Invited Talk

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Moving objects at sea: trends and challenges

Over the past few years moving objects have been a subject of considerable research attention in the fields of spatio-temporal databases and geographical information science. The range of potential applications is large and cover many areas, but has been so far limited to conventional domains of GIS. This talk will take a different perspective, by considering moving objets not in land but at sea, and will survey current techniques, research advances and issues of the specific domains around objects at sea. The talk will survey current maritime information systems and navigation-aided systems and some of the research projects developed so far at the Naval Academy Research Institute in France, while emphasizing some of the research challenges still open.

Moving objects at sea: trends and challenges

Prof. Christophe Claramunt

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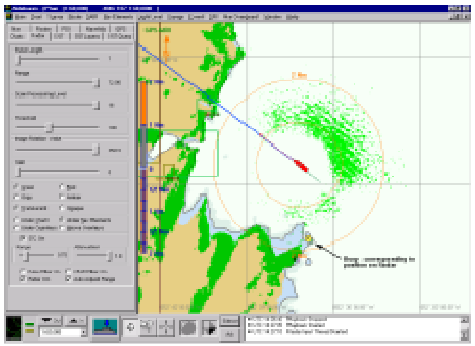
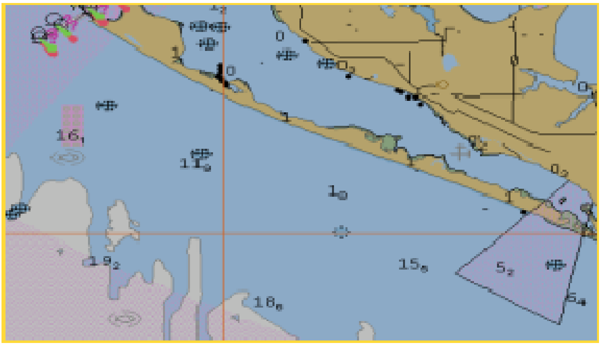
cost
EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

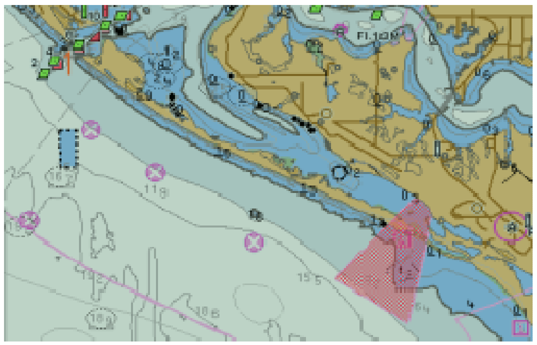
MOVE (Knowledge Discovery from Moving Objects)

Moving objects at sea: trends and challenges

Part I Current trends

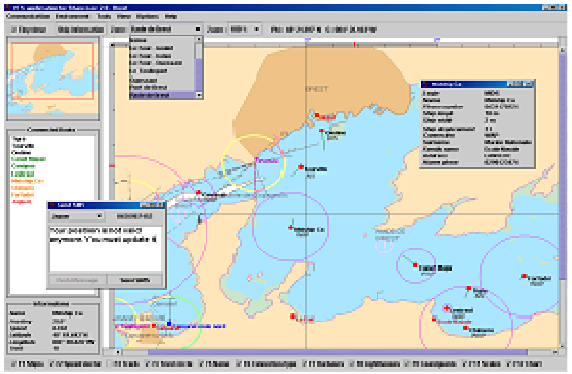






Moving objects at sea: scope

- The way we consider moving objects at sea are the ones, **mainly ships**, closely related to the modelling, monitoring, simulation, visualization and analysis of maritime data, while applications cover transportation, environmental studies and security (amongst others)
- Research and application fields :
  - Maritime and geographical information systems
  - Spatio-temporal data analysis and spatio-temporal data mining
  - Visualisation, simulation and decision-aid systems
  - Human factors, …



Maritime Navigation: context

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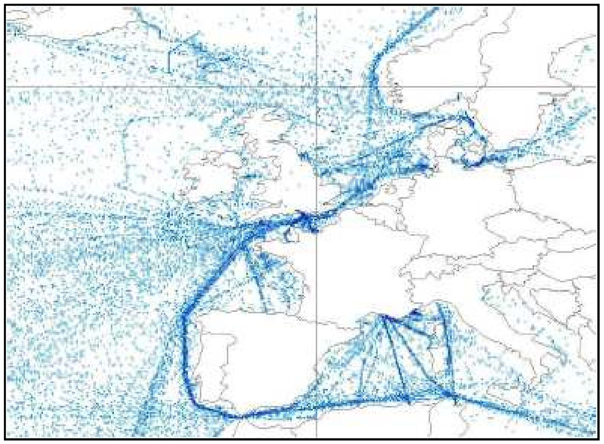
- Ships and control centres have to face many safety problems due to :
  - Staff reduction
  - Traffic increase, dangerous materials
  - Piracy and terrorism risks
  - Multiple and heterogeneous positioning and navigation systems to integrate (AIS, ARPA, Argos, Iridium, ECDIS,)
  - …



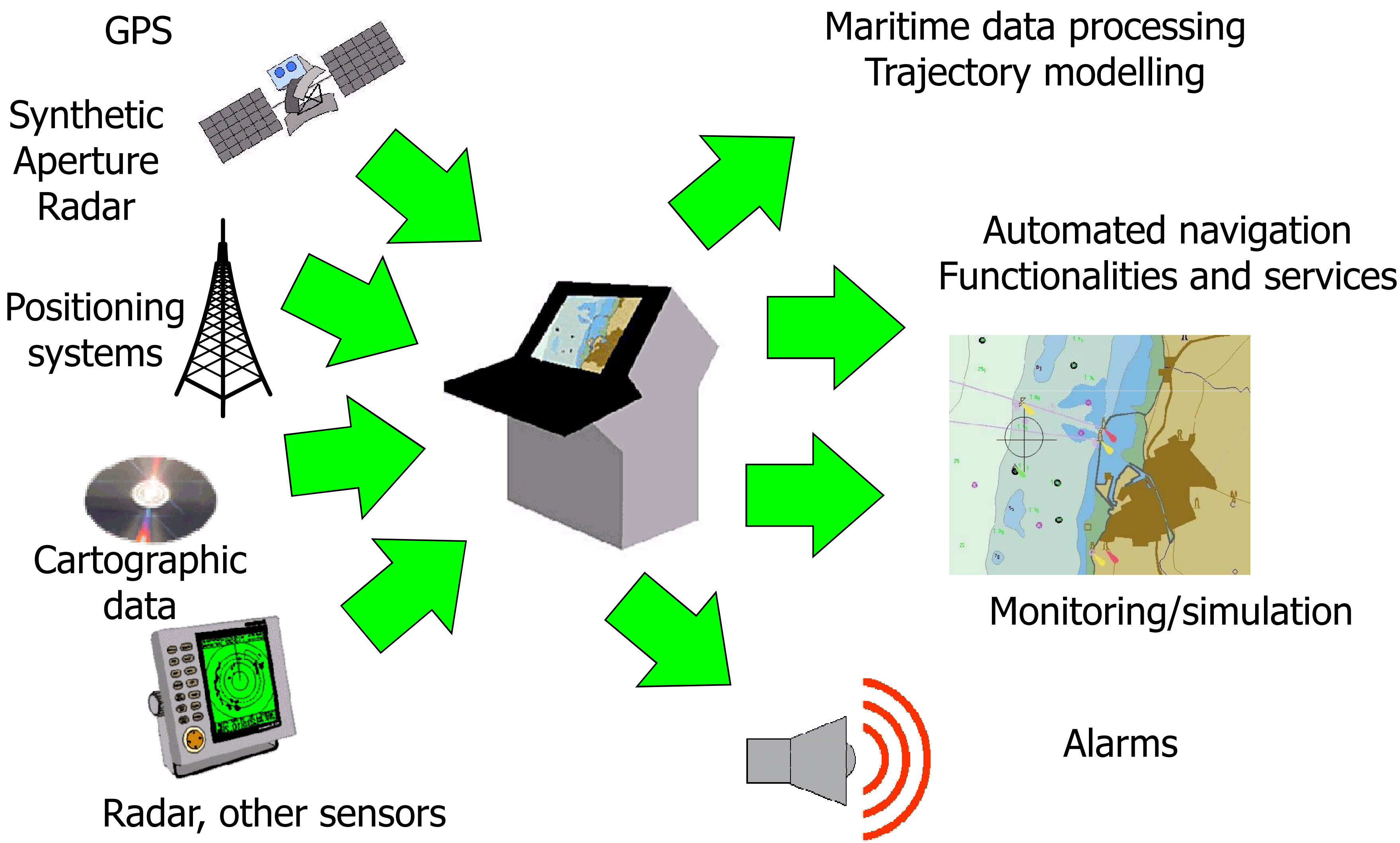
Maritime Navigation: Context

- Identifying new rules and promoting new standards and products for the improvement of safety at sea is a constant objective of the International Maritime Organisation (IMO)

- Recent progress in automated navigation includes navigation-aid systems that combine automated positioning systems
  - Global Positioning Systems (GPS)
  - Automatic Radar Plotting Aids (ARPA)
  - Automatic Identification System (AIS)
  - Satellite-based systems (LRIT, LORAN, INMARSAT)

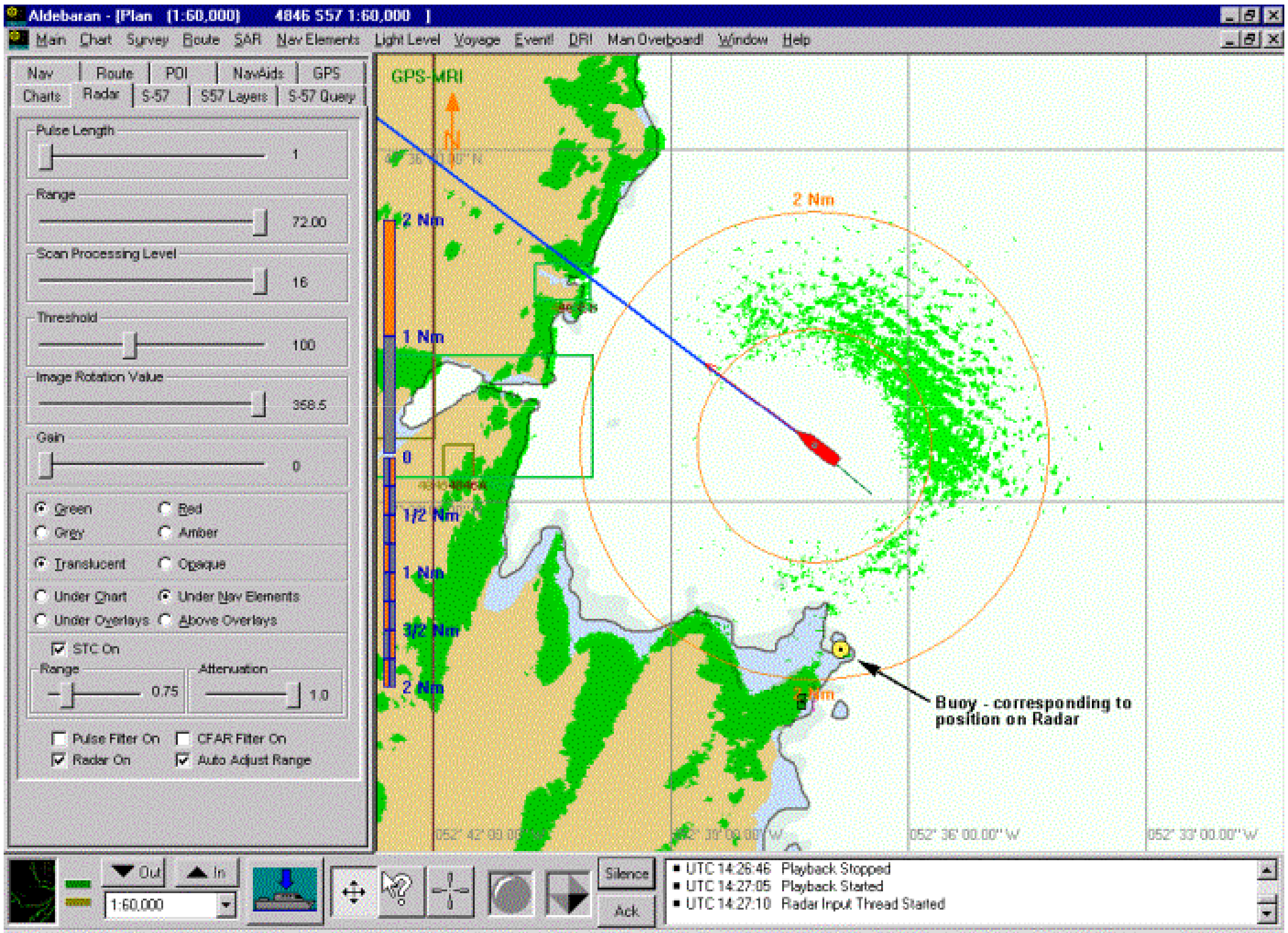
- With Electronic Chart Display and Information Systems (ECDIS)

Maritime Data Integration Environment



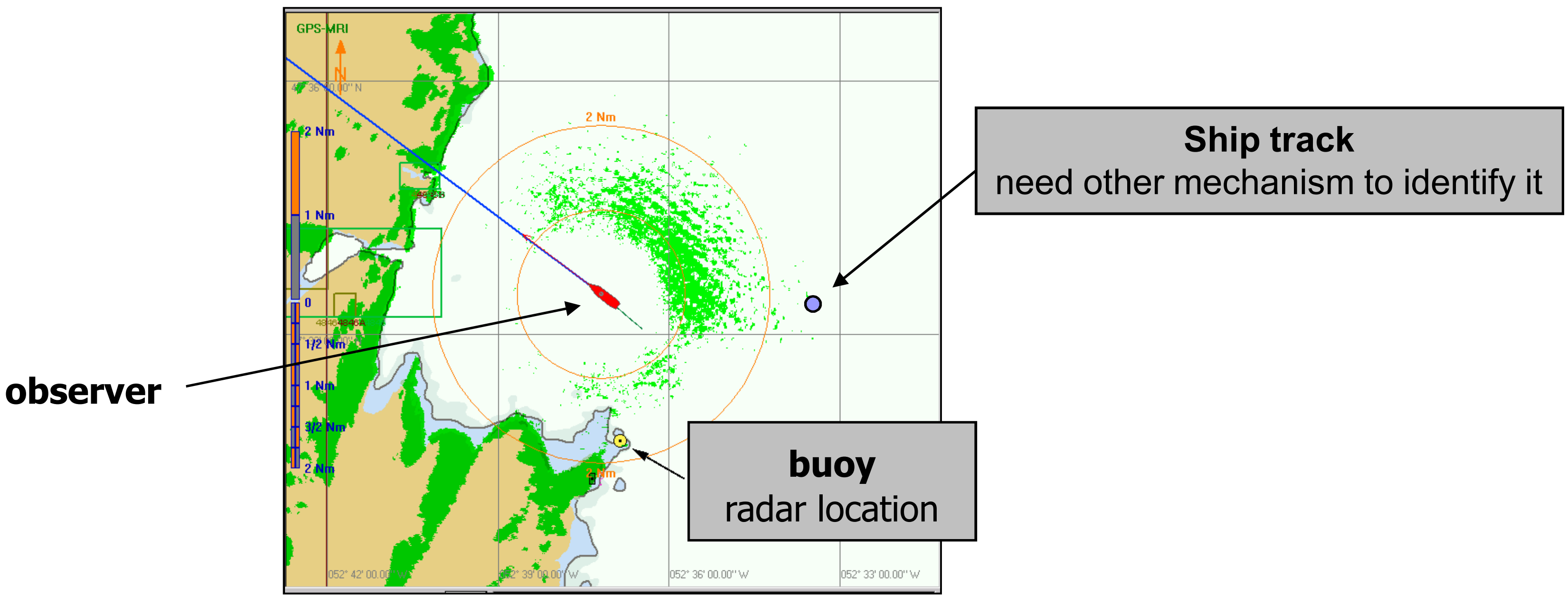
Automatic Radar Plotting Aid (ARPA)

ARPA: equipment associated to navigation radar in order to follow tracks and avoid collision



Radar Track Identification

- ARPA systems identify
  - Route or heading of observed ships
  - Speed
  - Closing Point of Approach (CPA): the nearest point that an echo can reach according observer
  - Time to Closing Point of Approach (TCPA): time to reach the CPA



Radar Limitations

- Small ships can be mistaken for sea echoes in the case of rough sea due to small echoes
- Non accessible areas
  - Hidden by the coast
  - Over the limit of the radar
- No direct distinction between stable and dynamic boats
- Track monitoring difficult when ships are crossing

Automatic Identification System (AIS)

- A ship fitted with AIS receives navigation data sent by surrounding ships, by its maritime VHF (one VHF transmitter, two VHF Time Division Multiple Access receivers and one VHF Digital Selective Calling receiver)
  - Mandatory (IMO) From july 2005 for ship of more of 500 T and 300 T with passengers
  - It is a solution comparable to aeronautic transponders
- Transmitted data include textual data such as name, length, speed and position of every AIS-connected ship in the neighbourhood. Incoming data come from different sources and sensors such as GPS and speed meters
- The AIS is able to operate in autonomous and continuous mode for operations in all areas, it is not constrained by the topography as is the ARPA system

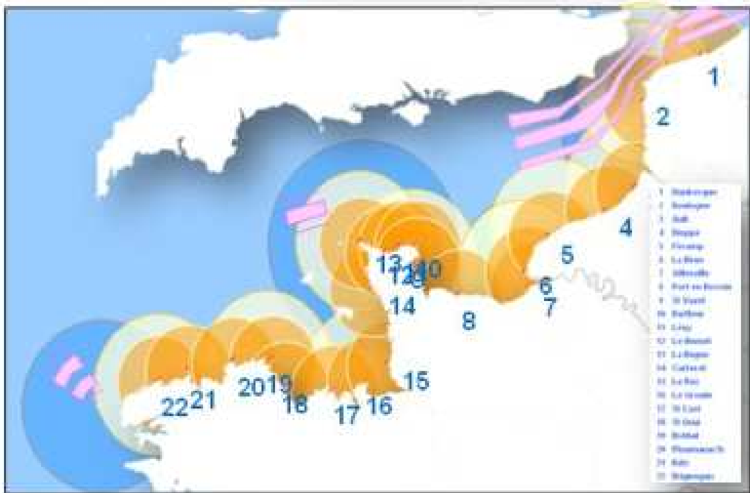
Automatic Identification System

- AIS system includes
  - GPS
  - Transponder itself
  - VHF antenna transmitting message using two bands,
    - 87B (161,975 MHz) (AIS1)
    - 88B (162,025 MHz) (AIS2)

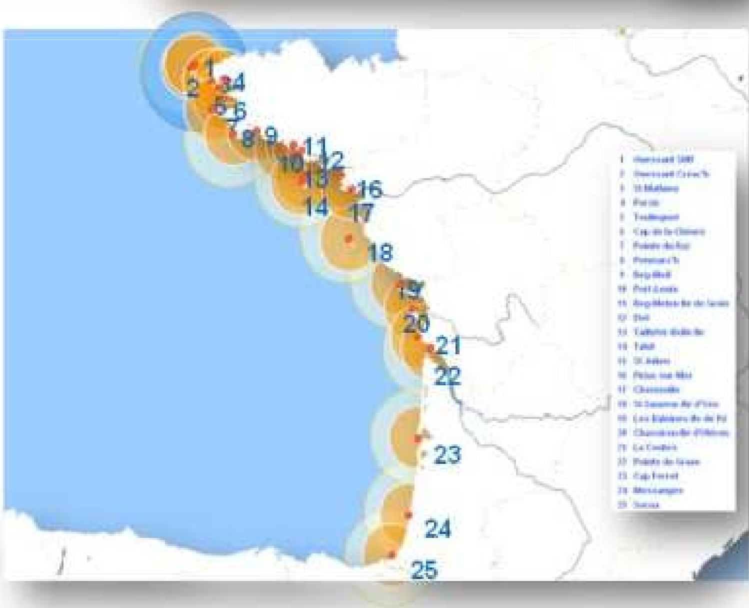
- AIS uses 21 messages that integrate
  - MMSI and OMI codes
  - Ship name and type
  - Latitude, longitude
  - Heading, speed

