The role of hydrological boundary conditions in hydrodynamic coastal modeling: the experience of ARPA FVG

6th Workshop on Water Resources in Developing Countries:
Hydroclimate Modeling, Information Tools and Simulation Techniques

A. Minigher

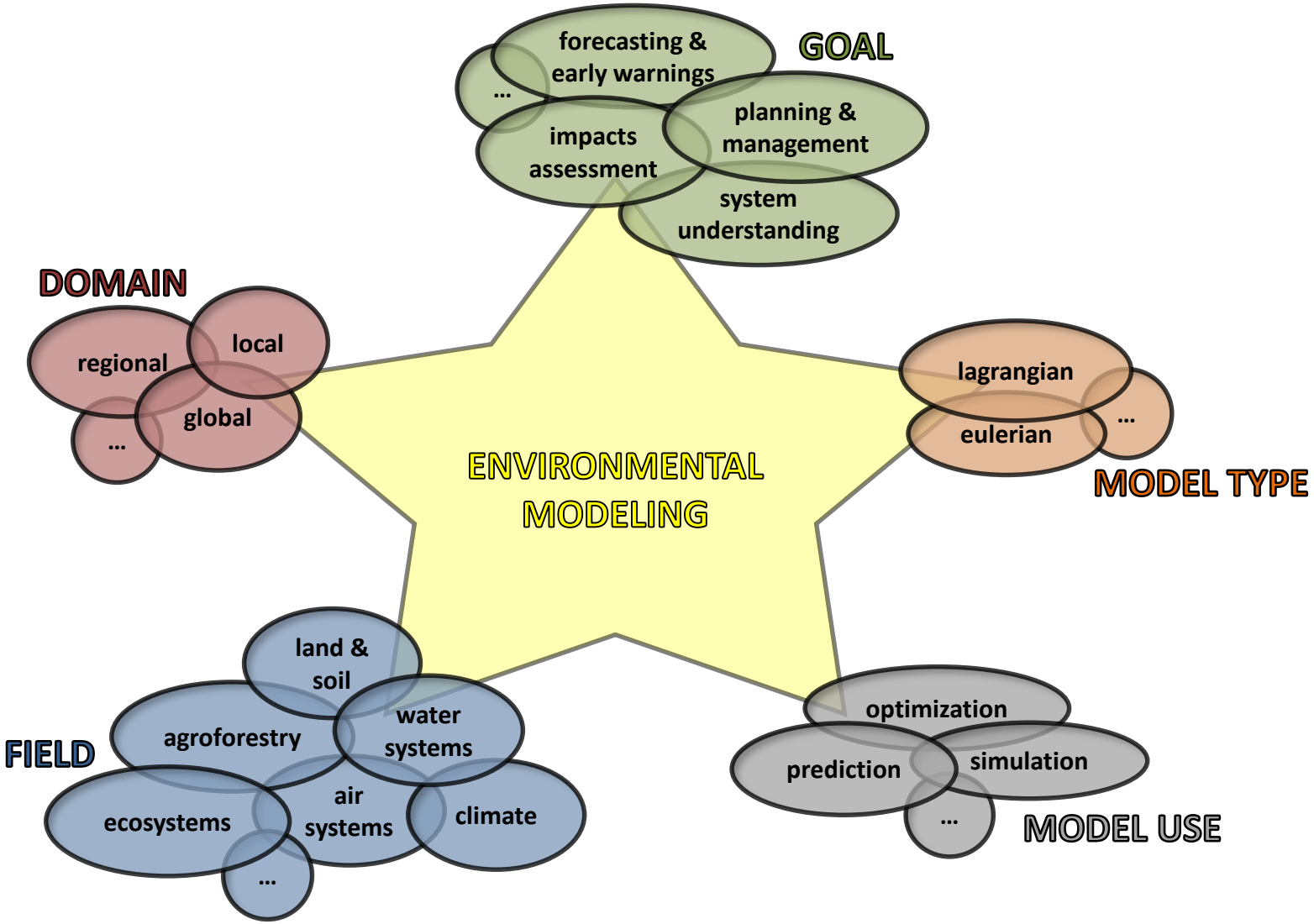
Regional Center for Environmental Modeling, ARPA FVG

Outline

- **Introduction**
  - Framework
  - Aim
- **Domain**
  - Overview
  - Gulf of Trieste
  - Marano-Grado lagoon
- **Modeling system**
  - SHYFEM: description
  - SHYFEM: I/O
  - SHYFEM: mesh
- **Hydrodynamics-Hydrology interaction**
  - Introduction
  - Who?
  - What?
  - When?
  - Where?
  - Why?
  - How?
- **Summary**

