April 26
2023

Interreg Sudoe

EUROPEAN UNION

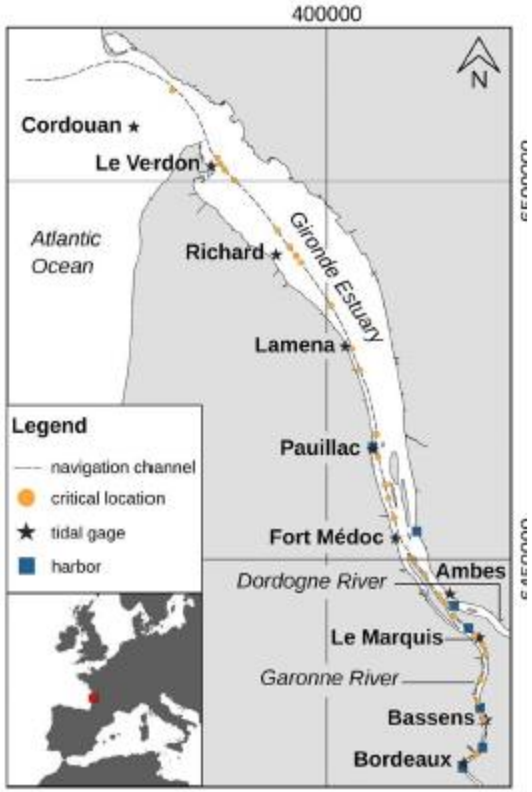
ecclipse

Ocean climate projection
Estuarine dynamics

Nicolas Huybrechts, Vanessya Laborie and Mohammad Traboulsie (Cerema, RHITME)

Fabrice Klein (GPMB)

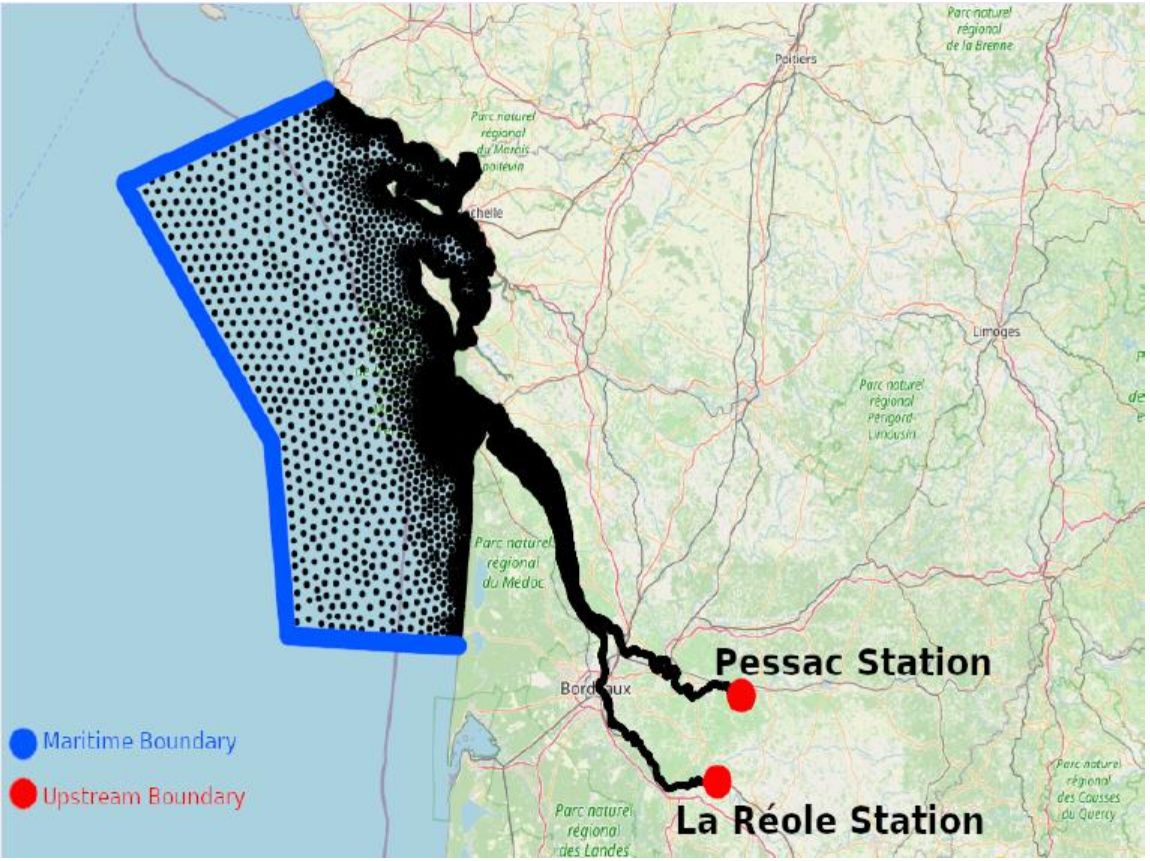
Introduction



- ➢ Port of Bordeaux located inside the Gironde estuary: several terminals
- ➢ Influenced by the coastal and/or fluvial environnements
- ➢ Representative of inland port as Rouen, Saint Laurent, Hamburg, Antwerp,…
- ➢ Port of Bordeaux and Cerema collaborate on R&D projects since 2017

Development of numerical modeling on Opensource code (Opentelemac)

Developped methodolgy



Master thesis of Mohamed Trabousi
(2021 funded by Cerema)

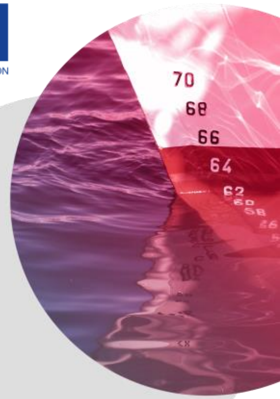
Aims

- Evolutions of the hydrodyamic patterns inside the estuary
- Offshore and upstream boundaries
- Methodology:
  - Hydrological model for flowrates
  - 2D storm surges model
  - 3D model

