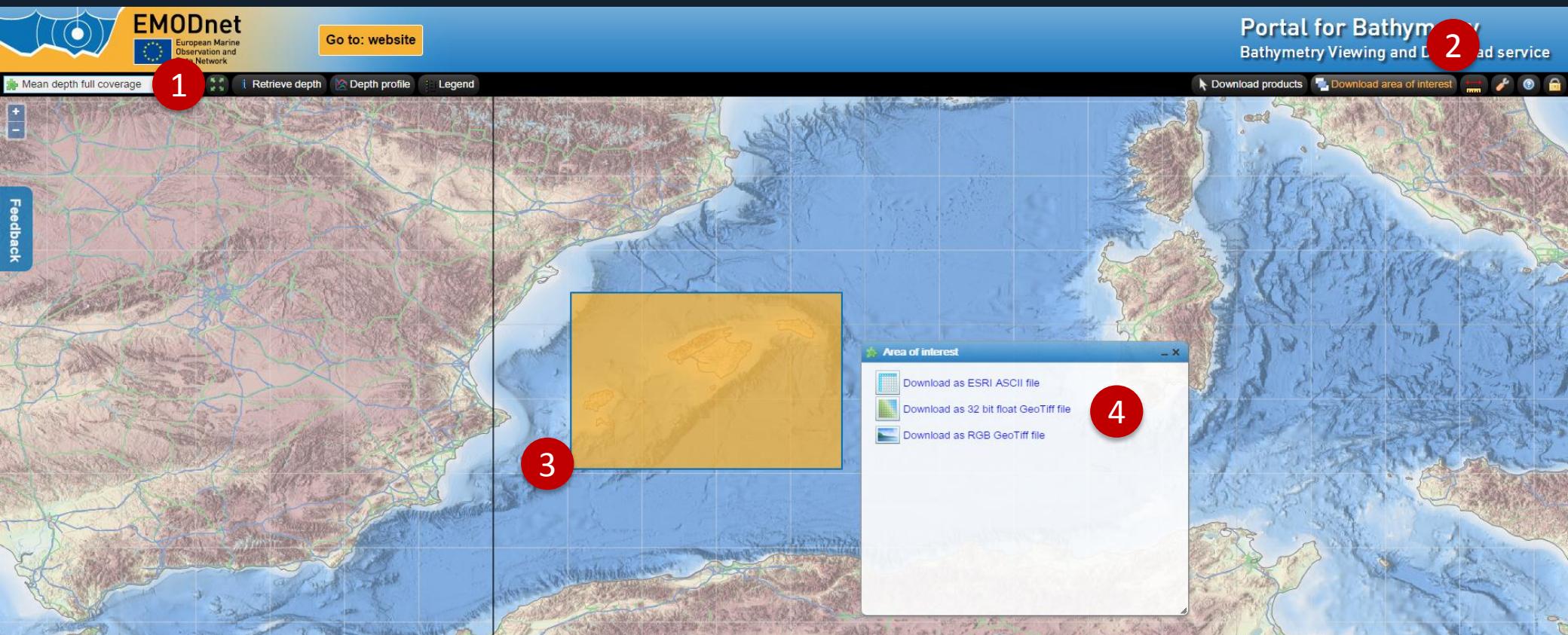


LESSON 2

BENTHIC TERRAIN MODELLING

- ✓ Access EMODnet data portal
 - ✓ Conduct terrain analysis
 - ✓ Plot your map in 3D
 - ✓ Import/export gridded data

LESSON 2 - DOWNLOAD BATHYMETRY FROM EMODNET

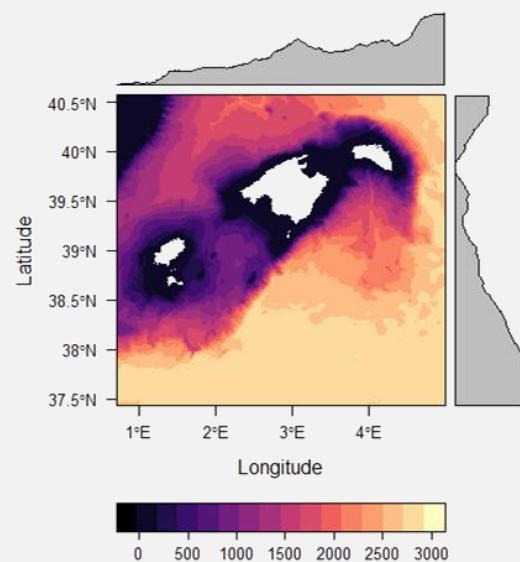
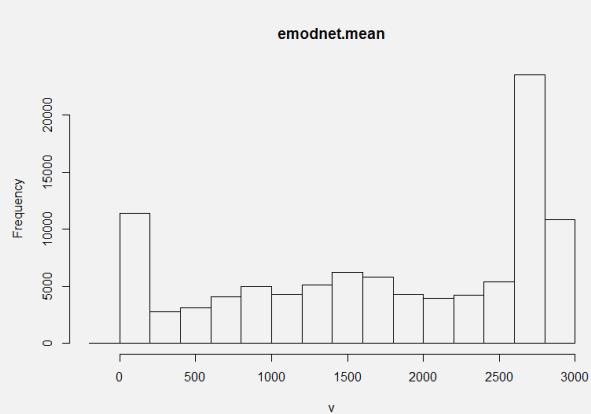


