

Invited Talk

Christophe Claramunt

Naval Academy Research Institute, France

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 objects 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

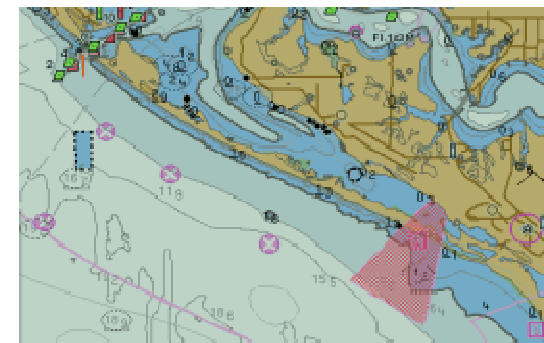
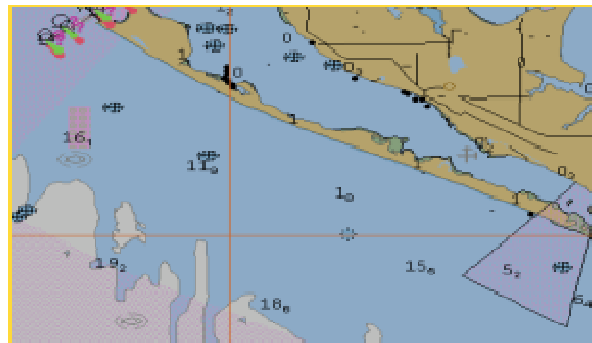
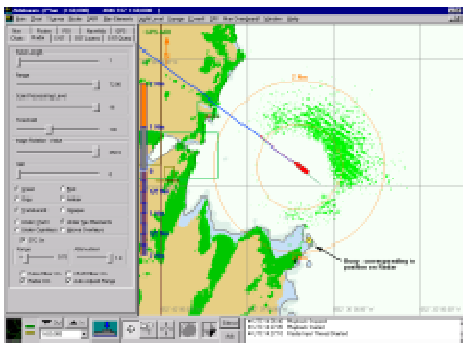
Naval Academy Research Institute, France



MOVE (Knowledge Discovery from Moving Objects)

Moving objects at sea: trends and challenges

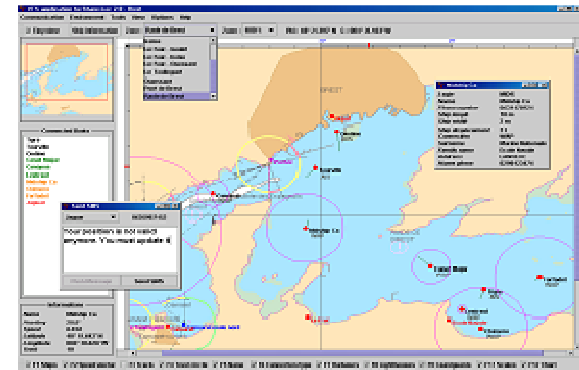
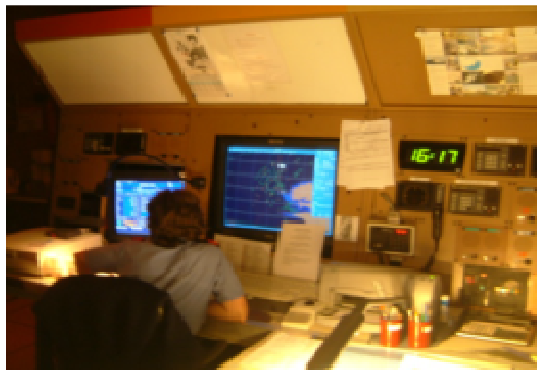
Part I Current trends



Moving objects at sea: scope

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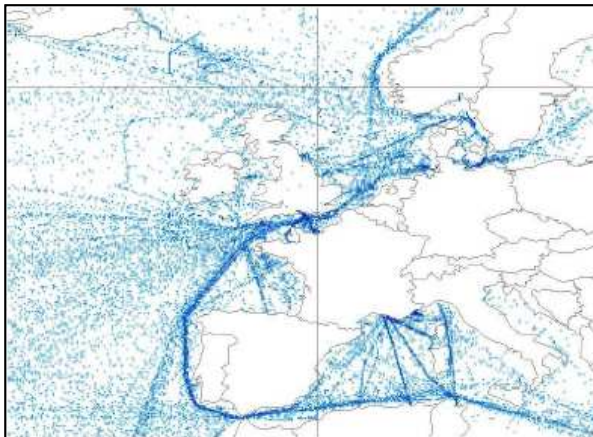
- The way we consider moving objects at sea are the ones, **mainly ships**, closely related to the **modelling, monitoring, simulation, visualization** and **analysis of maritime data**, while applications cover **transportation, environmental studies and security** (amongst others)
- Research and application 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

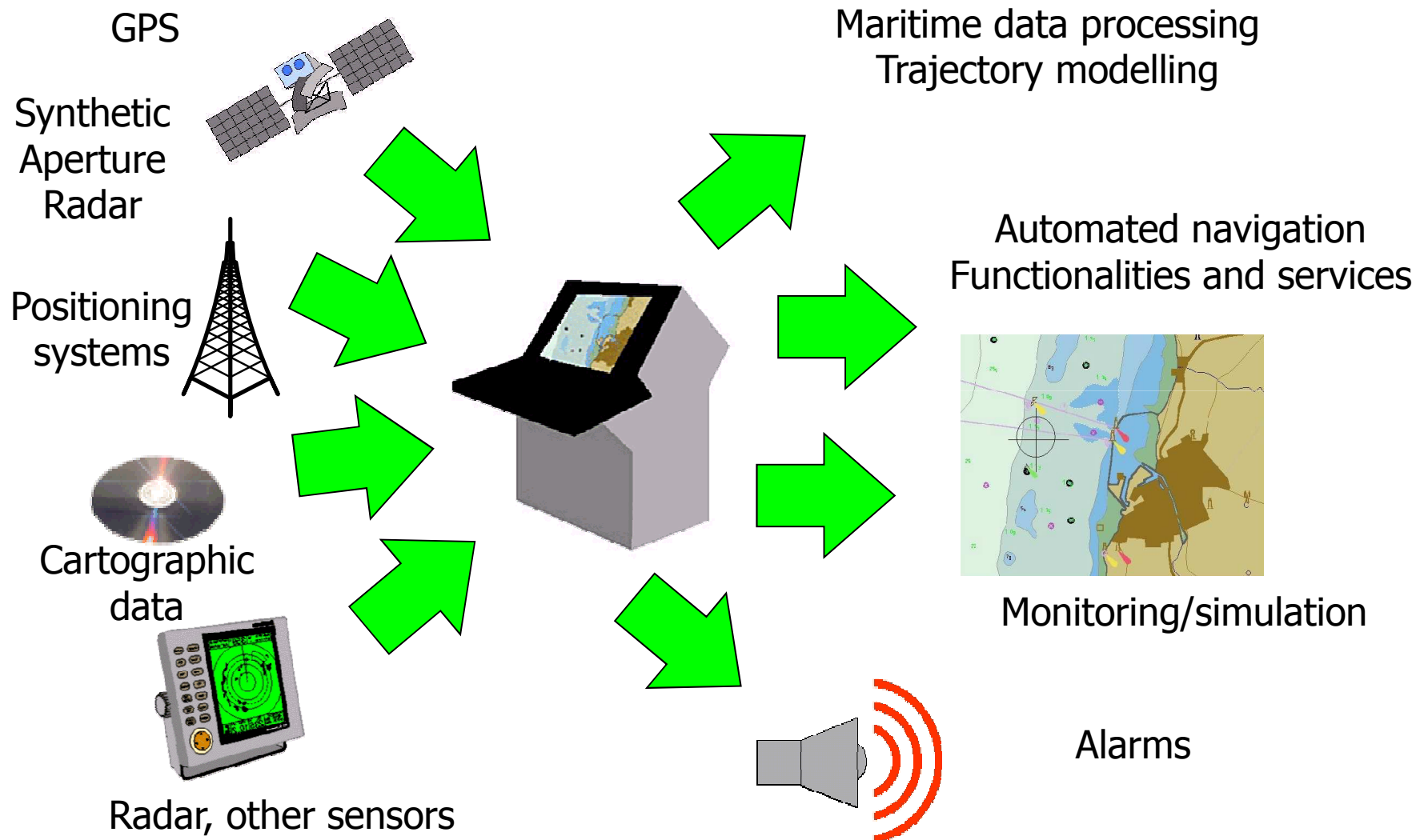
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- Identifying new **rules** and promoting new **standards** and products for the improvement of safety at sea is a constant objective of the **International Maritime Organisation (IMO)**
- Recent progress in automated navigation includes **navigation-aid 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

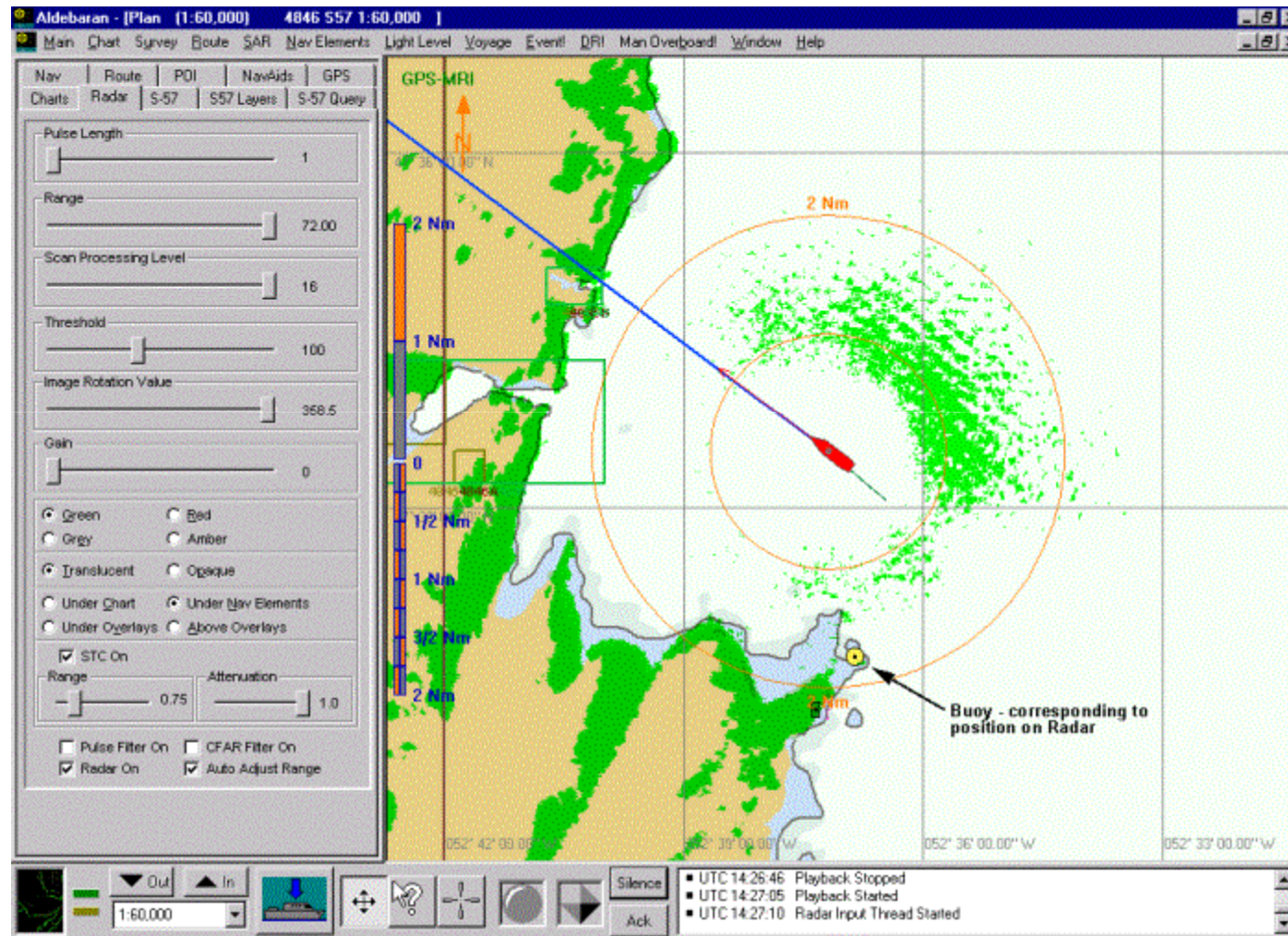
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Automatic Radar Plotting Aid (ARPA)

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

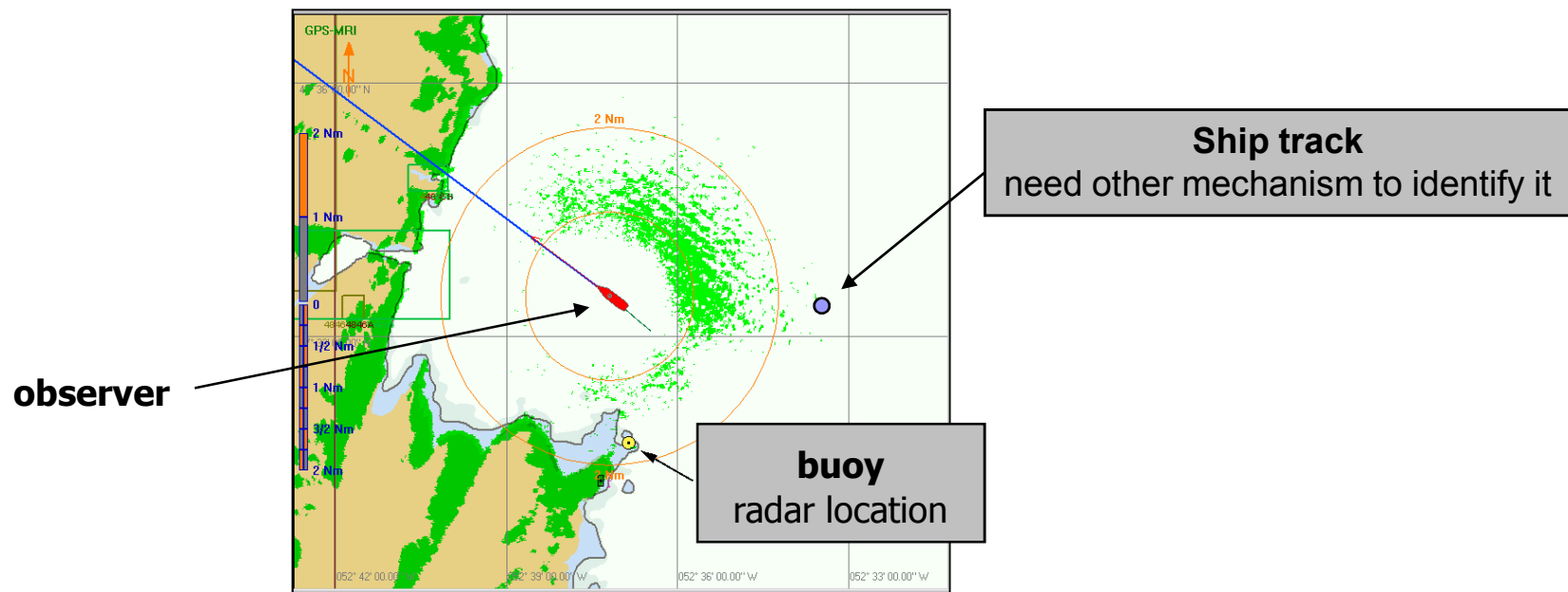


Radar Track Identification

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- 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

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- 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)

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- 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

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

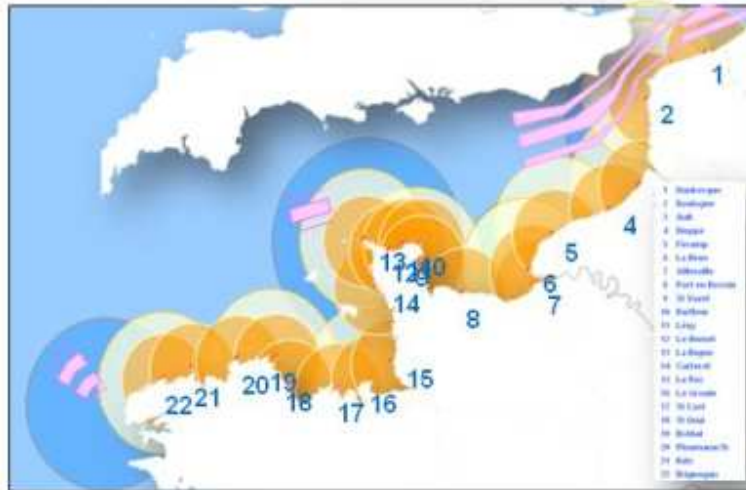
- AIS uses 21 messages that integrate
 - MMSI and OMI codes
 - Ship name and type
 - Latitude, longitude
 - Heading, speed



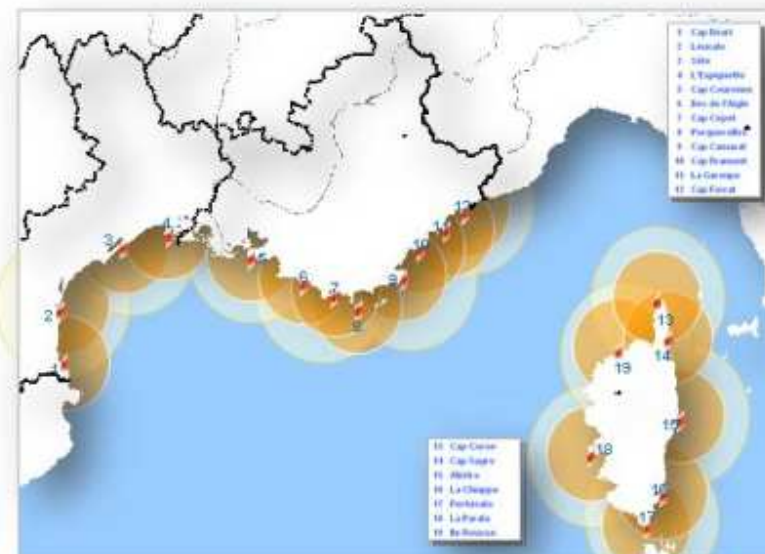
| Ship Type | Interval |
|--|----------|
| Static ship | 3 min |
| Ship from 0 to 14 knots | 12 s |
| Ship from 0 to 14 knots + change of route | 4 s |
| Ship from 14 to 23 knots | 6 s |
| Ship from 14 to 23 knots + change of route | 2 s |
| Ship more than 23 knots | 3 s |
| Ship more than 23 knots +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

AIS Metropolitan coverage

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59 « **sémaphores** »
 7 CROSS
 18 mobile stations



AIS contribution to the ARPA

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- 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)