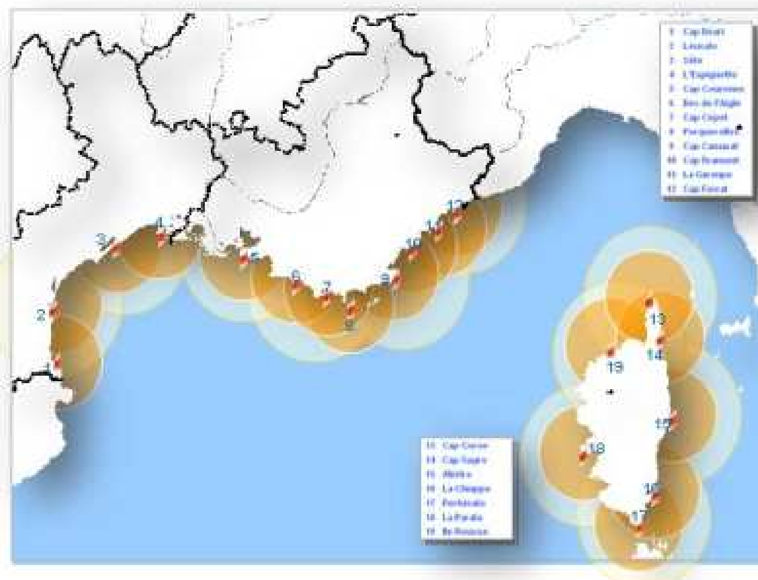
Ship Type	Interval
Static ship	3 min
Ship from 0 to 14 knots	12 s
Ship from 0 to 14 knots + change of route	4 s
Ship from 14 to 23 knots	6 s
Ship from 14 to 23 knots + change of route	2 s
Ship more than 23 knots	3 s
Ship more than 23 knots + change of route	2 s

AIS Metropolitan coverage



59 « sémaphores »
7 CROSS
18 mobile stations





AIS contribution to the ARPA

- It helps the radar to distinguish the tracks
  - Useful nearby rocky coasts
- It identifies radar tracks
  - Ship name obtained via VHF
- It improves CPA and TCPA calculation
  - Turn radius taken into account
- It anticipates tracks
  - Routes
  - Destination ports

Electronic Chart Display & Information Systems (ECDIS)

" *e-navigation is the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment* "

Electronic Chart Display & Information Systems (ECDIS)

- Combines a location-based navigation database, electronic vector charts, navigation tools, route planning and warning functionality to provide a navigation tool that can reduce the risk of human error in navigation
- It is intended to replace conventional paper charts as the legal base for safe navigation
- ECDIS is already being installed in large vessels that have fully operational installations

Electronic Chart Display & Information Systems (ECDIS)

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Location

Heading

Speed

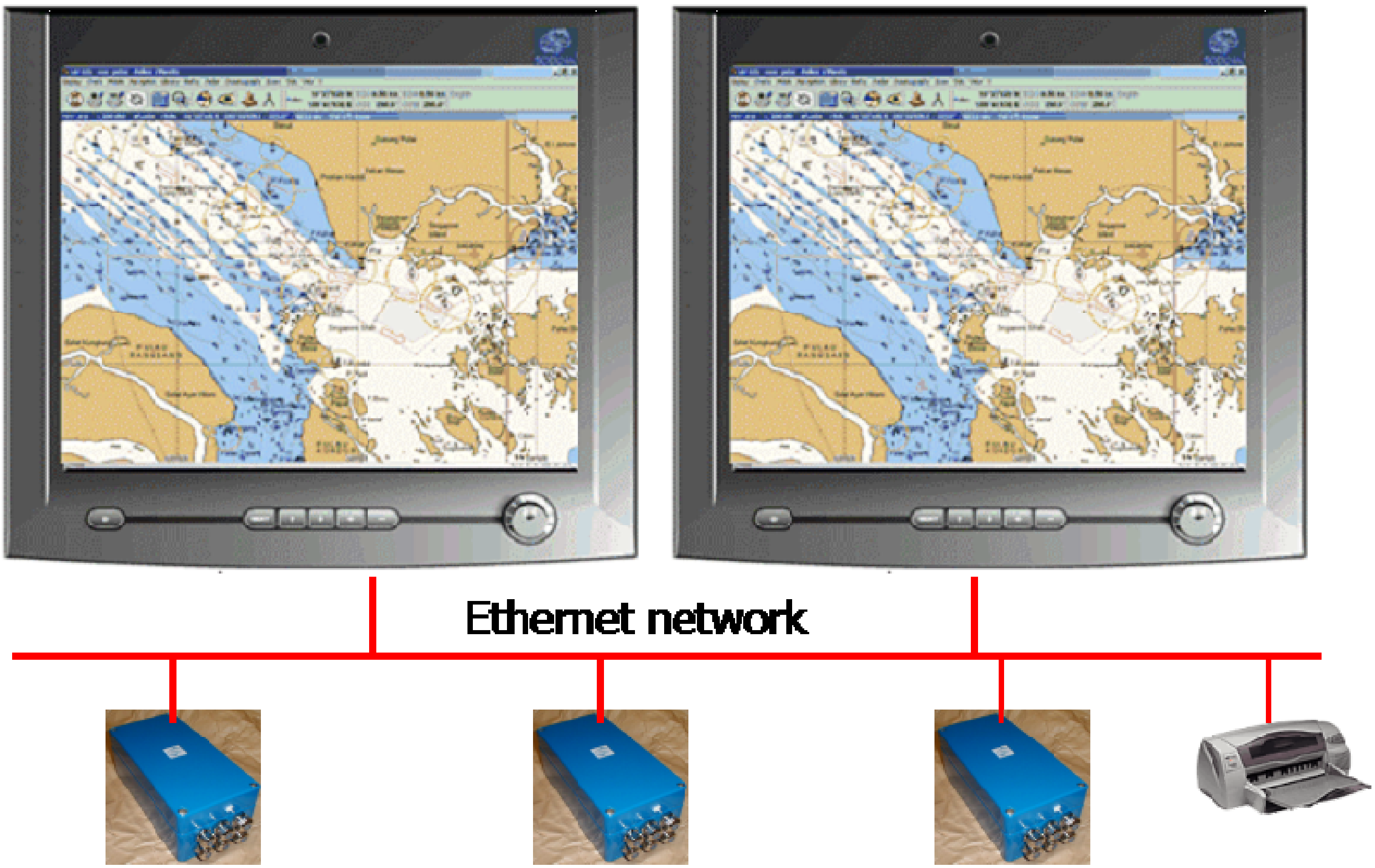
Wind

...

AIS
ARPA

Radar OVERLAY

Electronic Chart Display & Information Systems (ECDIS)



ECDIS: Route Planning

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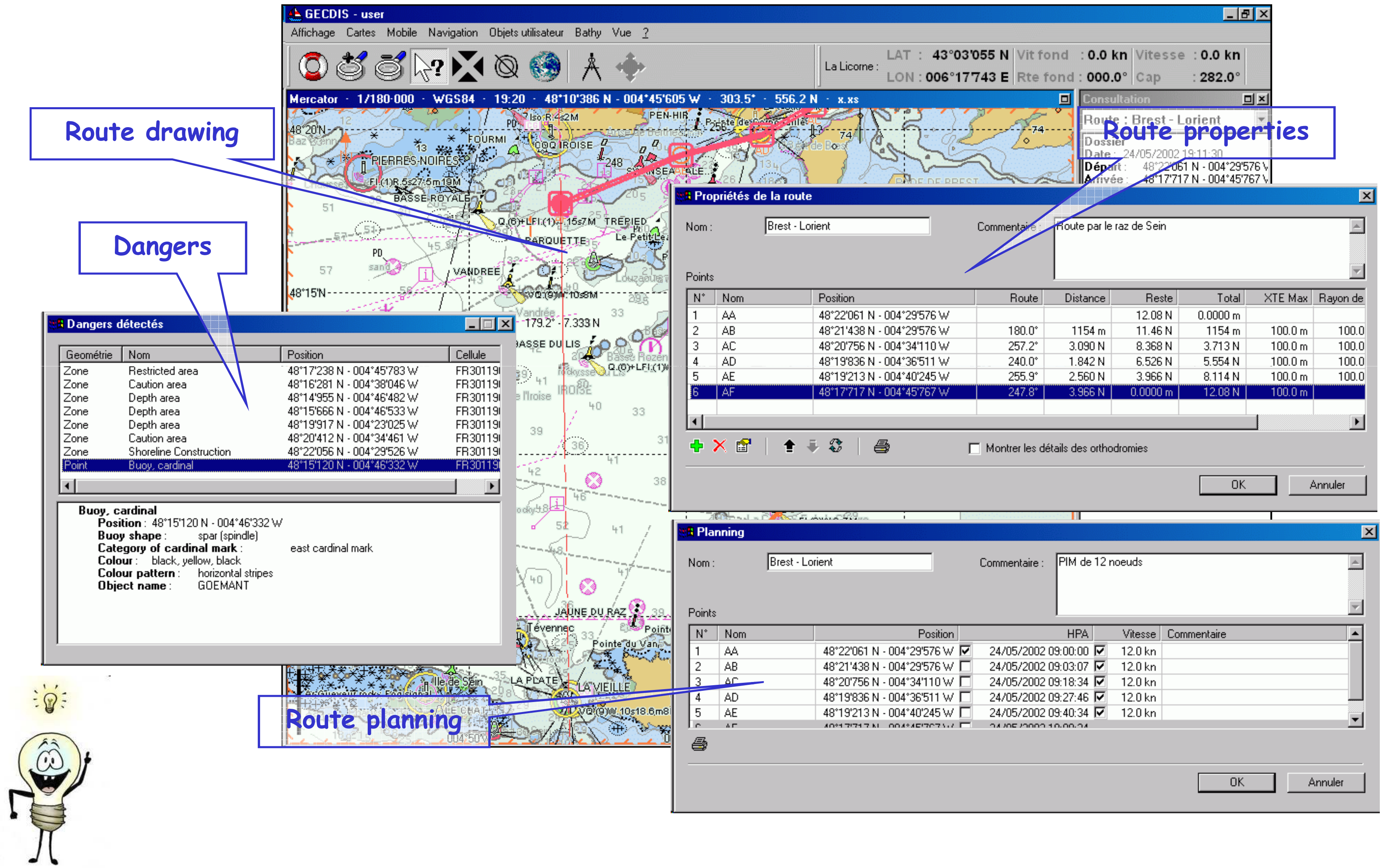
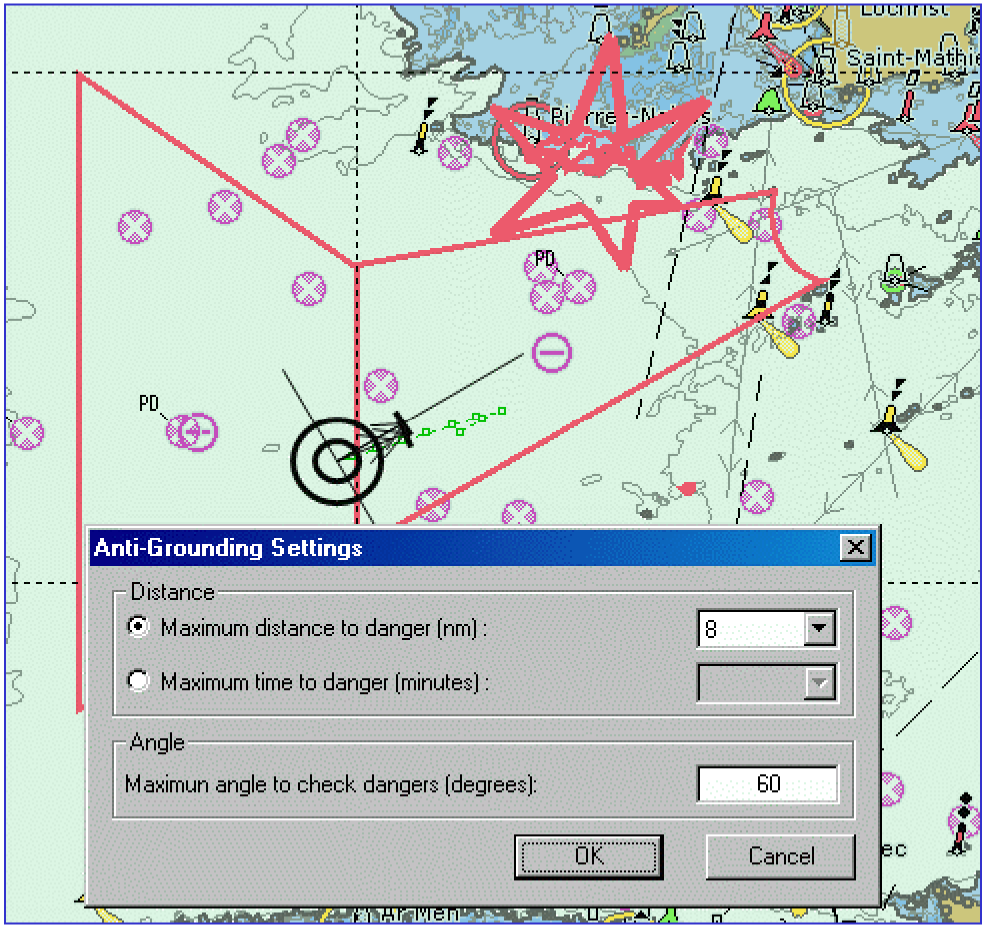


ECDIS: Alarms



Alarm !

settings

ECDIS: Additional Data - Tides

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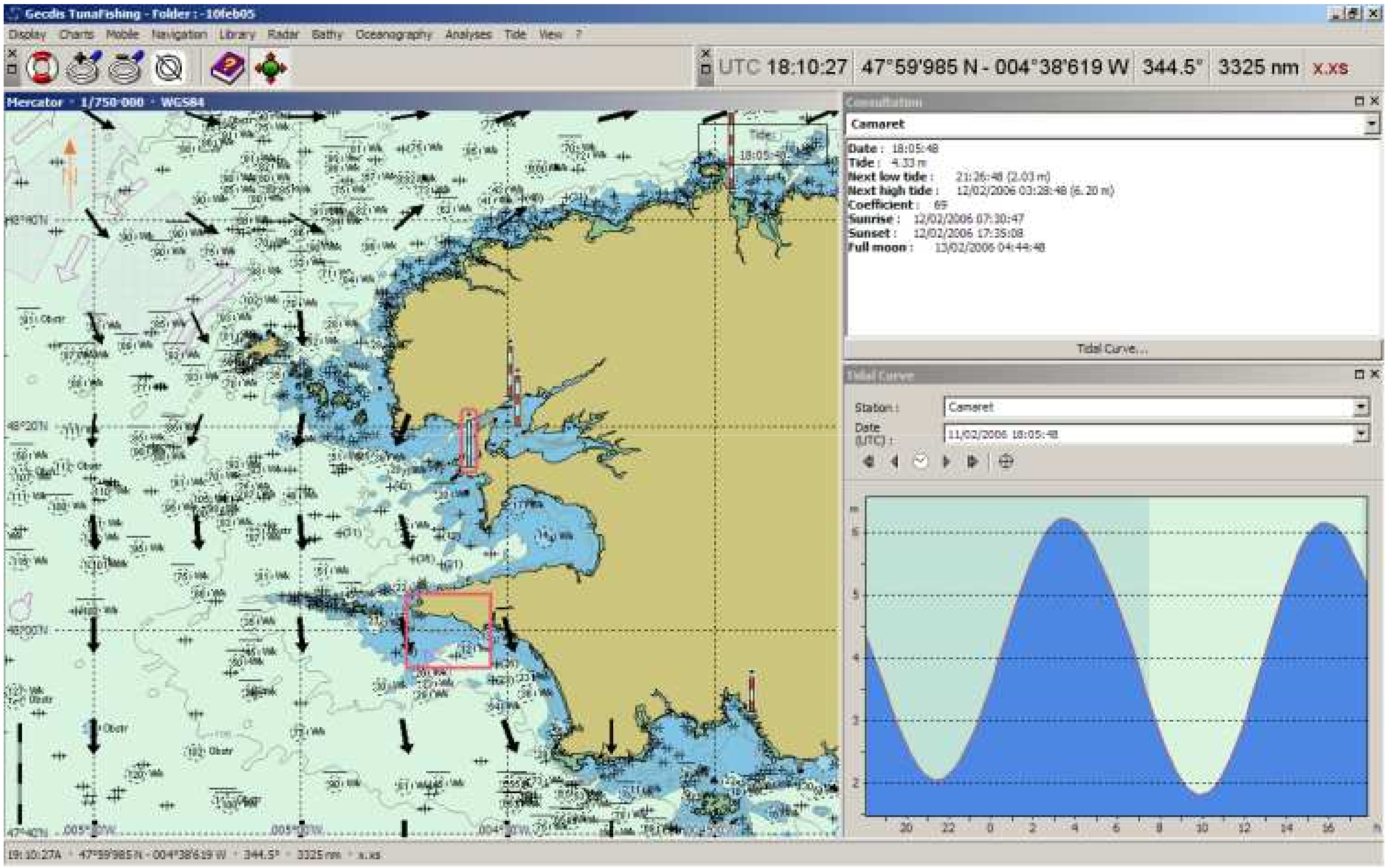

ECDIS: Additional Data - Weather

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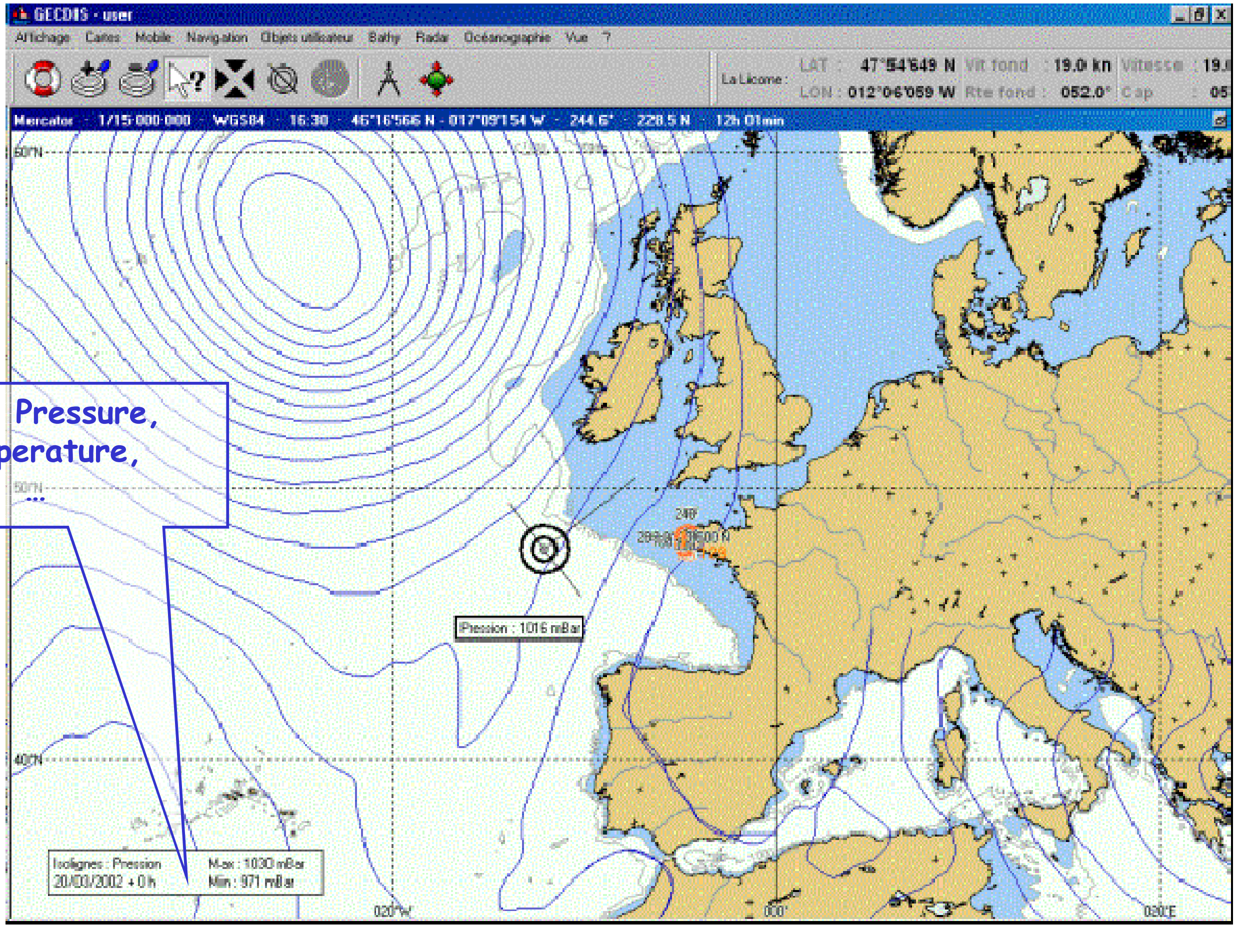


Wind, Pressure, Temperature, ...

