



Tidal Streams along Brittany Northern Coast, France

Lucia Pineau, ATLANTIDE (formally at Hocer), France

Tide and tidal streams can be predicted with the help of numerical models, at any point in a zone of study. The numerical model is based on the available data (coast line, bathymetry and boundary conditions). It is then validated by comparing the calculated values with the measured water depths and currents. The validated numerical model is the basis for the tidal streams charts, published by SHOM (Service Hydrographique et Océanographique de la Marine, France).

Presentation of the Zone of Study

Morphology

The zone of study is located between Aber Wrac'h and Héaux de Bréhat. The coastline of northern Brittany is very rugged; throughout its length there are many exposed rocks. The morphology of the zone is presented on Figure 1:

- From Héaux de Bréhat to Grande island, the rocky coast is penetrated by the Jaudy river and creeks, the Perros creek being the most important. Numerous rocks and islets appear along the coast. The group of the Sept Islands protrudes to the north of Ploumarnanac'h. The coves provide sheltered harbours
- A large bay opens on the islands of Grande and of Batz, separated by 16.5 miles. The rocky platform of la Méloine extends in the centre of the bay and divides it into two parts, the Lannion Bay to the east and Morlaix Bay to the

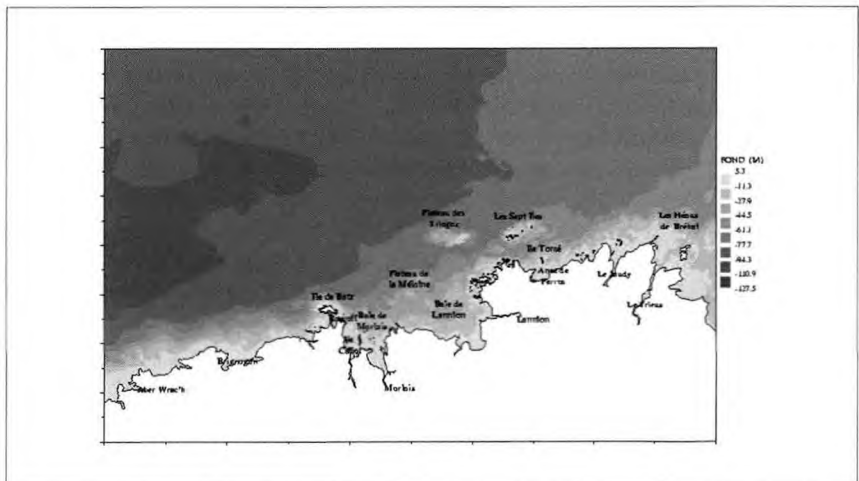


Figure 1: Morphology of Northern Brittany

west. The Roscoff Harbour located at the headland closes Morlaix Bay to the West

- From Roscoff to Aber Wrac'h, the coast has many dangers extending up to several miles seaward

These many rocks, islands and shoals have to be taken into account and make navigation dangerous:

- The main islands are: Sept Islands, Tomé Island, Callot Island and Batz Island
- The main platforms are the platforms of Triagoz, la Méloine and les Duons, at the entrance of Morlaix Bay

Oceanography

The tide is of a semi-diurnal type. It is the result of a wave propagation coming from the west of the English Channel. On the French coast, the tidal amplitude varies from less than 6 metres in the western end of the zone, to about 9 metres in the eastern end.

The coastal currents are strong and sometimes run across channels.

For a medium spring-tide, currents velocity can reach:

- 3 knots in the Batz channel
- More than 4 knots in the north of the Batz Island
- More than 4 knots at the Sept Islands
- 3 knots between the platform of Triagoz and Grande Island

Model Set Up

Grid

The available data come from the different EPSHOM (Etablissement Principal du Service Hydrographique et Océanographique de la Marine) bases (coast line and bathymetry). The coastline data has taken a long time to process, as the different files were not at the same scale: a global file at the scale 1:375,000, Morlaix Bay and Lannion Bay at a scale of 1:150,000, the islands and five ports at a scale of 1:25,000.

The grid has been processed by the gridding system MATISSE, developed by the Laboratoire National d'Hydraulique d'EDF (Electricité de France) (Pinau, 1997). The resulting grid is made of 27,300 nodes, 51,700 elements and 102 islands and is presented in Figure 2. The Bays of Lannion and Morlaix have been represented more precisely (Figure 3), as well as the ports of Roscoff, Perros-Guirrec, Trebeurden and Batz island. The gridding step varies between 20 m and 15 km.

Bathymetry

The bathymetric data comes from soundings on the charts (22,000 points), isobaths of the large scale charts (45,000 points) and recordings available for the zone (1,500,000 points). A land digital model had to be used to cover certain areas such as around Grande island. The final file for the bottom includes:

- 61,000 points coming from the bathymetric charts
- 383,000 points coming from the land digital model of charts and recordings
- 220,000 points coming from the recordings of Morlaix Bay

Boundary Conditions

The boundary condition have been automatically generated by harmonic prediction. They have been defined through prediction models developed by EPSHOM, for medium spring-tides (coef. 95) and low tides (coef.45).