Interreg Sudoe

EUROPEAN UNION

ecclipse

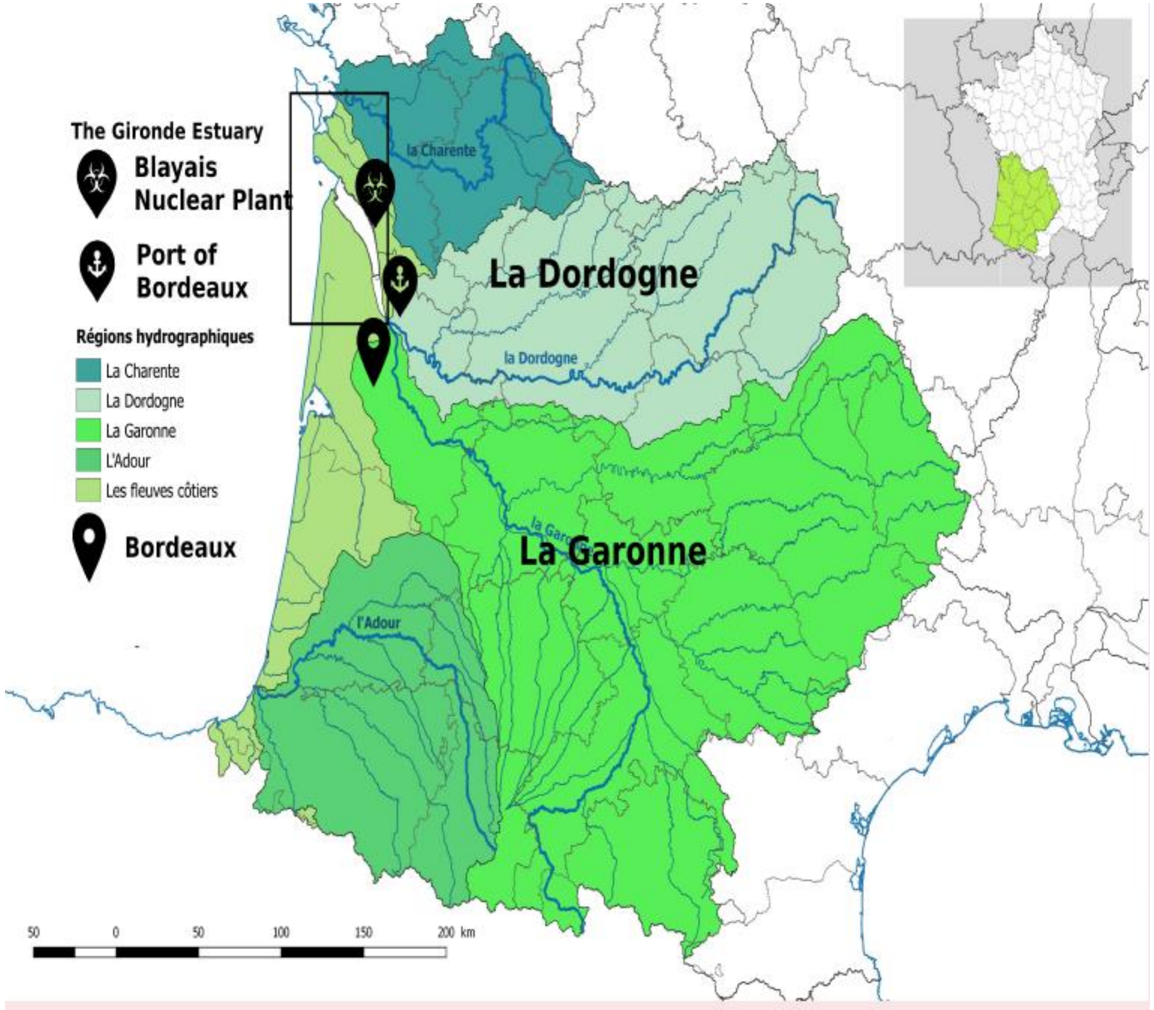


01 Aims and key facts

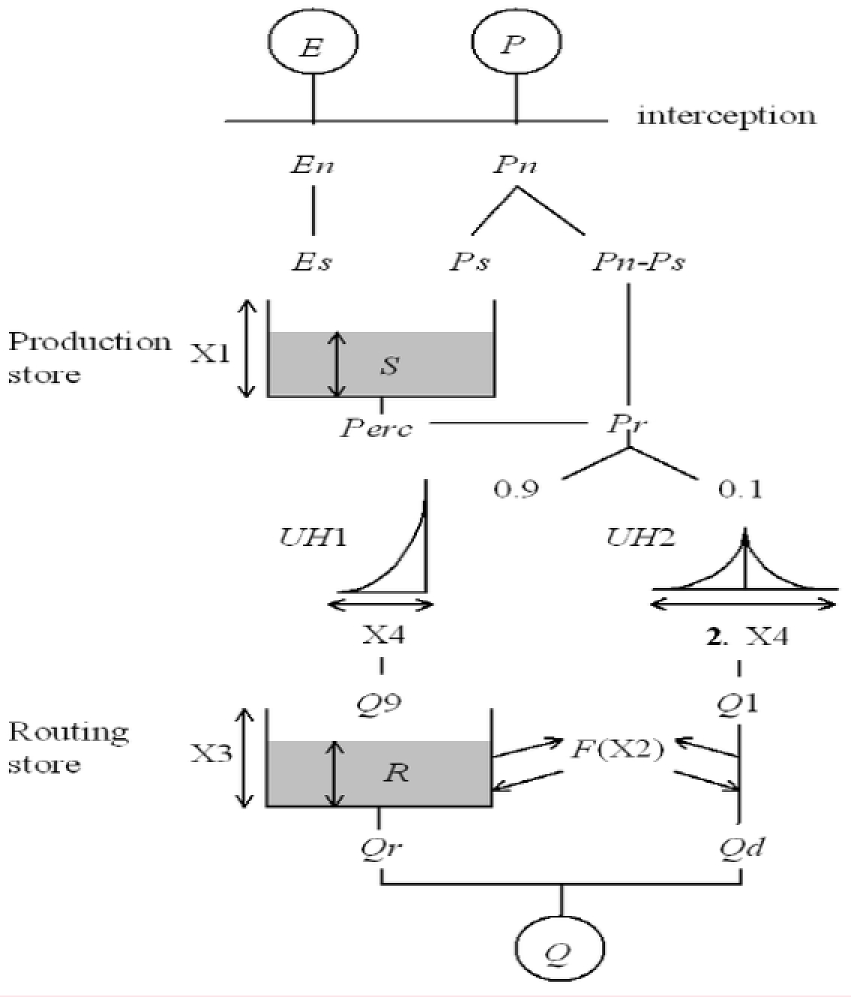
02 Main results

03 Conclusions

Hydrological model



Hydrological model



GR4J: principe scheme (Michel and Andréassian 2003)

GR4J: modèle du Génie Rural à 4 paramètres Journalier

- **Oudin Formula**: Temperature to Evapotranspiration

Parameters

- X1: maximum capacity of the production store (*mm*).
- X2: groundwater exchange coefficient (*mm*).
- X3: maximum capacity of the routing store (*mm*).
- X4: time peak of the hydrograph ordinate limit (days)

Hydrological models

Calibration