- 1 Select product "Mean depth full coverage"
- 2 Download area of interest

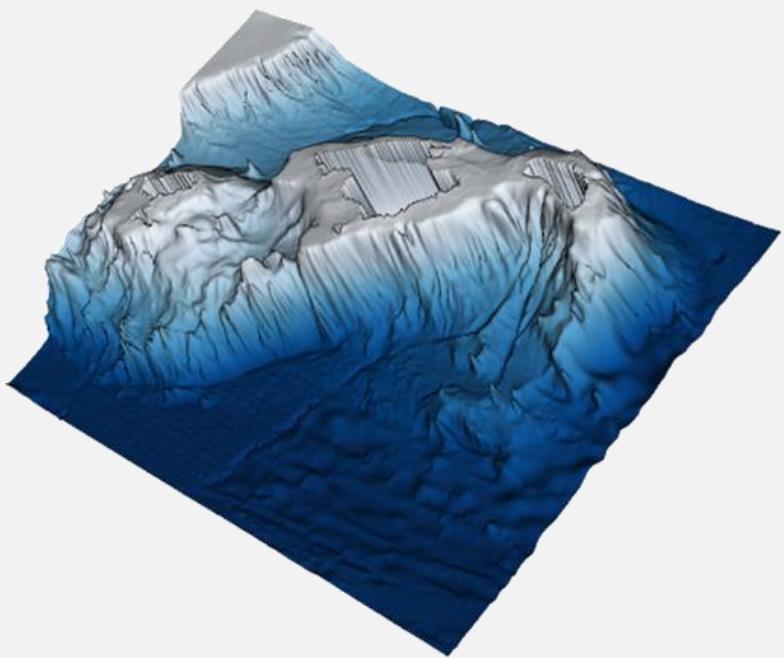
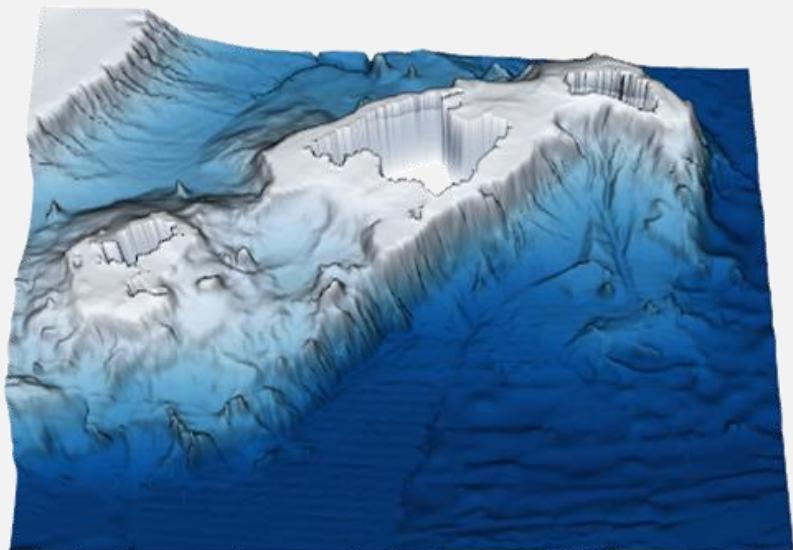
- 3 Draw bounding box
- 4 Download as 32 bit float GeoTiff file