Introduction

Framework

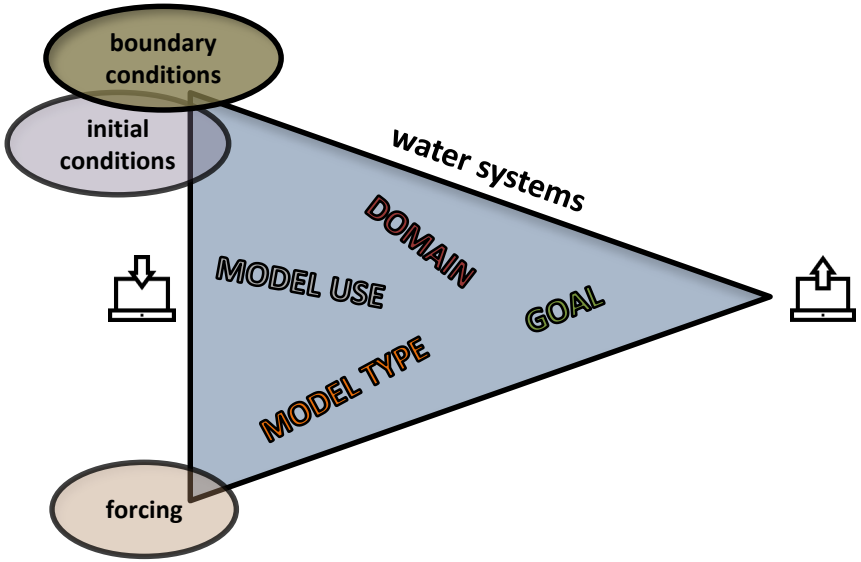


Inspired by [1]

Aim

Emphasize the importance of **hydrological boundary conditions** for **hydrodynamic coastal modeling**, especially in

- **specific domain** that is strongly affected by riverine freshwater inputs
- **operational** applications
- **ARPA FVG**'s experiences and activities



Domain

Overview

Gulf of Trieste and **Marano-Grado lagoon**

Gulf of Trieste

- **Northernmost part** of the **Adriatic Sea**
- **Small** (29 × 21 km^2), **semi-enclosed** and **shallow** (max. depth 25 m)
- Shared by **3 nations** (Italy, Slovenia and Croatia)
- Remarkable **seasonal variability** in ocean properties
  - **temperature**: 4 ÷ 29.2 °C [2]
  - **salinity**: 10 ÷ 38.5 PSU [2]
  - **stratified** water column in **late-spring** and **summer**
  - **weakly stratified** water column in **autumn** and **winter**
- **Circulation** mainly determined by [3]
  - **winds**
  - **riverine freshwater inputs**
  - **sea surface heat fluxes**
  - **remote control of the Adriatic Sea**

Gulf of Trieste

- **Bora** (ENE)
  - first for both frequency and intensity [4]
  - dominant role in mixing water masses, affecting the circulation and thermohaline properties of the Gulf [5]
- **Sirocco** (SE)
  - main responsible for storm surges
- **Land and sea breezes**

- **Isonzo river**
  - largest discharge and major impact on the dynamics of the Gulf
- **Timavo river**
  - second largest discharge
  - secondary role in determining the freshwater balance of the Gulf [6]
- **Others**
  - minor, but still important role

- Largely control the **heat balance** [7]: the Gulf is a **heat sink** where the Mediterranean Sea reaches its lowest temperatures

- Semidiurnal and diurnal **tides** (affect vertical mixing and general circulation)
- High-amplitude **seiches**
- **General circulation** of the Adriatic Sea (highly-cyclonic)

Marano-Grado lagoon

- **Northern** part of the **Adriatic Sea**
- **32 × 5 km²** of **channels**, **tidal flats**, **islands**, **marshes** and large **emerged areas** [8]
- **Shallow** coastal system (average depth 1.12 m [9])
- **Multi-inlet** system (6 mouths)
- **Leaky** lagoon (its response to climate change is comparable with that of the open sea)
- **Habitat** of numerous vegetal and animal species
- **Dynamics** dominated by
  - **interaction with the open sea**
  - **semidiurnal tide** (mean tidal range 65 cm [10])
  - **surface heat fluxes**
  - **riverine freshwater inputs**
  - **winds**

Marano sub-basin

- ❖ western part
- ❖ shallow
- ❖ few marshes
- ❖ several channels
- ❖ **6 tributaries**

Grado sub-basin

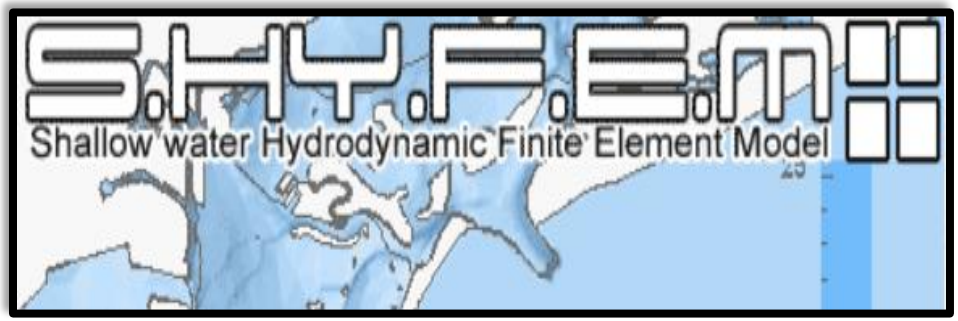
- ❖ eastern part
- ❖ shallower
- ❖ several marshes
- ❖ several islands
- ❖ **1 tributary**