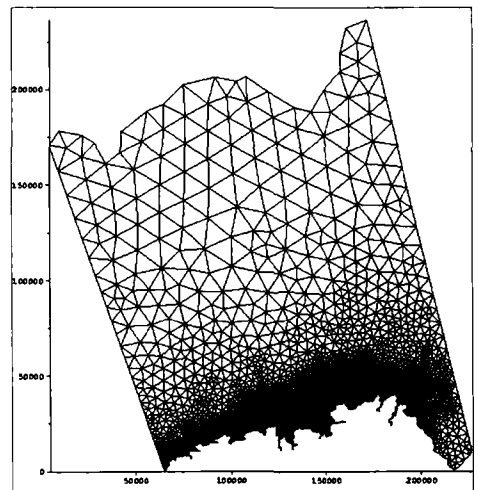


Figure 2: Grid over Northern Brittany

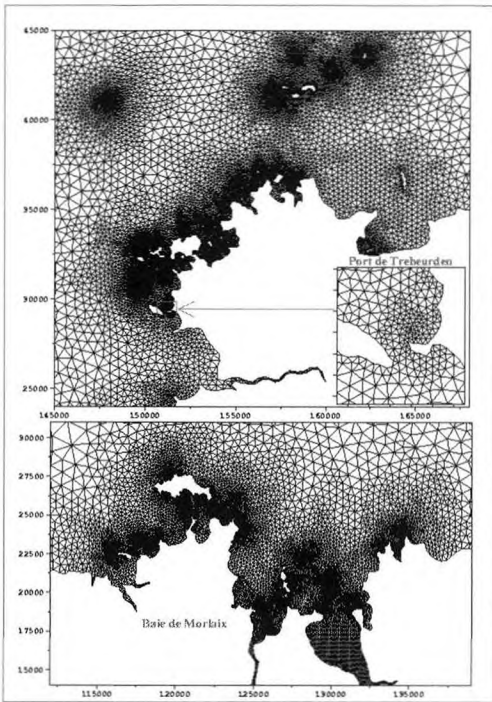


Figure 3: Grid detail over Northern Brittany

Hydrodynamic Software

The hydrodynamic software used to calculate tide and currents is TELEMAC2D, developed by the Laboratoire National d'Hydraulique d'EDF (Electricité de France) and commercialised by SOGREAH (in Grenoble, France). This software resolves the Saint-Venant equations. To insure the model stability, steep bottom gradients must be avoided (Janin, 1992), the grid size must be adapted, small and large grid cells must not be juxtaposed, the triangles must be as equilateral as possible, ... Setting up the model is a long process. Once the model is stable, some physical and numerical parameters still must be adjusted (*to suppres*).

Model Validation

Tide

Comparison with Predictions

Water depths have been calculated for 19 chosen points, spread out inside the zone (cf. Figure 4). These values calculated by the modal for tide coefficients of 45 and 95 have been compared with harmonic predictions (software cc/ 45-95) and the superimposition of the two are presented in Figure 5. The values coincide

perfectly in the southern area (points 1 to 13), but start to diverge towards the English coast (points 14 to 19).

- In the northern part, points 14, 17 and 18, have divergences of 15 to 22 cm in medium spring-tide. Points 16 and 19 show a good coincidence, but it is due to the proximity with the western boundary (near tide boundary conditions)

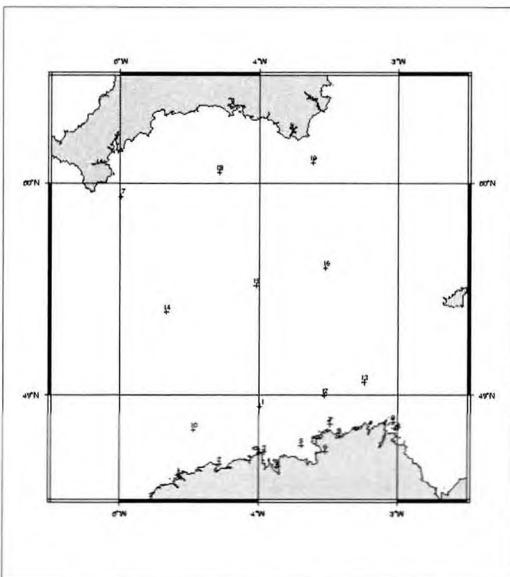


Figure 4: Location of the reference points for the water depths

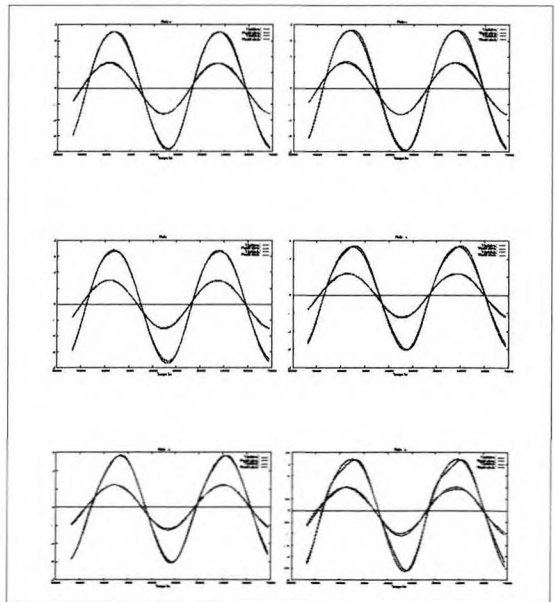


Figure 5: Comparison between the water depths from the model and the predicted water depths

- In the southern part, differences between the values and the predictions vary from 1 to 12 cm. Only the points 10 and 11, which are the farthest north, have divergences over 10 cm. Many points have divergences less than 3 cm

This difference in the coincidence of the results between the north and the south can be explained by the variation of the size of the grid cells: from small detailed in the south, to large cells up to 15 km in the middle of the English Channel (cf. Figure 2). This shows the influence of the grid size on the quality of results.

The model is satisfactory in the south, which is the zone of interest and presents divergences between model and predictions, generally less than 10 cm and frequently less than 5 cm. There is a phase displacement of less than 10 minutes. This phenomenon is probably due to the physical parameters which have an effect on the tide wave propagation (friction, viscosity, ...).

