# LONG-TERM HYDRODYNAMICS AND SEDIMENT TRANSPORT MODELLING UNDER A FUTURE CLIMATE CHANGE SCENARIO

C JONES (INTEGRAL CONSULTING INC)
S CECCON, B GROPPELLI, L ZILIANI, F COLOMBO (RAMBOLL ENVIRON)
D BOCCHIOLA, M C RULLI, A SONCINI, G RAVAZZANI, R ROSSO (POLITECNICO DI MILANO)
M MARANGON, L ZANINETTA, A BASCIU, L CONTI (SYNDIAL SPA)

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# HYDRODYNAMIC AND SEDIMENT TRANSPORT MODELLING AND CLIMATE CHANGE

- Prediction of hydrodynamic, sediment and contaminant transport processes in rivers and natural water bodies is challenging due to numerous factors and uncertainties that drive the phenomena
- Physically based 3D hydrodynamic models can be applied as a tool to evaluate long-term system evolution trends, also taking into account climate change scenarios
- This case study presents  a 'multi-model chain' approach that couples general circulation models (GCM), regional downscaling, hydrological and sedimentological watershed modelling and 3D hydrodynamic modelling

## Technical Team

- Politecnico di Milano
- Ramboll Environ Italy
- Integral Consulting

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# CASE STUDY: PALLANZA BAY (LAKE MAGGIORE)

## Site

Pieve Vergonte, Remediation National Site (SIN), Piemonte, Italy

## Main issue

Historical Dichlorodiphenyltrichloroethane (DDT) production and waste water discharge since 1948 (main production 1970s) in the Toce River that flows to Pallanza Bay

## Subjects of the study

The Pallanza Bay (Lake Maggiore) ≈22km$^2$


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# PALLANZA BAY: PREVIOUS STUDIES

## 2009-2010 field campaign

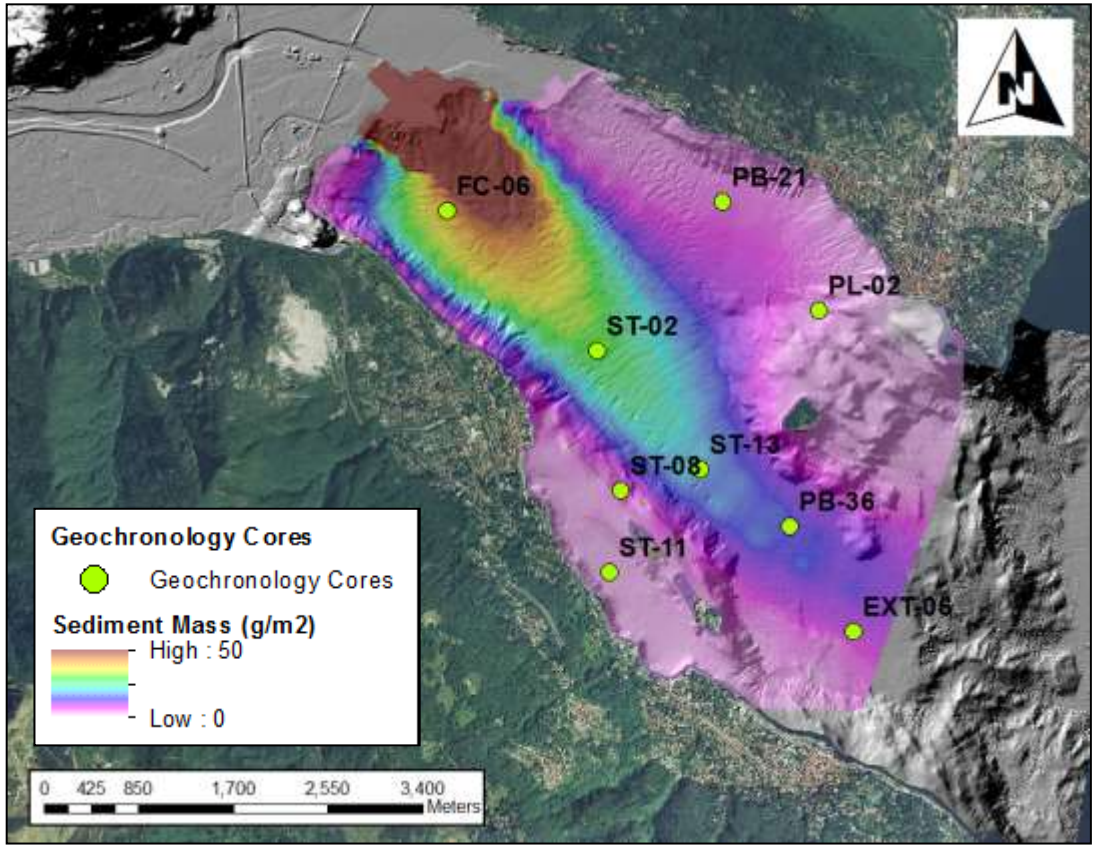
Bathymetric survey, current and water quality measurements, Sedflume cores, SPI camera, geochronology cores, in sediment DDT concentrations analysis