Modeling system

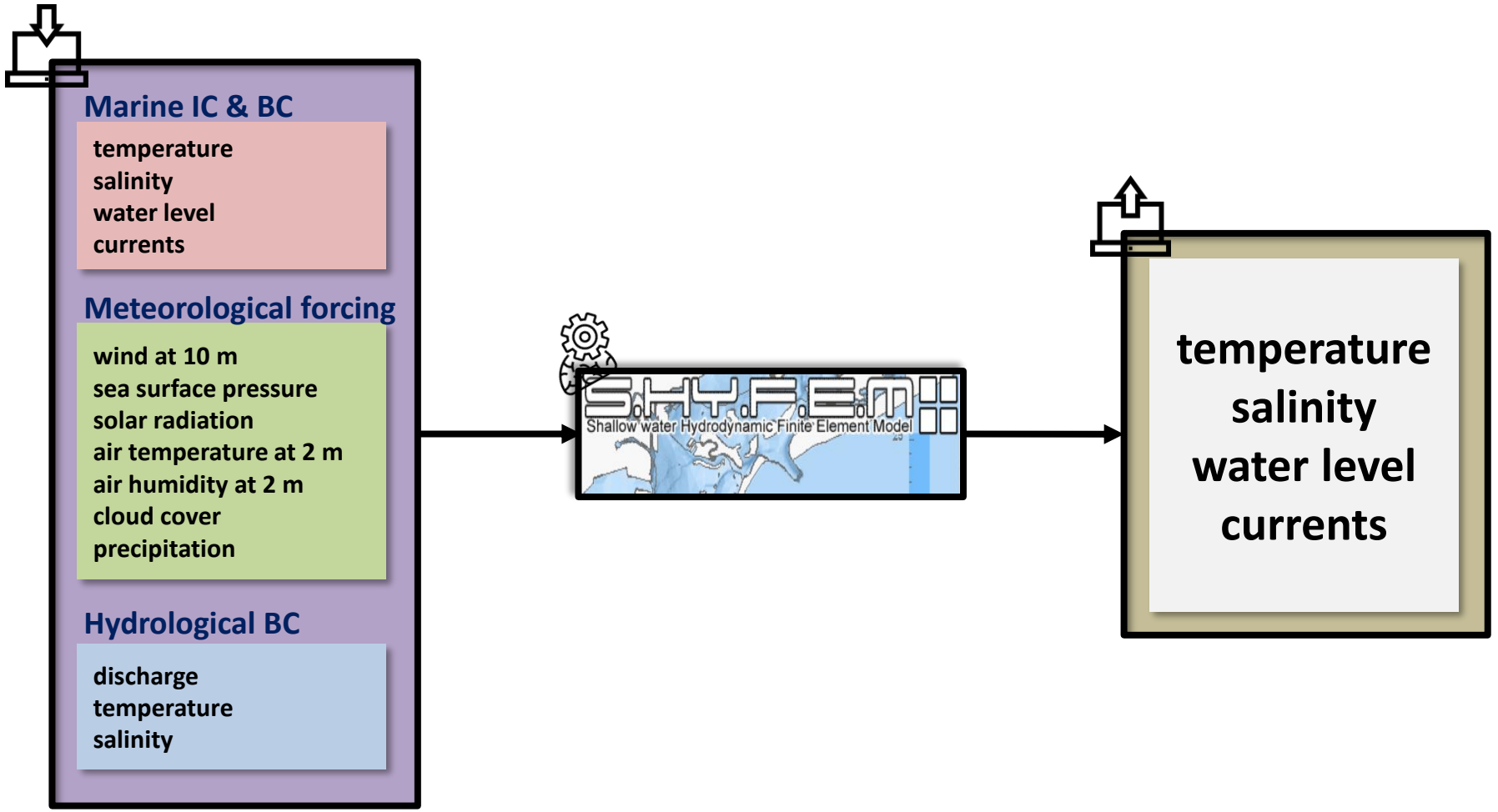
SHYFEM: description

Shallow water **HY**drodynamic **F**inite **E**lement **M**odel

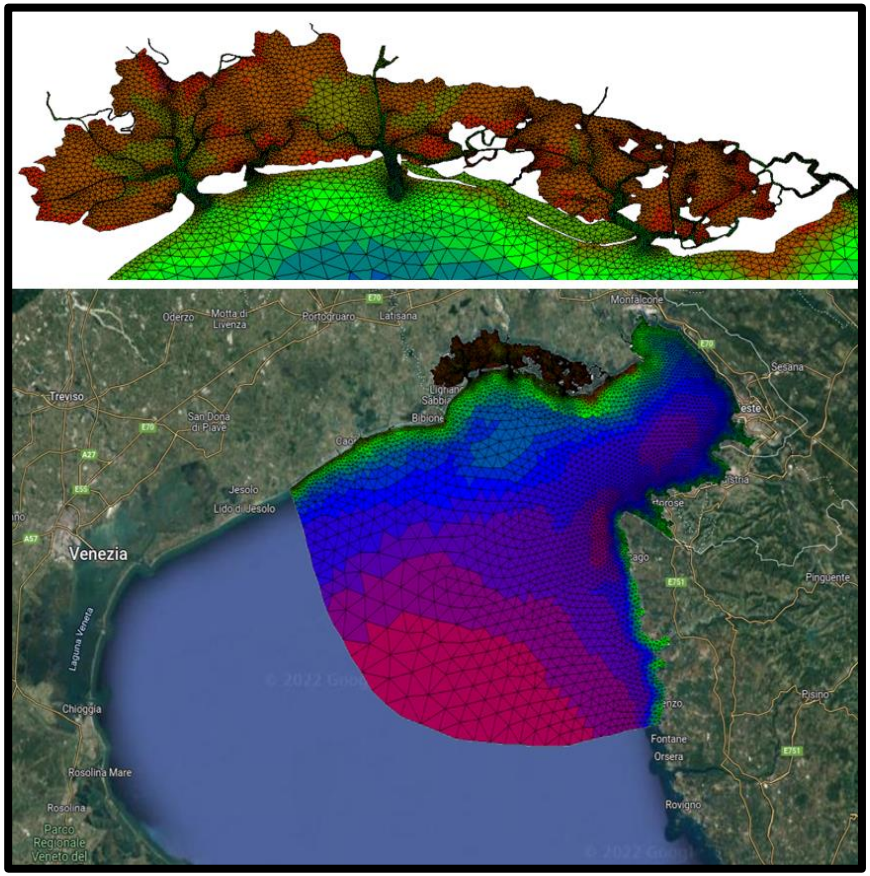
- **Open source** program package (GPL license) [11]
- **3D**, vertically integrated **hydrodynamic equations** in **shallow water** conditions
- **Finite elements** → suitable for **complicated morphology** and **bathymetry**
- Developed at **CNR-ISMAR** [12][13]



SHYFEM: I/O


Marine IC & BC
temperature
salinity
water level
currents
Meteorological forcing
wind at 10 m
sea surface pressure
solar radiation
air temperature at 2 m
air humidity at 2 m
cloud cover
precipitation
Hydrological BC
