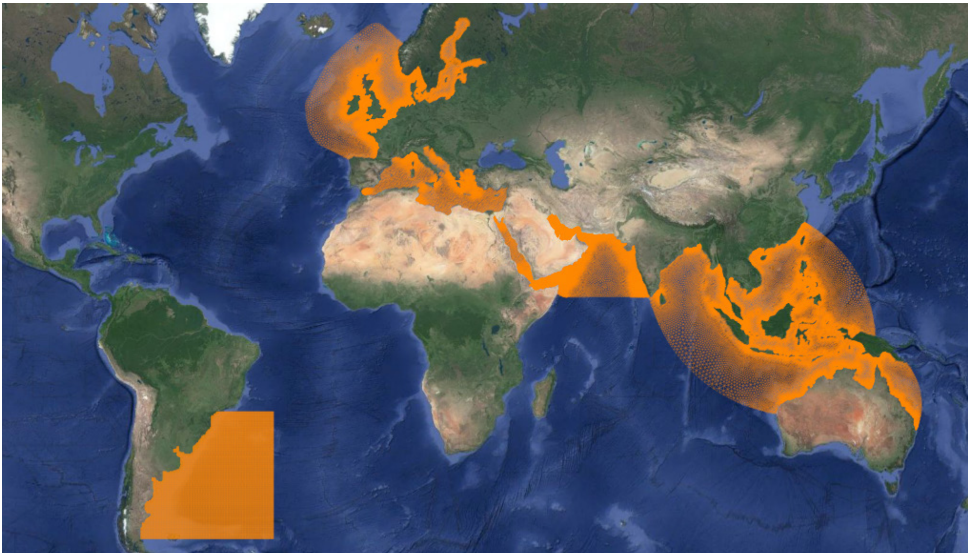
International Marine and Dredging Consultants (IMDC) is an engineering and consultancy company specialised in a vast range of water related projects. Our highly qualified staff offers advice based on recent research results of leading universities and research institutes and hands-on experience acquired throughout the years.

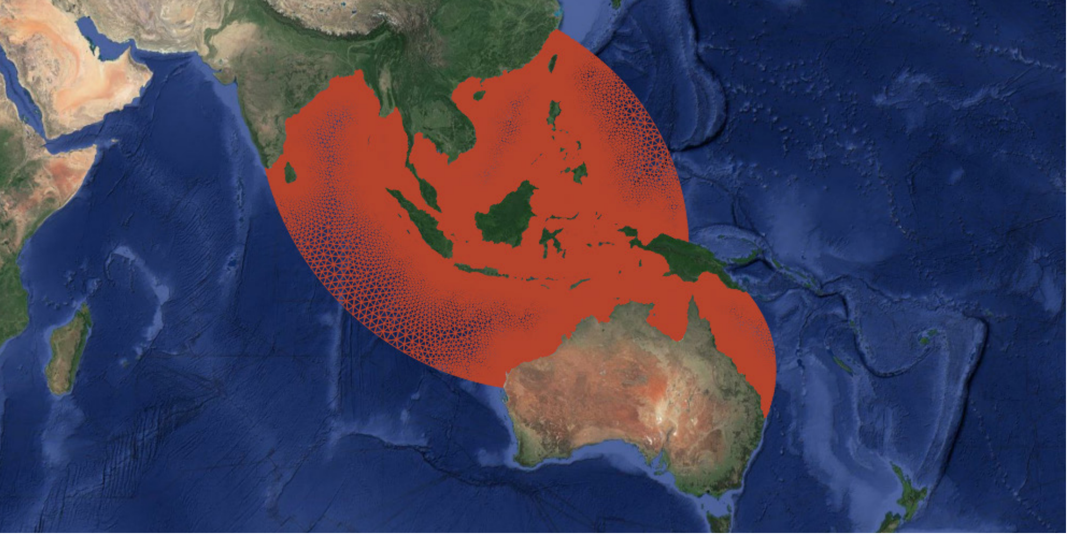
One of IMDC's core activities is presented in this booklet: Development of large-scale models.