- Period: 1997-2005
- NSE criterion

Validation

- Period: 2014-2019
- Statistical Indicators/Observed data

Application

- Selected Model
- Statistical rebuilding/Future data

- **NSE**: Nash-Sutcliffe Efficiency (1970)

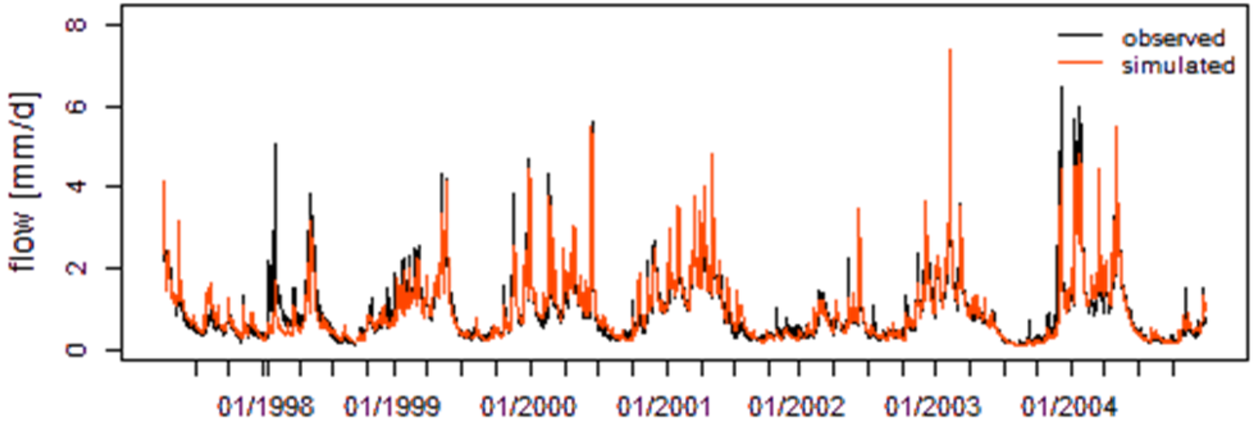
$$= 1 - \frac{\sum_{i=1}^{n} (Q_{obs,i} - Q_{sim,i})^2}{\sum_{i=1}^{n} \left(Q_{obs,i} - \overline{Q_{obs}}\right)^2}$$

- **KGE**: Kling-Gupta Efficiency

$$= 1 - \sqrt{(1-r)^2 + (1-\alpha)^2 + (1-\beta)^2}$$

- **QJXA10**, Maximum annual daily flow with a return period of 10-years (flood indicator)
- **QMNA5**, Minimum monthly flow per year with a return period of 5-years (low-flow indicator).