The Tide at Brignogan

During our first comparison model/prediction, we have noticed that the divergences were clearly less than 10 cm at the coast, except at Brignogan (11.4 cm). We then had to review the predictions: the recent value measured at Brignogan has not been introduced into the model. After reintegration of the data and new calculation, the divergence was reduced to 1.6 cm. Figure 6 shows the tide calculated by the model at Brignogan (Model 95), the prediction before the introduction of the harmonic constants of Brignogan (Prediction95-old) and the new predictions (Prediction95): with missing points of measurement at Brignogan, the model gives better results than the harmonic prediction. This is particularly interesting and shows that there are possibilities of improving the tide predictions with the help of the numerical model.

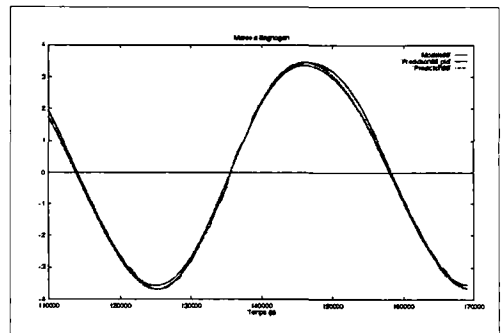


Figure 6: Improvement of the prediction for the case of Brignogan

Tidal Streams

Available Data

The available tidal stream data come from various information sources:

- Publication n°550 (SHOM, 1976) gives a lot of information on currents, but with sometimes overestimated strength values
- SHOM stream measurements
- EDF stream measurements from the study for the project Salmor (Latteux, Thellier, 1987)
- Work from the biologic station of Roscoff (Cabioc'h, Douvillé, 1979)
- The previous atlases published: Normandy-Brittany Gulf (SHOM, 1998) and Western coast of Brittany (SHOM, 1994)

Points of measurements for the currents are presented on Figures 8 and 9. Over our study zone, 18 points are available:

- At sea, points 207, 208, 209, 211, 221, 222, 204, 1102, 1130, & 1131 (cf. Figure 8)
- In Morlaix Bay, points 1128, 220, 1058, 217, 218, 219, & 1129 (cf. Figure 9)

For 1129, 1130, & 1131, measurements have been made in April 1998, to be incorporated into the model. Some data cannot be used:

- In Morlaix Bay, points 937, 938, 939, 940, & 941. Those measurements have been made by the Laboratoire National d'Hydraulique (EDF), at 5 m from the sea bottom, between 27 November and 10

December 1987. During this period, the tide coefficient has varied from 54 to 81. We only have original recordings on paper: there have not been any analyses done, to allow the deduction of currents with coefficients of 45 and 95. Moreover, these measurements are contradictory with the values coming from the Biologic Station of Roscoff and also the data from publication n°550: the current amplitude is clearly smaller. The EDF report (Latteux, Thellier, 1987) does mention this contradiction and suggests that "it could possibly be a local phenomenon, non visible on a marine map and which locally disturbs the flow". The logarithmic model of the vertical profile could help evaluate the speed in subsurface, but we do not know the phase difference between the surface and the bottom

- Points 222, 225, 1104, & 205. These points are too close to the south-western and south-eastern corners, where there are problems of numerical instability due to the fact that we only impose one value to a flow in (water depth), when we should impose two (also the velocity). Unfortunately, velocities are generally not well known at the boundaries. To mitigate this lack of information, we have imposed a strong shearing in those corners. The current then becomes slower than the measurements and out of phase: the exploitable area must be far enough from the zone boundaries.

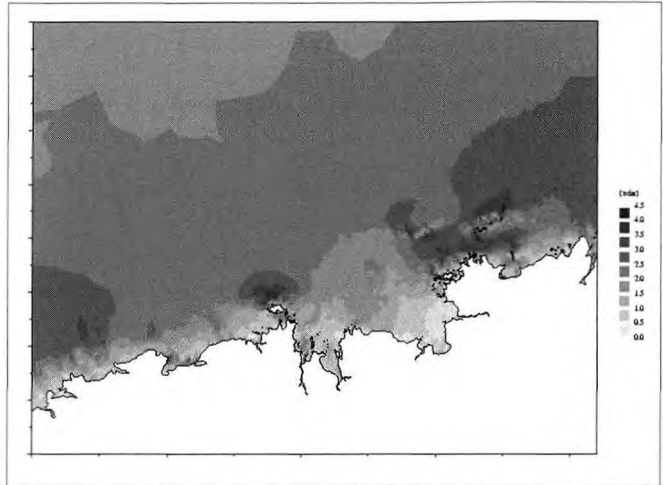


Figure 7: Maximum currents within the zone of study

Open-sea Tidal Streams

Publication n°550

The general information provided by publication 550 is verified by the model: velocities are well over 2 knots in the north of the Batz Island, towards only 1.8 knots in the middle of the English channel and decreasing progressively northward to less than 1 knot at the north of a line from Start Point to Lizard Cape. However, in front of the big capes, such as these two, the current is locally much stronger, over 2 knots. Near to the coast, the currents are generally weaker, less than 2 knots, except in the passes and channels.

The turn of tide happens earlier in the west than the east and in the south than the north, meaning that the turn occurs first at the coast, which is obvious on currents charts (see in Figure 11). Here are some maximum values given by the publication 550 and by the model (cf Figure 7):

- In the north of the Sept Islands: 2.5 to 3 knots/2.5 to 4.1 knots
- Channel of the Sept Islands: 2.5 to 3 knots/2.5 to 4.1 knots
- 2 miles north of Grande Island: 3.5 to 4 knots/3.5 knots
- Between Triagoz and Grande Island: 2.5 to 3 knots/2.5 to 3 knots
- North of Batz Island: 4 knots/4.3 knots

Values coming from the model coincide well with information found in publication 550. The currents around the Sept Islands reach 4 knots, though the publication states only 3 knots.