<http://portal.emodnet-bathymetry.eu/>

LESSON 2 – INSPECT THE BATHYMETRY AND CREATE YOUR MAP

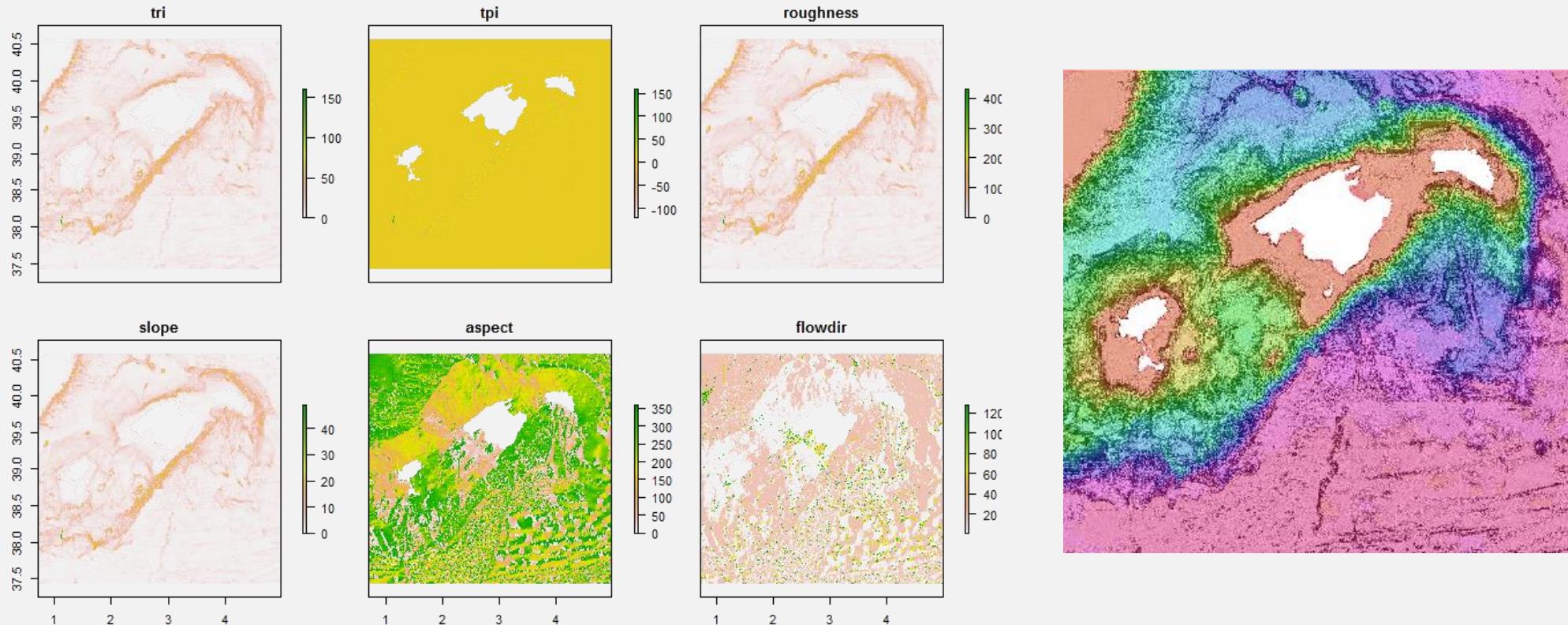


LESSON 3D – 3D PLOT



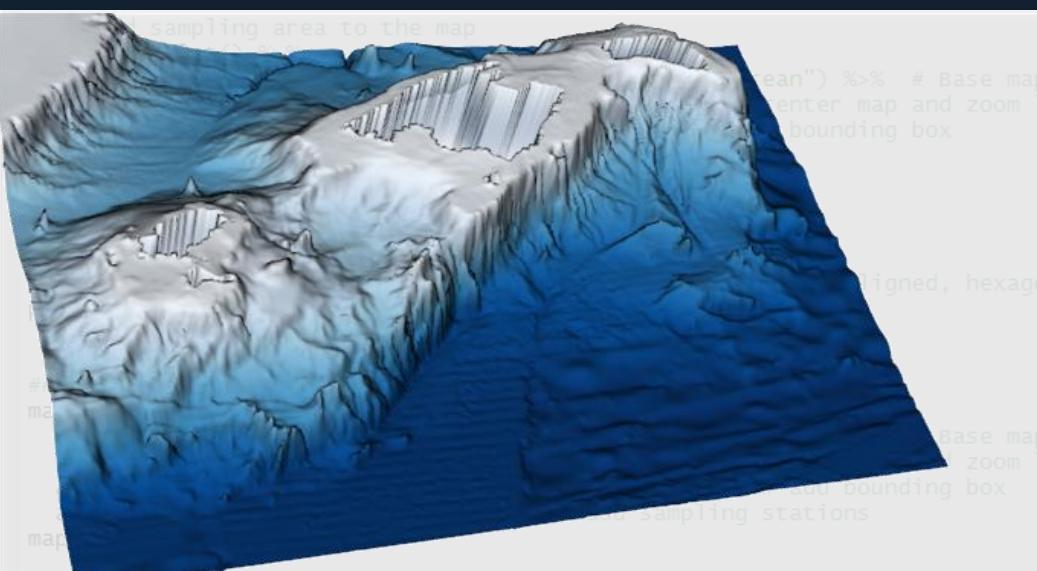
NOTE: Use map algebra to convert to negative values

LESSON 2 - BATHYMETRIC TERRAIN MODELING



Different terrain characteristics can be computed using `terrain()`. Combine `slope` and `aspect` to plot hillshade

EXERCISE: Use Pearson correlation coefficients to assess the correlation between terrain characteristics