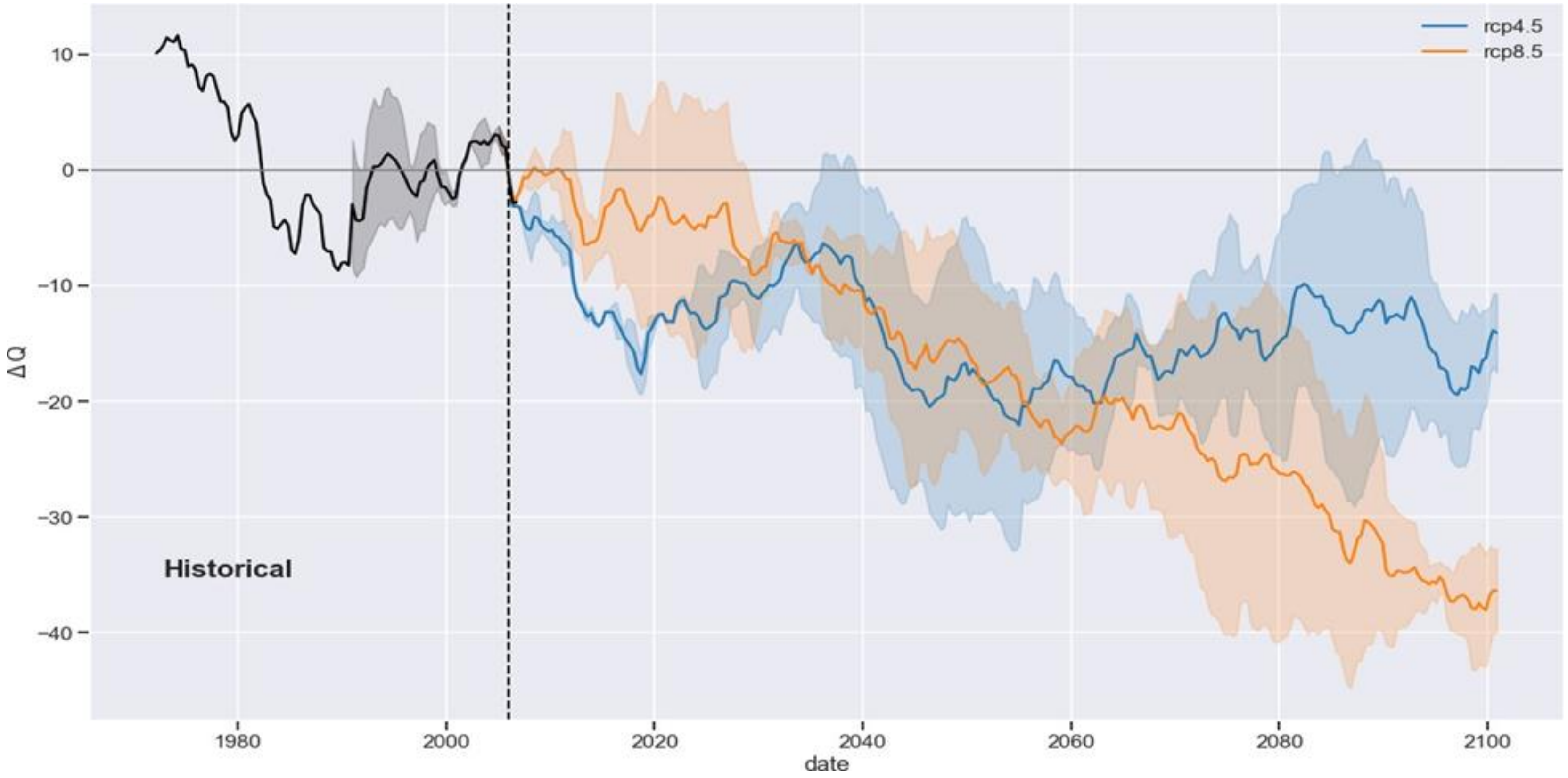
Hydrological model



	NSE	KGE	Annual mean (m³/s)	QJXA10 (m³/s)	QMNA5 (m³/s)
GR4J	0.88	0.93	550	3531	133
GR5J	0.89	0.93	562	3517	210
GR6J	0.83	0.87	577	3277	187
Observed	**-**	**-**	**547**	**3654**	**138**

- Tests of more complex models with more parameters => GR4J
- Similar results for the Garonne
- From 2006 to 2100 with Ecclipse scenario