SHOM Measurements

The 11 points are evenly spread, as shown in Figure 8. Streams from the model and from the measurements have been superimposed in Figure 10. With a tide coefficient of 95, the distributions coincide perfectly for points 221, 222, 207, 202, 1102, & 1130. For the points 211, 209, & 204, the model distri-

bution are slightly out of phase of 15 minutes. The maximum phase difference is 30 minutes (points 211). The minimum amplitude divergence is 0 (point 1102), when the maximum is of 30 per cent (point 204). Directions coincide generally well, but the model tends to smooth the distributions (ie 1131).

Streams within Morlaix Bay

Publication n°550

In Morlaix Bay, currents change considerably from point to point and according to the presence of passes and rocks. Here are some maximum values respectively provided by the publication and by the model (cf. Figure 7):

- 2 miles north of Batz island: 4 knots/4.3 knots
- In the eastern entrance of the channel of Batz island: 2.5 to 3 knots/3.2 knots
- Between the platform of Duons and the headland of Bloscon: 2.5 to 3.5 knots/2 knots
- In the channels of the Morlaix Bay: 1.5 to 2 knots/1 to 1.5 knots
- At the entrance of Penzé river: 1.5 to 2 knots/1.5 to 2 knots
- In the Penzé river: 2.5 to 3 knots/2.5 to 3 knots

Except for the channels where they are weaker, the values of the model coincide well with the measurements provided by the publication 550. However, the publication tends to overestimate some velocities, which is preferable for the safety of navigation.

SHOM Measurements

The seven reliable points of the bay are presented on Figure 9. Overall, the results are satisfying (Pineau, 1998), except for point 1058. For that case, the measurement was made at 3.5 m from the bottom, with a total water depth of 15.3 m. The maximum amplitude measured is 1.2 knots, when the model gives 1.6 knots. However, by applying the logarithmic model of the vertical profile, the surface velocity would be 1.65 knots, which is comparable to the velocity of the model (Pineau, 1998). Concerning the difference in phase, doppler measurements confirm that there can be a shift between bottom and surface, although we do not know of any study which would provide a reliable way of estimating it. This point 1056 is to be discarded.

Point 1129 has a correct amplitude, but not for the turn of tide. It is surprising to notice that for a 95 coefficient, a shift of half an hour appears, when for a 45 coefficient they are in phase. In this area, with rough bathymetry, the current distribution is complicated and cannot be determined numerically.

There is no shift for the points 1128, 217, & 218

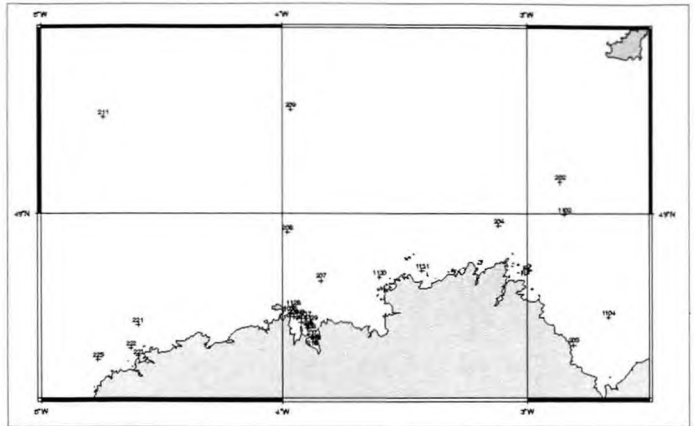


Figure 8: Location of the measurements point for the streams

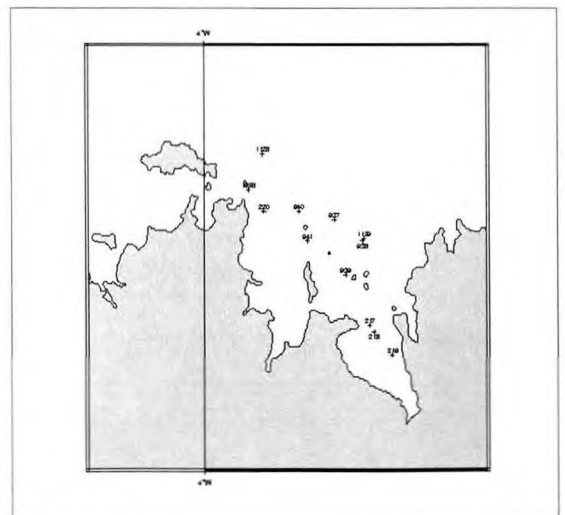


Figure 9: Location of the measurements points for the streams within the Morlaix Bay