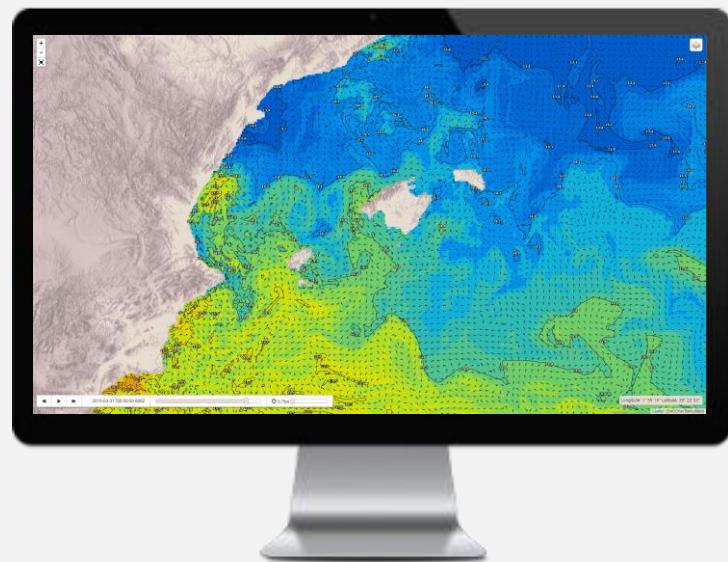
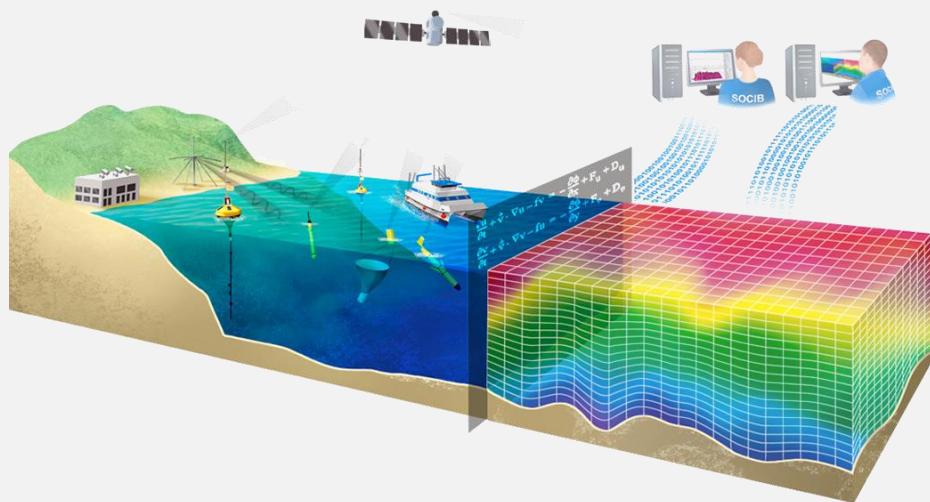


LESSON 3

PELAGIC ECOSYSTEMS

- ✓ Access SOCIB data portal
- ✓ Multidimensional data: ROMS model
- ✓ Spatial operations: overlay
- ✓ Plot time series

LESSON 3 – NUMERICAL MODELS



LESSON 3 - DOWNLOAD WMOP MODEL FROM SOCIB DATA PORTAL

Catalog <http://thredds.socib.es/thredds/catalog.html>

Dataset

SOCIB DATA
observational
satellite/
mooring/
drifter/
auv/
hf_radar/
research_vessel/
aggregated_data/
operational_models
oceanographical
hydrodynamics
wmp/
model_run_aggregation
wmp/



3

1 Select Data Center

2 Clic on Data Access (THREDDS)

3 Model run aggregation of WMOP > Best Time Series

TIP: You can access directly to SOCIB Thredds catalog using <http://thredds.socib.es/>

<http://www.socib.es>

LESSON 3 - DOWNLOAD WMOP MODEL FROM SOCIB DATA PORTAL

SOCIB TDs
THREDDS Data Server

Catalog http://thredds.socib.es/thredds/catalog/operational_models/oceanographical/hydrodynamics/model_run_aggregation/wmop/catalog.html

Dataset: **wmop/Best Time Series**

- Data type: GRID
- ID: operational_models/oceanographical/hydrodynamics/model_run_aggregation/wmop/wmop_best.nc

Documentation:

- summary: Best time series, taking the data from the most recent run available.

Access:

- OPENDAP: http://thredds.socib.es/thredds/OPENDAP/operational_models/oceanographical/hydrodynamics/model_run_aggregation/wmop/wmop_best.ncd
- WCS: http://thredds.socib.es/thredds/WCS/operational_models/oceanographical/hydrodynamics/model_run_aggregation/wmop/wmop_best.nc
- WMS: http://thredds.socib.es/thredds/WMS/operational_models/oceanographical/hydrodynamics/model_run_aggregation/wmop/wmop_best.nc
- NetCDFSubset: http://thredds.socib.es/thredds/NetCDFSubset/operational_models/oceanographical/hydrodynamics/model_run_aggregation/wmop/wmop_best.nc
- NCML: http://thredds.socib.es/thredds/NCML/operational_models/oceanographical/hydrodynamics/model_run_aggregation/wmop/wmop_best.nc
- UDCD: http://thredds.socib.es/thredds/UDCD/operational_models/oceanographical/hydrodynamics/model_run_aggregation/wmop/wmop_best.nc
- ISO: http://thredds.socib.es/thredds/ISO/operational_models/oceanographical/hydrodynamics/model_run_aggregation/wmop/wmop_best.nc
- SOS: http://thredds.socib.es/thredds/SOS/operational_models/oceanographical/hydrodynamics/model_run_aggregation/wmop/wmop_best.nc