discharge
temperature
salinity
SHYFEM
Shallow water Hydrodynamic Finite Element Model
temperature
salinity
water level
currents

SHYFEM: mesh



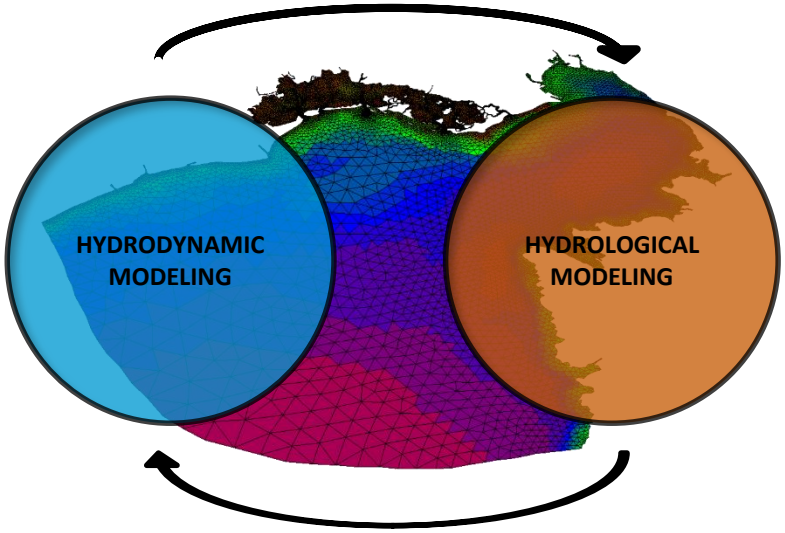
Gulf of Trieste and **Marano-Grado lagoon**

+ part of the Venetian coast
+ part of the Croatian coast

- **Lon. [°E]**: 12.7512 ÷ 13.8122
- **Lat. [°N]**: 45.1594 ÷ 45.8030
- **Average depth [m]**: 21.5
- **Max. depth [m]**: 34.7
- **N. of nodes**: 18311
- **N. of elements**: 33100 (triangles)
- **N. of vertical levels**: 22
- **Spatial resolution**: from a few km (open sea) to about 10 m (lagoon channels)
- **River-sea continuum**: lower part of rivers included
- **N. of tributaries**: 19