More information can be found on our website: www.imdc.be

Development of Large-scale Shelf Sea Models



The objective of IMDC's development of a set of large-scale models is to provide more detailed simulations of water level and flow velocity compared to the class of global ocean models such as e.g. HYCOM, which focus on the 3D dynamics of deep oceans. IMDC's shelf sea models focus on the correct propagation of tides along more shallow seas and gulfs, including the effect of storms on water level and flow velocity.



MASC Model

Products

The products we provide using these large-scale models include water level and flow velocity from:

- Long-term hindcasts
- Real-time forecasting
  (e.g. 6-hourly, 7 days)

The large-scale models provide forcings for smaller and more detailed project-specific models of e.g. a coastline, port area or offshore construction site.

These models can provide:

- Detailed 3D current patterns
- Vertical distribution of flow velocity temperature, salinity and tracers
- Oil slick propagation
- Sediment transport and bed level changes

Applications and Clients

Our hindcast and forecast products are provided to clients in the offshore industry, dredging industry, governmental agencies and coastal communities, amongst others.

The model results are applied in the fields of:

- Offshore renewables
- Dredging and reclamation
- Flood forecasting
- Coastal management
- Ports and navigation studies

General Model Properties

The models solve the shallow-water equations and are driven by tidal forcing at the boundaries and by wind shear at the water surface. The open boundaries are located off the shelf and are driven by the harmonic constituents from the TPXO global tidal inversion. TPXO is one of the most accurate global model of ocean tides, but performs less in more shallow seas, which is another motivation to develop shelf sea models.
The wind forcing is provided from either ECWMF or NOAA global wind solutions, and can be run in either operational forecast or hindcast (historic scenarios) mode.
The shelf models are relatively fast: simulation of one month takes in general a wall time of less than one hour.

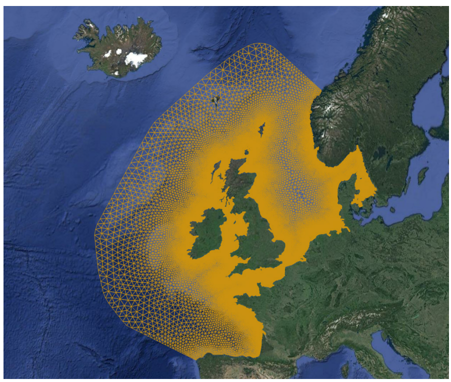
Accuracy

All models are calibrated by adapting model parameters in order to achieve good correspondence with measured water levels. Water level time series measured at stations throughout the model domain are used to assess the model's performance.
In general, it is considered state-of-the-art to aim at a root-mean-squared error of simulated water levels of 0.1 m or less.

Examples of Models

IMDC Continental Shelf Model of the North Sea (iCSM)

The iCSM model is a large-scale 2D TELEMAC flow model created by IMDC to force local North Sea and coastal models. The model covers the North Sea, Celtic Sea, English Channel, Baltic Sea and the Gulf of Bothnia.
The grid consists of 49440 nodes with a minimal grid size of 500 m in the Belgian Coastal Zone, which increases to a grid size of 35 km in the open sea. Grid refinement is applied in some zones such as the Dutch Wadden Islands, and Eastern Denmark.
The iCSM model has been calibrated against measured water level data at several locations. During the event of cyclone Xaver, the model's capability to reproduce storm setup was tested.



iCSM Model

Tethys Model

The Tethys model covers the Arabian Sea, the Red Sea, and the Persian Gulf, the Gulf of Oman, and the west coast of India (the approximate location of the Tethys Ocean that existed over 200 million years ago). The southern (open) boundary of the model is fixed to the 8.25° N latitude, which is the southernmost latitude circle that intersects with India and is on the 0.25° output grid of TPXO (tidal boundary condition). This intersects the coastline near the southern tip of the Indian peninsula in the east, and the coast of Somalia.