Variables:

- Vocabulary (GT-DB)
 - salt = salinity
 - temp = sea_surface_temperature
 - u (meter second⁻¹) = u-momentum component = eastward_sea_surface_velocity
 - ubar (meter second⁻¹) = vertically integrated u-momentum component = eastward_barotropic_velocity
 - v (meter second⁻¹) = v-momentum component = northward_sea_surface_velocity
 - vbar (meter second⁻¹) = vertically integrated v-momentum component = northward_barotropic_velocity
 - zeta (meter) = free-surface

GeospatialCoverage:

- Longitude: 5.8 to 9.2 degrees_east
- Latitude: 34.1 to 44.7129100948723 degrees_north

TimeCoverage:

- Start: 2013-09-27T00:00:00Z
- End: 2016-10-28T00:00:00Z

Viewers:

```
8 # Get data though NetcdfSubset service from SOCIB (http://thredds.socib.es/thredds)
9 url <- "http://thredds.socib.es/thredds/ncss/operational_models/oceanographical/hydrodynamics/wmop/latest.nc?var=salt&var=
10 junk <- GET(url, write_disk("data/wmop.nc", overwrite = TRUE))
11
12
13
14
15
```

NCSS for Grids (Grid as Point Dataset)

Dataset: /thredds/ncss/operational_models/oceanographical/hydrodynamics/wmop/latest.nc ([Dataset Description](#))

Base Time: 2016-10-24T00:00:00Z

Select Variable(s):

Variables with available Times: 1.5280704E9 1.5280812E9 1.528092E9 1.5281028E9 1.5281136E9 1.5281244E9 1.5281352E9 1.5281468E9 1.5281568E9 1.5281676E9 1.5281784E9 1.5281892E9 1.5282108E9 1.5282216E9 1.5282324E9 1.5282432E9 seconds since 1960-05-23 00:00:00 GMT

5

Choose Spatial Subset:

Lat/Lon subset Coordinate subset
Bounding Box, in decimal degrees (initial extents are approximate): north: 39, west: 2, east: 4, south: 38

6

Choose Time Subset:

Time range Single Time
Start: 2016-10-24T00:00:00Z
End: 2016-10-26T00:00:00Z
Stride: 1
Request full extension

Add 2D Lat/Lon to file (If needed)
 Add CF compliance
 Add Lat/Lon variables

Choose Output Format:
Format: netcdf □

7

NCSS Request URL:

http://thredds.socib.es/thredds/ncss/operational_models/oceanographical/hydrodynamics/wmop/latest.nc?var=salt&var=v&start=2016-10-24T00:00:00Z&end=2016-10-26T00:00:00Z&subset=lon:2:4;lat:38:39&stride=1&time_start=2016-10-24T00:00:00Z&time_end=2016-10-26T00:00:00Z&time_stride=1&time_resolution=1&accept=netcdf

Submit Reset

4 Select product “NetcdfSubset”

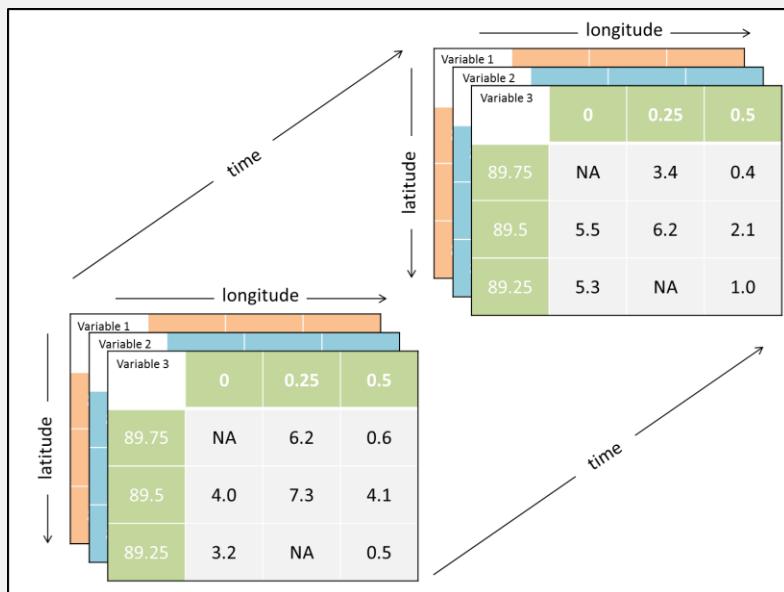
6 Choose spatial and time subsets
Add Lat/Ion