## 2012

Calibration and validation of hydro-sedimentological watershed model (FEST-WB/ERODE) and 3D hydrodynamic and sediment transport model (EFDC)
Reconstruction of historical sediment dynamic from 1982-2010 (hindcast scenario)

## 2014

Hydrodynamic and temperature measurements, sediment trap collection

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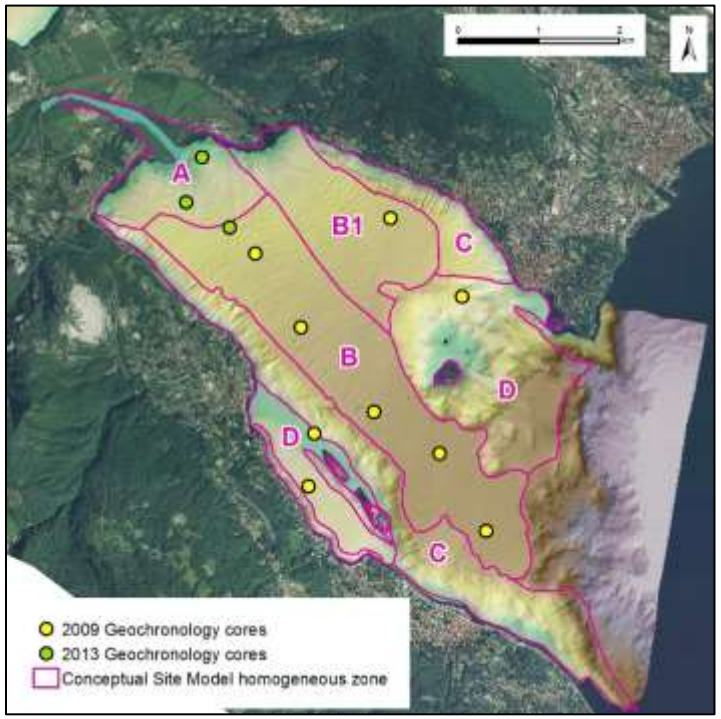
# PALLANZA BAY: CONCEPTUAL MODEL

## Key components

- Bay slopes from shallow river mouth and delta steadily to deep lake. Deposition rates spatially variable (high in zone A, low in zones D)
- No evidence of sediment resuspension observed in SPI camera studies, monitoring, coring
- 'Natural capping' process (incoming sediment is cleaner than historical deposition) in progress on the whole bay




**Homogeneous zones**

A. Shallow water Toce river delta
B. Deeper central part of the bay
C. Steep slope
D. Lateral flat areas

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# OBJECTIVES

Will ‘natural capping’ continue in Pallanza Bay?