ECDIS: Advantages

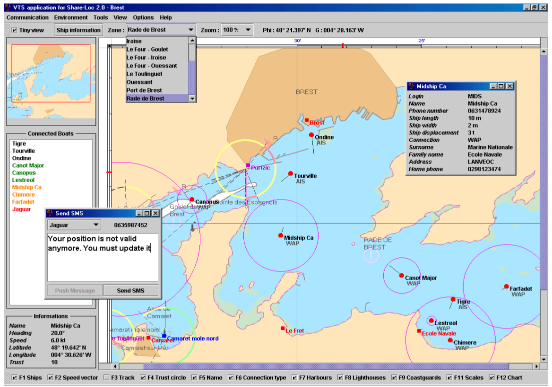
- Flexible displays (contextual)
- Navigation-aid
  - Speed, heading, route planning & monitoring
- Security functions
  - Anti-grounding, anti-collision, rescue
- Automated mapping updates
- Sensor connections
  - Radar, GPS, sonar, …
- Personalisation
  - Ship’s draught, length, turn radius
  - Tide height, time (day vs. night)
- Error control

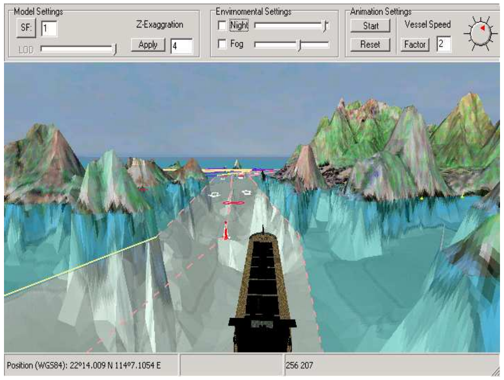
ECDIS: Limitations

- Data integration still not straightforward
- Legal issues: maritime data are controlled by national agencies
- Visualisation and functional issues are still basic
- Heterogeneity of data integration systems
- Lack of decision-aid and simulation functions
- Personalisation still not considered
- ECDIS is only a tool that helps a mariner safely and effectively navigate a ship. One of the biggest risks with the transition to ECDIS is an over reliance in the information provided

Moving objects at sea: trends and challenges

Part II Research challenges





Moving objects at sea: research challenges

Maritime data integration

Modelling and tracking of maritime navigations

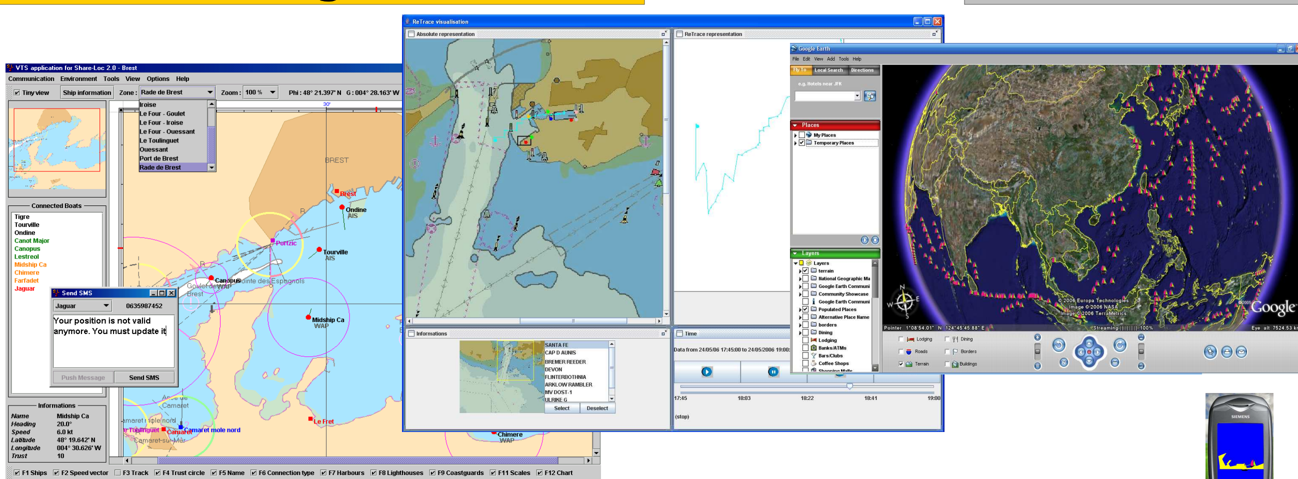
Diffusion of services to clients and monitoring authorities

- Heterogeneous databases

- Traffic control
- Safety
- Event tracking

- Patterns discovery & analysis
- Search And Rescue (SAR)

- Simulation & Decision-aid systems
- Visualisation and user interfaces



Moving objects at sea: research challenges

- We should make a difference between

  - Vessels Traffic Services stations (VTS, i.e. maritime authorities) that monitor and analyse a given navigation area

  - Ships concerned by their location and the routes of neighbouring ships

  - Other End-users

Moving objects at sea: research challenges

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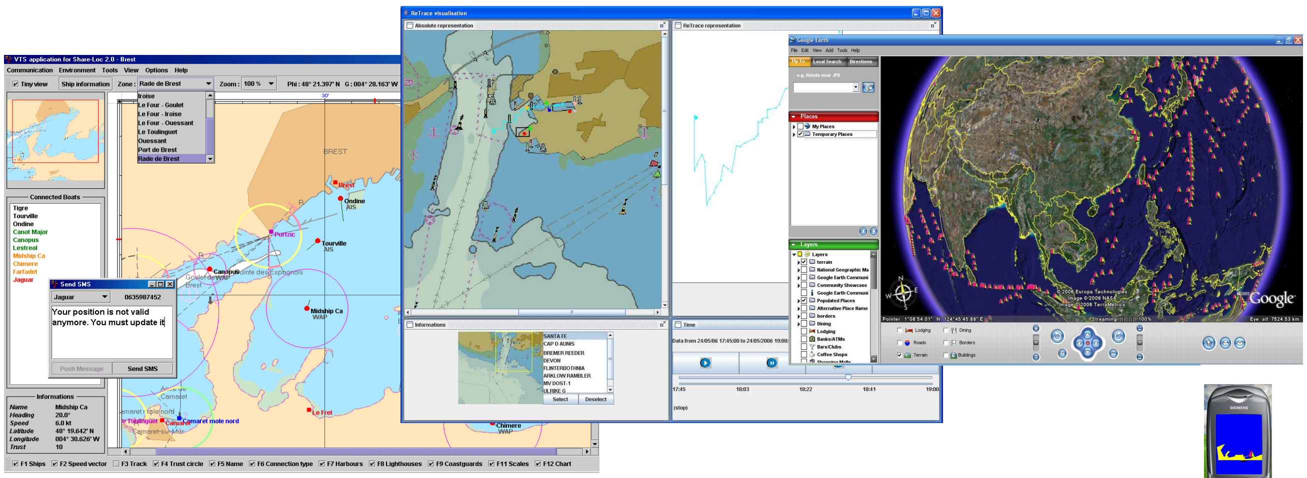
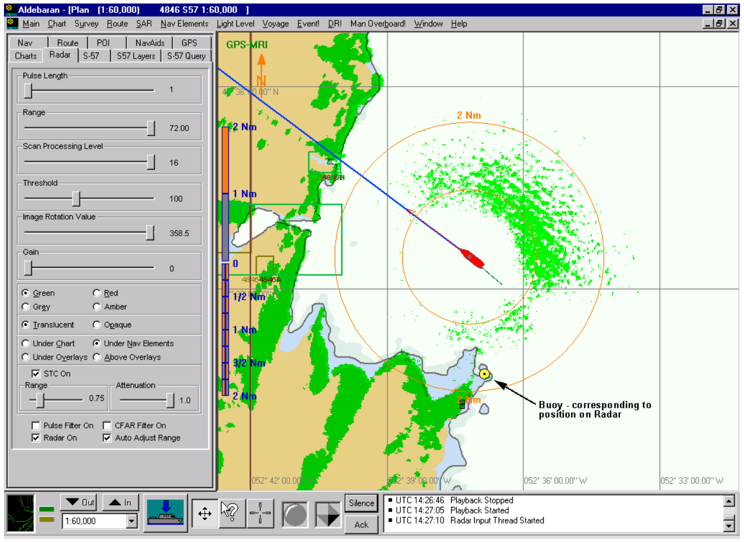
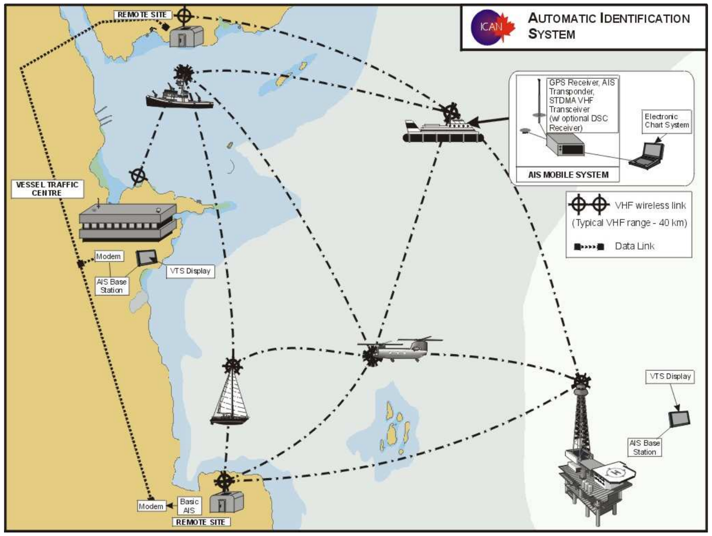


Integration of heterogeneous databases: semantic issues

ARPA



AIS

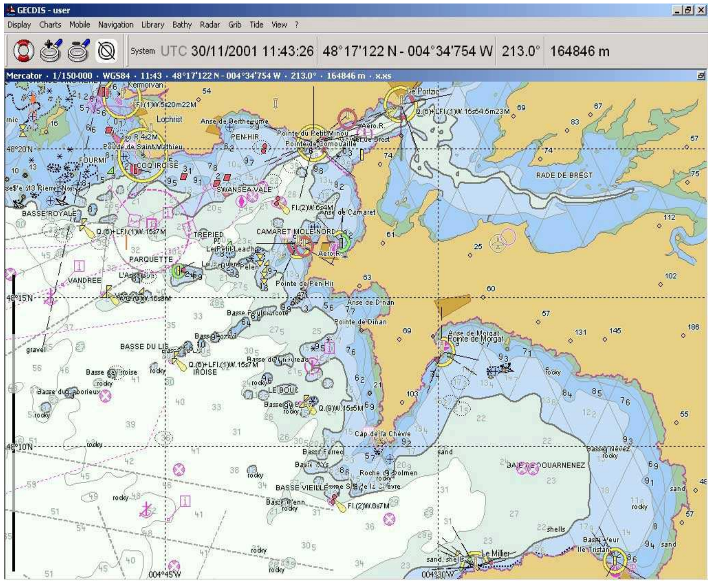


- Integration of different models, ontologies and visualisation paradigms

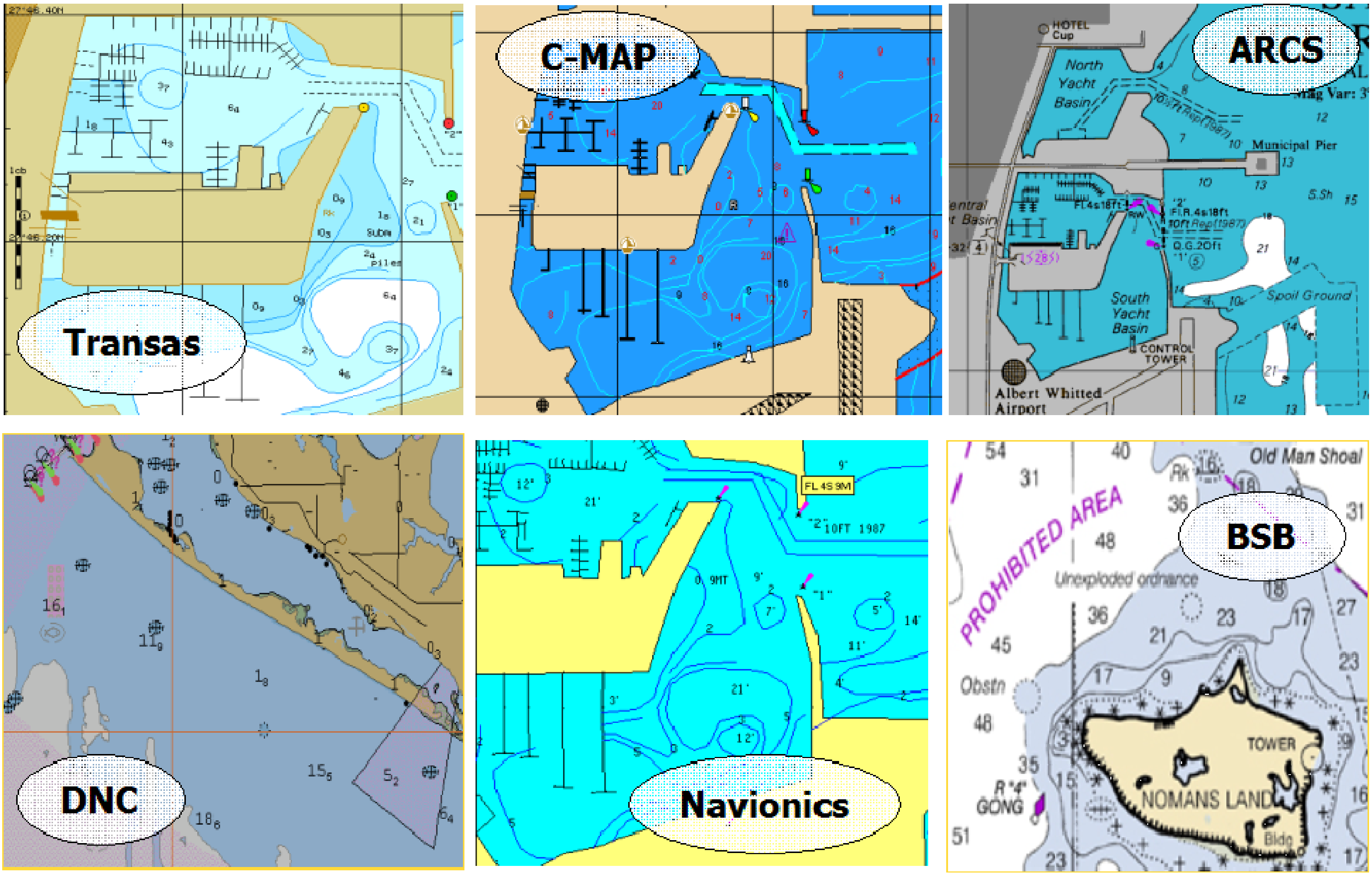
- Different levels of abstraction

- Normalisation (IMO)

ECDIS

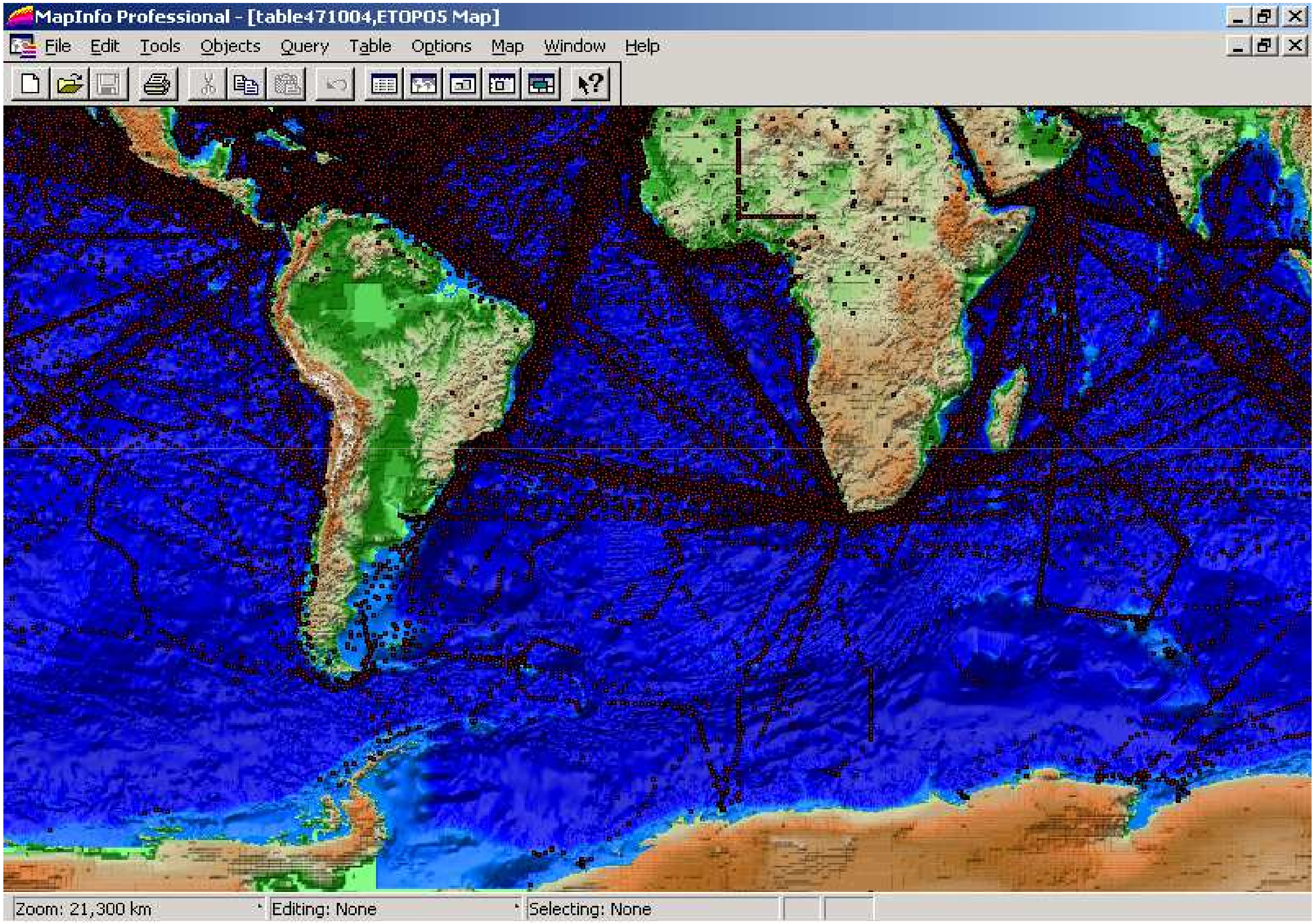


Integration of heterogeneous databases: semantic issues



Integration of heterogeneous databases

Real-time tracking of large volumes of maritime data (NOAA volunteered weather data)