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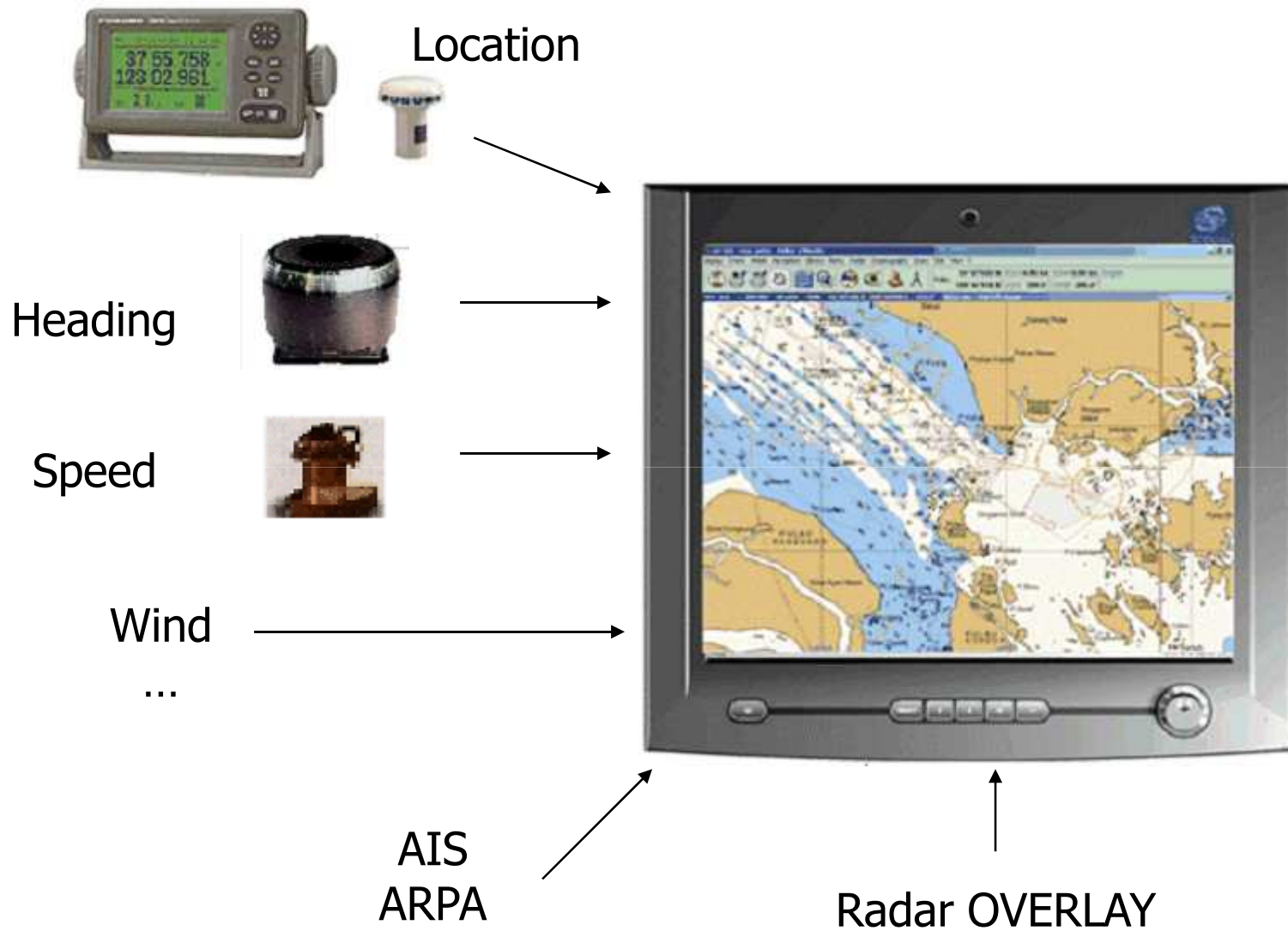
" e-navigation is the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment "

Electronic Chart Display & Information Systems (ECDIS)

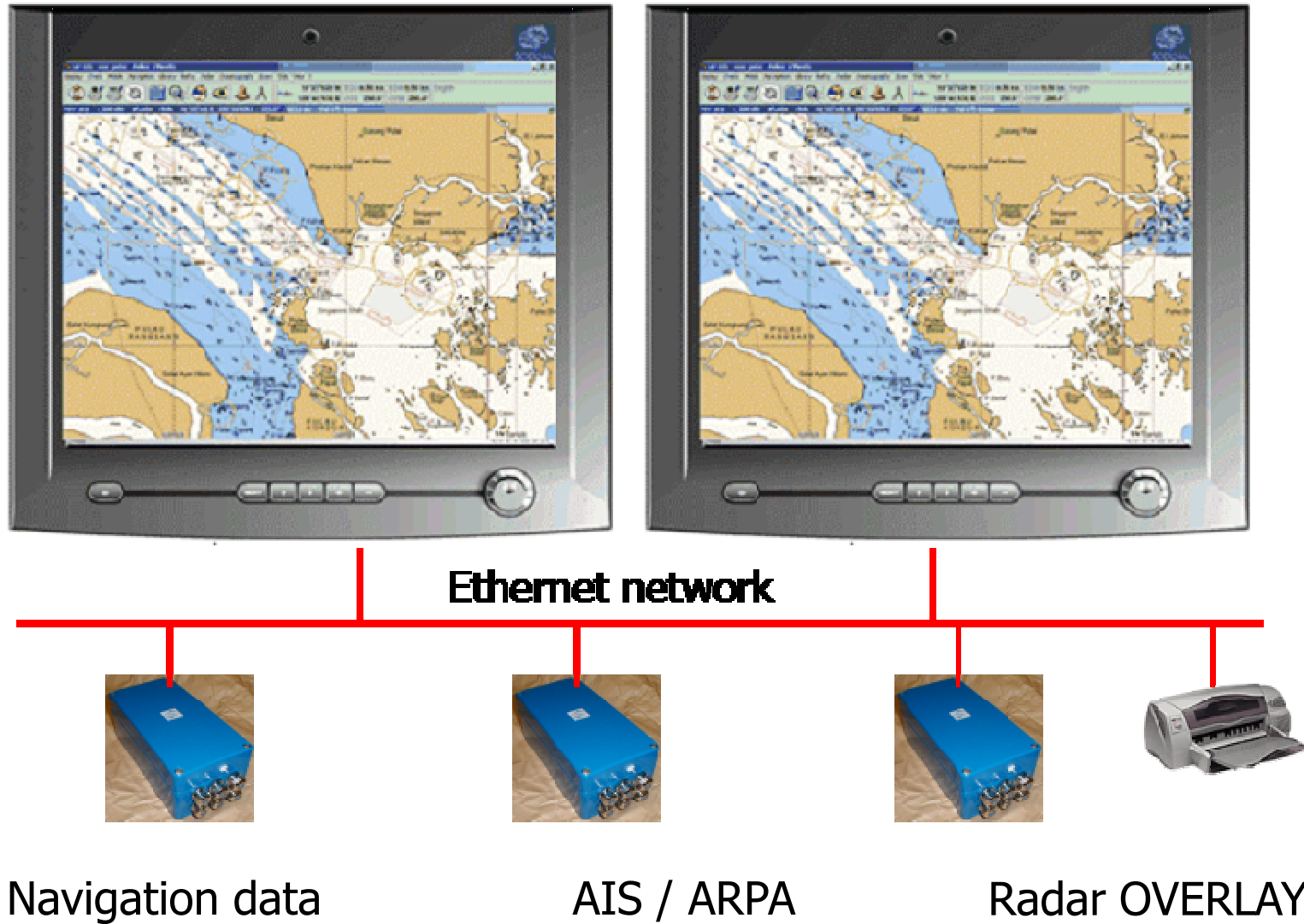
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- Combines a **location-based navigation database, electronic vector charts, navigation tools, route planning and warning functionality** to provide a navigation tool that can reduce the risk of human error in navigation
- It is intended **to replace 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)



Electronic Chart Display & Information Systems (ECDIS)



ECDIS: Route Planning

Route drawing

Dangers

Route properties

Route planning

Dangers détectés

| Zone | Nom | Position | Cellule |
|-------|------------------------|----------------------------|----------|
| Zone | Restricted area | 48°17'238 N - 004°45'793 W | FR301191 |
| Zone | Caution area | 48°16'281 N - 004°38'046 W | FR301191 |
| Zone | Depth area | 48°14'955 N - 004°46'482 W | FR301191 |
| Zone | Depth area | 48°15'666 N - 004°46'533 W | FR301191 |
| Zone | Depth area | 48°19'917 N - 004°23'025 W | FR301191 |
| Zone | Caution area | 48°20'412 N - 004°34'461 W | FR301191 |
| Zone | Shoreline Construction | 48°22'056 N - 004°29'526 W | FR301191 |
| Point | Buoy, cardinal | 48°15'120 N - 004°46'332 W | FR301191 |

Buoy, cardinal
 Position : 48°15'120 N - 004°46'332 W
 Buoy shape : spar (spindle)
 Category of cardinal mark : east cardinal mark
 Colour : black, yellow, black
 Colour pattern : horizontal stripes
 Object name : GOEMANT

Propriétés de la route

Nom : Brest - Lorient
 Commentaire : Route par le raz de Sein

| N° | Nom | Position | Route | Distance | Reste | Total | XTE Max | Rayon de |
|----|-----|----------------------------|--------|----------|----------|----------|---------|----------|
| 1 | AA | 48°22'061 N - 004°29'576 W | | | 12.08 N | 0.0000 m | | |
| 2 | AB | 48°21'438 N - 004°29'576 W | 180.0° | 1154 m | 11.46 N | 1154 m | 100.0 m | 100.0 |
| 3 | AC | 48°20'756 N - 004°34'110 W | 257.2° | 3.090 N | 8.368 N | 3.713 N | 100.0 m | 100.0 |
| 4 | AD | 48°19'836 N - 004°36'511 W | 240.0° | 1.842 N | 6.526 N | 5.554 N | 100.0 m | 100.0 |
| 5 | AE | 48°19'213 N - 004°40'245 W | 255.9° | 2.560 N | 3.966 N | 8.114 N | 100.0 m | 100.0 |
| 6 | AF | 48°17'717 N - 004°45'767 W | 247.8° | 3.966 N | 0.0000 m | 12.08 N | 100.0 m | |

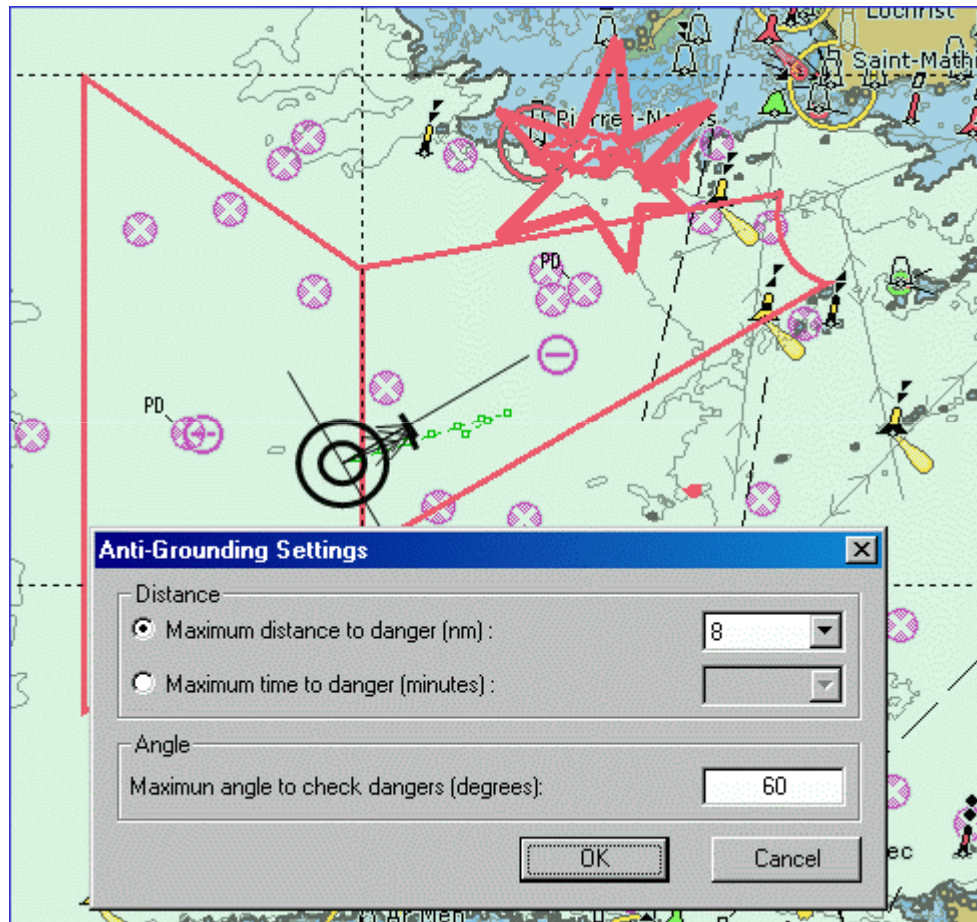
Planning

Nom : Brest - Lorient
 Commentaire : PIM de 12 noeuds

| N° | Nom | Position | HPA | Vitesse | Commentaire |
|----|-----|----------------------------|---------------------|---------|-------------|
| 1 | AA | 48°22'061 N - 004°29'576 W | 24/05/2002 09:00:00 | 12.0 kn | |
| 2 | AB | 48°21'438 N - 004°29'576 W | 24/05/2002 09:03:07 | 12.0 kn | |
| 3 | AC | 48°20'756 N - 004°34'110 W | 24/05/2002 09:18:34 | 12.0 kn | |
| 4 | AD | 48°19'836 N - 004°36'511 W | 24/05/2002 09:27:46 | 12.0 kn | |
| 5 | AE | 48°19'213 N - 004°40'245 W | 24/05/2002 09:40:34 | 12.0 kn | |
| 6 | AF | 48°17'717 N - 004°45'767 W | 24/05/2002 10:00:00 | 12.0 kn | |



ECDIS: Alarms

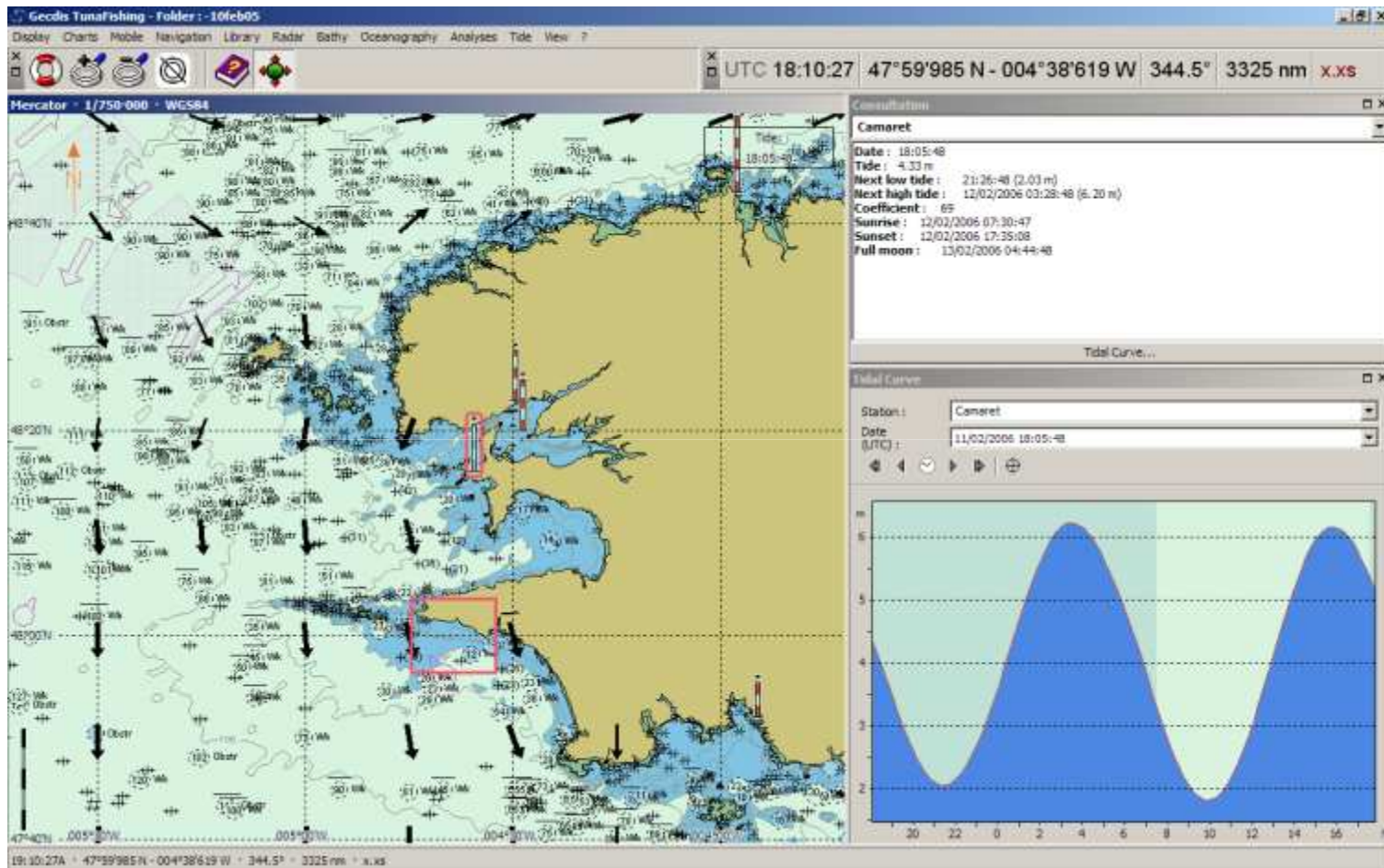


← Alarm !