Hydrodynamics-Hydrology interaction

Introduction

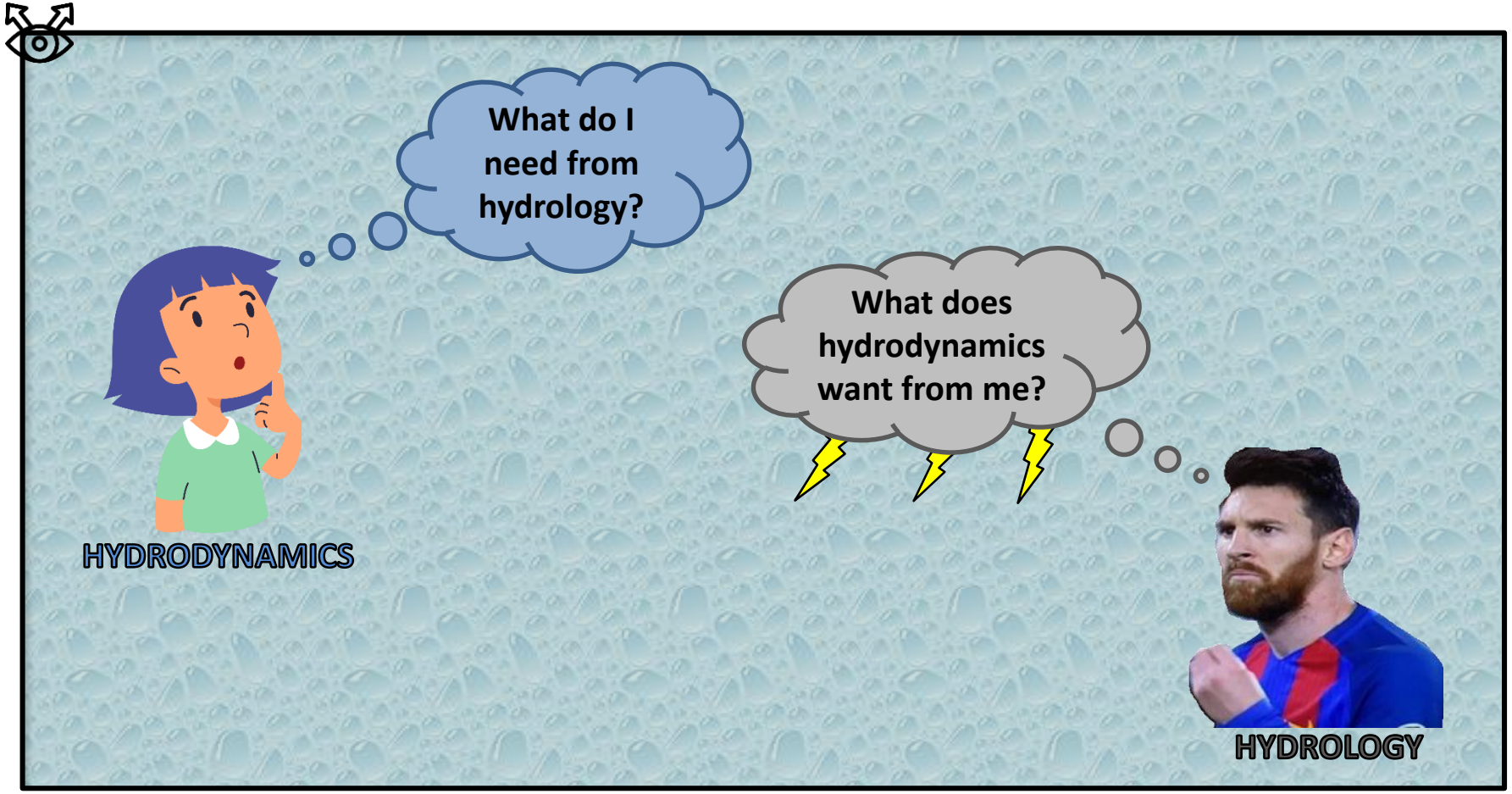


The **hydrodynamic-hydrological modeling interaction** can be addressed from various aspects, including the type of **application**

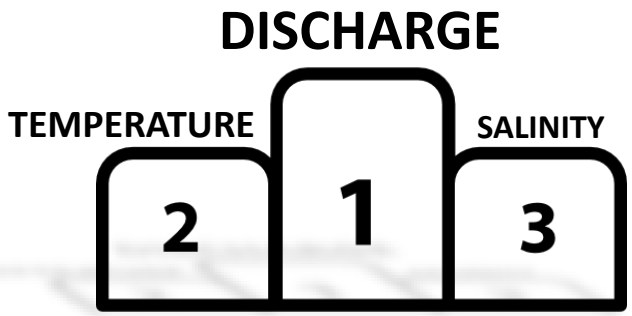
- **occasional** (e.g. climate simulations)
- **operational** (e.g. forecast & early warnings)

Who?