- Simulate sediment dynamic in Pallanza Bay using a long-term projection under extreme climate change scenarios between 2017-2050
- Characterise future sediment dynamics in Pallanza Bay in terms of distributed expected deposited sediment (i) cumulative thickness, (ii) annual average deposition rate and (iii) spatio-temporal deposition trends in the next 34 years

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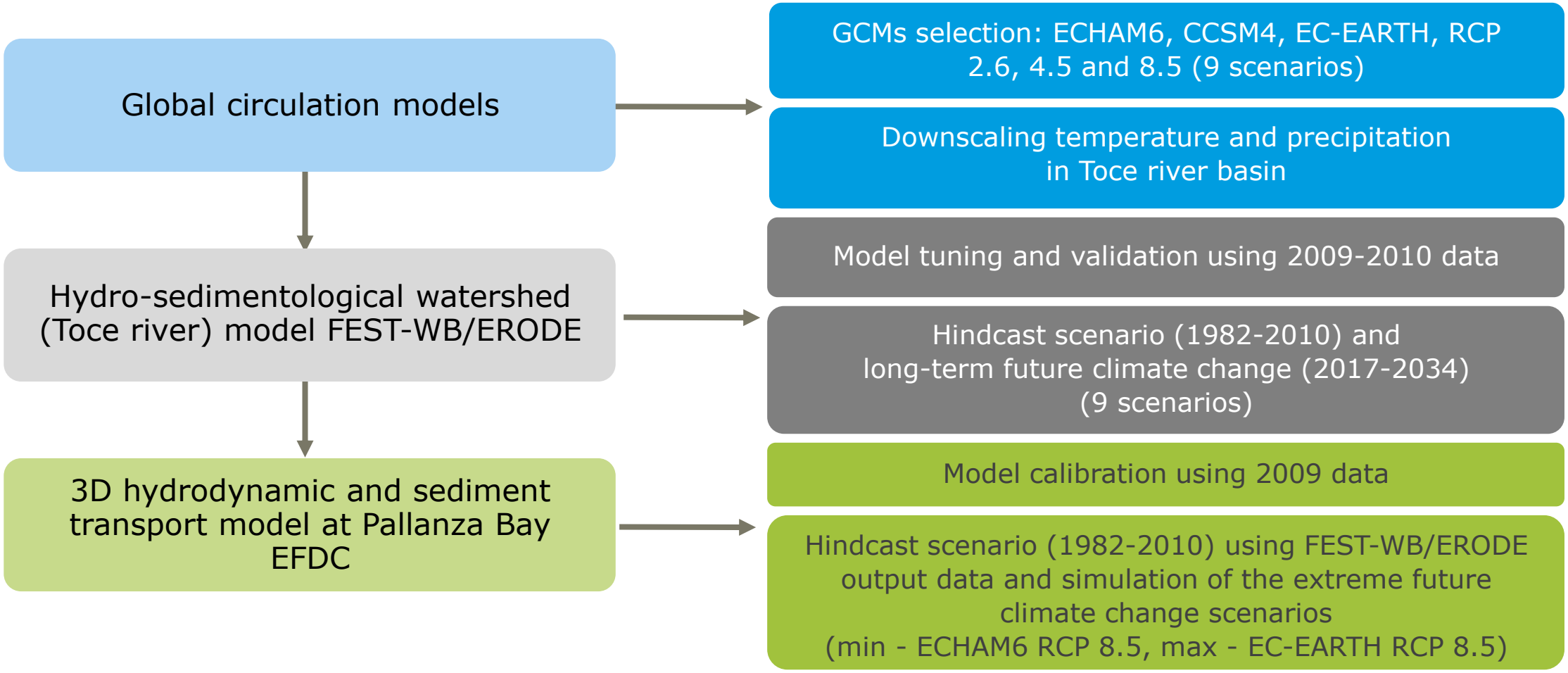
# MODEL CHAIN