5 Select variables

7 Copy NCSS Request Url

8 Paste url on R code

LESSON 3 – INSPECT THE NETCDF



- **Dimensions**

Ex. time, latitude, longitude, height

- **Variables**

Ex. temperature, salinity

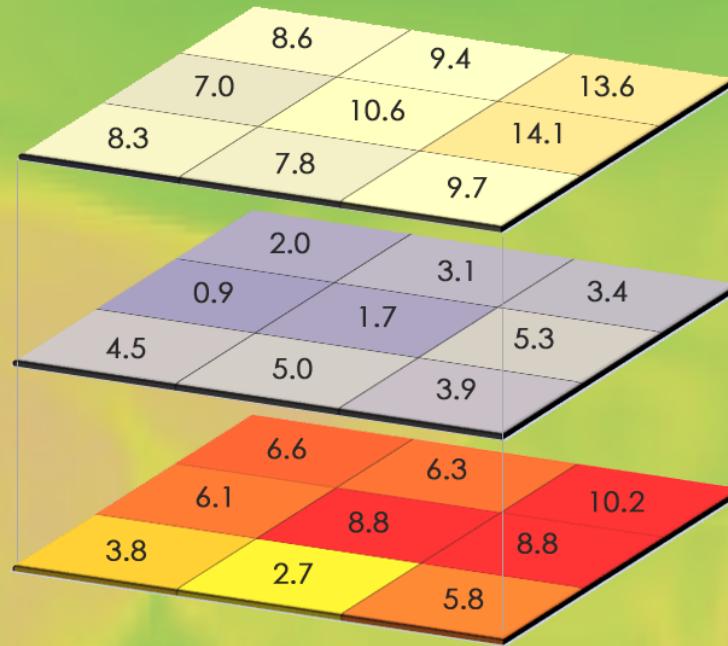
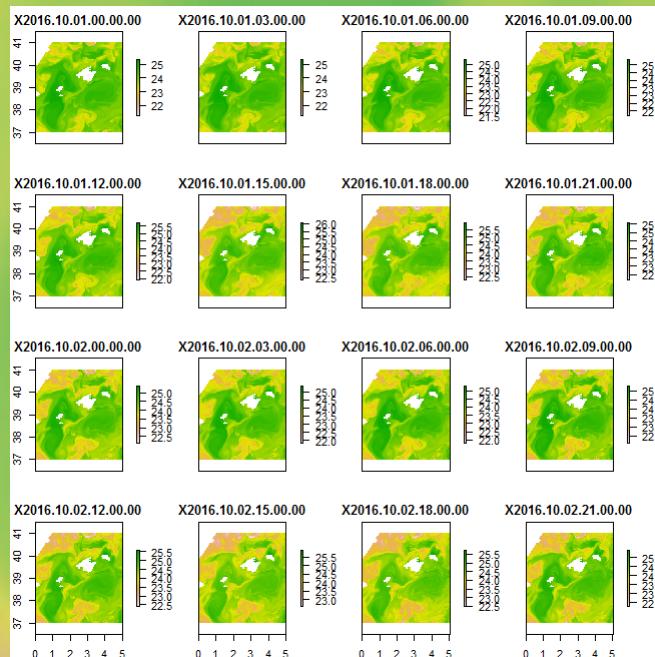
- **Attributes**

Ex. metadata, units

QUESTION 1: How many dimensions are in your dataset?

QUESTION 2: What is the purpose of the global attributes?

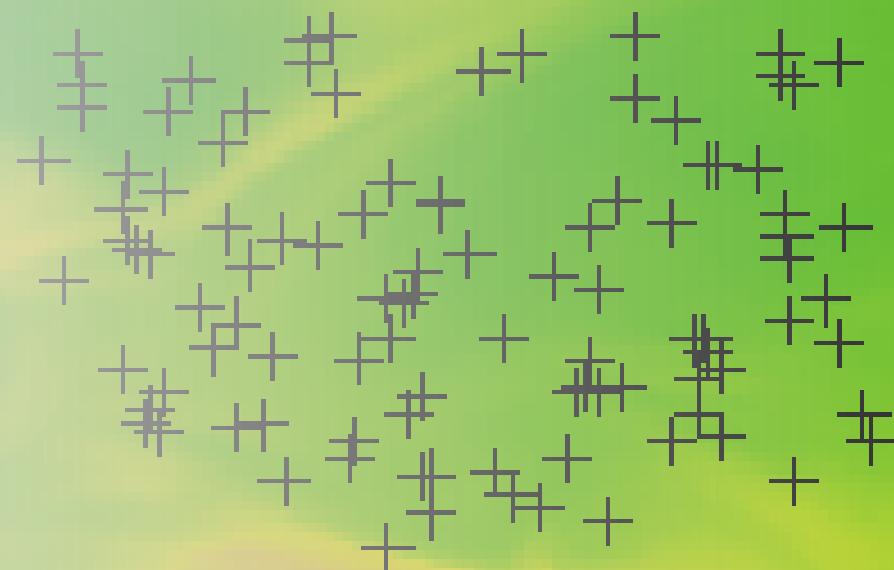
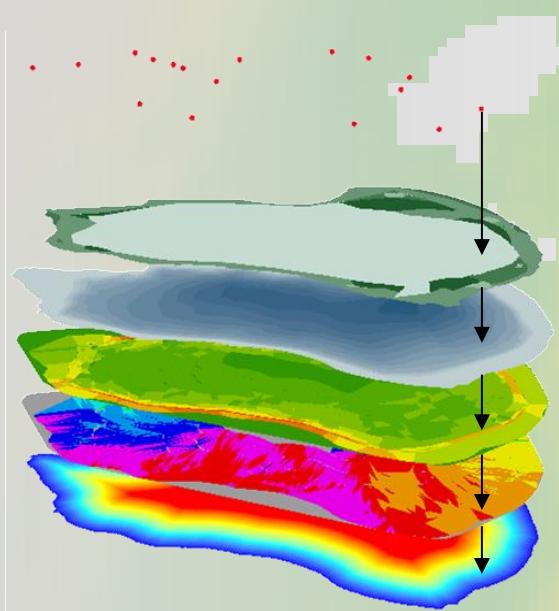
LESSON 3 – MULTIDIMENSIONAL GRIDDED DATA