Hydrodynamics asks **hydrology**



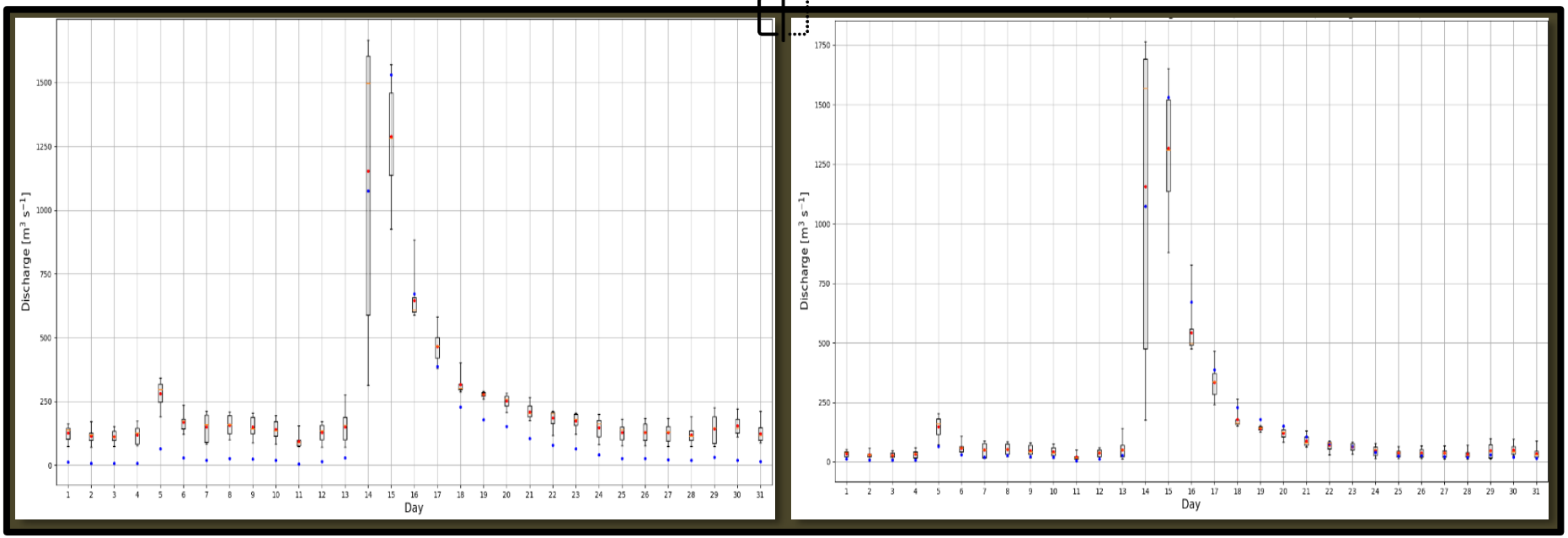
What?



- Different **discharge** values = different **amounts** of **freshwater interacting** with **seawater**
- Different **discharge** values = different **current** and **water level**
- In **our domain** of interest, **discharge measures** are **rare**
  - mainly **hydrometric heights** measures
  - **direct measures** are **sporadic** (e.g. once a month)
  - **main rivers** only
  - **old climatology** for **minor rivers** (made even older by current climate change's speed)
  - even updated climatology is **not always enough** for **operational applications**, especially for the **torrential regime** of tributaries

What?

- In **our domain** of interest, **useful discharge forecasts** are often **difficult to retrieve**
  - **main rivers** only
  - from **global** or **regional** models
  - usually **unavailable where** it is **convenient**
  - produced for **other purposes** (e.g. hydraulic and hydrogeological risk = calibrated on floods → **adjustment**, **software development**, **time use**)



What?

- **Discharge data** may be provided by **different sources** and in **different file formats**, but hydrodynamic models generally **require** a **unique specific format** → **pre-processing**, **software development, time use**

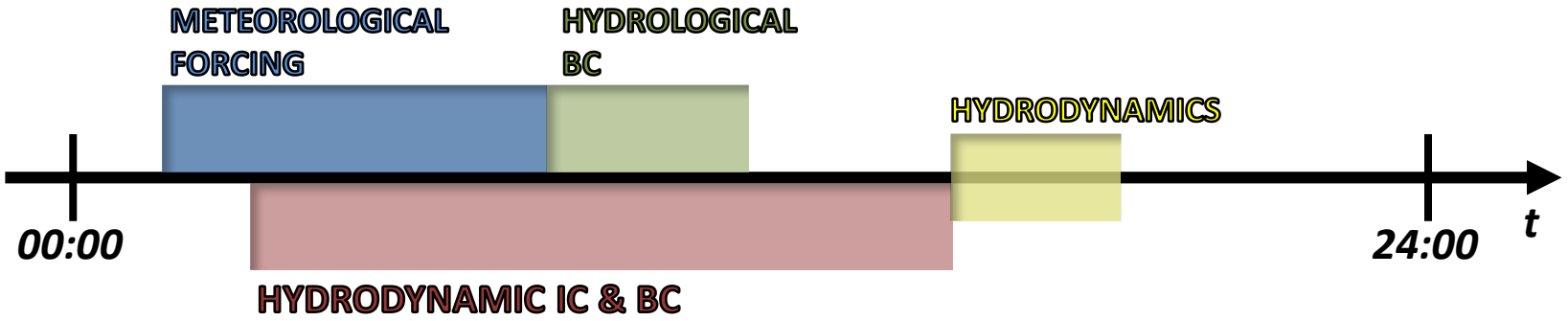
It is important to **run a hydrological model *at home***