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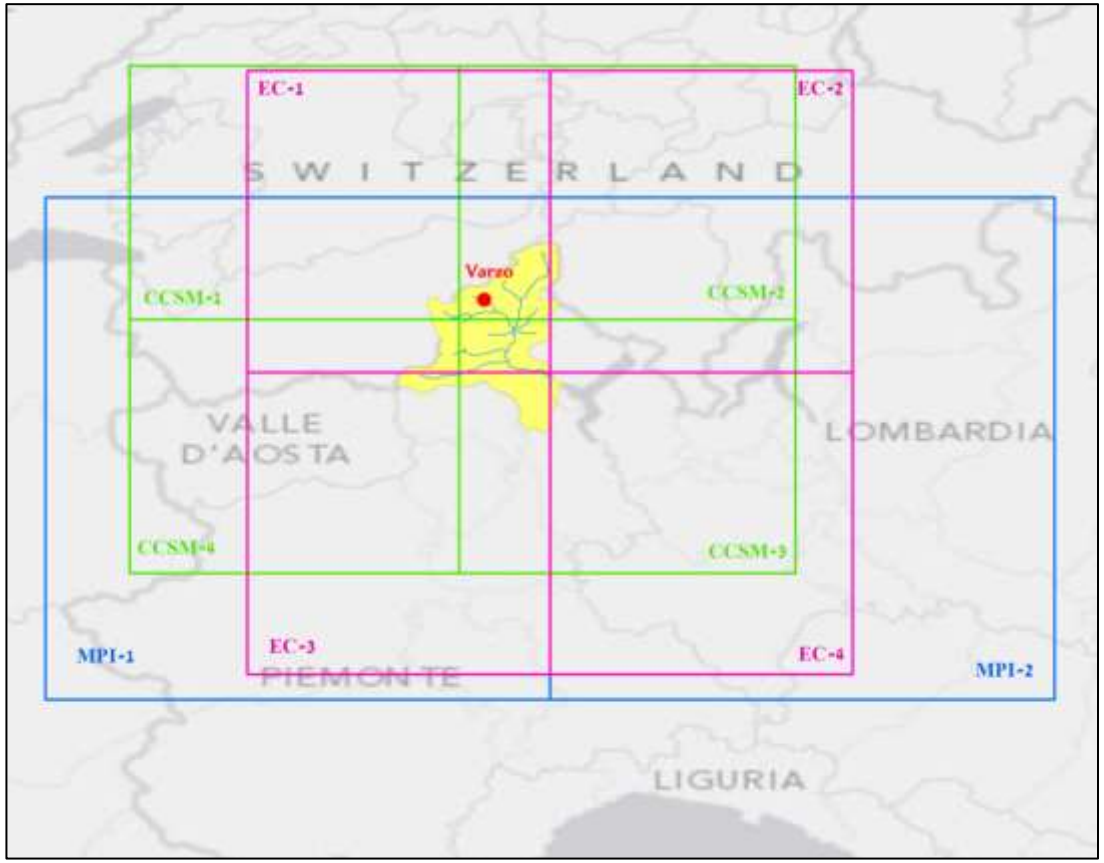
# GLOBAL CIRCULATION MODELS

Benchmarking of nine scenarios created using 2017-2034 forecasting data downscaled to Toce river basin provided by three GCMs and three representative concentration pathways (RPCs) as estimation of global radiation forcing levels in watt/$m^2$
(2.6, 4.5 and 8.5).

| GCMs | Developer | Cell dimension |
|---|---|---|
| EC-EARTH | Europe-wide consortium | 1.125° x 1.125° |
| ECHAM6 | Max Planck Institute for Meteorology | 1.875° x1.875° |
| CCSM4 | National Center for Atmospheric Research | 1.25° x 1.25° |

- Multi-decadal warming coherently forecasted by selected GCMs, increasing with RCPs
- Less coherence in terms of precipitation forecast EC-EARTH model tends to show annual rainfall growth, unlike ECHAM6 and CCSM4 models