Integration of heterogeneous databases

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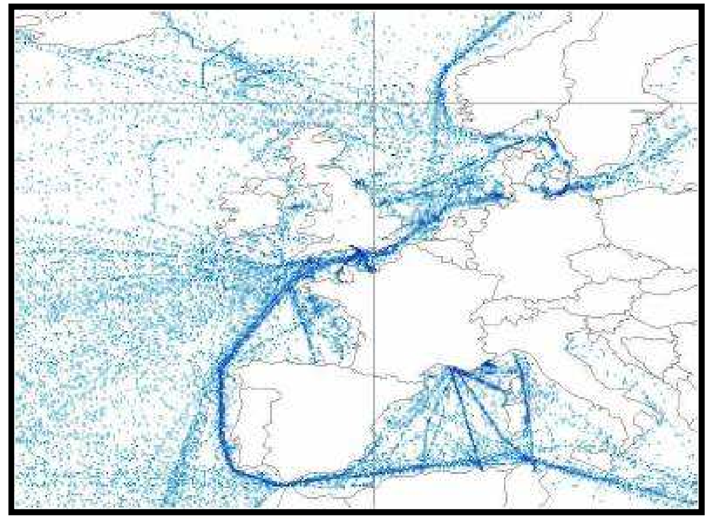
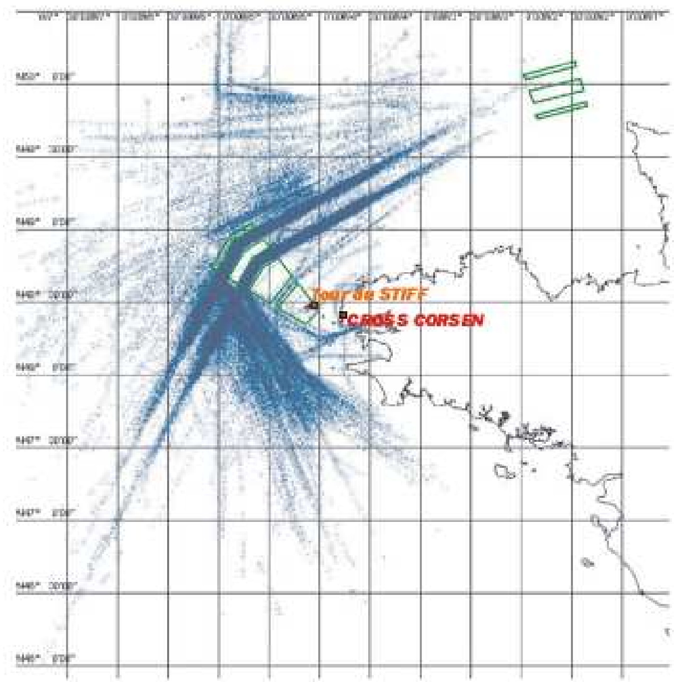
Real-time tracking of large volumes of maritime data (-> physical data structures and indexing)

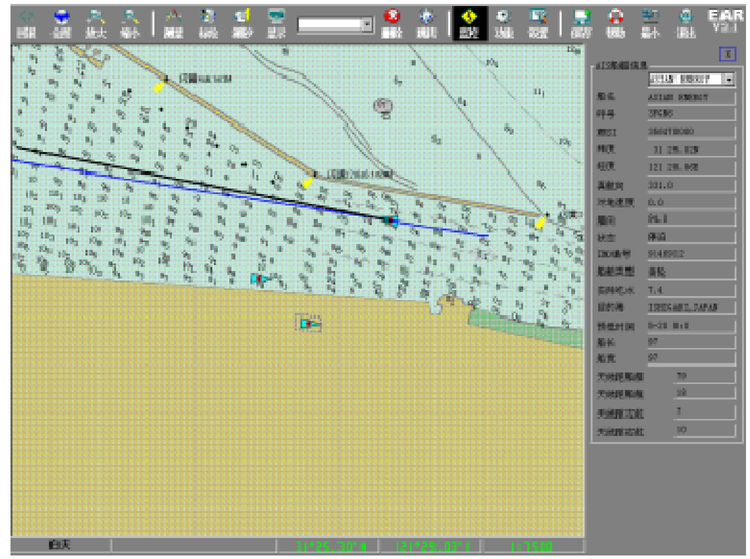


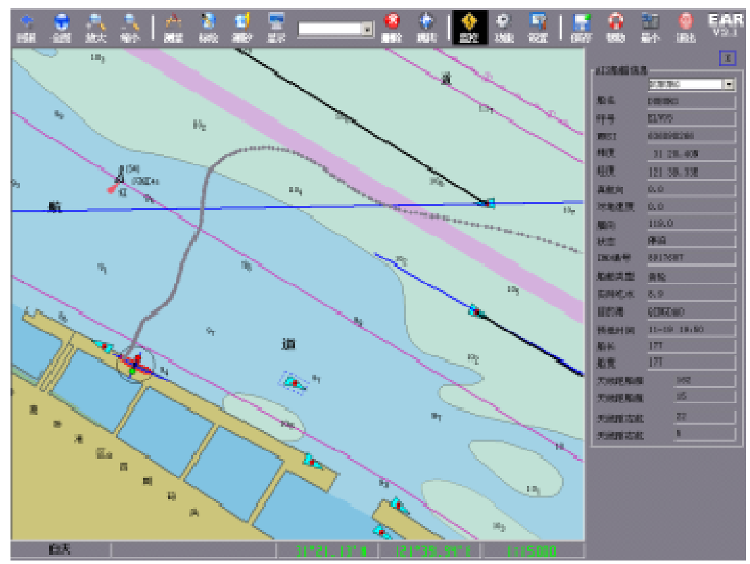


Integration of heterogeneous databases

Data filtering

Integration of heterogeneous databases



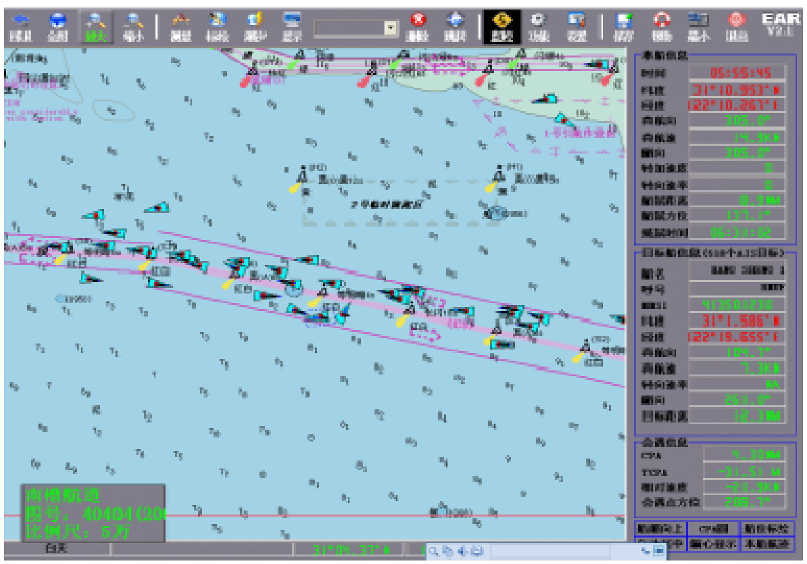


Error control:

- Differences in geodetic systems
- Practical installations of GPS receivers …

Integration of heterogeneous databases

Error control: Deficiency of heading



COG is from GPS and Heading is from GYRO

AIS can connecting LOG and GPS, therefore the transmit speed is equal to LOG speed. When ship is under strong current, speed error will be larger. So the computed CPA and TCPA are incorrect.

Moving objects at sea: research challenges

Maritime data integration

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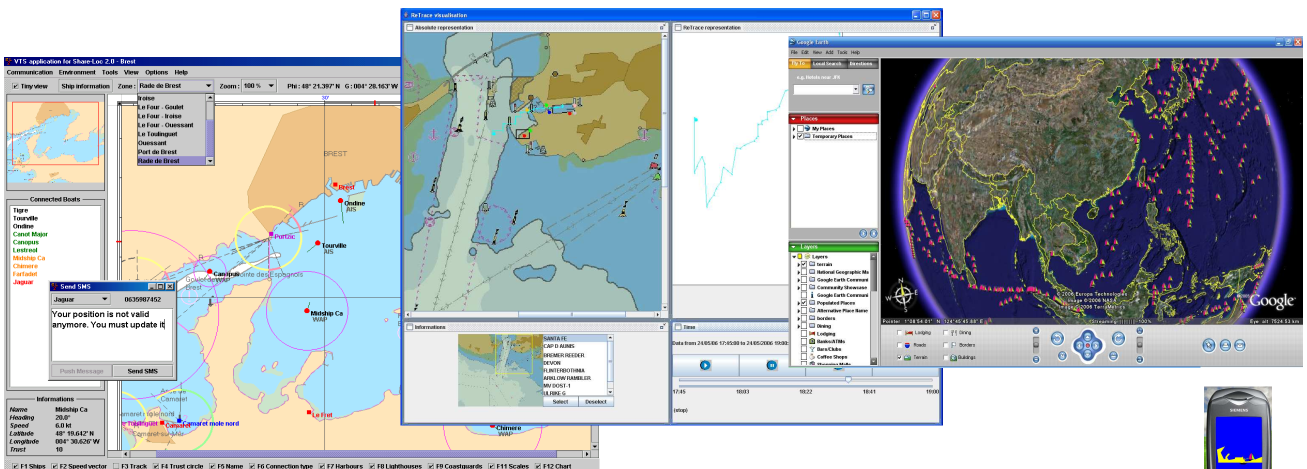
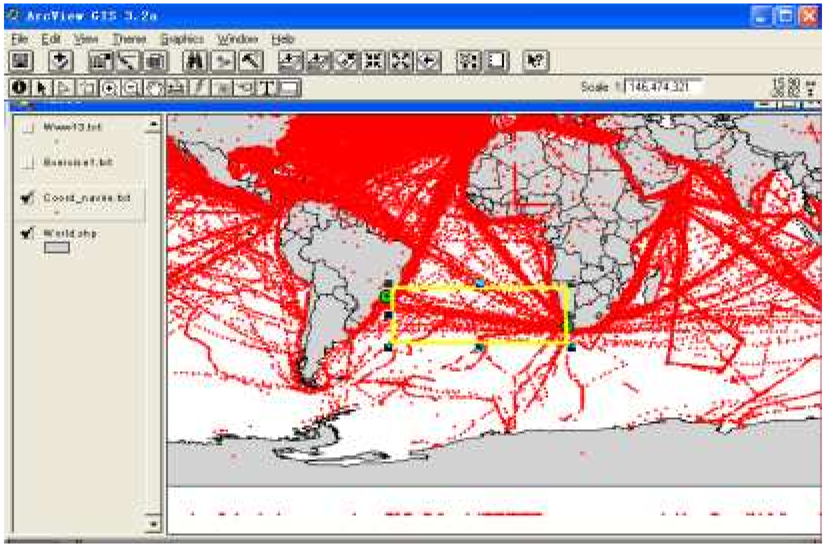


Patterns analysis and discovery



Modelling and analysis maritime trajectories trends and patterns at a global level (NOAA data)

Analyzing maritime trajectories and behaviours at a local level (e.g. port management and safety)

Event tracking

Real-time monitoring of maritime trajectories and behaviours (e.g. trajectory vs. navigation path)

Detecting regular and irregular behaviours, incidents etc.

Event tracking

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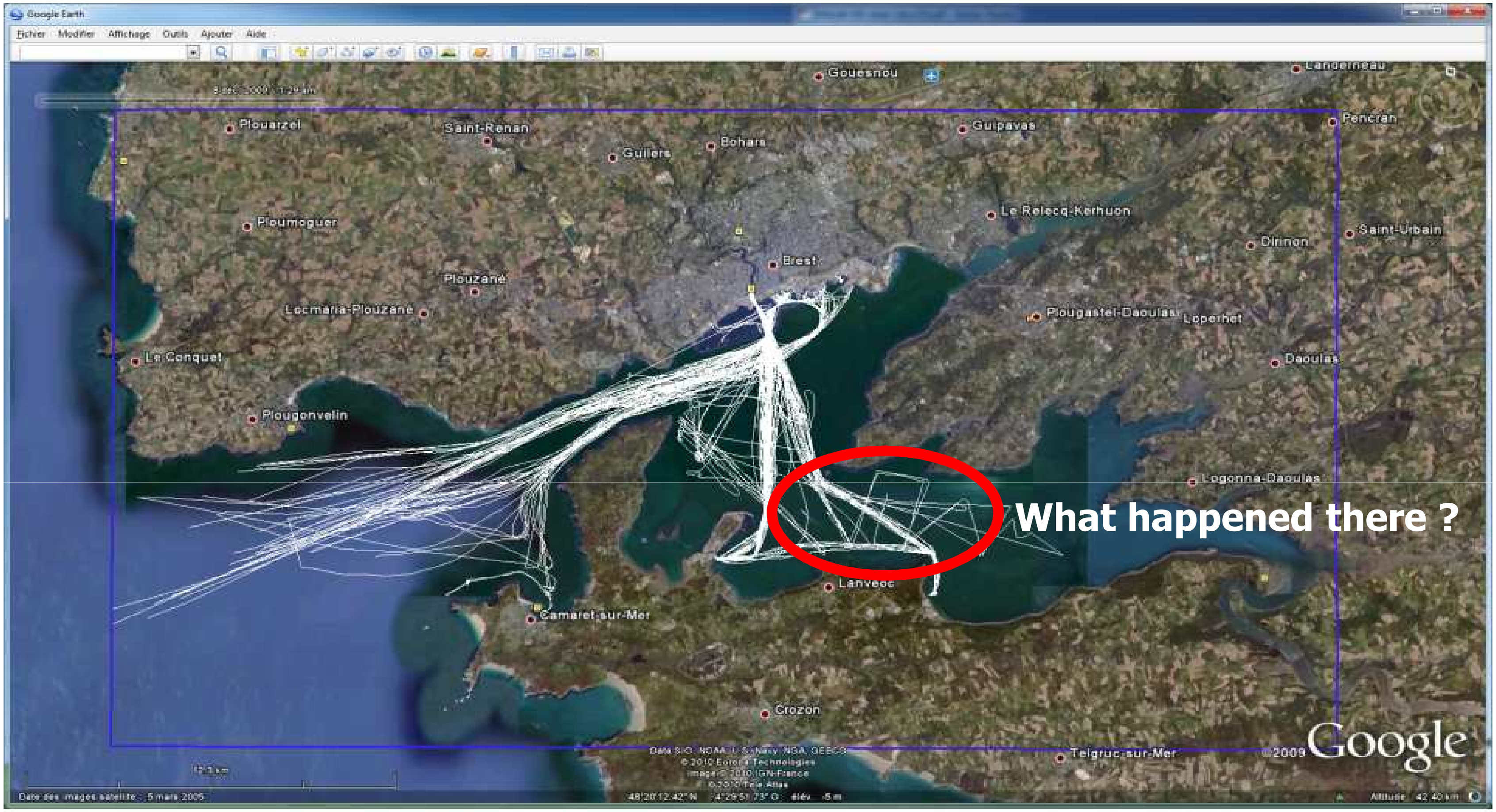
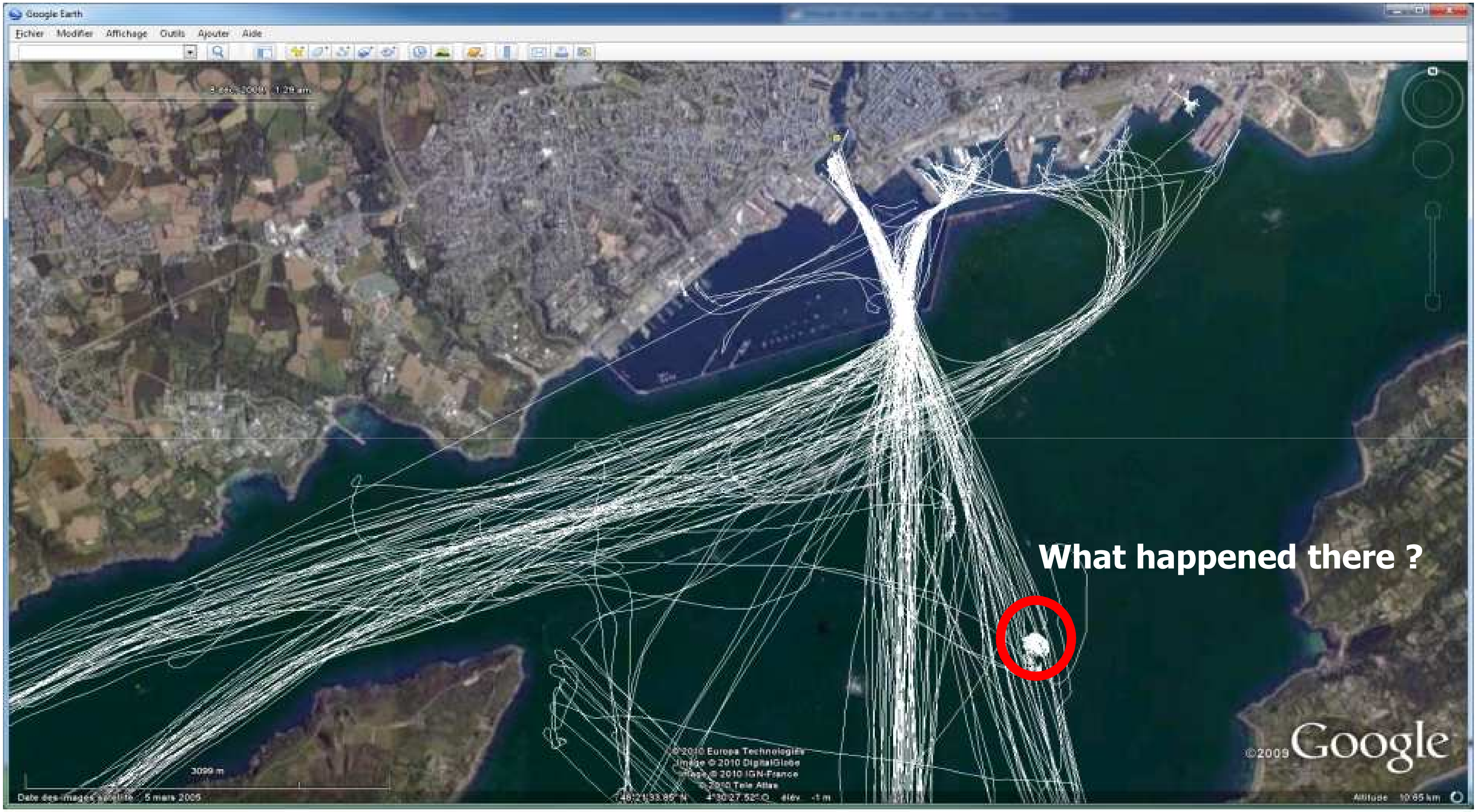