When?

Hydrology should be available **as soon as possible**

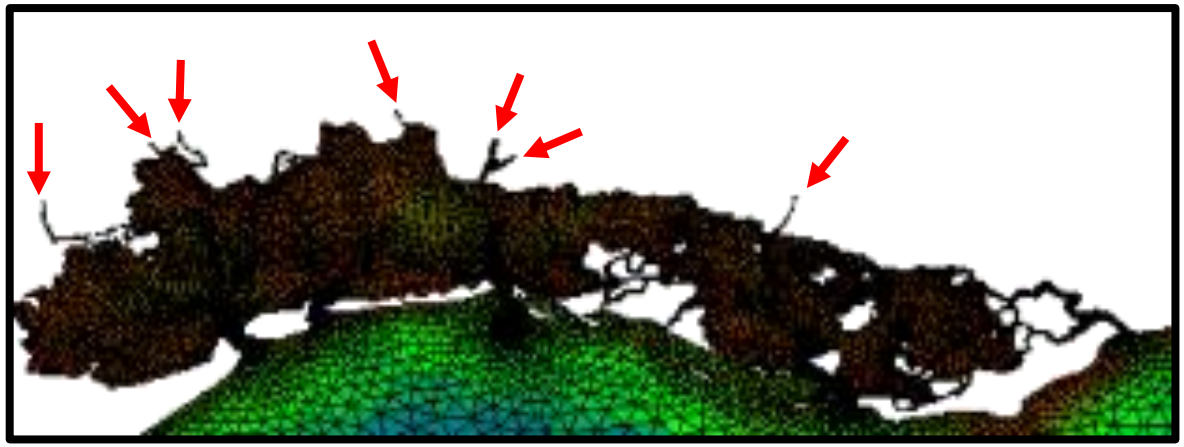
Local-scale hydrodynamics is the **last element** of the **modelling chain**

- waiting inputs
- pre-processing
- running
- post-processing
- archiving & publication



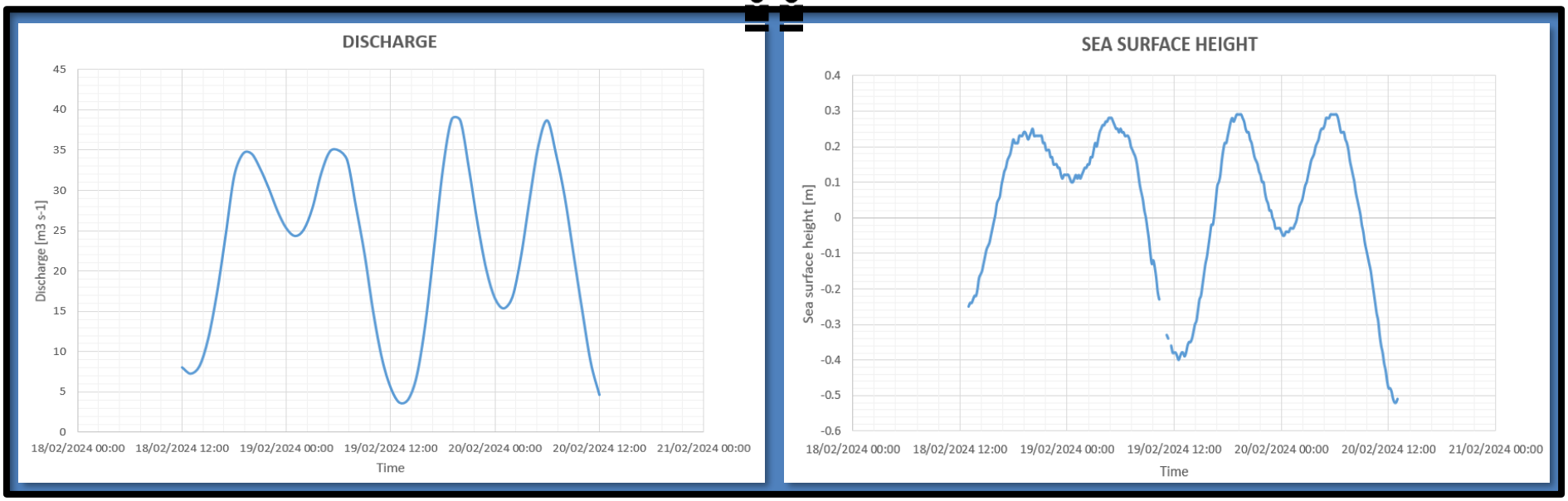
Where?