The model has an irregular mesh consisting of over 96,000 triangular elements (50,000 nodes). It has a grid size ranging from over 80 km in the Indian Ocean to less than 800 m at the Strait of Hormuz.

The Tethys model has been calibrated against measured CMAP tidal data and admiralty chart data at several locations around the whole model area. For most stations, a root-mean-squared error of order 0.10 m was obtained.

The MASC model

The MASC model covers the Malacca Strait, Andaman Sea, South China Sea and Java Sea. Coastlines of Myanmar, Thailand, Sumatra, Malaysia, Singapore, Cambodia, Vietnam, Hong Kong, Eastern Philippines and Southern China are included.

The grid consists of approximately 50,000 nodes and 95,000 elements. The numerical mesh is especially refined in areas with larger tidal range, in coastal zones and in more narrow straits, such as the Singapore Strait and the Malacca Strait.

The MASC model has been calibrated against measured water level data at several locations. The tides in the South China Sea are predominantly diurnal to mixed diurnal-semidiurnal. In the map below, the spatial distribution of the K1 tidal constituent is shown. It shows a pattern very similar to what can be found in literature.

The model performs well with an average error of 0.09 m compared to measured water levels.

The model takes into account the effects of the different monsoon seasons. As found in literature, the model predicts residual flows to the SSW in the winter monsoon and to the NNE in summer monsoon.

The MASC model is running in real-time forecasting mode on a permanent basis and takes only 10 minutes to simulate one week of tides and flow, including the effect of wind.

IMDC South Asia Model

As an extension of the MASC model, the iSAM model was conceived to incorporate the complex archipelagos of Indonesia and The Philippines. In addition, it includes the east coast of India, Sri Lanka, the south coast of Papua and the northern half of Australia.

Refined computational grids have been laid around the many coastlines of the mentioned archipelagos. This allows for a good tidal propagation through the narrow straits and shallow seas. Based on this model, detailed flow and transport simulations using local models can be carried out in any location in the Bay of Bengal and South China, Andaman, Indonesian and Philippine seas.

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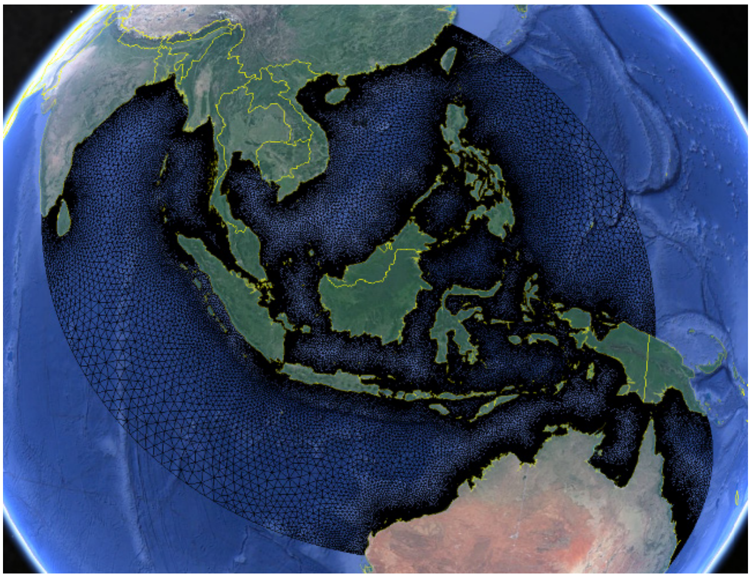
IMDC's South Asia Tidal Flow Model is presented in this product sheet.

More information can be found on ourwebsite: www.imdc.be

IMDC's South Asia Tidal Flow Model



IMDC's South Asia Model (iSAM) is a large-scale, 2D TELEMAC flow model created by IMDC. The model includes Eastern Atlantic Ocean, Western Pacific Ocean, as well as the Southeast Asian and Northern Australian waters between them.