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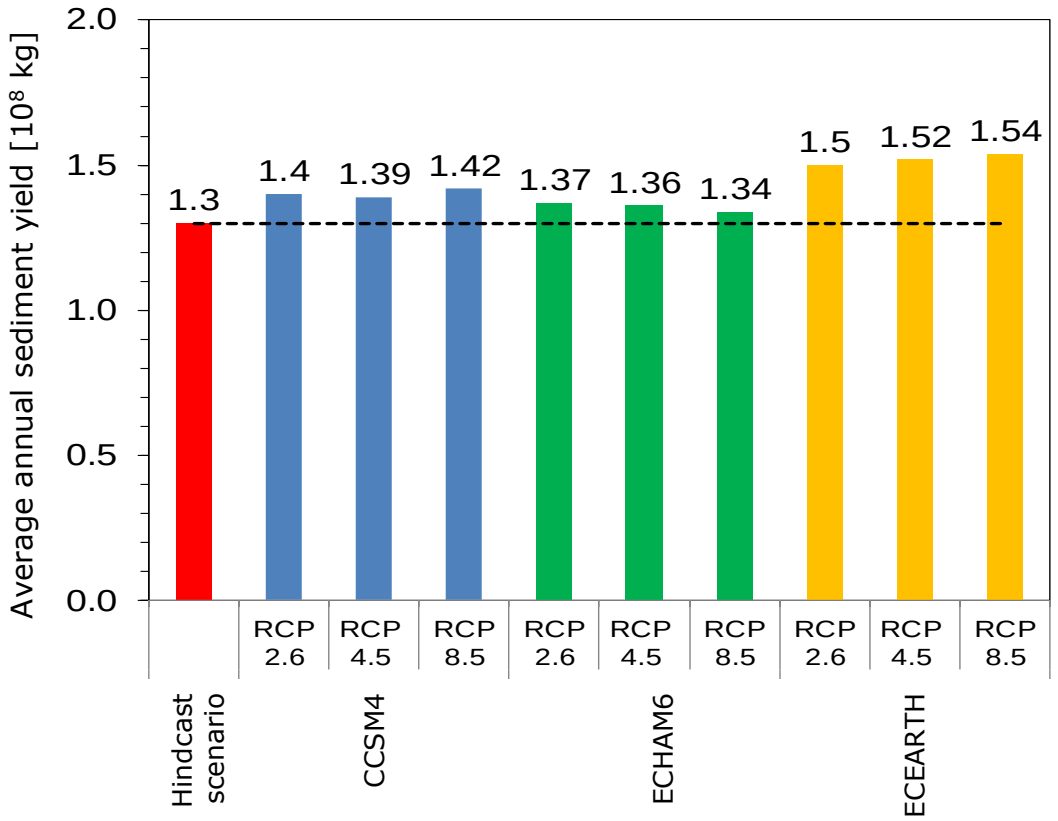
# HYDRO-SEDIMENTOLOGICAL MODEL: FEST-WB/ERODE

GCMs results used as forcing scenario for distributed hydrological (FEST-WB) and sedimentological (ERODE) models in Toce basin

- Slight decrease of the annual outflow (up to -16%, -7% on average using various models and scenarios)
- All scenarios forecast increase of average annual total sediment yield ranging between 3%-18%
- Among all nine simulated scenarios, the EC-EARTH RCP 8.5 and ECHAM6 RCP 8.5 scenarios respectively have highest ('best' scenario) and lowest ('worst' scenario) average annual sediment yield (extreme scenarios)