EXERCISE 1: Calculate daily means for salinity

BONUS: Calculate daily SST anomalies

LESSON 3 – INTEGRATE DATA



EXERCISE 1: Integrate mean salinity to sampling stations

LESSON 3 - TIME SERIES

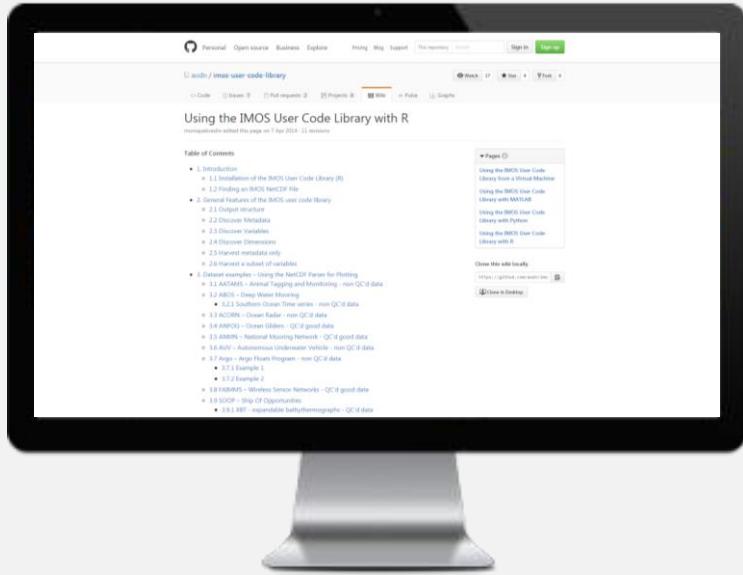


TIP: NetcdfSubset Service allow to get time series data for a sampling location

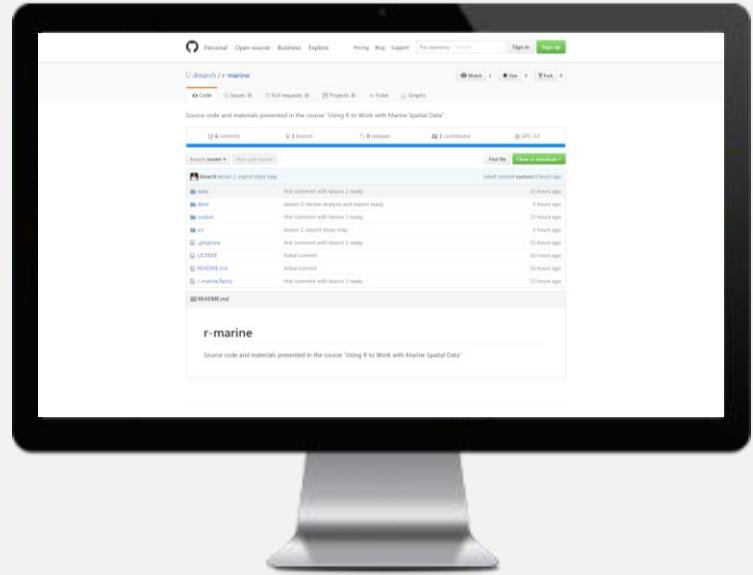
WEB APPLICATIONS WITH SHINY



FURTHER REFERENCES - CODE REPOSITORIES