← settings

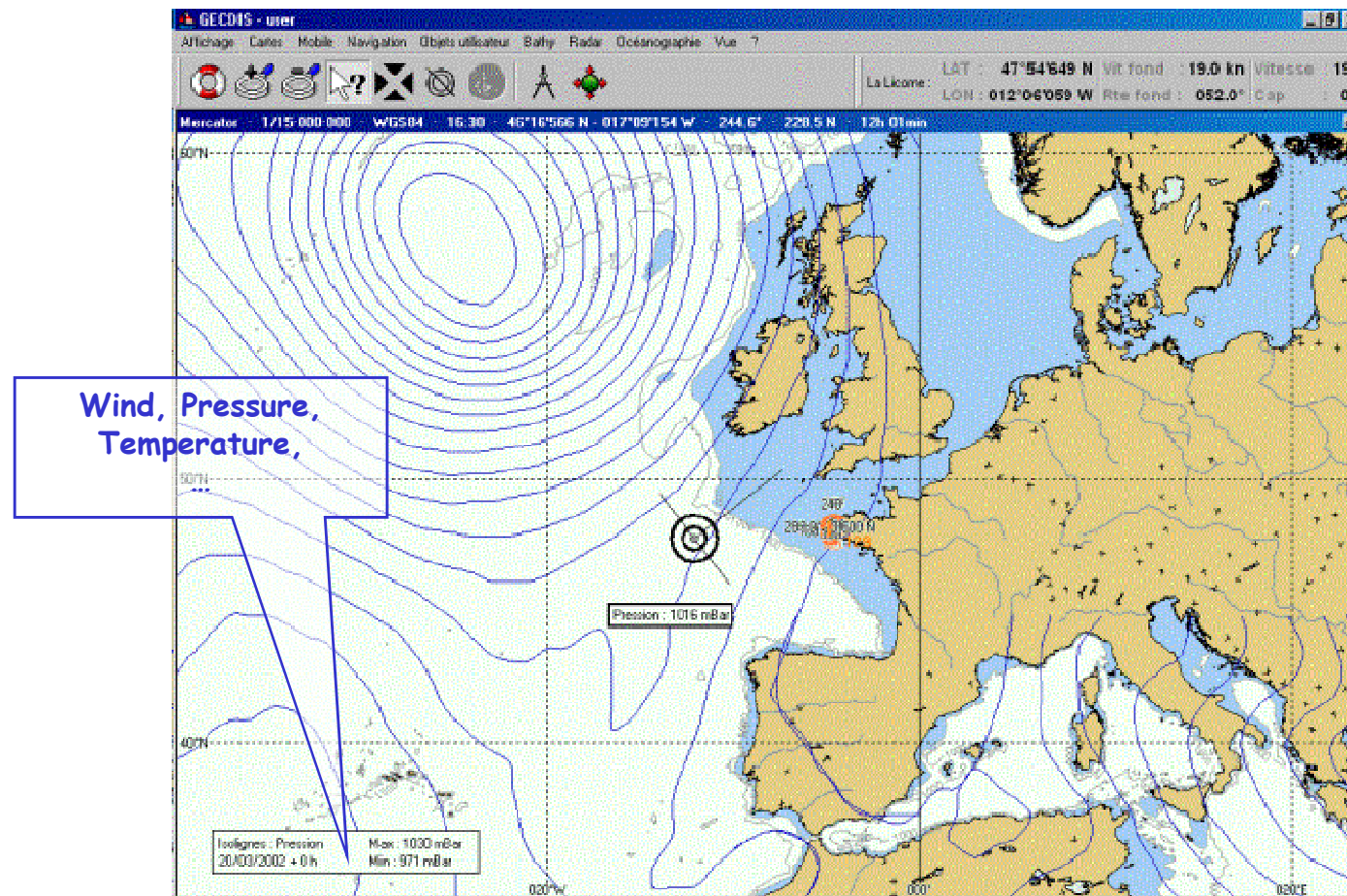
ECDIS: Additional Data - Tides

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ECDIS: Additional Data - Weather

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ECDIS: Advantages

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- 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

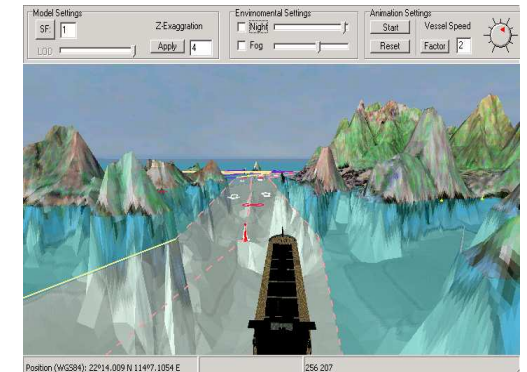
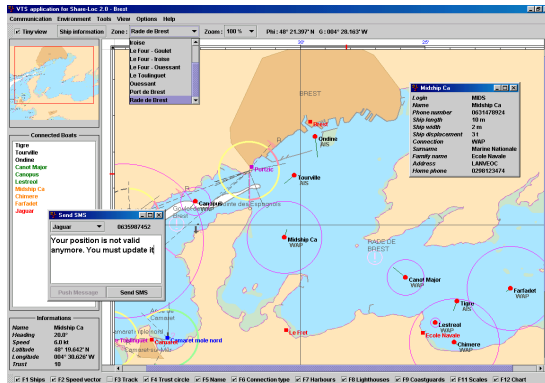
23

- 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

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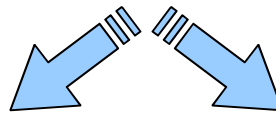
Maritime data integration

Modelling and tracking of maritime navigations

Diffusion of services to clients and monitoring authorities

Heterogeneous databases

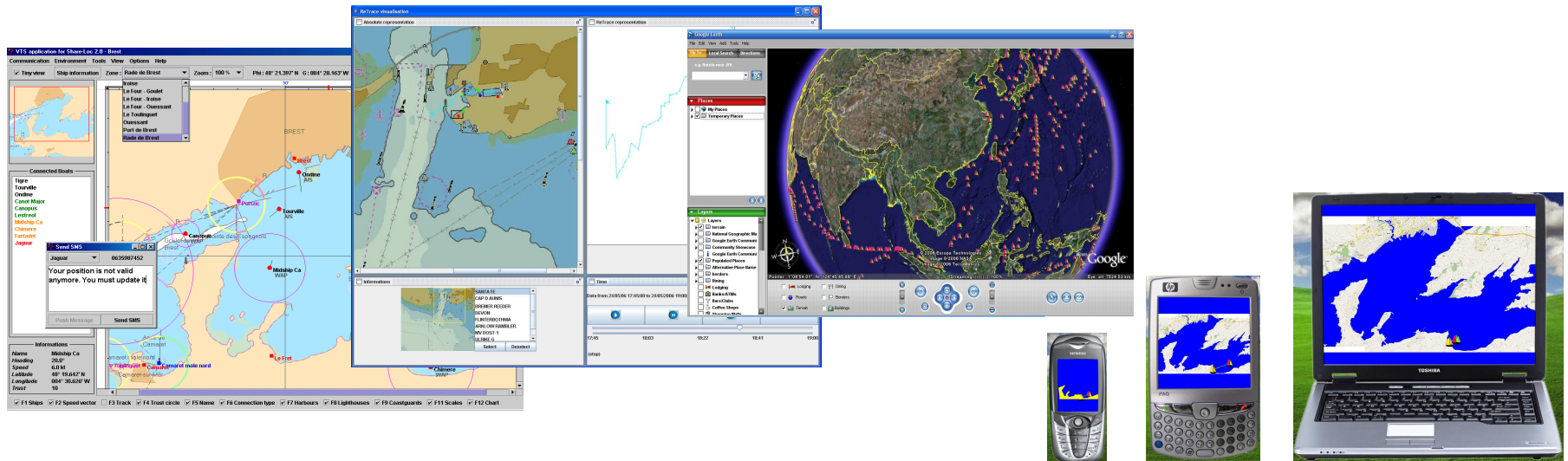
- Traffic control
- Safety
- Event tracking



Patterns discovery & analysis

Search And Rescue (SAR)

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



Moving objects at sea: research challenges

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- 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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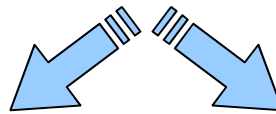
Maritime data integration

Modelling and tracking of maritime navigations

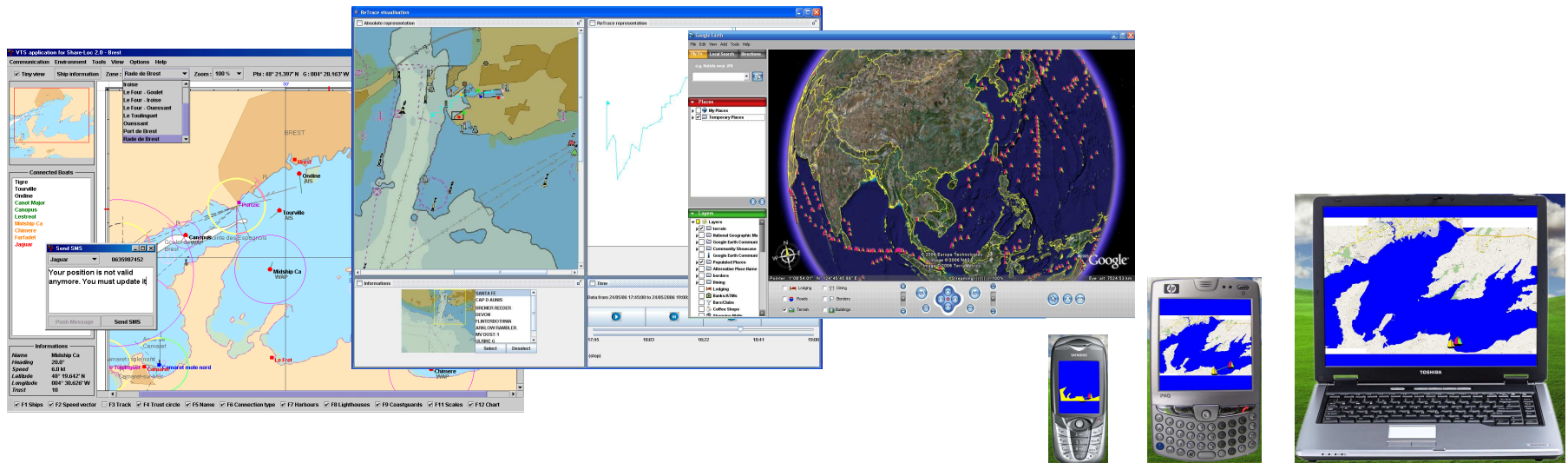
Diffusion of services to clients and monitoring authorities

Heterogeneous databases

- Traffic control
- Safety
- Event tracking

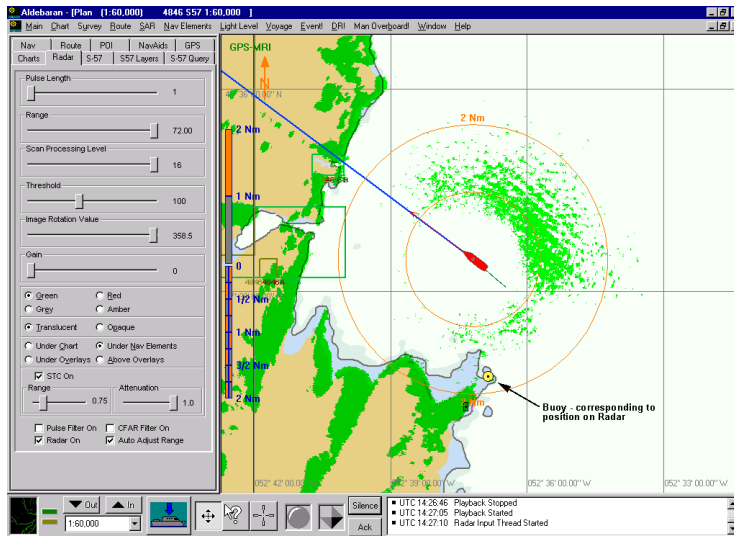


- Patterns discovery & analysis
- Search And Rescue (SAR)
- Simulation & Decision-aid systems
- Visualisation and user interfaces

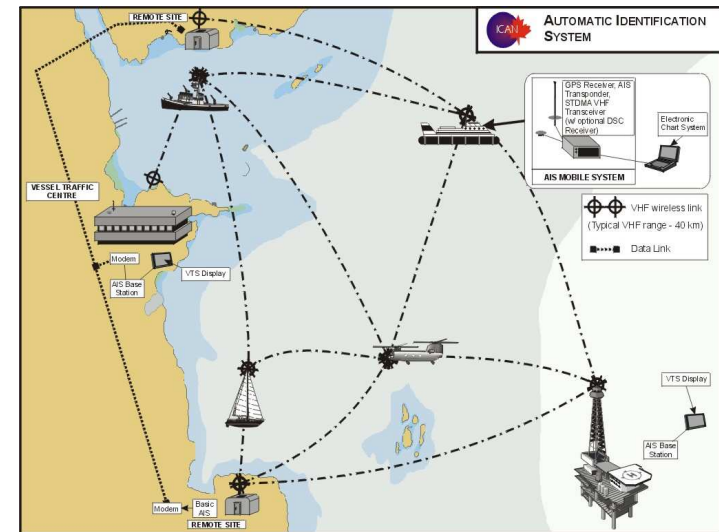


Integration of heterogeneous databases: semantic issues

ARPA



AIS



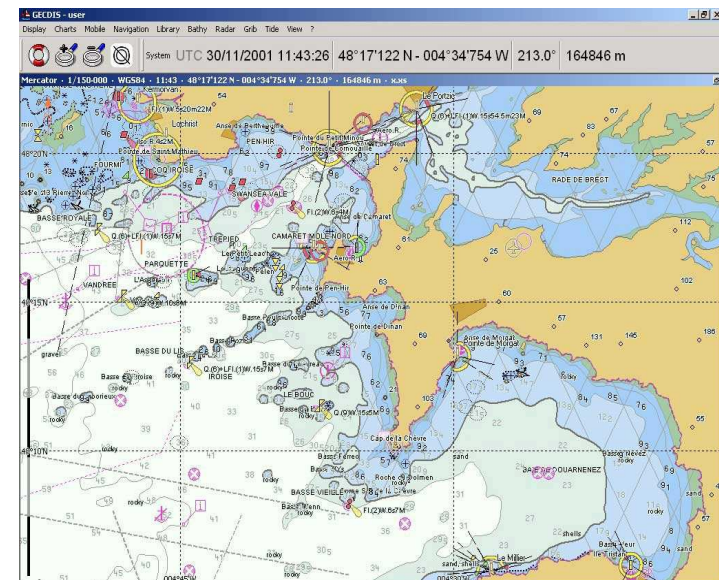
- Integration of different models, ontologies and visualisation paradigms



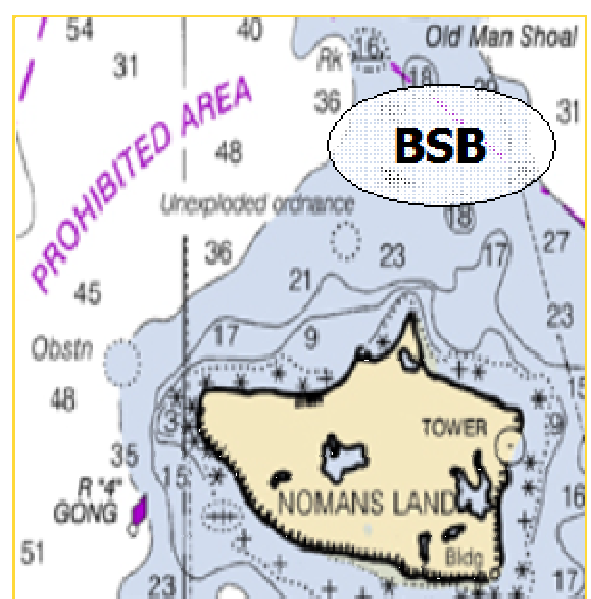
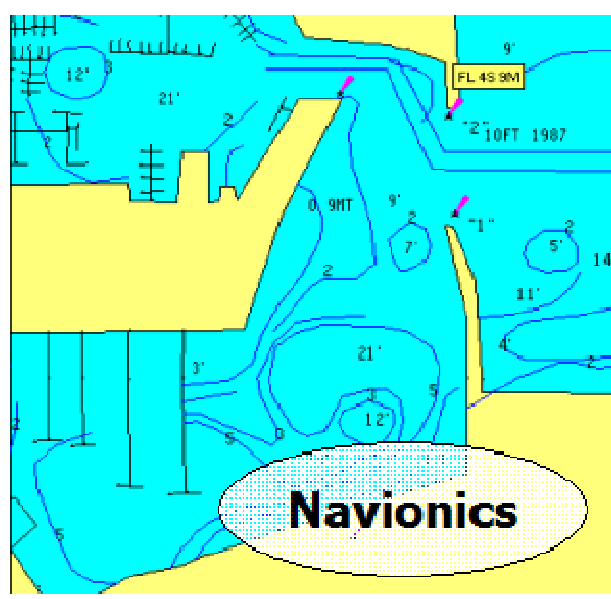
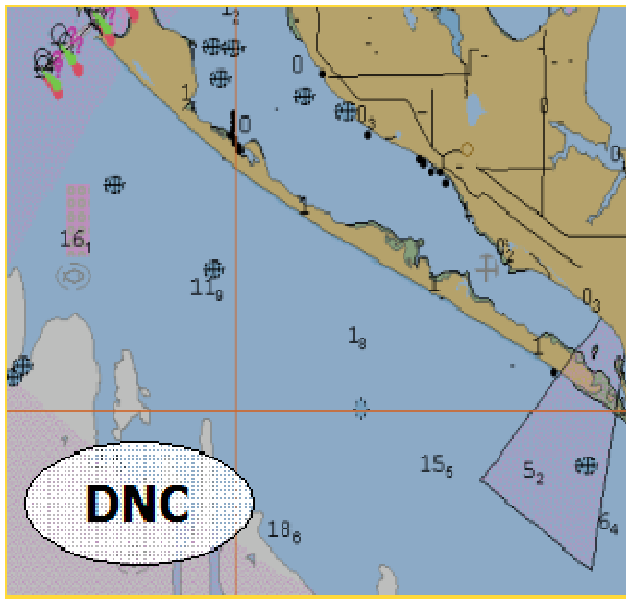
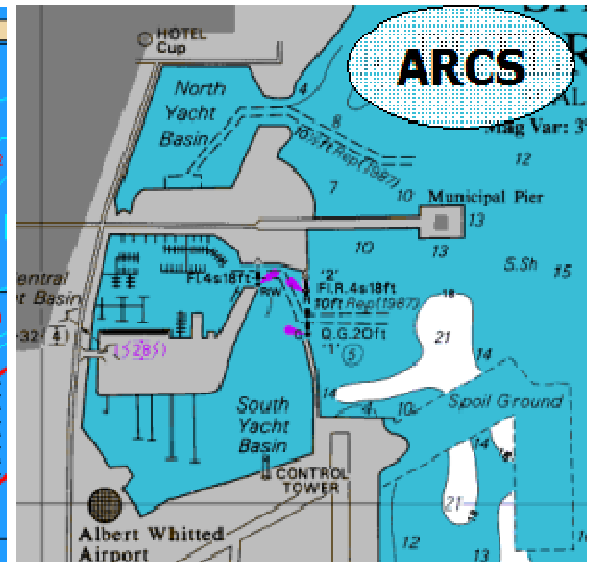
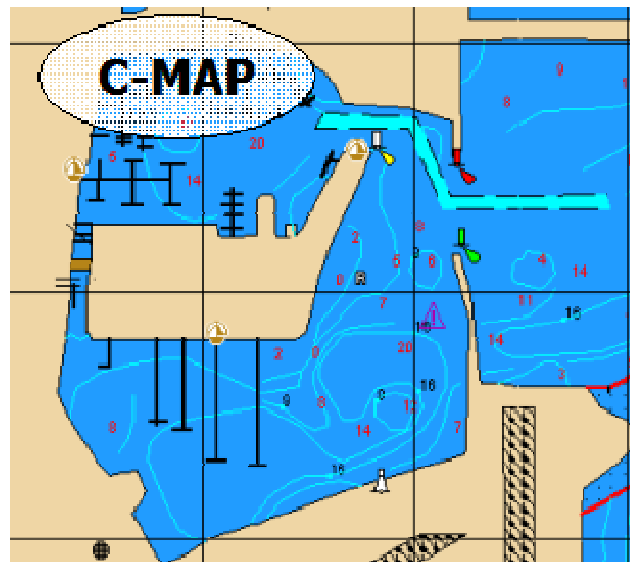
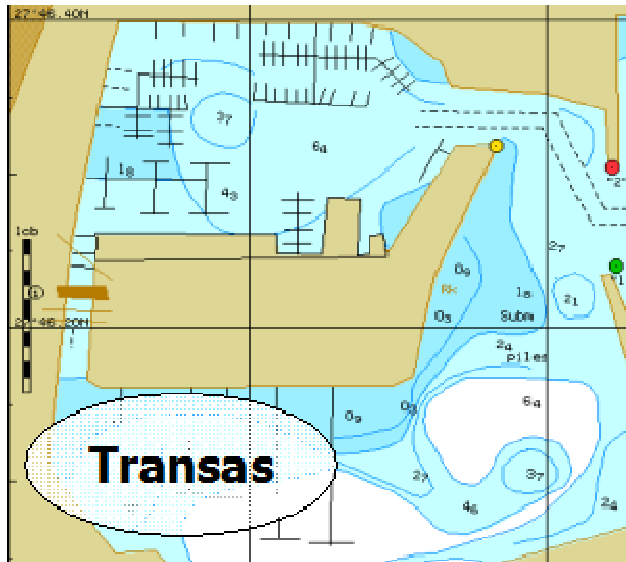
- Different levels of abstraction