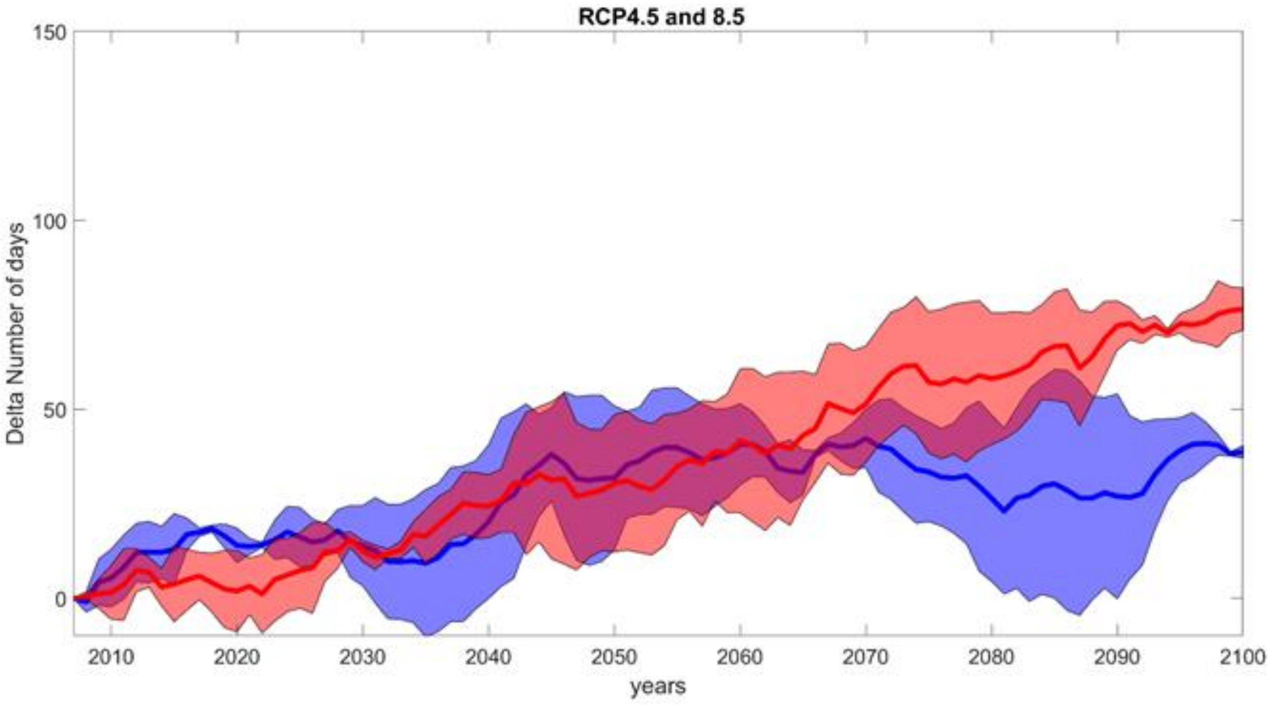
Evolution of the Garonne



- Mean annual flowrates
- Three different patterns: 2025,2060 2100

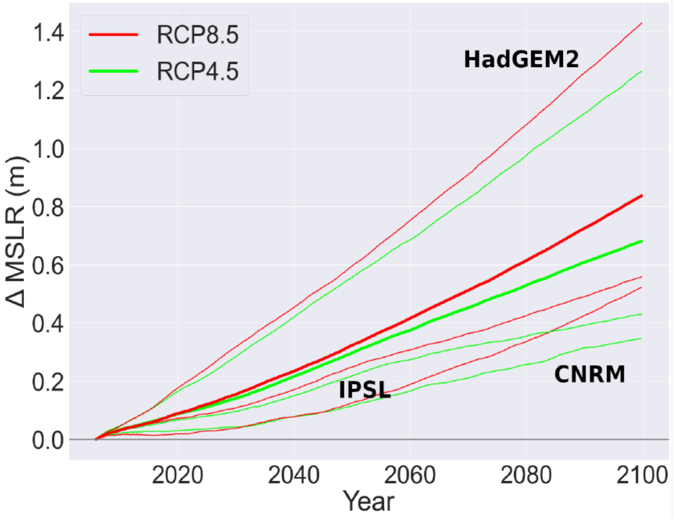
Likelihood rating for the flowrate

Number of days with flowrate <400 m³/s, low flowrates

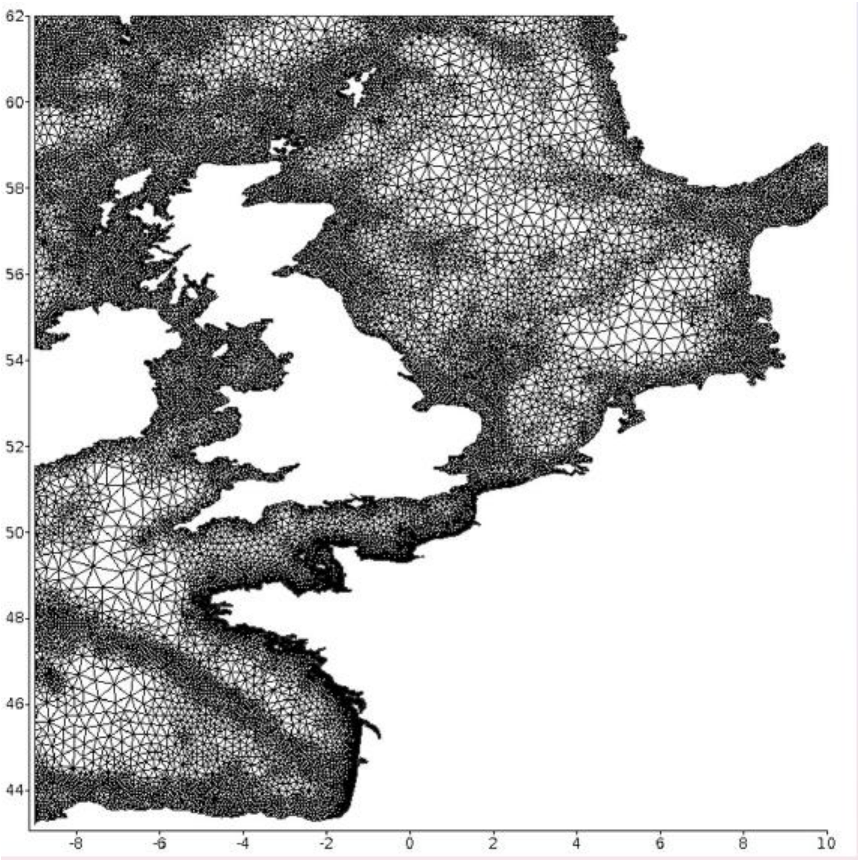


	Historical	RCP 4.5			RCP 8.5		
		2016-2040	2041-2070	2071-2100	2016-2040	2041-2070	2071-2100
Mean Dordogne Discharge	263	-8% (-13 -4)	-9.5% (-10 -8.7)	-12.5% (-15 -9)	-5% (-6 -4)	-12.1% (-15.9 -8.9)	-12.5% (-14 -10)
Mean Garonne Discharge	554	-11% (-24 +1)	-18% (-25 -12)	-16.9% (-28. -6)	-12.2% (-17 -7)	-22.2% (- 33 -10)	-37.5% (- 43 -31)
Number of days <400	119	+18% (-8 +44)	+35 (21 49.5)	+31% (10 51)	+17.6 (1 34)	+36.6 (9 63)	+60% (43 78)
Number of days > 1500	47	-10% (-20 -2)	-14%. (-17 -12)	-13 (- 17 -10)	-13 (-17 -10)	-30 (-36 -23)	-37 (-37 -35)