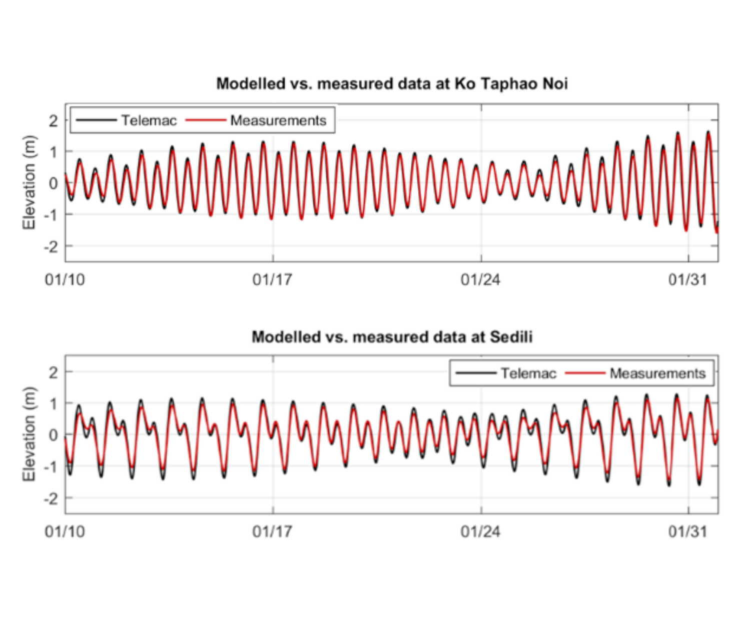
iSAM domain and mesh

The grid consists of approximately 120,000 nodes and 224,000 elements. The numerical mesh is especially refined in areas with larger tidal range, in coastal zones and in more narrow straights.

The model is driven by tidal forcing. The open boundaries are driven by the harmonic constituents from the TPXO global tidal inversion. TPXO is one of the most accurate global model of ocean tides, and best-fits, in a least-squares sense, the Laplace Tidal Equations from TOPEX / Poseidon and Jason.

A time step of 200 s is used in the model, and the CPU time needed to run the model is only approximately 15 minutes per simulated month, on 16 CPU's.

The model has been calibrated against measured water level data at many locations. The figures below show the modelled and measured tidal water levels at Ko Taphao Noi and Sedili. The mixed diurnal-semidiurnal tides are successfully captured by the model.