- Normalisation (IMO)

ECDIS



Integration of heterogeneous databases: semantic issues

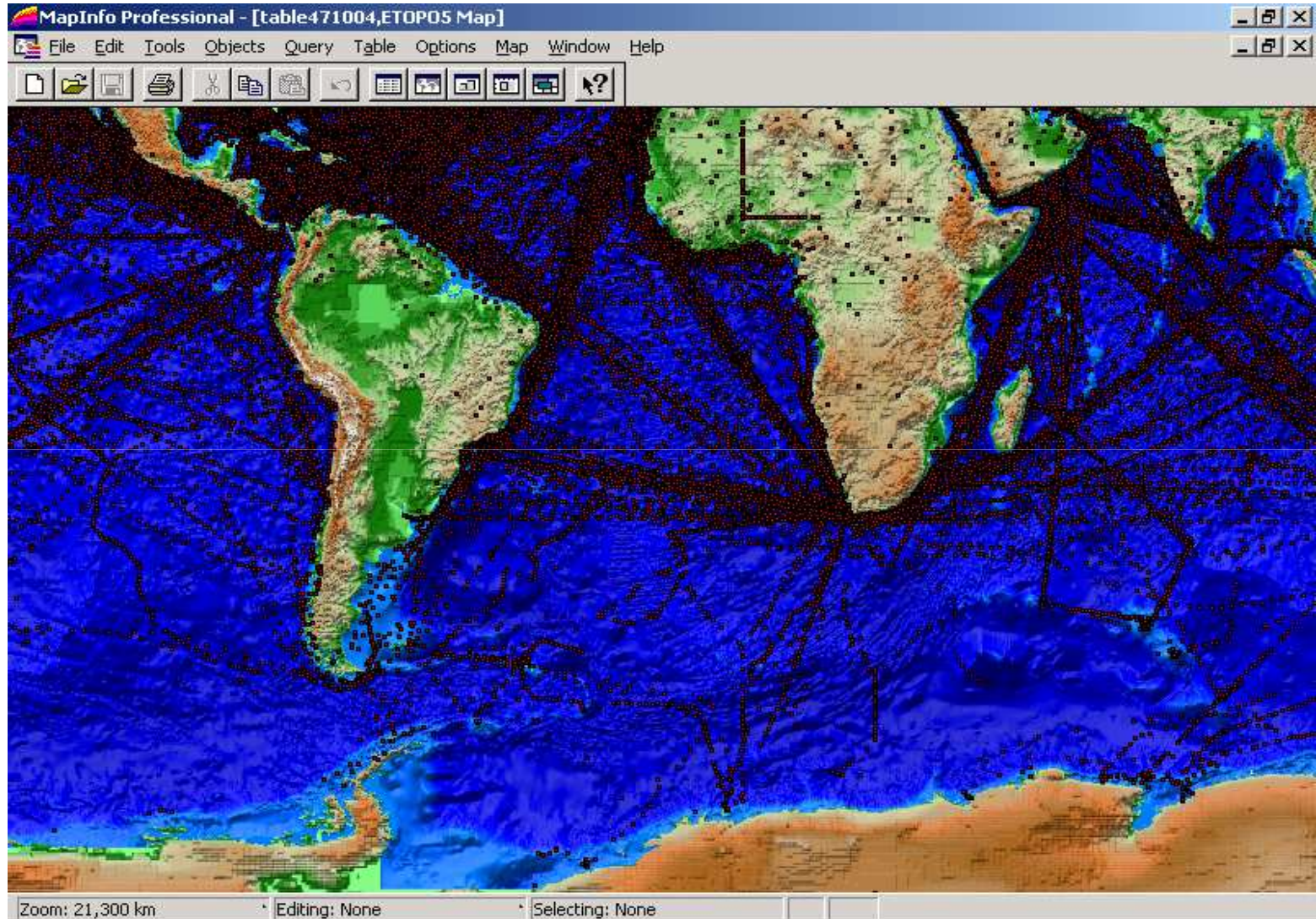


Integration of heterogeneous databases

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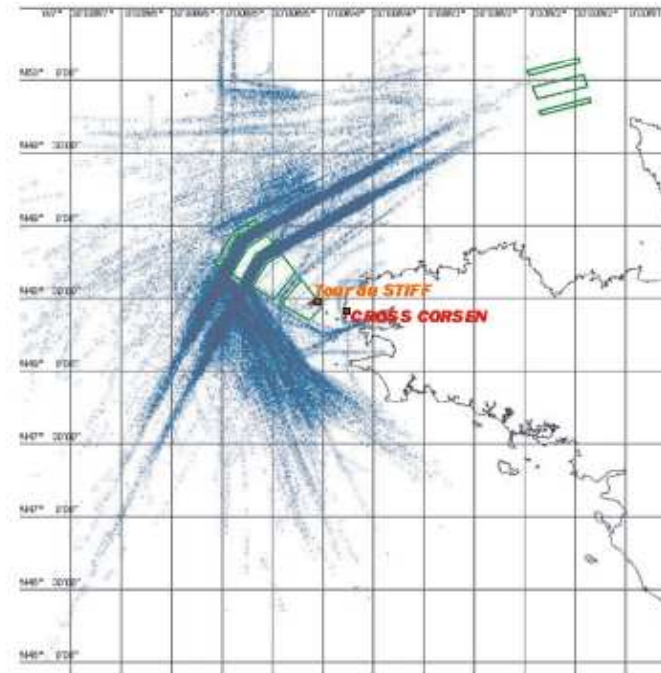
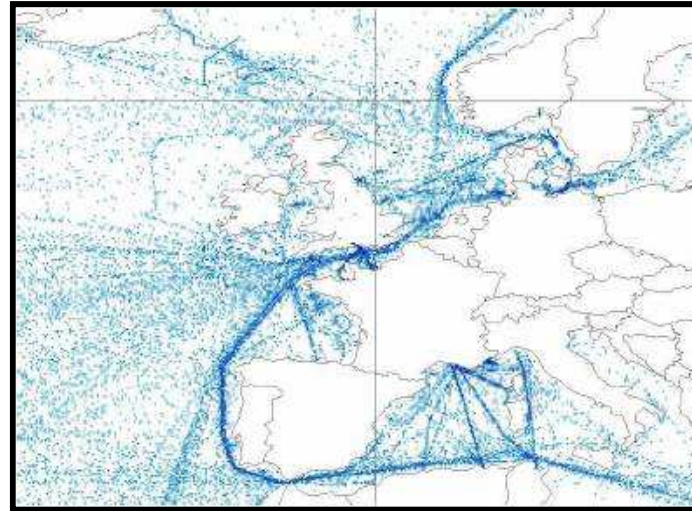
Real-time tracking of large volumes of maritime data (NOAA volunteered weather data)



Integration of heterogeneous databases

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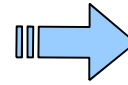
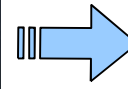
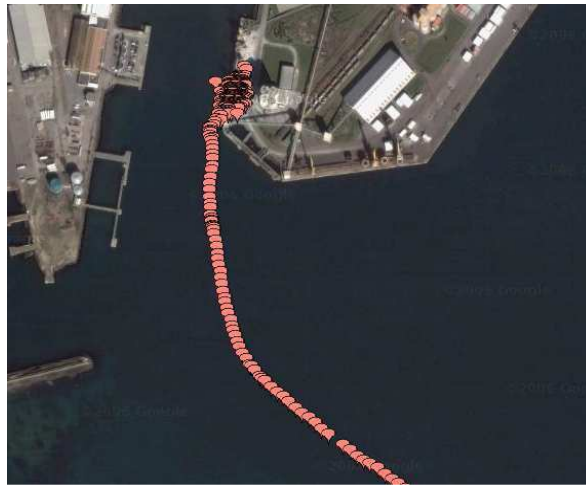
Real-time tracking of large volumes of maritime data (-> physical data structures and indexing)



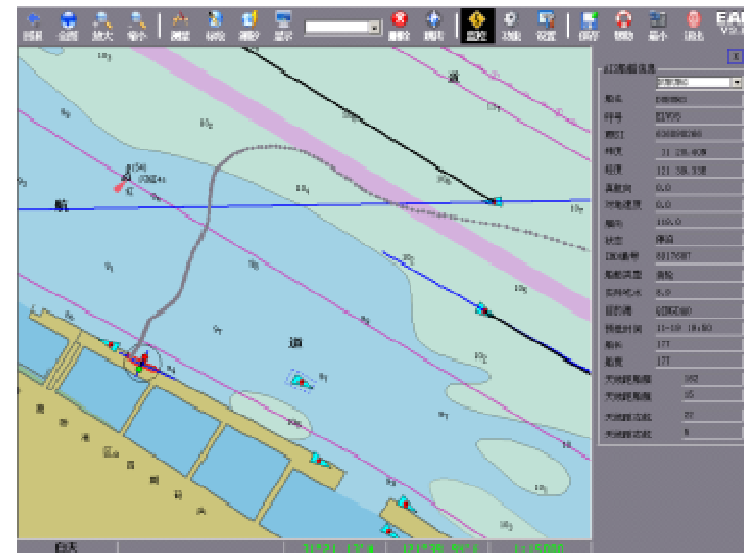
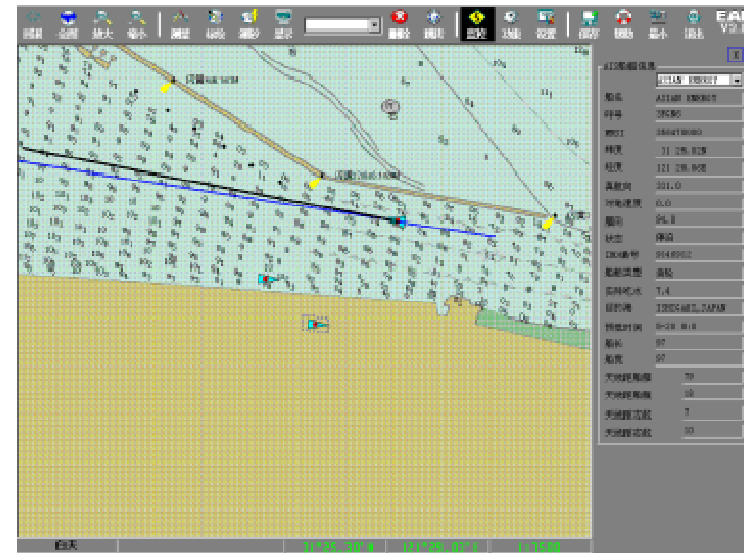
Integration of heterogeneous databases



Data filtering



Integration of heterogeneous databases



Error control:

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



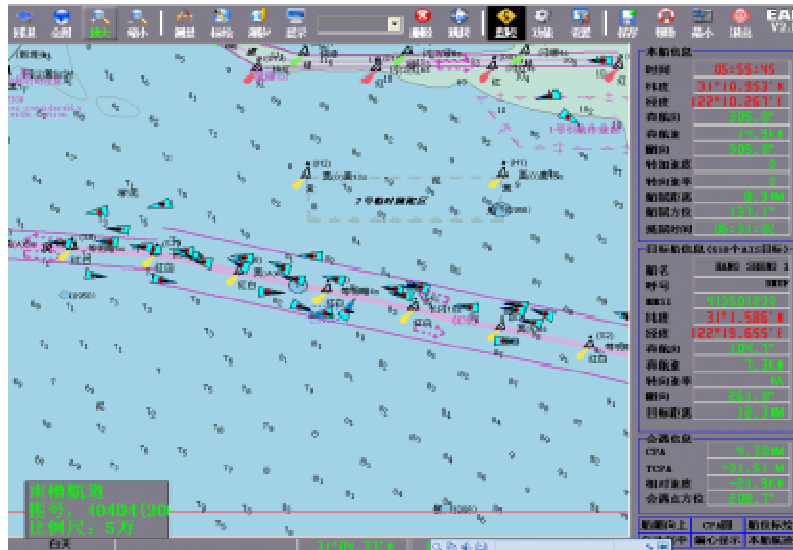
Integration of heterogeneous databases

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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

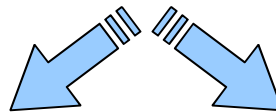
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Maritime data integration

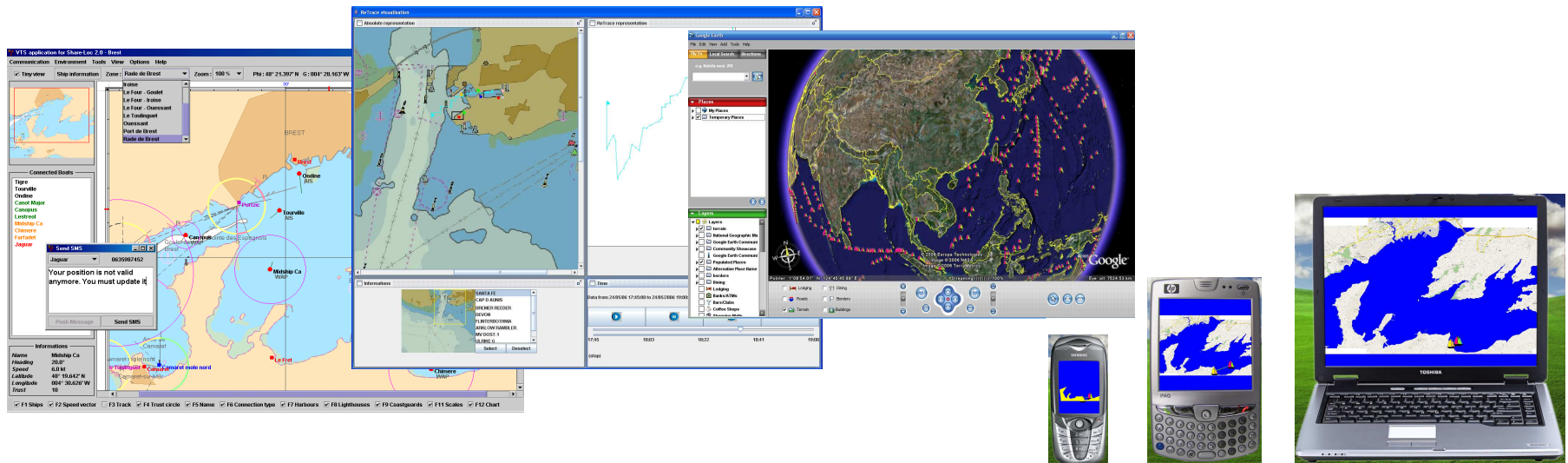
Modelling and tracking of maritime navigations

Diffusion of services to clients and monitoring authorities

- Heterogeneous databases
- Traffic control
- Safety
- Event tracking

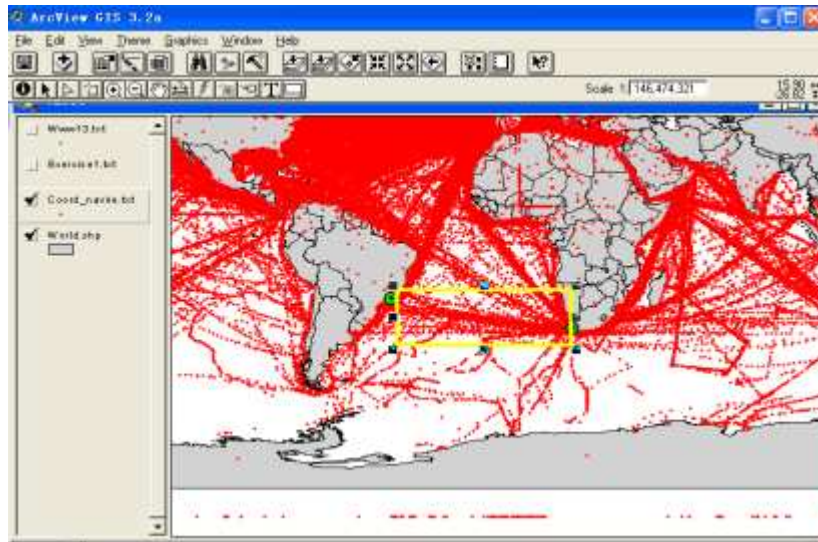


- Patterns discovery & analysis
- Search And Rescue (SAR)
- Simulation & Decision-aid systems
- Visualisation and user interfaces



Patterns analysis and discovery

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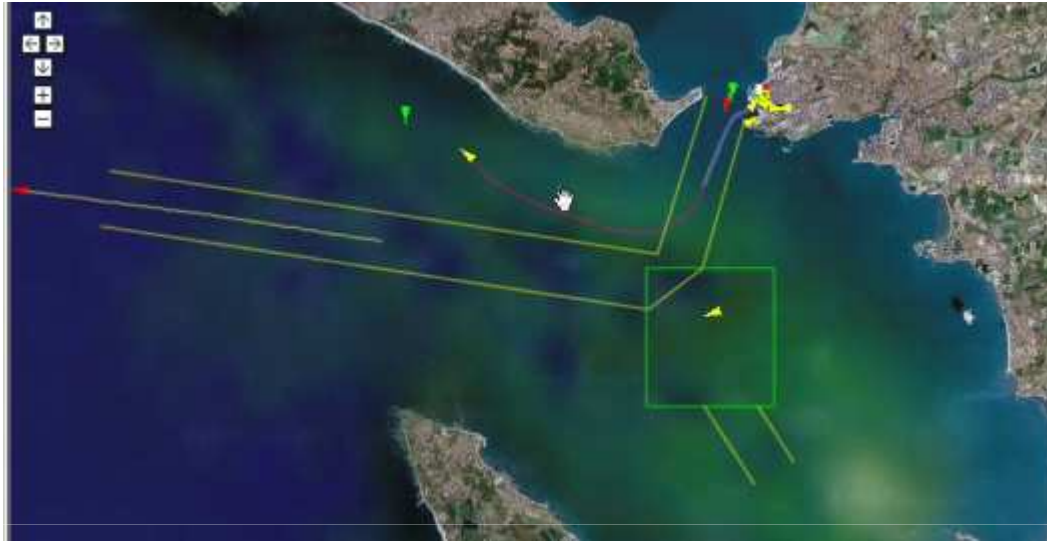
**Modelling and analysis
maritime trajectories
trends and patterns at a
global level (NOAA data)**