Storm surges

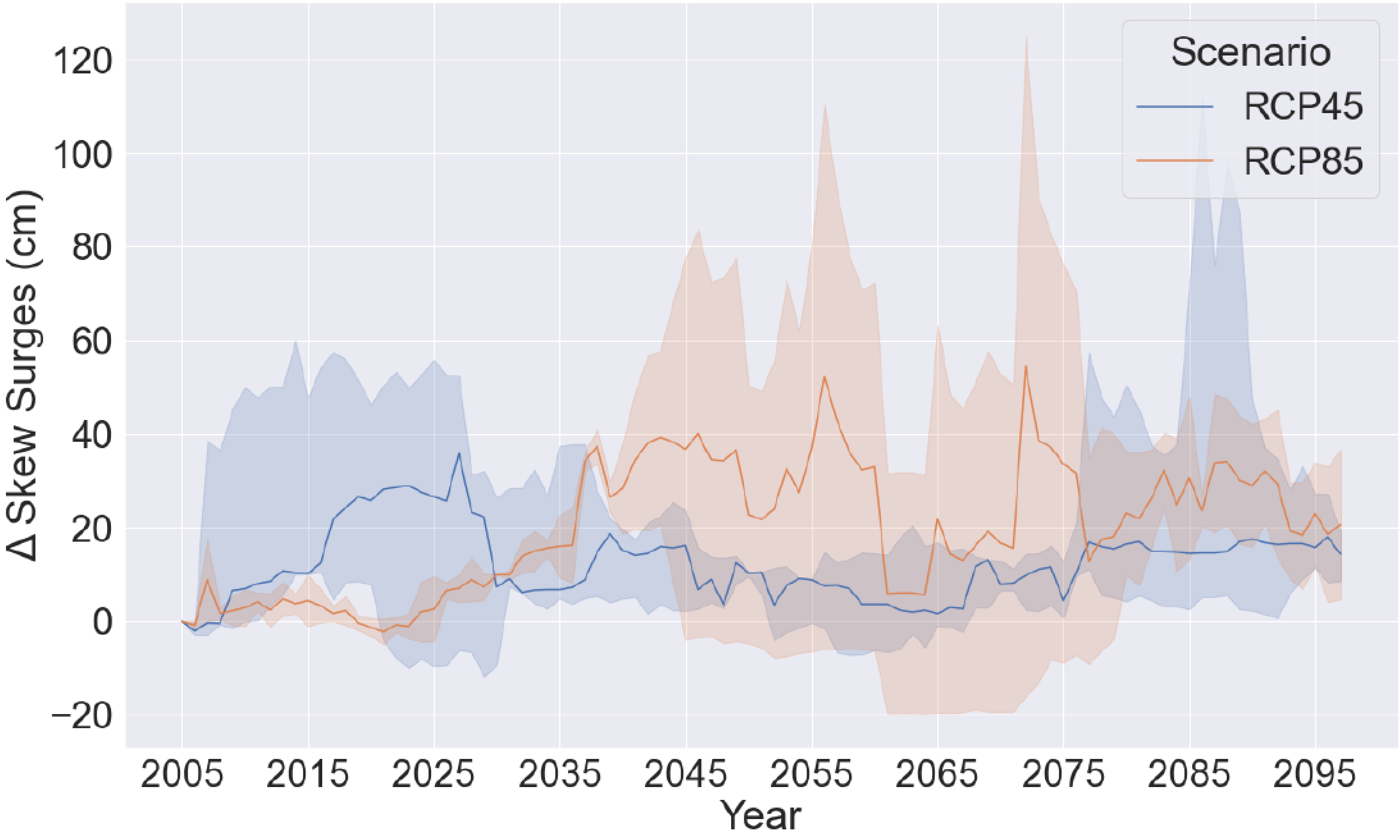


Input:
- ➢ Mean sea level at the maritime boundaries
- ➢ Wind/pressure fields
- ➢ Telemac 2D
- ➢ The mesh contains 32644 nodes and 59159 elements.

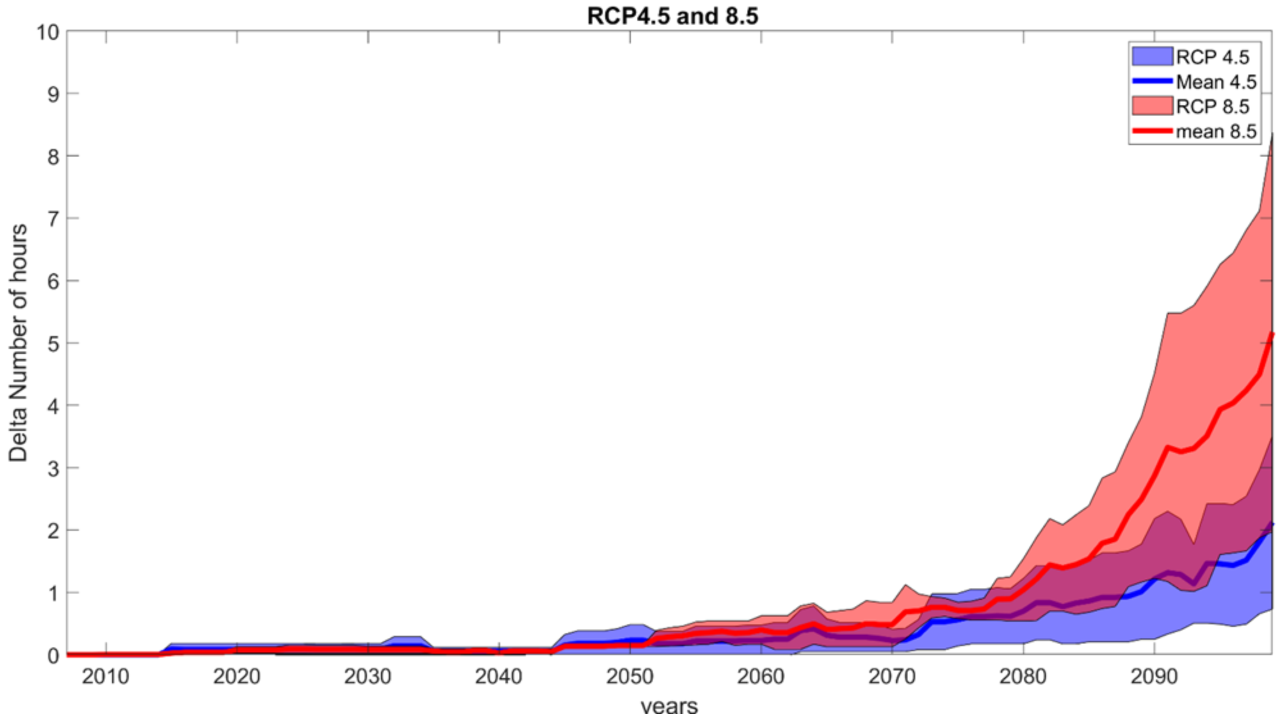


MSFA model (Laborie et al 2015)