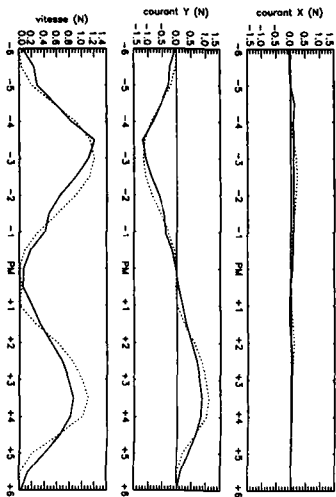
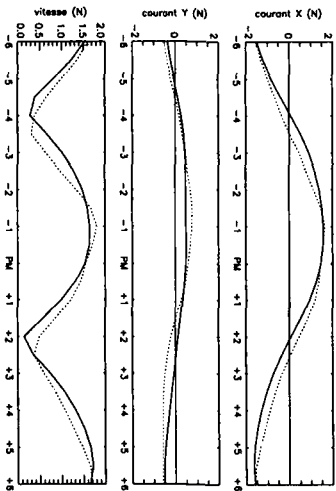
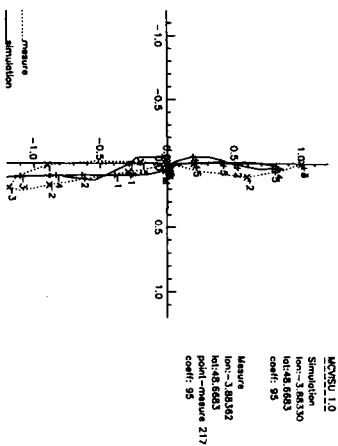
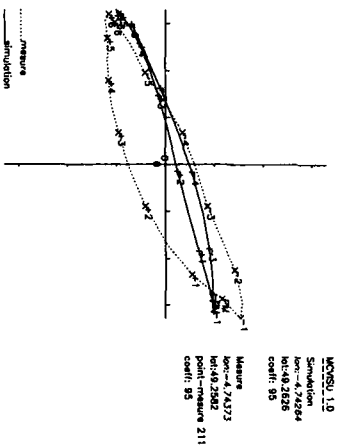
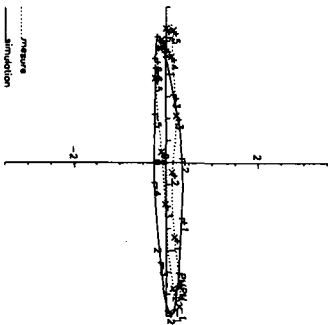
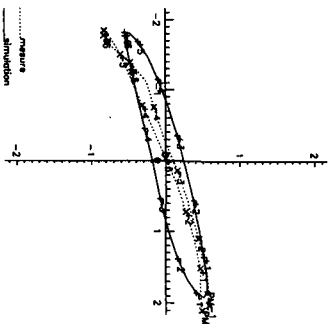


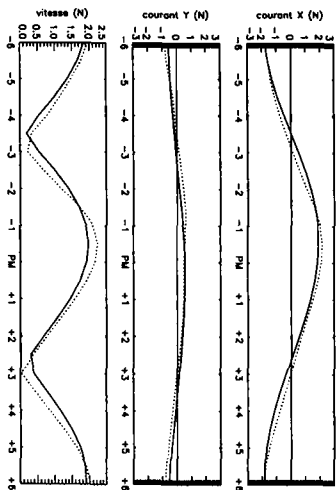
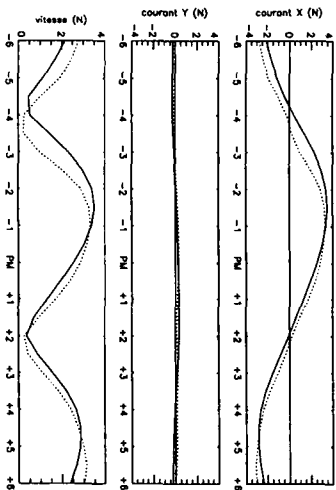
Figure 10: Superimposition of the streams from the model and from the measurements

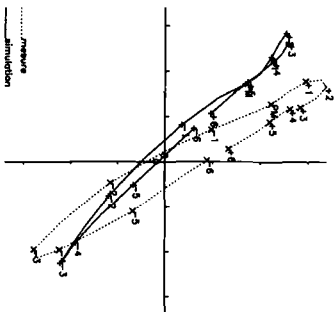


MCRSL 110
 Simulation
 lon: -3.11718
 lat: 48.8058
 coef: 95
 Mesure
 lon: -3.2231
 lat: 48.8048
 point: mesure 204
 coef: 95

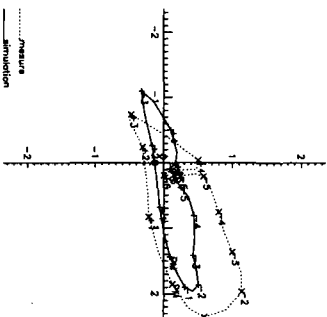


MCRSL 110
 Simulation
 lon: -3.89795
 lat: 48.2808
 coef: 95
 Mesure
 lon: -3.92044
 lat: 48.2764
 point: mesure 209
 coef: 95

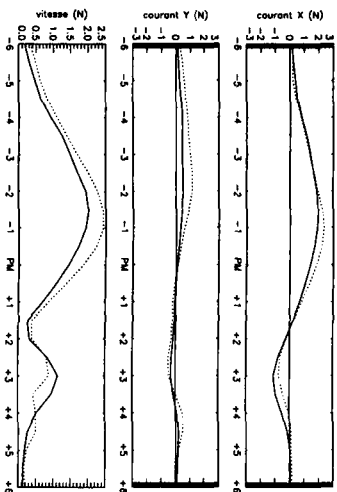
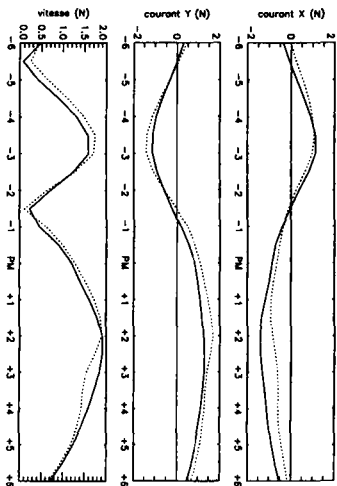


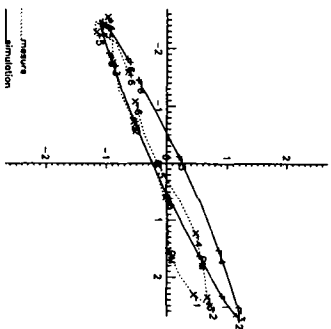


MONSU 1.0
 Simulation
 lon - 3.82856
 lat - 43.7500
 coeff: 95
 Mesure
 lon - 3.82856
 lat - 43.7487
 point - mesure 1128
 coeff: 95