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

Event tracking

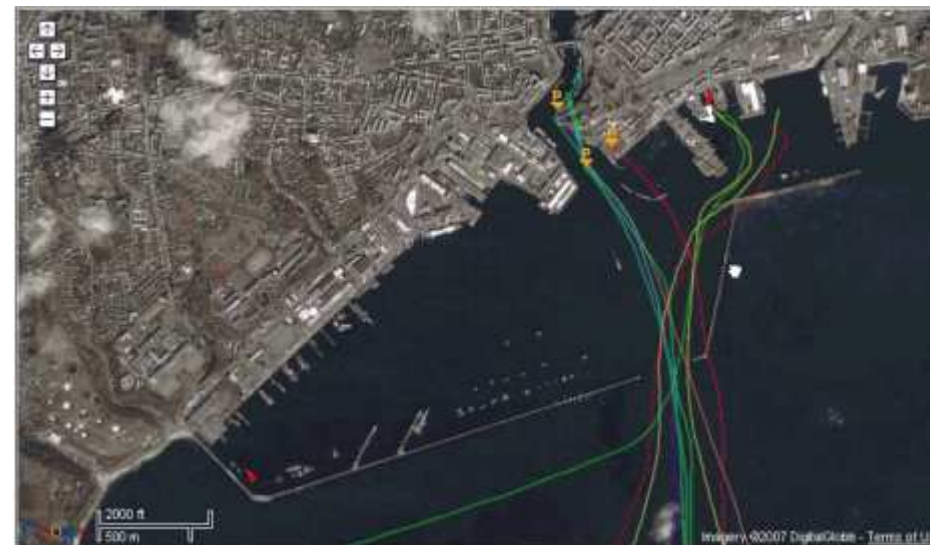
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Real-time monitoring of maritime trajectories and behaviours (e.g. trajectory vs. navigation path)

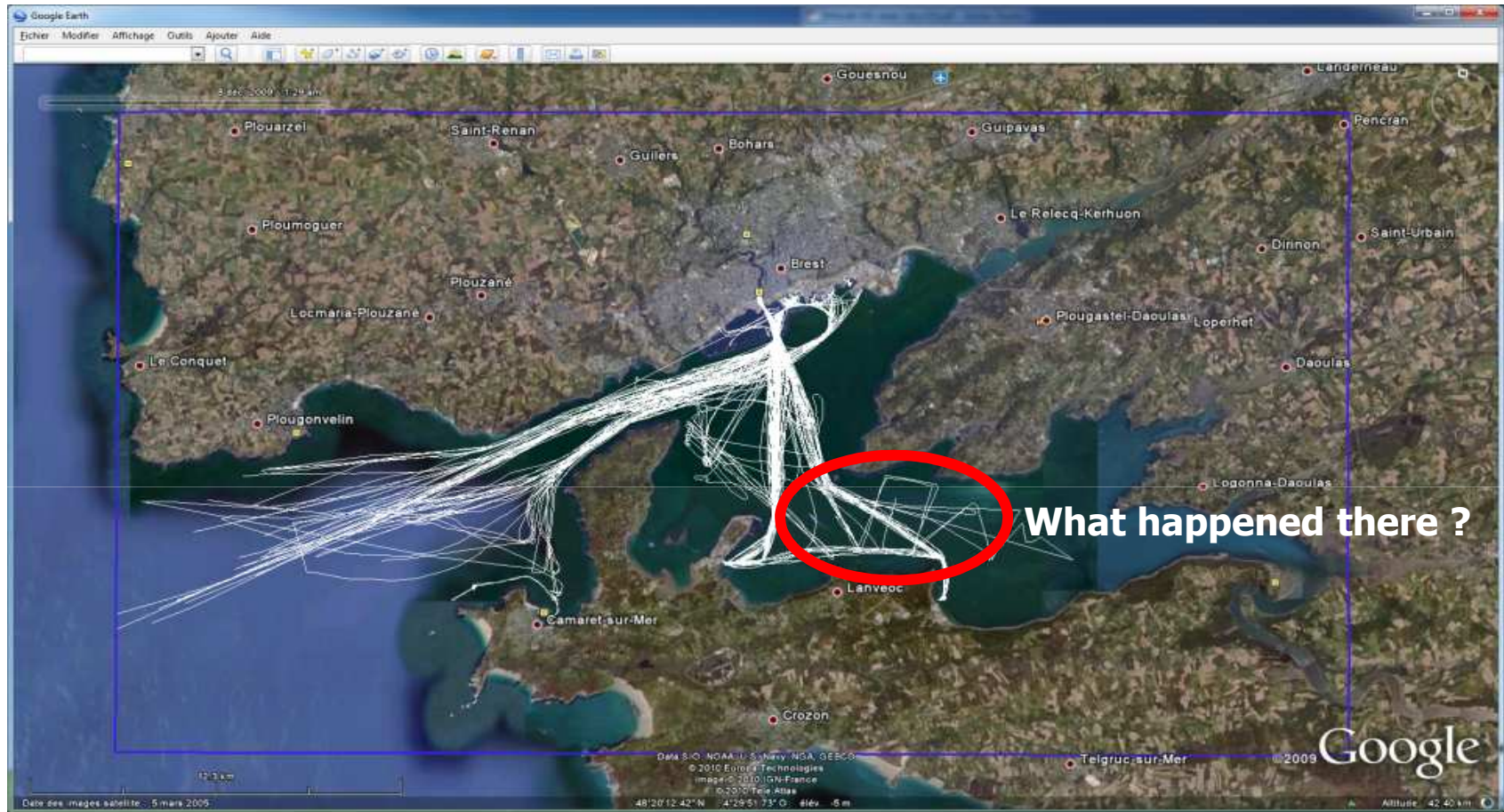


Detecting regular and irregular behaviours, incidents etc.



Event tracking

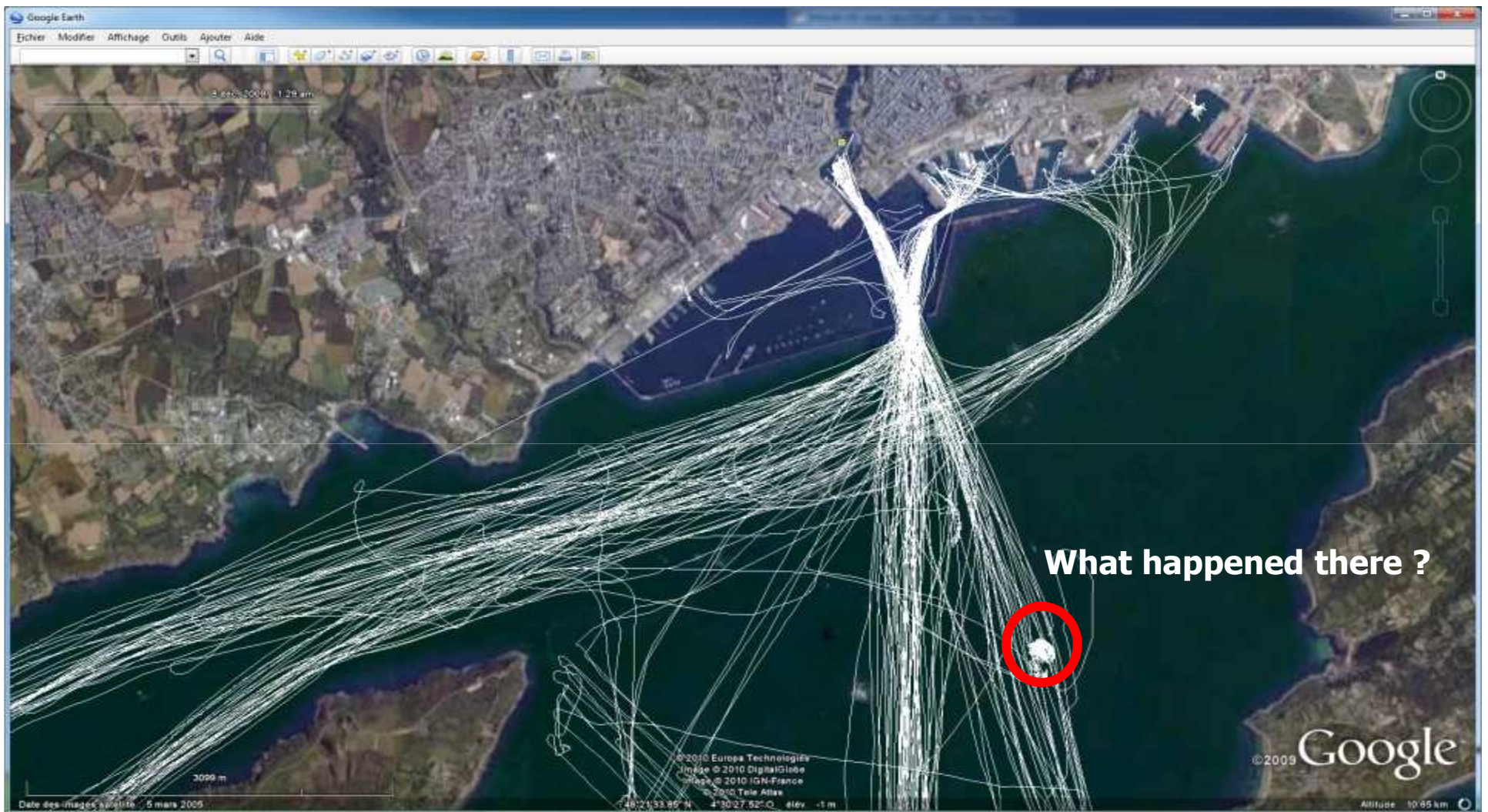
38



Detecting irregular behaviours

Event tracking

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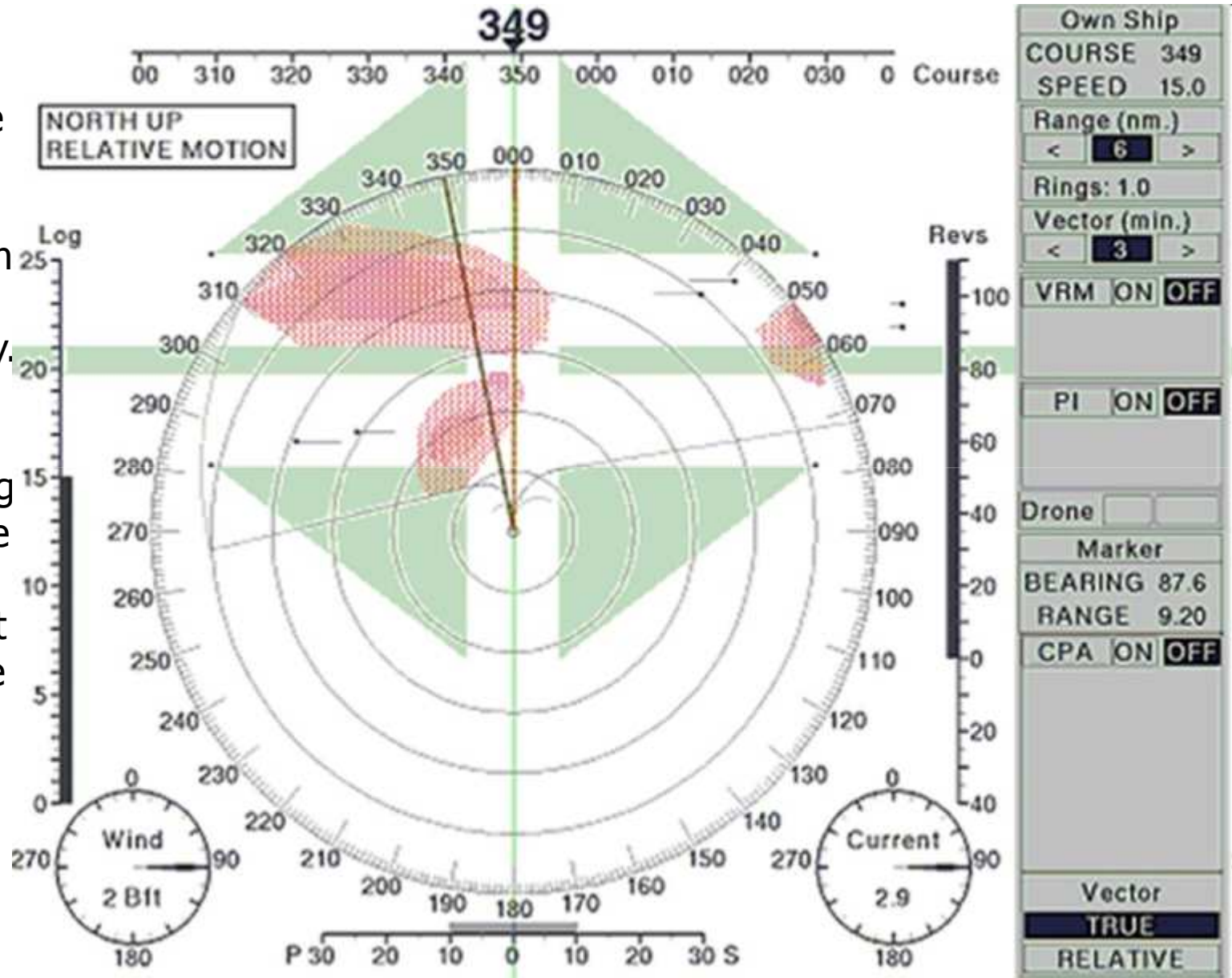