Statistical indicators



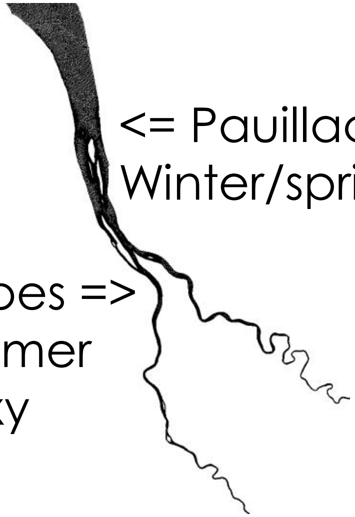
Likelihood for water levels

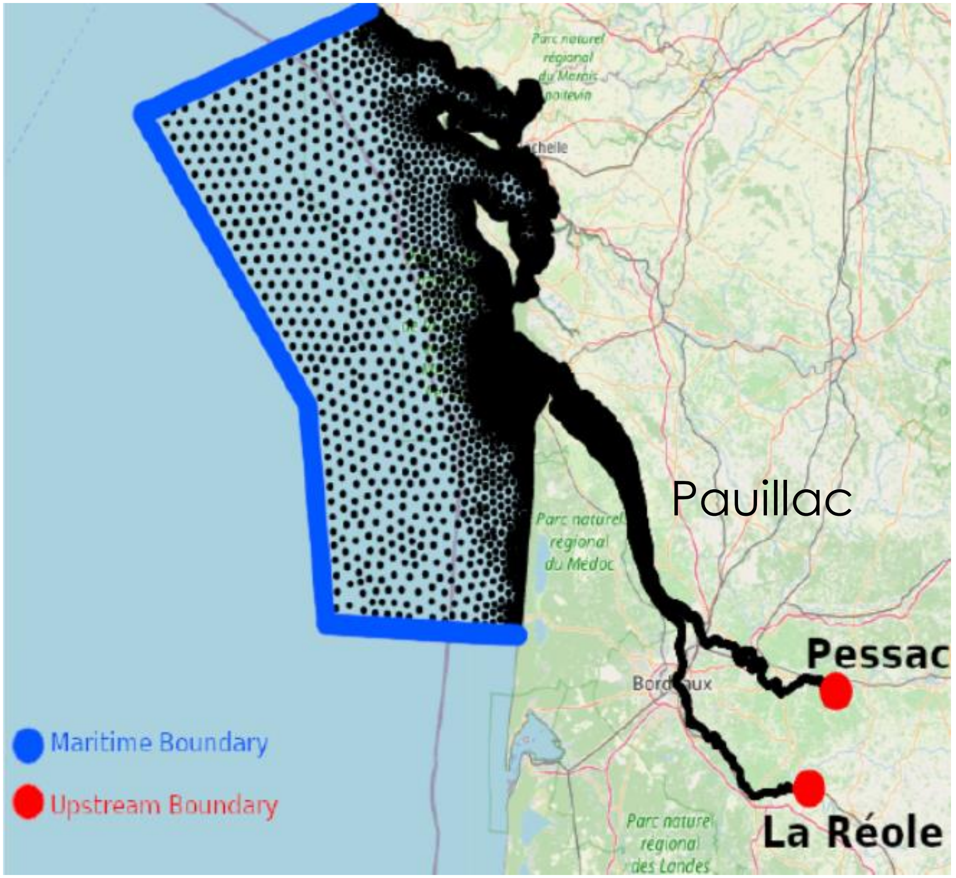


	Historical	RCP 4.5			RCP 8.5		
		2016-2040	2041-2070	2071-2100	2016-2040	2041-2070	2071-2100
Number of minutes > 3.32m	0.5 (0. 1)	3.2 (0.8-5.6)	17 (2.7-31.3)	106 (36.2-176)	5.5 (4.4-6.5)	34 (26.7-40.33)	234 (90-379)

- At the mouth, the level 3,32 m is considered (Full moon high tide + 30 cm)
- Effect of tide, surges, and mean sea level
- Mean contribution: sea level rise