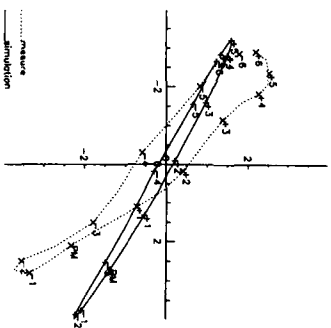


MONSU 1.0
 Simulation
 lon - 3.82844
 lat - 43.8470
 coeff: 95
 Mesure
 lon - 3.83163
 lat - 43.8470
 point - mesure 1131
 coeff: 95

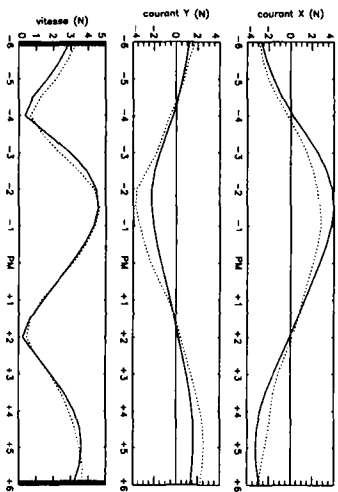
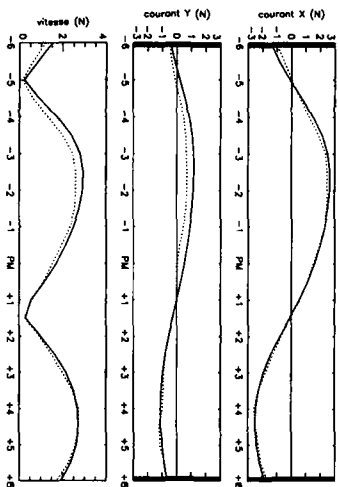




MORSE, 1.0
 Simulation
 point-mesure 221
 lat: 46.7008
 lon: -4.60072
 point-simulation 221
 lat: 46.7008
 lon: -4.60072
 coeff: 95



MORSE, 1.0
 Simulation
 point-mesure 1102
 lat: 46.8977
 lon: -2.85418
 point-simulation 1102
 lat: 46.8977
 lon: -2.85418
 coeff: 95



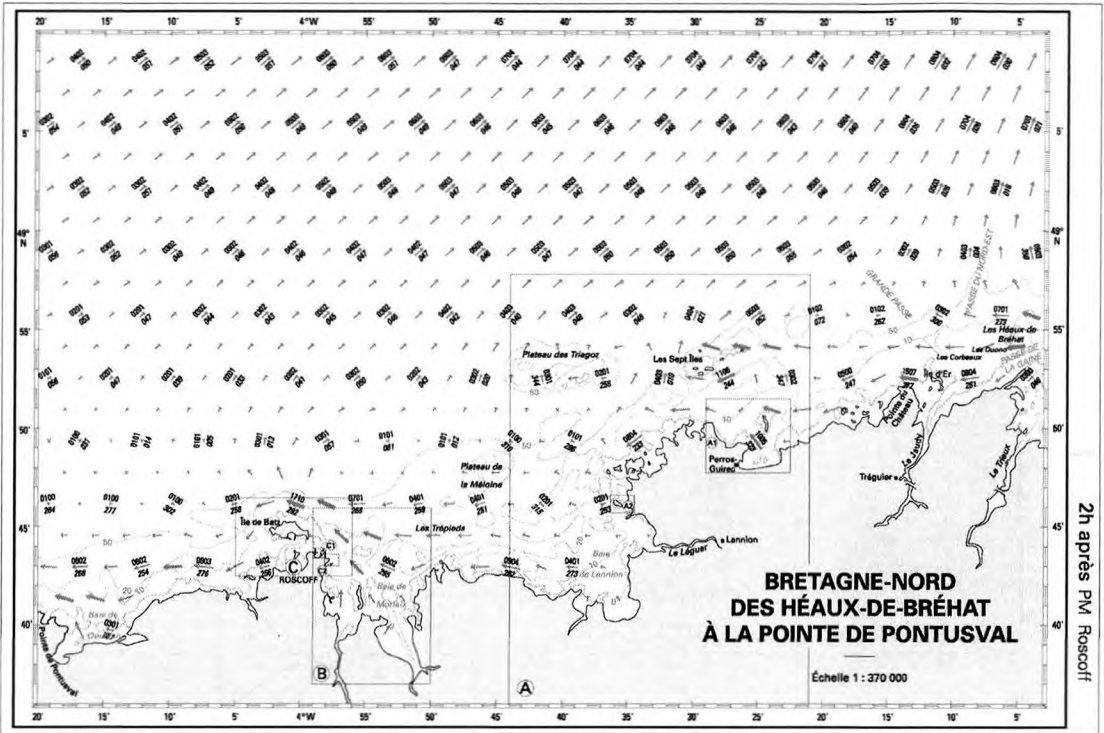


Figure 11: Tidal streams along Brittany Northern Coast

and in any case, the shift is of less than half an hour. The amplitude variation remains below 30 per cent.

1998 SHOM Measurements

We have requested the establishment of 3 current profilers to validate the model. We did not have any measurement between Morlaix bay and the Jaudy river, in the zone where the currents are very strong, particularly between the Sept Islands and the coast and between the Triagoz platform and Grande Island. Measurements at 1130 and 1131 have confirmed the predicted values of the model (around 2.5 knots).

In Morlaix Bay, the model did not agree with the EDF results (Latteux, Thellier, 1987). Predicted values were systematically higher than the measurements (ie, for point 938, 0.8 knots for the model and 0.5 knots measured, thus a 60 per cent error). Point 1129, located near the EDF point 938 (cf Figure 9) has validated the model with a value of 0.8 knots.