Detecting irregular behaviours

Event tracking



Detecting irregular behaviours

Event tracking: CPA

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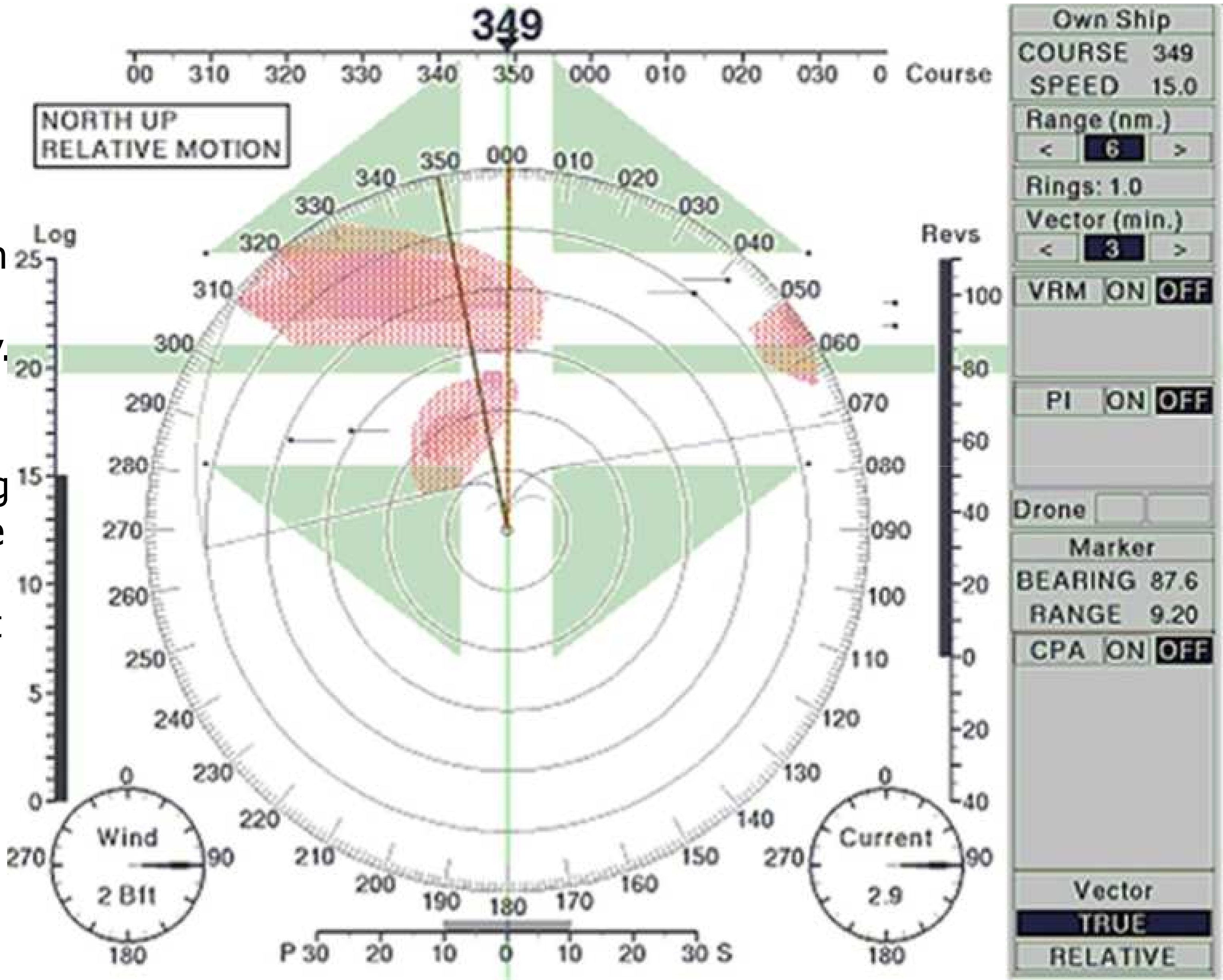
« In the example above, you are about to cross a shipping lane with two vessels crossing each way. Turning left will make things worse, but turning right between the red "danger clouds" will result in a safe passage (assuming the other vessels maintain course and speed). «



Event tracking: CPA

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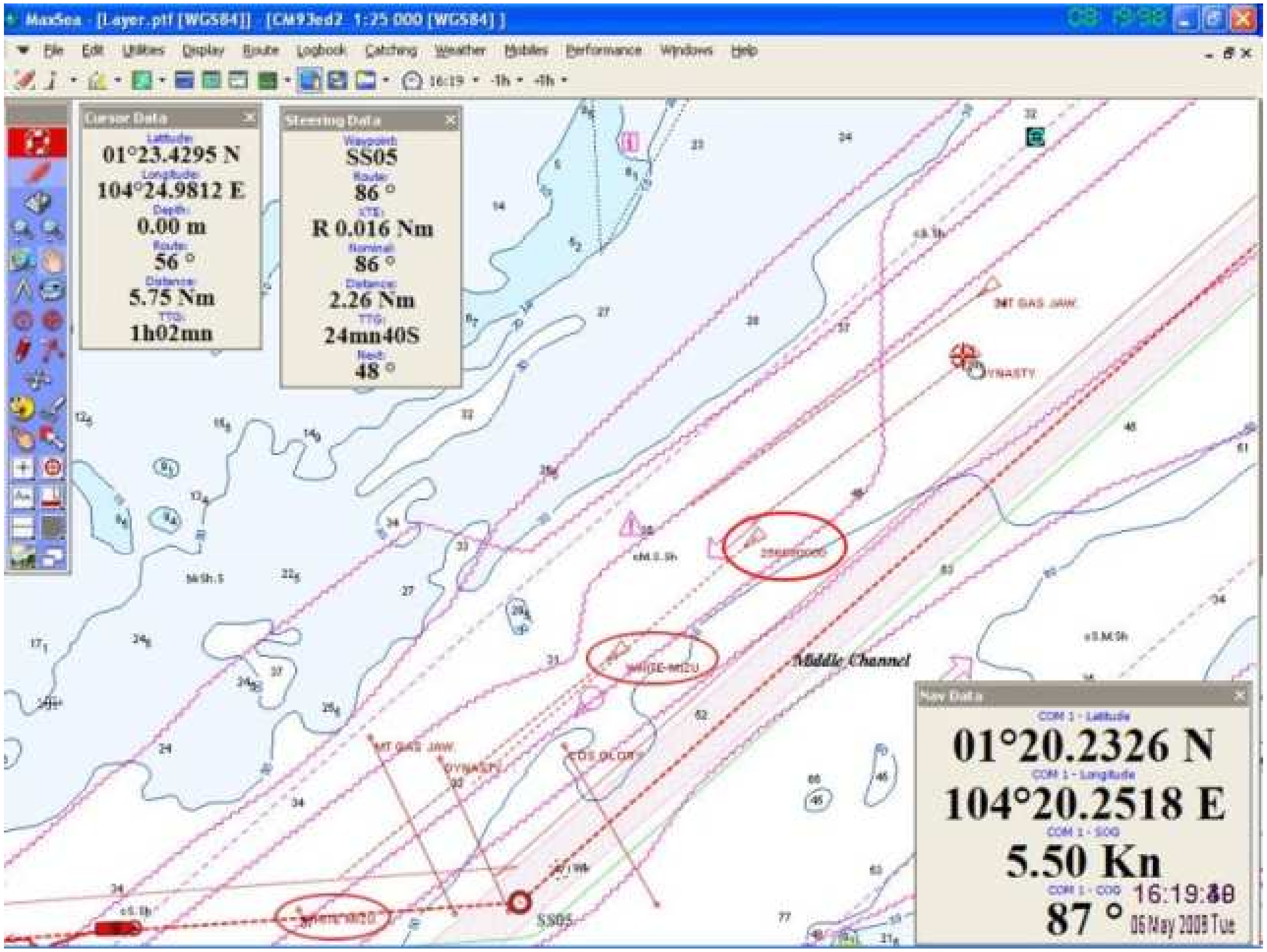
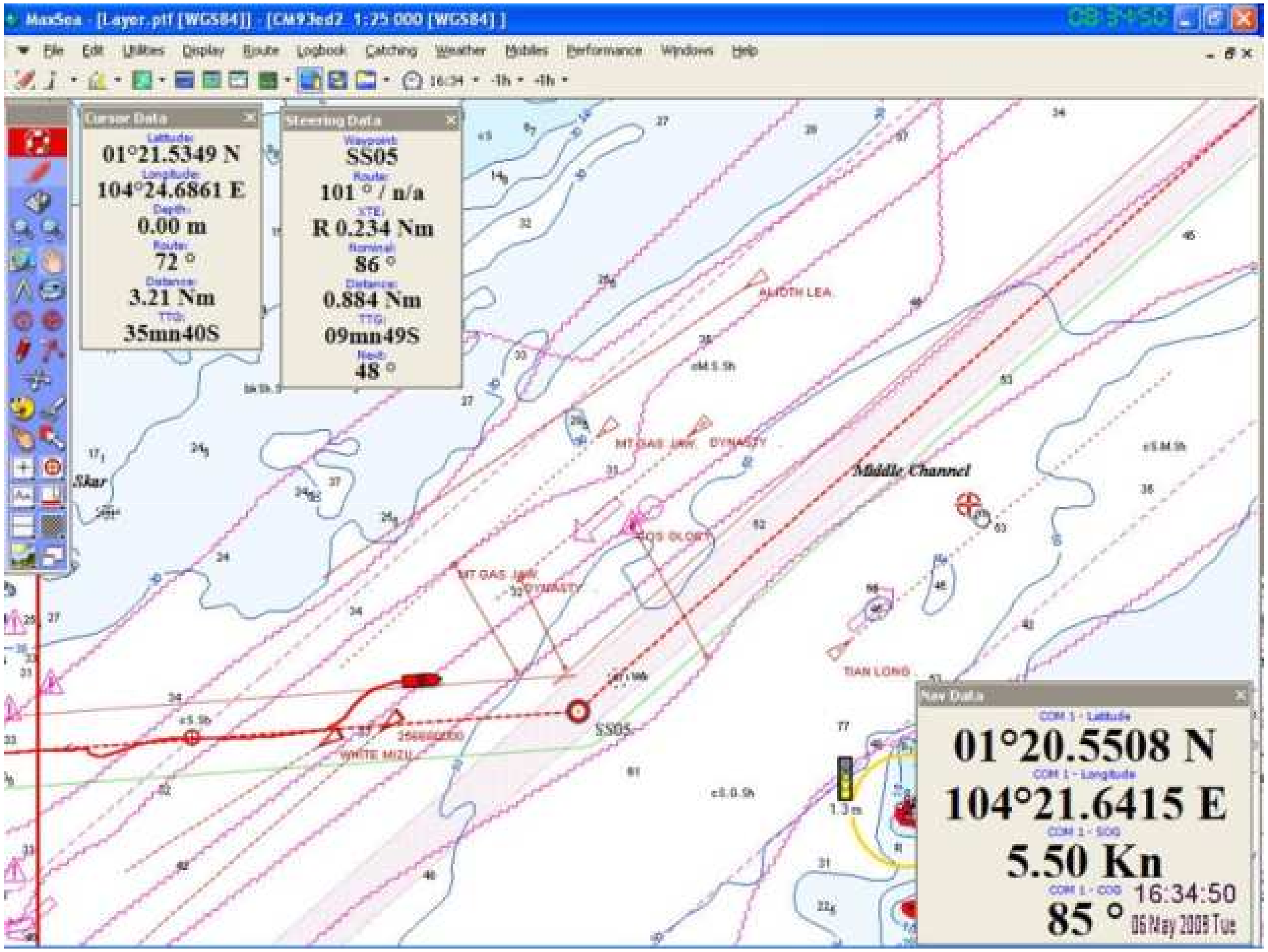


«The AIS graphic display shown here has one ship, WHITE MIZU, with a CPA (closest point of approach) that was too close for comfort. Another ship (25680000) was following WHITE MIZU and closing, giving further concern. »

Event tracking: CPA

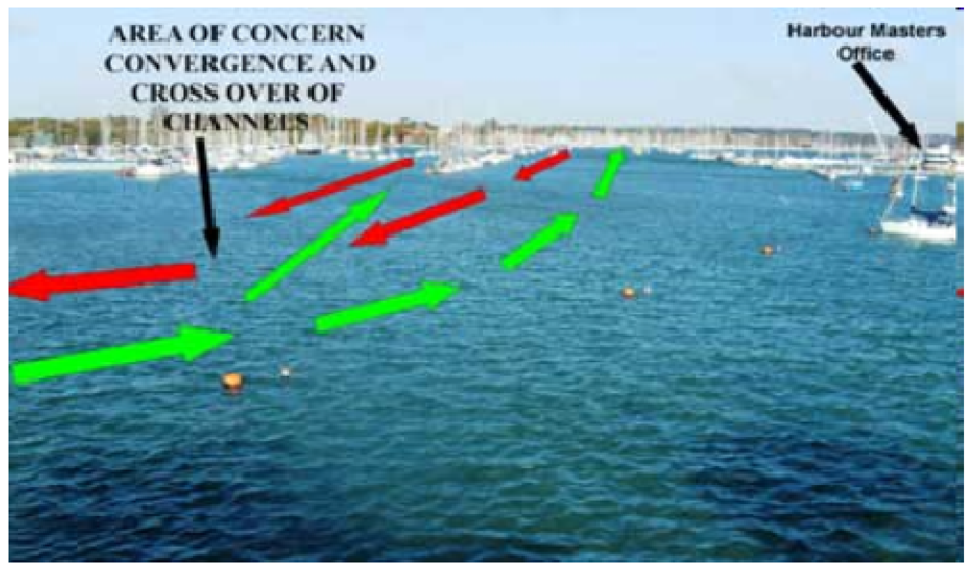


« Here you can see the maneuver behind the two ships of concern »

Navigation control

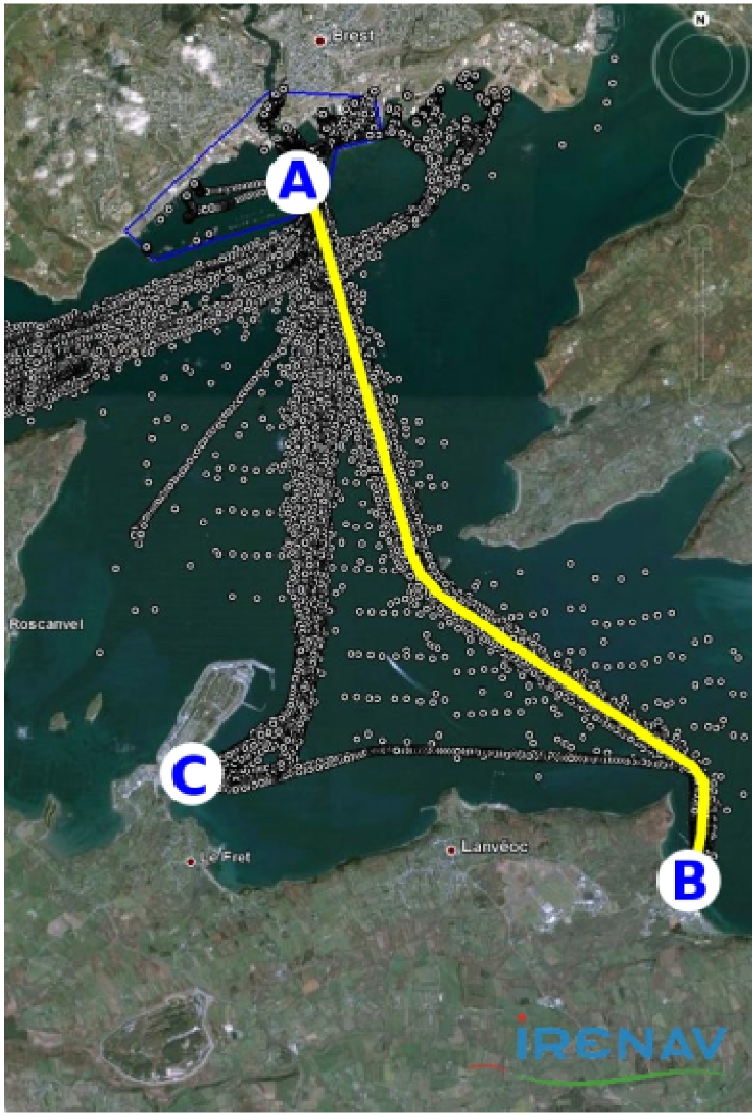
All vessels should monitor VHF Channel 68 when underway in the harbour

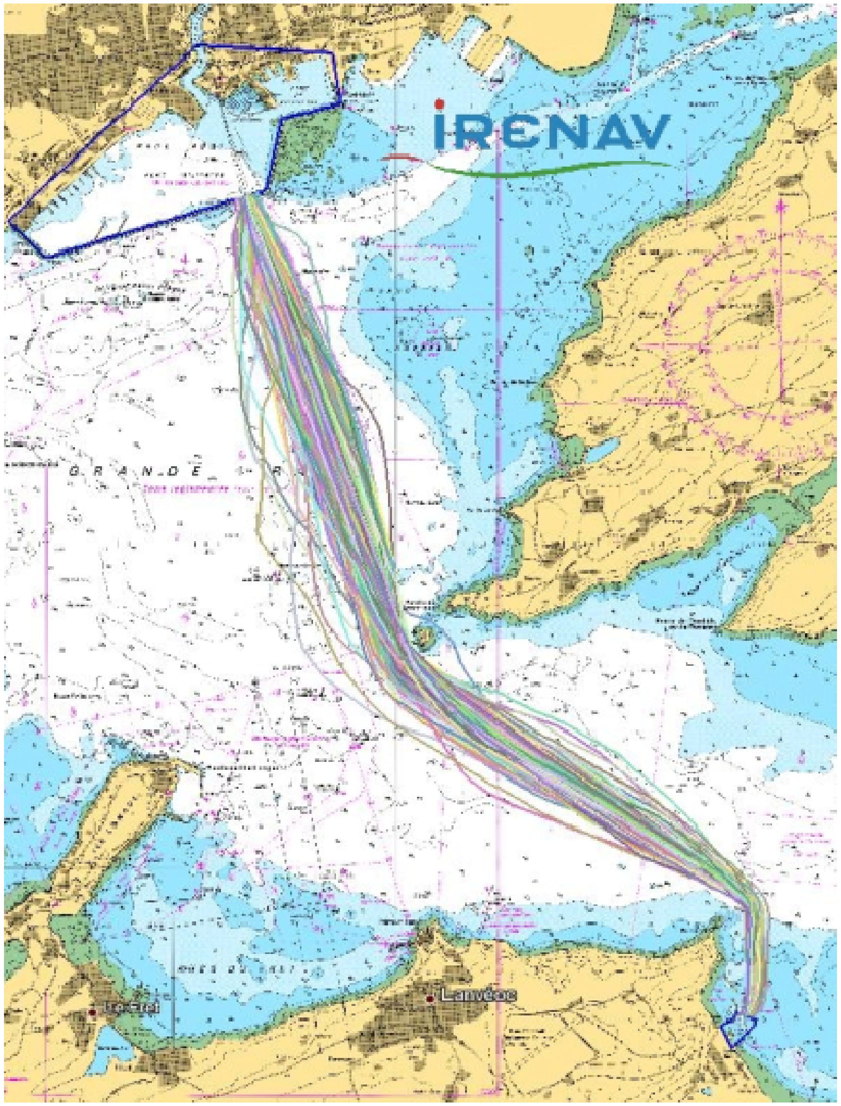
A River wide 6 knot speed limit with a wash limit commences at Beacon Number 2