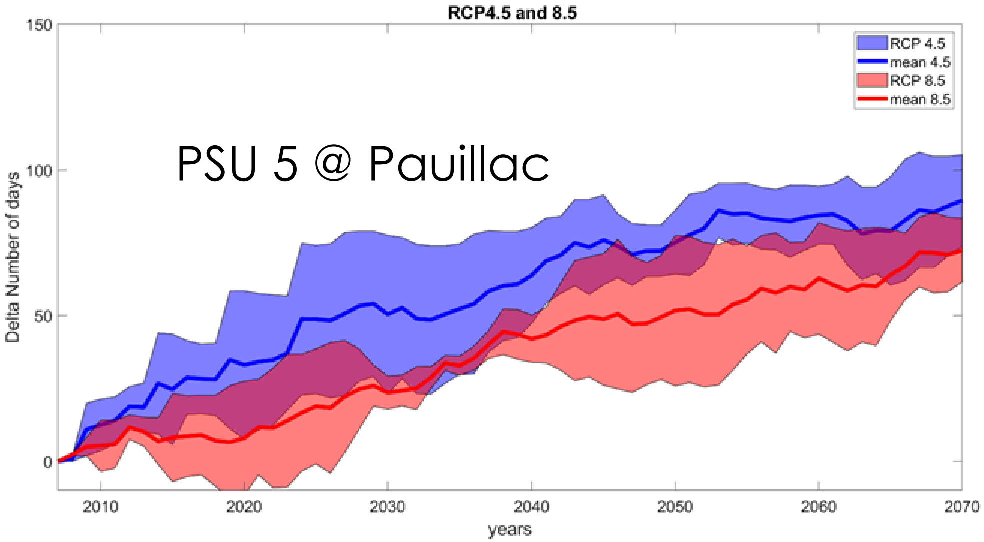
Salinity

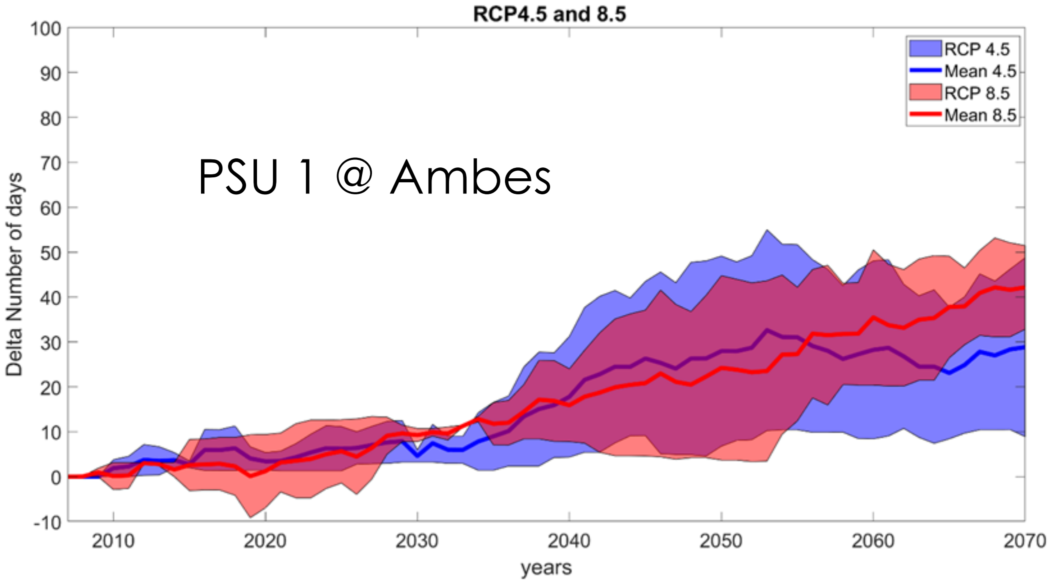




- Telemac 3D
- 280000 nodes
- K-epsilon for turbulence
- Salinity and velocity
- Issues for the port but also for others (turbines, fisheries, agricultures..)
- One run of 375 days: 1 CPU day
- Issues of memory and big file (15GB/run)
- Upstream Pauillac: section more narrow => turbidity max
- Ambes: Garonne river dredging issue during low flowrate

Evolution of salinity





	Historical	RCP 4.5		RCP 8.5	
		2016-2040	2041-2070	2016-2040	2041-2070
Number of days > 5 Pauillac	40 (16 63)	165% (140 188)	230% (205 -252)	100 (27.5 -173)	175 (62 -285)
Number of days > 1 Ambes	11.5 (2-21)	160% (-48 372)	269% (13 -520)	122% (-21 -265)	335% (100 -573)

Interreg Sudoe

EUROPEAN UNION

ecclipse

01 Aims and key facts

02 Main results

03 Next steps

Main conclusions

- Database of the forcings for Sudoe: coastal storm surges (available on the whole atlantic shoreline and in construction for the mediteranean sea) and riverflows

- Introduction of these forcings into a 3D numerical modeling : salinity and current (not shown)

- For the Gironde estuary the most affected variables are:

  Air temperature and heat waves (FIC) =>water temperature?
  Salinity and dredging activities
  Water level and submersion
  River discharge

Introduction

- Survey performed in 2020
  - ✓ Identify the most relevant issues and associated variables
  - ✓ The horizon (<2070)
  - ✓ The thresholds

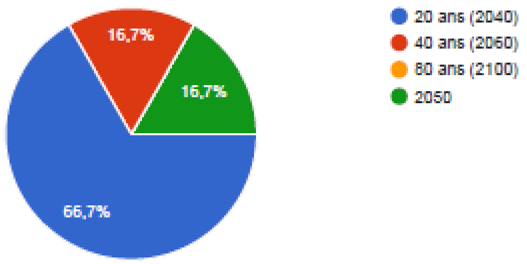
Changement climatique dans le port de Bordeaux

7 réponses

Publier les données analytiques

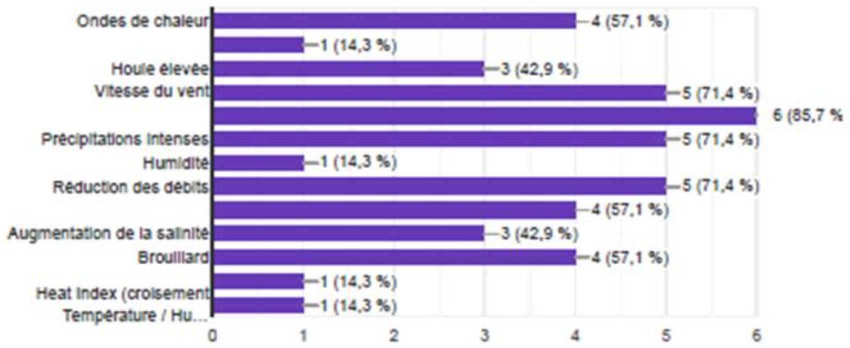
L'horizon de planification que vous jugez pertinent pour le fonctionnement, et les investissements associés, est:

6 réponses



Quels phénomènes sont susceptibles d'affecter les opérations portuaires?

7 réponses



Introduction
Summary of threshold

Variables	Navigation	Port operation	Infrastructure	How	who
Current	2,57 m/s			3D model	Cerema
Flowrate	300 m^3/s	same	same	Hydrologic model	Cerema
Water level		High tide + 30-40 cm	High tide + 30-40 cm	2D Storm surges models	Cerema
Salinity	1 PSU	same	same	3D model	Cerema
Wind	10-20 m/s	36 m/s		RCM/statistical	FIC
Vissibility	1000m	200m		RCM/statistical	FIC
Air temperature		33		RCM/statical	FIC