At ***riverine*** **open boundaries** (i.e. for **specific cross sections**)



Where?

- Generally **near river mouths**, but
  - **not too far away** (larger mesh = higher computational time)
  - **not too close** (issues in finding the actual discharge due to tide)



Where?

- **Discharge data** generally available for **cross sections** that are **different** from those that have to be considered → **adjustment**, **software development**, **time use**

It is important to **run a hydrological model *at home***

Why?

No hydrology, no hydrodynamics

at least constant values have to be provided (climatology)

Our suggestions for providing an **operational** (hydrodynamic) **service**, focusing on (hydrological) **inputs**:

- **list all available sources** of **input data** (**climatology included**) and **rank** them
- **consider all input data according to the ranking**; in this way
  - if the first is missing, it would be replaced by the second, or by the third, and so on…until climatology
  - the **service** will **always** be **guaranteed**
- **provide** the service **even if you have climatology only**
  - it is a **start** (you will never provide any service if you wait until you have the best data available)
  - it is an **information** (with several weaknesses, but also strengths)
- **improve** the service **step by step** and **over time**
  - **don't be satisfied** with having developed an operational service, but **continue to improve** it

How?

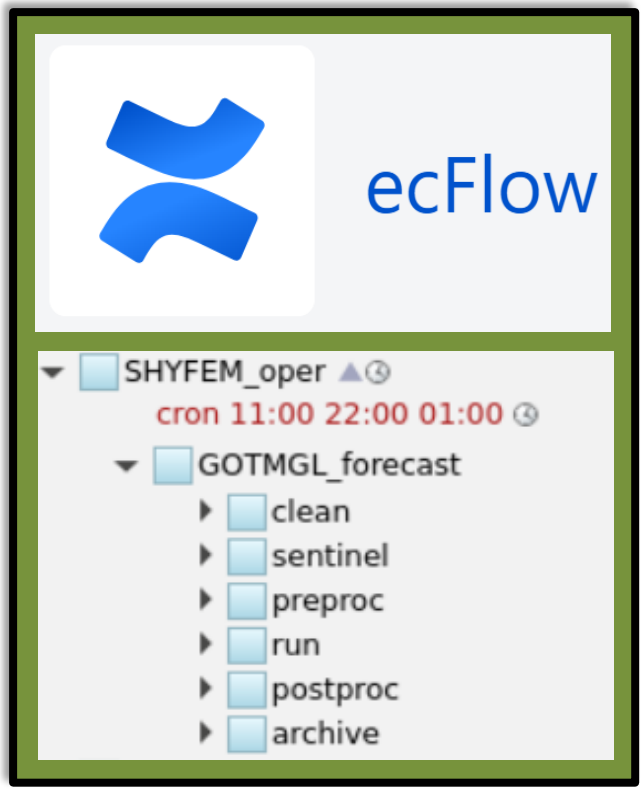
HPC infrastructure (**computation** and **storage**)

FENICE (**F**vg **EN**hanced **I**nfrastructure and **C**omputational **E**nvironment) [14]

- **Linux** CentOS
- **14 nodes** (**640 CPUs**) for **computation**
- **4 nodes** (**140 CPUs**) for **user access**, **data storage** and other services
- **4 queues**
- ***PBS Pro*** queuing system
- High-performance ***InfiniBand*** **network**
- ***Lustre*** **filesystem** for data storage (≈**200 TB**)

How?

Workflow manager



ecFlow [15]

- Enables users to **run a large number of programs** (**with dependencies** on each other and on time) in a **controlled environment**
- Provides **reasonable tolerance** for hardware and software failures, combined with good **restart capabilities**
- Complemented by a **graphical interface** that allows users to have immediate grasp on the status of programs or processes
- Runs as a **server** receiving requests from clients (**TCP/IP** communication)
- Is a **scheduler** (not a queuing system), but can submit jobs to queuing systems
- Developed at **ECMWF**

Summary

Summary

- **Hydrological boundary conditions** play an **important role** in **hydrodynamic coastal modeling** (they get asked a lot)
  - especially in **domains** that are affected by **freshwater inputs** of **different entities** and **regimes**
  - especially in **operational** applications
  - how about the **sensitivity** of **hydrodynamic** outputs to **hydrological** inputs?

    HANDS ON SESSION

- Data availability **issues**
  - **what**
  - **when**
  - **where**
- **Importance** of running a **hydrological model *at home***
- Need of **HPC infrastructure**
- Need of **workflow manager**
- **Start** to provide an **operational service** with what you have **available** and **continue to improve** it **over time**, **step by step**

Thank you

for your attention

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