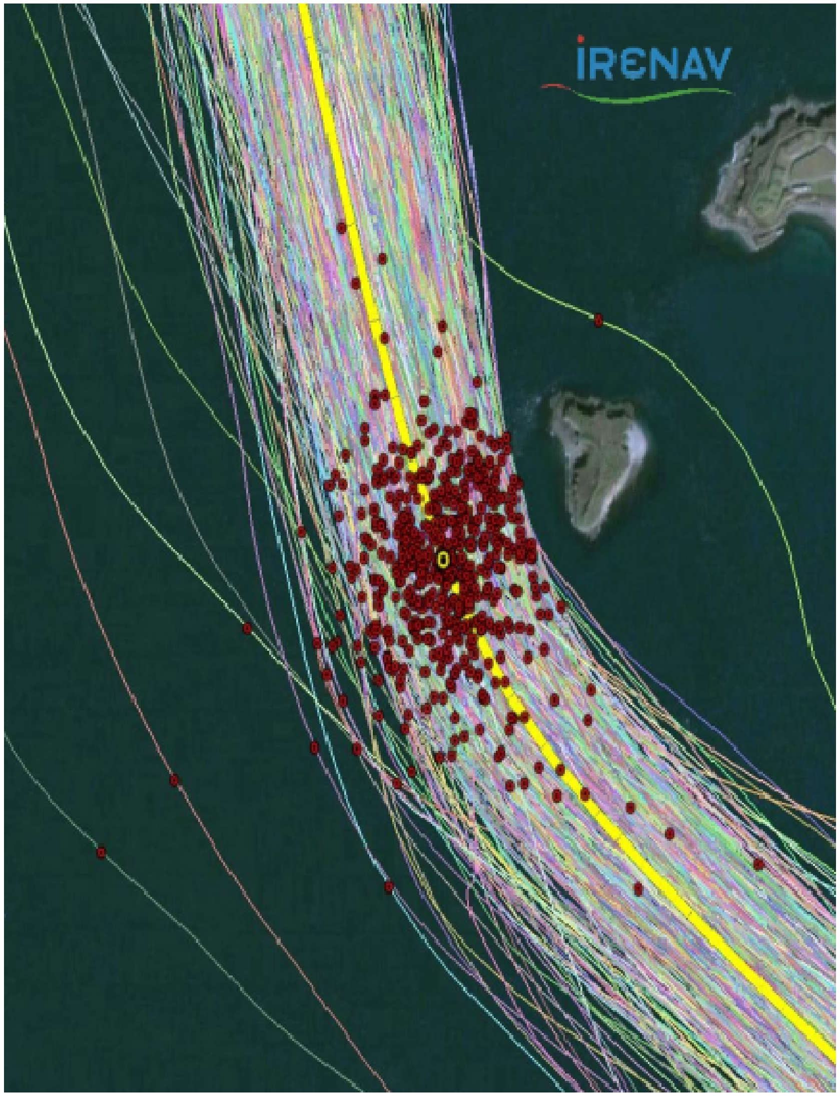
Caution is required at low water, depending on the state of the tide, as some marks stand in shallow water

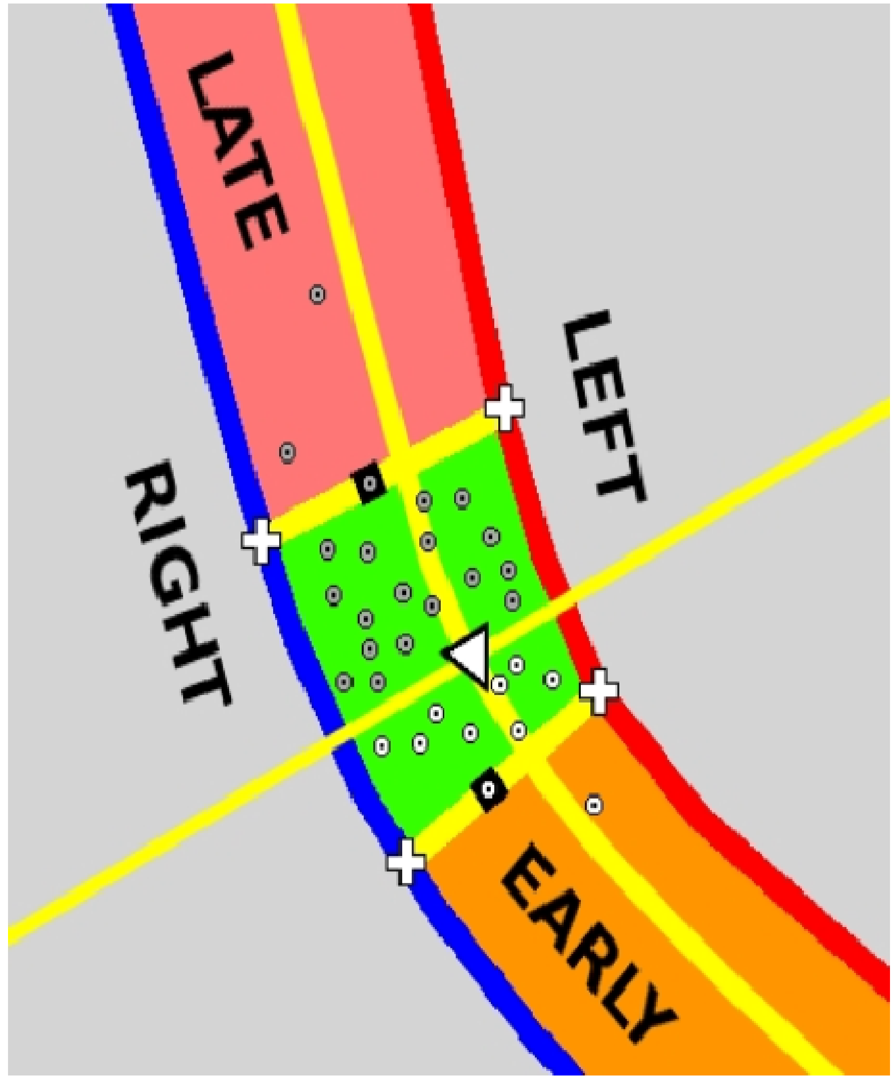
Patterns analysis and discovery



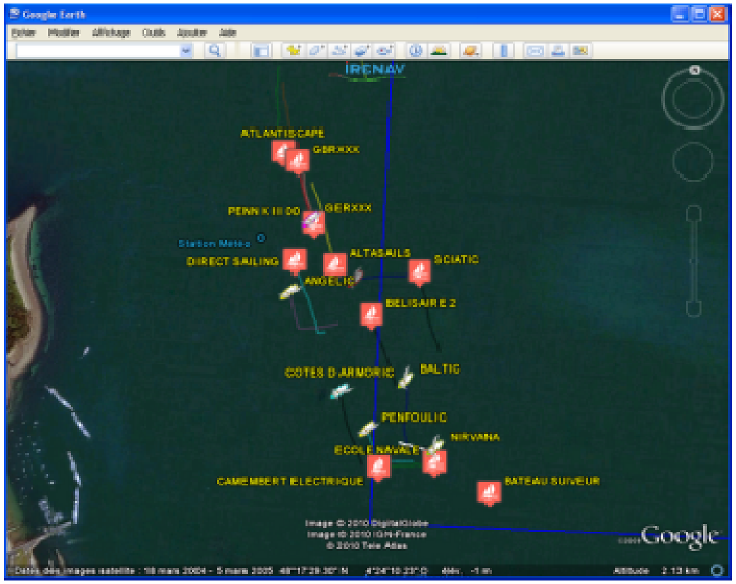


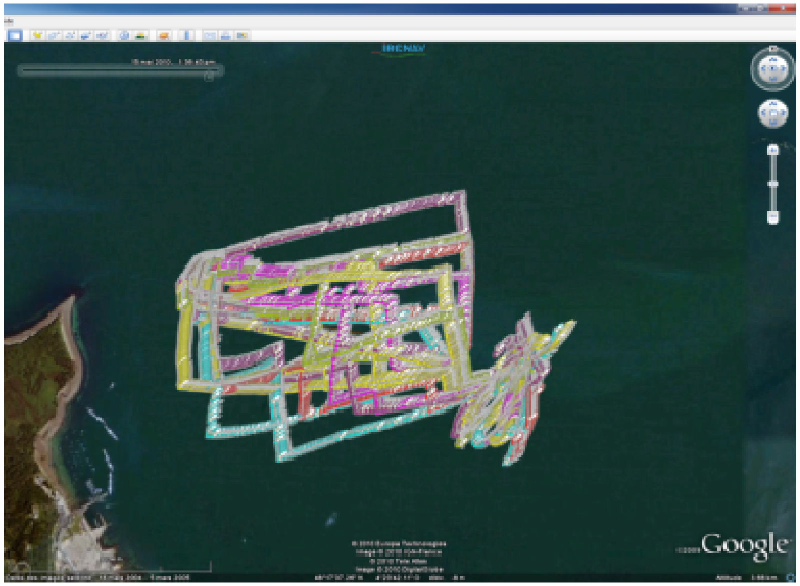
Patterns analysis and discovery

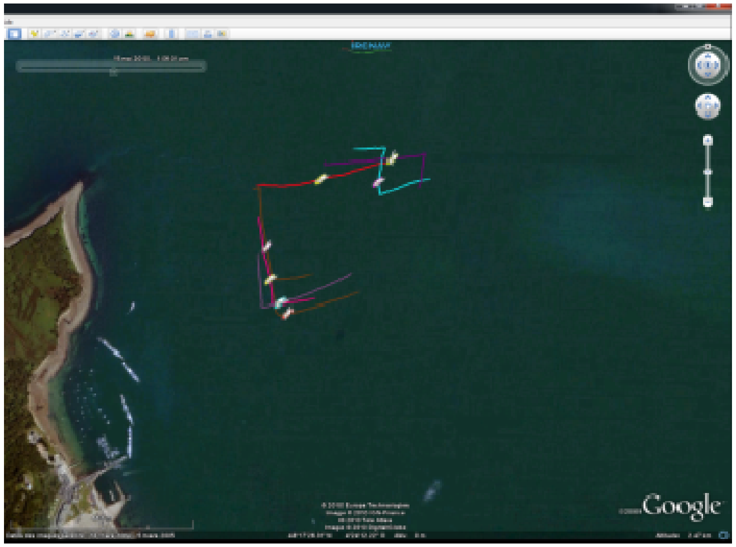




Patterns analysis and discovery







Trajectory analysis and discovery

Arctic Sea's strange journey

Russian cargo ship was first attacked by pirates, then lost, then found again; now eight possible hijackers have been arrested.

1. **July 23** Artic Sea leaves Jakobstad carrying timber
2. **July 24** Ship is boarded by masked men posing as police
3. **July 28** Last radio contact at Dover Strait
4. **July 30** Tracked off the coast of France
5. **Aug. 1** Spotted off Portuguese coast
6. **Aug. 16** Russian navy finds Artic Sea 300 miles (483 km) off Cape Verde islands

Source: BBC, Reuters Graphic: Eeli Polli © 2009 MCT

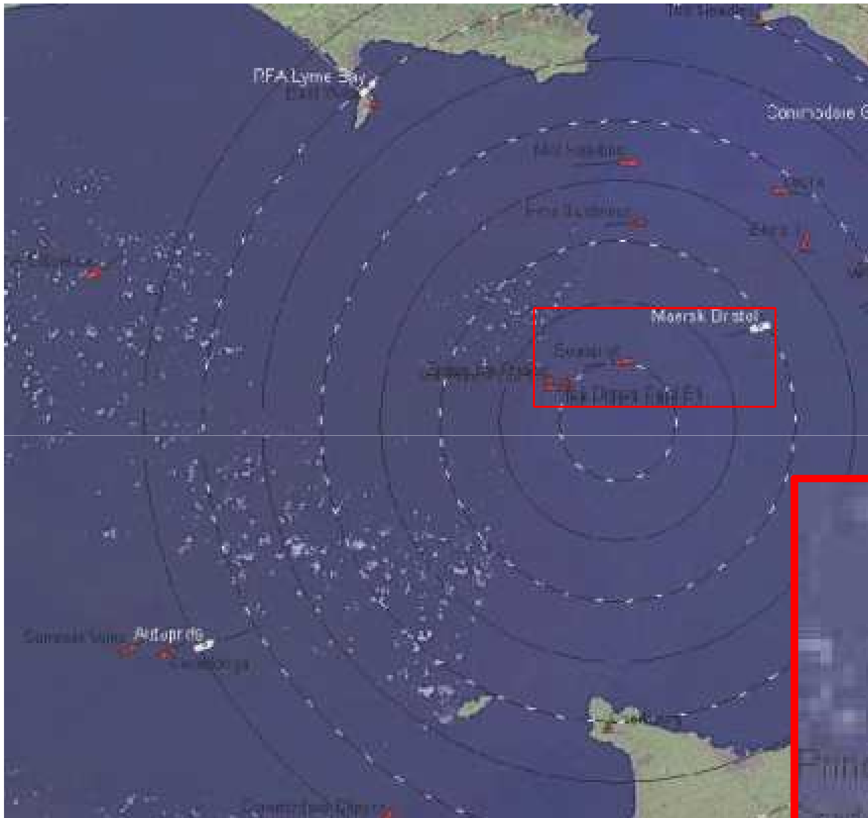
Container tracking

International reports indicate that between 2,000 and 10,000 containers are dropped into the sea each year.

The problem is to retrieve container trajectories according to current and winds, or to retrieve the ships they came from

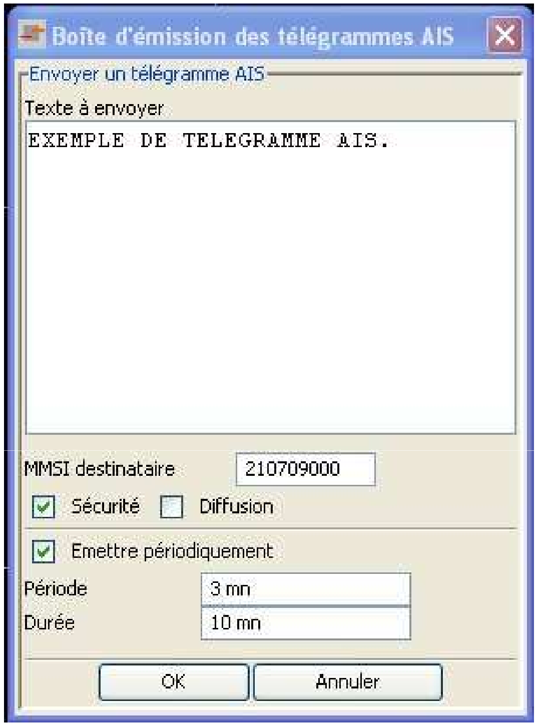
Container tracking

Virtual AtoN



Sinking of Ice Prince 01/15/2008

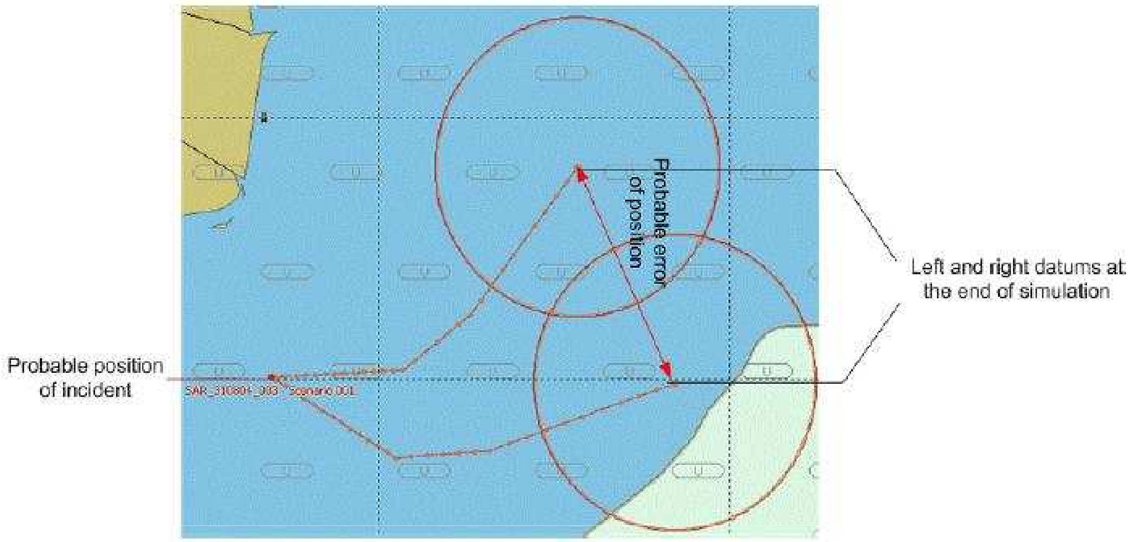
Searc and rescue (SAR)



Broadcasting of safety messages

Localization, tracking and guidance of SAR means

Searc and rescue (SAR)

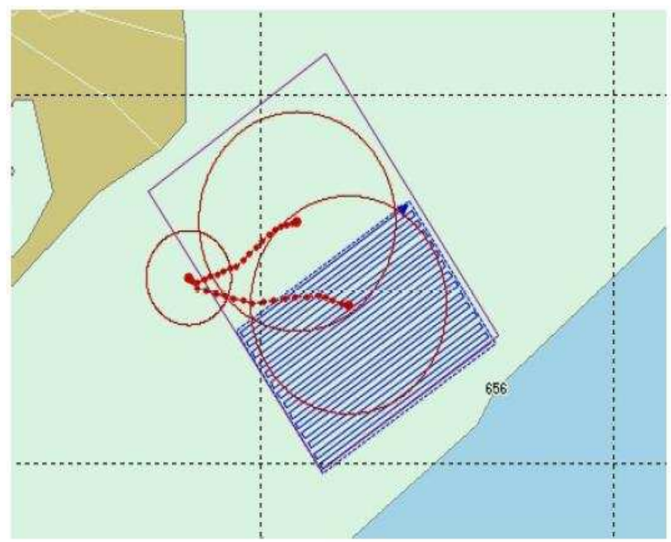


Search And Rescue:

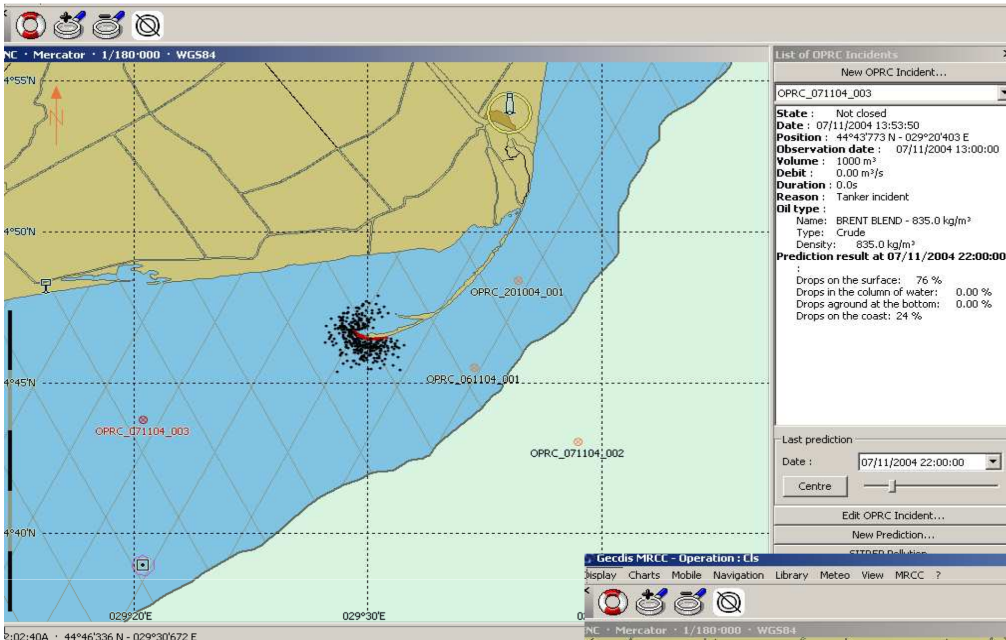
. Location of incident
. Type of rescue
. Availability of resources
. Wind and currents

Compute of probability of detection:

. Compute optimum rescue route
. Record operations into logbook
. Provide debriefing tools