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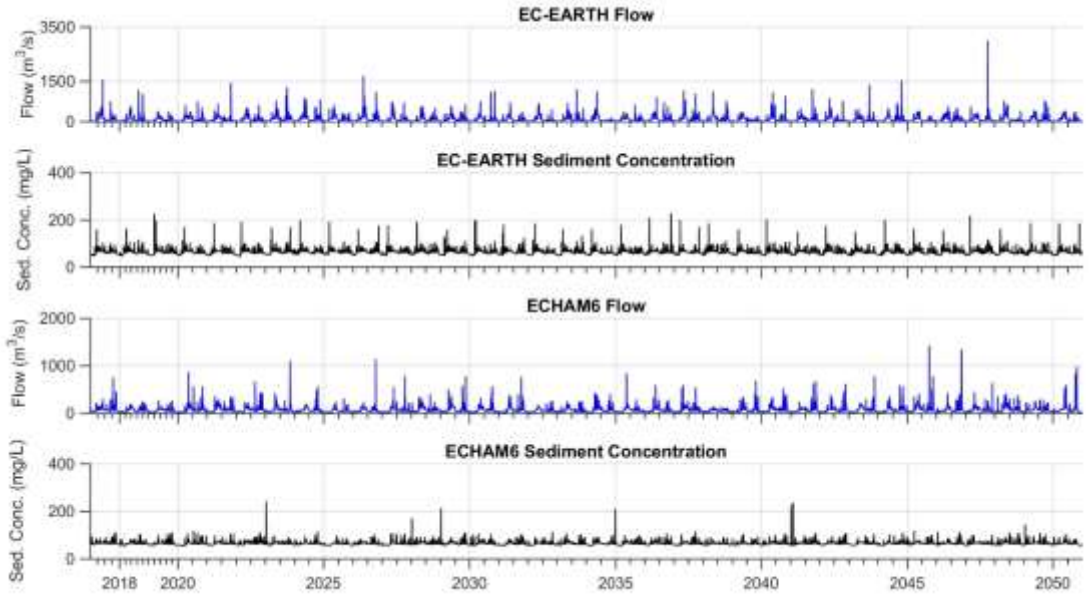
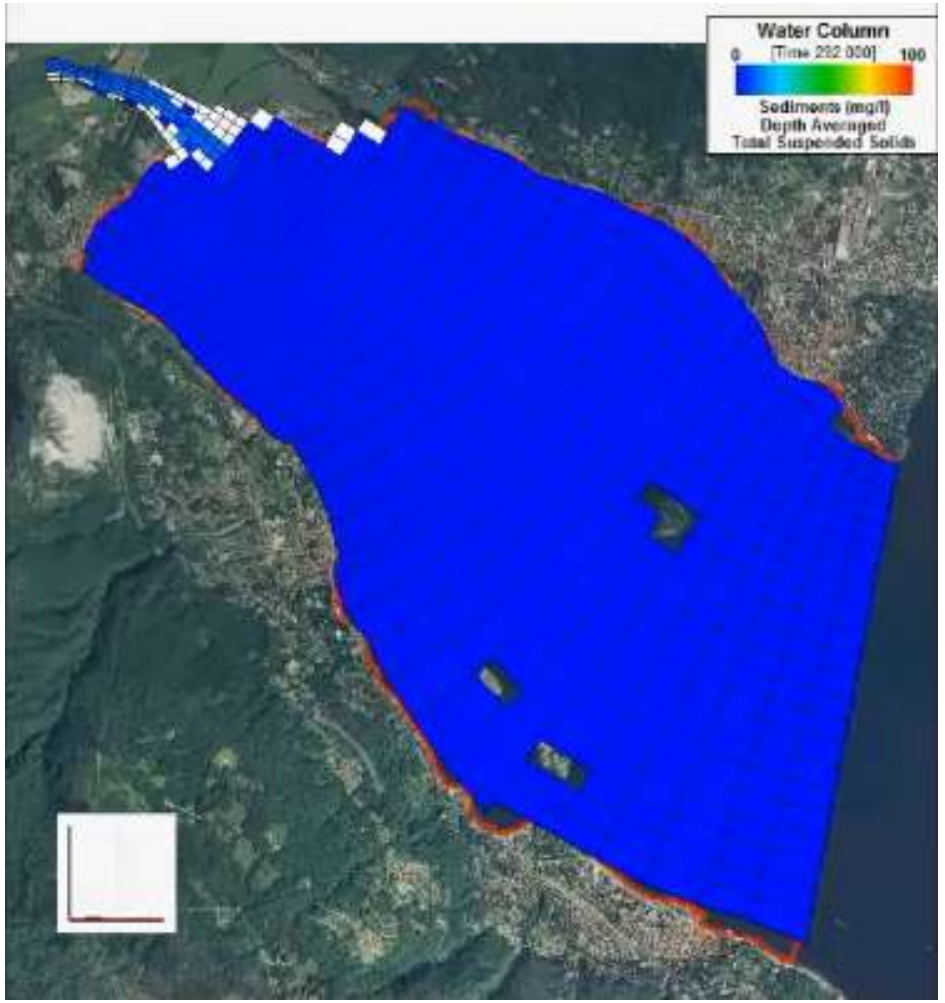
# 3D HYDRODYNAMIC MODEL: EFDC




The FEST-WB-ERODE model output for extreme scenarios expressed in terms of flow and total sediment load have been used here as boundary condition for the simulation of the future sediment deposition dynamics in the Pallanza Bay, using EFDC