Comparison with the Other Atlases

The turn of tide coincides with the Atlas for the

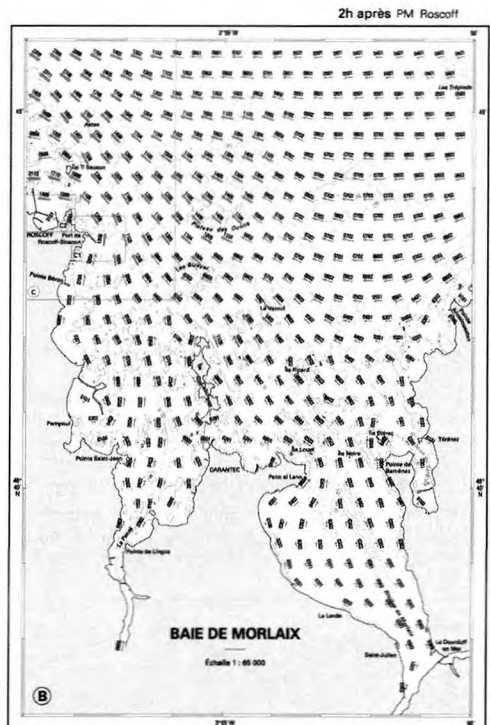


Figure 12: Tidal streams Morlaix Bay

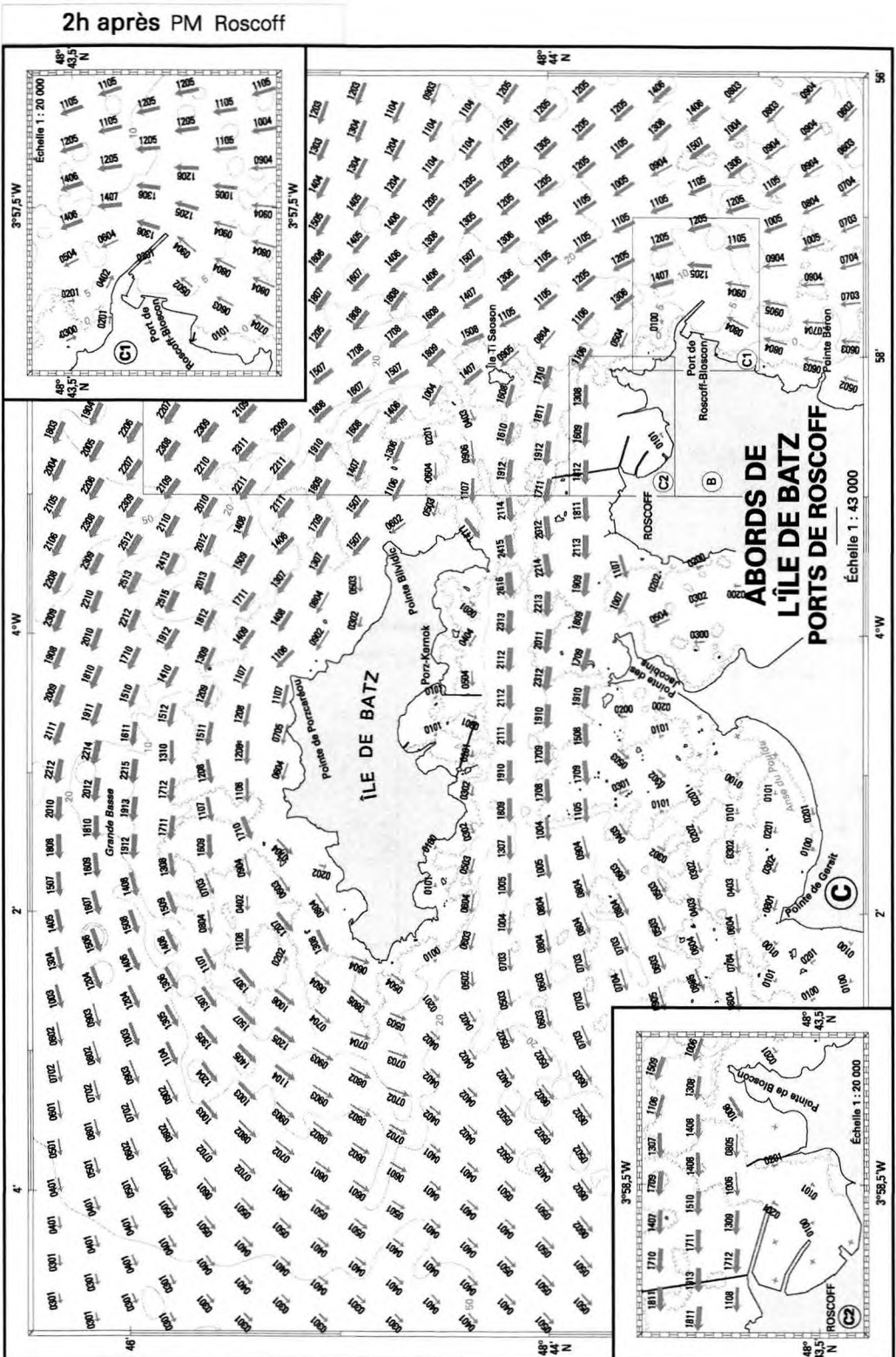


Figure 13: Tidal streams around Batz Island

2h après PM Roscoff

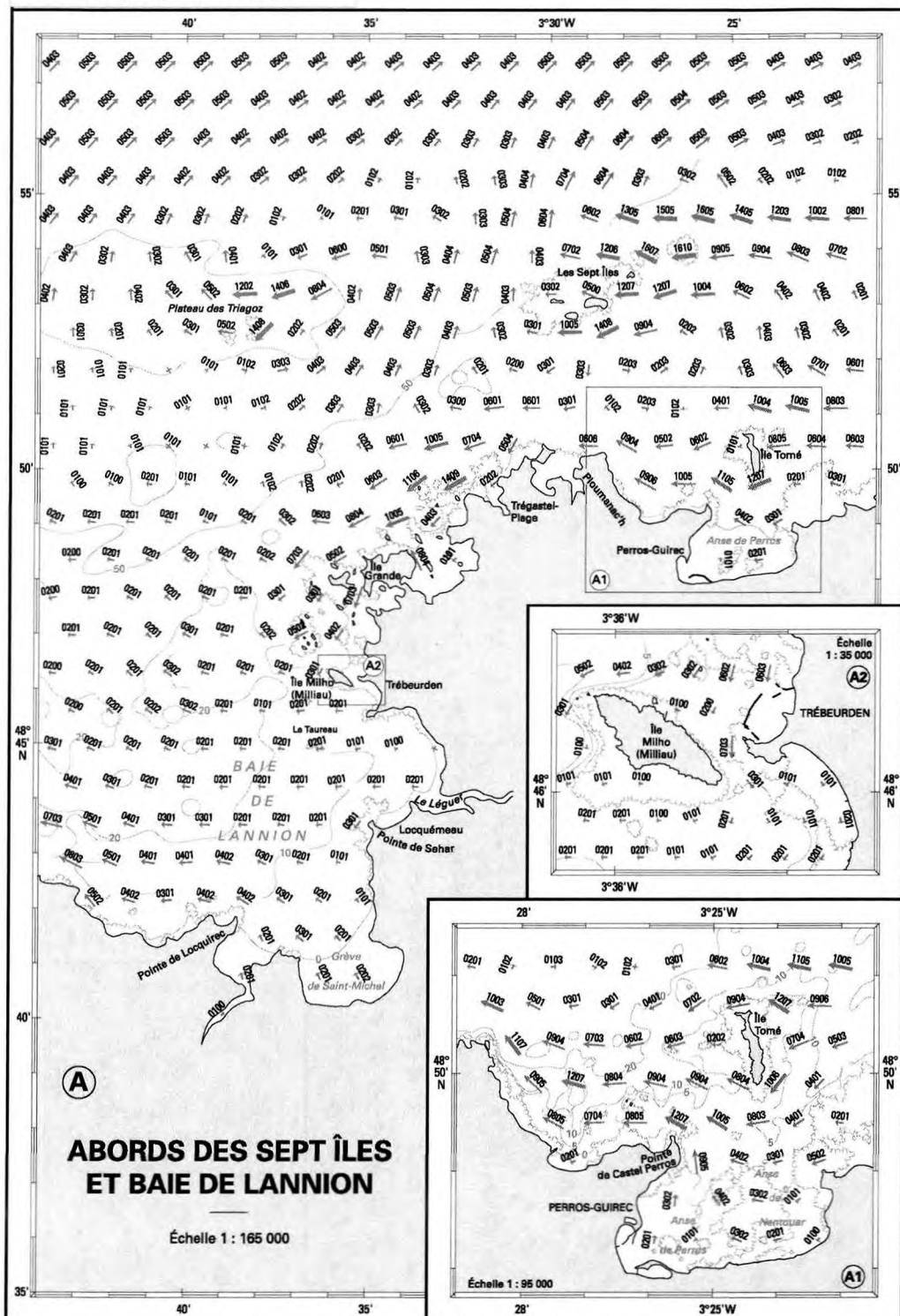


Figure 14: Tidal streams in Lannion Bay

western coast of Brittany, but, there is a small shift of a few minutes, with the Normandy-Brittany Gulf. Considering the currents distributions at the western boundary of the zone of study (no shift at 1102 and 202), the northern Brittany model is correctly adjusted at the boundary. So, results from the Northern Brittany model should not be adjusted to those of the Normandy-Brittany Gulf.

Results of the Model

The currents charts issued from the model are presented Figures 11, 12, 13 and 14. The Atlas including the complete work has been published by SHOM (1999) 'Tidal streams along Brittany Northern Coast'.

Conclusions

Globally, the results from the Northern Brittany model are satisfying and very encouraging compared with previous models. For the model of the Normandy-Brittany Gulf, there was a systematic shift in certain areas, which could reach 1 hour. On the contrary, currents from the Northern Brittany model are generally in phase and at the most, half hour of shift can appear. This allows a better reliability to the results.