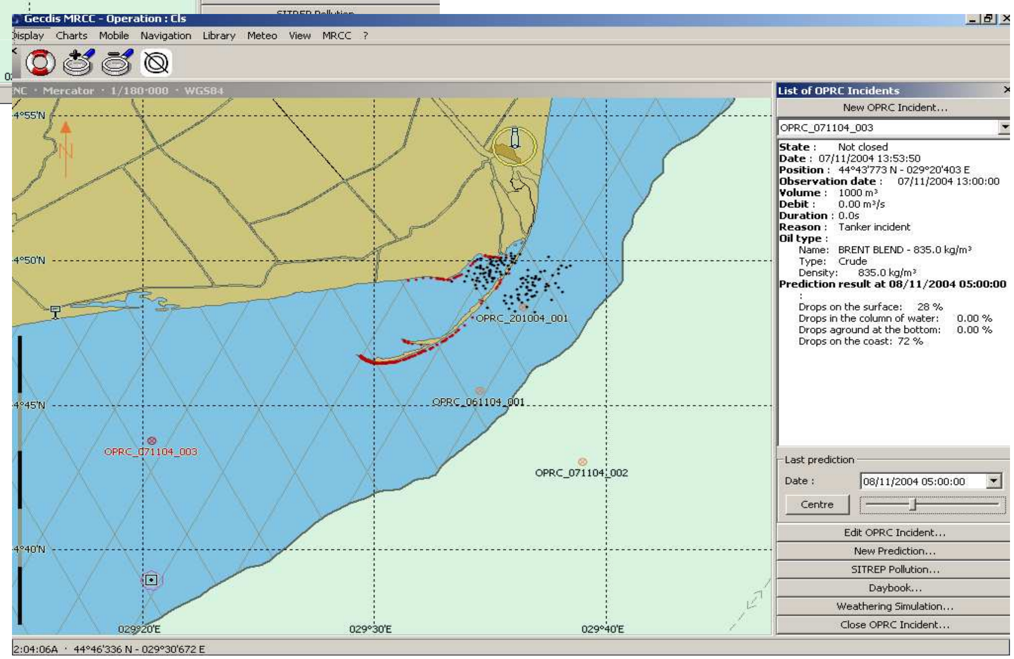


Searc and rescue (SAR)



Oil spill:

. Oil quality
. Currents
. Winds

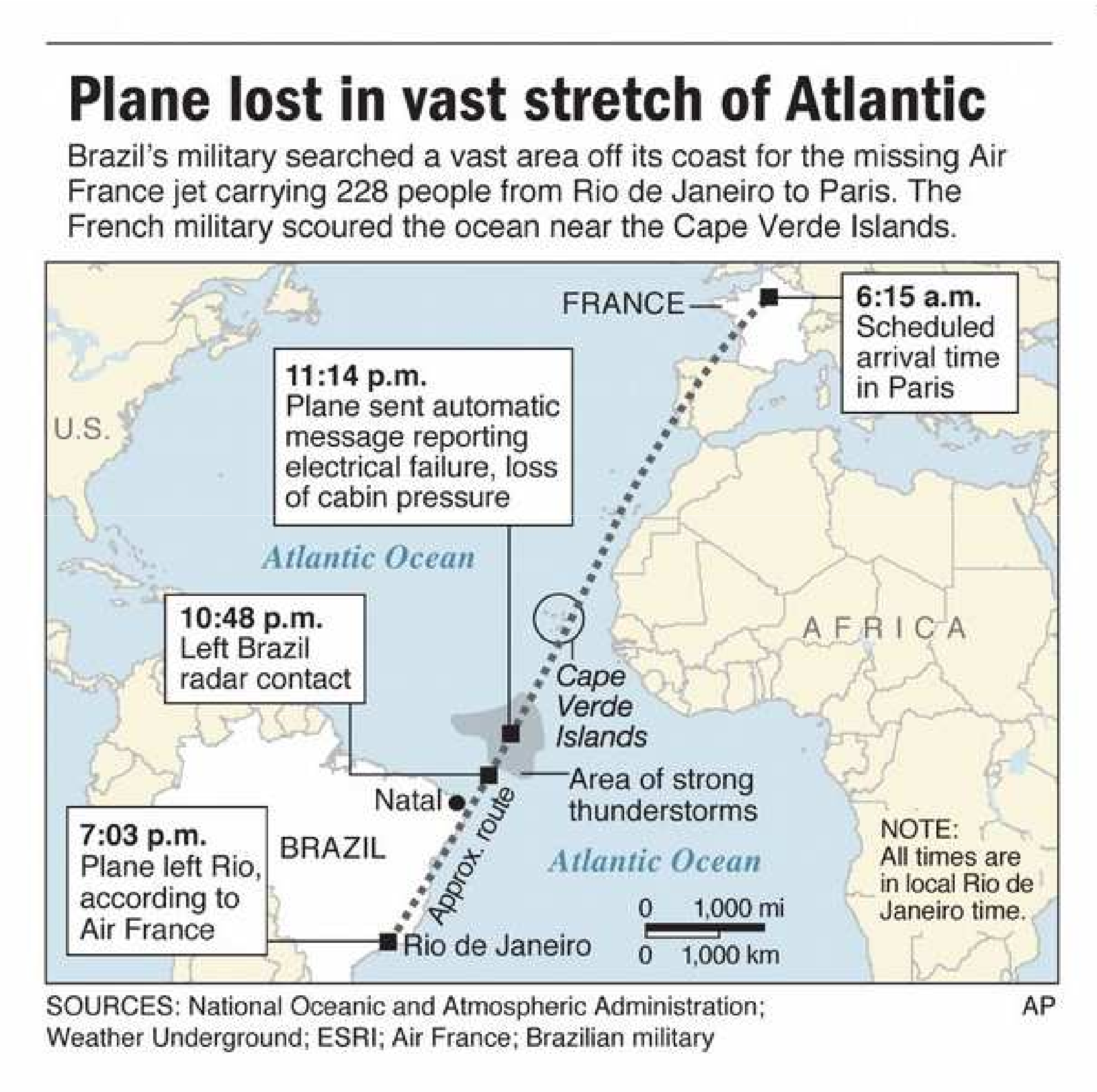


Compute quantity of oil:

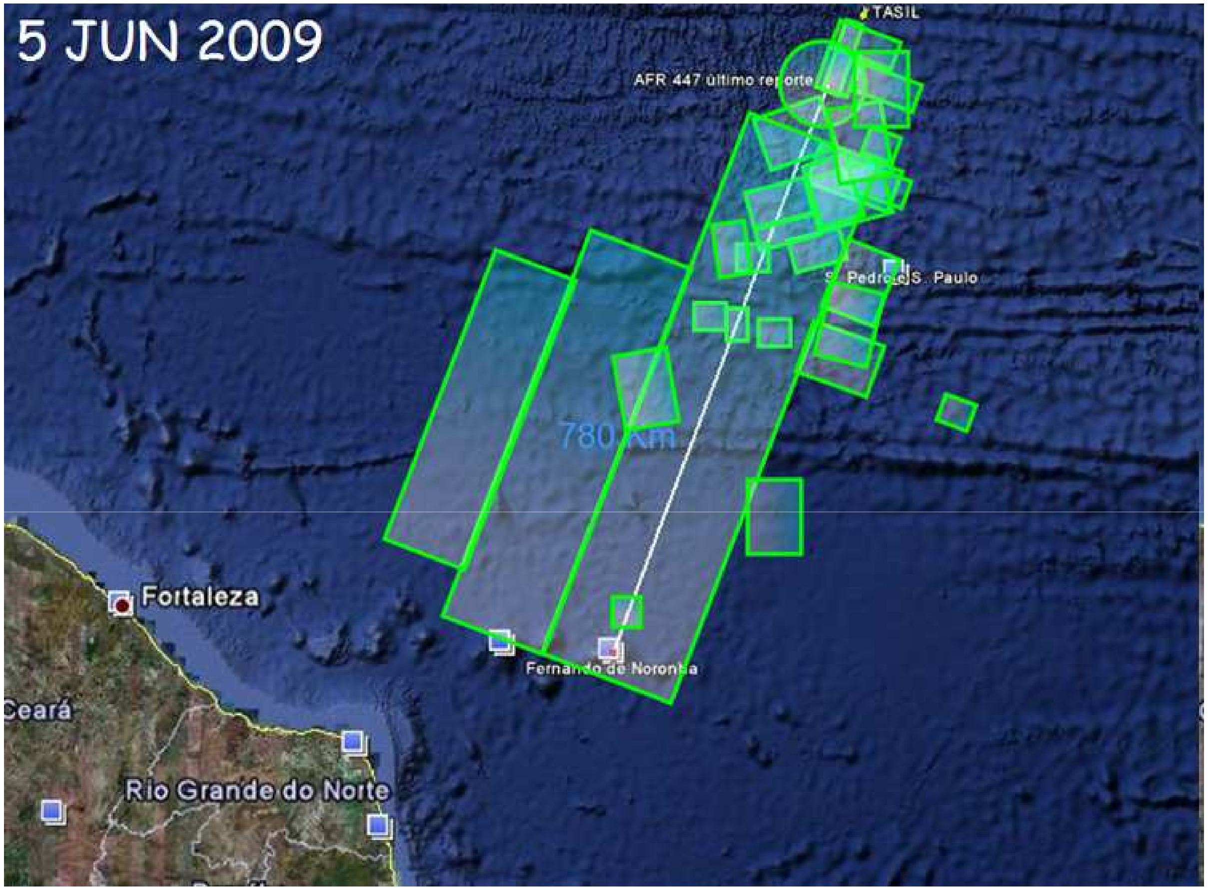
. On shore
. On sea bed
. Evaporated

Search and rescue (SAR)

Searc and rescue (SAR)

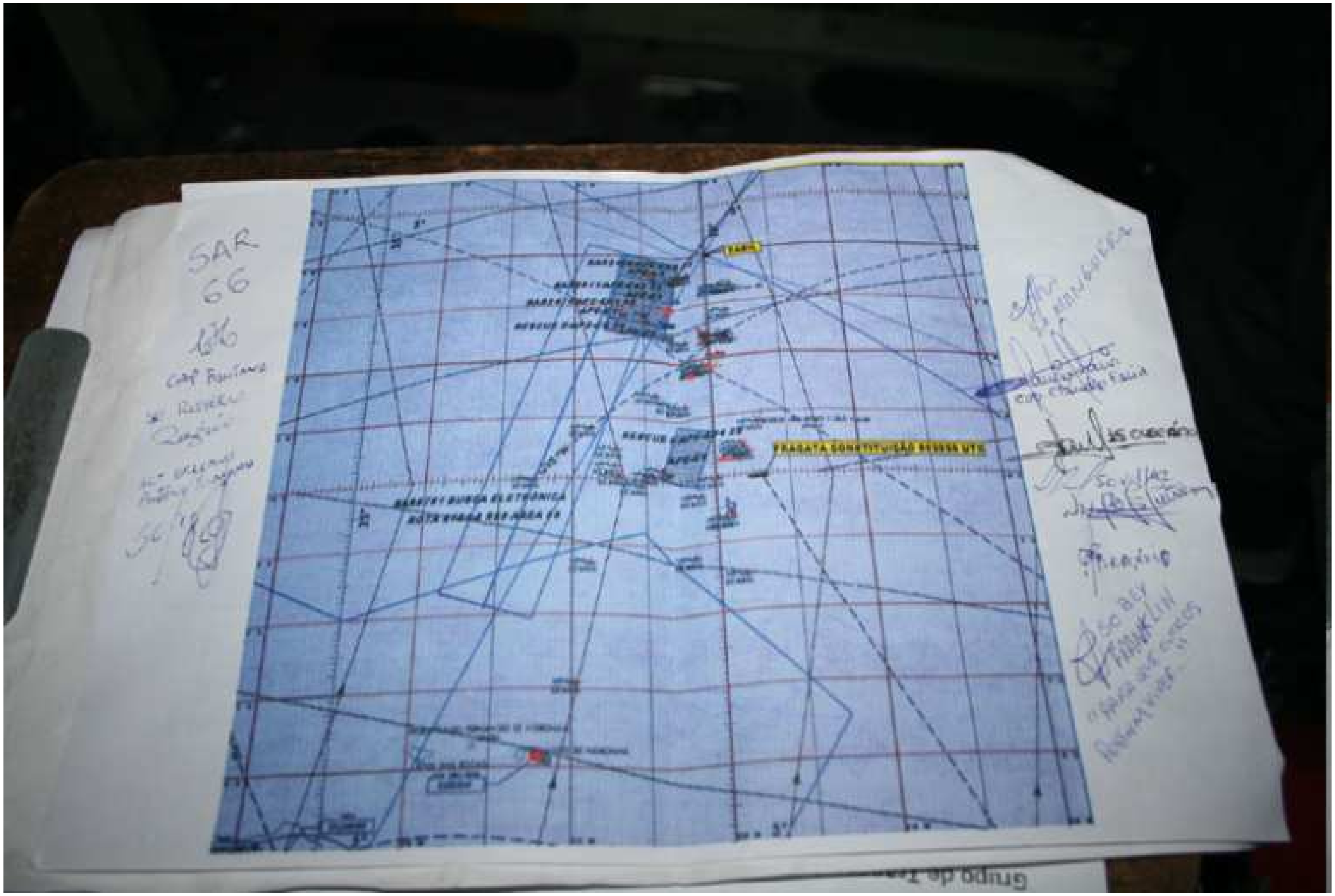


Searc and rescue (SAR)



Search area

Searc and rescue (SAR)



Search area + rescue ships trajectories…

Ship pollution

Observing

Retrieving

Moving objects at sea: research challenges

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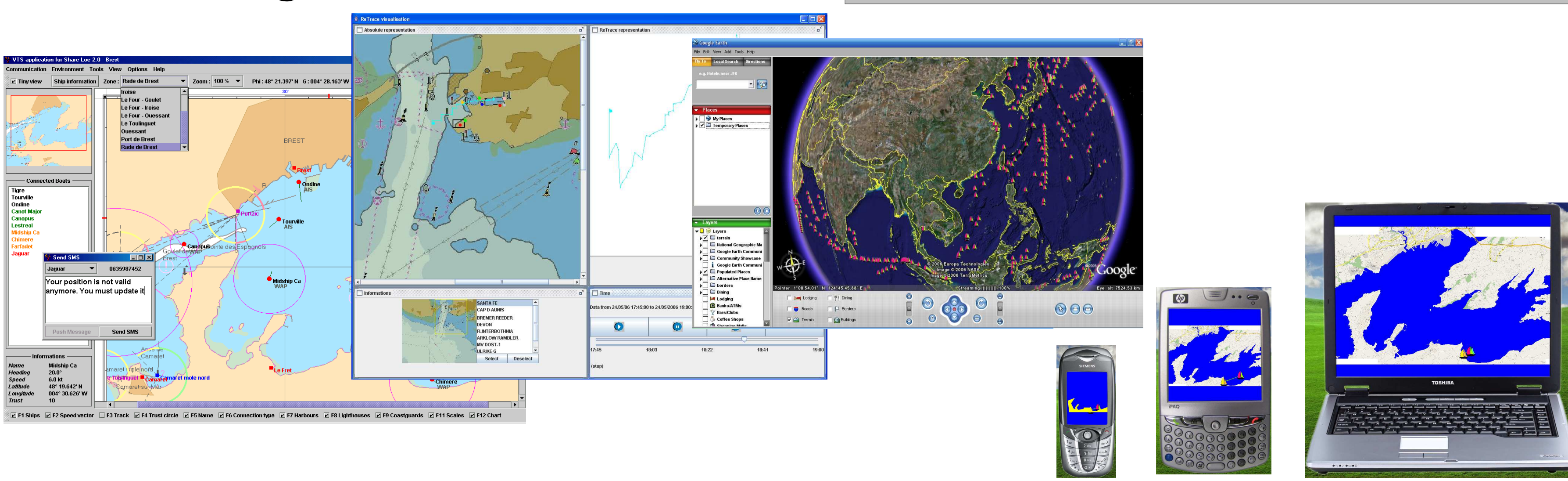
Maritime data integration

Modelling and tracking of maritime navigations

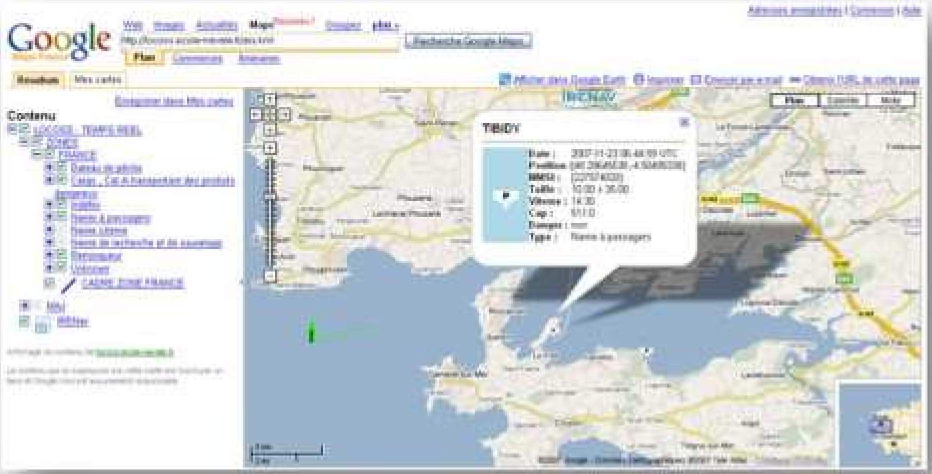
Diffusion of services to clients and monitoring authorities

- Heterogeneous databases
- Traffic control
- Safety
- Event tracking

- Patterns discovery & analysis
- Search And Rescue (SAR)
- Simulation & Decision-aid systems
- Visualisation and user interfaces