Detecting irregular behaviours

Event tracking: CPA

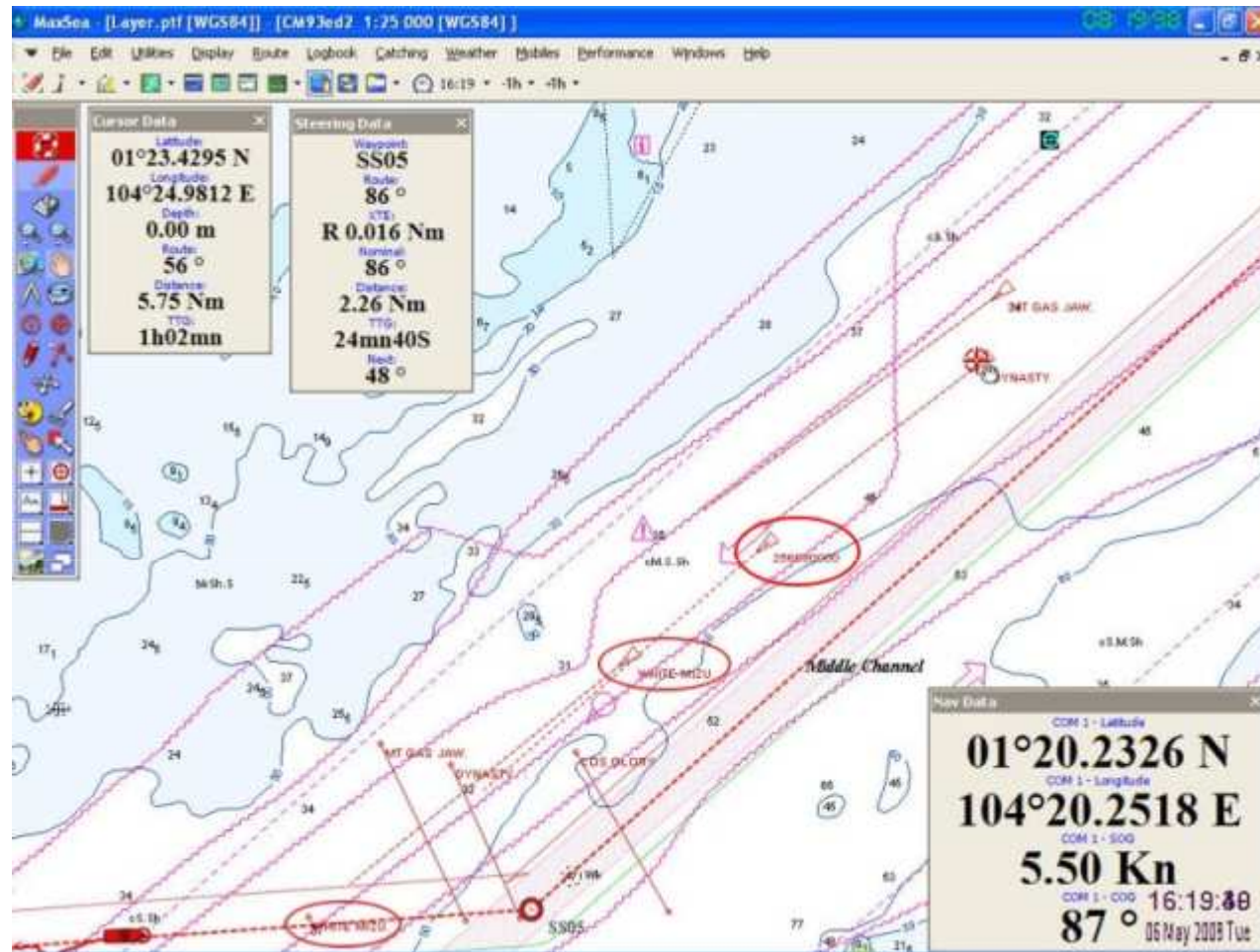
40

« 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

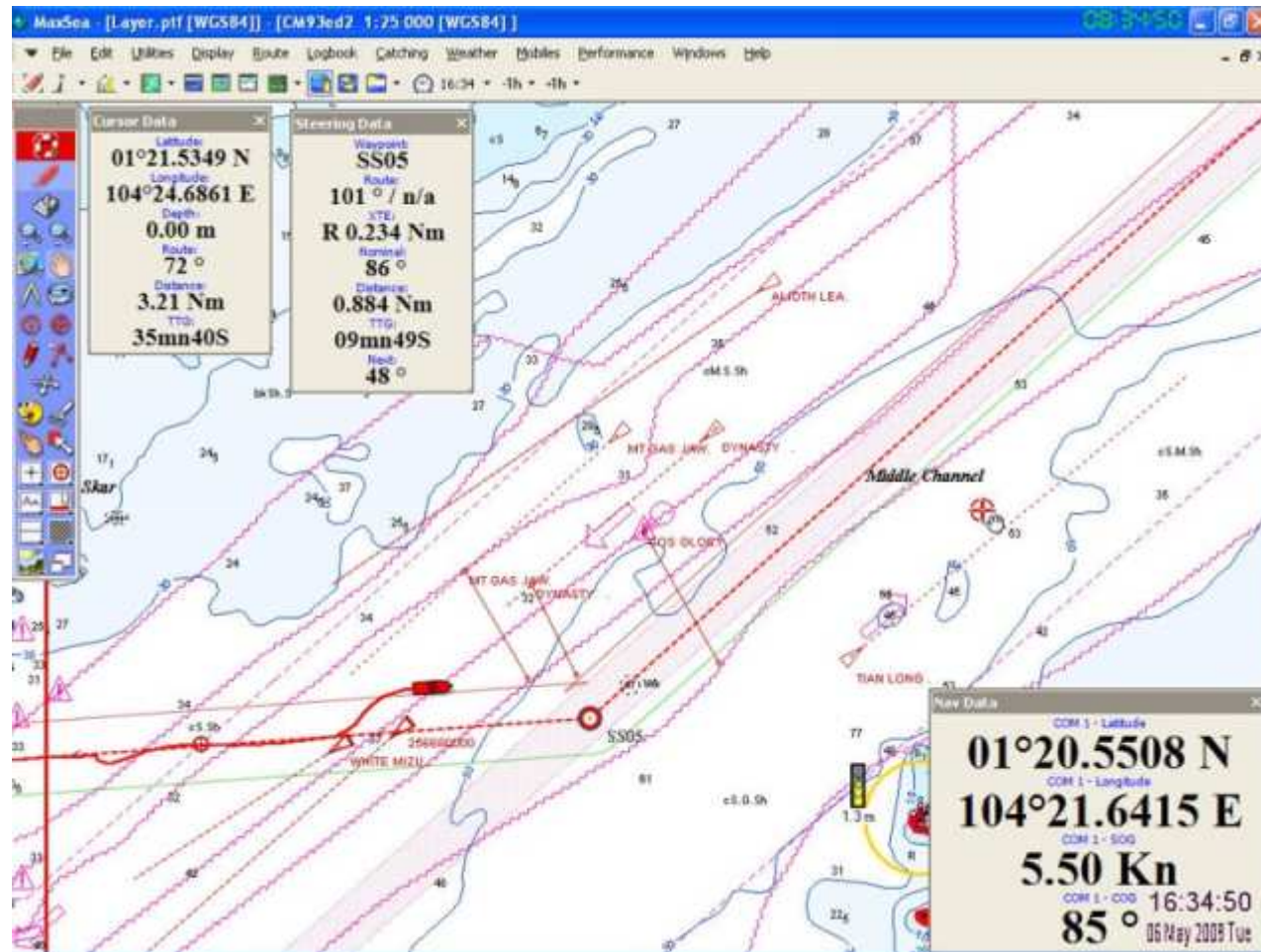
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«The AIS graphic display shown here has one ship, WHITE MIZU, with a CPA (closest point of approach) that was too close for comfort. Another ship (25680000) was following WHITE MIZU and closing, giving further concern. »

Event tracking: CPA

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

Navigation control

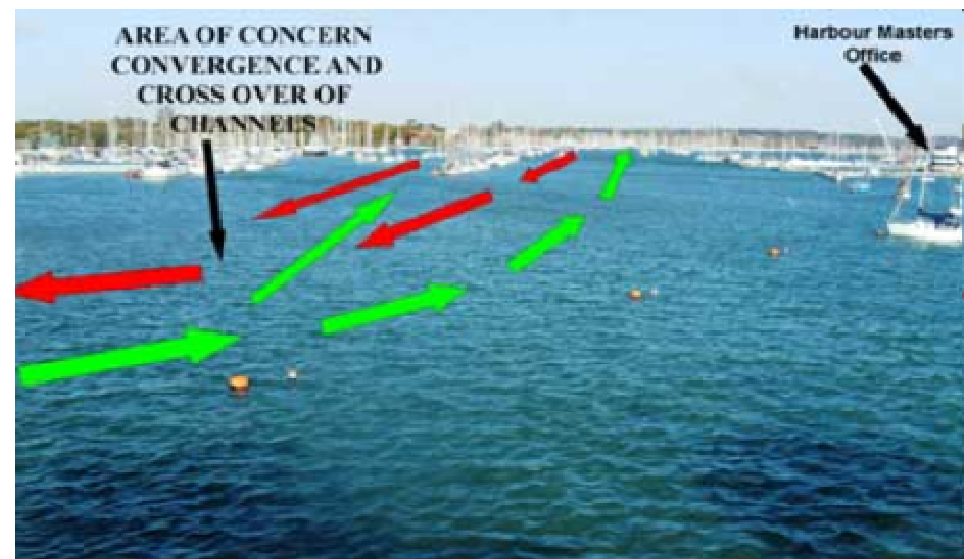
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All vessels should monitor VHF Channel 68 when underway in the harbour

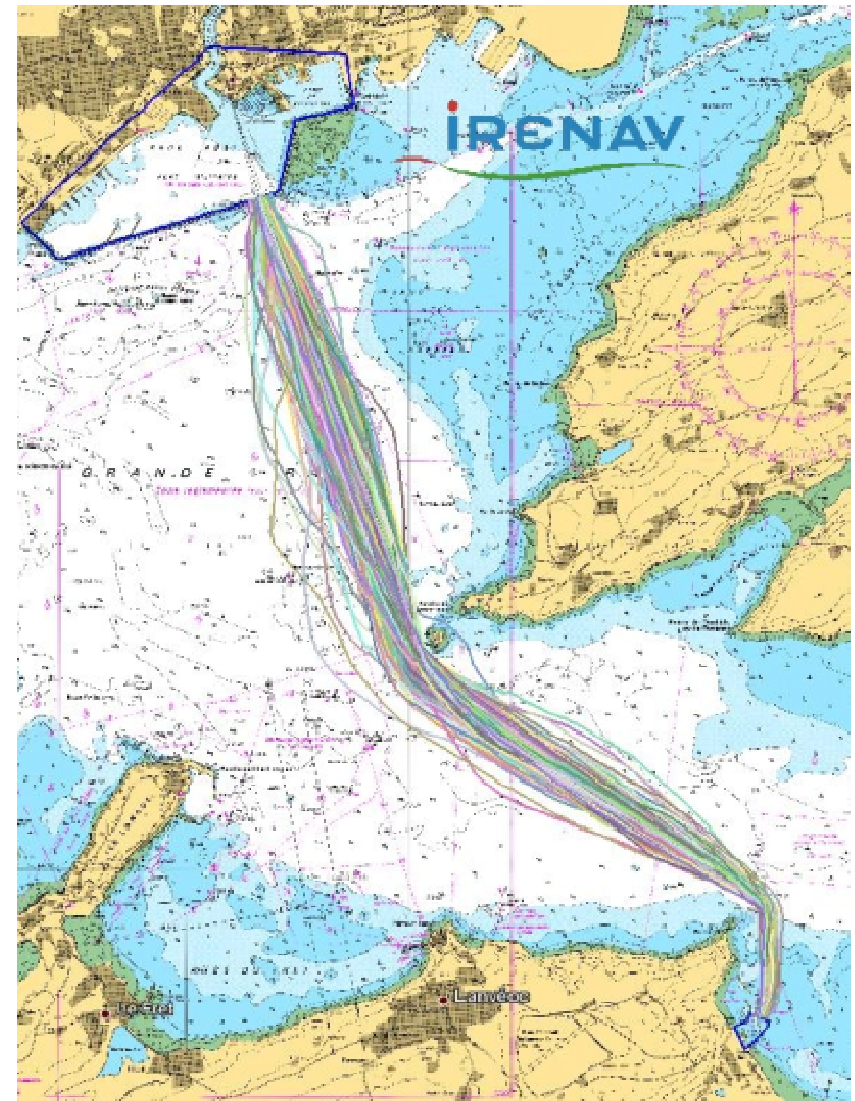
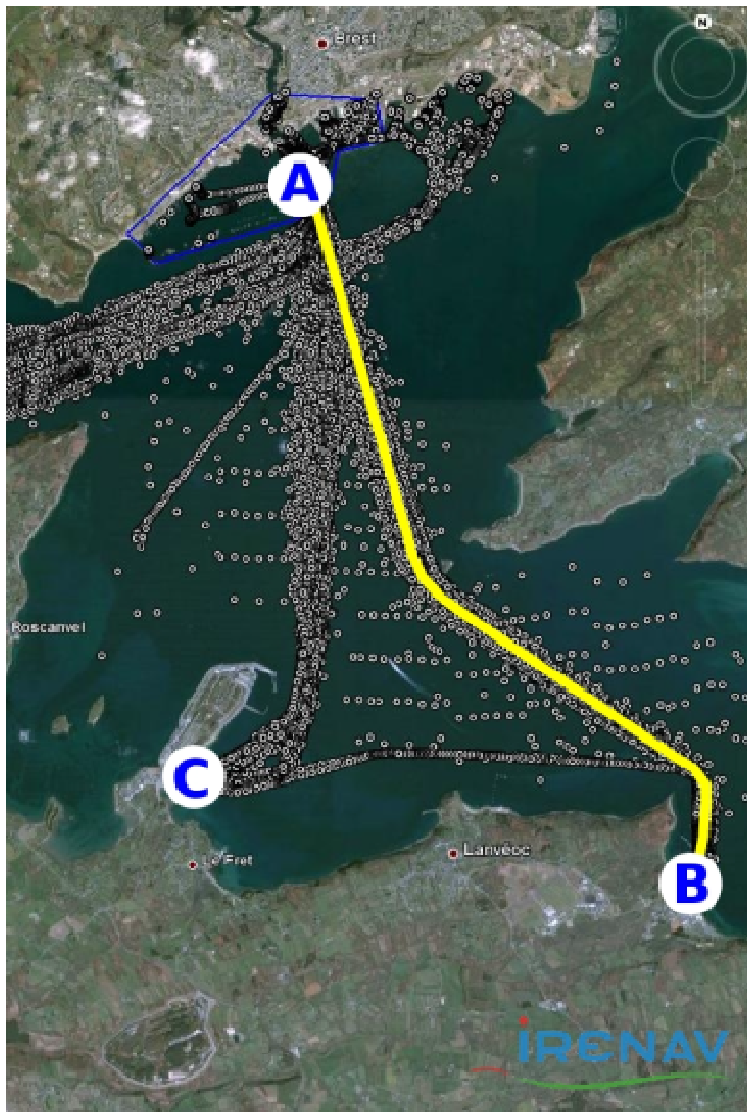


A River wide 6 knot speed limit with a wash limit commences at Beacon Number 2



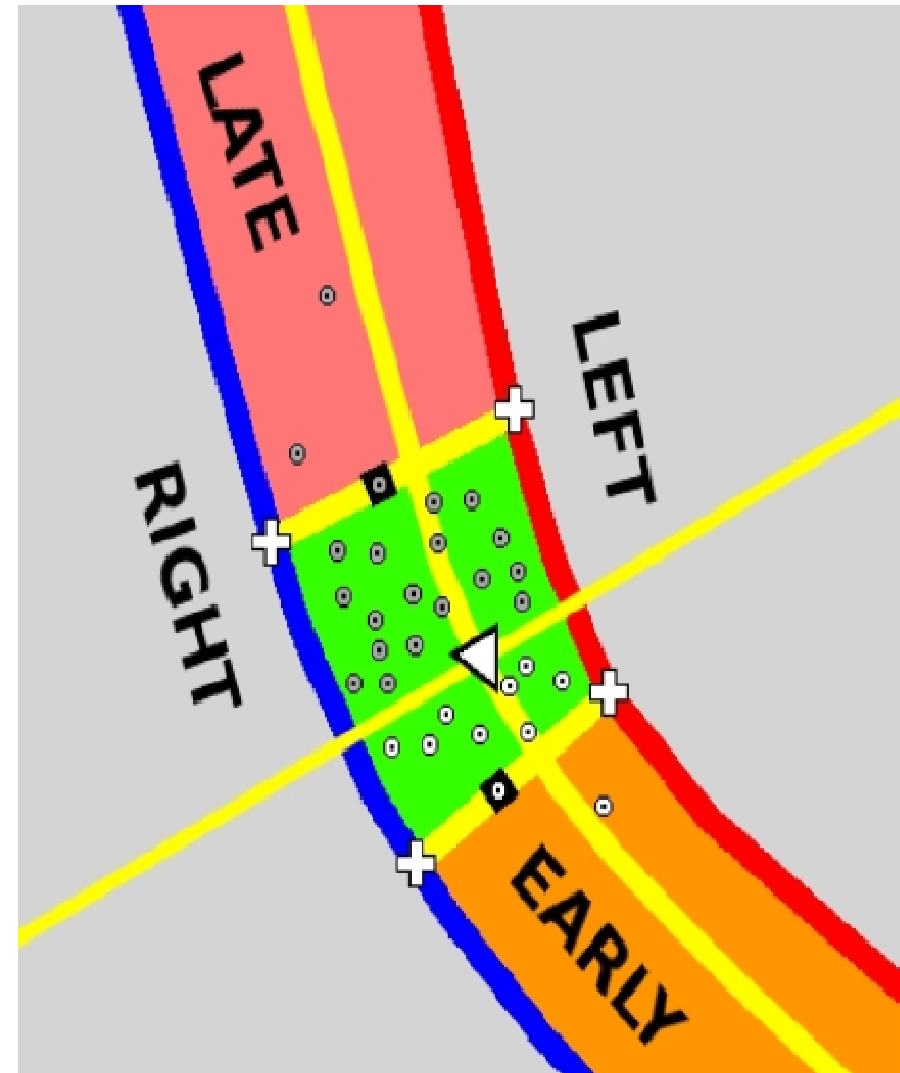
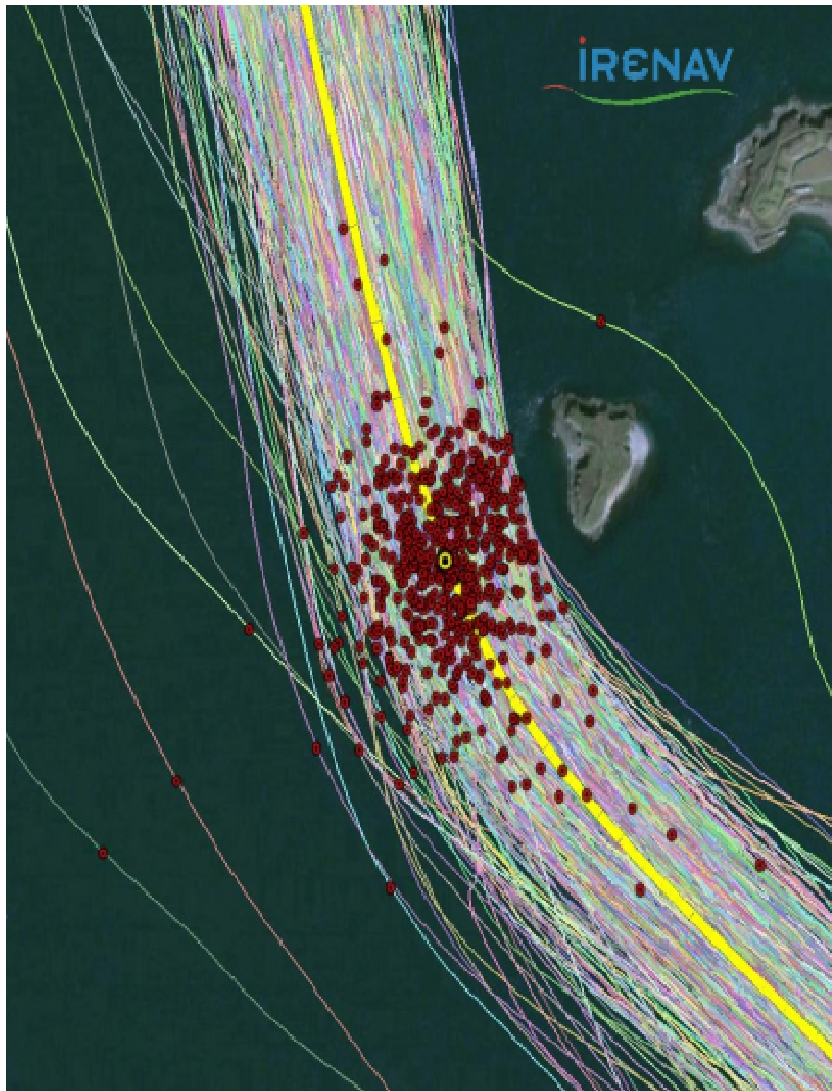
Caution is required at low water, depending on the state of the tide, as some marks stand in shallow water

Patterns analysis and discovery



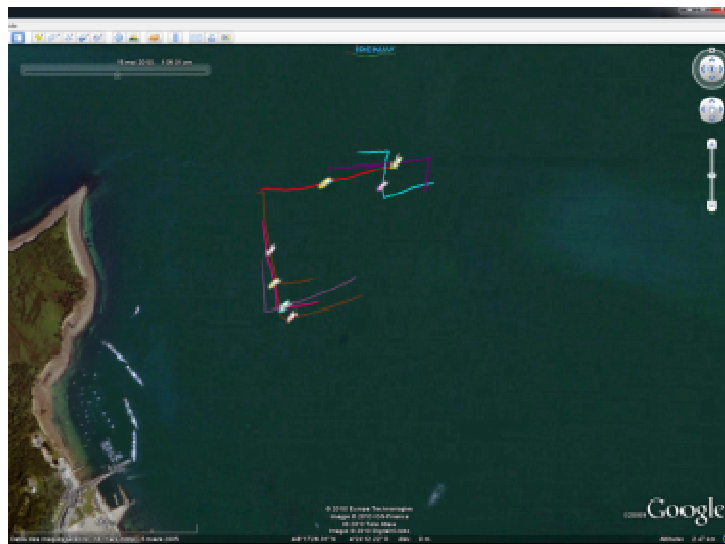
Patterns analysis and discovery

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Patterns analysis and discovery

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Trajectory analysis and discovery

47

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 Arctic 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 Arctic Sea 300 miles (483 km) off Cape Verde islands



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

Container tracking

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

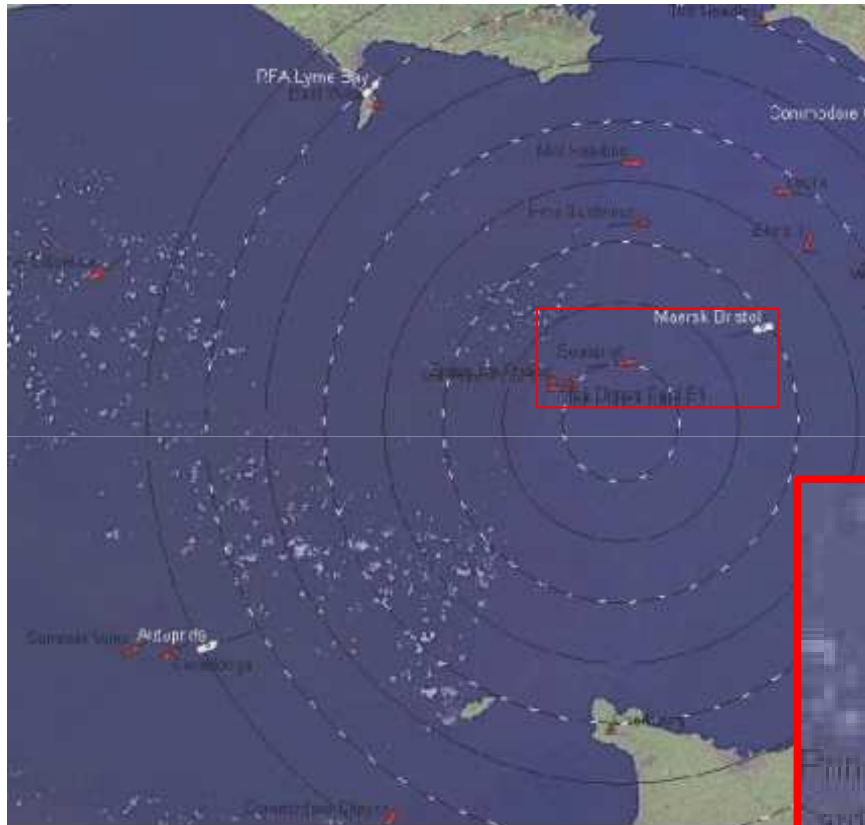


The problem is to retrieve container trajectories according to current and winds, or to retrieve the ships they came from



Container tracking

Virtual AtoN



Sinking of Ice Prince 01/15/2008



Search and rescue (SAR)

50

Boîte d'émission des télégrammes AIS

Envoyer un télégramme AIS

Texte à envoyer
EXEMPLE DE TELEGRAMME AIS.