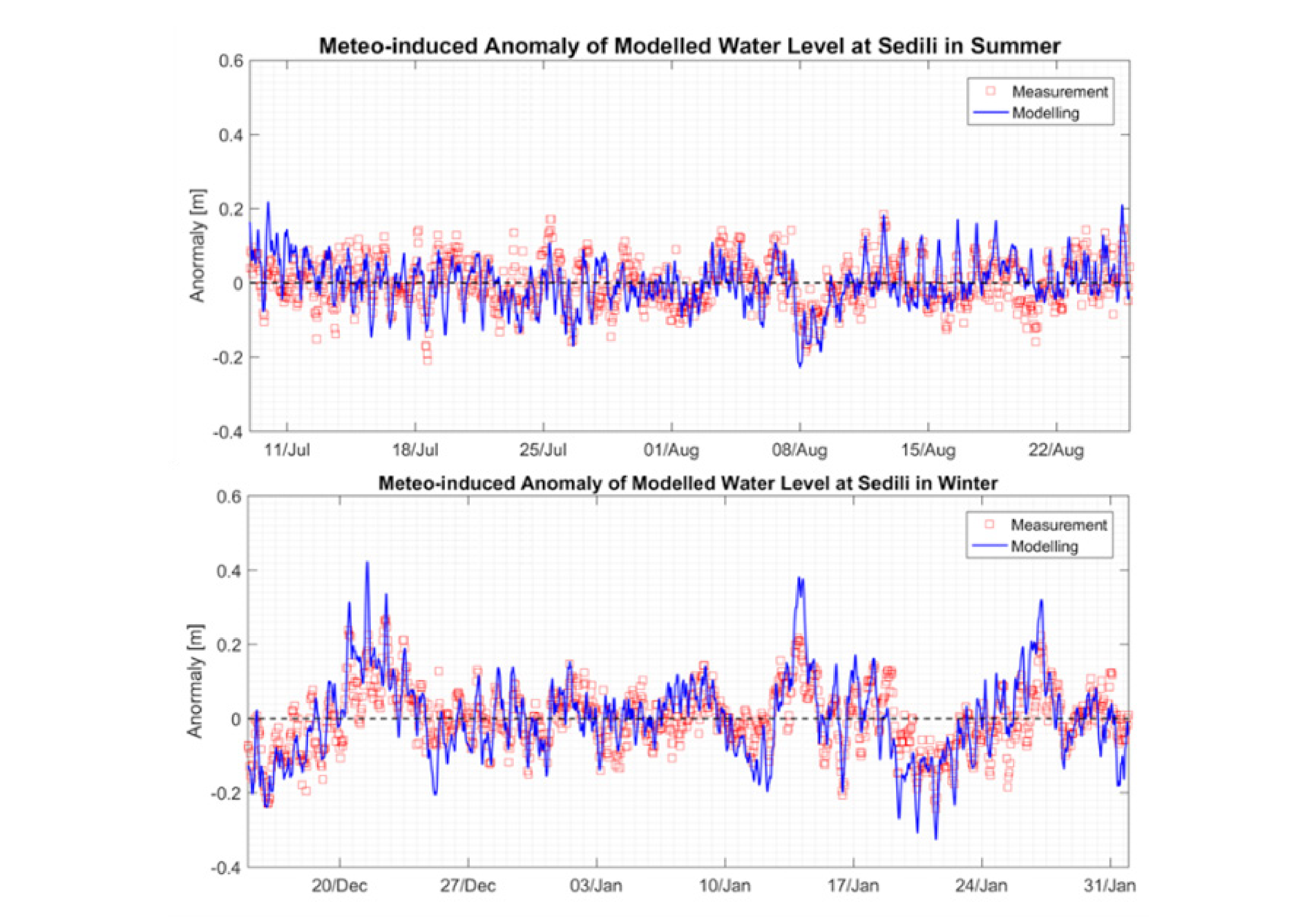
Comparison of water level between model and measurement

In addition to the tidal forcing, the waters in this region are strongly influenced by monsoons which prevail south-westward from November to February (winter) whereas north-eastward from June to August (summer).

In order to take into account effects of the different monsoon seasons, the model can be also imposed with meteorological forces consisting of wind and air pressure fields. The meteorological data is provided from GFS global wind solutions (NOAA), and can be run in either operational forecast or hindcast (historic scenarios) mode. The figure below shows the modelled and measured anomalies of water level at Sedili in summer and winter respectively.

Comparison of water level anomalies between model and measurement

The iSAM model can be used to generate boundary conditions for more refined project specific models, which can be adjusted according to the clients requirements. The more refined models allow detailed assessment of local hydrodynamics, sediment transport and medium to long term morphological changes.



Scan the QR for more informaton

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The IMDC North Sea Continental Shelf Model is presented in this product sheet.

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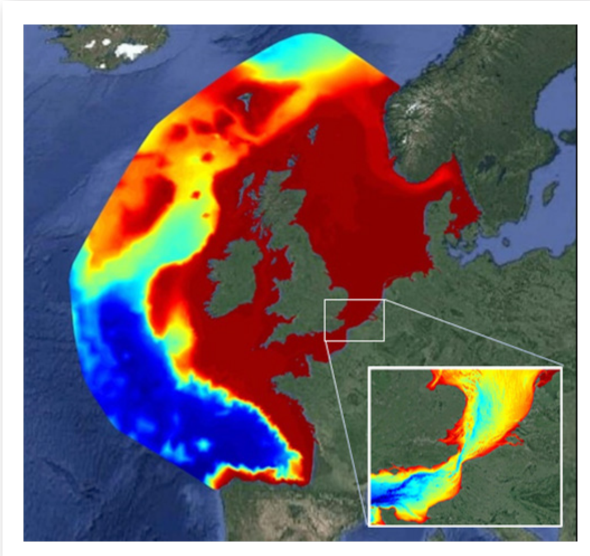
A North Sea Continental Shelf Model by IMDC