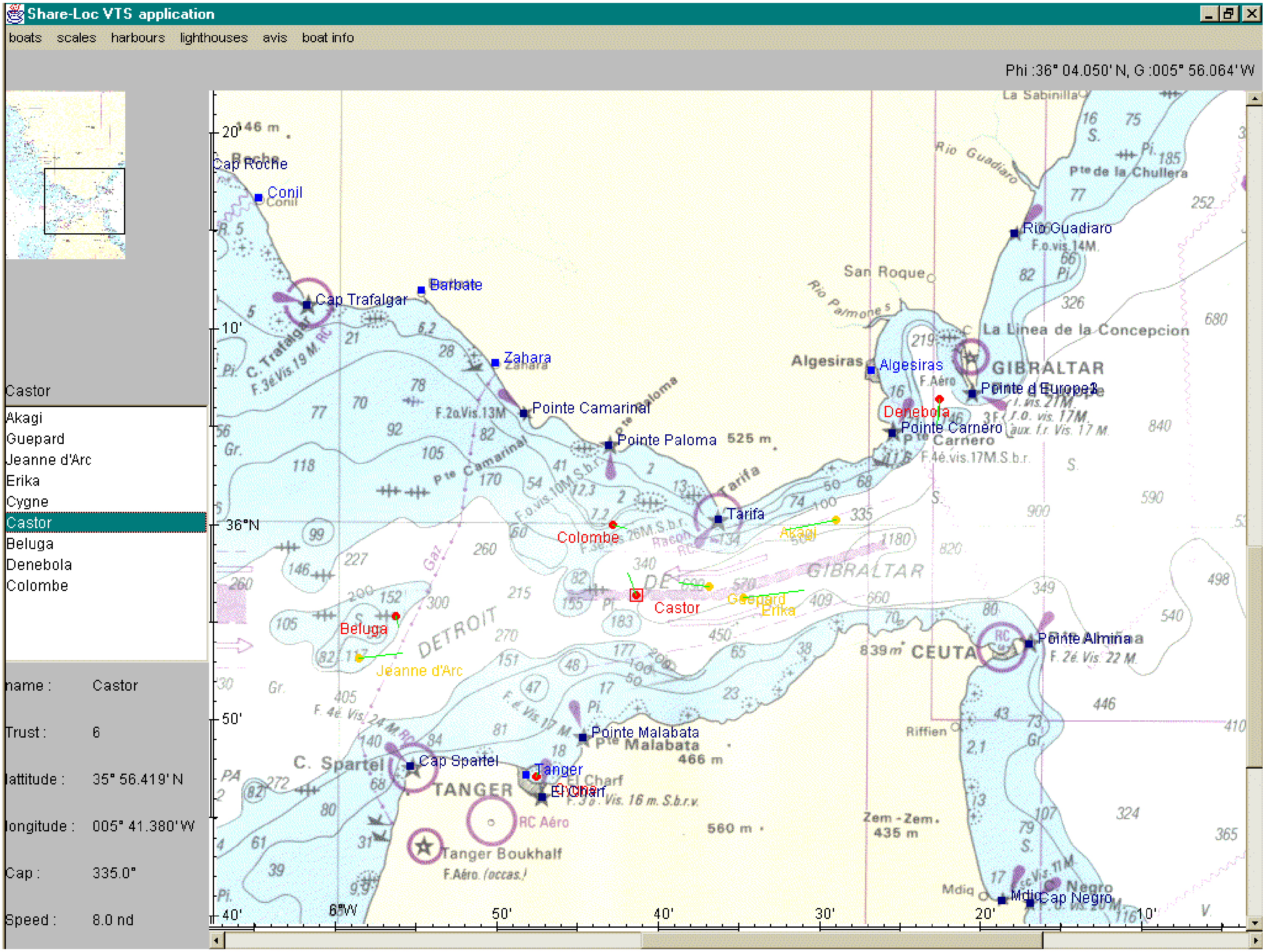
Web-based visualisation



http://locoss.ecole-navale.fr

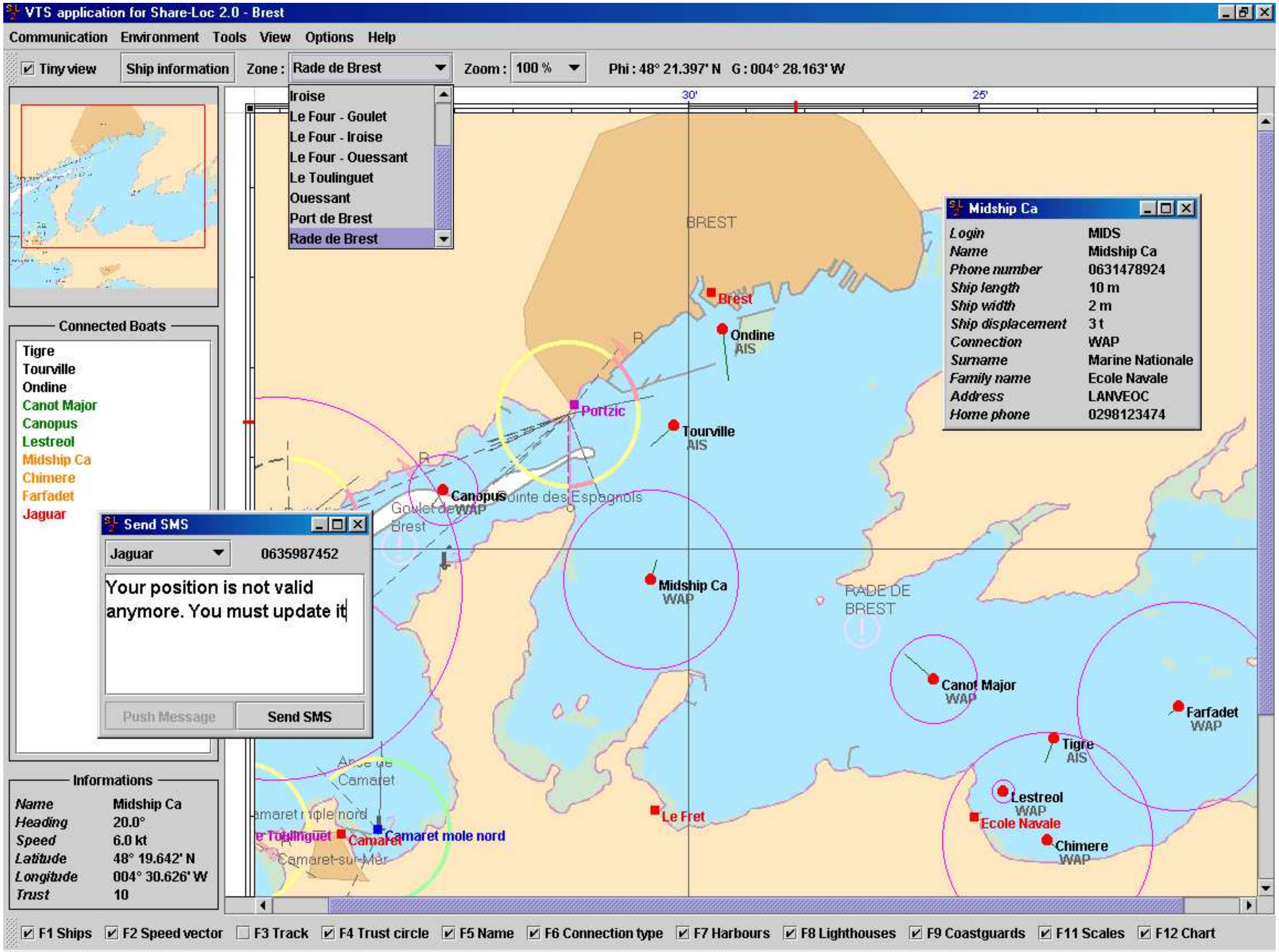
VTS Services within GIS

60

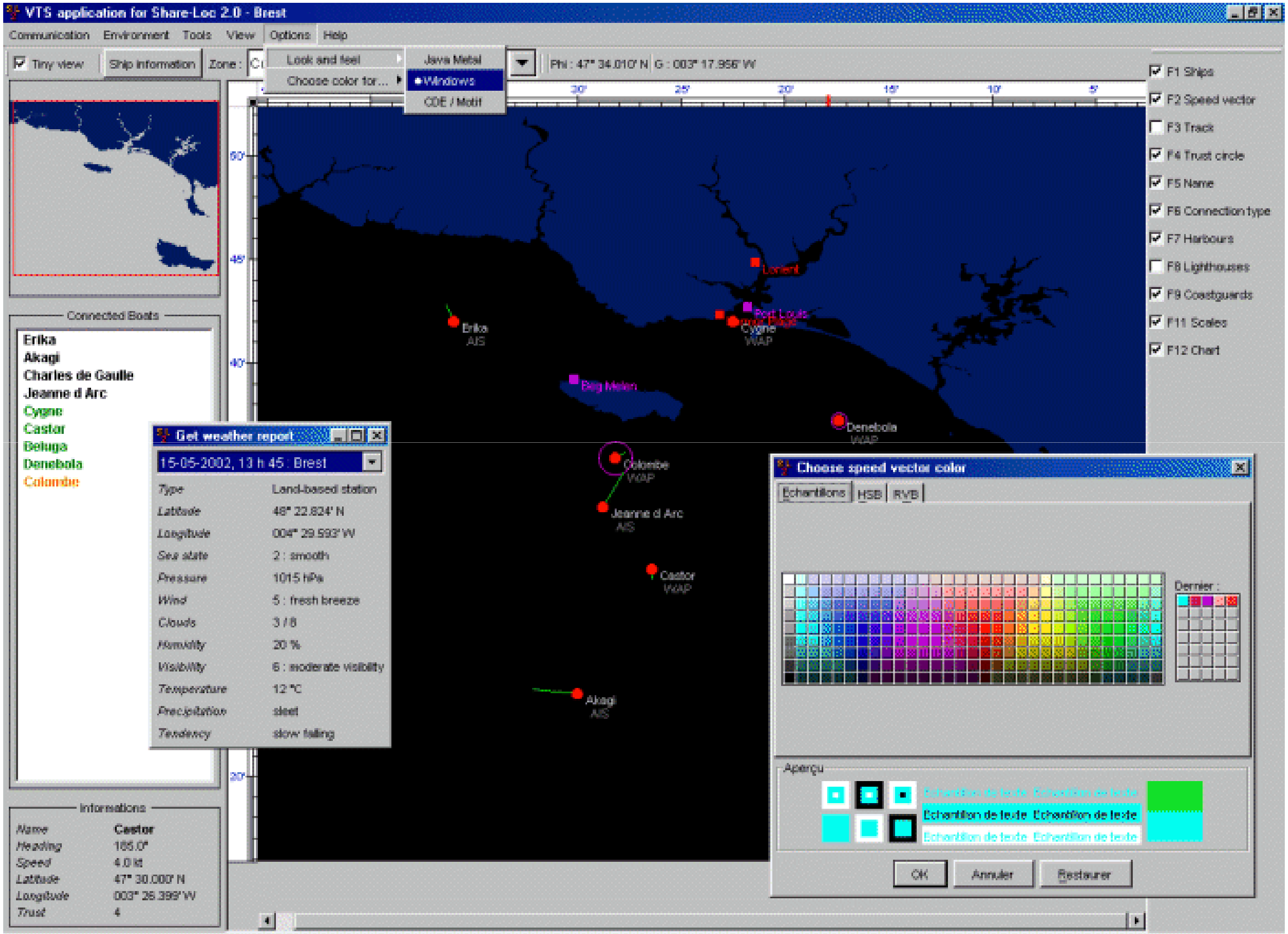


VTS Services Within GIS

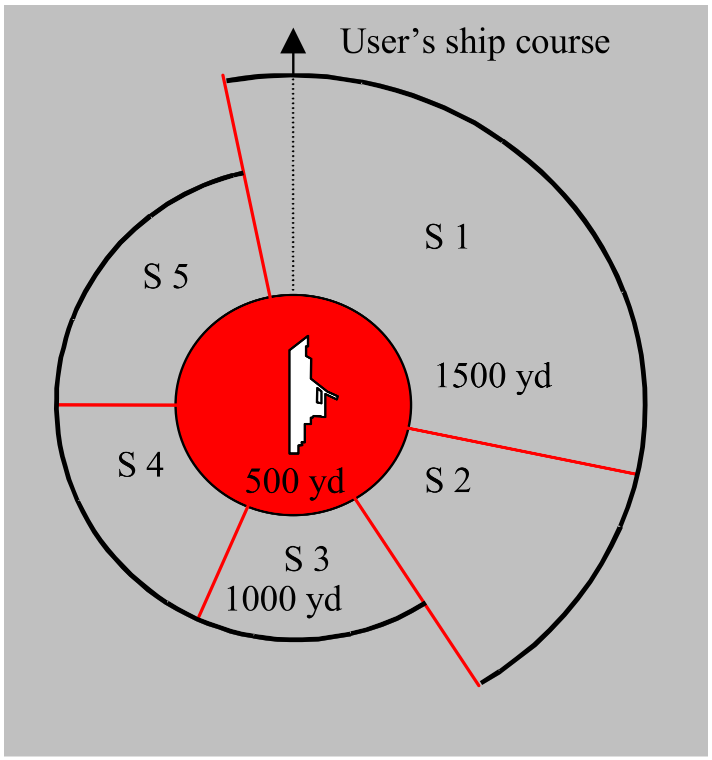
61



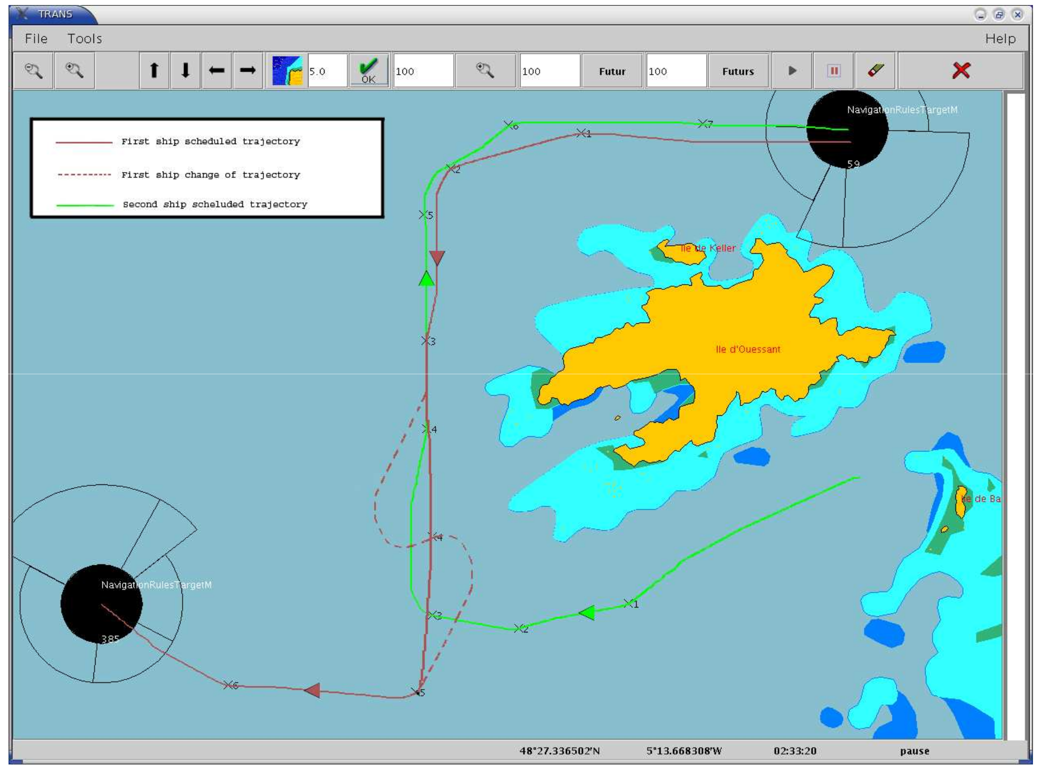
VTS Services Within GIS



Navigation modelling and simulation



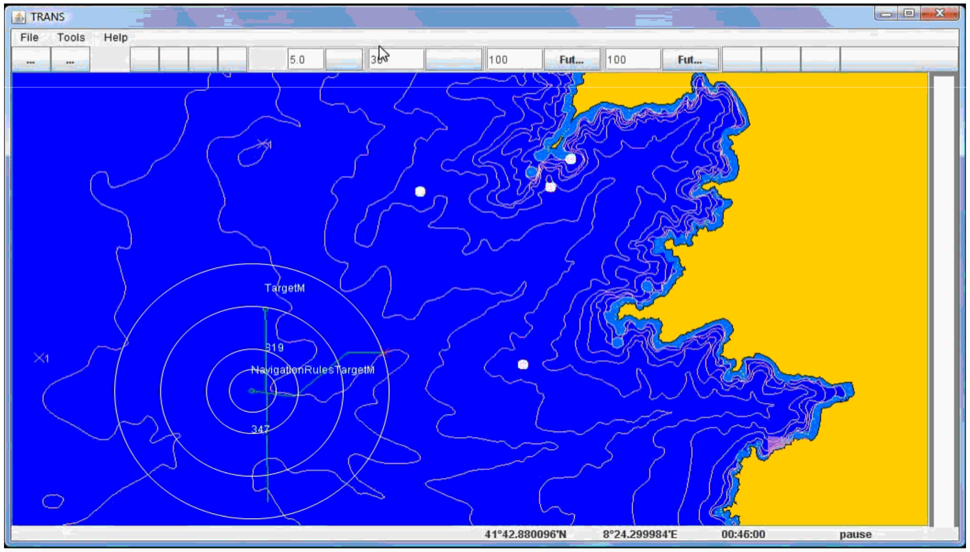
Navigation rules



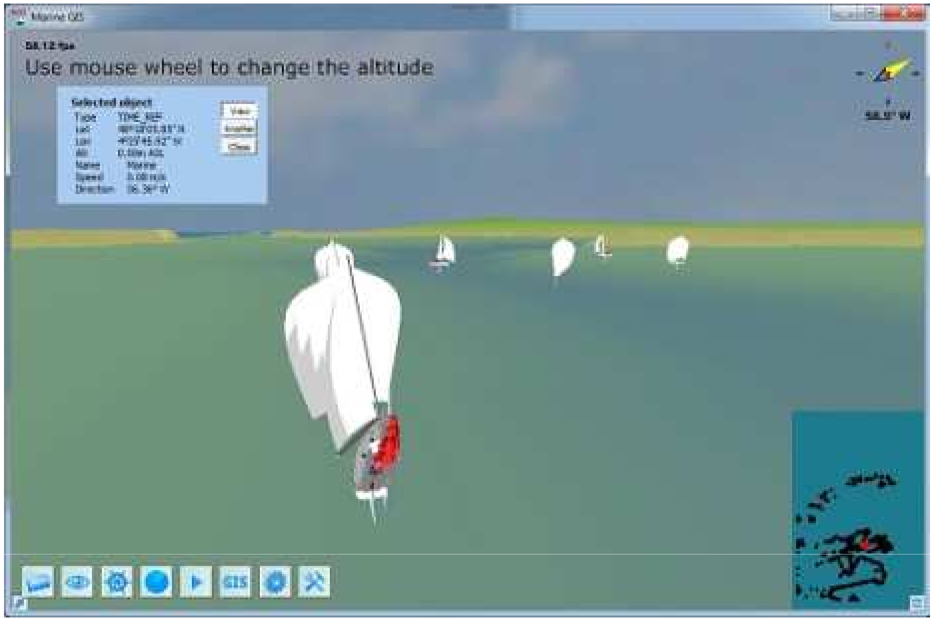
Collaborative navigation modelling

Navigation modelling and decision processes

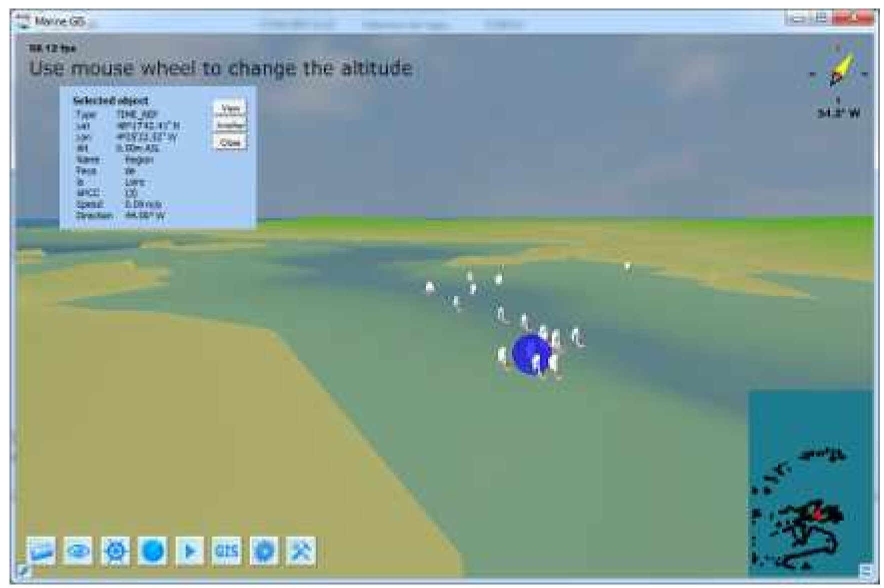
- Integration of an expert decision process into simulation platforms
  - Whose objective is to build realistic maritime traffic simulations and by taking into account actors and decision processes



3D Marine GIS



Replay (« Grand Prix 2009 »)

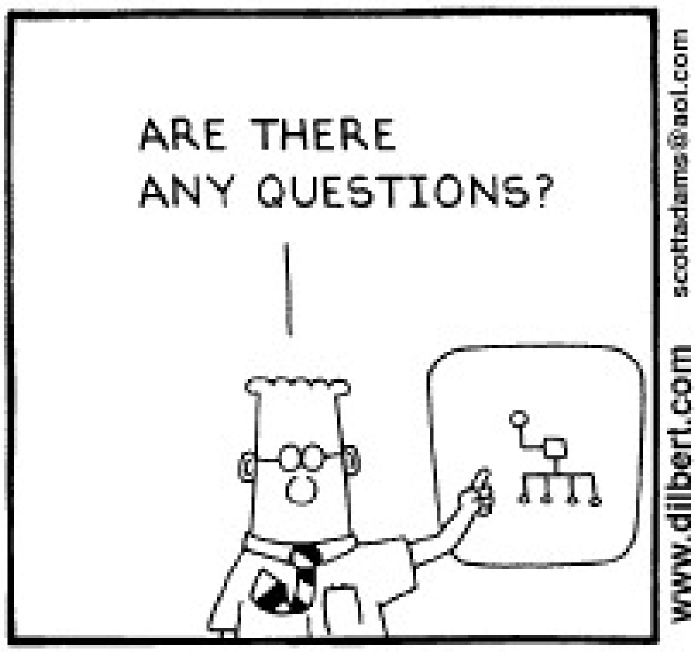


What should we retain ?

As citizen: we don't care too much to what is really happening at sea,

and we don't know too much about it

Conclusion



Thank you very much for your attention !

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