MMSI destinataire: 210709000

Sécurité Diffusion

Emettre périodiquement

Période: 3 mn

Durée: 10 mn

OK Annuler

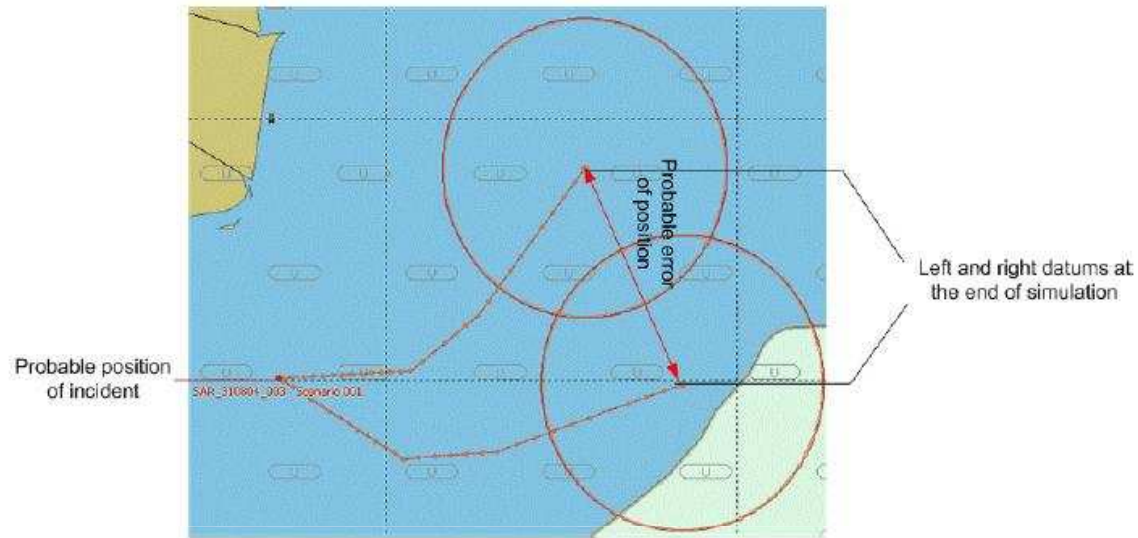
Broadcasting of safety messages



Localization, tracking and guidance of SAR means

Search and rescue (SAR)

51

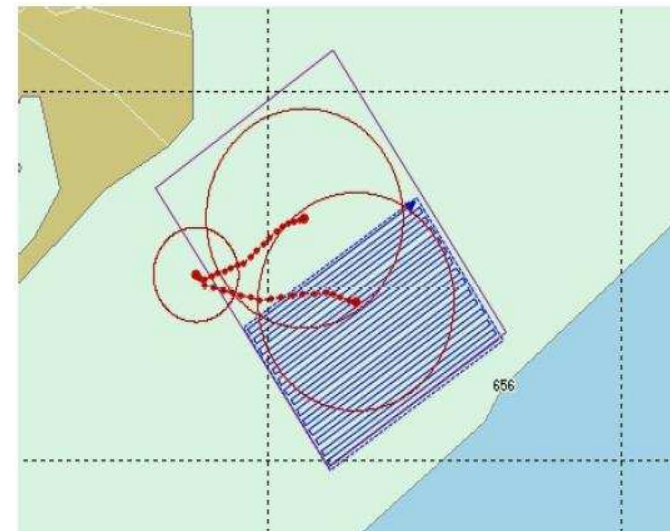


Search And Rescue:

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

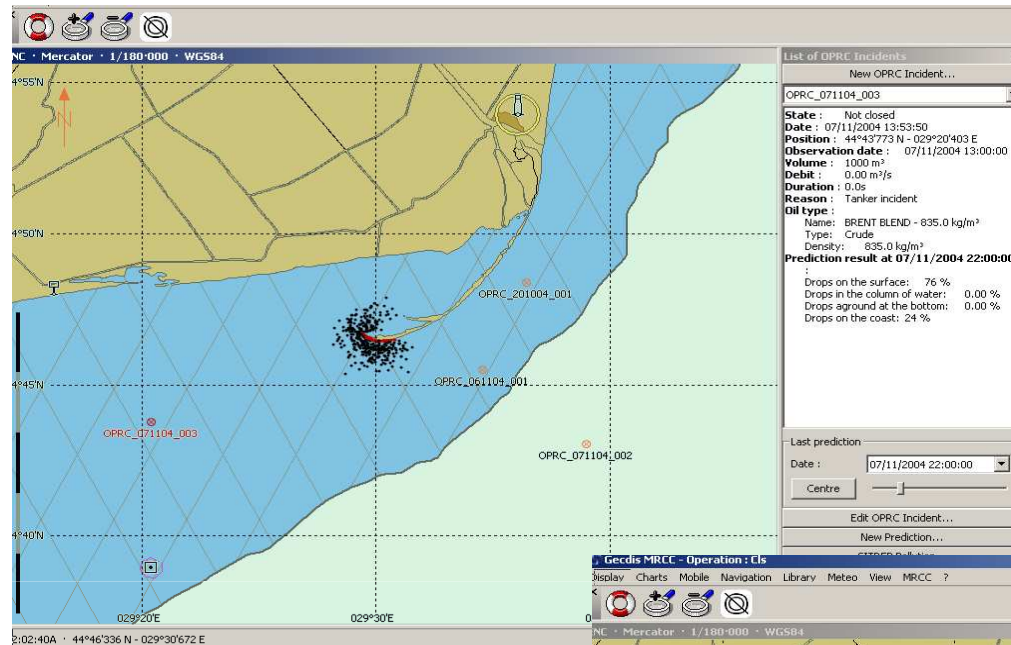
Compute of probability of detection:

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



Search and rescue (SAR)

52

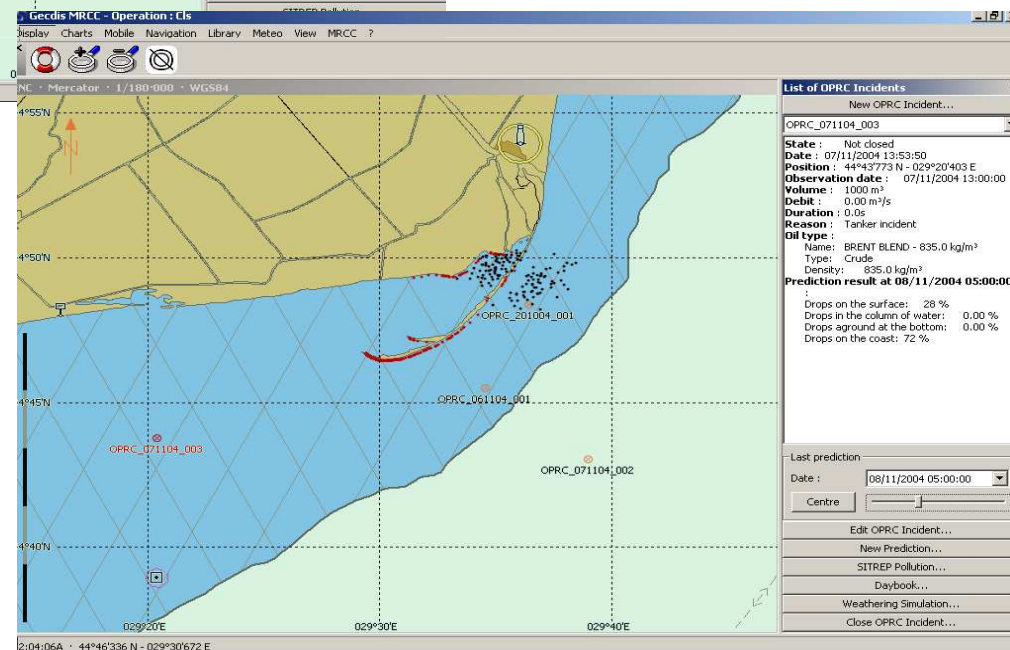


Oil spill:

- Oil quality
- Currents
- Winds

Compute quantity of oil:

- On shore
- On sea bed
- Evaporated



Search and rescue (SAR)

53

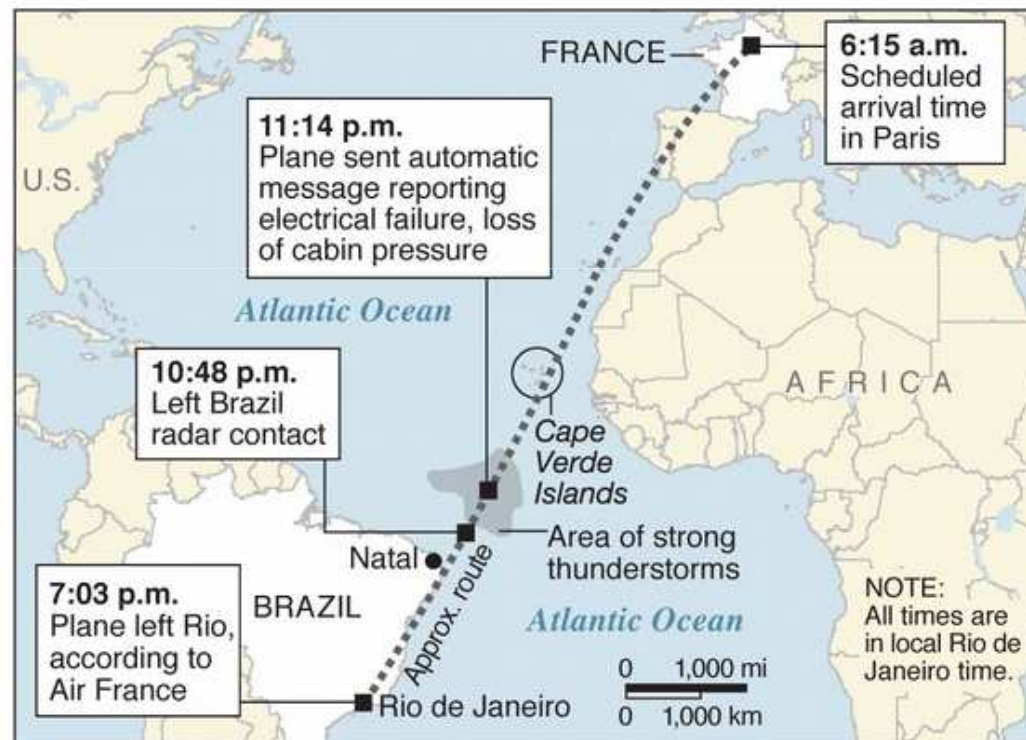


Search and rescue (SAR)

54

Plane lost in vast stretch of Atlantic

Brazil's military searched a vast area off its coast for the missing Air France jet carrying 228 people from Rio de Janeiro to Paris. The French military scoured the ocean near the Cape Verde Islands.

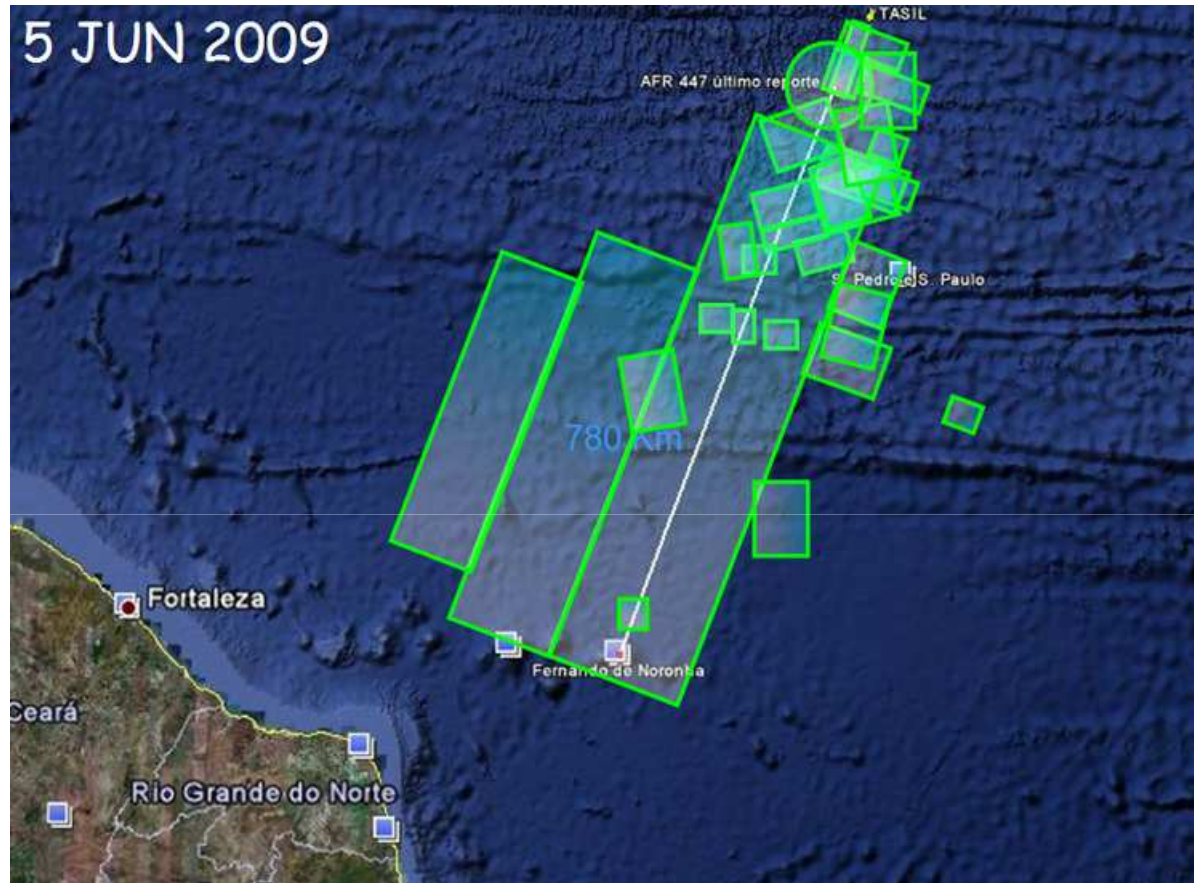


SOURCES: National Oceanic and Atmospheric Administration; Weather Underground; ESRI; Air France; Brazilian military

AP

Search and rescue (SAR)

55



Search area

Ship pollution

57

Observing



Retrieving



Moving objects at sea: research challenges

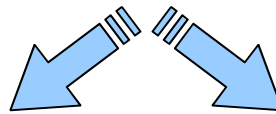
58

Maritime data integration

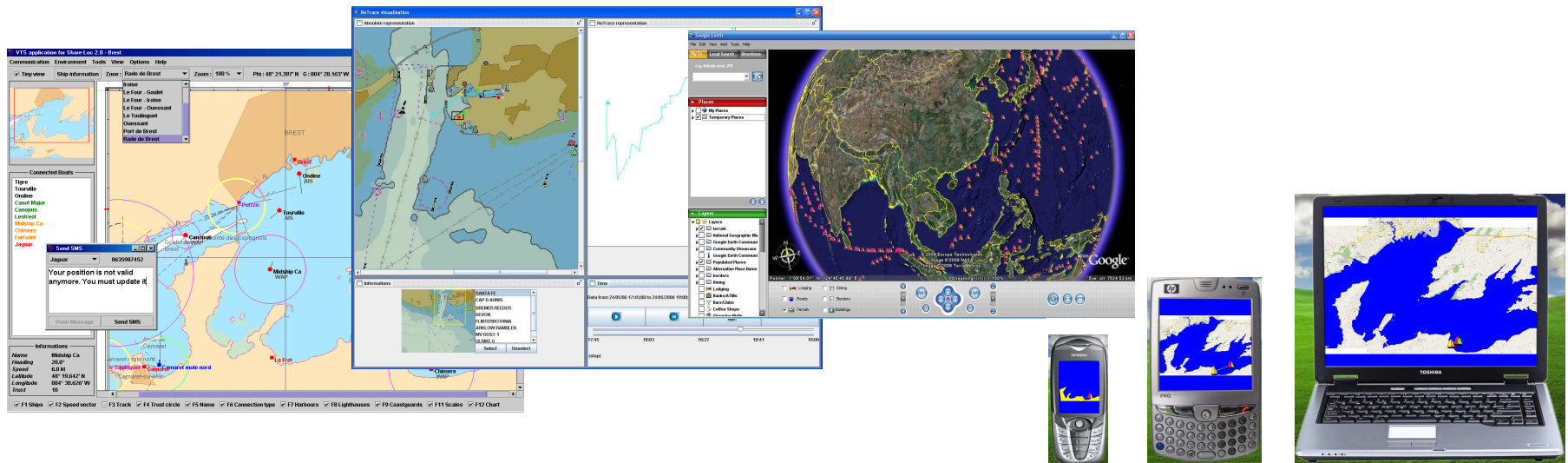
Modelling and tracking of maritime navigations