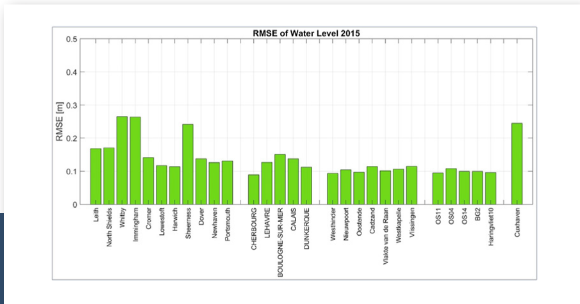
The IMDC's continental shelf model (iCSM) is a TELEMAC-2D barotropic tidal-surge model developed in-house, covering the domain of the North Sea, the Irish Sea, the Celtic Sea and the Bay of Biscay.

The model mesh consists of 150,000 computation nodes. A time step of 2 minutes is used, running 2 hours for 1 year simulation with 48 cores which is extremely efficient. The model is recently updated with EMODNET 2018 bathymetry (~115 × 115 meters) and ERA5 hourly data of space- and time varying wind (at 10-meter height) and air pressure at MSL. At open boundaries, the model is forced by both harmonic tide (TPXO9.v1) and surges due to variations of atmospheric pressure (inverse barometer correction) and ocean water density changes (steric sea level correction). Besides, the pronounced internal tide dissipation occurred in Bay of Biscay is successfully simulated in the model, together with the impact of self-attraction and loading.

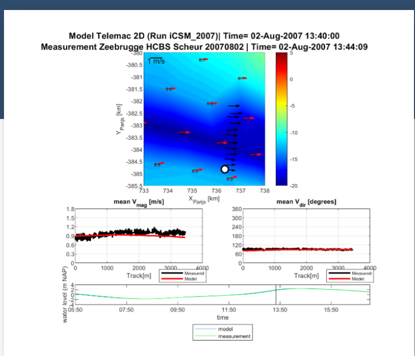
The model is automatically calibrated on bottom friction on the platform of SALOME – Hydro with three-dimensional variational assimilation (3D-Var). The model shows reliable ability to precisely reproduce the hydrodynamics in the North Sea. The averaged Root-Mean-Square Error (RMSE) of water level at the Belgian coast is **10** cm.

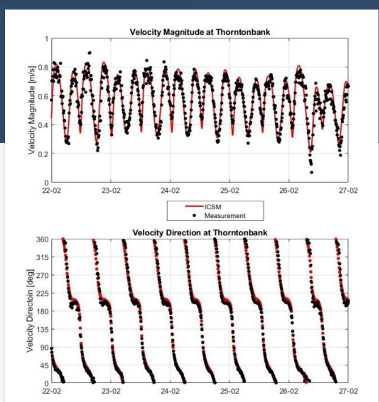


Region	|BIAS| [cm]	RMSE [cm]	|ΔM2| [cm]	|ΔM2| [deg]
Eastern British	8.0	17.1	1.8	2.9
French	2.2	12.3	6.3	0.8
Belgium & Western Scheldt	1.6	10.4	1.8	0.6
Dutch Eastern Scheldt	2.2	10.0	1.6	0.5
All	3.5	12.4	2.8	1.3



iCSM is a powerful tool for both hindcasting and forecasting of hydrodynamics in the North Sea. As an end product, the IMDC's Metocean Database fulfills the needs of using reliable metocean data for various engineering and scientific studies.





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