The adjustments of the Northern Brittany model again confirm the importance of the boundary conditions and bathymetry in numerical modelling. The channel of Batz island and the Roscoff harbour could not have been covered without the availability of the SHOM bathymetry data base, in particular the Morlaix Bay recordings. SHOM has the most extensive and most detailed data base for the waters of the French coast and the development of this model allows to valorise these data.

We would also like to insist on the importance of the measurements: if the bathymetry and the boundary conditions are the base of the model, validation is only possible thanks to measurements. For various reasons, the model does not always perfectly fit the reality (too big grid step, imprecise bathymetry, non verified hypotheses...). The degree of accuracy and reliability of the model depends on the conclusions about the comparison with the measurements. It would be nonsense to make all efforts to develop models and neglect to validate them.

Lastly, this study shows new opportunities in terms of tide predictions: the Northern Brittany model provides very accurate water depths with an accuracy greater than 10 cm. This model confirms the possibilities for improvements in tidal predictions with the help of numerical simulation.

Biography

Lucia Pineau is an engineer in numerical hydraulics, 1997' ENSEEIHT (French National School of Hydraulics, Toulouse, France) graduate. She has been working for French Naval Hydrographic and Oceanographic Service (SHOM) on different coastal hydrodynamics modelling projects: development of tidal streams charts along French coasts and enhancement of tidal prediction software. She presently works at ATLANTIDE, a French innovative technologies company, which one core competency is sea sciences and technologies (www.ago.fr).