Diffusion of services to clients and monitoring authorities

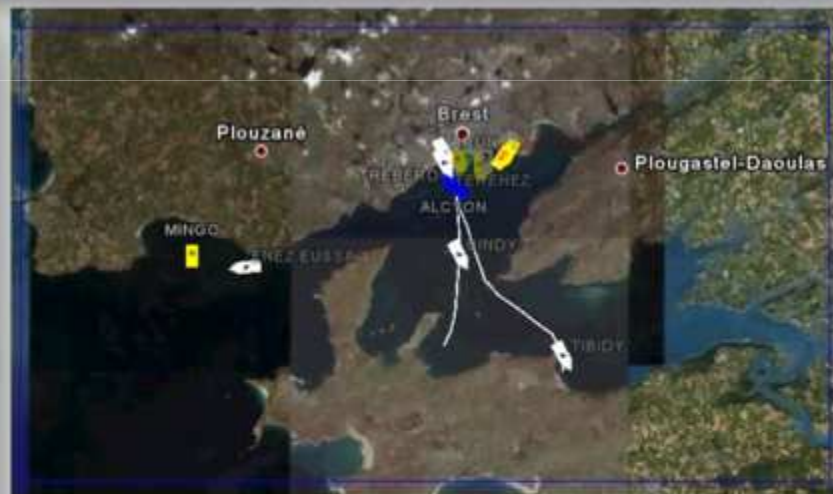
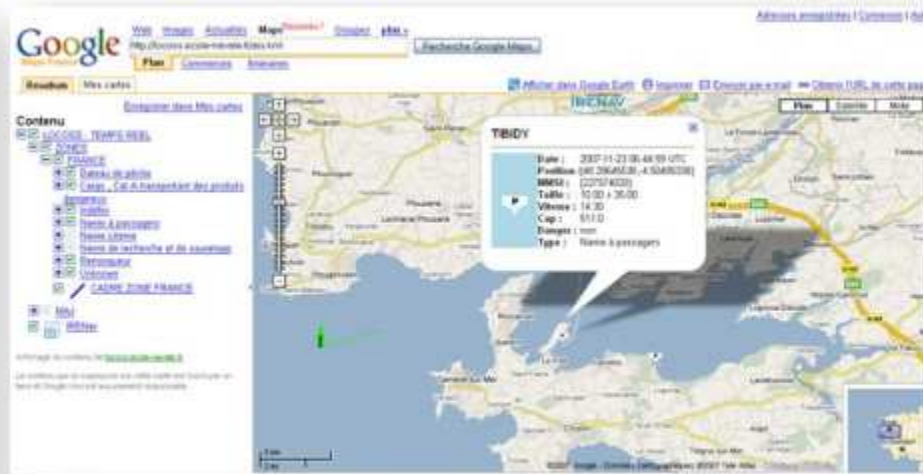
- Heterogeneous databases
- Traffic control
- Safety
- Event tracking



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

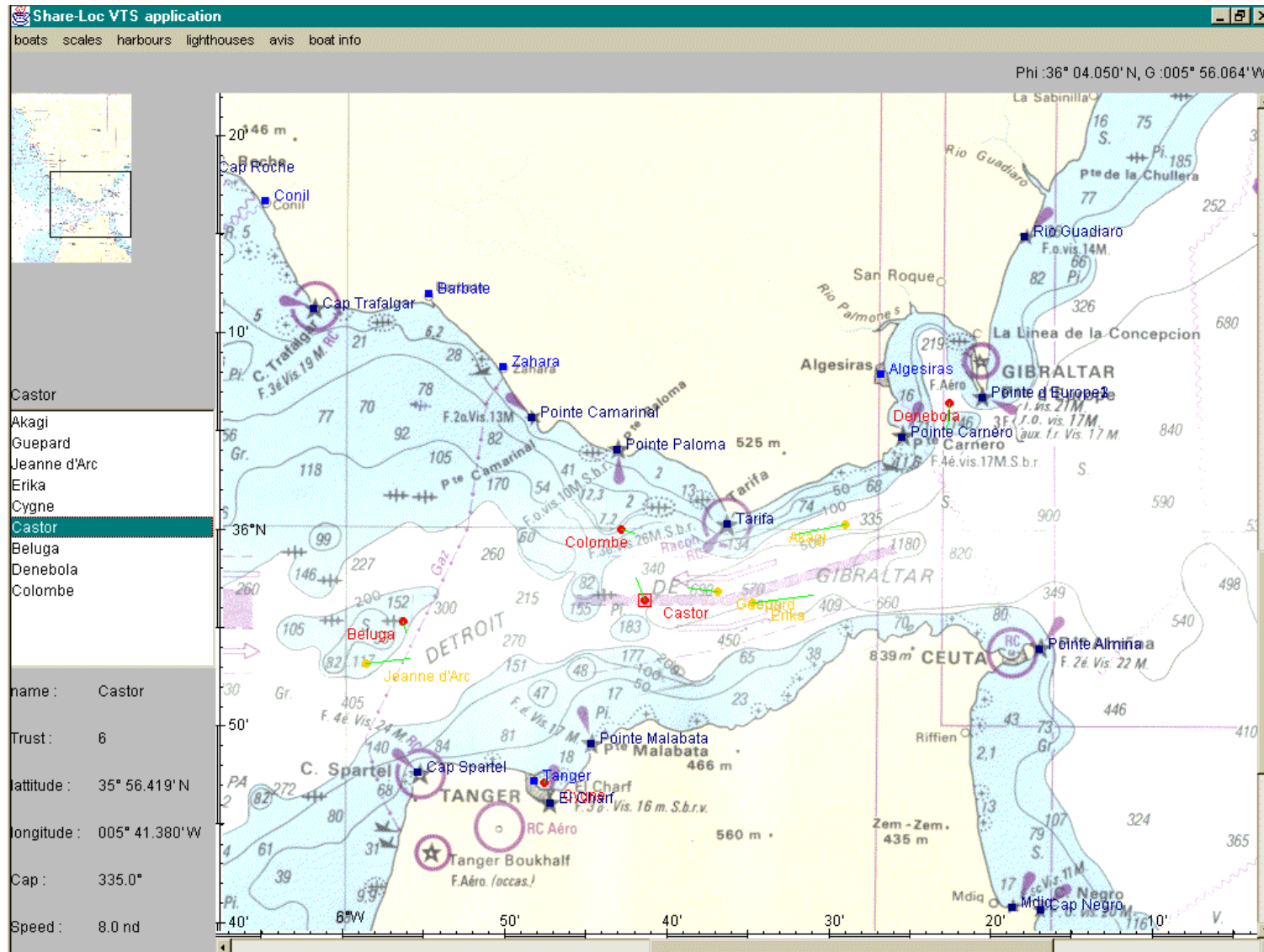


Web-based visualisation



<http://locoss.ecole-navale.fr>

VTS Services within GIS



VTS Services Within GIS

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VTS application for Share-Loc 2.0 - Brest

Communication Environment Tools View Options Help

Tiny view Ship information Zone: Rade de Brest Zoom: 100% Phi: 48° 21.397' N G: 004° 28.163' W

Iroise
 Le Four - Goulet
 Le Four - Iroise
 Le Four - Ouessant
 Le Toulinguet
 Ouessant
 Port de Brest
 Rade de Brest

Tigre
 Tourville
 Ondine
 Canot Major
 Canopus
 Lestreal
 Midship Ca
 Chimere
 Farfadet
 Jaguar

Login: MIDS
 Name: Midship Ca
 Phone number: 0631478924
 Ship length: 10 m
 Ship width: 2 m
 Ship displacement: 3 t
 Connection: WAP
 Surname: Marine Nationale
 Family name: Ecole Navale
 Address: LANVEOC
 Home phone: 0298123474

Jaguar 0635987452
 Your position is not valid anymore. You must update it

Name: Midship Ca
 Heading: 20.0°
 Speed: 6.0 kt
 Latitude: 48° 19.642' N
 Longitude: 004° 30.626' W
 Trust: 10

F1 Ships F2 Speed vector F3 Track F4 Trust circle F5 Name F6 Connection type F7 Harbours F8 Lighthouses F9 Coastguards F11 Scales F12 Chart

VTS Services Within GIS

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The screenshot displays the VTS application for Share-Loc 2.0 - Brest. The main window shows a map of the Brest harbor with several ships and AIS data points. The interface includes a menu bar (Communication, Environment, Tools, View, Options, Help), a toolbar, and a map view. The map shows the harbor area with various ships and AIS data points, including Erika, Akagi, Charles de Gaulle, Jeanne d'Arc, Cygne, Castor, Beluga, Denebola, and Colombe. The map also displays the coastline and various navigational markers.

Key components of the interface include:

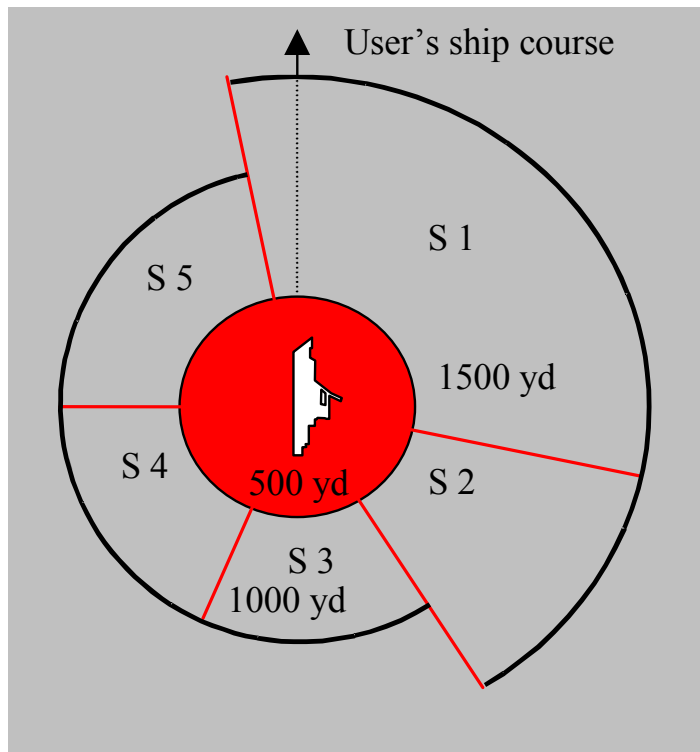
- Map View:** Shows the harbor area with various ships and AIS data points. The map is centered on the harbor area, with a scale bar at the top indicating distances from 30' to 5'.
- Connected Boats Panel:** Lists the following ships: Erika, Akagi, Charles de Gaulle, Jeanne d'Arc, Cygne, Castor, Beluga, Denebola, and Colombe.
- Get weather report Panel:** Displays weather data for Brest on 15-05-2002 at 13 h 45. The data includes:

| | |
|---------------|-------------------------|
| Type | Land-based station |
| Latitude | 48° 22.824' N |
| Longitude | 004° 29.593' W |
| Sea state | 2 : smooth |
| Pressure | 1015 hPa |
| Wind | 5 : fresh breeze |
| Clouds | 3 / 8 |
| Humidity | 20 % |
| Visibility | 6 : moderate visibility |
| Temperature | 12 °C |
| Precipitation | steel |
| Tendency | slow falling |
- Choose speed vector color Panel:** Allows users to select a color for speed vectors. It includes a color palette and a preview area.
- Information Panel:** Displays details for the selected ship, Castor:

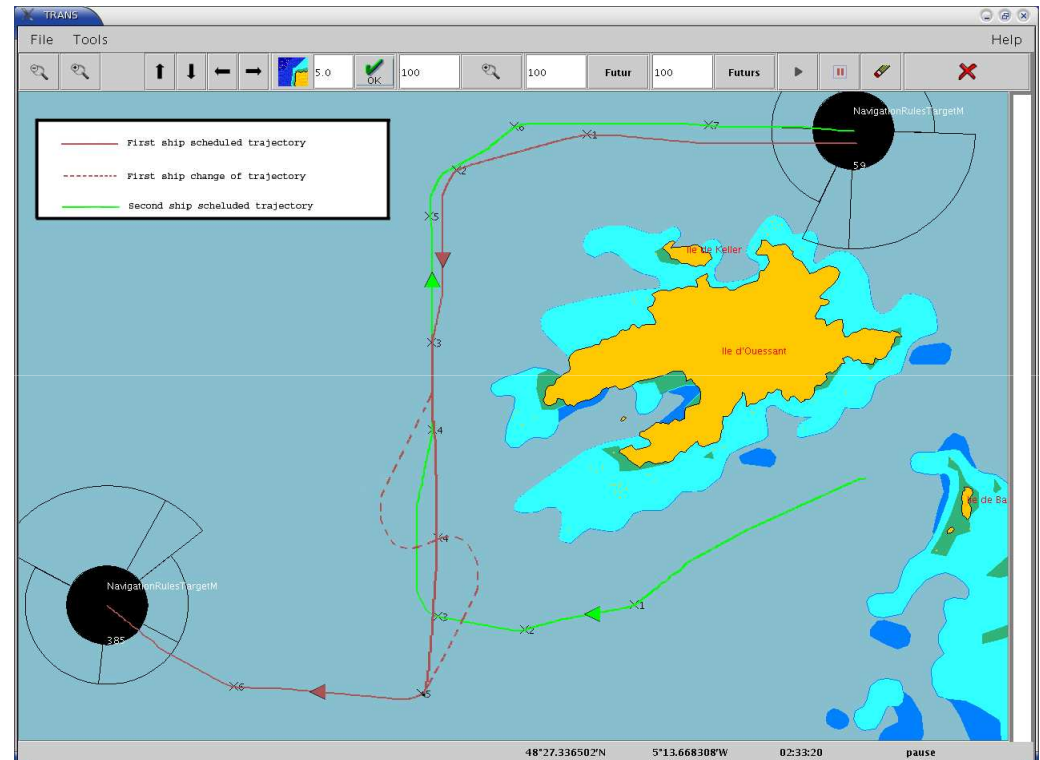
| | |
|-----------|----------------|
| Name | Castor |
| Heading | 165.0° |
| Speed | 4.0 kt |
| Latitude | 47° 30.000' N |
| Longitude | 003° 26.399' W |
| Trust | 4 |

Navigation modelling and simulation

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Navigation rules

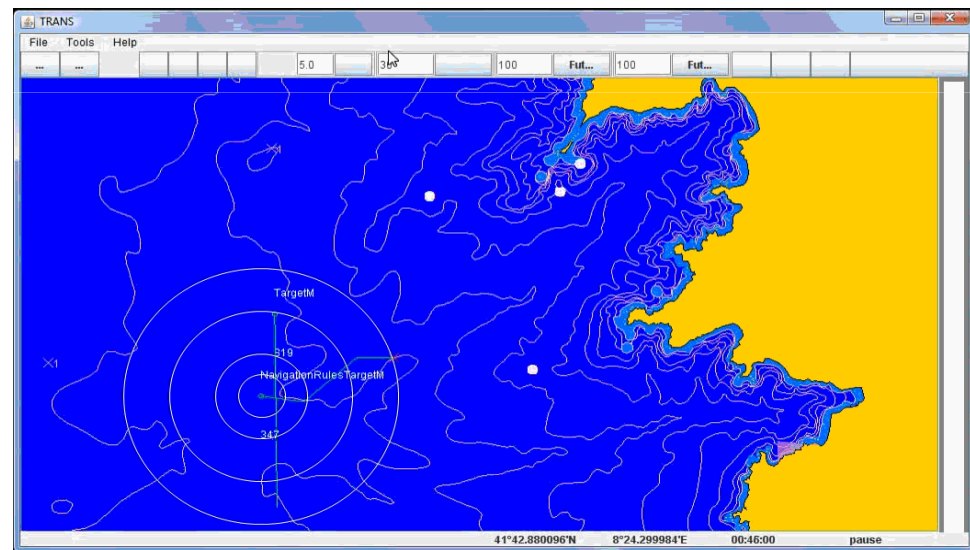


Collaborative navigation modelling

Navigation modelling and decision processes

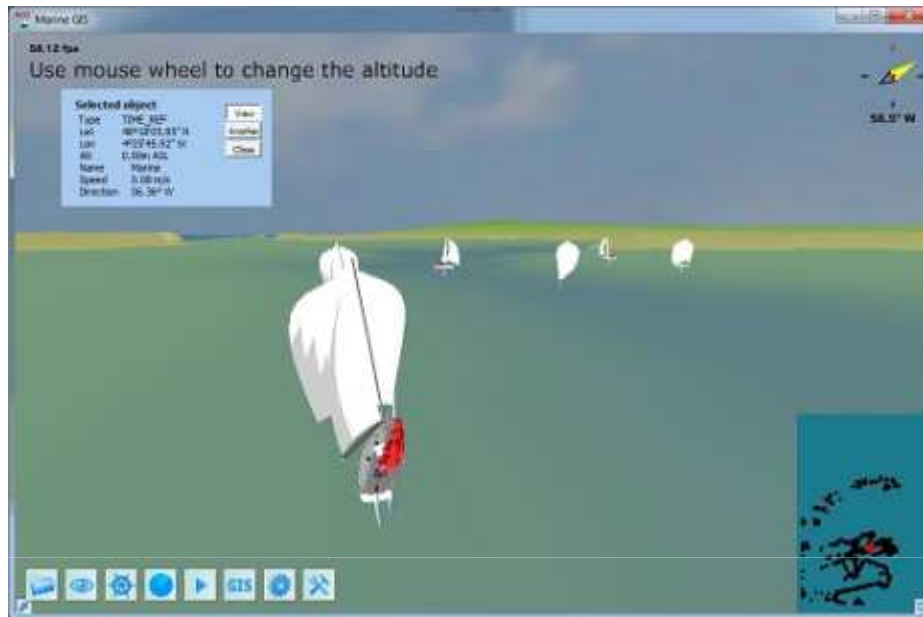
64

- 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

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Replay (« Grand Prix 2009 »)



What should we retain ?

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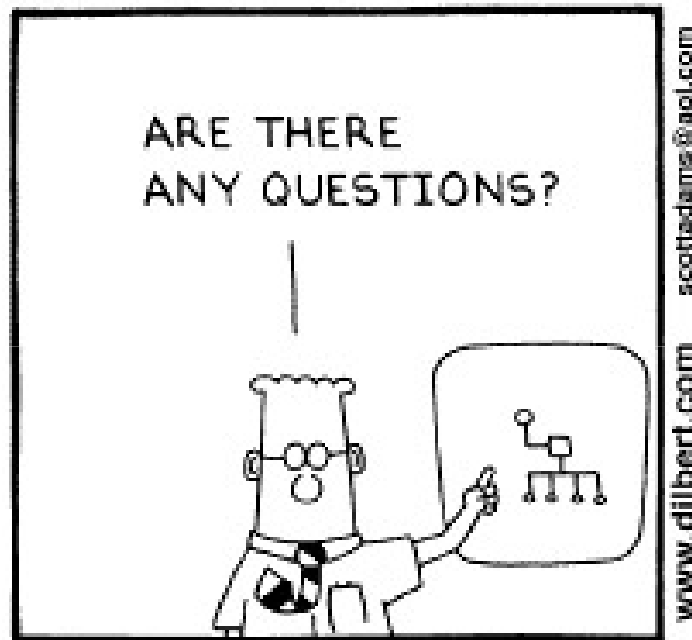


As citizen: we
don't care too
much to what is
really happening
at sea,

and we don't
know too much
about it

Conclusion

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Thank you very much for your attention !

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<http://christophe.claramunt.free.fr>