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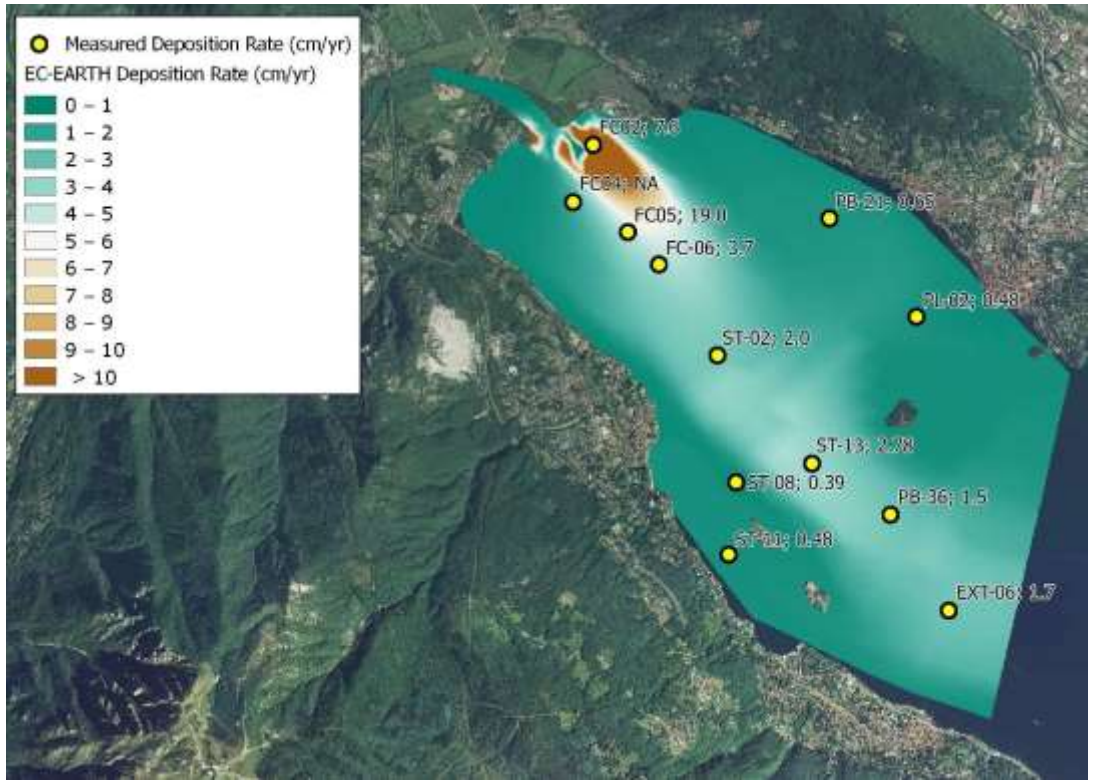
# RESULTS

## Projected sediment deposition rates

- ECHAM6 (worst scenario): projected deposition rate results the same as the hindcast 1982 to 2010 modelled historical period
- EC-EARTH (best scenario): about 19% higher



# KEY FINDINGS

- Projected deposition rates throughout bay are higher (+19%, for the best scenario) or close (worst scenario) to the values provided by the 1982 to 2010 hindcast
- Simulations have similar pattern
- The model simulations show no potential for net sediment erosion in the shallow water areas of Pallanza Bay (zone B1, C and D), as found in previous studies
- Significant portion of mass input from the Toce river is captured in Pallanza Bay

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# UNCERTAINTY OF MODELS

- Results are projections achieved through a multi-model chain application comprised of climate change models (ECHAM6 and EC-EARTH, by IPCC), a hydrosedimentological model (FAST-EWB/ERODE by the Polytechnic University of Milan), and a hydrodynamic-sediment transport model (EFDC by USEPA)
- Several boundary conditions (i.e. incoming sediment grain size distribution, temperature distributions in lake and Lake Maggiore water stage) have uncertain long-term values, as they are also related to climate change
- Climate change scenarios are periodically updated. Although GCM releases used in this case are up-to-date as of 2014, future releases may change significantly

# CONCLUSION

- Both scenarios indicate persistence of ‘natural capping’ process in Pallanza Bay in the long-term
- Due to uncertainties associated with the model chain, further monitoring and modelling of the system is recommended to validate findings

# THANK YOU

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