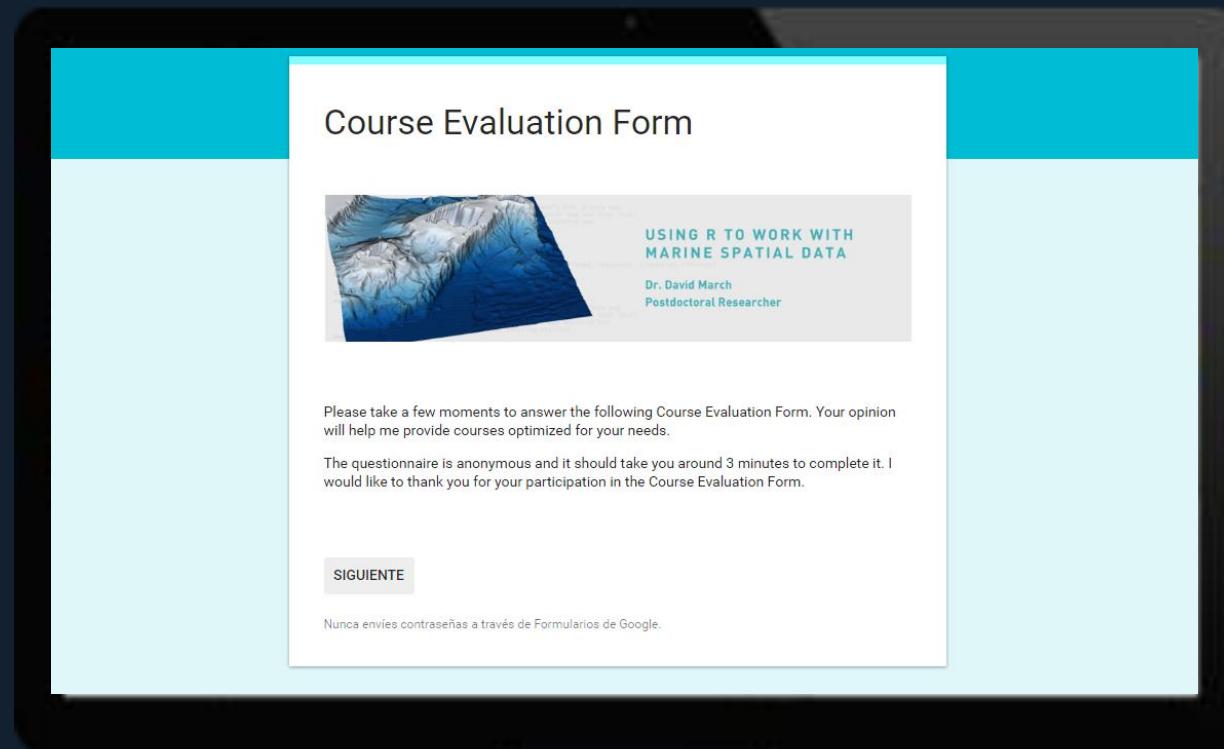


<https://github.com/aodn/imos-user-code-library/wiki/Using-the-IMOS-User-Code-Library-with-R>

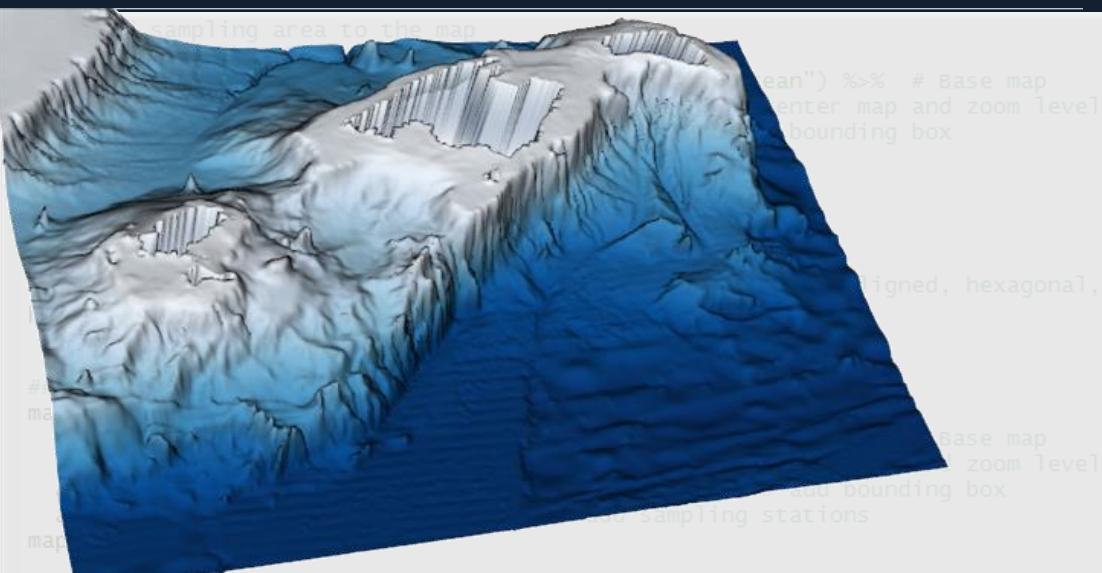


<https://github.com/dmarch/r-marine>

COURSE EVALUATION FORM



<https://goo.gl/forms/QfFRNWo7Tbpiu2dx1>



USING R TO WORK WITH MARINE SPATIAL DATA

Dr. David March
Postdoctoral Researcher



<https://github.com/dmarch/r-marine>